Eight Characterizing Trends in the Barnegat Bay Watershed, Ocean County, New Jersey

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ABSTRACT

To characterize the impacts of development along the New Jersey coastal zone, long term trends describing cumulative impacts were developed for eight environmental parameters in the Barnegat Bay watershed. The eight parameters evaluated were population, landcover, freshwater ambient quality, beach closings, wetlands acreage, fecal coliform averages in marine waters, nonpoint source loads of phosphorus to marine waters and nonpoint source loads of nitrogen to marine waters. Results reveal a quadrupling of population; a significant increase in residential/commercial landcovers; freshwater problems with fecal coliform, pH, and phosphorus; unacceptable numbers of backbay beach closings; inadequate wetland information; unacceptable levels of fecal coliform in some sections of the backbay waters; and lower than expected loads of nonpoint source phosphorus and nitrogen to marine waters. Analyses conducted using a Geographical Information System (GIS) were essential to the evaluation and interpretation of the available scientific data for the watershed.

INTRODUCTION

The Coastal Zone Management Program in the Office of Environmental Planning, New Jersey Department of Environmental Protection (NJDEP) is characterizing cumulative environmental impacts in the coastal zone as part of a contract with the National Ocean & Atmospheric Administration (NOAA). Cumulative impacts are those caused by the sum of many individual activities, which separately are not problems, but together result in environmental degradation. The Barnegat Bay watershed was selected for the initial research in cumulative coastal impacts because of its status as a National Estuary, and because of its high level of development since the 1970s. The Barnegat Bay watershed consists of all or part of 29 municipalities in Ocean County, New Jersey. It was anticipated that cumulative impacts would be more readily identified and measured in an area which has experienced high population growth and land cover change in a relatively short time period.

Initially, it was decided to examine cumulative impact trends over the 20-year period from 1970 to 1990, for 20 different cumulative indicators. However, upon examination of the available data it was discovered that reliable, consistent information was available for only eight cumulative indicators. Limitations of the NOAA contract restricted this study to the evaluation of existing data sets and precluded the collection of additional information. Thus, the result of this project is the development of trends for the following eight indicators: population, landcover, freshwater quality (22 chemicals), beach closings, wetlands, fecal coliform levels in marine waters, nonpoint source phosphorus and

nonpoint source nitrogen loads into marine waters.

Upon NOAA approval, a detailed methodology and findings report will be available for each of the eight trends developed. Most of the work performed for this study was conducted using the Geographic Information System (GIS), to facilitate spatial analysis, in addition to straightforward numerical calculation of trends. The spatial analysis proved extremely important and should help to target specific management strategies to specific environmental problems which are localized within the watershed.

POPULATION TRENDS

Population data from the U.S. Bureau of the Census is available for the study area. Data from 1960 to 1990 was evaluated. The 1960 population for the study area was 97,927 persons. On average, the population of the study area increased by about 98,000 persons per decade up to the 1990s. By 1990 the population had reached 391,549 persons, and had in essence quadrupled. Population increases were greatest in Jackson, Brick, Lakewood and Dover townships during the period from 1960 to 1970. Population increases were greatest in Brick, Lakewood, Dover, Manchester and Berkeley townships between 1970 and 1980. Population increases were greatest in Brick, Dover and Berkeley between 1980 and 1990. Today, each of these municipalities has over 30,000 residents. The distribution of the population increases is greatest in the north and steadily decreases to south. The population is concentrated along the streams, backbay, ocean waterways, and barrier island.

In an earlier document, <u>Profile of the Barnegat Bay</u> (Rogers et al., 1990), the population in the study area was projected to grow to 362,100 persons by the year 2000. The 1990 population actually exceeded that earlier estimate by 29,449 persons. The important lesson to be gained from this observation is that it is critical to periodically re-examine important trends. Future studies in the area should be careful to update existing information sets.

Clearly the area is under significant development pressure. In addition to the development pressure exerted by the permanent residents, it is estimated that in the bay communities the ratio of season population to permanent population is 2:1 and in the coastal beach community the ratio is 10:1 (Rogers et al., 1990). Management strategies developed for the watershed must account for the continued population stresses on the land, environment and infrastructure capacity.

LANDCOVER TRENDS

Landcover information for the study area was available for the years 1972 and 1989. The classification scheme used in the 1972 data set was quite generalized and only differentiated between residential/commercial, agricultural, forested, and water landcovers. In contrast, the classification scheme used in 1989 was elaborate and differentiated among various types of residential, commercial, and agricultural landcovers. To compare the two data sets, the 1989 landcover parcels were "clumped" to match the classification scheme used in 1972, and a change analysis was performed.

Residential/commercial landcovers increased from 19% of the study area in 1972 to 29% in 1989, a 10% increase. Agricultural landcovers decreased from 3% of the study area in 1972 to 2% in 1989, a 1% decrease. Forested landcovers decreased from 78% of the study area in 1972 to 69% in 1989, a 9% decrease. Spatially, the residential/commercial increases in landcover are concentrated in the northeastern portion of the watershed, and along the streams, backbay and ocean waters.

FRESHWATER AMBIENT QUALITY TRENDS

Trends of twelve chemical parameters at two surface water quality monitoring stations were evaluated for the period from 1975 through 1994. One monitoring station is located on the Toms River and drains an area of 318.57 square kilometers. The second station is located on the Manasquan River and drains an area of 113.96 square kilometers. The chemicals evaluated were fecal coliform (summer), unionized ammonia (summer), dissolved oxygen (summer), nitrate nitrogen, total Kjeldahl nitrogen, total phosphorus, total organic carbon, pH, the percent of dissolved oxygen saturation (summer and year), and the percent of dissolved chloride (winter and year). Statistical analysis was performed by Dr. Hal Wilson of CES, Inc.

Fecal coliform analysis shows no trend at either monitoring station. Unionized ammonia, total Kjeldahl, total organic carbon, and percent of dissolved chloride (year) reveal one station with an increasing trend and one station with a decreasing trend. Dissolved oxygen and percent of dissolved chloride (winter) exhibit one station with an increasing trend and one station with no trend. Nitrate nitrogen and percent of dissolved oxygen saturation (year) show one station with a decreasing trend and one station with no trend.   Total phosphorus and percent of dissolved oxygen saturation (summer) reveal two stations with decreasing trends. PH exhibits two stations with increasing trends.

Following the trend analysis, a comparison of the analytical values to the water quality standards was performed. Fecal coliform, while showing stable trends, violates the water quality standard at both stations (92% and 25% of the time). PH violates the water quality standard 100% of the time at one station and 23% of the time at the second station. Total phosphorus frequently violates the water quality standard at one station (48%). However, violations are infrequent at both stations now, and the phosphorus trend is decreasing at both stations. Dissolved oxygen, dissolved chloride and nitrate nitrogen have never violated the water quality standard at either station.

Finally, available data were examined for 10 additional chemical species: copper (water), lead (water), mercury (water), suspended sediment, copper (sediment), lead (sediment), mercury (sediment), DDT (sediment), gross PCBs (sediment) and phosphorus (sediment). Trends were not calculated for these species due to insufficient data. The levels of pesticides appear to be decreasing. Both mercury and lead levels in the water frequently violate the water quality standard; however, there are some recently recognized problems with the sample collection methodologies used in the past. Therefore, one cannot validly conclude that there are problem levels of metals in the fresh surface waters. Future work should be conducted to determine if there are actual violations in the levels

of metals in the water.

BEACH CLOSINGS

Beach closing information was obtained from the Cooperative Coastal Monitoring Network (NJDEP, Enforcement) from 1988 to 1995 for both the ocean side and backbay beaches in the study area.   Beach closing is predicated on fecal coliform sample results. Repeat fecal coliform values above 200 MPN will cause a beach to be closed. Fecal coliform, while a broadly used indicator for human pathogens, is produced by all warm blooded animals. Therefore, the presence of fecal coliform may indicate the presence of human sewage, or other fecal sources. High fecal coliform counts can be found following a rainstorm, at localities near feedlots and under various other circumstances.

There were less than 10 ocean side beach closings each year from 1988 to 1995. This indicates that fecal coliform contamination is not a serious problem for the ocean side beaches. Conversely, there were more than 20 backbay beach closings every year from 1988 to 1995. In 1989, 1990, and 1994 there were more than 140 backbay beach closings per year (a high of 187 in 1989).   Clearly, fecal coliform contamination in the backbay marine waters is a serious issue that must be addressed.

WETLANDS TRENDS

Unfortunately, accurate historical wetlands mapping is not available for the coastal zone portion of the study area. However, wetlands acreage was considered to be such an important trend that the highly detailed freshwater wetlands maps (1986) and integrated terrain unit maps (1986) were used to develop freshwater and saline wetlands acreage. In essence the goal is to begin the trend with the available data, making 1986 the first point in the trend line. Based on the GIS analysis, there were 5,591 hectares of wetlands in the coastal zone in 1986. These can be further subdivided into 6 hectares of freshwater tidal wetlands; 4,978 hectares of saline wetlands; and 607 hectares of vegetated dune community wetlands.   Important future work should include the development of recent wetlands maps and plans to update those maps every decade.

FECAL COLIFORM TRENDS IN MARINE WATERS

Fecal coliform data in marine waters of the backbay and ocean were available for 1974 through 1992. The data were obtained from sampling performed for the National Shellfish Sanitation Program and the Cooperative Coastal Monitoring Network. In total, 57,251 sample results were evaluated for 700 sampling stations in the backbay and ocean waters. The geometric means of the data were evaluated for violations of the water quality standards for recreational contact (50 and 200 MPN), and violations of the water quality standards for consumption (14 MPN).   They were modeled to determine order of magnitude changes over time.

To average out confounding factors in the data trends, the sample results were grouped into three time intervals (1974-78, 1984-88 and 1989-92). All data for each of the 700 monitoring stations were then geometrically averaged to produce one average value for each station in each time period. There were about 19,000 samples used in each time

period. Approximately 27 samples were averaged for each station in each time period.

The findings of the preliminary comparison of the geometric means of fecal coliform levels to the near shore recreational contact standard (50 MPN) are that 38 stations (5%) violated the standard in the 1974-78 time interval. The number dropped to 7 stations (1%) in the 1984-88 interval, which is a significant improvement.   However, the number increased to 35 stations (5%) in the 1989-92 interval. The return to higher numbers of violations is surprising given the extensive point source controls instituted between 1974 and 1992. These measures included controls on all point sources of pollution regulated by NJDEP, the substantial elimination of on-site-waste-water disposal (septic) systems, and the elimination of combined sewer overflows in the study area.

In comparison to the far shore recreational contact standard (200 MPN), the geometric mean at 13 stations (2%) violated the standard in the 1974-78 interval. This number dropped to 0 stations (0%) in the 1984-88, but then rose again to 4 stations (1%) in the 1989-92 interval. Thus, the same trend occurs when fecal coliform geometric averages are compared to either the near or far shore recreational contact standard. Water quality in the early 1970s shows some violations, but the situation improves during the 1980s. Water quality begins to degrade again by the early 1990s.

The water quality standard for the protection of shellfish growing waters are very restrictive, at 14 MPN.   There were 187 stations whose geometric mean was found to violate the standard in the 1974-78 interval. This represents 26% of all stations. With the construction of regional sewage treatment, the elimination of combined sewer overflows, and the institution of point source controls, the situation improved. In the 1984-88 time interval 80 stations (12%) violated the consumption fecal coliform standards. However, by the 1988-92 interval the number of stations violating the standard increases again, to 128 stations (19%).

Based on the preliminary comparisons of the number of stations violating the various water quality standards plus the range and distribution of the geometric averages it was decided that an order-of-magnitude TIN model should be completed. This type of analysis could be used to distinguish fecal coliform "hot spots" from low-level chronic degradation of the water, in addition to targeting localities for additional management efforts.

For this analysis, water quality was considered *pristine* if the geometric average for the fecal coliform samples for each station in each time period was between 0 and 10 MPN. These levels of fecal coliform are common in non-developed areas. Waters surrounding stations with geometric averages between 10.1 and 100 were considered as low level degradation. Waters surrounding stations with geometric averages between 100.1 and 1000 MPN were considered as degraded. The operational definition of degraded, as used here, represents a two order-of-magnitude increase in average fecal coliform levels above pristine conditions.

A triangulated irregular network (TIN) model of the backbay and ocean waters was used to generate a "geometrically averaged fecal coliform surface". A TIN was used because this model type makes good use of the station distribution geometry. A TIN can properly manage the high curvature of the shoreline and is able to accommodate both the barrier island and the many small islands which exist in the middle of the model surface. Once TIN surfaces were generated for each of the three time intervals, the surfaces were contoured as pristine, low level degradation or degraded. Total areas of each contour class were calculated for each time interval surface.

In the time interval between 1974-78, about 99% of the study area's waters were pristine, and about 1% showed either low-level or acute degradation. By the 1984-88 time interval, conditions had improved so that no waters were acutely degraded, although the area of pristine water quality had dropped to 94% (5% decrease), with 6% of the waters showing low-level degradation. By the 1989-92 time interval, the area of pristine water quality had dropped to 90% of the total area (4% decrease below 1984-88). About 9% of the area showed low-level degradation (3% increase over 1984-88), and acute degradation had returned to 1% of the area. The acute degradation is seen dominantly in the northern portion of the backbay waters, where water turnover rates are low and the population density is very high.

The order-of-magnitude trends do not mimic those from the comparison to water quality standards for the 1974-78 time interval. In the case of the comparison to regulatory standards, the early time interval showed significant violations, while the TIN model revealed 99% of the area to be pristine. This is because a portion of the sampling is purposely repeated at "known hot spots" (i.e. sewage treatment outfalls, etc.). Hot spot sampling skews the results for that station. Since the monitoring station is the unit for comparison against the regulatory standards it is expected that all "hot spot stations" will appear as violations. In comparison, the TIN model calculates a value for an area on the model surface using both the geometric average for the station and the weighted values of neighboring stations. Several adjacent stations with degraded levels of fecal coliform would be necessary to show area-wide degradation in the surface model. The sewage outfalls in existence during the 1974-78 time interval are thought to be responsible for this discrepancy. Other than this 1974-78 discrepancy, the trends comparing the fecal coliform averages to standards and the trends based on a surface analysis follow the same pattern: improvements in conditions during the 1984-88 time interval, and increasing fecal coliform levels in the 1989-92 time period.

NONPOINT SOURCE PHOSPHORUS LOADS TO MARINE WATERS

In the late 1980s, Cahill Associates (Cahill Associates et al., 1992) was hired by the NJDEP to perform a general analysis of phosphorus and nitrogen loadings to the marine waters of the entire Atlantic coastal drainage basin in New Jersey. Their analysis evaluated point source, nonpoint source and sewage treatment plant discharges to marine waters. Point source and nonpoint source loads were developed using NJDEP and other data. Nonpoint source loads were estimated using a "nonpoint source pervious estimation model." This was developed using 1988 aerial photography, 1989 USGS base maps, field

measurements and field reconnaissance. In essence, Cahill Associates (Cahill Associates et al., 1992) determined the size and classification for each landcover parcel in the Atlantic coastal drainage basin. Landcover was classified as residential, commercial, STP, agriculture or forest. Subsequently, estimation equations were developed and field verified for each landcover class. The general equation for nonpoint source phosphorus loads is as follows:

(parcel size in hectares) x (pervious percentage of the parcel) x (phosphorus application rate in kg/hectare/year) x (loading factor) x (delivery ratio) = (nonpoint phosphorus load in kg/year per parcel)

Cahill Associates (Cahill Associates et al., 1992) varied the equation slightly to accommodate differences among the land classes and parcel types. For example, commercial or residential parcels were coded as either low, medium or high maintenance. Maintenance reflects the amount of phosphorus expected to be generated from a landscape, wether due to high application of fertilizer or pesticides, or due to wildlife or other natural causes. Application rates varied depending upon the type of crop grown on agricultural lands, the length of the fallow periods for that crop type or the type of landscaping, since golf courses would have different application rates than residential lawns, commercial lawns or wooded lots. Forested parcels were accommodated by substituting a natural phosphorus release rate (in kg/hectare/year) for the application term shown above. The objective of the first three terms in the general equation is to determine the maximum amount of nonpoint source phosphorus which is available from a given parcel.

There were several loading factors and delivery ratios used. The purpose of the loading factors and delivery ratios is to calculate the percentage of the phosphorus applied to, or released from, each parcel which would not be used or lost, and the percentage that would reach the waterways. Delivery ratios varied between and within each landcover class. The precise numbers used are based on theoretical and field studies, plus aerial photographic and field reconnaissance of the landcover parcels.

The Cahill Associates work is extremely valuable for two reasons. First, it showed that sewage treatment plant discharges were responsible for between 80% and 90% of total phosphorus loads to marine waters. Point sources accounted for an additional 1% of the total loads, and nonpoint sources were responsible for between 9% and 19 % of the total loads. These values are particularly important when one recognizes that the STPs discharge to the nearshore ocean waters. Therefore, nonpoint source phosphorus loads represent the bulk of the discharge to the backbay waters. Second, the Cahill Associates work is valuable for the amount of research, photographic identification and field work conducted to develop the values used in their nonpoint load estimation equation.

As required by their contract, Cahill Associates only generated values for the entire Atlantic drainage basin. Also, they did not use the GIS to do the work. Therefore, it was not possible to easily generate nonpoint source values for individual watersheds,

or examine the spatial location of high loadings areas. The purpose of this analysis was to develop a corresponding Cahill file on the GIS for the Barnegat Bay watershed. Using that, estimates of the nonpoint source phosphorus loads and relative contributions from the different landcover classes could be calculated. Problem localities in the watershed can also be targeted in future work. In addition, the Cahill model was applied to the available 1972 landuse cover already on the GIS, so that estimates of the change in nonpoint source loads over time could be made. The GIS is an important tool for this type of spatial model because it allows the precise size and location of each parcel (distance to water body) to be taken into account when developing a parcel-by-parcel estimate of the loading. The accuracy of the parcel size and location is often rounded significantly when grid-based models are used. Furthermore, application of the GIS for this analysis can be useful in generating maps which show the localities within the watershed that are responsible for high loadings.

The findings of the study are that nonpoint source phosphorus loads have increased from 35 metric tons per year (mt/yr) in 1972 to 37 mt/yr in the late 1980s. While the residential/commercial landuse accounts for only 29% of the late 1980s landuse (by area), it is responsible for 92% of the phosphorus loads in the Barnegat Bay watershed. The nonpoint source phosphorus loadings are concentrated in the northern portion of the backbay. There does not appear to be a linear relationship between increases in population (100% increase from 1970-1990), increases in residential/commercial landcovers (10% increase 1972-1989), and nonpoint source phosphorus loadings (almost 6% increase 1972-1989). It should be noted that these values do not include nonpoint source loads from atmospheric sources, point source loadings, or sewage treatment plant loadings.

NONPOINT SOURCE NITROGEN LOADS TO MARINE WATERS
The nitrogen model employed was the previously described Cahill model, except that unique values were provided by Cahill for nitrogen application rates, release rates, loading factors and delivery ratios. As before, the purpose of estimating nonpoint source nitrogen loads is to calculate estimated loads for the Barnegat Bay watershed area, to determine the relative contributions to the load from the different landcover classes, and to target problem localities in the watershed.

The findings of the nonpoint source nitrogen loads to the watershed are that loads have increased from 441mt/yr in 1972 to 454 mt/yr in the late 1980s. While the residential/commercial landuse accounts for only 29% of the late 1980s landuse (by area), it accounts for 79% of the nitrogen loads in the Barnegat Bay watershed.   The nonpoint source nitrogen loadings should be concentrated in the northern portion of the backbay. Again, there does not appear to be a linear relationship between increases in population (100% increase from 1970-1990), increases in residential/commercial landcovers (10% increase 1972-1989), and nonpoint source nitrogen loadings (almost 3% increase 1972-1989). It should be noted that these values do not include nonpoint source loads from atmospheric sources, point source loadings, or sewage treatment plant loadings.

SUMMARY
The use of the GIS to perform a number of analyses was essential. For four of the trends developed (population, fecal coliform levels in marine waters, nonpoint phosphorus, and nonpoint nitrogen loadings to marine waters), the final maps show that a problem locality is the northern portion of the study area, adjacent to or in the backbay waters. This area is where water turnover rates are low and population concentrations very dense.

Four important lessons were learned from this study. First, it is critical to periodically re-evaluate estimated future trends, as was demonstrated with the population estimates. Second, it is always important to verify assumptions with actual measurements or field-based estimates. The conventional wisdom had held that the nonpoint source loads of phosphorus and nitrogen would be higher than the results indicate given the tremendous increase in population and high nonpoint source landcover types. Additional field work should be conducted to further verify these results. Third, the beach closing data would be more meaningful if the closings were located at specific beaches; instead of having general values for the entire study area. In the future, measurements should be collected with accurate location data so that spatial/GIS analysis can be conducted. Fourth, the analysis of the surface water data has shown that it is important to have multiple lines of converging evidence to support general conclusions concerning environmental systems in the watershed. Several of the water quality parameters are improving, but at the same monitoring station other parameters may reveal no trend or worsening conditions. Therefore, it is important to continue to collect additional scientific data to support conclusions about the Barnegat Bay ecosystem, as opposed to relying heavily on a few general indicators.

Much more work needs to be conducted in the watershed. A short list would include updating the landcover maps (including the wetlands information), developing additional trends for shellfish classification areas, air quality, air deposition loads, ground water quality, shore erosion, additional nonpoint source parameters (such as oil and grease), and habitat changes. Additional freshwater ambient water quality data are needed to provide a more comprehensive picture of metal contamination, and trends of phytoplankton blooms. Another important research topic is the development of a human specific pathogen indicator which is as robust, rapid and inexpensive as fecal coliform.

In conclusion, the evidence presented in this study should be used by environmental, resource and land use managers to target particular activities and actions in the watershed. The northeastern portion of the watershed, especially in the backbay, is highly stressed by the population densities, landcover types and cumulative contamination. Actions to control fecal coliform inputs throughout the watershed would be valuable given the levels of fecal coliform detected at the freshwater ambient monitoring stations and in marine waters.

REFERENCES

Cahill Associates. 1992. Limiting Nonpoint Source Pollution from New Development in the New Jersey Coastal Zone: Summary. Report Prepared for the Office of Regulatory Policy, New Jersey Department of Environmental Protection, Trenton, NJ.

Rogers, Golden, and Halpern. 1990. Profile of the Barnegat Bay. Report Prepared for the Barnegat Bay Study Group, New Jersey Department of Environmental Protection, Trenton, NJ.