

NEW YORK / NEW JERSEY HARBOR & ESTUARY PROGRAM

Harbor-Wide Water Quality Monitoring Report 2021



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Executive Summary

Water quality affects everything that the New York – New Jersey Harbor & Estuary Program (HEP) and our partners strive for. It is the key to a healthy ecosystem, safe public recreation, and sustainable sediment management. Both states have invested billions of dollars towards attaining the goals of the 1972 Clean Water Act. Long term trends in water quality dating back to the 1970s show conditions improving over time leading most notably to the Harbor's increased public access and use in addition to other benefits. This third edition of the *Harbor-wide Water Quality Report*¹ provides the most current water quality data in the estuary and its relationship to public access and habitat health. The objective of this report is to illustrate where we are relative to the fishable and swimmable goals of the Clean Water Act and current regulatory standards.

Understanding water quality improvements in shared waters like the Harbor Estuary can be difficult. New York and New Jersey each have different laws, policies, and management approaches when it comes to water quality criteria and designated uses. But looking across geographic and legal jurisdictions is critical to help the responsible parties make collaborative decisions.

This report presents water quality data collected from 2010 to 2017 from both New York and New Jersey. We have analyzed the data jointly to advance discussions about water management across all the waters of the Harbor Estuary. Data collected by the New York City Department of Environmental Protection (NYCDEP) and the New Jersey Harbor

Dischargers Group (NJHDG) were assessed by aggregating 59 individual sampling stations into individual “master stations,” representing each of 10 principal regional waterbodies in the estuary. Water quality is described by using parameters, for example concentrations of pathogenic bacteria, such as *Enterococcus* and fecal coliform, and dissolved oxygen. These two parameters are the primary criteria for evaluating waterbodies and their designated uses; the presence/absence of pathogenic bacteria indicating safety for recreation and dissolved oxygen being a measure of habitat health for fish and other aquatic organisms. In addition, this report explores total nitrogen and chlorophyll-a to further understand dissolved oxygen levels. Evaluated together, these parameters provide a comprehensive determination whether uses are being met.

To understand how swimmable and fishable the estuary's waters are, these four parameters were assessed against federal recreational water quality recommendations and guidance documents. For each of the 10 regional waterbodies, water quality is described using New York's and/or New Jersey's standards and criteria as of 2020 for pathogens (fecal coliform, *enterococci*, and *E. coli*) and DO. Proposed rulemaking to amend standards and/or criteria introduced by the states are not explored in this report. This report does not serve to replace New York's or New Jersey's Integrated Water Quality Reports, nor is it meant to be used for compliance purposes.

1. New York-New Jersey Harbor Estuary Program (2011). *Harbor-Wide Water Quality Monitoring Report for the New York-New Jersey Harbor Estuary*, 2nd Edition. www.slideshare.net/hudsonriverfoundation/harborwide-water-quality-monitoring-report-for-the-new-yorknew-jersey-harbor-estuary.

Water quality in the Harbor Estuary has continued to improve from 2010 to 2017. The number of safe recreational days for swimming and other primary contact recreational activities between June 1st and September 30th is increasing. On average and in much of the estuary, especially the Lower Hudson River, Upper New York Bay, Lower Bay, and Jamaica Bay, it is safe to swim. Dissolved oxygen levels, critical for fish and other aquatic organisms, are generally favorable and above federal threshold values. This extraordinary achievement, especially relative to conditions just a generation ago, is due to the collective efforts of EPA, both states, local government, wastewater utilities, and environmental and community advocates. These parties have taken significant steps to improve the 25 Publically-Owned Treatment Works (POTWs) that discharge to the estuary, have implemented controls that reduce the volume of combined sewer overflows (CSOs) discharging into waterbodies, and are carrying out policies and plans to manage stormwater at the source, such as stormwater management plans.

However, there are still areas of the Harbor Estuary where further investments are needed to achieve the swimmable and fishable goals of the Clean Water Act. For example, data in the Lower Passaic River and Newark Bay, Hackensack River, and the Lower Raritan River do not show consistently safe pathogenic bacteria levels that would permit safe swimming. For these smaller waterways (as well as other enclosed and confined waterways) pathogen levels indicate limits to the public's ability to enjoy their waterways for even non-contact recreation. In addition, the Bronx River and Western Long Island Sound, Jamaica Bay, and the Hackensack Rivers show levels of dissolved oxygen, total nitrogen, and chlorophyll-*a* levels where conditions may harm fish and other aquatic organisms and reduce the health of the whole ecosystem.

Addressing these conditions, and continuing to demonstrate progress towards current state standards and overall fishable and swimmable goals will require further action to address ongoing sources of pollutants. This includes addressing discharges from POTWs, CSOs, municipal separate storm sewer

The collaborative mission of HEP and our partners' is to bring the benefits of the Clean Water Act to the people and wildlife of the estuary by reducing the sources of pollution, improving habitat, and enabling public access and engagement. For more information, please visit www.harborestuary.org.

systems (MS4), illicit discharges as well as nonpoint source pollutants carried by stormwater. As summarized for each of the 10 regional waterbody summaries, there are still a number of other challenges to consider when determining safe use and making future investments towards achieving the Clean Water Act's fishable and swimmable waters goal. Notably, the region's long history of industrial activity has left a legacy of toxic contaminants such as polychlorinated biphenyls (PCBs), heavy metals (e.g. mercury), pesticides, and polyaromatic hydrocarbons (PAHs) (Lodge, et al. 2015).

Government, utilities, and landowners are planning to invest billions of dollars in an attempt to minimize and control sewage and stormwater discharges. This includes the work of New York City and the 17 CSO municipalities and four utilities in New Jersey to implement Long Term Control Plans (LTCPs) to reduce the volume of CSOs. In addition, 211 municipalities across both states are working to improve stormwater management by implementing plans via MS4 permits. Continued capital investments and other improvements in water management will be required to address the pathogen and nutrient pollution that still limit public use and threaten the ecological health of the estuary. This report is intended to help inform HEP and our government, academic, civic and community partners as they make decisions about how best to make those future investments.

Figure 1.

Point Source Pollution Proximity to Recreational Areas

- Public and private boat launches
- Public and private beaches
- Waterfront parks

Combined Sewer Outfalls (CSO)

- within 1/2 mile of beach
- within 1/2 mile of boat launch
- other CSOs

Municipal Separate Storm Sewer System (MS4) Outfalls

- within 1/2 mile of beach
- within 1/2 mile of boat launch
- other MS4 outfalls

- Harbor Estuary Watershed Boundary

NJ MS4 Outfall areas:
Incomplete or missing
outfall location data

0 5 miles

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The Harbor Estuary and Shared Waters

The New York-New Jersey Harbor Estuary is the biggest public resource in the nation's largest and most densely developed metropolitan area. There are more than 250 square miles of open water from the Mario Cuomo (Tappan Zee) Bridge south to Sandy Hook, NJ, including the lower reaches of the Hudson, Passaic, Hackensack, and Raritan Rivers. Water quality in the Harbor Estuary is key to safe swimming and boating as well as the underlying environmental quality of shoreline parks and waterfront neighborhoods. Healthy populations of fish, birds and other wildlife also depend on clean water. Since the passage and implementation of the federal Clean Water Act in 1972, significant investments have been made to improve water quality in the Harbor Estuary. The benefits are readily apparent in the public's demand and enjoyment for waterfront access as well as many new residences and offices built along the waterfront. Less visible are the growing numbers of fish, whales, seals and other marine organisms.

The New York-New Jersey Harbor & Estuary Program (HEP) and its partners continue to work towards achieving fishable, swimmable waters,

where attainable, throughout the estuary. Responsibility for water infrastructure and water quality is fragmented across political jurisdictions and agency, utility, municipal, and landowner responsibilities. But understanding current water quality requires looking across these geographic and legal jurisdictions. This holistic approach is critical to helping responsible parties make difficult and collaborative decisions.

Water quality monitoring and reporting those results to the public is necessary to collect evidence and inform decisions that protect public health and sustain the estuary's ecology. Stormwater and sanitary discharges continue to deliver pollution to our waters, often in close proximity to recreational areas (Figure 1). Primary water quality parameters that challenge the health of the estuary include pathogen contamination, low dissolved oxygen, and excessive levels of nutrients. This report compiles the best available data from 2010-2017 on four water quality parameters to assess the Harbor Estuary as a whole as well as for 10 principal regional waterbodies.

Measuring Water Quality Parameters

A number of parameters are used to measure water quality, provide important information on the health of the biota living in the estuary, and human use of the estuary for activities such as swimming and shellfishing. This report focuses on four primary water quality parameters: pathogenic bacteria (Enterococcus and fecal coliform), dissolved oxygen, nitrogen, and chlorophyll-a. There are other important water quality parameters that are not explored in this report. Some of these parameters are explored in the State of the Estuary report (www.hudsonriver.org/NYNJHEPStateoftheEstuary.pdf). HEP's Environmental Monitoring Plan (www.hudsonriver.org/article/environmental-monitoring-plan) identifies parameters where further research and data collection are necessary.

Pathogenic Bacteria: Enterococcus and Fecal Coliform

The presence of pathogenic (disease-producing) bacteria in both marine and freshwaters are the result of fecal contamination from untreated waste and stormwater, including human and non-human sources. State and federal agencies use pathogenic bacteria as parameters to determine whether waters are safe for primary contact recreation (swimming) and consuming shellfish. Fecal coliform bacteria are commonly used as a parameter to measure levels of pathogenic bacteria. In 1986, the U.S. Environmental Protection Agency (EPA) chose *Enterococcus* as its recommended parameter to measure pathogenic bacteria in saline waters. Like fecal coliform, *Enterococcus* bacteria are commonly found in the feces of humans and other warm-blooded animals. *Enterococcus* bacteria have a slower decay rate and are more likely to survive longer in highly saline waters. For these reasons, *Enterococcus* bacteria have a greater correlation to swimming-associated illnesses than fecal coliform. Fecal coliform are typically measured in waterbodies that are suitable for secondary contact recreation or on-water recreational activities, such as kayaking or rowing. Another commonly measured pathogenic bacterium is *Escherichia coli*, or *E. coli*, which is a good predictor of swimming-associated illnesses in freshwater systems.

Dissolved Oxygen

The level of dissolved oxygen (DO) in the water is used to measure habitat quality for fish and other aquatic organisms. Fish tend to swim away from and are otherwise stressed by areas of low DO, but benthic invertebrates are likely to die in low DO areas. The amount of DO is influenced by the time of day (sunlight promotes photosynthesis and therefore the production of oxygen), tidal cycle, season, temperature, and depth of the water. In addition, the consumption of oxygen (i.e., respiration) by microbes, algae, and fish can also reduce the DO in a waterbody. As these factors change the concentration of DO, the abundance of aquatic organisms also changes. Acute hypoxia (very low dissolved oxygen) can cause fish kills, and if levels remain chronically low, predator-prey relationships in the estuary can be affected (Yozzo, 2018). Hypoxia is most problematic in slow-moving tributaries, bays, and deeper parts of the estuary where the water is not well mixed.

Nitrogen

Among the major nutrients, nitrogen is the one that is most limiting in the estuaries. While nutrients like carbon and phosphorus are plentiful in the marine environment, it is the relative inputs of nitrogen that control excessive growth and reproduction of marine plants and algae (Nixon, 1995). Nitrogen can enter our waterways through treated wastewater as well as untreated sewage discharges. Atmospheric deposition² and stormwater runoff from over-fertilized lawns and farms are additional sources of nitrogen to the estuary. Generally, nitrogen concentrations are most problematic during the spring and summer growing seasons. This is due to the combination of increased nutrients, organic matter (including organic matter produced over the winter season), and higher temperatures that result in enhanced biological activity (i.e., biodegradation and decomposition of organic matter). Coupled with decreased oxygen solubility, this reduces the amount of DO available in the water column for fish and other organisms in the waterbody. In addition, respiring algae exert DO depletion on a daily timescale in some parts of the estuary.

Chlorophyll-a

Chlorophyll-a is a general indication of phytoplankton, more commonly known as microalgae and algae, in the water. Algae are a vital food resource at the base of the food web, and thus play a linchpin role in ecosystem health. Like any healthy diet, both the amount and type of food are important. Some algae production is needed to support the estuary's food web. However, excessive algae growth can negatively influence the estuary by causing low DO levels and aesthetic problems such as green scum or bad odors. Some algae produce toxins that can be an ecological and public health concern.

Kayakers at the boathouse on New York City's Pier 26 kayaking in the Hudson River, credit: Rosana Da Silva.



². Atmospheric deposition is the process where particles, aerosols, and gases move from the atmosphere to the earth's surface. Atmospheric deposition by wet deposition, such as rainfall, fog, or snow, or dry deposition, such as dust carried by wind, are examples of how particles and gases settle onto the surface of land and water.

Water Quality Standards and Criteria

New York and New Jersey take a primary role in establishing the specific water quality standards that set regulatory goals for the estuary and its waterways. These state standards must be consistent with the fishable and swimmable goals of the federal Clean Water Act and be based on the best available science.

Pathogenic bacteria and dissolved oxygen are the primary parameters that are used by EPA, New York, and New Jersey to set protective standards to achieve the designated uses of individual waterbodies in the estuary. While the federal Clean Water Act calls for all waters to be fishable and swimmable, where attainable, the designated use sets a specific goal for each individual waterbody, for example supporting aquatic life and/or enabling on-water recreational activities. While there are other designated uses, this report focuses only on recreation and supporting fish and other aquatic organisms. The designated uses determine the water quality condition and the management needed to support that specific designated use. Existing uses are specifically defined as the past or present condition that have actually been attained in a waterbody on or after November 28, 1975 – the day EPA promulgated the original water quality standards regulation. EPA defines recreational activities as either primary contact (such as swimming and bathing) or secondary contact (such as boating). The specific regulatory definitions of these recreational uses, and thus the management implications, are determined by New York and by New Jersey, in collaboration with EPA.

As a partner to the states, the federal EPA provides guidance and oversight. The EPA has established national guidance values for a variety of water quality parameters. The states choose

specific parameters and establish numerical values to measure these parameters for each waterbody. These can be based on EPA's recommendations, modified to reflect site-specific conditions, or based on their own standard that is scientifically defensible and protective of the waterbody's designated use. In addition, Total Maximum Daily Loads (TMDLs) can be used by the states and EPA to determine the amount of a pollutant that a waterway can take in and still meet their designated uses and water quality criteria. Past research on possible TMDLs for the Harbor Estuary on pathogens, dissolved oxygen, nutrients, toxic contaminants and trace metals are available at www.hudson-river.org/article/tmdl.

For this report, water quality data for the selected parameters in the Harbor Estuary are analyzed against EPA's national guidance, referred to as the 2012 Recreational Water Quality Criteria (RWQC), as well as against state criteria and standards in the 10 principal regional waterbodies. Where there is no national or state guidance for the selected parameters, literature reviews were conducted to identify appropriate thresholds for select parameters in the Harbor Estuary. These are presented as a useful reference in the absence of local thresholds. Like the slight differences in regulatory definitions of recreational uses, water quality standards also vary throughout the estuary according to the designated uses set by the states for those waterbodies. For example, the areas designated for shellfishing and bathing have the most stringent bacterial standards, whereas areas designated for fish survival have the least stringent bacterial standards (see Appendix A: *Current Waterbody Classifications and Criteria in New York and New Jersey waters*).

Primary and Secondary Contact

New York 10 NYCRR Part 700.1 (regulatory definitions):

Primary contact recreation means recreational activities where the human body may come in direct contact with raw water to the point of complete body submergence. Primary contact recreation includes, but is not limited to, swimming, diving, water skiing, skin diving and surfing.

Secondary contact recreation means recreational activities where contact with the water is minimal and where ingestion of the water is not probable. Secondary contact recreation includes, but is not limited to, fishing and boating.

New Jersey NJAC 7:9B-1.4 (regulatory definitions):

Primary contact recreation means water related recreational activities that involve significant ingestion risks and includes, but is not limited to, wading, swimming, diving, surfing, and water skiing.

Secondary contact recreation means recreational activities where the probability of water ingestion is minimal and includes, but is not limited to, boating and fishing.

Pathogenic Bacteria: *Enterococcus* and Fecal Coliform

This report explores available data from 2010-2017 against two threshold values set by the EPA³. EPA's 2012 RWQC for pathogens consists of two values⁴, a geometric mean and a statistical threshold value. A geometric mean (GM) is the central tendency of a dataset, indicating a typical value or median across the waterbody for a given period. Epidemiological studies have determined that waters having a GM of 35 or less colony-forming units (cfu)⁵ of *Enterococci* per 100 milliliters (mL) of water (35 cfu/100 mL) is protective of public health, meaning it is acceptable for primary contact such as swimming. Exceeding this value means that the water is not generally safe for primary contact. In addition, a statistical threshold value (STV) is used to express the frequency of pathogenic bacteria samples above a safe limit. The STV standard is that no more than 10% of the water samples should exceed 130 cfu/100 mL. Together, the GM and STV provide a holistic understanding of water quality that endeavors to protect the public from exposure to harmful levels of pathogens (EPA, 2015).

Dissolved Oxygen

EPA's 2000 Dissolved Oxygen Criteria recommends two threshold values for hypoxia: acute hypoxia, the dissolved oxygen level at which marine life has a greater potential to die, is a minimum of 2.3 milligrams per liter (mg/L); and chronic hypoxia, the continuous level at which dissolved oxygen hinders growth of marine life, is 4.8 mg/L. These threshold values aim to be protective of biological health—survival of juvenile and adult fish and other aquatic organisms, their growth, and larval recruitment.

Total Nitrogen

Nitrogen is essential for marine life, but too much of a nutrient can lead to excessive growth of algae and other microscopic plants. These organisms and the marine species that feed on them respire, die, and decompose, depleting the oxygen in the water. Unlike pathogens and dissolved oxygen, nitrogen does not have a threshold value recommendation from EPA. The states of New York and New Jersey have a narrative water quality standard that lays out a descriptive condition that needs to be met⁶. However, other estuaries in the country have begun to define numeric threshold values for nitrogen such as in the Chesapeake Bay. The Mid-Atlantic Tributary Assessment Coalition (MTAC) developed a protocol as a means to increase scientific validity in reporting their data. For tidal tributaries and estuaries, the MTAC recommends the following thresholds to evaluate total nitrogen levels: >1.2 milligrams per liter (mg/L) as poor, values between 0.4-1.2 mg/L as fair, and any value ≤0.4 mg/L as good (EcoCheck, 2011).

Chlorophyll-a

Chlorophyll-a relates to the abundance of the microscopic algae that consume nutrients like nitrogen that have entered the waterbody. Too much chlorophyll-a can indicate excessive growth and conditions that can lead to low DO concentrations and at times, toxic algal blooms. Having low levels of algae promotes clearer water that supports healthier habitats for fish survival and propagation. EPA conducts a *National Coastal Condition Assessment* (NCCA) every five years to assess the ecological condition and recreational potential of coastal waters. Although not a guidance document, EPA's NCCA program uses the following thresholds to evaluate levels of chlorophyll-a in estuaries: >20 micrograms per liter (µg/L) as poor, a value between 5 and 20 µg/L as fair, and <5 µg/L as good (EPA, 2015).

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3. The 10 regional summaries, at the end of this report, will explore the state's water quality criteria per each region's water quality standard and criteria.
 4. EPA's 2012 RWQC for pathogens allows for a geometric mean of either 30 or 35 cfu/100 mL as well as a STV of 110 or 130 cfu/100 mL. This is due to epidemiological studies that provided these results in terms of illness rates (32 or 36, respectively, out of 1,000 individuals with swimming-related illnesses) and both values are protective of public health.
 5. Due to culture-based methods to detect the presence of *Enterococci* or other pathogenic bacteria, the criteria is expressed as colony forming units.
 6. New York State's narrative standard for phosphorus and nitrogen states: "None in amounts that result in the growths of algae, weeds and slimes that will impair the waters for their best usages." New Jersey's narrative standard for nutrients states: Except as due to natural conditions, nutrients shall not be allowed in concentrations that render the waters unsuitable for the existing or designated uses due to objectionable algal densities, nuisance aquatic vegetation, diurnal fluctuations in dissolved oxygen or pH indicative of excessive photosynthetic activity, detrimental changes to the composition of aquatic ecosystems, or other indicators of use impairment caused by nutrients.

Challenges of Regulating Shared Waters

EPA, the states, wastewater utilities, and other stakeholders are committed to working towards achieving our shared goal—reducing the sources of pollution so that the waters of the Harbor Estuary will meet the fishable/swimmable goal of the Clean Water Act, where attainable (Pirani, et al, 2018). With two states and two sets of water quality standards and classifications, it is challenging to assess progress towards this goal in the shared waters of the Harbor Estuary⁷. In particular, the Hudson River, the Kill van Kull, Arthur Kill, and the Raritan Bay have different standards and classifications per state. These standards and classifications determine whether or not the waterbody is considered suitable for primary or secondary recreation, or if fishing is allowed (see Appendix A: *Current Waterbody Classifications and Criteria in New York and New Jersey waters*). For example, the Arthur Kill on the New York side is classified as SD and on the

New Jersey side is classified as SE3. New York’s SD waters best use is fishing and suitable for fish survival, but not for primary or secondary contact recreation or fish propagation. However, in New Jersey, the Arthur Kill’s SE3 classification indicates best use is suitable for secondary contact recreation, maintenance and migration of fish populations.

Moreover, the metrics for each class are distinct. New Jersey uses fecal coliform for SE3 waters, but New York uses total coliform and fecal coliform as its pathogen parameter for SD waters. These differences create obstacles when defining what constitutes fishable and swimmable waters in the Harbor Estuary, how to communicate safe use to the public and decision makers, and ultimately, the conditions placed on utility and municipal discharge permits.

	New York	New Jersey
Waterbody Class	SD	SE3
Pathogens: Total Coliform	Monthly Median ≤ 2,400/100mL and 80% ≤ 5,000/100mL	Not applicable for this class
Pathogens: Fecal Coliform	Monthly GM ≤200/100mL	Monthly GM ≤1,500/100mL
Pathogens: Enterococci	Not applicable for this class	Not applicable for this class
Dissolved Oxygen	≥3.0 mg/L	≥3.0 mg/L

There are several different waterbody classes and water quality criteria per state. To review New York and New Jersey waterbody classes and water quality standards, see Appendix A: *Current Waterbody Classifications and Criteria in New York and New Jersey waters*.

⁷ In addition to the two states, the Interstate Environmental Commission (IEC) has also adopted water quality regulations, that outline water classifications intended uses, and water quality standards supportive of those designated uses in the waters of the Interstate Environmental district which encompasses portions of the shared waters of New York, New Jersey, and Connecticut. These regulations can be found at www.iec-nynjct.org/do/water/regulations. IEC supports efforts to move towards more consistent standards in the shared waters.

Factors that Affect Water Quality in the Harbor Estuary

Under the Clean Water Act, the EPA recognizes two broad categories of pollution: point source pollution and nonpoint source pollution. Point source pollution is defined as any contaminant that enters the environment from an easily identified and confined single source. Common examples of point source water pollution are wastewater treatment outfalls and combined sewer system outfalls. Nonpoint source pollution, on the other hand, is where the source(s) of the pollutant are widely distributed or pervasive, and not as easily identifiable. The pollutant is likely carried over land by stormwater

runoff or seeping into groundwater, eventually making its way into local streams, rivers, the estuary, and ocean. Examples of nonpoint source pollution include litter, oil and grease, particles of tire rubber, pet waste (pathogenic bacteria), and fertilizers used in gardens or lawns. In the Harbor Estuary today, water quality is challenged by both point and nonpoint sources of pollution. In addition, the region's long history of industrial activity has left a legacy of toxic contamination in these waters.

Major Point Sources of Pollution

Publicly Owned Treatment Works (POTWs)

The most important point source discharges into the Harbor Estuary are from wastewater managed at publicly-owned treatment works (POTWs). There are 25 POTWs in the Harbor Estuary, each with a National Pollutant Discharge Elimination System (NPDES) permit. The NPDES permit, issued by the states and approved by EPA, dictates the quality and quantity of pollutants that pass through the POTW and discharge into the local waterways, including pathogenic bacteria and nutrients such as nitrogen. Of the 25 POTWs, 14 are in New York City, one is in Yonkers and 10 are found along the New Jersey coastline of the Harbor Estuary. Collectively, these 25 POTWs treat over two billion gallons of sewage per day from industrial and commercial sources and over 12 million residents. This volume does not include smaller discharges from publicly and privately-owned wastewater treatment facilities that discharge into freshwater streams, groundwater, or the Atlantic Ocean.

All wastewater that is treated by each of these POTWs receives both primary and secondary treatment per their respective NPDES permits. Primary treatment refers to the removal of coarse material by screening and settling, while secondary treatment refers to the biological and chemical digestion and removal of organic matter, followed by a final clarification. The wastewater is then disinfected with chlorine, or other disinfectant chemical, to remove pathogenic bacteria before it is discharged into a nearby waterbody through the permitted POTW outfall. Some POTWs also include tertiary treatment that aim to remove remaining inorganic compounds like nitrogen and phosphorus as well as dichlorination treatment to reduce chlorine from the effluent.

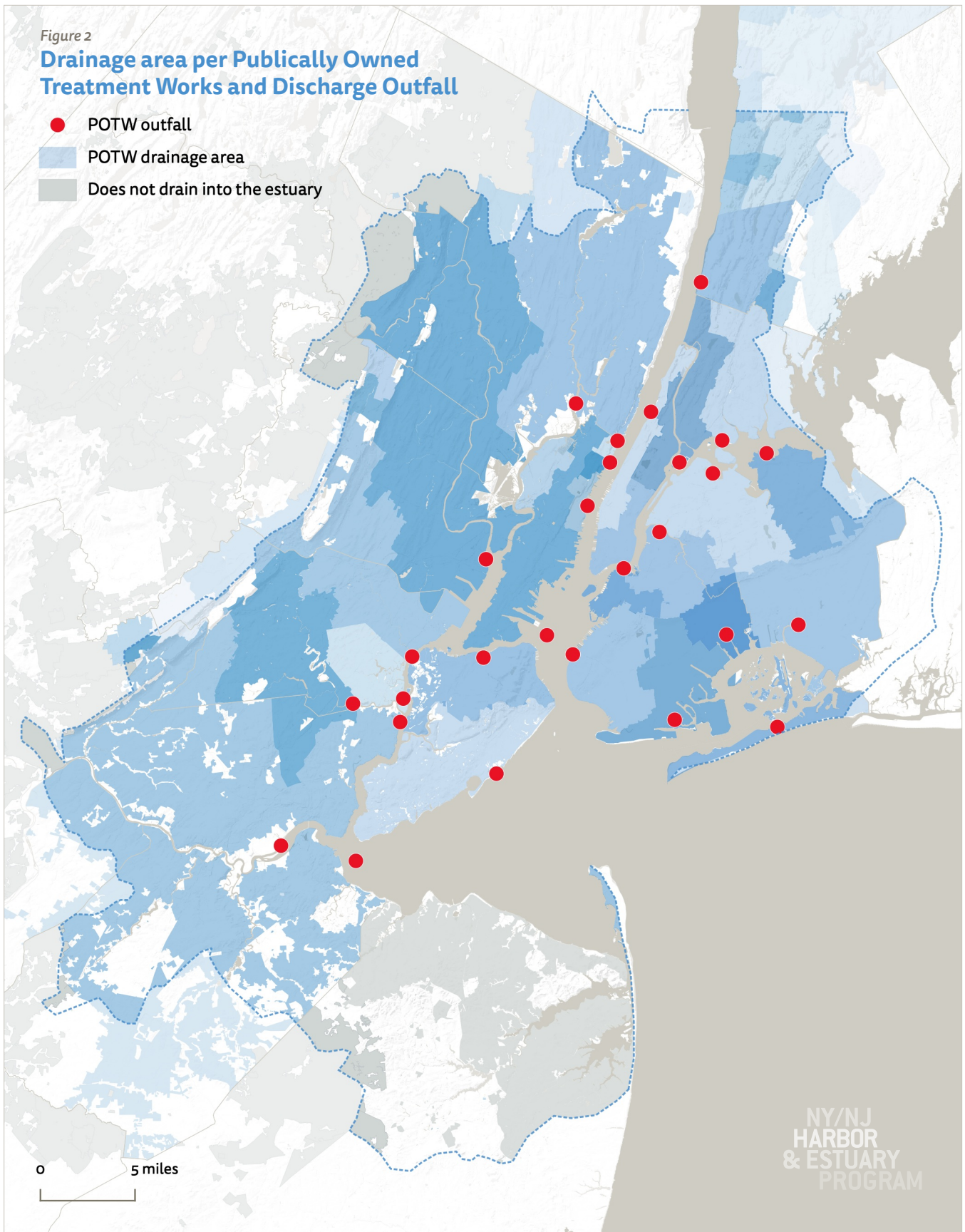


Left: Newtown Creek wastewater facility in Brooklyn, NY, credit: NYCDEP; right: Passaic Valley Sewerage Commission's (PVSC) wastewater facility in Newark, NJ, credit: PVSC

Figure 2

Drainage area per Publicly Owned Treatment Works and Discharge Outfall

- POTW outfall
- POTW drainage area
- Does not drain into the estuary

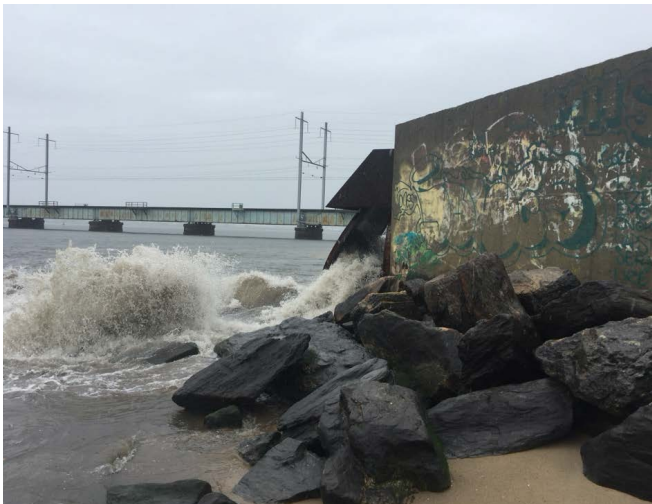


Combined Sewer Systems (CSS) or Combined Sewer Overflow (CSO)

For much of the region, wastewater arrives at the POTW through a combined sewer system (CSS): a complex of pipelines that collect both stormwater and sanitary waste (sewage) and sends the combined flows to a POTW for treatment. During heavy rainfall or snowmelt events, the excess volume of stormwater in addition to sanitary flows may exceed the capacity of the pipeline, the POTW, or both. When this occurs, the excess volume of mixed, untreated sewage water is discharged into a local waterbody. This is referred to as a combined sewer overflow (CSO) and the term CSO is commonly used to describe combined sewer systems. CSOs, common in older cities across the country, were designed this way to prevent flooding in streets and homes, and operational problems at the POTWs during wet weather events. There are 607 CSO outfalls across the estuary that discharge

an annual estimate of 43 billion gallons of stormwater and untreated sewage water into the estuary (NRDC, 2020; Jersey Water Works, 2018).

To address CSOs, permittees in both New Jersey and New York have developed and are currently implementing Long Term Control Plans (LTCPs) to identify and evaluate solutions for reducing the impacts of CSOs (NYCDEP, 2018; NJDEP, 2020). The NYCDEP has 11 LTCPs in varying degrees of development and approvals while in Yonkers, the Yonkers Joint Wastewater Treatment Plant completed their LTCP in 1995 for 13 CSOs. In New Jersey, 21 municipalities (17 of which are within the Harbor Estuary) and four utilities that have active CSO permits and are finalizing LTCPs in 2020.



Left: An active CSO discharging into the Raritan River in Perth Amboy, NJ, credit: Raritan Riverkeeper. Right: Volunteers helping to pick up marine debris (litter) along the shoreline of the Passaic River in Lyndhurst, NJ, credit: Christopher Brooks.



Municipal Separate Storm Sewer Systems (MS4)

In contrast to CSSs, municipal separate sewer systems (MS4s) are designed to address wet weather flows by separating the sanitary and wet weather flows. During rain or snowmelt events, the stormwater flows are collected in a series of separate sewer lines and discharged directly into a nearby waterbody through a stormwater outfall (SWO). The sanitary flows to the POTWs remain largely unaffected during wet weather events as they are in separate pipelines. Like CSSs, MS4s are also regulated under the NPDES to reduce pollution in stormwater runoff. Not only are MS4 permits issued to municipalities, but they are also issued to industrial and commercial facilities that need to obtain coverage for stormwater discharges. Sediments, nutrients (from fertilizers or otherwise), pathogens (bacteria and viruses), road salts, oils and grease, organic compounds and heavy metals, and litter are widely recognized as nonpoint source pollutants that may discharge directly into a waterbody during wet weather events as stormwater runoff. Residential and commercial properties, roadways and parking lots, agricultural operations, faulty septic systems, construction sites, and direct deposition from

the atmosphere as precipitation or settling dust all contribute these nonpoint source pollutants to stormwater runoff. These pollutants harm fish and wildlife populations, kill vegetation, and make recreational areas unsafe and unpleasant.

Once a pollutant is picked up by water from a sidewalk or other hard surfaces, it is most likely carried into a local waterbody without receiving treatment. Managing stormwater poses a number of challenges. In New Jersey, the state issued its MS4 permits and finalized its stormwater rules in 2004 while in New York City, the first MS4 permit was received in 2015 that aim to address the challenges posed by nonpoint source pollutants in these systems. Dominated by urban and suburban land uses, the watersheds of the Harbor Estuary are covered by buildings, pavement, and compacted landscapes. These impervious surfaces significantly reduce the amount of rain and snowmelt that can soak into the ground to be naturally filtered by soil and vegetation. In turn, there is a sharp increase in the volume and velocity of stormwater runoff that carries nonpoint source pollutants.

Illicit Discharges

In addition to nonpoint source pollutants, waterbodies are also challenged by illicit discharges. An illicit discharge is defined as an enclosed storm drain or open channel with a measurable flow of polluted water during dry weather (Brown, et al, 2004). Illicit discharges can happen when a sewage pipe breaks or cracks, causing sewage (i.e., pathogenic bacteria) to seep into the storm

drain and discharge into a local waterbody. However, not all dry weather flows constitute an illicit discharge. Dry weather flows can be relatively clean, if they originate from springs, groundwater seepage, or leaks from drinking water distribution pipes. Water quality sampling and track downs are needed to confirm whether pollutants are present and address their sources.

Legacy Toxic Pollution

The Harbor Estuary has a legacy of toxic contamination due to years of unregulated industrial pollution. These chemicals originated from electric capacitor manufacturing (polychlorinated biphenyls commonly referred to as PCBs), coal gasification (dioxins and volatile hydrocarbon compounds), coal-powered energy production (mercury), battery manufacturing (cadmium), herbicides and pesticide production and application (dioxins released from Agent Orange, dichlorodiphenyltrichloroethane or DDT, chlordane, and dieldrin), and many other industrial processes. The passage of the Clean Water Act in 1972, the Resource Conservation and Recovery

Act in 1976, and other federal and state laws greatly reduced the discharge of these chemicals into the Harbor Estuary. But these and other toxic chemicals still reside at high concentrations in the sediments, soils and groundwater of brownfields, landfills, and federally-designated Superfund sites throughout the watershed. Federal and state programs designed to clean up these legacy contaminants are actively working towards remediation at many sites across the estuary, but contamination is widespread and progress has been slow. The impact of industrial pollutants on water quality will continue to be a challenge for many decades to come.

Improving Water Quality in the Harbor

Investments in water pollution control programs have significantly improved water quality in the estuary. As indicated in HEP's 2018 State of the Estuary Report, water quality improvement is one of the Harbor Estuary's biggest success stories, with conditions improving over time for a number of parameters including pathogenic bacteria, dissolved oxygen, and nutrients (Stinnette, et al, 2018).

These improvements are the result of billions of dollars of investments in upgrading POTWs, implementing stormwater controls, and dredging and other remediation to remove or control legacy toxics (see figure 3). While water quality in the Harbor Estuary has markedly improved, additional investment is needed to address pollutants that continue to limit public use and impair the ecological health of the estuary and to realize the fishable, swimmable waters called for in the Clean Water Act.

Government, utilities, and landowners have already invested billions of dollars in an attempt to minimize and control CSOs over the last 40 years and will continue to do so for the foreseeable future. Between New York and New Jersey, 28 LTCPs will be developed by 2020 with the goal of meeting receiving waterbody

water quality standards. Implementation of these LTCPs will require additional financial support as well as continued coordination, collaboration, research and communication with the numerous stakeholders. MS4 permits, required of the 214 municipalities in the estuary, likewise require additional investment and actions to manage stormwater.

For example, the NYCDEP has estimated that \$45 billion in POTW and other wastewater infrastructure investments alone have been made since the 1970s, with plans for an additional \$6 billion of capital investments in the implementation of the City's 11 LTCPs. New Jersey ratepayers and local governments have made similar expenditures and are estimating between \$2.3 and \$2.8 billion in future costs of implementing 18 municipal LTCPs. Improving the public's common understanding of current water quality in the estuary, and how it compares to the standards and classifications that benchmark progress, would allow EPA and the States to establish specific metrics for success that resonate with the public. Such clarity is essential to advance these shared waters toward the Clean Water Act's fishable and swimmable goals.

INDICATORS	Long Term Trend	Short Term Trend
Dissolved Oxygen	↗	↗
Enterococcus	↗	~
Nitrogen	↗	↗
Water Temperature	↘	~
Debris Collected by Skimmers and Booms	●	↗
Debris Collected on Beaches	↗	↗
Microplastics	●	●
Chemical Contaminants of Emerging Concern	●	●

TREND IDENTIFIERS

- ↗ Indicates a trend that is improving in terms of environmental health
- ↘ Indicates a trend that is deteriorating in terms of environmental health
- ~ Indicates that the data are not trending, are stable or variable
- Indicates that there are insufficient data to determine a trend or that this type of analysis is not applicable



HEP's adopted water quality goal is to reduce the sources of pollution so that the waters of the Harbor Estuary will meet the fishable, swimmable goal of the Clean Water Act, where attainable. The indicators and trends (above) are from HEP's State of the Estuary report that show our progress.

Figure 3.

Timeline of major Clean Water Act investments and improvements

1970 – 1989	<ul style="list-style-type: none">1970 EPA was officially established to protect human health by safeguarding the air we breathe, water we drink and land on which we live.1972 Clean Water Act and the establishment of the National Pollution Discharge Elimination System (NPDES) permit program.1984 NYCDEP developed a city-wide CSO abatement program.1985 EPA, NYSDEC, and NJDEP initiated the Use Attainability Analysis to document the assessment of waters in the New York Harbor Complex.1986 NYCDEP opened the North River WWTP Facility.1987 NYCDEP opened the Red Hook WWTP Facility.1988 North Hudson Sewage Authority opened their Adams Street WWTP Facility.1989 EPA's Office of Water issued a National Combined Sewer Overflow Control Policy (54 Federal Register 37370)
1990 – 1999	<ul style="list-style-type: none">1991 Secaucus Municipal Utility Authority opened their WWTP Facility.1992 NYCDEP entered into an Administrative Consent Order with NYSDEC.1994 EPA issued a National CSO Policy requiring the development of CSO Long Term Control Plans (LTCs).1995 All POTWs conducted 100% treatment of dry weather sewage in the Harbor Estuary.1996 North Hudson Sewage Authority opened their West New York WWTP Facility.1997 New York and New Jersey signed on to HEP's Comprehensive Conservation Management Plan.1999 NJDEP required all CSO permit holders to implement floatable controls. Congress directed the U.S. Army Corps of Engineers to develop a long-term Comprehensive Restoration Plan for the Hudson-Raritan Estuary.
2000 – 2009	<ul style="list-style-type: none">2000 EPA's National CSO Policy became law.2003 New Jersey CSO permit holders completed installation of floatable controls.2004 NJDEP's General CSO Permit updated to require the Nine Minimum Controls.2004 NJDEP finalized its stormwater rules and issued MS4 permits to municipalities and industrial facilities.2005 NYCDEP entered into a CSO consent order with NYSDEC to develop 11 waterbody/watershed facility plans. New Jersey Harbor Dischargers Group established a harbor-wide water monitoring program in NJ's portion of the harbor.

FACTORS THAT AFFECT WATER QUALITY IN THE HARBOR ESTUARY

2000 – 2009	<p>2006 Adoption of the System-Wide Eutrophication Model (SWEM) by NYSDEC and NJDEP.</p> <p>2006 NYSDEC issued a Nitrogen Consent Order in the Long Island Sound / East River and Jamaica Bay with NYCDEP and approved by EPA.</p> <p>2007 NYCDEP commissioned the Flushing Bay CSO Facility.</p>
2010 – 2019	<p>2010 NYCDEP published the NYC Green Infrastructure Plan.</p> <p>2011 NYCDEP commissioned Paerdegat and Alley Creek Facilities.</p> <p>2012 NYCDEP received approval from NYSDEC on the modified CSO consent order which incorporates green infrastructure and commits to 11 LTCPs.</p> <p>2015 NJDEP issued new CSO Permits requiring LTCPs.</p> <p>2015 NYSDEC issued an MS4 permit to NYCDEP.</p> <p>2017 NYCDEP received approval for the following LTCPs: Alley Creek, Westchester Creek, Hutchinson River, Flushing Creek, Flushing Bay, Bronx River, and Gowanus Canal. NYCDEP completed nitrogen controls in the Long Island Sound/East River Consent Order.</p> <p>2018 NYCDEP received approval for the following LTCPs: Coney Island Creek and Newtown Creek; and is pending approval for Jamaica Bay and Tributaries. New York and New Jersey sign on to HEP's Comprehensive Conservation Management Plan.</p>
2020 – 2030	<p>2020 NYCDEP submitted an LTCP for the City-wide/Open Waters. NJDEP received LTCPs from 25 CSO permittees in the state, 18 of which are within the Harbor Estuary. New Jersey's 25 CSO permit holders planned capital investments between \$2.3-2.8 billion dollars to implement LTCPs, based upon draft LTCPs subjected to future NJDEP review and approval.</p> <p>2022 NYCDEP to complete nitrogen removal upgrades in Jamaica Bay per the 2006 Consent Order.</p>

Data Sources and Assessment Methodology

Water quality monitoring provides the evidence necessary for policy experts, water managers and the public to make sound decisions regarding the effectiveness of policies such as the NPDES CSO Control Policy. Monitoring improves our understanding of whether water quality is getting better or worse over time, and to alert the community of both existing and emerging problems that require action to protect human health and the environment. For the purpose of this report, the water quality of the Harbor Estuary is assessed using federal recreational water quality recommendations, considering the estuary relative to the standards of waters suitable for swimming and other primary contact recreation (see *Is the Harbor Estuary Swimmable and Fishable?* section of this

report). Water quality data are assessed relative to the state standards and designated uses in 10 principal regional waterbodies of the Harbor Estuary (see *Regional Waterbody Summaries* section of this report). These principal regional waterbodies reflect the recommendations from the five technical work groups and committees organized by HEP and past HEP publications, including the last Harbor-Wide Water Quality Monitoring Report. By combining these two considerations, this report provides a common basis for understanding current data and will help advance discussion of appropriate policies in the shared efforts to achieve the Clean Water Act goals of fishable and swimmable waters, where attainable⁸.

8. This report does not serve to replace New York's or New Jersey's Integrated Water Quality Reports, nor is it meant to be used for compliance purposes.

Survey Regions and Sampling Sites

There are a number of water quality monitoring programs undertaken by federal, state, and municipal agencies; water and wastewater utilities; and scientists and citizen scientists across the Harbor Estuary⁹.

To assess water quality, monitoring data were gathered from two comprehensive harbor-wide monitoring programs: the NYCDEP and the NJHDG harbor surveys. Where available, data from the Interstate Environmental Commission (IEC), Meadowlands Environmental Research Institute (MERI), Hudson River Environmental Observing System (HRECOS), New Jersey Department of Environmental Protection (NJDEP), and the United States Geological Survey (USGS) were reviewed to further assess water quality as indicated by the two comprehensive harbor-wide programs. This report is organized by 10 regional waterbodies. These include:

- Bronx River and the Western Long Island Sound
- East River and Harlem River
- Jamaica Bay
- Lower Passaic River and Newark Bay
- Hackensack River
- Lower Raritan River
- Lower Hudson River
- Upper New York Bay
- Arthur Kill and Kill van Kull
- Lower Bay (includes Raritan Bay, Sandy Hook Bay, and the Lower New York Bay)

Methodology

These data were analyzed from June 1st through September 30th for the eight years from 2010 to 2017¹⁰. Figure 4 highlights the number of sampling stations in the Harbor Estuary and identifies the stations used in this assessment. Data from these sampling stations within each region were consolidated to create one “master station” for each region and present results for that waterbody. Monitoring occurred on a weekly basis using grab samples within the water column. Typically, both a top and bottom water sample is collected, or if the waterbody is too shallow, one meter from the bottom. Sampling locations are typically determined by areas of concern, upstream and downstream of wastewater discharges, and/or tributary entrances. Pathogenic standards are based on five samples taken within a 30-day period for regulatory purposes and dissolved oxygen standards include durational concentrations, which were not explored and a limitation to this report. This methodology does not allow for true comparisons between the data and water quality standards and the report should not be used for regulatory compliance. Please note that this analysis is solely focused on the critical recreational season (although data are collected year-round). While water quality parameters are displayed individually, reviewing parameters holistically offer important insights to the status of the waterbody. Data from smaller tributaries of the Harbor Estuary, such as the Second River or Newtown Creek, were not included in the assessment as these enclosed and confined waterbodies and their existing impairments are not as representative of the conditions in the overall regions as the downstream sampling stations. It is important to note that the generally poorer quality of water in these enclosed and confined waterbodies is the subject of considerable attention by the public, water managers, and regulatory agencies. For more information about enclosed and confined waterbodies, the *Hudson-Raritan Estuary Comprehensive Restoration Plan* (www.hudsonriver.org/article/hrecrp) details what is desirable and achievable for these waterbodies.

⁹ For additional information, HEP’s 2018 State of the Estuary report utilizes the best available data from these programs to illuminate both long-term (roughly 30 years) and shorter-term trends for water quality, habitat, toxics, and other parameters. HEP’s Environmental Monitoring Plan identifies and inventories monitoring programs and makes data available while also identifying priorities for future environmental monitoring, including gaps in currently available data for parameters such as pathogenic bacteria and dissolved oxygen. Past TMDL efforts and reports for the Harbor Estuary on pathogens, dissolved oxygen, nutrients, toxic contaminants and trace metals are available at www.hudsonriver.org/article/tmdl.

¹⁰ Dates were selected as a reflection of high recreational activity, though it is noted that both New York City and the state of New Jersey define the recreational season differently from the dates chosen for this report.

Figure 4

Harbor Estuary Sampling Regions

Primary stations used in analysis

● NJHDG sampling site

● NYCDEP sampling site

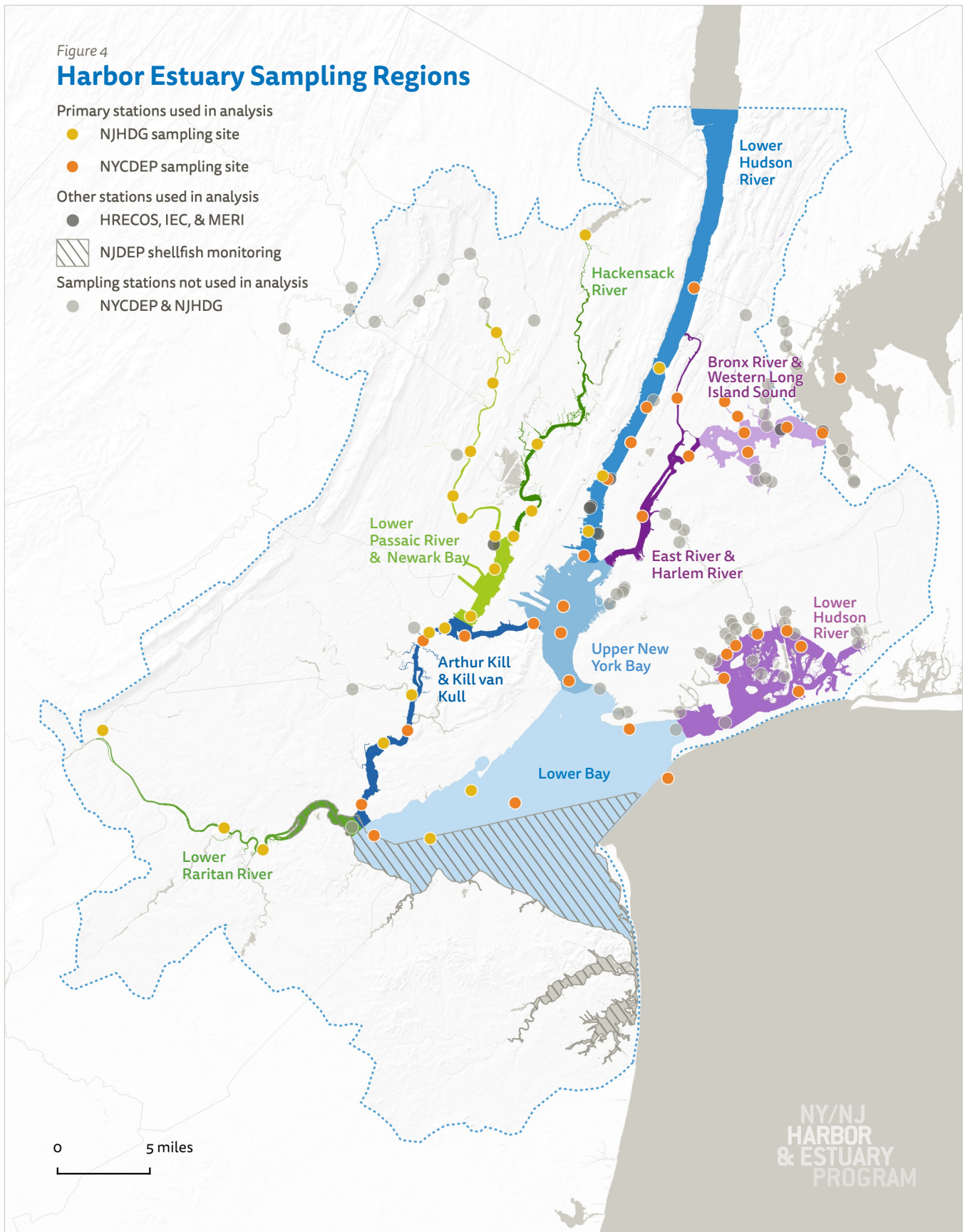
Other stations used in analysis

● HRECOS, IEC, & MERI

▨ NJDEP shellfish monitoring

Sampling stations not used in analysis

● NYCDEP & NJHDG





City of Water Day – In Your Neighborhood Event at the Hoboken Cove Community Boathouse, credit: Rob Pirani

Is the Harbor Estuary Swimmable and Fishable?

The quality of the water in the Harbor Estuary is described using four key parameters: pathogens, dissolved oxygen, total nitrogen, and chlorophyll-*a*.

To make this assessment, data from individual sampling stations from 2010-2017 were aggregated into a single master station for each of the 10 regional waterbodies in the Harbor Estuary. The data, primarily from June 1 through September 30, were compiled from two comparable harbor surveys conducted by NYCDEP and by the NJHDG (see Data Sources and Assessment Methodology section of this report).

To understand how swimmable our waters are, this information was compared against federal recreational water quality recommendations for pathogens, as if the estuary were considered a bathing beach. To generally determine the quality of these waters for fish and wildlife (or how fishable they are), EPA and other nationally recognized standards for dissolved oxygen, total nitrogen, and chlorophyll-*a* are used. Together, along with the many factors that impact water quality (see Factors

that Affect Water Quality in the Harbor Estuary), these parameters provide a holistic evaluation of how fishable and swimmable are the waterbodies in the Harbor Estuary.

Overall water quality in the Harbor Estuary is improving. The degree of improvements varies from parameter to parameter, where some areas of the estuary have a dissolved oxygen problem and others a pathogen problem. Conditions overall are improving and we expect improvements to continue as NYCDEP and New Jersey municipalities collectively work to reduce combined sewer overflows, improve POTW discharges, and continue to address stormwater discharges.

This report does not serve to replace New York's or New Jersey's Integrated Water Quality Reports, nor is it meant to be used for compliance purposes. State standards that inform water quality trends and advancement towards the goals of the Clean Water Act are also used when exploring the 10 principal geographic regions in the next section, *Regional Waterbody Summaries*.

Pathogenic Bacteria

Enterococcus

The number of recreational days deemed acceptable for primary contact between June 1 and September 30 is increasing over time in the majority of the Harbor Estuary. The data in the Lower Passaic River and Newark Bay, Hackensack River, and the Lower Raritan River presents a less consistent picture. In these regions, a noticeable positive decrease was observed between 2012 through 2015 followed by a negative increase in 2016 and 2017. This assessment is based on monthly averages (the 30-day geometric mean concentrations) of *Enterococcus* bacteria in the 10 regional waterbodies of the Harbor Estuary as well as how often the level of this pathogenic bacteria was found to be unsafe in individual samples (the Standard Threshold Value or STV).

The 30-day geometric mean concentrations are compiled for the master station in the 10 principal regional waterbodies for each year between 2010 and 2017. Figure 5 illustrates the percent of time, or summer days, that the geometric mean exceeds the threshold of 35 cfu/100 mL for safe primary contact activities¹¹.

Six of the 10 regional waterbodies in the Harbor Estuary have a geometric mean of *Enterococcus* that is decreasing over time.

In addition to the 30-day geometric mean value, EPA's 2012 recreational water quality criteria also calls for a STV, which indicate the frequency of pathogen levels found in samples. If 10% or more of samples (the 10th percentile) from the sampling period exceed 130 cfu/100 mL, then the water is deemed unsafe for primary recreation like swimming. Figure 6 illustrates the percentiles of all discrete samples taken between June 1 and September 30 of each year (2010-2017) that are found to be greater than 130 cfu/100 mL. Throughout the eight years, about half of the 10 regional waterbodies in the estuary consistently exceed the 10th percentile. The Lower Passaic River and Newark Bay and the Lower Raritan River remain over the 10th percentile for all the years assessed, while the Hackensack River, East River and Harlem River, and the Bronx River and Western Long Island Sound regions fluctuate between just below the 10th and just above the 20th percentiles from year to year.

Enterococcus

Percent Summer Days, 30 - Day Geomean Above 35 cfu/100 ml

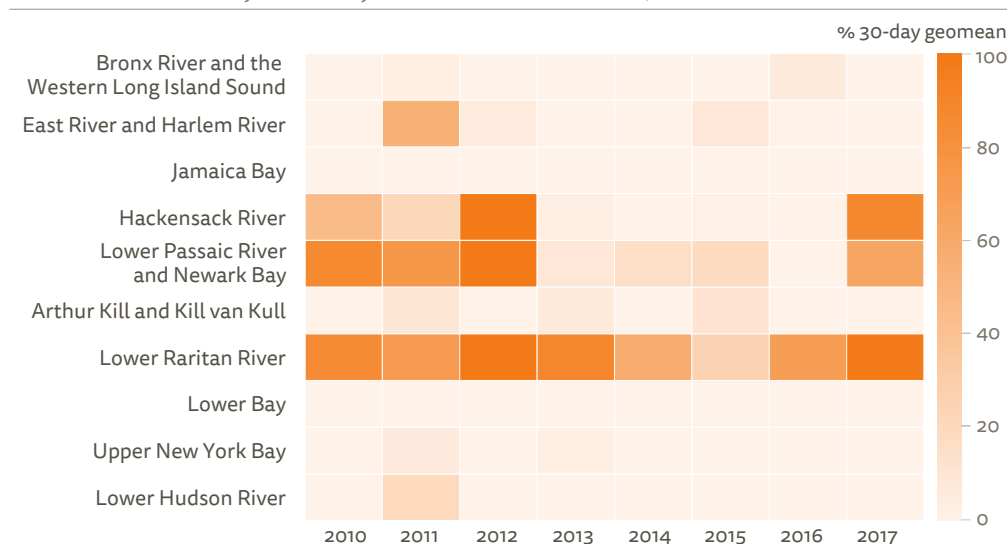


Figure 5. Changes in *Enterococci* 30-day geometric mean analysis showing percent of time (days) where the geometric mean is greater than EPA's 2012 Recreational Water Quality Standard of 35 cfu/100 mL over the summer season for each sampling year.

¹¹ It is important to note that there are discrete samples greater than 35 throughout the Harbor Estuary in each summer period. When computing the 30-day geometric mean, the distributions of those high value samples are not necessarily greater than 35 cfu.

There are variables that make it more difficult for every waterbody in the estuary to achieve the fishable and swimmable goals of the Clean Water Act. There are discharges of point and nonpoint source pollutants into the water, including pathogens like *Enterococci*, during wet weather events. Generally, the more urbanized the watershed, the more polluted the stormwater runoff. Rainfall intensity and storm duration affect the quantity and variability of runoff and, therefore, the pathogen loadings from land sources. The median summer season precipitation throughout the 2010-2017 timeframe was 12.89 inches of rain (NOAA, 2020). The spikes seen in 2011 are likely due to increased precipitation from two tropical storms, Hurricane Irene and Tropical Storm Lee. The 31.7 inches of rainfall that fell from June 1 through September 30 make 2011 it the wettest year of the study period. In addition, *Enterococci* levels in New Jersey waters are typically higher than in New York waters largely due to less dilution relative to the pathogen loadings in these waterbodies but also contributed to the influence of the tidal cycles, water circulation, salinity distribution, freshwater inputs, and higher ambient water temperature (Wen, et al, 2017). Large volume of tides in areas like the Hudson River allow for greater and faster

flushing of pathogens out to more open waters. The areas in the Harbor Estuary that show the most fluctuation and impact of *Enterococci* levels are seen in the Lower Passaic River and Newark Bay, Hackensack River, Lower Raritan River, East River and Harlem River, and the Bronx River and Western Long Island. The many small tributaries of these waterways likely influence the level of pathogens seen in this analysis.

Enterococcus is more likely to survive longer in highly saline waters due to their slow decay rate, and is correlated to swimming-associated illnesses. To measure Enterococcus, EPA's 2012 Recreational Water Quality Criteria looks at two values, a geometric mean and a statistical threshold value (STV). A geometric mean (weighted average of multiple samples) should not exceed 35 or less colony-forming units (cfu) of Enterococci per 100 milliliters (mL) of water (35 cfu/100 mL) for primary contact activities (i.e., swimming). The STV expresses the duration and frequency of the samples and if the STV exceeds 130 cfu/100 mL by more than 10% of all water samples, then the pathogens exist at harmful levels and is not protective of public health.

Enterococcus

Percent Discrete Samples Exceeding 130 cfu/100 ml

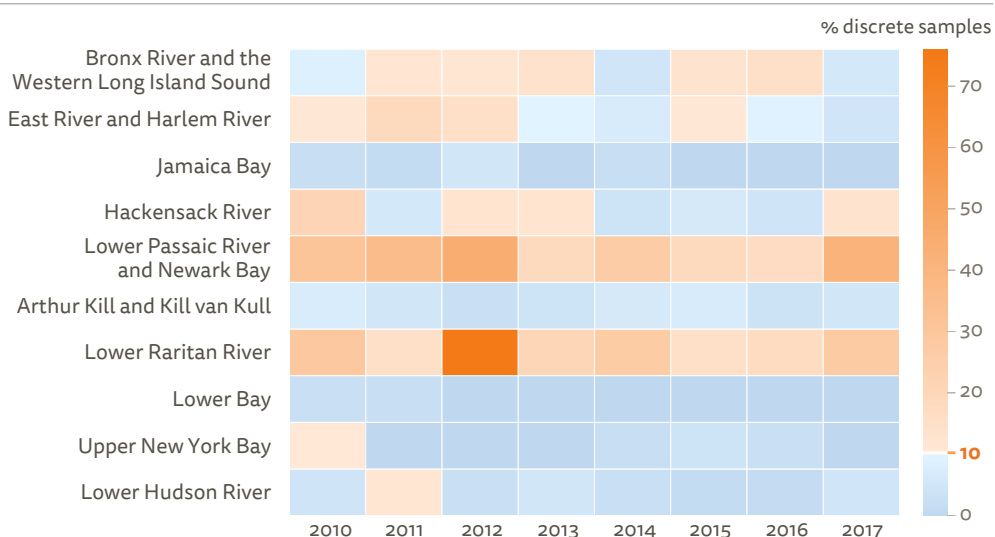


Figure 6. Frequency (shown as percentiles) of all discrete *Enterococci* samples taken during June 1 and September 30 that are greater than EPA's 2012 Recreational Water Quality Standard's statistical threshold value (STV) of 130 cfu/100 mL for each year.

Pathogenic Bacteria

Fecal Coliform

Levels of fecal coliform bacteria (another pathogen) generally improved over time indicating the suitability of water for contact recreation. While fecal coliform has been used historically in the Harbor Estuary, and thus allows for long-term comparison, it is more typically used today as a parameter in fresh water systems. Figure 7 illustrates the changes in fecal coliform seasonal geometric means as calculated over the summer recreational season (June 1 – September 30) for each sampling year¹². In 2011, fecal coliform levels are at least double for almost all waterbodies in the Harbor Estuary. This could be indicative of the high precipitation from the two tropical storms, Hurricane Irene and Tropical Storm Lee, that year. The Lower Passaic River and Newark Bay also showed a notable spike in 2017. Several high discrete measurements were found in this region throughout the summer season, pointing to some notable source(s) of pathogenic bacteria.

Fecal coliform is typically used as a parameter in waterbodies that are deemed suitable for secondary contact, including on-water recreational activities like kayaking or rowing. In 1976, EPA announced safety standards for acceptable levels of fecal coliform to protect public health. They recommended that fecal coliform levels should not exceed a geometric mean of 200 cfu/100mL and that no more than 10% of all samples taken in a 30-day period exceed 400 cfu/100 mL.

Fecal Coliform

Summer Geometric Mean

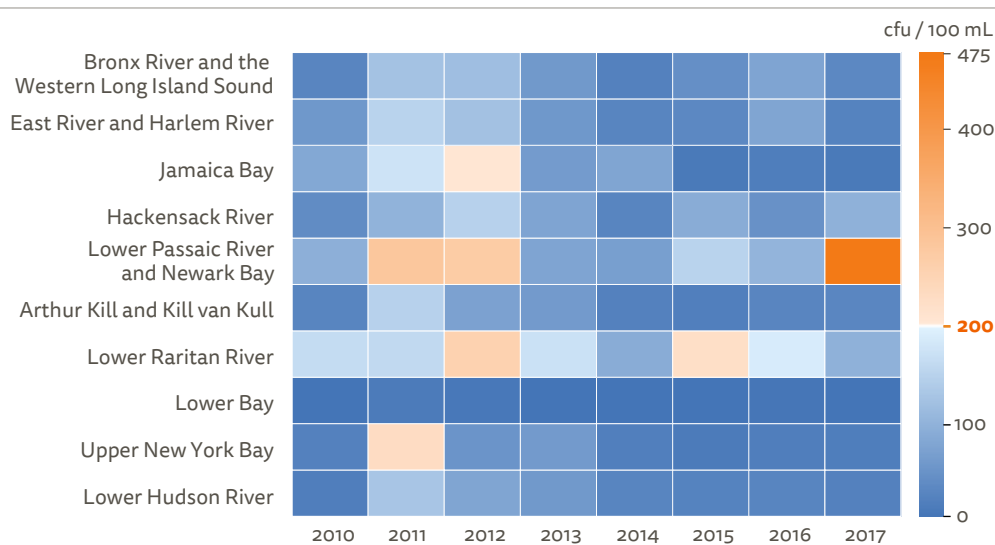


Figure 7. Fecal coliform seasonal geometric mean concentrations in cfu per 100 mL over the summer recreational season for each sampling year.

¹². This analysis builds upon the last Harbor-Wide Water Quality Reports, published in 2006 and 2011, to assess fecal coliform from 2004-2006 and 2007-2009 respectively, where seasonal geometric means were assessed for each summer period per year.

Dissolved Oxygen

Minimum levels of dissolved oxygen (DO) appear to be improving throughout the estuary over time. This is indicated by values related to average chronic conditions that generally stress fish as well as values associated with episodic acute conditions that can cause fish kills. But ensuring fish survival during critical times of the year is still an issue for some waterways.

The level of DO in most of the estuary, critical for fish and other aquatic organisms, is generally greater than the EPA threshold for chronic hypoxia (4.8 mg/L). In seven of the 10 waterbodies, the number of individual samples where DO was below 4.8 mg/L ranges between 5% and 20%. The areas where fish are most consistently stressed are the Hackensack River and the Bronx River and Western Long Island Sound. About 60% of the samples from the Hackensack River showed conditions indicating chronic hypoxia. It is important to note that data collected from 2015-2017 by the IEC for Western Long Island Sound also show low DO levels, but higher percentages of discrete DO samples found below 4.8 mg/L than the NYCDEP's harbor survey.

Figure 8 captures the changes in the seasonal average and the range of discrete samples of DO at the bottom layer throughout the Harbor Estuary, where each minimum value per seasonal year represents at least one sampling event. On average, DO values generally increase in the open waters, whereas there is more fluctuation of the percentage of samples below 4.8 mg/L in the more confined waterbodies of the Lower Passaic River and Newark Bay. The lowest minimum DO samples are found largely

in Jamaica Bay and the Bronx River and Western Long Island where values were found to be below 1.0, much lower than the acute hypoxic threshold of 2.3 mg/L where marine life begin to die off.

These findings are similar to the long term trends (1950-2016) presented in HEP's 2018 State of the Estuary report, which showed that low DO occurrences have decreased significantly throughout the Harbor Estuary over time. This is likely due to POTW upgrades and improved sewer system maintenance that are decreasing nutrient loads to local receiving waters, thereby reducing algal growth.

The level of dissolved oxygen (DO) in the water is used as a measure for habitat quality for fish and other aquatic organisms. Hypoxia (low dissolved oxygen) is most commonly problematic in slow-moving tributaries, bays, and deeper parts of the estuary where the water is not well mixed. There are two threshold values for hypoxia: acute hypoxia, the DO level at which marine life has a greater potential to die, is indicated when water has less than 2.3 milligrams of DO per liter (mg/L); and chronic hypoxia, the continuous level at which DO hinders growth of marine life and is indicated by DO levels less than 4.8 mg/L. To get a more complete picture of DO throughout a given waterbody, DO is measured at both the surface layer and bottom layer of the water column. Typically, the lowest DO concentrations occur in the bottom layer due to the lack of interaction with the atmosphere and oxygen-demanding microorganisms in the sediment.

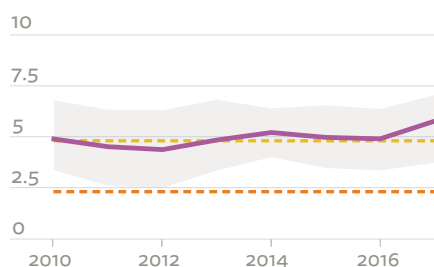
IS THE HARBOR ESTUARY SWIMMABLE AND FISHABLE?

Dissolved Oxygen, Summer Bottom Mean

New York Waters

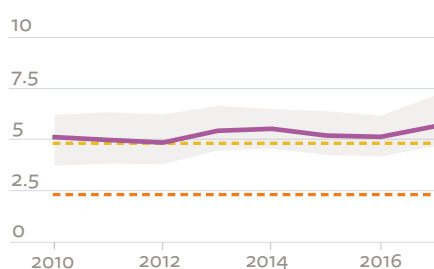
Bronx River and Western LIS

12.5 mg/L concentration



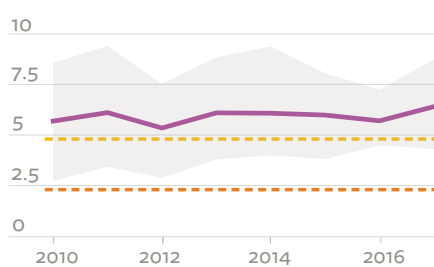
East River and Harlem River

12.5 mg/L concentration



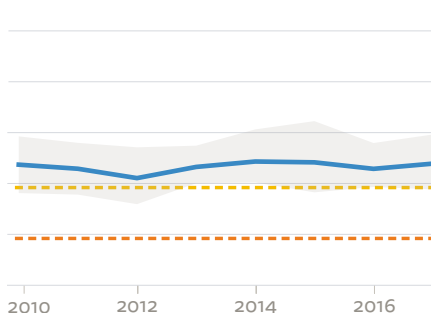
Jamaica Bay

12.5 mg/L concentration

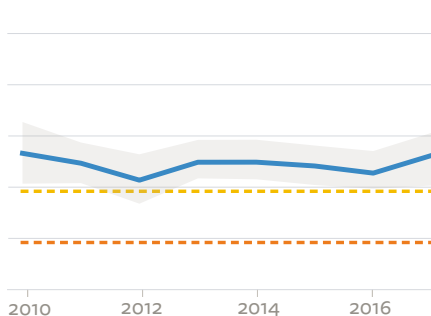


Shared Waters

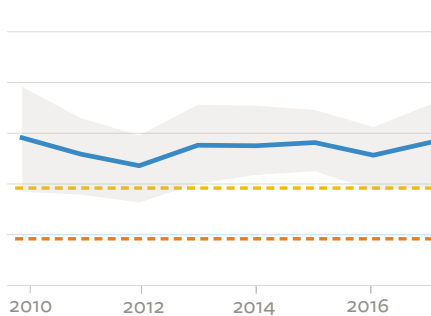
Lower Hudson River



Upper New York Bay

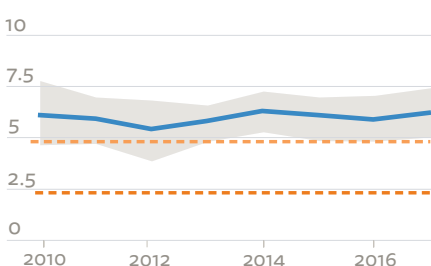


Lower Bay



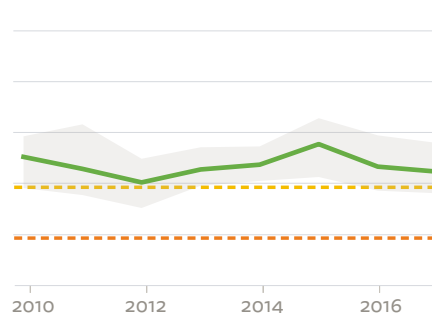
Arthur Kill and Kill van Kull

12.5 mg/L concentration

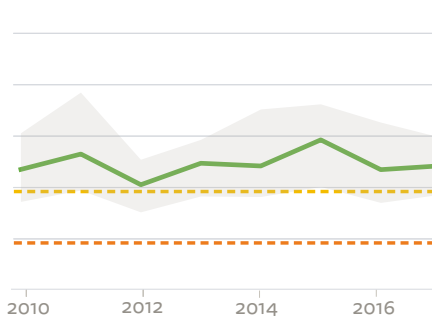


New Jersey Waters

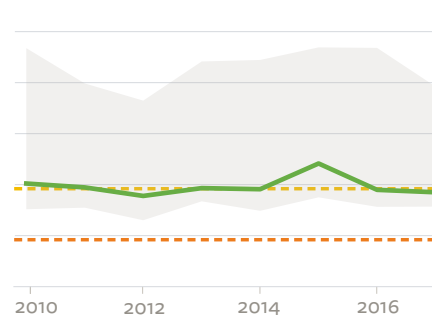
Lower Passaic River and Newark Bay



Lower Raritan River



Hackensack River



Summer mean, bottom, mg/L

Sample range 10-90th percentile, bottom, mg/L

EPA guidance criteria:

- Values below 4.8 mg/L are Hypoxic
- Values below 2.3 mg/L represent Acute Hypoxia

Figure 8. (left) Changes in seasonal average DO concentration (bottom layer) and the lowest discrete sample value from 2010-2017 over the summer season. See chapter 6 for a more detailed view of Dissolved Oxygen in each waterbody.

Dissolved Oxygen, continued

The DO grab sampling utilized in this report only provides a snapshot of DO levels for a given time of day. However, DO is influenced by many variables: amount of sunlight promoting photosynthesis, tidal cycle, water temperature (stimulating or impeding phytoplankton growth), season, and depth of water (IEC, 2018). These factors can change the concentration of DO, even in a 24-hour period. Continuous monitoring programs, like the Hudson River Environmental Conditions Observing System (HRECOS), that collect water quality data on a 15-minute interval can provide a more accurate picture of DO in the estuary as shown in Figure 9.

HEP's Environmental Monitoring Plan inventories monitoring programs to make data accessible while also identifying priorities for future environmental monitoring, including gaps in currently available data for parameters such as DO. Expanding the number of the monitoring sites, especially in the Upper New York Bay or the Arthur Kill and Kill van Kull is a recommendation in the plan that would allow managers to capture early morning DO levels where DO is known to be at its lowest.

Dissolved Oxygen in Newark Bay,
One Week Continuous Monitoring, 2016

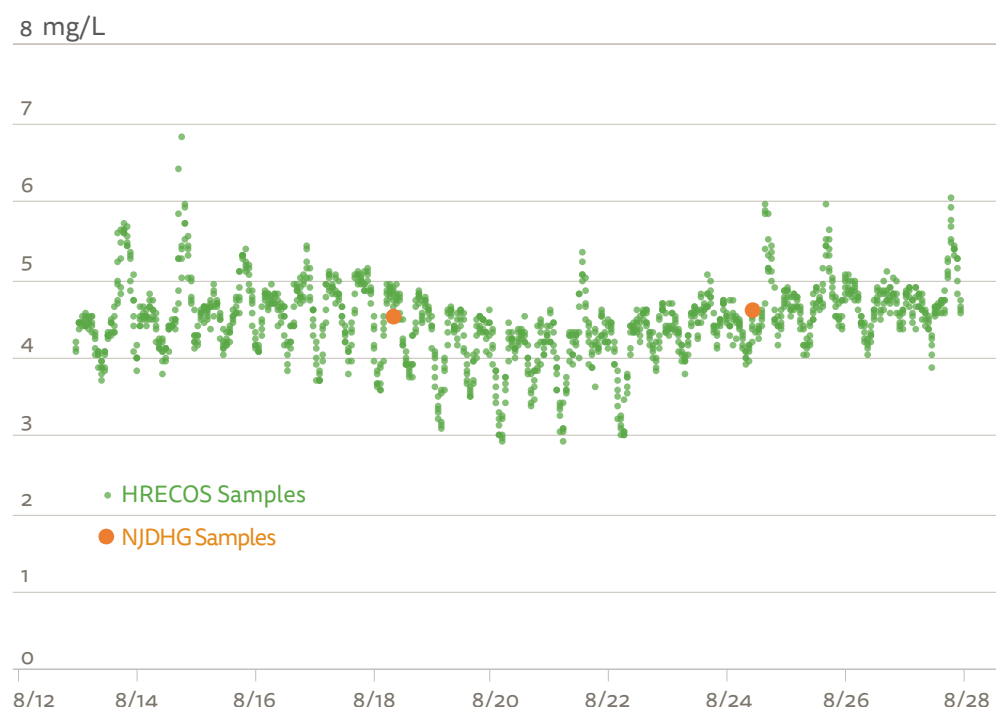


Figure 9. Continuous Dissolved Oxygen in Newark Bay

Total Nitrogen

Nitrogen is a key nutrient for algal and plant production. The loading of excessive nutrients in a waterbody can lead to algal blooms that deplete oxygen in the water as the algae die and decompose, potentially impacting fish survival. Some of these blooms can produce toxins, often called harmful algal blooms (HABs) and can pose a threat to people and wildlife as well.

Over the eight year period across the estuary, total nitrogen levels have decreased (a positive indication to the quality of these waterbodies), and most of the estuary is below the 1.2 mg/L threshold that indicates poor conditions. However, there are several exceptions, and considerable fluctuation over the eight-year period, making it difficult to identify a definitive change in total nitrogen concentration over the study period of this report. The short term and long term trends of average annual nitrogen concentrations in the Harbor Estuary were found to be trending down significantly in the 2018 State of the Estuary Report.

Figure 10 displays the changes in total nitrogen concentrations in the recreational season over time. Utilizing guidance by the MTAC for tidal tributaries and estuaries, levels of total nitrogen exceeding 1.2 milligrams per liter (mg/L) is considered to be poor, and levels found equal to or less than 0.4 mg/L is considered to be good.

Nutrient loading in the estuary, particularly the loading of nitrogen and phosphorus, is largely contributed by POTWs and municipal separate storm sewer systems where runoff from lawns and farms carry fertilizer that enter into a local waterbody (Taillie, 2019). It is not surprising that the data shows high levels of nitrogen in the tributaries of the estuary, such as the Lower Raritan River and the Hackensack River, while lower nitrogen concentrations are found in the waterbodies that are well flushed by the incoming tides.

Total Nitrogen
Summer Mean

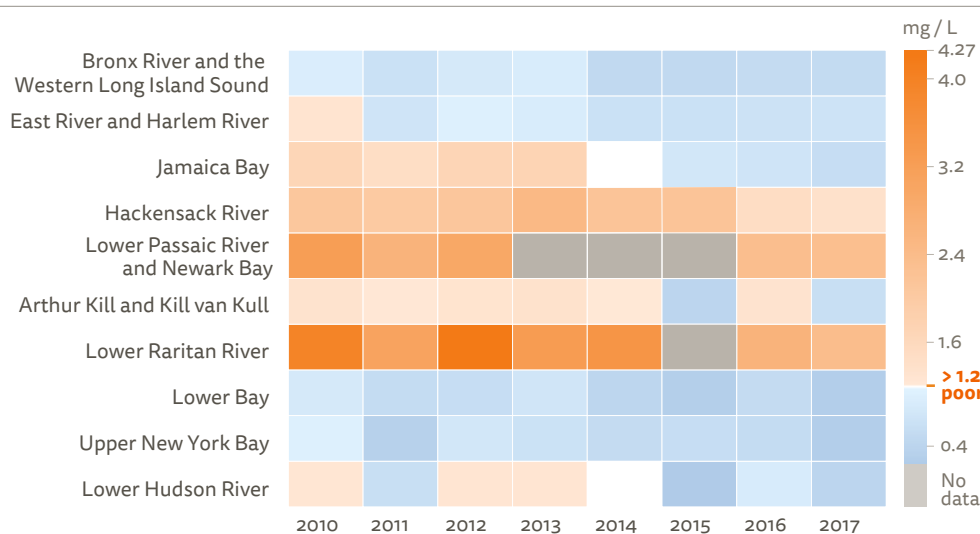


Figure 10. Change in total nitrogen concentrations, represented as mg/L seasonal means, over the recreational season. Please note 2015 data in New Jersey was not included due to quality assurance and control procedures that make the data unusable.

Chlorophyll-a

Chlorophyll-a is a general indication of the amount of microscopic photosynthetic algae that consume nutrients (like nitrogen) that are present in the waterbody. High levels of algae can reduce the amount of oxygen available to fish and may lead to excessive, and sometimes toxic, algal blooms.

There are many factors that impact the amount of chlorophyll-a in the water column including nutrient concentration, light intensity, light penetration, temperature and hydrodynamics (residence time) of the waterbody. In the Harbor Estuary, chlorophyll-a levels have a high degree of variability over time. As with total nitrogen, chlorophyll-a concentrations in the open waters of the estuary (where there is more tidal flushing) are consistently lower and are better able to support fish survival and propagation. Shallower bays with greater light penetration,

like Jamaica Bay, are more susceptible to algae growth. Since algal respiration removes oxygen from the water column, especially at night, it is not surprising that Jamaica Bay also has the lowest DO minimums (see Figure 8).

EPA's NCCA program uses a chlorophyll-a threshold of greater than 20 micrograms per liter ($\mu\text{g/L}$) to indicate poor quality while considering values of less than 5 $\mu\text{g/L}$ as supportive of healthier habitats for fish survival and propagation. Figure 11 highlights the changes in chlorophyll-a concentrations over time. Blooms are typically seen in summer months, though some do occur in the spring and fall. The 90th percentile of chlorophyll-a concentrations provide insight into when higher intensity algal blooms may occur.

Harmful algal bloom (HABs) identified in marine waters, photo credit: NJDEP.

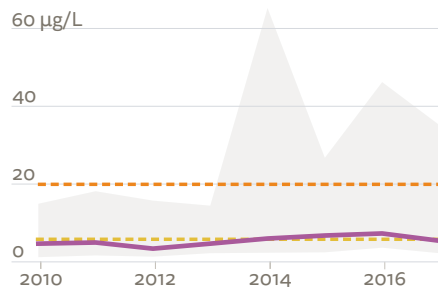


IS THE HARBOR ESTUARY SWIMMABLE AND FISHABLE?

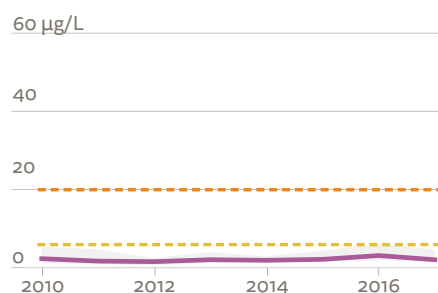
Chlorophyll-a, Surface

New York Waterbodies

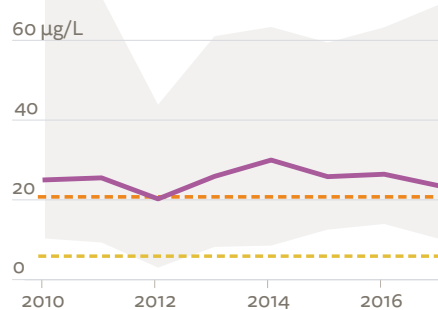
Bronx River and Western LIS



East River and Harlem River

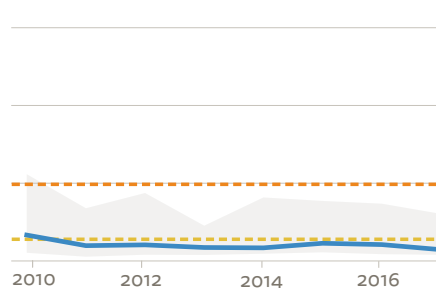


Jamaica Bay

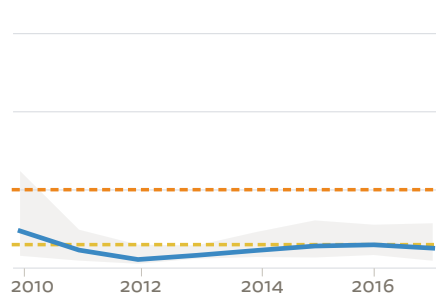


Shared Waters

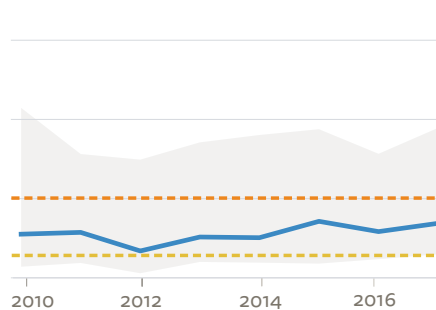
Lower Hudson River



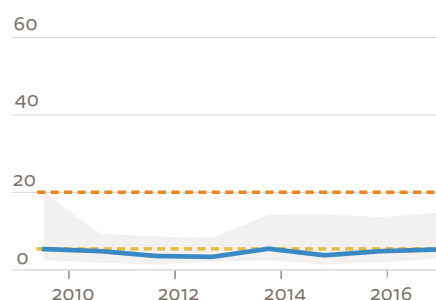
Upper New York Bay



Lower Bay

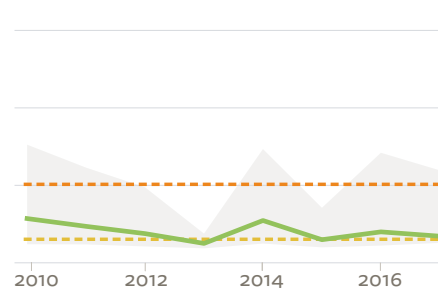


Arthur Kill and Kill van Kull

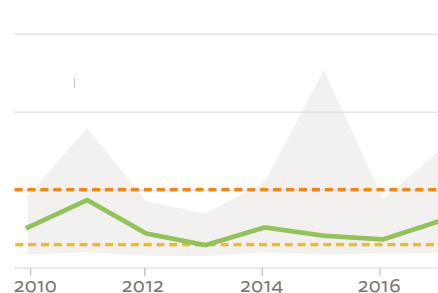


New Jersey Waters

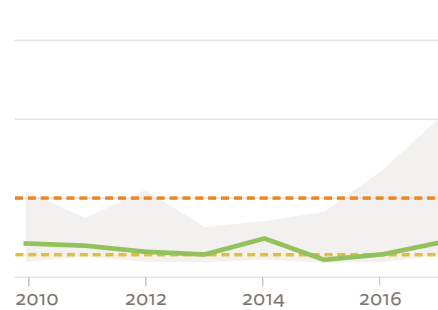
Lower Passaic River and Newark Bay



Lower Raritan River



Hackensack River



Mean Chlorophyll-a

90th percentile range of discrete samples

EPA guidance criteria:

Values above 20 µg/L are poor

Values above 5 µg/L are fair, below are good

Figure 11. Changes in chlorophyll-a concentration (in µg/L) 90th percentile computed over the summer season for each sampling year.

Regional Waterbody Summaries

Water quality varies across the 10 regional waterbodies of the Harbor Estuary. There are a number of challenges to consider when determining safe use and how best to make future investments towards achieving the Clean Water Act's fishable and swimmable waters goals.

The following section will explore water quality and some of the key challenges and opportunities for improvement in each of the 10 regional waterbodies of the Harbor Estuary. Water quality is described using New York's and/or New Jersey's standards and criteria as of 2020 for pathogens (fecal coliform, *enterococci*, and *E. coli*) and DO. Proposed rulemaking to amend standards and/or criteria introduced by the states are not explored in this report. In the case where multiple water quality standards are used in a region, the highest criteria that is supportive of primary or secondary contact is displayed as the threshold. The following parameters are used for swimmable waters: pathogen levels must meet a state's criteria and designated use (i.e., supporting secondary or primary contact recreation) and the potential future standard of *Enterococcus* is also discussed where applicable. For fishable, in terms of stress to fish and their habitat, dissolved oxygen levels must meet and exceed the state's criteria and levels of total nitrogen and chlorophyll-*a* must show at least fair conditions to support aquatic life.

Data from individual sampling stations from 2010-2017 were aggregated into a single master station for each of the 10 regional waterbodies. This data, primarily from June 1 through September 30,

was compiled from two comparable harbor surveys conducted by NYCDEP and by the NJHDG. As available, select secondary data sources were used to complement results from these two primary data sources. The following 10 regional waterbody summaries do not serve to replace New York's or New Jersey's Integrated Water Quality Reports, nor are they meant to be used for compliance purposes. The purpose of the summaries is to inform current water quality trends and advance discussions to achieve the fishable and swimmable goals of the 1972 Clean Water Act. A compliance analysis for 2017, using the master station across all 10 regional waterbodies, has also been tabulated in Appendix B where state standards for pathogens and dissolved oxygen may be reviewed.

Potential investments and opportunities for improvement showcase the efforts of the government, advocates and utilities to address water quality. Tools, such as the CSO, MS4, and POTW permits, are used by the states of New York and New Jersey to ensure designated uses of each waterbody are met. In addition, Total Maximum Daily Loads (TMDLs) can be used by the states and EPA to determine the amount of a pollutant that a waterway can take in and still meet their designated uses and water quality criteria. The region's long history of industrial activity has left a significant number of contaminated brownfield, landfill, and Superfund sites throughout the Harbor Estuary, and a legacy of toxics in soils, sediment and waters (Lodge, et al. 2015). The most significant of these are also discussed.

Waterbody Classes and Criteria

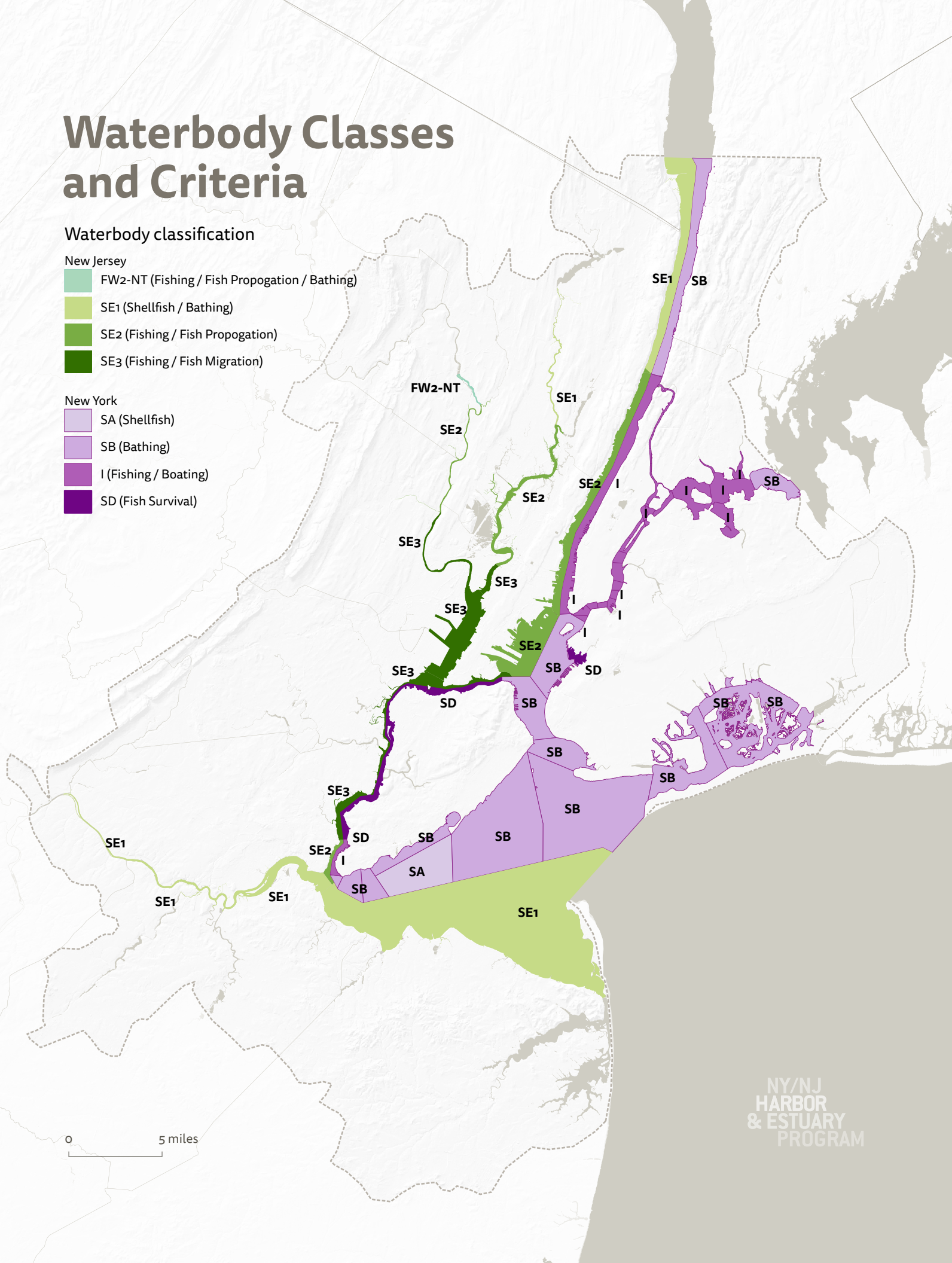
Waterbody classification

New Jersey

- FW2-NT (Fishing / Fish Propagation / Bathing)
- SE1 (Shellfish / Bathing)
- SE2 (Fishing / Fish Propagation)
- SE3 (Fishing / Fish Migration)

New York

- SA (Shellfish)
- SB (Bathing)
- I (Fishing / Boating)
- SD (Fish Survival)

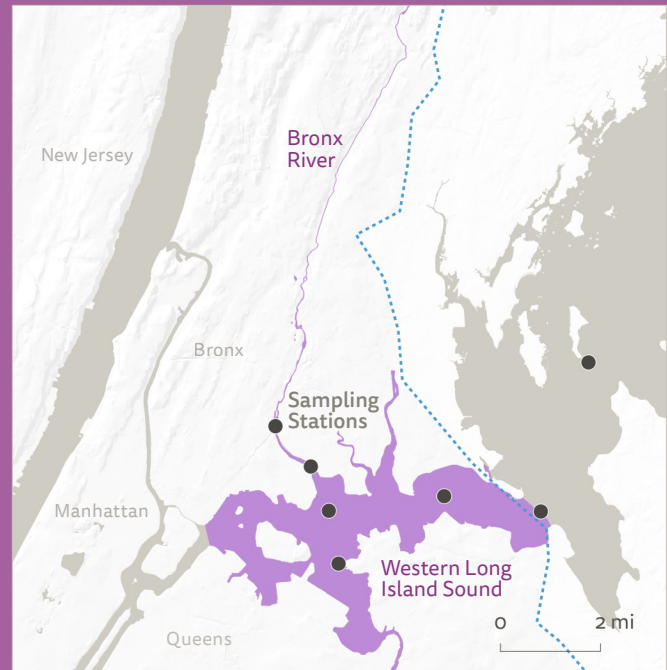


NY/NJ
HARBOR
& ESTUARY
PROGRAM

The Bronx River and Western Long Island Sound

The Bronx River runs south from White Plains, NY, emptying into the Western Long Island Sound and the Upper East River. Included in this region are the New York City Boroughs of the Bronx and Queens, as well as parts of Westchester County. An industrial thruway with a history of exposure to raw sewage, the Bronx River faces serious challenges with managing pollution and contamination. The Western Long Island Sound and its other tributaries have similar issues. Popular waterfront parks include Soundview and Concrete Plant Park in the Bronx and the Flushing Bay Promenade in Queens.

Major factors influencing water quality in this region include CSOs, municipal discharges/sewage, industrial point source discharge, stormwater runoff, spills and unpermitted discharges, streambank erosion, habitat alteration, and flow alterations from water diversions. The state reports to EPA through their 303(d) and 305(b) impairments to aquatic life, fish consumption, public bathing, recreation, and shellfishing. Use of these public resources has been lost due to low dissolved oxygen, fish passage



barriers, floatables, pathogens, and nitrogen. The state 303(d) and 305(b) reports to EPA also indicate that assessments of TMDLs are needed for the Upper Bronx River, while alternative controls to be implemented through Long Term Control Plans (LTCPs) have been identified to address dissolved oxygen levels, floatables, and pathogens throughout the Middle and Lower Bronx River. For the Upper East River and Western Long Island Sound, alternative controls identified in the LTCPs will address pathogens and floatables while additional monitoring efforts in the Western Long Island Sound will help address dissolved oxygen levels.

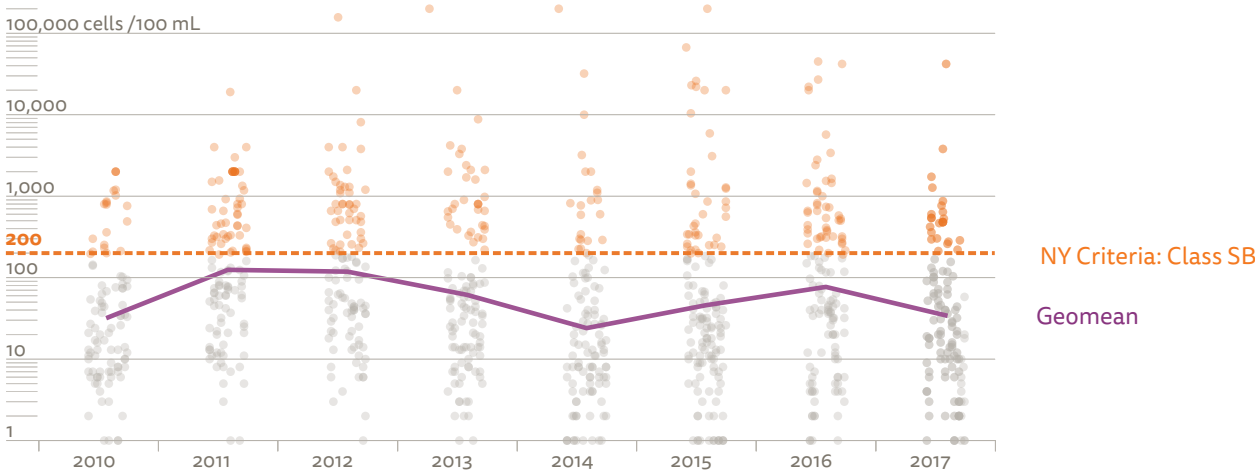
Waterbody	Water Class 6 CRR-NY 703.3 & 6 CRR-NY 703.4	Water Quality Criteria	
		Pathogenic Bacteria (cfus/100mL)	Dissolved Oxygen (mg/L)
Bronx River	Class I: Fishing and Boating	Fecal Coliform: Monthly GM ≤ 200 from 5 or more samples	Never < 4.0
Upper East River to the Western Long Island Sound	Class SB: Bathing	Fecal Coliform: Monthly GM ≤ 200 from 5 or more samples	Never < 3.0
		<i>Enterococcus</i> : Monthly GM ≤ 35 and single sample max > 130	

Pathogens

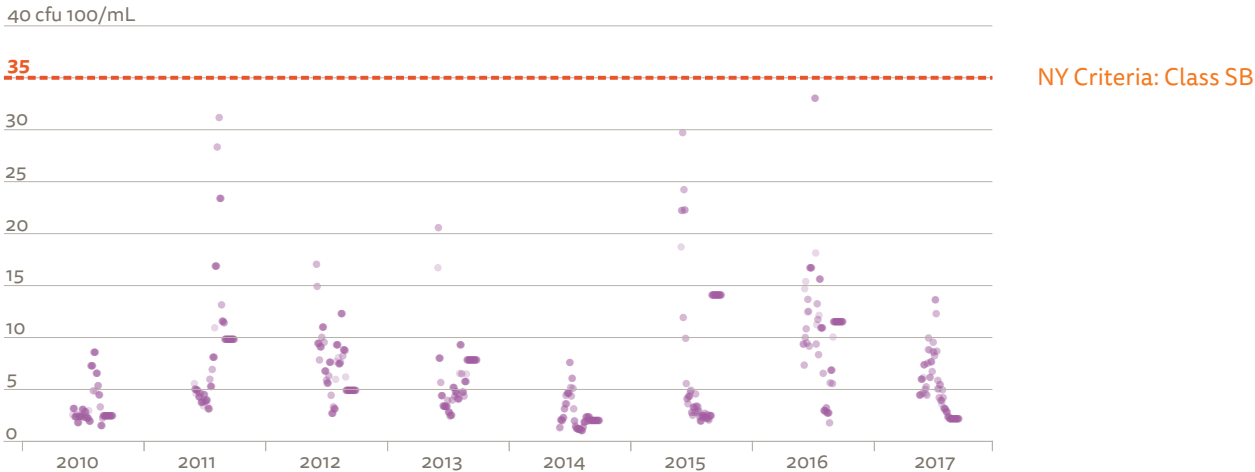
The presence of pathogenic bacteria can limit recreational use of these waterways. Sampling data show improvement over time to support secondary contact recreation, though discrete samples, do vary throughout the region and still limit primary contact recreational activities, like swimming. The geometric means of samples from the Bronx River and Western Long Island Sound region show compliance when it comes to Class I and Class SB criteria for fecal coliform. Samples tested for *Enterococcus* criteria, applicable only in the Western Long Island Sound, shows more variability over time and were out of compliance in 2011 and 2016.

The fecal coliform summer discrete measurements ranged from 1 cfu/100mL to 200,000 cfu/100mL over the eight-year period. With an average of 137 discrete samples per recreational season each year (June-September), the average geomean for fecal coliform in this region is 65 cfu/100mL. *Enterococcus* summer geometric means ranged from 1.04 cfu/100mL to 84.7 cfu/100mL over the same periods. Out of over 1,000 samples, the average geomean of *Enterococcus* for this region is 7 cfu/100mL and 10.9% of discrete samples exceeded the single sample maximum (>130 cfus/100mL) of the *Enterococcus* criteria.

Fecal Coliform, Surface Summer Mean and Discrete Samples



Enterococcus, 30 Day Moving Geomean



Dissolved Oxygen

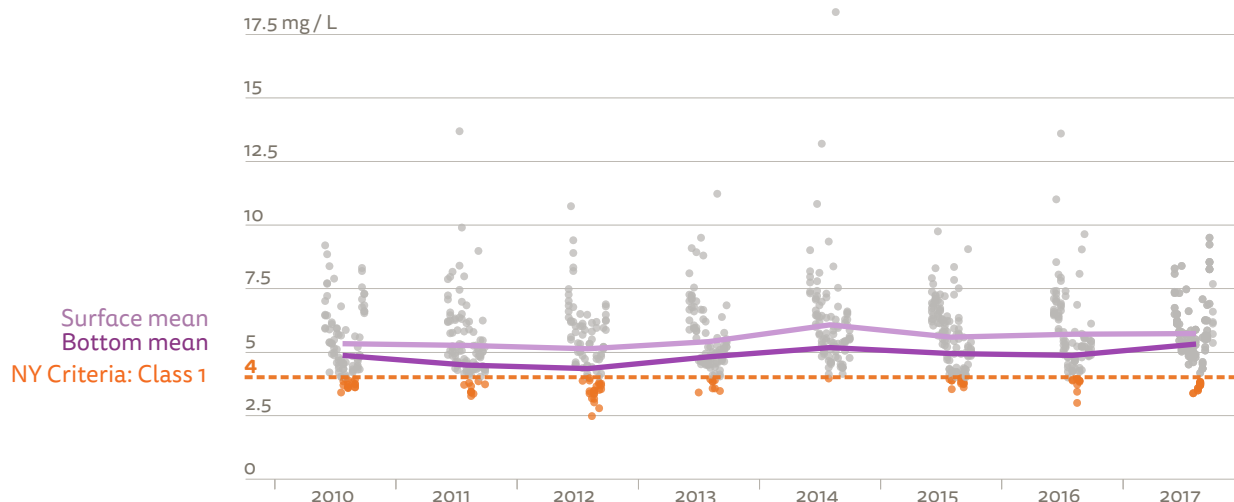
Dissolved oxygen (DO) is a critical measure of habitat quality for fish and other wildlife. It is measured at the surface, where sunlight can penetrate to generate photosynthesis, as well as at the bottom, where sunlight is less available. In general, bottom DO concentrations are consistently lower than surface DO concentrations. Compliance with DO criteria has varied. Fish in this region are consistently stressed as indicated by the low discrete sample values recorded over the eight years. For example, in 2017, the Bronx River was in full compliance with the criteria while samples from the Western Long Island Sound were not. The percent of time DO samples were less than 4 mg/L was between 1-20% for surface DO and 11-40% for bottom DO. The percent of time DO samples were less than 5 mg/L has been between 22-52% for surface DO and 45-58% for bottom DO.

The data presented are from the New York City Harbor Survey, conducted by the NYCDEP. The Interstate Environmental Commission (IEC) has also been monitoring approximately 22 sampling stations in the Upper East River and Western Long

Island Sound.. Samples from the two data sources are reasonably consistent in their characterization of the region. However, the data collected by IEC shows more severe conditions in the Western Long Island Sound between 2015 and 2017. For example, in 2015, the percent of bottom DO samples that were less than 4.8 mg/L near NYCDEP's Upper East River stations was 45%, while the IEC stations for the same period was 72%.

	Data Source	Average Bottom DO (mg/L)	% samples < 4.8 mg/L	Min. Bottom DO (mg/L)
2015	IEC	4.1	72	2.2
2015	NYCDEP	4.9	45	2.2
2016	IEC	4.4	60	1.4
2016	NYCDEP	4.9	40	2.2
2017	IEC	4.7	47	1.5
2017	NYCDEP	5.7	33	2.6

Dissolved Oxygen, Summer Mean, Surface and Bottom

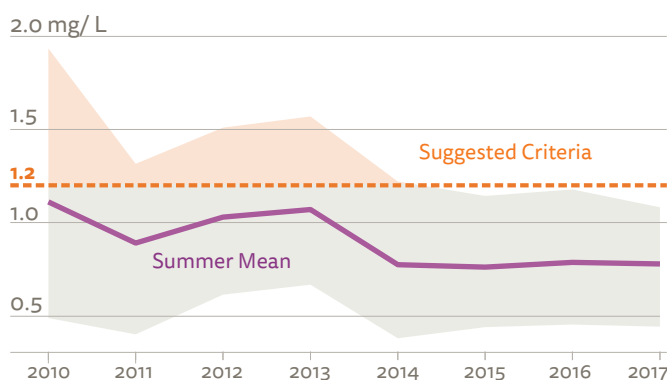


Other Water Quality Parameters

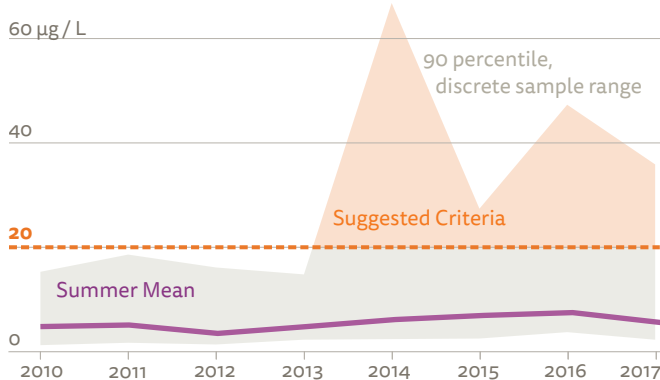
While pathogenic bacteria and dissolved oxygen are the primary criteria used to set water quality standards in New York, measurement of total nitrogen and chlorophyll-*a* provide additional information as to possible causes of low DO as well as the presence of photosynthetic algae and algal blooms. Between 2010 and 2017, the summer means for total nitrogen ranged between 0.76 and 1.11 mg/L, though daily values fluctuated over time. Total nitrogen levels between 0.4 and 1.2 mg/L is indicative of fair

conditions, and water quality would improve with nitrogen levels equal to or below 0.4 mg/L. Chlorophyll-*a* in this region shows great fluctuation over time, with high levels beginning in 2014. Concentrations of 5 µg/L or below support healthier habitats for fish survival and propagation, while concentrations at or above 20 µg/L indicate increased algal growth. Concentrations of chlorophyll-*a* during the summer season, where blooms are typically seen, are largely found to be above 20 µg/L.

Total Nitrogen, Summer Mean



Chlorophyll-*a*, 90th percentile Surface



Investments and Opportunities for Improvement

EPA and New York State have identified CSOs as a key source of pathogenic bacteria (and other pollutants) that limit recreational use. There are six Long Term Control Plans (LTCPs), developed by NYCDEP and submitted to NYSDEC, to address this issue. Plans for Alley Creek, Hutchinson River, Flushing Creek, Flushing Bay, Bronx River, and Westchester Creek have been approved by NYSDEC and improvements to the sewer system are underway. Additional green infrastructure, chemical disinfection of discharge using chlorination, floatables control programs, and storage tunnels or tanks to allow for treatment should result in significant improvements by reducing CSO volume discharged into these waterbodies and therefore reducing the presence of pathogenic bacteria. A combined pre-LTCP and LTCP-approved investment of approximately \$2.8 billion will reduce CSO volume from 11% in the Hutchinson River and 63% in Westchester Creek in the decades to come (NYCDEP, 2020).

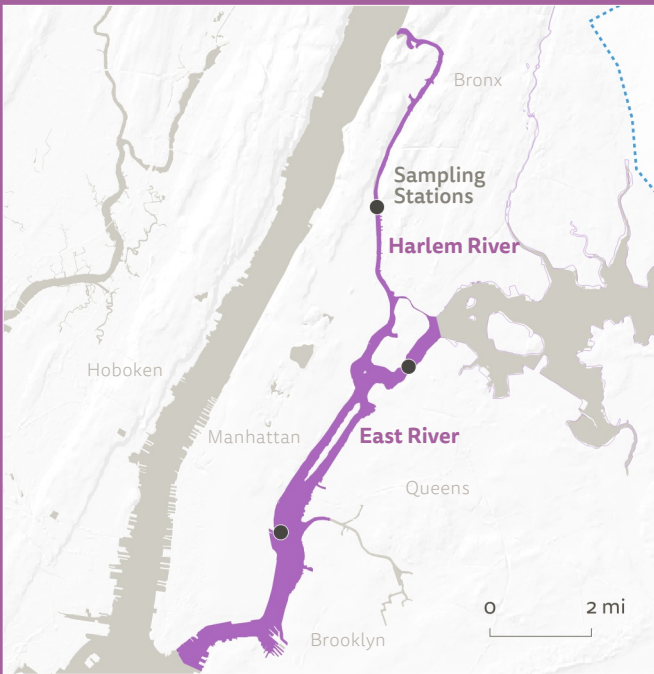
The Western Long Island Sound is included in New York City's Citywide and East River/Open Water LTCP, submitted to the state

in 2020. Preliminary planning suggests the optimization of CSO regulators as well as the implementation of CSO storage tunnels. With the implementation of all the LTCPs, there will be a reduction in CSOs and discharge of pathogens through the next several decades. LTCPs in New York City also require implementation of green infrastructure projects such as rain gardens, which potentially reduce levels of nutrient loading and total suspended solids from stormwater runoff. In addition, New York City received its first MS4 permit in 2015 which enables NYCDEP and other city agencies to further implement measures to reduce pollutants in stormwater runoff. To improve water quality for fish propagation and survival as well as reduce the occurrence of algal blooms, further efforts are needed to address nutrients, such as nitrogen, and chlorophyll-*a* levels in this region. Monitoring and modeling efforts now underway through the efforts of Long Island Sound Study and NYCDEP will determine the best path forward.

East River and Harlem River

The Harlem River is a narrow tidal strait that divides the island of Manhattan from the Bronx. Starting from the northwestern tip of Manhattan, the Harlem River joins the East River to flow south to the Upper New York Bay. The Harlem River is home to two large public parks at either end of the river—Inwood Hill Park and Randall’s Island Park—as well as Roberto Clemente State Park in between. The East River is an important shipping channel connecting the Western Long Island Sound with the New York Harbor. Numerous parks and public spaces, including Queensbridge, Brooklyn Bridge, and East River, line its shorelines in Queens, Brooklyn, and Manhattan.

Major factors influencing water quality in this region include CSOs, contaminated sediments, industrial point source discharges, municipal discharges/sewage, spills and unpermitted discharges,



and stormwater runoff. The state reports to EPA through their 303(d) and 305(b) lists impairments to aquatic life, fish consumption, public bathing, recreation, and shellfishing. TMDLs are needed to address PCBs and additional efforts to address floatables, while a TMDL has been implemented for DO. Alternative controls identified through the Long Term Control Plans (LTCPs) have been identified to help address floatables and pathogens levels throughout the East and Harlem Rivers.

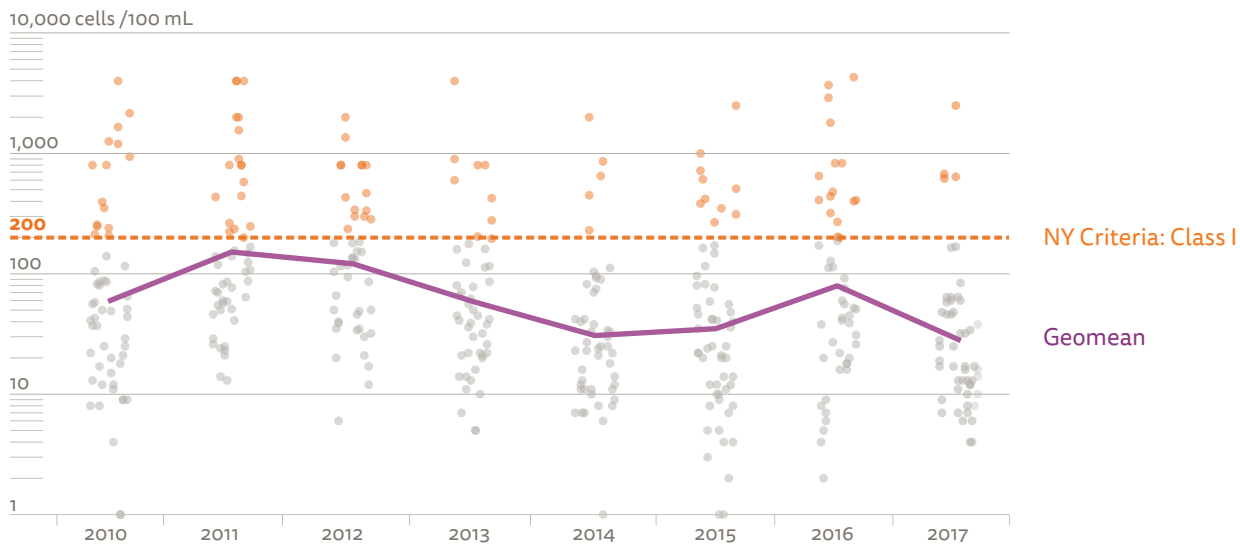
Waterbody	Water Class 6 CRR-NY 703.3 6 CRR-NY 703.4	Water Quality Criteria	
		Pathogenic Bacteria (cfus/100mL)	Dissolved Oxygen (mg/L)
East River Harlem River	Class I: Fishing and Boating	Fecal Coliform: Monthly GM ≤200 from 5 or more samples	Never < 4.0

Pathogens

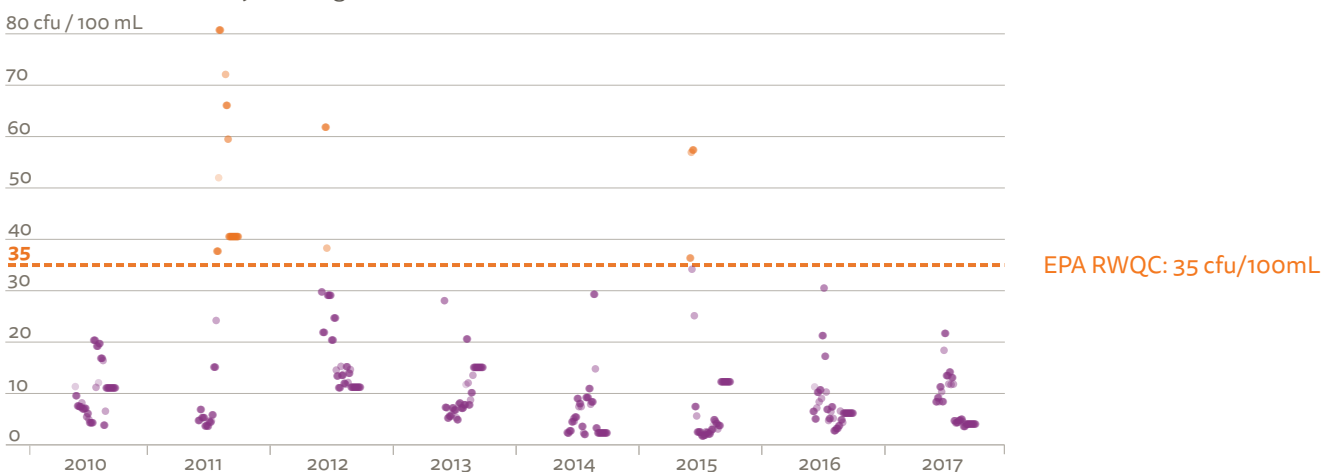
The presence of pathogenic bacteria can limit recreational use of these waterways. Sampling data shows fluctuation over time, with counts that are in and out of compliance, limiting secondary contact recreation. The fecal coliform summer discrete measurements ranged from 1 cfu/100mL to 4,300 cfu/100mL over the eight-year period. With an average of 57 discrete samples per recreational season (June-September), the average geomean for fecal coliform in this region is 70.7

cfu/100mL. While *Enterococcus* is not used by New York for Class I waters, the geometric mean should not exceed 35 cfu/100mL to support primary contact recreational activities. *Enterococcus* summer geometric means ranged from 1.84 cfu/100mL to 246 cfu/100mL from 2010 to 2017. Out of over 400 samples, the average geomean for this region is 14.3 cfu/100mL and 11% of discrete samples exceeded the single sample *Enterococcus* maximum (>130 cfu/100mL) of the criterion.

Fecal Coliform, Surface Summer Mean and Discrete Samples



Enterococcus, 30 Day Moving Geomean



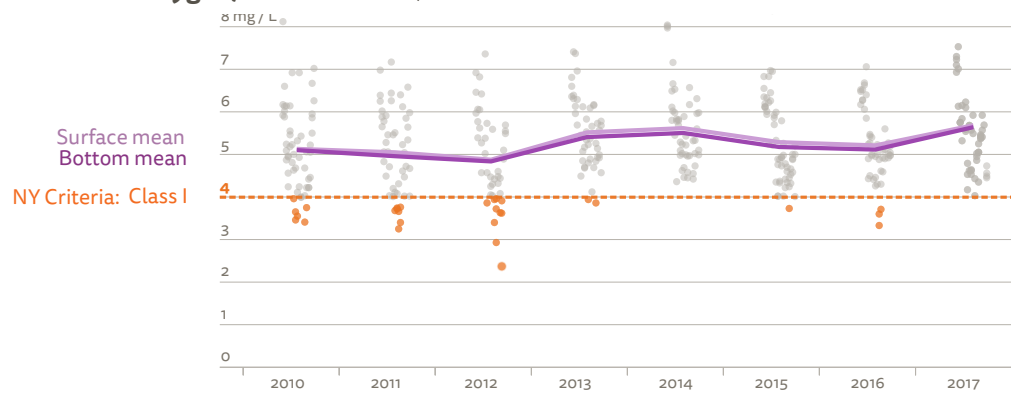
Dissolved Oxygen

Dissolved oxygen (DO) is a critical measure of habitat quality for fish and other wildlife. It is measured at the surface, where sunlight can penetrate to generate photosynthesis, as well as at the bottom, where sunlight is less available. In general, bottom DO concentrations are consistently lower than surface DO concentrations. This region is found to be in compliance with

the DO criteria. In general, fish in this region are not consistently stressed as indicated by the low discrete sample values recorded over the eight years, though low DO concentrations were frequent in 2012. The percent of time DO samples were less than 4 mg/L was between 0-28% for surface DO and 0-22% for bottom DO over the eight-year period.



Dissolved Oxygen, Summer Mean, Surface and Bottom

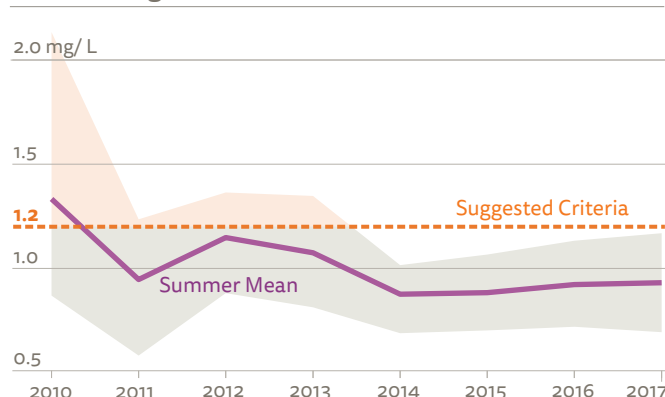


Other Water Quality Parameters

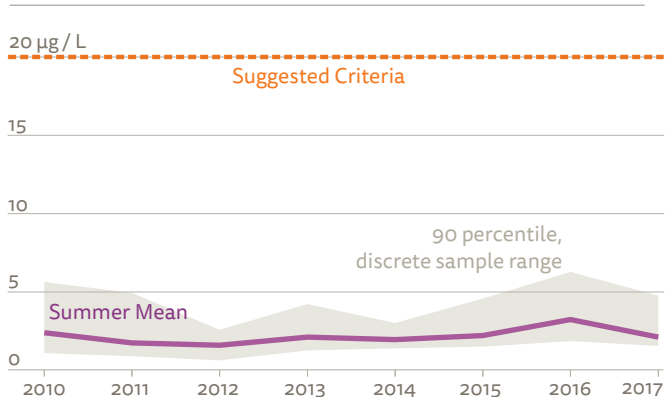
While pathogenic bacteria and dissolved oxygen are the primary criteria used to set water quality standards in New York, measurement of total nitrogen and chlorophyll-*a* provide additional information as to possible causes of low DO as well as the presence of photosynthetic algae and algal blooms. Between 2010 and 2017, the summer means for total nitrogen ranged between

0.39 and 2.62 mg/L. Total nitrogen levels between 0.4 and 1.2 mg/L is indicative of fair conditions, and water quality would improve with nitrogen levels equal to or below 0.4 mg/L. Chlorophyll-*a* in this region shows concentrations below 5 µg/L, which supports healthier habitats for fish survival and propagation.

Total Nitrogen, Summer Mean



Chlorophyll-*a*, 90th percentile Surface



Investments and Opportunities for Improvement

This region is part of New York City's Citywide and East River/Open Water LTCP, submitted to the state in 2020. Preliminary drafts suggest the optimization of CSO regulators, as well as the installation of a bending weir to reduce CSOs. The proposed improvements in the Citywide and East River/Open Water LTCP for a planned \$6 million investment to the East River and no additional investments to the Harlem River in the draft plan (NYCDEP, 2020). Additionally, Newtown Creek, a tributary to the East River, has its own LTCP and is also a Superfund site. While the LTCP was approved in 2018 and anticipates various sewage management improvements that reduce CSO events, future remedial efforts under the EPA Superfund Program will either contain or reduce exposure to PCBs, dioxins, and pesticides. For Newtown Creek, the combined pre-LTCP and LTCP-approved controls estimated at up to \$1.6 billion will reduce 69% of the CSO volume by 2042 (NYCDEP, 2020). LTCPs in New York City also require planning for the implementation of green infrastructure

projects such as the conversion of impervious surface into rain gardens, which potentially reduce levels of nutrient loading and total suspended solids. In addition, NYCDEP received its first MS4 permit in 2015 which enables NYCDEP to further implement measures to reduce pollutants in stormwater runoff.

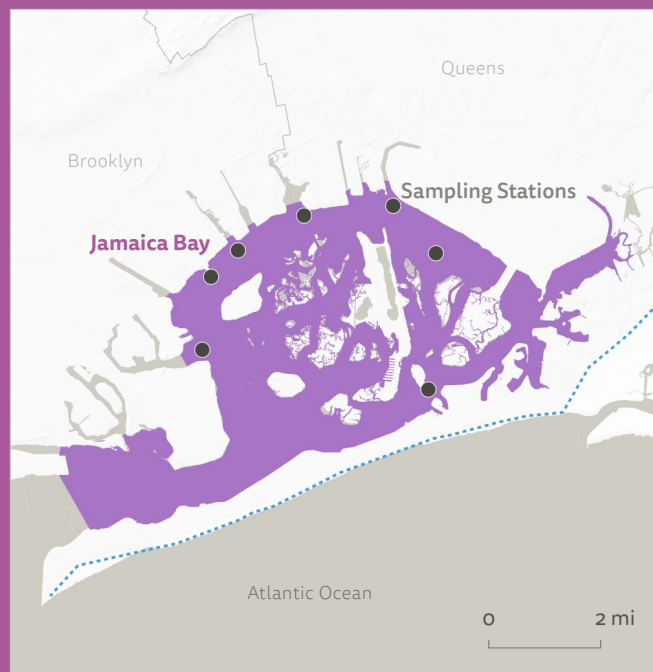
A large portion of the LTCP investment in this region is dedicated to the NYCDEP's plan to daylight the Tibbetts Brook, which would route this historic stream along a former railroad in the Bronx. Currently, the Brook flows from Van Cortlandt Lake directly into the sewer system, limiting the dry and wet weather load of the city's wastewater infrastructure. By restoring connection to the Harlem River, this project would add capacity to the Wards Island Treatment Plant while reducing CSO discharges. This would be complemented by improvements to Van Cortlandt Lake, restoration of other habitats, and development of a greenway and other enhancements.

Jamaica Bay

Fed by the Lower New York Bay, Jamaica Bay is surrounded by Queens and southern Brooklyn neighborhoods and the Rockaway Peninsula. Jamaica Bay was famous for its oysters up until the 1920s when populations largely died due to development, landfills, pollution and overfishing.

Now a complex network of open water, salt marsh, grasslands, coastal woodlands, maritime shrublands, and brackish and freshwater wetlands, the Bay hosts an important collection of National (Jamaica Bay Wildlife Refuge), State (including the new Shirley Chisholm State Park) and city parkland (such as Marine Park). Its location on the North Atlantic Flyway makes Jamaica Bay a globally important ecological resource.

Major factors influencing water quality in this region include chemical leaks and spills, CSOs, de-icing fluid (storage/application) from the nearby John F. Kennedy International Airport, habitat



alteration, industrial point source discharge, municipal discharges/sewage, septic and other decentralized systems, spills and unpermitted discharges, and stormwater runoff. This leaves the bay impaired due to low dissolved oxygen, floatables, nitrogen, and pathogens. The state 303(d) and 305(b) reports to EPA indicate that TMDL alternatives have been identified, but the region's aquatic life, fish consumption, swimming, boating, and shellfishing are still impaired.

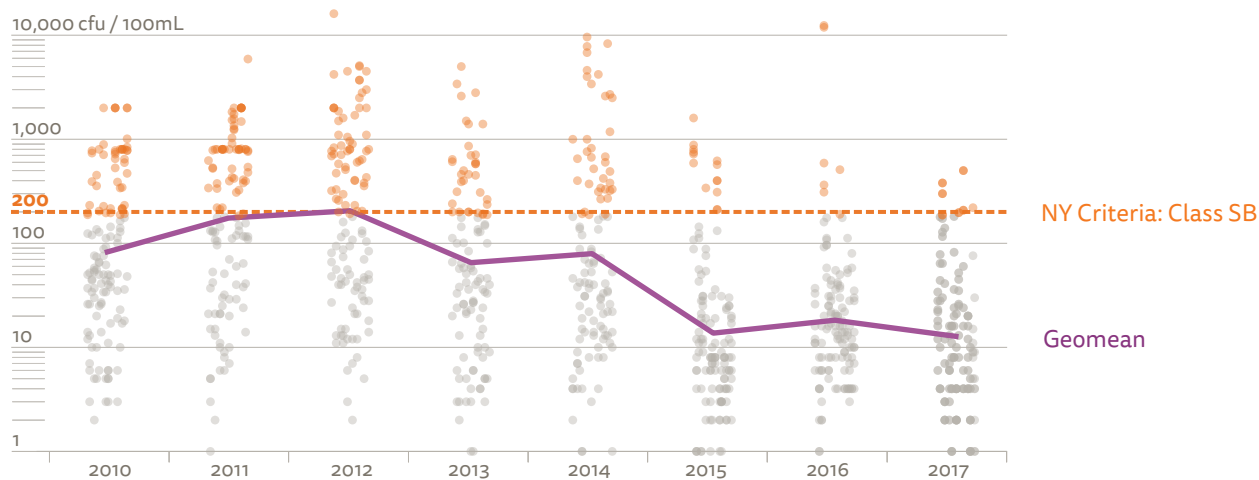
Waterbody	Water Class 6 CRR-NY 703.3 & 6 CRR-NY 703.4	Water Quality Criteria	
		Pathogenic Bacteria (cfus/100mL)	Dissolved Oxygen (mg/L)
Jamaica Bay	Class SB: Bathing	Fecal Coliform: Monthly GM ≤200 from 5 or more samples	Never < 3.0
		Enterococcus: Monthly GM ≤ 35 and single sample max > 130	

Pathogens

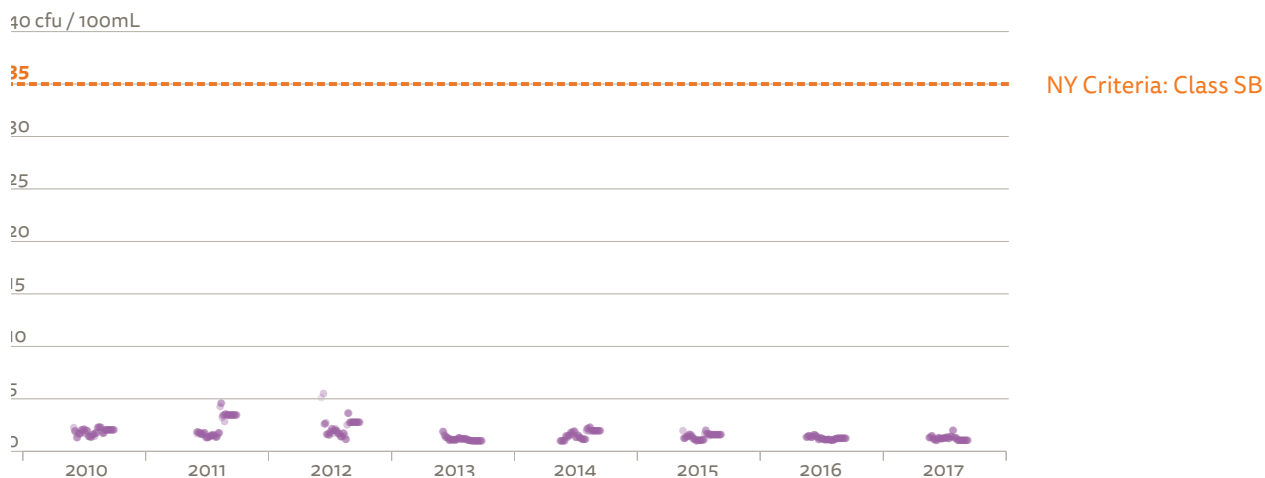
The presence of pathogenic bacteria can limit recreational use of these waterways. Sampling data shows improvement over time in these Class SB waters in term of compliance for fecal coliform and *Enterococcus*. This region is largely meeting primary contact recreation standards. The fecal coliform summer discrete measurements ranged from 1 cfu/100mL to 16,100 cfu/100mL over the eight-year period. With an average of 138 discrete samples

per recreational season (June-September), the average geomean for fecal coliform in this region is 81.5 cfu/100mL. *Enterococcus* summer geometric means ranged from 1 cfu/100mL to 8.8 cfu/100mL over the same periods. Out of over 1,000 samples, the average geomean of *Enterococcus* for this region is less than 1 cfu/100mL and 1.5% of discrete samples exceeded the single sample *Enterococcus* maximum (>130 cfu/100mL) of the criterion.

Fecal Coliform, Surface Summer Mean and Discrete Samples



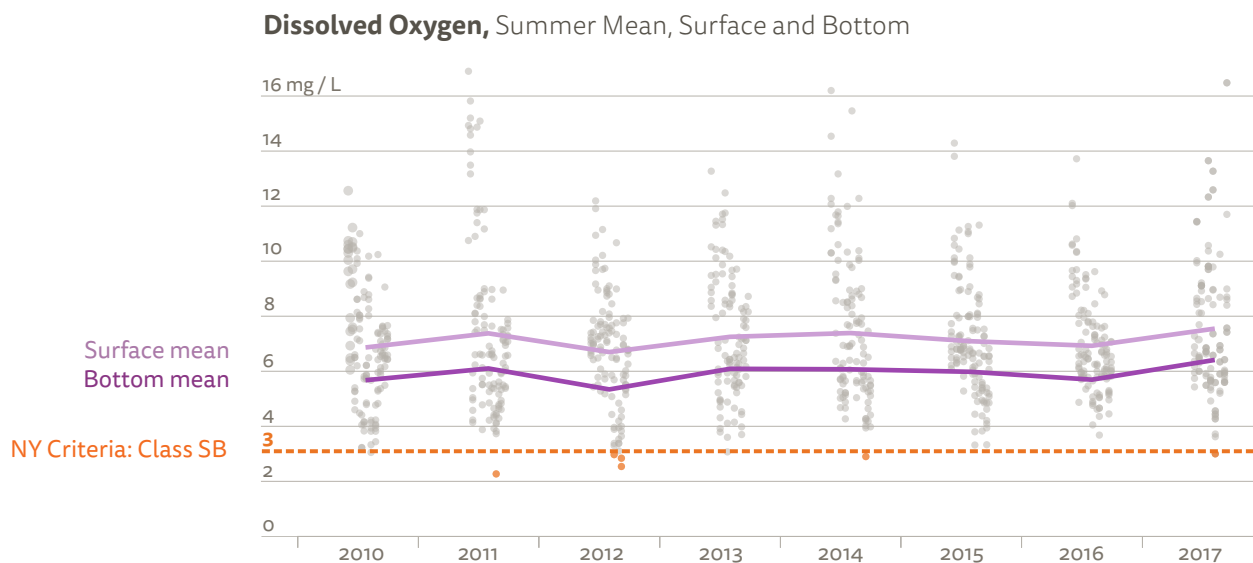
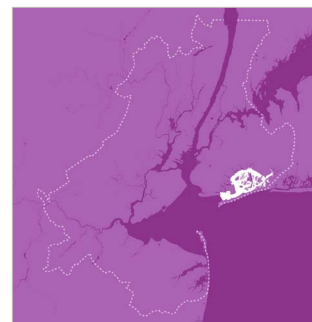
Enterococcus, 30 Day Moving Geomean



Dissolved Oxygen

Dissolved oxygen (DO) is a critical measure of habitat quality for fish and other wildlife. It is measured at the surface, where sunlight can penetrate to generate photosynthesis, as well as at the bottom, where sunlight is less available. In general, bottom DO concentrations are consistently lower than surface DO concentrations. Compliance with DO criterion has varied daily

throughout the eight-years evaluated, but summer means are found to be above the 5 mg/L criterion. Fish in this region are consistently stressed as indicated by the low discrete sample values recorded over the eight years. The percent of time DO samples were less than 5 mg/L was between 8-23% for surface DO and 20-41% for bottom DO.

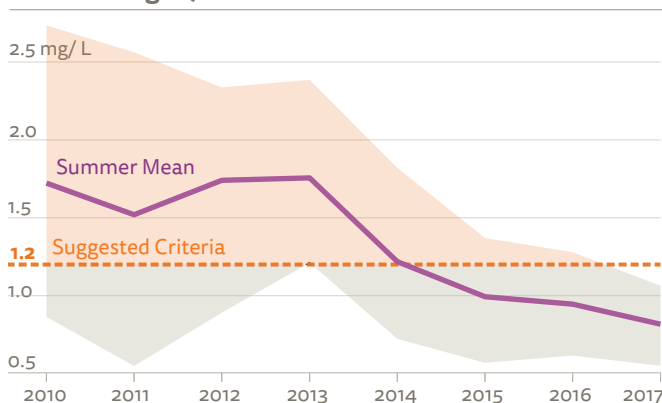


Other Water Quality Parameters

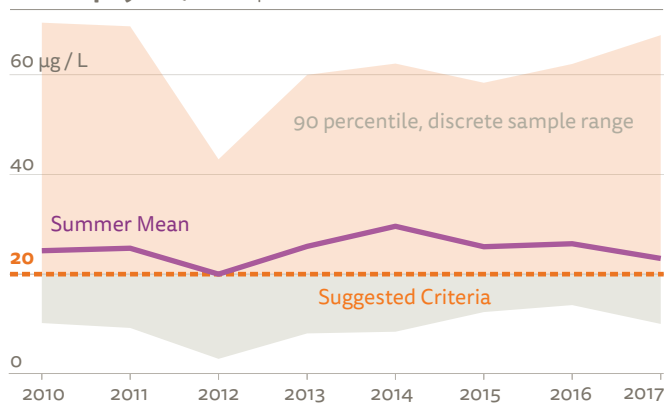
While pathogenic bacteria and dissolved oxygen are the primary criteria used to set water quality standards in New York, measurement of total nitrogen and chlorophyll-*a* provide additional information as to possible causes of low DO as well as the presence of photosynthetic algae and algal blooms. Between 2010 and 2017, the summer means for total nitrogen ranged between 0.82 and 1.76 mg/L, though daily values are improving in recent years. Total nitrogen levels at or below 1.2 mg/L would support

healthy habitats. Chlorophyll-*a* levels in this region show greater fluctuation over time, ranging between 0.7 and 200.3 µg/L. Concentrations of 5 µg/L or below support healthier habitats for fish survival and propagation, while concentrations at or above 20 µg/L indicate increased algal growth. Concentrations of chlorophyll-*a* during the summer season, where algae blooms are typically seen, are largely found to occur above 20 µg/L.

Total Nitrogen, Summer Mean



Chlorophyll-*a*, 90th percentile Surface



Investments and Opportunities for Improvement

EPA and New York State have identified combined sewer overflows as a key source of pathogenic bacteria (and other pollutants) that limit recreational use. A Long Term Control Plan (LTCPs) for Jamaica Bay and its tributaries (Bergen Basin, Thurston Basin, Hendrix Creek, Fresh Creek, Spring Creek and Paerdegat Basin), have been developed by NYCDEP and submitted to NYSDEC to address this issue. The LTCP, pending approval, will result in an estimated 10% annual reduction in CSO volume at an estimated cost of \$1.285 billion (NYCDEP, 2020). This includes funding spent to date in some tributaries and upgrades to POTW facilities, such as the Paerdegat Basin, as well as anticipated implementation of Jamaica Bay and its Tributaries' LTCP. Guided by NYCDEP's Jamaica Bay Watershed Protection Plan, the City is focusing on implementing further green infrastructure practices in the region, using ribbed mussels for biofiltration,

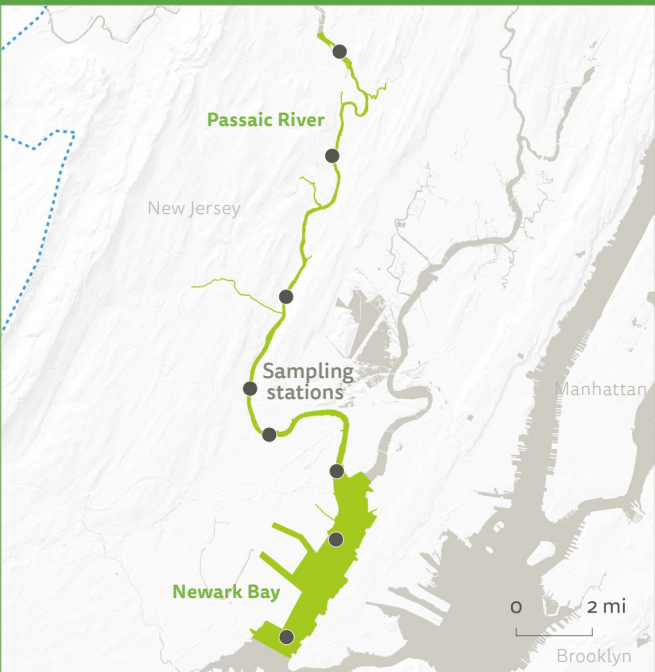
environmental dredging, and wetland restoration that will result in the reduction of pathogens, nutrient loading, and total suspended solids from entering the waterbody.

In addition to LTCPs and the Watershed Protection Plan, NYCDEP received its first MS4 permit in 2015 which enables NYCDEP to further implement measures to reduce pollutants in stormwater runoff. To improve water quality for fish propagation and survival as well as reduce the potential occurrence of algal blooms, further efforts are needed to address nutrients and accompanying chlorophyll-*a*, in this region. Investments towards the implementation of the LTCP will provide opportunity for the state to consider TMDLs while the proposed green infrastructure practices are anticipated to aid in addressing nutrient levels in Jamaica Bay and its tributaries.

Lower Passaic River and Newark Bay

The Silicon Valley of the 1800s, the Lower Passaic River flows through the historic industrial heart-land of New Jersey. From the Dundee Island Dam, the tidal Passaic River flows south to Newark Bay, where its waters mix with those of three other major waterbodies: the Arthur Kill, Kill van Kull, and the Hackensack River. The entire watershed includes portions of Essex, Passaic, Hudson, Bergen, and Union Counties. While the shorelines still harbor major industrial uses, including the port and related facilities in Newark and Elizabeth, there are some important public access points such as Newark’s Riverfront Park, and Stephen Gregg Park in Bayonne.

Major factors impacting water quality in this region include chemical leaks and spills, CSOs, contaminated sediments, industrial post source discharge, landfills, municipal discharge and sewage, unpermitted discharges, and urban runoff. The Lower Passaic River, designated as a Superfund site, has borne a heavy burden of pollution from a century of industrialization and manufacturing



that has left layers of dioxin (including 2,3,7,8-TCDD), PCBs, arsenic, benzo[a]pyrene (PAHs), dieldrin, heptachlor epoxide, chlordane, and DDT in the waterbody and in fish tissue. In addition to these impairments, the Lower Passaic River and Newark Bay are also affected by floatables, low levels of dissolved oxygen, high phosphorus levels, total suspended solids, and pH levels. The EPA currently reports that aquatic life, fish consumption, public bathing, recreation, and shellfishing are impaired throughout the region. TMDLs are needed for all aforementioned causes of impairment.

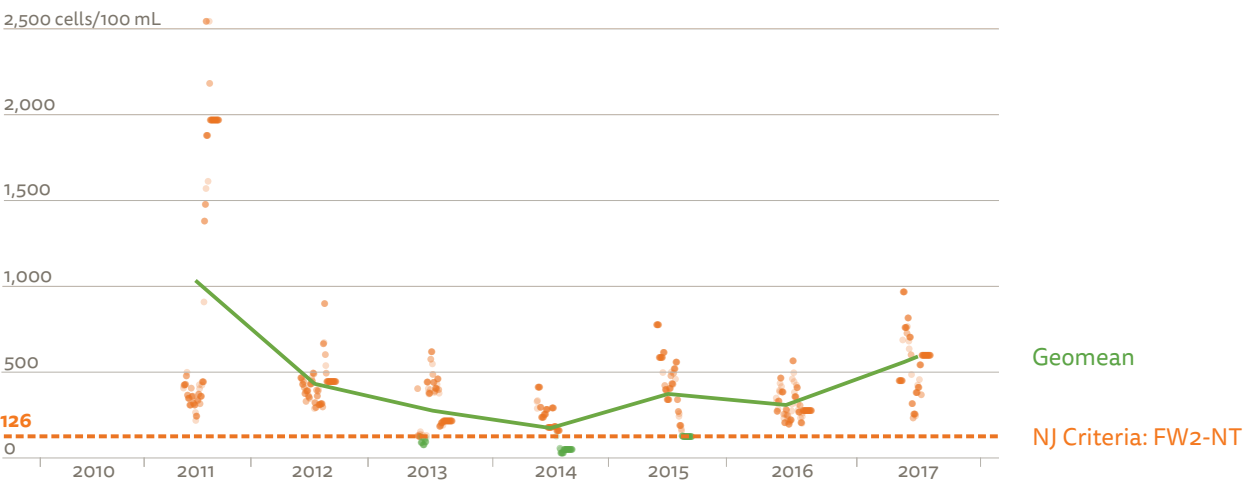
Waterbody	Water Class NJAC 7: 9B-1.14(d)(1)	Water Quality Criteria	
		Pathogenic Bacteria (cfus/100mL)	Dissolved Oxygen (mg/L)
Upper Passaic River	FW2-NT: Fishing, Fish Propagation, and Bathing	E. Coli: Monthly GM ≤126 and a single sample max >235	Never < 4.0 at any time
			24-hour average ≥ 5.0
Passaic River	Class SE2: Fishing and Fish Propagation	Fecal Coliform: Monthly GM ≤770	Never < 4.0
Lower Passaic River and Newark Bay	Class SE3: Fishing and Fish Migration	Fecal Coliform: Monthly GM ≤1,500	Never < 3.0

Pathogens

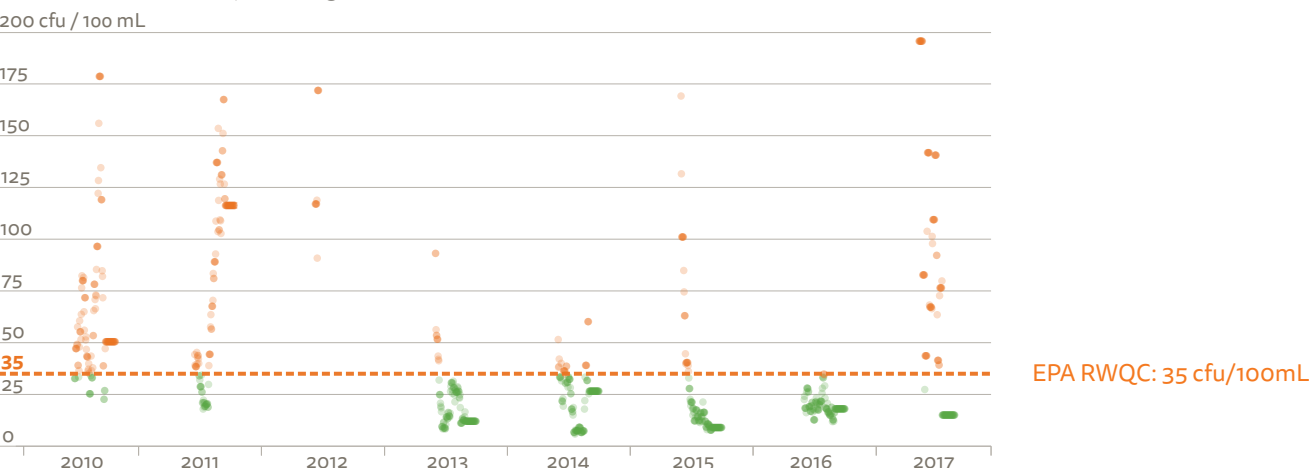
The presence of pathogenic bacteria can limit recreational use of these waterways. While sampling data shows some improvement, additional efforts are needed to reduce pathogenic bacteria in the Lower Passaic River and Newark Bay to support primary contact recreation. The geometric means of samples from the region show non-compliance for *Enterococcus* and *Escherichia coli*, commonly referred to as *E.coli*, used to measure pathogenic bacteria in freshwater systems. *E.coli* summer discrete measurements ranged from 29 cfu/100mL to 2,544 cfu/100mL over the eight-year period. With an average of

56 discrete samples per recreational season (June-September) per year, the average geomean value for *E. coli* in this region is 399 cfu/100mL. Samples tested for *Enterococci* show inconsistencies over time and were found to be in compliance during 2016. *Enterococcus* summer geometric means ranged from 6 cfu/100mL to 222 cfu/100mL over the same periods. Out of over 100 samples, the average geomean of *Enterococcus* for this region is 51 cfu/100mL and 30% of discrete samples exceeded the single sample maximum (>130 cfus/100mL) of the criterion.

E. Coli, Surface Summer Mean and Discrete Samples



Enterococcus, 30 Day Moving Geomean



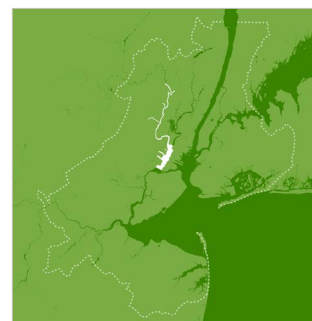
Dissolved Oxygen

Dissolved oxygen (DO) is a critical measure of habitat quality for fish and other wildlife. It is measured at the surface, where sunlight can penetrate to generate photosynthesis, as well as at the bottom, where sunlight is less available. In general, bottom DO concentrations are consistently lower than surface DO concentrations. Compliance with DO criteria has varied throughout the eight-year period. The Lower Passaic River and Newark Bay have been in compliance with the criteria throughout the eight-year period, though daily values have fluctuated below 4 mg/L. The percent of time DO samples were less than 4 mg/L was between 2-14% for surface DO and 0-15% for bottom DO. The percent of time DO samples were less than 5 mg/L has been between 7.7-22% for surface DO and 3-48% for bottom DO.

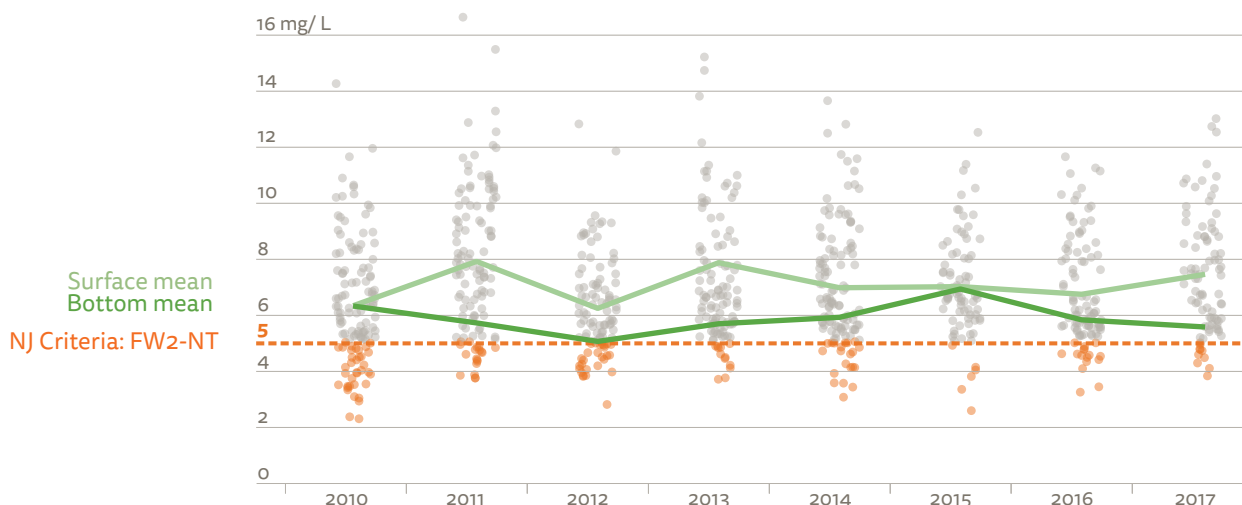
The data presented are from the Long-term Ambient Water Quality Monitoring of the New Jersey Portion of the New York/New Jersey Harbor Waters discrete sampling program, conducted by the NJHDG. The Hudson River Environmental Conditions

Observing System (HRECOS) has a continuous monitoring station located in the Newark Bay that is operated and maintained by the Passaic Valley Sewerage Commission (PVSC). The HRECOS station was installed in 2014 in Newark Bay near the confluence with the Passaic River and collects data every 15-minutes year round. Results from the two data sources do show inconsistencies, with the HRECOS data being more severe. For example, in 2016, the percent of bottom DO samples that were less than 4.0 mg/L at the NJHDG stations was 3%, while the HRECOS stations for the same period was 8%.

2016	NJHDG	HRECOS
Average (mg/L)	5.84	4.99
% < 4.0 mg/L	3	7.9
% < 5.0 mg/L	16.4	52.2
Discrete Minimum Sample (mg/L)	3.56	2.74



Dissolved Oxygen, Summer Mean, Surface and Bottom

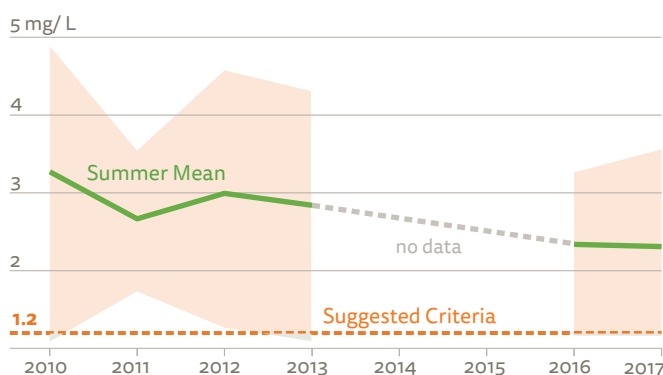


Other Water Quality Parameters

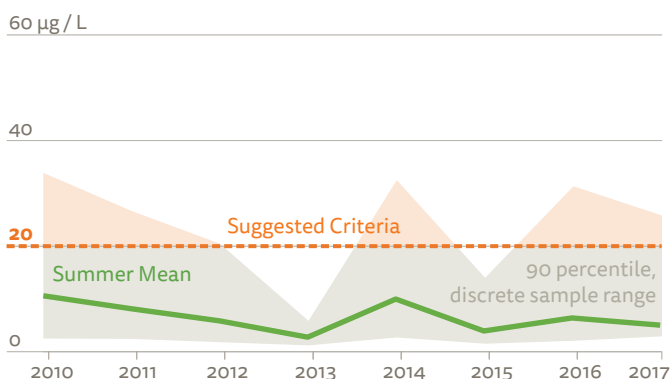
While pathogenic bacteria and dissolved oxygen are the primary criteria used to set water quality standards in New Jersey, measurement of total nitrogen and chlorophyll-*a* provide additional information as to possible causes of low DO as well as the presence of photosynthetic algae and algal blooms. Between 2010 and 2017, the summer means for total nitrogen ranged between 2.35 and 3.27 mg/L, though daily values fluctuated over time and data

were not available between 2013 and 2015. Total nitrogen levels between 0.4 and 1.2 mg/L is considered indicative of fair conditions, and water quality would improve with nitrogen levels equal to or below 0.4 mg/L. Chlorophyll-*a* in this region shows daily fluctuation over the eight-year period. Concentrations of 5 µg/L or below support healthier habitats for fish survival and propagation, while concentrations at or above 20 µg/L increase algal growth.

Total Nitrogen, Summer Mean



Chlorophyll-*a*, 90th Percentile Surface



Investments and Opportunities for Improvement

EPA and New Jersey have identified CSOs as a key source of pathogenic bacteria (and other pollutants) that limit recreational use. Eight of New Jersey's 25 CSO permit holders are located in this region, and each is responsible for producing a Long Term Control Plan (LTCP) intended to reduce the number of CSOs. New Jersey LTCPs, submitted to the state in 2020, have a long term (20-40 year) implementation process. New Jersey municipalities' planned investments through the LTCPs range from \$16.2 million to upwards of \$1.8 billion per each of the CSO permit holders in the region (NJDEP, 2020). Potential investments in chemical disinfection of discharge using Peracetic acid (PAA), storage tunnels or tanks, and green infrastructure should result in significant improvements to water quality in the region. In addition, MS4 permits in the region address stormwater quality issues related to new development, redevelopment and existing development.

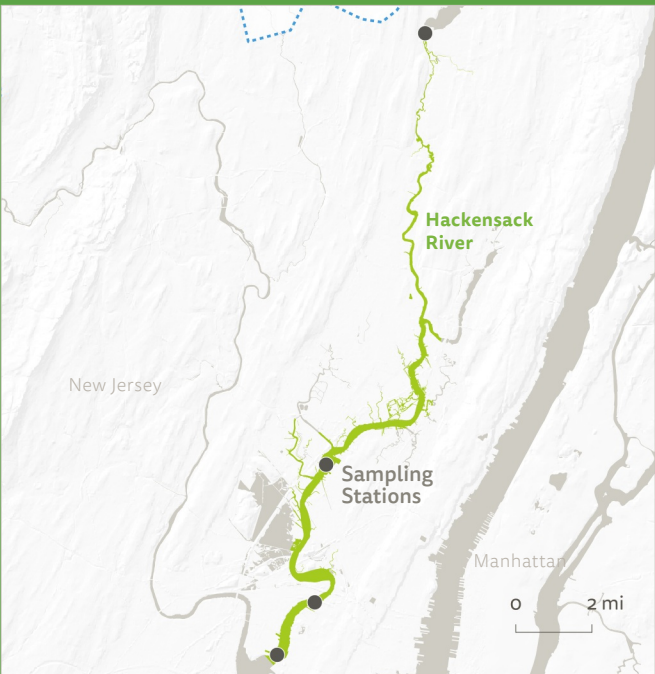
With the implementation of LTCPs and efforts to prevent pollution through the MS4 permits, reduction in pathogens is

anticipated, specifically *E.coli* and *enterococci*, and nutrients. New Jersey CSO permittees are required to consider green infrastructure as a CSO alternative. Green infrastructure projects such as the conversion of impervious surface into rain gardens will also improve levels of nutrient loading and total suspended solids by managing stormwater runoff in the region. To improve water quality for fish propagation and survival as well as reduce the occurrence of algal blooms, further efforts are needed to mitigate nutrients such as nitrogen and chlorophyll-*a* in this region. Under the EPA Superfund Program, efforts to remediate the lower 8.3 miles of the Passaic River, from Newark Bay to the Newark/Belleville border, will remove 3.5 million cubic yards of toxic sediment (NJDEP, 2020). What will become the largest environmental dredging project in the history of the federal Superfund program, the cleanup will provide opportunities to create, enhance, and restore habitat and improve water quality.

Hackensack River

The Hackensack River flows roughly parallel to the Hudson River, from New York State into New Jersey, where it merges with Newark Bay. Most of the watershed lies within Rockland County, NY and the New Jersey counties of Bergen and Hudson. The completion of the Oradell Dam in 1923 greatly changed the makeup of the river's lower reaches, impounding a northern freshwater system above the dam, and creating a brackish estuary system south of it. This lower, tidal portion of the Hackensack River flows through the Hackensack Meadowlands, a complex of wetlands that includes extensive salt marshes. This rich ecosystem is home to several rare, threatened and endangered plant and animal species. There are popular river-side parks in Hackensack, Teaneck, Secaucus, and Carlstadt; and the Meadowlands Environmental Center at Richard W. DeKorte Park in Lyndhurst is a gateway to the Meadowlands.

The industrialized and commercialized land surrounding the lower Hackensack River has made



it subject to a long history of pollution. The state reports to EPA through their 303(d) and 305(b) lists impairments to aquatic life and fish consumption, though secondary contact recreation is deemed supported. Large portions of this region are impaired due to benzo[a]pyrene (PAHs), chlordane in fish tissue, DDT in fish tissue, dieldrin, dioxin (including 2,3,7,8-TCDD), heptachlor epoxide, mercury in fish tissue, PCBs in fish tissue, and CSOs. TMDLs are needed for all aforementioned causes of impairment. A TMDL has been completed for nickel.

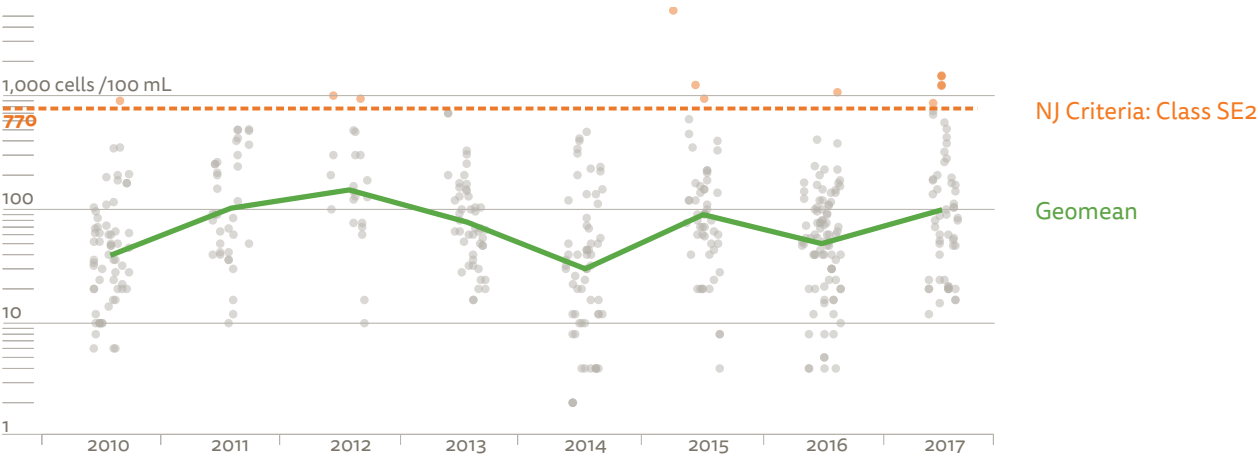
Waterbody	Water Class NJAC 7: 9B-1.14(d)(1)	Water Quality Criteria	
		Pathogenic Bacteria (cfus/100mL)	Dissolved Oxygen (mg/L)
Upper Hackensack River	Class SE1: Shellfish and Bathing	Enterococcus: Monthly GM ≤35 or a single sample max > 104	Never < 4.0 at any time
			24-hour average ≥ 5.0
Hackensack River	Class SE2: Fishing and Fish Propagation	Fecal Coliform: Monthly GM ≤770	Never < 4.0
Lower Hackensack River	Class SE3: Fishing and Fish Migration	Fecal Coliform: Monthly GM ≤1,500	Never < 3.0

Pathogens

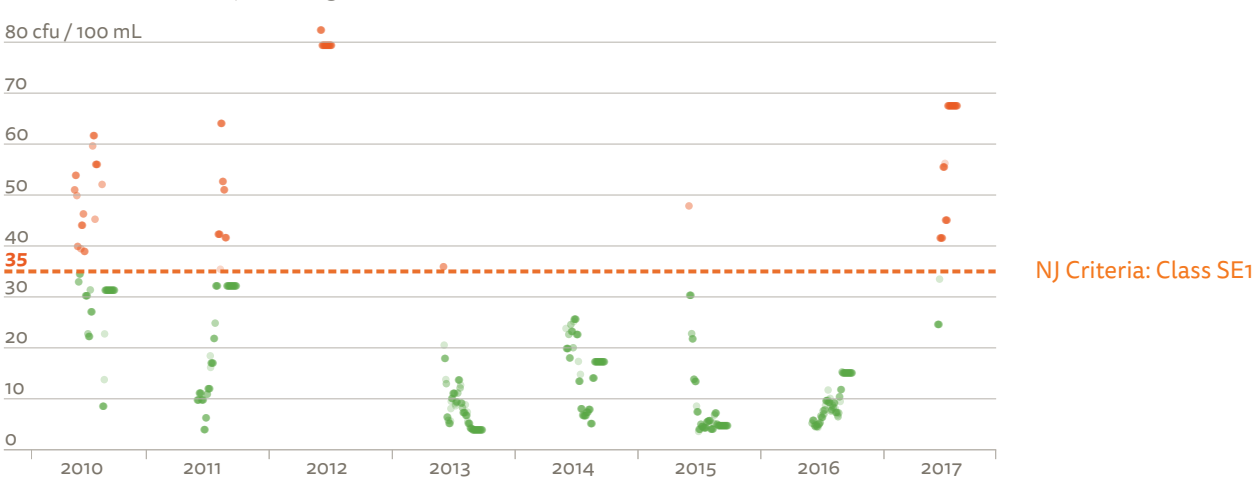
The presence of pathogenic bacteria can limit recreational use of these waterways. Sampling data shows variability over time, but the geometric means show compliance when it comes to Class SE2 criteria for fecal coliform and is supportive of secondary contact recreation. Samples tested for *Enterococcus* criteria, applicable only to the upper portion of the Hackensack River by the Oradell Reservoir, shows more inconsistency and limit primary contact recreation. For example, in 2017, 88% of samples were out of compliance while the previous four years had less than 3% that were non-compliance for *Enterococci*. The

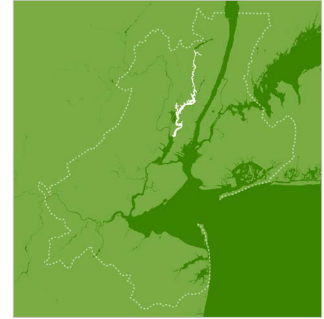
fecal coliform summer discreet measurements ranged from 2 cfu/100mL to 5,600 cfu/100mL over the eight-year period. With an average of 75 discrete samples per recreational season (June-September) per year, the average geomean for fecal coliform in this region is 80 cfu/100mL. *Enterococcus* summer discreet measurements ranged from 3.6 cfu/100mL to 113 cfu/100mL over the same periods. Out of over 550 samples, the average geomean of *Enterococci* for this region is 24 cfu/100mL and 12.4% of discrete samples exceeded the single sample maximum (>104 cfus/100mL) *Enterococcus* criterion.

Fecal Coliform, Surface Summer Mean and Discrete Samples



Enterococcus, 30 Day Moving Geomean





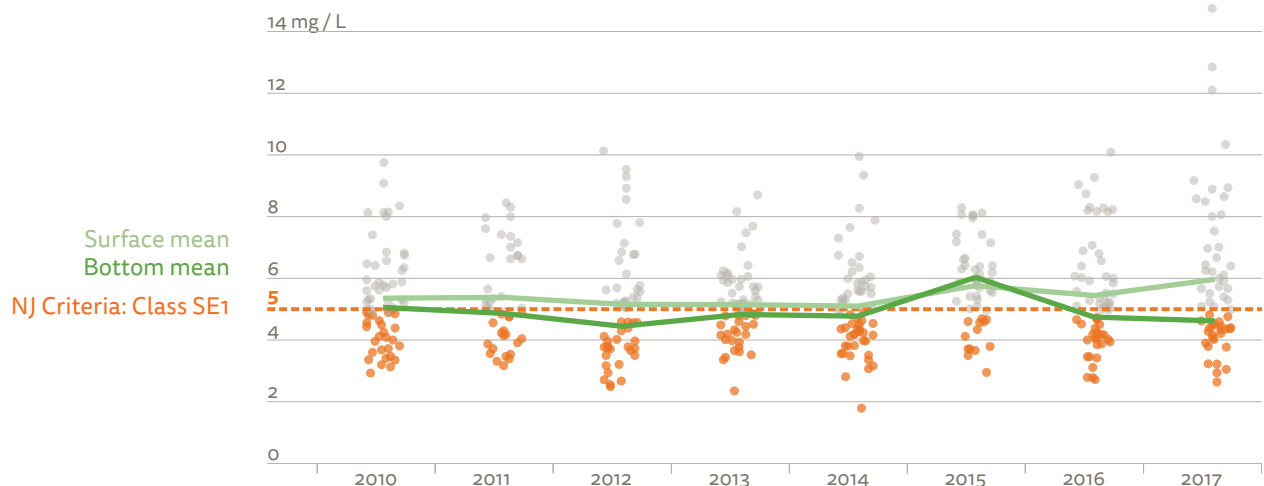
Dissolved Oxygen

Dissolved oxygen (DO) is a critical measure of habitat quality for fish and other wildlife. It is measured at the surface, where sunlight can penetrate to generate photosynthesis, as well as at the bottom, where sunlight is less available. In general, bottom DO concentrations are consistently lower than surface DO concentrations. Daily average concentrations are in compliance with the DO criteria throughout the eight-years evaluated. In general, fish in this region are consistently stressed. The minimum discrete samples do fall close to EPA's suggested threshold of 2.3 mg/L, which is indicative of hypoxic conditions. The percent of time DO samples were less than 4 mg/L was between 15-34% for surface DO and 13-29% for bottom DO. The percent of time DO samples were less than 5 mg/L has been between 30-53% for surface DO and 31-67% for bottom DO.

The Meadowlands Environmental Research Institute (MERI) has also been monitoring approximately 14 sampling stations in this region since 2010 and has two continuous monitoring stations to measure DO at the River Barge Park Marina and Kearny, adjacent to the NJ Transit Lower Hack Bridge. Samples from MERI and the NJHDG show similar conditions for DO in the lower portions of the river, near the Meadowlands district. However, the data collected by MERI at the River Barge Park Marina, in the upper portions just above the Meadowlands district near NJHDG's station 14, shows slightly more severe conditions. Both data sources reach the same overall conclusion the Hackensack River exhibits below desirable DO levels when compared to the SE2 criteria and more so when compared to EPA's guidance of 4.8 and 2.3 mg/L

Data Source	Average (mg/L)	% of Samples <4.8 mg/L	% of Samples <2.3 mg/L	% of Samples <4.0 mg/L
NJHDG (Upper Portion)	6.0	42	0	15
MERI – Barge (Upper Portion)	4.6	65	11	46
NJHDG (Lower Portion)	4.3	55	0	25
MERI – Kearny (Lower Portion)	4.9	46	0	15

Dissolved Oxygen, Summer Mean, Surface and Bottom

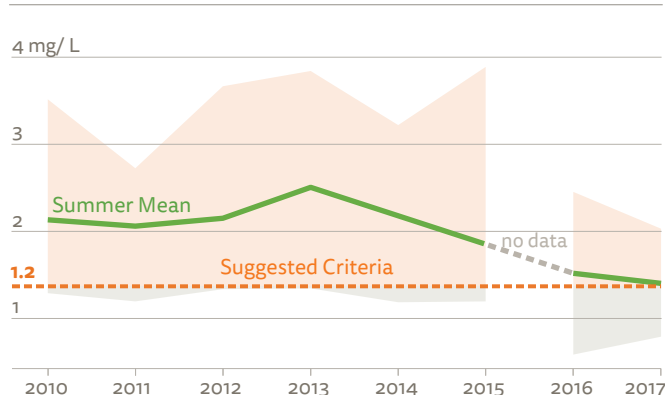


Other Water Quality Parameters

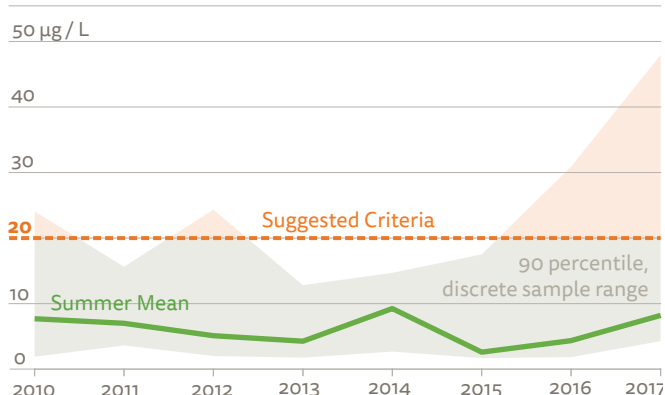
While pathogenic bacteria and dissolved oxygen are the primary criteria used to set water quality standards in New Jersey, measurement of total nitrogen and chlorophyll-*a* provide additional information as to possible causes of low DO as well as the presence of photosynthetic algae and algal blooms. Between 2010 and 2017, the summer means for total nitrogen ranged between 1.41 and 2.51 mg/L, though daily values fluctuated over time and

data was not available in 2015. Total nitrogen levels between 0.4 and 1.2 mg/L is indicative of fair conditions, and water quality would improve with nitrogen levels equal to or below 0.4 mg/L. Chlorophyll-*a* levels in this region shows an upward increase beginning in 2015. Concentrations of 5 µg/L or below support healthier habitats for fish survival and propagation, while concentrations at or above 20 µg/L increase algal growth.

Total Nitrogen, Summer Mean



Chlorophyll-*a*, 90th percentile Surface



Investments and Opportunities for Improvement

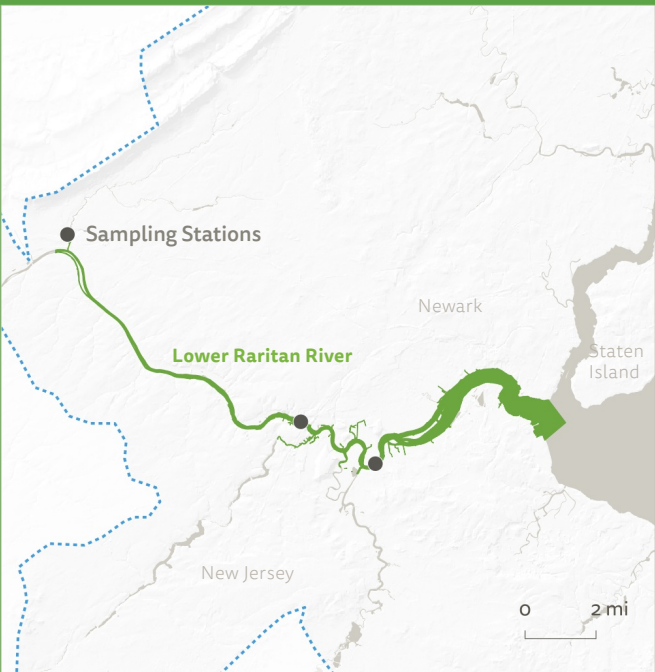
EPA and New Jersey have identified CSOs as a key source of pathogenic bacteria (and other pollutants) that limit recreational use. Four of New Jersey's 25 CSO permit holders are located in this region, and each is responsible for producing a Long Term Control Plan (LTCP). These plans are intended to reduce the number of CSOs, therefore improving water quality through the management of pathogens. New Jersey LTCPs, submitted to the state in 2020, have a long term (20-40 year) implementation process. New Jersey municipalities' planned investments through the LTCPs range from \$15.8 million to upwards of \$859 million per each of the CSO permit holders in the region (NJDEP, 2019; NJDEP, 2020). Potential investments towards the implementation of chemical disinfection of discharge using Peracetic acid (PAA), storage tunnels or tanks, and green infrastructure should result in significant improvements to water quality in the region. In addition, MS4 permits in the region address stormwater quality issues related to new development, redevelopment and existing development.

With the implementation of LTCPs and efforts to prevent pollution through the MS4 permits, a reduction in pathogens is anticipated, specifically for fecal coliform and *Enterococci*, and nutrients. New Jersey CSO permittees are required to consider green infrastructure as a CSO alternative in their current planning phase before the submittal of LTCPs. Green infrastructure projects such as the conversion of impervious surface into rain gardens should reduce levels of nutrient loading and total suspended solids by managing stormwater runoff in the region. The Meadowlands is also home to several Superfund sites and a recent EPA interim plan will invest an additional \$18.6 million in the region to remove 16,300 cubic yards of sediment from the cleanup area at the Universal Oil Products site in East Rutherford (NJDEP, 2019; NJDEP, 2020). Further efforts by the Bergen County Utilities Authority, a POTW in the region, to reduce nitrogen loadings will support healthier habitats for fish survival and propagation as well as potentially reduce the occurrence of algal blooms in this region.

Lower Raritan River

The Raritan River runs eastward through central New Jersey, from Somerset County in the Watchung Mountains out to coastal plains towards Raritan Bay in Middlesex County. This regional analysis addresses the River up to the head of tide near South Bound Brook, New Jersey. The Raritan River has served as a water supply, transportation and trade route that became home to mills and factories from pre-colonial times through the Industrial Revolution. Massive clay deposits along the river allowed for brick manufacturers to flourish in addition to the transportation network from steamboats to rails and highways. A number of riverfront parks, such as Boyd Park in New Brunswick, Johnson Park in Edison, and the Perth Amboy's waterfront and fishing piers can be found in this region.

The economic prosperity that the Raritan brought to the region was threatened in the 1920s by the uncontrolled and accelerated disposal of industrial toxic waste in the river, coupled with an unregulated flow of sewage from a growing population. By 1997, the Raritan was ranked the 14th most polluted river in the United States with over 200 contaminated sites in its watershed, 24 of them federally designated Superfund sites. The historical industrial waste and release of sewage through the CSOs are major factors that affect water quality. In



addition, the number of dams that were built throughout the history of the river has disrupted habitat and fish migrations.

The state reports to EPA through their 303(d) and 305(b) lists impairments to aquatic life, fish consumption, primary contact recreation, and shellfish harvesting. This region is impaired due to benzo[a]pyrene (PAHs), chlordane, DDT, dieldrin, dioxin (including 2,3,7,8-TCDD), *Enterococcus* bacteria, heptachlor epoxide, mercury, PCBs, arsenic, benzene, phosphorus, total suspended solids (TSS), water temperature, and pH. Chlordane, DDT, mercury, and PCBs were all found in fish tissue within this region. TMDLs are needed for all aforementioned causes of impairment. TMDLs have been completed for fecal coliform and mercury in fish tissue for portions of the Raritan.

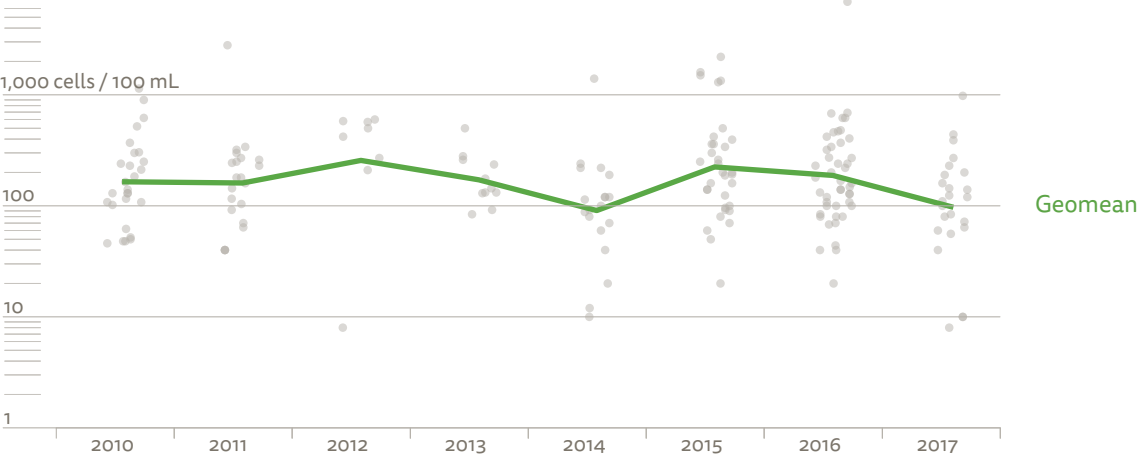
Waterbody	Water Class NJAC 7: 9B-1.14(d)(1)	Water Quality Criteria	
		Pathogenic Bacteria (cfus/100mL)	Dissolved Oxygen (mg/L)
Raritan River	Class SE1: Shellfish and Bathing	<i>Enterococcus</i> : Monthly GM ≤ 35 or a single sample max > 104	Never < 4.0 at any time
			24-hour average ≥ 5.0

Pathogens

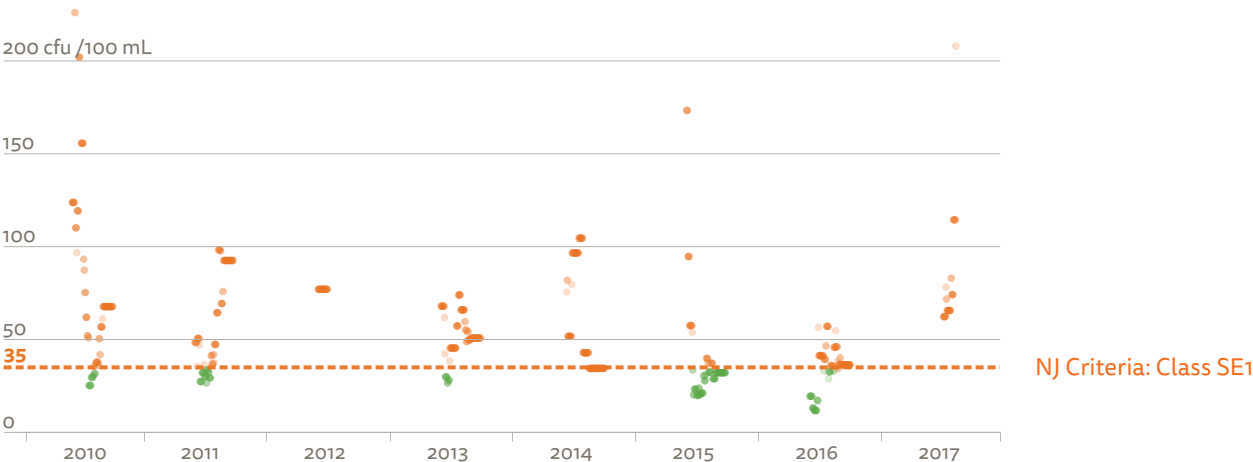
The presence of pathogenic bacteria can limit recreational use of these waterways. Sampling data shows variability over time where the geometric means show non-compliance for primary contact recreation in most years. For example, in 2017, 100% of samples for *Enterococcus* were found above the geometric mean criterion and only in 2015 the samples fell below 50%.

With an average of 172 discrete samples per recreational season (June-September) per year, the average geomean for *Enterococcus* in this region is 65 cfu/100mL. *Enterococcus* summer geometric means ranged from 11.7 cfu/100mL to 456 cfu/100mL over the same periods and 25.3% of discrete samples exceeded the *Enterococcus* single sample maximum (>104 cfus/100mL) criterion.

Fecal Coliform, Summer Mean Surface and Discrete Samples



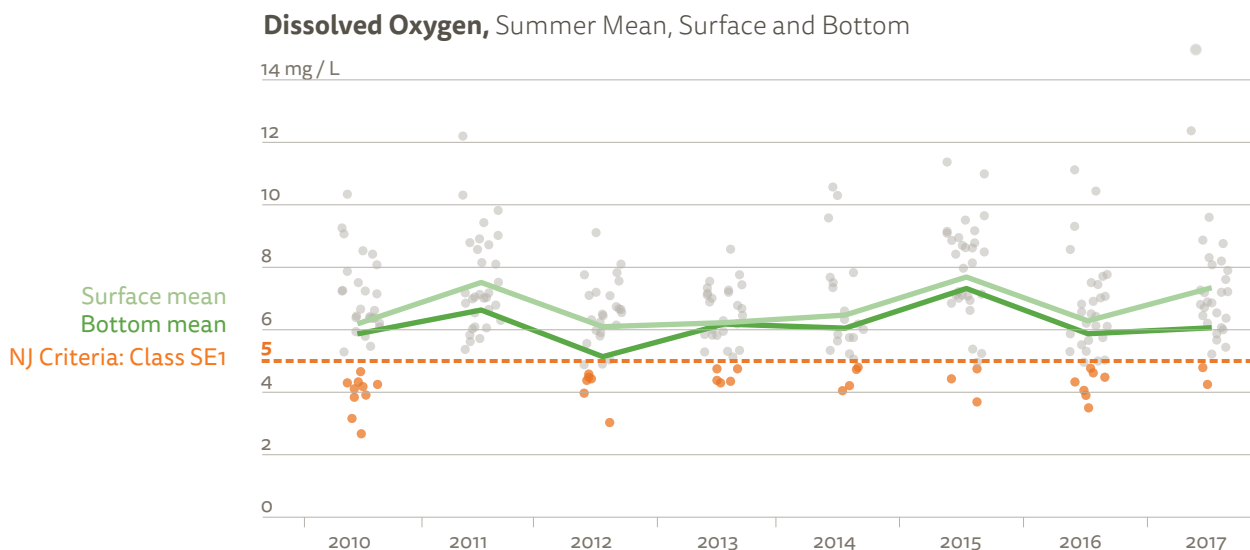
Enterococcus, 30 Day Moving Geomean



Dissolved Oxygen

Dissolved oxygen (DO) is a critical measure of habitat quality for fish and other wildlife. It is measured at the surface, where sunlight can penetrate to generate photosynthesis, as well as at the bottom, where sunlight is less available. In general, bottom DO concentrations are consistently lower than surface DO concentrations. Daily average concentrations in this region are in compliance with the DO criteria throughout the years

evaluated. In general, fish in this region are not consistently stressed. However, minimum discrete sample concentrations of less than 4.0 mg/L are recorded in four of the eight years evaluated. The percent of time DO samples were less than 4 mg/L was between 0-12% for surface DO and 0-16% for bottom DO. The percent of time DO samples were less than 5 mg/L was between 0-28% for surface DO and between 13-47% for bottom DO.

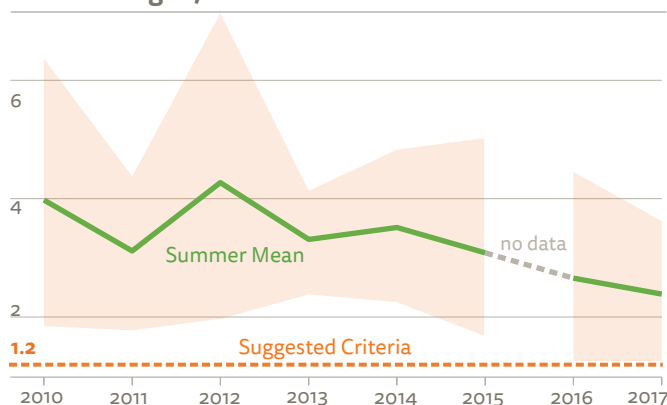


Other Water Quality Parameters

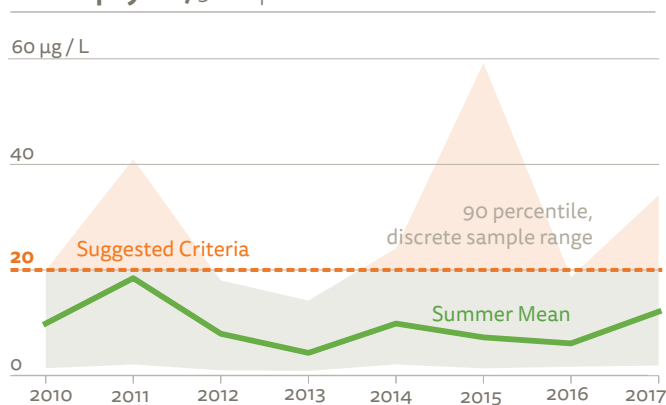
While pathogenic bacteria and dissolved oxygen are the primary criteria used to set water quality standards in New Jersey, measurement of total nitrogen and chlorophyll-*a* provide additional information as to possible causes of low DO as well as the presence of photosynthetic algae and algal blooms. Between 2010 and 2017, the summer means for total nitrogen ranged between 2.39 and 4.27 mg/L, though daily values fluctuated over time and data were not available in 2015. Total nitrogen

levels between 0.4 and 1.2 mg/L is indicative of fair conditions, and water quality would improve with nitrogen levels equal to or below 0.4 mg/L. Concentrations of chlorophyll-*a* of 5 µg/L or below support healthier habitats for fish survival and propagation, while concentrations at or above 20 µg/L increase algal growth. There was a significant spike in 2015 where discrete samples are ranged well above the 20 µg/L suggested threshold.

Total Nitrogen, Summer Mean



Chlorophyll-*a*, 90th percentile Surface



Investments and Opportunities for Improvement

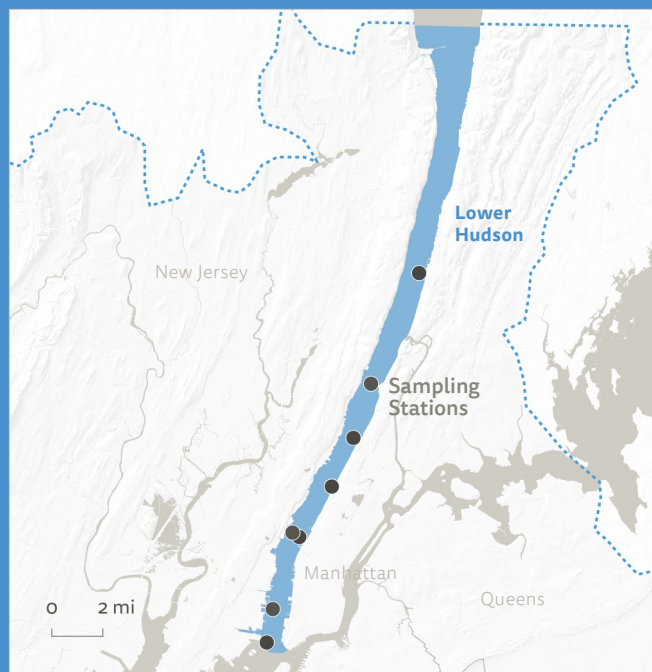
EPA and New Jersey have identified combined sewer overflows as a key source of pathogenic bacteria (and other pollutants) that limit recreational use. The City of Perth Amboy is the only CSO permit holder in this region and is responsible for producing a Long Term Control Plan (LTCP). This plan is intended to reduce the volume of CSOs, therefore improving water quality through the management of pathogens. New Jersey LTCPs, submitted to the state in 2020, have a long term (20-40 year) implementation process. The City of Perth Amboy's planned investments through the LTCP ranged from \$375.5 million to upwards of \$396 million (NJDEP, 2020). Potential investments towards the implementation of chemical disinfection of discharge using Peracetic acid (PAA), storage tunnels or tanks, and green infrastructure should result in significant improvements to water quality in the region. In addition, MS4 permits in the region will further address stormwater quality issues related to new development, redevelopment and existing development.

New Jersey CSO permittees are required to consider green infrastructure as a CSO alternative in their current planning phase before the submittal of LTCPs. Green infrastructure projects such as the conversion of impervious surface into rain gardens will reduce levels of nutrient loading and total suspended solids by managing stormwater runoff in the region. With the implementation of LTCPs and efforts to prevent pollution through the MS4 permits, a reduction in pathogens is anticipated, specifically for fecal coliform and *Enterococci*, and nutrients. To improve water quality for fish propagation and survival as well as reduce the occurrence of algal blooms, further efforts are needed to address nutrients such as nitrogen in this region. Additional efforts to remove dams, such as the Weston Mill Dam, will improve habitat connectivity to support fish migrations and aid to reduce flooding throughout the watershed.

Lower Hudson River

Running from the Mario Cuomo Bridge to the Battery at the southern tip of Manhattan, the Lower Hudson River is made up of tidal urban waters shared between the states of New York and New Jersey. This region includes portions of Hudson and Bergen counties in New Jersey, parts of Westchester and Rockland Counties in New York, and the New York City boroughs of Manhattan and the Bronx. As a result of its location near the mouth of the Hudson River and its tidal nature, the Lower Hudson River played a key role in the Revolutionary War and continues to be a major transportation route. Much of its shoreline is accessible to the public, including the entire west side of Manhattan, the Hudson River Waterfront Walkway and adjoining parks in Hudson County, and Palisades Interstate Park.

With a long history of industrial pollution, including the discharge of large amounts of polychlorinated biphenyls (PCBs) from the electrical capacitor manufacturing at two General Electric Inc. facilities on the upper Hudson River from 1947-1977, has led to contaminated sediments that still impact the water quality of the river today. Major factors influencing water quality in this region include massive tidal exchange with the ocean, legacies of contaminated sediments, habitat alter-



ation, power generation discharges, urban runoff, CSOs and municipal discharge/sewage.

The state reports to EPA through their 303(d) and 305(b) impairments to aquatic life, fish consumption, primary contact recreation, shellfish harvesting, and water supply, with most occurring south of the Bronx border. This region is impaired due to PCBs, Benzo[a]pyrene (PAHs), chlordane, DDT, dieldrin, dioxin (including 2,3,7,8-TCDD, hexachlorobenzene, and mercury. Secondary contact recreation, such as boating and fishing, is listed as in good condition throughout the region by both states while north of the Bronx border, primary contact recreation, such as bathing, is listed as in good condition by New York State. TMDLs are needed for all aforementioned causes of impairment.

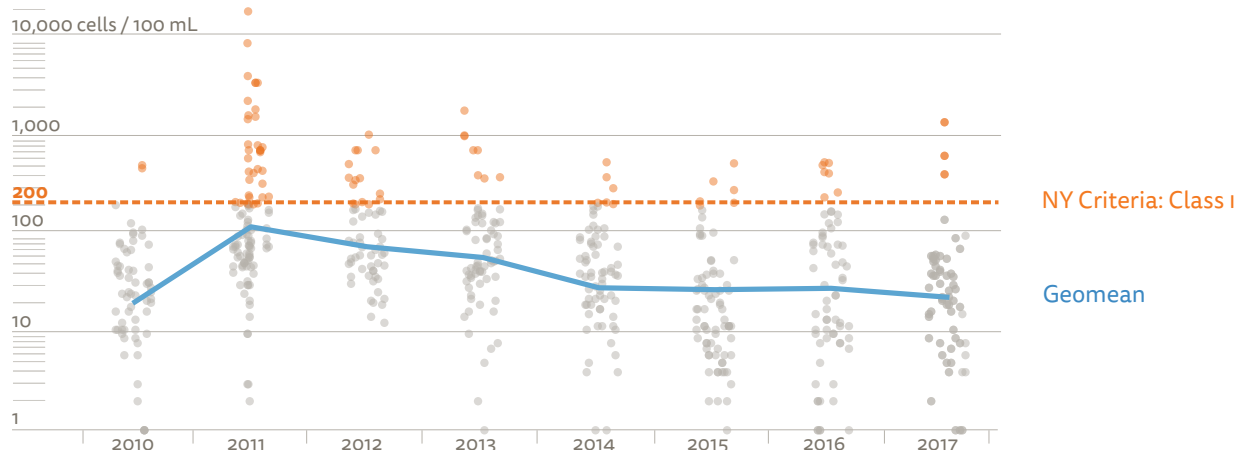
Waterbody	Water Class (NY) 6 CRR-NY 703.3 & 6 CRR-NY 703.4	Water Quality Criteria	
		Pathogenic Bacteria (cfus/100mL)	Dissolved Oxygen (mg/L)
Hudson River	Class I: Fishing and Boating	Fecal Coliform: Monthly GM ≤200 from 5 or more samples	Never < 4.0
Water Class (NJ) (NJAC 7:9B-1.14(d)(1))			
Hudson River	Class SE2: Fishing and Fish Propagation	Fecal Coliform: Monthly GM ≤770	Never < 4.0
	Class SE1: Shellfish and Bathing	Enterococcus: Monthly GM ≤ 35 or single sample max > 104	Never < 4.0 at any time, 24-hour average ≥ 5.0

Pathogens

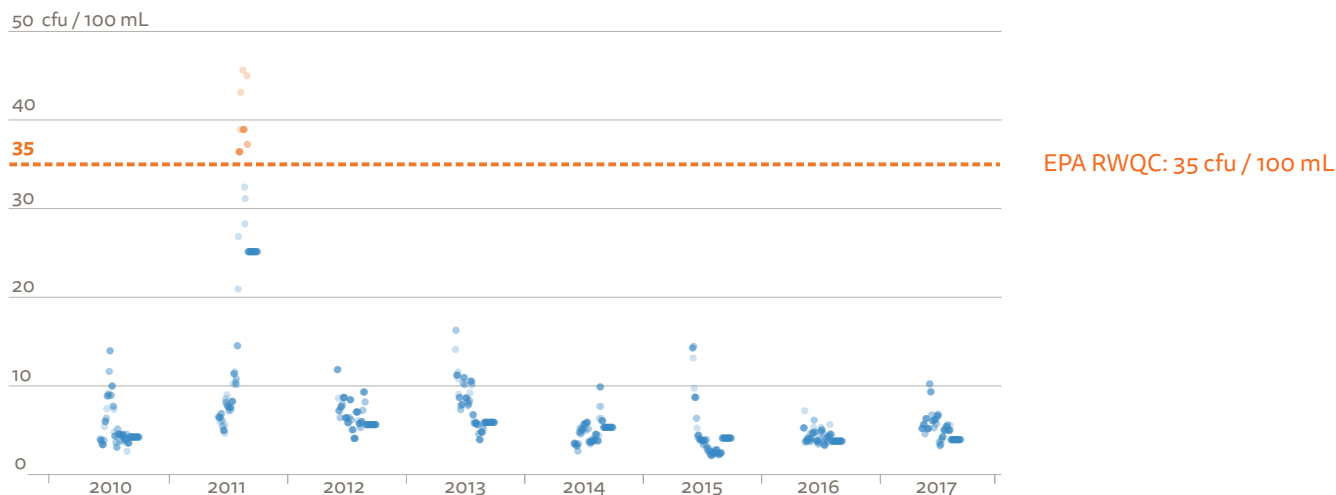
The presence of pathogenic bacteria can limit recreational use of these waterways. Sampling data shows improvement over time. The geometric means of samples collected show compliance for fecal coliform in Class I in New York state waters and Class SE2 for New Jersey state waters, with only 2011 being out of compliance. The fecal coliform summer discrete measurements ranged from 1 cfu/100mL to 22,000 cfu/100mL over the eight-year period. With an average of 112 discrete samples per recreational season (June-September) per year, the average geomean for fecal coliform in this region is 55 cfu/100mL. While *Enterococcus* is not

used by New York or New Jersey for this region, the geometric mean should not exceed 35 cfu/100mL to support primary contact recreational activities. *Enterococcus* summer geometric means ranged from 2.15 cfu/100mL to 61.5 cfu/100mL over the same periods. Out of over 1,000 samples, the average geomean of *Enterococcus* is 7.3 cfu/100mL, with 2011 being the only year out of compliance with over 20% of the moving 30-day geometric means greater than EPA's recommended 35 cfu/100mL and 12% greater than 130 cfu/100mL (above the recommended 10% of the STV).

Fecal Coliform, Summer Surface Bottom and Discrete Samples



Enterococcus, 30 Day Moving Geomean

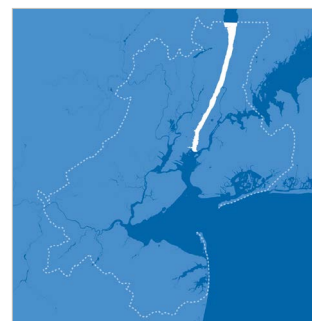


Dissolved Oxygen

Dissolved oxygen (DO) is a critical measure of habitat quality for fish and other wildlife. It is measured at the surface, where sunlight can penetrate to generate photosynthesis, as well as at the bottom, where sunlight is less available. In general, bottom DO concentrations are consistently lower than surface DO concentrations. Daily average concentrations are in compliance with the DO criteria throughout the years evaluated. In general, fish in this region are not stressed. The percent of time DO concentrations were less than 4 mg/L was between 0-4.6% for surface DO and between 0-11.2% for bottom DO. Although this region is doing well with respect to DO, minimum discrete sample concentrations of less than 4.0 mg/L are recorded in two of the eight years evaluated.

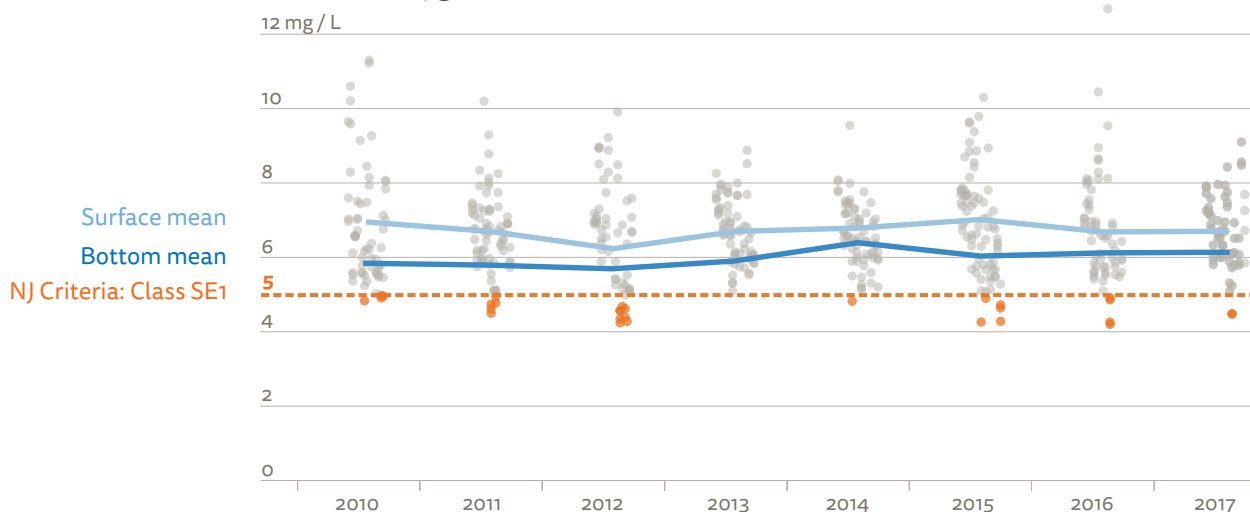
The data presented are from the New Jersey Long-term Ambient Water Quality Monitoring and the New York City

Harbor Survey. The Hudson River Environmental Conditions Observing System (HRECOS) has a continuous monitoring station located at Pier 84 and at Castle Point that are operated and maintained by the Hudson River Park Trust and Stevens Institute of Technology, respectively. The HRECOS stations are located along the Hudson River in close proximity to the grab-sampling sites, station N4 monitored by NYCDEP and station 33 monitored by NJHDG, and collect data every 15-minutes year round. Samples from the two data sources do show similarities. For example, in 2016, the average bottom DO concentration from the grab samples were 6.7 and 6.1 mg/L, while the HRECOS stations for the same period were 5.7 and 6.3 mg/L respectively.



	Hudson River (near Pier 84)	HRECOS Pier 84	Hudson River (near Castle Point)	HRECOS Castle Pt
2016				
Average	6.7	5.7	6.1	6.3
% < 4.8	3.3	10.3	10	5.2
% < 2.3	0	0	0	0
Minimum	4.3	4.1	3.7	4.1

Dissolved Oxygen, Summer Mean, Surface and Bottom

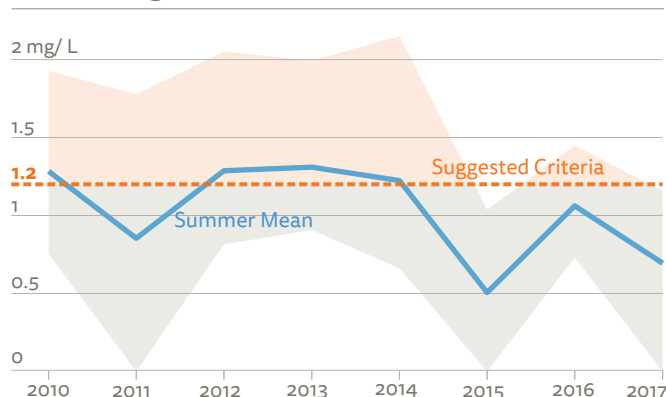


Other Water Quality Parameters

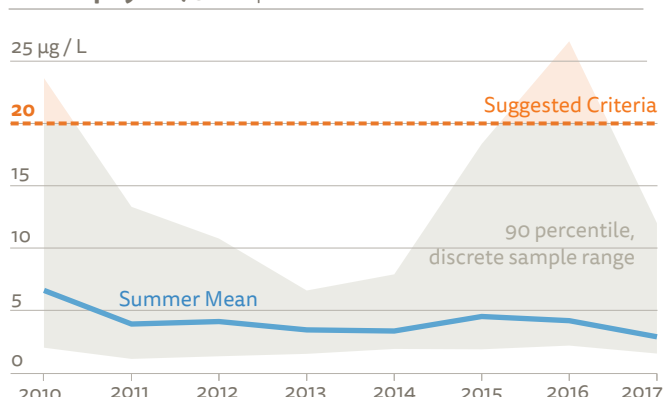
While pathogenic bacteria and dissolved oxygen are the primary criteria used to establish water quality standards in New Jersey and in New York, measurement of total nitrogen and chlorophyll-*a* provide additional information as to possible causes of low DO as well as the presence of photosynthetic algae and algal blooms. Between 2010 and 2017, the summer means for total nitrogen ranged between 0.51 and 1.31 mg/L with minimal daily

fluctuation over time. Total nitrogen levels between 0.4 and 1.2 mg/L is indicative of fair conditions, and water quality would improve with nitrogen levels equal to or below 0.4 mg/L. Chlorophyll-*a* levels in this region show some variability, with higher levels in 2015 through 2016. Concentrations of 5 µg/L or below support healthier habitats for fish survival and propagation, while concentrations at or above 20 µg/L increase algal growth.

Total Nitrogen, Summer Mean



Chlorophyll-*a*, 90th percentile Surface



Investments and Opportunities for Improvement

EPA, New York, and New Jersey have identified CSOs as a key source of pathogenic bacteria (and other pollutants) that limit recreational use. Four of New Jersey's 25 CSO permit holders are located in this region, and each is responsible for producing a Long Term Control Plan (LTCP). These plans are intended to reduce the number of CSOs, therefore improving water quality through the management of pathogens. New Jersey LTCPs, submitted to the state in 2020, have a long term (20-40 year) implementation process. New Jersey municipalities' planned investments through the LTCPs range from \$3.72 million to upwards of \$859 million (NJDEP, 2020). Potential investments towards the implementation of chemical disinfection of discharge using Peracetic acid (PAA), storage tunnels or tanks, and green infrastructure should result in significant improvements to water quality in the region. In addition, this region is part of New York City's Citywide and East River/Open Water LTCP, submitted to the state on in 2020. Preliminary reports on this plan suggest the optimization of CSO regulators, as well as the installation of a bending weir and CSO storage tunnels.

A considerable capital investment of \$45 billion has been invested by New York City as well as additional investments by New Jersey municipalities and POTWs to achieve the goals of the Clean Water Act (NYCDEP, 2020). In addition, MS4 permits in the region will further address stormwater quality issues related to new development, redevelopment and existing development. With the implementation of the new LTCP in New York City and those LTCPs in New Jersey as well as preventing pollution through the MS4 permits, a reduction in pathogens is anticipated, specifically for fecal coliform and *Enterococci*, and for nutrients. LTCPs in New York City also require planning for the implementation of green infrastructure projects such as the conversion of impervious surface into rain gardens, which will potentially reduce levels of nutrient loading and total suspended solids. New Jersey CSO permittees are required to consider green infrastructure as a CSO alternative in their current planning phase before the submission of their LTCPs.

Upper New York Bay

Running from the Battery to the Verrazano Narrows, the shared waters of Upper New York Bay joins the Lower Hudson River, the East River, and the Kill van Kull and Arthur Kill with the Lower New York Bay. This region includes Hudson County in New Jersey and the NYC boroughs of Manhattan, Staten Island, and Brooklyn. Major factors influencing water quality in this region include CSOs, municipal discharges/sewage, industrial point source discharge, stormwater runoff, legacies of contaminated sediments, and tidal exchange with connecting waterbodies. The state reports to EPA through their 303(d) and 305(b) lists impairments to aquatic life, fish consumption, public bathing, recreation, and shellfishing, impacting visitors to important local and regional public access areas including Liberty State Park in New Jersey and Governors Island, Bush Terminal Pier Park and the Shore Parkway in New York.

As a result of its location, the Upper New York Bay is impacted not just by its immediate shorelines, but by the water quality of adjacent waterways. A long



history of pollution prior to the Clean Water Act resulted in contaminated sediments that still provide water quality challenges today. There are also active CSOs in this region, from both states. This region is impaired due to chlordane, copper, PCBs, Benzo[a]pyrene (PAHs), DDT, dieldren, dioxin (including 2,3,7,8-TCDD), heptachlor epoxide, hexachlorobenzene, and mercury. Legacy contaminants such as PCBs, chlordane, DDT, and mercury were all found in fish tissue within this region. TMDLs have been established for copper in New York and mercury found in fish tissue in the New Jersey portion of the Upper New York Bay.

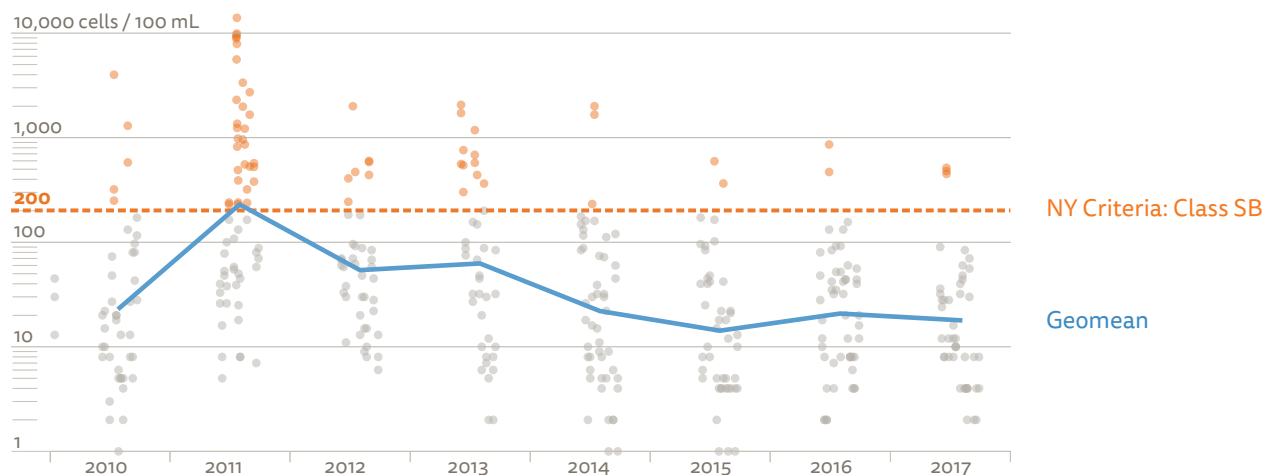
		Water Quality Criteria	
Water Class (NY) 6 CRR-NY 703.3 & 6 CRR-NY 703.4		Pathogenic Bacteria (cfus/100mL)	Dissolved Oxygen (mg/L)
Upper New York Bay	Class SB: Bathing	Fecal Coliform: Monthly GM ≤200 from 5 or more samples	Never < 5.0
		Enterococcus: Monthly GM ≤ 35 and a single sample max > 130	
Water Class (NJ) NJAC 7: 9B-1.14(d)(1)			
Upper New York Bay	Class SE2: Fishing and Fish Propagation	Fecal Coliform: Monthly GM ≤770	Never < 4.0

Pathogens

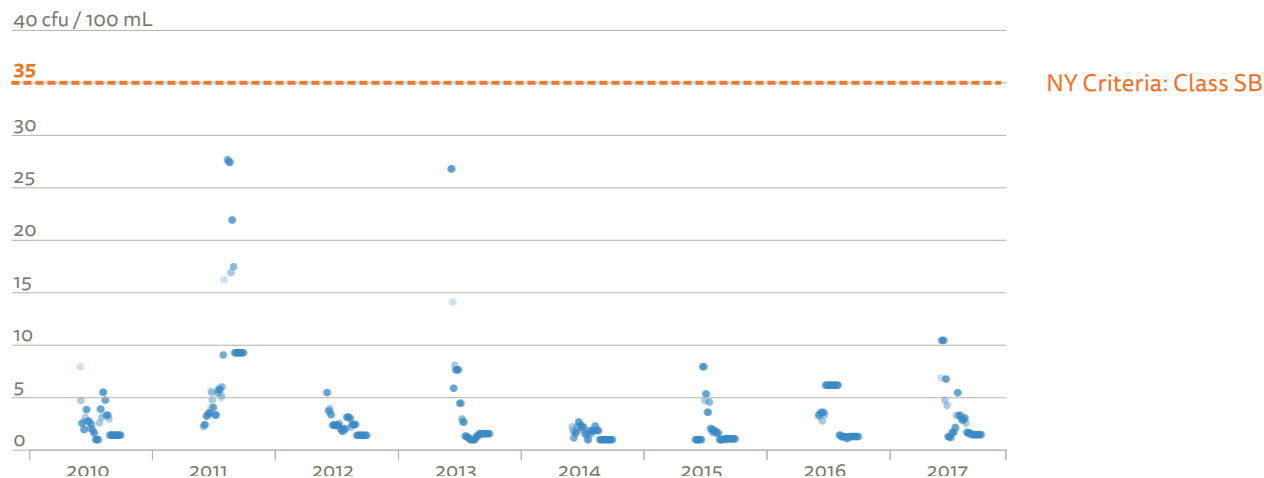
The presence of pathogenic bacteria can limit recreational use of these waterways. Sampling data shows improvement over time. The geometric means of samples from the Upper New York Bay region show compliance for fecal coliform in Class SB in New York state waters and Class SE2 for New Jersey state waters, with the exception of two years. The fecal coliform summer discrete measurements ranged from 1 cfu/100mL to 14,000 cfu/100mL over the eight-year period. With an average of 52 discrete samples per recreational season (June-September) per year, the average single sample value for fecal coliform in this region is

336 cfu/100mL. *Enterococcus* is used by New York, but not New Jersey for this region, where the geometric mean should not exceed 35 cfu/100mL to support primary contact recreational activities. *Enterococcus* summer geometric means ranged from 1 cfu/100mL to 40.1 cfu/100mL over the same periods. Out of over 400 samples, the average geomean for this region is 4 cfu/100mL, 2011 and 2013 being the only two years out of compliance with over 7% and 3%, respectively, of the moving 30-day geometric means greater than EPA's recommended 35 cfu/100mL, but less than 10% of the samples were greater than 130 cfu/100mL.

Fecal Coliform, Summer Surface Mean and Discrete Samples



Enterococcus, 30 Day Moving Geomean

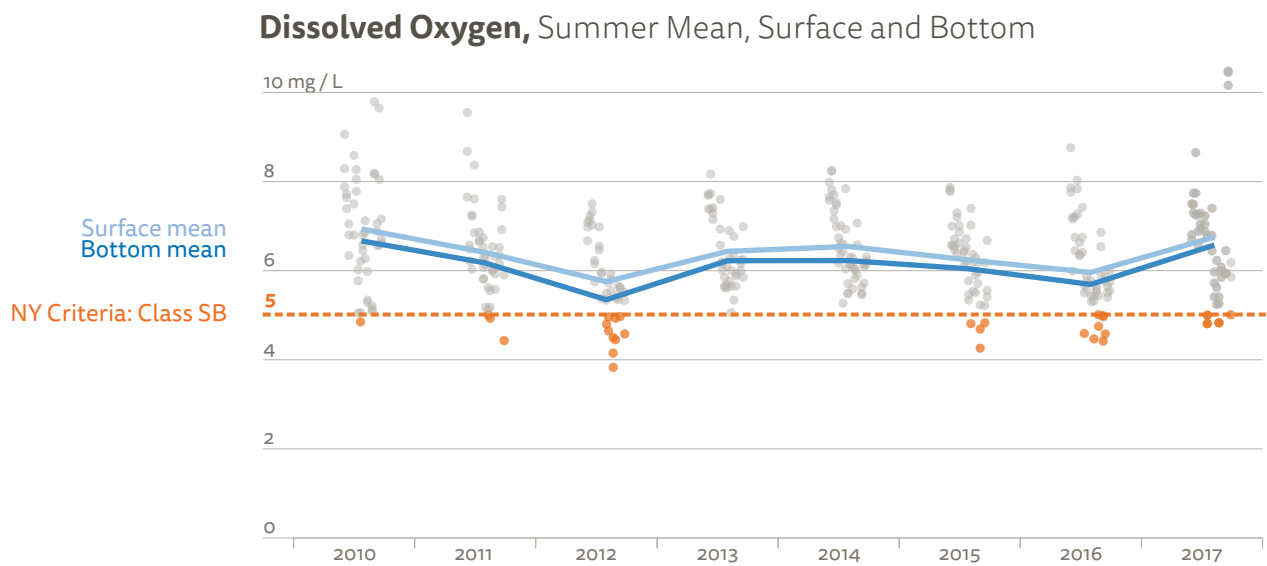




Dissolved Oxygen

Dissolved oxygen (DO) is a critical measure of habitat quality for fish and other wildlife. It is measured at the surface, where sunlight can penetrate to generate photosynthesis, as well as at the bottom, where sunlight is less available. In general, bottom DO concentrations are consistently lower than surface DO concentrations.

Daily average concentrations are in compliance with the DO criteria throughout the years evaluated. In general, fish in this region are not stressed. The percent of time DO measurements were less than 4 mg/L was between 0-3.6% for surface DO, and between 0-9.1% for bottom DO.

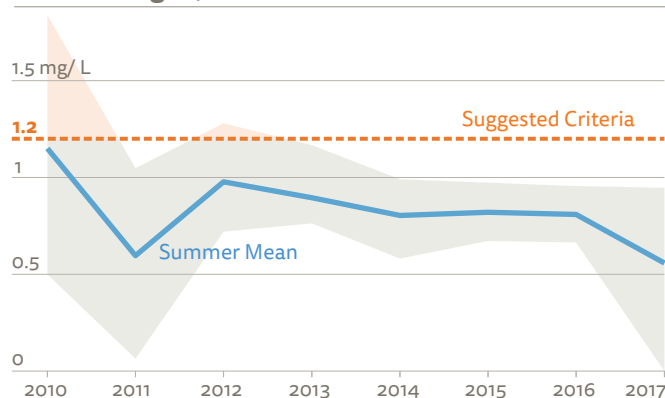


Other Water Quality Parameters

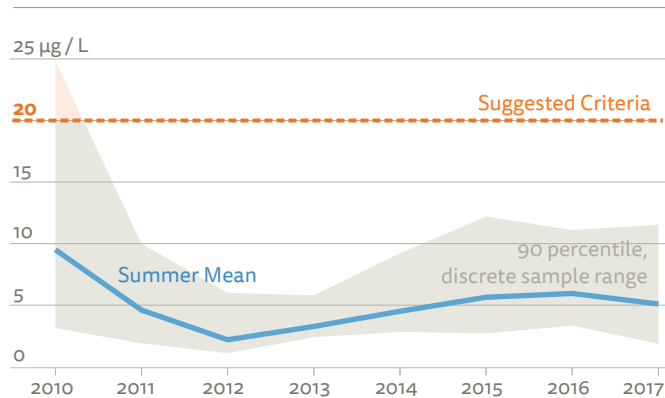
While pathogenic bacteria and dissolved oxygen are the primary criteria used to set water quality standards in New Jersey and New York, measurement of total nitrogen and chlorophyll-*a* provide additional information as to possible causes of low DO as well as presence of photosynthetic algae and algal blooms. Between 2010 and 2017, the summer means for total nitrogen ranged between 0.56 and 1.15 mg/L. Total nitrogen levels between 0.4

and 1.2 mg/L is indicative of fair conditions, and water quality would improve with nitrogen levels equal to or below 0.4 mg/L. Chlorophyll-*a* in this region has shown decreasing values since 2010. Concentrations of 5 µg/L and below support healthier habitats for fish survival and propagation while concentrations at or above 20 µg/L increase algal growth.

Total Nitrogen, Summer Mean



Chlorophyll-*a*, 90th percentile Surface



Investments and Opportunities for Improvement

EPA, New York, and New Jersey have identified combined sewer overflows as a key source of pathogenic bacteria (and other pollutants) that limit recreational use. Two of New Jersey's 25 CSO permit holders are located in this region, and each is responsible for producing a Long Term Control Plan (LTCP). These plans are intended to reduce the number of CSOs, therefore improving water quality through the management of pathogens. New Jersey LTCPs, submitted to the state in 2020, have a long term (20-40 year) implementation process. New Jersey municipalities' planned investments through the LTCPs range from \$16 million to upwards of \$859 million (NJDEP, 2020). Potential investments towards the implementation of chemical disinfection of discharge using Peracetic acid (PAA), storage tunnels or tanks, and green infrastructure should result in significant improvements to water quality in the region. In addition, this region is part of New York City's Citywide and East River/Open Water LTCP, submitted to the state in 2020. Preliminary reports on this plan suggest the optimization of CSO regulators, as well as the addition of a pumping station bypass and CSO storage tunnels. Additionally, the Gowanus Canal, a tributary to the Upper New York Bay,

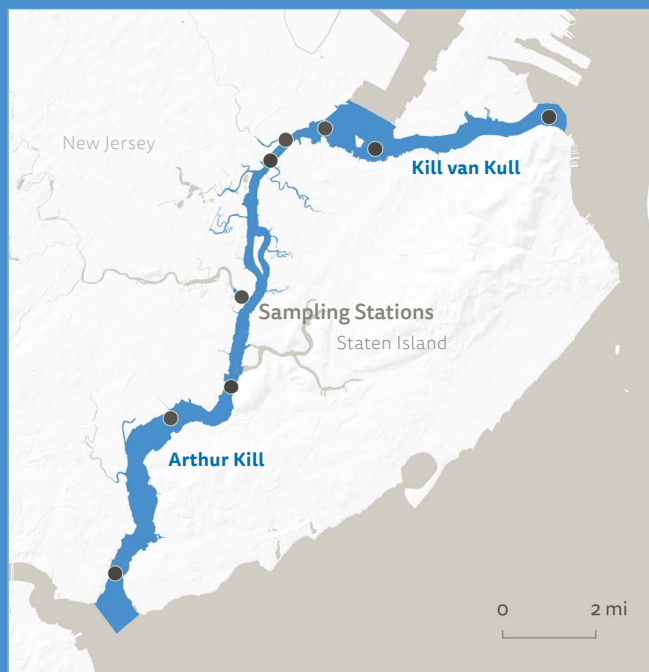
has its own approved LTCP, which calls for construction of CSO storage tanks and other measures. This will result in a predicted 76% decrease in CSO volume to the Gowanus Canal as a result of the proposed \$1.18 billion in LTCP projects. The Gowanus Canal is also an EPA Superfund site where an additional \$500 million will be invested to implement a three-phased remedy plan in coordination with NYCDEP's LTCP (NYCDEP, 2020).

MS4 permits in the region will further address stormwater quality issues related to new and existing development and redevelopment. With the implementation of the new LTCP in New York City and those LTCPs in New Jersey as well as preventing pollution through the MS4 permits, a reduction in pathogens is anticipated, specifically for fecal coliform and *Enterococci*, and for nutrients. LTCPs in New York City also require planning for the implementation of green infrastructure projects such as the conversion of impervious surface into rain gardens, which will reduce levels of nutrient loading and total suspended solids. New Jersey CSO permittees are required to consider green infrastructure as a CSO alternative in their current planning phase before the submittal of LTCPs.

Arthur Kill and Kill van Kull (The Kills)

The Arthur Kill and the Kill van Kull sit between New Jersey and the western side of New York's Staten Island. Commonly referred to as The Kills, the tidal straits connect three waterbodies: the Newark Bay, the Upper New York Bay, and the Raritan Bay. Major tributaries includes the Elizabeth and Rahway Rivers in Union and Middlesex counties. The Kills are one of the most important channels for commerce in the region, providing a passage for marine traffic between Upper New York Bay and the port facilities of Staten Island and northeastern New Jersey. Public parks in the area include Fresh Kills and Sailors Snug Harbor in Staten Island and waterfront parks in Elizabeth, Carteret and Bayonne.

Major factors influencing water quality in this region include CSOs, municipal discharges/sewage, industrial point source discharge, stormwater runoff, spills and unpermitted discharges, contaminated sediments, chemical leaks and spills, and landfills. The state reports to EPA through their 303(d) and 305(b) lists impairments to aquatic life, fish consumption, public bathing, recreation, and shellfishing. Due to its narrow geography and a number of CSO outfalls between Staten Island and the coast of New Jersey, this region is a hotspot for



pathogen loading into the waterways due to CSO events. Additionally, both channels are adjacent to industrial uses and former landfills, highly traveled by commercial vessels, and have endured many oil spills over time. The majority of this region is impaired due to dissolved oxygen, floatables, PCBs, benzo[a]pyrene (PAHs), chlordane, DDT, dieldrin, dioxin (including 2,3,7,8-TCDD), heptachlor epoxide, hexachlorobenzene, and mercury. In addition, PCBs, chlordane, and DDT have been found in fish tissue within this region. TMDLs are needed for The Kills, while TMDLs have been completed for mercury in both fish tissue and in the water column.

Water Quality Criteria			
Waterbody	Water Class (NY) 6 CRR-NY 703.3 & 6 CRR-NY 703.4	Pathogenic Bacteria (cfus/100mL)	Dissolved Oxygen (mg/L)
Arthur Kill	Class SD: Fish Survival	Total Coliform: Monthly Median ≤ 2,400 from 5 or more samples and no more than 20% of samples > 5,000s	Never < 3.0
Kill van Kull		Fecal Coliform: Monthly GM ≤200 from 5 or more samples	

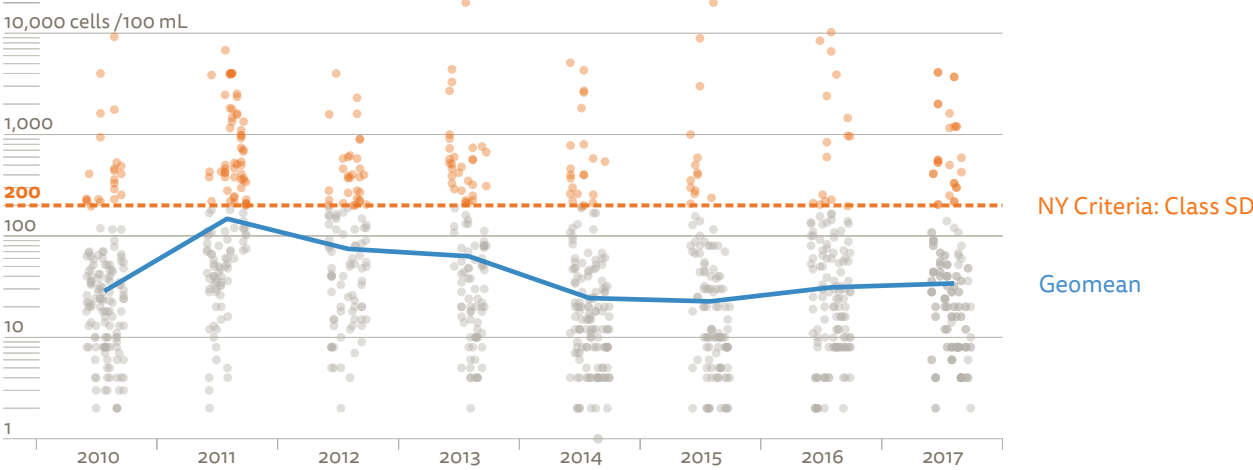
Water Quality Criteria			
Waterbody	Water Class (NJ) (NJAC 7:9B-1.14(d)(1))	Pathogenic Bacteria (cfus/100mL)	Dissolved Oxygen (mg/L)
Arthur Kill	Class SE2: Fishing and Fish Propagation	Fecal Coliform: Monthly GM ≤770	Never < 4.0
Arthur Kill Kill van Kull	Class SE3: Fishing and Fish Migration	Fecal Coliform: Monthly GM ≤1,500	Never < 3.0

Pathogens

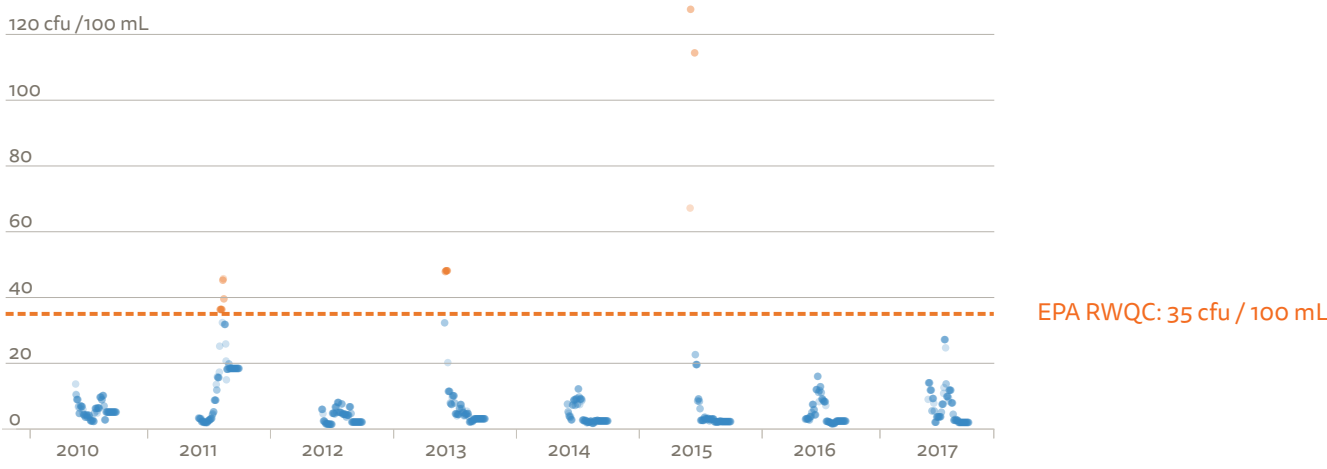
The presence of pathogenic bacteria can limit recreational use of these waterways. Sampling data shows a slight, steady improvement over time, but still are not meeting secondary contact recreation requirements. The geometric means of samples from The Kills region show compliance for fecal coliform in Class SD in New York state waters and Class SE3 for New Jersey state waters. The fecal coliform summer discrete measurements ranged from 0 cfu/100mL to 20,000 cfu/100mL over the eight-year period. With an average of 134 discrete samples per recreational season (June-September) per year, the average geomean

for fecal coliform in this region is 53 cfu/100mL. While *Enterococcus* is not used by New York or New Jersey for this region, the geometric mean should not exceed 35 cfu/100mL to support primary contact recreational activities. *Enterococcus* summer geometric means ranged from 0 cfu/100mL to 14,400 cfu/100mL over the same periods. Out of over 1,200 samples, the average geomean for this region is 10 cfu/100mL with 2011 (10%), 2013 (7%), and 2015 (12%) found to be out of compliance of EPA's recommended moving 30-day geometric means of 35 cfu/100mL.

Fecal Coliform, Summer Surface Mean and Discrete Samples



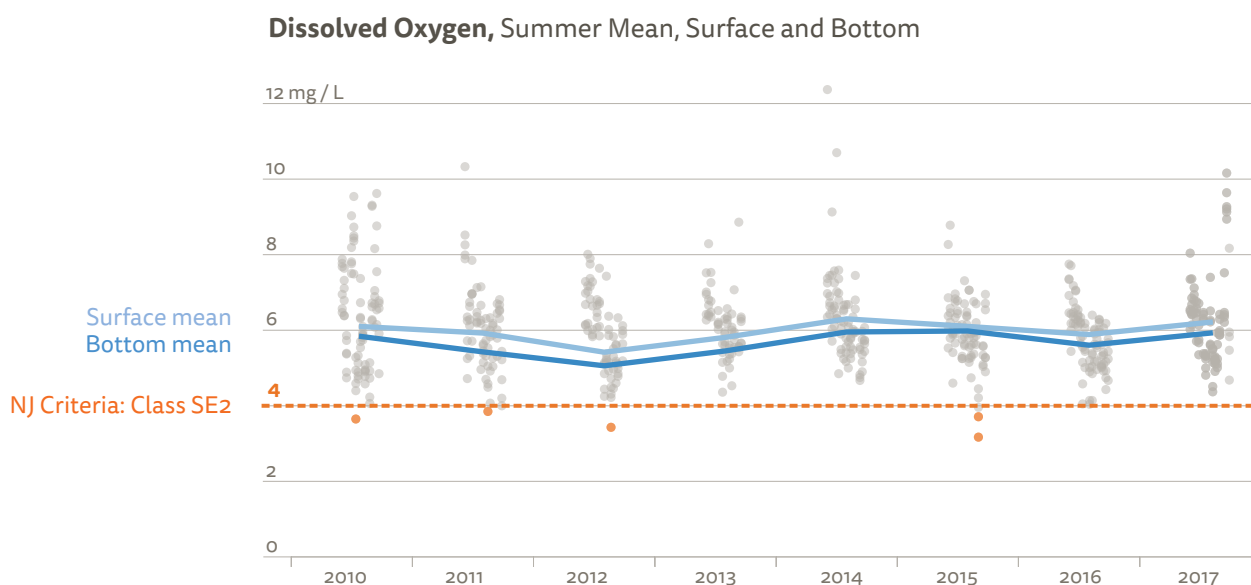
Enterococcus, 30 Day Moving Geomean



Dissolved Oxygen

Dissolved oxygen (DO) is a critical measure of habitat quality for fish and other wildlife. It is measured at the surface, where sunlight can penetrate to generate photosynthesis, as well as at the bottom, where sunlight is less available. In general, bottom DO concentrations are consistently lower than surface DO concentrations. Daily average concentrations are in compliance with the DO criteria throughout the years evaluated. In

general, fish in this region are not stressed. The percent of time DO concentrations were less than 4 mg/L was between 0-10% for surface DO, and between 0-16% for bottom DO. Although this region is doing well with DO compliance, minimum discrete sample concentrations of less than 4.0 mg/L were recorded in 2010, 2012, and 2015.

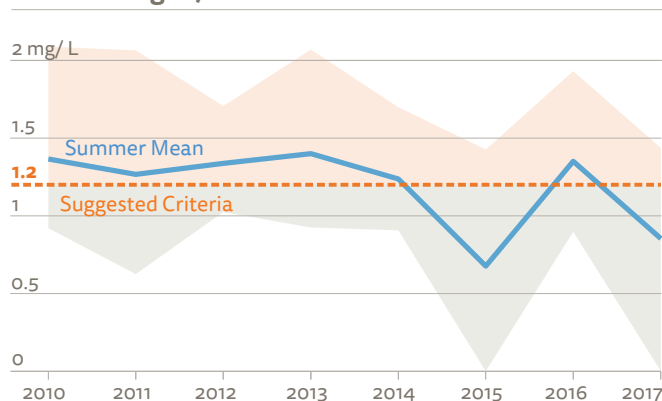


Other Water Quality Parameters

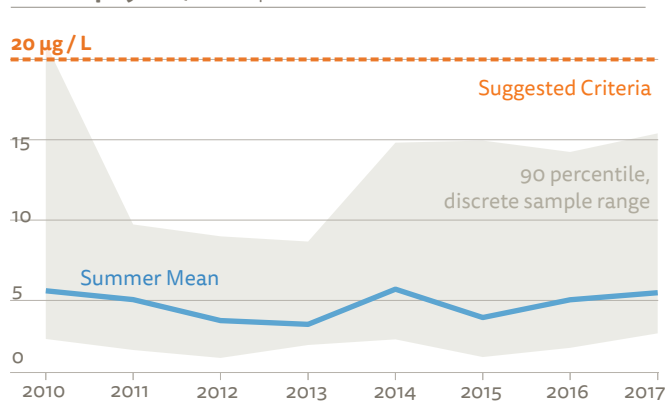
While pathogenic bacteria and dissolved oxygen are the primary criteria used to set water quality standards in New Jersey or New York, measurement of total nitrogen and chlorophyll-*a* provide additional information as to possible causes of low DO as well as the presence of photosynthetic algae and algal blooms. Between 2010 and 2017, the summer means for total nitrogen ranged between 0.68 and 1.4 mg/L. Total nitrogen levels between 0.4

and 1.2 mg/L is indicative of fair conditions, and water quality would improve with nitrogen levels equal to or below 0.4 mg/L. Chlorophyll-*a* in this region show decreasing values largely ranging below the 20 µg/L recommended threshold. Concentrations of 5 µg/L or below support healthier habitats for fish survival and propagation, while concentrations at or above 20 µg/L potentially increase algal growth.

Total Nitrogen, Summer Mean



Chlorophyll-*a*, 90th percentile Surface



Investments and Opportunities for Improvement

EPA, New York, and New Jersey have identified combined sewer overflows as a key source of pathogenic bacteria (and other pollutants) that limit recreational use. Three of New Jersey's 25 CSO permit holders are located in this region, and each is responsible for producing a Long Term Control Plan (LTCP). These plans are intended to reduce the number of CSOs, therefore improving water quality through the management of pathogens. New Jersey LTCPs, submitted to the state in 2020, have a long term (20-40 year) implementation process. New Jersey municipalities' planned investments through the LTCPs range from \$44 million to upwards of \$1.4 billion (NJDEP, 2020). Potential investments towards the implementation of chemical disinfection of discharge using Peracetic acid (PAA), storage tunnels or tanks, and green infrastructure should result in significant improvements to water quality in the region. In addition, this region is part of New York City's Citywide and East River/Open Water LTCP, submitted to the state in 2020. Preliminary reports

on this plan suggest the optimization of CSO regulators, as well as the implementation of CSO storage tunnels.

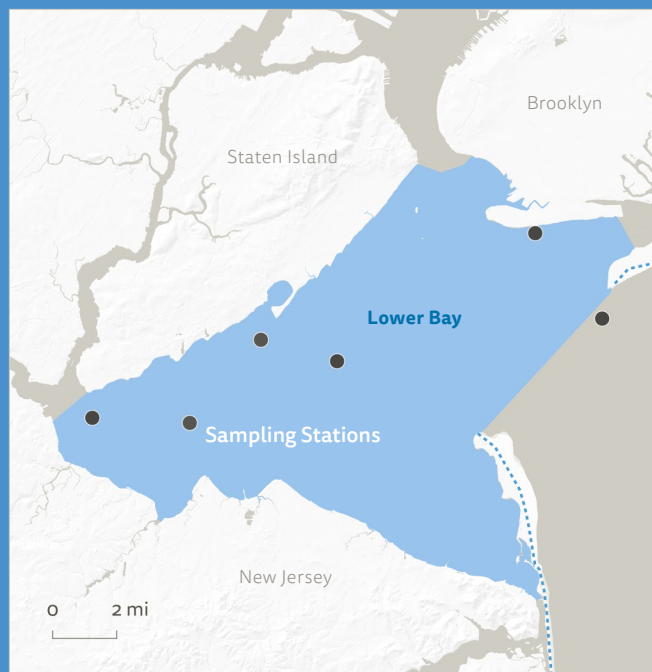
MS4 permits in the region will further address stormwater quality issues related to new development, redevelopment and existing development. With the implementation of the new LTCP in New York City and those LTCPs in New Jersey as well as preventing pollution through the MS4 permits, a reduction in pathogens is anticipated, specifically for fecal coliform and *Enterococci*, and for nutrients. LTCPs in New York City also require planning for the implementation of green infrastructure projects such as the conversion of impervious surface into rain gardens, which will potentially reduce levels of nutrient loading and total suspended solids. New Jersey CSO permittees are required to consider green infrastructure as a CSO alternative in their current planning phase before the submittal of LTCPs. To improve water quality for fish propagation and survival as well as reduce the occurrence of algal blooms, further efforts may be needed to address nutrients in this region.

Lower Bay

(Raritan Bay, Sandy Hook Bay, and Lower New York Bay)

The Lower Bay is where the estuary meets the salty waters of the ocean. From the Verrazano Narrows to the Sandy Hook and the Rockaways, this water-body includes the Raritan Bay to the west, the Sandy Hook Bay to the southwest, Gravesend Bay and Coney Island to the north. Included in this region are the New Jersey Counties of Middlesex and Monmouth, as well as the New York City boroughs of Staten Island, Brooklyn, and Queens. Beaches along Coney Island, the New Jersey Bayshore and Gateway National Recreation Area draw millions of visitors each year.

Major factors influencing water quality in this region include CSOs, stormwater runoff, spills and unpermitted discharges, contaminated sediments, on-site waste treatment systems (such as septic systems or similar decentralized systems), and tidal exchanges with surrounding waterbodies. The state reports to EPA through their 303(d) and 305(b) lists impairments to primary contact recreation, such as fishing and swimming. In the more open Lower New



York Bay, aquatic life, fish consumption, public bathing, recreation, and shellfishing are all designated as good. However, in the more sheltered Raritan and Sandy Hook Bays, aquatic life, fish consumption, public bathing, recreation, and shellfishing were all determined to be impaired. The majority of this region is impaired due to PCBs, benzo[a]pyrene (PAHs), chlordane, DDT, dieldrin, dioxin (including 2,3,7,8-TCDD), dissolved oxygen, total coliform, and pH. In addition, PCBs, chlordane, and DDT have been found in fish tissue within this region. TMDLs are needed for all aforementioned toxics.

Waterbody	Water Class Use (NY) 6 CRR-NY 703.3 & 6 CRR-NY 703.4	Water Quality Criteria	
		Pathogenic Bacteria (cfus/100mL)	Dissolved Oxygen (mg/L)
Lower New York Bay and Raritan Bay	Class SB: Bathing	Fecal Coliform: Monthly GM ≤200 from 5 or more samples	Never < 5.0
		Enterococcus: Monthly GM ≤ 35 and a single sample max > 130	
Raritan Bay	Class SA: Shellfish	Total Coliform: Median ≤ 70 MPN (most probable number)/100mL	Never < 3.0
		Enterococcus: Monthly GM ≤35 and no more than 10% of samples > 130	
	Water Class Use (NJ) (NJAC 7:9B-1.14(d)(1))	Pathogenic Bacteria (cfus/100mL)	Dissolved Oxygen (mg/L)
Raritan Bay	Class SE1: Shellfish and Bathing	Enterococcus: Monthly GM ≤35 or a single sample max > 104	Never < 4.0 at any time
Sandy Hook Bay			24-hour average ≥ 5.0

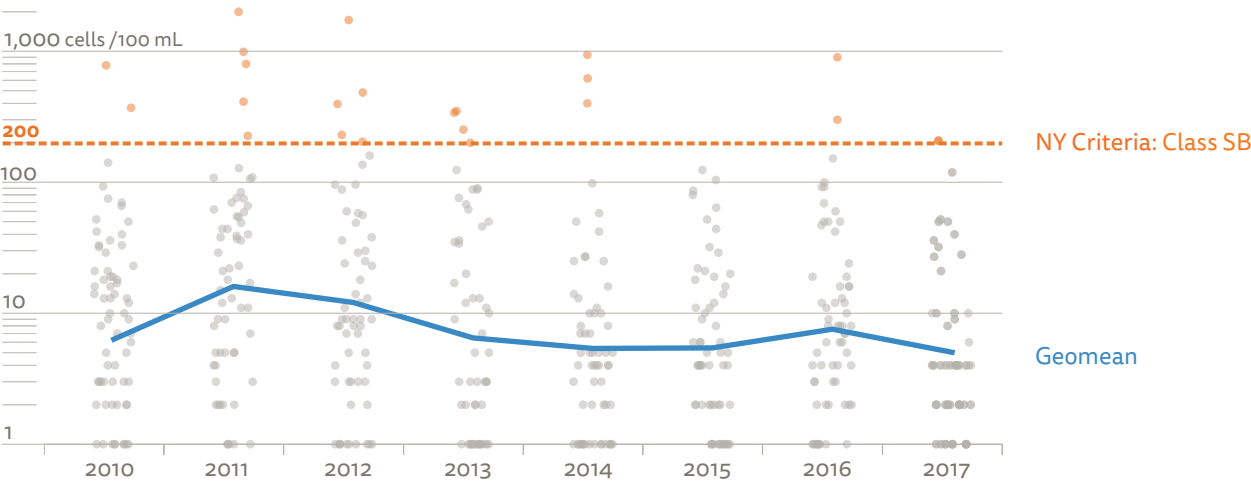
Pathogens

The presence of pathogenic bacteria can limit recreational use of these waterways. Sampling data show improvement over time, but are highly variable. The geometric means of samples from the Lower Bay region show compliance with all criteria over the eight years evaluated. Fecal coliform summer discrete measurements ranged from 1 cfu/100mL to 2,000 cfu/100mL over the eight-year period. With an average of 84 discrete samples per recreational season (June-September) per year, the average geomean for fecal coliform in this region is 8 cfu/100mL. *Enterococcus* summer geometric means ranged from 1.1 cfu/100mL to 5.68 cfu/100mL over the same

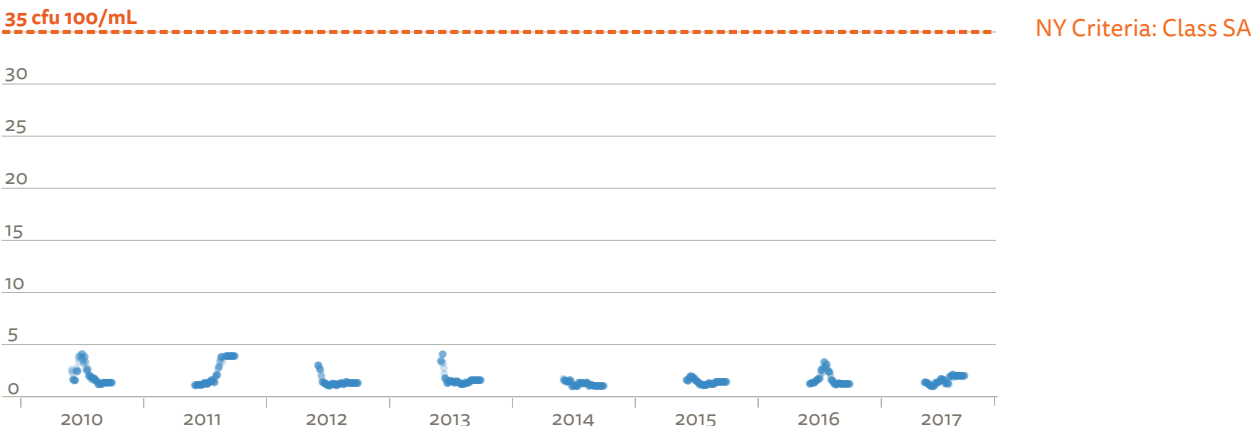
periods and 0.8% of discrete samples exceeded the *Enterococcus* single sample maximum (>104 cfus/100mL) of the criterion.

The NJDEP has continuously monitored the lower Raritan Bay and Sandy Hook Bay for shellfish compliance, an area where harvesting shellfish is allowed through special permitting. Through the NJDEP Shellfish Monitoring Program, results indicate that samples were in compliance with the restricted shellfish criteria from 2012 through 2016. With over 2,300 discrete samples across 53 stations, this program shows similarities to the two data sources provided by NYCDEP and NJHDG.

Fecal Coliform, Summer Surface Mean and Discrete Samples



Enterococcus, 30 Day Moving Geomean

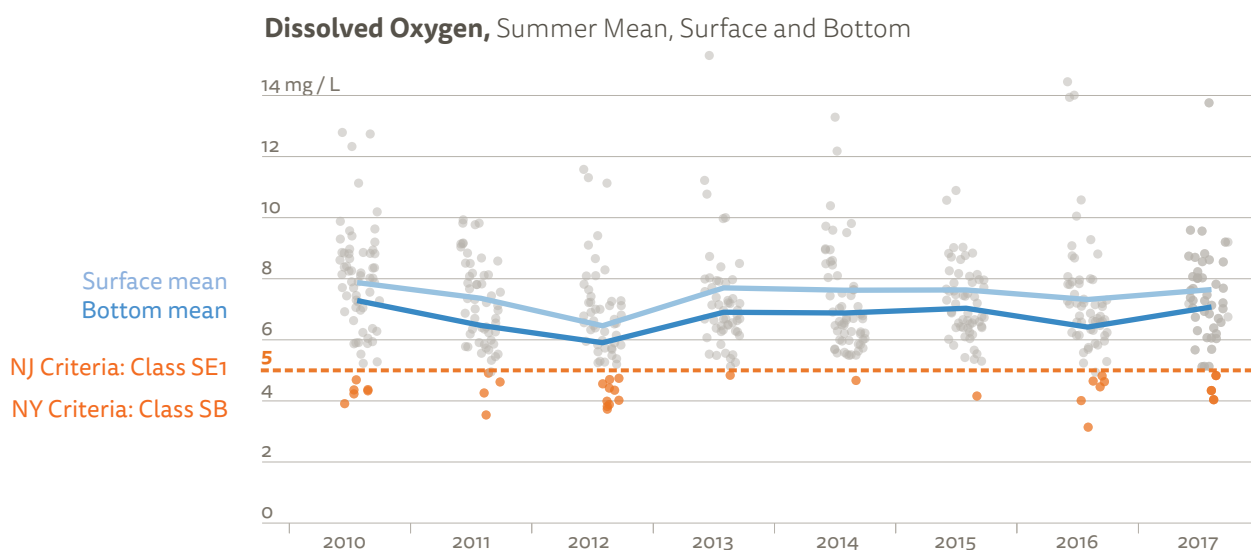




Dissolved Oxygen

Dissolved oxygen (DO) is a critical measure of habitat quality for fish and other wildlife. It is measured at the surface, where sunlight can penetrate to generate photosynthesis, as well as at the bottom, where sunlight is less available. In general, bottom DO concentrations are consistently lower than surface DO concentrations. Daily average concentrations are in compliance with the DO criteria throughout the years evaluated. In general,

fish in this region are not consistently stressed. The percent of time DO concentrations were less than 4 mg/L was between 0-8.2% for surface DO, and between 0-10% for bottom DO. Although this region is doing well with respect to DO, minimum discrete sample concentrations of less than 4.0 mg/L were recorded in six of the eight years evaluated.

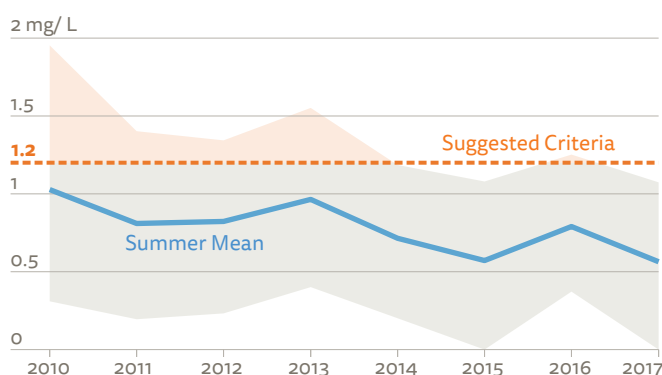


Other Water Quality Parameters

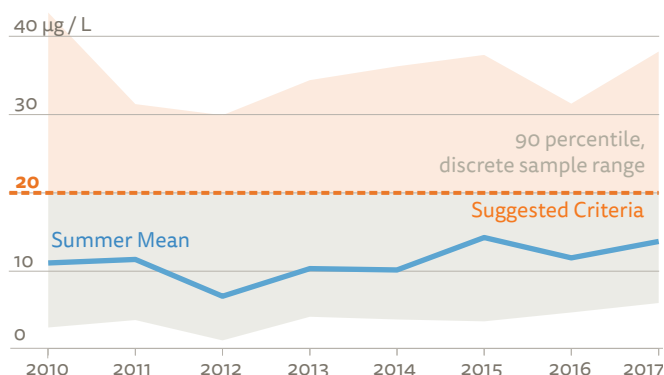
While pathogenic bacteria and dissolved oxygen are the primary criteria used to set water quality standards in New Jersey and New York, measurement of total nitrogen and chlorophyll-*a* provide additional information as to possible causes of low DO as well as the presence of photosynthetic algae and algal blooms. Between 2010 and 2017, the summer means for total nitrogen ranged between 0.56 and 1.03 mg/L. Total nitrogen levels between 0.4 and 1.2 mg/L

are indicative of fair conditions, and water quality would improve with nitrogen levels equal to or below 0.4 mg/L. Chlorophyll-*a* in this region fluctuated over the eight-year period with discrete sample concentrations ranging above the 20 µg/L recommended threshold. Concentrations of 5 µg/L or below support healthier habitats for fish survival and propagation while concentrations at or above 20 µg/L potentially increase algal growth.

Total Nitrogen, Summer Mean



Chlorophyll-*a*, 90th percentile Surface



Investments and Opportunities for Improvement

EPA, New York, and New Jersey have identified CSOs as a key source of pathogenic bacteria (and other pollutants) that limit recreational use. One of New Jersey's 25 CSO permit holders, the City of Perth Amboy, is located in this region and is responsible for producing a Long Term Control Plan (LTCP). This plan will reduce the number of CSOs, therefore improving water quality through the management of pathogens. New Jersey LTCPs, submitted to the state in 2020, have a long term (20-40 year) implementation process. The City of Perth Amboy's planned investments through the LTCP range from \$375 million to upwards of \$396 million (NJDEP, 2020). Potential investments towards the implementation of chemical disinfection of discharge using Peracetic acid (PAA), storage tunnels or tanks, and green infrastructure should result in significant improvements to water quality. In addition, this region is part of New York City's Citywide and East River/Open Water LTCP, submitted in 2020. Preliminary reports on this plan suggest the implementation of CSO storage tunnels. Additionally, Coney Island Creek, which feeds into Gravesend Bay, has its own LTCP, approved in 2018 by New York State. The Coney

Island Creek LTCP calls for no additional projects to pre-LTCP investments, totaling \$197 million for the Avenue V Pumping Station Expansion and a new wet weather force main, resulting in a predicted 68% reduction in CSO (NYCDEP, 2020).

MS4 permits in the region will further address stormwater quality issues related to new development and redevelopment. With the implementation of the new LTCP in both states as well as preventing pollution through the MS4 permits, a reduction in pathogens is anticipated, specifically for fecal coliform and *Enterococci*, and nutrients. LTCPs in New York City also require planning for the implementation of green infrastructure projects such as the conversion of impervious surface into rain gardens, which will reduce levels of nutrient loading and total suspended solids. New Jersey CSO permittees are required to consider green infrastructure as a CSO alternative in their current planning phase of LTCPs. To improve water quality for fish propagation/survival and reduce the occurrence of algal blooms, further efforts may be needed to address nutrients in this region.

Appendices

Acronyms/Glossary

CCMP	Comprehensive Conservation and Management Plan
cfus	Colony-forming Units
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
DDT	Dichlorodiphenyltrichloroethane
DO	Dissolved Oxygen
EPA	United States Environmental Protection Agency
GM	Geometric Mean
HEP	New York-New Jersey Harbor & Estuary Program
HRECOS	Hudson River Environmental Conditions Observing System
HRF	Hudson River Foundation
EPA	United States Environmental Protection Agency
IEC	Interstate Environmental Commission
LTCP	Long Term Control Plan
µg	Micrograms
mg	Milligrams
mL	Milliliters
MERI	Meadowlands Environmental Research Institute
MS4	Municipal Separate Storm Sewer System
MTAC	Mid-Atlantic Tributary Assessment Coalition
NCCA	National Coastal Condition Assessment
NPDES	National Pollutant Discharge Elimination System
NJDEP	New Jersey Department of Environmental Protection
NJHDG	New Jersey Harbor Dischargers Group
NYCDEP	New York City Department of Environmental Protection
PAH	Polyaromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
POTW	Publically-Owned Treatment Works
PVSC	Passaic Valley Sewerage Commission
RWQC	Recreational Water Quality Criteria
SWO	Stormwater Outfall
STV	Standard Threshold Value
TMDL	Total Maximum Daily Loads
WQWG	Water Quality Work Group
USGS	United States Geological Survey

Appendix A

SA (Shellfish)

The best use of Class SA waters are shellfishing for market purposes, primary and secondary contact recreation, and fishing. These waters must be suitable for fish propagation and survival.

SB (Bathing)

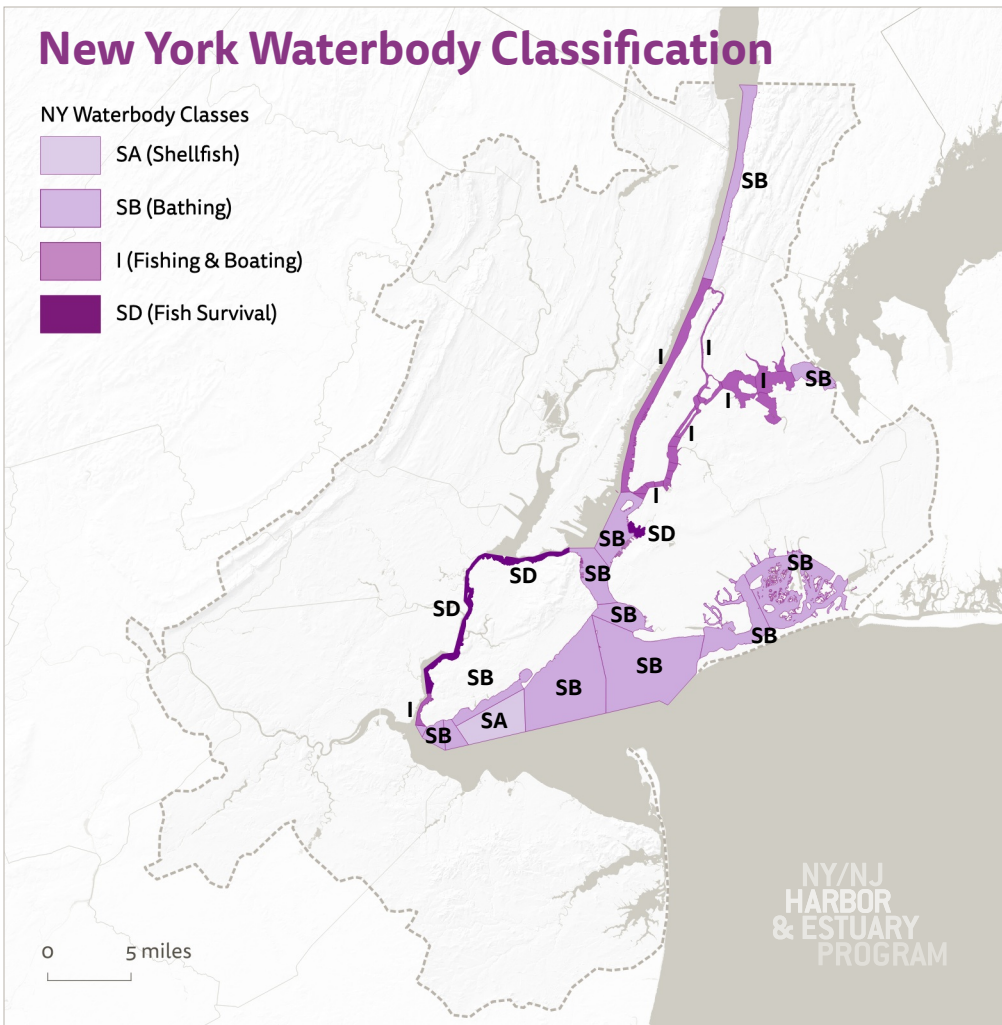
The best use of Class SB waters are primary and secondary contact recreation and fishing. These waters must be suitable for fish propagation and survival.

I (Boating/Fishing)

The best use of Class I waters are secondary contact recreation and fishing. These waters must be suitable for fish propagation and survival.

SD (Fish Survival)

The best use of Class SD waters is fishing. These waters must be suitable for fish survival. This classification may be given to those waters that (because of natural or man-made conditions) cannot meet the requirements for primary and secondary contact recreation and fish propagation.



New York State Saline Surface Water Quality Criteria (6 CRR-NY 703.3 & 6 CRR-NY 703.4)

Water Class Use	Pathogenic Bacteria (cfus/100mL)			Dissolved Oxygen (mg/L)
	Total Coliform	Fecal Coliform	Enterococcus	
Class SA Shellfish	Median ≤ 70 MPN (most probable number)/100mL		Monthly GM ≤ 35 and no more than 10% of samples > 130	Never < 3.0
Class SB Bathing	Monthly Median $\leq 2,400$ from 5 or more samples and no more than 20% of samples $> 5,000$	Monthly GM ≤ 200 from 5 or more samples	Monthly GM ≤ 35 and a single sample max > 104	Never < 3.0
Class I Fishing and Boating	Monthly Median $\leq 2,400$ from 5 or more samples and no more than 20% of samples $> 5,000$	Monthly GM ≤ 200 from 5 or more samples		Never < 4.0
Class SD Fish Survival	Monthly Median $\leq 2,400$ from 5 or more samples and no more than 20% of samples $> 5,000$	Monthly GM ≤ 200 from 5 or more samples		Never < 3.0

New Jersey Waterbody Classification

NJ Waterbody Classes

- FW2-NT (Fishing / Fish Propagation / Bathing)
- SE1 (Shellfish / Bathing)
- SE2 (Fishing / Fish Propagation)
- SE3 (Fishing / Fish Migration)



FW2-NT (Fishing/Fish Propagation/Bathing)

Maintenance; migration and propagation of the natural and established biota; primary and secondary contact recreation; industrial and agricultural water supply; public potable water supply after conventional filtration treatment and disinfection; and any other reasonable uses.

SE1 (Shellfishing/Bathing)

Shellfishing harvesting; maintenance, migration, and propagation of the natural and established biota; primary and secondary contact recreation; and any other reasonable uses.

SE2 (Fishing/Fish Propagation)

Maintenance, migration and propagation of the natural and established biota; migration of diadromous fish; maintenance of wildlife; secondary contact recreation; and any other reasonable uses.

SE3 (Fishing/Fish Migration)

Secondary contact recreation; Maintenance and migration of fish populations; migration of diadromous fish; maintenance of wildlife; any other reasonable uses.

New Jersey Saline Surface Water Quality Criteria

(NJAC 7:9B-1.14(d)(1))

Water Class Use	Pathogenic Bacteria (cfus/100mL)			Dissolved Oxygen (mg/L)
	E. Coli	Fecal Coliform	Enterococcus	
FW2-NT Fishing, Fish Propagation, and Bathing	Monthly GM ≤ 126 and a single sample max > 235			24-hour average ≥ 5.0 , but never < 4.0 at any time
Class SE1 Shellfish and Bathing			Monthly GM ≤ 35 or a single sample max > 104	24-hour average ≥ 5.0 , but never < 4.0 at any time
Class SE2 Fishing and Fish Propagation		Monthly GM ≤ 770		Never < 4.0
Class SE3 Fishing and Fish Migration		Monthly GM $\leq 1,500$		Never < 3.0

Appendix B

Compliance analysis for year 2017 using the master station across all ten regions and varying by state standards, for pathogens (a) and surface samples of dissolved oxygen (b). Value of geomean for each month and each region shown in (a). For dissolved oxygen, slight noncompliance assigned when number of samples below standard is less than 10 percent of total number of samples.

(a) Pathogen 2017 Compliance Analysis

Region	Parameter	Standard (cfu/100 mL)		Geomean by Month (cfu/100 mL)	Summary (cfu/100 mL)
		New York (6 CRR-NY 703.4)	New Jersey (NJAC 7:9B-1.14(d)(1))		
Lower Hudson River	Fecal coliform	Class I: monthly GM < 200	Class SE2: GM < 770	Jun: 27 Jul: 21 Aug: 15 Sep: 11	Full compliance
Upper New York Bay	Fecal coliform	Class SB: monthly GM < 200	Class SE2: GM < 770	Jun: 38 Jul: 12 Aug: 18 Sep: 4	Full compliance
Lower Bay (Raritan Bay, Sandy Hook Bay, Lower New York Bay)	Fecal coliform	Class SB: monthly GM < 200	Class SE1: GM < 14 90 th percentile value < 49	Jun: 10 Jul: 4 Aug: 5 Sep: 3	Full compliance
	Enterococci	Class SB: 30-d GM < 35 90 th pct value < 130	Class SE1: monthly GM ≤ 35 maximum < 104		Full compliance
Arthur Kill & Kill Van Kull	Fecal coliform	Class SD: monthly GM < 200	Class SE3: GM < 1,500	Jun: 60 Jul: 39 Aug: 30 Sep: 10	Full compliance
Lower Raritan River	Fecal coliform		Class SE1: GM < 14 90 th percentile value < 49		
	Enterococci		Class SE1: monthly GM ≤ 35 maximum < 104	Jun: 60 Jul: 39 Aug: 30 Sep: 10	Full compliance
Lower Passaic River & Newark Bay (Upper Tidal)	Fecal coliform		Class SE2: GM < 770	560	Full compliance
	<i>E. coli</i>		Class FW2: 30-d GM < 126 maximum < 235	122 GM (100%) > 126	Non-compliance
	Fecal coliform		Class SE3: GM < 1,500	287	Full compliance

Region	Parameter	Standard (cfu/100 mL)		Geomean by Month (cfu/100 mL)	Summary (cfu/100 mL)
		New York (6 CRR-NY 703.4)	New Jersey (NJAC 7:9B-1.14(d)(1))		
Hackensack River	Fecal coliform		Class SE2: geomean <770		Full compliance
Jamaica Bay	Fecal coliform	Class SB: monthly GM <200		Jun: 16 Jul: 9 Aug: 15 Sep: 5	Full compliance
East River and Harlem River	Fecal coliform	Class I: monthly GM <200		Jun: 43 Jul: 61 Aug: 17 Sep: 11	Full compliance
Bronx River & Western Long Island Sound (Bronx River)	Fecal coliform	Class I: monthly GM <200		Jul: 309	Non compliance
Bronx River & Western Long Island Sound (Upper East River)	Fecal coliform	Class SB: monthly GM <200			Full compliance

(b) Dissolved Oxygen 2017 Compliance Analysis

Region	Standard (cfu/100 mL)		Summary (mg/L)
	New York (6 CRR-NY 703.4)	New Jersey (NJAC 7:9B-1.14(d)(1))	
Lower Hudson River	Class I: individual value ≥ 4.0 at any time	Class SE2: individual value ≥ 4.0 at any time	Full compliance
Upper New York Bay	Class SB: 24-hour average ≥ 4.8 minimum ≥ 3.0	Class SE2: individual value ≥ 4.0 at any time	Full compliance
Lower Bay (Raritan Bay, Sandy Hook Bay, Lower New York Bay)	Class SB: 24-hour average ≥ 4.8 minimum ≥ 3.0	Class SE1: individual value ≥ 4.0 at any time 24-h average ≥ 5.0	Slight non-compliance with NJ all values > 3.0 2.1% of values < 4.0
Arthur Kill & Kill Van Kull	Class SD: individual value ≥ 3.0 at any time	Class SE3: individual value ≥ 3.0 at any time	Full compliance
Lower Raritan River		Class SE1: individual value ≥ 4.0 at any time 24-hour average ≥ 5.0	Slight non-compliance 6% of values < 4.0
Lower Passaic River & Newark Bay (Upper Tidal)		Class FW2/SE2: individual value ≥ 4.0 at any time	Full compliance
Lower Passaic River & Newark Bay (Second River to mouth)		Class SE3: individual value ≥ 3.0 at any time	Full compliance
Hackensack River		Class SE2: individual value ≥ 4.0 at any time	Non-compliance 25% of values < 4.0

Region	Standard (cfu/100 mL)		Summary (mg/L)
	New York (6 CRR-NY 703.4)	New Jersey (NJAC 7:9B-1.14(d)(1))	
Jamaica Bay	Class SB: 24-hour average ≥ 4.8 minimum ≥ 3.0		Non-compliance 17% of values < 4.8 2% of values < 3.0
East River and Harlem River	Class I: individual value ≥ 4.0 at any time		Slight non-compliance 4% of values < 4.0
Bronx River & Western Long Island Sound (Upper East River)	Class I: individual value ≥ 4.0 at any time		Full compliance
Bronx River & Western Long Island Sound (Upper East River)	Class SB: 24-hour average ≥ 4.8 minimum ≥ 3.0		Non-compliance bottom layer samples: 33% of values < 4.8 2% of values < 3.0
Bronx River & Western Long Island Sound (Upper East River – IEC)	Class SB: 24-hour average ≥ 4.8 minimum ≥ 3.0		Non-compliance bottom layer samples: 72% of values < 4.8 14% of values < 3.0

Acknowledgements

Many organizations and individuals contributed to this effort with their time and data. The New York-New Jersey Harbor & Estuary Program (HEP) would like to acknowledge the input of its Management Committee, Water Quality Work Group, Citizens Advisory Committee and its Science and Technical Advisory Committee for this report. We would like to thank our partners for sharing data and we thank the following individuals for their generous help with review of the parameters, data, or final document. Members of HEP's Science and Technology Committee are indicated with a *.

Marco Alebus, Francisco J. Artigas*, Pinar Balci, Brett Branco*, Jason Fagel, Brent Gaylord, Chris Gobler*, Biswarup Guha, James Lodge*, Keith Mahoney, Michael McCann, Bridget McKenna, Rosella O'Connor, Philip Orton*, Evelyn Powers, Beau Ranheim, Jacqueline Ríos, Susan Rosenwinkel, Shino Tanikawa, and Judith Weis*

HEP's Water Quality Work Group formed an ad hoc committee to plan and inform on the development of the third edition of the water quality monitoring report for the Harbor Estuary. Organizations represented on the ad hoc committee included the New Jersey Department of Environmental Protection (NJDEP), the New York State Department of Environmental Conservation (NYSDEC), the New York City Department of Environmental Protection (NYCDEP), the US Environmental Protection Agency (EPA), the New Jersey Harbor Dischargers Group (NJHDG), the Passaic Valley Sewerage Commission (PVSC), the Interstate Environmental Commission (IEC), the Hudson River Foundation (HRF), and The Nature Conservancy (TNC).

NYCDEP and NJHDG generated the data that are presented in this report. HEP was responsible for the overall coordination for preparing this report. The report was prepared by HEP staff – Rosana Da Silva (project manager), Lucy Christiana, Lindsey Strehlau, and Robert Pirani – and the Great Lakes Environmental Center, Inc. – Charlie Dujardin and Dale White. Graphic design, mapping and data visualization by Sara Eichner and the Pratt Institute Spatial Analysis and Visualization Initiative.

Disclaimer

Although the information in this document has been funded wholly or in part by the United States Environmental Protection Agency (EPA) under agreement to the Hudson River Foundation, it has not undergone the Agency's publications review process and therefore, may not necessarily reflect the views of the Agency, and no official endorsement should be inferred. This report is neither a proposed Total Maximum Daily Load (TMDL), nor proposed water quality criteria, nor recommended criteria. The report is not a regulation, is not guidance, and cannot impose legally binding requirements on EPA, States, Tribes, or the regulated community. The purpose of this report is to compile harbor-wide water quality data and help address the desire for clear and easily accessible information on water quality trends and impairments in the Harbor.

Preferred Citation

Da Silva, R., Dujardin, C., White, D., Christiana, L., Pirani, R., Strehlau, L. (2021). New York-New Jersey Harbor-Wide Water Quality Report 2010-2017. Hudson River Foundation. New York, NY.

Cover Photo: At the Race for the River swimming race competitors swim in the Hudson River by Frances M. Roberts, Alamy

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