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Land Use Management
Water Monitoring & Standards
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Water Monitoring Project

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SANITARY SURVEY

Great Bay & Mullica River

January 1, 2000 – December 31, 2003

August 2006

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SANITARY SURVEY

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New Jersey Department of Environmental Protection
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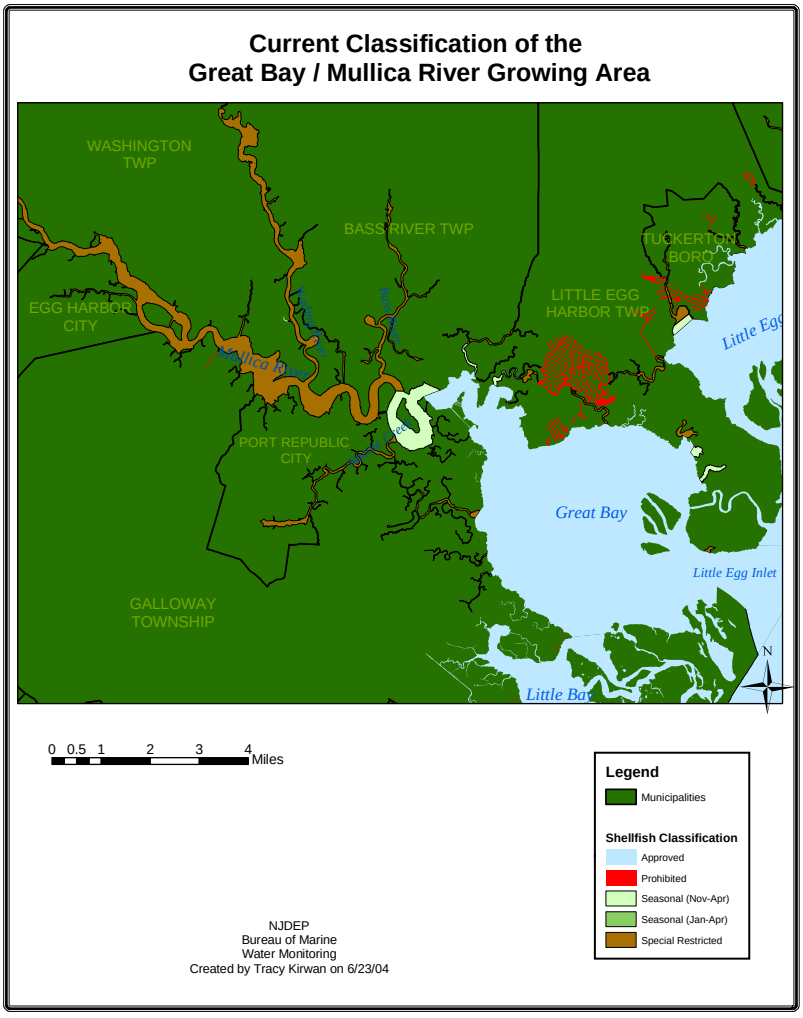
EXECUTIVE SUMMARY

The Great Bay and Mullica River are located in southern New Jersey; with Burlington County and Ocean County to the north and Atlantic County to the south. Currently, most of the Great Bay is *Approved* for shellfish harvesting. The western portion of the Mullica River is classified as *Special Restricted*, then going in an easterly direction, there is a section of *Seasonal (Nov-Apr)* waters before is turns to *Approved* waters, where it adjoins Great Bay. Water samples from the Great Bay & Mullica River were collected using the Systematic Random Sampling strategy and analyzed from 89 sampling stations for total coliform during the period of January 1, 2000 through December 31, 2003 for this Sanitary Survey Report. All sampling stations comply with their respective criteria for their *Approved, Seasonal, Special Restricted, or Prohibited* classification. There are no direct discharges into the Great Bay / Mullica River; however, there are storm water outfalls and some indirect discharges. The results of this data evaluation prove to be consistent with the existing shellfish growing water classifications (see Figure 1).

This sanitary survey recommends changes in the monitoring schedule for the Great Bay/Mullica River growing area. Sampling at station 1928, sampled under assignment 132, should be terminated; stations 1818 &1818A are in close proximity to station 1928 and the area is adequately sampled. Sampling at station 1824B should be terminated; stations 1824 & 1824C are in close proximity and the area is adequately sampled. Stations 1822A, 1822B, and 1823 are presently sampled on assignment run 131, however they should be sampled on assignment 151 due to their location. Since assignment 151 already has 55 stations, stations 1902G, 1905C, 1906C, and 1911B will be terminated to allow stations 1822A, 1822B, and 1823 to be sampled in this assignment run. For the next sampling season station 1907 should be moved slightly southeast. Due to flow change it no longer is an accurate indicator of the coliform input into Great Bay from that tributary (N: 39° 29” 31’, W: 74° 23” 44’). Otherwise, continue sampling under the existing sampling protocol and analyzing the samples for total coliform

FIGURE 1: CURRENT CLASSIFICATION IN THE GREAT BAY/MULLICA RIVER



INTRODUCTION

PURPOSE

This report is part of a series of studies having a dual purpose. The first and primary purpose is to comply with the guidelines of the National Shellfish Sanitation Program (NSSP) that are established by the Interstate Shellfish Sanitation Conference (ISSC). Reports generated under this program form the basis for classifying shellfish waters for the purpose of harvesting shellfish for human consumption. As such, they provide a critical link in protecting human health.

The second purpose is to provide input to the Integrated Water Quality Monitoring and Assessment Report, which is prepared pursuant to Sections 305(b) and 303(d) of the Federal Clean Water Act (P.L. 95-217). The information contained in the growing area reports is used for the 305b portion of the Integrated Report, which provides an assessment to Congress every two years of current water quality conditions in the State's major rivers, lakes, estuaries, and ocean waters. The reports provide valuable information for the 305(b) portion of the Integrated Report, which describes the waters that are attaining state designated water uses and national clean water goals; the pollution problems identified in surface waters; and the actual or potential sources of pollution. Similarly, the reports utilize relevant information contained in the 305(b) portion of the Integrated Report, since the latter assessments are based on in-stream monitoring data (temperature, oxygen, pH, total and fecal coliform bacteria, nutrients, solids, ammonia and metals), land-use profiles, drainage basin characteristics and other pollution source information.

From the perspective of the Shellfish Classification Program, the reciprocal use of water quality information from reports represent two sides of the same coin: the growing area report focuses on the estuary itself, while the 305(b) report describes the watershed that drains to that estuary.

The Department participates in a cooperative National Environmental Performance Partnership System (NEPPS) with the USEPA which emphasizes ongoing evaluation of issues associated with environmental regulation, including assessing impacts on water bodies and measuring improvements in various indicators of environmental health. The shellfish growing area reports are intended to provide a brief assessment of the growing area, with particular emphasis on those factors that affect the quantity and quality of the shellfish resource. The shellfish growing area reports provide valuable information on the overall quality of the saline waters in the most downstream sections of each major watershed. In addition, the reports assess the quality of the biological resource and provide a reliable indicator of potential areas of concern and/or areas where additional information is needed to accurately assess watershed dynamics.

HISTORY OF NSSP REGULATIONS

As a brief history, the NSSP developed from public health principles and program controls formulated at the original conference on shellfish sanitation called by the Surgeon General of the United States Public Health Service in 1925. This conference was called after oysters were implicated in causing over 1500 cases of typhoid fever and 150 deaths in 1924. The tripartite cooperative program (federal, state and shellfish industry) has updated the program procedures and guidelines through workshops held periodically until 1977. Because of concern by many states that the NSSP guidelines were not being enforced uniformly, a delegation of state shellfish officials from 22 states met in 1982 in Annapolis, Maryland, and formed the ISSC. The first annual

meeting was held in 1983 and continues to meet annually at various locations throughout the United States.

The NSSP *Guide for the Control of Molluscan Shellfish* sets forth the principles and requirements for the sanitary control of shellfish produced and shipped in interstate commerce in the United States. It provides the basis used by the Federal Food and Drug Administration (FDA) in evaluating state shellfish sanitation programs. The five major points on which the state is evaluated by the FDA include:

l. The classification of all actual and potential shellfish growing areas as to their suitability for shellfish harvesting.

2. The control of the harvesting of shellfish from areas that are classified as restricted, prohibited, or otherwise closed.

3. The regulation and supervision of shellfish resource recovery programs.

4. The ability to restrict the harvest of shellfish from areas in a public health emergency, and

5. Prevent the sale, shipment or possession of shellfish that cannot be identified as being produced in accordance with the NSSP and have the ability to condemn, seize or embargo such shellfish.

FUNCTIONAL AUTHORITY

The authority to carry out these functions is divided between the Department of Environmental Protection (DEP), the Department of Health and Senior Services, and the Department of Law and Public Safety. The Bureau of Marine Water Monitoring (BMWM), under the authority of N.J.S.A. 58:24, classifies the shellfish growing waters and administers the special resource recovery programs. Regulations delineating the growing areas are promulgated at N.J.A.C. 7:12 and are revised annually. Special Permit rules are also found at N.J.A.C. 7:12 and are revised as necessary.

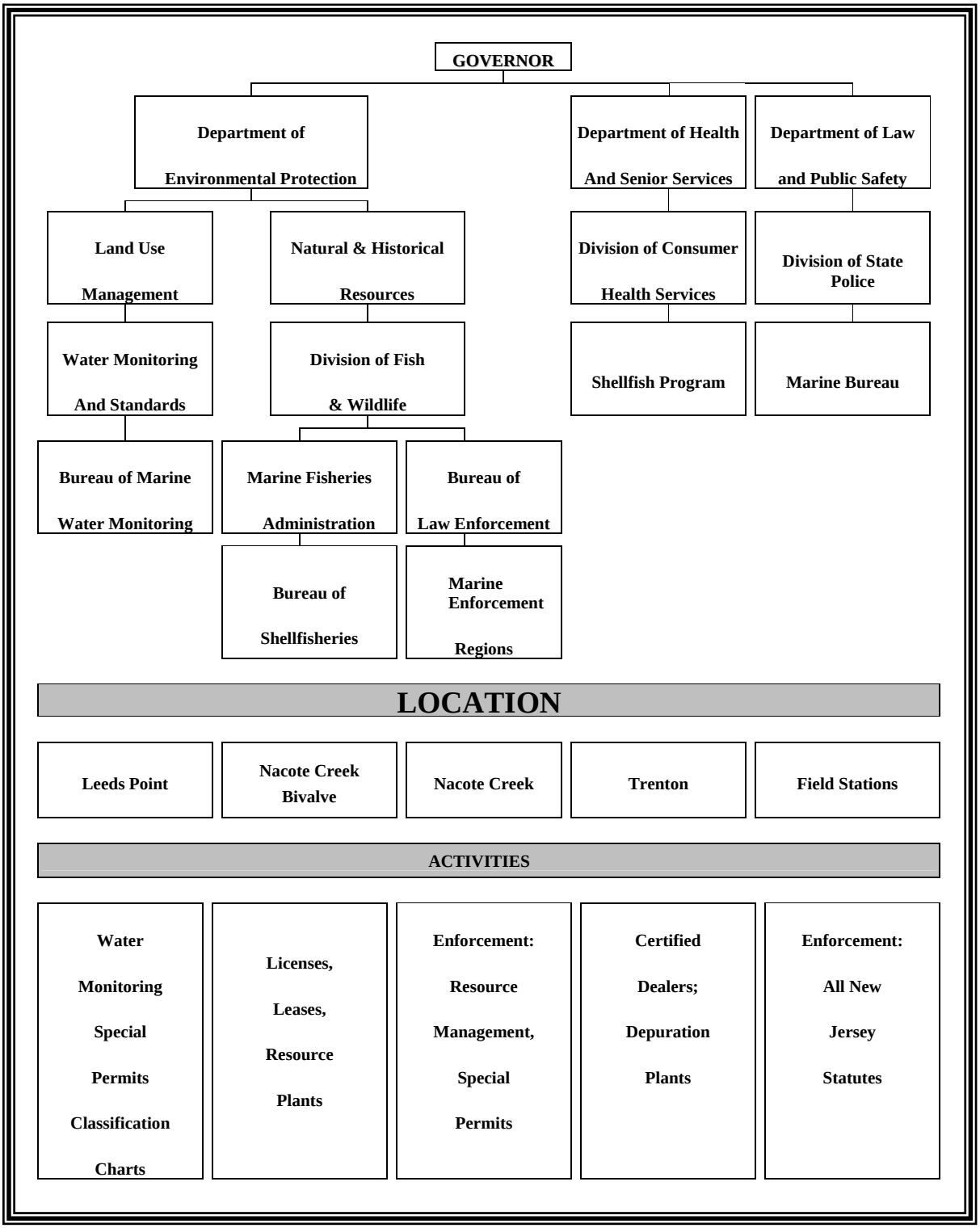
The Bureau of Shellfisheries, in the Division of Fish and Wildlife, issues harvesting licenses and leases for shellfish grounds under the Authority of N.J.S.A. 50:2 and N.J.A.C. 7:25. This bureau, in conjunction with the BMWM, administers the Hard Clam Relay Program.

The Bureau of Law Enforcement in the DEP, Division of Fish and Wildlife, and the Division of State Police, in the Department of Law and Public Safety, enforce the provisions of the statutes and rules mentioned above.

The Department of Health and Senior Services is responsible for the certifications of wholesale shellfish establishments and, in conjunction with the BMWM, administers the depuration program.

The division of authority between the three agencies can be seen in Figure 2.

FIGURE 2: ORGANIZATIONAL CHART OF SHELLFISH AGENCIES



IMPORTANCE OF SANITARY CONTROL OF SHELLFISH

Emphasis is placed on the sanitary control of these shellfish because of the direct relationship between the pollution of shellfish growing areas and the transmission of diseases to humans. Shellfish borne infectious diseases are generally transmitted via a fecal-oral route. The pathway is complex and quite circuitous. The cycle usually begins with fecal contamination of the shellfish growing waters. Contamination often reaches the waterways via runoff and direct discharges. Sources of such contamination are many and varied, and include urban and storm water runoffs, faulty septic systems, boat dumping, agricultural runoff, waterfowl, and animal wastes.

Filter feeding Molluscan shellfish, known as bivalves (clams, oysters, and mussels) pump large quantities of water through their bodies during the normal feeding process (see Figure 3). During this process the shellfish also collect microorganisms, which may include pathogenic microbes, and toxic heavy metals/chemicals. It is imperative that a system is in place to reduce the human health risk of consuming shellfish from areas of contamination.

Accurate classifications of shellfish growing areas are completed through a comprehensive sanitary survey. The principal components of the sanitary survey report include:

1. An evaluation of all actual and potential sources of pollution,
2. An evaluation of the hydrography of the area, and
3. An assessment of water quality.

Complete intensive sanitary surveys are conducted every 12 years with interim narrative evaluations, and reappraisals, completed on a three-year basis. Reappraisal reports are less detailed discussions of the principle components included in the sanitary surveys. In addition, the reappraisal report does not require a full shoreline survey. If major changes to the shoreline or bacterial quality occur, then the intensive sanitary survey report is initiated prior to its l2 year schedule. If only a section of a growing area is either upgraded or downgraded from its current shellfish classification, a partial intensive report (Partial Sanitary Survey) is conducted for that shellfish growing area. Annual Reviews are written on a yearly basis for each shellfish growing area.

This report is a Sanitary Survey of the Great Bay & Mullica River growing area.

After assessment, the accurate classification is determined for that particular area. The possible classifications are *Approved, Seasonal, Special Restricted*, and *Prohibited*. *Approved* waters can be harvested for shellfish year round. *Seasonal* waters can be harvested for all, or part, of the winter; there is a *Seasonal (Nov-Apr)* classification and a *Seasonal (Jan-Apr)* classification. *Special Restricted* waters are approved for harvest, followed by depuration or relay, which help to cleanse bacteria from the shellfish.

Depuration is a process that purifies the shellfish by pumping UV treated

bacteria-free water through clam holding tanks for a minimum of 48 hours, which will, "render the depurated shellfish alive, and microbiologically acceptable within the meaning of State statutes and regulations" (NJDEP 2003 REGS). Relay is when market size shellfish from *Special Restricted* waters are replanted in *Approved* areas where they purge for a minimum of 30 days. Harvesting clams for either depuration or relay requires issuance of a Special Permit, acquired at the Bureau of Marine Water Monitoring. No harvest is allowed in *Prohibited* waters.

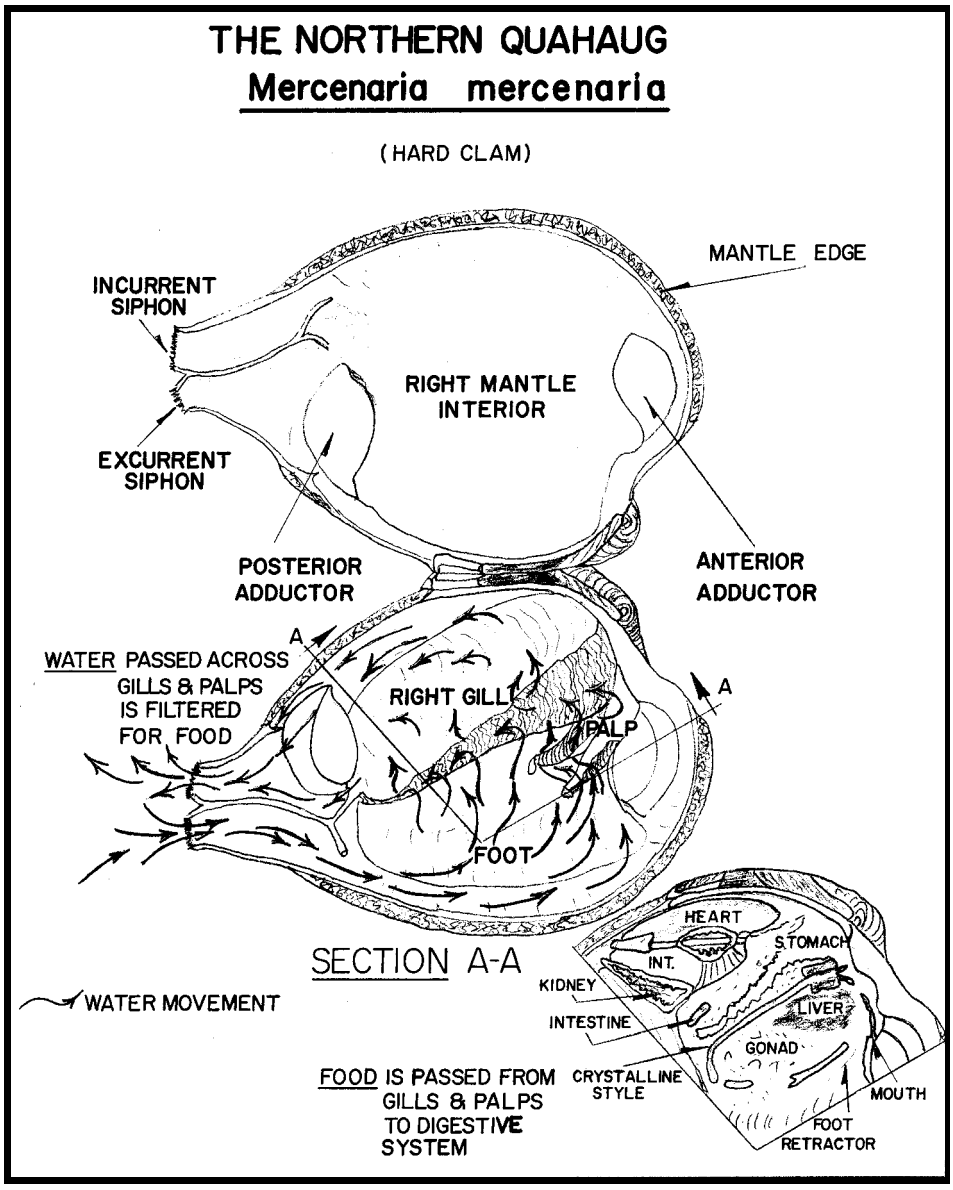
Any discrepancies in the current classification require a change in order to correctly classify the area. If, over time, the data support improving water quality and are within the requisite criteria, then, an upgrade in classification can be made. However, if the data shows values exceeding criteria, then the downgrading of that particular area is required.

According to harvesting regulations, there can be no shellfish taken from waters before sunrise or after sunset or on Sundays, except as provided in N.J.S.A. 50:2-1 (NJDEP Shellfish Growing Water Classification Chart, 2004). Only those who hold a Commercial Clam License may catch more than 150 clams a day or sell or offer the clams for sale. All hard clams harvested must be at least 1½ inches in length (NJDEP Shellfish Growing Water Classification Chart, 2004).

The 1st offense penalty, Petty Disorderly Persons, for illegally harvesting shellfish includes fines up to $500 and/or up to 30 days imprisonment. The 2nd offense penalty, Disorderly Persons, includes fines up to $1000 and/or up to 6 months imprisonment. Boats and equipment may also be seized or made forfeit for any offense (NJDEP Shellfish Growing Water Classification Charts, 2004).

The following narrative constitutes this bureau's assessment of the above mentioned components to comply with the 12 year sanitary survey. Additionally, a shoreline survey was completed.

FIGURE 3: MERCENARIA MERCENARIA



PROFILE OF THE GROWING AREA

LOCATION OF THE GROWING AREA

Shellfish Growing Area SE1, Great Bay & Mullica River, is located in the southern portion of New Jersey. The Great Bay and Mullica River serve as borders between Ocean, Burlington, and Atlantic Counties (see Figures 4 & 6). An imaginary horizontal line halfway through Great Bay is the border that divides Ocean County, in the north, from Atlantic County, in the south. The border between Ocean and Burlington Counties rests between Little Egg Harbor Township (Ocean County) and Bass River Township (Burlington County). Atlantic and Burlington Counties converge at the Mullica River; Burlington County is to the north and Atlantic County is to the south.

There are six municipalities that surround this shellfish growing area; these are Bass River Township, Egg Harbor City, Galloway Township, Little Egg Harbor Township, Port Republic City, and Washington Township (see Figure 5). Bass River Township and Washington Township are located in Burlington County, Little Egg Harbor Township is located in Ocean County, and Egg Harbor City, Port Republic City, and Galloway Township are located in Atlantic County. The population statistics for the adjacent municipalities are shown in Table 1 (Census 2000).

There are several small communities within the Great Bay / Mullica River growing area. These communities include Oyster Creek and Motts Creek in Galloway Township and Chestnut Neck in Port Republic. Nacote Creek and developments along Route 9 also exist in both Galloway Township and Port Republic City. Mystic Island is a large lagoon community within Little Egg Harbor Township.

This growing area report only includes the waters of Great Bay and the Mullica River, although other water bodies surround these locales. Little Egg Inlet is to the east of Great Bay and allows in tidal water from the Atlantic Ocean. To the north is Little Egg Harbor and to the south is Little Bay. The Mullica River continues about 48 miles inland, but this report concentrates on the tidal waters of the Mullica, where shellfish beds reside. All of these surrounding water bodies have the potential to affect the water quality of the Great Bay and/or Mullica River and will be mentioned throughout this report.

This area is also displayed on chart # 6 of the current State of New Jersey Shellfish Growing Water Classification Chart.

FIGURE 4: LOCATION OF THE GREAT BAY / MULLICA RIVER GROWING AREA

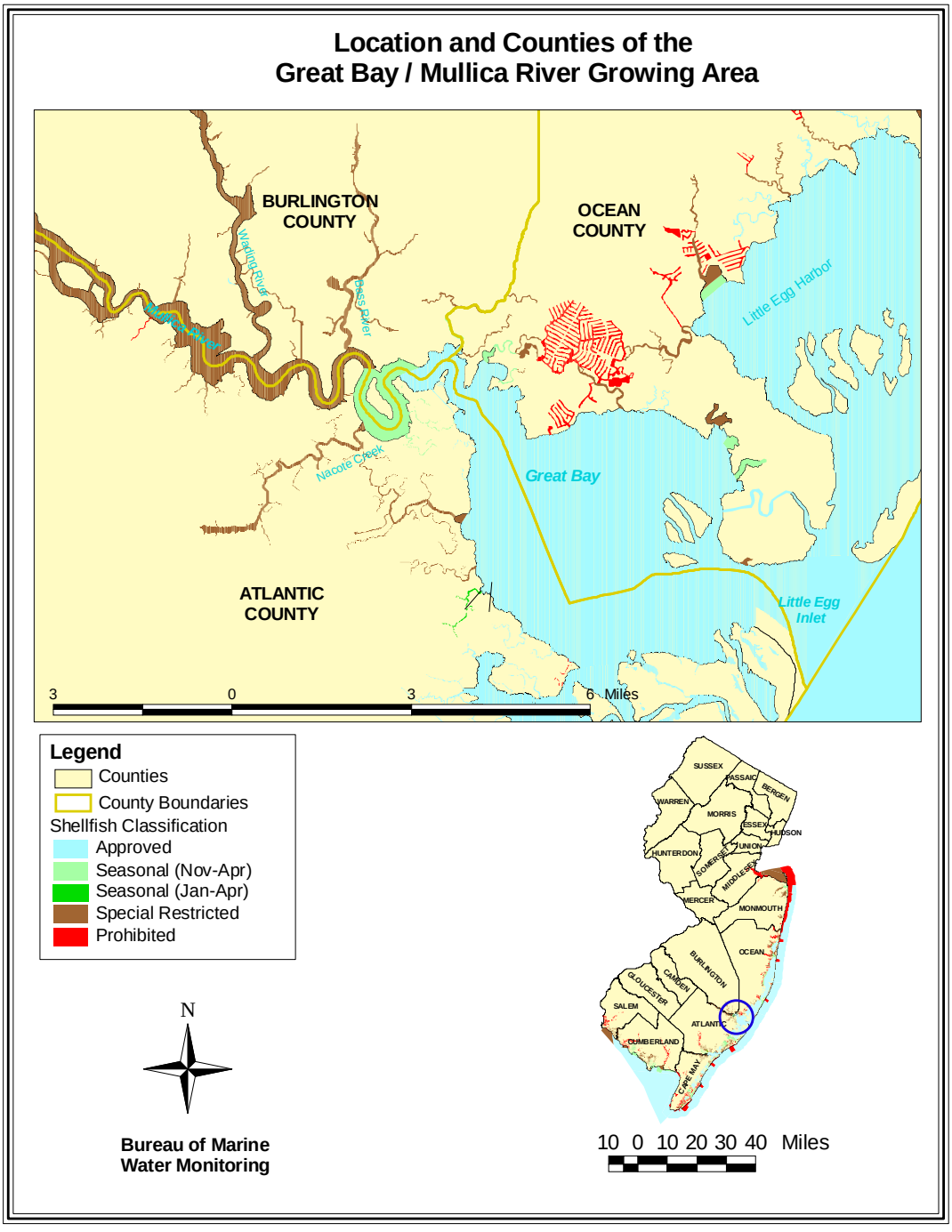


FIGURE 5: MUNICIPALITIES IN THE GREAT BAY / MULLICA RIVER GROWING AREA

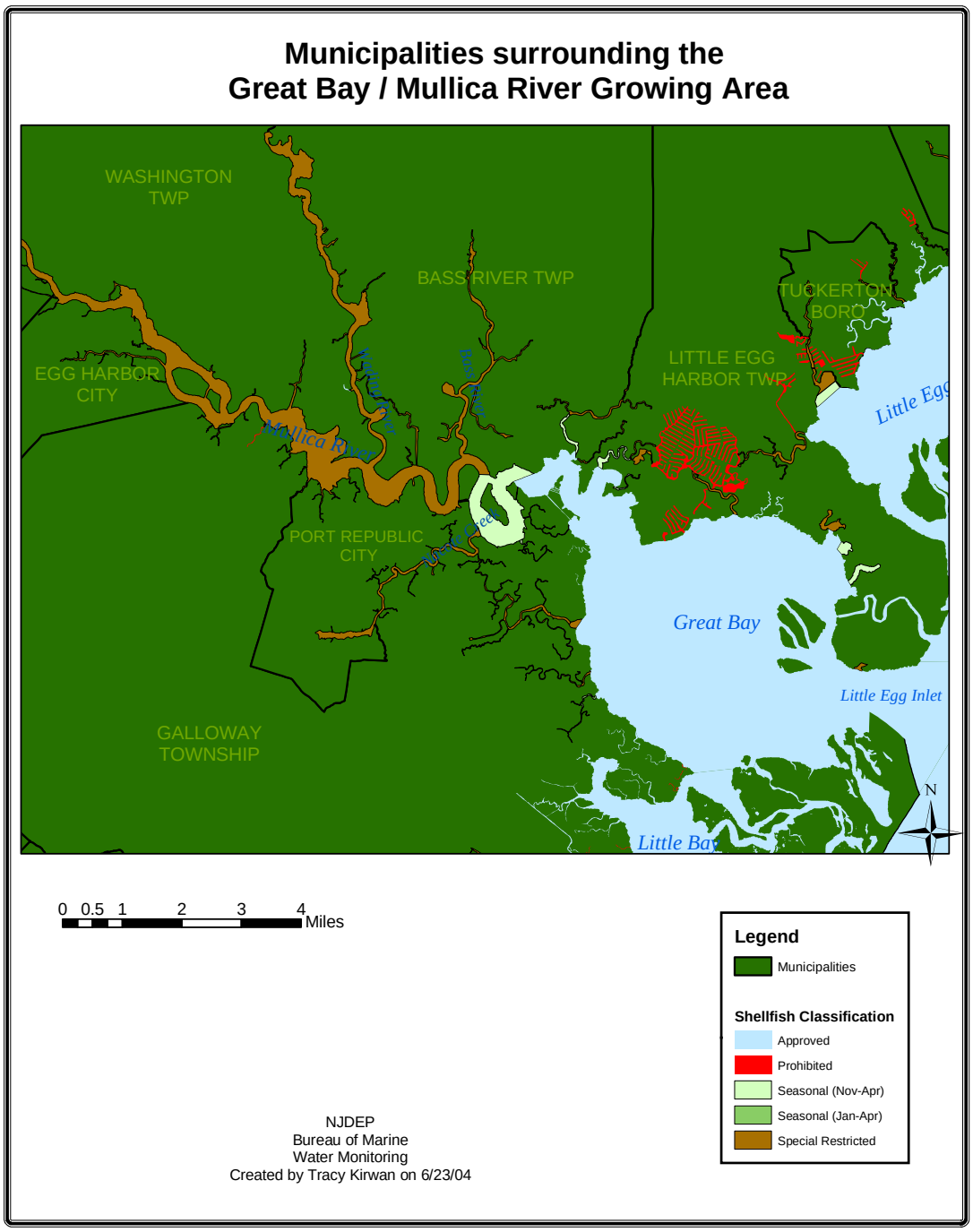
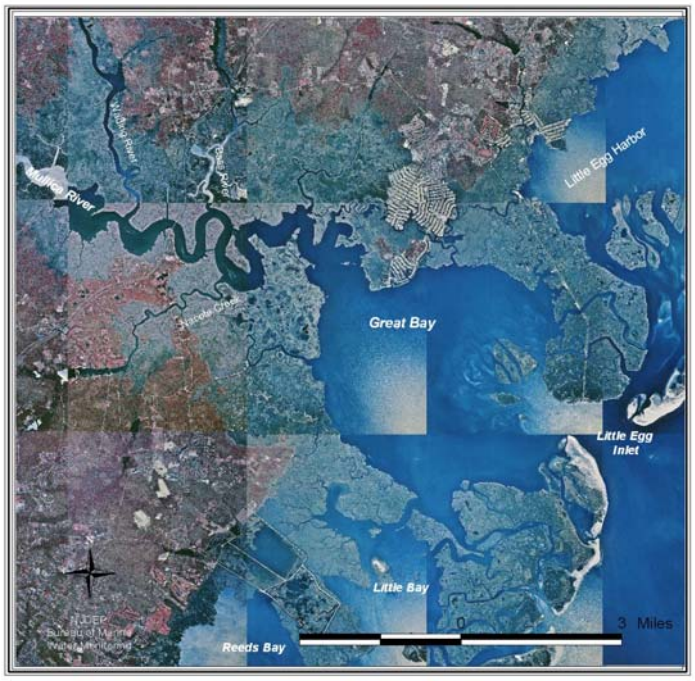


TABLE 1: POPULATION INFORMATION FOR THE GREAT BAY & MULLICA RIVER GROWING AREA

Community	Area (sq. mi.)	Population (2000 Census)	Population Density (persons/sq. mi.)
Bass River Township	75.9	1,510	19.9
Egg Harbor City	11.1	4,545	409.5
Galloway Township	111.4	31,209	280.2
Little Egg Harbor Township	49.5	15,945	322.1
Port Republic City	7.6	1,037	136.4
Washington Township	100.1	621	6.2

FIGURE 6 : OVERHEAD VIEW



DESCRIPTION OF THE GROWING AREA

This report concentrates on the main portions of the Great Bay and Mullica River, where the shellfish beds reside. The whole estuary, however, will be considered when evaluating such things as runoff.

The shellfish classifications for this growing area include *Approved, Seasonal (November-April), Seasonal (January-April), Special Restricted,* and *Prohibited* (see Table 2). The *Approved* waters are located in Great Bay. The *Seasonal (November-April)* waters are located at the mouth of the Mullica River. The *Seasonal (January-April)* waters are located in a small tributary of the Great Bay. The *Special Restricted* waters are located throughout the rest of the Mullica River and its tributaries. The *Prohibited* waters are located in the lagoon systems north of Great Bay, and some small tributaries of the Mullica River (see Figure 7).

The Cohansey Aquifer, a huge underground reservoir (estimated to hold some 17 trillion gallons of water), supplies the tributaries of the Mullica River. This water then makes its way in a southeasterly direction toward the Great Bay, where it is then introduced to the Atlantic Ocean (JCNERR, 2004). Meanwhile, tidal water from the Atlantic Ocean makes its way in the Little Egg Inlet, through the Great Bay, and up a portion of the Mullica River.

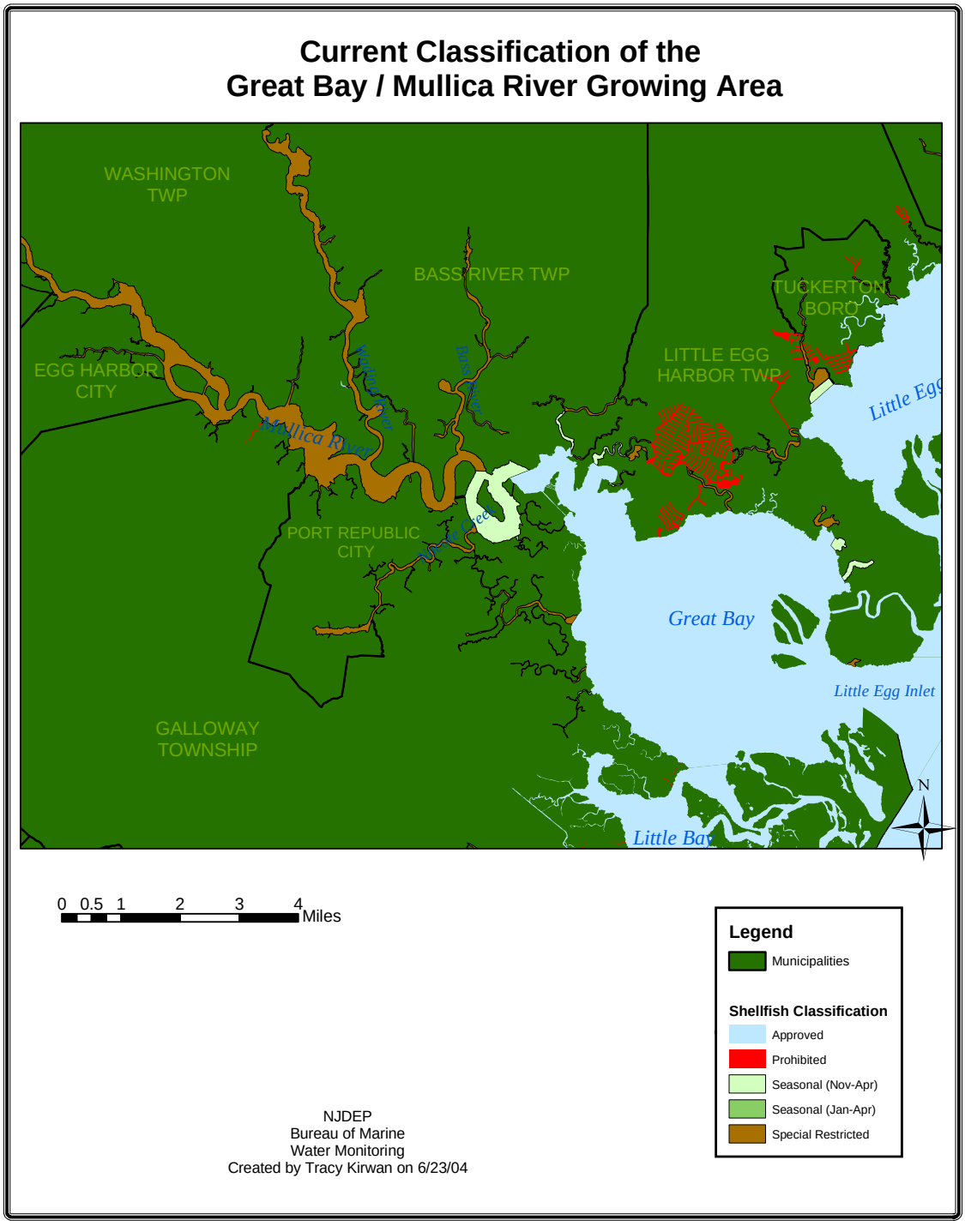
The freshwater from the headwaters of the Mullica River (48 miles inland) is acidic and 'tea stained' color from the humic and tanic acids from decaying vegetation and iron release from the nearby soils (JCNERR, 2004). This darker water blocks light penetration and therefore limits phytoplankton growth. The ocean water has a slightly basic pH (~8) and is blue in color, allowing more phytoplankton growth. The ocean water and river water meet and mix within the western portion of the Great Bay and the mouth of the Mullica River.

The average tidal range is approximately 3 feet throughout this growing area. The average depth of the Great Bay is 6 feet and the average range of depth in the Mullica River is 15 to 27 feet (JCNERR, 2004).

TABLE 2: SHELLFISH CLASSIFICATION BREAKDOWN

CLASSIFICATION	ACREAGE	PERCENTAGE OF TOTAL
Approved	12,996	72.57%
Seasonal (Nov-Apr)	643	3.59%
Seasonal (Jan-Apr)	15	0.08%
Special Restricted	3,834	21.41%
Prohibited	420	2.35%
TOTAL	**17,908**	

FIGURE 7: CURRENT CLASSIFICATION OF GREAT BAY & MULLICA RIVER



All or portions of Edwin B. Forsythe National Refuge, North Brigantine Natural Area, Swan Bay Wildlife Management Area, Port Republic Wildlife Management Area, Wharton State Forest, and Great Bay Wildlife Management Area are within this growing area.

Edwin B. Forsythe National Refuge is over 43,000 acres, 80% of which is tidal salt meadows and marshlands (Edwin B. Forsythe National Wildlife Refuge, 2004). Much of the Great Bay is surrounded by this refuge, which helps to protect its waters. This area offers many and varied habitats to shore birds and wildlife, as well as nurseries for shellfish.

The North Brigantine Natural Area is the Brigantine Division of the Edwin B. Forsythe National Wildlife Refuge. The North Brigantine Natural Area is 773 acres and takes up the northern 2.5 miles of the 6 mile long Brigantine Island (Wild NJ, 2004).

Swan Bay Wildlife Management Area is 1,777 acres and is located in Washington Township (NJDEP Division of Fish and Wildlife, 2004).

The Port Republic Wildlife Management Area is a state-owned, 755-acre property that is 75% salt marsh.

Wharton State Forest is located on the upper reaches of the Mullica River and is the "largest single tract of land within the New Jersey State Park System," covering over 110,000 acres (NJDEP Parks and Forestry, 2004). This state forest is within the New Jersey pinelands and includes the historic villages of Atsion and Batsto (see History of the Growing Area for more information).

The Great Bay Wildlife Management Area is over five thousand square acres (5,346 acres) and is owned by the state of New Jersey. Most of this area is salt marsh, although there are also barrier islands and portions of forests. Little Egg Harbor, Great Bay, and the Atlantic Ocean border this peninsula and the barrier islands. The location and habitats make this a great area for various kinds of wildlife, and seals are known to inhabit this region in late winter. Four marinas are within this wildlife management area; Rand's Boats, Cape Horns, Captain Mike's, and First Bridge Marina.

HISTORY OF THE GROWING AREA

The Lenni Lenape Native Americans were early inhabitants of the Great Bay / Mullica River area. In 1758, a reservation was created near present day Indian Mills, Burlington County. Years later this reservation was relocated, but while in this region the Native Americans were known to be hunters and fishers of fin and shellfish (JCNERR, 2004). In revolutionary times pirating and privateering occurred throughout the area. The villages of Batsto and Atsion also created muskets and balls from bog iron that were then shipped to cities like New York and Philadelphia (JCNERR, 2004). The lime needed to make the iron was provided

from the clam and oyster shells that were abundant to the area. Once there was no longer a demand for the iron, Batsto became a large glassmaking industry, which lasted into the 1800's. The glassmaking industry was such a success because of the abundance of fine sand from the Pinelands.

The cranberry industries began harvesting in the early 1830's and the blueberry industry started in the early 1900's; both still remain in the area to this day (Growing Cranberries in New Jersey, 2004; Whitesbog, 2004).

Currently, much of the land remains natural and offers a variety of habitats for both plants and animals. Some portions of this growing area are developed, although the majority remains wetlands. The area is still fished regularly, although the oyster populations declined drastically since the 1950's.

In the 1997 NJDEP Shellfish Growing Water Classification Chart a downgrade was made from *Approved to Special Restricted* in the small creek next to the research station at the end of Seven Bridges Road. The 2001 Reappraisal report (1995-1999) of this area also downgraded 55 acres as a result of the determination of buffer zones around existing marinas (Watkins, 2001). Approximately, 22 acres of shellfish waters were downgraded from *Approved* to *Seasonal (Nov-Apr)* around Rand's Boats, and an additional 33 (approximate) acres were downgraded from *Approved* to *Seasonal (Nov-Apr)* around Captain Mikes (see Figure 23). These downgrades were approved for the 2002 Shellfish Growing Area Classification Chart.

In the 2003 Annual Review of this shellfish growing area no classification change was proposed (NJDEP, 2003). Currently, no sampling stations in this shellfish growing area exceed the existing shellfish classification criteria, and the data supports the existing shellfish classification for this area. The last Sanitary Survey for Shellfish Growing Area SE1 (Great Bay & Mullica River) was written in 1992.

This shellfish growing area is appropriately classified as *Approved, Seasonal (November-April), Seasonal (January-April), Special Restricted,* and *Prohibited* depending on the area. There are also some marinas and storm water outfalls that require buffer zones, which determine the shellfish classification of the particular area.

OUTSIDE ORGANIZATIONS LOCATED IN THIS GROWING AREA

Rutgers University Marine Field Station (RUMFS) and the Jacques Cousteau National Estuarine Research Reserve (JCNERR) are located in Little Egg Harbor Township, within the Great Bay Wildlife Management Area. "The Jacques Cousteau National Estuarine Research Reserve (JCNERR, 2004) collects physical water quality and meteorological data in the Great Bay-Mullica River estuarine system using guidelines established by the National Estuarine Research Reserve System. The Rutgers University Institute of Marine and Coastal Sciences (IMCS), the managing agency for the JCNERR, has been performing research within this system since the acquisition of the Rutgers University Marine Field Station

(RUMFS) on Great Bay in 1972, and has many data sets which predate the designation of the Reserve in 1997. Other partners of the reserve who are conducting research in this system include the Richard Stockton College of New Jersey and the New Jersey Department of Environmental Protection. In addition, IMCS has established a Long-term Ecosystem Observatory (LEO) along the inner continental shelf off the coast of New Jersey to continuously monitor physical, chemical, and biological conditions in the dynamic coastal ocean. (JCNERR, 2004)."

The Pinelands Commission is a state organization that monitors and cares for the 22% of the state that is part of the pinelands. "In 1978 and 1979, Congress and the State of New Jersey passed legislation to protect the Pinelands and its unique natural and cultural resources" (NJPC, 2003). The Pinelands is the country's first National Reserve. A large portion of the Great Bay / Mullica River is located within the Pinelands. The Pinelands are very important to New Jersey, including its waters. Within this area, there is a huge underground aquifer system, holding 17 trillion gallons of pure water, which feeds into nearby bays and marshes via streams (NJPC, 2003).

METHODS

Approximately 3,595 water samples were collected for total coliform testing between January 1, 2000 and December 31, 2003 and analyzed by the three tube MPN (Most Probable Number) method (the indicator density of bacteria colonies most likely to produce a particular combination of positive and negative results in test tubes) (APHA, 1970). Testing for fecal coliform levels stopped in June 2003; beyond this date only total coliform levels were tested for in this area. Figure 8 shows the Shellfish Growing Water Quality monitoring stations in the Great Bay and Mullica River. Nearly 1,640 stations are monitored for coliform levels each year throughout the state; 89 of these stations are located in the Great Bay/Mullica River growing area.

Water sampling was performed in accordance with the Field Procedures Manual (NJDEP, 1992). Water quality sampling, shoreline and watershed surveys were conducted in accordance with the NSSP *Guide for the Control of Molluscan Shellfish* (NSSP, 2001 Revision).

Data management and analysis were accomplished using database applications developed for the Bureau. Mapping was performed with Geographic Information System (GIS: Arcview®/ArcMap®).

BACTERIOLOGICAL INVESTIGATION AND DATA ANALYSIS

The water quality of each growing area must be evaluated before an area can be classified as *Approved, Seasonal (Nov-Apr or Jan-Apr), Special Restricted,* or *Prohibited*. *Seasonal* areas must be sampled and meet the criterion during the time of the year that it is approved for the harvesting of shellfish. Criteria for the bacterial acceptability of shellfish growing waters are provided in the NSSP *Guide for the Control of Molluscan Shellfish* (NSSP, 2001 Revision).

SAMPLING STRATEGY

The State Shellfish Control Authority has the option of choosing one of two water monitoring sampling strategies for each growing area.

The Adverse Pollution Condition Strategy requires that a minimum of five samples be collected each year under conditions that have historically resulted in elevated coliform levels in the particular growing area. The results must be evaluated by adding the individual station sample results to the preexisting bacteriological sampling results to constitute a data set of at least 15 samples for each station. The adverse pollution conditions usually are related to tide and/or rainfall, but could be from a point source of pollution or variation could occur during a specific time of the year (Connell, 1991).

The Systematic Random Sampling strategy requires that a random sampling plan be in place before field sampling begins. This strategy can only be used in areas that are not affected by point sources of contamination. A minimum of six samples per station are to be collected each year and added to the database to obtain a sample size of 30 for statistical analysis.

The Great Bay / Mullica River growing area is sampled under Systematic Random Sampling strategy described above. Assignment 151, Great Bay, has 55 stations within this growing area and has a seasonal preference for the summer months. Assignment 145, Mullica River, has 28 stations within this growing area and has special instructions to sample at least once a month from November to April because there are *Seasonal (Nov-Apr)* waters within this run. Assignment 131, Little Egg Harbor (East), has 4 stations within this growing area and has special instructions to sample once a month from October to April and three times during the summer because of conditions in the Southern Barnegat Bay growing area. Assignment 132, Little Egg Harbor (West), has 1 station within this growing area and has special instructions to sample once a month from January to April and six times during the remainder of the year (because of conditions in the Southern Barnegat Bay growing area). There are sampling assignment changes proposed in this report - see 'Recommended Changes in Sampling Schedule'.

NSSP CRITERIA

Each shellfish-producing state is directed to adopt either the total coliform criterion or the fecal coliform criterion. While New Jersey bases its growing water classifications on the total coliform criterion, the laboratory does have the ability to make corresponding fecal coliform determinations for each sampling station. The fecal data are often viewed as adjunct information and are not directly used for classification.

The criteria were developed to ensure that shellfish harvested from the designated waters would be free of pathogenic (disease-producing) bacteria. Each classification criterion is composed of a measure of the statistical 'central tendency' (geometric mean) and the relative variability of the data set. For the Adverse Pollution Condition sampling strategy, variability is expressed as the percentage that exceeds the variability criteria (see Table 3). For the Systematic Random Sampling Strategy, variability is expressed as the 90th percentile (see Table 4).

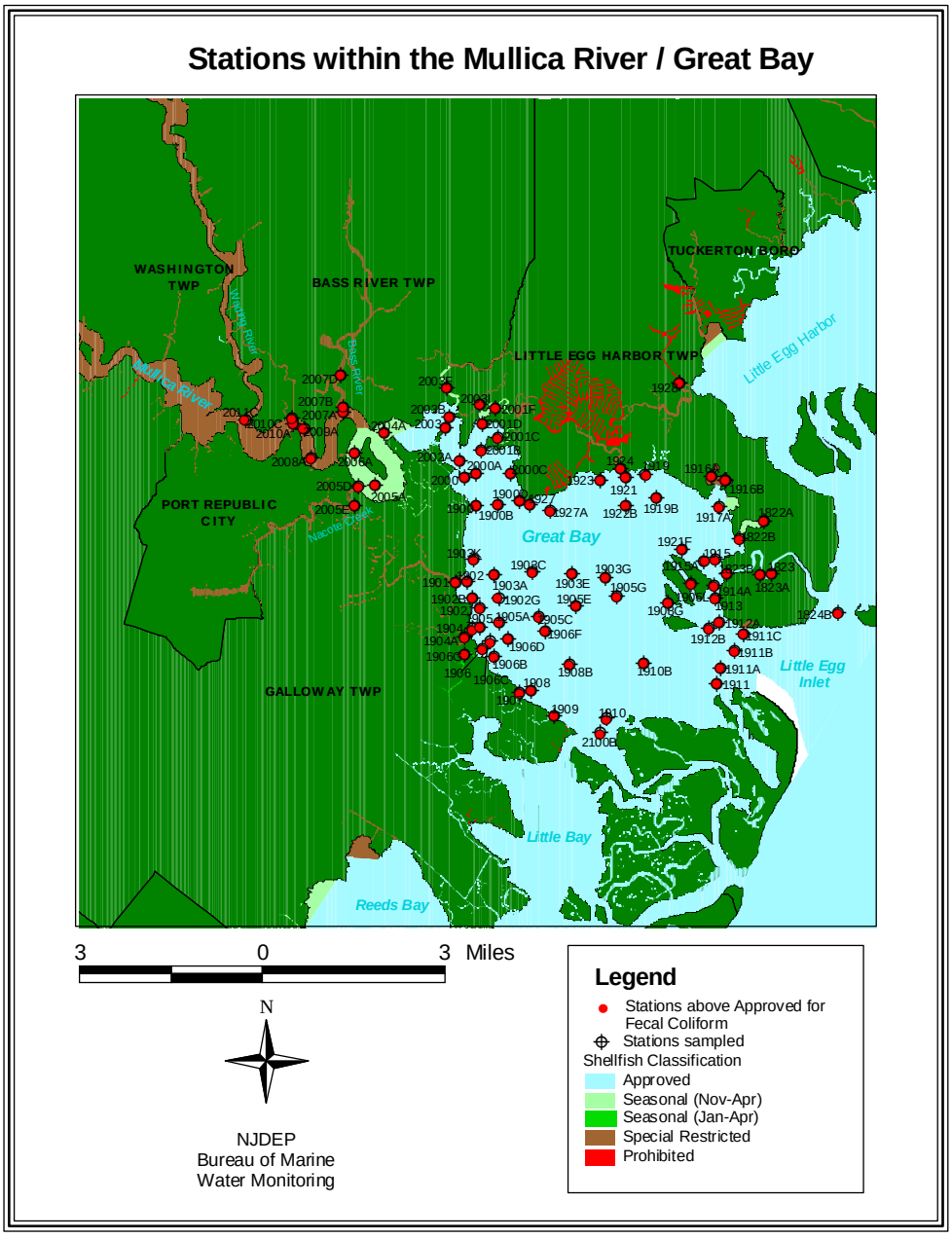
TABLE 3: CRITERIA FOR ADVERSE POLLUTION CONDITION SAMPLING STRATEGY

	Total Coliform Criteria		Fecal Coliform Criteria	
	Geometric mean (MPN/100 mL)	**No more than 10% of samples can exceed (MPN/100 mL)**	**Geometric mean (MPN/100 mL)**	**No more than 10% of samples can exceed (MPN/100 mL)**
Approved Water Classification	70	330	14	49
Special Restricted Water Classification	700	3300	88	300

TABLE 4: CRITERIA FOR SYSTEMATIC RANDOM SAMPLING STRATEGY

	Total Coliform Criteria		Fecal Coliform Criteria	
	Geometric mean (MPN/100 mL)	**Estimated 90th percentile (MPN/100 mL)**	**Geometric mean (MPN/100 mL)**	**Estimated 90th percentile (MPN/100 mL)**
Approved Water Classification	70	330	14	49
Special Restricted Water Classification	700	3300	88	300

FIGURE 8: SAMPLING STATIONS IN THE GREAT BAY / MULLICA RIVER GROWING AREA



SHORELINE SURVEY

CHANGES SINCE LAST SURVEY

There were no significant changes visible since the last shoreline survey. There are some single-family residences being constructed in the area of Mystic Island, and the nearby condominium structure that was mentioned in the last reappraisal report (2001) is fully constructed. In addition, there were observations of bulkhead repair in Mystic Island (see Figure 9).

The Little Egg Harbor Municipal Utilities Authority reported no major problems with the operation of the sanitary collector lines or pump stations in Mystic Island within the last three years. Excluding roughly seven homes, all of Mystic Island remains on city sewer.

The rest of the shoreline remains predominately wetlands, mostly protected by federal and state governments.

The Route 9 Bridge over the Bass River, a tributary of the Mullica, is currently being rebuilt (see Figure 10).

On July 7, 2004 the NJDEP announced its intention to join forces with the Army Corps to build a fish Ladder on the Batsto River in Wharton State Forest within the next year (NJDEP, 2004). This fish ladder will allow various species to use the upstream reaches for spawning, which were previously blocked by dams.

FIGURE 9: BULKHEAD REPAIR IN MYSTIC ISLAND (TAKEN ON 7/26/04)

FIGURE 10: ROUTE 9 BRIDGE CONSTRUCTION OVER BASS RIVER (TAKEN ON 8/26/04)

LAND USE

There are some sections of urban land and forests, as well as sparse areas of agricultural and barren land, but the predominant land use in the Great Bay/Mullica River growing area is wetlands (see Figures 11). This generally flat land is just above sea level and is made up of many tidal marshes and sandbar deposits (see Figure 12). The various wildlife management areas protect a large majority of these wetlands. As mentioned previously, all or portions of the Edwin B. Forsythe National Refuge, North Brigantine Natural Area, Swan Bay Wildlife Management Area, Port Republic Wildlife Management Area, Wharton State Forest, and Great Bay Wildlife Management Area are within this growing area. Most of the urban portions of this growing area are bordered from the main waterbodies by wetlands. There are a variety of habitats in this growing area that support large and varied populations of waterfowl.

Mystic Island is a lagoon system, north of Great Bay, in Little Egg Harbor Township (see Figure 13). A lagoon is essentially a manmade canal, surrounded by bulkheaded properties, with access to a larger water body. Lagoon areas are laden with stormwater outfalls that often drain directly into the canal water. Additionally, many homeowners have docks which are used to store their own boats. Although there are pump out stations at many marinas, some boat owners will discharge sanitary waste directly into the water. For these reasons, all lagoons are classified as *Prohibited*. The area directly outside the lagoon is appropriately classified as *Prohibited, Seasonal (Nov - Apr),* *Seasonal (Jan - Apr),* or *Special Restricted.* The access to the Mystic Island lagoon system is classified as *Special Restricted*. There are many private docks within this lagoon system and the runoff has the potential to negatively affect the surrounding water quality.

FIGURE 11: LAND USE PATTERNS

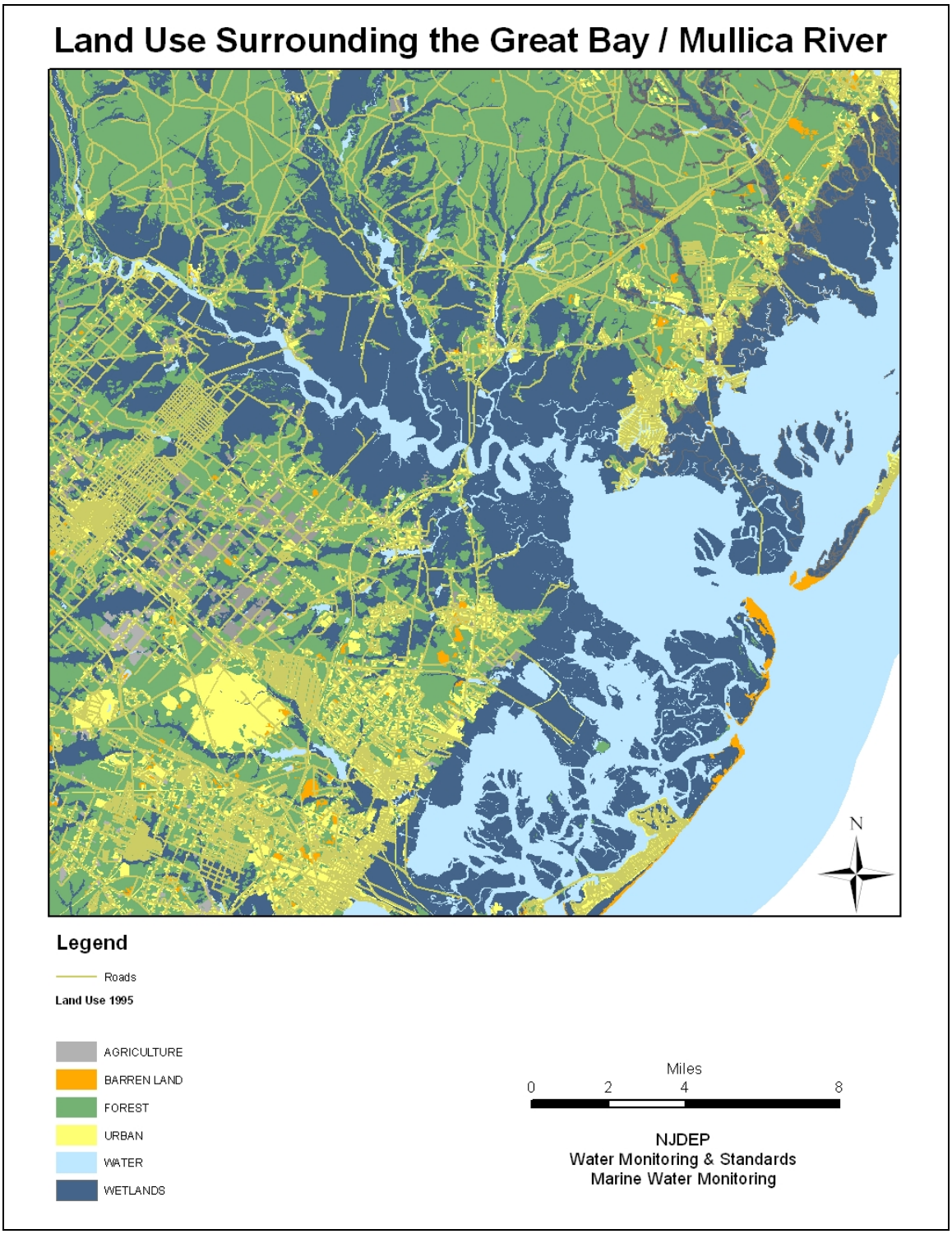


FIGURE 12: WETLANDS (PICTURE TAKEN 8/20/04)

FIGURE 13: MYSTIC ISLAND LAGOON (PICTURE TAKEN 7/26/04)

EVALUATION OF BIOLOGICAL RESOURCES

This growing area has a wide diversity of biological resources. Hard clams (*Mercenaria mercenaria*) exist in much of the Great Bay and the Mullica River, as well as in some tributaries. Figure 14, which was created in 1988 by NJDEP Fish, Game & Wildlife, shows an occurrence of hard clams throughout most of the growing area with small sections of moderate to high occurrences. Large populations of oysters were once known to inhabit portions of the Mullica River; although these populations have declined drastically since the 1950's-1960's, some still remain.

In 2004, two special permits were issued to harvest oysters from the Mullica River to be transplanted to leased lots in *Approved* waters for purging of pollutants, growth, and ultimate marketing after written release by the Bureau of Marine Water Monitoring (NJDEP Permit #7, 2004).

Many species of animals and vegetation can be found in the marshes of this shellfish growing area (see Figures 15 & 16). Wildlife populations (birds and animals) are significant influences on the water quality in Great Bay and Mullica River, especially during the migration periods in early May and early November (see Figure 17). Birds sometimes accumulate around the groins, jetties, seawalls, and bulkheads on the coast of this shellfish growing area, and fecal matter from these birds has the potential to negatively affect the surrounding water quality.

"Expect to find outstanding wildlife watching, especially for nesting shorebirds and waterfowl. During migration, sandpipers, knots, dowitches, curlews, willets, plovers, turnstones and yellowlegs feed and rest in the area. Also present are gulls, terns, skimmers, American bitterns, glossy ibis, oystercatchers, marsh hawks, ospreys, egrets and herons. Virginia rail, coot, grebes, loons and an occasional bald eagle pass through as well. Crabbing and fishing, for sea bass, sharks, flounder, bluefish and striped bass, are excellent along the coastal bays" (L.L.Bean, 2004).

This shellfish growing area is almost completely surrounded by a shoreline of marshes, with small areas of bulkheads, erodable shorelines, and beaches composing the remainder of the shoreline. Bulkheads are located within Mystic Islands and at the marinas. The shore structures and shore types for this area are shown in Figure 18.

This area also includes a wide variety of marsh types and vegetation, including vegetated salt marshes, tidal ponds, tidal waters, tidal mud flats, tidal sand flats, non-tidal ponds, sandy developed beaches, developed areas, and small areas of coastal scrub shrub (Wesighan, 2003). These marsh types and

vegetation are located throughout the shoreline of this shellfish growing area.

FIGURE 14: SHELLFISH RESOURCES IN THE GREAT BAY / MULLICA RIVER (1988 NJDEP FISH, GAME, AND WILDLIFE)

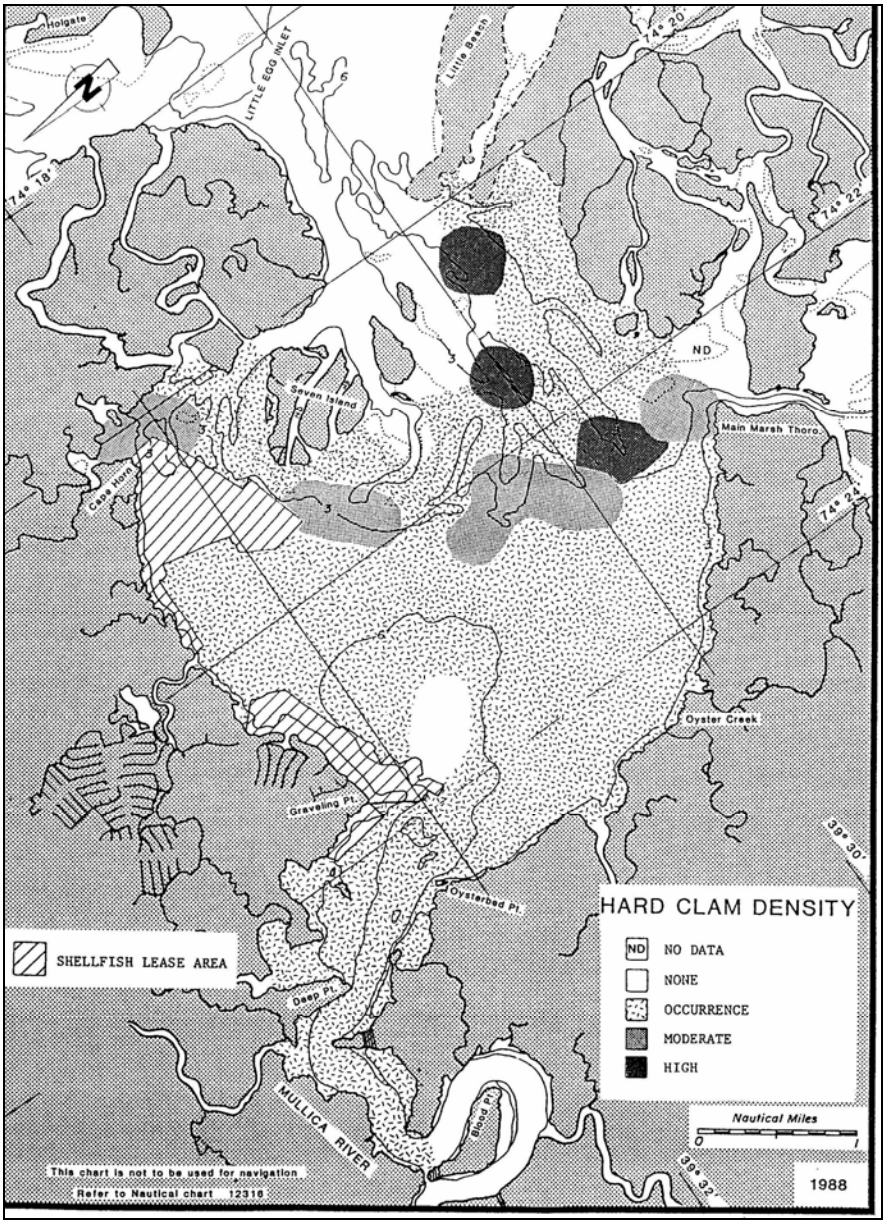


FIGURE 15: TURTLE CROSSING SIGN (TAKEN ON 8/20/04)

FIGURE 16: DIAMONDBACK TURTLE (TAKEN ON 7/13/04

FIGURE 17: BIRD WILDLIFE AROUND MYSTIC ISLAND (TAKEN ON 7/26/04)

FIGURE 18: LOCATION OF SHORELINE STRUCTURES IN THE GREAT BAY/MULLICA RIVER GROWING AREA

Shoreline Type in the Great Bay / Mullica River Growing Area

3 0 3 Miles

N

NJDEP
Bureau of Marine
Water Monitoring

Legend

Shore Type
- BEACH
- BULKHEAD
- EARTHEN DIKE
- ERODABLE
- MARSH
- OPEN WATER
- ROCK

Water

Municipalities

IDENTIFICATION AND EVALUATION OF SOURCES

There is no permitted municipal point source discharge in the Great Bay/Mullica River Growing Area. However, there are several indirect ground water discharges, known contaminated sites, and solid waste landfills located in this shellfish growing area (see Figure 19). Currently, there is no evidence that these sites are negatively impacting the shellfish growing water quality in this area. Since there is a potential for pollutant inputs from these indirect sources to get into these shellfish growing waters, it is important to continue monitoring the water quality of these areas to determine the presence or absence of these indirect sources of pollution

DIRECT DISCHARGES

There are no direct discharges in the Great Bay / Mullica River Growing Area.

INDIRECT DISCHARGES

Known contaminated sites are scattered throughout this region, mostly within urban areas (see Figure 19). However, few of these known contaminated sites are in close proximity to the shoreline. Some frequently known contaminated sites include leaking underground storage tanks, septic/sewer outflows, and spills at gas stations. Since these known sites are potential sources of chemical contamination, action of the responsible party is required to eliminate these polluted sites. Any indirect or direct source contamination can be reported to the NJDEP toll free hotline at 1-877-WARNDEP.

Many of the contaminated sites are underground storage tanks that contain petroleum fuel. When petroleum fuel is mixed with water, the petroleum rises to the top, not directly affecting bottom-dwelling clams. Also, soils surrounding the underground tanks absorb the leakage, making it less likely to migrate to marine waters. These explanations lessen the possibility of the petroleum leaks negatively affecting the shellfish, although it does not completely prevent contamination.

The quality of a sewer system depends heavily on the municipal planning and maintenance of the sewer lines. New residential developments joining into a sewer system must be adequately planned for in order for the system to handle the increased volume. The age of the pipes and facilities also factors in when assessing the potential for sewer problems. Little Egg Harbor Municipal Utilities Authority supervises the sewer lines in Mystic Island and reports that there were no major incidents with the lines and pump stations within the last three years (LEHMUA, 2004). Only about seven homes in Mystic Island are

on septic, the rest are connected to city sewer.

Septic systems are harder to regulate since they are not the responsibility of the municipality, but of the property owner. Faulty septic systems can add bacteria into runoff, which can then enter into waterbodies, causing high bacteria counts.

There are fourteen landfills within the Great Bay / Mullica River growing area, all of which are currently closed. (NJDEP Division of Solid & Hazardous Waste, 2004). Ten of these landfills are government-owned, and two of the privately owned landfills are currently on the Superfund list. The names and addresses of these landfills are located in Table 5.

The indirect ground water discharges, the currently active known contaminated sites, and the closed solid waste landfills have the potential to impact the water quality of this shellfish growing area. Therefore, the water quality in the Great Bay/Mullica River is constantly monitored to determine the presence or absence of these contaminants

FIGURE 19: INDIRECT DISCHARGES TO THE WATERS OF THE GREAT BAY/MULLICA RIVER GROWING AREA

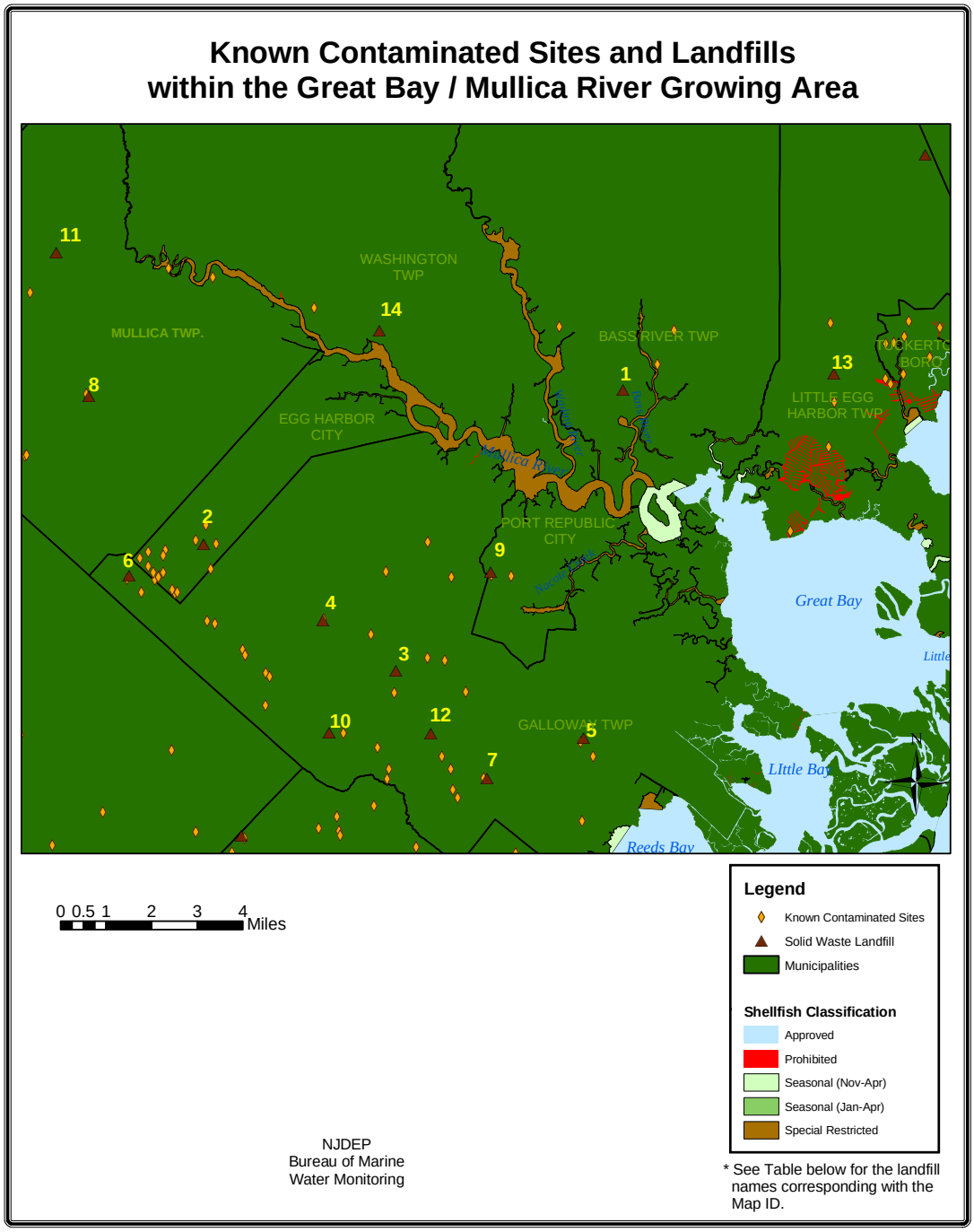


TABLE 5: LANDFILLS IN THE GREAT BAY / MULLICA RIVER GROWING AREA (NJDEP DIVISION OF SOLID & HAZARDOUS WASTE, 2004)

Map ID #	Landfill Name	Address	Municipality
1	Bass River Landfill	South Maple St.	Bass River Twp.
2	Egg Harbor City Landfill	Antwerp Ave.	Egg Harbor City
3	Emmell's Landfill	Zurich Ave.	Galloway Twp.
4	Galloway Twp. – Herschel St.	Herschel St. & Prague Ave.	Galloway Twp.
5	Galloway Twp. – Oak St.	Oceanville Dr.	Galloway Twp.
6	Galloway Twp. – Pittsburgh Ave.	Pittsburgh Ave. & Pershington Ave.	Galloway Twp.
7	Galloway Twp. – Ridgewood Ave.	Ridgewood Ave. & 4th Ave.	Galloway Twp.
8	Mullica Twp. Landfill	Elwood-Weekstown Rd.	Mullica Twp.
9	Port Republic City Landfill	Cologne – Port Republic Rd.	Port Republic City
10	Price Trucking Co., Landfill #2	English Creek	Egg Harbor Twp.
11	Rocco Logiovino	Moore St.	Mullica Twp.
12	Stockton State College	Jimmy Leeds Rd.	Galloway Twp.
13	Tuckerton Sand & Gravel	Block 286 Lot 2 & Block 284 Lot 4	Little Egg Harbor Twp.
14	Washington Twp. Landfill	Church Rd.	Washington Twp.

STORM WATER INPUTS

Runoff is a term for the surface water that moves from land to the ocean. During this transition, the water picks up both nutrients and pollutants. While some of this runoff provides nutrients for plants and animals, excessive nutrients can lead to eutrophic conditions in the coastal waters. Runoff also carries pollutants such as pathogens, heavy metals, pesticides and petroleum products that can potentially contaminate the waters. The stormwater inputs to this shellfish growing area are the result of rainwater which would normally be absorbed into vegetated soils and used to recharge the Cohansey aquifer, maintain stream base flow, and maintain waterway health. In urban areas there are many impervious surfaces that reroute the rain to detention basins where it is then transported into streams, creeks, wetlands, lakes, bays, and rivers. This runoff can carry a variety of waste materials. Some pollutants include bird waste, agricultural pesticides, animal waste, and bacteria from faulty septic systems (NJDEP Clean Water NJ, 2006).

Storm drains along roads collect the runoff and transmit it to stormwater outfalls. The outfalls deposit the runoff into streams, bays, oceans, and other bodies of water. Stormwater outfalls are one of the most significant non-point sources of pollution. They are often

found in urban areas, and are especially common within lagoon communities. The first flush after a rain event often carries the most pollutants.

The only stormwater inputs that directly enter into the Great Bay/Mullica River Growing Area (see Figures 20 & 21) are those located in Mystic Islands. However, all of the stormwater inputs in Figure 21 have the potential to negatively impact the water quality within this growing area.

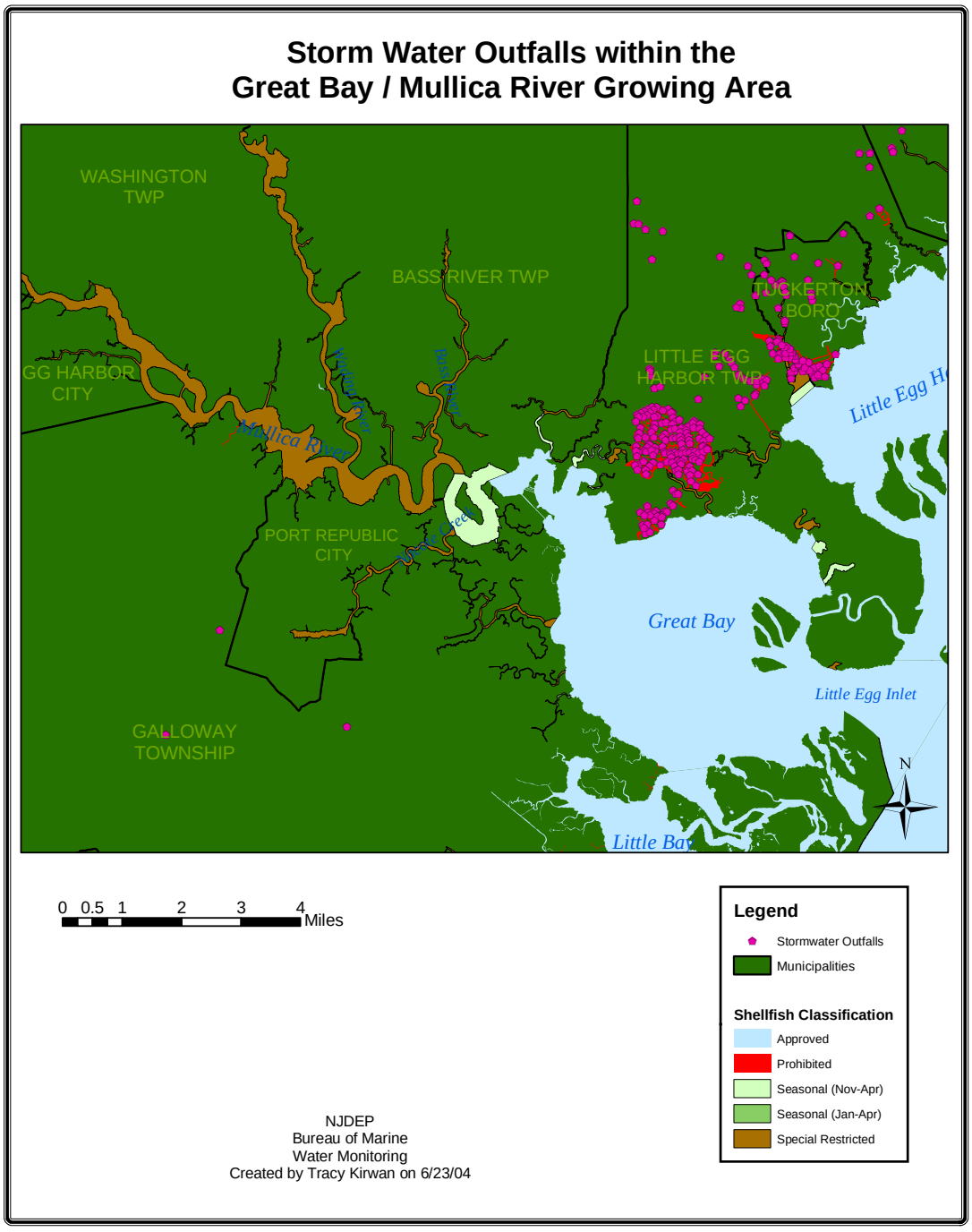
The impact of animal waste on water contamination is of significant concern. Fecal waste carries a great deal of bacteria, and runoff can easily bring the bacteria to swimming beaches and other waterbodies. Among other things, this can cause human sickness through recreational contact or through consumption of contaminated shellfish. Faulty septic systems create the same problem, bringing bacteria-laden runoff back to streams, lakes, bays, and eventually the Atlantic Ocean.

As mentioned previously, contaminated runoff reaching stormwater outfalls is a major contributor to the pollution of waterbodies. Pesticides, animal wastes, and petroleum fuel are among the harmful contributors (NJDEP Clean Water NJ, 2006). Considering the substantial amount of outfalls throughout New Jersey, their regulation is important in order to reduce pollution.

The Bureau of Marine Water Monitoring conducts stormwater projects. Water samples are taken during a storm event and the preceding days in order to determine the effect of runoff. Once a possible source of the problem is identified, the appropriate people (usually the municipality/county) are notified to remedy the situation. Currently, there are not projects planned for this growing area.

FIGURE 20: MYSTIC ISLAND LAGOON

FIGURE 21: STORM WATER OUTFALLS IN THE GREAT BAY/MULLICA RIVER GROWING AREA



MARINAS

Boating is a relatively popular summertime activity within the Great Bay. In this growing area there are a total of fourteen marinas (Figures 22, 23, and 24). Great Bay is often used for recreational and commercial boating and fishing.

Marinas and the accompanying boats, can discharge pollutants into the water. Gas fumes, oil, and grease from boats and marinas can then contribute to the contamination of the waters. Therefore, marina facilities have the potential to affect the suitability of shellfish growing areas for the harvest of shellfish. The biological and chemical contamination associated with marina facilities may be of public health significance.

New Jersey defines a marina as "any structure (docks, piers, bulkheads, floating docks, etc.) that supports five or more boats, built on or near the water, which is utilized for docking, storing, or otherwise mooring vessels and usually, but not necessarily, provides services to vessels such as repairing, fueling, security or other related activities" and designates the confines of the marina as *Prohibited* for the harvest of shellfish (N.J.A.C 7:12). Adjacent waters are classified using a dilution analysis formula (see Equation 1).

It is recognized by the NSSP *Guide for the Control of Molluscan Shellfish,* 1997, that there are significant regional differences in all factors that affect marina pollutant loading. The manual, therefore, allows each state the latitude in applying specified occupancy and discharge rates. The NSSP guidelines assume the worst case scenario for each factor.

EQUATION 1: MARINA BUFFER EQUATION. (ADAPTED FROM FDA. 1989):

$$BufferRadius(ft) = \sqrt{\frac{2x10^{9}(FC/person/day)x2(person/boat)x[(.25slips \geq 24') + (0.065 \times slips < 24')]x2}{140000(FC/M^{3})xdepth(ft)x0.3048(M/ft)x\pi x2(tides/day)}}x3.28(ft/M)$$

Explanation of terms in equation:

Fecal coliform per person per day:	2×10^{9}
Number of people per boat:	2
For slips able to accommodate boats > 24 feet (combination of factors yields multiplier of 0.25):	
Number of slips occupied:	50%
Number of boats occupied:	50%
For boats < 24':	6.5% discharge waste
Angle of shoreline:	180^{o}, which results in factor of 2
Number of tides per day:	2
Depth in meters:	depth in feet x conversion factor
Water quality to be achieved:	140000 FC/$meter^{3}$
Convert meters to feet:	3.28

Marina buffer zones can be calculated using the above formula. The State of Virginia and the USFDA also developed an alternative to this formula, which determines buffer zones using a dilution analysis computer program. The formula above considers only dilution and occupancy rates. The computer program is used for complex configurations and considers tidal exchange and bacterial die-off.

There are fourteen marinas in the Great Bay/Mullica River growing area. The waters enclosed by the marina are classified as *Prohibited*; depending on the size of the marina and the water quality, water immediately adjacent to each marina may be classified as *Prohibited*, *Special Restricted*, or *Seasonally Approved* (no harvest during summer months when the marina is active). Marina buffer zones are calculated using the Virginia Model or the marina buffer equation, depending on the location. The size of each buffer zone is shown in Table 6.

FIGURE 22: CHESTNUT NECK MARINA ON THE MULLICA RIVER (PICTURE TAKEN ON 8/26/04)

FIGURE 23 : MARINA FACILITIES LOCATED IN THE GREAT BAY/MULLICA RIVER GROWING AREA

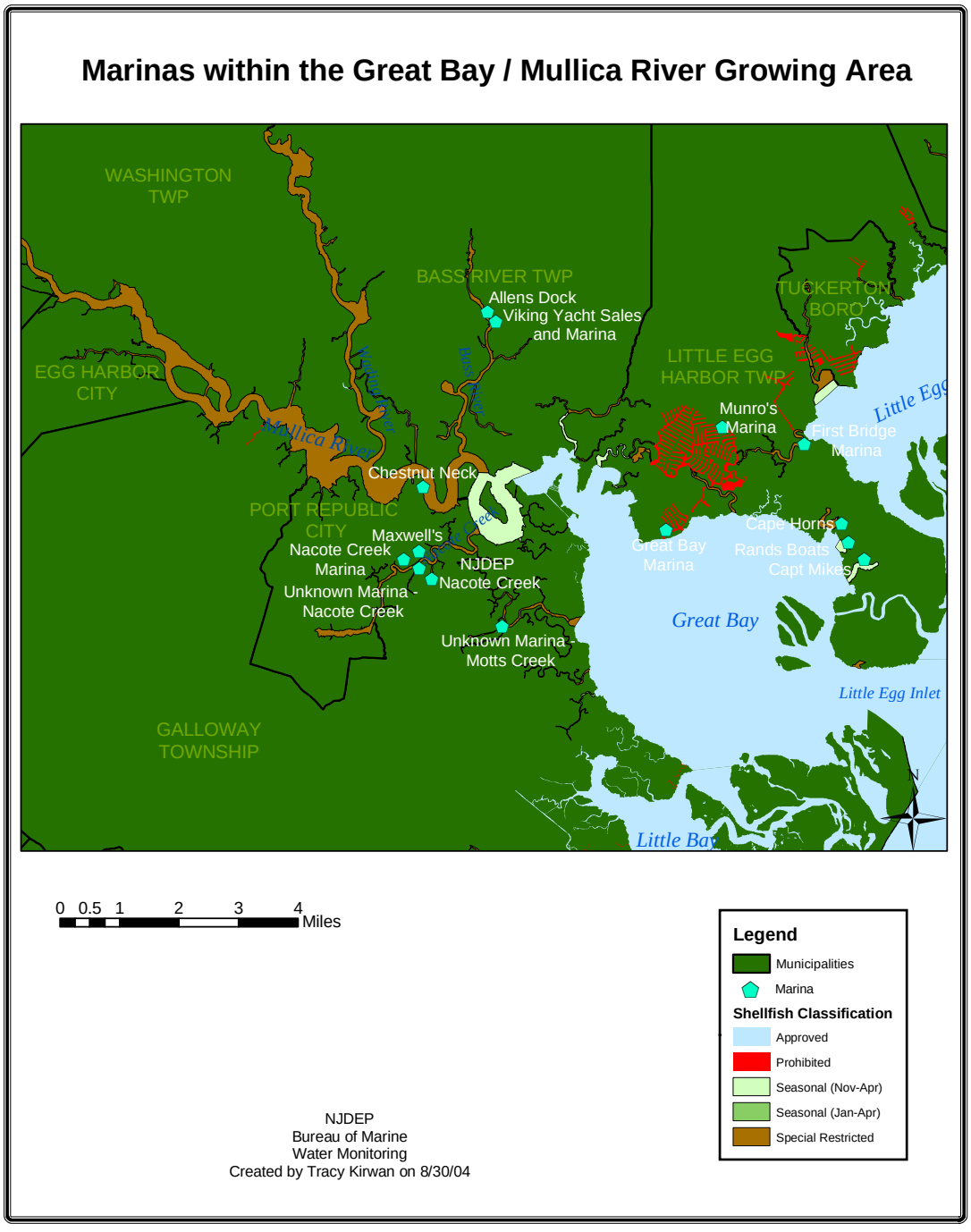


TABLE 6: MARINA FACILITIES LOCATED IN THE GREAT BAY/MULLICA RIVER GROWING AREA

Marina Name	# of Slips	Size of Buffer Area (radius; feet)
Allen's Dock	50	594
Cape Horns Marina	117	983
Captain Mike's Marina	62	1299
Chestnut Neck Marina	33	284
First Bridge Marina	30	776
Great Bay Marina	137	1080
Maxwell's	15	169
Muron's Marina	29	246
Nacote Creek Marina	45	521
NJDEP Nacote Creek	6	144
Rand's Boats Rentals	80	772
Unknown Marina – Motts Creek	20	228
Unknown Marina – Nacote Creek	16	218
Viking Yacht Sales	240	1581

FIGURE 24 : RAND'S BOAT RENTALS LOCATED IN GREAT BAY (PICTURE TAKEN 7/26/04)

SPILLS OR OTHER UNPERMITTED DISCHARGES

Any marine spill reported to the DEP hotline, 1-877-WARNDEP, is passed on to the Bureau of Marine Water Monitoring. Since there is a direct relationship between the pollution of shellfish growing areas and the transmission of diseases to humans, the Bureau must carefully assess each spill occurrence. If the spill is determined to be harmful to the shellfish then a closure is made on the impacted area. The closure is not lifted until the source of the problem is fixed and all samples in the area fit within the appropriate classification criteria.

There were no significant spill incidents within this growing area from January 2000 through December 2003.

HYDROGRAPHY AND METEOROLOGY

PATTERNS OF PRECIPITATION

Precipitation patterns in the coastal areas of New Jersey are typical of the Mid-Atlantic coastal region. Typical summer storms are localized storms associated with thunderstorms. Winter storms are frequently associated with northeasters. Hurricanes can occur during the summer and early fall. The yearly average of precipitation for this area is between 100 to 122 cm/yr (Able, et al., 1999 via Kennish & O'Donnell, 2002).

HYDROGRAPHY

An evaluation of hydrographic characteristics and pollution sources was used to assess the water quality in the Great Bay/Mullica River. Precipitation inputs to the area for the period 2000 through 2003 are shown in Appendix D. There have been no significant changes in hydrography since the last Reappraisal Report (2001). The primary weather station for this area is Atlantic City International Airport. The secondary weather station for this area is Toms River. The secondary station data are used when data from the primary station are incomplete.

Little Egg Inlet connects the Atlantic Ocean to Great Bay, where tidal currents enter at a velocity of more than 2m/s (Kennish & O'Donnell, 2002). This tidal water mixes with the existing saltwater within the Great Bay before it reaches the freshwater influences of the Mullica River. The freshwater moves southwest back toward the Little Egg Inlet, creating a counterclockwise flow (Kennish & O'Donnell, 2002).

Typical winter winds are from the northwest, and summer winds tend to come from the south (Kennish & O'Donnell, 2002). Air temperatures typically range from 30°F to 86°F.

"Intermediate salinity levels (~15%) are found at Chestnut Neck, located ~13 km upstream of the Mullica River mouth. Highest salinity levels (>25%) are recorded at Buoy 126," which is located northwest of the Little Egg Inlet (Kennish & O'Donnell, 2002)

WATER QUALITY STUDIES

BACTERIOLOGICAL QUALITY

The data for this report was collected from 89 stations in the Great Bay / Mullica River Growing Area (see Figure 25). A total of 3,595 surface water samples were analyzed from this growing area for total coliform (TC) during the period January 2000 through December 2003.

Assorted areas in the Great Bay & Mullica River are classified as *Approved, Special Restricted, Seasonal (November-April), Seasonal (January-April)* and *Prohibited* (see Figure 24). Any sampling station located in *Prohibited*, *Special Restricted*, or *Seasonal* waters has the potential for an upgrade in classification based on improved bacteriological water quality. Likewise, any sampling station in *Special Restricted*, *Seasonal*, or *Approved* waters has the potential to be downgraded based on declining water quality.

This report drew data from January 1, 2000 to December 31, 2003. During this time period all stations were sampled using the Systematic Random Sampling (SRS) strategy. Systematic Random Sampling is used since there are no point sources contributing to bacterial contaminants in this area. There are four separate assignment runs that are required for this growing area. Assignment 131, Little Egg Harbor (east), contains 39 stations, 4 of which are in this growing area, and is sampled 10 times a year. Assignment 132, Little Egg Harbor (west), contains only one station from this growing area. Currently, assignment 132 has a total of 53 stations and it is completed 10 times a year. Assignment 145, Mullica River, has 28 stations, all within this growing area, and is sampled 10 times a year. Assignment 151, Great Bay, has 55 stations, all within this growing area, and is sampled 10 times a year. This report recommends changes in the sampling schedule for the 2005-monitoring season; to facilitate ease of sampling. These changes are located in 'Recommended Changes in Monitoring Schedule' in the 'Recommendations' section of this report.

This report examined the data from the assignment runs done between January 1, 2000 and December 31, 2003. These assignment runs provided sufficient samples for evaluation, bearing in mind the sample size must be at least 30 for each station according to the Systematic Random Sampling strategy.

COMPLIANCE WITH NSSP "APPROVED" CRITERIA

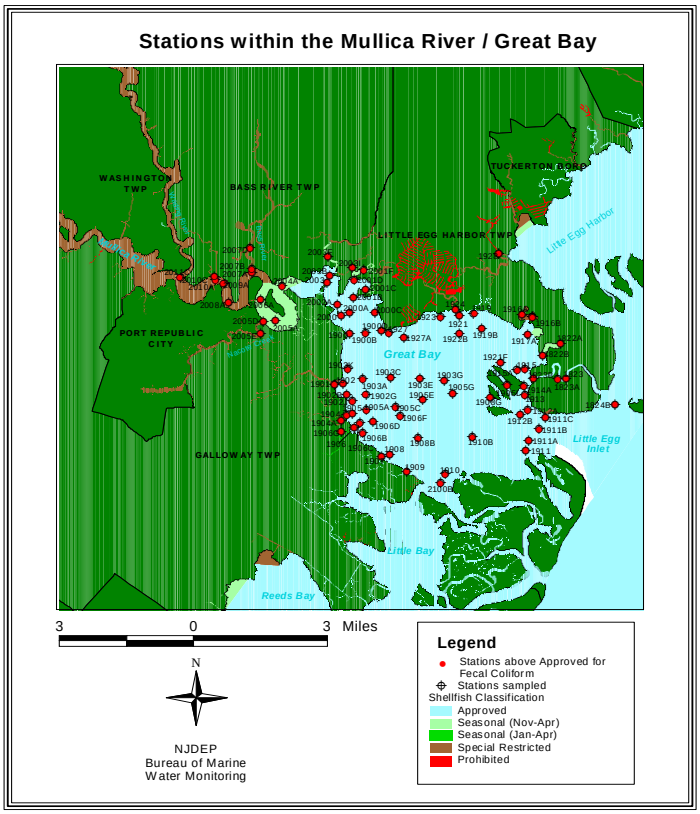
Each sampling station must comply with its respective criteria in the National Shellfish Sanitation Program (NSSP) Model Ordinance (2001 Revision) for *Approved*, *Seasonal*, or *Special Restricted* waters, based on a minimum of 30 data sets.

In order for waters to be classified as *Approved*, the total coliform Geometric Mean must be below 70 MPN/100ml and the total coliform Est. 90th Percentile must be below 330 MPN/100ml. All stations within this growing area fit within the established criteria for *Approved* waters.

COMPLIANCE WITH NSSP "SPECIAL RESTRICTED" CRITERIA

All stations sampled complied with the NSSP total coliform criteria for *Special Restricted* waters. For waters to be classified as *Special Restricted*, the Geometric Mean must be below 700 MPN/100ml and the Est. 90th Percentile must be below 3300 MPN/100ml.

FIGURE 25: SAMPLING STATIONS FOR GREAT BAY / MULLICA RIVER GROWING AREA



COMPLIANCE WITH NSSP "APPROVED" CRITERIA DURING SEASONS

All Data (Summer and Winter)

The year round data are divided between the summer and winter sampling seasons. The summer season runs from May through October, and the winter season runs from November through April.

Winter Data (November – April)

All stations in the Great Bay / Mullica River growing area met the total coliform *Approved* criteria during the winter months (see Appendix A).

Summer Data (May – October)

All stations in the Great Bay/Mullica River growing area met the total coliform *Approved* criteria during the summer months. One station, 2011C, came close to exceeding the *Approved* criteria for the summer months; however, this station did not exceed criterion and it is located in *Special Restricted* waters (see Appendix A).

TIDAL EFFECTS

Ebb and flood currents describe the horizontal motions associated with the fall and rise of the tide in restricted regions along the coast. Ebb tide is when the waters are receding and flood tide is when the waters are advancing. The tidal effects, or preferences, can be either ebb currents, flood currents, or neither of these two types of currents (Wesighan, 2003).

Tidal currents can affect the water quality of a shellfish growing area, because hydrographic and meteorological characteristics, such as tidal amplitude and type, water circulation patterns, depth, salinity, stratification characteristics, rainfall patterns and intensity, and prevailing winds may affect the distribution of pollutants in a specific area (Ingmanson and Wallace, 1989). Tidal exchange provides a mechanism to mix the impaired water with higher quality water. This is why an evaluation of pollution sources and hydrographic characteristics are used to evaluate the water quality in a shellfish growing area. Five sampling stations in this shellfish growing area show a relationship between tidal effects and water quality by having a T-statistic probability less than or equal to 0.050 (see Table 7). Figure 26 shows the locations of these sampling stations. This shellfish growing area was sampled with no tidal preferences. The complete tidal evaluation data set can be seen in Appendix C.

The geometric means for total coliform

levels were higher during ebb than during flood for all of the noted stations. Stations 1822A and 2100B probably have higher coliform levels during ebb tide due to the bird and animal wastes being introduced from the wetlands following high tide. The remaining three stations, 2009A, 2010A, and 2010C, are in the Mullica River where it is possible that negative upstream influences are being washed back toward the bay. However, none of these stations have drastic differences between the coliform levels at ebb and flood and all of these stations fit within their current classification criteria.

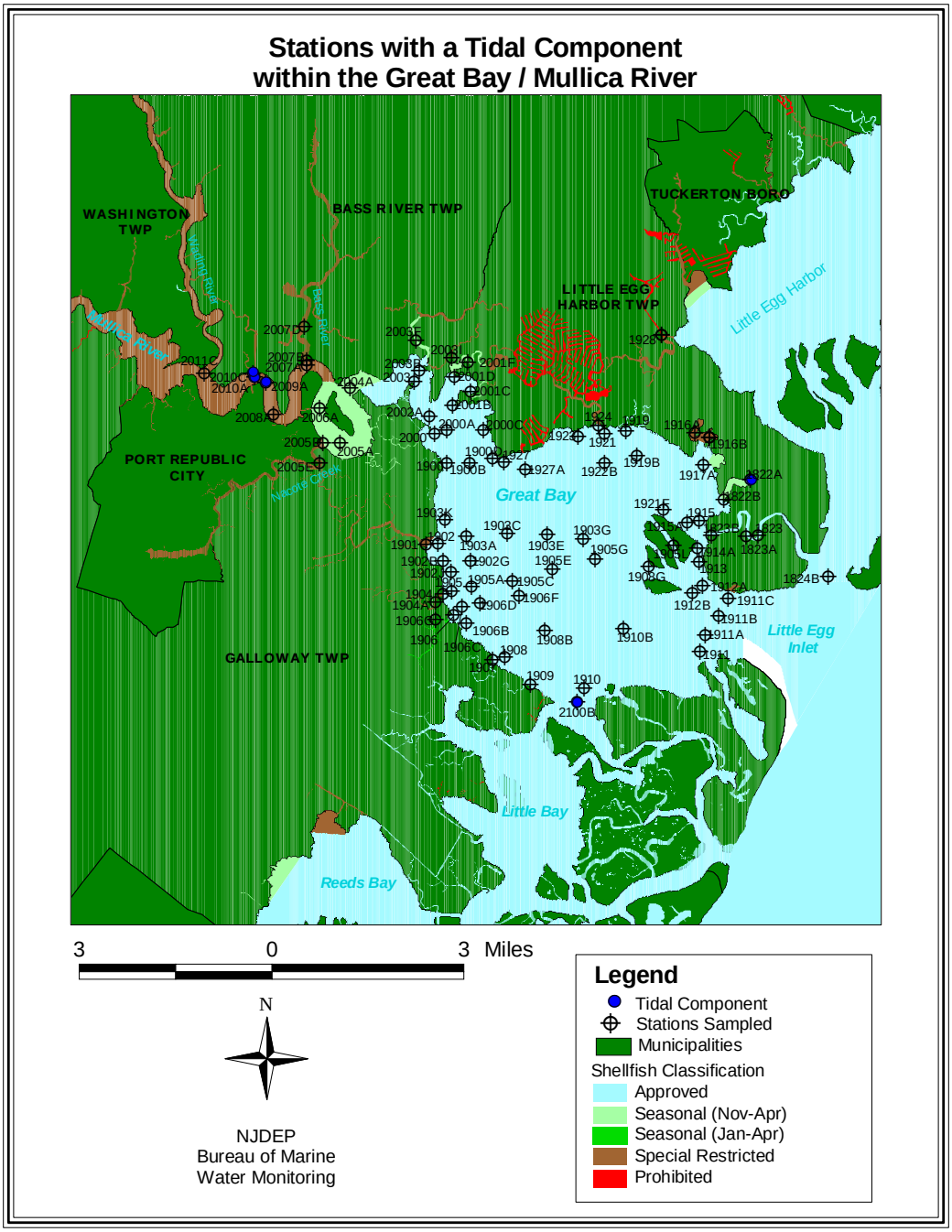
When extending the timeframe back to try to include 30 samples for both ebb and flood, eight stations had a tidal component; including both 1822A and 2100B. These two stations are very close to marshland where runoff could greatly impact the water quality on the ebb tide. However, the total coliform levels are very low at each station year-round. These stations will be monitored closely. All eight stations, however, still fit within their current classification criterion.

Presently, no changes in classification are needed as a result of the tidal components at these stations.

TABLE 7: TIDAL EFFECTS

Station	Geometric Mean Total Coliform MPN		Probability>[T]
	Ebb	Flow	
1822A	6.0	3.8	**0.034**
2009A	33.8	10.6	**0.040**
2010A	34.7	10.7	**0.012**
2010C	34.5	11.2	**0.021**
2100B	6.0	3.6	**0.009**

FIGURE 26: SAMPLING STATIONS AFFECTED BY TIDE



SEASONAL EFFECTS

Shellfish are filter-feeding organisms that live in the sand, silt, and mud on the bottom of oceans and bays. They have a range of tolerance to specific environmental conditions, such as temperature, salinity levels, oxygen levels, quantity and availability of food, and water quality. Seasonal effects on these variables can have an effect on shellfish populations. For example, different species of shellfish require very specific salinity levels for survival. Since salinity levels can have an effect on the species found in certain waters of an area, the salinity level is important for a complete understanding of the complex ecological balance in the marine environment (Wesighan, 2003). At a time of the year when rainfall is low, where evaporation exceeds precipitation, the salinity of the marine environment in certain areas is higher than it is in regions where precipitation exceeds evaporation (Ingmanson and Wallace, 1989). This can affect the quantity and type of shellfish found in a specific area.

It is important to understand the factors that can contribute to high total coliform levels and which season these factors impact. Temperature is one such factor, but, here are also many factors stemming from human populations. Boat use is a major factor in this area and most recreational boating occurs during the summer. Runoff from agricultural and urban areas also influences the coliform levels in this growing area. Runoff occurs year-round, however, things like pesticides and bug sprays are used more heavily in the summer season. This growing area is a frequent stopping ground for migrating birds, which are common during early May (summer) and early November (winter). Bird waste has the ability to negatively influence the water quality. Overall, there are more factors that can increase the levels of coliform during the summer than during the winter season.

Seasonal components were observed at 17 stations. The T-statistic probability must be less than or equal to 0.05 for a station to have a seasonal component (see Table 8). Figure 27 shows the locations of these sampling stations. The complete seasonal evaluation data set can be seen in Appendix C.

Stations within the Mullica River and west of Mystic Island show higher values in the summer, while stations in the southwest portion of Great Bay show higher winter values. Usually the higher summer temperatures and seasonal recreational uses contribute to high summer coliform values. The best explanation for the higher winter coliform levels would be the fecal matter from the bird and wildlife populations.

When the timeframe was extended to get a data set of 30 for both the summer and the winter, twenty-one stations had a seasonal component. However, all of these stations still comply with the current classification of the shellfish waters in this area, based on NSSP total coliform criteria. These stations may be affected by non-point source pollution from increased summer population and/or increased use of water related activities (boating, etc.). Although these stations do not require changes in present shellfish classifications, they are

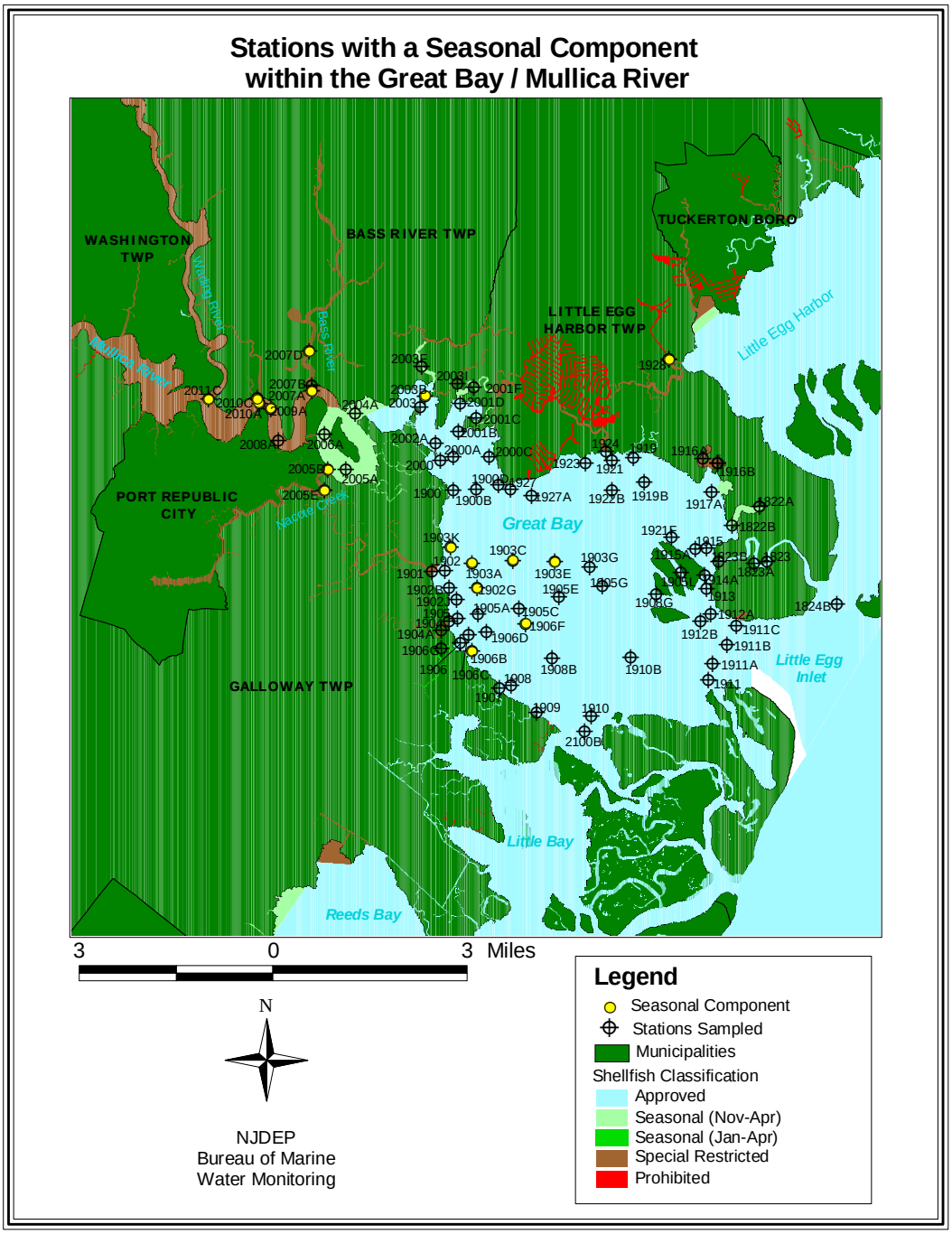
areas where potential problems could arise in the future and will be monitored.

All stations that were impacted by season remain in compliance with their respective classification criteria.

TABLE 8: SEASONAL EFFECTS

Station	Total Coliform Geometric Mean		Probability > [T]
	Summer	Winter	
1902G	3.1	12.7	**0.000**
1903A	3.5	9.5	**0.000**
1903C	3.9	7.8	**0.010**
1903E	3.1	7.0	**0.000**
1903K	4.2	8.6	**0.031**
1906B	10.2	3.8	**0.003**
1906F	11.2	6.2	**0.021**
1928	8.0	4.0	**0.030**
2003B	13.2	5.4	**0.035**
2005D	15.0	5.3	**0.018**
2005E	28.5	9.3	**0.005**
2007A	14.3	6.5	**0.045**
2007D	42.4	11.0	**0.005**
2009A	45.6	13.1	**0.031**
2010A	41.3	14.3	**0.028**
2010C	43.7	13.7	**0.020**
2011C	61.2	19.6	**0.031**

FIGURE 27: SAMPLING STATIONS AFFECTED BY SEASON



RAINFALL EFFECTS

Non-point source pressures on shellfish beds in New Jersey originate in materials that enter the water via stormwater. These materials include bacteria, as well as other wastes that enter the storm water collection system. A relationship between rainfall amounts and total coliform levels is suggested if the rainfall correlation coefficient is greater than 0.600.

The Bureau of Marine Water Monitoring has begun to identify particular storm water outfalls that discharge excessive bacteriological loads during storm events. In some cases, specific discharge points can be identified. When specific outfalls are identified as significant sources, the Department works with the county and municipality to further refine the source(s) of the contamination and implement remediation activities.

It should be noted that a particular short-term data set might not indicate significant rainfall effects even if the historical data indicate that a significant effect occurs in a particular area. This is due to one or more of the following factors:

- Data during the short term may consist of primarily rainfall data or dry weather data. In this case, if there are insufficient data points in each category, the test for significance can not be done.
- Data collected after rainfall in the normal sampling regime may miss the effects of the 'first flush'.
- Rainfall data are based on the closest established NOAA station. Since rainfall patterns along the coastline, particularly during the summer months, tends to include locally heavy rainfall, the rainfall amounts recorded at the NOAA station may not accurately reflect the rainfall at the sampling station(s).

The four assignment runs for this growing area are almost always sampled on different days. Therefore, the complexity of analyzing the impact of rain events on the total coliform levels is increased. For example, it might occur that one assignment run is only sampled with no rain in the prior two days, while another run is frequently sampled one day after a rain event. To streamline this, and for cohesivness, changes in the 2005 monitoring schedule are being made so that this growing area will only require two assignment runs. Only assignment runs 145 and 151 will remain.

Twelve stations in this growing area showed a rainfall correlation of 0.600 or greater two days prior to the day of sampling (see Figure 28). Twelve stations (some the same as those mentioned above, and some different) showed a rainfall correlation on one day prior to the day of sampling. Fifteen various stations showed a rainfall correlation on the day of sampling (see Table 9, Appendix D). These stations are all in close vicinity to the shoreline and are probably influenced by bird and animal wastes being washed in the water from the wetlands when a rain event occurs. All stations remain in compliance with their existing shellfish classification.

FIGURE 28: SAMPLING STATIONS AFFECTED BY RAINFALL

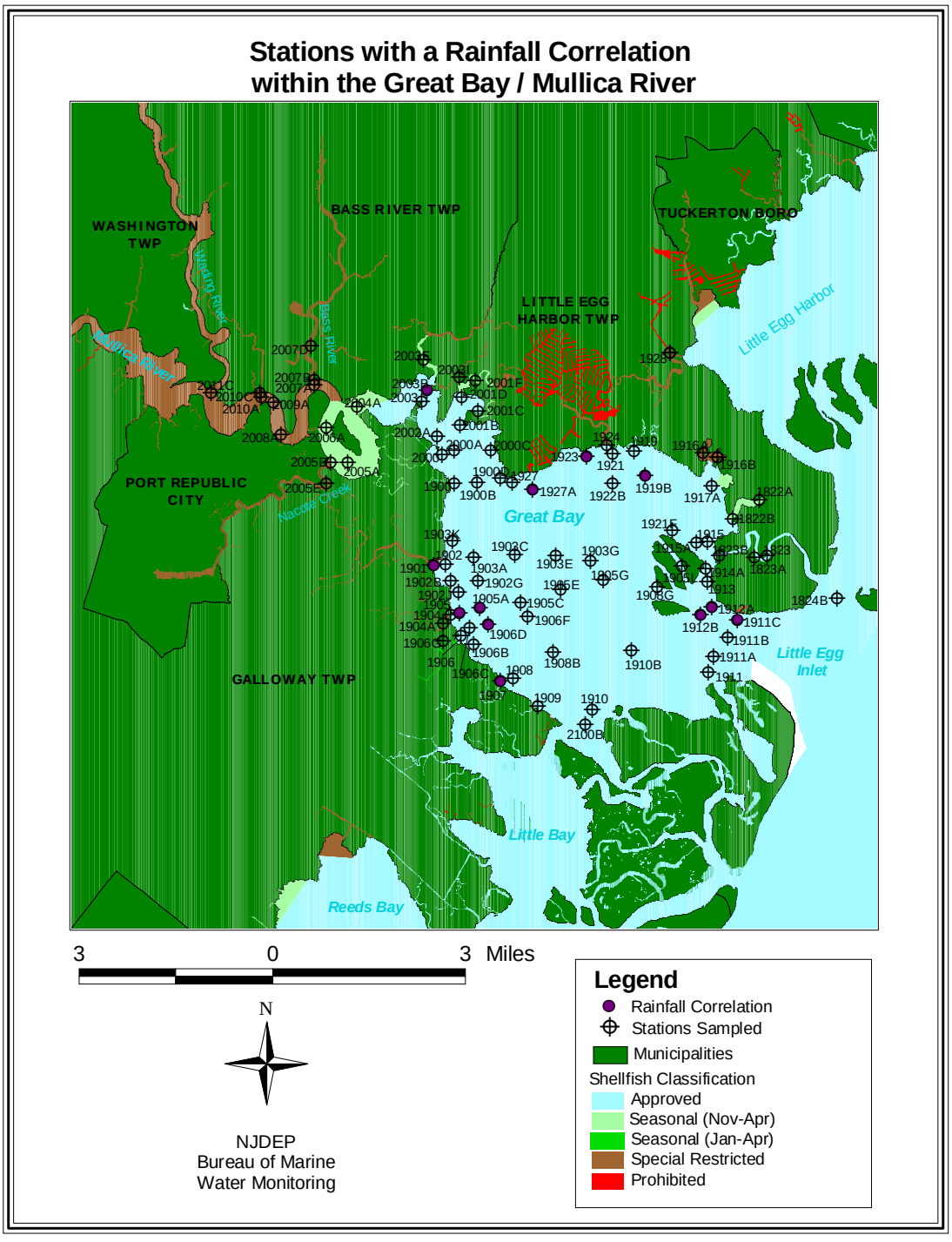


TABLE 9: CORRELATION OF TOTAL COLIFORM VALUES WITH CUMULATIVE RAINFALL (BOLD VALUES ARE THOSE OVER THE 0.600 – INDICATING A RAINFALL CORRELATION)

Station	Correlation of Total coliform with rainfall			Number of Observations
	Day of Sampling	24 hours prior	48 hours prior	
1823A	**0.663**	**0.611**	0.497	42
1901	0.563	0.581	**0.613**	41
1905	**0.654**	**0.786**	**0.711**	41
1905A	0.531	0.333	**0.691**	42
1906B	**0.600**	0.506	0.345	42
1906D	0.538	0.557	**0.711**	41
1906G	**0.605**	**0.695**	0.536	42
1907	**0.660**	**0.708**	**0.637**	41
1911A	**0.612**	0.383	0.330	42
1911B	**0.812**	0.512	0.511	42
1911C	**0.683**	**0.884**	**0.689**	42
1912A	0.576	**0.888**	**0.615**	42
1912B	**0.744**	0.538	**0.607**	42
1916A	**0.751**	0.491	0.455	42
1916B	**0.666**	0.583	0.489	42
1919B	**0.750**	0.536	**0.622**	42
1921	**0.681**	0.595	0.492	42
1921F	0.241	**0.668**	0.472	42
1923	**0.614**	**0.732**	**0.654**	42
1924	0.319	0.161	0.389	42
1927	**0.631**	**0.670**	0.599	42
1927A	0.517	**0.663**	**0.654**	42
2003B	0.154	**0.651**	**0.639**	38

RELATED STUDIES

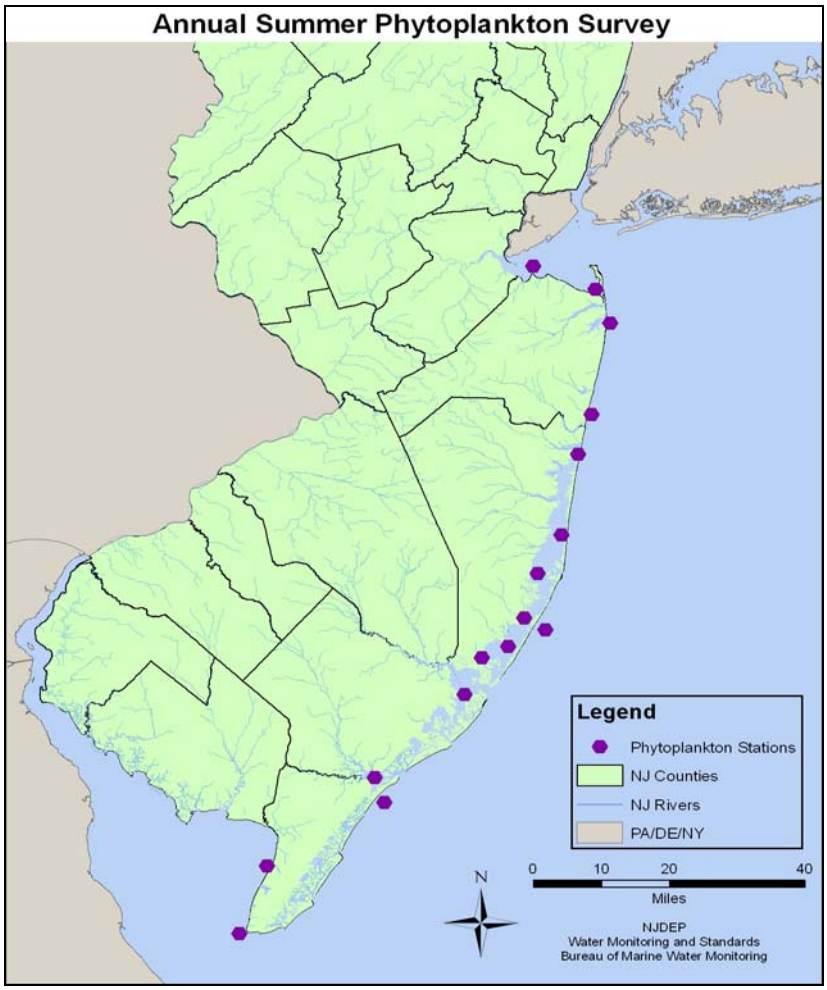
Although the Bureau of Marine Water Monitoring assesses classification based on total coliform, there are many other tests run on the retrieved water samples. In addition to measuring total coliform, the laboratory is also capable of testing for fecal coliform levels. Testing can also be done for levels of phytoplankton, metals (as of 2003), and nutrients in the shellfish waters.

Phytoplankton

Phytoplankton are photosynthetic algae that play a critical role at the base of aquatic food webs. Phytoplankton studies are used to show what species are present and in what concentration (measured by the amount of chlorophyll). The Bureau of Marine Water Monitoring collects samples at regular intervals throughout the summer to determine the occurrence of marine biotoxins (see Figure 29). There is a phytoplankton station in southern Great Bay. The Bureau of Marine Water Monitoring, in accordance with the NSSP requirements, also analyzes the data. The NJDEP and USEPA (United States Environmental Protection Agency) conduct a routine helicopter surveillance, which looks for color abnormalities in New Jersey waters, indicating an algal bloom. There have been no incidents of algal blooms with acute toxic Phytoplankton in New Jersey (NJDEP, 2000).

Phytoplankton reports are available at the Bureau of Marine Water Monitoring website, www.nj.gov/dep/bmw.

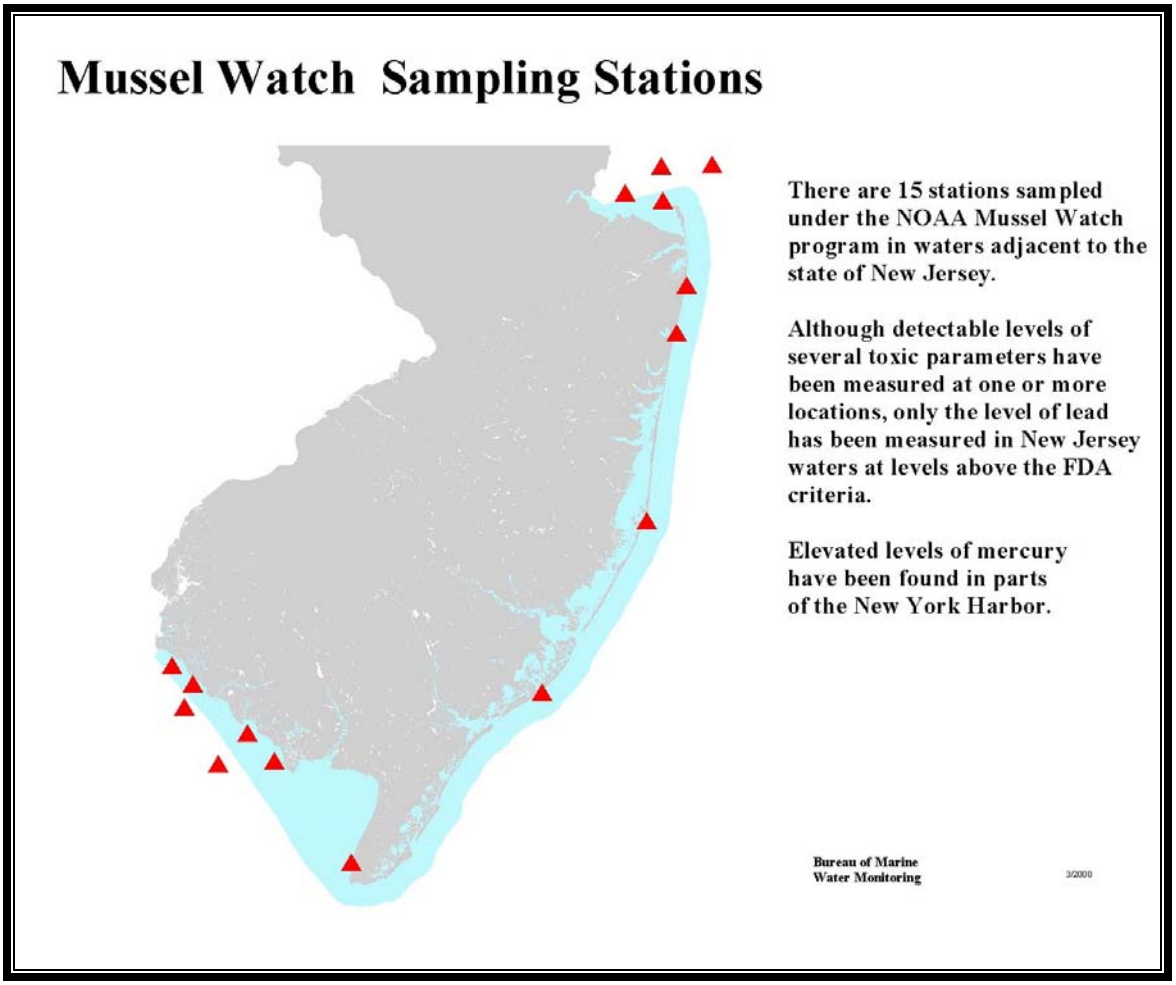
FIGURE 29: PHYTOPLANKTON STATIONS



NOAA Mussel Watch Program

The NOAA Mussel Watch Program monitors the levels of toxins and metals in coastal waters (see Figure 30). The blue mussel, *Mytilus edulis*, occurs worldwide, and effectively takes up toxins and metals from seawater and sediment. The toxins and metals become concentrated in their living tissues. Assays from the living tissues of this shellfish can be made easily and cheaply. The Mussel Watch Program monitors metals such as mercury, lead, zinc, nickel, cadmium, copper, chromium, aluminum, silicon, manganese, iron, arsenic, selenium, tin, antimony, thallium, and silver. The program also monitors toxins such as the synthetic organic compounds that are widely used in pesticides, solvents, flame-retardants, and other products. There is no mussel watch station in this growing area; the closest one is located in the Absecon Inlet near Atlantic City.

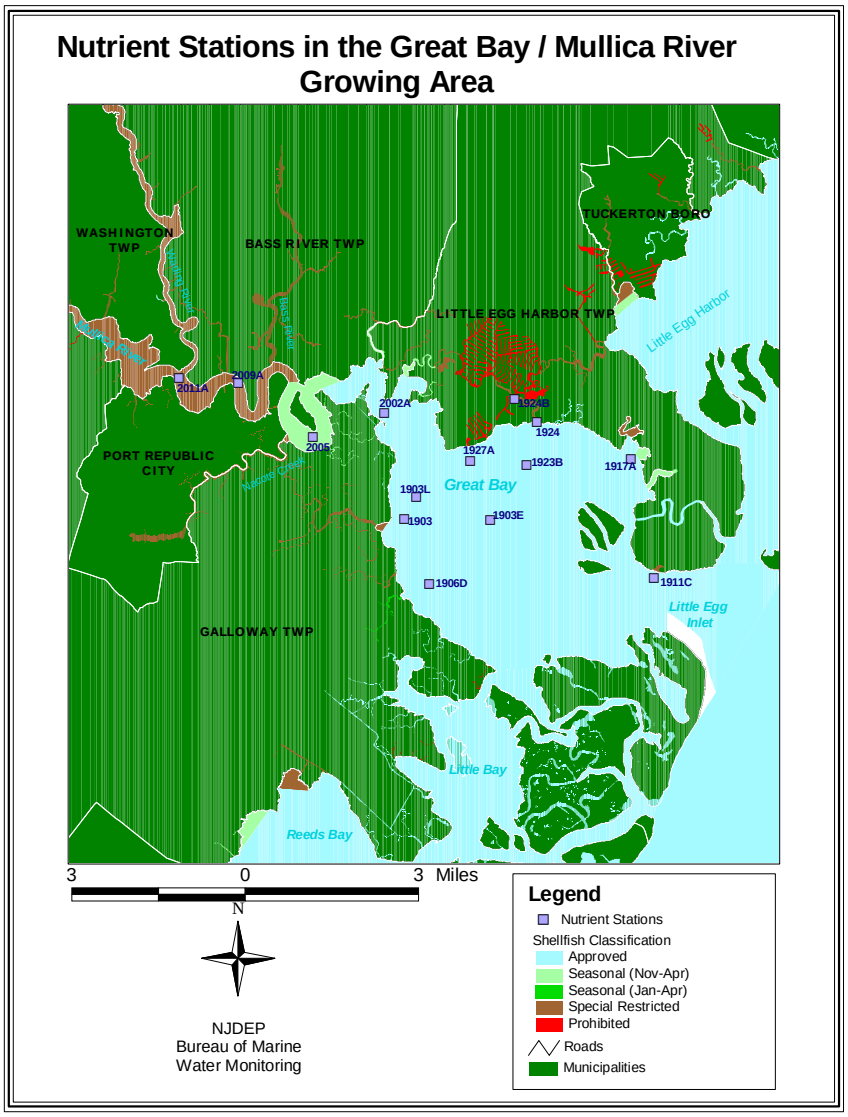
FIGURE 30: SAMPLING SITES WHERE NOAA MUSSEL WATCH DATA HAS BEEN COLLECTED



Nutrients

Nutrient and dissolved oxygen samples are collected at fourteen stations in this growing area (see Figure 31). At these nutrient stations, the various parameters measured include water temperature (in Celsius), salinity levels, Secchi Depth, total suspended solids, dissolved oxygen levels, ammonia levels, nitrate and nitrite levels, orthophosphate levels, total nitrogen levels, and the inorganic nitrogen to phosphorus ratios (Zimmer, 2000, Zimmer, 2001). The parameters are evaluated, analyzed, and written in a separate report by the Bureau of Marine Water Monitoring, available on the web at: www.nj.gov/dep/bmw. Averages of nutrient data are also available for each nutrient station on the above website.

FIGURE 31: SAMPLING SITES WHERE ADDITIONAL DATA HAS BEEN COLLECTED FOR NUTRIENTS



INTERPETATION AND DISCUSSION OF DATA

BACTERIOLOGICAL

Total Coliform Evaluation

The water quality data obtained from the sampling period January 1, 2000 to December 31, 2003 are listed in Appendix E. The Systematic Random Sampling Strategy was used to collect the samples, laboratory tests were run for total coliform, and a thorough analysis of the data was assembled for this report.

The data analysis is based on the total coliform results in which the total coliform median or geometric mean MPN (most probable number) for *Approved* classification shall not exceed 70/100 mL and the estimated 90th percentile shall not exceed an MPN of 330/100 mL. The three tube decimal dilution test is used for Systematic Random Sampling (SRS) strategy (see Table 4) (NSSP, 2001 Revision). Also, the total coliform median or geometric mean MPN for *Special Restricted* classification shall not exceed 700/100 mL and the estimated 90th percentile shall not exceed an MPN of 3300/100mL, where the three tube decimal dilution test is used for Systematic Random Sampling (SRS) (see Table 4) (NSSP, 2001 Revision).

The bacteriological data for each station supports their respective criteria for *Approved, Seasonal,* or *Special Restricted* classification under the total coliform standard. Based on all of these data, this growing area is properly classified.

All of the sampling stations in this shellfish growing area meet the *Approved* criteria for water quality (see Figure 32). However, if any of these sampling stations are located in shellfish waters near a marina, then the shellfish waters around these sampling stations are classified based on the required marina buffer.

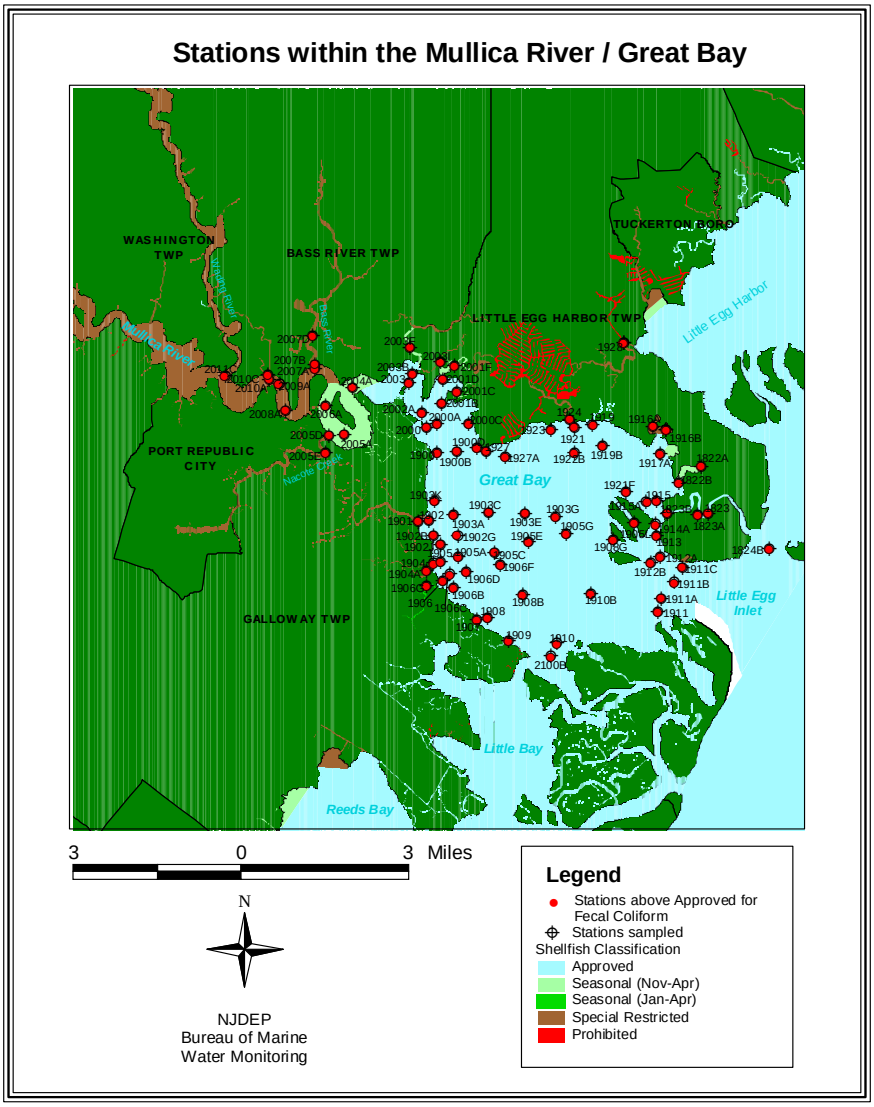
There were five stations that showed a significant tidal component (see Figure 26 and Table 7). Tidal impacts were evaluated by performing a t-test on log-transformed total coliform MPN values. On analysis it was found that all stations in this area complied with the current shellfish classification.

There were seventeen sampling stations that showed a seasonal component in this shellfish growing area (see Figure 27 and Table 8). SRS seasonal components were assessed using a t-test to compare log-transformed total coliform values for summer verses winter data. However, the total coliform levels still met the existing shellfish classification criteria for these shellfish waters.

A correlation between total coliform MPN and rainfall occurred at 23 of the 89 sampling stations in this shellfish growing area (see Figure 28 and Table 9). Rainfall impacts were assessed by

correlating total coliform MPN values with cumulative rainfall on the day of sampling, 24 hours prior to the day of sampling, and 48 hours prior to the day of sampling. A relationship between rainfall amounts and total coliform levels is suggested if the rainfall correlation coefficient is greater than 0.6 on 48 hours prior to the day of sampling. All stations in this shellfish growing area remained in compliance with the current shellfish classification.

FIGURE 32 : STATIONS IN THE GREAT BAY / MULLICA RIVER GROWING AREA



CONCLUSIONS

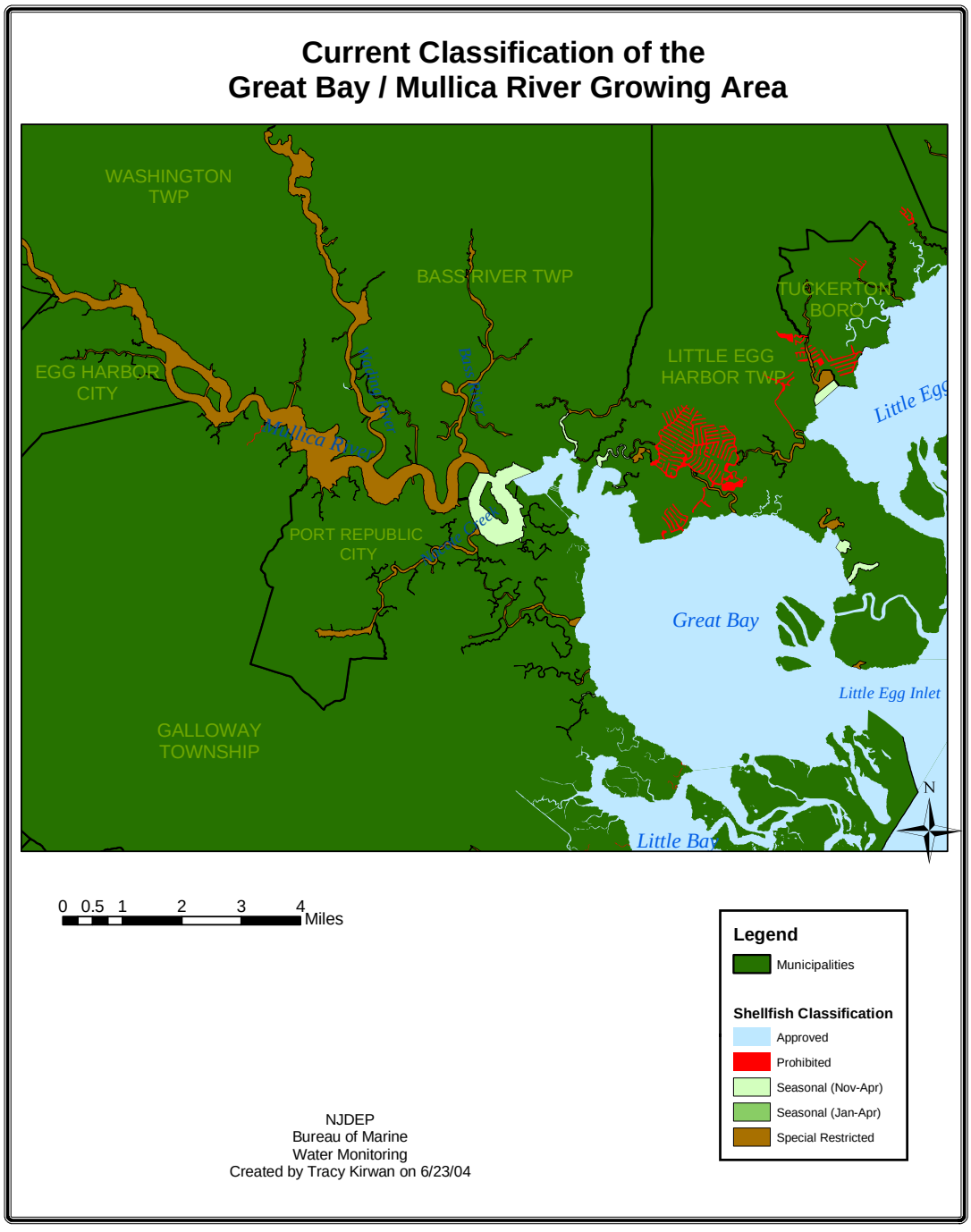
BACTERIOLOGICAL EVALUATION

Analysis of the Great Bay / Mullica River shellfish growing area samples indicate that total coliform levels meet the standards of the National Shellfish Sanitation Program (NSSP, 2001 Revision).

This area was sampled using the Systematic Random Sampling (SRS) strategy. All of the sampling stations are in compliance with the requirements of the *Approved*, *Seasonal (November - April)*, *Seasonal (January - April)*, *Special Restricted*, and *Prohibited* shellfish classification for the waters in this area, based on NSSP total coliform criteria. Currently, no classification changes are recommended for the Great Bay / Mullica River growing area (see Figure 33 for current classification). However, continued improvements in water quality in this growing area could lead to upgrades in the future.

The waters of this growing area are some of the most pristine in all of New Jersey. The lack of urban influences and the tidal exchange with the Atlantic Ocean keep the coliform levels low in the Great Bay and Mullica River. The protection coming from the state and federal governments for the various refuges, wildlife management areas, and forests surrounding these waterbodies has also been of critical importance in keeping the coliform levels under criteria. For this reason, the Great Bay and Mullica River have become prime waterbodies to study. The natural environments and the natural wildlife attract scientists and birdwatchers alike. The hard clam and oyster populations have not yet risen to what they were in the early 1900's, but with investigations, time, and continued protection, the future of the shellfishing industry in the Great Bay and/or Mullica River may again reach such a milestone.

FIGURE 33: CURRENT CLASSIFICATION OF THE GREAT BAY / MULLICA RIVER GROWING AREA



RECOMMENDATIONS

BACTERIOLOGICAL EVALUATION

RECOMMENDED CLASSIFICATION CHANGES

Currently, there is no recommendation for classification changes to the SE1 Great Bay/ Mullica River.

RECOMMENDED CHANGES FOR THE 2005 MONITORING SCHEDULE

1. Sampling at station 1928, sampled under assignment 132, should be terminated. Stations 1818 &1818A are in close proximity and the area is adequately sampled.
2. Sampling at station 1824B should be terminated; stations 1824 & 1824C are in close proximity and the area is adequately sampled.
3. Stations 1822A, 1822B, and 1823 are presently sampled on assignment run 131, however they should be sampled on assignment 151 due to their location. Since assignment 151 already has 55 stations, stations 1902G, 1905C, 1906C, and 1911B will be terminated to allow stations 1822A, 1822B, and 1823 to be sampled in this assignment run.
4. For the next sampling season station 1907 should be moved slightly southeast. Due to flow change it no longer is an accurate indicator of the coliform input into Great Bay from that tributary (N: 39° 29” 31’, W: 74° 23” 44’).
5. Otherwise, continue sampling under the existing sampling protocol and analyzing the samples for total coliform.

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APPENDICES

A. Statistical Summary

B. Tidal Evaluation

C. Seasonal Evaluation

D. Precipitation

Rainfall Correlation

Rainfall Amounts

E. Data Listing: January 1, 2000 – December 31, 2003

F. 2003 Regulations (highlighting this growing area)