Storm and Wastewater

TEC Significance

The Hudson River Valley is designated a National Heritage Area, with a growing recreation and tourism economy centered on the Hudson River estuary itself and the towns and villages along its shores. However, both the perception, and reality, of continued poor water quality in the estuary limit opportunities for expanding post-industrial uses of the estuary and the waterfronts of its communities. Water quality problems in the Hudson River estuary are related to a long legacy of past contamination, as well as ongoing pollutant discharges. This TEC report focuses on water quality impacts of ongoing discharges of storm and wastewater to the Hudson River estuary. Storm and wastewater discharges have been highlighted by the NYS Department of Environmental Conservation (NYSDEC) as the dominant reason for listing water bodies statewide as having impaired or impacted water quality (with respect to the requirements of the Federal Clean Water Act), which highlights the relative importance of these ongoing sources of contamination compared to other water quality problems. Focusing on the Hudson River estuary, one way to consider the scale of the storm and wastewater issues is that the combined population of the 10 counties bordering the estuary is approximately 2.8 million people. Since these 10 counties comprise most of the watershed, the estuary thus receives storm and wastewater from communities that house nearly 75 % of New Yorkers and 1% of the U.S. population, either through direct discharges, or indirectly through tributaries. Despite long-term positive trends, these storm and wastewater discharges continue to be major sources of multiple pollutants that threaten public health, impede recreational use, depress economic activity related to recreation and waterfront revitalization, and degrade environmental functions of the estuary.

Wastewater is water that has been used in homes, businesses, or for agricultural purposes. During use, the water can pick up contaminants such as feces, organic matter, nutrients, industrial chemicals, pharmaceuticals, and sediment. Stormwater is runoff generated from rain or snowmelt that flows over land or impervious surfaces, such as paved streets and building rooftops, and does not soak into the ground before reaching a waterway. During travel over surfaces, or through infrastructure pipes, stormwater picks up contaminants like trash, metals, road salt, pesticides, oil, nutrients, animal waste, and sediment. Unless properly treated, the various contaminants picked up by storm and wastewater in Hudson River estuary communities will be discharged to the estuary or its tributaries. The pollutants carried by inadequately-treated waste and storm water can lead to many different types of water quality problems (Fig. 1). Fecal matter transported to the estuary contains a wide array of microbial pathogens that can infect people who contact the water, especially prolonged contact during recreation. Chemical contaminants can harm aquatic organisms, or the people who eat fish or drink the water from the estuary. High concentrations of nutrients and organic matter can promote algal blooms and oxygen depletion, which could disrupt ecosystem functioning and fisheries. High organic matter concentrations and algal blooms can also create problems for purifying drinking water (over 100,000 people rely on the Hudson River estuary for drinking water). Recent research also indicates potentially significant impacts of nutrients and organic matter discharges on estuarine greenhouse gas emissions. Discharge of trash and sediments can impact wildlife and aquatic plants and create visual problems that can greatly impact at least the perception of water quality, and thus the willingness to recreate on or near the water. Because of such problems, releases of pollutants into the estuary are subject to regulation under the Federal Clean Water Act and other Federal and State laws. The guiding principle of these laws is to restore and maintain the integrity of the nation's waters by achieving two fundamental national goals: eliminating pollutant discharges and achieving water quality levels that are fishable and swimmable. Ongoing discharges of inadequately-treated storm and wastewater are major reasons why the Hudson River estuary fails to achieve these national goals. The ongoing discharges compound other water quality issues related to legacy contaminants, which are described in the Contaminants TEC.

Within the Hudson River estuary, most municipal and industrial wastewater currently undergoes treatment to reduce or remove pollutants before discharge. Treatment may occur on site, such as in domestic septic systems, or at one of the 44 municipally-owned wastewater treatment plants (WWTPs) that discharge directly to the estuary or its tidal tributaries (Fig. 2). Unfortunately, the complex wastewater infrastructure in many estuary communities suffers from age, outdated design, deferred maintenance, and from being close to exceeding its designed capacity. For example, among the estuary's 44 WWTPs, more than half are fed through sewer pipes with an average age over 60 years; three of those plants have pipe networks with average ages over 100 years. In addition, about 10% of the WWTPs that discharge to the estuary are averaging at or above 75% capacity (over the last 5 years). Wastewater systems that are old, poorly maintained, or near capacity are more likely to experience sewer overflows, which occur frequently in many communities along the estuary.

Stormwater infrastructure in communities along the estuary is diverse, with some stormwater discharging directly to the estuary and its tributaries, and some routed to WWTPs or a wide variety of other facilities and infrastructure (such as retention basins, etc.). Treatment of stormwater prior to discharge is therefore quite variable. In addition, because of the infrastructure design in some estuary communities, when large stormwater volumes are generated by rain or snowmelt, much of the stormwater may be discharged after mixing with untreated wastewater. Such "combined sewer overflows" (CSOs) are a large source of pollutants near the eight estuary communities that have combined sewer systems (CSO communities). Other connections between storm and wastewater sewers also contribute to the transport of wastewater-derived contaminants to the estuary via stormwater systems. Thus, while technology and facilities for treatment exist, there are many reasons why untreated, or inadequately-treated, storm and wastewater are currently discharged to the estuary.

Stormwater is also a common cause of localized flooding in estuary communities and within the larger watershed. Street flooding occurs when rain or snowmelt volume exceeds the capacity of the stormwater system to carry water away fast enough. Stormwater can similarly cause tributary flooding, if the stormwater discharges into a tributary before flowing to the estuary. Because of the relatively small volume and restricted channels of many tributaries, the addition of stormwater can greatly increase flow, potentially overtopping the banks, scouring shoreline habitats and causing bank erosion. While a very different problem from contaminant transport to the estuary, many of the solutions for managing stormwater contaminants also have the potential to decrease flooding (and vice versa).

It should be noted that storm and wastewater issues do not recognize the limited geographic scope of this report. Communities throughout the greater Hudson River watershed, both N and S of this report's focus, discharge storm and wastewater that impact the Hudson River estuary. Similarly, tributary flooding, while outside of this report's geographic scope, also affects conditions downstream in the Estuary. Many of the actions described below can and should be applied in communities outside of the estuary proper. In fact, unless such actions are pursued throughout the watershed, it is likely that many localized water quality problems in the estuary will persist beyond the time frames outlined below.

The actions outlined in this report to decrease the impacts of storm and wastewater in the Hudson River estuary are important for several of the other Target Ecosystem Characteristics. Storm and wastewater are significant sources of pollutants such as toxic organic compounds, heavy metals, petroleum, and pharmaceuticals that are described in more detail in the Contaminants TEC. While water quality assessments are conducted independently for each identified contaminant, management should be holistic. Thus, the best management practices selected to achieve any of the actions outlined here should be those that result in water quality improvements regarding multiple contaminants. Therefore, the actions of this TEC are fully consistent with those of the Contaminant TEC. An important part of the "fishability" goal of water quality is the ability to eat the fish that are caught. Therefore, decreasing contaminant inputs according to the actions described in this and the Contaminants TEC are also relevant to the Fisheries TEC. As the actions outlined here are implemented, knowledge of improving water quality should be spread to the many different user groups that exist within estuary communities, presenting an overlap with the goals of the Estuary Education TEC. Increased awareness of improving water quality will lead then to greater demand for recreational opportunities, which is considered under the Public Access and Navigation Safety and Nature Resource Interactions TECs. Finally, storm and wastewater infrastructure in some estuary communities are highly vulnerable to flooding from storms and sea level rise. These vulnerabilities are addressed here and in the Resilient Waterfronts and Community Shorelines TEC. It should also be noted that the overall goal, as well as many of the actions recommended below are consistent with goals and actions described in the Hudson River Estuary Program's "Hudson River Estuary Action Agenda 2015-2020".

Goal

Storm and wastewater discharges to the Hudson River estuary are monitored and managed so that the entire estuary is known to have water quality that consistently supports recreation and associated economic activity, as well as healthy aquatic ecosystems.

TEC Context

Water Quality Standards

A key component of assessing problems related to storm and wastewater is comparing measured quantities of contaminants to water quality standards that also consider the "best" intended uses of the waterway (drinking, swimming, fishing, navigation, etc.). These standards are the basis for limits in wastewater discharge permits, and the tool used to assess whether waters have sufficient water quality to meet their best uses. For example, when storm and wastewater contaminate a waterway with fecal matter, microbial pathogens carried with the fecal material present a health risk for people who contact the water (i.e., while swimming). Water quality monitoring therefore compares counts of "fecal indicator bacteria" (FIB) in water samples to standards specific for the type of FIB used. When FIB levels are low relative to their standard, water quality is thought to be high, at least with respect to pathogen contamination. Standards for many contaminants exist, and each type of contaminant should have its own standard. For example, standards based on FIB levels are independent of standards related to chemical contaminants, and vice versa. Some standards protect people during recreation, such as FIB-based standards that are primarily focused on protecting recreational swimmers. Other standards protect aquatic organisms or other functions. For example, standards based on biological oxygen demand are intended to maintain adequate oxygen for fish and other aquatic life. Where waters fail to meet any one of the applicable Water Quality Standards, the Clean Water Act provides tools for restoring water quality to support the best uses of the waterway. The NYSDEC has primary responsibility for regulating the estuary's water quality in accordance with the Clean Water Act.

As research advances, measurement techniques change, and new information may show that older standards were not sufficiently stringent. Thus, standards should be updated when new information becomes available. In addition, the safe levels for many potential pollutants are still not known, so new standards will be developed in the future for contaminants that currently lack them. NY State is currently in the process of reviewing and updating its water quality standards, some of which are decades out of date with respect to federal guidance and the best available science. As NY State water quality standards continue to change over the next 50 years, management of storm and wastewater infrastructure will also have to change. This will require updated monitoring strategies, as well as infrastructure upgrades to meet these new standards.

Historical Context and Current State

The best available historical data on water quality indicators related to storm and wastewater in the Hudson River estuary, such as FIB counts and oxygen concentrations, are restricted to the regions around New York City and Albany (the Capital District). Because similar management actions occurred throughout the estuary, it is likely that temporal trends for these two regions at either end of the system reflect general trends for the entire estuary. The data show dramatic improvements in estuary water quality since the 1970s. Data going back to the early 1900s, and other related observations, such as the incidence of waterborne diseases, suggest that water quality in the estuary was highly impaired because of untreated wastewater discharges for at least the century preceding the 1970's. Thus, actions taken to decrease pollutants in storm and wastewater in the Hudson River estuary over the last 40 years have dramatically changed a century-long trajectory. This notable achievement, especially considering the growth in population and economic activity during that time frame, provides a very positive context for the future. Nevertheless, many problems remain. For example, although data show that FIB levels have generally decreased, recent monitoring shows that intermittent FIB problems remain in nearly every location sampled within the estuary (Fig 2). The Capital District, with its many CSO discharge points, is currently the portion of the estuary that most frequently shows elevated FIB counts compared to other regions. Outside the Capital District, tidal tributaries are also often more contaminated with FIB than the main stem of the Hudson into which the tributaries flow. Widespread increases in FIB following wet weather strongly indicate that CSOs and other stormwater discharges play a large role throughout the estuary in the intermittent FIB elevations observed. In addition to pathogens, stormwater and CSOs continue to be major sources of floating trash and debris in the estuary, though levels are likely much lower than in past decades. While oxygen concentrations that were detrimental to fish and other aquatic life were once common in the estuary, such conditions no longer appear to be widespread, though oxygen data are limited for many locations (especially for tidal tributaries and embayments that might be particularly susceptible to having low oxygen). Maintaining these improved oxygen conditions, as for all other water quality improvements noted, requires continuous attention and reinvestment to keep up with aging infrastructure, and continued vigilance in terms of monitoring, so that current conditions do not degrade over time. Wastewater is also a large source of nutrients to the estuary. However, unlike many other estuaries, nutrient loading does not appear to currently be a high priority concern because of relatively short water residence time and because algal blooms within the estuary are strongly light limited. Negative consequences of high nutrient loading, such as algal blooms, are apparent in some tributaries (though outside the geographic scope of this report). Finally, as mentioned above, storm and wastewater are also contributing sources of other contaminants that are described further in other TEC reports.

Ongoing sources of storm and wastewater to the Hudson River estuary include the 44 WWTPs that discharge directly to the estuary or tidal tributaries. In addition, there are approximately 150 CSO discharge points spread among the eight CSO communities found along the estuary. Occasional overflows of untreated wastewater are also reported from many of the estuary communities with separated sewer systems. All shoreline communities release stormwater to the estuary through thousands of discharge pipes. Furthermore, although outside of the explicit geographic scope of this report, it should nevertheless be noted that many tributaries to the estuary appear to be sources of FIB, with more frequently elevated FIB counts than the main stem of the Hudson into which they flow. It is likely that storm and wastewater inputs to the tributaries are at least partly responsible for the frequent FIB contamination observed there, and it is therefore also likely that many tributaries are similarly sources of other pollutants to the estuary, even where direct measurements are lacking. The need to infer this connection between FIB and other contaminants demonstrates that continued research and monitoring will be essential for progress toward the goal.

Challenges

The immediate challenge in reducing storm and wastewater impacts in the Hudson River estuary is to decrease CSO and stormwater flows and improve storm and wastewater treatment where necessary. Considering the complexity and age of the infrastructure, the number of communities and expense involved, careful study and planning is essential to ensure that actions are appropriately prioritized. For example, the NYSDEC has been planning a soon to be launched pilot program to aid up to 20 communities (statewide) in developing sewage system asset management plans and the tools (such as computerized asset management systems) needed to implement their plans, at no cost to the participating municipalities. While such efforts are critical for setting priorities, only about one third of estuary communities have submitted 2017 costs estimates to State databases for projects related to wastewater system maintenance, rehab and replacement. This low level of participation suggests that sewage system asset planning efforts could be significantly improved, although the costs associated with producing such plans are at least partly responsible for limited efforts on the part of individual municipalities. Looking toward the future, storm and wastewater improvement plans may become even more complex, as the scale of activities necessary to continue producing improvements changes. While the large initial improvements in water quality related to storm and wastewater in past decades were primarily achieved by focusing on improving treatment at large WWTPs, further progress will require expanding efforts to address the far greater number of more localized sources of untreated, or poorly treated, storm and wastewater found throughout the watershed.

Over the longer term, the key challenge will shift towards maintaining the functionality of aging storm and wastewater infrastructure, particularly in the face of changing climate. Current predictions of more frequent extreme storms imply a need to handle increased stormwater flows, as well as flooding damage to infrastructure from storm surges (as occurred during Hurricanes Irene and Sandy). Rising sea levels pose a long-term threat to storm and wastewater infrastructure in estuary communities because much of the infrastructure is in the floodplain. For example, around a quarter of the municipally-owned WWTPs along the estuary would have their plant footprint heavily inundated during a 100-year flood, even at current sea level. On the other hand, around half of the estuary’s WWTPs would suffer little to no inundation during the same flood, making for straightforward prioritization.

Considering that the WWTPs along the estuary are served through over 1500 miles of sewer pipes, built over many decades, it should be apparent that maintaining and upgrading storm and wastewater infrastructure is expensive, and can require a considerable time to achieve measurable results. For example, implementing the long-term control plan (LTCP) to reduce CSO impacts in the Albany region is projected to cost approximately $140 million through 2030. Public engagement is therefore critical to support long-term investments, and to reap the rewards from those investments through economic development and expanded enjoyment of the estuary. Unfortunately, public access to water quality information related to storm and wastewater inputs to the estuary is spotty at best, because the data either don't exist, are difficult to find, or are presented in an overly-technical format. In addition to increasing access to timely, quality-assured information on estuary water quality, public engagement can also be enhanced by highlighting the actions individuals and businesses themselves can take to decrease storm and wastewater problems. Thus, considerable benefits will accrue from expanding monitoring, public outreach, and education related to storm and wastewater specifically, and to water quality in general.

The goal of consistently high-water quality for the Hudson River estuary is achieved by implementing the actions outlined below. Actions 1-3 promote proper assessment and dissemination of current water quality conditions and trends; implementation can begin immediately. Actions 4-5 relate to decreasing sources of contaminants carried by waste- and stormwater to the estuary. Implementation can begin immediately based on existing plans, though plans will require updating through time. Following these actions, consistently high-water quality throughout the Hudson River estuary can be achieved by 2040, most areas will reach the goal sooner. After that, the ongoing challenge increasingly shifts towards maintaining high water quality as standards are updated, preparing for reinvestment once design capacity and lifespan limits for infrastructure are met, and responding to continued climate change and rising sea level (Action 6).

Action Table

Objective	Actions	Timeframe
Objective 1. The most up-to-date water quality standards are used to assess water quality	1. A. NYS sets water quality standards consistent with best available science and Federal Clean Water Act criteria	2020, update as necessary
	1. B. All areas of the estuary are classified to uniformly support swimming and fishing as "best uses", drinking water classification is supported where it is an existing use	2020
	1. B. 1. To support uniform management, the same standards are used throughout the Estuary	
	1. C. Water quality standards for emerging pollutants (microplastics, nutrients, pharmaceuticals, etc.) are adopted as they are developed according to the best available science (as mirrored in the Contaminants TEC)	Ongoing
Objective 2. Monitoring of contaminants derived from waste and storm water is supported into perpetuity	2. A. State and local authorities, community groups, and academic scientists work together to sample all areas of the estuary with sufficient frequency (i.e., at least weekly for pathogens) such that water quality throughout the system can be assessed in accordance with standards	2020 and ongoing
	2. A. 1. Each year, 3-5 source tracking studies are conducted in areas/communities where standards are violated, to identify the source of the contaminants	Ongoing, until violations cease
Objective 3. Outreach and intervention encourages	3. A. All shoreline communities provide timely water quality information for their region of the estuary to their residents to	2020

actions that improve water quality	enable residents to make informed choices about how they interact with the water	
	3. B. All shoreline communities develop Interventions (e.g., demonstration projects, public awareness campaigns with action pledges, etc.) for targeted segments of their residents or business community to motivate behavioral changes that decrease storm water runoff, sewer overflows, and/or contaminant inputs	2030
Objective 4. Combined sewer overflows (CSOs) no longer cause violations of water quality standards	4. A. The 8 CSO communities along the estuary are taking steps to reduce CSO impacts by implementing existing long-term control plans (LTCPs)	2020
	4. B. LTCPs are updated as more stringent water quality standards are developed	Ongoing
	4. B. 1. LTCPs for all CSO communities include climate change impacts including changes in precipitation and sea level rise	2030
	4.C. All CSO communities develop green infrastructure plans to reduce CSOs	2030
	4. C. 1. All CSO communities have at least one demonstration green infrastructure project to reduce CSOs	2030
Objective 5. Other discharges of contaminants no longer cause violations of water quality standards	5. A. Existing municipal separate storm sewer system (MS4) mitigation plans are implemented and updated as needed to achieve water quality standards in the receiving water	Ongoing
	5. B. Septic systems abutting the estuary are upgraded or connected to sewer lines (as mirrored in the Contaminants TEC)	2070
	5. C. Improved on-site management decreases releases of nutrients and emerging contaminants (e.g., pharmaceuticals) from large producers such as industrial facilities, health care facilities, and agricultural fields	Ongoing
	5. C. 1. Each year, 5-6 large producers of such emerging contaminants are assisted in developing a voluntary contaminant reduction plan (ideally connected to source tracking studies mentioned in Action 2. A. 1.)	2020 and ongoing
Objective 6. Existing waste- and storm water infrastructure is maintained and improved	6. A. Estuary communities have access to predictable funding streams to deal with the existing backlog of maintenance projects, maintain existing assets, and conduct future upgrades	2020 and ongoing
	6. B. Seven communities with WWTPs develop asset management plans by 2020, followed by at least 3 community plans per year until all communities with WWTPs discharging to the estuary have quantified their infrastructure needs and prioritized the required investments	2020-2030
	6. C. WWTPs are upgraded/retrofitted as new standards are adopted (Actions 1A and 1C, and as mirrored in the Contaminants TEC)	Ongoing

	6. D. Improved stormwater management decreases the frequency of street flooding in estuary communities by 50%	2070
	6. D. 1. Green infrastructure and low impact development are prioritized for stormwater water management because of their concomitant benefits (e.g. aesthetics, contaminant reduction)	Ongoing
	6. D. 2. Adoption of green infrastructure approaches are accelerated by developing novel financing mechanisms	2030
	6. E. All new wastewater infrastructure is built at high enough elevation to avoid damage by rising sea level (100-year storm plus 54", as mirrored in the Resilient Waterfronts and Community Shorelines TEC)	2020 and ongoing
	6. F. Existing infrastructure is moved, replaced, or hardened to avoid damage by rising sea level (100-year storm plus 54", as mirrored in the Resilient Waterfronts and Community Shorelines TEC)	2070

Action Narrative

Can the goal of consistently high-water quality throughout the Hudson River estuary be achieved by 2040? – Yes, the Albany region LTCP will be complete by 2030. Although other CSO communities still have a way to go for full implementation of their LTCP plans, 2040 is realistic, and most of the estuary will be much improved/acceptable long before then.

Information on municipally-owned WWTPs comes from NYSDEC databases. WWTPs discharging directly into the estuary, as well as into tidal portions of tributaries were included. The Yonkers WWTP in Westchester County, and the Orangetown WWTP in Rockland County were also included, although the plants and most of their discharge points are south of the Governor Mario M. Cuomo Bridge, because these two plants do serve communities and have associated infrastructure north of the Cuomo bridge. However, private, commercial, and industrial wastewater treatment facilities, which tend to be relatively small, but very numerous in the Hudson watershed, were not included.

1. The most up-to-date water quality standards are used to assess water quality.
1. A. NYS sets water quality standards consistent with best available science and Federal Clean Water Act criteria.
For example, NYS microbial water quality standards for the Hudson River estuary are still based on the geometric mean of fecal coliform counts in water samples, an approach superseded by alternate indicators in 1986.
1. B. All areas of the estuary are classified to uniformly support swimming and fishing as “best uses”, drinking water classification is supported where it is an existing use.
People already swim everywhere within the Hudson River estuary, the “designated use” for the entire system should reflect this, and thus the water quality standards for recreational swimming should apply throughout the system.
1. B. 1. To support uniform management, the same standards are used throughout the estuary.
For example, although E. coli and enterococci are both considered equally effective indicator bacteria in freshwater, only enterococci are recommended for monitoring water quality in saline and brackish water. Given the estuarine nature and the inherent connectivity of the Hudson River estuary, use of a

single indicator throughout the system would facilitate monitoring activity and data comparisons between fresh and salty regions. Similar arguments of geographic consistency apply to other standards.
1. C. Water quality standards for emerging pollutants (microplastics, nutrients, pharmaceuticals, etc.) are adopted as they are developed according to the best available science.
Standards for many of these types of contaminants do not currently exist. However, they are likely to be developed in the future. Management will have to adapt to changing requirements, which are also likely to be more stringent for contaminants that already have standards. This action is mirrored in the Contaminants TEC.

2. Monitoring of contaminants derived from storm and wastewater is supported into perpetuity.
2. A. State and local authorities, community groups, and academic scientists work together to sample all areas of the estuary with sufficient frequency (i.e., at least weekly for pathogens) such that water quality throughout the system can be assessed in accordance with standards.
Few, if any, portions of the estuary currently receive sufficient testing to fully assess water quality standards related to recreational contact. Although state and local agencies have ultimate responsibility for assuring estuary water quality, recent experience demonstrates that community groups and academic researchers can collect and process water quality samples from many locations in a very cost-effective way. Supporting the activity of these groups, in collaboration with agency-based efforts, will be the most efficient path towards more comprehensive monitoring.
2. A. 2. Each year, 3-5 source tracking studies are conducted in areas/communities where standards are violated.
Source tracking studies identify the source(s) of contaminants, so that a management/mitigation strategy, such as a Total Maximum Daily Load (TMDL) plan can be developed.

3. Support outreach and intervention to encourage actions that improve water quality.
3. A. All shoreline communities provide timely water quality information for their region of the estuary to their residents, to enable their residents to make informed choices about how they interact with the water.
Communities can start by making available information accessible, even if the information is insufficient to assess water quality relative to standards (for example, if sampling is too infrequent). Providing this information will create the public demand and support for expanded sampling.
3. B. All shoreline communities develop Interventions (e.g., demonstration projects, public awareness campaigns with action pledges, etc.) for targeted segments of their residents or business community to motivate behavioral changes that decrease stormwater runoff, sewer overflows, and/or contaminant inputs.
For example, one of the most common causes of sewer line blockages, which can cause overflows, is cooking oil that has improperly been disposed of down drains. Progress on this issue can only be made by changing the behavior of home cooks and restaurant owners.

4. Combined sewer overflows (CSOs) no longer cause violations of water quality standards.
4. A. The eight CSO communities along the estuary are taking steps to reduce CSO impacts by implementing existing long-term control plans (LTCPs).
Sewer systems (whether combined or separated) often serve multiple communities, requiring cross-jurisdictional decision making. County and State authorities can play an important role as facilitators between various stakeholders. The Albany Pool CSO LTCP provides an example of multiple communities and other stakeholders working together to improve shared local water quality.
4. B. LTCPs are updated as more stringent water quality standards are developed.

Because storm and wastewater carry many contaminants, decreasing flows, capture and treatment should be the primary objectives, rather than "end of pipe" solutions targeted at single contaminants, such as disinfection prior to discharge that only lowers pathogen levels, but does not improve other contaminants.
4. B. 1. LTCPs for all CSO communities include climate change impacts including changes in precipitation and sea level rise.
4. C. All CSO communities develop green infrastructure plans to reduce CSOs
Use of "green" infrastructure to decrease stormwater flows into CSOs should be emphasized where feasible. "Green" infrastructure is not always the most direct or narrowly cost-effective solution, however, it often also provides other ancillary benefits, such as improved aesthetics, habitat, and/or reduction of street flooding in addition to decreased stormwater flow.
4.C. 1. All CSO communities have at least one demonstration green infrastructure project to reduce CSOs.

5. Other discharges of contaminants no longer cause violations of water quality standards.
Other discharges mean discharges other than CSOs, including non-point discharges.
5. A. Existing municipal separate storm sewer system (MS4) mitigation plans are implemented and updated as needed to achieve water quality standards in the receiving water.
MS4 systems carry stormwater through a separated system (not CSO). These can nevertheless be sources of pathogens, other contaminants, trash, etc. Relevant water quality standards relate to the receiving water (the estuary, in this case), not the level of contaminants in the stormwater flow itself, which would be unfeasible to sample comprehensively because there are so many discharge points. The comment under action 4.A. also applies to decision making related to separated sewer systems.
5. B. Septic systems abutting the estuary are upgraded or connected to sewer lines.
Poorly maintained septic systems are more likely to be a significant source of contaminants in tributary watersheds (which is outside of the geographic scope of this report). However, many homes along the estuary main stem continue to use septic systems. This action is mirrored in the Contaminants TEC.
5. C. Improved on-site management decreases releases of nutrients and emerging contaminants (e.g., pharmaceuticals) from large producers such as industrial facilities, health care facilities, and agricultural fields.
For example, health care facilities (e.g., hospitals, senior care facilities) can be large sources of pharmaceuticals to wastewater streams. It may be more cost effective to limit on-site pharmaceutical inputs by changing behaviors (such as stopping the flushing of unused medications down the toilet), than to upgrade treatment at WWTPs to remove the pharmaceuticals that end up in the wastewater.
5. C. 1. Each year, 5-6 large producers of such emerging contaminants are assisted in developing a voluntary contaminant reduction plan.
Incentives to participate will probably be needed to implement this action. It would make the most sense to connect these efforts to the source-tracking studies mentioned in action 2. A. 1., both to identify large producers and to demonstrate the impact of reduction efforts.

6. Existing waste- and stormwater infrastructure is maintained and improved.
6. A. Estuary communities have access to a predictable funding stream to deal with the existing backlog of maintenance projects, maintain existing assets, and conduct future upgrades.
Three separate funding streams are probably needed: 1) for the backlog of deferred projects, 2) for assessing and maintaining current infrastructure, and 3) to do future upgrades. Assessing and maintaining current infrastructure requires stable, long-term funding.
Over the next 50 years, it is likely that the available technologies and favored approaches to storm and wastewater capture and treatment will continue to change, as we see in the continuing adoption of

green infrastructure approaches to stormwater management. Given the many potential contaminants and problems that can derive from waste-and stormwater (fig. 1), novel approaches that lower multiple contaminants while embracing broader sustainability goals (such as improving habitat, lowering greenhouse gas emissions, lowering energy costs, and recharging groundwater) may become more common. Because different solutions will be best for different situations, it is important that planning efforts not require a specific technology or design as systems are improved or replaced in the future.
6. B. Seven communities with WWTPs develop asset management plans by 2020, followed by at least three community plans per year until all communities with WWTPs discharging to the estuary have quantified their infrastructure needs and prioritized the required investments.
6. C. Wastewater treatment plants are upgraded/retrofitted as new standards are adopted (Actions 1A and 1C).
This action is mirrored in the Contaminants TEC.
6. D. Improved stormwater management decreases the frequency of street flooding in estuary communities by 50%.
6. D. 1. Green infrastructure and low impact development are prioritized for stormwater water management because of their concomitant benefits (e.g. aesthetics, contaminant reduction).
6. D. 2. Adoption of green infrastructure approaches are accelerated by developing novel financing mechanisms.
For example, the NYSDEC is considering how to foster creation of green infrastructure banks in CSO communities.
6. E. All new sewage and wastewater infrastructure is built at high enough elevation to avoid damage by rising sea level (100-year storm plus 54").
This action is mirrored in the Resilient Waterfronts and Community Shorelines TEC.
6. F. Existing infrastructure is moved, replaced, or hardened to avoid damage by rising sea level (100-year storm plus 54").

This action is mirrored in the Resilient Waterfronts and Community Shorelines TEC. As described in the Hudson River Shorelines and Riparian Areas t TEC, solutions that result in living shorelines should be prioritized where feasible.

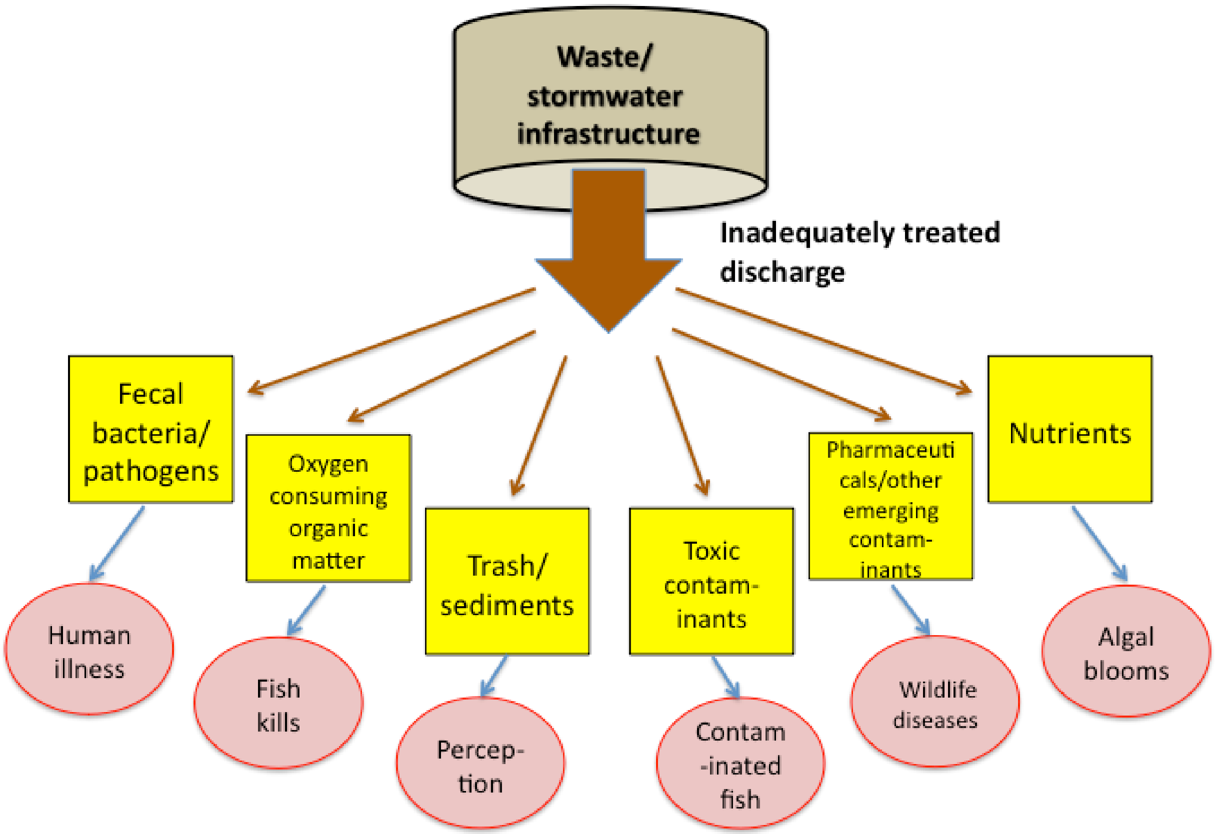

Figure 1. Storm and wastewater, released into the Hudson River estuary via infrastructure found in every community along the estuary, can carry many different contaminants if not treated properly before discharge. Yellow boxes exemplify different categories of contaminants that can be measured and compared to water quality standards. Water quality standards should be set to avoid negative outcomes, some of which are exemplified in the red circles connected to each contaminant category. The best management approaches for storm and wastewater will be those that improve conditions regarding multiple contaminants, thus avoiding multiple problems simultaneously.

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