Feasibility Study for a New Wastewater Resource Recovery Facility on Rikers Island

NYC Environmental Protection

March 2024

DEP staff working on a digester upgrade project at the Hunts Point WRRF.
(*Courtesy of NYCDEP*)

Front Cover:
Aerial view rendering of the new WRRF on Rikers Island.

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Kayakers at Brooklyn Bridge Park, Pier 4, in July 2023.
(*Courtesy of NYCDEP*)

LETTER FROM THE COMMISSIONER

Dear Friends:

The New York City Department of Environmental Protection (DEP) is always considering how to best serve the people of New York City. As our mission expands, so must our vision for what's possible. This Feasibility Study evaluated the viability of constructing a new Wastewater Resource Recovery Facility (WRRF), and found that doing so is not only feasible, but important for us to continue delivering excellent service to New Yorkers for generations to come.

The water surrounding us in the New York Harbor is the cleanest it's been in over a century. This has been achieved by generations of planning and investment led by our predecessors at the New York City Department of Environmental Protection who designed and constructed the wastewater treatment system we rely on today. Today, DEP continues this legacy of ambitious infrastructure planning to enable a growing, healthy, and vibrant New York City.

Every day, we treat over 1.3 billion gallons of wastewater at our 14 Wastewater Resource Recovery Facilities across the city. The smooth operation of this system is critical to protecting public health and the environment, as it works around the clock to remove organic matter, bacteria and other pollutants from wastewater, returning clean water back into New York City's water bodies.

However, our current system of WRRFs is not perfect. Having been in operation for decades - in some cases nearly 90 years - they now face significant space constraints that are slowing the pace and increasing the cost of needed upgrades and repairs. The drainage areas served by each of our 14 WRRFS remain unconnected, forcing our system to operate with limited flexibility since our plants cannot act as a single, interlinked fleet. Further, despite meaningful gains in ambient water quality, we could be doing even more to improve the health and ecological function of New York City's waterways. More than half of the city is served by a combined sewer system carrying both stormwater and sewage that was not designed to handle the large volume of water generated during heavy rainstorms, resulting in the discharge of this untreated wastewater directly into the City's waterways. To reduce these combined sewer overflows (CSOs), the City must build large underground storage tunnels in impacted water bodies like Newtown Creek and Flushing Bay to hold this surplus of wastewater until it can be treated.

This study demonstrates that a new WRRF in the upper East River could transform DEP's operations by creating new state-of-the-art facilities. This may lower operating costs, enhance performance, and improve environmental outcomes by capturing and transforming the byproducts of wastewater treatment – biogas and biosolids – into green renewable energy and fertilizer products. A new WRRF could connect several separate drainage areas to provide valuable flexibility while building in additional space to accommodate future upgrades and maintenance. By designing the tunnels serving the new WRRF intentionally for CSO storage, the facility would also make a significant contribution towards the City's goal of virtually eliminating CSOs by 2060.

The report that follows shows that it would be technically feasible to build this integrated WRRF on Rikers Island, but not without a substantial commitment. While the facility's footprint must be determined through further master planning, it would not require the entire island. In addition, DEP would need to retain all or most of the existing land that the surrounding WRRFs occupy to support its operations. Further, preliminary estimates suggest that building a new WRRF may be similar in cost as rehabilitating the existing WRRFs, but these estimates are still early and require more analysis. The payoff for this investment would be a modern WRRF capable of serving more than 3 million New Yorkers.

Even if building a WRRF on Rikers Island should prove not viable for whatever reason, this study makes clear the opportunities that DEP should reach for in reinventing its facilities. We know we can build an interconnected and state-of-the-art system, and we can design it to ensure its reliable operation over the long term. Significant strategic planning and investments will be required from us either way.

This study represents the type of bold, ambitious thinking we need to continue meeting our mission for the coming generations, and I am thrilled to offer it as a glimpse into the potential future of New York City.

Thank you,

Rohit T. Aggarwala
Commissioner

The New York City Department of Environmental Protection holds the critical mission of enriching the environment and protecting public health for all New Yorkers by providing high quality drinking water, managing wastewater and stormwater, and reducing air, noise, and hazardous materials pollution.

As part of the mission, DEP operates 14 Wastewater Resource Recovery Facilities across the city, in all five boroughs. In this Feasibility Study (study) DEP assessed the feasibility of building a new WRRF on Rikers Island. The new WRRF would replace four WRRFs that are located in close proximity to Rikers Island: Hunts Point, Tallman Island, Bowery Bay and Wards Island. These WRRFs are all located along - and discharge treated water to - the Upper East River.

This study is required by Local Law 31 of 2021 and is timely. Today, more than ever, DEP is challenged to continue delivering critical public health protection for a growing city with aging infrastructure while combatting the impacts of climate change.

The WRRFs in the study have been in operation for many decades – almost 90 years for three of them - and will require significant investment over the next few decades to address four key challenges: operations and maintenance; water quality; stormwater management; and resource recovery. Finding additional space is essential to addressing each of these challenges. There is minimal space available at the existing WRRF sites, which will limit what is possible and drive up costs.

The opportunity to assess the possibility of a new, modern WRRF with state-of-the-art technology posed a tremendous opportunity for DEP to consider how to best serve the City of New York long into the future. This study allowed DEP to look at the four existing WRRFs as a network and to solve for their common challenges all at once as part of one holistic solution for the Upper East River.

The concept for a new WRRF on Rikers Island represents the culmination of more than a year of technical engineering analysis, thinking big about DEP's historic and expanded mission, and a continued commitment to protecting public health and the environment into the next century.

A new WRRF on Rikers Island is a feasible long-term strategy for DEP's treatment system in the Upper East River, offering a multitude of benefits that are not possible at the existing WRRFs.

A new WRRF on Rikers Island would improve harbor water quality; produce green renewable energy; improve stormwater capture; and help grow the circular economy for all New Yorkers. It would be more reliable and resilient and enable DEP to maximize infrastructure investments by incorporating solutions that serve multiple purposes at once– like solar panels installed above tanks and tunnels that convey flow and capture more stormwater. It would also reduce the impact of DEP operations at the existing WRRFs on adjacent neighborhoods.

Overview of the Feasibility Study sites including the four WRRFs and Rikers Island.

Aerial view rendering of the new WRRF on Rikers Island.

The cost of a new WRRF on Rikers Island is estimated at $34 billion – equal to the estimated cost of necessary upgrades to the existing WRRFs. This cost estimate is discounted to present dollar value and is not representative of the anticipated cost at the time of construction - it is intended for comparative purposes only. This cost estimate requires further development, however, there appears to be potential for long term savings due to lower operating costs.

DEP will need to upgrade for the future whether a new WRRF is built on Rikers Island or the four WRRFs continue to operate at the existing sites. The estimated upfront costs of building a new state-of-the-art WRRF on Rikers Island and rehabilitating the four existing WRRFs is equivalent. No matter what, New York City will have to invest significant resources in wastewater infrastructure in this area alone in coming decades.

The non-monetary benefits a new WRRF on Rikers Island are potentially significant. Removing wastewater treatment operations from densely populated neighborhoods, reduced environmental impacts, increased energy efficiencies, and more resilient performance and service are just a few of the advantages a new WRRF would offer.

The preliminary concept for a new WRRF on Rikers Island estimated using approximately 245 acres (60%) of the island, leaving the rest of the island to be developed for other uses.

A new WRRF on Rikers Island would utilize approximately 245 acres (60%) on Rikers Island. The new WRRF would be built on the western half of the island, leaving a portion of the eastern extent of the island for other uses.

DEP would continue to use the existing four WRRF sites. Roughly 25% of each site would be used for facilities associated with the new WRRF on Rikers Island. The remainder of the existing sites would be used to realize DEP's commitment to end Combined Sewer Overflow (CSOs) by 2060, to better protect public health and the environment, and to manage flooding in NYC.

DEP could start construction of a new WRRF on Rikers Island in 2035 with startup in 2045 and full implementation completed over a 40 year period.

DEP would not require immediate use of Rikers Island for a new WRRF. Several years' worth of planning and design work is required to advance the new WRRF and tunneling concepts presented in this study to determine the optimal design, the phasing of the WRRF flows to Rikers Island, and the future design of the existing WRRF sites to maximize CSO benefits. Public works projects of this magnitude require careful planning and design – over a decade more of work is needed to complete these critical activities.

This study shows what is possible.

Constructing a new WRRF on Rikers Island is not only feasible; it would expand and tremendously improve wastewater treatment and resource recovery operations in New York City. DEP has a long, proud history of taking on ambitious and forward-thinking challenges – beyond the imaginable - to protect public health and the environment for all New Yorkers. Seizing on a rare, once in a lifetime opportunity to build a new state-of-the-art WRRF in the heart of New York City could be a pillar of this continuing legacy.

It is important to note that this is a study intended to determine the feasibility of constructing a new WRRF on Rikers Island. Many high level assumptions were made that would need to be further developed and evaluated through careful planning and analysis.

Feasibility Study for a New WRRF on Rikers Island

View of Rikers Island sign on Rikers Island. (*Courtesy of NYCDEP*)

In 2021, the New York City Council passed a series of laws, collectively known as the "Renewable Rikers Laws" that require various City agencies to examine potential uses for Rikers Island following the cessation of Department of Correction operations there. The Laws focus on future uses that promote broad public benefit, renewable energy, and critical environmental infrastructure.

One of the laws - Local Law 31 of 2021 - required DEP to assess the feasibility of building a new WRRF on Rikers Island. This study was intended to determine the capacity for organics and wastewater processing on Rikers Island and to assess the possibility of diverting wastewater flows from four existing WRRFs in the region - Hunts Point, Tallman Island, Bowery Bay, and Wards Island - to a new WRRF on Rikers Island.

This study is timely for DEP. The infrastructure that is here today was a well-served vision from over 100 years ago that has transformed over time. DEP is challenged to continue delivering critical public health services for a growing city while combatting the impacts of climate change. Now more than ever, the chance to build a new state-of-the-art WRRF poses a tremendous opportunity for DEP to best serve the City of New York long into the future.

Decades old Final Settling Tanks at a DEP WRRF are taken out of service for maintenance and repairs. Taking critical infrastructure temporarily out of service is necessary to maintain regulatory compliance. (*Courtesy of NYCDEP*)

DEP: Protecting New Yorkers Now and Always

An Enduring Mission

DEP is the largest combined water and wastewater utility in North America. It holds the critical mission of enriching the environment and protecting public health for all New Yorkers by providing high-quality drinking water, managing wastewater and stormwater, and reducing air, noise, and hazardous materials pollution.

As part of this mission, starting in the early 19th Century, New York City has worked to protect public health and the environment with an ever-improving wastewater collection and treatment system.

Today, DEP's expansive wastewater and stormwater system consists of 7,500 miles of sewer pipes; 153,000 catch basins; over 495 permitted outfalls for the discharge of CSOs; and 96 pumping stations, 80 of which transport flows to 14 WRRFs located throughout all five boroughs of New York City.

The wastewater system treats more than 1.3 billion gallons of water each day. During heavy rains, that amount can more than double. Thanks to the work of DEP, New Yorkers are enjoying the cleanest harbor water quality in well over a century.

DEP is always working to improve New York City's water infrastructure, from our water supply system to our wastewater treatment operations. These steel pipe liners are part of a major project to re-enforce the water supply system so we can continue providing New Yorkers with excellent water services for generations to come. (*Courtesy of NYCDEP*)

DEP is responsible for...

Water Supply

Delivers: **1B** gallons of high-quality water **every day**

Maintains: **7,000** miles of water mains

Wastewater Treatment

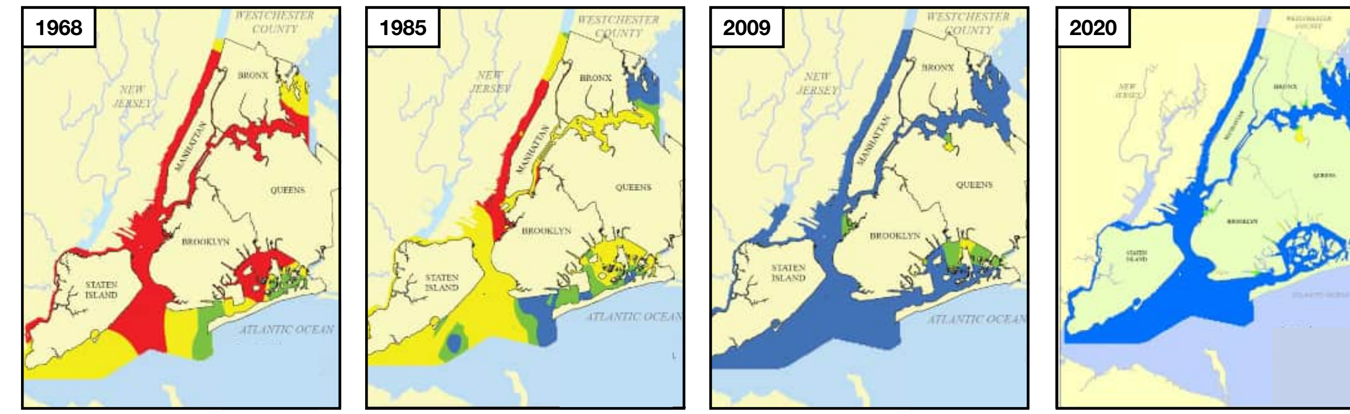
Treats: **1.3B** gallons of wastewater **every day**

Operates: **14** WRRFs, **96** pumping stations, **7,500** miles of sewers

Air, Noise, & Hazardous Waste

Enforces: NYC Air Pollution Control Code and NYC Noise Code

Reduces: Local emissions



Water quality monitoring data illustrates a significant improvement in fecal coliform bacteria levels from 1968 to 2020. *(Courtesy of NYCDEP)*

New York Harbor is cleaner today than it has been in more than a century. DEP is approaching current challenges with the same focus and care that created these improvements.

Dolphins spotted swimming in the New York Harbor in September 2017 (*Courtesy of NYCDEP*)

Improving the Quality of Our Waterways

The water quality of New York Harbor has shown significant improvement over time. Efforts to reduce pollution and improve wastewater treatment by DEP have played a crucial role in this progress.

Sightings of dolphins, whales, and other marine life in the New York City harbor are indicative of just how far the city has come. They are indicative of the substantial efforts made over the last century to reverse the damage done in the past by improving wastewater treatment and reducing the runoff from rainstorms to improve water quality.

DEP: Protecting New Yorkers Now and Always

An Expanding Mission

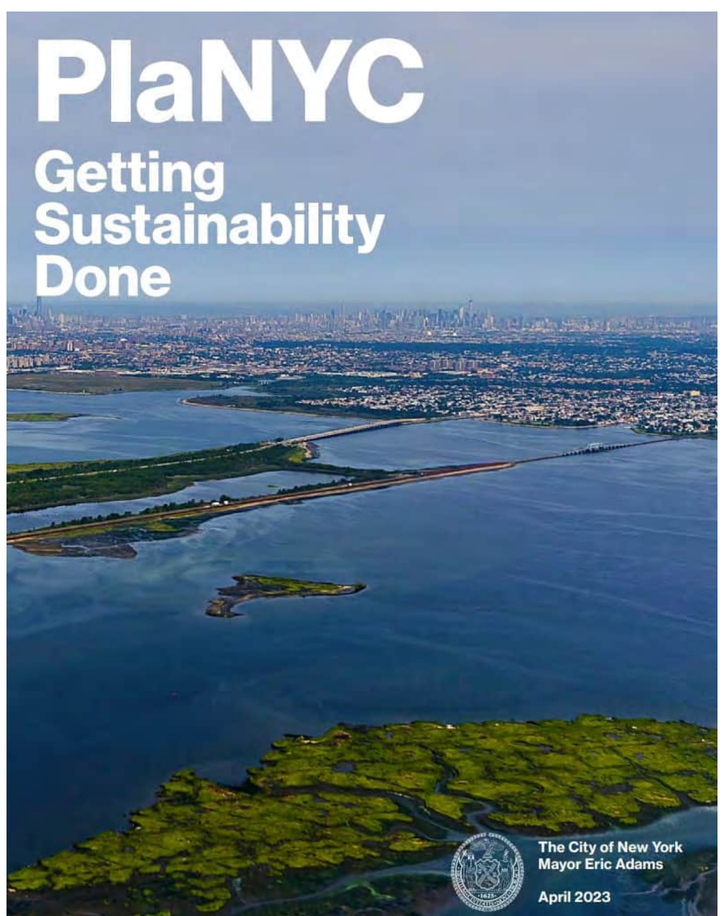
In the Spring of 2023, *PlaNYC: Getting Sustainability Done* - the City's new citywide sustainability plan – was released. DEP plays a prominent role in *PlaNYC*, including the following major initiatives related to wastewater treatment.

Flooding: DEP has been given lead responsibility for coastal flood resilience and will think of flooding holistically – whether from rain, coastal storms, or sea level rise. Through this responsibility, DEP will implement a multi-layered strategy for flood resilience.

Water Quality: DEP plans to reduce CSOs by more than 4 billion gallons per year by 2045 and to develop a strategy to end the discharge of CSOs and polluted stormwater during most extreme storm conditions by 2060.

Circular Economy: DEP will leverage existing infrastructure to process collected organics into renewable energy and compost within the city.

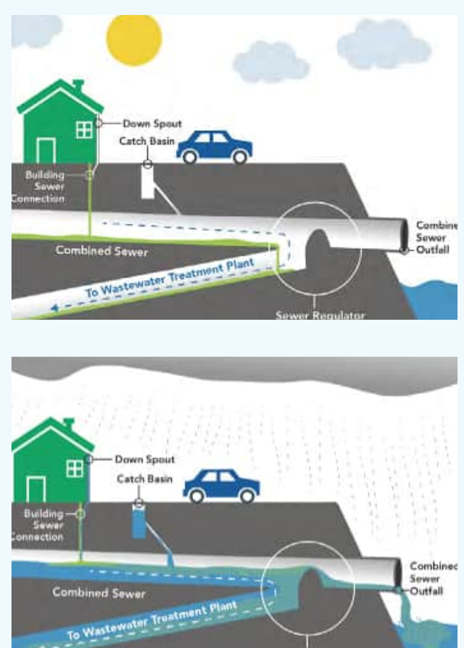
These important initiatives expand the services DEP provides and challenge DEP to think more holistically about developing comprehensive solutions to effectively deliver its historic and expanding mission.



Learn more about the City's new sustainability plan, *PlaNYC*, here.
(Courtesy of NYC Mayor's Office of Climate and Environmental Justice)

What is a CSO?

About 60% of New York City has a combined sewer system. In a combined sewer system, there is a single pipe that carries both stormwater runoff and sewage from buildings. This mix of stormwater and sewage is usually sent to a WRRF. During heavy rainstorms, combined sewers receive higher than normal flows. The WRRFs are unable to handle flows that are more than twice the design capacity. When this occurs, a mix of stormwater and untreated sewage discharges directly into the City's waterways. These events are called CSOs. DEP is concerned about CSOs because of the effect on water quality and the recreational use of local water bodies. DEP has goals to end the discharges of CSOs.



(Courtesy of NYCDEP)

The Critical Role of Wastewater Treatment

DEP's wastewater infrastructure is critical to protecting public health and the environment. The Newtown Creek WRRF is one of 14 in the New York City system. *(Courtesy of NYCDEP)*

Wastewater treatment is critical to protecting the public health and the environment.

The wastewater treatment process removes organic matter, bacteria and other pollutants from wastewater to prevent the spread of disease and also to protect the environment. The collection and treatment of wastewater is the foundation for population growth and development as well as fishable and swimmable waters.

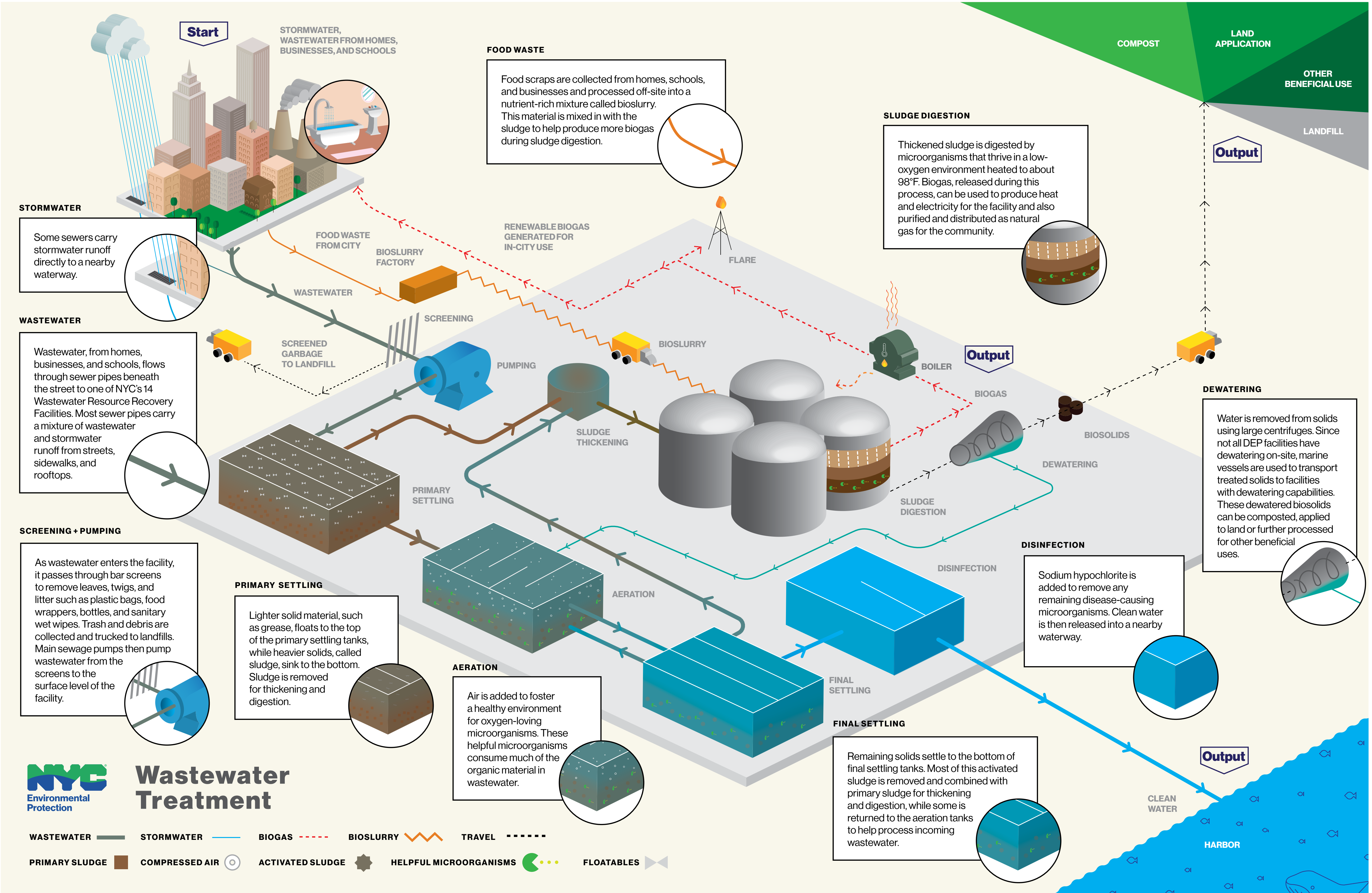
At the 14 WRRFs operated by DEP, wastewater undergoes five major processes of treatment, which closely mimic and accelerate how wetlands, rivers, streams, and lakes naturally purify water. After only 8 to 10 hours, the WRRFs have removed pollutants from wastewater and release the cleaned water into New York City waterways.

Today, the WRRFs are evolving to do even more - modern technology can transform the natural byproducts of the treatment process into valuable renewable resources and can foster a carbon neutral, circular economy.

Learn more about DEP's wastewater treatment operations at: Wastewater Treatment System - DEP (click here)

DEP's historical and expanding mission challenges DEP to look far ahead to the future of the services it provides. That is why this study is so timely.

What is a Wastewater Resource Recovery Facility?



Wastewater is generated every time someone flushes a toilet or uses a sink, and it's sent to one of NYC's 14 WRRFs for processing. Each day, NYC's 14 WRRFs treat 1.3 billion gallons of wastewater, using a process that mimics and expedites processes found in nature, before distributing the processed water into NYC's waterways. To learn more about this process, click here
(Courtesy of NYCDEP)

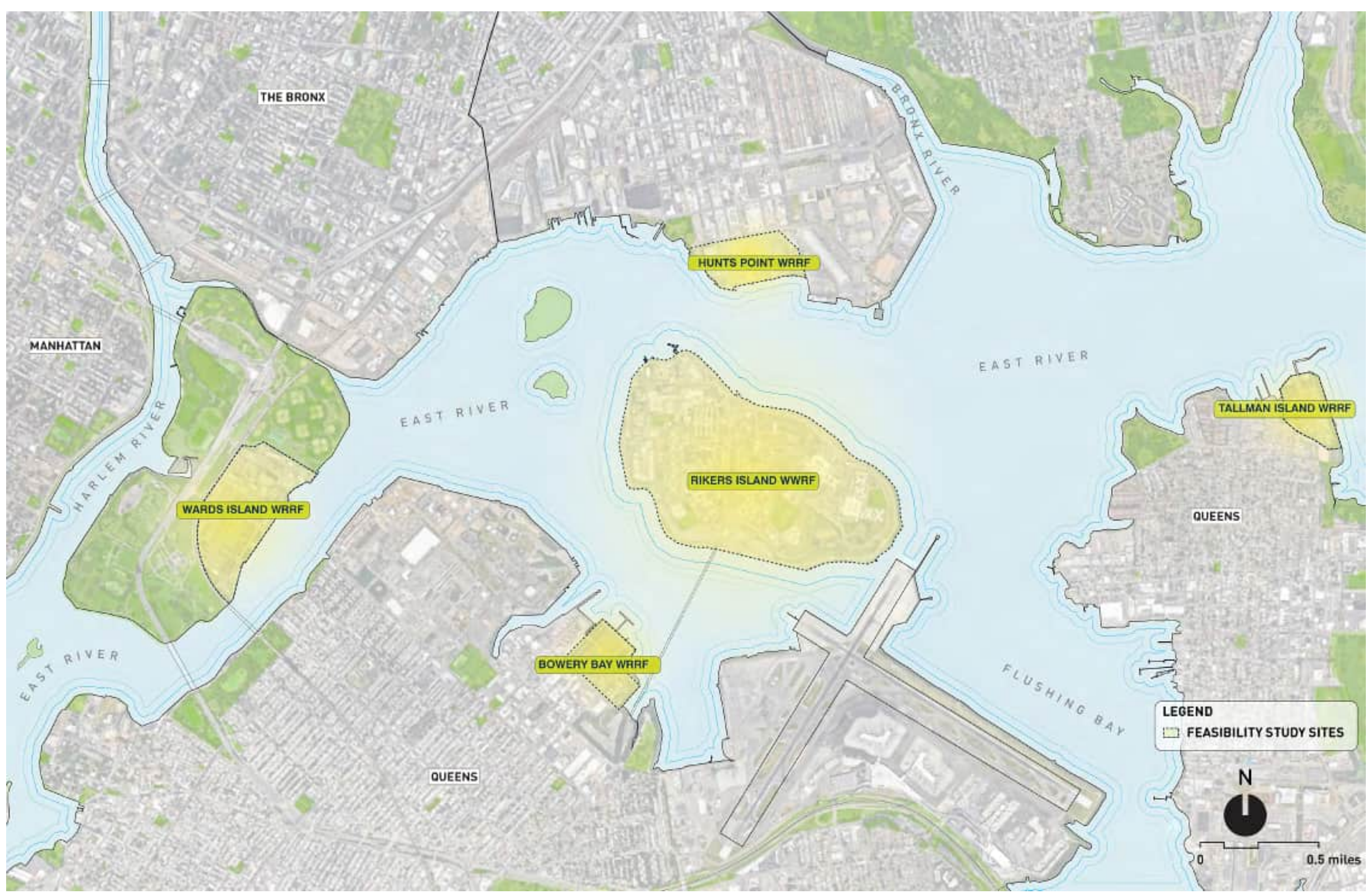
Rikers Island

An Opportunity for DEP

Rikers Island is an island located in the Upper East River in New York City that borders the Boroughs of Manhattan, the Bronx, and Queens. The Upper East River represents a portion of the larger East River, which connects to the Atlantic Ocean on both ends.

The area of Rikers Island is more than 400 acres. The New York City Department of Correction currently operates a Correctional Facility on Rikers Island. In 2019, the New York City Council passed a law requiring that the Department of Correction stop operating on Rikers Island and to replace the current jail system with a smaller borough-based jail system. That decision opened the land on Rikers Island for alternative uses in the future.

The area of Rikers Island offers an almost unprecedented amount of land for development in New York City. However, there is one bridge to the island from the Borough of Queens and limited public transportation. It is also a short distance from LaGuardia Airport resulting in building height and other restrictions. The island geology is also predominantly historic landfill, resulting in geotechnical challenges. While these characteristics represent a challenge for many potential uses, they present an opportunity for wastewater treatment operations. Further, a new WRRF could turn the relative isolation of the island into a real advantage.



Overview of the Feasibility Study sites including the four WRRFs of the Upper East River region and Rikers Island.

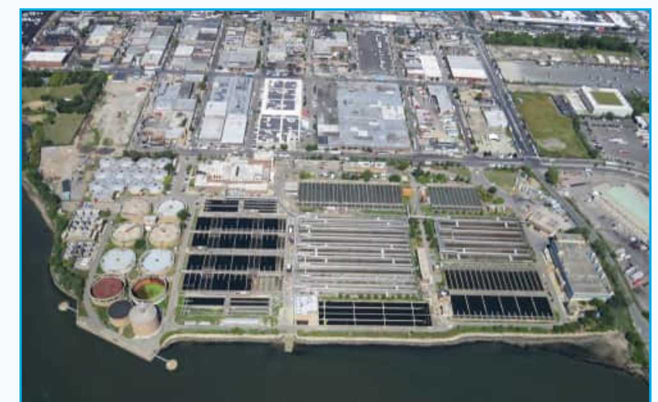
The Upper East River WRRFs

A Challenge for DEP

There are four WRRFs in the study area: Bowery Bay, Hunts Point, Tallman Island, and Wards Island. Each of these WRRFs are located along - and discharge treated water into - the Upper East River. The quality of the treated water from these WRRFs is critically important to protecting public health and the environment. The quality of the treated water is highly regulated and the water quality in the area is carefully monitored.

Overview of the four WRRFs:

- Located in the Boroughs of the Bronx, Manhattan, and Queens
- Built between 70 and 90 years ago
- Treat flows between 80 and 275 million gallons per day (MGD)
- Collectively serve over three million New Yorkers



HUNTS POINT WRRF

Borough: **Bronx**
Operating Since: **1952**
Flow (MGD*): **200**
Population Served: **684,569**

TALLMAN ISLAND WRRF

Borough: **Queens**
Operating Since: **1939**
Flow (MGD*): **80**
Population Served: **410,812**

BOWERY BAY WRRF

Borough: **Queens**
Operating Since: **1939**
Flow (MGD*): **150**
Population Served: **848,328**

WARDS ISLAND WRRF

Borough: **Manhattan**
Operating Since: **1937**
Flow (MGD*): **275**
Population Served: **1,061,558**

(*Courtesy of NYCDEP*)

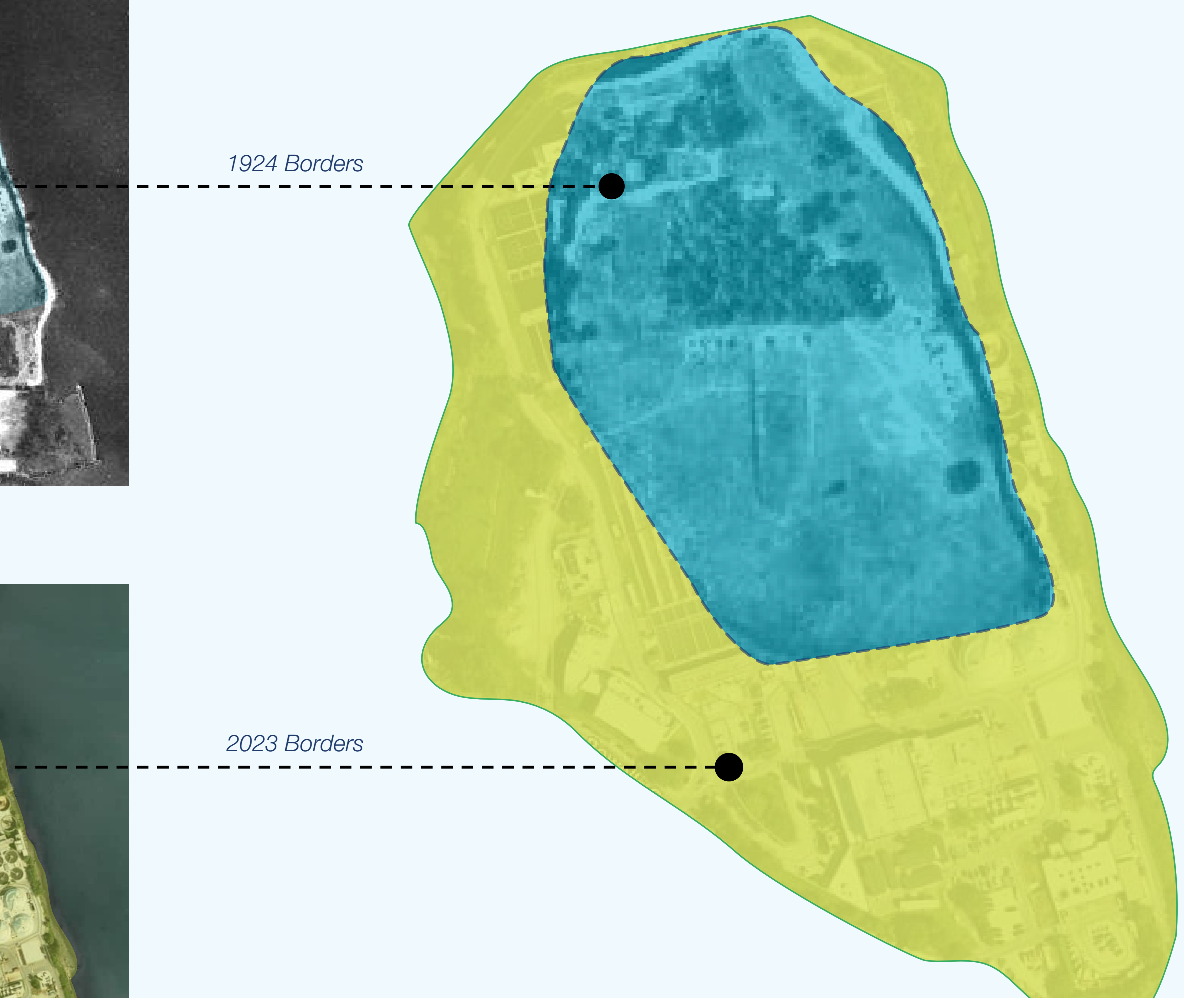
Finding space to sustain existing operations and to meet future water quality and population growth requirements is a major challenge for DEP.

When the locations of the original WRRFs were chosen in the early- to mid-1900’s, the areas were largely underdeveloped. Over the last century, however, there has been tremendous development around each of them. As new water quality regulations have been introduced, the WRRFs have also expanded to nearly the full extent of their existing properties. The WRRFs are critical to supporting continued population growth and development. For example, the WRRFs are central to some of New York City’s most recent zoning projects such as Hunters Point and Flushing West in Queens.

Tallman Island Expansion

Aerial views of the Tallman Island WRRF in 1924 and present day, illustrating how much wastewater operations have expanded over the last century to meet water quality goals and how little space remains for further expansion. This is the case at all 14 WRRFs in the New York City system. The views also illustrate how the neighborhood surrounding Tallman Island WRRF has been dramatically developed over the decades.

(*Courtesy of Esri*)



(*Courtesy of NYCityMap*)

Proximity of the WRRFs along the Upper East River to Rikers Island

The four WRRFs along the Upper East River are each less than two miles from Rikers Island. Rikers Island is located relatively central to the four WRRFs. The geographic proximity of the existing WRRFs make them ideal candidates to have their flows connected to a new WRRF on Rikers Island.

The outfall that discharges treated water from the Hunts Point WRRF is located just across the East River from Rikers Island (seen in the background).
(*Courtesy of NYCDEP*)

The Rikers Island bridge can be seen beyond the disinfection tanks at the Bowery Bay WRRF.
(*Courtesy of NYCDEP*)

Key Challenges at the Upper East River WRRFs

While each WRRF has its own unique challenges, there are many shared challenges to their ability to continue serving New Yorkers in the future.

OPERATIONS AND MAINTENANCE

The four WRRFs along the Upper East River are approaching a century of operations. Increasingly, upgrades to critical equipment and process areas become more urgent. Their technologies are inefficient and becoming obsolete, and old systems are harder to repair or replace. The sites do not have adequate space to expand. Facilities cannot be shut down to allow thorough renovations to be completed – so work needs to be completed in phases adding time and cost. DEP carefully plans upgrades, replacements, and repairs to the WRRFs; however, competing needs mean the WRRFs are challenged to meet optimal performance. Most WRRFs in the DEP system are around the same age, which means that all 14 WRRFs will be competing for the same, finite resources into the future.

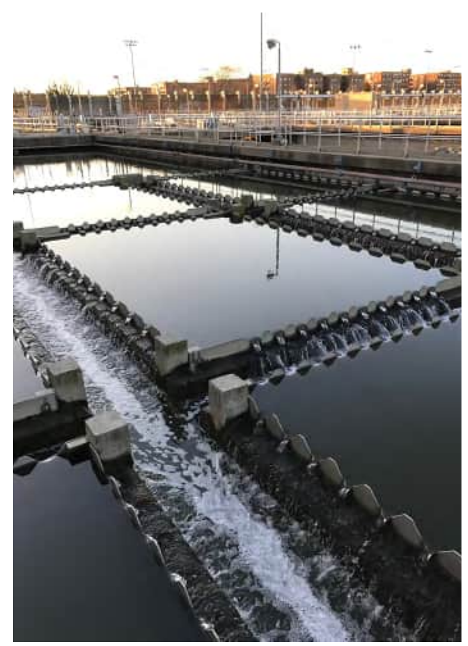
WATER QUALITY

Water quality regulations are developed for the treated water that is discharged by WRRFs into different waterbodies. These regulations are critical to protecting public health and the environment. DEP is required to meet water quality regulations as part of the permit it has to discharge water from each WRRF. These permits establish specific discharge limits, monitoring, and reporting requirements. The permits are updated periodically to meet stricter limits or for a new pollutant. While some future regulations can be anticipated, others cannot. In the coming decades, the DEP WRRFs will have to meet requirements for nitrogen, enterococcus bacteria, and residual chlorine. Additionally, emerging contaminants, such as the "forever chemical" PFAS, will likely require additional treatment systems that are just starting to be researched. Meeting new regulations commonly requires new treatment processes and upgrades at the WRRFs. However, the existing WRRFs have very little space available for the new systems that will be required to meet future regulations.

RESOURCE RECOVERY

WRRFs have enormous potential to support resource recovery goals, including co-digestion of organics, production of green renewable energy, and biosolids reuse. The opportunities are only possible when a WRRF is upgraded for the right treatment processes and is operating optimally. The existing WRRFs are not equipped to support all of these goals. Significant investment is required to upgrade the WRRFs to facilitate more resource recovery, particularly for solids processing which makes many of the goals possible.

Finding additional space is essential to effectively address almost every challenge DEP faces. There is little to no available space at the existing WRRF sites, which limits what is possible and will drive up costs.



Upgrading critical WRRF infrastructure while maintaining operations is a major challenge for DEP. (*Courtesy of NYCDEP*)

STORMWATER MANAGEMENT

WRRFs are necessarily located along shorelines because they release treated water into nearby waterways. In New York City, that means that the WRRFs are in low-lying coastal areas where they are vulnerable to sea level rise and flooding from extreme storm events. As the climate continues to change, more frequent and intense stormwater event are projected. New York City is already experiencing this today. These changes stress the wastewater collection system's ability to effectively capture wastewater and stormwater because they were designed for different conditions in the 1900s. As a result, more Combined Sewer Overflow (CSO) events may occur. At the same time, *PlaNYC* calls for a larger portion of stormwater to be captured and treated. The WRRFs will need to treat more frequent and increased stormwater flows. This requires significant investments to both retrofit the WRRFs to be more resilient to flooding conditions so they can continue to operate in most extreme storm events and restart operations following upsets from extreme events as quickly as possible. This also requires enhanced collections and CSO capture to better manage flooding throughout New York City.

DEP needs to address all of these challenges and more, whether a new WRRF is built on Rikers Island or the four WRRFs continue to operate at the existing sites. Significant strategic planning and investments will be required either way.

Ten WRRFs and more than 40 wastewater pumping stations were affected by Superstorm Sandy in 2012. This image shows the High Water Mark from Superstorm Sandy at the at the Hunts Point WRRF, in blue, demonstrating that most of the tanks were submerged and unable to maintain treatment. In addition, much of the equipment and materials below ground – of which there are many – were heavily damaged. (*Courtesy of NYCDEP*)

A new WRRF is a way to comprehensively address the key challenges DEP faces at its existing WRRFs:

- ✓ Operations and Maintenance
- ✓ Stormwater Management
- ✓ Water Quality
- ✓ Resource Recovery

State-of-the-Art Treatment & Operational Excellence

The opportunity to build a new WRRF on Rikers Island would enable DEP to consider modern, efficient technologies and innovative treatment processes, some of which would be very difficult to retrofit into the existing WRRFs. Since the existing WRRFs were built, significant advancements in the field of wastewater treatment have been made to more efficiently meet water quality goals and to improve biosolids quality and resource recovery.

In planning what a new WRRF on Rikers Island could look like, DEP was able to consider many more options to meet future needs than what would be practical with the space-constrained existing sites. In this process, DEP was committed to conceptualizing a modern, state-of-the-art WRRF that protects public health and the environment, reduces greenhouse gas emissions, supports a circular economy, and improves harbor water quality for all New Yorkers.

A major part of DEP's work is the long-term, dependable operation of complex infrastructure. State-of-the-art treatment and commitment to operational excellence go hand in hand.

DEP has envisioned a facility that uses 21st-century technology to achieve 21st-century needs, yet is constructed with future needs in mind, well beyond the next 100 years.

This study evaluated whether a new WRRF could be built on Rikers Island. Evaluating the possibility of a new, state-of-the-art WRRF presents a tremendous opportunity to think of a better way for DEP to continue to deliver its historical and expanding mission to New Yorkers.

Laying the Foundation for Expanded Benefits to New Yorkers

Besides state-of-the-art treatment and operational excellence, a new WRRF on Rikers Island provides a foundation upon which many other tremendous benefits are made more possible:

IMPROVED HARBOR WATER QUALITY

New York City's harbor water is cleaner than it has been in over a century. A new WRRF at Rikers Island as part of an integrated system with the Hunts Point, Tallman Island, Bowery Bay, and Wards Island WRRFs would expand CSO capture and include modern wastewater treatment processes. This expanded and updated treatment would allow DEP to continue increasing the high quality of New York City's harbor waters.

PRODUCE RENEWABLE ENERGY

New York City is committed to achieving a clean energy future. A new WRRF on Rikers Island provides a new platform for green renewable energy production from solar arrays, captured biogas, and heat extraction.

MAXIMIZE STORMWATER MANAGEMENT

New York City is working to keep untreated wastewater and other pollutants out of waterways by reducing CSO discharges. There are also long-term goals for expanded flood management. A new WRRF on Rikers Island would provide the critical additional space required to capture and treat stormwater and reduce CSOs and localized flooding. In addition, the WRRF would be constructed to be resilient so that it can continue to operate in most extreme storm events and restart operations following upsets from extreme events.

GROW THE CIRCULAR ECONOMY

New York City is committed to transforming into a circular economy – an economic system that eliminates unnecessary waste and produces goods in a sustainable way. A new WRRF on Rikers Island opens many possibilities to support these ambitious initiatives, including organics processing, biogas utilization, water reuse, and biosolids reuse.

The Feasibility Study Process

For more than a year, DEP studied the potential of constructing a new WRRF on Rikers Island. Taking advantage of a "blank slate", DEP envisioned a new WRRF built on a foundation of state-of-the-art treatment and operational excellence.

The feasibility study was a complex undertaking and included:

- ✓ Site visits to Rikers Island and the four study WRRFs to perform firsthand assessments of layout, features, conditions, and property boundaries.
- ✓ Information collection for the four WRRFs, including process layouts, recent and planned upgrades, and long-term investment needs.
- ✓ Research into the history and geology of Rikers Island.
- ✓ Selection of state-of-the-art treatment processes and technology for a new WRRF on Rikers Island to meet forecasted water quality requirements and resource recovery goals.
- ✓ Engineering analysis to configure the treatment process at the new WRRF and required operations to remain at the existing WRRF sites.
- ✓ Engineering analysis of tunneling and conveyance requirements from the four existing WRRFs to the new WRRF on Rikers Island.
- ✓ Preliminary assessment of the Environmental Impacts of constructing a new WRRF on Rikers Island.
- ✓ Development of a preliminary conceptual design for the new WRRF on Rikers Island.
- ✓ Development of preliminary capital and lifecycle cost estimates.
- ✓ Development of a conceptual schedule for future planning, design, and construction.

DEP staff conducted a site visit to Rikers Island in 2022. The Hunts Point WRRF can be seen across the river. (*Courtesy of NYCDEP*)

Conceptualized Facility Overview

(Courtesy of NYCDEP)

A new state-of-the-art WRRF on Rikers Island represents the culmination of over a year of intensive technical engineering analysis, thinking big about DEP's historical and expanded mission, and a continued commitment to public health and the environment.

Based on this high level feasibility study, a new WRRF could boast the following statistics:

ESTIMATED COST (IN 2024 DOLLARS)
$34 billion

TARGET STARTUP YEAR
2045

AVERAGE DAILY FLOW
705 million gallons per day

PEAK WET WEATHER FLOW
1,410 million gallons per day

REGULATORY TARGETS
- **Nitrogen**
- **Enterococcus**
- **Free Cyanide**
- **Total Residual Chlorine**
- **Whole Effluent Toxicity**

BIOSOLIDS QUALITY
Class A
the highest quality possible

ORGANICS COMPOSTING CAPACITY
500 wet tons per day

ORGANICS CO-DIGESTION CAPACITY
420 wet tons per day

WRRF AREA
245 acres
approximately **60%** of Rikers Island

POPULATION SERVED
3 million

THE SCHEMATICS THAT FOLLOW PROVIDE:

1. A technical overview of the conceptualized wastewater treatment processes for a new WRRF, from the conveyance tunnels that route the wastewater flow from the existing WRRFs to Rikers Island, to the new effluent outfall that releases the clean water to the Upper East River.

2. A bird's-eye view of the Upper East River wastewater treatment system, including the existing WRRF sites and their connections to a conceptualized WRRF on Rikers Island, to highlight all of the features and advantages a new WRRF would offer.

State-of-the-Art Treatment

1 **Screening Shaft:** Wastewater entering the facility passes through screens to remove larger debris like leaves, twigs, and litter.

2 **Influent Pump Station:** Wastewater is pumped from the deeper tunnels underground through the influent screens to the surface level of the facility.

3 **Grit Removal:** Wastewater flow is slowed down causing smaller debris like pebbles, sand, and other heavy particles to drop to the bottom and be disposed of.

4 **A- Stage Aeration & Enhanced Primary Settling:** Wastewater is pumped to tanks where air is added to promote growth of beneficial microorganisms that consume organic material. The beneficial microorganisms are then settled out and reused.

5 **Ultra-Fine Screening:** Small particles such as hair, fibers, and stringy material are screened and removed.

6 **Secondary Aeration:** Beneficial microorganisms are used to remove nitrogen from the wastewater.

7 **Supplemental Carbon:** Glycerol – an environmentally friendly product - is added to the Secondary Aeration process to feed the beneficial microorganisms and enhance the nitrogen removal process.

8 **Membrane Filtration:** Treated water is separated from the beneficial microorganisms that grow in the aeration process using membrane bioreactor (MBR) technology that allows only the cleanest water to pass through.

9 **UV Disinfection:** Treated water is disinfected with Ultraviolet (UV) light to remove any disease-causing microorganisms.

10 **Effluent Outfall:** Clean water is released into the Upper East River.

11 **Pre-Dewatering:** Large centrifuges that rapidly spin are used to separate liquids and solids (sludge) produced in the A-stage aeration process.

12 **Thermal Hydrolysis Process Boilers:** High-pressure steam that is needed for the Thermal Hydrolysis process is produced in boilers.

13 **Thermal Hydrolysis Process:** Heat and pressure are applied to sludge to break down organic matter.

14 **Sludge Digestion:** Organic matter in sludge is decomposed by beneficial microorganisms that thrive in an environment heated to about 98°F.

15 **Post-Dewatering:** More wastewater is removed from digested sludge using large centrifuges and is returned to the sidestream treatment system .

16 **Biogas Treatment:** Biogas released during the digestion process is purified and converted to renewable natural gas for distribution to the community.

17 **Sidestream Treatment:** The ammonia content in the wastewater leaving the Post-Dewatering process is removed and is recycled ahead of the Primary Treatment process.

18 **Dryer:** The solids that have been digested and dewatered are dried using large heat dryers. The nutrient-rich product is a valuable fertilizer product for landscaping and farming.

19 **Odor Control:** Wastewater treatment processes are ventilated, and the foul-smelling air is collected and treated in a filter.

20 **Laboratory:** Treated and untreated wastewater from the Rikers Island WRRF and other DEP facilities is analyzed to ensure permit compliance and to ensure treatment processes are operating correctly.

21 **Administration and Operations Building:** Offices, a mail room, kitchen, locker rooms, training rooms, and a central control room for WRRF staff.

22 **Warehouse and Maintenance Shop:** Parts and materials needed for routine facility maintenance are stored.

23 **Marine Transfer Station:** Materials are processed for maritime transport into and out of the facility.

24 **Compost:** Organic waste in the form of food scraps and yard trimmings is converted into nutrient-rich soil which can be used to fertilize gardens, lawns, and farms.

Expansive Benefits for the Public and the Environment

Improved Water Quality based on modern, reliable, resilient treatment technologies.

Expanded Wastewater Treatment with a larger, state-of-the-art WRRF.

Expanded CSO Capture with double barrel tunnels that can capture and store more stormwater.

Infrastructure maximizing the features of a new build to achieve synergies for energy and carbon neutrality.

Design for Sea Level Rise by positioning the new WRRF above the 2100 projected sea level elevation.

Flood Mitigation Strategies for reduced inland flooding and sewer backups based on collections system changes.

Resiliency from Storms taking advantage of a new site to elevate and hard armor WRRF and protect below-grade assets from water inundation.

Electrical Resiliency with redundant power systems to prevent disruptions to operations during extreme weather.

Reduced Odors with odor control technology and placement of new WRRF away from neighborhoods.

Reduced Traffic in all four neighborhoods due to changed operations at the 4 WRRF sites and increased reliance on barges at the new WRRF.

Workforce Development Facilities with job training and workforce development programs for a new green economy.

High-Quality Water Reclamation for water reuse at the new WRRF and at other facilities on Rikers Island or nearby.

Marine Transfer Station to maximize barge use for transporting biosolids and organics.

Expanded Composting Capability based on a new and larger organics collection and composting facility that can share co-benefits of co-located organics co-digestion operations.

Advanced Biosolids Processing to produce high quality renewable gas and biosolids that can be beneficially used instead of landfilled to create renewable natural gas.

Renewable Energy Production using energy derived from natural wastewater sources.

Thermal Energy Recovery from treated effluent to heat/cool facilities on Rikers Island.

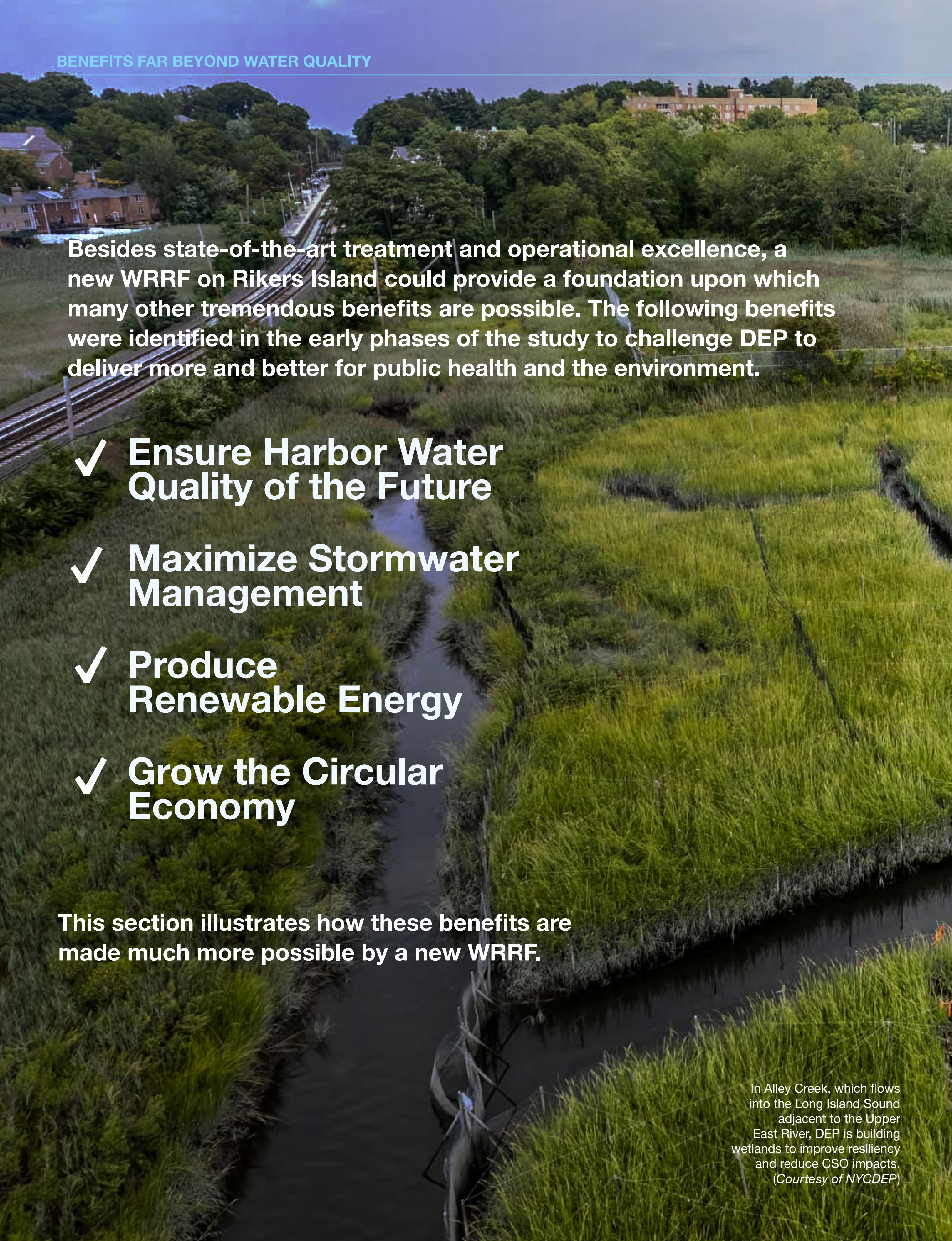
Solar Energy Recovery with solar arrays to produce renewable energy.

Largest MBR Plant on Earth which produces a high-quality effluent that offers many opportunities for reuse.

Beneficial Services at Existing Sites like expanded floodwater capture.

Integrated System A new WRRF at the center of a more robust, integrated wastewater and resource recovery system.

Double-Duty Infrastructure that allows for additional conveyance and storage of wet weather flow as well as periodic shutdowns for inspections, cleaning and maintenance.



Besides state-of-the-art treatment and operational excellence, a new WRRF on Rikers Island could provide a foundation upon which many other tremendous benefits are possible. The following benefits were identified in the early phases of the study to challenge DEP to deliver more and better for public health and the environment.

- ✓ **Ensure Harbor Water Quality of the Future**
- ✓ **Maximize Stormwater Management**
- ✓ **Produce Renewable Energy**
- ✓ **Grow the Circular Economy**

This section illustrates how these benefits are made much more possible by a new WRRF.

In Alley Creek, which flows into the Long Island Sound adjacent to the Upper East River, DEP is building wetlands to improve resiliency and reduce CSO impacts. *(Courtesy of NYCDEP)*

Ensure Harbor Water Quality of the Future

Sightings of whales and other marine life in New York City are testament to improved water quality in part due to upgraded wastewater treatment. *(Courtesy of NYCDEP)*

New York City's harbor water is the cleanest it's been in a century based in part on DEP's wastewater treatment operations. In recent years, several notable improvements in water quality in New York Harbor are being celebrated. Marine life that hadn't been seen in decades – like whales and dolphins – have been observed more and more. In the last decade, these sightings have become so frequent that whale watching is now possible for New Yorkers.

DEP is challenged to maintain responsible foresight in long-term planning for water and wastewater operations by anticipating and building for the future known regulatory horizon and also leaving space for the unknown regulatory horizon. More stringent requirements for a wide range of parameters like nitrogen, enterococcus, free cyanide, whole effluent toxicity, and emerging contaminants, like the "forever chemical" PFAS, will require additional treatment and different types of treatment. These will all require space, which is extremely limited at the existing WRRF sites. A new WRRF offers a more cost effective and technologically efficient means to further improve harbor water quality.

Constructing a new WRRF on Rikers Island is an opportunity to incorporate state-of-the-art treatment and operational excellence into a platform for excellence in water quality well into the future.

Maximize Stormwater Management

EXPANDED CSO CAPTURE AND PROTECTION FROM EXTREME STORMS

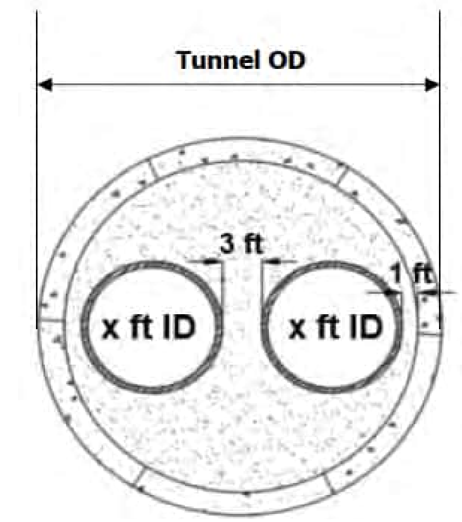
DEP is actively working to reduce CSOs by more than four billion gallons per year by 2045, targeting the delivery of CSO Long Term Control Plans. The CSO Long Term Control Plans require DEP - by law - to implement solutions that reduce the discharges of CSOs throughout New York City. Potential solutions to reducing CSOs include storage tanks, sewer separation, and green infrastructure. In the long term, based on *PlaNYC: Getting Sustainability Done*, DEP will lead coastal flood resilience for New York City and will develop a strategy to end the discharge of most CSOs and polluted stormwater by 2060. In addition, DEP must address the impacts of climate change - sea level rise, storm surge, cloudbursts, and flooding – on the wastewater collection and treatment system.

By incorporating plans for future expansion and treatment facilities on Rikers Island, DEP would have an opportunity to increase treatment capacity, and flood mitigation to the existing sewershed. Furthermore, shifting a large portion of the region's wastewater to a new WRRF on Rikers Island could make space available at the existing WRRF sites for additional stormwater and resiliency uses.

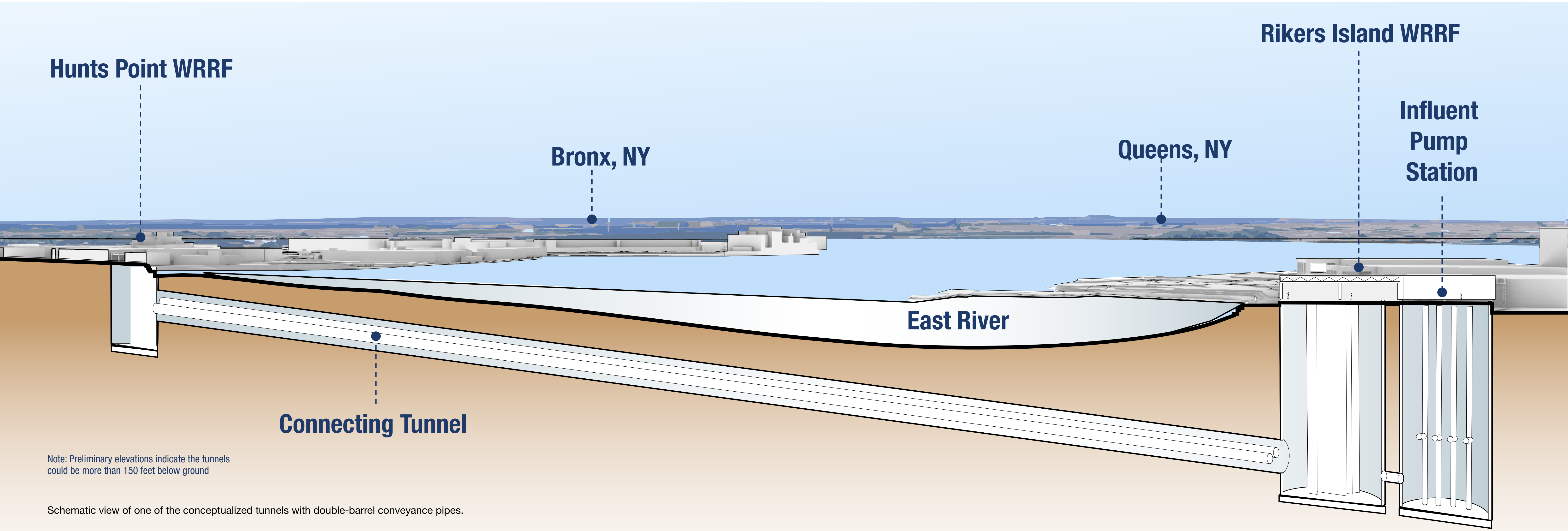
This study sought to conceptualize a better, more holistic way to deliver all of these important requirements in a way that maximizes both effectiveness and return on investment.

CONVEYANCE TUNNELS: DOUBLE-DUTY INFRASTRUCTURE

Constructing a new WRRF on Rikers Island would involve building four new connecting tunnels deep under the Upper East River from each of the existing WRRFs. These tunnels would convey wastewater flows from the existing WRRF locations to the new WRRF on Rikers Island. Each of the four tunnels would contain two fully redundant conveyance pipes, each sized to handle the flow of the connected WRRF. There are many advantages to this approach, including allowance for periodic shutdowns for inspections, cleaning, and maintenance, and additional conveyance and storage of wet weather flow. This concept would add flexibility for future projects aimed at reducing CSOs and neighborhood flooding by increasing underground water storage. Creating a redundant pipe from each existing facility essentially modifies a typical CSO storage tunnel and would allow a new WRRF on Rikers Island to maximize overall wet weather capacity The tunnel size will also be large enough to use the space around the conveyance pipes to run additional utilities to and from the existing WRRF sites and the new WRRF on Rikers Island, such as potable and reclaimed water, steam for district heating, electricity, and gas.



Cross-section view of double barrel tunnel showing outer diameter (OD) and inner diameters (ID).



Schematic view of one of the conceptualized tunnels with double-barrel conveyance pipes.

STORMWATER MANAGEMENT AND CSO REDUCTION

A new WRRF on Rikers Island and its tunnel system would provide opportunities for enhanced CSO capture and stormwater management. As weather patterns continue to change, heavy downpours, also known as cloudbursts, are expected to happen more frequently. These high-intensity storms release an incredible volume of rain in a short period of time, exacerbate the wastewater collection system, and are difficult to manage with traditional infrastructure, causing severe damage. DEP's facilities were not designed for these changing precipitation patterns so these types of storms can overwhelm aging infrastructure.

A new WRRF on Rikers Island would provide a significant opportunity to design new infrastructure that aims to solve stormwater and flooding issues on a grander scale, while eliminating single-use facilities, such as standalone CSO storage tunnels. Expanding the stormwater capture area across the vast region of the Upper East River collection system and conveying the wet weather flows to a new WRRF on Rikers Island would result in larger volumes of water treated and fewer CSOs. This expanded capture, storage, and treatment could also be incorporated into, or supplement, the existing CSO reduction plans being developed such as the Flushing Bay CSO Storage Tunnel project that is currently required in the Long Term Control Plan for Flushing Bay – located in the Upper East River.

Expanding wet weather capture and treatment at a new WRRF on Rikers Island will not be the only method of reducing CSOs and flooding. Additional wet weather facilities are likely required at the existing WRRF sites. Space at the existing WRRF sites would be used to supplement overall capacity, maintain operational flexibility, and protect the public and infrastructure from loss.

RESILIENT WASTEWATER INFRASTRUCTURE

A new WRRF on Rikers Island would be built to protect all the equipment and processes from flooding damage while sustaining effective operations during extreme storm events. Protection from sea level rise would be provided by locating critical facilities above predicted flood levels and proactively designing protection measures before it is built. Creating the same level of protection is extremely difficult at the existing WRRFs.

The ground elevation on Rikers Island varies. The general location of the new WRRF on Rikers Island currently has an elevation ranging from about 20 to 24 feet with some lower elevations near the shoreline. The 100-yr Adjusted Design Flood Elevation in the year 2100 is 24 feet. Because it is a new site, a lot could be achieved compared to what is possible at the existing WRRFs:

- Construction of a wetlands and vegetation buffer on the perimeter of the island to protect against storm surge. Shoreline improvements would also include breakers, revetments and/or bulkheads where/as needed.
- Re-grading of the island so that major roadways and all access into buildings (including below-ground spaces) are located above the Design Flood Elevation.
- Electrical equipment (transformers, generators, etc.) constructed above the Design Flood Elevation.
- Treatment facilities designed at a higher elevation and pumping systems sized so that treated water can flow by gravity out the outfall, even at high tides.
- Stormwater collected at the facility is routed to green infrastructure and away from buildings/entryways.

DEP is investing $1.6 Billion to capture 12 million gallons of CSO in the Gowanus Canal. These are the types of strategies DEP will pursue across New York City to capture and treat more stormwater. (*Courtesy of NYCDEP*)

Produce Renewable Energy

CHARTING A CLEAN ENERGY FUTURE

New York City is committed to achieving a clean energy future and has made significant strides in bringing large-scale renewable energy to the city. However, much more needs to be accomplished to reach clean energy goals. One DEP objective, which is also an initiative of *PlaNYC,* is to maximize climate infrastructure on city-owned property.

The construction of a new WRRF on Rikers Island presents a rare opportunity to intentionally address the new challenges of climate change with proven, state-of-the-art technologies. Furthermore, there are opportunities for energy efficiencies at a new WRRF that would not be possible at the four existing WRRFs.

In addition to energy efficiencies within a new WRRF at Rikers Island, several opportunities exist to maximize the production of green renewable energy.

RENEWABLE ENERGY FROM SOLAR

New York City WRRFs necessarily require significant area for operations, which presents an opportunity for solar arrays to be installed throughout a new WRRF, on roofs, tanks, and other buildings. Energy generated by these solar arrays could be used to power the new WRRF or other facilities. DEP is planning a major installation of a solar array at the Wards Island WRRF and already has a solar array installation at the Port Richmond WRRF.

The solar array at the Port Richmond WRRF on Staten Island has been in operation since 2015. Another more expansive installation is being planned at the Wards Island WRRF, including over process tanks. (*Courtesy of NYCDEP*)

DEP's Gas-to-Grid Project at the Newtown Creek WRRF

Ribbon Cutting for Gas to Grid project at the Newtown Creek WRRF in collaboration with National Grid, June 14, 2023. The project, a first of its kind, is producing a reliable source of clean, renewable energy, reducing the amount of organic waste sent to landfills, and is already improving air quality. The collaborative endeavor has the potential to produce enough renewable energy to heat up to 5,200 homes in Brooklyn and reduce annual greenhouse gas emissions by more than 90,000 metric tons—the equivalent of removing nearly 19,000 cars from the road per year or growing 1.5 million trees for 10 years.

(*Courtesy of NYCDEP*)

(*Courtesy of NYCDEP*)

GREEN RENEWABLE ENERGY FROM BIOGAS

The digesters used by DEP WRRFs to treat biosolids produce green renewable energy. One method of harnessing this energy is with a "gas-to-grid" system which cleans the biogas created by the digesters during the solids digestion process and injects it into the natural gas grid for customers and industry in the area to use. DEP has been cleaning biogas and distributing it to the grid at the Newtown Creek WRRF since 2016 and DEP is working to achieve 100% biogas beneficial use there. A "gas-to-grid" concept was selected for a new WRRF on Rikers Island since it is already used by DEP and has a lot of near term potential to offset natural gas demand. The optimal way to use biogas in the future may change based on renewable energy technology, economics, regulations, or other initiatives. If "gas-to-grid" is no longer a sustainable or viable option when the new WRRF on Rikers Island is being designed and constructed, other options for beneficial use could be evaluated. For example, the biogas may be used in fuel cells, to produce other in-demand bioproducts like readily biodegradable bioplastics, or onsite to heat biosolids treatment processes like the thermal dryers or digesters.

RENEWABLE ENERGY FROM HEAT EXTRACTION

The high-quality effluent from a new WRRF on Rikers Island will have relatively stable temperatures compared to ambient air temperatures, making it an excellent heat sink and source for heating and cooling using a heat pump. This system could be utilized to heat and cool the WRRF buildings using a heat pump. As a future consideration, the recovered heat could be used for district heating for other facilities co-located on the island and for other nearby facilities.

Renewable Energy Study on Rikers Island

Local Law 17 of 2021 - required the Mayor's Office of Long-Term Planning and Sustainability, now the Mayor's Office of Climate and Environmental Justice (MOCEJ), to complete a study that evaluates the feasibility of siting renewable energy infrastructure combined with battery storage on Rikers Island. One of the scenarios included in the energy feasibility study depicts renewable energy infrastructure that can be co-located with a new WRRF on Rikers Island.

Grow the Circular Economy

CLOSING THE LOOP

Circular economies are economic systems that eliminate unnecessary waste and produce goods in a sustainable way. New York City is committed to transforming into a circular economy. To achieve this, a holistic approach should be taken to "close the loop" on waste, energy, and heat—while simultaneously considering how an entire network can become circular.

Elements would be incorporated into a new WRRF on Rikers Island that provide opportunities to grow the circular economy in New York City by expanding the recovery of valuable green resources from wastewater and other waste streams such as food waste and yard waste. This study developed several concepts to achieve circular economy objectives with a new WRRF as the foundation.

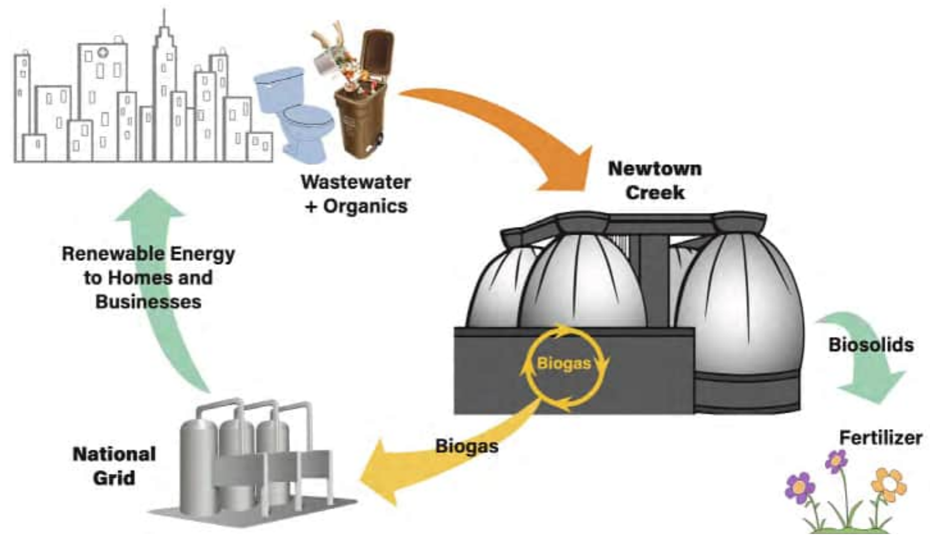


Diagram of the waste to energy process currently in place at the Newtown Creek WRRF. (*Courtesy of NYCDEP*)

ORGANICS PROCESSING

More than one-third of New York City's residential waste comes from organics — materials originating from living sources that are suitable for composting, such as food scraps and yard waste. New York City is making strides to divert these types of organic wastes from landfills and has a plan to implement the nation's largest composting program. A new WRRF at Rikers Island was conceptualized as a major organics outlet that offers two ways to help meet and sustain this goal in a very significant way.

One-third of what New Yorkers throw away is food scraps and yard waste. Instead of being sent to landfills, these organics can be used to create compost and renewable energy – saving money and combatting climate change. *(Courtesy of NYCDEP)*

Organics Co-Digestion

Co-digestion involves adding food waste to the solids that are processed in the digestion phase of the wastewater treatment process. Co-digestion capability is built into the concept for the new WRRF on Rikers Island to easily add a large volume of organic food scraps from New York City's expanding organics collection program. Approximately 420 wet tons per day could be processed in the digesters of a new WRRF. In addition to keeping organics out of landfills, co-digestion increases the biogas that is generated in the digesters, which can provide more green renewable energy for onsite and offsite use.

Composting

In addition to co-digestion, a complementary composting facility could be constructed on Rikers Island adjacent to the new WRRF. This composting facility would replace the New York City Department of Sanitation (DSNY) composting facility currently in operation on Rikers Island. The new compost facility would be significantly expanded from the current one acre operation to 30 acres with the ability to process 500 wet tons per day using technology similar to what DSNY currently uses at other newer compost facilities. Pending future regulation, dried biosolids from the new WRRF could be added to the compost as a nutrient rich enhancement.

BIOSOLIDS PROCESSING AND BENEFICIAL USE

DEP plans to beneficially use 100% of the treated biosolids from all WRRFs by 2030. This goal helps New York City meet goals to divert organics from landfills and acknowledges that treated biosolids are a resource that should not be discarded. The biosolids treatment process selected for a new WRRF on Rikers Island would include thermal hydrolysis followed by anaerobic digestion. Thermal hydrolysis helps produce more biogas – green renewable energy – in the digestion process. Using thermal hydrolysis makes it easier to remove water from biosolids – so they are easier to dry in the next step, which is thermal drying. Thermal drying removes as much water as possible from the biosolids. This reduces the volume – and cost - of biosolids that have to be transported, further reducing truck and ship traffic.

These treatment steps produce an organically nutrient rich "Class A" biosolids product – the highest quality possible – that is ready for a variety of beneficial use options, including land application. It is possible that future regulations will limit land application and landfilling of biosolids. The biosolids treatment process selected for a new WRRF on Rikers Island would offer flexibility to be complemented by other processes, such as pyrolysis or gasification, which are emerging treatment technologies that show promise in the area of PFAS destruction.

BIOGAS UTILIZATION

The digesters used by DEP WRRFs to treat biosolids produce green renewable energy. This energy produced can be harnessed for beneficial use through a "gas-to-grid" system or used onsite for processes like thermal drying of biosolids. It can also be used in fuel cells to produce other in-demand bioproducts like readily biodegradable bioplastics. When organics are added to the digesters for co-digestion even more green renewable energy is produced.

WATER RECLAMATION AND REUSE

Across the United States the value of treated wastewater as a resource is widely recognized and municipalities are finding ways to reclaim and reuse treated water in a wide range of applications such as toilet flushing and irrigation. The membrane bioreactor technology (MBR) selected for the new WRRF would produce high-quality water that offers many opportunities for reuse. Reclaimed water from a new WRRF on Rikers Island could be reused on-site to reduce potable water consumption. As a future consideration, reclaimed water could be distributed to other nearby users, including other facilities co-located on Rikers Island or nearby La Guardia Airport.

GREEN JOBS

The work of DEP is green by nature and everyone who works at DEP has a green job. The technologies selected for a new WRRF on Rikers Island would play an integral role in further growing the circular economy of New York City because they would increase the services provided to expand stormwater management, and renewable energy production. The planning, design, construction, and ongoing operation of a new WRRF on Rikers Island would require a wide range of skills, from science and engineering to construction trades, operations, and maintenance. Supporting New York City's green job economy would be yet another lasting benefit of a new WRRF.

DEP has installed more than 12,000 rain gardens throughout NYC to reduce CSOs, reduce ponding, provide summer shade, and green communities. These features created new green jobs for the City, as DEP hires staff to help maintain them. (*Courtesy of NYCDEP*)

Estimated Cost Requirements and Implementation Horizon

ACTIVITY	START YEAR	END YEAR	2025	2035	2045	2055	2065
Master Planning, Design, Site Prep and Permitting	2025	2035					
Rikers Island WRRF Site Construction	2035	2039					
Rikers Island WRRF Phase 1 Construction	2039	2045					
Tunnel Construction: WRRF 1 to Rikers Island	2040	2045					
WRRF 1 Flow Diverted to Rikers Island WRRF		2045					
Rikers Island WRRF Phase 2 Construction	2046	2050					
Tunnel Construction: WRRF 2 to Rikers Island	2044	2050					
WRRF 2 Flow Diverted to Rikers Island WRRF		2050					
Rikers Island WRRF Phase 3 Construction	2051	2055					
Tunnel Construction: WRRF 3 to Rikers Island	2050	2055					
WRRF 3 Flow Diverted to Rikers Island WRRF		2055					
Rikers Island WRRF Phase 4 Construction	2056	2060					
Tunnel Construction: WRRF 4 to Rikers Island	2055	2060					
WRRF 4 Flow Diverted to Rikers Island WRRF		2060					

A conceptual implementation timeline for a new WRRF on Rikers Island includes phased connection of each of the four WRRFs.

CONCEPTUAL COST ESTIMATE

The estimated cost of the conceptualized WRRF on Rikers Island presented in this report is $34 billion.

This cost estimate is discounted to present dollar value and is not representative of the anticipated cost at the time of construction - it is intended for comparative purposes only. This estimate is very preliminary and requires further development. This estimate includes all infrastructure needed for wastewater treatment, resource recovery, emergency electricity generation, geotechnical site requirements, an effluent outfall as well as support facilities like laboratory facilities, administration structures, training rooms, a composting facility, and a marine transfer station.

This estimate also includes the significant cost of the tunneling and tunnel infrastructure needed to convey the flow from the existing four WRRFs to the new WRRF on Rikers Island. These tunnels could be designed to help capture more CSO flow thus offsetting other planned investments by DEP to capture and treat more stormwater.

In addition to the costs associated with the new WRRF, wastewater must continue to be treated effectively while the new WRRF is being built. This necessitates continued investment in the four existing WRRFs during the planning, design, construction, and phasing period for the new WRRF. The cost estimate includes the improvements that will be required at the existing WRRFs to maintain treatment until the flow is transferred to the new WRRF on Rikers Island.

While the estimated cost is significant, DEP will need to upgrade for the future whether a new WRRF is built on Rikers Island or the four WRRFs continue to operate at the existing sites.

The estimated upfront cost of the new WRRF on Rikers is potentially equal to the estimated cost to rehabilitate and upgrade the four existing WRRFs.

The significant financial benefit of a new WRRF on Rikers Island comes into focus when considering long term operation and maintenance costs and the cost of future replacement work. These are the required annual costs and long term capital upgrade costs to keep a WRRF running once it is built – also known as the lifecycle cost. The new WRRF on Rikers Island would result in lifecycle cost savings of approximately $10 billion.

Additionally, the cost of the new WRRF does not account for the savings realized from non-monetized benefits, including reduced impacts to the public and the environment, increased energy efficiencies, and more resilient performance and service.

CONCEPTUAL SCHEDULE

The conceptual schedule for a new WRRF on Rikers Island assumes that ten years will be required for additional planning activities and subsequent tunneling design, WRRF design, and environmental impact assessments. Site preparation and construction of the new WRRF would start in 2035. Startup of the initial phase of the new WRRF is estimated in 2045 with complete implementation over 40 years.

DEP would start work on Rikers Island to prepare to build the new WRRF in 2035 with startup of the new WRRF in 2045.

Given the magnitude and complexity of New York City's clean water programs, implementation can span decades. WRRFs the size of the new WRRF on Rikers Island exist around the globe. These WRRFs are a testament to the significant implementation timeline required for planning, designing, constructing, and starting up operations of a new WRRF.

An implementation horizon of 40 years also considers the phasing of tunnels and diverting flow from the existing WRRF sites to the new WRRF on Rikers Island.

Future studies are required to determine the optimal phasing of flow from the existing WRRFs to the new WRRF on Rikers Island. Factors that would affect the sequencing include: treatment constraints, regulatory performance, estimated useful life of equipment, and funding. Opportunities for schedule acceleration should also be evaluated during subsequent planning and design phases.

Funding Major Public Works Projects in NYC

A new WRRF on Rikers Island would require investment over several decades. This can be compared to other planned projects such as the Hudson Tunnel Project and the JFK Airport Redevelopment project – both valued at $19 billion.

Estimated Space Requirements

Rikers Island provides an opportunity to capitalize on a large footprint to design the optimal treatment processes and layout for reducing energy use and operational and maintenance costs.

The area of a new WRRF on Rikers Island is estimated at 245 acres, or approximately 60% of Rikers Island.

Within the 245 acres, DEP could operate a modern WRRF reserving space for unknown treatment requirements that inevitably arise. The additional space also facilitates co-location of other uses such as composting, green renewable energy, or other New York City operations.

The new WRRF on Rikers Island was sited on the western portion of Rikers Island to keep taller infrastructure and buildings out of the flight zone of aircraft from nearby LaGuardia Airport. This area also includes the original geological extent of the island, which is more structurally stable, which would reduce construction costs for complex foundations.

One of the biggest challenges faced by DEP is the availability of property for critical public health infrastructure to meet future regulatory requirements and to support citywide goals to address the impacts of climate change.

At the existing WRRFs, DEP would utilize approximately 25% of each site for shaft maintenance and facilities required for the management wastewater and stormwater to support the new WRRF on Rikers Island. The remainder of the existing WRRF sites would be used to meet goals for ending the discharge of CSOs and implementing a multi-layered strategy for flood resilience – both of which are so important to keeping New Yorkers safe and making strides to improving the water quality. At this stage in the planning of a new WRRF, DEP would not relinquish existing sites for other uses.

This study used approximations to estimate cost, schedule and space requirements for one conceptualized WRRF on Rikers Island. Assumptions about buildable acreage must be revisited during further planning and design. Alternative approaches for constructing wastewater treatment processes on Rikers Island will have different cost, schedule and space requirements.

Building a new WRRF on Rikers Island creates another potential opportunity - utilizing the remainder of the existing WRRF properties for new uses, including brand new CSO reduction and climate change infrastructure to serve New York City.

Aerial view of the estimated area of a new WRRF on Rikers Island. (*Courtesy of Esri*)

The Future of the Existing WRRF Sites

The future of the existing sites will require further exploration. The existing WRRF sites are critical for repurposed and enhanced uses. Depending on the design of the new WRRF on Rikers Island, it may be necessary to use these properties to augment the treatment process for:

- Enhanced Pre-treatment Facilities for the new WRRF
- Additional Wet Weather Treatment
- Floodwater Management, including Citywide Drainage Support

Building Redundancy into One WRRF

All WRRFs are required to have redundancy to maintain operations. If one treatment unit or process fails, alternative units are available to continue treating wastewater. When considering the design and layout of a new WRRF, DEP would take into consideration required redundancy measures along with current standard practices for treatment plant design.

Sufficient redundancy will be built into the facility to reduce the risk of service disruptions and ensure continuous wastewater treatment even during maintenance or unforeseen events.

FLEXIBILITY IN OPERATIONS

A new WRRF on Rikers Island offers greater flexibility in managing wastewater treatment processes. It is easier to adjust treatment capacity based on fluctuating demands or changes in regulatory requirements at one facility than across four facilities. The flexibility to adapt and optimize operations could result in improved overall performance and responsiveness to changing conditions.

ECONOMIES OF SCALE

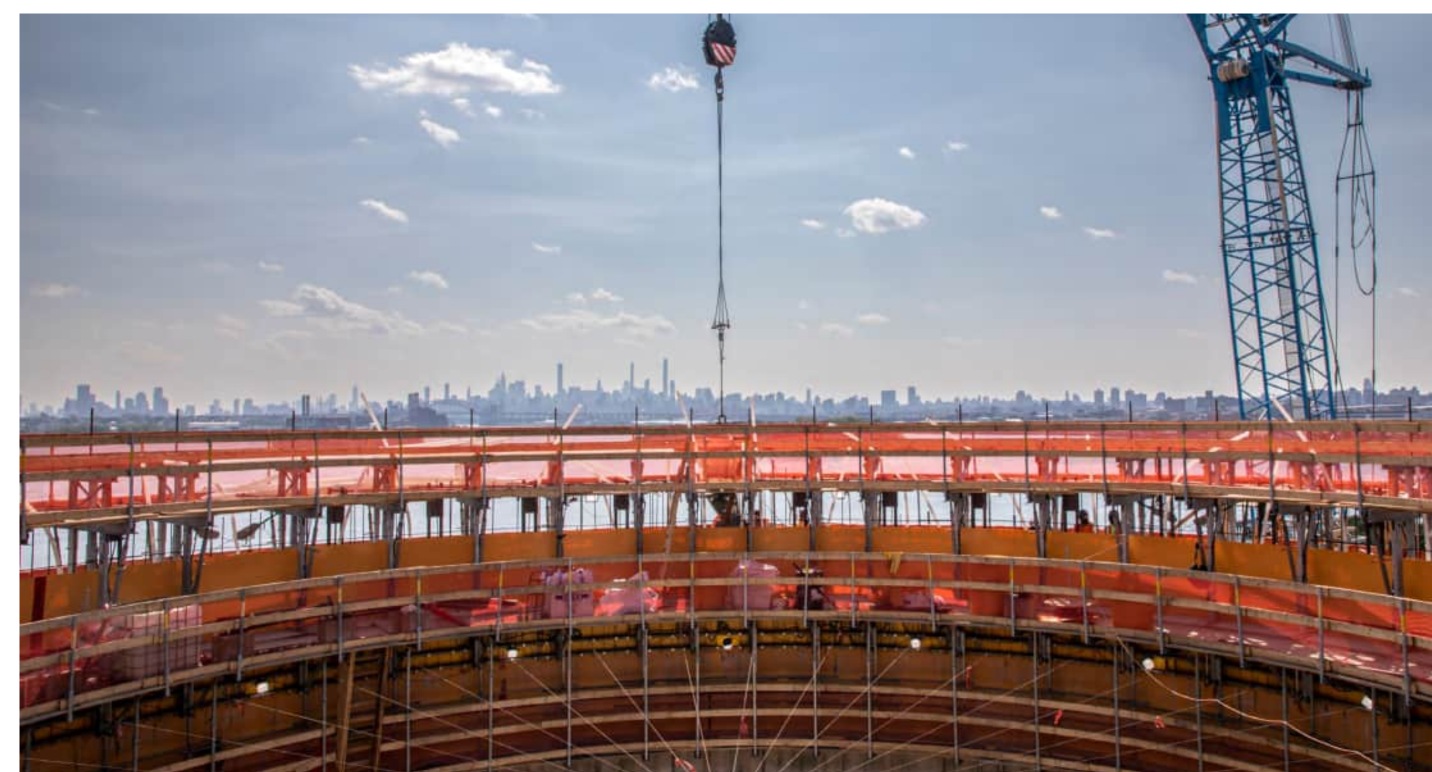
A new WRRF on Rikers Island could lead to economies of scale. Large WRRFs can benefit from reduced unit costs, because they take advantage of bulk receiving to a single location, streamlined operations, and optimized resource utilization. The cost savings could be reinvested in infrastructure upgrades, advanced treatment technologies, or other WRRFs in the system.

IMPROVED MAINTENANCE AND UPGRADES

A new WRRF on Rikers Island would allow for centralized maintenance and upgrades. Instead of managing multiple facilities separately, maintenance efforts could be focused on a single location. This simplifies scheduling, reduces downtime, and enables more efficient implementation of improvements and technological advancements.

EFFICIENT RESOURCE ALLOCATION

A new WRRF on Rikers Island would allow for better allocation of resources, such as equipment, personnel, and maintenance activities. Instead of duplicating these resources across multiple WRRFs, they could be concentrated in a single facility. This could lead to improved operational efficiency.



New solids treatment is being constructed at the Hunts Point WRRF that is designed for the future and enhanced resource recovery. (*Courtesy of NYCDEP*)

Comparing a New WRRF to the Existing WRRFs

Building a new WRRF on Rikers Island and continuing to operate the four existing WRRFs would require the same financial commitment. Beyond the upfront cost, however, there are few similarities between the two alternatives. The table on the opposite page illustrates the magnitude of the benefits a new WRRF may potentially offer.

Aerial view rendering of the new WRRF on Rikers Island.

Being a Good Neighbor

DEP is committed to the positive integration of future infrastructure projects into communities, which involves creating greater connectivity to local communities and, in general, "being a good neighbor" by helping to improve the lives of New Yorkers. A new WRRF on Rikers Island would deliver a number of these benefits, including allowing for fewer trucks in the neighborhoods of the existing four WRRFs, resulting in less traffic and exhaust. Similarly, upgraded treatment infrastructure at a new WRRF would reduce odors in surrounding communities. DEP would also plan to maintain the existing WRRF properties to plan for expanded services for New Yorkers like CSO capture and flood management.

Feature	Existing Upper East River WRRFs		New WRRF on Rikers Island	
Years of Operation	🔴	72-87 Years	🟢	Brand new
Space Constraints	🔴	Almost completely built out	🟢	Sufficient property for known needs and reserve
Neighborhood Impacts	🔴	The four WRRFs operate in densely populated residential and industrial communities or parkland – including Environmental Justice areas	🟢	The new WRRF would benefit from the relative isolation of Rikers Island and would remove significant wastewater operations from the neighborhoods of the existing WRRFs
Truck Traffic	🔴	Trucks necessary for transporting biosolids and trash and for delivery of equipment, supplies and chemicals	🟢	Reduced truck traffic due to reliance on marine transport as well as isolation from neighborhoods and parkland
Odor Control	🟡	Odor control systems in place but aging and proximity to neighborhoods and parkland increases potential	🟢	Reduced potential due to relative isolation from sensitive receptors and state of the art odor control technology
Solar Energy	🟡	Small solar installation planned at the Wards Island WRRF	🟢	Solar would be installed over all process tanks and roofing
Biogas Utilization	🟡	Some biogas utilization at some WRRFs of varying degrees	🟢	Biogas utilization system will be designed into the new WRRF
Stormwater Management	🔴	Limited opportunities to modify the current collection system for expanded stormwater management beyond CSO storage tanks	🟢	Multitasking infrastructure and a new build allows for increased stormwater capture upstream in the collections system and the use of existing WRRF sites for expanded flood protection
CSO Reduction	🟡	20 Million Gallon CSO Storage Tank planned to connect to the Bowery Bay WRRF; two other CSO storage tanks in operation that connect to the Tallman Island WRRF	🟢	CSO capture and storage solution could be integrated into the design of the tunnel system and/or could reduce the size of a storage tunnel with multitasking infrastructure
Resiliency	🟡	Some protective measures installed post-Superstorm Sandy – system is still vulnerable	🟢	Resiliency would be part of the upfront design accounting for flood elevations and protection of below grade assets
Organics Co-Digestion	🟡	Co-digestion being evaluated at the Hunts Point WRRF	🟢	Co-digestion fully integrated into the design
Composting	🔴	None	🟢	Co-location of 30-acre compost facility
Biosolids Quality	🟡	Targeting Class B	🟢	Class A – highest quality
Digital Transformation	🔴	Limited and decentralized digital infrastructure	🟢	Advanced technological capability built in - ranging from asset management to remote monitoring and automation

Legend
🟢 Maximized benefit 🟡 Moderate benefit 🔴 Limited benefit

CONCLUSION

Looking Ahead

The New York City DEP has an extremely important mission to protect public health and the environment. DEP delivers this mission in part by managing wastewater and stormwater for all New Yorkers. Wastewater treatment is a universal need, cannot be compromised, and is critical to New York City's continued population growth and development.

The 14 WRRFs that operate across New York City are aging and challenged in their existing sites, which cannot be expanded to accommodate the technology that will be needed to meet future regulations and goals to combat climate change. The four WRRFs in the study area – Hunts Point, Tallman Island, Bowery Bay, and Wards Island – all face these challenges.

This study confirmed that building a new state-of-the-art WRRF on Rikers Island is feasible. More than that, it is a potentially significant cost saving investment and a viable long-term strategy for DEP's treatment system in the Upper East River presenting advantages far beyond water quality.

Relative to the four existing WRRFs, a new WRRF on Rikers Island would improve environmental quality, produce more renewable energy, maximize stormwater management, and grow the circular economy. It would also reduce the impact of DEP operations in four different areas of New York City.

Regardless of whether the four WRRFs continue to operate in their current locations or a new WRRF is built on Rikers Island, a significant investment in New York City's clean water future is inescapable. Over the long term, however, a new WRRF could achieve significant public benefits and financial savings by reducing operation and maintenance costs, reducing environmental impacts and waste, increasing efficiency, and better protecting assets.

There is a lot more work to do to progress the possibility of a new WRRF on Rikers Island. This feasibility study is a first step.

Several years worth of planning, engineering, and cost estimating is required to advance a new WRRF and tunneling concepts like those presented in this study to determine the optimal design and construction phasing. Public works projects of this magnitude require careful planning and design – over a decade more of work is needed to complete these critical activities.

WRRFs began operating in New York City over a century ago. Building a new state-of-the-art WRRF on Rikers Island represents a highly promising opportunity for DEP to ensure the next century of wastewater treatment and to continue to fulfill its legacy of ambitious infrastructure planning to continue delivery of the highest quality services for all who live, work, and play in New York City.

Rendered view of DEP staff looking out at the New York City skyline from Rikers Island

Glossary of Terms

Adsorption The adhesion of molecules of gas, liquid, or dissolved solids to a surface.

Adsorption Chillers Any device designed to cool interior spaces through adsorption. Instead of using large amounts of electricity, the cooling process is an adsorption chiller is driven by the evaporation and condensation of water.

Aeration Process that promotes biological degradation of organic matter in water. The process may be passive (as when waste is exposed to air) or active (as when a mixing or bubbling device introduces the air)

Ambient Air Any confined portion of the atmosphere; open air; surrounding air.

Biogas Gas resulting from the decomposition of organic matter under anaerobic conditions. The principal constituents are methane and carbon dioxide.

Biosolids Nutrient-rich organic materials resulting from the treatment of sewage in a treatment facility. When treated and processed, these residuals can be recycled and applied as fertilizer to improve and maintain productive soils and stimulate plant growth.

Capital Cost The total investment needed to complete a project and bring it to operable status.

Carbon Footprint The total amount of greenhouse gases that are emitted into the atmosphere each year by a person, family, building, organization, or company.

Carbon Neutrality A state in which the same amount of carbon dioxide is released into the atmosphere as is removed by various means.

Carbon Sequestration Both natural and deliberate processes by which carbon dioxide is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils, and sediment), and geologic formations.

Circular Economy An economic system that minimizes waste and maximizes resource efficiency and reuse.

Class A Biosolids Biosolids treated to reduce the presence of pathogens to below detectable levels and can be used without any pathogen-related restrictions at the application site.

Clean Energy Energy derived from renewable, zero-emission fuel sources.

Climate Change Climate change refers to the buildup of man-made gases in the atmosphere that trap the sun's heat, causing changes in weather patterns on a global scale. The effects include changes in rainfall patterns, sea level rise, potential droughts, habitat loss, and heat stress.

Climate Infrastructure The infrastructure and systems that are planned, implemented, and managed in a way that prepares for and adapts to changing climate conditions.

Cloudburst A extreme amount of rain in a short period of time, often over a small geographic area.

Coastal Flood Resilience The ability of coastal communities to bounce back after change or adversity. Resilient coastal infrastructure such as seawalls, revetments, beach nourishment or dune restoration within an environment can be introduced with the intent of reducing damage to a natural or human community.

Co-Digestion The process of adding food waste to the anaerobic digestion (sludge digestion) phase of wastewater treatment to produce biogas, compost, and other soil amendments.

Combined Sewer Overflow A discharge of untreated wastewater from a combined sewer system at a point prior to the headworks of a publicly owned treatment works. Combined sewer overflows generally occur during wet weather (rainfall or snowmelt). During periods of wet weather, these systems become overloaded, bypass treatment works, and discharge directly to receiving waters.

Combined Sewer System A wastewater collection system that conveys sanitary wastewaters (domestic, commercial and industrial wastewaters) and stormwater through a single pipe to a publicly owned treatment works for treatment before discharge to surface waters.

Composting The controlled biological decomposition of organic material in the presence of air. Controlled methods of composting include mechanical mixing and aerating, ventilating the materials by dropping them through a vertical series of aerated chambers, or placing the compost in piles out in the open air and mixing it or turning it periodically.

Dewatering Removing or separating a portion of the water in a sludge or slurry to dry the sludge so it can be handled and disposed of.

Digester A tank that aids in the decomposition of natural or organic waste.

Digestion The biological decomposition of organic matter in sludge by anaerobic or aerobic microorganisms.

Disinfection The process designed to kill most microorganisms in water, including essentially all pathogenic (disease-causing) bacteria. There are several ways to disinfect, with chlorine being most frequently used in water treatment.

District Heating and Cooling Systems characterized by one or more central plants producing hot water, steam, and/or chilled water, which then flows through a network of insulated pipes to provide hot water, space heating, and/or air conditioning for nearby buildings.

Environmental Justice The fair treatment and meaningful involvement of all people in the development, implementation, and enforcement of environmental laws, regulations, and policies.

Effluent Partially or completely treated wastewater flowing out of a basin, treatment process or treatment plant.

Effluent Outfall The outlet or structure through which treated effluent is finally discharged to a receiving water body.

Emergency Electricity Generation A secondary source of mechanical or electrical power whenever the primary energy supply is disrupted or discontinued during power outages or natural disasters that are beyond the control of the owner or operator of a facility.

Energy Grid An interconnected system that maintains an instantaneous balance between supply and demand (generation and load) while moving electricity from generation source to customer.

Gas-to-Grid Operational system that separates pure methane from the other components of biogas, creating a product called Renewable Natural Gas (RNG) which is then injected into an energy grid's distribution system

Gasification Conversion of solid material such as coal into a gas for use as a fuel.

Geotechnical Site Requirements Considers the existing subsurface conditions, and their associated impacts on structure foundations and necessary ground improvements.

Grit The heavy inorganic material present in wastewater, such as sand, gravel and cinders.

Grit Chamber A chamber or tank in which primary influent flow is slowed down causing pebbles, sand, seeds, and other heavy particles to drop to the bottom.

Grit Removal Wastewater flow is slowed down causing smaller debris like pebbles, sand, and other heavy particles to drop to the bottom and be disposed of.

Green Infrastructure An array of practices that use or mimic natural systems to manage urban stormwater runoff. Water is either directed to engineered systems for infiltration or detained for longer periods before it enters the sewer system.

Headworks The initial process in wastewater treatment in which large debris is removed from the wastewater.

Influent Wastewater flowing into a basin, treatment process or treatment plant.

Influent Pump Station Wastewater is pumped from the deeper tunnels underground through the influent screens to the surface level of the facility.

Lifecycle Cost An economic measurement used to determine the total cost of an investment project or activity over its lifetime.

Long-Term Control Plan An extensive evaluation of a municipal collection system that evaluates alternatives and recommends a series of improvement projects that, when implemented, will reduce or eliminate CSO discharges and ensure that any remaining CSO discharges do not cause or contribute to violations of water quality standards.

Membrane Bioreactor A process which combines a ultrafiltration membrane unit with a suspended growth bioreactor.

Membrane Filtration Treated water is separated from the beneficial microorganisms that grow in the aeration process using membrane bioreactor (MBR) technology that allows only the cleanest water to pass through.

Microorganisms Microscopic animals and plants of simple cell structure that feed on the wastes in wastewater. This feeding removes the organic pollutants in wastewater.

Mitigation An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases.

Odor Control Wastewater treatment processes are ventilated, and the foul-smelling air is collected and treated in a filter.

PFAS Group of man-made chemicals. PFAS have been manufactured and used in a variety of industries around the globe, including in the United States since the 1940s. PFAS chemicals are very persistent in the environment and in the human body – meaning they don't break down and they can accumulate over time.

Potable Water Raw or treated water that is considered safe and satisfactory for drinking and cooking.

Preliminary Treatment The removal of rocks, rags, sticks and similar materials which may hinder the operation of a treatment plant. Preliminary treatment is accomplished by using equipment such as bar screens and grit removal systems.

Primary Treatment A wastewater treatment process using physical methods to remove most of the organic and inorganic solids in wastewater that settle or float.

Pyrolysis Decomposition of a chemical by extreme heat.

Reclaimed Water Treated wastewater that can be used for beneficial purposes, such as irrigating certain plants.

Screening Shaft Wastewater entering the facility passes through screens to remove larger debris like leaves, twigs, and litter.

Sea Level Rise The increase in ocean water levels at a specific location, taking into account both global sea level rise and local factors, such as local land subsidence and uplift.

Glossary of Terms

Secondary Treatment A wastewater treatment process using enhanced, natural biological methods to convert dissolved or suspended materials into a form more readily separated from the water being treated.

Sludge The accumulated, settled, organic solids which must be separated from the liquid portion of wastewater during the treatment process.

Storm Surge An abnormal rise of water generated by a storm, over and above predicted astronomical tides.

Stormwater The portion of precipitation that does not naturally percolate into the ground or evaporate but flows overland.

Stormwater Management Communities can manage stormwater using structural and non-structural best-management practices, including green infrastructure.

Supplemental Carbon Glycerol, an environmentally friendly product, is added to the aeration process to feed the beneficial microorganisms and enhance the nitrogen removal process.

Thermal Hydrolysis Process of applying heat and pressure to decompose organic matter in sludge into smaller molecules that are more easily digestible by the microorganisms in the digestion process.

Ultra-Fine Screening Small particles such as hair, fibers, and stringy material are screened and removed.

UV Disinfection Treated water is disinfected with Ultraviolet (UV) light to remove any disease-causing microorganisms.

Water Reclamation The treatment of wastewater to ensure it is suitable for safe reuse.

Wastewater The used water and solids from a community that flow to a treatment plant.

Wastewater Treatment Chemical, biological, and mechanical procedures applied to industrial and municipal discharge contaminants.

Wet Weather Flow Dry weather flow combined with stormwater introduced into a combined sewer, and dry weather flow combined with inflow in a separate sewer.

Abbreviations

BGD	Billion Gallons per Day
CSO	Combined Sewer Overflow
DEP	New York City Department of Environmental Protection
DSNY	New York City Department of Sanitation
ID	Inner Diameter
MBR	Membrane Bio-Reactor
MGD	Million Gallons per Day
MOCEJ	Mayor’s Office of Climate and Environmental Justice
NYC	New York City
OD	Outer Diameter
PFAS	Polyfluoroalkyl Substances
UV	Ultraviolet
WRRF	Wastewater Resource Recovery Facility

References

Aggarwala, Rohit. "NYC Climate Chief Says City Committed to Sustainability." Interview by Spectrum News NY1, September 18, 2023.

"Alley Creek Wetland." NYC Water Flickr, August 26, 2022. https://flickr.com/photos/nycwater/52610824242/in/album-72177720305048079/

"Construction progress of the new Hunts Point Digesters." NYC Water Flickr, August 9, 2023. https://flickr.com/photos/nycwater/53154282672/in/album-72177720305911055/

Esri. "World Imagery" [Tile Layer]. Scale Not Given. "World Imagery". December 12, 2009. https://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9. (January 18, 2024)

Gerba, Charles P., and Ian L. Pepper. "Wastewater Treatment and Biosolids Reuse." *Environmental Microbiology* (2009): 503-530. doi:10.1016/B978-0-12-370519-8.00024-9. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7171382/

"Gowanus Canal Worksite." NYC Water Flickr, January 17, 2024. https://flickr.com/photos/nycwater/53519664975/in/album-72177720314183097/

Hosansky, David. "adsorption chiller". *Encyclopedia Britannica, September 9, 2014.* https://www.britannica.com/topic/adsorption-chiller

"Humpback Whale in NY Harbor." NYC Water Flickr, November 17, 2017. https://flic.kr/p/21xK5sC

"Kayaking at Brooklyn Bridge Park, Pier 4." NYC Water Flickr, August 28, 2023. https://flic.kr/p/2oYAZAY

New York State Department of Environmental Conservation. *Combined Sewer Overflow (CSO).* https://www.dec.ny.gov/environmental-protection/water/water-quality/combined-sewer-overflow#:~:text=The%20USEPA%20CSO%20Control%20Policy%20required%20each%20CSO%20community%20to,discharges%20do%20not%20cause%20or

New York City Department of Environmental Protection (DEP). September 16, 2022. *2019-2021 Harbor Survey Report.* https://storymaps.arcgis.com/stories/79dd5df97d794d27b6fb9d76e1937bf1

New York City Department of Environmental Protection. September 2022. Bowery Bay WRRF aerial image.

New York City Department of Environmental Protection. July 2023. *Clarifiers.*

New York City Department of Environmental Protection. *Combined Sewer Overflows.* https://www.nyc.gov/site/dep/water/combined-sewer-overflows.page

New York City Department of Environmental Protection. December 2023. *DSNY Curbside Compositing Bin.*

New York City Department of Environmental Protection. July 2023. *Final Settling Tank.*

New York City Department of Environmental Protection. *Grease Glossary*. https://www.nyc.gov/assets/dep/downloads/pdf/environment/education/sewers-glossary.pdf

New York City Department of Environmental Protection. September 2022. Hunts Point WRRF aerial image.

New York City Department of Environmental Protection. February 2024. Newtown Creek WRRF.

New York City Department of Environmental Protection. 2023. *NYC DEP Beneficial Reuse of Wastewater Resource Recovery Facility Biogas*. https://www.nyc.gov/assets/dep/downloads/pdf/about/bids-and-proposals/rfei-beneficial-reuse-of-wastewater-resource-recovery-facility-biogas.pdf

New York City Department of Environmental Protection. 2013. *NYC Wastewater Resiliency Plan Climate Risk and Adaptation Study.* https://www1.nyc.gov/assets/dep/downloads/pdf/climate-*resiliency/climate-plan-single-page.pdf*

New York City Department of Environmental Protection. September 2022. Tallman Island WRRF aerial image.

New York City Department of Environmental Protection. September 2022. Wards Island WRRF aerial image.

New York City Department of Environmental Protection. *Wastewater Treatment.* https://www.nyc.gov/assets/dep/downloads/pdf/water/wastewater/wastewater-treatment-process.pdf

New York City Department of Environmental Protection. June 23, 2023. *Weekly Pipeline.* https://www.nyc.gov/assets/dep/downloads/pdf/about/weekly-pipeline/14702-pipeline.pdf

New York City Mayor's Office of Climate & Environmental Justice. April 2023. *PlaNYC: Getting Sustainability Done.* https://climate.cityofnewyork.us/wp-content/uploads/2023/06/PlaNYC-2023-Full-Report.pdf

New York City Mayor's Office of Resiliency. 2020. *Climate Resiliency Design Guidelines. Version 4.0.* https://climate.cityofnewyork.us/initiatives/climate-resiliency-design-guidelines/.

"Rain Garden Maintenance." NYC Water Flickr, May 17, 2019. *https://www.flickr.com/photos/nycwater/47080618474*

"Renewable Energy-Circular Economy." NYC Water Flickr, June 14, 2023. https://flickr.com/photos/nycwater/52974934598/in/album-72177720309052140/

"Ribbon Cutting for Gas to Grid Project at Newtown Creek." NYC Water Flickr, June 14, 2023. https://flic.kr/p/2oHewVD

"Rikers WRRF Consolidation Study – DEP Wastewater 101 Session." *YouTube, uploaded by NYC Water, September 13, 2022.* https://www.youtube.com/watch?v=vK_WbwqCrIQ

"Solar Panels at Port Richmond WRRF." NYC Water Flickr, March 4, 2020. https://flic.kr/p/2iAHbc8

"Statue of Liberty with Steel Liners." NYC Water Flickr, June 13, 2017. https://flickr.com/photos/nycwater/35021168260/

The City of New York. *NYCityMap*. 2023. http://maps.nyc.gov/doitt/nycitymap/

The Organisation for Economic Co-operation and Development (OECD). 2018. *Climate-Resilient Infrastructure*. https://www.oecd.org/environment/cc/policy-perspectives-climate-resilient-infrastructure.pdf

"Tour of the Hunts Point digesters construction site with BEDC" NYC Water Flickr, October 3, 2023. https://flickr.com/photos/nycwater/53249342105/in/album-72177720305911055/

United States Department of Commerce. 2003. *Guide to Computing and Reporting the Life Cycle Cost of Environmental Management Projects.* https://www.govinfo.gov/content/pkg/GOVPUB-C13-92fc4d76815457fe8926443a2b9d1a71/pdf/GOVPUB-C13-92fc4d76815457fe8926443a2b9d1a71.pdf

United States Department of Energy. 2020. *Combined Heat and Power Technology Fact Sheet Series.* https://www.energy.gov/eere/amo/articles/combined-heat-and-power-technology-fact-sheet-series-district-energy#:~:text=District%20energy%20systems%20are%20characterized,condi-%20tioning%20for%20nearby%20buildings.

United States Environmental Protection Agency. March 2023. *Regulatory and Guidance Information by Topic: Water.* https://www.epa.gov/regulatory-information-topic/regulatory-and-guidance-information-topic-water

United States Environmental Protection Agency. *Renewable Natural Gas.* https://www.epa.gov/lmop/renewable-natural-gas

United States Environmental Protection Agency. *Terminology Services (TS).* https://sor.epa.gov/sor_internet/registry/termreg/searchandretrieve/termsandacronyms/search.do

United States Environmental Protection Agency. September 2007. *Wastewater Management Fact Sheet*. https://www.epa.gov/sites/default/files/2019-08/documents/membrane_bioreactor_fact_sheet_p100il7g.pdf

"Water pipe inspection at Shaft 4" NYC Water Flickr, February 10, 2023. https://flickr.com/photos/nycwater/52681259550/in/album-72177720305911055/