DEVELOPMENT AND EVALUATION OF ALTERNATIVES

CSO Permit Compliance

City of Perth Amboy

Middlesex County Utilities Authority (MCUA)

Middlesex County, New Jersey

City of Perth Amboy –
NJPDES Permit No.
NJ0156132

MCUA –
NJPDES Permit No.
NJ0020141

Original Submission:

July 1, 2019

CDM Smith

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Passaic Valley Sewerage Commissioners CSO Long Term Control Plan Updated Technical Guidance Manual, January 2018

List of Abbreviations

AGC	Aerated Grit Chamber
BCMR	Baseline Compliance Monitoring Report
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CEPT	Chemical Enhanced Primary Treatment
CIP	Cast Iron Pipe
CIPP	Cured-In-Place Pipe
CMP	Corrugated Metal Pipe

COD	Chemical Oxygen Demand
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
CTP	Central Treatment Plant
CWA	Clean Water Act
DEAR	Development and Evaluation of Alternatives Report
DIP	Ductile Iron Pipe
ENR CCI	Engineering News Record Construction Cost Indices
FCA	Financial Capability Analysis
FM	Force Main
fps	feet per second
FSS	Fixed Suspended Solids
FST	Final Settling Tank
GC	General Contractor
GI	Green Infrastructure
HDD	Horizontal Directional Drilling
HLR	Hydraulic Loading Rate
HRT	High Rate Treatment
I/I	Inflow and Infiltration
LTCP	Long Term Control Plan
MCUA	Middlesex County Utilities Authority
MG	Million Gallons
MGD	Million Gallons per Day
MUA	Municipal Utility Authority
NJDEP	New Jersey Department of Environmental Protection
NJPDES	New Jersey Pollutant Discharge Elimination System
NMC	Nine Minimum Controls
OH&P	Overhead & Profit
O&M	Operation and Maintenance
OT	Oxygenation Tanks
PAA	Peracetic Acid
PCCP	Prestressed Concrete Cylinder Pipe
PS	Pumping Station
PST	Primary Settling Tanks
PV	Performance Value
PVSC	Passaic Valley Sewerage Commission
RAS	Return Activated Sludge
RCP	Reinforced Concrete Pipe
SE1	Saline Estuary 1
SE2	Saline Estuary 2
SIU	Significant Industrial User
TBL	Triple Bottom Line
TGM	Technical Guidance Manual
THM	Trihalomethanes
TKN	Total Kjeldahl Nitrogen

TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
UVT	Ultraviolet Transmittance
VCP	Vitrified Clay Pipe
VSS	Volatile Suspended Solids
WAS	Waste Activated Sludge
WQS	Water Quality Standards
WRF	Water Reclamation Facility
WWTP	Wastewater Treatment Plant

Section 1

Introduction

This document constitutes the Development and Evaluation of Alternatives Report (DEAR) that has been developed by the City of Perth Amboy and Middlesex County Utilities Authority (MCUA) jointly for the required "Consideration of Sensitive Areas," "Evaluation of Alternatives," and "Cost Performance Considerations" under Part IV Section G.3 through G.5 of Perth Amboy's New Jersey Pollutant Discharge Elimination System (NJPDES) permit action (Permit number NJ0156132; October 9, 2015, Permit Correction November 2, 2015, Minor Modification January 22, 2016). This document serves as the DEAR for the City of Perth Amboy and the portion of the hydraulically connected system that is owned / operated by the MCUA that services the City of Perth Amboy. The MCUA has indicated to the City and the Department that it will work cooperatively with the City in providing information the City may require regarding the MCUA's owned and operated facilities to complete the joint Long-Term Control Plan.

This report documents that Perth Amboy has evaluated a reasonable range of combined sewer overflow (CSO) control alternatives that will meet the requirements of the Clean Water Act (CWA) using either the Presumption Approach or the Demonstration Approach. The objective of the DEAR is to enable Perth Amboy, in consultation with the Department, the public, owners and/or operators of the entire collection system that conveys flows to the treatment works, to select the alternatives to ensure the CSO controls will meet the water quality-based requirements of the CWA, will be protective of the existing and designated uses in accordance with N.J.A.C. 7:9B, giving the highest priority to controlling CSOs to sensitive areas, and address minimizing impacts from Significant Industrial User (SIU) discharges.

1.1 Regulatory Context and Objectives

1.1.1 USEPA Combined Sewer Overflow Control Policy

United States Environmental Protection Agency's (USEPA) CSO Control Policy (Policy) was issued in April of 1994[1-1] to elaborate on the 1989 National CSO Control Strategy and to expedite compliance with the requirements of the CWA. The Policy provided guidance to municipal permittees with CSOs, to the state agencies issuing National Pollution Discharge Elimination permits (e.g. NJDEP and NJPDES permits) and to interstate environmental commission (e.g. the Delaware River Basin Commission). The Policy establishes a framework for the coordination, planning, selection and implementation of CSO controls required for permittee compliance with the CWA.

The Policy includes three major activities required of municipalities with CSO related permits:

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1 59 FR 18688 et seq.

- ***System Characterization*** – The identification of current combined sewer system assets and current performance characteristics;
- ***Implementation of the Nine Minimum Controls***[2] – identified in the Policy to ensure that the current combined sewer system is being optimized and property maintained; and
- ***Development of a Long-Term Control Plan (LTCP)*** – The analysis and selection of long-term capital and institutional improvements to the combined sewer system that once fully implemented will result in compliance with the CWA.

The Policy includes provisions for public and stakeholder involvement (e.g. the CSO Supplemental Committees), the assessment of affordability (rate-payer impacts) and financial capability (permittee ability to finance the long-term controls) as a driver of implementation schedules and two CSO control alternatives. The "presumption" approach is premised on the presumption that the achievement of certain performance standards, e.g. the capture of at least 85% of wet weather flows during a typical year would result in CWA compliance subject to post-implementation verification. Under the "demonstration" approach, permittees demonstrate that their proposed controls do not cause or contribute to a violation of receiving stream water quality standards.

1.1.2 New Jersey Pollution Discharge Elimination System (NJPDES) Permit Requirements

Under Section 1311 of the CWA, all point source discharges to the waters of the United States must be permitted. USEPA Region II has delegated permitting authority in New Jersey to the New Jersey Department of Environmental Protection (NJDEP). The permits are reissued on a nominal five-year cycle. All twenty-one New Jersey municipalities and municipal authorities with combined sewer systems were issued new permits in 2015 that set forth requirements for the completion of the system characterization and the development of LTCPs on the following schedule:

- Submittal of the System Characterization Report to NJDEP – July 1, 2018;
- Development & Evaluation of CSO Control Alternatives – July 1, 2019; and
- Selection and Implementation of Alternatives – June 1, 2020.

With minor exceptions such as lists of applicable previous studies, the 2015 permits are standardized. The 2015 information to be included in the Development and Evaluation of Alternatives Report is specified in Part IV (Specific Requirement: Narrative) paragraph G-3, G-4, and G-5 of the permits. These requirements are reproduced on Table 1-3along with the section of

2 The nine minimum controls include: 1) proper operation and regular maintenance; 2) maximizing the use of the collection system for storage where feasible; 3) review and modification of the Industrial Pretreatment Program to minimize CSO impacts; 4) maximization of flow to the wastewater treatment plant; 5) the prohibition of CSOs during dry weather; 6) control of solids and floatables (addressed by NJDEP's requirement of screening or other facilities in the late 2000s); 7) pollution prevention; 8) public notification; and 9) monitoring CSO impacts and controls. 59 FR 18691.

this Development and Evaluation of Alternatives Report in which the requirements are addressed and a list of the principal sources of data used for each requirement.

All flow from Perth Amboy's sewer system that reaches the Second Street Pumping Station (previously referred to as the Main Pumping Station) is pumped to the Woodbridge Township's Keasbey Interceptor which ultimately gets pumped to the Middlesex County Utilities Authority's Edward J. Patten Water Reclamation Center for treatment.

In 2018 the City and MCUA submitted individual system characterization report and were subsequently approved by NJDEP. For the second submittal, the City and MCUA worked together on evaluating an array of alternatives and jointly produced the Development and Evaluation of Alternatives Report.

1.2 Presumption and Demonstration Approaches

The City's NJDPES permit indicates in Section G.4 that they shall evaluate a reasonable range of CSO control alternatives, in accordance with MCUA and the NMCs detailed in Part IV.G that will meet the water quality-based requirements of the CWA using either the Presumption Approach or the Demonstration Approach (as described in Sections G.4.f.and G.4.g).

1.2.1 Presumption Approach

In accordance with the USEPA CSO Policy and as described in the City's NJPDES permit at G.4.f, the Presumption Approach is indicated as:

A program that meets any of the criteria listed below will be presumed to provide an adequate level of control to meet the water quality-based requirements of the CWA, provided the Department determines that such presumption is reasonable in light of the data and analysis conducted in the characterization, monitoring, and modeling of the system and the consideration of sensitive areas described above.

Combined sewer flows remaining after implementation of the NMCs and within the criteria specified below shall receive minimum treatment in accordance with:

Primary clarification (removal of floatables and settleable solids may be achieved by any combination of treatment technologies or methods that are shown to be equivalent to primary clarification);

Solids and floatables disposal; and

Disinfection of effluent, if necessary, to meet WQS, protect designated uses and protect human health, including removal of harmful disinfection chemical residuals/by-products (e.g. chlorine produced oxidants), where necessary.

The permittee must demonstrate any of the following three criteria below:

i. *No more than an average of four overflow events (see below) per year from a hydraulically connected system as the result of a precipitation event that does not receive the minimum treatment specified below. The Department may allow up to two additional overflow events per year. For the purpose of this criterion, an 'event' is:*

In a hydraulically connected system that contains only one CSO outfall, multiple periods of overflow are considered one overflow event if the time between periods of overflow is no more than 24 hours.

In a hydraulically connected system that contains more than one CSO outfall, multiple periods of overflow from one or more outfalls are considered one overflow event if the time between periods of overflow is no more than 24 hours without a discharge from any outfall.

ii. *The elimination or the capture for treatment of no less than 85% by volume of the combined sewage collected in the CSS during precipitation events on a hydraulically connected system-wide annual average basis.*

iii. *The elimination or removal of no less than the mass of the pollutants, identified as causing water quality impairment through the sewer system characterization, monitoring, and modeling effort, for the volumes that would be eliminated or captured for treatment under Section (ii) above.*

1.2.2 Demonstration Approach

In accordance with the USEPA CSO Policy and as described in the City's NJPDES permit at G.4.g, the Demonstration Approach is indicated as:

A permittee may demonstrate that a selected control program, though not meeting the criteria specified under the Presumption Approach above, is adequate to meet the water quality-based requirements of the CWA.

The permittee must demonstrate each of the following below:

i. *The planned control program is adequate to meet WQS and protect designated uses, unless WQS or uses cannot be met as a result of natural background conditions or pollution sources other than CSOs.*

ii. *The CSO discharges remaining after implementation of the planned control program will not preclude the attainment of WQS or the receiving waters' designated uses or contribute to their impairment.*

iii. *The planned control program will provide the maximum pollution reduction benefits reasonably attainable.*

iv. *The planned control program is designed to allow cost effective expansion or cost-effective retrofitting if additional controls are subsequently determined to be necessary to meet WQS or designated uses.*

1.2.3 Comparison of Two Approaches

The following table summarizes the major differences between the Presumption and Demonstration Approach described above.

Table 1-1 - Comparison of Presumption and Demonstration Approaches

Description	Presumption Approach	Demonstration Approach
Criteria	Meet one of three criteria and compliance is presumed: 1) No more than an average of 4-6 overflow events per year; 2) 85% capture (by volume); or 3) Elimination or removal of the mass of pollutants, identified as causing water quality impairment.	Requires the permittee to show both that WQS are met and that its control program "provide[s] the maximum pollution reduction benefits reasonably attainable." The demonstration approach is particularly appropriate where attainment of WQS cannot be achieved through CSO control alone, due to the impacts of non-CSO sources of pollution.
Monitoring Data and Collection	Flow metering of the collection system and/or water quality sampling of CSOs.	Flow metering of the collection system and water quality sampling of CSOs and receiving water bodies
Modeling	Combined sewer system (CSS) hydrologic and hydraulic (H&H) model.	CSS H&H Model and Receiving Water Quality Model(s).
Pollutant Sources Evaluated	Only CSOs	The contributing pollutant sources in the watershed other than CSO including urban stormwater, wildlife, etc.

1.3 Combined Sewer System and Service Area Overview

The City of Perth Amboy is served mostly by combined sewers with pockets of separate sewers. While the City retains ownership of existing sewer infrastructure, the operations of the City's CSO system is performed by Utility Service Affiliates-Perth Amboy (USA-PA), a subsidiary of Middlesex Water Company.

According to the 2010 Census, the total population of City of Perth Amboy was 50,814. An estimated 84% of the City's residents are served directly by a combined sewer system which covers approximately 2.5 square miles. The other 16% of the residents are served directly by a separated sewer system. The combined sewer system includes sixteen combined sewer outfalls, with eight outfalls draining to the Arthur Kill and eight outfalls draining to the Raritan Estuary. The separated sewer areas discharge stormwater to the receiving waters and deliver sanitary sewerage to the combined sewer system. Both sanitary and combined sewer flow are conveyed through the City's 4.3 miles of the interceptor pipes which are divided into an Eastside Interceptor (2.7 miles) and Westside Interceptor (1.6 miles). The confluence of the two branches is located on the influent sewer line at the City's Second Street Pumping Station, located on Second Street along the shore of the Raritan Estuary. There are four pumping stations within the system: Amboy Avenue Pumping Station, State Street Pumping Station, Front Street Pumping Station, and Second Street Pumping Station.

All flow from the Second Street Pumping station is delivered to the Woodbridge Township's Keasbey Interceptor which ultimately flows to the Middlesex County Utilities Authority's Edward J. Patten Water Reclamation Center, also called the Central Treatment Plant (CTP), for treatment. Perth Amboy's Second Street Pumping Station is contractually limited to 13.6 MGD. For the purposes of this report, the rated capacity is assumed to be 13 MGD to MCUA during wet weather. The force main is 24" in diameter. Perth Amboy's flow is recorded in MCUA's Perth Amboy meter chamber, which is located upstream of the Woodbridge Township's Keasbey Interceptor. From there, flow is conveyed by gravity sewer to the MCUA's Edison Pumping Station and then to the CTP headworks, which is located on the Raritan Bay shoreline, upstream and on the opposite bank from Perth Amboy. Figure 1-1 displays a map of Perth Amboy's service area system and how it connects to Woodbridge and MCUA.

For the purposes of this report and for simplicity of comparison to other options, references to the rated capacity have been made as "13 MGD." Any references to 13 MGD should be understood to also refer to the contractual limit of 13.6 MGD (of the Second Street Pumping Station).

1.4 Regional Sewer System Overview

Currently Perth Amboy's combined sewer flows reach the MCUA's CTP via infrastructure owned and operated by two municipalities and one regional authority; City of Perth Amboy, Woodbridge Township and MCUA, respectively. This infrastructure includes:

- <u>Perth Amboy's Infrastructure:</u> Combined Sewer System, Second Street Pumping Station, Force Main and gravity sewer connection to Woodbridge Township's Keasbey Interceptor;
- <u>Woodbridge' Infrastructure:</u> Upper and Lower Keasbey Interceptor to the MCUA's Heyden Gravity Sewer;
- <u>MCUA's Infrastructure:</u> Heyden Gravity Sewer, Perth Amboy Meter Chamber, Woodbridge Meter chamber, Edison Pumping Station and Force Mains to the CTP

The City of Perth Amboy's Interceptor Sewer System is described in further detail in Section 2.1.2.

The infrastructure owned and operated by each municipality has capacity limitations that are addressed in the MCUA's System Characterization Report - Heyden Gravity Sewer (June 2018, Revised December 2018). The report describes the conveyance system in detail and the capacities of the Perth Amboy, Woodbridge and MCUA components of the system. The interrelationship between the various flow sources entering the Heyden Gravity Sewer and Edison Pumping Station are illustrated in Figure 1-2 (Figure 4-1 of the Characterization Report). It is important to note there are several participant meter chambers that also contribute flows to this conveyance system between Perth Amboy and the MCUA. The available capacity in each portion of this conveyance system during the Top 20 Storm Events of 2004 is summarized in Table 1-2. Please note that Table 1-2 is the same as in the MCUA's System Characterization Report, except it has been revised to include the capacity and flows for the Woodbridge's Lower Keasbey Interceptor, as requested by Mr. Dwayne Kobesky in his January 15, 2019 NJDEP letter to MCUA. In addition to the capacity limitations described in the MCUA's aforementioned System Characterization Report, there are constraints to the conveyance of Perth Amboy's flows to the CTP via Woodbridge's infrastructure by the terms and conditions in the service agreement between the City of Perth Amboy and Woodbridge Township. The capacity limitations and contractual terms and conditions in the service agreements make this existing conveyance system a very complex as well as contractually and hydraulically limited system.

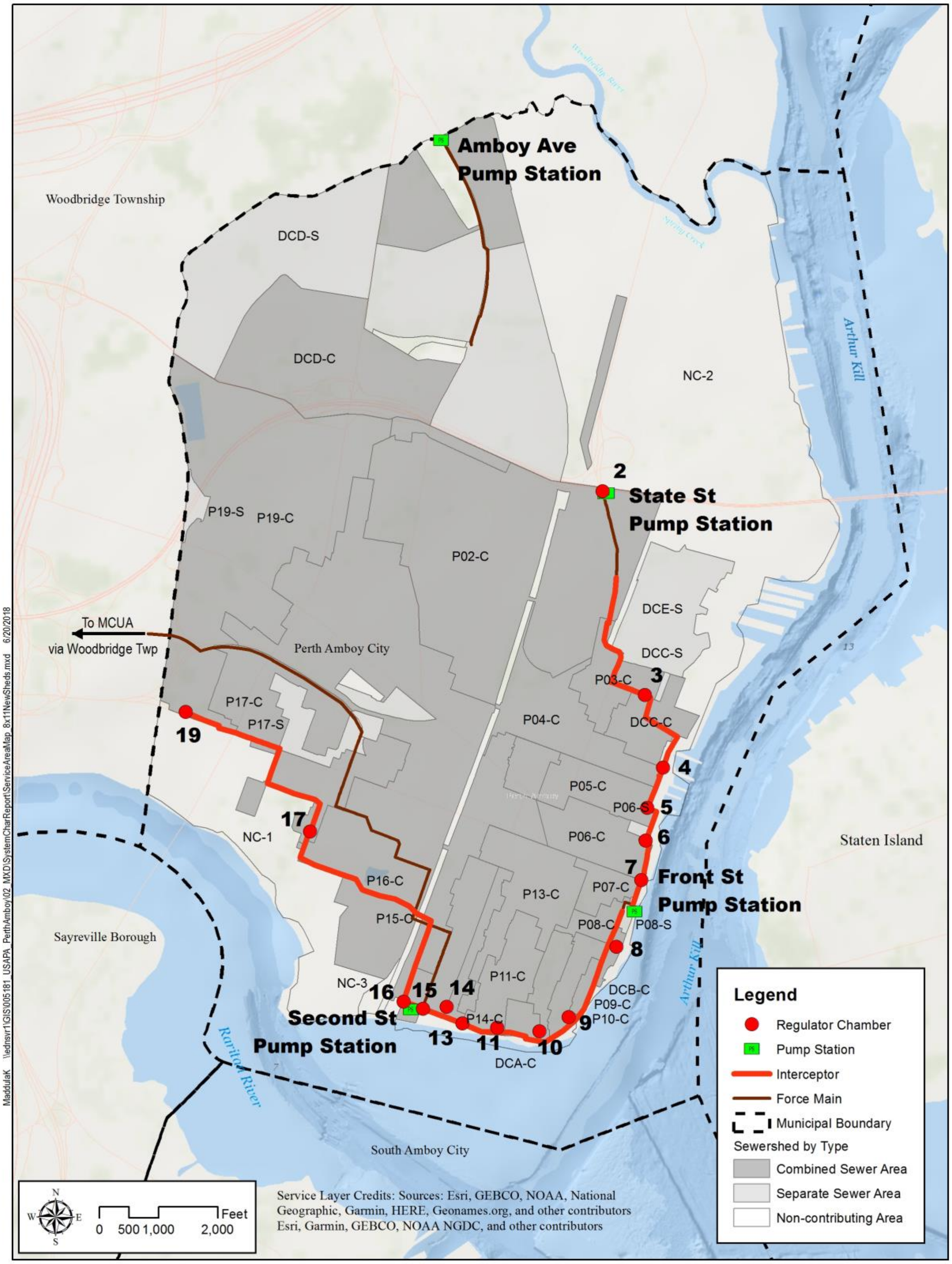


Figure 1-1 - Perth Amboy Service Area

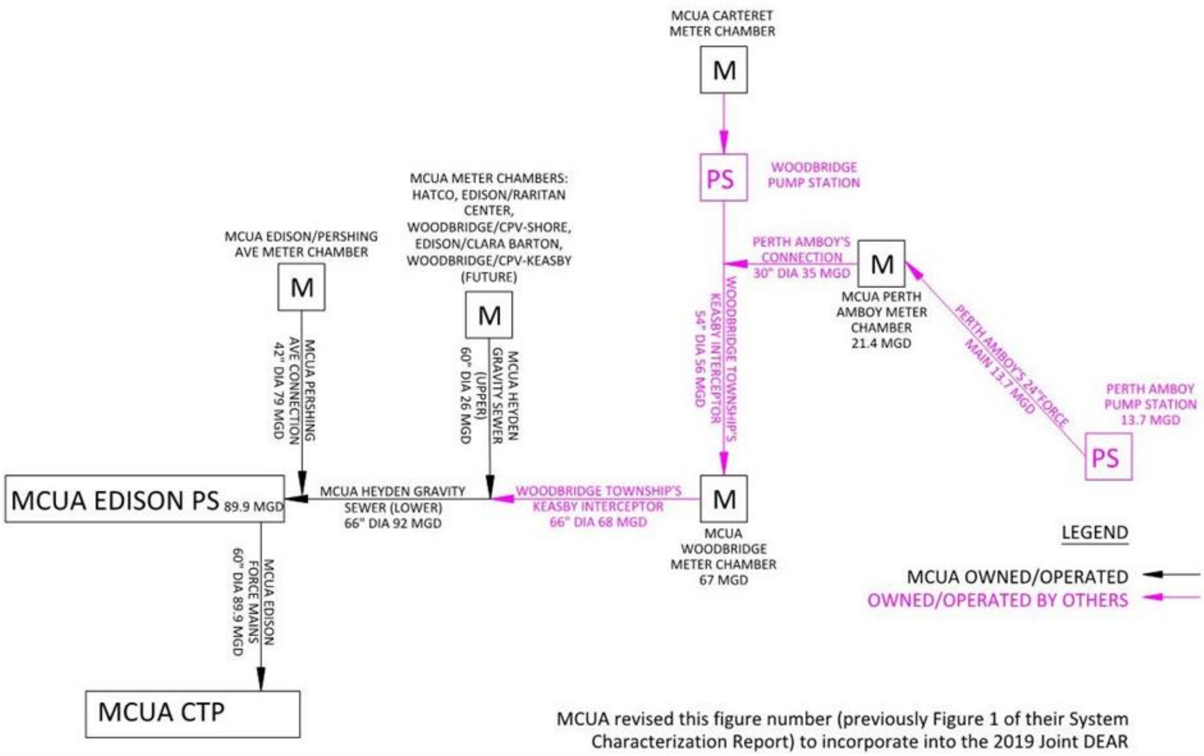


Figure 1-2 - Middlesex County Utilities Authority's Heyden Gravity Collection System Diagram

The MCUA owns and operates a regional sewerage system that collects wastewater flows from thirty-six (36) communities in Middlesex, Somerset, and Union Counties and provides secondary treatment of these flows at its Central Treatment Plant (CTP) located at 2571 Main Street Extension in Sayreville, New Jersey. The City of Perth Amboy is the only municipality whose collection system has combined sewers. The wastewater is collected by these communities with their own collection systems and discharged to the CTP through seventy-five (75) meter chambers owned and operated by the MCUA. In addition, the MCUA meters flows from four (4) direct industrial participants. The metered flows are then conveyed to the CTP via the MCUA's system of interceptors, trunk sewers and siphons that convey the flows to three regional pumping stations and force mains to the CTP. All flows are pumped to the CTP for treatment and disinfection prior to discharge into the Raritan Bay and the North Channel of the Raritan River. These conveyance facilities are located throughout the MCUA's service area as shown on Figure 1-3.

Refer to Section 4.2.3 for the Description of the MCUA's CTP (processes, capacity, limitation, etc.).

Table 1-2 - Sewer Capacities and Actual Sewage Flows During Top 20 Storm Event in 2004

Typical Year (2004) Storms -- Ranked by Total Rainfall by PVSC (in)*		Newark Rainfall	Perth Amboy P.S. (Note 1)	Perth Amboy M.C. (Note 1)	Woodbridge Upper Keasbey Interceptor (Notes 3&4)	Woodbridge M.C. (Note 1)	Woodbridge Lower Keasbey Interceptor (Notes 3&4)	Upper Heyden Gravity Sewer (Note 1)	Lower Heyden Gravity Sewer (Note 1)	Edison P.S. (Note 1)	CTP (Note 2)
			Capacity (MGD)								
			13.7	21.4	56	67	68	26	92	89.9	147
Ranking	DATE	(in)	Actual Flow / Capacity (%)								
1	9/28/2004	3.10	80%	51%	78%	65%	64%	35%	57%	63%	109%
	9/29/2004	0.57	68%	44%	63%	52%	52%	28%	46%	50%	214%
2	9/8/2004	2.08	58%	37%	45%	38%	37%	20%	33%	36%	91%
	9/9/2004	0.29	41%	26%	29%	24%	24%	18%	23%	25%	86%
3	7/12/2004	1.59	84%	54%	66%	56%	55%	30%	49%	53%	108%
	7/13/2004	0.40	54%	34%	44%	36%	36%	29%	35%	38%	133%
4	4/12/2004	0.62	58%	37%	41%	34%	33%	24%	31%	34%	79%
	4/13/2004	1.05	59%	38%	61%	51%	50%	24%	44%	47%	135%
	4/14/2004	0.43	59%	38%	56%	47%	46%	27%	42%	45%	158%
5	4/25/2004	0.09	51%	33%	31%	26%	26%	21%	25%	27%	83%
	4/26/2004	1.58	70%	45%	51%	42%	42%	29%	39%	43%	108%
6	7/23/2004	1.63	71%	46%	58%	49%	48%	37%	46%	49%	103%
7	2/6/2004	1.58	75%	48%	73%	61%	60%	34%	54%	58%	151%
8	7/18/2004	1.58	68%	43%	46%	38%	38%	26%	35%	38%	90%
9	11/28/2004	1.50	72%	46%	58%	48%	48%	26%	43%	45%	133%
10	7/27/2004	1.39	64%	41%	60%	50%	49%	29%	45%	48%	106%
11	9/17/2004	0.03	34%	21%	21%	18%	18%	19%	18%	20%	76%
	9/18/2004	1.41	45%	29%	30%	25%	25%	19%	23%	25%	85%
12	6/25/2004	1.39	44%	28%	40%	33%	33%	26%	31%	34%	83%
13	11/12/2004	0.94	81%	52%	46%	38%	38%	20%	33%	35%	89%
14	5/12/2004	1.08	43%	28%	28%	24%	23%	22%	24%	26%	85%
15	11/4/2004	1.00	58%	37%	36%	30%	29%	13%	25%	27%	82%
16	7/5/2004	1.00	49%	32%	30%	25%	25%	20%	24%	26%	88%
17	12/1/2004	1.00	68%	44%	55%	46%	46%	22%	40%	43%	132%
18	8/16/2004	0.94	54%	34%	34%	28%	28%	21%	26%	29%	91%
19	8/21/2004	0.85	43%	27%	27%	23%	22%	21%	22%	24%	84%
20	12/6/2004	0.19	47%	30%	28%	24%	23%	18%	22%	24%	84%
	12/7/2004	0.57	79%	51%	54%	45%	44%	21%	39%	41%	102%
	12/8/2004	0.07	51%	33%	38%	32%	31%	23%	30%	32%	119%

* Reference: Table 2-6, Passaic Valley Sewerage Commission (PVSC) - Typical Hydrologic Year Report, dated May 2018.

Notes:

1. In 2004, the MCUA's CTP effluent discharge was in compliance with the monthly average discharge concentration and loading limitations set forth in its NJPDES Permit No. NJ0020141.
2. Per MCUA's NJPDES Permit No. NJ0020141, the current permitted design capacity of the MCUA Central Treatment Plant is 147 mgd.
3. Woodbridge's Upper and Lower Keasbey Interceptor capacities were calculated based upon available information.
4. MCUA revised this table (previously Table 4-1 in the System Characterization Report) by including the capacity and flows for Woodbridge's Keasbey Interceptor, as requested by Mr. Dwayne Kobesky in the NJDEP's January 15, 2019 letter to MCUA.

Rainfall as total inches per day.

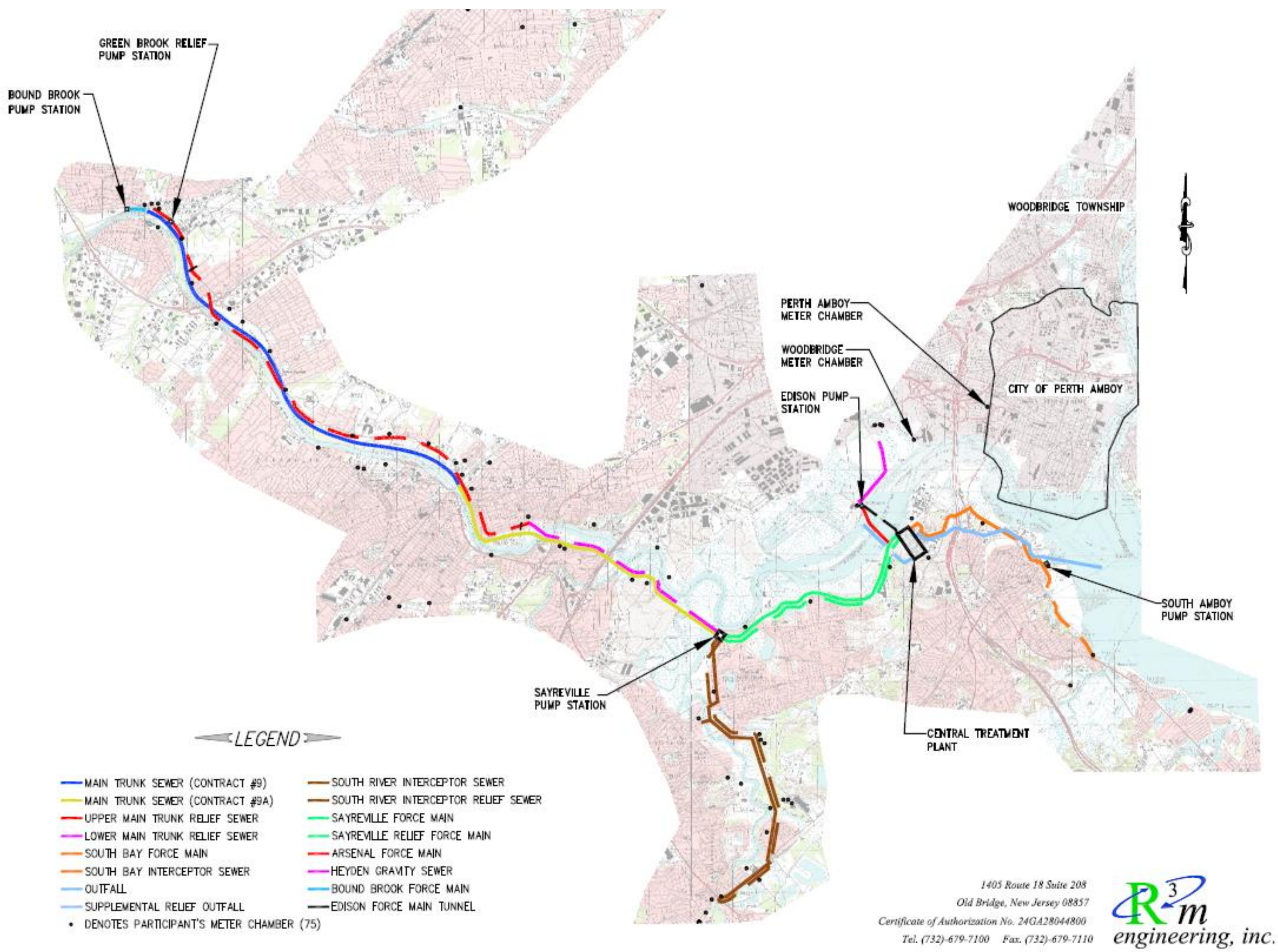


Figure 1-3 - MCUA Conveyance Facilities

1.5 Previous Studies

Several reports are referenced in the DEAR. They are listed below.

Long Term Combined Sewer Overflow Control Plan Cost and Performance Analysis Report for the City of Perth Amboy Utilities Service Affiliates USAPA, prepared by CDM Smith, Dated April 2007 and revised August 2008.

- This document presents the results of a hydraulic and hydrologic assessment of the City's CSS and cost and performance information for 1) pretreatment and disinfection alternatives, 2) collection and conveyance system operation, and 3) collection and conveyance system and control facilities operation.

Central Treatment Plant Conveyance and Capacity Analysis, Cost Performance Analysis Report NJPDES Permit No. NJ0020141, prepared by CDM Smith, dated August 2007.

- This document presents the evaluation of MCUA's collection system, existing treatment facilities, technology review of rapid primary treatment options, technology review of disinfection options, and treatment alternatives to achieve permit compliance at various scenarios and performance values.

System Characterization Report, CSO Permit Compliance, City of Perth Amboy, NJPDES Permit No. NJ0156132, prepared by CDM Smith, Dated June 2018 and revised December 2018. Approved January 2019.

- This document constitutes the City of Perth Amboy's Sewer System Characterization Report (SCR) developed by the City of Perth Amboy on behalf of the City of Perth Amboy and Middlesex County Utilities Authority (MCUA) for the required "Characterization Monitoring and Modeling of the Combined Sewer System" under Part IV Section G.1 of Perth Amboy's New Jersey Pollutant Discharge Elimination System (NJPEDS) permit action (Permit number NJ0156132; October 9, 2015). This document serves as the SCR for the City of Perth Amboy and the portion of the hydraulically connected system that is owned / operated by the MCUA that services the City of Perth Amboy. The MCUA has indicated to the City and the Department that it will work cooperatively with the City in providing information the City may require regarding the MCUA's owned and operated facilities to complete the joint Long-Term Control Plan.

System Characterization Report, CSO Permit Compliance, Middlesex County Utilities Authority , NJPDES Permit No. NJ0020141, prepared by R3M, Dated June 2018 and revised December 2018.

Identification of Sensitive Areas Report, CSO Long Term Control Plan, Submitted on behalf of the participating permittees by the Passaic Valley Sewerage Commission (NJ0021016) to Satisfy Permit Condition Part IV.D.3.b.iv, prepared by Greeley and Hansen and CDM Smith, dated June 2018. Approved April 2019.

- This document presents the State and Federal Agencies that were researched, and other means utilized in order to identify the location of potential sensitive areas as they may relate to the development of the CSO Long Term Control Plan (LTCP). This evaluation will allow the Permittees to develop a plan that incorporates consideration of these areas as physically possible and economically achievable.

NJCSO Group Compliance Monitoring Program Report, prepared on behalf of the following participating Permittees by Passaic Valley Sewerage Commission (NJ0021016) to Satisfy Permit Condition Part IV.D.3.d, prepared by Greeley and Hansen and CDM Smith, dated June 30, 2018, revised Oct 5, 2018. Approved March 2019

- This document is the Baseline Compliance Monitoring Program to be utilized by the NJ CSO Group. This report describes the methodology that was utilized for the Baseline Compliance Monitoring Program, the analysis that was completed, and the Compliance Monitoring results to be used in the development of a CSO LTCP.

Public Participation Process Report, CSO Permit Compliance, City of Perth Amboy and Middlesex County Utilities Authority, PA NJPDES Permit No. NJ0156132 and MCUA NJPDES Permit No. NJ0020141, prepared by CDM Smith, Dated June 29, 2018 and revised December 12, 2018.

- This document constitutes the Public Participation Process Report developed by the City of Perth Amboy and MCUA for the required "Public Participation Process Report" under Part IV Section G.2 of Perth Amboy's NJPDES permit action and MCUA's permit action. This document summarizes the ongoing and planned processes for engaging public participation during the City of Perth Amboy's LTCP development, and the development and activities of the Perth Amboy Supplemental CSO Team.

Passaic Valley Sewerage Commissioners CSO Long Term Control Plan Updated Technical Guidance Manual, prepared by Greeley and Hansen and CDM Smith, Dated January 2018.

- This document was developed by the Passaic Valley Sewerage Commissioners (PVSC) to assist the communities in performing their alternatives evaluation as part of the CSO LTCP development. This Technical Guidance Manual (TGM) provides an overview of various green infrastructure, screening, pretreatment, disinfection, and storage technologies along with guidance on costs. The TGM is intended as a guidance document to assist the individual permittees in performing their LTCP alternatives evaluations. The information and costs provided throughout the document are for planning purposes only.

1.6 Organization of Report

Table 1-3 provides a summary of the permit requirements along with the applicable section of the Development and Evaluation of Alternatives Report, and principal data sources that were used to develop the report. The technical approaches for addressing the major elements of the Development and Evaluation of Alternatives Report are detailed for each anticipated section of the report.

Table 1-3 - Review of Elements of the Development of Alternatives Report

Permit Section	Permit Requirement	Development and Evaluation of Alternatives Report Section	Data Sources Used
Part IV G.3.a and b	"The permittee's LTCP shall give the highest priority to controlling overflows to sensitive areas."	Section 3	▪ System Characterization Report, CSO Permit Compliance, City of Perth Amboy, NJPDES Permit No. NJ0156132, prepared by CDM Smith, Dated June 2018 and revised December 2018 ▪ Identification of Sensitive Areas Report, CSO Long Term Control Plan, submitted on behalf of the participating permittees by the Passaic Valley Sewerage Commission (NJ0021016) to Satisfy Permit Condition Part IV.D.3.b.iv, prepared by Greeley and Hansen and CDM Smith, dated June 2018
Part IV G.4.a, b, d and G.4.e.i. through vii.	Evaluate CSO Control Alternatives	Section 4 and Section 6	▪ Collection system model ▪ Long Term Combined Sewer Overflow Control Plan Cost and Performance Analysis Report for the City of Perth Amboy Utilities Service Affiliates USAPA, prepared by CDM Smith, Dated April 2007 and revised August 2008 ▪ System Characterization Report, CSO Permit Compliance, City of Perth Amboy, NJPDES Permit No. NJ0156132, prepared by CDM Smith, Dated June 2018 and revised December 2018 ▪ Passaic Valley Sewerage Commissioners CSO Long Term Control Plan Updated Technical Guidance Manual, prepared by Greeley and Hansen and CDM Smith, Dated January 2018
Part IV G.5.a	Cost Performance Considerations	Section 5 and Section 6	▪ Long Term Combined Sewer Overflow Control Plan Cost and Performance Analysis Report for the City of Perth Amboy Utilities Service Affiliates USAPA, prepared by CDM Smith, Dated April 2007 and revised August 2008 ▪ Central Treatment Plant Conveyance and Capacity Analysis, Cost Performance Analysis Report NJPDES Permit No. NJ0020141, prepared by CDM Smith, dated August 2007 ▪ Passaic Valley Sewerage Commissioners CSO Long Term Control Plan Updated Technical Guidance Manual, prepared by Greeley and Hansen and CDM Smith, Dated January 2018

1.7 City of Perth Amboy – Certification

I certify under penalty of law that those portions of this document relating to the collection system owned and operated by the permittee and all attachments related thereto were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative effort performed by members of the NJ CSO group in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system owned and operated by the permittee, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Luis A. Perez Jimenez [signature] 6/27/19

Luis A. Perez Jimenez, P.E., MBA, CME
Director of Operations

Date

1.8 Middlesex County Utilities Authority – Certification

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that those portions of this document relating to the treatment and collection system owned and operated by the permittee and all attachments related thereto were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative effort performed by members of the NJ CSO group in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system owned and operated by the permittee, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

6/29/19

Joseph P. Cryan
Executive Director

Date

Section 2

Overview of Combined Sewer Overflow Locations and Impacts on Receiving Waterbodies

2.1 Combined Sewer System

The details of the City of Perth Amboy's Combined Sewer System are described in the System Characterization Report dated June 28, 2018.

2.1.1 Combined Sewer Service Area

Perth Amboy's collection system serves 50,814 residents per the 2010 Census and 3,525 business customers (2007, Census Business QuikFacts). An estimated 84% of the City of Perth Amboy's residents are served directly by a combined sewer system which covers approximately 2.5 square miles. The other 16% of the residents are served directly by a separated sewer system which is conveyed to the combined sewer system.

While the City retains ownership of the existing sewer infrastructure, the operation of the City's wastewater collection system is performed by a private subcontractor. The subcontractor officially began management of the system in January 1, 1999.

Section 2 of the System Characterization Report (SCR) has detailed descriptions of the combined sewer collection system, the interceptor sewer system, the combined sewer regulators, the combined sewer outfalls, the pumping stations and force mains, other flow controls (tide gates), and the regional wastewater treatment plant.

2.1.2 Interceptor Sewer System

A schematic view of the interceptor system is illustrated in Figure 2-2. The Eastside Interceptor branch begins at the State Street Pumping Station, which is located beneath the Outerbridge Crossing along the Arthur Kill. The pumping station accepts influent flow from the sewershed area tributary to the regulator structure at outfall P-002 and from the area that was previously tributary outfall P-001, which was closed following a sewer separation project. The regulator structure at outfall P-002 is a "leaping weir" structure which is mounted in the crown of the interceptor pipe. Flow enters the leaping weir in an 84" trunk sewer. Incoming flow falls into a 33"interceptor during dry weather conditions. During rainfall events, the flow increases and gains enough energy to "leap" over the interceptor into an 84" overflow pipe which discharges into a small tributary to the Arthur Kill. A netting chamber is located downstream of the diversion chamber to remove solids and floatables before they are discharged though the outfall pipe.

The discharge from the State Street Pumping Station travels south along State Street and then east along Buckingham Avenue, first by a 24" force main, then by a 24" gravity sewer, and then by a 36" gravity sewer until it reaches the regulator structure on Buckingham Avenue (P-003), which is a leaping weir type structure. Prior to reaching the regulator structure, a small amount of additional contributing area is connected to the interceptor. During dry weather flow conditions, sewerage entering the regulator structure at outfall P-003 drops over the leaping weir and into a 48" interceptor sewer. Overflows "leap" over the weir into the 36" outfall which discharges into the Arthur Kill. A netting chamber is located downstream of the diversion chamber to remove solids and floatables before they are discharged though the outfall pipe.

Downstream from the P-003 sewershed, the Eastside Interceptor branch continues through a 48"interceptor to travel south along High Street and then Front Street, picking up an additional sanitary contribution from a large separate sewered development (Harbortown) and the regulated combined sewer flow from diversion structures upstream of outfalls P-004, P-005, P-006 and P-007, which are all leaping weir type structures located on the crown of the interceptor. The influent trunk sewer sizes are 42" by 54", 36", 24" by 36", and 30" by 42", respectively. The overflow pipe sizes are 48", 36", 48", and 42", respectively. All of the overflow pipes have a netting chamber located downstream of the diversion chamber. Outfalls P-005, P-006, and P-007 all have tide gates.

The 48" Eastside Interceptor branch continues to travel south until it reaches the Front Street Pumping Station which also accepts the regulated combined sewer flow from the sewershed tributary to outfall P-008, which travels north along Front Street in a 15" sewer. The regulator structure at P-008 is leaping weir type structure with a 36" influent trunk sewer and a 36" overflow pipe that discharges to the Arthur Kill. A netting chamber is located downstream of the diversion chamber.

The discharge from the Front Street Pumping Station travels west by 36"force main and then south by a 36" gravity sewer along Water Street, accepting the regulated flow from the final Arthur Kill regulator structure, upstream of outfall P-009. This structure is a leaping weir type structure located remotely from the interceptor. Flow enters the regulator structure in a 18" trunk sewer. During dry weather flow conditions, flow drops into an 8" lateral which connects to the interceptor near the intersection of Lewis Street and Water Street. During rainfall events, the flow increases and gains enough energy to "leap" over the interceptor into a 24" overflow pipe which discharges into the Arthur Kill. A netting chamber is located downstream of the diversion chamber.

The 36"interceptor turns west along Sadowski Parkway where it accepts the regulated combined sewer flow from diversion structures P-010, P-011, P-013, P-014, and P-015, which are all leaping weir type structures, before it reaches the Second Street Pumping Station. Regulator structures at outfalls P-013 and P-015 are located on the crown of the interceptor. Regulator structures at outfalls P-010, P-11 and P-014 are all located remotely from the interceptor and connect to the interceptor via 12" lateral sewers. The influent trunk sewer sizes are each 24" by 36" and the overflow pipes are each 36" with tide gates. All of the overflow pipes have a netting chamber located downstream of the diversion chamber to remove solids and floatables before they are discharged though the outfall pipe to the Raritan River. All of these outfalls have tide inflow prevention gates.

The Westside Interceptor branch begins at the regulator structure of P-019, located on Smith Street. The diversion structure is a leaping weir type structure in an elevated chamber. Flow enters the chamber in a 72" sewer. During dry weather flow conditions/ sewerage entering the P-019 structure drops over the leaping weir and into a 15" interceptor sewer. Overflows "leap" over the weir into the 72" outfall which discharges into a swale on the Hess Oil property and eventually into Raritan River. A netting chamber is located downstream of the diversion chamber to remove solids and floatables before they are discharged though the outfall pipe.

The interceptor runs east along Smith Street and eventually south along Sheridan Street, increasing to 24", until it reaches on Sheridan Street, to the regulator structure at outfall P-017. Prior to reaching the diversion structure, some additional contributing area is connected to the interceptor. This includes area which was formerly regulated by the now decommissioned diversion structure at the former P-018 outfall. The diversion structure at outfall P-017 does not have a leaping weir. The structure consists of the 24" influent, a 30" effluent interceptor in the side wall of the chamber, and a 24" overflow pipe with an elevated invert located in-line with the influent pipe. During dry weather flow conditions, sewage entering the P-017 regulator structure continues through the side wall into to 30" effluent interceptor. During wet weather events, when the level in the chamber increases, surcharge conditions in the interceptor develop and the excess flow is discharged through the overflow pipe. The invert of the overflow pipe is only slightly above the crown of the effluent interceptor pipe. During dry weather conditions, it was observed that the effluent interceptor pipe is close to surcharge.

The 30" interceptor continues south along Sheridan Street, turns east along Patterson Street and runs beneath industrial property at the end of Patterson Street, between Grant Street and Elm Street. A 66"trunk sewer connects to the interceptor on Elm Street, and the effluent 78" interceptor continues to Second Street where it increases to 84" and turns south towards the diversion structure at outfall P-016. Regulator structure P-016 is a "leaping weir" structure. The 84" interceptor enters the leaping weir. Incoming flow falls into a 30"sewer during dry weather conditions and combines with the Eastside Interceptor behind the Second Street Pumping Station. During rainfall events, the flow increases and gains enough energy to "leap" over the interceptor into an 84" overflow pipe which discharges into the Raritan River. A netting chamber is located downstream of the diversion chamber.

2.1.3 Combined Sewer Regulators

The City of Perth Amboy collection system has been designed to regulate flows into the interceptor sewers via a series of “leaping weir” structures. These regulator structures allow dry weather flow to be conveyed through an orifice leading to the interceptor collection system, and during rainfall events, the flow increases and gains enough energy to “leap” over the orifice and enter the outfall pipe for discharging into the receiving water. A schematic of a leaping weir configuration is displayed in Figure 2-1.

The exact year of installation of all CSO outfalls is unknown; information presented in this report was taken from drawings dated 1934. These drawings, obtained from the City of Perth Amboy sewer department and prepared by Carr Engineering Associates, P. A., for multiple sewer system projects contain the dimensions of the majority of the regulator structures including configurations of leaping weirs. The dimensions for those leaping weirs not identified in the available plans were assumed using information gathered at the other diversion structures. The leaping weir openings were modeled as bottom outlet orifices connecting the influent trunk sewer with the lower interceptor pipe. A summary of combined sewer regulator structures associated with each permitted CSO outfall is presented in Table 2-1, and a summary of the configurations for the leaping weir diversion structures is presented in Table 2-2.

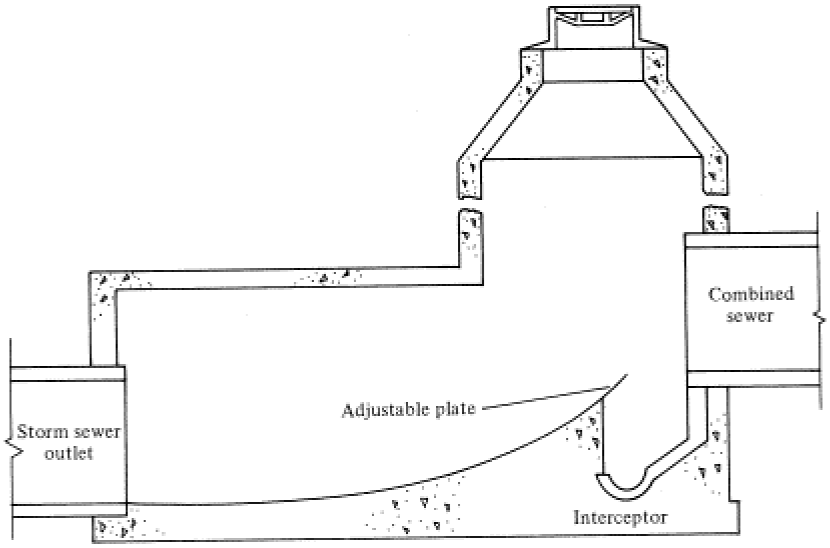


Figure 2-1 - Schematic of Adjustable Leaping Weir Regulator Structure

Source: Wastewater Engineering: Collection and Pumping of Wastewater. Metcalf & Eddy, Inc., 1981.

Table 2-1 - City of Perth Amboy Combined Regulator Structures

CSO Outfall ID	Regulator Location (Street)	Influent Sewer Invert Elevation (ft)	Influent Sewer Size & Material	Outfall Sewer Invert Elevation (ft)	Outfall Sewer Size & Material	Interceptor Sewer Invert Elevation (ft)	Interceptor Sewer Size & Material	Manhole Rim Elevation (ft)	Chamber Dimensions L x W x D (ft)
P-002	Rudyk Park	9.37	33" RCP	9.37	84" Brick	4.77	36" RCP	19.4	4' x 11'-3" x 14'-8"
P-003	Buckingham Ave.	7.6	36" Brick	7.6	36" CIP	5.1	48"RCP	30.3	4' x 7'-6" x 25'-2"
P-004	Washington St.	6	3'-6" x 4'-6" Brick	6	3' x 3'-6" Brick	3	48"RCP	22.8	4' x 8'-2" x 19'-10"
P-005	Commerce St.	4.3	36" Brick	5.32	36" RCP	1.7	48"RCP	11.3	4' x 6'-3" x 9'-7"
P-006	Fayette St.	4.14	2' x 3' Brick	2.94	48" CIP	1.04	48"RCP	15.9	5'-6" x 8' x 14'-10"
P-007	Smith St.	5.5	2'-6" x 3'-6" Brick	5.44	3' x 3'-6" RCP	0.7	48"RCP	11.5	4' x 7'-4" x 10'-10"
P-008	Gordon St.	N/A	36" RCP	N/A	3-4"' x 2'-6" Brick	2.9	15" RCP	15.27	10' x 10' x 9'
P-009	Lewis St.	8.65	15" VCP	8.75	16" CIP	5.68	36" RCP	16.95	4' x 5'-8" x 9'-1"
P-010	High St.	5.28	2' x 3' Brick	5.28	42" Brick	4.22	33" RCP	14	4' x 6'-2" x 10'-1"
P-011	State St.	4.52	2' x 3' Brick	4.52	36" RCP	2.74	33" RCP	16.77	4' x 6'-2" x 13'-8"
P-013	Brighton Ave.	5.02	2' x 3' Brick	3.17	36" RCP	1.65	33" RCP	15.82*	4' x 7'-6" x 14'-2"
P-014	Madison Ave.	5.4	2' x 3' Brick	3.69	36" RCP	N/A	33" RCP	14.88*	4' x 6'-6" x 10'-11"
P-015	First St.	4.49*	2' x 3' Brick	4.14	36" RCP	0.46	33" RCP	9.62*	4' x 7'-2" x 5'-2"
P-016	Second St.	3.32	84" RCP	3.32	84" RCP	0.32	30" RCP	14.3	4' x 11'-3" x 14'
P-017	Sheridan St.	13.53*	24" RCP	13.53	36" DIP	11.67*	30" RCP	29.82*	4' x 6'-2" x 18'-2"
P-019	Outer Smith St.	N/A	72" Brick	N/A	72" Brick	30.32	18" RCP	41.8	4' x 6'-3" x 18'-2"

Legend

CIP – Cast Iron Pipe; DIP – Ductile Iron Pipe; N/A – Not Applicable; RCP – Reinforced Concrete Pipe; VCP – Vitrified Clay Pipe

Elevations marked (*) are N.J. Geological Survey Datum, which equals City Datum +3.62 from 1934 Proposed City Plans.

Table 2-2 - Leaping Weir Diversion Structure Summary

Diversion Structure ID Number	Influent Pipe Size (ft)	Weir Widt h (ft)	Weir Length (ft)	Weir Width / Influent Pipe Width	Influent Cross Section (ft^2)	Sump Orifice Cross Section (ft^2)
2	7	3.33	0.667	0.48	38.5	2.2
3	3	1.08	0.667	0.36	7.1	0.7
4	3.5 x 4.5	1.67	0.583	0.48	15.8	1.0
5	2 x 3	1.25	0.417	0.63	6.0	0.5
6	2.33 x 3.5	1.83	0.583	0.79	8.2	1.1
7	2.33 x 3.5	1.33	0.542	0.57	8.2	0.7
8	3	1.08	0.667	0.36	7.1	0.7
9	1.25	0.70	0.700	0.56	1.2	0.5
10	2 x 3	1.25	0.458	0.63	6.0	0.6
11	2 x 3	1.25	0.458	0.63	6.0	0.6
13	2 x 3	1.25	0.458	0.63	6.0	0.6
14	2 x 3	1.25	0.458	0.63	6.0	0.6
15	2 x 3	1.25	0.458	0.63	6.0	0.6
16	7	3.33	0.667	0.48	38.5	2.2
17	Not a leaping weir					
19	6	3.33	0.667	0.56	28.3	2.2

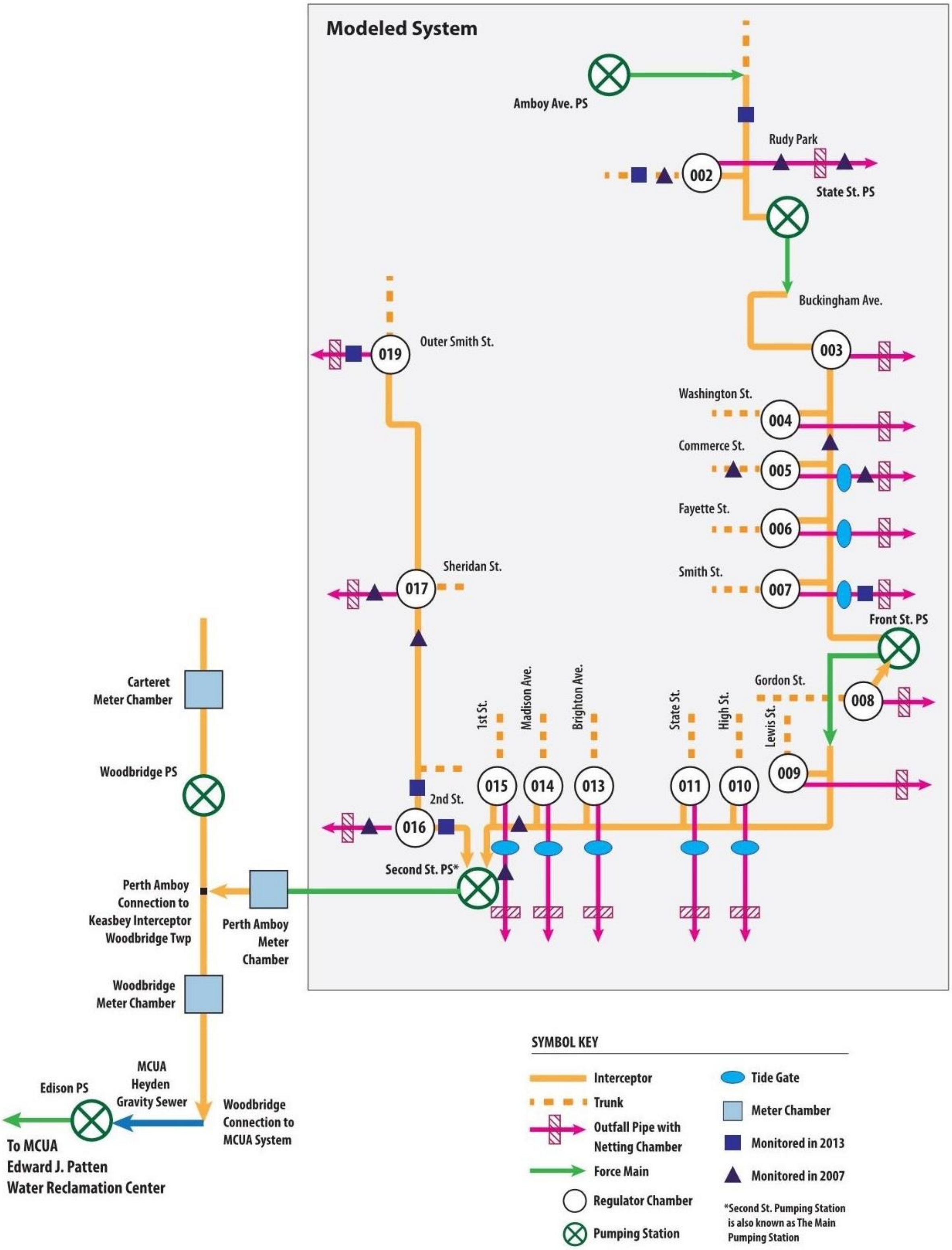


Figure 2-2 - Perth Amboy Combined Sewer Service System Schematic

2.1.4 Combined Sewer Outfalls

There are 16 combined sewer outfalls within the City of Perth Amboy, all owned by the city. A summary of these outfalls is in Table 2-3. The information presented in Table 2-3 is referenced from data contained in the original combined sewer system plans dated 1934; the exact age of the combined sewer outfalls is unknown. All outfalls have solids and floatables controls that were installed in 2000.

Table 2-3 - Combined Sewer Outfall Summary

CSO Outfall Number	CSO Outfall Location	Receiving Water	Outfall Pipe Diameter	Type of Material	Tide Gate?
P-002	Rudyk Park	Arthur Kill	84" elliptical	Brick	No
P-003	Buckingham Ave.	Arthur Kill	36"	Unknown	No
P-004	Washington St.	Arthur Kill	36"	Unknown	No
P-005	Commerce St.	Arthur Kill	36"	Unknown	Yes
P-006	Fayette St.	Arthur Kill	48"	Unknown	Yes
P-007	Smith St.	Arthur Kill	36"*	Brick	Yes
P-008	Gordon St.	Arthur Kill	36"	Unknown	No
P-009	Lewis St.	Arthur Kill	15"	Unknown	No
P-010	High St.	Raritan River	36"	Brick	Yes
P-011[1]	State St.	Raritan River	36"	Unknown	Yes
P-013	Brighton Ave.	Raritan River	24"	Unknown	Yes
P-014	Madison Ave.	Raritan River	36"	Unknown	Yes
P-015	First St.	Raritan River	36"	Unknown	Yes
P-016	Second St.	Raritan River	72"	Unknown	Yes
P-017	Sheridan St.	Raritan River	24"	Unknown	No
P-019	Outer Smith St.	Raritan River	60"	Unknown	No

[1] CSO Outfall P-012 was connected into the State St. outfall (Outfall P-011) during reconstruction of the bulkhead area netting chamber at sidewalk at intersection of Sadowsky Pkwy and Catalpa Ave.

▪

2.2 Baseline Condition Performance

2.2.1 Baseline Overflow Statistics

The Baseline Condition Model estimates the total overflow volume in the typical year using 2004 Newark Airport to be 386 MG. Table 2-4 lists the simulated annual CSO statistics for each CSO outfall. CSO volume, duration, and frequency were calculated using 24-hour inter event time.

P016 discharges over 100 MG in the typical year and is the largest CSO discharge point by volume, making up 26% of the system wide annual volume. P002 and P019 are the next two largest overflows with each discharging roughly 60 MG in the typical year. Together these three largest CSO discharge points account for about 60% of the total annual CSO volume in the system.

Two of these three largest CSO discharge points are located along the Westside Interceptor and discharge to the Raritan River.

The annual overflow duration ranges from over 900 hours to about 80 hours. P003 has the longest overflow duration of 939 hours. This duration is exceptionally long and impacted by two factors. First, P003 is located on the Eastside Interceptor immediately downstream of the State Street Pumping Station. Second, the capacity of the State Street Pumping Station is less than the peak flow rate from the upstream trunk sewers during most storms, which requires storage of the excess flow in the wet well and upstream trunk sewers. Stored flow is then gradually released into the downstream interceptor, which causes a prolonged period of elevated flow entering P003 regulator after each storm and long overflow durations.

Table 2-4 - Simulated Annual CSO Volume, Duration and Frequency

Location	Volume (MG/yr)	Duration (Hours/yr)	Frequency (Events/yr)	Peak Overflow Rate (mgd)	Percent of Total CSO	Receiving Water
P002	63.2	501	70	195.9	16%	Arthur Kill
P003	32.0	939	61	46.0	8%	Arthur Kill
P004	9.2	382	71	31.4	2%	Arthur Kill
P005	10.0	321	64	27.5	3%	Arthur Kill
P006	19.0	174	36	62.7	5%	Arthur Kill
P007	5.2	218	64	24.6	1%	Arthur Kill
P008	2.8	132	59	18.5	1%	Arthur Kill
P009	1.7	161	63	15.9	0%	Arthur Kill
P010	1.6	114	59	21.5	0%	Raritan River
P011	10.2	377	66	47.1	3%	Raritan River
P013	33.1	394	69	44.5	9%	Raritan River
P014	12.3	334	65	18.5	3%	Raritan River
P015	14.0	418	71	33.8	4%	Raritan River
P016	101.0	327	61	148.5	26%	Raritan River
P017	8.6	82	33	35.9	2%	Raritan River
P019	62.3	274	56	135.2	16%	Raritan River
System Total	386.4					
Maximum	101.0	939	71	195.9		
Minimum	1.6	82	33	15.9		
Average	24.1	321	61	56.7		
Median	11.3	324	64	34.9		

Outfall-specific overflow frequency ranges from 71 to 33 events for the typical year with a system-wide average of 61 events per year. Peak overflow rate is the largest flow rate that discharges from an outfall during the typical year. It ranges from 16 mgd (P009) to 196 mgd

(P002). P016 and P019 also have very high peak overflow rates of over 100 mgd. The outfalls that have high annual CSO volumes also have high peak overflow rates.

2.2.2 Baseline Percentage Capture

Percentage capture is used in the USEPA CSO Control Policy as one means to establish targets for CSO control in the LTCP. This metric is therefore useful for both the characterization of baseline performance and for the forthcoming evaluation of CSO control alternatives. Under the Policy's Presumption Approach, one control option is "the elimination or the capture for treatment of no less than 85% by volume of the combined sewage collected in the combined sewer system (CSS) during precipitation events on a system-wide annual average basis…" [59 FR 18962 section II-C4(a)(ii)].

Percentage capture is a more complex metric than CSO volume and frequency. This is the fraction (as a percentage) of wet weather flow in the combined sewer system that is captured for treatment. On a system wide basis, captured flow is the wet weather flow that passes through the headworks of the treatment plant or in Perth Amboy's case, it is the discharge of the Second Street Pumping Station. Of all the wet weather flow that enters the sewer system, the portion that is not captured includes overflows to area waterways at the CSO outfalls or to the surface as combined sewer system flooding.

To calculate percentage capture, first the wet weather period needs to be defined. In this case, simulated total flow entering the sewer system is compared to the dry weather flow rate (base groundwater flow and sanitary diurnal flow) for every time step. When the former is more than 10% greater than the latter, this time step is flagged as a wet weather time step. Wet weather time steps are flagged for the entire typical year. Simulated total wet weather flow (total system wet weather inflow) that entered the modeled sewer network is then summed for all the wet weather time steps. Finally, the system wide percentage capture is calculated using the following formula for fraction captured (which can be converted to a percentage):

$$Percentage\ Capture = 1 - \frac{(Total\ CSO\ Volume + Total\ Flooding\ Volume)}{(Total\ System\ Wet\ Weather\ Inflow)}$$

The system wide capture for Perth Amboy is 57%. The exact same method is used in alternative analysis to evaluate the impact on system wide percent capture.

2.3 Impacts on Receiving Water Bodies

The sixteen outfalls in the City discharge into two receiving waters, Arthur Kill and Raritan River.

Arthur Kill is a tidal straight of approximately 10 miles that connects Newark Bay with Raritan Bay. Perth Amboy sits on the western shore of the Arthur Kill. Arthur Kill serves as a boundary between New York and New Jersey and is primary used as a navigational channel for nearby industrial sites. It is periodically dredged for maintenance as a navigation route for commercial ship passage. The New Jersey stream classification for Arthur Kill along Perth Amboy's boundary is Saline Estuary 2 (SE2).

The Raritan Estuary is a tidally influenced body of water at the base of the approximately 70 mile long Raritan River and extends easterly to the Raritan Bay and further to the Atlantic Ocean.

Portions of the estuary are at the border of New Jersey and New York state. The New Jersey stream classification for Raritan Estuary is Saline Estuary 1 (SE1). In the *NJCSO Group Compliance Monitoring Program Report* (CMPR) developed by PVSC on behalf of the NJ CSO Group which Perth Amboy is a member of, the beach area between P010 and P016 was identified as a potential sensitive area.

The baseline discharges into each receiving water are listed below in Table 2-5.

Table 2-5 - Baseline CSO Discharge by Receiving Water

Receiving Water	Baseline Annual CSO, MG
Arthur Kill	141.5
Raritan River	244.9
Total	386.4

A Pathogen Water Quality Model of the complete NY/NJ harbor, including the Arthur Kill and Raritan River/Bay, has been developed by the NJ CSO Group and this model is being used to understand the pollutant sources and their relative contributions for the affected study area. Use of the NJ CSO Group water quality model is expected to indicate which level of control evaluated for the CSO outfalls is needed to demonstrate attainment of WQS and designated uses of the corresponding receiving waters. The Pathogen Water Quality Model is also intended to demonstrate the maximum pollutant reduction benefits reasonably attainable for the receiving waters. Final selection of the CSO controls for the LTCP will be supported by the forthcoming results of the modeling effort and presented in the subsequent Selection and Implementation of Alternatives Report.

2.4 Identification of CSO Outfall Groups

As identified in Section 2.1, the City of Perth Amboy owns and operates 16 CSO outfall points which discharge to the Arthur Kill (Saline Estuary SE2) and Raritan River (Raritan Estuary)(Saline Estuary SE1) as shown in Table 2-6.

The outfalls that discharge to the Arthur Kill include CSOs P-002 through P-009, and the outfalls that discharge to the Raritan River include CSOs P-010, P-011, P-013 through P-017, and P-019.

The CSOs are divided into groups to evaluate consolidation alternatives. The groups are identified by receiving water and the proximity of the CSO outfall points to each other. Table 2-6 summarizes the CSO groups and Figure 2-3 shows the CSO Groups on the service area map.

Table 2-6 - CSO Groups Shown on Service Area Map

CSO Oufall Group Number	CSO Outfall Number	CSO Outfall Location	Receiving Water	Outfall Pipe Diameter
1	P-002	Rudyk Park	Arthur Kill	84" elliptical
2	P-003	Buckingham Ave.	Arthur Kill	36"
	P-004	Washington St.	Arthur Kill	36"

CSO Oufall Group Number	CSO Outfall Number	CSO Outfall Location	Receiving Water	Outfall Pipe Diameter
	P-005	Commerce St.	Arthur Kill	36"
	P-006	Fayette St.	Arthur Kill	48"
	P-007	Smith St.	Arthur Kill	36"
	P-008	Gordon St.	Arthur Kill	36"
3	P-009	Lewis St.	Arthur Kill	15"
	P-010	High St.	Raritan River	36"
	P-011[1]	State St.	Raritan River	36"
	P-013	Brighton Ave.	Raritan River	24"
	P-014	Madison Ave.	Raritan River	36"
	P-015	First St.	Raritan River	36"
	P-016	Second St.	Raritan River	72"
4	P-017	Sheridan St.	Raritan River	24"
5	P-019	Outer Smith St.	Raritan River	60"

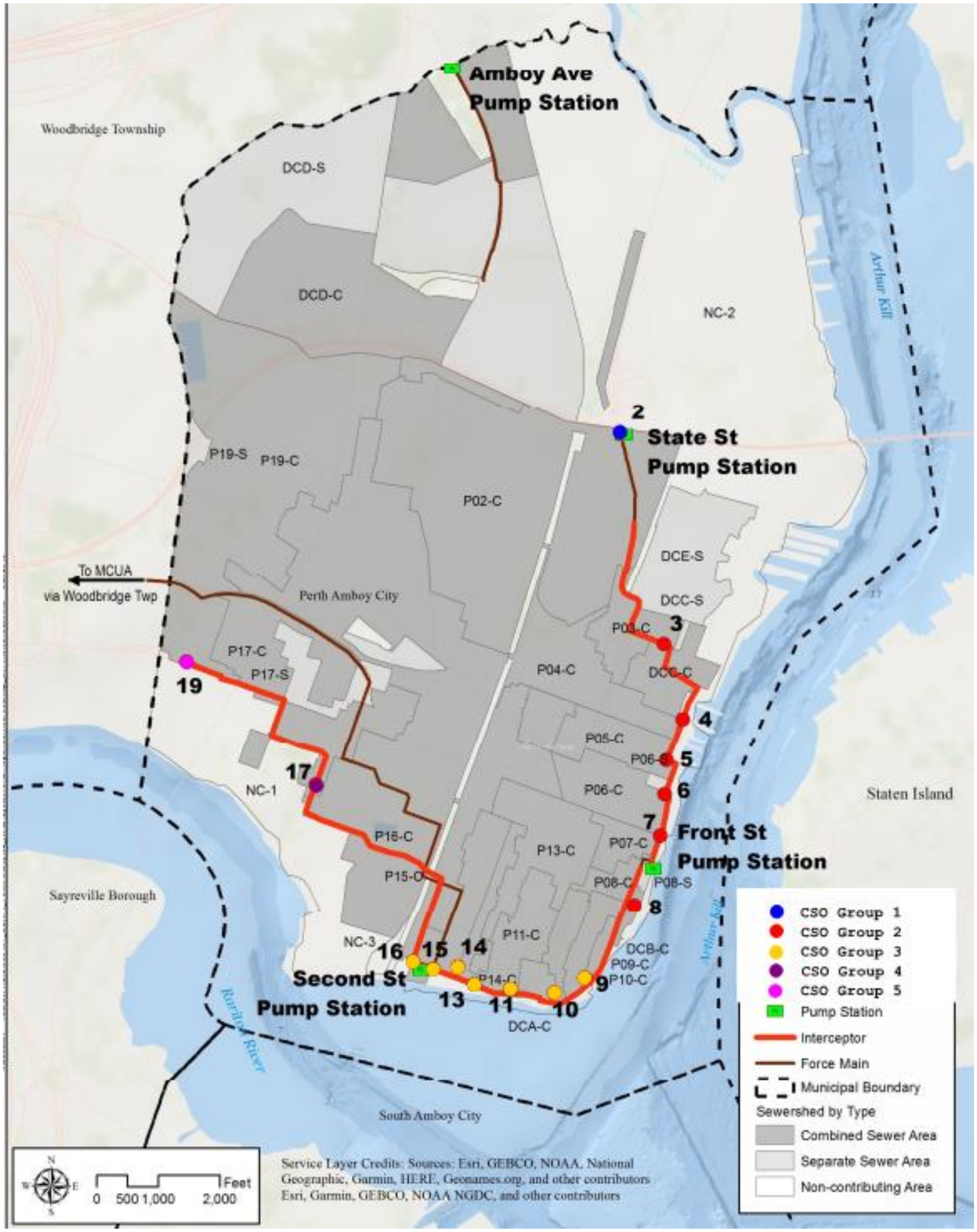


Figure 2-3 - CSO Groups Shown on System Schematic

2.4.1 CSO Group 1

The CSO P-002 diversion chamber is located at the northern-most CSO point on the Eastside Interceptor. The outfall discharges to a marsh area below the Outerbridge Crossing. From the outfall, the discharge flows by gravity along a small tributary feeding into the Arthur Kill. This CSO will be evaluated separately because of the distance to the other CSOs and its large annual CSO volume (36%).

2.4.2 CSO Group 2

CSO P-003 through P-008 are located along the eastern shoreline of Perth Amboy and the outfalls discharge to the Arthur Kill. They are located upstream of Front Street Pumping Station and make up to 20% of the total annual CSO volume.

2.4.3 CSO Group 3

Although CSO P-009 discharges to the Arthur Kill, near the confluence with the Raritan Bay, it is grouped with P-010, P-011, and P-013 through P-016 because they are all near the beach along the southern shoreline of Perth Amboy and downstream from Front Street Pumping Station. The total annual CSO from these seven outfalls add up to 45% of the system total annual CSO volume and is the biggest group by volume or peak flow. P-016 is the single largest CSO (26%) in the entire system.

2.4.4 CSO Group 4

CSO P-017 outfall discharges to a creek west of Sheridan Street, tributary to the Raritan Bay. This CSO will be evaluated separately because of the distance to other CSOs.

2.4.5 CSO Group 5

CSO P-019 outfall discharges to a swale on Hess Oil property, and from this swale, the outfall transitions to an RCP and discharges at a bulkhead on the Raritan Bay. This CSO will also be evaluated separately because of the distance to other CSOs.

Section 3

CSO Control Objectives

3.1 Compliance with NJPDES Permit Requirements

The CSO control objectives for both the City of Perth Amboy and MCUA are to comply with the current requirements of the following NJPDES Permits:

- City of Perth Amboy –NJPDES Permit No. NJ0156132
- MCUA – NJPDES Permit No. NJ0020141

MCUA's additional objective in this regard is to assist the City of Perth Amboy in developing any CSO alternatives that maximize storage or treatment at the CTP.

More specifically, both the City's and MCUA's NJPDES CSO permits indicate at least one of the following criteria must be met if the permittee chooses the Presumption Approach (G.4.f)

i. No more than an average of 4 overflows events per year.

ii. The capture for treatment of at least 85% by volume of the combined sewage collected by the combined sewer system on a system wide annual average basis.

iii. The elimination or removal of the mass of pollutants causing water quality impairment for volume that would be captured in (ii) above.

These objectives address the Presumption Approach requirements in the EPA CSO Policy and the NJPDES CSO permits, and a range of control levels has been evaluated to enable cost/performance considerations to be incorporated into the final selection of controls.

In order to address the Demonstration Approach requirements, the Pathogen Water Quality Model simulations are being undertaken through the NJ CSO Group to understand the pollutant sources and their relative contributions for the affected study area. Use of the NJ CSO Group water quality model is expected to indicate which level of control evaluated for the CSO outfalls is needed to demonstrate attainment of WQS and designated uses of the corresponding receiving waters. The Pathogen Water Quality Model is also intended to demonstrate the maximum pollutant reduction benefits reasonably attainable for the receiving waters. Final selection of the CSO control approach (either Presumption or Demonstration) will be made when identifying the selected controls for implementation and will be presented in the subsequent Selection and Implementation of Alternatives Report.

3.2 Protection of Sensitive Areas

There has been a detailed investigation of the subject waterbodies relative to the established criteria used to designate Sensitive Areas as defined in the USEPA CSO Control Policy (59 FR 18,688; April 19, 1994) and reiterated in the NJDEP Combined Sewer Management permit issued in October 2015 to Perth Amboy. This work has been performed by PVSC on behalf of the NJ CSO

Group, as part of the current efforts under the October 2015 Combined Sewer Management permits issued by NJDEP to the individual members of the Group. The reader is directed to the Consideration of Sensitive Areas Report, submitted by PVSC on behalf of the NJ CSO Group, for further information about Sensitive Areas in the subject waterbodies. It should be noted that the PVSC report describes one area in Perth Amboy that the City has identified for special consideration. This area is also described below in this section.

A proposed bathing beach is located on the north shore of the Raritan Bay, near the confluence of the Raritan River and the Arthur Kill, at the southeastern boundary of the City of Perth Amboy, displayed in Figure 3-1. These beaches are not currently designated by the City for recreational bathing use due to water quality concerns, specifically periodic non-attainment of pathogen water quality standards in the vicinity of the beaches. For this reason, signs have been installed by the City at the beaches to advise the public not to swim or enter the water in this area. However, there is significant public interest in restoring public use of the beaches for recreational bathing and there are active discussions underway to accomplish this objective.

The cause or causes of non-attainment are not yet fully known, but the discharge of CSOs at seven CSO outfalls located in the immediate area of the beaches is believed to be a significant factor. The City plans to conduct additional analysis of water quality conditions in the subject waterbody to determine the feasibility of achieving sufficient improvement to support restoration of public use of the beaches for recreational bathing. This additional analysis will be conducted during development of the final LTCP documentation.

The City of Perth Amboy advised PVSC of these circumstances for purposes of the aforementioned Consideration of Sensitive Areas Report prepared by PVSC on behalf of the NJ CSO Group. The City took this action recognizing that the USEPA CSO Control Policy defines Sensitive Areas to include "waters with primary contact recreation" (which includes recreational bathing beach waters). The CSO Policy states that such areas should be given special consideration in the Long-Term Control Plan, including elimination or relocation of CSO discharges.

Because the subject beaches are not currently designated by the City as public use bathing beaches, and only occasional and unauthorized recreational bathing occurs there, the City does not regard the beaches as a Sensitive Area. Further, as noted above, the City has not yet determined that it is feasible to restore water quality to the extent necessary to support safe public use of the beaches for recreational bathing, as pathogen discharges upstream on the Raritan River and/or from other sources into the Raritan Bay may preclude attainment of water quality standards even after the local CSO discharges are addressed.

However, because there has been significant public interest in and discussion of restoring the beaches for public use as recreational bathing beaches, this area is being acknowledged here. If the City at some future time determines that it is feasible to achieve sufficient water quality improvement to support safe public use of the beaches for recreational bathing, the subject beach area could be designated as a Sensitive Area at that time.

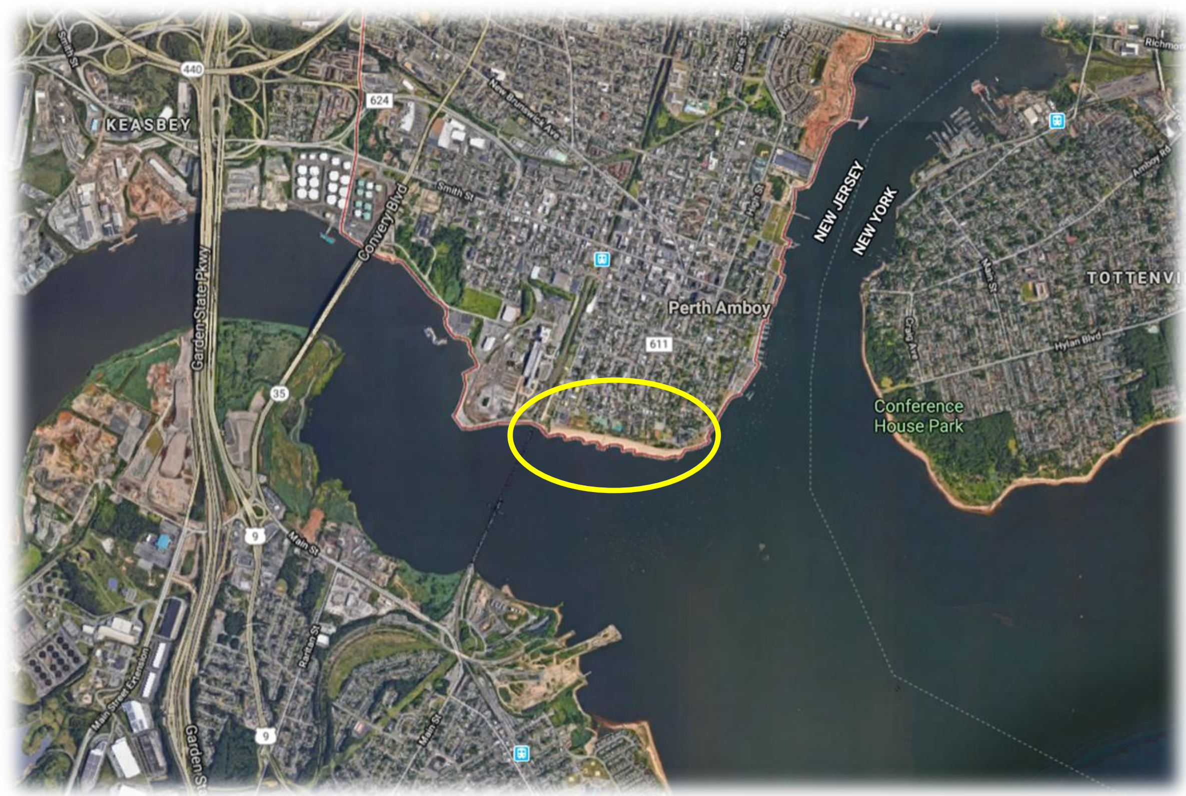


Figure 3-1 - Area of Proposed Bathing Beach (not currently used)

3.3 Improve Water Quality

This LTCP will seek to provide water quality benefits to the receiving water bodies commensurate with the expenditure of public funds. As noted above, the evaluations necessary to define these benefits are being performed pursuant to the Presumption and Demonstration Approaches defined by both national policy and the NJPDES CSO permits.

In support of the Presumption Approach, various technologies are evaluated in the following sections of this report for a series of control levels, e.g. 85% capture, 0 to 20 overflows per year.

3.4 Supplemental CSO Team

The Supplemental CSO Team has further indicated the following should be considered CSO Control Objectives.

- Any new infrastructure should be as unobtrusive as possible.
- Incorporate as much green infrastructure as possible into the LTCP. The Team has suggested the City consider up to 15-20% reductions in impervious area throughout the City.
- New infrastructure implemented as part of the LTCP should be resilient as required by NJDEP and code requirements. In light of the City's past history with regard to damage suffered during Superstorm Sandy, facilities should be designed for climate change as well.

- Integrate the planning for the LTCP into the City's Redevelopment Plan so the two plans are coordinated.

Section 4

Identification and Screening of CSO Control Technologies

4.1 Screening Process

Each technology is described below and evaluated in general terms of effectiveness and feasibility. Technologies that have major drawbacks or are not applicable for implementation or that offer no benefit to the CSO mitigation program were eliminated from further consideration. Technologies that should be considered as long-term CSO mitigation alternatives are evaluated further in Section 6. Specific factors that deem whether a technology is appropriate include: the current condition of the sewer system, the characteristics of the wet weather flow (location, peak flow rate, volume, frequency and duration), hydraulic and pollutant loading, climate, implementation requirements (land, neighborhood, noise, disruption), and maintenance requirements.

The CSO abatement technologies considered for this report are listed in The applicability of the technologies is summarized in the table below.

Table 4-16 and the results of the technology evaluation/screening are identified. The technologies have been identified by the following categories:

1. Viable Technologies for Significant Control;
2. Useful but Limited Application;
3. Technologies with Major Drawbacks (eliminated from further consideration); and
4. Not Applicable (eliminated from further consideration).

4.1.1 Viable Technologies for Significant Control

Viable technologies for significant control include those technologies that will reduce and/or eliminate CSO discharges and impacts and are being carried forward for further evaluation as a LTCP technology.

4.1.2 Useful but Limited Application

Technologies that are useful but with limited application include those that are only applicable in combination with other approaches (e.g. fine screens as a pre-treatment for chlorination, etc.) and approaches that only have limited effectiveness (e.g. source controls, regulator adjustments, etc.).

4.1.3 Technologies with Major Drawbacks

Technologies with major drawbacks include those that cannot justify their implementation due to complexity or severely limited costs vs. benefits. These technologies are not considered appropriate for CSO control for Perth Amboy or MCUA because they will not work effectively, costs outweigh the water quality benefits, or they will not reduce water quality impacts to the extent required. Once designated, such technologies are eliminated from further consideration.

4.1.4 Not Applicable

Technologies that could not be implemented in the Perth Amboy system, such as siting limitation for satellite facilities at specific outfalls, are deemed "Not Applicable" and are eliminated from further consideration. .

4.2 CSO Control Technologies

In the Passaic Valley Sewerage Commissioners CSO Long Term Control Plan Updated Technical Guidance Manual (TGM), CSO abatement technologies were divided into five general categories:

- Source Control Measures - Source control techniques can be employed to either decrease the quantity of water entering the system or minimize certain pollutants from the waste stream at their source (quality control). Generally, source control techniques do not require significant structural improvements and thus have minimal capital costs. However, these measures can be labor intensive and, therefore, have high operation and maintenance costs. The intent of implementing a source control measure is ultimately to help reduce or eliminate more capital-intensive downstream (structural) CSO control facilities.

    - Quantity Control Measures - Quantity control measures are intended to reduce and/or eliminate portions of the wet weather flow generated in the basin tributary to the CSO regulator. Quantity control measures include Green Infrastructure (GI) including the use of vegetated practices and permeable pavements.

    - Quality Control Measures - Quality control measures help to reduce pollutant concentrations at sources in the tributary basins and improve stormwater runoff quality before it enters the combined sewer system. Measures that have previously been implemented include Fat, Oil, and Grease Control Maintenance Program and end of pipe controls. Fats, oil and grease buildup in the sewers have been known to cause sewer backups in certain areas, however, a regular maintenance program has been instated in these areas which has allowed issues to be resolved in a timely manner. Perth Amboy installed solids and floatable controls on all of its CSO outfalls in 2000. No additional quality control measures are evaluated.

- Storage Technologies - Storage facilities are typically used to hold CSO discharge until after a storm event, at which time the flow can be conveyed to the treatment plant. Storage of CSO flows can be performed either at a local site adjacent to a regulator (or other control device), or downstream at a central site that consolidates the need for several facilities. Storage technologies generally represent larger, more costly structural modifications to a combined sewer system. These modifications are rarely undertaken without a complete assessment of the CSO discharges and interceptor system and the preparation of a system-wide facilities plan. These technologies include inline storage, off-line storage, and a storage option at the MCUA CTP.

- Collection System Controls - Collection system controls and modifications are intended to reduce CSO flows within the interceptor system by removing inflow sources, increasing the use of existing interceptor capacity and pipeline storage, and/or optimizing performance of the collection system. These controls include regulator modifications, sewer separation, and infiltration/inflow control.

- Treatment Technologies - Treatment technologies target reduction of pollutant loads in combined sewer overflows to receiving waters. In accordance with the USEPA CSO Policy, minimum treatment is defined as primary clarification, solids and floatables disposal, and disinfection, if necessary. The treatment technologies evaluated herein address specific pollutants, such as suspended solids, floatables, chemicals, or bacteria. Treatment residuals must be addressed as part of the implementation plan. Technologies used for treating CSOs prior to discharge are presented below.

The TGM provided detailed description of each technology, discussed their applicability and limitations, and presented available cost information. It is included in this report as Appendix A for easy reference. The following subsections discuss the applicability of each technology specific to the City and MCUA.

4.2.1 Green Infrastructure

The NJPDES permits issued in 2015 require permittees to evaluate Green Infrastructure as one of the CSO control alternatives.

The term "Green Infrastructure" is sometimes used to describe an array of source controls measures designed to capture stormwater before it enters the combined sewer collection system, as well as initiatives and regulatory requirements that reduce or limit runoff and pollutant loads. The Green Infrastructure described in this section refers to physical structures that retain or detain stormwater runoff near where it originates. These structures are not necessary "green" in terms of being vegetated.

Green Infrastructure practices are designed to reduce the volume and/or peak of stormwater runoff that entering the combined sewer system. In retention systems, such as a rain garden, the runoff is routed to a permeable surface and allowed to infiltrate back into the ground. By preventing this stormwater from ever entering the collection system, the volume of overflow and associated pollutant loads discharging to the receiving waters is reduced. In detention systems, runoff is routed to a storage unit and returned to the combined sewer collection system, ideally after conveyance and treatment capacity have returned. By attenuating these flows, the conveyance system can accept a greater percentage of the overall runoff volume over a longer period of time, resulting in a net reduction of overflow volume and pollutant loads to the receiving waters.

There are many different types of GI as detailed in the TGM and listed below.

- Vegetated Practices
  - Rain Gardens

- Right-of-Way Bioswales
- Enhanced Tree Pits
- Green Roofs

▪ Permeable Pavements

- Porous Asphalt
- Pervious Concrete
- Permeable Interlocking Concrete Pavers

Green Infrastructure (GI) is a useful CSO control technology. For the purpose of this report, GI is applied as a planning level alternative assuming 10% of the runoff from impervious areas of the City is treated by GI. Specific GI projects will be evaluated during the next phase of the LTCP on a site-specific basis as to which type of GI is most suitable and effective.

For the purpose of this LTCP, where Green Infrastructure is integrated into a planning scenario or alternative, we have assumed 10% reductions in pervious areas. This is slightly less than the goal of 15-20% recommended by the Supplemental CSO team. If the City is able to achieve implementation of higher levels of green infrastructure, this can be viewed as a factor of safety for the provisions contained the LTCP or can be used to rationalize the design of improvements once those improvements are undertaken by the City.

4.2.1.1 Vegetated Practices

Many green infrastructure practices are in fact “green”, in that they have a vegetative layer. That vegetative layer usually aides in the retention of stormwater runoff through transpiration, and the root system helps to promote soil porosity and aids infiltration. The green infrastructure practices also provide ancillary benefits, such as beautifying neighborhoods, improving air quality, and reducing urban heat. Through this section, several vegetated green infrastructure practices will be discussed:

- Rain Gardens
- Right-of-Way Bioswales
- Tree Pits
- Green Roofs

4.2.1.1.1 Rain Gardens

Description of Practice

A rain garden consists of a shallow depressed area that is designed to collect stormwater runoff from surrounding surfaces. The collected water infiltrates into the ground, evaporates back into the atmosphere, or is transpired by the vegetation. To increase water absorption and promote infiltration, rain garden designs typically include an upper layer of amended soil with high porosity.

Plant selection and maintenance is critical to the long-term viability of a rain garden. Native plants should be selected that are capable of withstanding periods of ponded water as well as periods of dryness. Using native plants helps to reduce the amount of maintenance that will be required. Figure 4-1provides a picture of a typical rain garden.

Figure 4-1 - Photo of Rain Garden

(Source: http://www.epa.gov/soakuptherain/soak-rain-rain-garden)

Applicability to The Project

Rain gardens can be implemented on public and private properties to capture and retain runoff. When properly designed and maintained they can provide aesthetic improvements to the urban landscape, natural wildlife habitat, and education opportunities for schools. Their shallow and relatively simple design means they can often be constructed without the use of heavy machinery.

Rain gardens are already used in CSO programs across the Country, and within the State of NJ. The Camden County Municipal Utility Authority (Camden County MUA) has installed an ~800 square foot rain garden that captures runoff from ~2,000 square feet of surrounding roadway.

Limitations

Proper rain garden design generally allows for a loading ratio of 5:1, with a maximum of about 10:1. The loading ratio is the ratio of contributing drainage area to the available infiltration area. In other words, to control runoff from a 500 square foot rooftop, a 100 square foot rain garden would be required. Infiltration practices that function at higher loading ratios have increased risk for failure due to the higher hydraulic, sediment, and pollutant loads.

The small loading ratio means that rain gardens require relatively large amounts of space. This makes them impractical for wide-spread public right-way application where such space is not available.

Construction Costs

The cost for constructing a rain garden can vary significantly based upon the complexity of the design, the location it is being built, and other local factors. The NJDEP guidance document "Review of GI as a Component of LTCPs" provides a range of $11/sf to $35/sf for construction costs, in 2016 dollars, compiled from projects across the United States. For wide-scale green infrastructure planning, costs are often normalized to units of dollars per impervious acre controlled. Using the 5:1 loading ratio, this range of construction costs is $96,000 to $305,000 per acre controlled which is in-line with local project experience.

4.2.1.1.2 Right-of-Way Bioswales

Description of Practice

The right-of-way bioswale is a curb-side green infrastructure design being widely employed as part of New York City's green infrastructure program for CSO control. To date several thousand units have been constructed or are in construction. There are several variations of the design with different widths and depth (right-of-way greenstrips, right-of-way raingardens) but the functionality is essentially the same.

The typical right-of-way bioswale is between 4 and 5 feet wide by 10 to 20 feet long. They are constructed in the existing sidewalk, with curb cuts to allow street runoff traveling along the gutter to enter the bioswale on the upstream side and excess flow to return to the street on the downstream side. It is this conveyance aspect of the practice that makes it a bioswale instead of a deep raingarden.

On the surface, the right-of-way bioswale looks and functions much like a rain garden described above. The unit includes a shallow ponding area, and a vegetative surface that may or may not include a tree. However, whereas a raingarden is generally less than a foot deep, the right-of-way bioswale is approximately 4 ½ feet deep. The first 2 ½ to 3', depending on the design is made up of an engineered soil designed to allow for rapid infiltration. The lower portion of the bioswale is a stone base to provide storage. A rendering of a New York City bioswale is provided in

Figure 4-2 - Rendering of Right-of-Way Bioswale

(Source: www.nyc.gov/html/dep/html/stormwater/bioswales.shtml)

Applicability to The Project

The right-of-way makes up a significant amount of a city' impervious cover. Sidewalks and streets are generally pitched to capture and convey runoff directly towards the collection system, making them efficient locations to intercept the flow. Furthermore, the municipality already has ownership of these areas.

New York City is constructing thousands of right-of-way bioswales to capture urban runoff before it enters their combined sewer collection systems. The designs could easily be adapted to meet the needs of other combined sewer municipalities.

Limitations

The New York City standard design process sizes the bioswales based upon the calculated volume that can be managed through infiltration through the native surrounding soils, and storage within the unit, during a specified period. This generally results in loading ratios well above standard rule of thumb loading ratios for bioinfiltration practices. To date New York City's post construction monitoring program has shown that overall the units are functioning at or beyond their intended designs, but long-term monitoring results are not yet available. Permittees should consider the potential failure risks of utilizing similarly high loading ratios.

Constructing bioinfiltration practices in the sidewalk requires that the existing sidewalks are wide enough to allow for the feature while still maintaining functionality for pedestrian traffic. The ability to site right-of-way bioswales will have to be determined by each permittee.

Construction Costs

The construction costs for right-of-way bioswales is estimated to be approximately $15,000 unit, which equates to approximately $150,000 per acre controlled. These costs are based on large construction contracts generally including 100 – 200 units where an economy of scale can be achieved. For single unit or low quantity construction estimates, the costs can be significantly higher.

4.2.1.1.3 Enhanced Tree Pits

Description of Practice

Enhanced tree pits, or stormwater trees, can appear similar to a standard city tree pit. Unlike a standard tree pit, however, they utilize an underground system designed to infiltrate runoff. The underground system includes engineered soil capable of rapidly infiltrating water, crushed stone, and an underdrain system. Although they can be built individually, they become more effective when they are installed as a connected multi-unit linear system. In such a system, permeable pavement can be used between the tree pits to allow additional water to infiltrate into a subsurface stone layer that connects the tree pits. A photo of an enhanced tree pit is provided in Figure 4-3.

Figure 4-3 - Photo of Enhanced Tree Pits

Applicability to The Project

Enhanced tree pits are already in use in cities across the United States as storwmater control measures. They can be constructed in sidewalks, in parking lots, courtyards, etc.

Limitations

The design of enhanced tree pits can vary greatly based on capture needs. The limitation for applicability is similar to those described for rain gardens and bioswales, depending on the desired loading ratio and available space.

Construction Costs

Pre-fabricated tree pits are available for approximately $10,000 each, and each and cost about $5,000 to install.

4.2.1.1.4 Green Roofs

Description of Practice

A green roof generally consists of a vegetated layer on top of a lightweight soil medium, below which lies an underdrain system and waterproof membrane. The depth of the soil medium will determine the type of vegetation that can be sustained and also the weight of the vegetated roof.

A portion of the precipitation that falls on the vegetated surface is retained in the soil medium and eventually released back to the atmosphere through evaporation and taken up through transpiration. The underdrain system acts as additional detention system before the excess water is eventually discharged through the buildings downspouts to the ground or directly into the combined sewer system. A photo of the green roof on Chicago's City Hall is shown in Figure 4-4.

Figure 4-4 - Photo of Green Roof on Chicago City Hall

(Source: www.greenroofs.com/)

Applicability to The Project

Green roofs have been constructed in cities around the world and across the country, including as part of CSO programs.

Limitations

Wide spread application of green roofs is generally cost prohibitive. Most existing buildings cannot support the additional weight of a green roof without costly retrofitting.

Green roofs are generally designed with a loading ratio of 1:1, meaning that the managed area is limited to the footprint of the vegetated area itself.

Construction Costs

The cost for constructing a green roof can vary significantly based upon the complexity of the design, the location it is being built, and other local factors. The NJDEP guidance document "Review of GI as a Component of LTCPs" provides a range of $11/sf to $56/sf for construction costs, in 2016 dollars, compiled from projects across the United States. Using the 1:1 loading ratio, this range of construction costs is $480,000 to $2,440,000 per acre controlled which is in-line with local project experience.

4.2.1.2 Permeable Pavements

The term Permeable Pavements refers to several distinct surfaces, each of which are intended to provide a reduction in stormwater runoff as compared with traditional paving methods. The nomenclature for these different surfaces is often used interchangeably and can be confusing. The major types of permeable pavements will be discussed in this section, including:

- Porous Asphalt
- Pervious Concrete
- Permeable Pavers

4.2.1.2.1 Porous Asphalt

Upon closer inspection, porous asphalt looks like a somewhat courser version of traditional asphalt, or "blacktop". Porous and traditional asphalt are made in a similar fashion, but the fine particles are left out of the porous asphalt mix. Without the fines, air becomes trapped in the asphalt mix creating pore space through which water can migrate.

Below the porous asphalt layer, a stone layer acts as a reservoir to store water before it infiltrates into the native soil. An underdrain system may also be included.

Figure 4-7 provides a picture of a parking lot in which half was paved using porous asphalt (right side of photo) and the other half was paved using traditional asphalt (left side of photo).

Figure 4-5 - Porous Asphalt Parking Lot

(Source: http://www.epa.gov/soakuptherain/soak-rain-permeable-pavement)

Applicability to The Project

Porous pavement has been used successfully for decades to reduce ponding, flooding, and stormwater discharges. Many combined sewer cities are now using porous pavement as part of their CSO control strategy. Porous asphalt should be considered when roads or parking lots are to be constructed or repaved.

Limitations

Porous pavement requires additional maintenance, including regular service with a vacuum truck to help maintain the open pore space. The use of salt or sand for snow melting is also discouraged. Applications of porous asphalt are typically not recommended in high traffic or heavy industrial sites due to the increased sediment and pollutant loads.

Construction Costs

The cost for porous asphalt can vary significantly based upon whether it new surface or a retrofit. The NJDEP guidance document "Review of GI as a Component of LTCPs" provides a range of $12/sf to $25/sf for construction costs, in 2016 dollars, compiled from projects across the United States. For wide-scale green infrastructure planning, costs are often normalized to units of dollars per impervious acre controlled. Using a 2:1 loading ratio, this range of construction costs is $260,000 to $545,000 per acre controlled which is in-line with local project experience.

4.2.1.2.2 Pervious Concrete

Description of Practice

Pervious concrete is a concrete mix containing little or no sand, which creates pore space through which water can migrate. Pervious concrete functions similarly to porous asphalt in that water migrates through the pavements void space down into an underlying stone bed, and either infiltrates to the natural soil or enters an underdrain system. A photo of a pervious concrete

Figure 4-6 - Pervious Concrete Panel

application is shown in

(Source: http://www.pacificpervious.com/portfolio-1)

Applicability to The Project

Pervious concrete pavement has been used successfully for decades to reduce ponding, flooding, and stormwater discharges. Many combined sewer cities are now using pervious concrete as part of their CSO control strategy. Pervious concrete can be considered for sidewalks, courtyards, or anywhere else that traditional concrete may be used.

Limitations

Pervious concrete requires additional maintenance, including regular service with a vacuum truck and pressure washing to help maintain the open pore space. The use of salt or sand for snow melting is also discouraged.

Construction Costs

The cost for pervious concrete can vary significantly based upon the type of application. The NJDEP guidance document "Review of GI as a Component of LTCPs" provides a range of $14/sf to $28/sf for construction costs, in 2016 dollars, compiled from projects across the United States. For wide-scale green infrastructure planning, costs are often normalized to units of dollars per impervious acre controlled. Using a 2:1 loading ratio, this range of construction costs is $305,000 to $610,000 per acre controlled which is in-line with local project experience.

4.2.1.2.3 Permeable Interlocking Concrete Pavers (PICP)

Description of Practice

Unlike previous concrete, permeable pavers do not allow water to pass through the concrete. Instead, the joints between the impervious concrete pavers are filled with a permeable medium such as small stone or sand, allowing water to infiltrate between the pavers. The subsurface includes as stone base and an underdrain, if required.

A photo of a Philadelphia parking lot utilizing concrete permeable pavers is shown in Figure 4-9.

Figure 4-7 - Permeable Interlocking Concrete Pavers

(Source: USEPA)

Applicability to The Project

As with the other types of permeable pavements, permeable interlocking concrete pavers are being used across the country for stormwater control.

Limitations

Permeable interlocking concrete pavers requires including regular service with a vacuum truck. Proper erosion control is required on the surrounding areas to prevent additional loading to the pavers and clogging.

Construction Costs

The cost for permeable pavers can vary significantly based upon the desired design and type of application. The NJDEP guidance document "Review of GI as a Component of LTCPs" provides a range of $12/sf to $34/sf for construction costs, in 2016 dollars, compiled from projects across the United States. For wide-scale green infrastructure planning, costs are often normalized to units of dollars per impervious acre controlled. Using a 4:1 loading ratio, this range of construction costs is $130,000 to $370,000 per acre controlled which is in-line with local project experience.

4.2.2 Increased Storage

Storage technologies are used to store flow for subsequent treatment at the wastewater treatment facility when downstream conveyance and treatment capacity are available. Two general types of storage need to be considered: in-line storage, which is storage in series with the sewer; and off-line storage, which is storage in parallel with the sewer. More detailed information on each type and sub-type is provided below.

4.2.2.1 In-Line Storage

In-line storage is generally developed in two ways. One way would be to use control structures to store the flows from smaller storm events (those below the design storm for the facilities) using the excess pipe capacity within the existing sewer. The other, also used with a control structure, is to replace segments of the existing sewer with larger diameter pipes to act as storage units. In both cases the use of in-line storage typically needs large diameter pipe with flat slopes. In-line storage within the existing combined sewer system is currently provided to some extent by the overflow weir typically used in existing CSO control facilities. Maximizing that storage, selecting the location of other flow control structures, and sizing of these facilities must be determined and verified by using a calibrated and verified hydraulic model.

In-line storage facilities require an extensive control and monitoring network. These includes flow regulators, such as orifices, weirs, flow throttle valves, automated gates and continues monitoring network such as level sensors, rain gages, flow monitors, and overflow detectors. Effective and efficient in-line storage requires the utilization of site-specific information together with modeling data and information on downstream flow elevations and available capacity.

Using Existing Sewers

Existing sewers can sometimes provide additional in-line storage by installing an in-line weir structure or flow regulator within a pipe section or at a manhole. On large diameter sewers, the weir structure would typically consist of an inflatable rubberized fabric dam, which could be pressurized to create an impoundment on the upstream of the regulator and thus create inline storage. Another flow regulator that has been used to develop in-line storage is an automatically controlled sluice gate. Instrumentation is typically provided for automatic control to prevent overloading the system. Sections of pipe utilized for in-line storage should not have any service lateral connections or should be deep enough to prevent sewage backups within the system.

The storage available in a sewer is directly related to the cross-sectional area of the sewer that is typically unused during typical wet weather events. Typical storage requirements for wet weather flows are in the tens or hundreds of thousands of gallons. A 4-foot (48- inch) diameter circular pipe has a total capacity of less than 100 gallons per foot, a 6- foot (72-inch) pipes has a total capacity of around 210 gallons per foot, while a 6-foot x 12-foot rectangular section has a total capacity of around 540 gallons per foot.

Most combined sewer systems within the region were constructed during the period of 1880 through 1920 when few paved roads and concrete sidewalks and other impervious areas were limited to roofs. Land development, changes within land use, and changes in sewer utilization over the past century have all impacted the flow characteristics of most combined sewer systems. Most of the combined sewer systems within the region have a diameter of 48-inch or less. These sewers are expected to have little or no storage capacity due to increase inflow rates and limited pipe size and slope.

A CSO Facility Plan was completed by Hatch Mott MacDonald in 1983 for the Passaic Valley Sewerage Commissioners on the combined sewer systems within the Cities of Newark and Paterson, and Towns of Harrison and Kearny, and the Borough of East Newark. The evaluation of in-line storage was conducted to review the feasibility of inline storage within the region. This study concluded that, with the exception of a few areas within the City of Newark, the volume of inline storage available within the sewer system was insignificant. It is anticipated that in-line storage using existing sewer will not provide a significant volume of storage.

4.2.2.1.1 Using New Large Diameter Sewers

In-line storage can also be developed by the construction of new large diameter sewers in place of, or parallel to existing combined sewers. The general principal that governs inline storage in either existing or new sewers are the same. In-line storage developed by replacing segments of the existing combined sewer system with larger diameter pipes still requires extensive controls and monitoring to assure proper operation. Accordingly, the cost of constructing the additional sewer capacity must be determined in addition to the cost of the control and monitoring network.

The PVSC TGM, January 2018, provides cost information suitable for the preliminary analysis of in-line storage using newly constructed large dimensional sewers in place of existing pipe. The cost estimates were based on an assumed minimum replacement length of 500 feet for circular conduit sizes varying from 24-inch to 72-inch. The cost of the control and monitoring network is site specific and should also be considered when evaluating the use of in-line storage.

4.2.2.1.2 System Evaluation

Effective control of in-line storage can be achieved through proper flow regulator equipment and hardware selection, a SCADA system that provides early warning and accurate storm forecast. Seasonal storm patterns and types need to be identified and thoroughly evaluated to assure that the control system can properly handle current and potential rainfall patterns within the drainage area. The cost of implementation is significant for areas with limited existing storage due to the cost and challenges associated with the construction of new sewers especially in urban areas, where the access to sewer can be limited and above ground vehicle and pedestrian traffic is heavier. One advantage of in-line storage is the potential of reducing flooding and other system problems that may be localized within the system.

Operational problems that have been noted include computer programming and hardware problems especially with telemetry or data transmission, which could lead to a loss of accuracy in system control. In addition, deposition of solids in the sewers can occur, since the flow velocity during dry weather can be lower than self-cleansing velocity in large diameter sewers. In areas where smaller diameter sewers are replaced with large diameter sewers to provide in-line storage, consideration should be given to provide a low flow channel within the invert. A thorough analysis should be conducted for the potential of sewage backups in service laterals due to surcharging the system above previous hydraulic grades.

In-line storage can be a viable CSO abatement technology if the existing sewer system pipelines are large enough and deep enough to provide significant storage volume. In Perth Amboy's gravity system, by design, the trunk sewers typically drop several feet into the regulator which makes inline storage difficult to achieve in a meaningful. Moreover, the LTCP model of the interceptor system only includes one trunk sewer upstream of each regulator and therefore cannot be used to evaluate capacity of inline storage in the trunk sewers upstream of the regulators. In-line storage of the trunk sewers would also entail increased risk of basement backups. For these reasons, in-line storage technology is not applicable for the City and will not be evaluated further as an CSO reduction measure.

4.2.2.2 Off-Line Storage

Off-line storage is storing the sewerage in a system that is not on the typical flow path of dry weather flow. Off-line storage systems use tanks, basins, tunnel or other structures located adjacent to the sewer system for storing wet weather flow that is above the capacity of the conveyance system. The wastewater flows from the collection or conveyance system is diverted to off-line storage when conveyance capacity of the collection system has been exceeded. They can be used to attenuate peak flows, capture the first flush, or to reduce the frequency and volume of overflows. Wastewater flows diverted to storage facilities must be stored until sufficient conveyance or treatment capacity becomes available in downstream facilities. Off-line storage is typically accomplished by the construction of storage tanks, lagoons, basins, or deep tunnels.

Off-line storage is the predominant form of CSO prevention method currently in operation throughout the United States. The major advantages of off-line storage include:

- It can accommodate intermittent and variable storms.
- It is not impacted by varying water quality flow characteristics.
- It can accommodate solids deposition and control; and
- Storage tanks are easily accessible.

Off-line storage is not a flow through facility and thus ancillary facilities must be constructed for a complete installation. Ancillary facilities typically include some type of flow diversion or regulator structure, possibly coarse screening to keep large solids from entering the tank, and some type of tank drain facility to divert the sewerage back to sewer system. To keep solids from accumulating within the tank, most storage facilities also provide facilities to flush solids from the bottom of the tanks into the pumping sump or gravity sewer.

Two types of off-line storage are typically used in CSO system depending on the volume of the overflows that need to be captured. The most prevalent form of off-line storage is concrete storage tank/structure. These tanks/structures can be constructed above or below ground. The second form is the deep tunnel, wherein a large diameter tunnel is construction to capture and store CSO discharges. While other forms, including uncovered earthen basins, have been used in less populated areas, open forms of CSO storage would not be applicable to highly urbanized areas.

4.2.2.2.1 *Off-line Storage Tanks*

The most prevalent form of off-line storage for CSO discharges is the concrete/steel tank. While large diameter parallel sewers can provide a mechanism for off-line storage, the storage volumes associated with these facilities are limited and thus are typically used within the collection system to prevent or minimized the surcharging associated with local restrictions or conditions. Large volume storage requirements can best be accommodated by the construction of off-line storage facilities at or near the CSO outfall. The design and sizing of these facilities are based upon computer modeling of drainage area and collection system to develop an understanding of the frequency and volumes associated with individual outfalls.

Advantages of off-line storage using concrete tanks are simplicity of operation and maintenance, and capability to handle high flow and water quality variations. In addition, storage tanks have the capacity for storage and collection of solids even when storm events exceed the design capacity of the off-line storage tank. In these cases, the off-line storage tank acts like a sedimentation tank. Storage tanks, in conjunction with fine screening of CSO discharges above the storage volume, are used as a primary means of CSO control throughout Europe.

As with in -line storage, the PVSC TGM, January 2018, provides cost information for off line storage. Those cost estimates were developed for concrete tanks of various storage volumes and are inclusive of all ancillary facilities and include construction costs for coarse screens, diversions, control gates, pumping facilities, flushing facilities and ventilation.

Offline storage tanks are a viable alternative for significant control and will be further evaluated in Section 6.

4.2.2.2.2 *Deep Tunnel Storage*

Deep tunnel storage has been gaining popularity as a positive means of reducing the volume of CSO discharges especially in large urban area where, property values and disruptions to existing utilities and structures prohibit other forms of control. This control alternative involves the capture and storage of CSO discharges in a tunnel during wet weather events and pumping the stored overflow back into sewer when conveyance and treatment capacity is available. New methods of construction have made deep tunnel storage a competitive option when considering the relatively low land requirements. Limitations of deep tunnels primarily include the need for specialized high-lift pumping stations and the inability to provide any treatment when the overflow exceeds the deep tunnel storage volume.

As with in -line and off-line storage, the original Technical Guidance Manual provided cost information for deep tunnel storage. Preliminary tunnel cost estimating graphs were prepared using compiled cost data from previously completed projects for the following tunneling scenarios:

- Tunnel in soft ground above the water table using an open-faced boring machine with ribs and lagging primary liner and cast-in-place concrete final liner.
- Tunnel in soft ground below the water table driven using an earth pressure balanced boring machine with full gasketed concrete segmental liner erected immediately behind.

- Tunnel in rock driven using a rock-boring machine with pattern rock bolting and mesh reinforcement in the tunnel crown for primary support and cast-in-place concrete final liner.

Since ground conditions may be unknown, an idealized cost estimate using certain assumptions on the amount of difficult conditions was also presented. A determination will need to be made as to the method that would need to be used based on general soil classifications and conditions within the region.

Notwithstanding the above, construction costs on tunneling projects are influenced by a multiplicity of factors. Tunnel cost estimates should only be used as a general initial guideline as they are based on several assumptions and are not project specific. The major factors influencing costs on tunneling projects are described below:

- Tunnel length - assuming similar size and type of tunnels, a longer tunnel will generally have a lower unit rate than a smaller tunnel due to economies of scale. The original Technical Guidance Manual cost graphs assumed a 1.5 miles length of tunnel.
- Tunnel depth relative to the surface - deeper tunnels have deeper access shafts, which adds to the overall cost of the project. The original Technical Guidance Manual cost graphs assumed a tunnel no deeper than 30ft.
- Ground type & water table elevation - this can often be the most important cost factor as it influences the advance rates achieved, and choice of equipment and tunnel support. The original Technical Guidance Manual cost graphs assumed reasonable ground conditions and minimal water ingress problems to hinder the tunneling effort.
- Rate of advance achieved in the prevailing ground conditions. Average advance rates were assumed in the preparation of the tunnel cost graphs.
- Local labor conditions including availability of experienced personnel, prevailing wage rates, and union rules governing workers conditions, hours, and the minimum number of personnel which should be utilized for construction of the tunnel. The tunnel cost graphs presented in the original Technical Guidance Manual utilized labor conditions and numbers, which were believed to be appropriate for New Jersey.
- Local availability of appropriate tunneling equipment. The tunnel original Technical Guidance Manual cost graphs assumed that appropriate tunneling equipment is readily available in New Jersey.
- Occurrences of unforeseen ground conditions and obstructions. The original Technical Guidance Manual cost graphs assumed no major unforeseen conditions.
- Presence of sub-surface utilities and structures above requiring advance protection or monitoring during construction. The original Technical Guidance Manual cost curves assumed that no advance protection is required.

The foregoing list represents only a few of the factors which influence tunnel construction costs, and beyond the earliest stages of conceptual design it is recommended that all tunnel cost estimating be undertaken by an experienced tunneling engineer with an intimate awareness of the factors influencing tunnel costs. To cater for the unknown components inherent in preparation of the cost curves a relatively large cost contingency of 65% was applied throughout. In practical cost estimating, the cost contingency is reduced to as low as 5% as the design develops and more is known about the conditions which are likely to be encountered, and the tunneling techniques which will be utilized for the project.

In addition to tunnel costs, there are costs associated with conveying the flow into the tunnels. Typically, the discharges from outfall are consolidated to decrease the number of drop shafts that will be needed. In addition, drop shafts are needed to transport flow from the regulators to the tunnel. The drop shaft consists of a large diameter shaft in which a vortex drop tube, vent shaft and access way are constructed. The space between the various components in a large diameter shaft is backfilled upon completion.

The PVSC TGM, January 2018 provides curves for deep tunnel costs.

Deep tunnel storage is a viable alternative for significant control and will be further evaluated in Section 6.

4.2.3 Treatment Plant Expansion or Storage at CTP

The MCUA and Perth Amboy are required to consider maximizing flow to the Treatment Plant as one of the Nine Minimum Controls established by the USEPA. This section outlines the ability and limitation on directing flows to the MCUA's Central Treatment Plant (CTP), and also outlines options for treating or storing flows that are received by the MCUA from Perth Amboy's combined sewer system.

MCUA's objectives for this project are to maintain compliance with all current requirements under NJPDES No. NJ0020141, assist the City of Perth Amboy in developing any CSO alternatives that maximize storage or treatment at the CTP, and provide water quality benefits commensurate with the expenditure of public funds. The various alternatives outlined below are intended to address these objectives.

4.2.3.1 Directing Combined Sewer Flows to the CTP

A new direct force main can be constructed to convey flow to the CTP. The proposed force main to convey flow directly from the Second Street Pumping Station in Perth Amboy to the CTP would be approximately 2 miles in length and would be installed by horizontal directional drilling (HDD) under the Raritan River as shown in Figure 4-8. This conceptual alignment could be significantly impacted by existing and future development in these areas. Depending on the flow rate of the Perth Amboy Second Street Pumping Station, there would be one 24-inch diameter force main, or multiple parallel 24-inch diameter force mains.

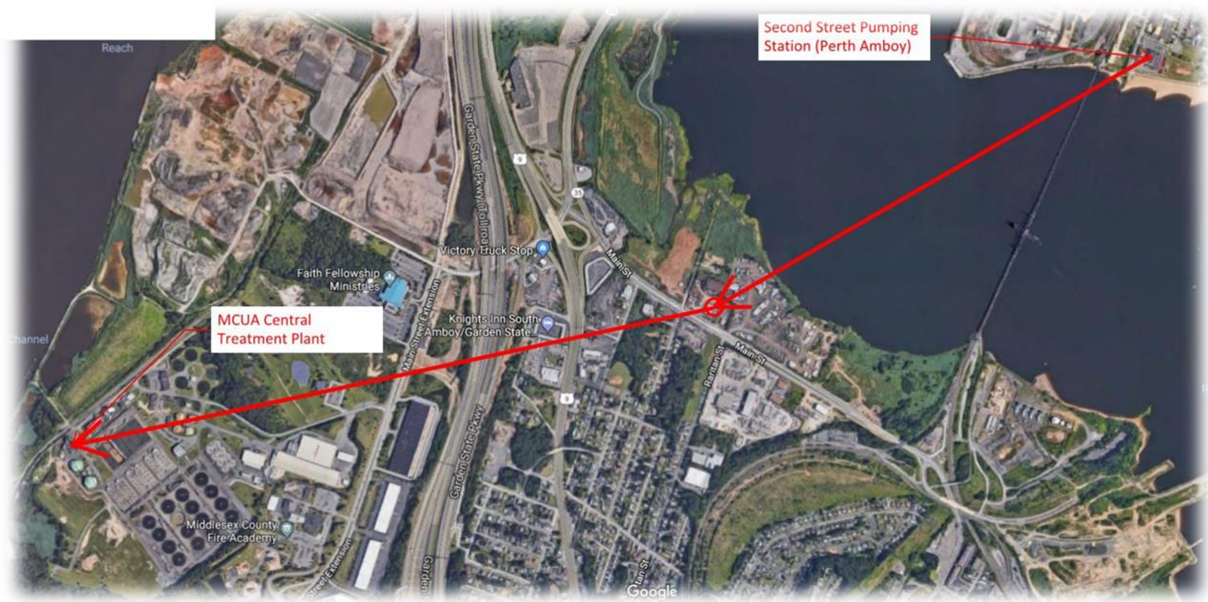


Figure 4-8 - Conceptual Force Main from Perth Amboy Second St Pumping Station to MCUA CTP

If Perth Amboy were to pump its CSS flow to the CTP directly, it would not pump any flow through the Keasbey Interceptor to the CTP. Therefore, flows will not be directed through both the existing interceptor and new force main at the same time. If Perth Amboy pumps CSS flows directly to the CTP up to a maximum of 13.6 MGD, the flow would be directed to a new receiving chamber at the CTP to be connected to the existing headworks and receive full-treatment. It is anticipated that Perth Amboy would provide fine-screening (maximum ½" clear spacing) before pumping to the CTP.

MCUA has upgraded the screening equipment at some of its pump stations and is considering screening upgrades to achieve a maximum 3/8" clear spacing at the three major pump stations.

If Perth Amboy were to pump CSS flow in excess of 13.6 MGD, the MCUA may provide a diversion chamber at the CTP to receive Perth Amboy's pumped CSS flows. Flows up to a maximum 13.6 MGD would be directed to the headworks for full treatment through the CTP. Flow in excess of 13.6 MGD would be diverted to either temporary on-site storage (Alternative 4.2.3.4.) or to high rate treatment and blending with disinfection (Alternative 4.2.3.5.).

It is anticipated that during dry weather flow periods Perth Amboy would pump a maximum of 13.6 MGD to the CTP on a regular basis to flush-out settled solids in the force mains. The 13.6 MGD maximum instantaneous flushing flow rates would be directed to the headworks to receive full treatment though the CTP.

4.2.3.2 Evaluation of Available Capacity at the CTP

The MCUA's CTP is rated for 147 MGD average daily flow. The influent flow is screened at the three (3) major pumping stations before pumping to the CTP: Edison Pumping Station, Sayreville Pumping Station, and South Amboy Pumping Station. This pumped flow is directed to CTP's headworks from where it flows by gravity through the plant.

Preliminary and primary treatment consists of four (4) aerated grit chambers and six (6) rectangular primary settling tanks. Primary effluent flows to the pure-oxygen activated sludge process, consisting of four (4) pure-oxygen oxygenation tanks equipped with mechanical aerators and sixteen (16) circular final settling tanks.

From the oxygenation tanks, the mixed liquor flows to the final settling tanks. The secondary effluent is then disinfected using sodium hypochlorite and discharged ultimately to the Raritan Bay. The plant effluent up to approximately 120 MGD is discharged through the Main Outfall directly to Raritan Bay; and effluent flows greater than approximately 120 MGD are discharged via the supplemental relief outfall to the North Channel of the Raritan River. Raritan Bay and the North Channel of the Raritan River are SE1 waters.

The primary sludge and waste activated sludge are pumped to eight (8) gravity thickener tanks. The thickened sludge is dewatered with ten (10) belt filter presses. The dewatered sludge cake is stabilized using the DuopHase alkaline-stabilization process. The thickener tanks overflow, belt filter press filtrate and the DuopHase process condensate are collected in the TTO Pumping Station, where it is screened and pumped to the Primary Effluent Channel for treatment.

4.2.3.2.1 CTP Existing Capacity Evaluation

The MCUA's CTP consistently achieves compliance with its NJPDES Permit. A graph showing the NJPDES Total Suspended Solids (TSS) monthly average limit, and a plot of the actual 1995-2018 Average Monthly Flow vs. Monthly Average TSS is provided on Figure 4-9.

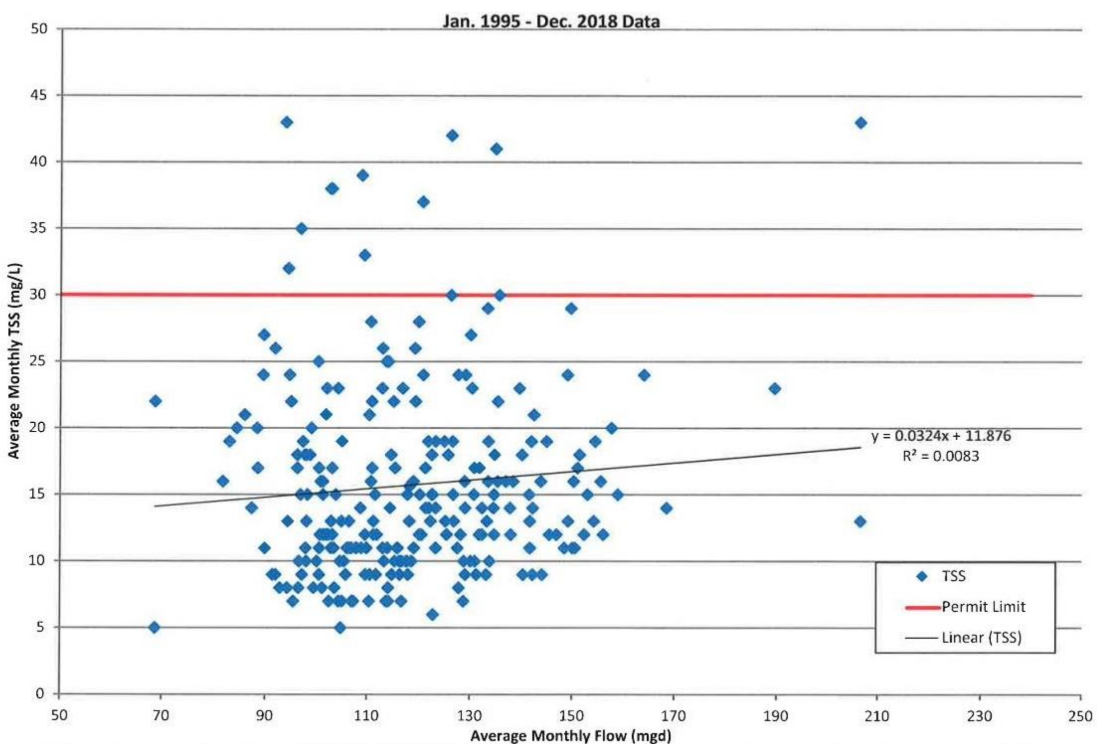


Figure 4-9 - MCUA Monthly TSS vs Flow

MCUA Monthly Average TSS excursions usually occur during the most extreme storm events and are not a common occurrence during typical wet weather events. The MCUA has not been notified by the regulatory agencies of any adverse environmental impacts to the Raritan Bay or North Channel of the Raritan River due to its discharge of treated effluent.

However, the CTP's capacity to receive and treat higher average daily flows and/or higher instantaneous peak flows, and continue to meet its NJPDES requirements, is limited.

The MCUA has been evaluating the CTP's treatment capacity on a regular basis and performing upgrades to unit processes as needed. These are some of the reports on capacity evaluations of the CTP conducted by MCUA:

- M&E (May 1972) Project Report on Secondary Treatment and Additional Facilities – Final Draft
- M&E (May 1972) Supplement to Project Report on Secondary Treatment and Additional Facilities – Final Draft
- CDM (August 1989) Computer Analysis of Plant Hydraulics for Expansion of Edward J. Patten Water Reclamation Facility
- CDM (October 1990) Results of Stress Testing at MCUA's UNOX Activated Sludge Treatment Plant, WPCF 63rd Annual Conference and Exposition, Washington, D.C.
- CDM (February 1990) Results of Stress Testing and Optimization for Expansion of Edward J. Patten Water Reclamation Facility
- CDM (March 1990) Needed Additional Facilities for Expansion of Edward J. Patten Water Reclamation Facility
- CDM (May 1990) Alternatives Evaluation and Preliminary Design of Facilities for Expansion of Edward J. Patten Water Reclamation Facility
- CDM (September 1991) Technical Design Report for Upgrading of Edward J. Patten Water Reclamation Facility
- CDM (October 1991) Technical Design Report for Upgrading of Edward J. Patten Water Reclamation Facility
- Malcolm Pirnie (November 1992) Conversion of Oxygenation Tanks at Edward J. Patten Water Reclamation Facility.
- CDM (August 1994) Upgrading the Edward J. Patten Water Reclamation Facility
- CDM (April 2007) Long Term Combined Sewer Overflow Control Plan – Cost and Performance Analysis Report, City of Perth Amboy Utilities Service Affiliates, USAPA
- CDM Smith (August 2007) MCUA Central Treatment Plant Conveyance Capacity Analysis and Cost and Performance Analysis Report - NJPDES Permit No. NJ0020141
- Remington & Vernick Engineers (Revised March 2019) Central Treatment Facility (Edward J. Patten Water Reclamation Center) – Capacity Report Cost and Performance Analysis

The March 1990 CDM report projected plant influent flows and concentrations of BOD and TSS for years 2000 and 2020. Table 4-1 shows the design criteria for the MCUA CTP in 2020 from the CDM report and the corresponding kilogram per day (kg/day) loadings calculated for this DEAR report.

Table 4-1 - Projected Design Criteria for MCUA CTP in 2020

Design Criteria (2020)	Influent Flow, (MGD)	Average Influent TSS (mg/L)	Average Influent TSS (kg/day)	Average Influent BOD (mg/L)	Average Influent BOD, (kg/day)
Average-day	169.2	350	224,318	300	192,273
Maximum-day	423.0	300	480,682	250	400,568
Peak-Hour	592.2	225	504,716	190	426,205

Courtesy: (CDM, March 1990) Needed Additional Facilities for Expansion of Edward J. Patten Water Reclamation Facility (Table 2-1 – Existing and Projected Wastewater Inflows and Quality Characteristics)

The March 1990 CDM report projected the additional unit processes that would be required by 2000 and 2020 based on the projected influent flow and loadings for those years, which are summarized in Table 4-2.

Table 4-2 - Projected Unit Processes for the CTP by 2000 and 2020

Unit Processes	Number of Units Currently Available	Number of Units Projected in 1990 to Be Required by 2000	Number of Units Projected in 1990 to Be Required by 2020
Plant Influent Flows	(Average 2014 - 2018)	---	---
Average Daily Flow, MGD	104	149	169
Maximum-day Flow, MGD	275	373	423
Peak-hour Flow, MGD	325	522	592
Aerated Grit Chambers	4	5	5
Primary Settling Tanks	6	8	10
Oxygenation Capacity	4	6	6
Final Settling Tanks	16	22	24

Since then, the MCUA has conducted additional studies of the plant capacity needs which have resulted in lower flows and loadings than the projections in the March 1990 CDM report.

The evaluations of maximizing available capacity of the CTP for the treatment of Perth Amboy's additional CSS flow are based on the three (3) potential flow conditions being considered:

- Direct CSO Flows up to 13.6 MGD to the CTP for full-treatment. The duration of this flow rate may extend beyond the normal peak period for various storm events to handle the CSS flows stored within Perth Amboy.

- Direct flows up to a maximum rate of 42 MGD to the CTP for treatment.
- Direct flows up a maximum rate of 54 MGD to the CTP for treatment.

Perth Amboy's CSS flow would be pumped from the Perth Amboy's Second Street Pumping Station (or a new pumping station) directly to the CTP's headworks. Perth Amboy's flow, together with the wet weather flows from the MCUA's service area, would then receive full treatment through the CTP.

The Remington & Vernick Engineers (Revised March 2019) report (the RVE report) evaluated the CTP's influent flow data and other parameters for the 3-year January 2015 through December 2017 period and developed the following Existing Large Wet Weather Influent and Effluent parameters for the CTP summarized in Table 4-3.

Table 4-3 - MCUA CTP Flows and Parameters (2015-2017)

Parameter	Large Wet Weather Average Influent	Large Wet Weather Average Effluent
Flow, MGD	192	192
Temperature, °C	13.8	14.4
Total Suspended Solids (TSS), mg/L	240	50.4
5-Day Biological Oxygen Demand (BOD), mg/L	182	25.4
Chemical Oxygen Demand (COD), mg/L	378	105

Courtesy: Revised MCUA CTP Capacity Report Cost and Performance Analysis (RVE, March 2019).

The RVE report states that during the 3-year period (2015-2017) the average daily flow to the CTP was 99 MGD; exceeded 160 MGD on 31 days; with the largest recorded Max-day flow of 263 MGD on April 1, 2017.

Based on the above Existing Large Wet Weather Influent and Effluent parameters, the following Performance Value (PV) Influent Concentrations and Loads were developed and summarized in Table 4-4.

Table 4-4 - Performance Value Flows and Estimated Parameters

Performance Value	Influent Flow, mgd	Influent TSS mg/L	Influent TSS kg/day	Influent BOD mg/L	Influent BOD, kg/day	Influent COD, mg/L	Influent COD, kg/day
PV1	350.5	240	318,891	182	241,826	378	520,254
PV2	361.0	240	328,445	182	249,070	378	517,300
PV3	371.5	240	337,997	182	256,315	378	532,346
PV4	382.0	240	347,550	182	263,559	378	547,392
PV5	392.5	240	357,104	182	270,804	378	562,438

Courtesy: Revised MCUA CTP Capacity Report Cost and Performance Analysis (RVE, March 2019).

The RVE report also performed capacity evaluations based on previous stress tests and evaluations performed by others and concluded that the Final Settling Tanks limit the CTP's treatment capacity to 340 MGD, as shown in Table 4-5.

The PV influent flows are based on the CTP's maximum capacity of 340 MGD plus 2, 4, 6, 8, and 10 multiples of the 5.25 MGD average daily flow from the City of Perth Amboy. For example, the PV1 flow is 340 MGD plus 10.5 MGD of Perth Amboy's CSS flow. For the purpose of utilizing the evaluation from the RVE report, PV4 and PV5 equate to an additional 42 and 54 MGD of the Perth Amboy's CSS flow, respectively.

Table 4-5 - MCUA CTP Unit Process Capacity

Unit Processes	Number of Units Available	Required Number of Units in Operation	Rated Capacity - Peak-hour Flow Rate, MGD
Aerated Grit Chambers	4	3	400
Primary Settling Tanks	6	6	390
Oxygenation Process	4	4	350
Final Settling Tanks	16	16	340
Combined: Original Outfall #001 & Supplemental Outfall #007	2	2	416

The RVE report also determined that the solids-handling facilities do not limit the CTP's capacity to receive the estimated peak-hour flows.

However, during the most recent 5-year period (2014 – 2018), the CTP influent average daily flows and the average Max-day flows exceeded those flows in the RVE report (99 MGD and 263 MGD, respectively), as indicated in Table 4-6.

Table 4-6 – Most Recent 5-year Period MCUA CTP Flow (2014 - 2018)

Flow Value	2014	2015	2016	2017	2018	Averages
Average-day	106.2	98.3	94.6	102.4	117.5	103.8
Max-day	361.7	220.5	257.1	263.0	271.8	274.8
Peak-hour	392.5	257.4	306.2	348.4	320.8	325.1

The Perth Amboy CSS flows are characterized by peak flow rates with relatively short durations. The MCUA's CTP peak-hour flows during the most recent 5-year 2014–2018 period averaged 325 MGD; with the largest recorded peak-hour flow of 392.5 MGD in 2014 (refer to Table 4-6). This peak flow rate exceeded the maximum rated capacity of the primary settling tanks, oxygenation process and final settling tanks. Consequently, the CTP is already operating its primary treatment process at maximum capacity, as required in MCUA's NJPDES permit under Part IV.G.4.e.vii.

Based on this evaluation, the CTP would not be able to receive and treat increased peak CSS flow rates greater than 13.6 MGD from Perth Amboy, such as the 42 MGD and 54 MGD of CSS flow rates being contemplated, without substantial capacity increases to most unit processes to most unit processes which are evaluated under Section 4.2.3 of this report. Therefore, this alternative is not being considered further.

4.2.3.3 Capacity Expansion at the MCUA CTP

As discussed in Section 4.2.3, the CTP is currently operating at its maximum capacity and would have to be expanded to accept additional Perth Amboy's peak CSS flow rates.

Perth Amboy's proposed force main(s) would discharge into a new receiving chamber at the CTP site, from where it would be conveyed to the CTP's headworks for full-treatment.

Evaluations to expand the CTP's capacity are based on the three (3) potential CSS flow rates being contemplated for Perth Amboy (see Section 6):

- Direct CSO Flows up to 13.6 MGD to the CTP for full-treatment. The duration of this flow rate may extend beyond the normal peak period for various storm events to handle the CSS flows stored within Perth Amboy.
- Direct flows up to a maximum rate of 42 MGD to the CTP for full-treatment.
- Direct flows up to a maximum rate of 54 MGD to the CTP for full-treatment.

Preliminary evaluations of the CTP suggest that extending the duration of flows up to 13.6 MGD to the CTP would not significantly impact CTP operations. However, depending on the duration of the extended flow, MCUA may require off-line storage within the CTP to accommodate such flows. This alternative is a viable alternative and will be evaluated further in Section 4.2.3.4. This is.

To accept additional peak CSS flows of 42 MGD and 54 MGD, a CTP expansion would be required. Based on the existing flow distribution through the CTP and good engineering practice, the capacity would be expanded in 25% increments; i.e., by 25%, 50%, 75% or 100% of its current capacity. The contemplated peak CSS flow rates from Perth Amboy are between 12% to 16% of the CTP's 340 MGD current Max-hour capacity. Therefore, a 25% plant expansion is being considered for this alternative, which would consist of the following additional infrastructure:

- One (1) Aerated Grit Chamber (AGC)
- Two (2) Primary Settling Tanks (PST)
- One (1) Oxygenation Tanks (OT)
- Four (4) Final Settling Tanks (FST)

It should be noted that the capacity increase indicated above is based on all tanks and support equipment being in service; i.e., there would not be tanks on standby service.

The RVE Report indicates that three of the four Aerated Grit Chambers (AGC) have a rated capacity of 400 MGD. However, the grit accumulates in the trough at the bottom of each chamber and is removed with a clam-bucket operated from a gantry crane located above the chambers on a regular basis and approximately twice per year. Depending on the depth of the settled grit, a sudden CSS flow rate increase could cause the settled grit to be pushed out of the chambers to the primary settling tanks. Therefore, a fifth AGC is being included in the 25% capacity expansion.

In addition to the infrastructure outlined above there would be ancillary systems required, such as AGC aeration blower and diffusers; grit removal equipment; AGC dewatering pumps and piping; extensions to pipe galleries; pure-oxygen-generating capacity, piping and oxygen mixer/diffusers; extensions to aerated channels, process air blowers, piping and air diffusers for extended aerated channels; extensions of channel surface-flushing water piping; electrical power supply, controls and instrumentation systems; RAS and WAS pumping stations, pumps and piping.

Since the additional CSO flow events would be of relatively short duration and processed through the primary and final tankage within the plant, the existing sludge handling processes should be capable of processing the additional CSS flow solids. Therefore, no additional sludge-handling units are being included for the 25% capacity expansion.

A Conceptual Design Site Plan for the 25% capacity expansion is shown on Figure 4-10. Based on the review of the current facility layout, it is proposed to construct one additional aerated grit chamber (AGC #5) in the available space next to the existing AGC #4 and to relocate the existing septage-receiving station to the west of the Edison Pumping Station Force Main tunnel shaft structure. The two (2) additional primary settling tanks would be located next to the primary settling tanks (PST #5 and PST #6). In the future, when PST #7 and PST #8 are expected to be required, the existing road to the west would be relocated further west. One of the two existing aerobic digesters (AD#1) which is located adjacent Oxygenation Tank #4 (OT#4), would be repurposed as the additional OT #5 for the 25% plant expansion. Finally, four (4) additional final settling tanks (FST#17 – FST#20) would be constructed northwest of the FST #12 - FST#16. Dedicated sludge pump stations would need to be added to the process expansion along with other ancillary process equipment. Based on the existing grade in this area, soil fill would be required for re-grading.

A detailed constructability review would have to be performed during the 25% capacity expansion planning stage to enable anticipated future expansions.

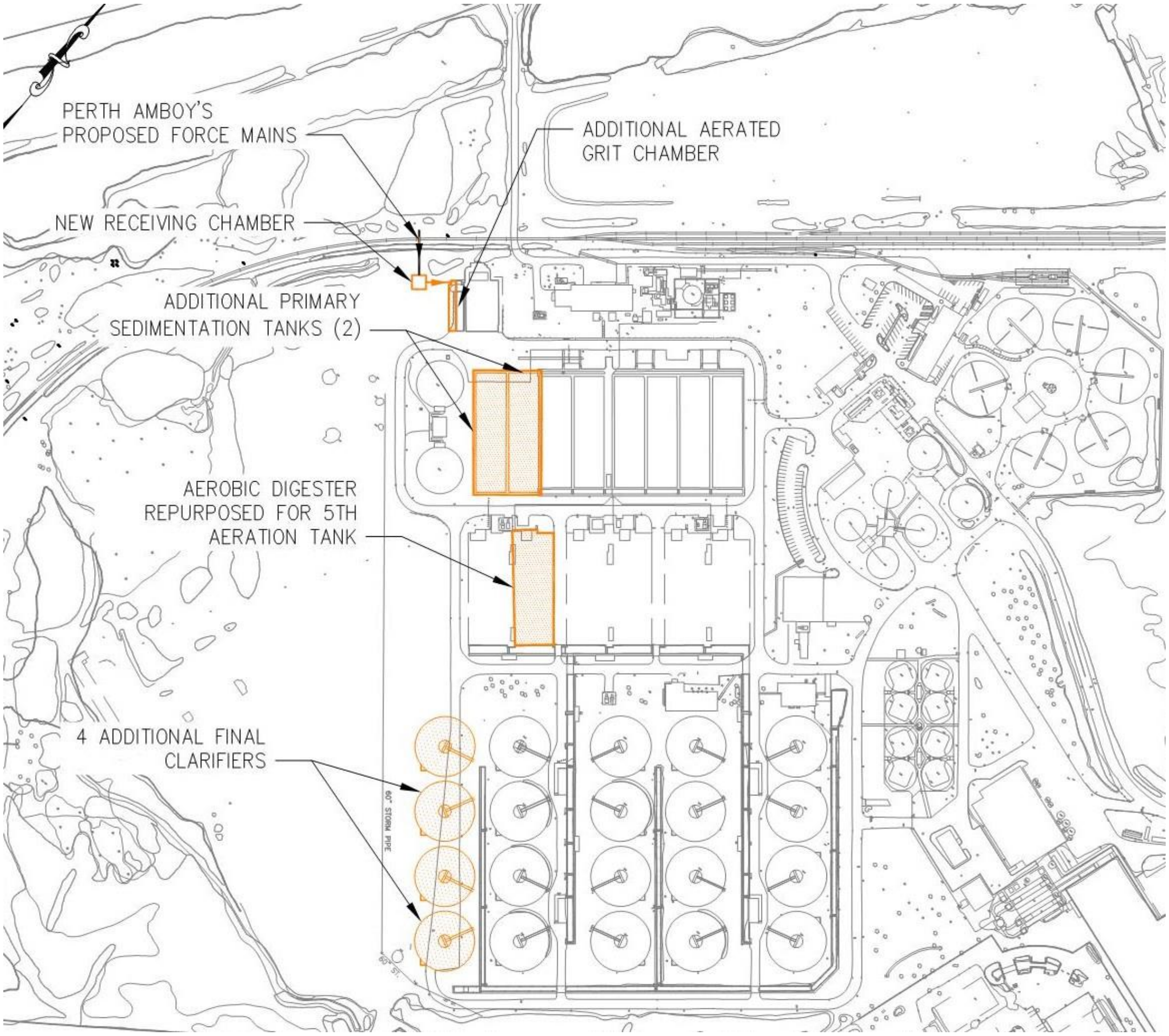


Figure 4-10 - Conceptual Design Site Plan for MCUA CTP Capacity Expansion

Based on the existing NJPDES permit, the CTP has a plant capacity of 147 MGD (average daily flow). Therefore, the 25% CTP capacity increase equates to 37 MGD average daily flow. In March 1990, CDM prepared a report that discussed plans for a potential CTP expansion, and it included the estimated construction costs. Based on those estimates, the construction cost for a 25% plant expansion would be approximately $195 million dollars ($195M).

The U.S. Environmental Protection Agency (USEPA) published “Construction Costs for Municipal Wastewater Treatment Plants: 1973-1978” dated April 1980, which includes construction cost curves developed from various publicly owned wastewater treatment facilities across the country. The construction cost curves were utilized to estimate the cost for the CTP’s 25% capacity expansion. Based on the USEPA cost curve for entire plant expansions (first order cost) in 1980 dollars, updated to 2018 dollars utilizing the ratio of the respective Engineering News Record Construction Cost Indices (ENR CCI) for the NY/NJ Metro Area, the estimated construction cost of a new wastewater treatment facility with a 37 MGD design capacity would be $285M.

Similarly, when utilizing the USEPA's second order cost curves for a 37 MGD plant capacity, the estimate construction cost would be $317M.

However, these costs are not likely to reflect the costs required for maintaining an existing plant in operation during construction such as bypass pumping, difficult site conditions requiring special foundations, process and drainage piping, and interconnections among existing plant processes involving large pipe sizes up to 102" diameter. Therefore, the 2018 estimated construction costs for the conceptual 25% plant expansion ranges from $300M to almost $500M depending on the various process, structural, and piping required throughout the plant; as well as temporary flow-bypasses and treatment systems that would be required to maintain all wastewater treatment processes in operation. The cost estimates include associated engineering, administrative and legal costs.

The average TSS, BOD and COD loadings in the 5-year (2014 - 2018) period are presented in Table 4-7. Based on the review of current CTP data (Table 4-6 and Table 4-7), the forecast (Table 4-1and Table 4-2) of influent flows and loadings projected in the March 1990 CDM report are significantly higher than the current actual CTP influent flows and loadings. A combination of changes from the projected demographics for the MCUA's service area and reduced Infiltration and Inflow rates could explain why the 2010 projected influent flow to the CTP has not materialized. Therefore, the CTP would not require a capacity expansion in the near future.

The CTP expansion alternative represents the most complex, costly and disruptive to plant operations alternative. Therefore, this alternative is not being considered further.

The other alternatives being considered in this report (Section 4.2.3) offer more cost-effective means to receive and treat the estimated 13.6 MGD, 42 MGD and 54 MGD peak CSS flow rates from Perth Amboy.

Table 4-7 - MCUA CTP Average Flows and Influent Concentrations (2014-2018)

Criteria / Year	Avg. Flow (MGD)	Influent TSS, (mg/L)	Influent TSS, (Kg/day)	Influent BOD, (mg/L)	Influent BOD, (Kg/day)	Influent COD, (mg/L)	Influent COD, (Kg/day)
2014	106.2	295	118,670	233	93,730	552	222,055
2015	98.3	314	116,917	245	91,225	538	200,323
2016	94.6	296	106,067	252	90,300	604	216,433
2017	102.4	299	115,976	249	96,582	626	242,812
2018	117.5	260	115,720	228	101,477	506	225,208

4.2.3.4 MCUA CTP Storage Alternatives

The Perth Amboy CSS flows are characterized by peak flow rates with relatively short durations, which result in relatively small CSS volumes.

Under this alternative, the CSS flows from Perth Amboy would be fine-screened at the Second Street Pumping Station (or a new pumping station located in Perth Amboy) before pumping it to the CTP. The Perth Amboy's force main(s) would discharge into a new diversion chamber at the

CTP site, where up to 13.6 MGD would be diverted to the CTP's headworks for full-treatment, and the excess CSS flow would be diverted to on-site storage, to be pumped to the headworks for full-treatment after the wet weather event has subsided.

The evaluations to provide CSO Storage at the CTP are based on the three (3) potential flow conditions projected from the Perth Amboy CSO system:

- Direct CSS flows up to 13.6 MGD to the CTP for full-treatment. The duration of this flow rate may extend beyond the normal peak period for various storm events to be able to handle the CSS flows stored within Perth Amboy.
- Direct CSS flows up to a maximum rate of 42 MGD to the CTP for full-treatment.
- Direct CSS flows up to a maximum rate of 54 MGD to the CTP for full-treatment.

The CTP's existing Aerobic Digester #2 was taken off-line in 1990 and has not been in use since that time. Preliminary engineering evaluations suggest this tank could serve as a CSS flow holding tank with a nominal capacity of 4 million gallons (MG). The Aerobic Digester #1 is being reserved by MCUA to address a capacity expansion or treatment modifications that may be required in the future and is therefore not available for consideration as a storage tank for Perth Amboy's CSS flow. A conceptual site plan for the CTP Storage alternative is shown on Figure 4-11.

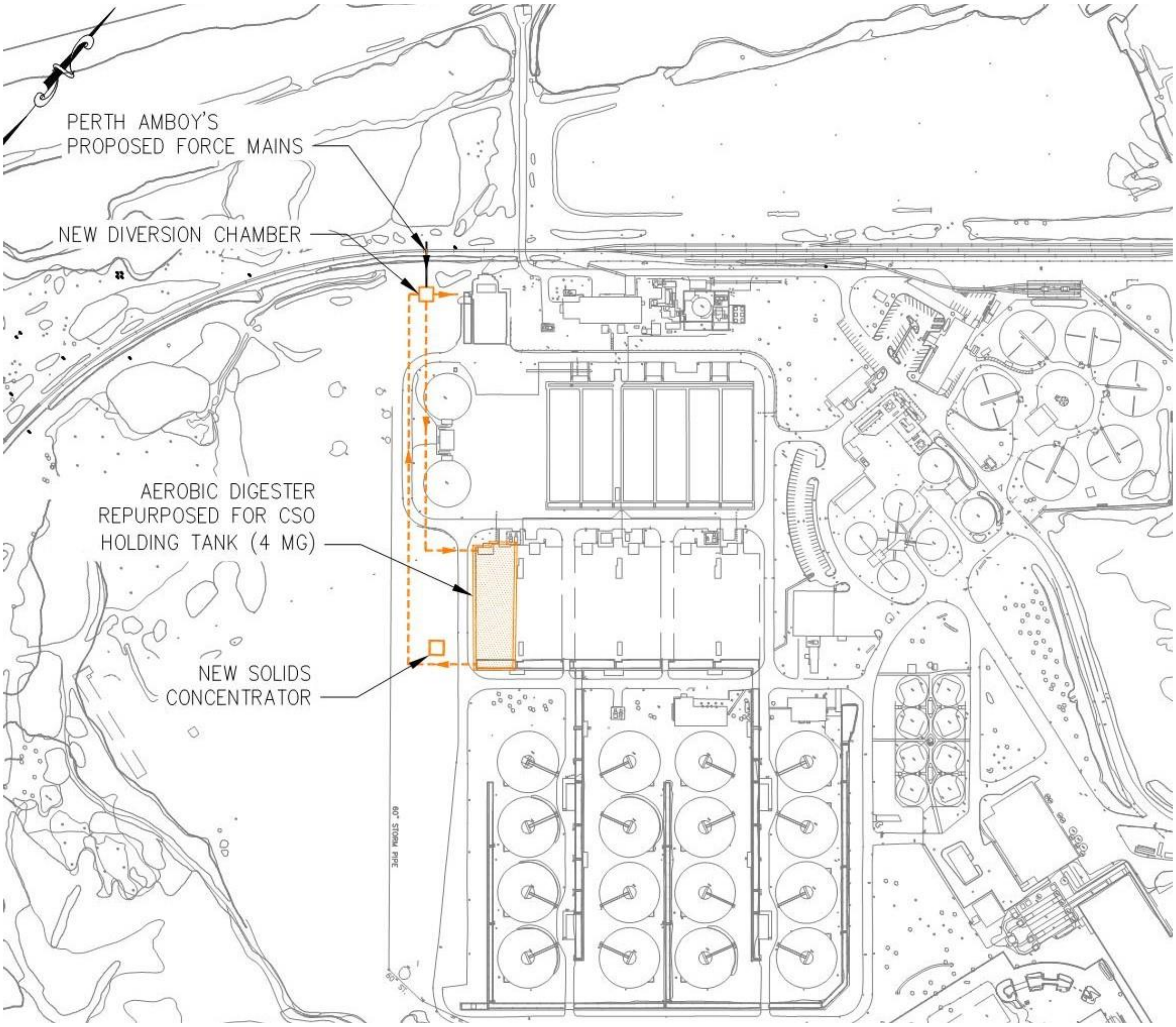


Figure 4-11 - MCUA CTP Storage Alternative

Utilizing the conceptual planning level hydrologic model developed by CDM for estimating Perth Amboy's CSS flows for various precipitation events in 2004, the Typical Hydraulic Year, the corresponding flow volumes were calculated (Table 4-8). The maximum CSS flow rate of 54 MGD occurred on September 18, 2004 and resulted in 1.7 million gallons (MG) of CSS flow volume that would have to be stored at the CTP. This volume was calculated as the difference between the model-estimated CSS flow rate and a 12 MGD baseline flow, which equates to the 13.6 MGD baseline flow that the CTP could currently receive and fully treat. Therefore, based on a 13.6 MGD baseline, the calculated storage volume required would be less than 1.7 MG. This concept also applies to the other calculated flow volumes in Table 4-8.

Based on Perth Amboy CSO flow data provided by CDM for twenty (20) CSS flow events in 2004 producing the highest CSS peak flow rates, which ranged from 33.8 MGD to 53.6 MGD with varying durations, the calculated volumes to be stored ranged from 1.2 MG to 10.6 MG.

The wet weather event on September 28, 2004 was modeled to produce a 44 MGD peak CSS flow rate, which although less intense than the September 18, 2004 event, due to its flow pattern and duration resulted in approximately 10.6 MG to be stored.

Based on the twenty (20) 2004 flow events, a 4 MG storage capacity at the CTP would be sufficient to hold the estimated volume from 16 out of the 20 CSS flow events. Considering that the baseline is approximately 1 MGD greater than the 12 MGD baseline used for the volume calculations, the calculated volumes are conservatively low. The modeled results are based on conceptual planning-level data and will need to be evaluated in more detail should this alternative be selected.

Table 4-8 - Perth Amboy CSO Flow Data During Storm Events (CDM, 2004)

	Date	Peak Flow Rate (MGD)	Duration (hr)	Vol above Baseline (MG)	Comments
1	2/6/2004	33.9	14	4.9	
2	4/1/2004	36.2	2.5	1.2	
3	4/13/2004	35.8	9	1.9	
4	5/11/2004	42.0	2.5	1.7	
5	5/12/2004	50.5	2	1.6	
6	6/25/2004	38.5	4.5	3.4	
7	6/22/2004	38.0	2	1.2	
8	7/5/2004	52.7	2	1.1	
9	7/12/2004	34.1	18	5.3	
10	7/14/2004	36.9	4.5	0.7	
11	7/18/2004	44.9	5	3.3	
12	7/23/2004	39.9	10	4.3	
13	7/27/2004	42.8	8.5	3.3	
14	8/16/2004	44.2	2	1.6	
15	8/21/2004	50.1	3	1.2	
16	[3.] 9/8/2004	44.2	6.5	4.2	[3.] Event with 5th Highest Flow Volume
17	[1.] 9/18/2004	53.6	2	1.6	[1.] Event with Highest flow rate
18	[2.] 9/28/2004	44.0	19	10.6	[2.]Event with Highest Volume
19	11/28/2004	50.7	6	3.2	
20	12/23/2004	43.6	4.5	1.2	

Excess CSS flows diverted from the new diversion chamber would be directed via a new pipe to the repurposed CSS Flow Storage Tank. This flow would be held in the CSS Flow Storage Tank for 24 to 48 hours, during which the solids would settle and accumulate at the bottom of the tank. Once the wet weather flows subside, the tank contents would be transferred with new pumps at a relatively low rate via a new force main to the CTP's headworks to receive full treatment.

The CSS Flow Storage Tank would be cleaned utilizing a tipping-bucket system for flushing the settled solids. The tipping-buckets would be filled with the CTP's treated effluent. Once the contents in the CSS Storage Tank have been drained by pumping its contents to the CTP's headworks for treatment, the tipping-buckets would release the water to cascade along the contoured tank wall to produce a standing wave to flush the accumulated solids via a trough toward a sump, to be pumped to a degritter and washer located at grade. The CSS Storage Tank would also be routinely cleaned with high pressure process water. The washed grit would be collected in a container for disposal off-site and the liquid portion conveyed to the headworks for treatment.

Based on this evaluation and the initial cost estimate, this alternative would apply to certain storm events with CSS flows below 54 MGD and above 13.6 MGD. The actual design flow rate to maximize storage would be evaluated in the development of Long Term Control Plan. Depending on the technical requirements and associated costs for pumping CSS flows directly to the CTP, storage at the CTP is therefore a viable and relatively low-cost alternative for accomplishing the project objectives and will be further evaluated.

4.2.3.5 MCUA CTP CSS Flow Bypass and HRT and Disinfection

In this alternative, CSS flow from Perth Amboy would be fine-screened at the Second Street Pump Station (or a new pump station) before pumping it to the CTP. The Perth Amboy's force main would discharge into a new diversion chamber at the CTP site, where up to 13.6 MGD would be diverted to the CTP's headworks for full-treatment, and the excess flow would be diverted to a new dedicated high-rate treatment (HRT) process train, thus bypassing the CTP's preliminary, primary and secondary treatment processes. The effluent from the HRT process train would be blended with the CTP's effluent flow and meet the NJPDES permit limits. The blended effluent would then be disinfected and discharged via the outfalls to Raritan Bay and the North Channel of the Raritan River. During normal dry-weather flows, the new high-rate treatment train would be drained and readied for the next wet-weather event.

The evaluations are based on the three (3) potential flow conditions being contemplated for Perth Amboy's CSS flows:

- Direct CSS Flows up to 13.6 MGD to the CTP for full-treatment. The duration of this flow rate may extend beyond the normal peak period for various storm events to handle the CSS flows stored within Perth Amboy.
- Direct CSS flows up to a maximum rate of 42 MGD to the CTP for treatment.
- Direct CSS flows up to a maximum rate of 54 MGD to the CTP for treatment.

This alternative was developed, evaluated and presented in CDM Smith (August 2007) *MCUA Central Treatment Plant Conveyance Capacity Analysis and Cost and Performance Analysis Report* and the Conveyance and Capacity Analysis Cost and Performance Analysis Report (CDM, August 2007) and in the RVE (March 2019) *Central Treatment Facility (Edward J. Patten Water Reclamation Center) – Capacity Report Cost and Performance Analysis report.*

Five (5) different Rapid Primary Treatment Technologies were evaluated and presented in the CDM (August 2007) report and in the RVE (March 2019) report, including Fine Screens;

Swirl/Vortex Separator; Ballasted Flocculation; Chemical Enhanced Primary Treatment (CEPT) and Microscreens. Based on the evaluations of the technologies, a treatment train consisting of Swirl/Vortex Separators, sodium hypochlorite disinfection, and blending with the CTP's secondary effluent was selected. Please refer to Section 4.2.7 of this report for more information on the Vortex Separator Technology.

Performance Value PV4 was developed in the RVE (March 2019) report for 42 MGD, which is equivalent to the 42 MGD peak flow rate alternative in this DEAR report. A conceptual site plan is presented in Figure 4-12.

The dedicated HRT train for the PV4 scenario is based on two (2) swirl/vortex separators and associated pumping and utility piping. The capacity of existing sodium hypochlorite tanks would be adequate to treat the PV4 flow; however, two (2) new chemical feed pumps would be required. The existing contact time in the outfalls would be adequate to disinfect the PV4 effluent flow. Based on a preliminary mass balance and the unit process capacities discussed in the RVE report, the capacity of existing solids-handling processes, except for the gravity thickeners, would be adequate to treat the additional sludge generated under PV4. Two (2) additional gravity thickeners would be added to keep the solids loading under the maximum recommended 16 lb. per day/sq. ft (RVE, 2019).

Table 4-9 presents the estimated combined TSS and BOD effluent concentrations and loadings for the PV5 scenario. The weekly and monthly values are presented to coincide with the existing permit limits for TSS and BOD. The weekly and monthly values were calculated based on the wet weather event lasting two (2) days. For the remainder of the week or month, it was based on the CTP operating at average conditions (i.e., existing average effluent values were used). Under this scenario, the CTP would continue to discharge by gravity via the outfalls and would meet current NJPDES permit limits.

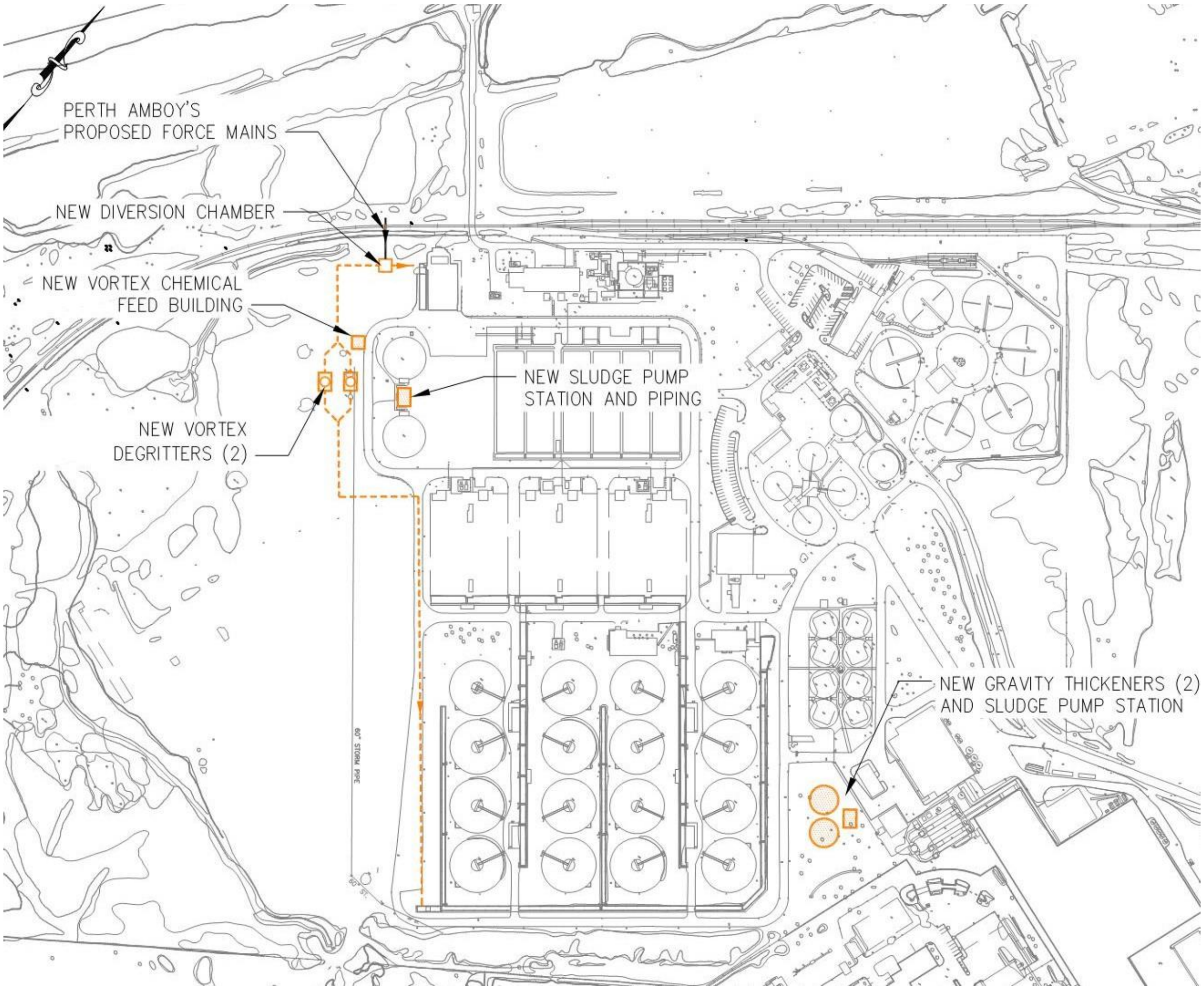


Figure 4-12 - MCUA CTP CSO Bypass Conceptual Design Site Plan

Table 4-9 presents the estimated combined TSS and BOD effluent concentrations and loadings for the PV4. The weekly and monthly values are presented to coincide with the existing permit limit for TSS and BOD. The weekly and monthly values were calculated based on the wet weather event lasting two (2) days. For the remainder of the week or month, it was based on the CTP operating at average conditions (i.e., current average effluent values were used). Under this scenario, the CTP would continue to discharge by gravity via the outfalls and would meet the current NJPDES permit limits. This alternative is a viable option and is evaluated further in this report.

Table 4-9 - MCUA CTP Estimated TSS and BOD Daily and Monthly Average Effluent Concentrations - PV4

Category	Wet Weather Effluent TSS, mg/L	Wet Weather Effluent BOD, mg/L	Combined Effluent TSS, kg/day	Combined Effluent BOD, kg/day	Combined Flow Meets All Permit Limits
Daily – PV4 Event	50.4	25.4	72,985	36,782	NA
Weekly	38.45	20.92	26,215	14,262	Yes
Monthly	25.16	15.59	11,242	6,966	Yes

Courtesy: Revised MCUA CTP Capacity Report Cost and Performance Analysis (RVE, March 2019).

Since the maximum CSS flow rate from Perth Amboy was estimated at 54 MGD, Performance Value PV5 was developed in the RVE (March 2019) report for 52.5 MGD. Performance Value PV5 was developed in the RVE (March 2019) report for 52.5 MGD, which is equivalent to the 54 MGD peak flow rate alternative in this DEAR report. A conceptual site plan is presented in Figure 4-12.

The dedicated HRT train for the PV5 scenario is based on two (2) swirl/vortex separators and associated pumping and utility piping. The capacity of existing sodium hypochlorite tanks would be adequate to treat the PV5 flow; however, three (3) new chemical feed pumps would be required. The existing contact time in the outfalls would be adequate to disinfect the PV5 effluent flow. Based on a preliminary mass balance and the unit process capacities discussed in the RVE report, the capacity of existing solids-handling processes, except for the gravity thickeners, would be adequate to treat the additional sludge generated under PV5. Two (2) additional gravity thickeners would be added to keep the solids loading under the maximum recommended 16 lb. per day/sq. ft (RVE, 2019).

Table 4-10 presents the estimated combined TSS and BOD effluent concentrations and loadings for the PV5 scenario. The weekly and monthly values are presented to coincide with the existing permit limits for TSS and BOD. The weekly and monthly values were calculated based on the wet weather event lasting two (2) days. For the remainder of the week or month, it was based on the CTP operating at average conditions (i.e., existing average effluent values were used). Under this scenario, the CTP would continue to discharge by gravity via the outfalls and would meet current NJPDES permit limits.

The MCUA CTP CSS Bypass with HRT and disinfection alternatives for the 42 MGD and 54 MGD CSS flow scenarios are viable alternatives for accomplishing the project objectives and are evaluated further in Section 6 of this report.

Table 4-10 - MCUA CTP Estimated TSS and BOD Daily and Monthly Average Effluent Concentrations - PV5

Category	Wet Weather Effluent TSS, mg/L	Wet Weather Effluent BOD, mg/L	Combined Effluent TSS, kg/day	Combined Effluent BOD, kg/day	Combined Flow Meets All Permit Limits
Daily – PV5 Event	50.4	25.4	72,992	37,794	NA
Weekly	38.64	20.99	26,788	14,551	Yes
Monthly	25.3	15.65	11,372	7,032	Yes

Courtesy: Revised MCUA CTP Capacity Report Cost and Performance Analysis (RVE, March 2019).

4.2.4 Regulator Modifications

Regulator modifications for CSO control often include enlarging the connection between the regulator and the interceptor or raising the overflow weir which lead to increased capture. It is a useful CSO control technology but have limited application when used alone. This technology will be further evaluated in Section 6. A $50,000 allowance per regulator for modifications has been assumed for cost estimation purposes.

4.2.5 Inflow and Infiltration Reduction

To maximize the combined sewer system's capacity, it is necessary to remove extraneous flows caused by infiltration and inflow (I/I) in the separate portion of the system. Infiltration is groundwater that enters the system through broken or cracked pipes, defective joints, depressed manholes, and manhole walls. Replacing or lining defective pipes, pipe joints and manholes can reduce infiltration. Infiltration problems are generally difficult to isolate, which impacts the cost-effectiveness of this measure. Often, significant lengths of sewer must be rehabilitated before gaining significant infiltration reductions. Inflow results from direct connections to the system from catch basins, roof leaders, cellar and yard drains, sump pumps, and commercial and industrial drains. Inflow sources could be diverted to existing separate storm drains in these separated areas.

4.2.5.1 Perth Amboy I/I Reduction Efforts

To maximize the collection system's capacity, it is necessary to remove extraneous flows caused by infiltration and inflow (I/I). Infiltration is groundwater that enters the system through broken or cracked pipes, defective joints, depressed manholes, and manhole walls. Replacing or lining defective pipes, pipe joints and manholes can reduce infiltration. Infiltration problems are generally difficult to isolate, which impacts the cost-effectiveness of this measure. Often, significant lengths of sewer must be rehabilitated before gaining significant infiltration reductions.

Only 16% of the City’s sewer system is separated, and this portion of the system contributes relatively little wet weather response compared to the 84% of the system that is combined. Infiltration and inflow reduction on a system-wide scale is extremely costly to achieve, and the actual reduction levels to be achieved are not known until after the extensive sewer rehabilitation efforts are completed and evaluated with post-improvement flow monitoring. Given these considerations, this LTCP will consider sewer separation in a limited way through

4.2.5.2 MCUA I/I Reduction Efforts

All municipalities serviced by MCUA, except the City of Perth Amboy, are separate sewer areas. The MCUA has been working with all connected sewer systems to maximize available flow capacity at the CTP. The MCUA has a program in place to encourage its participants to reduce Infiltration and Inflow (I/I) from entering their respective collection systems as required by each Participant in accordance with Article VI (I) of the Agreement between MCUA and each Participant, which states the following:

> *“Each Municipality and all public corporations discharging sewage into the Local Sewerage System of a Municipality will maintain its Local Sewerage System in such a manner as to exclude any excessive infiltration and/or inflow from entering into the local Sewerage System.*

If excessive infiltration and/or inflow exists or occurs, the Municipality and public corporation will affect such repairs, or other measures, so as to eliminate the excessive infiltration inflow to normally allowable limits which are acceptable to the DEP and / or USEPA. Furthermore, if as a result of a sewer evaluation survey, rehabilitation work is shown to be required, each Municipality and public corporation will perform such work as may be necessary to rehabilitate its Local Sewerage System."

MCUA provided a summary of this Program in its May 10, 2019 letter to NJDEP and USEPA. The May 10 letter provided a summary of the current program which is indicated in italics below:

The MCUA's Infiltration and Inflow Reduction Program which has been in place since 1998 continues to identify those Participant Meter Chambers with wet weather flows greater than 2.5 times normal flows as contributing excessive flow to the MCUA during storm events. Attached hereto as Exhibit A is the MCUA's 2018 Infiltration/Inflow evaluation for each of the MCUA Meter Chambers. In 2018, the MCUA decided to focus on Municipal Participants that have an overall contribution of excessive Infiltration and Inflow to the MCUA's owned, operated and maintained trunk sewer system in excess of 2.5 times there 2017 dry weather and average flows.

By letter of August 22, 2018, the MCUA requested updated Infiltration/Inflow Reduction Programs from those Municipal Participants identified as contributing excessive Infiltration/Inflow. Attached hereto as Exhibit B, are copies of the letter sent to those Municipal Participants identified as having an overall contribution of excessive Infiltration/Inflow to the MCUA and requesting an updated Infiltration/Inflow Reduction Program be submitted to the MCUA. The Infiltration/Inflow Reduction Program submitted by the Municipal Participants, at a minimum, should contain the following elements:

Infiltration/Inflow Identification

Short Term/long Term Corrective Action

Schedule Indicating date/time for corrective actions to be initiated and completed

Quarterly Progress Report submittal schedule to the MCUA

As in the past, if a Municipal Participant fails to submit the required Infiltration and Inflow Reduction Program and quarterly reports on its progress, the Authority may withhold endorsing new projects until such time a progress report is submitted or only endorse new projects within for Construction Only. Subsequently, to obtain the Authority's endorsement for "Operation" the Participant must fulfill the requirements of the MCUA Infiltration/Inflow Reduction Program.

This program has proven successful over the years by reducing excessive Infiltration and Inflow entering the MCUA's Central Treatment Plant, via its Trunk System, from its Participants local sewerage collection system drainage areas as monitored by the MCUA daily at each of the Participants Meter Chambers. Attached hereto as Exhibit C, is a graph depicting the overall reduction in Infiltration/Inflow entering the MCUA Central Treatment Plant prior to and after the implementation of the MCUA Infiltration/Inflow Reduction Program.

> *To assist the USEPA and NJDEP in their efforts to reduce excessive Infiltration and Inflow from entering publicly and privately owned operated and maintained sewerage systems within the MCUA's service area, the MCUA through its flow monitoring program will continue to monitor and inform its Participants on a quarterly basis of their daily flows. In addition, the MCUA will continue its annual evaluation of the flows from each of its Participant Meter Chambers to determine which Participant sewerage drainage areas are exhibiting excessive flows. Upon completion of the evaluation, the MCUA will request those Participants that have drainage areas exhibiting excessive flows during storm events to provide a summary of their Infiltration/Inflow reduction efforts to date and, if necessary, update their Infiltration/Inflow Reduction efforts*.

The MCUA has undertaken several capital projects to address infiltration/inflow concerns within portions of their existing Main Trunk Sewer system. The MCUA initiated planning studies for the long-term rehabilitation of approximately 35,000 lineal feet of 60-inch and 66-inch CMP extending along the Raritan River between Bound Brook and Highland Park where the pipe is constructed of asphalt line Corrugated Metal Pipe (CMP) installed in 1955. To date, the MCUA has committed over $13 million to reline and rehabilitate approximately 13,000 feet of trunk sewer using trenchless technologies including segmental slip lining and Cured-In-Place Pipe (CIPP) technologies, or replacement of certain sections that may be required. Phase I involving approximately 6,000 feet of 60-in and 66-inch CMP has been completed, and approximately 8,000 feet of 60-in and 66-inch are currently being rehabilitated, as well as over 2,000 feet of smaller connecting sewers.

MCUA is currently coordinating the design for Phase III rehabilitation of approximately 4,400 LF of CMP pipe as well as several siphons, meter chambers and connecting gravity sewer pipes with an estimated construction cost of approximately $12 million, and a final phase of rehabilitation for the remaining CMP portions of the MTS is planned for 2020/2021 at a range of costs between $10 million and $15 million dollars. In total, the MCUA will be committing between $35 million and $40 million to rehabilitate its CMP portions of the Main Trunk Sewer. These projects will significantly reduce I/I within these sections of the MTS system.

The MCUA is also implementing an Asset Management Plan for its collection system to further evaluate and prioritize improvements, if necessary, to the remaining Reinforced Concrete Pipe (RCP) and Prestressed Concrete Cylinder Pipe (PCCP) portions of the Main Trunk and South River Interceptor systems to further reduce I/I across the system.

4.2.6 Sewer Separation

Sewer separation is defined as the reconstruction of an existing combined sewer system into separate non-interconnected sanitary and storm sewer systems. The sanitary sewer system is tributary to the wastewater treatment plant, and the storm sewer system discharges directly to local receiving waters.

Typically, to separate an existing combined sewer area, either a new drainage system is constructed, or new sewer pipelines are installed, and the existing combined sewer is used as the sanitary or separate storm drain, respectively. Construction of new sanitary sewers is preferable due to the added benefit of reducing infiltration associated with deficiencies in the existing sewers. If portions of the combined sewer system were found to be susceptible to structural failure, they would likely require complete replacement and two new pipes would likely be constructed for the separate sewer and storm drain systems.

Unlike storage and treatment alternatives, which reduce the frequency of CSO discharges, full sewer separation of a combined sewer system eliminates CSOs by diverting all sanitary flow to the wastewater treatment plant and discharging stormwater to receiving waters. The USEPA CSO abatement policies require that combined sewer system separation be evaluated as a step in CSO facilities planning. Although full separation eliminates CSOs, it may not, in all cases, be the most appropriate alternative in terms of addressing site-specific water quality objectives. Full separation eliminates pollutant loadings to receiving waters caused by the sanitary flow in CSOs; however, impacts caused by stormwater pollutants remain and often increase. Such pollutants may include bottles, cans, cups, wrappers, cigarette butts, leaves, sediment, and other items that enter the storm drains.

Under the USEPA Phase II stormwater program, communities are required to assess their stormwater quality. The USEPA "Report to Congress, Impacts and Control of CSOs and SSOs" dated August 2004 states that implementation of stormwater controls may be necessary following separation to obtain pollutant load reductions necessary for attainment of water quality standards.

Partial separation is a useful CSO control technology, but with limited application. Partial separation projects target specific areas where CSO reduction benefits may outweigh the construction costs and other impacts. This technology will be further evaluated in Section 6.

4.2.7 Treatment of the CSO Discharge

Treatment technologies are intended to reduce the pollutant loads to receiving waters by treating wet weather flows prior to discharging to the environment. Specific technologies can address different pollutant constituents, such as settleable solids, floatables, or bacteria. To satisfy CSO treatment objectives, treatment technologies for each unit processes of screenings/pretreatment/disinfection alternatives have been evaluated in the following aspects.

- Applicability for CSO control
- Performance
- Hydraulics
- Waste Stream generation
- Complexity
- Limitations
- Construction costs
- Operation and maintenance cost
- And Space requirement.

4.2.7.1 Screening Technology

Screening technologies can either represent minimal treatment of a CSO before disinfection or can be used to remove larger particles upstream of vortex/swirl separation, ballasted flocculation, or compressed media filtration before high rate disinfection processes. The screening technologies and their related clearances, reviewed for the PVSC TGM, are as follows:

- Mechanical Bar Screens 0.25" to 2" (6-50 mm) bar spacing
- Fine Screens 0.125" to 0.5" (3-13 mm) bar spacing
- Band and Belt Screens 0.08" to 0.4" (2-10 mm) openings
- Drum screens 0.0004" (0.01 mm) openings

As indicated above screening technology will remove large material or particles as small as 0.0004" from the waste stream. The choice of a particular screening technology is a function of the general purpose of the screen, and what additional treatment process or equipment lies downstream. Screens with smaller openings, such as belt and micro screens, typically require pretreatment with a mechanical bar screen to prevent damage from large objects. Screenings equipment which are not continuously cleaned, such as manually cleaned bar screens, were eliminated from this evaluation due to the potential for backup and surcharging of the collection system. In general, screening systems are very effective in removing floatable and visible solids, but do not remove a significant amount of TSS, fecal coliform, enterococci, BOD, COD, NH3, TN, total phosphorous, and total nitrogen.

The following sections describe the types of screens and equipment, as well as its capability to remove the various pollutants of concern. At the end of the section a summary of performance, operation, and environmental impacts will be presented. Based upon this summary some of the screening technologies will be eliminated from further consideration. Each process was rated from 1 to 5, with 5 being the highest. While somewhat subjective, this method does provide a mechanism for comparing each screening process. The results of the evaluation are illustrated in Table 4-11.

Table 4-11 - Evaluation of Screening Technology

Criteria	Mechanical Bar Screens	Fine Screens	Band and Belt Screens	Drum Screens
Applicability	5	5	1	1
Performance				
TSS	1	3	4	4
Solids and Floatables	1	2	4	4
Hydraulics	4	4	1	1
Waste streams	3	5	1	1
Complexity	5	5	1	1
Limitations	2	2	1	1
Construction Cost	4	2	1	1
Operations	4	4	1	1
Maintenance	4	3	1	1
Space Requirements	3	2	1	1
Total	31	32	16	16

Source: TGM Table 2-7

4.2.7.1.1 Mechanical Bar Screens

Description of Equipment

The three most common types of mechanically cleaned bar screens are: (1) chain driven, (2) climber type rake, and (3) catenary. Chain driven mechanical raking systems consist of a series of bar rakes connected to chains on each side of the bar rack. During the cleaning cycle, the rakes travel continuously from the bottom to the top of the bar rack, removing material retained on the bars and discharging them at the top of the rack. A disadvantage of chain-driven systems is that the lower bearings and sprockets are submerged in the flow and are susceptible to blockage and damage from grit and other materials. Climber-type systems employ a single rake mechanism mounted on a gear driven rack and pinion system. The gear drive turns cog wheels that move along a pin rack mounted on each side of the bar rack. During the cleaning cycle, the rake mechanism travels up and down the bar rack to remove materials retained on the bars. Screenings are typically discharged from the bars at the top of the rack. This type of bar screen has no submerged bearings or sprockets and is less susceptible to blockages, damage and corrosion. Catenary systems also employ chain drive rake mechanisms, but all sprockets, bearings, and shafts are located above the flow level in the screen channel. This in turn reduces the potential for damage and corrosion and facilitates routine maintenance. During the cleaning cycle, the rakes travel continuously from the bottom to the top of the bar rack to remove materials retained on the bars. Screenings are typically discharged from the bars at the top of the rack. The cleaning rake is held against the bars by the weight of its chains, allowing the rake to be pulled over large objects that are lodged in the bars and that might otherwise jam the rake mechanism.

Bar screens will remove essentially 100% of all rigid objects of which the minimum dimension is more than the spacing between the bars. Removing screenings from CSOs essentially does not remove any dissolved solids, or nutrients such as TKN, total nitrogen and total phosphorous. Screenings removed from overflows can however contain some larger rigid materials that reflect a BOD loading. Solids, such as fecal material, can also be contained within screenings collected on the bar screen, however the velocity between the bars increases with increasing flow, thus this material can be broken up and pass through the bars. Therefore, it is difficult to quantify on a consistent basis any BOD loading, fecal coliform and enterococci count, and TSS concentrations removed by the screening technologies. Nevertheless, some removal estimates, as provided by the manufacturer, have been included within the analysis procedure for further consideration.

For the purposes of the Technical Guidance Manual, the mechanical bar screen evaluation is based on the use of Climber Screens® since these have been found to be more reliable and significantly lower in operation and maintenance requirements than others. Figure 4-13 shows photos of typical climber screens. The Technical Guidance Manual analysis is based on mechanical bar screens with a minimum bar spacing of 1/2", a maximum velocity between the bars of 4.5 feet per second (fps), and a peak velocity of approach of 3.0 fps. These are the standard criteria for designing bar screens for use in wastewater treatment plants, where flow is continuous and the diurnal patterns more predictable. Since CSOs are intermittent, with widely varying flow rates, these standards are more likely to be violated for short periods of time. The mechanical bar screen selections are also based upon an anticipated head loss of less than one foot, a peak flow level of six feet under peak flow conditions, with an operating floor located twelve feet above the water surface.

Figure 4-13 - Photo of Typical Climber Screen

(Source: Vulcan Industries)

Applicability to The Project

Mechanical bar screens have proven to be a relatively simple and inexpensive means of removing floatables and visible solids. They are typically the screen of choice in treatment facilities and are used at a many CSO treatment facilities. There have been hundreds of Climber Screens® installed in CSO applications across the US. A list is provided in Appendix A focused on Type IIS and IIIAS installations in NJ, NY, and PA since 2000.

Performance Under Similar Conditions

As stated above, mechanical bar screens are already installed in many CSO facilities and operate successfully to remove floatables and visible solids over the fluctuations in flow rates seen in CSOs. Slight removal of TSS, total phosphorous, and total nitrogen (typically 5%, 3%, and 2%, respectively) can be achieved with the solids removal.

Hydraulics

Hydraulic losses through bar screens are a function of approach velocity, and the velocity through the bars. The head loss across the bar screen increases as the bar screen becomes clogged, or blinded. Instrumentation provided with mechanically cleaned screens is typically configured to send a signal to the cleaning mechanism so the head loss across the screen is limited to 6 inches.

Generation of Waste Streams

As screenings are removed from the CSO flows they generate a waste stream for disposal. Studies have found that the average CSO screenings loads vary from approximately 0.5 to 11 cubic feet per million gallons, with peaking factors based upon hourly flows ranging from 2:1 to greater than 20:1. These screenings must be either transferred to the interceptor sewer for ultimate disposal at the WWTP, or removed and stored in a container for onsite removal at a convenient time. The collection of screenings can be performed using conveyors, screenings compactors, or pumps. Any enclosure around the screenings equipment should provide space for a container and odor control.

Complexity

Mechanical bar screens are able to function intermittently, at remote locations with a minimum level of instrumentation. A level detector is needed to determine when a CSO is occurring and to activate the screen. Differential head sensors located upstream and downstream of the screen will detect head loss and initiate a cleaning cycle. During periods where there are no overflows, a timer can be utilized to periodically exercise the screen, so it is ready for use.

Limitations

When mechanical bar screens are installed in a WWTP, the flows vary within an anticipated range which is predetermined so the screens can be sized for the necessary peak flows, and redundant units can be provided. In CSO installations there are wide variations in flow rates that can pass through the screens, but the high flow rates are usually of short duration. Due to the intermittent nature of CSOs, it is not considered cost effective, nor necessary to provide redundancy. Nevertheless, providing multiple units in separate channels is a means of handling equipment out of service. The quickness with which CSO flows can increase however can lead to problems in getting units in other channels into operation quickly enough given the operating speeds of motor operated sluice gates. A review of the pollutant removal rates as reported by the manufacturer indicates that only about 5% of the TSS is removed by the screen. While screening of solids may be adequate for the lower treatment objects (50%, 85%, and 95% removals) where TSS levels are not as critical, the literature does not indicate that screening alone will remove adequate solids to provide for consistent and reliable disinfection at higher treatment objectives.

Construction Costs

The PVSC TGM, January 2018, presents the preliminary planning level construction cost estimates of Climber Screens® for design flows ranging from 10 MGD to approximately 450 MGD. It includes equipment cost, installation cost, general contractor (GC) field general conditions, GC overhead & profit (OH&P), and contingency. This cost estimates assume that the Climber Screens® will be installed in existing CSO channels. The installation cost is assumed at 50% of the equipment cost based on the complexity of the installation. Budgetary equipment pricing information for Climber Screens® was gathered from equipment manufacturer Suez, formerly Infilco Degremont, Inc..

Climber Screens® pricing is primarily determined by channel size which is dictated by the flow and plant specific parameters or design. Therefore, the Type IIS is suitable for channels up to 7'-0" wide. Pricing provided by the manufacturer is based on assumed channel dimensions of 5'-0" wide by 10'-6" deep. A single unit of this model of Climber Screen® would be suitable for up to 50 MGD or larger depending on channel dimensions. The Type IIIAS is suitable-for channels 6'-6" to

12'-0" wide. The pricing provided by the manufacturer is accurate up to the 8'-0" wide and 10'-6" deep dimensions. For the large 450MGD flow, multiple units each designed for a peak flow of 112 MGD are recommended. Capacity can be adjusted based on channel dimensions, bar rack clear spacing, and number of units desired.

Operation and Maintenance

Costs associated with operation include the electrical cost for operating the motor(s) on the mechanical bar screens. Regular maintenance requires visits to the site after each storm to inspect the screens for damage, remove any large material in the channels, clean up any screenings on the floor or equipment, and general wash down of the area. Regular maintenance also includes routine lubrication and maintenance of the tracks, racks, drives, and gear boxes. It is important to keep the pin racks and carriage bearings greased and oiled. It is also important to inspect the bearings for excessive wear. The Type IIS and IIIAS carriage assemblies utilize self-greasing/oiling canisters which are easily replaced at the recommended intervals. The follower shaft bearings and carriage drive bearings are replaced utilizing access points built into the side frames (i.e. carriage does not need to be removed). It is recommended to perform periodic visual inspections to ensure proper operation, lubrication and bearing wear.

Estimated annual operation costs and estimated annual maintenance labor costs for the Climber Screen® are presented in the PVSC TGM, January 2018.

Space Requirements

The space required for mechanical bar screens consists of the building and area on the exterior of the building for access to remove the screenings container.

Case Study

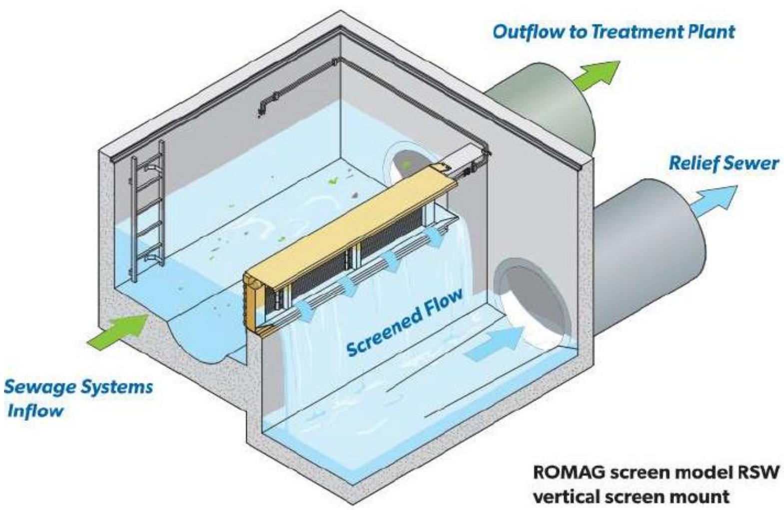
New York City utilized TypeIIIAS Climber Screens® at their 110th St. Manhattan and Bronx Pumping Stations from 1986 until 2016. These pumping stations deliver combined sewage to the Wards Island WWTP, which has a total plant flow of approximately 500 MGD. After the first 6 years of using the Climber Screens®, the chain and sprockets were beyond their useable life. Although initially designed for 5HP per pump based on the average weight of debris, it was later found that 7.5 HP was required to handle the harsher conditions imposed by the combined sewage.Mechanical bar screen is a viable treatment alternative for significant control. However, screening alone will remove only floatables and large solids and does not address coliform contributions to receiving waters. To meet all water quality goals, the CSO control alternatives evaluations will consider mechanical bar screens in combination with high rate treatment and chlorination/dechlorination.

4.2.7.1.2 Fine Screens

Description of Process

These screens have openings ranging from 1/8" to 1/2" and will capture suspended and floatable material with smaller dimensions. The equipment evaluated under this category of screenings technology includes ROMAG™ Screens as manufactured by WesTech Engineering, Inc.

The ROMAG Screens consist of parallel bars similar to a bar screen, with spacing varying from 0.16" to 0.47". The screens are cleaned by combs, which extend through the rack and are attached to a hydraulically driven mechanism on the downstream side of the screen. The hydraulic unit is located above grade in an enclosure. The material collected on the upstream side of the screen is cleaned off the face of the screen by the combs and kept in the flow in the interceptor. They are not removed or collected but continue toward the wastewater treatment plant for removal. As the flow increases beyond the capacity of the screens, the upstream water surface rises and overflows a baffle that is part of the screen assembly, discharging directly to the outfall. All the fine screens of this category are located such that the solids are retained on one side of the screen and transported to the interceptor or other facility for ultimate disposal Figure 4-14 shows the cross section of vertical mount ROMAG Screens.



(Source: WesTech Engineering Inc.)

Figure 4-14 - Cross Section of ROMAG Screens

Applicability to the Project

Fine screens have proven to be a relatively simple and inexpensive means of removing floatables and visible solids where the overflow is controlled by a weir. They are typically constructed in the regulator, sometimes requiring modifications to the regulator, such as moving the weirs, and extending the weir lengths. The required screening capabilities for the maximum flow rate would need to be provided, since flows exceeding the capacities of the screens will continue to overflow unscreened.

Performance Under Similar Conditions

As stated above, fine screens are typically installed in CSO regulators and operate successfully to remove floatables and visible solids over the fluctuations in flow rates seen in CSOs. Slight removal of TSS, total phosphorous, and total nitrogen (typically 10%, 8%, and 5%, respectively) can be achieved with the solids removal.

Hydraulics

The typical head loss reported through the unit is 4 inches, while additional freeboard from the maximum flow through the screens to the baffle height is typically 2 inches. The total head loss through the screen is typically about 6 inches at the design flow.

Flows exceeding the capacity of the screens would overflow the baffle and by-pass the screen. Usually additional weir length is needed so that the existing upstream water surface elevations are maintained after the screen is installed

Generation of Waste Streams

Fine screens are located in the regulator with flow passing up and through the screen, overflowing the weir and going out the outfall. Since the flow direction is up through the screen, the screened material is kept on the interceptor side of the screen and remains in the interceptor when the cleaning mechanism cleans the face of the screen. Since the screenings remain in the interceptor, there is no collection at the screen and therefore no waste stream. Nevertheless, the limitation is that there be adequate flow and solids transport within the interceptor sewer system. The additional screening material that remains in the interceptor will find its way to any downstream regulators, and eventually to the WWTP.

Complexity

Fine screens can function intermittently, at remote locations with the minimum of instrumentation. A level detector is needed to determine when a CSO is occurring and to activate the screen. Differential head sensors located upstream and downstream of the screen will detect head loss and initiate a cleaning cycle. During periods where there are no overflows, a timer can be utilized to periodically exercise the screen, so it is ready for use.

Limitations

Fine screens would need to be installed on regulators with weirs. Other types of regulators would require the construction of a weir, at which point the use of a mechanical bar screen may be preferable. Also, any regulators where the fine screens would be installed would need to be accessible for routine inspection and maintenance of the screens. A review of the pollutant removal rates as reported by the manufacturer indicates that only about 10% of the TSS is removed by the screen. While screening of solids may be adequate for the lower treatment objectives (50%, 85%, and 95% removals) where TSS levels are not as critical, the literature does not indicate that screening alone will remove adequate solids to provide for consistent and reliable disinfection at higher treatment objectives. The higher TSS removal rates of fine screens versus mechanical bar screens (10% vs 5% respectively) may result in TSS levels acceptable for disinfection at lower treatment objectives.

Construction Costs

The preliminary planning level construction cost estimates are provided in PVSC TGM, January 2018, for ROMAG™ Screens of design flow ranging from 10 MGD to 450 MGD. It includes equipment cost, installation costs, GC field general conditions, GC OH&P, and contingency. This cost estimates assume that the ROMAG™ Screens will be installed in existing regulators. The costs for modifying the regulator to accommodate the installation of the screen is included in the installation cost. The installation cost is assumed at 50% of the equipment cost based on the complexity of the installation. Budgetary equipment pricing information for ROMAG™ Screen was gathered from equipment manufacturer WesTech Engineering, Inc. Based on vendor provided information, the largest individual screen can potentially handle up to 100 MGD, and in the case of higher demand multiple screens would be applied side by side. Velocities should be restricted to 5 ft/s. The equipment cost includes the controls, hydraulic power pack and everything needed to operate.

Operation and Maintenance Costs

The operating costs include the electrical cost for operating the hydraulic power pack and an in-tank (hydraulic fluid) heater (700W-120V). The hydraulic pack operates the cleaning comb action across the screen. Each single ROMAG Screen has a hydraulic power pack that consists of a 5HP motor to drive the hydraulic pump. An 1HP in-tank heater for each screen is used to keep the hydraulic fluid at right temperature. Routine maintenance of the ROMAGTM Screens includes visits to the site after each storm to inspect the screens for damage, remove any large material in the channels, and cleanup of any screenings on the floor or equipment, and general wash-down of the area. Routine maintenance also includes the monthly maintenance of the screen such as replacing combs, repairing leaks in the hydraulic lines, maintaining the oil level in the hydraulic drive, and cleaning any level sensors, etc.

Estimated annual operation costs and annual maintenance labor costs for the ROMAGTM Screens are presented in the PVSC TGM, January 2018.

Space Requirements

Since the fine screens would be installed in the regulators, which would probably be located in the street or existing easement, it is anticipated that there would be no additional space requirements for the fine screens.

Case Studies

Chattanooga, Tennessee utilizes ROMAG™ Screens at their downtown CSO treatment facility. Two RSW 8x7 screens were installed in 2000 and are still in use treating approximately 180 MGD. The maintenance of the screens was reported as minimum, and the automatic cleaning function had been working well with the exception of one instance where the screens became stuck.

The City of Binghamton, NY, has been using CSO screens for floatable control at four CSO locations since 2003. According to conversations with the site supervisor, the screens have been trouble free. Both sides of the screens can be observed without entering the channel, and weekly inspection takes approximately 5 minutes. Typically, operators hose down the screens to remove residual debris after a storm event. Binghamton operators check the tension of the bars annually and change hydraulic oil and filters per the Operations and Maintenance manual. No parts have required replacement to date.

Chattanooga, Tennessee utilizes ROMAG™ Screens at their downtown CSO treatment facility. Two RSW 8x7 screens were installed in 2000 and are still in use treating approximately 180 MGD. The

maintenance of the screens was reported as minimum, and the automatic cleaning function had been working well with the exception of one instance where the screens became stuck.

Fine screens will be considered further as part of mixed technology alternatives.

4.2.7.1.3 Band and Belt Screens

Description of Process The common characteristic of these screens is that they contain stainless steel perforated elements forming a continuous band traveling either parallel or perpendicular to the flow stream. In the case where the band is parallel to the channel, flow enters the center of the screen, turns 90 degrees and passes through the sieve elements, exiting through the sides of the unit. Where the band is perpendicular to the channel flow passes through the screen, with the screened flow continuing down the channel.

Figure 4-15 - Finescreen Monster

Figure 4-15 shows a photo of Finescreen Monster, manufactured by JWC Environmental. These screens utilize either stainless steel, or UHMW sheets with perforations between 0.08" to 0.4" mm in diameter.

Figure 4-16 - Photo of Bandscreen

(Courtesy of JWC Environmental)

Applicability for the Project

These screens are typically used for polishing wastewater treatment flows. Their perforated panels are very prone to clogging from fibrous materials and are not easily cleaned. To protect these screens from larger objects that could damage or clog them, the manufacturers recommend installing ¾ inch screens upstream of them. However, that ¾ inch screen upstream of the belt and band screen would have the same pollutant removal efficiency and thus the belt and band screen would be ineffective. Accordingly, it does not appear to be practical to utilize these types of screens in a CSO application. There currently are no known installations on CSO discharges.

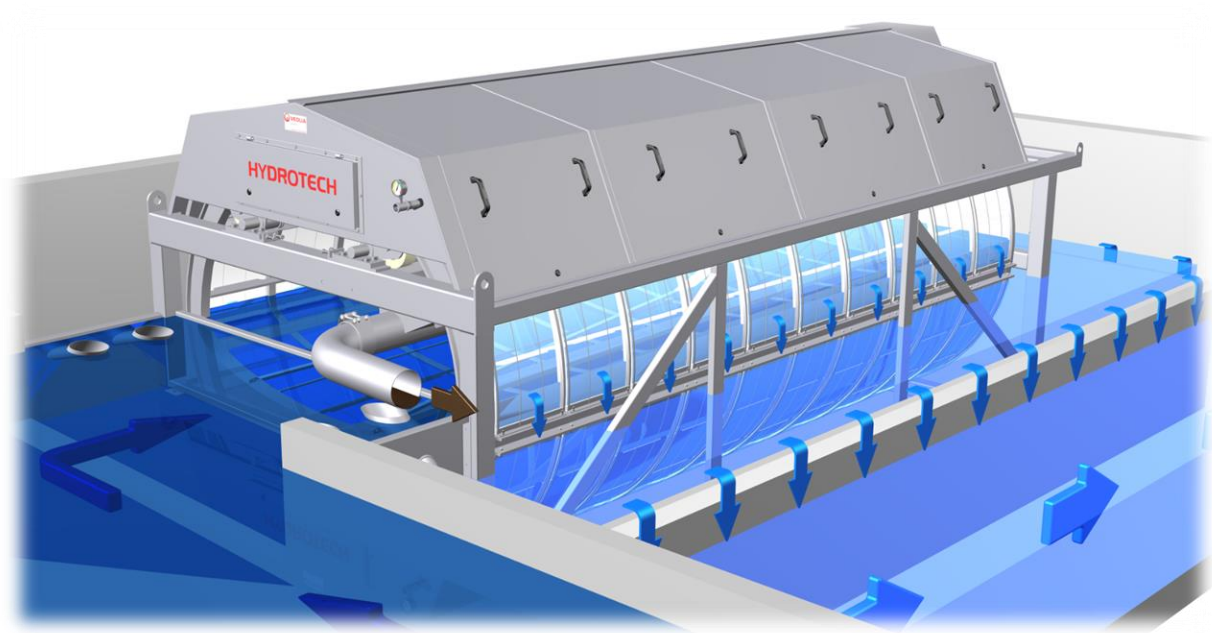
These screens are not considered applicable for CSO treatment and are not further evaluated.

4.2.7.1.4 Drum Screens

Description of Process

A drum screen is a fine filter with openings from 10 to 1000 microns. The filter cloth is made of acid proof steel or polyester. Three, four, or five filter elements are placed in sections over a rotating drum, depending upon the drum diameter. The drum rotates in a tank. The liquid is filtered through the periphery of the slowly rotating drum. Assisted by the filter elements special cell structure, the particles are carefully separated from the liquid. Separated solids are rinsed off the filter cloth into the solids collection tray and discharged. The operation of the drum can be continuous or automatically controlled. The unit evaluated for this application was the

HydroTech Drumfilter by Veolia Water Technologies. Figure 4-17 shows a cross section HydroTech Drumfilter.



(Source: Veolia Water Technologies)

Figure 4-17 - Drumfilter

Applicability for the Project

Drum filters are currently used as a polishing unit at WWTPs. The disc media is polyethylene and the size openings are 10 microns for wastewater. The hydraulic loading for drum filters is 50 to 100 gpm, based upon an influent TSS concentration of 20 mg/L. The manufacturer expects an influent TSS concentration of 10 to 100 mg/L upstream of the unit. Accordingly, significant TSS removal equipment would be needed upstream of the screen. There currently are no known installations on CSO discharges.

These screens are not considered applicable for CSO treatment and are not further evaluated.

4.2.7.2 Pre-Treatment Technology

Pretreatment technology is used to remove floatable and total suspended solids (TSS) prior to high rate disinfection in CSO applications. The pretreatment technology evaluated includes:

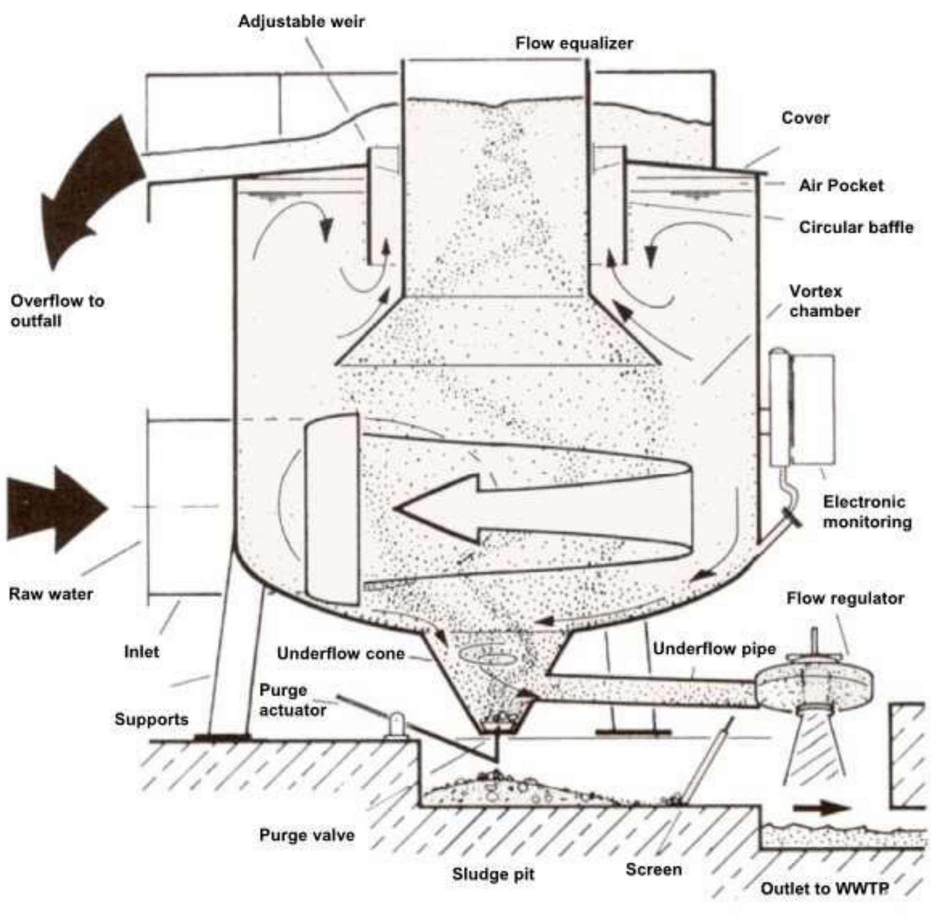
- vortex/swirl separation technology,
- ballasted flocculation, and
- compressed media filtration.

The choice of a pretreatment technology is a function of construction costs, space requirements, and type of disinfection treatment process downstream. In general, pretreatment is very effective in removing floatable and TSS. It can also remove certain amount of fecal coliform, enterococci, BOD, COD, NH3, TKN, total phosphorous, and total nitrogen, which is attached to the TSS. The following sections describe the types of pretreatment technology, as well as its capability to remove the various pollutants of concern.

4.2.7.2.1 Vortex/Swirl Separation Technology

Description of Process

Vortex/swirl separation technology utilizes naturally occurring forces to remove solids and floatable material. Flow enters a circular tank tangentially causing the contents to rotate slowly about the vertical axis. The flow spirals down the perimeter allowing the solids to settle out. This process is aided by rotary forces, shear forces, and drag forces at the boundary layer on the wall and base of the vessel. The internal components direct the main flow away from the perimeter and back up the middle of the vessel as a broad spiraling column, rotating at a slower velocity than the outer downward flow. Per manufacturer claims, by the time the flow reaches the top of the vessel it is virtually free of settleable solids and is discharged to the outlet channel. The collected solids are then discharged by gravity or pumped out from the base of the unit to the interceptor sewer or auxiliary storage tank if interceptor capacity is not available.



(Source: John Meunier, Inc.)

Figure 4-18 - Cross Section of a HYDROVEX® FluidSep Vortex Separator

Applicability to the Project

The HYDROVEX® FluidSep Vortex Separator was developed in 1985 by a German firm, Umwelt- und Fluid-Technik (UFT) as a tool in the treatment of CSO and stormwater. The first HYDROVEX® Fluidsep unit was installed in 1987 in the City of Tengen near Schaffhausen in Germany. The units are still operating successfully. A special research program that ended in the summer of 1990 supplied evidence of CSO treatment efficiency of the HYDROVEX® FluidSep (H. Brombach, et al., 1993). The program was based on the qualitative evaluation of sampling campaigns performed at the installation.

HYDROVEX® FluidSep is currently in full operation in Germany, France, Canada, and the United States of America. John Meunier Inc./Veolia Water Technologies designs and manufactures HYDROVEX® FluidSep units for the North America under license from UFT. HYDROVEX® FluidSep Vortex Separator are most effective on removing settleable solids and floatable material. The units have been installed in remote locations, away from treatment plants and have performed well. There are no moving parts within the vortex unit itself. Underflow from the unit can be discharged by gravity to sewers or continuously pumped to an ancillary tank where it would be stored until there is capacity in the interceptor sewer system.

Performance

The HYDROVEX® FluidSep vortex separator is most effective in removing heavier settleable solids, floatable material, and inorganic solids. The performance information provided by the manufacturer indicates that the percent removal of TSS, BOD and COD drops off as the hydraulic loading rate increases. TSS removal ranges from 35-50%, and BOD removal is typically 15-25%. Vortex units achieve removal by two means: the consolidation of solids material; and flow separation, which is accomplished by the underflow removal. When the vortex unit operates under low hydraulic loading rates, and there is a significant amount of settleable solids, both removal mechanisms are operating. As the hydraulic loading rate increases, or the settleable solids concentration decreases, there is less consolidation and the vortex unit functions more as a flow separator. At the highest hydraulic loading rates recommended, the unit functions strictly as a flow separator. The vortex units usually have an underflow that is 10% of the design capacity of the unit. So even under the worst conditions, when there is no consolidation of solids taking place, they would theoretically remove 10% of the pollutants. While this would hold true for the soluble portion of pollutants, in the case where the pollutant was associated with fine particles, the removal would be less. The reason for this decrease is that since fine particles weigh less, more of these particles would be carried out in the effluent especially at higher hydraulic loading rates. Some of the removals associated with these units are for lower volume storms when the volume associated with the unit acts as a storage system.

In the Bayonne Municipal Utility Authority (Bayonne MUA) Pilot Study, the Storm King® vortex units experienced operating issues due to their screens clogging with materials that appeared to be primarily toilet paper. Performance issues of less than 10% TSS removals were experienced when Volatile Suspended Solids (VSS) accounted for a high percent of the influent TSS. The TSS removal efficiencies improved when evaluating the inorganic component of TSS, or Fixed Suspended Solids (FSS). The FSS removal efficiencies for Storm King® units averaged around 17%, with the maximum removal efficiencies of 45.2%. The low removal of VSS (or inorganic) fraction of TSS indicated that the Storm King® units will be ineffective on their own with UV disinfection due to low ultraviolet light transmittance of the effluent.

Hydraulics

Vortex units are hydraulically efficient. The head loss through the unit consists of the losses through the inlet to the unit, and the head loss over the effluent weir. The losses in the lower hydraulic loading rates will be limited to less than six inches. At higher hydraulic loading rates, the losses will increase significantly, possibly up to a couple of feet, unless diverted upstream.

Generation of Waste Streams

As discussed under the description of the process and the performance, 10% of the design flow must continuously be removed as underflow. In many cases this flow will need to be pumped from the vortex unit due to the depth of the underflow pipe. While permittees with conveyance facilities must evaluate means of increasing conveyance to the WWTP, it is doubtful that the underflow can be consistently and constantly transported to the interceptor. In locations where interceptor capacity is not available during the overflow, the underflow must be stored in ancillary tanks. The capacity of these ancillary tanks is based upon the underflow flow rate and the duration of the overflow event. Once the event is over the contents of the storage tank can be pumped back into the interceptor. Floatable material captured in the tank is removed at the end of the overflow event as the tank is emptied and is also sent back into the interceptor.

Complexity

The vortex/swirl separator is a simple process, especially since there are no moving parts within the unit. Removals are achieved using natural forces and no adjustment of equipment is necessary. The only controls that are needed are in the flow coming to the unit to ensure that the unit operates within its hydraulic loading rates. This can be accomplished using sluice gates or overflow weirs. The other area requiring instrumentation would be the control of the underflow sump where underflow is pumped out. The control of the pumping units would be by floats, bubblers, or ultrasonic level sensors.

Limitations

As previously indicated, the hydraulic loading rate is key to the performance of the vortex/swirl separator. Therefore, the limitation to this process occurs for the more stringent treatment objectives. Since a required and consistent effluent TSS must be achieved for the disinfection process to be effective, the variations in flows, particularly above the required hydraulic loading rate, result in a reduced removal of TSS and a corresponding decrease in the efficiency of the disinfection process. If the excess flows are by-passed around the vortex unit, going directly to disinfection, as required by the NJPDES requirement for complete disinfection, the higher TSS concentrations will again result in decreased disinfection efficiency. This represents a limitation on the process for the higher treatment objectives.

Swirl concentrators represent a potentially low cost and efficient technique to regulate and treat combined wastewater. These units, however, have some limitations and potential drawbacks, including:

- Underflow diversion rate is subject to design limitations, relative to incoming combined flow and downstream interceptor capacity;
- Relatively short detention time requires high rate disinfection, or construction of contact tanks, to provide adequate detention time for bacteria kill before discharge to receiving water;
- Loss of floatables to overflow during extremely high flows,
- Tank configuration results in a large hydraulic headloss requirement between the influent combined sewer and the underflow pipe;
- Limited long-term data available concerning performance and reliability;
- Fair to poor removal of oil and grease, nutrients, and colloidal material; and
- Negligible removal of soluble solids and pollutants.

The first and fourth potential drawbacks, as listed above, can be overcome by using storage and pump-back facilities in conjunction with the swirl concentrator. Interceptor and treatment capacity must be available for underflow during a storm event. If underflow rates exceed the available interceptor capacity, or sufficient grade is not available, the underflow may need to be stored and pumped back following the storm.

To adequately address bacteria removal, disinfection is required for any proposed CSO control technology. Disinfection tanks large enough to provide adequate contact time will have to be constructed downstream of any swirl concentrators. While the swirl concentrators alone may have a relatively small footprint, the disinfections tanks will need to be large, and in this situation, there is no longer the benefit of a small area requirement.

In order to operate effectively, most swirl concentrators need to be cleaned regularly. A maintenance schedule should be established based on solids loading and accumulation rates. Some types of swirl concentrators must be dewatered and cleaned with a vacuum truck, which will increase work demands of the collection system maintenance crews. Other types of systems are designed to pump out the debris that is screened out of the flow, which can potentially create sedimentation and grit accumulation in pipelines.

Construction Costs

Budgetary equipment pricing for vortex/swirl separation technology is provided in the PVSC TGM January 2018 referenced document. Tables were developed that included preliminary planning level construction cost estimates for flows ranging from 10 to 450 MGD.

Operation and Maintenance

Estimated annual operation and costs and annual maintenance labor costs for the vortex/swirl separation technology are included in the PVSC TGM January 2018 document.

Space Requirements

The space requirements of a vortex separator shall be based upon a square area utilizing the diameter of the tank and a buffer of 5 feet on each side.

The variable performance history concerning solids removal efficiencies, the additional space requirements to accommodate disinfection, and the level of maintenance required are some of the reasons why vortex/swirl separation is considered an alternative with major drawbacks and not given further consideration.

4.2.7.2.2 Ballasted Flocculation

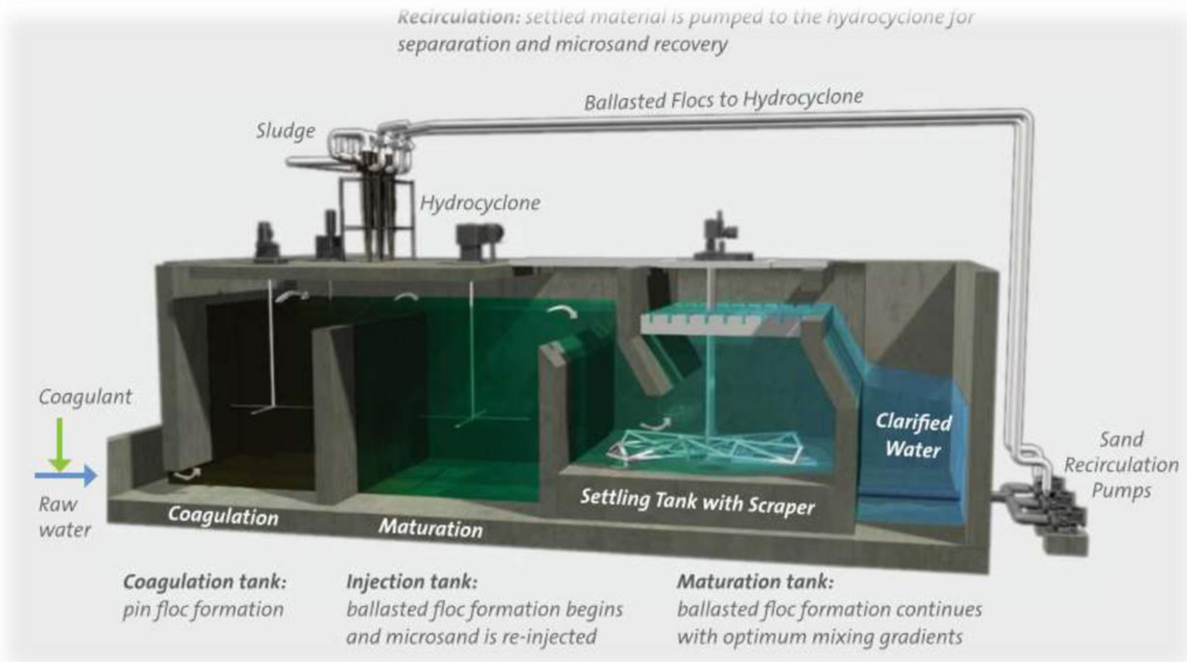
Ballasted flocculation, also known as high rate clarification, is a physical-chemical treatment process that uses microsand, or sludge and a variety of additives to improve the settling properties of suspended solids through improved floc bridging. The objective of this process is to form floc particles with a specific gravity of greater than two. Faster floc formation and decreased particle settling time allow clarification to occur up to ten times faster than with conventional clarification, allowing treatment of flows at a significantly higher rate than allowed by traditional unit processes. Ballasted flocculation units function through the addition of a coagulant, such as ferric chloride; an anionic polymer; and a ballast material such as microsand, a microcarrier, or chemically enhanced sludge. When coupled with chemical addition, this ballast material has been shown to be effective in reducing coagulation-sedimentation time.

The ballasted flocculation processes, using chemical addition as a critical part of their operation, have higher removal percentages than vortex/swirl separation processes for virtually all the pollutants with the exception of total nitrogen and NH3. The compact size of ballasted flocculation units can significantly reduce land acquisition and construction costs. This technology has been applied both within traditional treatment trains and as overflow treatment for peak wet weather flows. Several different ballasted flocculation systems are discussed in more details in sections below.

ACTIFLO® Ballasted Flocculation Process

Description of Process

ACTIFLO® is a microsand ballasted clarification process that may be used to treat water or wastewater. The process begins with the addition of a coagulant, such as an iron or aluminum salt, to destabilize suspended solids. The flow enters the coagulation tank for flash mixing to allow the coagulant to rapid mix with the flow after which it overflows into the injection tank where microsand is added. The microsand serves as a seed for floc formation, providing a large surface area for suspended solids to bond to, and is the key to the ACTIFLO® process. The larger flocculation particles allow solids to settle out more quickly, thereby requiring a smaller footprint than conventional clarification. Polymer may either be added in the injection tank or at the next step, the maturation tank. Mixing is slower in the maturation tank, allowing the polymer to help bond the microsand to the destabilized suspended solids. Finally, the settling tank effectively removes the floc with help from the plate settlers. The plate settlers allow the settling tank size to be reduced. Clarified water exits the process by overflowing weirs above the plate settlers. The sand and sludge mixture is collected at the bottom of the settling tank with a conventional scraper system and pumped back to a hydrocyclone, located above the injection tank. The hydrocyclone converts the pumping energy into centrifugal forces to separate the higher-density sand from the lower density sludge. The sludge is discharged out of the top of the hydrocyclone while the sand is recycled back into the ACTIFLO® process for further use. Screening is required upstream of ACTIFLO® so that particles larger than 0.1 - 0.25 mm do not clog the hydrocyclone. Cross section of ACTIFLO® unit is shown in Figure 4-19.



(Source: Veolia Water Technologies)

Figure 4-19 - Cross Section of ACTIFLO® Unit

Applicability to the Project

High rate clarification (HRC) was traditionally used for water treatment until in the late 1990s when HRC demonstration testing programs were performed to verify whether HRC technology would be able to be used for wastewater and CSO treatment. The results of the demonstration programs indicated that HRC can be used for CSO treatment and the effluent quality produced during pilot-testing surpassed CSO treatment standards, making it amenable to subsequent UV disinfection.

The ACTIFLO® system, as one type of HRC that uses ballasted flocculation, can be installed at the treatment plant or at a satellite facility within the collection system. The Actiflo process can be fully automated and the process train(s) can sit idle for extended periods of time and still be fully operational within 15 minutes of start-up. Installations at the WWTP also enable the sludge produced by the unit to be processed with existing systems. When installing the ACTIFLO® unit in a remote CSO location, the flows will vary widely, and the sludge must be stored in ancillary tanks, so it can be put back into the interceptor during periods of low flow. Appendix F summarizes ACTIFLO® installations in the USA. The table lists only installations used for wastewater treatment operations. System applications include Primary WW, Primary WW/CSO, Primary WW/ Tertiary WW, CSO, CSO/Tertiary WW, and Tertiary WW treatment operations.

Performance

The ACTIFLO® ballasted flocculation process is sized for the peak hour or day flow to prevent flow from exceeding the capacity of the unit. The units are designed for a surface-loading rate of 60 gallons per minute per square foot, at a peak hydraulic loading rate of 150%. When starting up the unit it takes between 15-30 minutes for the process to reach steady state conditions. Accordingly, the initial 15-30 minutes of operation receives only little or partial treatment. The ACTIFLO® ballasted flocculation process is very effective in removing most of the pollutants; especially since the addition of flocculants and polymers helps remove smaller particles. Performance for removal of pollutants is reportedly constant up to for a surface-loading rate of 60 gallons per minute per square foot. See Table 4-12 for manufacturer provided performance efficiency. Performance deteriorates quickly for higher surface loading rates than 60 gallons per minute per square foot.

Table 4-12 - ACTIFLO Anticipated Performance Efficiency

Parameter	Removal Rate
TSS	80 - 95%
COD	50 - 70%
Total BOD	50 - 80%
Soluble BOD	10 - 20%
Total P	80 - 95%
TKN	15 - 20%
Heavy Metals	85 - 100%
Oils & Grease	50 - 80%
Fecal Coliform	85 - 95%

Hydraulics

The head loss through the units at peak flow rates are reported at less than two feet.

Generation of Waste Streams

As previously noted, the initial 15-30 minutes of operation of the unit provides no or only partial treatment. Since the disinfection process requires consistent pretreatment removals of TSS, the discharge of this partially treated flow will result in only partial disinfection. One potential means of eliminating this problem would be to provide ancillary tanks for storage of the initial discharge. This storage can then be reintroduced to the treatment process once the unit is fully operational. Under the description of the process, sludge is produced and separated in a hydrocyclone unit. The solids percentage of the waste sludge will vary depending on the concentration of the influent TSS and the coagulant dosage. In most cases the solids concentrations will vary from 0.1 to 1.0% with an average of 0.3%. Sludge from the ACTIFLO® process is easily treated and dewatered. When the ACTIFLO® process is located at the WWTP the sludge is sent back to the head of the plant or primary clarifiers, in some cases it is sent to intermediate gravity thickeners and then on to centrifuges or belt thickeners for final processing. The sludge production is approximately 4.8% of the design capacity of the unit.

Complexity

The ACTIFLO® ballasted flocculation process is more complex than the vortex/swirl separator process. The ACTIFLO® ballasted flocculation process consists of chemical addition, which must be controlled by the flow rate, mixers and flocculators, sludge pumps and a hydrocyclone, which separates the sludge from the microsand.

Limitations

The startup time for the ACTIFLO® process of from 15 to 30 minutes is a limitation in that for stringent treatment objectives the flow from the unit during this time period must be stored and fed back into the system later. For some drainage areas, this startup period may correspond to the first flush when the loading is the greatest. Also, the ACTIFLO® process has 4:1 turndown ratio, which means the minimum flow through the unit is 25% of the unit's capacity. Flows lower than this result in process problems. There is a maximum TSS limit on the ACTIFLO® process at the higher loading rate of 60 gpm/sf, of between 500 to 1000 mg/L TSS. This value is high and should not provide a routine problem in the operation of the unit. In remote locations, the ACTIFLO® process will see intermittent operation which will make operation more challenging.

Construction Costs

The preliminary planning level construction cost estimates are provided in the PVSC TGM January 2018 for ACTIFLO® Ballasted Flocculation Unit of design flow ranging from 10 MGD to 450 MGD.

Operation and Maintenance

Operating costs for the ACTIFLO® Ballasted Flocculation unit consists of the power and chemical costs. Power costs are based upon the horsepower of the mixers, flocculators, chemical feed equipment and pumps. Chemical costs are based on usage of coagulant and polymer. Regular maintenance includes routine lubrication and maintenance of the mixers, scrapers, pumps, hydrocyclones and other mechanical components. Weekly inspections and preventive maintenance are important to keep an intermittent-use facility ready to operate at a moment's notice. When the unit will be offline for more than 8 hours, the units will be completely drained and all equipment stopped.

Factors for calculation operating costs and estimating annual maintenance labor costs are also included in the referenced PVSC TGM January 2018.

Space Requirements

The space requirements of the ACTIFLO® units consist of the size of the tanks and a buffer of 5 feet around the unit for access and maintenance.

Case Study

The Water Environment Federation's (WEF) February 2012 issue of Water Environment and Technology (WE&T) provided a case study on the use of HRC in the city of Bremerton, Washington. Bremerton adopted a proprietary high rate compact clarification process to reduce its CSO discharges. Followed by an ultraviolet disinfection treatment, the HRC process was piloted by CDM Smith in 1999. The pilot testing determined effluent capable of being discharged into sensitive waterways would be produced by the HRC process and that a UV disinfection treatment could be added to the process. This project received the 2002 Grand Award in Small Projects by the American Academy of Environmental Engineers (Annapolis, MD).

The process takes wet weather flow that cannot be handled by the wastewater treatment plant, and puts it through a flash mixing tank with polymer added, and a maturation tank before it is sent through a clarifier. Reduction of BOD5 and TSS is typically 60-65% and 90-95%, respectively. Sludge from the clarifier is pumped back to the hydrocyclone and then either to the solids processing plant, or through a microsand filter and into the flash mixing tank. The facility utilizes a 10 MGD nominal capacity with a maximum hydraulic capacity of 20MGD. Additionally, flow to the facility is minimized by a 100,000-gallon storage tank, which has reduced overall CSO occurrences by 80% in the surrounding collection system. The HRC facility only receives flow when the storage tank fills over a weir wall.

Weekly inspection and maintenance is required to ensure the facility is ready to operate when the next rainfall occurs. Additionally, a small flow (less than 3 gal/min) of chlorinated potable water is discharged into the injection tank during periods of dry weather to eliminate the chance of biofouling on lamella tubes and other components. The facility has had issues with UV ballast burnout due to short durations of high intensity operation. Since installation, operators have adjusted the coagulant injection point to increase flocculation time. Additionally, the discharge was relocated from the hydrocyclone to the far side of the storage tank to reduce sand loss and resuspension of separated solids. Operators spent several years altering the chemical dosing to meet permitted discharge requirements as there are very few events each year which trigger the HRC.

DensaDeg® Ballasted Flocculation Process

Description of Process

The DensaDeg® is a is a high-rate settling clarifier process combining solids contact, ballast addition and solids recirculation to provide enhanced, high-rate settling of solids. Different from ACTIFLO®, recycled sludge, instead of microsand, is added to increase floc density and precipitation. The process consists of:

5. Rapid mix / coagulation stage: Raw water flows into the rapid (flash) mix zone where a coagulant is added. Coagulation is the destabilization of colloidal particles, which facilitates their aggregation and is achieved by the injection of a coagulant such as alum or ferric chloride.

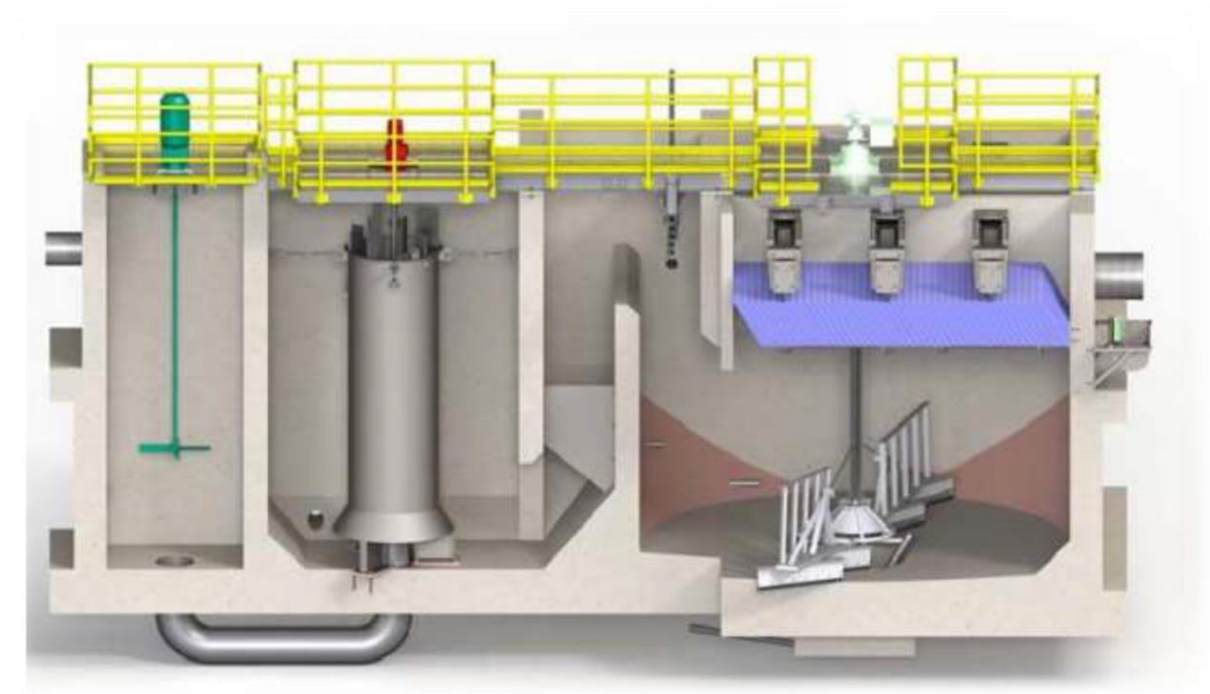
6. Flocculation zone: Coagulated water then flows to the flocculation zone where, with a lower energy vertical turbine mixer, a continuous ballast media recirculation feed and a low dose of a flocculating agent (polymer) are added to begin the process of agglomerating the coagulated water into floc particles.

7. Maturation zone: Flocculated particles are then developed and grown into large, very dense mature particles. This is achieved with optimized mixing energy and detention time. The result is a floc which settles at extremely high rates.

8. Settling & clarification zone: Flocculated solids enter the settling zone, over a submerged weir wall, where dense, suspended matter settles to the bottom of the clarifier. Clarified water is displaced upward from the downward moving slurry, through inclined plate settlers. The plate modules act as a polishing step for lighter, low density solids.

9. Hydrocyclone and ballast recovery: Settled sludge is continuously recycled via a recirculation pump to the hydrocyclone where the ballast media is separated from the waste stream. Ballast is returned to the flocculation zone and the waste stream is sent to sludge handling.

10. Effluent Collection: Uniform collection of clarified water is accomplished in effluent launders above the settling plate assembly.



(Source: Suez North America)

Figure 4-20 - Cross Section of DensaDeg Unit

Applicability to the Project

The DensaDeg® ballasted flocculation process is a treatment process that combines solids contact, ballast addition and solids recirculation in a packaged system. It started with the original solidscontact clarifier, the Accelator, which was the first to incorporate internal sludge recycling. In the late 1980’s the original DensaDeg clarifier was introduced to the market for high-rate sludge ballasted and solids recirculation systems. The earliest DensaDeg® CSO installation was in 1995.

The DensaDeg® process can be fully automated and the process train(s) can sit idle for extended periods of time and still be fully operational within 30 minutes of start-up. It can be installed at the treatment plant or at a satellite facility within the collection system. Installations at the WWTP also enable the sludge produced by the unit to be processed. When installing the DensaDeg unit in a remote CSO location, the flows will vary widely, and the sludge must be stored so it can be put back into the interceptor at periods of low flow.

Performance

The DensaDeg® ballasted flocculation process is sized for the peak hour or day flow to prevent flow from exceeding the capacity of the unit. The units are designed for a surface-loading rate of 40-60 gallons per minute per square foot. When starting up the unit it takes 30 minutes for the process to reach steady state conditions and no sludge inventory is required for startup. The DensaDeg® ballasted flocculation process is very effective in removing vast quantities of pollutants. Its performance is comparable to ACTIFLO® in terms of contaminants removal with TSS removal of 80-90%, typically providing effluent <30mg/L TSS (inlet dependent) and BOD %-removal similar in magnitude to TSS %-removal, when treating typical municipal WW which is 30-40% of total BOD. Removal could be higher depending on soluble ratio.

Hydraulics

The head loss through the units at peak flow rates are reportedly less than two feet.

Generation of Waste Streams

As previously indicated in the description of the process, a portion of the sludge is wasted. The solids percentage of the waste sludge will vary depending on the concentration of the influent TSS and the coagulant dosage. In most cases the solids concentrations will 4%. The quantity of sludge is approximately equal to 0.5% of the capacity of the DensaDeg® unit. When the DensaDeg® process is located at the WWTP, the sludge is sent back to the head of the plant or primary clarifiers, in some cases it is sent to intermediate gravity thickeners and then on to centrifuges or belt thickeners for final processing.

Complexity

Similar to ACTIFLO®, the DensaDeg® ballasted flocculation process consists of chemical addition, which must be controlled by the flow rate, mixers and flocculators, and sludge pumps.

Limitations

DensaDeg® has similar limitations as previously stated for ACTIFLO® plus it requires a longer start time.

Construction Costs

The preliminary planning level construction cost estimates are provided for ACTIFLO® Ballasted Flocculation Unit in the PVSC TGM January 2018 for design flows ranging from 10 to 450 MGD.

Operation and Maintenance

Similar to ACTIFLO® ballasted flocculation system, operating costs for the DensaDeg® Ballasted Flocculation unit consist of the power and chemical costs. Power costs are based upon the horsepower of the mixers, flocculators, chemical feed equipment and pumps. Chemical costs are based on usage of coagulant and polymer. Routine maintenance and preventive care measures are similar to those for ACTIFLO® unit.

Factors for calculation operating costs and estimating annual maintenance labor costs are also included in the referenced PVSC TGM January 2018.

Space Requirements

The space requirements of the DensaDeg® unit shall consist of the size of the tanks and a buffer of 5 feet around the unit for access and maintenance.

Case Study

Veolia Water Technologies provided a white paper[3] detailing the City of Akron, OH, BIOACTIFLO™ demonstration project. Beginning in March of 2012, a pilot plant at the City of Akron Water Reclamation Facility (WRF) was constructed to demonstrate effectiveness of the BIOACTIFLO™ technology. Incorporating high-rate activated sludge in the ACTIFLO™ high-rate ballasted flocculation process, BIOACTIFLO™ is designed to remove soluble BOD that would not otherwise be removed. Influent flow to the pilot plant was pumped from a location that had already undergone preliminary treatment, consistent with plans for the full-scale configuration. Return activated sludge (RAS) was supplied to the pilot plant from the gravity belt thickener building of the WWTP, consistent with plans for the full-scale configuration. Optimal doses for coagulant (alum) and polymer were determined. Both BIOACTIFLO™ and main plant secondary effluent were disinfected in a 0.53 MLD (0.14 mgd) pilot UV disinfection system and comparable results were obtained. Following all testing, effluent from the BIOACTIFLO™ pilot was sent back to the main plant for complete secondary treatment.

The pilot unit was operated during a total of twenty (20) wet weather events between April and December 2012, however the last two events (19 and 20) were performed using slightly different Operational Criteria. Pilot plant operation and sampling was conducted over a range of event durations and volumes, ranging from just under an hour to nearly a day in duration. Results showed an average 85% reduction in CBOD (90% reduction for events 19 and 20). Soluble CBOD concentration dropped from 9.2 mg/L in the influent of the BIOACTIFLO™ to 4.1 mg/L in the effluent from the BIOACTIFLO™. Meanwhile, TSS was reduced by 97%, from influent 144.8 mg/L to 4.0 mg/L effluent. Overall results document the effectiveness of BIOACTIFLO™ as a potential parallel wet weather treatment process at facilities facing wet weather treatment challenges.

Both ballasted flocculation processes are viable treatment alternatives for significant control. However, to meet all water quality goals, the CSO control alternatives evaluations will consider mechanical bar screens in combination with ballasted flocculation and chlorination/dechlorination.

[3] Heath, Gregory; Gsellman, Patrick; Hanna, Genny; Starkey, Daniel. Pilot Testing of BIOACTIFLO for Wet Weather Treatment at the Akron, Ohio Water Reclamation Facility.

4.2.7.2.3 Compressed Media Filtration

Description of Process

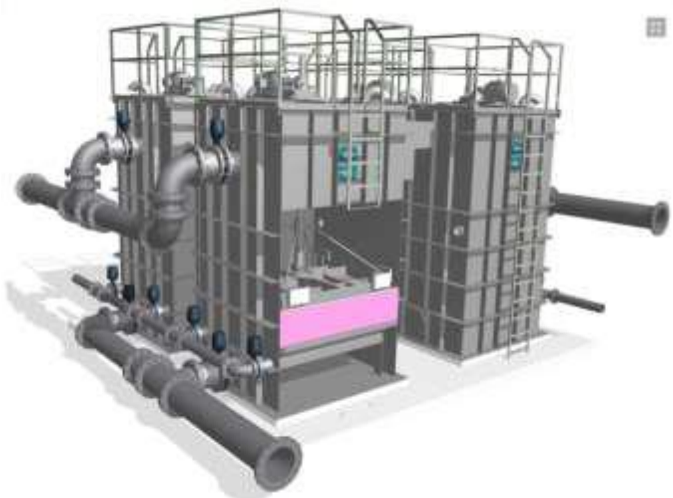
The compressible media filtration is a process that uses a synthetic, porous filter media. The filter is unusual in a number of ways: (1) the synthetic media is highly porous (89%), (2) filter media and bed properties can be modified because the media is compressible, (3) the fluid to be filtered flows both around and through the media instead of only flowing around the filtering media (as in granular media filters), (4) the fluid that is filtered is used to backwash the filter, (5) to backwash the filter, filter bed volume is increased mechanically, and (6) the filter operates at high filtration rates (up to 40 gal/min/sq. ft.) Performance of the filter, with respect to removal of turbidity and total suspended solids, is similar to the performance of other more conventional filters with the exception that filtration rate is more than 3 to 6 times the rate of other filters. Also, percent backwash water required is significantly less than that used in conventional filtration technologies (typically 1 to 2% versus 6 to 15%).

Compressible media filtration is commercially available as either the “Fuzzy Filter” by Schreiber Industries or the “FlexFilter” by WesTech (both are proprietary technologies covered by patents or pending patents). Both technologies use synthetic fiber spheres as filter media; however, they have different flow configuration, method of bed compression, composition of the synthetic fibers, and media washing details.

The Fuzzy Filter receives the influent at the inlet pipe located at the bottom of the unit. The influent is pressurized upward through the compressed filter media and the effluent is piped out towards the top of the unit, as shown in the process diagram found in Figure 4-21. Porous plates are used to both compress the filter media as well as open up the filter bed to allow movement during backwashing. Figure 4-21 provides a cross-sectional view of the Fuzzy Filter process, and Figure 4-22 provides an overall picture of the Fuzzy Filter Unit.

The FlexFilter receives the inflow from the influent channel. The influent channel is connected to the influent basin where the filter vessels are located. As the influent water accumulates in the influent basin, compression is added to the reinforced rubber sidewalls on the bottom of the filter vessel and compresses the filter bed laterally as the water elevation rises. As the water level in the influent basin reaches the inlet weir elevation, the influent water pours over the influent weir and passes downward through the compressed media bed. Since the bottom of the filter bed compresses more than the top of the filter bed, a porosity gradient is established through the filter bed to capture the largest particles in the upper portion of the filter bed while reserving the deeper portions of the bed to trap finer particles. As particles collect within the media bed, the influent level above the bed rises to a point that signals the need for the media to be cleaned.

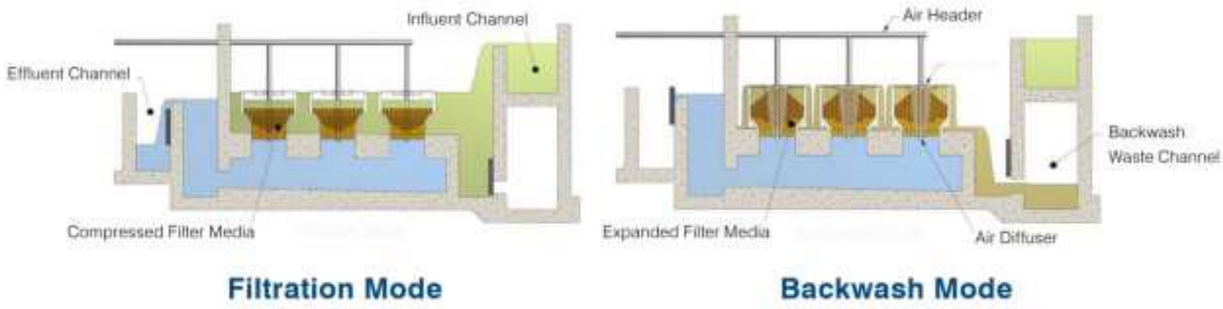
Figure 4-21 - Fuzzy Filter Process Diagram



(Source: Schreiber, LLC.)

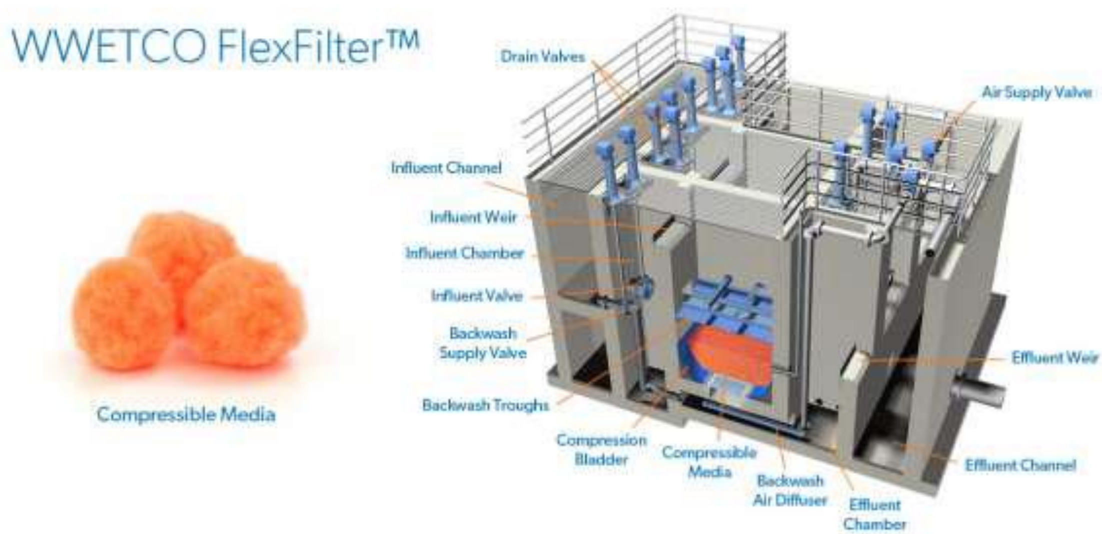
Figure 4-22 - Fuzzy Filter Unit

The filters use air scouring in the wash cycle to clean the media. During the wash cycle, the feed to the filter is stopped, allowing the media to uncompress. The air scour is initiated along with a small amount of backwash water. The length of the backwash cycle is adjustable. Once cleaned, the filter is put back into service. Figure 4-23 provides a cross-sectional view of the FlexFilter process, and Figure 4-24 provides an overall picture of the FlexFilter Unit.



(Source: WesTech Engineering, Inc.)

Figure 4-23 - FlexFilter Process Diagram



(Source: WesTech Engineering, Inc.)

Figure 4-24 - FlexFilter Unit

Applicability to the Project

The Fuzzy Filter is only used as a polishing step for CSO treatment to meet the most stringent treatment objectives. It does not have a history of treating flows larger than 50 MGD while the FlexFilter has been applied at the 100 MGD Springfield Ohio WWTP treating combined sewer overflow. In addition, the FlexFilter is a simple gravity system requiring no moving parts. The compression of the media is accomplished through a lateral hydraulic force applied from the incoming liquid, eliminating mechanically actuated internal components. For the purpose of the Technical Guidance Manual, FlexFilter was selected for further evaluation.

Performance

For CSO applications FlexFilter is typically operated at 4 gpm/sq. ft. hydraulic loading rate (HLR) during the first flush portion of a CSO event and gradually increases the operating HLR as the CSO flow rate increases and solids concentration decrease. The maximum HLR of CSO treatment is typically limited to 10 gpm/sq. ft. at design peak flow. The performance information provided by the manufacturer indicates that the contaminants removal efficiency of WWETCO FlexFilter™ in CSO application ranges from 73% to 94% for TSS removal and 16% to 69% for CBOD removal.

In the Bayonne MUA pilot study, FlexFilter was evaluated in terms of TSS removal. The influent to the FlexFilter was pumped from the Storm King effluent. No raw CSO feed to the FlexFilter was evaluated due to limited wet weather events during the time of the pilot test. The FlexFilter units experienced operating issues primarily related to the pumps and the time needed to backwash. Shorter filter run times and frequent backwashing were experienced when testing was conducted at the higher end of the filter loading rate recommended for CSO treatment.

The pilot study showed that the compressed media filter was consistent and effective in removing finer and organic suspended solids. Overall the FlexFilter was capable of removing 90% of the TSS even at a HLR of 12 to 18 gpm/sq. ft. The unit as tested spent up to 1/2 of the typical four hour run time in backwash cycle, however it was operated at 3 to 4 the recommended hydraulic loading rate in order to supply downstream disinfection with higher flows. TSS removal rates for the FlexFilter improved the ultraviolet transmittance (UVT) of the effluent flow; however, UVT values were still modest. The effluent from the FlexFilter averaged approximately 25 mg/L for TSS and 40% on UVT.

Hydraulics

The headloss through the FlexFilter structure, under the conditions stated above, is about 8 feet.

Generation of Waste Streams

The only waste stream produced by the FlexFilter is the backwashing of the filters. The FlexFilter utilizes low head air to accomplish the media scrubbing while lifting the backwash water to waste, thus minimizing backwash waste volumes. Portions of the backwash water would be diluted with filter drains and recycled back to filter influent. The concentrated backwash water would be stored and put back into the interceptor system when there was available capacity, for removal at the WWTP.

Complexity

As a result of how this unit operates; the automated valves, hydraulically operated porous plate, the air injection into the beds during backwashing, and the monitoring needed for the flow and headloss conditions, this process is the most complex of the pretreatment processes being considered.

Limitations

The influent TSS concentration to the FlexFilter is limited to less than 100 mg/L. Higher TSS concentrations will increase the backwash time resulting in overall reduced performance of the units. The 7 feet of headloss through the units is also a limitation since there is usually minimal head available from the regulator to the discharge at the water body. The valves in the FlexFilter unit are an issue during outdoor operation in freezing weather conditions.

Construction Costs

The preliminary planning level construction cost estimates are provided in the PVSC TGM January 2018 for FlexFilter design flows ranging from 10 MGD to 450 MGD.

Operation and Maintenance

Estimated annual operation and maintenance costs for FlexFilter unit are presented in the PVSC TGM January 2018 based on vendor provided information. It consists of the power costs for the blowers, recycle pumps, and backwash pumps as well as media change-out cost, labor for preventative and routine maintenance, and labor for post event clean-out.

Case Study

According to literature obtained from WWETCO (a subsidiary of WesTech), the FlexFilter™ was installed at the Weracoba Creek Stormwater Treatment system in Columbus, GA. This 10 MGD filter capacity with 2 MGD UV disinfection capacity, was funded by a $0.9 million USEPA 319(h) grant to evaluate treatment of urban stormwater runoff. The treatment system has been in operation since 2007. Influent solids ranged from 300 mg/L to 100 mg/L TSS. Effluent TSS was between 5 mg/L and 15 mg/L. Additionally, total maximum daily load (TMDL) requirements for fecal coliform and macro-invertebrates were met. This facility also installed the WWETCO FlexFlow™ Control Valve which allows aquatic biology passage during dry weather flow and causes the head differential needed to operate the filter during wet-weather flow.

Compressed media filters are useful but with limited application due to the following requirements:

- 7 to 8 feet of headloss;
- Influent TSS concentration to the FlexFilter is limited to less than 100 mg/L. Higher TSS concentrations will increase the backwash time resulting in overall reduced performance of the units. The Fuzzy Filter is only used as a polishing step for CSO treatment to meet the most stringent treatment objectives;
- Fuzzy Filter does not have a history of treating flows larger than 50 MGD while the FlexFilter has been applied at the 100 MGD Springfield Ohio WWTP treating combined sewer overflow.

4.2.7.3 Disinfection

Disinfection is more difficult to design and operate in CSO applications than in wastewater treatment plants due to the complex characteristics of CSOs. The flowrates of CSOs are highly variable which makes it difficult to regulate the addition of disinfectant. The concentration of suspended solids is high and the temperature and bacterial composition varies widely. Pilot studies are commonly conducted to characterize the range of conditions that exist for a particular area and the design criteria to be considered.

The chemical and physical disinfection technologies evaluated in the TGM include the following:

- Chlorination (consisting of Chlorine Dioxide, Sodium Hypochlorite, and Calcium Hypochlorite)
- Peracetic Acid
- Ultraviolet (UV) Disinfection
- Ozonation

In the cases of chemical addition; chlorine dioxide, sodium hypochlorite, calcium hypochlorite, and peracetic acid, the disinfectant must be mixed with the liquid to be disinfected. Experience has shown that the long contact time required for conventional wastewater treatment is not appropriate for the treatment of CSOs; however, chemical disinfection of CSOs can be accomplished using high-rate disinfection. High-rate disinfection is defined as employing high-intensity mixing to accomplish disinfection within a short contact time, generally five minutes. For this report, a chemical induction flash mixer, such as manufactured by The Mastrr Company, will be used to mix either the gas or liquid with the flow to be disinfected. The mixer develops a "G" value of 1,000/sec. The detention time in the mixing zone of the mixer is 3 seconds. Following the mixer, a tank area with a detention time of 5 minutes at the design rate, will be used to provide adequate mixing. In the case of sodium hypochlorite and calcium hypochlorite, a second induction mixer will be used to mix the dechlorination chemicals, sodium bisulfite, with the flow before discharging to the receiving water. No tankage would be provided following the addition of dechlorination chemicals.

The efficiencies of virtually all the disinfection processes being considered in this report are dependent upon the TSS concentration of the liquid being disinfected. The required TSS concentration for each of the disinfection processes for different treatment objectives is shown in Table 4-13.

Table 4-13 - Maximum TSS Concentration for Each Disinfection Process

Fecal Coliform Objectives (MPN/100 mL)	Maximum TSS Concentration (mg/L)			
	Chlorine Dioxide	Sodium Hypochlorite	Peracetic Acid	Ultraviolet Disinfection
200	70	45	70	25
770	70	45	70	25
1,500	70	45	70	25

Table 4-14 - Evaluation of Disinfection Technologies

Criteria	Sodium Hypochlorite	Peracetic Acid	Ultraviolet Disinfection
Complexity	5	5	2
Safety	4	4	5
Limitations	3	3	3
Inhibitors	3	5	3
De-chlorination Requirement	1	5	5
Commercial Product Availability	5	1	5
CSO Application	5	2	2
Total	26	25	25

Source: TGM Table 2-35

4.2.7.3.1 Chlorine Dioxide

Process Description

Chlorine dioxide (ClO_2) is most commonly used for drinking water treatment to oxidize reduced iron, manganese, sulfur compounds, and certain odor-causing organic substances in raw water. Chlorine dioxide is often used as a pre-oxidant because, unlike chlorine, it will not chlorinate organic compounds and therefore will not react with organic matter in the water to form trihalomethanes (THMs) or other byproducts. In industrial markets, chlorine dioxide has been most readily used in the paper and pulping industry. In this application, chlorine dioxide is used as bleach for paper pulp since it does not react with the organic lignin in the wastewater to form byproducts such as the THMs.

The data for chlorine dioxide shows that it is a more effective disinfectant than sodium hypochlorite. However, chlorine dioxide needs to be generated on site because it is too unstable even for short periods of time. There is one type of chlorine dioxide generator that utilizes hydrochloric acid and sodium chlorite in either commercially available or diluted concentrations to generate chlorine dioxide. They produce chlorine dioxide and consistently maintain a product yield greater than 95%, making it ideal for drinking water treatment. The use of chlorine gas is not required when using these systems. These systems produce relatively small amounts of chlorine dioxide for disinfection in water systems where low concentrations of ClO_2 are needed.

There is a second process, which produces "large quantities" of gas for disinfection of drinking water and wastewater. This is the Ben Franklin™ process, manufactured by CDG Environmental, LLC. The Ben Franklin™ process uses the chemical reaction of hydrochloric acid with sodium chlorate to generate chlorine dioxide to produce a mixture of chlorine and chlorine dioxide, both in the gas phase. These gases, as produced by the Ben Franklin™ generator, may be applied directly to water as a combination, or they may be separated and applied at different points in the water treatment process. In its most direct application, the mixed chlorine/chlorine dioxide product can be injected into the water to be treated. The result is a mixed disinfectant containing chlorine dioxide and chlorine. The chlorine dioxide acts as a very rapid disinfectant/oxidant while the chlorine persists longer. This can be an advantage in the water systems where a residual is desired but a disadvantage in the receiving water where disinfection byproduct is a concern.

The use of chlorine dioxide in wastewater disinfection has been very limited in US. Technologies are currently unavailable to provide an easier and safer way to produce chlorine dioxide at a concentration for CSO treatment at remote satellite locations. Chlorine dioxide is extremely unstable and explosive and any means of transport is potentially hazardous. Chlorine dioxide can produce potentially toxic byproducts such as chlorite and chlorate. Chlorine dioxide will not be considered further.

4.2.7.3.2 Sodium Hypochlorite

Description of Process

Hypochlorite is a commonly used disinfectant in water and wastewater treatment and has been applied as a CSO disinfectant. It can be produced on site or can be delivered in tanker trunks with concentrations between 3 to 15% of available chlorine. Hypochlorite decays over time. The decay rate can increase as a result of exposure to light, time, temperature increase or increased concentration of the compound. The solution can be stored for 60 to 90 days before the disinfecting ability degrades below recommended values (5% concentration). Degradation of the solution over time is a major disadvantage of sodium hypochlorite for CSO applications, due the variability of the size and frequency of rain events. There are two types of hypochlorite: Sodium hypochlorite (NaOCl) and Calcium hypochlorite ($Ca(ClO)_2$). Sodium hypochlorite is often referred to as liquid bleach or soda bleach liquor, while Calcium hypochlorite is manufactured either as a grain or powder under various names, and all have either approximately 35% or 65% available chlorine content. Sodium hypochlorite is the most widely used of the hypochlorites for potable water and waste treatment purposes. Although it requires much more storage space than high-test calcium hypochlorite and is costlier to transport over long distances, it is more easily handled and gives the least maintenance problems with pumping and metering equipment. It will be used as the basis for evaluating disinfection alternatives.

Based on molecular weight, the amount available as chlorine is 0.83 lbs/gal for a 10% solution of sodium hypochlorite and 1.25 lbs/gal for a 15% solution.

Required Concentrations

The application of sodium hypochlorite as a disinfectant was studied by the USEPA in Syracuse, New York. An equation was developed to estimate the chlorine concentration needed to achieve a particular log-kill of fecal coliform. The parameters included in the equation include the pH of the liquid, the influent fecal coliform count to the disinfection process, the TSS concentration, and the mixing factor of GT. The equation is as follows:

$$\text{Log-kill} = (0.08C^{0.36}) * (GT^{0.42}) * (SS^{-0.07}) * (FC^{0.02}) * (10^{(-0.03pH)})$$

Where: C = concentration of disinfectant (mg/L as Cl2)
SS = concentration of SS (mg/L)
FC = Influent level of fecal Coliform, (counts/100 ml)
pH = pH
GT = mixing intensity x detention time.

This is based upon the G of 1000 discussed above, and a three second detention time in the mixing zone of the mixer.

Computations done using this equation, for the range of parameters expected in CSO waters, indicate that a chlorine concentration of between 18-24 mg/L will disinfect the fecal coliform concentrations to the levels expected in the LTCP treatment objectives.

Equipment Needed

Sodium hypochlorite is delivered to the site in liquid form as either a 10% or 15% solution. The sodium hypochlorite is stored in a tank and is fed into a rapid induction type mixer at a rate established by the flow, through a chemical feed pump. A 12.5% solution may degrade to 10% in 6 to 8 weeks, in which case the degradation rate slows. Typically it is stored as a 5% solution of available chlorine. It should be stored at temperatures below 85 degrees Fahrenheit in a corrosion resistant tank and protected from light exposure. For the purpose of this TGM, the chemical storage is estimated to store enough chemical for 24-hours of continuous treatment at the design overflow rate plus a safety factor of 1.5.

The chemical storage tank and the feed pump would be stored in a building with the induction mixer installed in a channel, followed by a detention tank with a 5-minute detention time, as described at the beginning of this section.

Limitations

One of the problems with sodium hypochlorite is that the solutions are vulnerable to a significant loss of available chlorine in a few days. This is described as the shelf life of the chemical. The stability of hypochlorite solutions is greatly affected by heat, light, pH, and the presence of heavy metal cations. The higher the concentration, and the temperature the higher the deterioration. A 15% solution will deteriorate to half strength in approximately 120 days. A 10% solution will take approximately 220 days.

The limited shelf life of sodium hypochlorite makes it difficult in an intermittent application like a CSO to ensure that the correct amount of disinfectant is being introduced into the waste stream. This can lead to under or over disinfecting, which can make it difficult to achieve the required treatment objective.

Inhibitors

High TSS concentrations would be an inhibitor to disinfection using sodium hypochlorite, primarily by shielding the fecal Coliform from the disinfectant.

Need for Dechlorination

The use of chlorine disinfection of wastewater can result in several adverse environmental impacts especially due to toxic levels of total residual chlorine in the receiving water and formation of potentially toxic halogenated organic compounds. Chlorine residuals have been found to be acutely toxic to some species of fish at very low levels. Other toxic or carcinogenic chlorinated compounds can bioaccumulate in aquatic life and contaminate public drinking water supplies. For this reason, excess chlorine must be dechlorinated. Gaseous sulfur dioxide, liquid sodium bisulfite, sodium thiosulfate, sodium sulfite, and sodium metabisulfite can be used for this purpose. Sodium bisulfite is the most commonly used chemical for dechlorination due to the ease of handling, fewer safety concerns, economic reasons, and availability. For this report the use of sodium bisulfite is assumed. Typical characteristics are shown in the Table 4-11 below. Sodium bisulfite can decay about 40 % over a period of six-months. The storage should consider the release of sulfur dioxide when the sodium bisulfite is stored in a warm environment; a water scrubber is typically used to diffuse and dissolve off-gas. Another operational problem is the crystallization of sodium bisulfite when the temperature drops below the saturation point: -6.7^{0}C for 25% solutions and 4.4^{0}C for 38% solutions. Key properties of sodium bisulfite are listed in Table 4-15.

Table 4-15 - Sodium Bisulfite Key Properties

Property	Value
Concentration	38% (25% solution)
Molecular Weight	104.06
Boiling Point	>100°C
Freezing Point	-12°C
Saturation Temperature	4.4°C @ 38%
Vapor Pressure	78 mm Hg @ 37.7°C
Specific Gravity	1.36 @ 25°C
pH	3 to 4
Solubility in water	Completely

Sodium bisulfite could be stored indoors in a conditioned building to minimize the degradation due to high temperature and sunlight exposure. To minimize the potential of chemical interaction the storage tanks of sodium hypochlorite and sodium bisulfite have to be isolated from each other.

A rapid induction mixer located in a channel downstream of the contact chamber, as described earlier in this section will accomplish the mixing of sodium bisulfite. Since the Dechlorination process is essentially instantaneous, no contact chamber is required downstream of the injection.

Costs

The costs for the sodium hypochlorite disinfection system include several components including chlorine contact tank, the chemical storage facility for sodium hypochlorite and sodium bisulfite, pumping system for disinfection and dechlorination, mixers, piping and storage tanks.

The preliminary report level construction cost estimates provided in the PVSC TGM, January 2018 for a sodium hypochlorite disinfection system of design flow ranging from 10 MGD to 450 MGD. Budgetary equipment pricing information was gathered from equipment manufacturers.

Operation and Maintenance

Operating costs for hypochlorite disinfection systems consist of the power and chemical costs. Power costs are based upon the horsepower of the metering pumps and rapid mixers. Chemical costs are based on usage of sodium hypochlorite and sodium bisulfite.

The equipment would be housed in a building; therefore, maintenance costs consist of labor costs for housekeeping of the building, preventative and corrective maintenance of the mechanical equipment including the chemical metering pumps, mixers, and other appurtenances, and restocking of the chemicals. The chlorine contact tanks will also need periodic maintenance to clean debris.

Factors for calculation of annual operation costs and estimated annual maintenance labor cost including cost factors for the hypochlorite disinfection system are presented in the PVSC TGM, January 2018.

Space Requirements

The space requirements of the facilities required for disinfection using sodium hypochlorite are based upon the size of the mixing chamber/tank size for chlorination, the chemical building size for chlorination and de-chlorination, the size of the mixing chamber for de-chlorination, and a buffer of 5 feet around each.

4.2.7.3.3 Peracetic Acid Disinfection

Description of Process

Peracetic acid (CH_3CO_3H), also known as PAA, is an organic peroxy compound, which has strong oxidizing properties. In the presence of water (H_2O), it breaks down into a mixture of hydrogen peroxide (H_2O_2) and acetic acid (CH_3CO_2H). The mixture is clear and colorless with no foaming capabilities and has a strong pungent acetic acid (vinegar) odor. PAA is a very strong oxidizing agent and has a stronger oxidation potential than chlorine or chlorine dioxide. It has been used as a bactericide and fungicide in various industries including the food and beverage industries, the textile and pulp and paper industries, as well as smaller, more confined applications, including hospital settings.

The USEPA approved peracetic acid (PAA) as a primary disinfectant for wastewater in 2007 while PAA has been used to treat wastewater in Europe for over a decade. Since the USEPA approval, only a limited number of wastewater treatment plants in the United States have adopted PAA as a primary disinfectant, including a wastewater treatment plant in St. Augustine, Florida that discharges treated flow to environmentally-sensitive wetlands. Case studies have also been conducted at a number of treatment plants including a wastewater treatment plant in Frankfort, Kentucky and the Bayonne MUA pilot study for CSO treatment.

PAA decomposes quickly and its ultimate fate in the environment is the basic molecules of carbon dioxide, oxygen, and water. Toxicity studies were conducted on PAA in the 1980's to evaluate impact of PAA disinfected primary effluent on the bay environment. The study concluded that there was no toxicity impact. The Bayonne MUA pilot study and other studies on PAA disinfection of wastewater did not experience toxicity of residual PAA. However, more studies are still required to prove that residual PAA poses no toxicity to aquatic life.

Solutions of PAA for wastewater disinfection are typically of 10% and 15% concentrations, higher concentrations have issues with stability. The shelf life of PAA is normally 12 months. However, PAA must be stored at the site where it is dispensed, as underground piping is not permitted. PAA are fed using a diaphragm pump with Teflon diaphragms and polypropylene, Teflon materials and degassing heads are recommended for feeding. The product should be fed into the waste stream at an area of good mixing to promote rapid dispersion. It may be introduced continuously or intermittently depending upon the needs of the user.

Required Concentrations

This is an area where more research and investigation is needed, particularly as it related to disinfection of CSOs. The application of PAA as a disinfectant was studied in the Bayonne MUA pilot study. PAA disinfection tests were performed with PAA dose of typically 2 to 3 mg/L, but up to 7 mg/L, targeting PAA residual in 1 to 2 mg/L range. The best-defined relationship derived from the study results was that between the applied dose of PAA as normalized by COD present in the wastewater and the log reduction of pathogen indicators. PAA dose of 0.01 mg/L of PAA per mg/L of COD present in wastewater resulted in 3-log reduction of fecal coliforms (on average), with slightly higher effectiveness for E. coli and slightly lower for Enterococci. Increasing the relative dose to above 0.015 mg/L of PAA per mg/L of COD increased log reduction to 4. Further increase of the PAA dose appeared to have limited effect on further increasing reduction of the bacterial densities, although data in that range are too limited to allow for a firm conclusion.

Equipment Needed

PAA is typically delivered to the site in liquid form as a 12% solution. The PAA is stored in a tank and is fed into a rapid induction type mixer at a rate established by the flow, through a chemical feed pump. The chemical storage tank and the feed pump would be stored in a building with the induction mixer installed in a channel, followed by a detention tank. Pilot testing has determined that the majority of kill happens in the first 10 minutes regardless of the concentration of PAA. Therefore, the contact time required by PAA has been determined to be between 2 and 10 minutes.

Limitations

The use of peracetic acid in wastewater disinfection has been very limited in the US. There is no known application of peracetic acid in CSO disinfection in the US. In addition, the cost of PAA may be of concern largely due to small consumer market worldwide and the limited production capacity. One manufacturer has listed the price per pound between $0.50 and $0.70 in 2008 dollars, which corresponds to between $3 per gallon and $5.50 per gallon depending on concentrations. Use of peracetic acid in CSO locations could also be complicated by a need for on-site storage of the chemical, which requires secondary containment and appropriate safety measures.

Inhibitors

Studies have shown that variations in water quality parameters related to NH_3, TSS, COD, dissolved oxygen and pH, did not have significant effect on the performance of PAA and PAA produces negligible disinfection by-products.

Need for Dechlorination

At the time of the PVSC TGM, there is no indication that de-chlorination will be required. The short halflife means that PAA is not persistent and rarely needs to be neutralized prior to discharge.

Costs

The Bayonne MUA pilot study provided equipment cost of PeraGreen, INJEXX™ unit for flowrate ranging from 5 MGD to 250 MGD, which are presented in a figure in the PVSC TGM, January 2018. The costs provided include the cost of equipment delivered to the site and are 2017 dollars as well the cost of a contact tank providing three minutes of hydraulic retention time.

Operation and Maintenance

O&M costs were also provided by the Bayonne MUA pilot study to maintain a PAA residual of 0.8-1.0 mg/l in flowrate ranging from 5 MGD to 250 MGD, which are also provided in a figure in the PVSC TGM, January 2018.

4.2.7.3.4 Ultraviolet Disinfection

Description of Process

The use of ultraviolet (UV) light is one of the common methods for disinfection of treated wastewaters. In fact, UV disinfection has become the favored technology for new plants and upgrades for existing plants. There are reportedly over 3,500 UV wastewater disinfection systems currently operating in North America, treating flows of up to 300 mgd. UV disinfection eliminates the operational and environmental hazards associated with the use of chlorine compounds, which is a strong oxidant (and sulfite compounds when dechlorination is required) and is cost competitive with alternative technologies. UV systems are modular and since they require smaller volumes than a chlorination contactor, they can be easily retrofitted into existing chlorination channels.

UV disinfection is a physical process, relying on the transfer of electromagnetic energy released from UV lamps to be absorbed by the nucleic acids (DNA and RNA) in the microorganisms. When the nucleic acids of the organisms are subjected to sufficient quantity of UV radiation (the "dose"), the energy damages the DNA strands by causing specific thymine monomers to combine, which in turn prevents the cell from replicating. This inability to reproduce is, in itself, the lethal effect of UV. Organisms rich in thymine such as *C. parvum* and *G. muris* tend to be more sensitive to UV radiation. The UV radiation in the spectral region between 220 and 320 nm is germicidal, where the wavelengths between 255 nm to 265 nm are considered to be most effective for microbial inactivation. UV disinfection is very effective in inactivation of protozoa, bacteria and viruses, where viruses generally require higher UV radiation dose than protozoa and bacteria.

Electrode type lamps are used to produce light at UV wavelength. Based on the internal operation of these lamps, there are three categories of UV lamps available for use in water/wastewater treatment. These are *low-pressure low-intensity/output (LP-LO), low-pressure high-intensity/output (LP-HO) and medium-pressure high intensity/output (MP-HO)* configurations.

In the low-pressure design, lamp output is optimized via mercury vapor pressure and electric current control to generate a broad spectrum of essentially monochromatic radiation in 200nm to 280 nm range (UV-C). Low-pressure lamps produce an intense peak at 254nm which is close to 260nm wavelength considered to be the most effective for microbial inactivation. These low-pressure lamps are highly efficient, converting 30-50% of their input energy to germicidal range of UV light, where 85 – 88 % of this light is at 254 nm. The difference between low-pressure low-intensity and high-intensity lamps are low-intensity lamps use liquid mercury where high intensity lamps use mercury-indium amalgam. Because of this difference, output of LP-LO lamps decreases when the lamp wall is not near optimum temperature of 40^{o}C. LP-HO lamps operate at temperature range of 100 -150^{o}C and can maintain greater stability of lamp output over a wide range of temperatures. In addition, UV output of LP-HO lamps can be modulated between 30 – 100% to adjust the UV dose.

The absolute output of LI-LO lamps is relatively low, with typical UV ratings of 25 to 27 Watts per lamp at 254 nm, for 40 to 100 W input lamps. In LP-HO higher input power (200 to 500 W) have resulted in higher lamp output at 254 nm (60 to 400 W), while retaining their highly efficient energy conversion characteristic. A number of medium-pressure high-intensity/output UV lamps have been developed over the last decade. MP-HO lamps operate at vapor pressure of 102 to 104 mm Hg while the low-pressure lamps operating at less than 0.8 mm Hg. Also, the operation temperature of MP-HO lamps are significantly higher (600 – 800^{o}C)_than the LP lamps. With the higher mercury pressures, the lamps are driven at substantially higher input power levels (in the range of 1,000 w to13,000 W). Medium-pressure lamps are polychromatic, effectively radiating 20 to 50 times more the total UV-C output (200 to 280 nm) compared to LP-HO lamps. However, MP-HO lamps have lower efficiency than LP-LO and LP-HO lamps. MP lamps can convert about 7 to 9% of their input power to 254 nm output, and 10 to 15% of the total output is in the germicidal region. Overall, the efficiency of the MP-HO lamps is 4 to 5-fold less than the efficiency of the low-pressure lamps. In addition, the lamp, sleeve and ballast life of MP-HO lamps are significantly lower than LP lamps. However, because of their much higher absolute output levels, fewer lamps are needed, often resulting in a smaller footprint for the UV system.

The actual application of UV to wastewater disinfection is fairly simple. The lamps are enclosed in quartz sleeves (highly transmissible in the UV region) and submerged in the flowing wastewater. The lamp/quartz assemblies are typically arranged in modules, with several modules comprising a bank of lamps. In wastewater applications, these banks of lamps are typically placed in open channels, either horizontally or vertically oriented, with level control devices that maintain water levels above the submergence level of the lamps. Pressure units, using closed-vessel reactors, are also used for wastewaters, although pressure units are more frequently applied in drinking water applications. Generally, automatic cleaning systems/wipers are integrated with each bank of lamps to periodically clean the surface of the quartz sleeve and prevent fouling of the sleeve surface and maintain high transmissivity of the sleeves.

There are many benefits associated with UV disinfection:

1. Since no harmful chemicals are added to the wastewater and no known disinfection byproducts are produced as a result of UV radiation.

2. UV system has a compact footprint and the inactivation of microorganisms occur almost instantaneously as the water passes through the UV lamps. Therefore, UV disinfections systems are set up as a modular system and can be easily configured in one or more channels.

3. Chemical storage, transportation and handling is eliminated for the purpose of disinfection.

UV disinfection does, however, require more power than chemical disinfection, which could be a significant consideration for the larger overflow applications.

Required Concentration

There are several factors that affect the design of a UV system for wastewater disinfection. The factors are focused on the design goal to efficiently deliver the necessary UV dose to the targeted microorganisms. Dose is defined as the product of the intensity of UV energy (the rate at which it is being delivered, mJ/cm2 and the exposure time of the organism to this intensity. Ideally, these factors can be applied such that every element in the water receives the same dose as it passes through the UV unit. However, in practice, the UV dose will not be identical for all particles in the water. There is a variation in the intensity field within the unit and variation in the exposure times, resulting in a dose distribution. Effective design optimizes this dose distribution and avoids any appearance of hydraulic short circuiting through the UV unit. Exposure time is dependent on the hydraulic characteristics of the unit, reflecting the spacing of the quartz/lamp assemblies, inlet and outlet conditions, and hydraulic loading rates. The output energy of the lamps, the transmissibility of the quartz sleeves, and the transmittance of the wastewater itself affect intensity. The loss of energy due to the aging of the lamps and degradation of the quartz sleeve transparency must be incorporated in the design of the UV units. Generally, the lamp output will decrease to between 50% and 80% of their nominal output by the end of lamp life (typically LP-HO lamps have 9,000 to 15,000 hours and MP-HO lamps have 3,000 to 8,000 hours lamp life). Sleeve fouling will typically account for a 20% to 30% decrease in transparency through the life of the quartz sleeve, even if they get cleaned regularly. The transmittance of treated wastewater effluents will range between 50% and 75%, depending on the influent water quality and the degree of treatment provided before disinfection. Combined sewer overflows and storm water have significantly low UV transmittances and it is generally in the range of 20% to 50% per cm at 254 nm. Since this directly affects the portion of the energy from UV lamps reaching the microorganism, design should call for closely spacing the lamps and using higher-powered lamps. The medium-pressure lamp units can meet these criteria, as can the LP-HO lamp technologies, although to a lesser degree. Head losses are generally manageable for these systems, typically in the order of 6 to 24 inches for the medium-pressure units. Typically, a dose of 30 to 40 mJ/cm2 is specified for treated wastewater disinfection, where three to four log inactivation rates are generally required to meet disinfection targets. Demonstration that the proposed unit will deliver this dose under design conditions (flow, UV transmittance, end-of-lamp life output, degraded quartz surfaces, etc.) is often required either as a prequalification for bidding, or at the time of commissioning. This is done through direct biodosimetric testing on full-scale or scaled systems, whereby a challenge organism of known dose-response is injected into the UV unit under design flow and UV transmittance conditions. By measuring the kill of the organism, the dose that was delivered by the unit can be estimated. This method has become an industry standard for validating the performance of UV systems. These protocols are articulated by the USEPA UV Design Guidance Manual (November 2006), the NWRI/AWWA RP UV Guidance (May 2003), and the USEPA Environmental Verification Program protocols for reuse, secondary effluents, and wet weather flows (2002). This method accounts for the variations in hydraulics through the UV lamps and UV radiation intensity in a system, and allows for a more consistent comparison of performance expectations and design sizing between different UV technology configurations.

The Bayonne MUA pilot study evaluated performance of Trojan UV3000Plus unit using low-pressure lamps. Correlation of all the individual data from the study indicated required approximately 25 mJ/cm2 effective irradiation dose input to achieve 3log inactivation of pathogen indicators.

Equipment Needed

For purposes of this preliminary assessment of cost associated with the disinfection of combined sewer overflows, the low-pressure high intensity lamp technology is considered. As discussed earlier, the LPHO lamps are very efficient and with advancement in UV lamp technology, there are up to 1,200 W lamps available. The Sigma low-pressure high-intensity lamps offered by Trojan Technologies has been used for preliminary sizing, layout, design and costs estimation; however, it is not the intent of this exercise to recommend a given manufacturer for such applications.

Limitations

In large applications, significant power is required for operation of UV system. In some locations power availability can be a limitation.

Inhibitors

Certain water quality parameters can have a big impact on the disinfection efficiency of the UV system. UV transmittance or UV absorbance is one the key parameter which impact the UV dose that the microorganisms get subjected to. Iron, ozone, manganese, natural organic matter (NOM), TSS are strong absorbers of UV light, which would reduce the UV transmittance. The threshold values for Ferric iron, Ferrous iron and ozone are set as 0.057 mg/L, 9.6 mg/L and 0.071 mg/L, respectively. If iron salts are used within the treatment process, alternative should be evaluated to compare savings of smaller UV system compared to cost associated with change of precipitation aid. Alkalinity, hardness (Ca, Mg and other salts) and TDS can form mineral deposits on quartz tubes and reduce the UV dose reaching microorganisms and would increase the frequency and sleeve cleaning. Alkalinity and pH also affect the solubility of metals carbonate which may absorb UV light. Oil and grease in the wastewater would accumulate on the quartz sleeves and reduce the UV transmittance.

Need for De-chlorination

Since no chemical is used in UV disinfection and there is no residual disinfectant in the wastewater due to UV disinfection, de-chlorination or residual disinfectant removal is not required in UV disinfection systems. If any chemical disinfectant is added in upstream of the UV disinfection, residual disinfectant removal may be required specific to chemical disinfectant used.

Costs

The costs for the ultraviolet disinfection system consist of the equipment cost, including its installation, the cost of the channels for the ultraviolet disinfection equipment. The preliminary report level construction cost estimates provided in PVSC TGM, January 2018 include the equipment, installation, building, and contingency for UV disinfection system of design flow ranging from 10 MGD to 450 MGD. Budgetary equipment pricing information was gathered from equipment manufacturers.

Operation and Maintenance

UV disinfection systems have been used for continuous operation for many years at various treatment facilities. Routine operation and maintenance programs and guidelines have been established for these continuous operations. However, in the case of CSO discharges, the O&M requirements for the UV disinfection technology would be intermittent during the year and be based on the number of storm events per week, month or year. The CSO locations at remote sites would require field crews to be on site before a storm event to make sure the system is in operating conditions and after the storm event to perform general washdowns and maintenance check.

The O&M requirements would center on lamp cleaning, parts replacement, and general maintenance. Recent applications of UV lamps have cleaning systems that employ chemically assisted mechanical wipers, which are effective for low-grade wastewater applications such as CSOs. This has significantly reduced labor time required for lamp cleaning and has also improved lamp effectiveness. However, one of the main challenges with CSO systems is that the lamps are not always submerged in the water and when there is long period between storm events, dust will accumulate on the sleeves. These dust particles would scratch the surface of the sleeve and reduce the penetration/transmittance of the UV light. Therefore, additional precaution and manual cleaning would be required from time to time. It is recommended that UV banks would be raised and inspected for debris after each event to ensure that there is not large debris caught up in the system. The wipers have a debris scraper that will handle smaller debris and push it out of the way, but it will be a good practice to inspect the equipment after each event.

Parts replacement is another major maintenance requirement and would include the replacement of lamps, ballasts, wipers and quartz sleeves. Since the UV system is not going to be operating continuously, lamp replacement is not going to be as often as continuously operating systems in wastewater treatment plants. While some manufacturers offer a lamp warranty only for set operation hours ranging from 12,000 hours to 16,000 hours for LP-HO lamps, which equates to 24 to 32 years of warranty for lamps. This long duration of lamp operation is not believed to be reasonable due to operational conditions of CSO systems. On the other hand, some manufacturers provide a warranty based on a set limit of operation hours or a set duration, which occurs first. The output of UV lamps decreases as lamps age. Generally, after 12,000 to 15,000 hours of operation, the lamps need to be replaced due to low power output. In this report, it is assumed that UV lamps would be replaced every 10 years. In addition to lamp replacement, the ballasts, a type of transformer that is used to limit the current to the lamps, will need to be replaced. For the specific brand and model used for cost estimation in this report, each ballast serves 2 lamps and has an expected life of 5 years.

The third major maintenance requirement would be general O&M requirements at the CSO site. General maintenance at each UV disinfection site would include repairs, cleaning the channels and surrounding areas, maintaining product inventories, system monitoring, and documenting site visits. Assuming that there would be a two-person field crew visiting each site for one hour before and after each storm event, the estimated maintenance hours per event would be 4 to 8 hours depending on the system sizes. UV disinfection systems for CSO discharges can be designed to operate intermittently during the year and also during winter conditions. Instrumentation for intermittent disinfection operations would be incorporated into the UV reactor's operation including monitoring CSO flows, CSO characteristics such as UVT and CSO water levels in the reactor and support channel. These controls would be programmed to turn the reactor on and off, increase or decrease the lamps' intensity based on UVT and open appropriate valves to drain the reactor when not in operation. Operations in the winter, however, would include other specific requirements in the reactor for controlling freezing conditions in the reactor. These requirements would include any or all of the following guidelines:

1. Drain the reactor and apply warm air to the module to maintain temperature above 32°F; and

2. Manually drain the cleaning solution from the wipers and refill the wipers before the next storm event (approximately 5 minutes per lamp). Leave the reactor full of water and provide a heat source to maintain the water temperature above 32°F during freezing temperatures.

Space Requirements

The space requirements of the facilities required for disinfection using UV are based upon the size of the contact chamber and a buffer of 5 feet on upstream and downstream of the UV lamps.

4.2.7.3.5 Ozone Disinfection

Description of Process

Ozone (O_3) is an unstable gas that is produced when oxygen molecules are dissociated into atomic oxygen and subsequently collide with another oxygen molecule to produce ozone. Due to the instability of ozone, it must be generated on-site from air or oxygen carrier gas. The most efficient method of producing ozone today is by the electric discharge technique, which involves passing the air or oxygen carrier gas across the gap of narrowly spaced electrodes under a high voltage. Due to this expensive method of producing ozone, it is extremely important that the ozone is efficiently transferred from the gas phase to the liquid phase. The two most often used contacting devices are bubble diffusers and turbine contactors. With the bubble diffusers, deep contact tanks are required. Ozone transfer efficiencies of 85% and greater can be obtained in most applications when the contactor is properly designed. The contactors must be covered to control the off-gas

discharges. Since any remaining ozone would be extremely irritating and possibly toxic, the off-gases from the contactor must be treated to destroy the remaining ozone. Ozone destruction is normally accomplished by thermal or thermal-catalytic means.

An ozonation system can be considered to be relatively complex to operate and maintain compared to chlorination. The process becomes still more complex if pure oxygen is generated on site for ozone production. Ozonation system process control can be accomplished by setting an applied dose responsive to wastewater flow rate (flow proportional), by residual control, or by off-gas control strategies. Ozone disinfection is relatively expensive with the cost of the ozone generation equipment being the primary capital cost item, especially since the equipment should be sized for the peak hourly flow rate as with all disinfectant technologies. Operating costs can also be very high depending on the power costs, since Ozonation is a power intensive system.

Since ozonation is expensive to operate, and maintain, produces off-gas that can be toxic, is a complex system, and not utilized for disinfection at wastewater treatment plants where flow is more controlled and less variable, we feel it is not an acceptable application for disinfection of CSO flows and will not be evaluated further.

4.2.7.4 Centralized CSO Treatment

The last CSO Treatment technology evaluated relates to centralized CSOs treatment at the current location of the Second Street PS through upsized or parallel interceptors. Under this alternative, the State St PS and Front St PS would also need to be upgraded.

The resulting peak flow at the centralized treatment location would be 748 mgd. The footprint required exceeds the amount of available land and cannot be accommodated. In addition, this alternative cannot accommodate the protection of the beach area. Therefore, it was not considered further.

4.3 Supplemental CSO Team

The Supplemental CSO Team has indicated that whatever methods of treatment are pursued, they should be resilient and address the potential for climate change (i.e. sea level rise) in some way.

4.4 Financial Capability

The City has undertaken a Financial Capability Analysis (FCA) for the purposes of this LTCP. The work associated with the FCA is ongoing.

4.5 Summary of Screening of CSO Control Technologies

The applicability of the technologies is summarized in the table below.

Table 4-16 - Screening of CSO Control Technologies

CSO Control Technology	Viable Alternative for Significant Control	Useful but Limited Application	Alternatives with Major Drawbacks	Not Applicable
Rain Gardens		X		
Right-of-Way Bioswales		X		
Enhanced Tree Pits		X		
Green Roofs		X		
Permeable Pavement		X		
In-Line Storage				X
Off-Line Storage	X			
Sewage Treatment Plant Expansion or Storage at STP	X			
Regulator Modifications		X		
Inflow and Infiltration Reduction			X	
Sewer Separation		X		
Screening	X			
Vortex/Swirl Separation			X	
Ballasted Flocculation	X			
Compressed Media Filtration		X		
Disinfection	X			
Bypass	X			

Section 5

Basis for Cost/Performance Consideration

5.1 Basis for Performance Evaluation

As stated in Section 3, one of the main objectives for CSO control is to support public use of the existing beach for swimming and other recreational uses. This objective is assumed to require full capture and control of CSO discharge for CSO group 3 through 5, i.e. outfalls P-009 through P-019.

The above outfall groups discharge to the Raritan River. In order to improve water quality in the Arthur Kill, a range of control levels were evaluated, i.e. 0, 4, 8, 12, and 20 overflows per year.

System wide percent capture was also considered during the evaluation to show the impact of CSO control on the overall system.

5.2 Basis for Cost Estimation

5.2.1 Basis for Perth Amboy's Cost Estimation

A majority of the preliminary planning level construction cost estimates, annual operation costs, and estimated annual maintenance labor costs referenced the Passaic Valley Sewerage Commissioners CSO Long Term Control Plan Updated Technical Guidance Manual, dated January 2018, by Greeley and Hansen and CDM Smith (PVSC TGM).

- Operation and maintenance cost basis are also calculated based on a draft memorandum entitled PVSC Alternatives Capital and Life Cycle Cost Assumptions, March 20, 2019 by Greeley and Hansen and CDM Smith (O&M costs for pumping stations, storage, tunnels, and conveyance pipelines/sewers)
- PVSC DEAR for Green Infrastructure construction cost per impervious acre controlled and annual O&M costs
- Deep ocean outfall unit cost ($10,000 per ft diameter/ft length) plus 25% on construction cost assumed to be 20-year present value for annual O&M
- Sewage pumping station construction costs were obtained from costing tools used by CDM Smith on other LTCP projects (Alcosan, Philadelphia Water Department).
- The 20-year present value for O&M is calculated using a discount rate of 2.75% (taken from the Rate for Federal Water Projects, NRCS Economics, Department of the Interior)

Where planning level costs were not available, allowances for smaller components of the work (like regulator modifications) were assigned based on professional judgement.

- Regulator modifications ($50,000 per regulator)
- Sewer separation unit cost per acre ($500,000 per acre)

5.2.1.1 Costs for Additional Flow to MCUA

Scenarios evaluated in Section 6 of the report have additional CSS flows from Perth Amboy that will be delivered to the MCUA CTP for treatment. The total costs for these alternatives include a line item cost for additional volume to be treated at the MCUA CTP. The 20-year present value for MCUA treatment was calculated based on a cost of $1,250/MG provided by MCUA and flows summarized in tables throughout Section 6. A discount rate of 2.75% was used in the present value calculation (from the Rate for Federal Water Projects, NRCS Economics, Department of the Interior).

5.2.2 Basis for MCUA's Cost Estimation

The construction cost estimates for the MCUA's CTP Capacity Expansion (Section 4.2.3.3) are based on USEPA cost curves (Reference: Construction Costs for Municipal Wastewater Treatment Plants: 1973-1978, dated April 1980). Utilizing the Engineering News Record Construction Cost Indices (ENR CCI) for the NY/NJ Metro Area, the 4Q 1978 USEPA costs estimates (ENR CCI 2776) were projected to 2018-dollars (ENR CCI 16406 for NY/NJ Metro Area (average values for NYC and Philadelphia CCIs)). The total capital cost includes 30% of non-construction costs (e.g., engineering, legal, and administrative costs) and 25% construction contingencies. The O&M costs are based on USEPA cost curves (Reference: Operation and Maintenance Costs for Municipal Wastewater Facilities, dated September 1981). The O&M costs from 1981 was escalated to 2018 dollars based on 3% inflation rate.

The construction cost estimates for the MCUA's CTP Storage Alternatives (Section 4.2.3.4) are based on 2018 equipment costs, unit costs and installation factors based on engineering experience. The total capital cost includes 30% of non-construction costs (e.g., engineering, legal, and administrative costs) and 25% construction contingencies. The O&M costs are based on 2018 estimates labor hours and labor costs, maintenance at 2% of the mechanical equipment costs and power at current costs.

The construction cost estimates for the MCUA's CTP CSS Bypass for High Rate Treatment and Disinfection (Section 4.2.3) are based on the March 2019 RVE report. The cost estimates for 2018 dollars in the RVE report were based on equipment costs, unit costs, installation factors based on engineering experience. The total capital cost includes 30% of non-construction costs (e.g., engineering, legal, and administrative costs) and 30% to 40% construction contingencies depending the value of the work. The O&M costs were based on 2018 estimates of labor hours and labor costs, maintenance at 2% of the mechanical equipment costs and current power costs.

Section 6

Development and Evaluation of Alternative Approaches for CSO Control

6.1 General

Viable CSO control technologies were discussed in Section 4 of this report, with detailed evaluation of their feasibility for the City of Perth Amboy and MCUA. The applicable CSO LTCP technologies are presented in Table 6-1followed by an evaluation of individual technologies and combinations of technologies in the following subsections.

Table 6-1 - Summary of Applicable BMP and CSO Control Technologies

BMP / CSO Control Technology	Type of Control
Green stormwater infrastructure	Source Quantity Control
Sewer Separation	Source Quantity Control
Regulator Modifications and Collection System Improvements	Collection System Control
Off-line Storage	Storage
WWTP Improvements	Treatment
Screening	Treatment
Ballasted Flocculation	Treatment
Compressed Media Filtration	Treatment
Disinfection	Treatment

A few of the above technologies were evaluated individually for system wide application at different levels of control. They are detailed in Section 6.3. Section 6.4 laid out four groups of scenarios which used different combinations of the technologies to achieve multiple levels of control in different parts of the system. Section 6.5 documented the alternatives inside of the CTP evaluated by MCUA. Section 6.6 summarized the different alternatives. The integration of inputs from CSO Supplemental Group was highlighted in Section 6.7.

6.2 Scenarios of Peak Flow to MCUA

The following scenarios have been developed to represent the range of flows that can be delivered to the downstream end of the Perth Amboy gravity collection system with minimal or no improvement to the existing interceptors and subsequently delivered directly to MCUA CTP by new pumping facilities at the downstream end of the Perth Amboy. All three scenarios have been used in evaluating CSO control alternatives in Section 6.3 and 6.4 where satellite facilities were sized to treat the remaining overflow.

6.2.1 Pumping Scenario 1: Peak Flow to MCUA – 13 mgd

Peak flow to MCUA of 13 mgd represents the current condition. For the purpose of the LTCP, this scenario applies to the construction of a new pumping station and force main conveying peak flow directly to MCUA for treatment.

6.2.2 Pumping Scenario 2: Peak Flow to MCUA – 42 mgd

Peak flow to MCUA of 42 mgd represents the maximum flow that can be conveyed to MCUA with no improvements to the gravity collection system in Perth Amboy and will require the construction of a new pumping station and force main conveying this peak flow directly to MCUA for treatment. This will reduce overflow volume along the beach area without eliminating them. Details of the impact are shown in Section 6.4.2.

6.2.3 Pumping Scenario 3: Peak Flow to MCUA – 54 mgd

Peak flow to MCUA of 54 mgd represents the maximum flow that can be conveyed to MCUA with limited improvements to the gravity collection system in Perth Amboy consisting of regulator modifications to P009-016 along the beach area and will require the construction of a new pumping station and force main conveying peak flow directly to MCUA for treatment. This will further reduce overflow volume along the beach area without eliminating them. Details of the impact are shown in Section 6.4.3.

6.3 Single Technology Alternatives

Three technologies considered feasible for potential system-wide control of CSO discharges were evaluated individually for system wide application. They are 1) satellite storage at each outfall group, 2) satellite CSO treatment at each outfall group, and 3) system-wide tunnel storage. Each technology was sized to achieve different level of controls (i.e. 0, 4, 8, 12, and 20 overflows per year) at all CSO Groups. The analysis in this subsection is based on Pumping Scenario 1 (13 MGD to MCUA defined in Section 6.2.1) and provides the initial evaluation of system-wide CSO control alternatives.

6.3.1 Satellite Storage

As discussed in Section 4, concrete storage tanks are an effective way of providing CSO control. In this alternative, the new pumping station pumps at an existing rate of 13 mgd (Pumping Scenario 1) and a storage tank is used for each CSO Group to store the overflow for different levels of control. Refer to Table 6-2 for the tank sizes needed for each CSO group to achieve 0, 4, 8, 12, and 20 overflows per year. They were calculated based on the CSO stats of the baseline condition.

Consolidation pipes will be needed to bring overflow from each individual outfall to the consolidated storage tank for CSO Groups 2 and 3. For CSO Group 2, land is available around CSO005. The estimated consolidation pipes needed to bring overflow from the other five overflows are roughly 4700 linear feet. For CSO Group 3, roughly 3,000 linear feet of consolidation pipes will be needed to convey overflows from 6 outfalls to the storage sited between CSO014 and CSO015. The consolidation pipe sizes needed to achieve the different levels of controls are listed in Table 6-3.

The amount of flow stored in these satellite tanks will be discharged back into the sewer system after the flow recedes to dry weather conditions and ultimately reaching MCUA's WWTP for treatment. This will increase the total amount of flow the City sends to MCUA in that the flow stored will be conveyed to MCUA at a maximum flow rate of 13 MGD over a longer period of time. This, in turn, will result in additional cost for the City. The annual volume of the additional flow for different levels of control are listed in Table 6-4.

Table 6-2 - Storage tank volume needed for each CSO group

CSO Group/ CSO Name		0/yr	4/yr	8/yr	12/yr	20/yr
1	P-002	7.6	3.5	2.8	1.8	1.0
2	P-003 - P-008	7.4	3.5	3.1	2.6	1.4
3	P-009 - P-016	17.9	7.8	7.1	5.6	3.4
4	P-017	1.1	0.6	0.3	0.2	0.1
5	P-019	7.7	2.9	2.6	2.0	1.1
Total		41.6	18.3	15.9	12.2	7.0

Table 6-3 - Consolidation Pipe Size Requirement for Storage

CSO Group		Pipe Diameter (ft)				
		0/yr	4/yr	8/yr	12/yr	20/yr
2	P-003 - P-008	5.5	5	5	5	4
3	P-009 - P-016	7	7	6.5	6.5	5.5

Table 6-4 - Stored volume sent to MCUA for treatment for the typical year

CSO Group/MG/yr		0/yr	4/yr	8/yr	12/yr	20/yr
1	P-002	63.2	55.2	50.7	40.8	27.8
2	P-003 - P-008	78.3	72.3	69.8	64.2	46.7
3	P-009 - P-016	173.9	160.7	156.3	141.1	107.3
4	P-017	8.6	7.5	5.2	3.3	1.3
5	P-019	62.3	55.9	54.0	47.2	32.2
	Total	386.4	351.6	336.0	296.6	215.4

With the satellite storage at each CSO group, the remaining annual overflows are summarized in Table 6-5 along with their corresponding system wide percent capture. Eighty five percent capture falls between 12 to 20 overflows per year. The life cycle costs of the storage tanks and necessary consolidation conduits are presented in Table 6-6. With 160 to 330 million dollars all the overflows in Perth Amboy can be controlled to 20 to 4 overflows per year. Figure 6-1 plots the total costs with their corresponding levels of control in both overflow frequency (primary X-axis) and system wide percent capture (secondary X-axis). As the targeted overflow frequency drops, the slope of the cost increase gets steeper.

Table 6-5 - Remaining CSO and System Wide Capture

CSO Group		0/yr	4/yr	8/yr	12/yr	20/yr
1	P-002	0.0	8.0	12.5	22.5	35.4
2	P-003 - P-008	0.0	6.0	8.5	14.1	31.6
3	P-009 - P-016	0.0	13.2	17.6	32.8	66.6
4	P-017	0.0	1.1	3.4	5.2	7.3
5	P-019	0.0	6.5	8.4	15.2	30.2
Total		0.0	34.8	50.3	89.8	171.0
SYSTEM WIDE CAPTURE		100%	96%	94%	90%	81%

Table 6-6 - Cost Table for Storage

CSO Group/ MG		Total Life Cycle Cost for Storage ($Million)				
		0/yr	4/yr	8/yr	12/yr	20/yr
1	P-002	$85.7	$58.3	$41.4	$32.9	$25.4
2	P-003 - P-008	$99.0	$73.0	$60.1	$55.1	$39.8
3	P-009 - P-016	$191.6	$133.8	$93.4	$80.0	$58.9
4	P-017	$25.4	$15.5	$11.0	$8.4	$6.6
5	P-019	$86.2	$49.5	$40.1	$34.4	$26.0
Total		$487.9	$330.0	$246.0	$210.8	$156.7

Notes:

1. This table includes the construction cost with contingency for the storage tanks and consolidation conduits, present value for 20 years of O&M Cost, the present value for 20 years of MCUA treatment cost for the additional volume treated at the CTP, and land acquisition costs.
2. The 20-year present value for MCUA treatment was calculated based on a cost of $1,250/MG provided by MCUA and flows summarized in Table 6-4.

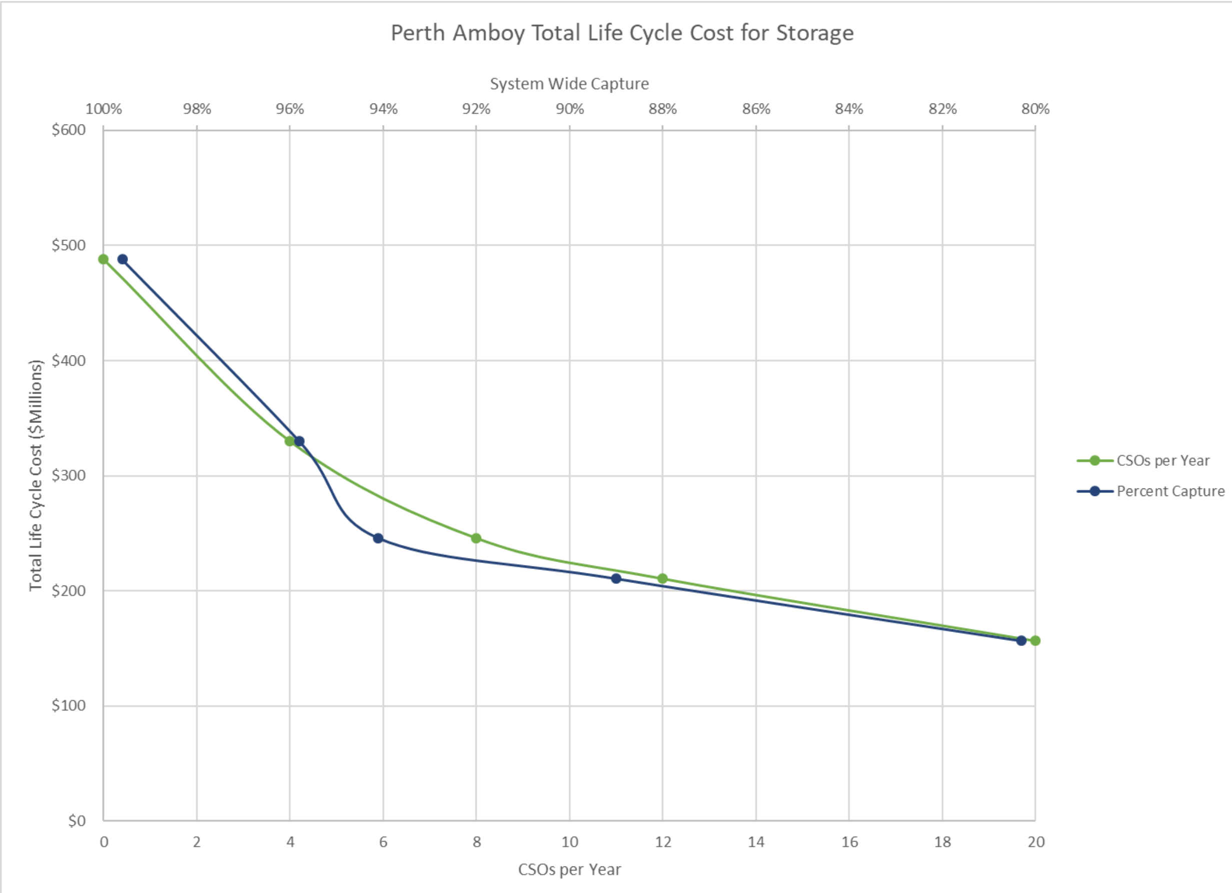


Figure 6-1 - Cost Curve for System Wide Satellite Storage

6.3.2 Satellite Treatment

According to the National CSO Policy and, satellite CSO treatment needs to meet primary treatment standard which requires multiple treatment processes. The combination of pre-treatment and disinfection has been used extensively throughout the county for effective CSO satellite treatment. Of the various types of technologies listed in Section 4, ballasted flocculation and compressed media filtration are considered for pre-treatment technology while sodium hypochlorite is the selected disinfectant, with sodium bisulfite for dechlorination before discharging into the receiving water.

In this alternative, the new pumping station pumps at existing pumping rate of 13 mgd (Pumping Scenario 1) and a satellite treatment facility is used for each CSO Group to treat the overflows to different levels of control. The maximum rate of treatment needed for each CSO group are listed in Table 6-7 to achieve different levels of control. The overflow will be treated at each of the five satellite treatment systems and discharged into the receiving waters. Thus, no extra volume will be sent to MCUA for treatment. The consolidation pipes needed for CSO Group 2 and 3 are listed in Table 6-8. The remaining system wide CSO and percent capture are summarized in Table 6-9.

Table 6-7 - High Rate Treatment Facility Sizing

CSO Group/mgd		0/yr	4/yr	8/yr	12/yr	20/yr
1	P-002	195.9	98.3	53.0	32.1	18.7
2	P-003 - P-008	210.7	112.2	68.5	38.5	23.7
3	P-009 - P-016	329.9	255.0	158.6	94.5	61.5
4	P-017	35.9	34.0	17.8	10.7	4.1
5	P-019	135.2	84.2	49.1	29.9	20.5

Table 6-8 - Consolidation Pipe Sizing

CSO Group		Pipe Diameter (ft)				
		0/yr	4/yr	8/yr	12/yr	20/yr
2	P-003 - P-008	5.5	4.5	4	3.5	3
3	P-009 - P-016	8	7.5	6.5	5.5	4.5

Table 6-9 - Remaining CSO and System Wide Capture

CSO Group		0/yr	4/yr	8/yr	12/yr	20/yr
1	P-002	0.0	1.4	4.3	7.6	12.5
2	P-003 - P-008	0.0	1.2	3.5	7.4	11.5
3	P-009 - P-016	0.0	0.7	5.2	13.4	22.9
4	P-017	0.0	0.0	1.5	2.9	5.0
5	P-019	0.0	0.5	2.8	6.2	9.7
Total		0.0	3.9	17.2	37.5	61.6
SYSTEM WIDE CAPTURE		100%	99%	98%	95%	93%

Between the two types of ballasted flocculation presented in PVSC's TGM, DensaDeg and Actiflo, the cost of DensaDeg is consistently cheaper at all targeted CSO frequencies. The compressed media filter presented in PVSC's TGM is the WWETCO FlexFilter™ by WesTech, had similar estimated total life cycle costs to the DensaDeg ballasted flocculation system. Figure 6-2 shows the cost curves for the two ballasted floc systems and the compressed media filter. Although the FlexFilter has lower costs than the DensaDeg system for 4, 8, and 12 CSOs per year, the DensaDeg system was chosen for costing analysis of satellite CSO treatment due to other drawbacks and limitations of the FlexFilter, including the high (up to 8 feet) headloss through the system and the low influent TSS concentration required.

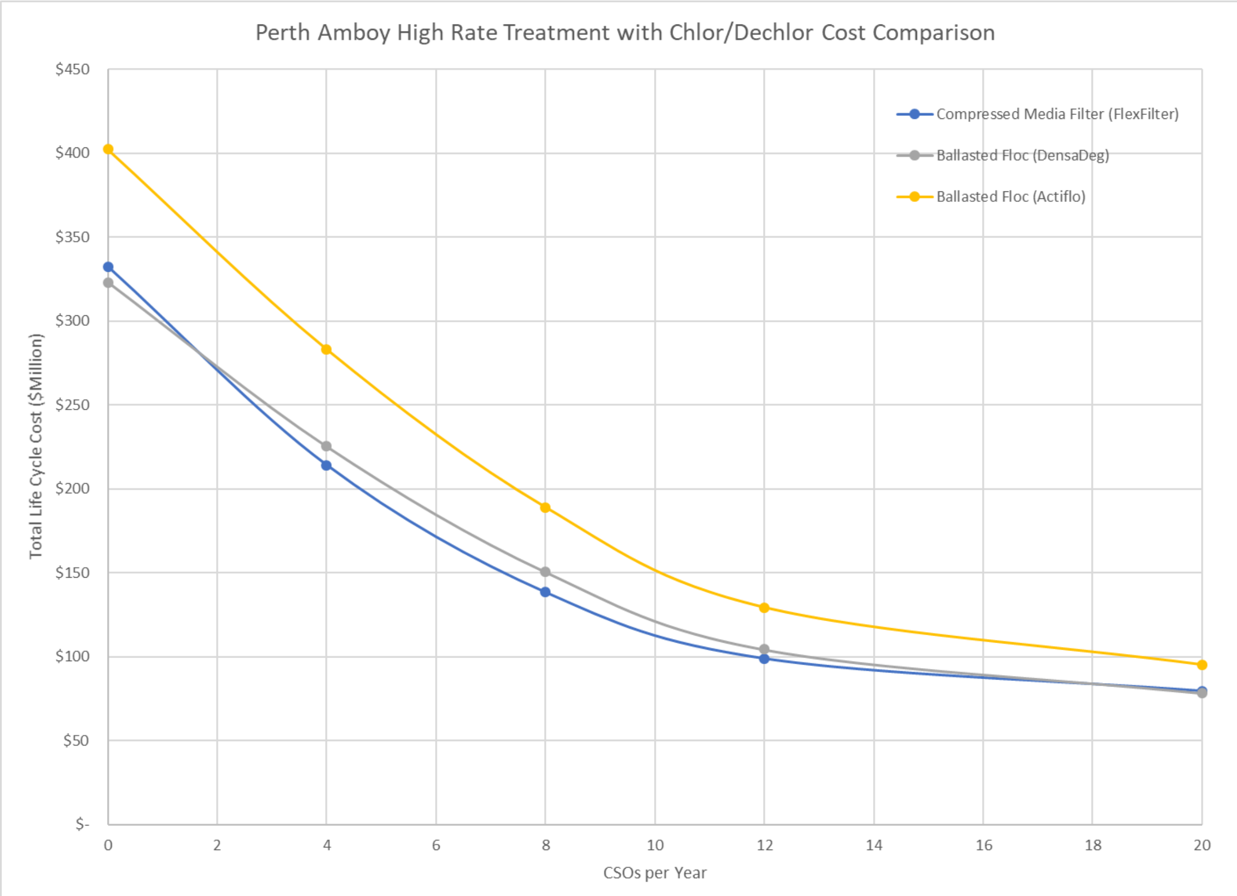


Figure 6-2 - High Rate Treatment Alternative Comparison

Table 6-10 summarizes the costs for applying satellite treatment system wide to achieve different levels of control. Due to the need of a new ocean outfall for the consolidated CSO treatment facility along the beach (CSO Group 3), the overall cost for CSO treatment is higher than that for storage. However, satellite treatment is more effective in system wide percent capture. At 20 overflows per year, system wide percent capture can reach over 90% (Table 6-9). Figure 6-3 plots the total costs of satellite treatment with their corresponding targeted overflow frequencies. Levels of control are shown in both overflow frequency (primary X-axis) and system wide percent capture (secondary X-axis). As the targeted overflow frequency drops, the slope of the cost increase gets steeper.

Table 6-10 - Total Lifecycle Costs for HRT

CSO Group/ MG		Total Life Cycle Cost for HRT ($Million)				
		0/yr	4/yr	8/yr	12/yr	20/yr
1	P-002	$82.7	$47.8	$30.8	$22.7	$17.5
2	P-003 - P-008	$102.9	$68.1	$51.8	$40.4	$28.1
3	P-009 - P-016	$337.7	$313.8	$280.9	$257.7	$245.3
4	P-017	$24.2	$23.5	$17.1	$14.4	$11.8
5	P-019	$61.3	$42.6	$29.7	$21.9	$18.2
Total		$608.8	$495.8	$409.9	$357.0	$320.9

Notes:

1. This table includes the construction cost with contingency for the climber screens, DensaDeg ballasted flocculation treatment, chlorination/dichlorination, consolidation conduits, ocean outfall, present value for 20 years of O&M costs, and land acquisition.
2. No costs for MCUA treatment are included in this table because It is assumed for this alternative no additional volume will be treated at the MCUA CTP.

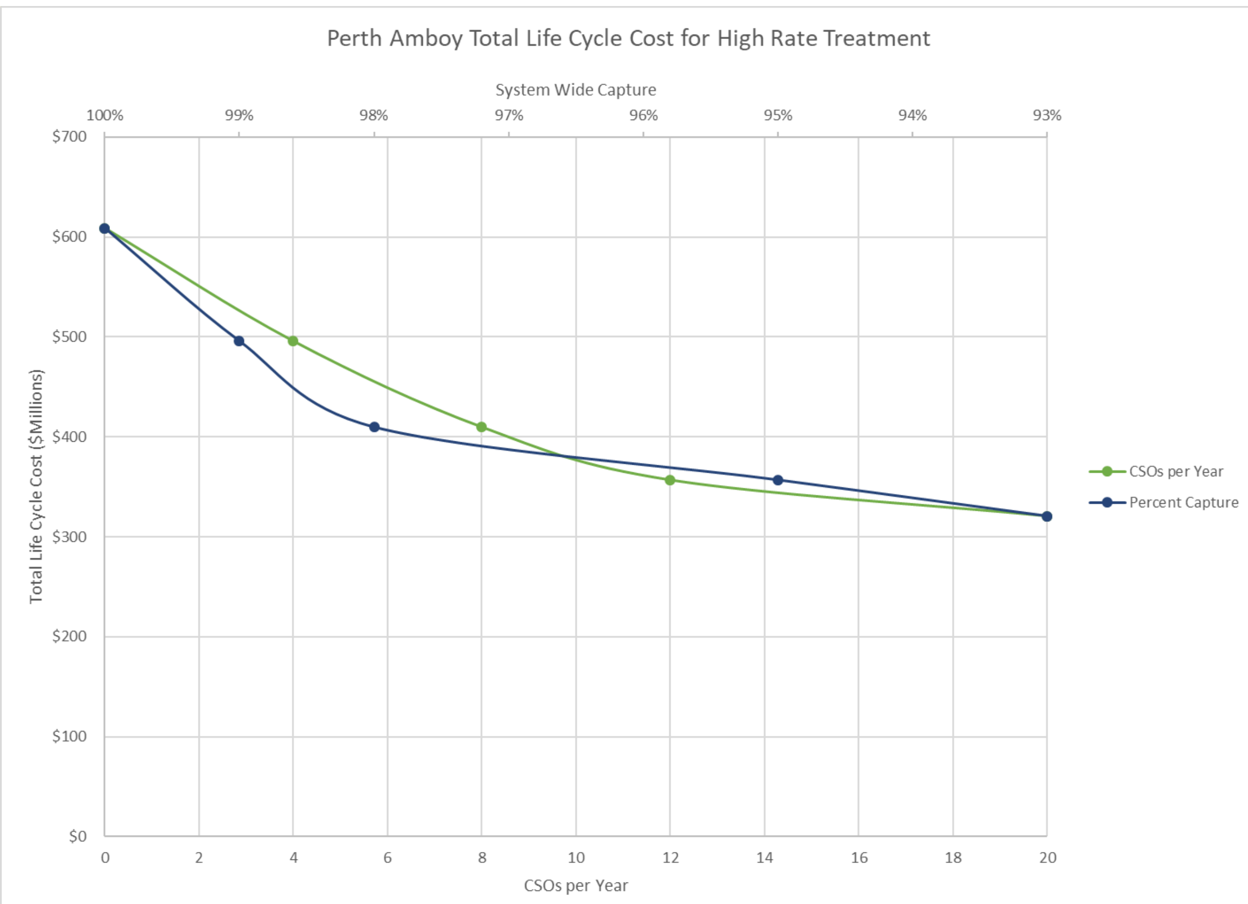


Figure 6-3 - Cost Curve for Mechanical Screens, DensaDeg HRT, and Chlorination/Dechlorination

6.3.3 Tunnel Storage

Another off-line storage technology using deep tunnel is also evaluated with Pumping Scenario 1 (13 MGD to MCUA defined in Section 6.2.1). A conceptual alignment of the tunnel is shown in Figure 6-4. Five drop shafts are sited with multiple consolidation pipes to bring overflows into the tunnel from each regulator that are far from the drop shaft. Table 6-11 lists the length and size of each tunnel section as well as those of the consolidation pipes for control level of 0 overflow per year. A pumping station located adjacent to the tunnel will be needed to pump flow stored in the tunnel into the downstream gravity system and ultimately MCUA's CTP for treatment. The additional annual volume is 386.5 MG for the typical year.

Table 6-12 lists the length and size of each tunnel section as well as those of the consolidation pipes for control level of 4 overflows per year. The additional annual volume is 279.3 MG for the typical year.

Figure 6-4 - Conceptual Tunnel Layout

Table 6-11 - Tunnel Details for 0 CSO Overflows per Year

<table>
<tr><th>Outfall</th><th>Vol (MG)</th><th>Qmax (MGD)</th><th>Consolidation sewer length, ft</th><th>Consolidation Sewer dia, in</th><th>Tunnel length, ft</th><th>Tunnel dia, ft</th></tr>
<tr><td>CSO-002</td><td>7.6</td><td>195.9</td><td>1,000</td><td>108</td><td rowspan="7">5750</td><td rowspan="16">22</td></tr>
<tr><td>CSO-003</td><td>1.8</td><td>46.0</td><td rowspan="3">2,200</td><td rowspan="3">84</td></tr>
<tr><td>CSO-004</td><td>1.0</td><td>30.6</td></tr>
<tr><td>CSO-005</td><td>1.2</td><td>27.5</td></tr>
<tr><td>CSO-006</td><td>2.4</td><td>62.7</td><td rowspan="3">2,500</td><td rowspan="3">84</td></tr>
<tr><td>CSO-007</td><td>0.7</td><td>24.6</td></tr>
<tr><td>CSO-008</td><td>0.3</td><td>18.5</td></tr>
<tr><td>CSO-009</td><td>0.1</td><td>15.91</td><td rowspan="5">2,900</td><td rowspan="5">96</td><td rowspan="6">6070</td></tr>
<tr><td>CSO-010</td><td>0.1</td><td>21.50</td></tr>
<tr><td>CSO-011</td><td>1.0</td><td>47.13</td></tr>
<tr><td>CSO-013</td><td>2.9</td><td>44.49</td></tr>
<tr><td>CSO-014</td><td>1.1</td><td>18.47</td></tr>
<tr><td>CSO-015</td><td>1.4</td><td>33.84</td><td>no need</td><td>-</td></tr>
<tr><td>CSO-016</td><td>11.2</td><td>148.55</td><td>600</td><td>96</td><td>1000</td></tr>
<tr><td>CSO-017</td><td>0.6</td><td>35.8</td><td>600</td><td>54</td><td rowspan="2">2900</td></tr>
<tr><td>CSO-019</td><td>7.7</td><td>135.2</td><td>3,400</td><td>90</td></tr>
<tr><td>Total</td><td>41.2</td><td></td><td>13,200</td><td></td><td>15,720</td><td></td></tr>
</table>

Note: Additional CSS flow to be treated at MCUA CTP is 386.5 MG per year.

Table 6-12 - Tunnel Details for 4 CSO Overflows per Year

Outfall	Vol (MG)	Peak Discharge (MGD)	Consolidation sewer length (ft)	Consolidation Sewer dia (in)	Tunnel length (ft)	Tunnel dia (ft)
CSO-002	3.33	98.32	1,000	84	5750	14
CSO-003	0.81	18.92	2,200	72		
CSO-004	0.51	25.90				
CSO-005	0.47	15.77				
CSO-006	0.98	32.09	2,500	66		
CSO-007	0.29	11.21				
CSO-008	0.17	8.36				
CSO-009	0.08	8.17	2,900	84	6070	
CSO-010	0.09	10.93				
CSO-011	0.60	25.14				
CSO-013	1.18	41.49				
CSO-014	0.43	16.33				
CSO-015	0.61	23.45	not required	-		
CSO-016	4.78	129.48	600	90	1000	
CSO-017	0.63	34.04	600	54	2900	
CSO-019	3.05	84.23	3,400	78		
Total	18.0		13,200		15,720	

Note: Additional CSS flow to be treated at MCUA CTP is 352.4 MG per year.

The costs for the tunnel alternative are presented in Table 6-13. It seems that for both 0 and 4 overflows per year, tunnel is a cheaper option than satellite storage or treatment. This option will be further evaluated during the LTCP phase to refine the tunnel layout, size, and cost.

Table 6-13 - Tunnel Costs

Description	CSO Per Year	
	0/yr	4/yr
	Costs ($Million)	Costs ($Million)
Consolidation Sewer Construction and 20 year O&M Present Worth	$53.5	$42.7
Deep Tunnel and Drop Shaft Construction and 20 year O&M Present Worth	$268.2	$188.0
Deep Tunnel Drainage Pumping Station	$20.4	$20.4
Second Street Pumping Station Upgrade[1]	$20.4	$20.4
New Force Mains from Second St PS to MCUA CTP (2 parallel 24-in)	$38.0	$38.0

Description	CSO Per Year	
	0/yr	4/yr
	Costs ($Million)	Costs ($Million)
Cost for Additional Treatment at MCUA CTP[2]	$7.4	$6.8
Total	$407.9	$316.3

1. Based on upgrading pumping station to drain the tunnel in two (2) days.
2. The 20-year present value for MCUA treatment was calculated based on a cost of approximately $1,250/MG provided by MCUA and flows summarized in Tables 6-11 and 6-12.

6.4 Mixed Technology Alternatives

Each of the alternatives in Section 6.3 considered only one type of technology to achieve varies levels of system-wide control represented by overflow frequency throughout the system. This was useful as an initial evaluation step and was followed by evaluation of more complex scenarios employing a mix of technologies. This section presents the mixed technology alternatives, e.g. increased conveyance, satellite storage or treatment, and sewer separation, as well as different levels of control targets in different parts of the system.

As stated in Section 3, the CSO control objectives are to support public use of the existing beach at the mouth of Raritan River and to improve water quality in Arthur Kill. These objectives lead to a control target of 0 overflow per year at all the outfalls on the Raritan River and 0 to 20 overflows per year levels of control at the outfalls on the Arthur Kill. System wide capture of 85% was also used as a criterion to evaluate system wide performance.

Increased conveyance is an important aspect of the mixed technology alternatives. The more the interceptor and downstream pumping stations can convey flow to MCUA, the less satellite treatment or storage would be needed in Perth Amboy. Pumping Scenarios 1, 2 and 3 reflect the variation in conveyance considered. Once this additional flow reaches the CTP, MCUA analyzed the different alternatives to handle the range of flows from the City. The alternatives related to the CTP are presented in Section 6.5.

Each mixed technology alternative was presented in a specific sequence. As each technology or technology group was implemented at a CSO group, the cumulative impact was assessed with remaining annual CSO volume and percent capture rate for the whole system. At the end of each Mixed Technology Alternative, summary tables are provided for facility sizing, system wide impact (CSO volume and percent capture), and costs.

6.4.1 Mixed Technology – Existing Pumpage

In this alternative, Pumping Scenario 1 is used while satellite storage or treatment are applied to achieve 0/year overflow on the Raritan River and 85% total system capture or 0-20/year overflow on the Arthur Kill. This does not include any increased conveyance at the pump station and is used as the baseline for comparing effectiveness of the rest of Mixed Technology Alternatives detailed in Section 6.4.

6.4.1.1 Second Street Pumping Station

This scenario does not include any increased conveyance (Pumping Scenario 1) thus does not increase the peak flow sent to MCUA. Annual CSO discharges remained the same as the baseline, 386.4 MG, and the system wide percent capture is at 57%.

6.4.1.2 CSO Group 3 (P009 – 016)

P010 to P016 locate along the beach area on Raritan River. Although P009 discharges into the Arthur Kill, its proximity to the confluence of the two receiving waters and the fact that it is downstream of Front Street Pumping Station make grouping it with P010 - 016 a logical choice. Two options were evaluated for this group of outfalls to achieve 0 overflow per year.

The first option is to use one consolidated storage as detailed below.

- New CSO storage facility with 17.9 MG capacity between P014 andP015
- Remaining overflows from P009-014 is diverted through a consolidation pipe and westwards to the new storage facility
- Remaining overflows from P015 and 016 are also diverted to the same storage facility
- The stored CSO can either be gravity drained or pumped back into the Second St PS once the flow in the system recedes back to dry weather flow.
- 173.9 MG/year more flow will be send to MCUA for treatment if storage is used.

Storage using a deep tunnel along the beach area can be another storage option and will be evaluated during the LTCP phase.

The second option is to have a consolidated CSO treatment facility for these overflows. The details are listed below.

- New CSO treatment facility with 374 mgd capacity at any potential site between P010 and P008
- Remaining overflows from P009 is conveyed through a consolidation pipe to the new treatment facility
- Remaining overflows from P010 and 016 are diverted eastwards through consolidation pipes to the same treatment facility
- A new outfall pipe to bring treated flow eastwards and discharge towards the Arthur Kill.

System wide capture with either of the above storage or treatment options can reach 76% with 212.4 MG remaining CSO for the entire system. However due to the beach, storage would be preferred over CSO treatment for that storage doesn't lead to any discharge of treated flows into the receiving waters in the vicinity of the beach.

6.4.1.3 CSO Group 4 (P017) and 5 (P019)

Since P017 and P019 both discharge to the Raritan River, these two outfalls are targeted for full containment in the typical year, i.e. 0 overflow per year. Either satellite storage or treatment can be used to achieve the control target.

If storage is used, a storage tank would be sited near each of the overflows with 1.1 MG at P017 and 7.7 MG at P019. The total stored volume at these two facilities that need to be sent to MCUA for treatment is 70.9 MG for the typical year.

If CSO treatment is used, a high rate treatment facility will be sited near each overflow with 35.9 mgd at P017 and 135.2 mgd at P019. Chlorination and dichlorination also need to be applied. Water quality model can be used to evaluate the impact of treated effluent to the beach in the next phase of the Long Term Control Plan.

With P017 and P019 fully contained during the typical year in addition to CSO group 3, system wide capture increases to 84% with 141.5 MG remaining annual CSO However these outfalls locate upstream from the beach, storage would be preferred over CSO treatment for that storage doesn't discharge treated flows into the receiving water at all and has no potential of impacting water quality around the beach area.

6.4.1.4 CSO Group 1 (P002)

P002 is the biggest CSO that discharges to Arthur Kill and it locates at the northeast corner of the system, three quarter of a mile north from P003. A satellite treatment or storage facility for P002 alone is recommended. The storage or treatment facilities were evaluated to control targets between 0 to 20 overflows per year. Overflow frequency lower than 20 per year was not considered.

If storage is used, the storage tank size needed to achieve the different levels of control are listed in Table 6-14. The table also includes the remaining CSO volume at P002, annual stored volume at P002 which needs to be sent to MCUA for treatment, and resulted annual system wide CSO and percent capture (these are the cumulative results from all aforementioned CSO Groups in Section 6.4.1).

Table 6-14 Mixed Technology - Existing Pumpage - CSO Group 1 - Storage Summary

Control Target Overflow Frequency	tank vol needed, MG	vol stored, MG	remaining CSO at P002, MG	System wide annual CSO, MG	System wide capture
0/year	7.6	63.2	0.0	78.3	90.9%
4/year	3.5	55.2	8.0	86.3	90.1%
8/year	2.8	50.7	12.5	90.8	89.6%
12/year	1.8	40.8	22.5	100.8	88.5%
20/year	1.0	27.8	35.4	113.7	87.1%

If CSO treatment is used instead of storage, the facility size and the impact on the system are summarized in Table 6-15. Since CSO Group 3 through 5 are already fully controlled for the typical year, the system wide annual CSO is the annual CSO discharge at CSO Group 2 (P003 – P008) plus the remaining CSO at P002 after the satellite treatment.

Table 6-15 - Mixed Technology Baseline - CSO Group 1 - Treatment Summary

Control Target Overflow Frequency	HRT needed (mgd)	remaining CSO at P002 (MG)	System wide annual CSO (MG)	System wide capture (%)
0/year	195.9	0.0	78.29	90.9%
4/year	98.3	1.4	79.7	90.8%
8/year	53.0	4.3	82.6	90.5%
12/year	32.1	7.6	85.9	90.1%
20/year	18.7	12.5	90.8	89.5%

With the overflows discharging to Raritan River fully contained, either CSO storage or treatment at P002 or CSO Group1 will result in higher than 85% system wide capture at 20 overflows per year at P002. Keep in mind that CSO Group 2, i.e. P003 through P008 have not been treated or stored at all up to this point. The next subsection evaluates the control scenarios for CSO Group 2 with the assumption that CSO Group 1 or P002 is controlled at 20 overflows per year.

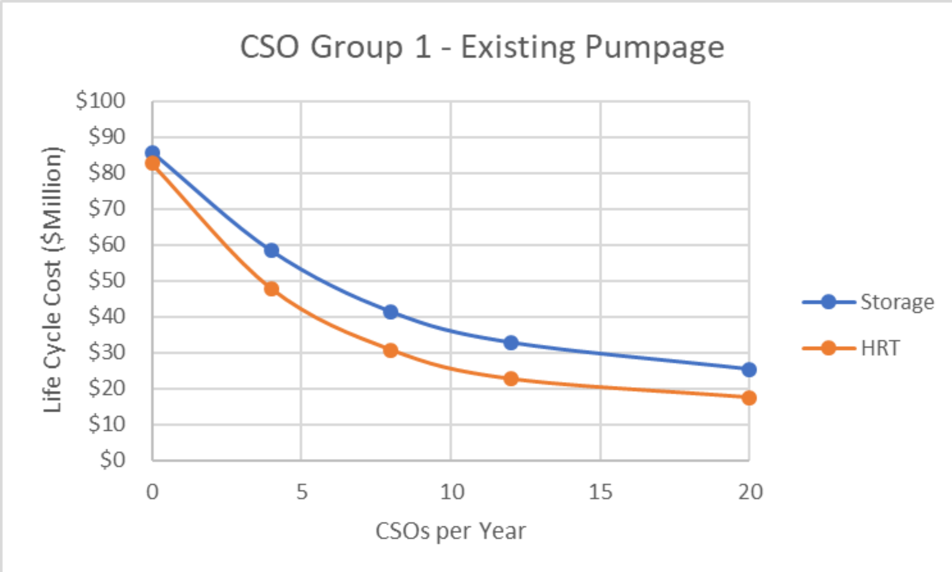
The costs for storage and treatment to achieve the different overflow frequency targets are summarized in Table 6-16. Treatment is consistently cheaper than storage and offers higher system wide percent capture (Figure 6-5).

Table 6-16 - Mixed Technology Baseline Group 1 Costs

Baseline - Total Life Cycle Cost for CSO Group 1 ($mil)					
CSOs per Year	0/yr	4/yr	8/yr	12/yr	20/yr
Storage[1]	$85.7	$58.3	$41.4	$32.9	$25.4
Treatment[2]	$82.7	$47.8	$30.8	$22.7	$17.5

Costs Include:

1. Storage tanks, coarse screens, diversions, control gates, pumping/flushing/ventilation facilities, 20 yr PV O&M, 20 yr PV MCUA additional treatment cost, and land acquisition. The 20-year present value for MCUA treatment was calculated based on a cost of $1,250/MG provided by MCUA and flows summarized in Table 6-14.
2. Climber Screens, DensaDeg ballasted floc, chlor/dechlor, 20 yr PV O&M, and land acquisition. There is no cost for additional flow to be treated at MCUA CTP for this alternative.



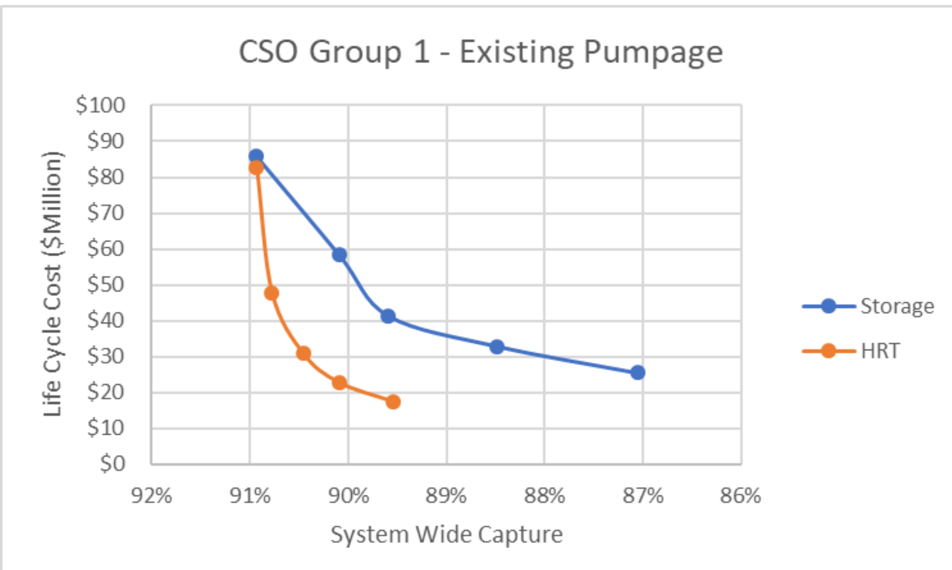


Figure 6-5 – Mixed Technology Existing Pumpage - CSO Group 1 Cost Curves

6.4.1.5 CSO Group 2 (P003 – 008)

The last CSO group considered is CSO Group 2 which include seven outfalls from P003 through P008. They discharge into Arthur Kill with 78.3 MG overflow in the typical year. A consolidated storage or treatment facility with consolidation pipes are proposed below to achieve 0 to 20 overflows per year.

If using storage, Table 6-17 below listed the size of the storage tank needed to achieve the different level of controls, the remaining CSO at CSO Group 2 assuming P002 is controlled at 20 overflows per year, and the additional stored volume which needs to be sent to MCUA for treatment. The resulted annual system wide CSO and percent capture were also detailed in the table.

Table 6-17 - Mixed Technology Baseline - CSO Group 2 - Summary Storage Statistics

Control Target Overflow Frequency	Tank Vol Needed (MG)	Vol Stored (MG)	Remaining CSO at CSO Group 2 (MG)	System-wide Annual CSO* (MG)	System Wide Capture (%)
0/year	7.4	78.3	0.0	35.4	95.7%
4/year	3.5	72.3	6.0	41.4	95.1%
8/year	3.1	69.8	8.5	43.9	94.7%
12/year	2.6	64.2	14.1	49.5	94.1%
20/year	1.4	46.7	31.6	67.0	92.2%

*Assuming P002 is controlled at 20 overflows per year.

If CSO treatment is used instead of storage, the facility size and the impact on the system are summarized in Table 6-18 below.

Table 6-18 - Baseline CSO Group 2 HRT Summary

Control Target Overflow Frequency	HRT needed (mgd)	Remaining CSO at CSO Group 2 (MG)	System wide annual CSO* (MG)	System wide capture (%)
0/year	210.7	0.0	12.5	98.2%
4/year	112.2	1.2	13.7	98.1%
8/year	68.5	3.5	16.1	97.8%
12/year	38.5	7.4	19.9	97.4%
20/year	23.7	11.5	24.0	96.9%

*Assuming P002 is controlled at 20 overflows per year.

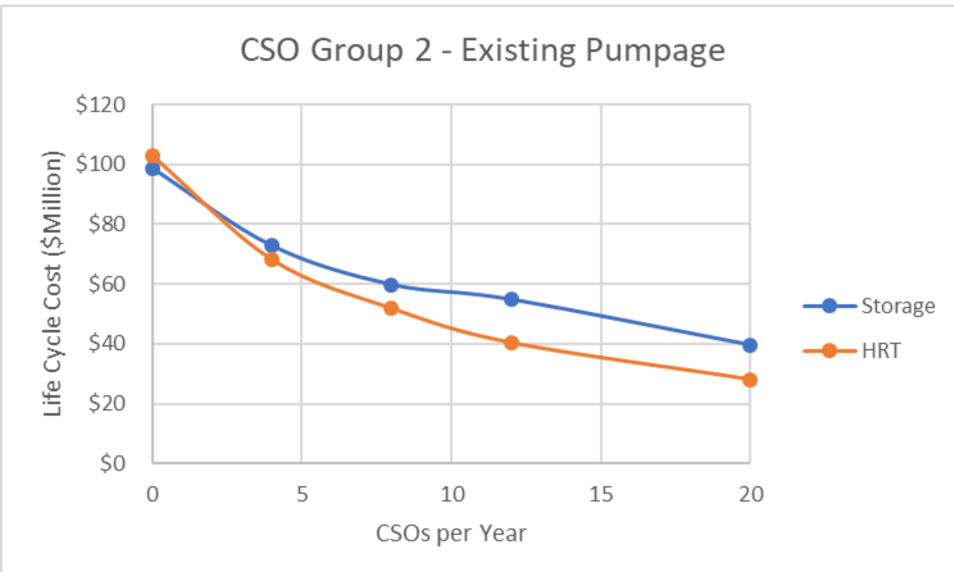
With the overflows discharging to Raritan River fully contained and P002 controlled to 20 overflows per year, either CSO storage or treatment will result in higher than 90% system wide capture. The cost curve in Figure 6-6 shows that CSO treatment is generally cheaper than storage and provides higher system wide capture at the same overflow frequency at CSO Group 2.

Table 6-19 – CSO Group 2 - Storage and Treatment Costs

Baseline – Total Life Cycle Cost for CSO Group 2 ($Million)					
CSOs per Year	0/yr	4/yr	8/yr	12/yr	20/yr
Storage[1]	$99.0	$73.0	$60.1	$55.1	$39.8
HRT[2]	$102.9	$68.1	$51.8	$40.4	$28.1

Costs Include:

1. Storage tanks, coarse screens, diversions, control gates, pumping/flushing/ventilation facilities, 20 yr PV O&M, 20 yr PV MCUA additional treatment cost, consolidation pipes, and land acquisition. The 20-year present value for MCUA treatment was calculated based on a cost of $1,250/MG provided by MCUA and flows summarized in Table 6-17.
2. Climber Screens, DensaDeg ballasted floc, chlor/dechlor, 20 yr PV O&M, consolidation pipes, and land acquisition. There is no cost for additional flow to be treated at MCUA CTP for this alternative.



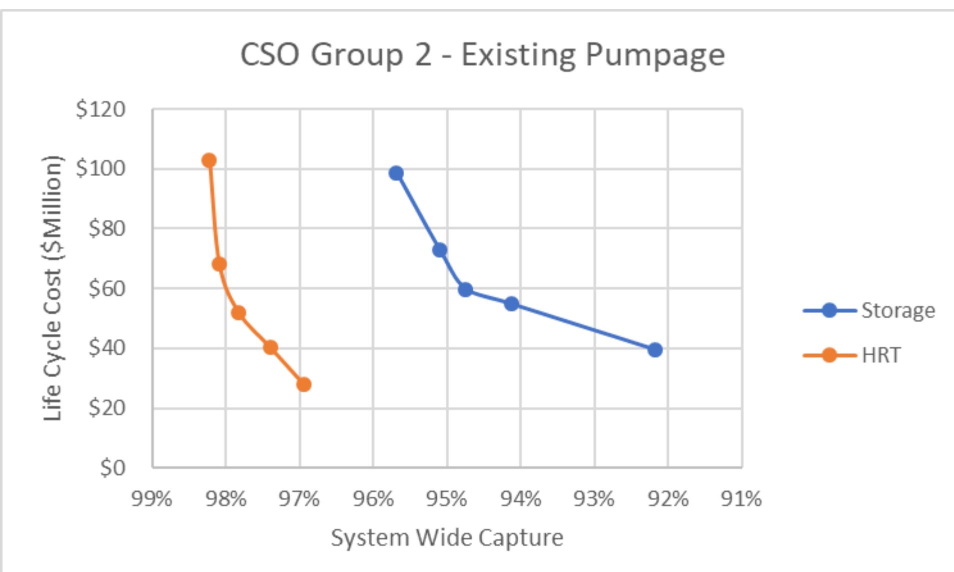


Figure 6-6 – Mixed Technology Existing Pumpage - CSO Group 2 - Cost Curves

6.4.1.6 Summary of Mixed Technology Existing Pumpage and Estimated Cost

Table 6-20 summarized the sizes of the facilities needed to achieve different level of controls at different outfall groups and the progression of CSO reduction and system wide capture increase as more overflows gets stored or treated.

Table 6-20 - Summary of Mixed Technology – Existing Pumpage

IS	Component	Target Level of control	Peak flow to MCUA (mgd)	Storage			Treatment	Remaining Annual CSO (MG)		System Wide Capture (%)	
				Tank Vol (MG)	Additional Vol/yr to MCUA (MG)	Cumulative vol/yr to MCUA (MG)	HRT facility size (mgd)				
1	Second St PS	NA	13	NA	NA	NA	NA	386.4		57%	
2	Storage at CSO Group 3	0/yr	13	17.9	173.9	173.9	374	212.4		76%	
3	Storage at CSO Group 4 and 5	0/yr	13	1.1 and 7.7	70.9	244.8	36 and 135.1	141.5		84%	
4	Storage at CSO Group 1	20/yr	13	1.0	27.8	272.6	18.7	113.7[S]	90.8[T]	87%[S]	90%[T]
5	Storage at CSO Group 2	20/yr	13	1.4	46.7	319.3	23.7	67.0[S]	24.0[T]	92%[S]	97%[T]

IS = Implementation Schedule

S: If storage is used to control CSO.

T: If treatment is used to control CSO.

Table 6-21 – Mixed Technology Baseline Storage Costs

Implementation sequence	Items		Cost ($Million)
1	New PS		$13.9
2	New FM		$20.8
3	CSO9-16	Storage	$164.5
		Consolidation pipe	$11.0
		Additional Cost for Treatment at MCUA[1]	$3.3
		Land acquisition	$12.8
		Sub Total	$191.6
4	CSO17	Storage	$24.5
		Additional Cost for Treatment at MCUA	$0.2
		Land acquisition	$0.8
		Sub Total	$25.4
5	CSO19	Storage	$79.5
		Additional cost for Treatment at MCUA	$1.2
		Land acquisition	$5.5
		Sub Total	$86.2
6	CSO2	Storage	$24.2
		Additional Cost for Treatment at MCUA	$0.5
		Land acquisition	$0.7
		Sub Total	$25.4
7	CSO3-8	Storage	$27.1
		Consolidation pipe	$10.8
		Additional Cost for Treatment at MCUA	$0.9
		Land acquisition	$1.0
		Sub Total	$39.8
	Total		$403.1

1. "Additional Cost for Treatment at MCUA" is the 20-year present value for MCUA treatment that was calculated based on a cost of $1,250/MG provided by MCUA and flows summarized in Table 6-20.

Table 6-22 – Mixed Technology Baseline – HRT Costs

Implementation sequence	Items		Cost
1	New PS		$13.9
2	New FM		$20.8
3	CSO9-16	HRT	$112.3

Implementation sequence	Items		Cost
		Consolidation pipe	$23.8
		New ocean outfall	$187.5
		Land acquisition	$15.8
		Sub Total	$339.3
4	CSO17	HRT	$20.7
		Land acquisition	$3.5
		Sub Total	$24.2
5	CSO19	HRT	$54.2
		Land acquisition	$7.1
		Sub Total	$61.3
6	CSO2	HRT	$14.6
		Land acquisition	$2.9
		Sub Total	$17.5
7	CSO3-8	HRT	$16.4
		Consolidation pipe	$8.6
		Land acquisition	$3.1
		Sub Total	$28.1
	Total		$505.1

Note: It is assumed that there is no additional flow for treatment at MCUA for this option.

Table 6-23 – Mixed Technology Baseline - Summary of Costs

IS	Components	Storage			Treatment		
		Cost	Cumulative Cost ($mil)	System Wide Capture (%)	Cost ($mil)	Cumulative Cost ($mil)	System Wide Capture (%)
1	Main PS & FM	$34.7	$34.7	57%	$34.7	$34.7	57%
2	CSO Group 3	$191.6	$226.3	76%	$339.3	$374.0	76%
3	CSO Group 4 and 5	$111.6	$337.9	84%	$85.5	$459.5	84%
4	CSO Group 1	$25.4	$363.3	87%	$17.5	$477.0	90%
5	CSO Group 2	$39.8	$403.1	92%	$28.1	$505.1	97%

IS = Implementation Schedule

Table 6-21 to Table 6-23 detailed the cost for Mixed Technology Baseline. For simplicity, Table 6-23 assumes that either storage or treatment is used at all CSO groups. In fact, depending on land availability and cost effectiveness, each CSO group may use either storage or treatment which will result in a mix of the two technologies.

Overall to control CSO group 3, storage is much cheaper than treatment primarily due to the new ocean outfall needed for the consolidated treatment for CSO group 3. For the rest of CSO Groups, treatment is cheaper than storage. In the case of CSO Group 1 and 2, treatment also leads to higher system wide capture when same overflow frequency is targeted.

6.4.2 Mixed Technology Alternative A - Impact of Increased Conveyance at Second Street Pumping Station

This alternative entails increased pumping capacity at the Second Street Pumping Station from 13 to 42 mgd (Pumping Scenario 2) and other satellite treatment or storage. The details are broken down by CSO groups below.

6.4.2.1 Second Street Pumping Station

Without any flow limitations at the new pumping station, the two interceptors can deliver 42 mgd flow to the pumping station without any other changes in the Perth Amboy's combine sewer system. This additional 29 mgd can be conveyed to MCUA but only through a new force main routed directly to MCUA because the existing Woodbridge system is at capacity. This results in an extra 55 MG being conveyed to MCUA under the typical year. This increased conveyance reduced the CSO by about 50 MG for the typical year and increased the system wide capture by 6% to 63%. The CSO reduction and system wide capture before any controls are implemented at each CSO group are listed in Table 6-24. This increased conveyance at the pumping station mostly benefited CSO Group 3 along the beach area.

Table 6-24 - Mixed Technology - Alternative A - Summary Statistics

Description	Existing Pumpage	Alt A
Second St PS, mgd	13	42
CSO group 1 overflow, MG	63.2	63.2
CSO group 2 overflow, MG	78.3	78.3
CSO group 3 overflow, MG	173.9	119.8
CSO group 4 overflow, MG	8.6	8.5
CSO group 5 overflow, MG	62.3	62.4
Total Annual overflow, MG	386.4	332.3
System wide capture	57%	63%

6.4.2.2 CSO Group 3 (P009 – 016)

This group of outfalls locate along the beach area and downstream of Front Street Pumping Station. Two options were evaluated to achieve 0 overflow per year.

The first option is detailed below using storage.

- New CSO storage facility with 12.7 MG capacity between P014 and P015
- Remaining overflows from P009-014 is diverted through a consolidation pipe and westwards to the new storage facility
- Remaining overflows from P015 and 016 are also diverted to the same storage facility

- The stored CSO can either be gravity drained or pumped back into the Second St PS once the flow in the system recedes back to dry weather flow
- 119.8 MG more flow will be send to MCUA for treatment.

Due to the increase conveyance anticipated under this alternative at the Second St PS, the storage tank size is 5.2 MG smaller than that in the Mixed Technology Existing Pumpage alternative. Storage using a deep tunnel along the beach area is another option with this alternative and will be evaluated during the next phase of LTCP preparation.

The second option is to have a consolidated CSO treatment facility for these overflows. The details are listed below.

- New CSO treatment facility with 352 mgd capacity at any potential site between P010 and P008
- Remaining overflows from P009 is conveyed through a consolidation pipe to the new treatment facility
- Remaining overflows from P010 and 016 are diverted eastwards through consolidation pipes to the same treatment facility
- A new outfall pipe to bring treated flow eastwards and discharge towards the Arthur Kill.

The siting for this treatment facility can be evaluated during the LTCP phase. System wide capture with either storage or treatment is 76% with 212.4 MG annual CSO remaining. Storage would be preferred over CSO treatment for that storage doesn't lead to any discharge of treated flows into the receiving waters in the vicinity of the beach.

6.4.2.3 CSO Group 4 (P017) and 5 (P019)

P017 and P019 both discharge to the Raritan River thus are targeted for full containment in the typical year, i.e. 0 overflow per year. Either satellite storage or treatment can be used to achieve the control target.

Since CSO Group 4 and 5 are not impacted by the increased conveyance at the Second Street Pumping Station, the facility sizing and the impact on system wide CSO and percent capture are identical to the Mixed Technology Existing Pumpage. See details in the summary table at the end of Mixed Technology Alternative A.

6.4.2.4 CSO Group 1 (P002)

For this alternative, the mixed technologies employed at this location are the same as the Mixed Technology Existing Pumpage since the increased conveyance at Second Street Pumping Station does not affect P002. For details, please refer to CSO Group 1 under the Mixed Technology Existing Pumpage Alternative(Section 6.4.1).

6.4.2.5 CSO Group 2 (P003 – 008)

The last CSO group considered is CSO Group 2 which include seven outfalls from P003 through P008. Since the increased conveyance at Second Street Pumping Station did not have any impact on this CSO Group, the facility sizes for storage or treatment remained the same as the Mixed Technology Baseline Alternative. The resulted system wide remaining CSO and percent capture were also unchanged. For details, please refer to CSO Group 2 under the Mixed Technology Existing Pumpage Alternative (Section 6.4.1).

6.4.2.6 Summary of Alternative A and Estimated Cost

Table 6-25 summarizes the different components of Mixed Technology Alternative A. Table 6-26 and Table 6-27 detail the costs of each component. Table 6-28 compares the costs from two simplified scenarios, i.e. either storage or treatment is used at all CSO groups.

Table 6-25 - Summary of Mixed Technology Alternative A

IS	Components	Level of control	Peak flow to MCUA (mgd)	Storage			Treatment	Result			
				Storage tank volume (MG)	Incremental vol/yr to MCUA (MG)	Cumulative vol/yr to MCUA (MG)	Facility size (mgd)	Remaining Annual System Wide CSO (MG)		System Wide Capture (%)	
1	Main PS & FM	NA	42	NA	55	55	NA	332.3		63%	
2	CSO Group 3	0/yr	42	12.7	119.8	174.8	352	212.4		76%	
3	CSO Group 4 and 5	0/yr	42	1.1 and 7.7	70.9	245.7	35.8 and 135.2	141.5		84%	
4	CSO Group 1	20/yr	42	1	27.8	273.5	18.7	113.7^{S}	90.8^{T}	87%^{S}	90%^{T}
5	CSO Group 2	20/yr	42	1.4	47.6	321.1	23.7	66.1^{S}	23.7^{T}	92%^{S}	97%^{T}

Note: IS = Implementation Schedule
S: If storage is used to control CSO.
T: If treatment is used to control CSO.

Table 6-26 – Mixed Technology Alternative A Storage Costs

Items		Cost ($ mil)
New PS		$39.6
New FM		$55.2
CSO9-16	Storage	$121.4
	Consolidation pipe	$11.0
	Additional Cost for Treatment at MCUA[1]	$2.3
	Land acquisition	$9.1
	sub total	$143.8
CSO17	Storage	$24.5
	Additional Cost for Treatment at MCUA	$0.2
	Land acquisition	$0.8
	sub total	$25.4
CSO19	Storage	$79.5
	Additional Cost for Treatment at MCUA	$0.9

Items		Cost ($ mil)
	Land acquisition	$5.5
	sub total	$86.2
CSO2	Storage	$24.2
	Additional Cost for Treatment at MCUA	$0.5
	Land acquisition	$0.7
	sub total	$25.4
CSO3-8	Storage	$27.4
	Consolidation pipe	$10.8
	Additional Cost for Treatment at MCUA	$0.9
	Land acquisition	$1.0
	sub total	$40.0
Total		$415.7

1. "Additional Cost for Treatment at MCUA" is the 20-year present value for MCUA treatment that was calculated based on a cost of $1,250/MG provided by MCUA and flows summarized in Table 6-25.

Table 6-27 - Mixed Technology - Alternative A - HRT Costs

Items		Cost ($ mil)
New PA		$39.6
New FM		$55.2
CSO9-16	HRT	$109.4
	Consolidation pipe	$23.8
	New ocean outfall	$187.5
	Land acquisition	$15.0
	sub total	$335.6
CSO17	HRT	$20.8
	Land acquisition	$3.5
	sub total	$24.3
CSO19	HRT	$54.3
	Land acquisition	$7.1
	sub total	$61.4
CSO2	HRT	$14.8
	Land acquisition	$2.9
	sub total	$17.7
CSO3-8	HRT	$16.5
	Consolidation pipe	$8.6

Items		Cost ($ mil)
	Land acquisition	$3.1
	sub total	$28.2
Total		$562.1

Note: It is assumed that there is no additional flow for treatment at MCUA for this option.

Table 6-28 - Mixed Technology Alternative A Summary of Costs

IS	Components	Storage			Treatment		
		Cost	Cumulative Cost	System Wide Capture (%)	Cost ($mil)	Cumulative Cost ($mil)	System Wide Capture (%)
1	Main PS & FM	$94.8	$94.8	63%	$94.8	$94.8	63%
2	CSO Group 3	$143.8	$238.7	76%	$335.6	$430.5	76%
3	CSO Group 4 and 5	$111.6	$350.3	84%	$85.7	$516.2	84%
4	CSO Group 1	$25.4	$375.7	87%	$17.7	$533.9	90%
5	CSO Group 2	$40.0	$415.7	92%	$28.2	$562.1	97%

IS = Implementation Schedule

Overall, implementing storage for CSO Group 3 is less expensive treatment primarily due to the new ocean outfall anticipated for the consolidated treatment for CSO Group 3. For the rest of CSO Groups, treatment is less expensive than storage. In the case of CSO Group 1 and 2, treatment also leads to higher system wide capture when same overflow frequency is targeted.

6.4.3 Mixed Technology Alternative B - Impact of Additional Capture

Compared to Alternative A, Alternative B further increased combined flow capture by modifying regulators along the beach area (P009 – 16). This increased the peak flow at the new pumping station from 42 to 54 mgd. Since this CSO Group is the largest of the system, other technologies were used in this alternative to reduce the amount of wet weather flow heading to this part of the system, such as sewer separation and pumping station operation modification. Satellite treatment or storage were used to contain the remaining overflows to different levels of controls. The details are broken down by CSO groups below.

6.4.3.1 Second Street Pumping Station and Measures to Reduce Wet Weather Flow Towards the Beach

The regulator modifications along the beach area (P009-016) increased the peak flow conveyed to the Second Street Pumping Station to 54 mgd with the existing interceptors. This additional 41 mgd can be conveyed to MCUA but only through new force mains routed directly to MCUA because the existing Woodbridge system is at capacity. This results in an extra 92 MG being conveyed to MCUA under the typical year.

Other measures were used to reduce the amount of wet weather flow entering this part of the system. On the Eastside Interceptor, Front Street Pumping Station operation was adjusted to only delivering dry weather flow of 3.5 mgd. The effect of this adjustment limits flow to the downstream regulators and forces more flow out of upstream regulators into the Arthur Kill. On the Westside Interceptor, modification of P017 regulator limited the wet weather flow heading towards P016. Moreover, a small area (8 acres) right downstream of Front Street Pumping Station that contributes runoff directly into the Eastside Interceptor along the beach is proposed to be separated to further reduce the wet weather flow in this part of the system.

The details of the above technologies are included in the following subsections based on their locations. The CSO statistics and system-wide capture are listed in Table 6-29. This information does not reflect any satellite storage or treatment implementation at each CSO group. The above described measures resulted in an overall reduction of 38 MG for the typical year and increased the system wide capture by 4% although overflow increased for Group 2 and 4.

Table 6-29 - Alternative B CSO Statistics and System Wide Capture

Description	Baseline	Alt A	Alt B
Second St PS, mgd	13	42	54
CSO group 1 overflow, MG	63.2	63.2	63.2
CSO group 2 overflow, MG	78.3	78.3	93.9
CSO group 3 overflow, MG	173.9	119.8	58.9
CSO group 4 overflow, MG	8.6	8.5	16.1
CSO group 5 overflow, MG	62.3	62.4	62.3
Total Annual overflow, MG	386.4	332.3	294.5
System wide capture	57%	63%	67%

6.4.3.2 CSO Group 3 (P009 – 016)

To reduce the amount of wet weather flow that enters into the Raritan River side of the Eastside Interceptor along the beach area, two measures were used. As indicated above, Front Street Pumping Station was limited to 3.5 mgd discharge. The second measure was to implement fifty percent sewer separation in an eight acre sewershed between P008 and 009 along the water front. This small sewershed contributes wet weather runoff directly into the Eastside Interceptor downstream of Front Street Pumping Station.

In addition, this alternative and CSO group also includes the modification of regulators to increase capture of combined sewer flow. The details of the modification are summarized in Table 6-30. The capture line (orifice) connecting the regulator to the interceptor was enlarged and the weir was raised for all but one regulator. This allowed more flow being conveyed into the interceptor and reaching the Second Street Pumping Station. The weir offset is anticipated to be less than or equal to the radius of the upstream trunk sewer. The model did not show any significant impact of the raised weir on hydraulic grade line in the trunk sewer.

Table 6-30 - Modifications to Regulators in CSO Group 3

CSO	Orifice (ft)		Weir crest offset (ft)		Trunk sewer diameter (ft)
	Before	After	Before	After	
P009	0.7'x0.667'	1'x1'	0.1	0.5	1.5
P010	1.25'x0.458'	1.25'x1'	0.1	1.5	3
P011	1.25'x0.458'	1.25'x1.25'	0.1	1.5	3
P013	1.25'x0.458'	1.25'x1'	0.15	1.5	3
P014	1.25'x0.458'	1.25'x1'	0.1	1	3
P015	1.25'x0.458'	1.25'x1'	0.1	1.5	3
P016	0.833'	3.33'x2.5'	NA	NA	7

With inflow reduction to the beach area and increased capture of the CSO along the beach at the new pumping station, the remaining overflows can be stored or treated as detailed below to achieve 0 overflow per year.

The first option is detailed below using storage.

- New CSO storage facility with 5.8 MG capacity between P014 and P015
- Remaining overflows from P009-014 is diverted through a consolidation pipe and westwards to the new storage facility
- Remaining overflows from P015 and 016 are also diverted to the same storage facility
- The stored CSO can either be gravity drained or pumped back into the Second St PS once the flow in the system recedes back to dry weather flow
- 58.9 MG more flow will be send to MCUA for treatment.

Due to the increase conveyance and inflow reduction to this part of the system, the storage tank size needed is almost 7 MG smaller than that in the Mixed Technology – Alternative A and only 32% of the size needed under the Mixed Technology Existing Pumpage Alternative. Storage using a deep tunnel along the beach area can be another storage option and will be evaluated during the next LTCP phase.

The second option is to have a consolidated CSO treatment facility for these overflows. The details are listed below.

- New CSO treatment facility with 352 mgd capacity at any potential site between P010 and P008
- Remaining overflows from P009 is conveyed through a consolidation pipe to the new treatment facility
- Remaining overflows from P010 and 016 are diverted eastwards through consolidation pipes to the same treatment facility
- A new outfall pipe to bring treated flow eastwards and discharge towards the Arthur Kill.

System wide capture with either storage or treatment can reach 74% with 235.6 MG CSO remaining. However due to the beach, storage would be preferred over CSO treatment for that storage doesn't discharge into the receiving water at all.

6.4.3.3 CSO Group 4 (P017) and 5 (P019)

Regulator modification at P017 (see Table 6-31) throttled the capture of combined flow from heading toward P016. Since P017 is not a large CSO while P016 is one of the largest, throttling capture flow at P017 will increase annual overflow at P017 by 7.6 MG and relieve the surcharge condition in the Westside Interceptor between P017 and P016 as well as reducing the size of the storage or treatment facility for the beach area.

Table 6-31 - Regulator Modifications at P017

CSO	Orifice, ft		Weir crest offset, ft		Trunk sewer diameter, ft
	Before	After	Before	After	
P017	1.5'x1.5'	1'x1'	2.6	2.2	2

P017 and P019 both discharge to the Raritan River thus are targeted for full containment in the typical year, i.e. 0 overflow per year. Either satellite storage or treatment can be used to achieve the control target.

If storage is used, a storage tank would be sited near each of the overflows with 1.5 MG at P017 and 7.7 MG at P019. The total stored volume at these two facilities that need to be sent to MCUA for treatment is 78.5 MG for the typical year.

If CSO treatment is used, a high rate treatment facility will be sited near each overflow with 37.2 mgd at P017 and 134.9 mgd at P019. Chlorination and dichlorination also need to be applied.

With P017 and P019 fully contained during the typical year in addition to CSO group 3, system wide capture increases to 82% with 157.1 MG remaining annual CSO. This is slightly lower than the previous two Mixed Technology alternatives due to the increased overflow at CSO Group 2.

Since these outfalls locate upstream from the beach, storage would be preferred over CSO treatment for that storage doesn't discharge into the receiving water at all and has no potential of impacting water quality around the beach area.

6.4.3.4 CSO Group 1 (P002)

P002 is the biggest CSO that discharges to Arthur Kill. Since the conditions in this area did not change from the Mixed Technology Existing Pumpage alternative, the storage or HRT sizes needed for the different level of controls are the same. However, CSO Group 2 had higher annual overflows in this alternative due to the throttling of wet weather flow at Front Street Pumping Station. Thus, the resulted annual system overflow and percent capture are different from those in the previous Mixed Technology alternatives.

The results for Mixed Technology Alternative B are summarized in Table 6-32 below including the storage tank size needed to achieve the different level of controls, annual stored volume which needs to be sent to MCUA for treatment, the remaining CSO volume at P002, and resulted annual system wide CSO and percent capture.

Table 6-32 - Alternative B CSO Group 1 Storage Summary

Control Target Overflow Frequency	Tank Volume (MG)	Volume Stored (MG)	Remaining CSO at P002 (MG)	System Wide Annual CSO (MG)	System Wide Capture (%)
0/year	7.6	63.2	0.0	93.9	89.3%
4/year	3.5	55.2	8.0	101.9	88.4%
8/year	2.8	50.7	12.5	106.4	87.9%
12/year	1.8	40.8	22.5	116.4	86.8%
20/year	1.0	27.8	35.4	129.3	85.3%

If CSO treatment is used instead of storage, the facility size and the impact on the system are summarized in Table 6-33 below. Since CSO group 3, 4 and 5 are already fully controlled for the typical year at this stage of Mixed Technology Alternative B, the system wide annual CSO is the annual CSO discharge at CSO group 2 plus the remaining CSO at CSO Group 1 after the satellite treatment.

Table 6-33 – Mixed Technology - Alternative B - CSO Group 1 - HRT Summary

Control Target Overflow Frequency	HRT Flow (MGD)	Remaining CSO at P002 (MG)	System Wide Annual CSO (MG)	System Wide Capture (%)
0/year	195.9	0.0	93.9	89.3%
4/year	98.3	1.4	95.3	89.1%
8/year	53.0	4.3	98.2	88.8%
12/year	32.1	7.6	101.5	88.4%
20/year	18.7	12.5	106.4	87.9%

With the overflows discharging to Raritan River fully contained, either CSO storage or treatment at CSO Group1 (P002) will result in higher than 85% system wide capture at 20 overflows per year. The next subsection evaluates the control scenarios for CSO Group 2 with the assumption that CSO Group 1 (P002) is controlled at 20 overflows per year.

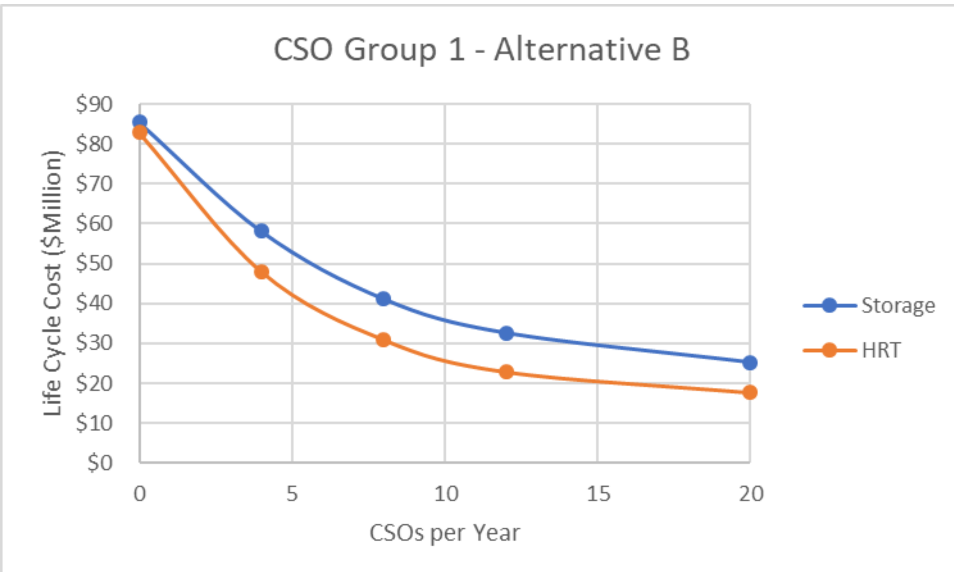
The costs for storage and treatment to achieve the different overflow frequency targets are summarized in Table 6-34. Treatment is consistently cheaper than storage and offers higher system wide percent capture (Figure 6-7).

Table 6-34 - Alternative B CSO Group 1 Storage and HRT Costs

Alternative B - Total Life Cycle Cost for CSO Group 1 ($Million)					
CSOs per Year	0/yr	4/yr	8/yr	12/yr	20/yr
Storage[1]	$85.7	$58.3	$41.4	$32.9	$25.4
HRT[2]	$82.8	$48.0	$30.9	$22.9	$17.7

Costs Include:

1. Storage tanks, coarse screens, diversions, control gates, pumping/flushing/ventilation facilities, 20 yr PV O&M, 20 yr PV MCUA additional treatment cost, and land acquisition. The 20-year present value for MCUA treatment was calculated based on a cost of $1,250/MG provided by MCUA and flows summarized in Table 6-32.
2. Climber Screens, DensaDeg ballasted floc, chlor/dechlor, 20 yr PV O&M, and land acquisition. There is no cost for additional flow to be treated at MCUA CTP for this alternative.



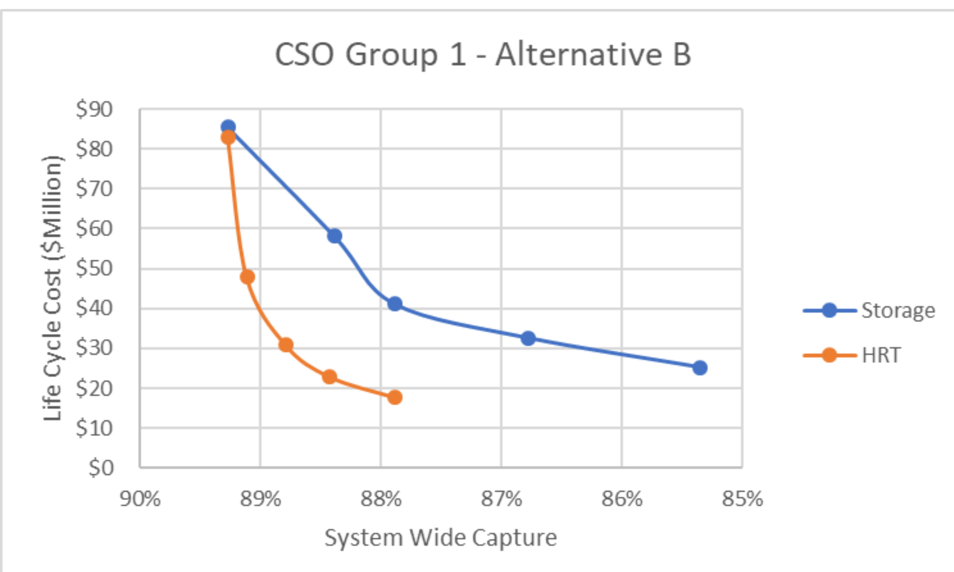


Figure 6-7 – Mixed Technology Alternative B - CSO Group 1 Cost Curves

6.4.3.5 CSO Group 2 (P003 – 008)

Under Mixed Technology Alternative B, the last CSO group considered is CSO Group 2 consisting of 7 outfalls from P003 through P008 that discharge into Arthur Kill. A consolidated storage or treatment facility with consolidation pipes are proposed below to achieve less than 20 overflows per year in this CSO Group.

If using storage, the table below listed the size of the storage tank needed to achieve the different level of controls, the remaining CSO at CSO Group 2 assuming P002 is controlled at 20 overflows per year, and the additional stored volume which needs to be sent to MCUA for treatment. The resulted annual system wide CSO and percent capture were also detailed in Table 6-35.

Table 6-35 - Alternative B CSO Group 2 Storage Summary

Control Target Overflow Frequency	Tank Volume (MG)	Volume Stored (MG)	Remaining CSO at CSO Group 2 (MG)	System Wide Annual CSO* (MG)	System Wide Capture (%)
0/year	8.4	93.9	0.0	35.4	95.7%
4/year	4.3	88.7	5.2	40.6	95.2%
8/year	3.5	83.9	10.0	45.4	94.6%
12/year	3.0	79.2	14.7	50.1	94.1%
20/year	1.7	57.3	36.6	72.0	91.7%

*Assuming P002 is controlled at 20 overflows per year.

If CSO treatment is used instead of storage, the facility size and the impact on the system are summarized in Table 6-36 below.

Table 6-36 - Alternative B - CSO Group 2 - HRT Summary

Control Target Overflow Frequency	HRT needed (MGD)	remaining CSO at CSO Group 2 (MG)	System wide annual CSO* (MG)	System Wide Capture (%)
0/year	209.7	0.0	12.5	98.3%
4/year	112.3	1.2	13.7	98.2%
8/year	75.0	3.1	15.6	97.9%
12/year	46.0	6.4	18.9	97.6%
20/year	30.4	9.8	22.4	97.2%

*Assuming P002 is controlled at 20 overflows per year.

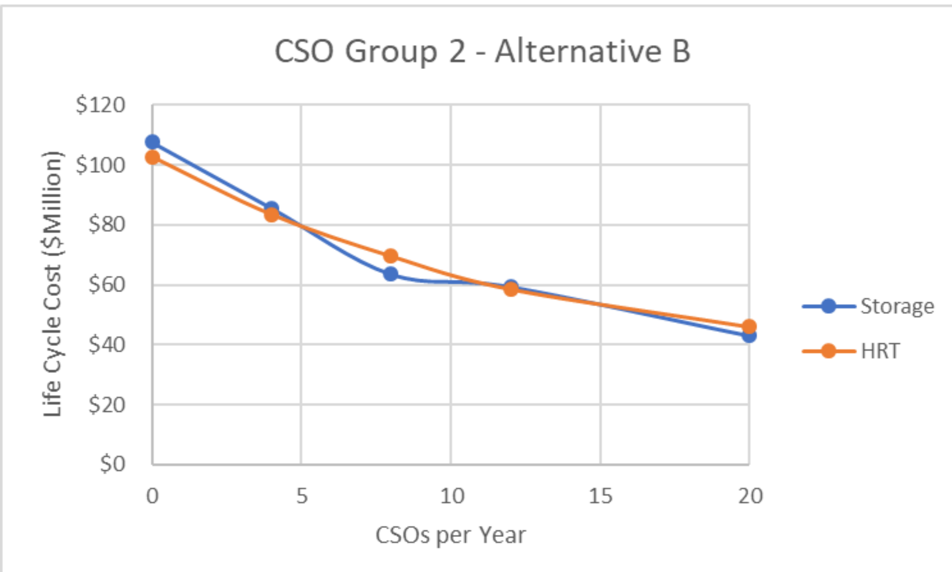
With the overflows discharging to Raritan River fully contained and P002 controlled to 20 overflows per year, either CSO storage or treatment will result in higher than 90% system wide capture with 20 overflows per year level of control for CSO group 2. CSO treatment to 20 overflows per year can result to over 95% system wide capture. The cost and curve (Table 6-37 and Figure 6-8) show that CSO treatment is cheaper than storage and provides higher system wide capture at the same overflow frequency at CSO Group 2.

Table 6-37 - Alternative B CSO Group 2 Storage and HRT Costs

Alternative B - Total Life Cycle Cost for CSO Group 2 ($Million)					
CSOs per Year	0/yr	4/yr	8/yr	12/yr	20/yr
Storage[1]	$108.7	$86.1	$64.0	$59.7	$43.2
HRT[2]	$102.8	$83.5	$69.6	$58.6	$46.0

Costs Include:

1. Storage tanks, coarse screens, diversions, control gates, pumping/flushing/ventilation facilities, 20 yr PV O&M, 20 yr PV MCUA additional treatment cost, consolidation pipes, and land acquisition. The 20-year present value for MCUA treatment was calculated based on a cost of $1,250/MG provided by MCUA and flows summarized in Table 6-35.
2. Climber Screens, DensaDeg ballasted floc, chlor/dechlor, 20 yr PV O&M, and land acquisition. There is no cost for additional flow to be treated at MCUA CTP for this alternative.



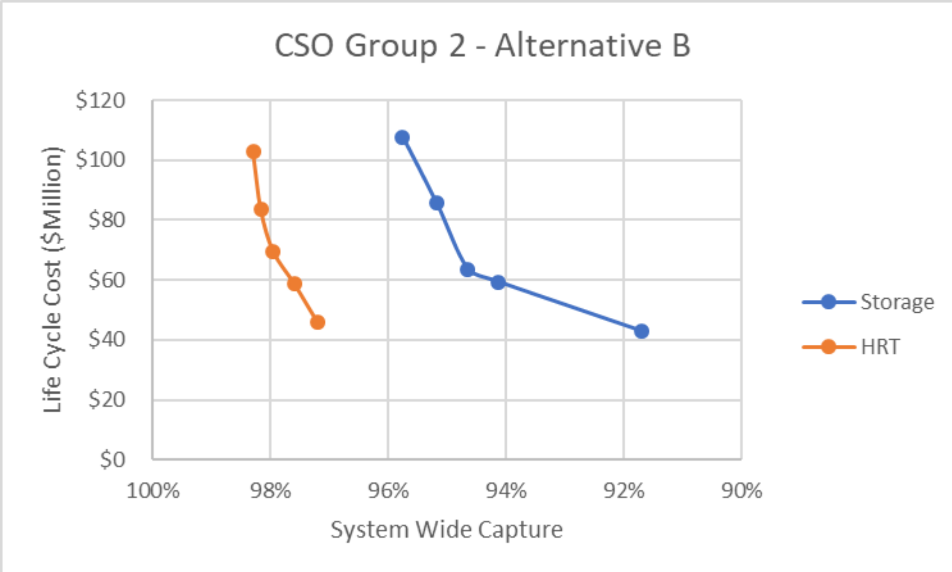


Figure 6-8 – Mixed Technology Alternative B - CSO Group 2 Cost Curves

6.4.3.6 Summary of Alternative B and Estimated Cost

Table 6-38 summarizes the different components of Mixed Technology Alternative B. Table 6-39 and Table 6-40 detail the costs of each component. Table 6-41 compares the costs from two simplified scenarios, i.e. either storage or treatment is used at all CSO groups.

Table 6-38 - Summary of Mixed Technology - Alternative B

IS	Components	Level of control	Peak flow to MCUA (mgd)	Storage			Treatment	Result			
				Storage tank volume (MG)	Incremental vol/yr to MCUA (MG)	Cumulative vol/yr to MCUA (MG)	Facility size (mgd)	Remaining Annual System Wide CSO (MG)		System Wide Capture (%)	
1	Main PS & FM	NA	54	NA	92	92	NA	294.5		67%	
2	CSO Group 3	0/yr	54	5.8	58.9	150.9	345	235.6		74%	
3	CSO Group 4 and 5	0/yr	54	1.5 and 7.7	78.5	229.4	37.2 and 134.9	157.1		82%	
4	CSO Group 1	20/yr	54	1.0	27.8	257.2	18.7	129.3[S]	106.4[T]	85%[S]	88%[T]
5	CSO Group 2	20/yr	54	1.7	57.3	314.5	30.4	72.0[S]	22.4[T]	92%[S]	97%[T]

Note: IS = Implementation Schedule
S: If storage is used to control CSO.
T: If treatment is used to control CSO.

Table 6-39 - Alternative B - Storage Costs

Items		Cost ($ mil)
New PA		$49.6
New FM		$72.5
9 Regulator Modification		$0.5
Sewer separation		$4.0
Front St PS modification		$0.1
CSO9-16	Storage	$63.8
	Consolidation pipe	$11.0
	Additional Cost for Treatment at MCUA	$1.1
	Land acquisition	$4.1
	sub total	$80.1
CSO17	Storage	$27.9
	Additional Cost for Treatment at MCUA	$0.3
	Land acquisition	$1.1
	sub total	$29.3
CSO19	Storage	$79.5
	Additional Cost for Treatment at MCUA	$1.2
	Land acquisition	$5.5
	sub total	$86.2
CSO2	Storage	$24.2
	Additional Cost for Treatment at MCUA	$0.5

Items		Cost ($ mil)
	Land acquisition	$0.7
	sub total	$25.4
CSO3-8	Storage	$29.5
	Consolidation pipe	$11.4
	Additional Cost for Treatment at MCUA	$1.1
	Land acquisition	$1.2
	sub total	$43.2
Total		$390.9

1. "Additional Cost for Treatment at MCUA" is the 20-year present value for MCUA treatment that was calculated based on a cost of $1,250/MG provided by MCUA and flows summarized in Table 6-38.

Table 6-40 - Alternative B - HRT Costs

Items		Cost ($mil)
New PA		$49.6
New FM		$72.5
9 Regulator Modification		$0.5
Sewer separation		$4.0
Front St PS modification		$0.1
CSO9-16	HRT	$108.4
	Consolidation pipe	$23.8
	New ocean outfall	$187.5
	Land acquisition	$14.7
	sub total	$334.3
CSO17	HRT	$21.3
	Land acquisition	$3.5
	sub total	$24.8
CSO19	HRT	$54.2
	Land acquisition	$7.1
	sub total	$61.3
CSO2	HRT	$14.8
	Land acquisition	$2.9
	sub total	$17.7
CSO3-8	HRT	$34.1
	Consolidation pipe	$8.6
	Land acquisition	$3.3
	sub total	$46.0
Total		$610.8

Note: It is assumed that there is no additional flow for treatment at MCUA for this option.

Table 6-41 – Mixed Technology - Alternative B - Summary of Costs

Implementation Sequence	Components	Storage		Treatment		Cumulative Cost ($mil)	Systemwide capture (%)
		Cost ($mil)	Cumulative Cost ($mil)	System Wide Capture	Cost ($mil)		
1	Main PS & FM	$122.0	$122.0		$122.0	$122.0	
2	9 Regulator Modification	$0.5	$122.5		$0.5	$122.5	
3	Sewer separation	$4.0	$126.5		$4.0	$126.5	
4	Front St PS modification	$0.1	$126.6		$0.1	$126.6	
	Total	$126.6	$126.6	67%	$126.6	$126.6	67%
5	CSO Group 3	$80.1	$206.7	74%	$334.3	$460.9	74%
6	CSO Group 4 and 5	$115.5	$322.2	82%	$86.2	$547.1	82%
7	CSO Group 1	$25.4	$347.6	85%	$17.7	$564.7	88%
8	CSO Group 2	$43.2	$390.9	92%	$46.0	$610.8	97%

To control CSO Group 3, storage is much less costly than treatment primarily due to the incorporation of a new ocean outfall needed for the consolidated treatment for CSO Group 3. This aspect of treatment was included to provide anticipated protection of the sensitive beach area. For the rest of CSO Groups, treatment is generally cheaper than storage. In the case of CSO Group 1 and 2, treatment also leads to higher system wide capture when same overflow frequency is targeted.

6.4.4 Mixed Technology Alternative C - Summary and Estimated Cost

This alternative is based on Alternative B with 10% green infrastructure applied to the entire City. The assumption for GI is that green technology is installed to control runoff coming from 10% of the pervious area. Although this reduced the amount of overflows at each outfall (as shown in Table 6-42), it did not change the peak flow at Second Street Pumping Station from Alternative B. Since the overflows were less than Alternative B at all CSOs, the storage or treatment needed to treat them were also similarly reduced. See the summary in Table 6-43 for details.

Table 6-42 – Mixed Technology - Alternative C - CSO Statistics and System Wide Capture

Description	Mixed Tech Existing Pumpage	Alt A	Alt B	Alt C
Second St PS, mgd	13	42	54	54

Description	Mixed Tech Existing Pumpage	Alt A	Alt B	Alt C
CSO group 1 overflow, MG	63.2	63.2	63.2	53.3
CSO group 2 overflow, MG	78.3	78.3	93.9	83.2
CSO group 3 overflow, MG	173.9	119.8	58.9	48.0
CSO group 4 overflow, MG	8.6	8.5	16.1	12.5
CSO group 5 overflow, MG	62.3	62.4	62.3	54.5
Total Annual overflow, MG	386.4	332.3	294.5	251.5
System wide capture	57%	63%	67%	72%

Table 6-43 - Alternative C - Storage and Treatment Summary Results

IS	Components	Level of Control	Peak flow to MCUA (mgd)	Storage			Treatment	Result			
				Storage tank volume (MG)	Incremental vol/yr to MCUA (MG)	Cumulative vol/yr to MCUA (MG)	Facility size (mgd)	Remaining Annual System Wide CSO (MG)		System Wide Capture (%)	
1	Main PS & FM	NA	54	NA	76	76	NA	251.5		72%	
2	CSO Group 3	0/yr	54	5	48	124	294	203.5		77%	
3	CSO Group 4 and 5	0/yr	54	1.2 and 6.9	67	191	37.2 and 124.6	136.5		85%	
4	CSO Group 1	20/yr	54	0.9	23	214	16.4	113.5 S	93.9 T	87% S	89% T
5	CSO Group 2	20/yr	54	1.5	51.2	265.2	27.1	62.3 S	18.7 T	93% S	98% T

Note: IS = Implementation Schedule
S: If storage is used to control CSO.
T: If treatment is used to control CSO.

The itemized cost for storage or treatment are presented in Table 6-44 and Table 6-45. Table 6-46 compares the costs from two simplified scenarios, i.e. either storage or treatment is used at all CSO groups.

As indicated above, to control CSO Group 3, storage is much less costly than treatment primarily due to the incorporation of a new ocean outfall needed for the consolidated treatment for CSO Group 3. This aspect of treatment was included to provide anticipated protection of the sensitive beach area. For the rest of CSO Groups, treatment is cheaper than storage. In the case of CSO Group 1 and 2, treatment also leads to higher system wide capture when same overflow frequency is targeted.

Table 6-44 – Mixed Technology - Alternative C - Storage Costs

Items	Cost ($mil)
New PA	$49.6
New FM	$72.5

Items		Cost ($mil)
9 Regulator Modification		$0.5
Sewer separation		$4.0
Front St PS modification		$0.1
GI		$24.3
CSO9-16	Storage	$57.1
	Consolidation pipe	$11.0
	Additional Cost for Treatment at MCUA	$0.9
	Land acquisition	$3.6
	sub total	$72.7
CSO17	Storage	$25.4
	Additional Cost for Treatment at MCUA	$0.2
	Land acquisition	$0.9
	sub total	$26.5
CSO19	Storage	$73.0
	Additional Cost for Treatment at MCUA	$1.0
	Land acquisition	$4.9
	sub total	$79.0
CSO2	Storage	$18.1
	Additional Cost for Treatment at MCUA	$0.4
	Land acquisition	$0.6
	sub total	$19.2
CSO3-8	Storage	$28.2
	Consolidation pipe	$10.8
	Additional Cost for Treatment at MCUA	$1.0
	Land acquisition	$1.1
	sub total	$41.1
Total		$389.4

1. "Additional Cost for Treatment at MCUA" is the 20-year present value for MCUA treatment that was calculated based on a cost of $1,250/MG provided by MCUA and flows summarized in Table 6-43.

Table 6-45 - Alternative C - HRT Costs

Items	Cost ($mil)
New PA	$49.6
New FM	$72.5
9 Regulator Modification	$0.5
Sewer separation	$4.0

Items		Cost ($mil)
Front St PS modification		$0.1
GI		$24.3
CSO9-16	HRT	$100.8
	Consolidation pipe	$23.8
	New ocean outfall	$187.5
	Land acquisition	$12.9
	sub total	$324.9
CSO17	HRT	$21.3
	Land acquisition	$3.5
	sub total	$24.8
CSO19	HRT	$50.9
	Land acquisition	$6.7
	sub total	$57.6
CSO2	HRT	$14.0
	Land acquisition	$2.8
	sub total	$16.8
CSO3-8	HRT	$17.8
	Consolidation pipe	$8.6
	Land acquisition	$3.2
	sub total	$29.6
Total		$604.6

Note: Assumed no additional flow for treatment at MCUA for this option.

Table 6-46 - Alternative C Summary of Costs

Implementation Sequence	Components	Storage			Treatment		
		Cost	Cumulative Cost	System Wide Capture (%)	Cost	Cumulative Cost	System Wide Capture
1	Main PS & FM	$122.0	$122.0		$122.0	$122.0	
2	9 Regulator Modification	$0.5	$122.5		$0.5	$122.5	
3	Sewer separation	$4.0	$126.5		$4.0	$126.5	
4	Front St PS modification	$0.1	$126.6		$0.1	$126.6	
5	GI	$24.3	$150.9		$24.3	$150.9	
	Total	$150.9	$150.9	72%	$150.9	$150.9	72%
6	CSO Group 3	$72.7	$223.6	77%	$324.9	$475.8	77%
7	CSO Group 4 and 5	$105.5	$329.1	85%	$82.4	$558.3	85%

Implementation Sequence	Components	Storage			Treatment		
		Cost	Cumulative Cost	System Wide Capture (%)	Cost	Cumulative Cost	System Wide Capture
8	CSO Group 1	$19.2	$348.3	87%	$16.8	$575.0	89%
9	CSO Group 2	$41.1	$389.4	93%	$29.6	$604.6	98%

6.5 MCUA Plant Alternatives

6.5.1 Perth Amboy Maintains Existing Pumpage Rates to CTP

In this alternative, the Perth Amboy's new Second Street Pumping Station and force mains will deliver a maximum pumpage rate of 13.6 MGD to the CTP while satellite storage or treatment are applied to achieve 0/year overflow on the Raritan River and 85% total system capture or 0-20/year overflow on Arthur Kill. This does not include any increased conveyance at the pump station.

If satellite storage is used, it may result in the new pumping station operating at maximum rates for longer durations to the MCUA. At a minimum, this may require on-site storage of excess CSS flows.

- Project capital costs to receive, divert, and store the flows at the CTP are approximately $15 Million.
- O&M costs for this alternative are estimated at $150,000/ year.

6.5.2 Mixed Technology A - Perth Amboy Increased Conveyance to 42 MGD

This alternative entails increased pumping capacity at the Second Street Pumping Station and associated force mains from 13 to 42 MGD to the CTP with other satellite treatment or storage within the Perth Amboy CSS. This increased flow rate may be adequately handled using on-site storage in small storms as defined in Section 4.2.3.4. However, certain big storm events may require these flows to be bypassed for HRT and Disinfection as defined in Section 4.2.3.5. CSS Bypass and HRT is the more costly alternative and is therefore used for this Mixed Technology Alternative.

- Project capital costs to bypass flows for HRT and Disinfection at the CTP are approximately $27.3 Million.
- O&M costs for this alternative are estimated at $621,000/ year.

6.5.3 Mixed Technology B - Perth Amboy Increased Conveyance to 54 MGD

Compared to Alternative A, Alternative B further increased combined flow capture by modifying regulators along the beach area. This increased the peak flow at the new Second Street Pumping Station from 42 to 54 MGD. This increased flow rate may be adequately handled using on-site storage in small storms as defined in Section 4.2.3.4. However, certain big storm events may require these flows to be bypassed for HRT and Disinfection as defined in Section 4.2.3.5. CSS

Bypass and HRT is the more costly alternative and is therefore used for this Mixed Technology Alternative.

- Project capital costs to bypass flows for HRT and Disinfection at the CTP are approximately $39.8 Million.
- O&M costs for this alternative are estimated at $897,000/ year.

6.6 Summary of Alternatives

The range of alternatives evaluated in this section will need to be refined in the LTCP phase with dynamic model simulation and more detailed cost analysis. Tunnel storage and combined sewer flow interaction with the CTP during peak flow periods will be further explored. At this point in the LTCP process the evaluations completed provide a useful understanding of the effectiveness of the alternative controls and the costs to achieve a range of control objectives.

6.6.1 Perth Amboy Alternatives

6.6.1.1 Single Technology Alternatives

Single technology alternatives evaluated the facility sizing and their impact with one type of CSO control technology. The target of control was consistent at all CSO groups. Table 6-47 summarizes the cost of using three different technologies to achieve system wide 0 to 20 overflows per year. Table 6-48 summarizes the resulted system wide percent captures at different overflow frequencies.

Table 6-47 - Summary of Single Technology Alternatives – Perth Amboy Costs

Description	0/yr	4/yr	8/yr	12/yr	20/yr
Tunnel	$407.9	$316.3	n/a	n/a	n/a
Satellite Storage	$487.9	$330.0	$246.0	$210.8	$156.7
Treatment	$608.8	$495.8	$409.9	$357.0	$320.9

Table 6-48 - Summary of Single Technology Alternative - System Wide Capture

Description	0/yr	4/yr	8/yr	12/yr	20/yr
Storage	100%	96%	94%	89%	80%
Treatment	100%	99%	98%	95%	93%

The single technology alternatives suggest the following.

- Satellite storage can provide system wide 85% capture when all overflows are controlled to between 12 and 20 overflows in the typical year;
- Satellite treatment can provide system wide capture well beyond 90% when all overflows are controlled to 20 overflows in the typical year;

- Achieving CSO reduction to 4 overflows in the typical year can result in 96% system wide capture if satellite storage is used and 99% capture if satellite treatment is used;

- The cost can range from $200-600 million dollars to achieve 85% or higher system wide capture.

6.6.1.2 Mixed Technology Alternatives

Mixed technology alternatives in Perth Amboy explored using a combination of increased conveyance and satellite treatment to achieve different levels of control on different receiving waters, i.e. 0 overflow per year on Raritan River and 20 overflow per year on Arthur Kill. Table 6-49 summarizes the cost for the four alternatives evaluated. Table 6-50 lists the resulting system-wide capture rates.

Table 6-49 - Summary of Mixed Technology Alternatives - Cost

Mixed Technology Alternative	Storage & HRT[1]	Storage[2]	HRT[3]
Existing Pumpage	$383.5	$403.1	$505.1
A	$396.2	$415.7	$562.1
B	$385.9	$390.9	$610.8
C	$375.5	$389.4	$604.6

1. Storage is used for CSO Group 3, 4, 5, while treatment is used for CSO Group 1 and 2.
2. Storage is used for all five CSO Groups.
3. Treatment is used for all five CSO Groups.

Table 6-50 - Summary of Mixed Technology Alternatives – System Wide Capture

Description	Storage	HRT
Existing Pumpage	92%	97%
A	92%	97%
B	92%	97%
C	93%	98%

The Mixed Technology Alternatives suggest the following.

- With zero overflows per year in the typical year on the Raritan River and 20 overflows on the Arthur Kill, system wide capture can reach 92% with various alternatives including satellite storage and HRT.

- The costs of different mixed technologies range from $400-600 million in the City of Perth Amboy.

- Storage and combined Storage & HRT alternatives tend to be less costly than the dedicated HRT alternatives.

- The cost for CTP alternatives will need to be incorporated to understand the full impact and is presented in the next subsection.

6.6.2 Combining Perth Amboy and MCUA Alternatives

Of the four scenarios evaluated by MCUA, plant expansion is the most costly and thus is not considered here. The other three scenarios can be combined with the Mixed Technology Alternatives in Perth Amboy.

Table 6-51 suggests that after incorporating MCUA costs, the Mixed Technology Existing Pumpage would offer the most cost effective overall LTCP.

Table 6-51 - Combined Alternatives

Mixed Technology Alternative	Store & Treat[1]	MCUA[2]	Total
Baseline	$383.5	$17.3	$400.8
A	$396.2	$36.8	$433.0
B	$385.9	$53.5	$439.4
C	$375.5	$53.5	$429.0

1. Storage is used for CSO Group 3, 4, 5, while treatment is used for CSO Group 1 and 2.
2. Based on capital and annual O&M costs included in Section 6.5. Includes 20-year present value for O&M calculated using a discount rate of 2.75%.

6.6.3 Triple Bottom Line

The Triple Bottom Line (TBL) approach to decision making refers to a methodology that considers project benefits from social, environmental, and economic perspectives. This LTCP offers an opportunity to implement some of these principles for the mutual benefit of all stakeholders, especially regarding the use of Green Infrastructure. Concurrent with the development of this LTCP, the City has pursued planning and technical support for incorporating green infrastructure in its LTCP and plans to pursue GI to the extent practicable and consistent with the CSO Control Objectives.

6.7 Supplemental CSO Team

<Describe discussion and commentary from Supplemental CSO team here>

Section 7

Development of Final Long Term Control Plan

This report provides the information necessary for the City and MCUA to complete the LTCP process with the Selection and Implementation of Alternatives in the next phase of their CSO program as defined in the NJDPES CSO permits. The description of the selected control program will include planning.

The following topics will be covered during preparation of the Long Term Control Plan for the City of Perth Amboy and MCUA.

- Affordability and Financial Capability Assessments, including evaluation of methods of financing the selected control program.
- Refinement of Control Alternatives:
  - Final selection of the Presumption or Demonstration Approach.
  - Planning level facility descriptions, sizing, cost estimates, implementation program and schedule, anticipated siting requirements and other relevant information.
  - Siting for satellite facilities
  - WQ impact of CSO treatment technology at CSO Group 3, 4, 5
  - Different tunnel configurations including but not limited to tunnel storage along the beach area
  - CTP storage use
  - Siting for potential GI
- Cost and Performance Considerations
- Scheduling and Adaptive Management
- Compliance Monitoring Program plan for the selected control program.

IDENTIFICATION OF SENSITIVE AREAS REPORT

Last revised 3/29/2019

IDENTIFICATION OF SENSITIVE AREAS REPORT
CSO Long Term Control Plan
Submitted on behalf of the participating permittees by the Passaic Valley Sewerage Commission (NJ0021016) to Satisfy Permit Condition Part IV.D.3.b.iv:

Passaic Valley Sewerage Commissioners (NJ0021016)
Bayonne City (NJ0109240)
East Newark Borough (NJ0117846)
Harrison Town (NJ0108871)
Jersey City MUA (NJ0108723)
Kearny Town (NJ0111244)
City of Newark (NJ0108758)
North Bergen MUA (NJ0108898)
City of Paterson (NJ0108880)
Joint Meeting of Essex and Union Counties (NJ0024741)
Middlesex County Utilities Authority (NJ0020141)
North Bergen MUA (Woodcliff) (NJ029084)
Town of Guttenberg (NJ0108715)
North Hudson Sewage Authority (Adams Street) (NJ0026085)
North Hudson Sewage Authority (River Road) (NJ0025321)
Borough of Fort Lee (NJ0034517)
City of Hackensack (NJ0108766)
Ridgefield Park Village (NJ0109118)
City of Elizabeth (NJ0108782)
Perth Amboy City (NJ0156132)
Bergen County Utilities Authority (NJ0020028)

Passaic Valley Sewerage Commission
Essex County
600 Wilson Avenue
Newark, New Jersey

"Protecting Public Health and the Environment"

June 2018
Revised 10/19/2018
Revised 01/31/2019
Revised 03/29/2019

ES-1 Background

The United States Environmental Protection Agency's (USEPA) Combined Sewer Overflow (CSO) Control Policy (Federal Register 59 [April 19, 1994]: 18688-18698) "expects a permittee's long-term CSO control plan to give the highest priority to controlling overflows to sensitive areas" (Section II.C.3). The purpose of this report is to document the State and Federal Agencies that were researched and other means utilized in order to identify the location of potential sensitive areas as they may relate to the development of the CSO Long Term Control Plan (LTCP). This will allow the Permittees to develop a plan that incorporates consideration of these areas as physically possible and economically achievable.

The Permitees included in the Report are in the process of developing a LTCP which follows the framework established by the USEPA. The Passaic Valley Sewerage Commission (PVSC) has prepared this report on behalf of the Permittees of the NJ CSO Group to identify all Sensitive Areas that are impacted by CSOs within the Study Area, which includes the receiving surface waters as well as the adjacent waters.

For the purposes of this report, the Sensitive Areas Study Area (Study Area) includes the combined sewer service areas, including all receiving and adjacent downstream waters that may be potentially affected by CSOs, from the various combined sewer service areas of the NJ CSO Group. Affected waters include the Passaic River, Hackensack River, Newark Bay, Hudson River, Kill Van Kull, Arthur Kill, Raritan River or Raritan Bay as well as their tributaries within the Study Area of this report.

ES-2 Sensitive Areas Summary

A comprehensive review of online databases, direct observations and correspondence with regulatory agencies and local environmental organizations was conducted to identify potential Sensitive Areas within the combined sewer system portion of the collection system and in the associated receiving waters.

Outstanding National Resource Waters (ONRW) are maintained and protected by Tier 3 of the USEPA's Anti-degradation Policy. Only waters of "exceptional ecological significance" qualify as ONRWs, as determined by States and Tribes. No Outstanding National Resource Waters were located within the project boundaries.

The Office of National Marine Sanctuaries (ONMS) is the trustee of all national marine sanctuaries which currently recognizes fourteen (14) national marine sanctuaries, none of which are located within the Study Area.

The US Fish and Wildlife Service, National Oceanic and Atmospheric Administration (NOAA), New Jersey Heritage Program (NJHP), and New Jersey DEP Division of Fish and Wildlife identified several Endangered or Threatened species which potentially could live in the project area. All species listed by United States Fish and Wildlife Service are included in NJDEP's lists. NOAA maps show potential areas that may have endangered or threatened species during parts of the year. However, both NJHP and NJDEP's correspondence indicate there are no critical habitats for these species found in the waters of the Study Area. No species identified on the NOAA maps has been confirmed to live, eat, and breed near a CSO in the study area. The endangered Atlantic and Shortnose sturgeon populations cited in the study area have been recovering since the 1970s, suggesting the current protections for water quality are sufficient – even near a heavily populated area. As such, there have been no sensitive areas determined as a result from waters with threatened and endangered species and their habits.

No primary contact recreation activities were witnessed in any waterbody at any time. Secondary contact recreation activities, including jet skiing, kayaking, and fishing, were observed in the Hudson River, Upper Bay, Passaic River, Newark Bay, Kill Van Kull, Arthur Kill, and Hackensack River. Therefore, Sensitive Areas, as may be indicated by waters with primary contact recreation, have not been identified within the Study Area.

One drinking water intake was identified on the Hackensack River half a mile downstream to a Hackensack City CSO. This drinking water intake was decommissioned decades ago, and the current utility provider of the area has no current interest to reopen the intake due to the tidal nature of the Hackensack River at this location. Therefore, no sensitive areas have been determined from public drinking water intakes or their designated protection areas.

The only commercial shellfish harvesting area operating within the Study Area is the restricted zone in the Raritan Bay and is separated by a few miles from the nearest Study Area CSO. No sensitive areas have been determined as a result of the location of shellfish beds.

SECTION A - PROJECT MANAGEMENT

A.0 SUMMARY OF CHANGES

This Report is for the Identification of Sensitive Areas to be utilized by the NJ CSO Group. This Report describes the methodology that was utilized for the identification of sensitive areas, the analysis that was completed, and the recommended Sensitive Areas to be used in the development of a CSO Long Term Control Plan (LTCP). In future versions, this section will include summaries of changes and when they were incorporated as appropriate. The history of this document and changes made to it are summarized below:

- June 28, 2018: Submitted Sensitive Areas Report in fulfillment of the LTCP Permit requirement.
- Revised October 19, 2018: Modified the Sensitive Areas Report to address comments made by NJDEP in letter dated September 20, 2018. A copy of the September 20, 2018 letter is included as Appendix F of this document. The 06/28/2018 submitted Sensitive Areas Report was 435 pages. This version includes updates that resulted in a page total of 435 pages plus the 10-page NJDEP comment letter and divider page for a total of 446 report pages plus the cover. The page numbers of the body of the report have been revised. Page number updates are not reflected with redline-strikeout in this document. The following pages in this document have been changed to address NJDEP comments, with changes shown in redline-strikeout throughout the document:

    a. DEP Comment 1 - No modifications required.
    b. DEP Comment 2 - No modifications required.
    c. DEP Comment 3 - Page 47 Modified.
    d. DEP Comment 4 - No modifications required.
    e. DEP Comment 5 - No modifications required.

- Revised January 31, 2019: The 10/19/2018 submitted Sensitive Areas Report was 447 pages. This version includes updates that resulted in a page total of 438 pages plus the cover.

    a. Page 47 modified.
    b. Appendix A modified – two blank pages removed.
    c. Appendix B modified – one blank page removed.
    d. Appendix C modified – two blank pages removed.
    e. Appendix D modified – one blank page removed.
    f. Appendix E modified – two blank pages removed.

- Revised March 29, 2019: Modified the PVSC LTCP Identification of Sensitive Areas Report to address comments made by NJDEP in letter dated March 1, 2019. A copy of the March 1, 2019 letter is included in Appendix G of this document. The 1/31/2019 submitted Sensitive Areas Report was 439 pages. This version includes updates that resulted in a page total of 453 pages including the report, appendices and cover page.

Table of Contents and page number updates are not reflected with redline-strikeout in this document. The following pages in this document have been changed to address NJDEP comments, with changes shown in redline-strikeout throughout the document:

a. Comment 1 - Pages 49 through 54 Modified.
b. Comment 2 - Pages 54 through 58 Modified.
c. Comment 3 - Pages 54 through 58 Modified.

In future versions, this section will be further updated to include summaries of changes and when they were incorporated as appropriate.

Passaic Valley Sewerage Commission
Identification of Sensitive Areas Report

A.1 TITLE OF PLAN AND APPROVAL

Title: Identification of Sensitive Areas Report

Preparer:

Identification of Sensitive Areas Project Officer: Michael J. Hope, P.E., Greeley and Hansen LLC — Date: 6/20/18

Identification of Sensitive Areas QA Officer: Timothy J. Dupuis, P.E., CDM Smith — Date: 6/20/18

PVSC LTCP Consultants

LTCP Consultant Project Officer: Michael J. Hope, P.E., Greeley and Hansen LLC — Date: 6/20/18

LTCP Consultant QA Officer: Timothy J. Dupuis, P.E., CDM Smith — Date: 6/20/18

Passaic Valley Sewerage Commission

PVSC Program Manager: Bridget McKenna, Chief Operating Officer, PVSC — Date: 06/20/2018

PVSC QA Officer: Marques Eley, PVSC — Date: 6/20/2018

New Jersey Department of Environmental Protection

DEP Permits: ____

Joseph Mannick, CSO Coordinator | Date

DEP BEARS: ____

Biswarup Guha, Bureau of Environmental Analysis Restoration and Standards (BEARS) | Date

Identification of Sensitive Areas for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0021016 (Passaic Valley Sewage Commission)

Approval of Report:

Permittee: ______________________________ 06/20/2018
Bridget McKenna — Date
Chief Operating Officer, Passaic Valley Sewerage Commission

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________________ 06/20/2018
Bridget McKenna — Date
Chief Operating Officer, Passaic Valley Sewerage Commission

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0109240 (Bayonne City)

Approval of Report:

Permittee: ______________________ 6.19.18

Timothy Boyle — Date
Superintendent, City of Bayonne Department of Public Works

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________ 6.19.18

Timothy Boyle — Date
Superintendent, City of Bayonne Department of Public Works

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0117846 (East Newark)

Approval of Report:

Permittee: 6/25/18

Frank Pestana — Date
Licensed Operator, Borough of East Newark

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: 6/25/18

Frank Pestana — Date
Licensed Operator, Borough of East Newark

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108871 (Harrison)

Approval of Report:

Permittee: ______________________________ 6/22/18
Rocco Russomano — Date
Town Engineer, Town of Harrison

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________________ 6/22/18
Rocco Russomano — Date
Town Engineer, Town of Harrison

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108723 (Jersey City MUA)

Approval of Report:

Permittee: [signature] 6/13/18

Rich Haytas — Date
Senior Engineer, Jersey City MUA

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: [signature] 6/13/18

Rich Haytas — Date
Senior Engineer, Jersey City MUA

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0111244 (Kearny)

Approval of Report:

Permittee: 6/20/18

Robert J.Smith — Date
Town Administrator, Town of Kearny

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: 6/20/18

Robert J. Smith — Date
Town Administrator, Town of Kearny

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108758 (Newark)

Approval of Report:

Permittee: ______________________________ 6/25/18
Ras J Baraka — Date
Mayor, City of Newark

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________________ 6/25/18
Ras J Baraka — Date
Mayor, City of Newark

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108898 (North Bergen MUA)

Approval of Report:

Permittee: _________________________ 6/25/18

Frank Pestana — Date
Exec. Director, North Bergen MUA

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: _________________________ 6/25/18

Frank Pestana — Date
Exec. Director, North Bergen MUA

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108880 (Paterson)

Approval of Report:

Permittee: ______________________________ 6/19/18
Manny Ojeda — Date
Director Public Works, City of Paterson

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________________ 6/19/18
Manny Ojeda — Date
Director Public Works, City of Paterson

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0024741 (Joint Meeting of Essex and Union Counties)

Approval of Report:

Permittee: ______________________ 6/21/18

Samuel McGhee — Date
Executive Director, Joint Meeting of Essex and Union Counties

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________ 6/21/18

Samuel McGhee — Date
Executive Director, Joint Meeting of Essex and Union Counties

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0020141 (Middlesex County UA)

Approval of Report:

Permittee: _____________________ 6/19/18

Joseph Cryan — Date
Executive Director, Middlesex County Utilities Authority

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: _____________________ 6/19/18

Joseph Cryan — Date
Executive Director, Middlesex County Utilities Authority

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0029084 (North Bergen Woodcliff)

Approval of Report:

Permittee: ______________________________ 6/25/18

Frank Pestana — Date
Exec. Director, North Bergen MUA

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________________ 6/25/18

Frank Pestana — Date
Exec. Director, North Bergen MUA

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108715 (Town of Guttenberg)

Approval of Report:

Permittee: 6/25/18

Frank Pestana — Date
Licensed Operator, Town of Guttenberg

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: 6/25/18

Frank Pestana — Date
Licensed Operator, Town of Guttenberg

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0025321 & NJ0026085 (North Hudson Sewerage Authority)

Approval of Report:

Permittee: 6/19/2018

Fredric J. Pocci, P.E. Date
Authority Engineer, North Hudson Sewerage Authority

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: 6/19/2018

Fredric J. Pocci, P.E. Date
Authority Engineer, North Hudson Sewerage Authority

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0034517 (Borough of Fort Lee)

Approval of Report:

Permittee: ______________________ 6-21-18
Alfred R. Restaino — Date
Borough Administrator, Borough of Fort Lee

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________ 6-21-18
Alfred R. Restaino — Date
Borough Administrator, Borough of Fort Lee

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108766 (City of Hackensack)

Approval of Report:

Permittee: Wayne Vriesema, Project Manager, City of Hackensack — Date: 6/20/18

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: Wayne Vriesema, Project Manager, City of Hackensack — Date: 6/20/18

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0109118 (Ridgefield Park Village)

Approval of Report:

Permittee: 6/27/18

Alan O'Grady — Date
Superintendent, Ridgefield Park Village

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: 6/27/18

Alan O'Grady — Date
Superintendent, Ridgefield Park Village

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108782 (City of Elizabeth)

Approval of Report:

Permittee: ______________________ 6/20/2018

Daniel Loomis, P.E. — Date
City Engineer, City of Elizabeth

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________ 6/20/2018

Daniel Loomis, P.E. — Date
City Engineer, City of Elizabeth

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0156132 (Perth Amboy City)

Approval of Report:

Permittee: Luis C. Perezjimenez 6/19/18

Luis Perez-Jimenez
Director of Water Operations, Perth Amboy City

Date

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: Luis C. Perezjimenez 6/19/18

Luis Perez-Jimenez
Director of Water Operations, Perth Amboy City

Date

Identification of Sensitive Areas Report for the NJ CSO Group

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0020028 (Bergen County Utilities Authority)

Approval of Data Report:

Permittee: ______________________________ 6/25/18
Robert Laux Date
Executive Director, Bergen County Utilities Authority

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who reviewed this report, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________________ 6/25/18
Robert Laux Date
Executive Director, Bergen County Utilities Authority

A.2 DISTRIBUTION LIST

Passaic Valley Sewerage Commission

Bridget McKenna

Marques Eley

Other Entities Participating by Associated Sewage Treatment Plant

Passaic Valley Sewerage Commission (PVSC): Paterson; Newark; Kearny; Harrison; Bayonne MUA; Jersey City MUA; North Bergen MUA

Bergen County Utility Authority (BCUA): Ridgefield Park; Fort Lee; Hackensack

Joint Meeting of Essex and Union Counties: Elizabeth City

North Bergen MUA – Woodcliff Plant: North Bergen Township; Guttenberg; Union City

North Hudson Sewerage Authority (NHSA) – River Road STP: Weehawken; West New York;
Union City

North Hudson Sewerage Authority (NHSA) – Adams Street STP: Hoboken

Middlesex County Utilities Authority (MCUA): Perth Amboy

New Jersey Department of Environmental Protection

Marzooq Alebus, Surface Water Permitting

Nancy Kempel, Surface Water Permitting

Dwayne Kobesky, Surface Water Permitting

Joseph Mannick, Surface Water Permitting

Marc Ferko, Office of Quality Assurance

Biswarup Guha, Water Monitoring and Standards

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City of Elizabeth
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Elizabeth, NJ 07201

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SECTION B - INTRODUCTION

B.1 IDENTIFICATION OF SENSITIVE AREA OBJECTIVES FOR CSO LTCP DEVELOPMENT

The USEPA's CSO Control Policy (Federal Register 59 [April 19, 1994]: 18688-18698) "expects a permittee's long-term CSO control plan to give the highest priority to controlling overflows to sensitive areas" (Section II.C.3). The purpose of this report is to document the State and Federal Agencies that were researched and other means utilized in order to identify the location of potential sensitive areas as they may relate to the development of the CSO LTCP.

For the purposes of this report, the Sensitive Areas Study Area (Study Area) includes the combined sewer service areas, including all receiving and adjacent downstream waters that may be potentially affected by CSOs, from the various combined sewer service areas of the NJ CSO Group. Affected waters include the Passaic River, Hackensack River, Newark Bay, Hudson River, Kill Van Kull, Arthur Kill, Raritan River or Raritan Bay as well as their tributaries on the Study Area of this report is shown in Figure B-1.

B.2 PRINCIPAL DATA USERS

The principal users of the identification of sensitive areas will be the permittees of the NJ CSO Group, hydraulically connected member municipalities of the NJ CSO Group, the LTCP engineering consultants supporting the Permittees of the NJ CSO Group, and other CSO municipalities who elect to utilize the identification of sensitive areas. PVSC is sharing the data generated for the identification of the sensitive areas with the cooperating members of the NJ CSO Group and, therefore, the NJ CSO Group members may use the data to satisfy certain NJPDES permit requirements related to the requirements of their NJPDES Permits. Table B-1 defines the list of primary data users.

Secondary users of the data, such as the New Jersey Department of Environmental Protection (NJDEP), are responsible for evaluating the data using quality criteria appropriate for their use and/or decision making process.

B.3 PROBLEM DEFINITION AND BACKGROUND

The NJ CSO Group was originally formed to work cooperatively to fulfill the requirements of the last CSO General Permit. The group was recently expanded to include more permittees that discharge to the tidally connected waterbodies in the NY/NJ Harbor Estuary. Member utilities provide service to multiple municipalities, and the interrelationships are numerous and varied as shown on Figure B-2.

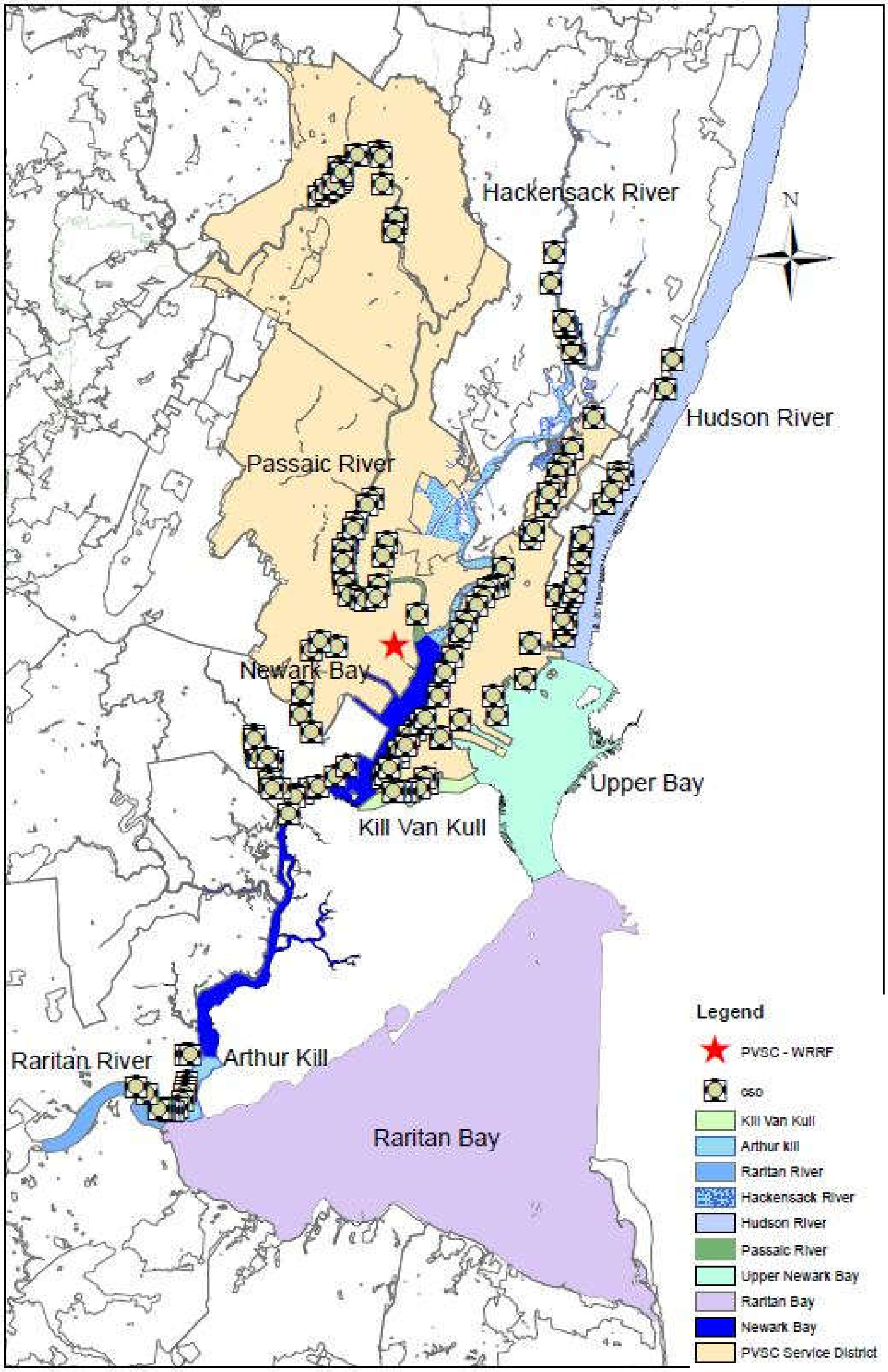

Figure B-1: Study Area Waterbodies

Table B-1: List of Primary Data Users

Central Sewage Treatment Facility	Hydraulically Connected CSO Municipalities and Permittees
Passaic Valley Sewage Commission (PVSC)	Paterson City[1]; Newark City[1]; Kearny Town[1]; Harrison Town[1]; East Newark Borough[1]; Bayonne MUA[1]; Jersey City MUA[1]; North Bergen MUA[1]
Bergen County Utility Authority (BCUA)	Village of Ridgefield Park[1] Fort Lee City[1] Hackensack City[1]
Joint Meeting of Essex and Union Counties[1] (JMEUC)	Elizabeth City[1]
North Bergen Municipal Utility Authority (NBMUA)[1] – Woodcliff Plant	North Bergen MUA[1] Guttenberg Town[1]
North Hudson Sewerage Authority (NHSA)-River Road STP	Weehawken Township[2] West New York Town[2] Union City[2]
North Hudson Sewerage Authority (NHSA) –Adams Street STP	Hoboken City[2] Union City[2]
Middlesex County Utilities Authority (MCUA)	Perth Amboy City[1]

[1] Owns CSO Permitted outfalls discharging to modeled receiving waters. [2]Municipality with CSOs within their limits but not a permit holder

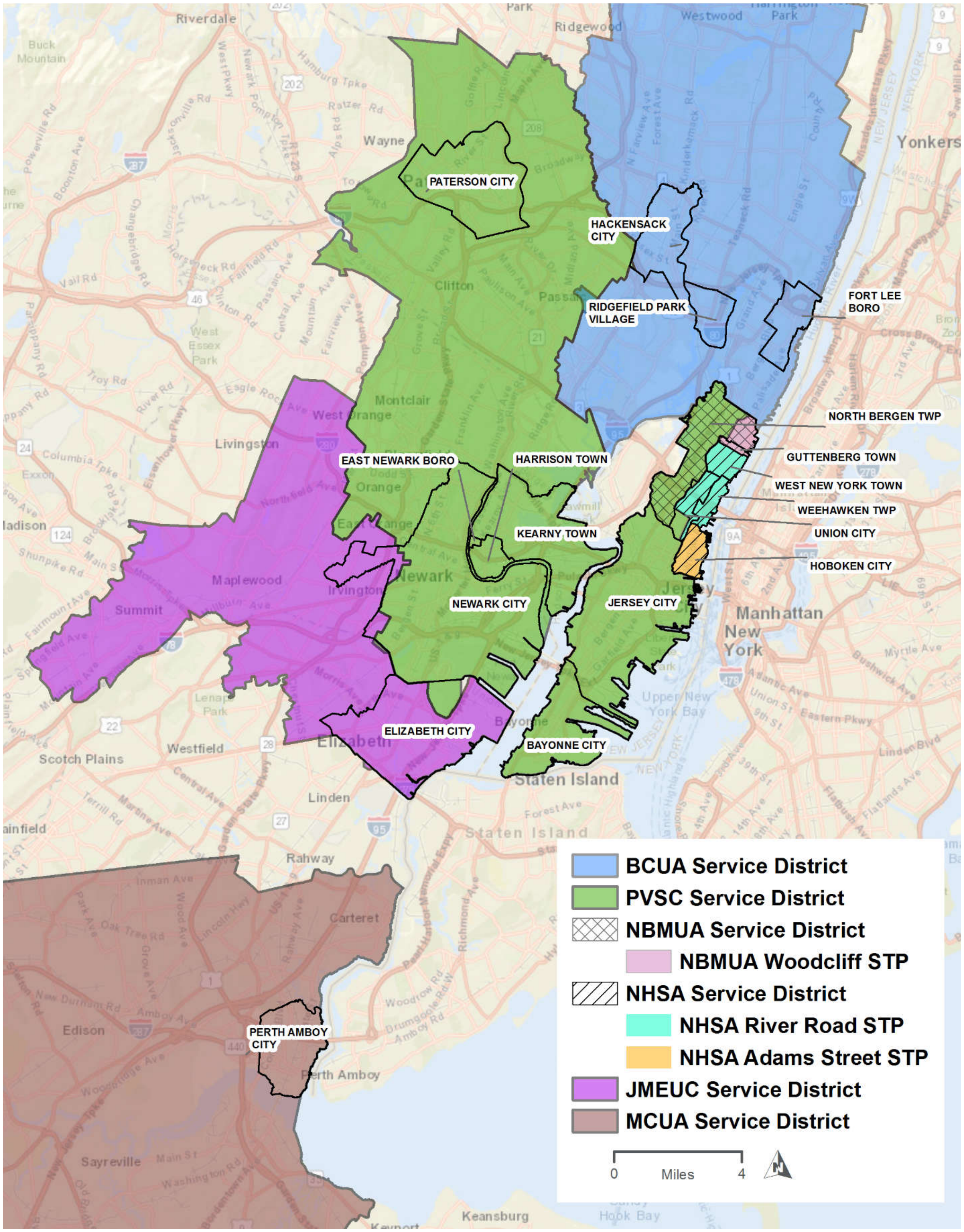

Figure B-2: Participating NJCSO Group Members and Associated Central Sewage Treatment Facilities

GREELEY AND HANSEN
CDM Smith

For example:

- The utilities responsible for providing treatment may not have permitted CSOs, which are the responsibility of the municipalities;
- The municipalities with permitted CSOs may not be able to reduce their discharges without the treatment utility modifying its treatment and/or conveyance system;
- Certain municipalities own and operate their own combined sewer systems, interceptors, CSO control facilities, and pumping stations, while others do not own their collection systems; and
- Combinations of utilities and municipalities may jointly own force mains, pumping stations, and other appurtenances but remain independently permitted by the State of New Jersey.

Because of these complex interrelationships, the NJ CSO Group elected to have PVSC lead the technical work required for CSO permit compliance relative to the identification of the sensitive areas. Participating members may use the results generated by the identification of sensitive areas for assessing CSO impacts and potential mitigation strategies.

SECTION C - IDENTIFICATION OF SENSITIVE AREAS

C.1 REGULATORY REQUIREMENTS

C.1.1 Requirements of the USEPA's CSO Control Policy and Sensitive Areas Definition

The USEPA's CSO Control Policy (Federal Register 59 [April 19, 1994]: 18688-18698) "expects a permittee's long-term CSO control plan to give the highest priority to controlling overflows to sensitive areas" (Section II.C.3).

The CSO Control Policy states the six (6) criteria for defining an area as a "Sensitive Area" include:

1. Designated Outstanding National Resource Waters
2. National Marine Sanctuaries
3. Waters with threatened or endangered species and their habitat
4. Waters with primary contact recreation
5. Public drinking water intakes or their designated protected areas
6. Shellfish beds

The CSO Control Policy states that if Sensitive Areas are present and impacted, the LTCP should include provisions to:

- Prohibit new or significantly increased overflows
- Eliminate or relocate overflows wherever physically possible and economically achievable
- Treat overflows where necessary
- Where elimination or treatment is not achievable, reassess impacts each permit cycle

Sensitive Areas should be considered prior to the evaluation of CSO control alternatives. This allows a CSO community to identify and estimate costs for controls that could eliminate or relocate CSOs from Sensitive Areas where pollutant loadings pose a high environmental or public health risk and where control efforts should be focused. The cost of these controls can then be considered, along with the community's financial capability, to evaluate cost-effective controls for all of the receiving waters.

C.1.2 Requirements of the NJPDES Permits

The NJPDES permits indicate that the permittee's LTCP shall give the highest priority to controlling overflows to sensitive areas. The NJPDES Permit further states that "Sensitive areas include designated Outstanding National Resource Waters, National Marine Sanctuaries, waters with threatened or endangered species and their habitat, waters used for primary contact recreation (including but not limited to bathing beaches), public drinking water intakes or their designated protection areas, and shellfish beds."

The NJPDES Permits indicate that if Sensitive Areas are present and impacted, the following requirements will apply:

- Prohibit new or significantly increased CSOs.

- Eliminate or relocate CSOs that discharge to sensitive areas wherever physically possible and economically achievable, except where elimination or relocation would provide less environmental protection than additional treatment.
- Where elimination or relocation is not physically possible and economically achievable, or would provide less environmental protection than additional treatment, the permittee shall provide the level of treatment for remaining CSOs deemed necessary to meet WQS for full protection of existing and designated uses.

C.2 ASSESSMENT OF SENSITIVE AREAS

The six criteria for Sensitive Areas identified in the CSO policy were evaluated for the waterbodies in the Study Area including reaches upstream of the CSOs. Special consideration was given to areas downstream and within the tidal influence of the CSOs, as any potential Sensitive Areas within hydraulic proximity to outfalls may be impacted by their discharge.

C.2.1 Methodology

In order to develop a comprehensive understanding of the presence of possible Sensitive Areas within the Study Area, multiple strategies were used to complete these investigations including searching online data resources, sending letters to regulatory agencies and environmental organizations, and conducting an observation survey. The goal of this multi-faceted approach was to gain a thorough understanding of the presence of factors that may be considered for the determination of potential Sensitive Areas to support the development of future CSO control alternatives.

Correspondance with Regulatory Agencies

Open Public Record Act Requests were drafted and issued to key regulatory agencies at the federal and state levels, and environmental organizations at the state and local levels. Contacts were identified based on their governance over the waterbodies of concern. Table C-1 lists the agencies which received requests for information. Follow-up telephone calls were made to all agencies that had not responded by April 15, 2017.

Table C-1: Letters Issued to Agencies and Organizations

Agency	Contact	Department	Date Sent	Response
US Department of the Interior	Robert Anderson	Fish and Wildlife	3/20/17	Directed to Nj.gov/dep/fwl/ensp/
New Jersey Department of Environmental Protection (NJDEP)	Elizabeth Semple	Coastal and Land Use Planning	3/20/17	Email Response Received
NJDEP	N/A	Division of Land Use Regulation	3/20/17	No Response

Agency	Contact	Department	Date Sent	Response
NJDEP	Bruce Friedman	Water Monitoring and Standards	3/20/17	Directed to http://www.nj.gov/dep/watersupply/swap/
NJDEP	Michele Putnam	Division of Water Quality	3/20/17	Request too broad
NJDEP	N/A	State Park Service	3/20/17	Request too broad
NJDEP	Dr. Gary Buchanan	Division of Science, Research and Environmental Health	3/20/17	Directed to Nj.gov/dep/gis/landscape
NJDEP	N/A	Division of Water Supply and Geoscience	3/20/17	Directed to www13.state.nj.us/dataminer; www.nj.gov/dep/swapsurfacewatersystems
New Jersey Department of Environmental Protection (NJDEP)	David Chanda	Director Fish and Wildlife	3/20/17	Use Nj.gov/dep/fwl/ensp/

Each letter requested information related to all six Sensitive Area criteria with the exception of the letter to the U.S. Fish and Wildlife Service, which was tailored based on telephone conversations held prior to issuance of the letter. Copies of the letters issued requesting information and the responses are included in Appendix A. Some requests were unable to be processed due to "request too broad". These agencies can only provide information for specific facilities, lots, owners, etc. and are not available for large areas such as the Study Area for this report. The NJDEP Division of Land Use Regulation had no response, based on a written request and telephone calls. These responses are shown in Appendix A.

Online Database Searches

An abundance of information is available online regarding the waterbodies in the Study Area. The following entities and on-line databases were searched for information related to Sensitive Areas within the Study Area boundary:

- National Oceanic and Atmospheric Administration (NOAA)
    - NOAA 2017 Environmental Sensitivity Index Maps
- United States Environmental Protection Agency
    - Anti-degradation Policy - Outstanding Natural Resource Water
- United States Fish and Wildlife Service (USFWS)
- New Jersey Department of Environmental Protection (NJDEP)
- Office of National Marine Sanctuaries

The results of these searches were used to determine the presence of Sensitive Areas located within the Study Area boundaries.

C.2.2 Outstanding National Resource Waters

Outstanding National Resource Waters (ONRW) are maintained and protected by Tier 3 of the USEPA's Anti-degradation Policy which can be accessed through the Agency's website listed in the reference section. Only waters of "exceptional ecological significance" qualify as ONRWs. Only States and Tribes determine whether or not a water body will be classified as such. No such waterbody in or adjacent to New Jersey, and/or the Study Area, is listed.

C.2.3 National Marine Sanctuaries

The goal of the National Marine Sanctuaries Act (Title 16, Chapter 32, Section 1431 last amended in November 2000) is to identify and designate National Marine Sanctuaries (NMS) areas of the marine environment which are of special national significance and to manage these areas as the National Marine Sanctuary System. Receiving this designation results in the conservation and management of these special habitats, support of the natural biological communities through protection and restoration, enhances the public's awareness, understanding and appreciation for the marine sanctuary, and supports the vitality of these communities through research and Federal, State and Local government collaboration.

In order for a marine environment to be designated a National Marine Sanctuary, the United States Secretary of Commerce will determine if any of the following criteria apply:

> *"Criteria 1*
> *The area's natural resources and ecological qualities are of special significance and contribute to: biological productivity or diversity; maintenance or enhancement of ecosystem structure and function; maintenance of ecologically or commercially important species or species assemblages, or both; or maintenance or enhancement of connectivity to other ecologically significant resources.*
>
> *Criteria 2*
> *The area contains submerged maritime heritage resources of special historical, cultural, or archaeological significance, that: individually or collectively are consistent with the criteria of eligibility for listing on the National Register of Historic Places; have met or which would meet the criteria for designation as a National Historic Landmark; or have special or sacred meaning to the indigenous people of the region or nation.*
>
> *Criteria 3*
> *The area supports present and potential economic uses, such as: tourism; commercial and recreational fishing; subsistence and traditional uses; diving; and other recreational uses that depend on conservation and management of the area's resources.*
>
> *Criteria 4*
> *The publically-derived benefits of the area, such as aesthetic value, public recreation, and access to places depend on conservation and management of the area's resources."*

The above criteria for National Marine Sanctuaries was taken directly from the Sanctuary Nomination Process Guide, which can be found on the NMS website listed in the Reference Section.

The Office of National Marine Sanctuaries (ONMS) is the trustee of all national marine sanctuaries and as such, it currently recognizes fourteen (14) national marine sanctuaries, none of which are located within New Jersey or adjacent waters. Therefore, none of the Study Area's receiving or surrounding waters are considered to be a National Marine Sanctuary.

C.2.4 Threatened or Endangerd Species Criterion

The Federal CSO Policy states "waters with threatened or endangered species and their habitat" are considered a Sensitive Area. The US Fish and Wildlife Service (USFWS), NJ Heritage Program (NJHP) and NJDEP Division of Fish and Wildlife (NJDFW) were contacted and response letters were received. In addition, the National Oceanic and Atmospheric Administration (NOAA) Environmental Sensitivity Index maps were obtained online and reviewed to identify any threatened or endangered species with habitats located within the Study Area. The NOAA maps outline the critical habitat areas based on the requirements of each species. When the USFWS proposes an animal or plant for listing as endangered or threatened under the Endangered Species Act (ESA), the specific areas that contain the physical or biological features essential to its conservation are identified. This is the species' "Critical Habitat". The ESA requires the designation of Critical Habitat when it is both "prudent and determinable." It considers physical and biological features that a species needs for life processes and successful reproduction including:

- Space for individual and overall population growth, and for normal behavior;
- Cover or shelter;
- Food, water, air, light, minerals, or other nutritional or physiological requirements;
- Sites for breeding and rearing offspring, germination, or seed dispersal;
- Habitats that are protected from disturbances or are representative of the historical geographical and ecological distributions of the species.

The threatened and endangered species that could potentially be present within the project Study Area waterbodies are listed in Tables C-2, C-3 and C-4. As per the USEPA CSO Control Policy, only endangered and threatened designations are documented in this section; special concern, vulnerable, or any other status are not included. If any habitat of an endangered or threatened species by either federal or state classification is overlapping with a CSO location this area was further evaluated to determine if it should be considered a Sensitive Area.

Federal Level Research

At the federal level, USFWS and NOAA were utilized to analyze the Study Area for federally listed endangered and threatened species. USFWS responded with a letter as shown in Appendix A. The response letter addresses each USFWS designated site individually by showing maps of the area. Areas included are Dundee Canal and Island, Dundee Island Park and Pulaski Park, Essex County Branch Brook Park, Kearny Point, Oak Island Yards, Harrison Marsh Phase 1, Meadowland Marsh, Metro Media Tract and Harrison Marsh Phase 2. Each location returned a response that no endangered species were found in the Study Area for federally-listed threatened and endangered species.

The NOAA Environmental Sensitivity Index Maps for the project area, ESI-19 through ESI-25, were reviewed to locate specific habitat for the listed species. The NOAA maps that show endangered or threatened species in the Study Area are included as Appendix C.

Table C-2: Federally-Listed Threatened and Endangered Species from NOAA

Species	Status	Waterbody	Months Present	NOAA Map
Atlantic Sturgeon	Endangered	Hudson River	Nov-Apr	21A
Short nose Sturgeon	Endangered	Hudson River	Jan-Dec	21A
Loggerhead Sea Turtle	Endangered	Lower Bay	May-Nov	21D
Humpback Whale	Endangered	Lower Bay	Apr-Nov	21D

The federally listed species in Table C-2 may potentially use the Study Area waters as a habitat during the months shown. Only the short nose sturgeon may be present year round. In Appendix C, Figures C-1 through C-7 show where NOAA designated habitats of both federal and state listed species are located relative to the CSO outfalls.

State Level Research

NJDEP's Division of Fish and Wildlife (DFW) does not have a map for a specific location; instead it lists the endangered and threatened species for the state as a whole. Therefore, the New Jersey National Heritage Program (NJNHP) and NOAA were used for New Jersey State level information. These both allow an inquiry to be specific to a project area and the vicinity around it, rather than to the state as a whole. The NJNHP response can be found in Appendix A. The following is a list of the reported state level endangered and threatened species that were evaluated in this report.

Table C-3: State-Listed Threatened and Endangered Species from NJNHP

Species	Status	Location
Bald Eagle	Endangered	Meadowlark Marsh, Metro Media Tract
Black Crowned Night Heron	Threatened	Kearny Point, Oak Island Yards
Cattle Egret	Threatened	Meadowlark Marsh
Northern Diamondback	Endangered	Harrison Marsh Phase 2
Northern Harrier	Endangered	Metro Media Tract, Harrison Marsh Phase 2
Peregrine Falcon	Endangered	Oak Island yards, Meadowlark Marsh, Metro Media Tract, Harrison Marsh Phase 2
Yellow Crowned Night Heron	Endangered	Meadowland Marsh, Metro Media Tract, Harrison Marsh Phase 2

The NJNHP locations listed in Table C-3 are within the greater waterbodies identified in the Study Area. Kearny Point is located in the southern part of Kearny in between the Hackensack and Passaic River. Oak Island Yards is the rail yard in eastern Newark which is adjacent to Newark Bay. Meadowlark Marsh is east of Ridgefield bordering the Hackensack River. Metro Media Tract and Harrison Marsh Phase 2 are both east of Carlstadt bordering the Hackensack River.

NJNHP found no critical habitats within the limits of the Study Area.

Table C-4: State-Listed Threatened and Endangered Species from NOAA

Species	NJ Status	NOAA Maps	Waterbodies
Atlantic Sturgeon	Endangered	20C, 21A, 21B	Hudson River
BC Night Heron	Threatened	20C, 21B, 21D	Hackensack River, Upper Bay
Cattle Egret	Threatened	22B	Newark Bay
Green Sea Turtle	Threatened	21A	Upper Bay
Humpback Whale	Endangered	21D	Lower Bay
K. Ridley Sea Turtle	Endangered	21A	Upper Bay
Least Tern	Endangered	20C, 21D	Hackensack River, Upper Bay
Leatherback Turtle	Endangered	21D	Lower Bay
Loggerhead Sea Turtle	Endangered	21A	Upper Bay
Northern Harrier	Endangered	20C	Hackensack River
Raptor 1	Endangered	20C, 21D, 22A, 22B, 24B	Hudson River, Hackensack River, Upper Bay, Passaic River, Kill Van Kull, Arthur Kill, Raritan River, Elizabeth River
Raptor 2	Endangered	20C	Hackensack River
Shortnose Sturgeon	Endangered	20C, 21A, 21B	Hudson River
YC Night Heron	Threatened	20C, 21D	Hackensack River, Upper Bay, Arthur Kill

The NOAA maps included both federal and state species on the same map and show critical habitat areas. Critical habitat areas differ in size depending on the species. Some species require large areas, with critical habitats shown to be polygonal areas, while others remain within a small radius and have critical habitats denoted as a circular marker.

Each of these agencies list different species depending on their criteria for listing, and the purpose of the inquiry. USFWS identifies any threatened or endangered species in the area. NJNHP requests are typically used for smaller-scale projects, and cannot, therefore, cover the entire study area. The selected sites were used as a measure of the endangered or threatened species in the area. The selected sites also extend an additional ¼ mile outside of the site boundaries to account for additional disturbances. NOAA maps are a quick reference to identify the species most susceptible in the event of an oil spill. To avoid the risk of vandalism and to protect endangered or threatened species, the NOAA maps can include the species' markers in an undisclosed radius from the real habitat areas. This is purposely done to make a species' exact location difficult to find, especially when these maps may not be as current as a detailed request to the USFWS or NJNHP.

Threatened or endangered species and their habitat, have been identified within the Study Area and are shown in Figures C-1 to C-7 in Appendix C. The figures identify 13 locations where threatened or endangered species have critical habitats within the Study Area. Note that figures may overlap in the area covered. Table C-5 below lists the areas where CSO outfalls are located inside the critical habitat of an endangered or threatened species. As such, these areas were evaluated further to determine if CSOs are having an impact on the species and critical habitats for the purposes of determining if any of these areas should be considered a sensitive area.

Table C-5: State-Listed Threatened and Endangered Species from NOAA

Species	NOAA Map - Number	Waterbody	# of CSO in Critical Habitat
Atlantic/Shortnose Sturgeon	499	Hudson River	15
Raptor 1	24B - 290	Raritan River	1
Raptor 1	22B - 129	Elizabeth River	1
Raptor 1	22A - 129	Passaic River	4
Wading Bird - Various	21D - 277	Upper Bay	1
Wading Bird – Various	21D - 295	Newark Bay	1
Wading Bird - Various	21B - 266	Marshes of Hackensack River	1

Six critical habitat areas are identified for various birds including the Raritan River, Elizabeth River, Passaic River, Upper Bay, Newark Bay and the marshes of the Hackensack River. Each of these critical habitat areas have one CSO per area, except the Passaic River location that has four CSO outfalls clustered together near the Raptor 1. Endangered species that are in the Study Area that do not specifically have a habitat in the receiving waters (i.e. birds) near CSO locations will not be considered. The migratory patterns of many species also mean sightings listed in an area are not enough evidence to surmise a habitat. Additionally, a species may not consider an entire area as a temporary cover or shelter during the time spent there. Many species of birds are relevant for this reason; they do not live in the water, migrate to warmer climates during winter to breed, and are not restricted to eating only aquatic life found in the rivers and streams. If a species lives, propagates, and eats in an area, the area can be considered its habitat. Otherwise, it is unclear if the identified area alone is critical for a species' conservation when other areas are providing similar if not additional needs. For this reason, CSOs located in these areas are not being considered to disrupt any of the birds above in their critical habitats and are, therefore, not sensitive areas.

The Atlantic and Shortnose Sturgeon critical habitats extend throughout the Hudson River. Both species are susceptible to environmental contamination due to their benthic foraging behavior and long life span. A total of 15 CSO outfalls discharge to the Hudson River and were further reviewed to determine if there are any impacts on the Sturgeon. A status review of Atlantic Sturgeon by NOAA concluded that commercial bycatch and decades of prior environmental degradation are the biggest threats to Atlantic sturgeon recovery in the New York Bight. The water quality in the Hudson River and New York Bight has improved in recent decades, and no longer appears to present a significant threat to Atlantic Sturgeon recovery. The review also does not specifically mention human enteric pathogens as a cause for poor water quality, referring only to sewer discharge as one of many point and non-point sources contributing to a low dissolved oxygen level. This document can be found in Appendix B. A separate review of the available published scientific articles, reports, and data by the Great Lakes Environmental Center specifically examined the impact of human enteric pathogens to find any specific effects on Atlantic sturgeon. Surface water conditions for the indicator bacteria used (fecal coliform, enterococcus, and E. Coli) make it significantly more difficult for survival outside of the mammalian digestive tracts where these bacteria usually live. Water temperatures of around 70°F instead of 100°F and a higher salinity from the tidal nature of the Lower Hudson River makes long-term survival difficult. The substantial water flow and depth in these areas also protects the bottom-dwelling sturgeon populations from contact with these bacteria. These conditions make extended human pathogen exposure to Atlantic sturgeon unlikely. The review also did not find any specific information to suggest any negative effects these pathogen have on Atlantic Sturgeon at any life stage of the fish, both now and in the future. This may be related to the lack of documented presence of Atlantic Sturgeon in the New Jersey portion of the lower Hudson River for feeding, osmotic acclimation, or any other purposes. Atlantic Surgeon are likely to pass through this segment of the Hudson, but are thought to travel in deep channel waters, reducing vulnerabilities to nearshore discharges and intermittent CSO discharges. This review is found in Appendix D. The adult population of Shortnose sturgeon in the Hudson River has also been increasing at rates higher than those expected by recovery criteria according to the population research study "Recovery of a US Endangered Fish" by Cornell University. Shortnose sturgeon population estimated in the late 1990s had increased more than 400% from the 1970s estimates, and mainly in the adult segment of the population. The sizes of Shortnose sturgeon marked in the estimate were larger than other estimated populations as well. The estimate's results suggest the current level of habitat protection is adequate toward growing and maintaining healthy sturgeon population. This study can be found in Appendix E. From these conclusions, these areas are not considered sensitive areas as they relate to the Sturgeon.

The Loggerhead Sea Turtle and Humpback Whale are located in the Lower Bay portion of the Raritan Bay, but outside of the Study Area's immediate water bodies adjacent to CSO discharges. The Green and Loggerhead sea turtles are similarly listed in the waters between the coasts of Manhattan and Long Islands, and their habitats do not appear to be relevant for the Study Area. Therefore, these areas are not considered sensitive areas as they relate to the Loggerhead Sea Turtle and Humpback Whale.

C.2.5 Primary Contact Recreation Criterion

The Study Area is located in a densely populated urban area with a mix of recreational uses including boating, fishing, and other uses by the public. The New Jersey Administrative Code (NJAC) defines "primary contact recreation" as water related recreational activities that involve significant ingestion risk including but not limited to wading, swimming, diving, surfing and water skiing. NJAC defines "secondary contact recreation" as water related activities where the probability of water ingestion is minimal and includes, but is not limited to, boating, kayaking, and fishing. The waters in the Study Area are differentiated as either fresh water or saline waters. The upstream portion of the Passaic River is rated as suitable for primary contact as shown in green highlight on the NOAA GIS map in Figure C-1.

The Passaic River is freshwater downstream to Dundee Dam which is just southeast of Paterson City and Dundee Lake, and coincides with where the green outline changes to orange in Figure C-1. Only the green delineation of FW2-NT (Fresh Water 2 – Non-Trout) is classified as primary contact on the NOAA GIS maps. All waters delineated orange and downstream in the Study Area are a mix of salt and fresh water. The mix varies based on tide, rainfall and river flow. For the purpose of this report, downstream of Dundee Dam is considered saline. Special water

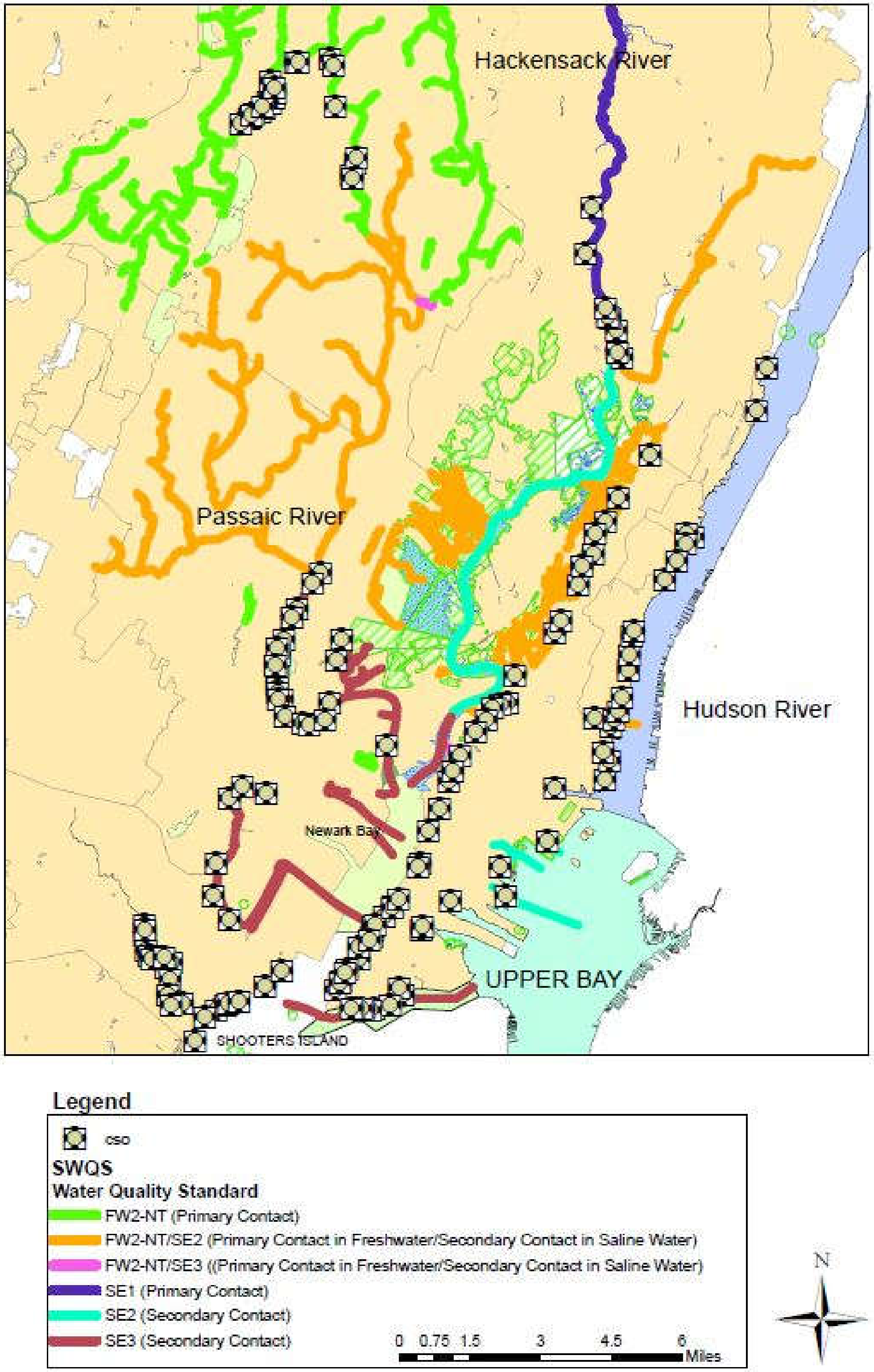

Figure C-1: CSOs in Primary Contact Waters

quality standards are used for water contact areas in order to protect the public from being exposed to waterborne diseases. All of Paterson's 24 CSO discharges occur in the area designated for primary contact. However, there are no beaches or other access ways to the Passaic River in Paterson that exist to facilitate primary contact recreation. Dundee Lake is also designated for primary contact, but there are no CSOs discharging into the water at this location.

Additionally, for the purposes of this report, the Hackensack River is identified as Upper and Lower segments at Overpeck Creek, where the river respectively switches from primary contact to secondary contact classification. The Upper Hackensack River segment relevant for the study area extends up to the Oradell Reservoir and contains 5 CSO discharge locations. Like Paterson, this segment of the Hackensack River does not have any designated beaches or other methods for riverside access for primary contact recreation. Overpeck Creek has 2 CSOs immediately prior to connecting to the Lower Hackensack River as a tributary. These CSOs are considered to be in the saline portion of Overpeck Creek and are thereby classified for secondary contact.

In addition, a tracking survey of primary and secondary recreation was conducted by the sampling team for the NJ CSO Group Baseline Compliance Monitoring Program. The results of this survey are summarized in Table C-6. The sampling crews recorded any recreational activity that they observed while they collected samples in the waterbodies throughout the Study Area. No authorized primary contact recreation activities were witnessed in any waterbody at any time. Secondary contact recreation activities including jet skiing, kayaking, and fishing, were observed in the Hudson River, Upper Bay, Passaic River, Newark Bay, Kill Van Kull, Arthur Kill, and Hackensack River. Secondary contact recreation opportunities within the Study Area are facilitated exclusively by access points such as boat launches. However, there are no authorized primary recreation areas within these portions of the Study Area. Furthermore, heavy container ship and barge traffic within the Study Area make these receiving waters non-conducive to primary contact recreation. Given the extensive service of the waterways for marine shipping and commercial navigation, swimming beaches, primary and secondary contact recreation, and other contact uses would likely not be encouraged as the large commercial vessel and boat traffic would endanger swimmers and boaters. Therefore, Sensitive Areas, as may be indicated by waters with primary contact recreation, have not been identified within the Study Area.

Although waters with primary contact recreation have not been identified, it is noted that there are existing beaches located on the north shore of the Raritan Bay, near the confluence of the Raritan River and the Arthur Kill, at the southeastern boundary of the of the City of Perth Amboy (see Figure C-2). These beaches are not currently designated by the City of Perth Amboy for recreational bathing use due to water quality concerns. Signs are installed at these beaches in order to advise the public not to swim or enter the water in this area. It is noted that there has been public interest in restoring these beaches for use as recreational bathing beaches and the City of Perth Amboy plans to evaluate the feasibility of accomplishing this objective. Although this area does not currently meet the requirements for a Sensitive Area, the Sensitive Area status will be revisited in the future if the City determines that it is feasible to support the safe public use of the beach in this area for recreational bathing.

Table C-6: Observations of Recreational Contact During Sampling in 2016

Waterbody	Designation	Observed Primary Contact	Observed Secondary Contact
Hudson River	Secondary Contact	No	Yes
Upper Bay	Secondary Contact	No	Yes
Passaic River	Primary Contact	No	Yes
Newark Bay	Secondary Contact	No	Yes
Kill Van Kull	Secondary Contact	No	Yes
Arthur Kill	Secondary Contact	No	Yes
Raritan River	Secondary Contact	No	No
Overpeck Creek	Secondary Contact	No	No
Elizabeth River	Secondary Contact	No	No
Lower Hackensack River	Secondary Contact	No	Yes
Upper Hackensack River	Primary Contact	No	Yes

All CSOs within the study area are shown in Table C-7 below. The table indicates whether or not the waterbody within the area of the outfall is accessible to the public. Public access includes public walkways, beach areas, and kayak or boat launches that are within 100 feet of a CSO outfall.

Table C-7: Public Accessibility to Each CSO Outfall

SPDES	Permittee	CSO Number	Receiving Water Body	Public Access
NJ0109240	Bayonne City	001A	Kill Van Kull	Yes
NJ0109240	Bayonne City	002A	Kill Van Kull	No
NJ0109240	Bayonne City	003A	Kill Van Kull	No
NJ0109240	Bayonne City	004A	Kill Van Kull	Yes
NJ0109240	Bayonne City	006A	Upper NY Bay	No
NJ0109240	Bayonne City	007A	Upper NY Bay	No
NJ0109240	Bayonne City	008A	Kill Van Kull	Yes
NJ0109240	Bayonne City	009A	Kill Van Kull	Yes
NJ0109240	Bayonne City	010A	Kill Van Kull	No
NJ0109240	Bayonne City	011A	Newark Bay	No
NJ0109240	Bayonne City	012A	Newark Bay	No
NJ0109240	Bayonne City	013A	Newark Bay	No
NJ0109240	Bayonne City	014A	Newark Bay	Yes
NJ0109240	Bayonne City	015A	Newark Bay	No
NJ0109240	Bayonne City	016A	Newark Bay	No
NJ0109240	Bayonne City	017A	Newark Bay	Yes
NJ0109240	Bayonne City	018A	Newark Bay	No
NJ0109240	Bayonne City	019A	Newark Bay	No

SPDES	Permittee	CSO Number	Receiving Water Body	Public Access
NJ0109240	Bayonne City	020A	Newark Bay	No
NJ0109240	Bayonne City	021A	Upper NY Bay	No
NJ0109240	Bayonne City	022A	Newark Bay	No
NJ0109240	Bayonne City	024A	Kill Van Kull	No
NJ0109240	Bayonne City	026A	Newark Bay	No
NJ0109240	Bayonne City	028A	Newark Bay	No
NJ0109240	Bayonne City	029A	Newark Bay	Yes
NJ0109240	Bayonne City	030A	Newark Bay	Yes
NJ0109240	Bayonne City	034A	Newark Bay	No
NJ0109240	Bayonne City	037A	Kill Van Kull	No
NJ0117846	East Newark	001A	Passaic River	None*
NJ0108782	City of Elizabeth	001A	Peripheral Ditch	No
NJ0108782	City of Elizabeth	002A	Great Ditch	No
NJ0108782	City of Elizabeth	003A	Elizabeth River	No
NJ0108782	City of Elizabeth	005A	Elizabeth River	No
NJ0108782	City of Elizabeth	008A	Elizabeth River	No
NJ0108782	City of Elizabeth	010A	Elizabeth River	No
NJ0108782	City of Elizabeth	012A	Elizabeth River	No
NJ0108782	City of Elizabeth	013A	Elizabeth River	No
NJ0108782	City of Elizabeth	014A	Elizabeth River	No
NJ0108782	City of Elizabeth	016A	Elizabeth River	No
NJ0108782	City of Elizabeth	021A	Elizabeth River	No
NJ0108782	City of Elizabeth	022A	Elizabeth River	No
NJ0108782	City of Elizabeth	026A	Elizabeth River	No
NJ0108782	City of Elizabeth	027A	Elizabeth River	No
NJ0108782	City of Elizabeth	028A	Elizabeth River	No
NJ0108782	City of Elizabeth	029A	Elizabeth River	No
NJ0108782	City of Elizabeth	030A	Arthur Kill	No
NJ0108782	City of Elizabeth	031A	Arthur Kill	No
NJ0108782	City of Elizabeth	032A	Arthur Kill	No
NJ0108782	City of Elizabeth	034A	Newark Bay	No
NJ0108782	City of Elizabeth	035A	Elizabeth River	No
NJ0108782	City of Elizabeth	036A	Elizabeth River	No
NJ0108782	City of Elizabeth	037A	Arthur Kill	No
NJ0108782	City of Elizabeth	038A	Elizabeth River	No
NJ0108782	City of Elizabeth	039A	Newark Bay	No
NJ0108782	City of Elizabeth	040A	Elizabeth River	No

SPDES	Permittee	CSO Number	Receiving Water Body	Public Access
NJ0108782	City of Elizabeth	041A	Elizabeth River	No
NJ0108782	City of Elizabeth	042A	Elizabeth River	No
NJ0108782	City of Elizabeth	043A	Elizabeth River	No
NJ0034517	Borough of Fort Lee	001A	Hudson River	None*
NJ0034517	Borough of Fort Lee	002A	Hudson River	None*
NJ0108715	Town of Guttenberg	GU001	Hudson River	No
NJ0108766	City of Hackensack	001A	Hackensack River	No
NJ0108766	City of Hackensack	002A	Hackensack River	No
NJ0108871	Harrison Town	001A	Passaic River	No
NJ0108871	Harrison Town	002A	Passaic River	No
NJ0108871	Harrison Town	003A	Passaic River	No
NJ0108871	Harrison Town	005A	Passaic River	No
NJ0108871	Harrison Town	006A	Passaic River	No
NJ0108871	Harrison Town	007A	Passaic River	No
NJ0108723	Jersey City MUA	001A	Penhorn Creek	No
NJ0108723	Jersey City MUA	002A	Penhorn Creek	No
NJ0108723	Jersey City MUA	003A	Hackensack River	No
NJ0108723	Jersey City MUA	004A	Hackensack River	No
NJ0108723	Jersey City MUA	005A	Hackensack River	No
NJ0108723	Jersey City MUA	006A	Hackensack River	No
NJ0108723	Jersey City MUA	007A	Hackensack River	No
NJ0108723	Jersey City MUA	008A	Hackensack River	No
NJ0108723	Jersey City MUA	009A	Hackensack River	No
NJ0108723	Jersey City MUA	010A	Hackensack River	No
NJ0108723	Jersey City MUA	011A	Newark Bay	No
NJ0108723	Jersey City MUA	013A	Newark Bay	No
NJ0108723	Jersey City MUA	014A	Hudson River	No
NJ0108723	Jersey City MUA	015A	Hudson River	No
NJ0108723	Jersey City MUA	016A	Hudson River	No
NJ0108723	Jersey City MUA	018A	Hudson River	No
NJ0108723	Jersey City MUA	020A	Hudson River	No
NJ0108723	Jersey City MUA	025A	Hudson River	No
NJ0108723	Jersey City MUA	026A	Hudson River	No
NJ0108723	Jersey City MUA	028A	Hudson River	No
NJ0108723	Jersey City MUA	029A	Hudson River	No
NJ0111244	Kearny Town	001A	Passaic River	No
NJ0111244	Kearny Town	004A	Passaic River	No

SPDES	Permittee	CSO Number	Receiving Water Body	Public Access
NJ0111244	Kearny Town	006A	Passaic River	No
NJ0111244	Kearny Town	007A	Frank's Creek	No
NJ0111244	Kearny Town	010A	Frank's Creek	No
NJ0108758	Newark City	002A	Passaic River	None*
NJ0108758	Newark City	003A	Passaic River	None*
NJ0108758	Newark City	004A	Passaic River	None*
NJ0108758	Newark City	005A	Passaic River	None*
NJ0108758	Newark City	008A	Passaic River	None*
NJ0108758	Newark City	009A	Passaic River	None*
NJ0108758	Newark City	010A	Passaic River	None*
NJ0108758	Newark City	014A	Passaic River	None*
NJ0108758	Newark City	015A	Passaic River	None*
NJ0108758	Newark City	016A	Passaic River	None*
NJ0108758	Newark City	017A	Passaic River	None*
NJ0108758	Newark City	018A	Passaic River	None*
NJ0108758	Newark City	022A	Passaic River	None*
NJ0108758	Newark City	023A	Peripheral Ditch / Elizabeth Channel	None*
NJ0108758	Newark City	025A	Peripheral Ditch / Elizabeth Channel	None*
NJ0108758	Newark City	026A	Queen Ditch	None*
NJ0108758	Newark City	027A/029A	Peripheral Ditch / Elizabeth Channel	None*
NJ0108758	Newark City	030A	Peripheral Ditch / Elizabeth Channel	None*
NJ0108898	North Bergen MUA	003A	Bellman's Creek	None*
NJ0108898	North Bergen MUA	005A	Cromakill Creek	None*
NJ0108898	North Bergen MUA	006A	Cromakill Creek	None*
NJ0108898	North Bergen MUA	007A	Cromakill Creek	None*
NJ0108898	North Bergen MUA	008A	Cromakill Creek	None*
NJ0108898	North Bergen MUA	009A	Cromakill Creek	None*
NJ0108898	North Bergen MUA	010A	Cromakill Creek	None*
NJ0108898	North Bergen MUA	011A	Cromakill Creek	None*
NJ0108898	North Bergen MUA	014A	Cromakill Creek	None*
NJ029084	North Bergen MUA (Woodcliff)	NB004	Hudson River	None*
NJ0026085	North Hudson (Adams Street)	002A	Hudson River	Yes
NJ0026085	North Hudson (Adams Street)	003A	Hudson River	Yes
NJ0026085	North Hudson (Adams Street)	005A	Hudson River	Yes

SPDES	Permittee	CSO Number	Receiving Water Body	Public Access
NJ0026085	North Hudson (Adams Street)	006A	Hudson River	Yes
NJ0026085	North Hudson (Adams Street)	008A	Hudson River	Yes
NJ0026085	North Hudson (Adams Street)	012A	Hudson River	Yes
NJ0026085	North Hudson (Adams Street)	013A	Hudson River	Yes
NJ0026085	North Hudson (Adams Street)	015A	Hudson River	Yes
NJ0025321	North Hudson (River Road)	002A	Hudson River	Yes
NJ0025321	North Hudson (River Road)	003A	Hudson River	Yes
NJ0108880	Paterson City	001A	Passaic River	None*
NJ0108880	Paterson City	003A	Passaic River	None*
NJ0108880	Paterson City	005A	Passaic River	None*
NJ0108880	Paterson City	006A	Passaic River	None*
NJ0108880	Paterson City	007A	Passaic River	None*
NJ0108880	Paterson City	010A	Passaic River	None*
NJ0108880	Paterson City	013A	Passaic River	None*
NJ0108880	Paterson City	014A	Passaic River	None*
NJ0108880	Paterson City	015A	Passaic River	None*
NJ0108880	Paterson City	016A	Passaic River	None*
NJ0108880	Paterson City	017A	Passaic River	None*
NJ0108880	Paterson City	021A	Passaic River	None*
NJ0108880	Paterson City	022A	Passaic River	None*
NJ0108880	Paterson City	023A	Passaic River	None*
NJ0108880	Paterson City	024A	Passaic River	None*
NJ0108880	Paterson City	025A	Passaic River	None*
NJ0108880	Paterson City	026A	Passaic River	None*
NJ0108880	Paterson City	027A	Passaic River	None*
NJ0108880	Paterson City	029A	Passaic River	None*
NJ0108880	Paterson City	030A	Passaic River	None*
NJ0108880	Paterson City	031A	Passaic River	None*
NJ0108880	Paterson City	032A	Passaic River	None*
NJ0108880	Paterson City	033A	Passaic River	None*
NJ0156132	Perth Amboy City	002A	Arthur Kill	No
NJ0156132	Perth Amboy City	003A	Arthur Kill	No
NJ0156132	Perth Amboy City	004A	Arthur Kill	No
NJ0156132	Perth Amboy City	005A	Arthur Kill	No
NJ0156132	Perth Amboy City	006A	Arthur Kill	No
NJ0156132	Perth Amboy City	007A	Arthur Kill	No
NJ0156132	Perth Amboy City	008A	Arthur Kill	No

SPDES	Permittee	CSO Number	Receiving Water Body	Public Access
NJ0156132	Perth Amboy City	009A	Arthur Kill	No
NJ0156132	Perth Amboy City	010A	Raritan River	Yes
NJ0156132	Perth Amboy City	011A	Raritan River	Yes
NJ0156132	Perth Amboy City	013A	Raritan River	Yes
NJ0156132	Perth Amboy City	014A	Raritan River	Yes
NJ0156132	Perth Amboy City	015A	Raritan River	Yes
NJ0156132	Perth Amboy City	016A	Raritan River	Yes
NJ0156132	Perth Amboy City	017A	Raritan River	No
NJ0156132	Perth Amboy City	019A	Raritan River	No
NJ0109118	Ridgefield Park Village	001A	Overpeck Creek	No
NJ0109118	Ridgefield Park Village	002A	Overpeck Creek	No
NJ0109118	Ridgefield Park Village	003A	Hackensack River	No
NJ0109118	Ridgefield Park Village	004A	Hackensack River	No
NJ0109118	Ridgefield Park Village	005A	Hackensack River	No
NJ0109118	Ridgefield Park Village	006A	Hackensack River	No

*Information requested from Permittee, but response not provided.

Below is a summary of the communication with municipal officials as to whether they have knowledge of any authorized and/or unauthorized primary contact recreation uses in the area of each CSO outfall within the official's municipality. Also, below is a summary of any discussions that took place during Supplemental CSO Team Meetings regarding primary contact recreation uses in the vicinity of CSOs. Supplemental CSO Team meeting dates are provided. If no response was received from an NJ CSO Group Member relating to the communication with municipal officials or discussions at Supplemental CSO Team meetings, then it has been noted.

Bergen County Utilities Authority (BCUA)
BCUA does not own or operate any Outfalls or CSOs.

City of Bayonne
The City of Bayonne corresponded with Alan Miller (NJDEP) in June 2018 regarding the rehabilitation of the existing CSO 017A. This facility is an inline chamber that is located in a pubic recreational (park) area used by local community members. When this facility experiences a CSO event, the storm effluent escapes overflowing onto a pedestrian walkway used by the public and may encounter the deposit of debris from the storm effluent.

Relative to discussion at the Regional Supplemental CSO Team meetings, the public has not provided specifics related to primary contact recreation uses.

East Newark Borough
Information requested from Permittee, but response not provided.

Relative to discussion at the Regional Supplemental CSO Team meetings, the public has not provided specifics related to primary contact recreation uses.

City of Elizabeth

We have discussed public access with Mr. Daniel J. Loomis, PE, CME, City Engineer, City of Elizabeth. The City is not aware of any regular authorized or unauthorized primary contact recreation uses in the area of any combined sewer outfalls within its municipal boundary. There have been no reports of any swimming and any reports of kayaking on the Arthur Kill would be rare and unusual and typically discouraged due to the dangerous nature of this activity in a Federal Navigation Channel with strong currents and heavy container ship, barge and tug boat traffic.

Input on the consideration of sensitive areas was solicited by the City of Elizabeth and JMEUC from their Supplemental CSO Team at meetings held on October 11, 2017, January 29, 2018, and June 5, 2018. The City and JMEUC sought input from the team on sensitive area locations, particularly related to primary contact recreational and public use activities. In response to the requested input, the Supplemental CSO Team generally indicated that areas around the CSO discharge points are not accessible to the public and would be unsafe for extensive contact recreational use. Members noted that fishing occurs along the Arthur Kill and Newark Bay off the piers at Marciante-Millet-Jackson (Slater) Park and Veterans Memorial Waterfront Park. Members also indicated that the municipal marina along the Arthur Kill serves numerous small pleasure boats. While important public uses, fishing and boating are not considered sensitive area attributes per the National CSO Policy.

No observations of persons swimming, wading, diving, or conducting other excessive contact recreational activities in the receiving waters were reported by the team. A team member stated that jet skiing and kayaking has been observed on the Arthur Kill, but the group indicated that such activities are unusual and occasional. The presence of heavy container ship and barge traffic on the Arthur Kill and Newark Bay was noted, which makes these receiving waters non-conducive to primary contact recreational or other activities such as kayaking, canoeing, or jet skiing.

When asked, the Supplemental CSO Team did not identify any specific CSO outfall location as being of greater prominence, concern, or ecological or recreational value than other locations.

Borough of Fort Lee

Information requested from Permittee, but response not provided.

Town of Guttenberg

The Town Administrator and DPW Director have no knowledge of any authorized or unauthorized primary contact usage on the waterfront.

Relative to discussion at the Regional Supplemental CSO Team meetings, the public has not provided specifics related to primary contact recreation uses.

City of Hackensack
The City of Hackensack has indicated none relating to communication with the Municipal Officials regarding authorized and / or unauthorized primary contact recreation uses in the area of each outfall. Hackensack has also indicated none regarding discussions that occurred at any CSO Supplemental Team meetings regarding primary contact recreational uses in the vicinity of CSO outfalls.

Harrison Town
We have discussed public access to the Passaic River with the City Engineer. It was determined that there are no public access points to the Passaic River within the Town of Harrison. There are sections of river walk adjacent to the River, but the public is separated from the River by a six foot high fence. There are no known places that are used for primary contact (swimming, bathing, surfing or similar water contact activities), regardless of if public access is provided. It is noted the Town is contemplating a kayak launch at the proposed Cape May Street Park. The park is planned for between Rodgers Blvd and Higgins Drive. However, this park is only being contemplated.

Harrison does not have an independent Supplemental CSO Team, so there has been no discussion of public access apart from what may have occurred at the PVSC Regional Supplemental CSO Team meetings.

Relative to discussion at the Regional Supplemental CSO Team meetings, the public has not provided specifics related to primary contact recreation uses.

Jersey City Municipal Utilities Authority (MUA)
Jersey City MUA has indicated none relating to communication with the Municipal Officials regarding authorized and / or unauthorized primary contact recreation uses in the area of each outfall. Jersey City MUA has also indicated none regarding discussions that occurred at any CSO Supplemental Team meetings regarding primary contact recreational uses in the vicinity of CSO outfalls.

Relative to discussion at the Regional Supplemental CSO Team meetings, the public has not provided specifics related to primary contact recreation uses.

Joint Meeting of Essex and Union Counties
Joint Meeting does not own or operate any CSOs or Outfalls.

Kearny Town
The Kearny Town has indicated none relating to communication with the Municipal Officials regarding authorized and / or unauthorized primary contact recreation uses in the area of each outfall. Kearny has also indicated none regarding discussions that occurred at any CSO Supplemental Team meetings regarding primary contact recreational uses in the vicinity of CSO outfalls.

Relative to discussion at the Regional Supplemental CSO Team meetings, the public has not provided specifics related to primary contact recreation uses.

Middlesex County Utilities Authority
Middlesex County Utilities Authority does not own or operate any CSOs or Outfalls.

City of Newark
Information requested from Permittee, but response not provided.

Relative to discussion at the Regional Supplemental CSO Team meetings, the public has not provided specifics related to primary contact recreation uses.

North Bergen MUA
Information requested from Permittee, but response not provided.

Relative to discussion at the Regional Supplemental CSO Team meetings, the public has not provided specifics related to primary contact recreation uses.

North Bergen MUA (Woodcliff)
Information requested from Permittee, but response not provided.

Relative to discussion at the Regional Supplemental CSO Team meetings, the public has not provided specifics related to primary contact recreation uses.

North Hudson Sewage Authority (NHSA) Adams Road and River Road
NHSA has indicated none relating to communication with the Municipal Officials regarding Authorized and / or unauthorized primary contact recreation uses in the area of each outfall. NHSA has indicated that discussions occurred at two meetings regarding primary contact recreational uses in the vicinity of CSO outfalls; 9/22/2017 Supplemental CSO Team (a.k.a. NHSA CSO Community Advisory Board) Meeting and 2/25/2019 CSO LTCP Public Meeting #1.

City of Paterson
Information requested from Permittee, but response not provided.

Relative to discussion at the Regional Supplemental CSO Team meetings, the public has not provided specifics related to primary contact recreation uses.

Passaic Valley Sewage Commissioners (PVSC)
PVSC does not own or operate any CSOs.

Relative to discussion at the Regional Supplemental CSO Team meetings, the public has not provided specifics related to primary contact recreation uses.

Ridgefield Park Village

We have had regular communication with the DPW director Alan O'Grady. As per our discussions and confirmed via email, the only public access in Ridgefield Park to the Hackensack River and tidal portion of the Overpeck Creek is the Wanda Canoe Club boat launch which is located behind the DPW. The boat launch is more than 100 feet from the nearest CSO outfalls.

Use of the waterbodies and sensitive areas were discussed at the Ridgefield Park Supplemental CSO Team Meetings on September 11, 2017 and March 12, 2018. The minutes from those meetings were reviewed and they do not indicate any usage for primary contact.

Perth Amboy City
Sunbathing is permitted in the Sandowski Beach area, but swimming is prohibited. The City has no knowledge of any unauthorized primary contact recreation uses in the area.

C.2.6 Drinking Water Intakes

Drinking water intake locations were identified from the NOAA maps and several drinking water providers are located within the Study Area. The majority of the Study Area is served by Passaic Valley Water Commission (PVWC). PVWS supplies an average of 83 MGD of water to Passaic, Bergen, Essex, Hudson and Morris Counties. Water intakes for PVWS comes from four reservoirs including Great Notch, New Street, Levine, and Point View. None of these are within the Study Area of waterbodies and are therefore not affected by CSO discharges.

Only NOAA Map #20 shows a water intake from a waterbody in the Study Area. Figure C-3 shows water intake locations that were identified from the NOAA maps. ID# 21 has SUEZ North America intakes located in the Hackensack River near Hackensack, Bogota and Teaneck. A CSO outfall is located approximately a half mile upstream of this water intake. Therefore, this water intake location was further evaluated. A representative from SUEZ North America, the drinking water provider for this intake, stated that all wells and intakes for Bogota, NJ have been decommissioned after they had purchased the Bogota Water Authority approximately 30 years ago. The river is also tidal, and SUEZ indicated that they have no current interest in drawing from the Hackensack River in the future for its drinking water. As such, there are no Sensitive Areas as a result of drinking water intakes.

C.2.7 Shellfish Beds

One of the National Shellfish Sanitation Program's (NSSP) goals is to control the safety of shellfish for human consumption by preventing shellfish harvests from contaminated growing areas. Shellfish concentrate microorganisms and poisonous or deleterious substances during their normal feeding process, and poisonous or deleterious substances from direct discharge points, disposal sites, or other non-point sources of pollution. In the interest of public safety of shellfish growing areas, a sanitary survey collects and evaluates information concerning actual and potential pollution sources that may adversely affect the water quality, and must be updated periodically. The report from this survey is used with other relevant resources to determine an appropriate classification of an area.

Figure C-2: Perth Amboy Existing Beach Area

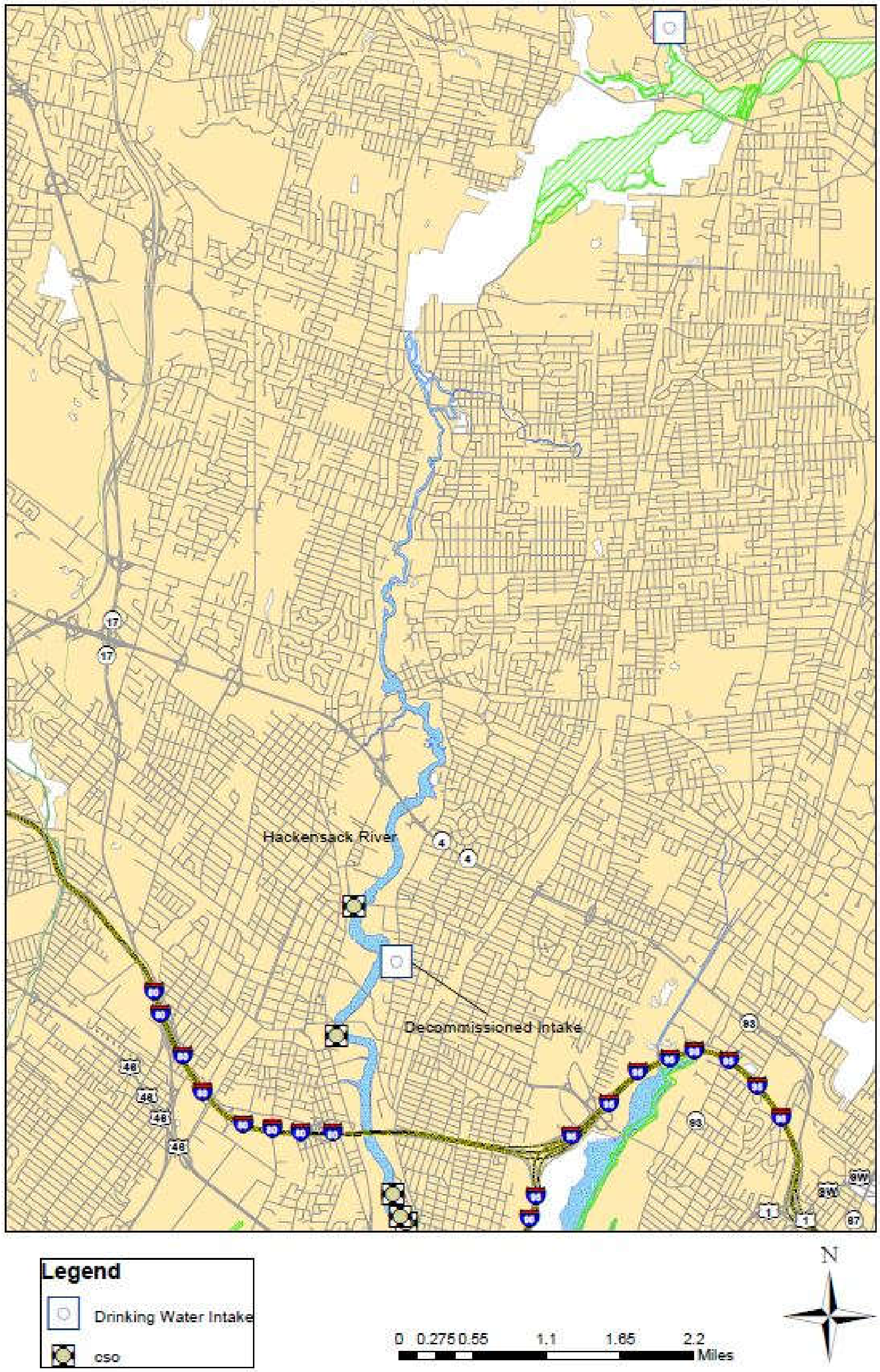

Figure C-3: Drinking Water Intake Locations

The only commercial shellfish beds classified by the NSSP for harvesting within the study area are restricted areas located in Raritan Bay, as shown in Figure C-4. However, this area is downstream of the closest CSO by a few miles. The influence of tidal mixing and dilution coupled with the separation between the most downstream discharge point and beginning of the shellfish harvest zone result in the CSO discharge having a negligible impact on the shellfish beds. Shellfish beds also extend up the Raritan River near Perth Amboy CSOs, but these are designated by the NSSP as prohibited harvesting locations and are only approved for depuration. Therefore, there are no Sensitive Areas due to the presence of shellfish beds in the Study Area.

C.2.8 Summary of Sensitive Areas

A comprehensive review of online databases, correspondence with regulatory agencies, direct observations and local environmental organizations was conducted to identify potential Sensitive Areas impacted by CSO's within the Study Area. The evaluation areas identified by this report can be found in Figure C-5. There are no Outstanding Natural Resource Waters or National Marine Sanctuaries in the Study Area. There were also no sensitive areas identified as it is related to waters with threatened or endangered species and their habitats. The Atlantic and Shortnose sturgeon populations in the Hudson River have both been successfully recovering since the species have been listed as endangered, and the coinciding improvements in water quality since the 1970s have had a positive impact. The current level of CSO discharge is not preventing the recovery of a healthy adult sturgeon population for either species. Primary contact recreation was also not observed in the Study Area, and are therefore there are no Sensitive Areas as a result of waters with primary contact recreation. The drinking water intake identified on the Hackensack River has been decommissioned decades ago and has no future plans for reopening. Also, there does not appear to be any measurable impact of any CSOs in the study area on shellfish beds due to the distance separating the structures from the harvesting location located in the Raritan Bay.

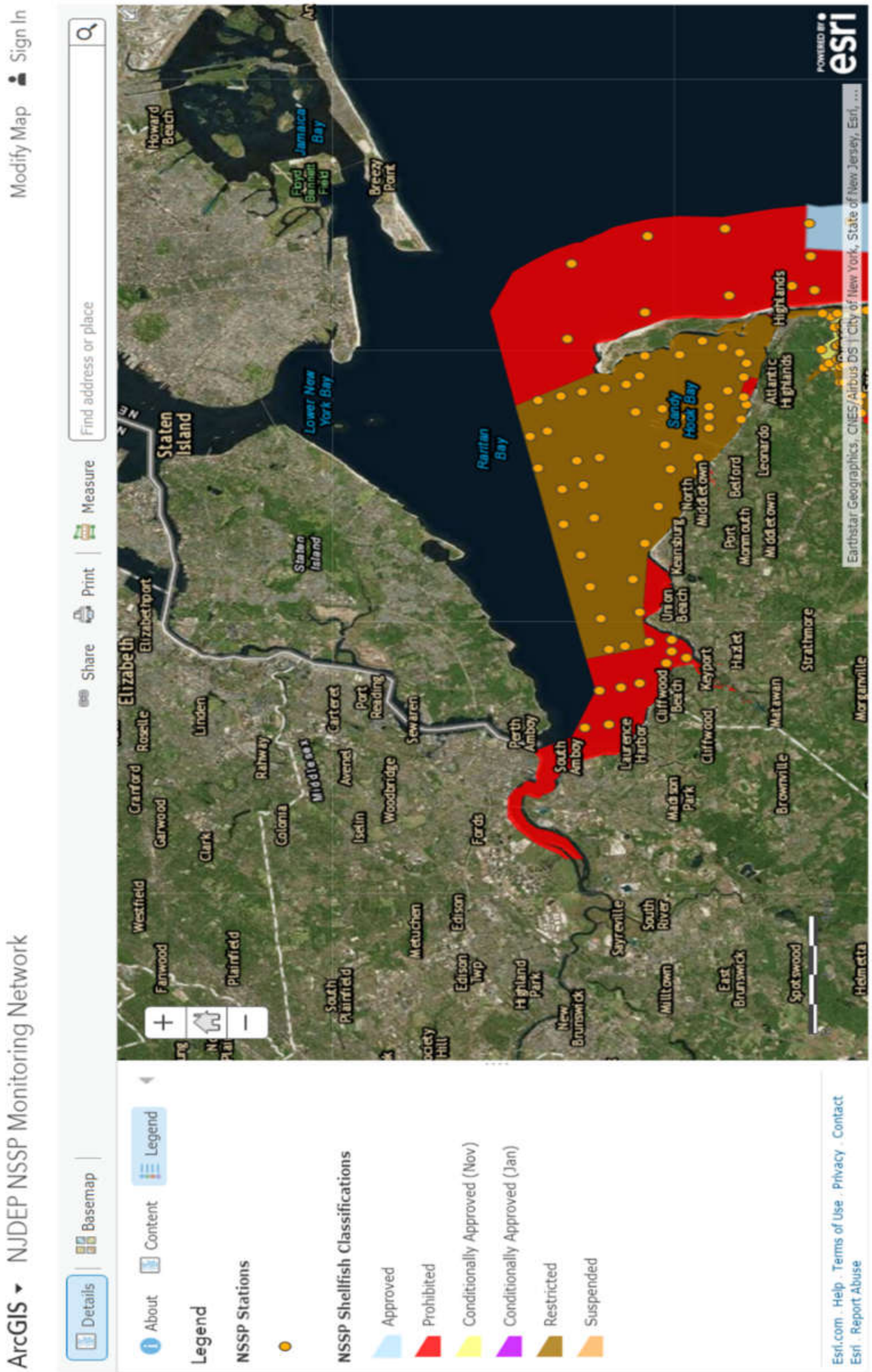

Figure C-4: Shellfish Harvesting Areas in Raritan Bay

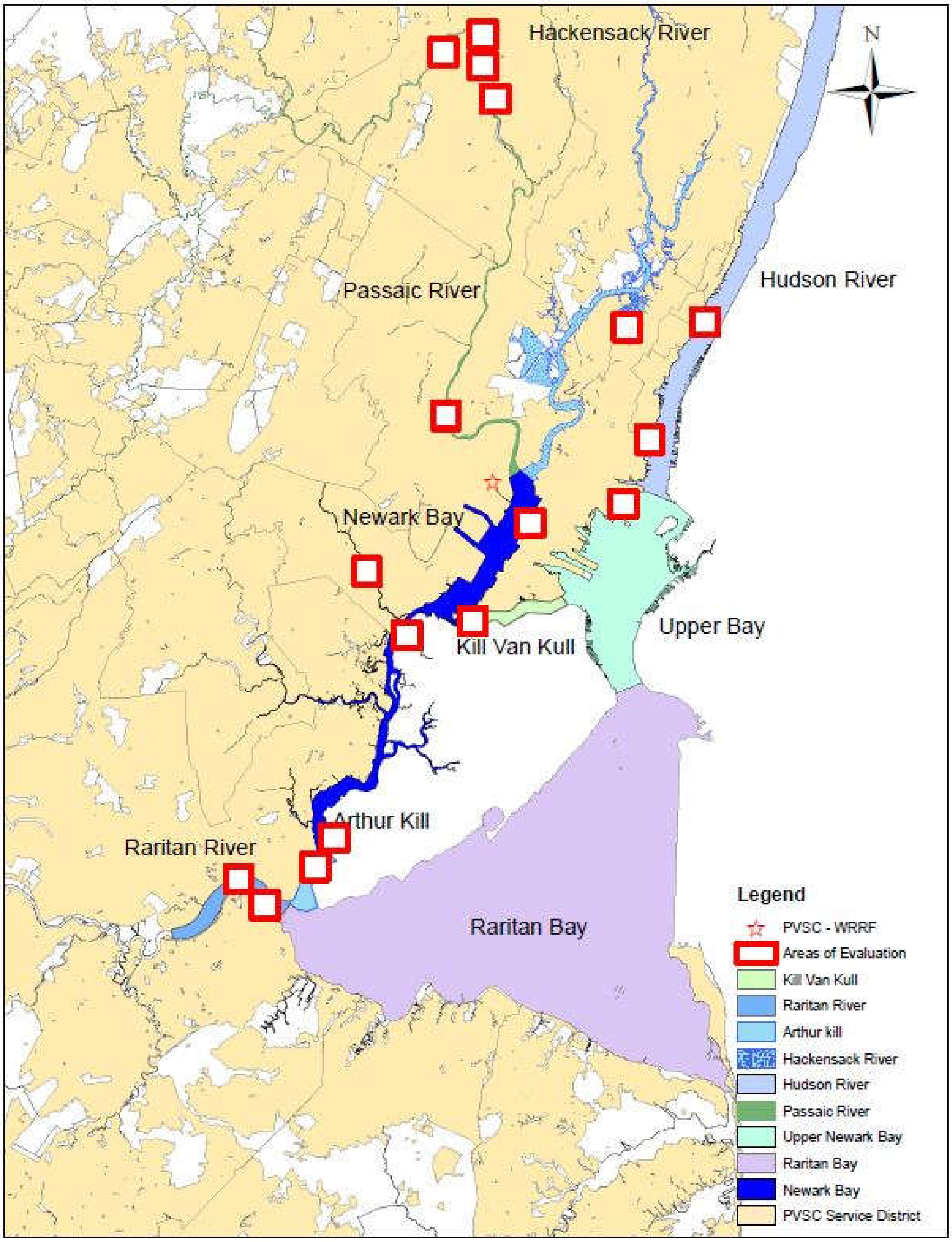

Figure C-5: Evaluation Area Locations

SECTION D - REFERENCES

1. Fish and Wildlife Service
   http://ecos.fws.gov/crithab/
   https://www.fws.gov/endangered/what-we-do/critical-habitats-faq.html

2. National Oceanic and Atmospheric Administration, National Marine Sanctuaries - NOAA Endangered Species List, 2015

3. National Oceanic and Atmospheric Administration, National Marine Sanctuaries
   http://sanctuaries.noaa.gov/visit/welcome.html#locations

4. National Oceanic and Atmospheric Administration, National Marine Sanctuaries
   http://www.nominate.noaa.gov/guide.html#document

5. National Oceanic and Atmospheric Administration, Waters with threatened or endangered species or their critical habitat, 2014
   http://response.restoration.noaa.gov/maps-and-spatial-data/download-esi-maps-and-gis-data.html

6. National Oceanic and Atmospheric Administration (NOAA) -_NJ_NY_2016_PDFs, 2016
   http://response.restoration.noaa.gov/maps-and-spatial-data/download-esi-maps-and-gis-data.html

7. New Jersey Department of Environmental Protection (NJDEP) Division of Fish and Wildlife
   http://www.state.nj.us/dep/fgw/

8. New Jersey Department of Environmental Protection (NJDEP) Office of Coastal and Land Use Planning
   http://www.nj.gov/dep/oclup/

9. New Jersey Department of Environmental Protection (NJDEP) Division of Land Use Regulation
   http://www.nj.gov/dep/landuse/

10. New Jersey Department of Environmental Protection (NJDEP) Division of Water Quality
    http://www.nj.gov/dep/dwq/

11. New Jersey Department of Environmental Protection (NJDEP) State Park Service
    http://www.state.nj.us/dep/parksandforests/parks/

12. New Jersey Department of Environmental Protection (NJDEP) Division of Science, Research and Environmental Health
    http://www.nj.gov/dep/dsr/

13. New Jersey Department of Environmental Protection (NJDEP) Division of Water Supply and Geoscience
    http://www.nj.gov/dep/watersupply/

14. United States Environmental Protection Agency (USEPA) -2006_12_01_standards_outstanding, 1989

http://www.epa.gov/sites/production/files/2014-10/documents/diamond-outstanding-memo.pdf

15. United States Environmental Protection Agency (USEPA) - EPA CSO Guidance for LTCP, September, 1995
http://water.epa.gov/polwaste/npdes/cso/upload/owm0272.pdf

16. United States Environmental Protection Agency (USEPA) - STORET Data Warehouse
http://www.epa.gov/storet/

17. National Marine Fisheries Service – Status Review of Atlantic Sturgeon, February 2007 (NOAA - Appendix B)
http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/atlanticsturgeon2007.pdf

18. Consideration of Sensitive Areas Information in the Study Area of the Long Term Control Plan for Final Surface Water Renewal Permit Action (Great Lakes Environmental Center - Appendix D)

19. Recovery of a US Endangered Fish (Department of Natural Resources, Cornell University - Appendix E)
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1828636/

Appendix A
Communications with Regulatory Agencies

Place Logo Here

AGENCY NAME HERE

OPEN PUBLIC RECORDS ACT REQUEST FORM

Agency Address
Agency Telephone Number & Fax Number
Agency e-mail address
Name of Agency Custodian

Place Logo Here

Important Notice

The last page of this form contains important information related to your rights concerning government records. Please read it carefully.

Requestor Information – Please Print

First Name Jean MI ______ Last Name Malafronte

E-mail Address jmalafronte@greeley-hansen.com

Mailing Address 1700 Market Street, Suite2130

City Philadelphia State PA Zip 19103

Telephone 215-553-7912 FAX 215-563-1139

Preferred Delivery: Pick Up ______ US Mail X On-Site Inspect ______ Fax ______ E-mail ______

If you are requesting records containing personal information, please circle one: Under penalty of N.J.S.A. 2C:28-3, I certify that I ***HAVE / HAVE NOT*** been convicted of any indictable offense under the laws of New Jersey, any other state, or the United States.

Signature ______________________ Date ______________

Payment Information

Maximum Authorization Cost $

Select Payment Method

Cash Check Money Order

Fees: Letter size pages - $0.05 per page
Legal size pages - $0.07 per page
Other materials (CD, DVD, etc) – actual cost of material

Delivery: Delivery / postage fees additional depending upon delivery type.

Extras: Special service charge dependent upon request.

Record Request Information: Please be as specific as possible in describing the records being requested. Also, please note that your preferred method of delivery will only be accommodated if the custodian has the technological means and the integrity of the records will not be jeopardized by such method of delivery.

Pursuant to the New Jersey Open Public Records Act and the common law right to inspect public records, please provide in electronic format any reports and documents from the NJDEP Division of Water Supply and Geoscience: New Jersey Geological and Water Survey that are dated or were developed between the years 2007-2016 regarding:

- Drinking Water Intakes or their designated protected areas

We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include:

- Passaic River from Montville to Newark Bay and its tributaries:
  Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel
- Hackensack River from the Oradell Reservoir to Newark Bay and its tributaries:
  Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek
- Newark Bay
- Hudson River from the George Washington Bridge to the Upper Newark Bay
- Upper Newark Bay
- Kill Van Kull
- Arthur Kill and its tributaries:
  Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek
- Raritan River from Bound Brook to the Raritan Bay and its tributaries:
  Bound Brook
- Raritan Bay

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Est. Document Cost ______
Est. Delivery Cost ______
Est. Extras Cost ______
Total Est. Cost ______
Deposit Amount ______
Estimated Balance ______
Deposit Date ______

AGENCY USE ONLY

Disposition Notes
Custodian: If any part of request cannot be delivered in seven business days, detail reasons here.

In Progress - Open ______
Denied - Closed ______
Filled - Closed ______
Partial - Closed ______

AGENCY USE ONLY

Tracking Information

Tracking # ______
Rec'd Date ______
Ready Date ______
Total Pages ______

Final Cost

Total ______
Deposit ______
Balance Due ______
Balance Paid ______

Records Provided

Custodian Signature **Date**

State of New Jersey
Department of Environmental Protection
GOVERNMENT RECORDS REQUEST FORM

IMPORTANT NOTICE

Please read this entire form carefully as it contains important information concerning the response to your record request, accessing records, disputing denials, and your rights concerning government records. For further information, access WWW.NJ.GOV/DEP/OPRA.

Requestor Information

First Name:	JEAN	MI		Last Name	MALAFRONTE		
Company:	GREELEY AND HANSEN						
Mailing Address:	1700 MARKET ST. SUITE 2130						
City:	Philadelphia	State:	PA	Zip:	19103	Email:	jmalafronte@greeley-hansen.com
Business Telephone:	(215) 553-7912					Extension	
Facsimile Telephone:	(215) 563-1139						

State Use Only

Tracking #	205586
Received Date	03/20/2017
Access Method	Send Electronic copies

All matters relating to the response and access of any records identified for this request should be directed to:

NJDEP – Office of Record Access
401 East State Street
PO Box 420 Mail Code 401-06Q
Trenton, New Jersey 08625-0420
Tele #: (609) 341-3121
Fax #: (609) 292-1177

Record Request Details:

Pursuant to the New Jersey Open Public Records Act and the common law right to inspect public records, please provide in electronic format any reports and documents from the NJDEP Division of Water Supply and Geoscience: New Jersey Geological and Water Survey that are dated or were developed between the years 2007-2016 regarding: __Drinking Water Intakes or their designated protected areas We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include: __Passaic River from Montville to Newark Bay and its tributaries: Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel __Hackensack River from the Oradell Reservoir to Newark Bay and its tributaries: Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek __Newark Bay __Hudson River from the George Washington Bridge to the Upper Newark Bay __Upper Newark Bay __Kill Van Kull __Arthur Kill and its tributaries: Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek __Raritan River from Bound Brook to the Raritan Bay and its tributaries: Bound Brook __Raritan Bay

Disposition Notes

Based on this record request, responsive records have been identified and available for direct access at the web address cited below. Requester should contact the Office of Record Access at 609-341-3121 with any further concerns.

Record Request Response

In Progress	–	Open	
Filled	–	Closed	X
Denied	–	Closed	
Partial	–	Closed	

Addendum Disposition Notes: Source Water info can be found at:www.nj.gov/dep/swapSurface Water Systems info:https://www13.state.nj.us/DataMiner

Matthew J. Coefer 04/03/2017

Custodian Signature Date

Information Regarding the Requested Records		
If your request is in reference to a single facility, please provide the name of the facility, and the name of the operator name of the facility:	Facility Name: Operator Name:	
Please provide the owner name the facility or parcel of land:	Owner Name:	
If your request is in reference to a specific parcel of land, please provide the street address, block, lot and property owner of the parcel of land: (Note: if the property in question is over multiple blocks and lots, please list all in the description field below)	Street Address 1: Street Address 2: Block: Lot:	
If your request is in reference to a facility, site or parcel of land, please provide the Municipality and County where the facility, site or parcel of land is located:	County: Municipality:	
If the request is in reference to a particular permit issued by NJDEP, please provide the type of permit and any identifying numbers such as permit, incident or case numbers. (i.e. Fishing, Hunting, Hazardous Waste, Solid Waste, Land Use, NJPDES, Pesticides, Stream Encroachment, TWA, UST, Water Allocation)	List Permit Type:	List ID Numbers:
If your request is in reference to an individual, please provide the individual's name and type, and if the individual is a DEP employee, your relationship with the individual:	Individual's name: Type of Individual: Relationship:	
If the an individual was specified above, the individual was DEP Licensed, please specify the license type the individual holds:	License Type:	

The New Jersey Department of Environmental Protection has responded to your submitted Open Public Records Act (OPRA) record request. The following information will help you understand the response and your next available actions.

Tracking #: This is the Department's assigned Tracking # to your OPRA record request, which should be used in all corresponding matters.

Record Request Response:

- **In Progress** – Based on the nature of the request, the records sought, and/or the manner to which the records may exists, the Department requires additional time to investigate and respond to the request.
- **Filled** – Based on the information provided in your request, the Department was able to investigate and respond to your record request.
- **Denied** – Based on the nature of the request and/or the records sought, the Department has denied your request pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.
- **Partial** – The Department has identified both responsive government records and records being denied based on the nature of the request and/or the records sought, that do not meet the definition of a government record pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.

Disposition Notes: Provides detailed information concerning the Department's response to your request.

Accessing Records: Dependent on the volume of records and your interest, there are five (5) methods available to access the responsive government records:

- **File Review** – Schedule a file review with the Department to directly access the records and take notes or tag records of interest for copying. Copying can be performed by either the Department's onsite Copying Unit at State duplication fee costs or by the requester employing a Copy Vendor Service. If there are records stored in archives, a five-day processing period will be included prior to scheduling a review.
- **Copy Request** – All records of interest will be copied by the Department's onsite Copying Unit at State duplication fee costs unless a Copy Vendor Service is employed.
- **Electronic Records Request** – Dependent on the size & nature of the e-records, the Department will email the records or provide a CD or DVD.
- **Fax Request** – Based on the number of pages, the Department faxes the responsive records.
- **Web Access** – The responsive records can be access directly through the Department's web site. Web address will be provided.

Access to Government Records Under the New Jersey Open Public Records Act (N.J.S.A. 47:1A-1 et seq.)

1. The fees for duplication of a government record are specified below. We will notify you of any special charges, special service charges or other additional charges authorized by State law or regulation before processing your request. Payment shall be made by check or money order payable to the State of New Jersey and mailed to the address specified below.

Hard Copies:	Letter & Legal size	= $0.05 per page	**Electronic Records:**	CDs = $0.55 per CD
	Oversized Maps (Color)	= $5.00 per map		DVDs = $0.55 per DVD
	Oversized Maps (B&W)	= $3.00 per map		

2. Pursuant to OPRA (C.47:1A-5c & C47:1A-5d), the Department will apply special service charge for any extraordinary expenditure of time and effort to accommodate a request. The special service charge will be based on the actual direct cost of providing the records. The requester shall have the opportunity to review and object to the charge prior to it being incurred; however, in the event the requester objects to the special service charge, the request will be closed and access to the records will not be granted.
3. By law, the Department must notify you that it grants or denies a request for access to government records within seven business days after the custodian of the record requested receives the request, provided that the record is currently available and not in storage. If the record requested is not currently available or is in storage, the custodian will advise you within seven business days when the record can be made available and the estimated cost. You may agree with the custodian to extend the time for making records available, or granting or denying your request.
4. You may be denied access to a government record if your request would substantially disrupt agency operations and the custodian is unable to reach a reasonable solution with you.
5. If the Department was unable to comply with your request for access to a government record, the custodian will indicate the reasons for denial on the request form.
6. Except as otherwise provided by law or by agreement with the requester, if the custodian of the record requested fails to respond to you within seven business days of receiving a request form, the failure to respond will be considered a denial of your request.
7. **Resolution of Disputed Findings:**

   In the event that a requester does not agree with the Department's record response, the requester should:

   No Records - Reexamined the request details to evaluate if all of the information was provided that could aid the Department in locating records. The Department's ability to identify records of interest is in direct correlation to matching the Department information with the information provided on the request. Such important identifiers are Facility/Site Name, Address, Case #, Permit #, Block/Lot.

   Denial - If your request for access to a government record has been denied or unfilled within the time permitted by law, you have a right to challenge the decision by the Department to deny access. The Department denies access to records only when those records do not meet the definition of a government record and/or public access is not allowed pursuant to the law. At your option, you may either:

   a. Contact the Office of Record Access to re-visit the matter or provide further explanation.

   b. Institute a proceeding in the Superior Court of New Jersey

   c. File a complaint in writing with the Government Records Council (GRC). You may contact the GRC by toll-free telephone at 866-850-0511, by mail at PO Box 819, Trenton, NJ, 08625, by e-mail at *grc@dca.state.nj.us*, or at their web site at *www.state.nj.us/grc*. The Council can also respond to other questions about the law.
8. Information provided on this form may be subject to disclosure under the Open Public Records Act.

Revised Addendum Disposition Notes: NONE

Place Logo Here

AGENCY NAME HERE

OPEN PUBLIC RECORDS ACT REQUEST FORM

Agency Address
Agency Telephone Number & Fax Number
Agency e-mail address
Name of Agency Custodian

Place Logo Here

Important Notice

The last page of this form contains important information related to your rights concerning government records. Please read it carefully.

Requestor Information – Please Print

First Name Jean MI ______ Last Name Malafronte

E-mail Address jmalafronte@greeley-hansen.com

Mailing Address 1700 Market Street, Suite 2130

City Philadelphia State PA Zip 19103

Telephone 215-553-7912 FAX 215-563-1139

Preferred Delivery: Pick Up ______ US Mail X On-Site Inspect ______ Fax ______ E-mail ______

If you are requesting records containing personal information, please circle one: Under penalty of N.J.S.A. 2C:28-3, I certify that I ***HAVE / HAVE NOT*** been convicted of any indictable offense under the laws of New Jersey, any other state, or the United States.

Signature ______________________ Date ______________

Payment Information

Maximum Authorization Cost $

Select Payment Method

Cash Check Money Order

Fees: Letter size pages - $0.05 per page
Legal size pages - $0.07 per page
Other materials (CD, DVD, etc) – actual cost of material

Delivery: Delivery / postage fees additional depending upon delivery type.

Extras: Special service charge dependent upon request.

Record Request Information: Please be as specific as possible in describing the records being requested. Also, please note that your preferred method of delivery will only be accommodated if the custodian has the technological means and the integrity of the records will not be jeopardized by such method of delivery.

Pursuant to the New Jersey Open Public Records Act and the common law right to inspect public records, please provide in electronic format any reports and documents from the NJDEP Division of Land Use Regulation that are dated or were developed between the years 2007-2016 regarding:

- Waters with Primary Contact Recreation
- Drinking Water Intakes or their designated protected areas

We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include:

- Passaic River from Montville to Newark Bay and its tributaries:
  Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel
- Hackensack River from the Oradell Reservoir to Newark Bay and its tributaries:
  Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek
- Newark Bay
- Hudson River from the George Washington Bridge to the Upper Newark Bay
- Upper Newark Bay
- Kill Van Kull
- Arthur Kill and its tributaries:
  Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek
- Raritan River from Bound Brook to the Raritan Bay and its tributaries:
  Bound Brook
- Raritan Bay

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Est. Document Cost	
Est. Delivery Cost	
Est. Extras Cost	
Total Est. Cost	
Deposit Amount	
Estimated Balance	
Deposit Date	

AGENCY USE ONLY

Disposition Notes

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In Progress	-	Open	
Denied	-	Closed	
Filled	-	Closed	
Partial	-	Closed	

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Tracking Information		Final Cost	
Tracking #		Total	
Rec'd Date		Deposit	
Ready Date		Balance Due	
Total Pages		Balance Paid	

Records Provided

Custodian Signature Date

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AGENCY NAME HERE

OPEN PUBLIC RECORDS ACT REQUEST FORM

Agency Address
Agency Telephone Number & Fax Number
Agency e-mail address
Name of Agency Custodian

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First Name Jean MI ______ Last Name Malafronte

E-mail Address jmalafronte@greeley-hansen.com

Mailing Address 1700 Market Street, Suite 2130

City Philadelphia State PA Zip 19103

Telephone 215-553-7912 FAX 215-563-1139

Preferred Delivery: Pick Up ______ US Mail X On-Site Inspect ______ Fax ______ E-mail ______

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- Waters with Primary Contact Recreation

We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include:

- Passaic River from Montville to Newark Bay and its tributaries:
  Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel
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  Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek
- Newark Bay
- Hudson River from the George Washington Bridge to the Upper Newark Bay
- Upper Newark Bay
- Kill Van Kull
- Arthur Kill and its tributaries:
  Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek
- Raritan River from Bound Brook to the Raritan Bay and its tributaries:
  Bound Brook
- Raritan Bay

AGENCY USE ONLY

Est. Document Cost ______
Est. Delivery Cost ______
Est. Extras Cost ______
Total Est. Cost ______
Deposit Amount ______
Estimated Balance ______
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AGENCY USE ONLY

Disposition Notes
Custodian: If any part of request cannot be delivered in seven business days, detail reasons here.

In Progress	-	Open	______
Denied	-	Closed	______
Filled	-	Closed	______
Partial	-	Closed	______

AGENCY USE ONLY

Tracking Information

Tracking # ______
Rec'd Date ______
Ready Date ______
Total Pages ______

Final Cost

Total ______
Deposit ______
Balance Due ______
Balance Paid ______

Records Provided

Custodian Signature **Date**

State of New Jersey
Department of Environmental Protection
GOVERNMENT RECORDS REQUEST FORM

IMPORTANT NOTICE

Please read this entire form carefully as it contains important information concerning the response to your record request, accessing records, disputing denials, and your rights concerning government records. For further information, access WWW.NJ.GOV/DEP/OPRA.

Requestor Information

First Name: JEAN	MI	Last Name MALAFRONTE	
Company: GREELEY AND HANSEN			
Mailing Address: 1700 MARKET ST., SUITE 2130			
City: Philadelphia	State: PA	Zip: 19103	Email: jmalafronte@greeley-hansen.com
Business Telephone: (215) 553-7912			Extension
Facsimile Telephone: (215) 563-1139			

State Use Only

Tracking #	205583
Received Date	03/20/2017
Access Method	**Send Electronic copies**

All matters relating to the response and access of any records identified for this request should be directed to:

NJDEP – Office of Record Access
401 East State Street
PO Box 420 Mail Code 401-06Q
Trenton, New Jersey 08625-0420

Tele #: (609) 341-3121
Fax #: (609) 292-1177

Record Request Details:

Pursuant to the New Jersey Open Public Records Act and the common law right to inspect public records, please provide in electronic format any reports and documents from the NJDEP State Park Service that are dated or were developed between the years 2007-2016 regarding: __Waters with Primary Contact Recreation We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include: __Passaic River from Montville to Newark Bay and its tributaries: Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel __Hackensack River from the Oradell Reservoir to Newark Bay and its tributaries: Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek __Newark Bay __Hudson River from the George Washington Bridge to the Upper Newark Bay __Upper Newark Bay __Kill Van Kull __Arthur Kill and its tributaries: Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek __Raritan River from Bound Brook to the Raritan Bay and its tributaries: Bound Brook __Raritan Bay

Disposition Notes

This request has been denied pursuant to N.J.S.A. 47:1A-1. See Addendum Disposition Notes below for further information.

Record Request Response

In Progress	–	Open	
Filled	–	Closed	
Denied	–	Closed	X
Partial	–	Closed	

Addendum Disposition Notes: Please be advised that the request is overbroad and improper as it does not define specific records. Government agencies are required to disclose identifiable government records that are specifically described in the OPRA request. See N.J.S.A. 47:1A-1 and -1.1. OPRA does not permit open-ended searches of agency files, nor does the law allow a request for every document an agency has on file on a specific subject matter. OPRA also does not require government agencies to conduct research in order to respond to a request for records. See, for e.g., MAG Entertainment LLC v Div of Alcoholic Bev Control, 375 NJ Super 534, 549 (App Div. 2005); Bent v Twp Of Stafford, 381 NJ Super 30, 37 (App Div 2005); Gannett NJ Partners v Middlesex, 379 NJ Super 205, 212 (App Div 2005), which address the principles stated above. Consequently, this request is denied and closed effective today.

Matthew J. Coefer 03/30/2017

Custodian Signature **Date**

Information Regarding the Requested Records		
If your request is in reference to a single facility, please provide the name of the facility, and the name of the operator name of the facility:	Facility Name: Operator Name:	
Please provide the owner name the facility or parcel of land:	Owner Name:	
If your request is in reference to a specific parcel of land, please provide the street address, block, lot and property owner of the parcel of land: (Note: if the property in question is over multiple blocks and lots, please list all in the description field below)	Street Address 1: Street Address 2: Block: Lot:	
If your request is in reference to a facility, site or parcel of land, please provide the Municipality and County where the facility, site or parcel of land is located:	County: Municipality:	
If the request is in reference to a particular permit issued by NJDEP, please provide the type of permit and any identifying numbers such as permit, incident or case numbers. (i.e. Fishing, Hunting, Hazardous Waste, Solid Waste, Land Use, NJPDES, Pesticides, Stream Encroachment, TWA, UST, Water Allocation)	List Permit Type:	List ID Numbers:
If your request is in reference to an individual, please provide the individual's name and type, and if the individual is a DEP employee, your relationship with the individual:	Individual's name: Type of Individual: Relationship:	
If the an individual was specified above, the individual was DEP Licensed, please specify the license type the individual holds:	License Type:	

The New Jersey Department of Environmental Protection has responded to your submitted Open Public Records Act (OPRA) record request. The following information will help you understand the response and your next available actions.

Tracking #: This is the Department's assigned Tracking # to your OPRA record request, which should be used in all corresponding matters.

Record Request Response:

- **In Progress** – Based on the nature of the request, the records sought, and/or the manner to which the records may exists, the Department requires additional time to investigate and respond to the request.
- **Filled** – Based on the information provided in your request, the Department was able to investigate and respond to your record request.
- **Denied** – Based on the nature of the request and/or the records sought, the Department has denied your request pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.
- **Partial** – The Department has identified both responsive government records and records being denied based on the nature of the request and/or the records sought, that do not meet the definition of a government record pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.

Disposition Notes: Provides detailed information concerning the Department's response to your request.

Accessing Records: Dependent on the volume of records and your interest, there are five (5) methods available to access the responsive government records:

- **File Review** – Schedule a file review with the Department to directly access the records and take notes or tag records of interest for copying. Copying can be performed by either the Department's onsite Copying Unit at State duplication fee costs or by the requester employing a Copy Vendor Service. If there are records stored in archives, a five-day processing period will be included prior to scheduling a review.
- **Copy Request** – All records of interest will be copied by the Department's onsite Copying Unit at State duplication fee costs unless a Copy Vendor Service is employed.
- **Electronic Records Request** – Dependent on the size & nature of the e-records, the Department will email the records or provide a CD or DVD.
- **Fax Request** – Based on the number of pages, the Department faxes the responsive records.
- **Web Access** – The responsive records can be access directly through the Department's web site. Web address will be provided.

Access to Government Records Under the New Jersey Open Public Records Act (N.J.S.A. 47:1A-1 et seq.)

1. The fees for duplication of a government record are specified below. We will notify you of any special charges, special service charges or other additional charges authorized by State law or regulation before processing your request. Payment shall be made by check or money order payable to the State of New Jersey and mailed to the address specified below.

Hard Copies:	Letter & Legal size	= $0.05 per page	**Electronic Records:**	CDs =	$0.55 per CD
	Oversized Maps (Color)	= $5.00 per map		DVDs =	$0.55 per DVD
	Oversized Maps (B&W)	= $3.00 per map			

2. Pursuant to OPRA (C.47:1A-5c & C47:1A-5d), the Department will apply special service charge for any extraordinary expenditure of time and effort to accommodate a request. The special service charge will be based on the actual direct cost of providing the records. The requester shall have the opportunity to review and object to the charge prior to it being incurred; however, in the event the requester objects to the special service charge, the request will be closed and access to the records will not be granted.

3. By law, the Department must notify you that it grants or denies a request for access to government records within seven business days after the custodian of the record requested receives the request, provided that the record is currently available and not in storage. If the record requested is not currently available or is in storage, the custodian will advise you within seven business days when the record can be made available and the estimated cost. You may agree with the custodian to extend the time for making records available, or granting or denying your request.

4. You may be denied access to a government record if your request would substantially disrupt agency operations and the custodian is unable to reach a reasonable solution with you.

5. If the Department was unable to comply with your request for access to a government record, the custodian will indicate the reasons for denial on the request form.

6. Except as otherwise provided by law or by agreement with the requester, if the custodian of the record requested fails to respond to you within seven business days of receiving a request form, the failure to respond will be considered a denial of your request.

7. **Resolution of Disputed Findings:**

   In the event that a requester does not agree with the Department's record response, the requester should:

   No Records - Reexamined the request details to evaluate if all of the information was provided that could aid the Department in locating records. The Department's ability to identify records of interest is in direct correlation to matching the Department information with the information provided on the request. Such important identifiers are Facility/Site Name, Address, Case #, Permit #, Block/Lot.

   Denial - If your request for access to a government record has been denied or unfilled within the time permitted by law, you have a right to challenge the decision by the Department to deny access. The Department denies access to records only when those records do not meet the definition of a government record and/or public access is not allowed pursuant to the law. At your option, you may either:

   a. Contact the Office of Record Access to re-visit the matter or provide further explanation.

   b. Institute a proceeding in the Superior Court of New Jersey

   c. File a complaint in writing with the Government Records Council (GRC). You may contact the GRC by toll-free telephone at 866-850-0511, by mail at PO Box 819, Trenton, NJ, 08625, by e-mail at *grc@dca.state.nj.us*, or at their web site at *www.state.nj.us/grc*. The Council can also respond to other questions about the law.

8. Information provided on this form may be subject to disclosure under the Open Public Records Act.

Revised Addendum Disposition Notes: NONE

Place Logo Here

AGENCY NAME HERE

OPEN PUBLIC RECORDS ACT REQUEST FORM

Agency Address
Agency Telephone Number & Fax Number
Agency e-mail address
Name of Agency Custodian

Place Logo Here

Important Notice

The last page of this form contains important information related to your rights concerning government records. Please read it carefully.

Requestor Information – Please Print

First Name Jean MI ___ Last Name Malafronte

E-mail Address jmalafronte@greeley-hansen.com

Mailing Address 1700 Market Street, Suite 2130

City Philadelphia State PA Zip 19103

Telephone 215-553-7912 FAX 215-563-1139

Preferred Delivery: Pick Up ___ US Mail X On-Site Inspect ___ Fax ___ E-mail ___

If you are requesting records containing personal information, please circle one: Under penalty of N.J.S.A. 2C:28-3, I certify that I ***HAVE*** / ***HAVE NOT*** been convicted of any indictable offense under the laws of New Jersey, any other state, or the United States.

Signature ___ Date ___

Payment Information

Maximum Authorization Cost $

Select Payment Method

Cash Check Money Order

Fees: Letter size pages - $0.05 per page
Legal size pages - $0.07 per page
Other materials (CD, DVD, etc) – actual cost of material

Delivery: Delivery / postage fees additional depending upon delivery type.

Extras: Special service charge dependent upon request.

Record Request Information: Please be as specific as possible in describing the records being requested. Also, please note that your preferred method of delivery will only be accommodated if the custodian has the technological means and the integrity of the records will not be jeopardized by such method of delivery.

Pursuant to the New Jersey Open Public Records Act and the common law right to inspect public records, please provide in electronic format any reports and documents from the NJDEP Office of Coastal and Land Use Planning that are dated or were developed between the years 2007-2016 regarding:

- Waters with Primary Contact Recreation

We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include:

- Passaic River from Montville to Newark Bay and its tributaries:
  Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel
- Hackensack River from the Oradell Reservoir to Newark Bay and its tributaries:
  Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek
- Newark Bay
- Hudson River from the George Washington Bridge to the Upper Newark Bay
- Upper Newark Bay
- Kill Van Kull
- Arthur Kill and its tributaries:
  Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek
- Raritan River from Bound Brook to the Raritan Bay and its tributaries:
  Bound Brook
- Raritan Bay

AGENCY USE ONLY

Est. Document Cost ___
Est. Delivery Cost ___
Est. Extras Cost ___
Total Est. Cost ___
Deposit Amount ___
Estimated Balance ___
Deposit Date ___

AGENCY USE ONLY

Disposition Notes
Custodian: If any part of request cannot be delivered in seven business days, detail reasons here.

In Progress - Open ___
Denied - Closed ___
Filled - Closed ___
Partial - Closed ___

AGENCY USE ONLY

Tracking Information

Tracking # ___
Rec'd Date ___
Ready Date ___
Total Pages ___

Final Cost

Total ___
Deposit ___
Balance Due ___
Balance Paid ___

Records Provided

Custodian Signature ___ Date ___

Mathieson, Marcus

From: Caldarelli, Adriana <Adriana.Caldarelli@dep.nj.gov>
Sent: Tuesday, December 20, 2016 3:37 PM
To: Loftin, Virginia; Foster, Rebecca
Subject: RE: Question

Good afternoon,

I passed on the information you gave me, Virginia, and my contacts at the City (William Kurzenberger and Annie Hindenlang) reached out to Middlesex County Health to coordinate testing, etc. The last I heard they would coordinate on the local level and get back to us if they needed any of the historic data that we have.

Becky, who reached out to you? I'd be happy to provide contact information for Billy and Annie if you'd like to get the person that reached out to you in contact with them.

Adriana

From: Loftin, Virginia
Sent: Tuesday, December 20, 2016 3:31 PM
To: Foster, Rebecca <Rebecca.Foster@dep.nj.gov>
Cc: Caldarelli, Adriana <Adriana.Caldarelli@dep.nj.gov>
Subject: Re: Question

Hi Becky,
Yet another request from Perth Amboy about opening the park as a bathing beach. Sorry, but he answer stays the same. They must meet water quality criteria and safety requirements. They have been working with Adriana Caldarelli most recently and she can probably weigh in.

All past monitoring data show that the water quality at the park in Perth Amboy may not support public recreational bathing. There are many years of data available from the days when we monitored that area as an "environmental" monitoring site only, NOT as a recreational beach. Those results indicate that the water there may not support primary contact. However, since this was an environmental site only, we do not have the repeat samples that are required after an exceedance of the bacteria standard as required at a true recreational bathing beach. I believed we stopped collecting those sample results sometime around 2006. I do have the old data that I can send to you when I get back to the office after the new year.

I'm not sure who you are talking to in Perth Amboy but if they want to open the beach area as a true swimming beach, the Public Recreational Bathing rule, N.J.A.C. 8:26 will provide them with the guidance they need. The beach must be inspected for safety (under water), have a full set of safety equipment, provide a lifeguard, and have water quality that supports swimming. They also may need to provide a restroom in the area. They would need to work with the Middlesex County Health Department to begin water quality monitoring again. As you may know, there are many potential water quality issues in that area, not just bacteria. Their first contact should be with the MxCoHD.

Adriana, what was the outcome when they were asking you about opening the park as a bathing beach? Are these repeated requests for a swimming beach coming from the same people?

Virginia

Virginia Loftin
NJDEP Cooperative Coastal Monitoring/Clean Shores Program
609-984-5599

From: Foster, Rebecca
Sent: Tuesday, December 20, 2016 9:39:04 AM
To: Loftin, Virginia
Subject: Question

Hi Virginia –

I'm pretty sure you aren't the exact person I need to be reaching out to, but I'm not sure who that person is and thought you could lead me in the right direction. Perth Amboy reached out to me to see what they would need to do to open up one of their public access areas as a swimming area. I know that DEP does some amount of testing, along with the county health departments, in the ocean and bay waters during the season, and that DOH has other requirements for swimming areas. So what I'm wondering is if a new swimming area is opened, what does the town do to make sure their waterbody is on the list to get tested?

Do you know who I'd talk to about this?
Thanks so much!! I hope you had a great holiday.
Becky

Rebecca Foster
NJ Coastal Management Program
Office of Coastal and Land Use Planning, NJDEP
401 East State St, 7W
Mail Code 401-07C, PO Box 420
Trenton, NJ 08625-0420
609-292-4612

Please note that my email address has changed to rebecca.foster@dep.nj.gov.

Mathieson, Marcus

From: Steve Jobin <sjobin@rbaymca.org>
Sent: Tuesday, December 20, 2016 4:20 PM
To: DEP MPAP
Cc: Caldarelli, Adriana
Subject: RE: Beach Swimming in Perth Amboy

Good afternoon Becky:

Thanks so much for the follow up.

I will forward your message to Ken Ortiz, the Director of Human Services.

I've already connected him to the Health Department.

Thanks again for the info.

Merry Christmas!!!!

Be well.

Steve

Steve Jobin
President/CEO
RARITAN BAY AREA YMCA
357 New Brunswick Avenue, Perth Amboy NJ 08861
(P) 732.442.3632 (F) 732.324.6359
(E) sjobin@rbaymca.org (W) www.rbaymca.org

From: DEP MPAP [mailto:MPAP@dep.nj.gov]
Sent: Tuesday, December 20, 2016 4:07 PM
To: Steve Jobin
Cc: Caldarelli, Adriana
Subject: RE: Beach Swimming in Perth Amboy

Hi Steve –
I looked into this issue a bit more and wanted to provide you with more detailed information so what I provided you wasn't complete.

To open a beach as a true swimming beach, the City should refer to the Public Recreational Bathing rule, N.J.A.C. 8:26, to provide you with the guidance you need. The beach must be inspected for safety (under water), have a full set of safety equipment, provide a lifeguard, and have water quality that supports swimming. There must also be a restroom area provided. You would need to work with the Middlesex County Health Department to begin water quality monitoring. Past monitoring of the area provided data that the water quality at the park in Perth Amboy may not support public recreational bathing. There are many potential water quality issues in this area, not just bacteria. So your first contact should be the county health department.

Perth Amboy has reached out to DEP in the past to inquire about creating a swimming beach. The Department contact for this information has been Adriana Caldarelli, who I've copied on this email. Her contacts at the City have been William Kurzenberger and Annie Hindenlang.

I hope this information is useful.
Becky

From: Steve Jobin [mailto:sjobin@rbaymca.org]
Sent: Monday, December 05, 2016 12:56 PM
To: DEP MPAP
Subject: Re: Beach Swimming in Perth Amboy

Thanks Becky.

Sent from my iPhone

On Dec 5, 2016, at 9:38 AM, DEP MPAP <MPAP@dep.nj.gov> wrote:

Hi Steve –
The process to create a swimming area is really under municipal authority. Some points to consider - the DEP, along with county health departments, will test ocean and bay waters during the summer season and may close waters as a result. The Department of Health has regulations that regulate swimming areas, in part that say that lifeguards and other things are required for an area to be open for swimming. Otherwise, municipalities have the authority under their police powers to open or close areas for swimming. So, if Perth Amboy wants to open this beach for swimming, and the State is not otherwise requiring it to be closed, they are allowed.

Please let me know if I can provide additional assistance.
Becky

Rebecca Foster
NJ Coastal Management Program
Office of Coastal and Land Use Planning, NJDEP
401 East State St, 7W
Mail Code 401-07C, PO Box 420
Trenton, NJ 08625-0420
609-292-4612

Please note that my email address has changed to rebecca.foster@dep.nj.gov.

From: Steve Jobin [mailto:sjobin@rbaymca.org]
Sent: Friday, November 25, 2016 10:53 AM
To: DEP MPAP
Subject: Beach Swimming in Perth Amboy

Good morning:

I've been asked by the City of Perth Amboy to inquire about creating swimming activities at the beach located on the Raritan Bay, in Perth Amboy, NJ.

Is this possible? And, if so, are you able to guide me on the process?

Feel free to call me at 732-882-8454.

Be well.

Steve
Steve Jobin
President/CEO
RARITAN BAY AREA YMCA
357 New Brunswick Avenue, Perth Amboy NJ 08861

(P) 732.442.3632 (F) 732.324.6359
(E) sjobin@rbaymca.org (W) www.rbaymca.org

Mathieson, Marcus

From: Loftin, Virginia <Virginia.Loftin@dep.nj.gov>
Sent: Thursday, February 02, 2017 11:16 AM
To: wkurzenberger@perthamboynj.org
Cc: Lindner, William; Caldarelli, Adriana; Foster, Rebecca; jrauch@centerstateengineering.com
Subject: Potential Perth Amboy bathing beach

Hi William,
It was a pleasure speaking with you this morning. As we discussed, I would be interested in seeing the water quality data your local group collected to get an idea of the recent bacteria results at the locations you identified. Since you mentioned that bacteria levels increase after rainfall, the proposed bathing beach should probably have a provisional rainfall policy where the beach would be closed following a predetermined rainfall threshold. That is something we can discuss after review of the data.

Below is a link to the NJ Department of Health Public Recreational Bathing rule. This document will give you the information on requirements to open a recreational bathing beach; inspections, lifeguards, safety equipment, etc. Since the beach is in marine waters, it would be included in the NJDEP Cooperative Coastal Monitoring Program. The beach would be shown on our beach web page and data would be required to be entered in to our beach data system. You can get information on the beach program on our website at www.njbeaches.org.

http://www.state.nj.us/health/ceohs/documents/phss/recbathing.pdf

I recommend that you contact the Middlesex County Health Department's environmental health program. I've worked with them in the past but don't know if the same staff is still there.

Please feel free to contact me if you have any questions or need any additional information.

Virginia

Virginia Loftin
NJDEP Bureau of Marine Water Monitoring
Cooperative Coastal Monitoring/Clean Shores Programs
PO Box 420 MC 401-041
Trenton, NJ 08625
ph: 609-984-5599
fax: 609-633-1276
www.njbeaches.org

Place Logo Here

AGENCY NAME HERE

OPEN PUBLIC RECORDS ACT REQUEST FORM

Agency Address
Agency Telephone Number & Fax Number
Agency e-mail address
Name of Agency Custodian

Place Logo Here

Important Notice

The last page of this form contains important information related to your rights concerning government records. Please read it carefully.

Requestor Information – Please Print

First Name Jean MI ______ Last Name Malafronte

E-mail Address jmalafronte@greeley-hansen.com

Mailing Address 1700 Market Street, Suite 2130

City Philadelphia State PA Zip 19103

Telephone 215-553-7912 FAX 215-563-1139

Preferred Delivery: Pick Up ______ US Mail X On-Site Inspect ______ Fax ______ E-mail ______

If you are requesting records containing personal information, please circle one: Under penalty of N.J.S.A. 2C:28-3, I certify that I ***HAVE / HAVE NOT*** been convicted of any indictable offense under the laws of New Jersey, any other state, or the United States.

Signature ______________________ Date ______________

Payment Information

Maximum Authorization Cost $

Select Payment Method

Cash Check Money Order

Fees: Letter size pages - $0.05 per page
Legal size pages - $0.07 per page
Other materials (CD, DVD, etc) – actual cost of material

Delivery: Delivery / postage fees additional depending upon delivery type.

Extras: Special service charge dependent upon request.

Record Request Information: Please be as specific as possible in describing the records being requested. Also, please note that your preferred method of delivery will only be accommodated if the custodian has the technological means and the integrity of the records will not be jeopardized by such method of delivery.

Pursuant to the New Jersey Open Public Records Act and the common law right to inspect public records, please provide in electronic format any reports and documents from the NJDEP Division of Science, Research and Environmental Health that are dated or were developed between the years 2007-2016 regarding:

- Waters with Shellfish Beds
- Waters with Primary Contact Recreation
- Waters with threatened or endangered species and their habitat

We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include:

- Passaic River from Montville to Newark Bay and its tributaries:
  Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel
- Hackensack River from the Oradell Reservoir to Newark Bay and its tributaries:
  Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek
- Newark Bay
- Hudson River from the George Washington Bridge to the Upper Newark Bay
- Upper Newark Bay
- Kill Van Kull
- Arthur Kill and its tributaries:
  Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek
- Raritan River from Bound Brook to the Raritan Bay and its tributaries:
  Bound Brook
- Raritan Bay

AGENCY USE ONLY

Est. Document Cost ______
Est. Delivery Cost ______
Est. Extras Cost ______
Total Est. Cost ______
Deposit Amount ______
Estimated Balance ______
Deposit Date ______

AGENCY USE ONLY

Disposition Notes
Custodian: If any part of request cannot be delivered in seven business days, detail reasons here.

In Progress	-	Open	
Denied	-	Closed	
Filled	-	Closed	
Partial	-	Closed	

AGENCY USE ONLY

Tracking Information		Final Cost	
Tracking #		Total	
Rec'd Date		Deposit	
Ready Date		Balance Due	
Total Pages		Balance Paid	

Records Provided

Custodian Signature Date

State of New Jersey
Department of Environmental Protection
GOVERNMENT RECORDS REQUEST FORM

IMPORTANT NOTICE

Please read this entire form carefully as it contains important information concerning the response to your record request, accessing records, disputing denials, and your rights concerning government records. For further information, access WWW.NJ.GOV/DEP/OPRA.

Requestor Information

First Name:	JEAN	MI		Last Name	MALAFRONTE
Company:	GREELEY AND HANSEN LLC				
Mailing Address:	1700 MARKET ST, SUITE 1230				
City:	Philadelphia	State: PA	Zip: 19103	Email:	jmalafronte@greeley-hansen.com
Business Telephone:	(215) 553-7912			Extension	
Facsimile Telephone:	(215) 563-1139				

State Use Only

Tracking #	205589
Received Date	03/20/2017
Access Method	**Send Electronic copies**

All matters relating to the response and access of any records identified for this request should be directed to:

NJDEP – Office of Record Access
401 East State Street
PO Box 420 Mail Code 401-06Q
Trenton, New Jersey 08625-0420
Tele #: (609) 341-3121
Fax #: (609) 292-1177

Record Request Details:

Pursuant to the New Jersey Open Public Records Act and the common law right to inspect public records, please provide in electronic format any reports and documents from the NJDEP Division of Science, Research and Environmental Health that are dated or were developed between the years 2007-2016 regarding: __Waters with Shellfish Beds __Waters with Primary Contact Recreation __Waters with threatened or endangered species and their habitat We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include: __Passaic River from Montville to Newark Bay and its tributaries: Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel __Hackensack River from the Oradell Reservoir to Newark Bay and its tributaries: Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek __Newark Bay __Hudson River from the George Washington Bridge to the Upper Newark Bay __Upper Newark Bay __Kill Van Kull __Arthur Kill and its tributaries: Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek __Raritan River from Bound Brook to the Raritan Bay and its tributaries: Bound Brook __Raritan Bay

Disposition Notes

The NJDEP has revised its response to your request. Please see the "Revised Addendum Disposition Notes" on Page 3.

Record Request Response

In Progress	–	Open	<NONE FOUND>
Filled	–	Closed	X
Denied	–	Closed	<NONE FOUND>
Partial	–	Closed	<NONE FOUND>

Addendum Disposition Notes: NONE

03/23/2017

Custodian Signature **Date**

Information Regarding the Requested Records		
If your request is in reference to a single facility, please provide the name of the facility, and the name of the operator name of the facility:	Facility Name: Operator Name:	
Please provide the owner name the facility or parcel of land:	Owner Name:	
If your request is in reference to a specific parcel of land, please provide the street address, block, lot and property owner of the parcel of land: (Note: if the property in question is over multiple blocks and lots, please list all in the description field below)	Street Address 1: Street Address 2: Block: Lot:	
If your request is in reference to a facility, site or parcel of land, please provide the Municipality and County where the facility, site or parcel of land is located:	County: Municipality:	
If the request is in reference to a particular permit issued by NJDEP, please provide the type of permit and any identifying numbers such as permit, incident or case numbers. (i.e. Fishing, Hunting, Hazardous Waste, Solid Waste, Land Use, NJPDES, Pesticides, Stream Encroachment, TWA, UST, Water Allocation)	List Permit Type:	List ID Numbers:
If your request is in reference to an individual, please provide the individual's name and type, and if the individual is a DEP employee, your relationship with the individual:	Individual's name: Type of Individual: Relationship:	
If the an individual was specified above, the individual was DEP Licensed, please specify the license type the individual holds:	License Type:	

The New Jersey Department of Environmental Protection has responded to your submitted Open Public Records Act (OPRA) record request. The following information will help you understand the response and your next available actions.

Tracking #: This is the Department's assigned Tracking # to your OPRA record request, which should be used in all corresponding matters.

Record Request Response:

- **In Progress** – Based on the nature of the request, the records sought, and/or the manner to which the records may exists, the Department requires additional time to investigate and respond to the request.
- **Filled** – Based on the information provided in your request, the Department was able to investigate and respond to your record request.
- **Denied** – Based on the nature of the request and/or the records sought, the Department has denied your request pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.
- **Partial** – The Department has identified both responsive government records and records being denied based on the nature of the request and/or the records sought, that do not meet the definition of a government record pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.

Disposition Notes: Provides detailed information concerning the Department's response to your request.

Accessing Records: Dependent on the volume of records and your interest, there are five (5) methods available to access the responsive government records:

- **File Review** – Schedule a file review with the Department to directly access the records and take notes or tag records of interest for copying. Copying can be performed by either the Department's onsite Copying Unit at State duplication fee costs or by the requester employing a Copy Vendor Service. If there are records stored in archives, a five-day processing period will be included prior to scheduling a review.
- **Copy Request** – All records of interest will be copied by the Department's onsite Copying Unit at State duplication fee costs unless a Copy Vendor Service is employed.
- **Electronic Records Request** – Dependent on the size & nature of the e-records, the Department will email the records or provide a CD or DVD.
- **Fax Request** – Based on the number of pages, the Department faxes the responsive records.
- **Web Access** – The responsive records can be access directly through the Department's web site. Web address will be provided.

Access to Government Records Under the New Jersey Open Public Records Act (N.J.S.A. 47:1A-1 et seq.)

1. The fees for duplication of a government record are specified below. We will notify you of any special charges, special service charges or other additional charges authorized by State law or regulation before processing your request. Payment shall be made by check or money order payable to the State of New Jersey and mailed to the address specified below.

Hard Copies:	Letter & Legal size	= $0.05 per page	**Electronic Records:**	CDs =	$0.55 per CD
	Oversized Maps (Color)	= $5.00 per map		DVDs =	$0.55 per DVD
	Oversized Maps (B&W)	= $3.00 per map			

2. Pursuant to OPRA (C.47:1A-5c & C47:1A-5d), the Department will apply special service charge for any extraordinary expenditure of time and effort to accommodate a request. The special service charge will be based on the actual direct cost of providing the records. The requester shall have the opportunity to review and object to the charge prior to it being incurred; however, in the event the requester objects to the special service charge, the request will be closed and access to the records will not be granted.
3. By law, the Department must notify you that it grants or denies a request for access to government records within seven business days after the custodian of the record requested receives the request, provided that the record is currently available and not in storage. If the record requested is not currently available or is in storage, the custodian will advise you within seven business days when the record can be made available and the estimated cost. You may agree with the custodian to extend the time for making records available, or granting or denying your request.
4. You may be denied access to a government record if your request would substantially disrupt agency operations and the custodian is unable to reach a reasonable solution with you.
5. If the Department was unable to comply with your request for access to a government record, the custodian will indicate the reasons for denial on the request form.
6. Except as otherwise provided by law or by agreement with the requester, if the custodian of the record requested fails to respond to you within seven business days of receiving a request form, the failure to respond will be considered a denial of your request.
7. **Resolution of Disputed Findings:**

   In the event that a requester does not agree with the Department's record response, the requester should:

   No Records - Reexamined the request details to evaluate if all of the information was provided that could aid the Department in locating records. The Department's ability to identify records of interest is in direct correlation to matching the Department information with the information provided on the request. Such important identifiers are Facility/Site Name, Address, Case #, Permit #, Block/Lot.

   Denial - If your request for access to a government record has been denied or unfilled within the time permitted by law, you have a right to challenge the decision by the Department to deny access. The Department denies access to records only when those records do not meet the definition of a government record and/or public access is not allowed pursuant to the law. At your option, you may either:

   a. Contact the Office of Record Access to re-visit the matter or provide further explanation.

   b. Institute a proceeding in the Superior Court of New Jersey

   c. File a complaint in writing with the Government Records Council (GRC). You may contact the GRC by toll-free telephone at 866-850-0511, by mail at PO Box 819, Trenton, NJ, 08625, by e-mail at *grc@dca.state.nj.us*, or at their web site at *www.state.nj.us/grc*. The Council can also respond to other questions about the law.
8. Information provided on this form may be subject to disclosure under the Open Public Records Act.

Revised Addendum Disposition Notes: Waters with threatened or endangered species and their habitat? are the already publicly available landscape maps. The maps are available at this site: http://www.nj.gov/dep/gis/landscape.html. Note that this currently provides links to Landscape Project data version 3.1. A new version will be released in the next few weeks. In addition, information regarding Waters with Shellfish Beds and Waters with Primary Contact Recreation may be available at the following link: http://www.state.nj.us/dep/dsr/publications/pub.htm. Requestor may reach the office with any questions at 609-341-3121.

State of New Jersey
Department of Environmental Protection
GOVERNMENT RECORDS REQUEST FORM

IMPORTANT NOTICE

Please read this entire form carefully as it contains important information concerning the response to your record request, accessing records, disputing denials, and your rights concerning government records. For further information, access WWW.NJ.GOV/DEP/OPRA.

Requestor Information

First Name: JEAN	MI	Last Name MALAFRONTE
Company: GREELEY AND HANSEN LLC	
Mailing Address: 1700 MARKET ST, SUITE 1230	
City: Philadelphia State: PA Zip: 19103	Email: jmalafronte@greeley-hansen.com
Business Telephone: (215) 553-7912	Extension
Facsimile Telephone: (215) 563-1139	

State Use Only

Tracking #	205589
Received Date	03/20/2017
Access Method	**Send Electronic copies**

All matters relating to the response and access of any records identified for this request should be directed to:

NJDEP – Office of Record Access
401 East State Street
PO Box 420 Mail Code 401-06Q
Trenton, New Jersey 08625-0420
Tele #: (609) 341-3121
Fax #: (609) 292-1177

Record Request Details:

Pursuant to the New Jersey Open Public Records Act and the common law right to inspect public records, please provide in electronic format any reports and documents from the NJDEP Division of Science, Research and Environmental Health that are dated or were developed between the years 2007-2016 regarding: __Waters with Shellfish Beds __Waters with Primary Contact Recreation __Waters with threatened or endangered species and their habitat We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include: __Passaic River from Montville to Newark Bay and its tributaries: Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel __Hackensack River from the Oradell Reservoir to Newark Bay and its tributaries: Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek __Newark Bay __Hudson River from the George Washington Bridge to the Upper Newark Bay __Upper Newark Bay __Kill Van Kull __Arthur Kill and its tributaries: Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek __Raritan River from Bound Brook to the Raritan Bay and its tributaries: Bound Brook __Raritan Bay

Disposition Notes

Based on this record request, responsive records have been identified and available for direct access at the web address cited below. Requester should contact the Office of Record Access at 609-341-3121 with any further concerns.

Record Request Response

In Progress	–	Open	
Filled	–	Closed	X
Denied	–	Closed	
Partial	–	Closed	

Addendum Disposition Notes: Waters with threatened or endangered species and their habitat? are the already publicly available landscape maps. The maps are available at this site: http://www.nj.gov/dep/gis/landscape.html. Note that this currently provides links to Landscape Project data version 3.1. A new version will be released in the next few weeks.

Matthew J. Coefer 03/21/2017

Custodian Signature **Date**

Information Regarding the Requested Records		
If your request is in reference to a single facility, please provide the name of the facility, and the name of the operator name of the facility:	Facility Name: Operator Name:	
Please provide the owner name the facility or parcel of land:	Owner Name:	
If your request is in reference to a specific parcel of land, please provide the street address, block, lot and property owner of the parcel of land: (Note: if the property in question is over multiple blocks and lots, please list all in the description field below)	Street Address 1: Street Address 2: Block: Lot:	
If your request is in reference to a facility, site or parcel of land, please provide the Municipality and County where the facility, site or parcel of land is located:	County: Municipality:	
If the request is in reference to a particular permit issued by NJDEP, please provide the type of permit and any identifying numbers such as permit, incident or case numbers. (i.e. Fishing, Hunting, Hazardous Waste, Solid Waste, Land Use, NJPDES, Pesticides, Stream Encroachment, TWA, UST, Water Allocation)	List Permit Type:	List ID Numbers:
If your request is in reference to an individual, please provide the individual's name and type, and if the individual is a DEP employee, your relationship with the individual:	Individual's name: Type of Individual: Relationship:	
If the an individual was specified above, the individual was DEP Licensed, please specify the license type the individual holds:	License Type:	

The New Jersey Department of Environmental Protection has responded to your submitted Open Public Records Act (OPRA) record request. The following information will help you understand the response and your next available actions.

Tracking #: This is the Department's assigned Tracking # to your OPRA record request, which should be used in all corresponding matters.

Record Request Response:

- **In Progress** – Based on the nature of the request, the records sought, and/or the manner to which the records may exists, the Department requires additional time to investigate and respond to the request.
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- **Partial** – The Department has identified both responsive government records and records being denied based on the nature of the request and/or the records sought, that do not meet the definition of a government record pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.

Disposition Notes: Provides detailed information concerning the Department's response to your request.

Accessing Records: Dependent on the volume of records and your interest, there are five (5) methods available to access the responsive government records:

- **File Review** – Schedule a file review with the Department to directly access the records and take notes or tag records of interest for copying. Copying can be performed by either the Department's onsite Copying Unit at State duplication fee costs or by the requester employing a Copy Vendor Service. If there are records stored in archives, a five-day processing period will be included prior to scheduling a review.
- **Copy Request** – All records of interest will be copied by the Department's onsite Copying Unit at State duplication fee costs unless a Copy Vendor Service is employed.
- **Electronic Records Request** – Dependent on the size & nature of the e-records, the Department will email the records or provide a CD or DVD.
- **Fax Request** – Based on the number of pages, the Department faxes the responsive records.
- **Web Access** – The responsive records can be access directly through the Department's web site. Web address will be provided.

1. The fees for duplication of a government record are specified below. We will notify you of any special charges, special service charges or other additional charges authorized by State law or regulation before processing your request. Payment shall be made by check or money order payable to the State of New Jersey and mailed to the address specified below.

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	Oversized Maps (Color)	= $5.00 per map		DVDs = $0.55 per DVD
	Oversized Maps (B&W)	= $3.00 per map		

2. Pursuant to OPRA (C.47:1A-5c & C47:1A-5d), the Department will apply special service charge for any extraordinary expenditure of time and effort to accommodate a request. The special service charge will be based on the actual direct cost of providing the records. The requester shall have the opportunity to review and object to the charge prior to it being incurred; however, in the event the requester objects to the special service charge, the request will be closed and access to the records will not be granted.

3. By law, the Department must notify you that it grants or denies a request for access to government records within seven business days after the custodian of the record requested receives the request, provided that the record is currently available and not in storage. If the record requested is not currently available or is in storage, the custodian will advise you within seven business days when the record can be made available and the estimated cost. You may agree with the custodian to extend the time for making records available, or granting or denying your request.

4. You may be denied access to a government record if your request would substantially disrupt agency operations and the custodian is unable to reach a reasonable solution with you.

5. If the Department was unable to comply with your request for access to a government record, the custodian will indicate the reasons for denial on the request form.

6. Except as otherwise provided by law or by agreement with the requester, if the custodian of the record requested fails to respond to you within seven business days of receiving a request form, the failure to respond will be considered a denial of your request.

7. **Resolution of Disputed Findings:**

In the event that a requester does not agree with the Department's record response, the requester should:

No Records - Reexamined the request details to evaluate if all of the information was provided that could aid the Department in locating records. The Department's ability to identify records of interest is in direct correlation to matching the Department information with the information provided on the request. Such important identifiers are Facility/Site Name, Address, Case #, Permit #, Block/Lot.

Denial - If your request for access to a government record has been denied or unfilled within the time permitted by law, you have a right to challenge the decision by the Department to deny access. The Department denies access to records only when those records do not meet the definition of a government record and/or public access is not allowed pursuant to the law. At your option, you may either:

a. Contact the Office of Record Access to re-visit the matter or provide further explanation.

b. Institute a proceeding in the Superior Court of New Jersey

c. File a complaint in writing with the Government Records Council (GRC). You may contact the GRC by toll-free telephone at 866-850-0511, by mail at PO Box 819, Trenton, NJ, 08625, by e-mail at *grc@dca.state.nj.us*, or at their web site at *www.state.nj.us/grc*. The Council can also respond to other questions about the law.

8. Information provided on this form may be subject to disclosure under the Open Public Records Act.

Revised Addendum Disposition Notes: NONE

Place Logo Here

AGENCY NAME HERE

OPEN PUBLIC RECORDS ACT REQUEST FORM

Agency Address
Agency Telephone Number & Fax Number
Agency e-mail address
Name of Agency Custodian

Place Logo Here

Important Notice

The last page of this form contains important information related to your rights concerning government records. Please read it carefully.

Requestor Information – Please Print

First Name Jean MI ______ Last Name Malafronte

E-mail Address jmalafronte@greeley-hansen.com

Mailing Address 1700 Market Street, Suite 2130

City Philadelphia State PA Zip 19103

Telephone 215-553-7912 FAX 215-563-1139

Preferred Delivery: Pick Up ______ US Mail X On-Site Inspect ______ Fax ______ E-mail ______

If you are requesting records containing personal information, please circle one: Under penalty of N.J.S.A. 2C:28-3, I certify that I ***HAVE / HAVE NOT*** been convicted of any indictable offense under the laws of New Jersey, any other state, or the United States.

Signature ______ Date ______

Payment Information

Maximum Authorization Cost $

Select Payment Method

Cash Check Money Order

Fees: Letter size pages - $0.05 per page
Legal size pages - $0.07 per page
Other materials (CD, DVD, etc) – actual cost of material

Delivery: Delivery / postage fees additional depending upon delivery type.

Extras: Special service charge dependent upon request.

Record Request Information: Please be as specific as possible in describing the records being requested. Also, please note that your preferred method of delivery will only be accommodated if the custodian has the technological means and the integrity of the records will not be jeopardized by such method of delivery.

Pursuant to the New Jersey Open Public Records Act and the common law right to inspect public records, please provide in electronic format any reports and documents from the NJDEP Division of Water Monitoring and Standards that are dated or were developed between the years 2007-2016 regarding:

- Waters with Primary Contact Recreation
- Drinking Water Intakes or their designated protected areas

We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include:

- Passaic River from Montville to Newark Bay and its tributaries:
  Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel
- Hackensack River from the Oradell Reservoir to Newark Bay and its tributaries:
  Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek
- Newark Bay
- Hudson River from the George Washington Bridge to the Upper Newark Bay
- Upper Newark Bay
- Kill Van Kull
- Arthur Kill and its tributaries:
  Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek
- Raritan River from Bound Brook to the Raritan Bay and its tributaries:
  Bound Brook
- Raritan Bay

AGENCY USE ONLY

Est. Document Cost ______
Est. Delivery Cost ______
Est. Extras Cost ______
Total Est. Cost ______
Deposit Amount ______
Estimated Balance ______
Deposit Date ______

AGENCY USE ONLY

Disposition Notes
Custodian: If any part of request cannot be delivered in seven business days, detail reasons here.

In Progress - Open ______
Denied - Closed ______
Filled - Closed ______
Partial - Closed ______

AGENCY USE ONLY

Tracking Information
Tracking # ______
Rec'd Date ______
Ready Date ______
Total Pages ______

Final Cost
Total ______
Deposit ______
Balance Due ______
Balance Paid ______

Records Provided

Custodian Signature ______ Date ______

State of New Jersey
Department of Environmental Protection
GOVERNMENT RECORDS REQUEST FORM

IMPORTANT NOTICE

Please read this entire form carefully as it contains important information concerning the response to your record request, accessing records, disputing denials, and your rights concerning government records. For further information, access WWW.NJ.GOV/DEP/OPRA.

Requestor Information

First Name: JEAN	MI	Last Name MALAFRONTE
Company: GREELEY AND HANSEN	
Mailing Address: 1700 MARKET ST, SUITE 2130	
City: Philadelphia State: PA Zip: 19103	Email: jmalafronte@greeley-hansen.com
Business Telephone: (215) 553-7912	Extension
Facsimile Telephone: (215) 563-1139	

State Use Only

Tracking #	205588
Received Date	03/20/2017
Access Method	**Send Electronic copies**

All matters relating to the response and access of any records identified for this request should be directed to:

NJDEP – Office of Record Access
401 East State Street
PO Box 420 Mail Code 401-06Q
Trenton, New Jersey 08625-0420
Tele #: (609) 341-3121
Fax #: (609) 292-1177

Record Request Details:

Pursuant to the New Jersey Open Public Records Act and the common law right to inspect public records, please provide in electronic format any reports and documents from the NJDEP Division of Water Monitoring and Standards that are dated or were developed between the years 2007-2016 regarding: __Waters with Primary Contact Recreation __Drinking Water Intakes or their designated protected areas We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include: __Passaic River from Montville to Newark Bay and its tributaries: Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel __Hackensack River from the Oradell Reservoir to Newark Bay and its tributaries: Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek __Newark Bay __Hudson River from the George Washington Bridge to the Upper Newark Bay __Upper Newark Bay __Kill Van Kull __Arthur Kill and its tributaries: Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek __Raritan River from Bound Brook to the Raritan Bay and its tributaries: Bound Brook __Raritan Bay

Disposition Notes

The Office of Record Access has identified this request to be duplicate of another request recently submitted by you and referencedbelow. Therefore this request has been closed. Requester may call 609-341-3121 to obtain further information.

Record Request Response

In Progress	–	Open	
Filled	–	Closed	X
Denied	–	Closed	
Partial	–	Closed	

Addendum Disposition Notes: Request is a duplicate of OPRA Request 205580.

Matthew J. Coefer 03/28/2017

Custodian Signature **Date**

Information Regarding the Requested Records		
If your request is in reference to a single facility, please provide the name of the facility, and the name of the operator name of the facility:	Facility Name: Operator Name:	
Please provide the owner name the facility or parcel of land:	Owner Name:	
If your request is in reference to a specific parcel of land, please provide the street address, block, lot and property owner of the parcel of land: (Note: if the property in question is over multiple blocks and lots, please list all in the description field below)	Street Address 1: Street Address 2: Block: Lot:	
If your request is in reference to a facility, site or parcel of land, please provide the Municipality and County where the facility, site or parcel of land is located:	County: Municipality:	
If the request is in reference to a particular permit issued by NJDEP, please provide the type of permit and any identifying numbers such as permit, incident or case numbers. (i.e. Fishing, Hunting, Hazardous Waste, Solid Waste, Land Use, NJPDES, Pesticides, Stream Encroachment, TWA, UST, Water Allocation)	List Permit Type:	List ID Numbers:
If your request is in reference to an individual, please provide the individual's name and type, and if the individual is a DEP employee, your relationship with the individual:	Individual's name: Type of Individual: Relationship:	
If the an individual was specified above, the individual was DEP Licensed, please specify the license type the individual holds:	License Type:	

The New Jersey Department of Environmental Protection has responded to your submitted Open Public Records Act (OPRA) record request. The following information will help you understand the response and your next available actions.

Tracking #: This is the Department's assigned Tracking # to your OPRA record request, which should be used in all corresponding matters.

Record Request Response:

- **In Progress** – Based on the nature of the request, the records sought, and/or the manner to which the records may exists, the Department requires additional time to investigate and respond to the request.
- **Filled** – Based on the information provided in your request, the Department was able to investigate and respond to your record request.
- **Denied** – Based on the nature of the request and/or the records sought, the Department has denied your request pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.
- **Partial** – The Department has identified both responsive government records and records being denied based on the nature of the request and/or the records sought, that do not meet the definition of a government record pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.

Disposition Notes: Provides detailed information concerning the Department's response to your request.

Accessing Records: Dependent on the volume of records and your interest, there are five (5) methods available to access the responsive government records:

- **File Review** – Schedule a file review with the Department to directly access the records and take notes or tag records of interest for copying. Copying can be performed by either the Department's onsite Copying Unit at State duplication fee costs or by the requester employing a Copy Vendor Service. If there are records stored in archives, a five-day processing period will be included prior to scheduling a review.
- **Copy Request** – All records of interest will be copied by the Department's onsite Copying Unit at State duplication fee costs unless a Copy Vendor Service is employed.
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- **Fax Request** – Based on the number of pages, the Department faxes the responsive records.
- **Web Access** – The responsive records can be access directly through the Department's web site. Web address will be provided.

Access to Government Records Under the New Jersey Open Public Records Act (N.J.S.A. 47:1A-1 et seq.)

1. The fees for duplication of a government record are specified below. We will notify you of any special charges, special service charges or other additional charges authorized by State law or regulation before processing your request. Payment shall be made by check or money order payable to the State of New Jersey and mailed to the address specified below.

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	Oversized Maps (Color)	= $5.00 per map		DVDs = $0.55 per DVD
	Oversized Maps (B&W)	= $3.00 per map		

2. Pursuant to OPRA (C.47:1A-5c & C47:1A-5d), the Department will apply special service charge for any extraordinary expenditure of time and effort to accommodate a request. The special service charge will be based on the actual direct cost of providing the records. The requester shall have the opportunity to review and object to the charge prior to it being incurred; however, in the event the requester objects to the special service charge, the request will be closed and access to the records will not be granted.
3. By law, the Department must notify you that it grants or denies a request for access to government records within seven business days after the custodian of the record requested receives the request, provided that the record is currently available and not in storage. If the record requested is not currently available or is in storage, the custodian will advise you within seven business days when the record can be made available and the estimated cost. You may agree with the custodian to extend the time for making records available, or granting or denying your request.
4. You may be denied access to a government record if your request would substantially disrupt agency operations and the custodian is unable to reach a reasonable solution with you.
5. If the Department was unable to comply with your request for access to a government record, the custodian will indicate the reasons for denial on the request form.
6. Except as otherwise provided by law or by agreement with the requester, if the custodian of the record requested fails to respond to you within seven business days of receiving a request form, the failure to respond will be considered a denial of your request.
7. **Resolution of Disputed Findings:**

   In the event that a requester does not agree with the Department's record response, the requester should:

   No Records - Reexamined the request details to evaluate if all of the information was provided that could aid the Department in locating records. The Department's ability to identify records of interest is in direct correlation to matching the Department information with the information provided on the request. Such important identifiers are Facility/Site Name, Address, Case #, Permit #, Block/Lot.

   Denial - If your request for access to a government record has been denied or unfilled within the time permitted by law, you have a right to challenge the decision by the Department to deny access. The Department denies access to records only when those records do not meet the definition of a government record and/or public access is not allowed pursuant to the law. At your option, you may either:

   a. Contact the Office of Record Access to re-visit the matter or provide further explanation.

   b. Institute a proceeding in the Superior Court of New Jersey

   c. File a complaint in writing with the Government Records Council (GRC). You may contact the GRC by toll-free telephone at 866-850-0511, by mail at PO Box 819, Trenton, NJ, 08625, by e-mail at *grc@dca.state.nj.us*, or at their web site at *www.state.nj.us/grc*. The Council can also respond to other questions about the law.
8. Information provided on this form may be subject to disclosure under the Open Public Records Act.

Revised Addendum Disposition Notes: NONE

State of New Jersey
Department of Environmental Protection
GOVERNMENT RECORDS REQUEST FORM

IMPORTANT NOTICE

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Requestor Information

First Name:	JEAN	MI		Last Name	MALAFRONTE		
Company:	GREELEY AND HANSEN						
Mailing Address:	1700 MARKET ST, SUITE 2130						
City:	Philadelphia	State:	PA	Zip:	19103	Email:	jmalafronte@greeley-hansen.com
Business Telephone:	(215) 553-7912					Extension	
Facsimile Telephone:	(215) 563-1139						

State Use Only

Tracking #	205588
Received Date	03/20/2017
Access Method	**Send Electronic copies**

All matters relating to the response and access of any records identified for this request should be directed to:

NJDEP – Office of Record Access
401 East State Street
PO Box 420 Mail Code 401-06Q
Trenton, New Jersey 08625-0420

Tele #: (609) 341-3121
Fax #: (609) 292-1177

Record Request Details:

Pursuant to the New Jersey Open Public Records Act and the common law right to inspect public records, please provide in electronic format any reports and documents from the NJDEP Division of Water Monitoring and Standards that are dated or were developed between the years 2007-2016 regarding: __Waters with Primary Contact Recreation __Drinking Water Intakes or their designated protected areas We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include: __Passaic River from Montville to Newark Bay and its tributaries: Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel __Hackensack River from the Oradell Reservoir to Newark Bay and its tributaries: Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek __Newark Bay __Hudson River from the George Washington Bridge to the Upper Newark Bay __Upper Newark Bay __Kill Van Kull __Arthur Kill and its tributaries: Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek __Raritan River from Bound Brook to the Raritan Bay and its tributaries: Bound Brook __Raritan Bay

Disposition Notes

The NJDEP has revised its response to your request. Please see the "Revised Addendum Disposition Notes" on Page 3.

Record Request Response

In Progress	–	Open	<NONE FOUND>
Filled	–	Closed	X
Denied	–	Closed	<NONE FOUND>
Partial	–	Closed	<NONE FOUND>

Addendum Disposition Notes: NONE

04/05/2017

Custodian Signature **Date**

Information Regarding the Requested Records		
If your request is in reference to a single facility, please provide the name of the facility, and the name of the operator name of the facility:	Facility Name: Operator Name:	
Please provide the owner name the facility or parcel of land:	Owner Name:	
If your request is in reference to a specific parcel of land, please provide the street address, block, lot and property owner of the parcel of land: (Note: if the property in question is over multiple blocks and lots, please list all in the description field below)	Street Address 1: Street Address 2: Block: Lot:	
If your request is in reference to a facility, site or parcel of land, please provide the Municipality and County where the facility, site or parcel of land is located:	County: Municipality:	
If the request is in reference to a particular permit issued by NJDEP, please provide the type of permit and any identifying numbers such as permit, incident or case numbers. (i.e. Fishing, Hunting, Hazardous Waste, Solid Waste, Land Use, NJPDES, Pesticides, Stream Encroachment, TWA, UST, Water Allocation)	List Permit Type:	List ID Numbers:
If your request is in reference to an individual, please provide the individual's name and type, and if the individual is a DEP employee, your relationship with the individual:	Individual's name: Type of Individual: Relationship:	
If the an individual was specified above, the individual was DEP Licensed, please specify the license type the individual holds:	License Type:	

The New Jersey Department of Environmental Protection has responded to your submitted Open Public Records Act (OPRA) record request. The following information will help you understand the response and your next available actions.

Tracking #: This is the Department's assigned Tracking # to your OPRA record request, which should be used in all corresponding matters.

Record Request Response:

- **In Progress** – Based on the nature of the request, the records sought, and/or the manner to which the records may exists, the Department requires additional time to investigate and respond to the request.
- **Filled** – Based on the information provided in your request, the Department was able to investigate and respond to your record request.
- **Denied** – Based on the nature of the request and/or the records sought, the Department has denied your request pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.
- **Partial** – The Department has identified both responsive government records and records being denied based on the nature of the request and/or the records sought, that do not meet the definition of a government record pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.

Disposition Notes: Provides detailed information concerning the Department's response to your request.

Accessing Records: Dependent on the volume of records and your interest, there are five (5) methods available to access the responsive government records:

- **File Review** – Schedule a file review with the Department to directly access the records and take notes or tag records of interest for copying. Copying can be performed by either the Department's onsite Copying Unit at State duplication fee costs or by the requester employing a Copy Vendor Service. If there are records stored in archives, a five-day processing period will be included prior to scheduling a review.
- **Copy Request** – All records of interest will be copied by the Department's onsite Copying Unit at State duplication fee costs unless a Copy Vendor Service is employed.
- **Electronic Records Request** – Dependent on the size & nature of the e-records, the Department will email the records or provide a CD or DVD.
- **Fax Request** – Based on the number of pages, the Department faxes the responsive records.
- **Web Access** – The responsive records can be access directly through the Department's web site. Web address will be provided.

Access to Government Records Under the New Jersey Open Public Records Act (N.J.S.A. 47:1A-1 et seq.)

1. The fees for duplication of a government record are specified below. We will notify you of any special charges, special service charges or other additional charges authorized by State law or regulation before processing your request. Payment shall be made by check or money order payable to the State of New Jersey and mailed to the address specified below.

Hard Copies:	Letter & Legal size	= $0.05 per page	**Electronic Records:**	CDs = $0.55 per CD
	Oversized Maps (Color)	= $5.00 per map		DVDs = $0.55 per DVD
	Oversized Maps (B&W)	= $3.00 per map		

2. Pursuant to OPRA (C.47:1A-5c & C47:1A-5d), the Department will apply special service charge for any extraordinary expenditure of time and effort to accommodate a request. The special service charge will be based on the actual direct cost of providing the records. The requester shall have the opportunity to review and object to the charge prior to it being incurred; however, in the event the requester objects to the special service charge, the request will be closed and access to the records will not be granted.
3. By law, the Department must notify you that it grants or denies a request for access to government records within seven business days after the custodian of the record requested receives the request, provided that the record is currently available and not in storage. If the record requested is not currently available or is in storage, the custodian will advise you within seven business days when the record can be made available and the estimated cost. You may agree with the custodian to extend the time for making records available, or granting or denying your request.
4. You may be denied access to a government record if your request would substantially disrupt agency operations and the custodian is unable to reach a reasonable solution with you.
5. If the Department was unable to comply with your request for access to a government record, the custodian will indicate the reasons for denial on the request form.
6. Except as otherwise provided by law or by agreement with the requester, if the custodian of the record requested fails to respond to you within seven business days of receiving a request form, the failure to respond will be considered a denial of your request.
7. **Resolution of Disputed Findings:**

   In the event that a requester does not agree with the Department's record response, the requester should:

   No Records - Reexamined the request details to evaluate if all of the information was provided that could aid the Department in locating records. The Department's ability to identify records of interest is in direct correlation to matching the Department information with the information provided on the request. Such important identifiers are Facility/Site Name, Address, Case #, Permit #, Block/Lot.

   Denial - If your request for access to a government record has been denied or unfilled within the time permitted by law, you have a right to challenge the decision by the Department to deny access. The Department denies access to records only when those records do not meet the definition of a government record and/or public access is not allowed pursuant to the law. At your option, you may either:

   a. Contact the Office of Record Access to re-visit the matter or provide further explanation.

   b. Institute a proceeding in the Superior Court of New Jersey

   c. File a complaint in writing with the Government Records Council (GRC). You may contact the GRC by toll-free telephone at 866-850-0511, by mail at PO Box 819, Trenton, NJ, 08625, by e-mail at *grc@dca.state.nj.us*, or at their web site at *www.state.nj.us/grc*. The Council can also respond to other questions about the law.
8. Information provided on this form may be subject to disclosure under the Open Public Records Act.

Revised Addendum Disposition Notes: Based on revisiting the record request & any additional information provided, responsive records have been identified and available for direct access on the NJDEP?s web address at: For Surface Water Systemhttps://www13.state.nj.us/DataMinerfor Source Water Assessment, http://www.nj.gov/dep/watersupply/swap/

Place Logo Here

AGENCY NAME HERE

OPEN PUBLIC RECORDS ACT REQUEST FORM

Agency Address
Agency Telephone Number & Fax Number
Agency e-mail address
Name of Agency Custodian

Place Logo Here

Important Notice

The last page of this form contains important information related to your rights concerning government records. Please read it carefully.

Requestor Information – Please Print

First Name Jean MI ______ Last Name Malafronte

E-mail Address jmalafronte@greeley-hansen.com

Mailing Address 1700 Market Street, Suite 2130

City Philadelphia State PA Zip 19103

Telephone 215-553-7912 FAX 215-563-1139

Preferred Delivery: Pick Up ______ US Mail X On-Site Inspect ________ Fax ________ E-mail ________

If you are requesting records containing personal information, please circle one: Under penalty of N.J.S.A. 2C:28-3, I certify that I ***HAVE*** / ***HAVE NOT*** been convicted of any indictable offense under the laws of New Jersey, any other state, or the United States.

Signature ______________________ Date ______________

Payment Information

Maximum Authorization Cost $

Select Payment Method

Cash Check Money Order

Fees: Letter size pages - $0.05 per page
Legal size pages - $0.07 per page
Other materials (CD, DVD, etc) – actual cost of material

Delivery: Delivery / postage fees additional depending upon delivery type.

Extras: Special service charge dependent upon request.

Record Request Information: Please be as specific as possible in describing the records being requested. Also, please note that your preferred method of delivery will only be accommodated if the custodian has the technological means and the integrity of the records will not be jeopardized by such method of delivery.

Pursuant to the New Jersey Open Public Records Act and the common law right to inspect public records, please provide in electronic format any reports and documents from the NJDEP Division of Water Quality that are dated or were developed between the years 2007-2016 regarding:

- Drinking Water Intakes or their designated protected areas

We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include:

- Passaic River from Montville to Newark Bay and its tributaries:
  Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel
- Hackensack River from the Oradell Reservoir to Newark Bay and its tributaries:
  Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek
- Newark Bay
- Hudson River from the George Washington Bridge to the Upper Newark Bay
- Upper Newark Bay
- Kill Van Kull
- Arthur Kill and its tributaries:
  Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek
- Raritan River from Bound Brook to the Raritan Bay and its tributaries:
  Bound Brook
- Raritan Bay

AGENCY USE ONLY

Est. Document Cost ________
Est. Delivery Cost ________
Est. Extras Cost ________
Total Est. Cost ________
Deposit Amount ________
Estimated Balance ________
Deposit Date ________

AGENCY USE ONLY

Disposition Notes
Custodian: If any part of request cannot be delivered in seven business days, detail reasons here.

In Progress - Open ________
Denied - Closed ________
Filled - Closed ________
Partial - Closed ________

AGENCY USE ONLY

Tracking Information
Tracking # ________
Rec'd Date ________
Ready Date ________
Total Pages ________

Final Cost
Total ________
Deposit ________
Balance Due ________
Balance Paid ________

Records Provided

Custodian Signature ________ Date ________

State of New Jersey
Department of Environmental Protection
GOVERNMENT RECORDS REQUEST FORM

IMPORTANT NOTICE

Please read this entire form carefully as it contains important information concerning the response to your record request, accessing records, disputing denials, and your rights concerning government records. For further information, access WWW.NJ.GOV/DEP/OPRA.

Requestor Information

First Name: JEAN	MI	Last Name MALAFRONTE	
Company: GREELEY AND HANSEN			
Mailing Address: 1700 MARKET ST. SUITE 2130			
City: Philadelphia	State: PA	Zip: 19103	Email: jmalafronte@greeley-hansen.com
Business Telephone: (215) 553-7912			Extension
Facsimile Telephone: (215) 563-1139			

State Use Only

Tracking #	205585
Received Date	03/20/2017
Access Method	**Send Electronic copies**

All matters relating to the response and access of any records identified for this request should be directed to:

**NJDEP – Office of Record Access
401 East State Street
PO Box 420 Mail Code 401-06Q
Trenton, New Jersey 08625-0420
Tele #: (609) 341-3121
Fax #: (609) 292-1177**

Record Request Details:

Pursuant to the New Jersey Open Public Records Act and the common law right to inspect public records, please provide in electronic format any reports and documents from the NJDEP Division of Water Quality that are dated or were developed between the years 2007-2016 regarding: __Drinking Water Intakes or their designated protected areas We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include: __Passaic River from Montville to Newark Bay and its tributaries: Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel __Hackensack River from the Oradell Reservoir to Newark Bay and its tributaries: Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek __Newark Bay __Hudson River from the George Washington Bridge to the Upper Newark Bay __Upper Newark Bay __Kill Van Kull __Arthur Kill and its tributaries: Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek __Raritan River from Bound Brook to the Raritan Bay and its tributaries: Bound Brook __Raritan Bay

Disposition Notes

This request has been denied pursuant to N.J.S.A. 47:1A-1. See Addendum Disposition Notes below for further information.

Record Request Response

In Progress	–	Open	
Filled	–	Closed	
Denied	–	Closed	X
Partial	–	Closed	

Addendum Disposition Notes: Please be advised that the request is overbroad and improper as it does not define specific records. Government agencies are required to disclose identifiable government records that are specifically described in the OPRA request. See N.J.S.A. 47:1A-1 and -1.1. OPRA does not permit open-ended searches of agency files, nor does the law allow a request for every document an agency has on file on a specific subject matter. OPRA also does not require government agencies to conduct research in order to respond to a request for records. See, for e.g., MAG Entertainment LLC v Div of Alcoholic Bev Control, 375 NJ Super 534, 549 (App Div. 2005); Bent v Twp Of Stafford, 381 NJ Super 30, 37 (App Div 2005); Gannett NJ Partners v Middlesex, 379 NJ Super 205, 212 (App Div 2005), which address the principles stated above. Consequently, this request is denied and closed effective today.

Matthew J. Coefer 03/28/2017

Custodian Signature **Date**

Information Regarding the Requested Records		
If your request is in reference to a single facility, please provide the name of the facility, and the name of the operator name of the facility:	Facility Name: Operator Name:	
Please provide the owner name the facility or parcel of land:	Owner Name:	
If your request is in reference to a specific parcel of land, please provide the street address, block, lot and property owner of the parcel of land: (Note: if the property in question is over multiple blocks and lots, please list all in the description field below)	Street Address 1: Street Address 2: Block: Lot:	
If your request is in reference to a facility, site or parcel of land, please provide the Municipality and County where the facility, site or parcel of land is located:	County: Municipality:	
If the request is in reference to a particular permit issued by NJDEP, please provide the type of permit and any identifying numbers such as permit, incident or case numbers. (i.e. Fishing, Hunting, Hazardous Waste, Solid Waste, Land Use, NJPDES, Pesticides, Stream Encroachment, TWA, UST, Water Allocation)	List Permit Type:	List ID Numbers:
If your request is in reference to an individual, please provide the individual's name and type, and if the individual is a DEP employee, your relationship with the individual:	Individual's name: Type of Individual: Relationship:	
If the an individual was specified above, the individual was DEP Licensed, please specify the license type the individual holds:	License Type:	

The New Jersey Department of Environmental Protection has responded to your submitted Open Public Records Act (OPRA) record request. The following information will help you understand the response and your next available actions.

Tracking #: This is the Department's assigned Tracking # to your OPRA record request, which should be used in all corresponding matters.

Record Request Response:

- **In Progress** – Based on the nature of the request, the records sought, and/or the manner to which the records may exists, the Department requires additional time to investigate and respond to the request.
- **Filled** – Based on the information provided in your request, the Department was able to investigate and respond to your record request.
- **Denied** – Based on the nature of the request and/or the records sought, the Department has denied your request pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.
- **Partial** – The Department has identified both responsive government records and records being denied based on the nature of the request and/or the records sought, that do not meet the definition of a government record pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.

Disposition Notes: Provides detailed information concerning the Department's response to your request.

Accessing Records: Dependent on the volume of records and your interest, there are five (5) methods available to access the responsive government records:

- **File Review** – Schedule a file review with the Department to directly access the records and take notes or tag records of interest for copying. Copying can be performed by either the Department's onsite Copying Unit at State duplication fee costs or by the requester employing a Copy Vendor Service. If there are records stored in archives, a five-day processing period will be included prior to scheduling a review.
- **Copy Request** – All records of interest will be copied by the Department's onsite Copying Unit at State duplication fee costs unless a Copy Vendor Service is employed.
- **Electronic Records Request** – Dependent on the size & nature of the e-records, the Department will email the records or provide a CD or DVD.
- **Fax Request** – Based on the number of pages, the Department faxes the responsive records.
- **Web Access** – The responsive records can be access directly through the Department's web site. Web address will be provided.

Access to Government Records Under the New Jersey Open Public Records Act (N.J.S.A. 47:1A-1 et seq.)

1. The fees for duplication of a government record are specified below. We will notify you of any special charges, special service charges or other additional charges authorized by State law or regulation before processing your request. Payment shall be made by check or money order payable to the State of New Jersey and mailed to the address specified below.

Hard Copies:	Letter & Legal size	= $0.05 per page	**Electronic Records:**	CDs = $0.55 per CD
	Oversized Maps (Color)	= $5.00 per map		DVDs = $0.55 per DVD
	Oversized Maps (B&W)	= $3.00 per map		

2. Pursuant to OPRA (C.47:1A-5c & C47:1A-5d), the Department will apply special service charge for any extraordinary expenditure of time and effort to accommodate a request. The special service charge will be based on the actual direct cost of providing the records. The requester shall have the opportunity to review and object to the charge prior to it being incurred; however, in the event the requester objects to the special service charge, the request will be closed and access to the records will not be granted.

3. By law, the Department must notify you that it grants or denies a request for access to government records within seven business days after the custodian of the record requested receives the request, provided that the record is currently available and not in storage. If the record requested is not currently available or is in storage, the custodian will advise you within seven business days when the record can be made available and the estimated cost. You may agree with the custodian to extend the time for making records available, or granting or denying your request.

4. You may be denied access to a government record if your request would substantially disrupt agency operations and the custodian is unable to reach a reasonable solution with you.

5. If the Department was unable to comply with your request for access to a government record, the custodian will indicate the reasons for denial on the request form.

6. Except as otherwise provided by law or by agreement with the requester, if the custodian of the record requested fails to respond to you within seven business days of receiving a request form, the failure to respond will be considered a denial of your request.

7. **Resolution of Disputed Findings:**

   In the event that a requester does not agree with the Department's record response, the requester should:

   No Records - Reexamined the request details to evaluate if all of the information was provided that could aid the Department in locating records. The Department's ability to identify records of interest is in direct correlation to matching the Department information with the information provided on the request. Such important identifiers are Facility/Site Name, Address, Case #, Permit #, Block/Lot.

   Denial - If your request for access to a government record has been denied or unfilled within the time permitted by law, you have a right to challenge the decision by the Department to deny access. The Department denies access to records only when those records do not meet the definition of a government record and/or public access is not allowed pursuant to the law. At your option, you may either:

   a. Contact the Office of Record Access to re-visit the matter or provide further explanation.

   b. Institute a proceeding in the Superior Court of New Jersey

   c. File a complaint in writing with the Government Records Council (GRC). You may contact the GRC by toll-free telephone at 866-850-0511, by mail at PO Box 819, Trenton, NJ, 08625, by e-mail at *grc@dca.state.nj.us*, or at their web site at *www.state.nj.us/grc*. The Council can also respond to other questions about the law.

8. Information provided on this form may be subject to disclosure under the Open Public Records Act.

Revised Addendum Disposition Notes: NONE

Place Logo Here

AGENCY NAME HERE

OPEN PUBLIC RECORDS ACT REQUEST FORM

Agency Address
Agency Telephone Number & Fax Number
Agency e-mail address
Name of Agency Custodian

Place Logo Here

Important Notice

The last page of this form contains important information related to your rights concerning government records. Please read it carefully.

Requestor Information – Please Print

First Name Jean MI ______ Last Name Malafronte

E-mail Address jmalafronte@greeley-hansen.com

Mailing Address 1700 Market Street, Suite 2130

City Philadelphia State PA Zip 19103

Telephone 215-553-7912 FAX 215-563-1139

Preferred Delivery: Pick Up ______ US Mail X On-Site Inspect ______ Fax ______ E-mail ______

If you are requesting records containing personal information, please circle one: Under penalty of N.J.S.A. 2C:28-3, I certify that I ***HAVE / HAVE NOT*** been convicted of any indictable offense under the laws of New Jersey, any other state, or the United States.

Signature ______________________ Date ______________

Payment Information

Maximum Authorization Cost $

Select Payment Method

Cash Check Money Order

Fees: Letter size pages - $0.05 per page
Legal size pages - $0.07 per page
Other materials (CD, DVD, etc) – actual cost of material

Delivery: Delivery / postage fees additional depending upon delivery type.

Extras: Special service charge dependent upon request.

Record Request Information: Please be as specific as possible in describing the records being requested. Also, please note that your preferred method of delivery will only be accommodated if the custodian has the technological means and the integrity of the records will not be jeopardized by such method of delivery.

Pursuant to the New Jersey Open Public Records Act and the common law right to inspect public records, please provide in electronic format any reports and documents from the NJDEP State Park Service that are dated or were developed between the years 2007-2016 regarding:

- Waters with Primary Contact Recreation

We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include:

- Passaic River from Montville to Newark Bay and its tributaries:
  Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel
- Hackensack River from the Oradell Reservoir to Newark Bay and its tributaries:
  Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek
- Newark Bay
- Hudson River from the George Washington Bridge to the Upper Newark Bay
- Upper Newark Bay
- Kill Van Kull
- Arthur Kill and its tributaries:
  Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek
- Raritan River from Bound Brook to the Raritan Bay and its tributaries:
  Bound Brook
- Raritan Bay

AGENCY USE ONLY

Est. Document Cost ________
Est. Delivery Cost ________
Est. Extras Cost ________
Total Est. Cost ________
Deposit Amount ________
Estimated Balance ________
Deposit Date ________

AGENCY USE ONLY

Disposition Notes
Custodian: If any part of request cannot be delivered in seven business days, detail reasons here.

In Progress - Open ________
Denied - Closed ________
Filled - Closed ________
Partial - Closed ________

AGENCY USE ONLY

Tracking Information

Tracking # ________
Rec'd Date ________
Ready Date ________
Total Pages ________

Final Cost

Total ________
Deposit ________
Balance Due ________
Balance Paid ________

Records Provided

Custodian Signature ________ Date ________

State of New Jersey
Department of Environmental Protection
GOVERNMENT RECORDS REQUEST FORM

IMPORTANT NOTICE

Please read this entire form carefully as it contains important information concerning the response to your record request, accessing records, disputing denials, and your rights concerning government records. For further information, access WWW.NJ.GOV/DEP/OPRA.

Requestor Information

First Name: JEAN MI Last Name MALAFRONTE

Company: GREELEY AND HANSEN

Mailing Address: 1700 MARKET ST., SUITE 2130

City: Philadelphia State: PA Zip: 19103 Email: jmalafronte@greeley-hansen.com

Business Telephone: (215) 553-7912 Extension

Facsimile Telephone: (215) 563-1139

State Use Only

Tracking #	205583
Received Date	03/20/2017
Access Method	**Send Electronic copies**

All matters relating to the response and access of any records identified for this request should be directed to:

NJDEP – Office of Record Access
401 East State Street
PO Box 420 Mail Code 401-06Q
Trenton, New Jersey 08625-0420
Tele #: (609) 341-3121
Fax #: (609) 292-1177

Record Request Details:

Pursuant to the New Jersey Open Public Records Act and the common law right to inspect public records, please provide in electronic format any reports and documents from the NJDEP State Park Service that are dated or were developed between the years 2007-2016 regarding: __Waters with Primary Contact Recreation We are interested in areas including Essex, Hudson, Bergen and Passaic Counties in NJ. The Waterbodies we are interested in include: __Passaic River from Montville to Newark Bay and its tributaries: Saddle River, Third River, Second River, Port Newark Channel, and Elizabeth Channel __Hackensack River from the Oradell Reservoir to Newark Bay and its tributaries: Overpeck Creek, Cromakill Creek, Berrys Creek, and Penhorn Creek __Newark Bay __Hudson River from the George Washington Bridge to the Upper Newark Bay __Upper Newark Bay __Kill Van Kull __Arthur Kill and its tributaries: Elizabeth River, Morses Creek, Rahway River, Fresh Kills, Woodbridge Creek __Raritan River from Bound Brook to the Raritan Bay and its tributaries: Bound Brook __Raritan Bay

Disposition Notes

This request has been denied pursuant to N.J.S.A. 47:1A-1. See Addendum Disposition Notes below for further information.

Record Request Response

In Progress	–	Open	
Filled	–	Closed	
Denied	–	Closed	x
Partial	–	Closed	

Addendum Disposition Notes: Please be advised that the request is overbroad and improper as it does not define specific records. Government agencies are required to disclose identifiable government records that are specifically described in the OPRA request. See N.J.S.A. 47:1A-1 and -1.1. OPRA does not permit open-ended searches of agency files, nor does the law allow a request for every document an agency has on file on a specific subject matter. OPRA also does not require government agencies to conduct research in order to respond to a request for records. See, for e.g., MAG Entertainment LLC v Div of Alcoholic Bev Control, 375 NJ Super 534, 549 (App Div. 2005); Bent v Twp Of Stafford, 381 NJ Super 30, 37 (App Div 2005); Gannett NJ Partners v Middlesex, 379 NJ Super 205, 212 (App Div 2005), which address the principles stated above. Consequently, this request is denied and closed effective today.

Matthew J. Coefer 03/30/2017

Custodian Signature **Date**

Information Regarding the Requested Records		
If your request is in reference to a single facility, please provide the name of the facility, and the name of the operator name of the facility:	Facility Name: Operator Name:	
Please provide the owner name the facility or parcel of land:	Owner Name:	
If your request is in reference to a specific parcel of land, please provide the street address, block, lot and property owner of the parcel of land: (Note: if the property in question is over multiple blocks and lots, please list all in the description field below)	Street Address 1: Street Address 2: Block: Lot:	
If your request is in reference to a facility, site or parcel of land, please provide the Municipality and County where the facility, site or parcel of land is located:	County: Municipality:	
If the request is in reference to a particular permit issued by NJDEP, please provide the type of permit and any identifying numbers such as permit, incident or case numbers. (i.e. Fishing, Hunting, Hazardous Waste, Solid Waste, Land Use, NJPDES, Pesticides, Stream Encroachment, TWA, UST, Water Allocation)	List Permit Type:	List ID Numbers:
If your request is in reference to an individual, please provide the individual's name and type, and if the individual is a DEP employee, your relationship with the individual:	Individual's name: Type of Individual: Relationship:	
If the an individual was specified above, the individual was DEP Licensed, please specify the license type the individual holds:	License Type:	

The New Jersey Department of Environmental Protection has responded to your submitted Open Public Records Act (OPRA) record request. The following information will help you understand the response and your next available actions.

Tracking #: This is the Department's assigned Tracking # to your OPRA record request, which should be used in all corresponding matters.

Record Request Response:

- **In Progress** – Based on the nature of the request, the records sought, and/or the manner to which the records may exists, the Department requires additional time to investigate and respond to the request.
- **Filled** – Based on the information provided in your request, the Department was able to investigate and respond to your record request.
- **Denied** – Based on the nature of the request and/or the records sought, the Department has denied your request pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.
- **Partial** – The Department has identified both responsive government records and records being denied based on the nature of the request and/or the records sought, that do not meet the definition of a government record pursuant to a specific exemption(s) cited in N.J.S.A. 47:1A-1 seq.

Disposition Notes: Provides detailed information concerning the Department's response to your request.

Accessing Records: Dependent on the volume of records and your interest, there are five (5) methods available to access the responsive government records:

- **File Review** – Schedule a file review with the Department to directly access the records and take notes or tag records of interest for copying. Copying can be performed by either the Department's onsite Copying Unit at State duplication fee costs or by the requester employing a Copy Vendor Service. If there are records stored in archives, a five-day processing period will be included prior to scheduling a review.
- **Copy Request** – All records of interest will be copied by the Department's onsite Copying Unit at State duplication fee costs unless a Copy Vendor Service is employed.
- **Electronic Records Request** – Dependent on the size & nature of the e-records, the Department will email the records or provide a CD or DVD.
- **Fax Request** – Based on the number of pages, the Department faxes the responsive records.
- **Web Access** – The responsive records can be access directly through the Department's web site. Web address will be provided.

1. The fees for duplication of a government record are specified below. We will notify you of any special charges, special service charges or other additional charges authorized by State law or regulation before processing your request. Payment shall be made by check or money order payable to the State of New Jersey and mailed to the address specified below.

Hard Copies:	Letter & Legal size	= $0.05 per page	**Electronic Records:**	CDs =	$0.55 per CD
	Oversized Maps (Color)	= $5.00 per map		DVDs =	$0.55 per DVD
	Oversized Maps (B&W)	= $3.00 per map			

2. Pursuant to OPRA (C.47:1A-5c & C47:1A-5d), the Department will apply special service charge for any extraordinary expenditure of time and effort to accommodate a request. The special service charge will be based on the actual direct cost of providing the records. The requester shall have the opportunity to review and object to the charge prior to it being incurred; however, in the event the requester objects to the special service charge, the request will be closed and access to the records will not be granted.

3. By law, the Department must notify you that it grants or denies a request for access to government records within seven business days after the custodian of the record requested receives the request, provided that the record is currently available and not in storage. If the record requested is not currently available or is in storage, the custodian will advise you within seven business days when the record can be made available and the estimated cost. You may agree with the custodian to extend the time for making records available, or granting or denying your request.

4. You may be denied access to a government record if your request would substantially disrupt agency operations and the custodian is unable to reach a reasonable solution with you.

5. If the Department was unable to comply with your request for access to a government record, the custodian will indicate the reasons for denial on the request form.

6. Except as otherwise provided by law or by agreement with the requester, if the custodian of the record requested fails to respond to you within seven business days of receiving a request form, the failure to respond will be considered a denial of your request.

7. **Resolution of Disputed Findings:**

In the event that a requester does not agree with the Department's record response, the requester should:

No Records - Reexamined the request details to evaluate if all of the information was provided that could aid the Department in locating records. The Department's ability to identify records of interest is in direct correlation to matching the Department information with the information provided on the request. Such important identifiers are Facility/Site Name, Address, Case #, Permit #, Block/Lot.

Denial - If your request for access to a government record has been denied or unfilled within the time permitted by law, you have a right to challenge the decision by the Department to deny access. The Department denies access to records only when those records do not meet the definition of a government record and/or public access is not allowed pursuant to the law. At your option, you may either:

a. Contact the Office of Record Access to re-visit the matter or provide further explanation.

b. Institute a proceeding in the Superior Court of New Jersey

c. File a complaint in writing with the Government Records Council (GRC). You may contact the GRC by toll-free telephone at 866-850-0511, by mail at PO Box 819, Trenton, NJ, 08625, by e-mail at *grc@dca.state.nj.us*, or at their web site at *www.state.nj.us/grc*. The Council can also respond to other questions about the law.

8. Information provided on this form may be subject to disclosure under the Open Public Records Act.

Revised Addendum Disposition Notes: NONE

New Jersey Natural Heritage Program
Threatened and Endangered Species Data

Site 902 - Dundee Canal Green Acres and Island Preserve

State of New Jersey

CHRIS CHRISTIE
Governor

KIM GUADAGNO
Lt. Governor

DEPARTMENT OF ENVIRONMENTAL PROTECTION
State Forestry Services
Mail Code 501-04
ONLM -Natural Heritage Program
P.O. Box 420
Trenton, NJ 08625-0420
Tel. #609-984-1339
Fax. #609-984-1427

BOB MARTIN
Commissioner

May 21, 2015

Tara Stewart
Louis Berger
412 Mount Kemble Avenue
Morristown, NJ 07962-1946

Re: HRE Ecosystem Restoration Feasibility - Dundee Canal Green Acres and Island Preserve

Dear Ms. Stewart:

Thank you for your data request regarding rare species information for the above referenced project site in Clifton City, Passaic County.

Searches of the Natural Heritage Database and the Landscape Project (Version 3.1) are based on a representation of the boundaries of your project site in our Geographic Information System (GIS). We make every effort to accurately transfer your project bounds from the topographic map(s) submitted with the Request for Data into our Geographic Information System. We do not typically verify that your project bounds are accurate, or check them against other sources.

We have checked the Landscape Project habitat mapping and the Biotics Database for occurrences of any rare wildlife species or wildlife habitat on the referenced site. The Natural Heritage Database was searched for occurrences of rare plant species or ecological communities that may be on the project site. Please refer to Table 1 (attached) to determine if any rare plant species, ecological communities, or rare wildlife species or wildlife habitat are documented on site. A detailed report is provided for each category coded as 'Yes' in Table 1.

We have also checked the Landscape Project habitat mapping and Biotics Database for occurrences of rare wildlife species or wildlife habitat in the immediate vicinity (within ¼ mile) of the referenced site. Additionally, the Natural Heritage Database was checked for occurrences of rare plant species or ecological communities within ¼ mile of the site. Please refer to Table 2 (attached) to determine if any rare plant species, ecological communities, or rare wildlife species or wildlife habitat are documented within the immediate vicinity of the site. Detailed reports are provided for all categories coded as 'Yes' in Table 2. These reports may include species that have also been documented on the project site.

The Natural Heritage Program reviews its data periodically to identify priority sites for natural diversity in the State. Included as priority sites are some of the State's best habitats for rare and endangered species and ecological communities. Please refer to Tables 1 and 2 (attached) to determine if any priority sites are located on or in the vicinity of the site.

A list of rare plant species and ecological communities that have been documented from the project site, referenced above, can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/countylist.html. If suitable habitat is present at the project site, the species in that list have potential to be present.

Status and rank codes used in the tables and lists are defined in EXPLANATION OF CODES USED IN NATURAL HERITAGE REPORTS, which can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/nhpcodes_2010.pdf.

If you have questions concerning the wildlife records or wildlife species mentioned in this response, we recommend that you visit the interactive NJ-GeoWeb website at the following URL, http://www.state.nj.us/dep/gis/geowebsplash.htm or contact the Division of Fish and Wildlife, Endangered and Nongame Species Program at (609) 292-9400.

NHP File No. 15-4007481-7665

PLEASE SEE 'CAUTIONS AND RESTRICTIONS ON NHP DATA', which can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/newcaution2008.pdf.

Thank you for consulting the Natural Heritage Program. The attached invoice details the payment due for processing this data request. Feel free to contact us again regarding any future data requests.

Sincerely,

Robert J. Cartica
Administrator

c: NHP File No. 15-4007481-7665

Table 1: On Site Data Request Search Results (7 Possible Reports)

Report Name	Included	Number of Pages
1. Possibly on Project Site Based on Search of Natural Heritage Database: Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
2. On or In the Immediate Vicinity of the Project Site Based on Search of the Natural Heritage Database: Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
3. Natural Heritage Priority Sites On Site	No	0 pages included
4. Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Species Based Patches	No	0 pages included
5. Vernal Pool Habitat on the Project Site Based on Search of Landscape Project 3.1	No	0 pages included
6. Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Stream Habitat File	No	0 pages included
7. Other Animal Species On the Project Site Based on Additional Species Tracked by Endangered and Nongame Species Program	No	0 pages included

Table 2: Vicinity Data Request Search Results (6 possible reports)

Report Name	Included	Number of Pages
1. Immediate Vicinity of the Project Site Based on Search of Natural Heritage Database Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
2. Natural Heritage Priority Sites within the Vicinity	No	0 pages included
3. Rare Wildlife Species or Wildlife Habitat Within the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Species Based Patches	No	0 pages included
4. Vernal Pool Habitat In the Immediate Vicinity of Project Site Based on Search of Landscape Project 3.1	No	0 pages included
5. Rare Wildlife Species or Wildlife Habitat In the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Stream Habitat File	No	0 pages included
6. Other Animal Species In the Immediate Vicinity of the Project Site Based on Additional Species Tracked by Endangered and Nongame Species Program	No	0 pages included

Site 865 - Kearny Point

State of New Jersey

CHRIS CHRISTIE
Governor

KIM GUADAGNO
Lt. Governor

DEPARTMENT OF ENVIRONMENTAL PROTECTION
State Forestry Services
Mail Code 501-04
ONLM -Natural Heritage Program
P.O. Box 420
Trenton, NJ 08625-0420
Tel. #609-984-1339
Fax. #609-984-1427

BOB MARTIN
Commissioner

May 21, 2015

Tara Stewart
Louis Berger
412 Mount Kemble Avenue
Morristown, NJ 07962-1946

Re: HRE Ecosystem Restoration Feasibility - Kearny Point

Dear Ms. Stewart:

Thank you for your data request regarding rare species information for the above referenced project site in Kearny Town, Hudson County.

Searches of the Natural Heritage Database and the Landscape Project (Version 3.1) are based on a representation of the boundaries of your project site in our Geographic Information System (GIS). We make every effort to accurately transfer your project bounds from the topographic map(s) submitted with the Request for Data into our Geographic Information System. We do not typically verify that your project bounds are accurate, or check them against other sources.

We have checked the Landscape Project habitat mapping and the Biotics Database for occurrences of any rare wildlife species or wildlife habitat on the referenced site. The Natural Heritage Database was searched for occurrences of rare plant species or ecological communities that may be on the project site. Please refer to Table 1 (attached) to determine if any rare plant species, ecological communities, or rare wildlife species or wildlife habitat are documented on site. A detailed report is provided for each category coded as 'Yes' in Table 1.

We have also checked the Landscape Project habitat mapping and Biotics Database for occurrences of rare wildlife species or wildlife habitat in the immediate vicinity (within ¼ mile) of the referenced site. Additionally, the Natural Heritage Database was checked for occurrences of rare plant species or ecological communities within ¼ mile of the site. Please refer to Table 2 (attached) to determine if any rare plant species, ecological communities, or rare wildlife species or wildlife habitat are documented within the immediate vicinity of the site. Detailed reports are provided for all categories coded as 'Yes' in Table 2. These reports may include species that have also been documented on the project site.

The Natural Heritage Program reviews its data periodically to identify priority sites for natural diversity in the State. Included as priority sites are some of the State's best habitats for rare and endangered species and ecological communities. Please refer to Tables 1 and 2 (attached) to determine if any priority sites are located on or in the vicinity of the site.

A list of rare plant species and ecological communities that have been documented from the project site, referenced above, can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/countylist.html. If suitable habitat is present at the project site, the species in that list have potential to be present.

Status and rank codes used in the tables and lists are defined in EXPLANATION OF CODES USED IN NATURAL HERITAGE REPORTS, which can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/nhpcodes_2010.pdf.

If you have questions concerning the wildlife records or wildlife species mentioned in this response, we recommend that you visit the interactive NJ-GeoWeb website at the following URL, http://www.state.nj.us/dep/gis/geowebsplash.htm or contact the Division of Fish and Wildlife, Endangered and Nongame Species Program at (609) 292-9400.

NHP File No. 15-4007461-7671

PLEASE SEE 'CAUTIONS AND RESTRICTIONS ON NHP DATA', which can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/newcaution2008.pdf.

Thank you for consulting the Natural Heritage Program. The attached invoice details the payment due for processing this data request. Feel free to contact us again regarding any future data requests.

Sincerely,

Robert J. Cartica
Administrator

c: NHP File No. 15-4007461-7671

Table 1: On Site Data Request Search Results (7 Possible Reports)

Report Name	Included	Number of Pages
1. Possibly on Project Site Based on Search of Natural Heritage Database: Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
2. On or In the Immediate Vicinity of the Project Site Based on Search of the Natural Heritage Database: Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
3. Natural Heritage Priority Sites On Site	No	0 pages included
4. Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Species Based Patches	Yes	1 page(s) included
5. Vernal Pool Habitat on the Project Site Based on Search of Landscape Project 3.1	No	0 pages included
6. Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Stream Habitat File	No	0 pages included
7. Other Animal Species On the Project Site Based on Additional Species Tracked by Endangered and Nongame Species Program	No	0 pages included

Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Species Based Patches

Class	Common Name	Scientific Name	Feature Type	Rank	Federal Protection Status	State Protection Status	Grank	Srank
Aves								
	Black-crowned Night-heron	Nycticorax nycticorax	Foraging	3	NA	State Threatened	G5	S2B,S3N
	Glossy Ibis	Plegadis falcinellus	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Little Blue Heron	Egretta caerulea	Foraging	2	NA	Special Concern	G5	S3B,S3N
	Snowy Egret	Egretta thula	Foraging	2	NA	Special Concern	G5	S3B,S4N

Table 2: Vicinity Data Request Search Results (6 possible reports)

Report Name	Included	Number of Pages
1. Immediate Vicinity of the Project Site Based on Search of Natural Heritage Database Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
2. Natural Heritage Priority Sites within the Vicinity	No	0 pages included
3. Rare Wildlife Species or Wildlife Habitat Within the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Species Based Patches	Yes	1 page(s) included
4. Vernal Pool Habitat In the Immediate Vicinity of Project Site Based on Search of Landscape Project 3.1	No	0 pages included
5. Rare Wildlife Species or Wildlife Habitat In the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Stream Habitat File	No	0 pages included
6. Other Animal Species In the Immediate Vicinity of the Project Site Based on Additional Species Tracked by Endangered and Nongame Species Program	No	0 pages included

Rare Wildlife Species or Wildlife Habitat Within the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Species Based Patches

Class	Common Name	Scientific Name	Feature Type	Rank	Federal Protection Status	State Protection Status	Grank	Srank
Aves								
	Black-crowned Night-heron	Nycticorax nycticorax	Foraging	3	NA	State Threatened	G5	S2B,S3N
	Glossy Ibis	Plegadis falcinellus	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Little Blue Heron	Egretta caerulea	Foraging	2	NA	Special Concern	G5	S3B,S3N
	Snowy Egret	Egretta thula	Foraging	2	NA	Special Concern	G5	S3B,S4N

Site 866 - Oak Island Yards

State of New Jersey

CHRIS CHRISTIE
Governor

KIM GUADAGNO
Lt. Governor

DEPARTMENT OF ENVIRONMENTAL PROTECTION
State Forestry Services
Mail Code 501-04
ONLM -Natural Heritage Program
P.O. Box 420
Trenton, NJ 08625-0420
Tel. #609-984-1339
Fax. #609-984-1427

BOB MARTIN
Commissioner

May 21, 2015

Tara Stewart
Louis Berger
412 Mount Kemble Avenue
Morristown, NJ 07962-1946

Re: HRE Ecosystem Restoration Feasibility - Oak Island Yards

Dear Ms. Stewart:

Thank you for your data request regarding rare species information for the above referenced project site in Newark City, Essex County.

Searches of the Natural Heritage Database and the Landscape Project (Version 3.1) are based on a representation of the boundaries of your project site in our Geographic Information System (GIS). We make every effort to accurately transfer your project bounds from the topographic map(s) submitted with the Request for Data into our Geographic Information System. We do not typically verify that your project bounds are accurate, or check them against other sources.

We have checked the Landscape Project habitat mapping and the Biotics Database for occurrences of any rare wildlife species or wildlife habitat on the referenced site. The Natural Heritage Database was searched for occurrences of rare plant species or ecological communities that may be on the project site. Please refer to Table 1 (attached) to determine if any rare plant species, ecological communities, or rare wildlife species or wildlife habitat are documented on site. A detailed report is provided for each category coded as 'Yes' in Table 1.

We have also checked the Landscape Project habitat mapping and Biotics Database for occurrences of rare wildlife species or wildlife habitat in the immediate vicinity (within ¼ mile) of the referenced site. Additionally, the Natural Heritage Database was checked for occurrences of rare plant species or ecological communities within ¼ mile of the site. Please refer to Table 2 (attached) to determine if any rare plant species, ecological communities, or rare wildlife species or wildlife habitat are documented within the immediate vicinity of the site. Detailed reports are provided for all categories coded as 'Yes' in Table 2. These reports may include species that have also been documented on the project site.

The Natural Heritage Program reviews its data periodically to identify priority sites for natural diversity in the State. Included as priority sites are some of the State's best habitats for rare and endangered species and ecological communities. Please refer to Tables 1 and 2 (attached) to determine if any priority sites are located on or in the vicinity of the site.

A list of rare plant species and ecological communities that have been documented from the project site, referenced above, can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/countylist.html. If suitable habitat is present at the project site, the species in that list have potential to be present.

Status and rank codes used in the tables and lists are defined in EXPLANATION OF CODES USED IN NATURAL HERITAGE REPORTS, which can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/nhpcodes_2010.pdf.

If you have questions concerning the wildlife records or wildlife species mentioned in this response, we recommend that you visit the interactive NJ-GeoWeb website at the following URL, http://www.state.nj.us/dep/gis/geowebsplash.htm or contact the Division of Fish and Wildlife, Endangered and Nongame Species Program at (609) 292-9400.

PLEASE SEE 'CAUTIONS AND RESTRICTIONS ON NHP DATA', which can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/newcaution2008.pdf.

Thank you for consulting the Natural Heritage Program. The attached invoice details the payment due for processing this data request. Feel free to contact us again regarding any future data requests.

Sincerely,

Robert J. Cartica
Administrator

c: NHP File No. 15-4007461-7672

Table 1: On Site Data Request Search Results (7 Possible Reports)

Report Name	**Included**	**Number of Pages**
1. Possibly on Project Site Based on Search of Natural Heritage Database: Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
2. On or In the Immediate Vicinity of the Project Site Based on Search of the Natural Heritage Database: Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
3. Natural Heritage Priority Sites On Site	No	0 pages included
4. Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Species Based Patches	Yes	1 page(s) included
5. Vernal Pool Habitat on the Project Site Based on Search of Landscape Project 3.1	No	0 pages included
6. Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Stream Habitat File	No	0 pages included
7. Other Animal Species On the Project Site Based on Additional Species Tracked by Endangered and Nongame Species Program	No	0 pages included

Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Species Based Patches

Class	Common Name	Scientific Name	Feature Type	Rank	Federal Protection Status	State Protection Status	Grank	Srank
Aves								
	Black-crowned Night-heron	Nycticorax nycticorax	Foraging	3	NA	State Threatened	G5	S2B,S3N
	Glossy Ibis	Plegadis falcinellus	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Little Blue Heron	Egretta caerulea	Foraging	2	NA	Special Concern	G5	S3B,S3N
	Peregrine Falcon	Falco peregrinus	Urban Nest	4	NA	State Endangered	G4	S1B,S3N
	Snowy Egret	Egretta thula	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Tricolored Heron	Egretta tricolor	Foraging	2	NA	Special Concern	G5	S3B,S3N

Table 2: Vicinity Data Request Search Results (6 possible reports)

Report Name	**Included**	**Number of Pages**
1. Immediate Vicinity of the Project Site Based on Search of Natural Heritage Database Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
2. Natural Heritage Priority Sites within the Vicinity	No	0 pages included
3. Rare Wildlife Species or Wildlife Habitat Within the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Species Based Patches	Yes	1 page(s) included
4. Vernal Pool Habitat In the Immediate Vicinity of Project Site Based on Search of Landscape Project 3.1	No	0 pages included
5. Rare Wildlife Species or Wildlife Habitat In the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Stream Habitat File	No	0 pages included
6. Other Animal Species In the Immediate Vicinity of the Project Site Based on Additional Species Tracked by Endangered and Nongame Species Program	No	0 pages included

Rare Wildlife Species or Wildlife Habitat Within the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Species Based Patches

Class	Common Name	Scientific Name	Feature Type	Rank	Federal Protection Status	State Protection Status	Grank	Srank
Aves								
	Black-crowned Night-heron	Nycticorax nycticorax	Foraging	3	NA	State Threatened	G5	S2B,S3N
	Cattle Egret	Bubulcus ibis	Foraging	3	NA	State Threatened	G5	S2B,S3N
	Glossy Ibis	Plegadis falcinellus	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Little Blue Heron	Egretta caerulea	Foraging	2	NA	Special Concern	G5	S3B,S3N
	Peregrine Falcon	Falco peregrinus	Urban Nest	4	NA	State Endangered	G4	S1B,S3N
	Snowy Egret	Egretta thula	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Tricolored Heron	Egretta tricolor	Foraging	2	NA	Special Concern	G5	S3B,S3N

Lower Passaic River Reference Site – Harrison Marsh

State of New Jersey

CHRIS CHRISTIE
Governor

KIM GUADAGNO
Lt. Governor

DEPARTMENT OF ENVIRONMENTAL PROTECTION
State Forestry Services
Mail Code 501-04
ONLM -Natural Heritage Program
P.O. Box 420
Trenton, NJ 08625-0420
Tel. #609-984-1339
Fax. #609-984-1427

BOB MARTIN
Commissioner

May 21, 2015

Tara Stewart
Louis Berger
412 Mount Kemble Avenue
Morristown, NJ 07962-1946

Re: HRE Ecosystem Restoration Feasibility - Harrison Marsh

Dear Ms. Stewart:

Thank you for your data request regarding rare species information for the above referenced project site in Harrison Town, Hudson County.

Searches of the Natural Heritage Database and the Landscape Project (Version 3.1) are based on a representation of the boundaries of your project site in our Geographic Information System (GIS). We make every effort to accurately transfer your project bounds from the topographic map(s) submitted with the Request for Data into our Geographic Information System. We do not typically verify that your project bounds are accurate, or check them against other sources.

We have checked the Landscape Project habitat mapping and the Biotics Database for occurrences of any rare wildlife species or wildlife habitat on the referenced site. The Natural Heritage Database was searched for occurrences of rare plant species or ecological communities that may be on the project site. Please refer to Table 1 (attached) to determine if any rare plant species, ecological communities, or rare wildlife species or wildlife habitat are documented on site. A detailed report is provided for each category coded as 'Yes' in Table 1.

We have also checked the Landscape Project habitat mapping and Biotics Database for occurrences of rare wildlife species or wildlife habitat in the immediate vicinity (within ¼ mile) of the referenced site. Additionally, the Natural Heritage Database was checked for occurrences of rare plant species or ecological communities within ¼ mile of the site. Please refer to Table 2 (attached) to determine if any rare plant species, ecological communities, or rare wildlife species or wildlife habitat are documented within the immediate vicinity of the site. Detailed reports are provided for all categories coded as 'Yes' in Table 2. These reports may include species that have also been documented on the project site.

The Natural Heritage Program reviews its data periodically to identify priority sites for natural diversity in the State. Included as priority sites are some of the State's best habitats for rare and endangered species and ecological communities. Please refer to Tables 1 and 2 (attached) to determine if any priority sites are located on or in the vicinity of the site.

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Status and rank codes used in the tables and lists are defined in EXPLANATION OF CODES USED IN NATURAL HERITAGE REPORTS, which can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/nhpcodes_2010.pdf.

If you have questions concerning the wildlife records or wildlife species mentioned in this response, we recommend that you visit the interactive NJ-GeoWeb website at the following URL, http://www.state.nj.us/dep/gis/geowebsplash.htm or contact the Division of Fish and Wildlife, Endangered and Nongame Species Program at (609) 292-9400.

PLEASE SEE 'CAUTIONS AND RESTRICTIONS ON NHP DATA', which can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/newcaution2008.pdf.

Thank you for consulting the Natural Heritage Program. The attached invoice details the payment due for processing this data request. Feel free to contact us again regarding any future data requests.

Sincerely,

Robert J. Cartica
Administrator

c: NHP File No. 15-4007462-7670

Table 1: On Site Data Request Search Results (7 Possible Reports)

Report Name	**Included**	**Number of Pages**
1. Possibly on Project Site Based on Search of Natural Heritage Database: Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
2. On or In the Immediate Vicinity of the Project Site Based on Search of the Natural Heritage Database: Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
3. Natural Heritage Priority Sites On Site	No	0 pages included
4. Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Species Based Patches	Yes	1 page(s) included
5. Vernal Pool Habitat on the Project Site Based on Search of Landscape Project 3.1	No	0 pages included
6. Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Stream Habitat File	No	0 pages included
7. Other Animal Species On the Project Site Based on Additional Species Tracked by Endangered and Nongame Species Program	No	0 pages included

Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Species Based Patches

Class	Common Name	Scientific Name	Feature Type	Rank	Federal Protection Status	State Protection Status	Grank	Srank
Aves								
	Glossy Ibis	Plegadis falcinellus	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Little Blue Heron	Egretta caerulea	Foraging	2	NA	Special Concern	G5	S3B,S3N
	Snowy Egret	Egretta thula	Foraging	2	NA	Special Concern	G5	S3B,S4N

Table 2: Vicinity Data Request Search Results (6 possible reports)

Report Name	Included	Number of Pages
1. Immediate Vicinity of the Project Site Based on Search of Natural Heritage Database Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
2. Natural Heritage Priority Sites within the Vicinity	No	0 pages included
3. Rare Wildlife Species or Wildlife Habitat Within the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Species Based Patches	Yes	1 page(s) included
4. Vernal Pool Habitat In the Immediate Vicinity of Project Site Based on Search of Landscape Project 3.1	No	0 pages included
5. Rare Wildlife Species or Wildlife Habitat In the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Stream Habitat File	No	0 pages included
6. Other Animal Species In the Immediate Vicinity of the Project Site Based on Additional Species Tracked by Endangered and Nongame Species Program	No	0 pages included

Rare Wildlife Species or Wildlife Habitat Within the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Species Based Patches

Class	Common Name	Scientific Name	Feature Type	Rank	Federal Protection Status	State Protection Status	Grank	Srank
Aves								
	Glossy Ibis	Plegadis falcinellus	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Little Blue Heron	Egretta caerulea	Foraging	2	NA	Special Concern	G5	S3B,S3N
	Snowy Egret	Egretta thula	Foraging	2	NA	Special Concern	G5	S3B,S4N

Site 719 - Meadowlark Marsh

State of New Jersey

CHRIS CHRISTIE
Governor

KIM GUADAGNO
Lt. Governor

DEPARTMENT OF ENVIRONMENTAL PROTECTION
State Forestry Services
Mail Code 501-04
ONLM -Natural Heritage Program
P.O. Box 420
Trenton, NJ 08625-0420
Tel. #609-984-1339
Fax. #609-984-1427

BOB MARTIN
Commissioner

May 21, 2015

Tara Stewart
Louis Berger
412 Mount Kemble Avenue
Morristown, NJ 07962-1946

Re: HRE Ecosystem Restoration Feasibility - Meadowlark Marsh

Dear Ms. Stewart:

Thank you for your data request regarding rare species information for the above referenced project site in Ridgefield Borough, Bergen County.

Searches of the Natural Heritage Database and the Landscape Project (Version 3.1) are based on a representation of the boundaries of your project site in our Geographic Information System (GIS). We make every effort to accurately transfer your project bounds from the topographic map(s) submitted with the Request for Data into our Geographic Information System. We do not typically verify that your project bounds are accurate, or check them against other sources.

We have checked the Landscape Project habitat mapping and the Biotics Database for occurrences of any rare wildlife species or wildlife habitat on the referenced site. The Natural Heritage Database was searched for occurrences of rare plant species or ecological communities that may be on the project site. Please refer to Table 1 (attached) to determine if any rare plant species, ecological communities, or rare wildlife species or wildlife habitat are documented on site. A detailed report is provided for each category coded as 'Yes' in Table 1.

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The Natural Heritage Program reviews its data periodically to identify priority sites for natural diversity in the State. Included as priority sites are some of the State's best habitats for rare and endangered species and ecological communities. Please refer to Tables 1 and 2 (attached) to determine if any priority sites are located on or in the vicinity of the site.

A list of rare plant species and ecological communities that have been documented from the project site, referenced above, can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/countylist.html. If suitable habitat is present at the project site, the species in that list have potential to be present.

Status and rank codes used in the tables and lists are defined in EXPLANATION OF CODES USED IN NATURAL HERITAGE REPORTS, which can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/nhpcodes_2010.pdf.

If you have questions concerning the wildlife records or wildlife species mentioned in this response, we recommend that you visit the interactive NJ-GeoWeb website at the following URL, http://www.state.nj.us/dep/gis/geowebsplash.htm or contact the Division of Fish and Wildlife, Endangered and Nongame Species Program at (609) 292-9400.

PLEASE SEE 'CAUTIONS AND RESTRICTIONS ON NHP DATA', which can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/newcaution2008.pdf.

Thank you for consulting the Natural Heritage Program. The attached invoice details the payment due for processing this data request. Feel free to contact us again regarding any future data requests.

Sincerely,

Robert J. Cartica
Administrator

c: NHP File No. 15-4007471-7675

Table 1: On Site Data Request Search Results (7 Possible Reports)

Report Name	Included	Number of Pages
1. Possibly on Project Site Based on Search of Natural Heritage Database: Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
2. On or In the Immediate Vicinity of the Project Site Based on Search of the Natural Heritage Database: Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
3. Natural Heritage Priority Sites On Site	No	0 pages included
4. Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Species Based Patches	Yes	1 page(s) included
5. Vernal Pool Habitat on the Project Site Based on Search of Landscape Project 3.1	No	0 pages included
6. Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Stream Habitat File	No	0 pages included
7. Other Animal Species On the Project Site Based on Additional Species Tracked by Endangered and Nongame Species Program	No	0 pages included

Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Species Based Patches

Class	Common Name	Scientific Name	Feature Type	Rank	Federal Protection Status	State Protection Status	Grank	Srank
Aves								
	Bald Eagle	Haliaeetus leucocephalus	Foraging	4	NA	State Endangered	G5	S1B,S2N
	Cattle Egret	Bubulcus ibis	Foraging	3	NA	State Threatened	G5	S2B,S3N
	Glossy Ibis	Plegadis falcinellus	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Little Blue Heron	Egretta caerulea	Foraging	2	NA	Special Concern	G5	S3B,S3N
	Peregrine Falcon	Falco peregrinus	Urban Nest	4	NA	State Endangered	G4	S1B,S3N
	Snowy Egret	Egretta thula	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Yellow-crowned Night-heron	Nyctanassa violacea	Foraging	3	NA	State Threatened	G5	S2B,S2N

Table 2: Vicinity Data Request Search Results (6 possible reports)

Report Name	**Included**	**Number of Pages**
1. Immediate Vicinity of the Project Site Based on Search of Natural Heritage Database Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
2. Natural Heritage Priority Sites within the Vicinity	No	0 pages included
3. Rare Wildlife Species or Wildlife Habitat Within the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Species Based Patches	Yes	1 page(s) included
4. Vernal Pool Habitat In the Immediate Vicinity of Project Site Based on Search of Landscape Project 3.1	No	0 pages included
5. Rare Wildlife Species or Wildlife Habitat In the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Stream Habitat File	No	0 pages included
6. Other Animal Species In the Immediate Vicinity of the Project Site Based on Additional Species Tracked by Endangered and Nongame Species Program	No	0 pages included

Rare Wildlife Species or Wildlife Habitat Within the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Species Based Patches

Class	Common Name	Scientific Name	Feature Type	Rank	Federal Protection Status	State Protection Status	Grank	Srank
Aves								
	Bald Eagle	Haliaeetus leucocephalus	Foraging	4	NA	State Endangered	G5	S1B,S2N
	Bald Eagle	Haliaeetus leucocephalus	Nest	4	NA	State Endangered	G5	S1B,S2N
	Cattle Egret	Bubulcus ibis	Foraging	3	NA	State Threatened	G5	S2B,S3N
	Glossy Ibis	Plegadis falcinellus	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Little Blue Heron	Egretta caerulea	Foraging	2	NA	Special Concern	G5	S3B,S3N
	Northern Harrier	Circus cyaneus	Breeding Sighting	4	NA	State Endangered	G5	S1B,S3N
	Northern Harrier	Circus cyaneus	Non-breeding Sighting	2	NA	Special Concern	G5	S1B,S3N
	Peregrine Falcon	Falco peregrinus	Urban Nest	4	NA	State Endangered	G4	S1B,S3N
	Snowy Egret	Egretta thula	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Yellow-crowned Night-heron	Nyctanassa violacea	Foraging	3	NA	State Threatened	G5	S2B,S2N

Site 721 - Metro Media Tract

State of New Jersey

CHRIS CHRISTIE
Governor

KIM GUADAGNO
Lt. Governor

DEPARTMENT OF ENVIRONMENTAL PROTECTION
State Forestry Services
Mail Code 501-04
ONLM -Natural Heritage Program
P.O. Box 420
Trenton, NJ 08625-0420
Tel. #609-984-1339
Fax. #609-984-1427

BOB MARTIN
Commissioner

May 21, 2015

Tara Stewart
Louis Berger
412 Mount Kemble Avenue
Morristown, NJ 07962-1946

Re: HRE Ecosystem Restoration Feasibility - Metro Media Tract

Dear Ms. Stewart:

Thank you for your data request regarding rare species information for the above referenced project site in Carlstadt Borough, Bergen County.

Searches of the Natural Heritage Database and the Landscape Project (Version 3.1) are based on a representation of the boundaries of your project site in our Geographic Information System (GIS). We make every effort to accurately transfer your project bounds from the topographic map(s) submitted with the Request for Data into our Geographic Information System. We do not typically verify that your project bounds are accurate, or check them against other sources.

We have checked the Landscape Project habitat mapping and the Biotics Database for occurrences of any rare wildlife species or wildlife habitat on the referenced site. The Natural Heritage Database was searched for occurrences of rare plant species or ecological communities that may be on the project site. Please refer to Table 1 (attached) to determine if any rare plant species, ecological communities, or rare wildlife species or wildlife habitat are documented on site. A detailed report is provided for each category coded as ‘Yes’ in Table 1.

We have also checked the Landscape Project habitat mapping and Biotics Database for occurrences of rare wildlife species or wildlife habitat in the immediate vicinity (within ¼ mile) of the referenced site. Additionally, the Natural Heritage Database was checked for occurrences of rare plant species or ecological communities within ¼ mile of the site. Please refer to Table 2 (attached) to determine if any rare plant species, ecological communities, or rare wildlife species or wildlife habitat are documented within the immediate vicinity of the site. Detailed reports are provided for all categories coded as ‘Yes’ in Table 2. These reports may include species that have also been documented on the project site.

The Natural Heritage Program reviews its data periodically to identify priority sites for natural diversity in the State. Included as priority sites are some of the State’s best habitats for rare and endangered species and ecological communities. Please refer to Tables 1 and 2 (attached) to determine if any priority sites are located on or in the vicinity of the site.

A list of rare plant species and ecological communities that have been documented from the project site, referenced above, can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/countylist.html. If suitable habitat is present at the project site, the species in that list have potential to be present.

Status and rank codes used in the tables and lists are defined in EXPLANATION OF CODES USED IN NATURAL HERITAGE REPORTS, which can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/nhpcodes_2010.pdf.

If you have questions concerning the wildlife records or wildlife species mentioned in this response, we recommend that you visit the interactive NJ-GeoWeb website at the following URL, http://www.state.nj.us/dep/gis/geowebsplash.htm or contact the Division of Fish and Wildlife, Endangered and Nongame Species Program at (609) 292-9400.

PLEASE SEE 'CAUTIONS AND RESTRICTIONS ON NHP DATA', which can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/newcaution2008.pdf.

Thank you for consulting the Natural Heritage Program. The attached invoice details the payment due for processing this data request. Feel free to contact us again regarding any future data requests.

Sincerely,

Robert J. Cartica
Administrator

c: NHP File No. 15-4007471-7674

Table 1: On Site Data Request Search Results (7 Possible Reports)

Report Name	**Included**	**Number of Pages**
1. Possibly on Project Site Based on Search of Natural Heritage Database: Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
2. On or In the Immediate Vicinity of the Project Site Based on Search of the Natural Heritage Database: Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
3. Natural Heritage Priority Sites On Site	No	0 pages included
4. Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Species Based Patches	Yes	1 page(s) included
5. Vernal Pool Habitat on the Project Site Based on Search of Landscape Project 3.1	No	0 pages included
6. Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Stream Habitat File	No	0 pages included
7. Other Animal Species On the Project Site Based on Additional Species Tracked by Endangered and Nongame Species Program	No	0 pages included

Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Species Based Patches

Class	Common Name	Scientific Name	Feature Type	Rank	Federal Protection Status	State Protection Status	Grank	Srank
Aves								
	Bald Eagle	Haliaeetus leucocephalus	Foraging	4	NA	State Endangered	G5	S1B,S2N
	Glossy Ibis	Plegadis falcinellus	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Little Blue Heron	Egretta caerulea	Foraging	2	NA	Special Concern	G5	S3B,S3N
	Northern Harrier	Circus cyaneus	Breeding Sighting	4	NA	State Endangered	G5	S1B,S3N
	Northern Harrier	Circus cyaneus	Non-breeding Sighting	2	NA	Special Concern	G5	S1B,S3N
	Peregrine Falcon	Falco peregrinus	Urban Nest	4	NA	State Endangered	G4	S1B,S3N
	Snowy Egret	Egretta thula	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Yellow-crowned Night-heron	Nyctanassa violacea	Foraging	3	NA	State Threatened	G5	S2B,S2N

Table 2: Vicinity Data Request Search Results (6 possible reports)

Report Name	Included	Number of Pages
1. Immediate Vicinity of the Project Site Based on Search of Natural Heritage Database Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
2. Natural Heritage Priority Sites within the Vicinity	No	0 pages included
3. Rare Wildlife Species or Wildlife Habitat Within the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Species Based Patches	Yes	1 page(s) included
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5. Rare Wildlife Species or Wildlife Habitat In the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Stream Habitat File	No	0 pages included
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Class	Common Name	Scientific Name	Feature Type	Rank	Federal Protection Status	State Protection Status	Grank	Srank
Aves								
	Bald Eagle	Haliaeetus leucocephalus	Foraging	4	NA	State Endangered	G5	S1B,S2N
	Cattle Egret	Bubulcus ibis	Foraging	3	NA	State Threatened	G5	S2B,S3N
	Glossy Ibis	Plegadis falcinellus	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Little Blue Heron	Egretta caerulea	Foraging	2	NA	Special Concern	G5	S3B,S3N
	Northern Harrier	Circus cyaneus	Breeding Sighting	4	NA	State Endangered	G5	S1B,S3N
	Northern Harrier	Circus cyaneus	Non-breeding Sighting	2	NA	Special Concern	G5	S1B,S3N
	Peregrine Falcon	Falco peregrinus	Urban Nest	4	NA	State Endangered	G4	S1B,S3N
	Snowy Egret	Egretta thula	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Yellow-crowned Night-heron	Nyctanassa violacea	Foraging	3	NA	State Threatened	G5	S2B,S2N

Hackensick River Reference Site – Marsh Resources Phase 2

State of New Jersey

CHRIS CHRISTIE
Governor

KIM GUADAGNO
Lt. Governor

DEPARTMENT OF ENVIRONMENTAL PROTECTION
State Forestry Services
Mail Code 501-04
ONLM -Natural Heritage Program
P.O. Box 420
Trenton, NJ 08625-0420
Tel. #609-984-1339
Fax. #609-984-1427

BOB MARTIN
Commissioner

May 21, 2015

Tara Stewart
Louis Berger
412 Mount Kemble Avenue
Morristown, NJ 07962-1946

Re: HRE Ecosystem Restoration Feasibility - Marsh Resources, Inc. Phase 2

Dear Ms. Stewart:

Thank you for your data request regarding rare species information for the above referenced project site in Carlstadt Borough, Bergen County.

Searches of the Natural Heritage Database and the Landscape Project (Version 3.1) are based on a representation of the boundaries of your project site in our Geographic Information System (GIS). We make every effort to accurately transfer your project bounds from the topographic map(s) submitted with the Request for Data into our Geographic Information System. We do not typically verify that your project bounds are accurate, or check them against other sources.

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PLEASE SEE 'CAUTIONS AND RESTRICTIONS ON NHP DATA', which can be downloaded from http://www.state.nj.us/dep/parksandforests/natural/heritage/newcaution2008.pdf.

Thank you for consulting the Natural Heritage Program. The attached invoice details the payment due for processing this data request. Feel free to contact us again regarding any future data requests.

Sincerely,

Robert J. Cartica
Administrator

c: NHP File No. 15-4007471-7673

Table 1: On Site Data Request Search Results (7 Possible Reports)

Report Name	Included	Number of Pages
1. Possibly on Project Site Based on Search of Natural Heritage Database: Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
2. On or In the Immediate Vicinity of the Project Site Based on Search of the Natural Heritage Database: Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
3. Natural Heritage Priority Sites On Site	No	0 pages included
4. Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Species Based Patches	Yes	1 page(s) included
5. Vernal Pool Habitat on the Project Site Based on Search of Landscape Project 3.1	No	0 pages included
6. Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Stream Habitat File	No	0 pages included
7. Other Animal Species On the Project Site Based on Additional Species Tracked by Endangered and Nongame Species Program	No	0 pages included

Rare Wildlife Species or Wildlife Habitat on the Project Site Based on Search of Landscape Project 3.1 Species Based Patches

Class	Common Name	Scientific Name	Feature Type	Rank	Federal Protection Status	State Protection Status	Grank	Srank
Aves								
	Bald Eagle	Haliaeetus leucocephalus	Foraging	4	NA	State Endangered	G5	S1B,S2N
	Glossy Ibis	Plegadis falcinellus	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Little Blue Heron	Egretta caerulea	Foraging	2	NA	Special Concern	G5	S3B,S3N
	Northern Harrier	Circus cyaneus	Breeding Sighting	4	NA	State Endangered	G5	S1B,S3N
	Northern Harrier	Circus cyaneus	Non-breeding Sighting	2	NA	Special Concern	G5	S1B,S3N
	Peregrine Falcon	Falco peregrinus	Urban Nest	4	NA	State Endangered	G4	S1B,S3N
	Snowy Egret	Egretta thula	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Yellow-crowned Night-heron	Nyctanassa violacea	Foraging	3	NA	State Threatened	G5	S2B,S2N

Table 2: Vicinity Data Request Search Results (6 possible reports)

Report Name	**Included**	**Number of Pages**
1. Immediate Vicinity of the Project Site Based on Search of Natural Heritage Database Rare Plant Species and Ecological Communities Currently Recorded in the New Jersey Natural Heritage Database	No	0 pages included
2. Natural Heritage Priority Sites within the Vicinity	No	0 pages included
3. Rare Wildlife Species or Wildlife Habitat Within the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Species Based Patches	Yes	1 page(s) included
4. Vernal Pool Habitat In the Immediate Vicinity of Project Site Based on Search of Landscape Project 3.1	No	0 pages included
5. Rare Wildlife Species or Wildlife Habitat In the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Stream Habitat File	No	0 pages included
6. Other Animal Species In the Immediate Vicinity of the Project Site Based on Additional Species Tracked by Endangered and Nongame Species Program	Yes	1 page(s) included

Rare Wildlife Species or Wildlife Habitat Within the Immediate Vicinity of the Project Site Based on Search of Landscape Project 3.1 Species Based Patches

Class	Common Name	Scientific Name	Feature Type	Rank	Federal Protection Status	State Protection Status	Grank	Srank
Aves								
	Bald Eagle	Haliaeetus leucocephalus	Foraging	4	NA	State Endangered	G5	S1B,S2N
	Barn Owl	Tyto alba	Non-breeding Sighting	2	NA	Special Concern	G5	S3B,S3N
	Cattle Egret	Bubulcus ibis	Foraging	3	NA	State Threatened	G5	S2B,S3N
	Glossy Ibis	Plegadis falcinellus	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Little Blue Heron	Egretta caerulea	Foraging	2	NA	Special Concern	G5	S3B,S3N
	Northern Harrier	Circus cyaneus	Breeding Sighting	4	NA	State Endangered	G5	S1B,S3N
	Northern Harrier	Circus cyaneus	Non-breeding Sighting	2	NA	Special Concern	G5	S1B,S3N
	Peregrine Falcon	Falco peregrinus	Urban Nest	4	NA	State Endangered	G4	S1B,S3N
	Snowy Egret	Egretta thula	Foraging	2	NA	Special Concern	G5	S3B,S4N
	Yellow-crowned Night-heron	Nyctanassa violacea	Foraging	3	NA	State Threatened	G5	S2B,S2N

Other Animal Species In the Immediate Vicinity of the Project Site Based on Additional Species Tracked by Endangered and Nongame Species Program

Scientific Name	Common Name	Federal Protection Status	State Protection Status	Grank	Srank
Vertebrate Animals					
Malaclemys terrapin terrapin	Northern Diamondback Terrapin			G4T4Q	S3

Total number of records: 1

USFWS Official Species Lists

Site 902 - Dundee Canal Green Acres Purchase and Dundee Island Preserve

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 8232
PHONE: (609)646-9310 FAX: (609)646-0352
URL: www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2015-SLI-0449 June 18, 2015
Event Code: 05E2NJ00-2015-E-00317
Project Name: Dundee Canal Green Acres Island Preserve

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed, and candidate species that may occur in your proposed action area and/or may be affected by your proposed project. This species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under Section 7(c) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*)

If the enclosed list indicates that any listed species may be present in your action area, please visit the New Jersey Field Office consultation web page as the next step in evaluating potential project impacts: http://www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

On the New Jersey Field Office consultation web page you will find:

- habitat descriptions, survey protocols, and recommended best management practices for listed species;
- recommended procedures for submitting information to this office; and
- links to other Federal and State agencies, the Section 7 Consultation Handbook, the Service's wind energy guidelines, communication tower recommendations, the National Bald Eagle Management Guidelines, and other resources and recommendations for protecting wildlife resources.

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is not limited to just the footprint of the project. The action area also includes all areas that may be indirectly affected through impacts such as noise, visual disturbance, erosion, sedimentation, hydrologic change, chemical exposure, reduced availability or access to food resources, barriers to movement, increased human intrusions or access, and all areas affected by reasonably forseeable future that would not occur without ("but for") the project that is currently being proposed.

We appreciate your concern for threatened and endangered species. The Service encourages Federal and non-Federal project proponents to consider listed, proposed, and candidate species early in the planning process. Feel free to contact this office if you would like more information or assistance evaluating potential project impacts to federally listed species or other wildlife resources. Please include the Consultation Tracking Number in the header of this letter with any correspondence about your project.

Attachment

United States Department of Interior
Fish and Wildlife Service

Project name: Dundee Canal Green Acres Island Preserve

Official Species List

Provided by:

New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 8232
(609) 646-9310
http://www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2015-SLI-0449
Event Code: 05E2NJ00-2015-E-00317

Project Type: LAND - RESTORATION / ENHANCEMENT

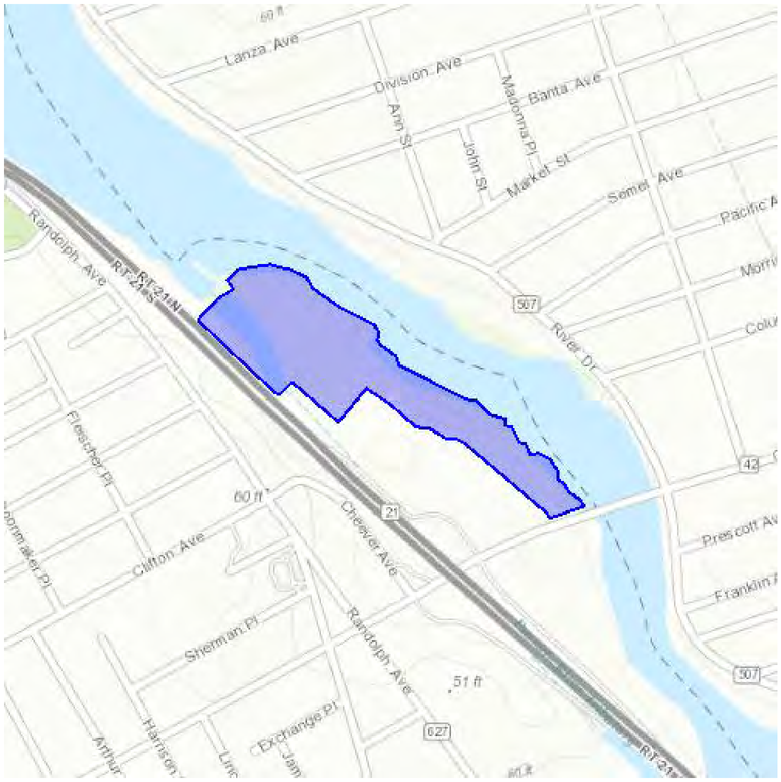
Project Name: Dundee Canal Green Acres Island Preserve
Project Description: Hudson Raritan Estuary (HRE) and HRE-Lower Passaic River Ecosystem Restoration Feasibility Study

Please Note: The FWS office may have modified the Project Name and/or Project Description, so it may be different from what was submitted in your previous request. If the Consultation Code matches, the FWS considers this to be the same project. Contact the office in the 'Provided by' section of your previous Official Species list if you have any questions or concerns.

United States Department of Interior
Fish and Wildlife Service

Project name: Dundee Canal Green Acres Island Preserve

Project Location Map:



Project Coordinates: The coordinates are too numerous to display here.

Project Counties: Passaic, NJ

United States Department of Interior
Fish and Wildlife Service

Project name: Dundee Canal Green Acres Island Preserve

Endangered Species Act Species List

There are a total of 0 threatened or endangered species on your species list. Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Critical habitats listed under the **Has Critical Habitat** column may or may not lie within your project area. See the **Critical habitats within your project area** section further below for critical habitat that lies within your project. Please contact the designated FWS office if you have questions.

There are no listed species identified for the vicinity of your project.

United States Department of Interior
Fish and Wildlife Service

Project name: Dundee Canal Green Acres Island Preserve

Critical habitats that lie within your project area

There are no critical habitats within your project area.

Site 900 – Dundee Island Park/Pulaski Park

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 08232
PHONE: (609)646-9310 FAX: (609)646-0352
URL: www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2016-SLI-0428
Event Code: 05E2NJ00-2016-E-00321
Project Name: Dundee Island Park/Pulaski Park

March 30, 2016

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed, and candidate species that may occur in your proposed action area and/or may be affected by your proposed project. This species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under Section 7(c) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*)

If the enclosed list indicates that any listed species may be present in your action area, please visit the New Jersey Field Office consultation web page as the next step in evaluating potential project impacts: http://www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

On the New Jersey Field Office consultation web page you will find:

- habitat descriptions, survey protocols, and recommended best management practices for listed species;
- recommended procedures for submitting information to this office; and
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is not limited to just the footprint of the project. The action area also includes all areas that may be indirectly affected through impacts such as noise, visual disturbance, erosion, sedimentation, hydrologic change, chemical exposure, reduced availability or access to food resources, barriers to movement, increased human intrusions or access, and all areas affected by reasonably forseeable future that would not occur without ("but for") the project that is currently being proposed.

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Attachment

United States Department of Interior
Fish and Wildlife Service

Project name: Dundee Island Park/Pulaski Park

Official Species List

Provided by:

New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 08232
(609) 646-9310
http://www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2016-SLI-0428
Event Code: 05E2NJ00-2016-E-00321

Project Type: LAND - RESTORATION / ENHANCEMENT

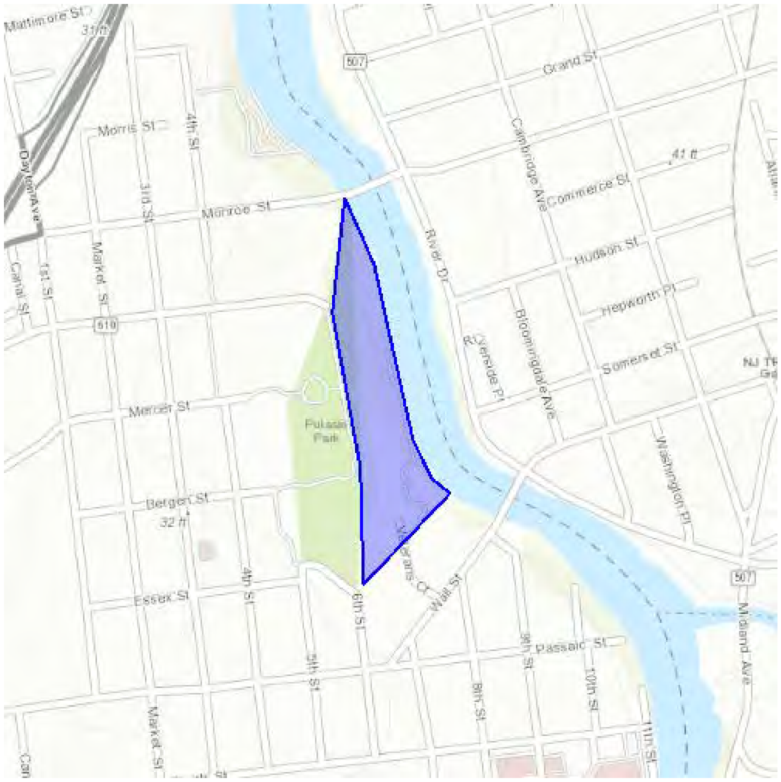
Project Name: Dundee Island Park/Pulaski Park
Project Description: Hudson Raritan Estuary (HRE) and HRE-Lower Passaic River Ecosystem Restoration Feasibility Study

Please Note: The FWS office may have modified the Project Name and/or Project Description, so it may be different from what was submitted in your previous request. If the Consultation Code matches, the FWS considers this to be the same project. Contact the office in the 'Provided by' section of your previous Official Species list if you have any questions or concerns.

United States Department of Interior
Fish and Wildlife Service

Project name: Dundee Island Park/Pulaski Park

Project Location Map:



Project Coordinates: MULTIPOLYGON (((-74.11291122436523 40.86867762652326, -74.11312580108643 40.86716854167582, -74.11263227462769 40.86514014765027, -74.11258935928345 40.86359852663907, -74.11108732223511 40.864783143872174, -74.1114091873169 40.86499410088275, -74.11173105239868 40.865513376815116, -74.11239624023438 40.867801387895646, -74.11291122436523 40.86867762652326)))

Project Counties: Passaic, NJ

United States Department of Interior
Fish and Wildlife Service

Project name: Dundee Island Park/Pulaski Park

Endangered Species Act Species List

There are a total of 0 threatened or endangered species on your species list. Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Critical habitats listed under the **Has Critical Habitat** column may or may not lie within your project area. See the **Critical habitats within your project area** section further below for critical habitat that lies within your project. Please contact the designated FWS office if you have questions.

There are no listed species identified for the vicinity of your project.

Critical habitats that lie within your project area

There are no critical habitats within your project area.

Site 887 – Essex County Branch Brook Park

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 08232
PHONE: (609)646-9310 FAX: (609)646-0352
URL: www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2016-SLI-0426 — March 30, 2016
Event Code: 05E2NJ00-2016-E-00319
Project Name: Essex County Branch Brook Park

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed, and candidate species that may occur in your proposed action area and/or may be affected by your proposed project. This species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under Section 7(c) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*)

If the enclosed list indicates that any listed species may be present in your action area, please visit the New Jersey Field Office consultation web page as the next step in evaluating potential project impacts: http://www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

On the New Jersey Field Office consultation web page you will find:

- habitat descriptions, survey protocols, and recommended best management practices for listed species;
- recommended procedures for submitting information to this office; and
- links to other Federal and State agencies, the Section 7 Consultation Handbook, the Service's wind energy guidelines, communication tower recommendations, the National Bald Eagle Management Guidelines, and other resources and recommendations for protecting wildlife resources.

The enclosed list may change as new information about listed species becomes available. As per Federal regulations at 50 CFR 402.12(e), the enclosed list is only valid for 90 days. Please return to the ECOS-IPaC website at regular intervals during project planning and implementation to obtain an updated species list. When using ECOS-IPaC, be careful about drawing the boundary of your Project Location. Remember that your action area under the ESA

is not limited to just the footprint of the project. The action area also includes all areas that may be indirectly affected through impacts such as noise, visual disturbance, erosion, sedimentation, hydrologic change, chemical exposure, reduced availability or access to food resources, barriers to movement, increased human intrusions or access, and all areas affected by reasonably forseeable future that would not occur without ("but for") the project that is currently being proposed.

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Attachment

United States Department of Interior
Fish and Wildlife Service

Project name: Essex County Branch Brook Park

Official Species List

Provided by:

New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 08232
(609) 646-9310
http://www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

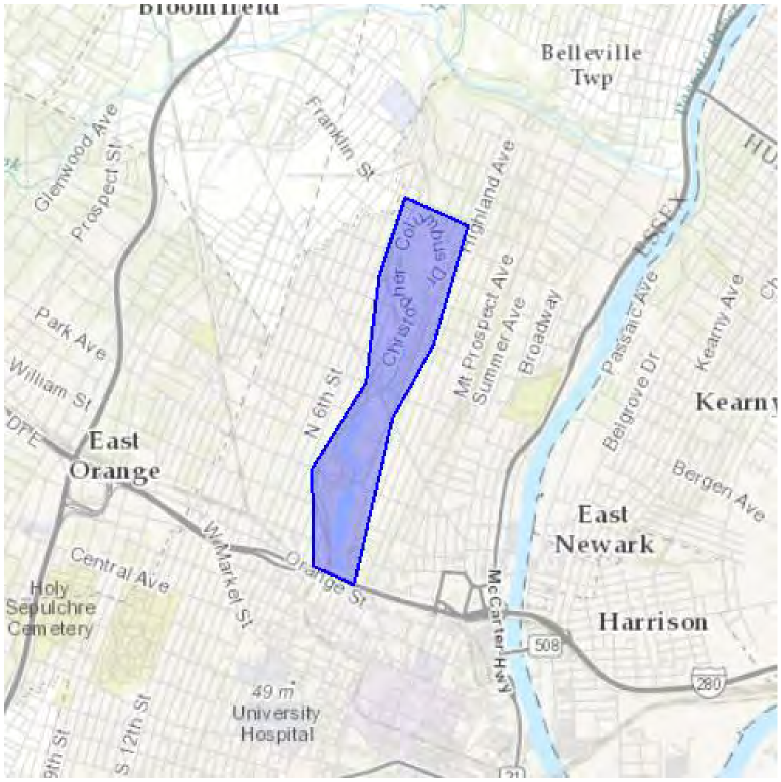
Consultation Code: 05E2NJ00-2016-SLI-0426
Event Code: 05E2NJ00-2016-E-00319

Project Type: LAND - RESTORATION / ENHANCEMENT

Project Name: Essex County Branch Brook Park
Project Description: Hudson Raritan Estuary (HRE) and HRE-Lower Passaic River Ecosystem Restoration Feasibility Study

Please Note: The FWS office may have modified the Project Name and/or Project Description, so it may be different from what was submitted in your previous request. If the Consultation Code matches, the FWS considers this to be the same project. Contact the office in the 'Provided by' section of your previous Official Species list if you have any questions or concerns.

Project Location Map:



Project Coordinates: MULTIPOLYGON (((-74.17651176452637 40.778721618334295, -74.17900085449219 40.772871880045216, -74.18028831481932 40.76507142776426, -74.1855239868164 40.75863536531348, -74.18543815612793 40.75148345390278, -74.18140411376953 40.75011800153818, -74.17762756347656 40.76247107352298, -74.17376518249512 40.76767168026598, -74.17024612426758 40.77664177039938, -74.17651176452637 40.778721618334295)))

Project Counties: Essex, NJ

United States Department of Interior
Fish and Wildlife Service

Project name: Essex County Branch Brook Park

Endangered Species Act Species List

There are a total of 0 threatened or endangered species on your species list. Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Critical habitats listed under the **Has Critical Habitat** column may or may not lie within your project area. See the **Critical habitats within your project area** section further below for critical habitat that lies within your project. Please contact the designated FWS office if you have questions.

There are no listed species identified for the vicinity of your project.

United States Department of Interior
Fish and Wildlife Service

Project name: Essex County Branch Brook Park

Critical habitats that lie within your project area

There are no critical habitats within your project area.

Site 865 - Kearny Point

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 8232
PHONE: (609)646-9310 FAX: (609)646-0352
URL: www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2015-SLI-0451 June 18, 2015
Event Code: 05E2NJ00-2015-E-00319
Project Name: Kearny Point

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed, and candidate species that may occur in your proposed action area and/or may be affected by your proposed project. This species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under Section 7(c) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*)

If the enclosed list indicates that any listed species may be present in your action area, please visit the New Jersey Field Office consultation web page as the next step in evaluating potential project impacts: http://www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

On the New Jersey Field Office consultation web page you will find:

- habitat descriptions, survey protocols, and recommended best management practices for listed species;
- recommended procedures for submitting information to this office; and
- links to other Federal and State agencies, the Section 7 Consultation Handbook, the Service's wind energy guidelines, communication tower recommendations, the National Bald Eagle Management Guidelines, and other resources and recommendations for protecting wildlife resources.

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Attachment

United States Department of Interior
Fish and Wildlife Service

Project name: Kearny Point

Official Species List

Provided by:

New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 8232
(609) 646-9310
http://www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2015-SLI-0451
Event Code: 05E2NJ00-2015-E-00319

Project Type: LAND - RESTORATION / ENHANCEMENT

Project Name: Kearny Point
Project Description: Hudson Raritan Estuary (HRE) and HRE-Lower Passaic River Ecosystem Restoration Feasibility Study

Please Note: The FWS office may have modified the Project Name and/or Project Description, so it may be different from what was submitted in your previous request. If the Consultation Code matches, the FWS considers this to be the same project. Contact the office in the 'Provided by' section of your previous Official Species list if you have any questions or concerns.

United States Department of Interior
Fish and Wildlife Service

Project name: Kearny Point

Project Location Map:

Project Coordinates: The coordinates are too numerous to display here.

Project Counties: Hudson, NJ

United States Department of Interior
Fish and Wildlife Service

Project name: Kearny Point

Endangered Species Act Species List

There are a total of 0 threatened or endangered species on your species list. Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Critical habitats listed under the **Has Critical Habitat** column may or may not lie within your project area. See the **Critical habitats within your project area** section further below for critical habitat that lies within your project. Please contact the designated FWS office if you have questions.

There are no listed species identified for the vicinity of your project.

United States Department of Interior
Fish and Wildlife Service

Project name: Kearny Point

Critical habitats that lie within your project area

There are no critical habitats within your project area.

Site 866 - Oak Island Yards

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 8232
PHONE: (609)646-9310 FAX: (609)646-0352
URL: www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2015-SLI-0455 June 18, 2015
Event Code: 05E2NJ00-2015-E-00323
Project Name: Oak Island Yards

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed, and candidate species that may occur in your proposed action area and/or may be affected by your proposed project. This species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under Section 7(c) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*)

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Attachment

United States Department of Interior
Fish and Wildlife Service

Project name: Oak Island Yards

Official Species List

Provided by:

New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 8232
(609) 646-9310
http://www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2015-SLI-0455
Event Code: 05E2NJ00-2015-E-00323

Project Type: LAND - RESTORATION / ENHANCEMENT

Project Name: Oak Island Yards
Project Description: Hudson Raritan Estuary (HRE) and HRE-Lower Passaic River Ecosystem Restoration Feasibility Study

Please Note: The FWS office may have modified the Project Name and/or Project Description, so it may be different from what was submitted in your previous request. If the Consultation Code matches, the FWS considers this to be the same project. Contact the office in the 'Provided by' section of your previous Official Species list if you have any questions or concerns.

United States Department of Interior
Fish and Wildlife Service

Project name: Oak Island Yards

Project Location Map:

Project Coordinates: The coordinates are too numerous to display here.

Project Counties: Essex, NJ

United States Department of Interior
Fish and Wildlife Service

Project name: Oak Island Yards

Endangered Species Act Species List

There are a total of 0 threatened or endangered species on your species list. Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Critical habitats listed under the **Has Critical Habitat** column may or may not lie within your project area. See the **Critical habitats within your project area** section further below for critical habitat that lies within your project. Please contact the designated FWS office if you have questions.

There are no listed species identified for the vicinity of your project.

Critical habitats that lie within your project area

There are no critical habitats within your project area.

Lower Passaic River Reference Site – Harrison Marsh

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 8232
PHONE: (609)646-9310 FAX: (609)646-0352
URL: www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2015-SLI-0450 June 18, 2015
Event Code: 05E2NJ00-2015-E-00318
Project Name: Harrison Marsh

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed, and candidate species that may occur in your proposed action area and/or may be affected by your proposed project. This species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under Section 7(c) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*)

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On the New Jersey Field Office consultation web page you will find:

- habitat descriptions, survey protocols, and recommended best management practices for listed species;
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Attachment

United States Department of Interior
Fish and Wildlife Service

Project name: Harrison Marsh

Official Species List

Provided by:

New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 8232
(609) 646-9310
http://www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2015-SLI-0450
Event Code: 05E2NJ00-2015-E-00318

Project Type: LAND - RESTORATION / ENHANCEMENT

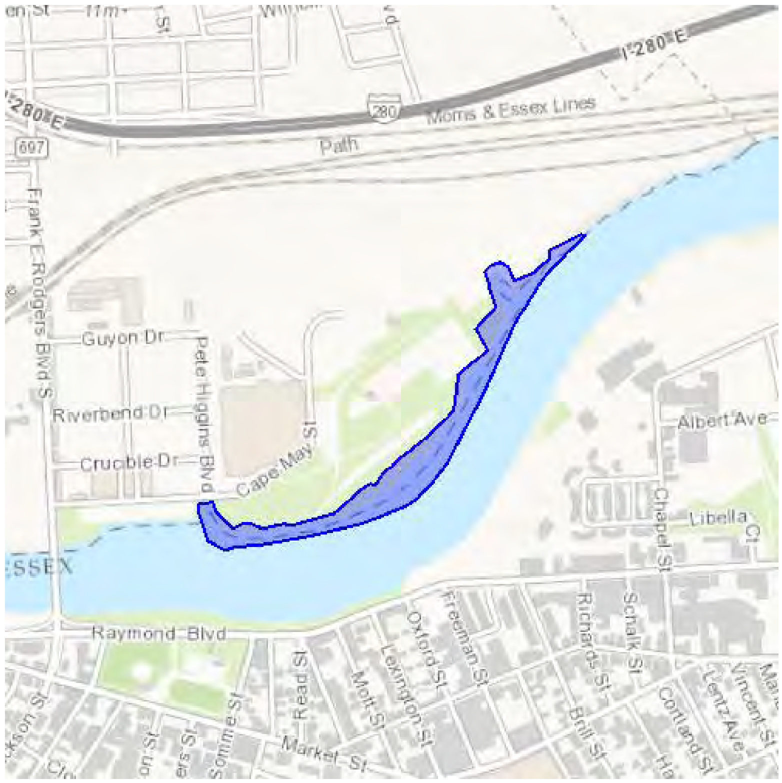
Project Name: Harrison Marsh
Project Description: Hudson Raritan Estuary (HRE) and HRE-Lower Passaic River Ecosystem Restoration Feasibility Study

Please Note: The FWS office may have modified the Project Name and/or Project Description, so it may be different from what was submitted in your previous request. If the Consultation Code matches, the FWS considers this to be the same project. Contact the office in the 'Provided by' section of your previous Official Species list if you have any questions or concerns.

United States Department of Interior
Fish and Wildlife Service

Project name: Harrison Marsh

Project Location Map:



Project Coordinates: The coordinates are too numerous to display here.

Project Counties: Hudson, NJ

United States Department of Interior
Fish and Wildlife Service

Project name: Harrison Marsh

Endangered Species Act Species List

There are a total of 0 threatened or endangered species on your species list. Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Critical habitats listed under the **Has Critical Habitat** column may or may not lie within your project area. See the **Critical habitats within your project area** section further below for critical habitat that lies within your project. Please contact the designated FWS office if you have questions.

There are no listed species identified for the vicinity of your project.

Critical habitats that lie within your project area

There are no critical habitats within your project area.

Site 719 - Meadowlark Marsh

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 8232
PHONE: (609)646-9310 FAX: (609)646-0352
URL: www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2015-SLI-0453 June 18, 2015
Event Code: 05E2NJ00-2015-E-00321
Project Name: Meadowlark Marsh

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed, and candidate species that may occur in your proposed action area and/or may be affected by your proposed project. This species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under Section 7(c) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*)

If the enclosed list indicates that any listed species may be present in your action area, please visit the New Jersey Field Office consultation web page as the next step in evaluating potential project impacts: http://www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

On the New Jersey Field Office consultation web page you will find:

- habitat descriptions, survey protocols, and recommended best management practices for listed species;
- recommended procedures for submitting information to this office; and
- links to other Federal and State agencies, the Section 7 Consultation Handbook, the Service's wind energy guidelines, communication tower recommendations, the National Bald Eagle Management Guidelines, and other resources and recommendations for protecting wildlife resources.

The enclosed list may change as new information about listed species becomes available. As per Federal regulations at 50 CFR 402.12(e), the enclosed list is only valid for 90 days. Please return to the ECOS-IPaC website at regular intervals during project planning and implementation to obtain an updated species list. When using ECOS-IPaC, be careful about drawing the boundary of your Project Location. Remember that your action area under the ESA

is not limited to just the footprint of the project. The action area also includes all areas that may be indirectly affected through impacts such as noise, visual disturbance, erosion, sedimentation, hydrologic change, chemical exposure, reduced availability or access to food resources, barriers to movement, increased human intrusions or access, and all areas affected by reasonably forseeable future that would not occur without ("but for") the project that is currently being proposed.

We appreciate your concern for threatened and endangered species. The Service encourages Federal and non-Federal project proponents to consider listed, proposed, and candidate species early in the planning process. Feel free to contact this office if you would like more information or assistance evaluating potential project impacts to federally listed species or other wildlife resources. Please include the Consultation Tracking Number in the header of this letter with any correspondence about your project.

Attachment

United States Department of Interior
Fish and Wildlife Service

Project name: Meadowlark Marsh

Official Species List

Provided by:

New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 8232
(609) 646-9310
http://www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2015-SLI-0453
Event Code: 05E2NJ00-2015-E-00321

Project Type: LAND - RESTORATION / ENHANCEMENT

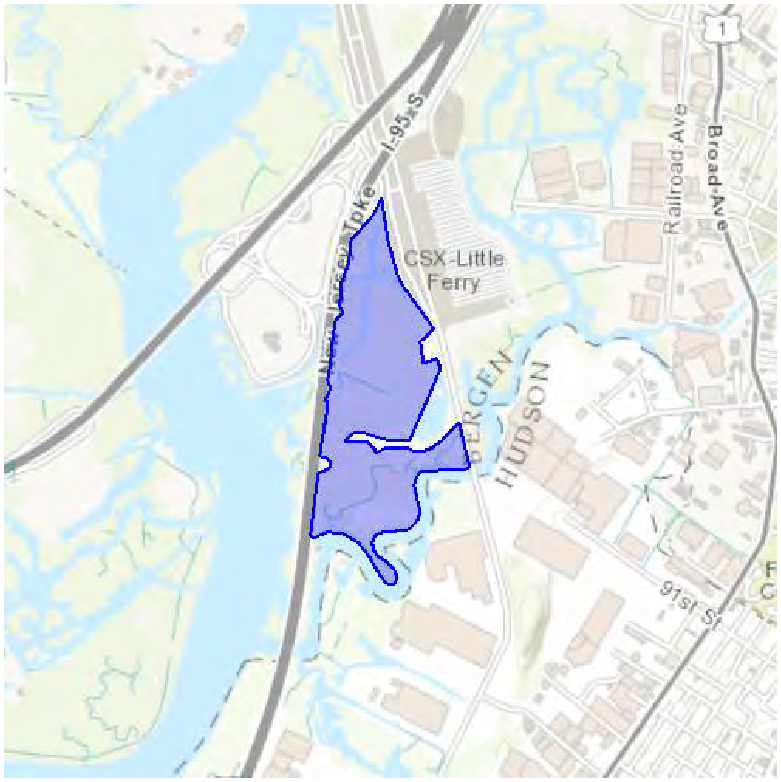
Project Name: Meadowlark Marsh
Project Description: Hudson Raritan Estuary (HRE) and HRE-Lower Passaic River Ecosystem Restoration Feasibility Study

Please Note: The FWS office may have modified the Project Name and/or Project Description, so it may be different from what was submitted in your previous request. If the Consultation Code matches, the FWS considers this to be the same project. Contact the office in the 'Provided by' section of your previous Official Species list if you have any questions or concerns.

United States Department of Interior
Fish and Wildlife Service

Project name: Meadowlark Marsh

Project Location Map:



Project Coordinates: The coordinates are too numerous to display here.

Project Counties: Bergen, NJ

United States Department of Interior
Fish and Wildlife Service

Project name: Meadowlark Marsh

Endangered Species Act Species List

There are a total of 0 threatened or endangered species on your species list. Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Critical habitats listed under the **Has Critical Habitat** column may or may not lie within your project area. See the **Critical habitats within your project area** section further below for critical habitat that lies within your project. Please contact the designated FWS office if you have questions.

There are no listed species identified for the vicinity of your project.

United States Department of Interior
Fish and Wildlife Service

Project name: Meadowlark Marsh

Critical habitats that lie within your project area

There are no critical habitats within your project area.

Site 721 - Metro Media Tract

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 8232
PHONE: (609)646-9310 FAX: (609)646-0352
URL: www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2015-SLI-0454 June 18, 2015
Event Code: 05E2NJ00-2015-E-00322
Project Name: Metro Media Tract

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed, and candidate species that may occur in your proposed action area and/or may be affected by your proposed project. This species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under Section 7(c) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*)

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- habitat descriptions, survey protocols, and recommended best management practices for listed species;
- recommended procedures for submitting information to this office; and
- links to other Federal and State agencies, the Section 7 Consultation Handbook, the Service's wind energy guidelines, communication tower recommendations, the National Bald Eagle Management Guidelines, and other resources and recommendations for protecting wildlife resources.

The enclosed list may change as new information about listed species becomes available. As per Federal regulations at 50 CFR 402.12(e), the enclosed list is only valid for 90 days. Please return to the ECOS-IPaC website at regular intervals during project planning and implementation to obtain an updated species list. When using ECOS-IPaC, be careful about drawing the boundary of your Project Location. Remember that your action area under the ESA

is not limited to just the footprint of the project. The action area also includes all areas that may be indirectly affected through impacts such as noise, visual disturbance, erosion, sedimentation, hydrologic change, chemical exposure, reduced availability or access to food resources, barriers to movement, increased human intrusions or access, and all areas affected by reasonably forseeable future that would not occur without ("but for") the project that is currently being proposed.

We appreciate your concern for threatened and endangered species. The Service encourages Federal and non-Federal project proponents to consider listed, proposed, and candidate species early in the planning process. Feel free to contact this office if you would like more information or assistance evaluating potential project impacts to federally listed species or other wildlife resources. Please include the Consultation Tracking Number in the header of this letter with any correspondence about your project.

Attachment

United States Department of Interior
Fish and Wildlife Service

Project name: Metro Media Tract

Official Species List

Provided by:

New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 8232
(609) 646-9310
http://www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2015-SLI-0454
Event Code: 05E2NJ00-2015-E-00322

Project Type: LAND - RESTORATION / ENHANCEMENT

Project Name: Metro Media Tract
Project Description: Hudson Raritan Estuary (HRE) and HRE-Lower Passaic River Ecosystem Restoration Feasibility Study

Please Note: The FWS office may have modified the Project Name and/or Project Description, so it may be different from what was submitted in your previous request. If the Consultation Code matches, the FWS considers this to be the same project. Contact the office in the 'Provided by' section of your previous Official Species list if you have any questions or concerns.

United States Department of Interior
Fish and Wildlife Service

Project name: Metro Media Tract

Project Location Map:

Project Coordinates: MULTIPOLYGON (((-74.03289628083866 40.8144290875324, -74.03303979015413 40.8138305959053, -74.03320586076183 40.81346189814815, -74.03331105536085 40.81304748964999, -74.03358937215177 40.81225600531047, -74.03359799844884 40.812120507155726, -74.03367119157218 40.81201906722623, -74.03367622777563 40.811880295539254, -74.03381454170767 40.811378867740586, -74.03403312462893 40.810796787841525, -74.03409748640985 40.81050487959658, -74.03429564572743 40.810162729826175, -74.03491876259079 40.80959240226758, -74.03572521254847 40.809119225771724, -74.03601564680463 40.80898040102471, -74.03673221491977 40.80883213519496, -74.03773031760005 40.80871999153442, -74.03900515606307 40.80875014040669, -74.04129915393275 40.81251201711598, -74.03615275744374 40.81412465532861, -74.03584882706167 40.814894672850926, -74.03289628083866 40.8144290875324)))

Project Counties: Bergen, NJ

United States Department of Interior
Fish and Wildlife Service

Project name: Metro Media Tract

Endangered Species Act Species List

There are a total of 0 threatened or endangered species on your species list. Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Critical habitats listed under the **Has Critical Habitat** column may or may not lie within your project area. See the **Critical habitats within your project area** section further below for critical habitat that lies within your project. Please contact the designated FWS office if you have questions.

There are no listed species identified for the vicinity of your project.

Critical habitats that lie within your project area

There are no critical habitats within your project area.

Hackensick River Reference Site – Marsh Resources Phase 2

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 8232
PHONE: (609)646-9310 FAX: (609)646-0352
URL: www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2015-SLI-0452 June 18, 2015
Event Code: 05E2NJ00-2015-E-00320
Project Name: Marsh Resources 2

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed, and candidate species that may occur in your proposed action area and/or may be affected by your proposed project. This species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under Section 7(c) of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*)

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On the New Jersey Field Office consultation web page you will find:

- habitat descriptions, survey protocols, and recommended best management practices for listed species;
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- links to other Federal and State agencies, the Section 7 Consultation Handbook, the Service's wind energy guidelines, communication tower recommendations, the National Bald Eagle Management Guidelines, and other resources and recommendations for protecting wildlife resources.

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We appreciate your concern for threatened and endangered species. The Service encourages Federal and non-Federal project proponents to consider listed, proposed, and candidate species early in the planning process. Feel free to contact this office if you would like more information or assistance evaluating potential project impacts to federally listed species or other wildlife resources. Please include the Consultation Tracking Number in the header of this letter with any correspondence about your project.

Attachment

United States Department of Interior
Fish and Wildlife Service

Project name: Marsh Resources 2

Official Species List

Provided by:

New Jersey Ecological Services Field Office
927 NORTH MAIN STREET, BUILDING D
PLEASANTVILLE, NJ 8232
(609) 646-9310
http://www.fws.gov/northeast/njfieldoffice/Endangered/consultation.html

Consultation Code: 05E2NJ00-2015-SLI-0452
Event Code: 05E2NJ00-2015-E-00320

Project Type: LAND - RESTORATION / ENHANCEMENT

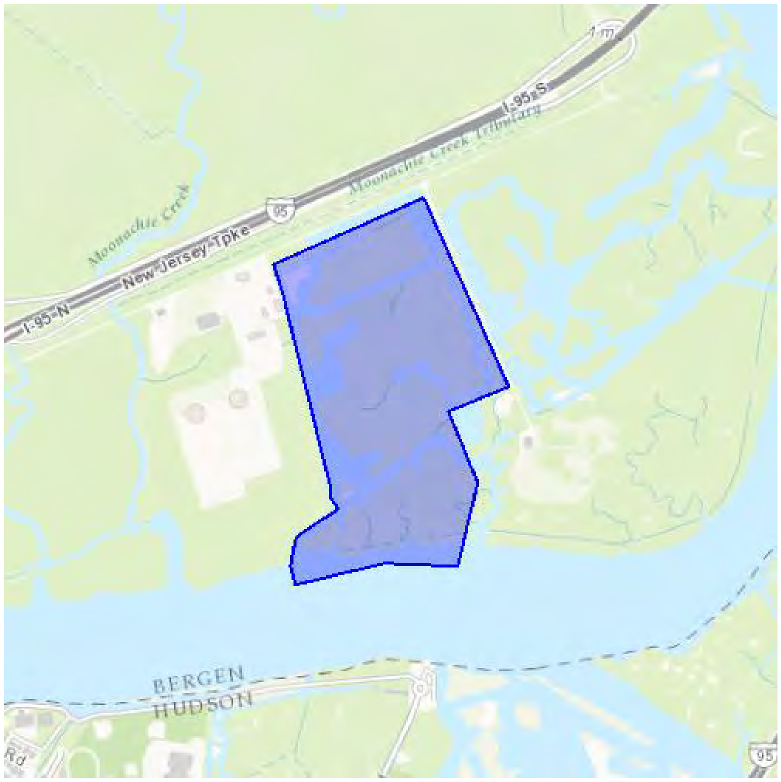
Project Name: Marsh Resources 2
Project Description: Hudson Raritan Estuary (HRE) and HRE-Lower Passaic River Ecosystem Restoration Feasibility Study

Please Note: The FWS office may have modified the Project Name and/or Project Description, so it may be different from what was submitted in your previous request. If the Consultation Code matches, the FWS considers this to be the same project. Contact the office in the 'Provided by' section of your previous Official Species list if you have any questions or concerns.

United States Department of Interior
Fish and Wildlife Service

Project name: Marsh Resources 2

Project Location Map:



Project Coordinates: MULTIPOLYGON (((-74.04808853535758 40.815217964737315, -74.04366626758411 40.81671173595788, -74.04120773335018 40.81251973689638, -74.04294871201341 40.81196934011302, -74.04208820021023 40.810398080607, -74.04270497595384 40.80857389127209, -74.04482415910763 40.808631061174594, -74.04744463606107 40.80816581310182, -74.0475635884888 40.808552592628075, -74.0474299150585 40.80914652289374, -74.04734484368953 40.80923581478106, -74.04618297176671 40.80982637888434, -74.04638956492641 40.810060803363456, -74.04641210733286 40.81027427633683, -74.04780596837071 40.814570330556364, -74.04808853535758 40.815217964737315)))

Project Counties: Bergen, NJ

United States Department of Interior
Fish and Wildlife Service

Project name: Marsh Resources 2

Endangered Species Act Species List

There are a total of 0 threatened or endangered species on your species list. Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Critical habitats listed under the **Has Critical Habitat** column may or may not lie within your project area. See the **Critical habitats within your project area** section further below for critical habitat that lies within your project. Please contact the designated FWS office if you have questions.

There are no listed species identified for the vicinity of your project.

Critical habitats that lie within your project area

There are no critical habitats within your project area.

Conserve Wildlife
New Jersey Department of Environmental Protection
Division of Fish & Wildlife
Endangered & Nongame Species Program

New Jersey's Endangered and Threatened Wildlife

State Wildlife Action Plan Being Updated

The lists of New Jersey's endangered and threatened wildlife species are maintained by the Division of Fish and Wildlife's Endangered and Nongame Species Program (ENSP). These lists are used to determine protection and management actions necessary to ensure the survival of the state's endangered, threatened and other nongame wildlife. See the Species Status Assessment page for information on the listing process.

This work is made possible through voluntary contributions received through Check-off donations to the Endangered Wildlife Conservation Fund on the State Income Tax Form, the sale of Conserve Wildlife License Plates, and donations.

To report a sighting of endangered or threatened wildlife, use the Rare Wildlife Sighting Report Form.

Endangered Species are those whose prospects for survival in New Jersey are in immediate danger because of a loss or change in habitat, over-exploitation, predation, competition, disease, disturbance or contamination. Assistance is needed to prevent future extinction in New Jersey.

Threatened Species are those who may become endangered if conditions surrounding them begin to or continue to deteriorate.

There are other classifications for wildlife as well, including Stable, Species of Special Concern and Undetermined. For a complete listing of species monitored by the ENSP, see the Species Status Listing on the Conserve Wildlife Foundation of NJ website.

Species names in the tables below link to PDF documents containing identification, habitat and status and conservation information. For more detailed descriptions, photographs, and range maps of New Jersey’s endangered, threatened, and special concern species, please refer to the Conserve Wildlife Foundation of NJ’s on-line field guide.

BIRDS			
Endangered		**Threatened**	
Bittern, American BR	*Botaurus lentiginosos* BR	Bobolink BR	*Dolichonyx oryzivorus* BR
Eagle, bald BR	*Haliaeetus leucocephalus* BR	Eagle, bald NB	*Haliaeetus leucocephalus* NB
Falcon, peregrine BR	*Falco peregrinus* BR	Egret, cattle BR	*Bubulcus ibis* BR
Goshawk, northern BR	*Accipiter gentilis* BR	Kestrel, American	*Falco sparverius*
Grebe, pied-billed BR	*Podilymbus podiceps* BR	Lark, horned BR	*Eremophila alpestris* BR
Harrier, northern BR	*Circus cyaneus* BR	Night-heron, black-crowned BR	*Nycticorax nycticorax* BR
Hawk, red-shouldered BR	*Buteo lineatus* BR	Night-heron, yellow-crowned	*Nyctanassa violacea*

Knot, red NB	*Calidris canutus* NB	Osprey BR	*Pandion haliaetus* BR
Owl, short-eared BR	*Asio flammeus* BR	Owl, barred	*Strix varia*
Plover, piping**	*Charadrius melodus***	Owl, long-eared	*Asio otus*
Rail, black BR	*Laterallus jamaicensis* BR	Rail, black NB	*Laterallus jamaicensis* NB
Sandpiper, upland	*Batramia longicauda*	Sparrow, grasshopper BR	*Ammodramus savannarum* BR
Shrike, loggerhead NB	*Lanius ludovicianus* NB	Sparrow, Savannah BR	*Passerculus sandwichensis* BR
Skimmer, black	*Rynchops niger*	Woodpecker, red-headed	*Melanerpes erythrocephalus*
Sparrow, Henslow's	*Ammodramus henslowii*		
Sparrow, vesper BR	*Pooecetes gramineus* BR		
Tern, least	*Sternula antillarum*		
Tern, roseate**	*Sterna dougallii***		
Warbler, golden-winged BR	*Vermivora chrysoptera* BR		
Wren, sedge	*Cistothorus platensis*		
**Federally endangered or threatened			
BR - Breeding population only; NB - non-breeding population only			

REPTILES			
Endangered		**Threatened**	
Rattlesnake, timber	*Crotalus h. horridus*	Snake, northern pine	*Pituophis m. melanoleucus*
Snake, corn	*Elaphe g. guttata*	Turtle, Atlantic green**	*Chelonia mydas***
Snake, queen	*Regina septemvittata*	Turtle, wood	*Glyptemys insculpta*
Turtle, bog**	*Glyptemys muhlenbergii***		
Hawksbill, Atlantic**	*Eretmochelys imbricata***		
Leatherback, Atlantic **	*Dermochelys coriacea***		
Loggerhead, Atlantic **	*Caretta caretta***		
Ridley, Atlantic **	*Lepidochelys kempii***		
**Federally endangered or threatened			

AMPHIBIANS			
Endangered		**Threatened**	
Salamander, blue-spotted	*Ambystoma laterale*	Salamander, eastern mud	*Pseudotriton montanus*
Salamander, eastern tiger	*Ambystoma tigrinum*	Salamander, long-tailed	*Eurycea longicauda*
Treefrog, southern gray	*Hyla chrysocelis*	Treefrog, pine barrens	*Hyla andersonii*

INVERTEBRATES			
Endangered		**Threatened**	
Beetle, American burying**	*Nicrophorus americanus***	Baskettail, robust(dragonfly)	*Epitheca spinosa*
Beetle, northeastern beach tiger**	*Cincindela d. dorsalis***	Clubtail, banner (dragonfly)	*Gomphus apomyius*
Copper, bronze	*Lycaena hyllus*	Clubtail, harpoon (dragonfly)	*Gomphus descriptus*
Floater, brook (mussel)	*Alasmidonta varicosa*	Elfin, frosted (butterfly)	*Callophrys irus*
Floater, green (mussel)	*Lasmigona subviridis*	Emerald, Kennedy's (dragonfly)	*Somatochlora kennedyi*
Petaltail, gray (dragonfly)	*Tachopteryx thoreyi*	Floater, triangle (mussel)	*Alasmidonta undulata*
Satyr, Mitchell's (butterfly)**	*Neonympha m. mitchellii***	Fritillary, silver-bordered (butterfly)	*Bolaria selene myrina*
Skipper, arogos (butterfly)	*Atrytone arogos arogos*	Jewelwing, superb (dragonfly)	*Calopteryx amata*
Skipper, Appalachian grizzled (butterfly)	*Pyrgus wyandot*	Lampmussel, eastern (mussel)	*Lampsilis radiata*
Wedgemussel, dwarf**	*Alasmidonta heterodon***	Lampmussel, yellow (mussel)	*Lampsilis cariosa*
		Mucket, tidewater (mussel)	*Leptodea ochracea*
		Pondmussel, eastern (mussel)	*Ligumia nasuta*
		Snaketail, brook, (dragonfly)	*Ophiogomphus asperses*
		White, checkered (butterfly)	*Pontia protodice*
**Federally endangered or threatened			

MAMMALS	
Endangered	
Bat, Indiana**	*Myotis sodalis***
Bobcat	*Lynx rufus*
Whale, North Atlantic right**	*Eubalaena glacialis***
Whale, blue**	*Balaenoptera musculus***
Whale, fin**	*Balaenoptera physalus***
Whale, humpback**	*Megaptera novaeangliae***
Whale, sei**	*Balaenoptera borealis***
Whale,sperm**	*Physeter macrocephalus***

FISH	
Endangered	
Sturgeon, Atlantic**	*Acipenser oxyrinchus oxyrinchus***
Sturgeon, shortnose**	*Acipenser brevirostrum***
**Federally Endangered	

Woodrat, Allegheny	*Neotoma magister*
**Federally Endangered	

List updated 4/2/12

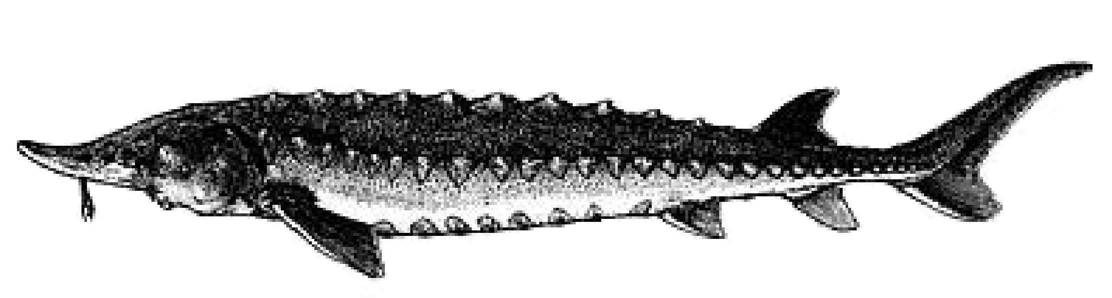
The lists of New Jersey's endangered and nongame wildlife species are maintained by the DEP's Division of Fish and Wildlife's Endangered and Nongame Species Program. These lists are used to determine protection and management actions necessary to ensure the survival of the state's endangered and nongame wildlife.

This work is made possible through voluntary contributions received through Check-off donations to the Endangered Wildlife Conservation Fund on the State Income Tax Form, the sale of Conserve Wildlife License Plates, and donations. For more information about the Endangered and Nongame Species Program or to report a sighting of endangered or threatened wildlife, contact the Endangered and Nongame Species, NJ Division of Fish and Wildlife, Mail Code 501-03, PO Box 420, Trenton, NJ 08625-0420.

Appendix B
Status Review of Atlantic Sturgeon

GREELEY AND HANSEN
CDM Smith

STATUS REVIEW OF ATLANTIC STURGEON
(*Acipenser oxyrinchus oxyrinchus*)



Prepared by the

Atlantic Sturgeon Status Review Team

for the

National Marine Fisheries Service
National Oceanic and Atmospheric Administration

February 23, 2007

Updated with corrections on July 27, 2007.

Acknowledgements

The status review for Atlantic sturgeon was conducted by a team of scientists from the National Marine Fisheries Service (NMFS), United States Fish and Wildlife Service (USFWS), and United States Geological Survey (USGS). This review was dependent on information from scientific literature or data provided by various state agencies and individuals. In addition to the regional biologists who contributed to this report (noted below), the status review team would like to acknowledge the contributions of Russ Allen, Prescott Brownell, Mary Colligan, Julie Crocker, Kristen Ferry, Charlton Godwin, Dana Hartley, Daniel Hatin, Kathy Hattala, Jennifer Lowery, Kent Nelson, Pete Kornegay, Blake Price, Mike Randall, Rory Saunders, Pasquale Scida, Tiffany Vidal, and Ike Wirgin. The SRT would also like to thank the peer reviewers, Mike Dadswell, Dewayne Fox, Boyd Kynard, Doug Peterson, David Secor, and John Waldman for their helpful comments and suggestions.

This document should be cited as:

Atlantic Sturgeon Status Review Team. 2007. Status Review of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). Report to National Marine Fisheries Service, Northeast Regional Office. February 23, 2007. 174 pp.

<u>Atlantic Sturgeon Status Review Team Members:</u>

Stephania Bolden, Ph.D.	NOAA – Fisheries, SERO, St. Petersburg, FL
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Joseph Hightower, Ph.D.	USGS – NCCFWRU, Raleigh, NC
Tim King, Ph.D.	USGS – LSC, Leetown, WV
Wilson Laney, Ph.D.	USFWS – SAFCO, Raleigh, NC
Steve Mierzykowski	USFWS – Ecological Services Maine Field Office, ME
Steve Minkkinen	USFWS – MDFRO, Annapolis, MD
Jerre Mohler	USFWS – NEFC, Lamar, PA
Wesley Patrick	NOAA – Fisheries, NERO, Gloucester, MA
Kenneth J. Sulak, Ph.D.	USGS – Florida Integrated Science Center, Gainesville, FL

<u>Atlantic Sturgeon Regional Experts:</u>

Mark Collins, Ph.D.	SCDNR – Charleston, SC
Andy Kahnle	NYSDEC – New Paltz, NY
Greg Murphy	DFW – Smyrna, DE
Tom Savoy	CTDEP – Old Lyme, CT
Tom Squiers	MEDMR – Augusta, ME
Brad Spear	ASMFC – Washington, DC
Dick St. Pierre	Retired USFWS – Millerstown, PA
Fritz Rohde	NCDMF – Wilmington, NC

Table of Contents

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List of Figures and Photos

List of Acronyms and Abbreviations

ACE Basin	Ashepoo, Combahee and Edisto rivers
ACFCMA	Atlantic Coastal Fisheries Cooperative Management Act
ACOE	Army Corps of Engineers
AENRD	Army Environmental and Natural Resources Division (Ft. Stewart)
AFS	American Fisheries Society
AICW	Atlantic Intercoastal Waterway
ASMFC	Atlantic States Marine Fisheries Commission
BIW	Bath Iron Works
BRD	bycatch reduction device
C	centigrade
CAFL	Conte Anadromous Fish Laboratory
CAFOs	concentrated animal feeding operations
Cd	cadmium
cfs	cubic feet per second
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
cm	centimeters
CONED	Consolidated Edison Company
CPUE	catch-per-unit-of-effort
CTDEP	Connecticut Department of Environmental Protection
Cu	copper
DDE	dichlorodiphenyl dichloroethylene
DDT	dichlorodiphenyl trichloroethane
DFO	Department of Fisheries and Oceans (Canada)
DFW	Delaware Division of Fish and Wildlife
DNR	Department of Natural Resources
DNREC	Delaware Department of Natural Resources and Environmental Control
DO	Dissolved Oxygen
DPS	Distinct Population Segment
EDUs	Ecological Drainage Units
EEZ	Economic Exclusive Zone
EFH	Essential Fish Habitat
EPA	Environmental Protection Agency
ERA	extinction risk analysis
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FL	fork length
FMP	Fishery Management Plan
FPA	Federal Power Act
FR	Federal Register
FSS	Fall Shoals Survey
FST	Fixation Index
FWCA	Fish and Wildlife Coordination Act
FWPA	Federal Water Pollution Control Act (Clean Water Act)

GIS	Geographic Information System
Hg	mercury
HNP	Hatch Nuclear Power Plant
hp	horsepower
hr	hour
ICW	Intercoastal Waterway
IFAS	Institute for Food and Agricultural Science
IGNS	Independent Gill Net Survey
IHNV	infectious hematopoietic necrosis virus
in	inches
IUCN	International Union for the Conservation of Nature and Natural Resources
km	kilometer
lbs	pounds
LD	lethal dose
LHRHα	luteinizing hormone releasing hormone analog
LNG	Liquefied Natural Gas
LIS	Long Island Sound
LRS	Long River Survey
m	meters
MADMF	Massachusetts Division of Marine Fisheries
MDFRO	Maryland Fishery Resource Office
MEDMR	Maine Department of Marine Resources
MEBOH	Maine Bureau of Health
MEDEP	Maine Department of Environmental Protection
MGD	million gallons per day
mg/L	milligrams per liter (parts-per-million)
mm	millimeters
MPUE	mortality per unit of effort
MPRSA	Marine Protection, Research and Sanctuaries Act
mt	metric ton
mtDNA	mitochondrial DNA
NASCO	North Atlantic Salmon Conservation Organization
NCCFWRU	North Carolina Cooperative Fish and Wildlife Research Unit.
NCDMF	North Carolina Division of Marine Fisheries
NCSU	North Carolina State University
nDNA	nuclear DNA
NEFC	Northeast Fisheries Center (USFWS)
NEFO	Northeast Fisheries Observer program
NEPA	National Environmental Policy Act
NHFG	New Hampshire Fish and Game
NIEM	Nelson Institute of Environmental Medicine
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NSBL&D	New Savannah Bluff Lock and Dam
NPDES	National Pollutant Discharge Elimination System
NYSDEC	New York State Department of Environmental Conservation

PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCDDs	polychlorinated dibenzo-*p*-dioxins
PCDF	polychlorinated dibenzofurans
PECE	Policy for Evaluation of Conservation Efforts
pers.	Personal
pg/g	picograms-per-gram (parts-per-trillion)
ppm	parts-per-million
ppt	parts-per-thousand
PVA	Population Viability Analysis
QSWP	Quebec Society for Wildlife and Parks
RIDEM	Rhode Island Department of Environmental Management
rkm	river kilometer
rm	river mile
SAFCO	South Atlantic Fisheries Coordination Office
SCDNR	South Carolina Department of Natural Resources
SCPSA	South Carolina Public Service Authority
SDCOE	Savannah District of the U. S. Corp of Engineers
SOC	Species of Concern
SPA	Shore Protection Act
SPOIR	significant portion of its range
SRT	Status Review Team
SSC	Scientific and Statistical Committees
TCDD	tetrachlorodibenzo-*p*-dioxin
TED	turtle excluder device
TL	total length
TNC	The Nature Conservancy
µ	micro
UGA	University of Georgia
UME	University of Maine
UNCW	University of North Carolina at Wilmington
UPGMA	Unweighted Pair Group Method with Arithmetic Mean
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VMRC	Virginia Marine Resources Commission
VIMS	Virginia Institute of Marine Science
WSHV-2	white sturgeon herpesvirus type-2
WSIV	white sturgeon iridovirus
Yds	yards
YOY	young-of-year
yr	year
Zn	zinc

Executive Summary

In 2003, a workshop sponsored by the National Marine Fish Service (NMFS) and U. S. Fish and Wildlife Service (USFWS) (collectively, the Services) was held to review the status of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). The workshop provided an opportunity to gain additional information to determine if a new review of the status of the species was warranted. The status of Atlantic sturgeon was initially reviewed in 1998 after the Services received a petition to list the species under the Endangered Species Act (ESA), and it was determined, at that time, that listing was not warranted. Also in 1998, the Atlantic States Marine Fisheries Commission (ASMFC) initiated a coast-wide fishing moratorium on Atlantic sturgeon, until 20 year classes of adult females could be established. The 2003 workshop attendees concluded that some populations seemed to be recovering while other populations continued to be depressed. As a result, NMFS initiated a second status review of Atlantic sturgeon in 2005 to reevaluate whether this species required protection under the ESA.

A status review team (SRT) consisting of four NMFS, four USFWS, and three US Geological Survey (USGS) personnel participated in the status review process. The team was supplemented by eight state and regional experts who provided their individual expert opinions on the information contained in the status review report and provided additional data to ensure the report provided the best available data.

The SRT determined that Atlantic sturgeon populations should be divided into five distinct population segments (DPSs). The five DPSs were named: 1) Gulf of Maine, 2) New York Bight, 3) Chesapeake Bay, 4) Carolina, and 5) South Atlantic. These Atlantic sturgeon populations are markedly separated based on physical, genetic, and physiological factors; are located in a unique ecological setting; have unique genetic characteristics; and would represent a significant gap in the range of the taxon if one of them were to become extinct.

The SRT evaluated the status of Atlantic sturgeon using the five-factor analysis described in section 4(a)(1) of the ESA. The SRT identified 15 stressors within these five factors and summarized their impacts on Atlantic sturgeon using a semi-quantitative extinction risk analysis (ERA), similar to that used by other status review reports (e.g. *Acropora*). Of the stressors evaluated, bycatch mortality, water quality, lack of adequate state and/or Federal regulatory mechanisms, and dredging activities were most often identified as the most significant threats to the viability of Atlantic sturgeon populations. Additionally, some populations were impacted by unique stressors, such as habitat impediments (e.g., Cape Fear and Santee-Cooper rivers) and apparent ship strikes (e.g., Delaware and James rivers).

The outcome of the ERA concluded that three of the five DPSs (Carolina, Chesapeake, and New York Bight) were likely (> 50% chance) to become endangered in the foreseeable future (20 years). The SRT recommended that these three DPSs should be listed as threatened under the ESA. The remaining DPSs (South Atlantic and Gulf of Maine) were found to have a moderate risk (<50% chance) of becoming endangered in the next 20 years. However, the SRT did not provide a listing recommendation for these remaining DPSs as available science was insufficient to allow a full assessment of these populations.

Introduction

1.1. Background of the Review

This document provides a summary of the information gathered for an Endangered Species Act (ESA) status review for Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). Initial reviews of the Atlantic sturgeon status began in 1977 when the Research Management Division of NMFS sponsored the preparation of a report on the biology and status of Atlantic sturgeon to assess the status of the stock and serve as a historical database and information library (Murawski and Pacheco 1977). Three years later, at the request of NMFS, another document was prepared by Hoff (1980) to assist in making future Atlantic sturgeon fisheries decisions and to determine what action was required, if any, to conserve the species under the ESA. In 1988, NMFS announced they would develop a “list of candidate species” under the ESA and requested information regarding the status of Atlantic sturgeon. At that time, a “candidate species” was any species being considered by the Secretary for listing as an endangered or a threatened species under the ESA, but not yet the subject of a proposed rule. NMFS added Atlantic sturgeon to its candidate species list published in 1997 (62 FR 37560). In April 2004, NMFS published a subsequent notice announcing that the NMFS “candidate species list” was being changed to the “Species of Concern (SOC) list” to better reflect the ESA definition of candidate species while maintaining a separate list of species potentially at risk (69 FR 19975). At that time, NMFS transferred 25 species from the candidate species list to the SOC list (including Atlantic sturgeon), placed 20 additional species on the SOC list, and removed 12 other species from the candidate species list. Candidate Species are those petitioned species that are actively being considered for listing as endangered or threatened under the ESA, as well as those species for which NMFS has initiated an ESA status review that it has announced in the *Federal Register*. NMFS SOC are defined as species about which NMFS has some concerns regarding status and threats but for which insufficient information is available to indicate a need to list the species under the ESA. NMFS believes it is important to highlight species for which listing may be warranted in the future so that Federal and state agencies, Native American tribes, and the private sector are aware of unlisted species that could benefit from proactive conservation efforts. Inclusion of a species on the SOC list is intended to stimulate voluntary conservation efforts that, if effective, may prevent an ESA listing. Currently, Atlantic sturgeon is a candidate species and by default, a SOC.

On June 2, 1997, a petition dated May 29, 1997, was received by the Services from the Biodiversity Legal Foundation. The petitioner requested that the Services list Atlantic sturgeon, where it continues to exist in the United States, as threatened or endangered and designate critical habitat within a reasonable period of time following the listing. The Services reviewed the request and determined that the petition presented substantial information indicating that the petitioned action may be warranted and announced the initiation of a status review (62 FR 54018). A review of the status of a species is required by section 4(b)(1)(A) of the ESA whenever a listing petition is found to contain substantial information. A status review consists of reviewing all the available information on a species to determine if protection under the ESA is warranted.

According to CFR424.11, a species shall be listed or reclassified if the Secretary determines, on the basis of the best scientific and commercial data available after conducting a review of the species' status, that the species is endangered or threatened because of any one or a combination of the following factors:

1) The present or threatened destruction, modification, or curtailment of habitat or range.
2) Overutilization for commercial, recreational or educational purposes.
3) Disease or predation.
4) The inadequacy of existing regulatory mechanisms.
5) Other natural or manmade factors affecting its continued existence.

The Services completed their status review in 1998 and concluded at that time Atlantic sturgeon were not threatened or endangered based on any of the five factors (NMFS and USFWS 1998). Concurrently, the Atlantic States Marine Fisheries Commission (ASMFC) completed Amendment 1 to the 1990 Atlantic Sturgeon Fishery Management Plan (FMP) that imposed a 20-40 year moratorium on all Atlantic sturgeon fisheries until the Atlantic Coast spawning stocks could be restored to a level where 20 subsequent year classes of adult females were protected (ASMFC 1998A). NMFS followed this action by closing the Exclusive Economic Zone (EEZ) to Atlantic sturgeon take in 1999. In 2003, a workshop on the "Status and Management of Atlantic Sturgeon" was held to discuss the current status of sturgeon along the Atlantic Coast and determine what obstacles, if any, were impeding the recovery of Atlantic sturgeon (Kahnle et al. 2005). The results of the conference reported "mixed" reviews where some populations seemed to be recovering while others were declining. Bycatch and habitat degradation were noted as possible causes for some population declines.

Based on the information gathered from the 2003 workshop on Atlantic sturgeon, NMFS decided that a second review of Atlantic sturgeon status was needed to determine if listing as threatened or endangered under the ESA was warranted. This document addresses the status of the species, addresses the five factors as they pertain to Atlantic sturgeon, and considers the effects of efforts underway to protect the species.[1]

1.2. Life History

While intensely studied since the 1970s, many important aspects of Atlantic sturgeon life history are still unknown (Murawski and Pacheco 1977, Van den Avyle 1983, Smith and Dingley 1984, Smith and Clugston 1997, Bain 1997, Bemis and Kynard 1997, Kynard and Horgan 2002). Although specifics vary latitudinally, the general life history pattern of Atlantic sturgeon is that of a long lived, late maturing, estuarine dependent, anadromous species.[2] The species' historic range included major estuarine and riverine systems that spanned from Hamilton Inlet on the coast of Labrador to the Saint Johns River in Florida (Reviewed in Murawski and Pacheco 1977, Smith and Clugston 1997). Interestingly, genetic, morphological, and archaeological evidence also suggest that Atlantic sturgeon once colonized the Baltic during the Middle Ages, and

[1] Since this document is an updated review of the status of Atlantic sturgeon, portions of the text were taken directly from the 1998 review to expedite the writing process (NMFS and USFWS 1998).
[2] An anadromous species is defined as a species that spends the majority of its life cycle in marine waters but reproduces in freshwater habitat.

replaced the native European sturgeon (*Acipenser sturio*) there, before recently becoming extinct itself in Europe as a result of human activities and climate change (Ludwig et al. 2002).

Atlantic sturgeon spawn in freshwater, but spend most of their adult life in the marine environment. Spawning adults generally migrate upriver in the spring/early summer; February-March in southern systems, April-May in mid-Atlantic systems, and May-July in Canadian systems (Murawski and Pacheco 1977, Smith 1985, Bain 1997, Smith and Clugston 1997, Caron et al. 2002). In some southern rivers, a fall spawning migration may also occur (Rogers and Weber 1995, Weber and Jennings 1996, Moser et al. 1998). A fall migration of ripening adults upriver in the Saint John River, NB is also observed; however, this fall migration is not considered a spawning run as adults do not spawn until the spring. Atlantic sturgeon spawning is believed to occur in flowing water between the salt front and fall line of large rivers, where optimal flows are 46-76 cm/s and depths of 11-27 meters (Borodin 1925, Leland 1968, Scott and Crossman 1973, Crance 1987, Bain et al. 2000). Sturgeon eggs are highly adhesive and are deposited on the bottom substrate, usually on hard surfaces (e.g., cobble) (Gilbert 1989, Smith and Clugston 1997). Hatching occurs approximately 94-140 hrs after egg deposition at temperatures of 20° and 18° C, respectively, and larvae assume a demersal existence (Smith et al. 1980). The yolksac larval stage is completed in about 8-12 days, during which time the larvae move downstream to rearing grounds over a 6 – 12 day period (Kynard and Horgan 2002). During the first half of their migration downstream, movement is limited to night. During the day, larvae use benthic structure (e.g., gravel matrix) as refugia (Kynard and Horgan 2002). During the later half of migration when larvae are more fully developed, movement to rearing grounds occurs both day and night. Juvenile sturgeon continue to move further downstream into brackish waters, and eventually become residents in estuarine waters for months or years.

Upon reaching a size of approximately 76-92 cm, the subadults may move to coastal waters (Murawski and Pacheco 1977, Smith 1985), where populations may undertake long range migrations (Dovel and Berggren 1983, Bain 1997, T. King supplemental data 2006). Tagging and genetic data indicate that subadult and adult Atlantic sturgeon may travel widely once they emigrate from rivers. Subadult Atlantic sturgeon wander among coastal and estuarine habitats, undergoing rapid growth (Dovel and Berggren 1983, Stevenson 1997).[3] These migratory subadults, as well as adult sturgeon, are normally captured in shallow (10-50m) near shore areas dominated by gravel and sand substrate (Stein et al. 2004a). Coastal features or shorelines where migratory Atlantic sturgeon commonly aggregate include the Bay of Fundy, Massachusetts Bay, Rhode Island, New Jersey, Delaware, Delaware Bay, Chesapeake Bay, and North Carolina, which presumably provide better foraging opportunities (Dovel and Berggren 1983, Johnson et al. 1997, Rochard et al. 1997, Kynard et al. 2000, Eyler et al. 2004, Stein et al. 2004a, Dadswell 2006). Despite extensive mixing in coastal waters, Atlantic sturgeon return to their natal river to spawn as indicated from tagging records (Collins et al. 2000a, K. Hattala, NYSDEC, Pers. Comm. 1998) and the relatively low rates of gene flow reported in population genetic studies (King et al. 2001, Waldman et al. 2002). Males usually begin their spawning migration early and leave after the spawning season, while females make rapid spawning migrations upstream and quickly depart following spawning (Bain 1997).

[3] Juveniles and subadults are used interchangeably throughout this report and are defined within this report as any sturgeon that is not considered a young-of-year (Age-0) or mature adult.

Atlantic sturgeon have been aged to 60 years (Mangin 1964); however, this should be taken as an approximation as the only age validation study conducted to date shows variations of ±5 years (Stevenson and Secor 1999). Vital parameters of sturgeon populations show clinal variation with faster growth and earlier age at maturation in more southern systems, though not all data sets conform to this trend. For example, Atlantic sturgeon mature in South Carolina at 5 – 19 years (Smith et al. 1982), in the Hudson River at 11 – 21 years (Young et al. 1998), and in the Saint Lawrence River at 22 – 34 years (Scott and Crossman 1973). Atlantic sturgeon likely do not spawn every year, where multiple studies have shown that spawning intervals range from 1-5 years for males (Smith 1985, Collins et al. 2000a, Caron et al. 2002) and 2-5 for females (Vladykov and Greeley 1963, Van Eenennaam et al. 1996, Stevenson and Secor 1999). Fecundity of Atlantic sturgeon has been correlated with age and body size (ranging from 400,000 – 8 million eggs) (Smith et al. 1982, Van Eenennaam and Doroshov 1998, Dadswell 2006). The average age at which 50% of maximum lifetime egg production is achieved estimated to be 29 years, approximately 3-10 times longer than for other bony fish species examined (Boreman 1997).

1.3. Distribution and Abundance

Assessment of the current distribution and abundance of Atlantic sturgeon is based on a comprehensive review of the literature and interviews with provincial, state, and Federal fishery management personnel regarding historic and ongoing sampling programs which targeted or incidentally captured Atlantic sturgeon. Water bodies where no information is available, either historic or current, were assessed as to whether Atlantic sturgeon could use the present habitat based on the geomorphology of the system and expert opinion. Riverine systems where gravid Atlantic sturgeon or young-of-year (YOY)(< age-1; ≤ 41 cm TL or 35 cm FL)[4] have been documented within the past 15 years were considered to contain extant spawning populations, as this is the average period of time to achieve sexual maturity. The presence of juveniles greater than age-0 (YOY) does not provide evidence of spawning within a river because subadults are known to undertake extensive migrations into non-natal riverine systems.[5]

Comprehensive information on current or historic abundance of Atlantic sturgeon is lacking for most river systems. Data are largely available from studies directed at other species and provide evidence primarily of presence or absence. Historic and current spawning populations of Atlantic sturgeon in East Coast estuarine systems of the United States are summarized in Table 1. Size and age data were used to indicate how a particular habitat (i.e., spawning, nursery, or migrating habitat) is utilized by sturgeon. The presence of multiple year classes demonstrates successful spawning in multiple years but not necessarily in that system. Available quantitative data on abundance and, where available, data that document changes in abundance of sturgeon populations are included in the text.

[4] Lengths of 41 cm total length (TL) and 35 cm fork length (FL) represent the mean length of age-1 Atlantic sturgeon reported in Secor et al. (2000), that reviewed the FL of Atlantic sturgeon at age-1 from the Saint Lawrence, Saint John, Hudson, Delaware, Chesapeake Bay, Winyah Bay, and Suwannee watersheds. To calculate the TL of age-1 Atlantic sturgeon, the following equation was used: TL = (FL / 0.86) + 2.01.
[5] Subadults and juveniles are used interchangeably throughout this document and are defined as any sturgeon that is not considered a YOY or mature adult.

1.3.1. Historic Overview

Historically, Atlantic sturgeon were present in approximately 38 rivers in the United States from St. Croix, ME to the Saint Johns River, FL, of which 35 rivers have been confirmed to have had a historical spawning population. Atlantic sturgeon are currently present in 35 rivers, and spawning occurs in at least 20 of these rivers (Table 1). In the mid-1800s, incidental catches of Atlantic sturgeon in the shad and river herring haul seine fisheries indicated that the species was very abundant (reviewed in Armstrong and Hightower 2002). Massachusetts and Maine have reports dating back to the early 1600s noting an important sturgeon fishery (Wheeler and Wheeler 1878, Jerome et al. 1965). However, a major fishery for this species did not exist until 1870 when a caviar market was established (reviewed in Smith and Clugston 1997). Record landings were reported in 1890, where over 3350 metric tons (mt) of Atlantic sturgeon were landed from coastal rivers along the Atlantic Coast (reviewed in Smith and Clugston 1997, Secor and Waldman 1999).[6] The majority of these landings (75%) were dominated by the Delaware River fishery that presumably supported the largest population along the Atlantic Coast (reviewed in Secor and Waldman 1999). Ten years after peak landings, the fishery collapsed in 1901, when less than 10% (295 mt) of its 1890 peak landings were reported (Figure 1). The landings continued to decline to about 5% of the peak until 1920 and have remained between 1-5% since then. During the 1950s, the remaining fishery switched to targeting sturgeon for flesh, rather than caviar. The Atlantic sturgeon fishery was closed by ASMFC in 1998, when a coast-wide fishing moratorium was imposed for 20-40 years, or at least until 20 year classes of mature female Atlantic sturgeon were present (ASMFC 1998A).[7] Presently, there are only two U.S. populations for which an abundance estimate is available; the Hudson (~870 spawning adults/yr) and Altamaha (~343 spawning adults/yr) (Schueller and Peterson 2006, Kahnle et al. *In* press,). The Hudson and Altamaha are presumed to be the healthiest populations within the U.S. Thus, other spawning populations within the U.S. are predicted to have less than 300 adults spawning per year.

The Atlantic sturgeon fishery in the Saint Lawrence River is somewhat different from that of the U.S. and Saint John River[8] market as it has never been a caviar market, instead focusing on the flesh market and local sales. Thus, large gravid females and males are rarely taken (Trencia et al. 2002). Landings have increased slightly from approximately 35 mt in the 1940s to 60 mt in the 1990s (Figure 1). Since 1993, harvest/fishing restrictions have been implemented and landings have averaged approximately 60 mt/year (the harvest quota) since 2000 (Figure 2). The Saint Lawrence fishery did experience a crash, however, during the late 1960s and 1970s. The cause of the crash is unknown. However, it is suspected to be related to the massive use of DDT above Montreal during 1966 and 1967 to eliminate the mayfly bloom for the 1967 Worlds Fair, which has also been linked to the extinction of striped bass in the river (Tremblay 1995; M. Dadswell, Acadia University, Pers. Comm. 2006).

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[6] Though shortnose and Atlantic sturgeon were not differentiated in the landing records at this time, it is believed that the larger Atlantic sturgeon were targeted more so than the smaller shortnose sturgeon for the caviar market (Secor and Waldman 1999).

[7] Some states had initiated a moratorium on the fishery prior to the ASMFC ruling (i.e., Maryland and Virginia 1973, South Carolina 1985, North Carolina 1991, etc.)

[8] All sturgeon captured in the Saint John were exported to the US for caviar and there were no local sales.

1.3.2. Recent River Specific Information

Canadian Rivers

Atlantic sturgeon have been reported to occur as far north as the lower George River in Ungave Bay and Hamilton Inlet in Labrador, Canada, but it is not known if spawning ever occurred in any Labrador river (Vladykov and Greeley 1963, Leim and Scott 1966). Very little systematic sampling had been conducted to document the presence of Atlantic sturgeon in many Canadian rivers; however, it is likely that Atlantic sturgeon spawn(ed) in the Miramichi, Shubenacadie, Avon, Annapolis, St. Croix, and in other systems of similar size (reviewed in Dadswell 2006). There are, however, two major river systems in Canada that are known to still support Atlantic sturgeon - the Saint Lawrence and Saint John rivers.

Saint Lawrence River – Quebec

Historical records indicate that Atlantic sturgeon were found from Maryland to Sorel (approximately river km (rkm) 760). Vladykov and Greeley (1963) reported that young Atlantic sturgeon (15-28 cm) were abundant at St. Vallier (about 30 km downstream of Quebec City). Although the exact location of spawning areas in the Saint Lawrence River is not well documented, Vladykov and Greeley (1963) suggested that Atlantic sturgeon spawned in pools below waterfalls on tributaries to the Saint Lawrence River (Bastican River on the south shore and Rivier-aux-Outardes on the north shore). In 1997 and 1998, one running ripe female and 32 running ripe males were captured, tagged, and released in a deep section of the river located about 100 km upriver from the saltwater front, near Portneuf (rkm 95-98) (Caron 1998, Hatin et al. 2002). Subsequent tracking of these fish identified six adult aggregation areas. Three of the aggregation areas were believed to be spawning areas (Richelieu Rapids, Saint – Antoinede-Tilly, mouth of the Chaudiere River). The other three areas were identified as feeding/resting areas (Saint-Charles River estuary, Traverse du Milieu Channel, and the northern channel between Sault-au-Cochon and Petite Riviere-Saint-Francois).

Fishing effort has been recorded since 1994 and indicates that populations have stabilized within the Kamouraska and Montmagny fishing areas, despite a dramatic decline in catch-per-unit-of-effort (CPUE) within the Kamouraska decreasing from 1.71 in 1994 to 0.44 in 1995 and remaining low between 0.44 – 0.52 until 2000. Reported size classes did change over the period of 1994-2000. In 1994, the majority of Atlantic sturgeon landed were split (50:50) between small (<100 cm FL) and medium (100-150 cm FL) sized fish. By 2000, 80% of the catch had shifted to medium sized fish, indicating that recruitment had been poor in prior years, and possibly over-fishing was occurring (Trencia et al. 2002). Since 2000, management regulations have restricted catch to 100-150 cm FL fish, and annual quotas of 60 mt have been met every year (including suspected bycatch mortality) (Figure 2). Recruitment seems to have been improving over the last two to three years (G. Trencia, QSWP, Pers. Comm. 2005) and based on recent tagging studies, Caron et al. (2002) suggest that the St. Lawrence population supports 500+ spawning adults.

Saint John River – New Brunswick

Atlantic sturgeon are thought to spawn in the mainstem of the Saint John River and tributaries such as the Kennebecasis, Canan, Grand Lake, and Oromocto (M. Dadswell, Acadia University, Pers. Comm. 2006). Atlantic sturgeon may also migrate occasionally above the head-of-tide, noting that construction of the Mactaquac Dam did not greatly diminish the amount of spawning habitat (M. Dadswell, Acadia University, Pers. Comm. 2006). Sampling conducted in the mid 1970s, 1980s, and 1990s with small and large mesh gill nets (up to 10" stretched mesh) resulted in the capture of a large number of juvenile and adult Atlantic sturgeon ranging in size from 19 – 480 cm in the Long Reach section of the Saint John River, the mouth of the Kennebecasis, and in the Wasademoak and Grand Lakes (Pottle and Dadswell 1979, Dadswell 2006). Within the Saint John River, Dadswell (2006) calculated that approximately 200 – 300 adults are captured each year in the Atlantic sturgeon fishery; based on the minimum size limit of 122 cm TL. It is unknown, however, if these landings are solely Saint John River Atlantic sturgeon or represent a mixed stock of neighboring populations. Overall, commercial landings within the Saint John River were relatively stable until the 1980s averaging approximately 10 mt per year (Figure 3). Landings increased drastically in the 1980s and peaked in 1994 at 80 mt. Following 1994, however, landings returned to 10 mt per year.

U. S. Rivers

Maine Rivers

The geomorphology of most small coastal rivers in Maine is not sufficient to support Atlantic sturgeon spawning populations, except for the Penobscot and the estuarial complex of the Kennebec, Androscoggin, and Sheepscot rivers. During the summer months, the salt wedge intrudes almost to the site of impassable falls in these systems: St. Croix River (rkm 16), Machias River (rkm 10), and the Saco River (rkm 10). Although surveys have not been conducted to document Atlantic sturgeon presence, subadults may use the estuaries of these smaller coastal drainages during the summer months.

St. Croix River – Maine/Nova Scotia

The historic and current status of a St. Croix Atlantic sturgeon population is largely unknown. Mike Dadswell (Arcadia University, Canada) notes from personal communications with Nova Scotia Power (in 1993) that a small population of large sturgeon may be spawning annually below the hydropower dam on the St. Croix River (Dadswell 2006). Other than this personal communication, there is no additional information that an Atlantic sturgeon population exists on the St. Croix or regarding their status.

Penobscot River – Maine

There have been two surveys conducted in the last 15 years to document the presence of shortnose and Atlantic sturgeon in the Penobscot River. The Maine Department of Marine Resources (MEDMR) conducted a limited sampling effort in 1994 and 1995 to assess whether shortnose sturgeon were present in the Penobscot River. The MEDMR made 55 sets of 90 meter experimental gill nets for a total fishing effort of 409 net hrs (1 net hr = 100 yds fished for 1 hr). The majority of the fishing effort in the Penobscot River was in the upper estuary near head-of-tide. No shortnose or Atlantic sturgeon were captured. The sampling was determined to be inadequate to assess the presence of adult Atlantic sturgeon because the mesh sizes would have been selective only for subadult Atlantic sturgeon that are commonly found in the lower estuary of larger river systems. In 2006, a similar gill net survey was implemented in the lower river using both 15 cm and 30 cm stretched mesh sinking gill nets. As of January 2007, sixty-two shortnose and seven Atlantic sturgeon have been captured in 1004.39 net hours, (506.18 net hours using the smaller mesh and 498.21 net hours using the larger mesh (M. Kinnison, UME, Pers. Comm. 2006). One of these Atlantic sturgeon, captured in July, may have been an adult based on its size (145 cm TL) and time of capture. Thus, it is probable that a small population of Atlantic sturgeon persists in the Penobscot River. This speculation is supported by archeological evidence that sturgeon were present, occasional observations by fishers, and at least one capture of an adult Atlantic sturgeon by a recreational fisherman (Bangor Daily News 2005).

Estuarial Complex of the Kennebec, Androscoggin, and Sheepscot Rivers – Maine

Atlantic sturgeon were historically abundant in the Kennebec River and its tributaries, including the Androscoggin and Sheepscot rivers (Bigelow and Schroeder 1953, Vladykov and Greeley 1963, Kennebec River Resource Management Plan 1993). In 1849, a directed fishery for Atlantic sturgeon landed 160 mt. Population estimates based on the landings indicated that approximately 10,240 adult sturgeon were present prior to 1843 (Kennebec River Resource Management Plan 1993). Three hundred and thirty-six Atlantic sturgeon (nine adults and 327 subadults) have been captured in the Kennebec River in a multi-filament gill net survey conducted intermittently from 1977-2000 (Squiers 2004). During this period, the CPUE of Atlantic sturgeon has increased by a factor of 10-25 (1977 – 1981 CPUE = 0.30 versus 1998 – 2000 CPUE = 7.43)(Figure 4).[9] The mean length of the 327 subadults was 86.7 cm TL with a range from 48-114.5 cm TL (a subadult was classified as being 40-130 cm TL). The majority of the adult captures were in July between Merrymeeting Bay and Gardiner. Additional insight concerning the timing of Atlantic sturgeon spawning season emerged from a small commercial fishery on the Kennebec River in South Gardiner near Rolling Dam from June 15 – July 26, 1980. Thirty-one adult Atlantic sturgeon (27 males, 4 of which were ripe and 4 females, 1 of which was ripe) were captured. Two adults tagged in 1978 by the MEDMR in South Gardiner were recaptured in this fishery.

On July 13, 1994, while sampling for sturgeon, the MEDMR captured seven adult Atlantic sturgeon just below the spillway of the Edwards Dam in Augusta. Five of the seven Atlantic sturgeon (56-195 cm TL) were males expressing milt. In 1997, a biweekly trawl survey conducted from April – November by Normandeau Associates in the lower Kennebec River, captured thirty-one subadults and one adult Atlantic sturgeon. Subadults were also captured by the MEDMR in September of 1997 in the Eastern River (n = 18) and the Cathance River (n = 5), which are freshwater tributaries to the Kennebec, in overnight sets of gill nets (T. Squiers, MEDMR, Pers. Comm. 1998). Additional sampling from 2000-2003 of the MEDMR inshore groundfish trawl survey collected 13 subadults at the mouth of the Kennebec River, which had the greatest occurrences of Atlantic sturgeon among five regions sampled along the New

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[9] A 10-25 fold increase in abundance was estimated because in 1998 the CPUE was extremely large (14.44) compared to 1999 and 2000 estimates of 4.17 and 3.70, respectively. Thus, the CPUE in 1998 may be an outlier skewing the data.

Hampshire and Maine coasts (Squiers 2003). The most recent capture of an adult Atlantic sturgeon occurred in June of 2005, where a 178 cm TL sturgeon was captured in an American shad gill net (12.7 cm stretched mesh) in Ticonic Bay, just upstream of the confluence between Sebasticook and the Kennebec rivers (Squiers 2005).

The presence of adult male Atlantic sturgeon in ripe condition near the head-of-tide during June and July of 1994, 1997, and possibly in 2005 presents strong evidence that a spawning population still exists in the Kennebec River. While no eggs, larvae, or YOY have been captured in the last 15 years, the presence of subadults (48 cm to over 100 cm TL) in tidal freshwater tributaries and the mid-estuary and mouth of the Kennebec River from at least April – November provides additional evidence that a spawning population of Atlantic sturgeon persists in the Kennebec River estuary.

The only documented occurrence of Atlantic sturgeon in the Androscoggin River was an adult captured and released approximately one km downstream of the Brunswick Dam in 1975. No studies have been conducted to assess whether Atlantic sturgeon are presently utilizing the Androscoggin River for spawning. Subadults have been captured in the Sheepscot River, which may function as a nursery area for Kennebec River Atlantic sturgeon.

<u>Piscataqua River/Great Bay Estuary System – New Hampshire</u>

Few Atlantic sturgeon have been captured in the Piscataqua River (Hoff 1980). A subadult Atlantic sturgeon (57 cm; likely age-1) was captured by New Hampshire Fish and Game (NHFG) in June 1981 at the mouth of the Oyster River in Great Bay (New Hampshire Fish and Game 1981). Between July 1, 1987, and June 30, 1989, New Hampshire Fish and Game surveyed the deeper tributaries of the Great Bay Estuary including the Piscataqua, Oyster, Little and Lamprey rivers, as well as the Great Bay for shortnose sturgeon, using 30.5 m nets (3 m deep with 14 and 19 cm stretch mesh) that were fished for 146 net days. In 1988, sampling occurred in suspected spawning areas (salinities 0-10 ppt) in the spring and in suspected feeding areas (salinities around 24 ppt) in the summer. In 1989, nets were fished in May and June only (salinities 6-15 ppt). No Atlantic sturgeon were captured. However, a large gravid female Atlantic sturgeon (228 cm TL) weighing 98 kg (of which 15.9 kg were eggs) was captured by a commercial fisherman in a small mesh gill net at the head-of-tide in the Salmon Falls River in South Berwick, ME on June 18, 1990 (D. Grout, NHFG, Pers. Comm. 2006). The Salmon Falls River is a shallow tributary of the Piscataqua and is the delineation between New Hampshire and Maine state lines. Since 1990, the NHFG has not observed or received reports of Atlantic sturgeon of any age-class being captured in the Great Bay Estuary and its tributaries (B. Smith, NHFG, Pers. Comm. 2006).[10] It is the conclusion of the SRT and NHFG biologists that the Great Bay Atlantic sturgeon population is likely extirpated.

<u>Merrimack River – New Hampshire and Massachusetts</u>

[10] Great Bay Estuary fishing effort is limited to a small mesh gill net bait fishery (< 3 in stretched mesh). New Hampshire Fish and Game require that all catch, including bycatch, be reported (D. Grout, NHFG, Pers. Comm. 2006).

Historical reports of Atlantic sturgeon in the Merrimack River include a 104 kg sturgeon taken at Newburyport on September 14, 1938, while netting for blueback herring (Hoover 1938). An intensive gill net survey was conducted in the Merrimack River from 1987-1990 to determine annual movements, spawning, summering, and wintering areas of shortnose and Atlantic sturgeon (Kieffer and Kynard 1993). Thirty-six Atlantic sturgeon were captured (70-156 cm TL); most being under 100 cm TL. One dead Atlantic sturgeon was found on June 30, 1990 at the shortnose spawning area in Haverhill, MA (between rkm 31-32). Of 23 subadult Atlantic sturgeon sonically tracked in the river, 11 left the river within seven days, and the rest left by September or October of each year (Kieffer and Kynard 1993). Fish captured in one year were not observed in the river during subsequent years. On June 9, 1998, a 24 inch (estimated length) Atlantic sturgeon was captured and released in the Merrimack River by the USFWS personnel, who were conducting a contaminant study on the river (D. Major, USFWS, Pers. Comm. 2006). This information provides no evidence of a spawning population of Atlantic sturgeon in the Merrimack River, although it seems that the estuary is used as a nursery area (B. Kynard, Conte Anadromous Fish Research Center, Pers. Comm. 1998).

Taunton River – Massachusetts and Rhode Island

Historical records indicate that Atlantic sturgeon spawned in the Taunton River at least until the turn of the century (Tracy 1905). A gill net survey was conducted in the Taunton River during 1991 and 1992 to document the use of this system by sturgeon. Three subadult Atlantic sturgeon were captured but were determined to be non-natal fish (Burkett and Kynard 1993). In June 2004, a fisherman fishing in state waters noted that the first three fathoms of towed up gear held three juvenile Atlantic or shortnose sturgeon (Anoushian 2004).[11] Trawlers fishing in state waters (less than three miles offshore) also occasionally report Atlantic sturgeon captures. Since 1997, only two sturgeon have been captured by the Rhode Island Department of Environmental Management Trawl Survey (RIDEM), one measuring 85 cm TL was captured in 1997 in Narragansett Bay, and another (130 cm TL) was captured in October 2005 in Rhode Island Sound (A. Libby, RIDEM, Pers. Comm. 2006). The NMFS observer program has also documented Atlantic sturgeon bycatch off the coast of Rhode Island in Federal waters. Since spawning adults were not found during the expected spawning period of May and June, it is likely that a spawning population of Atlantic sturgeon does not occur in the Taunton River, though the system is used as a nursery area for Atlantic sturgeon (Burkett and Kynard 1993).

Thames River – Connecticut

The Thames River is formed by the joining of the Yantic and Shetucket rivers in Norwich Harbor, Connecticut. Information on abundance of Atlantic sturgeon in the Thames River is scarce. Sturgeon scutes have been documented at an archeological site along the river, and historical reports note sturgeon use by Native Americans. Atlantic sturgeon were reportedly abundant in the system until the 1830s (reviewed in Minta 1992). Whitworth (1996) speculated that populations of both shortnose and Atlantic sturgeon in the Thames were always low because the fall line is located near the limit of saltwater intrusion, leaving little to no freshwater habitat for spawning. The construction of the Greenville Dam in 1825 further restricted available habitat and probably prevented sturgeon from spawning in the river. There have been some

[11] It is expected that these three juveniles were not shortnose sturgeon due to their rarity in this system.

reports of low dissolved oxygen (DO) levels during the summer months. The mouth of the river is dredged to accommodate the shipyard, and the channel was recently improved to provide deeper depths to accommodate the Sea Wolf submarine. Subadult Atlantic sturgeon have been captured in the estuary (Whitworth 1996), but it is unlikely that a spawning population is present.

Connecticut River – Massachusetts and Connecticut

Judd (1905) reports that sturgeon were speared at South Hadley Falls in the mid 1700s. There are historical reports of sturgeon migration as far as Hadley, MA, but regular migration of Atlantic sturgeon beyond Enfield, CT is doubtful due to presence of significant rapids (Judd 1905). A dam constructed at Enfield in 1827 effectively blocked any migration beyond this point, until 1977 when the dam was breached. Until recently, there has been no evidence that Atlantic sturgeon currently use the Massachusetts portion of the Connecticut River. On August 31, 2006, a 152.4 cm TL Atlantic sturgeon was observed in the Holyoke Dam spillway lift (~ rkm 143). The Atlantic sturgeon was not sexed and was described as a subadult (R. Murray, Holyoke Gas and Electric, Pers. Comm. 2006). However, based on the size of the Atlantic sturgeon it is possible that the fish was a mature adult. This is the first time an Atlantic sturgeon has been reported at the Holyoke Dam fish lift.

Six juvenile fish (9-11 kg) were reportedly taken opposite Haddam Meadows in 1959, but it is unclear if these were Atlantic or shortnose sturgeon. As late as the 1980s, the Connecticut Department of Environmental Protection (CTDEP) fisheries staff reported occasional visual observations of Atlantic sturgeon below the Enfield Dam during May and June. From 1984-2000, the CTDEP studied the abundance, locations, and seasonal movement patterns of shortnose sturgeon in the lower Connecticut River and Long Island Sound (Savoy and Pacileo 2003). Sampling was conducted using gill nets ranging from 10-18 cm stretched mesh in the lower Connecticut River (1988-2005) and a stratified random-block designed trawl survey (12.8 m 1984-1990 and 15.2 m 1990-2005) in the Long Island Sound (also referred to as the LIS Trawl Survey). One hundred and thirty-one Atlantic sturgeon were collected from the lower Connecticut River gill net survey, and average lengths of fish reported from 1988-2000 were 77 cm FL (51-107 cm FL). The majority of these subadult Atlantic sturgeon were captured in the lower river (between rkm 10-26) within the summer range of the salt wedge (Savoy and Shake 1993).[12] A total of 347 fish were collected in the LIS trawl survey from 1984-2004, of these with reported lengths (1984-2000) the mean length was 105 cm FL (ranging from 63-191 cm FL) (Figure 5). Data from 1984-2000, indicated that 68% of the Atlantic sturgeon captured in the trawl survey came from the Central Basin (off Faulkner Island), while 6% of catches occurred in northern portions of the LIS survey near the mouth of the Connecticut River.

While research efforts have not specifically investigated the occurrence of Atlantic sturgeon in the upper Connecticut River, the species has never been collected incidentally in this region during extensive sampling for shortnose sturgeon. Occasional reports, sightings, and capture of large Atlantic sturgeon (150-300 cm) are made, but most Atlantic sturgeon captured within tidal waters or freshwater in Connecticut are consistent with the size and seasonal locations of immature Atlantic sturgeon from the Hudson River (Savoy 1996). Based on the lack of evidence

[12] Three Atlantic sturgeon were captured in September (1 in 1990, 2 in 2000) at rkm 46, however the date of capture does not overlap with the region's spawning period from April to May.

of spawning adults, stocks of Atlantic sturgeon native to Connecticut waters are believed to be extirpated (Savoy 1996).

Housatonic River – Connecticut

Coffin (1947) reports that Atlantic sturgeon were abundant in the Housatonic River and were captured by Native Americans. According to Whitworth (1996), there was a large fishing industry for sturgeon in this basin, and subadults have been captured in the estuary. Atlantic sturgeon likely spawned at a natural fall (Great Falls) at rkm 123 until 1870 when the Derby Dam was constructed at rkm 23.5. The Derby Dam restricted access to approximately 100 km or 81% of historical habitat. The Housatonic has not been systematically sampled for sturgeon in recent years (last 15 years), but it is unlikely that a spawning population is present (NMFS and FWS 1998).

Hudson River – New York

Atlantic sturgeon in the Hudson River have supported subsistence and commercial fishing since colonial times (Kahnle et al. 1998). No data on abundance of juveniles are available prior to the 1970s; however, catch depletion analysis estimated conservatively that 6,000-6,800 females contributed to the spawning stock during the late 1800s (Secor 2002, Kahnle et al. 2005). Two estimates of immature Atlantic sturgeon have been calculated for the Hudson River stock, one for the 1976 year class and one for the 1994 year class. Dovel and Berggren (1983) marked immature fish from 1976-1978. Estimates for the 1976 year class at age one ranged from 14,500-36,000 individuals (mean of 25,000). In October of 1994, the NY State Department of Environmental Conservation (NYSDEC) stocked 4,929 marked age-0 Atlantic sturgeon, provided by a USFWS hatchery, into the Hudson Estuary at Newburgh Bay. These fish were reared from Hudson River brood stock. In 1995, Cornell University sampling crews collected 15 stocked and 14 wild age-1 Atlantic sturgeon (Peterson et al. 2000). A Petersen mark-recapture population estimate from these data suggests that there were 9,529 (95% CI = 1,916 – 10,473) age-0 Atlantic sturgeon in the estuary in 1994. Since 4,929 were stocked, 4,600 fish were of wild origin, assuming equal survival for both hatchery and wild fish and that stocking mortality for hatchery fish was zero. Estimates of spawning adults were also calculated by dividing the mean annual harvest from 1985 to 1995 by the exploitation rate (u). The mean annual spawning stock size (spawning adults) was 870 (600 males and 270 females) (Kahnle et al. *In press*).[13]

Current abundance trends for Atlantic sturgeon in the Hudson River are available from a number of surveys. From July to November during 1982-1990 and 1993, the NYSDEC sampled the abundance of juvenile fish in Haverstraw Bay and the Tappan Zee Bay. The CPUE of immature Atlantic sturgeon was 0.269 in 1982 and declined to zero by 1990. The American shad gill net fishery in the Hudson River estuary, conducted from early April to late May, incidentally captures young Atlantic sturgeon (< 100 cm) and therefore, has been monitored by onboard observers since 1980. Annual CPUE data from the observer program were summarized as total observed catch/total observed effort. Catch-per-unit-of-effort of Atlantic sturgeon as bycatch was greatest in the early 1980s and decreased until the mid 1990s. It has gradually begun to increase since then (Figure 6).

[13] Confidence intervals were not provided.

Hudson River Valley utilities (Central Hudson Electric and Gas Corp., Consolidated Edison Company of New York, Inc., New York Power Authority, Niagara Mohawk Power Corporation, Orange and Rockland Utilities, Inc.) conduct extensive river-wide fishery surveys to obtain data for estimating impacts of power plant operations. Detailed survey descriptions are provided in the utilities' annual reports (CONED 1997). Two surveys regularly catch sturgeon, despite the fact that these surveys were not specifically designed to capture sturgeon. The Long River Survey (LRS) samples ichthyoplankton river-wide from the George Washington Bridge (rkm 19) to Troy (rkm 246) using a stratified random design (CONED 1997). These data, which are collected from May-July, provide an annual index of juvenile Atlantic sturgeon in the Hudson River estuary since 1974. The Fall Shoals Survey (FSS), conducted from July – October by the utilities, calculates an annual index of the number of fish captured per haul. Between 1974 and 1984, the shoals in the entire river (rkm 19-246) were sampled by epibenthic sled; in 1985 the gear was changed to a three-meter beam trawl. Length data are only available for the beam trawl survey from 1989 to the present; fish length ranged from 10 – 100 cm TL, with most fish less than 70 cm TL. Based on these length data, it seems that ages-0 (YOY), 1, and 2 sturgeon are present in the river. Indices from utility surveys conducted from 1974 to the present (LRS and FSS) indicate a trend consistent with NYSDEC American shad monitoring data. Abundance of young juvenile Atlantic sturgeon has been declining, with CPUE peaking at 12.29 in 1986 (peak in this survey) and declining to 0.47 in 1990. Since 1990, the CPUE has ranged from 0.47-3.17, increasing in recent years to 3.85 (2003). In 2000, the NYSDEC created a sturgeon juvenile survey program to supplement the utilities' survey; however, funds were cut in 2000, and the USFWS was contracted in 2003 to continue the program. In 2003 – 2005, 579 juveniles were collected (N = 122, 208, and 289, respectively) (Sweka et al. 2006). Pectoral spine analysis showed they ranged from 1 – 8 years of age, with the majority being ages 2 – 6. None of the captures were found to be YOY (< 41 cm TL).

Indices for post-migrant Atlantic sturgeon are provided by the New Jersey Bureau of Marine Fisheries from surveys of the coastal waters along the entire state (Sandy Hook to Delaware Bay). Since 1988 when the survey was initiated, a total of 96 Atlantic sturgeon have been captured.[14] Abundances of post-migrants seem to be declining as CPUE has decreased from a high of 8.75 in 1989 to 1.5 in 2003. This trend differs from Hudson River Fall Shoals Utility Survey, which indicated an increasing or stable trend over the last several years (Figure 7).

All available data on abundance of juvenile Atlantic sturgeon in the Hudson River estuary (i.e., mark/recapture studies, bycatch data from commercial gill net fishery, and utilities sampling) indicate a substantial drop in production of young since the mid 1970s. The greatest decline seemed to occur in the middle to late 1970s, followed by a secondary drop in the late 1980s. Sturgeon are still present, and juveniles (age-0 (YOY), 1, and 2 years) were captured in recent years and a slight increasing trend in CPUE has been observed. The capture of YOY sturgeon in 1991, 1993-1996, and 2003, provides evidence of successful spawning.

Delaware River – New Jersey, Delaware, and Pennsylvania

[14] No data for 2004 and 2005.

The Delaware River, flowing through New Jersey, Delaware, Pennsylvania and into Delaware Bay, historically may have supported the largest stock of Atlantic sturgeon of any Atlantic coastal river system (Kahnle et al. 1998; Secor and Waldman 1999, Secor 2002). Prior to 1890, it is expected that more than 180,000 adult females were spawning in the Delaware River (Secor and Waldman 1999, Secor 2002). Juveniles were once abundant enough to be considered a nuisance bycatch of the American shad fishery. Very little is known about adult stock size and spawning of Atlantic sturgeon in the Delaware river; however, based on reported catches in gill nets and by harpoons during the 1830s, they may have spawned as far north as Bordentown, south of Trenton, NJ (Pennsylvania Commission of Fisheries 1897). A recent sonic tracking project, on-going in 2006, has reported at least one adult Atlantic sturgeon migrating to Bordentown during the spawning season (D. Fox, DSU, Pers. Comm. 2006). Borodin (1925) reported that running-ripe sturgeon were captured near Delaware City, DE adjacent to Pea Patch Island. Spawning grounds with appropriate substrate occurred near Chester, Pennsylvania. Ryder (1888) suggested that juvenile Atlantic sturgeon used the tidal freshwater reach of the estuary as a nursery area. Lazzari et al. (1986) reported that the Roebling-Trenton stretch of the river may be an important nursery area for the species.

The current abundance of all Atlantic sturgeon life stages in the Delaware River has been greatly reduced from the historical level. Brundage and Meadows (1982) recorded 130 Atlantic sturgeon captures between the years of 1958 – 1980. The Delaware Division of Fish and Wildlife (DFW) began sampling Delaware Bay in 1966 by bottom trawl and have rarely captured Atlantic sturgeon. During the period from 1990 to 2004, the trawl survey captured 17 Atlantic sturgeon (Murphy 2005). However, there are several areas within the estuary where juvenile sturgeon regularly occur. Lazzari et al. (1986) frequently captured juvenile Atlantic sturgeon from May-December in the upper tidal portion of the river below Trenton, New Jersey (N = 89, 1981 – 1984). In addition, directed gill net surveys by DFW from 1991-1998 consistently took juvenile (N > 1,700 overall) Atlantic sturgeon in the lower Delaware River near Artificial Island and Cherry Island Flats from late spring to early fall (Shirey et al. 1999). The number of fish captured in the lower river annually has declined dramatically throughout this time period from 565 individuals in 1991 to 14 in 1998. Population estimates based on mark and recapture of juvenile Atlantic sturgeon declined from a high of 5,600 in 1991 to less than 1,000 in 1995; however, it is important to note that population estimates violated most tagging study assumptions and should not be used as unequivocal evidence that the population has declined dramatically. No population estimates are available from 1996 and 1997, given the low number of recaptures.

Voluntary logbook reporting of Atlantic sturgeon bycatch in the spring gill net fishery indicate that abundance varies year to year with no indication of decline or increase mainly because the number of bycatch reports varies considerably by commercial fishers reporting. Bycatch data are represented as the average bycatch per fisher per year (total bycatch/number of fishers). An annual small mesh gill net survey began in 1991 until 1998 when sampling was restricted to every three years in the lower Delaware River. The results of this study indicated that CPUE (fish per gill net hr) estimates have declined from 32 fish/effort hr in 1991 to only 2 fish/effort hr in 2004 (Figure 8).

Carcasses of large adult fish (> 150 cm TL) are commonly reported along the lower Delaware River and upper Delaware Bay during the historic spawning season (G. Murphy, DFW, Pers. Comm. 2006). Fifteen adult size fish have been documented since 1994, including several gravid females and males. A 2.4 m female Atlantic sturgeon was found dead on June 14, 1994, adjacent to Port Penn; ageing of a pectoral spine indicated it was approximately 25 years old (D. Secor, University of Maryland, Pers. Comm. 1998). Three years later, a second female sturgeon was found in late spring/early summer of 1997 adjacent to Port Penn, just south of the eastern end of the Chesapeake/Delaware Canal. A male sturgeon carcass was found on May 19, 1997, just north of the mouth of the Cohansey River, on Beechwood Beach; it seemed that the fish was cut in half by the propeller of a large vessel. Gonadal tissue and a pectoral spine were collected and sent to USFWS-Northeast Fisheries Center (NEFC), Fish Technology Section, Lamar, PA for analysis, where it was confirmed to be a male (W. Andrews, New Jersey Division of Fish, Game, and Wildlife, Pers. Comm. 1998). In 2005, DFW began tracking reported sturgeon mortalities during the spawning season. During the first year, six adults were found dead washed ashore in May 2005, including two from Woodland Beach (~250 cm and 170 cm TL), one from Artificial Island (>180 cm TL), one from South Bowers Beach (205 cm TL), one from Conch Bar (160 cm TL) and one from Slaughter Beach (160 cm TL). Six additional carcasses, presumed adults, were found during April-May 2006, including a gravid female at Augustine Beach (144 cm), a gravid male at Sleusch Ditch (180 cm), one at South Bowers Beach (119 cm), one at Brockonbridge Gut (112 cm), one at Kitts Hummock (208 cm), and one at Little Tinicum Island, PA (106 cm). The majority of adults documented had substantial external injuries and were severed.

In addition to the carcasses reported annually during the spawning season, several males were captured by directed gill net efforts and a reward program conducted by Delaware State University during April and May 2006. These males were collected in the lower Delaware River and upper Delaware Bay and were implanted with sonic transmitters to assist in determining spawning locations in the Delaware River.

Although catch rates declined throughout the mid 1990s, the mature adults documented within the Delaware System provide evidence that a reproducing population exists. It is speculated, however, that the abundance of subadults within the Delaware River during the 1980s and early 1990s was the result of a mixture of stocks including the Hudson River stock. However, genetic data indicate that the Delaware River has a distinct genetic signature of a remnant population (Waldman et al. 1996, Wirgin 2006, King supplemental data 2006).

<u>Chesapeake Bay and Tributaries (Potomac, Rappahannock, York, James, Susquehanna, Nanticoke) – Pennsylvania, Maryland, and Virginia</u>

Historically, Atlantic sturgeon were common throughout the Chesapeake Bay and its tributaries (Kahnle et al. 1998, Wharton 1957, Bushnoe et al. 2005). There are several newspaper accounts of large sturgeon in the lower reaches of the Susquehanna River from 1765-1895, indicating that at one time, Atlantic sturgeon may have spawned there. Commercial landings data during the 1880s are available for the Rappahannock (8 mt), York (23 mt), and James (49 mt) providing evidence that Atlantic sturgeon were historically present in these rivers as well (Bushnoe et al. 2005). Historical harvests were also reported in the Patuxent, Potomac, Choptank, Nanticoke, and Wicomico/Pocomoke rivers (S. Minkkinen, USFWS, Pers. Comm. 2006). Prior to 1890, when a sturgeon fishery began, Secor (2002), using U.S. Fish Commission landings, estimated approximately 20,000 adult females inhabited the Chesapeake Bay and its tributaries.

For the past several decades, state fishery agencies and research facilities operating in the Chesapeake Bay have conducted extensive finfish sampling surveys in the mainstem Bay and all major tributaries. These surveys occurred in all seasons and were conducted using many gear types, including trawls, seines, and gill nets. While no surveys were directed at sturgeon, incidental captures were recorded. These data supplement reports of sturgeon captures from commercial fishers using gill nets, pound nets, and fyke nets with occasional visual observations of large sturgeon, including carcasses found on beaches during the summer.

A mixed stock analysis, performed from nDNA microsatellite markers, indicated that the Chesapeake Bay population was comprised of three main stocks: 1) Hudson River (23-30%), 2) Chesapeake Bay (0-35%), and 3) Delaware River (17-27%) (King et al. 2001). The contribution of fish with Chesapeake Bay origin fish, which had not been identified in previous genetic studies, indicates the likely existence of a reproducing population within the Bay. This is further supported and substantiated by the capture of young juveniles at the mouth of the James River and two YOY Atlantic sturgeon captured in the river in 2002 and 2004 (Florida Museum of Natural History 2004, A. Spells, USFWS, Pers. Comm. 2006).

Several sturgeon sightings were made by commercial fishers and researchers between 1978 and 1987 near the Susquehanna River mouth. A deep hole (19 m) on the Susquehanna River near Perryville, MD also supported a limited sturgeon fishery (R. St. Pierre, USFWS retired, Pers. Comm. 1998). Maryland DNR personnel reported a large mature female Atlantic sturgeon in the Potomac in 1970 and another in the Nanticoke River in 1972 (H. Speir, Maryland DNR, Pers. Comm. 1998).

A Virginia Institute of Marine Science (VIMS) trawl survey was initiated in 1955 to investigate finfish dynamics within the Chesapeake Bay; the survey was standardized in 1979. Since 1955, 40 Atlantic sturgeon have been captured, 16 of which were captured since 1990, and two of these collections may have been YOY based on size. No fish were captured between 1990 and 1996; however, seven were captured in 1998. In subsequent years, catch declined ranging between zero and three fish per year. Similarly, American shad monitoring programs (independent stake gill net survey) also recorded a spike in Atlantic sturgeon bycatch that peaked in 1998 (N = 34; 27 from James River) and declined dramatically in later years to only one to three sturgeon being captured in each year from 2002-2004 (Figure 9). These observations could be biased by stocking 3,200 juveniles in the Nanticoke River in 1996; however, the capture of wild fish in the Maryland Reward Tagging program conducted from 1996 to present shows identical rates of capture for wild fish (see additional information below and Figure 9).

The Maryland reward tagging has resulted in the capture of 1,700 Atlantic sturgeon. Five hundred and sixty seven of these fish were hatchery fish, of which 462 were first time captures (14% recapture rate), the remaining captures (1,133) were wild (Figure 9). However, none of these 1,700 Atlantic sturgeon were considered YOY based on length data (S. Minkkinen, USFWS, Pers. Comm. 2006). Similarly, Virginia initiated a reward tagging program in 1996 through 1998. The majority of their recaptures were wild Atlantic sturgeon taken from the lower James and York rivers in the 20 – 40 cm size range and are believed to be YOY (A. Spells, USFWS, Pers. Comm. 1998). Captures of YOY and age-1 sturgeon in the James River during 1996 and 1997 suggest spawning has occurred in that system.[15] Since then, captures from the reward program have varied, declining from 1999 to 2002 and then increasing in 2005 to levels similar to that of 1998 and with record levels during 2006 (Figure 9). Further evidence that spawning may have occurred recently is provided by three carcasses of large adults found in the James River in 2000-2003, the discovery of a 213 cm carcass of an adult found in the Appomattox River in 2005, as well as the release of a 2.4 m Atlantic sturgeon near Hoopers Island (the Bay) in April, 1998 (S. Minkkinen, USFWS, Pers. Comm. 2006).

These data indicate that some of the Chesapeake Bay tributaries may continue to support spawning populations as evidenced by YOY captures (James River) and carcasses of mature adults being found occasionally within the Bay during the spawning season. Commercial fishers have regularly reported observations of YOY or age-1 juveniles in the York River over the past few years (K. Place, Commercial Fisherman, Pers. Comm. 2006). In 2006, tissue samples from 38 juvenile Atlantic sturgeon measuring between 500 – 600 mm TL (~ age-1) were haplotyped and genotyped by researchers (I. Wirgin – NIEM and T. King – USGS, supplemental data 2006). These 38 juveniles from the York River were significantly different ($P < 0.01$) from neighboring subpopulations including the James River subpopulation, based on frequency differences in mtDNA and nDNA markers. However, the York River does not contain unique mtDNA haplotypes differentiating it directly from other sturgeon populations, and the population could not be differentiated from the James River population using classification techniques (Figure 10). Additionally, a review of spawning habitat availability in the Chesapeake Bay and its tributaries indicated that spawning habitat is available in the James, York, and Appomattox rivers (Bushnoe et al. 2005). Therefore, the above information provides some evidence that a spawning population may exist in the York River, as the population exhibits significantly different haplotype frequencies from its neighboring subpopulations, and spawning habitat appears to be available. However, there is a possibility that samples taken from the York River were of a mixed stock since they measured 500 – 600 mm in total length (the size range of migratory subadults) and many of the collections were taken from the mouth of the river.

North Carolina Rivers

Historically, Atlantic sturgeon were abundant in most North Carolina coastal rivers and estuaries; the largest fishery occurring in the Roanoke River/Albemarle Sound system and in the Cape Fear River (Kahnle et al. 1998). Historic landing records from the late 1800s indicated that Atlantic sturgeon were very abundant within the Albemarle Sound (~ 61.5 mt/yr); however, these landings are relatively small compared to the Delaware fishery (~2,700 mt/yr) (Secor 2002). Abundance estimates derived from these historical landings records indicated that between 7,200 and 10,500 adult females were present within North Carolina prior to 1890 (Armstrong and Hightower 2002, Secor 2002).

[15] Other references (Kahnle et al. 2005) noted that 90% of the wild Atlantic sturgeon captured in the reward program were thought to be from a 1995 year class.

Albemarle Sound (Roanoke and Chowan/Nottoway Rivers) – North Carolina

Historic and current survey data indicate that spawning occurs in the Roanoke River/Albemarle Sound system, where both adults and small juveniles have been captured. Since 1990, the NC Division of Marine Fisheries (NCDMF) has conducted the Albemarle Sound Independent Gill Net Survey (IGNS), initially designed to target striped bass. The survey is conducted from November-May, using a randomized block sampling design and employing 439 m of gill net, both sinking and floating, with stretched mesh sizes ranges from 63.5 mm (2.5 in) to 254 mm (10 in). Since 1990, 842 sturgeon have been captured ranging from 15.3 to 100 cm FL, averaging 47.2 cm FL. One hundred and thirty-three (16%) of the 842 sturgeon captured could be classified as YOY (≤ 41 cm TL, ≤ 35 cm FL); the others were subadults. Incidental take of Atlantic sturgeon in the IGNS indicate that the subpopulation has been increasing in recent years (1990-2000), but since then recruitment has dramatically declined (Figure 11). Similarly, the NCDMF Observer Program documented the capture of 30 Atlantic sturgeon in large and small mesh gill nets; two of these individuals being YOY (< 410 mm TL) (Blake Price, NCDMF, Pers. Comm. 2006).

In 1997 and 1998, NC State University (NCSU) researchers characterized the habitat use, growth, and movement of juvenile Atlantic sturgeon (Armstrong and Hightower 2002). Their survey collected 107 Atlantic sturgeon, of which 15 (14%) could be considered YOY (≤ 41 cm TL or 35 cm FL). Young juveniles were observed more often over organic rich mud bottoms and at depths of 3.6-5.4 meters. Adult running ripe sturgeon have not been collected in the Roanoke River even though the NC Wildlife Resources Commission has sampled the spawning grounds since the 1990s during their annual striped bass electrofishing survey.[16] However, in 2005, an angler captured a YOY (39 cm TL) Atlantic sturgeon in the Roanoke River, near the city of Jamesville, NC (see Figure 12). These multiple observations of YOY from the Albemarle Sound and Roanoke River provide evidence that spawning continues, and catch records indicate that this population seemed to be increasing until 2000, when recruitment began to decline.

Pamlico Sound (Tar and Neuse Rivers) – North Carolina

Evidence of spawning was reported by Hoff (1980), who noted captures of very young juveniles in the Tar and Neuse rivers. More recently, two juveniles (approximately 45 and 60 cm TL) were observed dead on the bank of Banjo Creek, a tributary to the Pamlico system (B. Brun, USFWS and US Army Corps of Engineers (retired), Pers. Comm. 1998). An independent gill net survey, following the Albemarle Sound IGNS methodology, was initiated in 2001. Collections were low during the periods of 2001-2003, ranging from zero to one fish/yr. However, in 2004, this survey collected 14 Atlantic sturgeon ranging from 460 to 802 mm FL, and averaging 575 mm FL. During the same time period (2002 – 2003), four Atlantic sturgeon (561 – 992 mm FL) were captured by NCSU personnel sampling in the Neuse River (Oakley 2003). Similarly, the NCDMF Observer Program documented the capture of 12 Atlantic sturgeon in the Pamlico Sound from April 2004 to December 2005; none of these were YOY or spawning adults, averaging approximately 600 mm TL (Blake Price, NCDMF, Pers. Comm. 2006).

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[16] Electrofishing does not usually collect sturgeon (P. Kornegay, NCWRC, Pers. Comm. 2006).

The incidental capture of two juvenile Atlantic sturgeon in the Tar (1) and Neuse rivers (1) in 2005 also provides evidence that spawning may be occurring within those rivers. The Tar River juvenile was captured near Greenville, NC by an angler and reported to be less than 40 cm in TL (P. Kornegay, NCWRC, Pers. Comm. 1998). The other juvenile was captured in an illegal gill net set upstream of New Bern, NC, and measured 46 cm TL (Figure 12). Although not confirmed as YOY, these two captures are important in that they represent the only evidence of possible spawning activities within the Pamlico Sound Drainage for at least the last 15 years.

Cape Fear River – North Carolina

A gill net survey for adult shortnose and juvenile Atlantic sturgeon was conducted in the Cape Fear River drainage from 1990-1992, and replicated 1997-2005. Each sampling period included two overnight sets (checked every 24 hrs). The 1990-1992 survey captured 100 Atlantic sturgeon below Lock and Dam #1 (rkm 95) for a CPUE of 0.11 fish/net-day. No sturgeon were collected during intensive sampling above Lock and Dam #1. In 1997, 16 Atlantic sturgeon were captured below Lock and Dam #1, an additional 60 Atlantic sturgeon were caught in the Brunswick (a tributary of the Cape Fear River), and 12 were caught in the Northeast Cape River (Moser et al. 1998). Relative abundance of Atlantic sturgeon below Lock and Dam #1 seemed to have increased dramatically since the survey was conducted in 1990-1992 (Moser et al. 1998) as the CPUE of Atlantic sturgeon was two to eight times greater during 1997 than in the earlier survey.[17] Since 1997, Atlantic sturgeon CPUE has been gradually increasing: a regression analysis revealed that CPUE doubled between the years of 1997 (~0.25 CPUE) and 2003 (0.50 CPUE) (Williams and Lankford, 2003) (Figure 13). This increase may reflect the effects of North Carolina's ban on Atlantic sturgeon fishing that began in 1991; however, the increase in CPUE may also be artificial as these estimates are similar among years except in 2002 (large increase) that likely skewed the regression analysis. In 2003, the NCDMF continued the sampling program (Cape Fear River Survey) and have collected 91 Atlantic sturgeon (427 - 1473 mm FL).

Adult Atlantic sturgeon have been observed migrating upstream in the fall within the Cape Fear River, indicating that there may be two spawning seasons or some upstream overwintering may be occurring (M. Williams, Former UNCW, Pers. Comm. 2006). One large Atlantic sturgeon was tracked moving upstream in the Black River, which is a tributary of the Cape Fear River, in early October. Moreover, all of the largest sturgeon collected by UNCW personnel were later captured only during September and October in both the Cape Fear and Northeast Cape Fear rivers. Finally, a carcass of an adult female Atlantic sturgeon with fully developed ovaries was discovered in an area well upstream of the saltwater-freshwater interface in mid-September. Studies in other river systems have also demonstrated that some sturgeon will participate in upstream spawning migrations in the fall (Rogers and Weber 1995, Weber and Jennings 1996, Moser et al. 1998).

South Carolina Rivers

[17] Data may be biased as some sampling sites varied between the two periods, and more sites were sampled in 1997-2003 compared to 1990-1992.

Historically, Atlantic sturgeon were likely present in many South Carolina river/estuary systems, but it is not known where spawning occurred. Secor (2002) estimated that 8,000 spawning females were likely present prior to 1890, based on US Fish Commission landing records. Since the 1800s, however, populations have declined dramatically (Collins and Smith 1997). During the last two decades, Atlantic sturgeon have been observed in most South Carolina coastal rivers, although it is not known if all rivers support a spawning subpopulation (Collins and Smith 1997).

Winyah Bay (Waccamaw, Great Pee Dee, and Sampit Rivers) – South Carolina

Recent shortnose sturgeon sampling (using 5, 5.5, 7, and 9 inch stretched mesh experimental gill nets; 16' otter trawl) conducted in Winyah Bay captured two sub-adult Atlantic sturgeon during 4.2 hrs of effort in 2004. Captures of age-1 juveniles from the Waccamaw River during the early 1980s suggest that a reproducing population of Atlantic sturgeon may persist in that river, although the fish could have been from the nearby Great Pee Dee River (Collins and Smith 1997). In 2003 and 2004, nine Atlantic sturgeon (48.4-112.2 cm FL) were captured in the Waccamaw River during the SC Department of Natural Resources (SCDNR) annual American shad gill net survey, although none were considered spawning adults or YOY. However, Collins et al. (1996) note that unlike northern populations, in South Carolina, YOY are considered to be less than 50 cm TL or 42.5 cm FL, as growth rates are greater in the warmer southern waters compared to cooler northern waters. Therefore, the capture of a 48.4 cm FL sturgeon provides some evidence that YOY may be present in the Waccamaw River and some evidence of a spawning subpopulation. Lastly, watermen on the lower Waccamaw and Pee Dee rivers have observed jumping sturgeon, which suggest that rivers either serve as a nursery/feeding habitat or support an extant subpopulation(s) (W. Laney, USFWS, Pers. Comm. 2007).

Until recently, there was no evidence that Atlantic sturgeon spawned in the Great Pee Dee River, although subadults were frequently captured and large adults were often observed by fishers. However, a fishery survey conducted by Progress Energy Carolinas Incorporated captured a running ripe male in October of 2003 and observed other large sturgeon, perhaps revealing a fall spawning run.

There are no data available regarding the presence of YOY or spawning adult Atlantic sturgeon in the Sampit River, although it did historically support a subpopulation and is thought to serve as a nursery ground for local stocks (ASMFC *In Prep*).

Santee and Cooper Rivers – South Carolina

The capture of 151 subadults, including age-1 juveniles, in the Santee River in 1997 suggests that an Atlantic sturgeon population exists in this river (Collins and Smith 1997). This is supported by three adult Atlantic sturgeon carcasses found above the Wilson and Pinopolis dams in Lakes Moultrie (Santee-Cooper reservoirs) during the 1990s (M. Collins, SCDNR, Pers. Comm. 2006). Although shortnose sturgeon spawning above the dam has been documented, there is scant information to support existence of a land-locked subpopulation of Atlantic sturgeon. In 2004, 15 subadult Atlantic sturgeon were captured in shortnose sturgeon surveys during 156.6 hrs of effort conducted in the Santee estuary. The previous winter, four juvenile (YOY and subadults) Atlantic sturgeon were captured (360 – 657 mm FL) from the Santee (N =

1) and Cooper (N = 3) rivers. These data support previous hypotheses that a fall spawning run occurs within this system, similar to that observed in other southern river systems. However, SCDNR biologists are skeptical as to whether these smaller sturgeon (360 and 378 mm FL) from the Santee-Cooper are resident YOY as flood waters from the Pee Dee or Waccamaw River could have transported these YOY to the Santee-Cooper system via Winyah Bay and the Intercoastal Waterway (ICW) (McCord 2004).

Ashley River – South Carolina

The Ashley River, along with the Cooper River, drains into Charleston Bay; only shortnose sturgeon have been sampled in these rivers. While the Ashley River historically supported an Atlantic sturgeon spawning subpopulation, it is unknown whether the subpopulation still exist.

ACE Basin (Ashepoo, Combahee, and Edisto Rivers) – South Carolina

From 1994 - 2001, over 3,000 juveniles have been collected in the ACE Basin including 1,331 YOY sturgeon (Collins and Smith 1997, M. Collins, SCDNR, Pers. Comm. 2005). Sampling for adults began in 1997, with two adult sturgeon captured in the first year of the survey, including one gravid female (234 cm TL) captured in the Edisto River and one running ripe male (193 cm TL) captured in the Combahee River. The running ripe male in the Combahee River was recaptured one week later in the Edisto River, which suggests that the three rivers that make up the ACE basin may support a single subpopulation that spawns in at least two of the rivers. In 1998, an additional 39 spawning adults were captured (M. Collins, SCDNR, Pers. Comm. 2006). These captures show that a current spawning subpopulation exists in the ACE Basin as both YOY and spawning adults are regularly captured.

Broad/Coosawatchie River – South Carolina

There has been little or no scientific sampling for Atlantic sturgeon in the Broad/Coosawatchie River. One fish of unknown size was reported from a small directed fishery during 1981-1982 (Smith and Dingley 1984).

Savannah River – South Carolina and Georgia

The Savannah River supports a reproducing subpopulation of Atlantic sturgeon (Collins and Smith 1997). According to the NOAA-National Ocean Service, 70 Atlantic sturgeon have been captured since 1999 (J. Carter, NOS, supplemental data 2006). Twenty-two of these fish have been YOY (< 410 mm TL). A running ripe male was captured at the base of the dam at Augusta during the late summer of 1997, which supports the hypothesis that spawning occurs there in the fall.

Georgia Rivers

Prior to the collapse of the fishery in the late 1800s, the sturgeon fishery was the third largest fishery in Georgia. Secor (2002) estimated from U.S. Fish Commission landing reports that approximately 11,000 spawning females were likely present prior to 1890. The sturgeon fishery was mainly centered on the Altamaha River, and in more recent years, peak landings were recorded in 1982 (13,000 lbs). Based on juvenile presence and abundance, the Altamaha seems to currently support one of the healthiest Atlantic sturgeon subpopulations in the southeast (D. Petersen, UGA, Pers. Comm. 2006). Atlantic sturgeon are also present in the Ogeechee River; however, the absence of age-1 fish during some years and the unbalanced age structure suggests that the subpopulation is highly stressed (Rogers and Weber 1995). Spawning adults have been collected in recent years from the Satilla River (Waldman et al. 1996b). Recent sampling of the St. Mary's River failed to locate any sturgeon, which suggests that the subpopulation may be extirpated (Rogers et al. 1994). In Georgia, Atlantic sturgeon are believed to spawn in the Savannah, Ogeechee, Altamaha, and Satilla rivers.

Ogeechee River – Georgia

Previous studies have shown the continued persistence of Atlantic sturgeon in this river, as indicated by the capture of age +1 fish. Sampling efforts (including 1991-1994, 1997 and 1998) to collect age-1 sturgeon as part of the Savannah River genetics study suggest that juvenile abundance is rare with high inter-annual variability, indicating spawning or recruitment failure. However, the Army's Environmental and Natural Resources Division (AENRD) at Fort Stewart, GA, collected 17 sturgeon in 2003 considered to be YOY (less than 30 cm TL) and an additional 137 fish in 2004, using a 30 m x 2 m experimental gill net (3.8, 7.7, 12.7, 15.2, 17.8 cm stretched mesh). Most of these fish were juveniles; however, nine of these fish measured less than 41 cm TL and were considered YOY. In 2003, 17 sturgeon captured in this survey were also considered YOY (reported as less than 30 cm TL). The AENRD survey provides the most recent captures of YOY in the Ogeechee.

Altamaha River – Georgia

The Altamaha River supports one of the healthiest Atlantic sturgeon subpopulations in the Southeast, with over 2,000 subadults captured in trammel nets, 800 of which were nominally age-1 as indicated by size. Independent monitoring of the American shad fishery also documents the incidental take of Atlantic sturgeon within the river. Using these data, the subpopulation does not seem to be increasing or decreasing, as catch trends are variable (Figure 14).[18]

A survey targeting Atlantic sturgeon was initiated in 2003 by the University of Georgia. Trammel nets (91 m x 3 m) and gill nets were set in the lower 27 rkm of the Altamaha River, and were fished for 20-40 minutes during slack tides only. Sampling for adults was conducted using large mesh-gill nets set by local commercial fishermen during the months of April through May 2003. During 2005, similar gill nets were drift set during slack tides to supplement catches. As of October 2005, 1,022 Atlantic sturgeon have been captured using these gear types (trammel and large gill nets). Two hundred and sixty seven of these fish were collected during the spring spawning run in 2004 (N = 74 adults) and 2005 (N = 139 Adults). From these captures, 308 (2004) and 378 (2005) adults were estimated to have participated in the spring spawning run, which is 1.5% of Georgia's historical spawning stock (females) that were estimated from U.S. Fish Commission landing records (Schueller and Peterson 2006, Secor 2002).

[18] Voluntary bycatch estimates are known to be severely underreported.

Satilla River – Georgia

Sampling results indicate that the Atlantic sturgeon subpopulation in the Satilla River is highly stressed (Rogers and Weber 1995). Only four spawning adults or YOY, which were used for genetic analysis (Ong et al. 1996), have been collected from this river since 1995.

St. Mary's River – Georgia and Florida

The lack of Atlantic sturgeon captures (in either scientific sampling and/or as bycatch in other fisheries) in the St. Mary's River indicates that the river neither supports a spawning subpopulation nor serves as a nursery ground for Atlantic sturgeon (Rogers and Weber 1995, Kahnle et al. 1998). However, no directed sampling surveys have been conducted in recent years.

St. Johns River – Florida

In the 1970s and 1980s, there were several reports of Atlantic sturgeon being captured by commercial fishermen, although these fish were considered juveniles measuring 69 – 84 cm in length (J. Holder, Florida Fish and Wildlife Commission, Pers. Comm. 2006). There have been reports of Atlantic sturgeon tagged in the Edisto River (South Carolina) having been recaptured in the St. Johns River, indicating this river may serve as a nursery ground; however, there are no data to support the existence of a spawning subpopulation (i.e., YOY or running ripe adults) (Rogers and Weber 1995, Kahnle et al. 1998).

2. Consideration as a Distinct Population Segment under the ESA

2.1. Distinct Population Segment Background

According to Section 3 of the ESA, the term "species" includes "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife that interbreeds when mature." Congress included the term "distinct population segment" in the 1978 amendments to the ESA. One of the purposes of establishing distinct population segments (DPSs) is to conserve genetic diversity. In February of 1996, the Services published a policy to clarify their interpretation of the phrase "distinct population segment" for the purpose of listing, delisting, and reclassifying species (61 FR 4721). The policy identified the following three elements to be considered in determining whether to designate a DPS and to list the DPS as endangered or threatened under the ESA:

1. The discreteness of the population segment in relation to the remainder of the species or subspecies to which it belongs;
2. The significance of the population segment to the species or subspecies to which it belongs;
3. The conservation status of the population segment in relation to the ESA's standards for listing (i.e., is the population segment, when treated as if it were a species, endangered or threatened?).

Determining if a population is discrete requires either one of the following conditions:

1. It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.
2. It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of Section 4(a)(1)(D) of the Act.

If a population is deemed discrete, then the population segment is evaluated on terms of significance which may include, but is not limited to, the following:

1. Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon.
2. Evidence that loss of the discrete population segment would result in a significant gap in the range of the taxon.
3. Evidence that the DPS represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range.
4. Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

If a population segment is deemed discrete and significant then it is a distinct population segment. The DPS should be evaluated for endangered and threatened status based on the Act's definitions of those terms and a review of the factors enumerated in Section 4(a)(1).[19]

2.2. DPS Determination

The SRT concluded that Atlantic sturgeon should be divided into five distinct population segments (Figure 15). The five DPSs were named: 1) Gulf of Maine, 2) New York Bight 3) Chesapeake Bay, 4) Carolina, and 5) South Atlantic. The Saint Lawrence and Saint John rivers were not evaluated as a DPS because of a combination of the following factors:

- Both mtDNA and nDNA studies have been performed on the Saint Lawrence and Saint John River populations (King et al. 2001, Waldman et al. 2002, Supplemental data from Ike Wirgin and Tim King 2006). Mitochondrial DNA analysis has shown that little divergence has occurred in northern populations of Atlantic sturgeon as populations ranging from the Kennebec River, ME to the Saint Lawrence River, Canada are predominately homogenous (1 genotype). However, nDNA microsatellite analysis has found these same rivers to be genetically diverse (T. King supplemental data 2006). The

[19] ESA Section 4(a)(1) states that a species is "threatened" or "endangered" if any one or more of following factors causes it to be, or likely to become, in danger of extinction throughout all or a significant portion of its range: (A) the present or threatened destruction, modification, or curtailment of habitat or range; (B) overutilization for commercial, recreational or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence.

SRT concluded that the difference in nDNA exhibited by the Saint Lawrence and Saint John subpopulations were sufficient to exclude them from DPS analysis.

- The SRT concluded that differences in terrestrial and marine ecoregional data, developed by the Nature Conservancy (TNC), illustrated that habitat variability between the Gulf of Maine and Saint Lawrence River was sufficient to exclude the Saint Lawrence subpopulations from analysis.
- The SRT concluded that the Saint Lawrence subpopulation was distinct from other Atlantic sturgeon populations due to the drastic difference in age of maturity between the U.S. populations (age range: 5 – 21; Smith 1982 and Young et al. 1998) and the Saint Lawrence (age range: 22 – 34; Scott and Crossman 1973).
- The SRT also concluded, that since the Saint Lawrence and Saint John River subpopulations still support a commercial fishery with annual quotas ranging from 10 to 60 mt, there are significant differences in control of exploitation and regulatory mechanisms for these subpopulations; therefore, they should be excluded from the DPS analysis.

Discreteness and significance criteria supporting the five U.S. distinct population segments determined by the SRT are described below.

2.2.1. Support for Discreteness

Markedly Separated Based on Physical Factors

Atlantic sturgeon do not have physical barriers that separate subpopulations from mixing, as evidenced from tagging studies that show extensive mixing of Atlantic sturgeon along the Atlantic coast. However, tagging studies, indirect gene flow estimates (< 2 individuals per generation (mtDNA), genetic distance, and assignment results (nDNA) indicate that Atlantic sturgeon home to their natal streams to spawn, and thus, are spatially and temporally separated during the spawning season (K. Hattala, NYSDEC, Pers. Comm. 1998; Wirgin et al. 2000, King et al. 2001, Waldman et al. 2002).

Markedly Separated Based on Genetic Factors

The genetic diversity of Atlantic sturgeon along its range has been well documented. Initial investigations began in the early 1990s and have continued to present (Bowen and Avise 1990, Ong et al. 1996, Waldman et al. 1996a, Waldman et al. 1996b, Waldman and Wirgin 1998, King et al. 2001, Wirgin et al. 2002). Overall, these studies have consistently found subpopulations to be genetically diverse and the majority can be readily differentiated (Table 2). The most recently published articles on Atlantic sturgeon genetic diversity [King et al. (2001), Wirgin et al. (2002), Waldman et al. (2002)] indicate that from the areas that have been sampled, there are between seven and 10 subpopulations that can be statistically differentiated; however, there are some differences between studies and results do not include samples from all rivers inhabited by Atlantic sturgeon. More recently, these authors (Wirgin and King) have increased their sample sizes from multiple rivers and have re-evaluated their data using only YOY and spawning adult samples; thus, reducing classification error introduced from migrating sub-adults in their sample by approximately 14% (King, nDNA supplemental data 2006). The results from these unpublished reports indicate that most, if not all, subpopulations are statistically different ($P < 0.05$) based on allelic/haplotype frequencies, AMOVA, and FST (and mtDNA equivalent) statistical tests using both mtDNA and nDNA genetic markers (Table 3, 4, and 5; Figure 16, 17, and 18). King also increased the number of loci used in his nDNA analysis from seven to 12, to help identify the genetic relatedness between Atlantic sturgeon subpopulations with greater certainty.[20] The use of 12 microsatellite markers resulted in an average accuracy of 88% for determining a sturgeon's natal origin and an average accuracy of 94% for correctly classifying it to a DPS determined by the SRT (Table 6). These results are an improvement to earlier findings using only 7 microsatellite markers and resulted in a 12% (~9 percentage points) increase in natal origin classification rates and 8% (~6percentage points) increase in DPS classification rates (Table 6). However, tissue samples from YOY and adults are limited to 12 subpopulations; thus, the SRT also evaluated subadults in some cases (18). There were no major differences observed between the two genetic tree analyses that included or excluded subadults. As a result of the high classification success rate using nDNA microsatellites and similar findings using mtDNA, the SRT concluded that nDNA analysis would be used for the remainder of the DPS analysis.

Markedly Separated Based on Physiological or Behavioral Factors

Though the genetic markers used to differentiate among the subpopulations examined were not linked to specific traits (mtDNA d-loop region and nDNA microsatellites), it is assumed that these genetic markers indicate differences in physiological, ecological, or behavioral factors as the level of genetic differentiation between subpopulations is high (Vannote et al. 1980, MacLean and Evans 1981, Avise 1992, Nielsen 1998). Some potential physiological or behavioral factors that are unique to Atlantic sturgeon are related to spawning conditions. The majority of southern subpopulations (specifically the Cape Fear, Pee Dee, ACE Basin, Savannah, Congaree, and Altamaha rivers) have been documented to participate in a fall spawning run, as well as a spring run (Collins et al. 2000a, D. Peterson, UGA, Pers. Comm. 2006). It is unknown why a fall run may be beneficial for Atlantic sturgeon, although many salmonids exhibit similar characteristics (NRC 1996). Benefits may include reduced competition or avoidance of unfavorable environmental conditions (e.g., low DO) occurring during the summer months.

Differences in the innate dispersal patterns of sturgeon species in early life stages also suggest that there are markedly separated differences in behavior between subpopulations of sturgeon (B. Kyndard, CAFL, Pers. Comm. 2006). Boyd Kynard (USGS), a researcher at Conte Anadromous Fish Laboratory (Turner Falls, Massachusetts), has noted major differences in innate dispersal patterns of early life stage sturgeon species including *Acipenser fulvescens* (Wolf and Menominee rivers), *A. brevirostrum* (Connecticut and Savannah rivers), *A. transmontanus* (Sacremento and Kootenai rivers), and Atlantic/Gulf sturgeon subpopulations (Hudson and Suwannee rivers). This research suggests that Atlantic sturgeon are likely adapted to unique features of their watershed, considering their genetic discreteness and differing migration behaviors. These findings are similar to research conducted on striped bass (*Morone saxatilis*), an anadromous fish like Atlantic sturgeon, which correlated egg characteristics (egg diameter, egg density, etc.) with watershed type (i.e., low, medium, high energy) (Bergey et al. 2003). Differences in egg characteristics likely are the result of subpopulation adaptations to the

[20] Only seven populations were analyzed using 12 loci: Kennebec, Hudson, James, Albemarle, Savannah, Ogeechee, and Altamaha rivers.

watershed, but the manner in which these adaptations were produced were not determined. The SRT concluded that unique behavioral and physiological traits likely exist for each extant subpopulation of Atlantic sturgeon – except those that share a drainage basin (similar adaptations).

Discreteness Conclusion

The SRT found that it was reasonable to conclude that all of the U.S. Atlantic sturgeon subpopulations could be considered discrete subpopulations. These conclusions are based on the information presented above, which note that Atlantic sturgeon are 1) physically separated from other subpopulations during the spawning season, 2) genetic analysis suggest that each subpopulation is statistically significant different ($P < 0.05$) from one another using both mtDNA and nDNA markers and multiple genetic analysis, and 3) migration behaviors of Atlantic sturgeon both as adults and developing larvae vary among river systems.

2.2.2. Support for Significance

Unique Ecological Setting

The SRT reviewed ecoregion maps for both terrestrial and marine ecosystems to describe habitat, climate, and physiographic differences throughout the range of the Atlantic sturgeon. The Nature Conservancy (TNC) ecoregion maps were chosen by the SRT, as they were the most current maps available depicting ecoregions for both terrestrial and marine systems and can be further examined as Ecological Drainage Units (EDUs) if smaller management units are required (Groves et al. 2002, Olivero 2003, Higgins et al. 2005). Marine ecoregion maps were limited to the United States, as indicated by Marine Ecoregion 3 (Figure 19), which ends near or at the international boundary between the US and Canada. Similarly, the New York Bight DPS consists of two separate terrestrial ecoregions named, the North Atlantic Coast (NAC) (a coastal ecoregion) and the Lower New England (LNE) (an inland ecoregion). These two terrestrial ecoregions were combined because both the Hudson and Delaware rivers transverse both ecoregions. Although the NAC and LNE ecoregion boundaries range from the Delaware River to just west of the Kennebec Estuarine Complex, the SRT concluded that the Gulf of Maine (Cape Cod Bay to the Penobscot River) should be considered a unique ecoregion based on TNC marine ecoregion 3 (Figure 19) and a review of sea surface water temperatures that demonstrate that the GOM is a much colder environment compared to southern regions (Figure 20). The resulting ecoregion map created by SRT correlates well with mtDNA and nDNA genetic trees of Atlantic sturgeon (Figure 15, 16, and 18), and suggests that regional subpopulations are adapted to ecological features that are unique to an ecoregion.

Differs Markedly in its Genetic Characteristics

As described earlier, Atlantic sturgeon population genetics have been extensively studied since the 1990s. These studies have continuously shown that Atlantic sturgeon subpopulations are genetically diverse and significantly different using multiple genetic techniques. However, until recently this genetic information has been unreliable as tissue samples were taken in many cases from subadults (possible strays from other systems). The SRTs most reliable genetic data is restricted to 12 subpopulations.

To further investigate significant relationships among Atlantic sturgeon subpopulations, the SRT used genetic distances and bootstrap values, and assignment test values to help determine subpopulation groupings. As described earlier, assignment or classification tests resulted in 94% accuracy for identifying sturgeon to their DPS with a range of 88 – 96% when using data collected only from YOY and adults (Table 6). Genetic trees produced from only YOY and adult samples were similar among mtDNA and nDNA, and bootstrap values for these trees were relatively high (at least for nDNA) (Figure 16 and 17). Based on the similarities seen between mtDNA and nDNA genetic trees, high bootstrap values and classification rates, the SRT identified five population groupings that were considered to be markedly different: 1) Gulf of Maine 2) New York Bight, 3) Chesapeake Bay, 4) Carolina, and 5) South Atlantic (Figure 15).

Significant Gap in the Range of the Taxon

Determining whether a gap in the range of taxon would be significant if a DPS went extinct is somewhat difficult to ascertain with an anadromous fish such as the Atlantic sturgeon. Atlantic sturgeon are known to migrate great distances between their natal rivers and overwintering areas. Therefore, estuarine and marine populations are comprised of mixed stocks. Despite this extensive mixing of migratory sub-adults and adults, adults are known to return to their natal river to spawn. Therefore, the loss of a DPS would mean the loss of riverine spawning subpopulations, while marine and estuarine habitat may still be occupied by migratory sturgeon from other DPSs. Because gene flow is low among subpopulations, Atlantic sturgeon from other DPSs are not expected to re-colonize systems except perhaps over a long time frame (e.g., greater than 100 years) (Secor and Waldman 1999). Thus, the loss of one or more DPSs is expected to result in a significant gap in the range of the species given that the DPSs as designated are relatively large. The SRT contends that the loss of one or more of these DPSs could negatively impact the species as a whole.

Significance Conclusion

The SRT concluded that it is reasonable to conclude that five population groupings of Atlantic sturgeon within the United States should be considered significant under the DPS policy guidelines. The five groupings are: 1) Gulf of Maine, 2) New York Bight, 3) Chesapeake Bay, 4) Carolina, and 5) South Atlantic. These conclusions are based on the information presented above, which note that Atlantic sturgeon are 1) found in five unique ecological settings, 2) genetic analyses suggest that subpopulations can be easily grouped into five populations with high certainty (94%) and these groupings correlate well with the five unique ecological settings, and 3) due to low gene flow among populations, the loss of one or more these five populations could negatively impact the species as a whole.

Though the SRT is recommending that five DPSs be designated for Atlantic sturgeon, the team also recommends that individual river subpopulations should be considered distinct management/recovery units within the DPS for any future recovery planning, as subpopulations within a DPS are genetically diverse, and it would be prudent to protect these smaller units as well.

3. Analysis of the ESA Listing Factors

The ESA defines an "endangered" species as any species in danger of extinction throughout all or a significant portion of its range and a "threatened" species as any species likely to become endangered throughout all or a significant portion of its range within the foreseeable future. Section 4(b)(1)(a) of the ESA requires that determinations of whether a species is threatened or endangered be based solely on the best scientific and commercial data available and after taking into account those efforts, if any, being made to protect such species. A species may be determined to be endangered or threatened due to one or more of the following five factors described in Section 4(a)(1) of the ESA:

1) The present or threatened destruction, modification, or curtailment of habitat or range;
2) Overutilization for commercial, recreational, scientific, or educational purposes;
3) Disease or predation;
4) The inadequacy of existing regulatory mechanisms; and
5) Other natural or manmade factors affecting its continued existence.

In the following section, each of these five factors is examined for its historic, current, and/or potential impact on Atlantic sturgeon status. It should be noted that current and potential threats, along with current distribution and abundance, determine present vulnerability to extinction. Information about historic threats is included to assist interpretation of historic population trends. The relationship between historic threats and population trends also provides insights that may help to project future population changes in response to current and potential threats.

3.1. The Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Atlantic sturgeon, like all anadromous fish, are vulnerable to a host of habitat impacts because they use rivers, estuaries, bays, and the ocean at various points of their life. Habitat alterations potentially affecting sturgeon include dam construction and operation, dredging and disposal, and water quality modifications such as changes in levels of DO, water temperature, and contaminants.

Loss of habitat and poor water quality have contributed to the decline of Atlantic sturgeon since European settlement; however, the importance of this threat has varied over time and from river to river. Some important aspects of habitat quality, especially water quality, have improved during the last thirty years. Examination of the impact of present or threatened destruction, modification, or curtailment of habitat or range on Atlantic sturgeon is presented. If information was not available specifically for Atlantic sturgeon, information relevant to other sturgeon species is presented. Similarities in sturgeon life history and physiology make these data and analyses applicable, with occasional qualification, to Atlantic sturgeon.

The following sections review the impact of dams, dredging, and water quality on Atlantic sturgeon and their habitat generally. River specific information is presented, as available and applicable, following the more general discussion.

3.1.1. Dams and Tidal Turbines

Dams for hydropower generation and flood control can have profound effects on anadromous species by impeding access to spawning and foraging habitat, modifying free-flowing rivers to reservoirs, physically damaging fish on up- and down-stream migrations, and altering downstream flows and water temperatures. Patrick (*unpublished data-a*) estimated that nationwide, over 50,000 miles of river/lake habitat were blocked by terminal dams (those lowest in the watershed), which includes the area between the terminal dam and the next upstream impediment, along the Atlantic, Pacific, and Gulf coasts. Similarly, about 62% of historical habitat once available to American shad is now impeded by dams (W. Patrick, NMFS, unpublished data-b). A nonrandom subsample (largest impediments) of these terminal dams indicated that the majority (65%) do not offer fish passage (Patrick *unpublished data*). Atlantic sturgeon do not regularly use fish passage devices; only four Atlantic sturgeon have been documented to have passed via a fish lift, as these passage facilities are not designed to accommodate adult-sized sturgeon. Three of the Atlantic sturgeon were found in Lake Molutrie, SC that evidently passed the St. Stephens fish lift. The only other observed Atlantic sturgeon using a fish passage device was recently observed in September of 2006 using the Holyoke Dam fish lift, which is located on the Connecticut River, Massachusetts. However, shortnose sturgeon have been observed frequently (4.7 sturgeon per year between 1975 and 2002) to have passed the Holyoke Dam via its fish lift (Kynard 1996, Gephard and McMeney 2004).

Physical damage and mortality can also occur from anadromous fish migrating through the turbines of traditional hydropower dams on their downstream migration. Though Atlantic sturgeon have not been observed to use fish passage devices, tidal power plants are a potential threat to Atlantic sturgeon migrating up- and down-stream (Dadswell and Rulifson 1994, Dadswell 2006). Tidal power plants use marine turbines, similar to windmill technology, to generate power using the force of both incoming and out-going tides. These marine turbines can strike migrating fish such as adult Atlantic sturgeon, thus causing physical damage or mortality; injuries or mortality can also occur via shear, pressure flux, and cavitation effects on fish during turbine passage (reviewed in Dadswell and Rulifson 1984). Currently, there are two tidal power projects in operation along the range of Atlantic sturgeon, with many more projects being proposed. The Annapolis River tidal power plant (Nova Scotia), built in 1982, was constructed as a demonstration site for marine STRAFLO turbines and consisted of a rock-filled dam housing the turbine and sluice gates (M. Dadswell, Arcadia University, Pers. Comm. 2006). The negative impacts of the Annapolis tidal turbine on Atlantic sturgeon (150 – 200 cm TL) appear to be great, as the probability of lethal strike from the turbine ranges between 40 –80% (M. Dadswell, Arcadia University, Pers. Comm. 2006) and at least three severed, gravid females have been observed below the power plant (Dadswell and Rulifson 1994) (Figure 21). Within the United States, one marine turbine project has been proposed on the East River, New York (Angelo 2005, CBS News 2006). Beginning in November of 2006, an 18-month pilot project using two slow speed tidal turbines were placed in the East River to determine their impacts on marine life. Following the 18-month project four more tidal turbines are to be installed to further test the prototype turbines (CBS News 2006). The energy company, Verdant Power, has plans to expand the project to up to 300 turbines to be located within a one-mile section of the river near Roosevelt Island (Angelo 2005).

In addition to dams impeding anadromous fish migration and associated mortalities, Hill (1996) identified the following potential impacts from hydropower plants: altered DO concentrations and temperature; artificial destratification; water withdrawal; changed sediment load and channel morphology; accelerated eutrophication and change in nutrient cycling; and contamination of water and sediment. The suitability of riverine habitat for Atlantic sturgeon spawning and rearing also likely depends on annual fluctuations in flow, which can be greatly altered or reduced by the presence of dams as has been shown for white sturgeon (*Acipenser transmontanus*) (Beamesderfer and Farr 1997). Activities associated with dam maintenance, such as dredging and minor excavations along the shore, can release silt and other fine river sediments that can be deposited in nearby spawning habitat.

It is difficult to assess the impact of dam construction on Atlantic sturgeon, as the locations of historic spawning areas are not known for many rivers (9 of 36 known). The geomorphology of rivers north of Georgia is often characterized by waterfalls and rapids, which are believed to be impassable to Atlantic sturgeon, and these features tend to be located in the vicinity of the fall line. Therefore, Atlantic sturgeon spawning sites above these areas are rare (Figure 22). A few exceptions are the Roanoke and Hudson rivers that have current and/or historical information suggesting that spawning occurred above the fall line (Kahnle 1998, Reviewed in Armstrong and Hightower 2002). In most cases, the first dam on a river was built at the site of natural falls and rapids. As a result, the SRT concluded that Atlantic sturgeon spawning habitat, for the most part, is unimpeded by dams along the Atlantic Coast. Only rivers with a dam located below the fall line or a subpopulation that spawns above the fall line were impeded. Using GIS tools and dam location data collected by Oakley (2005) as a reference point for river kilometer measurements, historical rivers in which Atlantic sturgeon spawned were mapped to determine the number of miles of available riverine habitat. The SRT assumed that the fall line was the upper boundary of habitat unless otherwise noted in the literature or by expert opinion. The distance from the fall line to the mouth of the river (mainstem only) was calculated in river kilometers, and in many cases, may not match Army Corp of Engineers (ACOE) estimates due to a difference in reference points. Proportionally, however, the estimates should be accurate.

Overall, 91% of Atlantic sturgeon habitat seems to be accessible. Four of the 36 rivers examined have lost more than 25% of their riverine habitat and include: Merrimack, NH/MA (58%); Cape Fear, NC (64%); Santee/Cooper, SC (62%); and St. Johns River, FL (63% loss) (Table 7). Though 91% of the Atlantic sturgeon habitat seems to be available, the quality of the remaining portions of habitat as spawning and nursery grounds is unknown. Therefore, estimates of 100% availability does not necessarily equate to 100% functionality.

Several dams within the Atlantic sturgeon historic range have been removed or naturally breached (Treat Falls Dam on the Penobscot River, ME; Edwards Dam on the Kennebec River, ME; Enfield Dam on the Connecticut River, CT; Quaker Neck Dam on the Neuse River, NC). While there has not been a large loss of Atlantic sturgeon habitat throughout the entire species' range due to the presence of dams, individual riverine systems (e.g., Cape Fear, Santee-Cooper, Merrimack) have been severely impacted by dams, as access to large portions of historical sturgeon spawning habitat have been eliminated or restricted. This may be the primary cause of the extirpation of several subpopulations.[21] Thus, it warrants consideration when assessing the extinction risk of subpopulations that are currently impacted by loss of accessible spawning habitat.

3.1.2. Dredging and Blasting

Riverine, nearshore, and offshore areas are often dredged to support commercial shipping and recreational boating, construction of infrastructure, and marine mining. Dredging activities can pose significant impacts to aquatic ecosystems by removing, disturbing, disposing, and resuspending bottom sediments, modifying substrate and impacting the community structure of benthic macrofauna. Environmental impacts of dredging include the following: direct removal/burial of organisms; turbidity/siltation effects; contaminant resuspension; noise/disturbance; alterations to hydrodynamic regime and physical habitat and actual loss of riparian habitat (Chytalo 1996, Winger et al. 2000). According to Smith and Clugston (1997), dredging and filling impact important habitat features of Atlantic sturgeon as they disturb benthic fauna, eliminate deep holes, and alter rock substrates. Nellis et al. (*in press*) documented similar impacts as dredge spoil was documented to drift 12 km downstream over a 10 year period in the Saint Lawrence River, and those spoils have significantly lower amounts of macrobenthic biomass compared to control sites. Using an acoustic trawl survey, researchers found that Atlantic and lake sturgeon were substrate dependent and avoided spoil dumping grounds (McQuinn and Nellis, *In* Press). Similarly, Hatin et al. (*In press*) tested whether dredging operations affected Atlantic sturgeon behavior by comparing CPUE before and after dredging events in 1999 and 2000. The authors documented a three to seven-fold reduction in Atlantic sturgeon presence after dredging operations began, indicating that sturgeon avoid these areas during operations.

Indirect impacts to sturgeon from either mechanical or hydraulic dredging include destruction of benthic feeding areas, disruption of spawning migrations, and deposition of resuspended fine sediments in spawning habitat. In addition to these indirect impacts, hydraulic dredging can directly harm sturgeon by lethally entraining fish up through the dredge drag-arms and impeller pumps. Dickerson (2005) summarized observed takings of sturgeon from dredging activities conducted by the ACOE; overall 24 sturgeon (2 – Gulf, 11 – Shortnose, and 11 – Atlantic sturgeon) were observed during the years of 1990-2005 (Table 8). Of these 24 sturgeon captured, 15 (62.5%) were reported as dead. Overall take during this time can be partially calculated as 100% of hopper dredges have been observed since 1995 during seasonal restrictions for shortnose sturgeon and sea turtles, with an unknown proportion of hydraulic pipeline and bucket-and-barge dredging operations being observed (Dena Dickerson, USACOE-ERDC, Pers. Comm. 2006). The SRT calculated a minimum take of 0.6 Atlantic sturgeon per year, based simply on hopper dredge takes since 1995 and that dredging efforts were relatively similar among years (USACOE 2006). It should be noted that all Atlantic sturgeon takes associated with dredging projects may not have been observed because seasonal restrictions for

[21] Within this report a subpopulation is considered a population unit of the species range or its DPS and is sometimes used interchangeably with the term population when referring to specific population units (e.g., Hudson River Population = Hudson River subpopulation)

listed species do not overlap fully with critical periods for Atlantic sturgeon, and also, observers are not required on some rivers that support Atlantic sturgeon as they do not support shortnose sturgeon or sea turtle populations. Dickerson (2005) noted that the largest take of sturgeon species was observed in the Delaware (N =6) and Kennebec (N = 6) rivers. Atlantic sturgeon have also been taken in both hydraulic pipeline and bucket-and-barge operations in the Cape Fear River, NC (M. Moser, University of North Carolina at Wilmington, Pers. Comm. 1998). To reduce the impacts of dredging on anadromous fish species, most of the Atlantic states impose work restrictions during sensitive time periods (spawning, migration, feeding) when anadromous fish are present. NMFS also imposes seasonal restrictions to protect shortnose sturgeon populations (where present) through Section 7 consultations that may have the added benefit of protecting Atlantic sturgeon.

3.1.3. Water Quality

The quality of water in river/estuary systems is affected by those activities conducted directly in the riparian zone and more remotely in the upland portion of the watershed. Industrial activities can result in discharges of pollutants, changes in water temperature and levels of DO, and the addition of nutrients. In addition, forestry and agricultural practices can result in erosion, run-off of fertilizers, herbicides, insecticides or other chemicals, nutrient enrichment and alteration of water flow. The coastal environment is also impacted by coastal development and urbanization that result in storm water discharges, non-point source pollution, and erosion. Secor (1995) noted a correlation between low abundances of sturgeon during this century and decreasing water quality caused by increased nutrient loading and increased spatial and temporal frequency of hypoxic conditions. Using a multivariable bioenergetics and survival model, Niklitschek and Secor (2005) demonstrated that within the Chesapeake Bay, a combination of low DO, water temperature, and salinity restricts available Atlantic sturgeon habitat to 0-35% of the Bay's modeled surface area during the summer. Pulp mill, silviculture, agriculture, and sewer discharge can elevate temperatures and/or increase biological oxygen demand resulting in reduced DO levels that can be stressful to aquatic life. Niklitschek and Secor (2005) also simulated the affects of achieving EPA's DO-criteria for the Chesapeake Bay and water temperature affects on available habitat.[22] It is interesting to note that the EPA adjusted their open water minimum DO-criteria for the Chesapeake Bay (increased from ~2 ppm to 3.5 ppm) to provide protection specifically for sturgeon species, which require higher levels of DO compared to other fish species. Niklitschek and Secor (2005) found that achieving EPA's new DO-criteria, would increase Atlantic sturgeon available habitat by 13% per year, while an increase of water temperature by just 1° C would reduce available habitat by 65%. Similar results may occur in southern rivers where high water temperatures and low DO are a common occurrence during the summer months.

Atlantic sturgeon may be particularly susceptible to impacts from environmental contamination due to their benthic foraging behavior and long-life span. Sturgeon using estuarine habitats near urbanized areas may be exposed to numerous suites of contaminants within the substrate. Contaminants, including toxic metals, polychlorinated aromatic hydrocarbons (PAHs), organophosphate and organochlorine pesticides, polychlorinated biphenyls (PCBs), and other

[22] Refer to http://www.chesapeakebay.net/wqcoxygen.htm for details on the EPA's DO criteria for the Chesapeake Bay Program.

chlorinated hydrocarbon compounds can have substantial deleterious effects on aquatic life. Effects from these elements and compounds on fish include production of acute lesions, growth retardation and reproductive impairment (Cooper 1989, Sinderman 1994).

Heavy metals and organochlorine compounds accumulate in sturgeon tissue, but their long-term effects are not known (Ruelle and Henry 1992, Ruelle and Keenlyne 1993). Elevated levels of contaminants, including chlorinated hydrocarbons, in several other fish species are associated with reproductive impairment (Cameron et al. 1992, Longwell et al. 1992, Hammerschmidt et al. 2002, Drevnick and Sandheinrich 2003), reduced egg viability (Von Westerhagen et al. 1981, Giesy et al. 1986, Mac and Edsall 1991, Matta et al. 1997, Billsson et al. 1998), reduced survival of larval fish (Berlin et al. 1981, Giesy et al. 1986), delayed maturity (Jorgensen et al. 2003) and posterior malformations (Billsson et al. 1998). Pesticide exposure in fish may affect anti-predator and homing behavior, reproductive function, physiological development, and swimming speed and distance (Beauvais et al. 2000, Scholz et al. 2000, Moore and Waring 2001, Waring and Moore 2004). Moser and Ross (1995) suggested that certain deformities and ulcerations found in Atlantic sturgeon in North Carolina's Brunswick River might be due to poor water quality in addition to possible boat propeller inflicted injuries. It should be noted that the effect of multiple contaminants or mixtures of compounds at sub-lethal levels on fish has not been adequately studied. Atlantic sturgeon use marine, estuarine, and freshwater habitats and are in direct contact through water, diet, or dermal exposure with multiple contaminants throughout their range.

Sensitivity to environmental contaminants varies among fish species and life stages. Early life stages of fish seem to be more susceptible to environmental and pollutant stress than older life stages (Rosenthal and Alderdice 1976). In aquatic toxicity tests (Dwyer et al. 2000), Atlantic sturgeon fry were more sensitive to five contaminants (carbaryl, copper sulfate, 4-nonylphenol, pentachlorophenol, and permethrin) than fathead minnow (*Pimephales promelas*), sheepshead minnow (*Cyprinodon variegatus*), and rainbow trout (*Oncorhynchus mykiss)* - three common toxicity test species - and 12 other species of threatened and endangered fishes. The authors note, however, that Atlantic sturgeon were difficult to test and conclusions regarding chemical sensitivity should be interpreted with caution. Shortnose sturgeon toxicity tests suggested that this sturgeon species had similar sensitivities to that of the fathead minnow (Dwyer et al. 2005). Conversely, ongoing research with shovelnose sturgeon (*Scaphirhynchus platorhynchus*), an inland sturgeon species, suggests that some sturgeon species may be less sensitive to dioxin, the most toxic organochlorine compound, than salmonid species (Tillitt et al. 2005).

The relationship between Atlantic sturgeon contamination and human health has been partially investigated because polychlorinated biphenyls (PCBs) have been detected in Atlantic sturgeon flesh from the Saint Lawrence and Hudson rivers (Sloan 1987). PCBs are known to have long-term deleterious environmental and health effects and are characterized as carcinogenic (Budavari et al. 1989). The U.S. Environmental Protection Agency (EPA) banned the production of PCBs and regulated their disposal because the compound was linked to cancer, liver damage, skin lesions, and reproductive disorders. To protect human health, the U.S. Food and Drug Administration set the upper limit for PCBs in the edible portions of fish and shellfish at 2 µg/g (parts per million) in 1984. Reproductive and developmental effects thresholds for PCBs in fish, however, may be lower or higher than the human health criterion (Niimi 1996, Monosson 2000, Meador et al. 2002). In fish, exposure to PCBs reportedly causes a higher incidence of fin erosion, epidermal lesions, blood anemia, and an altered immune response (Kennish et al. 1992). PCBs probably have the greatest effect on reproduction where PCB residues have been related to mortality and reproductive failure in Baltic flounder – *Platichthys flesus* (Von Westernhagen et al. 1981), charr – *Salvelinus sp.* (Monod 1985), fathead minnows (Post 1987), lake trout – *S. namaycush* (Mac and Swartz 1992), rainbow and westslope cutthroat (*Oncorhynchus clarki lewisi)* trout (Matta et al. 1997), and zebrafish – *Danio rerio* (Billsson et al. 1998).

Another suite of contaminants occurring in fish are metals (mercury, cadmium, selenium, lead, etc.), also referred to as trace metals, trace elements, or inorganic contaminants. Post (1987) states that toxic metals may cause death or sub-lethal effects to fish in a variety of ways and that chronic toxicity of some metals may lead to the loss of reproductive capabilities, body malformation, inability to avoid predation, and susceptibility to infectious organisms. Dietary methylmercury experiments using fathead minnows inhibited gonadal development of females and reduced reproductive success by a factor of three (Hammerschmidt et al. 2002, Drevnick and Sandheinrich 2003). Chronic dietary mercury exposure in Atlantic salmon (*Salmo salar*) parr caused oxidative stress, brain lesions, and altered behavior (Berntssen et al. 2003). Arsenic, lead, cadmium, and selenium were the major inorganic contaminants found in striped bass (*Morone saxatilis*) sampled in the Hudson, Nanticoke, and Potomac rivers (Mehrle et al. 1982). In the same study, the authors found that vertebrae from Hudson River striped bass had lower strength, stiffness, toughness, and ruptured more easily than vertebrae of hatchery striped bass and suggested that contaminants such as PCB, cadmium, and lead could affect survival of larvae and abundance of striped bass.

Dadswell (1975) and Rehwoldt et al. (1978) were the only references found which specifically associated Atlantic sturgeon with any of these contaminants. Dadswell (1975) examined 30 juvenile Atlantic sturgeon collected in the Saint John River estuary, New Brunswick. The mean concentration of mercury was 0.29 ppm of wet weight with a range of 0.06 – 1.38 ppm. Rewoldt et al. (1978) examined a limited number of freshly captured Hudson River fish in 1976 and 1977 along with a number of reference samples from the Hudson River that had been stored in preservation between 1924 and 1953. These tissue samples were analyzed for cadmium, mercury, and lead and compared with other fish species taken from the Hudson River during those time periods. Average values of contaminant levels did not show any chronological relationship, such that Atlantic sturgeon samples from 1924 and 1976 showed little difference for all three metal residues. The 1976-1977 average concentrations (µg/g; ppm, wet weight) in Atlantic sturgeon tissue were as follows: cadmium 0.02, mercury 0.09, and lead 0.16.

As noted above, few references regarding contaminants in Atlantic sturgeon tissue or species-specific potential biological effects were found. However, information is available regarding contaminants in other sturgeon species:

- Gulf sturgeon (*Acipenser oxyrinchus desotoi*) collected from a number of rivers between 1985 and 1991 were analyzed for pesticides and heavy metals (Bateman and Brim 1994). Concentrations of arsenic, mercury, DDT metabolities, toxaphene, polycyclic aromatic hydrocarbons, and aliphatic hydrocarbons were sufficiently high to warrant concern.

- Twenty juvenile Gulf sturgeon from the Suwannee River in Florida exhibited an increase in metals burdens with an increase in fish length (Alam et al. 2000).
- In a California study involving laboratory exposures, white sturgeon larvae had a significantly increased incidence of defects with selenium levels greater than 15 µg/g (R. Linville, UC-Davis. Pers. Comm. 2006).
- Kootenai River white sturgeon exhibited organochlorine levels that could potentially affect reproduction or other physiological functions (Kruse and Scarnecchia (2002a).
- Growth and reproductive impacts were observed in Columbia River white sturgeon, where plasma triglycerides and conditions factors were negatively correlated with total DDT, total pesticides, and PCBs (Feist et al. 2005). In males, plasma androgens and gonad size were also negatively correlated with total DDT, total pesticides, and PCBs.
- Kruse and Scarnecchia (2002b) noted that the mortality of white sturgeon embryos was significantly different between individuals reared in different media (Fuller's earth 12.6% versus river bottom sediment 20.6%), which was related to copper and Aroclor 125 (PCB) concentrations.
- Dioxin and furans were detected in ovarian tissue from shortnose sturgeon caught in the Sampit River/Winyah Bay system (SC). Results showed that four out of seven fish tissues analyzed contained tetrachlorodibenzo-*p*-dioxin (TCDD) concentrations greater than 50 pg/g (parts-per-trillion), a level which can adversely affect the development of sturgeon fry (J. LLIff, NOAA, Damage Assessment Center, Silver Spring, MD, unpublished data).
- Shortnose sturgeon collected from the Delaware and Kennebec rivers had total toxicity equivalent concentrations of polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), PCBs, dichlorodiphenyldichloroethylene (DDE), aluminum, cadmium, and copper above adverse effect concentration levels reported in the literature (Environmental Research and Consulting 2002, 2003).
- In a study of white sturgeon from the Columbia River (Webb et al. 2006), mercury concentrations were measured in several types of tissues from legal-size fish (110 – 137 cm FL) and a mature adult female (170 kg, 262 cm FL). Tissue mercury content was correlated with suppressed circulating sex steroids, decreased condition factor and relative weight, and a lower gonadosomatic index in immature male fish. A significant positive linear relationship was determined between age and liver mercury concentrations. Mercury concentration in muscle tissue from the mature adult female (1.094 ppm) exceeded state and Federal action limits.

The EPA published its second edition of the National Coastal Condition Report (NCCR II) in 2004, which is a "report card" summarizing the status of coastal environments along the coast of the United States (EPA 2004). The report analyzes water quality, sediment, coastal habitat, benthos, and fish contaminant indices to determine status. An overall grade of F was given to the Northeast region (Virginia - Maine) where water quality, sediment, benthos, and fish tissues received a grade of D or F (Table 9). The Chesapeake Bay was also analyzed as a separate region within the Northeast and received a score of F in all status indices, except for coastal habitat, which was not evaluated (no coastal habitat). However, the Southeast region (North Carolina - Florida) received an overall grade of B-, which is the best rating in the nation with no indices below a grade of C (Table 9). Areas of concern that had poor index scores were: 1) Hudson River – water quality, sediment, and tissue contaminants, 2) Delaware River – water quality and tissue contaminants, 3) Upper Chesapeake Bay – water quality and sediment, 4) Narragansett Bay – tissue contaminants, 5) Potomac River – sediment, 6) Pamlico Sound – water quality, 7) ACE Basin – water quality, and 8) St. Johns River – sediment. There was also a mixture of poor benthic scores scattered along the Northeast and Southeast region.

3.1.4 River Specific Habitat Information

Gulf of Maine DPS

Penobscot River – Maine

There are two obstructions to Atlantic sturgeon historical spawning habitat in the Penobscot River, Maine. In 1833, the Veazie Dam was constructed on the Penobscot River at rkm 56, blocking 29 km of habitat that was historically accessible to Atlantic sturgeon. Five kilometers downstream of the Veazie, the Treats Falls Bangor Dam also impeded migration upstream during the summer months. The Bangor Dam, however, was breached in 1977 and now allows diadromous fish migration. Thus, there are currently 50 km of tidal and freshwater habitat available for spawning and nursery habitat. Historically, the first natural obstacle to Atlantic sturgeon migration on the Penobscot River may have been the falls at Milford, rkm 71 (L. Flagg, MEDMR, Pers. Comm. 1998). If Atlantic sturgeon were able to ascend the falls at Milford, they could have migrated without obstruction to Mattaseunk (rkm 171). In June 2004, the Penobscot Accord was signed which gave the Penobscot River Restoration Trust, a non-profit corporation established in May 2004, the ability to buy Veazie, Great Works and Howland dams on the Penobscot River over a five year period. If bought, the Trust has the right to decommission and/or remove the Veazie Dam, decommission the Great Works Dam, and install fish passage or remove the Howland Dam. However, these options cannot be initiated until 2007-2010 and sufficient money is garnered to fund all aspects of the project. If the Accord is successfully implemented, large portions of historical habitat once available to Atlantic sturgeon will be opened.

Dissolved oxygen levels reached 0 ppm in the Penobscot River estuary during the summer months in the late 1960s (Hatch 1971). These low DO levels occurred at the freshwater/saltwater interface (salinities 0-10 ppt), which is an important zone for subadult Atlantic sturgeon. Dissolved oxygen levels improved significantly in the late 1970s and 1980s to levels sufficient to support aquatic life coincident with improved point source treatment of municipal and industrial waste, although the substrate is still severely degraded (Squiers 1988), which has decreased the diversity of benthic fauna (USEPA 1994).

The predominant substrate types in the Penobscot River from Winterport to Bucksport, Maine, consist of wood chips, silt/sawdust, and *Mytilus* mussel beds (Metcalf & Eddy 1994). Data on the substrate and benthic communities above Winterport (in the tidal freshwater section) are limited, but it is likely that the mid-estuary and freshwater tidal zones are impacted from organic debris deposits (Metcalf & Eddy 1994). Also, a coal tar deposit has been discovered in the tidal section of the Penobscot River in Bangor, but the impacts on fish and benthic biota are unknown. Notably, the presence of coal tar deposits in the Connecticut River has been linked to tumors and reduced reproductive success (See Connecticut River Section for more information on coal tar, page 43). The former Holtra-Chem facility in Orrington, ME on the Penobscot River was known to use large quantities of mercury in the production of chemicals for subsequent sale to paper mills. A portion of the site remedy includes the removal of mercury hot-spots in the river (MEDEP 2006). Dioxin, likely generated from wastewater discharges from pulp and paper mills and municipal wastewater treatment plants, has been found in fish samples collected in the Penobscot River. Dioxin levels in fish from the Penobscot River have dropped from a high of 7.6 pg/g (parts-per trillion) in 1984 to < 0.1 pg/g in 2004 (MEDEP 2005).

While dredging is somewhat limited in the Penobscot River, eight projects were proposed in 2000 (Fishermen's Voice 2000) and appropriations to dredge the Penobscot Harbor were approved in 2003 (House Bill 107-681, 2003).

In summary, dams on the Penobscot River reduced accessibility of Atlantic sturgeon spawning habitat. Water quality was severely degraded in the Penobscot River for several years but seems to be improving. Further modification for access to historical habitats will likely improve status of Atlantic sturgeon as both spawning and nursery habitats will be reopened.

<u>Estuarial Complex of the Kennebec, Androscoggin, and Sheepscot Rivers – Maine</u>

Historically, the upstream migration of Atlantic sturgeon in the Kennebec River was limited to Waterville, ME, which is the location of Ticonic Falls (rkm 98) (NMFS and USFWS 1998). The Ticonic Falls are located 65 rkm downstream of the fall line (based on reference points provided by Oakley 2005). The construction of Edwards Dam in 1837, downstream of the Ticonic Falls, denied Atlantic sturgeon access to historical habitat in the Kennebec River until 1999 when it was removed. Since its removal, 100% of historic habitat has been opened. Since the removal of the Edwards Dam, shortnose sturgeon have been documented at the Lockwood Dam (rkm 98), indicating that this habitat is being utilized again by a sturgeon species.

In the Androscoggin River, the Brunswick Hydroelectric Dam is located at the head-of-tide at the site of natural falls. Given its limited storage capacity, the Brunswick Dam does not have the capacity to influence river flows and therefore, no minimum flow requirement is necessary. The location of historical spawning grounds on the Androscoggin is unknown, but it is unlikely that Atlantic sturgeon could navigate the natural falls located at Brunswick Dam (NMFS and USFWS 1998). Similarly, within the Sheepscot River Atlantic sturgeon upstream migration is thought to be historically limited to the lower river (rkm 32) just below the head-of-tide dam (rkm 35), which is the first dam on the river; therefore, 100% of the historical habitat (based on river kilometers) is available to Atlantic sturgeon in the Sheepscot.

Historically, the Kennebec River has been dredged along Swan Island, at Gardiner, and from Hallowell to Augusta. The upriver dredging projects are all located in tidal freshwater habitat. No channel maintenance dredging above Bath, where spawning habitat used to be located prior to the removal of Edwards Dam, has been conducted since 1963. In the lower Kennebec River, the ACOE routinely conducts dredging operations to facilitate movement of Navy ships to Bath Iron Works (BIW) in Bath, ME. Maintenance dredging is also conducted by BIW around its docking facilities. Dredging in this region of the river is known to have resulted in sturgeon mortality. In April 2003, a shortnose sturgeon was killed in a closed bucket dredge on the last hour of the last day of dredging (K. Damon-Randall, NOAA, Pers. Comm. 2006). The dredging of the Doubling Point reach of the Kennebec River resulted in the take of five shortnose sturgeon on October 6, 2003, four of which were observed by the endangered species observer. All four sturgeon were removed alive from the hopper and placed in a tub of water. Two of the four fish showed signs of external trauma but showed signs of mobility and respiration. These two fish were released approximately 2.5 nautical miles downriver of the dredge site. One of the fish went straight down and swam away, while the other was last seen trying to swim but was not descending. The other two fish showed signs of more significant trauma and were less active and subsequently died onboard the barge. On October 8, 2003, one shortnose sturgeon was observed in the hopper. This fish was retrieved and placed in an aerated holding tank. The fish was very lively but showed signs of injury. The fish was released at the same release location as the other fish and was last seen swimming and descending to depth. Another two sturgeon (one Atlantic and one shortnose) were found dead on a BIW dock, possibly the result of operations within BIW.

A trawl survey in the Kennebec River near BIW captured subadult Atlantic sturgeon from April 17, 1997, (the start of the sampling project) through November 17, 1997. Neither subadult shortnose nor Atlantic sturgeon were captured from December 1997 through February 1998. However, the researchers did track tagged fish around BIW until ice impeded the researchers' navigation; providing evidence that sturgeon are likely present year-round. Atlantic and shortnose sturgeon were manually tracked in the Bath region of the river in 1998 and 1999. Two Atlantic sturgeon were tracked in October and November 1998, and one was relocated in December 1998 in Merrymeeting Bay (presumably overwintering with shortnose sturgeon). These two fish (along with an additional Atlantic sturgeon) were manually tracked again from April through November 1999. They were observed to move in and out of BIW, up to Swan Island and Chops Point and down to Hospital Point.

State and Federal resource agencies have imposed seasonal restrictions for dredging activities in the Kennebec River. Dredging activities have been restricted to the time period between November 1st and April 1st, which is the time of year when the least number of diadromous fish species would be present, with special emphasis on the Federally-endangered shortnose sturgeon. It is difficult to completely assess the potential impact of dredging on subadult Atlantic sturgeon without knowing if they overwinter in the tidal freshwaters of Merrymeeting Bay or in the estuary below Bath, ME, or leave the river system entirely. There are no Federal navigation projects in the Androscoggin River or Sheepscot rivers.

During the late 1960s and early 1970s, DO levels reached zero ppm in the Kennebec and Androscoggin rivers from the head-of-tide to the mid-estuary during the summer months. The drop in oxygen levels commonly caused fish kills. Dissolved oxygen levels improved significantly in the late 1970s and 1980s, coincident with improved point source treatment of municipal and industrial waste. Although the DO levels were at severely low levels until the late 1970s, a population of shortnose sturgeon managed to persist in the system during this time period. The substrate in the upper freshwater portions of both the Kennebec and Androscoggin rivers was severely degraded by wood chips, sawdust and organic debris until the late 1970s. This accumulation was quickly flushed from the river systems after the cessation of log drives and the construction of water treatment plants.

Dioxin, likely generated from wastewater discharges from pulp and paper mills and municipal wastewater treatment plants, has been found in fish samples collected in the Kennebec and Androscoggin rivers (MEDEP 2005). The levels of dioxin found in fish have declined significantly since sampling was initiated in 1984. The Androscoggin River has had the highest dioxin levels for fish in the state of Maine. Levels of tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) were as high as 20 - 30 pg/g (parts-per-trillion) in fish sampled from the Androscoggin and Kennebec rivers during 1984-1986, before dropping to 0.1 pg/g in 2004 (MEDEP 2005). The discharge of dioxin into Maine river systems has steadily declined since the 1980s. In 1997, the Maine Legislature passed LD 1633, an act to make fish in Maine rivers safe to eat and to reduce color pollution. The LD 1633 established specific enforceable milestones for eliminating dioxin discharges from Maine's kraft mills. The milestones include: non-detectable dibenzo-*p*-dioxin at bleach plants by 1998; non-detectable dibenzofuran at bleach plants by 2000, and compliance with an above/below fish tissue test.

The MEDEP has conducted limited testing for heavy metals, PCBs, and organochlorine pesticides in the tidal waters of the Kennebec River. One shortnose sturgeon collected from the Kennebec River in 2003, as a result of BIW dredging mortality, had total toxicity equivalent concentrations of polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), PCBs, dichlorodiphenyldichloroethylene (DDE), aluminum, cadmium, and copper above adverse effect concentration levels reported in the literature (Environmental Research and Consulting 2003). Mercury levels were above those considered safe for human consumption and also exceeded levels reported in the literature as harmful to wildlife in all Maine rivers and streams tested, including the Kennebec River (Sowles et al. 1997). In 1995, PCB levels in both striped bass and bluefish (*Pomatomus saltatrix*) from the Kennebec River were higher than EPA's screening value but much lower than the EPA's national median level (Sowles et al. 1997). Currently, fish consumption advisories are in place for the Androscoggin and Kennebec rivers (MEBOH 2001). No consumption of lobster tomalley (hepatopancreas) due to organochlorine contamination is also advised.

Despite water quality degradation described above, the Kennebec estuarial complex continues to support sturgeon populations. Improvements in habitat quality from the 1980s to the present will likely facilitate recovery of the Atlantic sturgeon subpopulation in this estuary. The removal of Edwards Dam in the Kennebec River has reopened additional access to historic habitat that will likely improve spawning success and accelerate recovery. However, the impacts of dredging projects to Atlantic sturgeon in the Kennebec are a concern. Though time-of-year restrictions likely minimize these impacts, the continued dredging of potential nursery grounds may impede the recovery of this species.

Merrimack River – New Hampshire and Maine

Hoover (1938) identifies Amoskeag Falls (rkm 116) as the historical limit of Atlantic sturgeon in the Merrimack River. The Essex Dam in Lawrence, MA (rkm 49) is the first upstream barrier, blocking the migration of Atlantic sturgeon to 58% of its historically available habitat. Tidal influence extends to rkm 35; however, in the summer months when river discharge is lowest, the salt wedge extends upriver to rkm 16, resulting in approximately 19 km of tidal freshwater and 9 km of freshwater habitat (Keiffer and Kynard 1993; rkm adjusted to correlate with GIS mapping). Based on a detailed description by Keiffer and Kynard (1993), the accessible portions of the Merrimack seem to be suitable for Atlantic sturgeon spawning and nursery habitat.

There has been little dredging activity in the Merrimack in recent years; the only project noted since 1998 was to deepen several sections of the Merrimack River near the town of Haverhill to open up more commercial opportunities in 2005 (Meehan 2005, Russo 2005).

In 2003, the ACOE and municipalities along the Merrimack River completed a watershed assessment of the Merrimack, which notes the lower basin of the river was highly urbanized with high levels of point and non-point sources of pollution (USACOE 2003). Other threats to anadromous fish in the watershed assessment noted impaired DO and pH levels. In 2005, there were two fish consumption public health advisories listed in the Merrimack River for mercury. A comprehensive analysis of biological data has identified the Merrimack River watershed in southeastern New Hampshire as a mercury hot-spot within the region (Evers et al. 2007). In an earlier fish tissue investigation conducted by USFWS (Major and Carr 1991), the following contaminant levels were measured in seven species of Merrimack River fish: mercury 0.20, lead 0.28, cadmium 0.04, chromium 0.29, copper 0.65, chlordane 0.12, DDT 0.16, dieldrin 0.01, and PCBs 1.38 - all in µg/g (ppm), wet weight. Sturgeon were not among the species examined by USFWS.

New York Bight DPS

Taunton River – Rhode Island and Massachusetts

Historic upstream migration of Atlantic sturgeon in the Taunton River is unknown. Currently, Atlantic sturgeon are restricted to the lower 70 km of the river as a result of the Town River Pond Dam, allowing access to 89% of the river. However, there has been no evidence of Atlantic sturgeon spawning in this river in recent years (last 15 years). Though spawning habitat is likely available, it is unlikely that water quality conditions are favorable for supporting nursery habitat as the river suffers from low DO (< 5 mg/L) and high ammonia-nitrogen levels (> 0.2 mg/L) (Taunton River Journal 2006). Surveys conducted in 1970 for American shad noted DO levels as low as 0.3 mg/L and ammonia-nitrogen levels as high as 1.22 mg/L (Taunton River Journal 2006). Low DO and excessive nutrient levels are still observed in the river, but water quality has slightly improved since 1970 (Taunton River Journal 2006). The river passes through several municipalities from which 23 million gallons of treated wastewater is added to the river daily; the majority of which is produced from a single treatment facility in the city of Brockton. In 2003, the EPA noted the Brockton facility was in violation of its discharge permit on many occasions, when it released water with excessive nutrient loads. There are no fish consumption advisories in effect for the Taunton River.

Connecticut River – Massachusetts and Connecticut

Questions exist regarding the historic range of Atlantic sturgeon in the Connecticut River. In all but low flow years, it is likely that Atlantic sturgeon could pass the Enfield rapids prior to dam construction (Enfield Dam), which occurred in three stages between 1829 and 1881 (Judd 1905).

The falls at South Hadley, MA, which is now the site of the Holyoke Dam, are considered the northern limit of sturgeon in this system; however, there is one historical record of an Atlantic sturgeon sighted as far north as Hadley, MA (24 rkm upstream from South Hadley). Since the Enfield Dam has been breached, an additional 90 km of habitat are available, and depending on the interpretation of historical spawning grounds, Atlantic sturgeon either have 100% (Holyoke Dam, South Hadley, MA), or 86% (Hadley, MA) of their historic habitat available. There is a chance that Atlantic sturgeon can reach habitat above the dam via a fish lift located at the Holyoke Dam, where 81 shortnose sturgeon have been observed to pass over the 21 years of the lift operation (Kynard 1996). However, no Atlantic sturgeon have been observed to pass the dam until just recently. On August 31, 2006, one 152.4 cm TL Atlantic sturgeon was observed in the spill way lift.

Water quality on the Connecticut River has improved dramatically in the last 40 years. It is now swimmable and fishable with some downstream exceptions, although there are still fish consumption advisories in Connecticut (T. Savoy, CTDEP, Pers. Comm. 2006). As of 2005, the Connecticut Department of Public Health had two species of fish listed as non-consumptive due to PCB contamination in the Connecticut River.

In the Connecticut River, coal tar leachate has been suspected of impairing sturgeon reproductive success. Kocan et al. (1993) and Kocan et al. (1996) conducted a laboratory study to investigate the survival of shortnose sturgeon eggs and larvae exposed to polycyclic aromatic hydrocarbons (PAHs), a by-product of coal distillation. Only 5% of sturgeon embryos and larvae survived after 18 days of exposure to Connecticut River coal tar (i.e., PAHs), demonstrating that contaminated sediment is toxic to shortnose sturgeon embryos and larvae under laboratory exposure conditions. Also, in 1988, it was observed that one out of every four female shortnose sturgeon which underwent surgical procedures for egg removal (N = 4) could not be spawned as a result of the presence of a tumor, thought to be related to coal tar or other industrial pollution present (B. Kynard, CAFL, Pers. Comm. 2006). Since the discovery of the coal tar deposits and impacts on biota, a significant amount of the coal tar has been removed. A more recent review of the contaminants within the Connecticut River revealed that total mercury and dioxin-like (coplanar) PCBs posed a risk to recreational and subsistence fishers, as well as the fish-eating mammals and birds, suggesting that contaminant levels were relatively high (Hellyer 2006).

Dredging is required about every six to seven years to maintain a Federal Navigation Project in the lower river from Hartford, CT to the mouth of the river. Seasonal restrictions have been implemented in the past to protect shad and Atlantic salmon (W. Neidermyer, USFWS, Pers. Comm. 1998); seasonal restrictions to protect shortnose sturgeon in this area likely benefit Atlantic sturgeon.

<u>Hudson River – New York</u>

The first impediment to migrating Atlantic sturgeon on the Hudson River is the Federal Dam, located at Troy (rkm 280, adjusted for GIS mapping). This dam location is upstream of Catskill (rkm 204), which is the northern extent of Atlantic sturgeon spawning and nursery habitat (Kahnle et al. 1998). The commercial shipping channel is maintained at a depth of 9.75 m (at mean low water) for nearly the entire length of the river to the Port of Albany; however, the section between Haverstraw Bay and Catskill is naturally deep and does not require dredging (D. Mann-Klager, USFWS, Pers. Comm. 1998). Dredge and fill operations have altered the river north of Catskill, but this is upstream from spawning and nursery habitat. There are infrequent dredging operations occurring south of Catskill for maintenance dredging and providing access to the channel (A. Kahnle, NYSDEC, Pers. Comm. 2006). Presently, all historic habitat in the Hudson River, from Haverstraw to Catskill, is accessible to Atlantic sturgeon as spawning and nursery habitat, although the quality or functionality of this habitat is unknown. Numerous studies from the early 1990s to the present have captured gravid adults and numerous year classes of juveniles, which indicates that at least some of the habitat is of functional quality (J. Mohler, USFWS, Pers. Comm. 2006). However, as noted above in section 3.1.1 (Dams and Tidal Turbines), potential foraging and nursery habitat of Atlantic sturgeon could be affected by a tidal turbine power project owned by Verdant Power that is currently testing two tidal turbines near Roosevelt Island, with plans to expand the project to 300 tidal turbines (Angelo 2005, CBS News 2006).

Population expansion in the Hudson River valley increased sewage output to the river, causing habitat impacts. Sewage decomposition produced several areas of inadequate oxygen (oxygen blocks) in the river. Best known was the block present in the Albany pool, located north of the Atlantic sturgeon's spawning and nursery habitat. Other blocks occurred at certain times in the southern stretch of river from the Tappan Zee Bridge south through New York Harbor (Brosnan and O'Shea 1997). Improvements to sewage treatment eliminated the problem near Albany by the late 1970s and the problem near New York City by the middle to late 1980s.

Data from the Saint Lawrence and Hudson rivers reported by Spagnoli and Skinner (1977), showed that average levels of PCBs in all sturgeon tissue sampled were higher than the FDA guidelines (> 2 µg/g; ppm) for edible portions of fish ranging from 6.72 ppm in the Hudson River to 11.89 ppm in the Saint Lawrence River. Belton et al. (1982) reported mean PCB levels in Atlantic sturgeon from the Hudson-Raritan estuary at 2.35 µg/g. In the Hudson River, there was a decline in PCB contamination from 1977-1988 where concentrations ranged from 0.15 – 1.7 µg/g in the muscle tissue, although the average concentration in the brain was 7.92 µg/g (Sloan 1987). Sloan and Armstrong (1988) observed that PCB concentrations were inversely proportional to body size of fish with Atlantic sturgeon PCB levels detected at less than 5 µg/g (Sloan and Armstrong 1988). Overall, PCB concentrations have declined to levels acceptable to EPA guidelines in recent years, but continual monitoring is needed to document the fate of PCB contamination in the river (Sloan et al. 2005). However, fish consumption advisories are still in place that advise against the consumption or reduced consumption of all species captured in the Hudson River between Troy Dam and Catskill due to PCB contamination. Other portions of the river include fish consumption advisories for three species due to mercury, PCBs, and cadmium contamination.

<u>Delaware River – New Jersey, Delaware, Pennsylvania</u>

The portion of the Delaware River and Bay that is available to Atlantic sturgeon extends from the Delaware Bay to the fall line at Trenton, NJ; a distance of 140 rkm. There are no dams within this reach of the river. Thus, 100% of the habitat is accessible, although habitat suitability is unknown due to river augmentation and water quality issues. Fox (2006) reviewed historical records that suggest that Atlantic sturgeon spawned in the Delaware River in two areas: 1) near Pea Patch Island and 2) near Pedrickston, NJ below Philadelphia, PA. However, Pea Patch Island habitat may be unsuitable spawning habitat depending on water flows as salt water often encroaches this area throughout the year, possibly due to hydrodynamic alterations to the river via past dredging operations and water sharing agreements with upstream municipalities (DiLorenzo et al. 1993, G. Murphy, DFW, Pers. Comm. 2006). However, these water diversion dams are managed to provide suitable habitat for trout and are so far upstream that they are not expected to affect sturgeon spawning. A flow analysis has not been conducted because the current location of Atlantic sturgeon spawning is unknown (C. Shirey, DNREC, Pers. Comm. 2005). The navigation channel undergoes maintenance dredging from the mouth of Delaware Bay to just north of Trenton. The Delaware River Fish and Wildlife Management Cooperative has imposed "no work" windows to reduce impacts from dredging on diadromous species. In addition, NMFS has consulted on the impacts of both dredging and blasting projects and has recommended restrictions for shortnose sturgeon, which may also benefit Atlantic sturgeon.

In 2006, Crown Landing, LLC, was approved by the Federal Energy Regulatory Commission (FERC) to construct and operate a Liquefied Natural Gas (LNG) import terminal on the Delaware River (RKM 126) near Logan, New Jersey. This location is suspected to be one of the historical spawning grounds of Atlantic sturgeon (Fox 2006); thus, it is suspected that the LNG terminal will likely threaten the viability of this subpopulation. However, site surveys conducted by the LNG researchers from May 2005 to April 2006, only documented 4 juvenile and 1 adult in the project area, suggesting the area is not utilized currently as a spawning ground.[23] The river is approximately 1.2 miles wide at the terminal location, and the facilities at the terminal will consist of a LNG pier (2,000 ft long) and berth in the Delaware River. The construction of the LNG terminal requires the hydraulic dredging of 1.24 million m^3 in the first year of construction followed by maintenance dredging of 67-97,000 m^3/year. Dredging spoil will be deposited in an upland disposal site, and dredging will be limited to the months of August through December. Crown Landing estimates that LNG shipments will occur approximately once every two to three days and that the Project will receive a maximum of 150 shipments per year. To maintain the stability of the LNG carriers, the carriers will take on ballast water from the Delaware River as they offload LNG. Approximately eight million gallons of water will be pumped into the LNG carriers over a 10-hour period to reach a minimum stability while at the berth, and an additional 5 to 11 million gallons of ballast water will be taken on after undocking just downstream of the berth area. Semi-daily ballast water withdrawals have the potential to entrain or impinge Atlantic sturgeon larvae, but it unknown if this area still supports spawning.

Until recently, poor water quality has been a significant factor for fish utilizing the upper tidal portion of the estuary. Inputs of chemicals and untreated sewage to the river and estuary have been reported for at least 200 years. Coal silt in the upper Delaware River was one of the major pollution problems from 1820-1940. Borodin (1925) and Horn (1957) suggest that pollution from oil and dyes was a factor in the decline of Atlantic sturgeon in the estuary. As late as the early 1970s, levels of DO between Wilmington and Philadelphia routinely dropped below levels that could support aquatic life from late spring through early fall. A portion of the Roebling-Trenton stretch of the river is an EPA Superfund site due to the presence of the Roebling Steel

[23] LNG contracted researchers did not report the type of gear used for sampling, frequency, or effort of sampling; thus this survey does not provide conclusive evidence that spawning does not occur in this area.

plant. The EPA has been considering ways to remove or cap the contamination in the river that resulted from the plant operations.

Since 1990, DO levels have remained above minimum state standards throughout the entire year (R. Green, Delaware DNREC, Pers. Comm. 1998). Other anadromous fish stocks, such as striped bass, American shad (*Alosa sapidissima*), and river herring (*A. pseudoharengus and aestivalis*) are utilizing the mainstem Delaware River for spawning and nursery habitats. The Delaware River striped bass stock has recently been defined as restored, is a significant contributor to the coastal stock, and supports significant in-river recreational and commercial fisheries since water quality has been restored. The Delaware River shortnose sturgeon population has also shown signs of recovery with population levels having increased to over 8,000 fish. Shortnose sturgeon have also been documented well downstream of Philadelphia, which was the downstream limit for this species over the last few decades due to degraded water quality conditions and into Delaware Bay. The restoration of other anadromous species suggests that environmental conditions are now adequate to support growth of the Atlantic sturgeon subpopulation if the fish are allowed to reach maturity and spawn (C. Shirey, DNREC, Pers. Comm. 2005). However, levels of PCBs, dioxins, mercury, and chlorinated pesticides are still elevated, and consumption advisories have been listed for numerous resident and migratory species of fish (Ashley et al. 2004). Two shortnose sturgeon collected during a 2002 mark/recapture study in the Delaware River had elevated levels of cadmium, copper, DDE, PCDD/Fs, and PCBs in gonad or liver tissue (Environmental Research and Consulting 2002). Though dredging is controlled by seasonal restrictions, the continual dredging of spawning and nursery grounds will likely reduce habitat quality through the redistribution of contaminants and further destruction of habitat; thereby, potentially subjecting sturgeon to degraded habitat conditions for longer periods of time.

Chesapeake Bay DPS

Chesapeake Bay (James, York, Rappahannock, Potomac, Susquehanna, and Nanticoke Rivers) – Maryland, Virginia, Pennsylvania

Due to their upriver locations, most dams in the Chesapeake Bay watershed have large freshwater tailways (unobstructed habitat downstream of the dam). Four dams constructed from 1904 – 1932 in the Susquehanna River have impeded diadromous fish migration, although none of these dams are suspected to have impeded Atlantic sturgeon spawning habitat as the lowermost dam (Conowingo) is suspected to be located above the historic spawning grounds (Steve Minkkinen, USFWS, Pers. Comm. 2006). Only two shortnose sturgeon and no Atlantic sturgeon have been noted to pass the fish lift operated at the Conowingo Dam during its years of operation; 1965 – 1966 and 1972 – present.

The Embrey Dam (built in 1910), located above the fall line, on the Rappahannock River may have potentially blocked the upstream migration of Atlantic sturgeon; however, this dam was breached (by explosives) in 2004. Constructed in 1823, the Bosher Dam on the James River impeded upstream diadromous fish migration until a vertical slot fish passage way was installed in 1999.[24] No Atlantic sturgeon have been observed to pass through this fishway (Bushnoe et al. 2005).

During the past 100 years, increased rates of urbanization along with residential and industrial development along the banks of sub-estuaries have continued to contribute to historical trends in sedimentation, deforestation, and pollution (Cooper and Lipton 1994). The period of Atlantic sturgeon population decline and low abundance in the Chesapeake Bay corresponds to a period of poor water quality caused by increased nutrient loading and increased frequency of hypoxia (Officer et al. 1984, Mackiernan 1987, Kemp et al. 1992, Cooper and Brush 1993). It is plausible that overharvesting of Atlantic sturgeon in the 1890s led to the dramatic decline in the fishery, and poor water quality since then has not been conducive to recovery. Secor and Gunderson (1998) showed that juvenile Atlantic sturgeon were less tolerant of summer-time hypoxia than juveniles of other estuarine species. Over the last 50 years, high nutrient inputs have contributed to high spatial and temporal incidence of summer-time hypoxia and anoxia in bottom waters (Taft 1980, Officer et al. 1984, Malone et al. 1993, Boesch et al. 2001). During spring and summer algal blooms, the Chesapeake supports extremely high primary production rates. Blooms accelerate bottom microbial respiration, which results in oxygen depletion in benthic waters. The Bay is especially vulnerable to the effects of nutrients due to its large surface area, volume ratio, relatively low exchange rates, and strong vertical stratification during spring and summer months. Niklitschek and Secor (2005) modeled suitable habitat availability for Atlantic sturgeon in the Chesapeake Bay and results indicated that the system was squeezed or stressed in the summer months as hypoxic conditions consumed 0-35% of the Bay from 1993-2002. Similar trends in low DO have been observed in the lower portions of the York and Potomac rivers (Chris Hager, VIMS, Pers. Comm. 2005).

Since 1984, the Chesapeake Bay Program and its member states (PA, MD, DC, and VA) have instituted programs related to nutrient abatement (Cooper and Lipton 1994, Boesch et al. 2001). Within Chesapeake Bay tributaries, improving conditions for macrobenthos have been observed, perhaps as a result of nutrient abatement programs (Dauer 1995). Furthermore, the survival and growth rates of hatchery-reared Atlantic sturgeon stocked in the Nanticoke River in 1996 provide some evidence of the suitability of nursery habitat. Fish consumption advisories, however, are in effect for at least 10 species in the Chesapeake Bay due to PCB, mercury, and kepone contamination.

However, one of the limiting habitat requirements for Chesapeake Bay sturgeons may be the availability of clean, hard substrate for attachment of demersal, adhesive eggs (Bushnoe et al. 2005, Chris Hager, VIMS, Pers. Comm. 2005). Rubble, cobble, and gravel size rock, as well as shell, forest litter, and submerged vegetation provide substrate for egg attachment. In the Chesapeake Bay's watershed, 18th and 19th century agricultural clear cutting (Miller 1986) contributed large sediment loads that presumably have buried or reduced most sturgeon spawning habitats (reviewed in Bushnoe et al. 2005).

The most significant impacts to Atlantic sturgeon spawning habitat likely occurred in 1843 and 1854 when the James River, which likely supported the largest subpopulation in the Chesapeake

[24] Originally, the James River had two additional impediments downstream of Bosher Dam: Browns Island Dam and Williams Island Dam were breached and notched in 1989 and 1993, respectively.

Bay based on commercial landings, had granite outcropping consisting of large and small boulders (called Rockett's) removed and dredged to improve ship navigation (Holton and Walsh 1995, Bushnoe et al. 2005). Similarly, Drewry's Island Channel had rock removed to improve navigation in 1878 (Holton and Walsh 1995). These granite outcroppings and boulder matrices are the types of habitats that are believed to be ideal spawning habitats for Atlantic sturgeon (Bushnoe et al. 2005). Existing spawning habitat in the Potomac River seems to be intact, although water quality is a major concern in this system.

No dredging is currently conducted within potential Atlantic sturgeon spawning areas in the Rappahannock, Potomac, York, or Nanticoke rivers. There are projects underway to deepen and widen the terminal near Richmond on the James River that may have a negative impact on Atlantic sturgeon spawning in that river. In addition, the James River is dredged on almost an annual basis to allow commercial ocean-going vessels to reach the Richmond terminal (Chris Hager, VIMS, Pers. Comm. 2005). Since 1998, six new permits have been issued for dredging within the James River, and an additional 24 maintenance projects have been approved (L. Gillingham, VMRC, Pers. Comm. 2005). There are dredging moratoriums in place for the Commonwealth of Virginia during the anadromous spawning season, although the ACOE is negotiating to dredge during this moratorium in areas not affecting anadromous fish (Chris Hager, VIMS, Pers. Comm. 2005; Albert Bell, USFWS, Pers. Comm. 2006).

There is evidence, however, that environmental conditions within the entire Chesapeake Bay ecosystem have not degraded to the point at which they can no longer support sturgeon. One year old hatchery sturgeon released in the Nanticoke River in 1996 survived and grew at favorable rates, indicating that the Bay is still able to support juvenile sturgeon (Secor et al. 2000). Also, over 1,100 wild sturgeon have been observed in the Maryland Reward Program during the last 11 years, indicating that sturgeon still use the Bay as an opportunistic place to forage. Overall, the SRT concluded that water quality and habitat degradation are threats to the viability and recovery of Atlantic sturgeon and that mitigation of these stressors would likely improve or accelerate the recovery of this species within the Bay.

Carolina DPS

Albemarle Sound/Roanoke River – North Carolina

The construction of Roanoke Rapids Dam in 1955 on the Roanoke River blocked access to diadromous fish above rkm 207. It is likely that Atlantic sturgeon ascended the Roanoke Rapids, based on locations above the rapids with sturgeon-related names and the capture of sturgeon in fish slides located at Roanoke Rapids as they were coming downstream in the 1800s (reviewed in Armstrong and Hightower 2002). Two additional dams, Gaston and Kerr, are immediately above Roanoke Rapids. It is uncertain how spawning has been affected by these dams as age-0 and 1 juveniles still occur in the Albemarle Sound portion of the system, and therefore, spawning must be continuing on the Roanoke River below the dams or in other Albemarle Sound tributaries. If spawning is limited to the fall line, 100% of Atlantic sturgeon spawning habitat is available as the Roanoke Rapids Dam is located at or near the fall line. If spawning historically occurred above the fall line, experts expect 45 rkm (18%) of habitat or more could be impeded (NMFS 2006).

A fishway prescription for the Roanoke Rapids and Gaston dams was filed in 2006 as a result of Dominion Generation applying for a "major new hydropower license" (NMFS 2006). The fishway prescription will allow for the passage of American shad (*Alosa sapidissima*), river herring (*A. psuedoharengus and A. aestivalis*), and American eel (*Anguilla rostrata*): phase 1 initial truck and trapping; phase 2 permanent truck and trapping; and phase 3 full capacity volitional passage. Atlantic sturgeon were not a management objective in this prescription due to their low population size and lack of safe and effective downstream passage mechanisms for post-spawn adults. However, NMFS reserved its authority to prescribe fishways or other modifications as appropriate in the future for both Atlantic and shortnose sturgeon in the event these circumstances change (NMFS 2006).

Flow, water temperature and oxygen levels in the Roanoke River are also affected by both the Kerr Dam, and the Gaston Dam/Roanoke Rapids facilities that both engage in peaking operations. NMFS, USFWS and other Federal and state fishery management agencies are currently working with the ACOE – Wilmington District, and Dominion Power (operators of the dams) to address environmental concerns through modification of dam operations. Riverine water flow has already been modified during the striped bas spawning season to simulate natural flow patterns; these modifications undoubtedly benefit Atlantic sturgeon. Regardless of the temporary modifications, lower water temperatures resulting from the hypolimnetic discharge from Kerr Dam have caused temporal shifts in the spawning peaks for both American shad and striped bass and likely have had the same impact for other diadromous species, including Atlantic sturgeon.

The ACOE conducts extensive annual dredging operations to maintain navigational access through Oregon Inlet, which is the main corridor into Albemarle Sound. However, dredging in the Sound itself and its major tributaries is relatively minor with the exception of the Atlantic Intercoastal Waterway (AICW). The Roanoke River has not been dredged since the 1940s. The USFWS, NMFS, ACOE, NC Division of Marine Fisheries, and NC Wildlife Resources Commission, all support the in-water moratorium coordinated by the NC Division of Coastal Management. Under this moratorium, work is restricted in certain coastal waters during the spring spawning season (February 1 through June 30) to protect diadromous fishes and also provides nursery ground dredging moratoriums from April 1 through September 30.

Water quality in the Albemarle Sound ecosystem and in its major tributaries is relatively good, due in large part to the fact that most of the watershed is rural and/or forested. Paper mill operations on the Roanoke River at Weldon and Plymouth have caused some localized areas of contamination. While the localized effect of the contaminants within the system to Atlantic sturgeon is unknown, as no tissue samples have been collected or analyzed, fish consumption advisories are in effect for two fish species in the Roanoke River based on dioxin and a general mercury advisory. Fish kills do occur occasionally in the Roanoke River, when high flows from Kerr Dam during the summer are coupled with high ambient temperatures and an influx of swamp water with low DO, creating a large, hypoxic plume within the river. Such events would affect potential Atlantic sturgeon nursery habitat in the lower river.

<u>Pamlico Sound and Tributaries (Tar and Neuse Rivers) – North Carolina</u>

Both the Tar-Pamlico and Neuse rivers, the two major tributaries to Pamlico Sound, are dammed. One hundred percent of the riverine habitat is available to Atlantic sturgeon in the Tar-Pamlico, as the low-head Rocky Mount Dam (rkm 199) is located on the fall line. It is likely that Atlantic sturgeon historically utilized habitat in the Neuse River up to the falls at rkm 378 where a dam (Falls Dam) is now located, although this site is above the fall line. Access to historic habitat was blocked by Quaker Neck Dam at Goldsboro and Milburnie Dam (rkm 349) in the vicinity of Raleigh, NC. Quaker Neck Dam was removed in 1998, and access was restored up to Milburnie Dam (rkm 349). However, if the fall line is an indicator of the upper limit of spawning migration then the Milburnie Dam is above the fall line, and 100% of historic Atlantic sturgeon spawning habitat may be available. The flow regime of Milburnie Dam has been temporarily increased to simulate natural conditions on the Neuse River, but these flow regimes are not permanently established and could be changed in the future.

The ACOE conducts navigational dredging operations in the AICW through Pamlico Sound and up major tributaries to facilitate boating access. All major inlets to Pamlico Sound, including Hatteras, Ocracoke, and Drum, are also dredged. The degree to which dredging operations affect the species in Pamlico Sound and tributaries is unknown; however, all dredging permits in North Carolina incorporate seasonal restrictions for the protection of diadromous species.

Water quality in the Pamlico system, especially in the lower Neuse River, is of serious concern (Paerl et al. 1998, Qian et al. 2000, Glasgow et al. 2001). The lower Neuse River has been the site of many fish kills and much concern in recent years because of outbreaks of a toxic dinoflagellate, *Pfiesteria piscicida*; however, this disease has not been detected in Atlantic sturgeon, and no sturgeon carcasses were found even during severe outbreaks.[25] The entire basin has been designated as nutrient-sensitive, and additional regulatory controls are being implemented to improve water quality. Both the Neuse and Pamlico portions of the estuary have been subject to seasonal episodes of anoxia that significantly affect the quality of Atlantic sturgeon nursery habitat. Concentrated animal feeding operations (CAFOs) are attributed to at least some portion of the current water quality problems in the Pamlico watershed (Mallin and Cahoon 2003). Farms that produce hogs, turkeys, and chickens have proliferated throughout the coastal portion of the basin in the last decade or so, with increases in both aquatic and atmospheric deposition of nitrogenous waste products. North Carolina passed a moratorium in 1997 limiting additional hog operations and is conducting a study of measures to address the problem; this bill was renewed in 1999 and 2003 (a four year cycle). There are three fish consumption advisories (carp, catfish, and largemouth bass) in effect for the Pamlico Sound and its tributaries due to mercury and PCB contamination.

Cape Fear River – North Carolina

The Cape Fear River has three locks and dams between Wilmington and Fayetteville that are located below the fall line; two additional dams, Buckhorn and B. Everette Jordan, are located above the fall line. Atlantic sturgeon movement is blocked at the first lock and dam located in Riegelwood, NC (rkm 90). Other pelagic species can pass over the three locks and dams during

[25] Atlantic and shortnose sturgeon are rarely found in this system and may be the reason no observations of *Pfiesteria piscicida* have occurred.

high water or may be locked around the low elevation dam; observations at Buckhorn Dam (rkm 292) confirm passage, although it is low. The benthic Atlantic and shortnose sturgeon are not known to pass over these three locks/dams. Over the last 18 years, there have only been two sightings of large adult Atlantic sturgeon (> 181 kg or 400 lbs) at the base of Lock and Dam #1, observed jumping just downstream (R. Hall, ACOE Lock Master, Pers. Comm. 2005). No Atlantic or shortnose sturgeon have been captured upstream of Lock and Dam #1 despite extensive sampling efforts (Moser et al 1998). Although locks are operated during the spring in an effort to provide upstream passage, sturgeon are not known to utilize the locks. Flows on the river are regulated upstream at the B. Everette Jordan Dam; however, the extent to which the flow departs from the historical hydrography has not been evaluated. Current flow regimes do not seem to have peaking hydrographs usually associated with hydropower dams. Historical spawning locations are unknown in the Cape Fear River; therefore, it is assumed that the fall line is the upper limit of spawning habitat. Using the fall line as guide, only 33% of the historical habitat is available to Atlantic sturgeon (96 km of 292 km). In some years, the salt water interface reaches the first lock and dam; therefore, spawning adults in the Cape Fear River, either do not spawn in such years or spawn in the major tributaries of the Cape Fear River(i.e., Black River or Northeast Cape Fear rivers) that are not obstructed by dams.

Dredging operations (including the blasting of rock) on the lower Cape Fear River, Brunswick River and port facilities at the U.S. Army's Sunny Point Military Ocean Terminal and Port of Wilmington are extensive. To protect diadromous fish, restrictions are placed on dredging to avoid sensitive seasons and locations, such as potential spawning habitat (February 1st through June 30th) and suspected nursery grounds (April 1st – September 30th). Dredging activities above Lock and Dam #1 in the Cape Fear River are less common and unlikely to impact Atlantic sturgeon.

Water quality in the Cape Fear River is less than desirable for aquatic life, due largely to industrial development and use, including the Port of Wilmington and numerous industrial point-source discharges. Development of CAFOs in the coastal portion of the Cape Fear River basin has been especially heavy (most concentrated operations of CAFOs occur in the Cape Fear River Drainage within NC) and contributes to both atmospheric and aquatic inputs of nitrogenous contamination possibly causing DO levels to regularly fall below the 5 mg/L state standard (Mallin and Cahoon 2003). In recent years, there have been fish kills observed, usually as a result of blackwater swamps (with low DO) being flushed after heavy rainfall. Fish advisories also exist for two species within the river drainage for mercury contamination.

Winyah Bay (Waccamaw, Great Pee Dee, Black and Sampit Rivers) – South Carolina

Only the Great Pee Dee Rive is dammed in this river system; Blewett Falls Dam is located at or near the fall line (305 km upstream). It is unknown how much of the river was used by Atlantic sturgeon prior to dam construction, but a historic fishery for sturgeon near Winston Salem has been noted and suggests that some portion of the historical spawning habitat is impeded. Access to historic spawning areas seems to be adequate in the Waccamaw, Black and Sampit rivers as these rivers are unimpeded, though habitat quality is unknown.

Winyah Bay and its shipping channel, which includes the salinity regime commonly inhabited by age 1-4 juveniles, are dredged with some regularity for navigation into the Port of Georgetown. In the Bay, a seasonal restriction to protect sea turtles restricts dredging during the summer months.

Industrialization, including paper and steel mills, in the upper portion (Sampit River arm) of Winyah Bay has impacted water quality. Riverine sediment samples contain high levels of various toxins including dioxins (NMFS and USFWS 1998). The effects of these contaminants are unknown, but there are fish consumption advisories for three fish species in the system due to mercury contamination.

Santee-Cooper – South Carolina

The Santee Basin originates in the Blue Ridge Mountains of North and South Carolina and includes a total of 182 separate rivers or named river segments. The Santee Basin is second only to the Susquehanna on the U.S. East Coast in terms of drainage area and volume of flow (Hughes 1994). Major watercourses within the Basin include the Broad, Saluda, Catawba-Wateree, Congaree, and the Santee rivers. The Broad and Saluda rivers merge to form the Congaree River, and the Wateree and Congaree rivers merge to form the Santee River. Based on the historical flow record (1908-1941) the mean annual Santee River inflow was 18,522 cfs, varying from a 7-day low flow average of 6,572 cfs to over 200,000 cfs. The present Santee-Cooper Project diverts a weekly average flow of 4,500 cfs through the Jefferies Hydroelectric Station to the Cooper River, with the remainder of the flow released at the Santee Hydroelectric Station and Spillway, and the ACOE St. Stephen Hydroelectric Project.

The Santee-Cooper Hydroelectric Project, which is owned by the South Carolina Public Service Authority (SCPSA), is located in the coastal plain of the Santee Basin on the Santee and Cooper rivers, South Carolina. The project was constructed in 1938 – 1942 and includes Lake Marion, which is impounded by the Santee Dam (Wilson Dam) on the Santee River at river mile (rm) 87, and Lake Moultrie, which is impounded by the Pinopolis Dam on the Cooper River at rm 48. The project structures consist of the Wilson Dam, Pinopolis Dam, Diversion Canal, Santee Spillway Hydroelectric Station, and Jefferies Hydroelectric Station. The ACOE Re-diversion Project is located on the Re-diversion Canal. It consists of the St. Stephen Hydroelectric Project and St. Stephen fish lift. The SCPSA operates both the Jefferies Hydroelectric Station and the ACOE St. Stephen station.

Although there is no license requirement, the navigation lock at Pinopolis Dam has been operated since the 1950s. This early passage began as a cooperative effort with South Carolina Wildlife Resources Department (now South Carolina Department of Natural Resources), the Fish and Wildlife Service's Bureau of Sport Fisheries and Wildlife, and SCPSA. The purpose of lock passage operations was originally to pass river herring as forage fish for the nationally recognized landlocked striped bass population discovered in the Santee Cooper Lakes in the early 1950s (Stevens 1957). Prior to the Santee Re-diversion Project, annual river herring passage estimates ranged as high as 10 million (Cooke and Leach 2003). It is likely that other diadromous species including American shad, striped bass, sturgeon, and American eel (*Anguilla rostrata*) were passed during those years; however, the hydroacoustic counting methods did not differentiate among species. After re-diversion of the Santee River in 1985-87 and construction of the St. Stephen Powerhouse and Fishway on the Re-diversion Canal, the Pinopolis Lock passage estimates declined substantially but remain important to the overall Santee Basin passage objectives.

The Santee Dam is located on a bypassed reach of the Santee River 37 miles upstream from the confluence of the Re-diversion Canal. Flows exceeding 600 cfs occur only during sporadic unregulated spill events at the Santee Dam Spillway, most frequently during March. Upstream migrations of diadromous fish, including American shad, blueback herring, American eel, and shortnose sturgeon, are documented during the winter and spring spawning season within the bypassed reach, and their upstream migrations are blocked by the dam. Upstream movements of diadromous fish in the bypassed reach are substantial during spill events or during lower flow years when the St. Stephen Hydroelectric Facility is not operating during the spawning runs (Cooke and Leach 2003).

Subsequent to completion of the Santee-Cooper Project, it was discovered that diversion of the Santee River flow into the Cooper River resulted in increased shoaling within Charleston Harbor, necessitating expensive and more frequent dredging. To alleviate the frequency of dredging within the Charleston Harbor, the Cooper River Re-diversion Project was constructed in 1980-1985 by the ACOE to return Santee River flow to the original basin. A re-diversion canal was constructed to divert flow from Lake Moultrie to the Santee River, which is 37 miles downstream from the Santee Diversion Dam. A new hydroelectric project dam, the St. Stephen Hydropower Project, was constructed on the re-diversion canal to replace lost hydropower generation capacity at the Jefferies Station at Pinopolis Dam. Because of sport fishing stakeholder and fishery resource agency concerns over loss of the Pinopolis Lock herring passage after re-diversion of the river flow, a new fishway was constructed at the St. Stephen Dam.

The St. Stephen Hydroelectric Project and Fish Lift were constructed by the ACOE as a part of the Cooper River Re-diversion Project. The Fish Lift is operated by the SCDNR under an agreement with the ACOE. It was primarily constructed to pass blueback herring into Lake Moultrie as forage fish for the stocked reservoir striped bass fishery and to mitigate for the shift in blueback herring runs from the Cooper River to the Santee River. The fish lift currently passes American shad, blueback herring, striped bass, and other non-diadromous fishes; however, the lift primarily attracts upper water column species and is not designed to attract or pass benthic-oriented shortnose or Atlantic sturgeon. Modifications to the fish lift will be necessary to effectively pass all Basin target species (Cooke and Leach 2003, 2005).

Although it is not known to what extent the Santee-Cooper River system was used by Atlantic sturgeon, it is assumed that the fall zone acts as the upper most limit to spawning habitat. Using the fall line as the upper region of habitat, it is estimated that only 41% of the historic habitat is available to Atlantic sturgeon today (the dam is located 211 km upstream from the mouth, the fall line is 516 km upstream from the mouth based on GIS tools). Although a fish lift operates at the dam during the spring, observations of sturgeons in the lift are extremely rare, and there is no record of an adult Atlantic sturgeon being lifted, although three dead Atlantic sturgeon were observed upstream of the lift in Lake Marion, above Wilson Dam in 1995-1997. There is no dredging in the Santee River that would have the potential to affect Atlantic sturgeon habitat. The Cooper River flows into Charleston Harbor, which is one of the busiest ports on the Atlantic Coast and is dredged regularly. The river channel is maintained by dredging all the way to the Pinopolis Dam. No seasonal restrictions are placed on dredging in the Cooper River; however, a restriction is placed on dredging conducted offshore of Charleston Harbor in the shipping channel during the summer months to protect sea turtles. Subadult Atlantic sturgeon form winter aggregations in the shipping channel outside Charleston Harbor. Although water quality is generally good in the harbor and river, sediments in some areas are still contaminated due to previous industrial operations and military facilities. Fish consumption advisories are in effect for three species in this river complex due to mercury contamination.

South Atlantic DPS

ACE Basin (Ashepoo, Combahee, Edisto) – South Carolina

The Ashepoo, Combahee, and Edisto rivers, and St. Helena Sound into which they flow, are among the least developed in the region with generally very good water quality. The area near their confluence has been designated the ACE Basin National Estuarine Research Reserve. There are only two dams on the Ashepoo River, the Cocker Pond and Bennetts Pond dams, which are located near the fall zone and impede nine kilometers of habitat from the dam to the fall line. All other ACE basin streams are not impeded by dams. Subpopulations in this system have received little impact from dredging, dams, or diminished water quality (NMFS and FWS 1998). There are currently three fish consumption advisories present within the ACE Basin for mercury contamination.

Savannah River – South Carolina and Georgia

The New Savannah Bluff Lock and Dam (NSBL&D) at the city of Augusta (rkm 299), is located just a few kilometers below impassible rapids, denying Atlantic sturgeon access to 7% of its historically available habitat (NMFS and USFWS 1998). The NSBL&D has five vertical spillway gates that could allow passage for anadromous fish during the normal spawning season flows in the Savannah River. Under normal spring flows when the gates are open, the headpond and tailwater elevations are often at the same level, and fish may pass upstream over the submerged weirs at each gate opening. Limited passage studies at the NSBL&D have documented significant passage by American shad, river herring, and striped bass for many years. Additionally, a recent study indicates significant numbers of shortnose sturgeon are present at the NSBL&D during the late winter-spring spawning period. While sturgeon passage has not yet been confirmed at the NSBL&D, the limited scope of passage studies conducted to date cannot exclude the possibility of passage by sturgeon. Recent Congressional Acts (the Water Resources Development Act of 2000, P.L. 106-541, and the Omnibus Appropriations Act 2001, P.L. 106-554) have authorized the Savannah District, United States Corps of Engineers (SDCOE) to repair and rehabilitate the NSBL&D to transfer the project to the City of North Augusta and Aiken County, South Carolina. The SDCOE commissioned a study to investigate terms for transfer of ownership of the NSBL&D. The study identified and investigated fish passage configurations that would readily pass many species, including sturgeon. It is highly likely that fish passage will be required as a term and condition when ownership of the NSBL&D

is transferred (S. Bolden, NMFS, Pers. Comm. 2006). Therefore, while the NSBL&D currently may hinder sturgeon passage to the Augusta Canal Hydropower project location, sturgeon passage cannot be discounted. Further, it is probable that once the fishway is installed at the NSBL&D both shortnose and Atlantic sturgeon will have free upstream passage to the Augusta Dam. Also, NMFS believes that vitally important spawning habitat is available in the Savannah River upriver from the NSBL&D and also the Augusta Dam, and the species will likely expand its geographic range to reoccupy these formerly available habitats.

Maintenance dredging, occurring primarily in nursery habitat, is frequent, and substantial channel deepening took place in 1994. A seasonal restriction on dredging operations has been imposed from March 16th – May 31st to protect striped bass in this river system. This spring closure likely benefits Atlantic sturgeon as well (M. Collins, SCDNR, Pers. Comm. 1998).

The Georgia Ports Authority is seeking to expand their port facility on the Savannah River. Within the 1999 Water Resources Act, Congress authorized the deepening of the Savannah Navigation Channel from the current depth of –42 ft to –48 feet mean low water. Hydrodynamic and water quality models have been developed to predict changes in water quality across depth and throughout the channel. Species-specific variables (season, DO, temperature, river flow, depth and slope) have been run through the model to evaluate impacts and predict post-construction habitat conditions. There are concerns that the deepening may negatively alter overall water quality (e.g., salinity and DO), creating inhospitable foraging/resting habitat in the lower Savannah River for sturgeon.

Other activities occurring on the Savannah River include an expansion of Container Berth 8 by Georgia Ports, which requires dredging and pile driving. Expansion of Berth 8 required construction of a commercial pile-supported, concrete berth facility. The location of the berth nearby known over-wintering habitat of juvenile shortnose sturgeon in the Middle River resulted in a pile-driving moratorium.

Plans to expand the Elba Island LNG Terminal near Savannah, Georgia, are currently being reviewed. The proposed expansion includes installation of an additional two 200,000 m^3 LNG storage tanks, six closed-loop submerged combustion vaporizers, and modification of the berthing area to accommodate larger LNG carriers. Activities required for the expansion include pile driving, dredging, and construction barge activities.

The lower Savannah River is heavily industrialized and serves as a major shipping port. Nursery habitat in the lower river has been heavily impacted by diminished water quality and channelization, but effects on juveniles have not been determined. Reduced DO levels and upriver movement of the salt wedge may result from channel deepening. Mercury contamination is also prevalent within the system, with five fish species listed on the fish consumption advisory list.

Ogeechee River - Georgia

Atlantic sturgeon have access to 97% of their historical spawning habitat as the Jordan Mill Pond Dam is located 10 km downstream of the fall line. Downstream nursery habitat is likely compromised during hot, dry summers. This occurs when water flow is minimal and non-point sources of hypoxic waters have a greater impact on the system as potential thermal refugia are lost when the aquifer is lowered. Since 1986, DO levels have dropped to approximately 4 mg/L annually (Ogeechee River Basin Plan 2001). There have been no dredging projects reported in the last 25 years.

Altamaha River - Georgia

The Altamaha River is one of the largest drainage basins east of the Mississippi River (662 km mainstem and major tributaries). Although the two major tributaries are impounded, all dams are well upriver, at or above, the fall line and the probable historic extent of Atlantic sturgeon habitat. The drainage basin is dominated by silviculture and agriculture, with two paper mills and over two dozen other industries or municipalities discharging effluent into the river. Nitrogen and phosphorus concentrations are increasing, and eutrophication and loss of thermal refugia are concerns (see Ogeechee River).

Dredging operations are restricted to maintenance dredging of the Hatch Nuclear Power Plant water intake structures located on the Altamaha River at rkm 180 (rm 112), which is approximately 11 miles northeast of Baxley, in Appling County, Georgia. Plant facilities include the use of a closed-cycle cooling system that takes water from the Altamaha River. The water intake structure is located on the southern bank of the river and is 150 feet long by 60 feet wide. The flow rate of water being taken into the plant has historically averaged 88 cubic feet per second (cfs). The intake structure is covered with trash racks for removal of large debris and a traveling vertical screen of 3/8-inch mesh for removing small debris. The plant discharges water that ranges from 62^{o} F in winter to 94^{o} F in summer into the river at a rate of 50 to 58 cfs.

The intake structure requires maintenance dredging about once per year; dredging only occurs during the summer months. Each dredging event requires the use of a hydraulic, clamshell, or dragline type of dredge and will remove approximately 14,000 cubic yards of spoil material. This material is disposed in upland areas.

Other activities conducted at the Hatch plant as a function of operation that may affect sturgeon include impingement of adults or juveniles on the trash racks, entrainment of eggs or larvae in the cooling water intakes, discharge of heated effluents, and dredging operations.

Satilla River – Georgia

No Atlantic sturgeon habitat is lost as a result of dam construction on the Satilla River. Three hundred seventy-six kilometers of habitat exists between the river mouth and the fall line. Water quality conditions seem to be favorable during most of the year within the Satilla River, although low DO (< 5 mg/L) was a common occurrence observed during 1998-1999 water quality surveys (Satilla River Basin Plan 2002). The main sources of low DO concentrations are related to non-point sources, as point sources (i.e., wastewater discharge) have been vastly improved since the 1980s.

St. Mary's River – Georgia and Florida

Over 274 km of Atlantic sturgeon habitat is accessible (100%) between the river mouth and the fall line, and as such, dam construction has not had a significant impact on this river. It seems that the extirpation of the Atlantic sturgeon subpopulation in this system was likely caused by reduced DO levels during the summer in the nursery habitat, probably due to eutrophication from non-point source pollution. Dredging in the system seems to be limited to maintenance dredging of the ICW as needed.

<u>St. Johns River – Florida</u>

Historically, Atlantic sturgeon likely accessed all parts of the St. Johns River, as American shad were reported as far upstream as Lake Poinsett (reviewed in McBride 2000). However, the construction of Kirkpatrick Dam (originally Rodman Dam) at rkm 153 has restricted migration to potential spawning habitat upstream. Spawning may have occurred in the Ocklawha River, a tributary of the St. Johns River, and historic sturgeon habitat may not have included upstream portions of the river (K. Sulak, USGS, Pers. Comm. 2006). Water quality in this system also seems to be degraded, and low DO is a common occurrence during the summer months when water temperatures rise. Dredging commonly occurs within the system and has been linked to the reduction in submerged aquatic vegetation where Atlantic sturgeon likely forage (Jordan 2002) and may have impacted nursery habitat. Although Atlantic sturgeon were likely historically present in this river, it is believed that the subpopulation has been extirpated, and the St. Johns River now only serves as a nursery (NMFS and USFWS 1998).

3.1.5. Summary and Evaluation

Summarizing the preceding review, it is apparent that some Atlantic sturgeon subpopulations are likely affected by anthropogenic impacts to the watershed. These subpopulations include:

- Penobscot River – Wood chip debris reducing benthic habitat quality, mercury hot spots, coal tar deposits.
- Kennebec River – Maintenance dredging on nursery grounds.
- Merrimack River – 58% of historic habitat impeded.
- Connecticut River – Coal tar deposit on suspected spawning grounds.
- Hudson River – Continual dredging of nursery grounds, elevated levels of heavy metal and PCB contamination.
- Delaware River – Continual dredging, LNG operations, dioxin, mercury, PCB, and chlorinated pesticide contamination.
- Chesapeake Bay – Low DO in waters of the Bay during the summer and poor sediment quality.
    - Potomac River – Poor sediment quality.
    - James River – Continual dredging of nursery and spawning grounds, sedimentation.
- Roanoke/Albemarle Sound – Low DO during the summer and hypolimnetic discharges from Kerr Dam.
- Neuse River – Low DO and altered water flows.
- Pamlico Sound – Low DO in the Sound during the summer.

- Cape Fear River – 64% of historic habitat impeded, continual dredging in nursery grounds although there is a dredging moratorium imposed during the spring and summer.
- Santee-Cooper River – 62% of historic habitat impeded, continual dredging in nursery and spawning grounds within the Cooper River.
- Ogeechee River – Low DO during the summer months.
- Satilla River – Low DO during the summer months.
- St. Johns River – 63% of historic habitat impeded, low DO, dredging.

Atlantic sturgeon throughout their range are exposed to a variety of habitat threats including: restricted access to riverine habitat; large portions of degraded habitat, which may result in high levels of tissue contamination and water quality standards that are below fish health standards; and/or poor quality of some benthic habitat. Without substantial mitigation and management to improve the habitat and water quality of these systems, Atlantic sturgeon subpopulations will likely continue to be depressed until suitable habitat and water quality conditions are achieved. This is evident in southern streams that are suspected to no longer support reproducing Atlantic sturgeon subpopulations, such as the St. Mary's and St. Johns rivers. Although these rivers are at the southern range of the species, the degradation of habitat via dredging and water pollution likely prohibit Atlantic sturgeon from recolonizing these systems. The recovery of Atlantic sturgeon along the Atlantic Coast, especially in areas where habitat and water quality is severely degraded, will require improvements in the following areas: 1) elimination of barriers to spawning habitat either through dam removal, breaching, or installation of successful fish passage options; 2) operation of water control structures to provide flows compatible with Atlantic sturgeon use in the lower portion of the river (especially during the spawning season); 3) imposition of restrictions on dredging, including seasonal restrictions and avoidance of spawning/nursery habitat; and 4) mitigation of water quality parameters that are restricting sturgeon use of a river (i.e., DO). Additional data regarding sturgeon use of riverine and estuarine environments is needed.

3.2. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Atlantic sturgeon have been directly harvested with various gears including gill nets, traps, pound nets, otter trawls, harpoons, trammel nets, weirs, stake row nets, and seines (Smith 1985, Van Den Avyle 1984). Many authors have cited commercial over-harvesting as the single major cause of the precipitous decline in abundance of Atlantic sturgeon (Ryder 1888, Vladykov and Greely 1963, Hoff 1980, ASMFC 1990, Smith and Clugston 1997). The ASMFC 1990 FMP stated that recreational hook and line fishing in the U.S. is insignificant but noted an emerging directed sport fishery for Atlantic sturgeon in the Canadian maritimes. There is no evidence that a recreational fishery ever developed in the U.S. for Atlantic sturgeon. General information is presented below on both directed and incidental catch of Atlantic sturgeon and is followed by more specific information on harvest by river system.

3.2.1. Directed Harvest

Harvest records indicate that fisheries for sturgeon were conducted in every major coastal river along the Atlantic coast at one time and were concentrated during the spawning migration (Smith 1985). By 1860, commercial fisheries were established in Delaware, Georgia, Maryland, New Jersey, New York, North Carolina, Pennsylvania, South Carolina, and Virginia (Smith 1990). Records of landings were first kept in 1880 when the U.S. Fisheries Commission started compiling statistical information on commercial fishery landings (ASMFC 1990). Harvest in these early years was heavy, and approximately 3350 mt (7.4 million lbs) were landed in 1890 (Smith and Clugston 1997). The majority of the fishery for a 50-year time period (from 1870-1920) was conducted on the Delaware River and the Chesapeake Bay System with New Jersey and Delaware reporting the greatest landings. Landings reported until 1967 likely included both Atlantic and shortnose sturgeon. Shortnose sturgeon were granted Federal protection in 1967; therefore, harvest has been illegal in subsequent years. During the 1970s and 1980s, the focus of fishing effort shifted to South Carolina, North Carolina, and Georgia, which accounted for nearly 80% of the total U.S. landings (64 mt). Catch between 1990 and 1996 (average 49 mt) was centered in the Hudson River and coastal areas of New York and New Jersey (Smith and Clugston 1997).

The ASMFC 1990 FMP summarized the history of Atlantic sturgeon exploitation but cautioned that one should not infer that the reported historic landings approximated sustainable yields for sturgeon fisheries. Instead, it was hypothesized that the data more likely depict rapid over exploitation leading to stock collapse and recruitment failure. By 1990, six jurisdictions prohibited sturgeon landings: Pennsylvania, Potomac River Fisheries Commission, District of Columbia, Virginia, South Carolina, and Florida. There were two kinds of management measures in states that allowed harvest: seasons and size limits. However, among the states in which harvesting was legal, only Georgia had a size limit which allowed females the opportunity to spawn once before being harvested (ASMFC 1990). The 1990 FMP concluded that the species was capable of sustaining only very modest rates of annual exploitation. It also included the management recommendation that each state should control harvest to increase spawning biomass through one of the following three means: 1) by adopting either a minimum total length of at least seven feet (2.13 m) and instituting a monitoring program that has mandatory reporting of commercial landings; 2) institute a moratorium on all harvest; or 3) if a state did not choose one of these first two options, it could submit alternative measures to the ASMFC Atlantic Sturgeon Plan Review Team for determination of conservation equivalency. By 1996, closures of the Atlantic sturgeon fishery had been instituted in all Atlantic Coast states except for Rhode Island, Connecticut, Delaware, Maryland, and Georgia, all of which adopted a seven-foot (2.13 m) minimum size limit. New York and New Jersey opted for the third choice under the 1990 FMP and instituted a five foot (1.5 m) minimum size limit with seasonal restrictions, quotas, mandatory reporting, and extensive monitoring, until 1996 when the fisheries were closed by the state.

In 1996, a review of the 1990 FMP concluded that the standard seven foot (2.13 m) minimum size mandated in the FMP protected only about 50% of the spawning females and about 80% of the spawning males in the stock. The review further concluded that the five foot (1.5 m) minimum size permitted in New York and New Jersey probably resulted in recruitment overfishing. The 1996 review document noted that New York had exceeded its set quota for both 1994 and 1995 but stated that both New York and New Jersey had committed to further restrictions that would help restore the Hudson stock.

In reviewing historical records of catch and stock abundances, Smith (1985) pointed out that Atlantic sturgeon was in need of immediate protection throughout much, if not all, of its range and suggested that the best strategy might be a total moratorium on exploitation of the species. The 1996 FMP review stated that the 1990 FMP for Atlantic sturgeon would not lead to the recovery of the East Coast stocks and therefore, should be amended. Recommendations in the plan review included a complete moratorium on harvest until 20 year classes were established (20-40 years), enhanced monitoring programs, specifications on the role of cultured fish in stock enhancement and restoration programs, and monitoring and commitment to reduce bycatch if necessary. The plan was adopted in early June 1998. A Canadian commercial fishery still exists, although it is highly regulated by size restrictions, seasonal closures, limited entry in some portions, and quotas.

Despite the fact that the fishery has been closed coastwide since 1995 and in certain states prior to then (NC, 1991; SC, 1985), poaching of Atlantic sturgeon continues and is a potentially significant threat to the species, but the present extent and magnitude of such activity is largely unknown. Instances of documented poaching have occurred since the previous Status Review, several of them very recent, indicating that poaching is contributing to Atlantic sturgeon mortality, and should be considered along with bycatch in other legal fisheries as a factor in assessing present threats. Poaching has been documented by law enforcement agencies in Virginia, South Carolina and New York. In Virginia, Marine Resources Commission law enforcement agents with the Virginia Marine Police, in collaboration with the National Marine Fisheries Service Division of Law Enforcement, arrested commercial fishermen who had killed approximately 95 Atlantic sturgeon from the James and Poquoson rivers, VA, during 1998-1999. The fish documented were purchased by undercover operatives, and the operation was terminated in order to preclude further loss of sturgeon (J. Croft, Virginia Marine Police, Pers. Comm. 2007). Virginia Marine Police indicated that the black market in Virginia continues to currently exist, with fishermen referring to sturgeon as “Canadian bacon.” In South Carolina, Department of Natural Resources law enforcement officers apprehended one individual with a two to three-foot Atlantic sturgeon in a cooler, in late 2006. The fish had been caught in a channel net set for catching shrimp. A commercial fisherman advised U.S. Fish and Wildlife Service staff that at least one other Atlantic sturgeon was killed and filleted for consumption, and also reported that sturgeon are illegally taken and sold during the American shad fishery (M. Sasser, Waccamaw National Wildlife Refuge, Pers. Comm. 2006). In New York, officers of the Department of Environmental Conservation recently arrested a commercial fisherman who had two Atlantic sturgeon in his possession. The fisherman advised the officers that there is a black market for Atlantic sturgeon (G. Colvin, NYDEC, Pers. Comm. 2007). These cases suggest that poaching of Atlantic sturgeon is regularly ongoing, is contributing to mortality, and is likely slowing the rate of recovery that otherwise would occur.

3.2.2. Bycatch

Insight into the extent to which Atlantic sturgeon are caught as bycatch in commercial fisheries and the percent released alive can be obtained from examining: 1) landing records for states without directed sturgeon fisheries, 2) tagging and recapture studies, 3) log books completed by fishermen, 4) the reward program instituted by the USFWS and the state of Maryland, 5) USFWS Coastal Tagging Database, and 6) NMFS observer program. While these data sets cannot provide a complete assessment of Atlantic sturgeon bycatch, these data allow us to gauge the severity of bycatch as a threat to the species. It would be desirable to know the effects of bycatch on each spawning subpopulation, but this would require the following data: 1) the size of the subpopulation in each river; 2) the proportion of sturgeon in each river caught as bycatch as affected by season and area of a fishery, gear type, and fishing effort; 3) the origin of fish captured; 4) the effort level in each of those fisheries; and 5) the mortality rate of sturgeon caught by each gear type. These data do not exist for most spawning subpopulations; however, bycatch of Atlantic sturgeon has been reported in many different fisheries conducted in rivers, estuaries, the nearshore ocean, and the EEZ. Since Atlantic sturgeon spend portions of their lives in all of these habitats, they are subject to incidental capture at greater rates than non-anadromous species. Relative importance of commercial bycatch in the Northeast from rivers, estuaries, territorial ocean waters, and the EEZ can be inferred from tagging and recapture data reported by Delaware DFW tagging studies (Shirey et al. 1997). Atlantic sturgeon from 65-165 cm (TL) were tagged (1,700) in the lower Delaware River from 1991-1997. Atlantic sturgeon recaptures came from commercial fisheries ranging from Maine to North Carolina. The majority of recaptures (61%) came from ocean waters within 4.8 km of shore, 20% of the recaptures came from rivers and estuaries, 18% from the EEZ, and 1% were captured at unreported locations. Similarly, Stein et al. (2004b) examined bycatch of Atlantic sturgeon using the NMFS sea-sampling/observer 1989-2000 database. The bycatch study identified that the majority of recaptures occurred in five distinct coastal locations (Massachusetts Bay, Rhode Island, New Jersey, Delaware, and North Carolina) in isobaths ranging from 10 to 50 m, although sampling was not randomly distributed. Similar results were reported in the Atlantic Coast Sturgeon Tagging Database (USFWS); noting most recaptures occurred off the coast of New Jersey, at the mouth of the Chesapeake Bay, within the Chesapeake Bay, and the eastern portion of the Albemarle Sound, NC (Eyler et al. 2004).

The season in which a fishery is conducted determines whether it can potentially intercept Atlantic sturgeon and if the sturgeon intercepted will survive (i.e., temperature-related mortalities). Stein et al. (2004b) showed that bycatch was the lowest in the ocean during the summer months (July – September); however, bycatch of Atlantic sturgeon in inland waters likely increases during the summer months (as evident from USFWS Tagging Program Data; greatest catches occur in May and June). Adults migrating to spawn can be intercepted within rivers in the spring in the southern portion of the range and later in the summer in the northern portion. Juveniles can be intercepted in rivers and estuaries when emigrating from nursery habitat or year-round. Fisheries conducted within rivers and estuaries may intercept any life stage, while fisheries conducted in the nearshore and ocean may intercept migrating juveniles and adults.

Target Fisheries of Concern

As mentioned previously, Stein et al. (2004b) examined the bycatch of Atlantic sturgeon using the sea-sampling/observer database (1989-2000) operated by NMFS. Overall, 30 directed fisheries were examined (Table 10). The five greatest bycatch rates were observed in the weakfish-striped bass (*Cynoscion regalis – Morone saxatilis*) fishery (0.1667 catch/monitor trip), followed by northern kingfish (*Menticirrhus saxatilis*), American shad, southern flounder (*Paralichthys lethostigma*) and red hake (*Urophycis chuss*). It should be noted, however, that the NMFS observer database does not have equal coverage among fisheries or months of sampling; thus, bycatch rates can be heavily biased and error rates can be large. For an example, during the years of 2000 – 2004 the NMFS Observer Program (NEFO) observed 71 fisheries, of these fisheries only 18 had more than 100 days-at-sea effort; effort in the other 53 fisheries averaged 20 days-at-sea. Though bias can occur from using the NMFS observer database, similar results were found in the Atlantic Coast Sturgeon Tagging Database where wild Atlantic sturgeon bycatch was observed in the striped bass fishery (43%), followed by flounder (*Paralichthys sp.)* (13%), shad (*Alosa sp.*) (8%), and other unidentified fish (8%) (Eyler 2006).[26] In South Carolina and Georgia, the American shad gill net (52%) and shrimp trawl (39%) fisheries were responsible for the majority of Atlantic sturgeon recaptures in a multi-year tagging program (Collins et al. 1996). While these fisheries have the greatest rate of bycatch, they may not have high associated mortality rates associated; thus, an analysis of primary gear used, season, and length of season are important variables in understanding Atlantic sturgeon mortality in these fisheries.

Since 2000, some Federally targeted fisheries have been modified (i.e., monkfish) or essentially eliminated (i.e., American shad ocean drift net fishery and spiny dogfish fishery) (ASMFC TC 2006), which suggests that these estimates are inapplicable for contemporary fisheries. The ASMFC Atlantic Sturgeon Technical Committee held a meeting on February 1 – 3, 2006, in Norfolk, Virginia to determine how these changes affected bycatch mortality (ASMFC Technical Committee 2006). Based upon the NMFS Observer Program Database, the ASMFC TC concluded:

1) Bycatch losses principally occur in sink-net fisheries, but may be occurring in substantial numbers in trawl fisheries.
2) Absolute number of dead Atlantic sturgeon in sink-net fisheries were similar between the periods 1995-2000 (average = 25/yr) and 2001-2004 (average = 32/yr). This trend, however, must be interpreted with caution because observer coverage varies year to year and across fishery types.
3) Mortality rates for the sink-net fishery are influenced by soak-time.
4) Until the bycatch rate matrix from Stein et al. (1999) can be modified, it is not possible to estimate absolute numbers of Atlantic sturgeon taken as bycatch.
5) Any estimate of bycatch from the NMFS observer dataset will be an underestimate because bycatch is under reported in state waters and no observer coverage exist South Atlantic (NC – FL) US Federal waters.

[26] The Atlantic Coast Sturgeon Tagging Database also contains records on 675 hatchery-reared Atlantic sturgeon.

Gear Effects

Gill nets

Survival of Atlantic sturgeon caught incidentally in gill nets is variable depending on water quality and the manner in which the gear is set and the length of time it is left before being tended (Table 11). Overall, bottom set gill nets incur the greatest mortality of Atlantic sturgeon, compared to other gill nets or types of gear (Stein et al. 2004b). The greatest observed mortality was from gill nets utilized for the monkfish fishery that were set for eleven days and averaged 70% mortality. Common soak times of two to three days averaged 36-50% mortality (NMFS Observer Database). The NEFO also observed high mortality rates in fisheries targeting Atlantic cod (30%). The smallest mortality rate was observed for trawl and pound net fisheries that had 0-0.2% mortality (Stein et al. 2004b, NEFO 2000-2004 data).

Stein et al. (2004b) examined bycatch and mortality of Atlantic sturgeon captured in the sea-sampling/observer program conducted from 1989 – 2000. Overall, 25,035 lbs of Atlantic sturgeon were captured in coastal waters from North Carolina to Maine while observers were onboard.[27] Eighty-four percent of these captures came from sinking gill nets. Only 357 lbs (1%) of sturgeon were captured in drift gill nets that were used in the bluefish and American shad ocean fisheries. Mortalities ranged from 10% to 22% in the drift and sink gill net fisheries, respectively. Stein et al. (2004b) estimated the annual bycatch of Atlantic sturgeon from the sink and drift net fisheries. The sink net fishery captured between an estimated 60,000 – 225,000 lbs of Atlantic sturgeon annually (1986-2000), increasing from 60,000 lbs in 1986 to 150,000 lbs in 2000. Sink net landings likely peaked at an estimated 225,000 lbs in 1996. Despite only 357 lbs of Atlantic sturgeon being observed in the drift net fisheries, these fisheries are evidently prolific, as estimates of annual Atlantic sturgeon catch ranged between 1,000 – 150,000 lbs annually, averaging around 50,000 lbs. Unlike the sink net fishery, the drift net fishery did not increase over the time, but rather remained relatively constant.

The Atlantic Coast Sturgeon Tagging Database has recorded that over 5,000 wild sturgeon have been tagged that were incidentally captured during the period of 1992-2003 (Eyler 2006). Three hundred and sixty eight of these tagged fish have been recaptured, some multiple times. Sixty-two percent of the recaptures came from anchored gill nets; other gear types interacted less with Atlantic sturgeon. The striped bass fishery intercepted the majority of these tagged Atlantic sturgeon using anchored gill nets (64%), drift gill nets (19%), and unspecified gill nets (12%). The NMFS sea-sampling program observed 433 Atlantic sturgeon captures between 2000 – 2004. Of these 433 sturgeon captured, 91% were taken in fixed gill nets, and the mortality rate was 30%. The remainder of the fish was captured in drift gill and purse nets, and trawls, and no mortalities were recorded.

Bycatch information in the Chesapeake Bay system is available primarily for the Maryland portion of the Bay from the reward programs conducted by the USFWS and the state of Maryland. All of the wild captures in this program (N = 1,133) were caught as bycatch from commercial gears. Most captures in Maryland and Virginia were from drift gill nets and pound nets. Since the USFWS reward program was restricted to live captures, few dead sturgeon were

[27] During the period of 1989-1997, some fisheries were targeting Atlantic sturgeon.

reported. It is likely, however, that rates of mortality were low. The gill net fishery, where most mortality is expected, occurs during months when water is cold; thereby, increasing survival of sturgeon caught as bycatch. Most captures in warm water months occurred in pound nets, which are presumed to have zero mortality.

The NCDMF initiated an observer program in April 2004 to monitor bycatch in the Albemarle and Pamlico Sounds. Overall, 42 sturgeon have been observed (April 2004 – December 2005). The majority of those captured were reported in larger mesh gill nets (> 5in stretched mesh) (B. Price, NCDMF, Pers. Comm. 2006). Twelve individuals were captured in the Pamlico Sound, averaging approximately 600 mm TL. Thirty individuals were captured in the Albemarle Sound, averaging 600 mm TL. Two of the Albemarle captures were YOY (< 410 mm TL). Overall, bycatch mortality was relatively low at 12% (5 deaths), with the majority of deaths occurring during the summer (June, April, August).[28]

Most Atlantic sturgeon tagged and recaptured by the Delaware DFW occurred in gill nets (78%), and mortality in anchored gill nets was 10% (C. Shirey, Delaware DFW, Pers. Comm. 1998). Collins et al. (1996) reported a mean mortality rate of 16% and a 20% injury rate of sturgeon caught in staked shad gill nets fished in Winyah Bay in 1994, 1995, and 1996. Atlantic sturgeon were tagged in the Altamaha River, Georgia in 1986-1992 (Collins et al. 1996), with most recaptures (52%) coming from American shad gill net fisheries in Georgia, and the majority of the remainder coming from the shrimp trawl fishery (39%). Somewhat larger rates of mortality have been reported in the Cape Fear River, where a monthly gill net survey has been conducted by the University of North Carolina at Wilmington (UNCW) and NCDMF personnel since 1990. Using 5.5 inch stretched mesh sink gill net and 24 hr soak times, mortality rates ranged from 25% during the periods of 1990 – 1998 and 37% from 2000 – 2004. Greatest mortality rates occurred during the summer months (June-August) where 34 of 69 (49%) sturgeon caught died.[29] In the Mid-Atlantic region, Atlantic sturgeon are caught as bycatch in gill nets and trawls targeting a variety of species including, dogfish, flounder, shad, striped bass, weakfish, and monkfish. Mortality of those taken in gill nets is greater than in trawls, especially in anchored nets fished for extended periods (1-2 days) (C. Shirey, Delaware DFW, Pers. Comm. 1998). Atlantic sturgeon bycatch in Delaware Bay typically occurs from March into May and is associated with the fixed gill net fisheries for a variety of species: primarily American shad, striped bass, weakfish, and white perch. Bycatch mortality, as reported by the Delaware Bay fishers, is low. Of ten Atlantic sturgeon reported captured in anchored gill nets, only one was reported as dead. Many fishery managers believe that Atlantic sturgeon bycatch and mortality are vastly underreported along the Atlantic coast (W. Patrick, NMFS, Pers. Comm. 2006).

Trawls

There are regional differences in how trawl fisheries operate and tow their gear. Trawl duration is generally shorter in northern areas (Maine to North Carolina) and longer from South Carolina and south. Bycatch survival is greater in the colder water temperatures of the north, but in the south, survival of sturgeon is likely to be enhanced by use of various bycatch reduction devices. The ASMFC Stock Assessment assumed a coast-wide value of 5% mortality in trawl fisheries

[28] Other mortalities occurred in January and March.
[29] Soak times are reduced to 4 hr sets during the summer.

(ASMFC 1998b). Stein et al. (2004b) reported no immediate Atlantic sturgeon mortality when captured in trawls over an 11-year period (1989-2000) where over 3,000 lbs of Atlantic sturgeon were captured from North Carolina to Maine. This is similar to NEFO data for the period of 2000-2004 that showed 0.2% Atlantic sturgeon mortality in fish and shrimp otter trawls. All Atlantic sturgeon captured by trawls during the 19 years of Cooperative Winter Tagging Cruises survived (N = 146, 1988 – 2006); however, all tows were 30 minutes or less in duration and all occurred during winter when water temperatures were low (Laney et al. *In prep*).

Observers on vessels in the trawl fisheries ranging from Maine to Maryland in 1990-1994 observed a mean bycatch rate of less than 0.05 kg per day (Kennelly 1996). McKiernan and King (1996) reported no captures of Atlantic sturgeon from 36 sea-days of monitoring trawlers north of Cape Cod during July through November 1996. Observations during the fall and winter of 1997 from Maryland through Massachusetts (both territorial seas and EEZ) found no Atlantic sturgeon in eight sea-days on trawlers. However, observers from the sea-sampling/observer program recorded the capture of 3,784 lbs of Atlantic sturgeon between 1989 and 2000 (Stein et al. 2004b). Estimates of annual landings of Atlantic sturgeon from trawl fisheries were between 100,000 – 200,000 lbs of Atlantic sturgeon yearly, with a peak capture in 1996 where as much as 625,000 lbs were landed. This is similar to sinking and drift gill net fisheries that averaged 100,000 lbs and 50,000 lbs each year, respectively (Stein et al. 2004b).

The trawl fishery accounted for 15% of the recaptures that occurred from Maine to North Carolina in Delaware DFW's 1997 study. Survival in trawl nets was estimated to be 100%. Atlantic sturgeon were tagged in the Altamaha River, GA during 1986-1992, and 39% of the recaptures were from the shrimp and whelk trawl fisheries in Georgia (Collins et al. 1996). One trawl recapture came from North Carolina. Turtle excluder device (TED) and bycatch reduction device (BRD) requirements may reduce Atlantic sturgeon bycatch in Southeast trawl fisheries.

Despite over 3,000 lbs of Atlantic sturgeon being captured in the ocean trawl fishery (as observed in the sea-sampling program) and other surveys also showing relatively large trawl bycatch rates, mortality of Atlantic sturgeon captured by trawls seems to be low, with most surveys reporting 0% mortality. However, these studies do not include post capture mortality or studies of mortality from trawl fisheries conducted in the south where tow times are longer and water temperatures are higher. Overall, trawls do not seem to pose a significant threat to Atlantic sturgeon.

Pound Nets

Some captures were reported in pound nets during the USFWS reward program in the Chesapeake Bay. Survival in pound nets is estimated to be 100% (Kahnle et al. 1998).

3.2.3. Projected Impacts of Bycatch

Because of the data limitations noted above, effects of bycatch at the species level are not readily available. Although there is not an estimate of bycatch mortality for Atlantic sturgeon range-wide due to the lack of data, bycatch mortality can be calculated for areas such as the Hudson

River, Mid-Atlantic and New England ocean fishery (Stein et al. 2004b), and Georgia/South Carolina American shad fishery (Collins et al. 2000b).

To estimate the effects of Atlantic sturgeon bycatch on the Hudson River subpopulation, the ASMFC Stock Assessment Team revised its yield and egg-per-recruit model to identify an F_{50} value for bycatch of the Hudson River stock (ASMFC 1998b).[30] The F_{50} is the fishing rate at which a cohort produces 50% of the eggs that it would produce with no fishing effort. Most fishery models use a less conservative target fishing level at the F_{30} or F_{20} level. The more conservative choice of F_{50} for Atlantic sturgeon is justified by their late age at maturity and because they are periodic spawners (Boreman 1997). The resulting estimate was F_{50} – bycatch = 0.03. This can roughly be interpreted to mean that, in the absence of a directed fishery, 3% of the subpopulation can be removed as bycatch mortality each year, while allowing the subpopulation to remain stable or recover. Mortality rates of 10-40%, 10% and 0% were applied to recaptures in gill nets, trawls, and pound nets, respectively. Resulting estimates of mortality (u) caused by reported bycatch ranged from a high of 0.3% - 1.25% during 1991-1992 to a low of 0.09-0.37% during 1995-1996. This estimate of bycatch mortality is considered to be a lower bound estimate because it assumes a 100% reporting rate of tagged fish, zero tag loss, zero tag-induced mortality, zero delayed mortality, and also ignores sublethal effects. Acknowledging that these levels are lower bound rough estimates, they are well below the F_{50} (3%), and the estimated natural mortality rate of 7% (Kahnle et al. 1998).

However, the ASMFC Technical Committee derived different results in 2006. The ASMFC TC determined that the majority of sink-net fisheries were located within the New York Bight, which is dominated by Hudson River Atlantic sturgeon stock (Waldman et al. 1996, ASMFC TC 2006). Based upon a likely range of Hudson River abundances ranging from 8,000 – 15,000 (Hattala and Kahnle unpublished data), and scenarios of contribution rates of the Hudson River stock to sink-net bycatch numbers (25-100%) the ASMFC TC found:

1. The bycatch observed by Stein et al. (2004), but not yet known for the recent period, is of an amplitude that would substantially curtail recovery of the Hudson River subpopulation.
2. Subpopulations smaller than the Hudson River will experience a higher relative rate of bycatch losses, depressing their recovery rates to a larger degree than the Hudson River subpopulation.
3. Considerable uncertainty exists in how individual subpopulations are impacted by bycatch due to lack of information on constituent population abundances and the degree to which they are taken in regional coastal fisheries.

Collins et al. (2000) investigated the bycatch and mortality rate of Atlantic sturgeon captured in the South Carolina and Georgia American shad gill net fishery (includes stake and drift nets). Two Winyah Bay (South Carolina) commercial fishermen were accompanied in 1994-1995 to estimate the mortality and condition of Atlantic sturgeon captured in the staked gill nets targeted for American shad. Using data collected from these fishermen, extrapolations show that 158 Atlantic sturgeon were captured each year in the American shad fishery in Winyah Bay proper.

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[30] A relatively good relationship with fishers during this period resulted in better estimates of bycatch than currently reported.

The bycatch mortality was 16%, with another 20% of the Atlantic sturgeon damaged in some manner, resulting in the annual bycatch mortality of 25 fish/year and 32 injuries/year.

The Altamaha River (Georgia) was surveyed to determine the magnitude of Atlantic sturgeon bycatch in that river during the American shad fishing season. Overall, 744 sturgeon (both species) were captured in the American shad fishery during the years of 1982-1983. Assuming trends from 1986-1992 Altamaha sturgeon catch data were similar to those in 1982 and 1983, it is expected that 89% (N = 662) of the catch consisted of Atlantic sturgeon. Also assuming 10% mortality (Stein et al. 2004b) as the fishery is dominated by drift gill nets, it is estimated that 33 Atlantic sturgeon [(662 * 0.10) / 2 years = 33 sturgeon] would die each year from the fishery. These data present evidence that bycatch mortality of Atlantic sturgeon in the American shad fishery, at least in South Carolina and Georgia, ranged between 25-33 Atlantic sturgeon/fishery/year.

3.2.4. Scientific Utilization and Recreational Impacts

Overall, scientific collections do not seem to be significantly affecting the status of Atlantic sturgeon as the SRT found few projects directly targeting Atlantic or shortnose sturgeon: 1) Altamaha River tag-recapture study, 2) a Hudson River juvenile index (FWS), 3) sampling program within Long Island Sound, 4) LNG terminal sampling on the Delaware River, 5) the Maryland Reward Program, 6) South Carolina diet study, 7) South Carolina recruitment index study, 8) distribution and abundance study in the Penobscot River, and 9) Delaware River juvenile and subadult monitoring program.

- The Altamaha River tag-recapture study has been underway since 2004 and is funded by NMFS until 2009. Atlantic and shortnose sturgeon are captured by large mesh gill net, trammel nets and trawling. In 2004 and 2005, over 2,000 adult and juvenile Atlantic sturgeon were captured by the principal investigator, with no mortalities (Doug Peterson, UGA, Pers. Comm. 2006).

- From October 2003 to November 2005 in the Hudson River, a total of 562 juvenile Atlantic sturgeon were captured in gill nets, measured, tagged, spine sampled, and released as part of a relative juvenile abundance study performed by the USFWS and NYSDEC (Sweka et al. 2006). No mortalities were observed during the course of the study (Jerre Mohler, USFWS, Pers. Comm. 2006).

- Research efforts directed at Atlantic sturgeon for tagging and food habits studies in Long Island Sound with both trawls and gill nets have resulted in the collection of 219 Atlantic sturgeon through 2005 (T. Savoy, CTDEP, Pers. Comm. 2006). No mortalities took place. Sampling within the Connecticut River (primarily with gill nets) resulted in the collection of 112 Atlantic sturgeon from 1988 through 2004. Seven mortalities (6%) took place up through 2004 as a result of gill net collections where nets excessively entangled fish for various reasons.

- A one-year survey to document the occurrence and distribution of juvenile sturgeon in the Delaware River in the vicinity of Oldmans Creek was initiated in May of 2005. Sampling for juvenile sturgeon was performed using trammel nets and small mesh gill nets. As of December 2005, only 4 juvenile Atlantic sturgeon had been captured, with no mortalities reported (G. Murphy, DFW, Pers. Comm. 2006)

- Within the Chesapeake Bay, the USFWS has been funding the Maryland Reward Program since 1996, which pays fishers $25 for hatchery-reared and $100 for wild sturgeon if the specimen is alive so that they can be measured, weighed, tagged, and released by USFWS personnel. Although sturgeon are sometimes held for long periods of time (days) and restrained by rope in some instances, there are only a few mortalities reported for the reward program.

- In a one-and-a-half year study (ongoing) of Atlantic sturgeon diets in the Savannah and Edisto rivers, approximately 250 subadult and adult sturgeon were lavaged (a non-lethal method of removing stomach contents) to determine diets.[31] No mortalities have occurred (M. Collins, SCDNR, Pers. Comm. 2006).

- For the past 10 years, South Carolina has conducted an annual survey targeting juvenile, especially age-1, Atlantic sturgeon in the Edisto River. The goal of the survey is to develop an index of abundance to estimated year class strength. Annual catches are usually on the order of magnitude of 100 fish, with no mortalities reported (M. Collins, SCDNR, Pers. Comm. 2006).

- A study was initiated in spring 2006 to assess the distribution, abundance and movements of adult and subadult Atlantic sturgeon in the Penobscot River system in Maine. A secondary goal of the study is to assess similar aspects of the ecology of shortnose sturgeon or other diadromous species of concern, where such activities are synergistic with the primary approaches. To date, 62 shortnose sturgeon have been captured and tagged (three mortalities,) and seven Atlantic sturgeon have been captured and tagged (two mortalities) and three have been tagged. This study is ongoing and will continue for at least one additional year.

- The state of Delaware monitors juvenile and subadult Atlantic sturgeon abundance in the lower Delaware River using small mesh gill nets, in addition to tagging and habitat utilization studies. Only one mortality has been observed during >1,700 captures.

Scientific studies directed at other species also have the potential to intercept sturgeon on a sporadic basis and may result in Atlantic sturgeon mortalities, as these studies are not specifically designed to capture and release live sturgeon. It is not possible for the SRT to identify all of these studies. However, the following are some of the studies which are known to the SRT and have the potential to take Atlantic sturgeon:

- The Cape Fear River Survey has been operating continuously since 1997. The objective of the survey is to document relative abundance of fish species within the river, especially sturgeon, using large mesh gill nets (5 in stretched meshed) and electrofishing. Prior to 2002, the gill net survey was conducted by UNCW and intercepted 88 Atlantic

[31] Only 12 of the 250 sturgeon examined were adults, which were collected from the Edisto River.

sturgeon, of which 22 (25%) were killed. The greatest mortality occurred during periods of highest water temperature (Moser et al. 1998). Since 2002, this survey has been continued by the NCDMF, and they have reported mortality rates of 37% overall. Similar to earlier findings, mortality was highest during the summer months (June-August), averaging 49% (34 of 69 sturgeon died) (F. Rohde, NCDMF, Pers. Comm. 2006).

- The Pamlico Sound Independent Gill Net Survey has been conducted since 2001, targeting striped bass and all other finfish species using an array of gill net mesh sizes. Overall, 14 sturgeon have been captured, with 0 mortalities reported. [F. Rohde, NCDMF, Pers. Comm. 2006).
- The Albemarle Sound Independent Gill Net Survey has been conducted since 1990, also targeting striped bass and other finfish species using an array of gill net mesh sizes. As of October 2005, 842 sturgeon had been captured with 67 mortalities (8%) (F. Rohde, NCDMF, Pers. Comm. 2006).
- The NMFS-USFWS Winter Tagging Cruise has been conducted since 1988, which is generally conducted in the nearshore Atlantic Ocean from Cape Lookout, NC to Cape Charles, VA. The trawl survey targets striped bass and as a result also captures a large variety of other species. From 1988 to 2006, 146 juvenile Atlantic sturgeon were captured, ranging from 0 to 23 fish captured per year. There have been no mortalities.
- Overall, there have been 54 Atlantic sturgeon captured in the Northeast Trawl survey from 1984 to 2004. No mortalities have been reported.
- The Connecticut Department of Environmental Protection Marine Fisheries Division has been monitoring abundance and distribution of finfish and selected invertebrates since 1984 with a stratified random trawl survey (three bottom types, four depth intervals). A total of 355 Atlantic sturgeon have been collected from 1984 through 2004, with no apparent mortalities from the trawl.

Of these projects described above, only the Cape Fear River Survey seems to have a high rate of mortality that could be affecting the status of that subpopulation. To reduce mortality, however, NCDMF has reduced soak times when water temperatures are above 30° C (F. Rohde, NCDMF, Pers. Comm. 2006). Given the relatively low numbers of mortalities identified in the majority of these studies, it does not seem that scientific sampling poses a significant threat to Atlantic sturgeon.

3.2.5. River Specific Overutilization Information

<u>Gulf of Maine DPS</u>

<u>Maine Rivers</u>

Maine had one of the earliest sturgeon fisheries with export back to England taking place as early as 1628. Commercial sturgeon landing statistics (shortnose and Atlantic sturgeon) are generally only available from the late 1800s. Landings peaked in the late 1800s and early 1900s and collapsed by the 1920s. Although there is the occasional story of anglers foul hooking large sturgeon, there was never a directed recreational fishery for this species. Regulations were passed in 1992 to make it illegal to take, catch, or possess Atlantic sturgeon in the state of Maine.

Penobscot River - Maine

Historical accounts of the Penobscot River are very limited; however, Atlantic sturgeon were utilized by native Americans. When there was substantial fishing effort for Atlantic salmon and American shad in the Penobscot River in the early 1800s there was no mention of a large sturgeon fishery. This suggests that there may not have been a large run of Atlantic sturgeon on the Penobscot River at the time.

Estuarial Complex of the Kennebec River - Maine

In 1628, the estuarial complex of the Kennebec River probably supported the largest fishery for Atlantic sturgeon in the State of Maine. This fishery occurring at the head-of-tide on the Androscoggin River persisted intermittently until 1675 (Wheeler and Wheeler 1878). Atkins (1887) described the Kennebec fishery as being an important intermittent fishery, which flourished into the 18th and early part of the 19th centuries. The last major landings on the Kennebec occurred in 1849 when 160 tons of sturgeon were landed (Atkins 1887).

There are no major commercial fisheries occurring in the estuarial complex of the Kennebec and Androscoggin rivers, but there are limited gill net fisheries for menhaden, alewives, blueback herring, sea herring, and mackerel. The use of purse, drag, and stop seines, and gill nets, with the exception of those that do not exceed a maximum stretch of 87.5 mm, are prohibited. If the nets are fixed or anchored to the bottom, they have to be tended continuously and hauled in and emptied every two hrs. There has been no reported or observed bycatch of Atlantic sturgeon.

From 1977-2000, a total of 20 mortalities of subadult Atlantic sturgeon occurred in the MEDMR gill net sampling program out of a total catch of 117 subadults. The relatively large mortality rate of subadult Atlantic sturgeon has been noted by other researchers (Collins et al. 1996, Stein et al. 2004b). Kieffer and Kynard (1993) attributed the large mortality rates of subadults captured in gill nets to the presence of dense dermal ossifications, which prevented the net strands from sliding beyond the operculum, and thus, restricting ventilation.

Merrimack River – New Hampshire and Maine

Jerome et al. (1965) stated that the Merrimack River had a very important Atlantic sturgeon fishery during colonial days and that it lasted until the late 1800s. In the early 1600s, the Merrimack River was known as one of the two best sturgeon fishing areas in the colonies. In 1882, Massachusetts passed a law enacting a minimum 30 cm (12 inch) stretched mesh for taking sturgeon. In 1887, only two tons were taken by ‘visiting fishermen,’ and it was generally considered that the fishery was eliminated.

Currently, there is an inshore permit fishery (for finfish) that occurs; however, these permits restrict gear to 100 foot drift gill nets that must be attended at all times. No overnight sets are allowed (K. Creighton, MAFWE, Pers. Comm. 2006). There are also offshore fisheries for dogfish, cod, and striped bass, which are susceptible to take sturgeon as bycatch, although mortality is relatively low (K. Creighton, MAFEW, Pers. Comm. 2006).

New York Bight DPS

Taunton River – Rhode Island and Massachusetts

Currently, there is an inshore permit fishery that occurs; however, these permits restrict gear to 100 foot drift gill nets that must be tended at all times. No overnight sets are allowed (K. Creighton, MA FWE, 2006). There are also offshore fisheries for dogfish, cod, and striped bass that are known to take Atlantic sturgeon as bycatch, although mortality is relatively low (K. Creighton, MA FWE, 2006).

Connecticut River – Massachusetts and Connecticut

Reported landings are only available since 1989. Prior to a Connecticut harvest moratorium in 1997, licensed fishermen were limited to a catch of three Atlantic sturgeon per day or per trip, whichever was the longer period of time. This was further restricted in 1992 with an increase in the minimum size from 122 cm to 213 cm TL. Recreational angler catches have been documented but are not generally thought to be a significant source of mortality for Atlantic sturgeon in Connecticut waters. Several other catches are known or suspected, but all Connecticut catches are dominated by immature or juvenile sturgeon.

Bycatch may occur in commercial fisheries, but legal possession of Atlantic sturgeon was prohibited in freshwaters of the state of Connecticut in 1973 and from Long Island Sound in 1997. Bycatch is known to take place in the commercial shad fishery that operates in the lower Connecticut River from April-June with large mesh gill nets (14 cm minimum stretched mesh).

Scientific monitoring for shortnose sturgeon and other species has resulted in the capture of 131 Atlantic sturgeon in the Connecticut River and 360 in Long Island Sound since 1984. Seven mortalities (6% in Connecticut River) have occurred, but scientific monitoring is thought to be a minor source of mortality. Collection of sturgeon for research purposes requires a scientific collector's permit and an annual report of the collections made.

Hudson River – New York

Atlantic sturgeon of the Hudson River Estuary have supported subsistence or commercial fishing since colonial times. Atlantic sturgeon were known to be taken occasionally by hook and line, but the recreational fishery was considered negligible in New York and New Jersey. Reported commercial landings of Atlantic sturgeon are available for New York from 1880-1996. Until 1980, most landings were from the Hudson River. After 1980, landings occurred from both the Hudson River and along Long Island. Largest annual landings of the time series (231 mt) occurred in 1898, after which landings quickly dropped to 15 mt or less per year and remained at low levels through the early 1980s. Fishing has been an important factor affecting abundance of Atlantic sturgeon in the Hudson River estuary for most of this century. In 1985, following the closure of the Atlantic sturgeon fishery in South Carolina, effort and harvest increased substantially in both New York and New Jersey to satisfy market demand. The commercial fishery harvested different sturgeon life stages in the river and ocean. The Hudson River fishery targeted adults during their spawning run. The ocean fishery along Long Island and New Jersey caught a few non-spawning mature adults but targeted juveniles, most of which were immature coastal migrants.

Consistent with the ASMFC FMP for Atlantic sturgeon, New York began to monitor harvest in 1990 and also initiated a population modeling study to determine acceptable levels of harvest from the Hudson River stock. In 1993-1995, New York regulated the Atlantic sturgeon fishery with size limits, seasons, area closures, and quotas derived from preliminary population modeling. As more data became available, it became apparent that the Hudson River stock was being overfished. In 1996, New York implemented a harvest moratorium, and New Jersey instituted a zero quota.

The American shad gill net fishery in the Hudson River Estuary incidentally captures sub-adult Atlantic sturgeon (< 1m). Atlantic sturgeon bycatch was greatest in the early 1980s and steadily decreased until the mid-1990s, and since then has begun to increase slightly. It is likely that the drop in abundance of juveniles in the late 1980s was in response to accumulated removals of older immature and mature fish from the subpopulation starting in the mid-1980s. Atlantic sturgeon are still recovering from fishing efforts in the late 1980s and early 1990s as apparent from current CPUE abundances of approximately two, which are at least one-fourth of that from 15 years ago (CPUE ~ 8) (CPUE = number per $yd^2 * hrs * 10^{-3}$ of net fished). Similarly, as noted above in Section 3.2.3, the ASMFC TC determined that sink-net fisheries operating in the New York Bight alone have the potential to curtail the recovery of the Hudson River subpopulation (ASMFC TC 2006).

Delaware River – New Jersey, Delaware, Pennsylvania

Landings data in the Delaware Estuary are available from 1880 through the present, with the greatest landings of 3,350 mt occurring in 1888. Overfishing was the most likely cause of the dramatic decline in landings and presumably in abundance of Delaware River Atlantic sturgeon in the early 1900s. No landings were reported after 1993 (1,524 kg), and the directed fishery was closed on April 1, 1998.

Recaptures from approximately 1,700 immature fish tagged by the Delaware DFW in the lower Delaware River from 1991-1997 occurred over a wide range of commercial gears in estuaries and the near-shore ocean from Maine through North Carolina (C. Shirey, Delaware DFW, Pers. Comm. 1998). Lowest survival of sturgeon captured as bycatch occurred in gill nets (87%). Overall, almost 90% of Atlantic sturgeon caught as bycatch were reported to be released alive. Current commercial fisheries in the Delaware Bay gill net fishery include striped bass, American shad, white perch, Atlantic menhaden, and weakfish. The majority of these landings occurs in March and April, but bycatch mortality of sturgeon during this period is typically low (C. Shirey, DNREC, Pers. Comm., 2005).

Chesapeake Bay DPS

Chesapeake Bay and Tributaries (Potomac, Rappahannock, York, James, Susquehanna, Nanticoke) – Maryland, Virginia, Pennsylvania.

During the late 1800s, the Chesapeake Bay supported the second greatest caviar fishery in the eastern United States (Murawski and Pacheco 1977). In the early 1900s, the subpopulation collapsed. Depletion of spawning stocks of Atlantic sturgeon in the Chesapeake Bay and elsewhere is often attributed to a period of high exploitation occurring in the late 1800s (Murawski and Pacheco 1977; Secor and Waldman 1999). Juvenile and subadult Atlantic sturgeon are routinely taken as bycatch throughout the Chesapeake Bay in a variety of fishing gears, including gill nets, pound nets, and fyke nets. Of the hundreds of sturgeon held for examination in the Maryland and Virginia reward programs, only a few fish were determined to be in poor physical condition, although it is important to note that the program was designed to examine live specimens for the reward to be granted (J. Skjeveland and A. Spells, USFWS, Pers. Comm. 1998).

Low rates of sturgeon bycatch mortality were also reported for striped bass gill nets (0-8%) and American shad staked gill nets (4%) within the Chesapeake Bay (Hager 2006). A multitude of other estuarine fisheries exist within the Chesapeake Bay, but these fisheries are not expected to have large rates of bycatch mortality either.

Carolina DPS

Albemarle and Pamlico Sound – North Carolina

Data on Atlantic sturgeon bycatch in the Albemarle and Pamlico Sound come from three sources 1) NCDMF independent gill net surveys (IGNS) that were initially designed to monitor striped bass, 2) NCDMF Observer Program and 3) NC Sea Grant Fishery Resource Grant project that examined sturgeon bycatch in the flounder fishery (White and Armstrong 2000). The Albemarle and Pamlico IGNS used identical gear, which consisted of sinking and floating gill nets ranging from 2.5-10 inch stretched mesh and 439 m long. Only a few fish have been captured in the Pamlico Sound gill net survey since 2000, although 842 Atlantic sturgeon were captured in the Albemarle Sound between 1990-2005. The size range of the fish captured in the Albemarle Sound was from 153 to 1000 mm FL and averaged 472 mm FL. Atlantic sturgeon were entangled in stretched mesh ranging from 2.5 – 9.0 inches, but the majority (76%) were captured in mesh sizes of 2.5-4.5 inches stretched mesh. These mesh sizes are similar to those used by shad/herring and the flounder fisheries.

The NCDMF Observer Program sampled both the Albemarle and Pamlico Sound monthly from April 2004 to December 2005. Thirty Atlantic sturgeon were observed in the Albemarle Sound, and 12 Atlantic sturgeon were observed in the Pamlico Sound. The majority of these observations occurred in large mesh gill nets (> 5 in mesh), where only six trips were made in the small mesh gill net fishery. Overall, Atlantic sturgeon averaged 600 mm TL and ranged from 355 to 820 mm TL. Only two of these individuals were YOY and they were captured in the Albemarle Sound. Overall, five (12%) observed mortalities were reported, occurring in June 2004 and April, August, January, and March 2005.

Similarly, the sturgeon bycatch and mortality in the Albemarle Sound flounder fishery included the capture of 131 Atlantic sturgeon in flounder gill nets fished from 1998-2000 by a single fishermen (White and Armstrong 2000). Of the 131 Atlantic sturgeon captured, no mortalities were reported, although four individuals were noted as having minor injuries. Other fisheries (spiny dogfish, ocean shrimp, flounder, and American shad) in the Albemarle and Pamlico Sound and Cape Fear River reported catches of zero to two sturgeon per fishery per year, including flounder fisheries. These data indicate that underreporting of sturgeon bycatch is occurring at extreme levels in this area. Additional fisheries also exist that could accidentally capture sturgeon in North Carolina including: spot (*Leiostomus xanthurus*), white perch (*Morone americana*), yellow perch (*Perca flavescens*), catfish (*Ictalurus sp.)*, striped bass, and river herring.

Cape Fear River – North Carolina

A gill net survey conducted in the Cape Fear River by UNCW personnel noted that twenty-five percent of sturgeon intercepted (22 of 88 caught) were killed. The gill nets were set one day, checked the second, and retrieved on the third. The greatest mortality occurred during periods of highest water temperature (Moser et al. 1998). Since 2002, this survey has been continued by the NCDMF, and they have reported mortality rates of 37% overall. Similar to earlier findings, mortality was greatest during the summer months (June-August), averaging 49% (34 of 69 sturgeon died) (F. Rohde, NCDMF, Pers. Comm. 2006). There are no estimates of bycatch in fishery dependent surveys.

Winyah Bay (Waccamaw, Great Pee Dee, Black, Sampit) – South Carolina

During the mid-1970s, nearly 50% of all U.S. landings of Atlantic sturgeon came from this area (Smith and Dingley 1984). However, the fishery was almost entirely restricted to coastal waters outside the Bay, making it impossible to assign landed fish to a particular subpopulation. The fishery in South Carolina was closed in 1985. The Bay is currently fished by gill net fishers targeting American shad. This fishery in the Bay has an estimated bycatch of 158 Atlantic sturgeon per year of which 16% die (25) and another 20% are injured to some degree (Collins et al. 1996). Shad fishers also operate within the rivers, but neither effort nor average numbers of Atlantic sturgeon encountered are known. Poaching of adult Atlantic sturgeon has been reported from the Winyah Bay area in recent years. Carcasses of large females have been found with the ovaries (caviar) removed.

Santee and Cooper Rivers – South Carolina

The mouth of Santee River is just south of Winyah Bay and has the largest shad landings in the Southeast (D. Cooke, SCDNR, Pers. Comm. 2006) likely resulting in similar mortality and injury of sturgeon captured in the Winyah Bay shad fishery. Upriver bycatch levels are unknown. The Cooper River also has an active hook and line shad fishery, because gill nets are restricted (D. Cooke, SCDNR, Pers. Comm. 2006).

South Atlantic DPS

ACE Basin (Ashepoo, Combahee, Edisto) – South Carolina

There was a directed commercial fishery for Atlantic sturgeon in this system prior to the 1985 fishery closure. The commercial sturgeon fishery operated in the lower and middle portions of both the Combahee and Edisto rivers. Commercial shad fisheries captured some juvenile Atlantic sturgeon, but most fishermen operate upriver from the areas of greatest abundance during that time of year. The shrimp trawl fishery in St. Helena Sound also captures juveniles, as evident from tag returns.

Port Royal Rivers (Broad and Cosawatchie) – South Carolina

Although a few commercial sturgeon fishers apparently operated in this area prior to 1985, the landing of only one Atlantic sturgeon has been recorded (Smith and Dingley 1984). Little, if any, shad fishing takes place in this system. It is not known whether there is any significant bycatch in the shrimp trawl fishery in this area.

Savannah River – South Carolina and Georgia

During 1989-1991, the commercial shad gill net fishery's bycatch included more endangered shortnose sturgeon than juvenile Atlantic sturgeon, which is considered unusual. Collins et al. (1996) reported that two commercial fishermen collected 14 fish over the period of 1990-1992, averaging seven Atlantic sturgeon/fisher/year. It seems that abundance within the Savannah River is extremely low, as evident from low bycatch and reported captures over the last 15 years. Thus, bycatch may be an issue if abundance is low and fishing effort is high.

Ogeechee River – Georgia

Bycatch in the shad fishery is a concern because evidence suggests that this Atlantic sturgeon subpopulation is stressed and that complete recruitment failure has occurred in some years. Bycatch mortality in the estuarine and lower river shad fishery is of particular concern, but no estimates of take are available.

Altamaha River – Georgia

Juvenile Atlantic sturgeon tagged (N = 1,534) in this river were recaptured primarily by shad gill nets (52%) and shrimp trawls (39%) (Collins et al. 1996). Estimated annual total bycatch of Atlantic sturgeon in the shad gill net fishery in the tidal portion of the river during 1982-1983 averaged 372 sturgeons (both species) (Collins et al. 1996). Percent mortality was not determined in the drift gill nets and was probably minimal. Juvenile Atlantic sturgeon from this river are relatively abundant in comparison to other rivers in the region, so a large percentage of the individuals in winter mixed-stock aggregations on the shelf are likely from this river. Most sturgeon occurring as shrimp trawl bycatch are from mixed-stock aggregations.

Assuming a 10% bycatch mortality rate from drift nets (Stein et al. 2004b), it is expected that 33 Atlantic sturgeon are taken each year as bycatch mortality. This estimate was made in the early 1980s, and it is likely that bycatch has increased as the sturgeon subpopulation has increased.

Satilla River – Georgia

Shad fishing effort is low in this river due to an apparently depleted shad population. However, because the Atlantic sturgeon subpopulation is depleted and highly stressed, any bycatch mortality could have an impact on the subpopulation.

3.2.6. Summary and Evaluation

Commercial fisheries for Atlantic sturgeon in the late 1800s led to significant reductions in population size. Population sizes were further reduced by overfishing during the 1970s through the early 1990s. In 1990, the ASMFC adopted an FMP, which made management recommendations to the coastal states for greater reduction of exploitation. In early 1998, a complete moratorium on possession of Atlantic sturgeon was implemented both in state and Federal waters, which eliminated the threat of both directed catch and bycatch incentives to retain Atlantic sturgeon. Furthermore, Amendment 1 to the ASMFC's FMP formalizes the moratorium as a mandatory compliance measure in all jurisdictions, and it can not be lifted for a spawning stock until 20 protected year classes of mature females are established. Since then, there has been some circumstantial evidence that the moratorium is allowing some recovery as the length of Atlantic sturgeon captured off North Carolina (a mixed stock) has been increasing since 1986, averaging 800 mm TL in 1986 and 1100 mm TL in 2003 (Laney et al. *In prep*). In the same survey, Atlantic sturgeon measuring greater than 1200 mm TL were first captured in 1997, which could possibly be the result of reduced fishing pressure.

Atlantic sturgeon are caught as bycatch in various commercial fisheries along the entire U.S. Atlantic Coast within inland, coastal, and Federal waters. While Atlantic sturgeon caught incidentally can no longer be landed, bycatch could still be a threat if they are injured or killed in the act of being caught. Bycatch mortality rates range between 0-51%, with greatest mortality occurring in sink gill nets. Mortality associated with bycatch has been estimated as high as 1400 deaths a year during the years of 1989 – 2000 in the ocean fisheries ranging from North Carolina to Maine (Stein et al. 2004b). These estimates are no longer considered applicable to contemporary fisheries due to changes in fishery practices and amount of effort (ASMFC TC 2006). However, the ASMFC TC reevaluated the impacts of bycatch on Atlantic sturgeon in 2006 and determined: 1) that bycatch losses principally occur in sink-net fisheries still and 2) the number of observed dead Atlantic sturgeon in sink-net fisheries was similar between the periods of 1995-2000 and 2001-2004[32]. The ASMFC TC also note that any estimate of bycatch from the NMFS ocean observer dataset will be an underestimate because bycatch is under reported in state waters and no observer coverage exist in South Atlantic (NC – FL) US Federal waters. Inland American shad gill net fisheries in two southern locations (Winyah Bay and Altamaha River) were estimated to capture 530 sturgeon, of which 58 Atlantic sturgeon likely die as a result of being captured.

Overall, these estimates suggest that bycatch could have a substantial impact on the status of Atlantic sturgeon, especially in rivers or estuaries that do not currently support a large subpopulation (< 300 spawning adults per year). Atlantic sturgeon are considered to be more

[32] This trends, however, must be interpreted with caution because observer coverage varies year to year and across fishery types (ASMFC TC 2006).

sensitive to fishing mortality as they are a long-lived species, have an older age at full maturity, have lower maximum fecundity values, and 50% lifetime egg production occurs later in life than other coastal species with no fishing mortality (Boreman 1997). Efforts should be made to better quantify data on bycatch levels and fishing effort to determine if specific river population estimates are valid for other river subpopulations as bycatch rates are vastly underreported (ASMFC 2005). This information will also allow more refined estimates of bycatch and potential impacts on the rate of recovery of individual river subpopulations.

There is no evidence that mortality associated with scientific research poses a significant threat to the species or to individual river subpopulations. However, bycatch mortality on the Cape Fear River, NC suggests that methods such as setting gill nets overnight as a method to capture Atlantic sturgeon should be used sparingly and under the appropriate conditions (e.g., water temperature, DO concentrations). There is no evidence that recreational fishing poses a threat to Atlantic sturgeon as the species is not a target of recreational fishers in the United States.

3.3. Competition, Predation, and Disease

3.3.1. Competition and Predation

Atlantic sturgeon are benthic predators and may compete for food with other bottom-feeding fishes and invertebrates including suckers (*Moxotoma sp*.), winter flounder (*Pleuronectes americanus*), tautog (*Tautoga onitis*), cunner (*Tautagolabrus adspersus*), porgies (Sparidae), croakers (Sciaenidae), and stingrays (*Dasyatis sp*.) (Gilbert 1989). Specific information concerning competition between Atlantic sturgeon and other species over habitat and food resources is scarce. There are no known exotic or non-native species that compete directly with Atlantic sturgeon. There is a chance that species such as suckers or other bottom forage fish would compete with Atlantic sturgeon, but these interactions have not been elucidated.

The relationship between the Federally endangered shortnose sturgeon and the Atlantic sturgeon has recently been explored. Shortnose sturgeon are sympatric with Atlantic sturgeon throughout most of their range. Larger, adult shortnose are suspected to compete for food and space with juvenile Atlantic sturgeon in rivers of co-occurrence (Pottle and Dadswell 1979, Bain 1997). Haley and Bain (1997) found that while shortnose and Atlantic sturgeon overlap in their use of the lower estuary, the overall distribution of the two species differed by river kilometers, providing evidence that Atlantic and shortnose sturgeon partition space within the Hudson River despite co-occurrence in channel habitats. This finding is consistent with Kieffer and Kynard (1993) who found that subadult Atlantic and adult shortnose sturgeon in the Merrimack River, MA were spatially separate except for brief use of the same saline reach in the spring. Kahnle and Hattala (1988) conducted late summer-fall bottom trawl collections in the lower Hudson River Estuary from 1981-1986 and found that most shortnose sturgeon occupied rkm 55-60 in water depths of greater than six meters. Even though there was overlap in river miles, there was separation by water depth. In Georgia, the distributions of adult shortnose and juvenile Atlantic sturgeons overlap somewhat, but Atlantic sturgeon tend to use more saline habitats than shortnose sturgeon (G. Roger, formerly Georgia DNR, Pers. Comm. 1998).

Juvenile shortnose sturgeon apparently avoid competition for food with Atlantic sturgeon in the Saint John River, Canada by spatial separation, but adult shortnose may compete for space with similar-sized juvenile Atlantic sturgeon (Dadswell et al. 1984). Haley and Bain (1997) analyzed stomach contents of Atlantic and shortnose sturgeon in the Hudson River using gastric lavage and found clear differences in their diets. Polychaetes and isopods were primary foods retrieved from Atlantic sturgeon while amphipods were the dominant prey obtained from shortnose sturgeon.

Very little is known about natural predators of Atlantic sturgeon. The presence of bony scutes are likely effective adaptations for minimizing predation of sturgeon greater than 25 mm TL (Gadomski and Parsley 2005). Documented predators of sturgeon (*Acipenser sp*.) include sea lampreys (*Petromyzon marinus*), gar (*Lepisosteus sp.*), striped bass, common carp (*Cyprinus carpio*), northern pikeminnow (*Ptychocheilus oregonensis*), channel catfish (*Ictalurus punctatus*), smallmouth bass (*Micropterus dolomieu*), walleye (*Sander vitreus*), grey seal (*Halichoerus grypus*), fallfish (*Semotilus corporalis)* and sea lion (*Zalophus californianus*) (Scott and Crossman 1973, Dadswell et al. 1984, Miller and Beckman 1996, Kynard and Horgan 2002, Gadomski and Parsley 2005, Fernandes 2006, Wurfel and Norman 2006). In contrast to these findings, Moser et al. 2000 tested whether flathead catfish (*Pylodictus olivaris*) preyed on shortnose sturgeon (30 cm) in a controlled system, and despite sturgeon being the only prey available none were consumed. However, Gadomksi and Parsely (2005) tested at what size white sturgeon were preyed upon by channel catfish, northern pikeminnow, walleyes, and prickly sculpins (*Cottus asper*). Their results found that channel catfish (mean TL = 472 mm), northern pikeminnow (mean TL = 464 mm), and prickly sculpin (mean TL = 126 mm) fed on juvenile sturgeon of an average size of 121 mm TL, 134 mm TL, and 50 mm TL, respectively. Oddly, similar size walleye (~470 mm TL) rarely fed on white sturgeon, but juvenile walleye (mean TL = 184 mm) consumed sturgeon with a mean size of 59 mm TL. Gadomski and Parsley (2005) suggest that these findings indicate that predation could play an important role in sturgeon recovery. Similarly, Brown et al. (2005) concluded that the "…introduction of [flathead catfish] has the potential to adversely affect ongoing anadromous fish restoration programs and native fish conservation efforts in the Delaware and Susquehanna basins." The same concern has been stated by fishery management agencies for south Atlantic river basins where flathead catfish are firmly established and have reached significant biomass, significantly altering native fish assemblages and biomass in the process. There is, however, no current evidence that predation rates on Atlantic sturgeon are elevated above "natural" levels.

3.3.2. Disease

Little information is available on diseases of Atlantic sturgeon. Since disease-related mortality is primarily documented in aquaculture facilities rather than in wild populations (Post 1983), the absence of large-scale controlled propagation of Atlantic sturgeon limits availability of disease information.

Appy and Dadswell (1978) examined Atlantic sturgeon from the Saint John River estuary, New Brunswick, Canada for parasites. They documented the presence of trematodes (flatworms), including *Nitzchia sturionis* on the gills of juveniles, *Derogenes varicus* in the esophagus, and *Deropristis hispida* in the spiral valve of the adult Atlantic sturgeon. The nematode (roundworm) *Truttaedacnitis sphaerocephala* and the acanthocephalan (thorny-headed worm) *Echinorhynchus* "gadi" complex were reported in the spiral valve of adults. In the same investigation, an arthropod, *Dichelesthium oblongum*, was observed in the gill cavity of an adult Atlantic sturgeon. The digenetic trematode, *Deropristis hispida* was also reported causing Distomiasis disease in Atlantic sturgeon taken from Raritan Bay, NJ (Murawski and Pacheco 1977). Another case involving a *Nitzchia sturionis* infestation was reported in 2006, this time from an adult held in captivity, which was captured from the main stem of Chesapeake Bay. In the 1995 field collection of Hudson River broodstock by the USFWS-NEFC, Lamar, PA, one adult sturgeon was found harboring *Argulus* sp. This ectoparasite is fairly common on juvenile Atlantic sturgeon in Georgia and South Carolina (M. Collins, unpublished data). However, Hoffman (1967) states that parasites are always present in natural populations, and fish are infected by a considerable range of species. Epizootics caused by parasites do not normally occur unless some environmental event alters the equilibrium between the parasites and the free-living community.

The Fish Health Unit-NEFC maintains files from 65 diagnostic cases dealing with Atlantic sturgeon captured in the wild and held at the NEFC. Files are also maintained on their hatchery-reared offspring. The majority of cases involved fish from the NEFC, Fish Technology Section, in Lamar, PA, while two cases involved fish received from the Harrison Lake National Fish Hatchery in Charles City, VA and one from Maryland. The data comprise details on disease assays conducted on 17 captive adults, 65 juveniles and subadults, 125 yearlings, 80 fingerlings, and 200 fry sampled since 1991. The common fish fungus *Saprolegnia* species was diagnosed on fish in seven cases and on Atlantic sturgeon eggs during incubation. External protozoan parasite infestations reported from the skin and gills include *Chilodonella*, *Ichthyobodo* (Costia), *Trichodina* and *Colponema* species. Internally, *Hexamita* species was observed in the intestinal tract. Numerous bacteria were also isolated from these cases. The following list comprises those species of bacteria that have been known to cause disease in other fish species and have been implicated as a possible cause of disease in a particular diagnostic case: *Streptococcus* sp.; *Vibrio* sp.; *Aeromonas hydrophila*; S*erratia liquqefaciens*; *Vibrio anguillarum*; *Flavobacterium columnare* (*Flexibacter columnaris*); *Aeromonas salmonicida*; and *Pasteurella haemolytica*. An unknown anomaly involving overinflation of the swim bladder in 0+, 2, and 3-year old cultured Atlantic sturgeon led to equilibrium problems and eventual death for many of these fish. Nutritional deficiencies were suspected, but no conclusive diagnosis was made (Fish Health Section case history records, 1991-1997). Overinflated swim bladders in age 0+ progeny cultured from eggs taken from Saint John River adults has also been observed (M. Litvak, University of New Brunswick, Pers. Comm. 1998). An unidentified systemic fungus infection was observed histologically through many organs of fingerling Atlantic sturgeon which were subjects in a feeding experiment (V. Blazer, Leetown Science Center, Pers. Comm. 1998). *Edwardsiella tarda* was isolated from Atlantic sturgeon fingerlings within ten days of a shipment in Florida, in 1999. Affected fish had not been handled well during shipment and may have been subject to high water temperatures while in transit due to flight delays en route. Mortality from this epizootic approached 50 % of the population (R. Francis-Floyd, Florida Sturgeon Culture Risk Assessment Workshop, 2000 Proceedings).

At the USFWS Bear's Bluff Hatchery, South Carolina, shortnose sturgeon that were collected several years ago as broodstock have been exhibiting some signs of stress from an unknown vector. The symptoms have been present since the hatchery received the shortnose broodstock, and only appear during the fall when shortnose sturgeon exhibit lesions on their body. The larger broodstock fish become lethargic, while offspring sometimes die. Hatchery officials have sent tissue samples of the lesions to two different labs, each have noted that the health issue is related to a virus, but each lab cited a different virus as the cause. In at least one year following the lab experiments, however, viruses were not detected and thus the symptoms could have been related to bacteria. Overall, the hatchery officials do not know what is causing the problem, but they do think it related to the environment conditions within Bears Bluff lab, because the sturgeon do not exhibit the same symptoms at a separate hatchery facility.

Atlantic sturgeon were also experimentally challenged with white sturgeon (*Acipenser transmontanus*) herpesvirus type-2 (WSHV-2). Waterborne exposure produced mortality, as well as clinical signs of infection, including hemorrhagic lesions and ulcers on both dorsal and ventral surfaces and particularly around the mouth (R. P. Hedrick and T. S. McDowell, University of California at Davis, Pers. Comm. 1998).

Susceptibility of Atlantic sturgeon to another west coast virus, the white sturgeon iridovirus (WSIV), is suspected but has not been demonstrated. WSIV is of concern because it is assumed to be carried by wild sturgeon and has been shown to cause significant mortalities in cultured sub-yearling white sturgeon (LaPatra et al. 1994). Transfers of carrier fish from the West Coast to the East Coast could create serious consequences for future Atlantic sturgeon aquaculturists and may pose a significant threat to East Coast populations of wild sturgeon if they, in fact, are shown to be susceptible to the virus.

LaPatra et al. (1995) demonstrated that a rhabdovirus, infectious hemotopoietic necrosis virus (IHNV), can be carried by white sturgeon. IHNV is one of the most lethal diseases of salmonids, but currently the disease is confined to the western United States. While LaPatra et al. (1995) states no mortality has been reported in sturgeon exposed to IHNV, there is concern among fish health biologists that any movement of sturgeon carrying the IHNV virus to the East Coast could spread the disease to salmonid populations with potentially devastating consequences.

The potential spread of fish pathogens from one geographic area to another is possible. Currently, there are several regulations or documents that apply to movement of fish or fish eggs from one area within the United States or for import into the United States from other countries. Included among them are: 1) 50 Code of Federal Regulations, Part 16 – Salmonid Importation Regulations; 2) the Lacey Act (18 U.S.C.); 3) the USFWS Health Policy (713 FW 1-4); 4) North Atlantic Salmon Conservation Organization (NASCO) – Protocols for the Introduction and Transfer of Salmonids (NAC [92]24 and NAC [94]14); 5) Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES); 6) laws promulgated by individual states; and 7) the ESA (16 U.S.C.). Although 50 CFR-Part 16, the USFWS Health Policy, and the NASCO Protocols control movement of salmonid fish and eggs and require fish health inspection prior to shipment, they offer no protection from pathogens that might be transferred to Atlantic sturgeon populations from movement of infected fish or eggs of non-salmonid species. All sturgeon species worldwide were afforded CITES protection on April 1, 1998, and Atlantic sturgeon received protection in 1975. However, CITES permitting requirements for moving sturgeon from one country to another do not have a fish health component (M. Maltese, USFWS, Pers. Comm. 1998). The ESA might be used to prevent non-listed sturgeon species from being moved from one geographic area to another or to require disease certification prior to movement, but it would be difficult to show why such action would be necessary to protect a listed sturgeon species given the current state of knowledge concerning Atlantic sturgeon disease or disease susceptibility. The Lacey Act makes it unlawful to import, export, sell, acquire, or purchase fish, wildlife or plants taken, possessed, transported, or sold: 1) in violation of U.S. or Indian law or 2) in interstate or foreign commerce involving any fish, wildlife, or plants taken, possessed or sold in violation of state or foreign law. There are no Federal laws regulating the movement of infected fish or eggs or requiring fish health inspections of non-salmonid species.

The potential for non-indigenous pathogens emanating from aquaculture facilities is being addressed by the ASMFC. Section 3.6.2 of Amendment 1 to the Interstate Fishery Management Plan for Atlantic Sturgeon recommends that public aquaculture facilities should be certified as disease-free. The Amendment further recommends that member states submit annual reports on the status of aquaculture operations and disease-free certification.

Protection of Atlantic sturgeon from non-indigenous pathogens would have to come from state laws, but because laws among the states along the eastern seaboard vary widely, they offer no real protection for the species over its entire range. For example, some states require a permit before any fish can be imported across their borders, while others require a permit only if a species is on their exotic species list (sturgeon are generally not on those lists). Also, some states do not regulate what fish might be reared by aquaculturists but require a permit only if the fish are to be stocked, and others have no restrictions. Permit requirements by the states are aimed principally at preventing introduction of non-native species and generally do not involve a fish health component.

Infection could conceivably arise from white sturgeon or other sturgeon species sold as pets in the aquarium trade and subsequently released into the wild. White sturgeon have been imported into North Carolina and possibly other East Coast states and sold in the aquarium trade. It is unclear whether a ban imposed by a fishery management agency on importation of a species would apply to the pet industry.

3.3.3. Summary and Evaluation

As benthic feeders, Atlantic sturgeon may compete with other bottom-feeding fishes and invertebrates for food, but there is no evidence of abnormally elevated interspecific competition. A potentially competitive relationship between shortnose and Atlantic sturgeon in the Hudson River is the only one studied in any detail. Results indicate that while shortnose and Atlantic sturgeon may overlap in their use of channel habitats, there are differences in their distribution by river kilometers, by depth, and the two species exhibit clear differences in diet.

While concerns have been raised regarding the potential for increased predation on juvenile Atlantic sturgeon by introduced flathead catfish (Brown et al. 2005 and others), Atlantic sturgeon subpopulations seem to be coexisting with flatheads in the Cape Fear River, NC, and Altamaha River, GA (where flatheads have been present for many years), at least in the absence of any directed fisheries for Atlantic sturgeon. Gadomski and Parsley (2005), however, have shown that catfish and other species do prey on juvenile sturgeon; thus, further research is warranted to determine at what level, if any, flatheads and other exotic species prey upon juvenile Atlantic sturgeon and to what extent such predation is affecting the sturgeon subpopulations.

While some disease organisms have been identified from wild Atlantic sturgeon, they are unlikely to threaten the survival of the wild populations. Disease organisms commonly occur among wild fish populations, but under favorable environmental conditions, these organisms are not expected to cause population-threatening epizootics. There is concern that non-indigenous sturgeon pathogens could be introduced, most likely through aquaculture operations. Due to this threat of impacts to wild populations, the ASMFC recommends requiring any sturgeon aquaculture operation to be certified as disease-free.

The aquarium industry is another possible source for transfer of non-indigenous pathogens or non-indigenous species from one geographic area to another, primarily through release of aquaria fish into public waters. With millions of aquaria fish sold to individuals annually, it is unlikely that such activity could ever be effectively regulated. Definitive evidence that aquaria fish could be blamed for transmitting a non-indigenous pathogen to wild fish (sturgeon) populations would be very difficult to collect (J. Coll and J. Thoesen, USFWS, Pers. Comm. 1998).

3.4. Existing Regulatory Authorities, Laws and Policies

As a wide-ranging anadromous species, Atlantic sturgeon are subject to numerous Federal (U.S. and Canadian), state and provincial, and inter-jurisdictional laws, regulations, and agency activities. Following is a list of the most important laws and government policies affecting Atlantic sturgeon and its habitat.

3.4.1 International Authorities

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

To ensure that commercial demand does not threaten their survival in the wild, many animal and plant species are protected through a system of permits by this international treaty that regulates trade in listed species. The full species *Acipenser oxyrinchus* has been listed under CITES Appendix II since 1975 (50 CFR 23.23). Appendix II includes species that may become threatened with extinction if trade is not regulated. Appendix II specimens require an export permit from the country of origin or re-export. Such permits are issued as long as the exportation is not detrimental to species' survival and the specimens were legally acquired. The USFWS Office of Management Authority administers CITES in the U.S. and processes any applications for Atlantic sturgeon export permits.

Canadian Authorities

Jurisdiction for sturgeon fisheries in Canada rests with the Canadian Department of Fisheries and Oceans (DFO) in the Maritime Provinces and with the provincial government in Quebec (B. Jessop, DFO, Pers. Comm. 1998).

Maritime Provinces

As of 2006, there were eight commercial licenses for directed Atlantic sturgeon harvest in the Maritimes, eight on the Saint John River, New Brunswick and one on the Shubenacadie River, Nova Scotia (R. Bradford, DFO, Pers. Comm. 2006). There are no sturgeon licenses in the Gulf of Saint Lawrence areas of New Brunswick, Nova Scotia, or Prince Edward Island, although small amounts of bycatch are reported (less than 0.3 tons per year in the last 10 years). Licenses are non-transferable and terminate with the death of the existing licensee, and new licenses are not available. Each license authorizes specific amounts of gear, with the nine New Brunswick licensees authorized a total of 2800 meters of gill net, while the single Nova Scotia licensee is authorized two set gill nets of unspecified length. The legal minimum mesh size is 33 cm (13 inches), the minimum size limit for fish harvest is 120 cm (48 inches), and the season is closed from June 1-30 to protect spawning fish. Retention of sturgeon bycatch has been prohibited throughout the Maritime Provinces since 1995 (B. Jessop, DFO, Pers. Comm. 1998).

Quebec

The Quebec Ministere de l'Environnement et de la Faune regulates the Saint Lawrence River Atlantic sturgeon fishery. A total harvest quota of 6,000 fish (approximately 60 mt) has been in effect since the spring of 1997, along with a size limit of 100-150 cm TL. Harvest quotas are enforced by issuing a specified number of tags to each commercial fisherman. The fishing season runs from May 1 – September 30, and all fishing zones are in brackish waters of the estuary (F. Caron, Quebec Ministere de l'Environnement et de la Faune, Pers. Comm. 1998).

3.4.2 U.S. Interstate/Federal Authorities

Atlantic States Marine Fisheries Commission (ASMFC) and Enabling Legislation

Authorized under the terms of the Atlantic States Marine Fisheries Compact, as amended (P.L. 81-721), the purpose of the ASMFC is to promote the better utilization of the fisheries (marine, shell, and anadromous) of the Atlantic seaboard "by the development of a joint program for the promotion and protection of such fisheries, and by the prevention of the physical waste of the fisheries from any cause."

Given management authority in 1993 under the Atlantic Coastal Fisheries Cooperative Management Act (16 U.S.C. 5101-5108), the ASMFC may issue interstate FMPs that must be administered by state agencies.[33] If the Commission believes that a state is not in compliance with a coastal FMP, it must notify the Secretaries of Commerce and Interior. If the Secretaries find the state not in compliance with the management plan, the Secretaries must declare a moratorium on the fishery in question. To date, this has only happened once when a state was not found in compliance with the striped bass coastal FMP.

[33] ASMFC was given management authority earlier in 1984 under the Atlantic Striped Bass Management Act, but authority was limited to that fishery. The Atlantic Coastal Fisheries Cooperative Management Act of 1993 and amendments gave ASMFC management authority for other interstate coastal species.

In 1998, the ASMFC amended the 1990 Atlantic Sturgeon Management Plan and established a moratorium for Atlantic sturgeon commercial fishing until 20 year classes of adults were established, thus closing the fishery for 20 – 40 years. Since the closure of the fishery, some subpopulations have shown signs of possible recovery while others have not.

Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA)

Authorized under the terms of the ASMFC Compact, as amended (P.L. 103-206), the Secretary of Commerce can implement EEZ regulations that are compatible to ASMFC FMPs in the absence of an approved Magnuson-Stevens FMP. Also, funding is provided to ASMFC, Atlantic Coast states, NMFS, and USFWS to conduct activities that are supportive of ASMFC FMPs. As mentioned previously, effective May 27, 1999, NMFS prohibited the take of Atlantic sturgeon in the EEZ. This rule followed the closure of the state waters under the ASMFC moratorium on the Atlantic sturgeon fishery.

Magnuson-Stevens Act (16 U.S.C. 1801 et. seq.)

This Act provides regional fishery management councils with authority to prepare plans for the conservation and management of Federally-managed fisheries in the EEZ, including the establishment of necessary habitat conservation measures. Essential Fish Habitat (EFH), including freshwater habitats for anadromous species, may also be delineated for species with approved Federal FMPs. Federal FMPs, approved by regional fishery management councils (which are different from the ASMFC), focus on management in the EEZ (3-200 miles) rather than state waters. An alternative mechanism for restricting harvest in the EEZ exists through NMFS' regulations based on recommendations in an ASMFC-approved FMP. Federal fishery management plans prepared under this statute must establish standardized reporting methodologies to assess the amount and type of bycatch occurring in the fishery and include conservation and management measure that, to the extent practicable, minimize unavoidable bycatch and bycatch mortality.

The Magnuson-Stevens Act was reauthorized on October 11, 1996 and again in 2006. The 1996 reauthorization directed the Regional Fishery Management Councils (Councils) and the Secretary of Commerce to describe and identify EFH in fishery management plans, including identification of adverse impacts from both fishing and mechanisms to enhance EFH. Although EFH is identified only for species managed under a Federal FMP, Councils are required to comment on any activity that is likely to substantially affect the habitat of an anadromous fishery resource under its authority. An anadromous fishery resource under a Council's authority is defined as an anadromous species that inhabits water under the Council's authority at some time during its life. The South Atlantic Fishery Management Council has decided to include a description of essential fish habitat for both anadromous and catadromous species in its Habitat Plan, which includes Atlantic sturgeon habitat.

The 2006 reauthorization sought to preserve and strengthen the Councils by establishing Council training programs, clarifying MSAs conflicts of interest and recusal requirements, and ensured that Council members and Scientific and Statistical Committees (SSC) disclose any financial conflicts of interest. The MSA reauthorization also mandated the use of allowable catch levels to prevent overfishing and preserve sustainable harvest; established national guidelines for limited access privilege programs; improved the uniformity of decision making for FMPs and aligns them with National Environmental Policy Act processes; improved data collection for better management; increased the role of science in decision making processes by defining roles of the SSC; and strengthened leadership in international conservation and management activities.

Lacey Act 1981 (16 U.S.C 3371-3378)

In addition to foreign, Federal, or tribal prohibitions, the Lacey Act makes it a Federal crime to import, export, and engage in interstate transport of any fish or wildlife taken in violation of a state law. By providing for Federal prosecution of state fish and wildlife laws and more stringent penalties, the Lacey Act further deters interstate transport of illegally-possessed Atlantic sturgeon.

Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531-1543)

The Endangered Species Act provides for the conservation of plant and animal species Federally listed as threatened or endangered. Atlantic sturgeon, as an unlisted species, may derive benefits from the Federal agency consultation requirements for the endangered shortnose sturgeon, where their ranges and conservation needs coincide. For example, restrictions imposed on ACOE dredging activities to protect shortnose sturgeon may also provide some protection to Atlantic sturgeon (R. St. Pierre, USFWS, Pers. Comm. 1998). To predict impacts from a proposed activity, Federal agencies may agree to fund studies to learn how a threatened or endangered species uses an area. In rivers, such as the Tar-Pamlico, Neuse, and Roanoke rivers in North Carolina, where only Atlantic sturgeon are documented to occur, no indirect protection via the ESA is afforded (S. Bolden, NMFS, Pers. Comm. 2006). Also, Atlantic sturgeon may not benefit from seasonal dredging restrictions to protect shortnose sturgeon spawning as spawning seasons for the two species do not coincide (T. Squiers, MEDMR, Pers. Comm. 1998).

Federal Power Act (FPA) (16 U.S.C. 791-828) and amendments

This Act, as amended, provides for protecting, mitigating damages to, and enhancing fish and wildlife resources (including anadromous fish) impacted by hydroelectric facilities regulated by FERC. Applicants must consult with state and Federal resource agencies who review proposed hydroelectric projects and make recommendations to FERC concerning fish and wildlife and their habitat, e.g., including spawning habitat, wetlands, instream flows (timing, quality, quantity), reservoir establishment and regulation, project construction and operation, fish entrainment and mortality, and recreational access. Section 10(j) of the Act provides that licenses issued by FERC contain conditions to protect, mitigate damages to, and enhance fish and wildlife based on recommendations received from state and Federal agencies during the licensing process. With regard to fish passage, Section 18 requires a FERC license to construct, maintain, and operate fishways prescribed by the Secretary of the Interior or the Secretary of Commerce. Under the Act, others may review proposed projects and make timely recommendations to FERC to represent additional interests. Interested parties may intervene in the FERC proceeding for any project to receive pertinent documentation and to appeal an adverse decision by FERC.

While the construction of hydroelectric dams contributed to some historic losses of Atlantic sturgeon spawning habitat, only a few new dams have been constructed in the range of this species in the last 50 years. The lack of successful fish passage devices for Atlantic sturgeon and the degradation of upstream habitat due to impoundment of the former free-flowing river, limit opportunities for this species to benefit from FPA fishway requirements during the re-licensing of existing hydroelectric dams.

Anadromous Fish Conservation Act (16 U.S.C. 757a-757f) as amended

This law authorizes the Secretaries of Interior and Commerce to enter into cost sharing with states and other non-Federal interests for the conservation, development, and enhancement of the nation's anadromous fish. Investigations, engineering, biological surveys, and research, as well as the construction, maintenance, and operations of hatcheries, are authorized. Surveys for Atlantic and shortnose sturgeon in New Hampshire (T. Squiers, MEDMR, Pers. Comm. 1998), tag and release studies in Delaware Bay (C. Shirey, Delaware DFW, Pers. Comm. 1998), and research on juvenile Atlantic sturgeon in the ACE Basin, SC (M. Collins, SC DNR, Pers. Comm. 1998) are examples of work funded by NMFS under this law. Research on other species conducted under this act has yielded data on Atlantic sturgeon; for example, striped bass studies in New York have furnished information on juvenile Atlantic sturgeon (A. Kahnle, New York State DEC, Pers. Comm. 1998).

Fish and Wildlife Coordination Act (FWCA) (16 U.S.C. 661-666)

The FWCA is the primary law providing for consideration of fish and wildlife habitat values in conjunction with Federal water development activities. Under this law, the Secretaries of Interior and Commerce may investigate and advise on the effects of Federal water development projects on fish and wildlife habitat. Such reports and recommendations, which require concurrence of the state fish and wildlife agency(ies) involved, must accompany the construction agency's request for congressional authorization, although the construction agency is not bound by the recommendations. Typical FWCA recommendations for maintenance dredging include construction "windows" to avoid times and locations where Atlantic sturgeon may be spawning.

The FWCA applies to water-related activities proposed by non-Federal entities for which a Federal permit or license is required. The most significant permits or licenses required are Section 404 and discharge permits under the Clean Water Act and Section 10 permits under the Rivers and Harbors Act. The USFWS and NMFS may review the proposed permit action and make recommendations to the permitting agencies to avoid or mitigate any potential adverse effects on fish and wildlife habitat. These recommendations must be given full consideration by the permitting agency but are not binding.

Federal Water Pollution Control Act, and amendments (FWPCA) (33 U.S.C. 1251-1376)

Also called the "Clean Water Act," the FWPCA mandates Federal protection of water quality. The law also provides for assessment of injury, destruction, or loss of natural resources caused by discharge of pollutants.

Of major significance is Section 404 of the FWPCA, which prohibits the discharge of dredged or fill material into navigable waters without a permit. Navigable waters are defined under the FWPCA to include all waters of the United States, including the territorial seas and wetlands adjacent to such waters. The permit program is administered by the ACOE. The EPA may approve delegation of Section 404 permit authority for certain waters (not including traditional navigable waters) to a state agency; however, the EPA retains the authority to prohibit or deny a proposed discharge under Section 404 of the FWPCA.

The FWPCA (Section 401) also authorizes programs to remove or limit the entry of various types of pollutants into the nation's waters. A point source permit system was established by the EPA and is now being administered at the state level in most states. This system, referred to as the National Pollutant Discharge Elimination System (NPDES), sets specific limits on discharge of various types of pollutants from point source outfalls. A non-point source control program focuses primarily on the reduction of agricultural siltation and chemical pollution resulting from rain runoff into the nation's streams. This control effort currently relies on the use of land management practices to reduce surface runoff through programs administered primarily by the Department of Agriculture.

Like the Fish and Wildlife Coordination and River and Harbors Acts, Sections 401 and 404 of the FWPCA have played a role in reducing discharges of pollutants, restricting the timing and location of dredge and fill operations, and affecting other changes that have improved Atlantic sturgeon habitat in many rivers and estuaries over the last several decades. Examples include reductions in sewage discharges into the Hudson River (A. Kahnle, New York State DEC, Pers. Comm. 1998) and nutrient reduction strategies implemented in the Chesapeake Bay (R. St. Pierre, USFWS, Pers. Comm. 1998).

Rivers and Harbors Act of 1899

Section 10 of the Rivers and Harbors Act requires a permit from the ACOE to place structures in navigable waters of the United States or modify a navigable stream by excavation or filling activities.

National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321-4347**)**

NEPA requires an environmental review process of all Federal actions. This includes preparation of an environmental impact statement for major Federal actions that may affect the quality of the human environment. Less rigorous environmental assessments are reviewed for most other actions, while some actions are categorically excluded from formal review. These reviews provide an opportunity for the agency and the public to comment on projects that may impact fish and wildlife habitat.

Coastal Zone Management Act (16 U.S.C. 1451-1464) and Estuarine Areas Act

Congress passed policy on values of estuaries and coastal areas through these Acts. Comprehensive planning programs, to be carried out at the state level, were established to enhance, protect, and utilize coastal resources. Federal activities must comply with the individual state programs. Habitat may be protected by planning and regulating development that could cause damage to sensitive coastal habitats.

Federal Land Management and Other Protective Designations

Protection and good stewardship of lands and waters managed by Federal conservation agencies, such as the Departments of Defense and Energy (as well as state-protected park, wildlife and other natural areas), contributes to the health of nearby aquatic systems that support important Atlantic sturgeon spawning and nursery habitats. Relevant examples include the Great Bay, Rachel Carson's and ACE Basin National Estuarine Research Reserves, Department of Defense properties in the Chesapeake Bay, and many National Wildlife Refuges.

Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA), Titles I and III and the Shore Protection Act of 1988 (SPA)

The MPRSA protects fish habitat through establishment and maintenance of marine sanctuaries. This Act and the SPA regulate ocean transportation and dumping of dredge materials, sewage sludge, and other materials. Criteria that the ACOE uses for issuing permits include considering the effects dumping has on the marine environment, ecological systems and fisheries resources.

Framework for the Management and Conservation of Paddlefish and Sturgeon Species in the United States

Prepared in 1993 by the National Paddlefish and Sturgeon Steering Committee (including representatives of the USFWS, several state agencies, the private aquaculture community, and academia), this document proposed a framework for the conservation of eight species of paddlefish and sturgeon (including both *Acipenser oxyrinchus* sub-species). The document carries no regulatory force but is intended to foster partnerships among agencies and organizations with an interest in the conservation of sturgeon species. Strategies include research on life history, population characteristics, and habitat requirements; development and coordination of culture and stocking protocols; habitat protection; mitigation of threats from over-harvest; public information and education; and national coordination of conservation efforts.

3.4.3. State Authorities

As noted under discussion of interstate authorities above, all fifteen states, the District of Columbia, and the Potomac River Fisheries Commission have closed their directed fisheries and prohibited landings of Atlantic sturgeon. Prohibitions on sturgeon landings in at least six of these jurisdictions (Pennsylvania, District of Columbia, Potomac River Fisheries Commission, Virginia, South Carolina, and Florida) pre-date 1990. At least four states presently list the

Atlantic sturgeon under state statutes for the recognition and/or protection of rare species. Atlantic sturgeon are listed as endangered in Massachusetts and as threatened in Rhode Island, Connecticut, and Pennsylvania (Northeast Nongame Technical Committee 1996). Protections afforded under the Massachusetts Endangered Species Act include a ban on take in rivers and within the three-mile offshore limit, as well as prohibitions on possession (T. French, Massachusetts DFW, Pers. Comm. 1998). Similar protections are provided under the Connecticut statute: the Connecticut DEP is required to review any project that requires a state permit and may affect Atlantic sturgeon (J. Victoria, Connecticut DEP, Pers. Comm. 1998). Recognition of their vulnerable status is the primary protection afforded to threatened species under the Rhode Island endangered species statute (C. Raithel, Rhode Island DFW, Pers. Comm. 1998). Pennsylvania law forbids taking, catching, killing, possessing, importing or exporting from the Commonwealth, selling, offering for sale any threatened species without a special permit (A. Shields, Pennsylvania Fish and Game Commission, Pers. Comm. 1998).

A variety of state laws may be employed by authorities to reduce threats of accidental release and transmission of diseases into wild Atlantic sturgeon populations from non-indigenous and cultured Atlantic sturgeon. For example, Georgia state law requires wild animal licenses that could be conditioned to prevent escapement for fish held in a system from which water may be discharged. Georgia state regulations also authorize state agencies to prohibit importation of fish or fish eggs that might spread diseases harmful to endemic fish populations (Shipman 1998).

In addition to laws focusing directly on harvest and other population management practices, state and local governments implement a wide variety of laws and regulations that effect the habitat of Atlantic sturgeon. These include laws effecting development in sensitive watersheds, forest practices, waste water discharges, and other activities. Efficacy of these laws to protect sturgeon habitat may be extremely variable and depends on the standards imposed, the types of activities and land areas and water designations by states, such as the designations of Significant Tidal Habitat on the Hudson River in New York and of Primary Nursery Areas in North Carolina contribute to Atlantic sturgeon habitat quality (A. Kahnle, New York State DEC, Pers. Comm. 1998).

3.4.4. Summary and Evaluation

Current regulatory mechanisms have effectively removed threats from legal, directed harvest in the U.S. as well as incentives for retention of bycatch. Formal adoption of a long-term coast-wide moratorium by the ASMFC occurred in June 1998. As requested by ASMFC, the EEZ was also closed by NMFS in 1999. Atlantic sturgeon fisheries in Canada are almost exclusively located at, or above, estuarine reaches of the rivers, and there is currently no evidence that sturgeon of U.S. origin migrate into Canadian rivers in great numbers.[34] Therefore, it is unlikely that Canadian fisheries pose a meaningful threat to fish of U.S. origin.

State and Federal agencies are actively employing a variety of legal authorities to implement proactive restoration activities for this species, and coordination of these efforts is being furnished through the ASMFC. Due to existing state and Federal laws, water quality and other habitat conditions have improved in many riverine habitats, although many systems still have

[34] Only one of 99 Atlantic sturgeon tagged in the Kennebec was returned in Canadian waters.

DO and toxic contaminants issues and habitat quality continues to be affected by dredging and/or alternating natural flow conditions. Remediation of continuing habitat deficiencies will require improved understanding of Atlantic sturgeon habitat needs, the factors adversely affecting habitat, and aggressive implementation of aquatic habitat protection measures.

3.5. Other Natural or Manmade Factors Affecting its Continued Existence

3.5.1. Impingement and Entrainment

The withdrawal of water directly from a river or water body for commercial uses may negatively impact the recovery of Atlantic sturgeon, as larvae, YOY, or small juveniles may become impinged on intake screens or entrained.[35] These impacts can be especially severe when intake structures are located in or near spawning grounds where smaller life stages of fishes are less active (i.e. drift) and are susceptible to intake flows (Carter and Reader 2000). Along the range of Atlantic sturgeon, most, if not all, subpopulations are at risk of possible entrainment or impingement in water withdrawal intakes for commercial uses, municipal water supply facilities, and agricultural irrigation intakes. For example, in North Carolina, over two billion gallons of water per day were withdrawn from the Cape Fear, Neuse, Tar, and Roanoke rivers in 1999 by agriculture (39 Million Gallons a Day (MGD)) and non-agricultural (1,982 MGD) industries (NCDNR 2006). However, the impacts of water withdrawal are dependent on the species, time of year, location of the intake structure, and the strength of the intake current; thus, it is hard to provide general impact estimates as each site is unique. Currently, there are only three surveys that have shown the impacts of water withdrawal on Atlantic sturgeon: 1) Hudson River Utility Surveys, 2) Delaware River Salem Power Plant survey, and 3) Edwin I. Hatch Nuclear Power Plant:

- The Hudson River has six power plants located between river km 34 – 74, which overlaps with known nursery grounds for Atlantic sturgeon larvae and early juveniles (located at rkm 43 – 100). Of the six power plants located in this area, the Danskammer, Roseton, Lovett, and Indian Point pose the greatest risk to Atlantic sturgeon, as the Bowline Point is located farther downriver and withdraws water from a collection pond. Intensive surveys (24 hr/day, four to seven days/week, and 10 – 12 weeks/year during the spring) conducted from 1972- 1998 examining entrainment and impingement of fish species only reported eight entrained sturgeon (larvae) and 63 impinged shortnose sturgeon (majority 200 – 700 mm) (Applied Science Associates 1999).[36] Entrained sturgeon species only occurred at the Danskammer Point Plant where four shortnose larvae and four unidentified sturgeon yolk sac larvae were observed during the spring in 1983 and 1984. Impingement of sturgeon occurred most often at the Danskammer Point Plant, averaging 4.2 – 5.2 impinged fish per year, followed by Indian Point (1.5 – 2.3 fish/year), Roseton (1.5 – 1.8 fish/year), Bowline Point (0 – 0.9 fish/year) and Lovett Point (0 fish per year). During the periods of 1989 to 1996, a total of five shortnose sturgeon was impinged

[35] Impingement is the entrapment of an organism on a water intake structure due to negative pressure (e.g., held against an intake filter screen). Entrainment is when the organism is entrapped within the intake structure.

[36] Only a few of these power plants conducted impingement and entrainment surveys throughout the period of 1972-1998, others conducted survey until take was found to be insignificant or intake structures were modified to reduce take.

(0.6/year) from the Roseton and Danskammer plants. Other plants (Bowline Point and Lovett) reported zero impingements during this period or were not sampled (Indian Point 1991-1996 no sampling).

- The Salem power plant located on the Delaware River/Bay has the potential to take sturgeon species via impingement or entrainment. During the years of 1991 – 1999, a total of eight shortnose sturgeon were reported as impinged. These fish were all juveniles greater than 400 mm TL.

- The Edwin I. Hatch Nuclear power plant (HNP) is located 11 miles north of Baxley, Georgia. The Plant uses a closed-loop system for main condenser cooling that withdraws from, and discharges to the Altamaha River via shoreline intake and offshore discharge structures. Preoperational drift surveys were conducted weekly from February through May in 1973 and every six weeks from June through December 1973. Cataostomids, cyprindis, and centrarchids were the dominant ichthyoplankton families collected. Only two *Acipenser* sp. larvae were collected during the drift surveys. Entrainment samples at HNP were collected for the years 1975, 1976, and 1980. Samples were collected weekly during 1975 and 1976, and monthly in 1980. No *Acipenser* sp. were observed in the entrainment survey (Sumner 2004).

Though most rivers have multiple intake structures which remove millions of gallons a day during the spring and summer months, it is believed that the migratory behavior of larval sturgeon allows them to avoid intake structures for the most part, since migration is active and occurs in deep water (Kynard and Horgan 2002). Effluent from these facilities can also affect subpopulations, as some facilities release heated water that acts as a thermal refuge during the winter months, but drastic changes in water temperature have the potential to cause mortality.

3.5.2. Ship Strikes

Dredging provides safe passage for commercial shipping and recreational boat traffic. With the increase in boating traffic, the potential for sturgeon to be struck by boats is greater, and this seems to happen commonly. Without surveys in place, ten adult Atlantic sturgeon were found in the Delaware River in 2004, six in 2005, and six to date in 2006 that were evidently struck by a passing ship or boat (Kahnle et al. 2005, Murphy 2006) (Figure 23). This observation is not unique as four to eight sturgeon are reported each spring to DFW, and these fish are usually 120 cm to 240 cm in length. Based on the external injuries observed, it is suspected that these strikes are from ocean going vessels and not smaller boats, although at least one fisher reported hitting a large sturgeon with his small craft (C. Shirey, DNREC, Pers. Comm. 2005). Similarly, five sturgeon were reported to have been struck by commercial vessels within the James River, VA in 2005, and one strike per five years is reported for the Cape Fear River. Subpopulations may be affected by these incidental strikes. It is unknown what the overall impact of boat strikes is to Atlantic sturgeon subpopulations, but in small subpopulations (< 300 spawners/year) the loss of any spawning adults could have a substantial impact on recovery. Locations that support large ports and have relatively narrow waterways seem to be more prone to ship strikes (e.g., Delaware, James, and Cape Fear rivers).

3.5.3. Artificial Propagation and Atlantic Sturgeon

Artificial propagation of Atlantic sturgeon for use in restoration of extirpated subpopulations or recovery of severely depleted wild subpopulations has the potential to be both a threat to the species and a tool for recovery. If conducted both in accordance with published guidelines and protocols (ASMFC 2006) and as part of a planned recovery program, artificial propagation may increase population numbers. Artificial propagation for commercial purposes can also be beneficial or detrimental to the species. Providing a cultured product to the market can remove the need to legally and illegally harvest wild stocks. However, aquaculture can make enforcement of a ban on possession of wild stock more difficult by enabling the disguising of poached wild animals as captive-produced. For example, enforcement of a ban on possession of wild stock becomes problematic if possession of cultured stock is permitted. Culture can also introduce the potential for disease or genetic impacts to wild stocks.

Historically, there have been six individuals or organizations that have performed artificial propagation of Atlantic sturgeon and achieved some degree of success. The first recorded propagation of the species was done on the Hudson River in 1875 by Seth Green and Aaron Marks of the New York State Fish Commission. By combining gametes removed from ripe fish during the spawning migration, about 100,000 fry were hatched over a two-week period as reported in the book: Fish Hatching and Fish Catching (Green 1879). Workers reported difficulty in simultaneously obtaining ripe fish of both sexes.

John Ryder (1890) studied Atlantic sturgeon and the sturgeon industry on the East Coast of the United States. He also performed culture experiments on the Delaware River, near the extreme eastern end of the Chesapeake and Delaware Canal, at the suggestion of the U.S. Commissioner of Fish and Fisheries, Professor Marshall McDonald. Ryder described in great detail the process of obtaining gametes, fertilizing, and incubating Atlantic sturgeon eggs. He gave detailed observations that fertilized eggs quickly tended to adhere to nearly any object contacted, including clumping to each other. His success was limited by several fungal infestations of eggs (~95%), which were incubated in floating wooden boxes containing a screen on which the sticky eggs had been spread. Ryder recommended disinfection of incubation water to reduce fungus and increase incubation success.

Further accounts of experimentation with sturgeon hatching on the Delaware River were reported by Bashford Dean (1894), an instructor in biology at Columbia University, NY. Dean incubated eggs in a floating case containing parallel screen-covered trays placed at different locations across the river channel and found that eggs incubated in strong currents and saltier water with less silt were practically exempt from fungus over a five day period. No account was given of the number of larvae hatched or their fate.

Nearly 100 years later, Smith et al. (1980) performed hormone-induced spawning and culturing of Atlantic sturgeon captured in the Atlantic Ocean off the Winyah Bay, SC jetties. Captured broodstock were transported to Orangeburg National Fish Hatchery, SC, where injections of sturgeon pituitary glands were administered to induce gonad maturity and enable collection of viable gametes. Attempts to manually strip eggs were not successful, but through an abdominal incision, 20,000-30,000 eggs were obtained. Workers found that diatomaceous earth was extremely efficient in preventing egg clumping and that eggs could be incubated in McDonald hatching jars where they were kept rolling slightly by circulating water. Despite these improvements over early culture attempts, eggs became fungus-covered in three days. Formalin treatments were then administered to minimize the infection. Hatching was completed by 140 hrs and resulted in the production of about 100 fry, some of which survived for 130 days. Various types of food were offered to the young fish, but they were predominantly fed a beef liver-salmon mash mixture beginning at 11 days post-hatch.

In 1981, an Atlantic sturgeon was again spawned in South Carolina and approximately 11,000 fry were hatched (Smith et al. 1981). They were fed live brine shrimp and liver-salmon mash mixture, and 10,000 fry were placed into an earthen pond for culture. Shortly thereafter, all pond-stocked fish succumbed to a high pH level caused by a phytoplankton bloom. A few of the remaining fish, which were not stocked in the pond, survived for 204 days and reached lengths of about 18 cm.

In 1991, the USFWS-NEFC, Lamar, Pennsylvania began a program to capture, transport, spawn, and culture Atlantic sturgeon. This program was in response to recommendations by the ASMFC in the 1990 FMP (ASMFC 1990) and Special Report No. 22: Recommendation Concerning the Culture and Stocking of Atlantic Sturgeon (ASMFC 1992). The first successful spawn at NEFC was achieved in 1993 using ripe Hudson River broodstock captured by commercial fishermen. The broodstock were transported six hrs by truck to NEFC's facility and given injections of luteinizing hormone releasing hormone analog (LHRHα) according to the schedule used for white sturgeon (as suggested by Conte et al. (1988)). Experiments were performed on incubation temperature and egg disinfection techniques, and approximately 13,000 fry were hatched using McDonald-style hatching jars. Experiments were also performed to identify favorable diets for first-feeding fry and fingerlings (Mohler et al. 1996). Approximately 175 individuals from that year class and others are currently being maintained at NEFC for use in a future broodstock.

Subsequent propagation attempts in 1994, 1995, 1996, and 1998 were also successful with as many as 160,000 fry being hatched in one year. These culture trials have resulted in much needed information relative to propagation and biology of this species, including favorable feed rations and rearing temperature (McPeck 1995), as well as other rearing parameters (Mohler et al. 2000; Jodun et al. 2002). Aside from experience in spawning and culturing propagated fish, knowledge of long-term holding of captive wild fish was obtained. Mohler and Fletcher (1999) found that mature males captured from the Hudson and Delaware rivers in 1991 could be maintained for at least six years in captivity and induced to produce viable milt. The work at Lamar resulted in the publication of the Culture Manual for the Atlantic sturgeon (Mohler 2004).

Artificial propagation of Atlantic sturgeon also took place at the University of New Brunswick, Canada in 1997 and 1998. Saint John River broodstock were collected and induced to provide viable gametes using LHRHα as the spawning hormone. Eggs were taken by manual stripping, in addition to making a small incision in the genital opening to facilitate manual stripping of eggs. Approximately 40,000 fry were hatched in September 1997 with about 10,000 surviving five months later (M. Litvak, University of New Brunswick, Pers. Comm. 1998).

Since NEFC's first successful spawning in 1993, many requests were made for excess progeny both inside and outside of the Department of the Interior. These requests were filled only under the condition that a study plan be submitted to NEFC for review by the Center Director and biologists. Study plans were required to include provisions that escapement of cultured sturgeon into the wild would be prevented, except where experimental stockings were conducted consistent with Federal and state regulations, and they should include a rigorous evaluation component. Accordingly, over 29,000 artificially propagated juvenile sturgeon have been shipped to 20 different organizations including Federal and state agencies, universities, public aquaria, and independent researchers. Some examples of research or education/outreach performed by outside organization using NEFC-produced juvenile sturgeon are: 1) swimming performance and velocity preference of larvae (ACOE); 2) tracking, recapture, growth, and survival of juveniles released in to the Chesapeake Bay (MD DNR); 3) growth and feeding efficiency of juveniles at various temperatures/salinities/oxygen levels (Chesapeake Biological Lab); 4) salinity tolerance and stress (Conte Anadromous Fish Lab); 5) polyculture of sturgeon and catfish to control proliferative gill disease (University of Georgia); 6) susceptibility of Atlantic sturgeon to white sturgeon herpesvirus (University of California-Davis); 7) mark/release study in the Hudson River (New York State DEC); 8) susceptibility of Atlantic sturgeon to *Aeromonas salmonicidia*, the causative agent of furunculosis in fish (Leeton Science Center); 9) public display in aquaria (New York City Aquarium, NY and Maritime Center, Norwalk, CT) and 10) movements and habitat use studies in the Hudson River (NYS DEC).

MDNR has been rearing sturgeon since 1995 with the intention of developing a captive spawning population for use in restoring extirpated subpopulations in Maryland. This program is being developed using the guidance provided by ASMFC. Approximately 75 fish are currently maintained in the captive brood population. Genetic analysis indicates low levels of relatedness and high potential for genetically responsible production and stocking. Restoration activities include captive broodstock culture, laparoscopy to identify sex and maturation, development of a genetically sound broodstock management plan, development of stocking and marking strategies, implementation of coast-wide standardized data collection, habitat assessment and target tributary identification. Research in progress includes development of sperm cryopreservation techniques, feed training of captive wild fish, larval nutrition studies and investigation of streamside culture techniques to mitigate imprinting concerns. Planned future research includes habitat evaluation, sex identification and maturity assessment. Habitat will be evaluated through telemetry monitoring of released sentinel fish and side scan sonar analysis. Sex identification and maturity will be investigated using hormone assays and ultrasound procedures, respectively.

Commercial Aquaculture

Currently, there are six known commercial aquaculture activities involving Atlantic sturgeon in Canada (N = 2), North Carolina (N = 1), and Florida (N = 4). The Canadian Caviar Company raises Atlantic sturgeon for purposes of selling the flesh and caviar. This company has also provided fry to academia for research purposes. The Canadian Sturgeon Conservation Center – New Brunswick is seeking buyers for Atlantic sturgeon fingerlings produced in 1997 from Saint John River wild broodstock (P. Soucy, Canadian Sturgeon Conservation Center – New Brunswick, Pers. Comm. 1998). No well-established commercial source for domestic or wild broodstock currently exists for the species. As a result of successful spawning of Hudson River

Atlantic sturgeon from 1993-1998, NEFC is currently rearing five year-classes of domestic fish. These fish could potentially be used as broodstock for aquaculture operations provided that there is no risk to wild fish. Aquaculturists in Florida, North Carolina, South Carolina, New York, and New Brunswick, Canada have contacted NEFC and expressed interest in initiating commercial production of Atlantic sturgeon.

In 2006, La Paz Aquaculture Group was approved by North Carolina state resource agencies and ASMFC to produce Atlantic sturgeon for flesh and caviar sales. However, their first year of production was halted because remnant storms from Hurricane Katrina destroyed their fry stock that was being raised in Canadian aquaculture facilities. In late 2005, the La Paz Group requested that their permit allow the production of Siberian sturgeon (*Acipenser baerii*) instead so that production could begin in 2006. In 2006, the production of Siberian sturgeon was approved by NC state resource agencies, and Siberian sturgeon eggs were supplied by AquaTech Inc, an Austrian supplier, to North Carolina State University. In August 2006, ASMFC re-evaluated the La Paz permit, and the Board voted to draft an addendum to allow La Paz to acquire Atlantic sturgeon from multiple Canadian aquaculture companies (previously restricted to one company), allowing them to resume Atlantic sturgeon culture. The eggs will initially be raised there under nursery conditions. The juveniles will be transferred to the LaPaz aquaculture facility, near Lenior, NC to be grown out. Resource managers who reviewed the permit found the LaPaz facility to pose little threat to Atlantic sturgeon or shortnose populations due to the facility location (far inland), use of a recirculating system and land application of any discharge (K. Nelson, NCWRC, Pers. Comm. 2006).

In 2001, the Canadian Caviar Company shipped 18,000 Atlantic sturgeon sac fry to the University of Florida. These fry were used to conduct early larval and feeding trials. Survivors of these experiments were transferred to four aquacultural businesses: 1) Evan's Fish Farm – Pierson, FL; 2) Watts Aquatics – Tampa, FL; 3) Hi-Tech Fisheries of Florida – Lakeland, FL; and 4) Rokaviar – Homestead, FL.

Evan's Fish Farm is a commercial food fish farm. The farm experienced a catastrophic systems failure in 2004 and currently has five Atlantic sturgeon on its premises. The farm intends to use these remaining sturgeon as broodstock and would like to acquire more Atlantic sturgeon. Watts Aquatics went out of business, and it is unknown what happened to the Atlantic sturgeon this farm received. Hi-Tech Fisheries of Florida is a commercial fish farm. It currently has around 300 Atlantic sturgeon which have been transferred to a quarry, and the company is in the process of evaluating stock size and health condition. Rokaviar is a commercial food fish farm. Originally, this business received 100 sturgeon, but due to a malfunction with the life support systems, the company now holds 20 Atlantic sturgeon.

All of these facilities are periodically screened for disease by an Institute for Food and Agricultural Science (IFAS) veterinarian. None have reported diseases. All facilities are above the 100-year flood plain and have zero discharge, where tank culture or quarry culture is utilized (Roberts and Huff 2004). These facilities may sell meat, fingerlings, and caviar in accordance with state, Federal, and international laws.

Commercial culture of other sturgeon also has the potential to impact wild Atlantic sturgeon. White sturgeon escaped from an aquacultural facility in Georgia in the early 1990s, and there have been at least two reports of white sturgeon captured by hook and line 150 miles downstream in the Mobile Basin in Alabama (M. Spencer, Georgia DNR, Pers. Comm. 1998). While this particular incident is unlikely to impact Atlantic sturgeon, it illustrates the potential for escapement of non-native sturgeon from aquacultural facilities that could have negative impacts on Atlantic sturgeon through competition for food and habitat, hybridization, and the spread of fish pathogens. For example, surveys of European sturgeon stocks have revealed a dramatic decline (eight fold decrease) in native European sturgeon (*Acipenser sturio*) but a dramatic increase (two to 33 fold increase) in non-native species such as the Siberian sturgeon (Arndt et al. 2000, Arndt et al. 2002). This dramatic increase in non-native captures was believed to be related to escapements from commercial aquaculture facilities. Amendment 1 to the ASMFC's Atlantic sturgeon FMP recommends that states may authorize aquaculture if conducted in accordance with ASMFC Special Report No. 22. Recommendations in the report state, "If non-native or hybrid sturgeon are permitted within a state, they should be restricted to culture operations where escapement and reproduction can and will be controlled."

3.5.4. Summary and Evaluation

Of these other natural and manmade factors assessed, few were considered to be major threats to the viability of Atlantic sturgeon populations. The vast withdrawal of water from rivers that support Atlantic sturgeon subpopulations was considered to be threat; however, data are lacking to determine the overall impact of this threat on sturgeon subpopulations, as impacts are dependent on a variety of factors (e.g., the species, time of year, location of the intake structure, and strength of the intake current). The observation of multiple suspected boat strikes in the Delaware and James rivers was considered to be a major threat to these subpopulations. The majority of mortalities observed in these rivers from potential boat strikes have been of large adult Atlantic sturgeon. As noted earlier in the bycatch section of this report, it is presumed that most extant Atlantic sturgeon subpopulations consist of less than 300 spawning adults, and the loss of only a few adults (~10) impedes the recovery of a subpopulation based on an F_{50} value of 0.3 (Boreman 1997). Lastly, the use of the artificial propagation of Atlantic sturgeon was also a concern to SRT members, as both stock enhancement programs and commercial aquaculture can have negative impacts on a recovering subpopulation (e.g., fish disease, escapement, out-breeding depression). In order to circumvent these potential threats, stock enhancement programs follow culture and stocking protocols approved by the ASMFC. Commercial aquaculture facilities are expected to maintain disease-free facilities and have safe guards in place to prevent escapement of sturgeon into the wild. While in at least one instance, cultured Atlantic sturgeon have gone unaccounted from a commercial aquaculture facility in Florida, this is not considered to be a significant threat.

4. Conservation and Restoration Options

4.1. Aquaculture

The Atlantic sturgeon FMP (ASMFC 1998A) contains many management recommendations, including one that encourages development of aquaculture techniques for breeding and rearing

Atlantic sturgeon and evaluating use of cultured sturgeon for stock restoration. With regard to potential use of cultured sturgeons, the ASMFC established an aquaculture subcommittee in 1995 to develop a breeding and stocking protocol in 1996, which was most recently updated in 2005 and approved in 2006 (ASMFC 2006). Specific recommendations in this protocol are:

6) Planning, Monitoring and Reporting – agencies must provide detailed proposals to the ASMFC Sturgeon Technical Committee for review and recommendation. The plan will also require annual monitoring of the status of the population, the effects of stocking, and possible interactions with shortnose sturgeon.
7) Habitat Quality and Population Surveys – prior to large scale stocking programs being implemented, areas targeted for stocking will be evaluated for the presence-absence of extant populations, determination of relative habitat quality and quantity, and possible human impacts.
8) Tagging of hatchery fish – all hatchery fish should be tagged, including broodstock. Tagging should be standardized.
9) Source of Broodstock – when possible, broodstock should be taken from natal rivers in which stocking will occur. When natal broodstock is not available, nearby sources should be used.
10) Number of spawners – broodstock collections and progeny production should meet genetic criteria for maximizing effective population size of broodstock while achieving an inbreeding rate less than 1%, preferably 0.5%.
11) Fate of Post-Spawn Broodstock – broodstock should typically be spawned only once and returned to its natal stream.
12) Fate of Progeny – excess progeny may be used for research purposes, educational exhibits, euthanized or provided to private aquacultural interests. Any excess progeny released into the wild for research or study purposes must be approved in advance by ASMFC.

Assessments of Atlantic sturgeon genetics identified strong stock structure, large genetic diversity, and low gene flow rates which suggest very slow natural recolonization potential. While stock rebuilding based solely on elimination of harvest avoids genetic risks associated with inter-stock transfer (cross stocking) and inbreeding, which may occur in hatchery-based programs, natural restoration of some stocks may take decades to centuries (Waldman and Wirgin 1998, St. Pierre 1999). These authors recommended the following be included in a restoration plan:

1) Develop clearly defined stock-specific restoration goals;
2) Conduct at least minimal stock specific demographic assessment;
3) Initiate extended stocking programs where Atlantic sturgeon are extirpated but maintain genetic variation among and within stocks;
4) If stocks show continuing decline, initiate extended supplemental stocking programs, but only after genetic risk analysis indicates that benefits outweigh hazards;
5) For viable stocks, allow populations to rebuild naturally by eliminating fishing pressures; and

6) Develop monitoring programs and regularly evaluate progress with adaptive management.

Before undertaking a large-scale program of using cultured fish for restoration stocking, the criteria identified above should be fully considered, and the following questions should be addressed. First, it must be determined with an acceptable level of probability whether genetically distinct river or region-specific stocks exist in waters still inhabited by Atlantic sturgeon. It is not considered sound fisheries management to superimpose progeny from one subpopulation onto another if significant genetic differences exist between the two, as the potential for out-breeding depression can occur.

Second, the difficulty in acquiring sufficient number of male and female broodstock required for a biologically sound breeding protocol (one designed to prevent loss of genetic diversity within subpopulations identified for restoration stocking) must be overcome. The difficulties in obtaining sufficient numbers of broodstock was illustrated in 1997 where capturing efforts of broodstock on the Hudson River, which included 164 gill net sets over a period of 22 tides, resulted in the capture of no females and 42 males (J. Fletcher, USFWS, Pers. Comm. 1998). From June 2-16, 1998, 131 gill net sets captured 87 adult Atlantic sturgeon, including three females. Realizing the scarcity of broodstock, NEFC decided in 1993 to rear a number of individuals from fry to adults from each successful hatchery spawn. As a result, five year classes of domestic Atlantic sturgeon comprising at least 20 genetically distinct families and numerous wild captives are currently being reared at NEFC and could be used in future artificial propagation efforts if deemed appropriate. Under the 2006 ASMFC Breeding and Stocking Protocol for Cultured Atlantic Sturgeon, broodstock can be collected from four sources: 1) recently captured ripe adults collected on or near the spawning grounds, 2) non-spawning adults which have been conditioned in captivity for spawning, 3) wild juveniles which have been reared to adult size in captivity for spawning or 4) juveniles which have been purchased from a commercial producer.

Three experimental releases provide some insight into the feasibility of using cultured Atlantic sturgeon as a management tool in wild stock replenishment. The first release of 4,929 fingerling fish took place in the Hudson River on October 31, 1994; the second release of 3,275 yearling fish took place on July 8, 1996, in the Nanticoke River, which is a tributary to the Chesapeake Bay, MD; and the third release of 210 subadults occurred in 2004 in the Hudson River. These studies are discussed below in more detail.

Hudson River 1994

With assistance from NEFC, the NYSDEC stocked 4,929 3-month old Atlantic sturgeon within the known nursery area of the Hudson River in October 1994. These fish were of Hudson River origin, averaged about 103 mm TL and all received left pelvic fin clips and coded wire tags (Northwest Marine Technologies, Seattle, WA) injected under the first dorsal scute.

The Cooperative Fish and Wildlife Research Unit at Cornell University in Ithaca, NY was contracted by the Hudson River Foundation to conduct long-term studies of abundance and distribution of adult and juvenile Atlantic sturgeon and shortnose sturgeon in the Hudson River.

Using anchored gill nets, Cornell researchers sampled 57 sites in a 150 km reach of the middle Hudson River and collected 29 yearling Atlantic sturgeon between June and mid-December 1995. Most age-1 fish were taken near the salt-freshwater interface near the sturgeon stocking area. Of the 29 yearling sturgeon collected in 1995, 15 (52%) were hatchery fish (identified by wire tags and fins clips). These fish grew an average of 335 mm FL and were distributed over 92 km of river. Wild yearlings were larger, averaging 441 mm, and were collected in a narrower but overlapping 45 km reach of the river.

With a known number of marked (stocked) fish, mark-recapture methodology was used to estimate population size of wild age-1 Atlantic sturgeon. Assuming 100% stocking survival of hatchery reared fish, the population estimate of 4,313 age-1 wild fish (95% confidence interval of 1,917-10,474) indicated that natural production in the Hudson River was very weak in 1994 (Peterson et al. 2000). Cornell researchers repeated their 1995 sampling methods during July-September 1996 and caught only eight juvenile Atlantic sturgeon in the presumed age-1 and age-2 year classes. Seven of these were cultured fish from the 1994 release and averaged 454 mm FL and 617 grams.

Cornell researchers continued to study the distribution and abundance of juvenile Atlantic sturgeon in the Hudson River in 1997. Seasonal aggregations were located using sonic tagged fish captured in early spring. From July-October, the greatest concentrations of both wild and hatchery fish were observed in a 20 km reach between North Haverstraw Bay and West Point. A total of 156 juveniles was collected using targeted gill netting in North Haverstraw Bay, and more than 50% (82 fish) of these were hatchery fish (greater than 3 years old). While survival and migration rates of these cultured fish are unknown, they are still smaller than the wild fish. Cold water rearing conditions best explain the smaller size of stocked fish.

Chesapeake Bay 1996

Maryland DNR requested cultured sturgeon from NEFC for an experimental stocking in the Nanticoke River, which is a tributary on the eastern shore of the Chesapeake Bay. Although a relatively small drainage, the Nanticoke once supported spawning sturgeon, but none have been seen there in over 15 years. The purpose of this experimental stocking was to learn more about habitat needs and preferences, growth and survival rates, feeding habits, seasonal distribution and movements throughout Chesapeake Bay.

In July 1996, 3,275 yearling Atlantic sturgeon of Hudson River origin (1995 year-class) were stocked into the Nanticoke River at two sites located 36 and 50 km above the river mouth. Because the fish were reared in different water temperatures, two size groups were represented (I: 6-15 cm; II: 22-36 cm). All fish were injected with coded wire tags under the third dorsal scute and sturgeon from the larger size group (II) were also tagged with streamer tags. Maryland DNR, USFWS, Virginia Marine Resources Commission and the private Chesapeake Bay Foundation pooled their funds to offer a reward for any sturgeon caught by commercial fishermen in waters of the Chesapeake Bay and held alive for examination. Notices of the reward, $25 for hatchery fish and $100 for others, were posted throughout the Bay along with a toll-free telephone number.

Between 1996 and 2000, 462 hatchery Atlantic sturgeon were colleted, the majority of which were captured in the first two years (Secor et al. 2000). Within eight months post-release, streamer tagged fish more than doubled in size to an average TL of 668 mm. These fish were spread throughout Maryland waters of the Chesapeake Bay, from Baltimore Harbor to the lower Potomac River, with heavy concentrations below the Bay Bridge near Cove Point. Several tagged fish were taken in Virginia (see below), and two were recovered in neighboring North Carolina.

It appears that growth and survival of stocked sturgeon was excellent indicating that the Bay is capable of supporting yearling and juvenile sturgeon. Their rapid dispersal may indicate it is unlikely that these yearlings imprinted to the Nanticoke River. It was recommended that future stockings involve younger fish of Chesapeake origin (e.g., James River fish), similar to the 1994 release in the Hudson River.

The Virginia reward program ran from February through early November 1997 and reported 202 total fish including 169 from the James River (13 hatchery fish), 6 from the York River (three hatchery), and 15 from the Rappahannock River (seven hatchery). Many of the fish taken in autumn months were less than 500 mm TL, suggesting that some natural reproduction occurs in the lower Bay, particularly in the James River. The Virginia reward program was reactivated for a few days in February 1998, and an additional 71 wild juvenile Atlantic sturgeon were reported from the James River (A. Spells, USFWS, Pers. Comm. 1998). Tissue samples from small sturgeon taken in Maryland and Virginia were archived for future genetic analysis to confirm whether one or more discrete Chesapeake Bay sub-populations exist. Subsequent analysis in 2002 indicated that samples from the James River were unique and statistically different from all other subpopulations. In both this and the previously-described experimental stocking, long-term evaluation is needed to determine whether stocked fish have imprinted to the watershed of release and will eventually help to rebuild depleted subpopulations through successful reproduction (Mohler 2000).

Hudson River 2004

In 2004, FWS released 210 subadults of Hudson River origin into the Hudson River. These fish averaged 875 mm TL and were offspring from the 1994-98 year classes, which were held at the Lamar aquaculture facility. Since 2004, 18 sturgeon have been reported (9% recapture rate). The majority of these fish were recaptured in the Hudson River; others were recaptured off the coast of North Carolina (K. Hattala, NYSDEC, Pers. Comm. 2006).

4.2. Summary and Evaluation

Recent experiments demonstrate the technical feasibility of culturing Atlantic sturgeon. While the technology exists, a role for culture has yet to be fully defined in the overall effort to manage, protect, and recover Atlantic sturgeon. As the ASMFC develops restoration goals on a river-by-river basis, they should evaluate whether cultured stocks play a role in restoration. Any proposal for culture of Atlantic sturgeon, for commercial or stocking purposes, should also be evaluated by the ASMFC Atlantic Sturgeon Technical Committee for compliance with applicable protocols

(ASMFC 2006, Waldman and Wirgin 1998), consistency with best management practices to minimize or avoid risk to wild stocks, and compatibility with programs for wild stock.

5. Current Conservation Efforts and PECE Analysis

Current conservation efforts underway to protect and restore Atlantic sturgeon must be evaluated under the Policy for Evaluation of Conservation Efforts (PECE), under the authority of the ESA. This policy is designed to determine whether any conservation efforts that have been recently adopted or implemented, but not yet proven to be successful, will result in recovering the species to the point at which listing is not warranted or contribute to forming a basis for listing a species as threatened rather than endangered (68 FR 15101). The purpose of PECE is to ensure consistent and adequate evaluation of future or recently implemented conservation efforts identified in conservation agreements, conservation plans, management plans, and similar documents when making listing decisions. The policy is expected to facilitate the development by states and other entities of conservation efforts that sufficiently improve a species' status so as to make listing the species as threatened or endangered unnecessary.

In 2003, the Services published guidelines for evaluating conservation efforts that have not yet been implemented or have not yet demonstrated effectiveness when making listing decisions under the ESA. The policy established two basic criteria: 1) the certainty that the conservation efforts will be implemented and 2) the certainty that the efforts will be effective. The first criterion, implementation, requires a high level of certainty that the resources necessary to carry out the conservation effort are available, ensures that the implementing agency has the authority to carry it out, determines if the regulatory or procedural mechanisms are in place to carry out the efforts, and that there is a schedule for completing and evaluating the efforts. The second criterion, effectiveness, requires the conservation effort to describe the nature and extent of the threats to the species to be addressed and how these threats are reduced by the conservation effort, determine if the conservation effort has established specific conservation objectives, determine if the conservation effort identifies the appropriate steps to reduce threats to the species, and evaluate whether the conservation effort includes quantifiable performance measures to monitor for both compliance and effectiveness. Overall, the PECE analysis ascertains whether the formalized conservation effort improves the status of the species at the time a listing determination is made.

The SRT determined that the following conservation efforts required further analysis under PECE: the ASMFC FMP, Roanoke Rapids and Gaston Dams fishway prescriptions, James River restoration plan, Hudson River estuary management plan, multi-state conservation program (ME, NH, MA), and Penobscot Accord.

5.1. ASMFC Management Plan 1998

The content of the 1998 Amendment to the ASMFC FMP for Atlantic sturgeon is presented in the section discussing regulatory authorities. The Amendment includes a stock rebuilding target of at least 20 protected mature age classes in each spawning stock, which is to be achieved by imposing a harvest moratorium. The Amendment requires states to monitor, assess, and annually report Atlantic sturgeon bycatch and mortality in other fisheries, although bycatch reporting is widely accepted as being underreported or not reported at all. The Amendment also requires that states annually report habitat protection and enhancement efforts. Finally, each jurisdiction with a reproducing subpopulation should conduct juvenile assessment surveys (including CPUE estimates, tag and release programs, and age analysis). States with rivers that lack a reproducing sturgeon subpopulation(s) but support nursery habitat for migrating juveniles should also conduct sampling. The Amendment strengthens conservation efforts by formalizing the closure of the directed fishery, and by banning possession of bycatch, eliminating any incentive to retain Atlantic sturgeon. Additional elements of the Amendment related to habitat, stock assessment, and stocking are designed to offer the species wider protection beyond closing a directed fishery and thereby, improve its chances for recovery.

5.2. Roanoke Rapids and Gaston Dams Fishway Prescriptions

In 2006, a final fishway prescription was completed for the Roanoke Rapids and Gaston dams, as a result of the owner (Dominion Generation) applying for a "major new license" (NMFS 2006). The fishway prescriptions have three phases of implementation for the passage of American shad (*Alosa sapidissima*), river herring (*A. psuedoharengus and A. aestivalis*), and American eel (*Anguilla rostrata*): phase 1 - initial truck and trapping; phase 2 - permanent truck and trapping; and phase 3 - full capacity volitional passage. Atlantic sturgeon were not a management objective in this prescription due to their small population size and lack of safe and effective downstream passage mechanisms for post-spawn adults. However, NMFS reserved its authority to prescribe fishways, or appropriate modifications for fishways, for Atlantic sturgeon in the event these circumstances change (NMFS 2006).

5.3. James River Atlantic Sturgeon Restoration Plan

In 2005, state and private partners began work to create a James River Atlantic Sturgeon Restoration Plan. The plan outlines several restoration goals to help preserve and recover the James River Atlantic sturgeon subpopulation. These goals include:

1) Identify essential habitats, assess subpopulation status, and refine life history investigations in the James River.
2) Protect the subpopulation of James River Atlantic sturgeon and its habitat.
3) Coordinate and facilitate exchange of information on James River Atlantic sturgeon conservation and restoration activities.
4) Implement the restoration program.

The plan also describes several milestones for reaching their goals, those of most interest to this review include:

A) Identify essential habitats and protect them using regulatory and/or incentive programs.
B) Develop and implement standardized population sampling and monitoring programs.
C) Develop population models.
D) Develop an experimental culture of James River Atlantic sturgeon.

E) Reduce or eliminate incidental mortality.
F) Identify and eliminate known or potentially harmful chemical contaminants that impede the recovery of James River sturgeon.
G) Maintain genetic integrity and diversity of the wild and hatchery-reared stocks.
H) Designate and fund a James River Atlantic sturgeon restoration lead office.

Though finalized, the plan has not been formally approved by regulatory agencies. However, portions of the plan have already been implemented including the collection of YOY and adult tissue samples for genetic analysis; electronic tracking of sturgeon to determine preferred habitat use and spawning locations; collecting spine samples to establish age distributions; and establishing a long-term YOY index survey (A. Spells, USFWS, Pers. Comm. 2007).

5.4. Hudson River Estuary Management Action Plan

A Hudson River Estuary Management Action Plan was adopted by the NYSDEC in May 1996. The goal of this Plan is to protect, restore and enhance the productivity and diversity of natural resources of the Hudson River estuary to sustain a wide array of present and future human benefits. Multiple projects have been initiated as a response to this Plan and include:

1) Coastal sampling.
2) Juvenile Atlantic sturgeon sonic tracking project.
3) Broodstock sonic tagging, PIT tagging to determine broodstock movements and spawning locations.
4) New York long-term juvenile abundance survey.

5.5. Multi-State Conservation Program (Maine/New Hampshire/ Massachusetts)

Three states, Maine, New Hampshire, and Massachusetts, have applied for and have received funding under NMFS' new Proactive Species Conservation Program grant. The project is entitled "Multi-State Collaborative to Develop and Implement a Conservation Program for Three Anadromous Fish Species of Concern in the Gulf of Maine," and includes the following proposed research on Atlantic sturgeon within the Kennebec River:

- Use acoustic biotelemetry (deploy acoustic array) to identify essential Atlantic sturgeon habitat in the Kennebec River/Androscoggin River complex.
- Conduct a mark-and-recapture study using PIT tags to estimate subpopulation size and external Carlin tags to investigate movements beyond the estuary. Investigate non-traditional population estimation methods because of spawning periodicity of adult sturgeon.
- Obtain tissue samples for sturgeon to conduct genetic analysis and determine stock structure.

5.6. Penobscot Accord

In June 2004, the Penobscot Accord was approved and gave the Penobscot River Restoration Trust, a non-profit corporation established in May 2004, the ability to buy Veazie, Great Works and Howland dams on the Penobscot River over a five-year period. If purchased, the Trust has the right to decommission and/or remove the Veazie Dam, decommission the Great Works Dam, and install fish passage or remove the Howland Dam. However, these options cannot be initiated until 2007-2010. If the Accord is successfully implemented, large portions of historical habitat once available to Atlantic sturgeon will be reopened. The Accord is directed toward Atlantic salmon, herring, and American eel restoration and the overall benefits to sturgeon species are unknown. However, it is anticipated that dam removal will provide benefits to Atlantic sturgeon.

The SRT identified several other threats to Atlantic sturgeon in the Penobscot River that are not addressed by the Penobscot Accord. As a result, the SRT decided that the Accord is beneficial for reopening spawning habitat to Atlantic sturgeon, but other threats to the subpopulation (e.g., dredging, water quality, bycatch, etc.) are not being addressed by other management plans; thus, this conservation effort does not change the risk of extinction for this subpopulation.

5.7. Summary

Overall, none of the current conservation efforts underway was considered to improve the status of the species to such an extent that a listing determination should be re-evaluated. The majority of the conservation efforts did not describe the threats to Atlantic sturgeon subpopulations in question and how these threats would be reduced or eliminated. Conservation efforts lacked recovery objectives or the appropriate steps to reduce threats, and they did not quantify performance measures for both compliance and effectiveness.

Though these plans were not applicable under the PECE analysis, these conservation efforts will and/or already are increasing our knowledge and understanding of Atlantic sturgeon life history strategies, their status, and identify methods or work toward restoring important habitat that is used as nursery and spawning grounds.

6. Needed Research

Though Atlantic sturgeon historically supported an important commercial fishery since the 1800s and many aspects of this species' life history have been investigated, current knowledge regarding threats to and the current status of this species in many areas of its range are lacking. To fill in some of these data gaps, the following research is needed:

- <u>Long-term population monitoring programs</u>: Currently, there are only three subpopulations (Hudson, Albemarle, and Edisto) with long-term monitoring programs in place to help determine the status of the species (e.g., whether it is decreasing, increasing, or remaining stable). It is critical that all other extant subpopulations be surveyed to better understand their status. Recently, Sweka et al. (2006) noted that the relative abundance (CPUE) of juvenile Atlantic sturgeon in the Hudson River could be determined with 95% 'power' if biologists sampled as little as 24 net sets per year over a

10-year period of sampling or 36 net sets every other year (biennial sampling). Though this model was developed for the Hudson River subpopulation and is based on the coefficient of variation on mean CPUE (1.019), variations to this methodology and data analysis may serve as a model when developing monitoring programs (J. Sweka, USFWS-NFC, Pers. Comm. 2006).

- Spawning population abundance estimates: As noted earlier in this report, there are only two extant subpopulations with estimates of yearly spawning adults, the Hudson (~860/year) and Altamaha (~350/year). These Atlantic sturgeon subpopulations are suspected to be the largest within the U.S. portion of the species' range. Therefore, all of the other U.S. subpopulations are expected to have less than 300 spawners per year. Using the F_{50} value of 0.03 as a guide, the loss of only nine spawners a year could impede the recovery of a subpopulation. As a result, it is very important to determine the average number of spawners per year for each subpopulation, as the risk of extinction increases greatly for smaller subpopulations.

- Population Genetics: Several subpopulation genetic studies have been performed on Atlantic sturgeon since the 1990s using both mtDNA and nDNA. However, many of the rivers that have been examined thus far have used results from juvenile tissue samples, which increase the chances that the sample was a migrant from another system. Researchers are now reanalyzing subpopulations only using YOY and spawning adult samples to reduce sampling error to provide increased certainty that Atlantic sturgeon subpopulations are likely adapted to unique habitats. This research will be very useful in the event that hatchery programs are needed to help recover this species.

- Estimate Bycatch and Bycatch Mortality: Though the ASMFC 1998A FMP stated that bycatch should be monitored to determine its impacts on Atlantic sturgeon recovery, the impacts of bycatch are still unclear. Currently, most states rely on fishers voluntarily reporting bycatch of Atlantic sturgeon. Very few to no Atlantic sturgeon have been documented each year by commercial fishers using this voluntary reporting scheme. In states and programs where observer coverage is present, however, Atlantic sturgeon are landed with some frequency and bycatch mortality ranges from 0 – 51% mortality. This dichotomy in reported bycatch has resulted in significant uncertainties regarding the extent of bycatch. The need for bycatch monitoring is especially great in the southern range of the species where observer coverage is lacking and only a few American shad fisheries have been monitored to determine bycatch.

- Identification of Spawning and Nursery Grounds: Overall, the location of spawning and nursery grounds for Atlantic sturgeon is not known. For instance, only nine of the 36 subpopulations that once supported a spawning subpopulation have had spawning grounds identified. Though generally found in the vicinity of the fall line, some spawning locations are known to occur above or below this area of elevation change. Identifying these critical habitats is an important step in determining potential stressors to the subpopulation and identifying areas that should be protected from degradation.

- Toxic Contaminant Impacts and Thresholds: Since Atlantic sturgeon are a long-lived species, they have the potential to bioaccumulate toxins. Though contaminants have been greatly reduced over the last two decades, the presence of dioxins, PCBs, and mercury is still apparent. In other fish species, the bioaccumulation of these contaminants has been shown to reduce reproductive capabilities, growth, and cause death. However, surveys for the Atlantic sturgeon concentrations are lacking where only a few systems have examined the contaminant levels of Atlantic sturgeon.

- Develop Fish Passage Devices for Sturgeon: Currently there is little information that Atlantic sturgeon utilize fish passage devices. However, the smaller shortnose sturgeon are frequently observed (4.7/year) passing the Holyoke Dam, Connecticut (Kynard 1996, Gephard and McMeney 2004). Though, shortnose sturgeon are capable of passing the Holyoke dam, managers now prevent sturgeon from passing the dam to prevent subsequent mortalities when they migrate back downstream and through the hydropower turbines. Thus, both up- and down-stream fish passage devices need to be engineered to help sturgeon species pass dams so that historic and possibly more suitable spawning habitat can be reached.

7. Extinction Risk Analysis (ERA)

Risks of extinction assessments are performed to help summarize the status of the species, and do not represent a decision by the SRT on whether the species should be proposed for listing as endangered or threatened under the ESA.[37] There are no standard methods or protocols employed to estimate the risk of extinction. Instead, the method used is dependent on the availability of data for the species in question. Information such as geographic range, population numbers, population trends, and expert opinion can be utilized in a purely qualitative methodology (reviewed in Regan et al. 2005), or through the use of ranking or scoring systems, in semi-quantitative analysis. Models relying on stochasticity and variances in genetics, birth-death demography, ecology and interactions among mechanisms can be employed in a highly quantitative methodology, such as Population Viability Analysis (PVA) (Boyce 1992, Ludwig 1999).

7.1. Determining the Best "Risk of Extinction" Method for Atlantic Sturgeon

The deciding factor in choosing a method to assess the biological status of a species is data availability. To utilize the most simple quantitative model – that which is often used by American Fisheries Society (AFS), the Convention on International Trade in Endangered Species

[37] Neither does the results of an extinction risk analysis represent a decision by the NMFS on whether this taxon (Atlantic sturgeon) should be proposed for listing as threatened or endangered under the ESA. That decision will be made by NMFS after reviewing this report, other relevant biological and threat data not included herein, and all relevant laws, regulations, and policies. The result of the decision will be posted on the NMFS website (http://www.nero.noaa.gov/prot_res/) and announced in the *Federal Register*.

(CITES), and the International Union for the Conservation of Nature and Natural Resources (IUCN) – at least ten years or three generations of time-series data are required, and 15 years of data are preferable (Dulvy et al. 2004). Because ten years of time-series data exist for only five of the 23 extant Atlantic sturgeon subpopulations undergoing review, even the most simplistic quantitative method cannot be used in the risk analysis of Atlantic sturgeon.

The SRT decided to use a semi-quantitative approach employing a scoring system that has been used previously in extinction risk analyses (Myers et al. 1998, Wainwright and Kope 1999, *Acropora* Biological Review Team 2005, Gustafson et al. 2006). Traditionally, the scoring system has been applied in three stressor categories: abundance, trend/productivity/variability, and genetic integrity (Myers et al. 1998, Wainwright and Kope 1999, Gustafson et al. 2006). Others have identified additional stressor categories (*Acropora* Biological Review Team 2005). In previous status review documents, a standardized 1 to 5 scoring scheme was used. Status Review Team members assigned individual scores ranging from 1 to 5 for each threat or stressor, where for any given stressor, a score of 1 indicated that it was not likely to cause a population to become extinct (low risk) and a score of 5 indicated a high risk for causing extinction of the population. The respondents' scores were then averaged for each category.

The Atlantic sturgeon SRT determined that it was important for this review to clearly address how these scores related to the five factors being evaluated, where the three most commonly used stressor categories in the qualitative ranking method are related to abundance, productivity trends and genetic integrity. A recent status review of coral (*Acropora palmata* and *A. cervicornis*) used the same extinction risk scoring methods (1-5 scale) but expanded the stressors to 15 separate categories, effectively breaking down the five broad factors outlined in Section 4(a)(1) of the ESA. These 15 stressor categories were described in detail within the status review (*Acropora* Biological Review Team 2005). The SRT preferred the use of a broader ranking system that was directly related to the five factor analysis.

The SRT also felt it was important to address the "significant portion of its range" (SPOIR) and timeframes inferred in the ESA definition of an endangered and threatened species. The ESA defines an "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range," while a "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." The phrase "throughout all or a significant portion of its range" is neither defined nor explained in the ESA and a final policy on how to interpret this language has not been developed by USFWS or NMFS. Recent internal guidance from NMFS developed the following definition for a SPOIR; extinction in a SPOIR is a spatial, functional, or character loss that poses a serious risk of eventual extinction to the species as a whole by substantially reducing the ability of a species to respond to demographic risks and future environmental challenges.

Similarly, the ESA refers to timeframes for which endangered and threatened status are determined. An endangered species is in danger of extinction while a threatened species is likely to become endangered in the foreseeable future. However, these timeframes are not explicitly defined within the ESA. Endangered status reflects imminent risks to a species' continued existence due to its present abundance, productivity, and/or spatial structure. Due to the uncertainties in species' dynamics at very low abundance, the exact timeframe in which the species is expected to become extinct cannot be reliably predicted. Thus, there is no explicit time horizon of risk that corresponds to endangered status, although timeframes have been suggested, e.g., 10 years (Gerber and DeMaster 1999), 20% probability of extinction of 20 years (Shelden et al. 2001). Concerning the foreseeable future, the appropriate period of time corresponding to the foreseeable future depends on the particular kinds of threats, the life-history characteristics, specific habitat requirements for the species under consideration and should be adequate for the conservation and recovery of the threatened species and the ecosystems upon which they depend. Timeframes that have been used in the past for defining the foreseeable future include 25 years for North Pacific Humpback Whale (Gerber et a. 1999) and 10% probability of extinction in 100 years for Bowhead Whales (Shelden et al. 2001). Determining these timeframes and associated probabilities is an important first step in assessing the extinction risk of Atlantic sturgeon, as it is important that the timeframes associated with assessing risk are clearly understood.

To address each of these issues, the Atlantic sturgeon SRT decided to modify previous approaches by using the five factor analysis as a guide for determining stressors to a species, including a SPOIR analysis to determine the status of the species and define timeframes and probabilities for "imminent extinction" and "foreseeable future" as they pertain to Atlantic sturgeon biology and recovery.

7.2. The Structure of the Semi-Quantitative Analysis

7.2.1. Stressor Evaluation and Scoring

Each of the five factors listed in Section 4(a)(1) is comprised of numerous stressors that could contribute to a species being listed as threatened or endangered. For instance, "Dredging on spawning grounds" is one of the stressors in the Factor A (related to habitat) and "Competition" is one of the stressors in Factor C (Disease or Predation). These individual stressors were evaluated by SRT members for each extant subpopulation unit within a DPS. Scores could range from 1 to 5 for each of these stressors:

1 – Low Risk
2 – Moderately Low Risk
3 – Moderate Risk
4 – Moderately High Risk
5 – High Risk

The SRT concluded a score of 4 (Moderately High Risk) should represent a stressor that had a >50% chance of causing the subpopulation unit to become endangered over the next 20 years, while a score of 5 (High Risk) had a >50% chance of causing the subpopulation unit to become extinct over the next 20 years. The rationale for a >50% probability was based on the SRT interpretation of "likely," which meant having a better chance of occurring than not; thus, a >50% chance. The SRT also concluded that 20 years is an appropriate timeframe for determining the status of a species, as it was not too far into future that qualitative analysis would prove to be ineffective or unreliable, allowed sufficient time (10+ years) to determine the productivity of Atlantic sturgeon subpopulations using standardized protocols (Sweka et al. 2006), and is the approximate age of maturity for Atlantic sturgeon or is approximately equal to one generation (Scott and Crossman 1973, Smith et al. 1982, Young et al. 1998).

Once the SRT had scored stressors for each extant subpopulation, the team revisited all of the subpopulations in which a score of 4 or 5 was given by at least one SRT member. The rationale for the scores was discussed, and the SRT had the opportunity to change their individual scores. The median values for each of these stressor categories were used to summarize the overall risk for each subpopulation. The greatest median stressor score (e.g., dams) within a factor score (e.g., Factor 1) was used as the overall factor score. The SRT also evaluated whether a factor score should be elevated after considering the cumulative impacts of each of the individual stressors.[38] Similarly, to determine the overall subpopulation score, the greatest of the five factor scores was used.

7.2.2. Significant Portion of its Range Criteria

After factor and subpopulation risk scores were determined, the SRT determined which subpopulations should be considered significant under the SPOIR language of the ESA. The SRT decided that a subpopulation should be considered significant to a DPS' viability if one or more of the following proposed SPOIR criteria were met:

1) the subpopulation historically supported a large population,
2) relative to the DPS, the current abundance is greater than other subpopulations,
3) if lost, would result in the loss of spatial structure within the DPS.

The historical abundance of a subpopulation was determined to be a good indicator of the DPS' potential to recover, because the subpopulation could contribute substantially to the ecological function of the DPS and therefore, reduce the susceptibility of becoming extinct. This criterion assumes the genetic diversity of the subpopulation and the habitat on which it depends are not beyond a restorable threshold.

The current abundance of a subpopulation was determined to be a good indicator of the DPS's viability because, all else being equal, a large subpopulation is more likely to subsist as compared to a small subpopulation. The protection of the most abundant subpopulations, in relation to the DPS, is essential for the recovery of a DPS.[39]

A DPS' spatial structure depends on habitat quality, spatial configuration, dynamics, and dispersal characteristics of subpopulations within the DPS. The loss of spatial structure has the potential to affect evolutionary processes and therefore, alter the ability of subpopulations within the DPS to respond to environmental change or catastrophic events, resulting in a DPS that may be more vulnerable to extinction.[40]

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[38] No factor scores were elevated in risk due to cumulative impacts.
[39] The current abundance significance and rationale were taken from Viable Salmonid Population language.
[40] The spatial structure definition was taken from Viable Salmonid Population language.

After group discussion and evaluation of the three criteria outlined to evaluate SPOIR, the SRT determined that 10 of the 18 subpopulations, from various DPSs, should be considered to constitute a significant portion of the range of the DPS (Table 12). This information was combined with ERA scores to determine if a DPS should be considered threatened or endangered.

7.3. Extinction Risk Analysis Results and Status of each DPS

The SRT evaluated the status of each DPS by comparing the risk of each subpopulation and whether or not it was considered a SPOIR. The SRT also evaluated whether there were sufficient data available to make a recommendation to list Atlantic sturgeon as threatened or endangered. There were three possible outcomes for making a recommendation: 1) there were sufficient data to recommend listing as threatened or endangered; (2) there were sufficient data to recommend that listing is not warranted; (3) there were insufficient data to allow a full assessment of these subpopulations within the DPS, and thus, a recommendation could not be provided. Of the five DPSs evaluated, the SRT concluded that three DPSs (Carolina, Chesapeake, and New York Bight) had a moderately high risk (>50% chance) of becoming endangered in the next 20 years, and the SRT recommended that these DPSs be listed as threatened (Table 13). The other two DPSs, South Atlantic and Gulf of Maine, were determined to have a moderate risk (<50% chance) of endangerment in the next 20 years; however, there were insufficient data to allow a full assessment of these subpopulations.

7.3.1. Gulf of Maine DPS

The Gulf of Maine (GOM) DPS historically supported at least four spawning subpopulations; however, today it is suspected that only two extant subpopulations exist (Penobscot and Kennebec rivers). Of these two extant subpopulations, the Kennebec was considered a subpopulation of significant value to the Gulf of Maine DPS, as this subpopulation was historically large, relative to the DPS its current population size is large, and if extirpated would likely result in the loss of spatial structure. The SRT found these two extant subpopulations to have a moderate risk (< 50% chance) of becoming endangered in the next 20 years. The extant subpopulations received median scores of 3 (moderate risk) on a number of stressors, including dredging, water quality, and commercial bycatch. It was speculated that the Penobscot subpopulation was extirpated until a fisherman captured an adult Atlantic sturgeon in 2005, and a gill net survey directed toward Atlantic sturgeon captured seven in 2006. Based on the time of year (spring) and length (1400 mm TL), one of the captures in 2006 may have been an adult. The SRT concluded that the Penobscot subpopulation had a moderate risk of becoming endangered due to its potentially small size (likely less than 300 spawning adults), recent approvals to dredge in the Penobscot Harbor along with eight other dredging projects, and poor water quality. Within the Penobscot, substrate has been severely degraded by upstream mills, and water quality has been negatively affected by the presence of coal deposits and mercury hot spots. The potential for commercial bycatch was also viewed as a moderate threat to this subpopulation due to its small size.

Historically, the Kennebec supported ~15,000 spawning adults. According to limited CPUE data, the CPUE increased by a factor of 10-25 over a 20 year period from 1977 to 2000.

However, these data were limited to eight years of sampling, where catch from 1977-1981 was compared to catch from 1998-2000, and sampling 1977-1981 is noted as conservative due to high flow years. Additional sampling from 2000-2003 in the MEDMR inshore groundfish trawl survey collected 13 subadults at the mouth of the Kennebec River, which had the largest occurrences of Atlantic sturgeon among five regions sampled along the New Hampshire and Maine coasts (Squiers 2003). The SRT concluded that there are several stressors within the Kennebec that result in a moderate risk of this subpopulation becoming endangered in the next 20 years. These stressors include poor water quality, dredging, and commercial bycatch.

Although the Gulf of Maine subpopulations were found to have a moderate risk of becoming endangered in the next 20 years, the SRT determined that there were insufficient data to allow a full assessment of these subpopulations within the DPS, and thus, a recommendation could not be provided.

7.3.2. New York Bight DPS

The New York Bight, ranging from the Delmarva Peninsula to Cape Cod, historically supported four or more spawning subpopulations. Currently, this DPS only supports two spawning subpopulations, the Delaware and Hudson River. The Delaware River supported the largest spawning subpopulation of Atlantic sturgeon in the U.S., with 3,200 mt of landings in 1888. Today, the capture of YOY and spawning adults within the Delaware River is sporadic, and the majority of sub-adults captured in the Delaware Bay are thought to be of Hudson River origin, based on genetic analysis. Population estimates based on mark and recapture of juvenile Atlantic sturgeon (declined from 5,600 juveniles in 1991 to less than 1,000 in 1995) and voluntary logbook reporting (declined from 32 fish/effort hr in 1991 to only 2 fish/effort hr in 2004) indicate that the Delaware subpopulation has been declining rather rapidly over the last 20 years (Figure 8). In the U.S., the Hudson River currently supports the largest subpopulation of spawning adults (~850 males and females) and ~8,000 subadults, although historically, it supported 6,000 to 7,000 spawning females. Long-term surveys indicate that the Hudson River subpopulation has been stable since 1995 and/or slightly increasing in abundance.

The SRT concluded that the Hudson River subpopulation had a moderate risk (< 50% chance) of becoming endangered in the next 20 years due to the threat of commercial bycatch. A study conducted by the ASMFC technical committee in February of 2006 determined that bycatch mortality from just the New York Bight sink net fishery had the potential to impede the recovery of Hudson River Atlantic sturgeon. Other stressors, such as water quality, have improved since the 1980s and no longer seem to present a significant threat to Hudson River Atlantic sturgeon.

However, the SRT found that the Delaware River subpopulation had a moderately high risk (>50% chance) of becoming endangered in the next 20 years, due to the loss of adults from ship strikes. Several other stressors received scores of moderate risk (i.e., dredging, water quality, and commercial bycatch). Dredging was considered a moderate risk, as the river is continually dredged from the Delaware Bay to Trenton, NJ (~150 kms). Dredging in the upper portions of the river near Philadelphia were considered detrimental to successful Atlantic sturgeon spawning as this is suspected to be the historical spawning grounds of Atlantic sturgeon. Though dredging restrictions are in place during the spawning season, the continued degradation of suspected spawning habitat likely increases the instability of the subpopulation and could lead to its endangerment in the foreseeable future. Commercial bycatch was considered to be a moderate risk to this subpopulation's viability, as the subpopulation is suspected to be relatively small with less than 300 spawning adults. As is the case in other DPSs, only a few adult mortalities (~10, $F_{50} = 0.03$) are needed to impeded the recovery of this subpopulation. The SRT also recognized that this region, especially the offshore portion of the New York Bight, is heavily fished by sink nets that commonly have a large number of associated bycatch mortalities.

Both the Hudson and Delaware rivers were considered to constitute a SPOIR within the New York Bight DPS, based on historical abundances (both), current abundance (Hudson), and if extirpated would likely result in the loss of spatial structure (both). The SRT concluded that the moderately high risk of the Delaware River, combined with the moderate risk of the Hudson River subpopulation, was sufficient to recommend the DPS be listed as threatened under the ESA.

7.3.3. Chesapeake Bay DPS

The Chesapeake Bay once supported at least six historical spawning subpopulations; however, today the Bay is believed to support at the most, only two spawning subpopulations (James and York). Of these two extant subpopulations, the James was considered a subpopulation of significant value to the Chesapeake Bay DPS, as this subpopulation was historically large, relative to the DPS its current population size is large, and if extirpated would likely result in the loss of spatial structure.

Though the York River has not been confirmed to support a spawning subpopulation, the capture of 38 age-1 juveniles suggest that a subpopulation may exist in this river. Genetic analyses of these York River captures indicated these fish were genetically unique and statistically different ($P < 0.05$) from neighboring subpopulations; however, geneticists were unable to differentiate James and York River fish from one another using classification techniques. Scientists do know that the majority of recaptures, reported in the Maryland tagging program, are from the York River, suggesting the river is a favorable nursery ground within the Bay. The highest ranked stressor for the York River was commercial bycatch, which received a median score of 3 (moderate risk).

The SRT concluded that the James River had a moderately high risk (>50% chance) of becoming endangered in the next 20 years, as it received median scores of 4 for impacts from commercial bycatch. Commercial bycatch was considered a moderately high risk to this subpopulation, because it is expected to be relatively small (<300 spawning adults) and only a few adult mortalities are needed to impede the recovery of this species (~10, $F_{50} = 0.03$).

Dredging was a concern to SRT members, receiving a score of three (moderate risk), as it has been extensively dredged since the 1800s, removing large portions of rock outcroppings called "the Rocket's" speculated to be the historic spawning grounds of Atlantic sturgeon in this river. Since the mass removal of these rock outcroppings (multiple locations), the quality of spawning habitat is suspected to have been significantly reduced. The continued maintenance dredging of the navigation channel and the recent approval to expand the terminal in Richmond requiring additional dredging is thought to further impact the remaining habitat.

Ship strikes were also found to be a moderate stressor for this subpopulation, as five Atlantic sturgeon are reported on average each year to have been struck by boats (likely ocean-going vessels). Though the reports are relatively low (~5/year), there are no surveys in place to estimate how many sturgeon are actually struck by ships in this system. In some places, the river narrows and the navigation channel is approximately the width of the river. Coupled with the relatively large number of ship strike sightings and the expected low abundance, this subpopulation is likely impacted by ship strikes.

The SRT concluded that there was sufficient evidence to suggest that the Chesapeake Bay DPS is at risk of becoming endangered in the foreseeable future and recommends it be listed as threatened under the ESA.

7.3.4. Carolina DPS

The Carolina DPS ranges from the Santee-Cooper River to the Albemarle Sound and consists of seven extant subpopulations, one subpopulation (Sampit) is believed to be extirpated. The current abundance of these subpopulations is likely less than 3% of their historical abundance based on 1890s commercial landings. The subpopulations within this DPS seem to be at moderate to moderately high risk of becoming endangered. Five to six of the extant subpopulations received multiple scores of moderate risks for impacts related to water quality, and/or commercial bycatch. Major causes of concern were related to the water quality conditions within the Pamlico Sound and Cape Fear River. The Pamlico Sound suffers from eutrophication and experiences periodically low DO events, mainly in the Neuse Estuary of the Sound. The Cape Fear River is a blackwater river; however, the low DO concentrations in this river can also be attributed to eutrophication. It was the opinion of the SRT that inhabitability of these waters posed moderate risk to the stability of these subpopulations. Water quality is also a problem in Winyah Bay, where portions of the Bay have high concentrations of dioxins that can adversely affect sturgeon development. Commercial bycatch was a concern for all of the subpopulations examined. Like the Chesapeake Bay DPS, the mortality of just a few sturgeon (~10, based on $F_{50} = 0.03$) could adversely affect these small subpopulations.

The Cape Fear and Santee-Cooper rivers, were found to have a moderately high risk (>50%) of becoming endangered in the next 20 years as a result of impeded habitat from dams. The Cape Fear and Santee-Cooper are the most impeded rivers along the range of the species, where dams are located in the lower coastal plain and impede between 62-66% of the habitat available between the fall line and mouth of the river. The SRT concluded that the limited habitat in which sturgeon could spawn and utilize for nursery habitat in these rivers likely leads to the instability of these subpopulations and to the entire DPS being at risk of endangerment. The SRT also concluded that the loss of both the Santee-Cooper and Cape Fear River subpopulations would likely result in the loss of spatial structure within the DPS and thus, constitutes a SPOIR. As a result of these findings, the SRT recommends that Carolina DPS be listed as threatened under the ESA.

7.3.5. South Atlantic DPS

The SA DPS historically supported eight spawning subpopulations ranging from the St. Johns River, FL to the ACE Basin in SC. Currently, this DPS supports five extant spawning subpopulations. Of these subpopulations, the Altamaha and ACE Basin support the largest number of spawning adults, and based on the available data, are considered to be the second and third largest subpopulations within the U.S., respectively. The current abundance of these subpopulations are suspected to be less than 6% of their historical abundance, extrapolated from the 1890s commercial landings. Few captures have been documented in other subpopulations within this DPS and are suspected to be less than 1% of their historic abundance.

A review of the literature and potential threats to this DPS revealed that dredging, water quality, and commercial bycatch were ranked as the greatest threats to this DPS - receiving ERA scores of 3 or moderate risk (<50% chance of becoming endangered over the next 20 years). Overall, the SRT found that the SA DPS had a moderate risk (<50% chance) of becoming endangered over the next 20 years. While the median value associated with the risk for the DPS was moderate and did not meet the threshold of >50% chance of becoming endangered, the team recognized that three of the eight historic subpopulations are likely extirpated and data is lacking for many of the other subpopulations. As a result, the SRT determined that available science was insufficient to allow a full assessment of these subpopulations within the SA DPS.

8. Conclusions of the Status Review

Previously in 1998, the status review team (different members) determined that the Atlantic sturgeon did not warrant listing at that time as the species had persisted through the late 1800s and earlier 1900s when fishing pressure was high and water quality was at its lowest. In 1998, direct fishing pressure was essentially removed by the ASMFC who imposed a 40-year moratorium on the fishery and water quality had improved substantially since the early 1900s. The 1998 status review team, also determined that bycatch of Atlantic sturgeon in other fisheries was unsubstantial and did not pose a threat to the viability of species.

However, since the 1998 status review only a few subpopulations seem to be increasing or stablizing. The majority of the subpopulations show no signs of recovery, and new information suggests that stressors such as bycatch, ship strikes, and low DO can and do have substantial impacts on subpopulations. Furthermore, population estimates of the relatively healthiest subpopulations of Atlantic sturgeon are low ranging from 300 – 800 spawning adults; thereby, suggesting that smaller subpopulations likely have less than 300 spawning adults and could be considered unstable. The lack of recovery in these subpopulations may be attributed to many years of habitat degradation and the continued take of Atlantic sturgeon as bycatch. Overall, the SRT concluded that at least three (New York Bight, Chesapeake Bay, and Carolina) of the five DPSs should be considered threatened under the ESA as it was determined that they had a moderately high risk of becoming threatened in the foreseeable future (next 20 years). The SRT determined that the remaining two DPSs had a moderate risk of becoming extinct, though there were insufficient data to allow for a full assessment of these subpopulations; thus, a listing recommendation was not provided.

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Table 1. Historic and current spawning status of Atlantic sturgeon throughout its natural range, and current uses of the riverine habitat.

State	River	Historical Spawning Status	Current Spawning Status	Use of River by Atlantic Sturgeon
QE	Saint Lawrence	Yes	Yes	Spawning, Nursery
NB	Miramichi	Unknown	Unknown	Nursery
NS	Avon	Yes	No	Unknown
NS	Annapolis	Yes	Yes	Spawning, Nursery
NB	Saint John	Yes	Yes	Spawning, Nursery
NB/ME	Saint Croix	Yes	Possibly	Nursery
ME	Penobscot	Yes	Possibly	Nursery
ME	Kennebec	Yes	Yes	Spawning, Nursery
ME	Androscoggin	Yes	Possibly	Nursery
ME	Sheepscot	Yes	Possibly	Nursery
NH	Piscataqua	Unknown	No	Unknown
NH/MA	Merrimack River	Yes	No	Nursery
MA/RI	Taunton	Yes	No	Nursery
RI/CT	Pawcatuck	Unknown	No	Unknown
MA/RI/CT	Thames	No	No	Unknown
CT	Connecticut	Yes	No	Nursery
CT	Housatonic	Unknown	No	Unknown
NY	Hudson	Yes	Yes	Spawning, Nursery
DE/NJ/PA	Delaware	Yes	Yes	Spawning, Nursery
MD/PA	Susquehanna	Yes	No	Nursery
MD/VA	Potomac	Yes	No	Nursery
VA	James	Yes	Yes	Spawning, Nursery
VA	York	Yes	Possibly	Spawning, Nursery
VA	Rappahannock	Yes	No	Nursery
VA	Nottoway	Yes	Unknown	Unknown
NC	Roanoke	Yes	Yes	Spawning, Nursery
NC	Tar-Pamlico	Yes	Yes	Spawning, Nursery
NC	Neuse	Yes	Possibly	Spawning, Nursery
NC	Cape Fear-New Brunswick	Yes	Yes	Spawning, Nursery
SC	Waccamaw	Yes	Yes	Spawning, Nursery
SC/NC	Great Pee Dee	Yes	Yes	Spawning, Nursery
SC	Black	Unknown	Unknown	Unknown
SC	Santee	Yes	Yes	Spawning, Nursery
SC	Cooper	Yes	Yes	Spawning, Nursery
SC	Ashley	Yes	Unknown	Nursery
SC	Ashepoo	Unknown	Unknown	Nursery
SC	Combahee	Yes	Yes	Spawning, Nursery
SC	Edisto	Yes	Yes	Spawning, Nursery
SC	Sampit	Yes	No	Nursery
SC	Broad-Coosawatchie	Yes	Unknown	Unknown
SC/GA	Savannah	Yes	Yes	Spawning, Nursery
GA	Ogeechee	Yes	Yes	Spawning, Nursery
GA	Altamaha	Yes	Yes	Spawning, Nursery
GA	Satilla	Yes	Yes	Spawning, Nursery
GA/FL	St. Mary's	Yes	No	Nursery
FL	St. John's	Unknown	No	Nursery

Table 2. Atlantic sturgeon pair-wise comparisons among sampled populations, indicating significant or visually interpreted differences between populations.

	Altamaha	Cape Fear	Chesapeake	Combahee	Combahee/Edisto	Delaware	Edisto	Hudson
Alatamaha								
Cape Fear	ns-B, VIS-D, ***E							
Chesapeake	**C							
Combahee	VIS-D, *E	VIS-D, **E						
Combahee/Edisto	*D	*D		ns-D				
Delaware	ns-A, **C		**C					
Edisto	ns-A, ****B, VIS-D, ****E	****B, VIS-D, ****E		ns-D, ns-E	ns-D	ns-A		
Hudson	****A, ****B, **C, VIS-D	****B, VIS-D	**C	VIS-D	*D	*A, **C	****A, ****B, VIS-D	
James	VIS-D	VIS-D		VIS-D	*D		VIS-D	****D, VIS-D
Kennebec	****B, VIS-D	****B, VIS-D		VIS-D	*D		*B, VIS-D	****B, VIS-D
Neuse		ns-E		ns-E			ns-E	
Ogeechee	ns-A, *B, VIS-D, ***E	ns-B, VIS-D, ****E		ns-VIS-D, ns-E	ns-D	ns-A	ns-A, ns-b, ns-VIS-D, ns-E	****A, ****B, VIS-D
Pee Dee	**E	ns-E					**E	
Roanoke	****B, **C, VIS-D	****B, VIS-D, ****E	**C	VIS-D, **E	*D	**C	****B, VIS-D, ****E	****B, **C, VIS-D
Savannah	ns-A, *B, VIS-D	****B, VIS-D, ***E		VIS-D, ns-E	*D	ns-A	ns-A, ****B, VIS-D, ****E	****A, ****B, VIS-D
St. John	****A, **B, **C, VIS-D	****B, VIS-D	**C	VIS-D	*D	****A, **C	****A, *B, VIS-D	****A, ****B, **C, VIS-D
St. Lawrence	****A, ****B, **C, VIS-D	****B, VIS-D	**C	VIS-D	*D	*A, C**	****A, *B, VIS-D	****A, ****B, **C, VIS-D

	James	Kennebec	Neuse	Ogeechee	Pee Dee	Roanoke	Savannah	St. John
Alatamaha								
Cape Fear								
Chesapeake								
Combahee								
Combahee/Edisto								
Delaware								
Edisto								
Hudson								
James								
Kennebec	VIS-D							
Neuse								
Ogeechee	VIS-D	****B, VIS-D	*E					
Pee Dee	****E		ns-E	***E				
Roanoke	****D	***B, VIS-D	****E	*B, VIS-D, ****E	****E			
Savannah	VIS-D	****B, VIS-D	ns-E	ns-A, ns-B, VIS-D, **E	ns-E	*B, ns-VIS-D, ****E		
St. John	VIS-D	ns-B, ns-VIS-D		****A, ****B, VIS-D		**B, **C, VIS-D	****A, **B, VIS-D	
St. Lawrence	VIS-D	ns-B, ns-VIS-D		****A, ****B, VIS-D		****B, **C, VIS-D	****A, ****B, VIS-D	ns-A, ns-B, **C, ns-VIS-D

A - Waldman et al. 1996 - RFLP (*Bgl* I, *Msp* I, *Eco* R V, *Hinf* I, and *Hinc* II)
B - Wirgin et al. 2000 - mtDNA Sequencing (203 bp TAS1 - Control Region)
C - King et al. 2001 - nDNA Microsatellites (Aox9, Aox10, Aox12, Aox23, Aox27, Aox45)
D - Waldman et al. 2002 - mtDNA Sequencing (203 bp TAS1 - Control Region)
E - Wirgin Personal Communication and Supplemental Data 2005

* - P < 0.05
** - P < 0.01
*** - P < 0.001
**** - P < 0.0001
VIS - Visually Different As Interpreted From UPGMA Tree

Table 3. (A) Statistical significance of FST (lower diagonal) and Monte-Carlo-based X^2 (upper diagonal) comparisons of mtDNA control region haplotype frequencies among Atlantic sturgeon collections. All p-values, corrected using sequential Bonferroni methods, were significantly different except those noted in bold font (Wirgin, supplemental data 2006). (B) Statistical significance of FST (lower diagonal) and allele frequency heterogeneity pair-wise comparisons of 12 locus nDNA markers among Atlantic sturgeon collections. All p-values, corrected using sequential Bonferroni methods, were significantly different (King, supplemental data 2006).

(A)

Subpopulation	St. Lawrence	St. John	Kennebec	Hudson	Delaware	James	Albermarle	Edisto	Combahee	Savannah	Ogeechee	Altamaha
St. Lawrence	***	<0.0063	**0.1271**	<0.0063	<0.0063	<0.0063	**0.0230**	**0.0195**	<0.0063	<0.0063	<0.0063	<0.0063
St. John	**0.9990**	***	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063
Kennebec	**0.2188**	**0.0332**	***	<0.0063	<0.0063	<0.0063	**0.0379**	**0.0108**	**0.1073**	<0.0063	<0.0063	<0.0063
Hudson	<0.0050	<0.0050	<0.0050	***	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063
Delaware	<0.0050	<0.0050	<0.0050	**0.0596**	***	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063
James	<0.0050	<0.0050	<0.0050	<0.0050	0.0000	***	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063
Albermarle	<0.0050	<0.0050	**0.0117**	<0.0050	<0.0050	<0.0050	***	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063
Edisto	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	***	**0.3947**	<0.0063	<0.0063	<0.0063
Combahee	<0.0050	<0.0050	**0.0293**	<0.0050	**0.0195**	<0.0050	**0.0938**	**0.2725**	***	**0.0558**	<0.0063	<0.0063
Savannah	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	***	<0.0063	<0.0063
Ogeechee	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	***	<0.0063
Altamaha	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	**0.0078**	<0.0050	<0.0050	***

(B)

Subpopulation	Kennebec	Hudson	James	Albermarle	Ogeechee	Altamaha
Kennebec	***	<0.001	<0.001	<0.001	<0.001	<0.001
Hudson	<0.0001	***	<0.001	<0.001	<0.001	<0.001
James	<0.0001	<0.0001	***	<0.001	<0.001	<0.001
Albermarle	<0.0001	<0.0001	<0.0001	***	<0.001	<0.001
Ogeechee	<0.0001	<0.0001	<0.0001	<0.0001	***	<0.001
Altamaha	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	***

Table 4. Analysis of Molecular Variance (AMOVA) results employing 12 locus nDNA markers and nine Atlantic sturgeon populations (King, supplemental data 2006).

DPSs	Population Groupings	Among Regions %	Among Populations within a Region %
2	1. Saint John, Kennebec, Hudson 2. York, James, Roanoke, Savannah, Ogeechee, Altamaha	7	10
3	1. Saint John, Kennebec, Hudson 2. York and James 3. Roanoke, Savannah, Ogeechee, Altamaha	8	7
4	1. Saint John, Kennebec, Hudson 2. York and James 3. Roanoke, Savannah, Altamaha 4. Ogeechee	10	6
5	1. Saint John and Kennebec 2. Hudson 3. York and James 4. Roanoke, Savannah, Altamaha 5. Ogeechee	11	5
6	1. Saint John and Kennebec 2. Hudson 3. York and James 4. Roanoke 5. Savannah and Altamaha 6. Ogeechee	12	3
7	1. Saint John 2. Kennebec 3. Hudson 4. York and James 5. Roanoke 6. Savannah and Altamaha 7. Ogeechee	13	2
8	1. Saint John 2. Kennebec 3. Hudson 4. York and James 5. Roanoke 6. Savannah 7. Ogeechee 8. Altamaha	13	1

Table 5. Analysis of Molecular Variance (AMOVA) results from 12 Atlantic sturgeon populations using mtDNA sequence data (Wirgin, supplemental data 2006).

DPSs	Population Groupings	Among Regions %	Among Populations within a Region %
3	1. Saint Lawrence, Saint John, Kennebec 2. Hudson, Delaware, James, Roanoke 3. Edisto, Combahee, Savannah, Ogeechee, Altamaha	15	15
4	1. Saint Lawrence, Saint John, Kennebec 2. Hudson and Delaware 3. James and Savannah 4. Roanoke, Edisto, Combahee, Savannah, Ogeechee, Altamaha	20	10
5	1. Saint Lawrence, Saint John, Kennebec 2. Hudson and Delaware 3. James and Savannah 4. Roanoke, Edisto, Combahee, Altamaha 5. Ogeechee	23	7
6	1. Saint Lawrence, Saint John, Kennebec 2. Hudson and Delaware 3. James and Savannah 4. Roanoke 5. Edisto, Combahee, Altamaha 6. Ogeechee	23	5
7	1. Saint Lawrence, Saint John, Kennebec 2. Hudson and Delaware 3. James and Savannah 4. Roanoke 5. Edisto and Combahee 6. Ogeechee 7. Altamaha	24	4
8	1. Saint Lawrence, Saint John, Kennebec 2. Hudson and Delaware 3. James 4. Roanoke 5. Edisto and Combahee 6. Savannah 7. Ogeechee 8. Altamaha	27	0
9	1. Saint Lawrence and Saint John 2. Kennebec 3. Hudson and Delaware 4. James 5. Roanoke 6. Edisto and Combahee 7. Savannah 8. Ogeechee 9. Altamaha	26	1

Table 6. Classification success rate for Atlantic sturgeon to their natal river and distinct population segment (DPS) using both 7 and 12 locus nDNA microsatellites. Top: a classification matrix, in which YOY or adults were exclusively used in the analysis employing a 12 locus nDNA marker. Bottom: a classification matrix, in which YOY or adults were exclusively used in the analysis employing a 7 locus nDNA marker.

12 – Locus nDNA microsatellites

Collection	Kennebec River	Hudson River	James River	Albemarle Sound	Savannah River	Ogeechee River	Altamaha River	**Correct Assign.**
Kennebec River	**37**	**3**	**2**					**88.1**
Hudson River	**3**	**49**	**1**					**92.5**
James River		**5**	**109**				**1**	**94.8**
Albemarle Sound	**1**	**1**		**33**	**1**			**91.7**
Savannah River			**2**	**2**	**21**		**10**	**60.0**
Ogeechee River			**1**		**2**	**34**		**91.9**
Altamaha River					**7**	**1**	**41**	**83.7**
DPS	**88.1**	**92.5**	**94.8**	**91.7**	**95.9**			**88.3** **93.7**

7 – Locus nDNA microsatellites

Collection	Kennebec River	Hudson River	James River	Albemarle Sound	Savannah River	Ogeechee River	Altamaha River	**Correct Assign.**
Kennebec River	**34**	**6**	**2**					**81.0**
Hudson River	**2**	**47**	**3**	**1**				**88.7**
James River	**2**	**9**	**97**		**3**		**4**	**84.4**
Albemarle Sound		**3**		**29**	**4**			**80.6**
Savannah River		**1**	**3**	**1**	**13**	**1**	**16**	**37.1**
Ogeechee River			**1**	**1**	**1**	**33**	**1**	**89.2**
Altamaha River			**1**	**1**	**6**	**3**	**38**	**77.6**
DPS	**81.0**	**88.7**	**84.4**	**80.6**	**91.7**			**79.0** **86.9**

Table 7. The percentage of riverine habitat (rkm) available to Atlantic sturgeon in each river system, ranging from the mouth of the river to the fall line or historic spawning grounds. Estimates of river kilometers were based on GIS mapping and reference points provided by Oakley 2005 and other sources. However, river kilometers is only an estimate of habitat availability and should not be confused as a reference to habitat suitability as many factors can reduce the quality of this available habitat (e.g., impeded by water flow, dredging, water quality and other similar factors).

State	River	Fall Line or Historic Spawning Location (rkm)	Current Upstream Migration (rkm)	% of Habitat Currently Available	% of Historic Habitat Impeded	Blockage	Fall Line or Historic Spawning RKM Source	Current RKM Source
QB	Saint Lawrence	760	760	100%	0%		GIS Mapping	GIS Mapping
NB	Saint John	110	110	100%	0%	Mactaquac Dam	GIS Mapping	GIS Mapping
ME	Penobscot	71	56	79%	21%	Veazie Dam	T. Squiers, PC, 2006	T. Squiers, PC, 2006
ME	Kennebec	98	98	100%	0%	Lockwood Dam	T. Squiers, PC, 2006	T. Squiers, PC, 2006
ME	Androscroggin	14	14	100%	0%	Brunswick Dam	GIS Mapping	Oakley 2005
ME	Sheepscot	32	32	100%	0%		T. Squiers, PC, 2006	T. Squiers, PC, 2006
NH/MA	Merrimack	116	49	42%	58%	Essex Dam	GIS Mapping	Oakley 2005
MA	Taunton	79	70	89%	11%	Town River Pond Dam	GIS Mapping	GIS Mapping
MA/CT	Connecticut	167	143	86%	14%	Holyoke Dam	GIS Mapping	Oakley 2005
NY	Hudson	204	280	100%	0%		GIS Mapping	Oakley 2005
NJ/DE/PA	Delaware	140	579	100%	0%		GIS Mapping	Oakley 2005
PA/MD	Susquehanna	-6	10	100%	0%	Conowingo Dam	GIS Mapping	GIS Mapping
MD/VA	Potomac	248	248	100%	0%		GIS Mapping	Oakley 2005
VA	Rappahanock	172	172	100%	0%		Bushnoe et al. 2005	GIS Mapping
VA	York	374	374	100%	0%		GIS Mapping	GIS Mapping
VA	James	203	203	100%	0%		Bushnoe et al. 2005	GIS Mapping
NC/VA	Chowan/Nottoway	227	227	100%	0%		GIS Mapping	GIS Mapping
NC	Roanoke	252	207	82%	18%	Roanoke Rapids Dam	GIS Mapping	GIS Mapping
NC	Tar-Pamlico	199	199	100%	0%	Rocky Mount Mill Pond Dam	GIS Mapping	GIS Mapping
NC	Neuse	253	253	100%	0%		GIS Mapping	GIS Mapping
NC	Cape Fear	267	95	36%	64%	Lock and Dam #1	GIS Mapping	Oakley 2005
SC	Waccammaw	214	214	100%	0%		GIS Mapping	Oakley 2005
SC	Great Pee Dee	266	276	100%	0%	Blewett Falls	GIS Mapping	Oakley 2005
SC	Sampit	40	40	100%	0%		GIS Mapping	GIS Mapping
SC	Ashley	95	95	100%	0%		GIS Mapping	GIS Mapping
SC	Santee/Cooper	311	119	38%	62%	Pinnpolis and Santee Dams	GIS Mapping	Oakley 2005
SC	Ashepoo	78	78	100%	0%		GIS Mapping	Oakley 2005
SC	Combahee	163	163	100%	0%		GIS Mapping	Oakley 2005
SC	Edisto	280	280	100%	0%		GIS Mapping	Oakley 2005
SC	Broad/Coosawatchi	90	90	100%	0%		GIS Mapping	GIS Mapping
SC/GA	Savannah	343	317	92%	8%	New Savannah Bluff L&D	GIS Mapping	Oakley 2005
GA	Ogeechee	375	375	100%	0%	Jordan Mill Pond Dam	GIS Mapping	Oakley 2005
GA	Altamaha	400	400	100%	0%		GIS Mapping	Oakley 2005
GA	Satilla	376	376	100%	0%		GIS Mapping	GIS Mapping
GA/FL	St. Mary's	274	274	100%	0%		GIS Mapping	GIS Mapping
FL	St. Johns	416	153	37%	63%	Kirkpatrick Dam	GIS Mapping	GIS Mapping
		AVERAGE		91%	9%			

Table 8. Atlantic sturgeon captured by dredge type as reported by the U.S. Army Corps of Engineers for the U.S. east coast from 1990 – 2005. Reports include only those trips when an observer was on board to document capture, and numbers do not reflect all sturgeon captures.

	Dredge Type		
Year	**Hopper**	**Clam**	**Pipeline**
1990	1		
1991			
1992			
1993			
1994	3		
1995			
1996			
1997			
1998	2	1	1
1999			
2000	2	1	
2001		1	
2002			
2003			
2004	1		
2005	1		
Totals	**10**	**3**	**1**

Table 9. Summary of the National Coastal Condition Report (NCCR II) for the U.S. east coast published by the U.S. Environmental Protection Agency (2004) that grades coastal environments. Northeast Region is Maine south through Virginia; southeast region is North Carolina south through Florida. Chesapeake Bay was also graded separately from the Northeast Region.

	Region		
Status Index	**Northeast**	**Chesapeake Bay**	**Southeast**
Water Quality	D	F	B
Sediment	F	F	B
Coastal Habitat	B	-	C
Benthos	F	F	C
Fish Tissue	F	F	A
Overall	**F**	**F**	**B-**

Table 10. Bycatch and bycatch rate of Atlantic sturgeon and landings for monitored trips by targeted species from 1989 – 2000. Estimates provided by Stein et al. 2004(b).

Rank	Target Species	Sturgeon catch (lbs)	Landings for monitored trips (lbs)	Bycatch rate (lbs/trip)
1	Weakfish - Striped bass	35	210	0.1667
2	Northern kingfish	85	3,511	0.0242
3	American shad	540	22,582	0.0239
4	Southern flounder	107	5,361	0.0200
5	Red hake	50	2,912	0.0172
6	Witch flounder	341	20,628	0.0165
7	Winter skate	105	7,008	0.0150
8	Scup	570	48,525	0.0117
9	Weakfish	116	11,163	0.0104
10	Striped bass	456	58,874	0.0077
11	Goosefish	7,975	1,599,948	0.0050
12	Atlantic cod	1,542	323,795	0.0048
13	Smooth dogfish	760	246,244	0.0031
14	Winter flounder	277	108,613	0.0026
15	Summer flounder	1,196	720,499	0.0017
16	Unidentified dogfish	2,107	1,320,843	0.0016
17	Tautog	10	8,906	0.0011
18	Spiny dogfish	3,910	4,126,878	0.0009
19	Butterfish	265	331,064	0.0008
20	Bluefish	169	257,215	0.0007
21	Yellowtail flounder	230	434,270	0.0005
22	Atlantic croaker	373	749,476	0.0005
23	Horseshoe crab	97	205,728	0.0005
24	Haddock	45	97,974	0.0005
25	Atlantic menhaden	8	25,792	0.0003
26	Weakfish - Atlantic croaker	10	45,290	0.0002
27	Longfin inshore squid	355	1,826,769	0.0002
28	Pollock	75	717,607	0.0001
29	Unidentified squid	50	519,933	0.0001
30	Unidentified tuna	8	843,336	0.0000

Table 11. Summary of Atlantic sturgeon bycatch mortality for different gear and target fisheries.

Region/State/River	Gear	Target Fishery	Mortality (%)	Source
Delaware	Anchor Gill Net	DFW Survey	10	C. Shirey, DFW
NC to MA	Drift Net	General	10	Stein et al. 2004
Chesapeake Bay	Gill Net	Striped Bass	0-8	C. Hager, VIMS
Winyah Bay, SC	Gill Net	American shad	16	M. Collins, SCDMF
Albemarle Sound, NC	Gill Net	Flounder	0	White and Armstrong 2000
NC to MA	Pound Net	General	0.2	NEFO 2000-2004
NC to MA	Sink Gill Net	Monkfish	51	NEFO 2000-2004
NC to MA	Sink Gill Net	Striped Bass	10	NEFO 2000-2004
NC to MA	Sink Gill Net	Smooth Dogfish	6	NEFO 2000-2004
NC to MA	Sink Gill Net	Spiny Dogfish	10	NEFO 2000-2004
NC to MA	Sink Gill Net	Atlantic Cod	30	NEFO 2000-2004
Cape Fear, NC	Sink Gill Net	UNCW Survey	25-37	F. Rohde, NCDMF
Chesapeake Bay	Staked Gill Net	American shad	4	C. Hager, VIMS
NC to MA	Trawl	General	0	Stein et al. 2004

Table 12. Significant portion of its range criteria collectively scored by the status review team.

Population Unit	DPS	Historic Pop	Current Pop	Spatial Structure	Number of Criteria Met
Penobscot	Gulf of Maine				
Kennebec		√	√	√	3
Androscoggin		-	-	-	
Sheepscot		-	-	-	
Piscatiquis		-	-	-	
Merrimack		-	-	-	
Taunton	NY Bight	-	-	-	
Connecticut		-	-	-	
Hudson		√	√	√	3
Delaware		√		√	2
James	Chesapeake Bay	√	√	√	3
York					
Rappahannock		-	-	-	
Potomac		-	-	-	
Susquehanna		-	-	-	
Nanticoke		-	-	-	
Roanoke	Carolina	√	√		2
Tar/Pamlico					
Neuse					
Cape Fear				√[1]	1
Waccamaw					
Pee Dee		√	√		2
Sampit		-	-	-	
Santee-Cooper				√[1]	1
ACE Basin	South Atlantic		√		1
Broad/Coosawatchie		-	-	-	
Savanah					
Ogeechee					
Altamaha		√	√	√	3
Satilla					
St. Mary's		-	-	-	
St. John's		-	-	-	

1 - In combination, the Cape Fear and Santee-Cooper River populations would represent a loss of spatial structure.

Table 13. Results of the extinction risk analysis by population unit and stressor categories. Scores reflect the status review team's median scores, and scores were defined as: 1 – low risk, 2 – moderately low risk, 3 – moderate risk, 4 – moderately high risk, and 5 – high risk of extinction. Cells with hyphens denote subpopulations that were considered extirpated and thus not examined.

Population Unit	DPS	Dams	Dredging	Water Quality	Factor 1 Score	Commercial Bycatch	Scientific Colletion	Factor 2 Score	Competition	Predation	Disease	Factor 3 Score	International Authorites	US Interstate-Federal Authorities	State Authorities	Factor 4 Score	Impingement and Entrainment	Ship Strikes	Artificial Propagation	Factor 5 Score	Overall Score	Subpopulation Risk Level	Considered Significant under SPOIR Criteria	DPS Recommendation
Penobscot	Gulf of Maine	2	2	3	3	3	1	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate		Insufficient Data
Kennebec		1	3	3	3	3	1	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate	Yes	
Androscoggin		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Sheepscot		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Piscatiquis		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Merrimack		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Taunton	NY Bight	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Threatened
Connecticut		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Hudson		1	1	2	2	3	1	3	1	1	1	1	1	2	2	2	2	1	2	2	3	Moderate	Yes	
Delaware		1	3	3	3	3	1	3	1	1	1	1	1	2	2	2	1	4	1	4	4	Moderately High	Yes	
York	Chesapeake Bay	1	1	2	2	3	1	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate		Threatened
James		1	3	3	3	4	1	4	1	1	1	1	1	2	2	2	1	3	1	3	4	Moderately High	Yes	
Rappahannock		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Potomac		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Susquehanna		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Nanticoke		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Roanoke	Carolina	2	1	2	2	3	2	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate	Yes	Threatened
Tar/Pamlico		1	1	3	3	3	1	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate		
Neuse		3	1	3	3	3	1	3	1	1	1	1	1	3	3	3	1	1	1	1	3	Moderate		
Cape Fear		4	3	3	4	3	3	3	1	1	1	1	1	2	2	2	1	2	1	2	4	Moderately High	Yes	
Waccamaw		1	1	3	3	3	1	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate		
Pee Dee		1	1	3	3	3	1	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate	Yes	
Sampit		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Santee-Cooper		4	2	2	4	2	1	2	1	1	1	1	1	2	3	3	1	1	1	1	4	Moderately High	Yes	
ACE Basin	South Atlantic	1	1	2	2	2	1	2	1	1	1	1	1	2	2	2	1	1	1	1	2	Moderately Low	Yes	Insufficient Data
Broad/Coosawatchie		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Savanah		2	3	2	3	2	1	2	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate		
Ogeechee		1	1	3	3	2	1	2	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate		
Altamaha		1	1	2	2	3	1	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate	Yes	
Satilla		1	1	2	2	2	1	2	1	1	1	1	1	2	2	2	1	1	1	1	2	Moderately Low		
St. Mary's		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
St. John's		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
ESA Factors		**(1) The Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range**				**(2) Overutilization for Commercial, Recreational, or Scientific Purposes**			**(3) Competition, Predation, and Disease**				**(4) Existing Regulatory Authorities, Laws and Policies**				**(5) Other Natural or Manmade Factors**				**Overall Score**	**Subpopulation Risk Level**	**Considered Significant under SPOIR Criteria**	**DPS Recommendation**

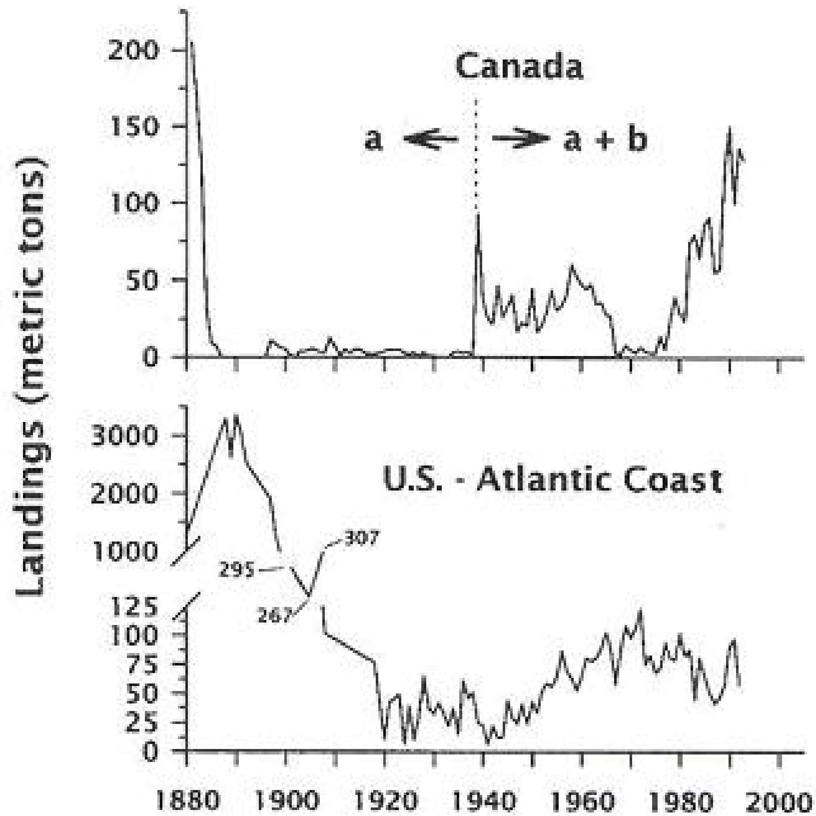

Figure 1. Reported landings of Atlantic sturgeon (1880 – 2000). Canadian estimates prior to 1940 only existed for the Saint John fishery. After 1940, landings data include both Saint John (a) and Saint Lawrence (b) fisheries. U.S. landings are based on NMFS data and may include shortnose sturgeon prior to 1972, as these species are difficult to differentiate. Courtesy of Smith and Clugston (1997).

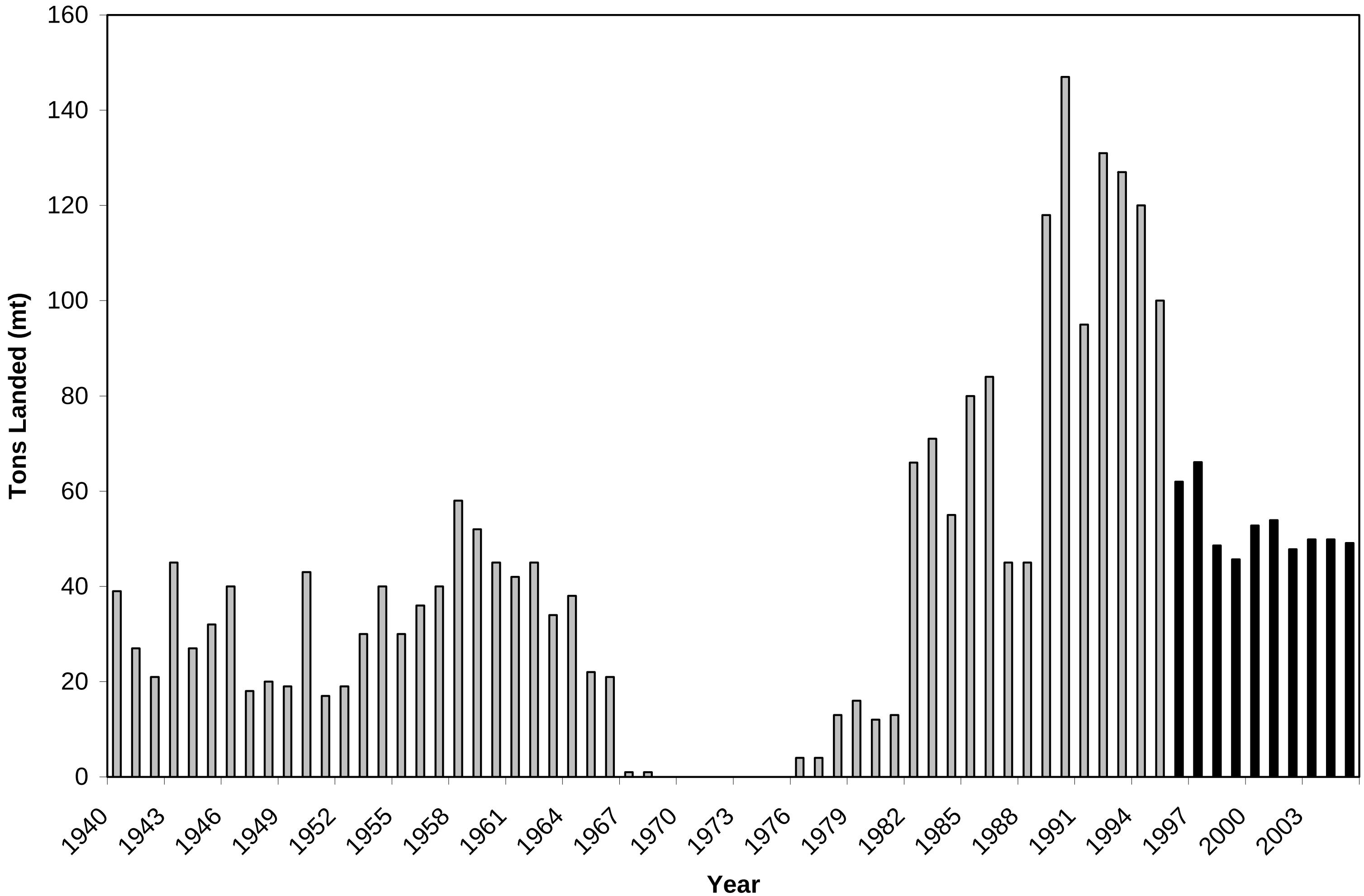

Figure 2. Atlantic sturgeon landings from the Saint Lawrence River 1940 – 2005. Black bars indicate years when a 60 mt quota was in place. Landings data from 1940 – 2000 were estimated from data presented in Trencia et al. (2002). There were no landings during 1970-1976.

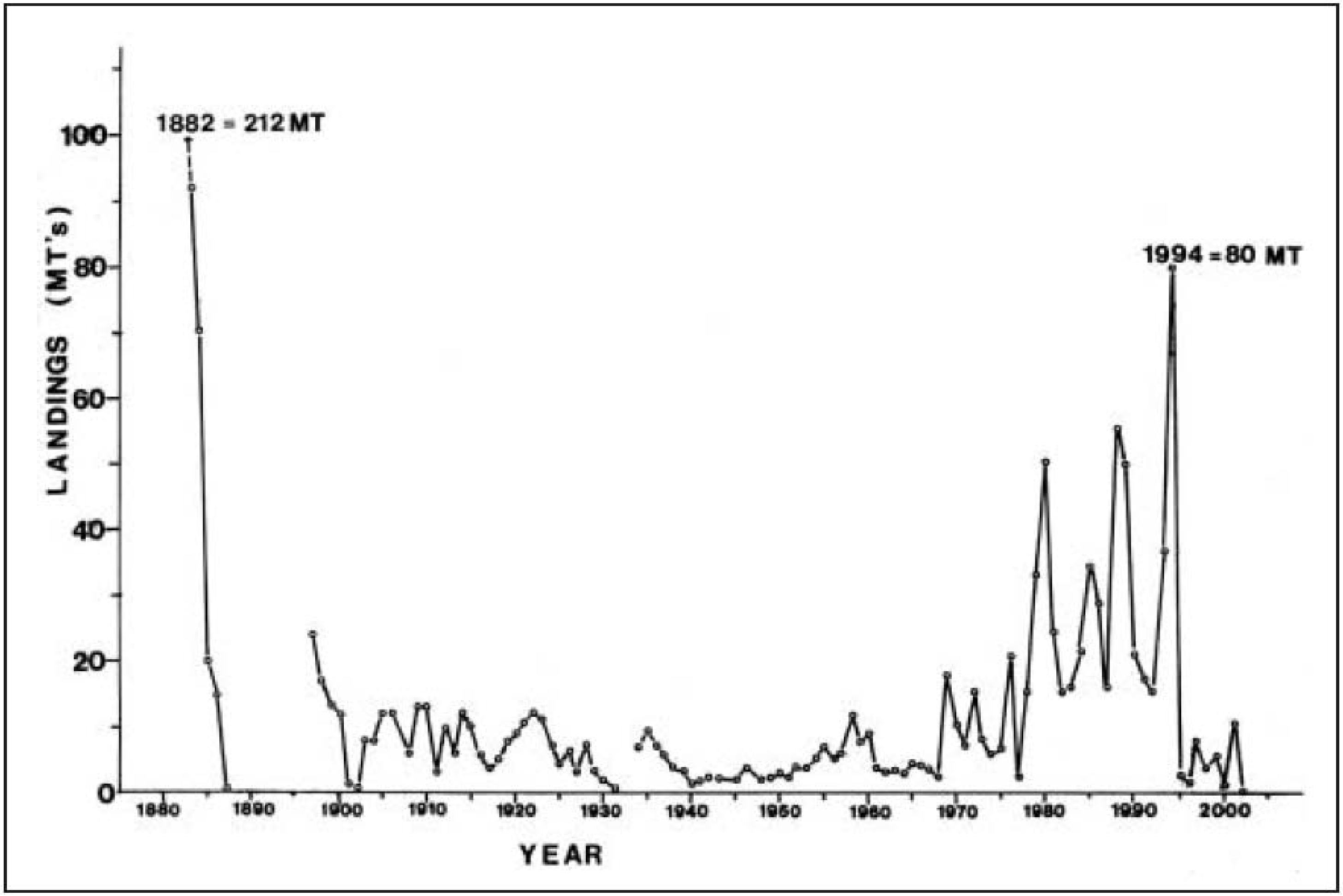

Figure 3. Atlantic sturgeon landings from the Saint John River 1882 – 2002. Courtesy of Dadswell (2006), based on data provided by Rogers (1936) and Canadian Fisheries Statistics.

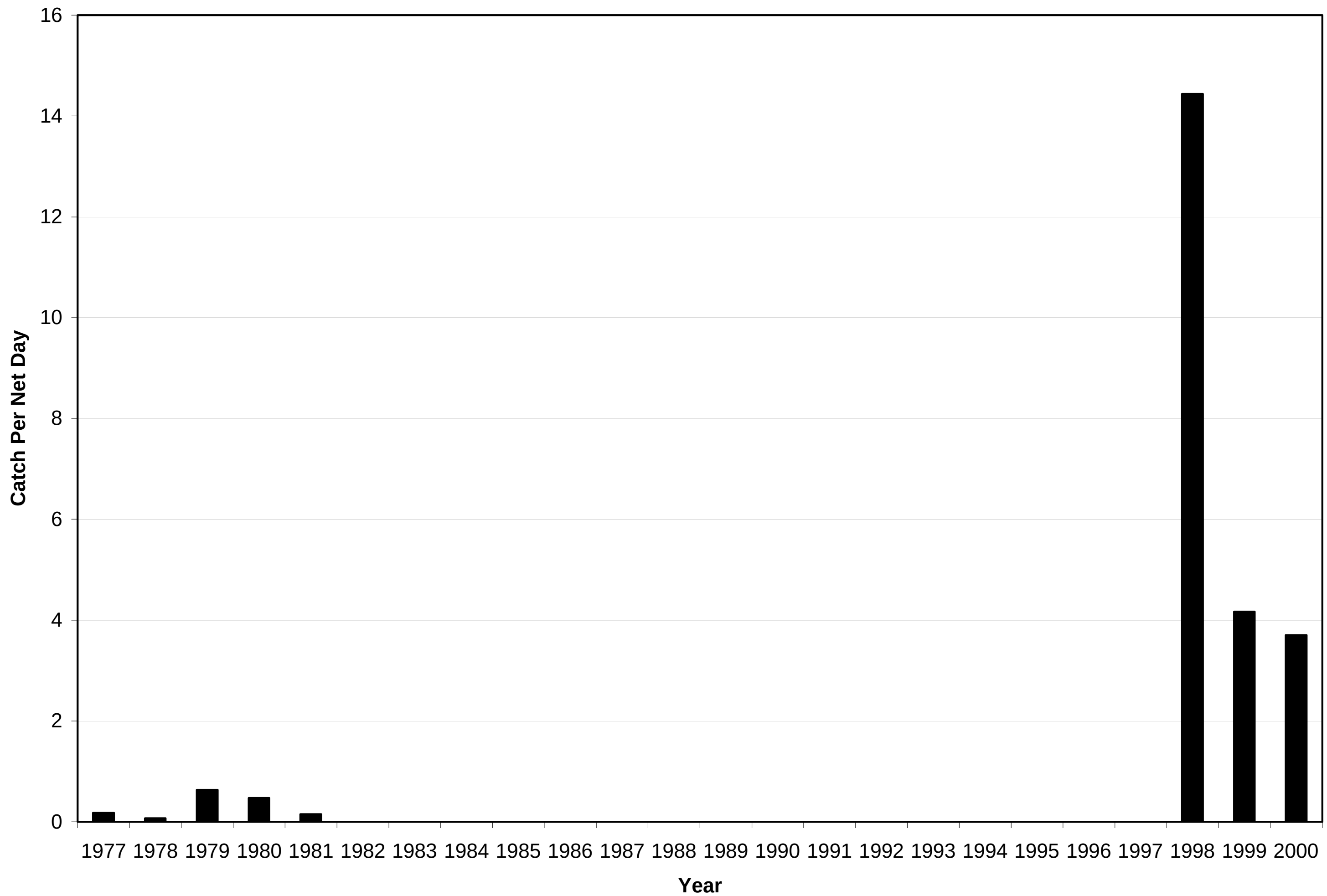

Figure 4. Atlantic sturgeon bycatch from a standardized shortnose sturgeon survey conducted between the periods of 1977-1981 and 1998-2000 in the Kennebec River, Maine.

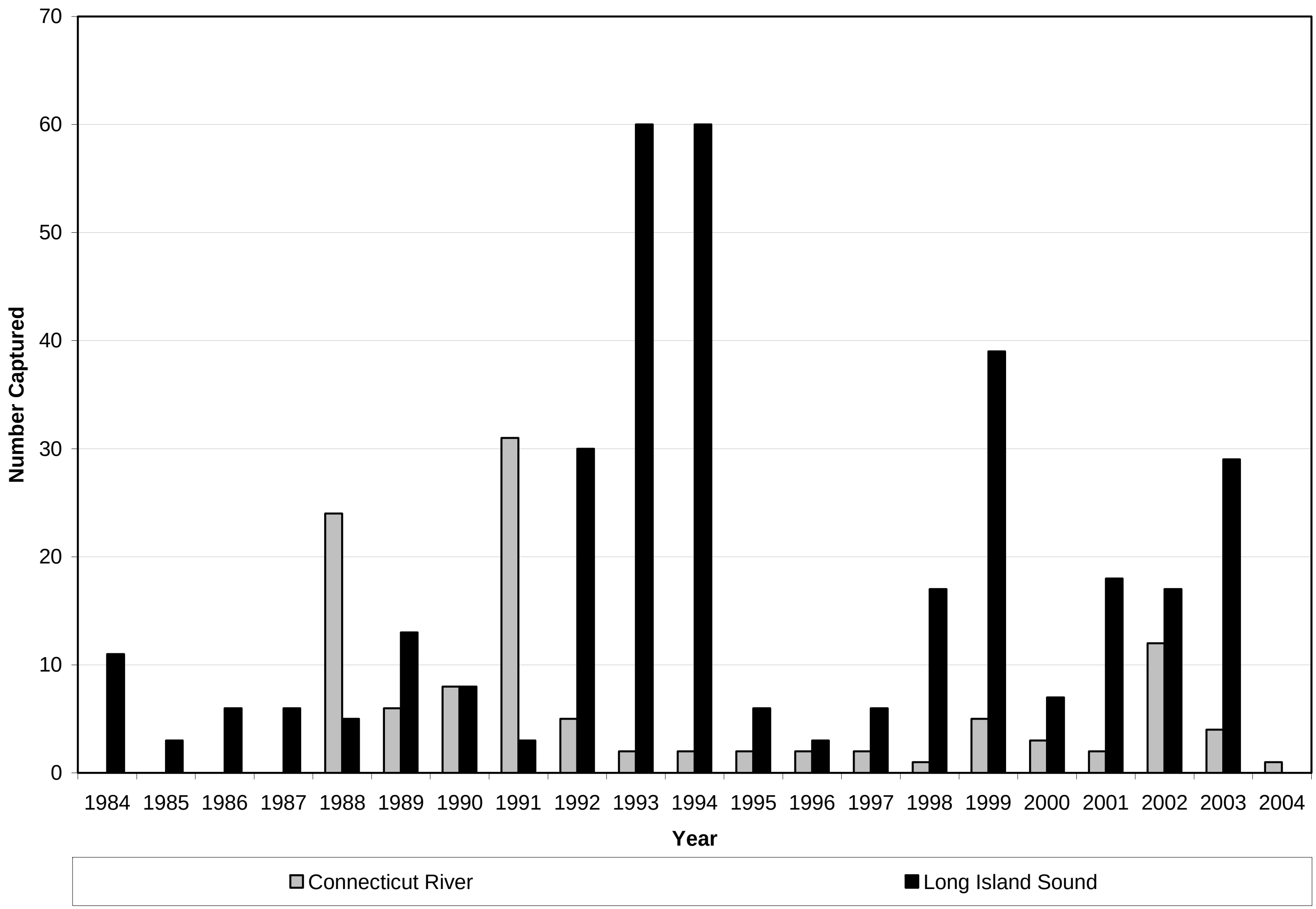

Figure 5. Atlantic sturgeon captures from the Long Island Sound Trawl and Connecticut DEP surveys. These sturgeon are believed to be of Hudson River origin.

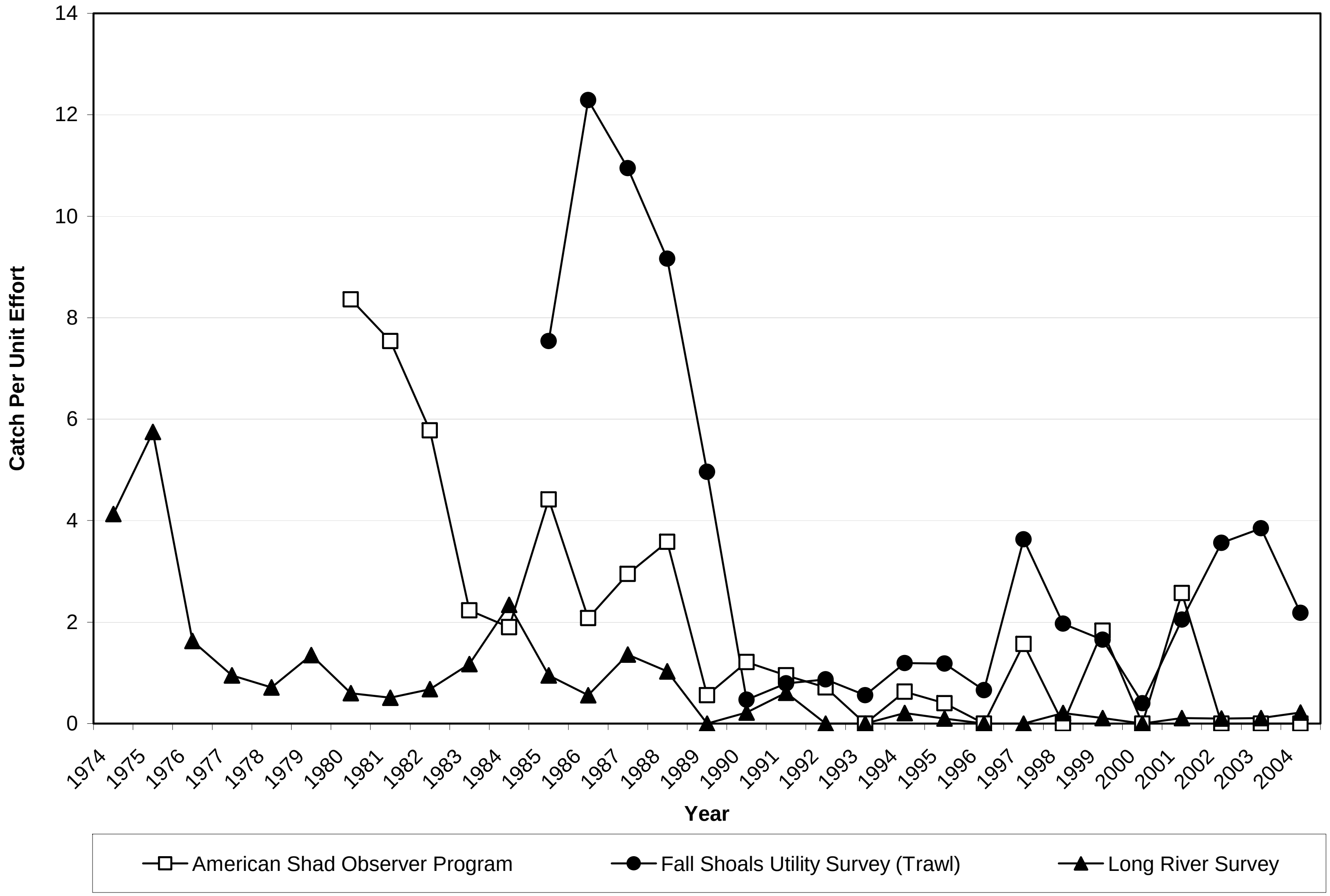

Figure 6. CPUE of Hudson River surveys that captured Atlantic sturgeon by year (1974-2004) and survey.

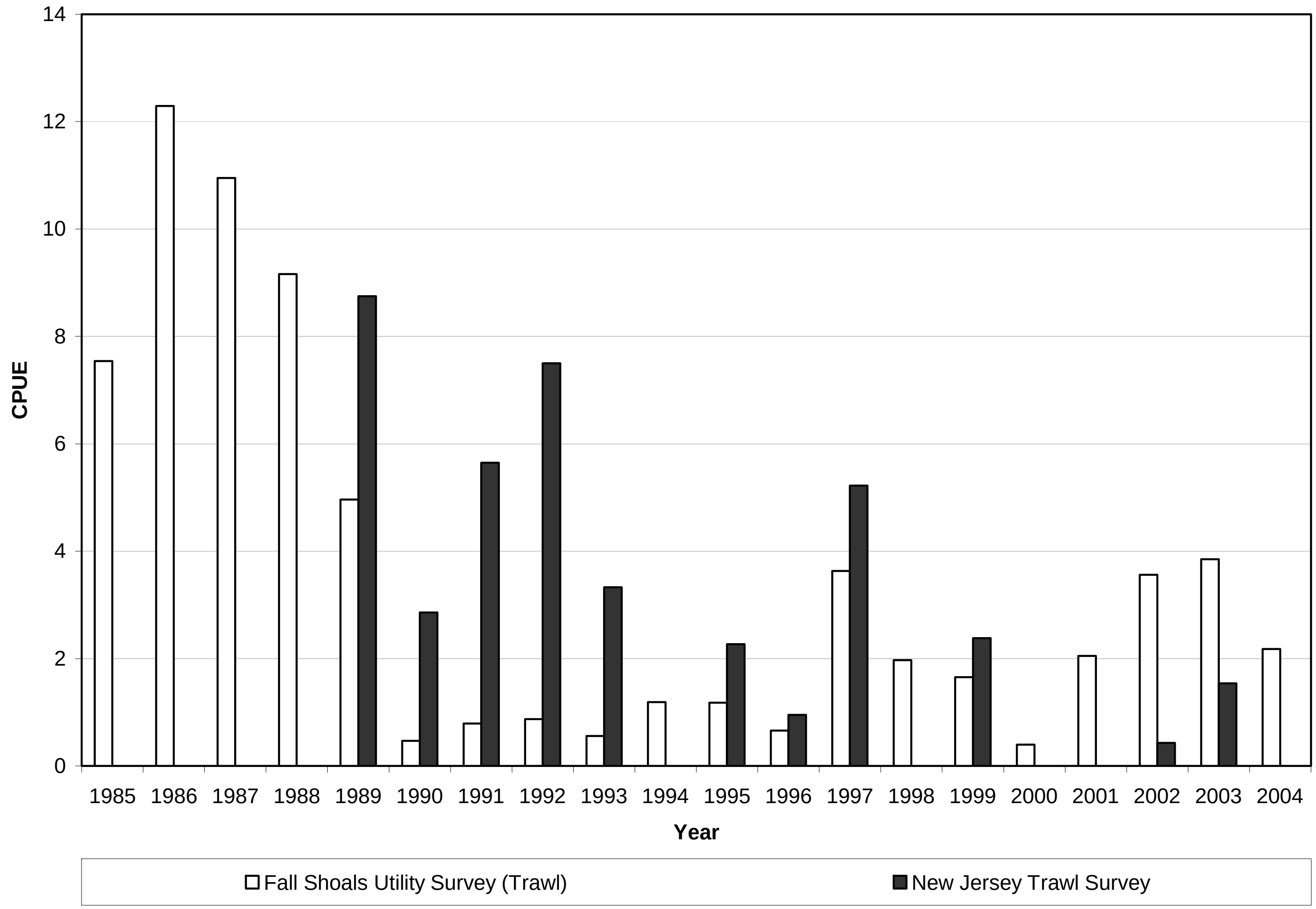

Figure 7. A comparison between Hudson River CPUE within the mainstem of the river (Fall Shoals Utility) and New York Bight (New Jersey Trawl Survey) captures. The Fall Shoals Utility CPUE is multiplied by 10 to adjust the y-axis.

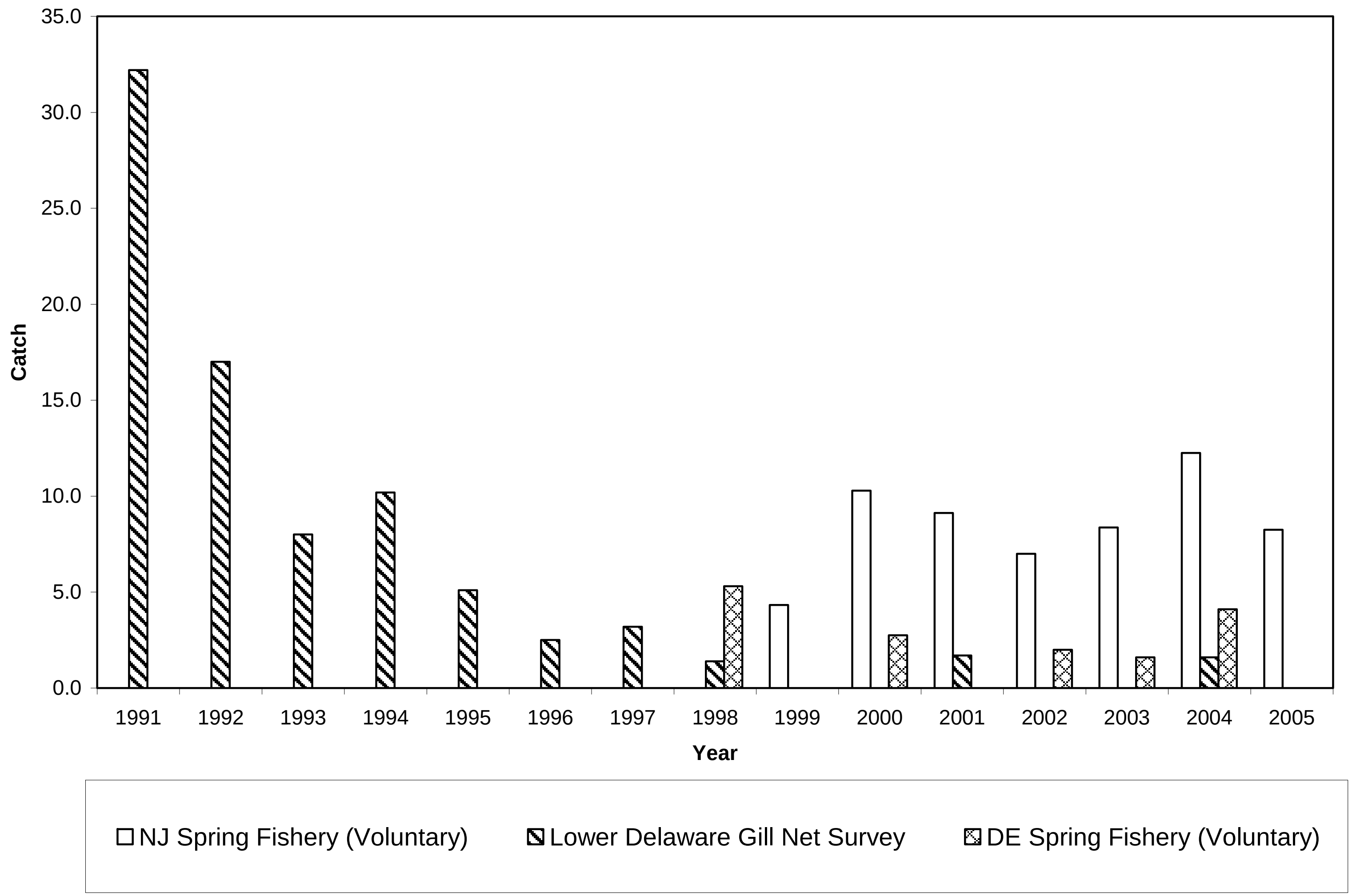

Figure 8. CPUE of Atlantic sturgeon from the Delaware River 1991 – 2005 from three surveys. The Delaware and New Jersey Spring Gill Net Fishery reports mean #/fisher and the Lower Delaware River Gill Net Survey reports number captured/hr.

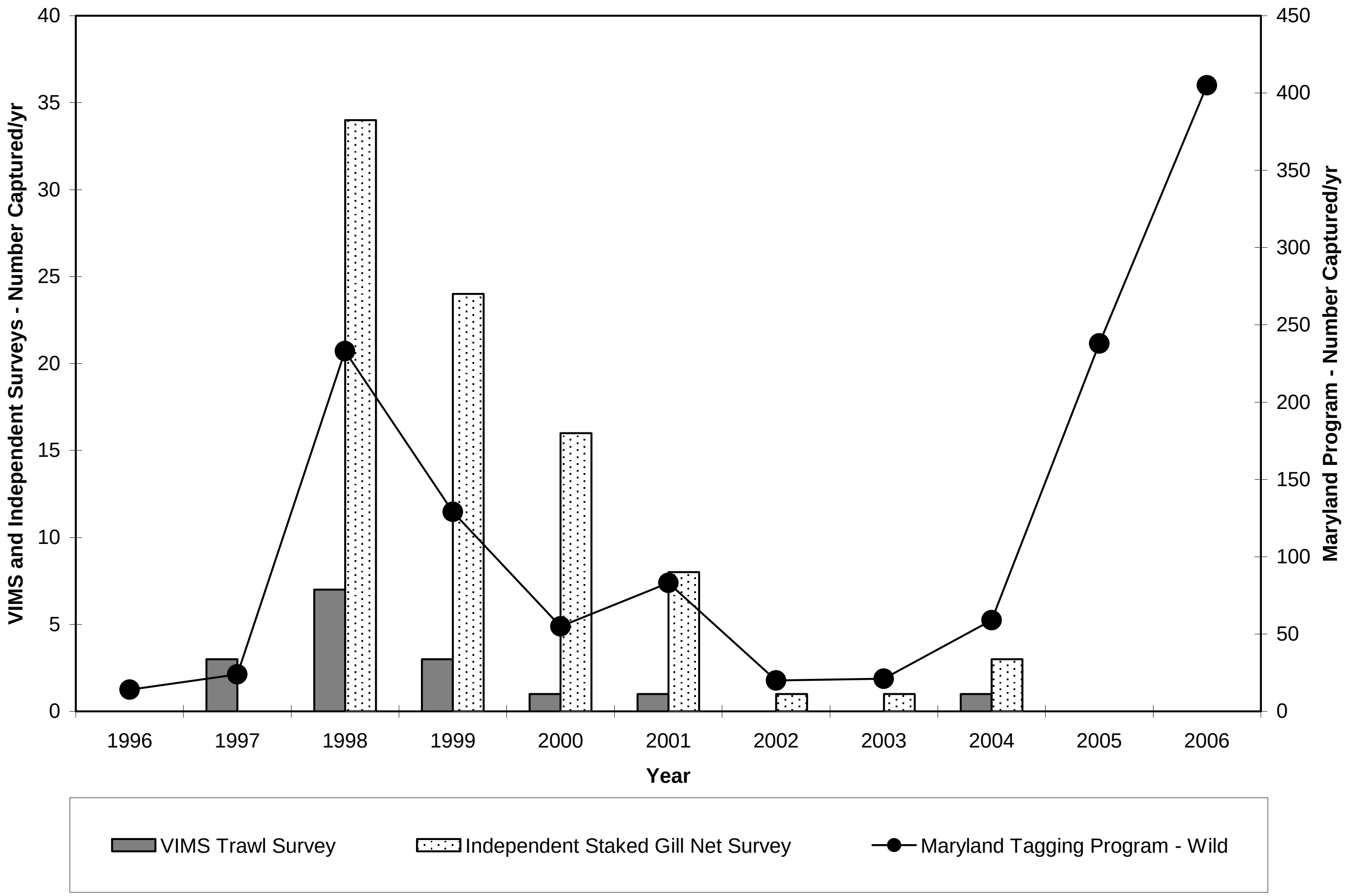

Figure 9. Reported catch rates of Atlantic sturgeon from the Chesapeake Bay (1996 – 2005) by survey. VIMS Trawl data are available from 1955 to 2004; however, zero sturgeon were captured between 1990 and 1996. Independent Staked Gill Net Survey data are available from 1997 to 2004.

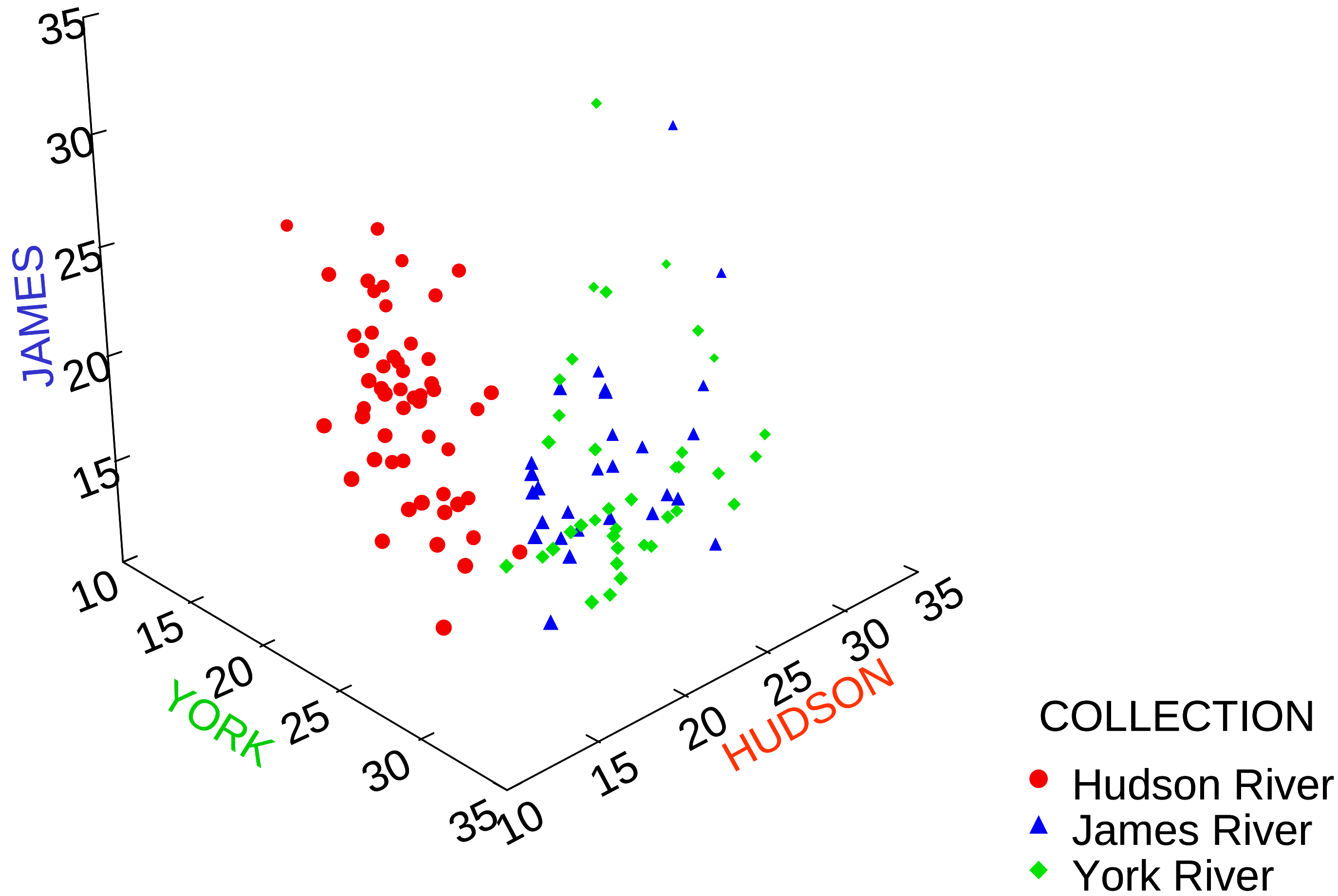

Figure 10. A 3-D scatter plot demonstrating how well York, James, and Hudson River Atlantic sturgeon can be differentiated from one another, using 12 locus nDNA markers.

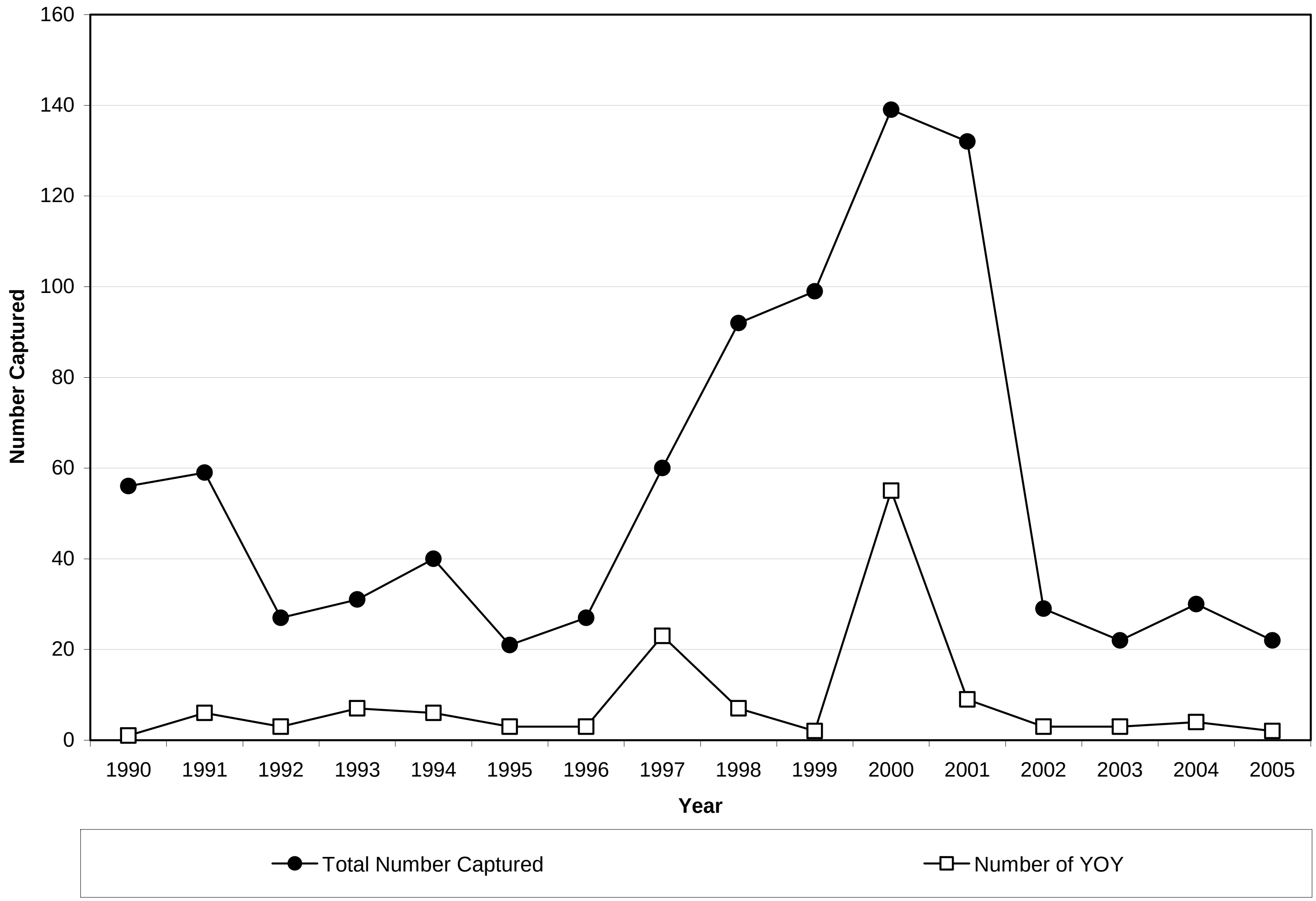

Figure 11. Comparison of total Atlantic sturgeon versus young-of-year captured during the NC Division of Marine Fisheries, Albemarle Sound Independent Gill Net Survey 1990 – 2006.

Figure 12. Left: A 39 cm TL young-of-year Atlantic sturgeon captured by recreational fishers on the Roanoke River near Jamesville, NC. Right: A 46 cm TL juvenile Atlantic sturgeon captured in the Neuse River, above New Bern, North Carolina (Photos courtesy of NCWRC).

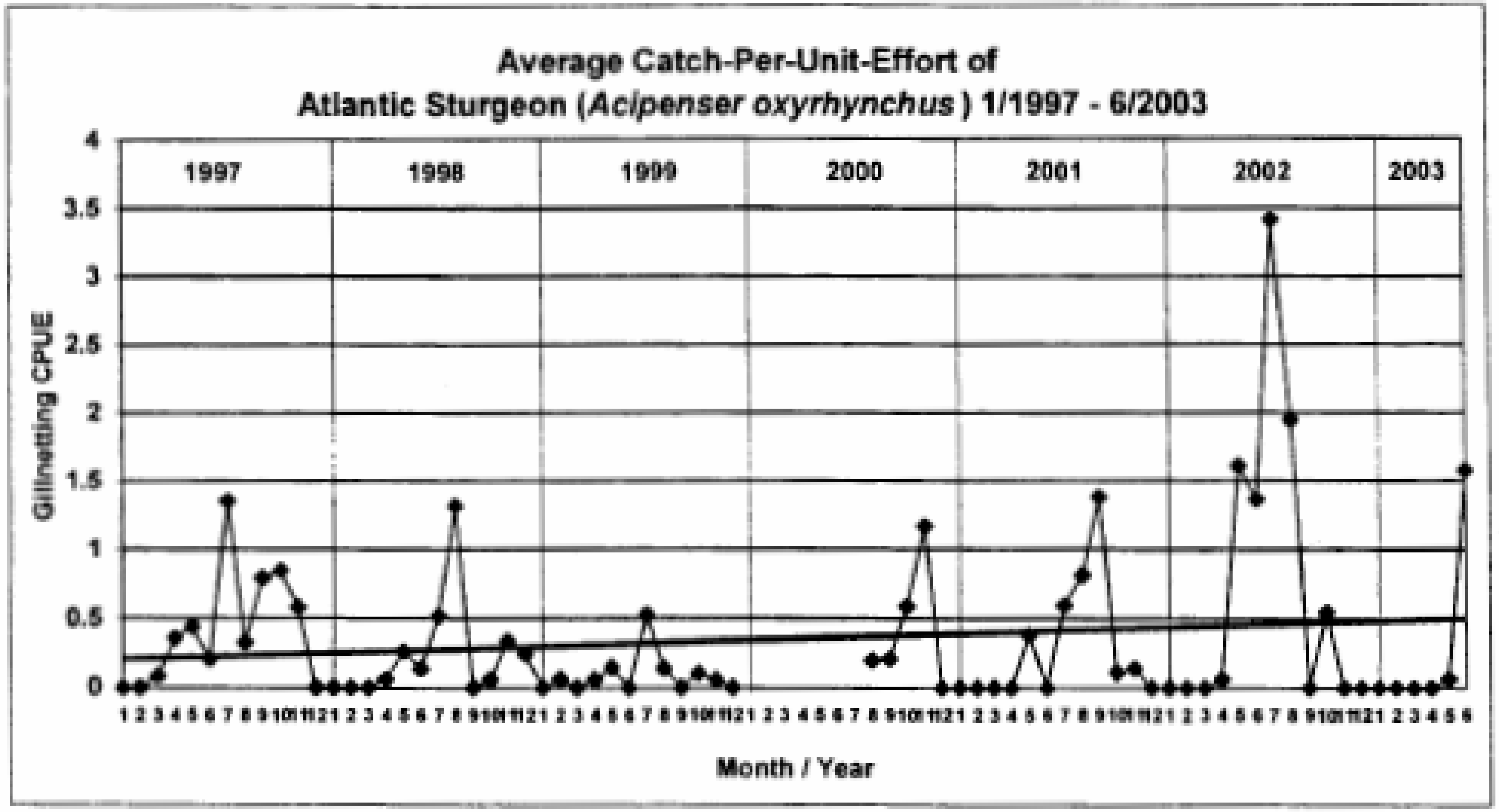

Figure 13. The average CPUE of Atlantic sturgeon captured on the Cape Fear River during the periods of 1997-2003. Courtesy of Williams and Lankford (2003).

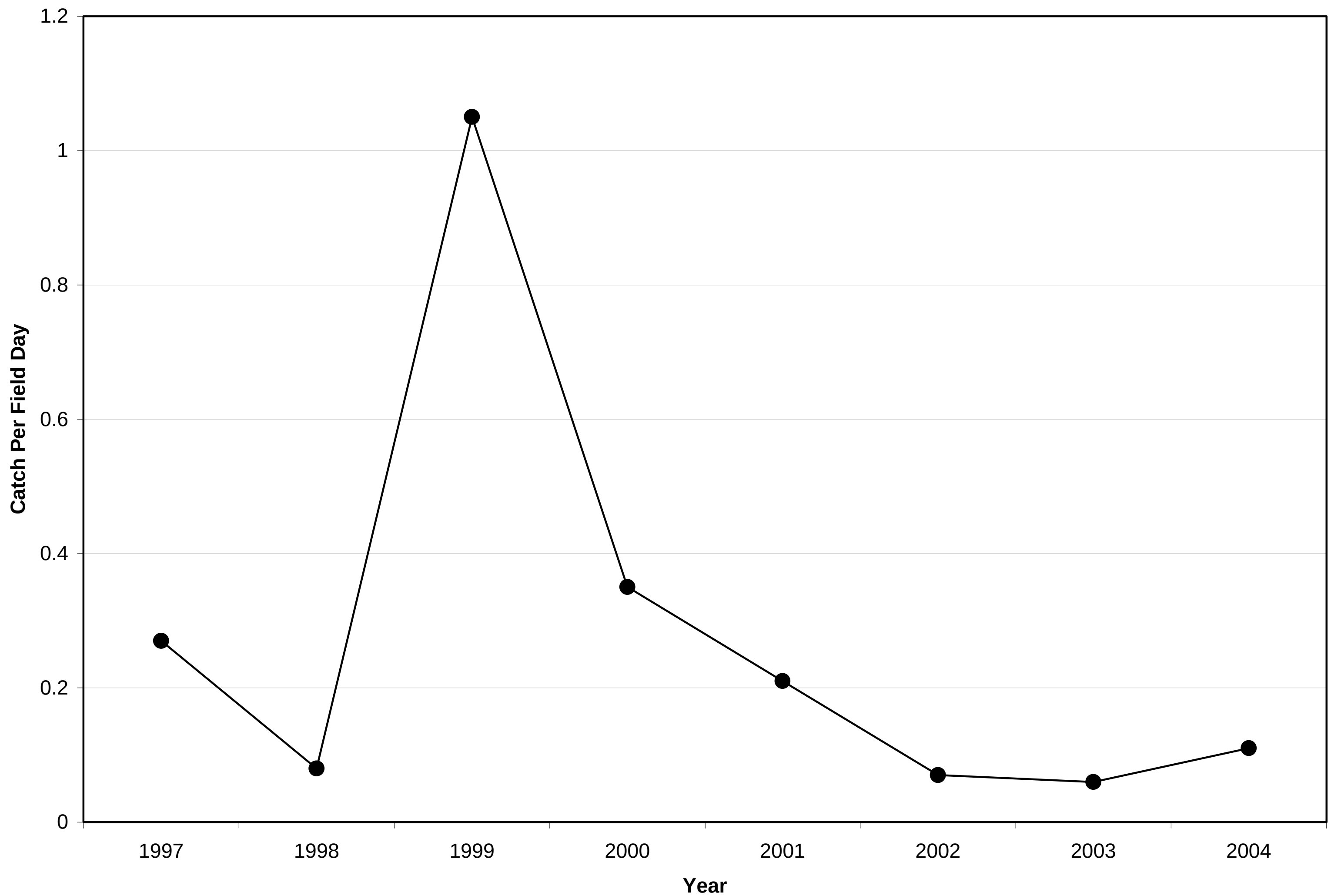

Figure 14. CPUE data of Atlantic sturgeon captures as bycatch in the Georgia Wildlife Resources Division Shad Monitoring Program 1997-2004, in the Georgia Altamaha River.

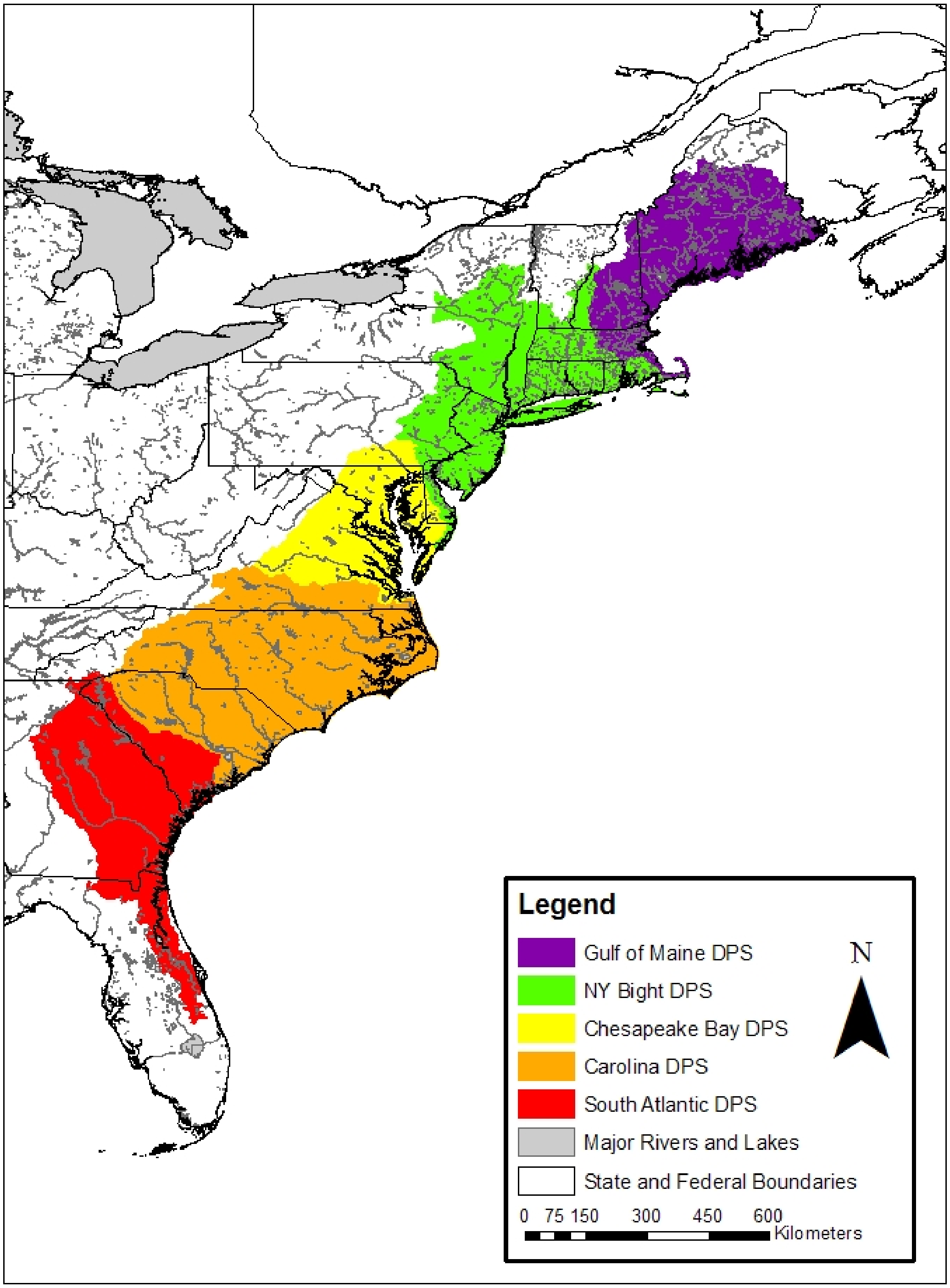
Legend
Gulf of Maine DPS
NY Bight DPS
Chesapeake Bay DPS
Carolina DPS
South Atlantic DPS
Major Rivers and Lakes
State and Federal Boundaries
N
0 75 150 300 450 600
Kilometers

Figure 15. Map depicting the five Distinct Population Segments (DPSs) of Atlantic sturgeon: Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic.

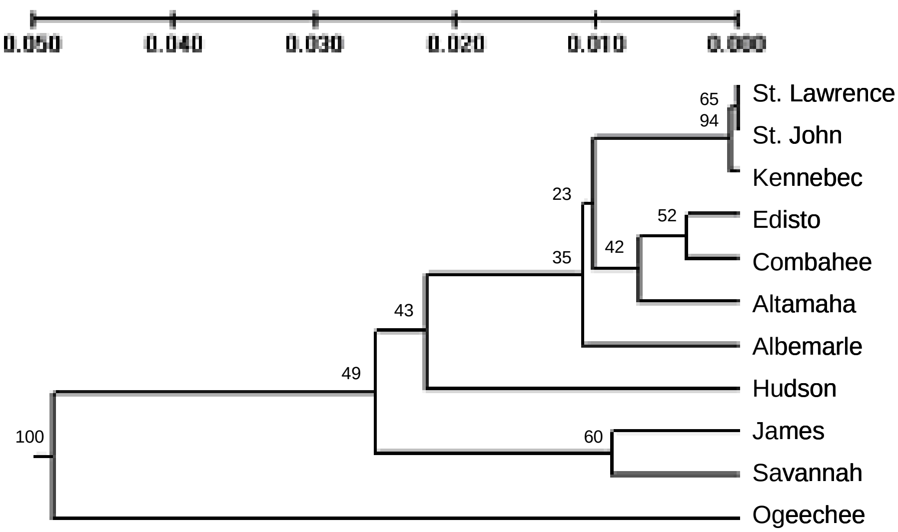

Figure 16. A UPGMA genetic tree and bootstrap values produced from mtDNA collected from Atlantic sturgeon young-of-year and spawning adults (Wirgin, supplemental data 2006).

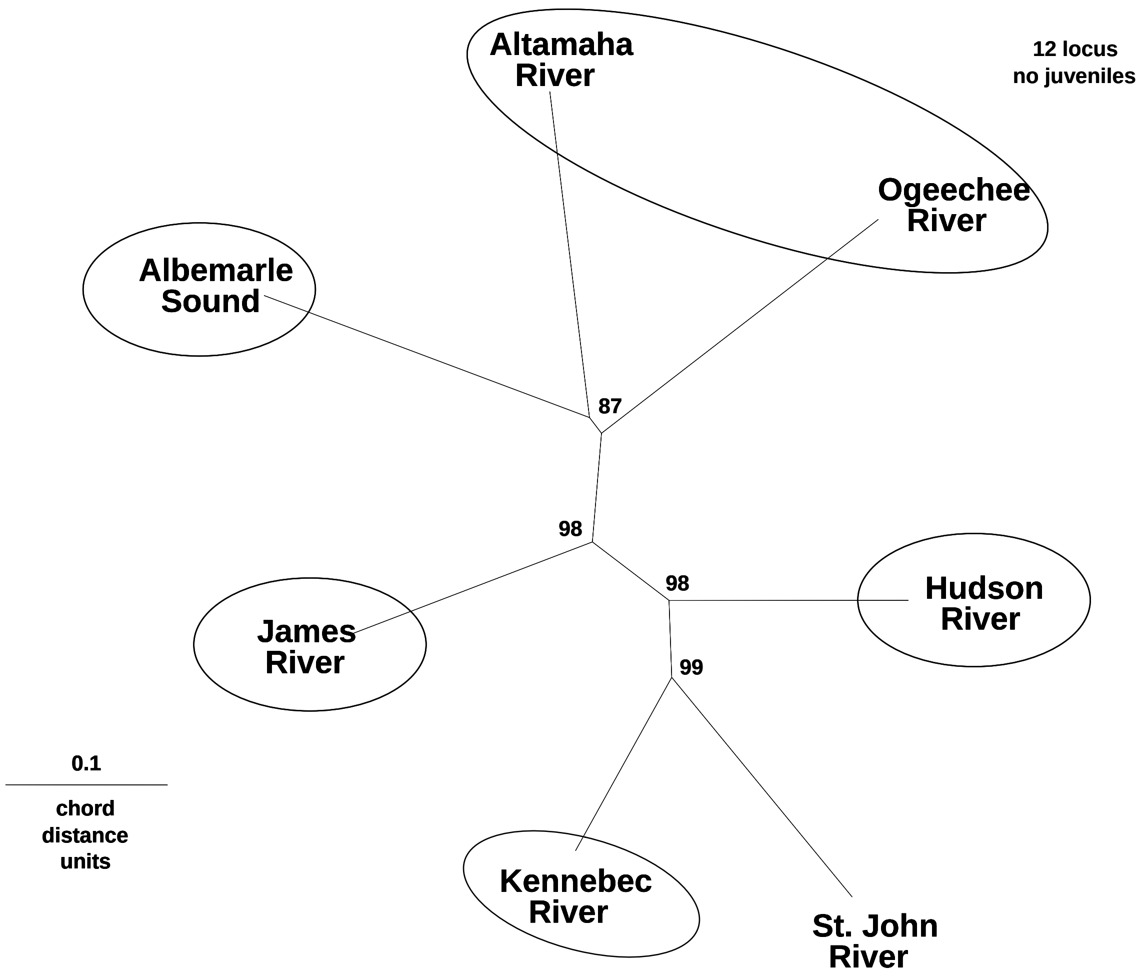

Figure 17. A neighbor-joining genetic tree and bootstrap values produced from nDNA (12 microsatellite markers) collected from Atlantic sturgeon young-of-year and spawning adults (King, supplemental data 2006).

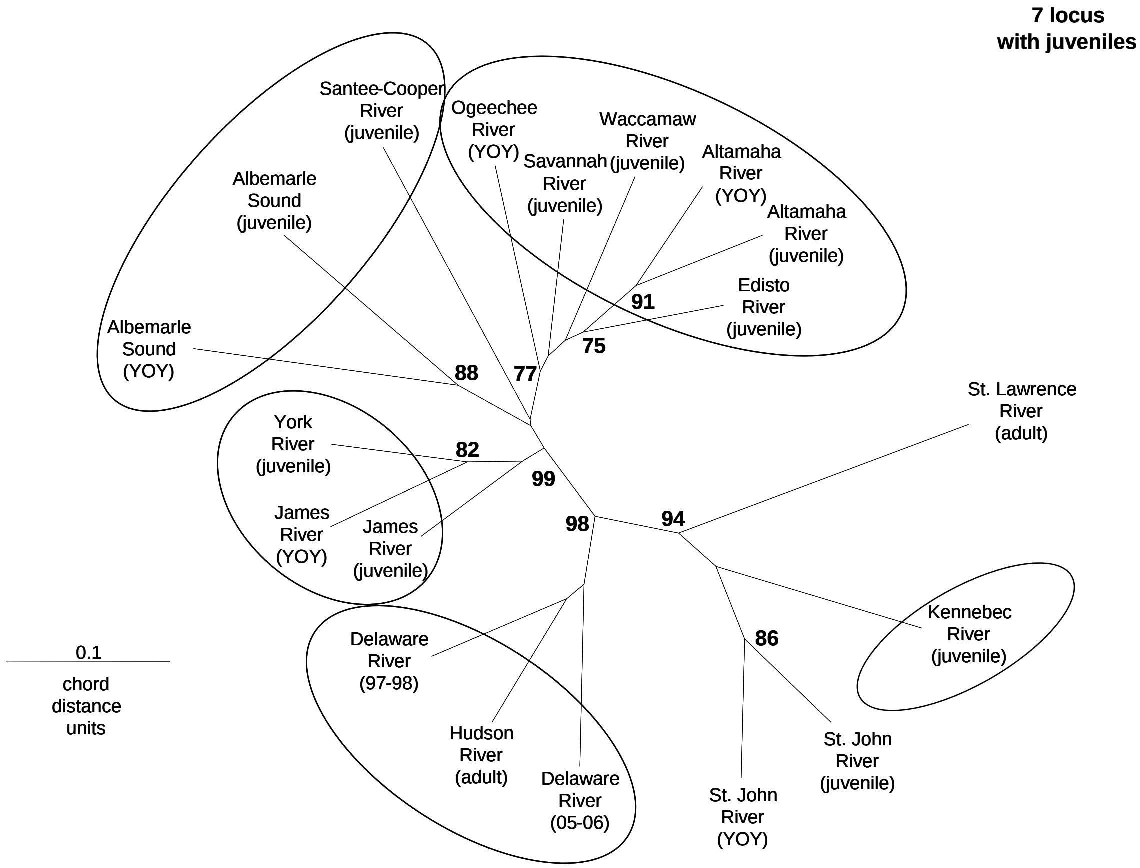

Figure 18. A neighbor-joining genetic tree and bootstrap values produced from nDNA (7 microsatellite markers) collected from Atlantic sturgeon YOY, subadults, and spawning adults (King, supplemental data 2006). Note that the Waccamaw River population is grouped with south Atlantic DPS populations, the SRT attribute this misclassification to the small sample size (N = 21), and the use of only juveniles that could be migrants from more southern populations.

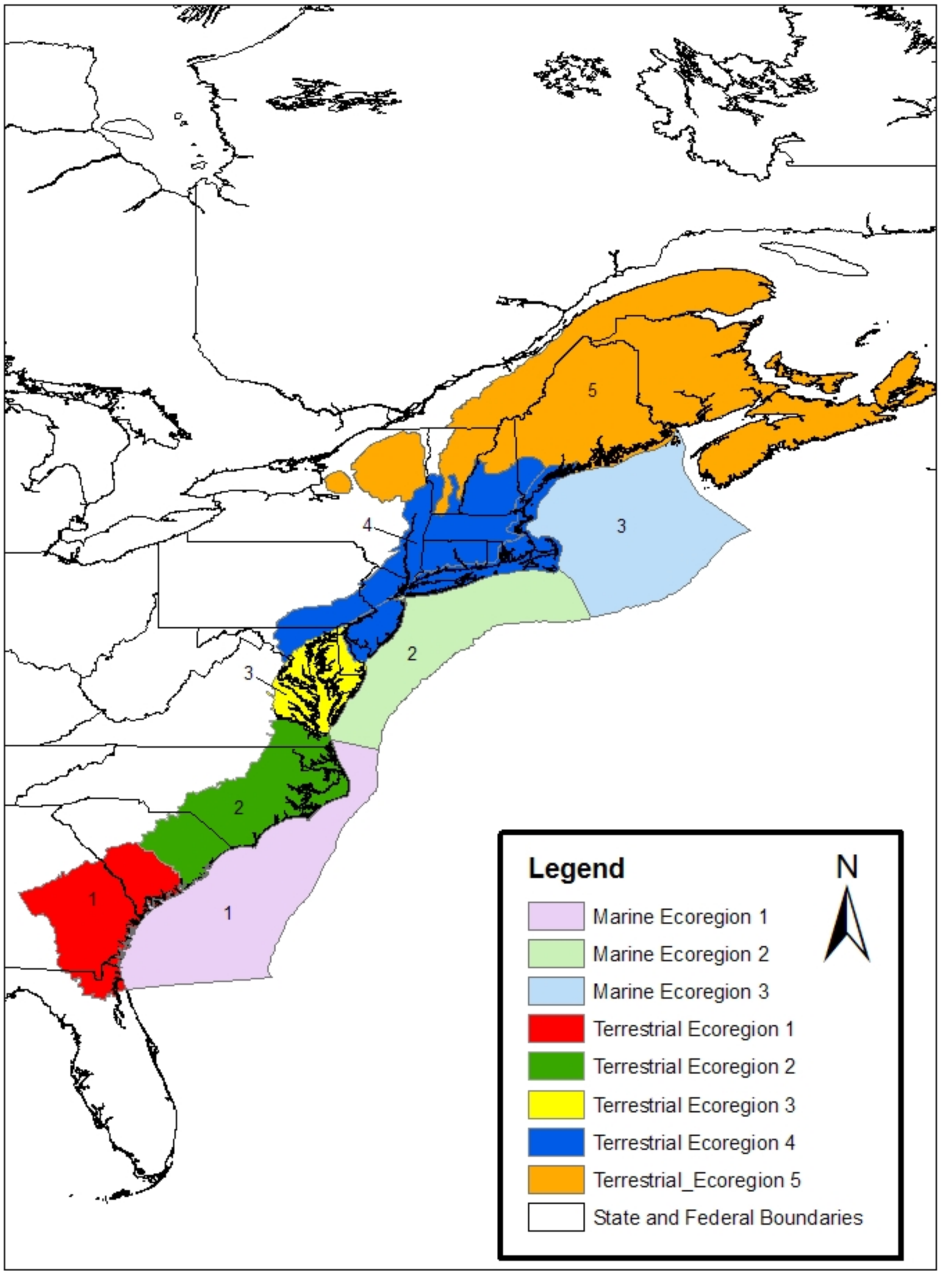

Figure 19. Terrestrial and marine ecoregions of eastern United States as determined by The Nature Conservancy (TNC). Each ecoregion has unique habitat characteristics. Terrestrial ecoregion #4 is comprised of two separate ecoregions: the Lower New England and North Atlantic regions that were combined for the Atlantic sturgeon status review because the Hudson and Delaware rivers cross both regions.

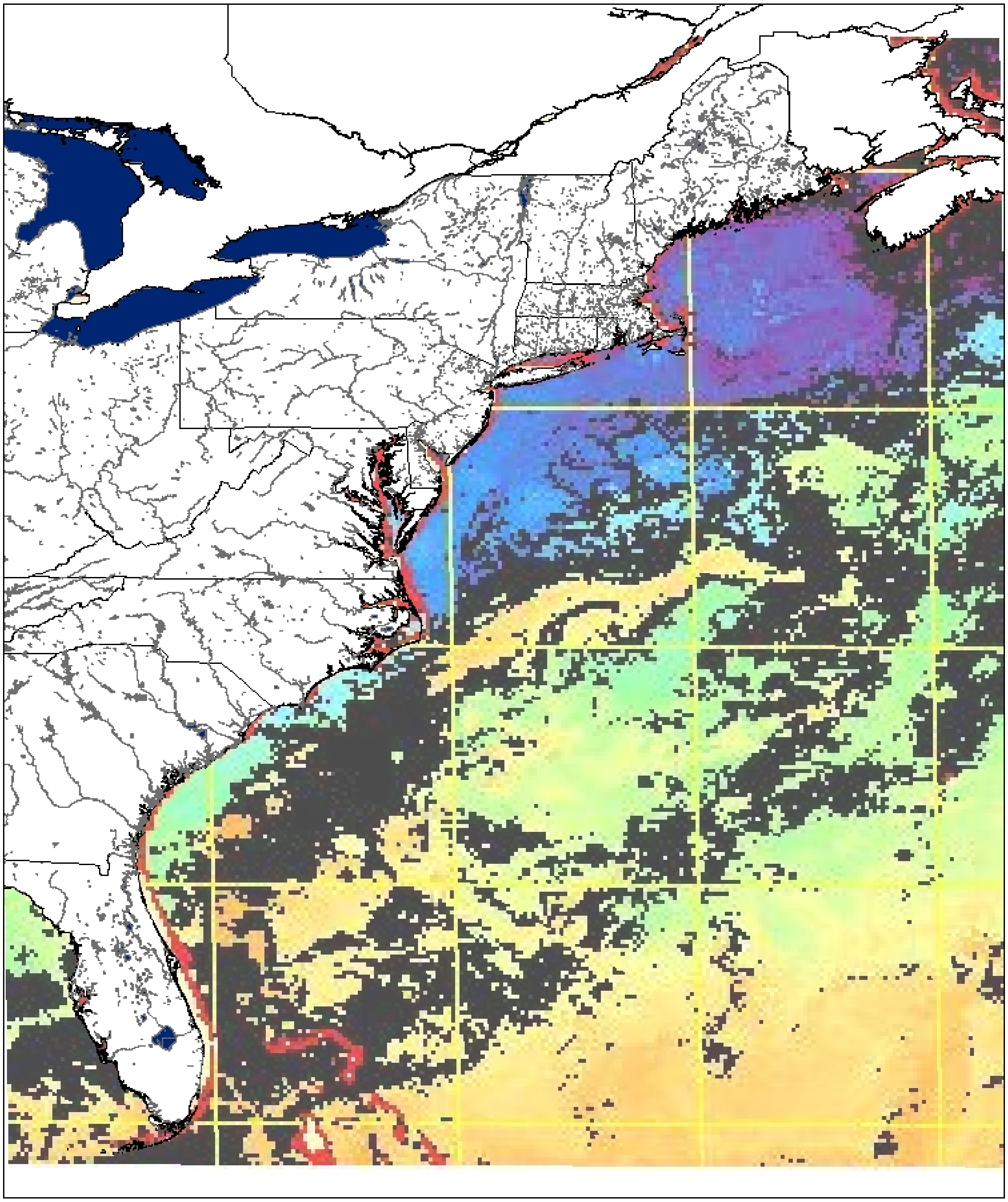

Figure 20. A map of sea surface temperatures along the Atlantic coast during the month of May (unknown year).

Figure 21. A gravid female Atlantic sturgeon found below the Annapolis River tidal power plant; decapitation of the fish was attributed to contact with the dam’s turbine blade (Courtesy of M. Dadswell, 2006).

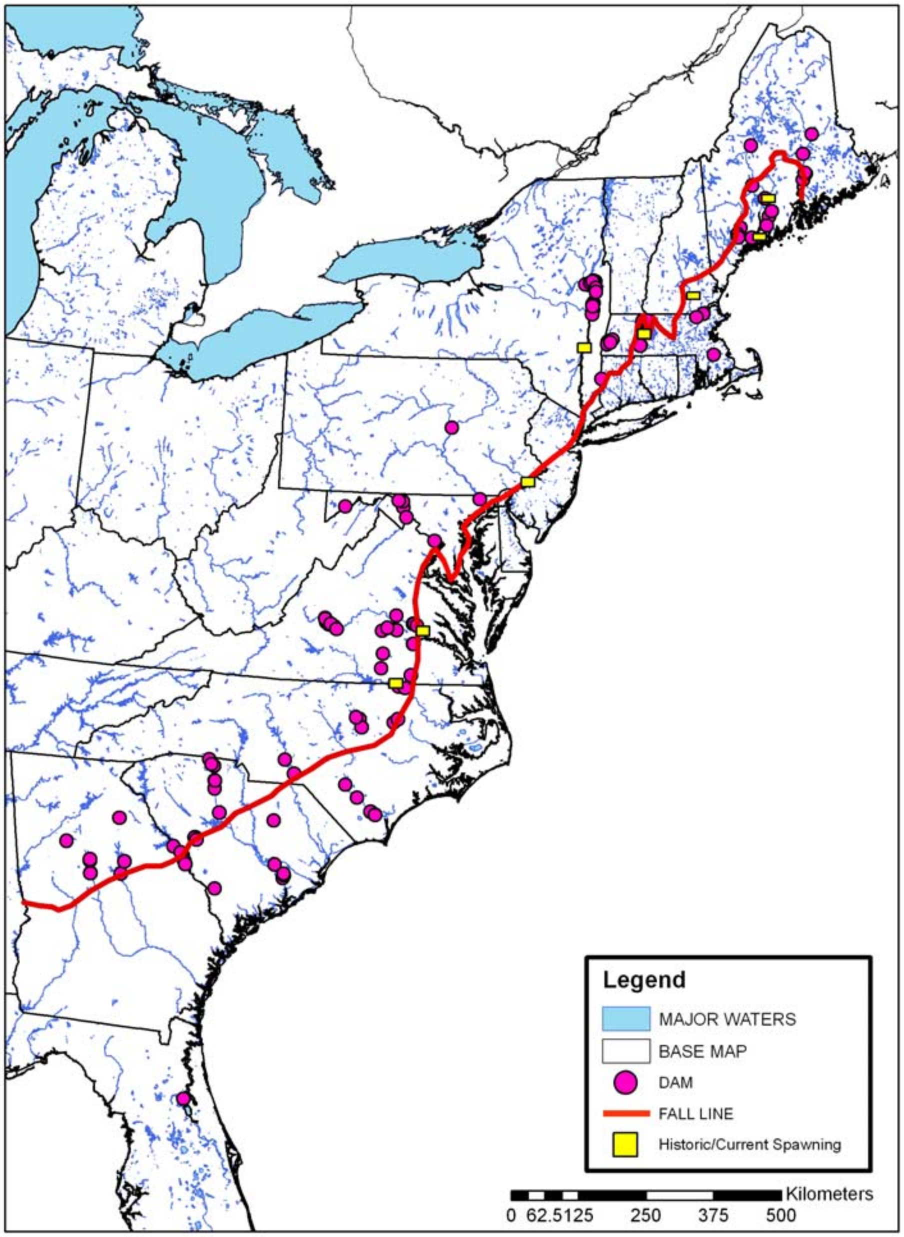

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Figure 22. Historic and current spawning locations of Atlantic sturgeon, locations of dams in rivers that have historically supported a spawning population, and their relationship to the fall line. Dam locations were provided by the U.S. Army Corp of Engineers National Inventory of Dams data layer and may be incomplete.

Figure 23. Photos of Atlantic sturgeon apparently struck by ships in the Delaware River. Photos courtesy of DFW.

Appendix C
Federal and State Endangered Species Maps from NOAA

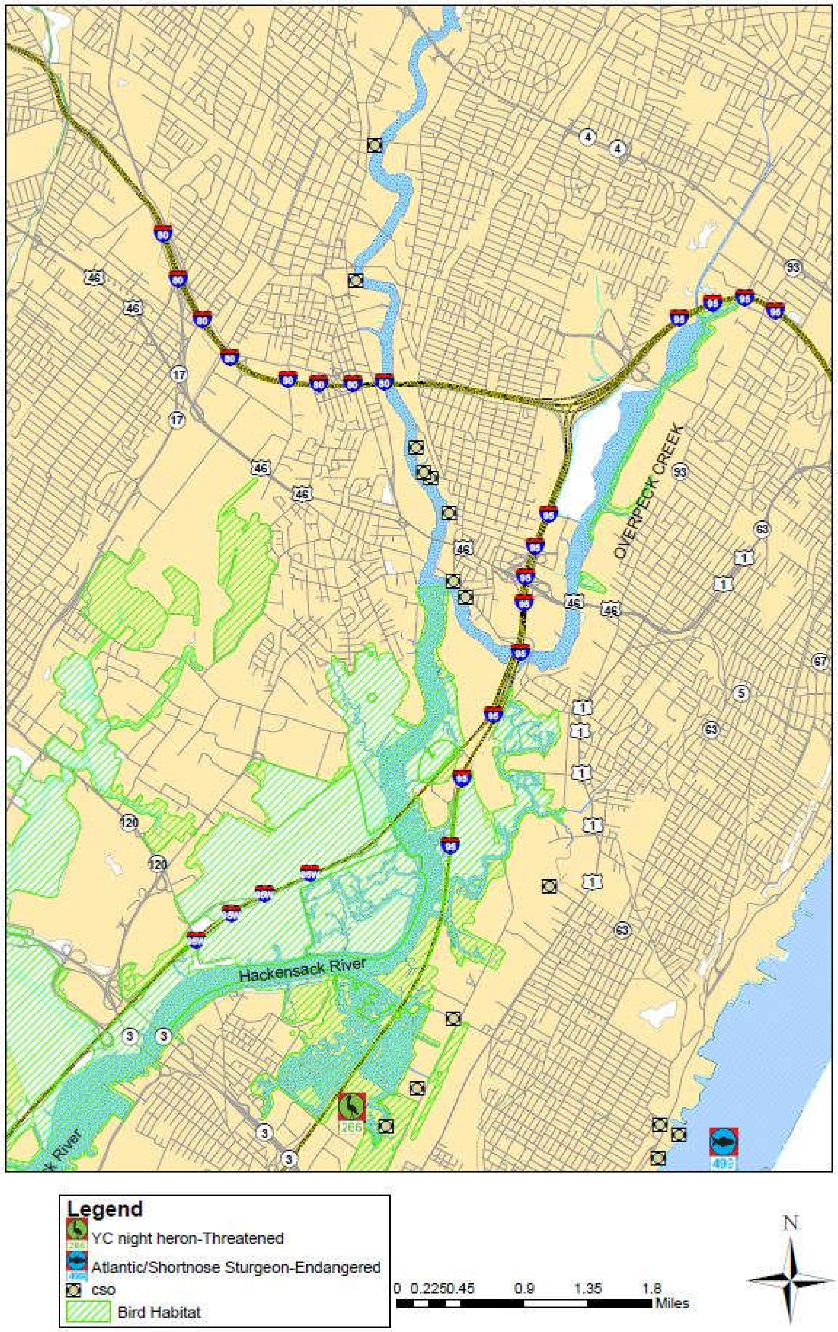

Figure C-1: Federal and State Endangered Species from NOAA Map 20C – North Bergen and Guttenberg

Figure C-2: Federal and State Endangered Species from NOAA Map 21A

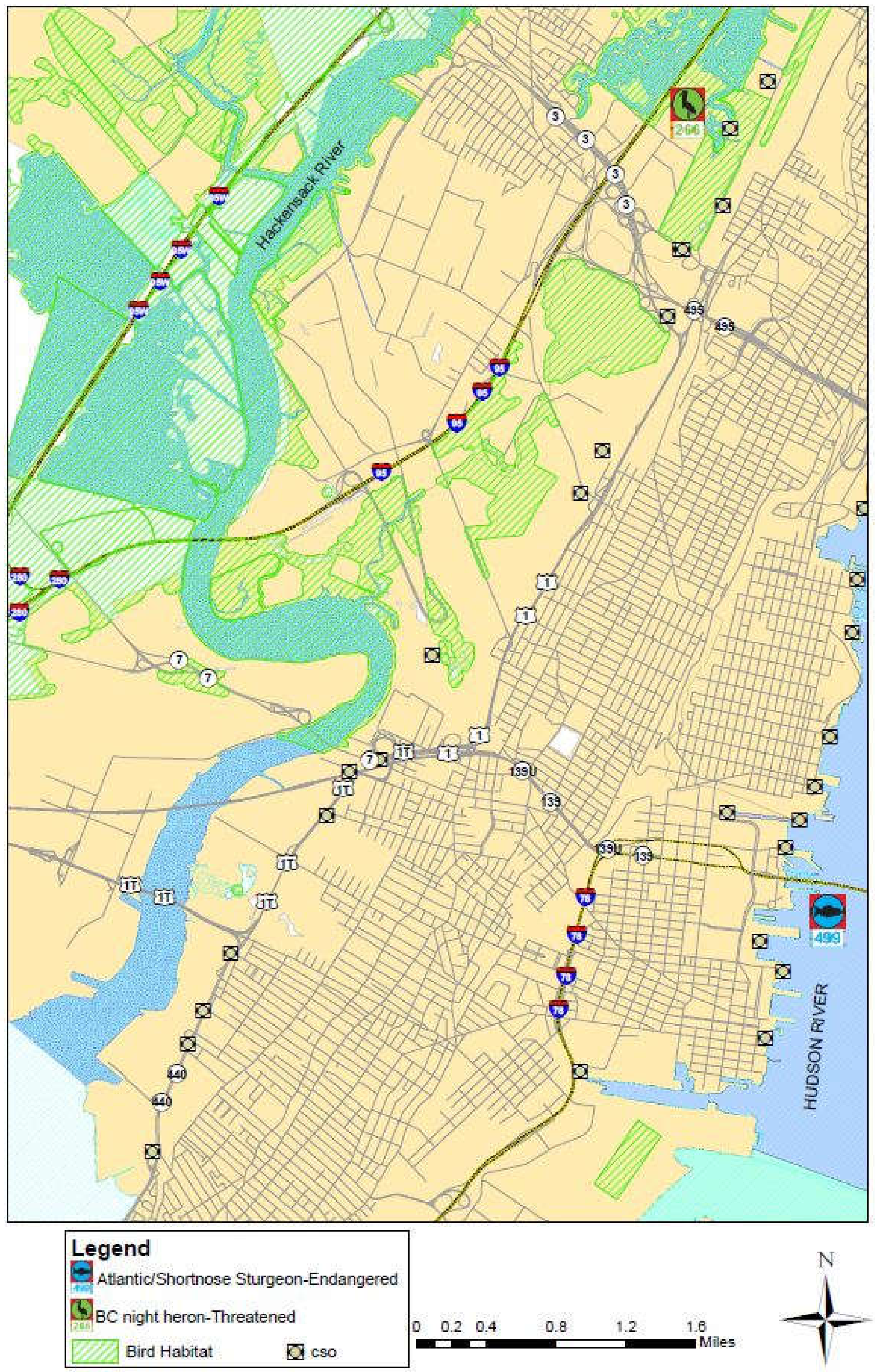

Figure C-3: Federal and State Endangered Species from NOAA Map 21B – North Bergen

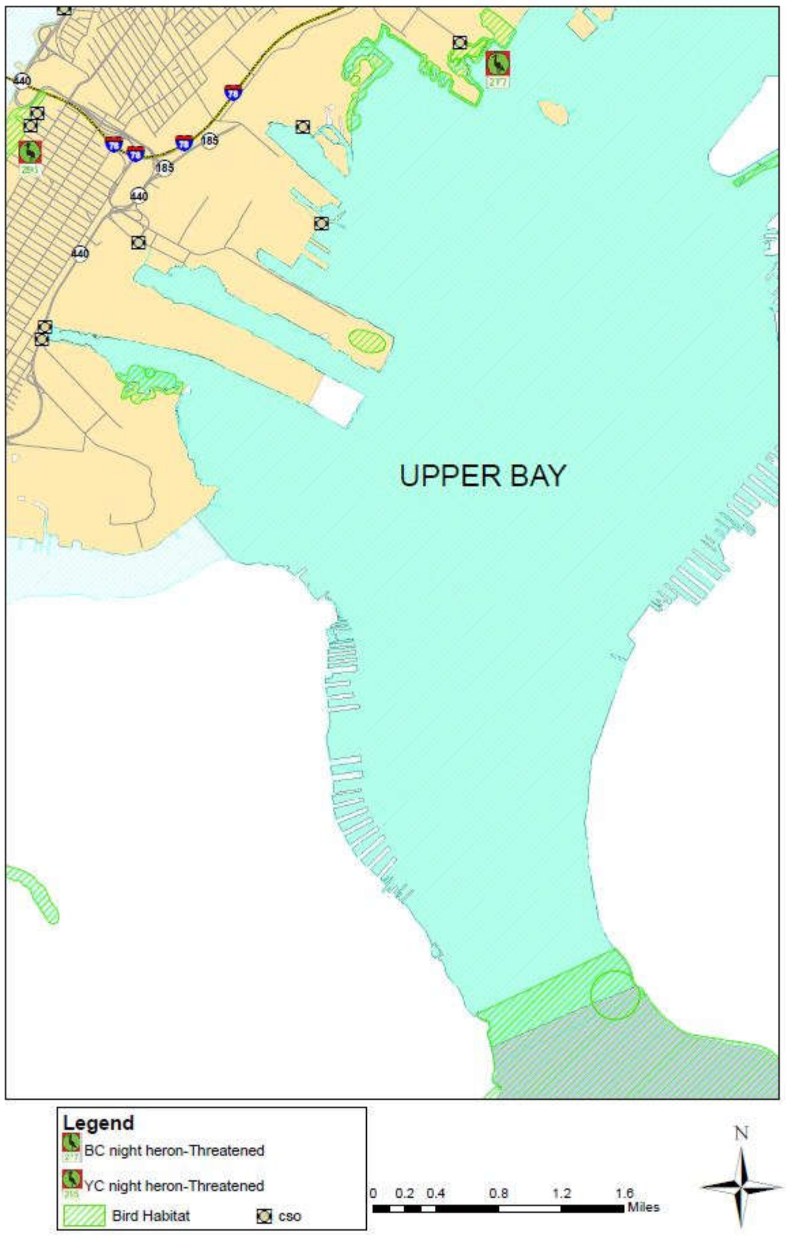

Figure C-4: Federal and State Endangered Species from NOAA Map 21D – Jersey City and Bayonne

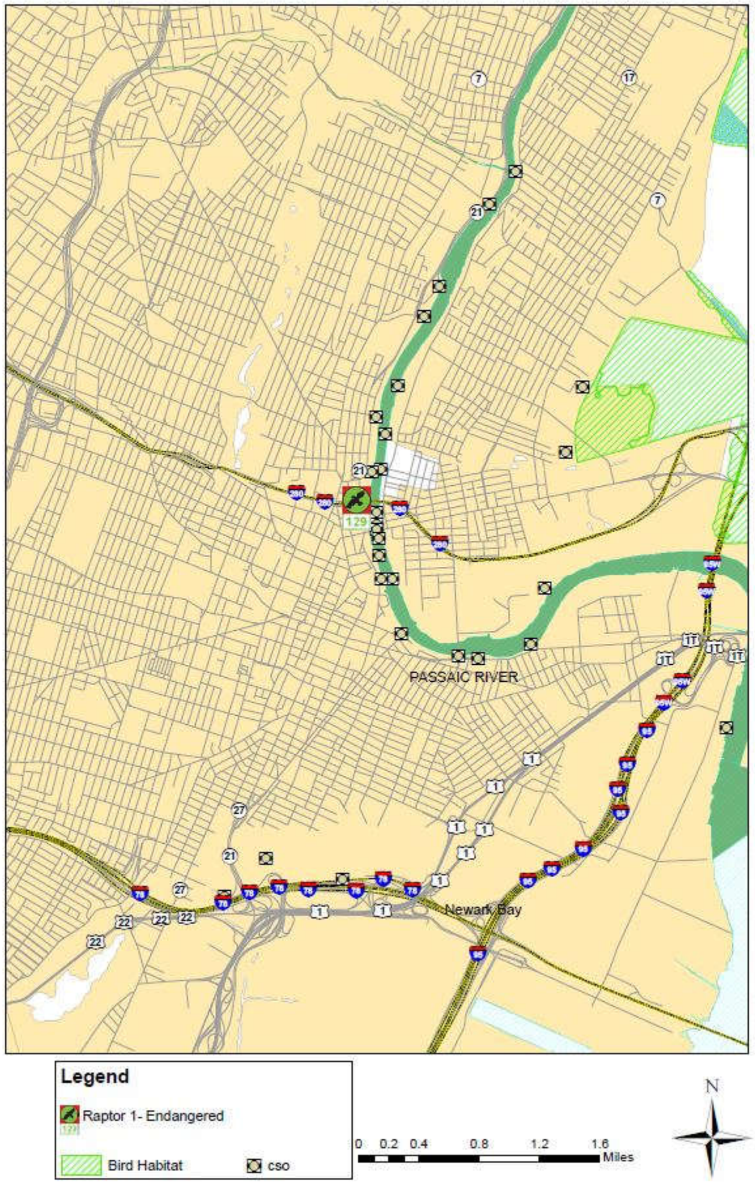

Figure C-5: Federal and State Endangered Species from NOAA Map 22A – Newark and Harrison

Figure C-6: Federal and State Endangered Species from NOAA Map 22B - Elizabeth

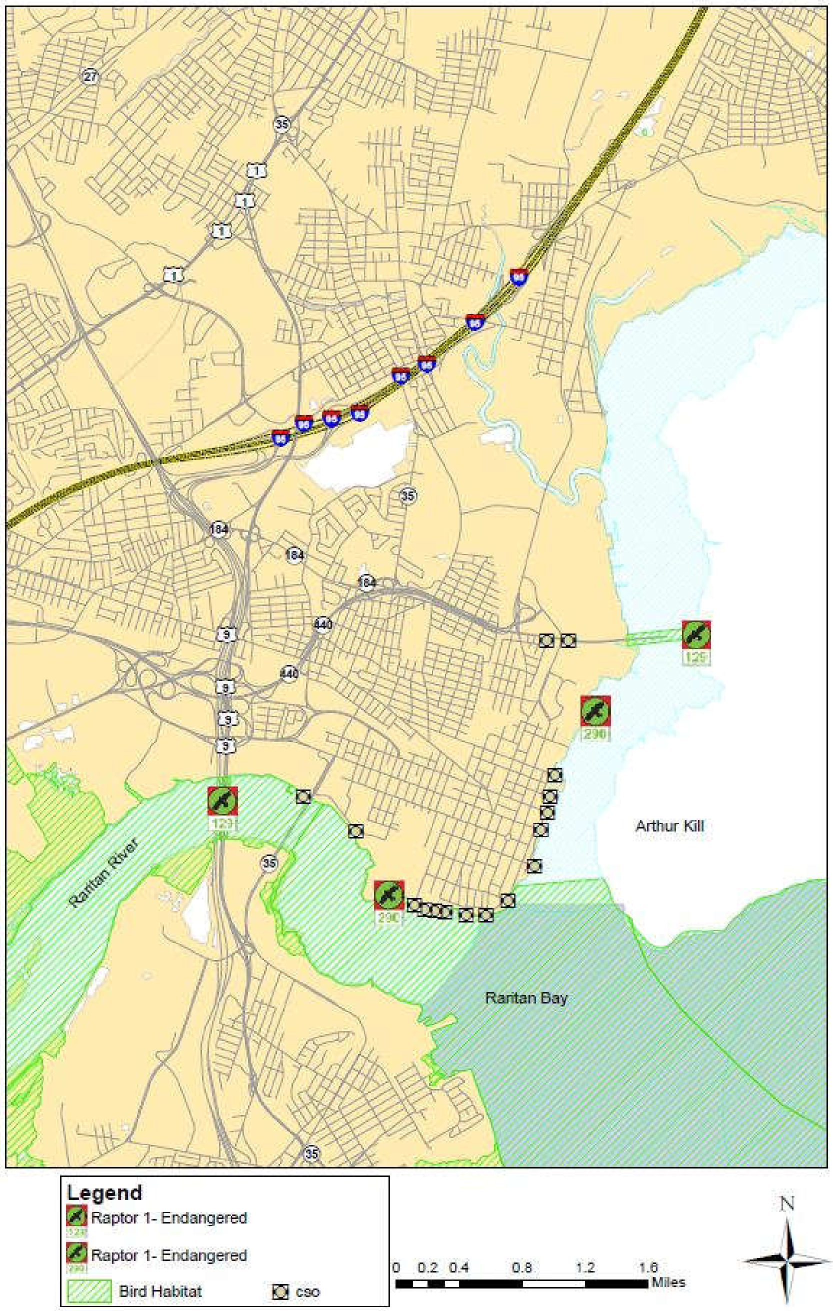

Figure C-7: Federal and State Endangered Species from NOAA Map 24B – Perth Amboy

Appendix D
Consideration of Sensitive Areas Information in the Study Area of the Long Term Control Plan for Final Surface Water Renewal Permit Action

GREELEY AND HANSEN
CDM Smith

Consideration of Sensitive Areas Information in the Study Area of the Long Term Control Plan for Final Surface Water Renewal Permit Action

Category: A - Sanitary Wastewater, CSM - Combined Sewer Management

NJPDES Permit No. NJ0021016, Passaic Valley Sewerage Comm.

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SUMMARY – Based on a comprehensive evaluation of existing data and scientific reports/data obtained via a literature search conducted March 2018, no information was found to suggest that pathogens entering the lower Hudson River (Study Area – New Jersey portion) will have a negative effect on Atlantic sturgeon (*Acipenser oxyrinchus*). The body of published research conducted on Atlantic sturgeon since the mid-1900s, combined with recent telemetry work all indicates that Atlantic sturgeon spend little time in the Study Area. Given their documented presence north of that reach within the Hudson River (and also outside of the Hudson River along the ocean coast), it is clear that Atlantic sturgeon must pass through this section of the Hudson. But, there is no evidence that they "stage" there for feeding, osmotic acclimation, or any other purposes. Moreover, based on observations elsewhere in the Hudson River, they likely pass through this reach in deep channel waters, making them less vulnerable to any nearshore discharges potentially associated with water quality, including intermittent combined sewer overflow (CSO) discharges.

Part I - Technical Assessment of the Potential for Effects of Human Enteric Pathogens on Atlantic Sturgeon in the Study Area of the lower Hudson River

A literature search was conducted in March 2018 for the most current and available published articles and reports related to the effects of human/mammalian enteric pathogens (bacteria or virus) on marine/estuarine fish of any kind, including Atlantic sturgeon. Google and Google Scholar were searched using the key terms: pathogens, enteric, pathogenesis, virus, fecal coliform, *E. coli*, enterococcus, fish, sturgeon, and various combinations of the terms. After a careful review of the available information, researchers were unable to find any specific effects of human enteric pathogens (fecal coliform, *E. coli*, enterococcus) on fish of any kind, including Atlantic sturgeon. Instead, all of the pathogen-related published information researchers were able to locate was focused on the presence of these (and other) pathogens in fish and shellfish [tissue], some of which may have originated from non-point sources (including CSOs), but with no risk reported for diseases transmitted to animals from humans. Thus, to our knowledge, there are no reported direct or indirect effects of exposure to fecal coliform, *E. coli* or enterococcus, specific to any life stage of fish (freshwater or marine).

Exposure to human pathogens is also expected to be negligible (or at least very limited) for both subadult and adult Atlantic sturgeon in the Study Area, as well as in the New York/New Jersey Harbor. Limited exposure is expected because there is strong field evidence demonstrating that fecal coliform, *E. coli*, and enterococcus abundance in receiving waters is inversely correlated with salinity, and that low pathogen levels are found in high salinity waters (Mallin et al., 2000; Lipp et al., 2001; Al-Bahry et al., 2009). Additionally, sunlight has been shown to inactivate human enteric pathogens and inactivation increases with increasing salinity for all three fecal indicator bacteria. However, enterococcus is comparatively less susceptible to sunlight inactivation in seawater compared to fecal coliform and *E. coli*, possibly because of greater cell wall resistance to the effects of salinity (Sinton et al., 2002). Interestingly, when enterococcus cells are damaged by sunlight, the damage appears to be reversible (Sinton et al., 2002).

Enterococci are also inactivated by sunlight in the presence of salinity far more at summer temperatures compared to winter.

The information above suggests a limited possibility of direct effects on Atlantic sturgeon from exposure to human pathogens in the Study Area due primarily to the lack of sensitivity of these species to the human indicator pathogens commonly used to determine NPDES permit compliance (fecal coliform, enterococcus and *E. coli*). This outcome is not particularly surprising given that human pathogenic bacteria have evolved to survive in the digestive tracts of mammals, which have internal body temperatures of approximately 100 degrees F. In contrast, the temperature of the surface waters of the lower Hudson River are never close to that temperature. In addition, the relatively high salinity in the lower Hudson River (compared to further upstream) in that reach of the Hudson River is outside of the salinity range where human enteric pathogens might be expected to be abundant. And finally, pathogens are unlikely to grow and multiply in the lower Hudson River because there is substantial flow/flushing in the Study Area, combined with adequate water depth (and more-than-adequate dissolved concentrations) in the deep channel providing refuge for sturgeons (and adequate buffer distance from any CSO discharge plumes).

Part II - Atlantic Sturgeon Life History Including Spatial Orientation in the Lower Hudson River

Atlantic sturgeon is one of about two-dozen extant sturgeon species in the world. Sturgeons are chondrosteans, a group of fishes that evolved some 200 million years ago, with sturgeon appearing about 70 million years ago. Atlantic sturgeon are found along most of the Atlantic coast, in rivers and coastal waters, from northern Florida, to Labrador, Canada (Smith and Clugston 1997). They are anadromous, migrating from the ocean into rivers to spawn between spring and autumn. Atlantic sturgeon may live more than 60 years, with females reaching sexual maturity between the ages of 7 to 30, and males between the ages of 5 to 24; populations at lower latitudes mature the earliest (ASSRT 2007). Individual females appear to spawn every 3 to 5 years, while males are believed to spawn every 1 to 5 years (Bain 1997).

Most subadult sturgeon remain in their natal (where they hatched) river from one to six years before migrating to the ocean. As subadults, Atlantic sturgeon feed on worms, small mollusks, and crustaceans. As adults, they are opportunistic feeders and prey mainly on mollusks, snails, worms, crustaceans, and benthic fish. In marine waters Atlantic sturgeon favor gravel and sand sediments at depths of approximately 10 to 50 m (Stein et al. 2011).

Since colonial times, Atlantic sturgeon have supported commercial fisheries of varying magnitude, for both their flesh and their eggs, which can be processed into valuable caviar (Hilton et al. 2016). In the late 1800s, Atlantic sturgeon were second only to lobster among important fisheries, with landings estimated at as high as seven million pounds per year just prior to the turn of the century. Overharvesting of sturgeon for flesh and eggs continued through the 1990s until the Atlantic States Marine Fisheries Commission and federal agencies implemented a coast wide moratorium in 1998 that was to last until 2038 (Hilton et al. 2016).

However, continued coast-wide declines of Atlantic sturgeon prompted a petition by environmental groups for its inclusion on the federal Endangered Species List. As part of its 2012 inclusion on this list, research was conducted to determine if populations in specific regions should be considered to be distinct population segments (DPS). This research resulted in a determination of five DPS: (1) Gulf of Maine (GOM), (2) New York Bight, (3) Chesapeake Bay, (4) Carolina and (5) South Atlantic. The Gulf of Maine DPS is currently considered as threatened, whereas the other four DPS are classified as endangered. The population of the Hudson River is part of the New York Bight DPS.

A stock assessment in 2017 concluded that Atlantic sturgeon was depleted coast-wide (ASMFC 2017). The "depleted" determination was used instead of "overfished" because the factors that contribute to the low abundance of Atlantic sturgeon are beyond that of direct fishing and bycatch, such as habitat loss, ship strikes, and climate change. While overall abundances of Atlantic sturgeon remain low, most populations appear to be slowly recovering since the implementation of more stringent protection measures (ASMFC 2017).

The Hudson River also has a population of a second sturgeon species, the shortnose sturgeon (*Acipenser brevirostrum*), which is also listed as federally endangered. However, the shortnose sturgeon is highly residential in the river, mainly inhabiting fresh and low salinity waters, well upstream of any New Jersey CSO discharge locations.

Historically, the Hudson River stock of Atlantic sturgeon had one period of high harvest (pre-1900s), a long span of minimal harvest and slow population recovery (1900-1979), a period of restored abundance and high harvest (1980-1992), and finally another decline and suspension of fishing (Bain et al. 2000). The extent of this last decline was examined by Peterson et al. (2000), who used mark–recapture to estimate there were 4,314 wild age-1 Atlantic sturgeon in the Hudson River in 1995, a decline of about 80% from the similarly conducted population estimate of 1977 (Dovel and Berggren 1983).

Based on recoveries of tagged individuals and, more recently, tracking performed with acoustic tags, it's known that the Hudson stock of Atlantic sturgeon ranges widely in coastal waters, from the Bay of Fundy to Cape Hatteras, but sometimes beyond (Dovel and Berggren 1983). However, using accumulated tagging data and genetic stock identification, Waldman et al. (1996) concluded that most Hudson River-individuals at sea typically remain within the Virginian Zoogeographic Province (Cape Cod to Cape Hatteras), the province which encompasses the Hudson River.

Subadult and adult Atlantic sturgeon are channel dwellers in the Hudson and other rivers, and are almost never captured in shallow nearshore waters. The sturgeon fishery of the Hudson historically operated using sunken gill nets fished around slack tidal stages. Atlantic sturgeon for research purposes are captured using gill nets (also fished at slack tidal stages) or bottom trawls.

Broad-scale patterns of movements by Atlantic sturgeon within the Hudson River are known from traditional mark-recapture studies and, more recently, via ultrasonic tagging.

Bain (1997) provided the most detailed assessment of life history of Atlantic sturgeon of the Hudson River, dividing their life cycles into six intervals and relying heavily on the findings of Dovel and Berggren (1983) and Van Eenennaam et al. (1996). In emphasizing his geographical conclusions, Bain (1997) characterized the following intervals: (Interval 1) the non-spawning adult interval, (Interval 2) adult females enter the Hudson River for spawning beginning in mid-May, which lasts through July, or possibly August, migrating directly to spawning grounds which are in deep channel or off-channel habitats. The sturgeon spawn near the salt wedge (river km 55) early in the season (late May), moving upstream to about river km 136 during June and early July. They return quickly to marine waters after spawning. (Interval 3) Males begin to enter the Hudson River in April and some remain in the river as late as November. Limited telemetry by Dovel and Berggren (1983) indicated males appear to move upstream on incoming tides and then to remain stationary for several hours. During the upstream migration males meander back and forth across the channel, but remain in water greater than 7.6 m deep.

(Interval 4) The egg, embryo, and larva interval is associated with fresh salinities. Eggs deposited on deep reefs are adhesive and therefore, don't drift with the tidal currents. Atlantic sturgeon embryos have been recorded in the Hudson River from river km 148 to river km 60. Embryos and larvae are believed to have limited salt tolerance, and so would not be expected to survive in the lower Hudson River. (Interval 5) The juvenile riverine interval in Bain's (1997) classification might be better defined as the young-of-the-year (age-0), yearling (age-1), and subadult interval (ages 2 – 6).

Little is known about the behavior of age-0 Atlantic sturgeon in the Hudson River inasmuch as they appear to be cryptic and not highly vulnerable to sampling gear. Yearlings and older subadults are well distributed over much of the Hudson from July through September, in deep channel habitats. The largest numbers appear to be located from river km 63 to km 140. As water temperatures drop below 20˚C in the fall, these fish aggregate to overwinter in brackish water between river km 19 – 74. They appear to move little between October through June, although some appear upriver around river km 134 as early as April. (Interval 6) In the river, subadults typically aggregate near the freshwater-saltwater interface, as found elsewhere such as in the Delaware (Lazzari et al. 1986), Cape Fear (Moser and Ross 1995), and St. Lawrence (Hatin et al. 2007) Rivers. Subadults eventually end their residence in the Hudson River and migrate to marine waters, males as young as age-2 and females not until age 5-6. After about 10 years at sea Atlantic sturgeon reach adult size (~150 cm total length).

In recent years there has been a coordinated effort to track the migrations of a number of fish species in the Northeast, including Atlantic sturgeon. Individuals are tagged with ultrasonic transmitters, which are detected by arrays of ultrasonic receivers in coastal and estuarine locations. So as to maximize the potential information obtained, all researchers use the same (Vemco Co.) equipment to ensure reciprocity of detections among species and arrays.

Some receivers have been placed in the Hudson River. When asked about information on movements of Atlantic sturgeon, Delaware State University researcher Dr. Dewayne Fox replied (March 23, 2018): "On the recent (2009-present) telemetry end of things our focus with adults has been upriver and we have had very limited receiver coverage in this stretch. As you know it is a big river with a lot of traffic but there are amazingly few navigational aids in the lower river. We maintained some sites in NY Harbor and then a couple up by the GW Bridge but our adults have largely gone through this reach quickly (few detections) or were not picked up due to the sparsity of receivers."

Justin Krebs of the consulting firm AKRF was asked about their telemetry work on Atlantic sturgeon in the Hudson connected with construction of the new Tappan Zee Bridge. He replied (March 26, 2018):

> "*We've had Vemco receivers in the river since 2013 in association with sturgeon monitoring for the new Tappan Zee Bridge. The majority of our monitoring has been at the receiver array at the TZ Bridge, but we did do two years of monitoring in 2013 and 2014 with gateway receivers placed approximately every 5 km between the GW Bridge and Stony Point on Haverstraw Bay. My recollection is that subadult and adult Atlantic sturgeon (most tagged by Dewayne and Keith) didn't spend a whole lot of time in our monitoring area (RM 12-39).*
>
> *We also did some mobile tracking of juvenile and subadult Atlantics (sturgeon) that were tagged as part of our work with the Thruway Authority during 2014 and 2015. Most of the sturgeon were tagged in Haverstraw Bay or upstream of there, and we got few detections of those fish downriver of Piermont Pier; most of those fish seemed to stay in the northern portion of Haverstraw or further upriver, suggesting that juvenile Atlantics are less likely to occur in your area of interest than the subadults or adults.*
>
> *Unfortunately, we didn't do any monitoring downriver of the GW Bridge at RM 12. And I'm not aware of any telemetry monitoring that focused on the first 15 miles of the river*."

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Appendix E
Recovery of a US Endangered Fish

Recovery of a US Endangered Fish

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Background. More fish have been afforded US Endangered Species Act protection than any other vertebrate taxonomic group, and none has been designated as recovered. Shortnose sturgeon (*Acipenser brevirostrum*) occupy large rivers and estuaries along the Atlantic coast of North America, and the species has been protected by the US Endangered Species Act since its enactment. ***Methodology/Principal Findings.*** Data on the shortnose sturgeon in the Hudson River (New York to Albany, NY, USA) were obtained from a 1970s population study, a population and fish distribution study we conducted in the late 1990s, and a fish monitoring program during the 1980s and 1990s. Population estimates indicate a late 1990s abundance of about 60,000 fish, dominated by adults. The Hudson River population has increased by more than 400% since the 1970s, appears healthy, and has attributes typical for a long-lived species. Our population estimates exceed the government and scientific population recovery criteria by more than 500%, we found a positive trend in population abundance, and key habitats have remained intact despite heavy human river use. ***Conclusions/Significance.*** Scientists and legislators have called for changes in the US Endangered Species Act, the Act is being debated in the US Congress, and the Act has been characterized as failing to recover species. Recovery of the Hudson River population of shortnose sturgeon suggests the combination of species and habitat protection with patience can yield successful species recovery, even near one of the world's largest human population centers.

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INTRODUCTION

In the last 100 years, three genera, 27 species, and 13 subspecies of fish have been extirpated from North America [1]. The US government currently lists more fish (101 [2]) as threatened and endangered species than any other vertebrate taxonomic group. A total of 149 [3] species and distinct populations are currently under federal government protection provided by the US Endangered Species Act, and many have been listed for decades. However, none of these fish species or populations have been designated as recovered and delisted in the three decades since passage of the US Endangered Species Act. Five fish species have been removed from the endangered species list: four by extinction and one by taxonomic revision [3]. Independent review of imperiled fishes [4] in North America also concluded that species recovery is lacking. However, data and research findings reported here on the endangered shortnose sturgeon (*Acipenser brevirostrum*) in the Hudson River of New York indicates this population meets government and scientific criteria for recovery.

The shortnose sturgeon was formally protected with the passage of the 1966 US Endangered Species Preservation Act and later designated as endangered under the current 1973 US Endangered Species Act [5]. The species was considered to be in peril or absent in coastal rivers throughout its range due to overfishing, pollution, and habitat losses from river damming. It is also on the IUCN (International Union for Conservation of Nature and Natural Resources) Red List of Threatened Species [6] because of reduced population size, decline in range and number of locations, and continued decline. Evidence reported here suggests this charter member of the US Endangered Species Act is the first fish to clearly merit designation as a recovered distinct population. The nature of the species, its habitat, and the evidence for a large and secure population is reported as an example of successful protected species management.

The shortnose sturgeon inhabits rivers along the North American Atlantic coast, from the Saint John River, New Brunswick to the St. John's River, Florida. The shortnose sturgeon is best described as an amphidromous [7] species because its use of marine waters is limited to the estuaries of natal rivers [8]. Captures in coastal marine waters and non-natal rivers have occurred but are rare. A long-lived species, shortnose sturgeon maturity is attained in 8 to 10 years and adults may live for 60 years or more [9]. Shortnose sturgeon occupy the lower Hudson River: 246 kilometers of tidal freshwater river and brackish estuary habitats. From late spring through early fall, shortnose sturgeon are dispersed throughout the deep, channel habitats of the freshwater and brackish reaches of this river-estuary [9]. Diet includes insects and crustaceans with mollusks being a major component (25 to 50% of the diet; [10, 11]). In the late fall, most or all adult shortnose sturgeon congregate at a single wintering site near Sturgeon Point (river kilometer, rkm, 139). These fish migrate upstream to spawn in the spring and later disperse throughout much of the estuary.

Hudson River shortnose sturgeon spawn in the spring (late-April to early Mary) downstream of the Troy Dam [9] where the river turbulent and relatively shallow. Eggs adhere to the river bottom, as do the newly hatched larvae [12, 13]. Hatching size ranges from

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Competing Interests: The authors have declared that no competing interests exist.

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7 to 11 mm total length (TL; [12, 13]), with Hudson River larvae ranging in size from 15 to 18 mm TL at 10 to 15 days of age [14]. After hatching, larvae gradually disperse downstream over much of the Hudson River Estuary [15]. Larval shortnose sturgeon captured in the Hudson River were associated with deep waters and strong currents [14, 15].

Juvenile shortnose sturgeon (2–55 cm TL), use a large portion of the tidal reach of the Hudson River. Yearling juvenile sturgeon grow rapidly (to 30 cm TL in first year) and disperse downriver to about rkm 55 by fall [16]. Juvenile distribution during the summer centers on the mid-river region [17] and shifts downriver (Haverstraw Bay, rkm 55–63 [16, 17]) for the late fall and winter seasons.

METHODS

From the Battery in New York (rkm 0) to the Troy Dam above Albany (rkm 246), the Hudson River (Figure 1) spans a river-estuary gradient providing tidal habitats that include freshwater river channels, a brackish fjord, and a rock confined estuary [18–20]. Although largely a glacially scoured channel, the Hudson River estuary varies inversely in width relative to depth; maximum width is 4.8 km (rkm 50) while the maximum depth is 66 m (rkm 81). The U.S. Army Corps of Engineers maintains a navigation channel depth of 9 to 11 m although much of the channel in much deeper [20]. Mean ebb and flood current velocities are 0.4 m/s and 0.36 m/s, respectively. The normal tidal amplitude ranges from 0.82 to 1.43 m causing a tidal volume (mean 5,670–8,500 m^3/s depending on location) from 10 to 100 times river discharge (mean 623 m^3/s; [20]). Saltwater intrusion extends from rkm 80 to 100 during the summer months (Figure 1) and varies with river discharge. Generally, the limnetic zone (<0.3l ppt) occurs upriver of rkm 80 (Croton Point). An oligohaline zone (0.3–5 ppt) ranges from rkm 40 to 80 with higher salinity (5–18 ppt, mesohaline) further downstream. Sediment characteristics of the Hudson River channel vary along the estuary from sand (dominant above rkm 164) to silty sand (rkm 164 to 148) to clayey silt (below rkm 148 to 64). Larger shell fragments and sandier sediments comprise a larger percentage of channel sediments below rkm 64. Isolated patches of coarser material (sand, gravel) occur near tributary mouths, within the Hudson Highlands, and near Peekskill.

Data on the shortnose sturgeon population in the Hudson River estuary were obtained from a field study we conducted from 1994 to 1997, a shortnose sturgeon population study conducted by William Dovel and others during the 1970s [16], and a standardized fish monitoring program [21, 22] by the Hudson River electric utilities (Central Hudson Gas and Electric Corporation, Consolidated Edison Corporation of New York, New York Power Authority, Niagara Mohawk Power Corporation, and Southern Energy New York). These studies provide a record of the shortnose sturgeon population spanning almost two decades with thorough population estimates made at the beginning and end of the period, and relative abundance data covering many of the intervening years.

Our shortnose sturgeon sampling was completed in two ways: (1) randomly dispersed sampling from June to mid-September (1995 and 1996) throughout the river when the sturgeon were feeding and widely distributed; and (2) targeted sampling of adult sturgeon at their wintering site in December, March, and early April, and their spawning grounds near Albany from mid-April through May (1994 to 1997, Table 1). For both types of sampling we used gill nets (3 m high by 91 m long) with mesh sizes measuring 5-, 10-, and 15-centimeters (stretch mesh). For random sampling, one gill net of each mesh size was anchored and set perpendicular to shore, positioned between mid-channel and the shoreline, parallel to one another and approximately 30 m apart, and deployed in daylight during slack tides (30 to 90 minutes). Targeted gill netting was done in a similar manner but on some occasions a single net was used because catch often exceeded the time available to safely process the fish.

Fish were removed from gill nets and were either processed immediately on the boat or placed in floating mesh pens along side the boat until being processed. Fish were checked for the presence of PIT (passive integrated transponder) tags, Carlin-Ritchie dangler tags, and Floy tags; PIT tags were applied if one was not present. Fork length (FL) and sometimes total length (TL) were measured to the nearest millimeter and weight measured to the nearest gram. All fish were measured and tagged unless the number of fish caught was so large that processing all of them would take many hours and delay release. At such times, only a subset of the catch was processed, but all were checked for existing tags.

Randomly dispersed sampling occurred between rkm 43 (Tappan Zee Bridge, Nyack, NY) and rkm 246 (Troy Dam) using seven strata based on geomorphological characteristics [18] of the Hudson system. The stratified random sampling design apportioned effort throughout the river. Individual sampling stations (located at river kilometers) were selected using a random numbers table and alternated in orientation to each shore when possible. An equal number of samples were taken in each stratum per month (i.e., June, July, August/September) to ensure equivalent effort throughout the study period.

William Dovel and his associated investigators [16] collected shortnose sturgeon in the Hudson River from 1975 through 1980. Sturgeon were sampled using 6.4 m and 10.7 m otter trawls and drifted, anchored, or staked gill nets of 5.1, 6.4, 7.6, 8.9 cm bar monofilament meshes. Sampling varied among years with trawling occurring between rkm 19 and 246, gill nets between rkm 208 and 246, and some gill net sets below rkm 64. Total or fork lengths were measured to the nearest millimeter and weight was measured to the nearest gram or ounce. Adult and juvenile fish greater than 228 mm TL were marked with Carlin-Ritchie dangler tags attached at the base of the anterior portion of the dorsal fin. Any recaptures were recorded. Sampling in 1979 was conducted from late April through June at the spawning site (rkm 246). For four days each week, two to four drift gill nets were set during slack tide and allowed to drift along the channel bottom for at least 15 minutes [14]. Anchored gill nets were set parallel to shore on both sides of the river in at least six locations each day and allowed to fish overnight. Extensive sampling was conducted between 24 October 1979 and 13 May 1980 at the wintering site near Esopus Meadows (rkm 140; [23]) to capture large numbers of adults.

The standardized fish monitoring program of the Hudson River electric utilities provided annual shortnose sturgeon catch data for years 1985 through 1996. Samples were collected biweekly for 15 weeks from midsummer through fall using a 3.0-m beam trawl. At least three samples were collected in the channel of each of 12 river sampling strata ranging from river rkm 1 through 245 for an annual total of about 1,240 samples. All shortnose sturgeon were recorded with total length in millimeters and weight in grams.

Data analyses were conducted to make comparisons across time and studies, and to provide the best possible population estimates with different data sets. Total length measurements were converted to fork length using the conversion formulae, FL = 0.90(TL) [24], as this relationship corresponds well with TL and FL measurements from double-measured sturgeon in our data sets. Sturgeon less than 500 mm FL were considered juveniles [9]. Fish

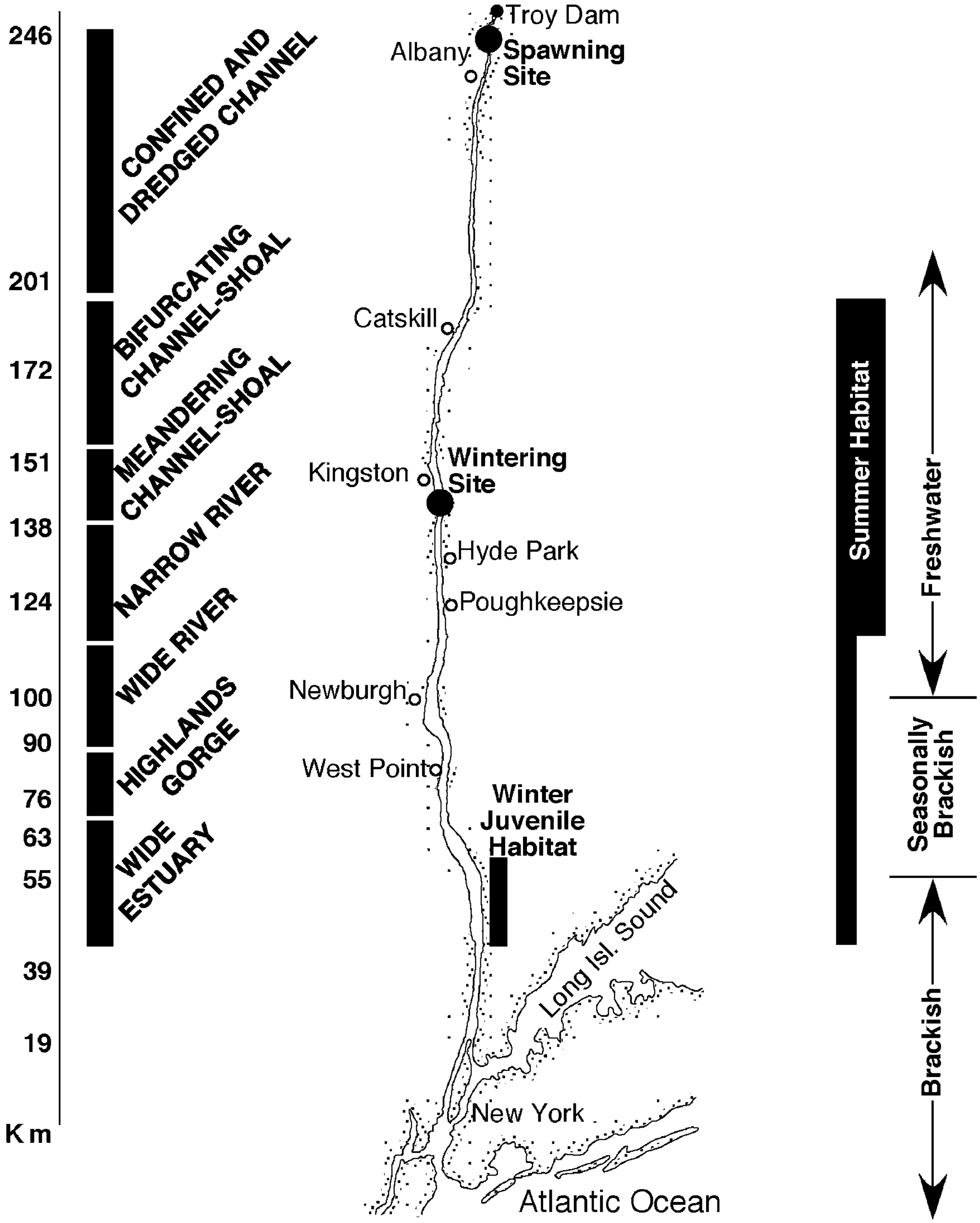

Figure 1. Map of the Hudson River estuary with key habitats used by shortnose sturgeon and the salinity zones in the system. Summer habitat, winter juvenile habitat, and salinity zones match horizontally on the figure with locations in the river. The width of the summer habitat designation corresponds with most and least heavily used sections of the river.
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body condition was calculated using Fulton's Condition Factor K [25], where $K(FL) = (weight \bullet 10^5)/FL^3$.

The shortnose sturgeon population was estimated from mark and recapture data using the Schnabel method that assumes a closed population [26]. This closed population method allowed direct comparison of population estimates from our data and those from the study by Dovel et al. [16, 23]. They also provide precise estimates when assumptions are largely satisfied. Mark and recapture periods were defined by season and location: wintering site in late fall, wintering site in early spring, spawning site in mid to late spring, and summer and early fall dispersed sampling. All marked fish captured in the same sampling period as the period of marking were deleted from the record as recaptures. Multiple recaptures of the same fish were counted as separate recaptures so long as each recapture occurred in separate sampling periods. Comparisons of our estimated population sizes to a population size

Table 1. Numbers of shortnose sturgeon marked and recaptured in targeted and random sampling during the study.

Year	Season	Location	Type of sampling	Number caught	Recaptures	New marks	Total marks
1994	Spring	Spawning site	Targeted	240	0	240	0
1994	Summer	Estuary-wide	Random	118	0	82	240
1994	Fall	Wintering site	Targeted	424	0	424	322
1995	Spring	Wintering site	Targeted	1024	13	1025	746
1995	Spring	Spawning site	Targeted	783	29	754	1771
1995	Summer	Estuary-wide	Random	180	1	164	2525
1995	Fall	Wintering site	Targeted	664	27	637	2689
1996	Spring	Wintering site	Targeted	808	33	775	3326
1996	Spring	Spawning site	Targeted	294	24	270	4101
1996	Summer	Estuary-wide	Random	194	10	184	4371
1996	Fall	Wintering site	Targeted	916	68	848	4555
1997	Spring	Spawning site	Targeted	620	64	556	5403
Totals				6265	269	5959	

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of 10,000 fish (considered adequate and safe under Endangered Species Act actions for shortnose sturgeon) were made by computing the probability of this observation under our estimated population parameters. A mean and confidence interval for the estimated change in population size between studies was calculated using the distribution of a 1000 randomly selected values from 95% confidence intervals of the population estimates [27].

Closed population estimates assume no significant change in population size occurs during the estimation period due to recruitment, mortality, and movements in or out of the study area. Our study population would not strictly be closed, but shortnose sturgeon are known to be very long-lived fish with low rates of annual mortality and recruitment. Nonetheless, we investigated the potential for bias in our closed population estimates using a series of open population estimates (Jolly-Seber method [26]) and by analyzing the ratio of marked fish in the catch and the known number of marked fish in the estuary through the study period [26]. Finally, we assessed population trend over most of the study period using annual catch rates in the fish monitoring survey of the Hudson River electric utilities.

T-tests were used to test for differences in fish lengths and body condition of sturgeon from our samples and those of Dovel et al. [16, 23]. Paired t-tests were used to determine if there was a significant increase in mean fish length between a series of individual fish marked in the 1970s and recaptured in the 1990s. Differences in fish condition were calculated only from summer catches to avoid potential biases associated with measures of body weights collected immediately prior to or after the spawning season. The dispersed summer distribution of sturgeon was analyzed with a chi-square frequency analysis (samples with and without sturgeon) against a uniform distribution. The presence versus absence data format was used in this analysis so that sites with multiple captures would not bias results.

RESULTS

We captured 6,265 different shortnose sturgeon and marked 5,959 of these fish. Most (3,836) shortnose sturgeon were captured and marked at the wintering site, high numbers (1,937) were captured and marked at the spawning site, and relatively few (492) sturgeon were handled in the summer random sampling that covered the estuary (Table 1). Recaptures started appearing in the second year of the study (1995) and increased to a total of 269 by the end of our study. Shortnose sturgeon captured during the targeted sampling were adults (Fig. 2), while the summer random sampling captured a broader size range of sturgeon including some juveniles (≤50 cm FL, 4% of total catch).

A closed population estimate (Schnabel method, [26]) based on nine targeted sampling periods yielded 56,708 adult fish with a narrow 95% confidence interval: 50,862–64,072 (Fig. 3). Using the same methods and algorithm, Dovel et al. [16, 23] estimated the number of adult shortnose sturgeon at 12,669 and 13,844 (Fig. 3, 95% confidence intervals of 9,080–17,735 and 10,014–19,224 respectively) in 1979 and 1980. The probability of our sturgeon population was within the range (95% interval) of the Dovel et al. estimates was remote ($P<0.001$). The population estimates yielded a mean adult sturgeon abundance increase of 407% (95% confidence interval of 290 to 580%) from the late 1970s to the 1990s. Also, the probability that the Hudson River shortnose sturgeon population was 10,000 or fewer fish is highly unlikely ($P<0.001$) indicating the population was clearly larger than the size considered adequate in Endangered Species Act rulings.

A second closed population estimate was computed using all 12 sampling periods resulting in an estimate of 61,057 shortnose sturgeon with a narrow 95% confidence interval: 52,898–72,191 (Fig. 3). This estimate is larger than the corresponding 9-period estimate, includes juveniles and possibly adults not using the wintering and spawning sites, and is our best estimate of the whole shortnose sturgeon population of the Hudson River. The addition of juvenile and possible non-spawning adult sturgeon in the population was minor (ca. 7% of the overall estimate) indicating that all or nearly all adult shortnose sturgeon are present annually at the overwintering and spawning sites. Also, the summer sampling included some juveniles (4% of total catch) which could account for much of the difference in the 9 and 12 period closed population estimates (Fig. 2).

Analyses addressing the closed population assumption support our population estimates. A regression of the number of marked fish in our targeted sampling catches and the known number of marked fish in the river was linear ($R^2=0.96$) indicating minimal effect of changing population size during the study. The relation was also linear ($R^2=0.84$) but less precise when all sampling periods were included. A series of six open population estimates

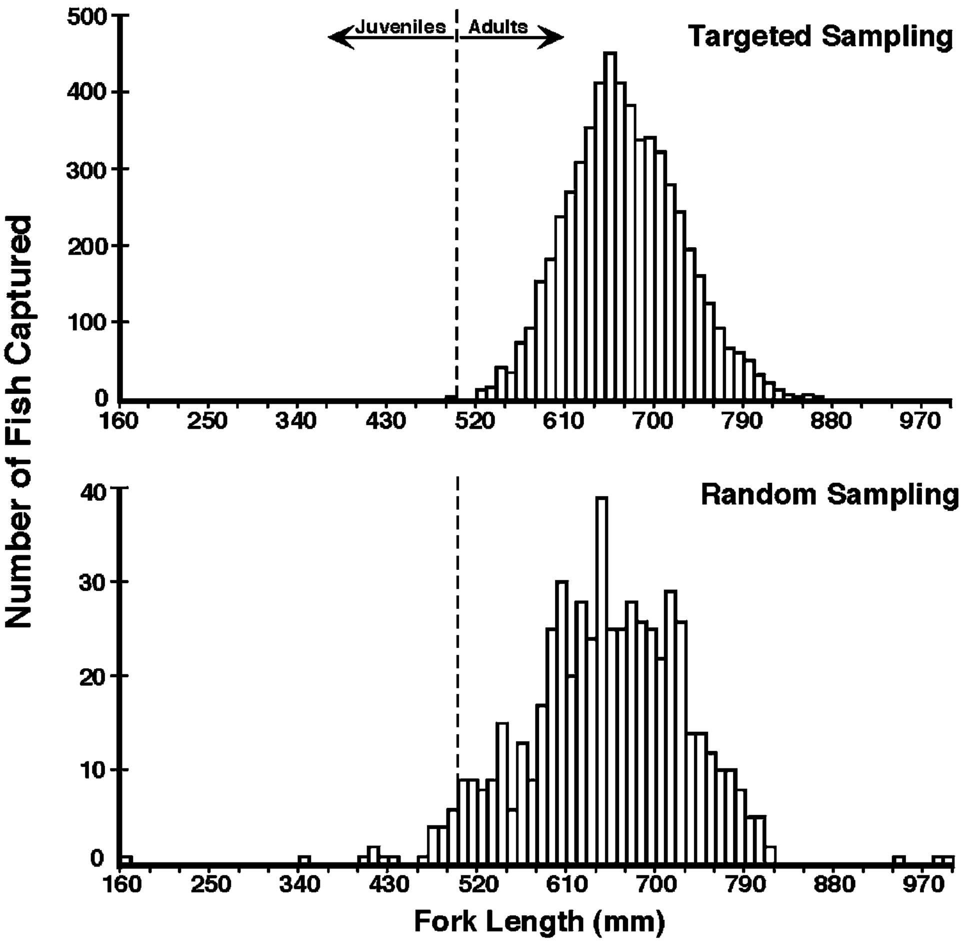

Figure 2. Size distribution of adult shortnose sturgeon captured in targeted sampling in spawning and adult wintering habitats, and the size distribution of shortnose sturgeon captured in random sampling during summer. Shortnose sturgeon greater than 50 cm fork length (FL) were classified as adults. During summer sampling, all life stages of shortnose sturgeon are well distributed in the river system.
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(Jolly-Seber method) varied in results as expected for this method [26] with initial and ending estimates in the series showing high variance. A mid-series set of three estimates had consistent results: population sizes centered on 59,545 with modest variation (coefficient of variation 27 to 30%). Findings using the open population estimates were not different than those using the closed

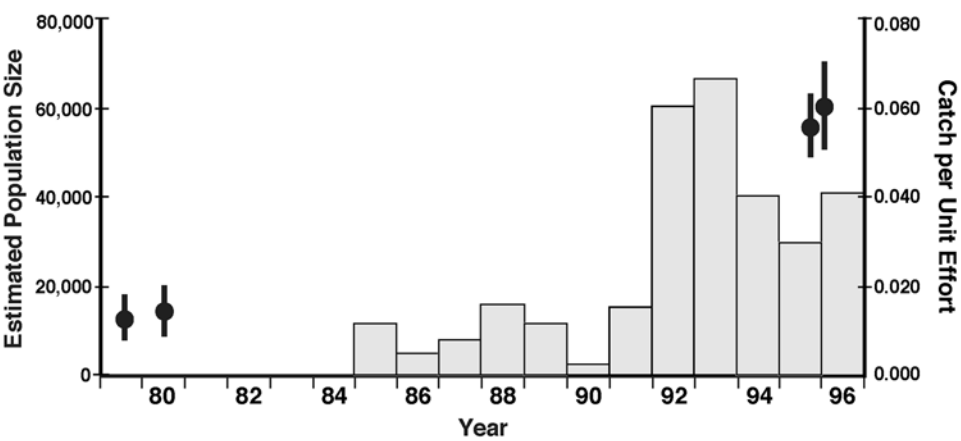

Figure 3. Population estimates and abundance trend for Hudson River shortnose sturgeon in the 1980s and 1990s. The paired symbols of circles (means) and heavy lines (95% confidence intervals) show the results of population estimates in the late 1970s and late 1990s. The catch per unit effort histogram bars are the average catch of shortnose sturgeon per trawl haul in a riverwide fish survey conducted annually by the Hudson River electric utilities.
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estimates: probabilities of the sturgeon population being 10,000 or fewer fish was remote ($P<0.003$) and unlikely ($P<0.05$) to be within the range of the Dovel et al. estimates.

Shortnose sturgeon captured in the 1970s and in our 1990s sampling were very similar in size composition with a slight (mean FL 655 and 665 mm, respectively) but significant (t-test, $P\leq0.0001$) increase in average size. A more equivalent comparison of shortnose sturgeon was made by comparing only those fish captured and measured at the wintering site. In the 1970s, 1,220 captured shortnose sturgeon had a mean fork length of 645 mm while 4,310 sturgeon recorded at the same location in the 1990s had a mean fork length of 663 mm. Again, there was a slight (18 mm) and significant (t-test, $P\leq0.0001$) difference among these large groups of sturgeon. Measures of body condition (Fulton K, [25]) for shortnose sturgeon captured during summers in the 1970s (Mean = 0.845, 95% CI = 0.813–0.877, 13) and 1990s (Mean = 0.835, 95% CI = 0.826–0.845) were similar and are comparable with other populations [24].

Some (37) shortnose sturgeon marked in 1979 and 1980 during the study by Dovel et al. [16] were recovered in our sampling in 1996 and 1997. The fork lengths of these 37 fish after 17 or 18 years in the river indicated very little growth on average (mean increase in FL = 28 mm, $P=0.038$). Of these 37 fish, four were juveniles at the time of capture and all of these fish grew (mean increase of 178 mm). There was no increase in length ($P=0.8243$) for the 33 sturgeon that were adults when initially measured and marked in the 1970s. Overall, there was very little growth found in fish recovered after 17 to 18 years except for some individuals that were small when initially caught.

From 1985 through 1996, the Hudson River electric utilities conducted an annual trawl survey typically composed of about 1,240 (range 1185–1549) highly standardized samples per year. These data show (Fig. 3) a clear increase in abundance of shortnose sturgeon during the period. Catch ranged from a low of 2 shortnose sturgeon in 1990 to a maximum catch of 82 sturgeon in 1993. The increase in average catch rate was more than four fold higher in the second half of the survey period. The trawl samples captured almost exclusively adult sturgeon with an average total length about 670 mm across years.

Shortnose sturgeon captured during randomly dispersed summer sampling (166 stations, 498 net sets) were distributed non-randomly ($X^2=16.87$, $P<0.01$) among seven distinct river strata (Fig. 1). Shortnose sturgeon were most frequently captured (63% of catch, present in 71% of samples) in the middle section of the estuary (Fig. 1, 3 strata from rkm 108 to 189) and were well represented (35% of catch, 51% of samples) in habitats downstream to persistently brackish waters (3 strata from rkm 43 to 107). The primary summer habitat for Hudson River shortnose sturgeon is a deep (regularly 13 to 42 m) tidal freshwater river channel. Downstream the estuary becomes brackish, deeper (regularly 18 to 48 m), and variable in width. The summer distribution of shortnose sturgeon in the Hudson River estuary combined with the wintering and spawning location forms a complete record of major habitats supporting almost all of the population.

DISCUSSION

Our different population estimates made under varying assumptions indicate a late 1990's shortnose sturgeon population in the Hudson River estuary of about 60,000 fish with adults comprising a very large portion (>90%) of the population. Compared to population estimates in the late 1970s, we conclude the Hudson River population has increased by more than 400%. Independent data from the Hudson River electric utilities annual trawl survey also indicate more than a four fold increase in abundance and again mainly in the adult segment of the population. For the species overall, the Hudson River population is very large and dominant to all others. The number of sturgeon marked during this study exceeds the estimated size of most other populations of shortnose sturgeon [5], and our population estimates are larger than the sum of all other estimated populations. Therefore, it is safe to conclude that Hudson River supports by far the largest population of shortnose sturgeon, and the system may harbor most individuals of the species.

While we assembled multiple lines of evidence supporting a large population increase over two decades, other findings suggest the population of shortnose sturgeon in the estuary is healthy. Shortnose sturgeon captured in the 1970s and in our 1990s sampling were very similar in size composition with a slight increase in average size. Measures of body condition for shortnose sturgeon captured during summers in the 1970s and 1990s were similar and are comparable with other populations [24]. A surprising number of adult sturgeon tagged in the 1970s were recaptured in our 1990s sampling, suggesting that many individual fish have lived for decades in the estuary without growing a measurable amount. These findings depict a population of long-lived fish that has increased in number over decades reaching a high abundance for the species.

Most shortnose sturgeon captured in the Hudson River estuary in research and monitoring programs have been adults ([17, 24], Utilities data set, and this study) regardless of sampling gear and time period. Shortnose sturgeon reach maturity at age-6 or younger with an adult lifespan of several decades [9]. Few unexploited populations of long-lived and large fish have been studied. Some fish populations like this were found to be composed overwhelmingly of slow growing, long-lived adults displaying a normal-shaped size distribution as in Figure 2 [28]. Few young are found in such populations and juveniles slowly add to the adult group, maintaining a very consistent population size structure. Hence, the Hudson River population of shortnose sturgeon displays the characteristics of an unexploited, long-lived fish population.

The availability and security of habitat is an important consideration in US Endangered Species Act decisions. The spawning and wintering habitats of shortnose sturgeon have been well known since the late 1800s when an intense sturgeon fishery operated in the estuary. The juvenile wintering habitat has been described [16], but the spatial extent of summer sturgeon habitat had not been documented. The sections of the Hudson River primarily used by shortnose sturgeon have remained physically intact with shoreline land use established early in the last century. Many historic residential structures and estates are located along the Hudson River, and very limited portions of the waterfront have been used for industrial uses. The spawning site for shortnose sturgeon is removed from the other habitats, because it is centered on turbulent river habitat between the head of tide and the Troy Dam. This section of the Hudson River is surrounded by urban areas and it is immediately upstream of a river section modified to accommodate a port facility. Nevertheless, the spawning site appears to be supporting adequate spawning in its current modified condition.

Section 7(a)(2) of the Endangered Species Act requires Federal agencies to ensure that actions they authorize, fund, or carry out do not jeopardize the continued existence of an endangered species or result in the destruction or adverse modification of critical habitat. The National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service is the responsible federal agency for planning recovery and implementing protection measures for shortnose sturgeon. Since 2000, the NOAA Fisheries Service has reviewed more than 50 proposed actions (e. g., dredging, shoreline stabilization and docks, pollution discharge permits, [29]) potentially affecting shortnose sturgeon in the Hudson River, often specifying protection measures (e.g., construction timing, design changes, local water quality standards). Shortnose sturgeon have also benefited from a cessation of fishing and other harm to individuals by capture, handling, and disturbance. Overall, the approach to recovery of shortnose sturgeon in the Hudson River has been to minimize interference with natural population processes and maintain habitat conditions able to support the species. This protect-and-wait approach to population recovery is in contrast to strategies employed for other species using hatchery-reared fish to actively promote population increases.

The US Endangered Species Act recognizes for listing and delisting populations that are discrete from other populations, and significant in relation to the entire species [distinct populations, 5]. Endangered species recovery plans specify the criteria to remove a species or a distinct population from the list of threatened and endangered species [30] making them key documents defining recovery [31]. The shortnose sturgeon plan [5] names 19 distinct populations and specifies three recovery criteria: adequate size with a favorable trend in abundance; habitat sufficient to support a recovered population; and potential causes of mortality insufficient to reduce the population. A shortnose sturgeon population composed of 10,000 spawning adults has been considered large enough to be at a low risk of extinction by the NOAA [32] and adequate for delisting under the US Endangered Species Act [32, 33]. This population threshold was based on analyses of minimum viable adult population sizes of vertebrates [34] applied to fish [35]. Population viability analysis was found to be an effective and realistic tool for endangered species protection in an analysis of 21 long-term population studies [36]. Other minimum population analyses have identified abundances less than the NOAA criteria for shortnose sturgeon [30, 37–42]. Following the criteria used by the NOAA for shortnose sturgeon, our total and spawning population estimates exceed the safe level by a wide margin (≥500%), clearly indicating recovery of this shortnose sturgeon population.

Aside from population size, estuary fish monitoring and the population estimates we report over two decades indicate a positive trend in population abundance. Shortnose sturgeon habitats in the Hudson River have supported the growing and now large population, and both the specific spawning and wintering areas and the widely dispersed growing season habitats have remained intact. No major changes are expected in the tidal portion of the Hudson River that would greatly alter or eliminate deep channel waters or the turbulent spawning reach. Finally, likely future causes of high mortality such as unregulated harvest, bycatch in active fisheries, and pollution stress have been and can be controlled through established fishery management and water quality regulations. By all three criteria specified in the shortnose sturgeon recovery plan, we believe the Hudson River estuary population merits designation as 'recovered' and qualifies for delisting from the US Endangered Species Act protection.

The NOAA Fisheries Service periodically reports on the status of shortnose sturgeon throughout their range [5, 43–45] using the latest information from field studies. A complex three-river estuary in Maine (Sheepscot, Kennebec, and Androscoggin Rivers) has had increasing numbers (7,222 fish in 1981 to 9,488 in 2000) of shortnose sturgeon recently approaching the safe population size, although there appears to be two distinct spawning populations contributing to the total numbers [46]. Substantial and stable populations occur in the Delaware River (6,408–14,080 in 1981–1984, near 10,000 in 2002, and 8,445 in 2004) and the Saint John River, New Brunswick (18,000 in 1970s). The Connecticut River appears to have a small (<150 fish) stable population isolated above the Holyoke Dam, and an increasing (895 in 1993, 1,800 in 2003[47]) population in the lower river. The Savannah River (South Carolina and Georgia) was stocked with 97,000 shortnose sturgeon between 1984 and 1992 but the most recent population estimate is modest (3,000 in 1999). The large Altamaha River of Georgia supports a modest population (798 in 1990, 468 in 1993, as many as 2,000 in 2004) of shortnose sturgeon. Another 12 mostly small Atlantic coast rivers have some evidence of shortnose sturgeon presence in low numbers (ca.<100) with increasingly frequent captures after decades of no records. Notable is the near lack (18 fish captured since 1996) of shortnose sturgeon in the largest Chesapeake Bay rivers (James, Potomac, and Susquehanna Rivers) although these rivers have dams and obstructions on or close to the tidal zone. What may make the Hudson River unique for shortnose sturgeon is the large area of tidal freshwater habitat used as the summer foraging range: the most commonly occupied 81 km of the tidal freshwater Hudson River. Other rivers with large summer habitat have sizable and near safe level populations (Maine rivers, Delaware River, Saint John River) except in the large southern rivers (Savannah, Altamaha Rivers) where mortality in river gillnet fisheries for shad (*Alosa* spp) is believed a critical impediment [5, 8, 45]. Overall, shortnose sturgeon in the Hudson River and across the species range suggest that slowly increasing populations could reach recovered status where they are managed under full protection in substantial foraging habitat.

Calls to change the US Endangered Species Act have come from scientists and legislators for more than a decade [48–50], and changes to this law are being debated in the US Congress [51, 52]. The Act has been characterized as failing to recover species [50, 52, 53], promote effective recovery programs [54–56], or properly assess species endangerment [57, 58]. One commonly reported flaw in government species recovery plans is that not enough is being done to increase population size and viability. Foin et al. [58] predict that most (63%) endangered species will not reach recovery criteria through habitat protection alone, and that more active management such as habitat restoration and population augmentation will be needed. Despite the multitude of anthropogenic influences on the Hudson River ecosystem, the shortnose sturgeon population appears to have achieved recovery and may merit removal from the list of threatened and endangered species. Other rivers with shortnose sturgeon appear to be slowly developing larger populations or have impediments that can be addressed with more determined species protection measures. Extension of a protect-and-wait conservation strategy seems viable for recovering shortnose sturgeon populations in the largest undammed rivers scattered along the Atlantic Coast.

Another assessment [59] of the Endangered Species Act concludes it is working more often than recognized because of poor reporting on the status and trends of endangered species populations. Few data have been collected following recovery efforts [31, 60, 61] making recovery and species management success difficult to recognize. The population status and trend of shortnose sturgeon in the Hudson River estuary had not been well documented prior to this study. The status of other shortnose sturgeon populations has been widely scattered through time and lacking for about half of the rivers suspected of harboring shortnose sturgeon [5]. More thorough and encompassing assessments of species status and trends could reveal additional recovery successes over time. Such findings provided evidence and optimism that public efforts for endangered species conservation can work. Our analysis of the shortnose sturgeon population in the Hudson River provides the first well documented case that fish species and habitat protection, combined with patience, can result in endangered species recovery; even in a human dominated ecosystem associated with one of the World's largest and most prominent cities.

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Author Contributions

Conceived and designed the experiments: MB NH DP. Performed the experiments: MB NH DP KA. Analyzed the data: MB KM KA. Contributed reagents/materials/analysis tools: KM PS. Wrote the paper: MB. Other: Arranged funding: MB.

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Appendix F
NJDEP Comment Letter

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CDM Smith

State of New Jersey

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CATHERINE R. McCABE
Commissioner

September 20, 2018

To: Distribution List

Re: Technical Comments on "Identification of Sensitive Areas Report"

Passaic Valley Sewage Commission, NJPDES Permit No. NJ0021016
Bayonne City Municipal Utilities Authority, NJPDES Permit No. NJ0109240
Borough of East Newark, NJPDES Permit No. NJ0117846
Town of Harrison, NJPDES Permit No. NJ0108871
Jersey City Municipal Utilities Authority, NJPDES Permit No. NJ0108723
Town of Kearny, NJPDES Permit No. NJ0111244
City of Newark, NJPDES Permit No. NJ0108758
North Bergen Municipal Utilities Authority, NJPDES Permit No. NJ0108898
City of Paterson, NJPDES Permit No. NJ0108880
Joint Meeting of Essex and Union, NJPDES Permit No. NJ0024741
Middlesex County Utilities Authority, NJPDES Permit No. NJ0020141
North Bergen MUA Woodcliff STP, NJPDES Permit No. No. NJ0029084
Town of Guttenberg, NJPDES Permit No. NJ0108715
North Hudson Sewage Authority - Adams Road STP, NJPDES Permit No. NJ0026085
North Hudson Sewage Authority - River Road STP, NJPDES Permit No. NJ0025321
Borough of Fort Lee, NJPDES Permit No. NJ0034517
City of Hackensack, NJPDES Permit No. NJ0108766
Ridgefield Park Village, NJPDES Permit No. NJ0109118
City of Elizabeth, NJPDES Permit No. NJ0108782
City of Perth Amboy, NJPDES Permit No. NJ0156132
Bergen County Utilities Authority, NJPDES Permit No. NJ0020028

Dear Permittees:

Thank you for your submission dated June 2018 as submitted cooperatively by Passaic Valley Sewage Commissioners with the above referenced permittees. The New Jersey Department of Environmental Protection (the Department or NJDEP) acknowledges that this report represents the above referenced permittees where appropriate certification statements were included as acknowledged in the Department's letter dated July 10, 2018. A description of the Study Area for the NJ CSO Group, as included on page 2 of the above referenced report, is as follows:

> "For the purposes of this report, the Sensitive Areas Study Area (Study Area) includes the combined sewer service areas, including all receiving and adjacent downstream waters that may be potentially affected by CSOs, from the various combined sewer service areas of the NJ CSO Group. Affected waters include the Passaic River, Hackensack River, Newark Bay, Hudson River, Kill Van Kull,

Arthur Kill, Raritan River or Raritan Bay as well as their tributaries within the Study Area of this report."

A total of 178 CSO outfalls are included within the above described Study Area. This letter serves to provide technical comments on your submission.

Regulatory Background

This report was submitted in accordance with Part IV.D.3.b.iv and Part IV.G.3 of your NJPDES CSO permit. This submission serves as a necessary element to the Long-Term Control Plan (LTCP) as due on June 1, 2020. Part IV.G.3 is specifically stated as follows:

"**3. Consideration of Sensitive Areas**

a. The permittee's LTCP shall give the highest priority to controlling overflows to sensitive areas, in accordance with D.3.a and G.10. Sensitive areas include designated Outstanding National Resource Waters, National Marine Sanctuaries, waters with threatened or endangered species and their habitat, waters used for primary contact recreation (including but not limited to bathing beaches), public drinking water intakes or their designated protection areas, and shellfish beds.

b. The LTCP shall comply with the following requirements:

   i. Prohibit new or significantly increased CSOs

   ii. Eliminate or relocate CSOs that discharge to sensitive areas wherever physically possible and economically achievable, except where elimination of relocation would provide less environmental protection than additional treatment.

   iii. Where elimination or relocation is not physically possible and economically achievable, or would provide less environmental protection than additional treatment, the permittee shall provide the level of treatment for remaining CSOs deemed necessary to meet [Water Quality Standards] WQS for full protection of existing and designed uses."

This permit condition stems from the Department's regulations at N.J.A.C. 7:14A-11, Appendix C as well as the 1994 National CSO Control Policy, 59 Fed. Reg. 18688 (April 19, 1994) which is identified below:

"Consideration of Sensitive Areas

EPA expects a permittee's long-term CSO control plan to give the highest priority to controlling overflows to sensitive areas. Sensitive areas, as determined by the NPDES authority in coordination with State and Federal agencies, as appropriate, include designated Outstanding National Resource Waters, National Marine Sanctuaries, waters with threatened or endangered species and their habitat, waters with primary contact recreation, public drinking water intakes or their designated protection areas, and shellfish beds. For such areas, the long-term CSO control plan should:

a. Prohibit new or significantly increased overflows;

b. i. Eliminate or relocate overflows that discharge to sensitive areas wherever physically possible and economically achievable, except where elimination or relocation would provide less environmental protection than additional treatment; or

ii. Where elimination or relocation is not physically possible and economically achievable, or would provide less environmental protection than additional treatment, provide the level of treatment for remaining overflows deemed necessary to meet WQS for full protection of existing and designated uses. In any event, the level of control should not be less than those described in Evaluation of Alternatives below; and

c. Where elimination or relocation has been proven not to be physically possible and economically achievable, permitting authorities should require, for each subsequent permit term, a reassessment based on new or improved techniques to eliminate or relocate, or on changed circumstances that influence economic achievability."

EPA guidance regarding sensitive areas is provided in the document entitled "Combined Sewer Overflows Guidance for Long-Term Control Plan" (EPA 832-B-95-002). Section 3.3.3.6 concerns Consideration of Sensitive Areas which reiterates the National CSO Control Policy yet also states the following:

> "As described in Chapter 1, the CSO Control Policy (II.C.3) provides a hierarchy of approaches for controlling overflows to sensitive areas. Each of the approaches to developing alternatives could be applied to controlling overflows to sensitive areas, and an awareness of the locations of sensitive areas might guide the development and selection of control alternatives, as well as the identification of priorities for project implementation."

<u>NJDEP Technical Review</u>

In order to perform a robust regulatory review, the Department evaluated information prepared by state and federal regulatory agencies; consulted with the Department's Division of Fish and Wildlife, Division of Water Supply and Geoscience, Bureau of Shellfisheries and other Department staff who have appropriate expertise; and evaluated sensitive area determinations within various long-term control plans throughout the nation. The Department also consulted with representatives of EPA Region 2 on September 18, 2018. The discussion below provides the Department's determination on each of the required elements in both the NJPDES CSO permit as well as in N.J.A.C. 7:14A-11, Appendix C.

1. <u>Outstanding National Resource Waters and National Marine Sanctuaries</u>

In your report on page 2 you explain that Outstanding National Resource Waters (ONRW) are maintained and protected by Tier 3 of the USEPA's Anti-degradation Policy. Only waters of "exceptional ecological significance" qualify as ONRWs, as determined by States and Tribes, where no ONRWs are located within the project boundaries.

You further state that the Office of National Marine Sanctuaries (ONMS) is the trustee of all national marine sanctuaries which currently recognizes fourteen (14) national marine sanctuaries, none of which are located within the Study Area.

> <u>Department's Conclusion</u>: N.J.A.C. 7:9B-1 <u>et seq</u>. defines ONRW as high-quality waters that constitute outstanding national resources (for example, waters of National/State Parks and Wildlife Refuges and waters of exceptional recreational or ecological significance) that includes Freshwater 1 (FW1) Waters and Pinelands Waters. The Department concurs that there are no designated ONRW for the waterbodies within the Study Area.

National Marine Sanctuaries are designated by NOAA (https://sanctuaries.noaa.gov). The Department concurs that there are no National Marine Sanctuaries for the waterbodies for which the CSO outfalls discharge to within the Study Area.

These review elements do not result in the identification of any sensitive areas at this time.

2. Waters with Threatened or Endangered Species

In your report you describe both Federal level and State level research. For the purposes of this letter the Department has only included excerpts that relate to aquatic species (i.e., avian and terrestrial species are not included in any summary) as described further in the Department's determination section below.

Federal level research

Federal level research is described on pages 42 through 43 of the report. At the federal level, the United States Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Association (NOAA) were utilized to analyze the Study Area for federally listed endangered and threatened species.

USFWS responded with a letter that addresses each USFWS designated site individually by showing maps of the area. Areas included are Dundee Canal and Island, Dundee Island Park and Pulaski Park, Essex County Branch Brook Park, Kearny Point, Oak Island Yards, Harrison Marsh Phase 1, Meadowland Marsh, Metro Media Tract and Harrison Marsh Phase 2. Each location returned a response that no endangered species were found in the Study Area for federally-listed threatened and endangered species.

The NOAA Environmental Sensitivity Index Maps for the project area were reviewed to locate specific habitat for the listed species where those maps were included in Appendix C of the report. As indicated in Table C-2, Atlantic Sturgeon (Endangered) was identified for Hudson River from the months of November to April whereas Shortnose Sturgeon (Endangered) was identified for the Hudson River for the months of January to December.

State Level Research

State level research is described on pages 43 through 46 of the report. As stated on page 43 you explain that NJDEP's Division of Fish and Wildlife (DFW) does not have a map for a specific location; instead it lists the endangered and threatened species for the state as a whole. Therefore, the New Jersey National Heritage Program (NJNHP) and NOAA were used for New Jersey State level information which allows an inquiry to be specific to a project area and the vicinity around it.

Table C-3 lists State-Listed Threatened and Endangered Species from the NJNHP project; however, no aquatic species are listed. You further state that "NJNHP found no critical habitats within the limits of the Study Area."

Regarding the NOAA review at the state level, the following is described on page 44:

> "The NOAA maps included both federal and state species on the same map and show critical habitat areas. Critical habitat areas differ in size depending on the species. Some species require large areas, with critical habitats shown to be polygonal areas, while others remain within a small radius and have critical habitats denoted as a circular marker.

> Each of these agencies list different species depending on their criteria for listing, and the purpose of the inquiry. USFWS identifies any threatened or endangered species in the area. NJNHP requests are typically used for smaller-scale projects, and cannot, therefore, cover the entire study area. The selected sites were used as a measure of the endangered or threatened species in the area. The selected sites also extend an additional ¼ mile outside of the site boundaries to account for additional disturbances. NOAA maps are a quick reference to identify the species most susceptible in the event of an oil spill. To avoid the risk of vandalism and to protect endangered or threatened species, the NOAA maps can include the species' markers in an undisclosed radius from the real habitat areas. This is purposely done to make a species' exact location difficult to find, especially when these maps may not be as current as a detailed request to the USFWS or NJNHP."

Threatened or endangered species and their habitat have been identified within the Study Area and are shown in Figures C-1 to C-7 in Appendix C of the report. Table C-5 of the report lists the areas where CSO outfalls are located inside the critical habitat of an endangered or threatened species. The only aquatic species identified are the Atlantic and Shortnose sturgeon in the Hudson River as indicated in NOAA Map-Number 499.

Research Specific to Atlantic Sturgeon and Shortnose Sturgeon

On page 45 you state the following:

> "The Atlantic and Shortnose Sturgeon critical habitats extend throughout the Hudson River. Both species are susceptible to environmental contamination due to their benthic foraging behavior and long life span. A total of 15 CSO outfalls discharge to the Hudson River and were further reviewed to determine if there are any impacts on the Sturgeon."

Appendix B of your report includes a "Status Review of Atlantic Sturgeon" as conducted by NOAA (see http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/atlanticsturgeon2007.pdf). A summary of the conclusions of this report is as follows:

- Commercial bycatch and decades of prior environmental degradation are the biggest threats to Atlantic sturgeon recovery in the New York Bight.
- The water quality in the Hudson River and New York Bight has improved in recent decades, and no longer appears to present a significant threat to Atlantic Sturgeon recovery.
- The review does not specifically mention human enteric pathogens as a cause for poor water quality. Rather the review refers only to sewer discharge as one of many point and non-point sources contributing to a low dissolved oxygen level.

A separate review of available published scientific articles, reports, and data by the Great Lakes Environmental Center as entitled "Consideration of Sensitive Areas Information in the Study Area of the Long Term Control Plan for Final Surface Water Renewal Permit Action" is included as Appendix D of the report. This review focused on an examination of any impact of human enteric pathogens to find any specific effects on Atlantic sturgeon. This study concludes the following:

- Surface water conditions for the indicator bacteria used (fecal coliform, enterococcus, and E. Coli) make it significantly more difficult for survival outside of the mammilian digestive tracts where these bacteria usually live.

- Water temperatures of around 70°F instead of 100°F and a higher salinity from the tidal nature of the Lower Hudson River makes long-term survival of bacteria difficult.

- The substantial water flow and depth in these areas also protects the bottom-dwelling sturgeon populations from contact with these bacteria making extended human pathogen exposure to Atlantic sturgeon unlikely.

- No specific information was found to suggest any negative effects these pathogen have on Atlantic Sturgeon at any life stage of the fish, both now and in the future. This may be related to the lack of documented presence of Atlantic Sturgeon in the New Jersey portion of the lower Hudson River for feeding, osmotic acclimation, or any other purposes.

- Atlantic Surgeon are likely to pass through this segment of the Hudson, but are thought to travel in deep channel waters, reducing vulnerabilities to nearshore discharges and intermittent CSO discharges.

Finally, Appendix E includes a population research study entitled "Recovery of a US Endangered Fish" as conducted by the Department of Natural Resources in Cornell University in January 2007. This review concludes:

- The adult population of Shortnose sturgeon in the Hudson River has also been increasing at rates higher than those expected by recovery criteria. The Shortnose sturgeon population estimated in the late 1990s had increased more than 400% from the 1970s estimates, and mainly in the adult segment of the population.

- The sizes of Shortnose sturgeon marked in the estimate were larger than other estimated populations as well. The estimate's results suggest the current level of habitat protection is adequate toward growing and maintaining healthy sturgeon population.

Based on the three studies cited above, you conclude there are no sensitive areas based on threatened and endangered species and their habitats.

Department's Conclusion: The Department has evaluated each CSO outfall for Threatened and Endangered aquatic species with the NJDEP Landscape Project Stream Habitat GIS database (see https://www.nj.gov/dep/gis/digidownload/metadata/landscape/Envr_hab_ls_v3_3_regions.html). Based upon a review of other LTCPs across the nation as well as input from the Department's Division of Fish, Game and Wildlife, the Department has identified aquatic species for this analysis. The Atlantic Loggerhead Turtle was also identified for one outfall within the Study Area, namely DSN 010A for Perth Amboy.

Based on the above, the Department has determined that certain areas for which CSO outfalls discharge either directly or indirectly to the Hudson River and Arthur Kill are potential habitat for the Atlantic sturgeon and Shortnose sturgeon. This includes the following permittees and outfalls:

CSO Outfalls that show potential habitat for Atlantic sturgeon and Shortnose sturgeon		
Permittee	**NJPDES No.**	**Outfall No.**
Fort Lee	NJ0034517	DSNs 001A and 002A
North Bergen MUA Woodcliff	NJ0029084	DSN 004A
Town of Guttenberg	NJ0108715	DSN 001A

Permittee	NJPDES No.	Outfall No.
NHSA Adams Street STP	NJ0026085	DSNs 002A, 003A, 005A, 006A, 008A, 012A, 013A, 015A
NHSA River Road STP	NJ0025321	DSNs 002A, 003A
Elizabeth City	NJ0108782	DSNs 029A, 031A, 032A, 034A, 037A
Jersey City	NJ0108723	DSNs 014A, 015A, 016A, 018A, 020A, 025A, 026A, 028A
Bayonne City	NJ0109240	DSNs 001A, 002A, 003A, 004A, 006A, 007A, 008A, 009A, 011A, 012A, 013A, 014A, 015A, 016A, 017A, 018A, 019A, 020A, 021A, 022A, 024A, 026A, 028A, 029A, 030A, 034A, 037A

3. Primary Contact

In your report on page 48 you state the following with respect to primary contact:

> "…a tracking survey of primary and secondary recreation was conducted by the sampling team for the NJ CSO Group Baseline Compliance Monitoring Program. The results of this survey are summarized in Table C-6. The sampling crews recorded any recreational activity that they observed while they collected samples in the waterbodies throughout the Study Area. No primary contact recreation activities were witnessed in any waterbody at any time. Secondary contact recreation activities including jet skiing, kayaking, and fishing, were observed in the Hudson River, Upper Bay, Passaic River, Newark Bay, Kill Van Kull, Arthur Kill, and Hackensack River. Therefore, Sensitive Areas, as may be indicated by waters with primary contact recreation, have not been identified within the Study Area."

As specified in Table C-6, you state that primary contact was not observed during sampling in 2016 for the study area. Secondary contact was observed for Hudson River, Upper Bay, Passaic River, Newark Bay, Kill Van Kull, Arthur Kill, Lower Hackensack River and the Upper Hackensack River. However, secondary contact was not observed for Raritan River, Overpeck Creek and the Elizabeth River.

In addition, as specified on page 49, the following is stated:

> "Although waters with primary contact recreation have not been identified, it is noted that there are existing beaches located on the north shore of the Raritan Bay, near the confluence of the Raritan River and the Arthur Kill, at the southeastern boundary of the of the City of Perth Amboy… These beaches are not currently designated by the City of Perth Amboy for recreational bathing use due to water quality concerns. Signs are installed at these beaches in order to advise the public not to swim or enter the water in this area. It is noted that there has been public interest in restoring these beaches for use as recreational bathing beaches and the City of Perth Amboy plans to evaluate the feasibility of accomplishing this objective. Although this area does not currently meet the requirements for a Sensitive Area, the Sensitive Area status will be revisited in the future if the City determines that it is feasible to support the safe public use of the beach in this area for recreational bathing."

Department's Conclusion: As per N.J.A.C. 7:9B-1 et seq., primary contact is defined as follows:

> ""Primary contact recreation" means water related recreational activities that involve significant ingestion risks and includes, but is not limited to, wading, swimming, diving, surfing, and water skiing."

The Department acknowledges that the NJPDES CSO permit states "waters used for primary contact recreation." This implies that the intent is to consider behaviors which is separate and distinct from the designated uses associated with the waterbody classification.

As per Part IV.F.8.a of the NJPDES CSO permit, the permittee was required to post CSO Identification Signs at every CSO outfall to include symbols prohibiting swimming, fishing and kayaking. The Department has anecdotal information that kayaking and swimming do occur at some locations in the Study Area; however, the report has limited information at this time documenting if these behaviors, or uses, are occurring. The Department acknowledges the inclusion of Table C-6 which serves to document behaviors within waters designated for primary contact within the Study Area. However, this information is limited to periods of time where the tracking survey was conducted. The report also does not have sufficient information regarding any specific primary contact amenities in the vicinity of the CSO outfalls. While kayaking is not specifically referenced in the primary contact recreation definition at N.J.A.C. 7:9B, the Department acknowledges that there are ingestion risks associated with kayaking activities and it should be addressed. **Please supplement the report with this information so that the Department can proceed with a final determination on sensitive areas due to Primary Contact.**

4. Public Drinking Water Intakes or their Designated Protected Areas

In your report on page 3 you state the following with respect to public drinking water intakes:

> "One drinking water intake was identified on the Hackensack River half a mile downstream to a Hackensack City CSO. This drinking water intake was decommissioned decades ago, and the current utility provider of the area has no current interest to reopen the intake due to the tidal nature of the Hackensack River at this location. Therefore, no sensitive areas have been determined from public drinking water intakes or their designated protection areas."

Department's Conclusion: The Department has consulted with the Department's Division of Water Supply and Geoscience that oversee data management for surface water intakes and have confirmed that there are no active surface water intakes used for drinking water in New Jersey in the vicinity of the CSO outfalls. In addition, the Department notes that the National CSO Control Policy and EPA guidance do not specify a set distance with respect to proximity of the CSO outfalls for this review element. In fact, the majority of the CSO outfalls within the Study Area discharge to saline waters.

This review element does not result in the identification of any sensitive areas at this time.

5. Shellfish Beds

In your report on page 52 you state:

> "The only commercial shellfish beds classified by the NSSP [National Shellfish Sanitation Program] for harvesting within the study area are restricted areas located in Raritan Bay… However, this area is downstream of the closest CSO by a few miles. The influence of tidal mixing and dilution coupled

with the separation between the most downstream discharge point and beginning of the shellfish harvest zone result in the CSO discharge having a negligible impact on the shellfish beds. Shellfish beds also extend up the Raritan River near Perth Amboy CSOs, but these are designated by the NSSP as prohibited harvesting locations and are only approved for depuration. Therefore, there are no Sensitive Areas due to the presence of shellfish beds in the Study Area."

Department's Conclusion: The Department has consulted with the Department's Bureau of Shellfisheries regarding this review element. The Department's interactive map showing the location of shellfish beds is available at: www.arcgis.com/home/webmap/viewer.html?webmap=5f6e08fc9e354467a2fd455790ef114a. The National CSO Control Policy and EPA guidance do not specify a set distance with respect to proximity of the CSO outfalls for this review element. The Department concurs that there are no operational shellfish beds in the vicinity of the CSO outfalls at this time.

This review element does not result in the identification of any sensitive areas at this time.

Overall Conclusion

As described above, based upon a review of the criteria of the National CSO Control Policy and associated guidance, the Department has determined that the report sufficiently addresses all review elements with the exception of primary contact. Please provide a supplement to this report within 30 days of this letter.

Thank you for your continued cooperation. Please feel free to contact Dwayne Kobesky if you have any questions regarding this letter.

Sincerely,

Susan Rosenwinkel
Acting Bureau Chief
Bureau of Surface Water Permitting

C: Dwayne Kobesky, Bureau of Surface Water Permitting, CSO Team Leader
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Appendix G
NJDEP Comment Letter Dated March 1, 2019

State of New Jersey

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Governor

SHEILA OLIVER
Lt. Governor

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Mail Code – 401-02B
Water Pollution Management Element
Bureau of Surface Water Permitting
P.O. Box 420 – 401 E State St
Trenton, NJ 08625-0420
Phone: (609) 292-4860 / Fax: (609) 984-7938

CATHERINE R. MCCABE
Commissioner

March 1, 2019

To: Distribution List

Re: Review of Revised "Identification of Sensitive Areas Report"

Passaic Valley Sewage Commissioners, NJPDES Permit No. NJ0021016
Bayonne City Municipal Utilities Authority, NJPDES Permit No. NJ0109240
Borough of East Newark, NJPDES Permit No. NJ0117846
Town of Harrison, NJPDES Permit No. NJ0108871
Jersey City Municipal Utilities Authority, NJPDES Permit No. NJ0108723
Town of Kearny, NJPDES Permit No. NJ0111244
City of Newark, NJPDES Permit No. NJ0108758
North Bergen Municipal Utilities Authority, NJPDES Permit No. NJ0108898
City of Paterson, NJPDES Permit No. NJ0108880
Joint Meeting of Essex and Union, NJPDES Permit No. NJ0024741
Middlesex County Utilities Authority, NJPDES Permit No. NJ0020141
North Bergen MUA Woodcliff STP, NJPDES Permit No. No. NJ0029084
Town of Guttenberg, NJPDES Permit No. NJ0108715
North Hudson Sewage Authority – Adams Road STP, NJPDES Permit No. NJ0026085
North Hudson Sewage Authority - River Road STP, NJPDES Permit No. NJ0025321
Borough of Fort Lee, NJPDES Permit No. NJ0034517
City of Hackensack, NJPDES Permit No. NJ0108766
Ridgefield Park Village, NJPDES Permit No. NJ0109118
City of Elizabeth, NJPDES Permit No. NJ0108782
City of Perth Amboy, NJPDES Permit No. NJ0156132
Bergen County Utilities Authority, NJPDES Permit No. NJ0020028

Dear Permittees:

Thank you for your submission dated October 18, 2018 which contains a revised version of the "Identification of Sensitive Areas Report" as well as a "Summary of Changes" document as submitted cooperatively by Passaic Valley Sewage Commissioners on behalf of the above referenced permittees. This October 18, 2018 submission serves to provide a response to the Department's comments dated September 20, 2018 on the June 30, 2018 "Identification of Sensitive Areas Report" (report). This report was submitted in accordance with Part IV.D.3.a and Part IV.G.3 of your NJPDES CSO permit where 178 CSO outfalls are included with the Study Area.

As described in the Department's September 20, 2018 letter, the Department had determined that the report sufficiently addressed all review elements with the exception of primary contact. Therefore, this subject letter serves to outline what additional information is needed regarding primary contact in order to ensure a technically complete report which will serve as a necessary element to the Long-Term Control Plan (LTCP) as due on June 1, 2020.

The information described below should be provided for all CSO outfalls within the affected CSO municipalities with the exception of the 6 outfalls within the City of Perth Amboy for which information was provided on pages 47 and 48 of your report. Please revise the report by providing the following information:

1. A list of all 172 CSO outfalls within the Study Area (not including the 6 outfalls for Perth Amboy) indicating whether or not the waterbody in the area of the outfall is accessible by the public. This should include, but is not limited to, public walkways, beach areas, kayak or boat launches within 100 feet of each outfall. While kayaking is not specifically referenced in the primary contact recreation definition at N.J.A.C. 7:9B, the Department acknowledges that there are ingestion risks associated with kayaking activities.

2. A summary of any communication with municipal official(s) (e.g.. Public Works Department, Recreation Department) of the affected CSO communities as to whether they have knowledge of any authorized and/or unauthorized primary contact recreation uses (e.g. swimming and kayaking) in the area of each outfall within their municipality.

3. A summary of any discussion(s) regarding primary contact recreation uses (e.g. swimming and kayaking) in the vicinity of CSO outfalls that may have occurred at any CSO Supplemental Team meetings as well as the date(s) of the meeting(s).

Please incorporate these changes to the report and submit a revised version to the Department no later than 30 days from this letter. Thank you for your continued cooperation.

Sincerely,

Susan Rosenwinkel

Susan Rosenwinkel
Bureau Chief
Bureau of Surface Water Permitting

C: Nancy Kempel, Bureau of Nonpoint Pollution Control, CSO Team Leader
Joe Mannick, Bureau of Surface Water Permitting, CSO Team Leader
Dwayne Kobesky, Bureau of Surface Water Permitting, CSO Team Leader
Josie Castaldo, Bureau of Surface Water Permitting
Robert Hall, Bureau of Surface Water Permitting

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Town of Guttenberg
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Guttenberg, NJ 07093

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Fort Lee Borough, NJ 07024

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Ridgefield Park, NJ 07660

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Richard Wolff, Executive Director
North Hudson Sewage Authority
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Susan Banzon
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65 Central Avenue
Hackensack, NJ 07602

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City of Elizabeth
50 Winfield Scott Plaza
Elizabeth, NJ 07201

Dominic DiSalvo, Director of Engineering
Bergen County Utilities Authority
P.O. Box 9 – Foot of Mehrhof Road
Little Ferry, NJ 07643

NJCSO GROUP COMPLIANCE MONITORING PROGRAM REPORT

Last revised 10/5/2018

NJCSO GROUP COMPLIANCE MONITORING PROGRAM REPORT

Prepared on behalf of the following participating Permittees by Passaic Valley Sewerage Commission (NJ0021016) to Satisfy Permit Condition Part IV.D.3.d:

Bayonne City (NJ0109240) PVSC
East Newark Borough (NJ0117846) PVSC
Harrison Town (NJ0108871) PVSC
Jersey City MUA (NJ0108723) PVSC
Kearny Town (NJ0111244) PVSC
Newark City (NJ0108758) PVSC
North Bergen MUA (NJ0108898) PVSC
Paterson City (NJ0108880) PVSC
Joint Meeting of Essex and Union Counties (NJ0024741) JMEUC
Middlesex County Utilities Authority (NJ0020141) MCUA
North Bergen MUA (Woodcliff) (NJ029084) NBMUA
Guttenberg Town (NJ0108715) NBMUA
North Hudson Sewage Authority - Adams Street STP (NJ0026085) NHSA
North Hudson Sewage Authority - River Road STP (NJ0025321) NHSA
Fort Lee Borough (NJ0034517) BCUA
Hackensack City (NJ0108766) BCUA
Ridgefield Park Village (NJ0109118) BCUA
Elizabeth City (NJ0108782) JMEUC
Perth Amboy City (NJ0156132) MCUA
Bergen County Utilities Authority (NJ0020028) BCUA

"Protecting Public Health and the Environment"

Passaic Valley Sewerage Commission
Essex County
600 Wilson Avenue
Newark, New Jersey
JUNE 30, 2018
Revised 10/5/2018

SUMMARY OF CHANGES

This Report is for the Baseline Compliance Monitoring Program to be utilized by the NJ CSO Group. This Report describes the methodology that was utilized for the Baseline Compliance Monitoring Program, the analysis that was completed, and the Compliance Monitoring results to be used in the development of a CSO Long Term Control Plan (LTCP). In future versions, this section will include summaries of changes and when they were incorporated as appropriate. The history of this document and changes made to it are summarized below:

- June 28, 2018: Submitted Baseline Compliance Monitoring Program Report in fulfillment of the LTCP Permit requirement.
- Revised October 4, 2018: Modified the Compliance Monitoring Program Report to address comments made by NJDEP in letter dated September 7, 2018. A copy of the September 7, 2018 letter is included as Attachment 4 of this document. The 06/28/2018 submitted Compliance Monitoring Program Report was 206 pages. This version includes updates that resulted in a page total of 206 pages plus the 7-page NJDEP comment letter and a divider page for a total of 214 report pages plus the cover. Page number updates are not reflected with redline-strikeout in this document. The following pages in this document have been changed to address NJDEP comments, with changes shown in redline-strikeout throughout the document:

  a. DEP Comment 1 – Page 25 Modified.
  b. DEP Comment 2 – Page 28 Modified.
  c. DEP Comment 3 – Page 31 Modified.
  d. DEP Comment 4 – Page 32 Modified.
  e. DEP Comment 5 – Page 35 Modified.
  f. DEP Comment 6 – Page 131 Modified.
  g. DEP Comment 7 – Page 35 Modified.
  h. DEP Comment 8 – Pages 57 and 131 Modified.
  i. DEP Comment 9 – BCMP data provided under separate cover.
  j. DEP Comment 10 – Attachments 1, 2 and 3. Charts were modified per comment.
  k. DEP Comment 11 – Variability in the strength of the sanitary flow, the amount of sedimentation in sewer pipes, the time between storms, the intensity of storms, upstream conditions, the temperature and salinity of the water column can all lead to variability in the receiving water concentrations. There are no indications that there were problems with the April sampling or laboratory analysis. No change.

In future versions, this section will be further updated to include summaries of changes and when they were incorporated as appropriate.

CERTIFICATIONS

Title: NJ CSO Group Baseline Compliance Monitoring Program Report

Preparer:

Project Officer: ______________________ 6/6/18
Michael J. Hope, P.E., Greeley & Hansen — Date

QA Officer: ______________________ 6/6/18
Timothy J. Dupuis, P.E., CDM Smith — Date

Passaic Valley Sewerage Commission:

Program Manager: ______________________ 06/06/2018
Bridget McKenna, Chief Operating Officer, PVSC — Date

New Jersey Department of Environmental Protection

DEP Permits: ______________________
Joseph Mannick, CSO Coordinator — Date

DEP QA: ______________________
Marc Ferko, Office of Quality Assurance — Date

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0021016 (Passaic Valley Sewage Commission)

Approval of Data Report:

Permittee: ______________________ 06/06/2018

Bridget McKenna — Date
Chief Operating Officer, Passaic Valley Sewage Commission

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________ 06/06/2018

Bridget McKenna — Date
Chief Operating Officer, Passaic Valley Sewage Commission

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0109240 (Bayonne City)

Approval of Data Report:

Permittee: ______________________ 5.31.18

Timothy Boyle — Date
Superintendent, City of Bayonne Department of Public Works

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________ 5.31.18

Timothy Boyle — Date
Superintendent, City of Bayonne Department of Public Works

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0117846 (East Newark)

Approval of Data Report:

Permittee: ______________________ 6/25/18

Frank Pestana — Date

Licensed Operator, Borough of East Newark

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________ 6/25/18

Frank Pestana — Date

Licensed Operator, Borough of East Newark

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108871 (Harrison)

Approval of Data Report:

Permittee: ________________________________ 6/8/18

Rocco Russomano Date
Town Engineer, Town of Harrison

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ________________________________ 6/8/18

Rocco Russomano Date
Town Engineer, Town of Harrison

BASELINE COMPLIANCE MONITORING PROGRAM
DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108723 (Jersey City MUA)

Approval of Data Report:

Permittee: Richard Haytas 6/4/18

Rich Haytas Date
Senior Engineer, Jersey City MUA

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: Richard Haytas 6/4/18

Rich Haytas Date
Senior Engineer, Jersey City MUA

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0111244 (Kearny)

Approval of Data Report:

Permittee: ______________________________ 6/20/18

Robert J. Smith
Town Administrator, Town of Kearny

Date

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________________ 6/20/18

Robert J. Smith
Town Administrator, Town of Kearny

Date

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108758 (Newark)

Approval of Data Report:

Permittee: ____

Ras J. Baraka Date
Mayor, City of Newark

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ____

Ras J. Baraka Date
Mayor, City of Newark

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108898 (North Bergen MUA)

Approval of Data Report:

Permittee: ______________________ 6/25/18

Frank Pestana — Date

Exec. Director, North Bergen MUA

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________ 6/25/18

Frank Pestana — Date

Exec. Director, North Bergen MUA

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108880 (Paterson)

Approval of Data Report:

Permittee: _______________________ 6/20/18. Date
Manny Ojeda
Director Public Works, City of Paterson

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: _______________________ 6/20/18. Date
Manny Ojeda
Director Public Works, City of Paterson

BASELINE COMPLIANCE MONITORING PROGRAM
DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0024741 (Joint Meeting of Essex and Union Counties)

Approval of Data Report:

Permittee: 6/11/18

Samuel McGhee Date
Executive Director, Joint Meeting of Essex and Union Counties

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: 6/11/18

Samuel McGhee Date
Executive Director, Joint Meeting of Essex and Union Counties

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0020141 (Middlesex County Utilities Authority)

Approval of Data Report:

Permittee: [signature] 6/19/18

Joseph Cryan Date
Executive Director, Middlesex County Utilities Authority

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: [signature] 6/19/18

Joseph Cryan Date
Executive Director, Middlesex County Utilities Authority

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0029084 (North Bergen Woodcliff)

Approval of Data Report:

Permittee: ______________________________ 6/25/18
Frank Pestana Date
Executive Director, North Bergen MUA

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________________ 6/25/18
Frank Pestana Date
Executive Director, North Bergen MUA

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108715 (Town of Guttenberg)

Approval of Data Report:

Permittee: [signature] 6/25/18

Frank Pestana, Date

Licensed Operator, Town of Guttenberg

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: [signature] 6/25/18

Frank Pestana, Date

Licensed Operator, Town of Guttenberg

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Numbers NJ0025321 & NJ0026085 (North Hudson Sewerage Authority)

Approval of Data Report:

Permittee: Fredric J Pocci June 6, 2018
Fredric J. Pocci, P.E. Date
Authority Engineer, North Hudson Sewerage Authority

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: Fredric J Pocci June 6, 2018
Fredric J. Pocci, P.E. Date
Authority Engineer, North Hudson Sewerage Authority

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0034517 (Borough of Fort Lee)

Approval of Data Report:

Permittee: [signature] 5/30/18

Alfred R. Restaino
Borough Administrator, Borough of Fort Lee
Date

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: [signature] 5/30/18

Alfred R. Restaino
Borough Administrator, Borough of Fort Lee
Date

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108766 (City of Hackensack)

Approval of Data Report:

Permittee: Wayne Vriesema 6/4/18
Wayne Vriesema Date
Project Manager, City of Hackensack

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: Wayne Vriesema 6/4/18
Wayne Vriesema Date
Project Manager, City of Hackensack

BASELINE COMPLIANCE MONITORING PROGRAM
DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ 0109118 (Village of Ridgefield Park)

Approval of Data Report:

Permittee: Alan O'Grady 6/5/18
Alan O'Grady Date
Superintendent, Ridgefield Park DPW

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who reviewed this report, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: Alan O'Grady 6/5/18
Alan O'Grady Date
Superintendent, Ridgefield Park DPW

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0108782 (City of Elizabeth)

Approval of Data Report:

Permittee: ______________________ 6/6/2018

Daniel Loomis, P.E. Date
City Engineer, City of Elizabeth

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: ______________________ 6/6/2018

Daniel Loomis, P.E. Date
City Engineer, City of Elizabeth

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0156132 (Perth Amboy City)

Approval of Data Report:

Permittee: Luis C. Perez-Jimenez 6/26/18

Luis Perez-Jimenez
Director of Water Operations, Perth Amboy City
Date

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: Luis C. Perez-Jimenez 6/26/18

Luis Perez-Jimenez
Director of Water Operations, Perth Amboy City
Date

BASELINE COMPLIANCE MONITORING PROGRAM DATA REPORT

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission on behalf of the NJ CSO Group

NJPDES Number NJ0020028 (Bergen County Utilities Authority)

Approval of Data Report:

Permittee: 6/4/18

Robert Laux
Executive Director, Bergen County Utilities Authority
Date

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared as part of a cooperation performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who reviewed this report, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: 6/4/18

Robert Laux
Executive Director, Bergen County Utilities Authority
Date

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SECTION 1 – INTRODUCTION

This report and its attachments summarize the data that HDR has collected in support of PVSC's LTCP modeling under the Baseline Compliance Monitoring Program (BCMP). The BCMP was designed to generate sufficient data to establish existing ambient water quality conditions for pathogens in the CSO receiving waters and to update, calibrate and validate a pathogen water quality model of the receiving water bodies. The resulting model will be used to support the development of CSO Long Term Control Plans (LTCPs) by the Passaic Valley Sewerage Commission (PVSC) and participating members of the NJ CSO Group. The data collected was paid for by the participating members of the NJ CSO group, who own the data and may use it to satisfy certain NJPDES permit requirements. Table 1 defines the participating members of the NJ CSO Group.

The BCMP conforms to the "Baseline Compliance Monitoring Program Quality Assurance Project Plan" (QAPP) prepared by PVSC on behalf of the NJ CSO Group and submitted to the New Jersey Department of Environmental Protection (DEP) December 31, 2015 as revised February 19, 2016.

The BCMP included three parallel data collection efforts:

1) Baseline Sampling, which was modeled after and intended to supplement the approved routine sampling program of the New Jersey Harbor Discharges Group (NJHDG), of which PVSC is a member. The sampling frequency matched NJHDG, varying with time of year as follows:
    a. Spring (May-Jun): Biweekly (4 dates);
    b. Summer (Jul-Sep): Weekly (12 dates); and
    c. Winter (Oct-Apr): Monthly (7 dates).

2) Source Sampling, which targeted the major influent streams within the study area to establish non-CSO loadings, and coincided with the NJHDG and Baseline Sampling. Any discussion of field activities applicable to Baseline Sampling is also applicable to Source Sampling because both sets of stations were sampled during the same field efforts.

3) Event Sampling, which was timed to coincide with rainfall to capture three discrete wet-weather events over the course of the year on each segment of the NY-NJ Harbor complex impacted by CSOs[1].

Field work for these three elements was completed on April 28, 2017; the last of the laboratory results were provided June 10, 2017. A total of 23 baseline and source sampling events were completed. The goal of the event sampling was to capture three significant wet weather events (precipitation >0.5 inches in 24 hours) at each targeted location, which was completed across four sampling events (one set of samples was collected across two precipitation events because of sampling logistics). All samples collected were analyzed for fecal coliform and enterococcus; freshwater samples were also analyzed for E. coli.

[1] Please refer to the companion System Characterization Report for any information related to CSO discharges.

The remainder of the body of this memo discusses methods and data quality. Assessment of the data quality will continue through the model calibration process, but a preliminary review indicates the data have met the goals of the QAPP and will be acceptable for its intended uses (baseline conditions assessment and model development).

The data itself is provided in two attachments and includes preliminary NJHDG data ~~includes preliminary NJHDG data collected between March and December 2016~~ in addition to the data collected by HDR. Data is shown in 6-panel time series plots of temperature, salinity, Secchi depth / turbidity, fecal coliform, enterococcus, and E. coli by sampling location, and are ordered spatially by waterbody, generally starting from the head end and continuing toward the mouth. Attachment 1 shows the sampling locations. Attachment 2 provides the Baseline, Source, and Event Sampling data for the full time period. Attachment 3 focuses on the Event Sampling, which is shown on a three-day timescale.

Table 1. NJ CSO Group Members and Associated Sewage Treatment Facilities

NJ CSO Group Member	Associated Sewage Treatment Facility[1]
Bayonne MUA	PVSC
East Newark	PVSC
Elizabeth	JMEUC
Fort Lee	BCUA
Guttenberg	NBMUA
Hackensack	BCUA
Harrison	PVSC
Hoboken[2]	NHSA
Jersey City	PVSC
Kearny	PVSC
Newark	PVSC
North Bergen MUA	PVSC
Paterson	PVSC
Perth Amboy	MCUA
Ridgefield Park	BCUA
Union City[2]	NHSA
Weehawken[2]	NHSA
West New York[2]	NHSA

[1]BCUA: Bergen County Utility Authority; JMEUC: Joint Meeting of Essex and Union Counties; MCUA: Middlesex County Utilities Authority; NBMUA: North Bergen Municipal Utility Authority; NHSA: North Hudson Sewage Authority; PVSC: Passaic Valley Sewage Commission. [2]Municipality with CSOs within their limits but not a permit holder.

SECTION 2 – METHODS

The BCMP is modeled in part on the program performed by the New Jersey Harbor Dischargers Group. NJHDG is a similarly allied collaborative undertaking that has been collecting data since 2003. PVSC has taken the lead for the NJHDG monitoring program which is modeled after the successful New York City Department of Environmental Protection (NYCDEP) Harbor Survey.

2.1 Field Methods

Field sampling activities were performed by HDR Engineering, Inc., in conformance with the applicable requirements of the NJDEP Field Sampling Procedures Manual (FSPM, 2005). HDR holds NJDEP certifications for all parameters for which field sampling was conducted. Table 2 presents the measurement methodologies.

Table 2. Field Sampling Parameters

Parameter	Method	RL[1]	MDL[2]	Holding Time
Temperature	SM 2550 B	0.1 °C	0 °C	Analyze Immediately
Salinity	SM 2520 B	0.1 ppt	0 ppt	Analyze Immediately
Dissolved Oxygen	SM 4500-O C, G	0.1 mg/L	0 mg/L	Analyze Immediately
pH	SM 4500-H B, EPA 150.2	0.1 Units	0 Units	Analyze Immediately
Light Penetration	Secchi Depth	0.1 ft	0.1 ft	Analyze Immediately
Turbidity	SM 2130 B	0 FNU	0 FNU	Analyze Immediately

[1]Reporting Limit. [2]Method Detection Limit

Data were collected during wet and dry conditions. At all locations, fecal coliform and enterococcus were sampled; E. coli was sampled at seven freshwater sites located on the Upper Passaic and Elizabeth Rivers. Table 3 lists details of the routine sampling locations; Table 4 presents the source sampling locations; and Table 5 lists the event sampling locations. A map of these sampling locations is provided in Attachment 1.

Table 3. Baseline Compliance Monitoring Routine Sampling Locations

Station		Waterbody	Samples[1]	Station		Waterbody	Samples
Passaic River	B24	Passaic R	1[2]	Hackensack River	B1	Hackensack R	1
	2	Passaic R	1[2]		B2	Hackensack R	1
	B22	Passaic R	1[2]		B11	Overpeck Cr	1
	S7	Third R	1[2]		S1	Berry's Cr	1
	11	Passaic R	1		B3	Cromakill Cr	2
	B8	Franks Cr	1		S2	Cromakill Cr	1
	B6	Passaic R	2		B4	Cromakill Cr	1
Hudson River	B5A	Hudson R	2		S3	Sawmill Cr	1
	B5B	Hudson R	2		B7	Hackensack R	2
	B18A	Hudson R	2		S5	Penhorn Cr	1
	B18B	Hudson R	2	Newark Bay	B10	Newark Bay	2
	B23A	Hudson R	2		B17	Newark Bay	1
	B23B	Hudson R	2		B16	Elizabeth R	1[2]
Upper Bay	B9	Upper Bay	2		B14	Elizabeth R	1[2]
	B20	Upper Bay	2		B13	Elizabeth R	1[2]
	B12	Kill Van Kull	2		S4	Peripheral Ditch	1
	B21B	Upper Bay	2		B25	Great Ditch Outlet	1
	B21A	Upper Bay	2	Arthur Kill, Raritan	24	Arthur Kill	2
	B26	Upper Bay	2		S6	Woodbridge Cr	1
	B27	Upper Bay	2		B15	Arthur Kill	2
	B28	Upper Bay	2		B19	Raritan R	2

[1]All locations sampled for enterococcus and fecal coliform. [2]Also sampled for E coli.

Table 4. Routine Source Monitoring Locations

Station[1]		Waterbody
Hackensack River	S1	Berry's Cr
	S2	Cromakill Cr
	S3	Sawmill Cr
	S5	Penhorn Cr
Newark Bay	S4	Peripheral Ditch
Arthur Kill	S6	Woodbridge Cr
Passaic River	S7[2]	Third River

[1]All locations sampled at mid-depth for enterococcus and fecal coliform. [2]Also sampled for E coli.

Table 5. Baseline Compliance Monitoring Event Sampling Locations

Station[1]		Waterbody	Samples	Station[1]		Waterbody	Samples
Passaic River	1[2]	Passaic R	1	Hudson River	31	Hudson R	2
	B24[2]	Passaic R	1		32	Hudson R	2
	3[2]	Passaic R	1		33[3]	Hudson R	2
	4[2]	Passaic R	1	Hackensack River	B1	Hackensack R	1
	7[2]	Passaic R	1		B2	Hackensack R	1
	8[2]	Passaic R	1		14	Hackensack R	2
	10[3]	Passaic R	1		15	Hackensack R	2
	B6	Passaic R	2	Newark Bay	17	Newark Bay	2
Upper Bay	B12	Kill Van Kull	2		18[3]	Newark Bay	2
	B26	Upper Bay	2		20	Elizabeth R	1
	B27	Upper Bay	2	Arthur Kill, Raritan	24	Arthur Kill	2
	B28	Upper Bay	2		B15	Arthur Kill	2
					29	Raritan Bay	2

[1]All locations sampled for enterococcus and fecal coliform twice per day for 3 days, except as noted. [2]Also sampled for E coli. [3]Sampled for enterococcus and fecal coliform four times per day for 3 days.

2.2 Laboratory Methods

Laboratory analyses for all samples collected by HDR were performed by Eurofins QC analytical laboratories, a New Jersey certified analytical testing laboratory. Laboratory analyses for all NHDG data were performed by the PVSC laboratory, also a New Jersey certified analytical testing laboratory. Table 6 presents the laboratory methodologies. The following parameters were analyzed in a laboratory:

- Fecal Coliform (all locations);
- Enterococcus (all locations); and
- E. coli (freshwater locations only; Elizabeth River & Upper Passaic River).

Table 6. Fecal Indicator Bacteria Laboratory Methodologies

Parameter	Laboratory Method	Preservation	Holding Time[1]	RL[2]
Fecal Coliform	EPA Micro Manual p. 124 (1978), Single Step Membrane Filtration	Cool $\leq$ 4°C	8 hrs	1, 2, 4, 10 CFU/100 mL
Enterococci	EPA 1600 (Dec 2009), Membrane Filtration	Cool $\leq$ 4°C	8 hrs	1, 2, 4, 10 PE/100 mL
E. coli	EPA 1603 (Dec 2009), Membrane Filtration	Cool $\leq$ 4°C	8 hrs	1, 2, 4, 10 CFU/100 mL

[1]Time between collection and initiation of analyses. [2]Reporting Limit; values are current as of issuance of QAPP and are based on dilutions, i.e., lower dilutions yield lower reporting limits and vice versa. CFU: colony forming units; PE: presumptive enterococci.

2.3 Data Quality Objectives

Quality control (QC) measures were applied in the field and the laboratory to characterize the data quality to ensure end-users are aware of any qualified data. Field measurements and sample collection addressed goals of completeness, precision, and representativeness through data validation, duplicate collection, and field and equipment blank samples. Laboratory quality controls addressed bias, accuracy, sensitivity, and comparability through analyzing Laboratory Fortified Blanks, establishing and reporting predetermined method detection and reporting limits, and analyzing Performance Test (PT) samples as part of annual laboratory & method certification. Tables 7 and 8 present the data quality criteria.

Table 7. Data Quality Criteria and Performance Measurement for Field Collection

Data Quality Indicator	Performance Criterion	Assessment Activity
Completeness	Valid data from 90% of collected samples	Percentage of valid measurements
Precision	RPD[1] < 30% for duplicates	1 field duplicate/crew-day
Representativeness	Blanks $\leq$MDL[2]	1 field blank/crew-day 1 equipment blank/crew-day

[1] Relative Percent Difference on a log basis; non-representative when (a) both the original and duplicate results are not detected or are less than 5x the reporting limit or (b) either result is estimated, rejected, or suspected of contamination. [2]Method Detection Limit, calculated where applicable.

Table 8. Data Quality Criteria and Performance Measurement for Laboratory Analyses

Data Quality Indicator	Performance Criterion	Assessment Activity
Bias/Accuracy	80%-120% Recovery	Reference material
Sensitivity	MDL[1] and RL[2]	Daily calibration curve
Comparability	Acceptable PT[3] samples	PT[3] samples and recertification

[1]Method Detection Limit. [2]Reporting Limit. [3]Performance Test. Part of annual laboratory & method certification for the laboratory performing the analysis.

SECTION 3 – RESULTS

Samples were collected during a 377-day span from April 17, 2016 through April 28, 2017. Table 9 summarizes the observed and normal precipitation at Newark Liberty International Airport (KEWR). Note that April 2016 included only 14 days and April 2017 included 28 days. Both the rainfall totals and number of days exceeding the target threshold were below normal for the time window the field program was executed.

Table 9. Precipitation Summary, April 17, 2016 – April 28, 2017

Month	Volume (inches)			Days ≥ 0.50 inches		
	Observed	Normal[1]	Difference	Observed	Normal[1]	Difference
Apr-16	0.17	1.91	(1.74)	0	1.2	(1.2)
May-16	3.85	4.02	(0.17)	3	2.9	0.1
Jun-16	2.40	4.76	(2.36)	2	2.7	(0.7)
Jul-16	6.08	3.70	2.38	4	3.0	1.0
Aug-16	0.93	3.82	(2.89)	0	2.6	(2.6)
Sep-16	2.17	3.60	(1.43)	1	2.7	(1.7)
Oct-16	3.00	3.65	(0.65)	3	2.5	0.5
Nov-16	6.51	3.81	2.70	3	2.7	0.3
Dec-16	2.46	3.54	(1.08)	1	2.9	(1.9)
Jan-17	3.86	2.88	0.98	3	2.6	0.4
Feb-17	2.09	4.18	(2.09)	2	2.1	(0.1)
Mar-17	5.09	4.20	0.89	3	2.7	0.3
Apr-17	3.28	3.82	(0.54)	3	2.4	0.6
Total	**41.89**	**47.89**	**(6.00)**	**28**	**33.0**	**(5.0)**

[1]Standardized three-decade average (1981-2010).

Table 10 shows the number of days of field measurement activities versus the precipitation condition. Water quality data was collected during 19 of the 28 target events that occurred during the field program (68%). Data was collected during an additional 36 wet weather days, and 81 days with little to no rain were also captured.

Table 10. Summary of Precipitation during Field Collection Days

Rainfall	Days	BCMP	Wet Weather[2]	Other Sampling[3][2]	No Sampling
Rain > Target[1]	28	5	5	9	9
Rain < Target[1]	94	27	6	3	58
No Rain / Trace	255	76	5	0	174
Total Days	**377**	**108**	**16**	**12**	**241**

[1]Precipitation >0.5 inches in 24 hours. [2]Includes prior day and three days of sampling (i.e., four Field Collection Days per Wet Weather Event) [2]~~System~~ [3]System Characterization sampling for CSO and stormwater was executed in parallel to the BCMP

3.1 Completeness

Tables 11 and 12 present the collection dates for routine and event sampling respectively, along with the percentage of samples collected during each survey. In total, 1,439 samples out of a targeted 1,449 samples were collected during the 23 baseline surveys (99.4%), and a 100% success rate was attained during 19 of the 23 routine surveys. Only one survey had more than one missed sample: survey 22, which was hindered by snowpack on the boat launch used to deploy the small boat. As a result, Stations B2 (1-depth), B3 (2-depths), B11 (1-depth), S2 (1-depth), S3 (1-depth) and S5 (1-depth) could not be sampled. These six stations are inaccessible by the larger boats, due to shallow station depths and low bridge clearances. The three remaining missed samples were due to site access (S4 during survey 6) or laboratory accident (B23A during survey 7 and B18A during survey 21).

Table 11. Routine Baseline and Source Sampling Dates and Completeness

Survey	Week of	Percent of Targeted Samples Collected	Number Missed	Survey	Week of	Percent of Targeted Samples Collected	Number Missed
1	4/25/2016	100	0	13	8/22/2016	100	0
2	5/9/2016	100	0	14	8/29/2016	100	0
3	5/23/2016	100	0	15	9/6/2016	100	0
4	6/9/2016	100	0	16	9/12/2016	100	0
5	6/22/2016	100	0	17	9/19/2016	100	0
6	7/5/2016	98.4	1	18	10/3/2016	100	0
7	7/11/2016	98.4	1	19	11/7/2016	100	0
8	7/18/2016	100	0	20	12/5/2016	100	0
9	7/25/2016	100	0	21	1/9/2017	98.4	1
10	8/1/2016	100	0	22	2/6/2017	88.9	7
11	8/8/2016	100	0	23	3/6/2017	100	0
12	8/15/2016	100	0	**Total**		**99.4**	**10**

Table 12. Baseline Compliance Monitoring Event Sampling Dates and Completeness

Survey, Date(s)	Antecedent Precipitation	Percent of Samples Collected	Number Missed
1. 6/6/2016	0.94”	97.4%	7 of 270
2a[1]. 1/4/2017 2b[2]~~[1]~~. 4/26/2017	0.36” 0.88”	100% 100%	0 of 110 0 of 160
3. 1/24/2017	1.24”	95.9%	11 of 270
Totals		**97.8%**	**18 of 810**

[1] Sampling locations accessible by land only, i.e., ~~split across two rain events due to sampling logistic limitations.~~ 1, 3, 4, 7, 8, 10, 20, B1, and B24. [2]Sampling locations accessible by boat only, i.e., 31, 14, 15, 17, 18, 24, 29, 31, 32, 33, B2, B6, B12, B15, B26, B27, B28)

In total, 792 of a targeted 810 samples were collected during the event sampling surveys. The seven samples not collected during the first event included B2 (2-depth), B6 (1-depth), 14 (2-depth), and 15 (2-depth). These stations were accessed using a small aluminum-hulled boat, and thunderstorms and high winds during the afternoon of the third day rendered it unsafe to sample. The eleven samples not collected during the third event included four at Station 29 (2-depth) and one at Station 18 (2-depth) due to high winds, and one at Station 20 that was not analyzed as the bottle broke in transit to the lab.

In addition to field issues, one sample at Station 20 on 6/8 was not analyzed for fecal coliform due to a lab accident, and all twelve samples collected on 6/8 were not analyzed for E. coli because of a lab oversight.

3.2 Qualified Data

The methodologies approved for bacteria require preparation of appropriate sample dilutions so that the number of colonies to be counted on the plate is between 20 and 60. Due to the wide variability of bacteria concentrations across ‘clean’ surface waters, stormwater, and sanitary sewage, it is not always possible to accurately estimate the level of dilution necessary. As a result, some of the concentrations reported are considered estimates because the number of colonies fell outside of this range when counted. These results are given a qualifier of “E.” E-qualified data still meet the needs of the program and can be used in the water quality analysis, but must be treated as estimates rather than direct measured values.

The bacteria measurements also have a specific holding time required by the laboratory methodology, which is less than 8 hours. When analysis is conducted outside of 8 hours, the concentrations are given a qualifier of “Q[2] .” Q-qualified data still meet the needs of the program and can be used in the water quality analysis, but could not be used for a regulatory assessment of compliance.

Q-qualified data occurred more frequently during the initial stages of the sampling program, most notably during the first event-based sampling in early June 2016. The laboratory processed coolers as they arrived rather than based on the coolers’ chain-of-custody end sample times. Procedures were adopted to address this issue and the number of Q-qualified data decreased over the course of the sampling program. Table 13 presents the number of non-qualified, E qualified, and Q qualified samples.

3.3 Precision

Precision assesses the variability associated with sample collection, handling, and storage in the field, as well as variability associated with the analytical processes. To measure this, one sample from each crew-day was collected in duplicate, and the laboratory analyses of duplicate samples were compared against one another. Table 14 summarizes these comparisons for routine, event, and source sampling by indicator bacteria. Overall, 92% of usable duplicates had a relative percent difference at or below 30% (on a log basis). Usable duplicates are those where both samples are at

[2] Other types of Q-qualifying issues can arise, but in this sampling program all Q-qualified data was flagged as such based on holding time exceedance.

least five times the reporting limit and neither is estimated, suspected of contamination, or otherwise rejected.

Table 13. Counts for Qualified Data

Qualifier	Routine			Event			Total		
	Fecal	Entero	Ecoli	Fecal	Entero	Ecoli	Fecal	Entero	Ecoli
None	1,125	1,210	99	417	361	63	1,542	1,571	162
E	313	229	40	349	390	30	662	619	70
Q	1	0	0	13	15	3	14	15	3
Both	0	0	0	11	25	0	11	25	0
Qualified	**22%**	**16%**	**29%**	**47%**	**54%**	**34%**	**31%**	**30%**	**31%**

Table 14. Analysis of Duplicates

Duplicates	Fecal	Entero	Ecoli	Total
Total Pairs	179	180	31	390
Usable Pairs	85	68	20	173
RPD <30%	80	60	20	160
Percent Good	**94%**	**88%**	**100%**	**92%**

3.4 Representativeness

Representativeness is a measure of the degree to which data accurately and precisely represent conditions at the sampling point. Programmatic and procedural controls are designed to minimize contamination between sample collection and the laboratory (or subsequent sample collections), and the effectiveness of these controls can be measured by analyzing blank samples that underwent similar handling to collected samples.

The sampling program relied on two types of blanks. Equipment blanks were generated each sampling crew-day by passing laboratory de-ionized (DI) water through sampling equipment prior to collecting the first sample. Field blanks were similarly prepared, but were collected between sampling events within the crew-day.

Table 15. Equipment and Field Blank Results, Routine, Event, and Source Sampling

Blanks	Equipment			Field			All Blanks		
	Fecal	Entero	Ecoli	Fecal	Entero	Ecoli	Fecal	Entero	Ecoli
Lab Analyses	181	181	61	180	180	60	361	361	121
≤MDL	150	179	45	144	164	42	294	343	87
Percent Good	**83%**	**99%**	**74%**	**80%**	**91%**	**70%**	**81%**	**95%**	**72%**

SECTION 4 –PRELIMINARY CONCLUSIONS

A preliminary review indicates that t~~T~~he data collected under the Baseline Compliance Monitoring Program is sufficient for the intended goal of calibrating the water quality model to be used for PVSC and NJCSO communities' LTCPs. Data quality met QAPP objectives, i.e.:

- The data completeness goal of valid data from 90% of collected samples was achieved. Over 99% of targeted samples were collected and analyzed, representing nearly 4,700 points of pathogen data. Of this data, 29% were reportable as estimates based on laboratory plate counts being outside of the recommended window, and less than 1% were qualified based on holding times. The preliminary review of flagged data shows that it is consistent with comparable non-flagged data and is likely to be informative to the model calibration process.
- The sample duplicate goal of calculated relative percent difference (RPD) being less than 30% on a log-basis was achieved in 92% of duplicates analyzed, which excludes pairs disqualified after collection and analysis for failure to meet reporting or method detection limit requirements, a determination that cannot be made prior to collecting and analyzing samples.
- The field and equipment blanks were below the method detection limit (MDL) for 86% of all blanks analyzed. The overwhelming majority of the remaining 14% were in the range of 1 to 10 colonies per 100 mL, indicating that sample contamination was very low in those cases and not likely to have altered the results.
- The BCMP was not designed to provide an adequate data volume for assessing attainment of water quality standards, which would have required five samples per month at each sampling location to compute monthly geometric means.~~ However, a review of the data collected can indicate the likelihood of attainment in a particular area:~~
- ~~The lower regions of the Passaic and Hackensack Rivers appear likely to violate water quality criteria, but attainment appears to improve closer to Newark Bay.~~
- ~~The larger waterbodies (Newark Bay, Hudson River, Arthur Kill, Kill Van Kull) appear to meet existing water quality criteria. Newark Bay and the Kills are primarily SE3 waterbodies, and Raritan Bay is subject to more stringent shellfishing water quality standards.~~
- ~~Several smaller riverine waterbodies appear unlikely to meet attainment. This includes the Rahway River, Saddle River, Second River, and Elizabeth River. The Raritan River may also have attainment issues.~~
- ~~Many rivers without CSOs have high bacteria loads. Data collected at source sampling locations indicate non-attainment of waters entering the Passaic and Hackensack Rivers, contributing pollutant loads into the study area from areas that do not have CSOs.~~

The attachments to this memo list the applicable water quality standards for each waterbody region, and provide the numeric criteria associated with those standards in a summary table at the front.

ATTACHMENT 1 – SAMPLING LOCATIONS

Figures are organized by associated sewage treatment facility

Passaic Valley Sewerage Commission (PVSC)

01 Overview
02 Bayonne City
03 East Newark
04 Harrison
05 Jersey City MUA
06 Kearny
07 Newark
08 North Bergen
09 Paterson

Bergen County Utilities Authority (BCUA)

10 Ridgefield Park Village
11 Borough of Fort Lee
12 City of Hackensack

Joint Meeting of Essex and Union Counties (JMEUC)

13 City of Elizabeth

North Bergen Municipal Utilities Authority (NBMUA)

14 North Bergen Woodcliff
15 Town of Guttenberg

North Hudson Sewerage Authority (NHSA)

16 Adams Street
17 River Road

Middlesex County Utilities Authority (MCUA)

18 Perth Amboy City

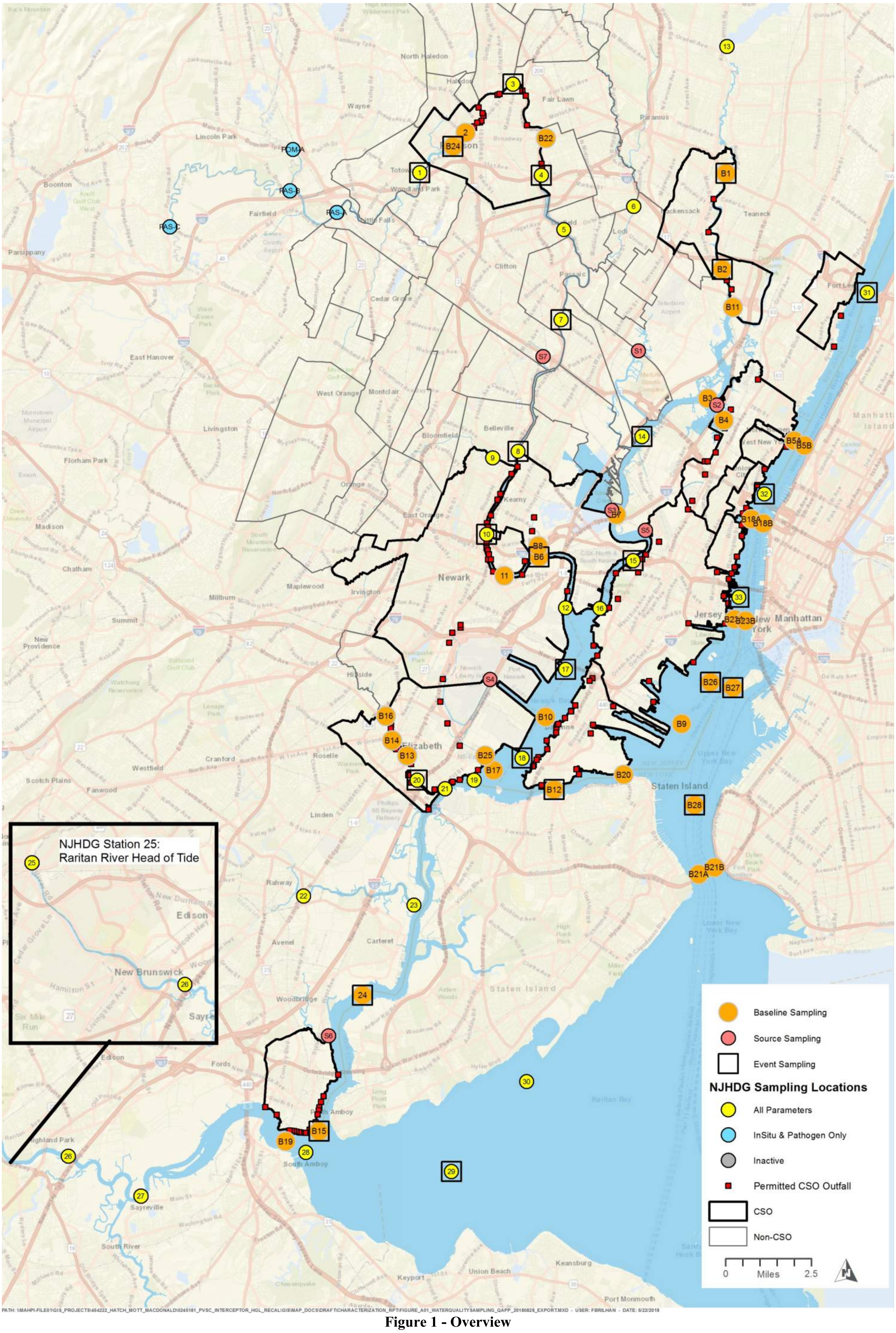

Figure 1 - Overview

Figure 2 – Bayonne City (PVSC)

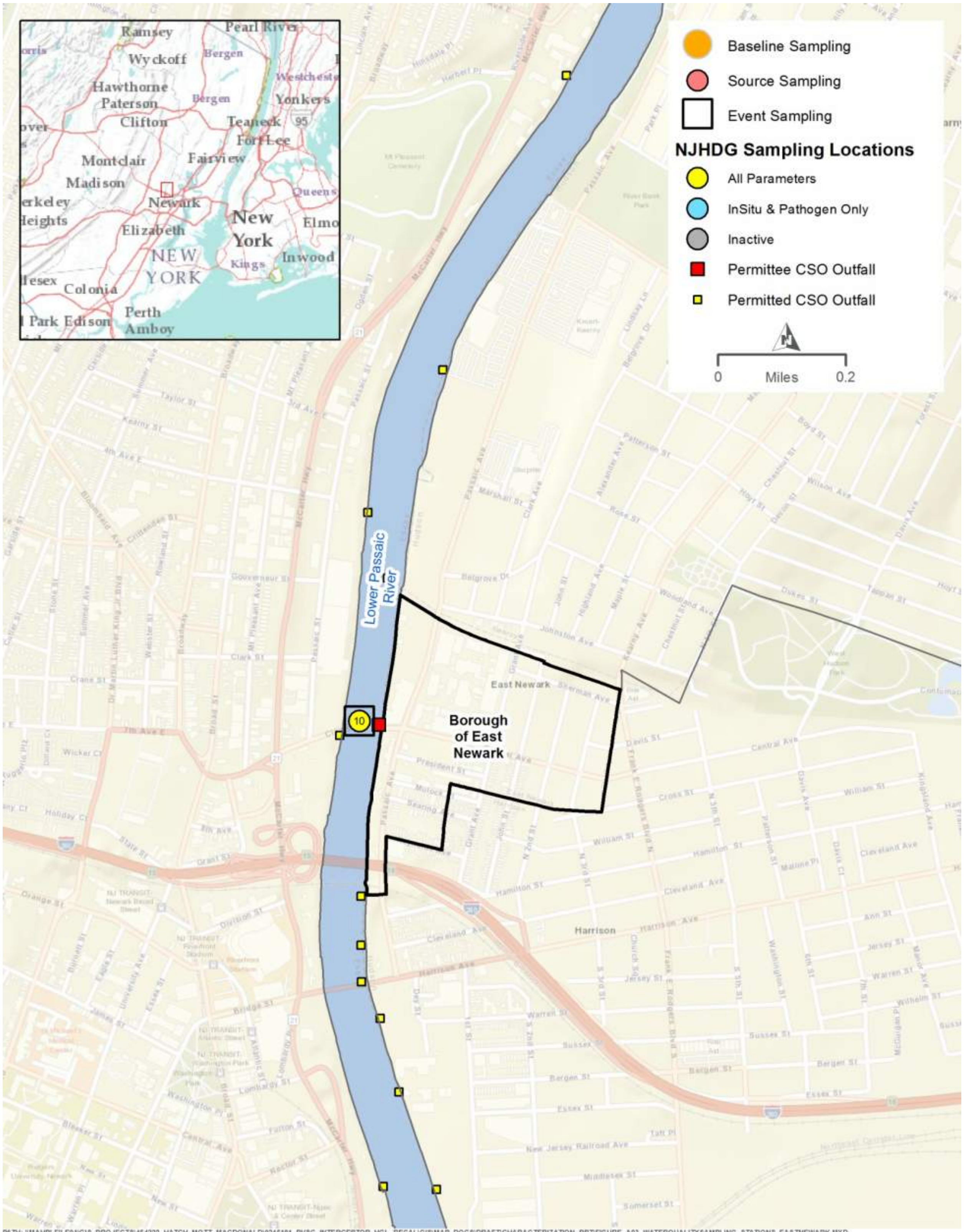

Figure 3 – East Newark Borough (PVSC)

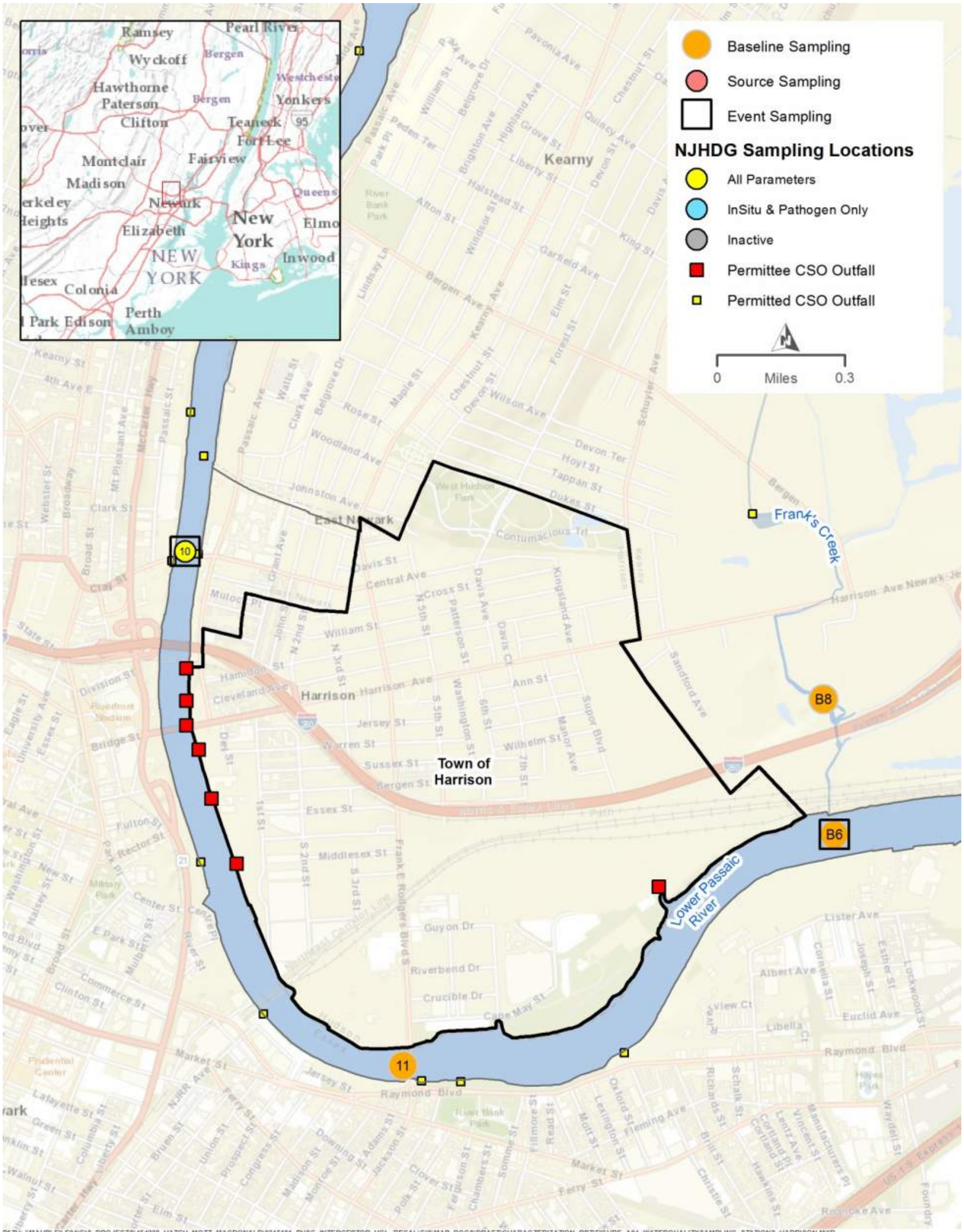

Figure 4 – Harrison Town (PVSC)

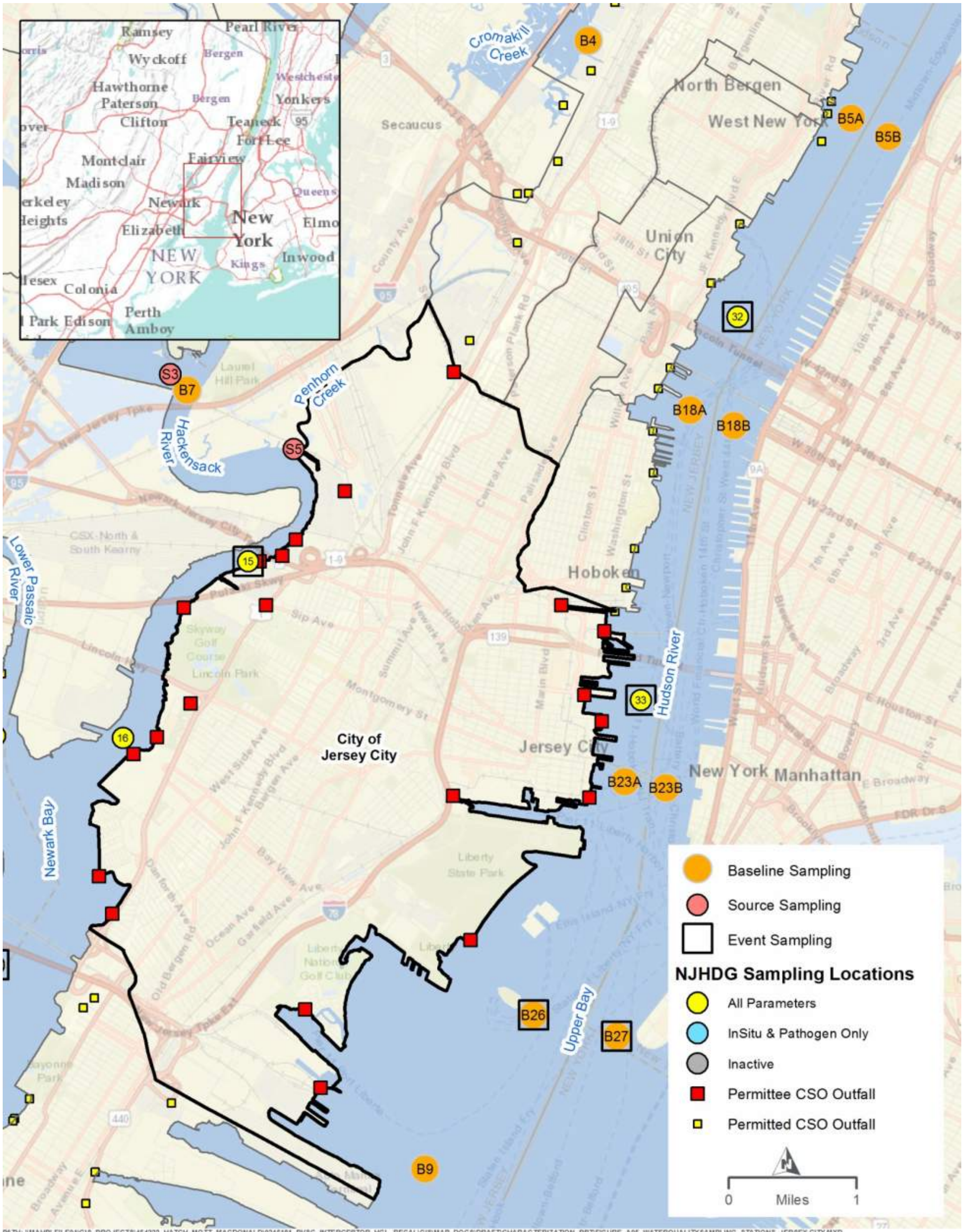

Figure 5 – Jersey City MUA (PVSC)

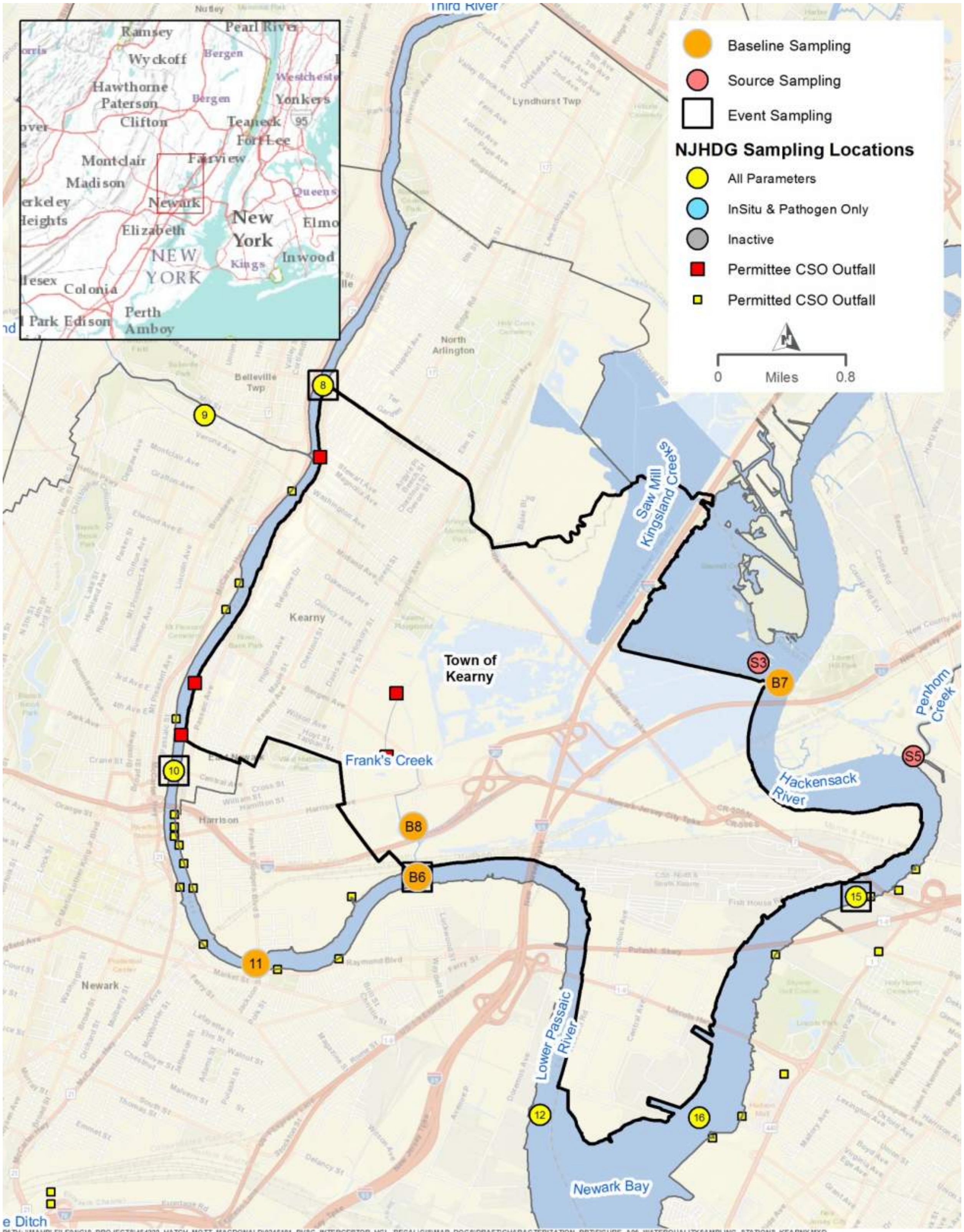

Figure 6 – Kearny Town (PVSC)

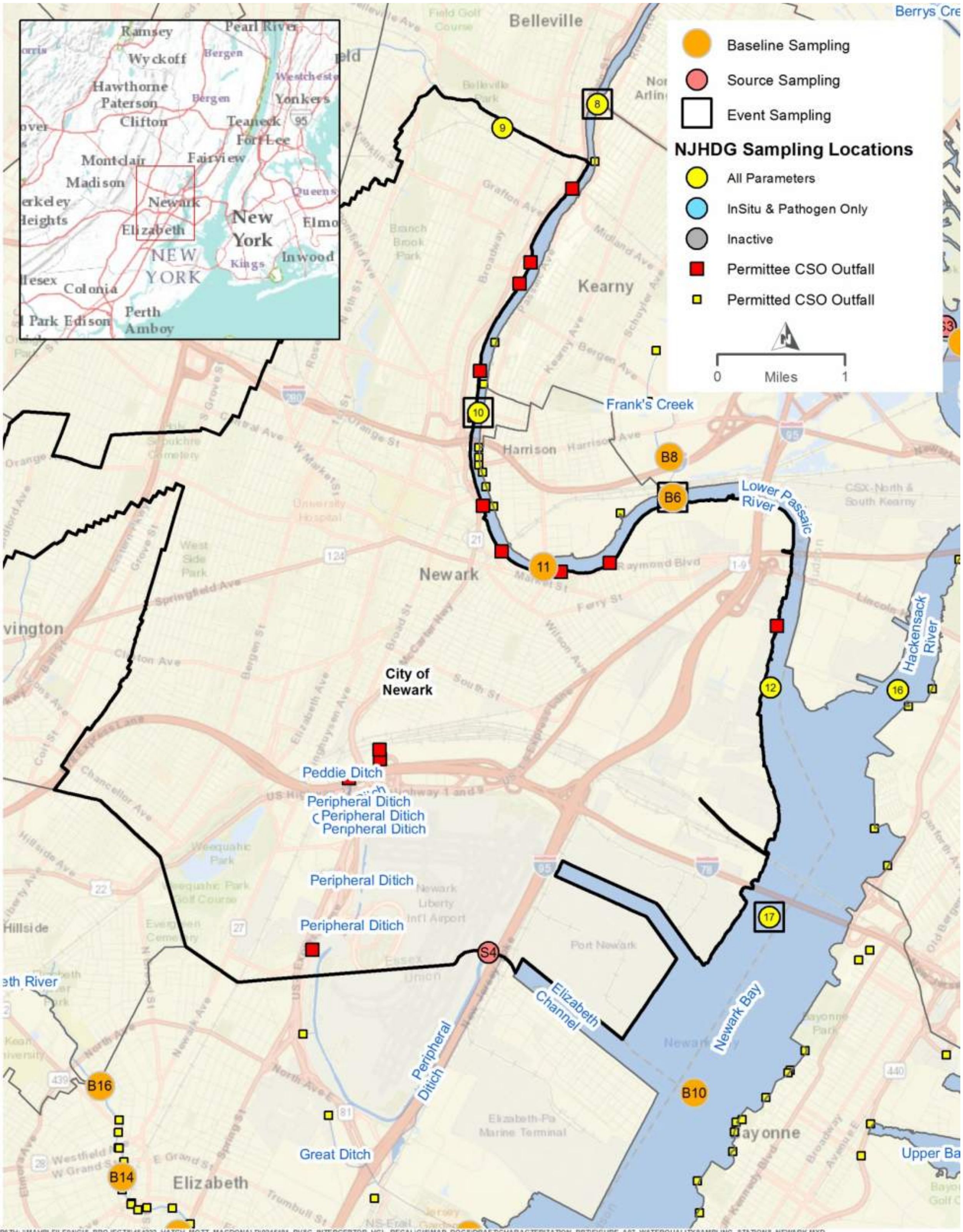

Figure 7 – Newark City (PVSC)

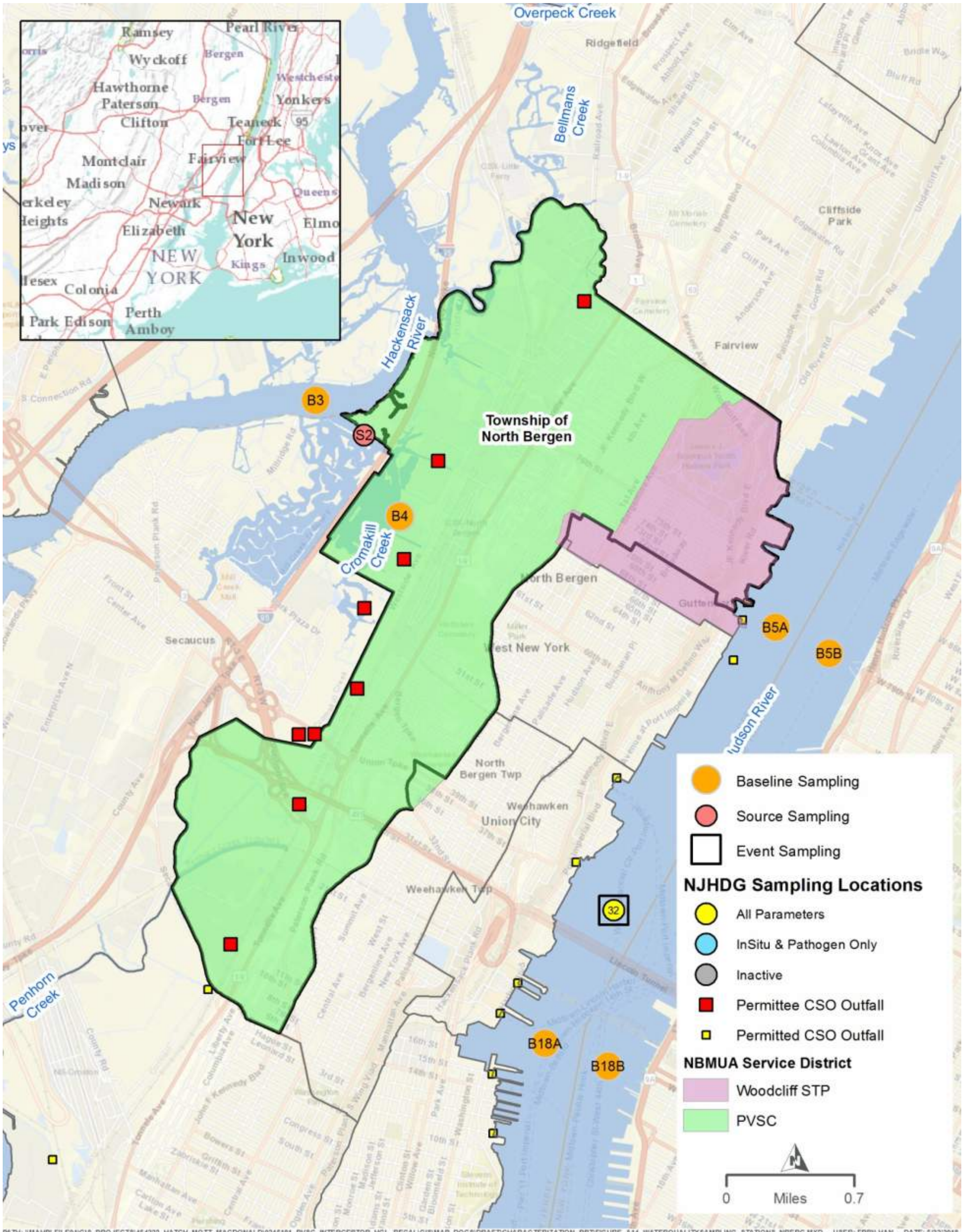

Figure 8 – North Bergen MUA (PVSC)

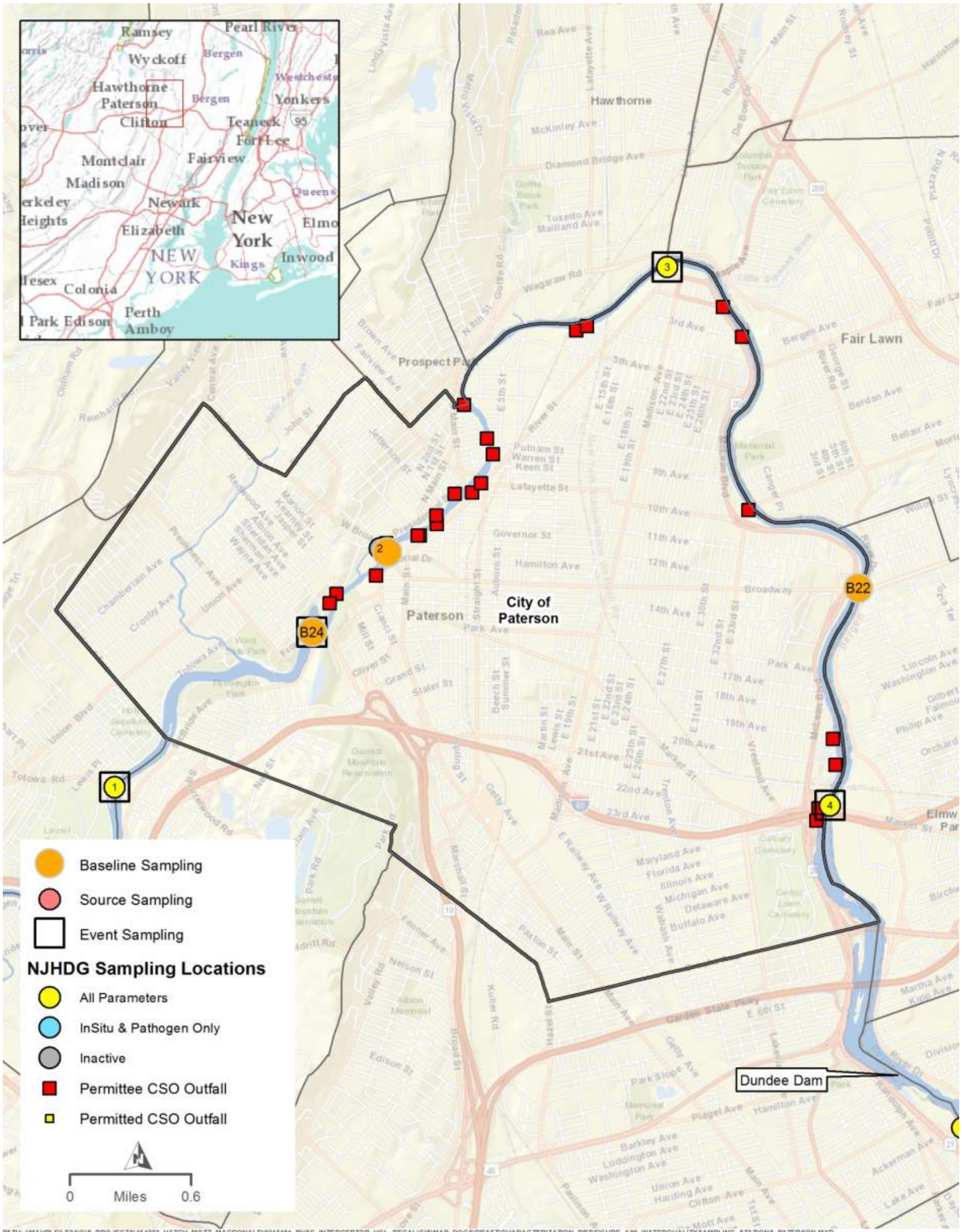

Figure 9 – Paterson (PVSC)

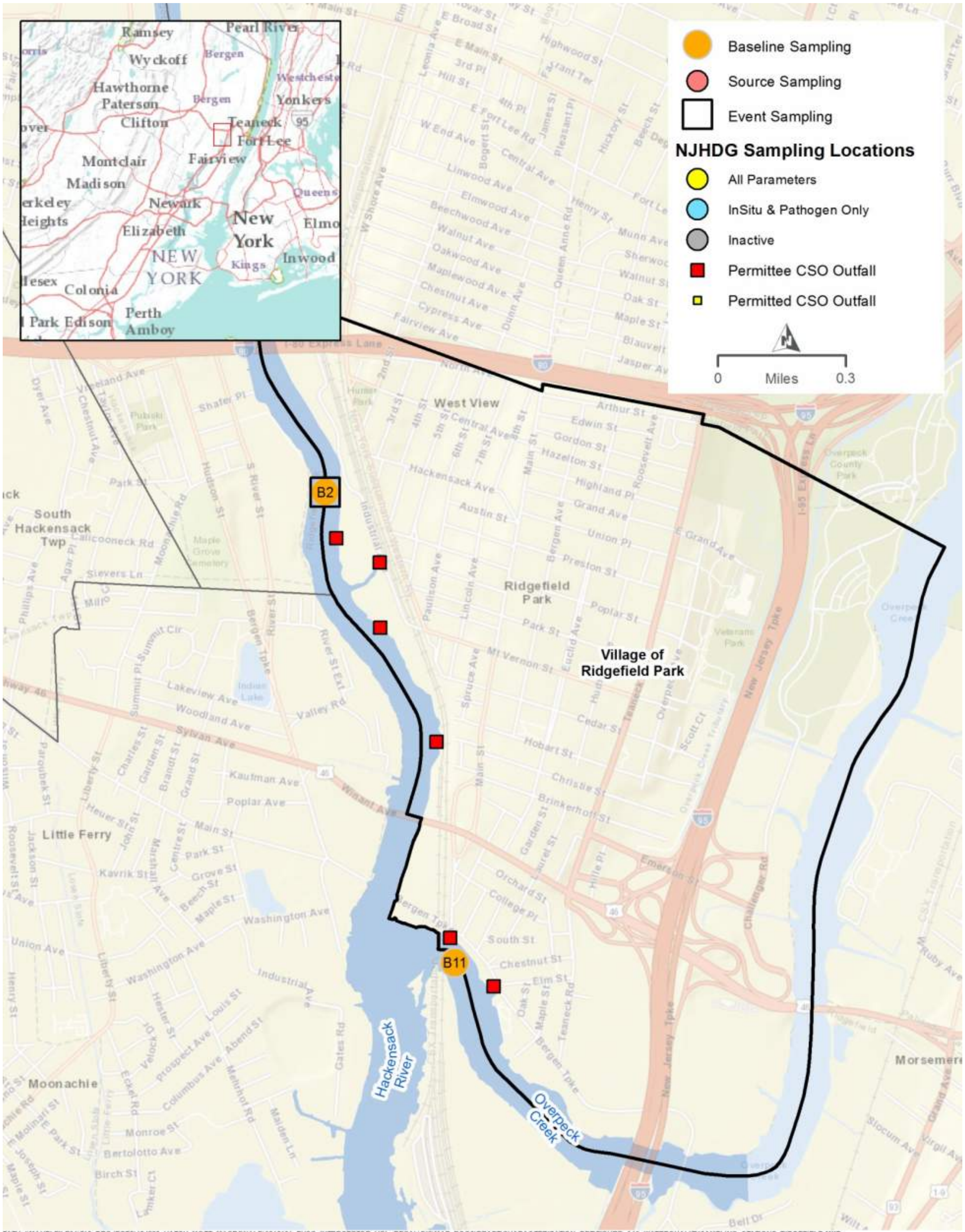

Figure 10 – Ridgefield Park Village (BCUA)

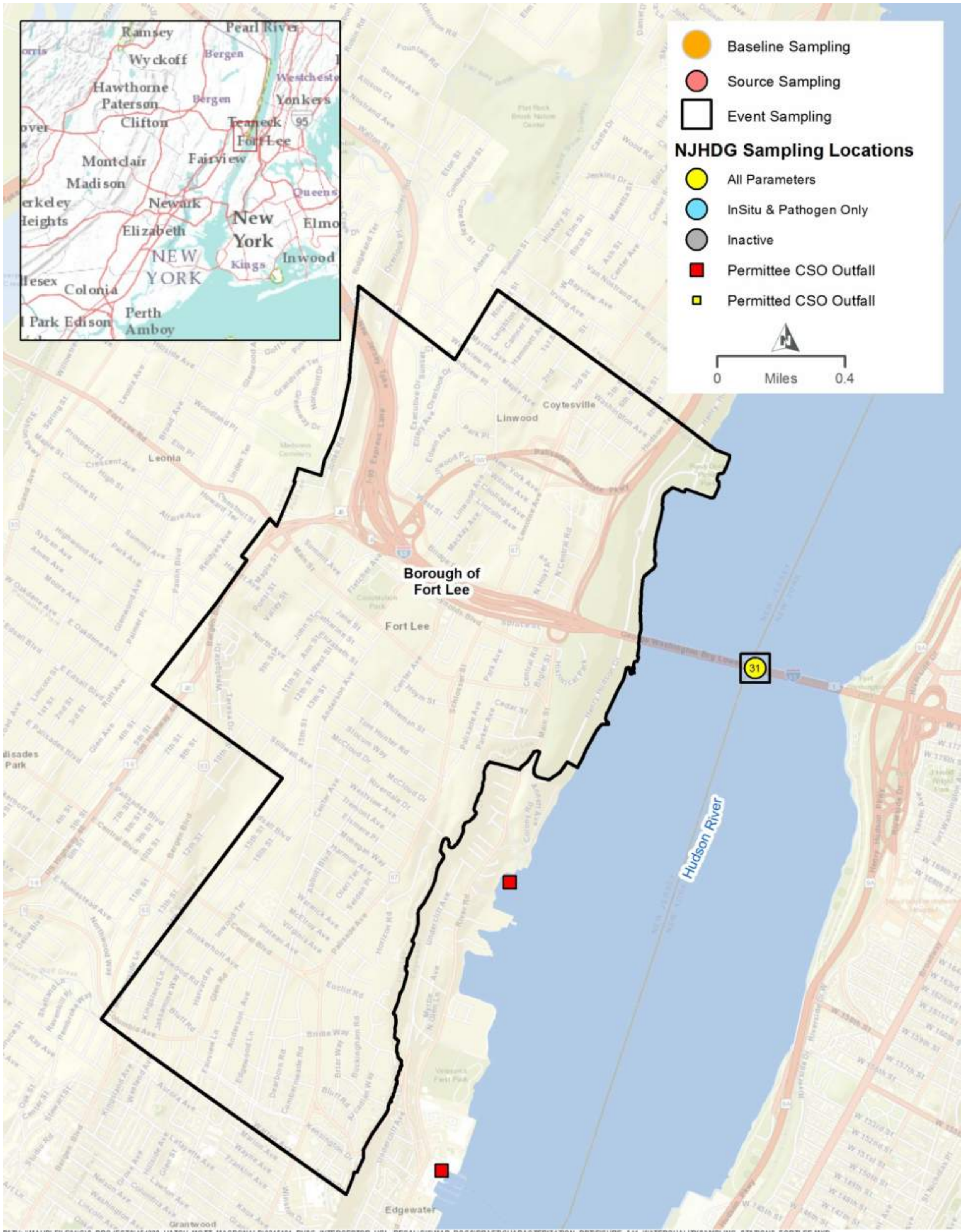

Figure 11 – Borough of Fort Lee (BCUA)

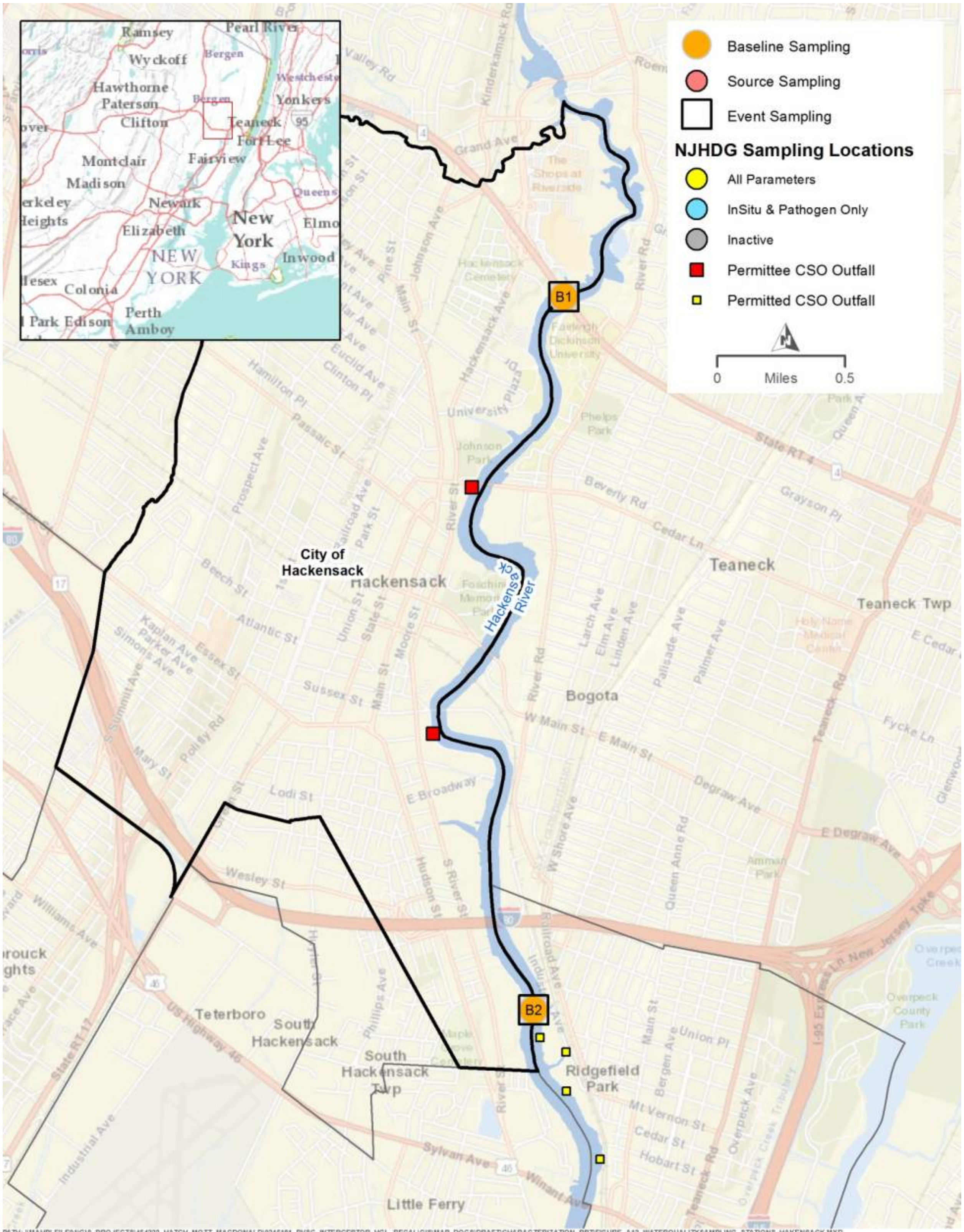

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Figure 12 – City of Hackensack (BCUA)

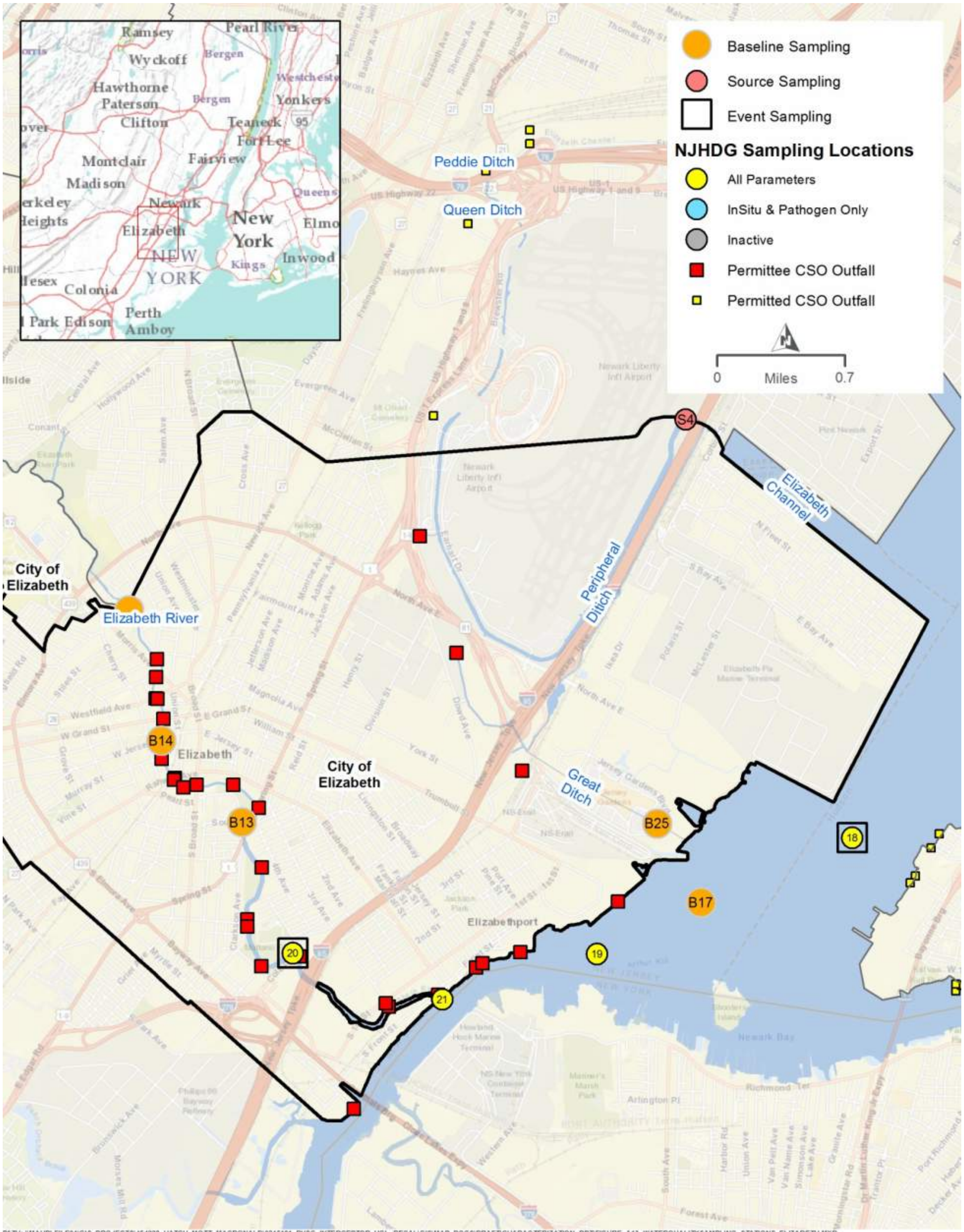


Figure 13 – City of Elizabeth (JMEUC)

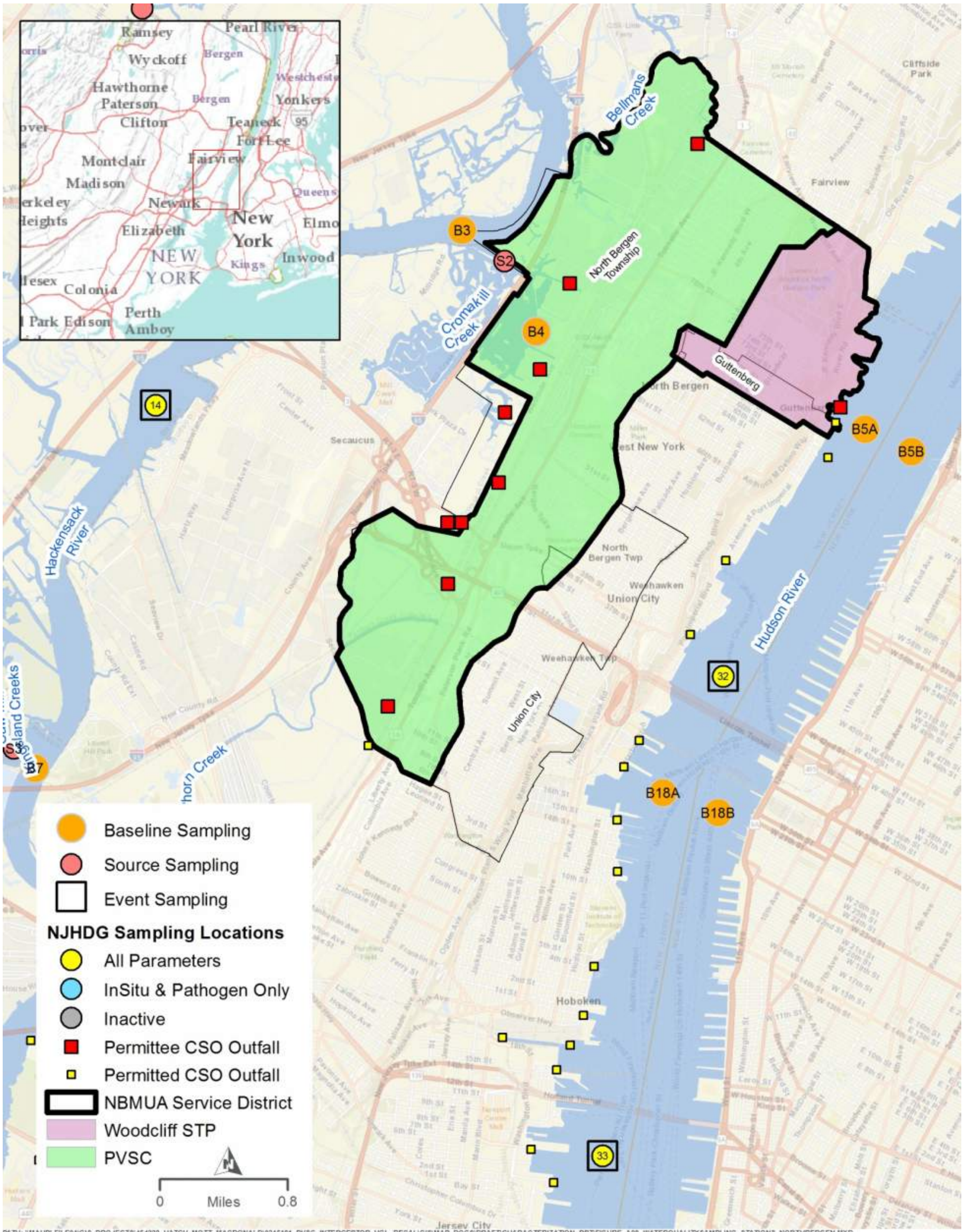


Figure 14 – North Bergen Woodcliff (NBMUA)

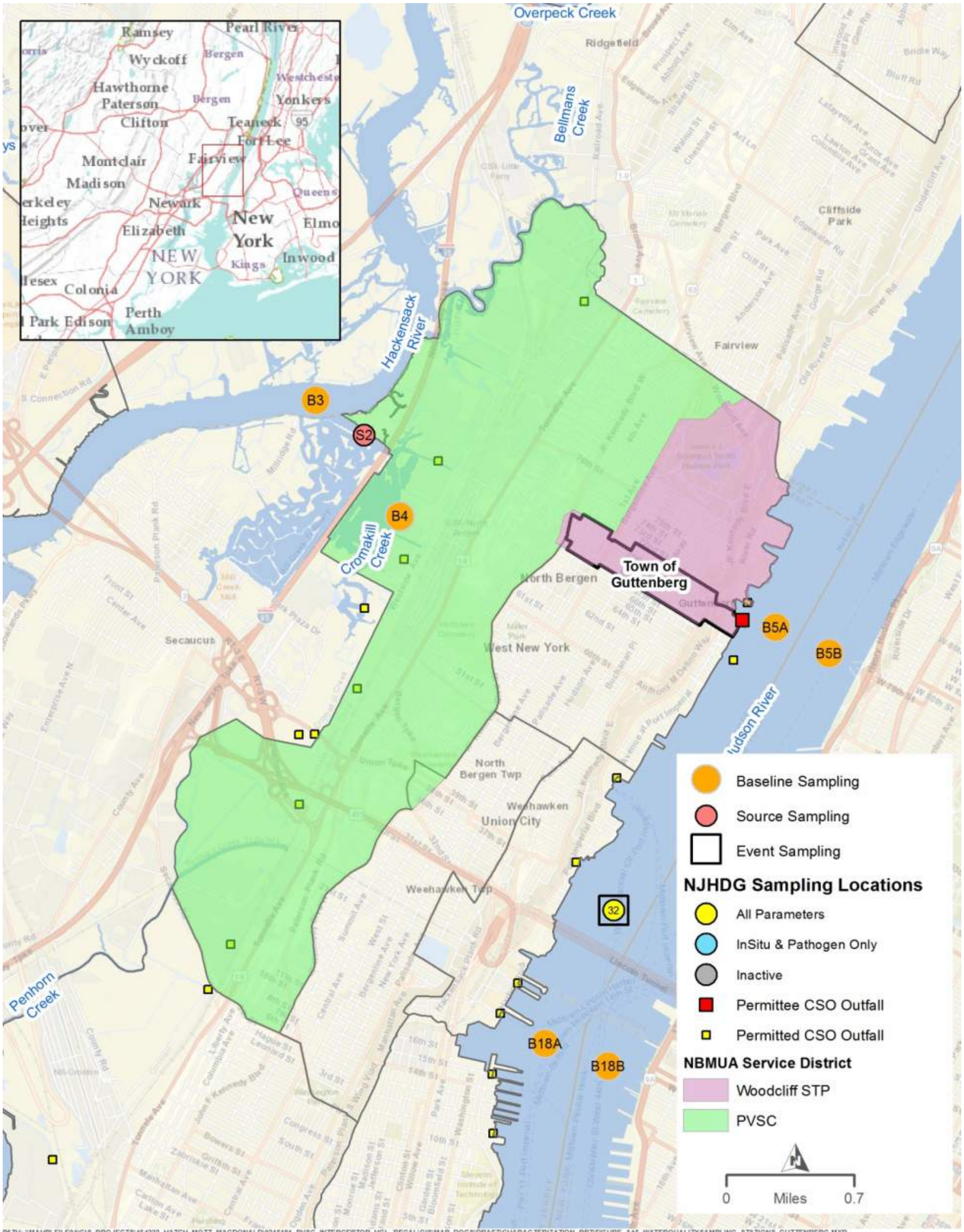


Figure 15 – Town of Guttenberg (NBMUA)

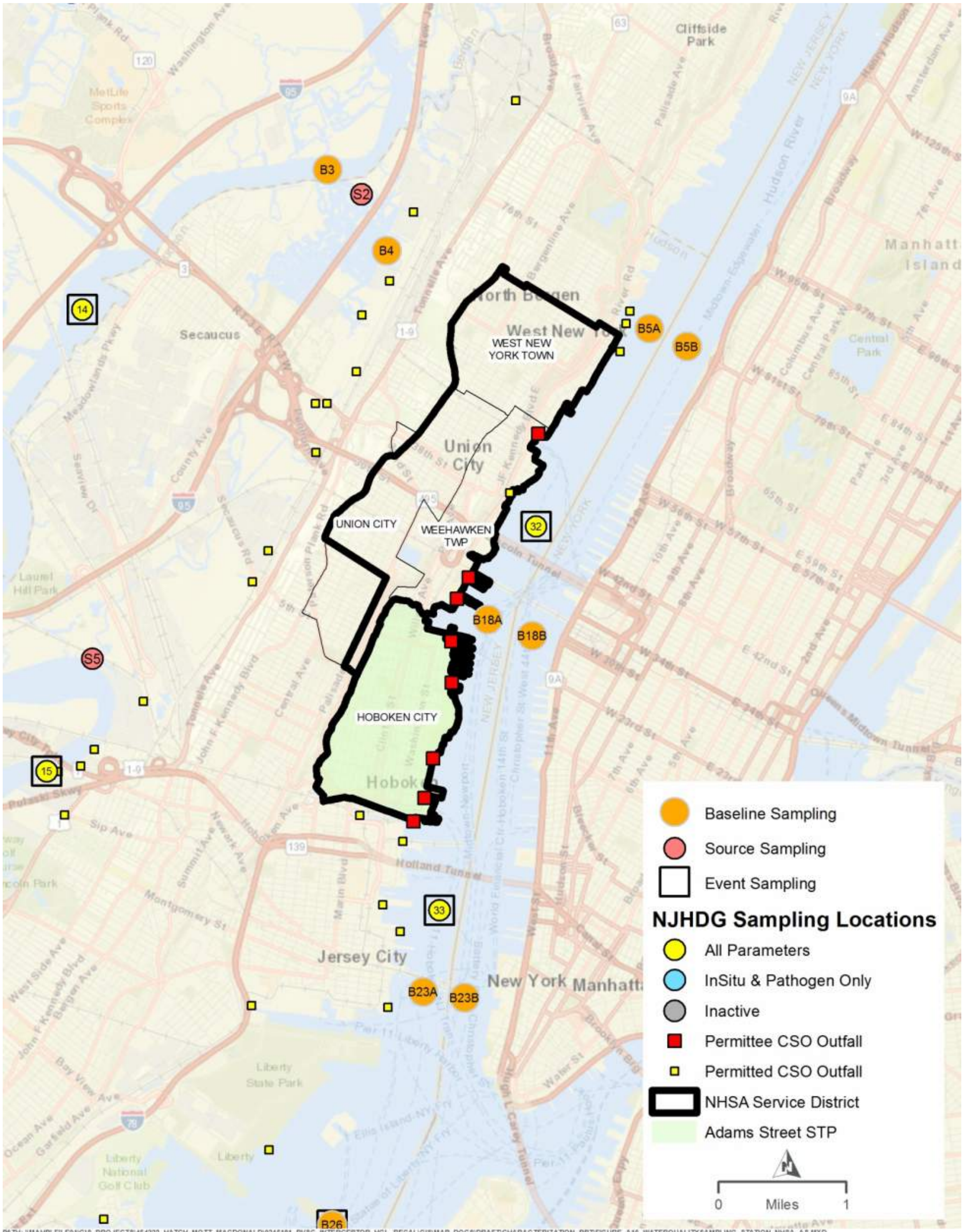


Figure 16 – Adams Street (NHSA)

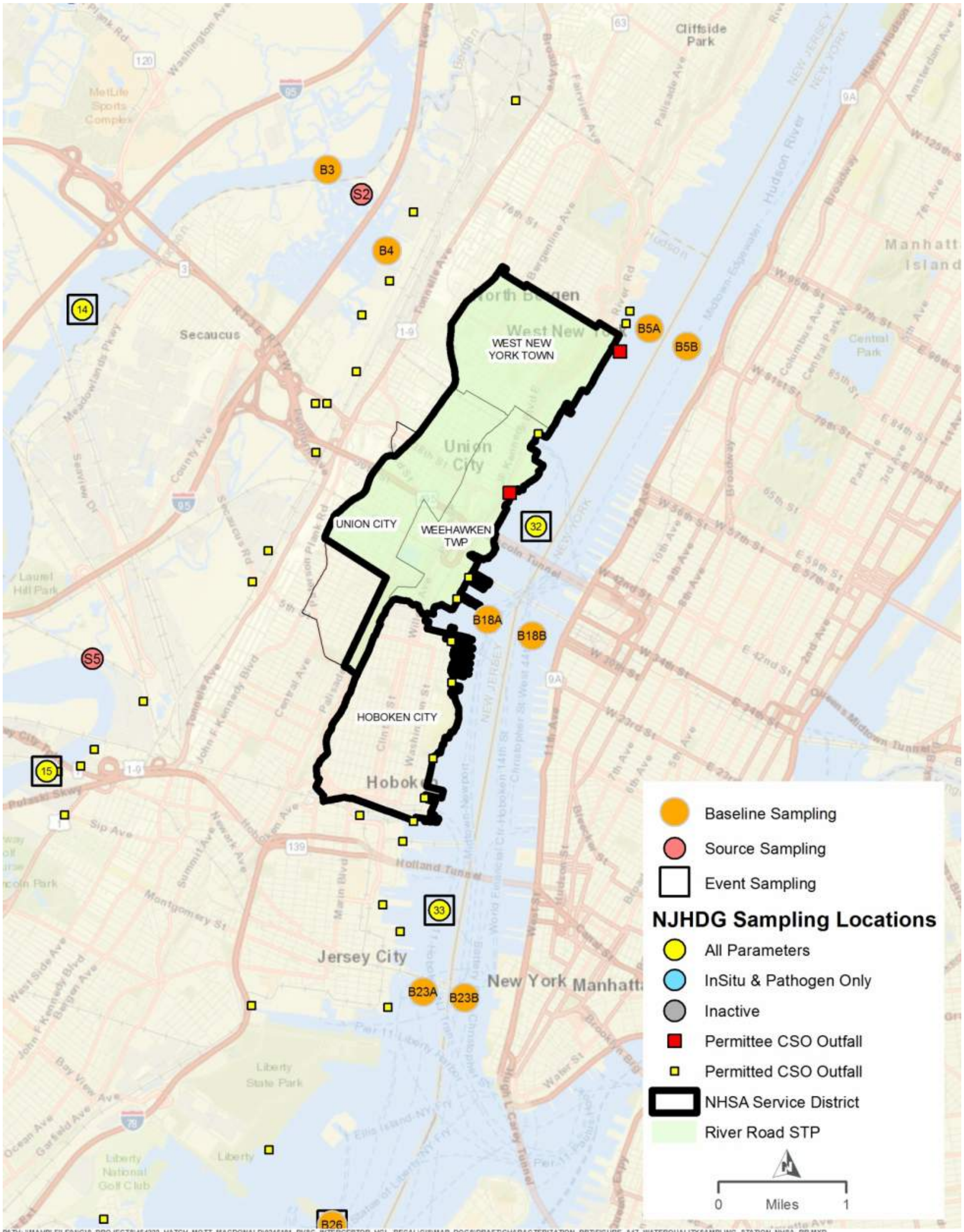


Figure 17 – River Road (NHSA)

Figure 18 – Perth Amboy City (MCUA)

ATTACHMENT 2 – RECEIVING WATER QUALITY DATA

EXPLANATION OF RECEIVING WATER QUALITY DATA PRESENTATION

Graphs of available receiving water data collected by HDR and NJHDG during April 2016 through March April 2017 and NJHDG data collected between March 2016 and December 2016 are presented here within. Note the NJHDG data is still considered preliminary. Refer to Attachment 1 figures for sampling locations. On the following figures, temperature, salinity, Secchi depth, turbidity, fecal coliform, enterococci, and E. coli are plotted by station. The pages are ordered spatially by waterbody, generally starting from the head end of a waterbody and continuing toward the mouth. Tributaries to the main waterbody are included in a manner consistent within the location of the tributary along the main waterbody. Figures are labeled with a waterbody grouping, specific waterbody name, station, and waterbody classification (see table below). Data collected during this period were not collected frequently enough to assess attainment of geometric mean standards, which require five samples within a 30-day period.

Data are presented as open circles for surface data, filled gray circles for mid-depth data, and filled black circles for bottom data. Secchi depth does not fall into a specific depth category, but is plotted with filled black circles. Turbidity is shown on the same panel as Secchi depth and is presented with filled green circles. Only the Data collected by HDR under this BCMP report includes laboratory qualifiers (either as estimated or as exceeding holding times) which are presented as a “Q”. These data still meet the needs of the program and can be used in the water quality analysis. Refer to Section 3.2 for details on data qualifiers. All planned receiving water data have been collected.

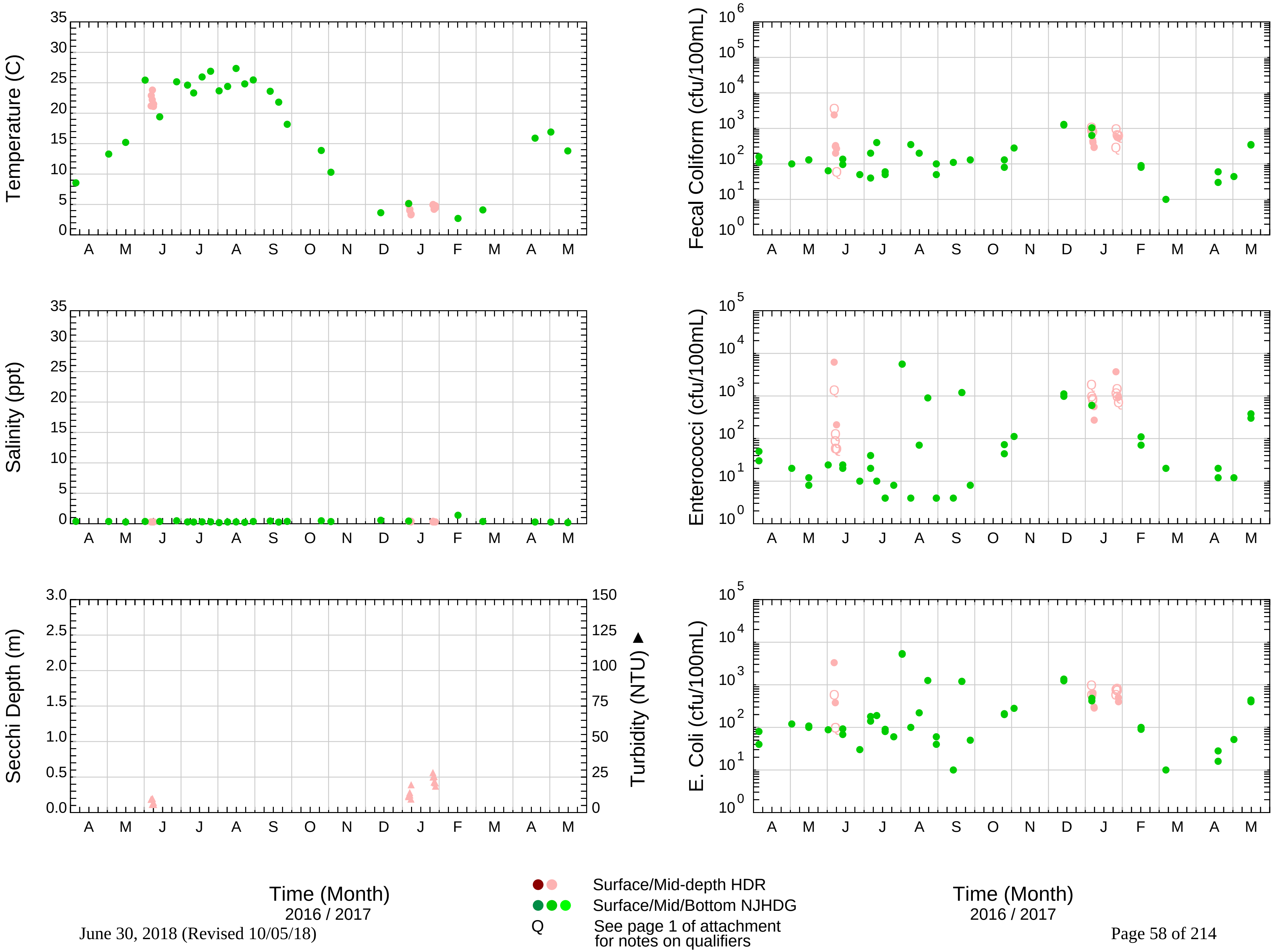
The post-collection review of the data indicates the data have met the goals of the QAPP and will be acceptable for use in baseline conditions assessment, and for use in the model calibration. Assessment of the data quality will continue through the model calibration process.

WATER QUALITY STANDARDS

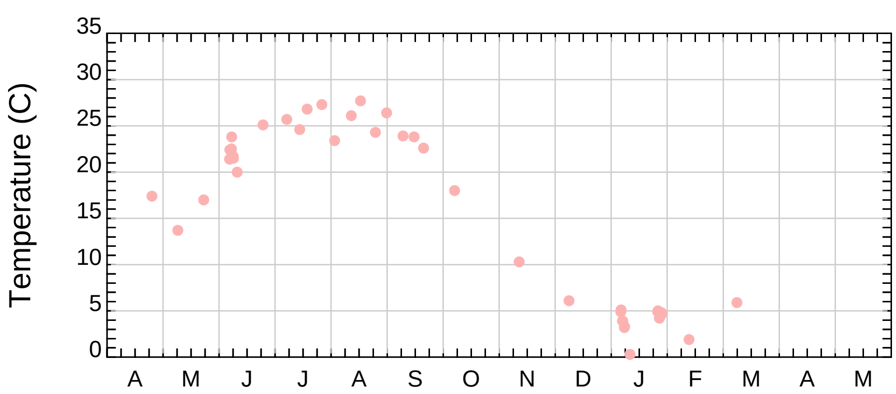
Class	Type	Bacteria Standard			Highest Protected Uses	
		Path	GM	SSM	Recreational	Other
SC	Saline	Entero	35	104	Primary	Shellfishing*
SE1	Saline	Entero	35	104	Primary	Shellfishing*
SE2	Saline	Fecal	770	na	Secondary	Diadromous fish migration
SE3	Saline	Fecal	1500	na	Secondary	Diadromous fish migration
FW2	Fresh	Ecoli	126	235	Primary	Public water supply

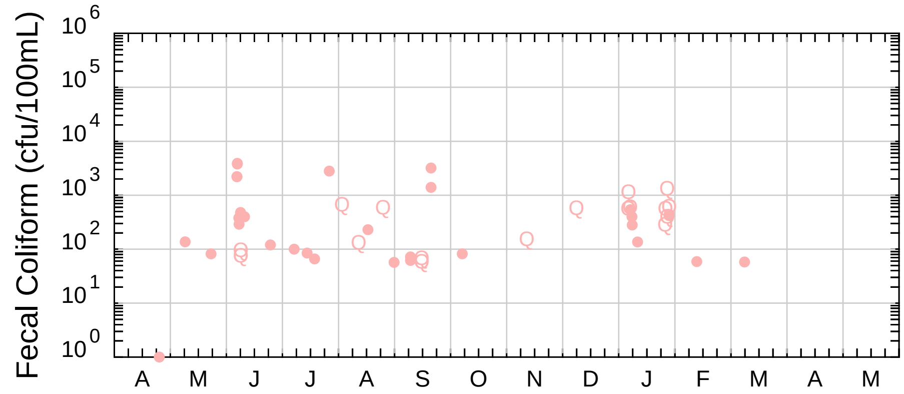
*Shellfish Waters are subject to the National Shellfish Sanitation Program standard for approved shellfish waters

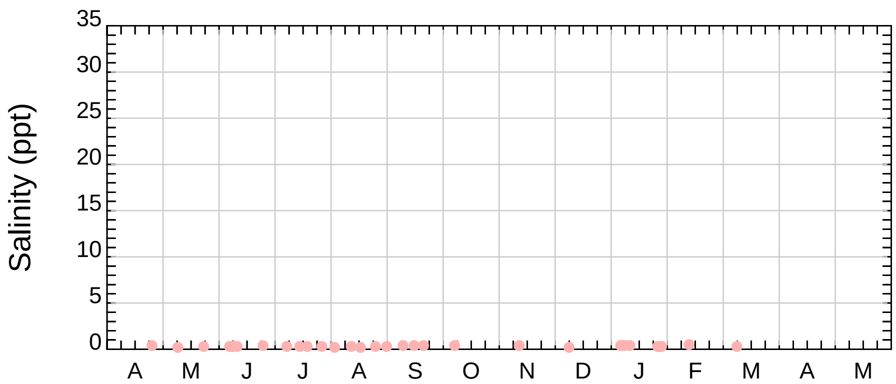
Passaic River & Tributaries, Passaic River, 1, (FW2)

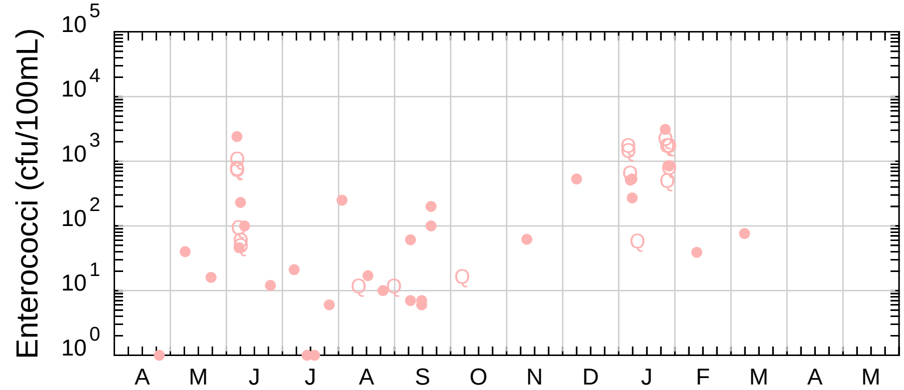


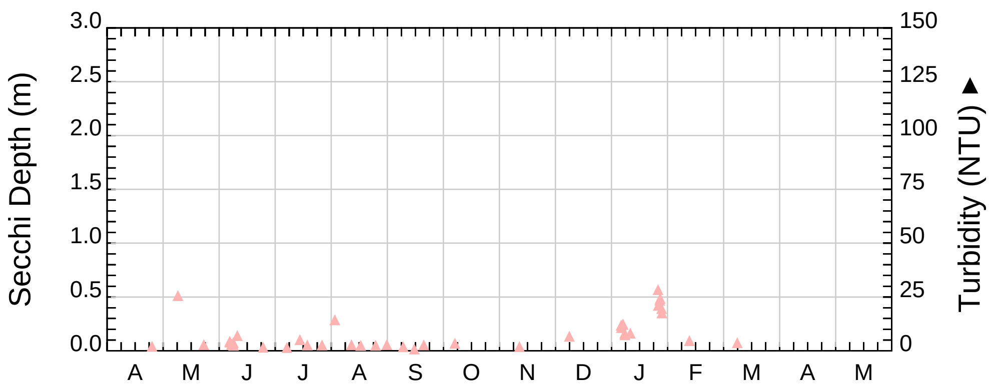
Passaic River & Tributaries, Passaic River, B24, (FW2)

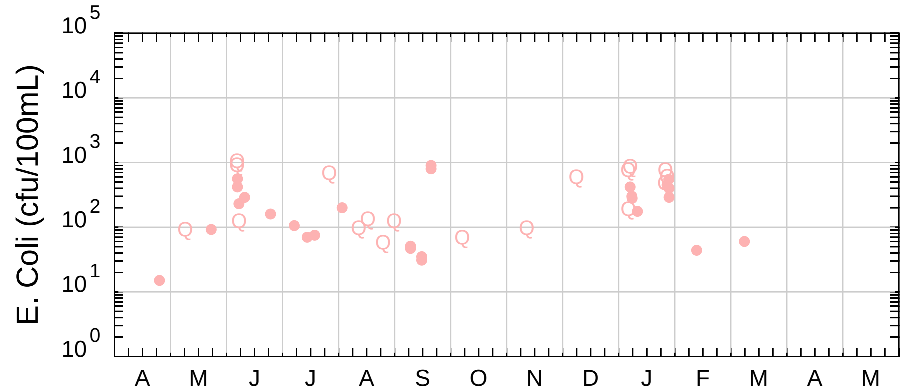










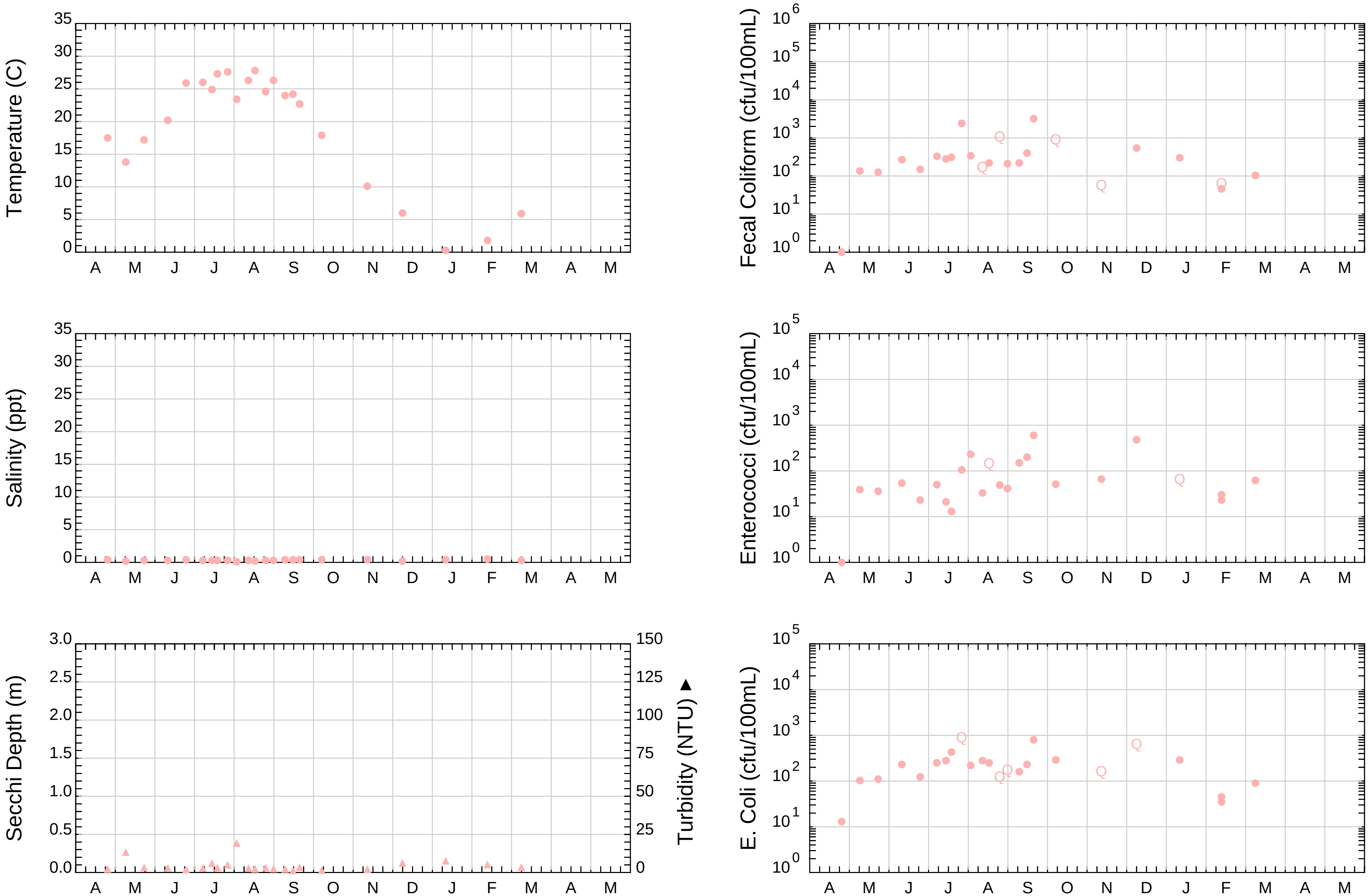


Time (Month)
2016 / 2017

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

Passaic River & Tributaries, Passaic River, 2, (FW2)

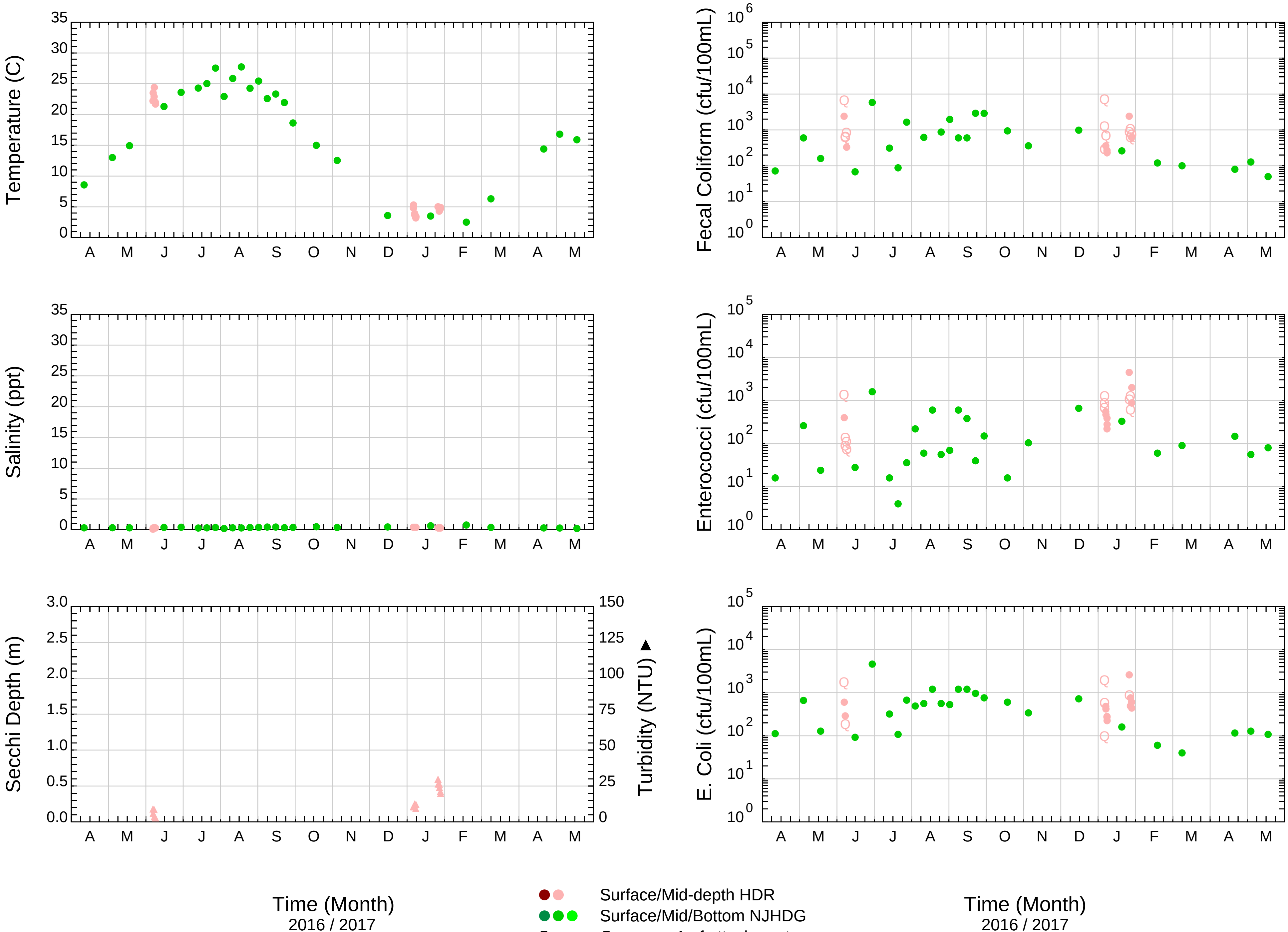


Time (Month)
2016 / 2017

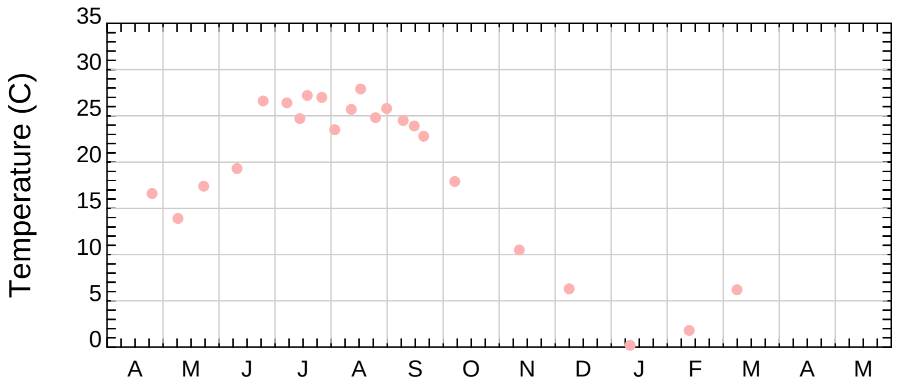
Time (Month)
2016 / 2017

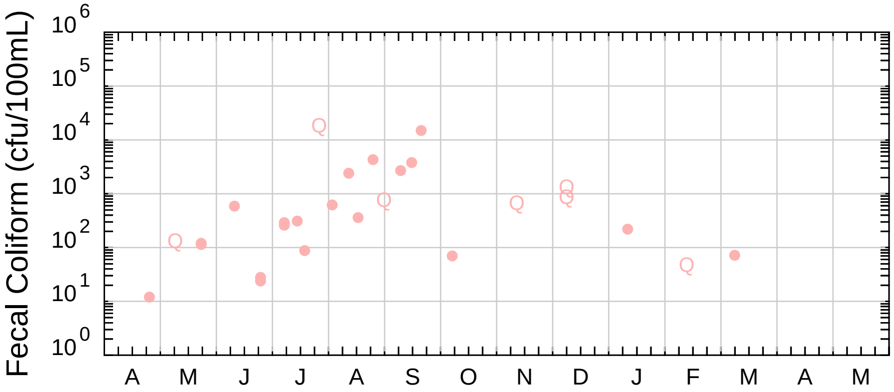
●● Surface/Mid-depth HDR
●●● Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

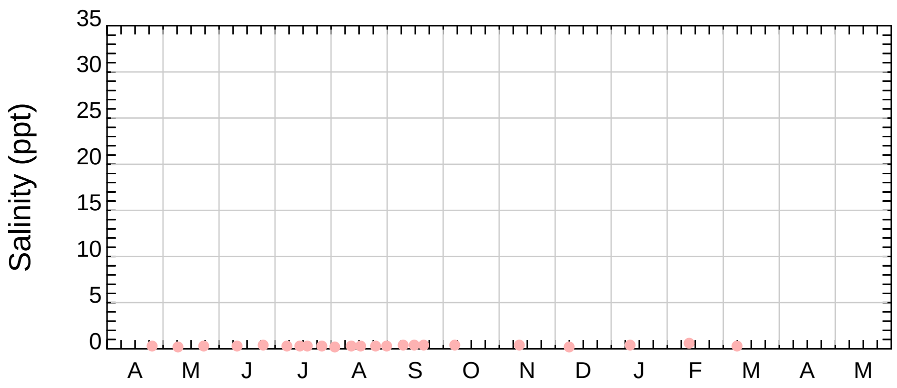
Passaic River & Tributaries, Passaic River, 3, (FW2)

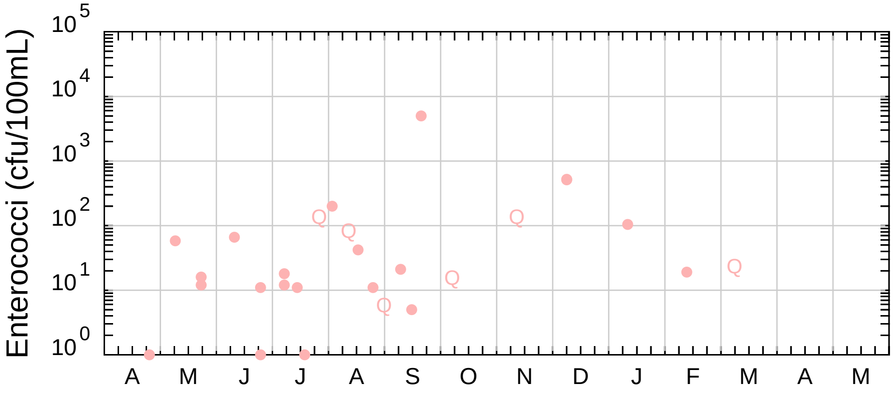


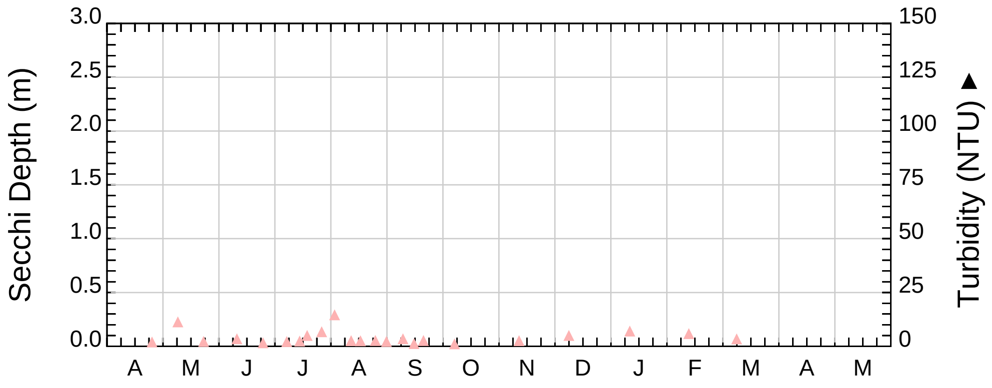
Passaic River & Tributaries, Passaic River, B22, (FW2)

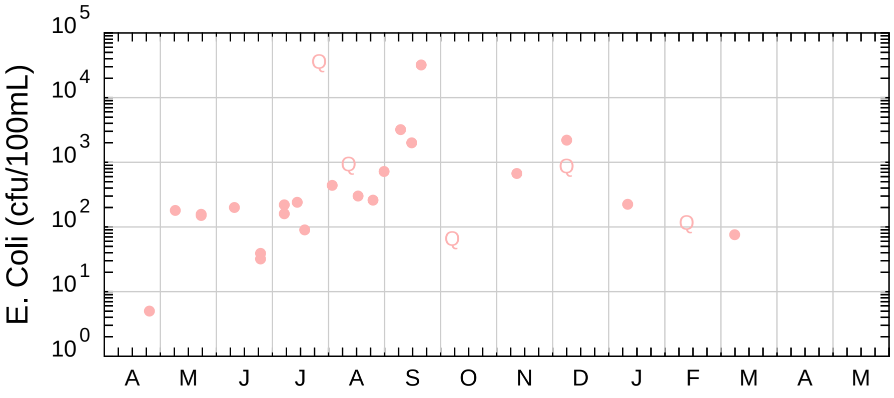








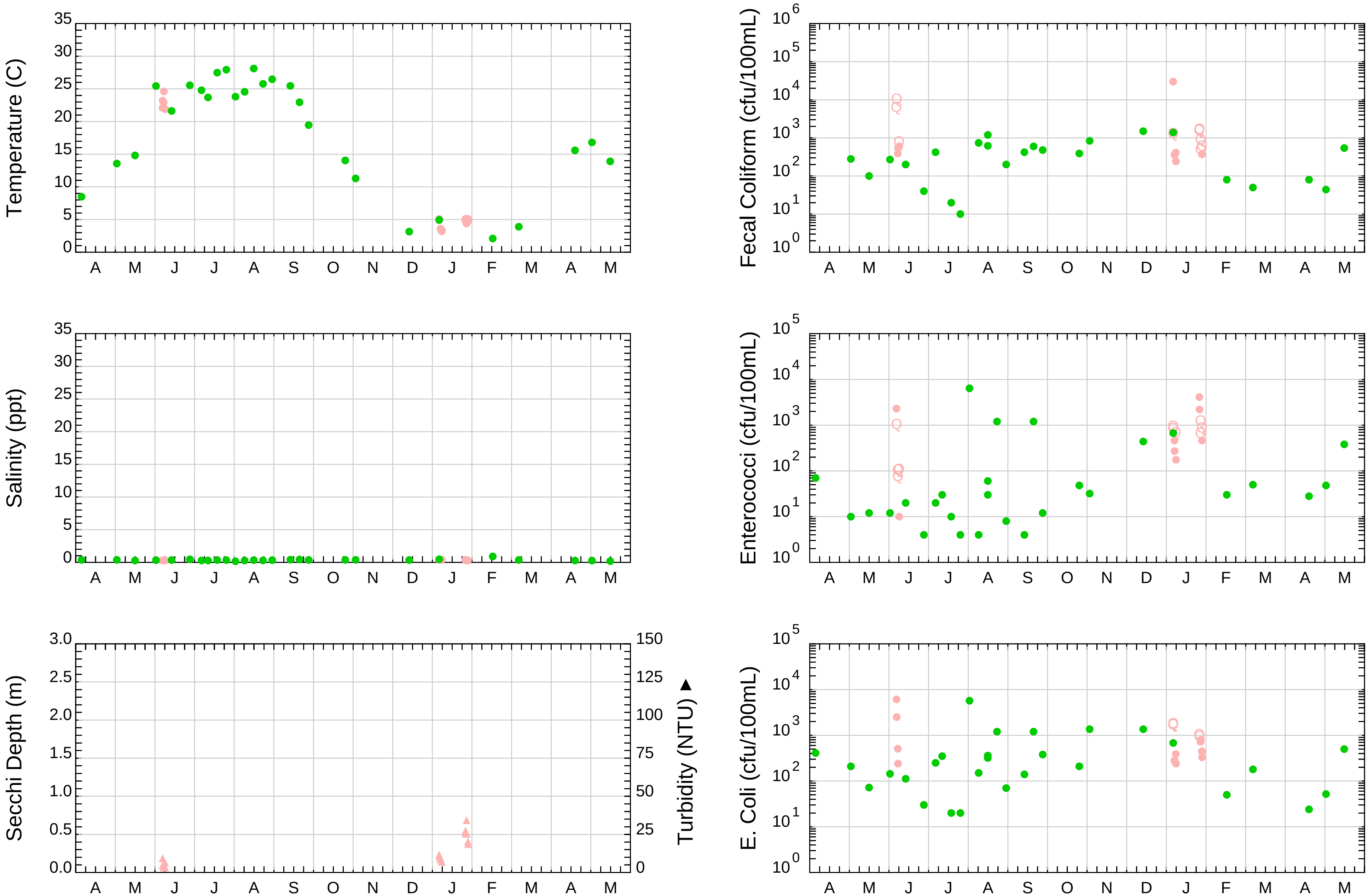




Time (Month)
2016 / 2017

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

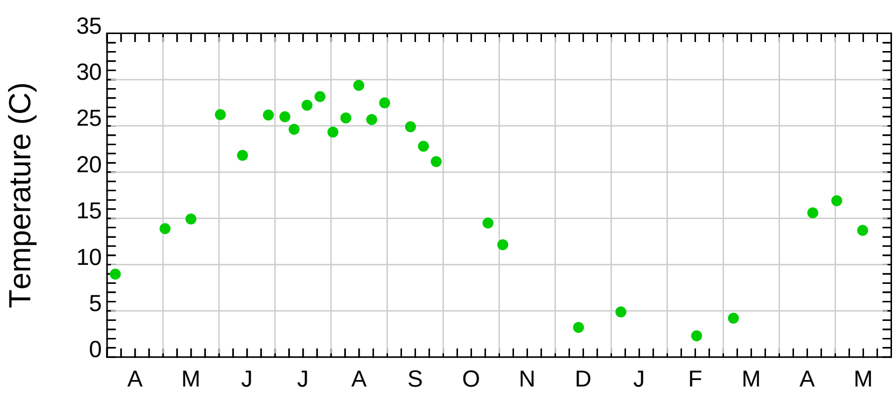


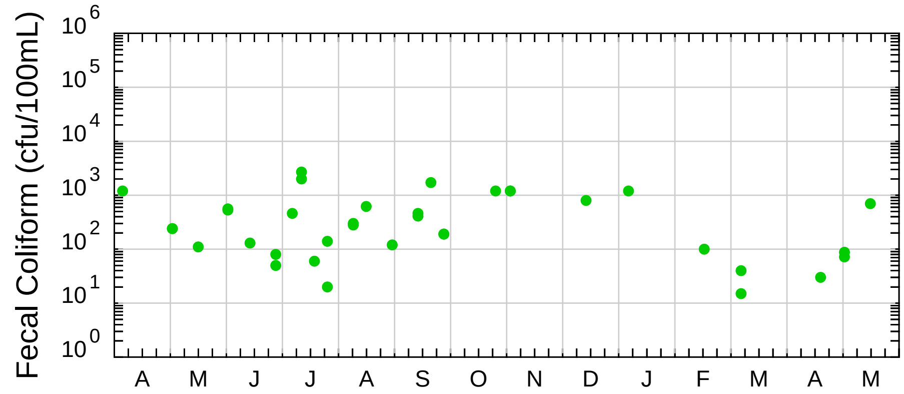
Time (Month)
2016 / 2017

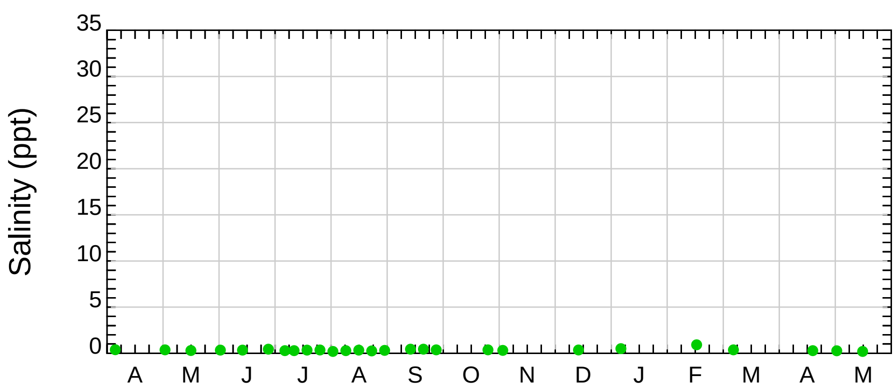
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

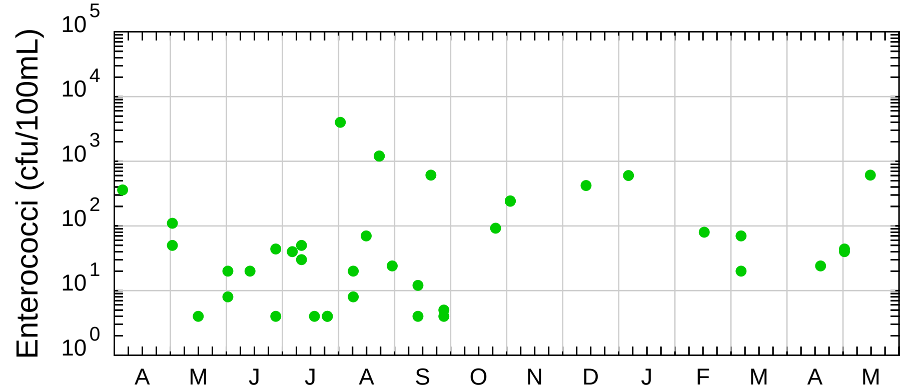
Time (Month)
2016 / 2017

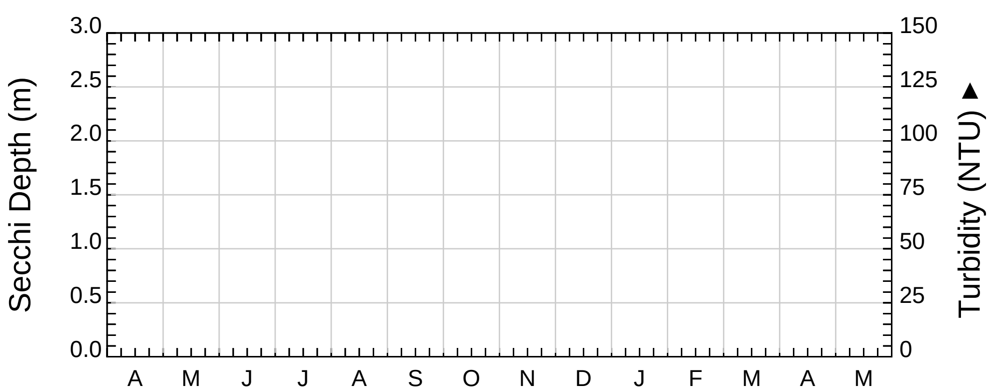
Passaic River & Tributaries, Passaic River, 5, (FW2)

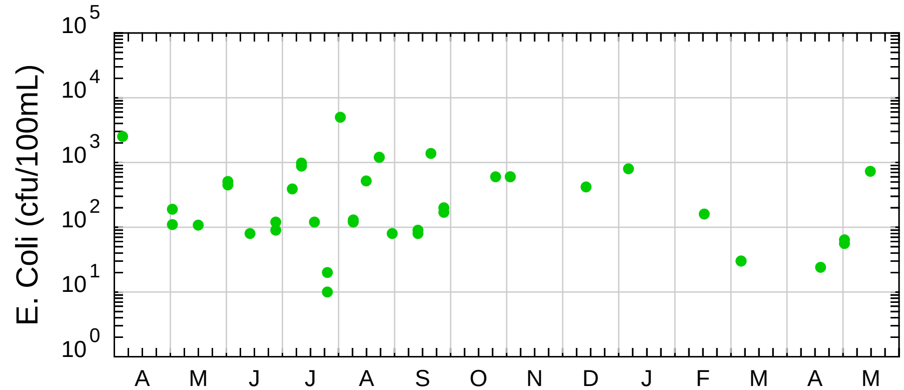










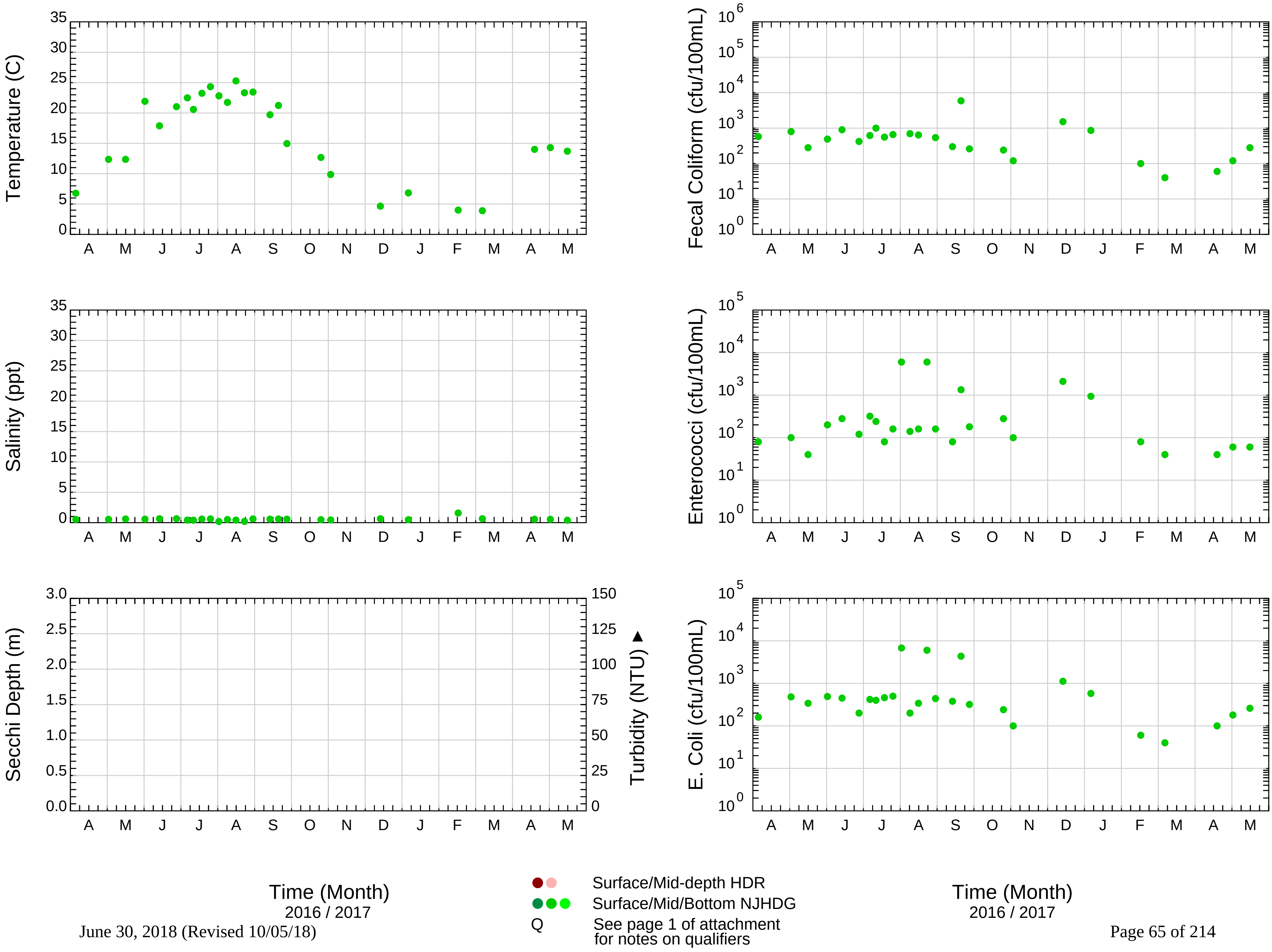


Time (Month)
2016 / 2017

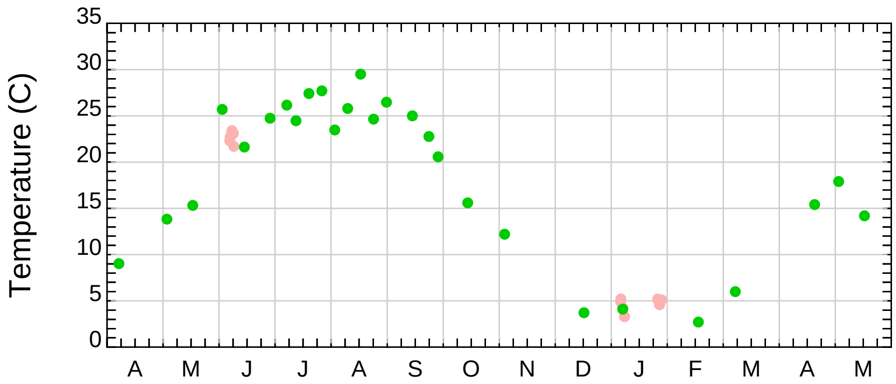
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

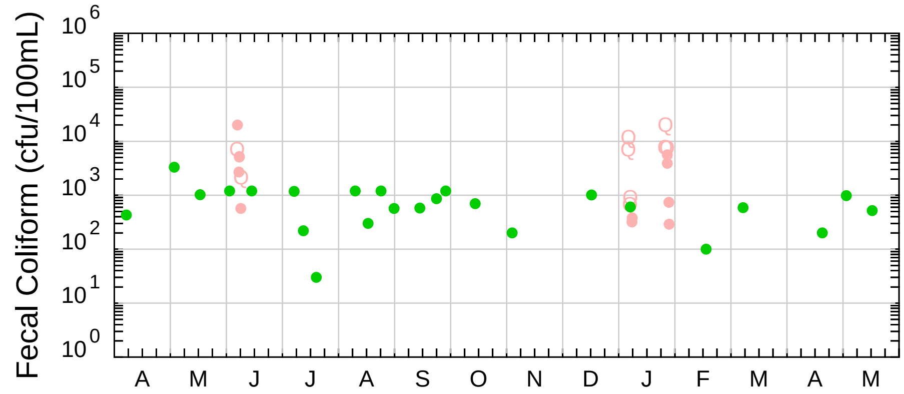
Time (Month)
2016 / 2017

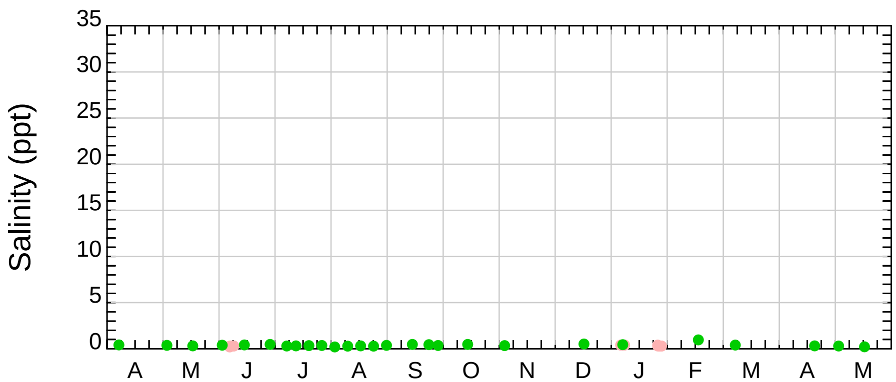
Passaic River & Tributaries, Saddle River, 6, (FW2)

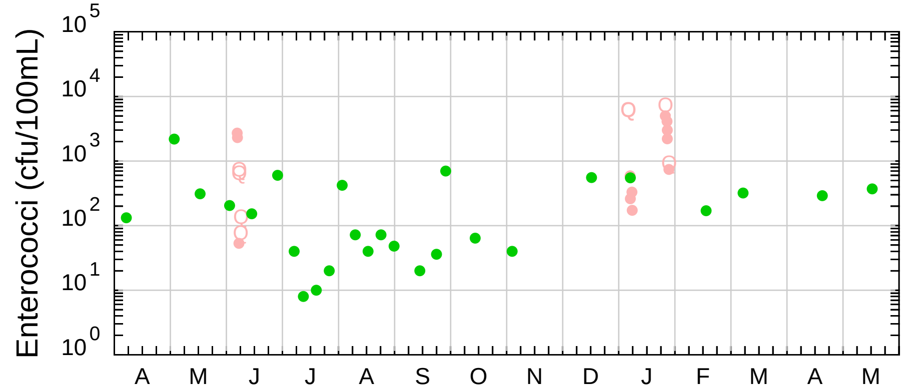


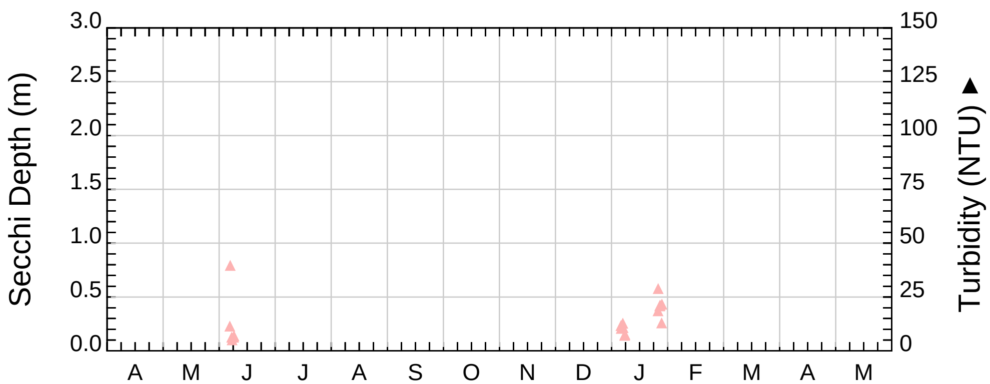
Passaic River & Tributaries, Passaic River, 7, (FW2/SE2)

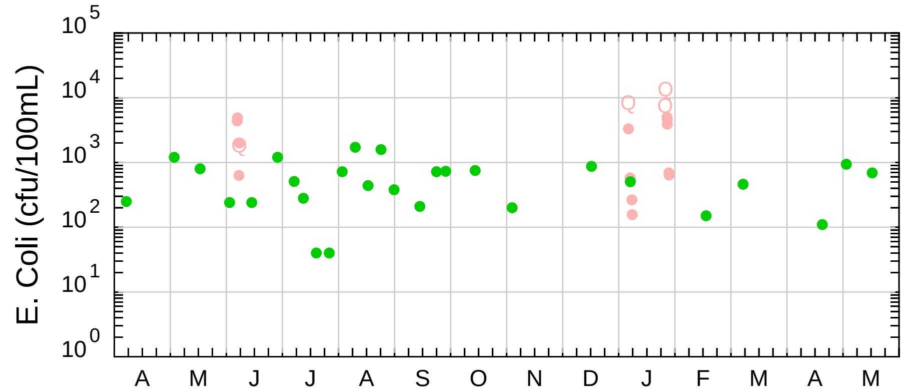










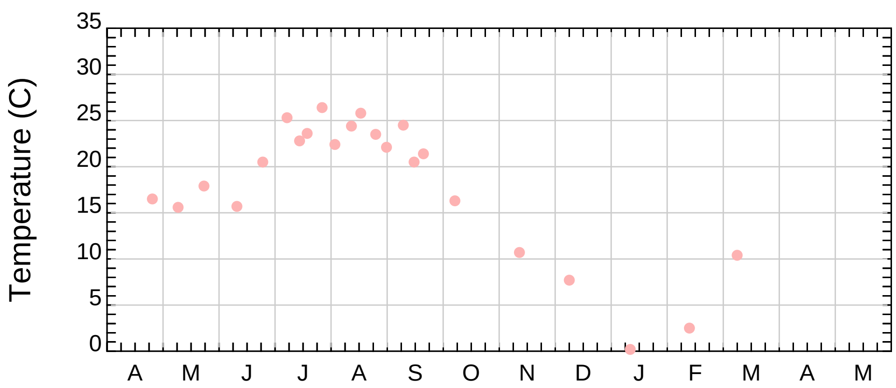


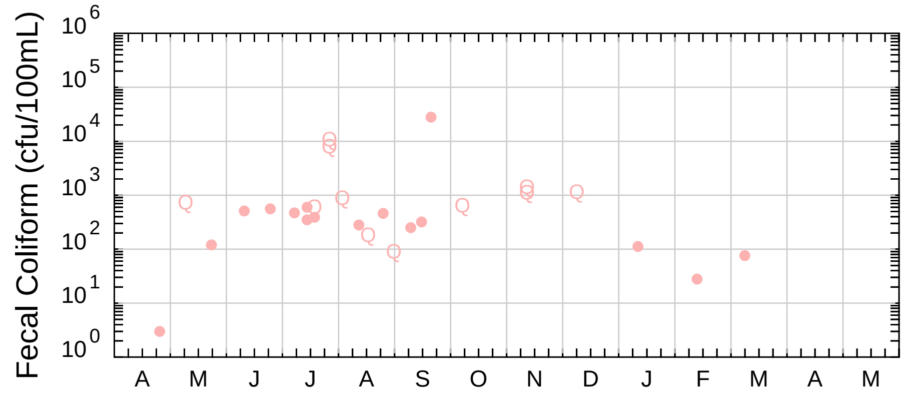
Time (Month)
2016 / 2017

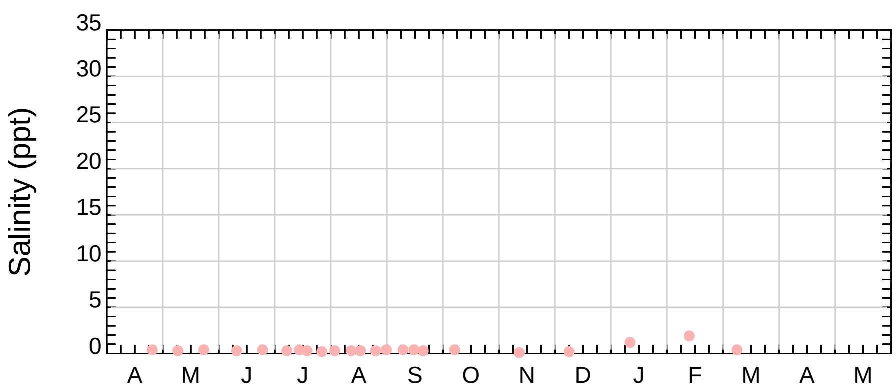
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

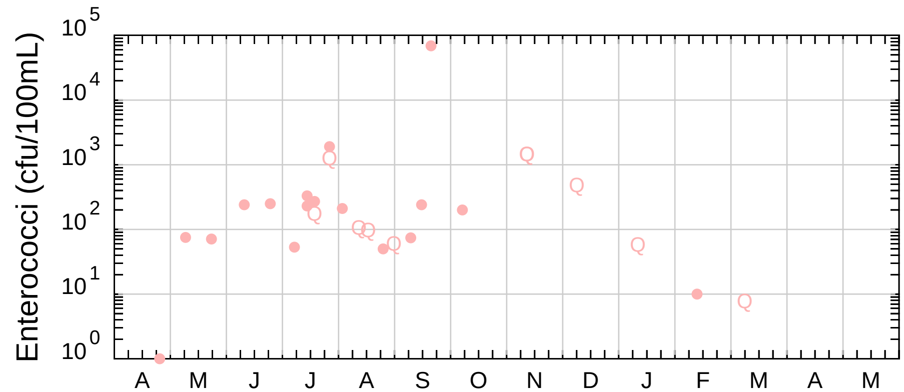
Time (Month)
2016 / 2017

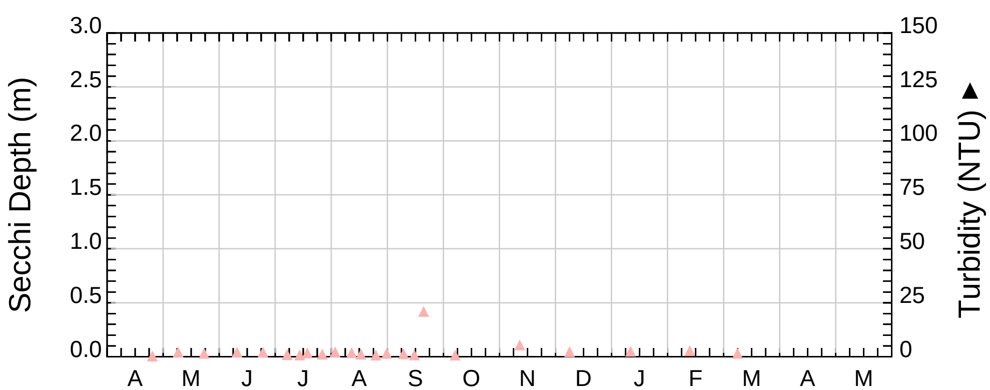
Passaic River & Tributaries, Third River, S7, (FW2/SE2)

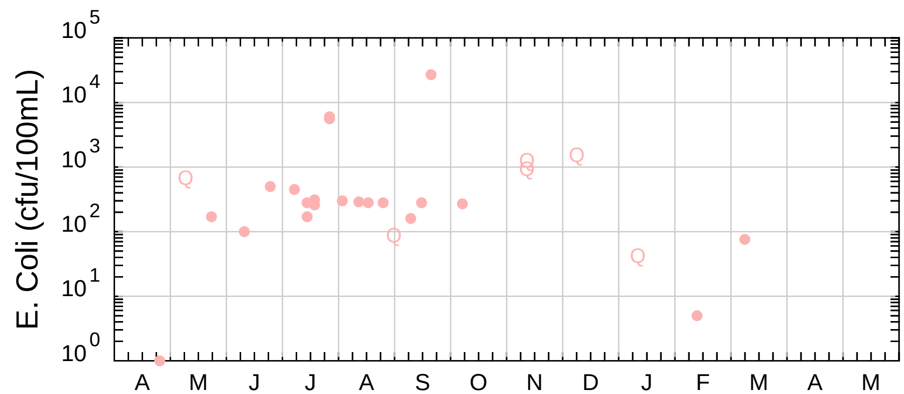










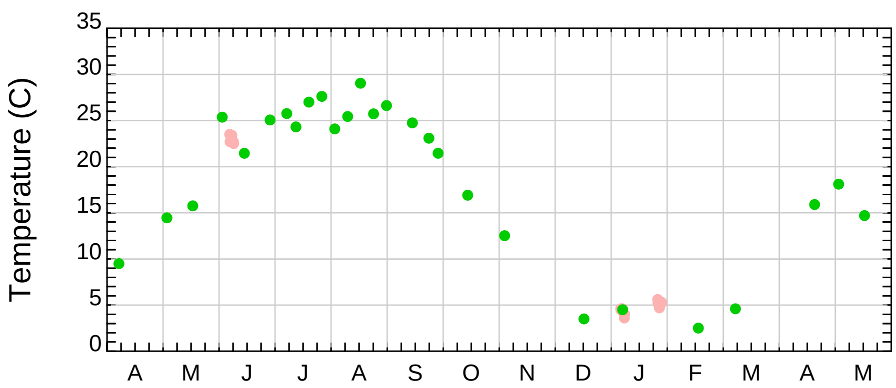


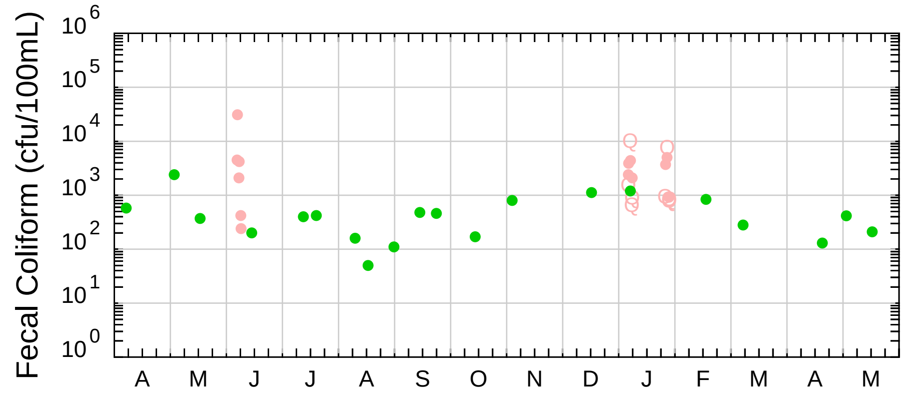
Time (Month)
2016 / 2017

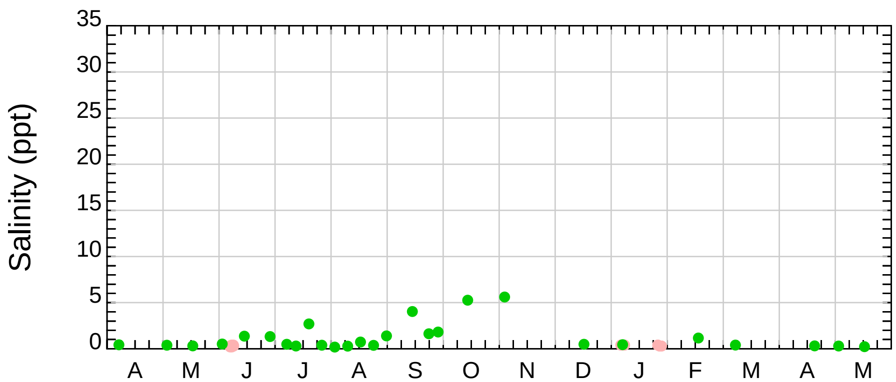
●● Surface/Mid-depth HDR
●●● Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

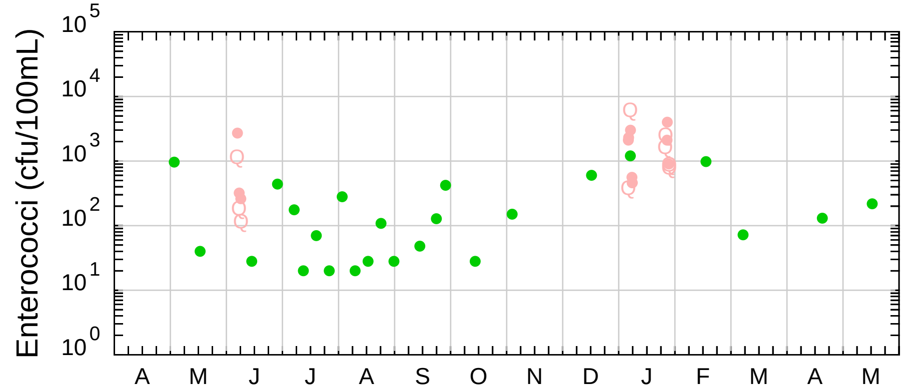
Time (Month)
2016 / 2017

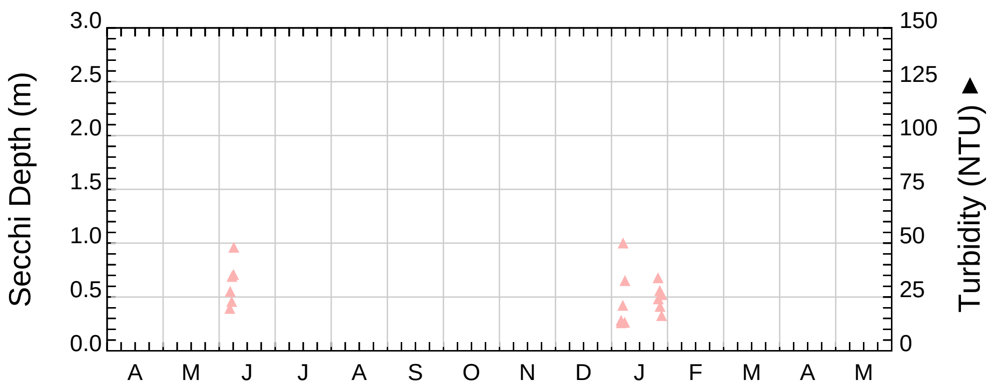
Passaic River & Tributaries, Passaic River, 8, (FW2/SE2)

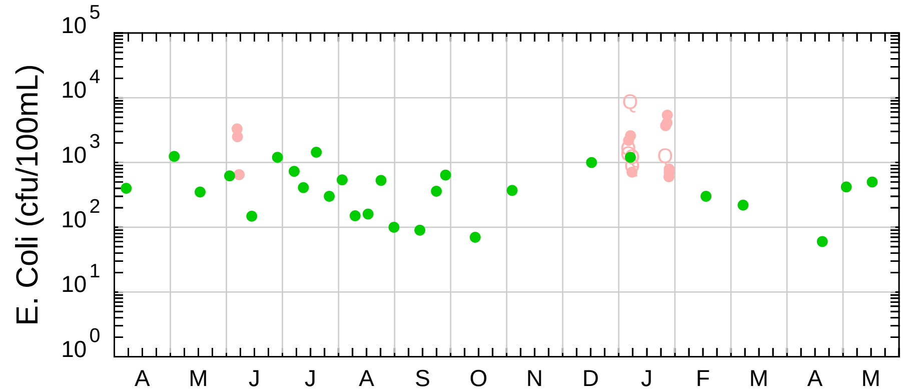










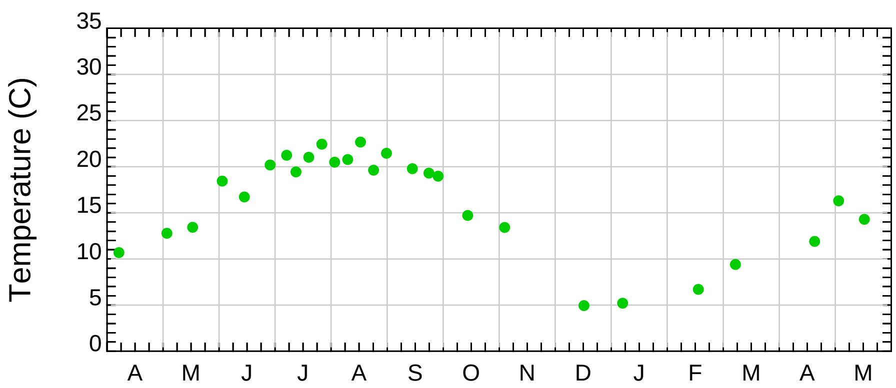


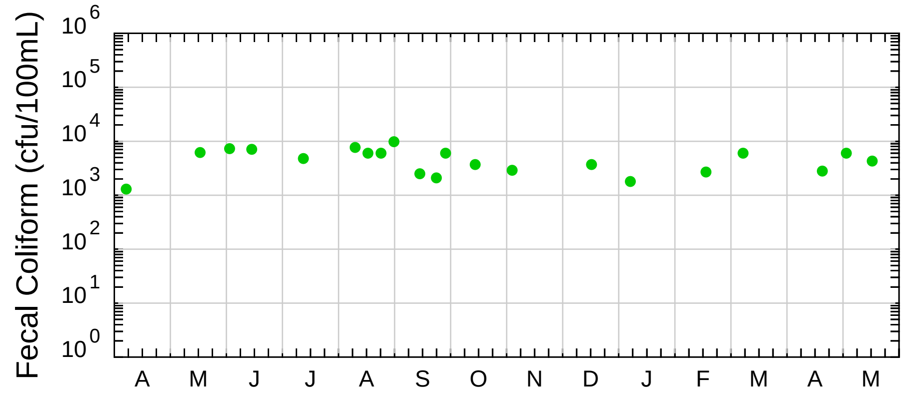
Time (Month)
2016 / 2017

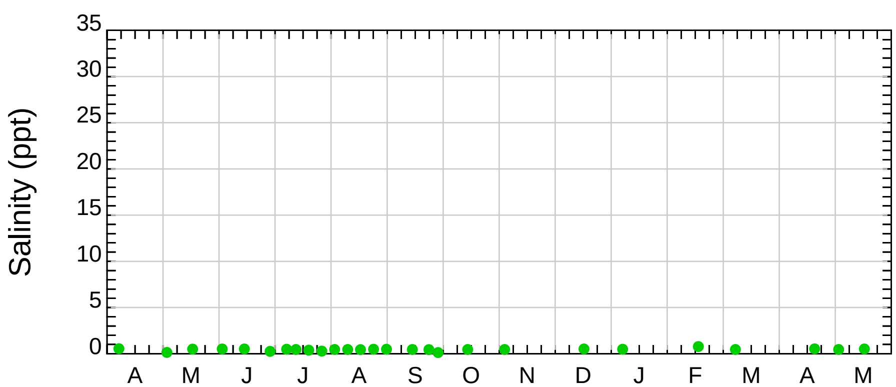
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

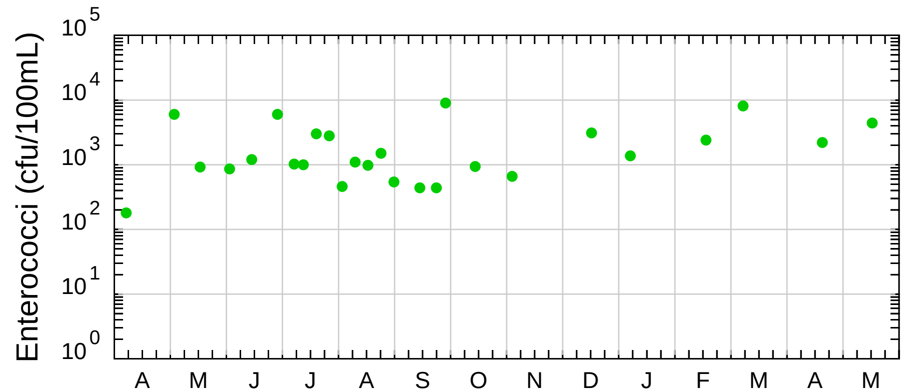
Time (Month)
2016 / 2017

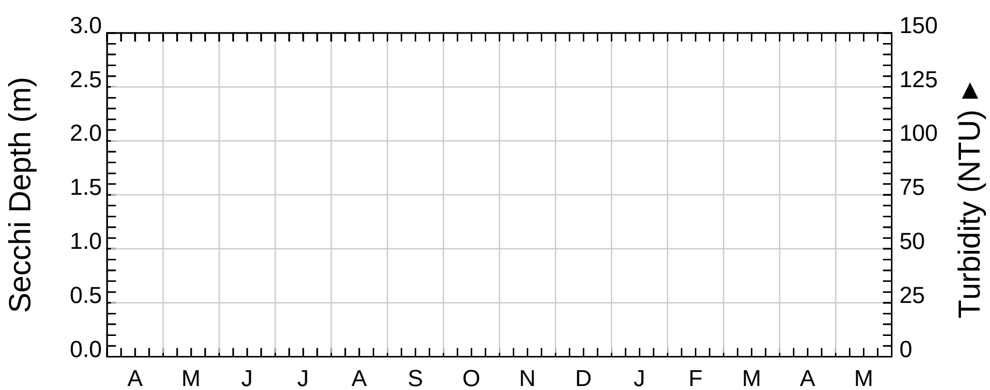
Passaic River & Tributaries, Second River, 9, (FW2)

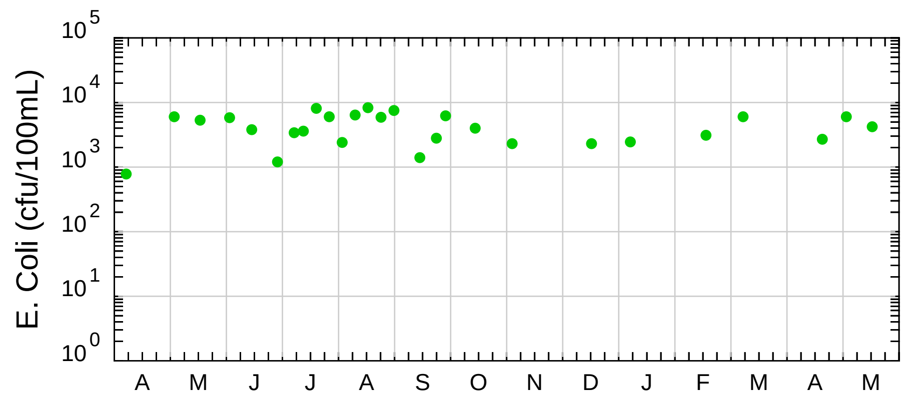










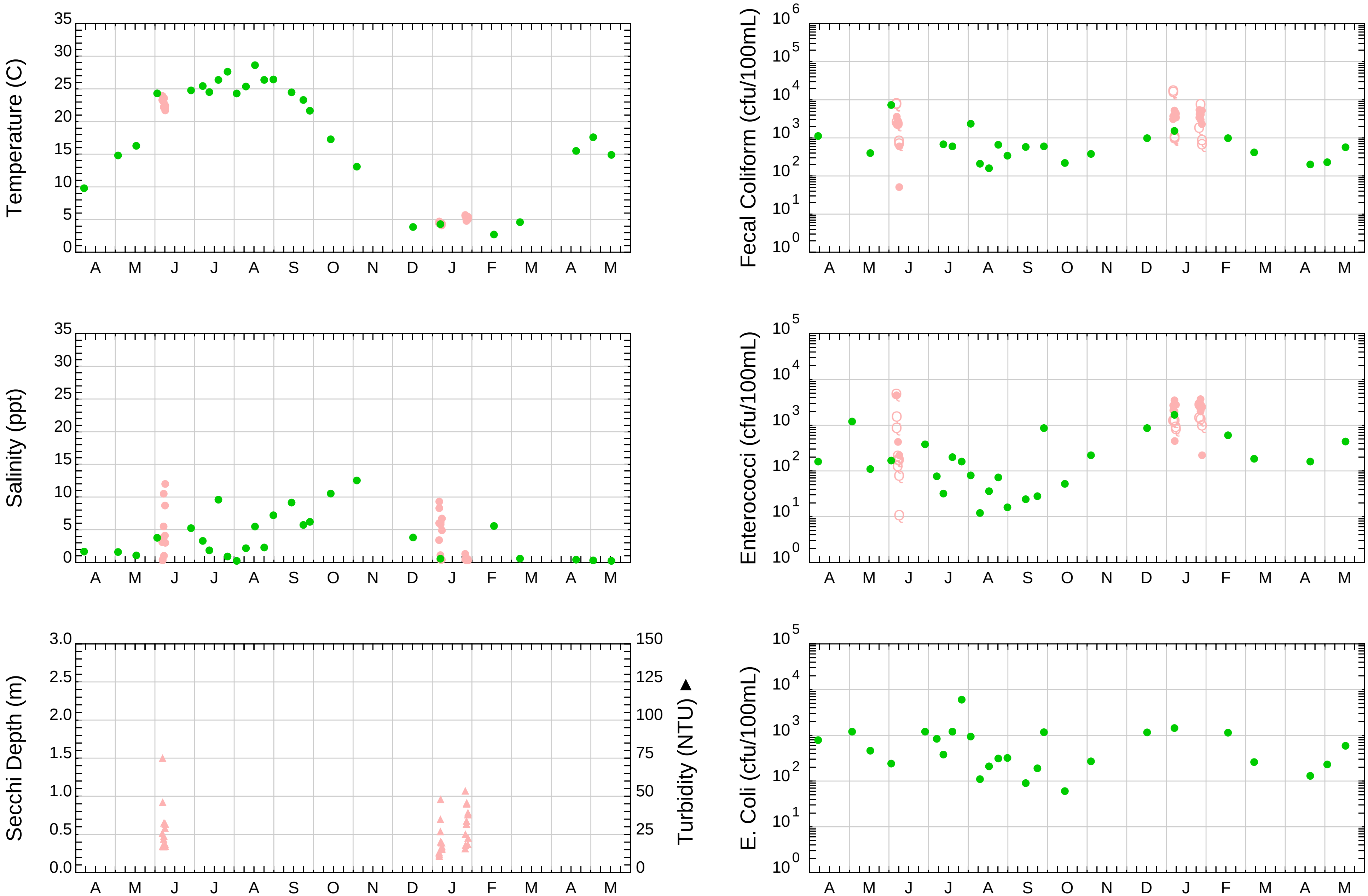


Time (Month)
2016 / 2017

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

Passaic River & Tributaries, Passaic River, 10, (SE3)



Time (Month)
2016 / 2017

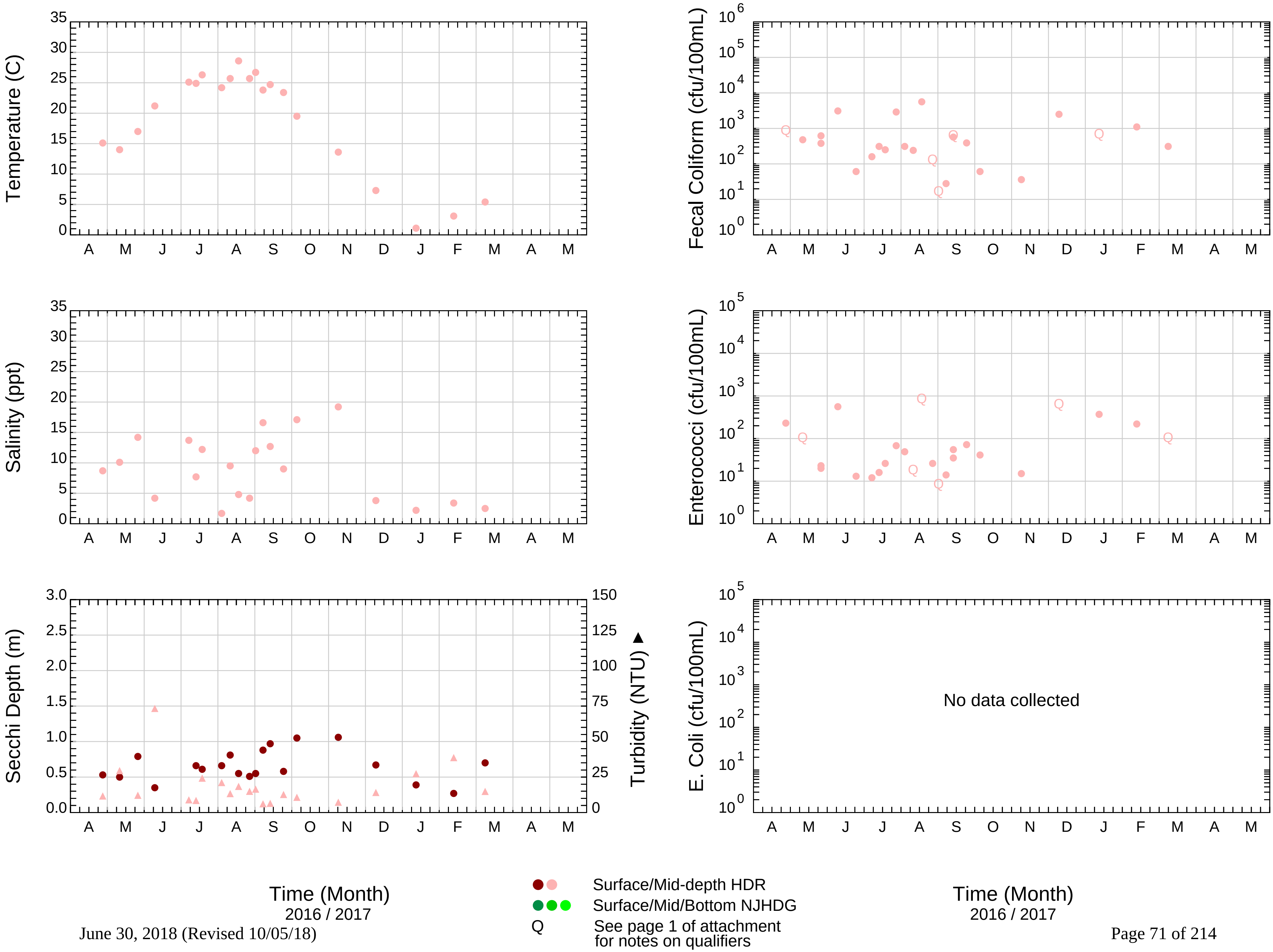
Time (Month)
2016 / 2017

Surface/Mid-depth HDR

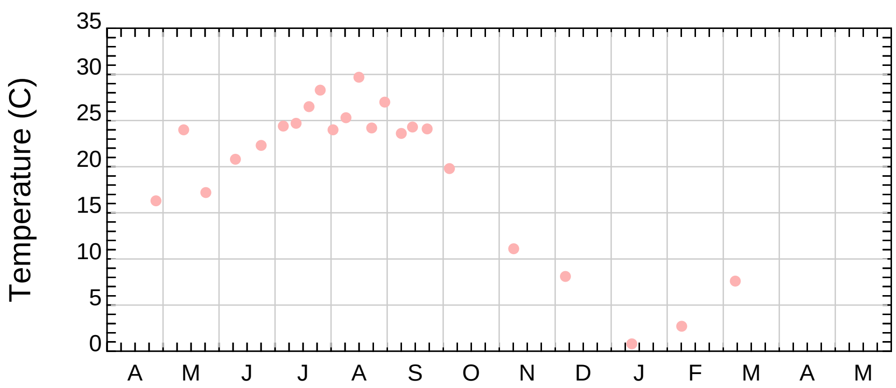
Surface/Mid/Bottom NJHDG

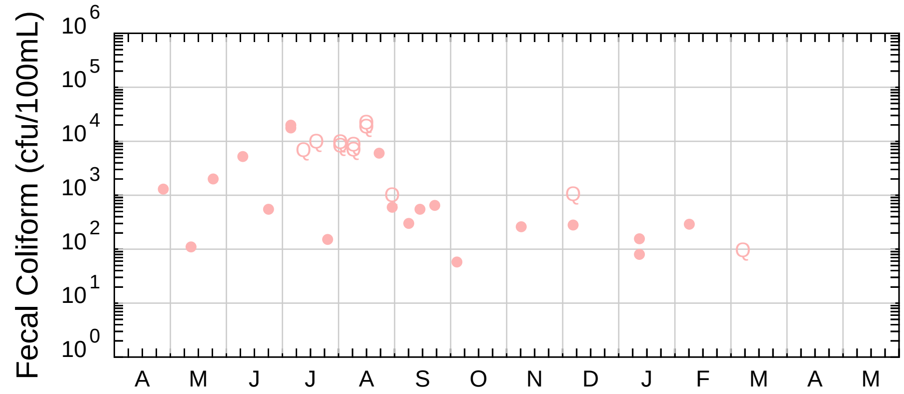
Q See page 1 of attachment for notes on qualifiers

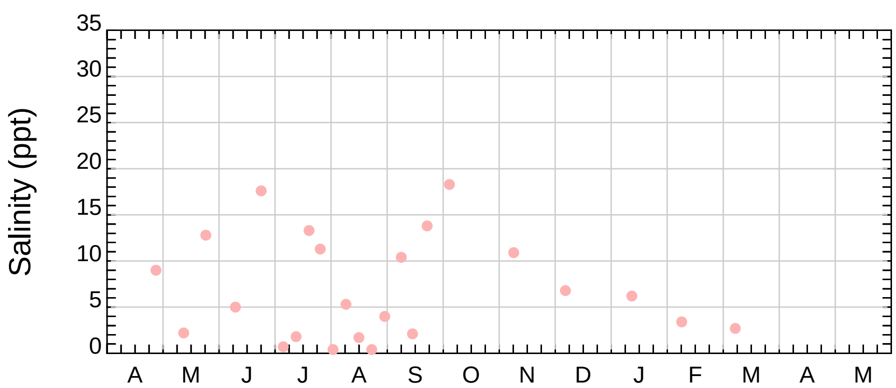
Passaic River & Tributaries, Passaic River, 11, (SE3)

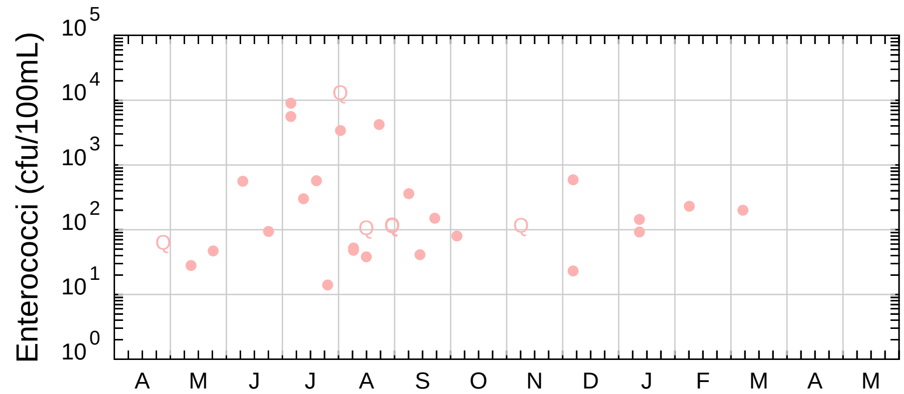


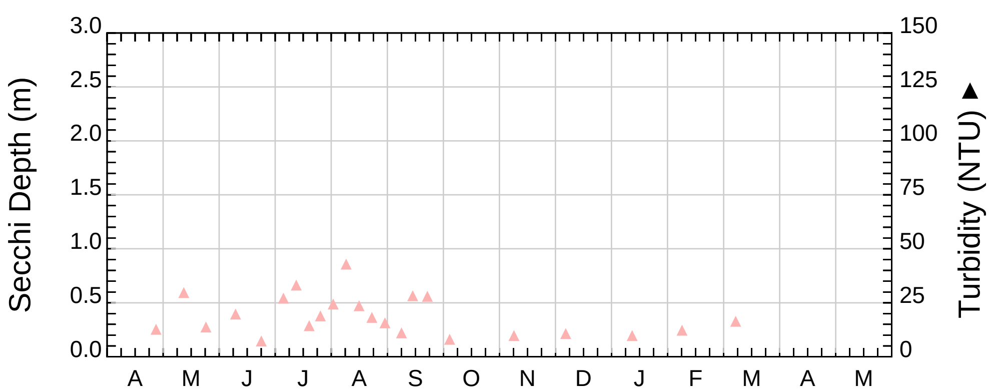
Passaic River & Tributaries, Franks Creek, B8, (SE3)

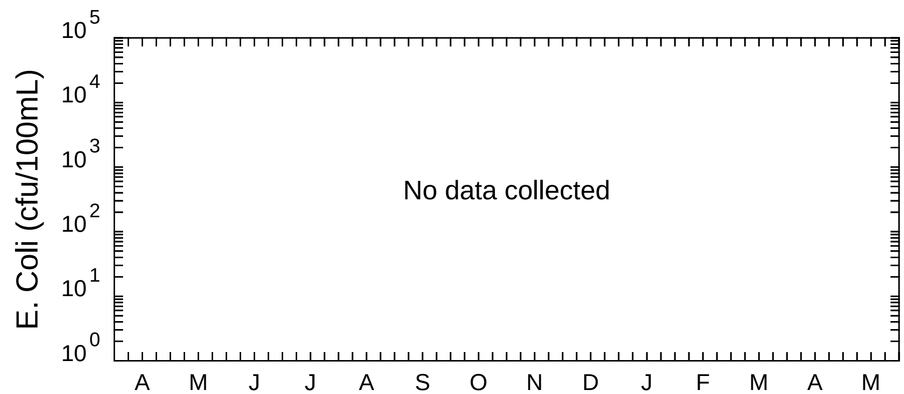










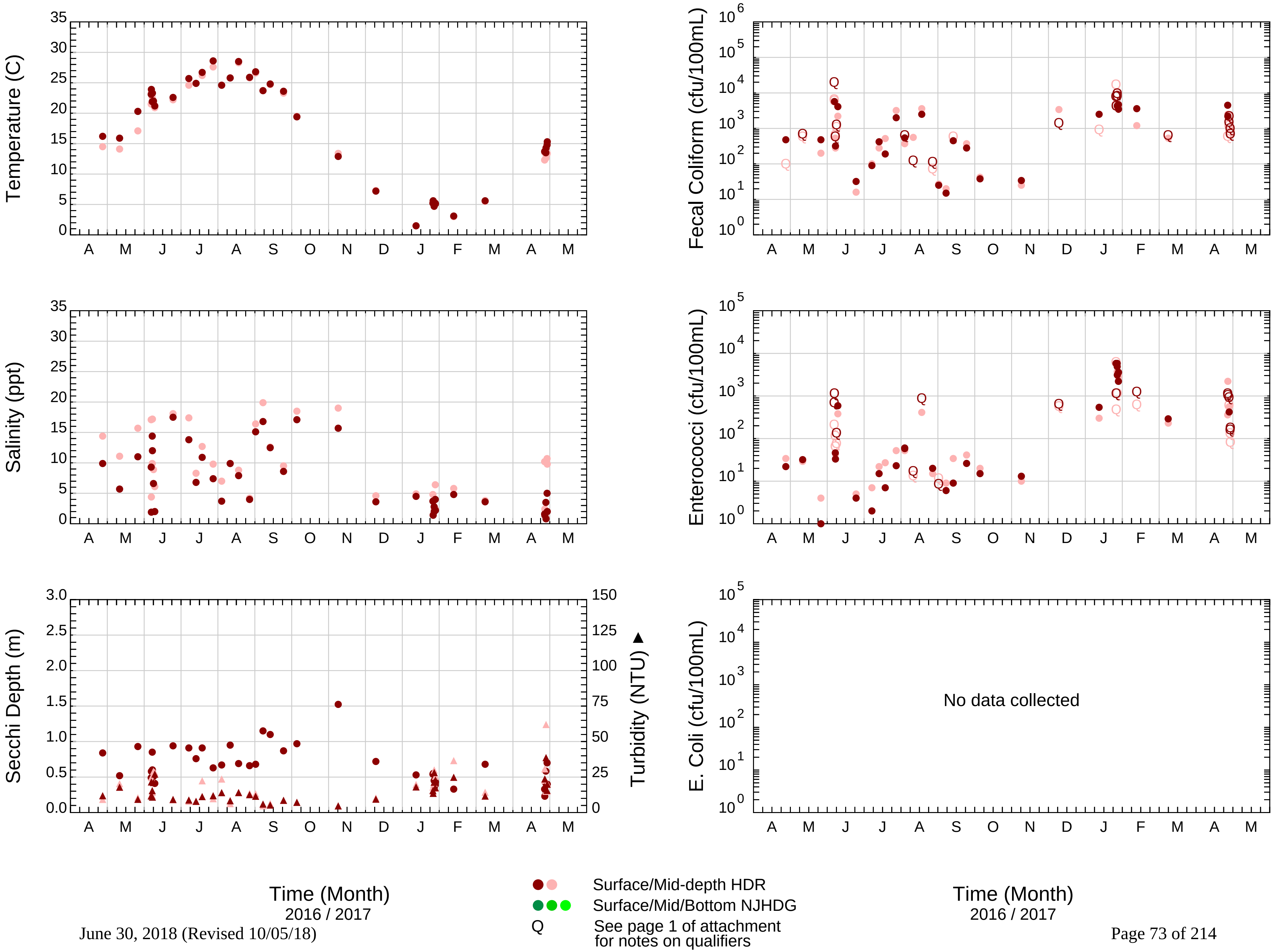


Time (Month)
2016 / 2017

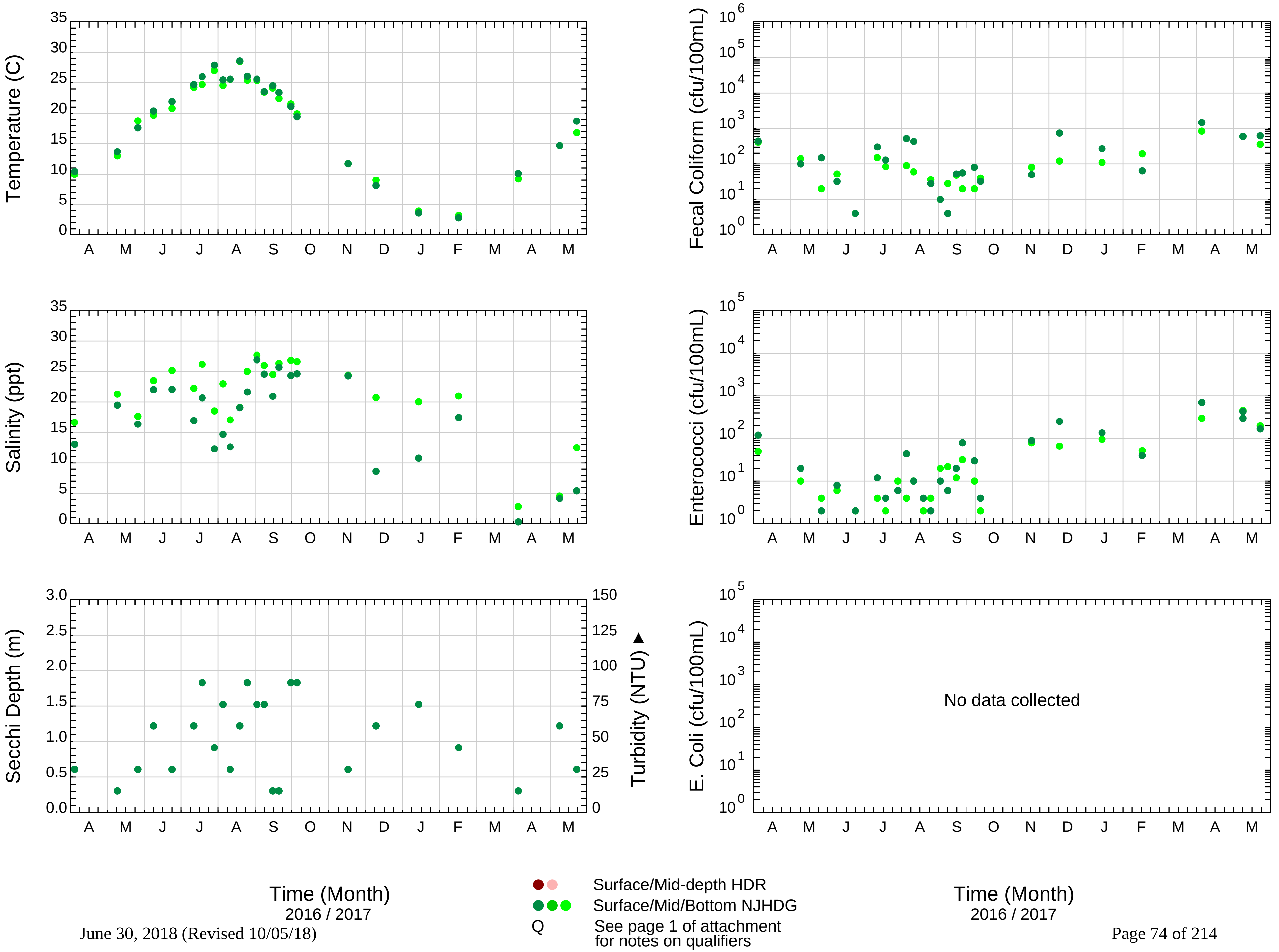
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

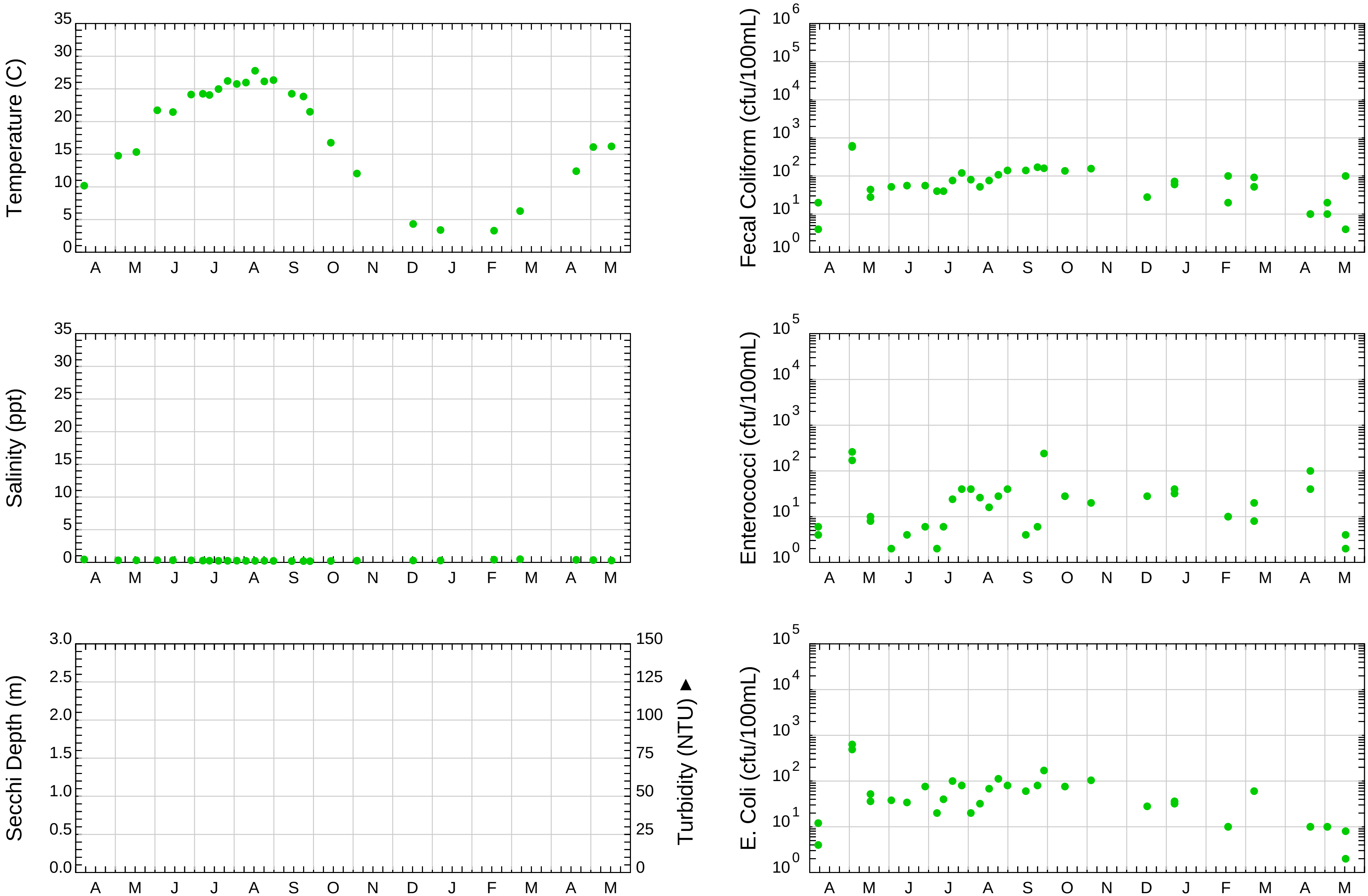
Passaic River & Tributaries, Passaic River, B6, (SE3)



Passaic River & Tributaries, Passaic River, 12, (SE3)



Hackensack River & Tributaries, Hackensack River, 13, (SE1)

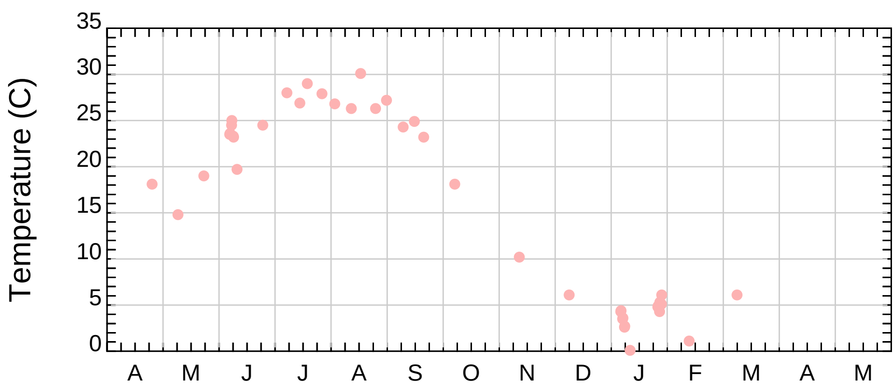


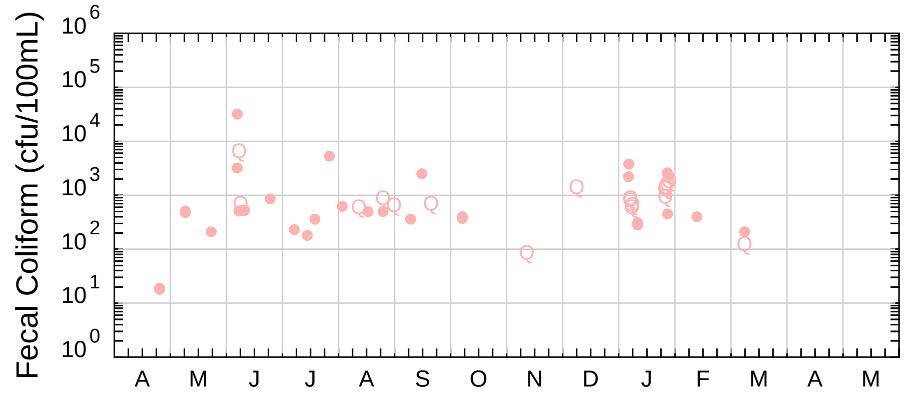
Time (Month)
2016 / 2017

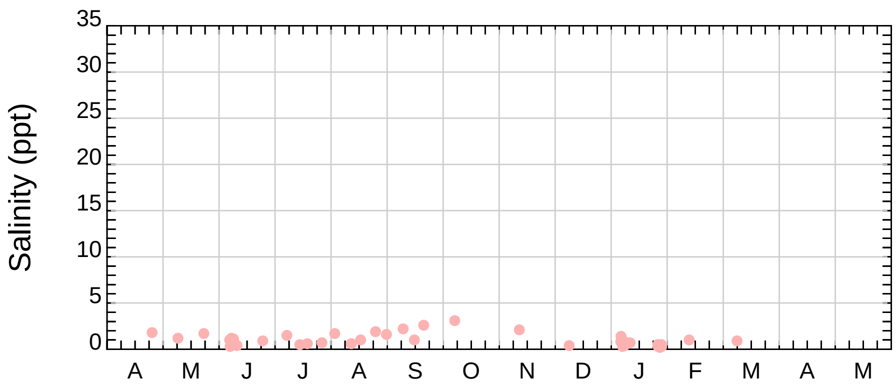
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

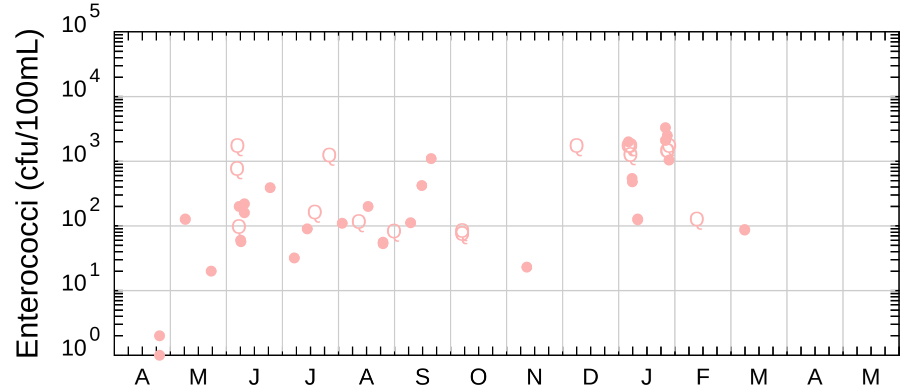
Time (Month)
2016 / 2017

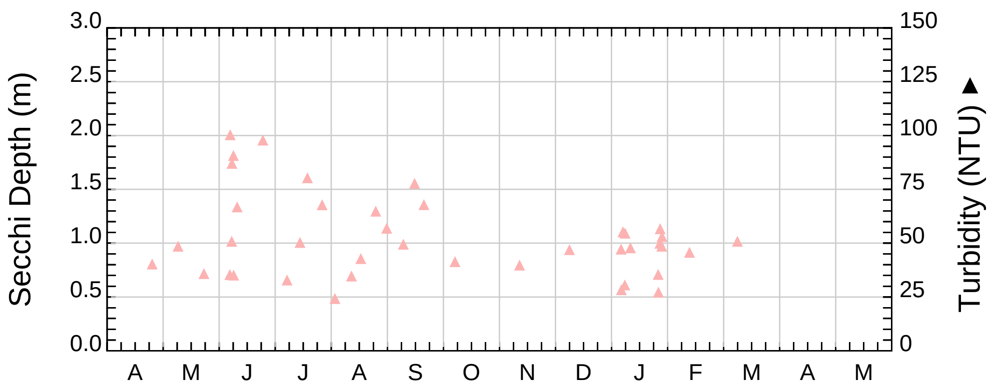
Hackensack River & Tributaries, Hackensack River, B1, (SE1)

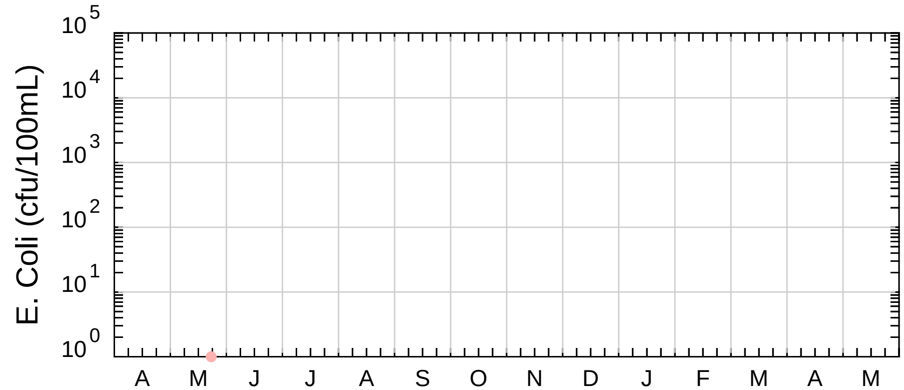










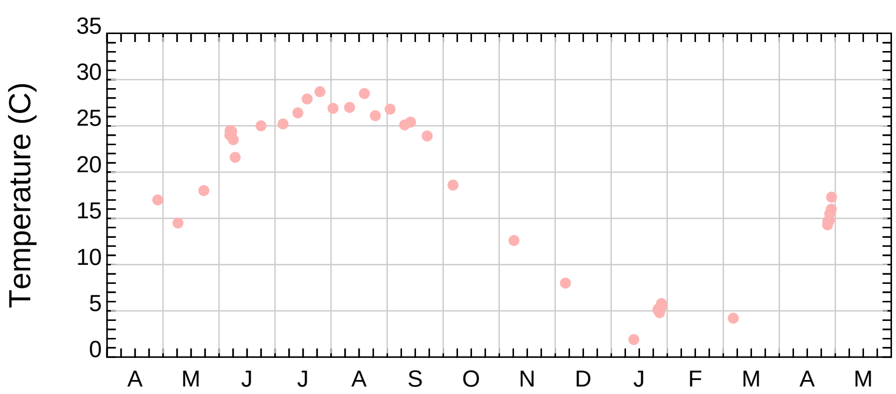


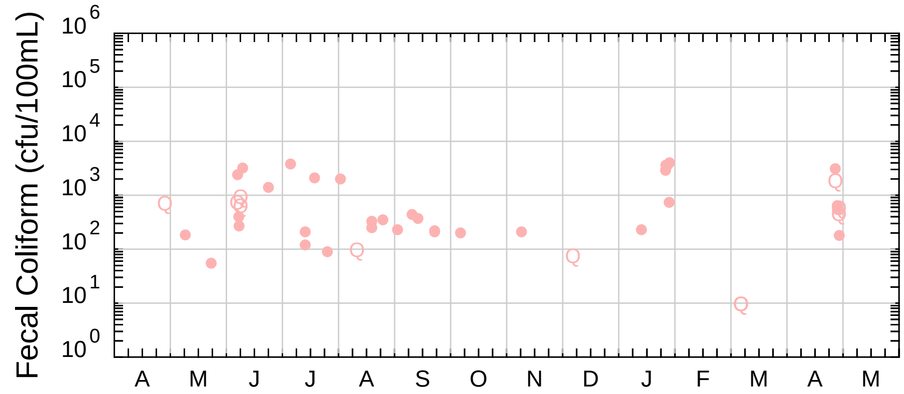
Time (Month)
2016 / 2017

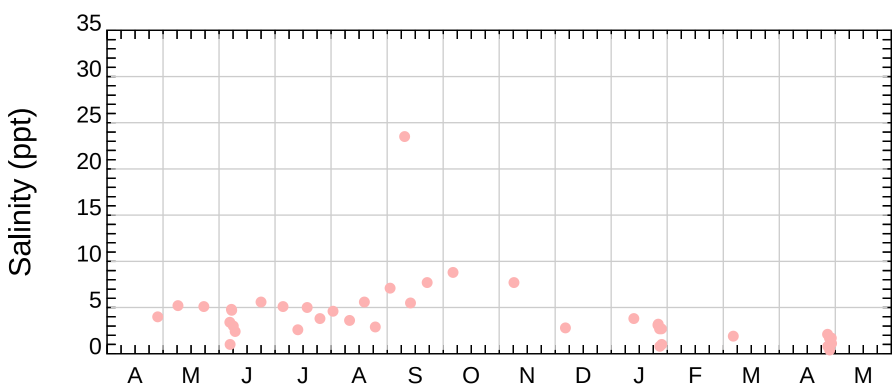
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

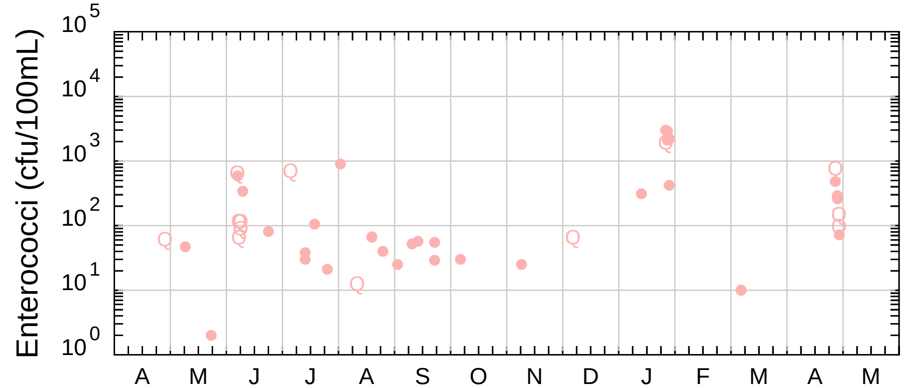
Time (Month)
2016 / 2017

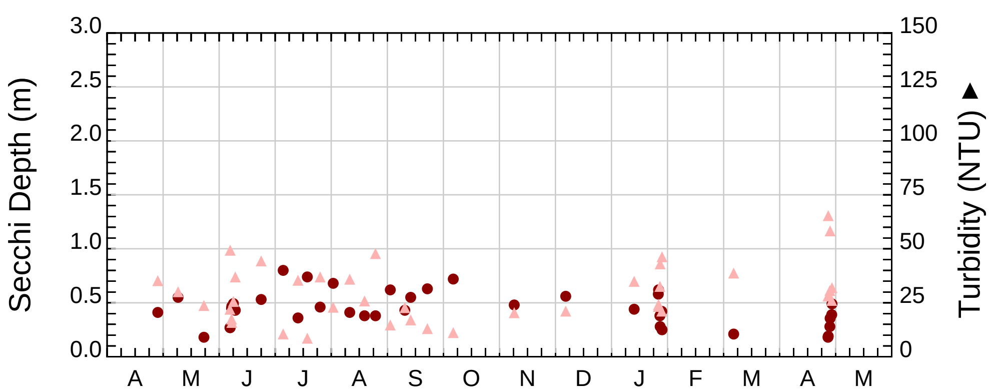
Hackensack River & Tributaries, Hackensack River, B2, (SE1)

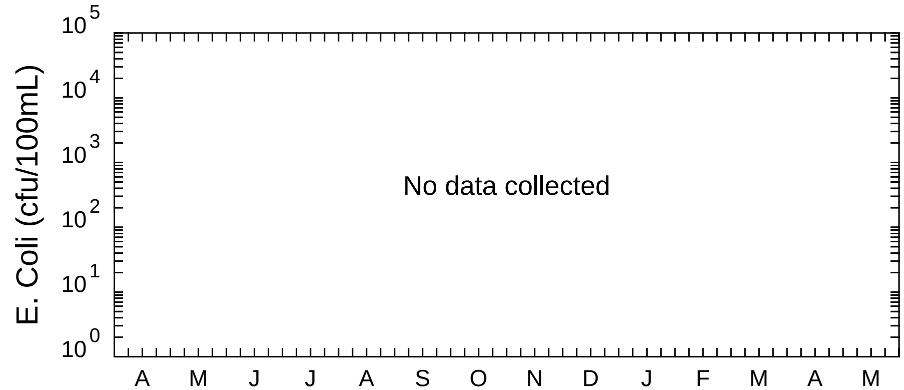










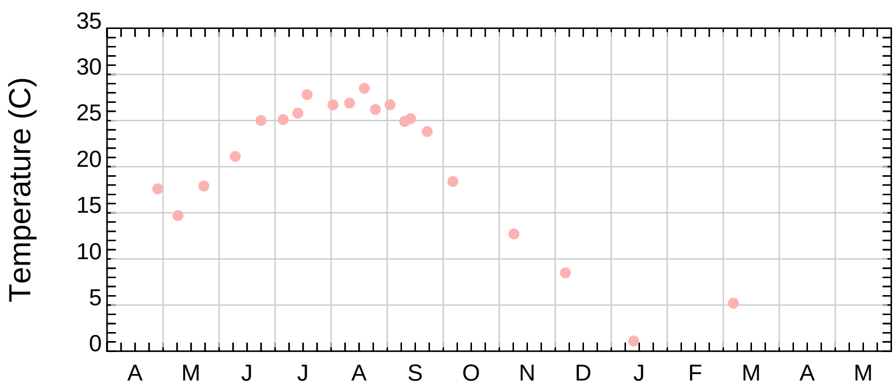


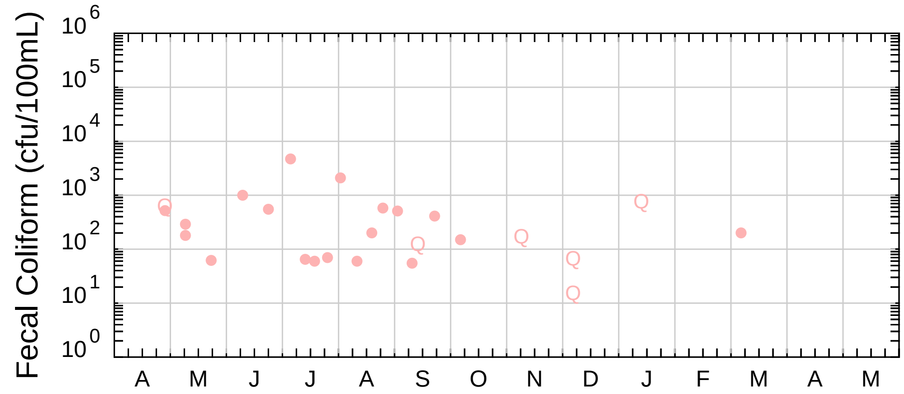
Time (Month)
2016 / 2017

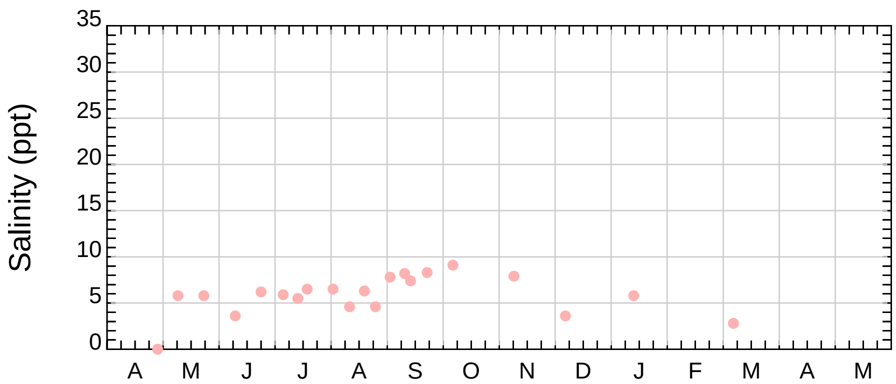
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

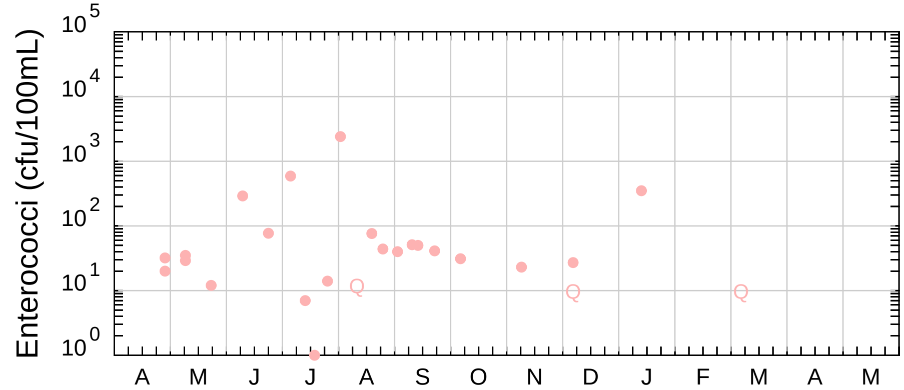
Time (Month)
2016 / 2017

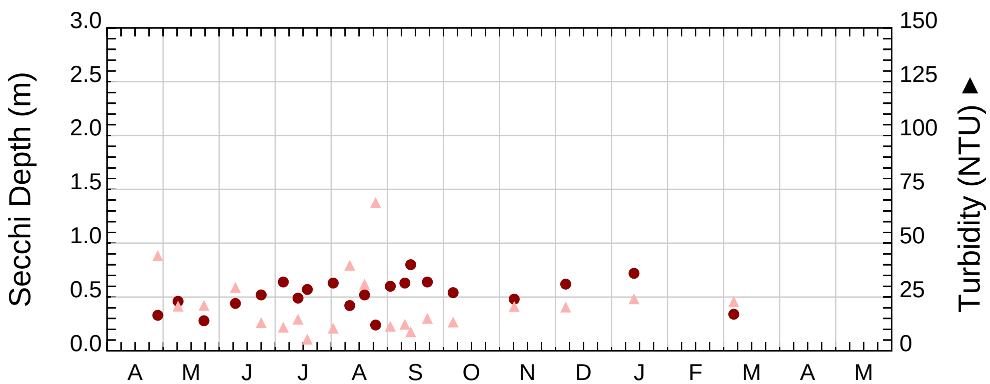
Hackensack River & Tributaries, Overpeck Creek, B11, (SE2)

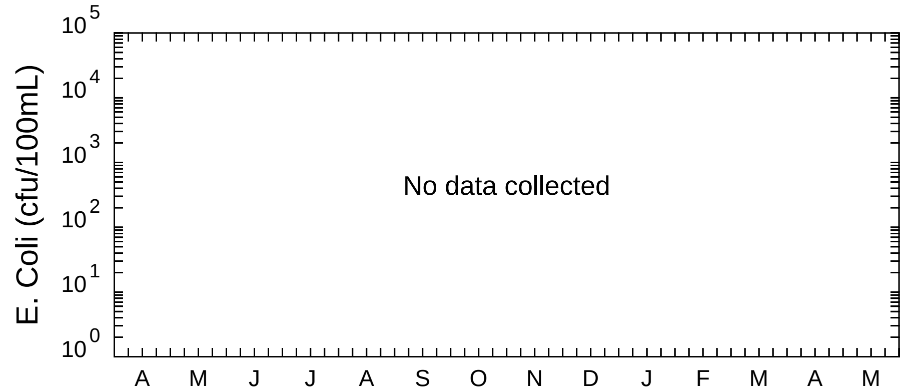










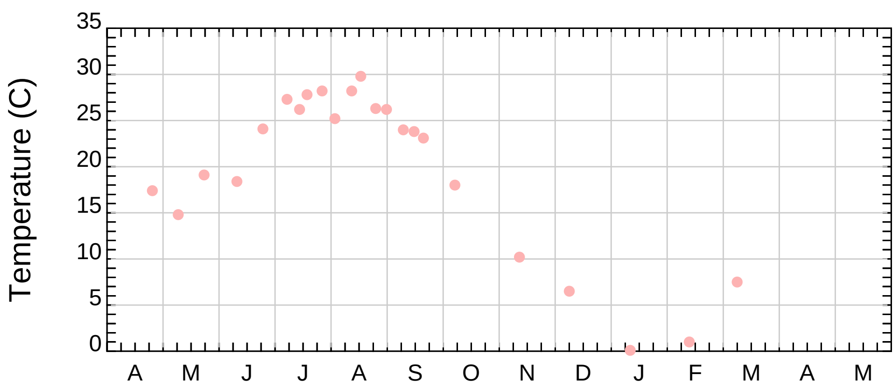


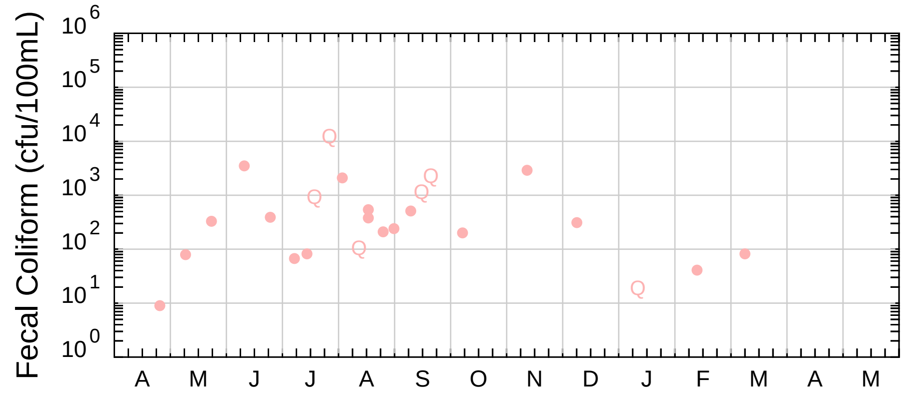
Time (Month)
2016 / 2017

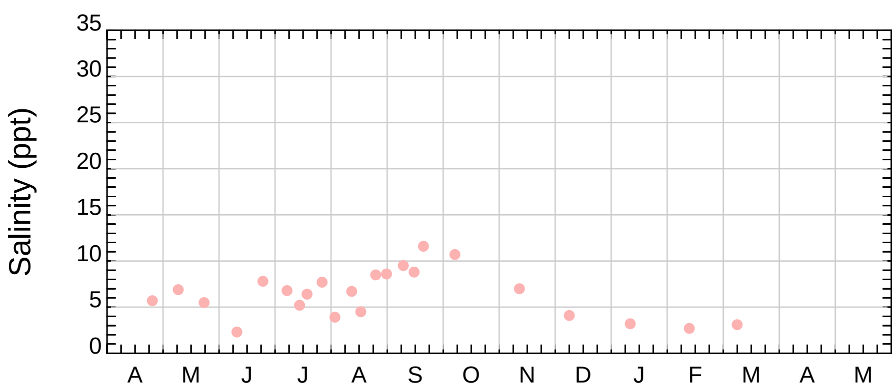
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

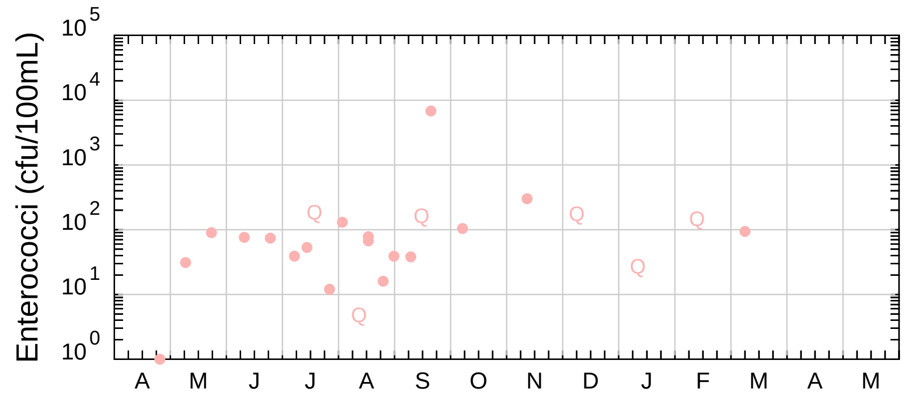
Time (Month)
2016 / 2017

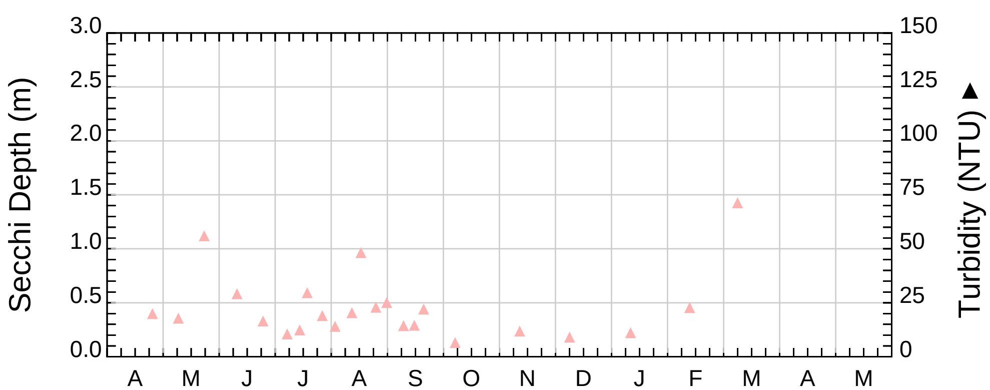
Hackensack River & Tributaries, Berry's Creek, S1, (SE2)

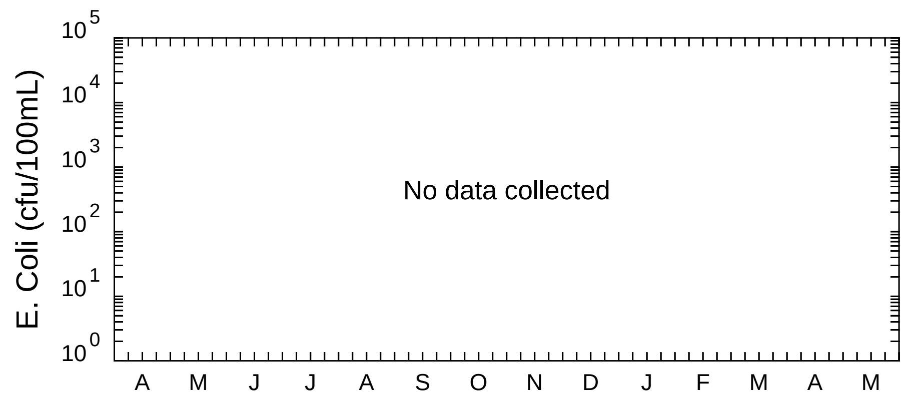










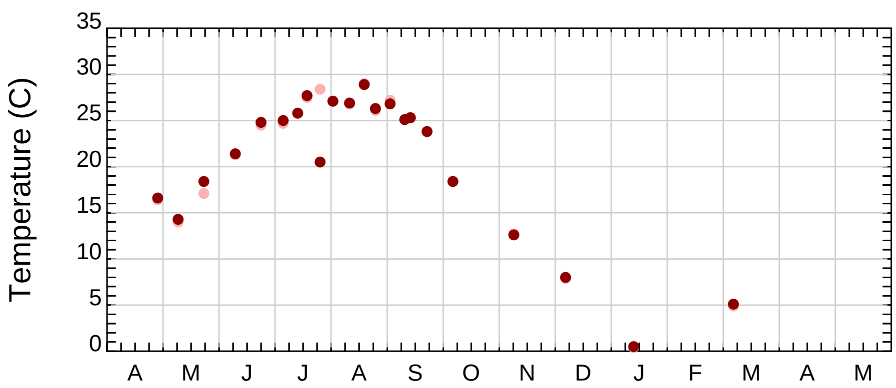


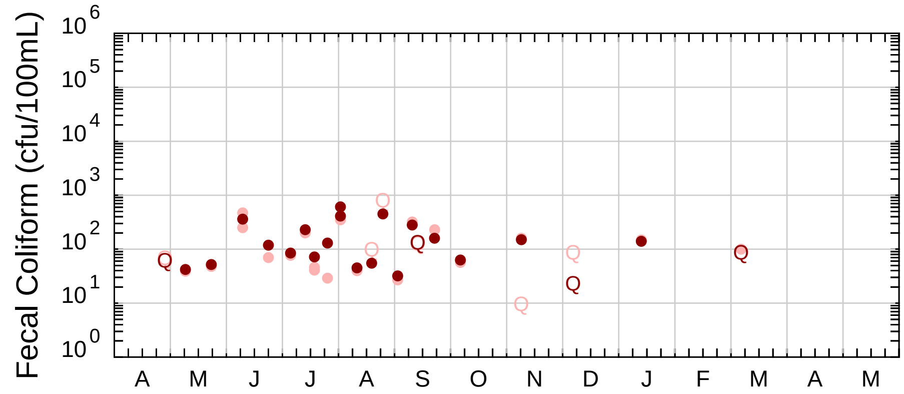
Time (Month)
2016 / 2017

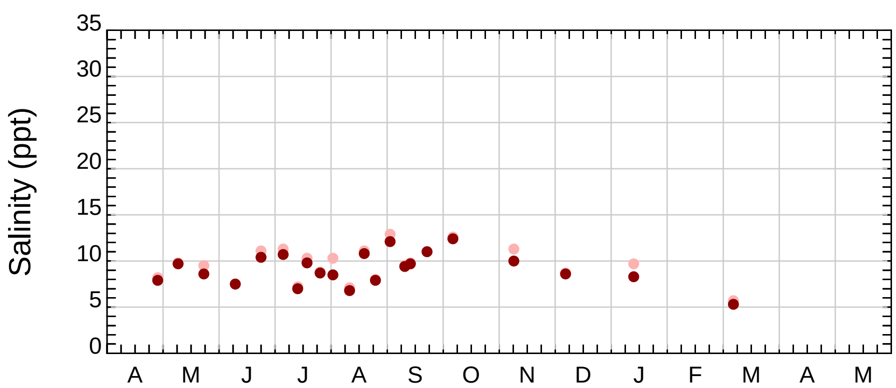
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

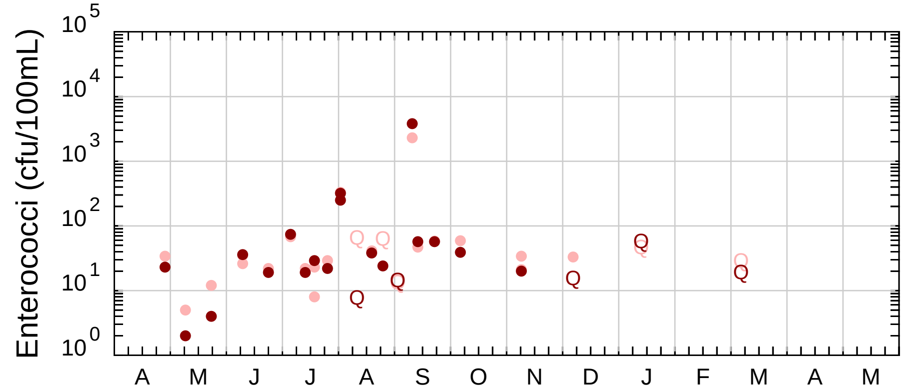
Time (Month)
2016 / 2017

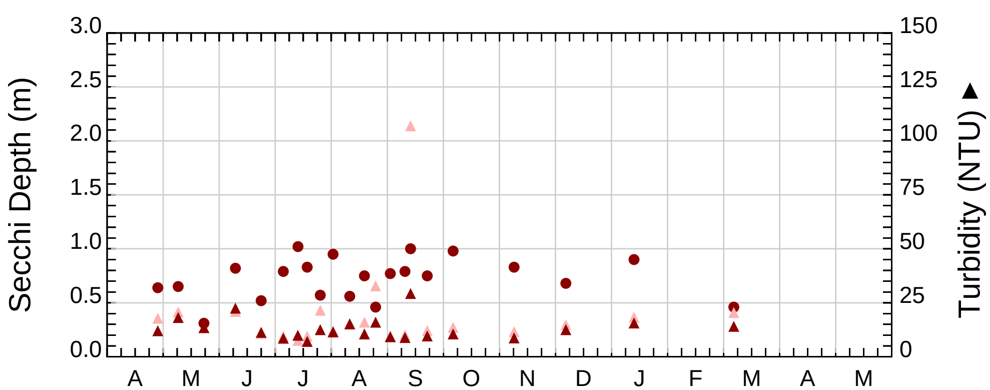
Hackensack River & Tributaries, Cromakill Creek, B3, (SE2)

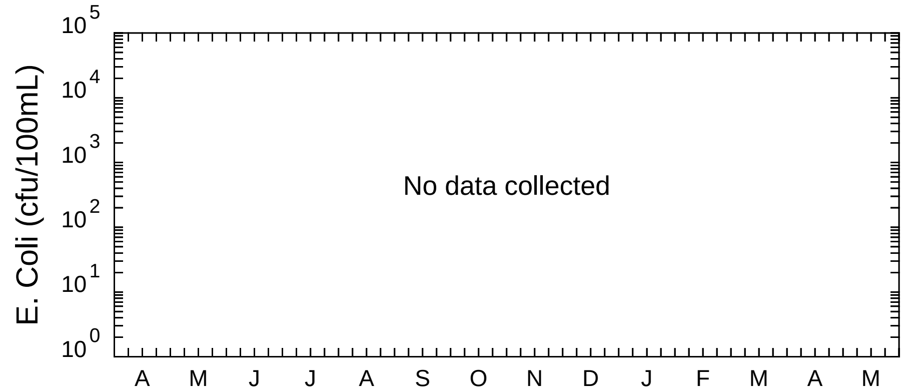










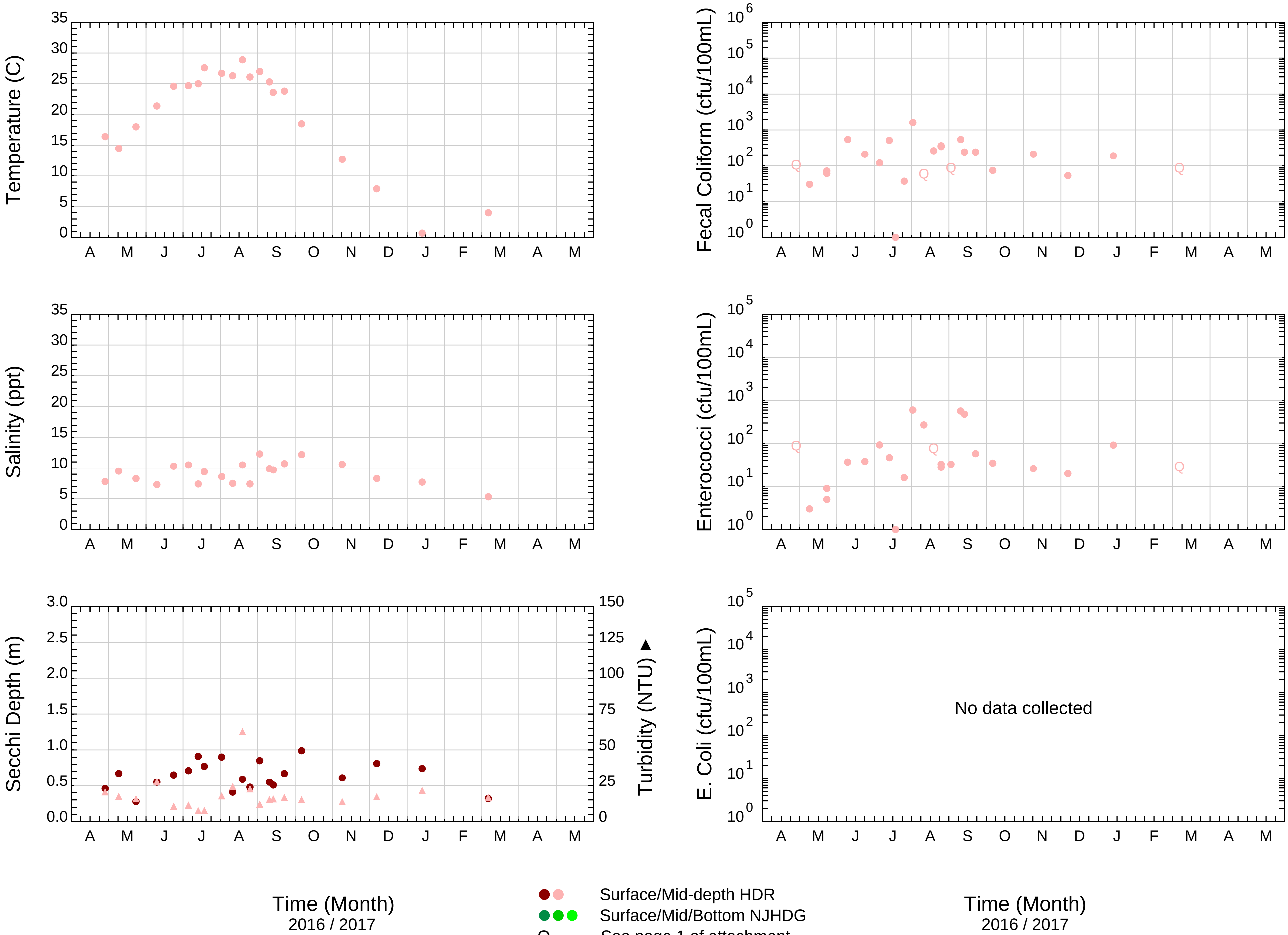


Time (Month)
2016 / 2017

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

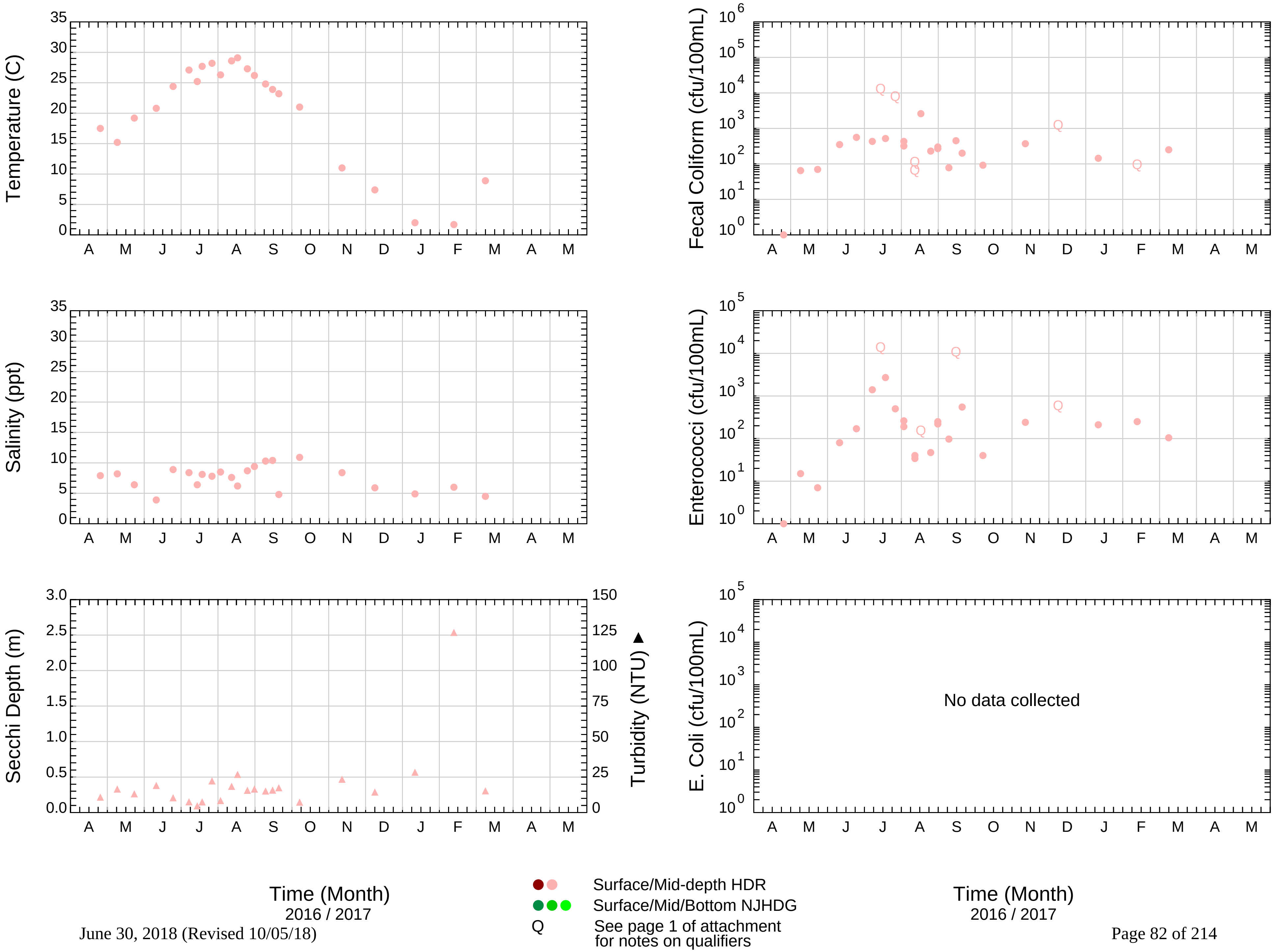
Time (Month)
2016 / 2017

Hackensack River & Tributaries, Cromakill Creek, S2, (SE2)

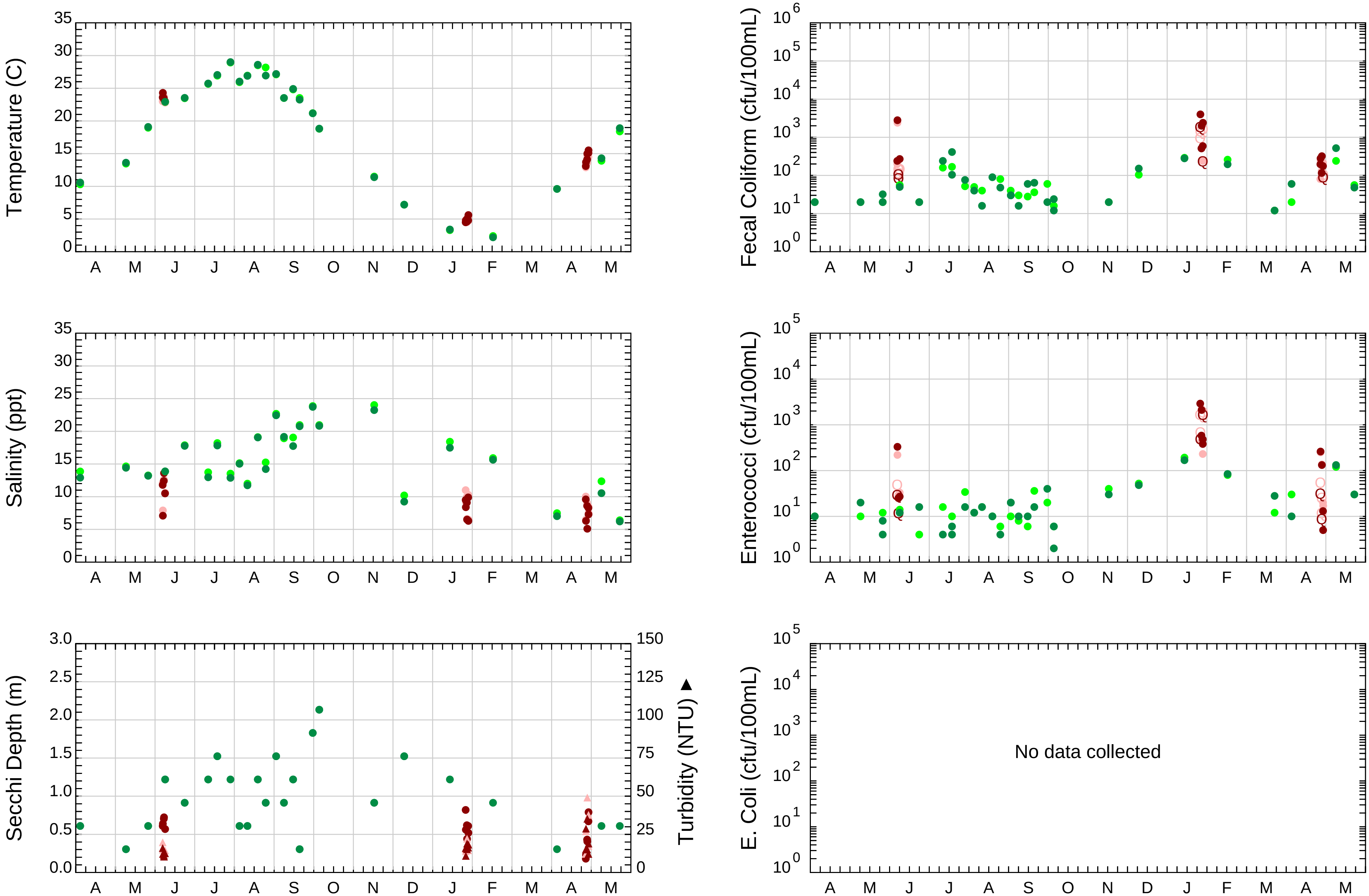


Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Hackensack River & Tributaries, Cromakill Creek, B4, (SE2)



Hackensack River & Tributaries, Hackensack River, 14, (SE2)

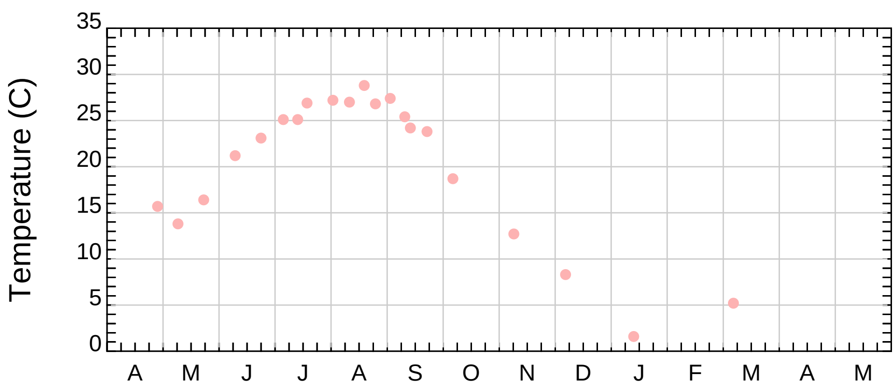


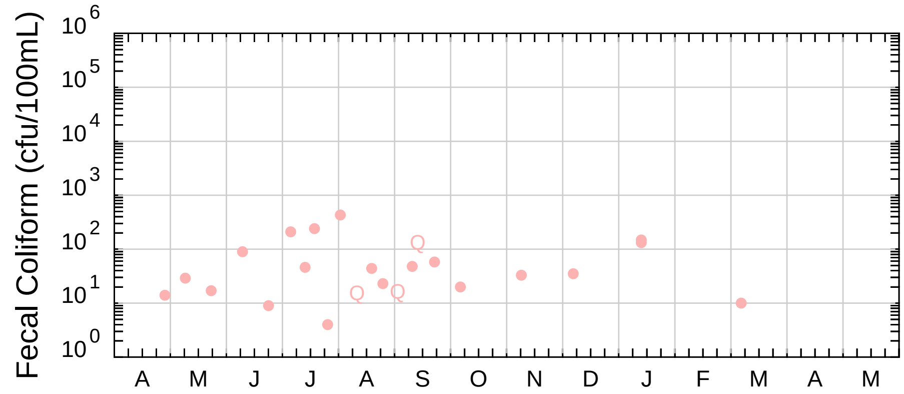
Time (Month)
2016 / 2017

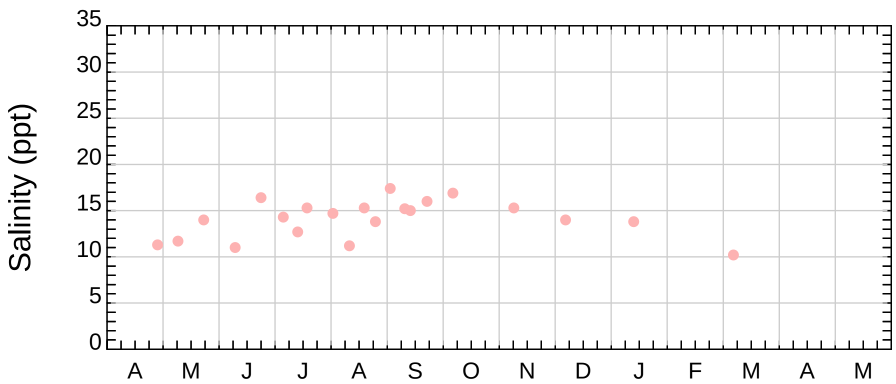
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

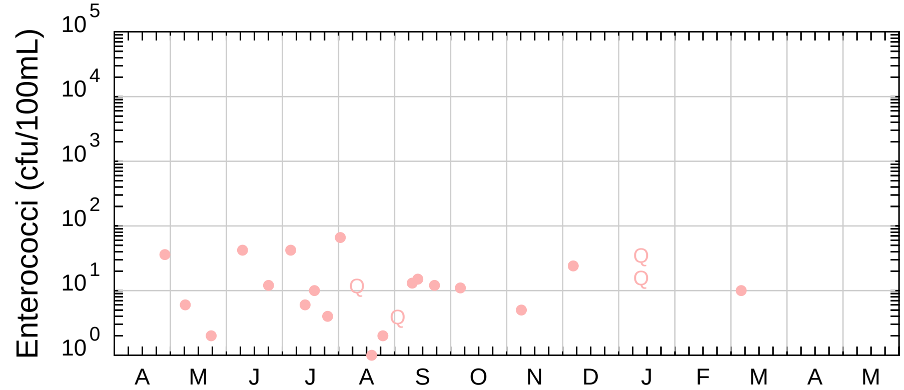
Time (Month)
2016 / 2017

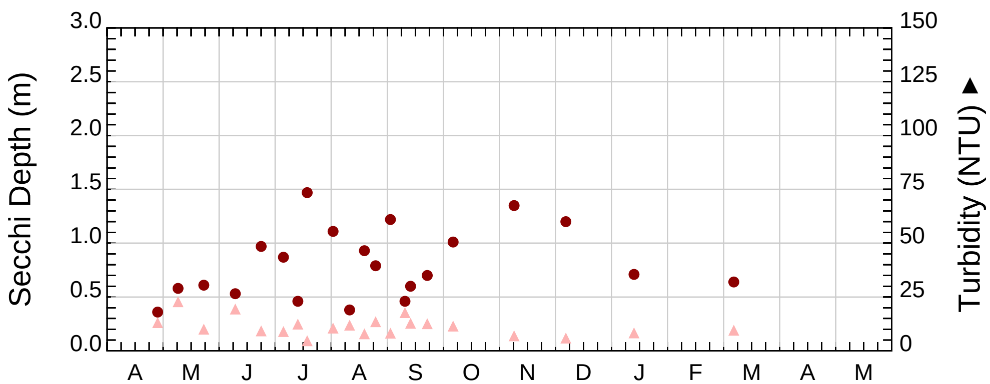
Hackensack River & Tributaries, Sawmill River, S3, (SE2)

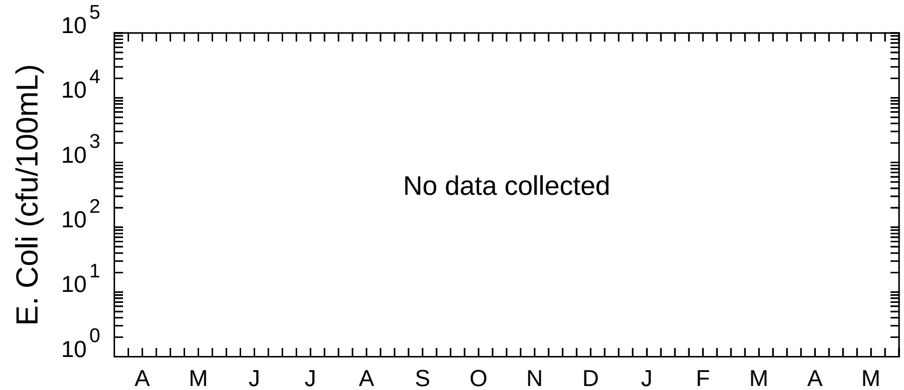










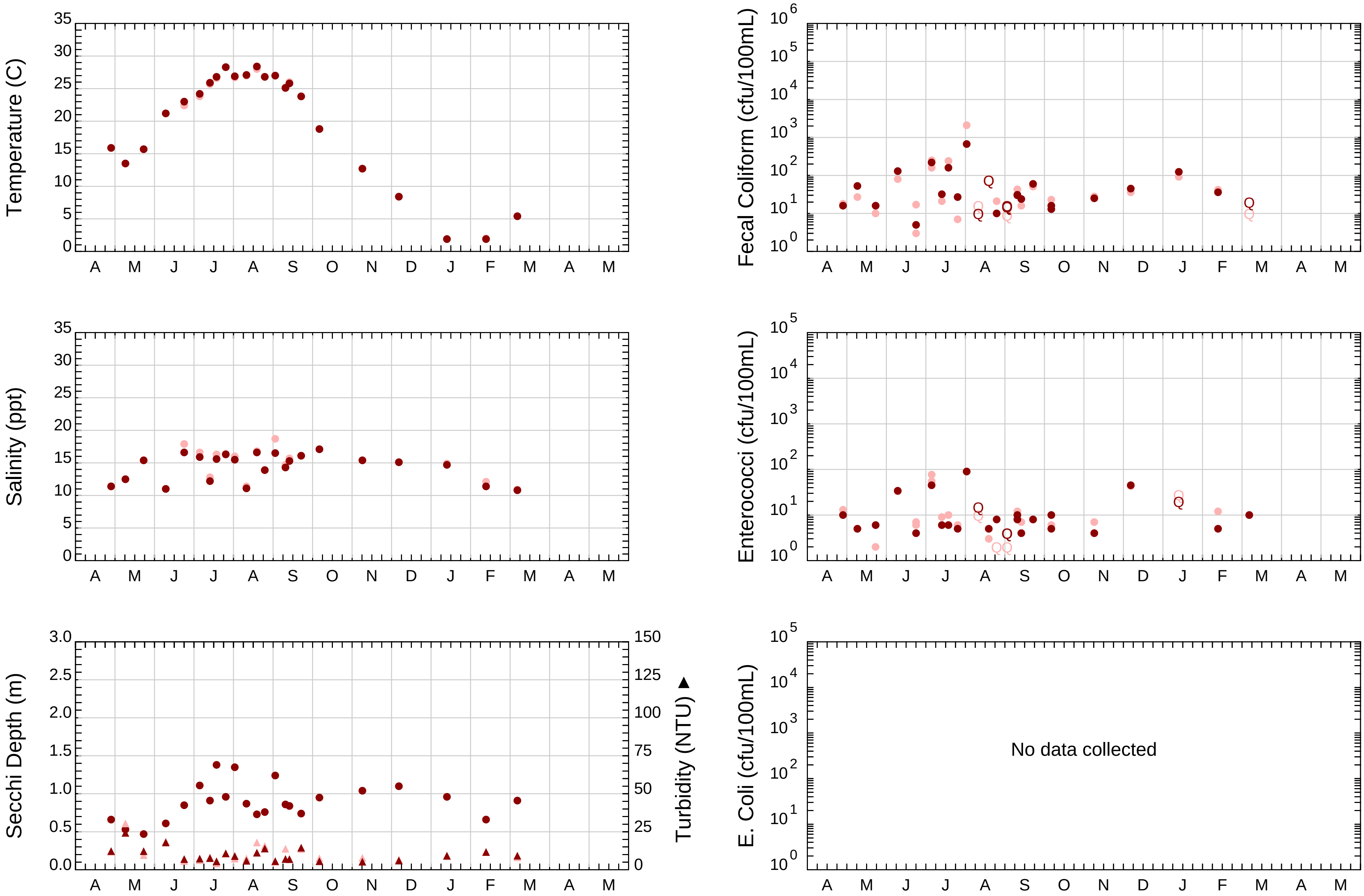


Time (Month)
2016 / 2017

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

Hackensack River & Tributaries, Hackensack River, B7, (SE2)

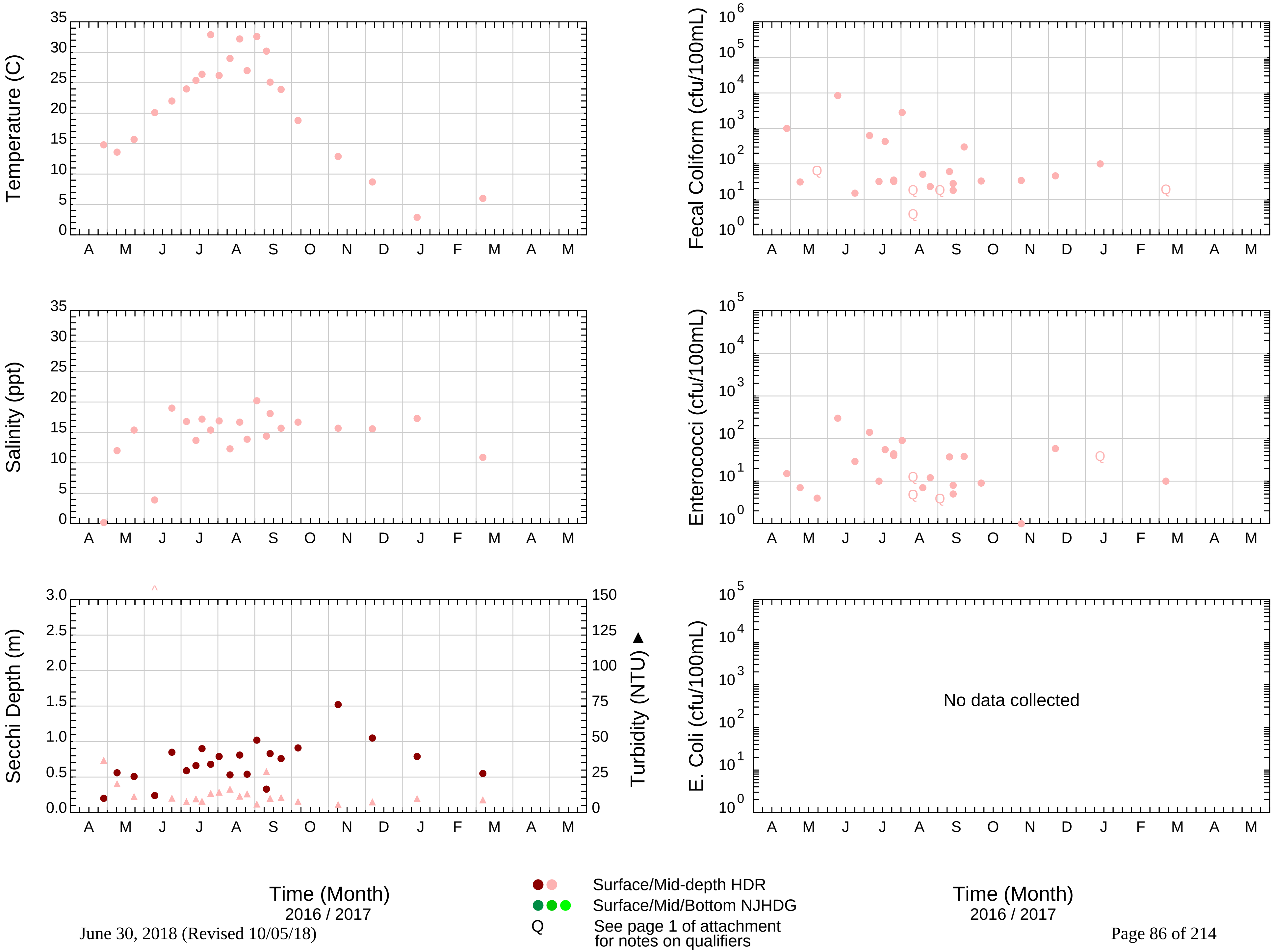


Time (Month)
2016 / 2017

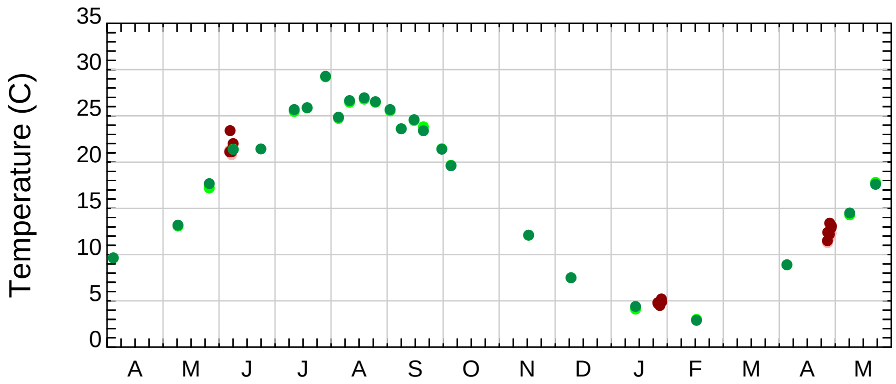
Time (Month)
2016 / 2017

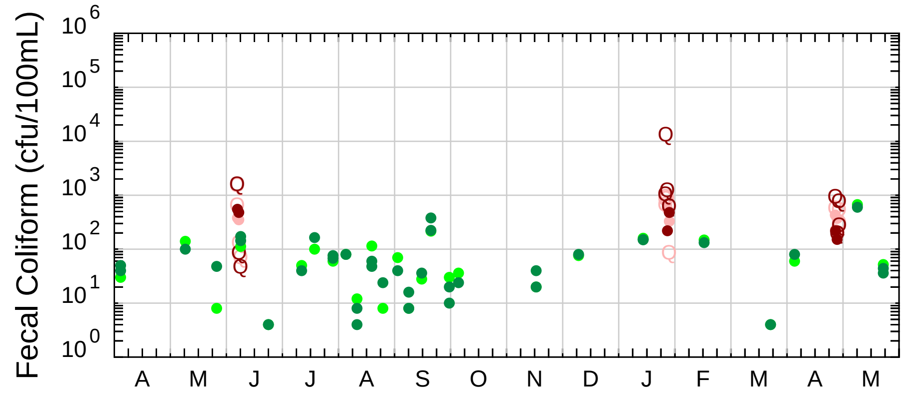
●● Surface/Mid-depth HDR
●●● Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

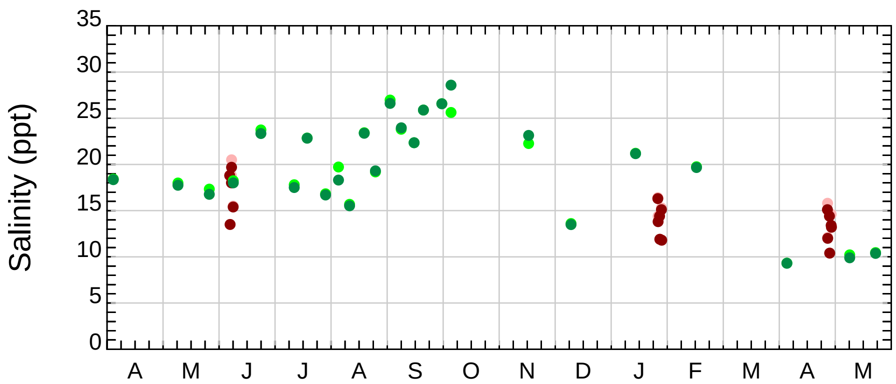
Hackensack River & Tributaries, Penhorn Creek, S5, (SE2)

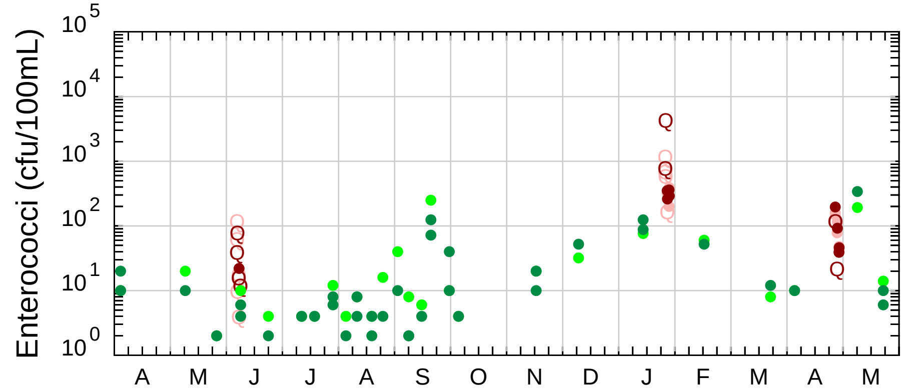


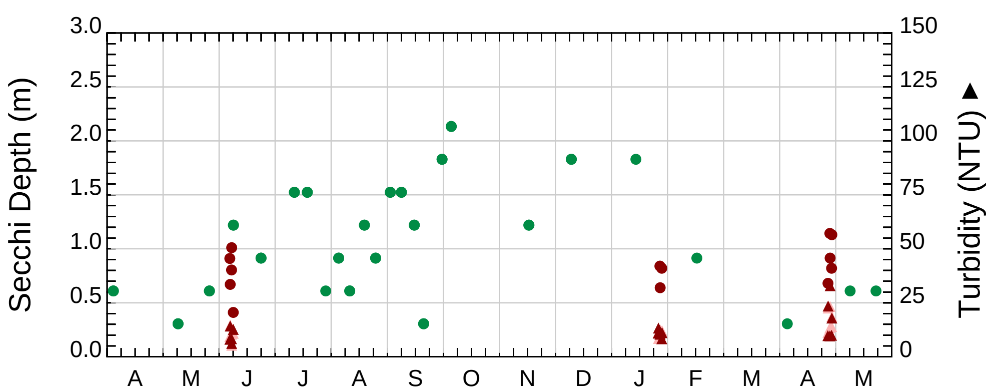
Hackensack River & Tributaries, Hackensack River, 15, (SE2)

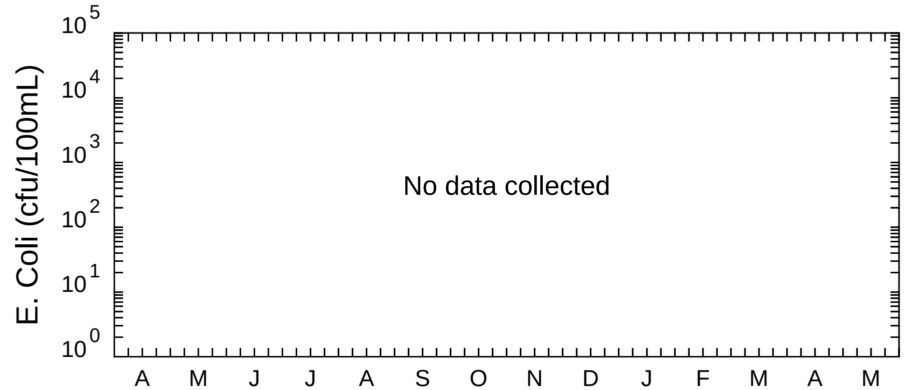












Time (Month)
2016 / 2017

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
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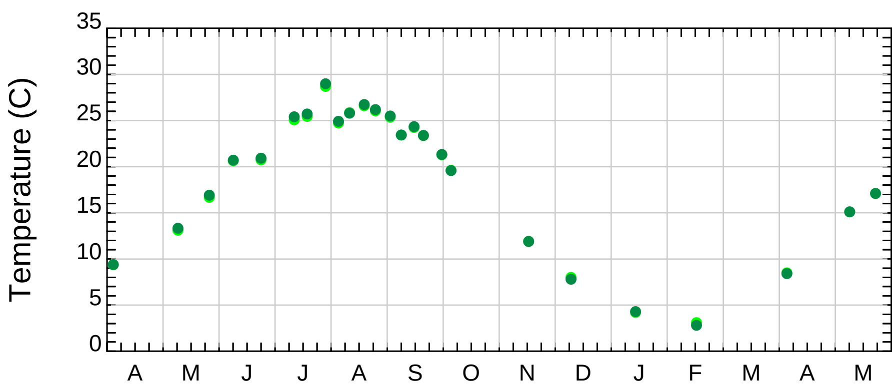
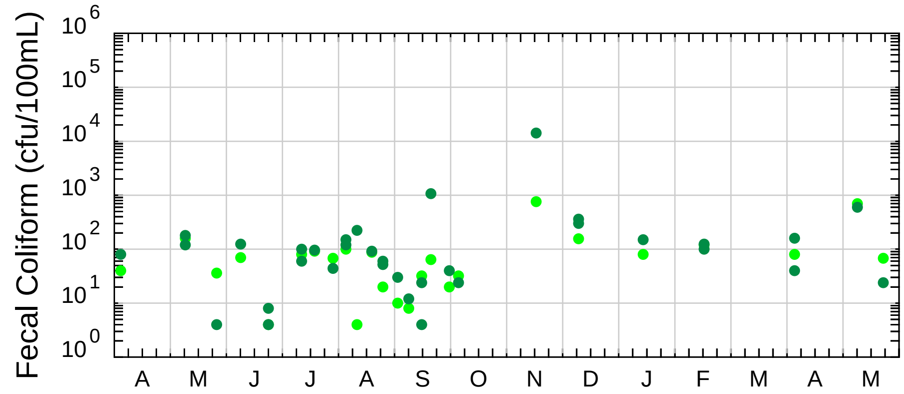
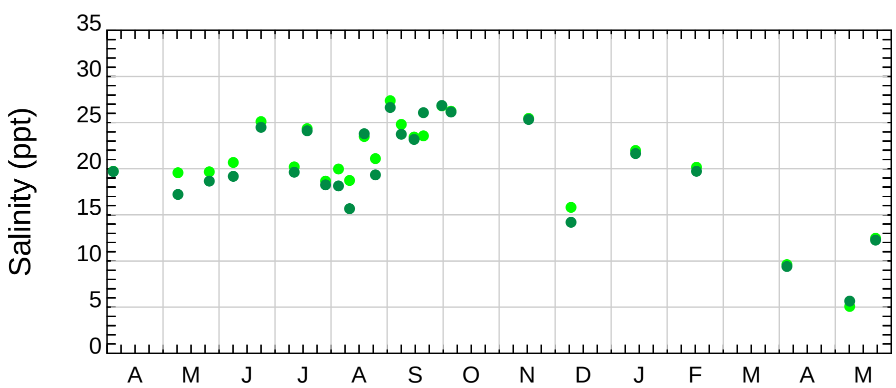
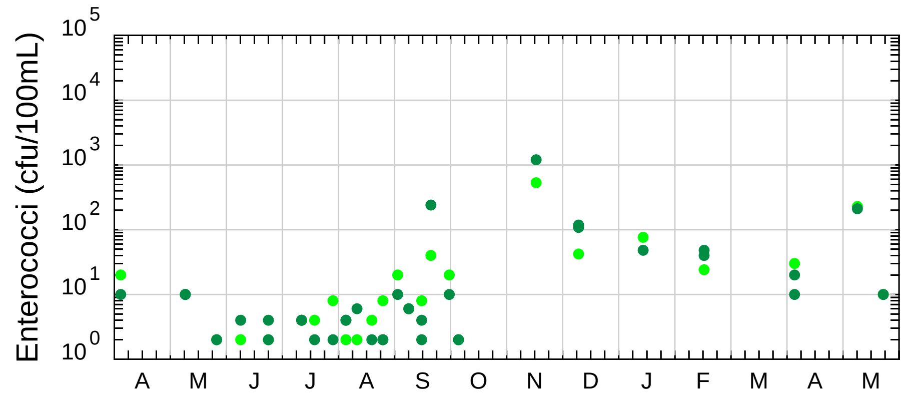
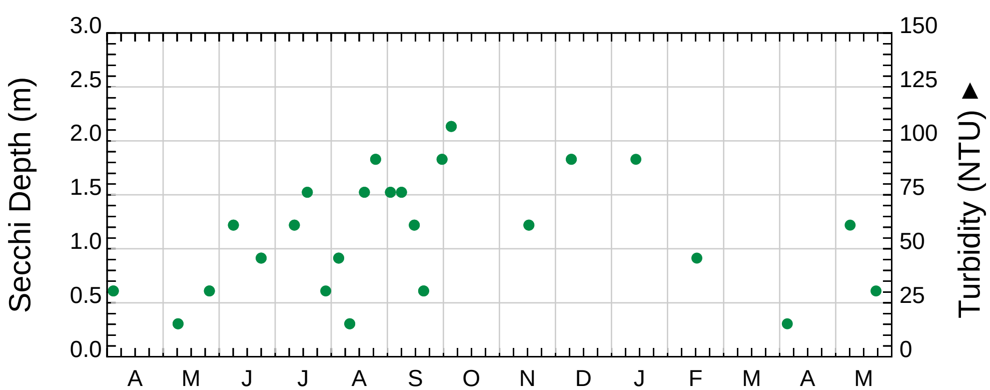
Hackensack River & Tributaries, Hackensack River, 16, (SE3)

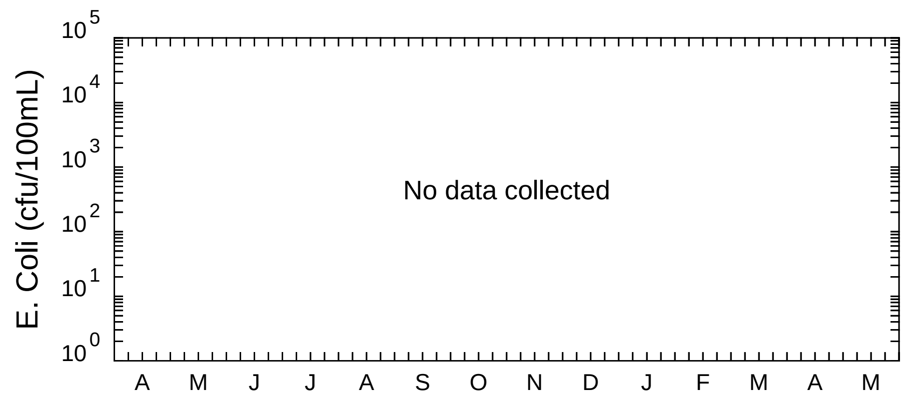










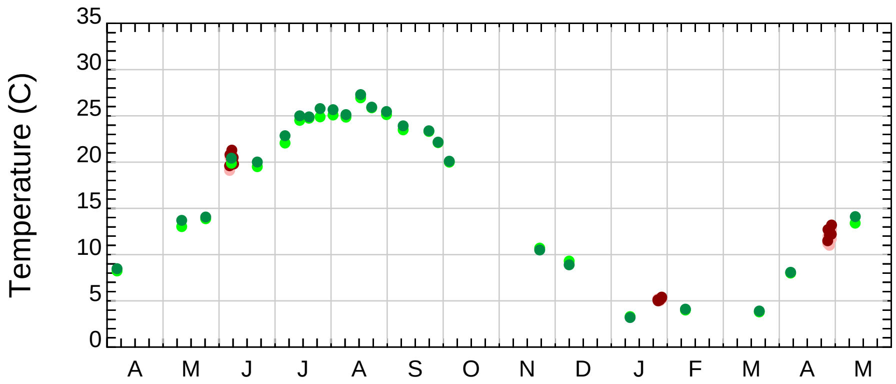


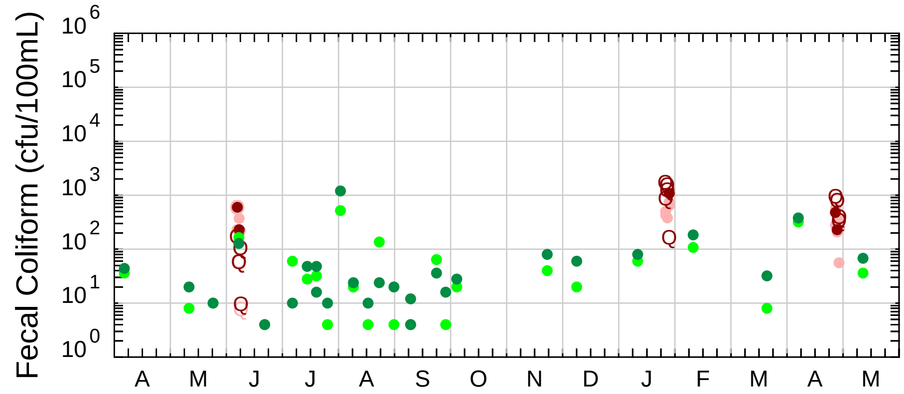
Time (Month)
2016 / 2017

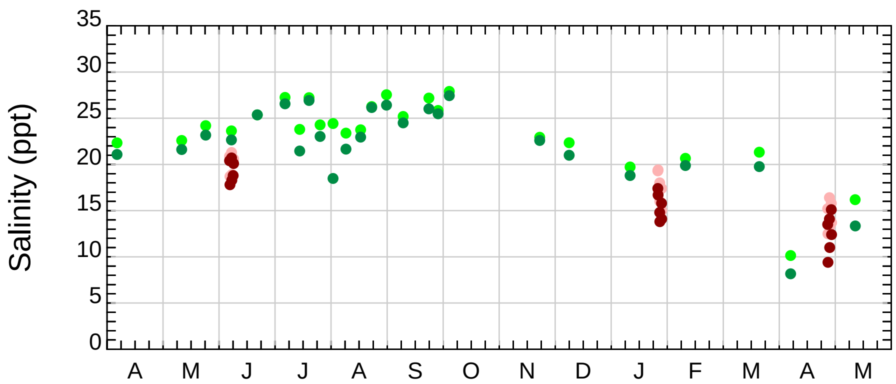
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

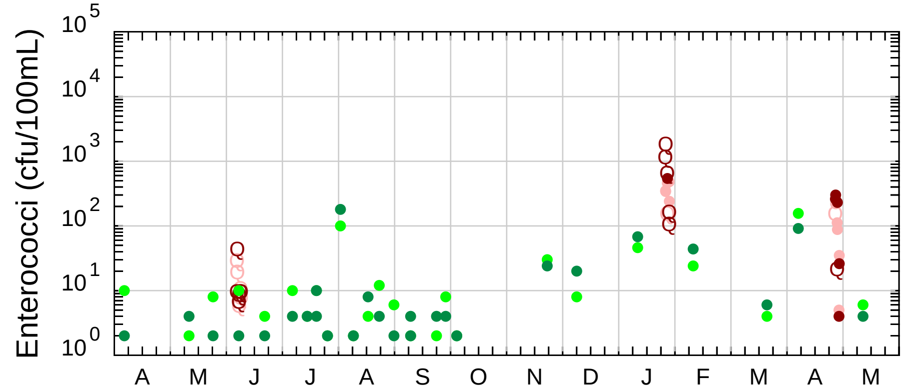
Time (Month)
2016 / 2017

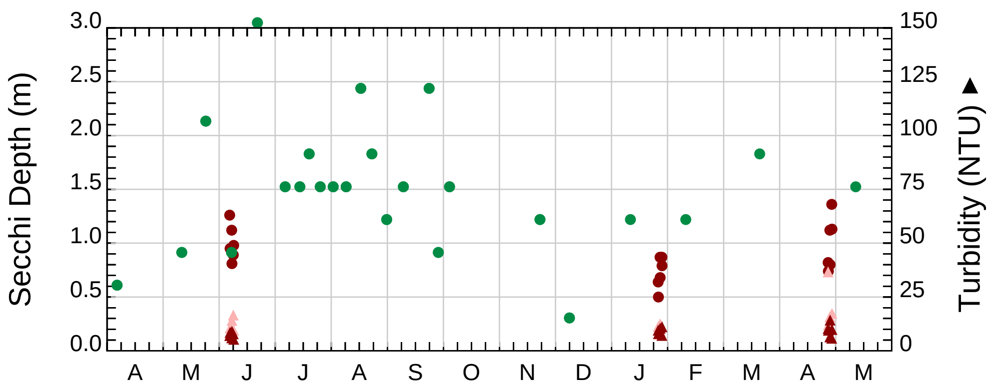
Newark Bay & Tributaries, Newark Bay, 17, (SE3)

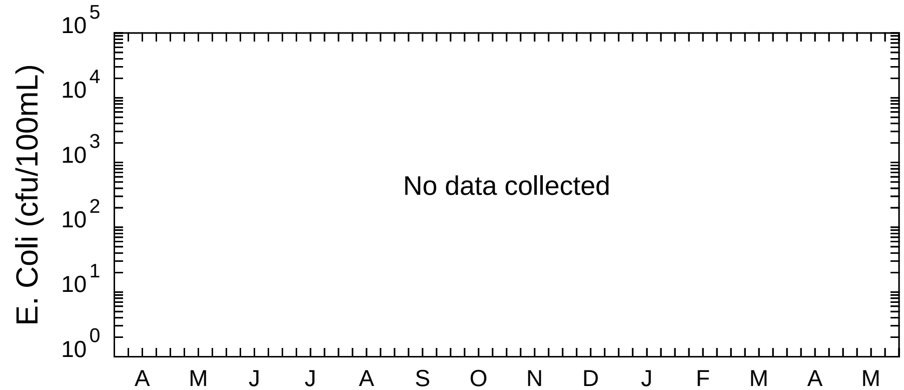










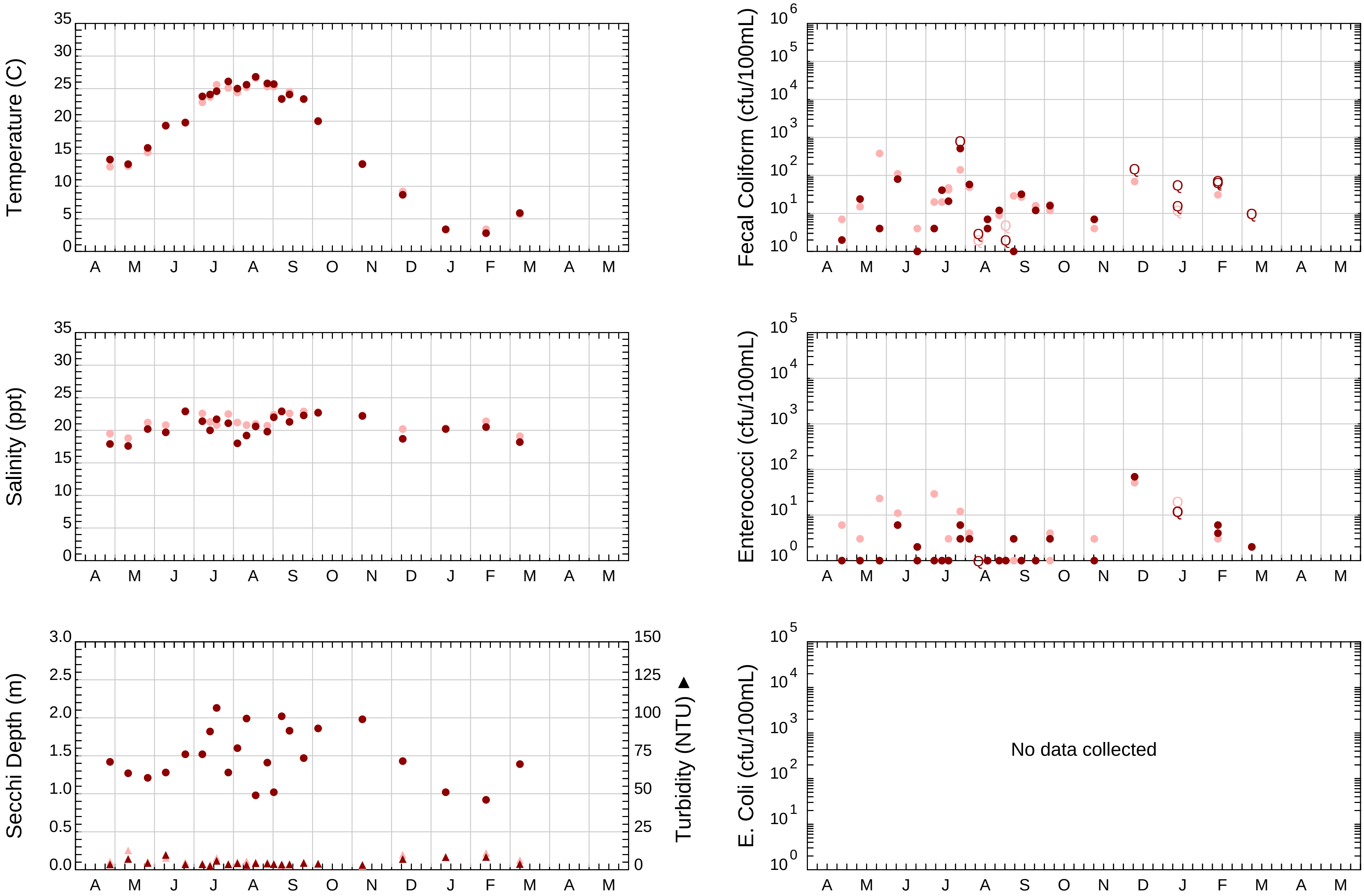


Time (Month)
2016 / 2017

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

Newark Bay & Tributaries, Newark Bay, B10, (SE3)



Time (Month)
2016 / 2017

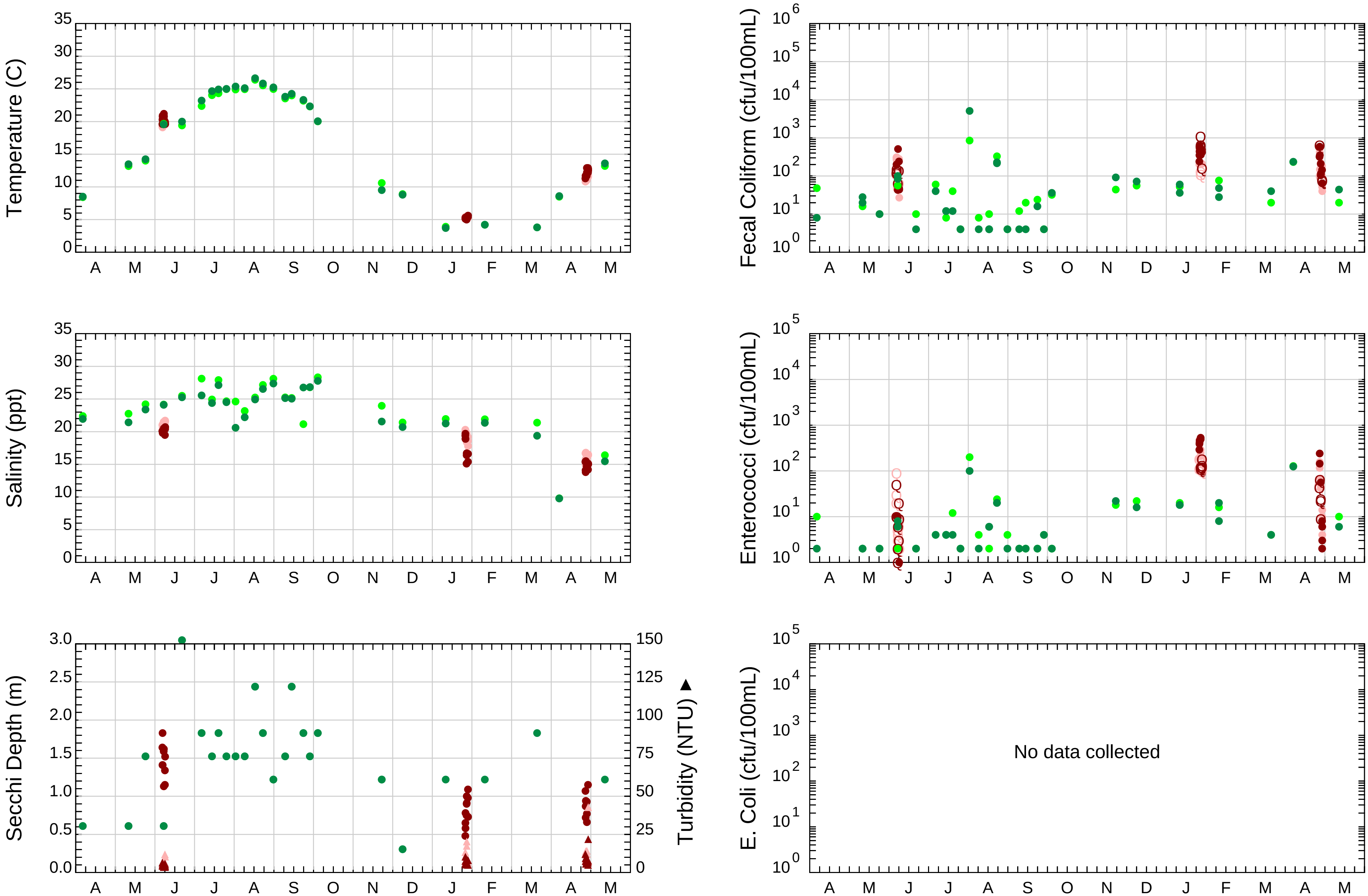
Surface/Mid-depth HDR

Surface/Mid/Bottom NJHDG

Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

Newark Bay & Tributaries, Newark Bay, 18, (SE3)

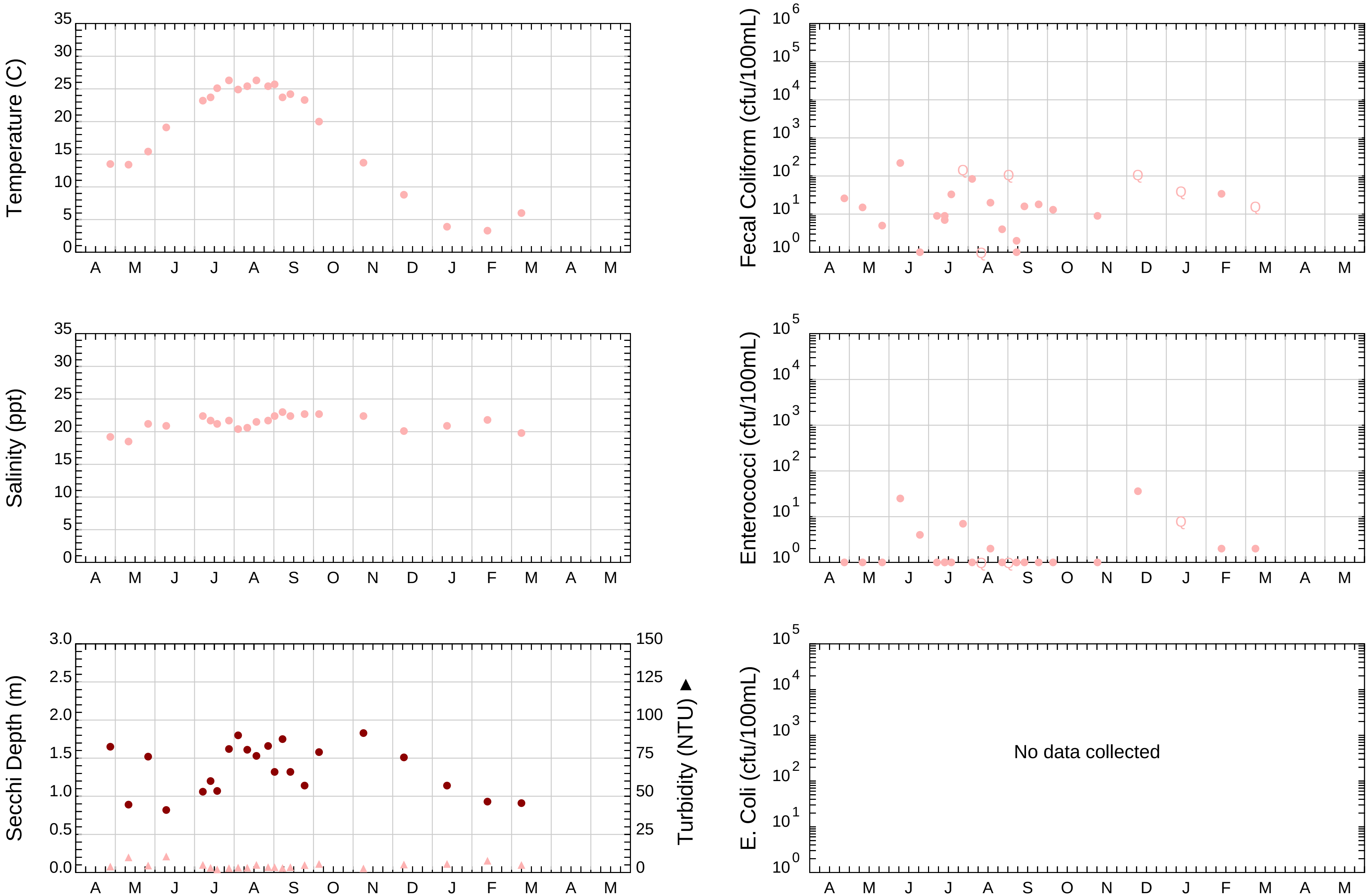


Time (Month)
2016 / 2017

Time (Month)
2016 / 2017

●● Surface/Mid-depth HDR
●●● Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Newark Bay & Tributaries, Newark Bay, B17, (SE3)

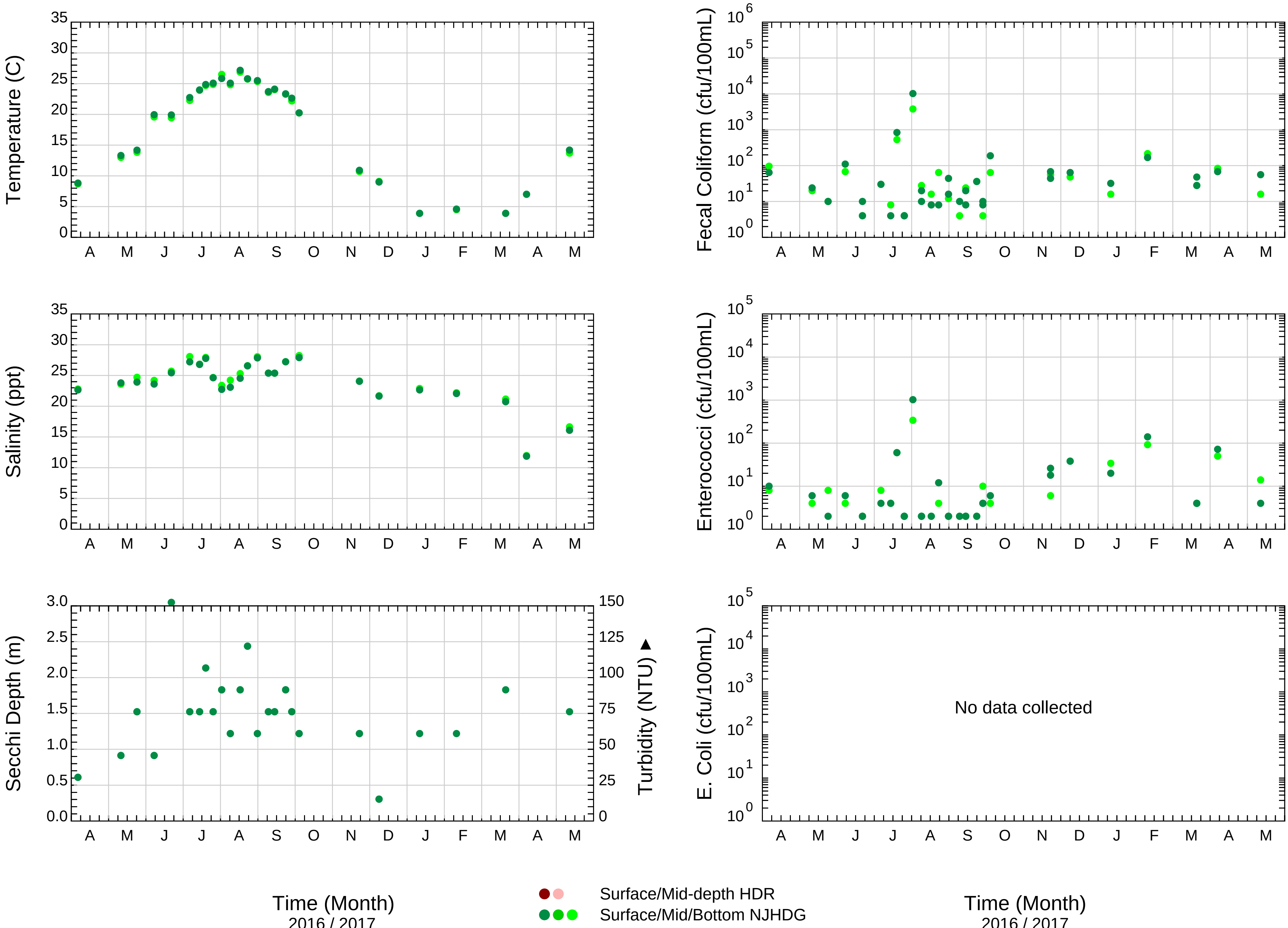


Time (Month)
2016 / 2017

Time (Month)
2016 / 2017

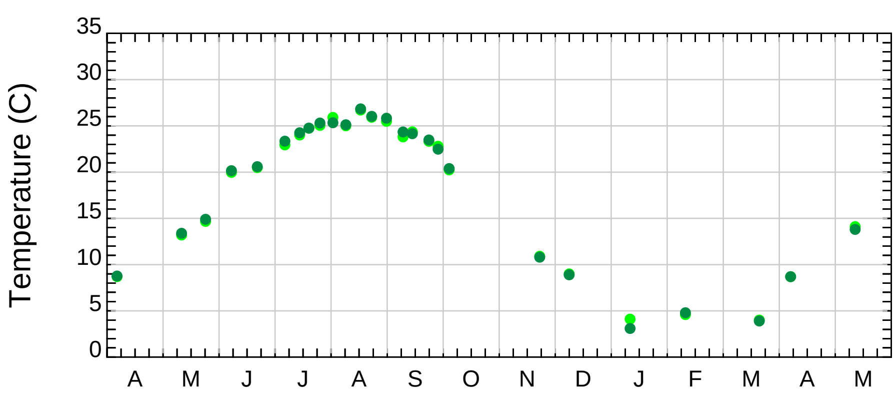
●● Surface/Mid-depth HDR
●●● Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

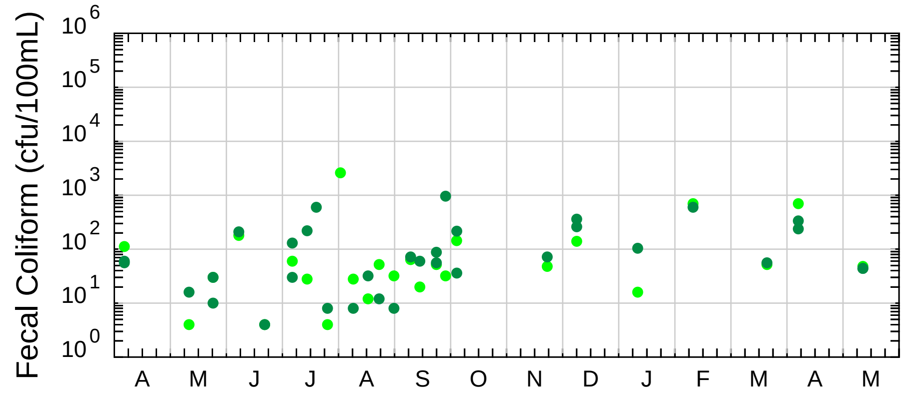
Newark Bay & Tributaries, Newark Bay, 19, (SE3)

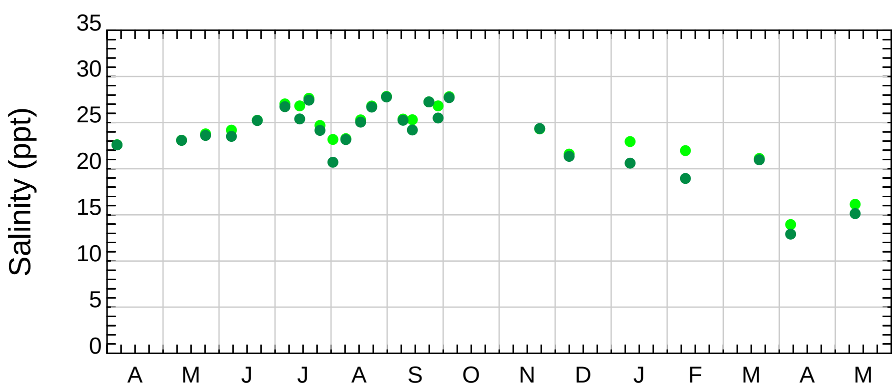


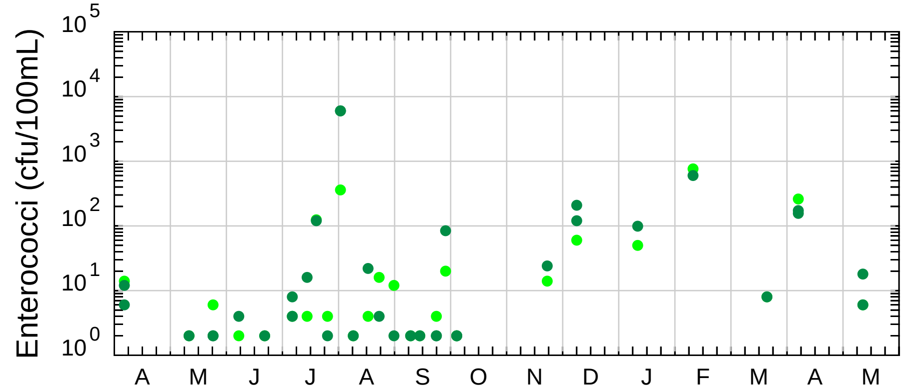
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

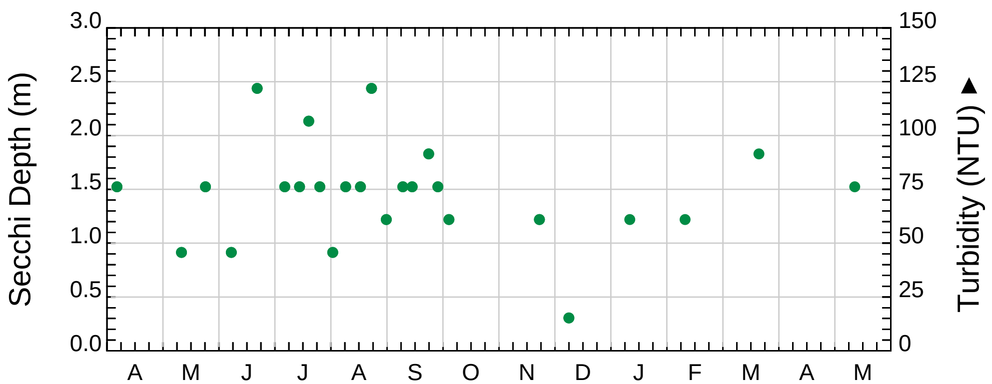
Newark Bay & Tributaries, Arthur Kill, 21, (SE3)

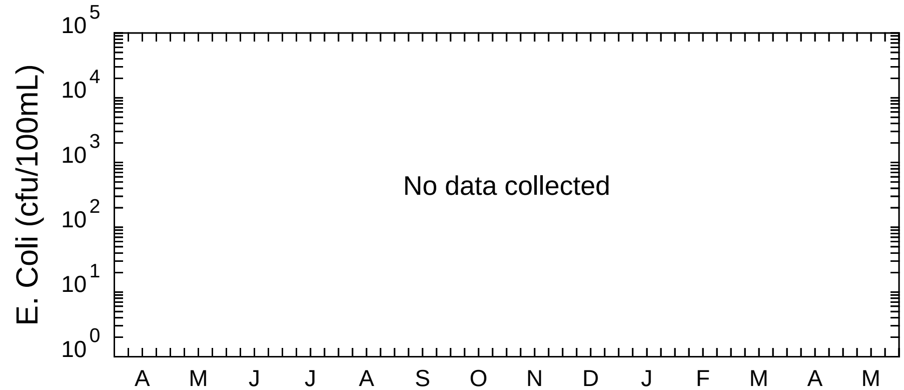










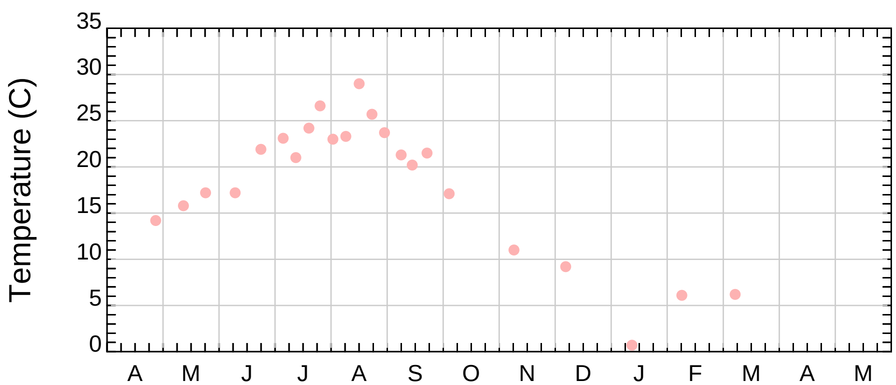


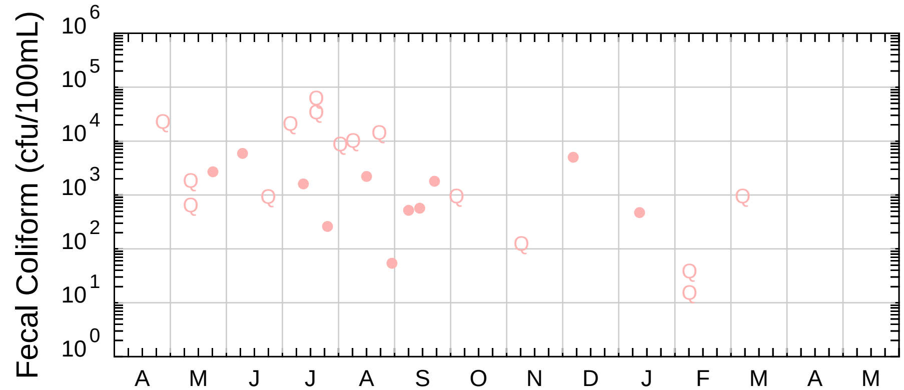
Time (Month)
2016 / 2017

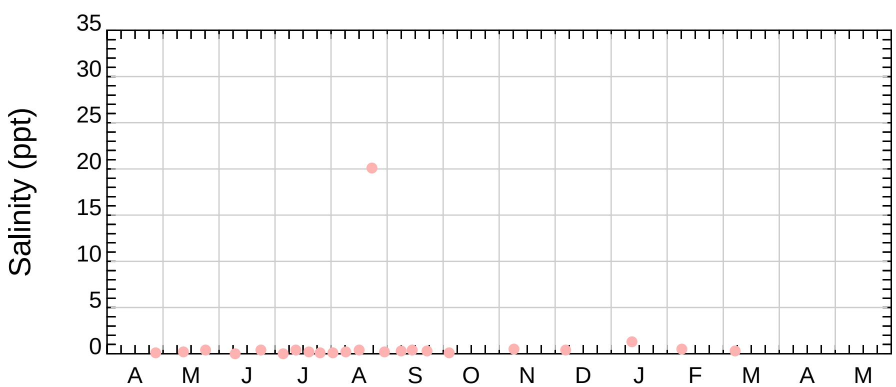
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

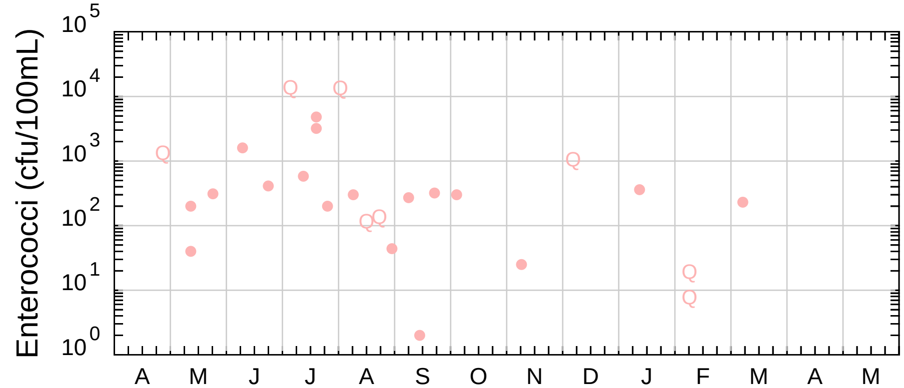
Time (Month)
2016 / 2017

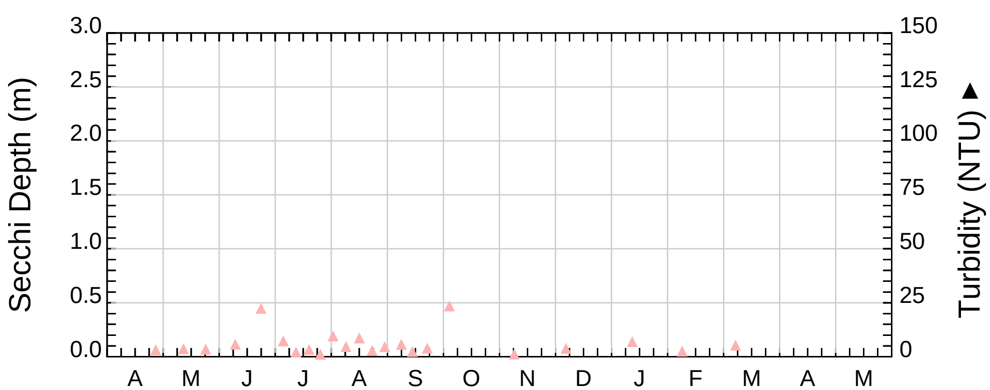
Newark Bay & Tributaries, Elizabeth River, B16, (FW2)

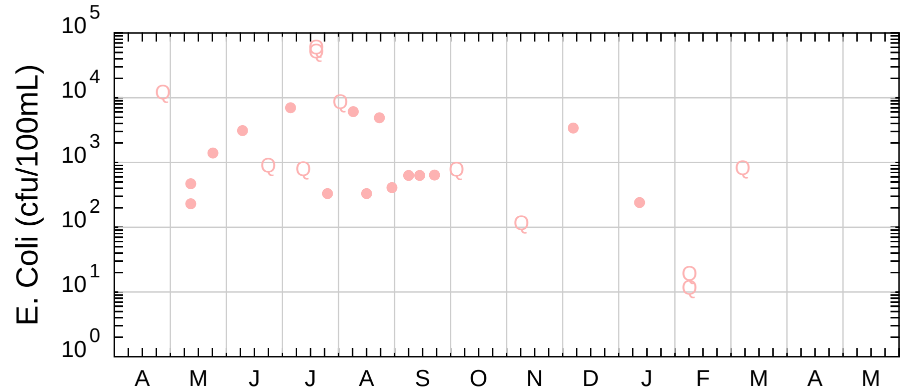










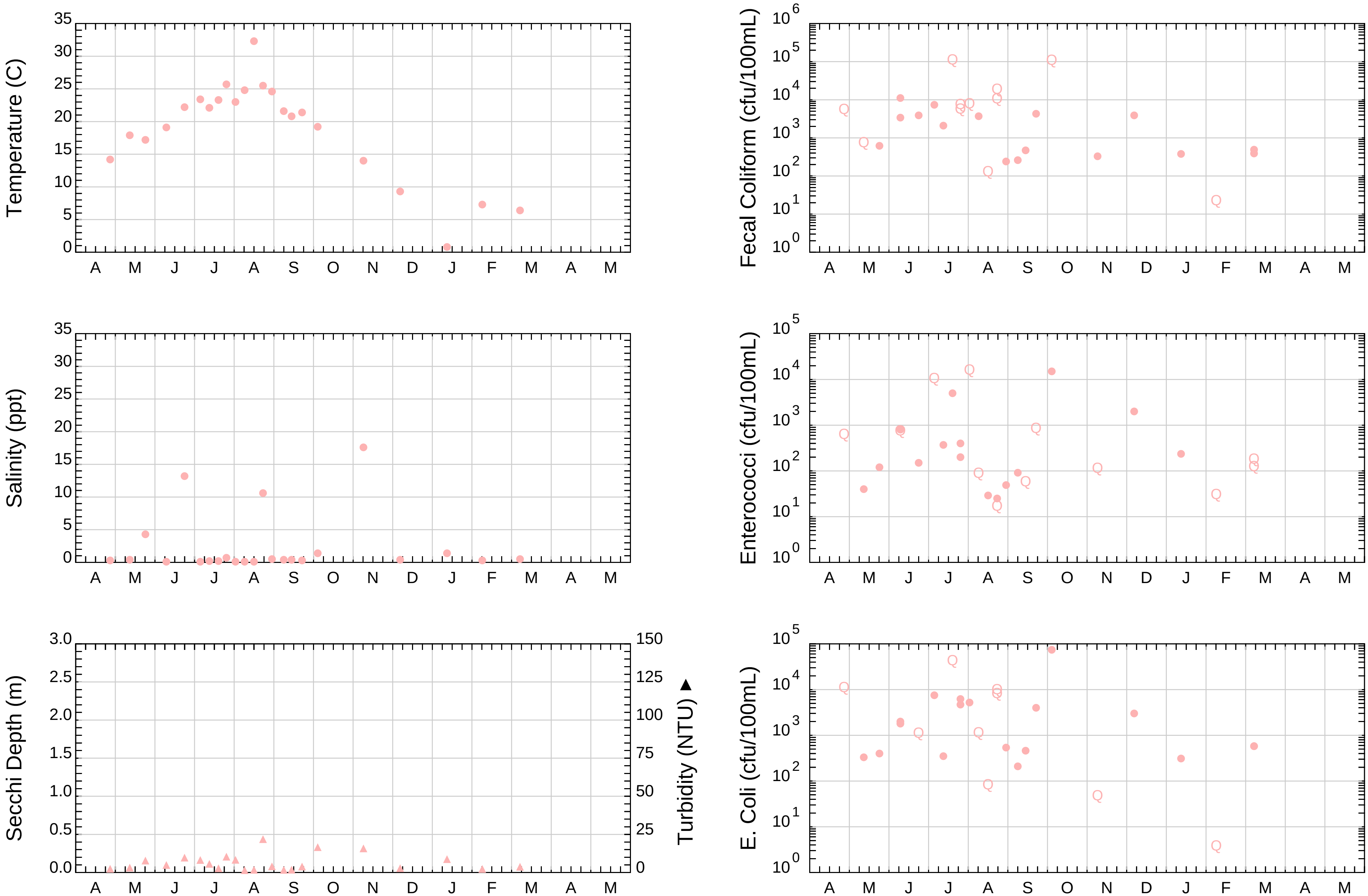


Time (Month)
2016 / 2017

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

Newark Bay & Tributaries, Elizabeth River, B14, (FW2)

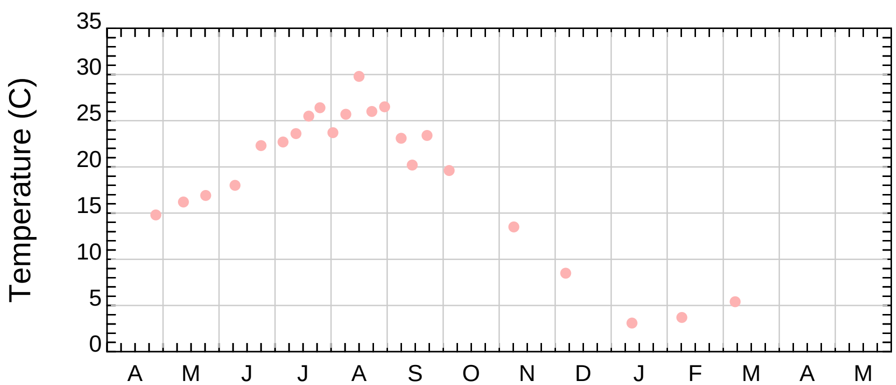


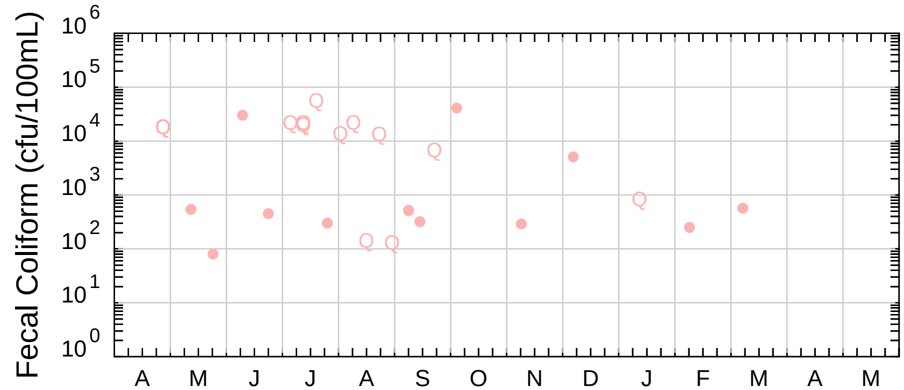
Time (Month)
2016 / 2017

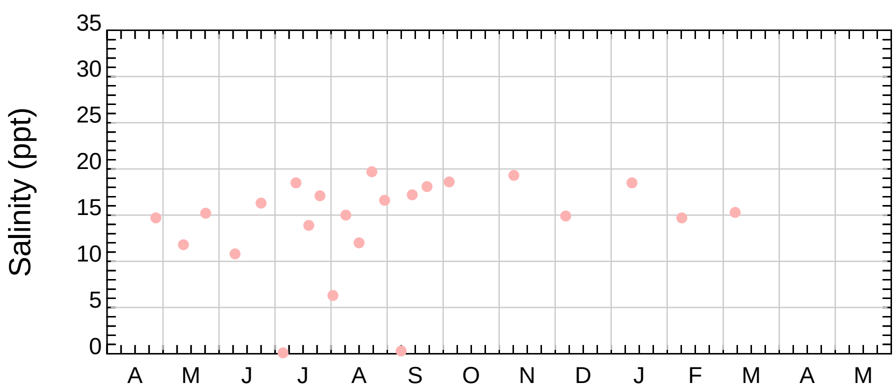
Time (Month)
2016 / 2017

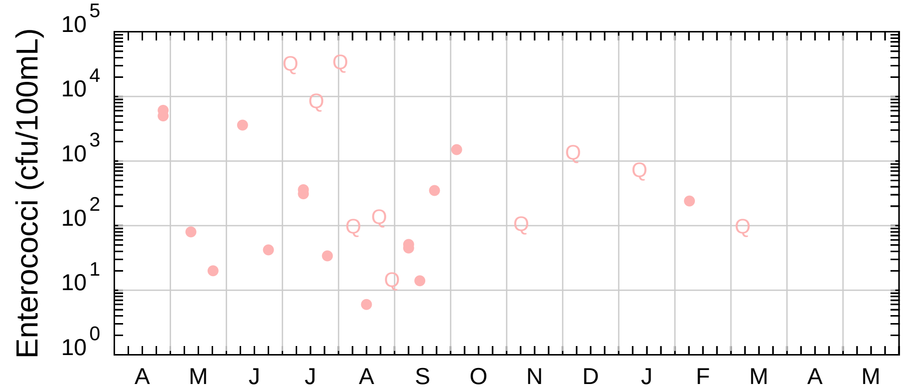
●● Surface/Mid-depth HDR
●●● Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

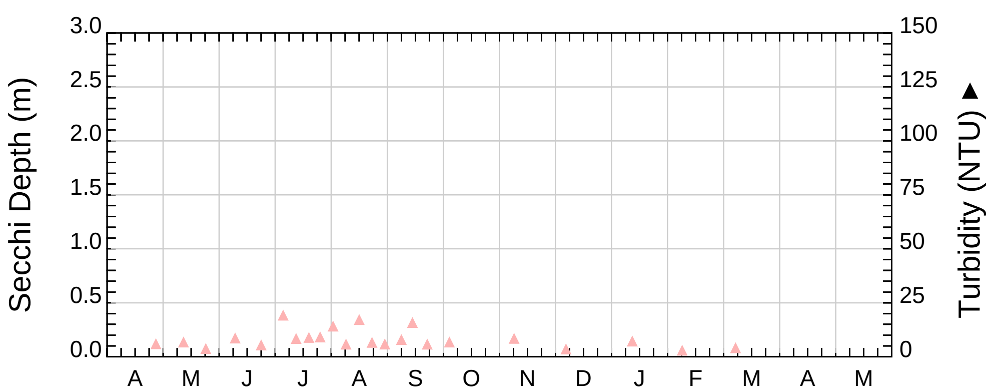
Newark Bay & Tributaries, Elizabeth River, B13, (SE3)

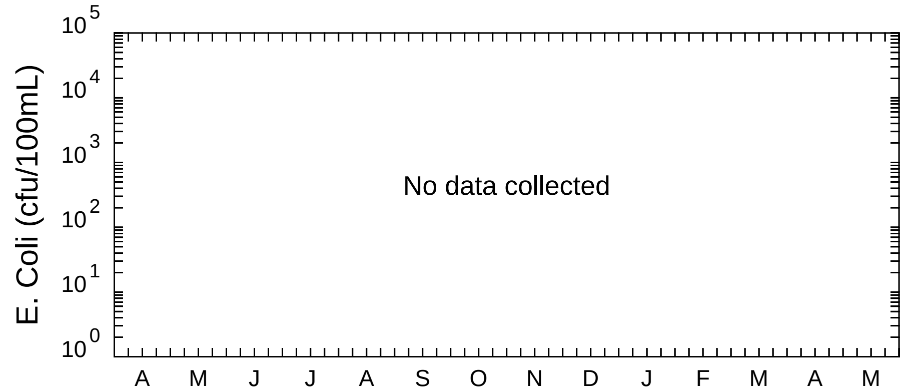










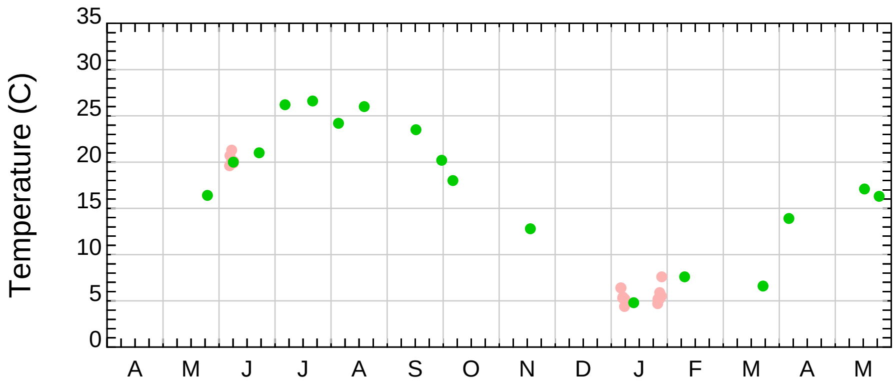


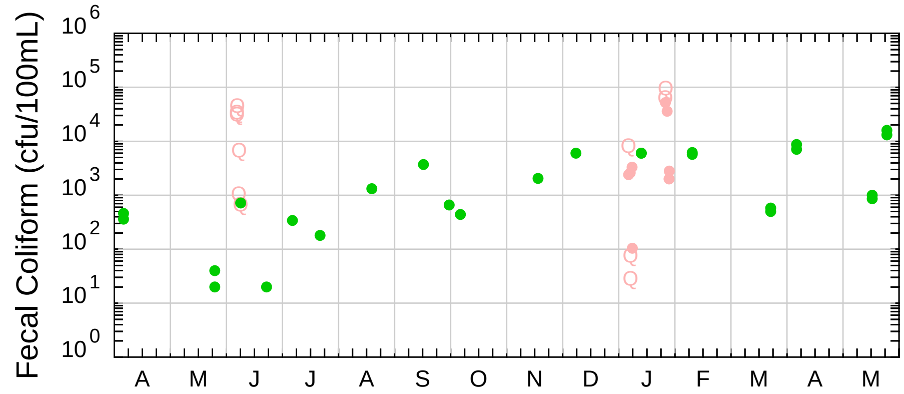
Time (Month)
2016 / 2017

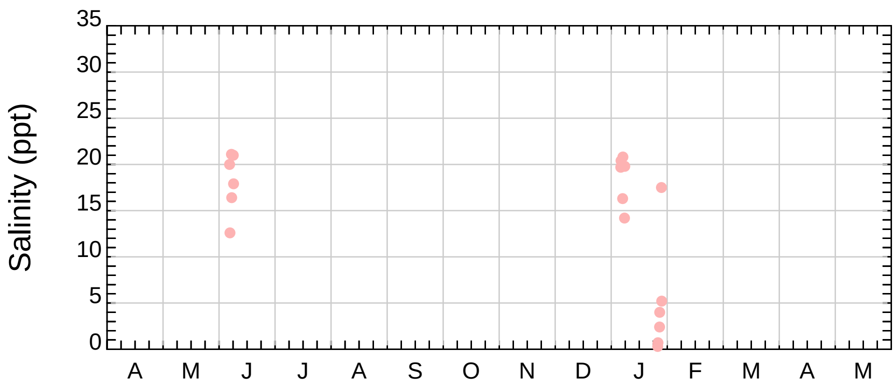
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

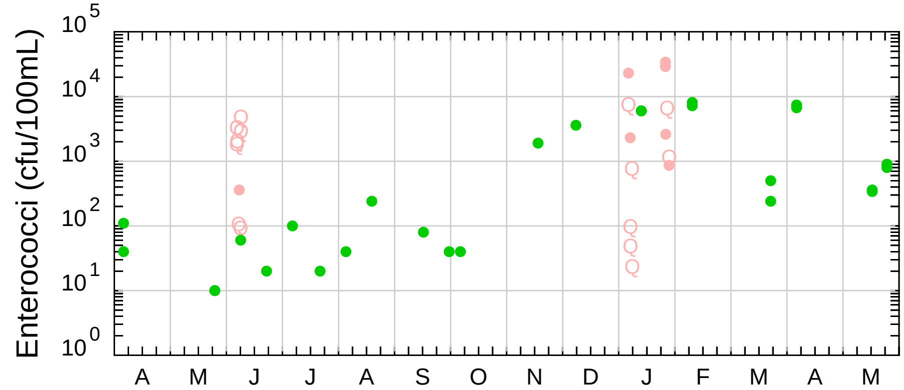
Time (Month)
2016 / 2017

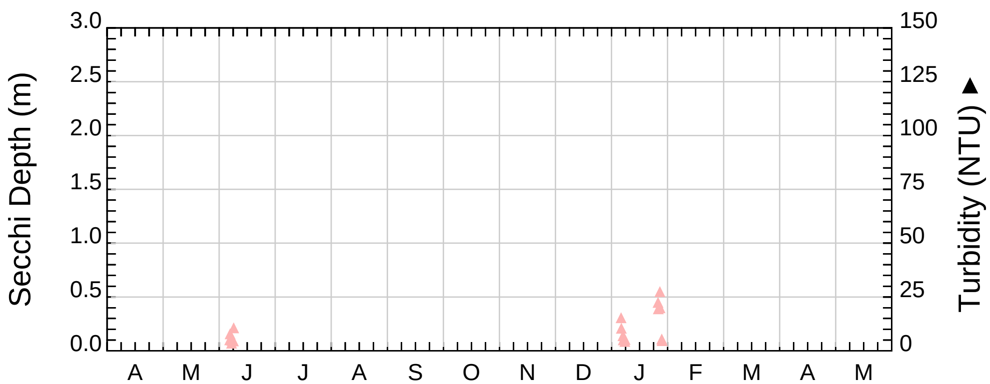
Newark Bay & Tributaries, Elizabeth River, 20, (SE3)

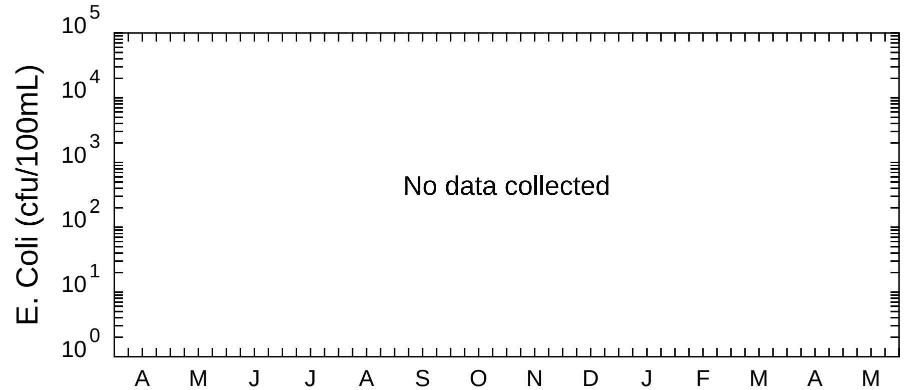










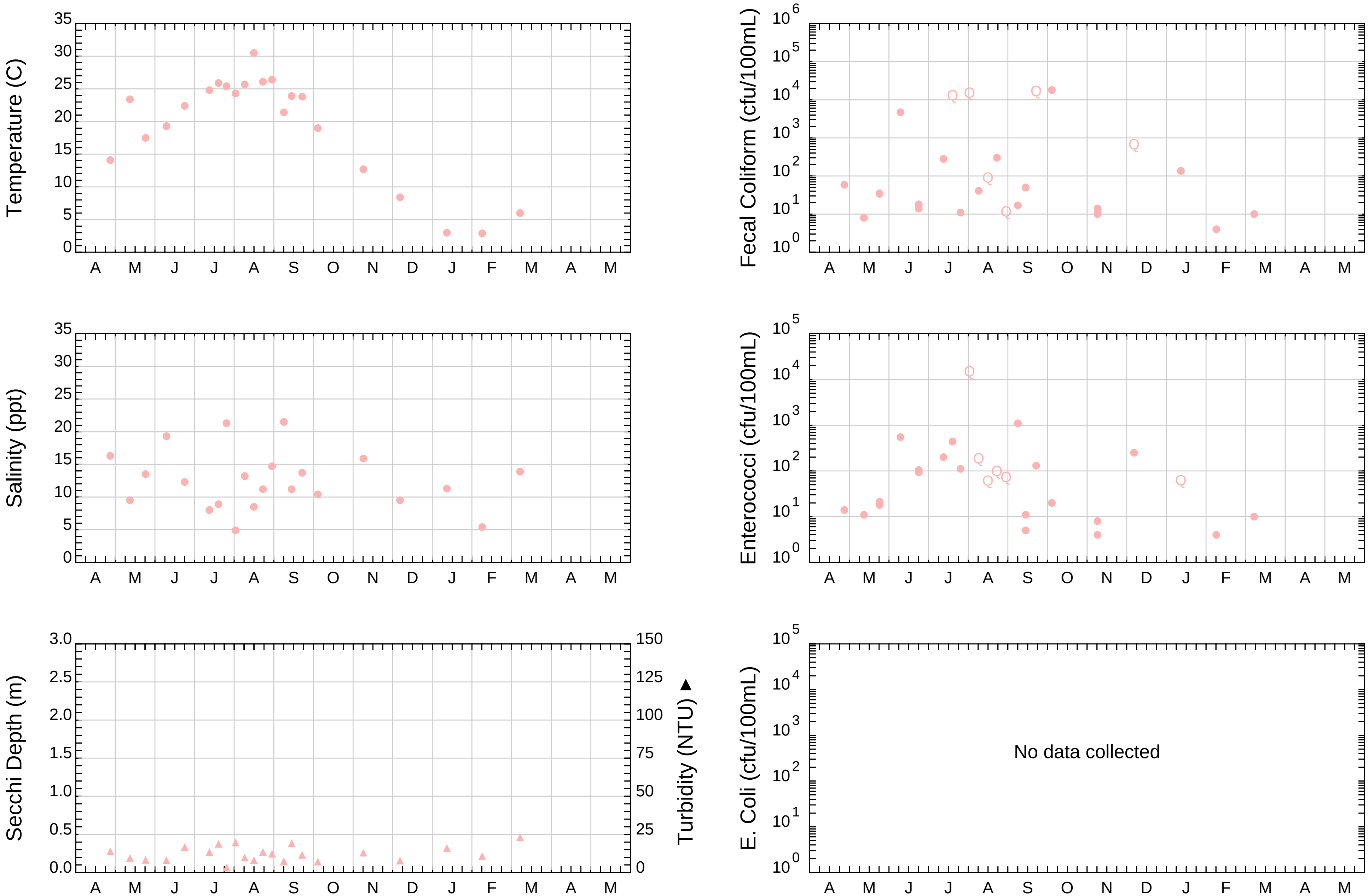


Time (Month)
2016 / 2017

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

Newark Bay & Tributaries, Peripheral Ditch, S4, (SE3)

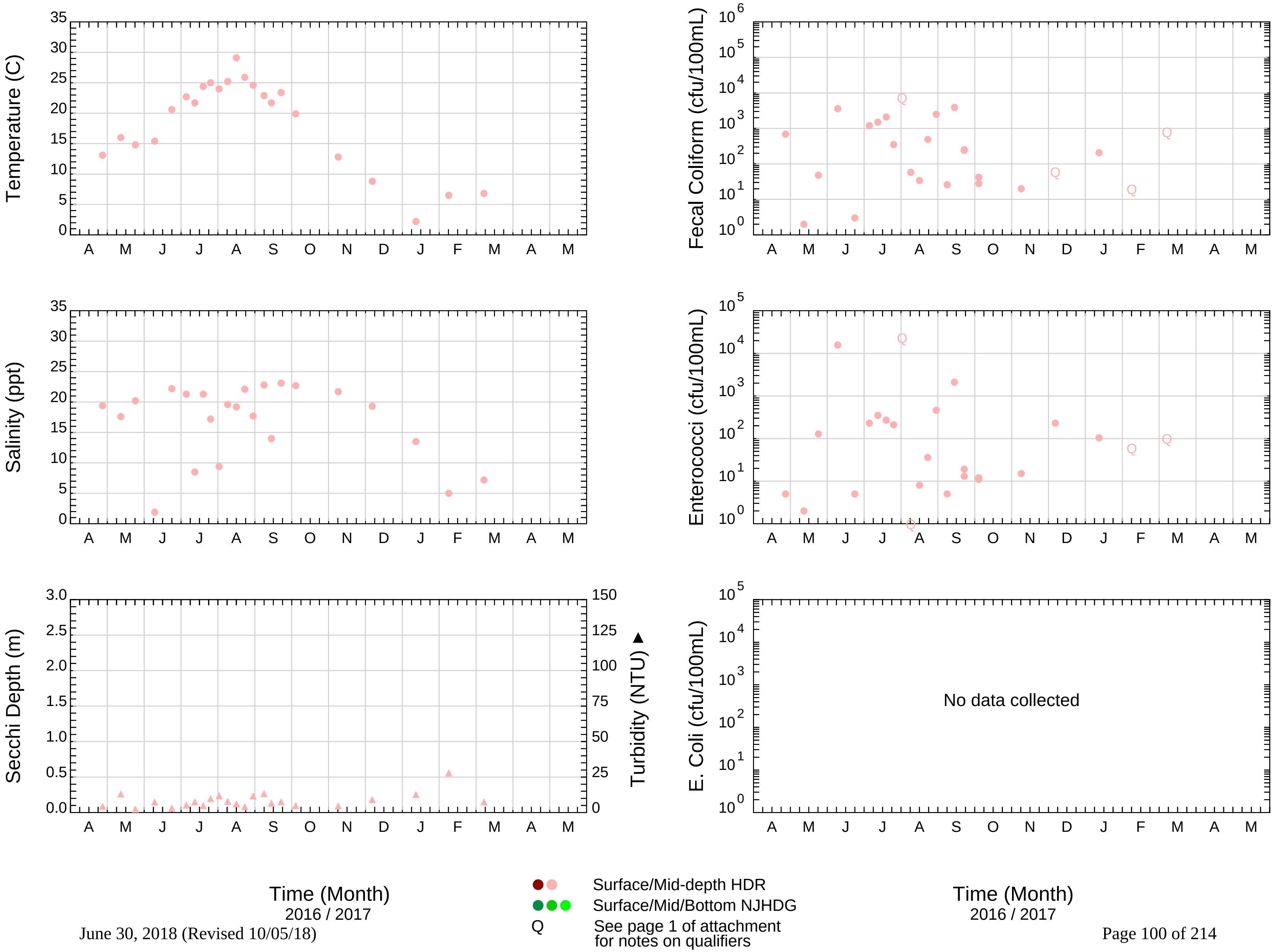


Time (Month)
2016 / 2017

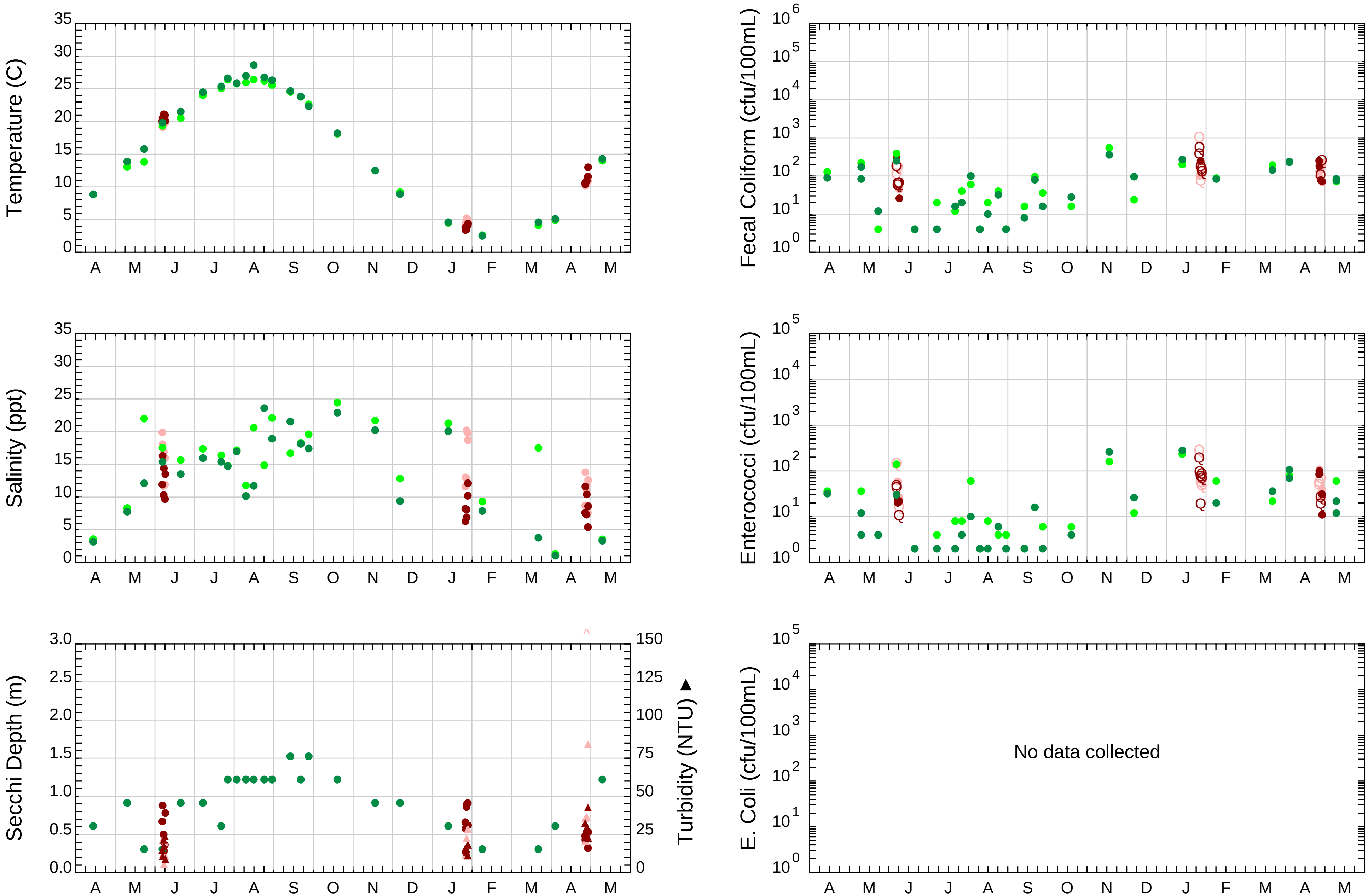
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

Newark Bay & Tributaries, Great Ditch Outlet, B25, (SE3)



Hudson River, Upper Bay, Hudson River, 31, (SE2)

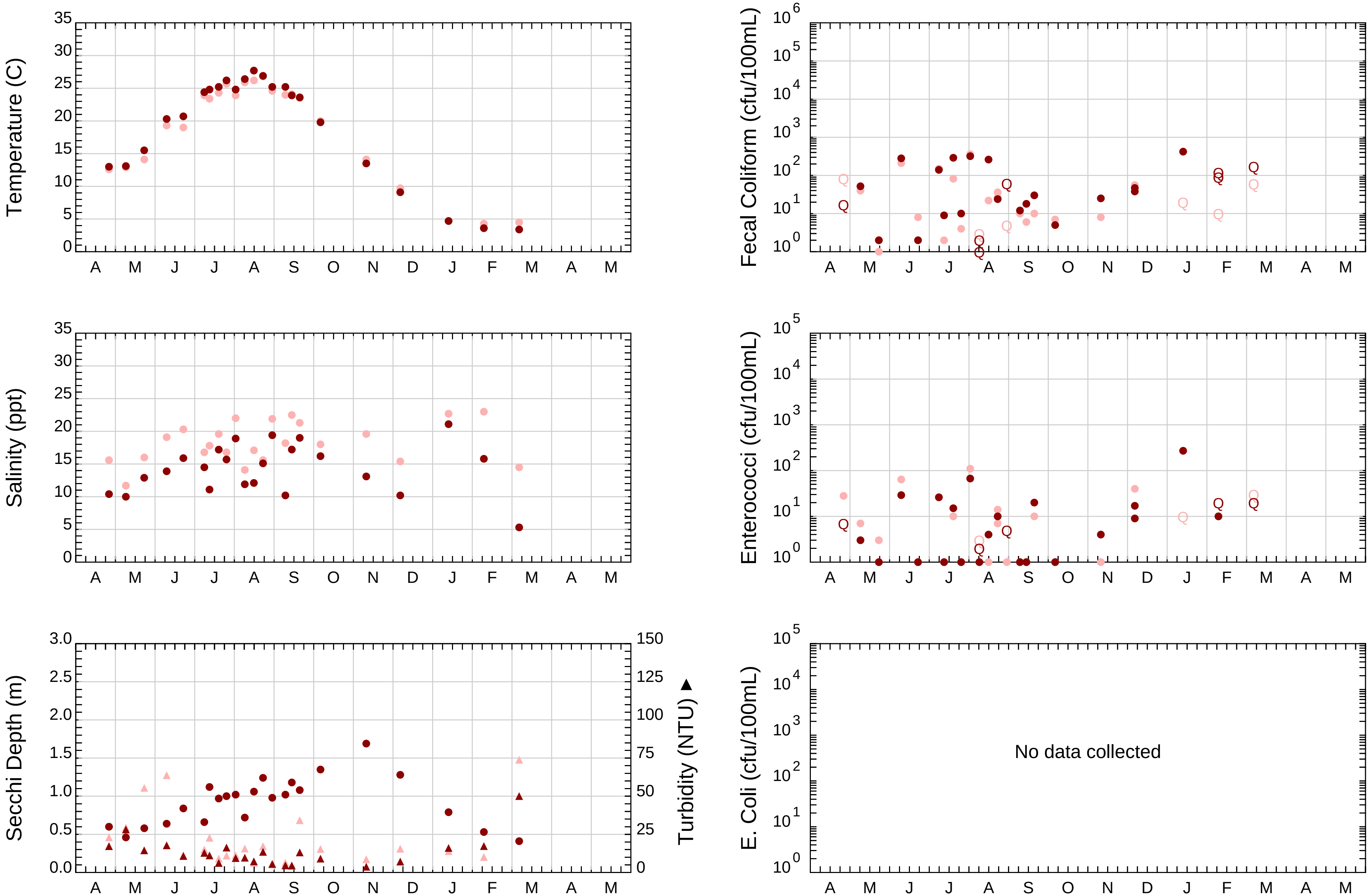


Time (Month)
2016 / 2017

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

Hudson River, Upper Bay, Hudson River, B5A, (SE2)

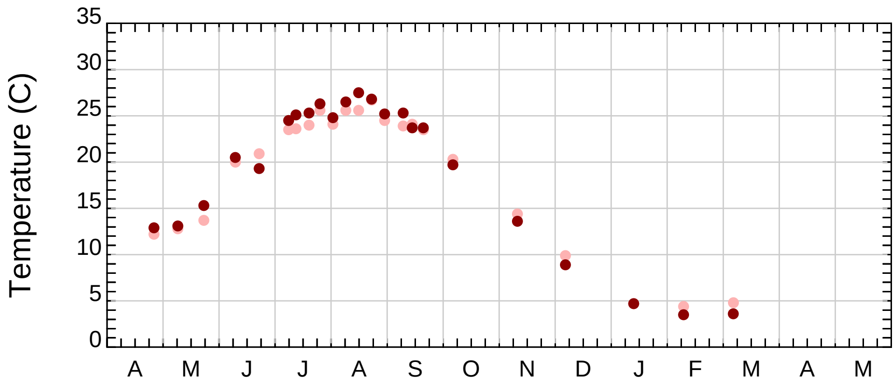


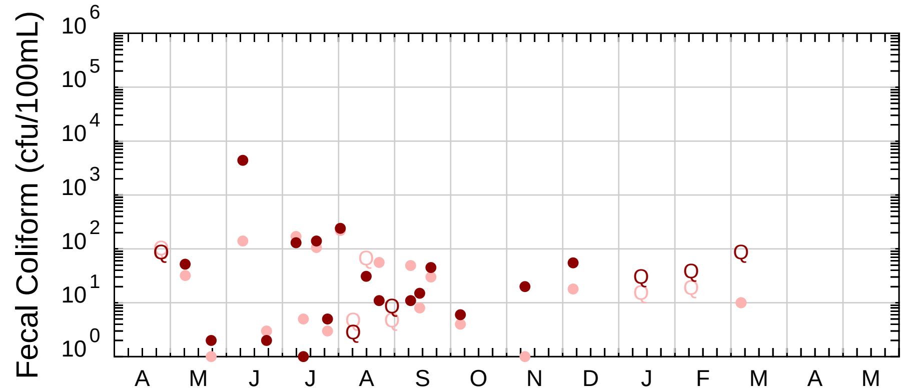
Time (Month)
2016 / 2017

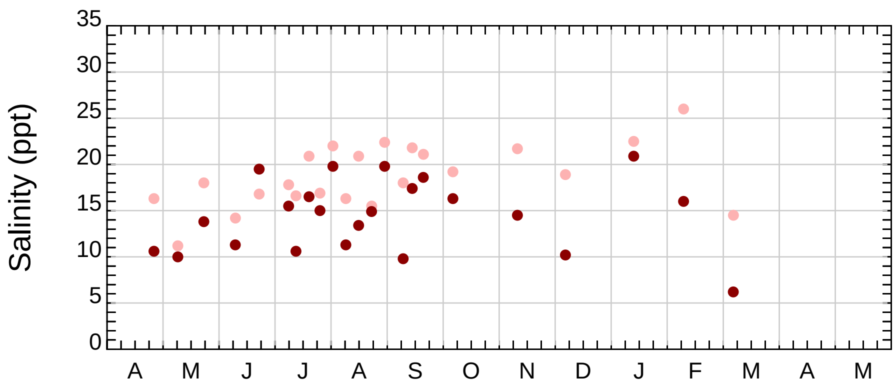
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

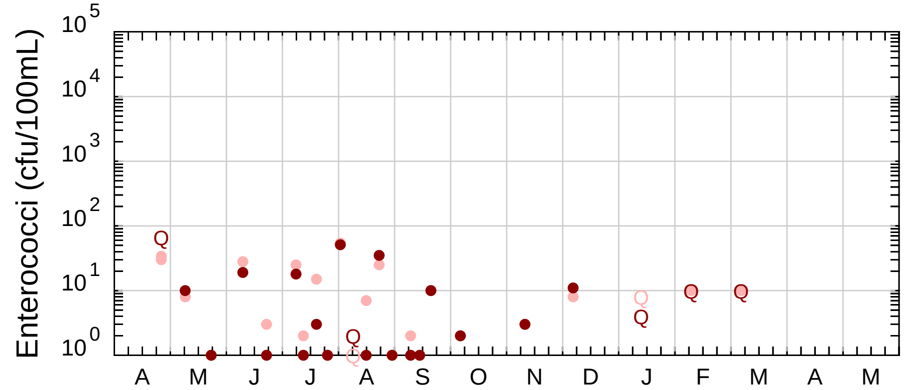
Time (Month)
2016 / 2017

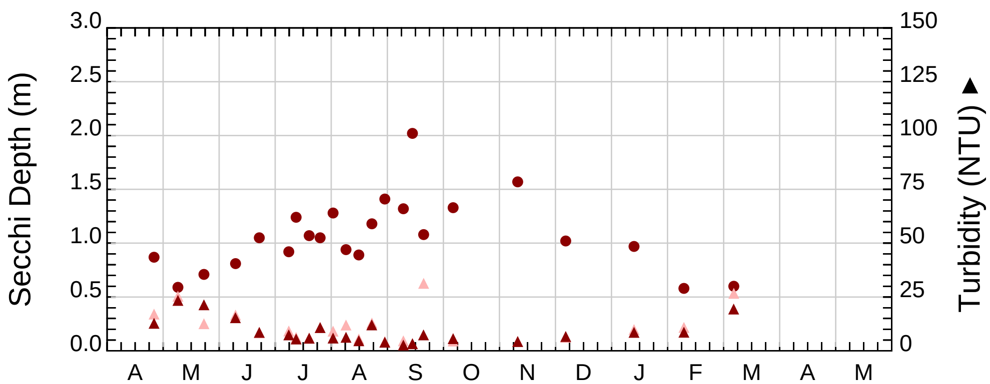
Hudson River, Upper Bay, Hudson River, B5B, (SE2)

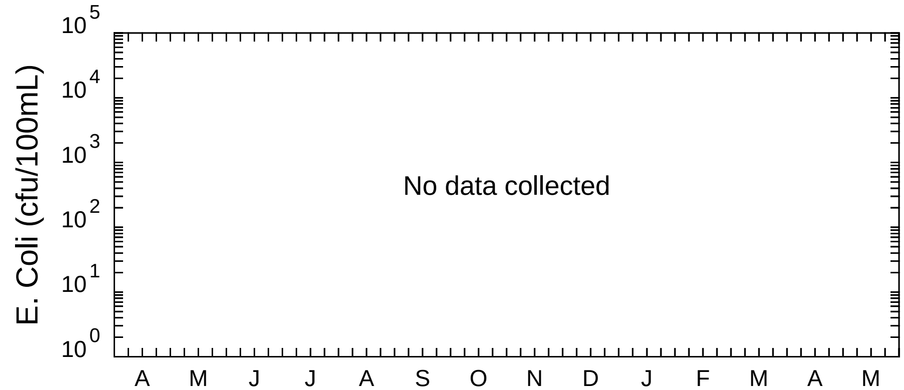










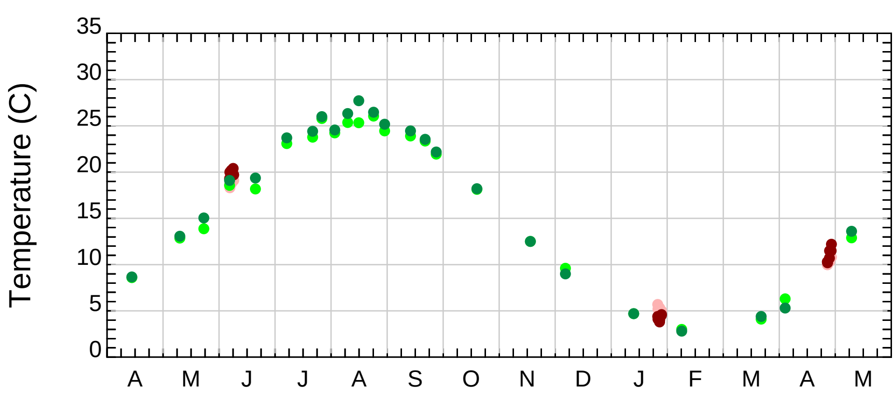


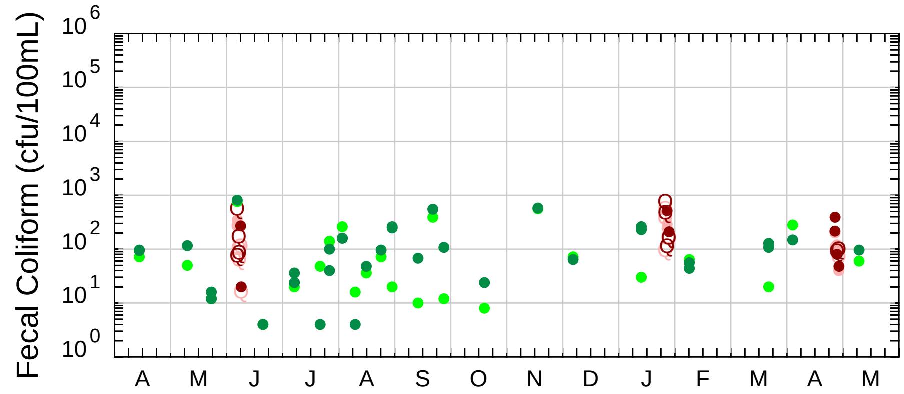
Time (Month)
2016 / 2017

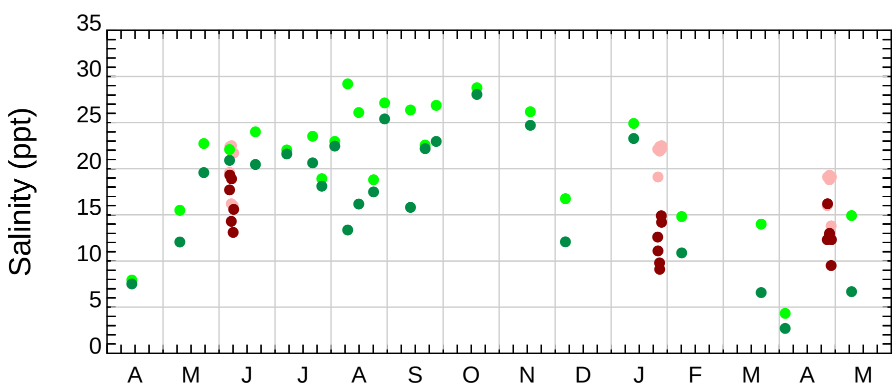
●● Surface/Mid-depth HDR
●●● Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

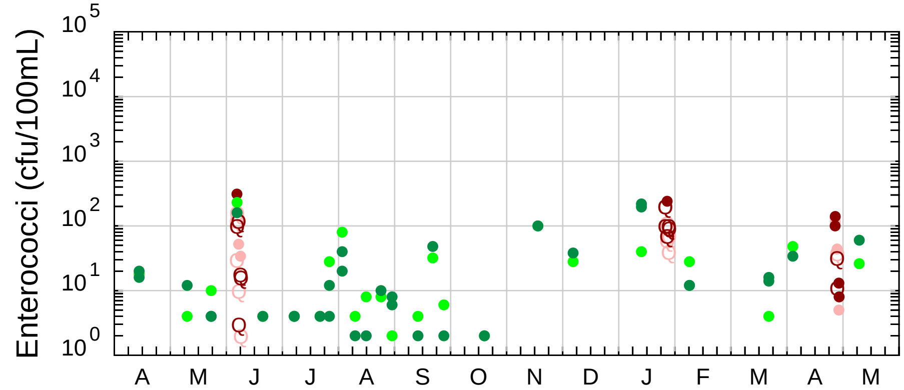
Time (Month)
2016 / 2017

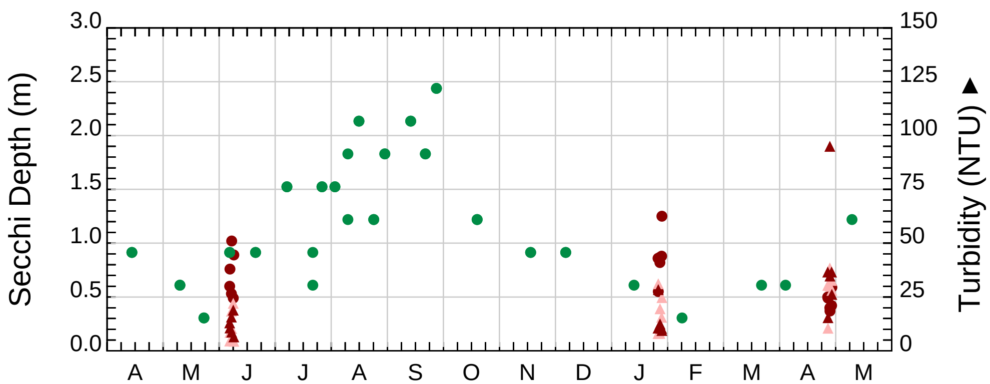
Hudson River, Upper Bay, Hudson River, 32, (SE2)

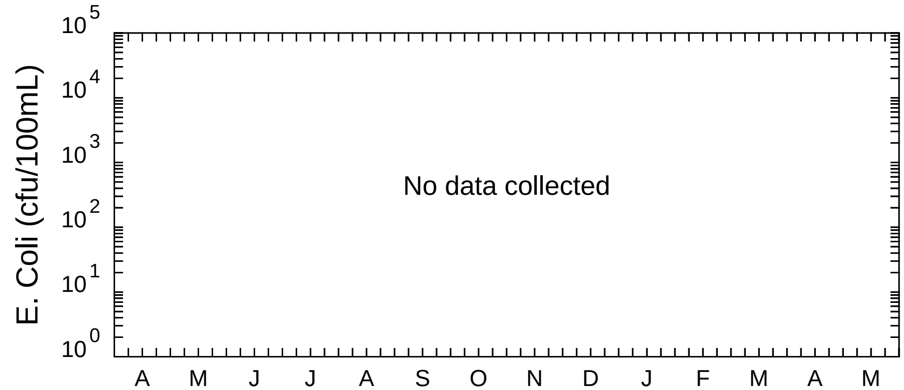










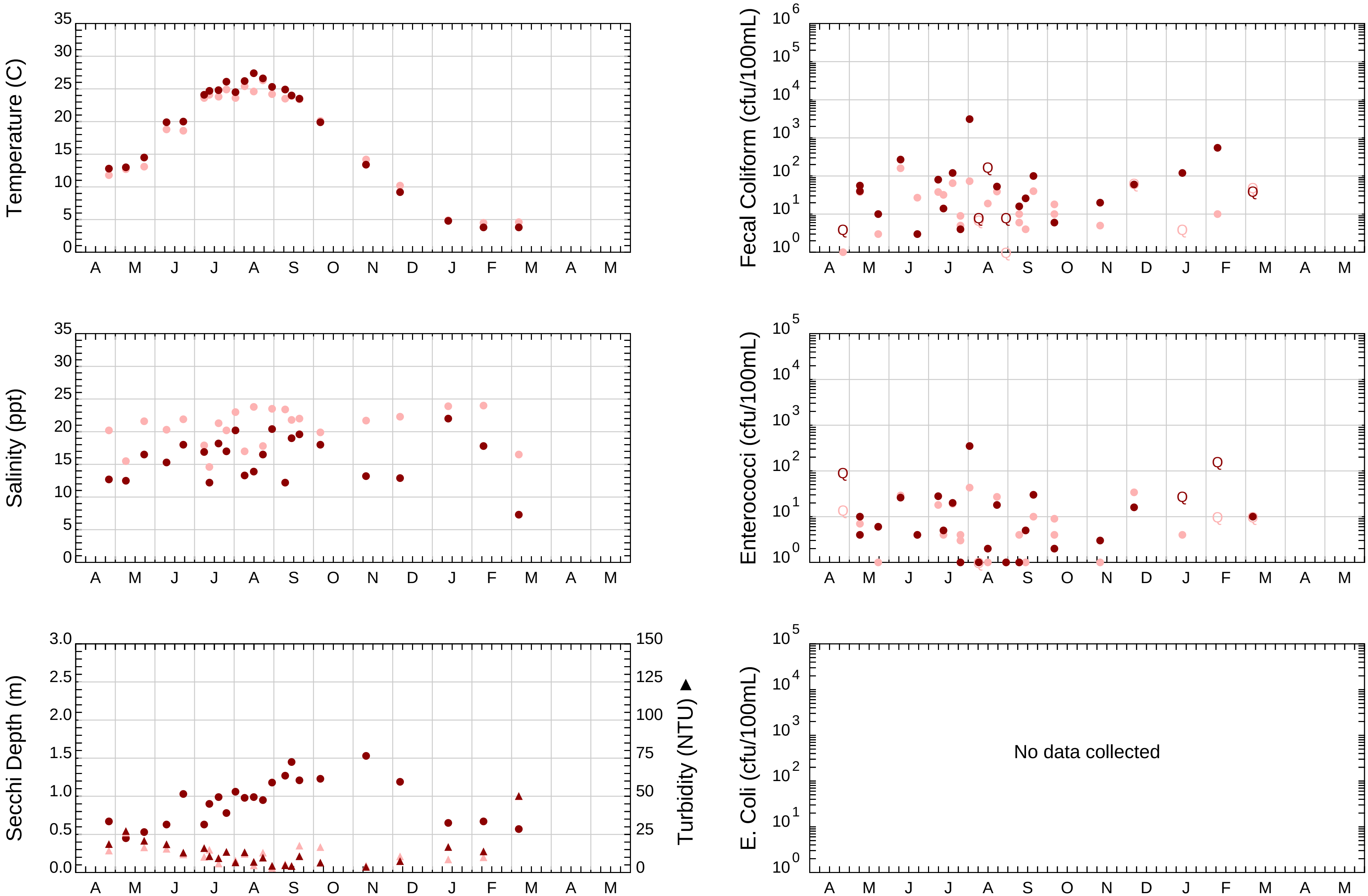


Time (Month)
2016 / 2017

●● Surface/Mid-depth HDR
●●● Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

Hudson River, Upper Bay, Hudson River, B18A, (SE2)

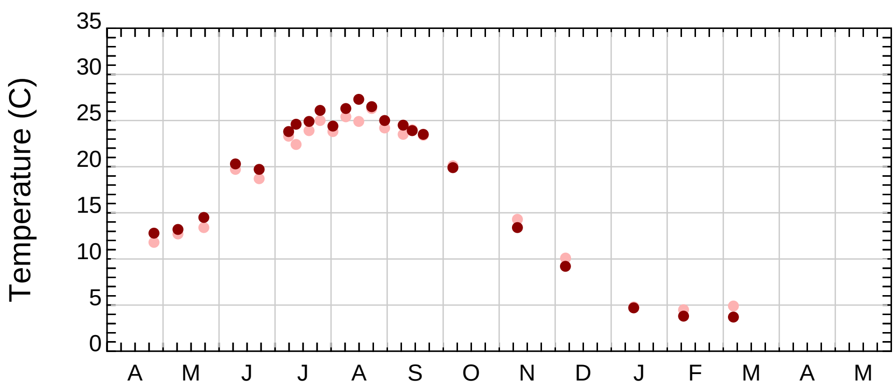


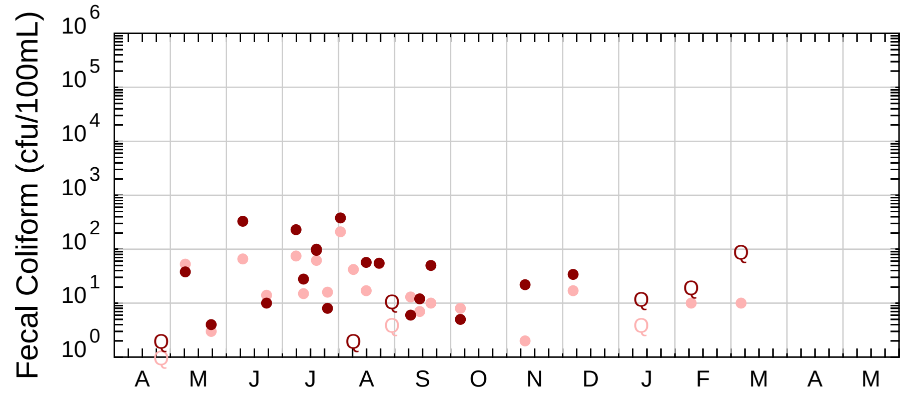
Time (Month)
2016 / 2017

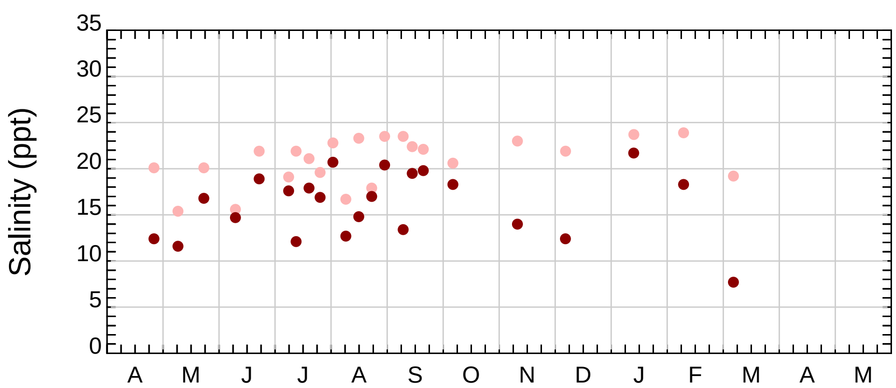
Time (Month)
2016 / 2017

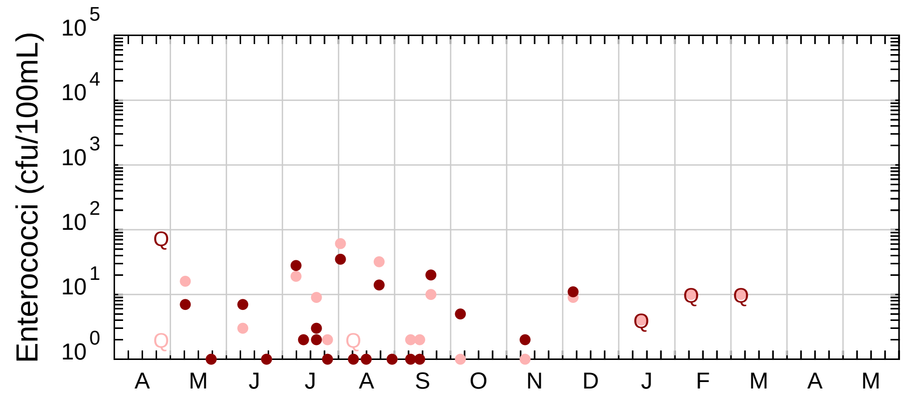
●● Surface/Mid-depth HDR
●●● Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

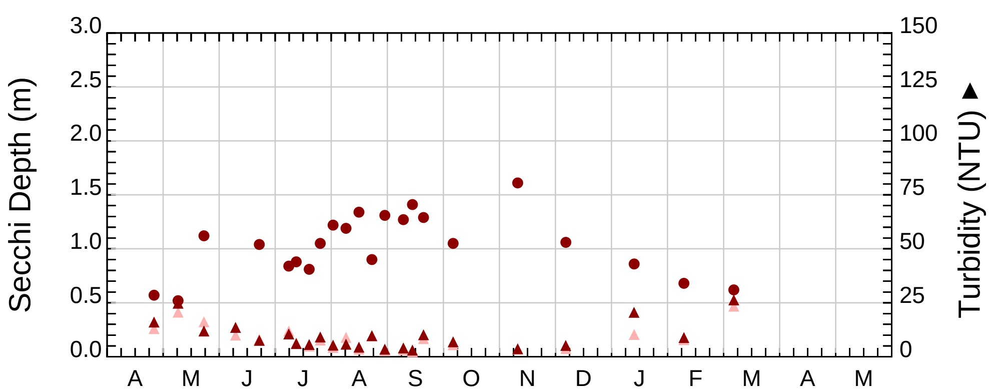
Hudson River, Upper Bay, Hudson River, B18B, (SE2)

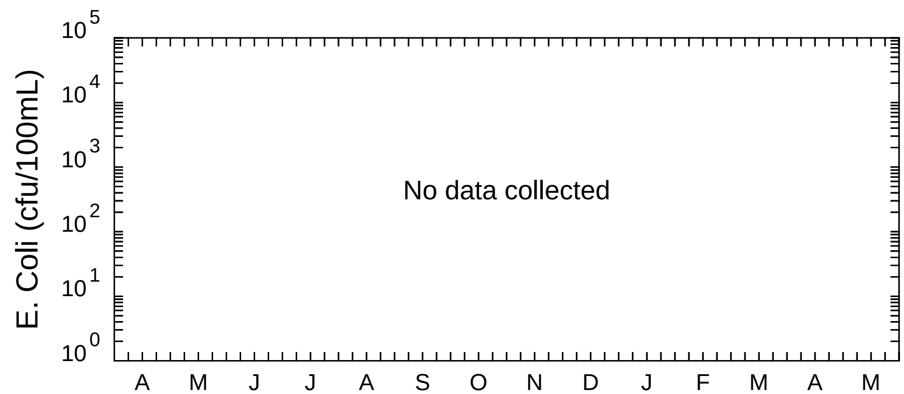








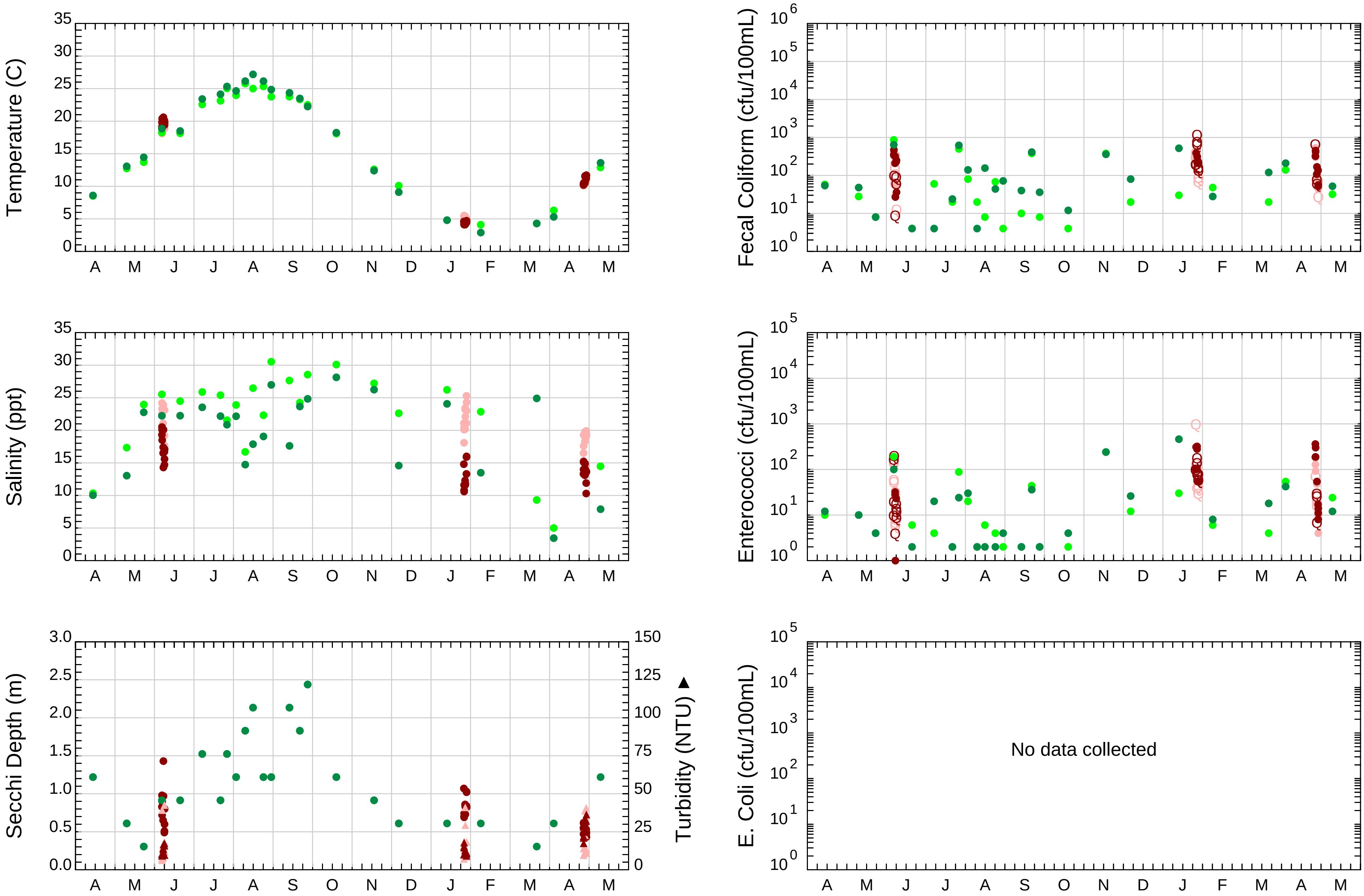




Time (Month)
2016 / 2017

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

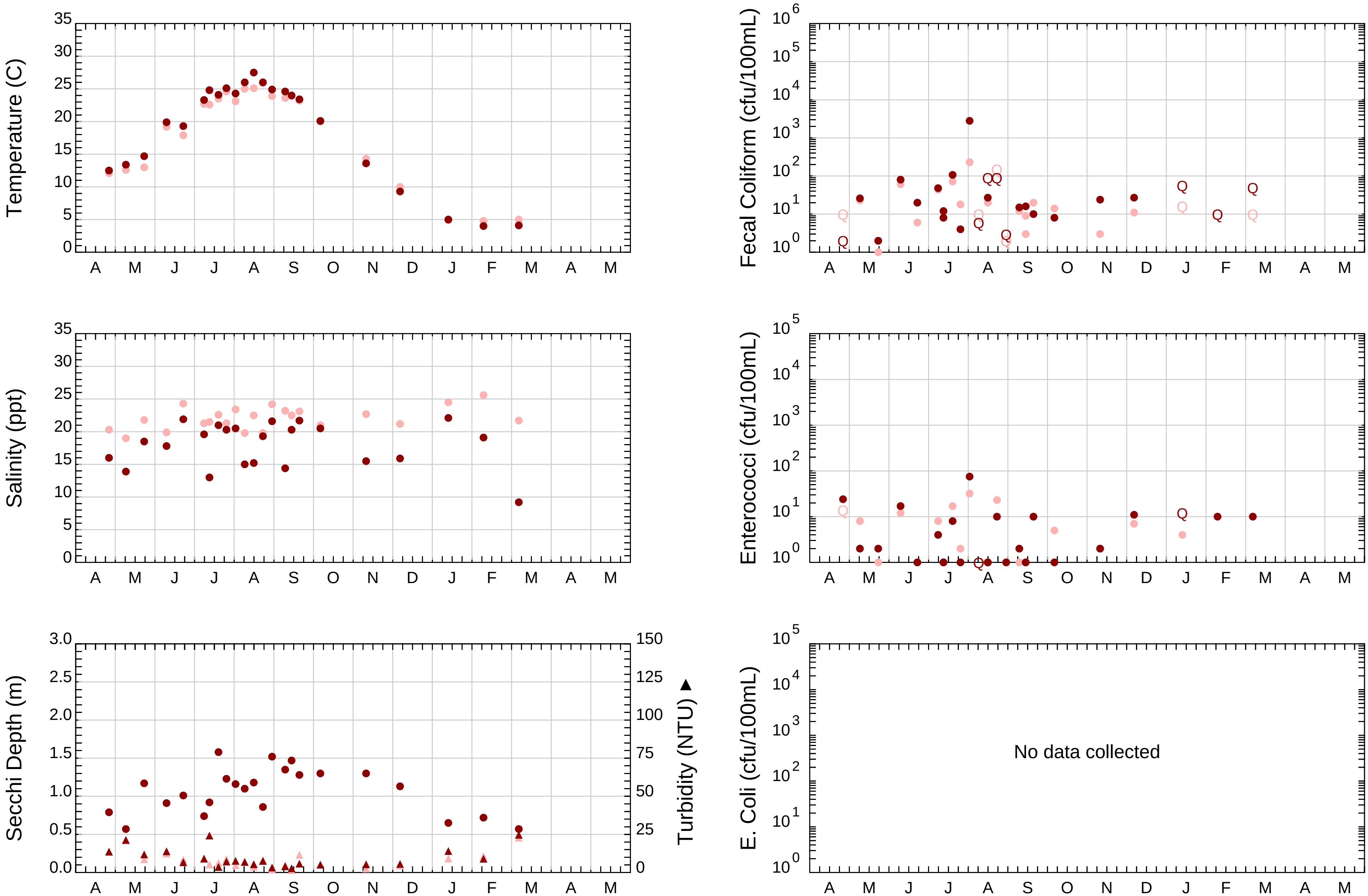


Time (Month)
2016 / 2017

Time (Month)
2016 / 2017

●● Surface/Mid-depth HDR
●●● Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Hudson River, Upper Bay, Hudson River, B23A, (SE2)

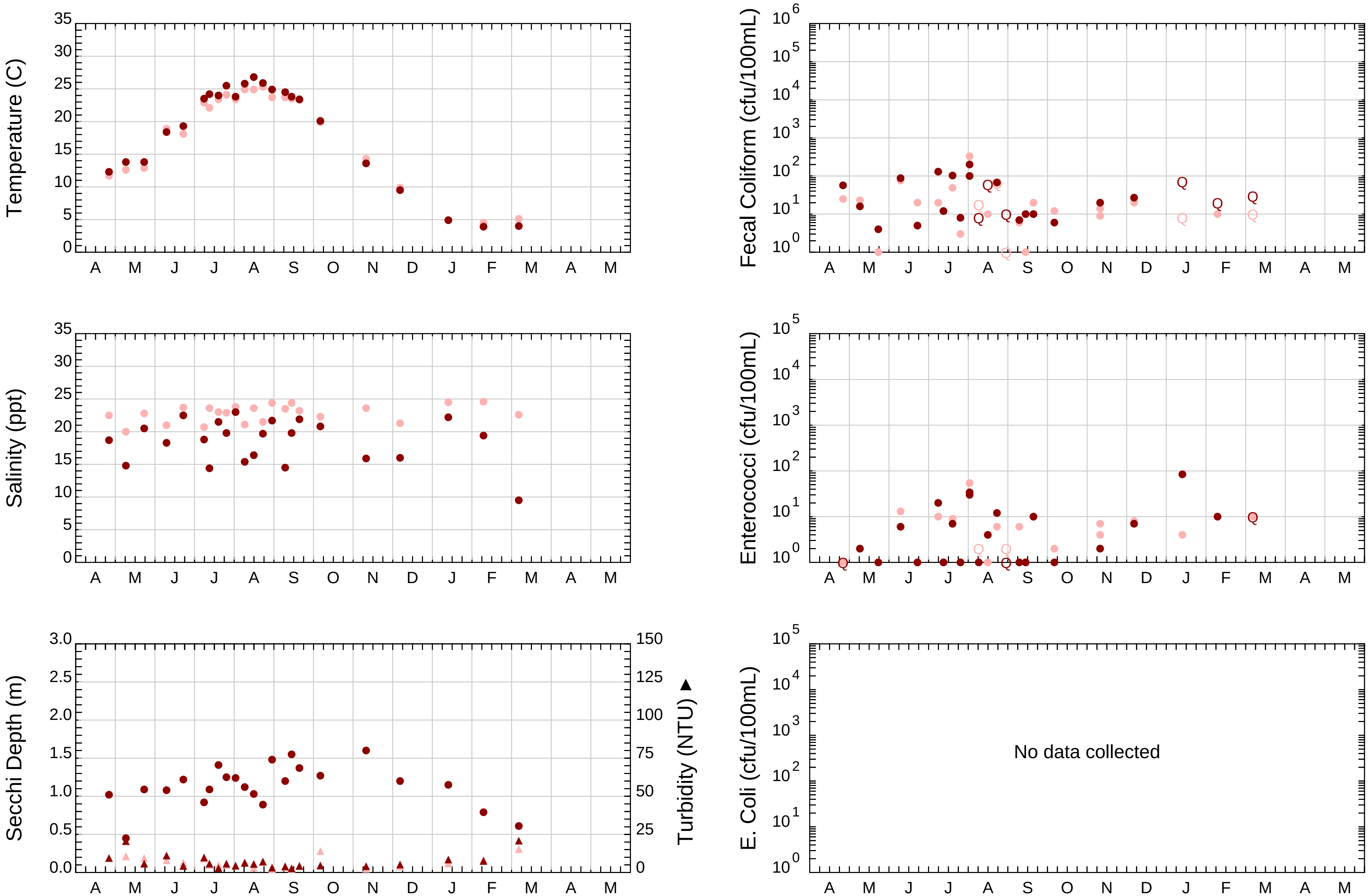


Time (Month)
2016 / 2017

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

Hudson River, Upper Bay, Hudson River, B23B, (SE2)

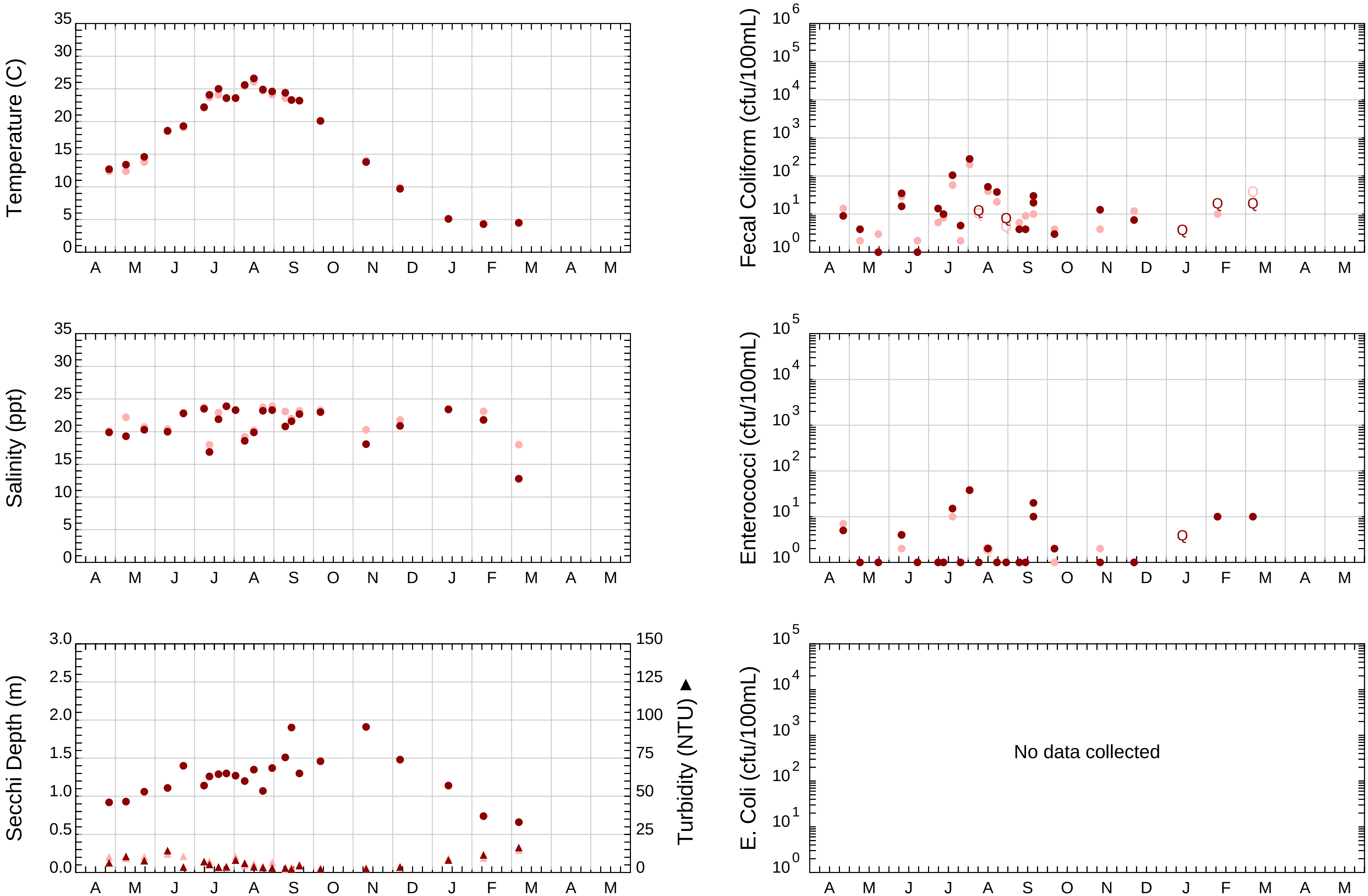


Time (Month)
2016 / 2017

Time (Month)
2016 / 2017

●● Surface/Mid-depth HDR
●●● Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Hudson River, Upper Bay, Upper Bay, B9, (SE2)

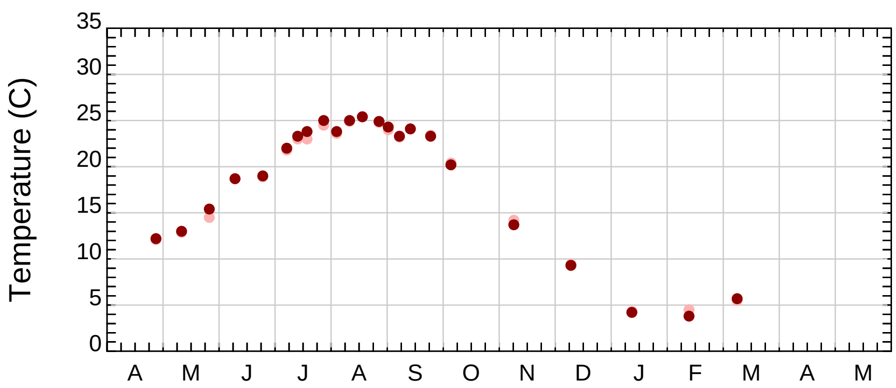


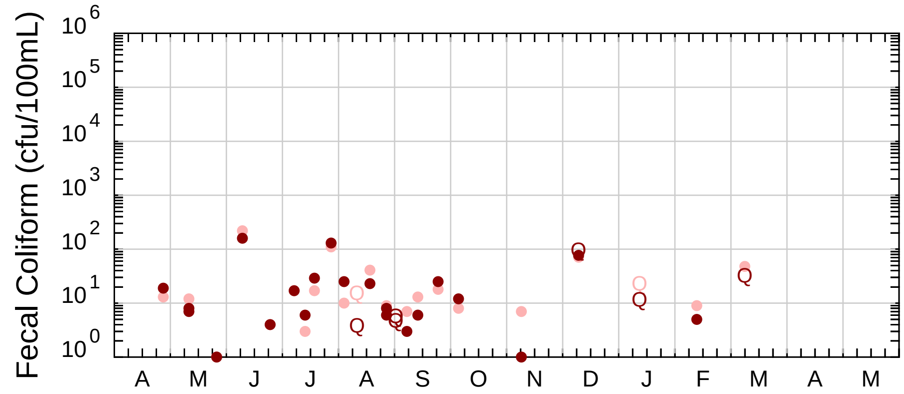
Time (Month)
2016 / 2017

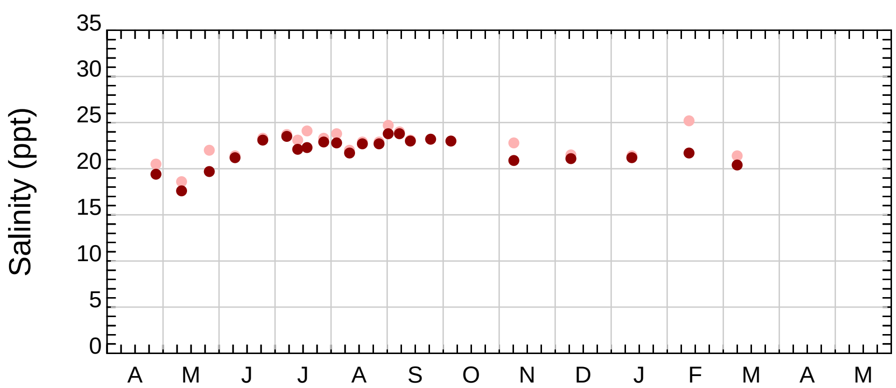
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

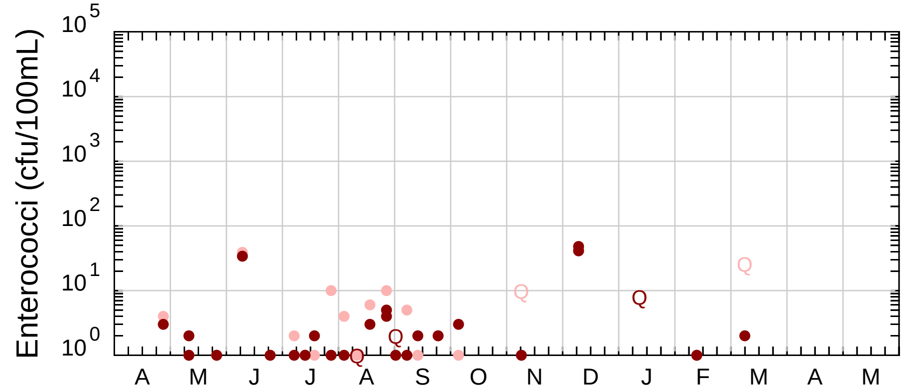
Time (Month)
2016 / 2017

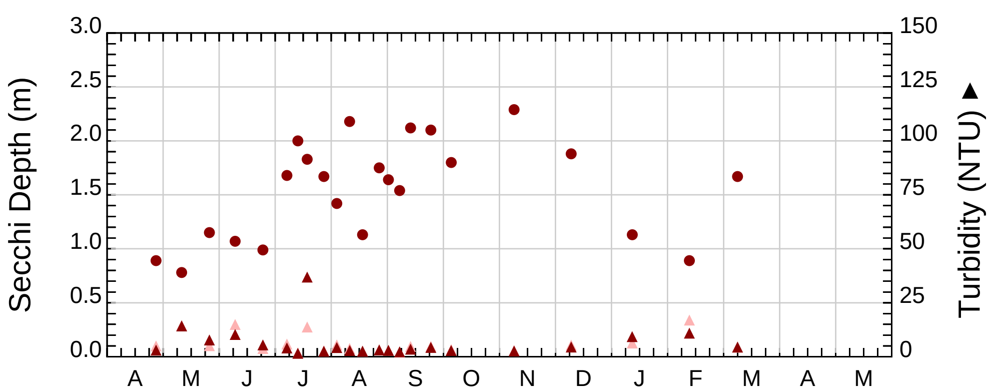
Hudson River, Upper Bay, Upper Bay, B20, (SE3)

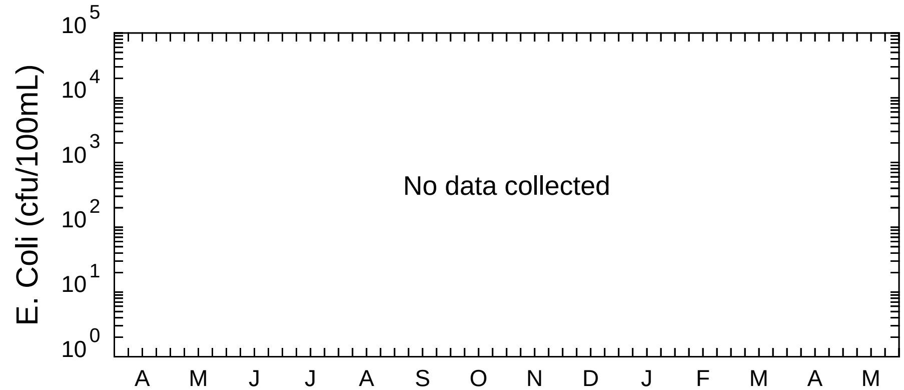










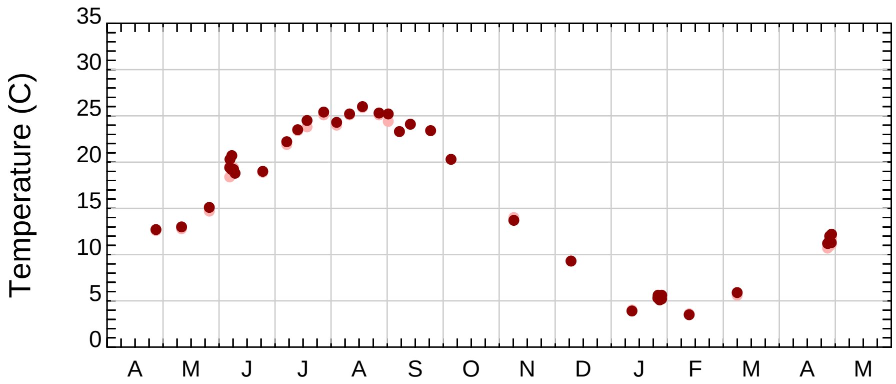


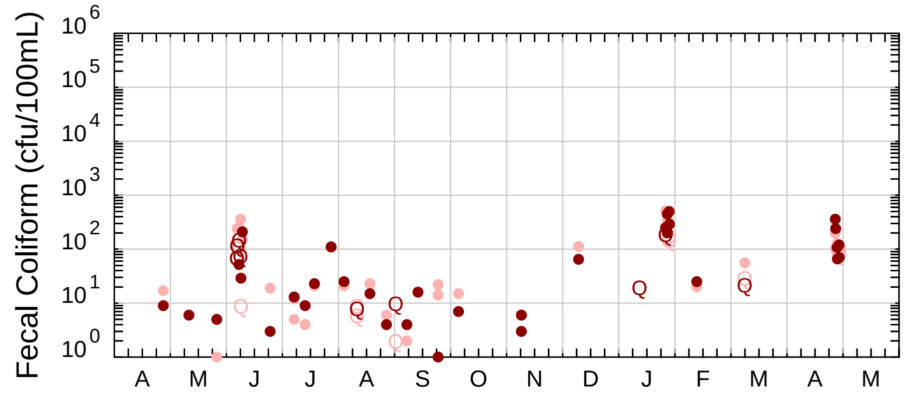
Time (Month)
2016 / 2017

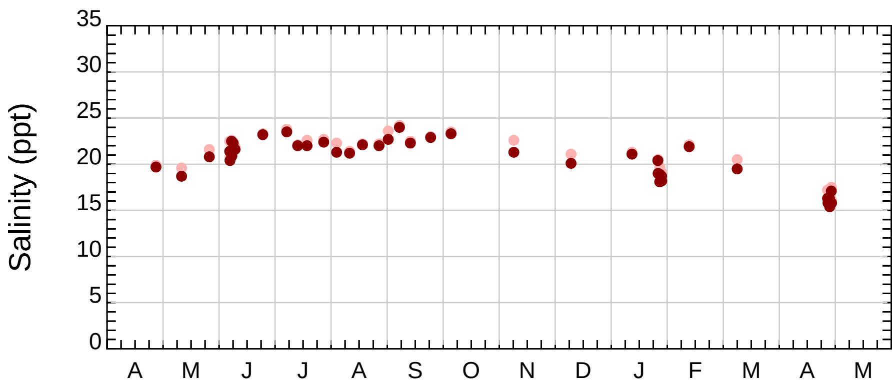
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

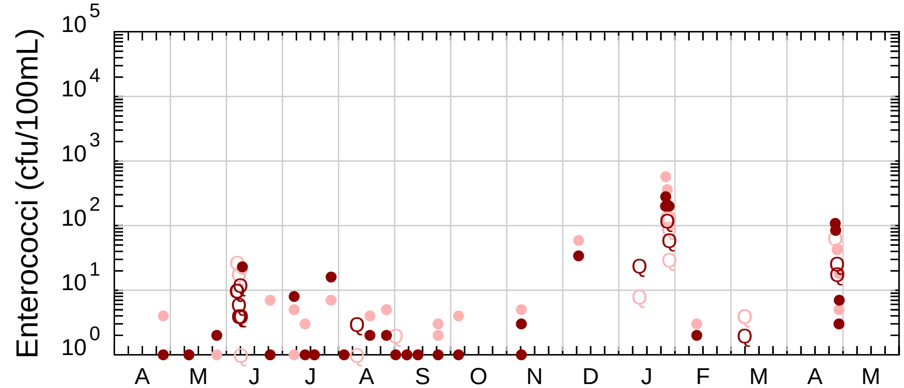
Time (Month)
2016 / 2017

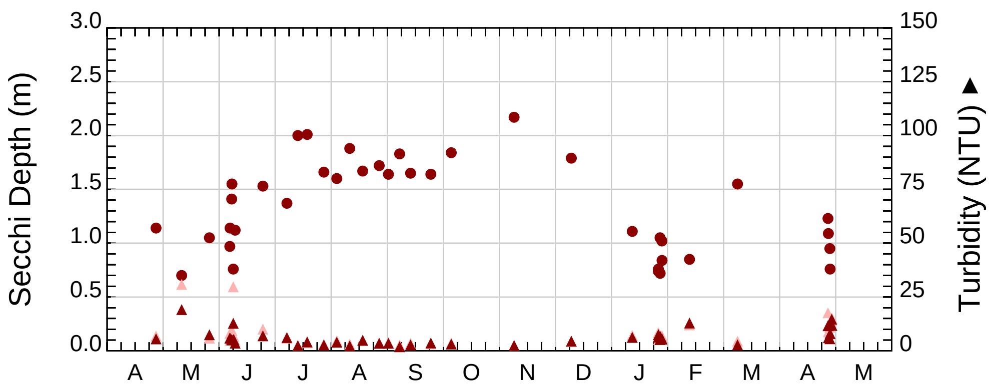
Hudson River, Upper Bay, Kill Van Kull, B12, (SE3)

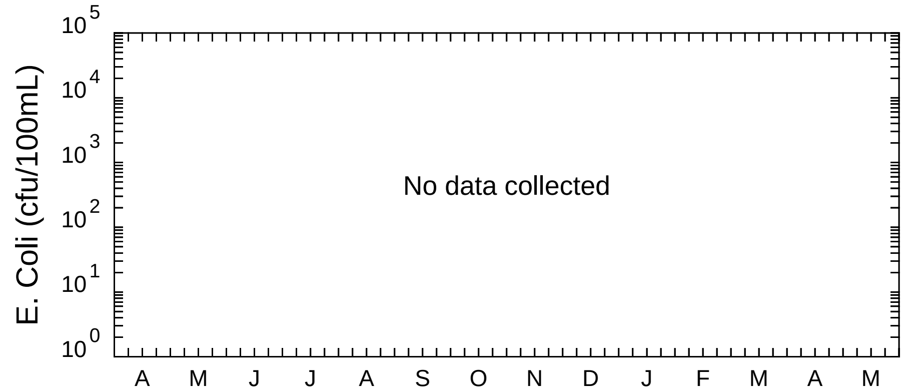










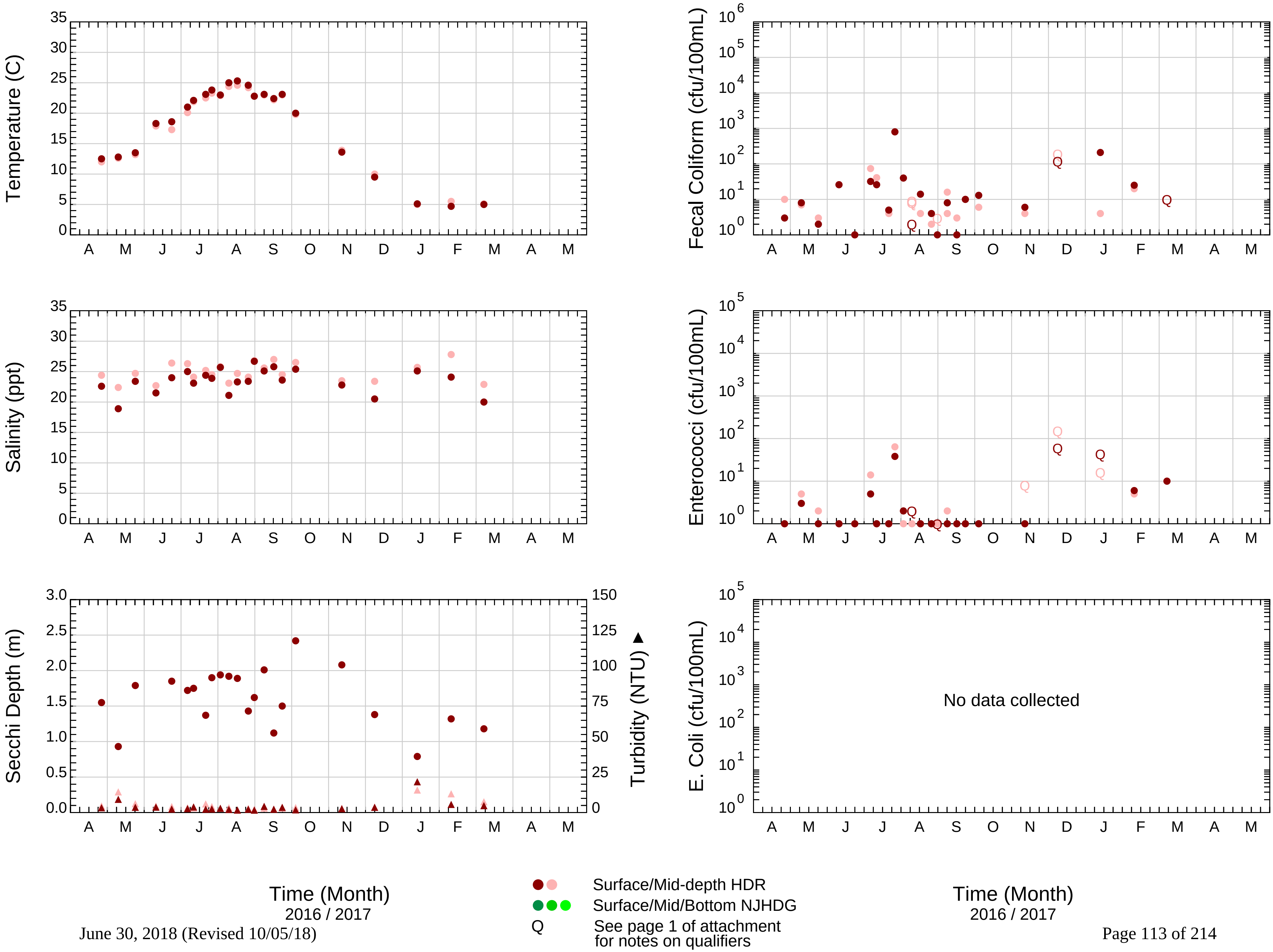


Time (Month)
2016 / 2017

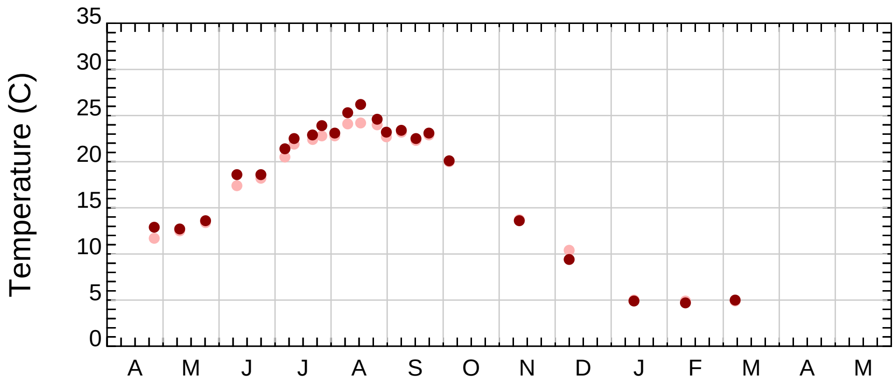
●● Surface/Mid-depth HDR
●●● Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

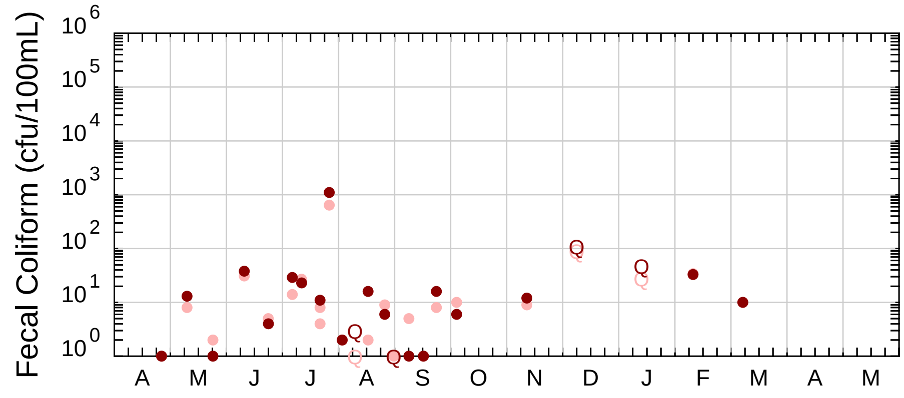
Time (Month)
2016 / 2017

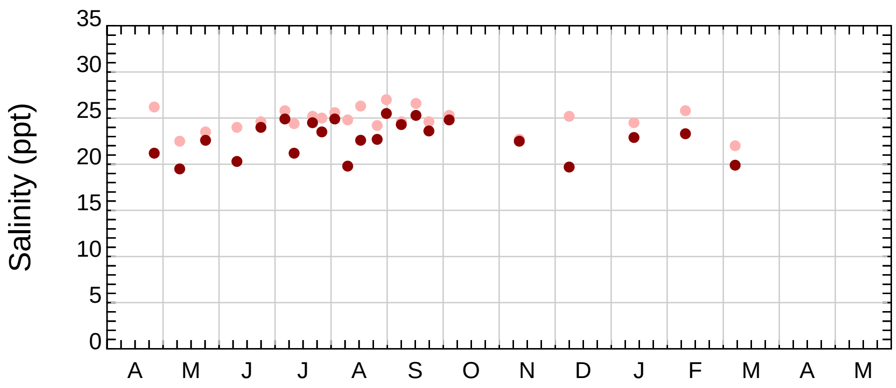
Hudson River, Upper Bay, Upper Bay, B21B, (SE2)

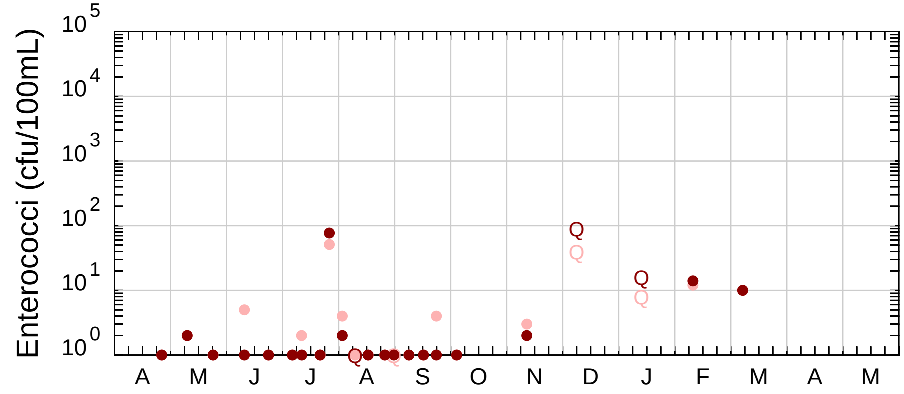


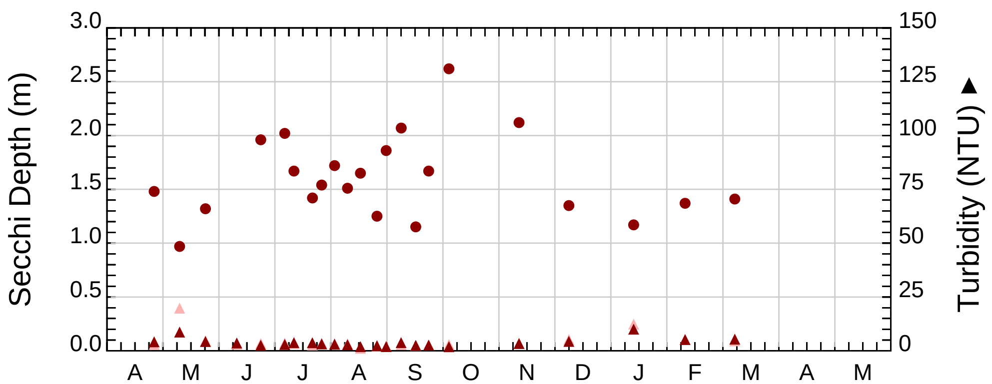
Hudson River, Upper Bay, Upper Bay, B21A, (SE2)

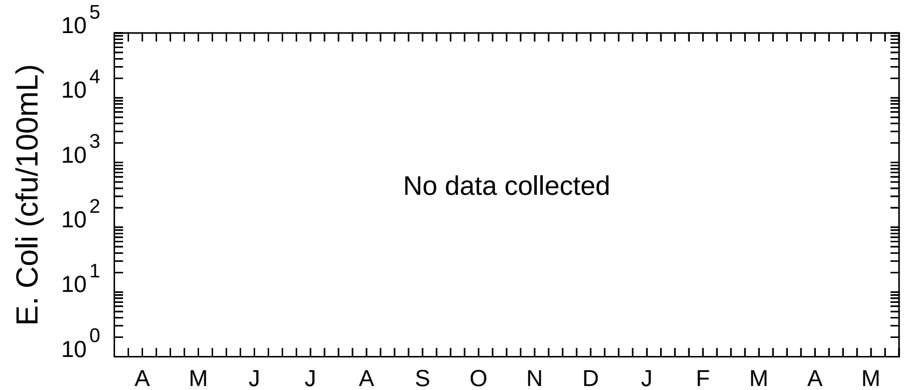










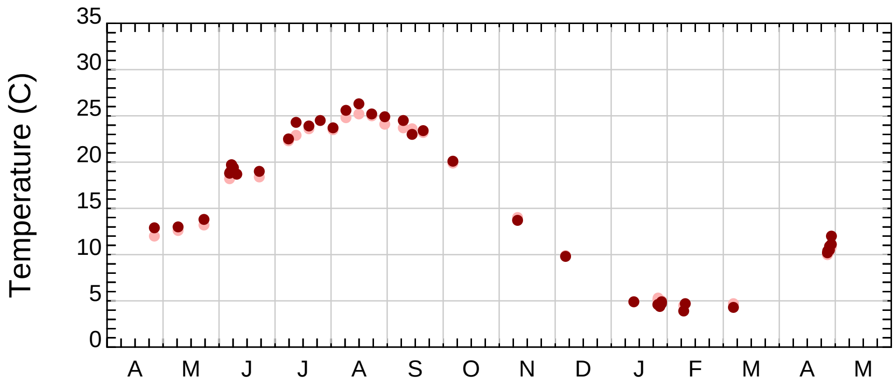


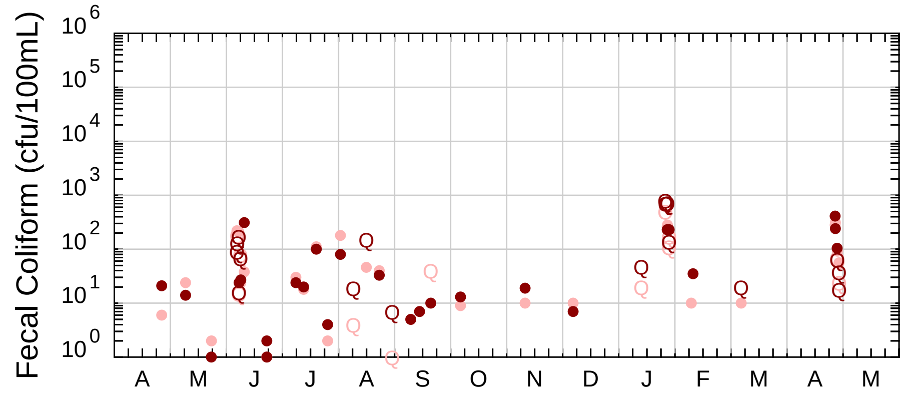
Time (Month)
2016 / 2017

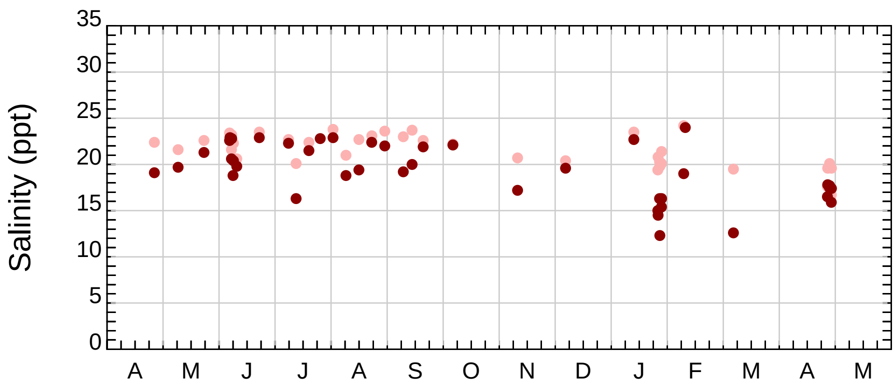
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

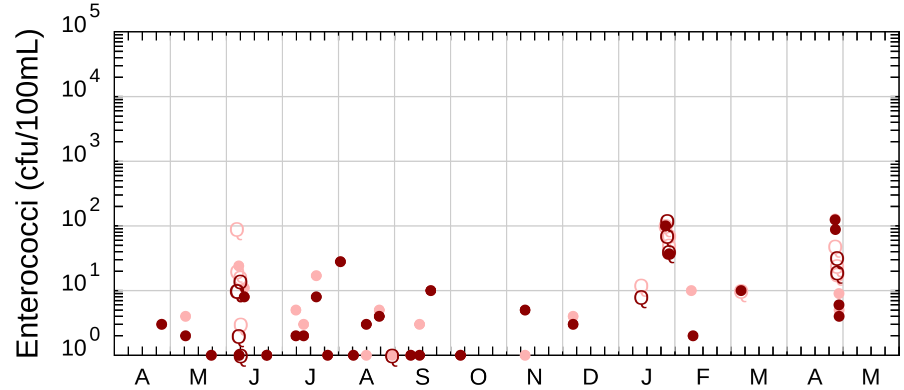
Time (Month)
2016 / 2017

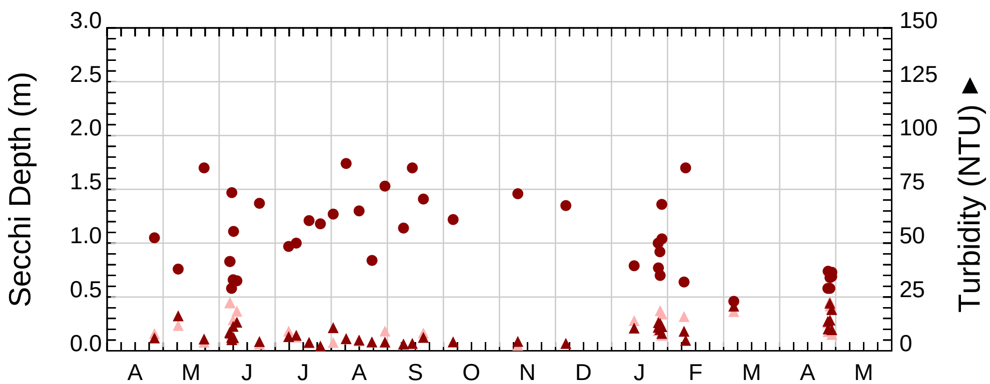
Hudson River, Upper Bay, Upper Bay, B26, (SE2)

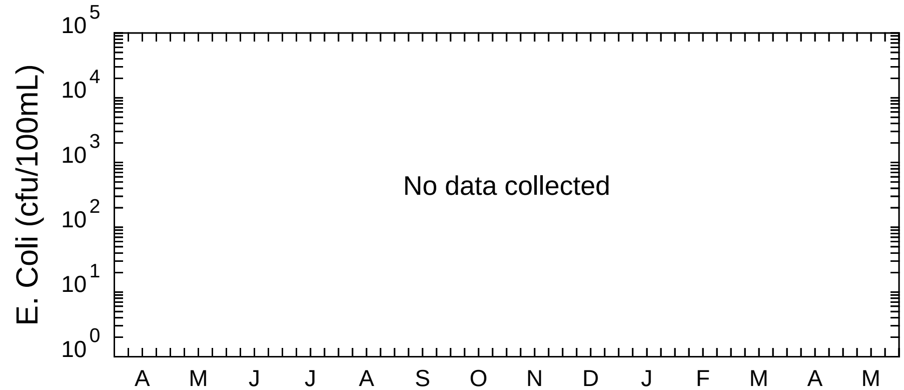










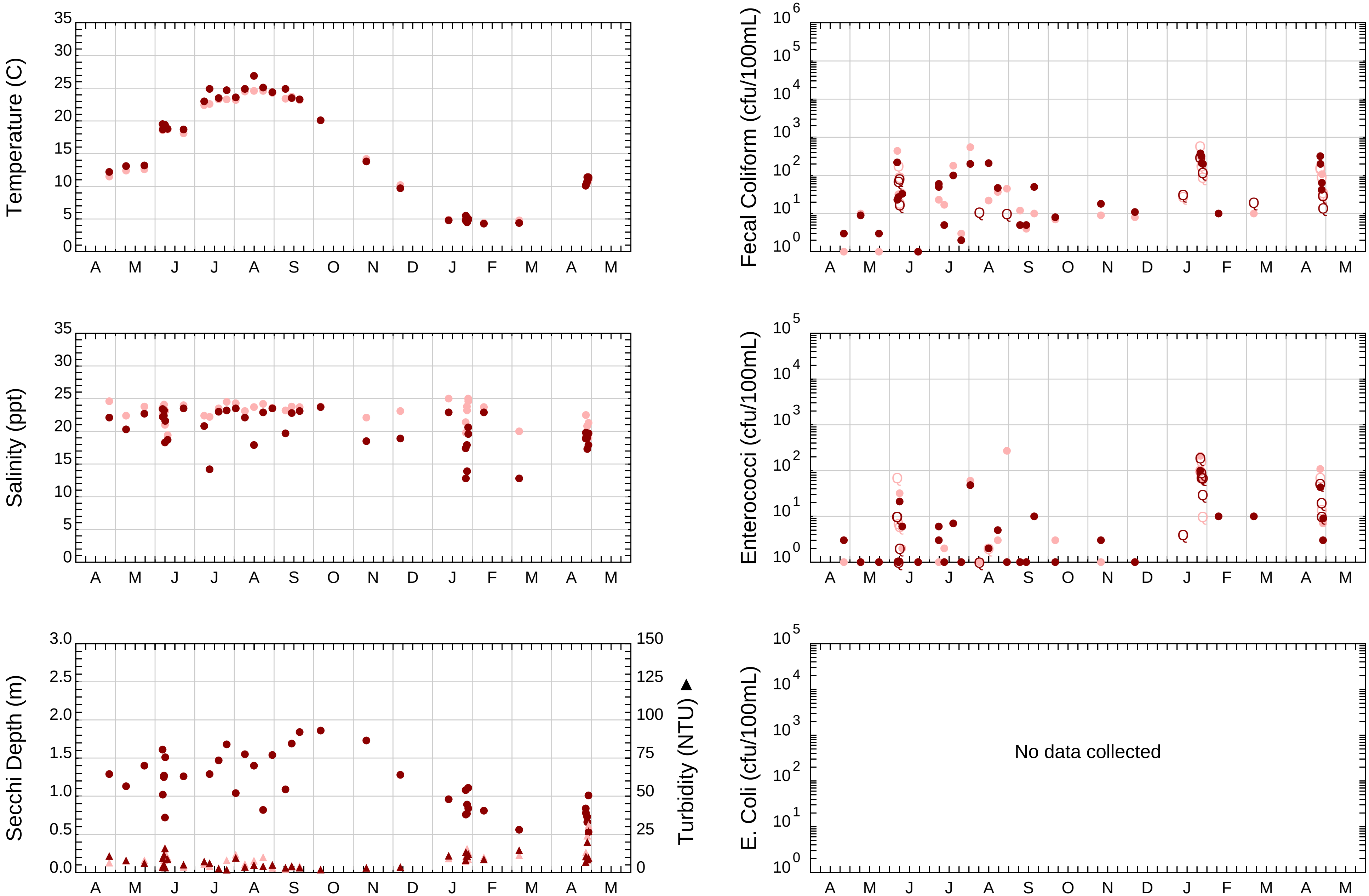


Time (Month)
2016 / 2017

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

Hudson River, Upper Bay, Upper Bay, B27, (SE2)



Time (Month)
2016 / 2017

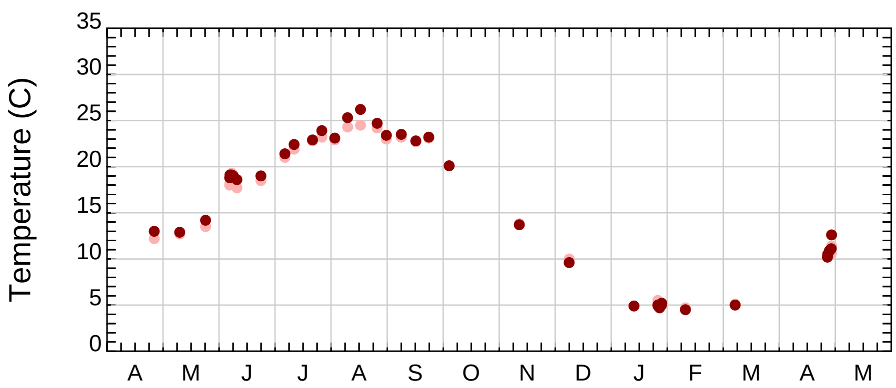
Surface/Mid-depth HDR

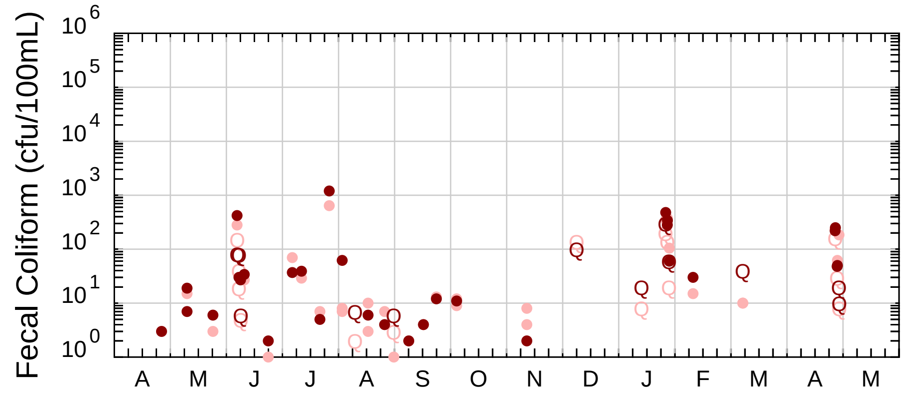
Surface/Mid/Bottom NJHDG

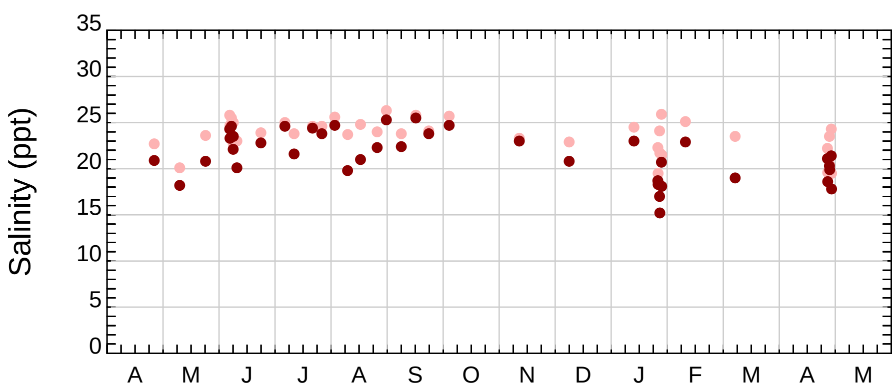
Q See page 1 of attachment for notes on qualifiers

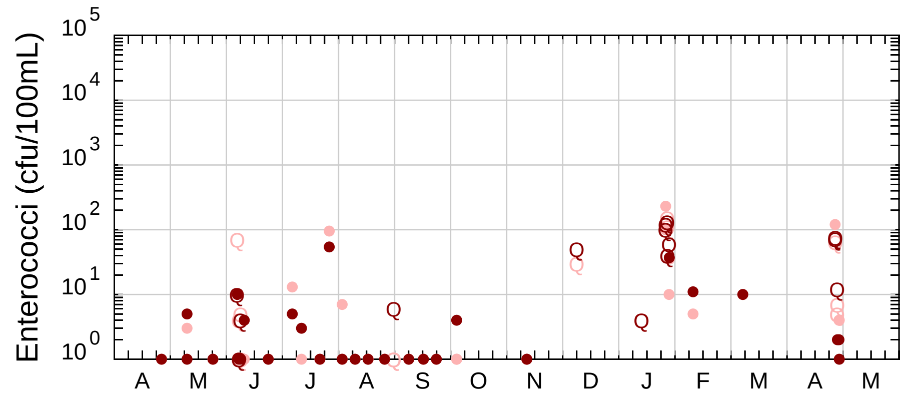
Time (Month)
2016 / 2017

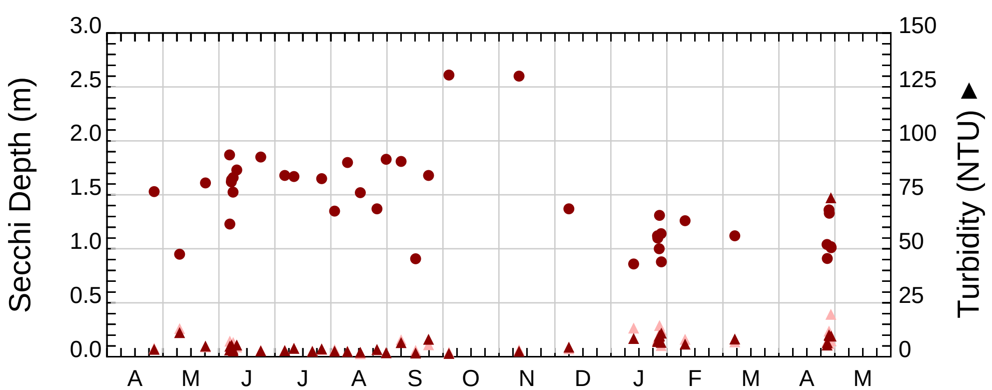
Hudson River, Upper Bay, Upper Bay, B28, (SE2)

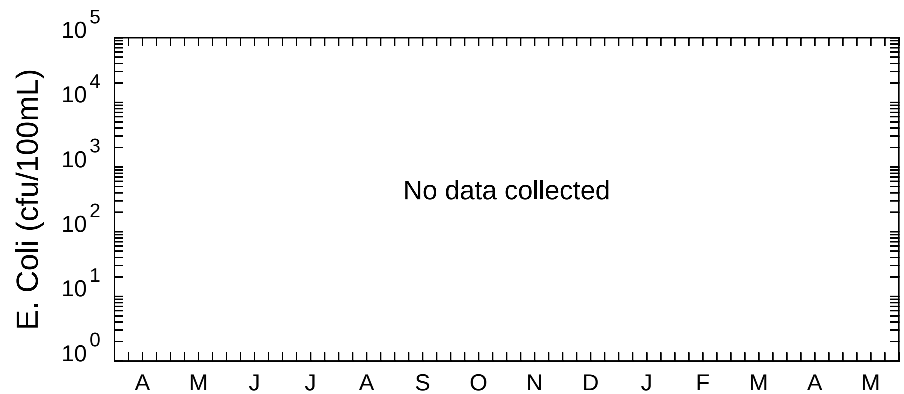










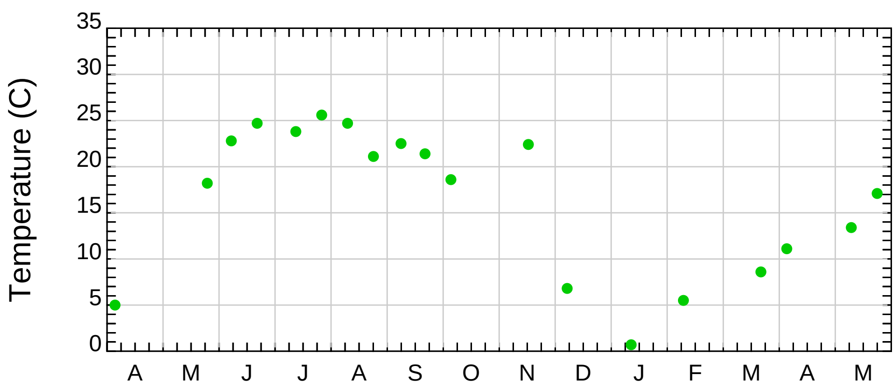


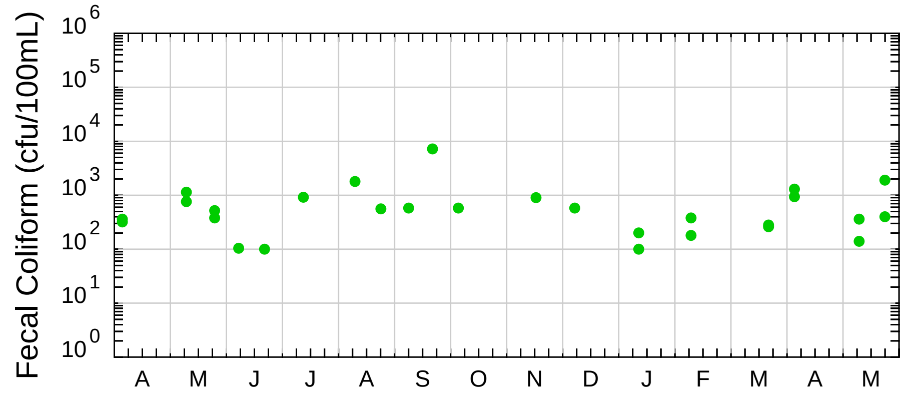
Time (Month)
2016 / 2017

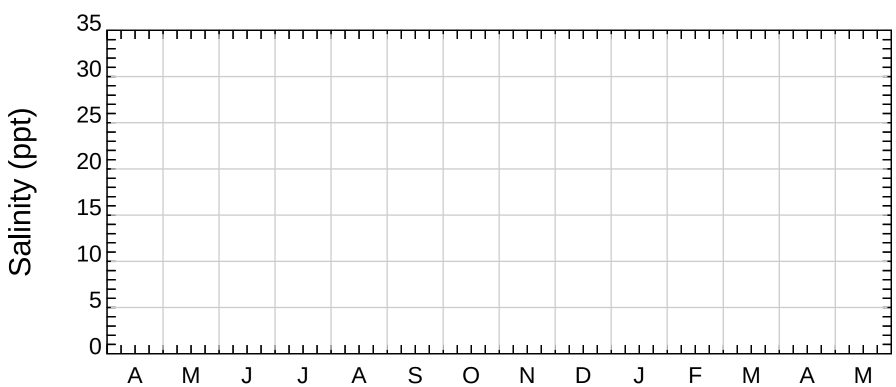
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

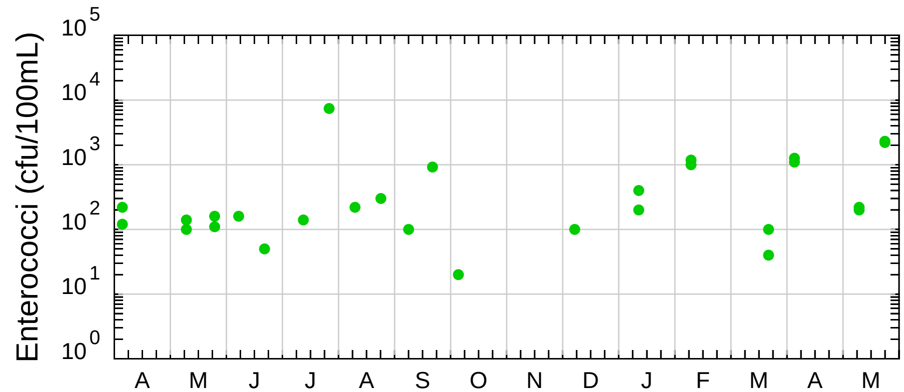
Time (Month)
2016 / 2017

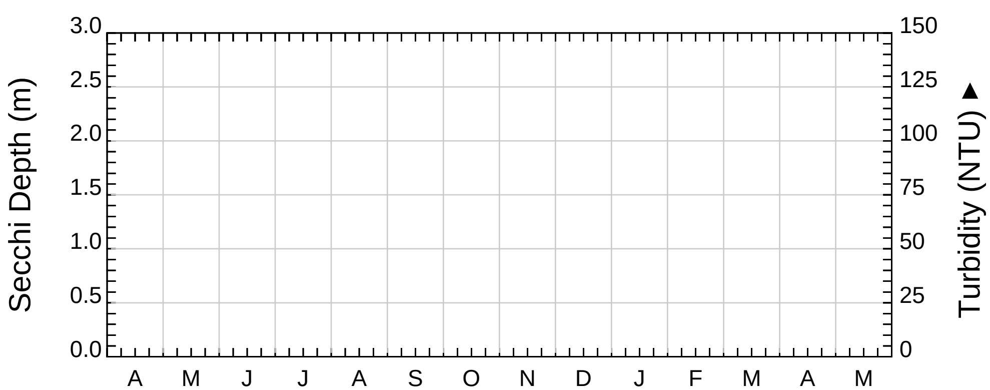
Arthur Kill, Raritan River/Bay & Tributaries, Rahway River, 22, (SE3)

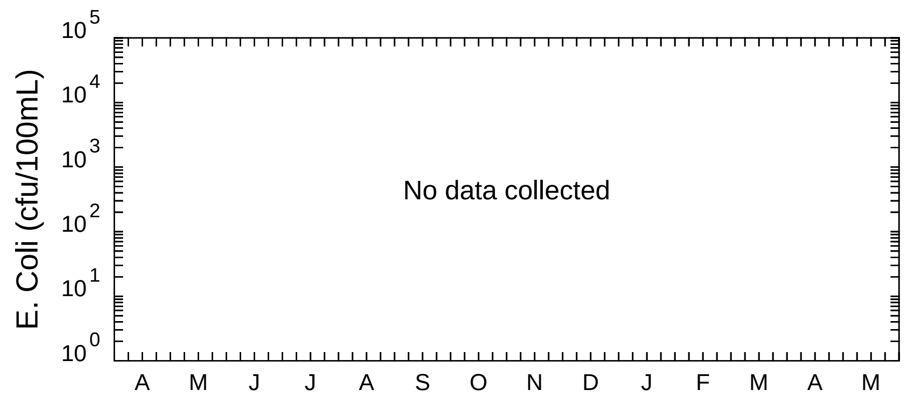










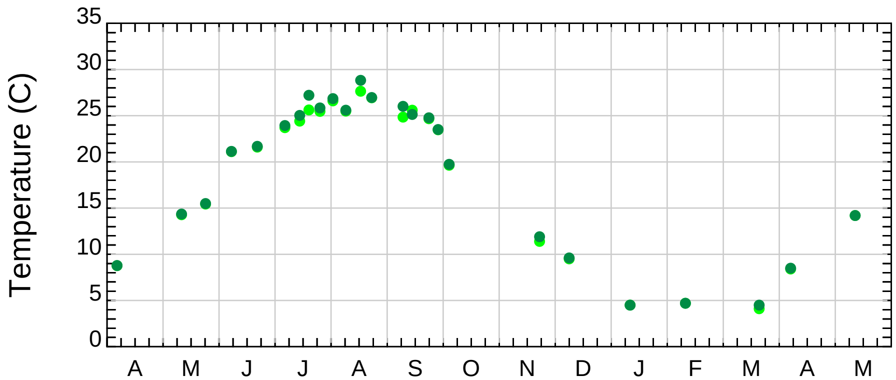


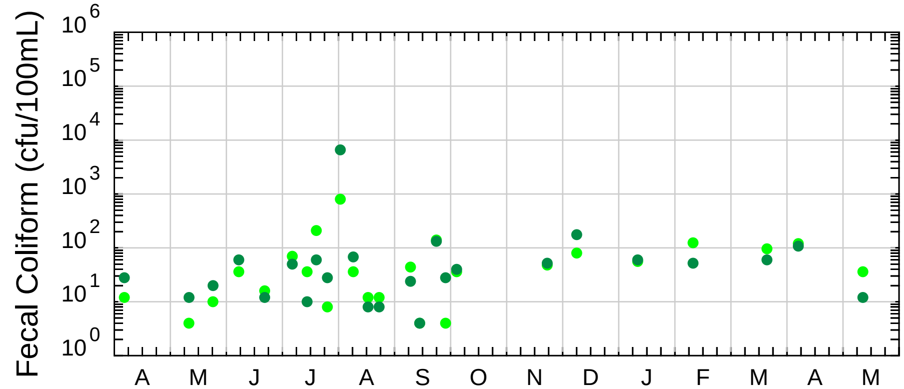
Time (Month)
2016 / 2017

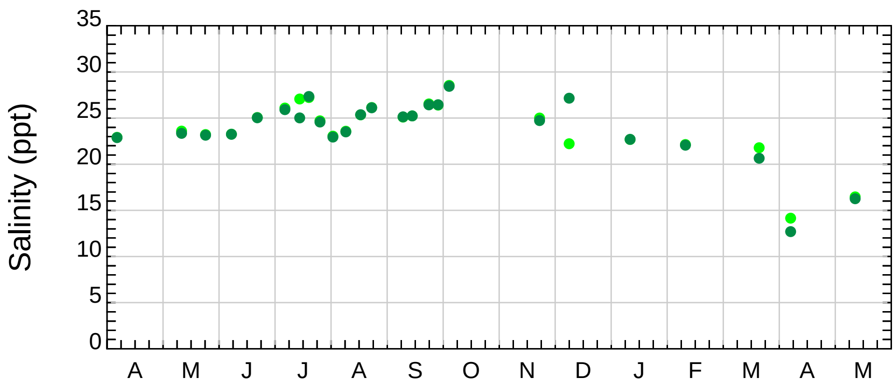
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

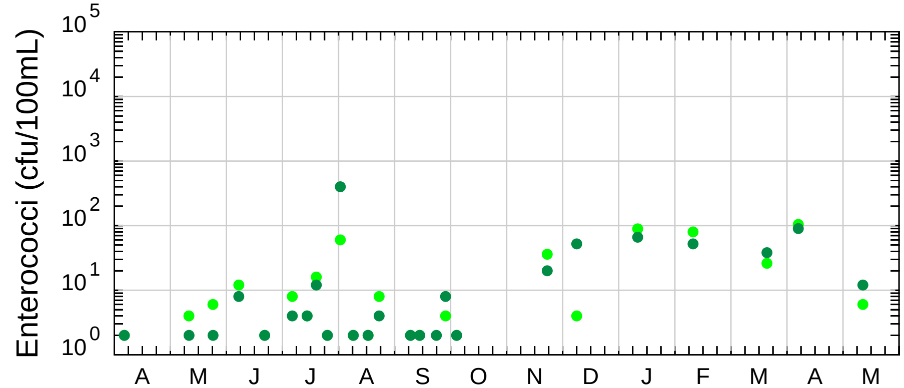
Time (Month)
2016 / 2017

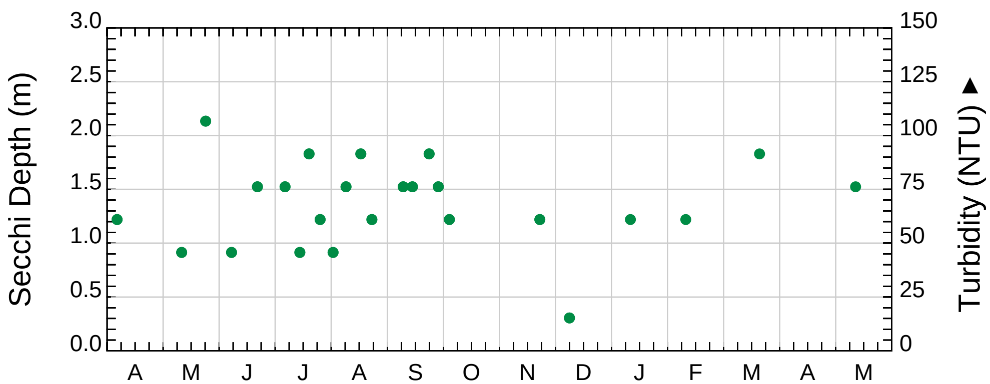
Arthur Kill, Raritan River/Bay & Tributaries, Arthur Kill, 23, (SE3)

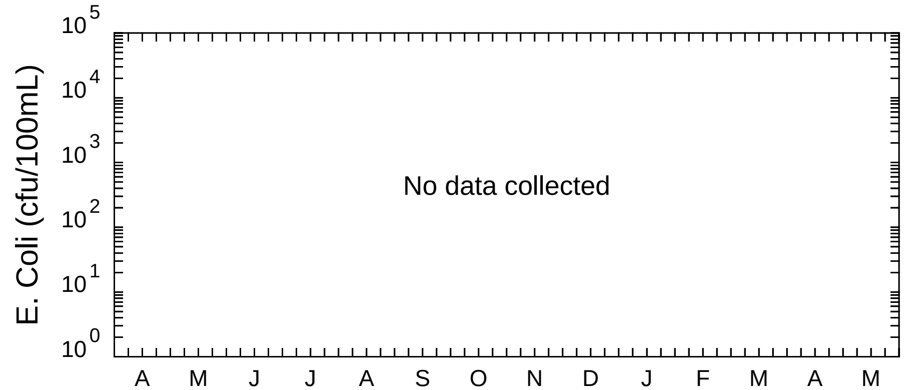










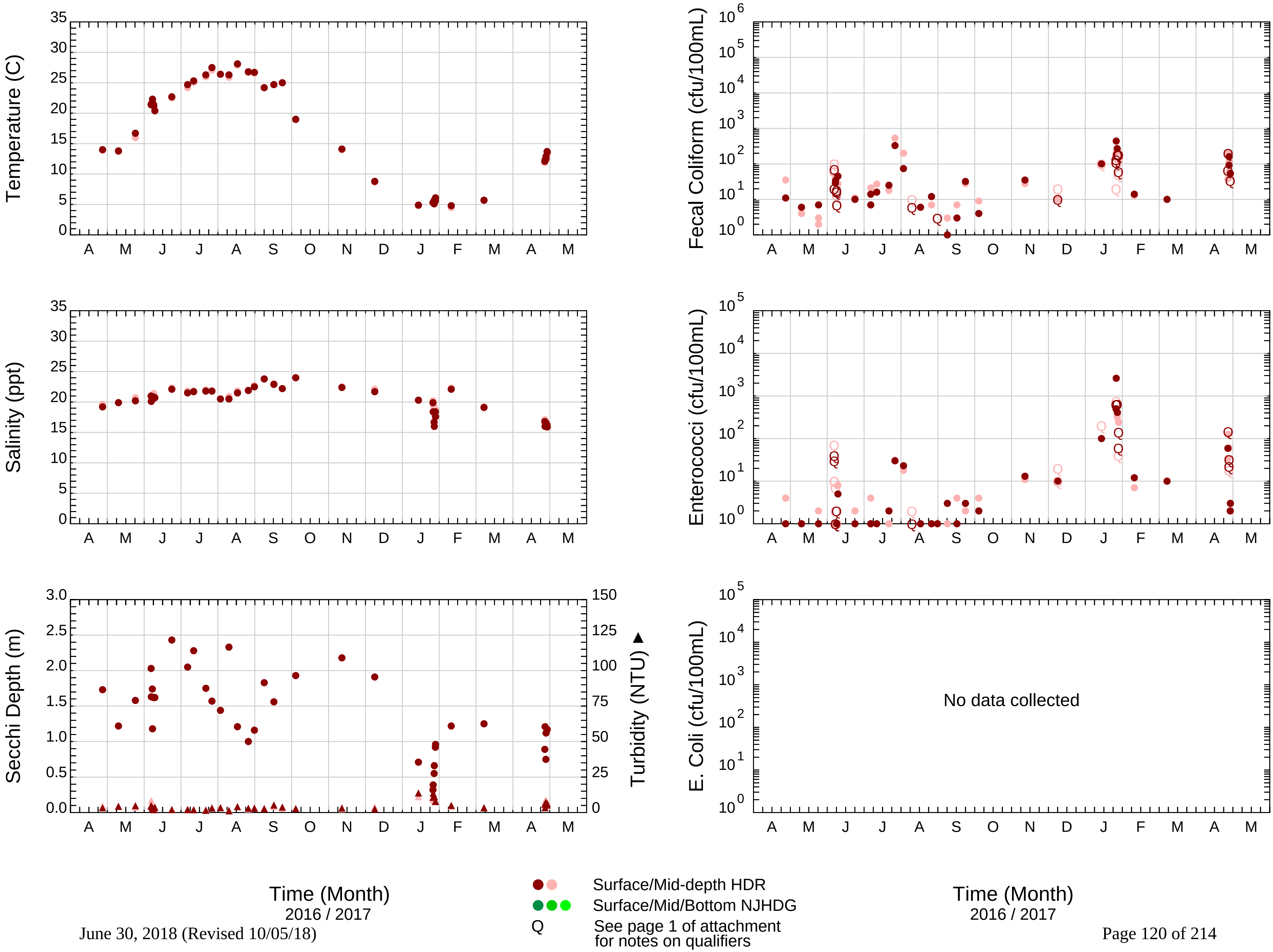


Time (Month)
2016 / 2017

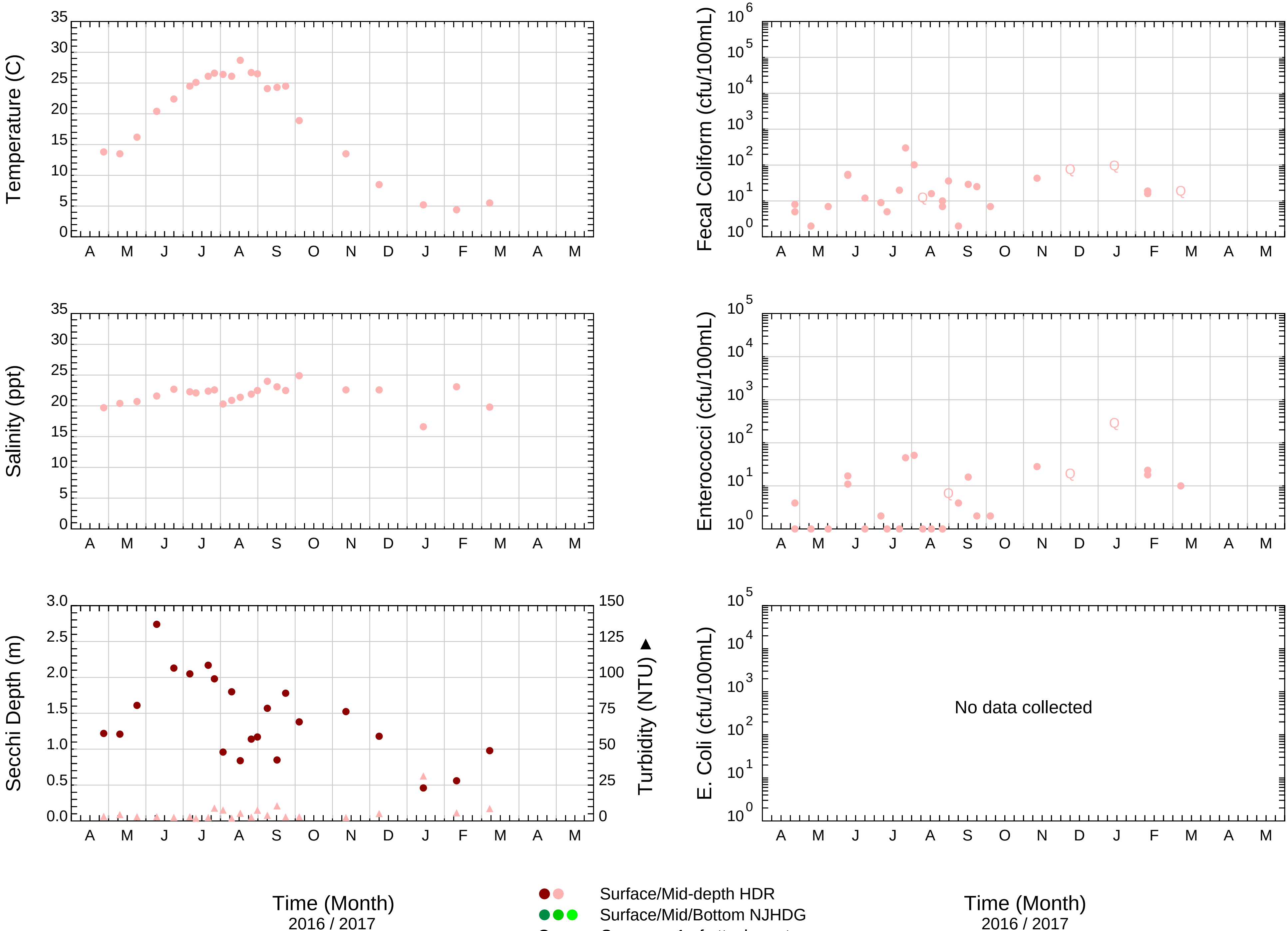
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

Arthur Kill, Raritan River/Bay & Tributaries, Arthur Kill, 24, (SE3)

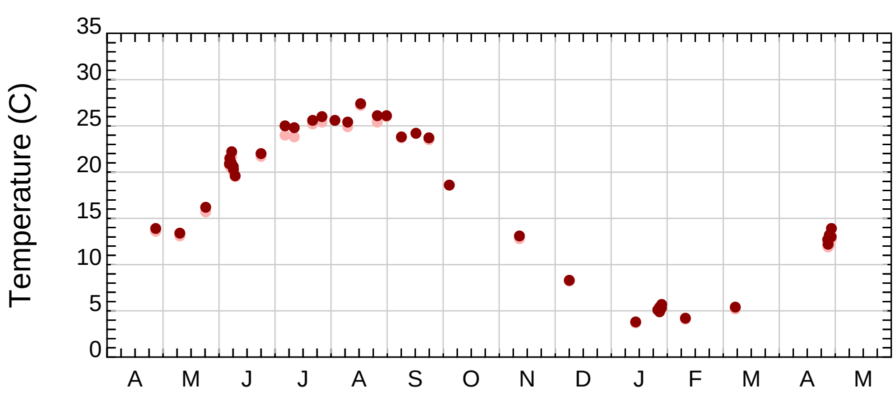


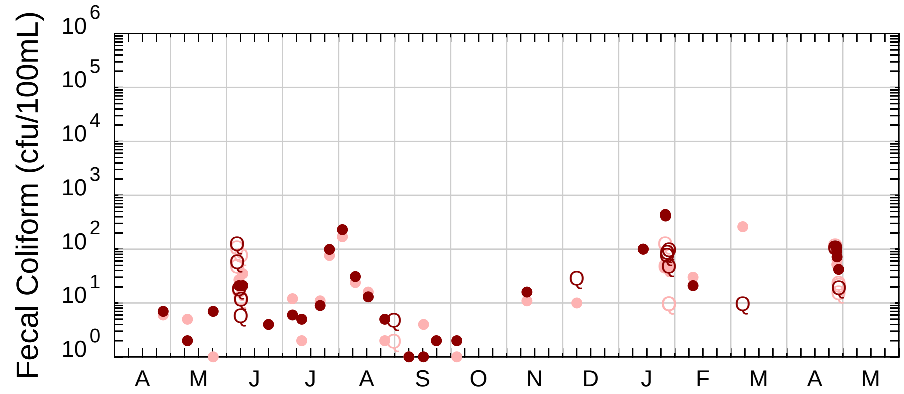
Arthur Kill, Raritan River/Bay & Tributaries, Woodbridge Creek, S6, (SE3)

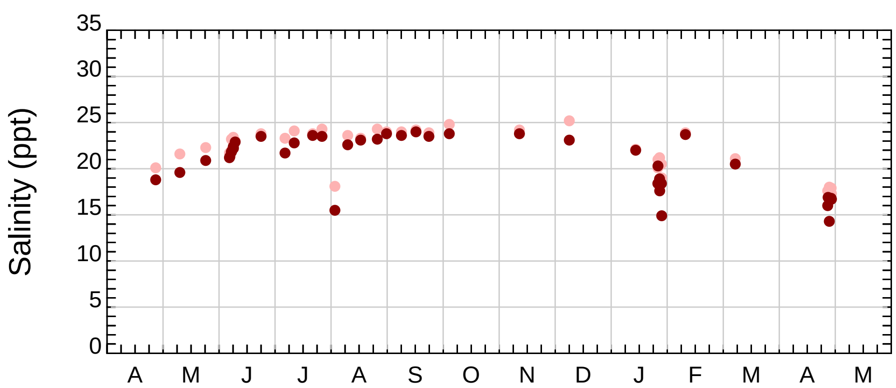


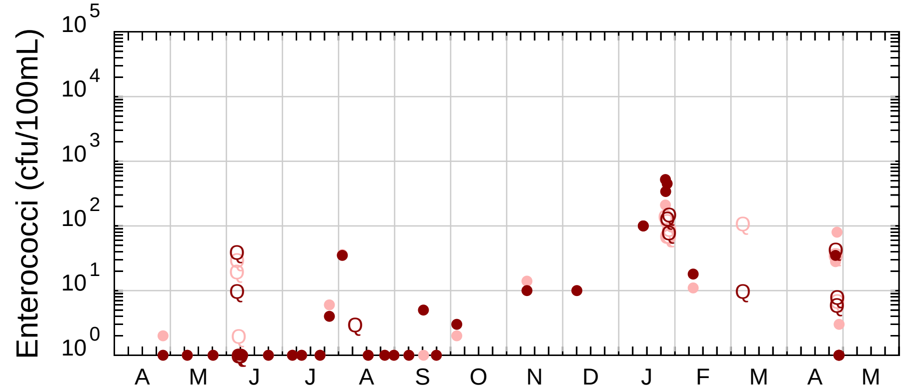
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

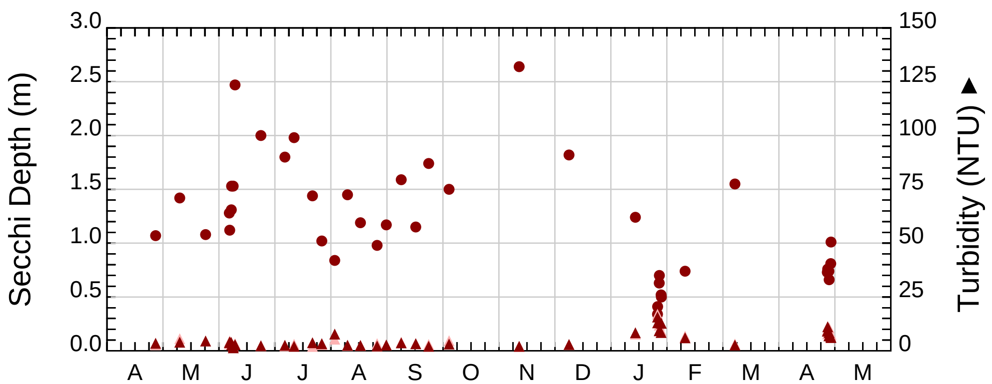
Arthur Kill, Raritan River/Bay & Tributaries, Arthur Kill, B15, (SE2)

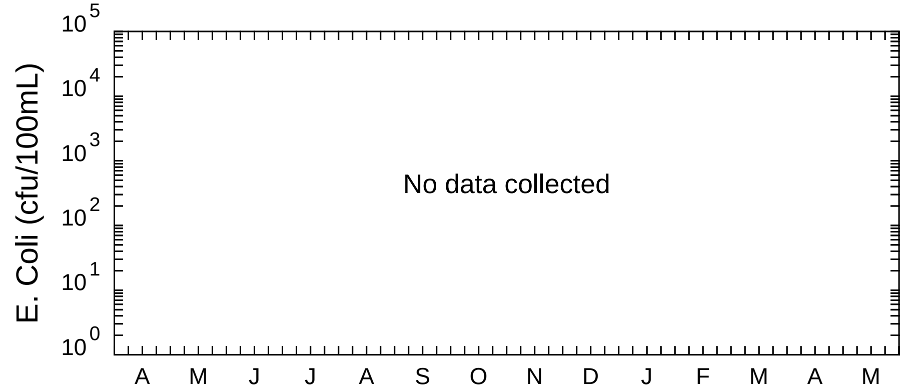










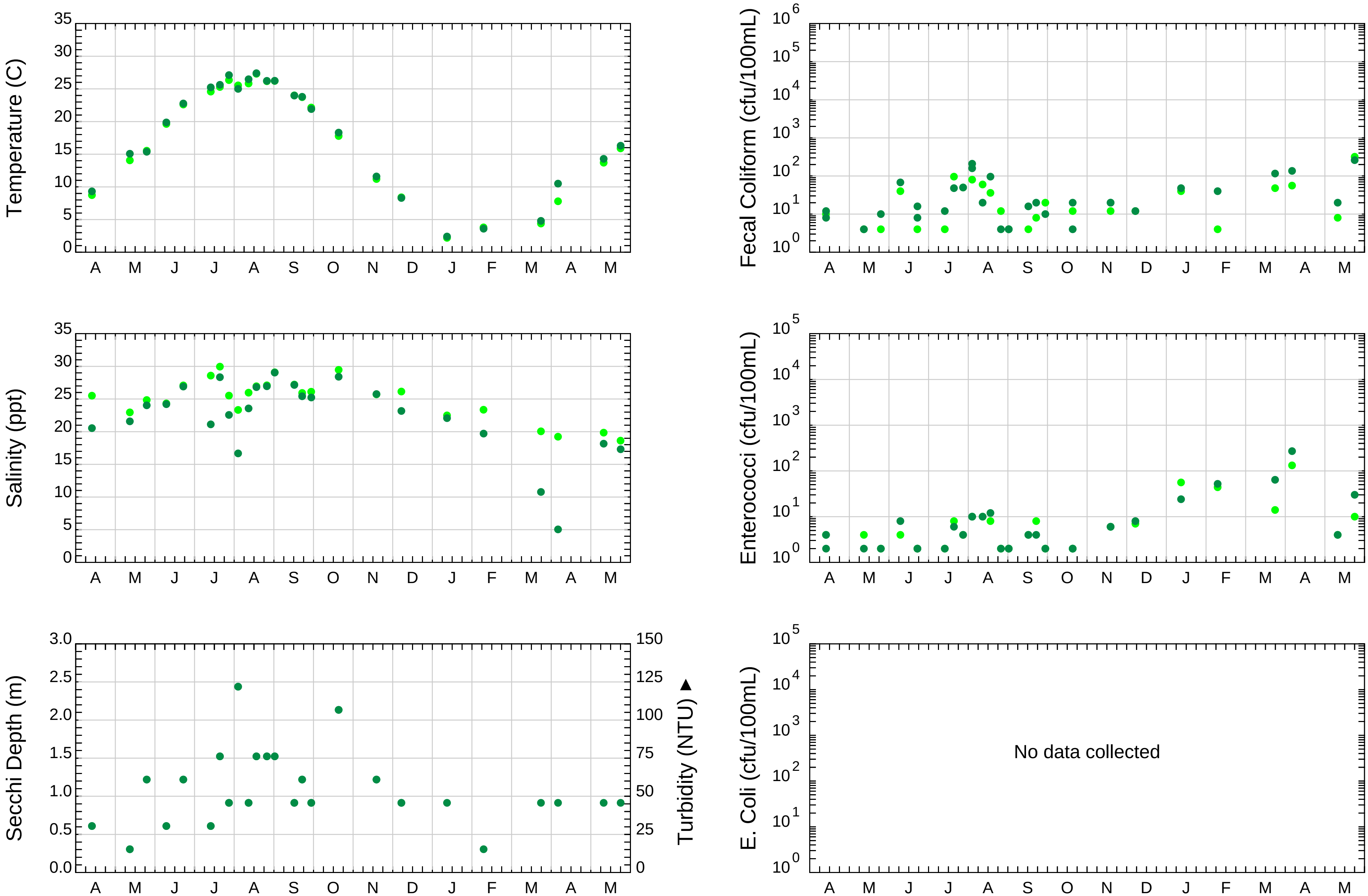


Time (Month)
2016 / 2017

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017

Arthur Kill, Raritan River/Bay & Tributaries, Raritan Bay, 28, (Shellfish)



Time (Month)
2016 / 2017

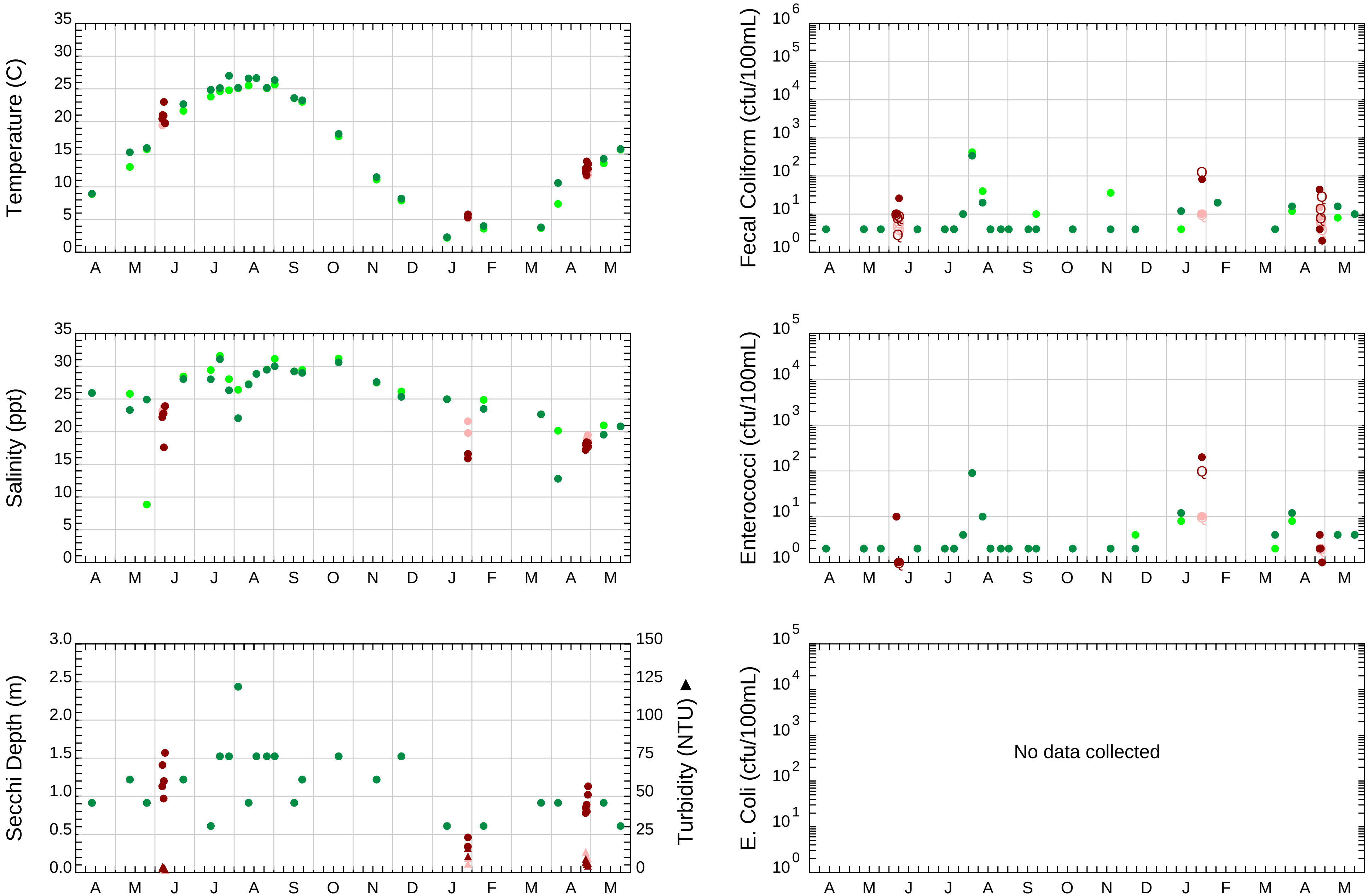
Time (Month)
2016 / 2017

●● Surface/Mid-depth HDR

●●● Surface/Mid/Bottom NJHDG

Q See page 1 of attachment for notes on qualifiers

Arthur Kill, Raritan River/Bay & Tributaries, Raritan Bay, 29, (Shellfish)

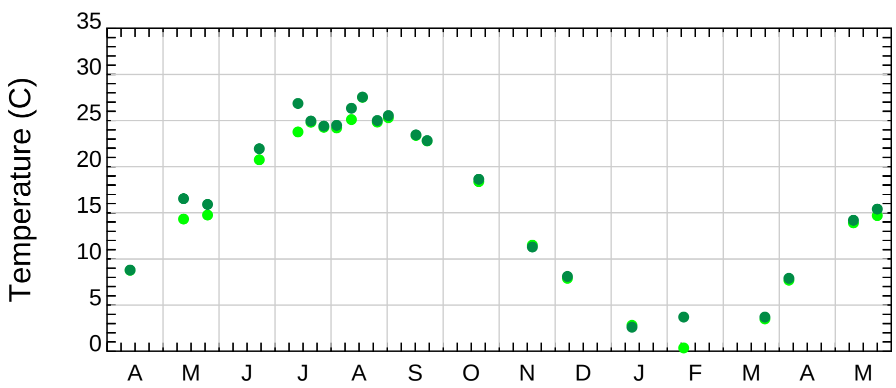


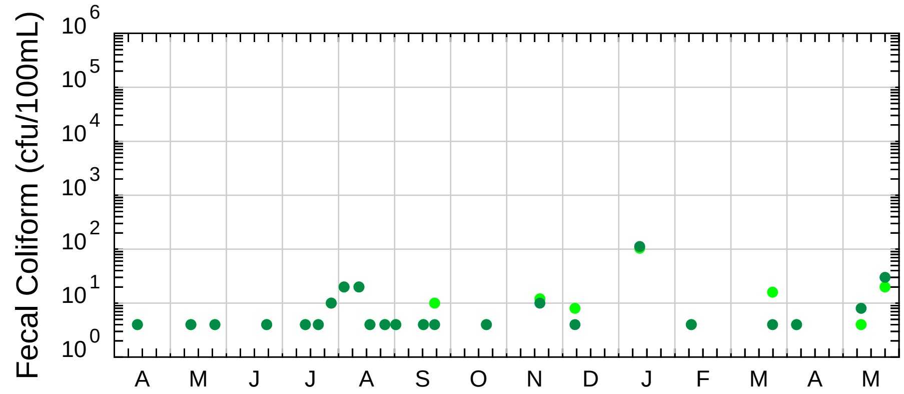
Time (Month)
2016 / 2017

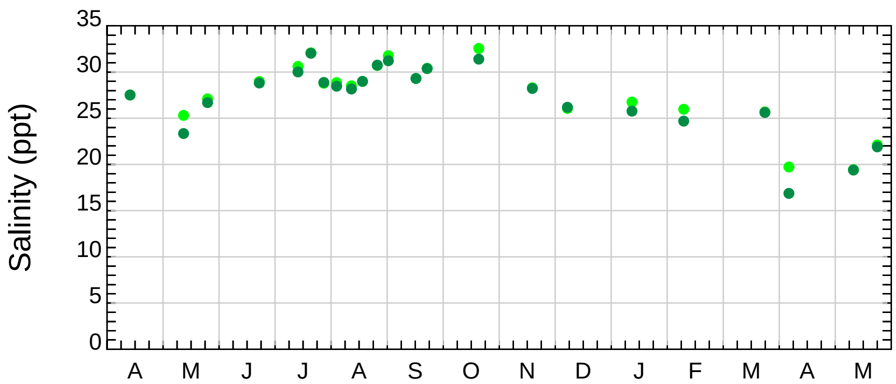
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

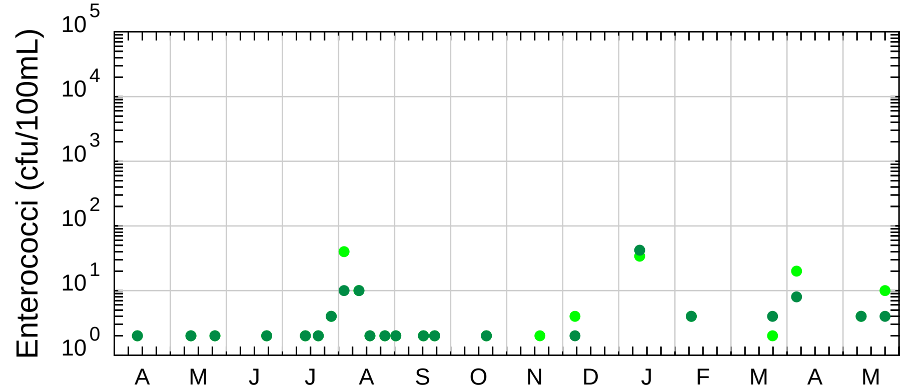
Time (Month)
2016 / 2017

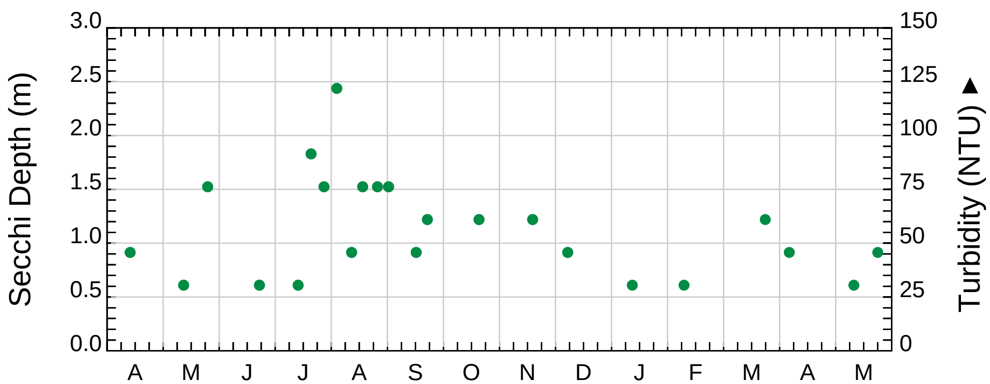
Arthur Kill, Raritan River/Bay & Tributaries, Raritan Bay, 30, (Shellfish)

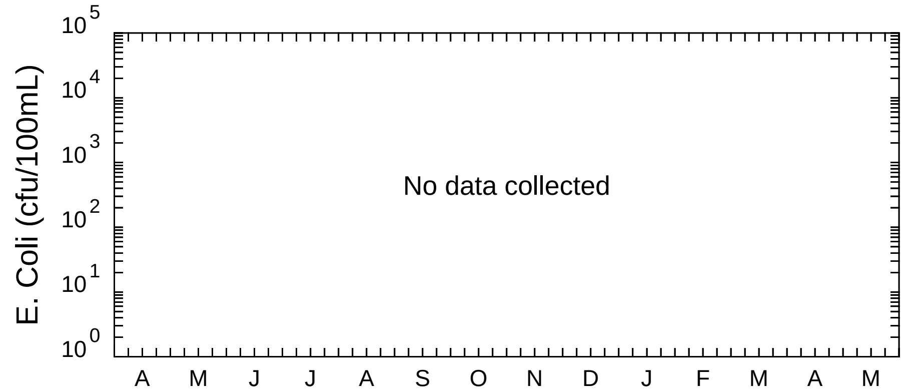










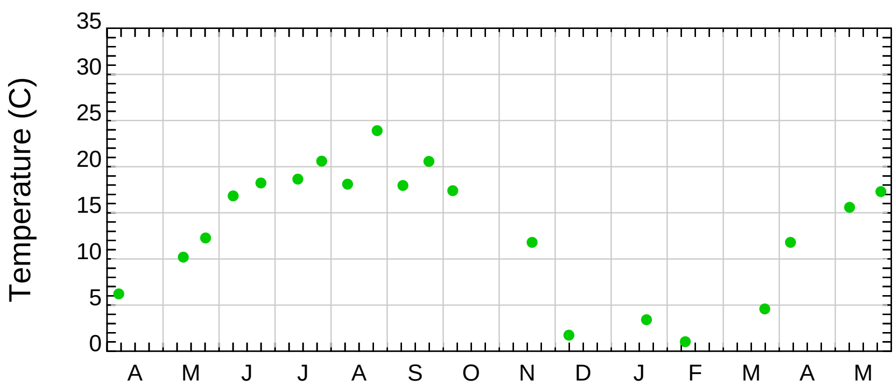


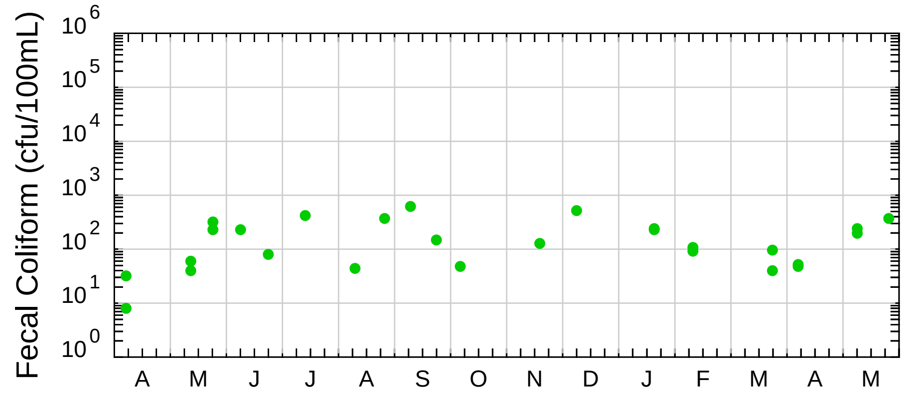
Time (Month)
2016 / 2017

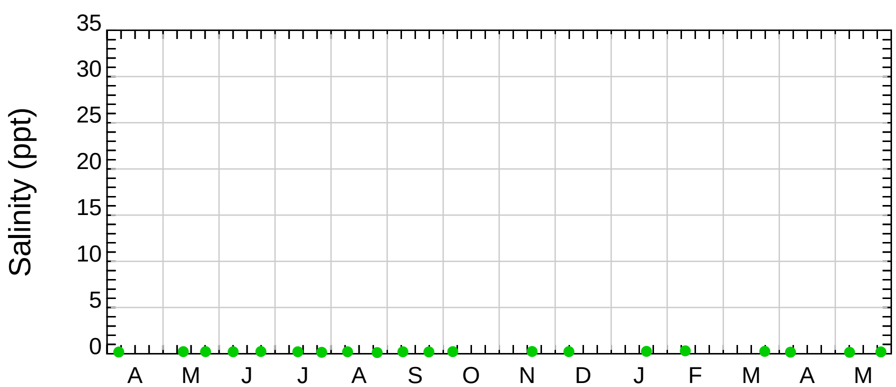
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

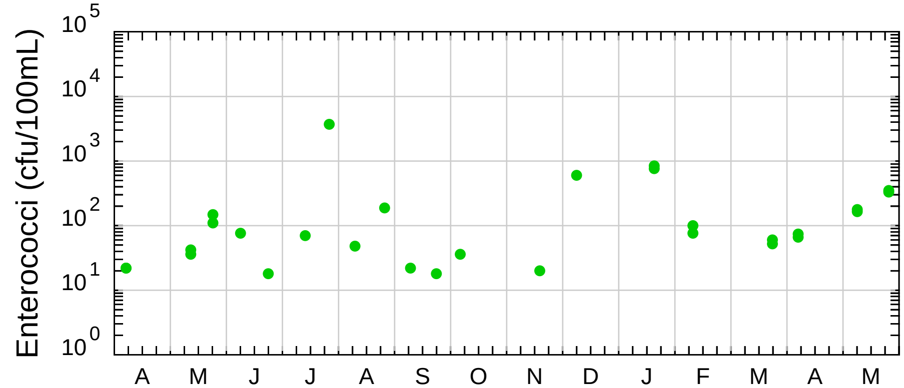
Time (Month)
2016 / 2017

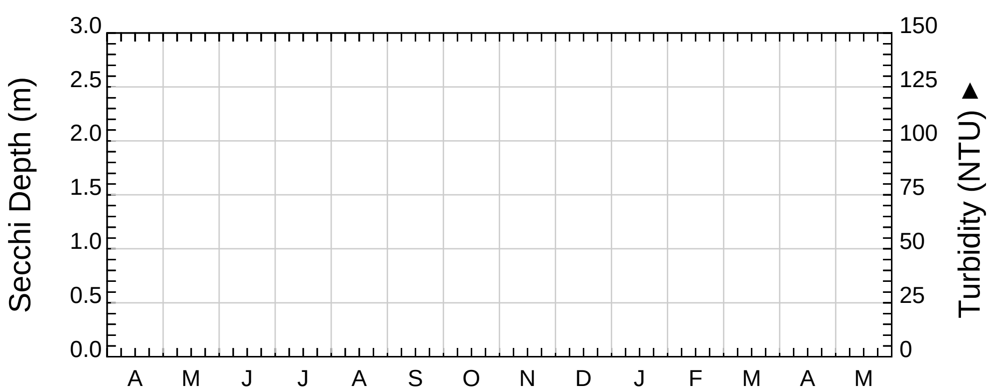
Arthur Kill, Raritan River/Bay & Tributaries, Raritan River, 25, (FW2)

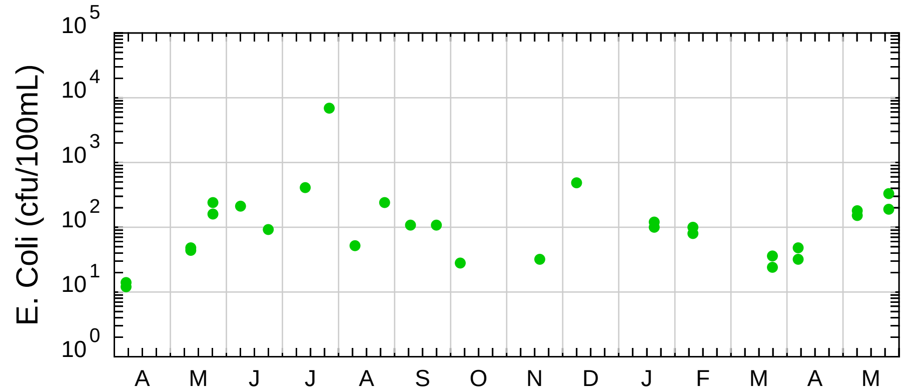










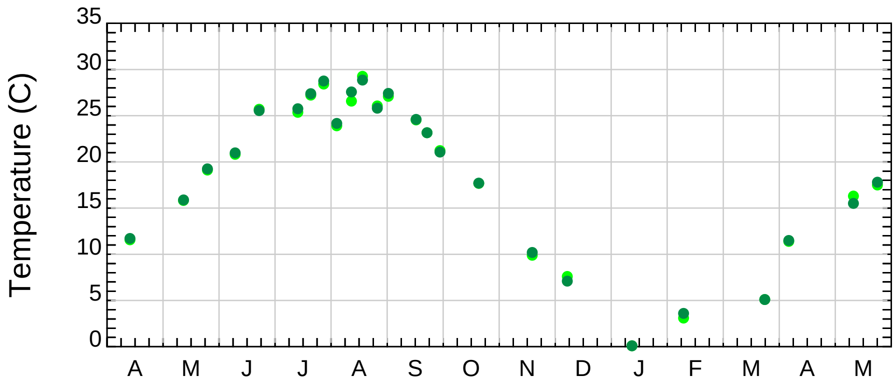


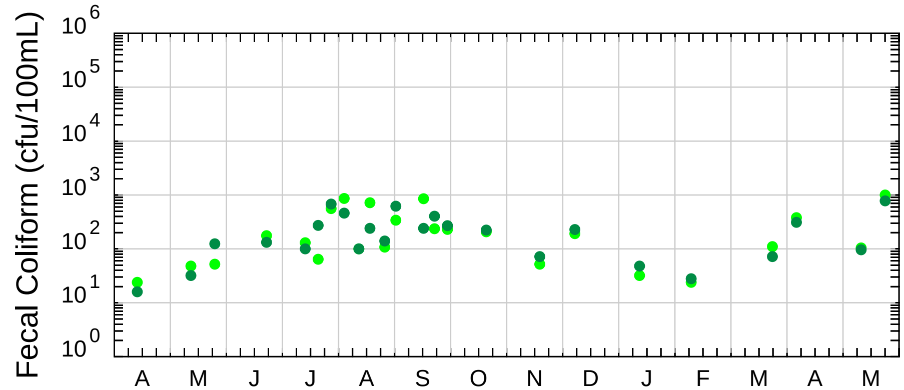
Time (Month)
2016 / 2017

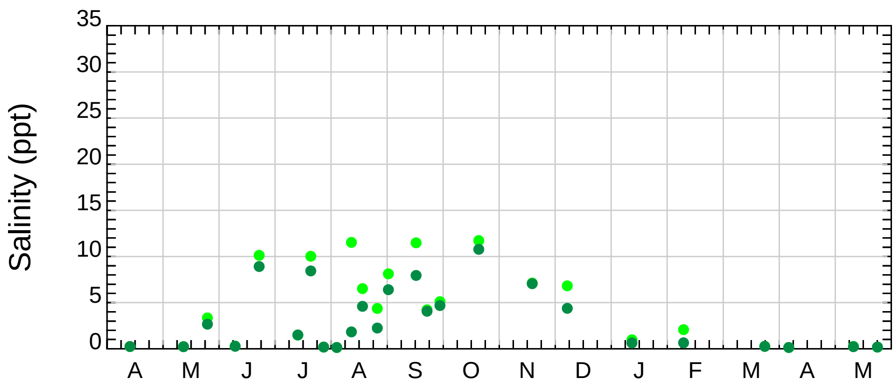
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

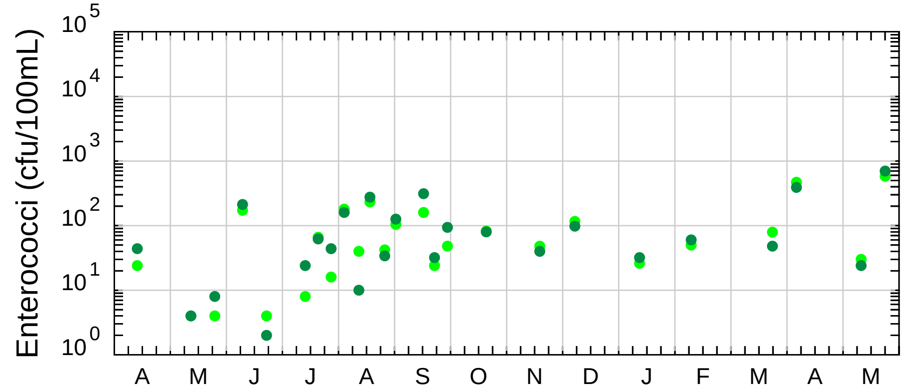
Time (Month)
2016 / 2017

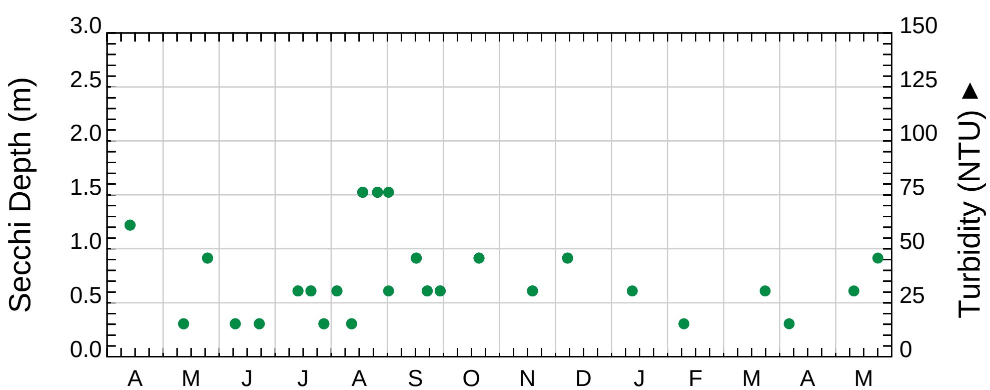
Arthur Kill, Raritan River/Bay & Tributaries, Raritan River, 26, (SE1)

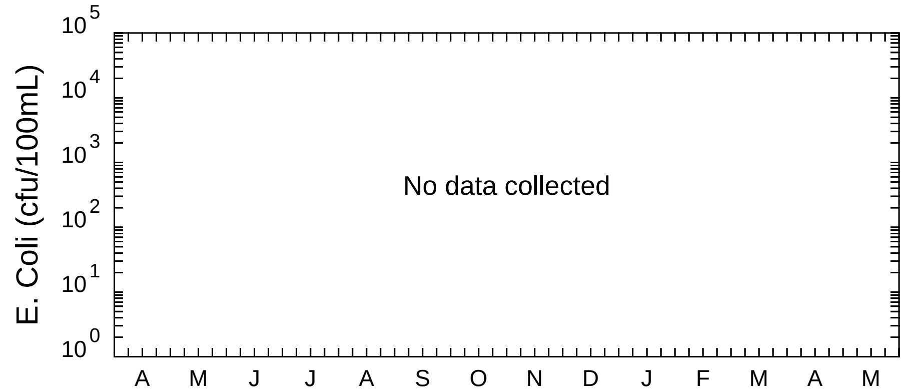










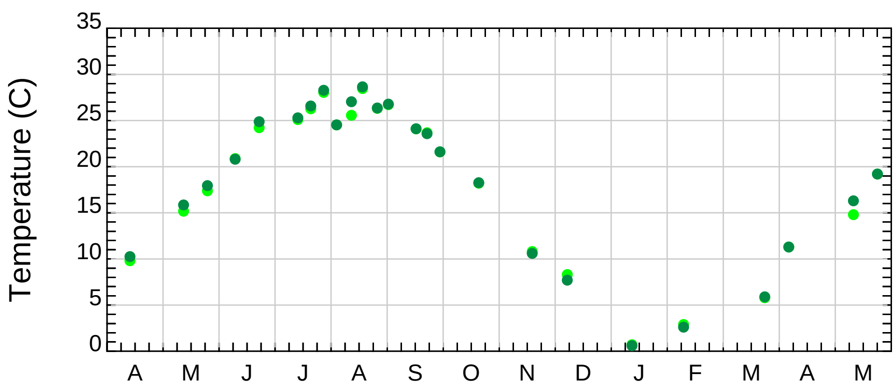


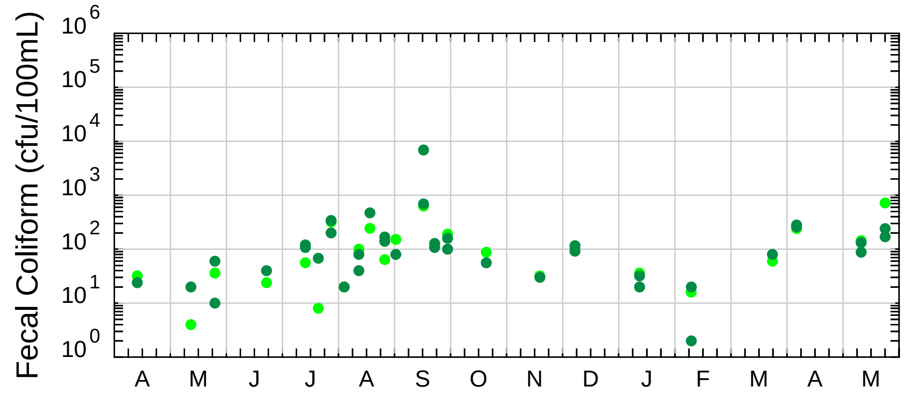
Time (Month)
2016 / 2017

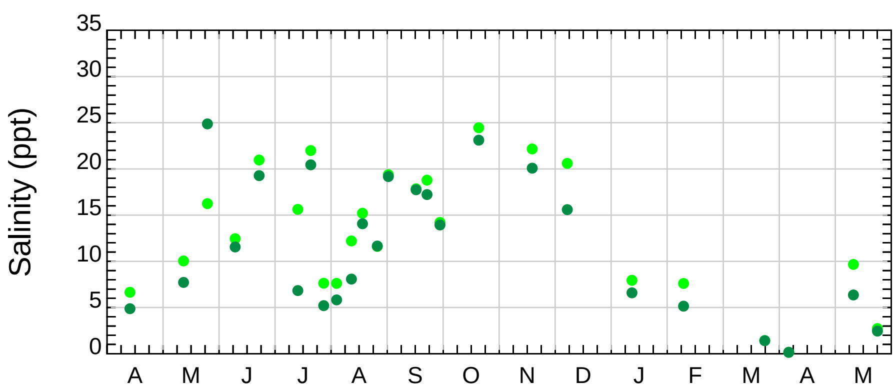
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

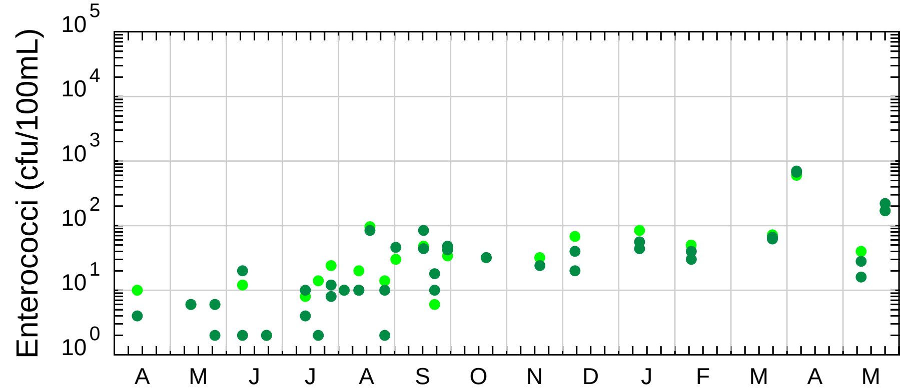
Time (Month)
2016 / 2017

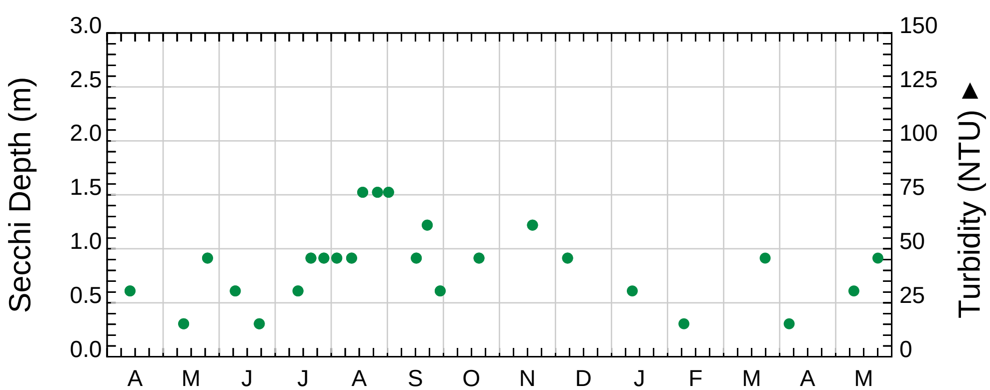
Arthur Kill, Raritan River/Bay & Tributaries, Raritan River, 27, (SE1)

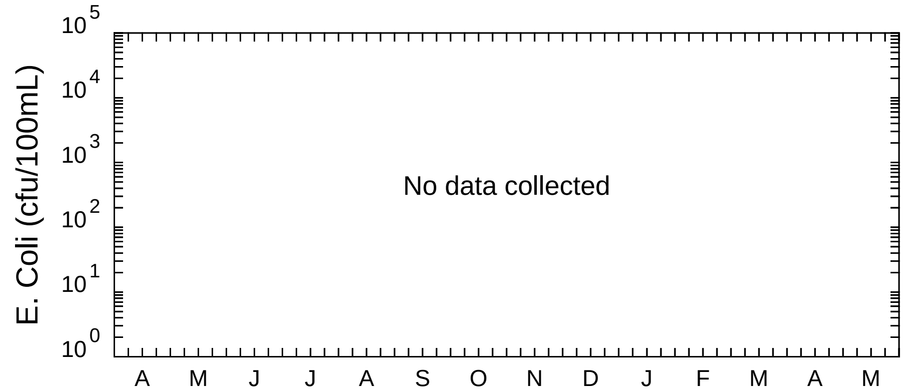








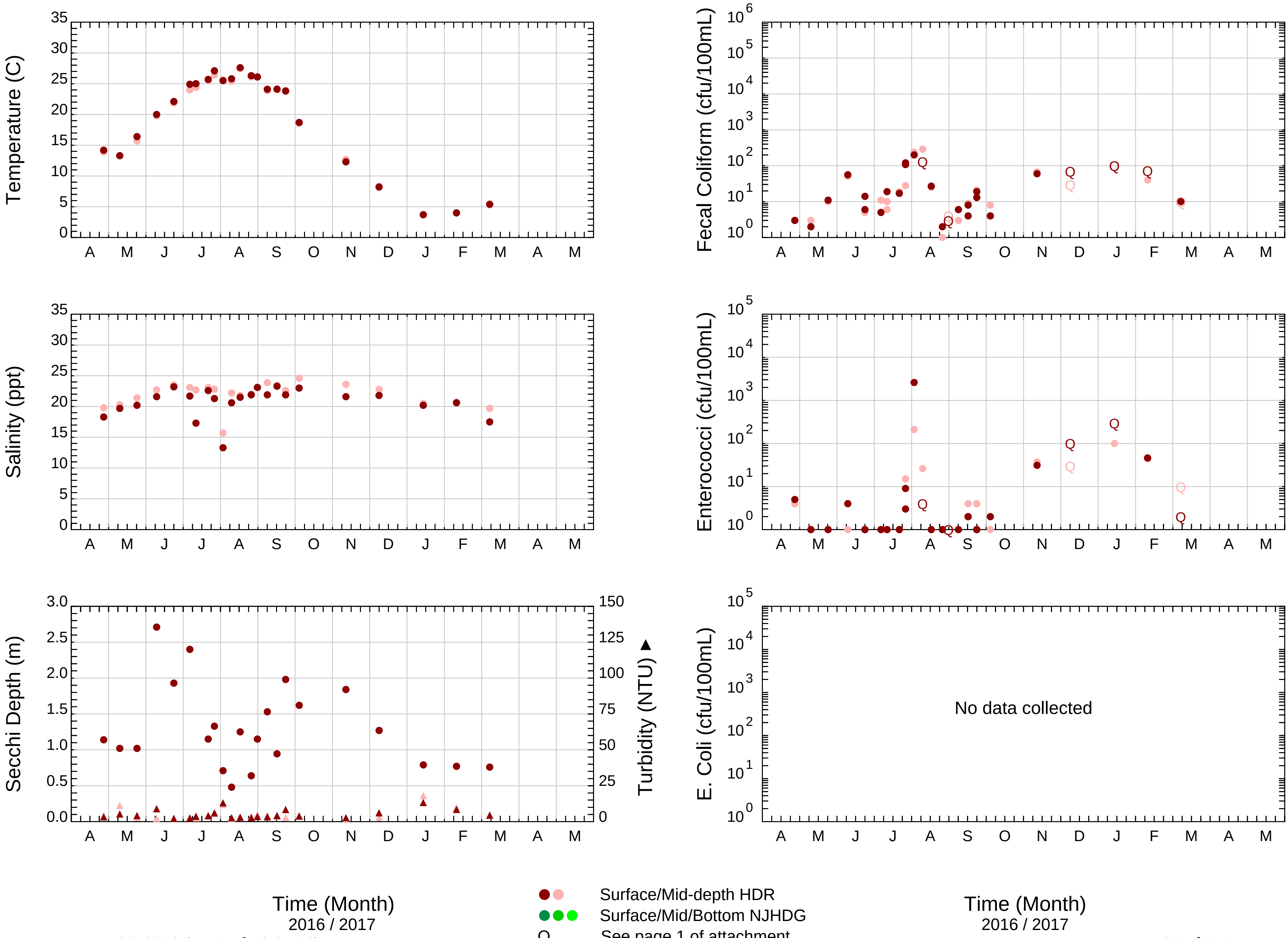




Time (Month)
2016 / 2017

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

Time (Month)
2016 / 2017



Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG
Q See page 1 of attachment for notes on qualifiers

ATTACHMENT 3 – WET WEATHER EVENTS

EXPLANATION OF WET WEATHER EVENT DATA PRESENTATION

Graphs are presented here within of available receiving water data collected by HDR during the following four wet weather sampling events:

- June 6, 2016
- January 4, 2017
- January 24, 2017
- April 26, 2017

Temperature, salinity, Secchi depth, turbidity, fecal coliform, enterococci, and E. coli are plotted by station. Refer to Attachment 1 figures for sampling locations. The pages are ordered by event, then spatially by waterbody in a manner similar to the figures in Attachment 2. Figures are labeled with a waterbody grouping, specific waterbody name, station, and waterbody classification. Refer to the table below for relevant water quality standards. Data collected during these events were meant to assess the trend of bacteria concentrations after a wet-weather event for the purposes of water quality modeling, and not to assess attainment of geometric mean standards..

Data are presented as color-coded circles, with darker tones representing surface data and lighter tones representing mid-depth and bottom data. Secchi depth does not fall into a specific depth category, but is plotted with filled circles. Turbidity is shown on the same panel as Secchi depth and is presented with filled triangles following the same light/dark tone. Only the Data collected by HDR under this BCMP report includes laboratory qualifiers (either as estimated or as exceeding holding times) which are presented as a "Q". These data still meet the needs of the program and can be used in the water quality analysis. Refer to Section 3.2 for details on data qualifiers. All planned receiving water data have been collected.

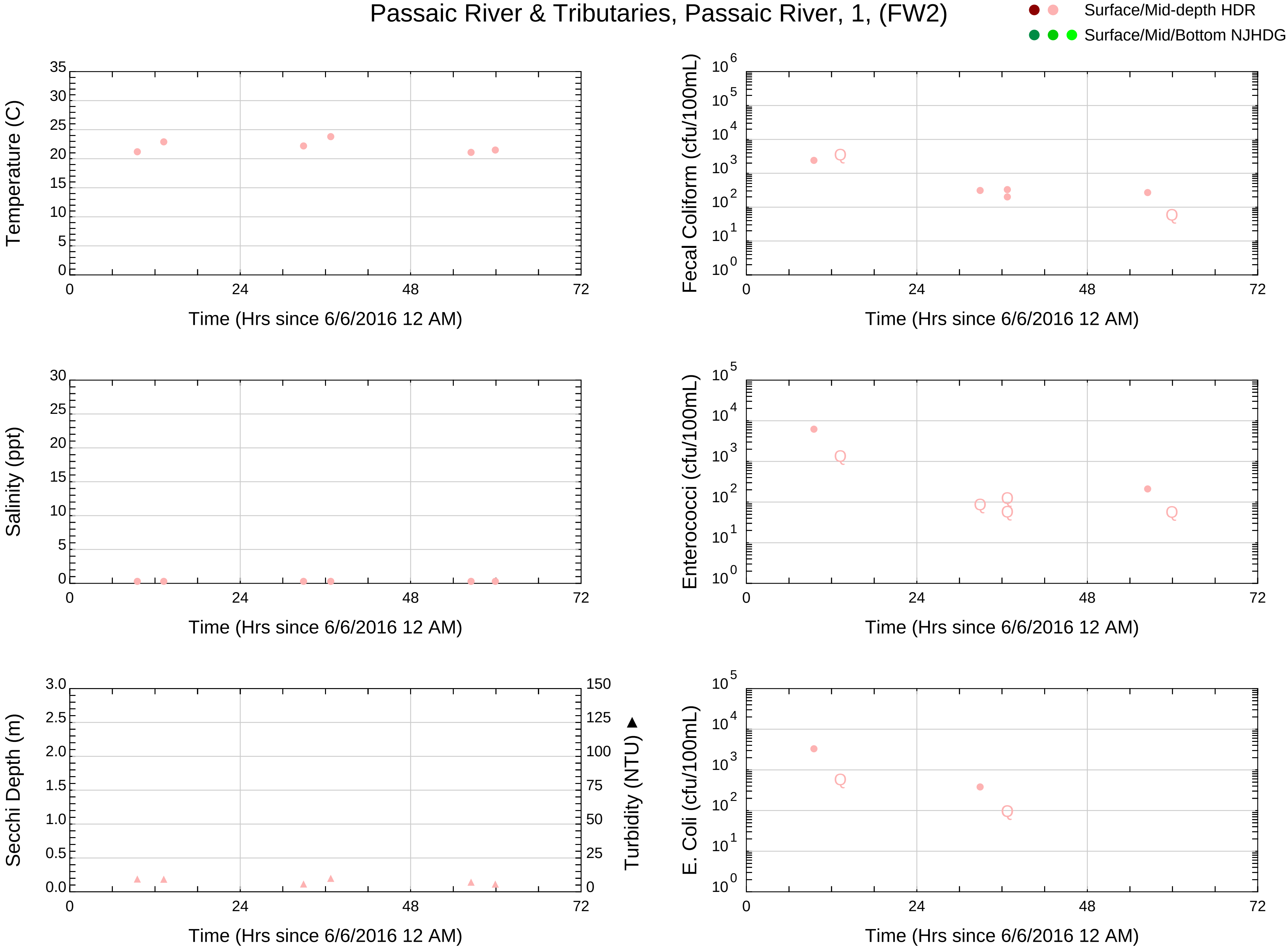
The post-collection review of the data indicates the data have met the goals of the QAPP and will be acceptable for use in baseline conditions assessment, and for use in the model calibration. Assessment of the data quality will continue through the model calibration process.

WATER QUALITY STANDARDS

Class	Type	Bacteria Standard			Highest Protected Uses	
		Path	GM	SSM	Recreational	Other
SC	Saline	Entero	35	104	Primary	Shellfishing*
SE1	Saline	Entero	35	104	Primary	Shellfishing*
SE2	Saline	Fecal	770	na	Secondary	Diadromous fish migration
SE3	Saline	Fecal	1500	na	Secondary	Diadromous fish migration
FW2	Fresh	Ecoli	126	235	Primary	Public water supply

*Shellfish Waters are subject to the National Shellfish Sanitation Program standard for approved shellfish waters

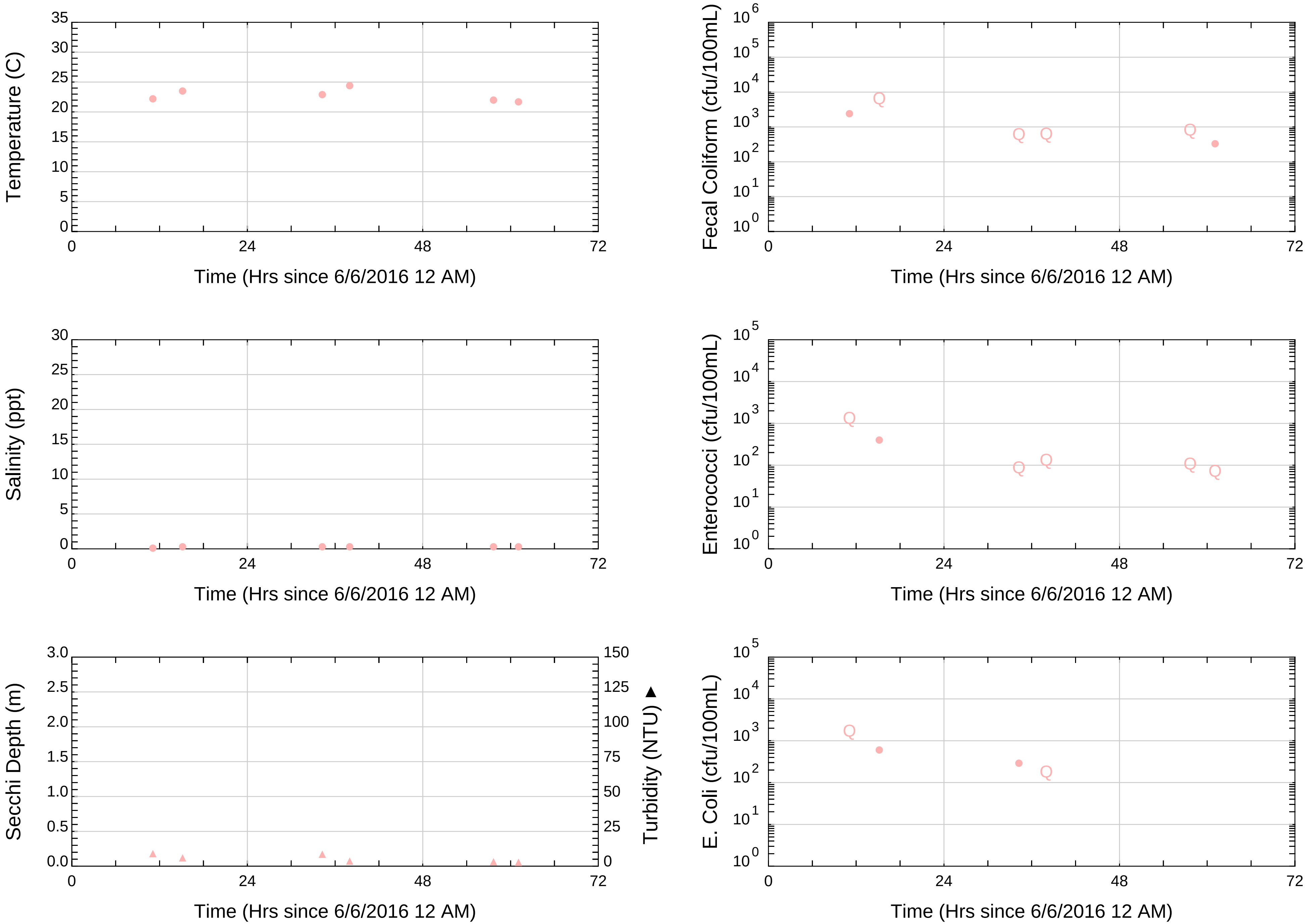
Passaic River & Tributaries, Passaic River, 1, (FW2)



Q: See page 1 of attachment
for notes on qualifiers

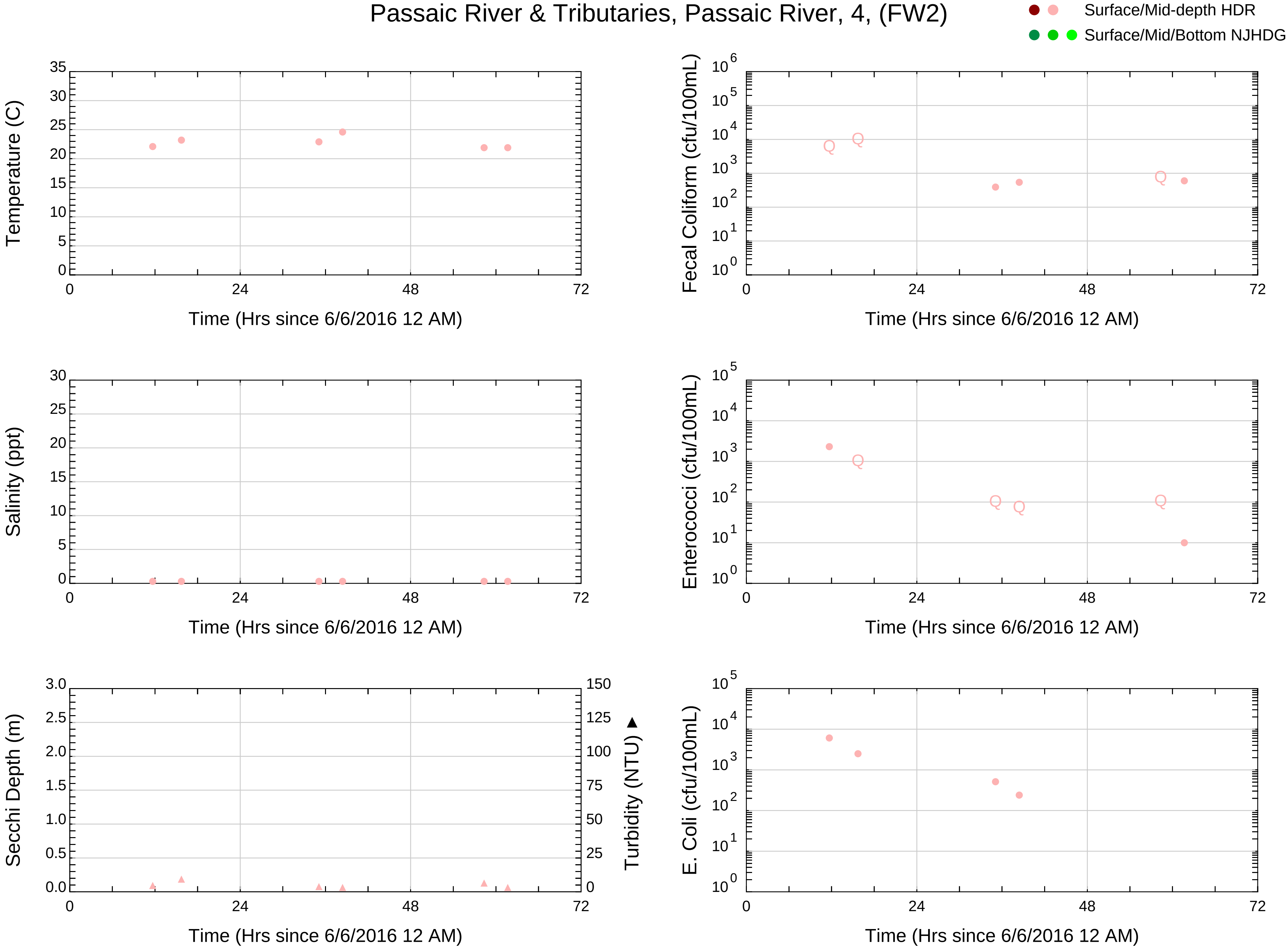
Passaic River & Tributaries, Passaic River, 3, (FW2)

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG



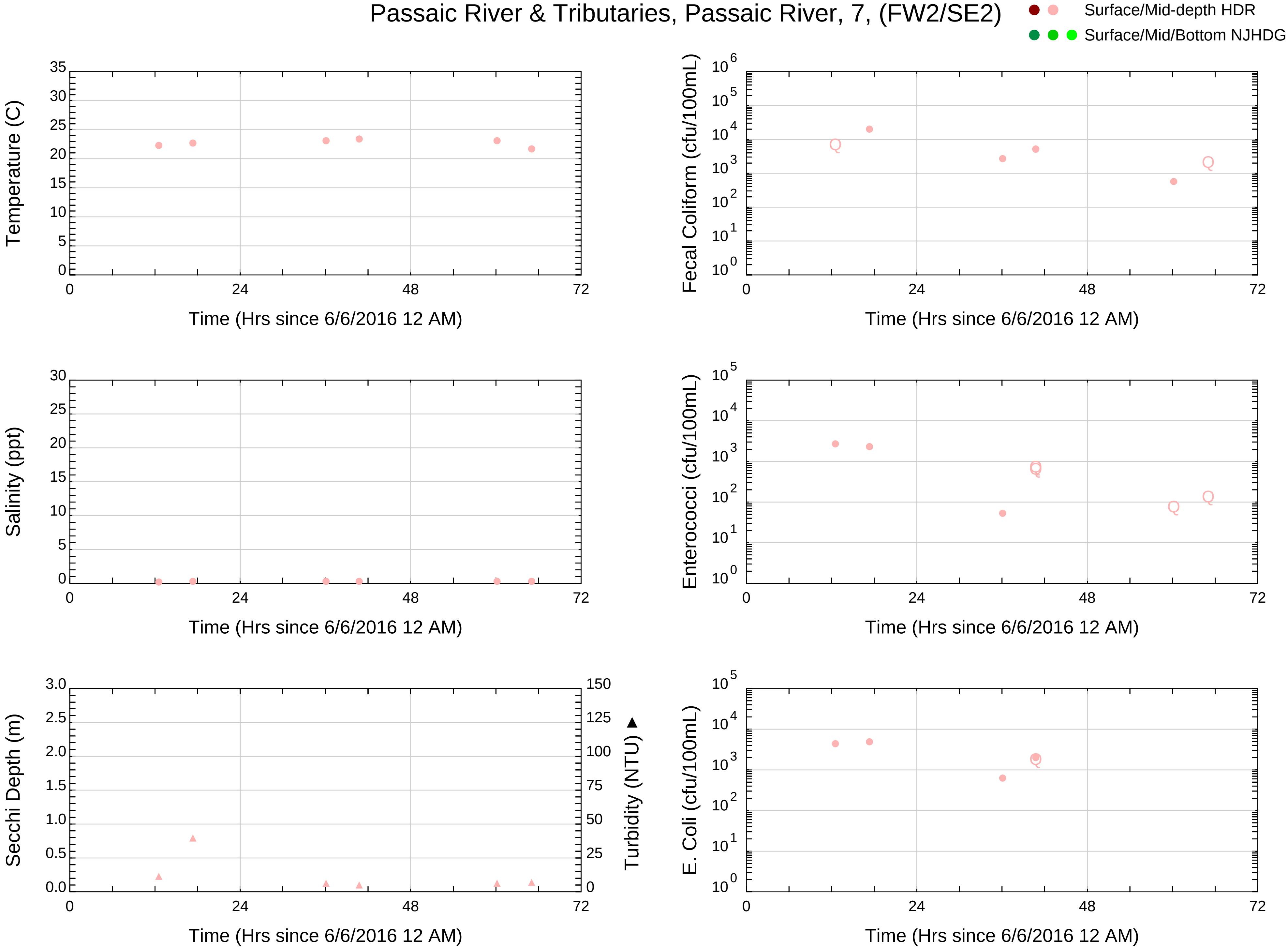
Q: See page 1 of attachment for notes on qualifiers

Passaic River & Tributaries, Passaic River, 4, (FW2)



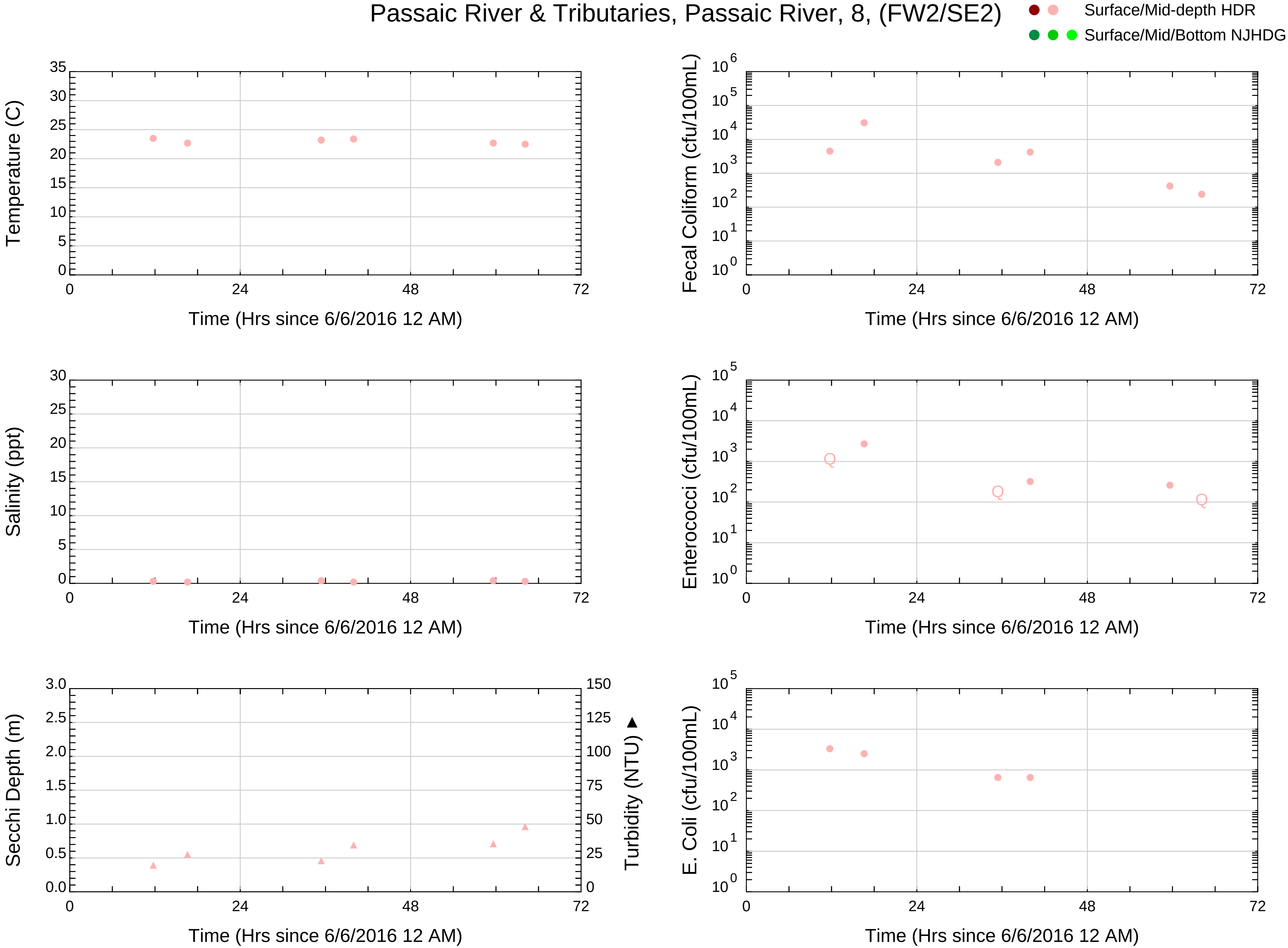
Q: See page 1 of attachment
for notes on qualifiers

Passaic River & Tributaries, Passaic River, 7, (FW2/SE2)



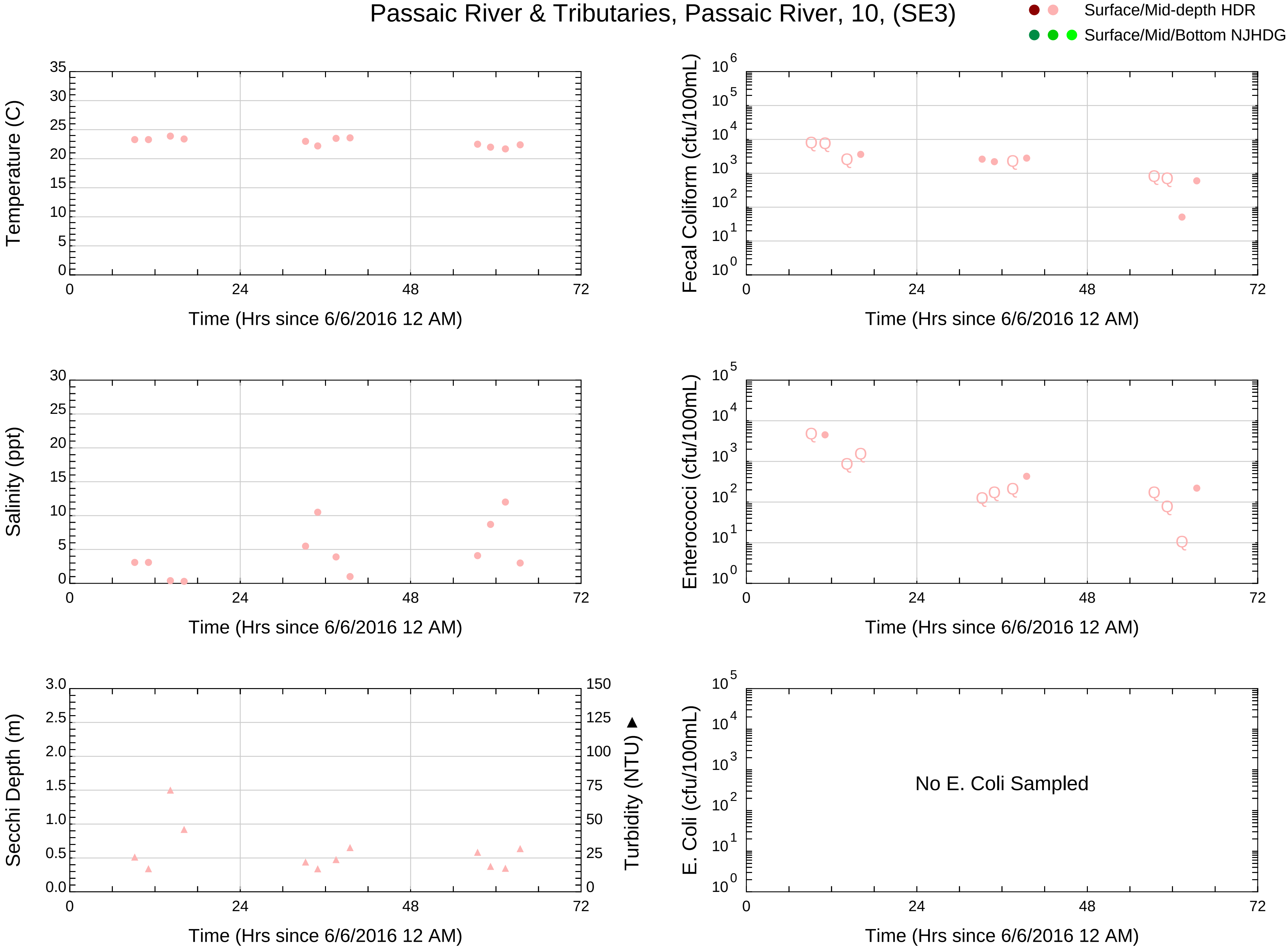
Q: See page 1 of attachment for notes on qualifiers

Passaic River & Tributaries, Passaic River, 8, (FW2/SE2)



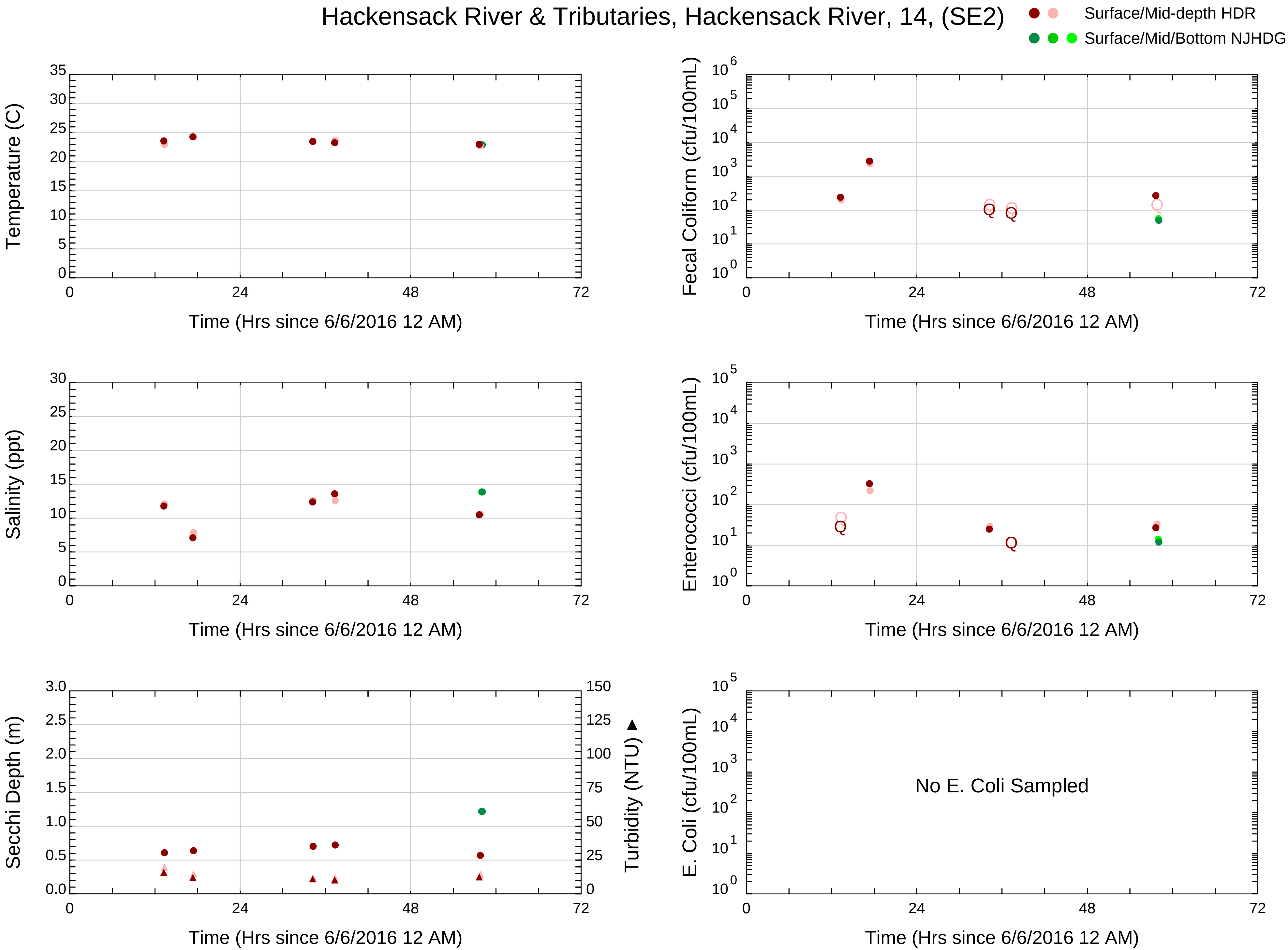
Q: See page 1 of attachment for notes on qualifiers

Passaic River & Tributaries, Passaic River, 10, (SE3)



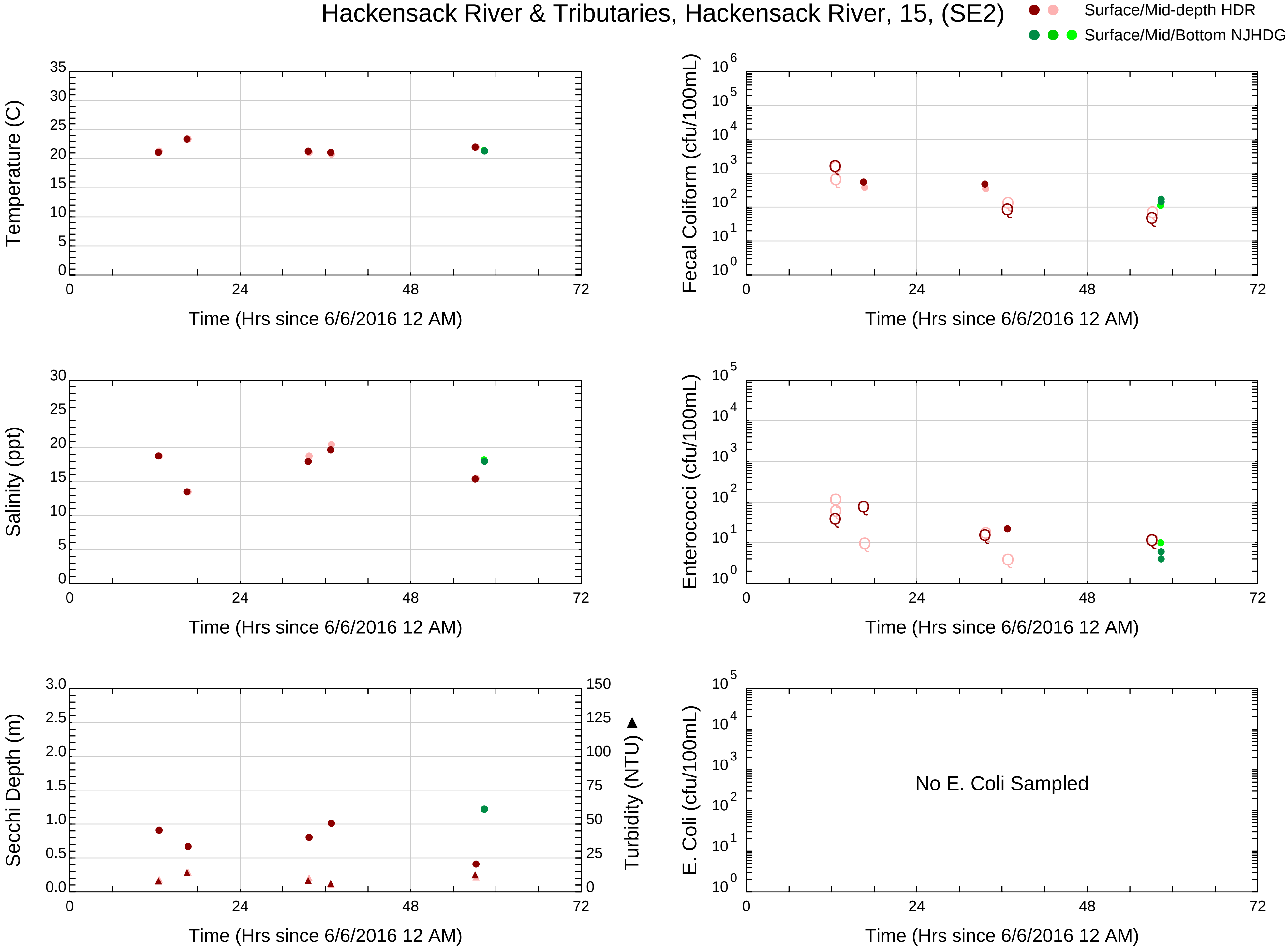
Q: See page 1 of attachment for notes on qualifiers

Hackensack River & Tributaries, Hackensack River, 14, (SE2)



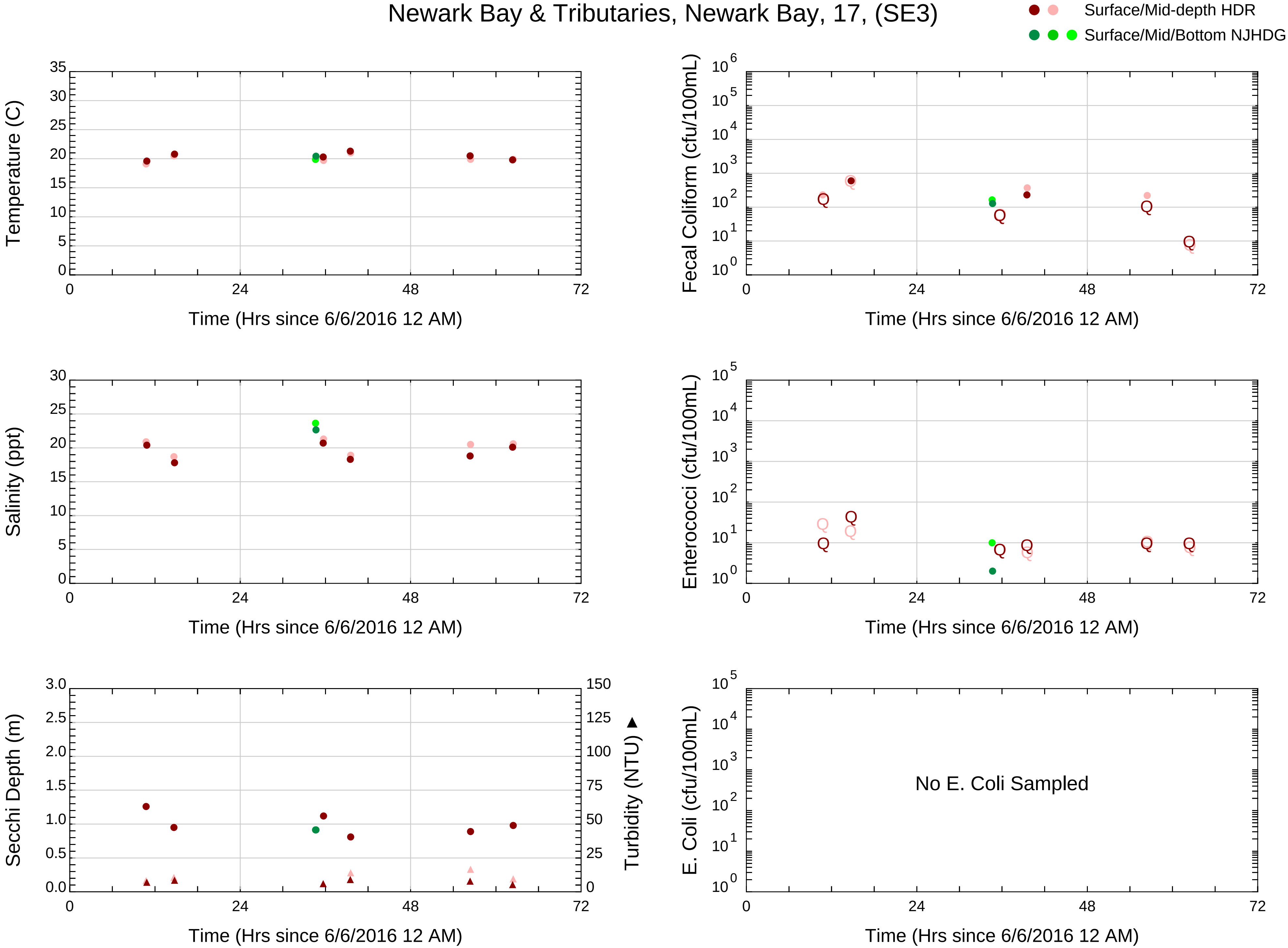
Q: See page 1 of attachment for notes on qualifiers

Hackensack River & Tributaries, Hackensack River, 15, (SE2)



Q: See page 1 of attachment
for notes on qualifiers

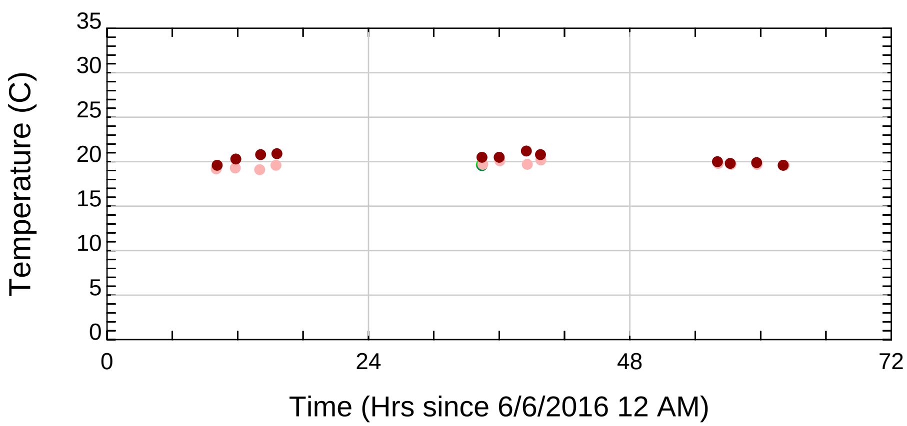
Newark Bay & Tributaries, Newark Bay, 17, (SE3)

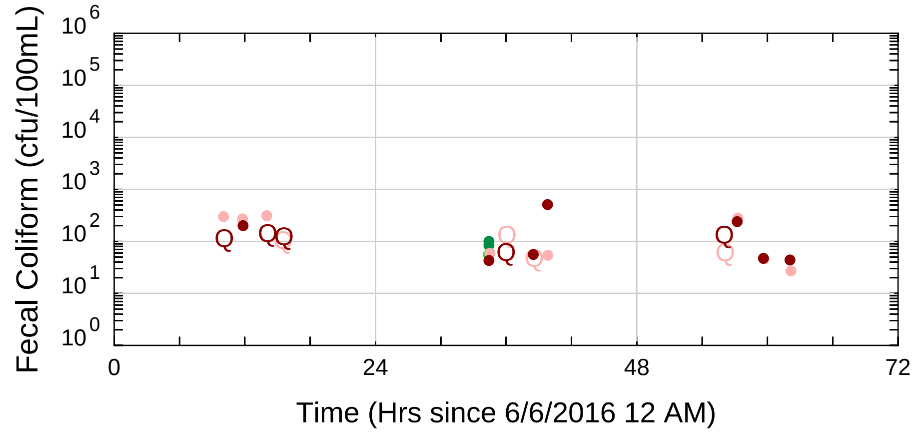


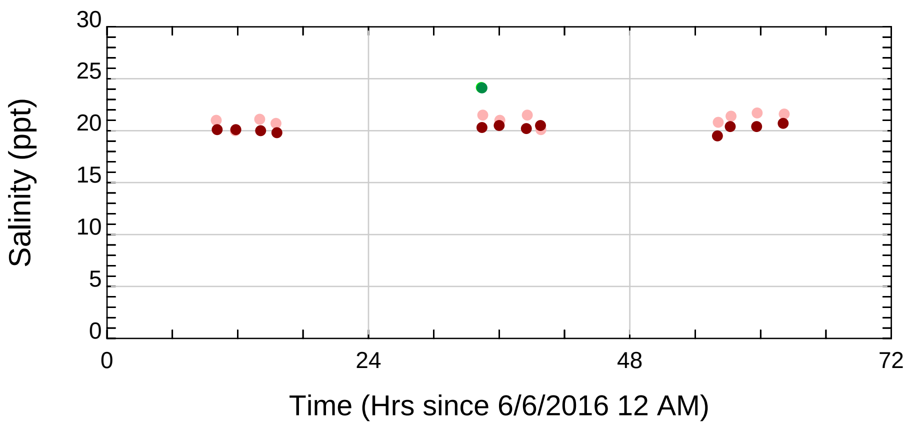
Q: See page 1 of attachment for notes on qualifiers

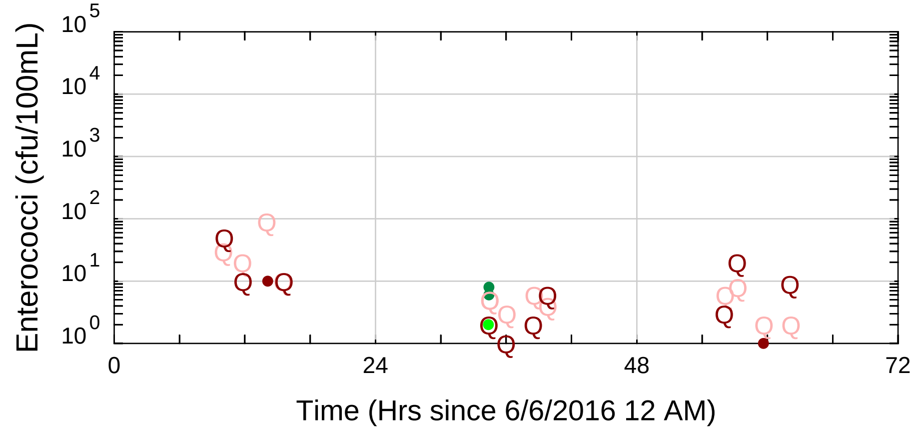
Newark Bay & Tributaries, Newark Bay, 18, (SE3)

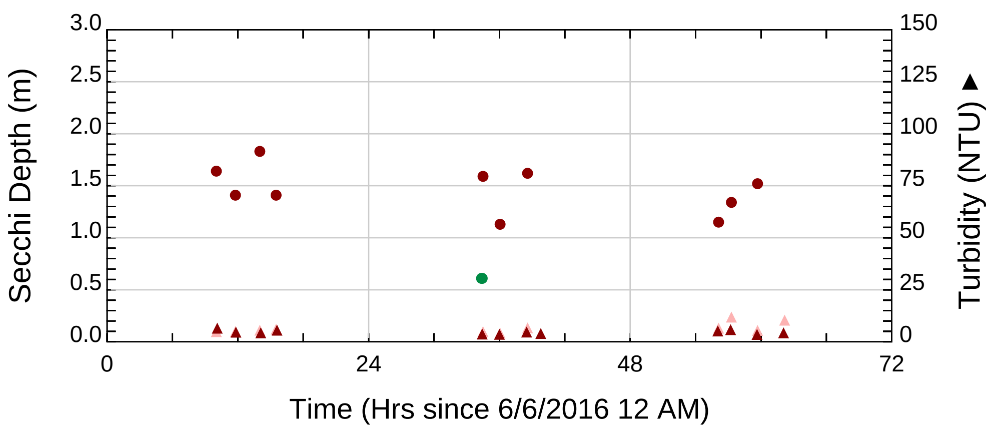
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

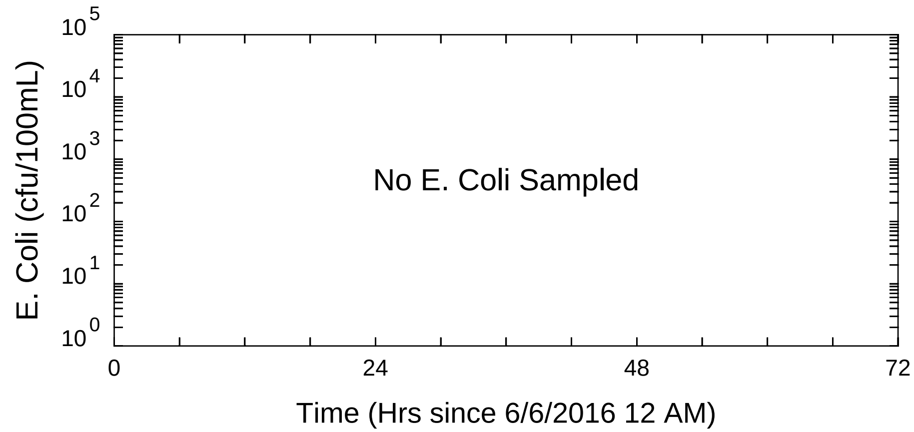








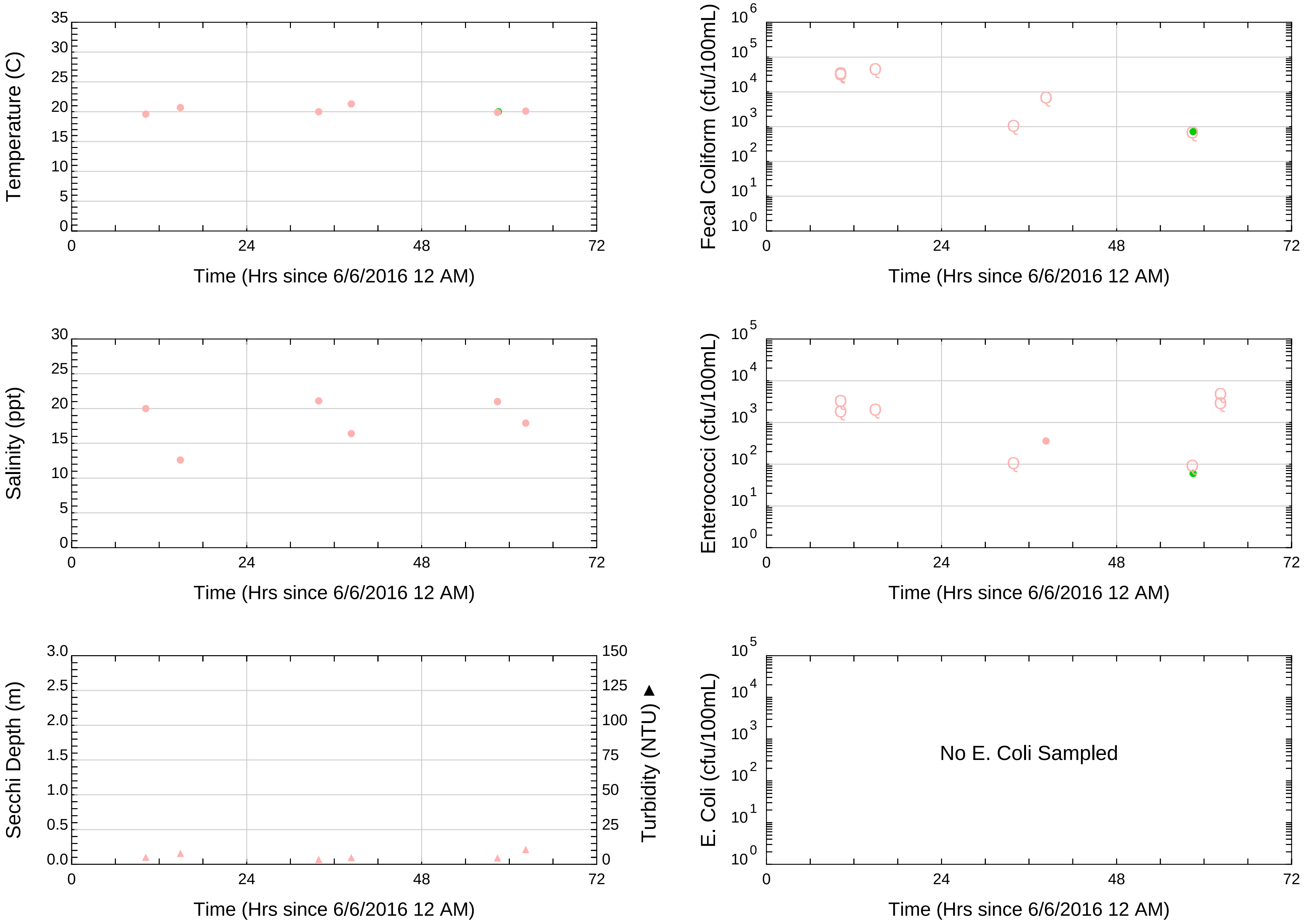




Q: See page 1 of attachment for notes on qualifiers

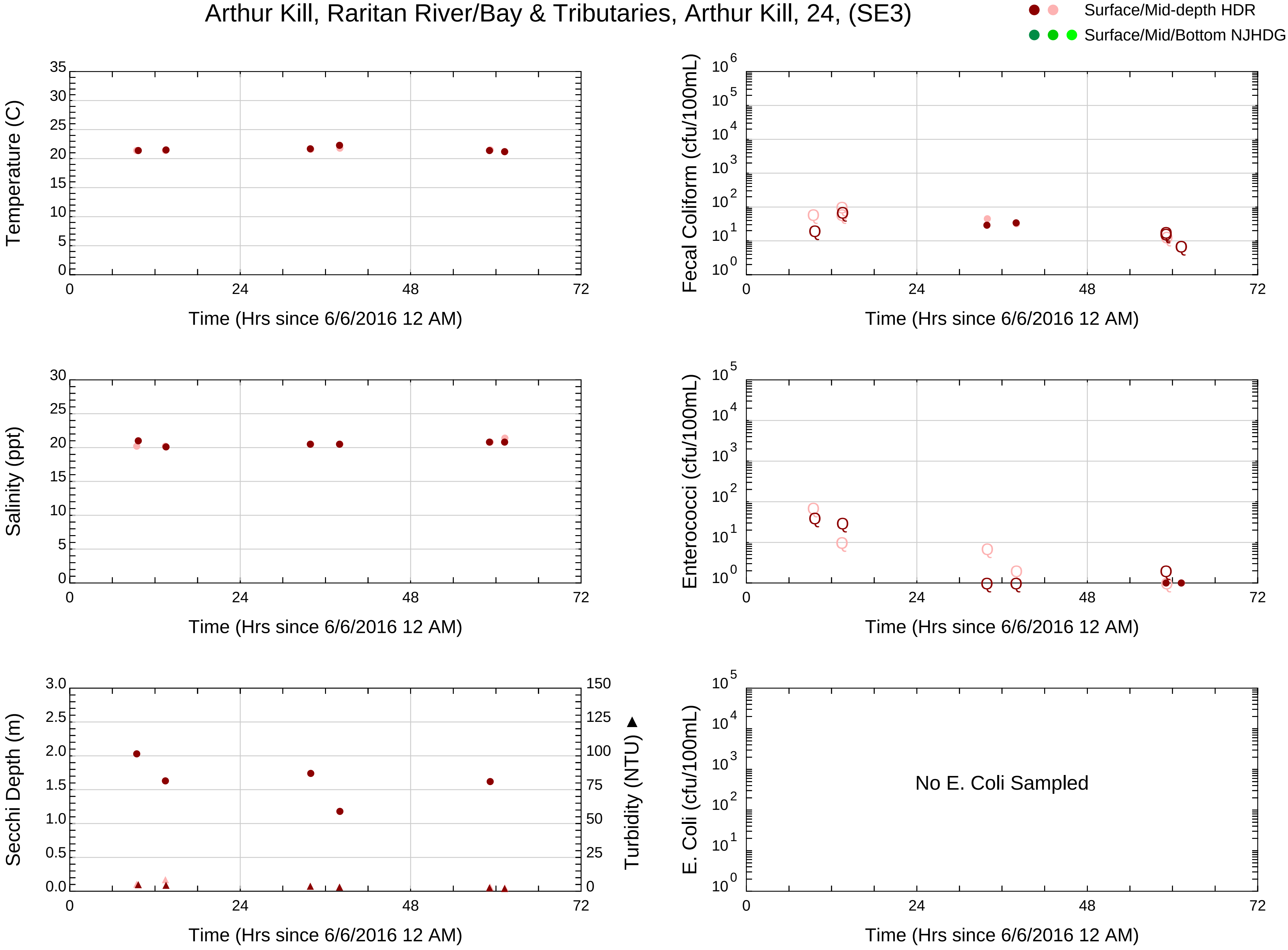
Newark Bay & Tributaries, Elizabeth River, 20, (SE3)

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG



Q: See page 1 of attachment
for notes on qualifiers

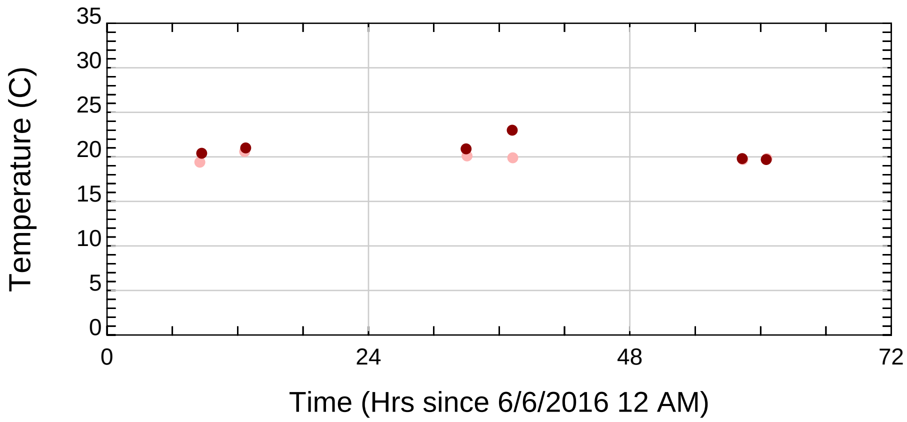
Arthur Kill, Raritan River/Bay & Tributaries, Arthur Kill, 24, (SE3)

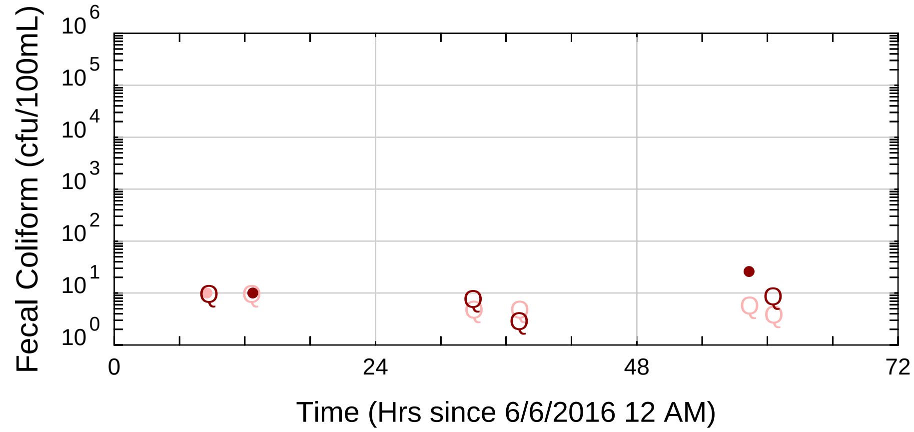


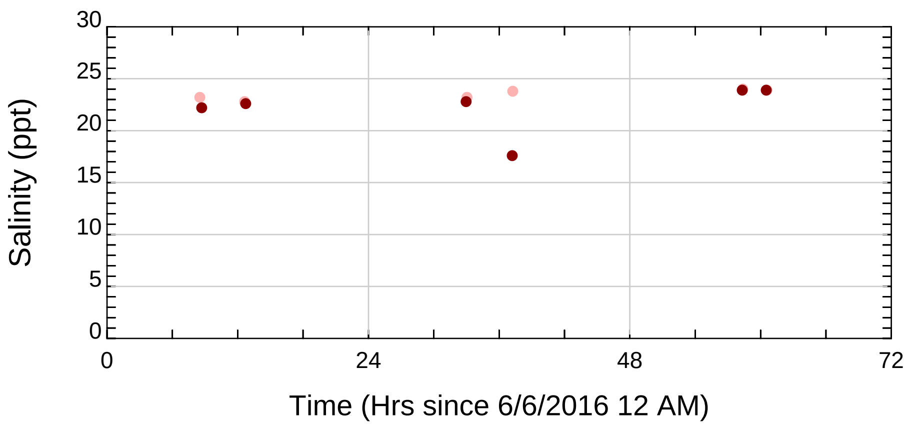
Q: See page 1 of attachment for notes on qualifiers

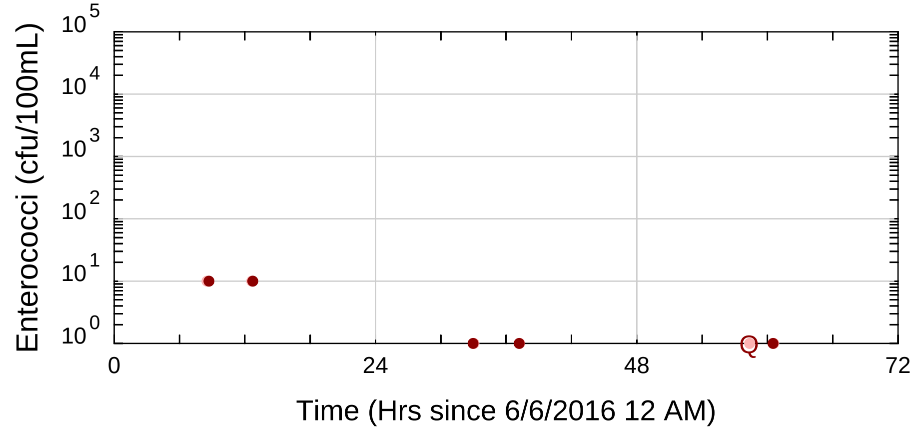
Arthur Kill, Raritan River/Bay & Tributaries, Raritan Bay, 29, (Shellfish)

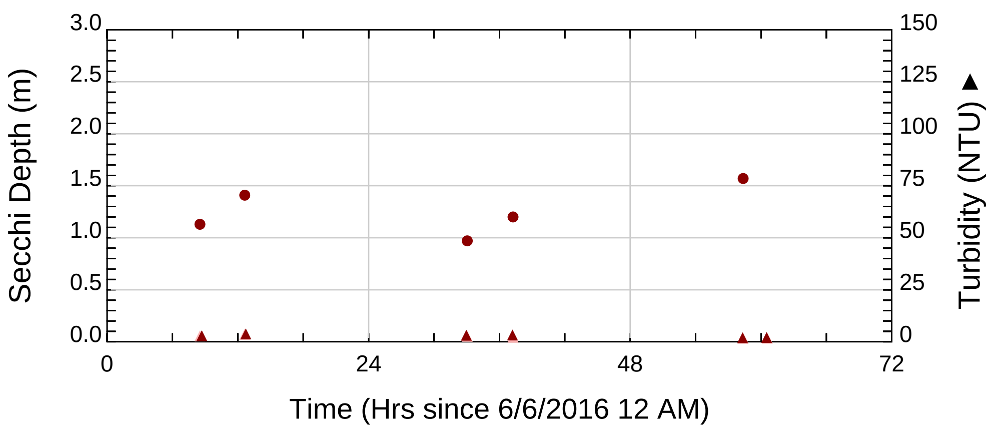
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

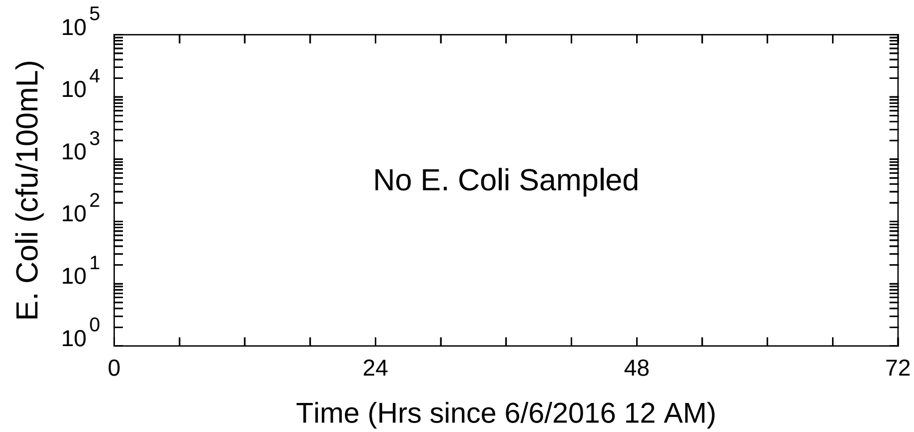






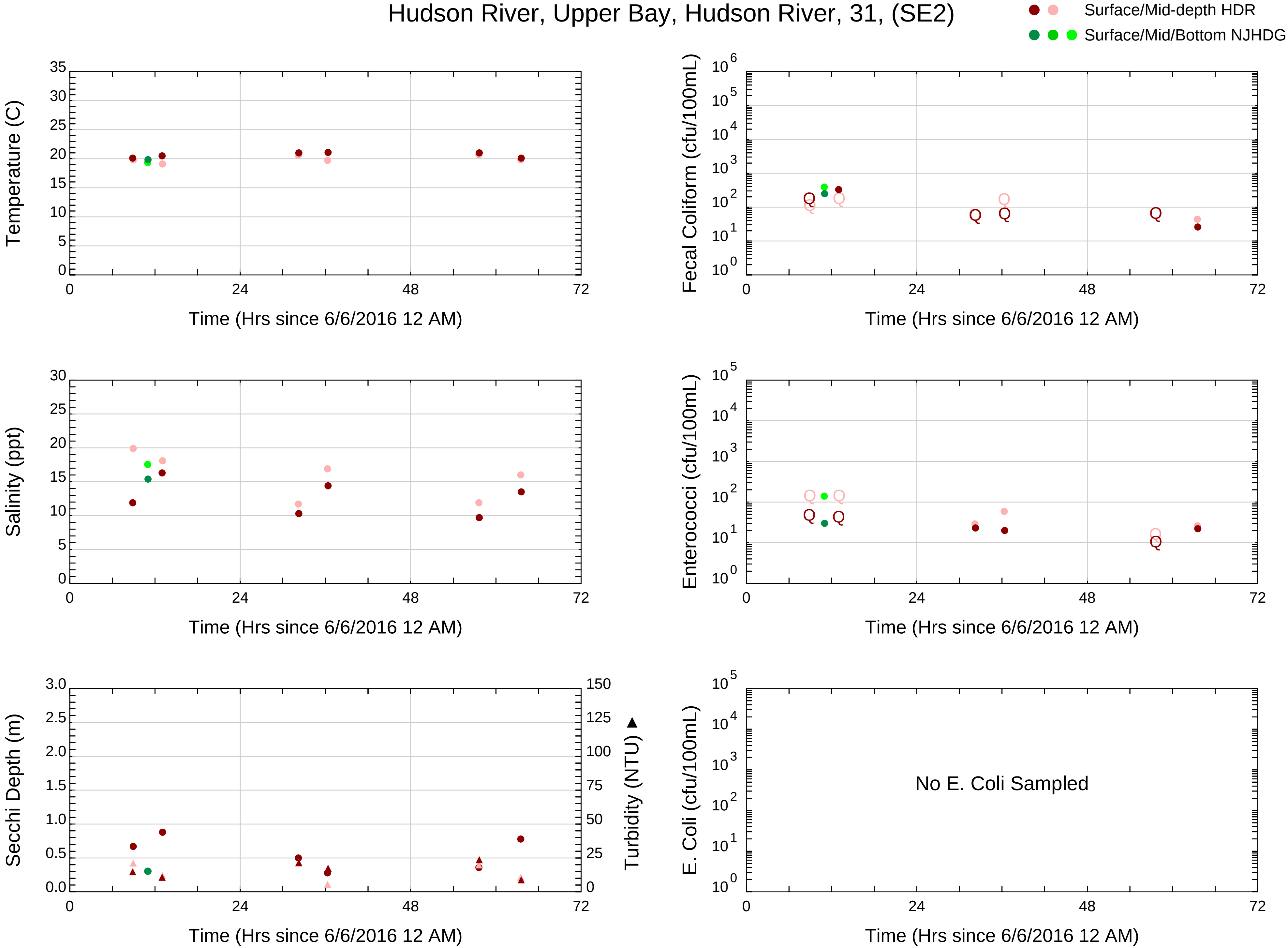






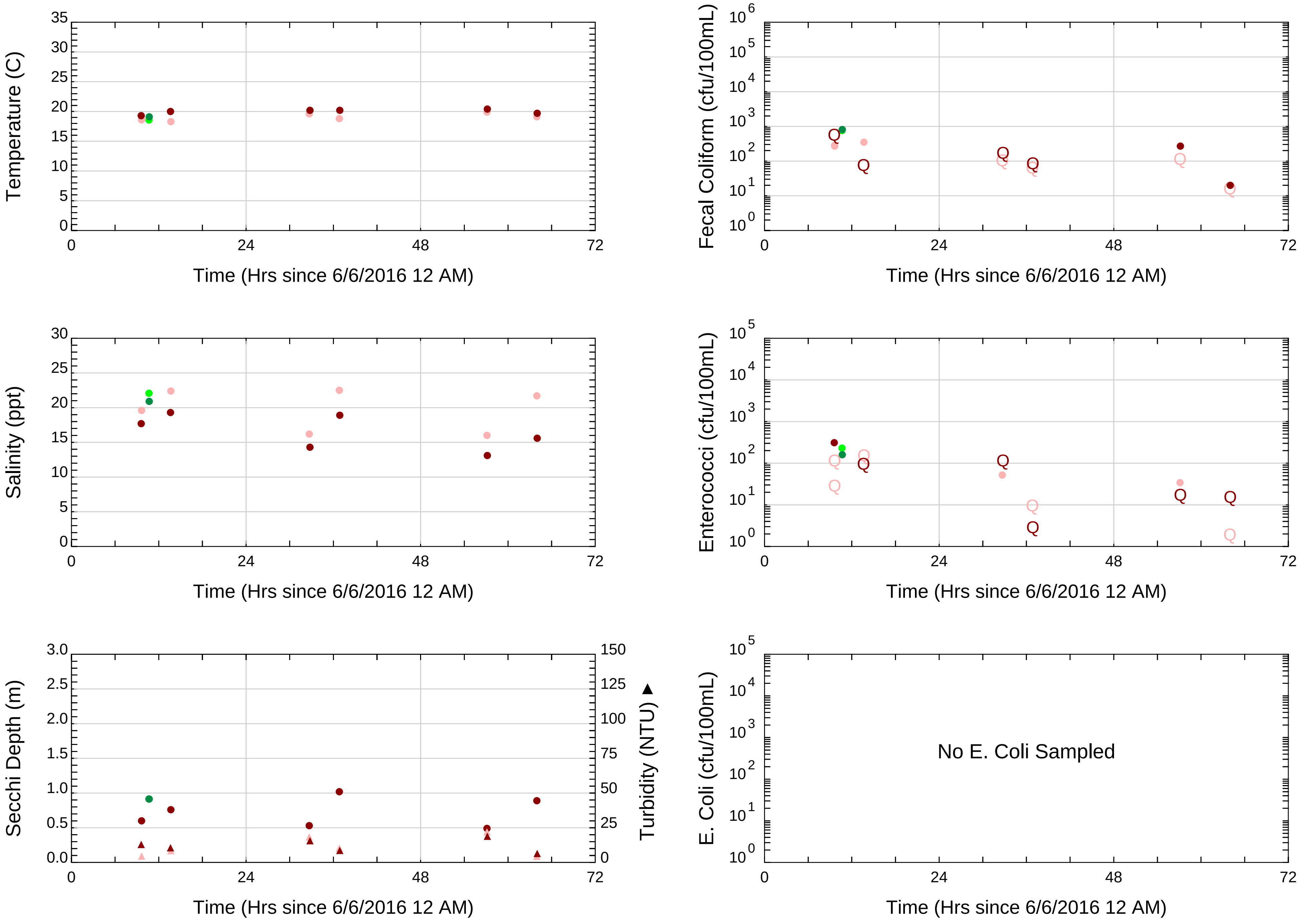
Q: See page 1 of attachment for notes on qualifiers

Hudson River, Upper Bay, Hudson River, 31, (SE2)



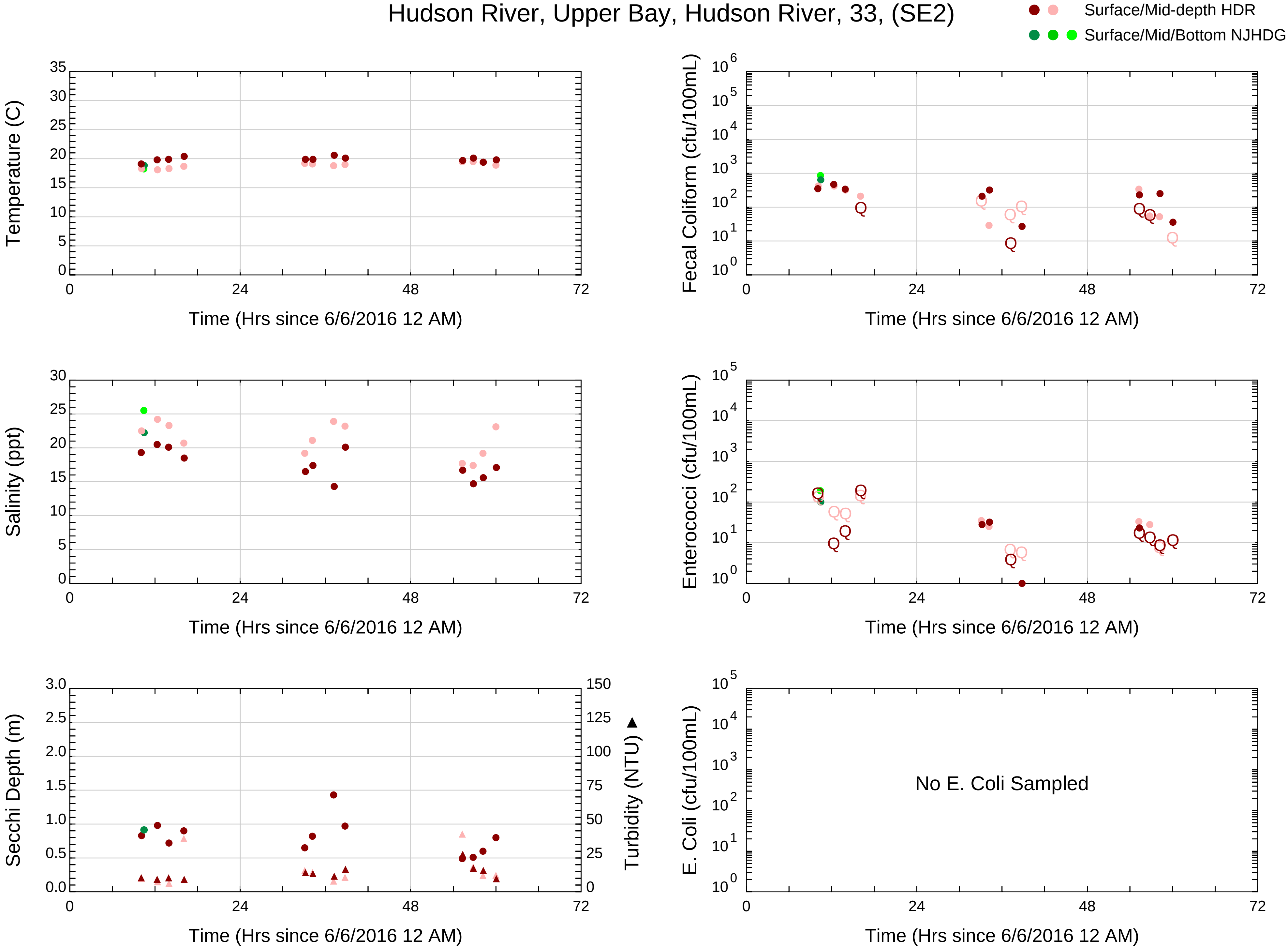
Q: See page 1 of attachment for notes on qualifiers

Hudson River, Upper Bay, Hudson River, 32, (SE2)



Q: See page 1 of attachment for notes on qualifiers

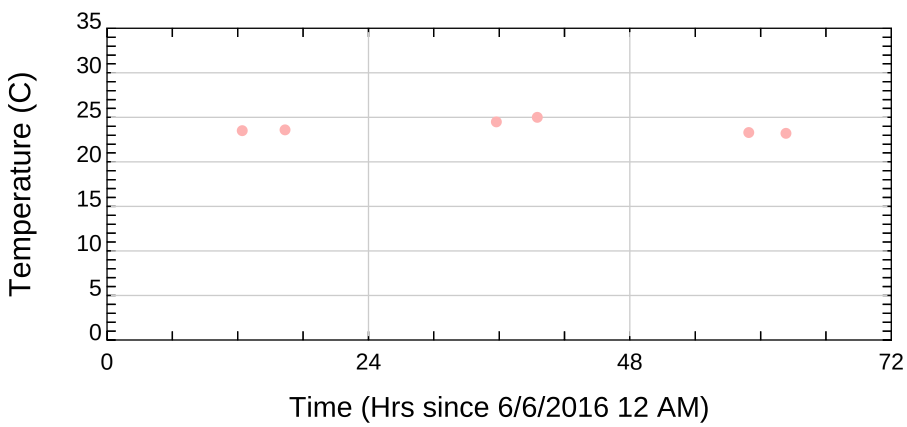
Hudson River, Upper Bay, Hudson River, 33, (SE2)

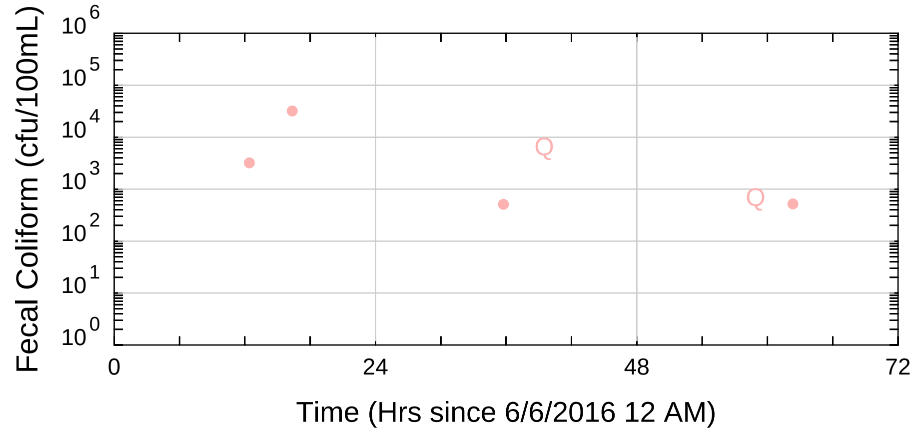


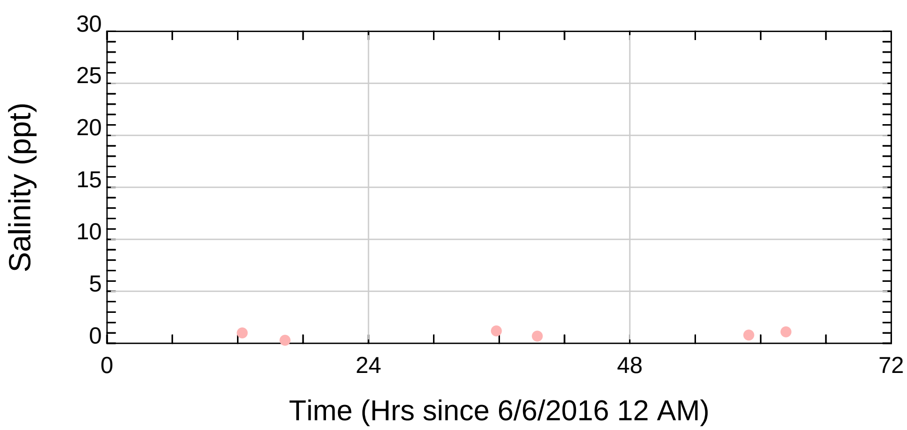
Q: See page 1 of attachment for notes on qualifiers

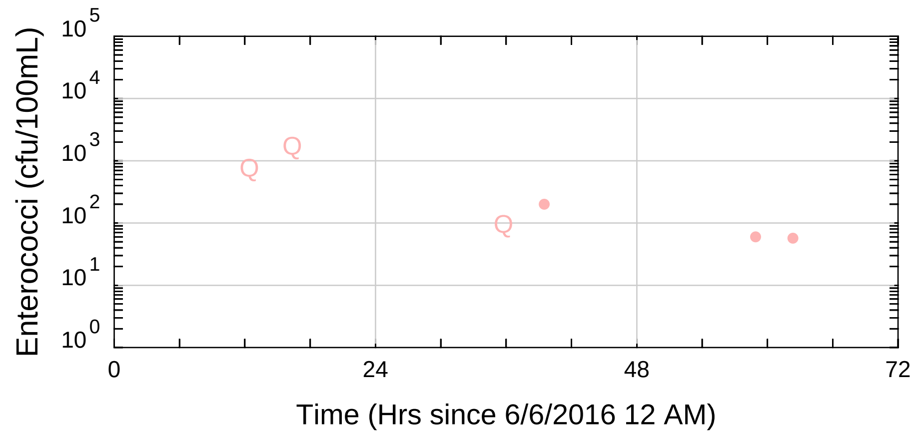
Hackensack River & Tributaries, Hackensack River, B1, (SE1)

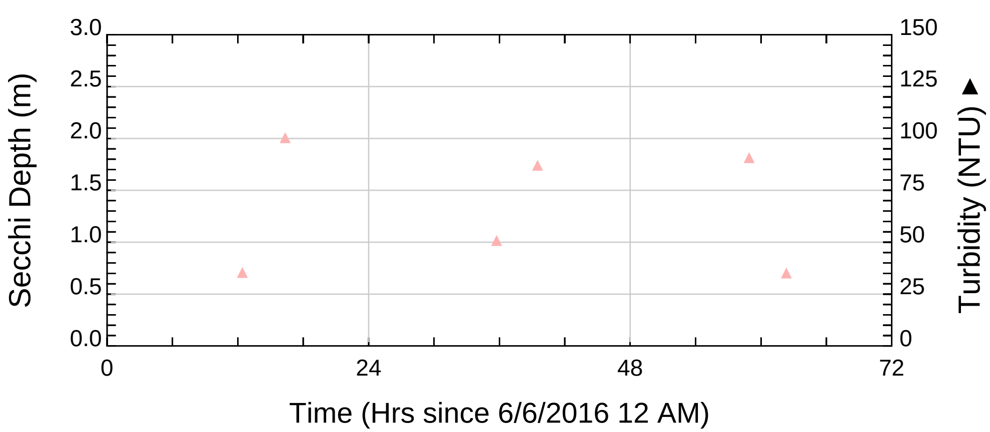
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

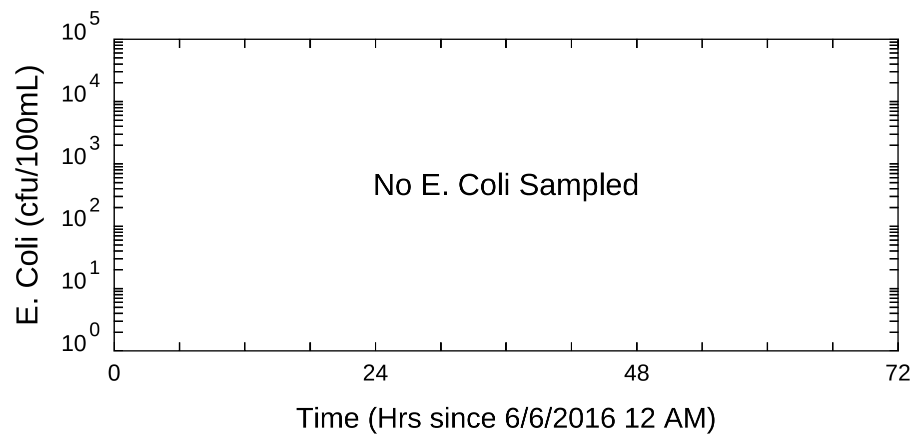






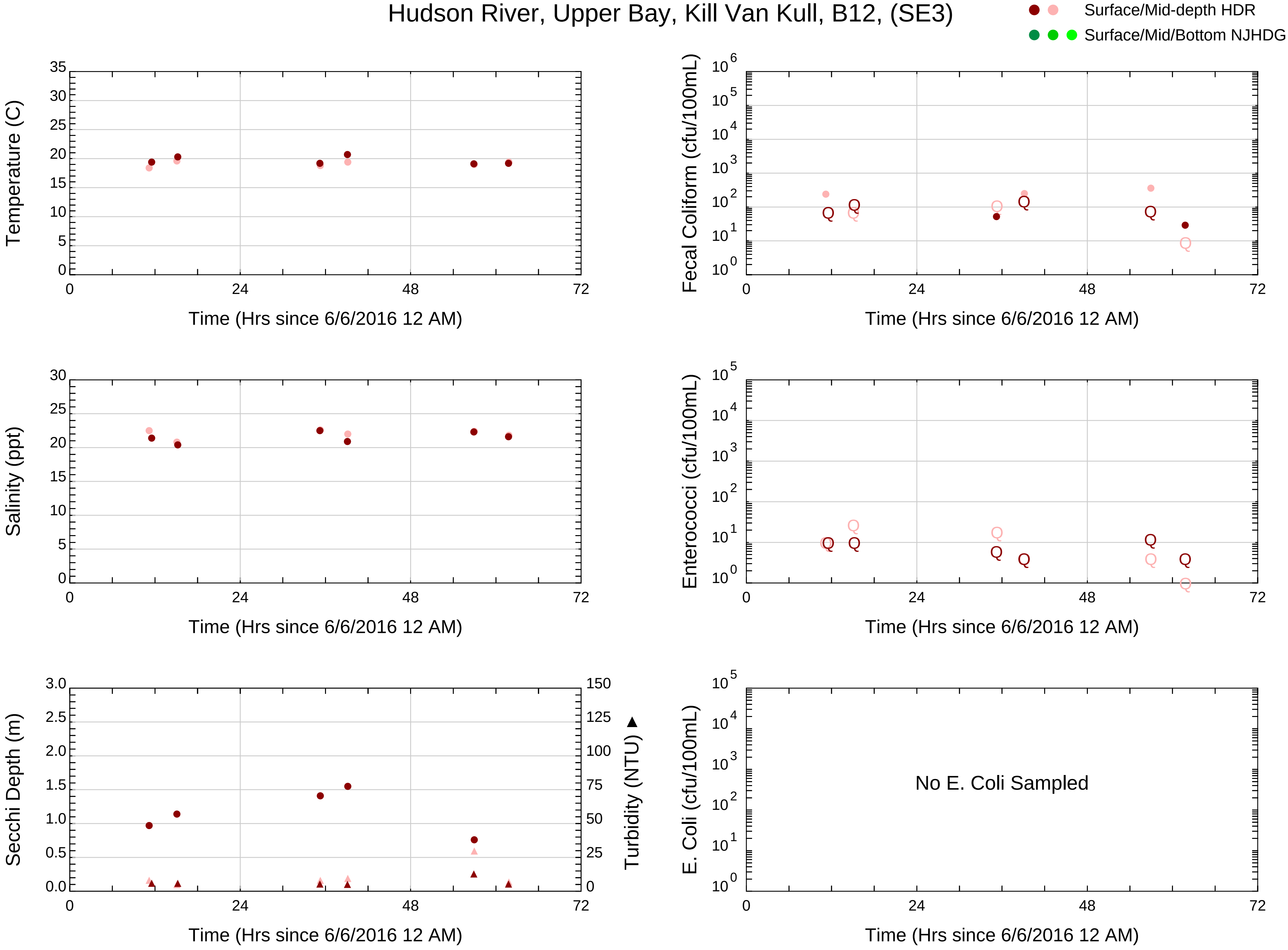






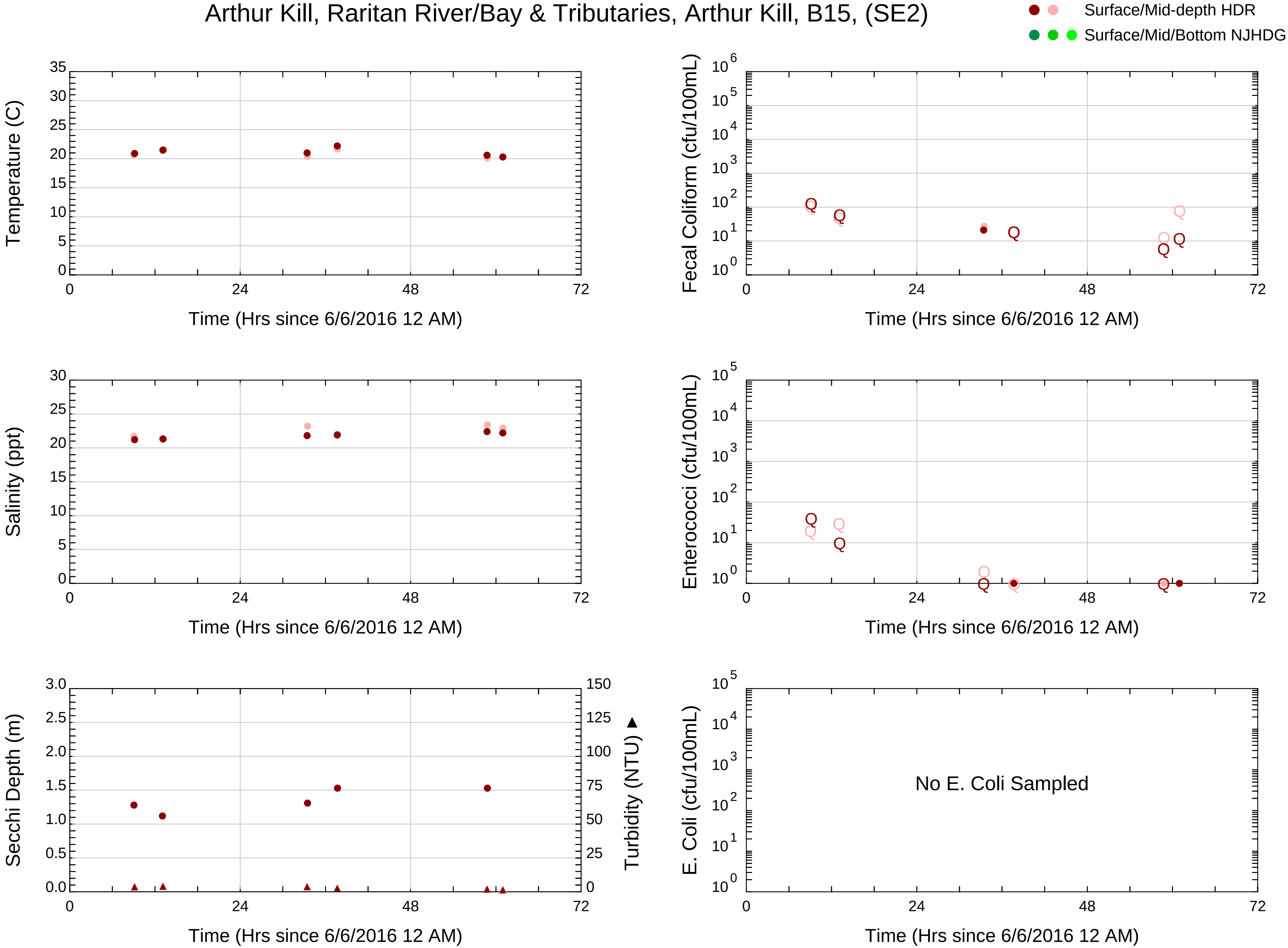
Q: See page 1 of attachment
for notes on qualifiers

Hudson River, Upper Bay, Kill Van Kull, B12, (SE3)



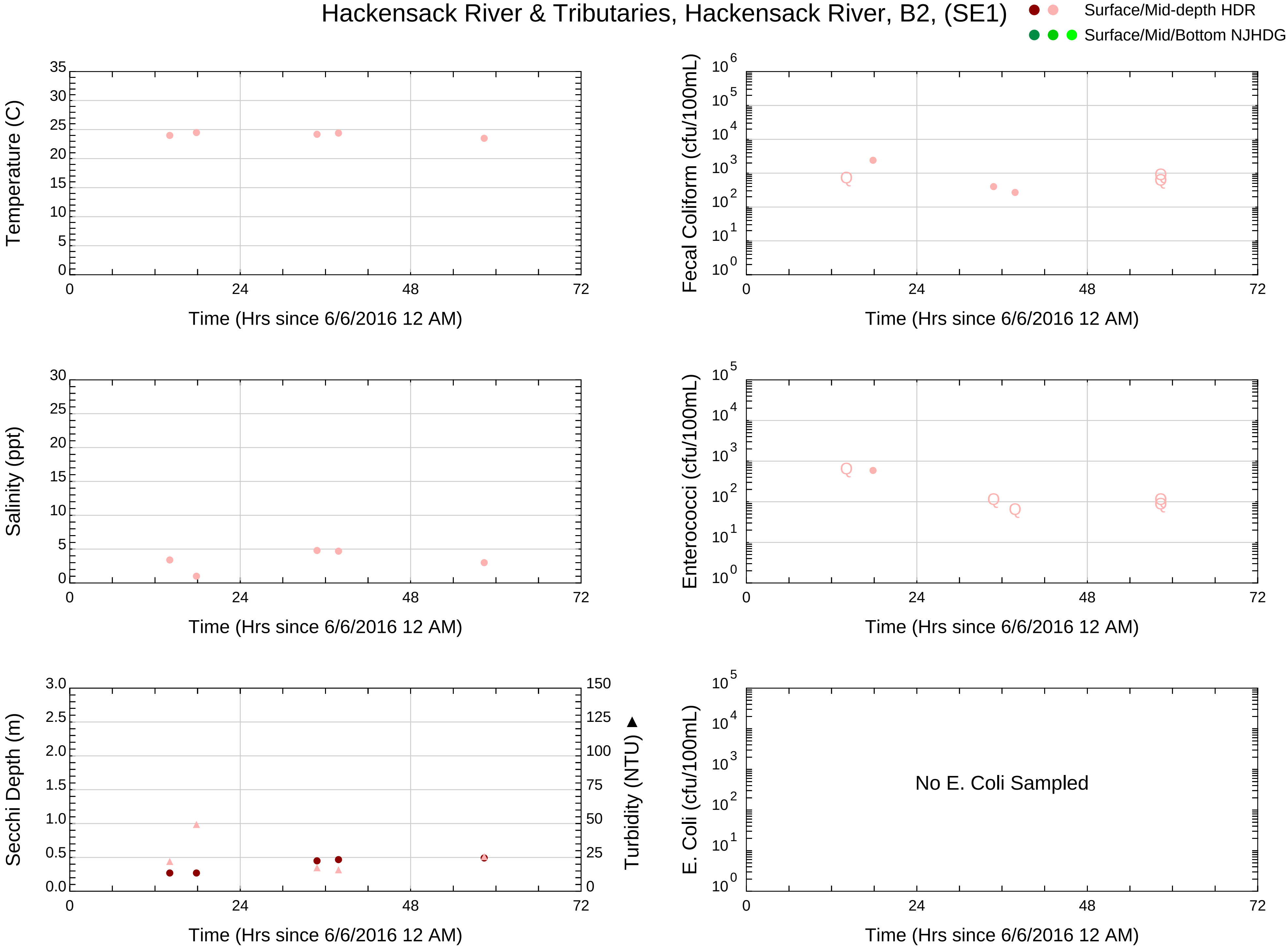
Q: See page 1 of attachment for notes on qualifiers

Arthur Kill, Raritan River/Bay & Tributaries, Arthur Kill, B15, (SE2)



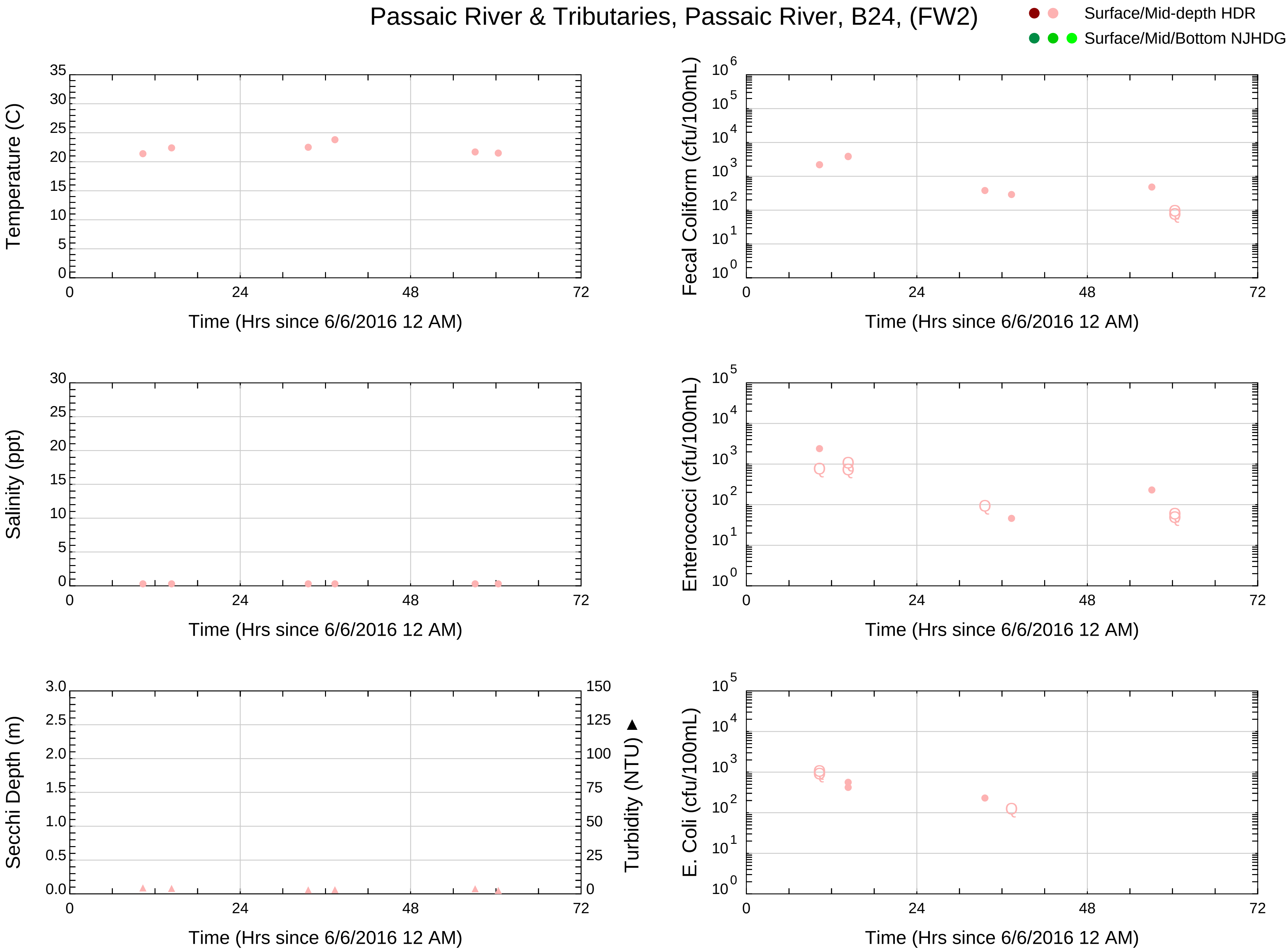
Q: See page 1 of attachment for notes on qualifiers

Hackensack River & Tributaries, Hackensack River, B2, (SE1)



Q: See page 1 of attachment for notes on qualifiers

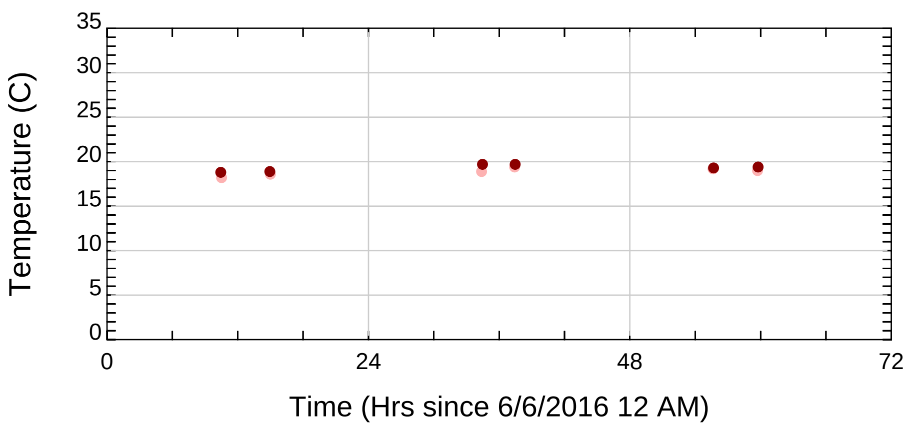
Passaic River & Tributaries, Passaic River, B24, (FW2)

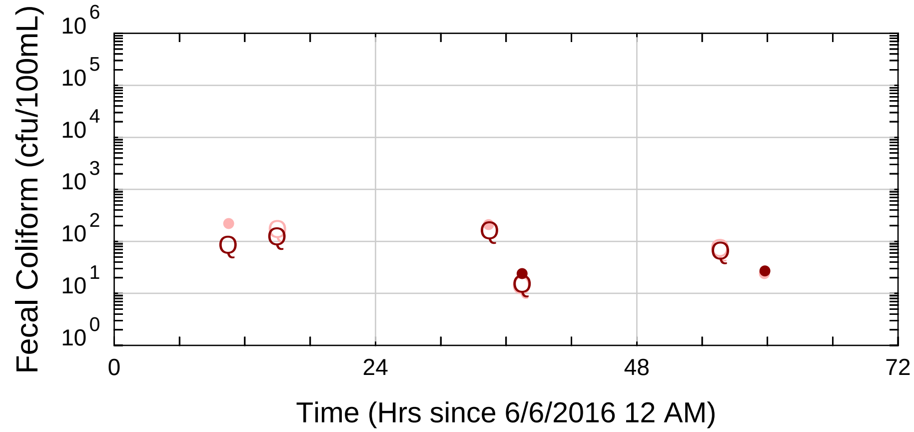


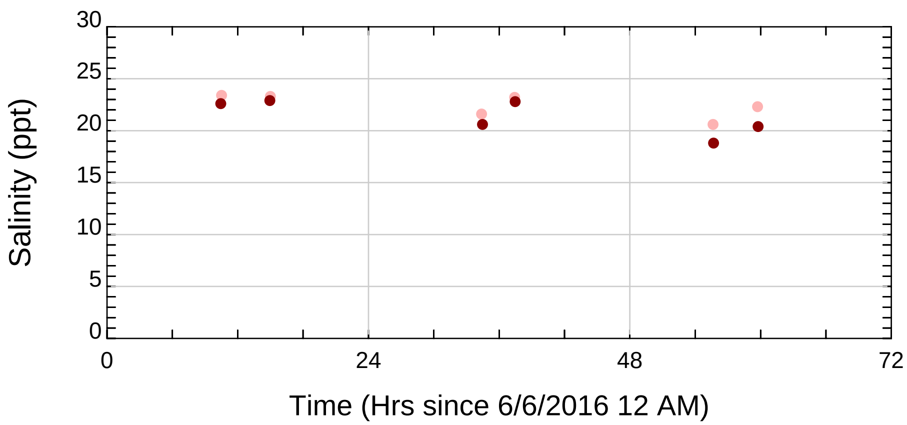
Q: See page 1 of attachment
for notes on qualifiers

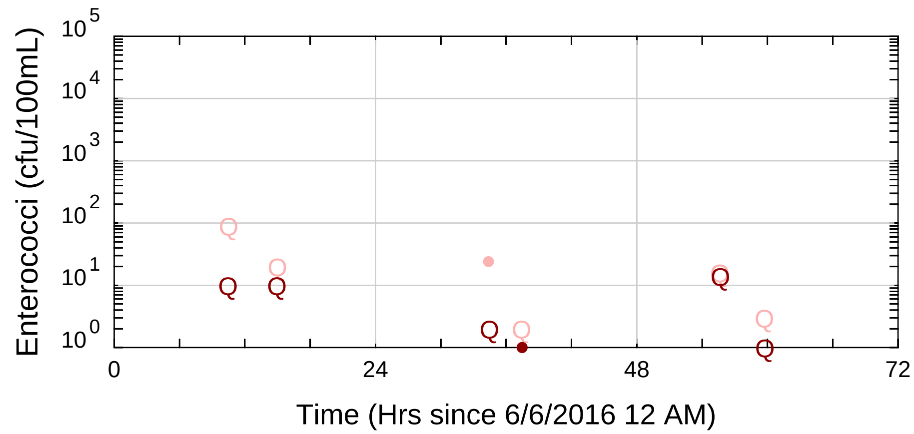
Hudson River, Upper Bay, Upper Bay, B26, (SE2)

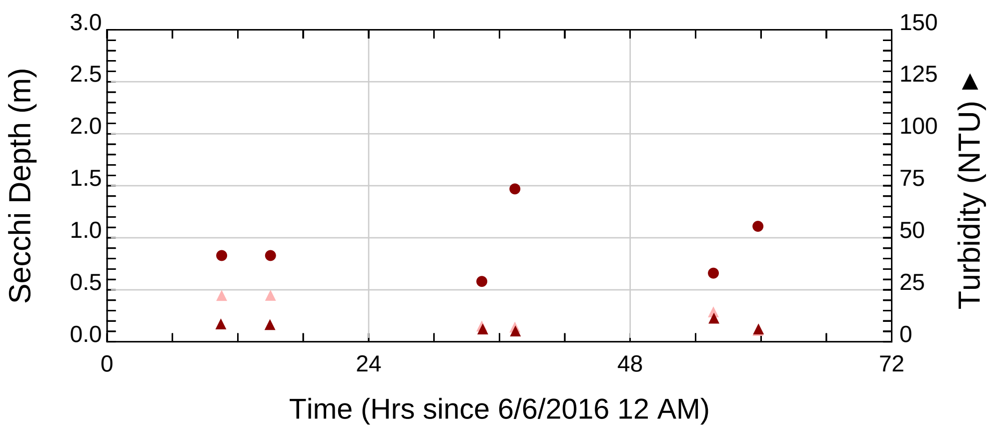
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

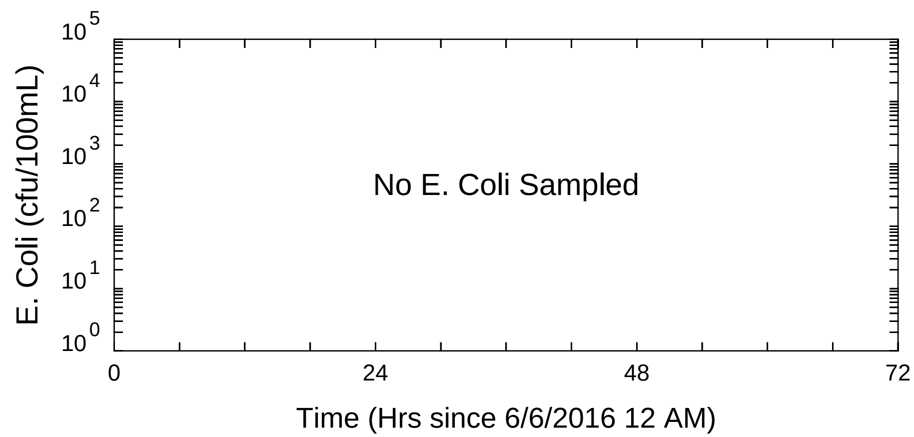








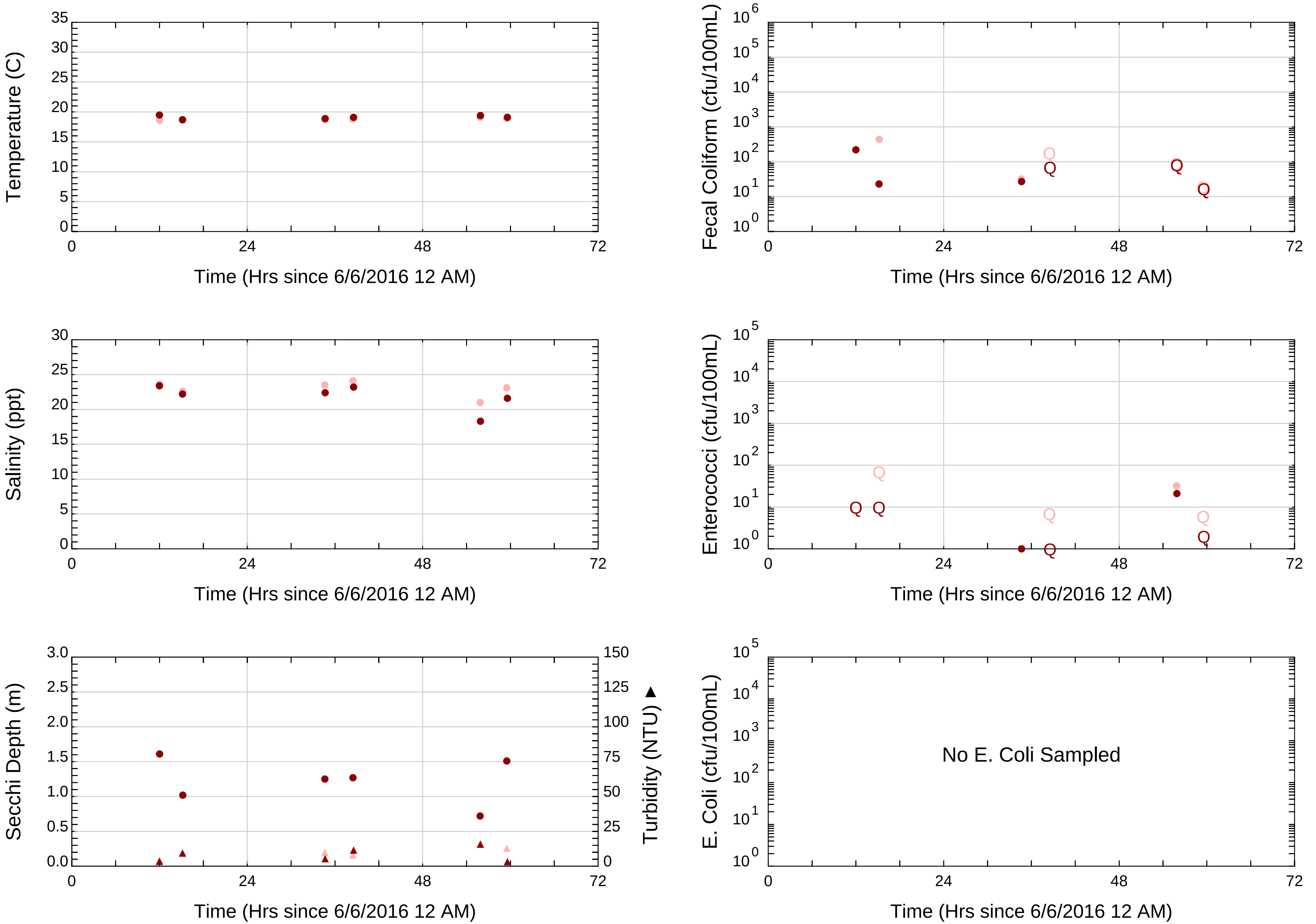




Q: See page 1 of attachment for notes on qualifiers

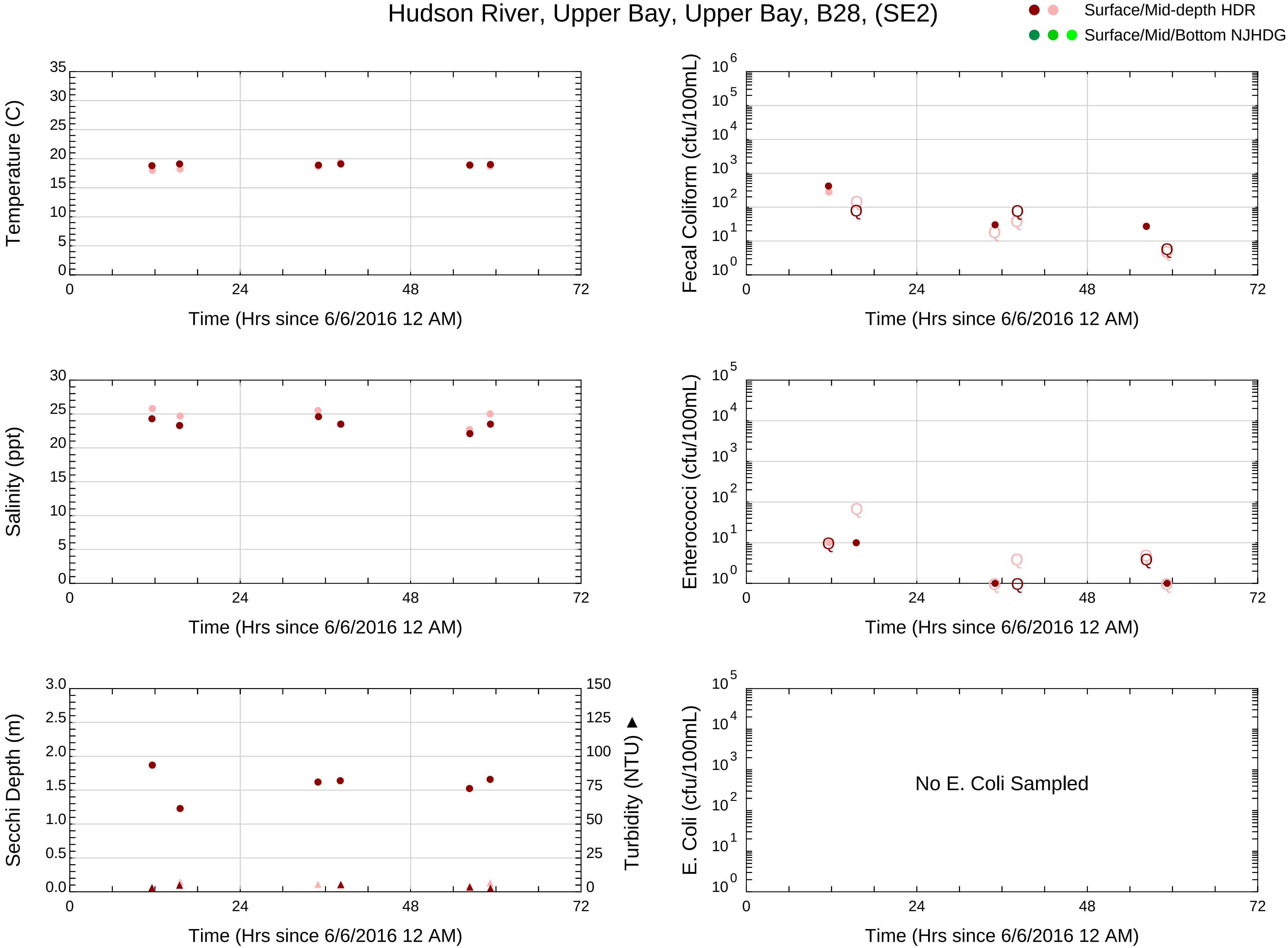
Hudson River, Upper Bay, Upper Bay, B27, (SE2)

● ● Surface/Mid-depth HDR
● ● ● Surface/Mid/Bottom NJHDG



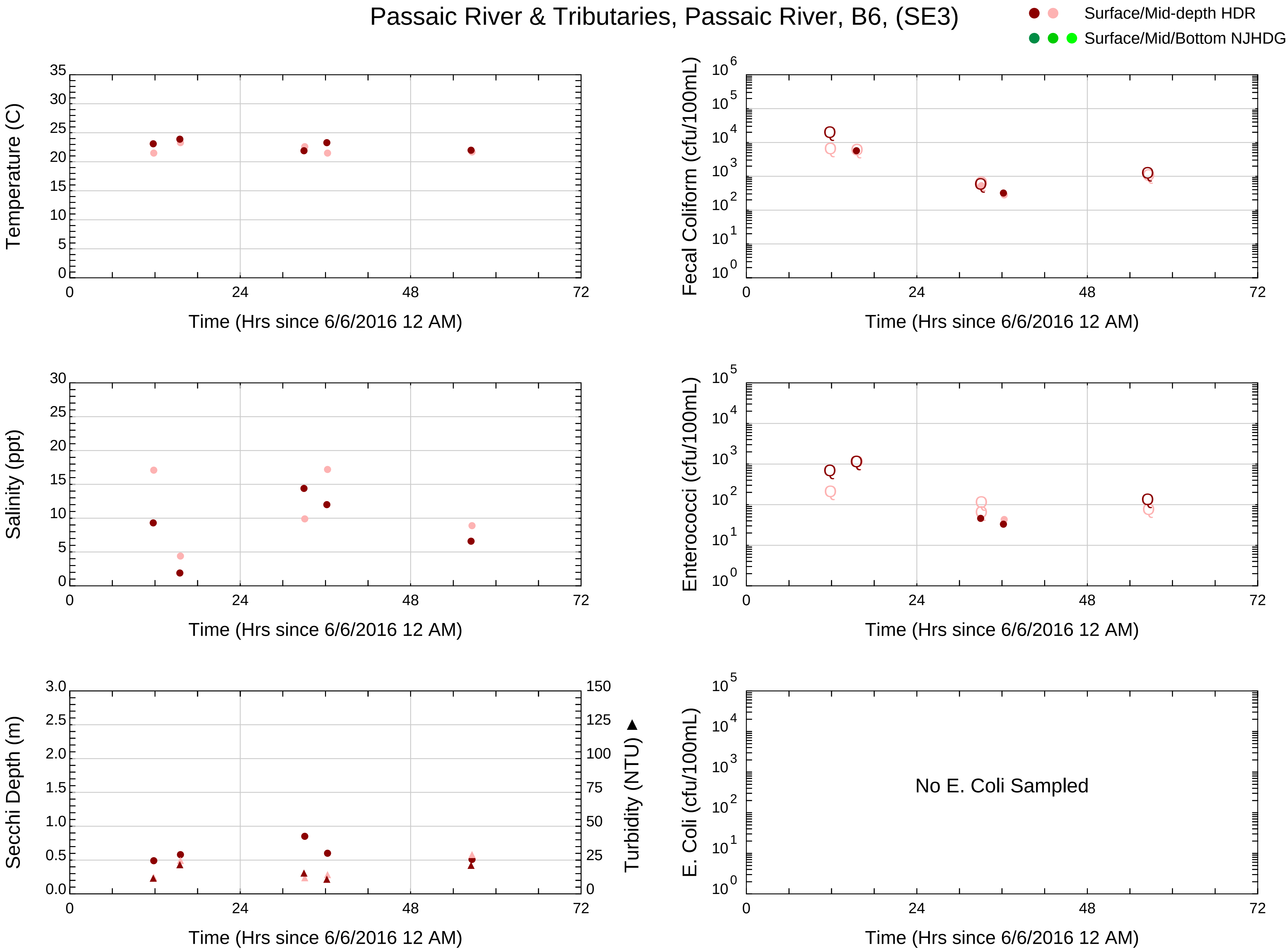
Q: See page 1 of attachment for notes on qualifiers

Hudson River, Upper Bay, Upper Bay, B28, (SE2)



Q: See page 1 of attachment
for notes on qualifiers

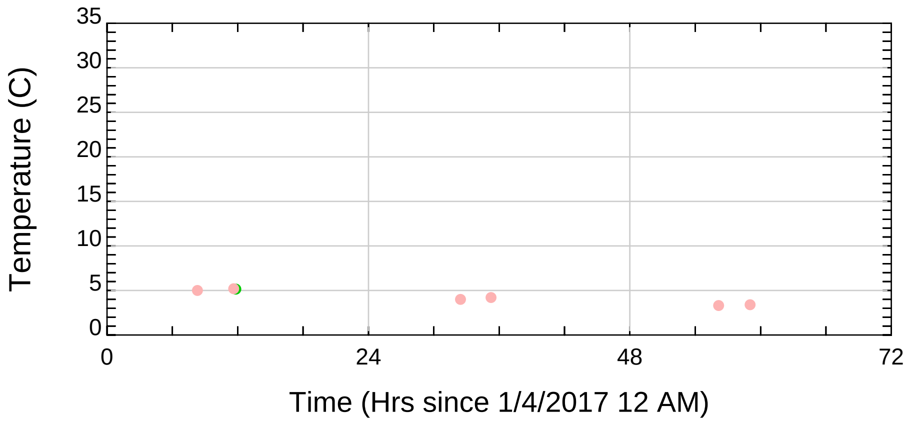
Passaic River & Tributaries, Passaic River, B6, (SE3)

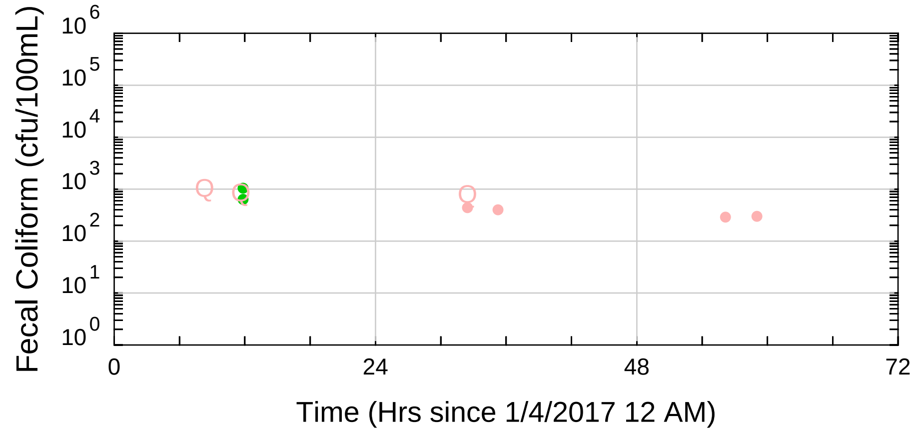


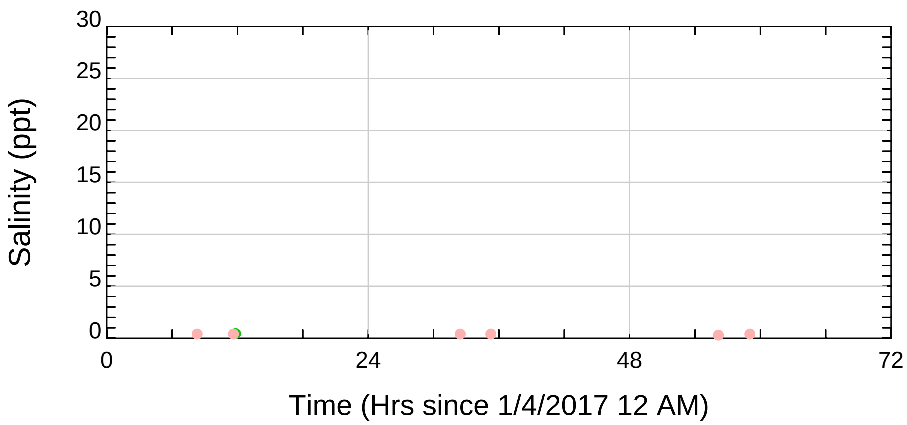
Q: See page 1 of attachment for notes on qualifiers

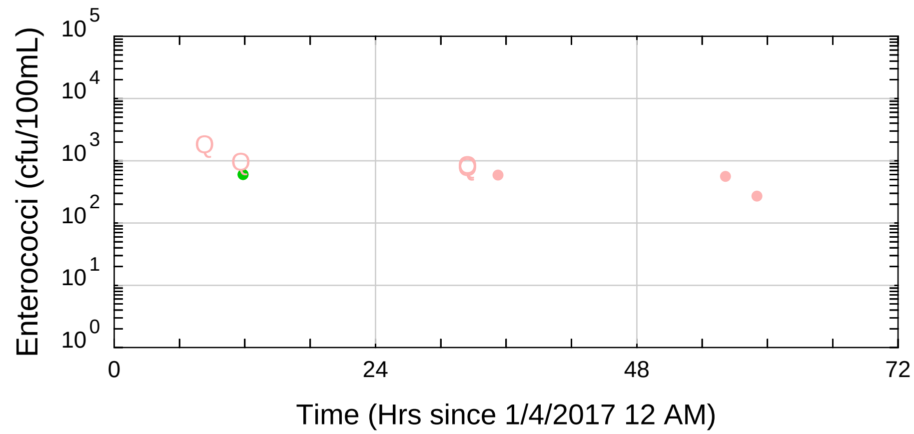
Passaic River & Tributaries, Passaic River, 1, (FW2)

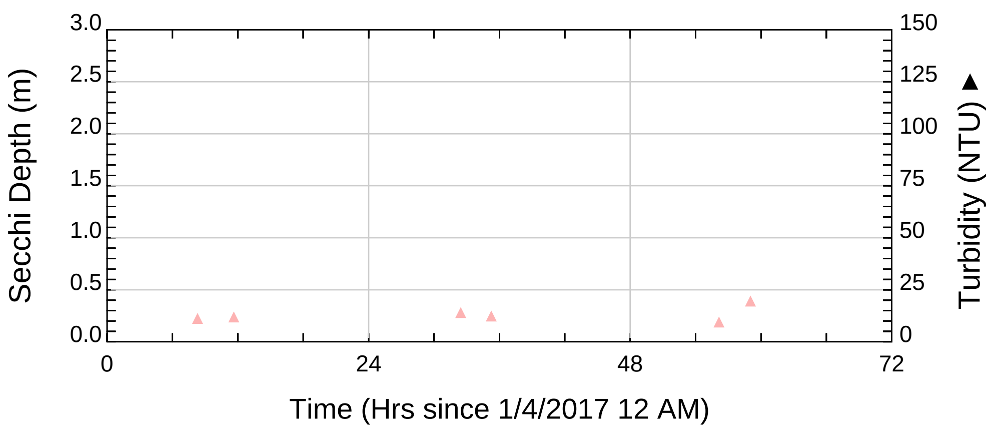
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

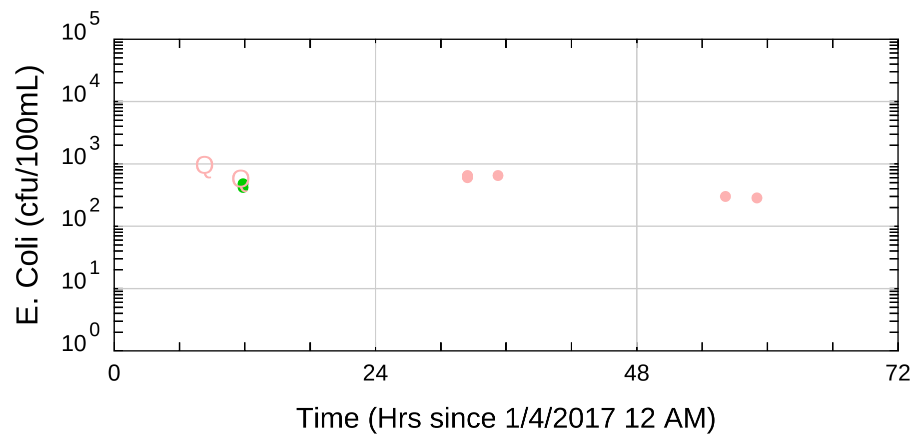








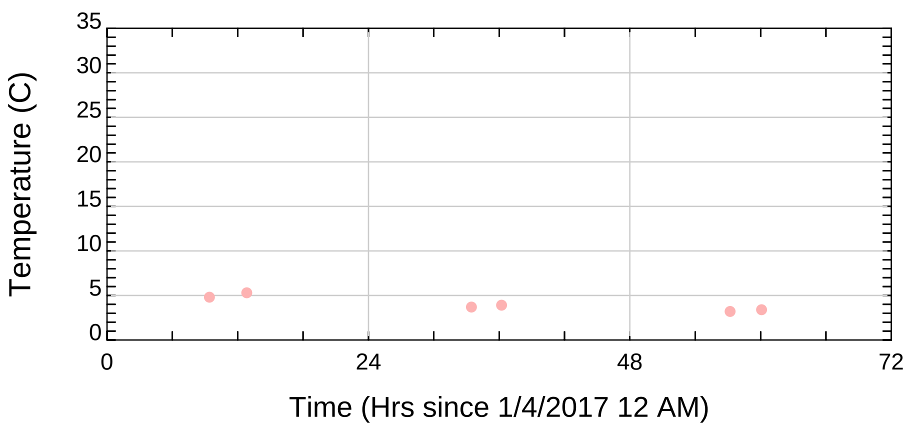


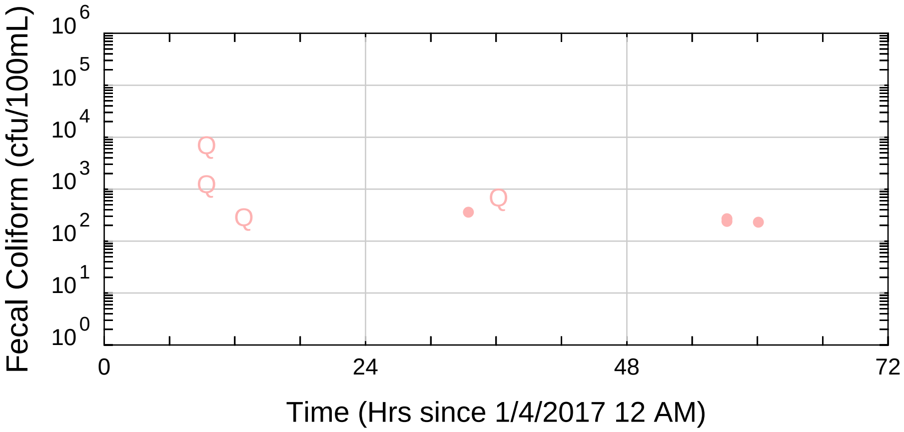


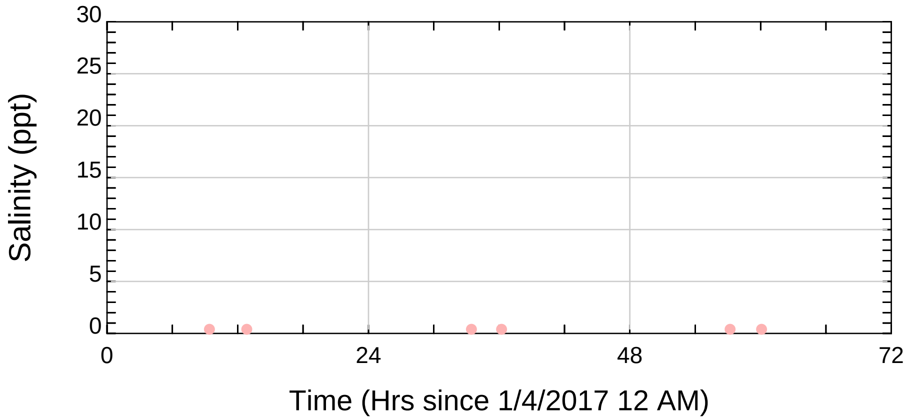
Q: See page 1 of attachment for notes on qualifiers

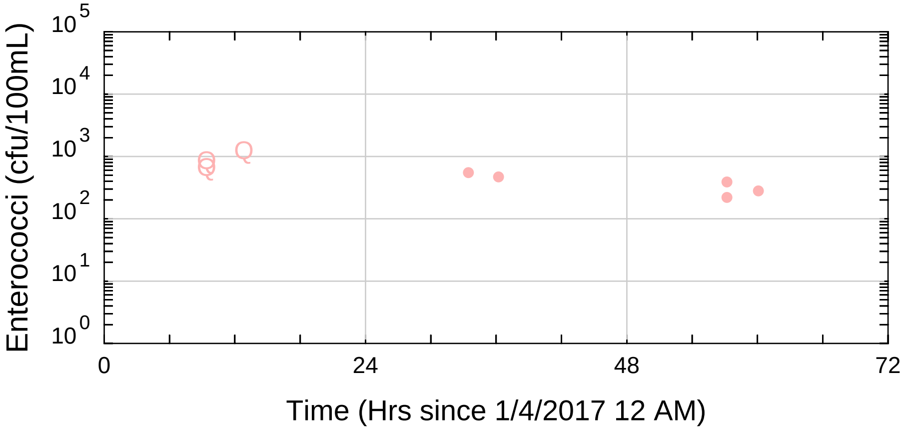
Passaic River & Tributaries, Passaic River, 3, (FW2)

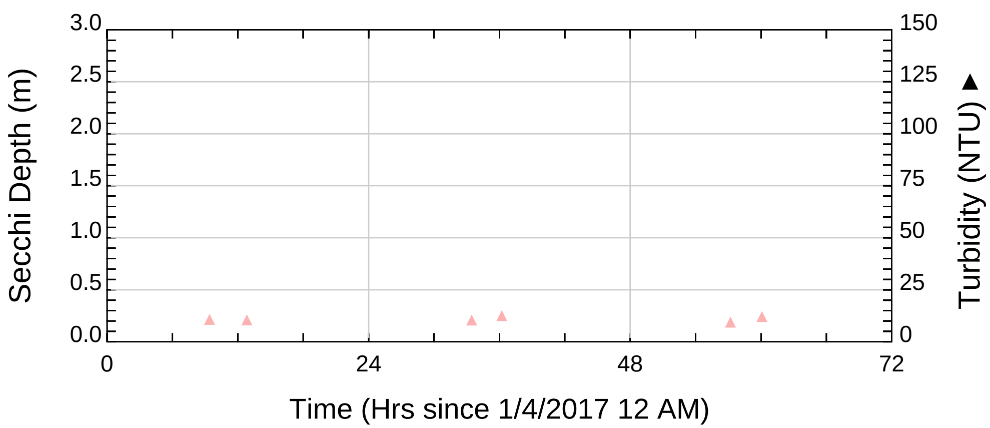
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

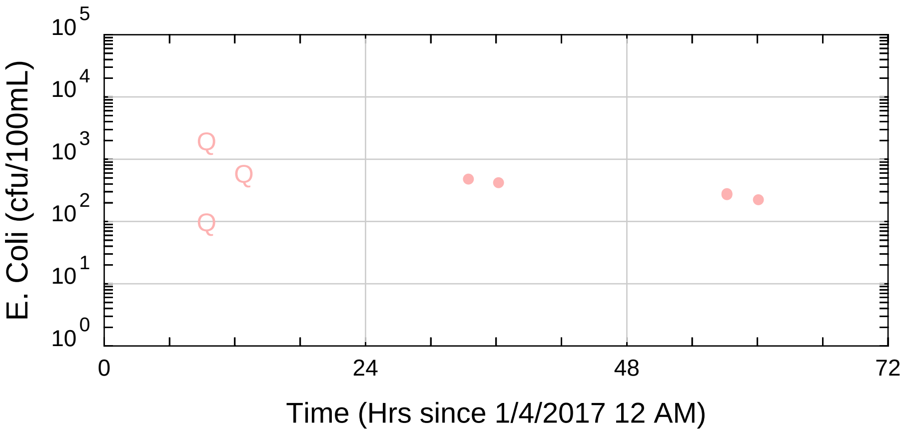








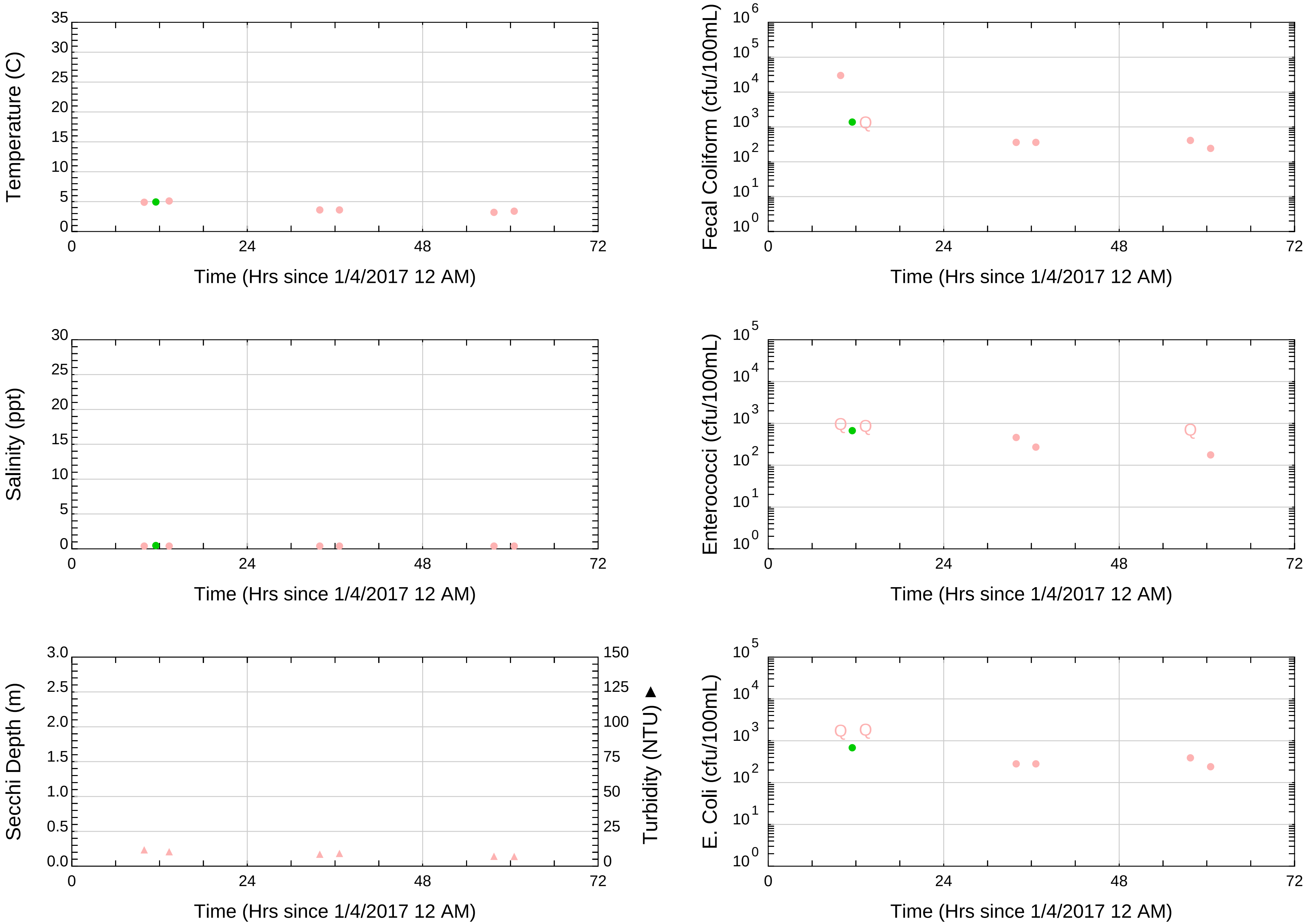




Q: See page 1 of attachment
for notes on qualifiers

Passaic River & Tributaries, Passaic River, 4, (FW2)

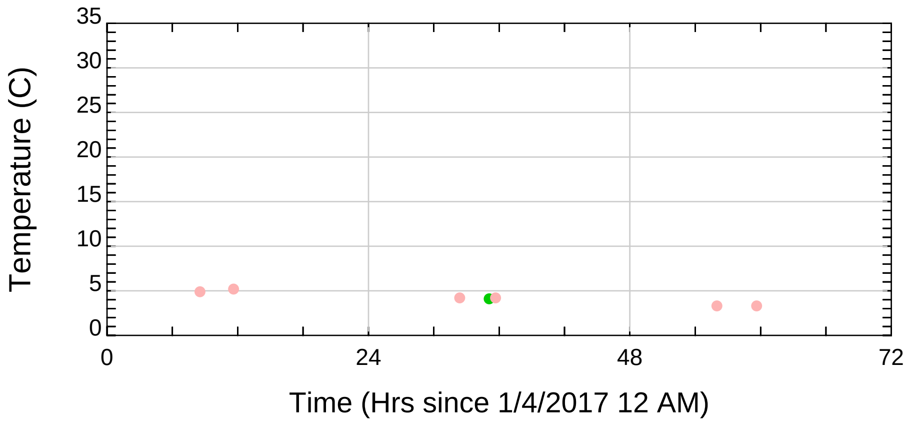
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

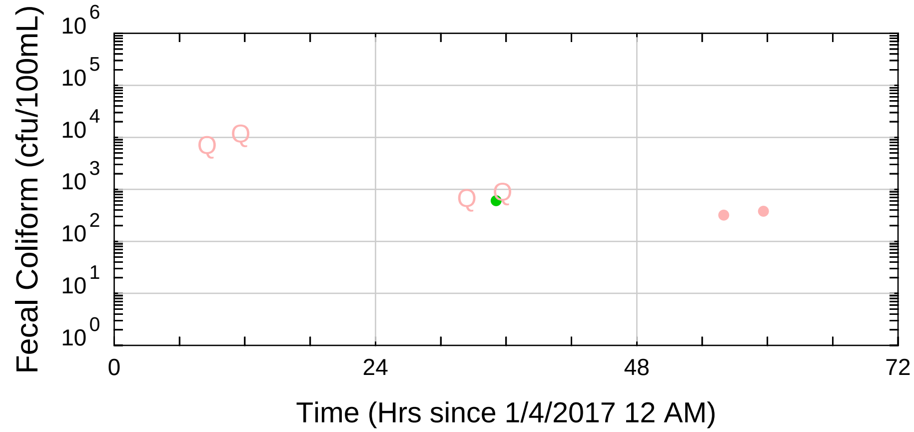


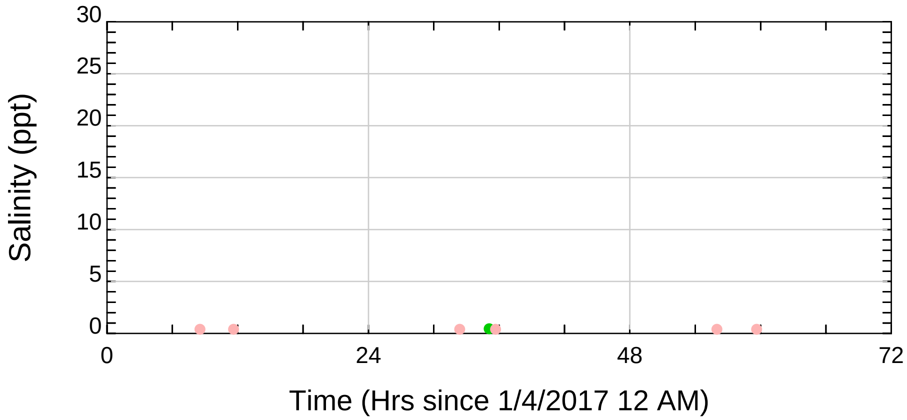
Q: See page 1 of attachment for notes on qualifiers

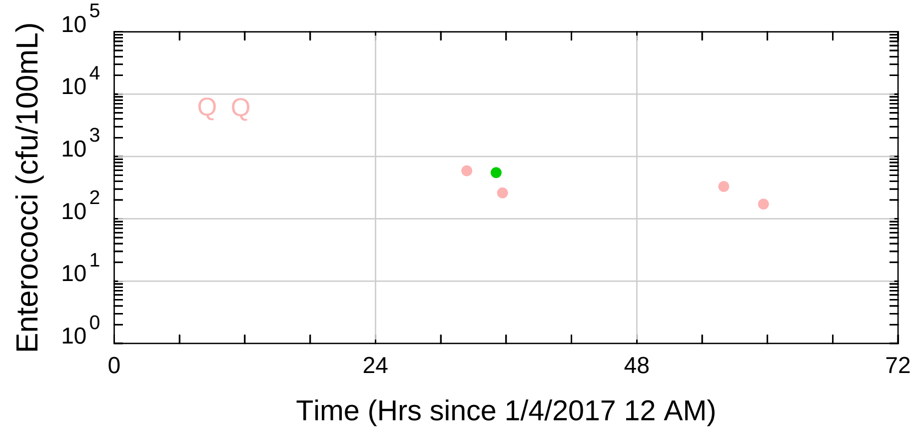
Passaic River & Tributaries, Passaic River, 7, (FW2/SE2)

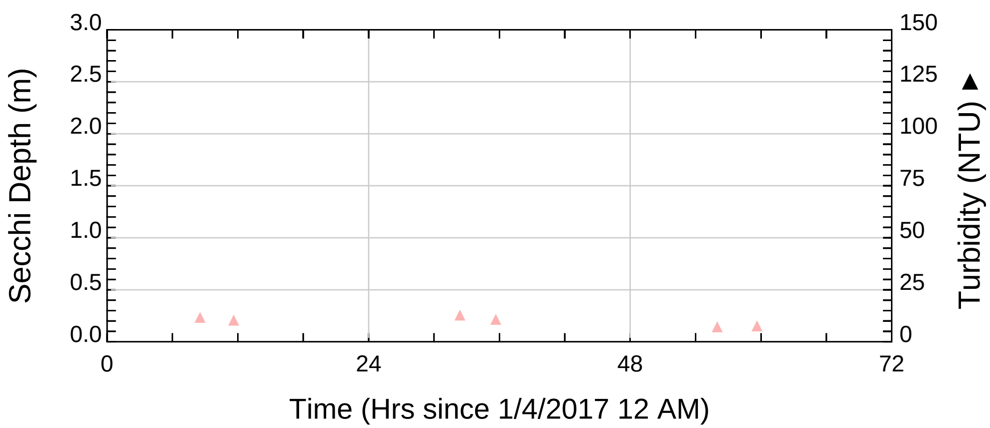
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

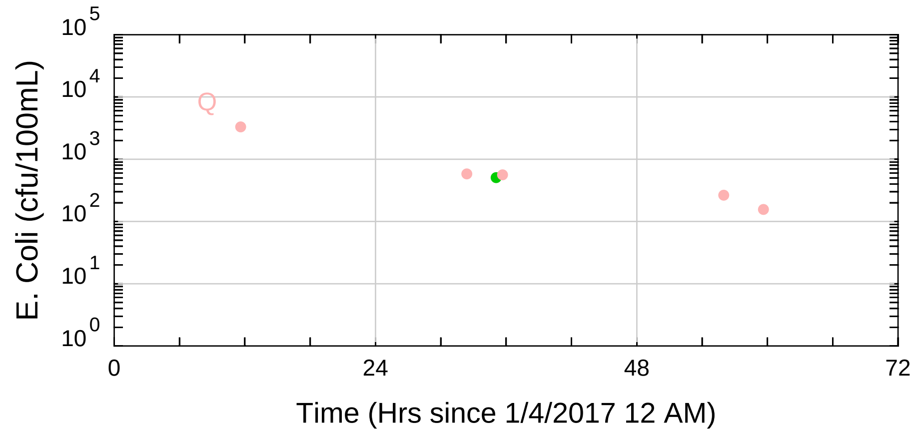






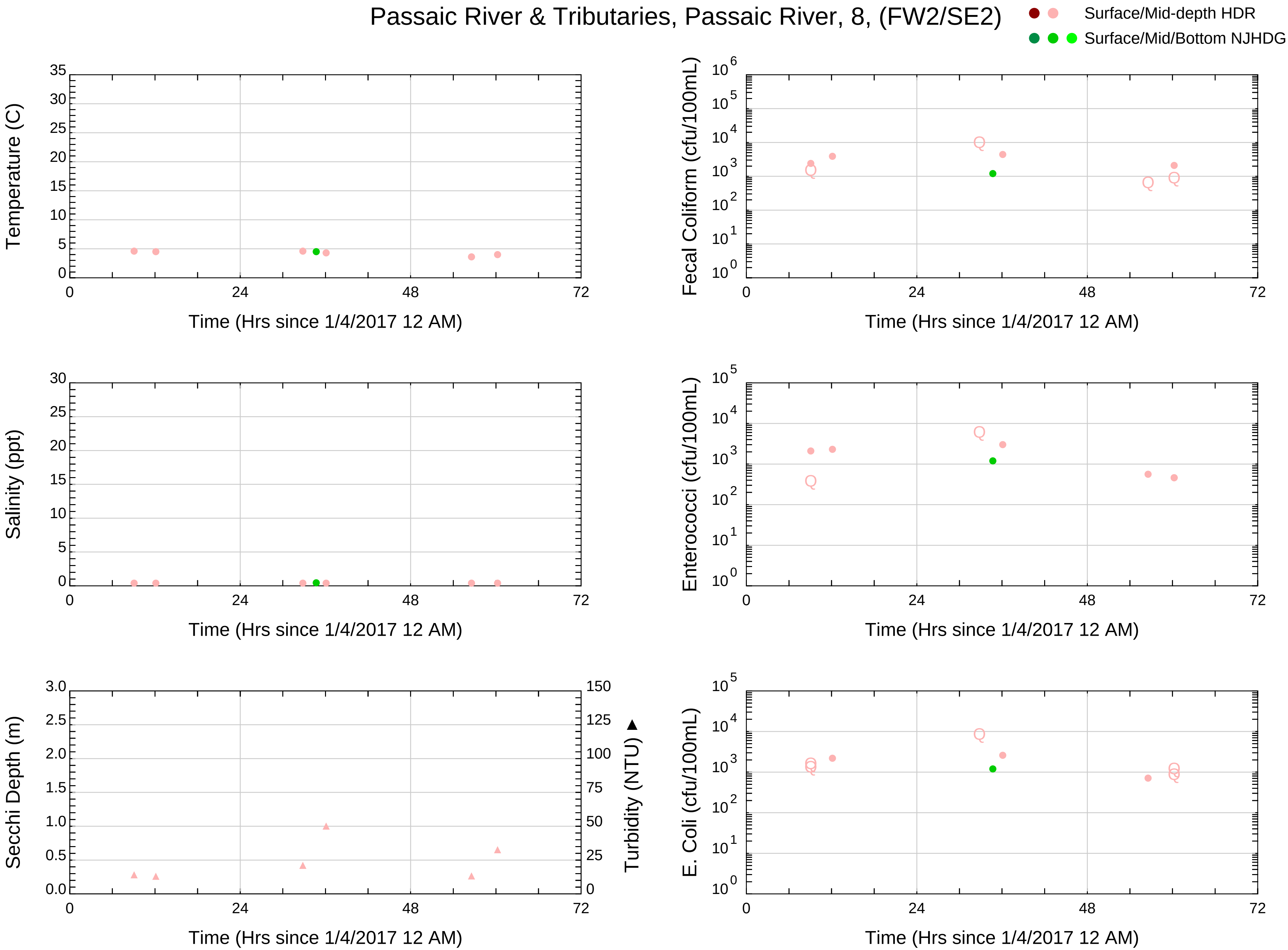






Q: See page 1 of attachment
for notes on qualifiers

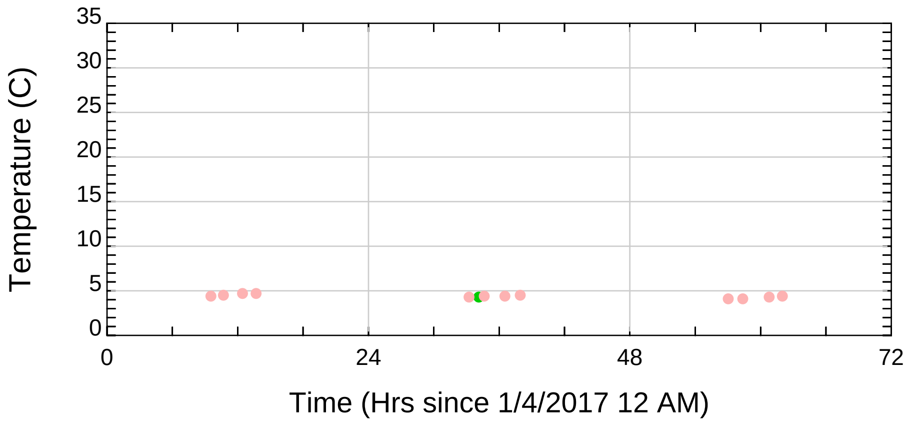
Passaic River & Tributaries, Passaic River, 8, (FW2/SE2)

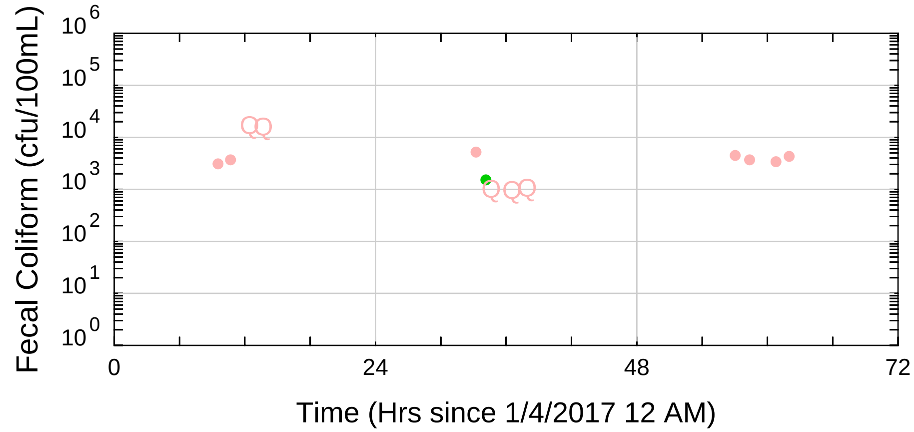


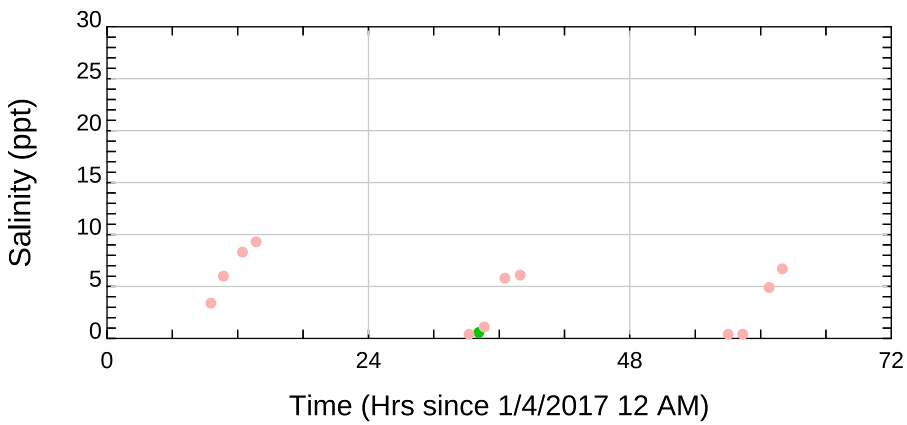
Q: See page 1 of attachment for notes on qualifiers

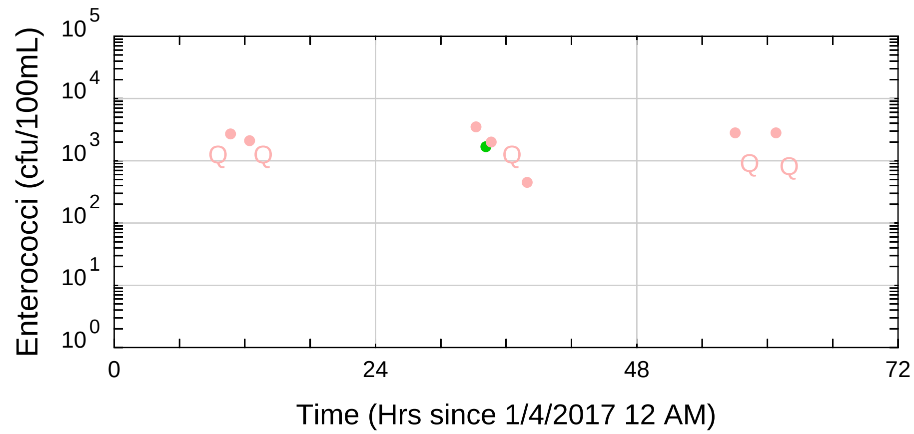
Passaic River & Tributaries, Passaic River, 10, (SE3)

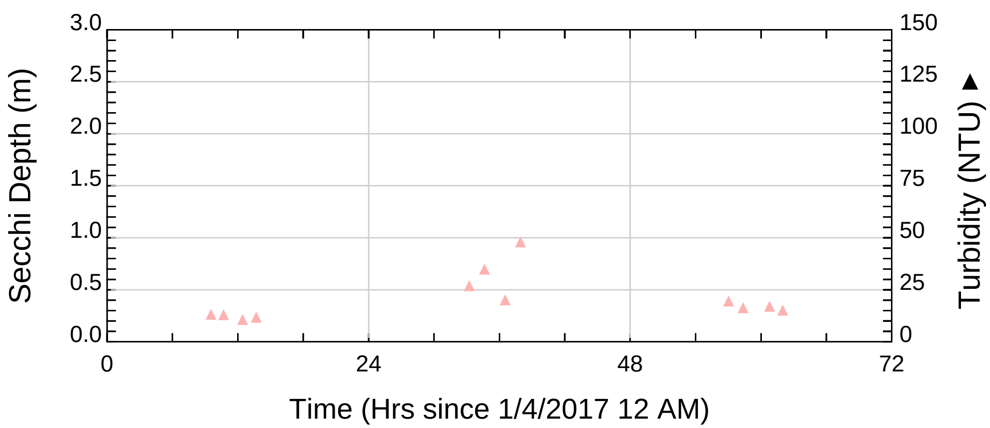
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

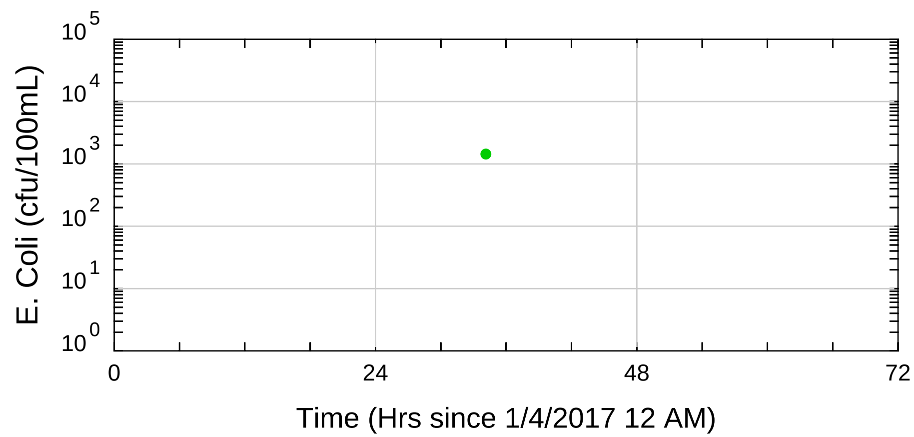








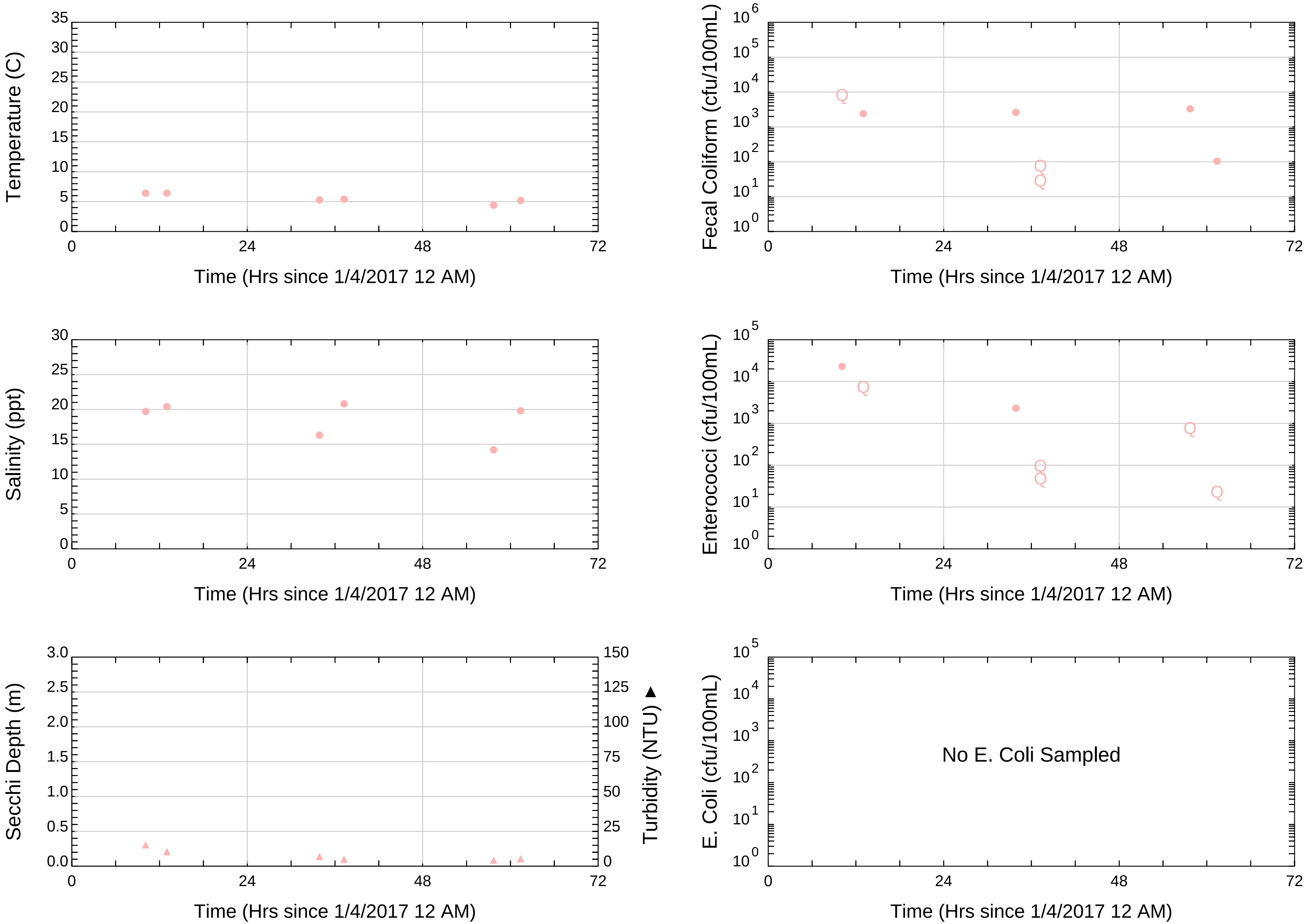




Q: See page 1 of attachment
for notes on qualifiers

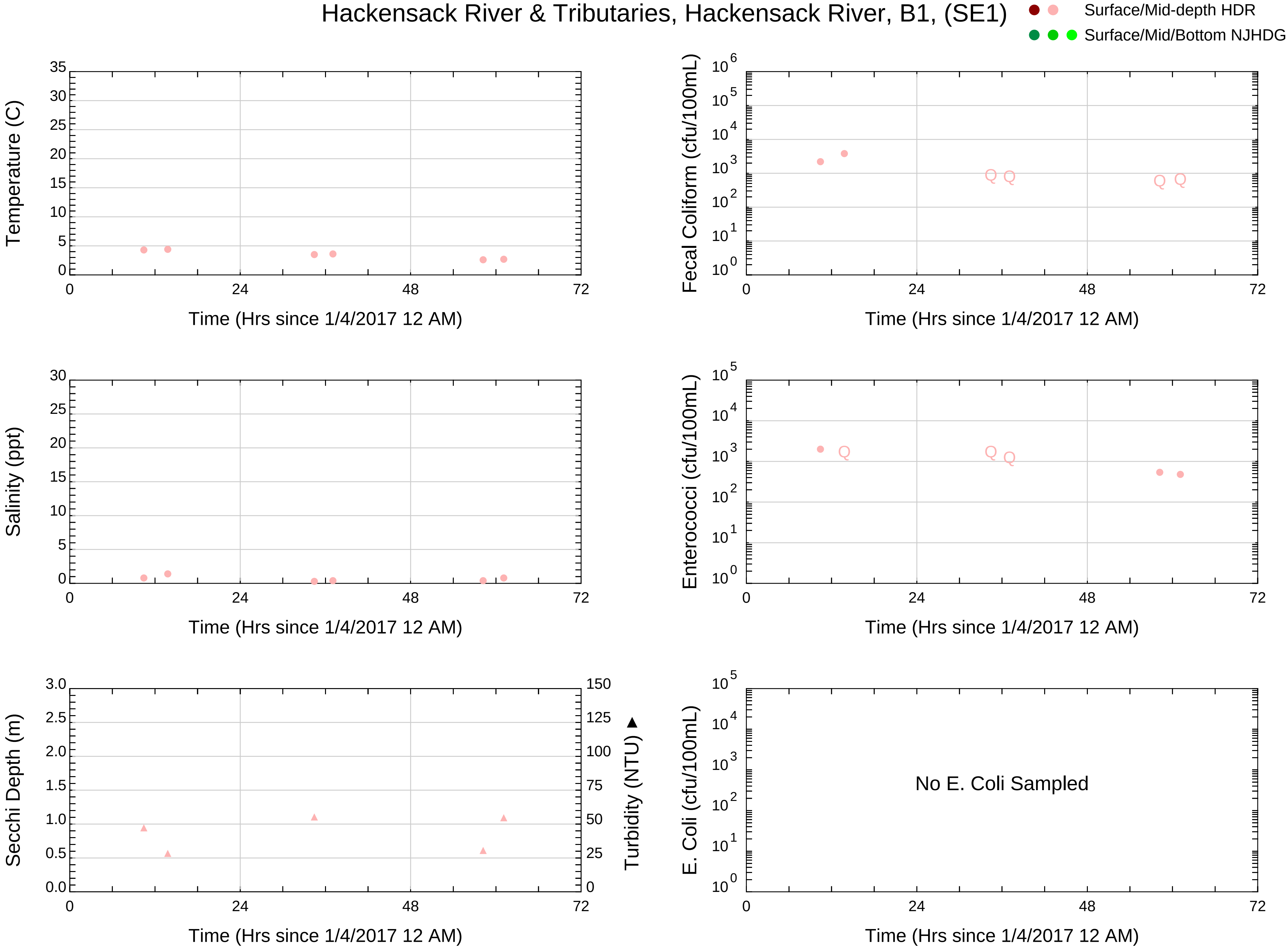
Newark Bay & Tributaries, Elizabeth River, 20, (SE3)

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG



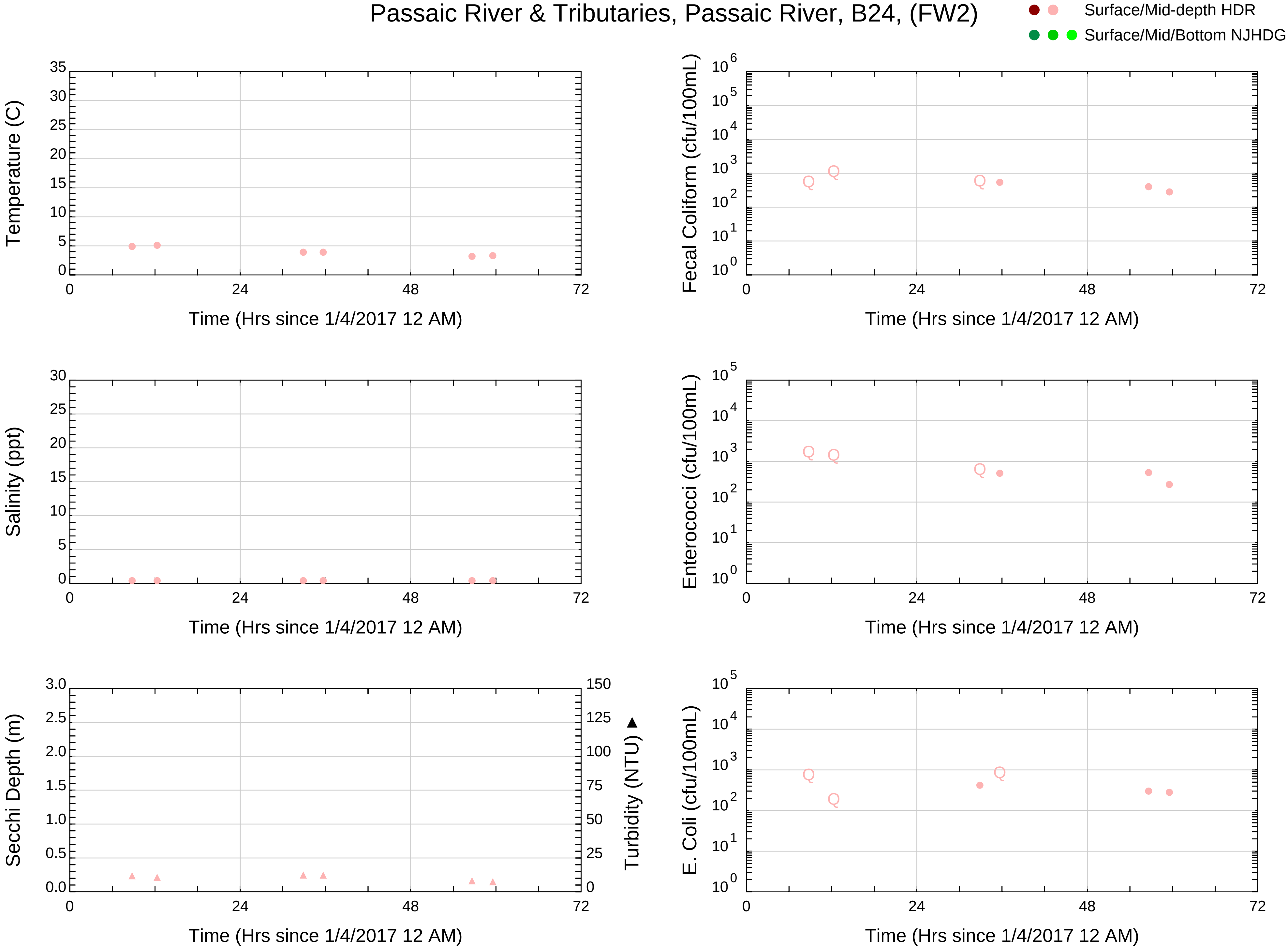
Q: See page 1 of attachment for notes on qualifiers

Hackensack River & Tributaries, Hackensack River, B1, (SE1)



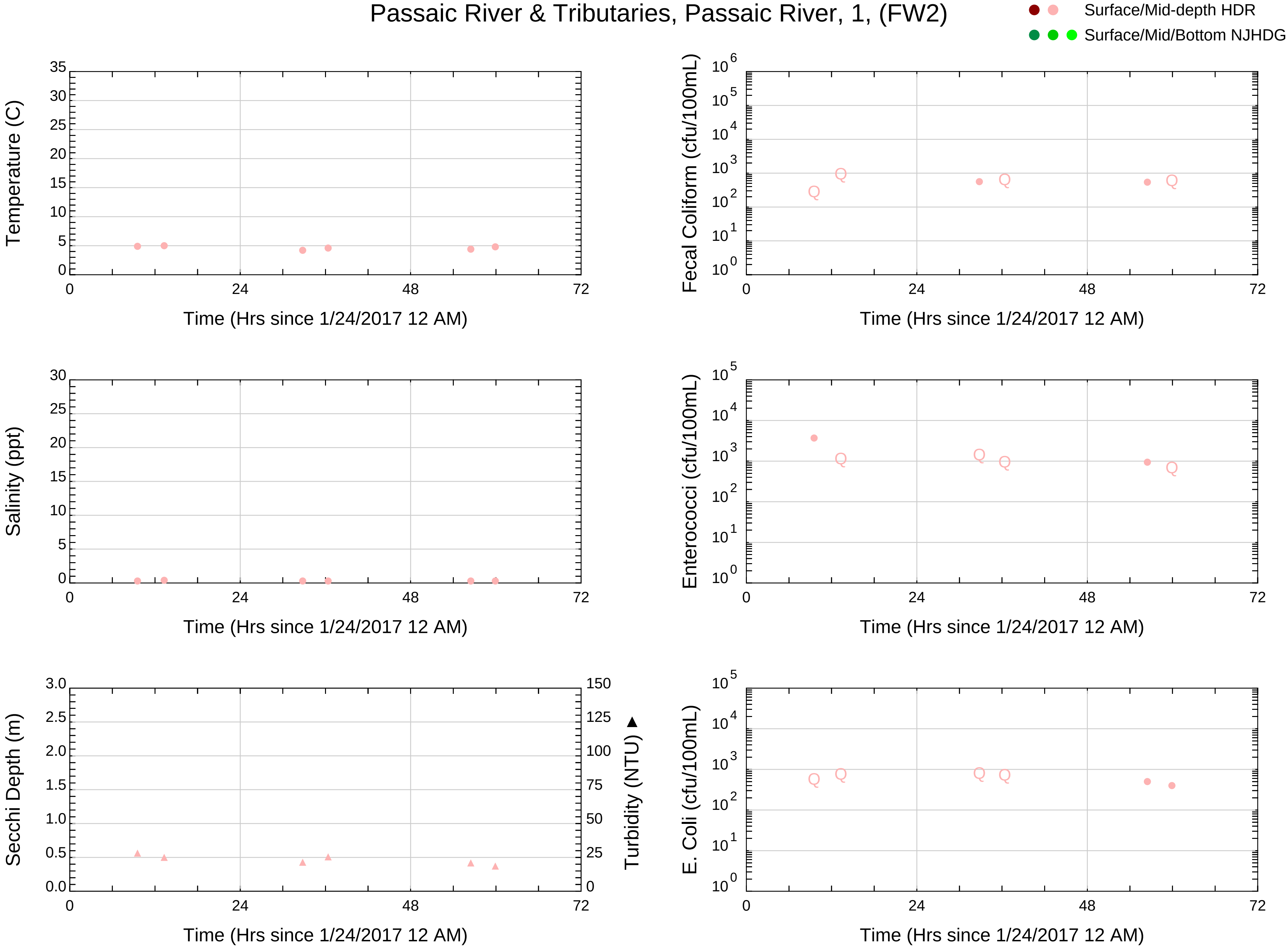
Q: See page 1 of attachment for notes on qualifiers

Passaic River & Tributaries, Passaic River, B24, (FW2)



Q: See page 1 of attachment for notes on qualifiers

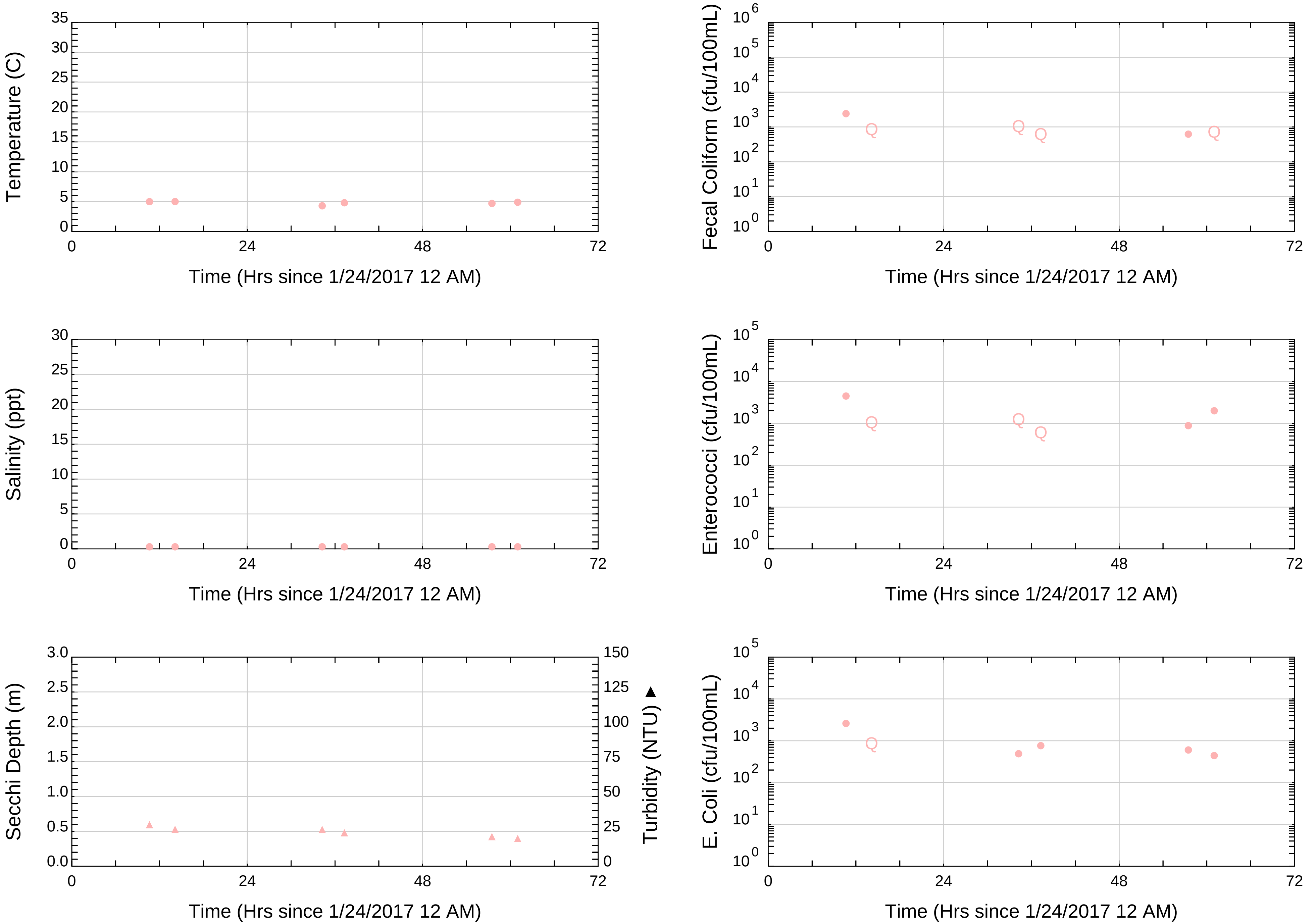
Passaic River & Tributaries, Passaic River, 1, (FW2)



Q: See page 1 of attachment for notes on qualifiers

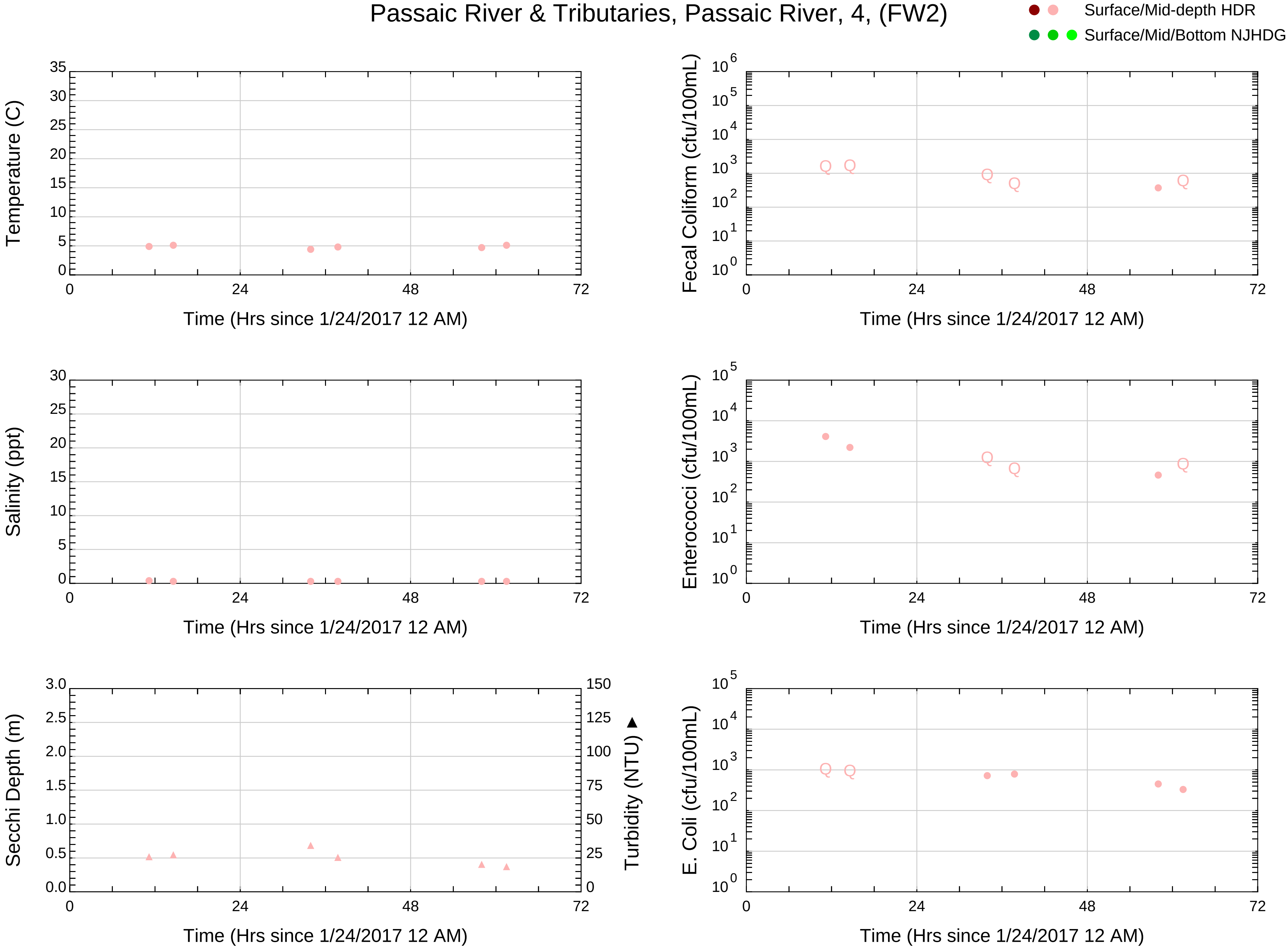
Passaic River & Tributaries, Passaic River, 3, (FW2)

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG



Q: See page 1 of attachment for notes on qualifiers

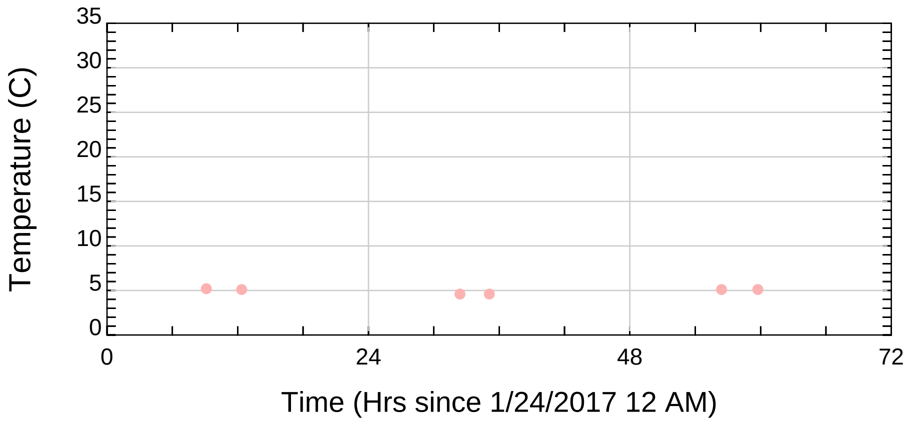
Passaic River & Tributaries, Passaic River, 4, (FW2)

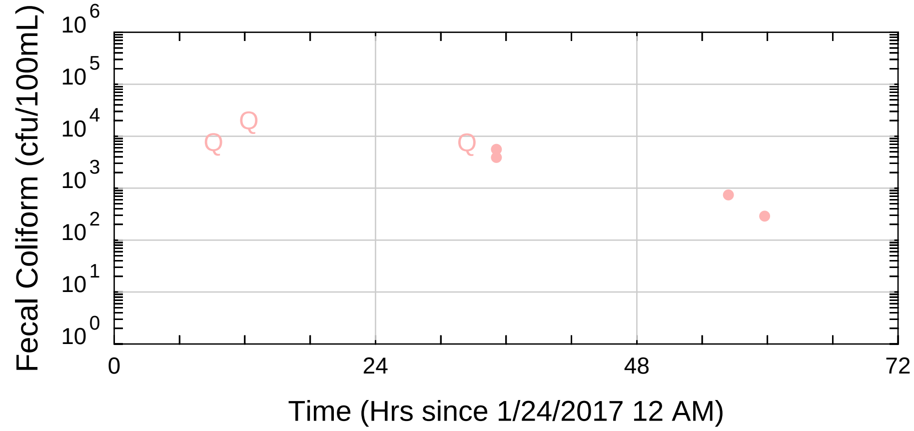


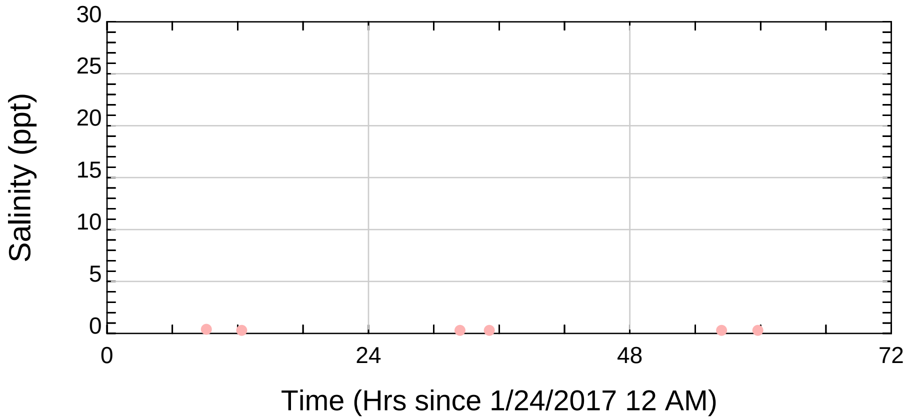
Q: See page 1 of attachment
for notes on qualifiers

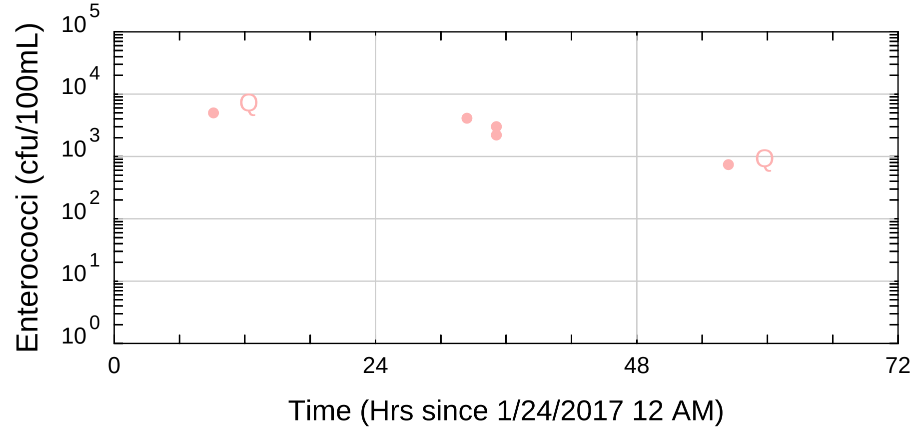
Passaic River & Tributaries, Passaic River, 7, (FW2/SE2)

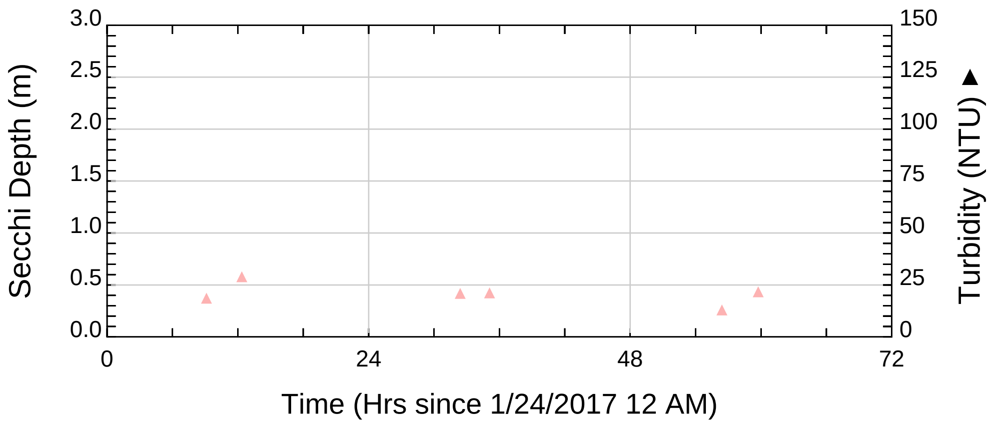
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

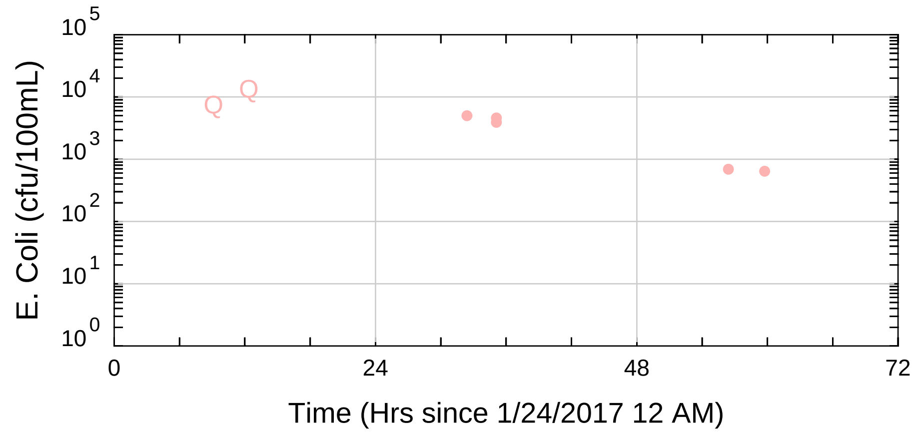






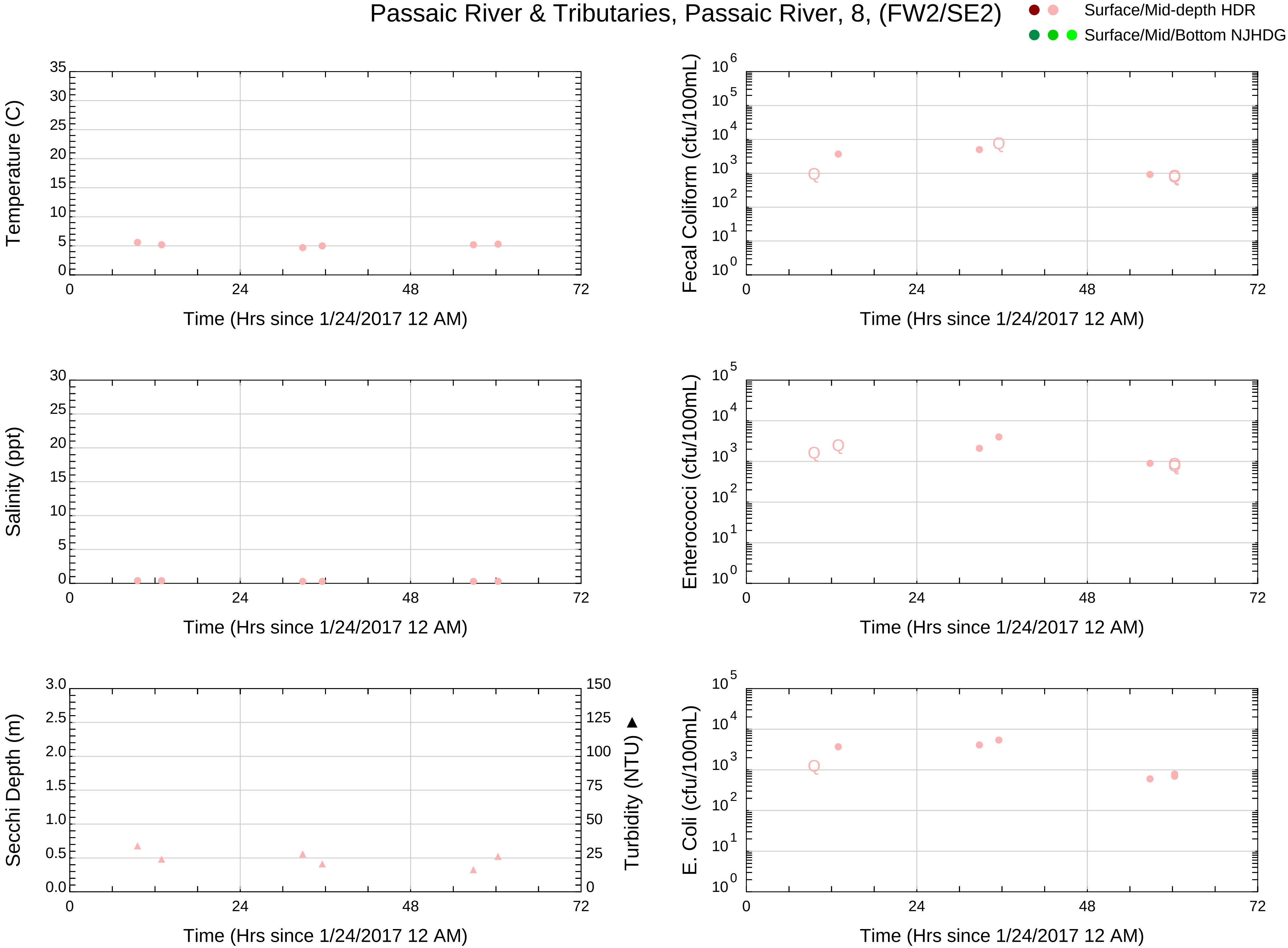






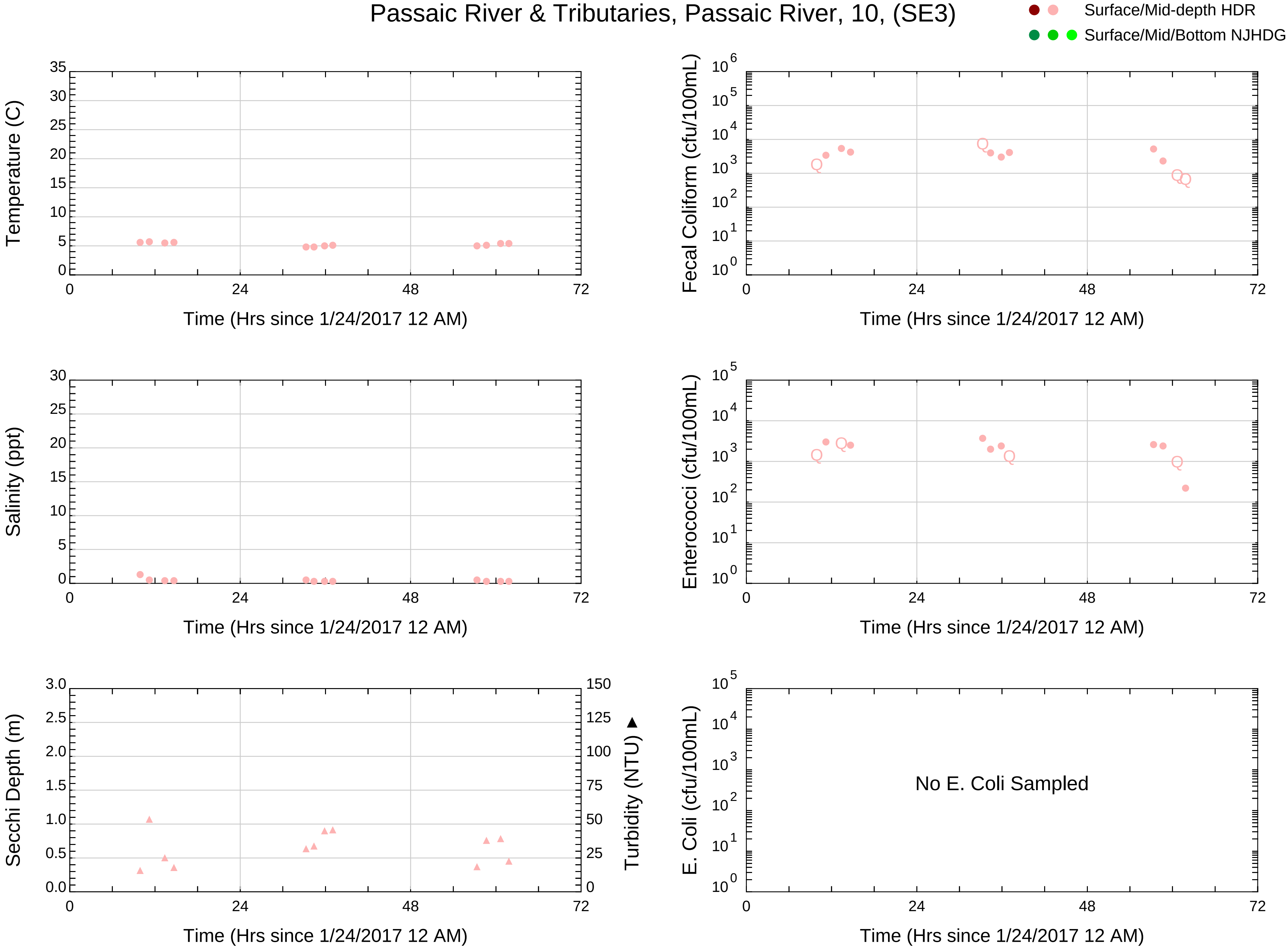
Q: See page 1 of attachment for notes on qualifiers

Passaic River & Tributaries, Passaic River, 8, (FW2/SE2)



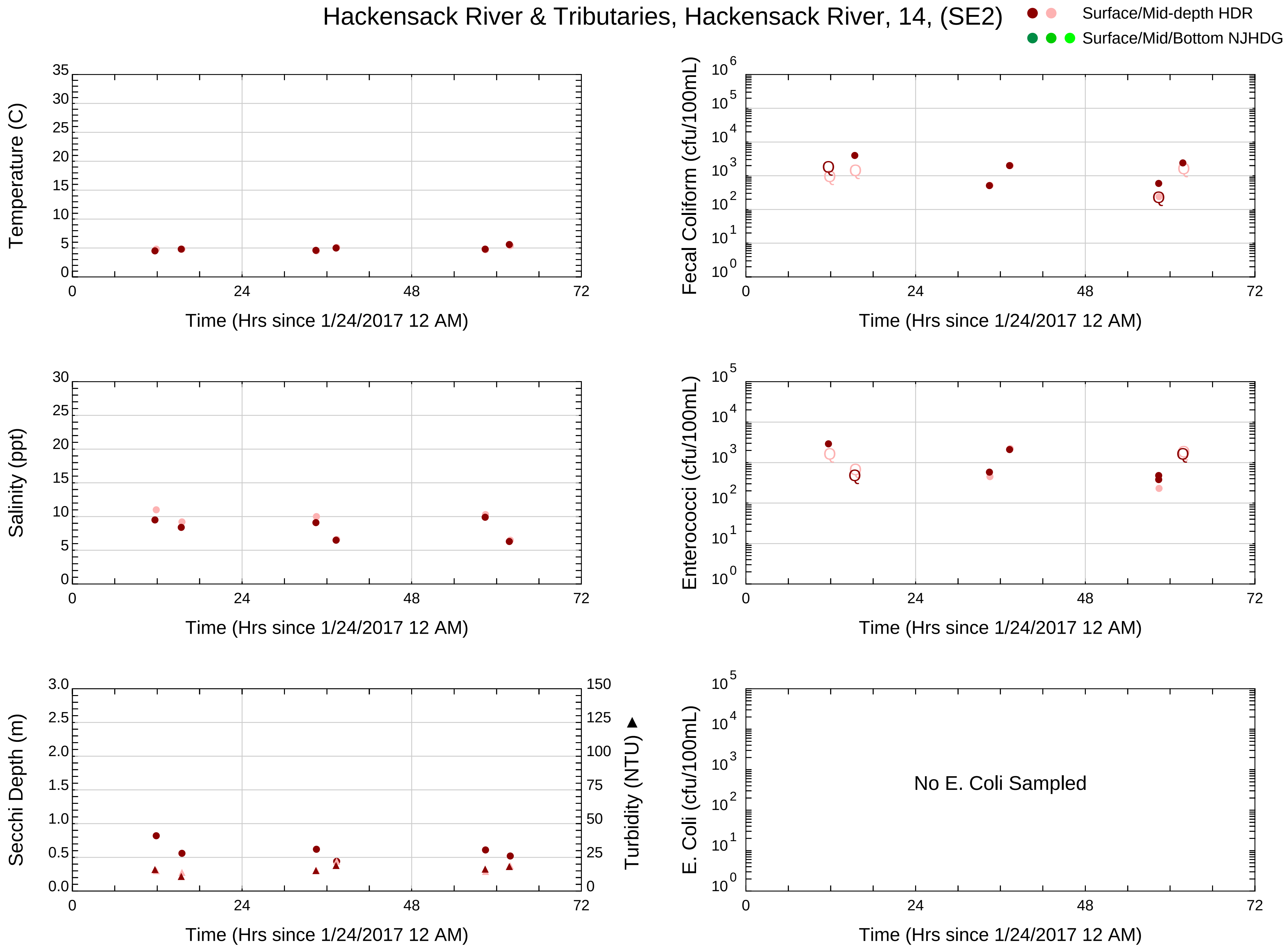
Q: See page 1 of attachment for notes on qualifiers

Passaic River & Tributaries, Passaic River, 10, (SE3)



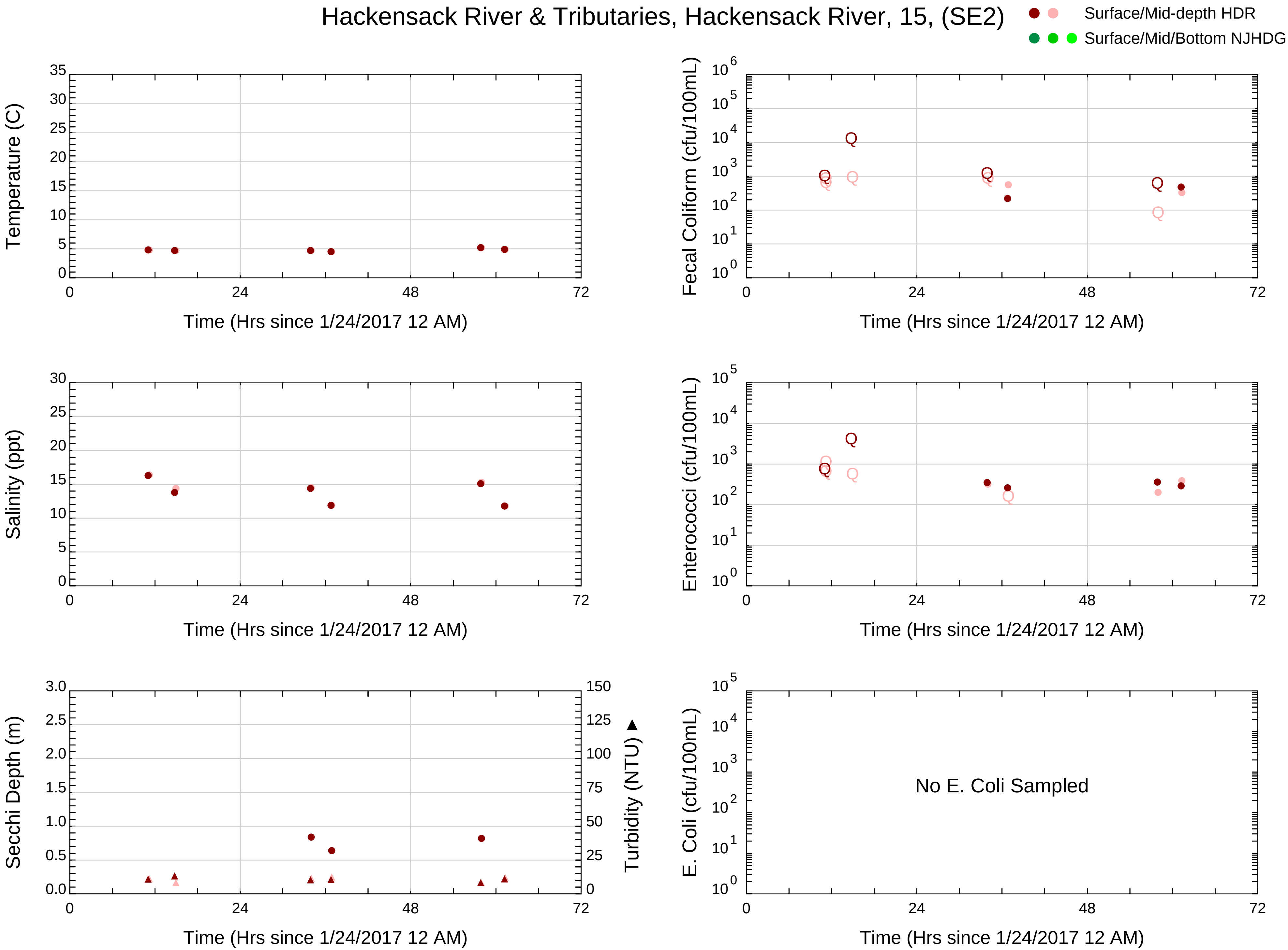
Q: See page 1 of attachment for notes on qualifiers

Hackensack River & Tributaries, Hackensack River, 14, (SE2)



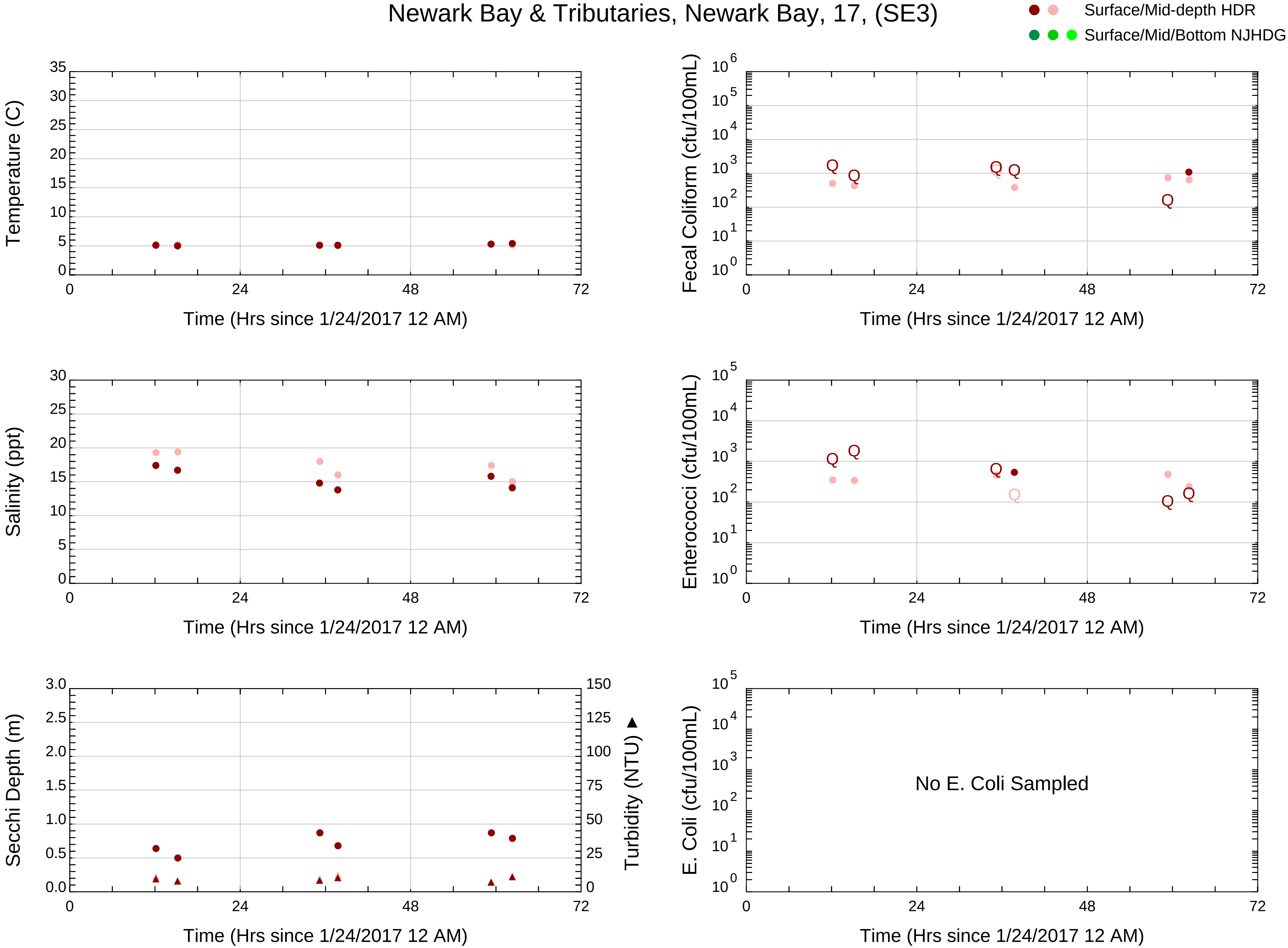
Q: See page 1 of attachment for notes on qualifiers

Hackensack River & Tributaries, Hackensack River, 15, (SE2)



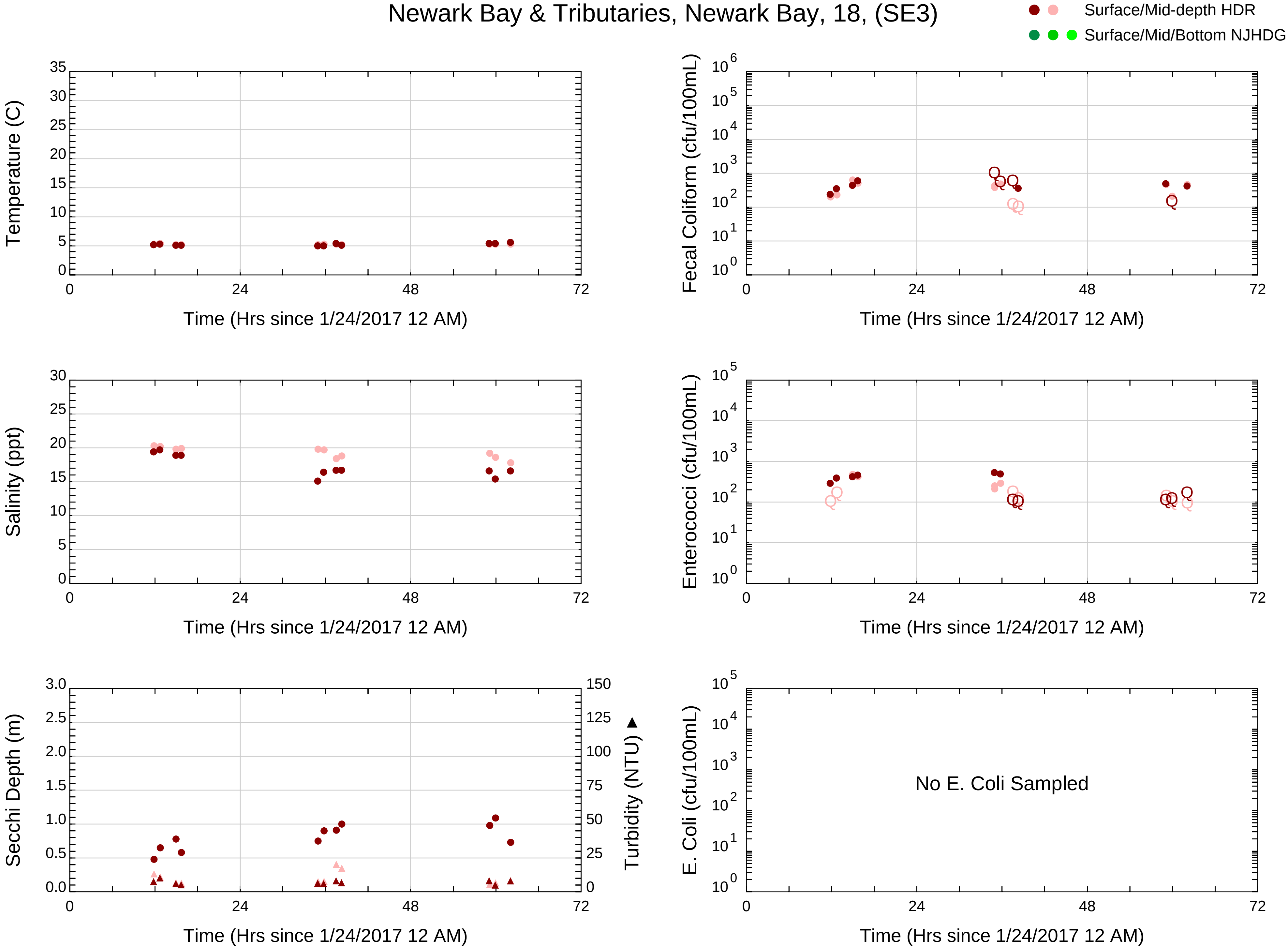
Q: See page 1 of attachment
for notes on qualifiers

Newark Bay & Tributaries, Newark Bay, 17, (SE3)



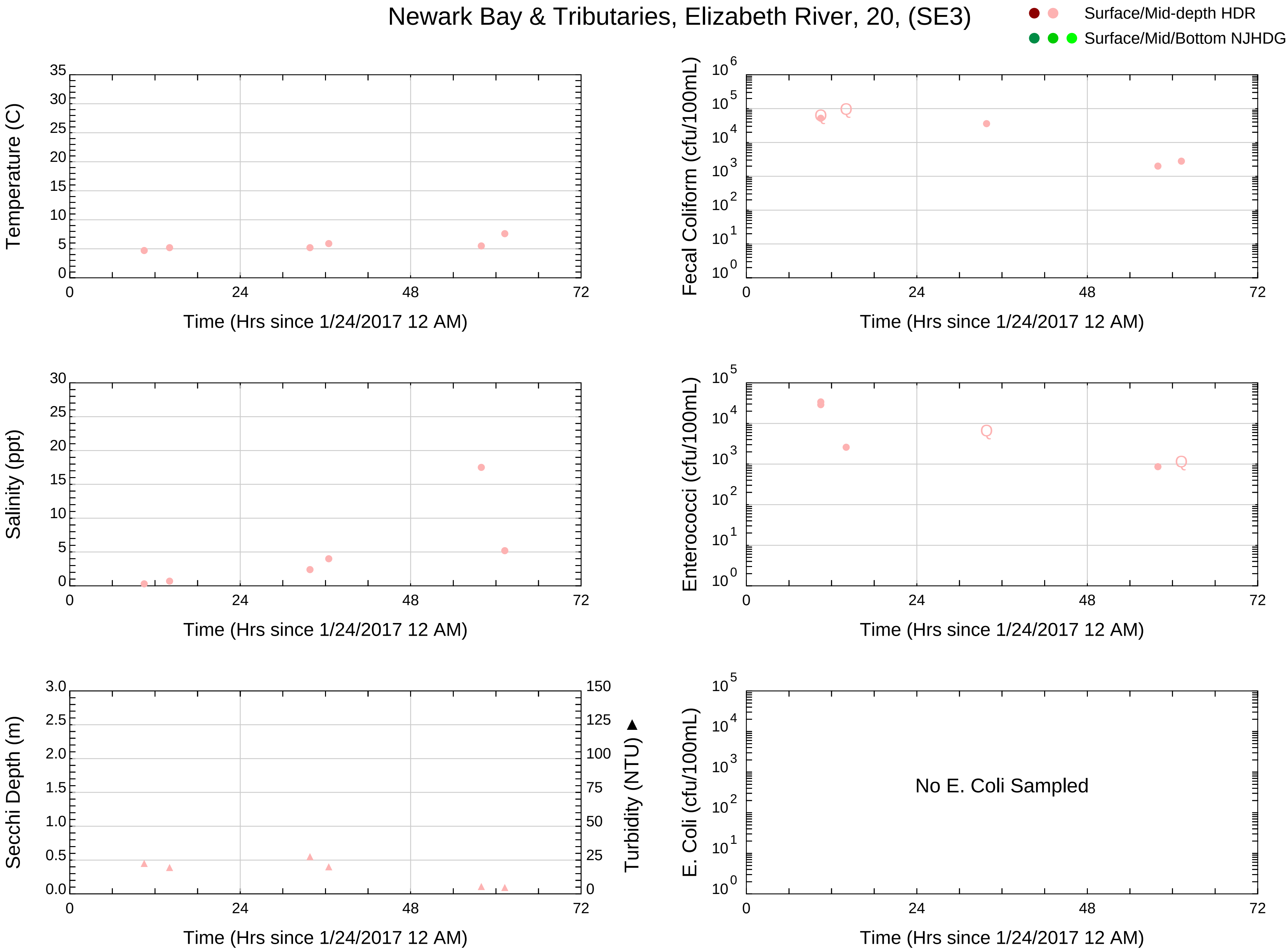
Q: See page 1 of attachment for notes on qualifiers

Newark Bay & Tributaries, Newark Bay, 18, (SE3)



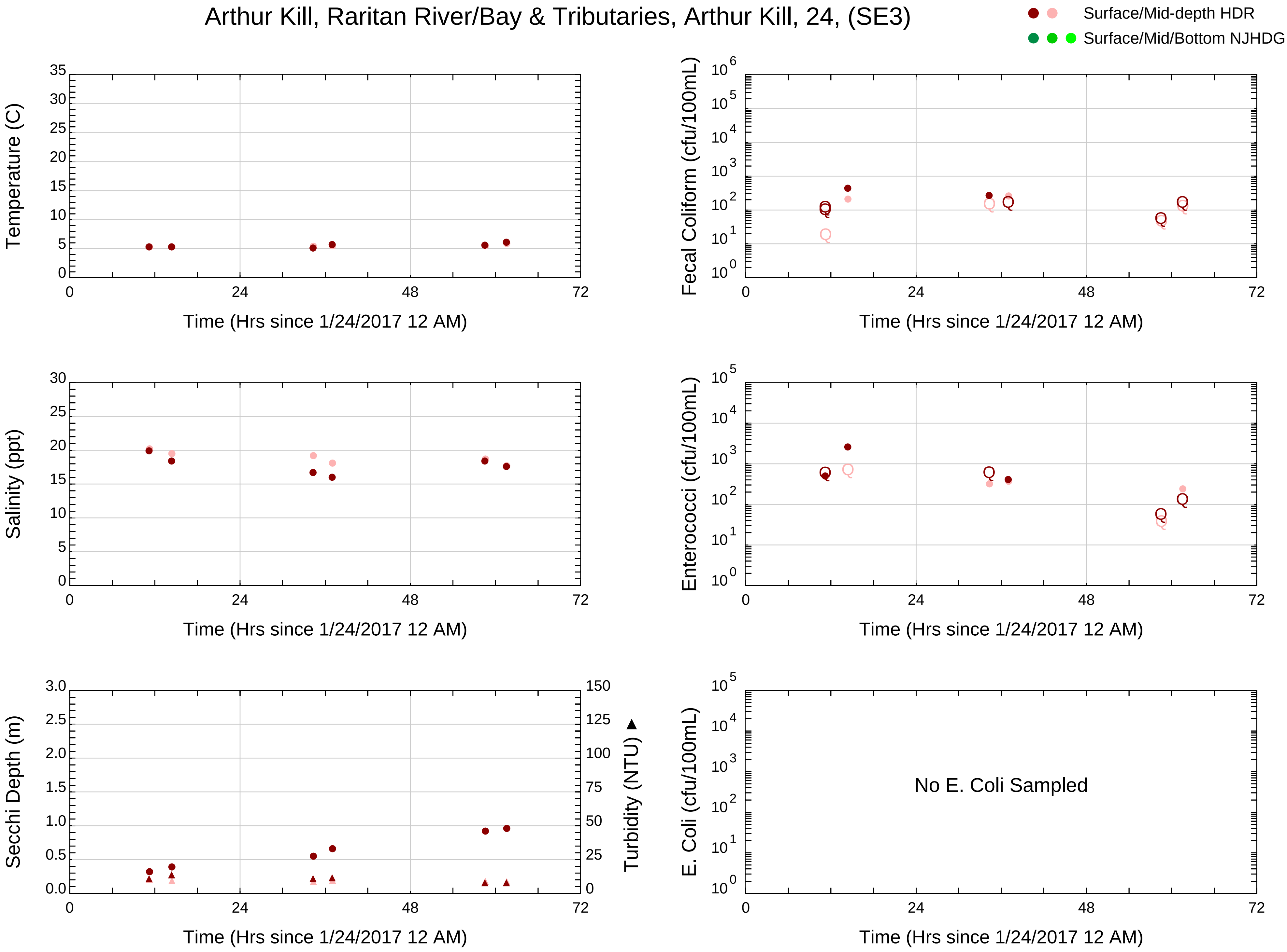
Q: See page 1 of attachment
for notes on qualifiers

Newark Bay & Tributaries, Elizabeth River, 20, (SE3)



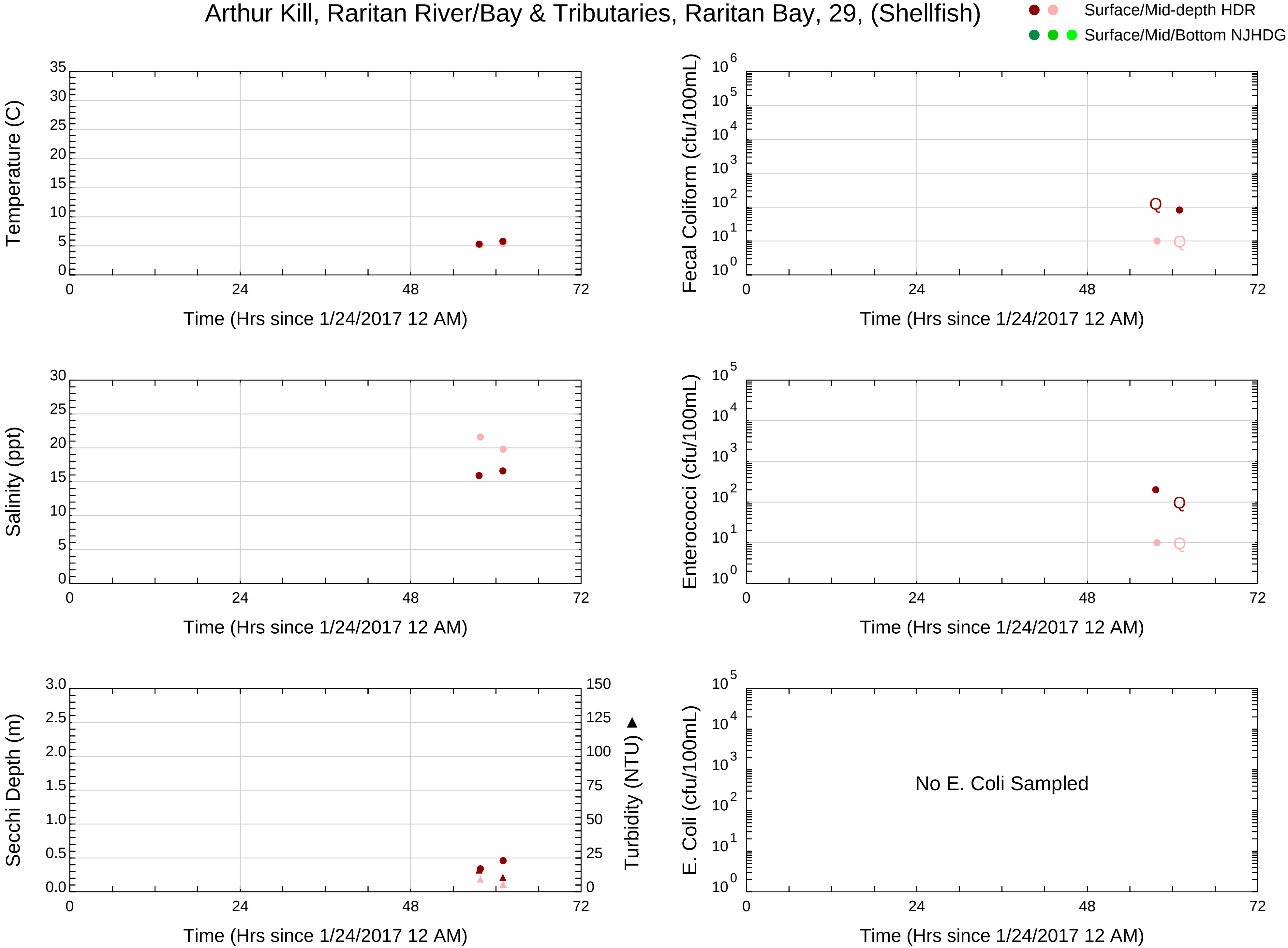
Q: See page 1 of attachment for notes on qualifiers

Arthur Kill, Raritan River/Bay & Tributaries, Arthur Kill, 24, (SE3)



Q: See page 1 of attachment
for notes on qualifiers

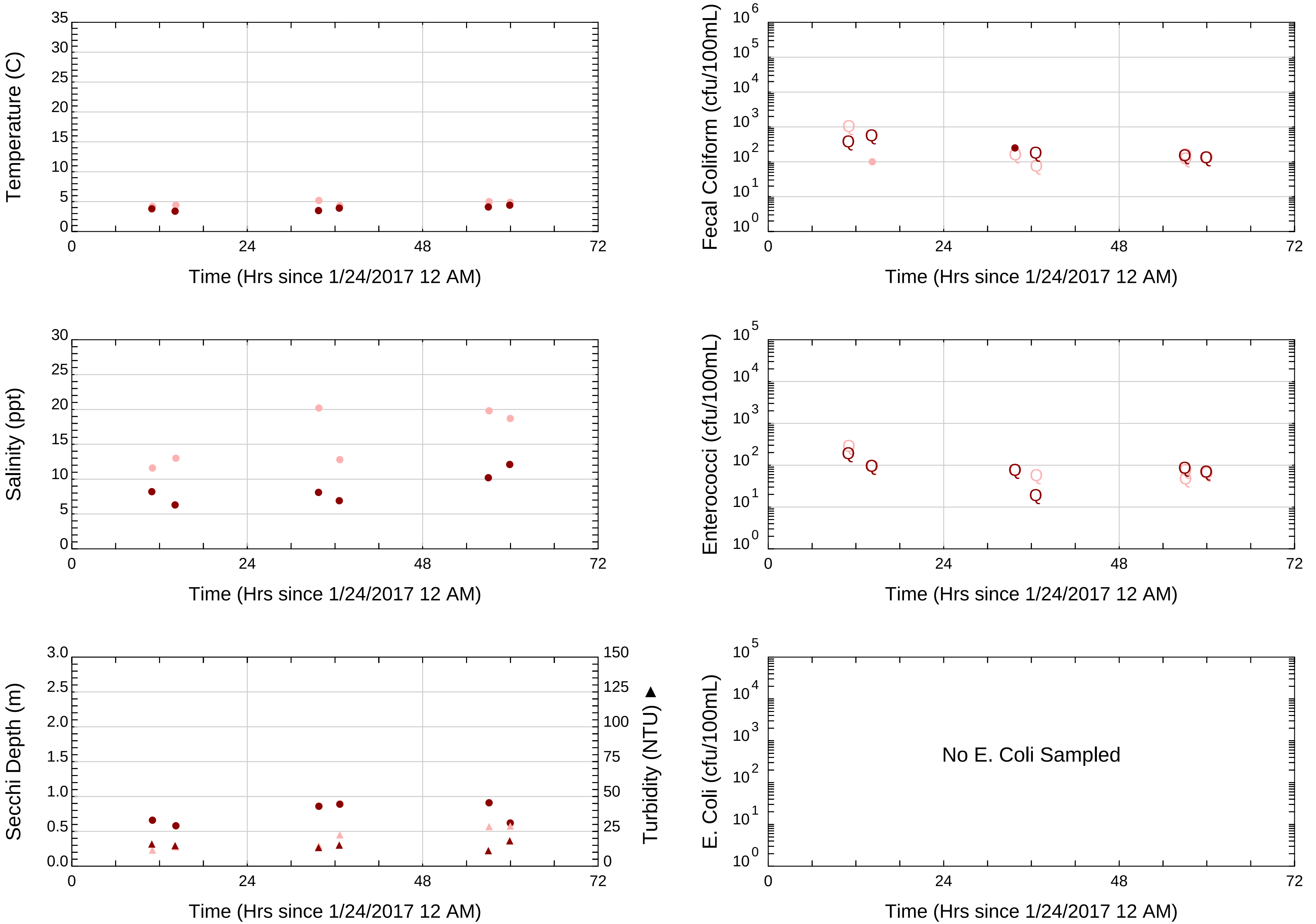
Arthur Kill, Raritan River/Bay & Tributaries, Raritan Bay, 29, (Shellfish)



Q: See page 1 of attachment for notes on qualifiers

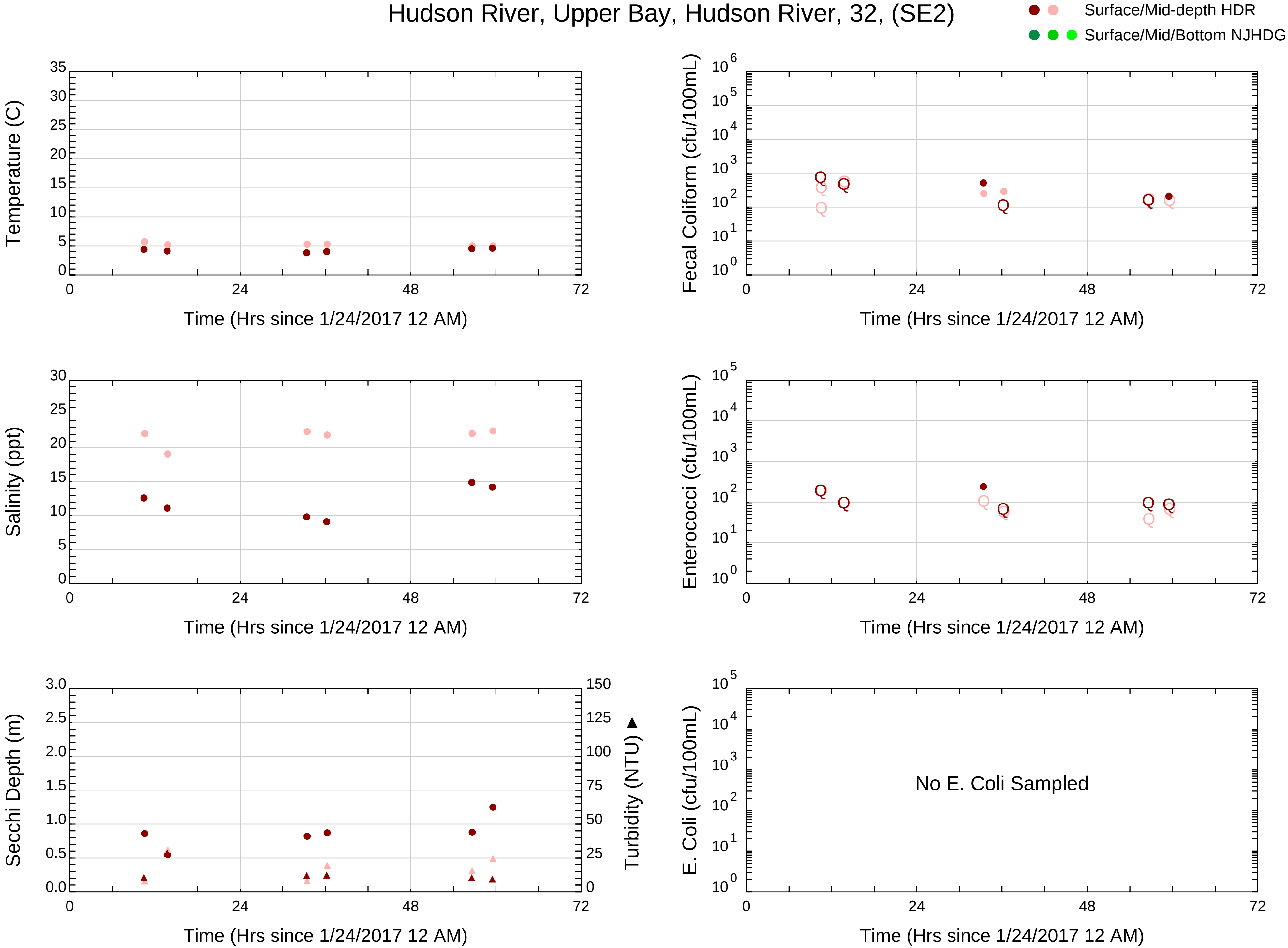
Hudson River, Upper Bay, Hudson River, 31, (SE2)

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG



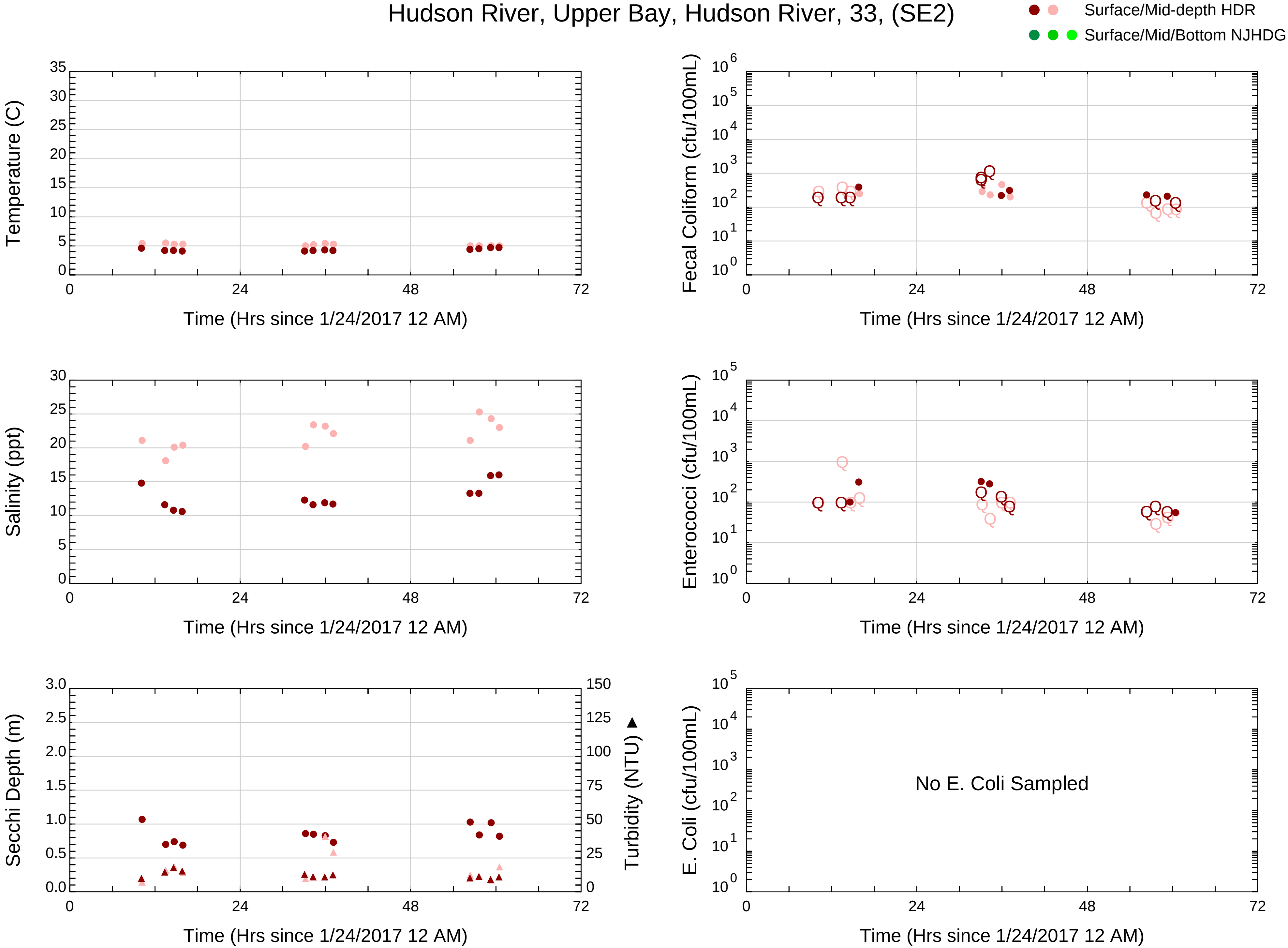
Q: See page 1 of attachment for notes on qualifiers

Hudson River, Upper Bay, Hudson River, 32, (SE2)



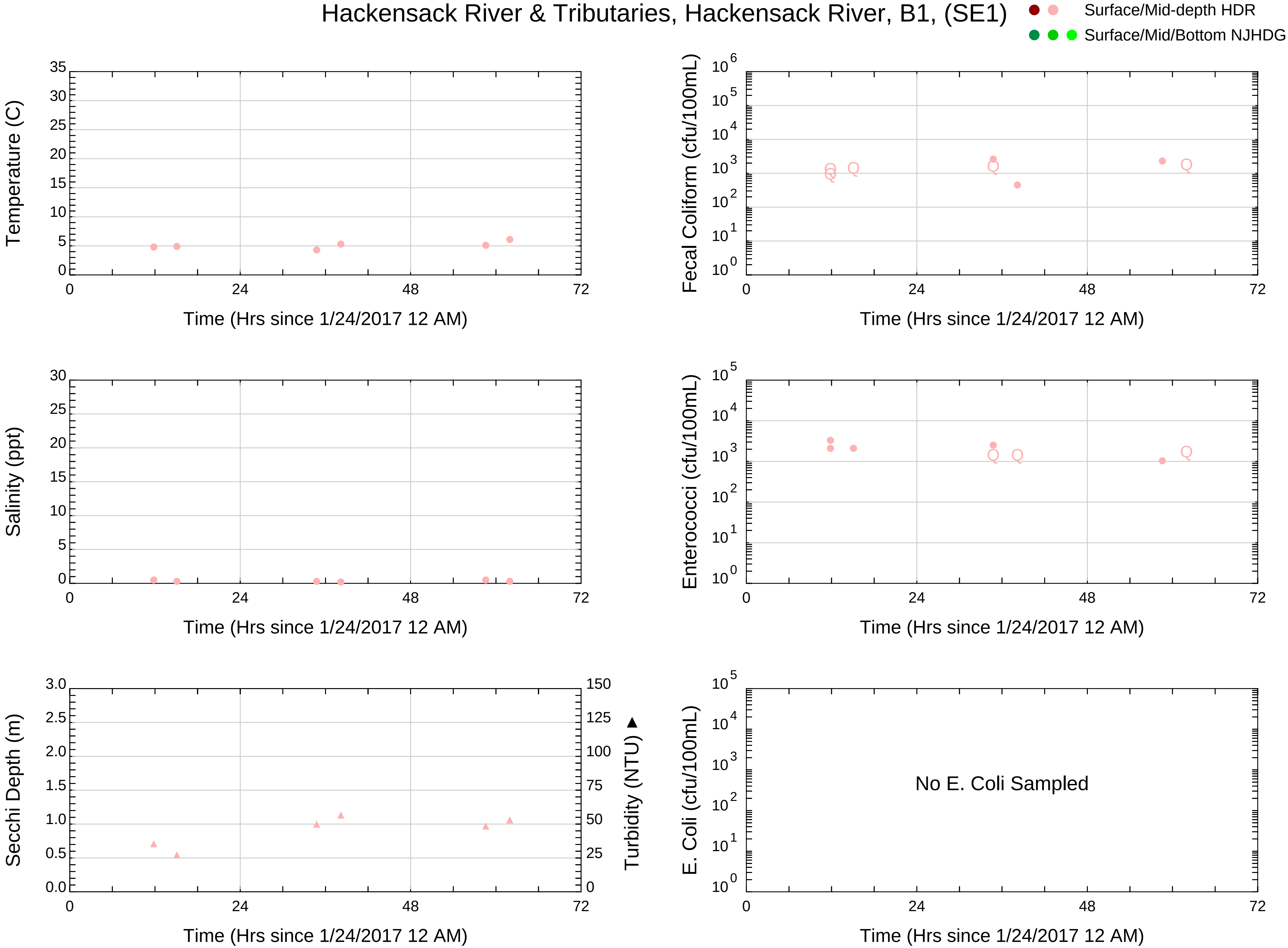
Q: See page 1 of attachment
for notes on qualifiers

Hudson River, Upper Bay, Hudson River, 33, (SE2)



Q: See page 1 of attachment for notes on qualifiers

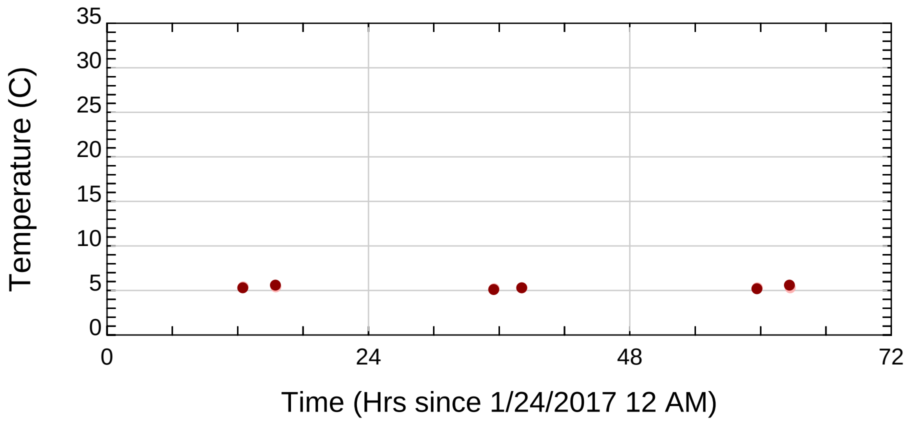
Hackensack River & Tributaries, Hackensack River, B1, (SE1)

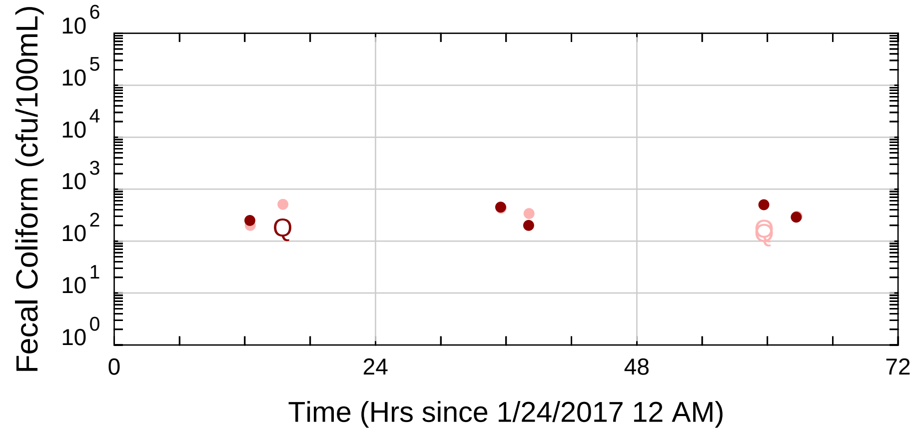


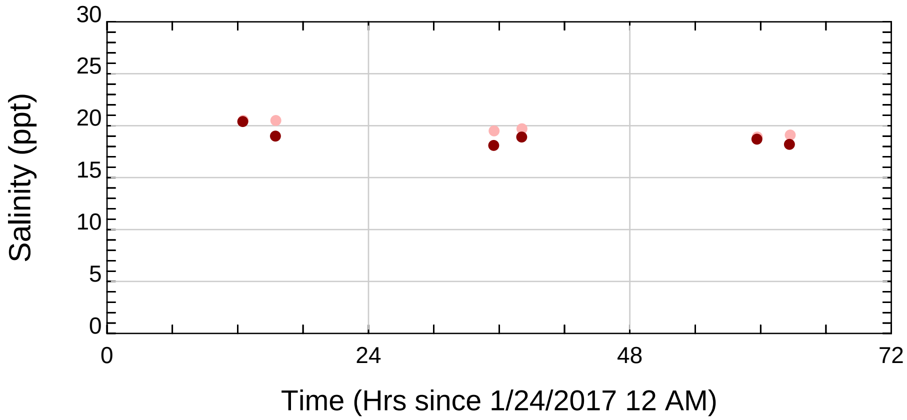
Q: See page 1 of attachment
for notes on qualifiers

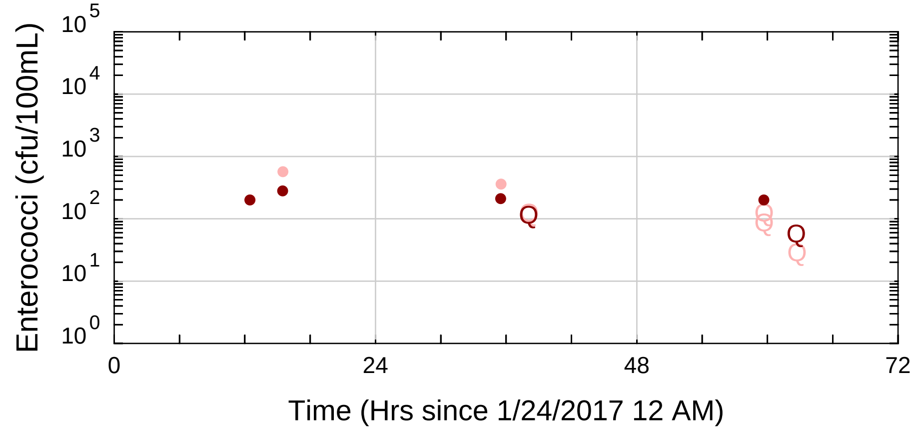
Hudson River, Upper Bay, Kill Van Kull, B12, (SE3)

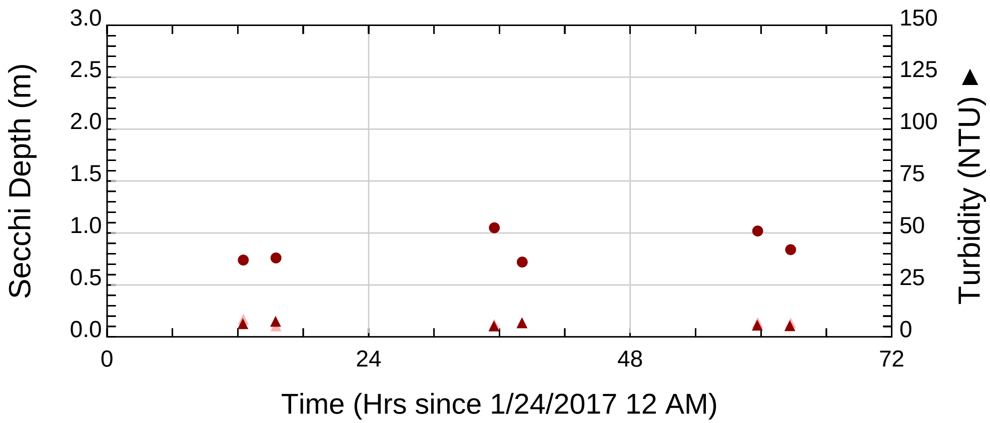
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

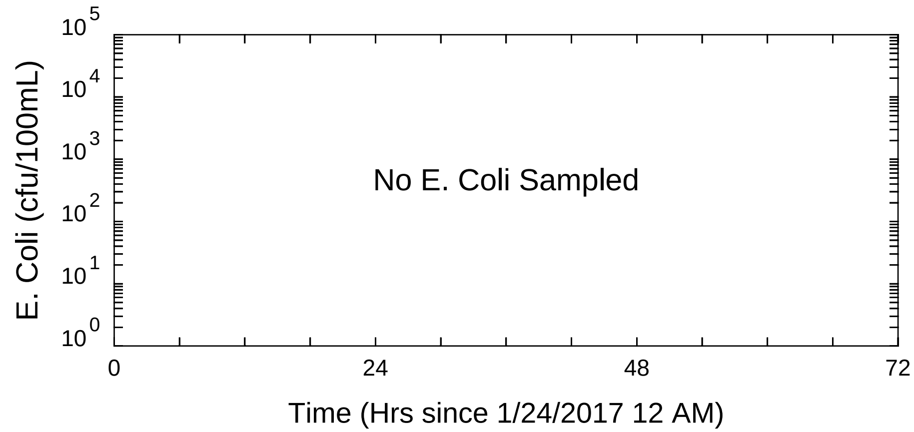








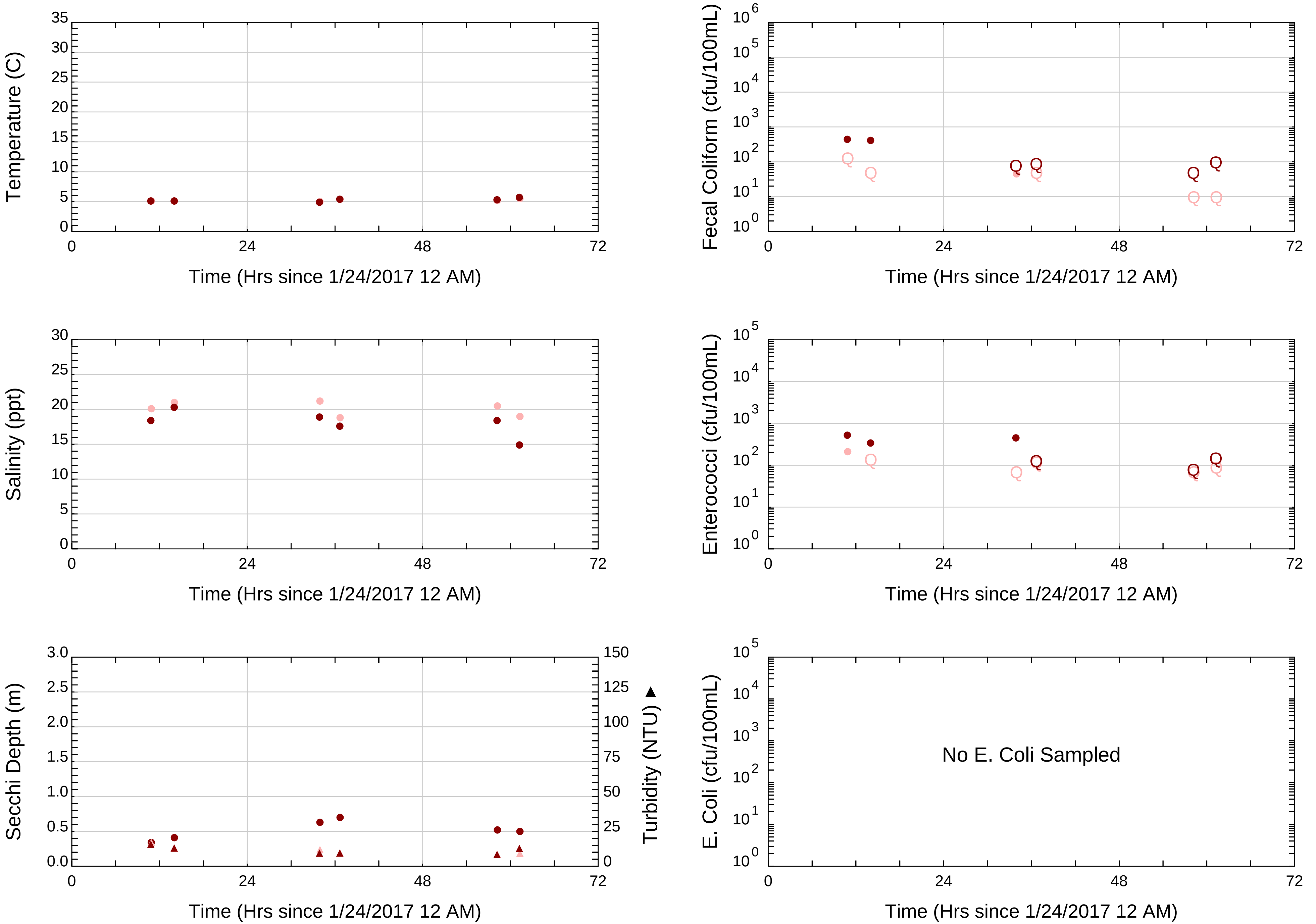




Q: See page 1 of attachment
for notes on qualifiers

Arthur Kill, Raritan River/Bay & Tributaries, Arthur Kill, B15, (SE2)

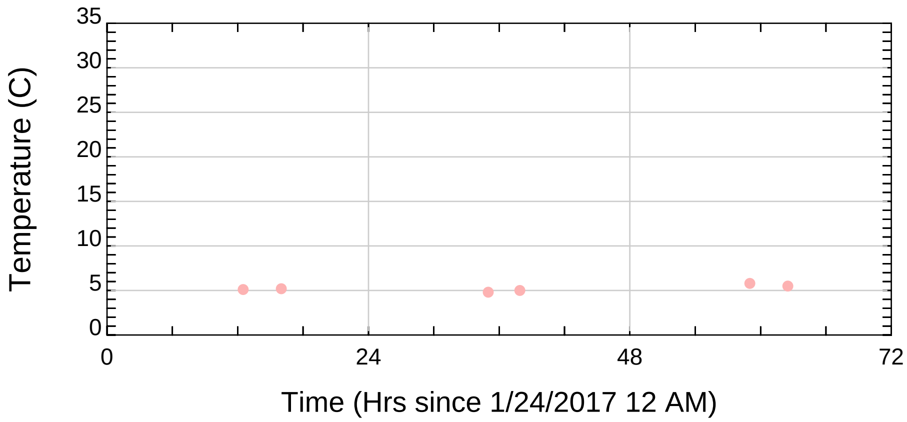
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

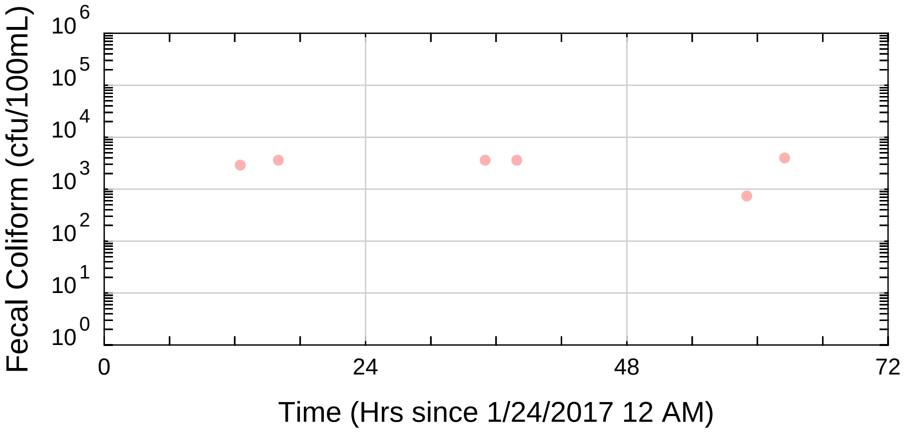


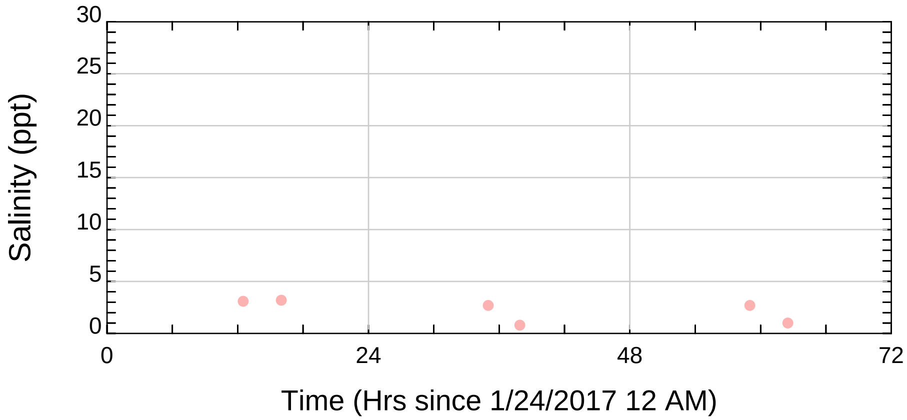
Q: See page 1 of attachment for notes on qualifiers

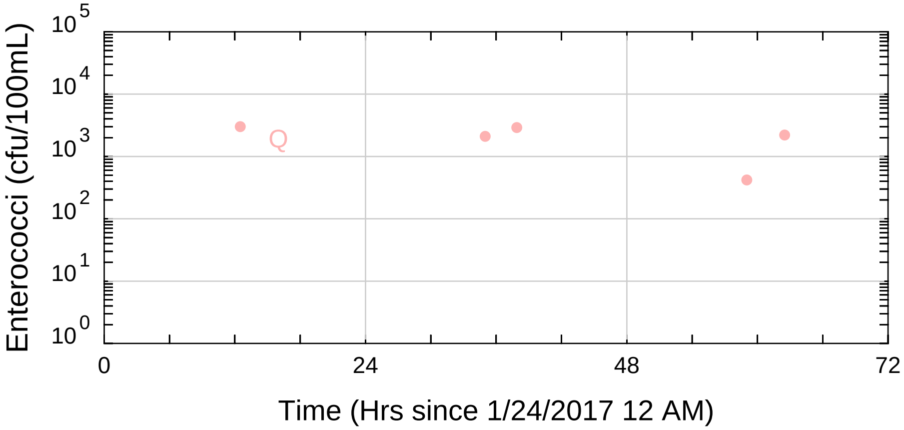
Hackensack River & Tributaries, Hackensack River, B2, (SE1)

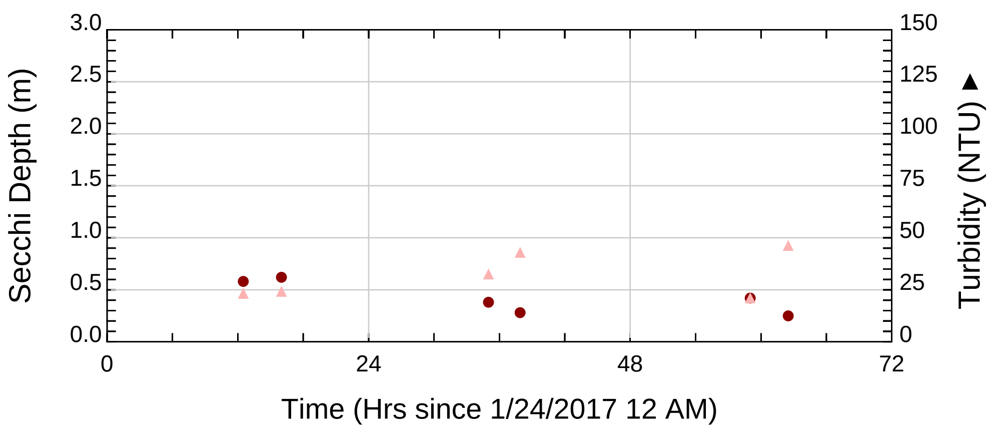
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

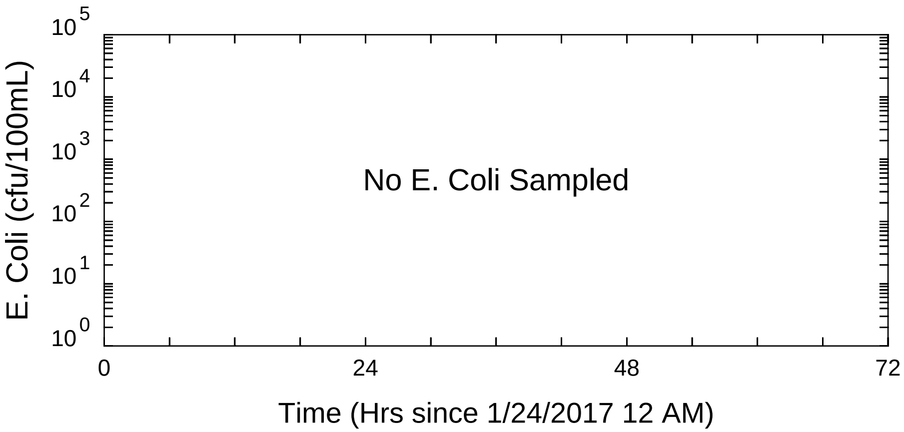






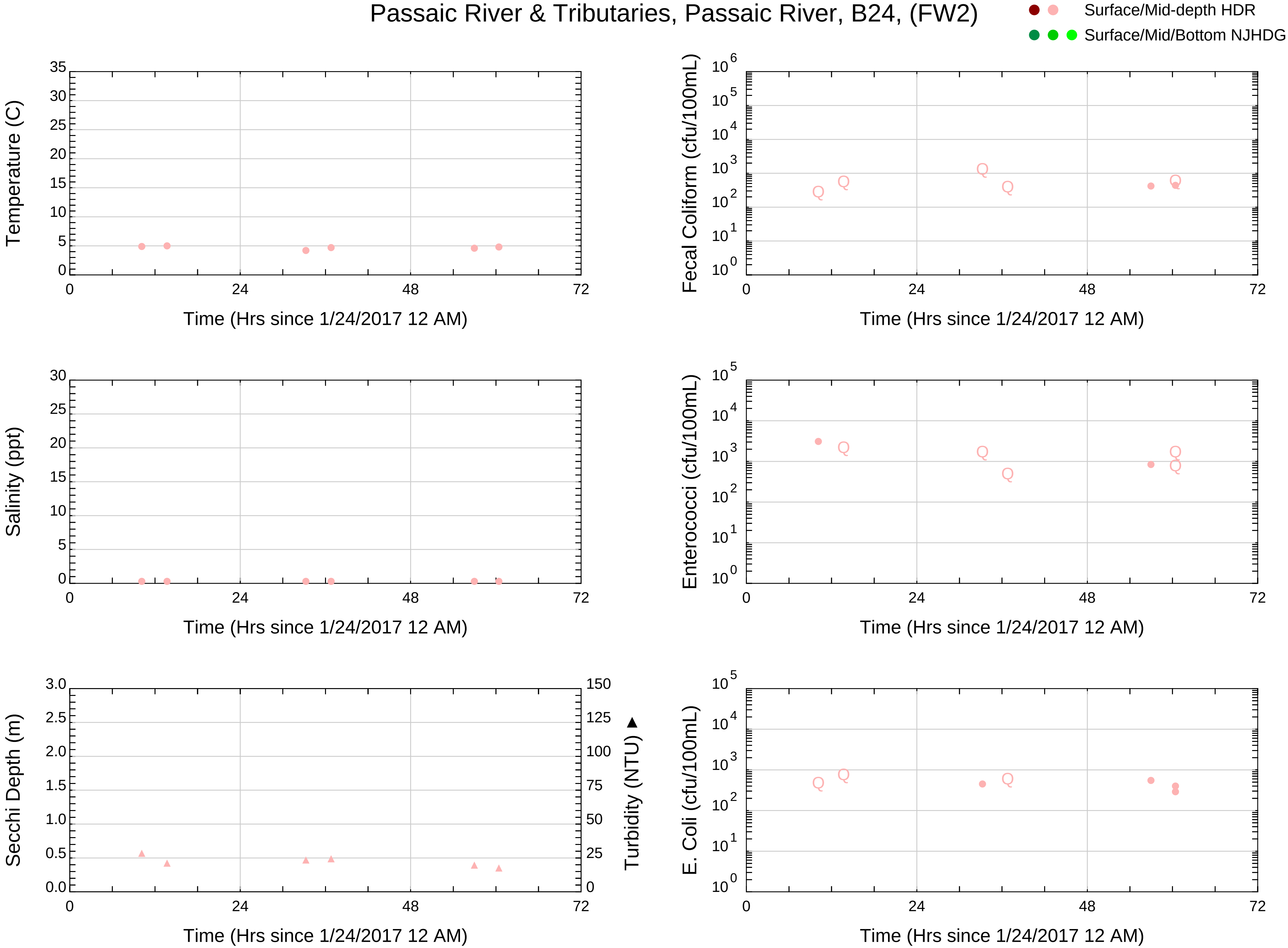






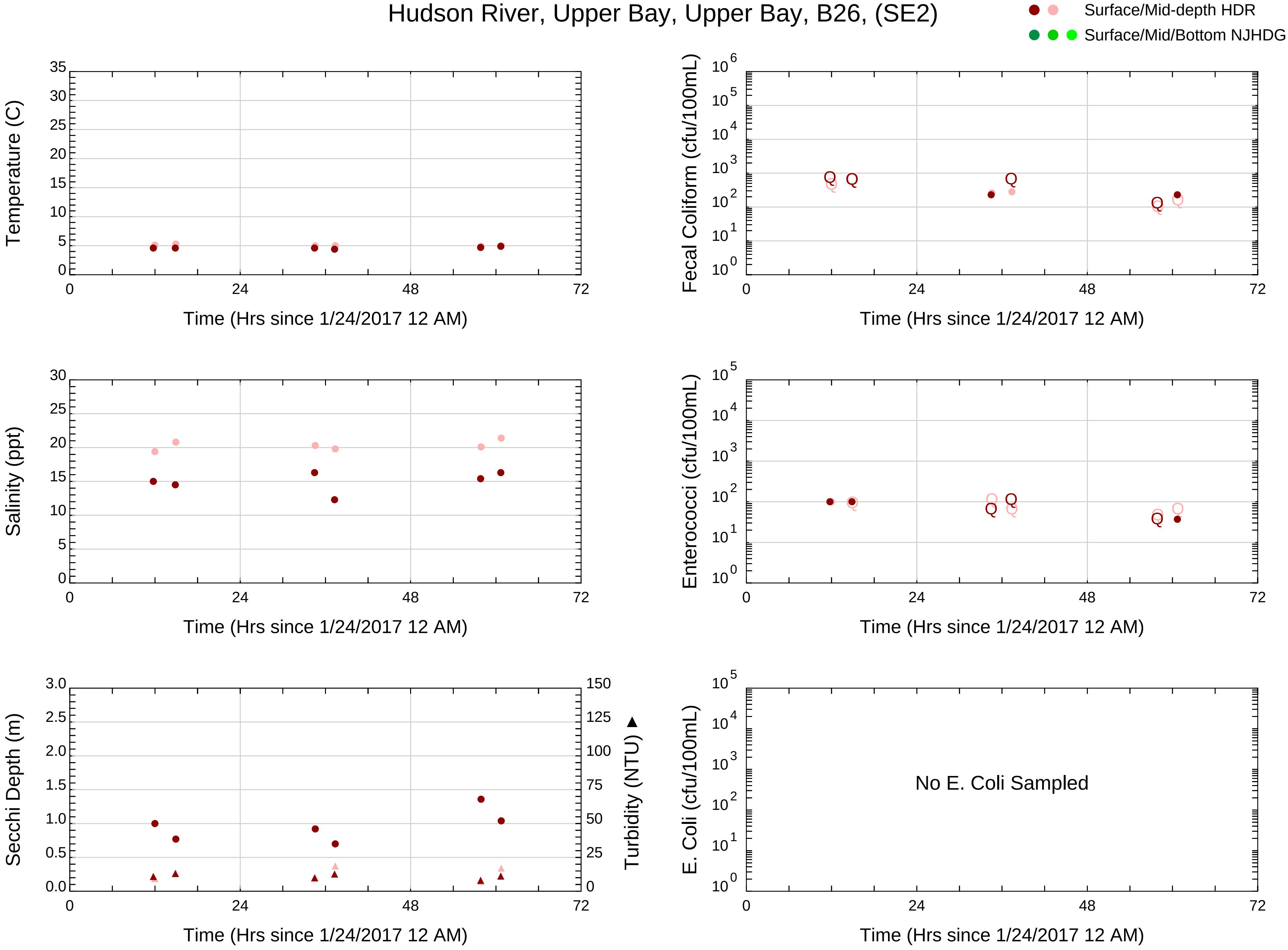
Q: See page 1 of attachment
for notes on qualifiers

Passaic River & Tributaries, Passaic River, B24, (FW2)



Q: See page 1 of attachment for notes on qualifiers

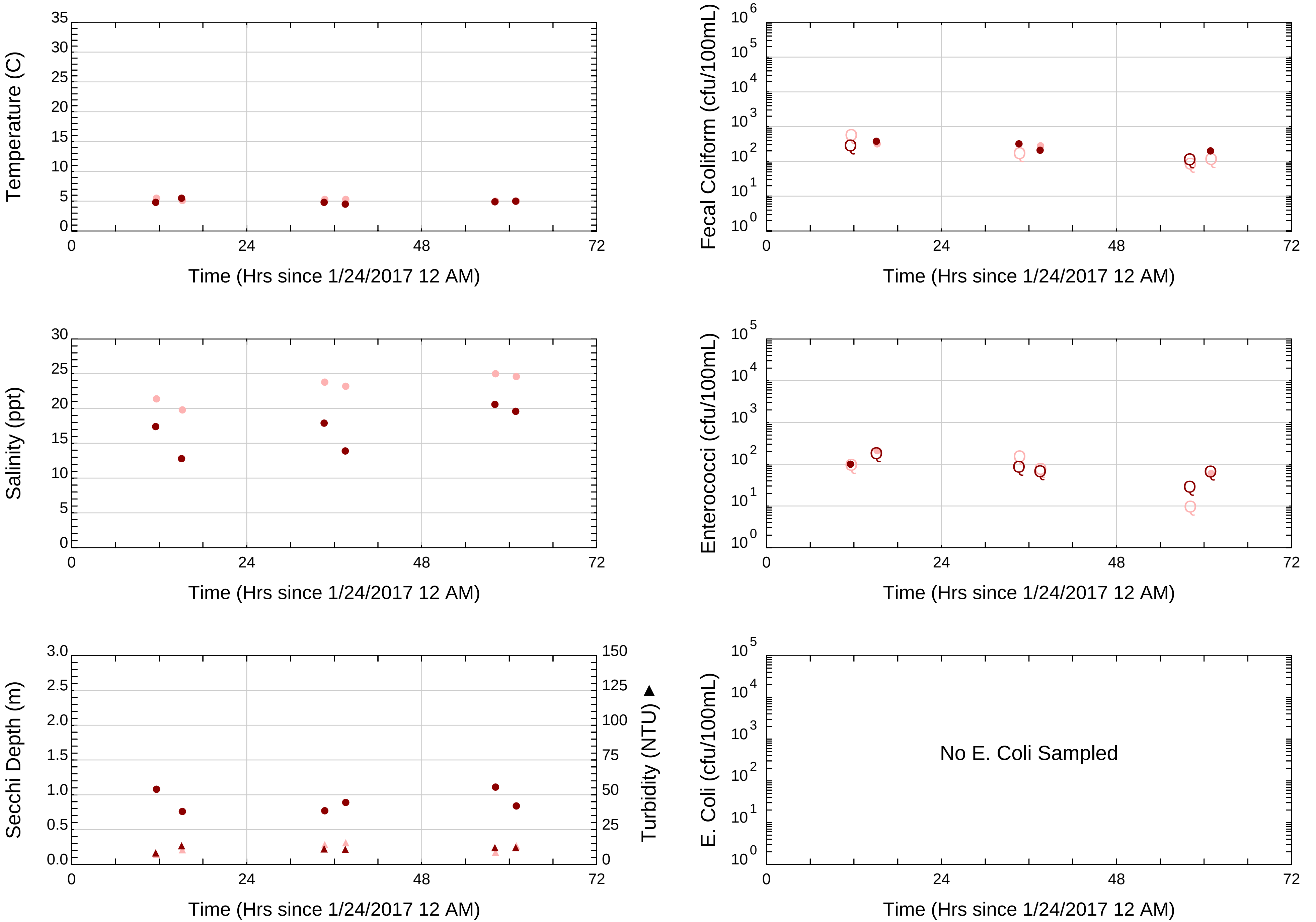
Hudson River, Upper Bay, Upper Bay, B26, (SE2)



Q: See page 1 of attachment for notes on qualifiers

Hudson River, Upper Bay, Upper Bay, B27, (SE2)

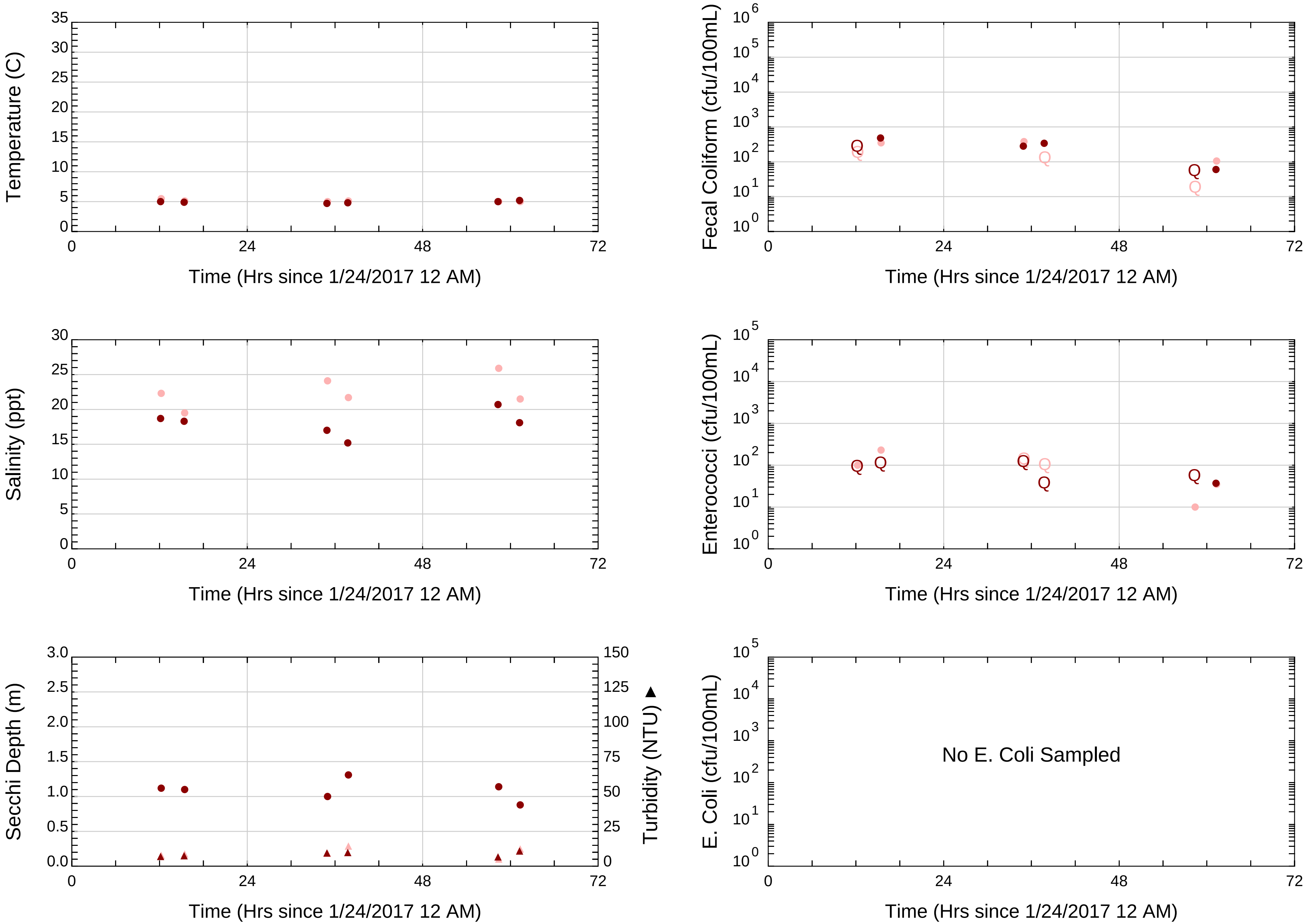
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG



Q: See page 1 of attachment for notes on qualifiers

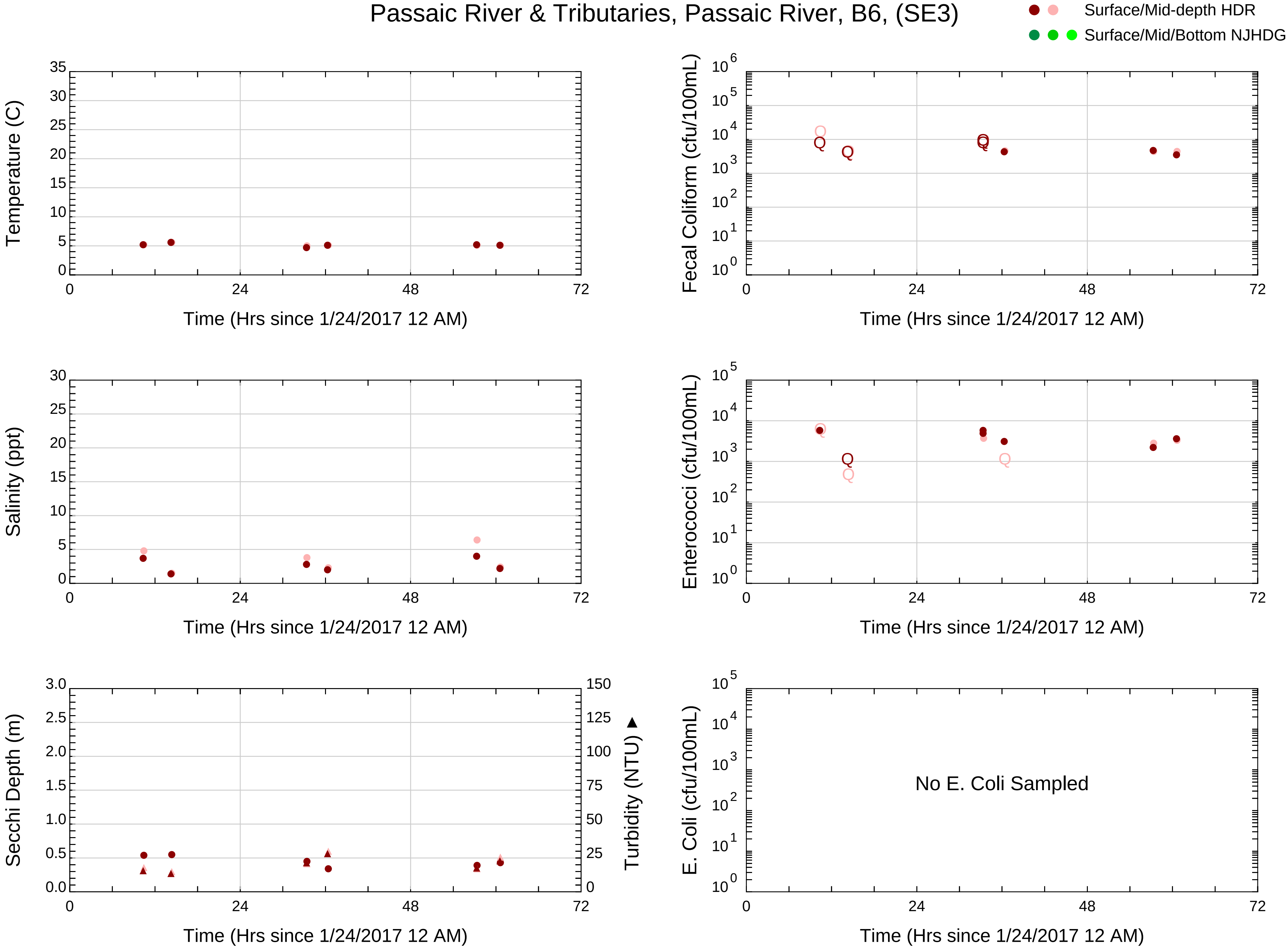
Hudson River, Upper Bay, Upper Bay, B28, (SE2)

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG



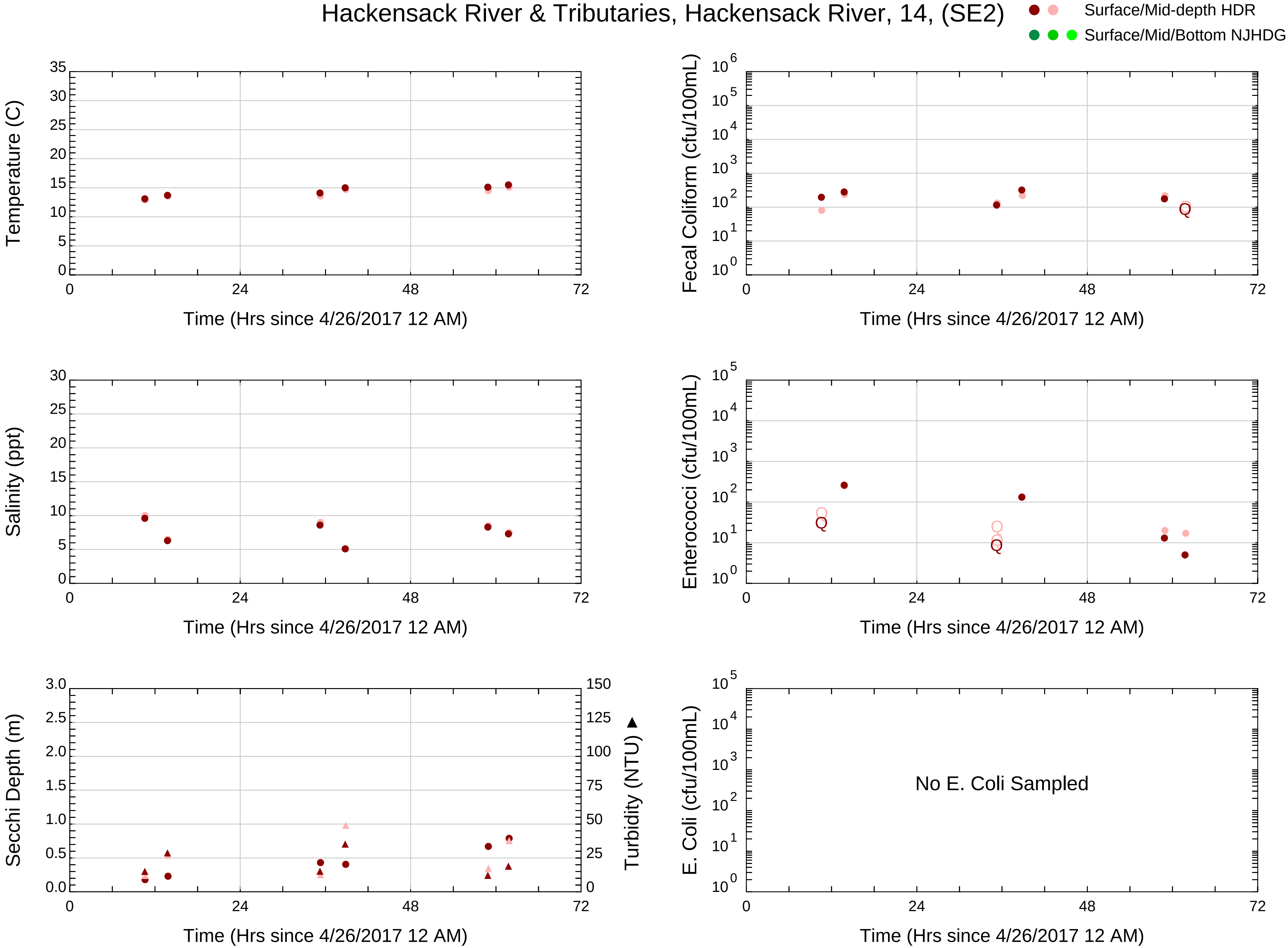
Q: See page 1 of attachment
for notes on qualifiers

Passaic River & Tributaries, Passaic River, B6, (SE3)



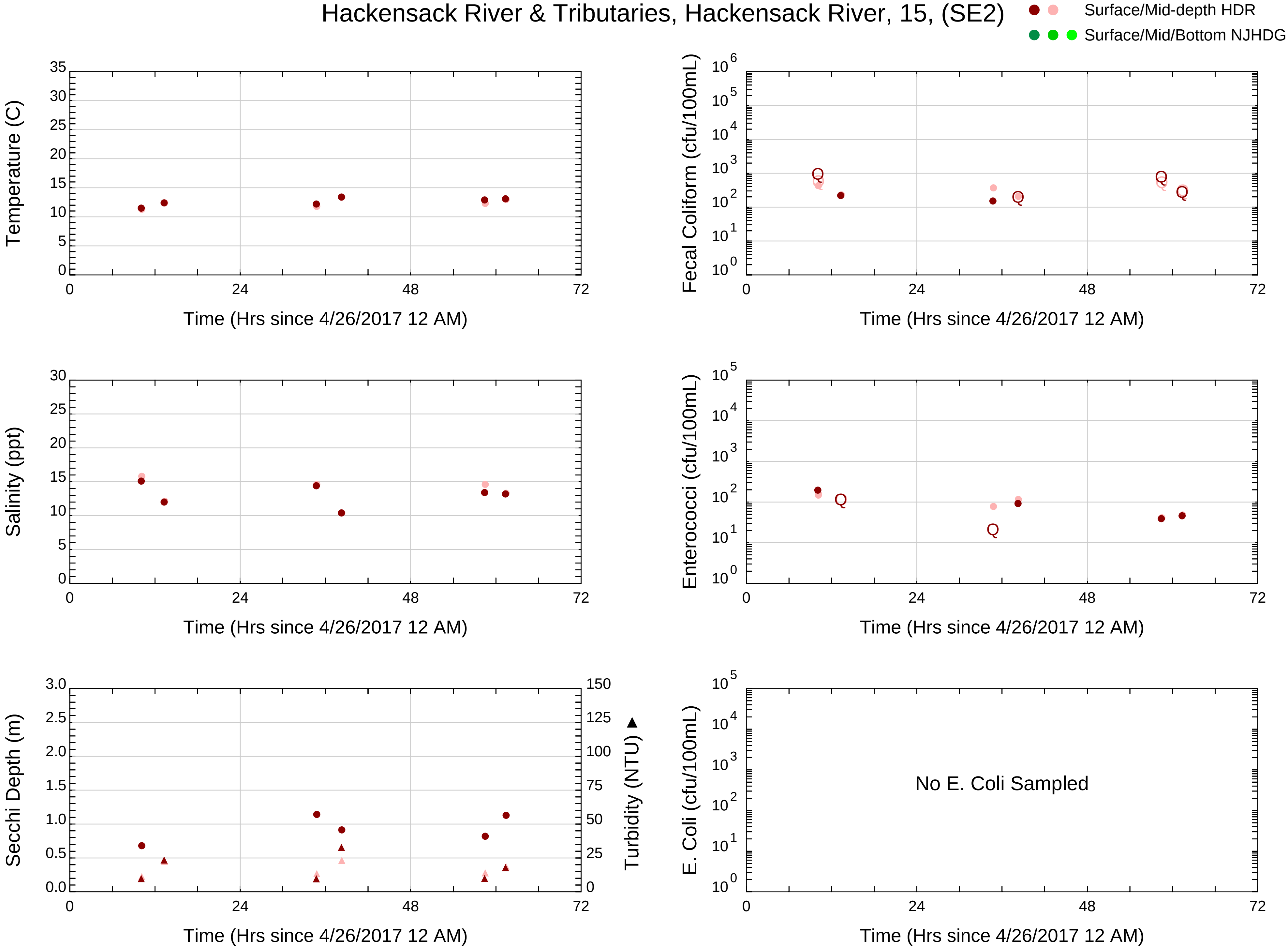
Q: See page 1 of attachment for notes on qualifiers

Hackensack River & Tributaries, Hackensack River, 14, (SE2)



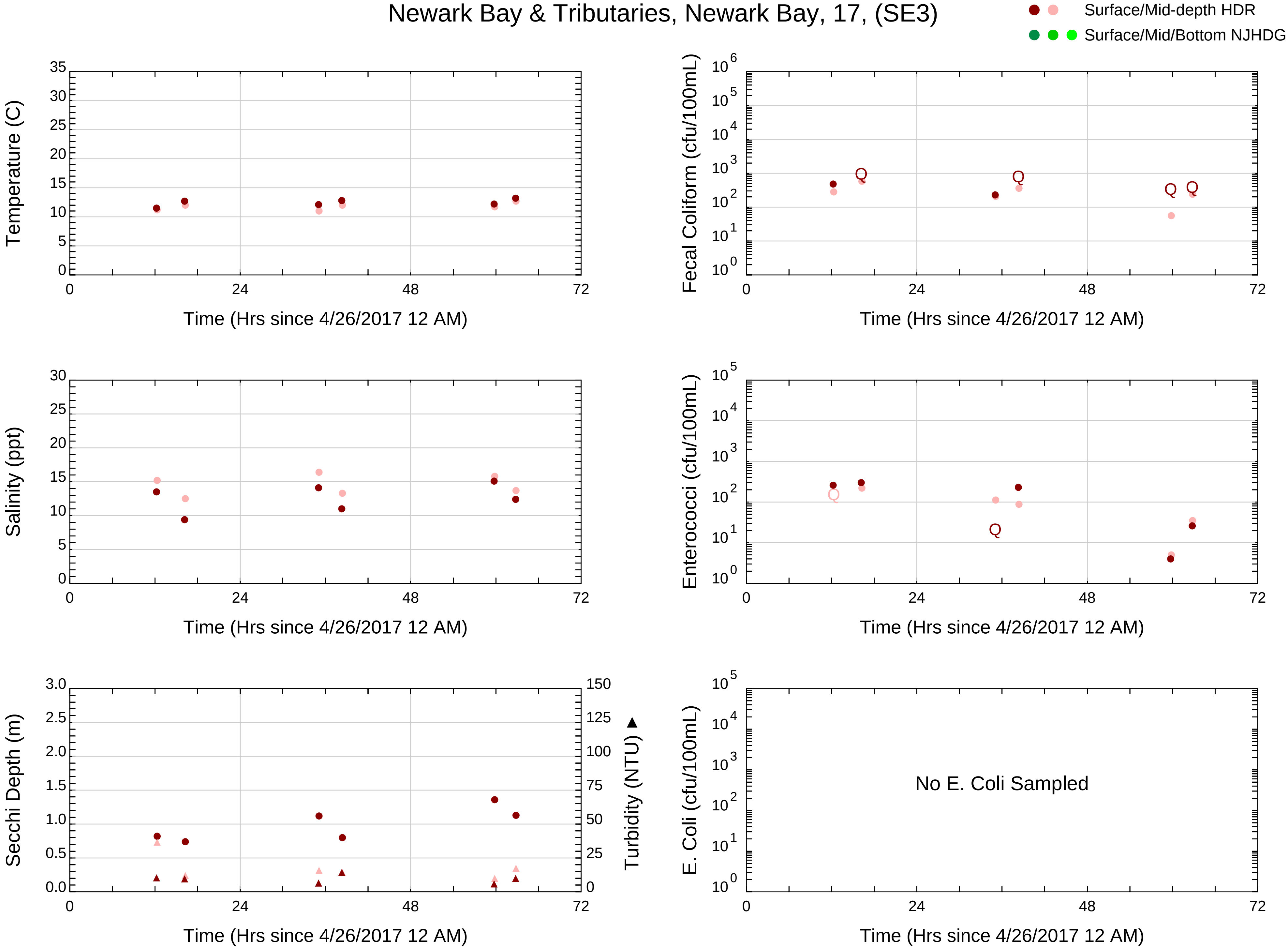
Q: See page 1 of attachment for notes on qualifiers

Hackensack River & Tributaries, Hackensack River, 15, (SE2)



Q: See page 1 of attachment for notes on qualifiers

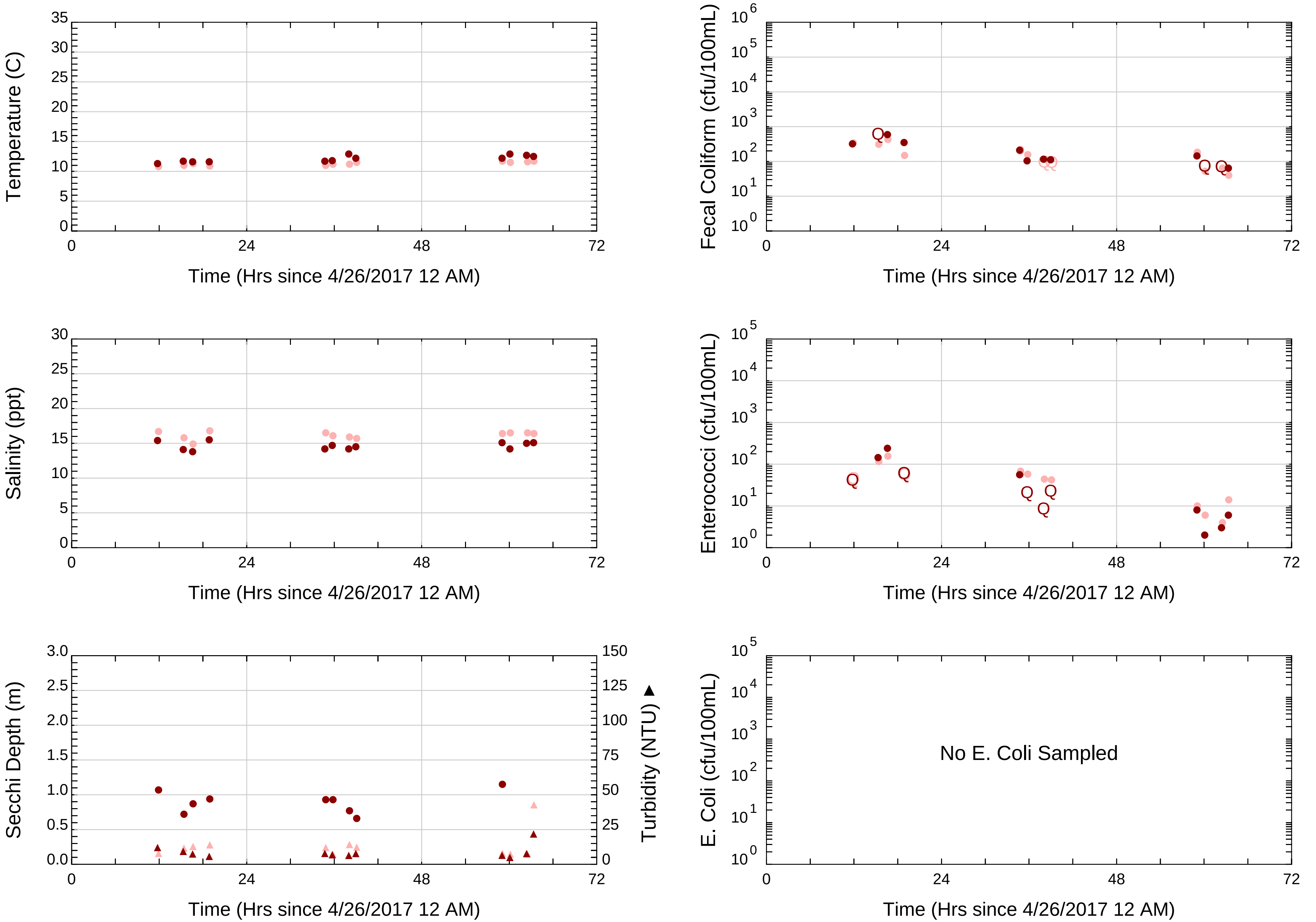
Newark Bay & Tributaries, Newark Bay, 17, (SE3)



Q: See page 1 of attachment for notes on qualifiers

Newark Bay & Tributaries, Newark Bay, 18, (SE3)

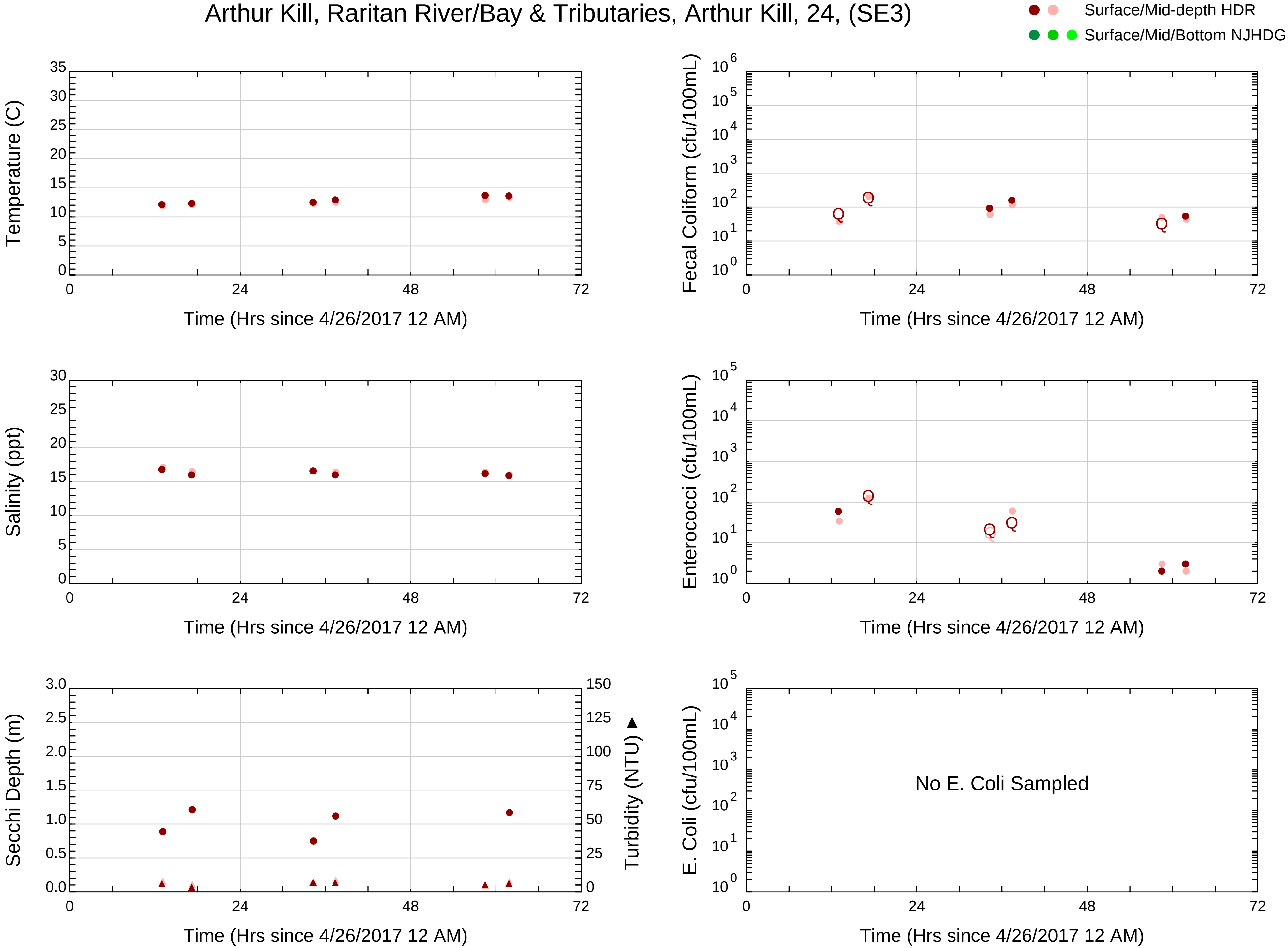
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG



Q: See page 1 of attachment
for notes on qualifiers

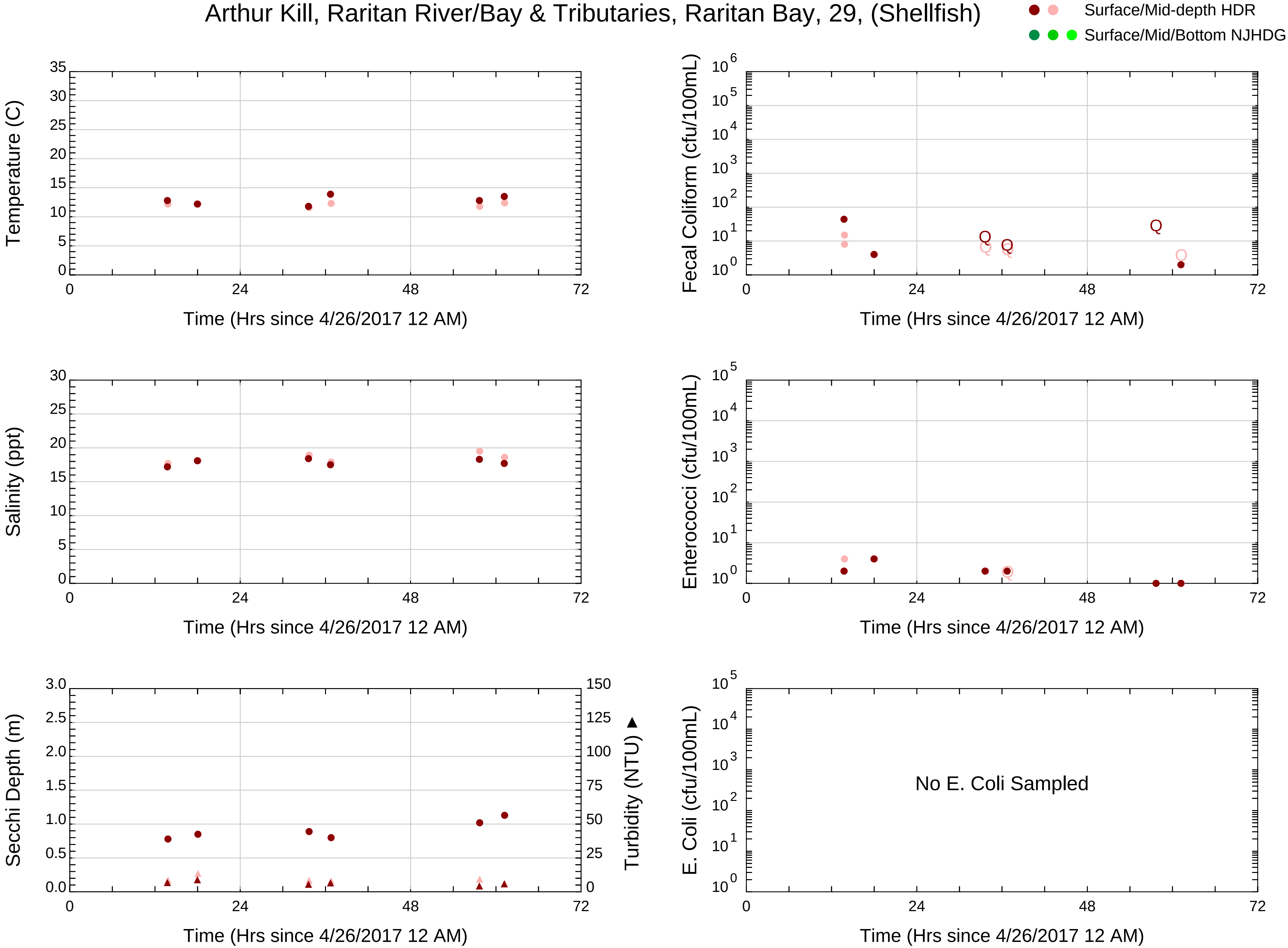
Wet-Weather Events 4/26/2017 - 4/28/2017

Arthur Kill, Raritan River/Bay & Tributaries, Arthur Kill, 24, (SE3)



Q: See page 1 of attachment for notes on qualifiers

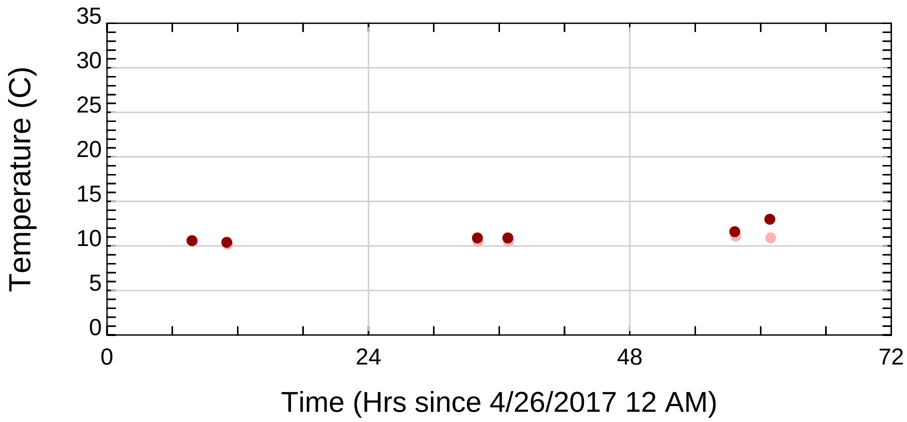
Arthur Kill, Raritan River/Bay & Tributaries, Raritan Bay, 29, (Shellfish)

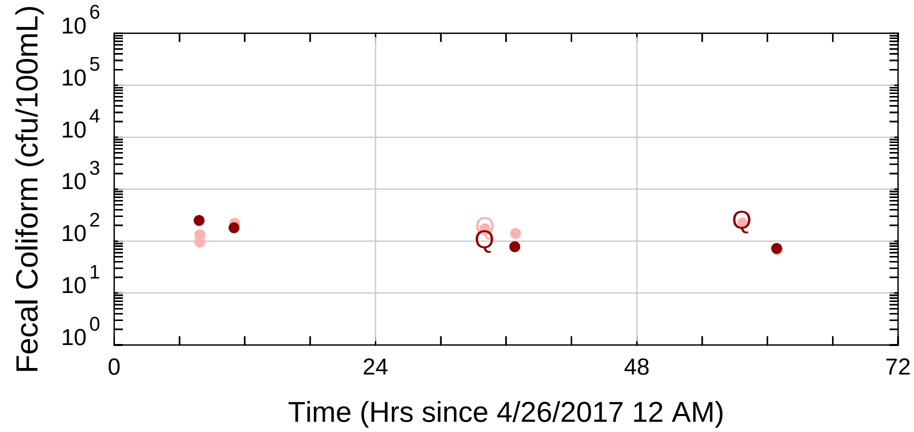


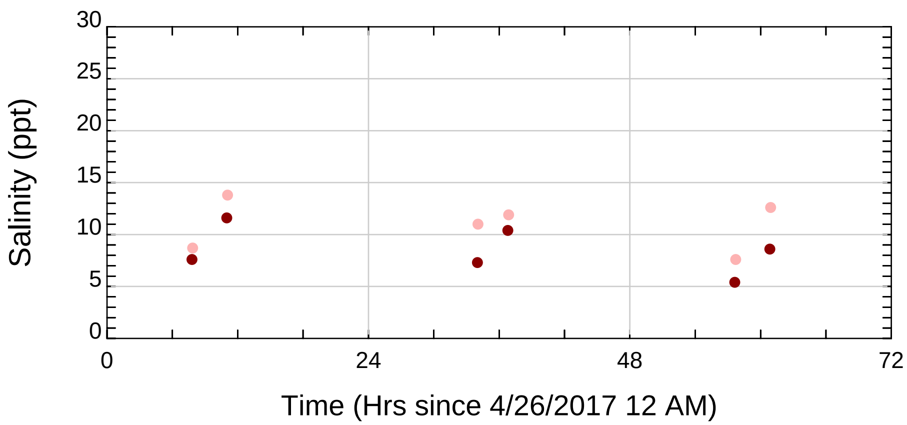
Q: See page 1 of attachment for notes on qualifiers

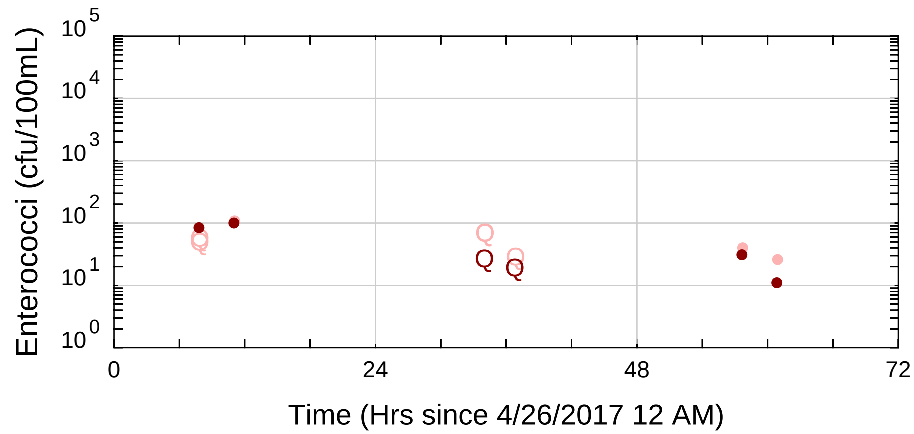
Hudson River, Upper Bay, Hudson River, 31, (SE2)

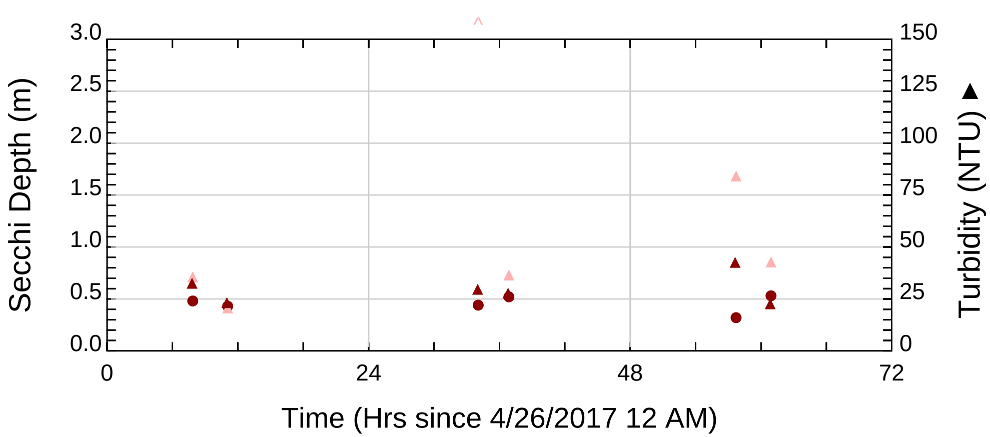
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

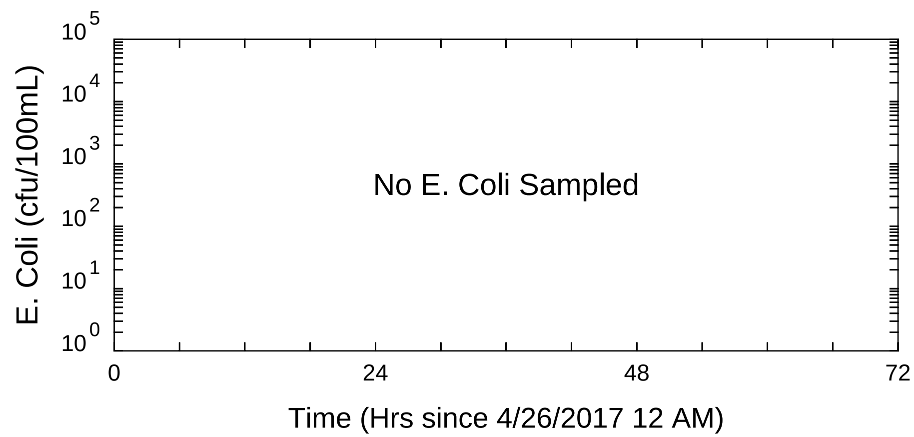






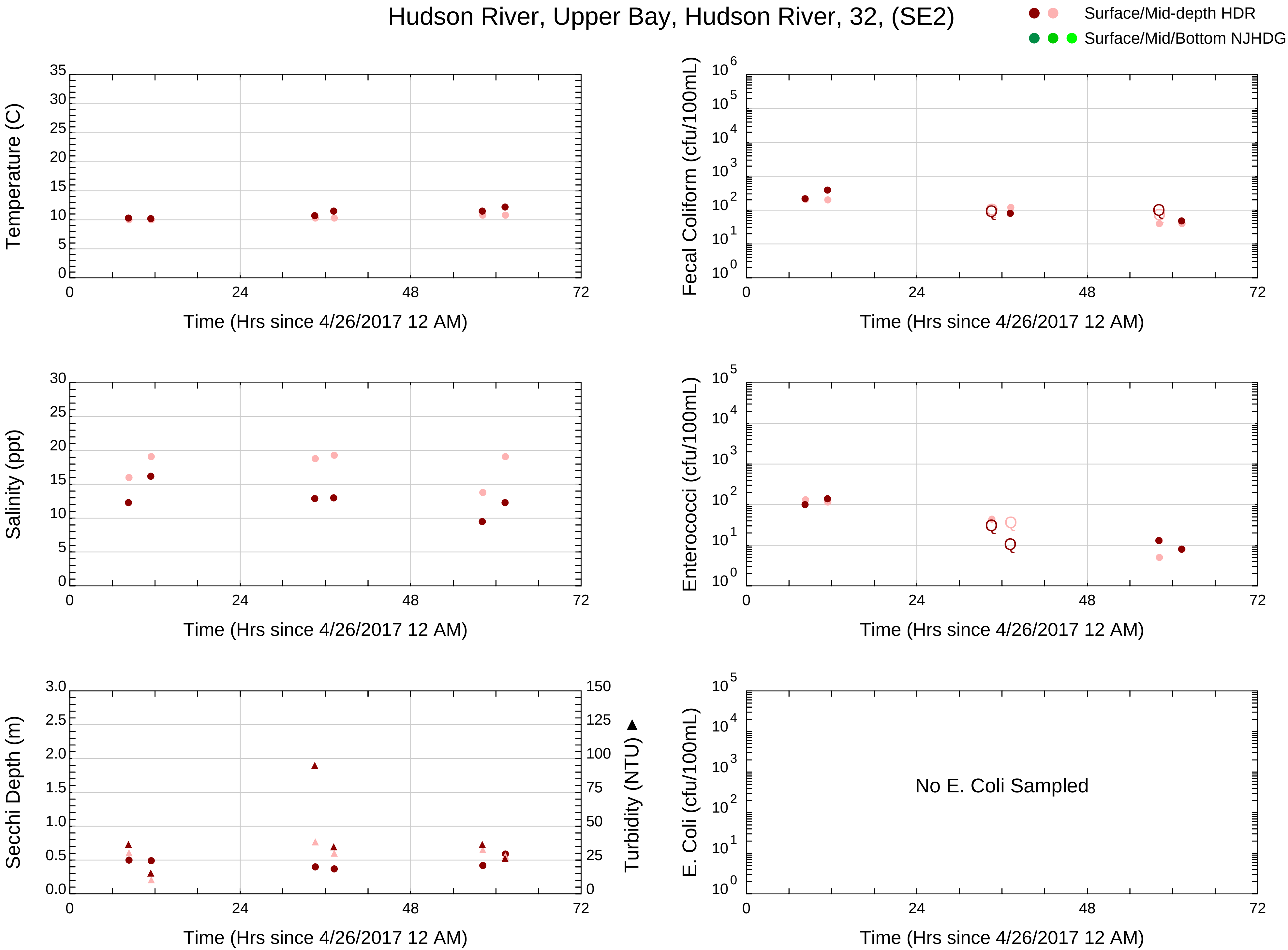






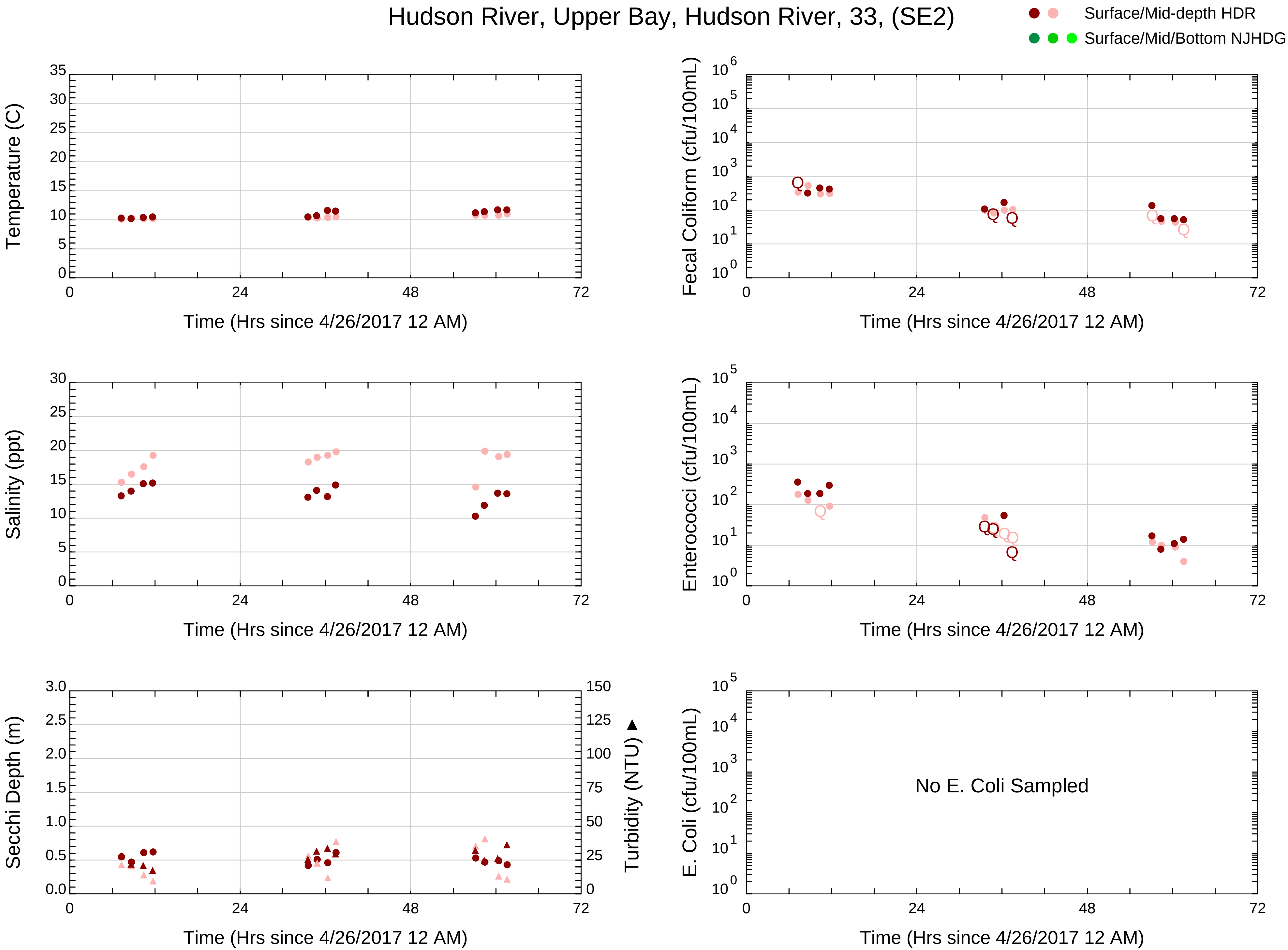
Q: See page 1 of attachment
for notes on qualifiers

Hudson River, Upper Bay, Hudson River, 32, (SE2)



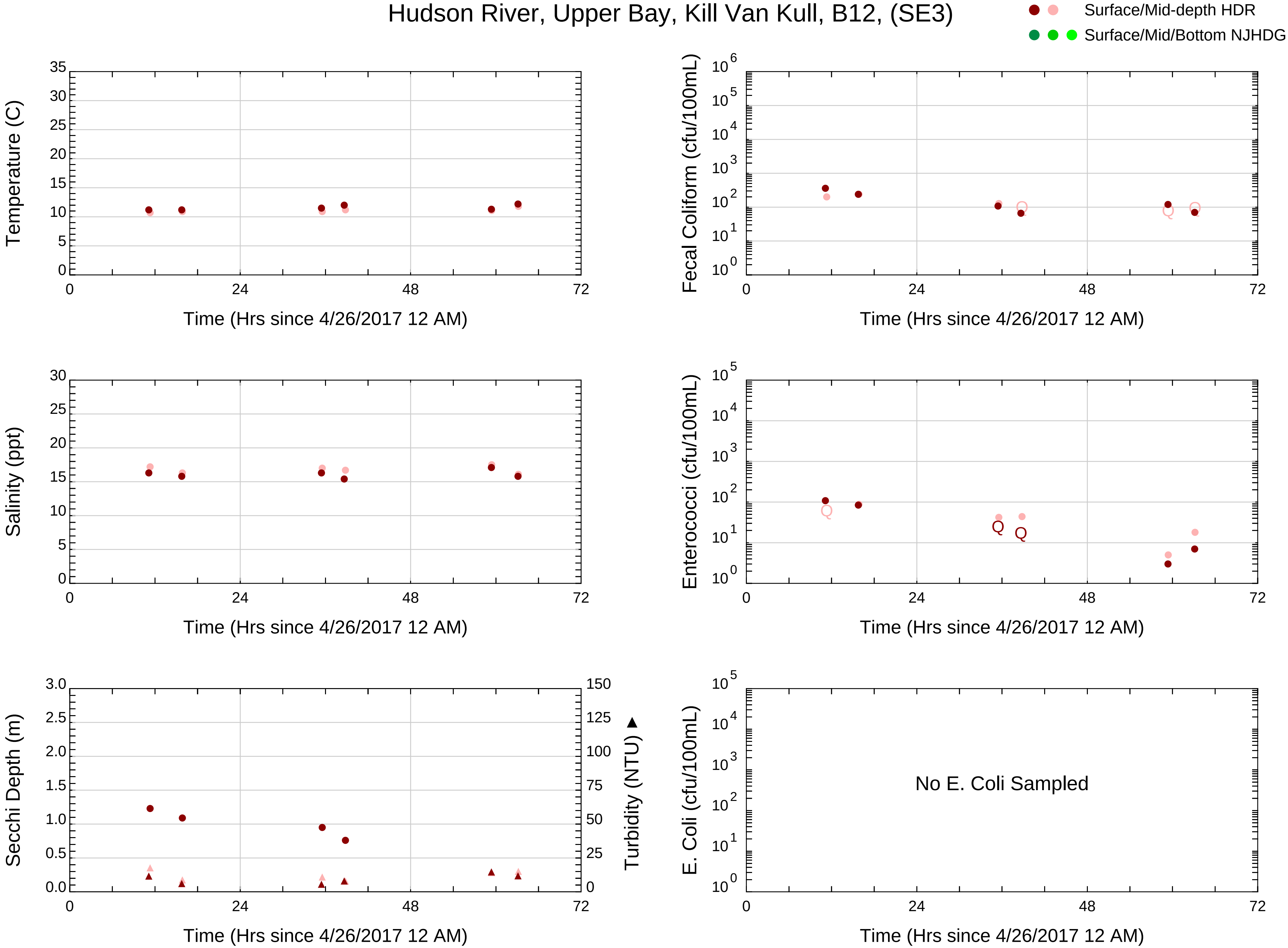
Q: See page 1 of attachment for notes on qualifiers

Hudson River, Upper Bay, Hudson River, 33, (SE2)



Q: See page 1 of attachment
for notes on qualifiers

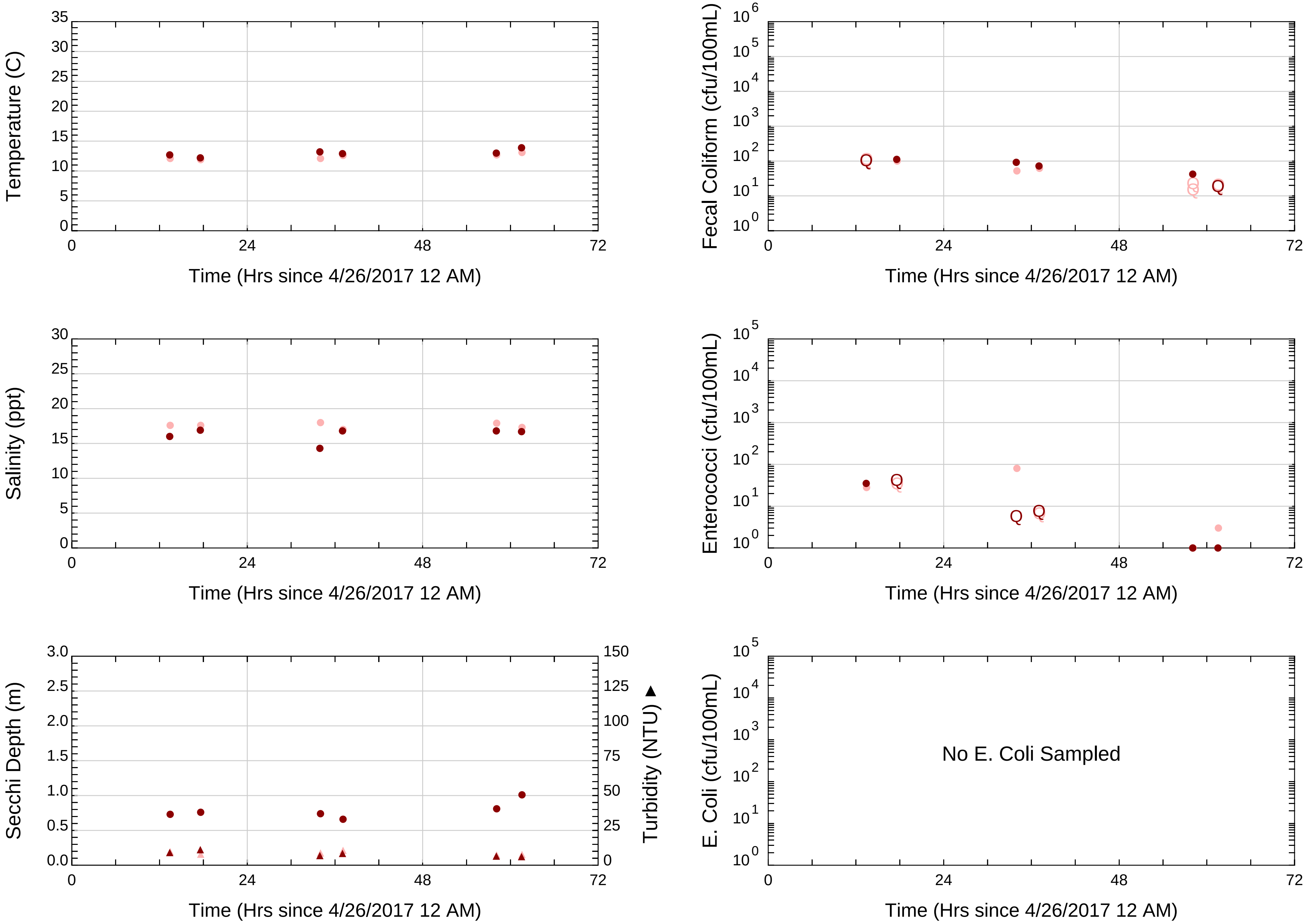
Hudson River, Upper Bay, Kill Van Kull, B12, (SE3)



Q: See page 1 of attachment for notes on qualifiers

Arthur Kill, Raritan River/Bay & Tributaries, Arthur Kill, B15, (SE2)

Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

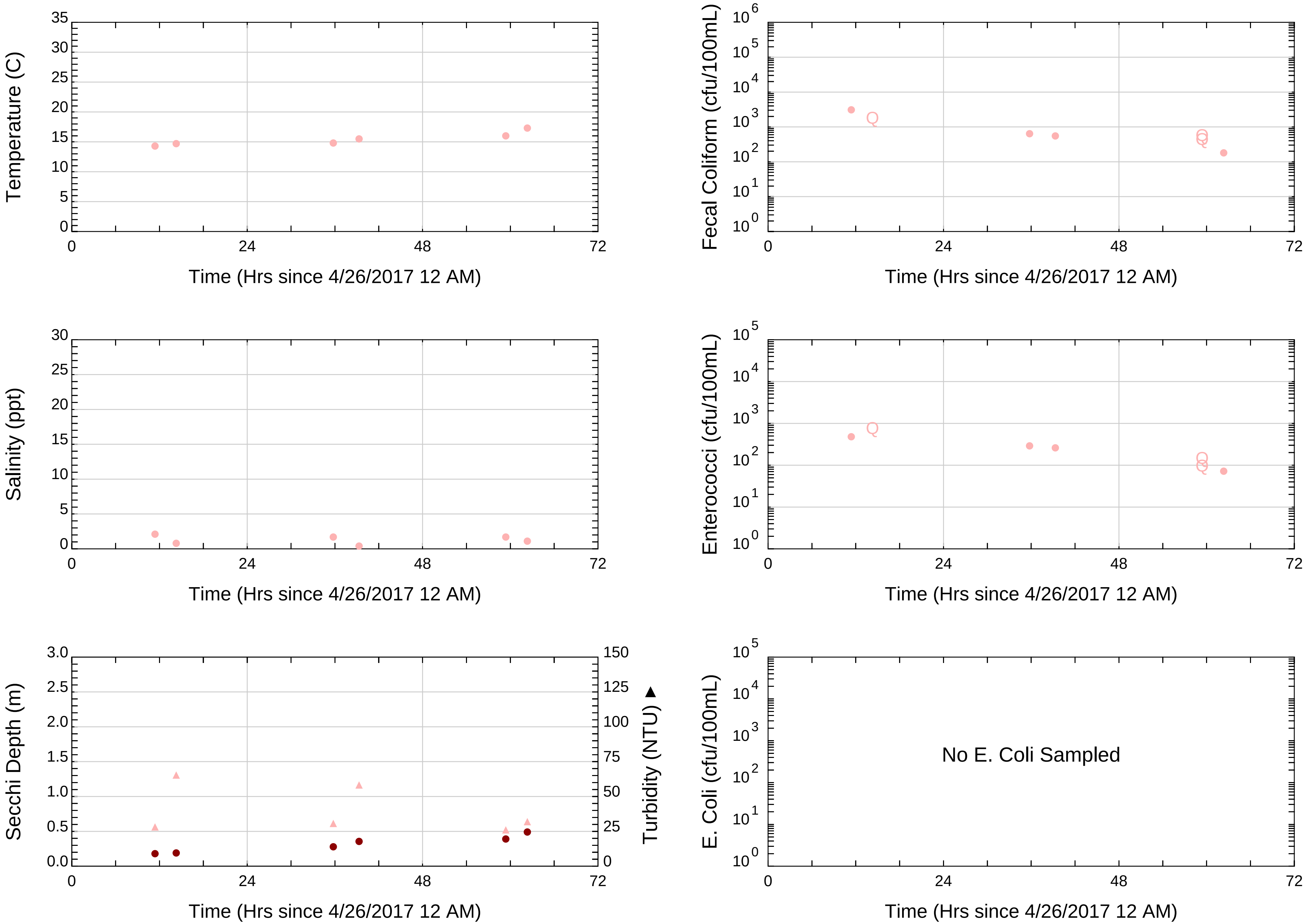


Q: See page 1 of attachment for notes on qualifiers

Hackensack River & Tributaries, Hackensack River, B2, (SE1)

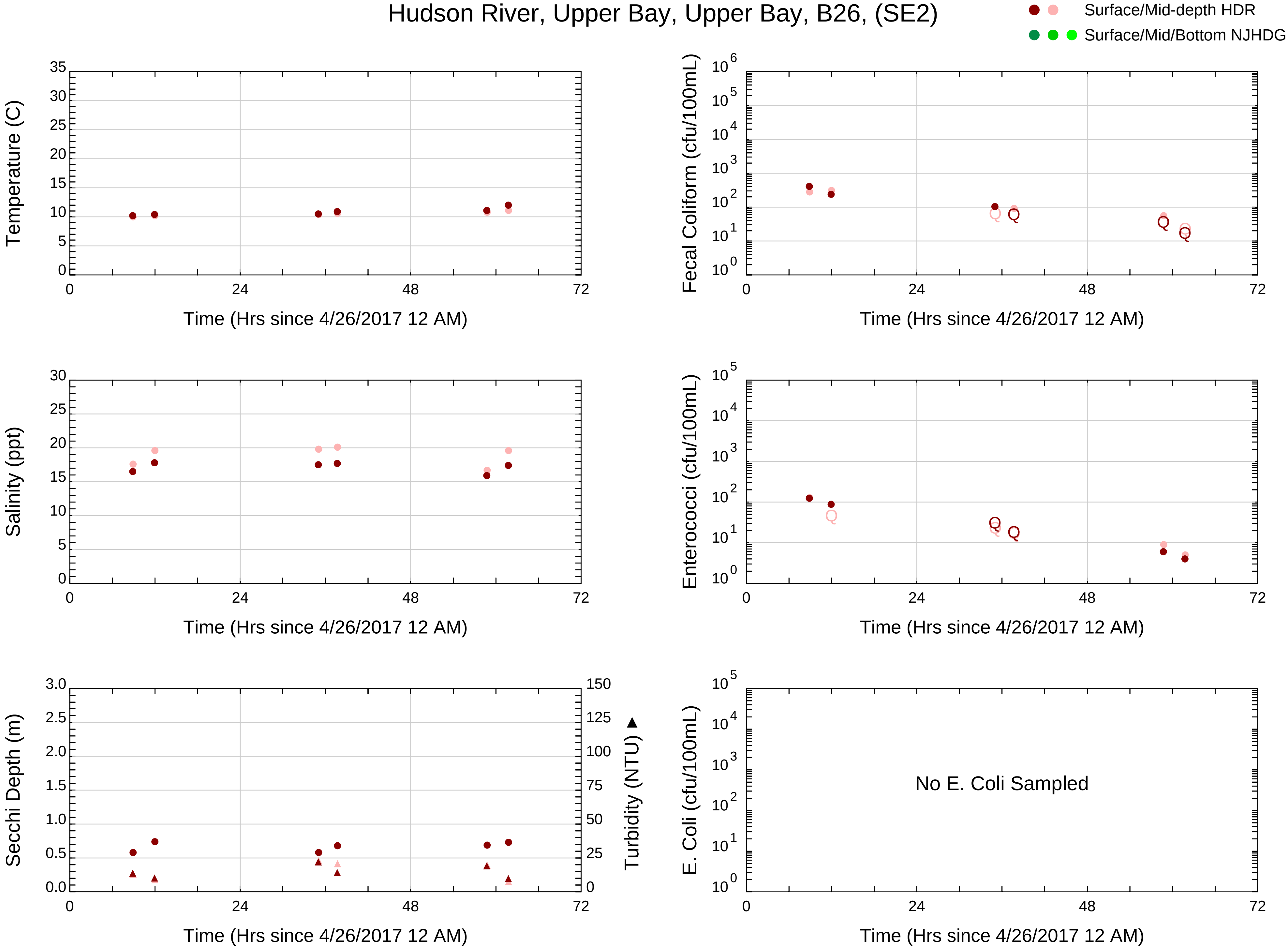
Surface/Mid-depth HDR

Surface/Mid/Bottom NJHDG



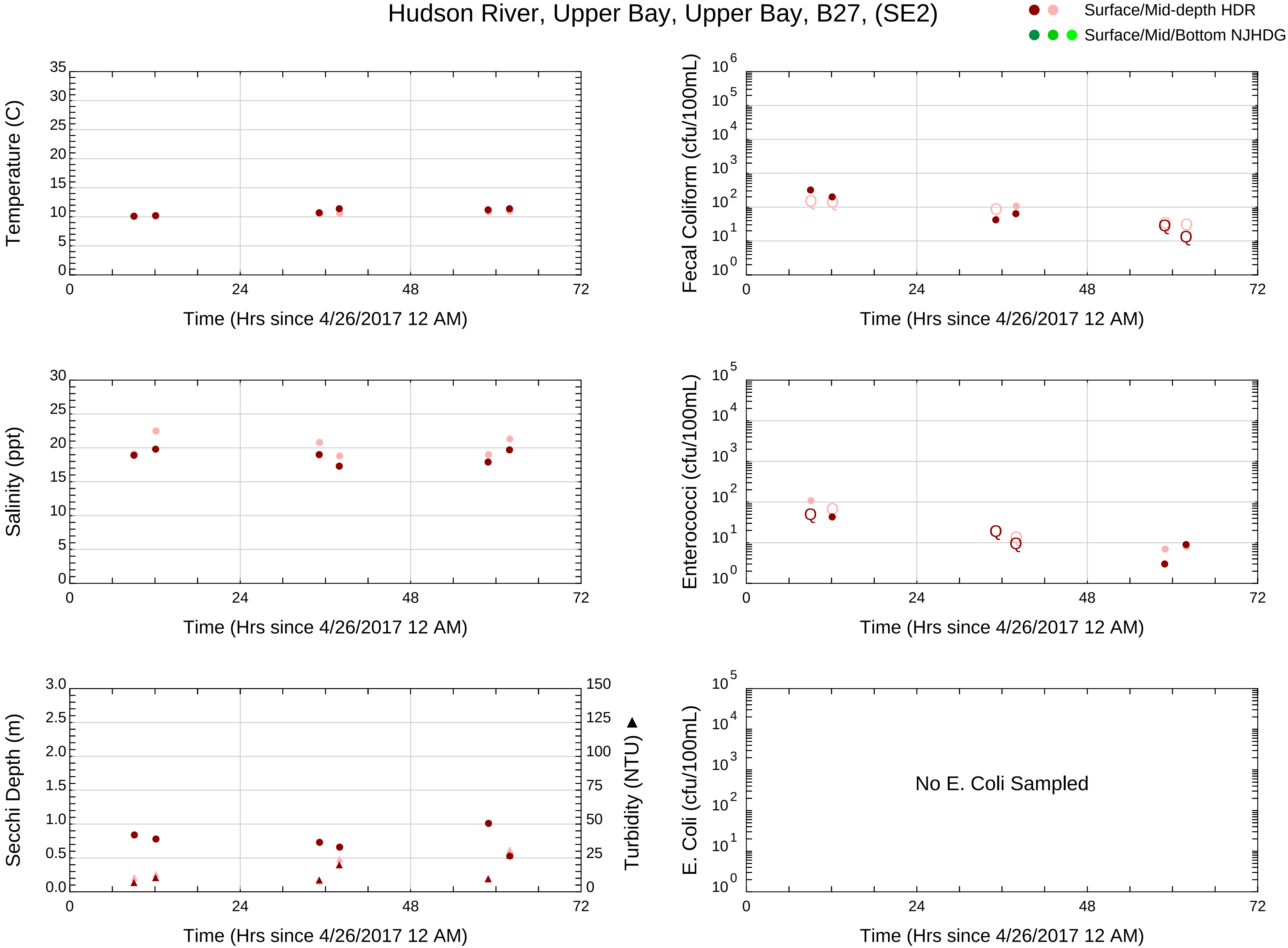
Q: See page 1 of attachment
for notes on qualifiers

Hudson River, Upper Bay, Upper Bay, B26, (SE2)



Q: See page 1 of attachment for notes on qualifiers

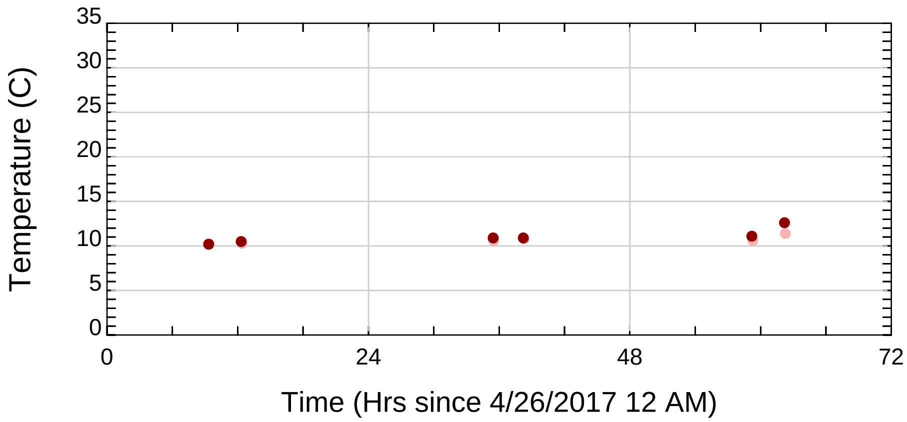
Hudson River, Upper Bay, Upper Bay, B27, (SE2)

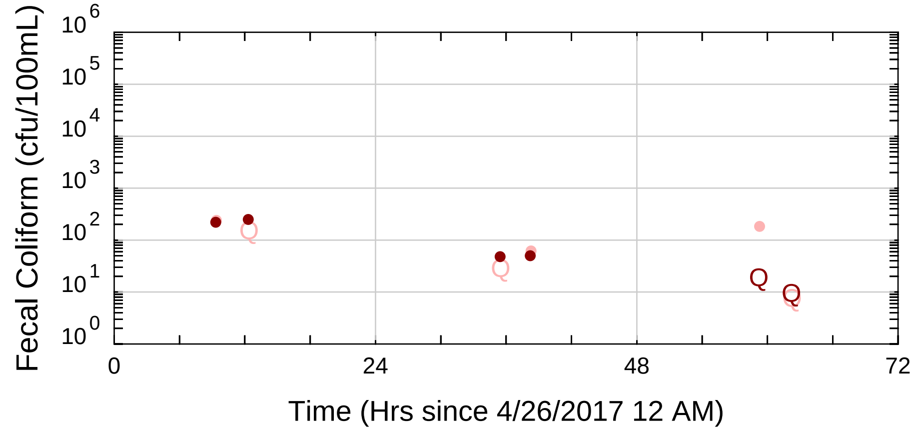


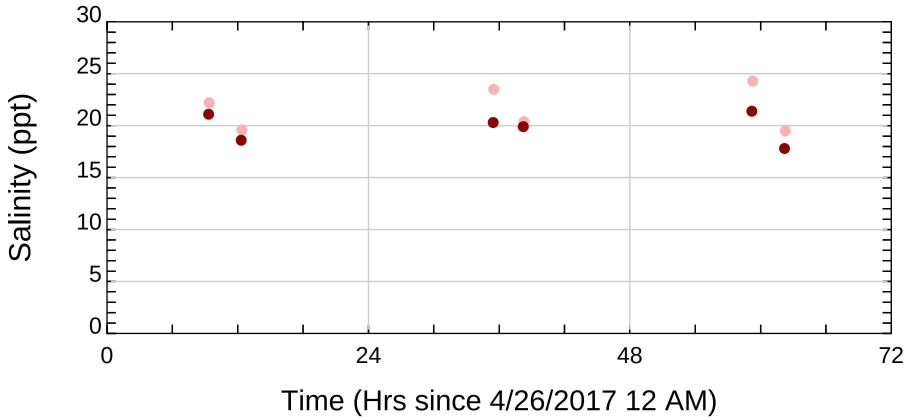
Q: See page 1 of attachment for notes on qualifiers

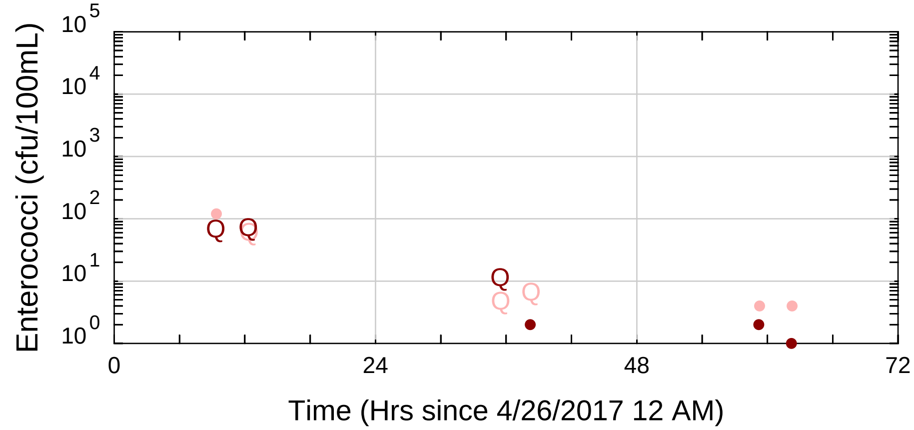
Hudson River, Upper Bay, Upper Bay, B28, (SE2)

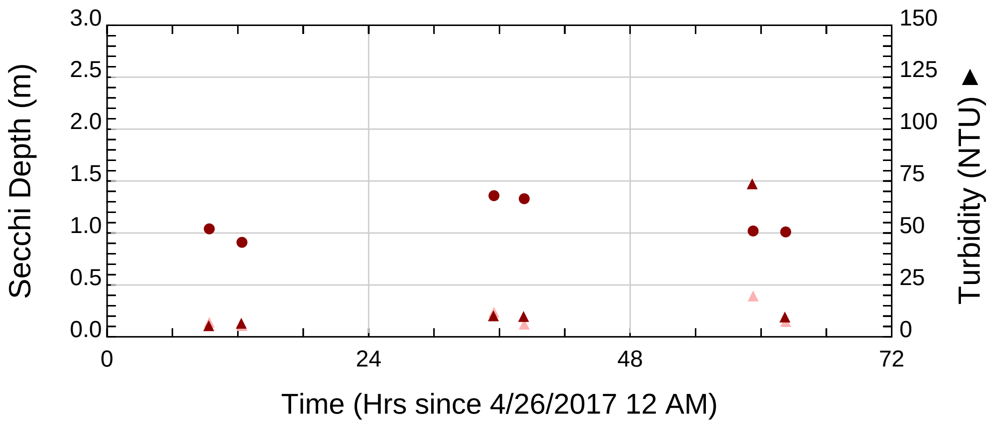
Surface/Mid-depth HDR
Surface/Mid/Bottom NJHDG

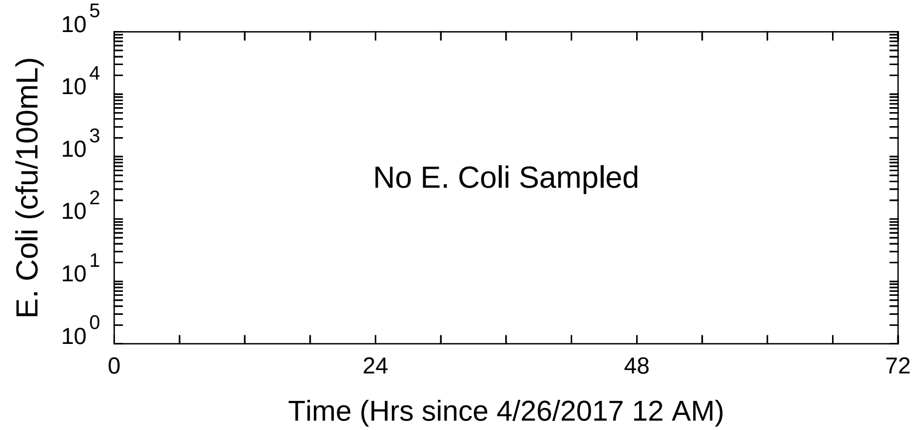






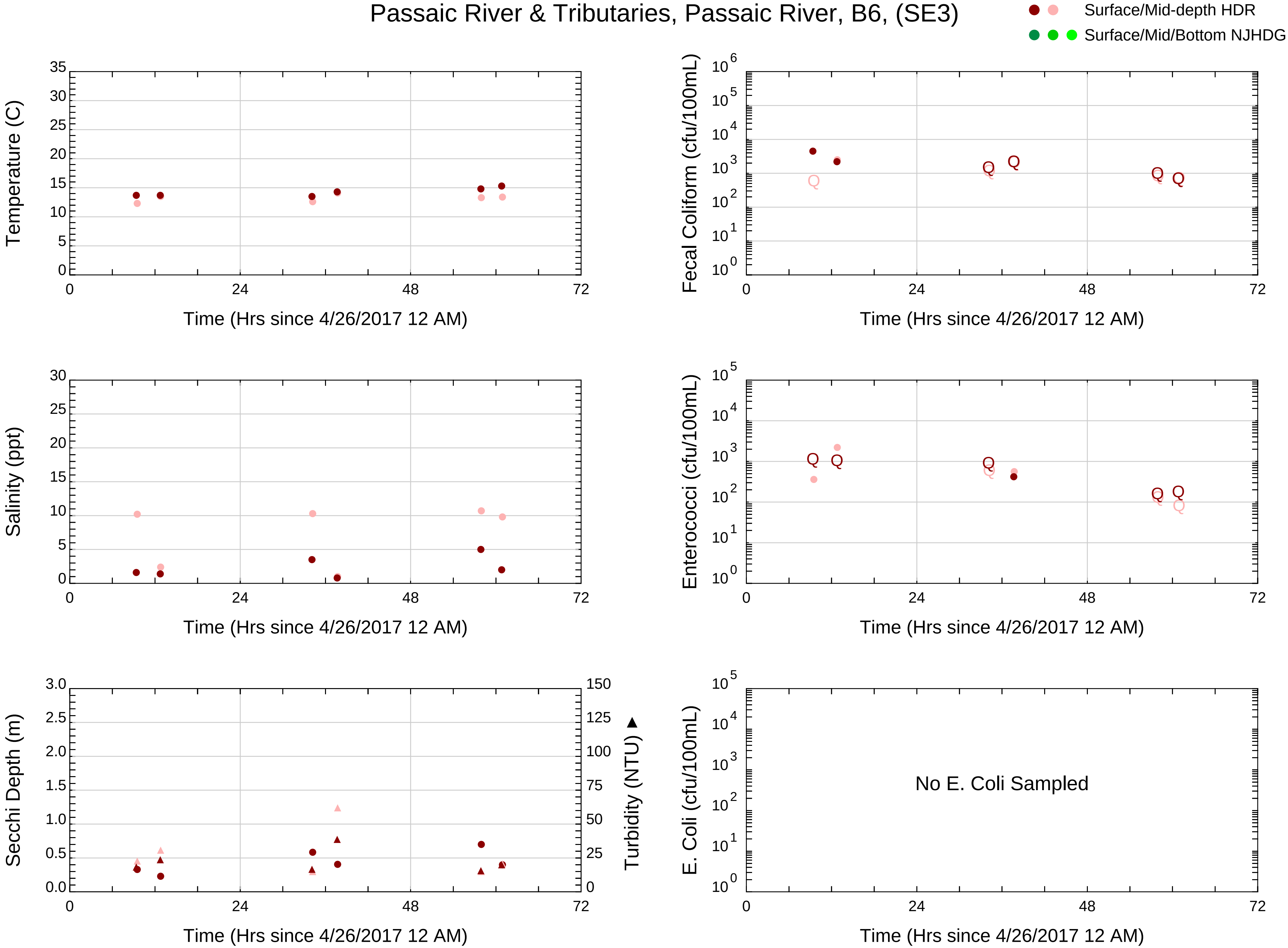






Q: See page 1 of attachment for notes on qualifiers

Passaic River & Tributaries, Passaic River, B6, (SE3)



Q: See page 1 of attachment for notes on qualifiers

ATTACHMENT 4 – COMMENT LETTER FROM NJDEP

State of New Jersey

PHIL MURPHY
Governor

SHEILA OLIVER
Lt. Governor

DEPARTMENT OF ENVIRONMENTAL PROTECTION
Mail Code – 401-02B
Water Pollution Management Element
Bureau of Surface Water Permitting
P.O. Box 420 – 401 E State St
Trenton, NJ 08625-0420
Phone: (609) 292-4860 / Fax: (609) 984-7938

CATHERINE R. MCCABE
Commissioner

September 7, 2018

To: Distribution List

Re: Technical Comments on "NJCSO Group Compliance Monitoring Program Report"

Passaic Valley Sewage Commission, NJPDES Permit No. NJ0021016
Bayonne City Municipal Utilities Authority, NJPDES Permit No. NJ0109240
Borough of East Newark, NJPDES Permit No. NJ0117846
Town of Harrison, NJPDES Permit No. NJ0108871
Jersey City Municipal Utilities Authority, NJPDES Permit No. NJ0108723
Town of Kearny, NJPDES Permit No. NJ0111244
City of Newark, NJPDES Permit No. NJ0108758
North Bergen Municipal Utilities Authority, NJPDES Permit No. NJ0108898
City of Paterson, NJPDES Permit No. NJ0108880
Joint Meeting of Essex and Union, NJPDES Permit No. NJ0024741
Middlesex County Utilities Authority, NJPDES Permit No. NJ0020141
North Bergen MUA Woodcliff STP, NJPDES Permit No. No. NJ0029084
Town of Guttenberg, NJPDES Permit No. NJ0108715
North Hudson Sewage Authority – Adams Road STP, NJPDES Permit No. NJ0026085
North Hudson Sewage Authority - River Road STP, NJPDES Permit No. NJ0025321
Borough of Fort Lee, NJPDES Permit No. NJ0034517
City of Hackensack, NJPDES Permit No. NJ0108766
Ridgefield Park Village, NJPDES Permit No. NJ0109118
City of Elizabeth, NJPDES Permit No. NJ0108782
City of Perth Amboy, NJPDES Permit No. NJ0156132
Bergen County Utilities Authority, NJPDES Permit No. NJ0020028

Dear Permittees:

Thank you for your submission dated June 30, 2018 as submitted cooperatively by Passaic Valley Sewage Commission on behalf of the above referenced permittees. The Department acknowledges that the above referenced permittees have committed to submitting single, coordinated Long Term Control Plans for each of the respective hydraulically connected groups and this report represents all above permittees for the purposes of permit compliance. This letter serves to provide technical comments on your submission.

Regulatory Background

This Baseline Compliance Monitoring Program (BCMP) report was submitted in accordance with Part IV.D.3.d and Part IV.G.1.d.3 and 9 of your NJPDES CSO permit. This submission serves as a necessary element to the Long-Term Control Plan (LTCP) as due on June 1, 2020 for all the above referenced NJPDES permits. An excerpt of Part IV.G.9.a and Part IV.G.9.b is provided as follows to frame the review objectives of this letter:

9. Compliance Monitoring Program (CMP)

"a. The monitoring information collected from the ambient baseline monitoring phase of the CMP, in accordance with D.3.a., will be compared to subsequent CMP events during and after LTCP implementation to evaluate the effectiveness of implemented CSO controls.

b. The permittee shall implement a CMP adequate to: verify baseline and existing conditions, the effectiveness of CSO controls, compliance with water quality standards, and protection of designated uses. This CMP shall be conducted before, during and after implementation of the LTCP and shall include a work plan to be approved by the Department that details the monitoring protocols to be followed…"

The Department prepared technical guidance entitled "Receiving Waters Monitoring Work Plan Guidance for the CSO Program" (see https://www.state.nj.us/dep/dwq/pdf/cso-receiving-water-mon-work-plan-guid-03-2015.pdf). As required by Part IV.G.1.d.3 and 9.b above, a work plan was required and was submitted on December 30, 2015 (revised on February 19, 2016 and May 10, 2016) as entitled "Baseline Compliance Monitoring Program Quality Assurance Project Plan (QAPP)." This QAPP set forth the sampling locations, data quality criteria, field measurement parameters, sampling methods and other key QAPP elements. The QAPP was approved by the Department on February 24, 2016 with a subsequent approval on June 8, 2016 (for the May 10, 2016 revisions).

Summary of Report

The stated objective of the BCMP report is included on page 24:

> "This report and its attachments summarize the data that HDR has collected in support of PVSC's LTCP modeling under the Baseline Compliance Monitoring Program (BCMP). The BCMP was designed to generate sufficient data to establish existing ambient water quality conditions for pathogens in the CSO receiving waters and to update, calibrate and validate a pathogen water quality model of the receiving water bodies."

Similarly, the February 19, 2016 BCMP QAPP states on page 34:

> "The Baseline Compliance Monitoring Program is a one-year sampling effort to characterize ambient waters receiving CSO discharges from participating NJCSO Group members to the extent necessary to gain confidence in the receiving water modeling, i.e., successfully calibrating and validating the receiving water quality model, that will be used to establish attainment of relevant water quality standards. An additional objective of the program is to provide water quality data that will represent pre-LTCP conditions."

As described on page 24 of the BCMP report, the report summarizes three parallel data collection efforts:

"1) Baseline Sampling, which was modeled after and intended to supplement the approved routine sampling program of the New Jersey Harbor Discharges Group (NJHDG), of which PVSC is a member. The sampling frequency matched NJHDG, varying with time of year as follows:

   a. Spring (May-Jun): Biweekly (4 dates);
   b. Summer (Jul-Sep): Weekly (12 dates); and
   c. Winter (Oct-Apr): Monthly (7 dates).

2) Source Sampling, which targeted the major influent streams within the study area to establish non-CSO loadings, and coincide with the NJHDG and Baseline Sampling. Any discussion of field activities applicable to Baseline Sampling is also applicable to Source Sampling because both sets of stations were sampled during the same field efforts.

3) Event Sampling, which was timed to coincide with rainfall to capture three discrete wet weather events over the course of the year on each segment of the NY-NJ Harbor complex impacted by CSOs.

   …A total of 23 baseline and source sampling events were completed. The goal of the event sampling was to capture three significant wet-weather events (precipitation >0.5 inches in 24 hours) at each targeted location, which was completed across four sampling events (one set of samples was collected across two precipitation events because of sampling logistics). All samples collected were analyzed for fecal coliform and enterococcus; freshwater samples were also analyzed for E. coli."

As further described on page 32:

> "…In total, 1,439 samples out of a targeted 1,449 samples were collected during the 23 baseline surveys (99.4%), and a 100% success rate was attained during 19 of the 23 routine surveys…."

> "…In total, 792 of a targeted 810 samples were collected during the event sampling surveys…."

As stated on page 26:

> "The BCMP is modeled in part on the program performed by the New Jersey Harbor Dischargers Group. NJHDG is a similarly allied collaborative undertaking that has been collecting data since 2003."

A portion of Attachment 1 from the BCMP report is included as an attachment to this letter to depict the locations of baseline sampling, source sampling and event sampling for the affected study area.

<u>NJDEP Technical Review</u>

General Findings

A great deal of effort went into the data collection under the BCMP; nevertheless, sampling results must be interpreted with caution due to unforeseen conditions that impact both data quality and/or data representativeness of an average annual rainfall conditions. For example:

- **Weather Conditions:** Water quality samples were collected during a 377-day span (April 17, 2016 – April 28, 2017). During this period, rainfall totals and number of days exceeding the target threshold (precipitation > 0.5 inches) were well below normal conditions. Specifically, as shown on "Table 9. Precipitation Summary, April 17, 2016 – April 28, 2017" the rainfall total for this period was 41.89 inches as compared to the standardized three-decade average (1981-2010) of 47.89 inches. Therefore, data collected during the BCMP period is more representative of dry weather conditions rather than wet conditions, which is the more needed sampling condition.

- **Data with Qualifiers:** Given the enormousness of the monitoring effort, it is expected that some data points will have qualifiers associated with them. Such data are usually estimated values, not from direct measurements, or fail the quality control requirements and thus cannot be used in a regulatory setting and/or for conducting water quality assessment. Roughly half of the data collected during the event sampling surveys were estimates due to sample dilutions and/or failure to follow proper laboratory procedures. Specifically, event sampling surveys to obtain targeted wet-weather events for model calibration and validation were performed during a 4-day span; however, of the data collected, 54% of the enterococcus samples and 47% of the fecal samples were deemed to have qualifiers associated with them (see "Table 13. Counts for Qualified Data").

- **Preliminary Conclusions:** Any conclusions pertaining to water quality assessment should be omitted from the report as the data collected under the BCMP was not designed to provide sufficient data for assessing attainment of water quality standards. In fact, this concern was stated within the BCMP report on page 35:

> "The BCMP was not designed to provide an adequate data volume for assessing attainment of water quality standards, which would have required five samples per month at each sampling location to compute monthly geometric means. However, a review of the data collected can indicate the likelihood of attainment in a particular area…"

Despite the above referenced limitations, the BCMP effort did result in valuable data that can be used to populate the receiving water model; and, to provide a snapshot to characterize the water quality conditions in the NY/NJ Harbor Area to represent pre-LTCP conditions. While specific comments are included below regarding required revisions to the BCMP report, the Department finds that the data collection effort does provide sufficient information for the purposes of data characterization for "baseline and existing conditions." As referenced in Part IV.G.9 "this CMP shall be conducted before, during and after implementation of the LTCP." A key factor in this finding of acceptability of the BCMP is the ongoing data collection efforts of the NJHDG Monitoring Network which is performed under a Department approved QAPP. Data collected as part of the on-going NJHDG Monitoring Network, with additional stations as needed, can be used to supplement the BCMP data for future conditions. In fact, any subsequent approval of the BCMP report, pending the revisions described below, will be conditional on the continuation of this monitoring program.

Provided the permittee(s) chooses the Demonstration Approach, ultimate attainment of water quality standards can be evaluated through modeled results, in addition to NJHDG data, which may require multi-year simulations. The use of modeling is allowable as described on page 4-7 of EPA's January 1999 guidance entitled "Combined Sewer Overflows Guidance for Monitoring and Modeling" (EPA 832-B-99-002):

> "Models should be chosen to simulate the physical and hydraulic characteristics of the CSS and the receiving water body, characteristics of the pollutants of concern, and the time and distance scales necessary to evaluate attainment of WQS [Water Quality Standards]."

As stated in the Pathogen Water Quality Model (PWQM) Quality Assurance Project Plan (QAPP)" as dated May 19, 2016 (revised January 14, 2017):

> "The enhanced, validated model will be used to project bacteria concentrations in the waters of the NY/NJ Harbor complex under existing and anticipated future conditions to demonstrate attainment of applicable water quality standards."

In addition to the above *General Findings,* the Department's specific comments are as follows:

Specific Comments

Comment 1: On page 25 the second paragraph states:

> "The data itself is provided in two attachments and includes preliminary NJHDG data collected between March and December 2016 in addition to the data collected by HDR."

It is unclear why this excerpt specifies data only between March and December 2016? Why not all data during the BCMP sampling period namely April 2016 thru April 2017? Please clarify.

Comment 2: On page 28, Section 2.2, please clarify if the PVSC laboratory or other laboratories were used for any of the analyses for this sampling project or if analyses were exclusively performed by Eurofins QC analytical laboratories.

Comment 3: On page 31, "Table 10. Summary of Precipitation during Field Collection Days", it is stated that there were five (5) days of "wet weather" sampling events where the rainfall was greater than the target of 0.5 inches. However, on the next page under "Table 12. Baseline Compliance Monitoring Event Sampling Dates and Completeness" only four (4) sampling dates are specified namely 6/6/2016, 1/4/20017, 4/26/2017 and 1/24/2017. Also, on 1/4/2017, rainfall was below the target of 0.5 inches (0.36 inches). Please clarify.

Comment 4: On page 31, Footnote 1 for Table 12 states "Sampling locations split across two rain events due to sampling logistic limitations." Please specify the sampling locations sampled on each of the two days: 1/4/2017 and 4/26/2017.

Comment 5: On page 35, the first paragraph states:

> "The data collected under the Baseline Compliance Monitoring Program is sufficient for the intended goal of calibrating the water quality model to be used for PVSC and NJCSO communities' LTCPs."

Please insert this phrase at the beginning of this sentence: "A preliminary review indicates that…" This clarification is needed as it is premature to conclude that the collected data is sufficient for this purpose since the Department has not been provided with the necessary information for a complete review. Additionally, this contradicts the statement on page 25 which states "…a preliminary review indicates the data have met the goals of the QAPP and will be acceptable for its intended uses (baseline conditions assessment and model development)."

Comment 6: On page 131, the end of the second paragraph states:

> "Data collected during these events were meant to assess the trend of bacteria concentrations after a wet-weather event for the purposes of water quality modeling, and not to assess attainment of geometric mean standards".

The Department concurs with this statement but it contradicts other statements in the report that pertain to water quality assessment in the Harbor area and/or likelihood of attainment. Specifically, on page 35, please revise the fourth bullet by deleting the last sentence which begins with "However":

> "The BCMP was not designed to provide an adequate data volume for assessing attainment of water quality standards, which would have required five samples per month at each sampling location to compute monthly geometric means. However, a review of the data collected can indicate the likelihood of attainment in a particular area:"

Comment 7: Similar to **Comment 6**, please delete bullets 5 thru 8 (as specified below) as included on page 35 which state the following:

"• The lower regions of the Passaic and Hackensack Rivers appear likely to violate water quality criteria, but attainment appears to improve closer to Newark Bay.
- The larger waterbodies (Newark Bay, Hudson River, Arthur Kill, Kill Van Kull) appear to meet existing water quality criteria. Newark Bay and the Kills are primarily SE3 waterbodies, and Raritan Bay is subject to more stringent shellfishing water quality standards.
- Several smaller riverine waterbodies appear unlikely to meet attainment. This includes the Rahway River, Saddle River, Second River, and Elizabeth River. The Raritan River may also have attainment issues.

- Many rivers without CSOs have high bacteria loads. Data collected at source sampling locations indicate non-attainment of waters entering the Passaic and Hackensack Rivers, contributing pollutant loads into the study area from areas that do not have CSOs."

Comment 8: Regarding pages 57 and 131, please note that there are no approved shellfish designated uses in the Harbor area.

Comment 9: An electronic copy of the raw water quality data must be submitted in Excel or electronic tabular format in addition to the data provided in tabular format in the attachments.

Comment 10: Attachments 1, 2 and 3: Please indicate on the chart if any of the data with qualifiers was included in the information plotted on the chart.

Comment 11: Regarding "Attachment 3-Wet Weather Events", pathogen concentrations from the Event Sampling on April 26, 2017 appear, on average, to be lower than those samples concentrations sampled on the other three events. Please provide discussion to clarify.

Please incorporate these changes to the final report and submit a revised version to the Department no later than 30 days from the date of this letter.

Thank you for your continued cooperation.

Sincerely,

Susan Rosenwinkel

Susan Rosenwinkel
Acting Bureau Chief
Bureau of Surface Water Permitting

Attachment – Map from Attachment 1

C: Marzooq Alebus, Bureau of Surface Water Permitting
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NJCSO GROUP UPDATED TECHNICAL GUIDANCE MANUAL

January 2018

Passaic Valley Sewerage Commissioners

CSO Long Term Control Plan

Updated Technical Guidance Manual

January 2018

GREELEY AND HANSEN

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Section 1

Introduction

The combined sewer systems (CSS) in the State of New Jersey are owned by a mix of municipal governments and authorities that are responsible for the State's 210 permitted outfalls. These collection systems are serviced by nine publicly owned treatment works (POTW) wastewater treatment facilities. The New Jersey Department of Environmental Protection has issued NJPDES permits to each of the CSS owners and POTWs requiring that the nine hydraulically connected systems develop and submit a Long Term Control Plan (LTCP) for reducing the impact of combined sewer overflow (CSO) to their receiving waters.

The Passaic Valley Sewerage Commission (PVSC) is one of the nine permitted POTW facilities and is coordinating the LTCP for its eight combined sewer communities: Bayonne, East Newark, Harrison, Jersey City, Kearny, Newark, North Bergen, and Paterson. The North Bergen Municipal Utility Authority also operates one of the nine permitted POTW facilities with its Woodcliff Wastewater Treatment plant, which services parts of North Bergen and Guttenberg. While a separate LTCP will be developed for that system, PVSC and NBMUA have agreed that PVSC would coordinate that LTCP development process as well.

The LTCP development process requires that the permittees each evaluate a variety of CSO control alternatives and submit an Evaluation of Alternatives Report. Although the PVSC and NBMUA hydraulically connected communities will submit system-wide LTCPs, each permittee will be responsible for evaluating the alternatives within their community.

To assist in the communities in performing their alternatives evaluations, PVSC has updated this Technical Guidance Manual (TGM) that was originally developed in 2007.

1.1 Background

In 2004, the NJDEP issued a General Permit (GP) for combined sewer systems that, in part, required combined sewer system owners to initiate the CSO LTCP development process and undergo a Cost and Performance Analysis for Combined Sewer Overflow Point Operation. That analysis required the permittees to evaluate alternatives at each CSO point that would provide continuous disinfection prior to discharge. To assist their communities in performing the analysis, PVSC developed a Technical Guidance Manual that provides an overview of various screening, pretreatment, disinfection, and storage technologies along with guidance on costs. The original TGM was released in 2007.

The New Jersey Pollutant Discharge Elimination System (NJPDES) permits issued in 2015 require the permittees to continue the CSO LTCP development process and perform a complete CSO control alternatives evaluation that will lead to a selected alternative and eventual implementation. While much of the information in the original TGM is still viable, a decade has passed since it was developed. To assist their permittees with the current permit, PVSC has updated the TGM to reflect new information, updated costs, and new permit requirements such as the evaluation of green infrastructure.

1.2 Purpose of the Technical Guidance Manual

The Technical Guidance Manual is intended as a guidance document to assist the individual permittees in performing their LTCP alternatives evaluations. The information and costs provided throughout the document are for planning purposes only, and the individual permittees should verify all of the assumptions and information contained herein.

Section 2

Treatment Technology

Treatment technologies are intended to reduce the pollutant loads to receiving waters by treating wet weather flows prior to discharging to the environment. Specific technologies can address different pollutant constituents, such as settleable solids, floatables, or bacteria. To satisfy CSO treatment objectives, treatment technologies for each unit processes of screenings/ pretreatment/ disinfection alternatives have been evaluated, including the following:

- Screenings - mechanical bar screens, fine screens, band and belt screens, and drum screens.
- Pretreatment - vortex/swirl Separation (Storm King® Vortex Separator, HYDROVEX® Fluidsep Vortex Separator, and SANSEP Process), ballasted flocculation (ACTIFLO® Ballasted Flocculation Process and DensaDeg Ballasted Flocculation), and compressible media filtration (FlexFilter Process)
- Disinfection – chlorination, peracetic acid, ozonation, and, UV disinfection.

CSOs are intermittent in nature and are characterized by highly variable flow rates relative to base sewage flow. Bacterial and organic loadings from the collection system also vary greatly, both within and between storm events. The screenings/pretreatment/disinfection system must be able to handle variable pollutant loadings and large fluctuations in flow that can change drastically. Where treatment facilities are to be considered, provisions for the handling, treatment, and ultimate disposal of sludge and other treatment residuals shall also be included.

2.1 Treatment Technology Evaluation Criteria

In the evaluation of each treatment technology as included in subsequent sections, the following description outlines the process used to evaluate each technology:

1. **Description of Process**: includes a verbal and graphical description of the treatment process and pertinent components.
2. **Applicability**: evaluates the applicability of technology for CSO control. Equipment manufacturers/vendors have been contacted to gather information on installation list for CSO applications, technology evaluation and case study. If determined not applicable for CSO control, no further evaluation will be performed.
3. **Performance**: Each process has been evaluated on a preliminary basis for its performance under similar conditions to CSO, particularly where flow and loading rates varied significantly. Individual processes have a different ability to handle varying loading rates and still maintain a reasonably consistent removal rate, or disinfection rate. The inability to maintain a required level of performance over varying hydraulic loadings may eliminate the process, or require that limitations to its use be considered.

4. **Hydraulics**: The screenings/ pre-treatment/ disinfection alternatives will need to be physically located between the CSO control facility and the receiving waters. In many locations, there may be limited difference in elevation between the water surface level in the regulator and the receiving water level. This will be particularly true wherein the receiving water elevations are affected by tides. Head loss within an individual control process will vary from negligible to as much as 8 feet. The total head loss for a treatment train consisting of screenings, pre-treatment, and disinfection may be as much as 10 feet. For this reason, the evaluation will identify the need for intermediate pumping. Screw pumps, which are capable of efficiently handling large flows under low head conditions, can be utilized for this purpose.

5. **Generation of Waste Streams:** Most if not all screening and pretreatment processes produce waste streams that must be contained and disposed of; however, none of the disinfection processes produce appreciable waste streams. Waste streams for the screening processes consist of the storing and/or disposal of collected screening materials. For the pre-treatment process, the waste streams are more varied. The vortex units produce underflow containing the solids removed by the process, which can be as much as 10% of the design flow of the vortex unit. Ballasted flocculation units produce waste sludge as part of the process. In addition, there is a startup period (approximately 20 minutes) for the ballasted flocculation system during which time the process effluent is of poor quality, and filtration processes produce filter backwash water. When these processes are located at a WWTP or along an interceptor sewer with available capacity, the waste streams can be discharged and treated. However, in remote locations, such as those envisioned for CSO treatment facilities, there is typically no place to dispose of the waste stream. While the permittees that own and operate the CSO conveyance systems will be evaluating the feasibility of increasing wet weather flows to the WWTP, most interceptor sewers during wet weather events are currently at capacity or surcharged. As a result, ancillary tankage must be provided to store the volume of the waste stream produced until such time that it can either be introduced into the process, or discharged to the interceptor sewer for treatment at the WWTP. Where applicable, the need for ancillary tanks must be included in the evaluation of the process.

6. **Complexity**: This portion of the evaluation will identify the level of complexity of the process, whether it is capable of functioning unmanned in a remote setting, and the level of instrumentation that would be needed to operate the system during the overflow events.

7. **Limitations**: Different processes can have limitations on the hydraulic and pollutant loading conditions that it can operate within, which can include both lower and upper limits. Any such limitation must be considered when determining the configuration of unit sizes for that process as needed to handle the variable flow/pollutant loading conditions. Limitations for each process are discussed in subsequent sections and have been considered in development of the evaluation process.

8. **Construction Costs**: This portion of the evaluation will provide preliminary report level construction cost estimates, which includes budgetary equipment costs as provided by the manufacturer, installation costs, building costs, and contingency for design flow ranging from 10 MGD to 450 MGD.

9. **Operation and Maintenance Costs**: Information on the operation and routine maintenance requirements was obtained from each of the equipment manufacturers and included in this section. Annual operation costs have been prepared based on power requirements for operation of the equipment, the estimated cost of power, and the estimated annual hours of operation of the equipment. In addition, annual maintenance costs reflecting those recommended by the equipment manufacturer, as well as the manpower required for anticipated post-overflow event clean up and service has been included.

10. **Space Requirements**: Due to the proximity of the regulators to the receiving water body, in most cases it is unlikely that there will be sufficient existing open land available to construct the screenings/pre-treatment/disinfection facilities. Therefore, it will likely be necessary for the Permittee to purchase land. The evaluation of the respective process shall include an evaluation of the space needed for the process. This area is not limited to the process or tank area but includes a small buffer for roadways and access base.

In the process of preparing this TGM, technology users were contacted to gather information on their experience with using the technology for CSO treatment.

2.1.1 Bayonne Wet Weather Demonstration Project

The Bayonne Wet Weather Flow Treatment and Disinfection Demonstration Project (Bayonne MUA Pilot Study) was conducted over a two-year period at the Oak Street facility in Bayonne, NJ which receives the CSO from Bayonne City. The project was sponsored by the Bayonne Municipal Utilities Authority (BMUA), with grants and collaboration from New Jersey Department of Environmental Protection (NJDEP) and the United States Environmental Protection Agency (USEPA). The primary focus of the Bayonne MUA Pilot Study was to verify the performance of selected technologies to treat CSO discharges for solids removal and disinfection under field conditions as suitable for remote satellite locations.

The treatment technologies evaluated included high rate solids removal (i.e., vortex and plate settler units) and enhanced high rate solids treatment (i.e., a compressed media filter). Three types of disinfection units were also included, namely chemical disinfection (i.e., Peracetic acid, PAA), and ultraviolet (UV) disinfection (low and medium pressure units). The evaluation results of the pilot study are discussed in the corresponding sections of the TGM.

2.2 Screenings

Screening technologies can either represent minimal treatment of a CSO before disinfection or can be used to remove larger particles upstream of vortex/swirl separation, ballasted flocculation, or compressed media filtration before high rate disinfection processes. The screening technologies and their related clearances, reviewed for this Technical Guidance Manual, are as follows:

- Mechanical Bar Screens 0.25" to 2" (6-50 mm) bar spacing
- Fine Screens 0.125" to 0.5" (3-13 mm) bar spacing
- Band and Belt Screens 0.08" to 0.4" (2-10 mm) openings
- Drum screens 0.0004" (0.01 mm) openings

As indicated above, screening technology will remove large material or particles as small as 0.0004" from the waste stream. The choice of a particular screening technology is a function of the general purpose of the screen, and what additional treatment process or equipment lies downstream. Screens with smaller openings, such as belt and micro screens, typically require pretreatment with a mechanical bar screen to prevent damage from large objects. Screenings equipment which are not continuously cleaned, such as manually cleaned bar screens, were eliminated from this evaluation due to the potential for backup and surcharging of the collection system. In general, screening systems are very effective in removing floatable and visible solids, but do not remove a significant amount of TSS, fecal coliform, enterococci, BOD, COD, NH3, TKN, total phosphorous, and total nitrogen.

The following sections describe the types of screens and equipment, as well as its capability to remove the various pollutants of concern. At the end of the section a summary of performance, operation, and environmental impacts will be presented. Based upon this summary some of the screening technologies will be eliminated from further consideration.

2.2.1 Mechanical Bar Screens

Description of Equipment

The three most common types of mechanically cleaned bar screens are: (1) chain driven, (2) climber type rake, and (3) catenary. Chain driven mechanical raking systems consist of a series of bar rakes connected to chains on each side of the bar rack. During the cleaning cycle, the rakes travel continuously from the bottom to the top of the bar rack, removing material retained on the bars and discharging them at the top of the rack. A disadvantage of chain-driven systems is that the lower bearings and sprockets are submerged in the flow and are susceptible to blockage and damage from grit and other materials. Climber-type systems employ a single rake mechanism mounted on a gear driven rack and pinion system. The gear drive turns cog wheels that move along a pin rack mounted on each side of the bar rack. During the cleaning cycle, the rake mechanism travels up and down the bar rack to remove materials retained on the bars. Screenings are typically discharged from the bars at the top of the rack. This type of bar screen has no submerged bearings or sprockets and is less susceptible to blockages, damage and corrosion. Catenary systems also employ chain drive rake mechanisms, but all sprockets, bearings, and shafts are located above the flow level in the screen channel. This in turn reduces the potential for damage and corrosion and facilitates routine maintenance. During the cleaning cycle, the rakes travel continuously from the bottom to the top of the bar rack to remove materials retained on the bars. Screenings are typically discharged from the bars at the top of the rack. The cleaning rake is held against the bars by the weight of its chains, allowing the rake to be pulled over large objects that are lodged in the bars and that might otherwise jam the rake mechanism.

Bar screens will remove essentially 100% of all rigid objects of which the minimum dimension is more than the spacing between the bars. Removing screenings from CSOs essentially does not remove any dissolved solids, or nutrients such as TKN, total nitrogen and total phosphorous. Screenings removed from overflows can however contain some larger rigid materials that reflect a BOD loading. Solids, such as fecal material, can also be contained within screenings collected on the bar screen, however the velocity between the bars increases with increasing flow, thus this material can be broken up and pass through the bars. Therefore, it is difficult to quantify on a consistent basis any BOD loading, fecal coliform and enterococci count, and TSS concentrations removed by the screening technologies. Nevertheless, some removal estimates, as provided by the manufacturer, have been included within the analysis procedure for further consideration.

For the purposes of the Technical Guidance Manual, the mechanical bar screen evaluation is based on the use of Climber Screens® since these have been found to be more reliable and significantly lower in operation and maintenance requirements than others. Figure 2-1 shows photos of typical climber screens. The Technical Guidance Manual analysis is based on mechanical bar screens with a maximum velocity between the bars of 4.5 feet per second (fps) and a peak velocity of approach of 3.0 fps. These are the standard criteria for designing bar screens for use in wastewater treatment plants, where flow is continuous and the diurnal patterns more predictable. Since CSOs are intermittent, with widely varying flow rates, these standards are more likely to be violated for short periods of time. The mechanical bar screen selections are also based upon an anticipated head loss of less than one foot, a peak flow level of six feet under peak flow conditions, with an operating floor located twelve feet above the water surface. For CSO applications where heavy debris loadings are likely, the minimum bar spacing should be approximately 1 inch.

Figure 2-1 - Photos of Typical Climber Screens

(Source: Infilco Degremont, Inc.)

Applicability to The Project

Mechanical bar screens have proven to be a relatively simple and inexpensive means of removing floatables and visible solids. They are typically the screen of choice in treatment facilities, and are used at a many CSO treatment facilities. There have been hundreds of Climber Screens® installed in CSO applications across the US. A list is provided in Appendix A focused on Type IIS and IIIAS installations in NJ, NY, and PA since 2000.

Performance Under Similar Conditions

As stated above, mechanical bar screens are already installed in many CSO facilities and operate successfully to remove floatables and visible solids over the fluctuations in flow rates seen in CSOs. Slight removal of TSS, total phosphorous, and total nitrogen (typically 5%, 3%, and 2%, respectively) can be achieved with the solids removal.

Hydraulics

Hydraulic losses through bar screens are a function of approach velocity, and the velocity through the bars. The head loss across the bar screen increases as the bar screen becomes clogged, or blinded. Instrumentation provided with mechanically cleaned screens is typically configured to send a signal to the cleaning mechanism so the head loss across the screen is limited to 6 inches.

Generation of Waste Streams

As screenings are removed from the CSO flows they generate a waste stream for disposal. Studies have found that the average CSO screenings loads vary from approximately 0.5 to 11 cubic feet per million gallons, with peaking factors based upon hourly flows ranging from 2:1 to greater than 20:1. These screenings must be either transferred to the interceptor sewer for ultimate disposal at the WWTP, or removed and stored in a container for onsite removal at a convenient time. The collection of screenings can be performed using conveyors, screenings compactors, or pumps. Any enclosure around the screenings equipment should provide space for a container and odor control.

Complexity

Mechanical bar screens are able to function intermittently, at remote locations with a minimum level of instrumentation. A level detector is needed to determine when a CSO is occurring and to activate the screen. Differential head sensors located upstream and downstream of the screen will detect head loss and initiate a cleaning cycle. During periods where there are no overflows, a timer can be utilized to periodically exercise the screen, so it is ready for use.

Limitations

When mechanical bar screens are installed in a WWTP, the flows vary within an anticipated range which is predetermined so the screens can be sized for the necessary peak flows, and redundant units can be provided. In CSO installations there are wide variations in flow rates that can pass through the screens, but the high flow rates are usually of short duration. Due to the intermittent nature of CSOs, it is not considered cost effective, nor necessary to provide redundancy. Nevertheless, providing multiple units in separate channels is a means of handling equipment out of service. The quickness with which CSO flows can increase however can lead to problems in getting units in other channels into operation quickly enough given the operating speeds of motor operated sluice gates. A review of the pollutant removal rates as reported by the manufacturer indicates that only about 5% of the TSS is removed by the screen. While screening of solids may be adequate for the lower treatment objects (50%, 85%, and 95% removals) where TSS levels are not as critical, the literature does not indicate that screening alone will remove adequate solids to provide for consistent and reliable disinfection at higher treatment objectives.

Construction Costs

Table 2-1 presents the preliminary planning level construction cost estimates of Climber Screens® for design flows ranging from 10 MGD to approximately 450 MGD. It includes equipment cost, installation cost, general contractor (GC) field general conditions, GC overhead & profit (OH&P), and contingency. This cost estimates assume that the Climber Screens® will be installed in existing CSO channels. If the existing CSO channel does not provide adequate channel width to maintain velocities below 3 fps, a new or modified chamber will be required at an additional cost. The installation cost is assumed at 50% of the equipment cost based on the complexity of the installation. Budgetary equipment pricing information for Climber Screens® was gathered from equipment manufacturer Suez, formerly Infilco Degremont, Inc. The estimated total construction costs for the Climber Screens® are plotted against flowrates from 10 MGD to approximately 450 MGD in Figure 2-2.

Climber Screens® pricing is primarily determined by channel size which is dictated by the flow and plant specific parameters or design. Therefore, the Type IIS is suitable for channels up to 7'-0" wide. Pricing provided by the manufacturer is based on assumed channel dimensions of 5'-0" wide by 10'-6" deep. A single unit of this model of Climber Screen® would be suitable for up to 50 MGD or larger depending on channel dimensions. The Type IIIAS is suitable-for channels 6'-6" to 12'-0" wide. The pricing provided by the manufacturer is accurate up to the 8'-0" wide and 10'-6" deep dimensions. For the large 450MGD flow, multiple units each designed for a peak flow of 112 MGD are recommended. Capacity can be adjusted based on channel dimensions, bar rack clear spacing, and number of units desired.

Operation and Maintenance

Costs associated with operation include the electrical cost for operating the motor(s) on the mechanical bar screens. Regular maintenance requires visits to the site after each storm to inspect the screens for damage, remove any large material in the channels, clean up any screenings on the floor or equipment, and general wash down of the area. Regular maintenance also includes routine lubrication and maintenance of the tracks, racks, drives, and gear boxes. It is important to keep the pin racks and carriage bearings greased and oiled. It is also important to inspect the bearings for excessive wear. The Type IIS and IIIAS carriage assemblies utilize self-greasing/oiling canisters which are easily replaced at the recommended intervals. The follower shaft bearings and carriage drive bearings are replaced utilizing access points built into the side frames (i.e. carriage does not need to be removed). It is recommended to perform periodic visual inspections to ensure proper operation, lubrication and bearing wear.

Estimated annual operation costs for the Climber Screen® are presented on Table 2-2 containing factors for calculation of operating costs; while estimated annual maintenance labor cost including cost factors are included on Table 2-3.

Space Requirements

The space required for mechanical bar screens consists of the building and area on the exterior of the building for access to remove the screenings container.

Case Study

New York City utilized TypeIIIAS Climber Screens® at their Manhattan and Bronx Grit Chambers from 1986 until 2016. These chambers deliver combined sewage to the Wards Island WWTP, which has a total plant flow of approximately 500 MGD. After the first 6 years of using the Climber Screens®, the shaft bearings were beyond their useable life. Although initially designed for 5HP per motor based on the average weight of debris, it was later found that 7.5 HP was required to handle the harsher conditions imposed by the combined sewage.

Table 2-1 - Preliminary Construction Cost Estimates for Climber Screens

Flow Range	System	Width x Depth	Budgetary Equipment Price	Install Cost(1)	GC General Conditions (2)	GC OH&P(3)	Contingency(4)	Total
10 MGD to 50 MGD	(1) Type IIS	5'-0" x 10'-6"	$305,000	$152,500	$45,750	$45,750	$274,500	$823,500
50 MGD to 112 MGD	(1) Type IIIAS	8'-0" x 10'-6"	$465,000	$232,500	$69,750	$69,750	$418,500	$1,255,500
112 MGD to 224 MGD	(2) Type IIIAS	8'-0" x 10'-6"	$465,000	$232,500	$69,750	$69,750	$418,500	$1,255,500
224 MGD to 336 MGD	(3) Type IIIAS	8'-0" x 10'-6"	$1,900,000	$950,000	$285,000	$285,000	$1,710,000	$5,130,000
336 MGD to 448 MGD	(4) Type IIIAS	8'-0" x 10'-6"	$1,900,000	$950,000	$285,000	$285,000	$1,710,000	$5,130,000

Notes:
(1) Installation cost is assumed at 50% of the equipment cost.
(2) GC general conditions are estimated at 10% of the total direct cost.
(3) GC OH&P are estimated at 10% of the total direct cost.
(4) 50% of Contingency is used for the planning level of cost estimates.

Figure 2-2 - Total Estimated Construction Cost of Climber Screens

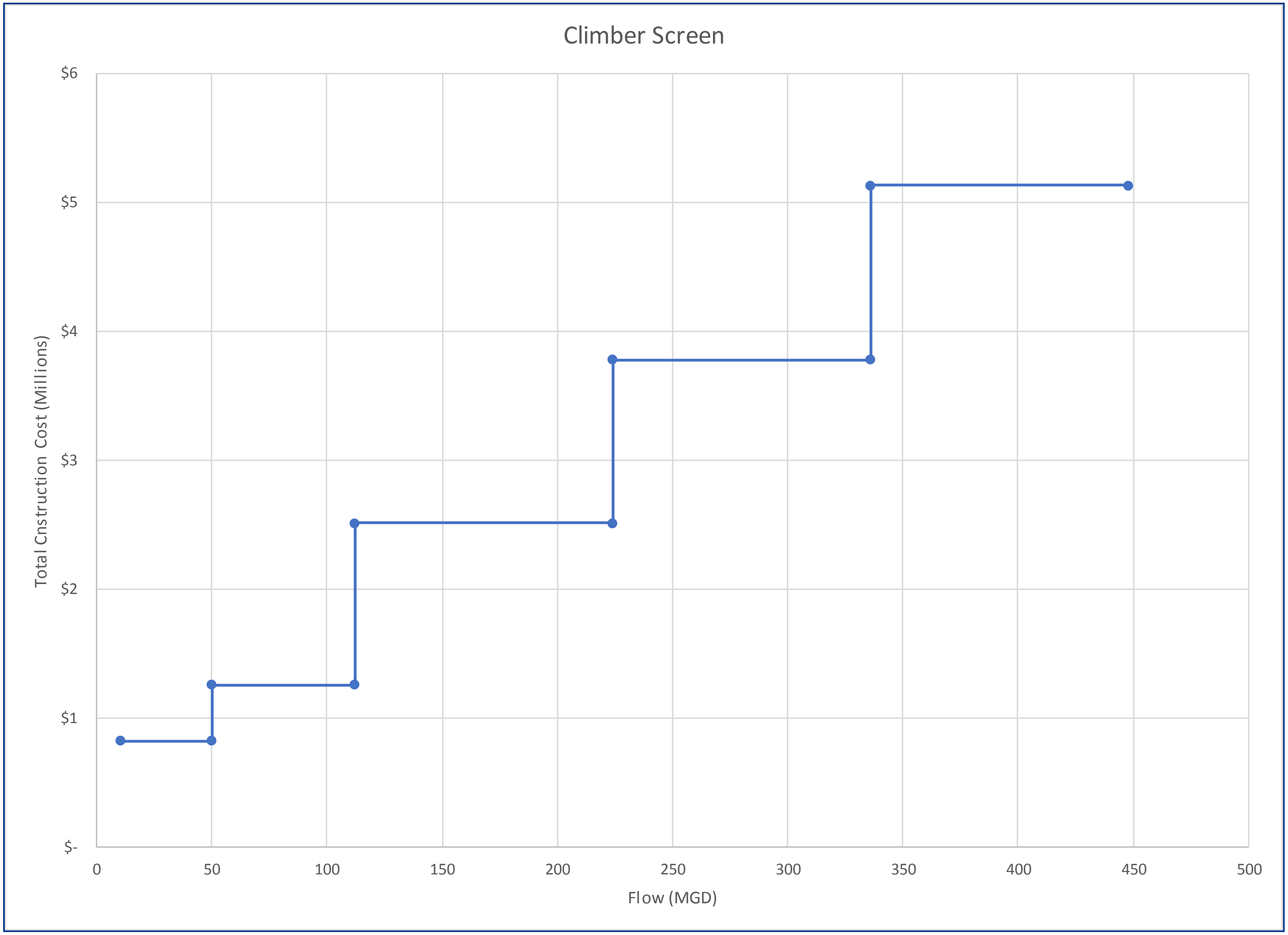


Table 2-2 - Annual Operation Costs of Climber Screens

Flow Range	System	Total Horsepower (HP)	Total Power (kW)(1)	Annual Energy Usage (kW-hr)(2)	Annual Cost(3)
10 MGD to 50 MGD	(1) Type IIS	3	2	1,119	$157
50 MGD to 112 MGD	(1) Type IIIAS	5	4	1,864	$261
112 MGD to 224 MGD	(2) Type IIIAS	10	7	3,729	$522
224 MGD to 336 MGD	(3) Type IIIAS	15	11	5,593	$783
336 MGD to 448 MGD	(4) Type IIIAS	20	15	7,457	$1,044

Notes:
(1) HP x 0.7457
(2) Assumes 500 hours of annual operation
(3) Assumes energy costs of $0.14/kW-hr

Table 2-3 - Annual Maintenance Labor Costs of Climber Screens

Maintenance Frequency	Parts	Description	Estimated Man-Hours	Annual Cost(1)(2)
Monthly	Cam Tracks and Pin Racks	Grease and inspection	0.5	$900
Bi-annually	Automatic Lubricators	Grease	0.5	$150
Annually	Automatic Lubricators	Oil	0.5	$75
2-3 years	Carriage Drive Shaft Bearing	Replace	1	$75
3-5 years	Follower Shaft Bearing	Inspect - replace as necessary	2	$100
5 years	Gear Box	Change fluid	2	$60
After Each CSO Event	Screens	Inspection and cleanup	2	$30,000
Total Annual Maintenance Labor Cost				$31,360

Notes:
(1) Assumes 100 events per year
(2) Assumes labor rate of $150/hour

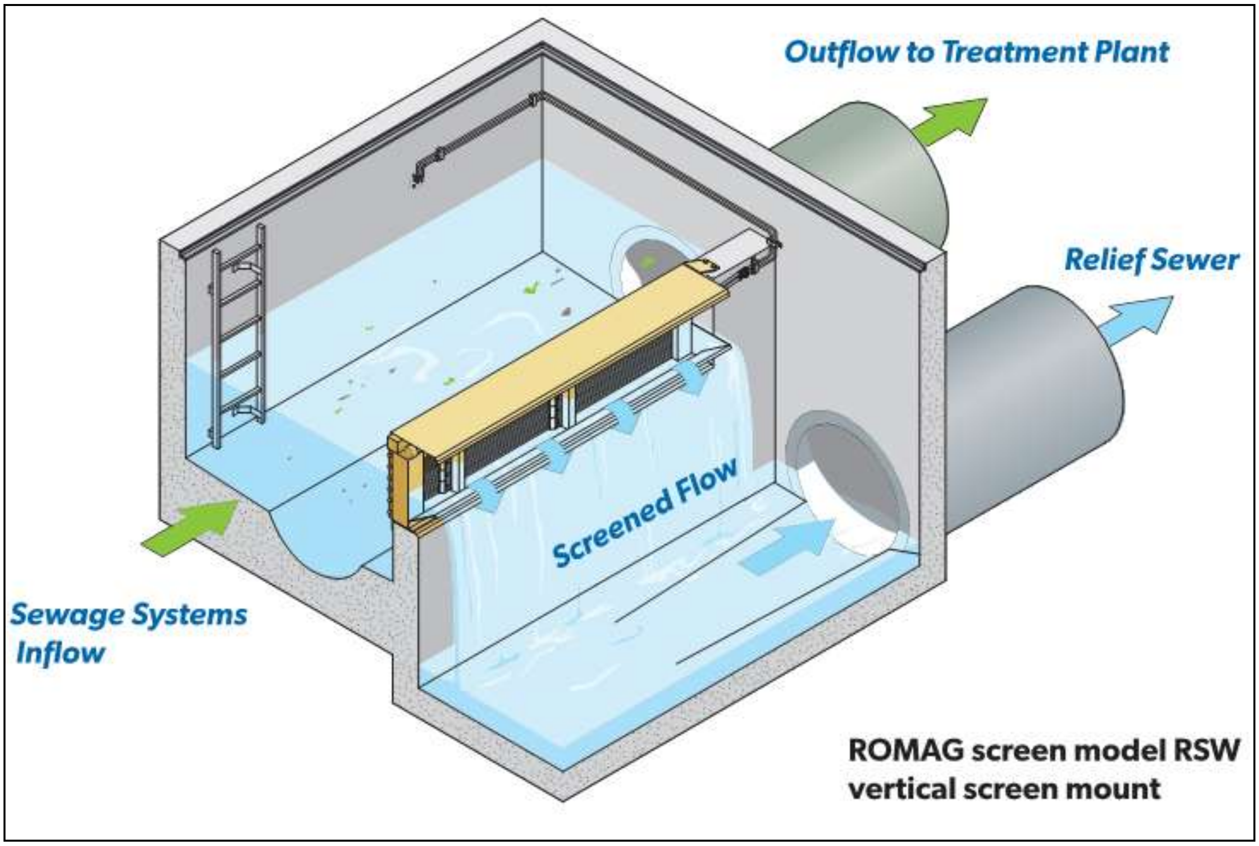
2.2.2 Fine Screens

Description of Process

These screens have openings ranging from 1/8" to 1/2", and will capture suspended and floatable material with smaller dimensions. The equipment evaluated under this category of screenings technology includes ROMAG™ Screens as manufactured by WesTech Engineering, Inc.

The ROMAG™ Screens consist of parallel bars similar to a bar screen, with spacing varying from 0.16" to 0.47". The screens are cleaned by combs, which extend through the rack and are attached to a hydraulically driven mechanism on the downstream side of the screen. The hydraulic unit is located above grade in an enclosure. The material collected on the upstream side of the screen is cleaned off the face of the screen by the combs and kept in the flow in the interceptor. They are not removed or collected, but continue toward the wastewater treatment plant for removal. As the flow increases beyond the capacity of the screens, the upstream water surface rises and overflows a baffle that is part of the screen assembly, discharging directly to the outfall. All the fine screens of this category are located such that the solids are retained on one side of the screen and transported to the interceptor or other facility for ultimate disposal. **Figure 2-3** shows the cross section of vertical mount ROMAG™ Screens.

Figure 2-3 - Cross Section of ROMAG Screens



(Source: WesTech Engineering, Inc.)

Applicability to the Project

Fine screens have proven to be a relatively simple and inexpensive means of removing floatables and visible solids where the overflow is controlled by a weir. They are typically constructed in the regulator, sometimes requiring modifications to the regulator, such as moving the weirs, and extending the weir lengths. The required screening capabilities for the maximum flow rate would need to be provided, since flows exceeding the capacities of the screens will continue to overflow unscreened. See Appendix B for a list of installation of ROMAG™ Screens for CSO application.

Performance Under Similar Conditions

As stated above, fine screens are typically installed in CSO regulators and operate successfully to remove floatables and visible solids over the fluctuations in flow rates seen in CSOs. Slight removal of TSS, total phosphorous, and total nitrogen (typically 10%, 8%, and 5%, respectively) can be achieved with the solids removal.

Hydraulics

The typical head loss reported through the unit is 4 inches, while additional freeboard from the maximum flow through the screens to the baffle height is typically 2 inches. The total head loss through the screen is typically about 6 inches at the design flow.

Flows exceeding the capacity of the screens would overflow the baffle and by-pass the screen. Usually additional weir length is needed so that the existing upstream water surface elevations are maintained after the screen is installed

Generation of Waste Streams

Fine screens are located in the regulator with flow passing up and through the screen, overflowing the weir and going out the outfall. Since the flow direction is up through the screen, the screened material is kept on the interceptor side of the screen, and remains in the interceptor when the cleaning mechanism cleans the face of the screen. Since the screenings remain in the interceptor, there is no collection at the screen and therefore no waste stream. Nevertheless, the limitation is that there be adequate flow and solids transport within the interceptor sewer system. The additional screening material that remains in the interceptor will find its way to any downstream regulators, and eventually to the WWTP.

Complexity

Fine screens can function intermittently, at remote locations with the minimum of instrumentation. A level detector is needed to determine when a CSO is occurring and to activate the screen. Differential head sensors located upstream and downstream of the screen will detect head loss and initiate a cleaning cycle. During periods where there are no overflows, a timer can be utilized to periodically exercise the screen, so it is ready for use.

Limitations

Fine screens would need to be installed on regulators with side overflow weirs. Other types of regulators would require the construction of a weir, at which point the use of a mechanical bar screen may be preferable. Also, any regulators where the fine screens would be installed would need to be accessible for routine inspection and maintenance of the screens. A review of the pollutant removal rates as reported by the manufacturer indicates that only about 10% of the TSS is removed by the screen. While screening of solids may be adequate for the lower treatment objectives (50%, 85%, and 95% removals) where TSS levels are not as critical, the literature does not indicate that screening alone will remove adequate solids to provide for consistent and reliable disinfection at higher treatment objectives. The higher TSS removal rates of fine screens versus mechanical bar screens (10% vs 5% respectively) may result in TSS levels acceptable for disinfection at lower treatment objectives.

Construction Costs

The preliminary planning level construction cost estimates are provided in Table 2-4 for ROMAG™ Screens of design flow ranging from 10 MGD to 450 MGD. It includes equipment cost, installation costs, GC field general conditions, GC OH&P, and contingency. This cost estimates assume that the ROMAG™ Screens will be installed in existing regulators. The costs for modifying a side overflow regulator to accommodate the installation of the screen is included in the installation cost. If the existing regulator cannot be modified to accommodate the ROMAG Screen and side overflow, a new and larger regulating chamber will be required at an additional cost. The installation cost is assumed at 50% of the equipment cost based on the complexity of the installation. Budgetary equipment pricing information for ROMAG™ Screen was gathered from equipment manufacturer WesTech Engineering, Inc. Based on vendor provided information, the largest individual screen can potentially handle up to 100 MGD, and in the case of higher demand multiple screens would be applied side by side. Velocities should be restricted to 5 ft/s. The equipment cost includes the controls, hydraulic power pack and everything needed to operate.

The estimated total construction costs for the ROMAG™ Screens are plotted against flowrate from 10 MGD to 450 MGD in

Figure 2-4.

Operation and Maintenance Costs

The operating costs include the electrical cost for operating the hydraulic power pack and an in-tank (hydraulic fluid) heater (700W-120V). The hydraulic pack operates the cleaning comb action across the screen. Each single ROMAG™ Screen has a hydraulic power pack that consists of a 5HP motor to drive the hydraulic pump. An 1HP in-tank heater for each screen is used to keep the hydraulic fluid at right temperature. Routine maintenance of the ROMAG™ Screens includes visits to the site after each storm to inspect the screens for damage, remove any large material in the channels, and cleanup of any screenings on the floor or equipment, and general wash-down of the area. Routine maintenance also includes the monthly maintenance of the screen such as replacing combs, repairing leaks in the hydraulic lines, maintaining the oil level in the hydraulic drive, and cleaning any level sensors, etc.

Estimated annual operation costs for the ROMAGTM Screens are presented on Table 2-5 containing factors for calculation of operating costs; while estimated annual maintenance labor cost including cost factors are included on Table 2-6.

Table 2-6Space Requirements

Since the fine screens would be installed in the regulators, which would probably be located in the street or existing easement, it is anticipated that there would be no additional space requirements for the fine screens.

Case Studies

Chattanooga, Tennessee utilizes ROMAG™ Screens at their downtown CSO treatment facility. Two RSW 8x7 screens were installed in 2000 and are still in use treating approximately 180 MGD. The maintenance of the screens was reported as minimum, and the automatic cleaning function had been working well with the exception of one instance where the screens became stuck.

The City of Binghamton, NY, has been using CSO screens for floatable control at four CSO locations since 2003. According to conversations with the site supervisor, the screens have been trouble-free. Both sides of the screens can be observed without entering the channel, and weekly inspection takes approximately 5 minutes. Typically, operators hose down the screens to remove residual debris after a storm event. Binghamton operators check the tension of the bars annually, and change hydraulic oil and filters per the Operations and Maintenance manual. No parts have required replacement to date.

Chattanooga, Tennessee utilizes ROMAG™ Screens at their downtown CSO treatment facility. Two RSW 8x7 screens were installed in 2000 and are still in use treating approximately 180 MGD. The maintenance of the screens was reported as minimum, and the automatic cleaning function had been working well with the exception of one instance where the screens became stuck.

Table 2-4 - Preliminary Construction Cost Estimates for ROMAG Screens

Flow	System	Length x Depth	Budgetary Equipment Price	Install Cost[1]	GC General Conditions[2]	GC OH&P[3]	Contingency[4]	Total
10 MGD	(1) Model RSW 4x3/4	9'-10" x 1'-9"	$252,000	$126,000	$37,800	$37,800	$226,800	$680,400
25 MGD	(1) Model RSW 7x4/4	13'-2" x 2'-8"	$305,000	$152,500	$45,750	$45,750	$274,500	$823,500
50 MGD	(1) Model RSW 12x4/4	13'-2" x 4'-3"	$393,000	$196,500	$58,950	$58,950	$353,700	$1,061,100
75 MGD	(1) Model RSW 14x5/4	16'-5" x 4'-11"	$450,000	$225,000	$67,500	$67,500	$405,000	$1,215,000
100 MGD	(1) Model RSW 14x6/4	19'-8" x 5'-1"	$475,000	$237,500	$71,250	$71,250	$427,500	$1,282,500
450 MGD	(6) Model RSW 14x5/4	98'-5" x 4'-11"	$2,700,000	$1,350,000	$405,000	$405,000	$2,430,000	$7,290,000

Notes:

Note:
(1) Installation cost is assumed at 50% of the equipment cost.
(2) GC general conditions are estimated at 10% of the total direct cost.
(3) GC OH&P are estimated at 10% of the total direct cost.
(4) 50% of Contingency is used for the planning level of cost estimates.

Figure 2-4 - Total Estimated Construction Cost of ROMAG Screens

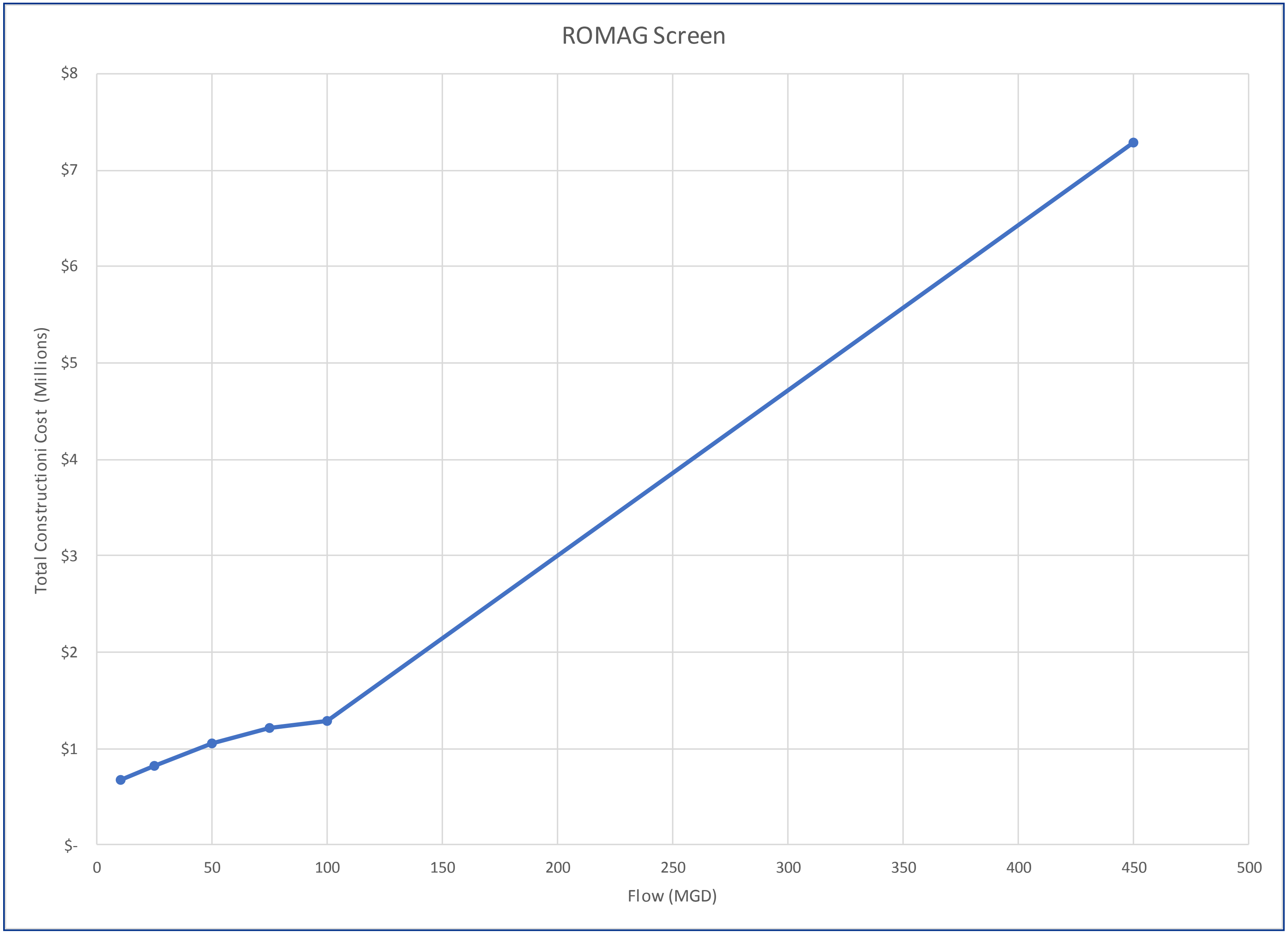


Table 2-5 - Annual Operation Costs of ROMAG Screens

Flow	System	Total Horsepower (HP)	Total Power (kW)[(1)]	Annual Energy Usage (kW-hr)[(2)]	Annual Cost[(3)]
10 MGD	(1) Model RSW 4x3/4	6	4	2,237	$313
25 MGD	(1) Model RSW 7x4/4	6	4	2,237	$313
50 MGD	(1) Model RSW 12x4/4	6	4	2,237	$313
75 MGD	(1) Model RSW 14x5/4	6	4	2,237	$313
100 MGD	(1) Model RSW 14x6/4	6	4	2,237	$313
450 MGD	(6) Model RSW 14x5/4	30	22	11,186	$1,566

Notes:
(1) HP x 0.7457
(2) Assumes 500 hours of annual operation
(3) Assumes energy costs of $0.14/kW-hr

Table 2-6 - Annual Maintenance Labor Costs of ROMAG Screens

Maintenance Frequency	Parts	Description	Estimated Man-Hours	Annual Cost$^{(1)(2)}$
Every 100 Operational Hours	Fasteners	Check for tightness	0.5	$375
Monthly	Screen bars	Check for clogging	0.5	$900
Monthly	Cleaning carriage	Check for proper operation	0.25	$450
Monthly	Piston rod locking nut	Check for tightness	0.25	$450
Monthly	Power pack oil level	Check for proper level and Check lines and piston rod for major fluid loss	0.5	$900
Monthly	Oil filter	Replace filter if necessary	0.25	$450
Annually	Screen Bars	Confirm tension with torque wrench	0.5	$75
Annually	Oil Temperature Probe	Check for proper operation and send sample to oil supplier; replace if required	0.5	$75
Annually	Motor	Lubricate	0.5	$75
After Each CSO Event	General Visual Inspection	Check for proper operation	1	$15,000
Total Annual Maintenance Cost				$18,750

Notes:
(1) Assumes 100 events per year
(2) Assumes labor rate of $150/hour

2.2.3 Band and Belt Screens

Description of Process

The common characteristic of these screens is that they contain stainless steel perforated elements forming a continuous band traveling either parallel or perpendicular to the flow stream. In the case where the band is parallel to the channel, flow enters the center of the screen, turns 90 degrees and passes through the sieve elements, exiting through the sides of the unit. Where the band is perpendicular to the channel flow passes through the screen, with the screened flow continuing down the channel.

Figure 2-5 shows a photo of Finescreen Monster, manufactured by JWC Environmental. These screens utilize either stainless steel, or UHMW sheets with perforations between 0.08" to 0.4" mm in diameter.

Figure 2-5 - Photo of Finescreen Monster

(Source: JWC Environmental)

Applicability for the Project

These screens are typically used for polishing wastewater treatment flows. Their perforated panels are very prone to clogging from fibrous materials and are not easily cleaned. To protect these screens from larger objects that could damage or clog them, the manufacturers recommend installing ¾ inch screens upstream of them. However, that ¾ inch screen upstream of the belt and band screen would have the same pollutant removal efficiency and thus the belt and band screen would be ineffective. Accordingly, it does not appear to be practical to utilize these types of screens in a CSO application. There currently are no known installations on CSO discharges.

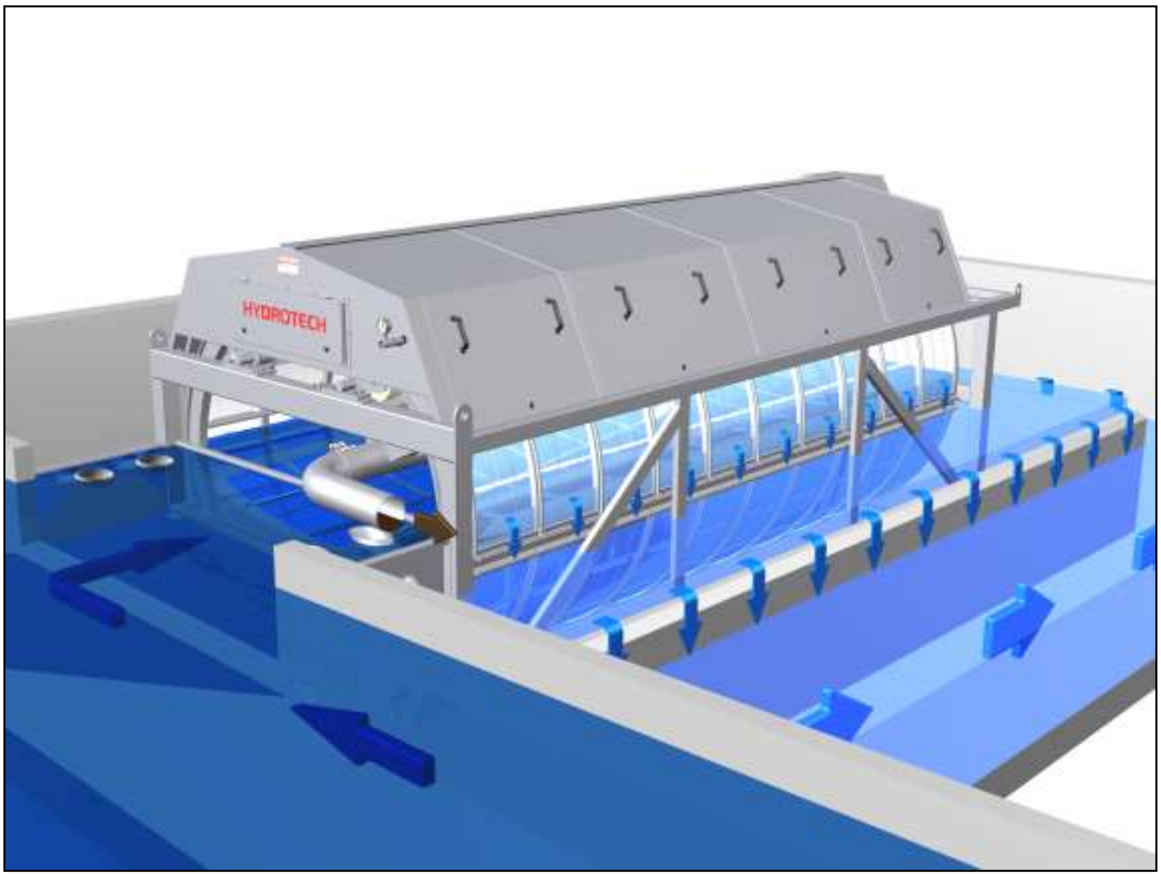
These screens are not considered applicable for CSO treatment and not further evaluated.

2.2.4 Drum Screens

Description of Process

A drum screen is a fine filter with openings from 10 to 1000 microns. The filter cloth is made of acid proof steel or polyester. Three, four, or five filter elements are placed in sections over a rotating drum, depending upon the drum diameter. The drum rotates in a tank. The liquid is filtered through the periphery of the slowly rotating drum. Assisted by the filter elements special cell structure, the particles are carefully separated from the liquid. Separated solids are rinsed off the filter cloth into the solids collection tray and discharged. The operation of the drum can be continuous or automatically controlled. The unit evaluated for this application was the HydroTech Drumfilter by Veolia Water Technologies. Figure 2-6 shows a cross section HydroTech Drumfilter.

Figure 2-6 - Cross Section of HydroTech Drumfilter



(Source: Veolia Water Technologies)

Applicability for the Project

Drum filters are currently used as a polishing unit at WWTPs. The disc media is polyethylene and the size openings are 10 microns for wastewater. The hydraulic loading for drum filters is 50 to 100 gpm/ft^2, based upon an influent TSS concentration of 20 mg/L. The manufacturer expects an influent TSS concentration of 10 to 100 mg/L upstream of the unit. Accordingly, significant TSS removal equipment would be needed upstream of the screen. There currently are no known installations on CSO discharges.

These screens are not considered applicable for CSO treatment and not further evaluated.

2.2.5 Evaluation of Screening Technology

The above sections evaluated each of the screening processes considered for pretreatment of CSO flow relative to criteria on cost, performance, limitations, and ancillary facilities. Each process was rated from 1 to 5, with 5 being the most effective, for approximately twenty different items and totaled. While somewhat subjective, this method does provide a mechanism for comparing each screening unit in relationship to each category and subcategory. The results of the evaluation are illustrated on Table 2-7.

Based upon the evaluation results in Table 2-7, fine screens received the highest results followed by mechanical bar screens, band and belt screens, and drum screen. requirements, which is reflected in their rating. Fine screens and mechanical bar screens should be considered as part of this TGM. Drum screens and band and belt screens were not considered applicable, and did not undergo further consideration.

Table 2-7 - Evaluation of Screening Technology

Criteria	Mechanical Bar Screens	Fine Screens	Band and Belt Screens	Drum Screens
Applicability	5	5	1	1
Performance				
TSS	1	3	4	4
Solids and Floatables	1	2	4	4
Hydraulics	4	4	1	1
Waste streams	3	5	1	1
Complexity	5	5	1	1
Limitations	2	2	1	1
Construction Cost	4	2	1	1
Operations	4	4	1	1
Maintenance	4	3	1	1
Space Requirements	3	2	1	1
Total	31	32	16	16

2.3 Pretreatment Technology

Pretreatment technology is used to remove floatable and total suspended solids (TSS) prior to high rate disinfection in CSO applications. The pretreatment technology evaluated for the TGM includes vortex/swirl separation technology, ballasted flocculation, and compressed media filtration.

The choice of a pretreatment technology is a function of construction costs, space requirements, and type of disinfection treatment process downstream. In general, pretreatment is very effective in removing floatable and TSS. It can also remove certain amount of fecal coliform, enterococci, BOD, COD, NH3, TKN, total phosphorous, and total nitrogen, which is attached to the TSS.

The following sections describe the types of pretreatment technology, as well as its capability to remove the various pollutants of concern. At the end of the section a summary of performance, operation, and environmental impacts will be presented.

2.3.1 Vortex/Swirl Separation Technology

Vortex/swirl separation technology utilizes naturally occurring forces to remove solids and floatable material. Flow enters a circular tank tangentially causing the contents to rotate slowly about the vertical axis. The flow spirals down the perimeter allowing the solids to settle out. This process is aided by rotary forces, shear forces, and drag forces at the boundary layer on the wall and base of the vessel. The internal components direct the main flow away from the perimeter and back up the middle of the vessel as a broad spiraling column, rotating at a slower velocity than the outer downward flow. Per manufacturer claims, by the time the flow reaches the top of the vessel it is virtually free of settleable solids and is discharged to the outlet channel. The collected solids are then discharged by gravity or pumped out from the base of the unit to the interceptor sewer or auxiliary storage tank if interceptor capacity is not available.

Conventional vortex separators such as Storm King®, manufactured by Hydro International, and the HYDROVEX® FluidSep manufactured by John Meunier were reviewed for this Technical Guidance Manual. A variation of the typical vortex/swirl separation process - the SanSep equipment from PWTech is evaluated as well.

The following provides a discussion of each of the above referenced unit processes, as well as its reported capability to remove the various pollutants of concern. A summary of performance, operation, and limitations or constraints, is provided at the end of this section.

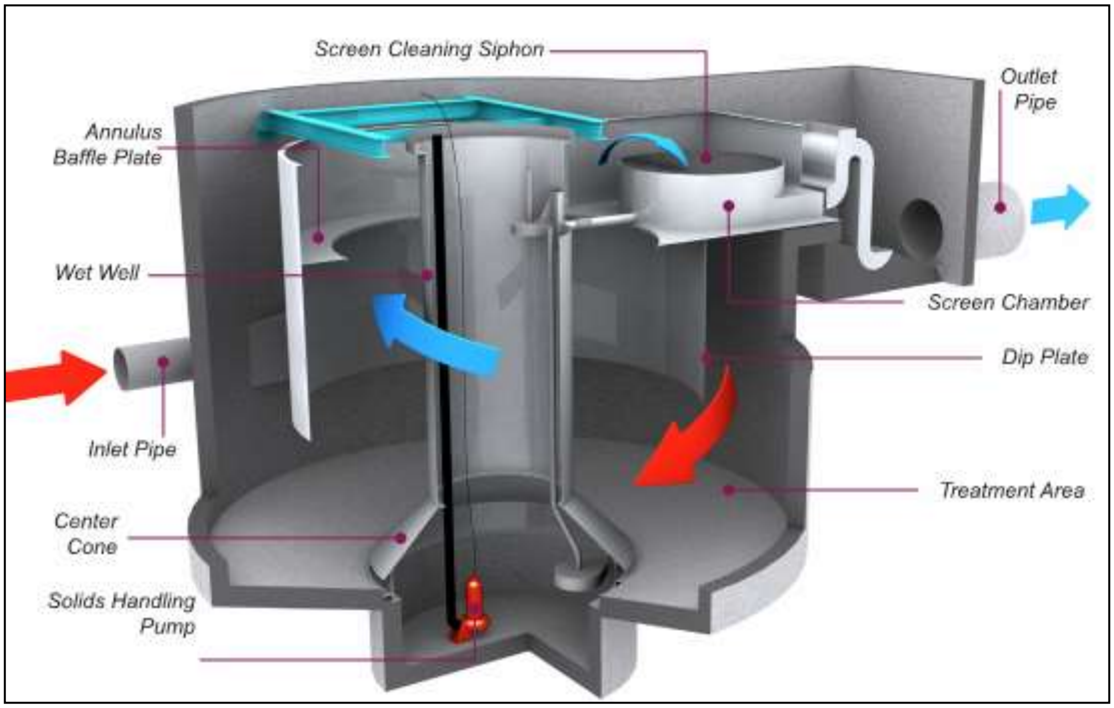
2.3.1.1 Storm King® Vortex Separator

Description of Process

Flow is introduced tangentially into the side of the Storm King®, causing the contents to rotate slowly about the vertical axis. The flow spirals down the perimeter allowing the solids to settle out. This process is aided by rotary forces, shear forces, and drag forces at the boundary layer on the wall and base of the vessel. The internal component directs the main flow away from the perimeter and back up the middle of the vessel as a broad spiraling column, rotating at a slower velocity than the outer downward flow. A dip plate locates the shear zone, the interface between the outer downward circulation and the inner upward circulation, where a marked difference in velocity encourages further solids separation. Settled solids are directed to the helical channel located under the center cone and are conveyed out of the main chamber through the underflow outlet. The flow passes down through the Swirl Cleanse screen which captures floatables and neutrally buoyant material greater than 4mm in diameter. The air regulated siphon provides an effective backwash mechanism to prevent the screen from blinding. Screened effluent is discharged into a receiving watercourse, a storage facility, or continues on to receive further treatment. The collected solids are then discharged by gravity or pumped out from the base of the unit to the sanitary sewer.

Typical design loading rates are from 7 to 44 gpm/sf. This loading rate is based on the flow coming in and the horizontal surface area of the circular vortex unit. Cross section of a Storm King® Vortex Separator in full operation is provided in Figure 2-7.

Figure 2-7 - Cross Section of Storm King Vortex Separator



(Source: Hydro International)

Applicability to the Project

Based on manufacturer publications, Storm King® units have been used for floatables control, primary treatment equivalency of CSOs and wet weather induced flows. The first installation of Storm King® units for CSO application was in mid-1995 in Hartford CT. See Appendix C for a list of Storm King® installation in the US for CSO application.

The units have been installed in remote locations, away from treatment plants and reportedly performed well. There are no moving parts within the vortex unit itself. Underflow from the unit can be discharged by gravity to sewers or continuously pumped to an ancillary tank where it would be stored until there is capacity in the interceptor sewer system. Underflows from the unit run approximately 10% of the design flow and thus the volume from the underflow can be significant.

Performance

The Storm King® vortex separator is most effective in removing heavier settleable solids, floatable material, and inorganic solids. The performance information provided by the manufacturer indicates that the percent removal of TSS, BOD and COD drops off as the hydraulic loading rate increases. TSS removal ranges from 35-50%, and BOD removal is typically 15-25%. Vortex units achieve removal by two means: the consolidation of solids material; and flow separation, which is accomplished by the underflow removal. When the vortex unit operates under low hydraulic loading rates, and there is a significant amount of settleable solids, both removal mechanisms are operating. As the hydraulic loading rate increases, or the settleable solids concentration decreases, there is less consolidation and the vortex unit functions more as a flow separator. At the highest hydraulic loading rates recommended, the unit functions strictly as a flow separator. The vortex units, the Storm King included, usually have an underflow that is 10% of the design capacity of the unit. So even under the worst conditions, when there is no consolidation of solids taking place, they would theoretically remove 10% of the pollutants. While this would hold true for the soluble portion of pollutants, in the case where the pollutant was associated with fine particles, the removal would be less. The reason for this decrease is that since fine particles weigh less, more of these particles would be carried out in the effluent especially at higher hydraulic loading rates. Some of the removals associated with these units are for lower volume storms when the volume associated with the unit acts as a storage system.

In the Bayonne MUA Pilot Study, the Storm King® units experienced operating issues due to their screens clogging with materials that appeared to be primarily toilet paper. Performance issues of less than 10% TSS removals were experienced when Volatile Suspended Solids (VSS) accounted for a high percent of the influent TSS. The TSS removal efficiencies improved when evaluating the inorganic component of TSS, or Fixed Suspended Solids (FSS). The FSS removal efficiencies for Storm King® units averaged around 17%, with the maximum removal efficiencies of 45.2%. The low removal of VSS (or inorganic) fraction of TSS indicated that the Storm King® units will be ineffective on their own with UV disinfection due to low ultraviolet light transmittance of the effluent.

Hydraulics

Vortex units are hydraulically efficient. The head loss through the unit consists of the losses through the inlet to the unit, and the head loss over the effluent weir. The losses in the lower hydraulic loading rates will be limited to less than six inches. At higher hydraulic loading rates, the losses will increase significantly, possibly up to a couple of feet, unless diverted upstream.

Generation of Waste Streams

As discussed under the description of the process and the performance: 10% of the design flow must continuously be removed as underflow. In many cases this flow will need to be pumped from the vortex unit due to the depth of the underflow pipe. While permittees with conveyance facilities must evaluate means of increasing conveyance to the WWTP, it is doubtful that the underflow can be consistently and constantly transported to the interceptor. In locations where interceptor capacity is not available during the overflow, the underflow must be stored in ancillary tanks. The capacity of these ancillary tanks is based upon the underflow flow rate and the duration of the overflow event. Once the event is over the contents of the storage tank can be pumped back into the interceptor. Floatable material captured in the tank is removed at the end of the overflow event as the tank is emptied, and is also sent back into the interceptor.

Complexity

The vortex/swirl separator is a simple process, especially since there are no moving parts within the unit. Removals are achieved using natural forces and no adjustment of equipment is necessary. The only controls that are needed are in the flow coming to the unit to ensure that the unit operates within its hydraulic loading rates. This can be accomplished using sluice gates or overflow weirs. The other area requiring instrumentation would be the control of the underflow sump where underflow is pumped out. The control of the pumping units would be by floats, bubblers, or ultrasonic level sensors.

Limitations

As previously indicated, the hydraulic loading rate is key to the performance of the vortex/swirl separator. Therefore, the limitation to this process occurs for the more stringent treatment objectives. Since a required and consistent effluent TSS must be achieved for the disinfection process to be effective, the variations in flows, particularly above the required hydraulic loading rate, result in a reduced removal of TSS and a corresponding decrease in the efficiency of the disinfection process. If the excess flows are by-passed around the vortex unit, going directly to disinfection, as required by the NJPDES requirement for complete disinfection, the higher TSS concentrations will again result in decreased disinfection efficiency. This represents a limitation on the process for the higher treatment objectives.

Construction Costs

Budgetary equipment pricing information for Storm King® vortex separator was obtained from equipment manufacturer Hydro International, Inc. Table 2-8 presents preliminary planning level construction cost estimates for flows ranging from 10 MGD to 450 MGD. It includes equipment cost, concrete cost associated with the construction of the tank containing the vortex structure, cost for ancillary tank for underflow storage, installation costs, GC field general conditions, GC OH&P, and contingency. Budgetary equipment pricing provided by the equipment manufacturer Hydro International includes only the fabricated stainless-steel vortex structures inside. Cost for outside concrete tank enclosure were estimated based on the sizes of the vortex units. Construction costs for excavation, sitework, soil support, and dewatering, as well as the underflow wet well and the pumps are included in the installation costs. The estimated total construction costs for the Storm King® Vortex Separator are plotted against flowrate from 10 MGD to 450 MGD in Figure 2-8.

Operation and Maintenance

The operating costs for the Storm King® vortex separator are associated with the power of the underflow pump. The horsepower of the pumps required increases as the size of the vortex separator, and corresponding underflow, increases. Regular maintenance required for the Storm King® unit includes inspection of the vortex separator after each rainfall event, replacement of the underflow pumps every 6 months for overhaul and sharpening of the cutter blades, and vacuuming out the floatable material that will accumulate in the underflow wet well.

Estimated annual operation costs for the Storm King® vortex separator are presented on Table 2-9 containing factors for calculation of operating costs; while estimated annual maintenance labor cost including cost factors are included on Table 2-10.

Space Requirements

The space requirements of the Storm King® vortex separator shall be based upon a square area utilizing the diameter of the tank and a buffer of 5 feet on each side.

Case Studies

According to literature obtained from Hydro International, Bucksport, ME, has been using Storm King® since 2008 as a solution to CSO related flooding caused by the nearby Penobscot River. The installation of satellite treatment within the collection system saved the city from expanding the capacity of their wastewater treatment plant. Solids which settle out from the Storm King® are fed via gravity from the base of the unit to the sewage treatment plant. Additionally, the system is used as a chlorine contact and mixing chamber for the reduction of fecal coliforms before effluent is discharged into the Penobscot River. Since the system was commissioned, all rain events the system has handled have been treated in accordance with regulatory requirements

The 18' (5.5 m) diameter Storm King® system was constructed in a park and is housed within a building which may resemble a restaurant. Residents are impressed with the installation. Bucksport has designed the facility such that a Swirl-Cleanse screening component may be added in the future which will allow capture of all floatables and neutrally buoyant material greater than 4 millimeters in diameter.

According to literature obtained from Hydro International, Saco, ME, has been using a 22-ft diameter Storm King® since November 2006. Sedimentation and screening are followed by disinfection using sodium hypochlorite ($NaClO$) in the flow tank. A Swirl-Cleanse screen is installed in this system which captures all floatables and neutrally buoyant material greater than 4 millimeters in diameter. Influent Total Suspended Solids (TSS) levels are in the range of 300 mg/L. Treated effluent TSS is typically 60mg/L or lower. Treated effluent is discharged directly into the Saco River, while the collected screenings and settleable solids are pumped back to the wastewater treatment plant for processing.

Engineers who worked on the Saco Sewer Project have been impressed with the performance of the Storm King® even in storms much larger than the set design criteria. The system requires maintenance crews to perform a quick wash down the tank after a storm. Additional maintenance is minimal.

Table 2-8- Preliminary Construction Cost Estimates for Storm King Vortex Separator

Flow	System	Diameter	Budgetary Equipment Price	Concrete Structure Cost	Auxiliary Tank Cost(1)	Install Cost(2)	GC General Conditions (3)	GC OH&P(4)	Contingency(5)	Total
10 MGD	(1) StormKing 10 MGD	28’	$739,000	$82,000	$871,200	$1,269,150	$296,135	$296,135	$1,776,810	$5,330,430
25 MGD	(1) StormKing 25 MGD	38’	$1,403,000	$181,000	$1,573,000	$2,367,750	$552,475	$552,475	$3,314,850	$9,944,550
50 MGD	(2) StormKing 25 MGD	38’	$2,797,000	$291,500	$2,300,000	$4,041,375	$942,988	$942,988	$5,657,925	$16,973,775
75 MGD	(2) StormKing 37 MGD	42’	$3,831,000	$291,500	$3,040,000	$5,371,875	$1,253,438	$1,253,438	$7,520,625	$22,561,875
100 MGD	(3) StormKing 35 MGD	42’	$5,733,000	$359,000	$3,720,000	$7,359,000	$1,717,100	$1,717,100	$10,302,600	$30,907,800
450 MGD	(10) StormKing 45 MGD	44’	$23,463,000	$718,000	$10,890,000	$26,303,250	$6,137,425	$6,137,425	$36,824,550	$110,473,650

Notes:
(1) Auxiliary Tank costs derived from quotation from Mid Atlantic Storage System on Aquastore Glass Fused to Steel Storage Tank of 150,000 gal
(2) Installation cost is assumed at 75% of the equipment cost.
(3) GC general conditions are estimated at 10% of the total direct cost.
(4) GC OH&P are estimated at 10% of the total direct cost.
(5) 50% of Contingency is used for the planning level of cost estimates.

Figure 2-8 - Total Estimated Construction Cost of Storm King Vortex Separator

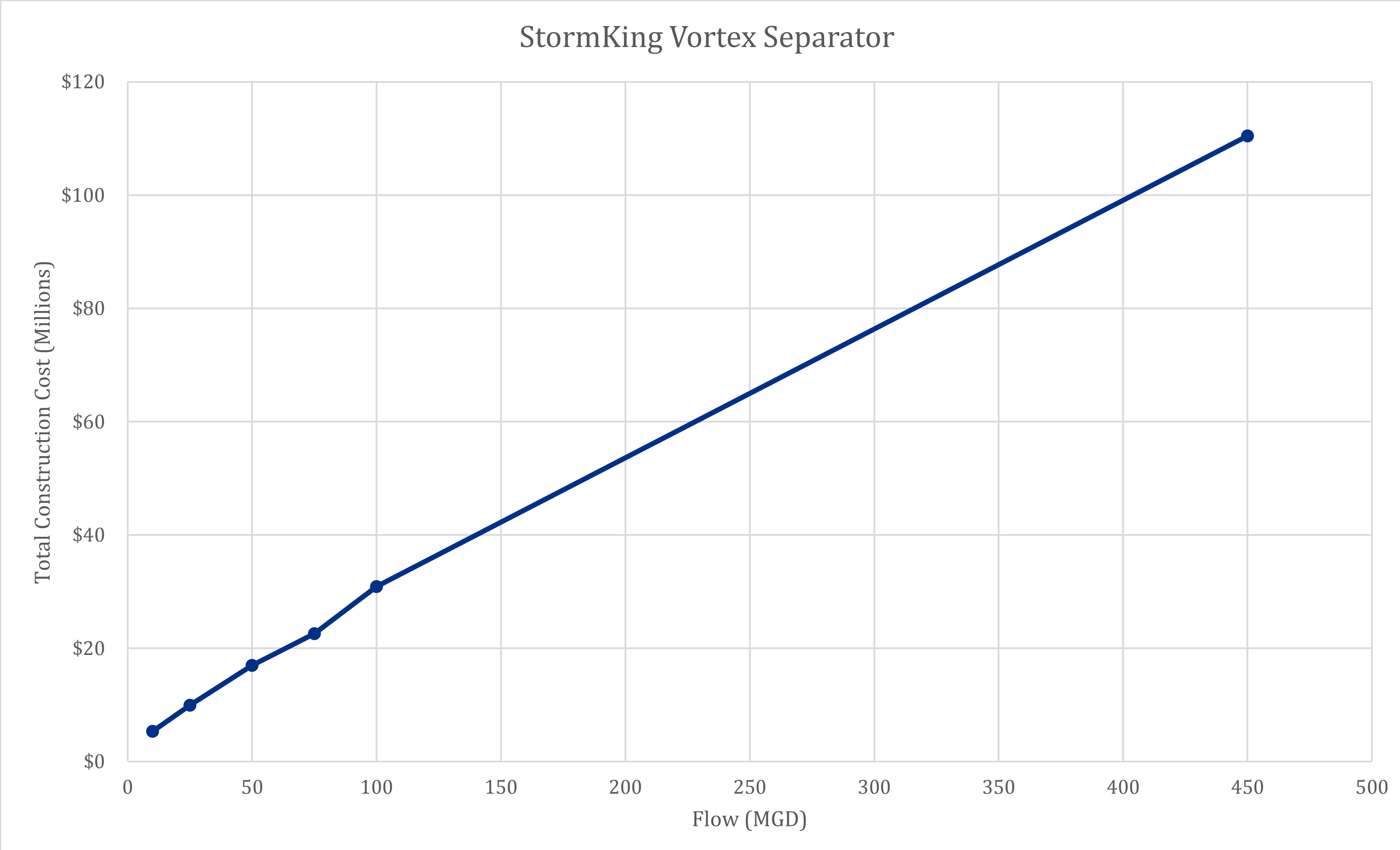


Table 2-9 - Annual Operation Costs of Storm King Vortex Separator

Flow	System	Total Horsepower (HP)	Total Power (kW)(1)	Annual Energy Usage (kW-hr)(2)	Annual Cost(3)
10 MGD	(1) StormKing 10 MGD	14	10	1	$731
25 MGD	(1) StormKing 25 MGD	35	26	4	$1,827
50 MGD	(2) StormKing 25 MGD	70	52	7	$3,654
75 MGD	(2) StormKing 37 MGD	104	78	11	$5,429
100 MGD	(3) StormKing 35 MGD	139	104	15	$7,256
450 MGD	(10) StormKing 45 MGD	625	466	65	$32,624

Notes:
(1) HP x 0.7457
(2) Assumes 500 hours of annual operation
(3) Assumes energy costs of $0.14/kW-hr

Table 2-10 - Annual Maintenance Labor Costs of Storm King Vortex Separator

Maintenance Frequency	Parts	Description	Estimated Man-Hours	Annual Cost(1)
Biannually	Valve inlet and outlet	Visual check and removal of coarse debris	1	300
Biannually	Underflow pumps	Visual check	1	300
Every three years	Underflow pumps	Replacement of underflow pumps	8	400
Total Annual Maintenance Cost				$1,000

Notes:

(1) Assumes labor rate of $150/hour

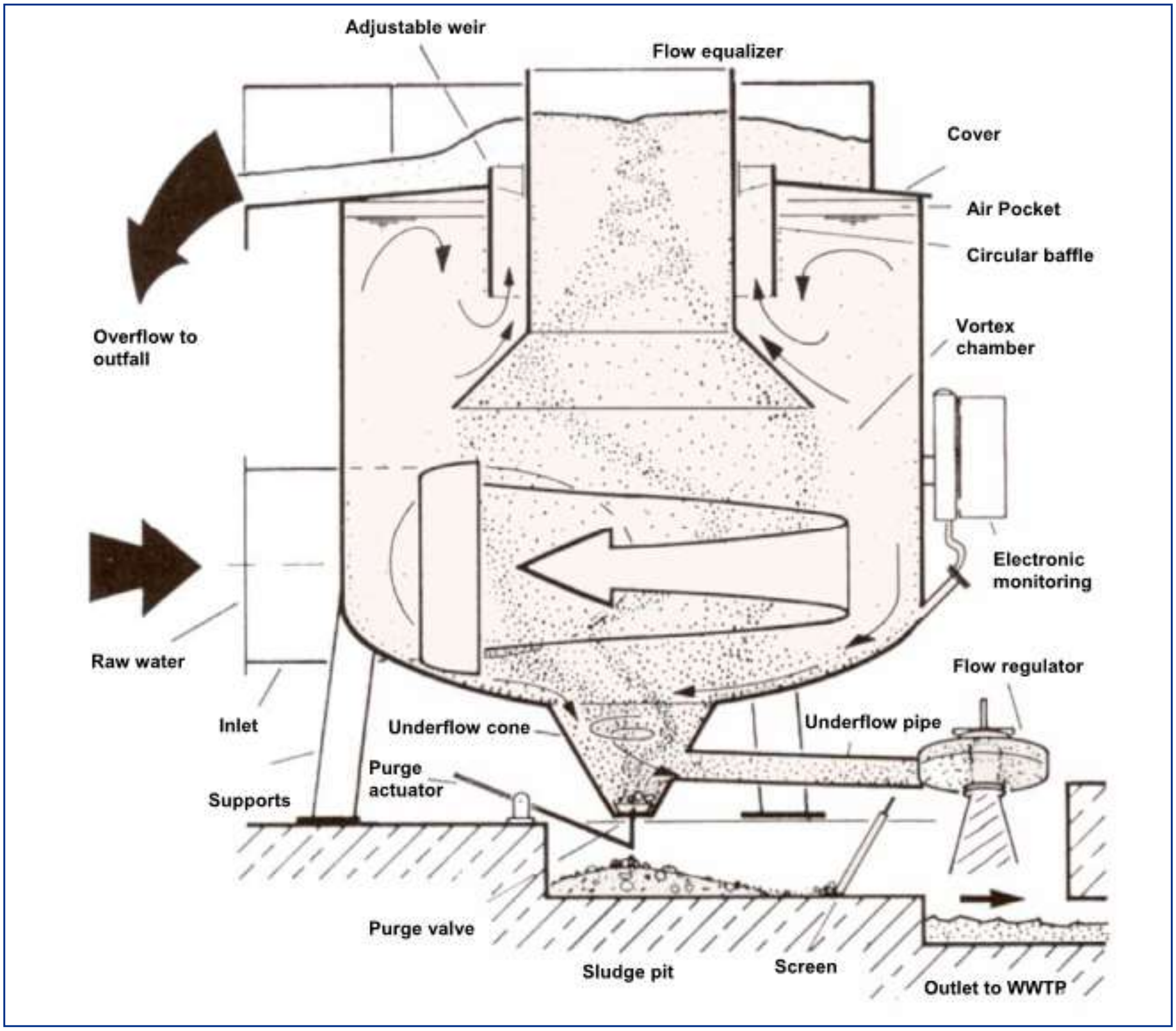
2.3.1.2 HYDROVEX® FluidSep Vortex Separator

Description of Process

In CSO installations, the dry weather flow that enters the HYDROVEX® FluidSep Vortex Separator passes by freely on the sloped bottom towards the central cone of evacuation and then through a flow regulator. During a storm event, the incoming flow becomes greater than the regulated outflow. This will effectively start the filling of the vortex separator. Many minor events can be fully intercepted and contained inside the vortex separator volume without actual overflow. For more intense or more durable storm events, the HYDROVEX® FluidSep Vortex Separator starts overflowing through its central annular overflow weir. This weir is made of two plunging cylindrical treatment baffles providing a double crown arrangement. The overflow water is evacuated through the ring-shaped opening formed by these two treatment baffles. The overflow is fixed in the circular opening of the top cover of the vortex separator structure. The overflowed water falls from the weir on the upper chamber of the separator and is then evacuated, either towards an additional treatment system or directly to the outfall. Due to its tangential inlet port, the incoming water brings the mass of retained water into a rotational movement inside the tank. The resulting flow pattern is non-turbulent and very favorable to the separation of suspended solids. These particles can readily settle and are furthermore pulled by the centrifugal currents towards the wall of the separator. Once the particles are caught on the limit layer along the walls, they fall to the structure bottom and are finally brought to the unit's evacuation cone. From there, they are carried out with the underflow water through the regulator. When the HYDROVEX® FluidSep Vortex Separator is filled, an air pocket is formed under the unit's cover, imprisoned by the baffle partition arrangement. The floatables entering the separator will be caught there and will simply circulate around until the unit progressively gets back to dry time flow conditions. The lower surface of the cover always remains free of water, due to the captured air pocket.

The proper selection of the HYDROVEX® FluidSep implies that the unit operating size is efficient for all flows up to the design flow. When flows higher than the design flow are received, the unit will operate at a lesser efficiency level. The collected solids are then discharged by gravity or pumped out from the base of the unit to the sanitary sewer. Loading rates vary from 3 gpm/sf to 21 gpm/sf. Cross section of a HYDROVEX® FluidSep Vortex Separator in full operation is shown in Figure 2-9.

Figure 2-9 - Cross Section of a HYDROVEX® FluidSep Vortex Separator



(Source: John Meunier, Inc.)

Applicability

The HYDROVEX® FluidSep Vortex Separator was developed in 1985 by a German firm, Umwelt-und Fluid-Technik (UFT) as a tool in the treatment of CSO and stormwater. The first HYDROVEX® Fluidsep unit was installed in 1987 in the City of Tengen near Schaffhausen in Germany. The units are still operating successfully. A special research program that ended in the summer of 1990 supplied evidence of CSO treatment efficiency of the HYDROVEX® FluidSep (H. Brombach, *et al.*, 1993). The program was based on the qualitative evaluation of sampling campaigns performed at the installation.

HYDROVEX® FluidSep is currently in full operation in Germany, France, Canada, and the United States of America. John Meunier Inc./Veolia Water Technologies designs and manufactures HYDROVEX® FluidSep units for the North America under license from UFT. See Appendix D for an installation list of HYDROVEX® FluidSep units in the North America. All the installations included on the list are for CSO applications. HYDROVEX® FluidSep Vortex Separator are most effective on removing settleable solids and floatable material. The units have been installed in remote locations, away from treatment plants and have performed well. There are no moving parts within the vortex unit itself. Underflow from the unit can be discharged by gravity to sewers or continuously pumped to an ancillary tank where it would be stored until there is capacity in the interceptor sewer system.

Performance

The performance of HYDROVEX® FluidSep Vortex Separator is similar to that described above for the Storm King® Vortex Separator in terms of contaminants removal since they use similar mechanism for solids removal.

Hydraulics

Vortex units are hydraulically efficient. The head loss is comparable to that described above for the Storm King® Vortex Separator.

Generation of Waste Streams

As discussed under the description of the process and the performance, 10% of the design flow will continuously be removed as underflow. This flow must be pumped from the vortex unit, and since the interceptor is full, no capacity will exist in the interceptor during an overflow event. Therefore, the underflow must be stored in ancillary tanks. The capacity of the ancillary tanks is based upon the underflow flow rate and the duration of the overflow event. Once the event is over the contents of the storage tank can be pumped back into the interceptor. Floatable material captured in the tank is removed at the end of the overflow event as the tank is emptied, and is also sent back into the interceptor.

Complexity

The vortex/swirl separator is a simple process. Hydraulic loading rates can be controlled using sluice gates or overflow weirs. Floats, bubblers, or ultrasonic level sensors would be used to control the underflow sump similar to the Storm King® Vortex Separator.

Limitations

The limitations of the HYDROVEX® FluidSep Vortex Separator are similar to those described above for the Storm King® Vortex Separator.

Construction Costs

Table 2-11 presents preliminary planning level construction cost estimates for flows ranging from 10 MGD to 450 MGD. It includes equipment cost, concrete cost associated with the construction of the tank containing the vortex structure, cost for ancillary tank for underflow storage, installation costs, GC field general conditions, GC OH&P, and contingency. Budgetary equipment pricing provided by the equipment manufacturer Veolia Water Technologies includes only the fabricated stainless-steel vortex structures inside. Cost for outside concrete tank enclosure were estimated based on the sizes of the vortex units. Construction cost for excavation, sitework, soil support, and dewatering, as well as the underflow wet well and the pumps are included in the installation costs. The estimated total construction costs for the HYDROVEX® FluidSep Vortex Separator are plotted against flowrate from 10 MGD to 450 MGD in Figure 2-8.

Operation and Maintenance

The operating costs for the HYDROVEX® FluidSep Vortex Separator are the power costs for the underflow pump. The horsepower of the pumps increases as the size of the vortex separator, and correspondingly the underflow, increase. Maintenance costs for the HYDROVEX® FluidSep unit include inspection of the vortex separator and removal of coarse debris (if any) after first heavy rainfall event and then every six months. Once every year, a full inspection of the unit is recommended, including cleaning of the area, visual inspection for abnormalities, like leaks, cracks in the unit's tank and pipe works. Perform visual inspection of all anchors and bolted assemblies. During visual inspection, all normal safety procedures are recommended to be used to prevent any kind of injury. Underflow pumps are recommended to be replaced every six months for overhaul and sharpening of the cutter blades.

Estimated annual operation costs for the HYDROVEX® FluidSep Vortex Separator are presented on Table 2-12 containing factors for calculation of operating costs; while estimated annual maintenance labor cost including cost factors are included on Table 2-13.

Space Requirements

The space requirements of the HYDROVEX® FluidSep Vortex Separator shall be based upon a square area utilizing the diameter of the tank and a buffer of 5 feet on each side.

Case Study

In 2016, Mattoon, IL installed a HYDROVEX® FluidSep Vortex Separator at their Riley Creek satellite CSO treatment facility. As of September 2017, the unit has not been in service yet. The Riley Creek facility is in a remote location and designed for 15 MGD. The application required a 12" gravity underflow line (at 2 ft/s flow) for 3 or 4 MGD of underflow, which will get pumped back to the wastewater treatment plant. This large amount of underflow requires having almost one pump dedicated to pumping it back to the WWTP.

Table 2-11 - Preliminary Construction Cost Estimates for HYDROVEX Fluidsep Vortex Separator

Flow	System	Diameter x Depth	Budgetary Equipment Price	Concrete Structure Cost	Auxiliary Tank Cost(1)	Install Cost(2)	GC General Conditions (3)	GC OH&P(4)	Contingency(5)	Total
10 MGD	(1) Type 1	20’-0” x 20’-0”	$60,000	$82,000	$871,200	$759,900	$177,310	$177,310	$1,063,860	$3,191,580
25 MGD	(1) Type 2	35’-0” x 19’-6”	$81,000	$181,000	$1,573,000	$1,376,250	$321,125	$321,125	$1,926,750	$5,780,250
50 MGD	(1) Type 2	45’-0” x 24’-6”	$85,700	$291,500	$2,300,000	$2,007,900	$468,510	$468,510	$2,811,060	$8,433,180
75 MGD	(1) Type 2	45’-0” x 24’-5”	$85,700	$291,500	$3,040,000	$2,562,900	$598,010	$598,010	$3,588,060	$10,764,180
100 MGD	(1) Type 2	50’-0” x 27’-5”	$113,900	$359,000	$3,720,000	$3,144,675	$733,758	$733,758	$4,402,545	$13,207,635
450 MGD	(4) Type 2	50’-0” x 27’-5”	$455,600	$718,000	$10,890,000	$9,047,700	$2,111,130	$2,111,130	$12,666,780	$38,000,340

Notes:
(1) Auxiliary Tank costs derived from quotation from Mid Atlantic Storage System on Aquastore Glass Fused to Steel Storage Tank of 150,000 gal
(2) Installation cost is assumed at 75% of the equipment cost.
(3) GC general conditions are estimated at 10% of the total direct cost.
(4) GC OH&P are estimated at 10% of the total direct cost.
(5) 50% of Contingency is used for the planning level of cost estimates.

Figure 2-10 - Total Estimated Construction Cost of HYDROVEX FluidSep Vortex Separator

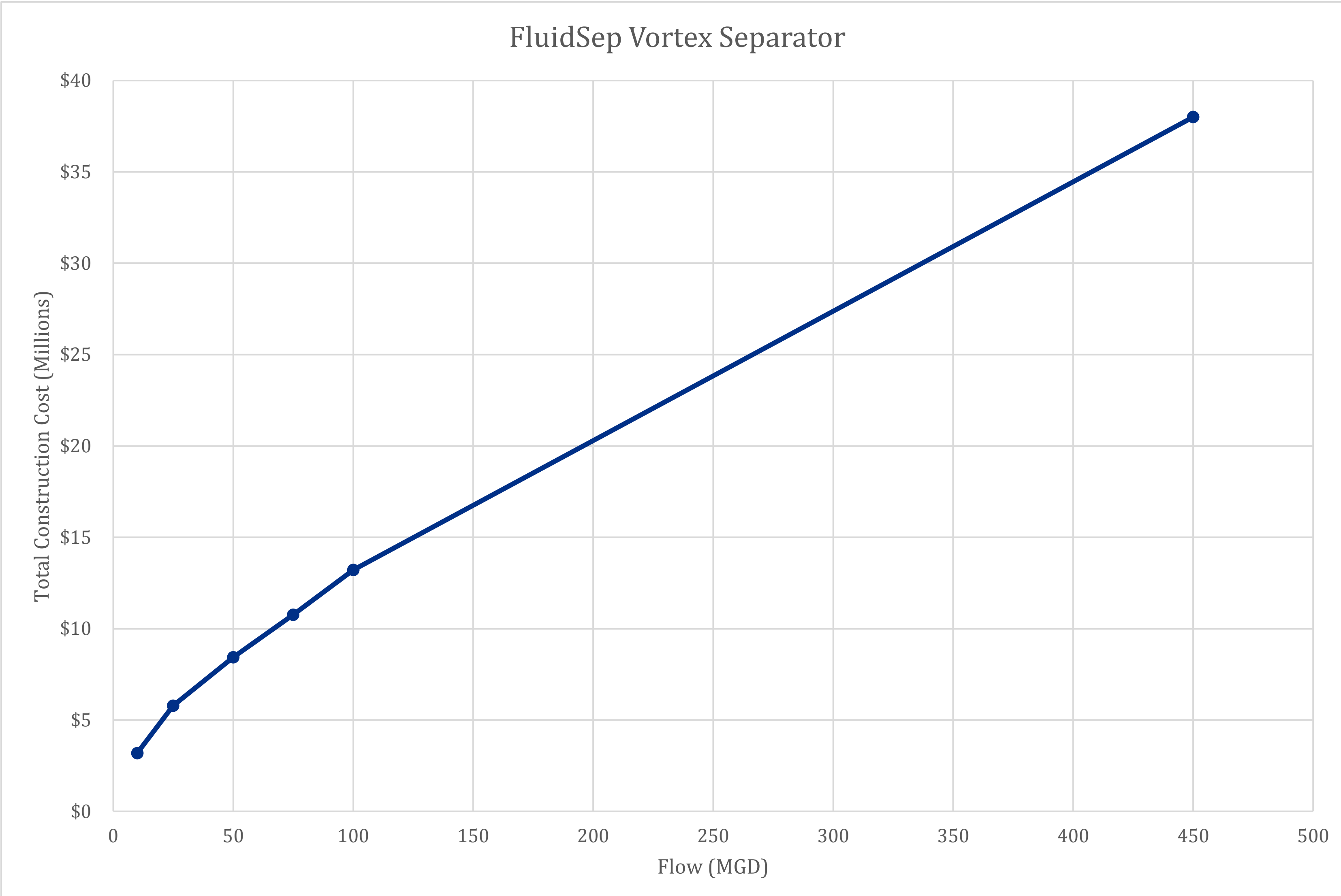


Table 2-12 - Annual Operation Cost of HYDROVEX Fluidsep Vortex Separator

Flow	System	Total Horsepower (HP)	Total Power (kW)(1)	Annual Energy Usage (kW-hr)(2)	Annual Cost(3)
10 MGD	(1) Type 1	14	10	1	$731
25 MGD	(1) Type 2	35	26	4	$1,827
50 MGD	(1) Type 2	70	52	7	$3,654
75 MGD	(1) Type 2	104	78	11	$5,429
100 MGD	(1) Type 2	139	104	15	$7,256
450 MGD	(4) Type 2	625	466	65	$32,624

Notes:
(1) HP x 0.7457
(2) Assumes 500 hours of annual operation
(3) Assumes energy costs of $0.14/kW-hr

Table 2-13 - Annual Maintenance Labor Cost of HYDROVEX Fluidsep Vortex Separator

Maintenance Frequency	Parts	Description	Estimated Man-Hours	Annual Cost(1)
Biannually	Tank and pipe	Visual check and removal of coarse debris (if any)	1	300
Annually	Full Inspection	Cleaning, check for leaks/cracks in unit tank and pipes; visual inspection of all anchors and bolted assemblies	2	300
Biannually	Underflow pumps	Replacement of underflow pumps	8	400
Total Annual Maintenance Cost				$1,000

Notes:
(1) Assumes labor rate of $150/hour

2.3.1.3 SANSEP

Description of Process

The SanSep process is a variation of the typical vortex/swirl separation process, in that it utilizes a screen at the mid-depth of the tank where the treated flow exits the tank. Using the patented non-blocking screen, all gross solids larger than 0.04" and finer sediments down to below 0.004" are captured and retained inside the unit. The settleable solid pollutants settle into the lower catchment chamber while the floatables are retained at the surface of the upper chamber. A flow of liquid is maintained across the face of the screen producing a "washing" effect that keeps the solids moving while the fluid passes through the screen. The SanSep is typically automated with an underflow pump, which periodically removes the solids and returns them to the interceptor sewer. The non-blocking screen operates continuously at its maximum design flow. Cross section of a SanSep unit is shown in Figure 2-11.

Figure 2-11 - Cross Section of a SanSep Unit

(Source:PWTech.)

Application to the Project

SanSep was initially developed in Australia as a stormwater treatment system by the corporate predecessor of PWTech (CDS Technologies). The system was introduced in the US in the mid 90's and first used for CSO applications in Louisville Kentucky. Three units have been in continuous operation there since the late 90s. SanSep units have been installed on CSO applications in Cohoes, New York since 2004, and in in Akron, OH and in Weehawken, NJ. since 2004. See Appendix E for an installation list for SanSep for CSO applications in the US, Europe and the Pacific Rim.

Performance

The SanSep unit is more efficient in removal of solids and other pollutants than conventional vortex/swirl separation units due to the use of the screen. The unit removes all solids larger than 1 mm, including organic debris such as vegetation and coarse sediments, fine organic sediments, and significant amounts of BOD and Phosphorus associated with the organic material and fine sediments captured. The SanSep units are also capable of operating at high separation efficiency, over a larger range of hydraulic loading rates than the conventional vortex/swirl separation units. Hydraulic loading rates for conventional units are based upon the horizontal area of the vortex unit, whereas the hydraulic loading rate for the SanSep units are based upon the area of the screen. The screening area, which is greater than the horizontal surface area, and the continuous cleaning action of the flow across the screen enables the SanSep unit to maintain the higher removal rates than conventional units over a wider range of hydraulic loading rates. The performance information from the manufacturer show that there is light drop in removal of TSS as the hydraulic loading rate increases. TSS removal can drop from approximately 70% to 50% as loading rate increases to about 60 gpm/sf.

Hydraulics

Vortex units are hydraulically efficient. The head loss through the unit consists of the losses through the inlet to the unit, and the head loss through the screen. The losses in the lower hydraulic loading rates will be limited to less than six inches. At higher hydraulic loading rates, the losses will increase.

Generation of Waste Stream

The SanSep process has a reduced underflow of 2-3% of the design flow which will continuously be removed as underflow, compared to conventional vortex units with an underflow of 10%. This flow must be pumped from the vortex unit, and since no or limited capacity will exist in the interceptor during an overflow event, the underflow must be stored in ancillary tanks. The capacity of the ancillary tanks is based upon the underflow flow rate and the duration of the overflow event. Once the event is over the contents of the storage tank can be pumped back into the interceptor. Floatable material captured in the tank is removed at the end of the overflow event as the tank is emptied, and is also sent back into the interceptor.

Complexity

The vortex/swirl separator is a simple process, especially since there are no moving parts within the unit. Removals are achieved using natural forces and no adjustment of equipment is necessary. The only controls that are needed are in the flow coming to the unit, in order to ensure that the unit operates within its hydraulic loading rates. This is typically accomplished using sluice gates or overflow weirs. The other area requiring instrumentation would be the control of the underflow sump where underflow is pumped out. The control of the pumping units would be by floats, bubblers, or ultrasonic level sensors.

Limitations

As stated above, the hydraulic loading rate is key to the performance of the vortex/swirl separator. However, since the SanSep unit is able to maintain high removal rates over a wider range of hydraulic loading they perform better in removing TSS, and as a result enable the downstream disinfection processes to be more effective.

Construction Costs

The preliminary report level construction cost estimates provided in Table 2-14 include the equipment, installation, building, land, and contingency for SanSep of design flow ranging from 10 MGD to 100 MGD. Budgetary equipment pricing information for SanSep was gathered from equipment manufacturer Echelon Environmental. Flowrate higher than 100 MGD was considered impractical to use the SanSep unit by the equipment manufacturer. Installation costs are estimated at 150% of the equipment cost per manufacture recommendation. The estimated total construction costs for the SanSep are plotted against flowrate from 10 MGD to 100 MGD in **Figure 2-**12.

Operation and Maintenance

The operating costs for the SanSep vortex separator are the power costs for the underflow pump. The horsepower of the pumps increases as the size of the vortex separator, and correspondingly the underflow, increase. Regular maintenance required for SanSep unit includes inspection of the vortex separator after each rainfall event. After each event, the PLC for the unit initiates a cleaning and wash-down cycle. During this cycle, the underflow pumps empty the unit, followed by a wash-down with clean water directed at the screen through a series of water jets. If a clean water source is not available, the wash-down can also be accomplished using the spray from a vactor truck. The screen should also receive a periodic inspection from the surface to ensure that the cleaning cycle is removing accumulated debris. Unless large debris is accumulating in the structure, it shouldn't be necessary to enter the unit. If it is ever necessary to enter the unit, confined space entry regulations would apply. The underflow pumps are recommended to be replaced every 6 months for overhaul and sharpening of the cutter blades.

Estimated annual operation costs for the SanSep separator are presented on Table 2-15 containing factors for calculation of operating costs; while estimated annual maintenance labor cost including cost factors are included on Table 2-16.

Space Requirements

The space requirements of the SanSep vortex separator shall be based upon a square area utilizing the diameter of the tank and a buffer of 5 feet on each side.

Case Study

The Fort Wayne, Indiana Public Utilities installed the SanSep unit in 2009 at one of their CSO locations to catch floatables half and inch and larger. Prior to the installation, a pilot study was completed in which baskets were installed to observe the types of materials collected. The pilot study showed that the unit was able to capture fine materials. According to the CSO Program Manager, the unit was in use until about 2015 at which point the CSO location was almost entirely eliminated due to Consent Decree regulations. During its operation, there had been no plugging or washdown of the system needed and maintenance consisted of the general routine maintenance. There was also a small pump station which pumps debris back into the wastewater treatment plant. Overall the CSO Program Manager was satisfied with the product.

Table 2-14 - Preliminary Construction Cost Estimates for SanSep

Flow	System	Length X Width	Budgetary Equipment Price	Auxiliary Tank Cost	Install Cost(1)	GC General Conditions (2)	GC OH&P(3)	Contingency(4)	Total
10 MGD	(1) Model 80_80	23'-0" x 25'-6"	$300,000	$420,000	$1,080,000	$180,000	$72,000	$1,026,000	$3,078,000
25 MGD	(2) Model 80_80	42'-0" x 25'-6"	$430,000	$680,000	$1,665,000	$277,500	$111,000	$1,581,750	$4,745,250
50 MGD	(3) Model 80_80	42'-0" x 38'-6"	$560,000	$1,000,000	$2,340,000	$390,000	$156,000	$2,223,000	$6,669,000
75 MGD	(4) Model 80_80	42'-0" x 51'-0"	$690,000	$1,300,000	$2,985,000	$497,500	$199,000	$2,835,750	$8,507,250
100 MGD	(4) Model 80_80	42'-0" x 51'-0"	$690,000	$1,570,000	$3,390,000	$565,000	$226,000	$3,220,500	$9,661,500

Notes:
(1) Installation costs are estimated at 150% of the equipment cost per manufacture recommendation.
(2) GC general conditions are estimated at 10% of the total direct cost.
(3) GC OH&P are estimated at 10% of the total direct cost.
(4) 50% of contingency is used for the planning level of cost estimates.

Figure 2-12 - Total Estimated Construction Cost of SanSep

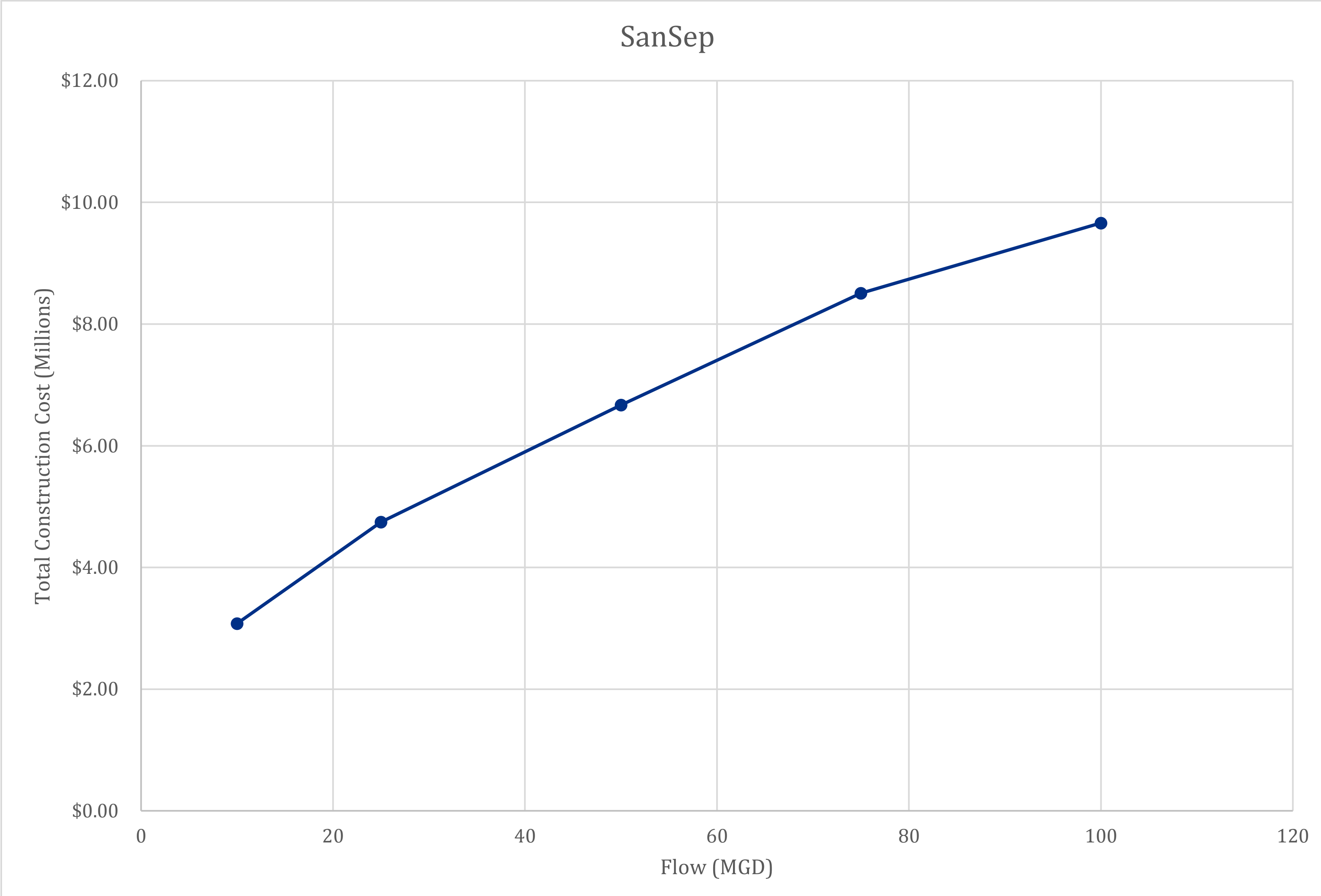


Table 2-15 - Annual Operation Cost of SanSep

Flow	System	Total Horsepower (HP)	Total Power (kW)[(1)]	Annual Energy Usage (kW-hr)[(2)]	Annual Cost[(3)]
10 MGD	(1) Model 80_80	6	4	1	$313
25 MGD	(2) Model 80_80	10	7	1	$522
50 MGD	(3) Model 80_80	10	7	1	$522
75 MGD	(4) Model 80_80	15	11	2	$783
100 MGD	(4) Model 80_80	20	15	2	$1,044

Notes:
(1) HP x 0.7457
(2) Assumes 500 hours of annual operation
(3) Assumes energy costs of $0.14/kW-hr

Table 2-16 - Annual Maintenance Labor Cost of SanSep

Maintenance Frequency	Parts	Description	Estimated Man-Hours	Annual Cost[(1)]
Biannually	Tank and pipe	Visual check and removal of coarse debris (if any)	1	$300
Annually	Full Inspection	Cleaning, check for leaks/cracks in unit tank and pipes; visual inspection of all anchors and bolted assemblies	2	$300
Biannually	Underflow pumps	Replacement of underflow pumps	8	$400
Total Annual Maintenance Cost				$1,900

Notes:
(1) Assumes labor rate of $150/hour

2.3.2 Ballasted Flocculation

Ballasted flocculation, also known as high rate clarification, is a physical-chemical treatment process that uses microsand, or sludge and a variety of additives to improve the settling properties of suspended solids through improved floc bridging. The objective of this process is to form floc particles with a specific gravity of greater than two. Faster floc formation and decreased particle settling time allow clarification to occur up to ten times faster than with conventional clarification, allowing treatment of flows at a significantly higher rate than allowed by traditional unit processes. Ballasted flocculation units function through the addition of a coagulant, such as ferric chloride; an anionic polymer; and a ballast material such as microsand, a microcarrier, or chemically enhanced sludge. When coupled with chemical addition, this ballast material has been shown to be effective in reducing coagulation-sedimentation time.

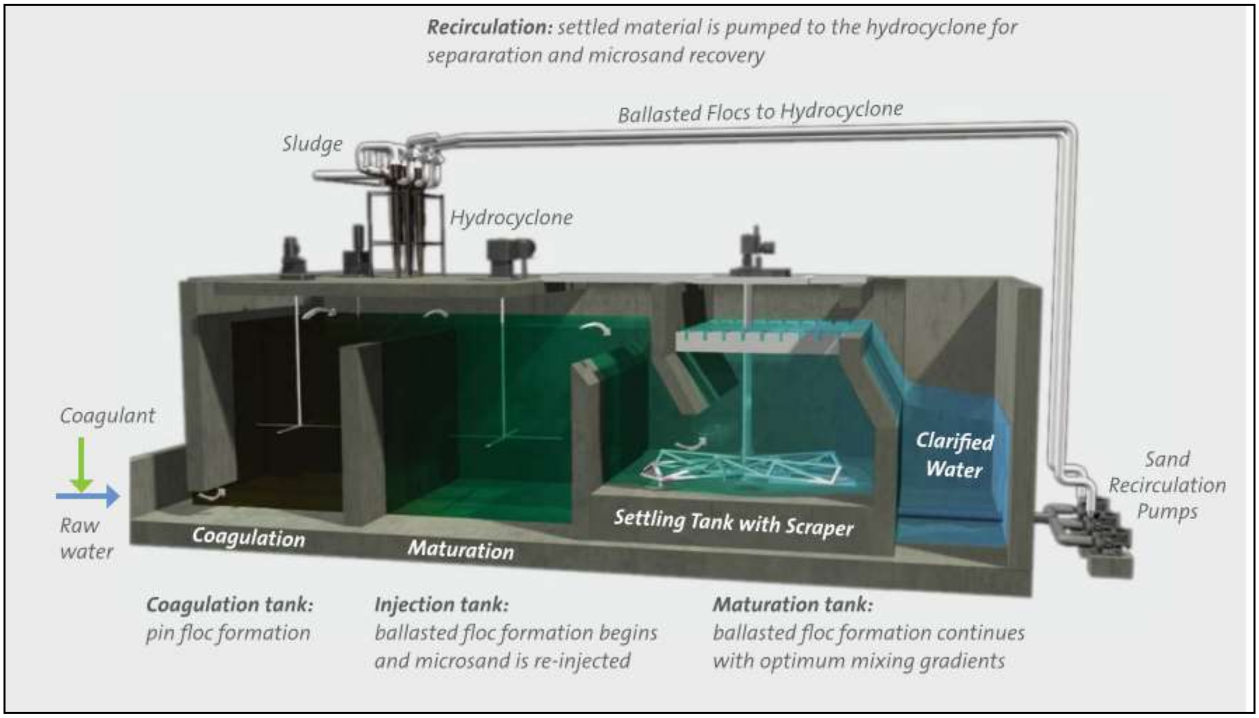
The ballasted flocculation processes, using chemical addition as a critical part of their operation, have higher removal percentages than vortex/swirl separation processes for virtually all the pollutants with the exception of total nitrogen and NH_3. The compact size of ballasted flocculation units can significantly reduce land acquisition and construction costs. This technology has been applied both within traditional treatment trains and as overflow treatment for peak wet weather flows. Several different ballasted flocculation systems are discussed in more details in sections below.

2.3.2.1 ACTIFLO® Ballasted Flocculation Process

Description of Process

ACTIFLO® is a microsand ballasted clarification process that may be used to treat water or wastewater. The process begins with the addition of a coagulant, such as an iron or aluminum salt, to destabilize suspended solids. The flow enters the coagulation tank for flash mixing to allow the coagulant to rapid mix with the flow after which it overflows into the injection tank where microsand is added. The microsand serves as a seed for floc formation, providing a large surface area for suspended solids to bond to, and is the key to the ACTIFLO® process. The larger flocculation particles allow solids to settle out more quickly, thereby requiring a smaller footprint than conventional clarification. Polymer may either be added in the injection tank or at the next step, the maturation tank. Mixing is slower in the maturation tank, allowing the polymer to help bond the microsand to the destabilized suspended solids. Finally, the settling tank effectively removes the floc with help from the plate settlers. The plate settlers allow the settling tank size to be reduced. Clarified water exits the process by overflowing weirs above the plate settlers. The sand and sludge mixture is collected at the bottom of the settling tank with a conventional scraper system and pumped back to a hydrocyclone, located above the injection tank. The hydrocyclone converts the pumping energy into centrifugal forces to separate the higher-density sand from the lower density sludge. The sludge is discharged out of the top of the hydrocyclone while the sand is recycled back into the ACTIFLO® process for further use. Screening is required upstream of ACTIFLO® so that particles larger than 0.1 - 0.25 mm do not clog the hydrocyclone. Cross section of ACTIFLO® unit is shown in Figure 2-13.

Figure 2-13 - Cross Section of ACTIFLO® Unit



(Source: Veolia Water Technologies)

Applicability to the Project

High rate clarification (HRC) was traditionally used for water treatment until in the late 1990s when HRC demonstration testing programs were performed to verify whether HRC technology would be able to be used for wastewater and CSO treatment. The results of the demonstration programs indicated that HRC can be used for CSO treatment and the effluent quality produced during pilot-testing surpassed CSO treatment standards, making it amenable to subsequent UV disinfection.

The ACTIFLO® system, as one type of HRC that uses ballasted flocculation, can be installed at the treatment plant or at a satellite facility within the collection system. The Actiflo process can be fully automated and the process train(s) can sit idle for extended periods of time and still be fully operational within 15 minutes of start-up. Installations at the WWTP also enable the sludge produced by the unit to be processed with existing systems. When installing the ACTIFLO® unit in a remote CSO location, the flows will vary widely, and the sludge must be stored in ancillary tanks so it can be put back into the interceptor during periods of low flow. Appendix F summarizes ACTIFLO® installations in the USA. The table lists only installations used for wastewater treatment operations. System applications include Primary WW, Primary WW/CSO, Primary WW/ Tertiary WW, CSO, CSO/Tertiary WW, and Tertiary WW treatment operations.

Performance

The ACTIFLO® ballasted flocculation process is sized for the peak hour or day flow to prevent flow from exceeding the capacity of the unit. The units are designed for a surface-loading rate of 60 gallons per minute per square foot, at a peak hydraulic loading rate of 150%. When starting up the unit it takes between 15-30 minutes for the process to reach steady state conditions. Accordingly, the initial 15-30 minutes of operation receives only little or partial treatment. The ACTIFLO® ballasted flocculation process is very effective in removing most of the pollutants; especially since the addition of flocculants and polymers helps remove smaller particles. Performance for removal of pollutants is reportedly constant up to for a surface-loading rate of 60 gallons per minute per square foot. See Table 2-17 for manufacturer provided performance efficiency. Performance deteriorates quickly for higher surface loading rates than 60 gallons per minute per square foot.

Table 2-17 - Anticipated Performance Efficiency

Parameter	Removal Rate
TSS	80 - 95%
COD	50 - 70%
Total BOD	50- 80%
Soluble BOD	10 - 20%
Total P	80 - 95%
TKN	15 -20%
Heavy Metals	85 -100%
Oils & Grease	50 -80%
Fecal Coliform	85 -95%

Hydraulics

The head loss through the units at peak flow rates are reported at less than two feet.

Generation of Waste Streams

As previously noted, the initial 15-30 minutes of operation of the unit provides no or only partial treatment. Since the disinfection process requires consistent pretreatment removals of TSS, the discharge of this partially treated flow will result in only partial disinfection. One potential means of eliminating this problem would be to provide ancillary tanks for storage of the initial discharge. This storage can then be reintroduced to the treatment process once the unit is fully operational. Under the description of the process, sludge is produced and separated in a hydrocyclone unit. The solids percentage of the waste sludge will vary depending on the concentration of the influent TSS and the coagulant dosage. In most cases the solids concentrations will vary from 0.1 to 1.0% with an average of 0.3%. Sludge from the ACTIFLO® process is easily treated and dewatered. When the ACTIFLO® process is located at the WWTP the sludge is sent back to the head of the plant or primary clarifiers, in some cases it is sent to intermediate gravity thickeners and then on to centrifuges or belt thickeners for final processing. The sludge production is approximately 4.8% of the design capacity of the unit.

Complexity

The ACTIFLO® ballasted flocculation process is more complex than the vortex/swirl separator process. The ACTIFLO® ballasted flocculation process consists of chemical addition, which must be controlled by the flow rate, mixers and flocculators, sludge pumps and a hydrocyclone, which separates the sludge from the microsand.

Limitations

The startup time for the ACTIFLO® process of from 15 to 30 minutes is a limitation in that for stringent treatment objectives the flow from the unit during this time period must be stored and fed back into the system later. For some drainage areas, this startup period may correspond to the first flush when the loading is the greatest. Also, the ACTIFLO® process has 4:1 turndown ratio, which means the minimum flow through the unit is 25% of the unit's capacity. Flows lower than this result in process problems. There is a maximum TSS limit on the ACTIFLO® process at the higher loading rate of 60 gpm/sf, of between 500 to 1000 mg/L TSS. This value is high and should not provide a routine problem in the operation of the unit. In remote locations, the ACTIFLO® process will see intermittent operation which will make operation more challenging.

Construction Costs

The preliminary planning level construction cost estimates are provided in Table 2-18 for ACTIFLO® Ballasted Flocculation Unit of design flow ranging from 10 MGD to 450 MGD. It includes equipment cost, installation costs, GC field general conditions, GC OH&P, and contingency. Budgetary equipment pricing information for ACTIFLO® Ballasted Flocculation Unit was gathered from equipment manufacturer Veolia Water Technologies. The equipment price includes engineering and project management time. Cost for concrete structure and auxiliary tank for waste sludge storage were also estimated based on equipment sizing and design flowrate. Installation cost was assumed at 115% of equipment cost based on equipment manufacturer's recommendations. The installation cost includes assembly of the ACTIFLO® ballasted flocculation unit, excavation and backfilling, and the cost of the Chemical Building and the chemical feed equipment. The estimated total construction costs for the ACTIFLO® Ballasted Flocculation Unit are plotted against flowrate from 10 MGD to 450 MGD in **Figure 2-**14.

Operation and Maintenance

Operating costs for the ACTIFLO® Ballasted Flocculation unit consists of the power and chemical costs. Power costs are based upon the horsepower of the mixers, flocculators, chemical feed equipment and pumps. Chemical costs are based on usage of coagulant and polymer. Regular maintenance includes routine lubrication and maintenance of the mixers, scrapers, pumps, hydrocyclones and other mechanical components. Weekly inspections and preventive maintenance are important to keep an intermittent-use facility ready to operate at a moment's notice. When the unit will be offline for more than 8 hours, the units will be completely drained and all equipment stopped.

Estimated annual operation costs for the ACTIFLO® system are presented on Table 2-19 containing factors for calculation of operating costs; while estimated annual maintenance labor cost including cost factors are included on Table 2-20.

Space Requirements

The space requirements of the ACTIFLO® units consist of the size of the tanks and a buffer of 5 feet around the unit for access and maintenance.

Case Study

The Water Environment Federation's (WEF) February 2012 issue of Water Environment and Technology (WE&T) provided a case study on the use of HRC in the city of Bremerton, Washington. Bremerton adopted a proprietary high rate compact clarification process to reduce its CSO discharges. Followed by an ultraviolet disinfection treatment, the HRC process was piloted by CDM Smith in 1999. The pilot testing determined effluent capable of being discharged into sensitive waterways would be produced by the HRC process and that a UV disinfection treatment could be added to the process. This project received the 2002 Grand Award in Small Projects by the American Academy of Environmental Engineers (Annapolis, MD).

The process takes wet weather flow that cannot be handled by the wastewater treatment plant, and puts it through a flash mixing tank with polymer added, and a maturation tank before it is sent through a clarifier. Reduction of BOD5 and TSS is typically 60-65% and 90-95%, respectively. Sludge from the clarifier is pumped back to the hydrocyclone and then either to the solids processing plant, or through a microsand filter and into the flash mixing tank. The facility utilizes a 10 MGD nominal capacity with a maximum hydraulic capacity of 20MGD. Additionally, flow to the facility is minimized by a 100,000-gallon storage tank, which has reduced overall CSO occurrences by 80% in the surrounding collection system. The HRC facility only receives flow when the storage tank fills over a weir wall.

Weekly inspection and maintenance is required to ensure the facility is ready to operate when the next rainfall occurs. Additionally, a small flow (less than 3 gal/min) of chlorinated potable water is discharged into the injection tank during periods of dry weather to eliminate the chance of biofouling on lamella tubes and other components. The facility has had issues with UV ballast burnout due to short durations of high intensity operation. Since installation, operators have adjusted the coagulant injection point to increase flocculation time. Additionally, the discharge was relocated from the hydrocyclone to the far side of the storage tank to reduce sand loss and resuspension of separated solids. Operators spent several years altering the chemical dosing to meet permitted discharge requirements as there are very few events each year which trigger the HRC.

Table 2-18 - Preliminary Construction Cost Estimates for ACTIFLO Ballasted Flocculation Unit

Flow	System	Length X Width of ACTFLO Unit	Auxiliary Tank Volume	Budgetary Equipment Price	Concrete Cost	Auxiliary Tank Cost	Install Cost(1)	GC General Conditions(2)	GC OH&P(3)	Contingency(4)	Total
10 MGD	(1) 10 MGD	44’-9” x 14’-0”	0.1 MG	$1,325,000	$204,300	$610,000	$1,604,475	$374,378	$374,378	$2,246,265	$6,738,795
25 MGD	(1) 25 MGD	60’-9” x 22’-0”	0.25 MG	$1,900,000	$341,100	$970,000	$2,408,325	$561,943	$561,943	$3,371,655	$10,114,965
50 MGD	(1) 50 MGD	82’-3” x 32’-0”	0.5 MG	$2,725,000	$532,800	$1,570,000	$3,620,850	$844,865	$844,865	$5,069,190	$15,207,570
75 MGD	(3) 25 MGD	60’-9” x 66’-0”	0.75 MG	$4,725,000	$675,000	$2,100,000	$5,625,000	$1,312,500	$1,312,500	$7,875,000	$23,625,000
100 MGD	(2) 50 MGD	82’-3” x 64’-0”	1.0 MG	$5,250,000	$801,900	$2,300,000	$6,263,925	$1,461,583	$1,461,583	$8,769,495	$26,308,485
450 MGD	(6) 75 MGD	116’-0” x 73’-2”	4.5 MG	$10,000,000	$3,204,900	$6,900,000	$15,078,675	$3,518,358	$3,518,358	$21,110,145	$63,330,435

Notes:
(1) Installation costs are estimated at 115% of the equipment cost per manufacture recommendation.
(2) GC general conditions are estimated at 10% of the total direct cost.
(3) GC OH&P are estimated at 10% of the total direct cost.
(4) 50% of contingency is used for the planning level of cost estimates.

Figure 2-14 - Total Estimated Construction Cost of ACTIFLO® Ballasted Flocculation Unit

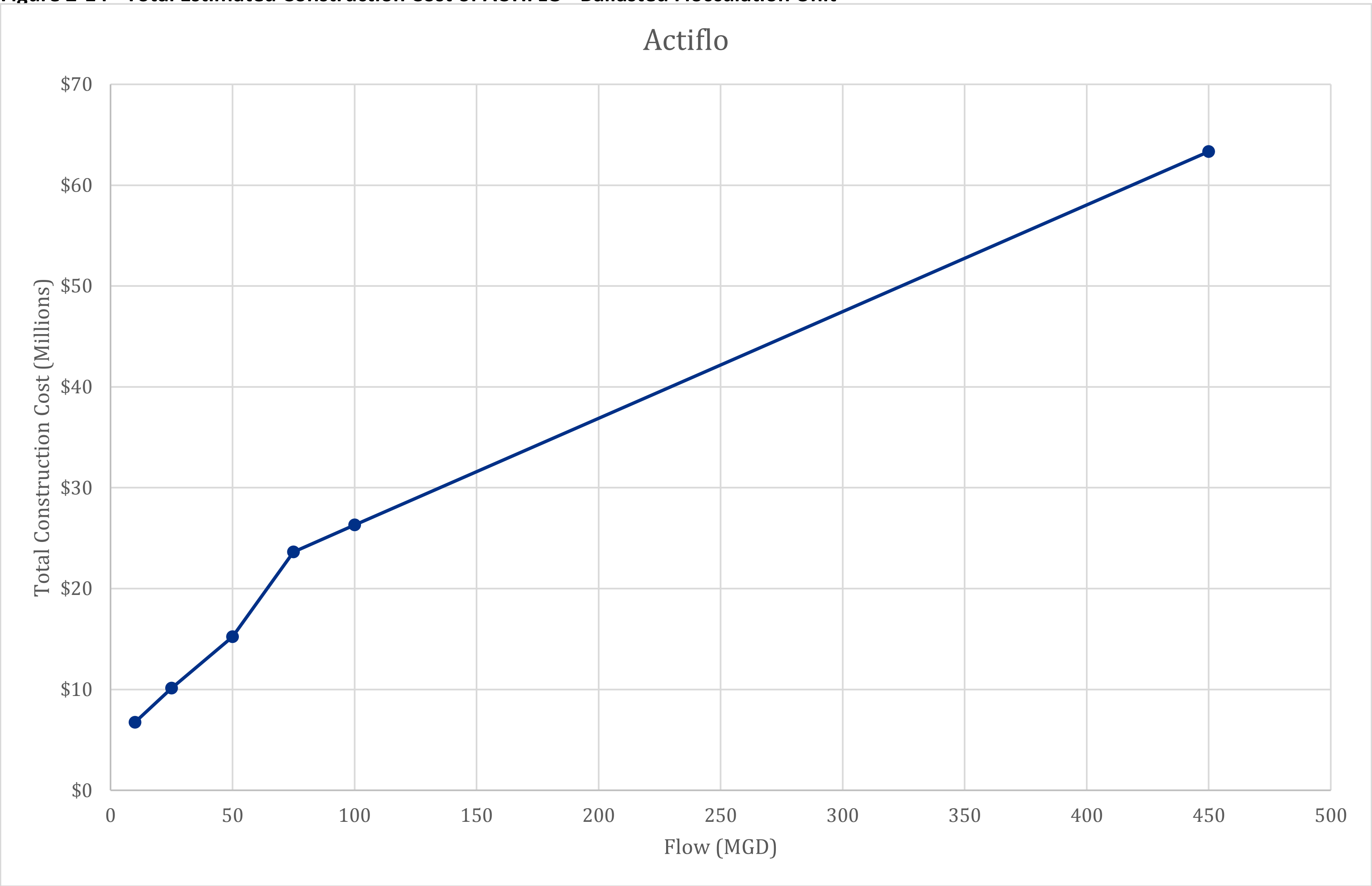


Table 2-19 - Annual Operation Cost of ACTIFLO® Ballasted Flocculation

Flow	Required Horsepower (HP)						Total Power (kW)(1)	Annual Energy Usage (kW-hr)(2)	Annual Power Cost(3)	Alum Usage (lbs)(4)	Polymer Usage (lbs)(5)	Alum Cost(6)	Polymer Cost(7)	Total Annual Cost
	Coag-ulation Mixer	Matur-ation Mixer	Scraper Drive & Mech-anism	Sand Pump	Chemical Pump	Total HP								
10 MGD	10	7.5	2	80	0.5	100	75	37,285	$5,220	173,854	3,477	$10,014	$6,676	$21,910
25 MGD	25	20	7.5	100	0.5	153	114	57,046	$7,986	434,635	8,693	$25,035	$16,690	$49,711
50 MGD	20	30	15	120	1	186	139	69,350	$9,709	869,271	17,385	$50,070	$33,380	$93,159
75 MGD	75	60	22.5	300	1	458.5	342	170,952	$23,933	1,303,906	26,078	$75,105	$50,070	$149,108
100 MGD	80	60	30	240	1.5	411.5	307	153,428	$21,480	1,738,542	34,771	$100,140	$66,760	$188,380
450 MGD	360	270	135	1,080	2	1847	1,377	688,654	$96,412	7,823,438	156,469	$450,630	$300,420	$847,462

Notes:

(1) HP x 0.7457
(2) Assumes 500 hours of annual operation
(3) Assumes energy costs of $0.14/kW-hr
(4) Assume an alum dosage of 100 mg/L
(5) Assumes a polymer dosage of 2 mg/L
(6) Assumes an alum cost of $0.0576/lb
(7) Assumes a polymer cost of $1.92/lb

Table 2-20 - Annual Maintenance Labor Cost of ACTIFLO Ballasted Flocculation Unit

Frequency	Parts	Description	Estimated Man-Hours	Annual Cost[(1)(2)]
Biannually	Coagulation Mixers	Change oil and grease bearings	1	$300
Biannually	Maturation Tank Mixer	Change oil and grease bearings	1	$300
Biannually	Scraper	Change oil and grease bearings	1	$300
Annually	Chemical pumps	Grease bearings	0.5	$75
Biannually	Sand Pumps	Grease bearings	0.5	$150
Annually	Sand Pumps	Change belts	1	$150
Annually	Hydrocyclone	Inspect / change apex tips	0.25	$38
Monthly	Lamella	Cleaning	1 / basin	$3,600
Weekly	System	Inspection and preventive maintenance	0.5	$3,900
After each overflow event	System	System shut down and drain	2	$30,000
Total Annual O&M Cost				$38,813

Notes:
(1) Assumes 100 events per year
(2) Assumes labor rate of $150/hour

2.3.2.2 DensaDeg® Ballasted Flocculation Process

Description of Process

The DensaDeg® is a is a high-rate settling clarifier process combining solids contact, ballast addition and solids recirculation to provide enhanced, high-rate settling of solids. Different from ACTIFLO®, recycled sludge, instead of microsand, is added to increase floc density and precipitation. The process consists of:

1. Rapid mix / coagulation stage: Raw water flows into the rapid (flash) mix zone where a coagulant is added. Coagulation is the destabilization of colloidal particles, which facilitates their aggregation and is achieved by the injection of a coagulant such as alum or ferric chloride.

2. Flocculation zone: Coagulated water then flows to the flocculation zone where, with a lower energy vertical turbine mixer, a continuous ballast media recirculation feed and a low dose of a flocculating agent (polymer) are added to begin the process of agglomerating the coagulated water into floc particles.

3. Maturation zone: Flocculated particles are then developed and grown into large, very dense mature particles. This is achieved with optimized mixing energy and detention time. The result is a floc which settles at extremely high rates.

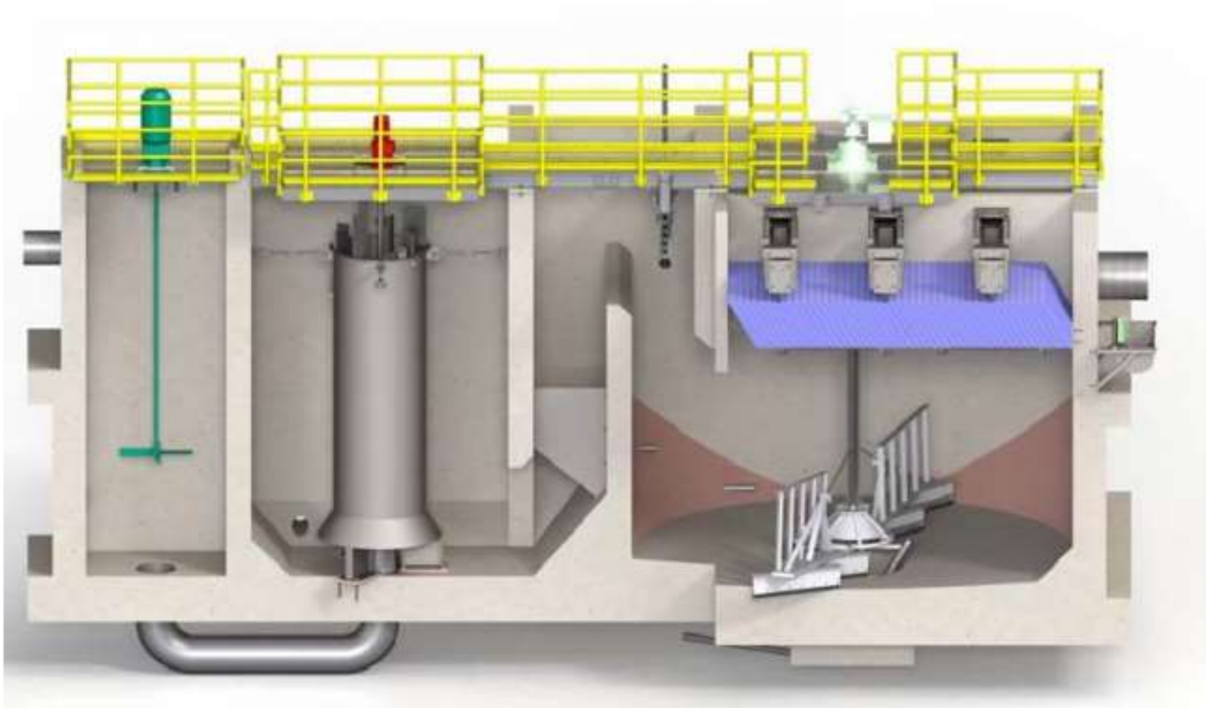
4. Settling & clarification zone: Flocculated solids enter the settling zone, over a submerged weir wall, where dense, suspended matter settles to the bottom of the clarifier. Clarified water is displaced upward from the downward moving slurry, through inclined plate settlers. The plate modules act as a polishing step for lighter, low density solids.

5. Hydrocyclone and ballast recovery: Settled sludge is continuously recycled via a recirculation pump to the hydrocyclone where the ballast media is separated from the waste stream. Ballast is returned to the flocculation zone and the waste stream is sent to sludge handling.

6. Effluent Collection: Uniform collection of clarified water is accomplished in effluent launders above the settling plate assembly.

Cross section of a DensaDeg® unit is shown in Figure 2-15.

Figure 2-15 - Cross Section of a DensaDeg Unit



(Source: Suez North America)

Applicability to the Project

The DensaDeg® ballasted flocculation process is a treatment process that combines solids contact, ballast addition and solids recirculation in a packaged system. It started with the original solids-contact clarifier, the Accelator, which was the first to incorporate internal sludge recycling. In the late 1980's the original DensaDeg clarifier was introduced to the market for high-rate sludge ballasted and solids recirculation systems. The earliest DensaDeg® CSO installation was in 1995.

The DensaDeg® process can be fully automated and the process train(s) can sit idle for extended periods of time and still be fully operational within 30 minutes of start-up. It can be installed at the treatment plant or at a satellite facility within the collection system. Installations at the WWTP also enable the sludge produced by the unit to be processed. When installing the DensaDeg unit in a remote CSO location, the flows will vary widely, and the sludge must be stored so it can be put back into the interceptor at periods of low flow.

Appendix G presents a list of select installations for the original DensaDeg® in CSO/SSO applications.

Performance

The DensaDeg® ballasted flocculation process is sized for the peak hour or day flow to prevent flow from exceeding the capacity of the unit. The units are designed for a surface-loading rate of 40-60 gallons per minute per square foot. When starting up the unit it takes 30 minutes for the process to reach steady state conditions and no sludge inventory is required for startup. The DensaDeg® ballasted flocculation process is very effective in removing vast quantities of pollutants. Its performance is comparable to ACTIFLO® in terms of contaminants removal with TSS removal of 80-90%, typically providing effluent <30mg/L TSS (inlet dependent) and BOD %-removal similar in magnitude to TSS %-removal, when treating typical municipal WW which is 30-40% of total BOD. Removal could be higher depending on soluble ratio.

Hydraulics

The head loss through the units at peak flow rates are reportedly less than two feet.

Generation of Waste Streams

As previously indicated in the description of the process, a portion of the sludge is wasted. The solids percentage of the waste sludge will vary depending on the concentration of the influent TSS and the coagulant dosage. In most cases the solids concentrations will 4%. The quantity of sludge is approximately equal to 0.5% of the capacity of the DensaDeg® unit. When the DensaDeg® process is located at the WWTP, the sludge is sent back to the head of the plant or primary clarifiers, in some cases it is sent to intermediate gravity thickeners and then on to centrifuges or belt thickeners for final processing.

Complexity

Similar to ACTIFLO®, the DensaDeg® ballasted flocculation process consists of chemical addition, which must be controlled by the flow rate, mixers and flocculators, and sludge pumps.

Limitations

DensaDeg® has similar limitations as previously stated for ACTIFLO® plus it requires a longer start time.

Construction Costs

The preliminary planning level construction cost estimates are provided in Table 2-21 for DensaDeg® ballasted flocculation equipment of design flow ranging from 10 MGD to 450 MGD. It includes equipment cost, installation costs, GC field general conditions, GC OH&P, and contingency. Budgetary equipment pricing information for DensaDeg® ballasted flocculation units was gathered from equipment manufacturer Suez. The equipment price includes engineering and project management time. Cost for concrete structure and auxiliary tank for waste sludge storage were also estimated based on equipment sizing and design flowrate. Installation cost was assumed at 115%. The installation cost includes assembly of the DensaDeg® ballasted flocculation unit, excavation and backfilling, and the cost of the Chemical Building and the chemical feed equipment. The estimated total construction costs for the DensaDeg® ballasted Flocculation Unit are plotted against flowrate from 10 MGD to 450 MGD in **Figure 2-**16.

Operation and Maintenance

Similar to ACTIFLO® ballasted flocculation system, operating costs for the DensaDeg® Ballasted Flocculation unit consist of the power and chemical costs. Power costs are based upon the horsepower of the mixers, flocculators, chemical feed equipment and pumps. Chemical costs are based on usage of coagulant and polymer. Routine maintenance and preventive care measures are similar to those for ACTIFLO® unit.

Estimated annual operation costs for the DensaDeg® Ballasted Flocculation unit are presented on

containing factors for calculation of operating costs; while estimated DensaDeg® Ballasted Flocculation unit annual maintenance labor cost including cost factors are included on Table 2-23.

Space Requirements

The space requirements of the DensaDeg® unit shall consist of the size of the tanks and a buffer of 5 feet around the unit for access and maintenance.

Case Study

Veolia Water Technologies provided a white paper[1] detailing the City of Akron, OH, BIOACTIFLO™ demonstration project. Beginning in March of 2012, a pilot plant at the City of Akron Water Reclamation Facility (WRF) was constructed to demonstrate effectiveness of the BIOACTIFLO™ technology. Incorporating high-rate activated sludge in the ACTIFLO™ high-rate ballasted flocculation process, BIOACTIFLO™ is designed to remove soluble BOD that would not otherwise be removed. Influent flow to the pilot plant was pumped from a location that had already undergone preliminary treatment, consistent with plans for the full-scale configuration. Return activated sludge (RAS) was supplied to the pilot plant from the gravity belt thickener building of the WWTP, consistent with plans for the full-scale configuration. Optimal doses for coagulant (alum) and polymer were determined. Both BIOACTIFLO™ and main plant secondary effluent were disinfected in a 0.53 MLD (0.14 mgd) pilot UV disinfection system and comparable results were obtained. Following all testing, effluent from the BIOACTIFLO™ pilot was sent back to the main plant for complete secondary treatment.

The pilot unit was operated during a total of twenty (20) wet weather events between April and December 2012, however the last two events (19 and 20) were performed using slightly different Operational Criteria. Pilot plant operation and sampling was conducted over a range of event durations and volumes, ranging from just under an hour to nearly a day in duration. Results showed an average 85% reduction in CBOD (90% reduction for events 19 and 20). Soluble CBOD concentration dropped from 9.2 mg/L in the influent of the BIOACTIFLO™ to 4.1 mg/L in the effluent from the BIOACTIFLO™. Meanwhile, TSS was reduced by 97%, from influent 144.8 mg/L to 4.0 mg/L effluent. Overall results document the effectiveness of BIOACTIFLO™ as a potential parallel wet weather treatment process at facilities facing wet weather treatment challenges.

[1] Heath, Gregory; Gsellman, Patrick; Hanna, Genny; Starkey, Daniel. Pilot Testing of BIOACTIFLO for Wet Weather Treatment at the Akron, Ohio Water Reclamation Facility

Table 2-21 - Preliminary Construction Cost Estimates for DensaDeg Ballasted Flocculation Unit

Flow	System	Length X Width	Budgetary Equipment Price	Concrete Cost	Auxiliary Tank Cost	Install Cost(1)	GC General Conditions (2)	GC OH&P(3)	Contingency(4)	Total
10 MGD	(1) XRC-2 Concrete	39' x 16'	$988,000	$204,300	$210,000	$1,612,645	$301,495	$301,495	$1,808,967	$5,426,901
25 MGD	(1) XRC-5 Concrete	54' x 22'	$1,111,400	$341,100	$320,000	$2,038,375	$381,088	$381,088	$2,286,525	$6,859,575
50 MGD	(1) XRC-8 Concrete	78' x 32'	$1,405,800	$532,800	$420,000	$2,712,390	$507,099	$507,099	$3,042,594	$9,127,782
75 MGD	(3) XRC-5 Concrete	54' x 66'	$2,458,320	$675,000	$550,000	$4,235,818	$791,914	$791,914	$4,751,483	$14,254,448
100 MGD	(2) XRC-8 Concrete	78' x 64'	$2,811,600	$801,900	$610,000	$4,857,025	$908,053	$908,053	$5,448,315	$16,344,945
450 MGD(5)	(8) XRC-9 Concrete	84' x 136'	$5,727,000	$3,204,900	$1,570,000	$12,077,185	$2,257,909	$2,257,909	$13,547,451	$40,642,353

Notes:
(1) Installation costs are estimated at 115% of the equipment cost per manufacture recommendation.
(2) GC general conditions are estimated at 10% of the total direct cost.
(3) GC OH&P are estimated at 10% of the total direct cost.
(4) 50% of contingency is used for the planning level of cost estimates.
(5) The cost was conservatively higher based on nine units of 50 MGD system.

Figure 2-16 - Total Estimated Construction Cost of DensaDeg Ballasted Flocculation Unit

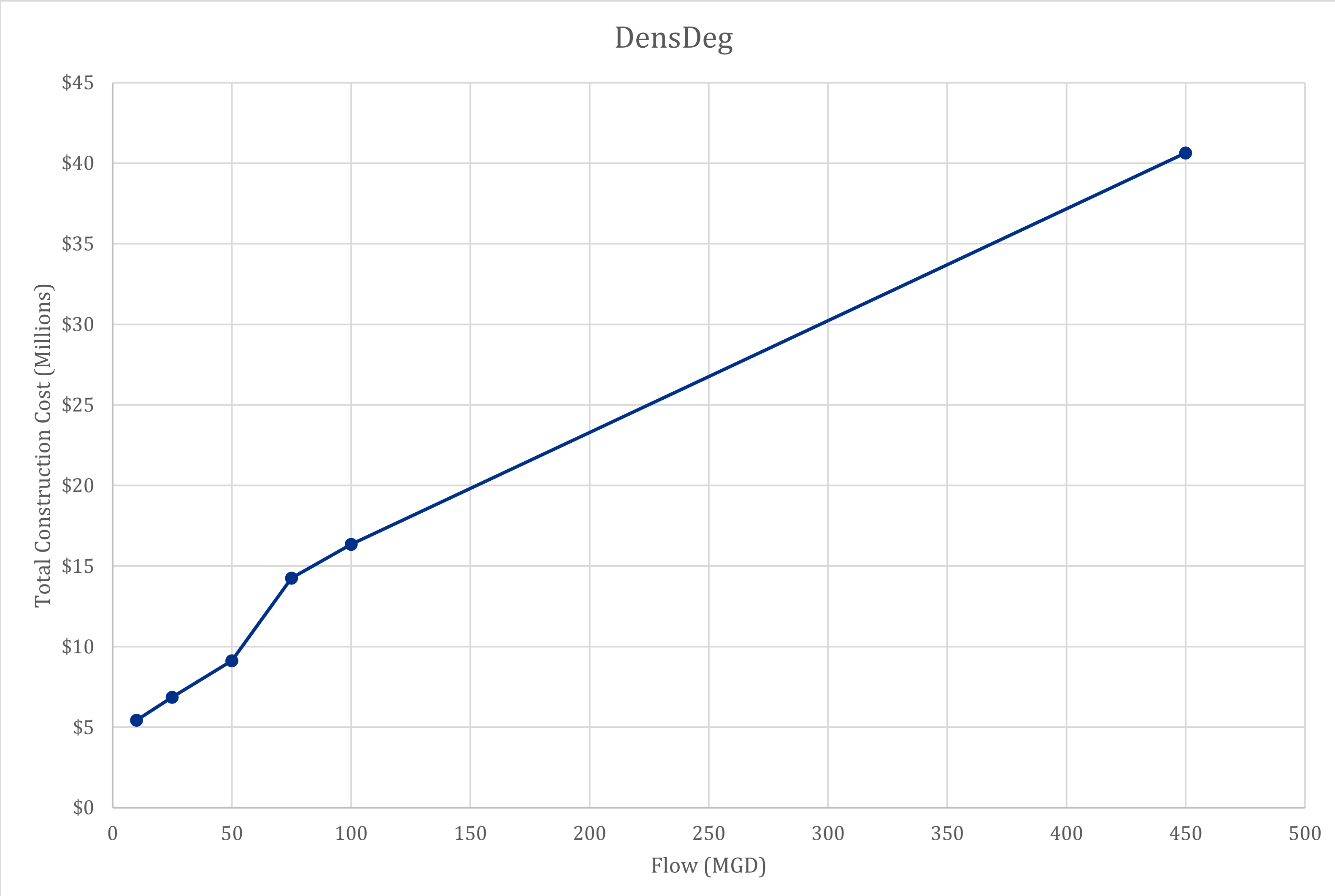


Table 2-22 - Annual Operation Cost of DensaDeg Ballasted Flocculation Unit

Flow	Required Horsepower (HP)						Total Power (kW)(1)	Annual Energy Usage (kW-hr)(2)	Annual Power Cost(3)	Alum Usage (lbs)(4)	Polymer Usage (lbs)(5)	Alum Cost(6)	Polymer Cost(7)	Total Annual Cost
	Rapid Mixer	Reactor Drive	Scraper Drive	Recycle Pump	Chemical Pump	Total HP								
10 MGD	3	5	0.5	30	0.5	39	29	14,541	$2,036	173,854	3,477	$10,014	$6,676	$18,726
25 MGD	5	15	0.5	50	0.5	71	53	26,472	$3,706	434,635	8,693	$25,035	$16,690	$45,431
50 MGD	7.5	15	0.75	50	1	74.25	55	27,684	$3,876	869,271	17,385	$50,070	$33,380	$87,326
75 MGD	12	25	1.25	75	1	114.25	85	42,598	$5,964	1,303,906	26,078	$75,105	$50,070	$131,139
100 MGD	15	30	1.5	100	1.5	148	110	55,182	$7,725	1,738,542	34,771	$100,140	$66,760	$174,625
450 MGD	45	240	6	350	2	643	479	239,743	$33,564	7,823,438	156,469	$450,630	$300,420	$784,614

Notes:
(1) HP x 0.7457
(2) Assumes 500 hours of annual operation
(3) Assumes energy costs of $0.14/kW-hr
(4) Assume an alum dosage of 100 mg/L
(5) Assumes a polymer dosage of 2 mg/L
(6) Assumes an alum cost of $0.0576/lb
(7) Assumes a polymer cost of $1.92/lb

Table 2-23 - Annual Maintenance Labor Cost of DensaDeg Ballasted Flocculation Unit

Frequency	Parts	Description	Estimated Man-Hours	Annual Cost(1)(2)	Frequency
Biannually	Coagulation Mixers	Change oil and grease bearings	1	150	$300
Biannually	Maturation Tank Mixer	Change oil and grease bearings	1	150	$300
Biannually	Scraper	Change oil and grease bearings	1	150	$300
Biannually	Sludge Pumps	Inspect, lubricate pumps and valves, and clean them	2	150	$600
Annually	Chemical pumps	Grease bearings	0.5	150	$75
Annually	Hydrocyclone	Inspect / change apex tips	0.25	150	$38
Monthly	Lamella	Cleaning	1 / basin	150	$3,600
Weekly	System	Inspection and preventive maintenance	0.5	150	$3,900
After each overflow event	System	System shut down and drain	2	150	$30,000
Total Annual O&M Cost					$39,113

Notes:
(1) Assumes 100 events per year
(2) Assumes labor rate of $150/hour

2.3.3 Compressible Media Filtration Process

Description of Process

The compressible media filtration is a process that uses a synthetic, porous filter media. The filter is unusual in a number of ways: (1) the synthetic media is highly porous (89%), (2) filter media and bed properties can be modified because the media is compressible, (3) the fluid to be filtered flows both around and through the media instead of only flowing around the filtering media (as in granular media filters), (4) the fluid that is filtered is used to backwash the filter, (5) to backwash the filter, filter bed volume is increased mechanically, and (6) the filter operates at high filtration rates (up to 40 gal/min/sq. ft.) Performance of the filter, with respect to removal of turbidity and total suspended solids, is similar to the performance of other more conventional filters with the exception that filtration rate is more than 3 to 6 times the rate of other filters. Also, percent backwash water required is significantly less than that used in conventional filtration technologies (typically 1 to 2% versus 6 to 15%).

Compressible media filtration is commercially available as either the “Fuzzy Filter” by Schreiber Industries or the “FlexFilter” by WesTech (both are proprietary technologies covered by patents or pending patents). Both technologies use synthetic fiber spheres as filter media; however, they have different flow configuration, method of bed compression, composition of the synthetic fibers, and media washing details.

The Fuzzy Filter receives the influent at the inlet pipe located at the bottom of the unit. The influent is pressurized upward through the compressed filter media and the effluent is piped out towards the top of the unit, as shown in the process diagram found in Figure 2-17. Porous plates are used to both compress the filter media as well as open up the filter bed to allow movement during backwashing. Figure 17 provides a cross-sectional view of the Fuzzy Filter process, and Figure 2-18 provides an overall picture of the Fuzzy Filter Unit.

Figure 2-17 - Fuzzy Filter Process Diagram

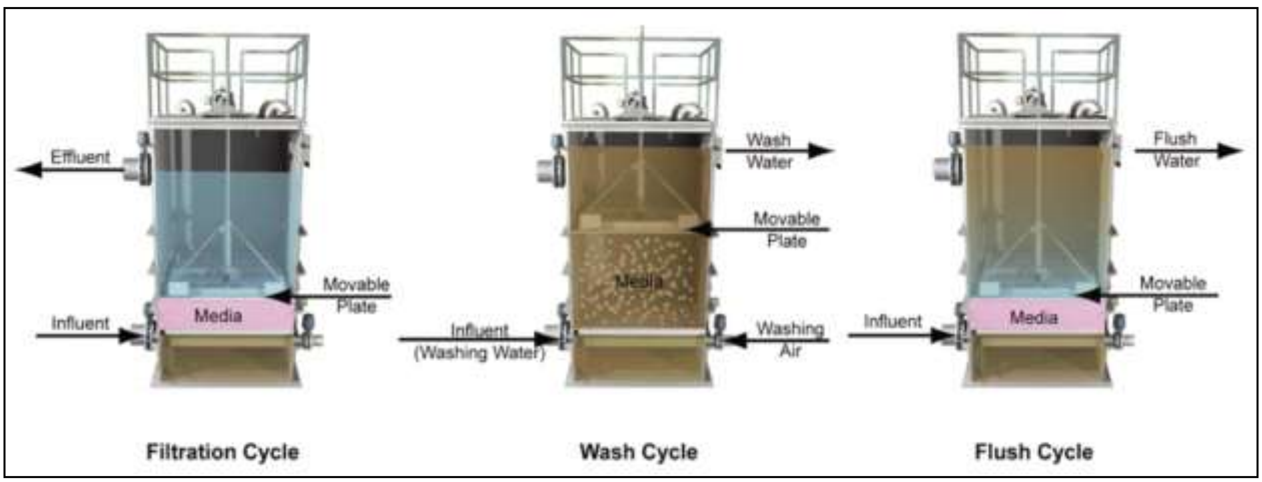
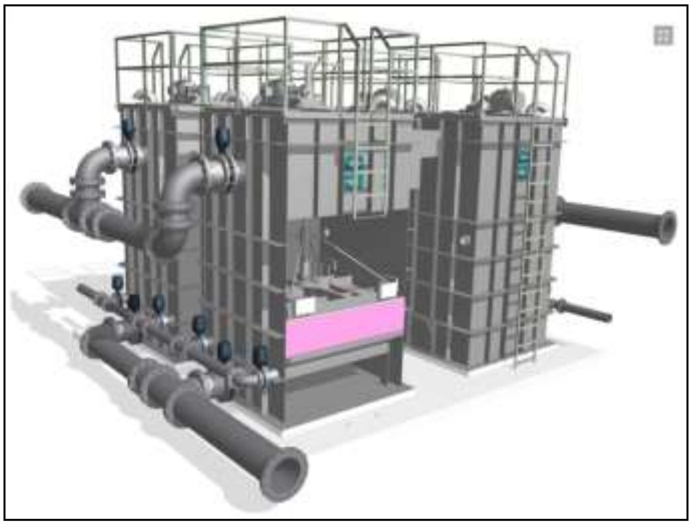


Figure 2-18 - Fuzzy Filter Unit

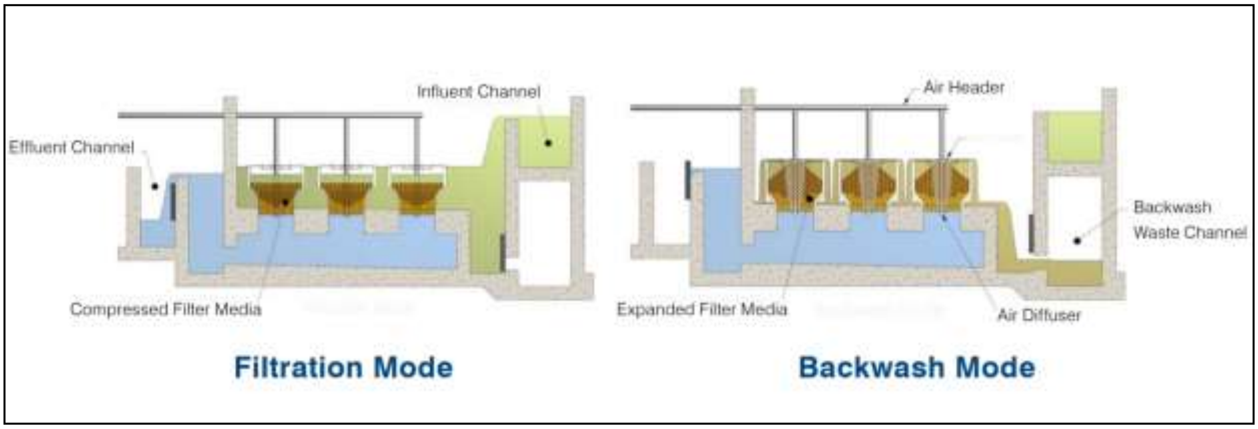


(Source: Schreiber, LLC.)

The FlexFilter receives the inflow from the influent channel. The influent channel is connected to the influent basin where the filter vessels are located. As the influent water accumulates in the influent basin, compression is added to the reinforced rubber sidewalls on the bottom of the filter vessel and compresses the filter bed laterally as the water elevation rises. As the water level in the influent basin reaches the inlet weir elevation, the influent water pours over the influent weir and passes downward through the compressed media bed. Since the bottom of the filter bed compresses more than the top of the filter bed, a porosity gradient is established through the filter bed to capture the largest particles in the upper portion of the filter bed while reserving the deeper portions of the bed to trap finer particles. As particles collect within the media bed, the influent level above the bed rises to a point that signals the need for the media to be cleaned.

The filters use air scouring in the wash cycle to clean the media. During the wash cycle, the feed to the filter is stopped, allowing the media to uncompress. The air scour is initiated along with a small amount of backwash water. The length of the backwash cycle is adjustable. Once cleaned, the filter is put back into service. Figure 2-19 provides a cross-sectional view of the FlexFilter process, and Figure 2-20 provides an overall picture of the FlexFilter Unit.

Figure 2-19 - FlexFilter Process Diagram (Source: WesTech)



(Source: WesTech Engineering, Inc.)

Figure 2-20 - FlexFilter Unit (Source: WesTech)

(Source: WesTech Engineering, Inc.)

Applicability to the Project

The Fuzzy Filter is only used as a polishing step for CSO treatment to meet the most stringent treatment objectives. It does not have a history of treating flows larger than 50 MGD while the FlexFilter has been applied at the 100 MGD Springfield Ohio WWTP treating combined sewer overflow. In addition, the FlexFilter is a simple gravity system requiring no moving parts. The compression of the media is accomplished through a lateral hydraulic force applied from the incoming liquid, eliminating mechanically actuated internal components. For the purpose of the Technical Guidance Manual, FlexFilter was selected for further evaluation.

Performance

For CSO applications FlexFilter is typically operated at 4 gpm/sq. ft. HLR during the first flush portion of a CSO event and gradually increases the operating HLR as the CSO flow rate increases and solids concentration decrease. The maximum HLR of CSO treatment is typically limited to 10 gpm/sq. ft. at design peak flow. The performance information provided by the manufacturer indicates that the contaminants removal efficiency of WWETCO FlexFilter in CSO application ranges from 73% to 94% for TSS removal and 16% to 69% for CBOD removal.

In the Bayonne MUA pilot study, FlexFilter was evaluated in terms of TSS removal. The influent to the FlexFilter was pumped from the Storm King effluent. No raw CSO feed to the FlexFilter was evaluated due to limited wet weather events during the time of the pilot test. The FlexFilter units experienced operating issues primarily related to the pumps and the time needed to backwash. Shorter filter run times and frequent backwashing were experienced when testing was conducted at the higher end of the filter loading rate recommended for CSO treatment.

The pilot study showed that the compressed media filter was consistent and effective in removing finer and organic suspended solids. Overall the FlexFilter was capable of removing 90% of the TSS even at a HLR of 12 to 18 gpm/sq. ft. The unit as tested spent up to 1/2 of the typical four hour run time in backwash cycle, however it was operated at 3 to 4 the recommended hydraulic loading rate in order to supply downstream disinfection with higher flows. TSS removal rates for the FlexFilter improved the ultraviolet transmittance (UVT) of the effluent flow; however, UVT values were still modest. The effluent from the FlexFilter averaged approximately 25 mg/L for TSS and 40% on UVT.

Hydraulics

The headloss through the FlexFilter structure, under the conditions stated above, is about 8 feet.

Generation of Waste Streams

The only waste stream produced by the FlexFilter is the backwashing of the filters. The FlexFilter utilizes low head air to accomplish the media scrubbing while lifting the backwash water to waste, thus minimizing backwash waste volumes. Portions of the backwash water would be diluted with filter drains and recycled back to filter influent. The concentrated backwash water would be stored and put back into the interceptor system when there was available capacity, for removal at the WWTP.

Complexity

As a result of how this unit operates; the automated valves, hydraulically operated porous plate, the air injection into the beds during backwashing, and the monitoring needed for the flow and headloss conditions, this process is the most complex of the pretreatment processes being considered as part of this Technical Guidance Manual.

Limitations

The influent TSS concentration to the FlexFilter is limited to less than 100 mg/L. Higher TSS concentrations will increase the backwash time resulting in overall reduced performance of the units. The 7 feet of headloss through the units is also a limitation since there is usually minimal head available from the regulator to the discharge at the water body. The valves in the FlexFilter unit are an issue during outdoor operation in freezing weather conditions.

Construction Costs

The preliminary planning level construction cost estimates are provided in Table 2-24 for FlexFilter design flows ranging from 10 MGD to 450 MGD. It includes equipment cost, installation costs, GC field general conditions, GC OH&P, and contingency. Budgetary equipment pricing information for FlexFilter was gathered from equipment manufacturer WesTech Engineering, Inc. The equipment price includes engineering and project management time. Installation cost was assumed at 150% of equipment cost based on equipment manufacturer's recommendations. The installation cost includes assembly of the FlexFilter system, excavation and backfilling, conduits, filter matrix, and backwash and effluent pumping. The estimated total construction costs for the FlexFilter are plotted against flowrate from 10 MGD to 450 MGD in Figure 2-21.

Operation and Maintenance

Estimated annual operation and maintenance costs for FlexFilter unit are presented Table 2-25 based on vendor provided information. It consists of the power costs for the blowers, recycle pumps, and backwash pumps as well as media change-out cost, labor for preventative and routine maintenance, and labor for post event clean-out.

Case Study

According to literature obtained from WWETCO (a subsidiary of WesTech), the FlexFilter™ was installed at the Weracoba Creek Stormwater Treatment system in Columbus, GA. This 10 MGD filter capacity with 2 MGD UV disinfection capacity, was funded by a $0.9 million EPA 319(h) grant to evaluate treatment of urban stormwater runoff. The treatment system has been in operation since 2007. Influent solids ranged from 300 mg/L to 100 mg/L TSS. Effluent TSS was between 5 mg/L and 15 mg/L. Additionally, total maximum daily load (TMDL) requirements for fecal coliform and macro-invertebrates were met. This facility also installed the WWETCO FlexFlow™ Control Valve which allows aquatic biology passage during dry weather flow and causes the head differential needed to operate the filter during wet-weather flow.

Table 2-24 - Preliminary Construction Cost of the FlexFilter

Flow	# Cells	Cell Filter Area (ft^2)	Budgetary Equipment Price	Install Cost[(1)]	GC General Conditions [(2)]	GC OH&P[(3)]	Contingency[(4)]	Total
10 MGD	5	720	$739,000	$1,108,500	$184,750	$184,750	$1,108,500	$3,325,500
25 MGD	5	1,800	$1,403,000	$2,104,500	$350,750	$350,750	$2,104,500	$6,313,500
30 MGD	5	2,340	$2,797,000	$4,195,500	$699,250	$699,250	$4,195,500	$12,586,500
100 MGD	10	7,200	$3,831,000	$5,746,500	$957,750	$957,750	$5,746,500	$17,239,500
200 MGD	18	12,960	$5,733,000	$8,599,500	$1,433,250	$1,433,250	$8,599,500	$25,798,500
450 MGD	32	23,040	$23,463,000	$35,194,500	$5,865,750	$5,865,750	$35,194,500	$105,583,500

Notes:
(1) Installation costs are estimated at 115% of the equipment cost per manufacture recommendation.
(2) GC general conditions are estimated at 10% of the total direct cost.
(3) GC OH&P are estimated at 10% of the total direct cost.
(4) 50% of contingency is used for the planning level of cost estimates.

Figure 2-21 - Total Estimated Construction Cost of FlexFilter

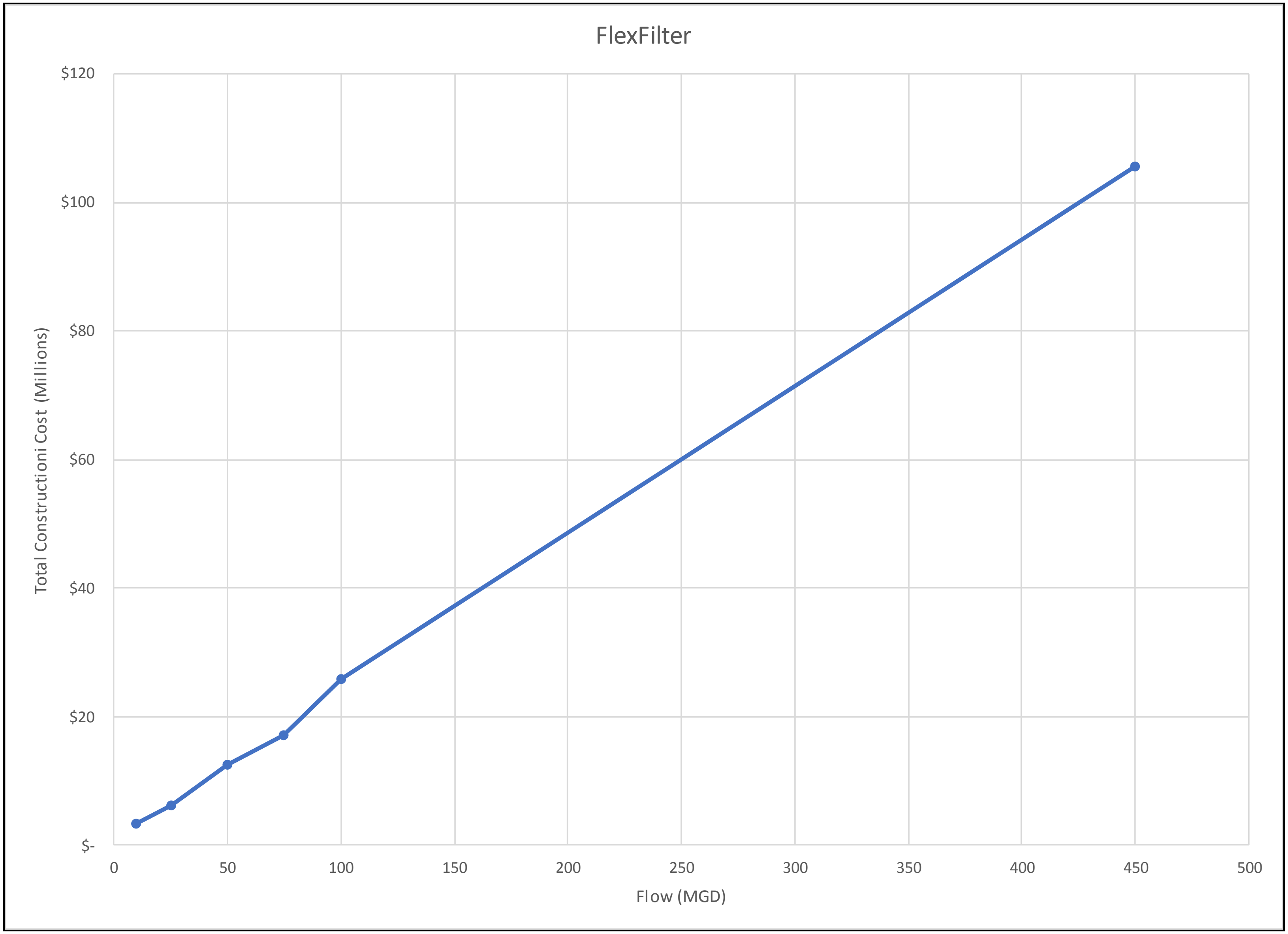


Table 2-25 - Annual Operation and Maintenance Cost of FlexFilter

Flow	Blower Power (kw-hr/MG Treated)	Blower Energy Costs(1)(2)	Media Addition after 10 yrs(3)	Event Labor	Preventative O&M	Backwash & Recycle Pumping	Effluent Pumping	Total Annual O&M
10 MGD	47	$700	$2,254	$20,000	$800	$703	$879	$25,336
25 MGD	48	$1,750	$5,636	$20,000	$2,000	$1,758	$2,198	$33,342
50 MGD	50	$3,500	$7,326	$20,000	$2,400	$2,110	$2,637	$37,973
100 MGD	48	$5,250	$22,542	$20,000	$8,000	$7,033	$8,791	$71,616
200 MGD	53	$7,000	$40,576	$20,000	$16,000	$14,066	$17,582	$115,224
450 MGD	50	$31,500	$72,135	$20,000	$36,000	$31,648	$39,561	$230,844

Notes:
(1) Assumes 500 hours of annual operation
(2) Assumes energy costs of $0.14/kW-hr
(3) Media cost is distributed annually based on given future cost

2.3.4 Evaluation of Pretreatment Technologies

The above process descriptions provide general information on pretreatment processes that may be required for disinfection of CSO discharges. These processes have been evaluated for pretreatment of CSO flow relative to criteria on cost, performance, limitations, and ancillary facilities. Each process was rated from 1 to 5, with 5 being the highest, for approximately twenty different items and totaled. While somewhat subjective, this method does provide a mechanism for comparing each pretreatment process in relationship to each category and subcategory. The results of the evaluation are illustrated in Table 2-26.

Based upon the evaluation results in Table 2-26, the SANSEP process has the highest rating, followed by the ACTIFLO® ballasted flocculation, the DensaDeg® ballasted flocculation, FluidSep vortex units and Storm King®. The Compressible Media Filter received the lowest rating, however this process is used only for polishing the effluent from the other processes in the most stringent treatment objective.

For the vortex/swirl process, the performance of the Storm King® and FluidSep vortex units are essentially the same, but the construction cost of the FluidSep is significantly less, due to the limited use of fabricated metal components, as compared to the Storm King® Unit.

For the ballasted flocculation processes, a similar simplification is possible. The ACTIFLO® process produces less sludge than the DensaDeg® process requiring less ancillary tankage, no cyclone separator and no sand replacement.

Table 2-26 - Evaluation of Pretreatment Technology

Criteria	Vortex Separator		Modified Vortex	Ballasted Flocculation		Polishing Filter
	Fluidsep Vortex	**StormKing Vortex**	**SANSEP**	**ACTIFLO® Ballasted Flocculation**	**DensaDeg® XRC Ballasted Flocculation**	**FlexFilter**
Applicability	5	5	4	4	4	2
Performance						
TSS	3	3	5	5	5	5
Hydraulics	3	3	4	3	3	1
Wastestreams	1	1	4	3	3	2
Complexity	5	5	4	3	3	1
Limitations	2	2	4	4	3	3
Construction Cost	4	2	5	3	3	1
Operations	4	4	4	2	2	1
Maintenance	4	4	4	2	2	1
Space Requirements	3	3	3	4	4	2
Requiring:						
Ancillary Tanks	1	1	4	3	3	5
Total	35	33	45	36	35	24

2.4 Disinfection

This section evaluates the implementation of the following chemical and physical disinfection technologies:

- Chlorination (consisting of Chlorine Dioxide, Sodium Hypochlorite, and Calcium Hypochlorite)
- Peracetic Acid
- Ultraviolet (UV) Disinfection
- Ozonation

The evaluation will consist of a description of the particular disinfection technology, the concentrations or intensities normally needed and the equipment or process used to apply the disinfectant. The evaluation will also discuss any limitations of the process or equipment. Also considered in the evaluation will be any inhibiters that will interfere with the disinfection process, and the need for any for dechlorination. The analysis will also consider the safety of the process and the availability of the chemicals or the equipment to produce them.

Disinfection is more difficult to design and operate in CSO applications than in wastewater treatment plants due to the complex characteristics of CSOs. The flowrates of CSOs are highly variable which makes it difficult to regulate the addition of disinfectant. The concentration of suspended solids is high and the temperature and bacterial composition varies widely. Pilot studies are commonly conducted to characterize the range of conditions that exist for a particular area and the design criteria to be considered.

In the cases of chemical addition; chlorine dioxide, sodium hypochlorite, calcium hypochlorite, and peracetic acid, the disinfectant must be mixed with the liquid to be disinfected. Experience has shown that the long contact time required for conventional wastewater treatment is not appropriate for the treatment of CSOs; however, chemical disinfection of CSOs can be accomplished using high-rate disinfection. High-rate disinfection is defined as employing high-intensity mixing to accomplish disinfection within a short contact time, generally five minutes. For this TGM, a chemical induction flash mixer, such as manufactured by The Mastrr Company, will be used to mix either the gas or liquid with the flow to be disinfected. The mixer develops a "G" value of 1,000/sec. The detention time in the mixing zone of the mixer is 3 seconds. Following the mixer, a tank area with a detention time of 5 minutes at the design rate, will be used to provide adequate mixing. In the case of sodium hypochlorite and calcium hypochlorite, a second induction mixer will be used to mix the dechlorination chemicals, sodium bisulfite, with the flow before discharging to the receiving water. No tankage would be provided following the addition of dechlorination chemicals.

The efficiencies of virtually all the disinfection processes being considered in this TGM are dependent upon the TSS concentration of the liquid being disinfected. The required TSS concentration for each of the disinfection processes for different treatment objectives is shown in

Table 2-27.

Table 2-27 - Maximum TSS Concentration for Each Disinfection Process

Fecal Coliform Objectives (MPN/100ml)	Maximum TSS Concentration (mg/L)			
	Chlorine Dioxide	Sodium Hypochlorite	Peracetic Acid	Ultraviolet Disinfection
200	70	45	70	25
770	70	45	70	25
1,500	70	45	70	25

2.4.1 Chlorine Dioxide

Process Description

Chlorine dioxide (ClO_2) is most commonly used for drinking water treatment to oxidize reduced iron, manganese, sulfur compounds, and certain odor-causing organic substances in raw water. Chlorine dioxide is often used as a pre-oxidant because, unlike chlorine, it will not chlorinate organic compounds and therefore will not react with organic matter in the water to form trihalomethanes (THMs) or other byproducts. In industrial markets, chlorine dioxide has been most readily used in the paper and pulping industry. In this application, chlorine dioxide is used as bleach for paper pulp since it does not react with the organic lignin in the wastewater to form by-products such as the THMs.

The data for chlorine dioxide shows that it is a more effective disinfectant than sodium hypochlorite. However, chlorine dioxide needs to be generated on site because it is too unstable even for short periods of time. There is one type of chlorine dioxide generator that utilizes hydrochloric acid and sodium chlorite in either commercially available or diluted concentrations to generate chlorine dioxide. They produce chlorine dioxide and consistently maintain a product yield greater than 95%, making it ideal for drinking water treatment. The use of chlorine gas is not required when using these systems. These systems produce relatively small amounts of chlorine dioxide for disinfection in water systems where low concentrations of ClO_2 are needed.

There is a second process, which produces "large quantities" of gas for disinfection of drinking water and wastewater. This is the Ben Franklin™ process, manufactured by CDG Environmental, LLC. The Ben Franklin™ process uses the chemical reaction of hydrochloric acid with sodium chlorate to generate chlorine dioxide to produce a mixture of chlorine and chlorine dioxide, both in the gas phase. These gases, as produced by the Ben Franklin™ generator, may be applied directly to water as a combination, or they may be separated and applied at different points in the water treatment process. In its most direct application, the mixed chlorine/chlorine dioxide product can be injected into the water to be treated. The result is a mixed disinfectant containing chlorine dioxide and chlorine. The chlorine dioxide acts as a very rapid disinfectant/oxidant while the chlorine persists longer. This can be an advantage in the water systems where a residual is desired but a disadvantage in the receiving water where disinfection byproduct is a concern.

The use of chlorine dioxide in wastewater disinfection has been very limited in US. Technologies are currently unavailable to provide an easier and safer way to produce chlorine dioxide at a concentration for CSO treatment at remote satellite locations. Chlorine dioxide is extremely unstable and explosive and any means of transport is potentially hazardous. Chlorine dioxide can produce potentially toxic byproducts such as chlorite and chlorate. Chlorine dioxide will not be considered further.

2.4.2 Sodium Hypochlorite

Description of Process

Hypochlorite is a commonly used disinfectant in water and wastewater treatment and has been applied as a CSO disinfectant. It can be produced on site or can be delivered in tanker trunks with concentrations between 3 to 15% of available chlorine. Hypochlorite decays over time. The decay rate can increase as a result of exposure to light, time, temperature increase or increased concentration of the compound. The solution can be stored for 60 to 90 days before the disinfecting ability degrades below recommended values (5% concentration). Degradation of the solution over time is a major disadvantage of sodium hypochlorite for CSO applications, due the variability of the size and frequency of rain events. There are two types of hypochlorite: Sodium hypochlorite (NaOCl) and Calcium hypochlorite ($Ca(ClO)_2$). Sodium hypochlorite is often referred to as liquid bleach or soda bleach liquor, while Calcium hypochlorite is manufactured either as a grain or powder under various names, and all have either approximately 35% or 65% available chlorine content. Sodium hypochlorite is the most widely used of the hypochlorites for potable water and waste treatment purposes. Although it requires much more storage space than high-test calcium hypochlorite and is costlier to transport over long distances, it is more easily handled and gives the least maintenance problems with pumping and metering equipment. It will be used as the basis for evaluating disinfection alternatives.

Based on molecular weight, the amount available as chlorine is 0.83 lbs/gal for a 10% solution of sodium hypochlorite and 1.25 lbs/gal for a 15% solution.

Required Concentrations

The application of sodium hypochlorite as a disinfectant was studied by the USEPA in Syracuse, New York. An equation was developed to estimate the chlorine concentration needed to achieve a particular log-kill of fecal coliform. The parameters included in the equation include the pH of the liquid, the influent fecal coliform count to the disinfection process, the TSS concentration, and the mixing factor of GT. The equation is as follows:

Log-kill = (0.08C^0.36) * (GT^0.42) * (SS^-0.07) * (FC^0.02) * (10^(-0.03pH))

Where:
C = concentration of disinfectant (mg/L as Cl_2)
SS = concentration of SS (mg/L)
FC = Influent level of fecal Coliform, (counts/100 ml)
pH = pH
GT = mixing intensity x detention time.

This is based upon the G of 1000 discussed above, and a three second detention time in the mixing zone of the mixer.

Computations done using this equation, for the range of parameters expected in CSO waters, indicate that a chlorine concentration of between 18-24 mg/L will disinfect the fecal coliform concentrations to the levels expected in the LTCP treatment objectives.

Equipment Needed

Sodium hypochlorite is delivered to the site in liquid form as either a 10% or 15% solution. The sodium hypochlorite is stored in a tank and is fed into a rapid induction type mixer at a rate established by the flow, through a chemical feed pump. A 12.5% solution may degrade to 10% in 6 to 8 weeks, in which case the degradation rate slows. Typically it is stored as a 5% solution of available chlorine. It should be stored at temperatures below 85 degrees Fahrenheit in a corrosion resistant tank and protected from light exposure. For the purpose of this TGM, the chemical storage is estimated to store enough chemical for 24-hours of continuous treatment at the design overflow rate plus a safety factor of 1.5.

The chemical storage tank and the feed pump would be stored in a building with the induction mixer installed in a channel, followed by a detention tank with a 5-minute detention time, as described at the beginning of this section.

Limitations

One of the problems with sodium hypochlorite is that the solutions are vulnerable to a significant loss of available chlorine in a few days. This is described as the shelf life of the chemical. The stability of hypochlorite solutions is greatly affected by heat, light, pH, and the presence of heavy metal cations. The higher the concentration, and the temperature the higher the deterioration. A 15% solution will deteriorate to half strength in approximately 120 days. A 10% solution will take approximately 220 days.

The limited shelf life of sodium hypochlorite makes it difficult in an intermittent application like a CSO to ensure that the correct amount of disinfectant is being introduced into the waste stream. This can lead to under or over disinfecting, which can make it difficult to achieve the required treatment objective.

Inhibitors

High TSS concentrations would be an inhibitor to disinfection using sodium hypochlorite, primarily by shielding the fecal Coliform from the disinfectant.

Need for Dechlorination

The use of chlorine disinfection of wastewater can result in several adverse environmental impacts especially due to toxic levels of total residual chlorine in the receiving water and formation of potentially toxic halogenated organic compounds. Chlorine residuals have been found to be acutely toxic to some species of fish at very low levels. Other toxic or carcinogenic chlorinated compounds can bioaccumulate in aquatic life and contaminate public drinking water supplies. For this reason, excess chlorine must be dechlorinated. Gaseous sulfur dioxide, liquid sodium bisulfite, sodium thiosulfate, sodium sulfite, and sodium metabisulfite can be used for this purpose. Sodium bisulfite is the most commonly used chemical for dechlorination due to the ease of handling, fewer safety concerns, economic reasons, and availability. For this TGM the use of sodium bisulfite is assumed. Typical characteristics are shown in the Table 2-28 below. Sodium bisulfite can decay about 40 % over a period of six-months. The storage should consider the release of sulfur dioxide when the sodium bisulfite is stored in a warm environment; a water scrubber is typically used to diffuse and dissolve off-gas. Another operational problem is the crystallization of sodium bisulfite when the temperature drops below the saturation point: -6.7^{0}C for 25% solutions and 4.4^{0}C for 38% solutions.

Table 2-28 - Sodium Bisulfite Key Properties

Property	Value
Concentration	38% (25% solutions)
Molecular Weight	104.06
Boiling Point	> 100˚C
Freezing Point	-12˚C
Saturation Temperature	4.4˚C @ 38%
Vapor Pressure	78 mm Hg @ 37.7˚C
Specific Gravity	1.36 @25˚C
pH	3 to 4
Solubility in water	Completely

Sodium bisulfite could be stored indoors in a conditioned building to minimize the degradation due to high temperature and sunlight exposure. To minimize the potential of chemical interaction the storage tanks of sodium hypochlorite and sodium bisulfite have to be isolated from each other.

A rapid induction mixer located in a channel downstream of the contact chamber, as described earlier in this section will accomplish the mixing of sodium bisulfite. Since the Dechlorination process is essentially instantaneous, no contact chamber is required downstream of the injection.

Costs

The costs for the sodium hypochlorite disinfection system include several components including chlorine contact tank, the chemical storage facility for sodium hypochlorite and sodium bisulfite, pumping system for disinfection and dechlorination, mixers, piping and storage tanks.

The preliminary report level construction cost estimates provided in Table 2-29 include the equipment, installation, building, and contingency for a sodium hypochlorite disinfection system of design flow ranging from 10 MGD to 450 MGD. Budgetary equipment pricing information was gathered from equipment manufacturers.

Operation and Maintenance

Operating costs for hypochlorite disinfection systems consist of the power and chemical costs. Power costs are based upon the horsepower of the metering pumps and rapid mixers. Chemical costs are based on usage of sodium hypochlorite and sodium bisulfite.

The equipment would be housed in a building; therefore, maintenance costs consist of labor costs for housekeeping of the building, preventative and corrective maintenance of the mechanical equipment including the chemical metering pumps, mixers, and other appurtenances, and restocking of the chemicals. The chlorine contact tanks will also need periodic maintenance to clean debris.

Estimated annual operation costs for the hypochlorite disinfection system are presented on Table 2-30 containing factors for calculation of operating costs; while estimated annual maintenance labor cost including cost factors are included on

Table 2-31.

Space Requirements

The space requirements of the facilities required for disinfection using sodium hypochlorite are based upon the size of the mixing chamber/tank size for chlorination, the chemical building size for chlorination and de-chlorination, the size of the mixing chamber for de-chlorination, and a buffer of 5 feet around each.

Table 2-29 - Preliminary Construction Cost for Chlorination Systems

Flow	Chlorine Contact Tank Cost	Building Cost	Hypochlorite Pump System and Apprt. Cost	Bisulfite Pump System and Apprt. Cost	Hypochlorite Storage Tank Cost	Bisulfite Tank Cost	Mixer and control valves Cost
10 MGD	$125,000	$156,475	$28,000	$16,450	$21,495	$7,900	$150,000
25 MGD	$310,000	$336,159	$35,700	$16,450	$44,990	$8,495	$200,000
50 MGD	$620,000	$507,778	$49,000	$19,250	$97,485	$10,685	$380,000
75 MGD	$930,000	$681,742	$50,750	$19,250	$129,980	$13,183	$450,000
100 MGD	$1,240,000	$820,039	$61,250	$27,300	$162,475	$13,483	$550,000
450 MGD	$5,580,000	$3,883,107	$231,000	$105,000	$779,880	$50,872	$2,000,000

Flow	Installation Cost(1)	GC General Conditions (2)	GC OH&P(3)	Contingency(4)	Total
10 MGD	$757,980	$126,330	$126,330	$757,980	$2,273,939
25 MGD	$1,427,690	$237,948	$237,948	$1,427,690	$4,283,071
50 MGD	$2,526,297	$421,050	$421,050	$2,526,297	$7,578,891
75 MGD	$3,412,357	$568,726	$568,726	$3,412,357	$10,237,072
100 MGD	$4,311,820	$718,637	$718,637	$4,311,820	$12,935,461
450 MGD	$18,944,788	$3,157,465	$3,157,465	$18,944,788	$56,834,364

Notes:
(1) Installation costs are estimated at 150% of the equipment cost.
(2) GC general conditions are estimated at 10% of the total direct cost.
(3) GC OH&P are estimated at 10% of the total direct cost.
(4) 50% of contingency is used for the planning level of cost estimates.

Table 2-30 - Annual Operation Cost for Hypochlorite Disinfection

Flow	Sodium Hypochlorite Metering Pump[(8)]	Sodium Bisulfite Metering Pump[(8)]	Total HP	Total Power (kW)[(1)]	Annual Energy Usage (kW-hr)[(2)]	Annual Power Cost[(3)]	Sodium Hypochlorite Usage (lbs)[(4)]	Sodium Bisulfite Usage (lbs)[(5)]	Sodium Hypochlorite Cost[(6)]	Sodium Bisulfite Cost[(7)]	Total Annual Cost
10 MGD	1.5	0.5	2	1	746	$104	39,986	8,693	$19,993	$17,385	$37,483
25 MGD	2	0.5	2.5	2	932	$130	99,966	21,732	$49,983	$43,464	$93,577
50 MGD	5	1	6	4	2237	$313	199,932	43,464	$99,966	$86,927	$187,206
75 MGD	7.5	1	8.5	6	3169	$444	299,898	65,195	$149,949	$130,391	$280,784
100 MGD	5	1.5	6.5	5	2424	$339	399,865	86,927	$199,932	$173,854	$374,126
450 MGD	25	4	29	22	10813	$1,514	1,799,391	391,172	$899,695	$782,344	$1,683,553

Notes:
(1) HP x 0.7457
(2) Assumes 500 hours of annual operation
(3) Assumes energy costs of $0.14/kW-hr
(4) Assumes a sodium hypochlorite dosage of 23 mg/L
(5) Assumes a sodium bisulfite dosage of 5 mg/L
(6) Assumes a sodium hypochlorite cost of $0.50/lb
(7) Assumes a sodium bisulfite cost of $2/lb
(8) Metering pump HP based on quotations by Pyrz Water Supply Co., Inc.

Table 2-31 - Annual Maintenance Labor Cost of Hypochlorite Disinfection

Frequency	Estimated Man-Hours	Annual Cost
Daily Check	1	$54,750
Weekly Check	4	$31,200
Monthly Check	8	$14,400
Quarterly Clean and Check	12	$7,200
Total Annual Maintenance Cost		$107,550

Notes:
(1) Assumes labor rate of $150/hour

2.4.3 Peracetic Acid Disinfection

Description of Process

Peracetic acid (CH_3CO_3H), also known as PAA, is an organic peroxy compound, which has strong oxidizing properties. In the presence of water (H_2O), it breaks down into a mixture of hydrogen peroxide (H_2O_2) and acetic acid (CH_3CO_2H). The mixture is clear and colorless with no foaming capabilities and has a strong pungent acetic acid (vinegar) odor. PAA is a very strong oxidizing agent and has a stronger oxidation potential than chlorine or chlorine dioxide. It has been used as a bactericide and fungicide in various industries including the food and beverage industries, the textile and pulp and paper industries, as well as smaller, more confined applications, including hospital settings.

The U.S. EPA approved peracetic acid as a primary disinfectant for wastewater in 2007 while PAA has been used to treat wastewater in Europe for over a decade. Since the EPA approval, only a limited number of wastewater treatment plants in the United States have adopted PAA as a primary disinfectant, including a wastewater treatment plant in St. Augustine, Florida that discharges treated flow to environmentally-sensitive wetlands. Case studies have also been conducted at a number of treatment plants including a wastewater treatment plant in Frankfort, Kentucky and the Bayonne MUA pilot study for CSO treatment.

PAA decomposes quickly and its ultimate fate in the environment is the basic molecules of carbon dioxide, oxygen, and water. Toxicity studies were conducted on PAA in the 1980's to evaluate impact of PAA disinfected primary effluent on the bay environment. The study concluded that there was no toxicity impact. The Bayonne MUA pilot study and other studies on PAA disinfection of wastewater did not experience toxicity of residual PAA. However, more studies are still required to prove that residual PAA poses no toxicity to aquatic life.

Solutions of PAA for wastewater disinfection are typically of 10% and 15% concentrations, higher concentrations have issues with stability. The shelf life of PAA is normally 12 months. However, PAA must be stored at the site where it is dispensed, as underground piping is not permitted. PAA are fed using a diaphragm pump with Teflon diaphragms and polypropylene, Teflon materials and degassing heads are recommended for feeding. The product should be fed into the waste stream at an area of good mixing to promote rapid dispersion. It may be introduced continuously or intermittently depending upon the needs of the user.

Required Concentrations

This is an area where more research and investigation needs to be done, particularly as it related to disinfection of CSOs. The application of PAA as a disinfectant was studied in the Bayonne MUA pilot study. PAA disinfection tests were performed with PAA dose of typically 2 to 3 mg/L, but up to 7 mg/L, targeting PAA residual in 1 to 2 mg/L range. The best-defined relationship derived from the study results was that between the applied dose of PAA as normalized by COD present in the wastewater and the log reduction of pathogen indicators. PAA dose of 0.01 mg/L of PAA per mg/L of COD present in wastewater resulted in 3-log reduction of fecal coliforms (on average), with slightly higher effectiveness for E. coli and slightly lower for Enterococci. Increasing the relative dose to above 0.015 mg/L of PAA per mg/L of COD increased log reduction to 4. Further increase of the PAA dose appeared to have limited effect on further increasing reduction of the bacterial densities, although data in that range are too limited to allow for a firm conclusion.

Equipment Needed

PAA is typically delivered to the site in liquid form as a 12% solution. The PAA is stored in a tank and is fed into a rapid induction type mixer at a rate established by the flow, through a chemical feed pump. The chemical storage tank and the feed pump would be stored in a building with the induction mixer installed in a channel, followed by a detention tank. Pilot testing has determined that the majority of kill happens in the first 10 minutes regardless of the concentration of PAA. Therefore, the contact time required by PAA has been determined to be between 2 and 10 minutes.

Limitations

The use of peracetic acid in wastewater disinfection has been very limited in the US. There is no known application of peracetic acid in CSO disinfection in the US. In addition, the cost of PAA may be of concern largely due to small consumer market worldwide and the limited production capacity. One manufacturer has listed the price per pound between $0.50 and $0.70 in 2008 dollars, which corresponds to between $3 per gallon and $5.50 per gallon depending on concentrations. Use of peracetic acid in CSO locations could also be complicated by a need for on-site storage of the chemical, which requires secondary containment and appropriate safety measures.

Inhibitors

Studies have shown that variations in water quality parameters related to NH3, TSS, COD, dissolved oxygen and pH, did not have significant effect on the performance of PAA and PAA produces negligible disinfection by-products.

Need for Dechlorination

At the time of this TGM, there is no indication that de-chlorination will be required. The short half-life means that PAA is not persistent and rarely needs to be neutralized prior to discharge.

Costs

The Bayonne MUA pilot study presented equipment cost of PeraGreen, INJEXX TM unit for flowrate ranging from 5 MGD to 250 MGD (Figure 2-22). The costs provided include the cost of equipment delivered to the site and are 2017 dollars as well the cost of a contact tank providing three minutes of hydraulic retention time.

Operation and Maintenance

O&M costs were also provided by the Bayonne MUA pilot study to maintain a PAA residual of 0.8-1.0 mg/l in flowrate ranging from 5 MGD to 250 MGD (Figure 2-23).

Figure 2-22 - Equipment Cost for Peracetic Acid System

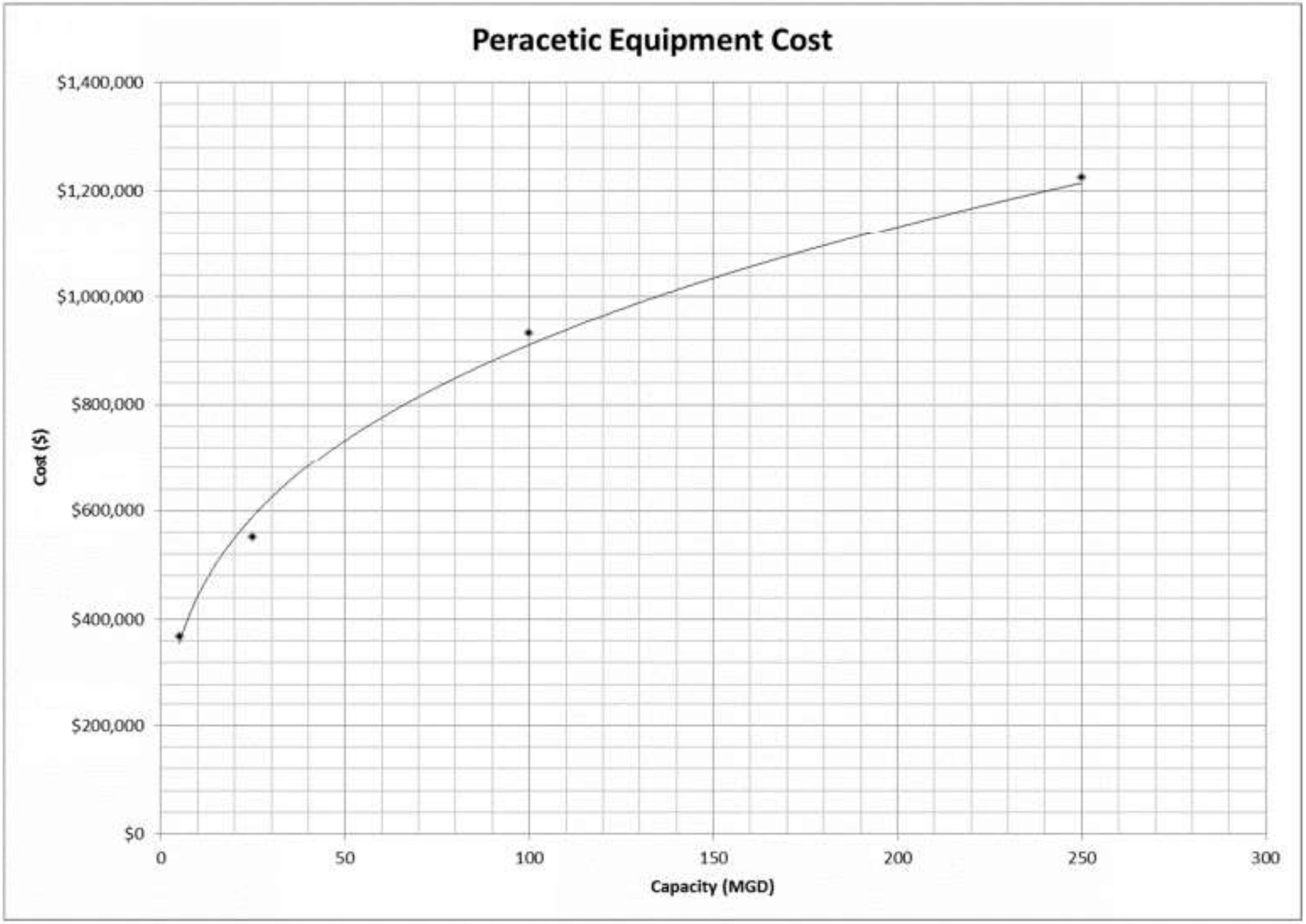
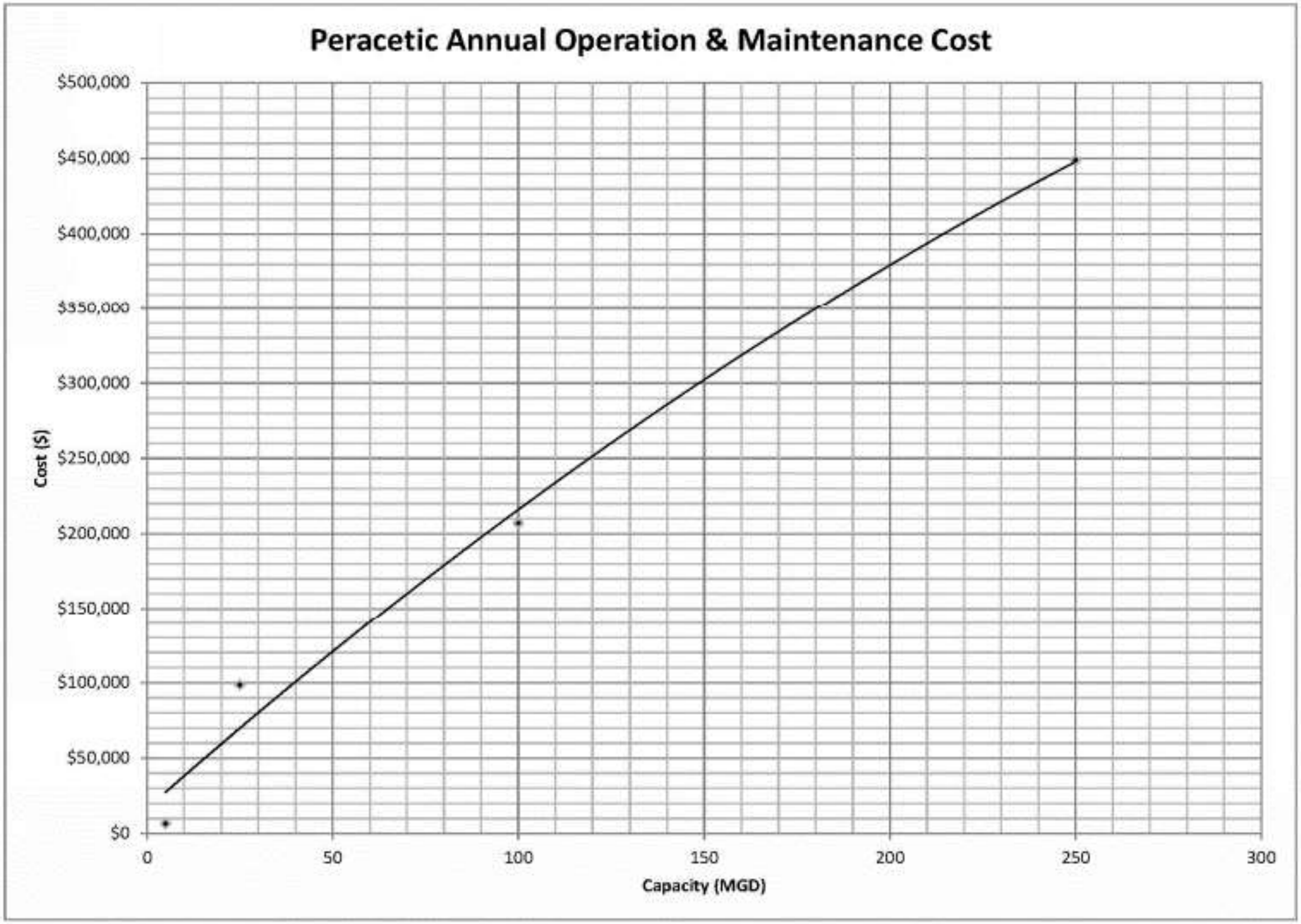


Figure 2-23 - Annual O&M Cost for Peracetic Acid System



2.4.4 Ultraviolet Disinfection

Description of Process

The use of ultraviolet (UV) light is one of the common methods for disinfection of treated wastewaters. In fact, UV disinfection has become the favored technology for new plants and upgrades for existing plants. There are reportedly over 3,500 UV wastewater disinfection systems currently operating in North America, treating flows of up to 300 mgd. UV disinfection eliminates the operational and environmental hazards associated with the use of chlorine compounds, which is a strong oxidant (and sulfite compounds when dechlorination is required), and is cost-competitive with alternative technologies. UV systems are modular and since they require smaller volumes than a chlorination contactor, they can be easily retrofitted into existing chlorination channels.

UV disinfection is a physical process, relying on the transfer of electromagnetic energy released from UV lamps to be absorbed by the nucleic acids (DNA and RNA) in the microorganisms. When the nucleic acids of the organisms are subjected to sufficient quantity of UV radiation (the "dose"), the energy damages the DNA strands by causing specific thymine monomers to combine, which in turn prevents the cell from replicating. This inability to reproduce is, in itself, the lethal effect of UV. Organisms rich in thymine such as *C. parvum* and *G. muris* tend to be more sensitive to UV radiation. The UV radiation in the spectral region between 220 and 320 nm is germicidal, where the wavelengths between 255 nm to 265 nm are considered to be most effective for microbial inactivation. UV disinfection is very effective in inactivation of protozoa, bacteria and viruses, where viruses generally require higher UV radiation dose than protozoa and bacteria.

Electrode type lamps are used to produce light at UV wavelength. Based on the internal operation of these lamps, there are three categories of UV lamps available for use in water/wastewater treatment. These are *low-pressure low-intensity/output (LP-LO)*, *low-pressure high-intensity/output (LP-HO)* and *medium-pressure high intensity/output (MP-HO)* configurations.

In the low-pressure design, lamp output is optimized via mercury vapor pressure and electric current control to generate a broad spectrum of essentially monochromatic radiation in 200nm to 280 nm range (UV-C). Low-pressure lamps produce an intense peak at 254nm which is close to 260nm wavelength considered to be the most effective for microbial inactivation. These low-pressure lamps are highly efficient, converting 30-50% of their input energy to germicidal range of UV light, where 85 – 88 % of this light is at 254 nm. The difference between low-pressure low-intensity and high-intensity lamps are low-intensity lamps use liquid mercury where high intensity lamps use mercury-indium amalgam. Because of this difference, output of LP-LO lamps decreases when the lamp wall is not near optimum temperature of 40^{o}C. LP-HO lamps operate at temperature range of 100 -150^{o}C and can maintain greater stability of lamp output over a wide range of temperatures. In addition, UV output of LP-HO lamps can be modulated between 30 – 100% to adjust the UV dose.

The absolute output of LI-LO lamps is relatively low, with typical UV ratings of 25 to 27 Watts per lamp at 254 nm, for 40 to 100 W input lamps. In LP-HO higher input power (200 to 500 W) have resulted in higher lamp output at 254 nm (60 to 400 W), while retaining their highly efficient energy conversion characteristic.

A number of medium-pressure high-intensity/output UV lamps have been developed over the last decade. MP-HO lamps operate at vapor pressure of 10^2 to 10^4 mm Hg while the low-pressure lamps operating at less than 0.8 mm Hg. Also, the operation temperature of MP-HO lamps are significantly higher (600 – 800°C)_than the LP lamps. With the higher mercury pressures, the lamps are driven at substantially higher input power levels (in the range of 1,000 w to13,000 W). Medium-pressure lamps are polychromatic, effectively radiating 20 to 50 times more the total UV-C output (200 to 280 nm) compared to LP-HO lamps. However, MP-HO lamps have lower efficiency than LP-LO and LP-HO lamps. MP lamps can convert about 7 to 9% of their input power to 254 nm output, and 10 to 15% of the total output is in the germicidal region. Overall, the efficiency of the MP-HO lamps is 4 to 5-fold less than the efficiency of the low-pressure lamps. In addition, the lamp, sleeve and ballast life of MP-HO lamps are significantly lower than LP lamps. However, because of their much higher absolute output levels, fewer lamps are needed, often resulting in a smaller footprint for the UV system.

The actual application of UV to wastewater disinfection is fairly simple. The lamps are enclosed in quartz sleeves (highly transmissible in the UV region), and submerged in the flowing wastewater. The lamp/quartz assemblies are typically arranged in modules, with several modules comprising a bank of lamps. In wastewater applications, these banks of lamps are typically placed in open channels, either horizontally or vertically oriented, with level control devices that maintain water levels above the submergence level of the lamps. Pressure units, using closed-vessel reactors, are also used for wastewaters, although pressure units are more frequently applied in drinking water applications. Generally, automatic cleaning systems/wipers are integrated with each bank of lamps to periodically clean the surface of the quartz sleeve and prevent fouling of the sleeve surface and maintain high transmissivity of the sleeves.

There are many benefits associated with UV disinfection:

1. Since no harmful chemicals are added to the wastewater and no known disinfection byproducts are produced as a result of UV radiation.

2. UV system has a compact footprint and the inactivation of microorganisms occur almost instantaneously as the water passes through the UV lamps. Therefore, UV disinfections systems are set up as a modular system and can be easily configured in one or more channels.

3. Chemical storage, transportation and handling is eliminated for the purpose of disinfection.

UV disinfection does, however, require more power than chemical disinfection, which could be a significant consideration for the larger overflow applications.

Required Concentration

There are several factors that affect the design of a UV system for wastewater disinfection. These center about the design goal to efficiently deliver the necessary UV dose to the targeted microorganisms. Dose is defined as the product of the intensity of UV energy (the rate at which it is being delivered, mJ/cm^2 and the exposure time of the organism to this intensity. Ideally, these factors can be applied such that every element in the water receives the same dose as it passes through the UV unit. However, in practice, the UV dose will not be identical for all particles in the water. There is a variation in the intensity field within the unit and variation in the exposure times, resulting in a dose distribution. Effective design optimizes this dose distribution and avoids any appearance of hydraulic short circuiting through the UV unit. Exposure time is dependent on the hydraulic characteristics of the unit, reflecting the spacing of the quartz/lamp assemblies, inlet and outlet conditions, and hydraulic loading rates. The output energy of the lamps, the transmissibility of the quartz sleeves, and the transmittance of the wastewater itself affect intensity. The loss of energy due to the aging of the lamps and degradation of the quartz sleeve transparency must be incorporated in the design of the UV units. Generally, the lamp output will decrease to between 50% and 80% of their nominal output by the end of lamp life (typically LP-HO lamps have 9,000 to 15,000 hours and MP-HO lamps have 3,000 to 8,000 hours lamp life). Sleeve fouling will typically account for a 20% to 30% decrease in transparency through the life of the quartz sleeve, even if they get cleaned regularly. The transmittance of treated wastewater effluents will range between 50% and 75%, depending on the influent water quality and the degree of treatment provided before disinfection. Combined sewer overflows and storm water have significantly low UV transmittances and it is generally in the range of 20% to 50% per cm at 254 nm. Since this directly affects the portion of the energy from UV lamps reaching the microorganism, design should call for closely spacing the lamps and using higher-powered lamps. The medium-pressure lamp units can meet these criteria, as can the LP-HO lamp technologies, although to a lesser degree. Head losses are generally manageable for these systems, typically in the order of 6 to 24 inches for the medium-pressure units. Typically, a dose of 30 to 40 mJ/cm^2 is specified for treated wastewater disinfection, where three to four log inactivation rates are generally required to meet disinfection targets. Demonstration that the proposed unit will deliver this dose under design conditions (flow, UV transmittance, end-of-lamp life output, degraded quartz surfaces, etc.) is often required either as a prequalification for bidding, or at the time of commissioning. This is done through direct bio-dosimetric testing on full-scale or scaled systems, whereby a challenge organism of known dose-response is injected into the UV unit under design flow and UV transmittance conditions. By measuring the kill of the organism, the dose that was delivered by the unit can be estimated. This method has become an industry standard for validating the performance of UV systems. These protocols are articulated by the USEPA UV Design Guidance Manual (November 2006), the NWRI/AWWA RP UV Guidance (May 2003), and the USEPA Environmental Verification Program protocols for reuse, secondary effluents, and wet weather flows (2002). This method accounts for the variations in hydraulics through the UV lamps and UV radiation intensity in a system, and allows for a more consistent comparison of performance expectations and design sizing between different UV technology configurations.

The Bayonne MUA pilot study evaluated performance of Trojan UV3000Plus unit using low-pressure lamps. Correlation of all the individual data from the study indicated required approximately 25 mJ/cm^2 effective irradiation dose input to achieve 3log inactivation of pathogen indicators.

Equipment Needed

For purposes of this preliminary assessment of cost associated with the disinfection of combined sewer overflows, the low-pressure high intensity lamp technology is considered. As discussed earlier, the LPHO lamps are very efficient and with advancement in UV lamp technology, there are up to 1,200 W lamps available. The Sigma low-pressure high-intensity lamps offered by Trojan

Technologies has been used for preliminary sizing, layout, design and costs estimation; however, it is not the intent of this exercise to recommend a given manufacturer for such applications.

Limitations

In large applications, significant power is required for operation of UV system. In some locations power availability can be a limitation.

Inhibitors

Certain water quality parameters can have a big impact on the disinfection efficiency of the UV system. UV transmittance or UV absorbance is one the key parameter which impact the UV dose that the microorganisms get subjected to. Iron, ozone, manganese, natural organic matter (NOM), TSS are strong absorbers of UV light, which would reduce the UV transmittance. The threshold values for Ferric iron, Ferrous iron and ozone are set as 0.057 mg/L, 9.6 mg/L and 0.071 mg/L, respectively. If iron salts are used within the treatment process, alternative should be evaluated to compare savings of smaller UV system compared to cost associated with change of precipitation aid. Alkalinity, hardness (Ca, Mg and other salts) and TDS can form mineral deposits on quartz tubes and reduce the UV dose reaching microorganisms and would increase the frequency and sleeve cleaning. Alkalinity and pH also effect the solubility of metals carbonate which may absorb UV light. Oil and grease in the wastewater would accumulate on the quartz sleeves and reduce the UV transmittance.

Need for De-chlorination

Since no chemical is used in UV disinfection and there is no residual disinfectant in the wastewater due to UV disinfection, de-chlorination or residual disinfectant removal is not required in UV disinfection systems. If any chemical disinfectant is added in upstream of the UV disinfection, residual disinfectant removal may be required specific to chemical disinfectant used.

Costs

The costs for the ultraviolet disinfection system consist of the equipment cost, including its installation, the cost of the channels for the ultraviolet disinfection equipment.

The preliminary report level construction cost estimates provided in Table 2-32 include the equipment, installation, building, and contingency for UV disinfection system of design flow ranging from 10 MGD to 450 MGD. Budgetary equipment pricing information was gathered from equipment manufacturers.

Operation and Maintenance

UV disinfection systems have been used for continuous operation for many years at various treatment facilities. Routine operating and maintenance programs and guidelines have been established for these continuous operations. However, in the case of CSO discharges, the O&M requirements for the UV disinfection technology would be intermittent during the year and be based on the number of storm events per week, month or year. The CSO locations at remote sites would require field crews to be on site before a storm event to make sure the system is in operating conditions and after the storm event to perform general washdowns and maintenance check.

The O&M requirements would center on lamp cleaning, parts replacement, and general maintenance. Recent applications of UV lamps have cleaning systems that employ chemically-assisted mechanical wipers, which are effective for low-grade wastewater applications such as CSOs. This has significantly reduced labor time required for lamp cleaning and has also improved lamp effectiveness. However, one of the main challenges with CSO systems is that the lamps are not always submerged in the water and when there is long period between storm events, dust will accumulate on the sleeves. These dust particles would scratch the surface of the sleeve and reduce the penetration/transmittance of the UV light. Therefore, additional precaution and manual cleaning would be required from time to time. It is recommended that UV banks would be raised and inspected for debris after each event to ensure that there is not large debris caught up in the system. The wipers have a debris scraper that will handle smaller debris and push it out of the way, but it will be a good practice to inspect the equipment after each event.

Parts replacement is another major maintenance requirement and would include the replacement of lamps, ballasts, wipers and quartz sleeves. Since the UV system is not going to be operating continuously, lamp replacement is not going to be as often as continuously operating systems in wastewater treatment plants. While some manufacturers offer a lamp warranty only for set operation hours ranging from 12,000 hours to 16,000 hours for LP-HO lamps, which equates to 24 to 32 years of warranty for lamps. This long duration of lamp operation is not believed to be reasonable due to operational conditions of CSO systems. On the other hand, some manufacturers provide a warranty based on a set limit of operation hours or a set duration, which occurs first. The output of UV lamps decreases as lamps age. Generally, after 12,000 to 15,000 hours of operation, the lamps need to be replaced due to low power output. In this report, it is assumed that UV lamps would be replaced every 10 years. In addition to lamp replacement, the ballasts, a type of transformer that is used to limit the current to the lamps, will need to be replaced. For the specific brand and model used for cost estimation in this report, each ballast serves 2 lamps and has an expected life of 5 years.

The third major maintenance requirement would be general O&M requirements at the CSO site. General maintenance at each UV disinfection site would include repairs, cleaning the channels and surrounding areas, maintaining product inventories, system monitoring, and documenting site visits. Assuming that there would be a two-person field crew visiting each site for one hour before and after each storm event, the estimated maintenance hours per event would be 4 to 8 hours depending on the system sizes. UV disinfection systems for CSO discharges can be designed to operate intermittently during the year and also during winter conditions.Instrumentation for intermittent disinfection operations would be incorporated into the UV reactor's operation including monitoring CSO flows, CSO characteristics such as UVT and CSO water levels in the reactor and support channel. These controls would be programmed to turn the reactor on and off, increase or decrease the lamps' intensity based on UVT and open appropriate valves to drain the reactor when not in operation. Operations in the winter, however, would include other specific requirements in the reactor for controlling freezing conditions in the reactor. These requirements would include any or all of the following guidelines:

1. Drain the reactor and apply warm air to the module to maintain temperature above 32°F; and

2. Manually drain the cleaning solution from the wipers and refill the wipers before the next storm event (approximately 5 minutes per lamp). Leave the reactor full of water and

provide a heat source to maintain the water temperature above 32°F during freezing temperatures.

Space Requirements

The space requirements of the facilities required for disinfection using UV are based upon the size of the contact chamber and a buffer of 5 feet on upstream and downstream of the UV lamps.

Table 2-32 - Preliminary Construction Cost Estimates for UV Disinfection

Flow	Length x Width X Depth(1)	Budgetary Equipment Price	Concrete Cost(2)	Install Cost(3)	GC General Conditions (4)	GC OH&P(5)	Contingency(6)	Total
10 MGD	4'-0" x 4'-0" x 9'-0"	$300,000	$885,600	$1,778,400	$296,400	$296,400	$1,778,400	$5,335,200
25 MGD	50'-5" x 5'-1" x 9'-0"	$625,000	$1,138,536	$2,645,304	$440,884	$440,884	$2,645,304	$7,935,912
50 MGD	50'-5"x 5'-1" x 9'-0"	$1,100,000	$1,959,552	$4,589,328	$764,888	$764,888	$4,589,328	$13,767,984
75 MGD	53'-5"x 5'-1" x 9'-0"	$1,400,000	$2,076,192	$5,214,288	$869,048	$869,048	$5,214,288	$15,642,864
100 MGD	52'-3" x 4'-10" x 9'-0"	$1,600,000	$2,931,552	$6,797,328	$1,132,888	$1,132,888	$6,797,328	$20,391,984
450 MGD	68'-8" x 8'-11" x 11'-9"	$8,480,000	$12,060,757	$30,811,136	$5,135,189	$5,135,189	$30,811,136	$92,433,408

Notes:
(1) Channel size based on assumed channel size with length of twice the width before and after UV lamp banks, and 1.5 feet of free board for the side walls
(2) Concrete costs based upon assumed $900 per cubic yard
(3) Installation costs are estimated at 150% of the equipment cost.
(4) GC general conditions are estimated at 10% of the total direct cost.
(5) GC OH&P are estimated at 10% of the total direct cost.
(6) 50% of contingency is used for the planning level of cost estimates.

Table 2-33 - Annual Operation Cost for Ultraviolet Disinfection

Flow	Total Number of UV Lamps	Power Consumption per Lamp (kW)	Total Power (kW)	Annual Energy Usage (kW-hr)(1)	Total Cost(2)
10 MGD	32	1	32	16,000	$2,240
25 MGD	66	1	66	33,000	$4,620
50 MGD	132	1	132	66,000	$9,240
75 MGD	176	1	176	88,000	$12,320
100 MGD	240	1	240	120,000	$16,800
450 MGD	1152	1	1152	576,000	$80,640

Notes:
(1) Assumes 500 hours of annual operation
(2) Assumes energy costs of $0.14/kW-hr

Table 2-34 - Annual Maintenance Cost for Ultraviolet Disinfection

		Annual Number of Units Replaced			
Flow	**Lamps**	**Lamps(1)**	**Ballasts(2)**	**Sleeves(3)**	**Wipers(4)**
10 MGD	32	3	3	6	16
25 MGD	66	7	7	13	33
50 MGD	132	13	13	26	66
75 MGD	176	18	18	35	88
100 MGD	240	24	24	48	120
450 MGD	1152	115	115	230	576

	Annual Maintenance Labor Costs (5)						
	Lamps	**Ballasts**	**Sleeves**	**Wipers**	**Check UV Sensors(6)**	**Routine(7)**	**Total Annual Labor**
Estimated Man Hours per Unit	*0.25*	*0.25*	*1*	*1*	*2*	*4 to 8*	
10 MGD	$150	$150	$1,050	$2,400	$7,800	$60,000	$71,550
25 MGD	$300	$300	$2,100	$4,950	$7,800	$60,000	$75,450
50 MGD	$600	$600	$4,050	$9,900	$7,800	$75,000	$97,950
75 MGD	$750	$750	$5,400	$13,200	$7,800	$90,000	$117,900
100 MGD	$900	$900	$7,200	$18,000	$7,800	$90,000	$124,800
450 MGD	$4,350	$4,350	$34,650	$86,400	$7,800	$120,000	$257,500

	Annual Maintenance Equipment Costs					
	Lamps	**Ballasts**	**Sleeves**	**Wipers**	**Total Annual**	**Total Annual Maintenance**
Unit Costs	*$300*	*$750*	*$175*	*$30*		
10 MGD	$960	$2,400	$1,120	$480	$4,960	$76,510
25 MGD	$1,980	$4,950	$2,310	$990	$10,230	$85,680
50 MGD	$3,960	$9,900	$4,620	$1,980	$20,460	$118,410
75 MGD	$5,280	$13,200	$6,160	$2,640	$27,280	$145,180
100 MGD	$7,200	$18,000	$8,400	$3,600	$37,200	$162,000
450 MGD	$34,560	$86,400	$40,320	$17,280	$178,560	$436,060

Notes:
(1) Assumes lamps replaced every 10 years
(2) Assumes ballasts replaced every 5 years
(3) Assumes sleeves replaced every 5 years
(4) Assumes wipers replaced every 2 years
(5) Assumes labor rate of $150/hour
(6) Assumes UV sensors are inspected bi-weekly
(7) Routine inspection and maintenance should be performed after each event with 4hr for 10MGD and 25 MGD system, 5 hours for 50 MGD System, 6 hours for 75MGD and 100 MGD systems, and 8 hours for 450 MGD system. Assumed 100 events.

2.4.5 Ozone Disinfection

Description of Process

Ozone (O_3) is an unstable gas that is produced when oxygen molecules are dissociated into atomic oxygen and subsequently collide with another oxygen molecule to produce ozone. Due to the instability of ozone, it must be generated on-site from air or oxygen carrier gas. The most efficient method of producing ozone today is by the electric discharge technique, which involves passing the air or oxygen carrier gas across the gap of narrowly spaced electrodes under a high voltage. Due to this expensive method of producing ozone, it is extremely important that the ozone is efficiently transferred from the gas phase to the liquid phase. The two most often used contacting devices are bubble diffusers and turbine contactors. With the bubble diffusers, deep contact tanks are required. Ozone transfer efficiencies of 85% and greater can be obtained in most applications when the contactor is properly designed. The contactors must be covered to control the off-gas discharges. Since any remaining ozone would be extremely irritating and possibly toxic, the off-gases from the contactor must be treated to destroy the remaining ozone. Ozone destruction is normally accomplished by thermal or thermal-catalytic means.

An ozonation system can be considered to be relatively complex to operate and maintain compared to chlorination. The process becomes still more complex if pure oxygen is generated on site for ozone production. Ozonation system process control can be accomplished by setting an applied dose responsive to wastewater flow rate (flow proportional), by residual control, or by off-gas control strategies. Ozone disinfection is relatively expensive with the cost of the ozone generation equipment being the primary capital cost item, especially since the equipment should be sized for the peak hourly flow rate as with all disinfectant technologies. Operating costs can also be very high depending on the power costs, since Ozonation is a power intensive system.

Since ozonation is expensive to operate, and maintain, produces off-gas that can be toxic, is a complex system, and not utilized for disinfection at wastewater treatment plants where flow is more controlled and less variable, we feel it is not an acceptable application for disinfection of CSO flows and will not be evaluated further.

2.4.6 Evaluation of Disinfection Technologies

The above sections evaluated each of the disinfection technologies considered for treatment of CSO flow relative to criteria on cost, performance, limitations, and ancillary facilities. Each process was rated from 1 to 5, with 5 being the most effective, for approximately twenty different items and totaled. While somewhat subjective, this method does provide a mechanism for comparing each screening unit in relationship to each category and subcategory. The results of the evaluation are illustrated on Table 2-35.

Table 2-35 presents the relative effectiveness of the different disinfection technologies with respect to bacteria, viruses, and encrusted parasites. For the purposes of this table the bacteria are identified as pathogens, E. coli, enterococci, and salmonella. Viruses are identified as the polio virus, with encrusted parasites consisting of giardia and cryptosporidium.

Table 2-35 - Evaluation of Disinfection Technologies

Criteria	Sodium Hypochlorite	Peracetic Acid	Ultraviolet Disinfection
Complexity	5	5	2
Safety	4	4	5
Limitations	3	3	3
Inhibitors	3	5	3
De-chlorination Requirement	1	5	5
Commercial Product Availability	5	1	5
CSO Application	5	2	2
Total	26	25	25

Section 3

Storage Technologies

Storage technologies are used to store flow for subsequent treatment at the wastewater treatment facility when downstream conveyance and treatment capacity are available. Two general types of storage need to be considered: in-line storage, which is storage in series with the sewer; and off-line storage, which is storage in parallel with the sewer. More detailed information on each type and sub-type is provided below.

3.1 In-Line Storage

In-line storage is generally developed in two ways. One way would be to use control structures to store the flows from smaller storm events (those below the design storm for the facilities) using the excess pipe capacity within the existing sewer. The other, also used with a control structure, is to replace segments of the existing sewer with larger diameter pipes to act as storage units. In both cases the use of in-line storage typically needs large diameter pipe with flat slopes. In-line storage within the existing combined sewer system is currently provided to some extent by the overflow weir typically used in existing CSO control facilities. Maximizing that storage, selecting the location of other flow control structures, and sizing of these facilities must be determined and verified by using a calibrated and verified hydraulic model.

In-line storage facilities require an extensive control and monitoring network. These includes flow regulators, such as orifices, weirs, flow throttle valves, automated gates and continues monitoring network such as level sensors, rain gages, flow monitors, and overflow detectors. Effective and efficient in-line storage requires the utilization of site-specific information together with modeling data and information on downstream flow elevations and available capacity.

3.1.1 Using Existing Sewers

Existing sewers can sometimes provide additional in-line storage by installing an in-line weir structure or flow regulator within a pipe section or at a manhole. On large diameter sewers, the weir structure would typically consist of an inflatable rubberized fabric dam, which could be pressurized to create an impoundment on the upstream of the regulator and thus create inline storage. Another flow regulator that has been used to develop in-line storage is an automatically controlled sluice gate. Instrumentation is typically provided for automatic control to prevent overloading the system. Sections of pipe utilized for in-line storage should not have any service lateral connections, or should be deep enough to prevent sewage backups within the system.

The storage available in a sewer is directly related to the cross-sectional area of the sewer that is typically unused during typical wet weather events. Typical storage requirements for wet weather flows are in the tens or hundreds of thousands of gallons. A 4-foot (48- inch) diameter circular pipe has a total capacity of less than 100 gallons per foot, a 6- foot (72-inch) pipes has a total capacity of around 210 gallons per foot, while a 6-foot x 12-foot rectangular section has a total capacity of around 540 gallons per foot.

Most combined sewer systems within the region were constructed during the period of 1880 through 1920 when few paved roads and concrete sidewalks and other impervious areas were limited to roofs. Land development, changes within land use, and changes in sewer utilization over the past century have all impacted the flow characteristics of most combined sewer systems. Most of the combined sewer systems within the region have a diameter of 48-inch or less. These sewers are expected to have little or no storage capacity due to increase inflow rates and limited pipe size and slope.

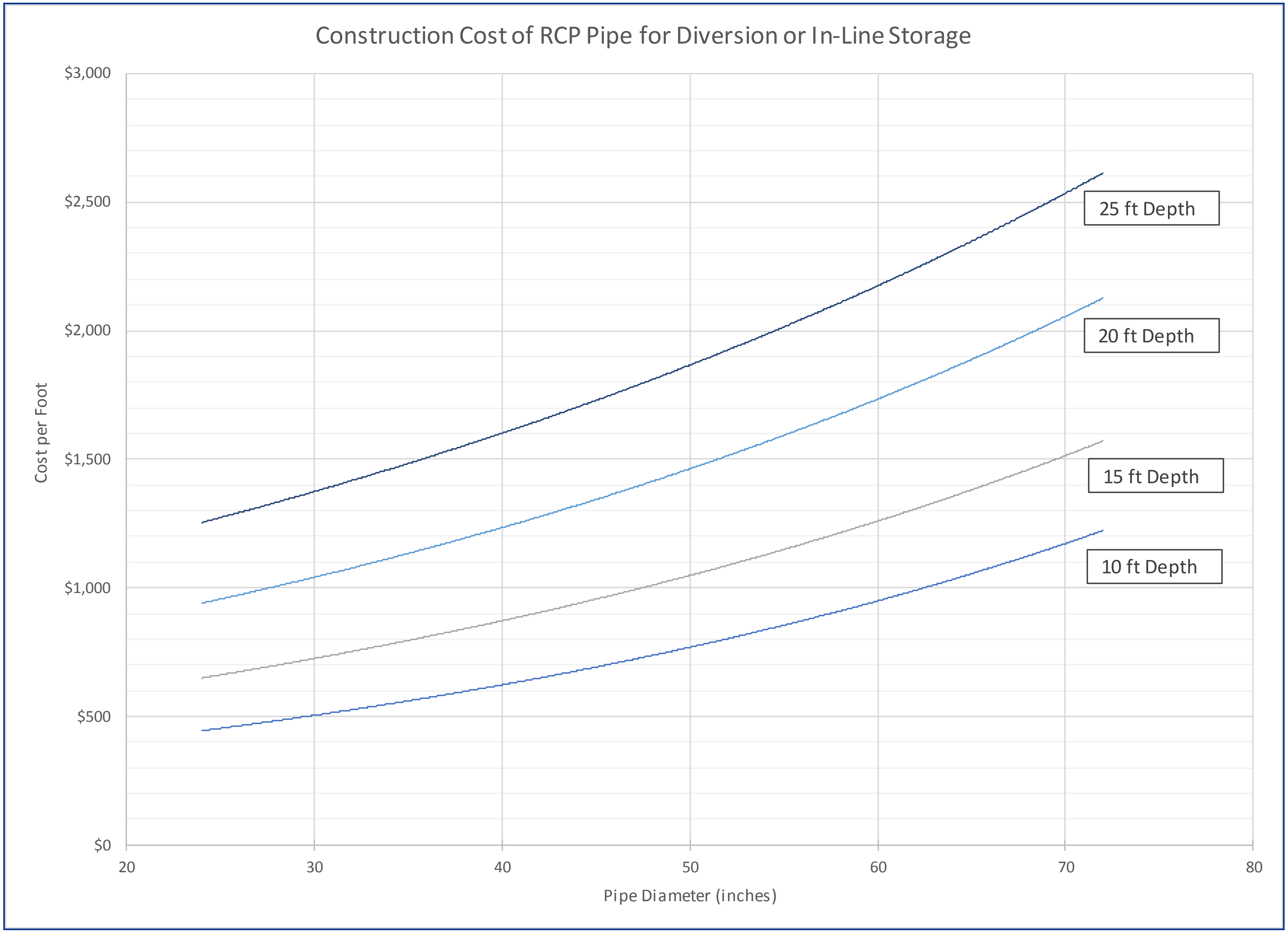
A CSO Facility Plan was completed by Killam Associates (now Mott MacDonald) in 1983 for the Passaic Valley Sewerage Commissioners on the combined sewer systems within the Cities of Newark and Paterson, and Towns of Harrison and Kearny, and the Borough of East Newark. The evaluation of in-line storage was conducted to review the feasibility of inline storage within the region. This study concluded that, with the exception of a few areas within the City of Newark, the volume of inline storage available within the sewer system was insignificant. It is anticipated that in-line storage using existing sewer will not provide a significant volume of storage.

3.1.2 Using New Large Dimension Sewers

In-line storage can also be developed by the construction of new large diameter sewers in place of, or parallel to existing combined sewers. The general principal that governs inline storage in either existing or new sewers are the same. In-line storage developed by replacing segments of the existing combined sewer system with larger diameter pipes still requires extensive controls and monitoring to assure proper operation. Accordingly, the cost of constructing the additional sewer capacity must be determined in addition to the cost of the control and monitoring network.

The original Technical Guidance Manual provided cost information suitable for the preliminary analysis of in-line storage using newly constructed large dimensional sewers in place of existing pipe. Those cost estimates were based on an assumed minimum replacement length of 500 feet for circular conduit sizes varying from 24-inch to 72-inch, and were based on an Engineering News Record (ENR) Construction Cost Index (CCI) of 7630. For this TGM update, that cost information was obtained from those cost curves and escalated to 2017 dollars using the October 2017 ENR CCI of 10817. The resultant cost estimates for the construction of segments of large diameter pipe are provided in Figure 3-1. The cost of the control and monitoring network is site specific, and should also be considered when evaluating the use of in-line storage.

Figure 3-1 - Construction Cost Estimates for RCP Pipe for Diversion or In-Line Storage



3.1.3 System Evaluation

Effective control of in-line storage can be achieved through proper flow regulator equipment and hardware selection, a SCADA system that provides early warning and accurate storm forecast. Seasonal storm patterns and types need to be identified and thoroughly evaluated to assure that the control system can properly handle current and potential rainfall patterns within the drainage area. The cost of implementation is significant for areas with limited existing storage due to the cost and challenges associated with the construction of new sewers especially in urban areas, where the access to sewer can be limited and above ground vehicle and pedestrian traffic is heavier. One advantage of in-line storage is the potential of reducing flooding and other system problems that may be localized within the system.

Operational problems that have been noted include computer programming and hardware problems especially with telemetry or data transmission, which could lead to a loss of accuracy in system control. In addition, deposition of solids in the sewers can occur, since the flow velocity during dry weather can be lower than self-cleansing velocity in large diameter sewers. In areas where smaller diameter sewers are replaced with large diameter sewers to provide in-line storage, consideration should be given to provide a low flow channel within the invert. A thorough analysis should be conducted for the potential of sewage backups in service laterals due to surcharging the system above previous hydraulic grades.

3.2 Off-line Storage

Off-line storage is storing the combined sewage in a storage system that is not on the typical flow path of dry weather flow. Off-line storage systems use tanks, basins, tunnels or other structures located adjacent to the sewer system for storing wet weather flow that is above the capacity of the conveyance system. The wastewater flows from the collection or conveyance system is diverted to off-line storage when conveyance capacity of the collection system has been exceeded. They can be used to attenuate peak flows, capture the first flush, or to reduce the frequency and volume of overflows. Wastewater flows diverted to storage facilities must be stored until sufficient conveyance or treatment capacity becomes available in downstream facilities. Off-line storage is typically accomplished by the construction of storage tanks, lagoons, basins, or deep tunnels.

Off-line storage is the predominant form of CSO prevention method currently in operation throughout the United States. The major advantages of off-line storage include:

- It can accommodate intermittent and variable storms.
- It is not impacted by varying water quality flow characteristics.
- It can accommodate solids deposition and control; and
- Storage tanks are easily accessible.

Off-line storage is not a flow through facility and thus ancillary facilities must be constructed for a complete installation. Ancillary facilities typically include some type of flow diversion or regulator structure, possibly coarse screening to keep large solids from entering the tank, and some type of tank drain facility to divert the sewage back to sewer system. To keep solids from accumulating within the tank, most storage facilities also provide facilities to flush solids from the bottom of the tanks into the pumping sump or gravity sewer.

Two types of off-line storage are typically used in CSO system depending on the volume of the overflows that need to be captured. The most prevalent form of off-line storage is a concrete storage tank/structure. These tanks/structures can be constructed above or below ground. The second form is the deep tunnel, wherein a large diameter tunnel is constructed to capture and store CSO discharges. While other forms, including uncovered earthen basins, have been used in less populated areas, open forms of CSO storage would not be applicable to highly urbanized areas.

3.2.1 Off-line Storage Tanks

The most prevalent form of off-line storage for CSO discharges is the concrete/steel tank. While large diameter parallel sewers can provide a mechanism for off-line storage, the storage volumes associated with these facilities are limited and thus are typically used within the collection system to prevent or minimized the surcharging associated with local restrictions or conditions. Large volume storage requirements can best be accommodated by the construction of off-line storage facilities at or near the CSO outfall. The design and sizing of these facilities are based upon computer modeling of drainage area and collection system to develop an understanding of the frequency and volumes associated with individual outfalls.

Advantages of off-line storage using concrete tanks are simplicity of operation and maintenance, and capability to handle high flow and water quality variations. In addition, storage tanks have the capacity for storage and collection of solids even when storm events exceed the design capacity of the off-line storage tank. In these cases, the off-line storage tank acts like a sedimentation tank. Storage tanks, in conjunction with fine screening of CSO discharges above the storage volume, are used as a primary means of CSO control throughout Europe.

As with in-line storage, the original Technical Guidance Manual provided cost information for off line storage that was obtained and escalated to 2017 dollars based on the ENC CCI. Those cost estimates were developed for concrete tanks of various storage volumes and are inclusive of all ancillary facilities and include construction costs for coarse screens, diversions, control gates, pumping facilities, flushing facilities and ventilation. The resultant cost curves are presented in Figures 3-2 through 3-4.

Figure 3-2 - Construction Cost Estimates for Off-Line Storage – 15' SWD Rectangular < 1 MG

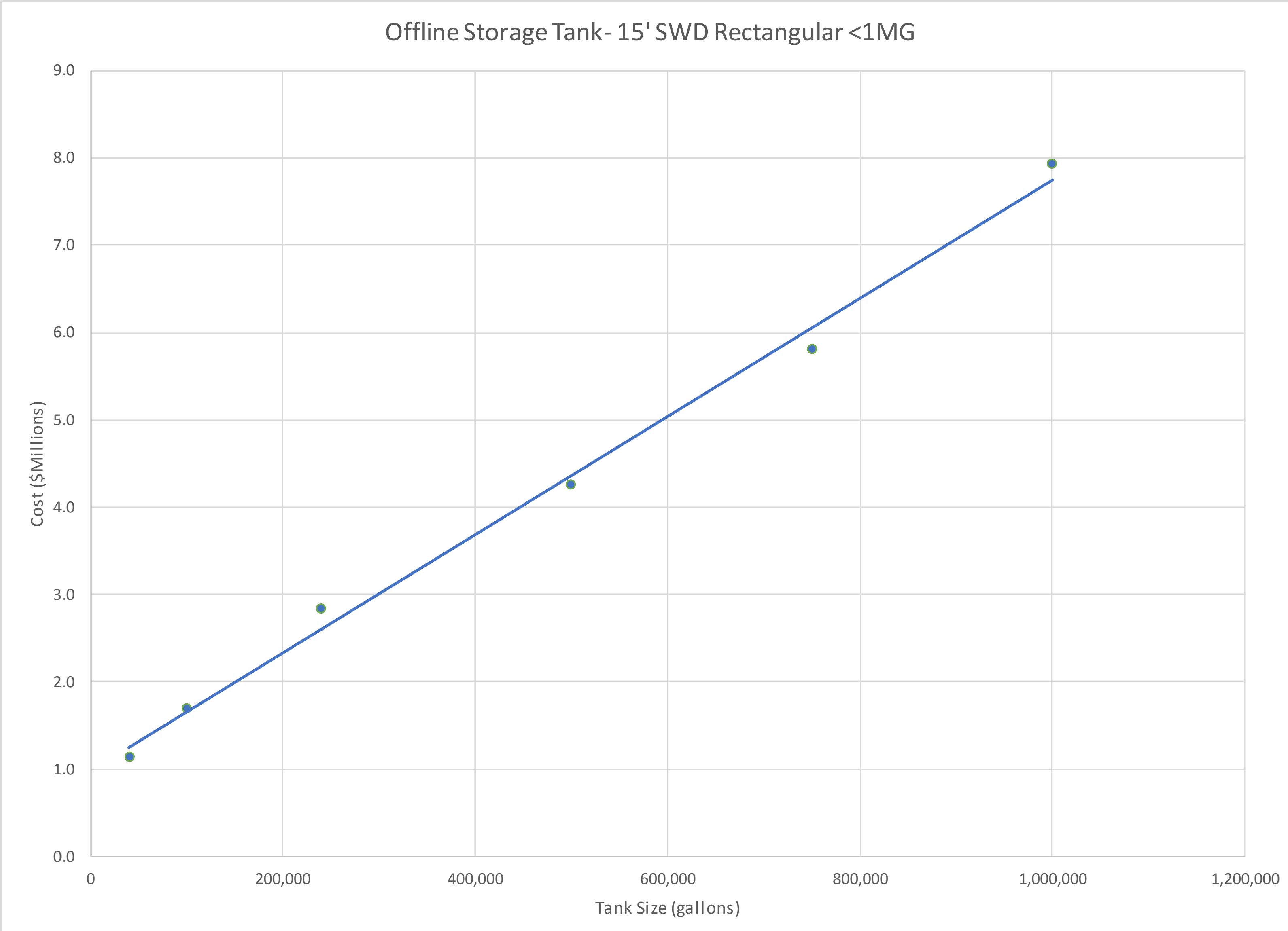


Figure 3-3 - Construction Cost Estimates for Off-Line Storage – 15’ SWD Rectangular > 1 MG

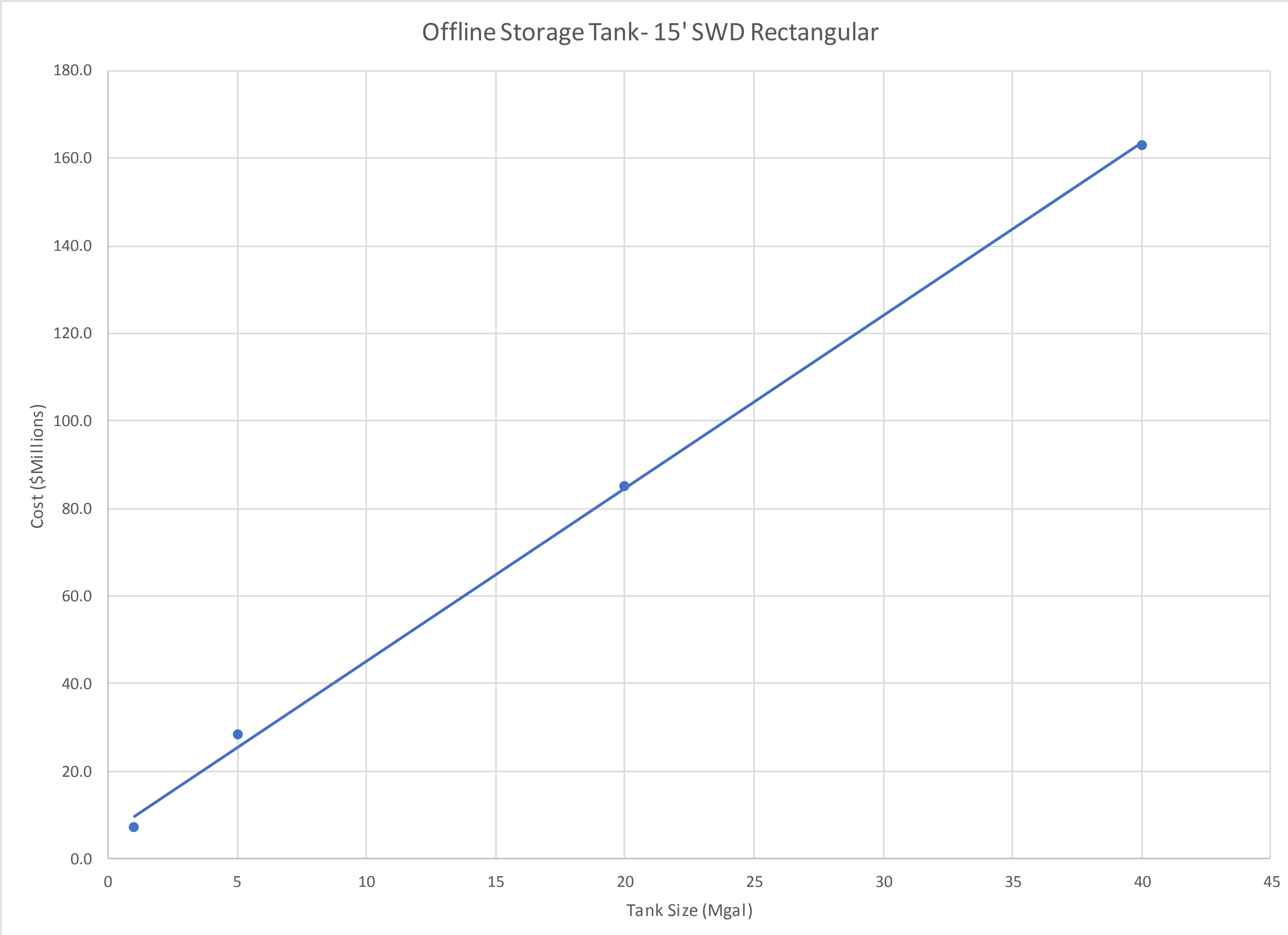


Figure 3-4 - Construction Cost Estimates for Off-Line Storage – 22’ SWD Rectangular

3.2.2 Deep Tunnel Storage

Deep tunnel storage has been gaining popularity as a positive means of reducing the volume of CSO discharges, especially in large urban areas where property values and disruptions to existing utilities and structures prohibit other forms of control. This control alternative involves the capture and storage of CSO discharges in a tunnel during wet weather events, and pumping the stored overflow back into sewer when conveyance and treatment capacity is available. New methods of construction have made deep tunnel storage a competitive option when considering the relatively low land requirements. Limitations of deep tunnels primarily include the need for specialized high-lift pumping stations and the inability to provide any treatment when the overflow exceeds the deep tunnel storage volume.

As with in -line and off-line storage, the original Technical Guidance Manual provided cost information for deep tunnel storage. Preliminary tunnel cost estimating graphs were prepared using compiled cost data from previously completed projects for the following tunneling scenarios:

- Tunnel in soft ground above the water table using an open faced boring machine with ribs and lagging primary liner and cast-in-place concrete final liner.
- Tunnel in soft ground below the water table driven using an earth pressure balanced boring machine with full gasketed concrete segmental liner erected immediately behind.
- Tunnel in rock driven using a rock-boring machine with pattern rock bolting and mesh reinforcement in the tunnel crown for primary support, and cast-in-place concrete final liner.

Since ground conditions may be unknown, an idealized cost estimate using certain assumptions on the amount of difficult conditions was also presented. A determination will need to be made as to the method that would need to be used based on general soil classifications and conditions within the region.

Notwithstanding the above, construction costs on tunneling projects are influenced by a multiplicity of factors. Tunnel cost estimates should only be used as a general initial guideline as they are based on a number of base assumptions and are not at all project specific. The major factors influencing costs on tunneling projects are described below:

- Tunnel length - assuming similar size and type of tunnels, a longer tunnel will generally have a lower unit rate than a smaller tunnel due to economies of scale. The original Technical Guidance Manual cost graphs assumed a 1.5 miles length of tunnel.
- Tunnel depth relative to the surface - deeper tunnels have deeper access shafts, which adds to the overall cost of the project. The original Technical Guidance Manual cost graphs assumed a tunnel no deeper than 30ft.
- Ground type & water table elevation - this can often be the most important cost factor as it influences the advance rates achieved, and choice of equipment and tunnel support. The original Technical Guidance Manual cost graphs assumed reasonable ground conditions and minimal water ingress problems to hinder the tunneling effort.

- Rate of advance achieved in the prevailing ground conditions. Average advance rates were assumed in the preparation of the tunnel cost graphs.
- Local labor conditions including availability of experienced personnel, prevailing wage rates, and union rules governing workers conditions, hours, and the minimum number of personnel which should be utilized for construction of the tunnel. The tunnel cost graphs presented in the original Technical Guidance Manual utilized labor conditions and numbers, which were believed to be appropriate for New Jersey.
- Local availability of appropriate tunneling equipment. The tunnel original Technical Guidance Manual cost graphs assumed that appropriate tunneling equipment is readily available in New Jersey.
- Occurrences of unforeseen ground conditions and obstructions. The original Technical Guidance Manual cost graphs assumed no major unforeseen conditions.
- Presence of sub-surface utilities and structures above requiring advance protection or monitoring during construction. The original Technical Guidance Manual cost curves assumed that no advance protection is required.

The foregoing list represents only a few of the factors which influence tunnel construction costs, and beyond the earliest stages of conceptual design it is recommended that all tunnel cost estimating be undertaken by an experienced tunneling engineer with an intimate awareness of the factors influencing tunnel costs. To cater for the unknown components inherent in preparation of the cost curves a relatively large cost contingency of 65% was applied throughout. In practical cost estimating, the cost contingency is reduced to as low as 5% as the design develops and more is known about the conditions which are likely to be encountered, and the tunneling techniques which will be utilized for the project.

In addition to tunnel costs, there are costs associated with conveying the flow into the tunnels. Typically, the discharges from outfalls are consolidated to decrease the number of drop shafts that will be needed. In addition, drop shafts are needed to transport flow from the regulators to the tunnel. The drop shaft consists of a large diameter shaft in which a vortex drop tube, vent shaft and access way are constructed. The space between the various components in a large diameter shaft is backfilled upon completion.

The original Technical Guidance Manual deep tunnel cost information was obtained and escalated to 2017 dollars based on the ENC CCI. The resultant cost curves are presented in Figures 3-6 through 3-8.

Figure 3-6 - Estimated Cost of Deep Tunnels Less Than 10,000 Linear Feet

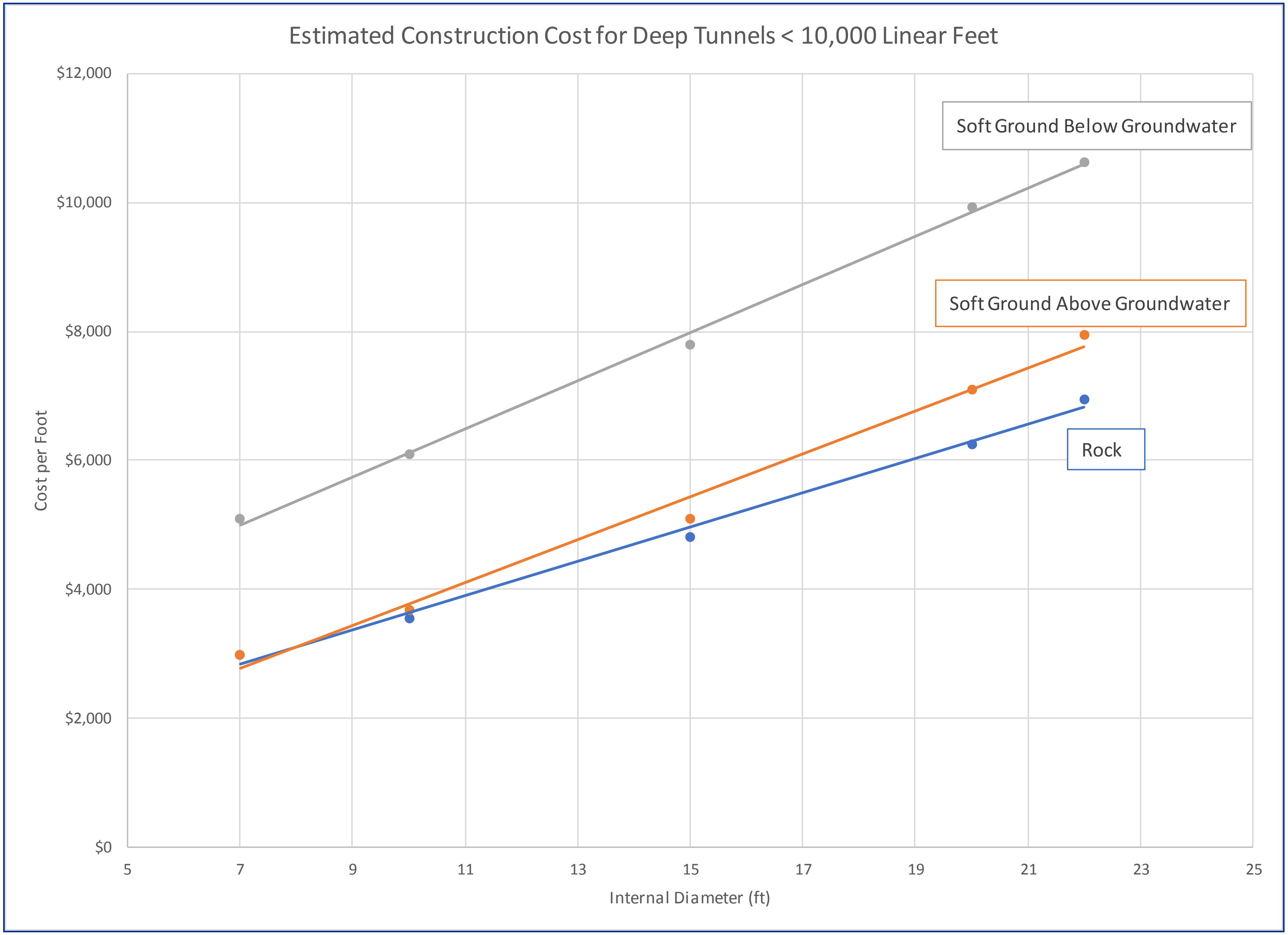


Figure 3-7 - Estimated Cost of Deep Tunnels Greater Than 10,000 Linear Feet

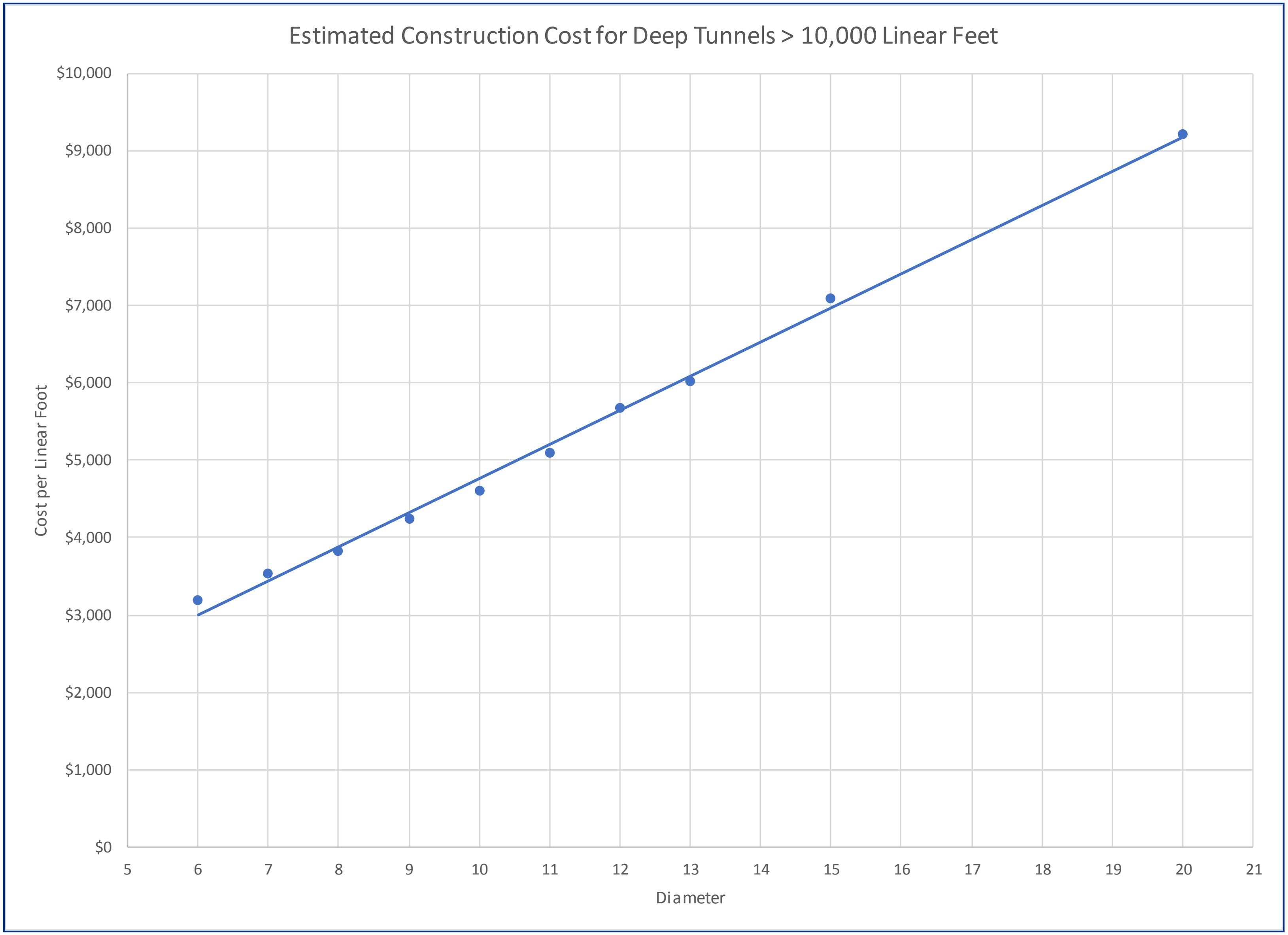
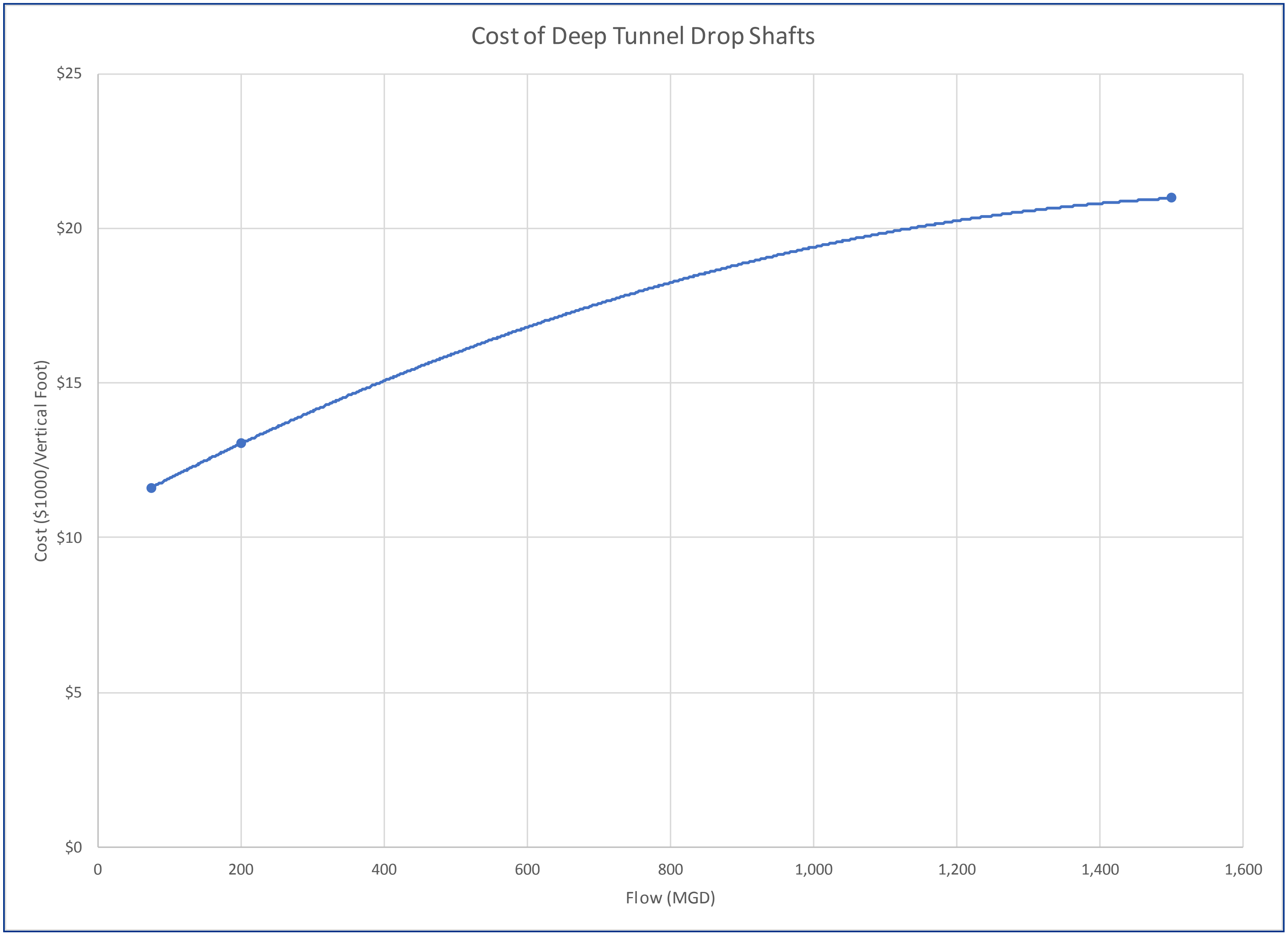


Figure 3-8 - Construction Cost Estimates for Tunnel Drop Shaft



Section 4

Green Infrastructure

The evaluation of Green Infrastructure for CSO control was not required by the prior NJPDES permit, and therefore was not included in the original Technical Guidance Manual. The NJPDES permits issued in 2015 however require permittees to evaluate Green Infrastructure as one of the CSO control alternatives.

The term "Green Infrastructure" is sometimes used to describe an array of source controls measures designed to capture stormwater before it enters the combined sewer collection system, as well as initiatives and regulatory requirements that reduce or limit runoff and pollutant loads. The Green Infrastructure described in this section of the TGM refers to physical structures that retain or detain stormwater runoff near where it originates. These structures are not necessary "green" in terms of being vegetated.

Green Infrastructure practices are designed to reduce the volume and/or peak of stormwater runoff that entering the combined sewer system. In retention systems, such as a rain garden, the runoff is routed to a permeable surface and allowed to infiltrate back into the ground. By preventing this stormwater from ever entering the collection system, the volume of overflow and associated pollutant loads discharging to the receiving waters is reduced. In detention systems, runoff is routed to a storage unit and returned to the combined sewer collection system, ideally after conveyance and treatment capacity have returned. By attenuating these flows, the conveyance system can accept a greater percentage of the overall runoff volume over a longer period of time, resulting in a net reduction of overflow volume and pollutant loads to the receiving waters.

4.1 Vegetated Practices

Many green infrastructure practices are in fact "green", in that they have a vegetative layer. That vegetative layer usually aides in the retention of stormwater runoff through transpiration, and the root system helps to promote soil porosity and aids infiltration. The green infrastructure practices also provide ancillary benefits, such as beautifying neighborhoods, improving air quality, and reducing urban heat. Through this section, several vegetated green infrastructure practices will be discussed:

- Rain Gardens
- Right-of-Way Bioswales
- Tree Pits
- Green Roofs
- Downspout Disconnection

4.1.1 Rain Gardens

Description of Practice

A rain garden consists of a shallow depressed area that is designed to collect stormwater runoff from surrounding surfaces. The collected water infiltrates into the ground, evaporates back into the atmosphere, or is transpired by the vegetation. To increase water absorption and promote infiltration, rain garden designs typically include an upper layer of amended soil with high porosity.

Plant selection and maintenance is critical to the long-term viability of a rain garden. Native plants should be selected that are capable of withstanding periods of ponded water as well as periods of dryness. Using native plants helps to reduce the amount of maintenance that will be required. Figure 4-1 provides a picture of a typical rain garden.

Figure 4-1 - Photo of Rain Garden

(Source: http://nemo.uconn.edu/raingardens/)

Applicability to The Project

Rain gardens can be implemented on public and private properties to capture and retain runoff. When properly designed and maintained they can provide aesthetic improvements to the urban landscape, natural wildlife habitat, and education opportunities for schools. Their shallow and relatively simple design means they can often be constructed without the use of heavy machinery.

Rain gardens are already used in CSO programs across the Country, and within the State of NJ. The Camden County MUA has installed an ~800 square foot rain garden that captures runoff from ~2,000 square feet of surrounding roadway.

Limitations

Proper rain garden design generally allows for a loading ratio of 5:1, with a maximum of about 10:1. The loading ratio is the ratio of contributing drainage area to the available infiltration area. In other words, to control runoff from a 500 square foot rooftop, a 100 square foot rain garden would be required. Infiltration practices that function at higher loading ratios have increased risk for failure due to the higher hydraulic, sediment, and pollutant loads.

The small loading ratio means that rain gardens require relatively large amounts of space. This makes them impractical for wide-spread public right-way application where such space is not available.

Construction Costs

The cost for constructing a rain garden can vary significantly based upon the complexity of the design, the location it is being built, and other local factors. The NJDEP guidance document "Review of GI as a Component of LTCPs" provides a range of $11/sf to $35/sf for construction costs, in 2016 dollars, compiled from projects across the United States. For wide-scale green infrastructure planning, costs are often normalized to units of dollars per impervious acre controlled. Using the 5:1 loading ratio, this range of construction costs is $96,000 to $305,000 per acre controlled which is in-line with local project experience.

4.1.2 Right-of-Way Bioswales

Description of Practice

The right-of-way bioswale is a curb-side green infrastructure design being widely employed as part of New York City's green infrastructure program for CSO control. To date several thousand units have been constructed or are in construction. There are several variations of the design with different widths and depth (right-of-way greenstrips, right-of-way raingardens) but the functionality is essentially the same.

The typical right-of-way bioswale is between 4 and 5 feet wide by 10 to 20 feet long. They are constructed in the existing sidewalk, with curb cuts to allow street runoff traveling along the gutter to enter the bioswale on the upstream side and excess flow to return to the street on the downstream side. It is this conveyance aspect of the practice that makes it a bioswale instead of a deep raingarden.

On the surface, the right-of-way bioswale looks and functions much like a rain garden described above. The unit includes a shallow ponding area, and a vegetative surface that may or may not include a tree. However, whereas a raingarden is generally less than a foot deep, the right-of-way bioswale is approximately 4 ½ feet deep. The first 2 ½ to 3', depending on the design is made up of an engineered soil designed to allow for rapid infiltration. The lower portion of the bioswale is a stone base to provide storage. A rendering of a New York City bioswale is provided in Figure 4-2.

Figure 4-2 - Rendering of Right-of-Way Bioswale

(Source www.nyc.gov/html/dep/html/stormwater/bioswales.shtml)

Applicability to The Project

The right-of-way makes up a significant amount of a city's impervious cover. Sidewalks and streets are generally pitched to capture and convey runoff directly towards the collection system, making them efficient locations to intercept the flow. Furthermore, the municipality already has ownership of these areas.

New York City is constructing thousands of right-of-way bioswales to capture urban runoff before it enters their combined sewer collection systems. The designs could easily be adapted to meet the needs of other combined sewer municipalities.

Limitations

The New York City standard design process sizes the bioswales based upon the calculated volume that can be managed through infiltration through the native surrounding soils, and storage within the unit, during a specified period. This generally results in loading ratios well above standard rule of thumb loading ratios for bio-infiltration practices. To date New York City's post construction monitoring program has shown that overall the units are functioning at or beyond their intended designs, but long-term monitoring results are not yet available. Permittees should consider the potential failure risks of utilizing similarly high loading ratios. Infiltration practices that function at higher loading ratios have increased risk for failure due to the higher hydraulic, sediment, and pollutant loads.

Constructing bio-infiltration practices in the sidewalk requires that the existing sidewalks are wide enough to allow for the feature while still maintaining functionality for pedestrian traffic. The ability to site right-of-way bioswales will have to be determined by each permittee.

Construction Costs

The actual construction costs for right-of-way bioswales is estimated to be approximately $15,000 unit, which equates to approximately $150,000 per acre controlled. These costs are based on large construction contracts generally including 100 – 200 units where an economy of scale can be achieved. For single unit or low quantity construction estimates, the costs can be significantly higher.

Prior to construction, identifying appropriate and effective locations for right-of-way bioswales requires planning, field work, and geotechnical investigations. When attempting to implement a wide-scale right-of-way green infrastructure program, many locations will be screened out due to site constraints or poorly infiltrating soils. Typical per-site survey and geotechnical costs can be approximately $4,000 to $5,000 per location. When sites are screened out after these costs have been incurred, the programmatic cost per constructed unit goes up to as much as $50,000 per unit.

4.1.3 Enhanced Tree Pits

Description of Practice

Enhanced tree pits, or stormwater trees, can appear similar to a standard city tree pit. Unlike a standard tree pit, however, they utilize an underground system designed to infiltrate runoff. The underground system includes engineered soil capable of rapidly infiltrating water, crushed stone, and an underdrain system. Although they can be built individually, they become more effective when they are installed as a connected multi-unit linear system. In such a system, permeable pavement can be used between the tree pits to allow additional water to infiltrate into a subsurface stone layer that connects the tree pits. A photo of an enhanced tree pit is provided in Figure 4-3.

Figure 4-3 - Photo of Enhanced Tree Pits

(Source: NJ Tree Foundation)

Applicability to The Project

Enhanced tree pits are already in use in cities across the United States as stormwater control measures. They can be constructed in sidewalks, in parking lots, courtyards, etc.

Limitations

The design of enhanced tree pits can vary greatly based on capture needs. The limitation for applicability are similar to those described for rain gardens and bioswales, depending on the desired loading ratio and available space.

Construction Costs

Pre-fabricated tree pits are available for approximately $10,000 each, and cost about $5,000 to install.

4.1.4 Green Roofs

Description of Practice

A green roof generally consists of a vegetated layer on top of a lightweight soil medium, below which lies an underdrain system and waterproof membrane. The depth of the soil medium will determine the type of vegetation that can be sustained and also the weight of the vegetated roof.

A portion of the precipitation that falls on the vegetated surface is retained in the soil medium and eventually released back to the atmosphere through evaporation and taken up through transpiration. The underdrain system acts as additional detention system before the excess water is eventually discharged through the buildings downspouts to the ground or directly into the combined sewer system. A photo of the green roof on Chicago's City Hall is shown in Figure 4-4.

Figure 4-4 - Photo of Green Roof on Chicago City Hall

(Source: www.greenroofs.com/)

Applicability to The Project

Green roofs have been constructed in cities around the world and across the country, including as part of CSO programs.

Limitations

Wide spread application of green roofs is generally cost prohibitive. Most existing buildings cannot support the additional weight of a green roof without costly retrofitting.

Green roofs are generally designed with a loading ratio of 1:1, meaning that the managed area is limited to the footprint of the vegetated area itself.

Construction Costs

The cost for constructing a green roof can vary significantly based upon the complexity of the design, the location it is being built, and other local factors. The NJDEP guidance document "Review of GI as a Component of LTCPs" provides a range of $11/sf to $56/sf for construction costs, in 2016 dollars, compiled from projects across the United States. Using the 1:1 loading ratio, this range of construction costs is $480,000 to $2,440,000 per acre controlled which is in-line with local project experience.

4.1.5 Downspout Disconnection

Description of Practice

In many urban areas, downspouts are connected directly into the combined sewer system. Disconnecting these downspouts provides opportunity for rooftop runoff to be infiltrated or intercepted before entering the combined sewer system. For buildings with exterior downspouts, disconnection can be as simple as cutting the existing downspout, installing an elbow, and routing the downspout to a pervious surface or storage unit, such as a rain barrel. For buildings with interior downspouts the process can be more complicated and may not be practical. However, opportunities may still exist where the internal drain can be located and re-routed through an exterior wall. A photo of the disconnected external downspout is shown in Figure 4-5.

Figure 4-5 - Photo of Disconnected Downspout

(Source: https://www.mmsd.com/what-you-can-do/downspout-disconnection)

Applicability to The Project

Many cities across the United States have adopted programs either requiring or encouraging downspout disconnection. A downspout disconnection program often provides the simplest and lowest cost for reduction in wet weather flow to the sewer system. The combined sewer communities within the PVSC service area should evaluate the potential for adopting such a program.

Construction Costs

Exterior downspout disconnections are usually simple, and can be accomplished for approximately $25 to $50.

4.2 Permeable Pavements

The term Permeable Pavements refers to several distinct surfaces, each of which are intended to provide a reduction in stormwater runoff as compared with traditional paving methods. The nomenclature for these different surfaces is often used interchangeably and can be confusing. The major types of permeable pavements will be discussed in this section, including:

- Porous Asphalt
- Pervious Concrete
- Permeable Pavers

4.2.1 Porous Asphalt

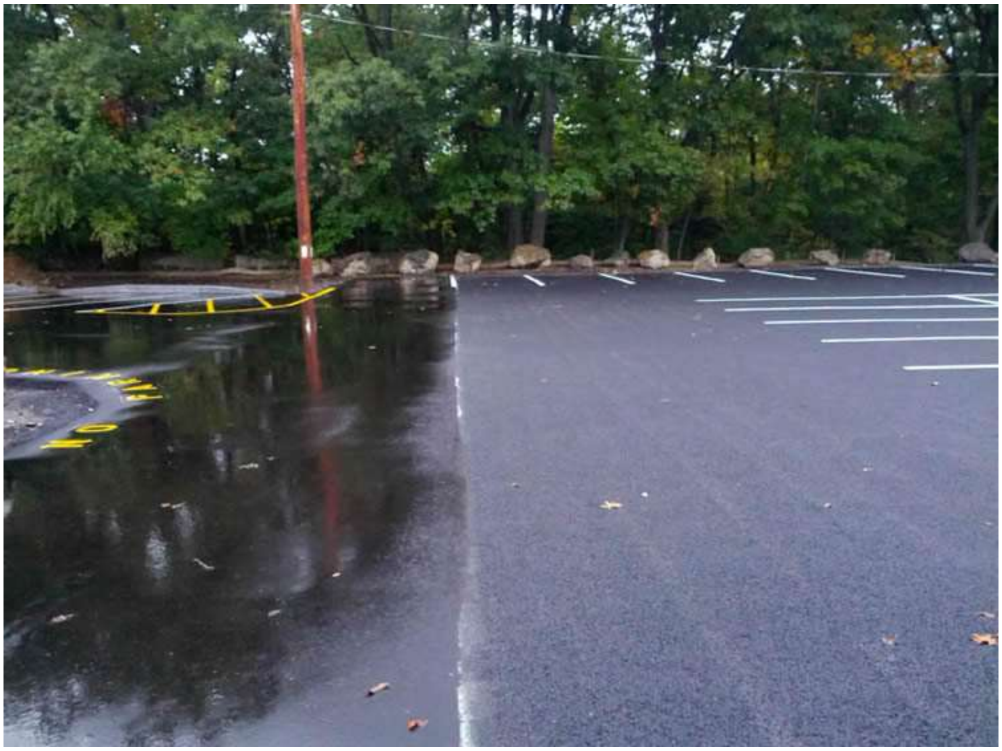
Description of Practice

Upon closer inspection, porous asphalt looks like a somewhat courser version of traditional asphalt, or “blacktop”. Porous and traditional asphalt are made in a similar fashion, but the fine particles are left out of the porous asphalt mix. Without the fines, air becomes trapped in the asphalt mix creating pore space through which water can migrate.

Below the porous asphalt layer, a stone layer acts as a reservoir to store water before it infiltrates into the native soil. An underdrain system may also be included

Figure 4-5 provides a picture of a parking lot in which half was paved using porous asphalt (right side of photo) and the other half was paved using traditional asphalt (left side of photo).

Figure 4-5 - Porous Asphalt Parking Lot



(Source: https://www.epa.gov/soakuptherain/soak-rain-permeable-pavement)

Applicability to The Project

Porous pavement has been used successfully for decades to reduce ponding , flooding, and stormwater discharges. Many combined sewer cities are now using porous pavement as part of their CSO control strategy. Porous asphalt should be considered when roads or parking lots are to be constructed or repaved.

Limitations

Porous pavement requires additional maintenance, including regular service with a vacuum truck to help maintain the open pore space. The use of salt or sand for snow melting is also discouraged. Applications of porous asphalt are typically not recommended in high traffic or heavy industrial sites due to the increased sediment and pollutant loads.

Construction Costs

The cost for porous asphalt can vary significantly based upon whether it new surface or a retrofit. The NJDEP guidance document "Review of GI as a Component of LTCPs" provides a range of $12/sf to $25/sf for construction costs, in 2016 dollars, compiled from projects across the United States. For wide-scale green infrastructure planning, costs are often normalized to units of dollars per impervious acre controlled. Using a 2:1 loading ratio, this range of construction costs is $260,000 to $545,000 per acre controlled which is in-line with local project experience.

4.2.2 Pervious Concrete

Description of Practice

Pervious concrete is a concrete mix containing little or no sand, which creates pore space through which water can migrate. Pervious concrete functions similarly to porous asphalt in that water migrates through the pavements void space down into an underlying stone bed, and either infiltrates to the natural soil or enters an underdrain system. A photo of a pervious concrete application is shown in Figure 4-6. Pre-fabricated pervious concrete panels were installed in the parking stalls.

Figure 4-6 – Pervious Concrete Panels

Applicability to The Project

Pervious concrete pavement has been used successfully for decades to reduce ponding, flooding, and stormwater discharges. Many combined sewer cities are now using pervious concrete as part of their CSO control strategy. Pervious concrete can be considered for sidewalks, courtyards, or anywhere else that traditional concrete may be used.

Limitations

Pervious concrete requires additional maintenance, including regular service with a vacuum truck and pressure washing to help maintain the open pore space. The use of salt or sand for snow melting is also discouraged.

Construction Costs

The cost for pervious concrete can vary significantly based upon the type of application. The NJDEP guidance document "Review of GI as a Component of LTCPs" provides a range of $14/sf to $28/sf for construction costs, in 2016 dollars, compiled from projects across the United States. For wide-scale green infrastructure planning, costs are often normalized to units of dollars per impervious acre controlled. Using a 2:1 loading ratio, this range of construction costs is $305,000 to $610,000 per acre controlled which is in-line with local project experience.

4.2.2 Permeable Interlocking Concrete Pavers (PICP)

Description of Practice

Unlike pervious concrete, permeable pavers do not allow water to pass through the concrete. Instead, the joints between the impervious concrete pavers are filled with a permeable medium such as small stone or sand, allowing water to infiltrate between the pavers. The subsurface includes as stone base and an underdrain, if required.

A photo of a Philadelphia parking lot utilizing concrete permeable pavers is shown in Figure 4-7.

Figure 4-7 – Permeable Interlocking Concrete Pavers (source: EPA)

Applicability to The Project

As with the other types of permeable pavements, permeable interlocking concrete pavers are being used across the country for stormwater control.

Limitations

Permeable interlocking concrete pavers require regular service with a vacuum truck. Proper erosion control is required on the surrounding areas to prevent additional loading to the pavers and clogging.

Construction Costs

The cost for permeable pavers can vary significantly based upon the desired design and type of application. The NJDEP guidance document "Review of GI as a Component of LTCPs" provides a range of $12/sf to $34/sf for construction costs, in 2016 dollars, compiled from projects across the United States. For wide-scale green infrastructure planning, costs are often normalized to units of dollars per impervious acre controlled. Using a 4:1 loading ratio, this range of construction costs is $130,000 to $370,000 per acre controlled which is in-line with local project experience.

Section 5

Water Conservation

Reducing overall water consumption can provide some reduction in CSO discharge volume by providing additional wet weather capacity in the collection system and helping to alleviate the stress on the existing wastewater treatment facilities. It is difficult to quantify the CSO reduction provided through water conservation practices without modeling, and this Technical Guidance Manual does not attempt to do so. The CSO reduction benefits provided through water conservation measures will be dependent upon the coincidence of wet weather events and the highs and lows of daily water usage

Water consumption reduction can be achieved through a variety of measures including public outreach and education; distribution system leak detection and repair; water efficient landscaping; and water efficient plumbing fixtures (i.e., toilets and urinals, faucets, and showerheads). Assuming that nearly all water use inside residences and commercial users will ultimately be disposed of in the sewer, outside water use, such as lawn watering and leaks in the distribution system will not be addressed in the TGM.

This section will focus on water efficient plumbing fixtures and discuss the water saving and costs while implementing water efficient plumbing fixtures.

5.1 Water Efficient Toilets and Urinals

Nearly one-third of total water consumption returns to the sewer system through flushed toilets and urinals. Many plumbing fixtures still in use today were designed at a time when little concern was given to water conservation. Prior to 1950, typical toilets consumed 7-gallons-per-flush (gpf). Toilets installed between 1950 and 1994 consumed 4-5 gpf. Federal laws enacted in 1994 required that residential toilets use no more than 1.6 gpf. A similar limit was established for commercial toilets in 1997, and urinals were limited to 1.0 gpf by the 1997 requirements.

Average water savings by using low-volume toilets compared to high-volume ones is shown for residential households in Table 5-1, and for industrial and commercial facilities in Table 5-2. Average water savings by using low-volume urinals compared to high-volume ones in industrial and commercial facilities only is shown in Table 5-3.

Table 5-1 - Estimated Water Savings Provided by Low Volume Toilets in Households

Year Installed	Average Toilet Water Use Rate (gpf)	Estimated Water Use (gal/household/day)	Estimated Water Use Annually (gal/household/year)	Estimated Annual Water Savings (gal/household/year)
1994 - Present	1.6	32	11,680	-
1980-1994	4.0	80	29,200	17,520
1950s - 1980	5.0	100	36,500	24,820
Pre-1950s	7.0	140	51,100	39,420

Notes: Assume a 4-person household at 5 uses per person per day.

Table 5-2 - Estimated Water Savings Provided by Low Volume Toilets in Commercial and Industrial Facilities

Year Installed	Average Toilet Water Use Rate (gpf)	Average Daily Use (gal/toilet/day)	Estimated Water Use Annually (gal/toilet/year)	Estimated Annual Water Savings (gal/toilet/year)
1997 - Present	1.6	38.4	14,016	-
1980-1994	4.0	96	35,040	21,024
1950s - 1980	5.0	120	43,800	29,784
Pre-1950s	7.0	168	61,320	47,304

Notes: Assume an average daily use of 24 times per toilet per day.

Table 5-3 - Estimated Water Savings Provided by Low Volume Urinals in Commercial and Industrial Facilities

Year Installed	Average Toilet Water Use Rate (gpf)	Estimated Average Daily Use (gal/urinal/day)	Estimated Water Use Annually (gal/urinal/year)	Estimated Annual Water Savings (gal/urinal/year)
1997 - Present	1	16	5,840	-
1980-1994	2.0	32	11,680	5,840
Pre 1980	5.0	80	29,200	23,360

Notes: Assume an average daily use of 16 times per urinal per day.

An estimate of the typical costs associated with replacing a toilet or urinal was developed using construction cost estimating database such as R.S. Means. In 2017 dollar, the equipment and labor costs were:

- Residential Floor Mounted Toilets = $645 per fixture
- Commercial Wall Hung Toilets = $1,225 per fixture
- Urinals = $615 per fixture

5.2 Water Efficient Faucets and Showerheads

Significant amounts of water and energy can be wasted through use of non-water efficient faucets and showerheads. Even a brief five-minute shower can consume 15-35 gallons of water with a conventional showerhead with a flow rate of 3-7 gpm.

Prior to 1980, typical faucets had a flowrate of 4 gpm. Faucets installed between 1980 and 1994 flowed at approximately 3 gpm. Federal guidelines in 1994 required that all lavatory and kitchen faucets and replacement aerators use no more than 2.5 gpm measured at normal water pressure (typically 80 pounds per square inch, psi). A similar limit was established for showerheads in 1994, which reduced the typical flowrate of a showerhead from 3-7 gpm to 2.5 gpm.

Average water savings by using low-flow faucets compared to high-flow ones is shown for residential households in Table 5-4, and for industrial and commercial facilities in Table 5-5. Average water savings by using low-flow showerheads compared to high-flow ones in residential households is shown in Table 5-6.

Table 5-4 - Estimated Water Savings Provided by Low Flow Faucets in Households

Year Installed	Average Faucet Flowrate (gpm)	Estimated Faucet Use (gal/household/day)	Estimated Water Use Annually (gal/household/year)	Estimated Annual Water Savings (gal/household/year)
1994 - Present	2.5	100	36,500	-
1980-1994	3.0	120	43,800	7,300
Pre-1980s	4.0	160	58,400	21,900

Notes: Assume a 4-person household at 10-minutes uses per person per day.

Table 5-5 - Estimated Water Savings Provided by Low Flow Faucets in Commercial and Industrial Facilities

Year Installed	Average Faucet Flowrate (gpm)	Average Daily Use (gal/faucet/day)	Estimated Water Use Annually (gal/faucet/year)	Estimated Annual Water Savings (gal/faucet/year)
1994 - Present	2.5	180	65,700	-
1980-1994	3.0	216	78,840	13,140
Pre-1980s	4.0	288	105,120	39,420

Notes: Assume an average daily use of 72 minutes per faucet per day.

Table 5-6 - Estimated Water Savings Provided by Low Flow Showerheads in Households

Year Installed	Average Showerhead Flowrate (gpm)	Average Daily Use (gal/household/day)	Estimated Water Use Annually (gal/household/year)	Estimated Annual Water Savings (gal/household/year)
1997 - Present	2.5	62.5	22,813	-
1980-1994	3.0	75	27,375	4,563
Pre 1980	7.0	175	63,875	41,063

Notes: Assume a 4-person household at 25-minutes uses per person per day.

An estimate of the typical costs associated with replacing a toilet or urinal was developed using construction cost estimating database such as R.S. Means. In 2017 dollar, the equipment and labor costs were:

- Residential Faucet Replacement = $189
- Residential Showerhead Replacement (including built-in, head, arm, and 2.5 gpm valve) = $350

Commercial Faucet Replacement (with automatic sensor and operator) = $675

Appendix A

Climber Screens® Installation List

(Source: Suez, formerly Infilco Degremont, Inc.)

Climber Screen® Installation List
Type IIS and IIIAS
NJ, NY, PA
2000-2015

July 2017

Serial Number	Contract#	State	Location	Name	Year	Qty	Type	Design Flow Rate	Unit of Measure	Channel Width	Channel Depth	Max. Water Depth	Clear Spacing	Channel Invert to Operating Floor	Material - Non Wetted	Material - Wetted
CS-1445	00012	NY	Brooklyn	Red Hook WPCP (Replaced 84-949)	2000	1	IIS	70.0	MGD	72	100.25	72	1	429.5	316SS	316SS
CS-1446	00012	NY	Brooklyn	Red Hook WPCP (Replaced 84-949)	2000	1	IIS	70.0	MGD	72	100.25	72	1	429.5	316SS	316SS
CS-1447	00012	NY	Brooklyn	Red Hook WPCP (Replaced 84-949)	2000	1	IIS	70.0	MGD	72	100.25	72	1	429.5	316SS	316SS
CS-1448	00012	NY	Brooklyn	Red Hook WPCP (Replaced 84-949)	2000	1	IIS	70.0	MGD	72	100.25	72	1	429.5	316SS	316SS
CS-1478	00103	PA	Erie	Erie WWTP - East Headworks	2000	1	IIS	58.0	MGD	72	120	90	1	120	Carbon Steel	304SS
CS-1479	00103	PA	Erie	Erie WWTP - East Headworks	2000	1	IIS	58.0	MGD	72	120	90	1	120	Carbon Steel	304SS
CS-1480	00103	PA	Erie	Erie WWTP - East Headworks	2000	1	IIS	58.0	MGD	72	120	90	1	120	Carbon Steel	304SS
CS-1499	01138	NY	Albany	Albany County WWTP	2001	1	IIS	50.0	MGD	48	88	82	1	450	Carbon Steel	304SS
CS-1500	01138	NY	Albany	Albany County WWTP	2001	1	IIS	50.0	MGD	48	88	82	1	450	Carbon Steel	304SS
CS-1501	01138	NY	Albany	Albany County WWTP	2001	1	IIS	50.0	MGD	48	114	108	1	474	Carbon Steel	304SS
CS-1502	01138	NY	Albany	Albany County WWTP	2001	1	IIS	50.0	MGD	48	114	108	1	474	Carbon Steel	304SS
CS-1503	01137	NY	Suffolk County	Bergen Point STP	2001	1	IIS			72	258		0.75			
CS-1527	01205	NY	Bronx	Hunts Point WPCP (Replaced 84-904)	2001	1	IIIAS	80.0	MGD	84	144	132	0.5	144	Carbon Steel	304SS
CS-1528	01205	NY	Bronx	Hunts Point WPCP (Replaced 84-904)	2001	1	IIIAS	80.0	MGD	84	144	132	0.5	144	Carbon Steel	304SS
CS-1529	01205	NY	Bronx	Hunts Point WPCP (Replaced 84-904)	2001	1	IIIAS	80.0	MGD	84	144	132	0.5	144	Carbon Steel	304SS
CS-1530	01205	NY	Bronx	Hunts Point WPCP (Replaced 84-904)	2001	1	IIIAS	80.0	MGD	84	144	132	0.5	144	Carbon Steel	304SS
CS-1531	01205	NY	Bronx	Hunts Point WPCP (Replaced 84-904)	2001	1	IIIAS	80.0	MGD	84	144	132	0.5	144	Carbon Steel	304SS
CS-1539	02253	NY	Binghamton	Binghamton-Johnson County WWTP	2002	1	IIS		MGD	48	270		0.75	381	Carbon Steel	304SS
CS-1540	02253	NY	Binghamton	Binghamton-Johnson County WWTP	2002	1	IIS		MGD	48	270		0.75	381	Carbon Steel	304SS
CS-1559	01137	NY	Suffolk County	Bergen Point STP	2001	1	IIS		MGD	72	258	135	0.75	414	304SS	304SS
CS-1560	01137	NY	Suffolk County	Bergen Point STP	2001	1	IIS		MGD	72	258	135	0.75	414	304SS	304SS
CS-1594	04401	NY	Brooklyn	Coney Island WPCP (Replaced 84-927 CS-32	2004	1	IIS		MGD	60	218.438		0.75	218.4375	Carbon Steel	304SS

July 2017

Climber Screen® Installation List
Type IIS and IIIAS
NJ, NY, PA
2000-2015

Serial Number	Contract#	State	Location	Name	Year	Qty	Type	Design Flow Rate	Unit of Measure	Channel Width	Channel Depth	Max. Water Depth	Clear Spacing	Channel Invert to Operating Floor	Material - Non Wetted	Material - Wetted
CS-1595	04401	NY	Brooklyn	Coney Island WPCP (Replaced 84-927 CS-32	2004	1	IIS		MGD	60	218.438		0.75	218.4375	Carbon Steel	304SS
CS-1596	04401	NY	Brooklyn	Coney Island WPCP (Replaced 84-927 CS-32	2004	1	IIS		MGD	60	218.438		0.75	218.4375	Carbon Steel	304SS
CS-1599	05462	NJ	Sayreville	Sayreville PS	2005	1	IIS	100.0	MGD	60	296.5		1	440.5	304SS	304SS
CS-1600	05462	NJ	Sayreville	Sayreville PS	2005	1	IIS	100.0	MGD	60	296.5		1	440.5	304SS	304SS
CS-1601	05462	NJ	Sayreville	Sayreville PS	2005	1	IIS	100.0	MGD	60	296.5		1	440.5	304SS	304SS
CS-1602	05462	NJ	Sayreville	Sayreville PS	2005	1	IIS	100.0	MGD	60	296.5		1	440.5	304SS	304SS
CS-1604	04451	NY	Brooklyn	Owls Head WPCP (Replaced 84-926 Coarse)	2004	1	IIIAS			81	174		1.25	336	Carbon Steel	304SS
CS-1605	04451	NY	Brooklyn	Owls Head WPCP (Replaced 84-926 Coarse)	2004	1	IIIAS			81	174		1.25	336	Carbon Steel	304SS
CS-1606	04451	NY	Brooklyn	Owls Head WPCP (Replaced 84-926 Coarse)	2004	1	IIIAS			81	174		1.25	336	Carbon Steel	304SS
CS-1607	04451	NY	Brooklyn	Owls Head WPCP (Replaced 84-926 Coarse)	2004	1	IIIAS			81	174		1.25	336	Carbon Steel	304SS
CS-1608	04451	NY	Brooklyn	Owls Head WPCP (Replaced 84-926 Fine)	2004	1	IIIAS			81	174		0.75	336	Carbon Steel	304SS
CS-1609	04451	NY	Brooklyn	Owls Head WPCP (Replaced 84-926 Fine)	2004	1	IIIAS			81	174		0.75	336	Carbon Steel	304SS
CS-1610	04451	NY	Brooklyn	Owls Head WPCP (Replaced 84-926 Fine)	2004	1	IIIAS			81	174		0.75	336	Carbon Steel	304SS
CS-1611	04451	NY	Brooklyn	Owls Head WPCP (Replaced 84-926 Fine)	2004	1	IIIAS			81	174		0.75	336	Carbon Steel	304SS
CS-1621	05476	NJ	Camden County	Camden County WWTP	2005	1	IIS	150.0	MGD	72	276	126	1	276	Carbon Steel	304SS
CS-1622	05476	NJ	Camden County	Camden County WWTP	2005	1	IIS	150.0	MGD	72	276	126	1	276	Carbon Steel	304SS
CS-1623	05476	NJ	Camden County	Camden County WWTP	2005	1	IIS	150.0	MGD	72	276	126	1	276	Carbon Steel	304SS
CS-1624	04441	NY	New York	13th St. Manhattan PS (Replaced 85-032)	2004	1	IIIAS	100.0	GPM	66	144	120	1	522	Carbon Steel	316SS
CS-1625	04441	NY	New York	13th St. Manhattan PS (Replaced 85-032)	2004	1	IIIAS	100.0	GPM	66	144	120	1	522	Carbon Steel	316SS
CS-1626	04441	NY	New York	13th St. Manhattan PS (Replaced 85-032)	2004	1	IIIAS	100.0	GPM	66	144	120	1	522	Carbon Steel	316SS
CS-1627	04441	NY	New York	13th St. Manhattan PS (Replaced 85-032)	2004	1	IIIAS	100.0	GPM	66	144	120	1	522	Carbon Steel	316SS
CS-1629	05486	NY	Onondaga County	Baldwinsville Senera Knolls	2005	1	IIS		MGD	48	66		1	360	304SS	304SS

July 2017

Climber Screen® Installation List
Type IIS and IIIAS
NJ, NY, PA
2000-2015

Serial Number	Contract#	State	Location	Name	Year	Qty	Type	Design Flow Rate	Unit of Measure	Channel Width	Channel Depth	Max. Water Depth	Clear Spacing	Channel Invert to Operating Floor	Material - Non Wetted	Material - Wetted
CS-1630	05486	NY	Onondaga County	Baldwinsville Senera Knolls	2005	1	IIS		MGD	48	66		1	360	304SS	304SS
CS-1631	05486	NY	Onondaga County	Ley Creek PS	2005	1	IIS		MGD	48	260.5		1	260.5	304SS	304SS
CS-1632	05486	NY	Onondaga County	Ley Creek PS	2005	1	IIS		MGD	48	260.5		1	260.5	304SS	304SS
CS-1633	05486	NY	Onondaga County	Metropolitan Syracuse Effluent Channel	2005	1	IIS		MGD	71	203.5		0.75	203.5	304SS	304SS
CS-1634	05486	NY	Onondaga County	Metropolitan Syracuse Effluent Channel	2005	1	IIS		MGD	71	203.5		0.75	203.5	304SS	304SS
CS-1635	05486	NY	Onondaga County	Metropolitan Syracuse Effluent Channel	2005	1	IIS		MGD	72	150.625		1.5	150.625	304SS	304SS
CS-1636	05486	NY	Onondaga County	Metropolitan Syracuse Effluent Channel	2005	1	IIS		MGD	72	150.625		1.5	150.625	304SS	304SS
CS-1650	05504	NJ	Rahway	Rahway Valley WWTP	2005	1	IIS	52.5	MGD	72	145	72	3	369	Carbon Steel	304SS
CS-1651	05504	NJ	Rahway	Rahway Valley WWTP	2005	1	IIS	52.5	MGD	72	145	72	3	369	Carbon Steel	304SS
CS-1652	05504	NJ	Rahway	Rahway Valley WWTP	2005	1	IIS	52.5	MGD	72	145	72	3	369	Carbon Steel	304SS
CS-1653	05504	NJ	Rahway	Rahway Valley WWTP	2005	1	IIS	52.5	MGD	72	145	72	3	369	Carbon Steel	304SS
CS-1654	05504	NJ	Rahway	Rahway Valley WWTP	2005	1	IIS	52.5	MGD	72	145	72	3	369	Carbon Steel	304SS
CS-1655	05504	NJ	Rahway	Rahway Valley WWTP	2005	1	IIS	52.5	MGD	72	145	72	3	369	Carbon Steel	304SS
CS-1657	05509	NY	Brooklyn	Paerdegat PS	2005	1	IIIAS	333.0	MGD	108	322	168	1.25	322	Carbon Steel	316SS
CS-1658	05509	NY	Brooklyn	Paerdegat PS	2005	1	IIIAS	333.0	MGD	108	322	168	1.25	322	Carbon Steel	316SS
CS-1659	05509	NY	Brooklyn	Paerdegat PS	2005	1	IIIAS	333.0	MGD	108	322	168	1.25	322	Carbon Steel	316SS
CS-1660	05509	NY	Brooklyn	Paerdegat PS	2005	1	IIIAS	333.0	MGD	108	322	168	1.25	322	Carbon Steel	316SS
CS-1661	05509	NY	Brooklyn	Paerdegat PS	2005	1	IIIAS	333.0	MGD	108	322	168	1.25	322	Carbon Steel	316SS
CS-1662	05509	NY	Brooklyn	Paerdegat PS	2005	1	IIIAS	333.0	MGD	108	322	168	1.25	322	Carbon Steel	316SS
CS-1690	08610	NY	Brooklyn	Newtown Creek WPCP (Replaced 86-119)	2008	1	IIIAS	100.0	MGD	78	148.5	86	1	496.5	Carbon Steel	316SS
CS-1691	08610	NY	Brooklyn	Newtown Creek WPCP (Replaced 86-119)	2008	1	IIIAS	100.0	MGD	78	148.5	86	1	496.5	Carbon Steel	316SS
CS-1692	08610	NY	Brooklyn	Newtown Creek WPCP (Replaced 86-119)	2008	1	IIIAS	100.0	MGD	78	148.5	86	1	496.5	Carbon Steel	316SS

Climber Screen® Installation List
Type IIS and IIIAS
NJ, NY, PA
2000-2015

July 2017

Serial Number	Contract#	State	Location	Name	Year	Qty	Type	Design Flow Rate	Unit of Measure	Channel Width	Channel Depth	Max. Water Depth	Clear Spacing	Channel Invert to Operating Floor	Material - Non Wetted	Material - Wetted
CS-1693	08610	NY	Brooklyn	Newtown Creek WPCP (Replaced 86-119)	2008	1	IIIAS	100.0	MGD	78	148.5	86	1	496.5	Carbon Steel	316SS
CS-1720	09657	NY	New York	Powell's Cove PS (Replaced 84-937)	2009	1	IIS		MGD	54	90		1.25	408	Carbon Steel	316LSS
CS-1739	09671	NY	Albany	Albany North & South WWTP	2009	1	IIS		MGD	60	114		1	468	Carbon Steel	304LSS
CS-1740	09671	NY	Albany	Albany North & South WWTP	2009	1	IIS		MGD	48	88		1	444	Carbon Steel	304LSS
CS-1751	10700	NY	Brooklyn	Newtown Creek WPCP (Secondary)	2010	1	IIS	70.0	MGD	76	276	156	0.375	276	Carbon Steel	304SS
CS-1752	10700	NY	Brooklyn	Newtown Creek WPCP (Secondary)	2010	1	IIS	70.0	MGD	76	276	156	0.375	276	Carbon Steel	304SS
CS-1753	10700	NY	Brooklyn	Newtown Creek WPCP (Secondary)	2010	1	IIS	70.0	MGD	76	276	156	0.375	276	Carbon Steel	304SS
CS-1754	10700	NY	Brooklyn	Newtown Creek WPCP (Secondary)	2010	1	IIS	70.0	MGD	76	276	156	0.375	276	Carbon Steel	304SS
CS-1755	10700	NY	Brooklyn	Newtown Creek WPCP (Secondary)	2010	1	IIS	70.0	MGD	76	276	156	0.375	276	Carbon Steel	304SS
CS-1756	10700	NY	Brooklyn	Newtown Creek WPCP (Secondary)	2010	1	IIS	70.0	MGD	76	276	156	0.375	276	Carbon Steel	304SS
CS-1757	10700	NY	Brooklyn	Newtown Creek WPCP (Secondary)	2010	1	IIS	70.0	MGD	76	276	156	0.375	276	Carbon Steel	304SS
CS-1758	10700	NY	Brooklyn	Newtown Creek WPCP (Secondary)	2010	1	IIS	70.0	MGD	76	276	156	0.375	276	Carbon Steel	304SS
CS-1759	10700	NY	Brooklyn	Newtown Creek WPCP (Secondary)	2010	1	IIS	70.0	MGD	76	276	156	0.375	276	Carbon Steel	304SS
CS-1760	10700	NY	Brooklyn	Newtown Creek WPCP (Secondary)	2010	1	IIS	70.0	MGD	76	276	156	0.375	276	Carbon Steel	304SS
CS-1761	10700	NY	Brooklyn	Newtown Creek WPCP (Secondary)	2010	1	IIS	70.0	MGD	76	276	156	0.375	276	Carbon Steel	304SS
CS-1762	10700	NY	Brooklyn	Newtown Creek WPCP (Secondary)	2010	1	IIS	70.0	MGD	76	276	156	0.375	276	Carbon Steel	304SS
CS-1768	10703	NY	Brooklyn	26th Ward WPCP (Replaced 89-441)	2010	1	IIIAS	45.0	MGD	66	98.5	98.5	1	300.5625	Carbon Steel	304SS
CS-1769	10703	NY	Brooklyn	26th Ward WPCP (Replaced 89-441)	2010	1	IIIAS	45.0	MGD	66	98.5	98.5	1	300.5625	Carbon Steel	304SS
CS-1770	10703	NY	Brooklyn	26th Ward WPCP (Replaced 89-441)	2010	1	IIIAS	45.0	MGD	66	102	102	1	288	Carbon Steel	304SS
CS-1771	10703	NY	Brooklyn	26th Ward WPCP (Replaced 89-441)	2010	1	IIIAS	45.0	MGD	66	93	93	1	413.25	Carbon Steel	304SS
CS-1772	10703	NY	Brooklyn	26th Ward WPCP (Replaced 89-441)	2010	1	IIIAS	45.0	MGD	66	93	93	1	413.25	Carbon Steel	304SS
CS-1773	10703	NY	Brooklyn	26th Ward WPCP (Replaced 89-441)	2010	1	IIIAS	45.0	MGD	66	88	88	1	413.25	Carbon Steel	304SS

Climber Screen® Installation List
Type IIS and IIIAS
NJ, NY, PA
2000-2015

July 2017

Serial Number	Contract#	State	Location	Name	Year	Qty	Type	Design Flow Rate	Unit of Measure	Channel Width	Channel Depth	Max. Water Depth	Clear Spacing	Channel Invert to Operating Floor	Material - Non Wetted	Material - Wetted
CS-1794	11751	NY	Troy	Rensselear County District #1 WWTP	2011	1	IIS	30.0	GPM	48	119	119	0.75	119	Carbon Steel	304SS
CS-1795	11751	NY	Troy	Rensselear County District #1 WWTP	2011	1	IIS	30.0	GPM	48	119	119	0.75	119	Carbon Steel	304SS
CS-1799	11762	NJ	Sayreville	MCUA Sayreville PS	2011	1	IIS	56.0	GPM	72	297		0.625	471	304SS	304SS
CS-1800	11762	NJ	Sayreville	MCUA Sayreville PS	2011	1	IIS	56.0	GPM	72	297		0.625	471	304SS	304SS
CS-1801	11762	NJ	Sayreville	MCUA Sayreville PS	2011	1	IIS	56.0	GPM	72	297		0.625	471	304SS	304SS
CS-1806	11771	NY	Jamaica	Jamaica WPCP (Replaced 88-271)	2011	1	IIIAS	67.0	MGD	99	112.5	112.5	1	398.5	Carbon Steel	304SS
CS-1807	11771	NY	Jamaica	Jamaica WPCP (Replaced 88-271)	2011	1	IIIAS	67.0	MGD	99	112.5	112.5	1	398.5	Carbon Steel	304SS
CS-1808	11771	NY	Jamaica	Jamaica WPCP (Replaced 88-271)	2011	1	IIIAS	67.0	MGD	99	112.5	112.5	1	398.5	Carbon Steel	304SS
CS-1809	11771	NY	Jamaica	Jamaica WPCP (Replaced 88-271)	2011	1	IIIAS	67.0	MGD	99	112.5	112.5	1	398.5	Carbon Steel	304SS
CS-1816	13819	PA	Allentown	Kline's Island WWTP	2013	1	IIS	88.0	MGD							
CS-1817	13819	PA	Allentown	Kline's Island WWTP	2013	1	IIS	88.0	MGD							
CS-1818	13821	NY	Syracuse	Metro Grit Facility	2013	1	IIS	45.0	MGD							
CS-1819	13821	NY	Syracuse	Metro Grit Facility	2013	1	IIS	45.0	MGD							
CS-1820	13821	NY	Syracuse	Metro Grit Facility	2013	1	IIS	45.0	MGD							
CS-1839	14846	NY	Hempstead	Bay Park STP	2014	1	IIS	80.0	MGD	66						
CS-1840	14846	NY	Hempstead	Bay Park STP	2014	1	IIS	80.0	MGD	66						
CS-1841	14846	NY	Hempstead	Bay Park STP	2014	1	IIS	80.0	MGD	66						
CS-1842	14846	NY	Hempstead	Bay Park STP	2014	1	IIS	80.0	MGD	66						
CS-1850	15866	NY	Astoria	Bowery Bay WPCP	2015	1	IIIAS	80.0	MGD	84	102	102	1	255	Carbon Steel	304SS
CS-1851	15866	NY	Astoria	Bowery Bay WPCP	2015	1	IIIAS	80.0	MGD	84	102	102	1	255	Carbon Steel	304SS
CS-1852	15866	NY	Astoria	Bowery Bay WPCP	2015	1	IIIAS	80.0	MGD	84	102	102	1	255	Carbon Steel	304SS
CS-1862	15893	NY	Flushing	Flushing Bay CSO	2015	1	IIIAS	280.0	MGD	138	367		1.25	367	Carbon Steel	304SS

July 2017

Climber Screen® Installation List
Type IIS and IIIAS
NJ, NY, PA
2000-2015

Serial Number	Contract#	State	Location	Name	Year	Qty	Type	Design Flow Rate	Unit of Measure	Channel Width	Channel Depth	Max. Water Depth	Clear Spacing	Channel Invert to Operating Floor	Material - Non Wetted	Material - Wetted
CS-1863	15893	NY	Flushing	Flushing Bay CSO	2015	1	IIIAS	280.0	MGD	138	367		1.25	367	Carbon Steel	304SS
CS-1864	15893	NY	Flushing	Flushing Bay CSO	2015	1	IIIAS	280.0	MGD	138	367		1.25	367	Carbon Steel	304SS
CS-1865	15893	NY	Flushing	Flushing Bay CSO	2015	1	IIIAS	280.0	MGD	138	367		1.25	367	Carbon Steel	304SS
CS-1866	15893	NY	Flushing	Flushing Bay CSO	2015	1	IIIAS	280.0	MGD	138	367		1.25	367	Carbon Steel	304SS
				Total Number:		**106**										

Appendix B

ROMAG^{TM} Installation List

(Source: WesTech Engineering, Inc.)

Job No.	Year	Location				Qty	Size	Equipment/Model
20855	2009	MUNCIE, IN WPCF	MUNCIE	IN	US	1		ROMAG CSO SCREEN RSW854
21335	2012	10TH STREET PUMP STATION	JEFFERSONVILLE	IN	US	1	1 Meters	ROMAG CSO SCREEN RSW115.54
21629	2013	FOURTH CREEK WWTP	KNOXVILLE	TN	US	1	1 Meters	ROMAG CSO SCREEN RSW-K1034
22138	2014	ARCHBALD WWTF	JERMYN	PA	US	1	1 Meters	ROMAG CSO SCREEN RSW724
22156	2014	CLINTON CSO LONG TERM CONTROL PLAN PHASE 1	CLINTON	IN	US	1	4 Meters	ROMAG CSO SCREEN RSW724
22430	2015	GLENS FALLS WWTP	GLENS FALLS	NY	US	1	16 MGD	ROMAG CSO SCREEN RSW-K724
22440	2015	LANCASTER NORTH PUMPING STATION	LANCASTER	PA	US	2	160 MGD	ROMAG CSO SCREEN RSW1254
22463	2016	TOWN BRANCH WET WEATHER STORAGE FACILITY	LEXINGTON	KY	US	1	57 MGD	ROMAG CSO SCREEN RSW864
22596	2016	WOLF RUN WET WEATHER STORAGE FACILITY	LEXINGTON	KY	US	1	7.3 MGD	ROMAG CSO SCREEN RSW824
22676	2016	KENTUCKY AVENUE INTERCEPTOR SEWER IMPROVEMENTS	FRANKFORT	KY	US	1	20 MGD	ROMAG™ CSO SCREEN RSW634
22742	2016	LOWER CANE RUN WET WEATHER STORAGE	LEXINGTON	KY	US	1	20 MGD	ROMAG™ CSO SCREEN RSW634
23133	2017	JOLIET CSO WET WEATHER TREATMENT FACILITY	JOLIET	IL	US	1		ROMAG™ CSO Screen RSW884

Total Qty = 13

Appendix C

Storm King® Vortex Separator Installation List

(Source: Hydro International)

Storm King Installation List

Plant / Job Name	Start-up Date	Contact	Plant Peak Flow, mgd	Equipment	Engineer	Rep	Appl
Hartford, CT WPCP	Jun-95		60.0	(2) 30' Storm King®	Blasland & Bouck Engineers	Aqua Solutions	CSO
Columbus, GA 19th Street - Uptown Park WRF Advanced Demostration Facility	Dec-95	Mike Burch 706-617-4981 mburch@cwwga.org	48 4.9	(6) 32' Storm King® (1) 8.5' FSU Grit King® (1) Classifier	Parsons Engineering Science	PEI	CSO-HW
Columbus, GA State Docks WRF South Commons	Sep-95	Mike Burch 706-617-4981 mburch@cwwga.org	48.0 4.0	(6) 35' Storm King® (2) 8' FSU Grit King® (2) Classifier	JJ & G	PEI	CSO
Lemont, IL WRP Wet Weather Treatment Facility and Reservoir	Jun-15		7.0	(1) 24' Storm King®	CH2M Hill	Drydon	CSO
Round Lake Beach, IL Round Lake Sanitary District	Jan-16		25.0	(1) 30' Storm King®	Christopher Burke Engineering 9575 W. Higgins Road, # 600 Rosemont, IL 60018	Drydon	CSO
Boonville, IN CSO North and South Basin	Feb-12		84.0	(2) 44' Storm King®	Midwestern Engineers	HPT	CSO
Bucksport, ME CSO	Apr-08	David Michaud, Opterator (207)469-0021 DEMichaud@aquaamerica.com	2.9	(1) 18' Storm King®	Wright Pierce Engineers	Aqua Solutions	CSO
Saco, ME CSO Treatment Facility	Nov-06	John Hart Superintendent (207) 282-3564	5.6 8.6	(1) 22' Storm King® (1) 12' ISU Grit King® (1) Type 2 Classifier	Deluca-Hoffman Associates	Aqua Solutions	HW/CSO
Redford, MI Rogue River CSO Retention Basin	Oct-96		61.0	(1) 35' Storm King®		Pumps Plus	CSO
New York, NY Corona Avenue	Oct-01		130.0	(1) 43' Storm King®	URS		CSO
Browndale, PA Clinton WWTP	Feb-06	Glenn Butler Bill Stanvitch Mike Dodgson	15.0	(1) 32' Storm King® (1) 6' ISU Grit King® (1) 12" Classifier	Montgomery Watson Harza	Sherwood Logan	CSO
Conyngham Borough, PA CSO	Nov-99	Jamie Wasilewski Operator (570)788-0608 ext.1	2.0	(1) 18' Storm King®	RDK Engineering	Sherwood Logan	CSO
Hazelton, PA Greater Hazelton JSC - CSO 002	May-11		14.0	(1) 30' Storm King®	Gannett Fleming	Sherwood Logan	CSO
Hazelton, PA Sixth & Ridge CSO	Jun-08	Chris Carcia Director of Operations (570)454-0851	2.6	(1) 18' Storm King®	Gannett Fleming		CSO

Appendix D

HYDROVEX® FluidSep Vortex Separator Installation List

(Source: Veolia Water Technologies)

VEOLIA
4105 Sartelon, Saint-Laurent, Québec, Canada, H4S 2B3
T: 514-334-7230
F: 514-334-5070
cso@veolia.com | www.hydrovex.com

HYDROVEX® FluidSep Vortex Separator
Installation List

	Country	Project	Qty	Type	Diameter (m)	Diameter (ft)	Inlet Flow Rate (L/s)	Inlet Flow Rate (MGD)	Installation Year
1	USA	Burlington, Vermont	1	2.5	12.20	40.03	2629	60	1990
2	USA	Decatur, Illinois, Lincoln Park	4	2.5	13.40	43.96	18230	416	1990
3	USA	Decatur, Illinois, 7th Ward	1	3	13.40	43.96	4951	113	1990
4	USA	Decatur, Illinois, Oakland Park	1	1.35	8.10	26.57	920	21	1991
5	USA	Saginaw, Michigan, 14th Street	3	2.5	11.00	36.09	8500	194	1991
6	USA	Saginaw, Michigan, Weiss	1	3	11.00	36.09	2848	65	1992
7	USA	Cincinnati, Ohio, Daly Rd.	1	3	12.20	40.03	2973	68	1993
8	USA	New York City, C80 #3	1	3	13.10	42.98	5663	129	1994
9	USA	Richmond, Virginia	1	1	2.60	8.53	150	3	1995
10	Canada	The Regional Municipality of Niagara, ON	2	2	12.00	39.37	2000	46	2006
11	USA	Riley Creek CSO, Mattoon, IL	1	2	6.40	21.00	657	15	2016
		Total	**17**	**Units**					

Hydrovex®
www.hydrovex.com

Revised: July 13, 2017

Appendix E

SanSep Installation List

(Source: Echelon Environmental)

SANSEP™ INSTALLATION & CONTACT LIST

Oct 2013

YEAR INSTALLED	LOCATION	OWNER	ENGINEER	DETAILS
1999	LOUISVILLE, KY CSO 50	LOUISVILLE & JEFFERSON CTY MSD Roddy Williams (now works for Strand Associates in Louisville) Derek Guthrie (now works for HDR in Louisville)	HDR (OMNI ENGINEER'ING) Gary Boblett Louisville & Jefferson Cty MSD Darren Thompson	Single PCS50_50; 10 cfs
2000	LOUISVILLE, KY CSO 108	LOUISVILLE & JEFFERSON COUNTY MSD	HDR (OMNI ENGINEERING)	Twin PCS70_70; 38 cfs
2002	AKRON, IN CITY LAKE CSO TREATMENT FACILITIES	AKRON, IN PUBLIC WORKS DEPT Marty Gearhart, Superintendent (574) 893-4674	COMMONWEALTH ENGINEERS Mark Sullivan, PE 7256 Company Drive Indianapolis, IN 46237 (317) 888-1177	PCSC56_40; 10 cfs. PCSC30_30; 4 cfs
2004	COHOES, NY N. NIAGARA AVE CSO OUTFALL	CITY OF COHOES, NY PUBLIC WORKS DEPT. Billy Kane, Maintenance Mgr. Office - (518) 488-8622 ALBANY REGIONAL SEWER DIST. Timothy S. Murphy, Permit Compliance Mgr. Office - (518) 447-1614	MALCOLM PIRNIE Robert E. Ostapczuk, PE 855 Route 146 Suite 210 Clifton Park, NY 12065 Office – (518) 250-7305	PCS100_100; 42 cfs
2004	WEEHAUKEN, NJ W5	NORTH HUDSON SEWER DISTRICT, WEEHAUKEN, NJ CONTRACT OPERATOR – OMI SERVICES JAMES HOWEY, Regional Mgr. 10 Brondesbury Drive Cherry Hill, NJ 08003 856-751-0213 Mohankumar Boraiah CH2M Hill 1600 Adams Street Hoboken, NJ 07030 Ph: 201-386-9847 Cell: 201-344-2783	CH2M-HILL Vincent Rubino, PE Kelly O'Connor, PE 119 Cherry Hill Road Parsippany, NJ 07054-1102 973-316-9300	Twin PCS70_80; 64 cfs

SANSEPtm INSTALLATION & CONTACT LIST

Oct 2013

YEAR INSTALLED	LOCATION	OWNER	ENGINEER	DETAILS
2006	NIAGARA FALLS, ON, CANADA MUDDY RUN PUMP STA. HRT COMPARISON	NIAGARA FALLS REGION AUTHORITY		Single PCS40_30 Demonstration site with StormKing 8 ft diameter unit.
2008	FORT WAYNE CSO 58, FORT WAYNE, IN.	FORT WAYNE PUBLIC UTILITIES Wendy Reust, PE, CSO Program Mgr. One Main St., Room 480 Fort Wayne, IN 46801-1804 Office - 260-427-1367	CDM Karl E. Tanner, PE 151 N. Delaware St. Suite 1520 Indianapolis, IN 46204 Office - 317-637-5424	Twin PCS70_70; 10 cfs
2013	CSO 026 – HARBOR BROOK WETLANDS PILOT PROJECT	ONONDAGA COUNTY DEPT OF WATER ENVIRONMENT	CHA – CH2M-HILL JOINT Rich DeGuida, PE (CHA) 441 S Salina St. Syracuse, NY 13202 Office – 315-471-3920	Double 80-80, 44 cfs
2015	Taylorville, Illinois	City of Taylorville	Crawford, Murphy and Tilly Jeffery Large 217 572-1131	Single 70_70 with gravity underdrain
EUROPEAN INSTALLATIONS				
2005	LONDON	LONDON SEWER DEPT		PCS70_70; 450 l/sec
PACIFIC RIM				
1998	SYDNEY, AUSTRALIA		CDS TECHNOLOGIES PTY LTD.	PCS100_100; 1000 l/sec
2002	BRISBANE, AUSTRALIA		CDS TECHNOLOGIES PTY LTD.	PCS65_65; 400 l/sec
2002	SEOUL, S. KOREA, CHUNG GAE CSO FACILITY	SEOUL PUBLIC WORKS DEPT	KOGET ENVIRONMENTAL TECH.	6 each PCS100_100, 1,000 l/sec each

PWTech
PROCESS WASTEWATER TECHNOLOGIES LLC

Appendix F

ACTIFLO® Ballasted Flocculation Unit Installation List

(Source: Veolia Water Technologies)

KRÜGER

ACTIFLO Wet Weather Installation List

Jul-17

Installation Number	Name	Application	Location	Year Startup	Total Capacity	Number of Trains
1	St. Bernard, LA	ACTIFLO	At WWTP	2001	10	1
		BIOACTIFLO	At WWTP	2011	7.5	1
2	Bremerton, WA	ACTIFLO	Satellite	2001	10	1
3	Lawrence, KS	ACTIFLO	At WWTP	2003	40	2
4	Fort Smith, AR (P Street)	ACTIFLO	At WWTP	2004	31	1
5	Port Clinton, OH	Dual Mode ACTIFLO*	At WWTP	2004	24	2
6	Greenfield, IN	Dual Mode ACTIFLO*	At WWTP	2004	8	2
7	Fort Worth, TX	ACTIFLO	At WWTP	2005	110	2
8	Port Orchard, WA	ACTIFLO	At WWTP	2006	6.7	1
9	Cincinnati SSO 700, OH	ACTIFLO	Satellite	2006	15	1
10	Heart of the Valley (HOV) Kaukauna, WI	Dual Mode ACTIFLO*	At WWTP	2007	60	2
11	Salem, OR	ACTIFLO	Satellite	2007	50	2
12	Cincinnati, OH Sycamore Creek	ACTIFLO	At WWTP	2008	32	2
13	Tacoma, WA	ACTIFLO	At WWTP	2008	76	2
14	Geneva, NY	ACTIFLO	Satellite	2008	23	1
15	Nashua, NH	ACTIFLO	At WWTP	2008	60	2
16	Fort Smith, AR (Sunnymede Pump Station)	ACTIFLO	Satellite	2010	25	1
17	Newark, OH	ACTIFLO	At WWTP	2011	28	2
18	Wilson Creek, TX Phase 1	Dual Mode BIOACTIFLO*	At WWTP	2012	36	1
	Wilson Creek, TX Phase 2 (under construction)		At WWTP	2017	36	1
19	Lowell, IN	ACTIFLO	At WWTP	2013	10	1
20	Rock Creek, OR	Dual Mode ACTIFLO*	At WWTP	2013	30	2
21	Knoxville, TN	BIOACTIFLO	At WWTP	2013	11	2
22	Terra Haute, IN	ACTIFLO	Satellite	2016	16.5	1
23	Nappanee, IN (under construction)	ACTIFLO	Satellite	2017	5	1
24	Cox Creek, MD (under construction)	BIOACTIFLO	At WWTP	2017	12	1
25	McHenry, IL (under construction)	BIOACTIFLO	At WWTP	2017	10	1
26	DC Water (under construction)	ACTIFLO	At WWTP	2018	250	3

* Note: Dual mode means the ACTIFLO treatment train is used during dry weather flows for either primary or tertiary treatment.

Appendix G

DensaDeg® Ballasted Flocculation Installation List

(Source: Suez)

DENSADEG CSO EXPERIENCE

SUEZ has been providing high rate solids contact system for over 85 years. The new DensaDeg XRC™ has been born out of decades of improvements, starting with the original solids-contact clarifier, the Accelator, which was the first to incorporated internal sludge recycling. In the late 1980's the original DensaDeg clarifier was introduced to the market and continues to lead the industry for high-rate sludge ballasted and solids recirculation systems. While the DensaDeg XRC™ is recently introduced in 2015, it is merely an improvement upon a history of existing installations and operating principles, including over 2,400 installations over this span.

<u>DENSADEG XRC</u>

A year-long pilot study was conducted at Petersburg WWTP, VA, which included testing of the primary influent and secondary effluent from the plant. A case study summary is provided in **Addendum 3** of this proposal.

<u>CSO/SSO REFERENCES</u>

Below you will find a list of select installations for the original DensaDeg in CSO/SSO applications.

1 – McLoughlin Point WWTP, British Columbia, Canada – 64.5 MGD, 2019

2 – Shreveport WWTP, Louisiana – 40 MGD, 2006

3 – Toledo WWTP, Ohio – 232 MGD, 2006

Mr. Alan Ruffle, 419-727-2618

4 – Halifax WWTP, Nova Scotia, Canada – 92 MGD, 2005

5 – Edinborough, Scotland, UK -- 2002

6 – Aix-En-Provence (De La Pioline) WWTP, France – 25MGD, 2001

7 – Bourg-End-Bresse (De Majornas) WWTP, France – 22MGD, 2000

8 – Limoges WWTP, France – 23.8 / 33.6 MGD, 2000

9 – Meru (De L'Eau D'Amont) WWTP, France – 3.2MGD, 1999

10 – Saint-Chamond WWTP, France – 63.5MGD, 1999

11 – Colombes (Seine Centre) WWTP, France – 277MGD, 1998

12 – Bonneuil-En-France WWTP, France – 81.5 MGD, 1996

13 – Metz (Station Nord) WWTP, France – 68.5MGD, 1995

Appendix H

FlexFilter Installation List

(Source: WesTech Engineering, Inc.)

WesTech

WWETCO FlexFilter™

Installation and Reference List

This partial list is composed of our key installations for this product. If you would like an expanded or more customized installation or reference list, please contact WesTech Engineering, Inc.

Plant Name	Location City/Sate	Quantity Size	Capacity Equipment Application	Contact Information
Springfield WWTP	Springfield, Ohio	11 30 ft. x 27 ft.	100 MGD Flex Filters CSO Treatment	Bill Young: Plant Superintendent, Springfield WWTP P: (937) 328.7626 E: byoung@springfieldohio.gov
Choctaw Pines	Dry Prong, Louisiana	2 2 ft. x 2 ft.	60 gpm FlexFilters Tertiary Treatment	Russell Turnage: Owner, Turnage Environmental Services P: (318) 447.5291 E: russellturnage@aol.com
Lamar WWTP	Lamar, Missouri	3 6 ft. x 6 ft.	2 MGD FlexFilter Lagoon Effluent Filtration	Rick Hornbeck: Water Plant Superintendent, City of Lamar P: 417-682-4480 E: rhornbeck@cityoflamar.org
Heard County	Franklin, Georgia	2 4 ft. x 4 ft.	0.75 MGD FlexFilters Tertiary Treatment	Jimmy Knight: Director, Heard County Water Authority P: (706) 594.2486 E: jknight@myhcwa.com
Weracoba Creek	Columbus, Georgia	3 6 ft. x 18 ft.	10 MGD FlexFilters Stormwater Treatment	Lynn Campbell: Vice President, Division of Water Resources, Operations, Columbus Waterworks P: (706) 649.3459 E: lcampbell@cwwga.org

WesTech

WWETCO FlexFilter™

Installation List

This partial list is composed of our key installations for this product. If you would like an expanded or more customized installation or reference list, please contact WesTech Engineering, Inc.

Plant Name	Location City/Sate	Quantity Size	Capacity Equipment Application
Solvay Polymer	Marietta, Ohio	3 6 ft. Diameter	1.44 MGD, Flex Filters Tertiary Treatment
Hope East WWTP	Hope, Arkansas	3 6ft. x13 ft	1.6 MGD, Flex Filters Tertiary Treatment
Hope West WWTP	Hope, Arkansas	3 6ft. x16 ft	2 MGD, Flex Filters Tertiary Treatment
Upper Tuscarawas WWTP	Akron, Ohio	10 6 ft. x 10 ft.	100 MGD, Flex Filters CSO Treatment
Springfield WWTP	Springfield, Ohio	11 30 ft. x 27 ft.	100 MGD, Flex Filters CSO Treatment
Choctaw Pines	Dry Prong, Louisiana	2 2 ft. x 2 ft.	60 gpm, FlexFilters Tertiary Treatment
Lamar WWTP	Lamar, Missouri	3 6 ft. x 6 ft.	2 MGD, FlexFilter Lagoon Effluent Filtration
Heard County	Franklin, Georgia	2 4 ft. x 4 ft.	0.75, MGD FlexFilters Tertiary Treatment
Weracoba Creek	Columbus, Georgia	3 6 ft. x 18 ft.	10 MGD, FlexFilters Stormwater Treatment

cdmsmith.com