Summary Report: State of Bacteria Pollution in the Toms River Subwatershed

Report Prepared Under the
Barnegat Bay Track-Down Project to Identify and Eliminate Pathogen Pollution from Sanitary Sewage Sources in the Toms River Subwatershed: WM20-022
A Find It, Fix It, No Blame Game Approach

Clean Ocean Action
Save Barnegat Bay
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Project Summary

Barnegat Bay faces significant challenges due to a variety of pollution sources most significantly caused by non-point source (NPS) pollution. NPS pollution primarily includes human related sources and the most important one is nitrogen pollution from improper use of fertilizers and organic wastes. Sanitary sewage pollution is a major source of organic wastes including pathogens and occurs due to aging/failing sanitary infrastructure and/or illicit sewer connections. Nutrient and pathogen pollution is a serious concern and is a threat to human health and the bay ecosystem. These directly and indirectly impact the recreational, aesthetic and economic benefits of the region.

The comprehensive Governor's action plan announced by New Jersey in 2010 focused on addressing the ecological health of the Barnegat Bay watershed through multiple approaches including scientific research on local water quality, stormwater management efforts, open space protection and implementation of stewardship projects. An interim assessment of the Barnegat Bay watershed by New Jersey Department of Environmental Protection (NJDEP) in 2014 showed that the Toms River Estuary did not support the designated uses of recreation, aquatic life, shellfish, and fish consumption. Pathogens, specifically *Enterococcus* and *E.coli*, were some of the causes for this decline in water quality. To address this issue and others, the NJDEP released the Barnegat Bay Restoration, Enhancement, and Protection Strategy (BB REPS) in October2017 under which various eligible projects would be funded to implement components of BB-REPs. Clean Ocean Action (COA) was awarded the grant (WM020-22) in 2020 for a track down project to identify and eliminate pathogen pollution from sanitary sewage sources in the Toms River sub-watershed. COA is collaborating with Save Barnegat Bay (SBB) and Marine Academy of Technology & Environmental Sciences (MATES) to form the Rally for Barnegat Bay to identify and eliminate these pathogen sources in six municipalities – Beachwood, Island Heights, Ocean Gate, Pine Beach, South Toms River, and Toms River.

The goal of this project is to track down and eliminate sources of sanitary sewage pollution in the Toms River area using an innovative framework that includes collaborative efforts and citizen science efforts. This report is the completion of deliverable under Task 2 – Objective One and is a summary of the state of bacteria pollution in the Toms River sub-watershed and identification of priority areas of concern for track down investigations under this project.

I. INTRODUCTION – BARNEGAT BAY ESTUARY

The Barnegat Bay-Little Egg Harbor Estuary (BB-LEH) in Ocean County, New Jersey was designated as part of the National Estuary Program (NEP) in 1995 and is one of the most valuable estuarine ecosystems in the coast of New Jersey. It is considered a lagoonal estuary and is separated from the Atlantic Ocean by a nearly continuous stretch of barrier islands along its eastern edge. BB-LEH is comprised of three micro-tidal watersheds (i) Barnegat Bay (ii) Manahawkin Bay (iii) Little Egg Harbor Bay and includes the embayment of Toms River and Metedeconk River. The 425,117-acre (660 sq. miles) Barnegat Bay watershed is about 70 km long and is located almost entirely within Ocean County in east-central New Jersey. It is relatively shallow (mean depth 1.6 m), narrow (~1 - 6 km wide), and has a mid-tide surface area of 279 km^2 and an approximate volume of 4.37 x 108 m^3 (Figure 1).

Figure 1. Barnegat Bay-Little Egg Harbor Estuary (BB-LEH)

The threat to the ecological health of the Bay from development activities and its potential adverse economic and recreation consequences resulted in the NJ legislature passing the Barnegat Bay Study Act (BBSA. P.L. 1987, chapter 397). Under this Act, the Barnegat Bay Study Group was created and tasked with the following.

1. A comprehensive profile of the Barnegat Bay on the nature and extent of impacts due to development

2. Management recommendations to improve the health of the Bay and mitigate/prevent pollution
3. Watershed wide management plan with meaningful and measurable strategies to sustain and improve the bay

It is noteworthy to mention that the citizen advisory group that was born out of this Act helped to advance the need for Federal recognition and protection of the Bay under the National Estuary Program in 1995.

I a. Physical features of the Bay

BB-LEH is a shallow estuary. Nearly seventy three percent of the bay is <2m deep at mean low water with depth ranging from about 1.3 m in the northern half of the system to ≥2.0 m in LEH. (Bricelj et al. 2012). Shallower depths allow for greater light penetration and promote submerged aquatic vegetation growth under other benign environmental conditions. Water temperature ranges from -1.5 to 30ºC, and salinity from ~10 to 32 ppt. Equally important are the nature of currents and circulation patterns in the Bay. While various factors such as winds, salinity gradient, freshwater inputs, and tidal forces influence Bay currents, winds appear to be the most dominant source. It has been observed that winds blow from the northwest during winter and from the south during summer. The most commonly-observed wind direction is from the south and north-northwest, the latter typically of higher velocities.

Exchange with ocean water occurs through Point Pleasant Canal, a dredged channel on the north, and primarily two natural inlets, Barnegat Bay Inlet in central BB, and Little Egg Inlet in the south, which connects with the Great Bay-Mullica River Estuary. Due to the physiographic features of the bay and barrier island complex, flushing is limited and leads to protracted bay water residence time, which is also seasonally influenced. Residence time in an estuary impacts water quality and many studies have been conducted in the Barnegat Bay to estimate it under multiple scenarios - e.g. tidal forcing, stream flow etc. (Kennish, 1984, 2001). Residence times vary between 24 days in winter to as long as 74 days in summer, with an average of 49 days (Guo et al., 2004). Large volumes in the northern part of the Bay during nor'easter is not unknown. Earlier studies based on a depth-averaged two-dimensional numerical circulation model indicated an average residence time of 7 weeks (up to 10 weeks in a less dynamic period during summer season) for Barnegat Bay. The U.S. Geological Survey (USGS) has been conducting extensive modeling studies on the physico-chemical and biological processes in BB-LEH estuary in collaboration with NJDEP (Defne and Ganju, 2012; 2015). These models showed that the southern half of the estuary is better flushed due to a pronounced northward subtidal flow (Little Egg inlet to Pt. Pleasant Canal) and results in particle retention in the northern part of the estuary. Tides were relatively inefficient in flushing the northern part of the bay. A three-dimensional hydrodynamic model of the Barnegat Bay-Little Egg Harbor system was developed and calibrated to investigate scenarios of residence time. The study showed that relative increase in flushing due to remote forcing and wind set up could be used to identify storm events. However, sustained winds and the direction of winds may either reduce or increase the residence time. Also, these residence times could be altered in a nonlinear manner with changes in storm strength and frequency in the future.

I b. Benefits of the Bay

Barnegat Bay watershed can be divided into three main regions from west to east, these roughly correlate with the extent and type of development found in the county:
(1) the Pinelands or headwaters region, (2) the coastal region on the west side of the estuary, and (3) the barrier island complex region on the east side of the estuary (Figure 2). While the coastal and barrier island complex regions support the most development, it decreases in intensity from north to south along the western coast of the estuary (TPL, 2008).

Figure 2: BB-LEH watershed regions

Nearly all of the freshwater that enters the Barnegat Bay estuary comes from the bay's watershed along the western side (with the exception of direct deposition from rainfall and possible ground-water inflow from the Mullica River watershed). The watershed of the bay provides most of the freshwater inputs to the estuary. According to NJDEP, the majority of freshwater inflow is from the Toms and Metedeconk Rivers in the northern part of the watershed and promotes a strong N-S salinity gradient (9 to 32 ppt). Other freshwater inputs include freshwater creeks, storm drains and groundwater seepage (Bricelj et al., 2012).

The BB-LEH estuary is valued for its recreational, economic and aesthetic benefits. A 2012 report on the Economic Value of the Barnegat Bay Watershed prepared for the Barnegat Bay Partnership by the University of Delaware determined that the economic value of the Barnegat Bay watershed from water quality, water supply, fish/wildlife, recreation, agriculture, forests, and public parks benefits exceeds $4 billion (Kaufmann and Cruz-Hortiz, 2012).
According to the 2015 Economic Impact of Tourism Report, Ocean County experienced $4.58 billion in direct sales and $636 million in recreational activities from tourism (NJDEP, 2017).

The surrounding watershed has year-round population of about 600 K residents and accommodates about 1.2 million people including visitors during the summer season (Kennish and Fertig, 2012). Rapid urban development of the watershed has been continuing for the past few decades mainly in the northern section and especially in the Toms River area. This has not been without significant environmental consequences: urban sprawls, shoreline development, loss of upland forests, increased impervious cover have resulted in increased surface runoff, and consequently increased nutrient and pathogen loadings that discharge to the Bay eventually. The rapid and exponential growth in Ocean County, especially in Toms River area, the watershed has been facing numerous challenges and concerns pertaining to water quality (TPL, 2008; BBP, 2016).

II. WATER QUALITY OF THE BAY

Barnegat Bay has been studied and researched for the past five decades by various State, Federal, local agencies, and other groups. One of the first comprehensive research was conducted in central Barnegat Bay between 1965 and 1980 as part of the permitting and operational requirements for the Oyster Creek nuclear generating station and was published (Kennish, 1984). Since then, several studies and research have been variously conducted, however, a concerted and detailed inventory for the entire Bay and its watersheds is still wanting. Other important literature on the state of the Bay is made available by Barnegat Bay Partnership every five years since 2006 under the National Estuary Program.

History of the Barnegat Bay can be described in two parts pre-2011 and post-2012 (before and after Superstorm Sandy). Superstorm Sandy's impacts on the Bay during and its aftermath have been unprecedented. Another major threat to the health of the Bay is eutrophication due to excessive nutrient loading, from land-based sources and atmospheric deposition, both of which in recent years has been exacerbated by climate change impacts also. According to the State of the Bay report (BBP, 2016), multiple research investigations in the last several years have shown that (i) nutrient loadings in the Bay are excessive (ii) significant nutrient loadings enter the Bay from offshore waters and stimulate the eutrophication, often recognized by a population explosion of phytoplankton and other benthic algal communities.

A 10-point Action Plan to address the ecological health of the Barnegat Bay watershed was announced by the Governor of New Jersey on Dec 09, 2010. This Plan, known as Barnegat Bay: Phase One was a strategic initiative proposed by the state to manage multiple stressors that potentially harms the bay including its water quality. Action Plan no. 7 specifically highlighted the need for adopting more rigorous standards as a starting point to establish goals towards restoring the Bay. Phase II, moving Science into Action was announced in 2017 under Barnegat Bay - Restoration, Protection, Enhancement Strategy (NJDEP 2017a), which is based on the findings from monitoring, modeling, and research under Phase One.

II a. Water Quality Criteria

Out of the 2,157 stream miles within the Barnegat Bay watershed, 75% of the stream miles are protected as Outstanding National Resource Waters (ONRW) and include waterbodies classified as Freshwater 1 (FW1), Pineland Bay waters (PL), and Category one (C1) waters. The Bay itself is primarily a saline estuary (SE1(C1). ONRWs are valued as exceptional for recreational significance, water supply, or fisheries resources and also have unique ecological significance. These stream classifications are established under New Jersey's surface water quality standards (SWQS), N.J.A.C. 7:9B (NJDEP 2016) and reflect the designated uses for these individual waterbodies in the State. There are five designated uses for NJ waters and include (i) public water supply (ii) aquatic life (iii) recreation (iv) fish consumption, and (v) shellfish harvest for consumption. Water quality criteria that correspond with each stream classification are described in SWQS. It is necessary for stream to meet these criteria to achieve the designated uses.

Following a guidance from U.S. Environmental Protection Agency (U.S.EPA) in 2000 that encouraged states to provide a single Integrated Water Quality Monitoring and Assessment Report, that included both the 305(b) Water Quality Inventory Report and the 303(d) list of impaired waters under the Clean Water Act, biennial reports are published by New Jersey. These reports identify the extent to which the state's waters are attaining SWQS, and also list impaired waters that need additional management such as establishing Total Maximum Daily Loads (TMDLs) for the pollutant(s) causing impairment. Since 2014, NJ has adopted a rotating regional approach to comprehensively assess one of the water regions during each cycle in accordance with the Clean Water Act, New Jersey Water Pollution Control Act, and New Jersey Water Quality Management Planning Act. The Atlantic Coast region, which includes the Barnegat Bay, was assessed thoroughly in the 2014 cycle (NJDEP 2017 b).

Water quality of a waterbody is determined by evaluating key indicators – nutrients and pathogens being the most significant that will impact the health of the waterways as well as public health. Rainfall over land and development, and resulting stormwater runoff cause nonpoint source pollution, which is the main source of pollution in surface waters in back bays and near-shore coastal waters. The relation among rainfall intensity, duration, impervious cover and pollution loadings in waterways are well-documented (USACE and NJDEP,2002).
A multi-year investigation into the influence of land use on surface water quality in coastal waters in NJ, Hunchak-Kariouk (1996) examined fecal coliform bacteria during baseflow and

stormflow conditions in Long Swamp Creek, Wrangle Brook, and Davenport Branch, the three main tributaries to the Toms River. Stormflows significantly influenced median fecal coliform loads by 2-3 orders of magnitude in Long Swamp Creek and Wrangle Brook, with highly and moderately developed drainage areas. The study also suggested that the total annual flow in Long Swamp Creek was more from stormflow than baseflow, due to the higher impervious cover in the drainage area. This investigation concluded that Long Swamp Creek and Wrangle Brook contribute significant fecal coliform loads to the Toms River during stormflow conditions, which is discussed with more recent findings in the later section in this report.

II b. Nonpoint source pollution inputs

Water quality is generally indicated by measuring levels of the following key parameters: nutrients (nitrogen/phosphorus), pathogens, floatable wastes, and toxics. Rainfall is an important parameter for studying water quality; runoff leads to nonpoint source pollution, and fresh water (rainfall, ground water seepage, runoff, and river discharge) can ultimately affect hydrodynamic circulation in the ocean. Total and fecal coliform bacteria are used as indicators for pathogens in measuring water quality. When the fecal coliform level exceeds state criteria (i.e. greater than 200 colonies per 100 ml of water) for two consecutive water samples, taken 24 hours apart, beach closures may result. Elevated total and fecal coliform counts along the coast of New Jersey may result from failing septic tanks, wastewater treatment plant discharges, combined sewer overflows, stormwater drainage, runoff from developed areas, domestic animals, wildlife and sewage discharge from boats. Nonpoint source pollution (NPS) is the primary pollution of back bay and near-shore coastal waters. NPS generally correlates directly with the intensity of land development and contains nutrients, heavy metals, oil and grease, fecal coliform, and possibly some toxic substances. By its very nature, NPS is difficult to identify and control. As early as 2003, the Barnegat Bay Monitoring Program Plan identified bacteria to be one of the secondary key indicators to track the progress and achievements of water quality under the Comprehensive Conservation Management Plan (BBP, 2003).

III. COOPERATIVE COASTAL MONITORING PROGRAM (CCMP)

The Barnegat Bay National Estuary Program established a plan to track six key environmental indicators to assess the health of the Bay and develop and manage measures towards the protection of the estuarine environment. These are (i) submerged aquatic vegetation (SAV) (ii) Shellfish beds (iii) Bathing beaches (iv) Algal blooms (v) Freshwater inputs (vi) Land use/Land cover (BBP State of the Bay reports 2005, 2011, 2016). According to the 2016 report, the amount of nitrogen entering the bay has been increasing and contributes to eutrophication, anoxic conditions and stresses the bay. One of the sources of land-based nitrogen inputs is sanitary sewage, with concomitant pathogen inputs into the bay. Pathogen pollution of the Bay is serious as it is deleterious to public health, recreational benefits and economic opportunities of Bay resources as stated earlier and the Barnegat Bay is no exception. Sources of pathogen pollution are varied – leaky septic systems, inadequate treatment and discharge of sewage, pet wastes, wildlife, local farms, boating and marina activities, and most importantly being carried by stormwater runoff.

Fecal indicator bacteria (FIB) have been used to assess the microbiological quality of water and include fecal coliforms, Escherichia coli, and Enterococcus. While these bacteria primarily are not disease-causing, their presence indicates fecal contamination of the waterbody in question and the possible presence of other disease-causing waterborne pathogens (bacteria, viruses, protozoan parasites etc). Fecal indicator bacteria criteria and methodologies are defined by U.S.EPA's surface, drinking, recreational water criteria (U.S.EPA, 2012) and FDA's National Shellfish Sanitation Program (FDA, 2019).

III a. CCMP basics

Since 1974, New Jersey has been monitoring the water quality of coastal recreation waters for pathogens through the Cooperative Coastal Monitoring Program (CCMP). This program is administered annually by the New Jersey Department of Environmental Protection (NJDEP), Bureau of Marine Water Monitoring (BMWM) and is coordinated with the participation of New Jersey Department of Health, county and local environmental health agencies. Since 2000, this program has been primarily funded by the United States Environmental Protection Agency (USEPA) under the requirements of the Beaches Environmental Assessment and Coastal Health (BEACHES) Act (2000). During the summer "beach season" (Memorial Day through Labor Day), samples are collected weekly from bathing beaches (oceans, rivers, bays) by local partners and analyzed by NJDEP for fecal indicator bacteria (fig.). Fecal coliforms were used as the standard till 2003 (200 cfu/100 ml, single sample maximum). However, based on EPA studies, Enterococcus is a better indicator of untreated fecal waste contamination and associated human illnesses in both marine and fresh waters. Enterococcus, a gram-positive bacterium while not harmful by itself, indicates the possible presence of other pathogenic bacteria and other organisms including viruses and protozoans that pose a risk to human health. Since 2004, NJDEP uses Enterococcus as the recreational water quality standard under the BEACH Act and amended State Sanitary Code.

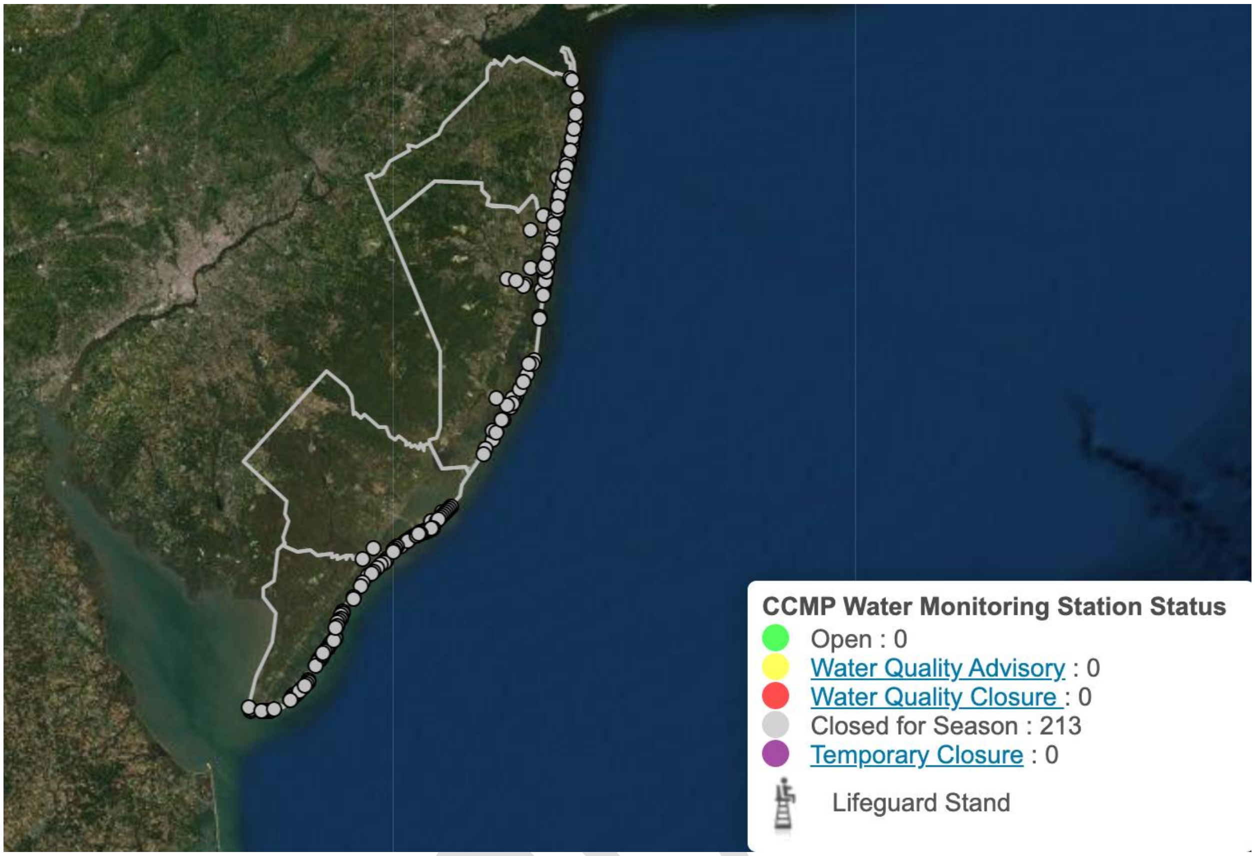

Figure 3: CCMP monitoring stations overview

New Jersey State Sanitary Code's water quality standard for bathing beaches is determined by the concentration of the indicator bacteria, enterococci (N.J.A.C.7:9-B). Enterococcus concentration in primary contact recreation waters (SE1 and SC) shall not exceed a single sample maximum of 104 colonies 100 milliliters (cfu/100 mL), and/or a geometric mean of 35 cfu/100 ml. An exceedance of the standard may indicate a pollutant impact to bathing waters (nj beaches.org). As of 2014, all counties participating in the CCMP are required to issue swimming advisories following the first exceedance of the bacteria water quality standard and repeat the sampling. When consecutive samples exceed the standard, it results in a beach closure and triggers additional sampling along with a sanitary survey to investigate possible pollution sources. The beach is re-opened only after the sample meets the water quality standard. In addition to the single sample maximum criteria, NJDEP uses the geometric mean to determine potential water quality issues. If the geomean (calculated from five sampling events during a 30-day period) of a recreational beach exceeds 30 cfu/100 ml with/without single sample exceedance, it warrants a sanitary survey to investigate potential sources of pollution. NJDEP uses yet another metric, the seasonal geomean calculated using data from the entire monitoring season, to determine areas which show persistent water quality problems and warrant more thorough investigations.

CCMP beach monitoring helps DEP and local health agencies to act upon and alert the public to potential health risks when samples fail to meet this water quality criteria (104 cfu/100 ml), by way of advisories and closures until the pollution issue is solved. Two hundred and nineteen (188-ocean, 22-bay, 9-river) primary beaches are monitored under CCMP. Ocean County has the maximum number of bay/river beaches (14 and 8) being monitored under CCMP. Water quality reports and data are available at www.njbeaches.org (NJDEP, 2019).

III b. Stormwater Runoff and Beach Water Quality

Beach closure incidents vary widely every year and for many reasons – e.g. floatables, waste, precautionary closure, other activities, and the most important one that impacts public health are closures related to undesirable bacteria water quality. Annual beach closures in New Jersey in the eighties were one of the highest, and in 1988 alone, ocean beaches were closed over 800 times for exceeding bacteria water quality criteria. One of the major factors was ocean discharges of untreated/improperly treated wastewater treatment plants. Subsequent improvements to wastewater treatment systems discharging to oceans resulted in a decline of these incidents. While NJ ranks among the top for clean ocean and bay beaches, not all is well with bay and river beaches. Changes in land use, increased upstream impervious cover from development activities in the last 2-3 decades contribute to increasing non-point sources of pollution and include pathogens. Stormwater runoff triggered by rainfall events from upstream is one of the most significant sources of bacteria pollution which cause beach closures routinely. Bacterial exceedances and subsequent beach actions (closure, swimming advisory) are observed more during "wetter" beach seasons characterized by precipitation events. Generally, ocean beaches are impacted for 24 hours or less in these instances. On the other hand, due to lower dilution and longer residence time, bay and river beaches experience higher bacteria exceedances after storm events, potentially influenced by physical and geographical features, especially tide cycles, currents and wind patterns.

Toms River, a brackish water body in the Barnegat Bay has many public recreational river and bay beaches. Stormwater discharges via outfalls and drains following a rain event frequently cause elevated bacterial levels in receiving waters. River locations with coves (Figure 4) exhibit lower circulation patterns and longer residence times for pollutants.

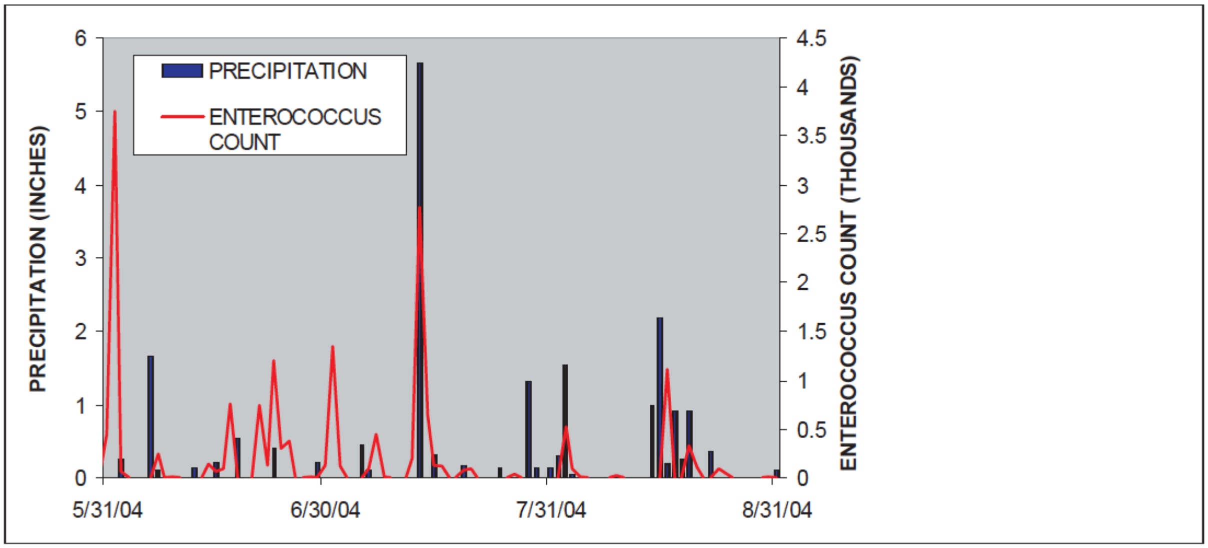

Figure 4: Enterococcus counts vs. daily precipitation - East Beach, Beachwood – May – Aug 2004

Intense rainfall and resulting stormwater discharges were major causative factors in the increase in ocean and bay beach closings in the 2001, 2003, 2004 and 2006 summer seasons (NJDEP, 2009). Despite these, recreational beaches in NJ were mostly cleaner and open for use all through the season. Between 2010 and 2018, a total of 37,297 samples (ocean/bay/river) were analyzed for recreational water quality under CCMP and 97% of the samples were within the bacteria water quality standard. However, an evaluation of the results between ocean and bay/river samples showed that bay/river beaches had more water quality exceedances. Only 90% of bay and river recreational bathing beach water quality samples (n = 7156) were within the water quality standard compared to 98% of ocean samples (n= 30,141) (NJDEP, 2019) (figure 5).

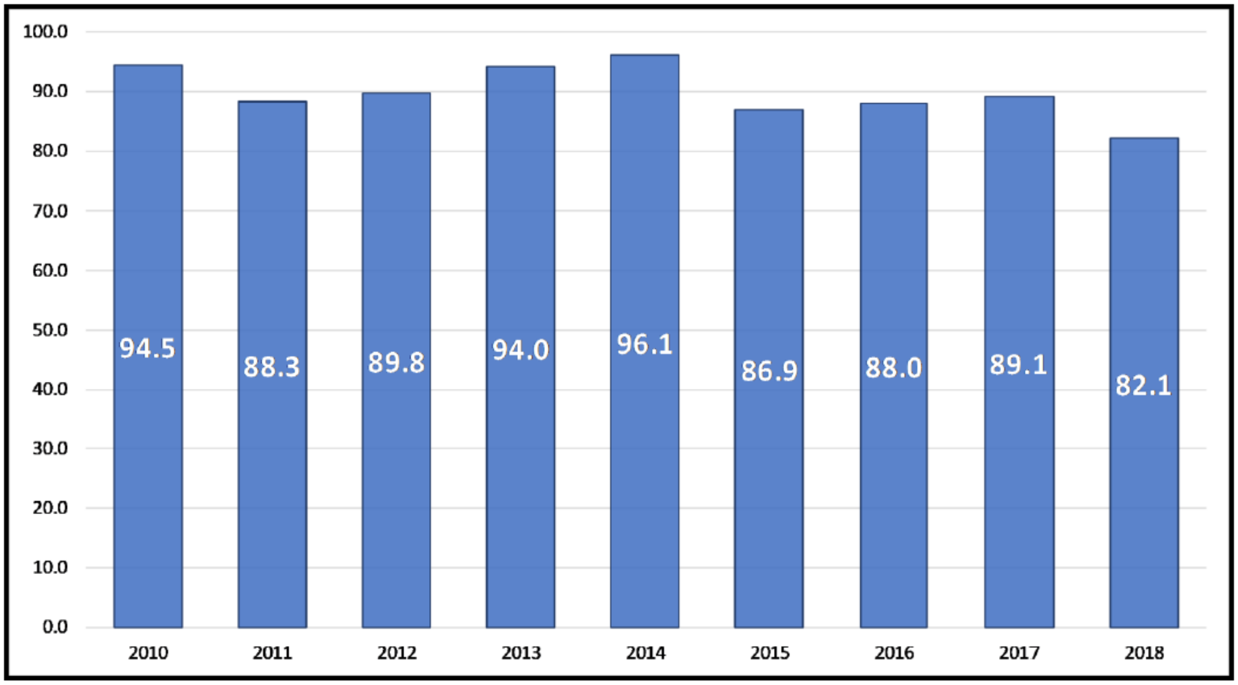

Figure 5. Percentage of bay and river bathing beach water samples meeting bacteria water quality standard (<104 cfu/100 ml) during 2010-2018

The percentage of "clean and safe" bay and river beaches has shown a decreasing trend since 2015. This is due to poorer water quality and also perhaps due to a 50% reduction in the number of stations and associated sampling. Nonpoint source inputs from stormwater discharges is a major reason for bay and river beach closings. The following figures (6-8) illustrate the trends in bay/river beaches in NJ and also summarize the actions status arising from bacteria exceedances (NJDEP 2015, 2016, 2019)

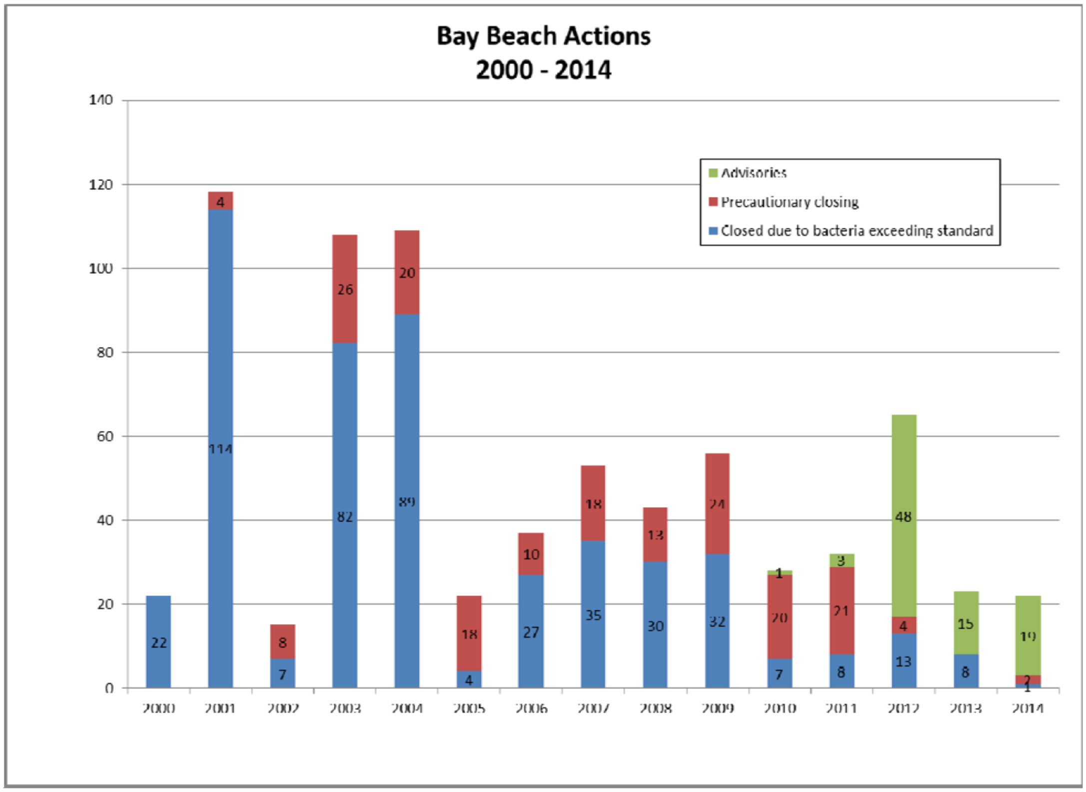

Figure 6. Bay Beach Actions 2000 – 2014 showing increased advisories

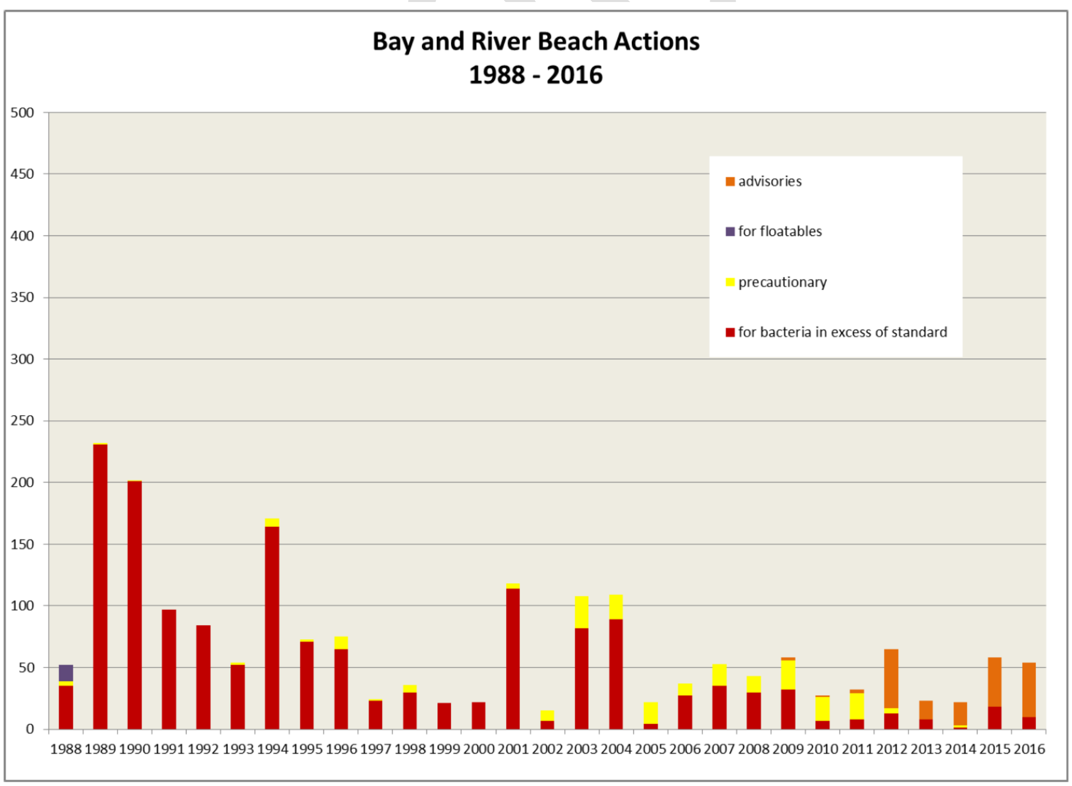

Figure 7: Bay and River actions 1988-2016

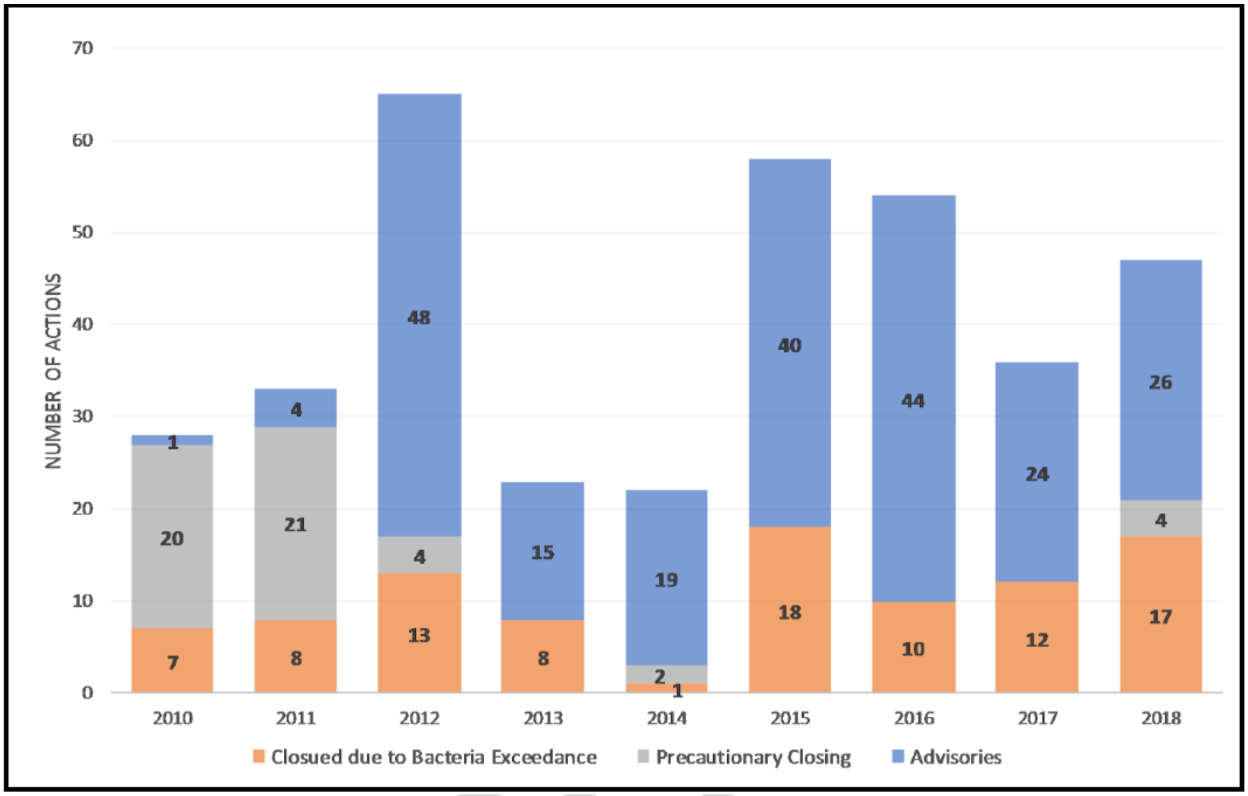

Figure 8: Bay and river actions during 2010-2018

Riverine systems account for a mere four percent of CCMP monitoring locations in NJ. There are nine river beaches, with eight of these located in the Barnegat Bay watershed, and one in Monmouth County (Shark River). Toms River has five river beaches in the Barnegat Bay watershed, and the remaining three are located on the Metedeconk (1) and within the Manasquan River (2). All riverine beaches are tidally influenced, hence tide significantly influences the flushing and residence time in these waters. Nonpoint source pollution and stormwater runoff adversely impact the water quality of riverine beaches and can result in actions ranging from advisories to beach closures that can last many days. Table 1 summarizes the river actions in NJ between 2014-2018 arising from failure to meet the recreational water quality standard for bacteria.

Table 1: River actions 2014-2018 (CCMP 2019)

	2014	2015	2016	2017	2018
Number of Advisories	12	14	21	6	8
Bacterial Closures	-	17	6	5	13
Precautionary Closure	-	-	-	-	4
Rainfall Provisional Closure	2	-	-	-	-
Floatable Closure	-	-	-	-	-
Total	14	31	27	11	25

These results clearly show that bay and river beaches are susceptible to exceeding bacteria water quality criteria more often, and more routinely. Bacteria loadings from stormwater runoff and its impacts on water quality last longer in bays and river beaches as these depend on the physical features – i.e. depth, current, circulation, wind and tides. Bacteria inputs into stormwater runoff is also related to changes in the upstream watershed and land use changes in adjoining coastal communities. This becomes very significant in Barnegat Bay, especially Toms River watershed in Ocean County with its numerous bay and river beaches and significant changes in development activities in the last few decades (NJDEP 2019 b).

IV. PATHOGEN POLLUTION IN TOMS RIVER WATERSHED

"Pathogens in the Toms River negatively affect river beaches, resulting in advisories and beach closures. An enhanced illicit connection identification and elimination requirement could include ambient water monitoring and the application of source tracking techniques to "find and fix" cross connections and breaks in a municipal sanitary sewer system." – 2017 BB-REPS

The Governor's Action Plan to restore the health of Barnegat Bay identified goals for addressing the key actions needed to restore water quality, several of which required additional water quality monitoring data. A monitoring plan was designed to determine the extent of the impairment, identify nutrient loading targets or numeric criteria, and develop models for use in directing water quality restoration of the Bay. The sampling plan currently involves twice-a-month, synoptic grab sampling and flow measurements at 14 tributary and 14 bay stations. This comprehensive design exceeded the sampling and analytical capacity.

Toms River watershed (124 sq.miles) is the largest drainage area in the Barnegat Bay watershed with more than a dozen small, upstream tributaries draining into it. With increased development, land use changes, increase in impervious cover, and resulting stormwater runoff, Toms River has been historically impacted by adverse bacteria levels. It is imperative to monitor the health of this waterbody to achieve the Bay-wide restoration goal successfully. Bacteria water quality monitoring is conducted by Ocean County Health Department (OCHD) with NJDEP's Bureau of Marine Water Monitoring on all public bathing beaches. Recreational beaches, both ocean and bay, are subject to opening and closing procedures of the State Sanitary Code and, therefore, must be resampled when during routine sampling bacteria concentrations exceed the primary contact standard (NJDEP, 2008). OCHD uses these results to determine (i) if beach water quality is safe for primary contact (ii) if brackish waters in bays are impacted by any non-point source pollution, and (iii) efforts to address non-point source impacts to water quality of bay, rivers and ocean. NJDEP is also committed to collaborating with local partners to track down and eliminate these sources of bacteria using appropriate mitigation strategies such as storm events monitoring, source track down, infrastructure condition assessment and improvement etc.

This report has been prepared after reviewing available data on bacteria water quality issues in the Toms River and determining that NJDEP's CCMP monitoring and SBB-MATES water quality investigations in the last decade reliably and consistently reflect the state of the River over the years. This report primarily summarizes CCMP bacteria water quality in the Toms River watershed between 2005 and 2020 as a first step towards understanding existing trends and identifying areas of concern. This report also compiles all water quality investigations done by MATES-SBB summer student program grantees between 2010 and 2020, which resulted in additional and ongoing investigations by NJDEP. Thirdly, this report compiles all the stormwater-specific investigations conducted by NJDEP collaboratively with OCHD since 2014 in the Toms River area (Figure 9).

Findings from this report will be used to determine source track down investigations of pathogen hotspots in the Toms River watershed to accomplish the goal of the DEP-grant funded project WM20-022. The report indicates that some municipalities experience bacteria exceedances more frequently than the others in the Toms River watershed. However, the goal of the project is to find sources and fix the whole Toms River sub-watershed collaboratively. To identify the actions needed to restore water quality, additional water quality monitoring data is necessary.

Figure 9. Toms River Map

V. TOMS RIVER – CCMP AND ENVIRONMENTAL MONITORING DATA

The following Table 2 and Figure 10 illustrate the CCMP monitoring stations in the Toms River and primarily these are located in the southern side of the river. Stations with* are not regulated public bathing beaches yet are being used for recreational purposes. DEP recognized the risk to public health from potential bacterial exceedances with these activities and has initiated water quality monitoring of these beaches since 2020 under the Environmental Coastal Monitoring (ECM) Program. Three ECM locations are in the Toms Rive and are being monitored These are Summit – Island Heights (archived CCMP station in 2008), Money Island – Toms River, and Cedar Point – south Toms River. Two of these ECM stations – Money Island and Summit were CCMP stations earlier and were closed due to staffing and other issues a few years ago. These are discussed briefly.

Table 2: NJDEP Water Quality Monitoring Stations in the Toms River (CCMP/ECM)

ID	GPS		Station	Town/Borough
OC0116	39.9428591	-74.184815	Beachwood beach West	Beachwood
OC0117	39.9381494	-74.1580825	East Beach Station Ave	Pine Beach
OC0118	39.9409452	-74.1697194	West Beach Avon Road	Pine Beach
OC0119	39.928686	-74.1351342	Wildwood	Ocean Gate
OC0140	39.9289309	-74.1282002	Anglesea	Ocean Gate
OC0115	39.9424517	-74.1336011	Summit	Island Heights
OC0340	39.948	-74.19199	Cedar Point* ECM	south Toms River
OC0111	39.94788	-74.16317	Money Island*ECM	Toms River
OC0115	39.94243	-74.13368	Summit*ECM	Island Heights

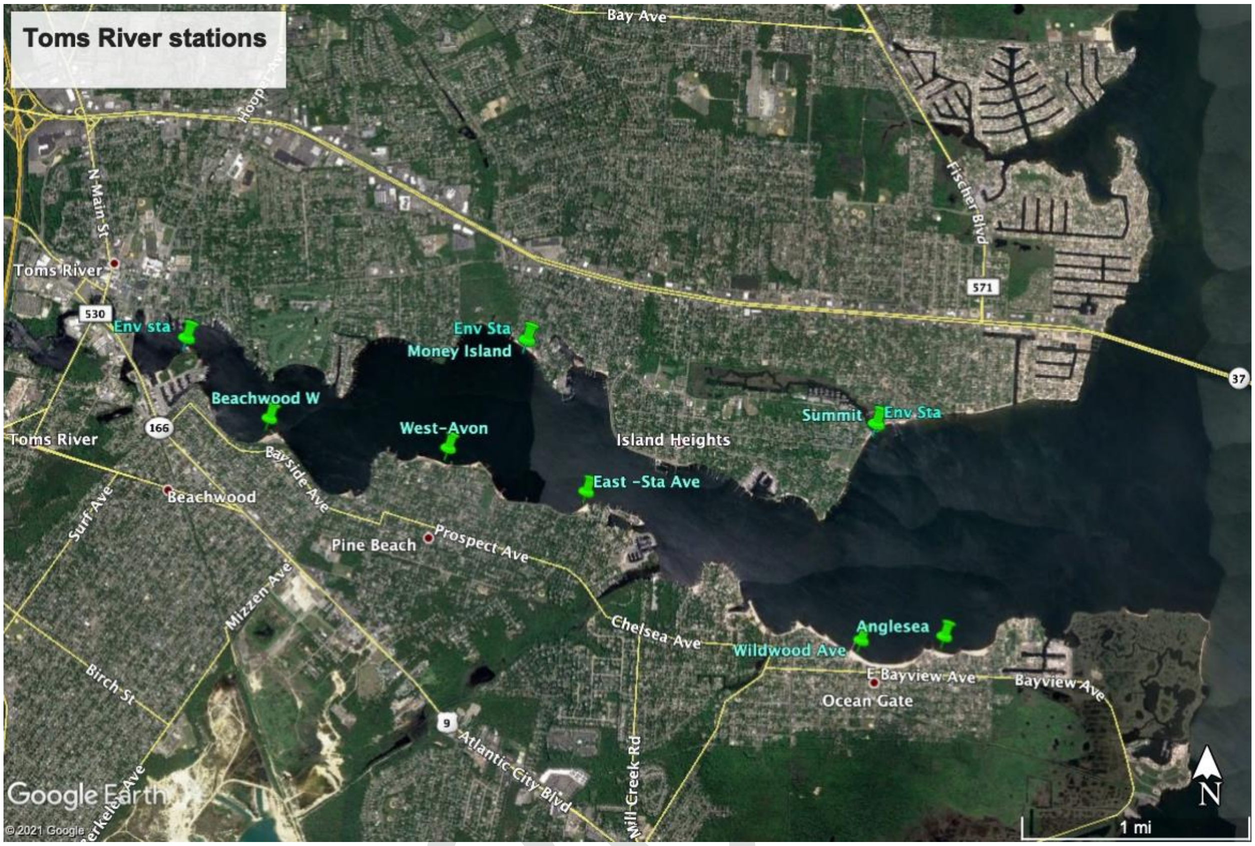

Figure 10: Toms River stations

In addition to the single sample maximum criteria (104 cfu/ml), DEP's surface water quality standards use a geometric mean criterion of 35 cfu/100 ml of Enterococci for five samples over a 30-day period. For the CCMP, the geomean is averaged for all samples collected from a station during the season and results evaluated. The first documented exceedance in river beaches since the enterococcus criterion took effect in 2004 in NJ was reported in 2006. Beachwood Beach (west) had a geomean of 142.9 cfu/ml and West Beach in Pine Beach had an exceedance of 36.5 cfu/100 ml (NJDEP, 2008). In 2007, in addition to observed exceedances in Beachwood and West Pine Beach, downstream stations in Pine Beach and Ocean Gate (Station Ave, Anglesea) also had geomean exceedances (TABLE). Except for Station Ave, Toms River stations had a closure ranging from 2 – 9 days related to wet-weather events during the summer of 2009 and Beachwood had the maximum closings. Rain events were lacking in 2010, yet Beachwood had the only closure in Ocean County river beaches that year, and in 2011 also, suggesting that stormwater conveyance system may influence bacteria concentrations in addition to the rain event itself. The impacts of wet weather and associated stormwater runoff in elevating enterococcus concentrations prompted some wet-weather specific monitoring of these river beaches by NJDEP/OCHD; however, the results were inconclusive. The first pilot water quality monitoring by students of MATES was conducted this year that indicated how increased rainfall increased bacteria levels at beaches in Beachwood and Pine Beach. This is discussed in more detail in a separate section. In 2012, two rain/storm events with precipitation of 0.55” and 1.01” resulted in the closure of both southern shore beaches of Beachwood and Avon Road (Pine Beach), and this beach season also saw many advisories in all beach stations on this river.

V a. Beachwood – Investigations

Beachwood Beach West is a recreational bathing beach in Beachwood Borough, Ocean County located on the Toms River and has had frequent beach closures due to bacteria exceedances. These closures have been associated with rainfall conditions and the waters of this beach are impacted by as little as 0.1 inch of rain. The DEP conducted a sanitary survey to identify potential sources of pollution, and sampling stations were strategically picked to represent potential problem sources identified in the sanitary survey. Fourteen (14) stations were sampled over ten (10) sampling events during dry weather, tide cycles, and intensive wet weather storm events. The results identified two nearby stormwater outfalls as the main contributors of bacterial pollution at the beach. In addition, it was found that the tidal movement and shoreline configuration held the water near the beach area resulting in a longer duration for closures. Working with local stakeholders, infrastructure repairs were completed and the two nearby stormwater outfalls were combined and relocated away from the recreational bathing beach. This resulted in a reduction in the number of beach closures during rain events with 0.5 inches of rain or less.

Between 2005 and 2013, Beachwood had 113 exceedances and multiple beach closures, and many of these were triggered by rain. These clearly necessitated an assessment of stormwater conveyance system, replacement or upgrade deficient storm sewers, and the most important goal to relocate the stormwater outfall away from the bathing area. A collaborative storm study was conducted by NJDEP with NJ Department of Transportation, Beachwood Borough, Health, Planning, Roads, and Engineering department, with a goal to reduce exceedances and closures and is presented in detail in a separate section. This investigation culminated in the following:

- The borough sewer system was cleaned prior to CCMP season in 2014
- Video surveillance of the stormwater system showed root infiltration that caused sewer blockages and was removed, and 200 ft of storm sewer line was replaced.
- A 50% forgiveness loan from Environmental Infrastructure Trust was awarded to Beachwood Borough to relocate the outfall away from the public beach
- DEP collaborated with FDA and conducted a dye study to confirm the new proposed outfall location (east of the parking lot) would have higher dilution rates so that contaminants will dissipate within hours of a storm
- Six manufactured treatment devices (MTD) were proposed to be installed in south Toms River (1), Beachwood (4) and Pine Beach (1) to capture and treat stormwater runoff before discharging to the river during 2015
- An upstream live-aboard community was relocated and remediated and were deemed to be of no causative reason for elevated bacteria concentrations.

The hypothesis that better management of stormwater inputs resulted in lowered bacterial concentrations was supported. There were no beach closures in Beachwood and the other Toms River stations during 2014. Beachwood also had one of the lowest number of advisories, at 5 during this year. Outfall relocation and MTD installation were completed in 2015. These remedial actions showed a positive trend towards improved water quality in 2014. However, it was not sustained in 2015, which turned out to be an exceptionally wet year with greater than three of inches of rainfall than in the previous decade. 99% of exceedances were associated with three storm events. These observations confirmed that any rain above 0.5 in. impacts bacteria concentration in this location and that water quality largely improved during dry weather.

- Years of CCMP monitoring data showed that while stormwater runoff does increase bacteria levels routinely, highest precipitation did not always result in high concentration of bacteria
- Samples tested before/during/ and after rain events demonstrated a decline in bacteria levels with time under ambient conditions, and these were variable
- Impacts from stormwater runoff prompted DEP to conduct additional specifically focused investigations
- Some towns/locations exhibited repeated bacteria exceedances and became "notorious" in popular media – Beachwood and Pine Beach
- **This led to an important conclusion and a way forward to water quality monitoring – it was the conclusion that no location or municipality can be individually studied in source tracking efforts. All municipalities along the entire Toms River should be monitored.**

Table 3 and Figure 10 summarize exceedances observed in Toms River stations during the last 15 CCMP seasons. Data clearly showed that tides and circulation influence the flushing and residence time of enterococcus in these river beaches.

Table 3. Table: Summary of bacteria exceedances in Toms River stations (2005 – 2020)

	Site	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
OC0111	Money Island	1	9	9	7	10	2			No CC	No CC	No CC	No CC	No CC	No CCN	No CC	ECM	**38**
OC0140	Anglesea (Ocean Gate)		4	5	3	12	1	4	3				2		6			40
OC0119	Wildwood (Ocean Gate)			3	3	8	1	1	2	1			3	1	6		1	30
OC0115	Summit (Island Heights)		4	3	3	4	1	2	3	1	1	4	3	2	No CCMP			31
OC0113	Central (Island Heights)		7	8	2	6	2	No CCMP										25
OC0205S	East Avon Road (Pine Beach)								1									1
OC0117	E. Beach Sta Ave (Pine Beach)		3	5	4	8	3	3	1	1		5	2		14	1		50
OC0118	W. Beach Avon Rd (Pine Beach)		3	5	5	13	4	4	10	2	1	8	10	5	10			80
OC0116	Beachwood Beach West	6	21	10	10	23	9	12	13	9	5	35	9	5	20	17	42	246
		7	51	48	37	84	23	26	33	14	7	52	29	13	56	18	43	541

A total of 541 Enterococcus exceedances were observed in the Toms River between 2005 and 2020 and include bracket stations as well as repeat sampling results, if any.

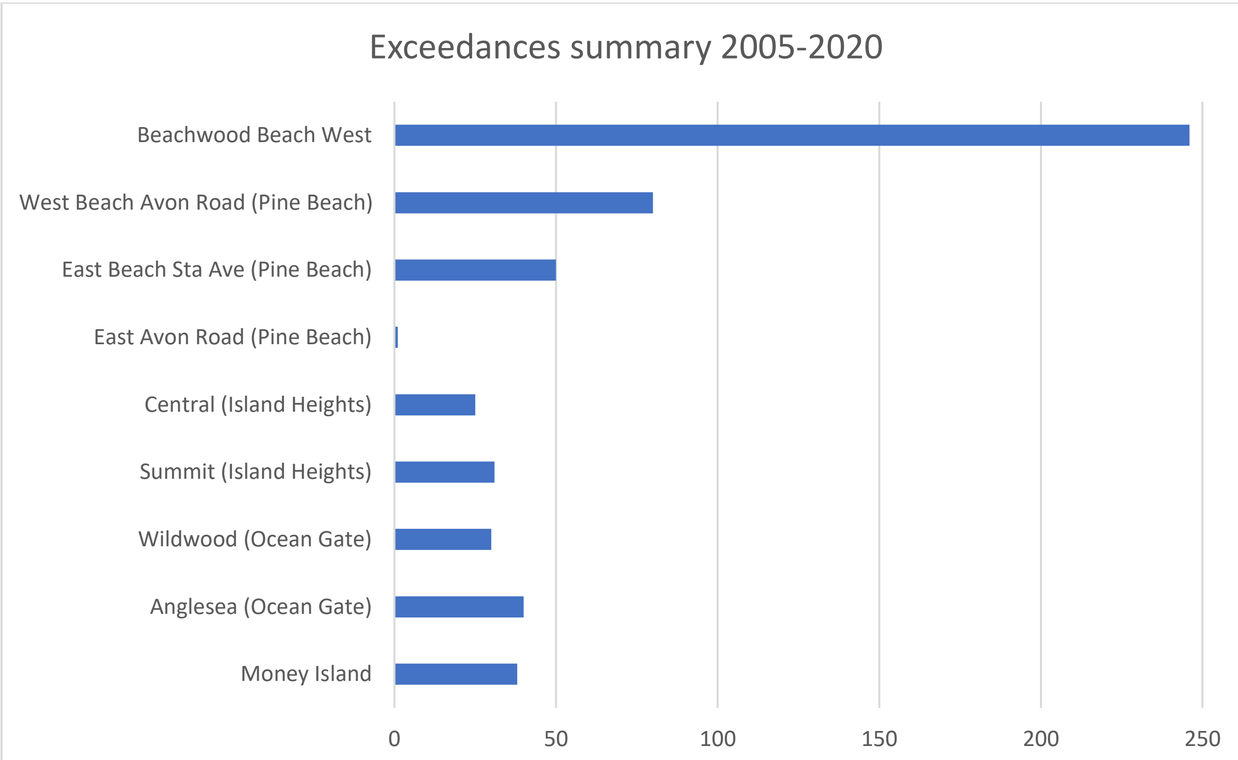

Figure 10. Summary of bacteria exceedances in Toms River stations (2005 – 2020)

Monitoring results in Toms River beaches routinely showed elevated bacteria levels following rain events often resulting in water quality advisories and/or beach closings during the summer Season (Table 4). Results from CCMP suggested that runoff from wet-weather events impact water quality negatively. A preliminary investigation in 2009 of seven bay beaches in Ocean County during wet-weather did not conclusively verify this hypothesis and highlighted the need for additional studies on stormwater runoff impacts.

Between 2009 and 2012, NJDEP conducted a number of water quality monitoring sessions at bay beaches in the Toms River during rain events. These investigations sometimes coincided with CCMP routine weekly monitoring and also included overnight precipitation and extended rain events. The lack of sufficient summer time rain events in 2010 did not yield useful results, prompting the studies to continue in 2011 and 2012. These efforts were complemented by dye testing studies of stormwater infrastructure by OCHD. Another significant research resource that has helped in assessing bacteria pollution impacts from stormwater runoff in the Toms River watershed is the water quality monitoring conducted by Marine Academy of Technology and Environmental Sciences (MATES), a local magnet high school in Ocean County, since 2010. The student science-monitoring of bay and river beaches has been conducted by MATES in the Toms River area independently and in collaboration with NJDEP's BMWM and OCHD. These bacteria track-down monitoring investigations are discussed in detail in a separate section titled "MATES-SBB investigations-a review". Results of these multi-year MATES investigations showed that stormwater runoff from rain events result in elevated bacteria levels in Beachwood and Pine Beach. These investigations led DEP and OCHD to continue this monitoring and investigate and map existing sanitary and stormwater infrastructure including outfalls.

Table 4. Table: Rain events and closures (Green – no closure, blank – CCMP discontinued)

	Station	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Days closed
OC0111	Money Island		06/28-06/29; 07/05-06	06/27-06/29	06/18-06/19; 07/09-07/10													11
OC0140	Anglesea (Ocean Gate)		07/05-07/06			06/20-06/21; 08/03-08/04												6
OC0119	Wildwood (Ocean Gate)				07/23-07/24	06/20-06/21; 08/03-08/04				07/30-07/31 storm adv								6
OC0115	Summit (Island Heights)		06/28-06/29							06/05-06/06 storm adv				07/25-07/26				4
OC0117	East Beach Sta Ave (Pine Beach)				06/18-06/19; 07/02-07/03					06/11-06/12; 07/30-07/31		07/01-07/03			06/13-06/15; 08/15-08/16			16
OC0118	West Beach Avon Road (Pine Beach)					06/26-06/27; 07/23-07/28			08/07-08/09	07/30-07/31 storm adv		07/01-07/05	07/27-07/28; 08/03-08/05	07/25-07/27	08/15-08/16			26
OC0116	Beachwood Beach West	07/07-07/08	06/28-06/29; 08/09-08/10; 08/16-08/17; 08/30-08/31	08/01-08/02; 08/22-08/24	06/18-06/19; 07/02-07/06	06/21-06/30; 07/26-07/28; 08/03-08/05	07/16-07/18	08/17-08/18	06/25-06/26; 07/18-07/19; 08/01-08/02;08/07-08/09; 08/13-08/14	07/10-07/13; 07/24-07/27; 07/30-07/31 (storm adv)		07/01-07/06; 07/15-07/18	07/27-07/28; 08/03-08/04	07/25-07/27	07/25-07/28		06/24-06/25; 07/01-07/07	88

V b. DEP Storm/Tide Studies

DEP's source track down efforts included elaborate storm and tide studies between 2013 and 2016 to assess the influence of tides on the movement of runoff and consequently bacteria along the Toms River. These studies were conducted during flood and ebb tides in ambient conditions, during wet-weather (0.2 – 0.55" storms) and included investigation of first flush and dilution effects on bacteria concentrations. One of the storm studies conducted in 2016 also investigated microbial track down to determine the sources of these fecal bacteria in stormwater runoff discharging to the waters of the Toms River. These studies supported the hypothesis (i) tides impact the duration and distribution of bacteria in the waters before discharging into the Bay (ii) Dispersion and dilution in the water takes a few minutes upto a few hours after a storm (iii) first flush and second flush are important factors that need to be determined in the Toms River area (iv) River bathymetry and shape/morphology of coves also seem to influence the concentration and distribution of bacteria in certain specific locations along the River in addition to possible deficiencies in stormwater infrastructure. A few figures (11-20) shown below illustrate some of these observations.

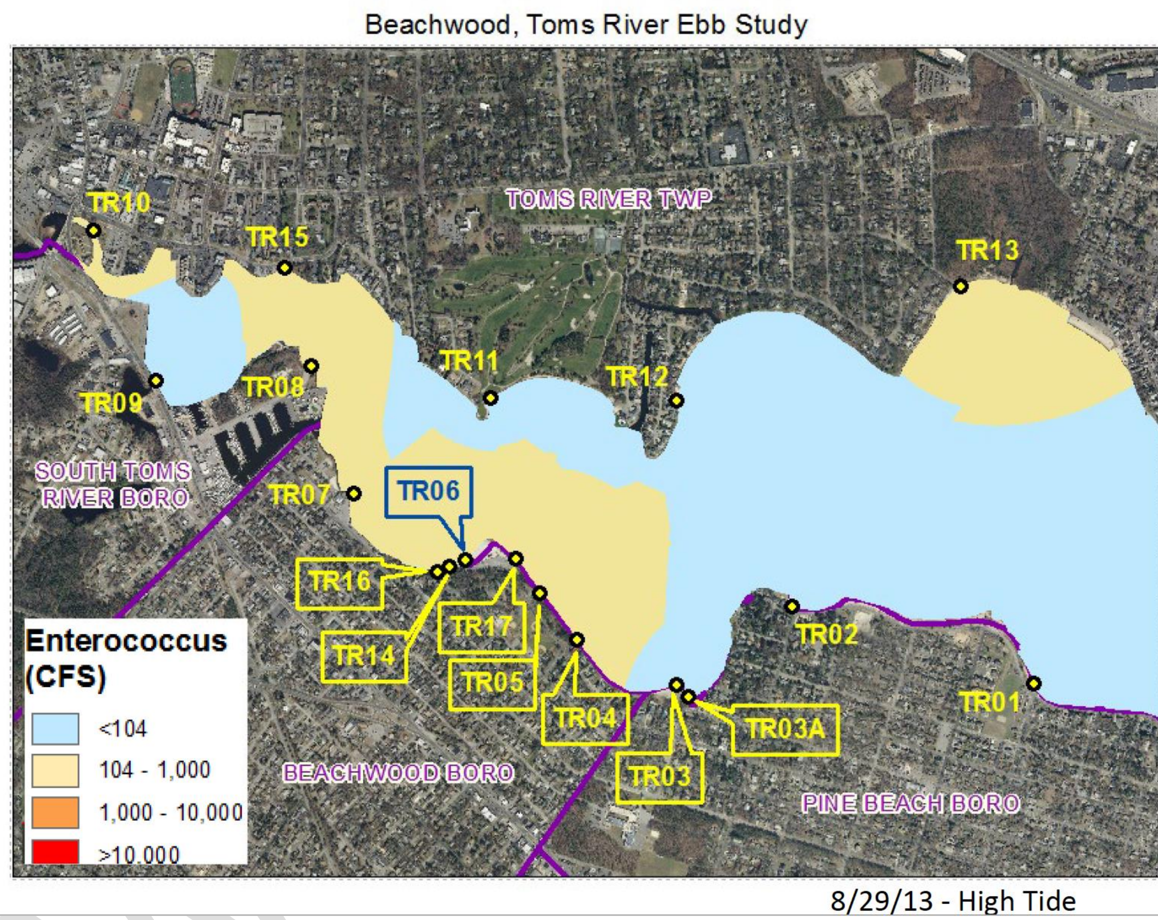

Figure 11. Beachwood ebb study – high tide 2013

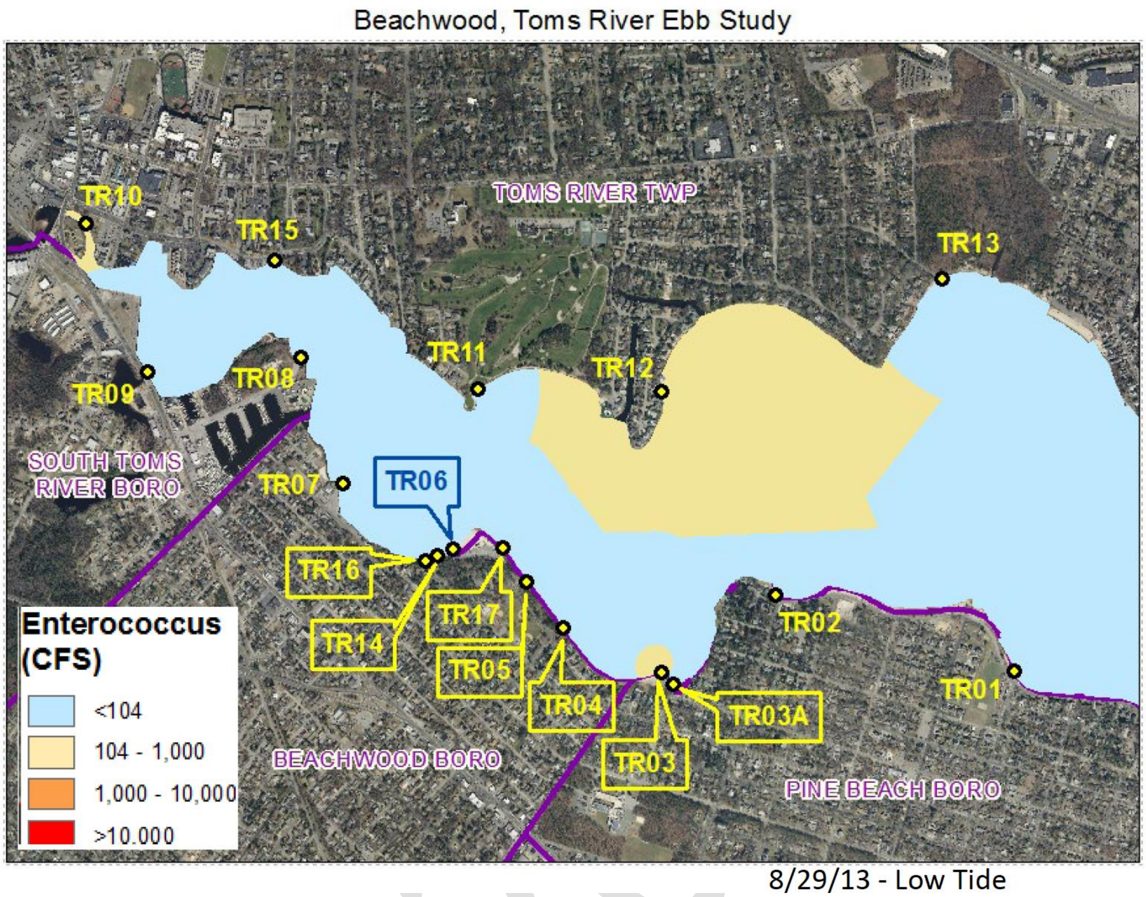

Figure 12. Beachwood ebb study – low tide 2013

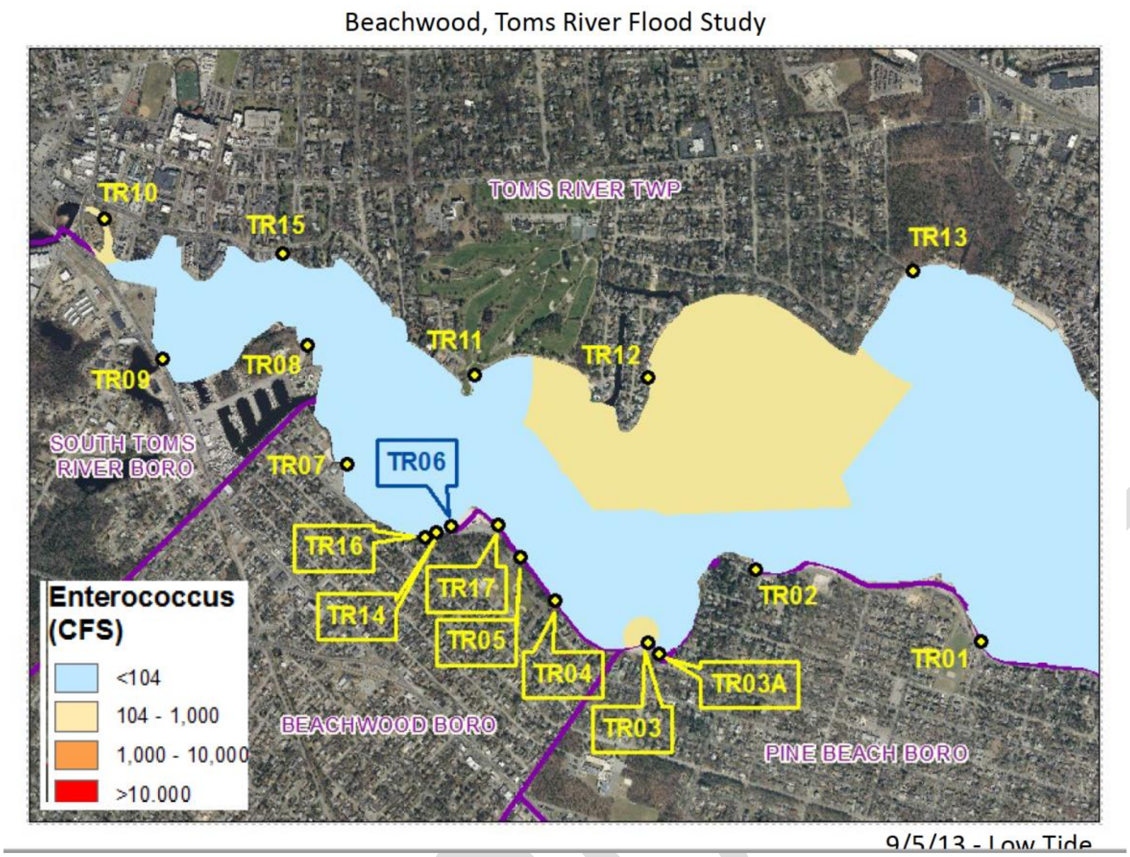

Figure 13. Beachwood Flood study – low tide 2013

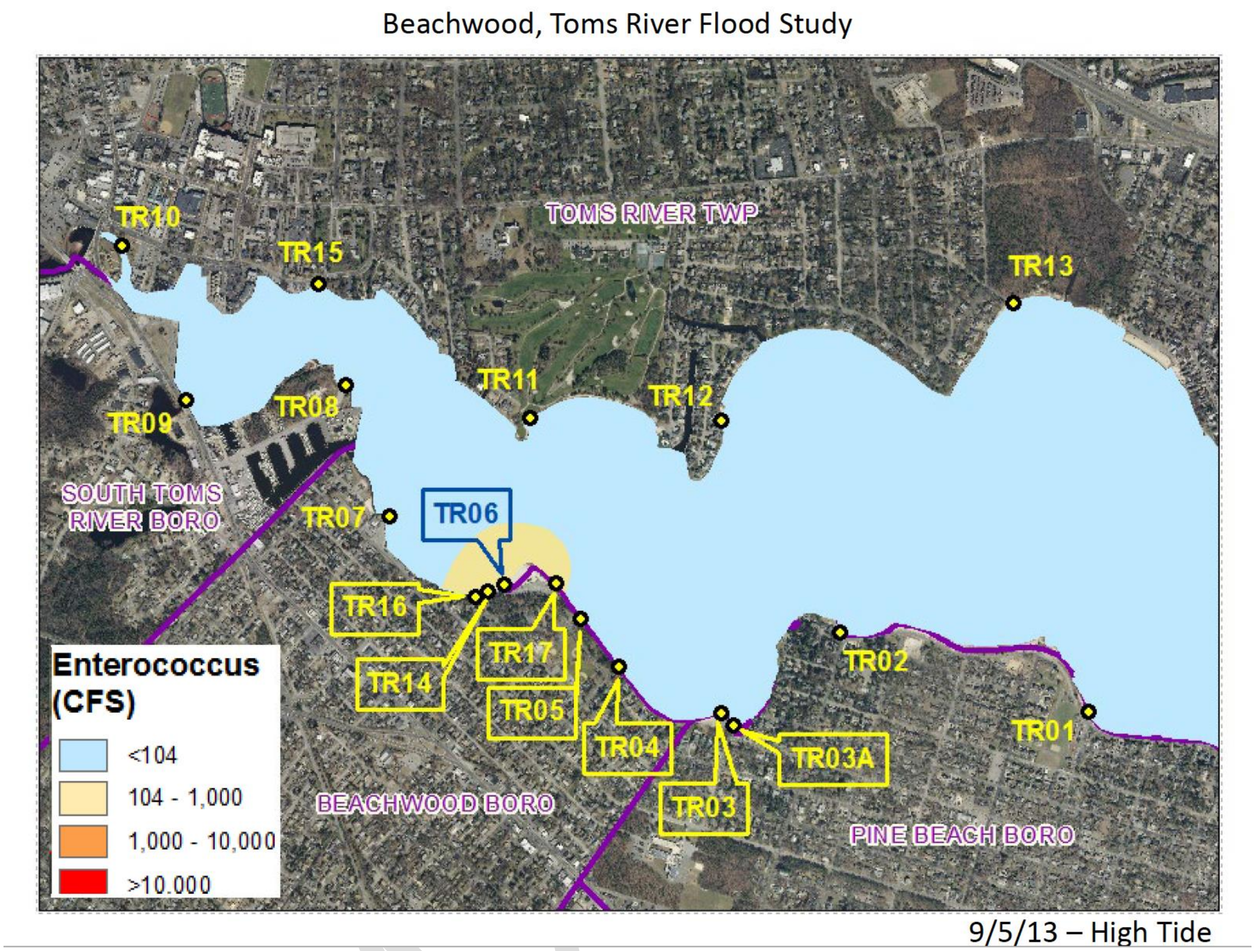

Figure 14. Beachwood Flood study – high tide 2013

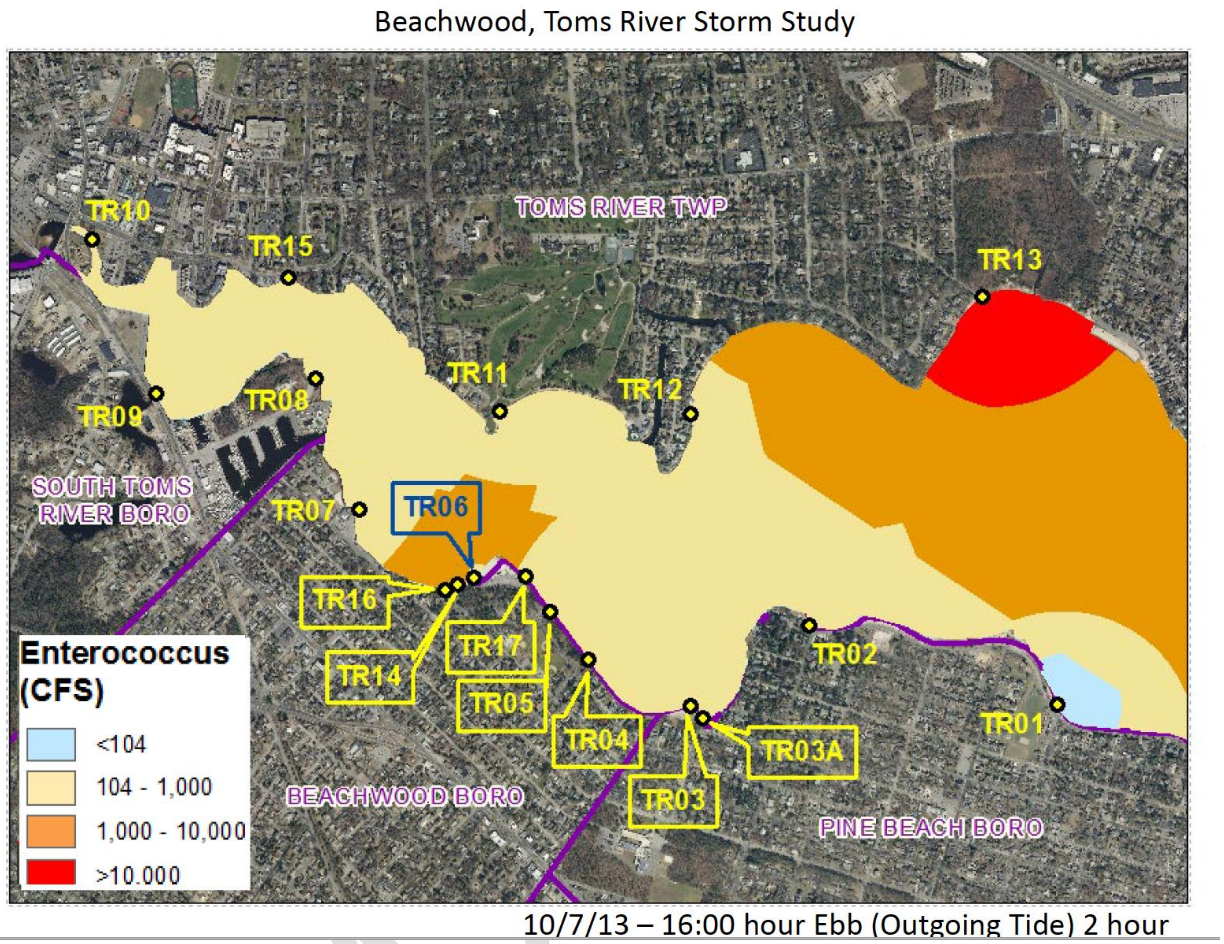

Figure 15. Beachwood storm study – 1

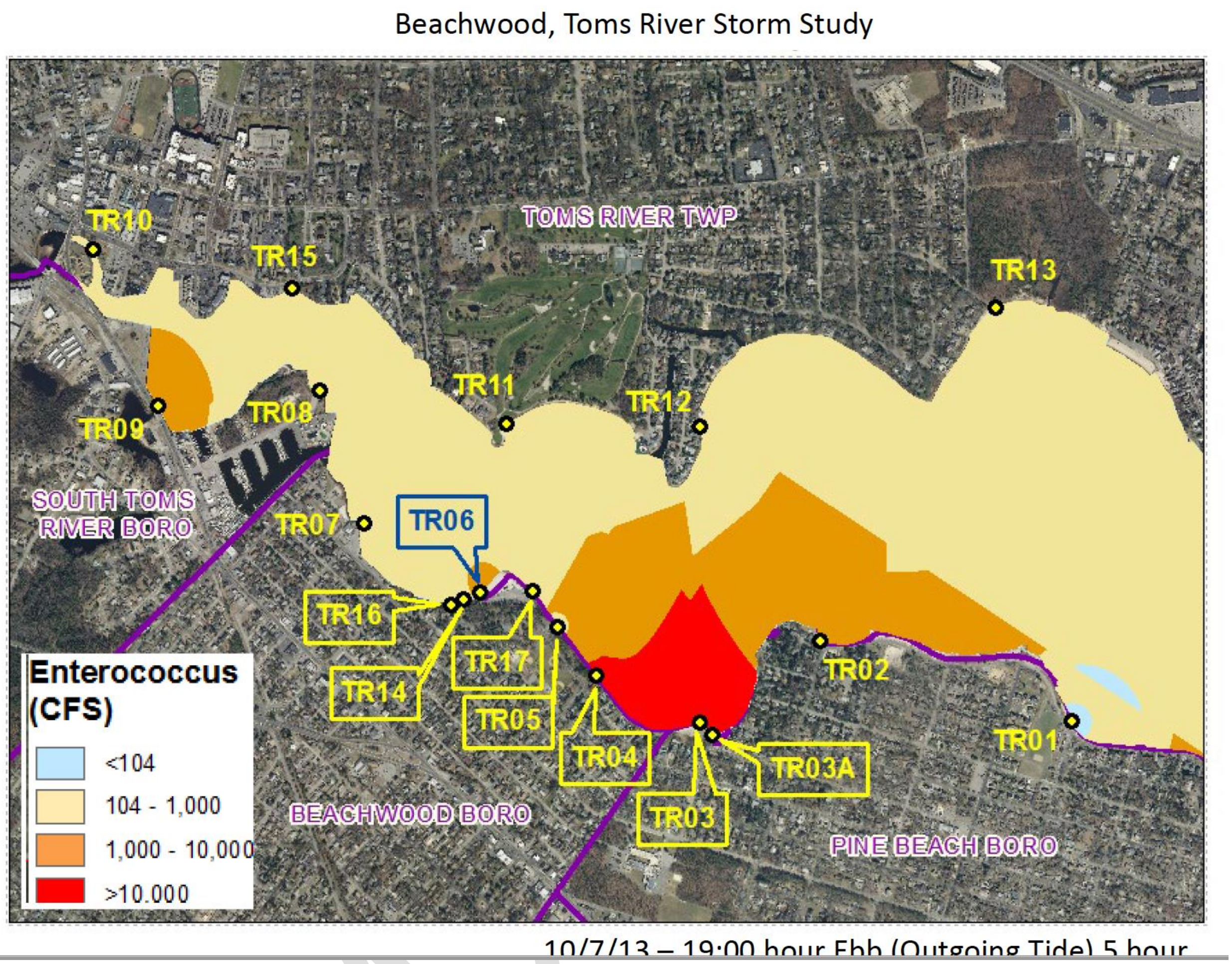

Figure 16. Beachwood storm study – 2

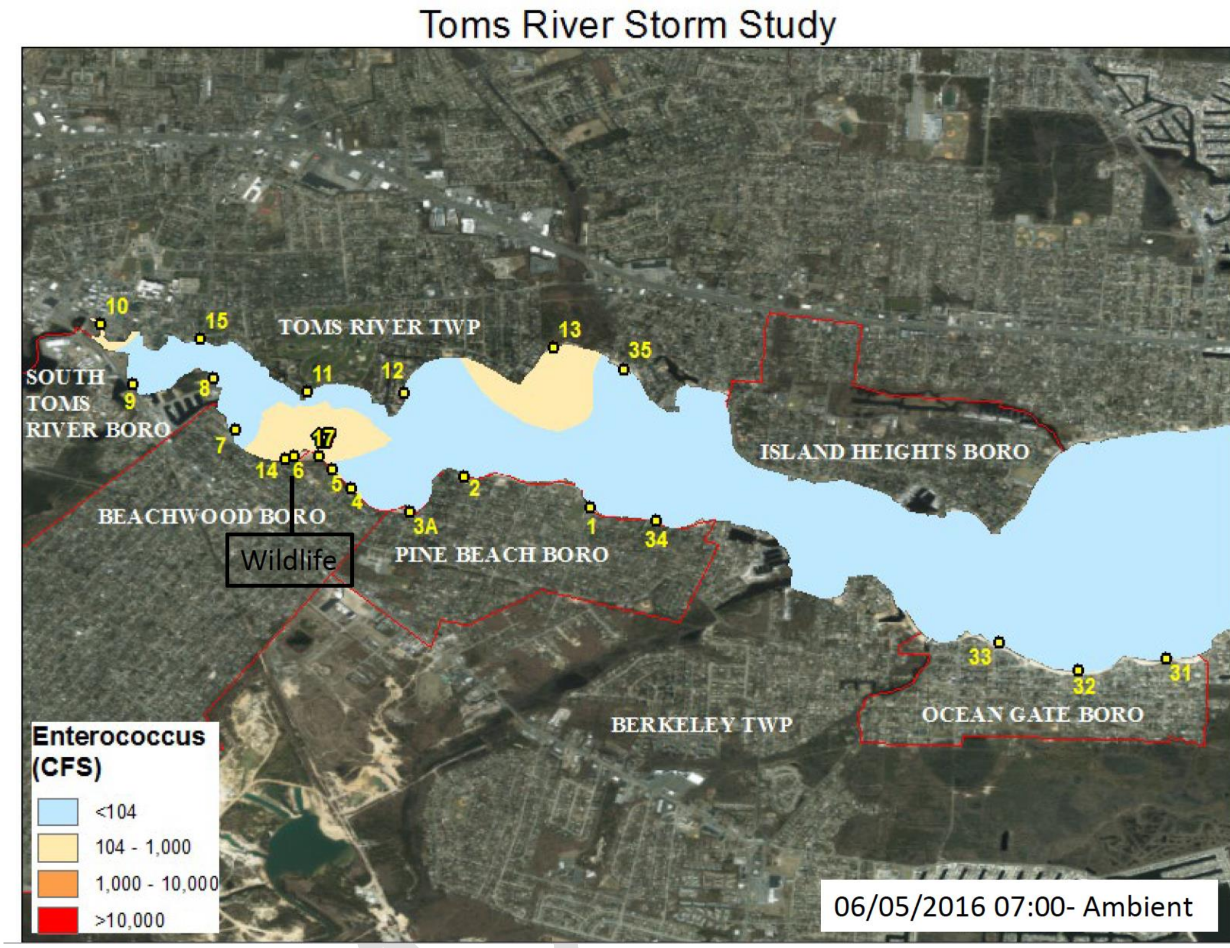

Figure 17. Toms River storm study – 1

Toms River Storm Study

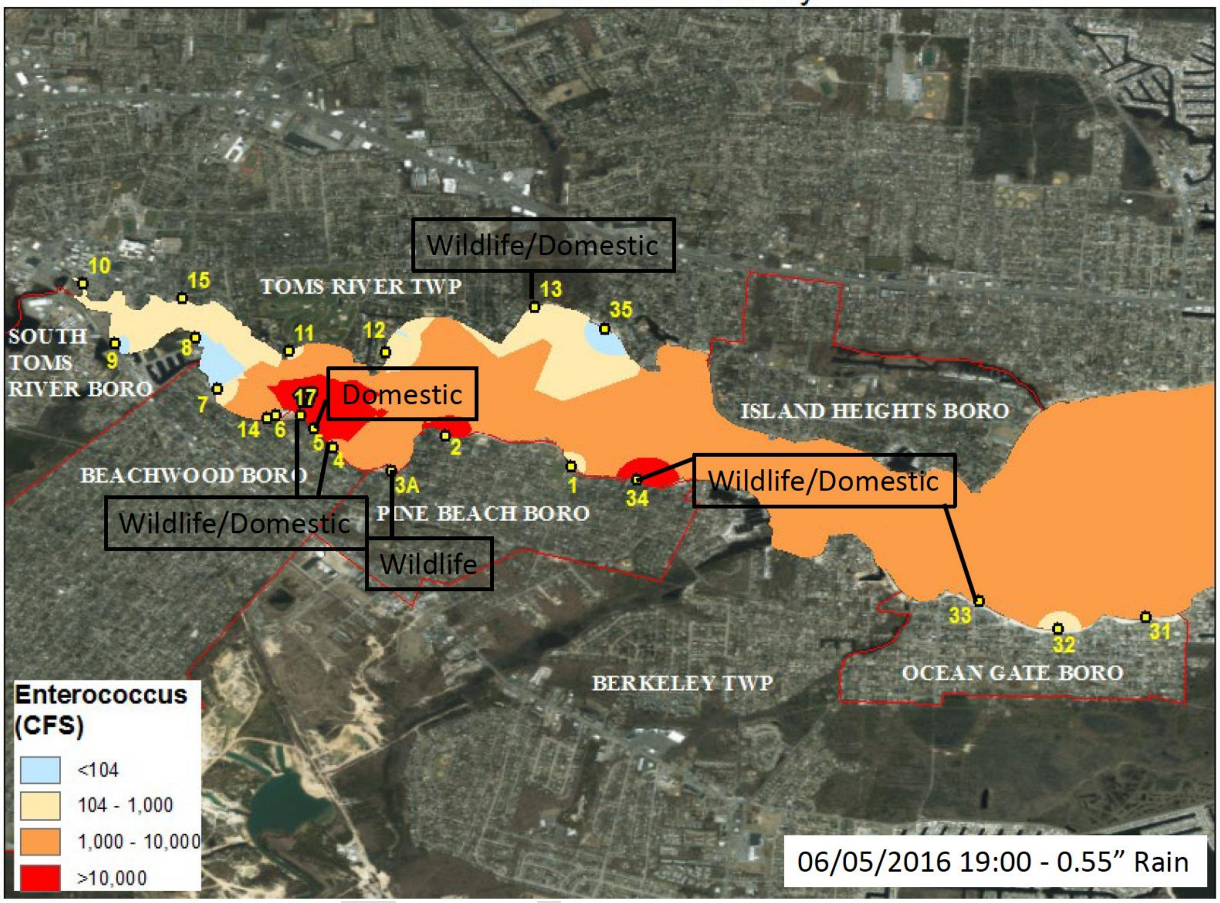

Figure 18. Toms River storm study – 2

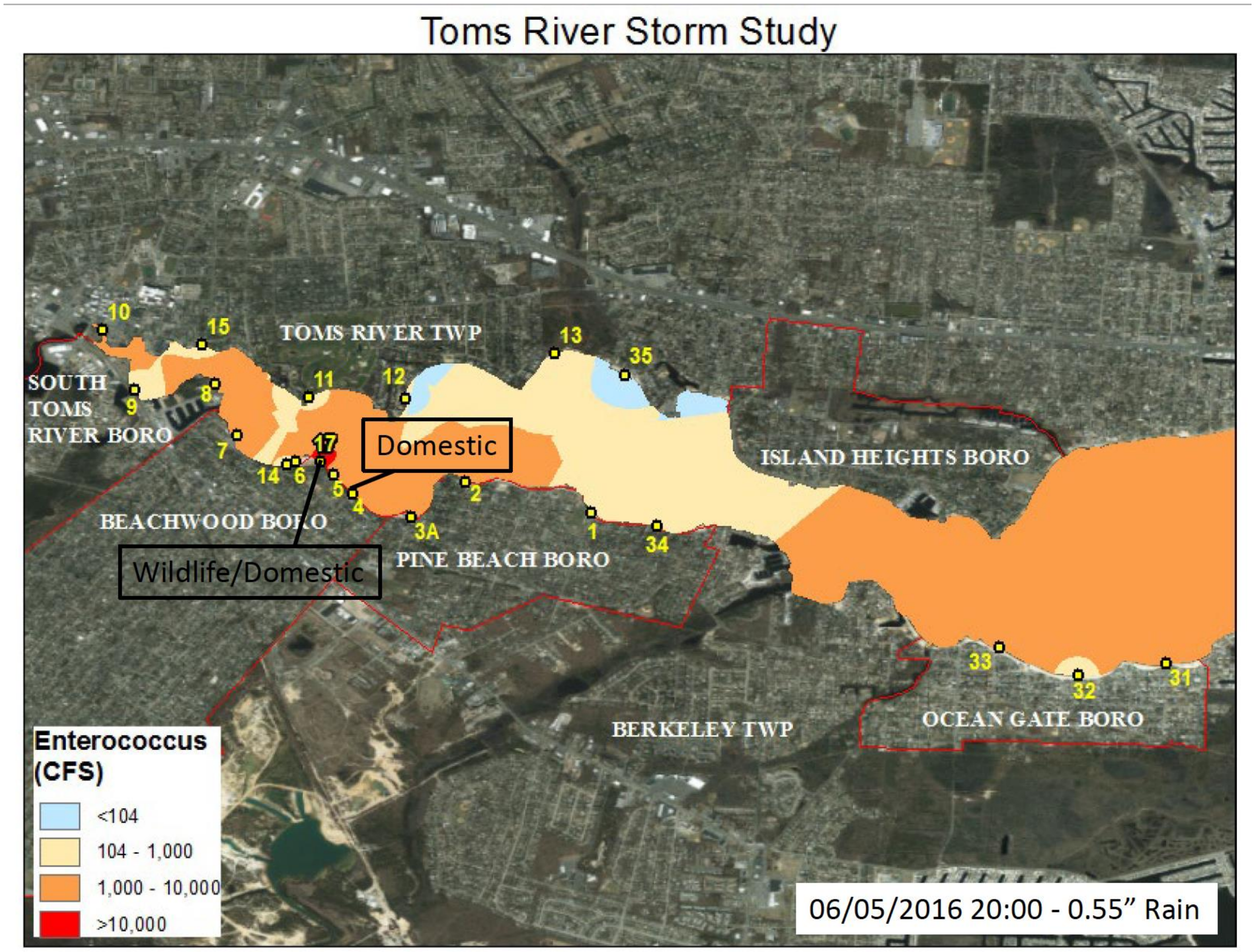

Figure 19. Toms River storm study – 3

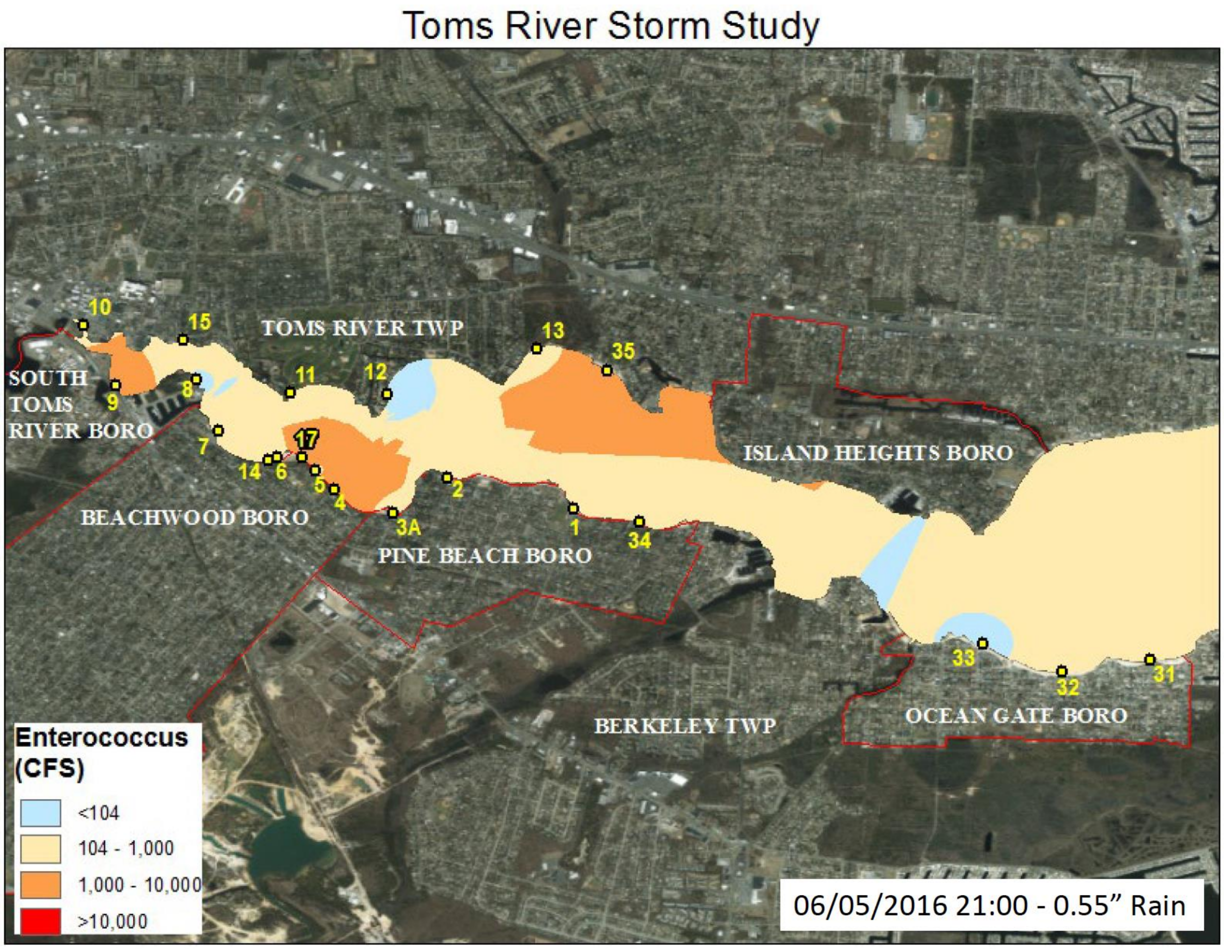

Figure 20. Toms River storm study – 4

V c. MATES-SBB-Investigations – A REVIEW

The Toms River subwatershed is 124 sq. miles and is the largest drainage area of any river in the Barnegat Bay watershed. Many tributaries from upstream drain into the river, the rapid development has resulted in stormwater-related impacts to water quality, as is evidenced by years of beach water quality monitoring under CCMP. MATES, in consultation with NJDEP, and subsequently supported by Save Barnegat Bay's Student Grant Program, began the first of its assessments of the Toms River water quality at selected sites.

This program was unique for a few reasons:

(i) Students conducted all sampling and analytical investigations, with/without additional analyses by NJDEP
(ii) These studies were conducted weekly during the summer and designed to include ambient and wet-weather
(iii) Key water quality parameters were monitored
(iv) Analyses of bacteria were done by Coliscan gel method for E. coli and IDEXX Enterolert method for Enterococcus. These are not NJDEP-approved methods, NJDEP recognizes

and acknowledges that these methods are compatible for screening studies in accordance with Tier B sampling and analysis requirements.

A 2010 pilot water quality study conducted in Toms River in consultation with NJDEP investigated the possible correlation between optical brighteners and bacteria (Kruz et al., 2010). Optical brighteners are found in most laundry detergents and fluoresce under UV and are used to determine human signatures in samples. NJDEP was consulted for site selection and experimental design. Prior to a 0.25" storm, control samples were collected. During the storm sampling, samples were collected at t=30 min and t=60 min approx. (first and second flush samples).

Most sites before and during the storm showed elevated bacteria concentrations (1000 – 4800 cfu/100 ml of total coliforms and also exceeded the fecal coliform recreational criteria (figure 21). However, not all storms necessarily resulted in higher bacteria levels as seen in this study as well as the DEP storm study conducted between 2009 and 2012. As summer progressed, bacteria concentrations seemed to increase at the test locations. While a direct correlation between optical brighteners and bacteria concentrations was insignificant, it was also observed that storm drain may transport sediments and associated bacteria and retain it longer in ambient conditions (site 3, Beachwood) possibly due to its location, thus indicating possible human signature. Turbidity was also found to significantly increase between first and second flush, especially where storm drains directly discharged to the river (sites 3 and 1 in Beachwood and Long Swamp creek, respectively).

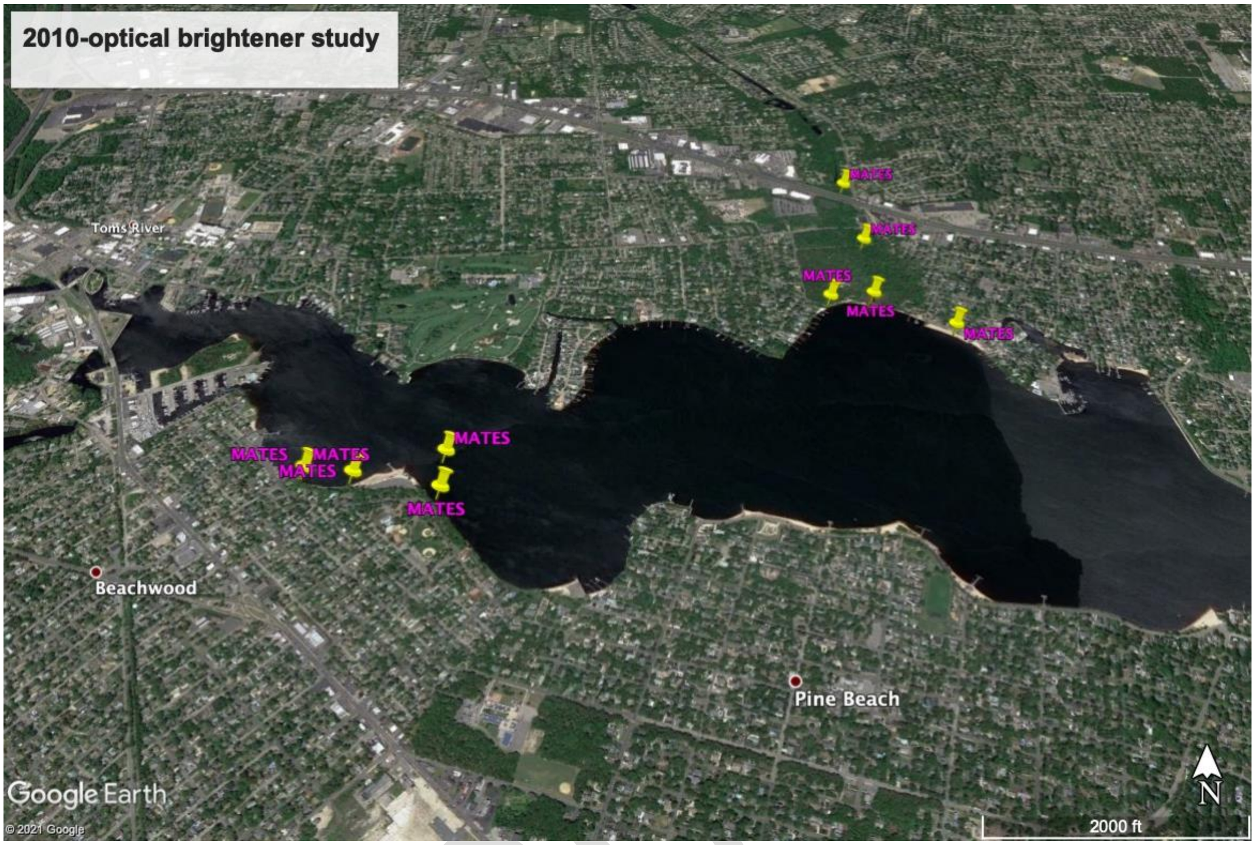

Figure 21. Optical brightener study, 2010

In 2011 summer, MATES and SBB continued additional water quality investigations in the summer in Toms River, this time focusing on Beachwood Beach and Avon Road West (Pine Beach) to determine the impacts of stormwater runoff into the river as well as the possibility of human signatures using optical brighteners. Pine Beach was included in the study – and investigated stormwater pipes before site selection. Beachwood sites were continued from a 2010 study. These studies were prompted by repeat exceedances in water quality under CCMP. This Tier-B screening study was done during first flush (within 30 minutes of a storm) and also included a “baseline” weekly assessment to compare results with NJDEP’s CCMP monitoring. In order to do this, IDEXX Enterolert method was used in addition to determining E.coli levels using the coliscan gel test. Another feature was the split-sampling to corroborate the results with NJDEP’s method 1600. Bacteria concentrations during the second flush (which was after the first 30 minutes) were observed to be higher than the first flush (first 30 minutes) and confirmed the impacts from stormwater runoff, and were statistically correlated. However, it was dependent on rainfall volume and time between two events. Baseline concentrations at Beachwood also routinely exceeded the threshold criteria. It also showed that IDEXX can be used as a screening method as results were comparable with NJDEP’s testing. (figures). This study also showed that stormwater runoff or bacteria exceedance is not just observed in Beachwood, but also downstream in Pine Beach discharge locations. (figures 22-27).

Figure 22. IDEXX monitoring, 2011

This research was significant for many reasons:

- It identified other areas in the Toms River that have bacteria pollution (ii)
- Higher bacteria levels under ambient conditions indicated that in stormwater conveyance systems need to be assessed routinely
- It showed an efficient way to collaborate with NJDEP/OCHD and use innovative methods like the IDEXX as an efficient screening-tool.

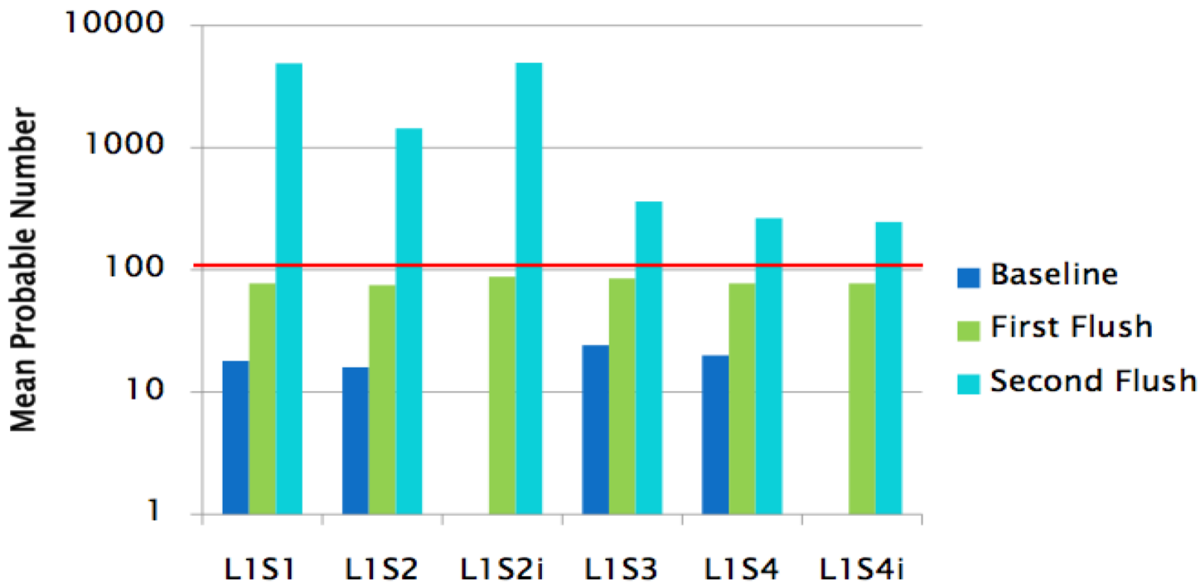

Figure 23. IDEXX wet-weather monitoring, Beachwood 2011

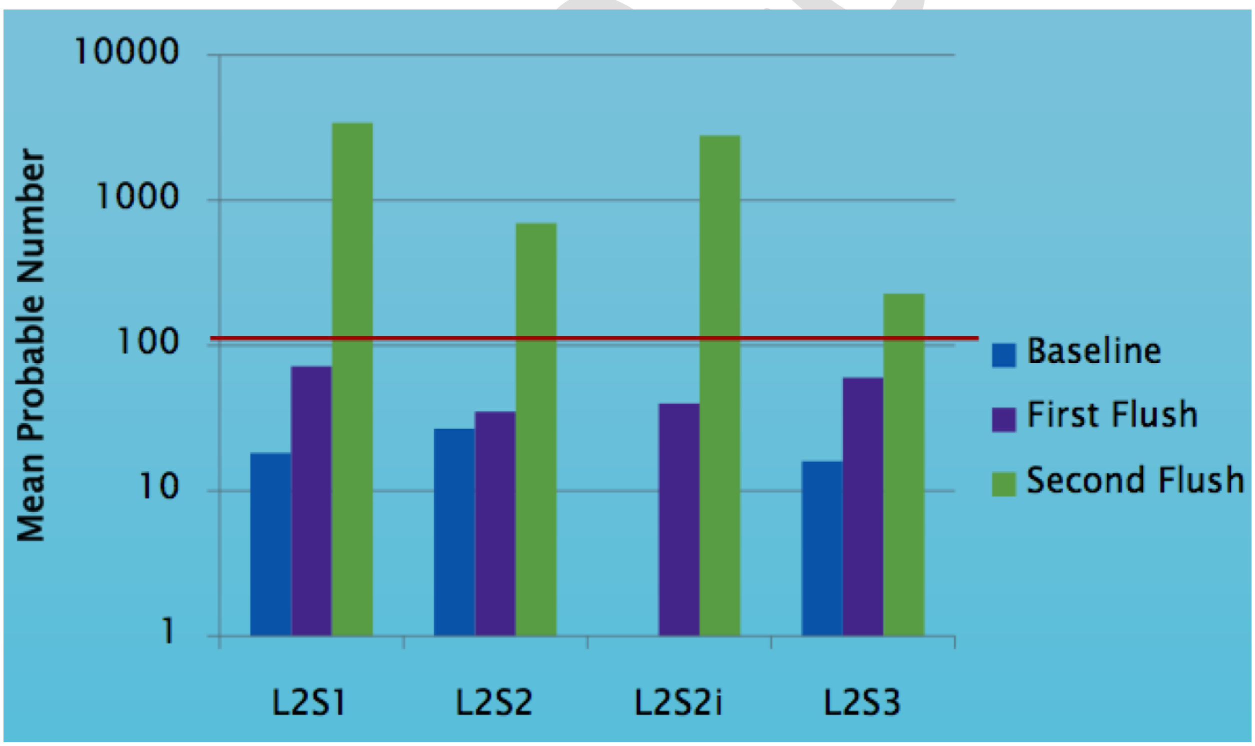

Figure 24. IDEXX wet-weather monitoring, Pine Beach 2011

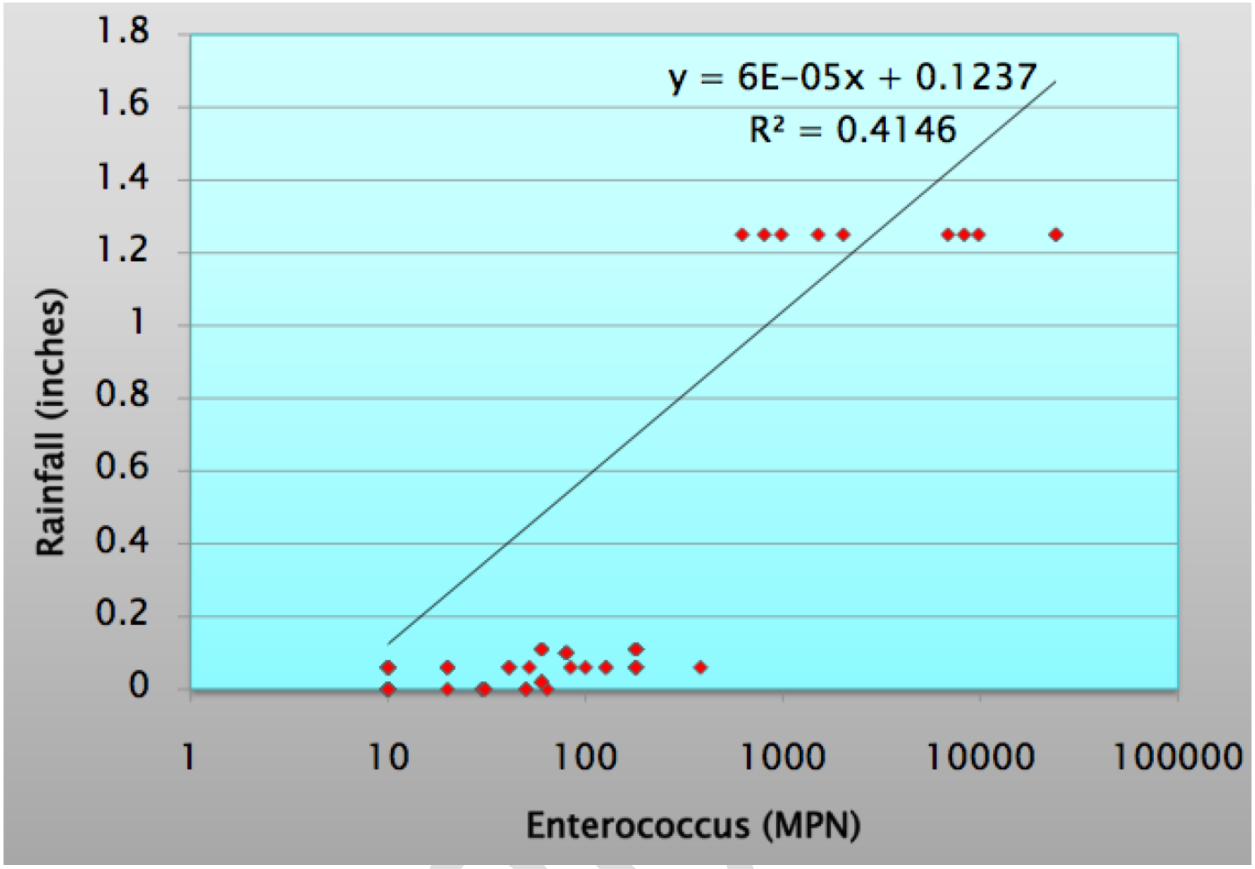

Figure 25. Rainfall impacts, 2011

Date	Beachwood (CFU/100 mL)		Avon (CFU/100 mL)	
	Health Dept.	Ours (Average)	Health Dept.	Ours (Average)
6/27/11	10	11.892	34.641	18.371
7/18/11	10	10	10	10
7/25/11	40	13.269	10	14.581
8/1/11	20	11.892	30	18.566

Location	Leed's (CFU/ 100 mL)	Ours (CFU/100 mL)
L1S1	30	10
L1S2	20	10
L1S3	37	10
L1S4	3	20

Figure 26. Method 1600 (DEP) vs IDEXX (MATES)

Figure 27. Pine Beach locations

ANOVA tests on Enterococcus concentrations showed that elevated concentrations observed during second flush sampling was significantly different from baseline concentrations ($\alpha = 0.05$, $p = 0.023$, $f = 5.130$, $df = 1$) (Figure 28). This supported the argument that stormwater runoff carries upstream bacteria loads, which variably disperses along the bay. The observation of higher concentrations in the second, rather than first, flush was one of the first indications that storm drain deficiencies are reducing and impeding the easier flow of runoff. With unclean storm drains, all sludge, bacteria, and other waste products dumped down roadside or parking lot drains will be disposed of directly into the Toms River through outflow pipes placed at beaches such as Beachwood Beach and West Beach. Such blockages may also result in biofilm development inside pipes, which could exacerbate the problem (Convery et al. 2011).

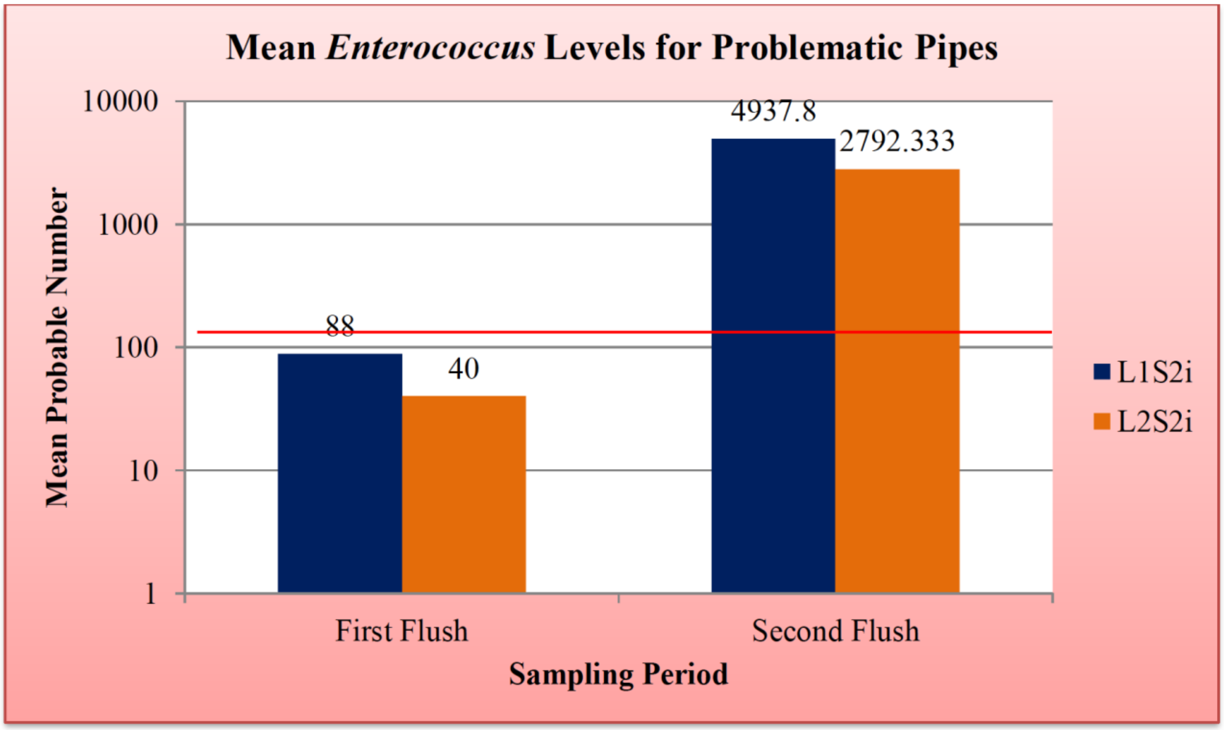

Figure 28. Storm drain condition vs first and second flush impacts 2011

Although this area of the bay has tidal influence, the considerable presence of *E. coli*, a freshwater indicator bacterium, in the baseline samples raised many concerns. Here, sources of bacteria may be anything from pet waste to trash on the beaches washing into the water, and even nearby boats pumping out human wastes. Allan et al. (2015) also noted tide effects and bathymetry of the bay appear to influence enterococcus concentrations in Beachwood and Pine Beach and recommended additional monitoring.

The results showed that Beachwood had a strong relationship between bacteria colonies and optical brightening agents. The Island Heights sites, located on Dillon's Creek, showed relationships between bacteria and optical brightening agents along with high levels of phosphates and nitrates, especially after rainfall events. Because of the strong correlation between optical brightening agents and bacteria colonies at various locations, it is necessary to investigate the quality of the storm drain pipes and sewage pipes throughout the Barnegat Bay watershed. The findings suggest that there may be some old pipes or illegal connections.

A more-detailed study in 2019 investigated upstream sources. MATES-SBB study in 2019 focused on stormwater/storm drain investigations in Pine Beach and Ocean Gate and included Jeffrey's Creek that drains into the Toms River and CCMP stations (figures 29-30). Currents and wind patterns appear to create eddy in site 1 and may have attributes of a closed system that allows for greater retention, similar to observations in Jeffrey's creek. ANOVA tests showed a statistical difference among all of the sites for bacteria parameters. A Tukey HSD Post-Hoc test performed on each dataset showed that all sites excluding Jeffrey's creek were similar in fecal coliforms. The research recommended continued monitoring of Jeffrey's Creek to determine if avian (waterfowl) signatures influenced these concentrations. The results also showed that any bacteria evaluation of Avon Road and Windy Cove should be considered in relation to upstream concentrations at Beachwood Beach (figure 30). Asbury Avenue and Stone Harbor Avenue, both in Ocean Gate, are the safest locations to swim due to their open systems and proximity to Barnegat Bay (Nevil et al., 2019).

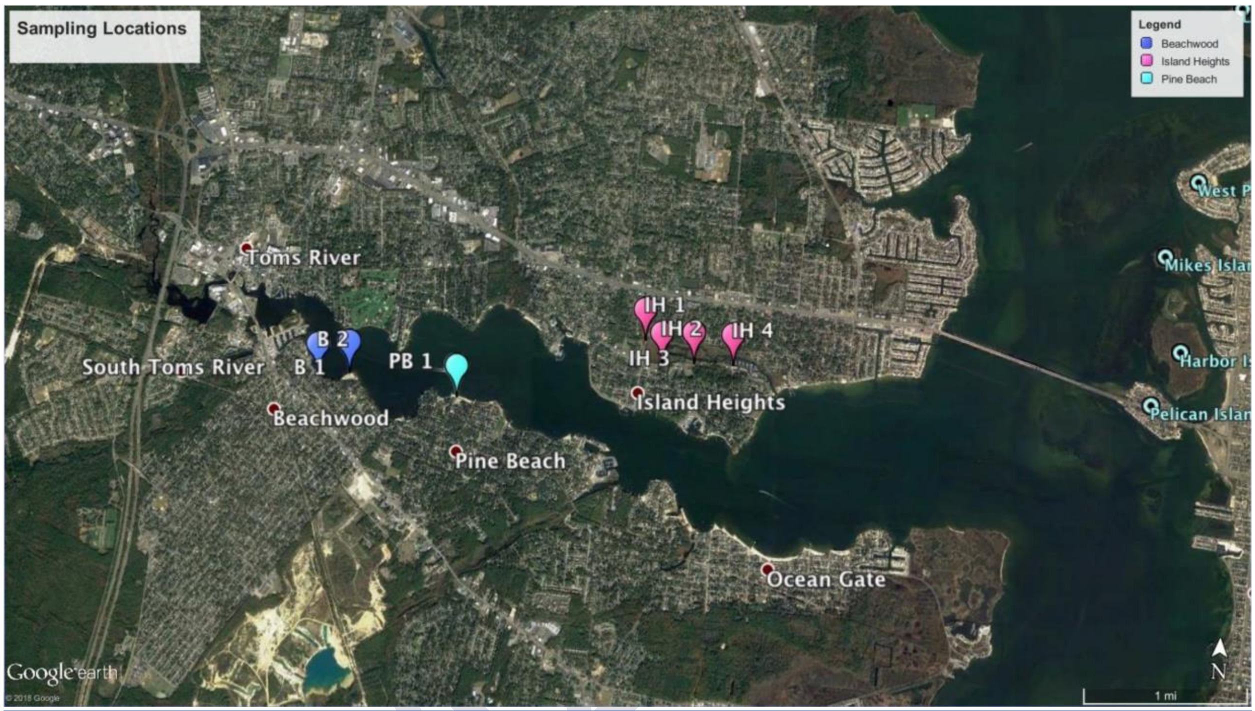

Figure 29. Storm drain investigations 2018

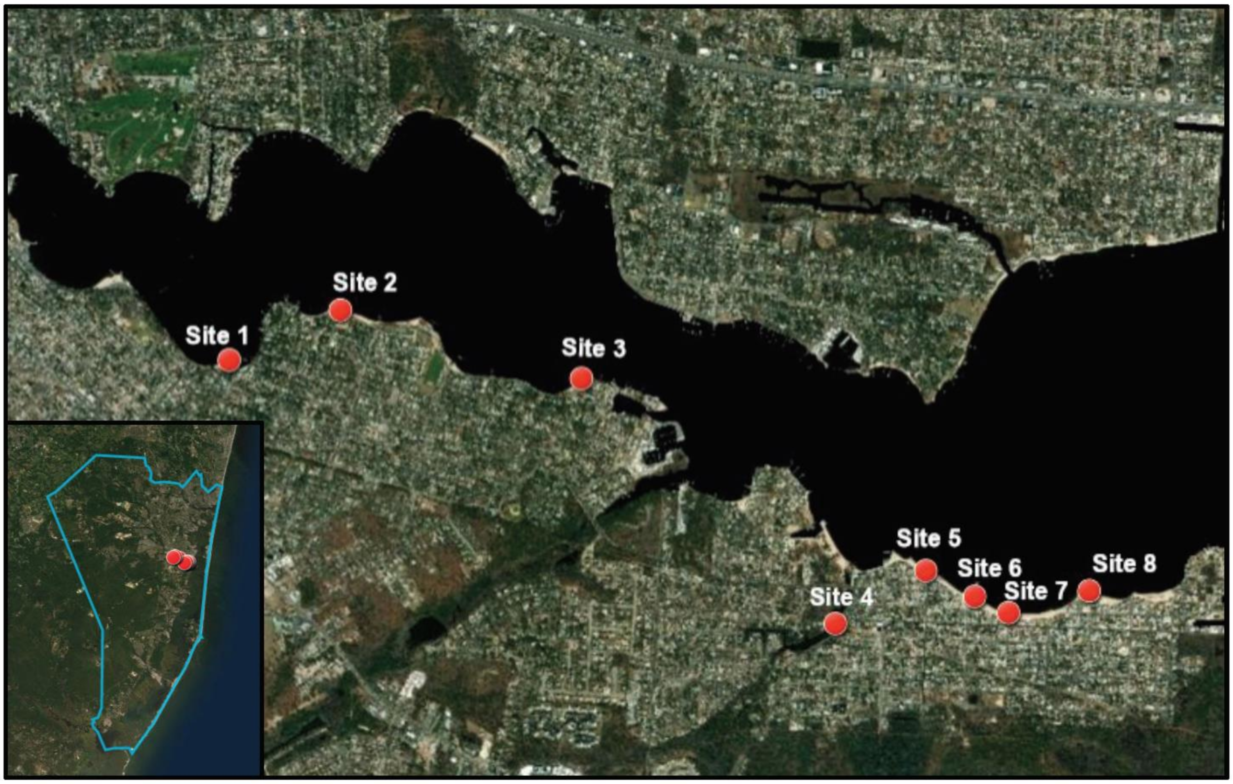

Figure 30. Pine Beach, Ocean Gate 2019

V d. 2020 Student Grant Program Water Quality Monitoring (in-kind under WMA20-022)

The most recent and most comprehensive water quality monitoring of the Toms River was conducted in the summer of 2020 under the student grant program by Save Barnegat Bay-MATES in consultation with Clean Ocean Action. This study assumes significance, in part, because this was a collaborative-in-kind support for the ongoing project WM20-022 to understand and obtain a baseline information, which is so critical to the project.

This study aims to gain a baseline of information about basic water quality conditions and pathogens along the Toms River, New Jersey. The main focus of the project is the identification of specific areas, "hotspots" that may be sources of pathogenic bacteria that have a negative impact on water quality at the Toms River and consequently Barnegat Bay (Figure 31). Data was collected by the Save Barnegat Bay water quality team from June 8 to July 29, 2020 from 12 sites along the Toms River from Ocean Gate to Island Heights. One site, Jeffrey's Creek in Ocean Gate (site A-1) was a semi-enclosed body of water with a high density of waterfowl used as a baseline indicator for pathogenic bacteria (*E. coli*). Jeffrey's Creek (A-1), Beachwood Beach (A-4), Dillon's Creek (B-10) reported an average test above the bacterial threshold of 200 colonies/100 mL for *E. coli* using the Coliscan EasyGel Method. Additionally, the water quality parameters of the northern part of the river varied, as a whole, from the southern areas which may have due to prevalent south to north winds during the summer season. Sixteen sampling events included four wet weather events.

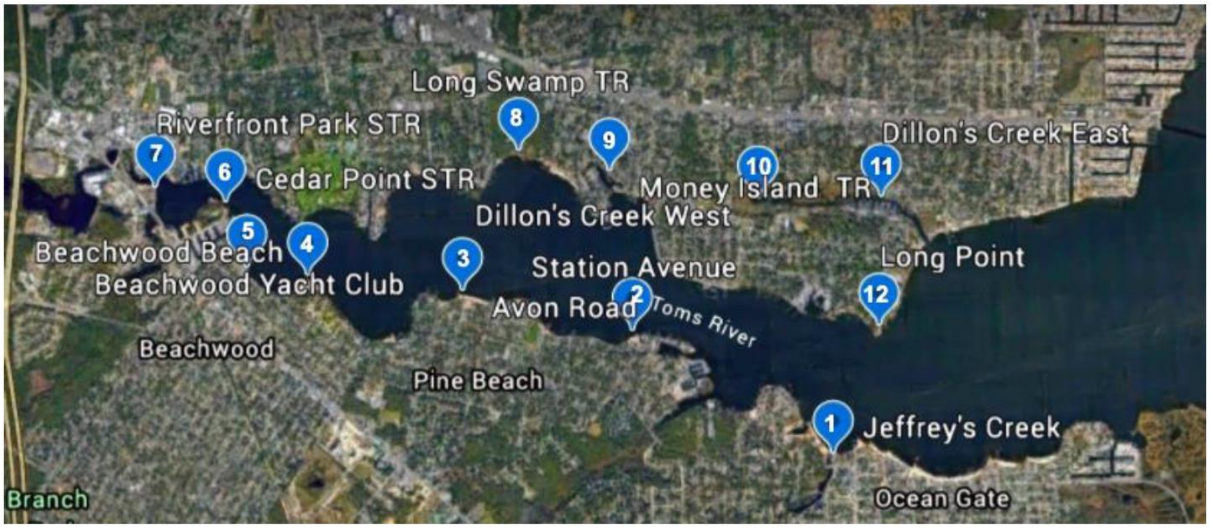

Figure 31. Twelve sites, in all six towns, based on existing data collected under CCMP and earlier monitoring by MATES-SBB.

Jeffrey's Creek (A-1), Beachwood Beach (A-4), Dillon's Creek (B-10) on average test above the bacterial threshold of 200 CFU/100 mL using the Coliscan EasyGel Method® (figure 32). Additionally, Jeffrey's Creek (A-1) and Beachwood Beach (A-4) consistently tested above the bacterial threshold of 200 CFU/100 mL (figure 33) . In the northern parts of the River (B-8 through B-12) water quality results may be largely dependent on prevalent south to north wind. Tidal conditions and flow may impact flow and therefore impact water quality parameters and should be studied as well. We recommend AIC modeling predictions to determine the effect of winds, tides and flow on water quality parameters along the Toms River.

Site	Mean Bacteria Count (CFU/100 mL)
Jeffrey's Creek (A-1)	481.3
Beachwood Beach (A-4)	381.3
Dillon's Creek (B-10)	355.9
Matthis Park (A-7)	190.6
Cedar Road (B-8)	143.8
Cedar Point (A-6)	140.6
Beachwood Yacht Club (A-5)	137.5
Dillon's Creek Marina (B-11)	108.8
Money Island (B-9)	94.1
Station Avenue (A-2)	62.5
Avon Road (A-3)	59.4
Summit Avenue (B-12)	55.9

Figure 32. WQ results showing exceedances above threshold-1

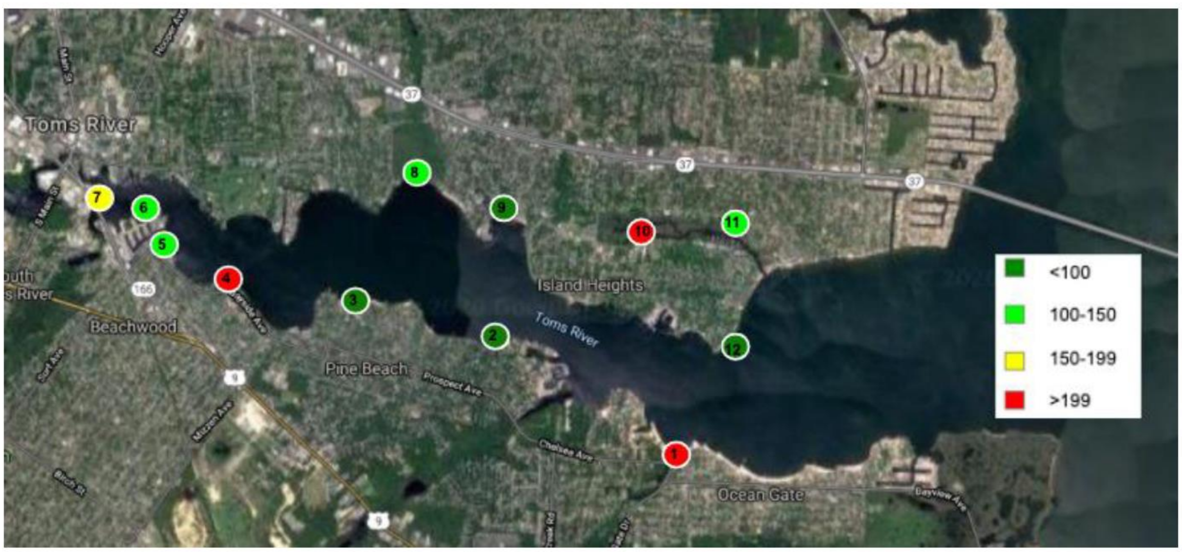

Figure 33. WQ results showing exceedances above threshold-2

VI. RECOMMENDATIONS

Several years of CCMP monitoring data showed that water quality exceedances are more routinely observed in the river and bay beaches on the Toms River. Toms River continues to experience routine water quality exceedances in bacteria levels, triggered by stormwater runoff from upstream sources. Equally important are tides and circulation patterns that impact how long the pollutant continues to reside in the water before being discharged to the bay. A third, and often overlooked factor is failing or deficient stormwater and sewer infrastructure. In certain sections of the River, a combination of one or more of these factors seem to trigger exceedances that results in closing these beaches for days and require additional monitoring efforts.

CCMP monitoring, MATES studies including optical brightener studies, DEP storm/tide studies have helped in understanding some of the processes of bacteria occurrence and transport in the Toms River and need to be continued consistently including upstream locations, to address the principal goal of this source track down project to eliminate bacteria pollution and improve the Toms River sub-watershed.

This summary report clearly highlights that the following water quality monitoring actions are necessary and need to be completed in order to meet the pathogen pollution reduction goal of WM20-022:

- Site selection is crucial – all twelve sites identified for 2020 MATES study should be monitored. Additionally, the most downstream location (Wildwood, Ocean Gate) should be included. Long Swamp Creek should be included.

- Ambient water quality monitoring should be conducted at all sites. Along with this, tide flow (incoming and outgoing) should be conducted.

- Wet-weather monitoring of all sites should be conducted and both first and second flush will be monitored.

- Canine scent tracking (ship and sniff/field) should be used as cost/time-efficient innovative screening strategy in hot spot areas to quickly identify upstream and local fecal inputs

- Water quality monitoring by summer student grant program awardees will be expanded to include upstream locations in the Toms River based on results from recent wet-weather and tide studies conducted by NJDEP in March 2021.

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