OPPORTUNITIES AND CHALLENGES FOR WATER REUSE POLICY IN NEW YORK CITY

APPLYING LESSONS LEARNED FROM THE US AND BEYOND

WORKSHOP IN APPLIED EARTH SYSTEMS MANAGEMENT | SPRING 2020

COLUMBIA | SIPA
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NYC Environmental Protection

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Applying Lessons Learned from the US and Beyond

Columbia University | School of International and Public Affairs | The Earth Institute
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The Workshop Team would like to thank Alan Cohn, the Managing Director of the Integrated Water Management office at NYC DEP for the opportunity to work on such a cutting-edge issue such as water reuse. We look forward to applying the skills we have learned through this process. The Workshop Team would also like to thank Erin Morey, Director of Demand Management and Resilience Policy and Hannah Doherty, Policy Analyst at NYC DEP for their knowledge and advice that helped guide this report. The Workshop Team would also like to thank all the experts we had the pleasure of interviewing in this process. Last, but certainly not least, we want to thank our faculty advisor, Dr. Nancy Degnan, for all her support throughout the semester, especially during these very unique times.

TABLE OF CONTENTS

ACRONYMS

CSO	Combined Sewer Overflows
DNW	Decentralized Non-Potable Water
GWRS	Groundwater Replenishment System
MGD	Million Gallons of Water per Day
NSU	Natural Systems Utilities
NYC	New York City
NYC DOB	New York City Department of Buildings
NYC DEP	New York City Department of Environmental Protection
NYC DOH	New York City Department of Health and Mental Hygiene
NYS	New York State
OCSD	Orange County Sanitation District
OWD	Orange County Water District
POE	Point-of-Entry
POE	Point-of-Use
RME	Response Management Entity
ROI	Return on Investment
SFDBI-PID	San Francisco Department of Building Inspection-Plumbing Inspection Division
SFDPH-EH	San Francisco Department of Public Health-Environmental Health
SFPUC	San Francisco Public Utilities Commission
SFPW	San Francisco Public Works
TAC	Texas Administrative Code
US EPA	United States Environmental Protection Agency

WORKSHOP GRADUATE COURSE IN BRIEF

This report describes the findings of a research team in its investigation of water reuse for New York City as part of a graduate capstone course: The Workshop in Applied Earth Systems Policy Analysis. The Workshop fulfills core requirements of the MPA degree in Environmental Science and Policy Program (MPA ESP) based at the Earth Institute and the School of International and Public Affairs, Columbia University.

In the Workshop, advanced graduate students – project teams -- undertake analytic projects for real-world clients in government and non-profit organizations. The teams engage in intensive research of the literature, conduct expert interviews, and review case studies to produce presentations and reports analyzing major environmental policies or problems faced by the client. A faculty member advises with the team through the Workshop process.

For this report on water reuse in New York City, the client is the New York City Department of Environmental Protection.

The goal of the MPA ESP Program is to educate and train the next generation of environmental policy professionals and sustainability advocates. Completed in the final semester, the authors of the following report have graduated from the university to work in an array of sustainability and environmental policy fields.

For a full list of Workshop team-member names and contact information, please see Appendix A.

EXECUTIVE SUMMARY

The New York City Department of Environmental Protection (NYC DEP) manages the New York City (NYC) quality of the surface water supply through collection and wastewater treatment. The mission of NYC DEP is:

> *"To enrich the environment and protect public health for all New Yorkers by providing high quality drinking water, managing wastewater and stormwater, and reducing air, noise, and hazardous materials pollution" (NYC DEP, 2020a).*

As the entity in charge of managing water supply, the NYC DEP seeks to promote water conservation, and serves both the City and upstate communities in Ulster, Orange, Putnam and Westchester Counties (NYS DEC, n.d.) NYC DEP is likewise focused on promoting healthy waterways, reinforcing infrastructure for resilience, and investing in major capital upgrades to improve harbor water quality. Investing in major capital not only improves harbor water quality, but also reinforces resilience and enhances recreational opportunities as a result.

From January through May 2020, a team of graduate students from the Environmental Science and Policy MPA Program, a joint program of the School of International and Public Affairs and the Earth Institute, Columbia University, undertook a project on behalf of NYC DEP's Integrated Water Management office. Integrated Water Management is a framework used for managing NYC's watersheds, water resources, and water facilities in a sustainable, economic, and socially beneficial manner. This office is headed by Alan Cohn, Managing Director. Mr. Cohn and his staff ensure the resilience and reliability of NYC's water supply, the management of wastewater and stormwater, and work to reduce water demand through conservation programs and public awareness campaigns.

Mr. Cohn asked our team to:
1. Summarize the questions, challenges and opportunities for water reuse in NYC;
2. Document "lessons learned" from the experiences of other municipalities in the United States; and,
3. Make recommendations for setting up a water reuse strategy in New York City.

This report describes each of these components, accompanied by appendices and a reference section.

We used a lens of four themes to structure primary and secondary research processes, including: technology, public health, finance, and governance. The team was organized into two sub-teams. The primary research team conducted thirteen expert interviews to probe for the "lessons learned" in water conservation and reuse (reclamation) policy and implementation. The secondary research team reviewed background information and analyzed publicly available data. From there, both sub-teams aggregated and assessed the data to formulate the recommendations in this report.

In summary, our team recommends that NYC DEP:

1. Use a decentralized system to address unique density issues: combination of individual building and district-scale water reuse system.

2. Allow a market driven approach to determine the technology used rather than mandating one specific treatment method.

3. Implement non-potable, rather than potable, water reuse systems.

4. Establish a response management entity (RME) to maintain a water reuse system.

5. Aid developers with financial planning for reuse system construction by way of financial guides with detailed figures for returns on investment.

6. Continue NYC DEP's existing reuse grant program and expand their outreach to developers, using the maps our team put together for upcoming construction projects throughout NYC. These maps can be found in Appendix C, Figures 7 through 9.

7. Approach the establishment of standards, practices and ordinances through a collaborative process with City agencies, specifically the NYC Department of Mental Health and Hygiene (NYC DOHMH), New York City Department of Buildings (NYC DOB), City of New York Department of Sanitation (DSNY), NYC Economic Development Corporation, and the Mayor's Office.

8. Set standards to the quality of water instead of the technology used.

9. Use building and plumbing codes to set a reuse mandate policy based on the size of new construction.

10. Deliver reuse-related messaging in clear and non-technical language, avoiding terms with negative connotations such as "sewage" and incorporating words with positive connotations such as "clean" and "sustainable" (Lim & Safford, 2019). NYC DEP should also highlight the low health risks of water reuse and the benefits of such an approach early in the project.

A. INTRODUCTION

This introduction describes what water reuse is and why water reuse is an important consideration for New York City.

WHAT IS WATER REUSE?

Water reuse systems reclaim, treat, and reuse water from a variety of sources for beneficial purposes such as agriculture and irrigation, potable water supplies, groundwater replenishment, industrial processes, and environmental restoration (US EPA, 2019). Wastewater reuse systems and rainwater reuse systems make up the two types of on-site water reuse systems regulated by the 2014 New York City Construction Codes (NYC DOB, 2014). Approved sources for wastewater systems include blackwater and greywater. For rainwater reuse systems, cooling tower condensate is an approved source, along with rainwater, itself. Water reuse systems are regulated by the NYC DOB (NYC DOB, 2014).

WHY DOES NEW YORK CITY REQUIRE A WATER REUSE STRATEGY?

New York City is situated in a water rich area with a water supply that originates in three watersheds: Croton, Catskill and Delaware. A map of these three watersheds can be found in the Appendix C, Figure 1. Most of NYC's water comes from precipitation (rain and snowfall) and enters 19 large reservoir basins, which are continuously monitored. Water travels from these reservoirs to taps in NYC through tunnels and aqueducts, and is then disinfected before being finally distributed. The Catskill and Delaware watersheds are the larger of the three watersheds and provide roughly 90% of water consumed daily by NYC residents. The Croton Watershed provides the remaining 10% (Watershed Agricultural Council, n.d.). Nearly 12 million people consume water on a daily basis in New York City, comprising 9 million City residents, and 3 million daily commuters (NYC DEP, 2020b). There are also about 1 million upstate customers as well.

The system supplies approximately 1 billion gallons of freshwater each day (NYS DEC, n.d.). New York City is known as a water rich area, meaning it has abundant resources with infrastructure to deliver high quality water. The average water distribution in NYC in 2019 was 987 million gallons of water per day (MGD). Appendix C, Figure 2 comes 2019 NYC DEP Planning Estimate. The figure describes New York City's water demand and population growth over the past seven decades. While NYC DEP has been able to advance conservation efforts that have achieved a savings of over 10 million gallons of water per day (MGD), the agency hopes to increase that number to 20 MGD saved by 2022 (NYC DEP, 2019a). A comprehensive water efficiency program is necessary to create system reliability and ensure adequate supply.

Thus, water conservation is still a priority for the City, and the need for water reuse is driven by three considerations: aging infrastructure, combined sewer overflow (CSO) events, and advancing climate change resilience.

First, aging infrastructure is a major concern for NYC--specifically, the repair and maintenance of the Delaware Aqueduct. The Delaware Aqueduct, which supplies nearly half of NYC's water, is currently leaking upwards of 20 million gallons per day (NYC DEP, 2019b). NYC DEP is planning to construct a bypass around the leak that will require the aqueduct to be turned off until 2022, visible in Appendix C, Figure 3. Aging infrastructure is a major reason for NYC DEP's interest in a water reuse policy for the City because it reduces demand on the water system by reducing flows. Aging infrastructure also contributes to stress put on the water supply system when infrastructure breakdowns and droughts occur.

The second consideration is water quality impacts due to CSO events. CSO events are where intense rain events cause stormwater to be mixed with untreated sewage to be directly discharged into the City's waterways. This happens because the water treatment plants are unable to handle flows that are more than twice the design capacity. On-site water reuse systems can reduce the flow and lighten the burden on the wastewater treatment plants during heavy storms. This will prevent future overflow and waterway pollution. The CSO outfall locations can be seen in Appendix C, Figure 4. CSOs are estimated to increase in the coming years due to frequent storms induced by climate change.

The nexus between water, energy, and climate change is clearer when we consider the stress on NYC's wastewater system due to CSO events. This is because NYC's fourteen wastewater treatment plants across the five boroughs account for 16% of NYC's total greenhouse gas emissions (de Blasio, 2017). A map of these facilities is visible in Appendix C, Figure 5. Methane is one of the most potent greenhouse gases in the grand scheme of the climate crisis. Safe and efficient water management positively impacts energy consumption, water quality, and emissions, and that is the goal of a municipal-level water reuse strategy.

Finally, water reuse can play a role in advancing climate resilience. For example, in 2012, Hurricane Sandy's storm surge flooded some of the City's pumping stations and wastewater treatment plants, rendering them partially non-operational for days. The wastewater treatment system was overwhelmed and spilled nearly two billion gallons of raw sewage into waterways. Nine of the fourteen wastewater treatment plants had spills that exceeded 10 million gallons (Kenward et al., 2013). In contrast, The Solaire, a Battery Park City building complex, with on-site water reuse systems continued to provide uninterrupted wastewater treatment.

B. RESEARCH APPROACH

This section elaborates on the approach the workshop team undertook to conduct secondary and primary research.

SECONDARY RESEARCH

Our secondary research focused on four areas of review: **i)** New York City's current water reuse policies and practices; **ii)** water reuse and conservation policy and practices, internationally; **iii)** water reuse and conservation policy and practices, nationally; and **iv)** set of key reports on different approaches to water reuse, including from a decentralized and national perspective.

i. For New York, our team reviewed numerous reports, a few of which are listed below, and engaged in substantive communication with the NYC DEP. Our client recommended that we break down our analysis into a framework consisting of four main components: **technology, public health, finance, and governance**.

ii. For the international perspectives, our team reviewed practices in Singapore, Israel, Denmark, Spain, and Namibia (Lefebvre, 2018; Fluence News Team, 2017; State of Green & Danish Water Forum, 2016; Navarro, 2018; Wood, 2014). The international perspectives were particularly valuable in terms of reinforcing the usefulness of the four-component framework, suggested by our client, while also helping to inform interview questions designed for our research with experts.

iii. For the national perspectives, a secondary research was conducted to round out the answers we recorded during our primary research with subject-matter specialists, as well as questions that went unanswered due to time constraints. This information also helped fill out our case studies for San Francisco, Orange County, and Austin, found later in this report.

iv. In order to understand the complicated nature of water reuse, the team went through the literature about water reuse. Key reports are:

RISK-BASED FRAMEWORK FOR THE DEVELOPMENT OF PUBLIC HEALTH GUIDANCE FOR DECENTRALIZED NON-POTABLE WATER SYSTEMS FINAL REPORT: This report introduces Decentralized Non-Potable Water (DNW) Systems, which are used to collect, treat, and reuse water from local sources (e.g., roof runoff, stormwater, greywater, and wastewater) for various non-potable applications in individual buildings, neighborhoods, or districts. Aside from management practices, the report explains treatment targets, monitoring, and guidance for regulators to support widespread adoption of DNW systems while protecting public health.

US EPA NATIONAL WATER REUSE ACTION PLAN: Aiming to accelerate the consideration of water reuse applications and build on existing science, research, and policy, The National Water Reuse Action Plan engaged stakeholders across the water sector to develop integrated and collaborative water resource planning approaches. This plan identifies proposed actions across a spectrum of needs (e.g., policy coordination, technology development, outreach and communication, and workforce development). At the same time, it seeks to identify the most important actions to be taken in the near term and describe the specific attributes of such actions that will successfully ensure the sustainability, security, and resilience of the nation's water resources.

2018-2019 NYC ON-SITE WATER REUSE SYSTEMS GRANT APPLICATION GUIDE: This guide developed New York City's regulations for its design, construction and operation of on-site water reuse systems and determined the eligibility for the NYC DEP cost-sharing grant program to incentivize the installation of such systems.

2019-2020 NYC ON-SITE WATER REUSE SYSTEMS GRANT APPLICATION GUIDE: This updated guide includes an introduction to the on-site water reuse program, water reuse design and construction considerations, the steps for receiving an on-site water reuse grant, ongoing operation of on-site water reuse systems, and grant assistance for on-site reuse projects.

OTHER RESOURCES:

- BLUE RIBBON COMMISSION FOR WATER REUSE
- ONE WATER NYC: 2018 WATER DEMAND MANAGEMENT PLAN
- SAN FRANCISCO'S NON-POTABLE WATER SYSTEM PROJECTS
- INNOVATIVE & INTEGRATED STORMWATER MANAGEMENT

PRIMARY RESEARCH

A series of five general questions were developed to guide the primary research for and then conducted interviews with 12 experts with six more individual questions to probe for insights, guidance, and advice regarding the four components of our framework. (See Appendix B for these general questions used for the interviews).

Team members spoke with policymakers and practitioners from municipalities with significant water reuse programs in the United States, including San Francisco, California; Orange County, California; as well as Austin, Texas. Additionally, the team interviewed researchers and decision makers from academia, research institutions, and private companies. This was a crucial phase because many of our findings were drawn from these various experts. Their knowledge greatly informed our recommendations to NYC DEP to implement a water reuse strategy. As part of our process, we compiled detailed notes from the interviews, shared these notes with the experts for confirmation, and requested permission to quote each directly, where appropriate.

These interviews included specialists in engineering, policy-making, and program managing fields. Our interviewees are listed below:

Name	Title	Organization
Robert Stefani	Conservation Program Specialist	City of Austin Water Utility
Ed Clerico, P.E.	CEO Emeritus	Natural System Utilities

Zach Gallagher	Executive Vice President, Business Development	Natural System Utilities
Mike Zavoda	Managing Engineer	Natural System Utilities
Dr. Miriam Hacker	Postdoctoral Researcher	Eawag
Jason Dadakis	Executive Director of Water Quality and Technical Resources	Orange County Water District
Molly Freed	Programs + Policy Manager	International Living Future Institute
Nate Kimball	Senior Policy Advisor, Infrastructure & Energy	Mayor's Office of Sustainability and Resilience
Paula Kehoe	Director of Water Resources	San Francisco Water Utility
Taylor Chang	Water Resources Analyst	San Francisco Water Utility
Venetia Lannon	Vice President	Matrix New World Engineering *(previously worked in Department of Environmental Conservation)*
Trevor McProud	Director, Office of Public Health Engineering	New York City Department of Mental Health and Hygiene

Our interviewees will be quoted throughout the rest of this report to emphasize our research and recommendations.

For our policy and management recommendations, we analyzed the data from our interviews as well as from our literature review. We organized findings from our secondary and primary research, intending to reveal "lessons learned" and remaining knowledge gaps for further research. Given the themes previously mentioned, the team has four main considerations for policy recommendations:

- **Technology:** What are the best technologies and practices used?
- **Public Health:** How to protect public health?
- **Finance:** How much do systems cost, and who bears it?
- **Governance:** What agencies to involve and how to monitor?

Finally, a group of recommendations is made regarding areas that require more research. We offer these recommendations from the perspective of gaps in information and/or policy and practice that we encountered, especially regarding availability of data, data access and ease of data use for decision- and policy-making purposes.

C. FINDINGS

The findings described are a combination of secondary and primary research and are informed by our research framework. From our secondary research, we learned about the background for each of the select municipalities before conducting expert interviews. Our findings are divided into two sections. The first section describes the current status of water reuse in NYC. The second section describes three case studies in San Francisco, California; Orange County, California; and Austin, Texas.

I. CURRENT STATUS OF WATER REUSE IN NEW YORK CITY

This section of the findings will outline the current status of water reuse in NYC by describing the technical, public health, financial, and governance considerations of water reuse in NYC. This was achieved by doing background secondary research to understand water reuse that later informed the questions we asked experts in the public and private sector in NYC. In addition to interviewing experts in the public sector, our framework guided the research process and helped lay out the current status of NYC water reuse in a way that the team could more readily identify research gaps and suggest recommendations which are described more in the "Policy and Management Recommendations" section.

As of today, water reuse is not widespread in NYC for several reasons. This is due in part by how relatively new water reuse is as well as NYC's location in a water rich area. Despite this, there have been steps made by NYC DEP to lower water demand and make water reuse more widespread because of its concerns about aging infrastructure, CSO events, and climate resilience.

TECHNICAL CONSIDERATIONS

Water reuse systems can generally be subdivided into two categories, centralized and decentralized systems. Centralized systems service many buildings at a very large scale, while decentralized systems are smaller and can service either one or more buildings.

Centralized water reuse systems are intended to operate at a scale that is similar to existing wastewater treatment systems (Kreissl & Ord, n.d.). Ensuring traditional wastewater treatment plant effluent meets adequate quality standards may be achieved by adding additional treatment processes. When used for non-potable uses recycled water necessitates the use of isolated pipes, which are often colored purple as a means of distributing recycled water for applications (Faloon, 2011).

Decentralized treatment relies on smaller water treatment systems. These systems provide greater flexibility primarily through savings in space requirements as compared to centralized systems. Decentralized water reuse systems operate with processes similar to larger scale centralized systems. Effluent disinfection in water is attained through various processes including ultraviolet light irradiation, ozone, and sodium hypochlorite (NSU, 2013).

NYC DEP continues to invest time, effort and resources to optimize the use of potable water through conservation. These conservation efforts are part of an integrated strategy. This strategy includes improving water efficiency, green infrastructure and to which water reuse systems might contribute to the City's ability to ensure adequate water supply into the future, and decrease the impact of CSO events to the receiving waters of the area.

Since 2016, NYC DEP's On-Site Water Reuse Grant Program has offered incentives for developers by covering a part of capital and technology costs for eligible mixed-use, commercial, or multi-family residential buildings to install water reuse systems (NYC DEP, 2018). A complementary although longer tenured program, the Comprehensive Water Reuse System program, offers a 25% discount on water and wastewater fees to those who successfully install water reuse systems in their buildings that result in a 25% reduction in water use (NYC DEP, n.d.-e).

Natural Systems Utilities (NSU) is currently the leading private firm in water reclamation and reuse innovation in NYC. They offer residential and commercial developers integrated and cost-effective water reuse solutions built with an individualized design approach based on their client's constraints and resources (NSU, n.d.). NSU has highlighted its work in both the Battery Park City development and the The New School.

In 2000, NSU partnered with the Battery Park City Authority in NYC to create a comprehensive sustainable urban development plan that integrates water reuse systems. Within Battery Park City, a 92-acre development, there are five residential water reuse systems servicing six buildings. Their reuse systems' treatment process includes hollow fiber microfiltration membranes, ultraviolet light disinfection, and biological nitrogen removal to comply with New York City's Department of building's direct reuse standards (NSU, 2013).

While metrics such as building permit information are available through the New York City Open Data portal, there is a lack of publicly available data regarding frequency and volume of discharge during CSO events. It would be helpful to better understand the levels of wastewater input into the municipal water collection network from properties to have a greater grasp on water use at finer spatial scales as a means of quantifying the impacts on wastewater volumes and their impact on CSO events.

Implementing water reuse in the context of the existing building stock would likely require greater information regarding the available space in buildings for the dual piping necessary to convey potable and non-potable water, though this problem would be mitigated in new construction situations as water reuse would have been incorporated from the planning phase forward. Testing and monitoring capacity would need to be increased to assure water quality metrics for bacteria concentration and water quality are being met.

Figure 1: Diagram illustrating centralized water reuse applications (Town of Davie Florida, n.d.)

PUBLIC HEALTH CONSIDERATIONS

One potential health impact of great concern for the DOHMH is the large-scale water quality testing that needs to be done in order to completely understand the potential risks of water reuse in NYC. Opportunistic pathogens such as *Legionella,* which causes Legionnaires disease and, have been a recent concern for the NYC DOH (NYC DOH, 2020). Though *Legionella* are not found in the water supply, its ability to multiply in cooling towers still poses a threat to the health of building occupants. With the recent worldwide Covid-19 outbreak beginning in December of 2019, allaying residents' fears regarding the safety of the water in their homes is all the more imperative.

Developing standards is an arduous and necessary process to develop water reuse strategies, even at a small, decentralized scale. The current building code that addresses on-site water reuse is the 2014 NYC Construction Codes PC C102 (NYC DOB, n.d.). The allowed source water under this code includes black water, gray water, and rainwater. This sourced water can be used for non-potable uses such as toilet water, cooling towers, laundry, surface irrigation, and other approved uses. The 2014 NYC Construction Codes PC C102 includes minimum effluent water quality standards as well and sets up key water quality parameters (NYC DEP, 2018). These parameters are visible in Table 1, found below.

Table 1: 2014 Construction codes minimum effluent water quality standards for water recycling systems (NYC DEP, 2018)

Permit Limits, Levels, and Monitoring[1]		
Parameter	Effluent Limit	
	Limit	Unit
BOD2	<10	mg/L
TSS	<10	mg/L
Total Coliform	<100	No./100 mL
E. Coli	<2.2	No./100 mL
pH	6.5- 8.0	SU
Turbidity3	<2.0	NTU

1. Facilities seeking to utilize rainwater capture or recycling water systems as a source of cooling tower system makeup water need to consult with and obtain approval from DOHMH regarding specific water quality standards and other requirements that may be required by DOHMH for cooling tower makeup water, per NYCRR, Title 24, Chapter 8.

2. Effluent from rainwater and condensate collected in separate tanks or compartments from wastewater shall not be required to meet the BOD limitations indicated above.

3. The wastewater facility effluent must meet the performance standards of < 2.0 NTU for turbidity for 95% of the measurements. At no time can the turbidity result be above 5 NTU. These results shall be recorded and compiled in the annual report.

In terms of fleshing out additional details to monitor reuse systems, the NYC DEP can work to support NYC DOHMH in training methods to ensure that the entities overseeing water quality of reuse systems are testing for all potential microbial pathogens.

FINANCIAL CONSIDERATIONS

The costs for decentralized systems depend upon required capacity, scale, and space constraints, and fall primarily on a building's owner. Cost effectiveness of reuse systems is based on their return on investment (ROI). A range of 25,000 gallons per day typically provides a 10-year return on investment, as is the case with the Solaire Building in NYC's Battery Park City. Larger scales, even multi-building or district-block scales, usually provide a return on investment in less than 5 years (E. Clerico, Personal Interview, 2020).

Costs of water with decentralized on-site reuse systems range between $18/gal to $50/gal at capacity depending upon scale and space constraints, with smaller systems being more expensive at capacity. They make up approximately 1.5% - 2.0% of building costs in New York City (E. Clerico, Personal Interview, 2020). A typical private system is owned by the building's owner, and the cost of water would be reflected in the tenants' rent or the water usage fees for the building owner.

Operations and maintenance can be contracted out by the private owners to companies. NSU oversees operations and maintenance of many of the water reuse systems they've helped to build, acting as a Response Management Entity (RME). A RME can be a public or private entity that oversees operations and maintenance of a system, and is responsible for customer service and liability for all aspects of system performance commensurate with a public utility. The entity must also be adequately funded and capable of funding all repair, replacement, and upgrades required to meet regulatory changes (E. Clerico, Personal Interview, 2020).

The NYC DEP has instituted a grant program to deploy water conservation technologies, and this could be used to encourage developers to implement reuse on a decentralized scale. Water reuse systems are roughly 1% of a building's capital costs for new construction (E. Clerico, Personal Interview, 2020).

A decentralized system, on a building-by-building or district-level scale, provides a more efficient use of capital for municipalities, as it doesn't require all capital up front because the systems are built in phases where private developers would be responsible for the initial investment of capital. Innovation can be incrementally implemented while building decentralized systems, allowing for continuous improvement overall. Centralized systems typically require longer operating life spans to achieve a return-on-investment.

> *"Centralized water reuse models are facing huge capital spends that are significantly impacting user rates. Decentralized systems are competitive right now given the NYC comprehensive water reuse program along with the capital grant program incentive."*
>
> *–Ed Clerico, NSU*

GOVERNANCE CONSIDERATIONS

Governance in New York City is a complex web of agencies working together to provide necessary services to NYC residents. In terms of developing a water reuse strategy, the main departments involved are NYC DEP, NYC DOHMH, and NYC DOB. NYC DEP is in charge of NYC's water supply and wastewater treatment, the NYC DOHMH is primarily concerned with ensuring the public is not at risk from opportunistic pathogens in the water, and the NYC DOB is involved with the construction codes of water reuse systems. In order to effectively manage a city-wide strategy, conversations should happen early and continue frequently. Further recommendations for NYC DEP to approach governance can be found in this report's "Policy and Management Recommendations" section.

As a water-rich city, NYC has not yet needed extensive public education campaigns to instill the importance of water conservation and the need for water reuse systems is a difficult task. Collaboration between the public and private sector is also required to set up a successful water reuse strategy. Widespread adoption and implementation of water reuse in New York City may have a tangible impact in reducing CSO events in New York City.

II. CASE STUDIES

For this section, the team interviewed with experts from San Francisco, California; Orange County, California; and Austin, Texas. Before interviewing began, the team reviewed each city according to our framework to prepare for interviews with the public sector and private sector experts in each municipality. The team developed these cases as a reference point to inform the City about water reuse across the country. Our background research was supported by insightful interviews, the majority of which are summarized in the case studies below.

1. SAN FRANCISCO, CALIFORNIA

San Francisco is in a water scarce area, and because of this, the City and County government have worked hard to ensure that the water needs of 2.6 million residents are met (SFPUC, n.d.-b). San Francisco suffers from droughts and has become an innovator in the field of water reuse and conservation to enhance their supply and reduce water demand. Article 12C, commonly known as the Non-Potable Water Ordinance that requires new buildings to capture and treat water sources for non-potable applications, was put into place in 2012. In 2015, Article 12C became mandatory so that any new building over 250,000 square feet or more of floor area is required to install and operate an onsite non-potable water system. There was political support for the ordinance to become mandatory after a drought in 2015, which highlighted the urgency of implementing onsite water reuse systems to mitigate the negative effects of climate change.

The responsibility to meet water demand is given to the San Francisco Public Utilities Commission (SFPUC), which is the public agency of the City and County of San Francisco, in charge of water, wastewater, and power services.

TECHNICAL CONSIDERATIONS

The design of a reuse system has multiple components: a collection system, equalization tank, treatment system, treated water storage, and non-potable water distribution system. One design challenge cited in San Francisco's *Non-Potable Water Program Guidebook* is water storage due to water quality concerns associated with long storage periods. System designers address this by efficiently sizing the storage tank and have operating systems that minimize water age (SFPUC, 2018). The guidebook also provides water treatment system options for engineers to choose from. These water treatment options include: microfiltration, membrane biological reactor, reverse osmosis, ultraviolet light disinfection, chlorine disinfection, and ozone disinfection. The *Non-Potable Water Program Guidebook* provides readers with the necessary treatment requirements of these systems.

The Non-Potable Water Ordinance and the Stormwater Management Ordinance together ensure that San Francisco's water is conserved and used as efficiently as possible to meet the City's demands. Together, the ordinances provide developers, architects, engineers, and designers with guidance about the technical considerations needed to determine the best alternate water source and type of water reuse system for a project. These considerations include comparing water storage sizes, water storage tank configurations, and available alternative water sources. The *Synergies for Compliance with the Non-Potable Ordinance and the Stormwater Management Ordinance* outlines the available resources to understand alternate water sources and types of water reuse systems that best fit a project given the project's compliance requirements, building type, and associated storage and treatment needs (SFPUC, 2017). To aid developers and designers, the synergies between these two ordinances are laid out with an outline of the necessary water reuse technical configurations to meet the requirements of both of these ordinances.

PUBLIC HEALTH CONSIDERATIONS

The San Francisco Department of Public Health (SFDPH) is the permitting agency for the operation of alternate water source systems in residential, mixed use, and non-residential buildings. The San Francisco Department of Public Health Environmental Health Branch (SFDPH-EH) is the responsible branch of the SFDPH for ensuring that the Alternate Water Source Systems are in compliance with the Non-Potable Ordinance. The SFDPH-EH performs ongoing monitoring, review, and inspections of permitted alternate water source systems to ensure compliance is maintained (SFDPH, 2017). Permits must be renewed on an annual basis.

In order to protect public health, the alternate water source project applicant must submit an application packet containing an Engineering Report, Operations and Maintenance Manual, an affidavit signed by the designated Treatment System Manager, evidence of a contract with a certified laboratory to perform water quality analysis, system construction verification, and evidence of a satisfactory cross connection test to the main water system (SFDPH, 2017). Once the alternate water source project is approved, the project applicants become permittees with responsibilities that include permit maintenance, as well as assurance that water collection, treatment, use, water quality monitoring and reporting are all consistent with the approved engineering report, the Operations and Maintenance Manual, and applicable state and local laws.

The Engineering Report is submitted by the project applicant to describe how the alternate water source system is in accordance with rules and regulations (SFDPH, 2017). The three main objectives of the Engineering Report are to discuss water quality criteria, monitoring and reporting content and frequencies, and operation and maintenance requirements.

The Engineering Report includes water quality requirements for pathogenic microorganism control for virus and protozoa by providing the log reduction levels as well as the pathogenic microorganism control for bacteria by providing the water quality limits for total coliform. To better understand the regulations to meet the Engineering Report requirements, the *San Francisco Department of Public Health Director's Rules and Regulations for the Operation of Alternate Water Source Systems* includes the water quality requirements of greywater treatment systems, blackwater treatment systems, foundation drainage treatment systems, stormwater treatment systems, and rainwater treatment systems (SFDPH, 2017).

For an example of what a log reduction target for a greywater system is, refer to Appendix D Table 1.

Also provided in the *San Francisco Department of Public Health Director's Rules and Regulations for the Operation of Alternate Water Source Systems* are example treatment process monitoring methods. Depending on the permit, source and end use, monitoring is required either quarterly, monthly, weekly, daily, or continuously (SFDPH, 2017). The monitoring methods varied depending on what the technology treatment process chosen was. More information on this can be found in Appendix D Table 2.

Results from monitoring must be reported to the SFDPH-EH on a monthly or annual basis depending on the permit issued (SFDPH, 2017). An example reporting frequency summary can be found in Appendix D Table 3.

Furthermore, an Operations and Maintenance Manual is required in the Alternate Water Source Application to provide SFDPH-EH with comprehensive information on the alternate water source system operation, maintenance, and repair. The Operations and Maintenance Manual also includes descriptions of the water quality and monitoring and reporting plan, troubleshooting, and emergency procedures. The manual is reviewed on an annual basis (SFDPH, 2017).

FINANCIAL CONSIDERATIONS

Major components for financial considerations are project costs, annual operations and maintenance costs, and service costs to residents or tenants. Project costs usually include the rainwater harvesting system, distribution piping cost, heating and cooling systems, non-potable water treatment systems, and total construction costs. Annual operations and maintenance cost, as well as service costs, are usually difficult to estimate because they can vary (SFPUC, 2014).

With an entrenched water conservation philosophy in mind, San Francisco was able to roll out several financial incentives for private developers and ratepayers. These include discounts on rain barrels, grants to install water efficient equipment, and information on how to best meet requirements. SFPUC offers a variety of 26 different programs, grants, rebates and incentives to their ratepayers. SFPUC has offers for both residential customers and commercial customers. These include discounts on rain barrels, grants to install water efficient equipment, energy efficiency, and grant programs for flood water management to list a few (SFPUC, n.d.-a). For water reuse specifically, they have a Non-Potable Grant Program that offers assistance to projects that implement an onsite non-potable water system in San Francisco that is not subject to the requirements of the Non-Potable Ordinance Article 12C. Besides saving money, among private developers, another financial driver is LEED Points. LEED Points mean that the project boasts two positive results: 1) money was saved and 2) it is a leader in water conservation.

GOVERNANCE CONSIDERATIONS

In order to successfully implement on site non-potable water reuse systems, SFPUC had to closely work with other departments such as SFDPH-EH, San Francisco Department of Building Inspection-Plumbing Inspection Division (SFDBI-PID), and San Francisco Public Works (SFPW).

A clear delegation of responsibility was essential to the success of water reuse in San Francisco. Although the ordinance was implemented in 2012, it took two years to develop the program. During these two years, stakeholders took this time to understand the needs and challenges of implementing a water reuse program. To streamline the application process, SFPUC has broken it down into steps with useful links to successfully implement a Non-potable Water Reuse System on their website. These steps include:

1. Submit a Water Budget Application to SFPUC
2. Submit a Non-Potable Implementation Plan to SFPUC (applicable to only district-scale systems)
3. Submit Engineering Report, Permit Application, and Fee to the SFDPH-EH
4. Obtain Plumbing Plan Check and Permits from SFDBI-PID and Complete System Construction
5. Obtain Encroachment Permit from SFPW
6. Conduct a Cross-Connection Test with SFPUC and SFDPH-EH
7. Obtain a Permit to Operate from SFDPH
8. Conduct Ongoing Monitoring, Reporting, and Inspections

At the time, the ordinance was filed on the local level because there was no state regulation to oversee the systems. San Francisco is unique because it is both a city and a county. This meant that the process to develop and implement water reuse was streamlined, and San Francisco developed a water reuse ordinance before there was impetus from the state government to draft a water recycling policy that supports San Francisco's efforts. San Francisco’s municipality acted as a leader in water reuse, and their work informs much of the rest of the United States.

2. ORANGE COUNTY, CALIFORNIA

Currently, Orange County, California receives water from two sources: the Orange County Groundwater Basin, which provides about 75% of local supply, and from treated, imported water which provides about 25% of local supply. The Orange County Groundwater Basin is supported by the Groundwater Replenishment System (GWRS) that went online in 2008. The GWRS reuse system supplies potable water to the county by recharging the groundwater basin. In order to create the GWRS, a partnership was made between the Orange County Water District (OCWD) and the Orange County Sanitation District (OCSD). In this situation though, both benefit from the GWRS partnership because OCSD needs disposal options beyond ocean disposal and OCWD needs alternative sources for groundwater supply. OCSD saw an increase in waterflow into their sewer systems from stormwater runoff, and began looking for an alternative for stormwater disposal instead of the ocean. The two agencies were able to work together while maintaining jurisdictional separation. Orange County is the only example in this report of potable use of water, making the technical, public health, financial, and governance considerations particularly unique.

TECHNICAL CONSIDERATIONS

The GWRS can produce up to 100 million gallons (379,000 cubic meters) of water per day of high-quality potable water. That is enough to meet the needs of nearly 850,000 residents in north and central Orange County. After the system's final expansion is complete, production will increase to up to 130 million gallons of water per day (J. Dadakis, Personal Interview, 2020). The GWRS is the world's largest advanced water purification system for potable use. The project was developed by the state, the county's health department, and local drinking water departments. The interest in potable reuse grew, so they generated draft regulations for case-by-case basis from 1980's to 2000. Then potable reuse regulations were adopted in 2020 for groundwater recharge or for direct injection into an aquifer. These regulations were formalized in 2014.

1. The water treatment process for the GWRS is separated into five steps:
2. Pre-Purification
3. Microfiltration
4. Reverse Osmosis
5. Ultraviolet Light
6. Water Delivery

Check the *GWRS Technical Brochure* on the GWRS website for more detailed information about the water treatment process.

PUBLIC HEALTH CONSIDERATIONS

OCWD has not had any public health issues related to their potable GWRS since coming online in 2008. They use reverse osmosis to treat and purify wastewater that gets pumped into their GWRS, and have gained a lot of experience over the years. It is a very good multi-spectrum barrier for the range of biological and chemical contaminants that occur in wastewater. However, their regulations might have allowed them to not treat all of the water with reverse osmosis, but it provides benefits from a water-quality standpoint as it is an improved method of treatment. It also addresses the public's concern regarding any contaminants left in the treated water before it is placed in the groundwater basin. Reverse osmosis serves to demonstrate that their utility has a robust purification process, which makes for a powerful public engagement process.

The Orange County Water District's GWRS monitors and assesses its water flows for both pathogens and chemical pollutants (Dadakis, 2015)

Pathogens:

- Giardia cysts
- Cryptosporidium oocysts
- Viruses

Chemical:

- Quarterly testing is conducted for over 400 chemical contaminants, including constituents of emerging concern, which are recent additions to California testing standards.

Monitoring of parameters occurs at various levels including both intermittent and continuous testing and utilizes critical control point pathways to ensure the safety of water processed through the facility (Dadakis, 2015).

FINANCIAL CONSIDERATIONS

There are two primary water supplies in Orange County: a groundwater basin, which comprises 75% of local supply, and treated imported water making up the remaining 25%. This water is imported from the Metropolitan Water District of Southern California which serves 19 million people.

When adding up wholesale costs from the Metropolitan Water District of Southern California and comparing that to pumped groundwater for Orange County, the cost of groundwater pumping is half that of imported water. According to the OCWD website, the GWRS produces water at a unit cost of $525 an acre-foot with subsidies and $850 an Acre-foot without subsidies, each being less than the cost of imported water (OCWD, n.d.)

After low-cost financing for the project from state and federal grants the GWRS was able to benefit local users. GWRS allowed for 25% of the groundwater pumped to be local, but now supports about ⅓ of the local groundwater pumped. Since the amount of water GWRS supports has increased, it is more sustainable at the local level in the long run and makes importing water less necessary and increases the resilience of the water delivery system (J. Dadakis, Personal Interview, 2020).

GOVERNANCE CONSIDERATIONS

Orange County urges other cities to face public perception head-on at the beginning of a water recycling program. The utility put together an independent oversight group to oversee the project's plans with academic and technical experts to inform the regulations and type of treatment used. They also started an active public outreach campaign with local, state and federal officials, local community groups, schools, universities, and even faith communities. Among others were cities in their service area, major environmental, health experts, minority leaders and Chambers of Commerce (Dadakis, Jason S., 2015)

OCWD did not want anyone to be surprised that the recycling system was going to come online, likewise, the utility wanted to address any public health concerns proactively, particularly for their customers. By taking these steps, the public was very well informed and there was little to no public opposition to the program. In fact, the program enjoyed broad public support from diverse communities across the political spectrum and continued through ongoing and frequent outreach.

OCWD realizes that what goes into wastewater is very important to officials working on the drinking water side, too. Wastewater stakeholders aren't always the same as the drinking water stakeholders under every municipality, creating jurisdictional and political issues when implementing a reuse program. In the case of the GWRS, the OCWD expanded their reuse system with a 13-mile pipeline, with the Sanitation District paying for half of the project. This expansion benefited both district agencies.

OCWD has had working relationships with state regulators over the years, including water system operators, owners and regulators. They collectively work together about best practices and management tactics as issues arise. Currently, water and wastewater are separate systems with different jurisdictional lines. Despite this collaboration between water and wastewater entities, it should be noted that even in California, public and private officials still separate water and wastewater systems rather than link the two together as one system. Thinking of water and wastewater systems as one continuous system requires looking at the life cycle of water as a continuous flow in one larger system rather than two smaller ones. If this approach was taken, the way public officials write policies and create regulations would have to be framed differently to account for this paradigm shift.

3. AUSTIN, TEXAS

From 2008-2016 Austin experienced a historic drought. At the time, Austin's water management portfolio included the Colorado River and Highland Lakes supply, reclaimed water supply, conservation water savings, and drought contingency plan savings (Austin Water Utility, 2018). With 964,000 people in Austin, this drought had significant impacts on the way state and local government thought about water demand and water supply. Austin decided to take proactive steps to meet future demand and improve supply strategies to mitigate the impact of the next major drought. The state code that addresses water reuse is the Texas Administrative Code (TAC) Chapter 210 Subchapter F, and Plumbing Code Chapters 15 & 16 of the Uniform Plumbing Code is the City code to address water reuse. Austin developers are subject to both state and local laws when implementing a water reuse system.

TECHNICAL CONSIDERATIONS

Since 2008, the City of Austin has made significant progress in implementing a cohesive effort to develop water reuse systems. Currently, Austin has an extensive network system for recycling water, and has also implemented a centralized reclaimed water system through its three wastewater treatment facilities (Austin Water Utility, n.d.-a).

Additionally, Austin has developed, and is in the process of enacting, its *Water Forward Plan.* The Plan details the City's current regulatory program's move to a mandatory program by 2032, which will require buildings between 500 to 250,000 square feet to connect to a centralized reuse system. Austin Water Utility officials hope to incentivize the Plan's early adoption, leading to full implementation within 12 years.

PUBLIC HEALTH CONSIDERATIONS

In contrast to other water utilities across the country, Austin Water Utility has jurisdictional control in overseeing and ensuring compliance of public health standards through an internal health department, and is not required to interface with outside municipal agencies. Public health of reclamation systems is not cited as a major concern for Austin. The only interfacing the Austin Water Utility does is with building officials for on-the-ground construction (Robert Stefani, Personal Interview, 2020).

There is also the Texas Administrative Code (TAC), which has water quality standards for using reclaimed water that are more general. The standards found in the TAC cover fecal coliform levels for Type I reclaimed water use and Type II reclaimed water use. Type I reclaimed water is defined as the use of reclaimed water where contact between humans and the reclaimed water is likely. The minimum sampling and analysis frequency for Type I is twice per week. Type II reclaimed water use is defined as use of reclaimed water where contact between humans and the reclaimed water is unlikely. The minimum sampling and analysis frequency for Type I water is once per week (TAC, n.d.)

FINANCIAL CONSIDERATIONS

While financial information regarding expenditures and costs for water recycling is limited, cost in terms of net present value for additional water treatment and distribution has been assessed at $4.00 and $0.64 per 1000 gallons respectively by Austin Water Utility in 2010. Austin's Water Forward plan estimates that unit costs for community scale reuse options range from approximately $1,100 to $11,000 dollars (Austin Water Utility, 2018). Under the utility's rebates offered to commercial, multi-family, or school consumers, the Bucks for Business incentive offers up to $100,000 to install water-efficient equipment or process upgrades (Austin Water Utility, n.d.-b)

GOVERNANCE CONSIDERATIONS

Austin manages its centralized reclaimed water policy and practices based upon state regulations for reclaimed water quality. For its on-site water reclamation, plumbing codes for connections and infrastructure form the requirements and specifications for reclamation.

Moreover, Austin's current practices are significantly informed by the *National Blue Ribbon Commission* which is an initiative from the *U.S. Water Alliance* for water quality requirements for on-site potable water systems, and applied risk assessment for non-potable water systems to their reclamation systems (US Water Alliance, n.d.). In an interview with Robert Stefani, from Austin Water Utility, he noted that the initiative aided them in their development process that led to the adoption of a reclamation system at the state and local level. Operations and maintenance are the most important aspects of their reclamation systems, as most decentralized systems are owned and operated by the public sector in Austin. The public sector in this case is considered to be a certified as a Class A Operator. The class system refers to how many gallons per day a treatment facility can handle, with Class A being the largest water volume type.

D. POLICY AND MANAGEMENT RECOMMENDATIONS

In this section our team offers its recommendations, drawing from lessons learned in each of the case studies and supported, where possible, with direct quotes from the experts we interviewed. The recommendations follow the research framework so that connections can be easily made throughout the report. Besides the technology, public health, finance, and government recommendations, we have an additional public education recommendation. The rationale behind this is that public education requires niche strategies, such as clear messaging, which we also found to be an important factor in the success of water reuse implementation.

TECHNOLOGY

Due to the space constraints and aging infrastructure across NYC, developing a city-wide centralized water reuse plan is likely impractical. Our team recommends that NYC DEP do the following in terms of technical considerations:

1. USE A DECENTRALIZED SYSTEM TO ADDRESS UNIQUE DENSITY ISSUES: COMBINATION OF INDIVIDUAL BUILDING AND DISTRICT-SCALE WATER REUSE SYSTEM.

To address the unique density issues of New York City, this would look like a combination of individual building and district-scale water reuse systems. For instance, homeowners in a neighborhood on Staten Island (considered a district-scale) will have different reuse systems than large capacity buildings, like the Solaire in Battery Park City. Engineers have cited that redundancy is essential for precautions against more extreme climate-induced disasters in the future, meaning that the scale for which a reuse system serves can always plug itself back into the normal water and wastewater plumbing. Should the reuse system run into difficulties with its operations, residents would not lose access to drinking water.

Molly Freed from International Living Futures Institute summarizes our team's position regarding a decentralization strategy:

"Most likely, a district-scale would work best [in NYC]. This would cut down on pumping over long distances but would also offer some resilience/backup capacity considering the possibility of a plant going down due to an extreme weather event."

2. ALLOW A MARKET DRIVEN APPROACH TO DETERMINE THE TYPE OF TECHNOLOGY TO USE RATHER THAN MANDATING ONE SPECIFIC TREATMENT METHOD.

An independent advisory panel, with experts working in the private sector, was essential to the successful launch of the GWRS. Academic experts in technical fields, including hydrogeology, toxicology, chemistry, microbiology, environmental engineering, public health, and water treatment technology, helped inform the county's regulations and treatment methods. Developers and building owners can determine the technology most suited for their project, as long as it achieves the highest quality non-potable water standards regulated by the NYC DOH.
Venetia Lannon from Matrix New World Engineering explains this further:

"Do not dictate a technology or type of technology. Instead, set the performance standard and let the market decide what technology is best….For example, instead of saying 'we are going to require this

system for everyone' say 'a system must be capable of treating waste water on-site to meet this standard.'"

PUBLIC HEALTH

Public health is the primary concern when developing and installing a water reuse system at any scale. Our team recommends that the DEP do the following in terms of public health considerations:

3. IMPLEMENT A NON-POTABLE, RATHER THAN POTABLE, WATER REUSE SYSTEM.

Non-potable water reuse is more feasible for New York City due to infrastructural and spatial limitations. Being in a geographically constrained area, such as the island of Manhattan, limits the possibilities of a potable water system, as it requires a greater amount of infrastructure. Standards are already set in the City's plumbing codes for water quality standards for non-potable applications.

4. ESTABLISH A RESPONSE MANAGEMENT ENTITY (RME) TO MAINTAIN WATER REUSE SYSTEMS.

The RME would need to be established on a city-wide and also be on a hyperlocal scale. The RME is a targeted operations and management staff that oversees repairs and upkeep of water reuse systems. The hyperlocal team would respond to a specific reuse system in terms of its day-to-day operations. A larger city-wide team would be responsible for managing any public health outbreaks. This team would most likely be a City agency, such as the NYC DOHMH. A hyperlocal team could be a building operator if properly trained in water reuse systems or a contracted specialized engineering company.

These team members will need certification that verifies knowledge, skills, and abilities to operate the permitted system. For example, in San Francisco Treatment System Managers must be certified by the State Water Resources Control Board's Office of Operator Certification or by the California Water Environmental Association or have comparable education and/or experience to operate a blackwater or graywater source system (SFDPH, 2017). Furthermore, SFPUC provides Training and Education Resources available for Treatment System Managers in their application packet (SFDPH-EH, 2019). In Appendix D Table 4 is a page taken from the application packet with the training and education resources available in California (SFDPH-EH, 2019).

Recommendations for how frequently systems should be monitored by RMEs can be found in the 2018-2019 NYC On-site Water Reuse Systems Grant Application Guide. New systems should be monitored five times per week, but once the system has been established and permitted it can limit its monitoring to occur once a month (NYC DEP, 2018).

FINANCE

The return on investment for reuse systems is typically made after the first 5 years of implementation at capacities larger than 25,000 gallons, while systems with capacities that are less than that see a return on investment in approximately 10 years. Water costs associated with reuse systems typically range between $18 to $50 per gallon for the building owners. Smaller systems tend to have higher water costs.

Ed Clerico from Natural Systems Utilities explained why decentralized reuse on a building-by-building scale is more economically feasible than a larger centralized scale in the short term:

"Centralized water reuse models are facing huge capital spends that are significantly impacting user rates. Decentralized systems are competitive right now given the NYC comprehensive water reuse program along with the capital grant program incentive."

Our team therefore recommends that the DEP do the following in terms of financial considerations:

5. AID DEVELOPERS WITH FINANCIAL PLANNING FOR REUSE SYSTEM CONSTRUCTION BY WAY OF FINANCIAL GUIDES WITH DETAILED FIGURES FOR RETURNS ON INVESTMENT.

Construction on a decentralized scale would be the first steps toward implementing a reuse strategy at a city-wide scale, and properly equipping developers with financial resources is necessary to get the ball rolling.

As shown in Appendix C Figure 6, the construction rates overall in the City appear to decrease while the residential and education construction rates appear to increase. This lull in construction may allow for a more intentional approach to introduce water reuse policy and adoption into the planning phases of these projects. New construction is an opportunity to introduce water reuse systems into the project, as systems typically make up a small portion of construction costs.

6. CONTINUE EXISTING REUSE GRANT PROGRAM AND EXPAND OUTREACH TO DEVELOPERS.

Our team created three maps for the NYC DEP to use as tools for seeking out developers who are managing new construction projects throughout the City. These maps can be found in Appendix C, Figures 7-9. Data for these GIS analyses were obtained from the NYC Open Data portal (NYC OpenData, n.d.). These figures visualize construction projects in New York City boroughs from 2018-2020, and distinguishes between new constructions and major alterations to structures.

Through our research process, we have noticed a research gap in financial information. There is a lack of straightforward information about financing reuse systems. This is in part due the fact that water reuse is widespread and relatively new. As of today, there is a lack of cost transparency and without a better understanding of the costs, figuring out the best financing tools for water reuse systems is more difficult. Once these financial gaps are filled, developers can make better decisions overall. Currently, water reuse systems are measured by their capacity to inform the ROI.

GOVERNANCE

Governance is a major concern because there is oftentimes difficulty deciding on appropriate codes and regulations for implementing a water reuse system. This difficulty partially stems from differing priorities among agencies. Setting the standards of a water reuse system requires collaboration among various departments. Conversations between agencies are necessary to build the foundation for a water reuse program, and this is made easier by starting these conversations early on.

Stakeholder engagement is crucial to the success of implementing a water reuse program. Stakeholders can be broken into two groups: internal stakeholders and external stakeholders. Internal stakeholders include the developer/owner, design team/builder, building occupants, and facility managers (William J

Worthen Foundation, 2018). External stakeholders include regulators, utilities, and financial institutions. Conversations with each of these stakeholders will vary since they all have their own interests. For example, conversations with building owners should focus on how water reuse can be feasible, reduce long term costs of water/sewer costs of the building, and can promote sustainability (William J Worthen Foundation, 2018).

Conversations with government agencies should highlight several topics: the safety of non-potable reuse, effective technologies available, how water reuse system designs meet building codes, how to develop a message for public outreach, and how water reuse is resilient but also reliable, as it remains connected to the city's centralized water and sewer systems as a backup (William J Worthen Foundation, 2018). Our team therefore recommends that NYC DEP do the following in terms of governance considerations:

7. APPROACH THE ESTABLISHMENT OF STANDARDS, PRACTICES AND ORDINANCES THROUGH A COLLABORATIVE PROCESS WITH CITY AGENCIES, SPECIFICALLY THE NYC DOHMH, NYC DOB, DSNY, NYC DEPARTMENT OF ECONOMIC DEVELOPMENT, AND THE MAYOR'S OFFICE.

As Taylor Chang from San Francisco's Public Utilities Commission noted, it is critical to identify agencies to direct and implement NYC's water reuse strategy with roles and responsibilities clearly specified.

"Everyone came to the table with their own challenges but they needed someone to champion [the water reuse program], which was the Water Utility. Everyone has their own interest, like how the Building Inspection Department is interested in enforcing plumbing codes and building codes, for instance."

Collaboration is key, but even more so is leadership in order to get a water reuse program started. NYC DEP is the agency in charge of managing water supply and treating wastewater. Thus, NYC DEP coordination and collaboration with other agencies is required to ensure compliance is met and maintained when water reuse systems are installed.

Jason Dadakis, from Orange County Public Works, further emphasized Chang's point based on his experience with the GWRS:

"For utilities implementing potable reuse, drinking water and wastewater departments must overcome their traditional separation in order to closely collaborate on the many overlapping aspects of these projects."

8. SET STANDARDS TO THE QUALITY OF WATER INSTEAD OF THE TECHNOLOGY USED.

By focusing on performance standards, governmental agencies are better able to craft the best standards possible while the market is left to find the tools that best achieve those standards.

9. USE BUILDING AND PLUMBING CODES TO SET A REUSE MANDATE POLICY BASED ON THE SIZE OF NEW CONSTRUCTION.

This final governance recommendation is based on the success that Article 12C in San Francisco has experienced, which requires that all new construction built at or above 250,000 square feet must include an onsite non-potable reuse system (SFPUC, n.d.-b).

PUBLIC EDUCATION

One of the greatest challenges to water reuse implementation is overcoming the stigma about reclaimed water and its risks. While technology already exists to treat reclaimed water to levels that meet or exceed health standards, only having adequate technical capacity is not sufficient. The idea of water reuse can trigger revulsion in some. Stakeholders, especially the public, may be reluctant to embrace water reuse due the “yuck factor,” a discomfort with the idea of using wastewater. Many people sense an inherent unpleasant and unsanitary feeling about reusing water from any source for any application (William J Worthen Foundation, 2018).

Research confirms that outreach and engagement strategies can overcome the “yuck factor” and help build a mindset of acceptance. A survey commissioned by Xylem Inc., a water technology company, found that about 89% of California residents were “more willing” to use recycled water after learning about the treatment process (Lim & Safford, 2019). Public engagement can create a sense of ownership and increase support and acceptance of water reuse projects.

Moreover, the delivery of the message is just as important as the content. The public reaction to water reuse is often influenced by “affect heuristic.” It is a psychological principle that represents an instinctive reliance on prior experiences in relation to a stimulus, which makes it harder for people to overcome the feelings of disgust associated with wastewater and accept the scientific evidence for safe use of reclaimed water. In order to combat this, tailoring the message about water reuse is critical. Our team therefore recommends that the DEP do the following in terms of public education considerations:

10. **DELIVER THEIR REUSE MESSAGE IN CLEAR AND NON-TECHNICAL LANGUAGE, AVOIDING TERMS WITH NEGATIVE CONNOTATIONS SUCH AS “SEWAGE” AND INCORPORATING WORDS WITH POSITIVE CONNOTATIONS SUCH AS “CLEAN” AND “SUSTAINABLE” (LIM & SAFFORD, 2019). THEY SHOULD ALSO HIGHLIGHT THE LOW RISKS OF WATER REUSE AND THE BENEFITS OF SUCH AN APPROACH EARLY IN THE PROJECT.**

    One informational interviewee overheard part of a conversation that sums it up best:

    "‘We all love our source water [in NYC]; why are we flushing it down our toilets? Why don't we be more efficient with it?’"

CONCLUSION

The research process was informative not only because it worked to uncover the great resources we found, but also because of the knowledge gaps that arose with them. The most difficult part of the research process was not understanding what water reuse is and what the process of onsite-water reuse entails, but rather what the financial aspects of reuse systems are. The costs of these systems vary case by case depending upon location, treatment type, and building size or amount. A future step for research would be to compile a guidebook that outlines the estimated cost of these systems according to the scale of the project as well as the selected treatment system. This would allow private developers, public officials, and policy-makers to make better-informed decisions about water reuse. Having an outline would streamline the implementation process for stakeholders.

Water has been central to New York City's development. Without the pristine reservoirs upstate and extensive infrastructure, the City could not have grown to the size that it is today. Due to aging infrastructure, stress on combined sewers, and need for climate resiliency––all compounded by climate change––New York City must look to innovative water conservation practices. We believe that a water reuse strategy would be effective at mitigating these presented issues. If executed correctly, a strategy for water conservation can be considered safe, innovative, and supportive of the City's path toward resiliency in the 21st century.

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APPENDIX B: INTERVIEW QUESTIONS

Below is a list of general interview questions used. More specific questions were formed for interviewees depending on his/her expertise.

1. What do you think prevents/impedes successful implementation of a water reuse system?
2. How do you think being in a water rich area vs. a water scarce area influences implementing a water reuse program?
    - How much do you think being in a water scarce area has influenced water reuse policy?
    - How did it shape the choices made in governance, finance, and technologies used?
3. What governance elements needed to be in place to have a successful reuse system?
4. What governance elements specifically?
5. *Is there any question that I haven't asked, that I should be asking? Is there anyone else you can direct us towards that can provide more insight?*

APPENDIX C: NEW YORK CITY MAPS

Figure 1: New York City's Water Supply System
Source: (NYC DEP, n.d.-c)

Figure 2: New York City Water Demand and Population Growth
Source: NYC DEP 2019 Planning Estimates

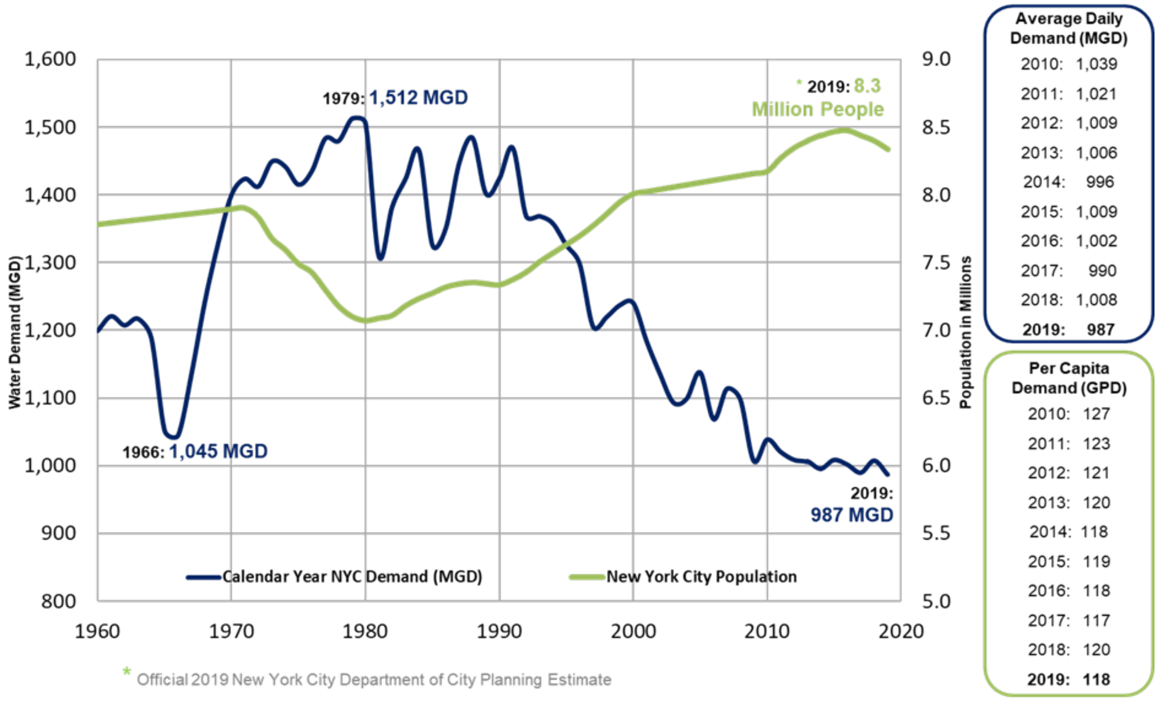


Figure 3: Map of Delaware Aqueduct Bypass Project.
Source: (Alle Gramiccio, 2017)

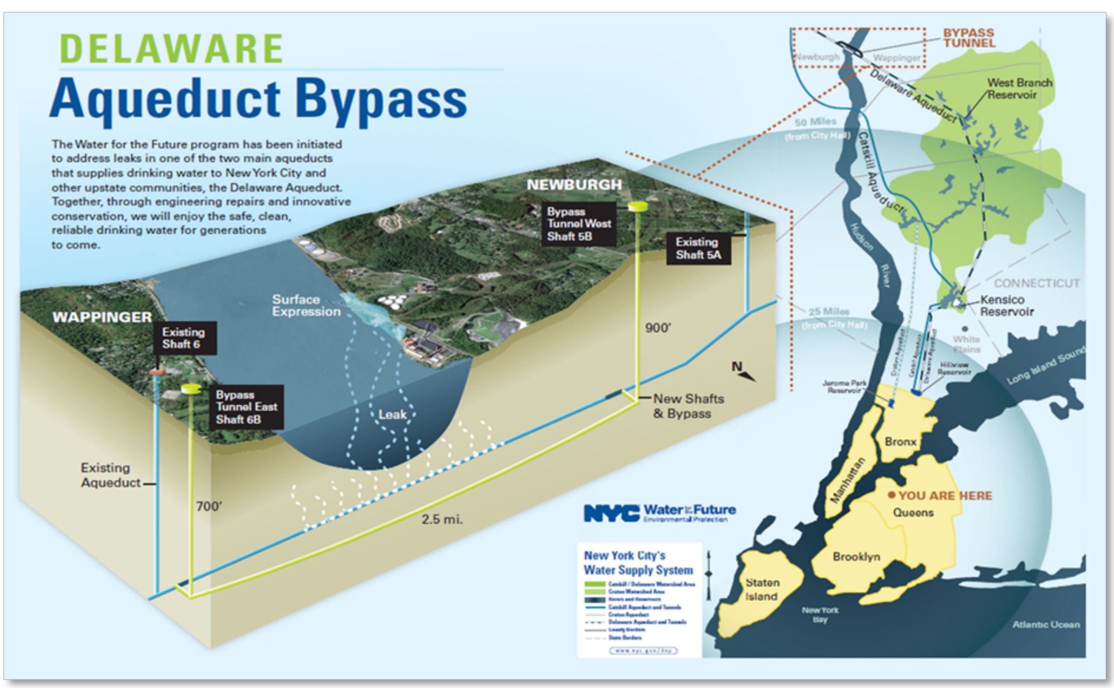


Figure 4: Map of CSO Outfalls
Source: (NYC DEP, n.d.-b)

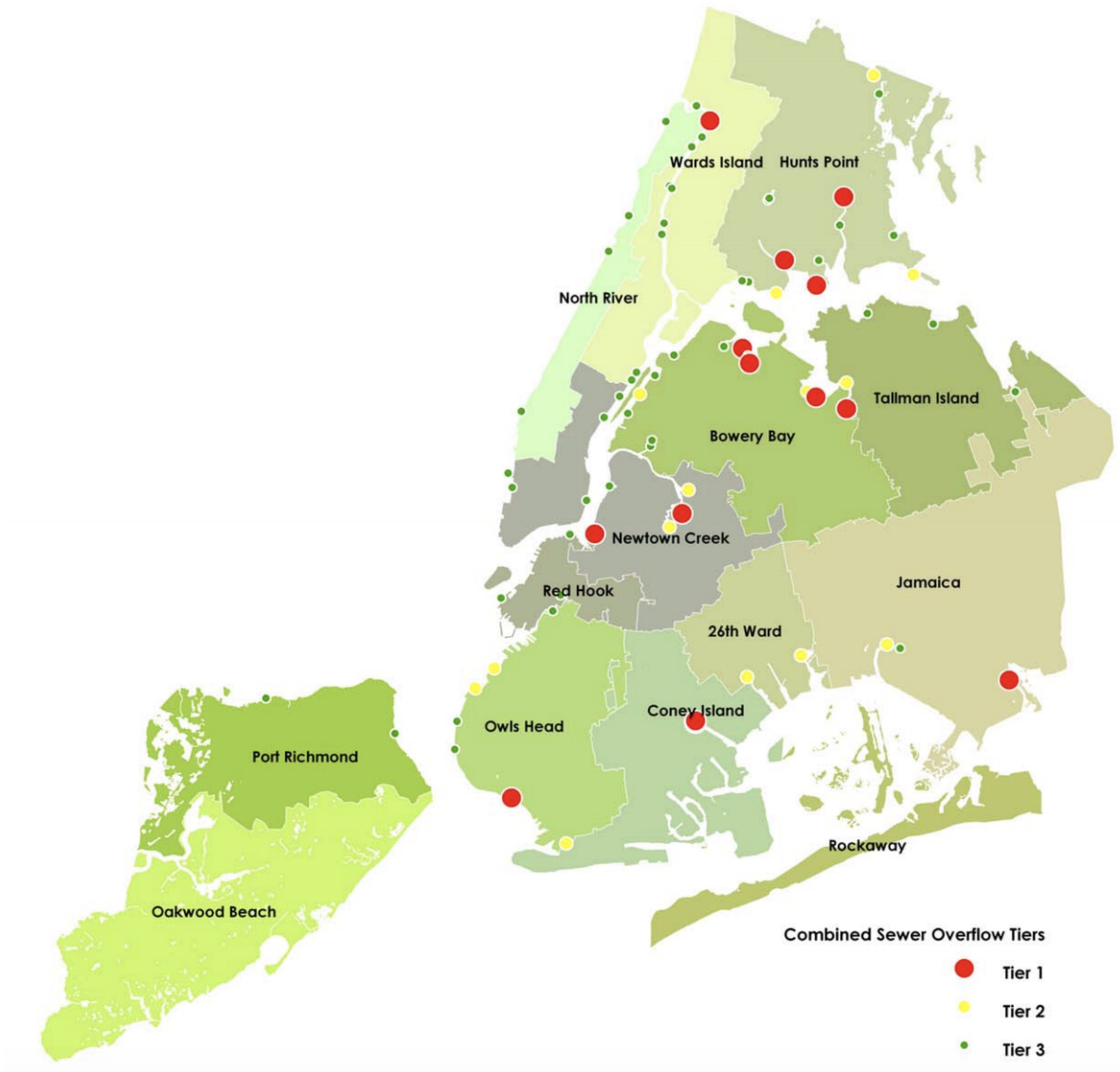


Figure 5: Map of Water Pollution Control Plants
Source: (NYC DEP, n.d.-d)

1.3 billion gallons of wastewater is treated each day across the 14 wastewater treatment plans in New York City. The treatment plants are located in Red Hook,Port Richmond,Tallman Island, Wards Island, Owls Head, Rockaway, Oakwood Beach, North River, Newtown Creek, Jamaica, Hunts Point, Coney Island, Bowery Bay, and 26th Ward.

Figure 6: Total Construction Market Volume by Sector (IHS)
Source: (Garcia, n.d.)

HISTORIC | FORECAST

Sector	2015	2016	2017	2018	2019	2020	2021	2022
Total (x $1m)	**71,265**	**64,537**	**62,816**	**60,121**	**59,951**	**56,801**	**55,074**	**53,259**
Residential	30,179	21,646	21,262	19,119	20,140	17,599	16,684	15,915
Commercial	7,959	9,653	9,976	10,278	9,519	9,131	8,750	8,246
Manufacturing	2,278	2,161	1,848	1,730	1,691	1,641	1,563	1,531
Healthcare	2,521	2,512	2,592	2,502	2,483	2,561	2,617	2,644
Education	9,328	9,966	10,301	10,018	9,486	9,650	10,020	10,284
Other Struct*	5,041	5,237	5,590	5,652	5,421	5,163	4,935	4,768
Infrastructure	13,959	13,363	11,248	10,822	11,212	11,055	10,505	9,872
Total Increase	**Y-O-Y %**	**-9.4%**	**-2.7%**	**-4.3%**	**-0.3%**	**-5.3%**	**-3.0%**	**-3.3%**
Residential	Y-O-Y %	-28.3%	-1.8%	-10.1%	5.3%	-12.6%	-5.2%	-4.6%
Commercial	Y-O-Y %	21.3%	3.4%	3.0%	-7.4%	-4.1%	-4.2%	-5.8%
Manufacturing	Y-O-Y %	-5.2%	-14.5%	-6.3%	-2.3%	-2.9%	-4.8%	-2.0%
Healthcare	Y-O-Y %	-0.3%	3.2%	-3.5%	-0.7%	3.1%	2.2%	1.0%
Education	Y-O-Y %	6.8%	3.4%	-2.7%	-5.3%	1.7%	3.8%	2.6%
Other Struct*	Y-O-Y %	3.9%	6.7%	1.1%	-4.1%	-4.8%	-4.4%	-3.4%
Infrastructure	Y-O-Y %	-4.3%	-15.8%	-3.8%	3.6%	-1.4%	-5.0%	-6.0%

Figure 7: GIS visualization of building projects in New York City by borough between 2018-2020.
Data Source: (NYC OpenData, n.d.)

Figure 8: GIS visualization of building projects for each year between 2018-2020. Data Source: (NYC OpenData, n.d.)

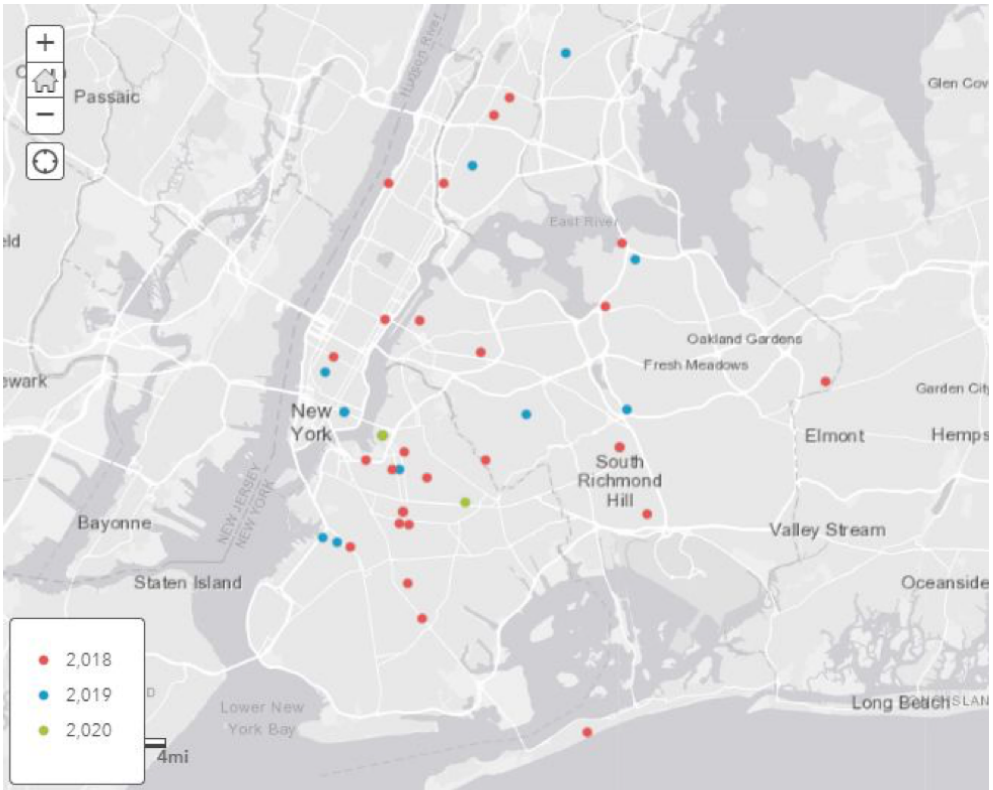
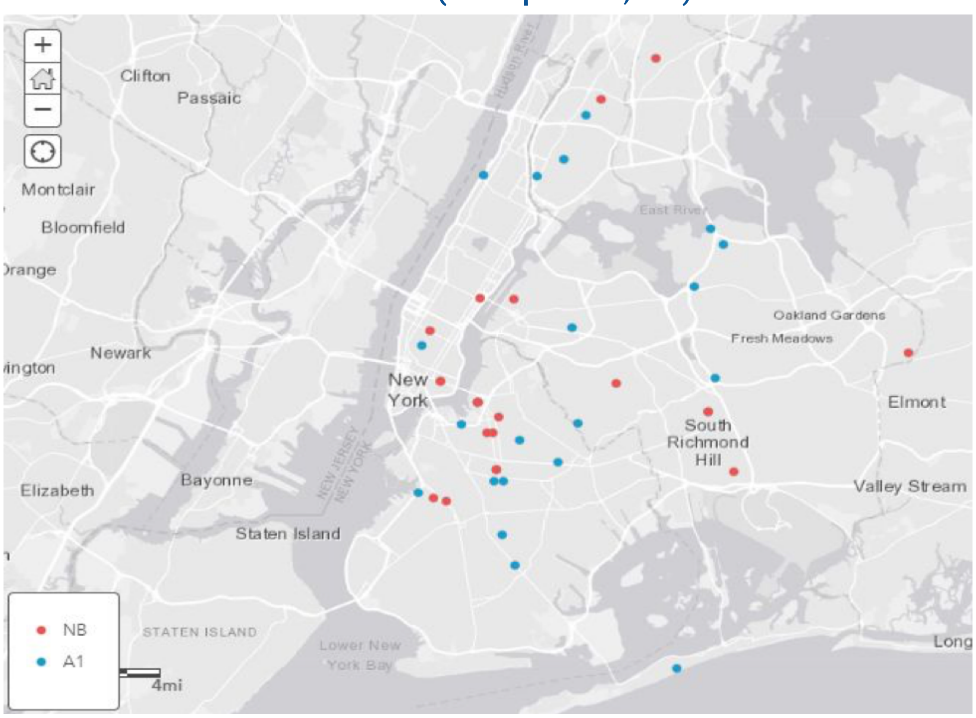


Figure 9: GIS visualization of building projects in New York City broken down by project type. NB: New building. A1: alterations, which impact the use or occupancy of a building.
Data Source: (NYC OpenData, n.d.)



APPENDIX D: SAN FRANCISCO TABLES

Table 1: Water Quality Requirements for Graywater Systems (SFDPH, 2017).

Parameter	Water Quality Limit	Monitoring Frequency
BOD_5	• The maximum concentration shall not exceed 25 mg/L at any time; and • The average concentration shall not exceed 10 mg/L utilizing the results of the last 4 weeks for which analyses have been completed (Start-Up).	Weekly, Monthly[1]
TSS	• The maximum concentration shall not exceed 30 mg/L at any time; and • The average concentration shall not exceed 10 mg/L utilizing the results of the last 4 weeks for which analyses have been completed (Start-Up).	Weekly, Monthly[1]
Virus	Treatment must achieve at least: • 6.0-log reduction in enteric virus for indoor reuse OR • 5.5-log reduction in enteric virus for outdoor reuse.	Continuously (via surrogate parameter(s))
Protozoa	Treatment must achieve at least 4.5-log reduction in parasitic protozoa for all end use applications.	Continuously (via surrogate parameter(s))
Bacteria[2]	Treatment must achieve at least 3.5-log reduction in enteric bacteria AND/OR meet the Total Coliform requirements listed below: • The median concentration shall not exceed an MPN of 2.2 /100 mL utilizing the bacteriological results of the last seven days for which analyses have been completed; and • The maximum number shall not exceed an MPN of 23 /100 mL in more than one sample in any 30 day period; and • No sample shall exceed an MPN of 240 /100 ml at any time.	Continuously (via surrogate parameter(s)) Daily, Other[2]
Turbidity	For media filter: • The median concentration shall not exceed 2 NTU within a 24-hour period; • The maximum shall not exceed 5 NTU more than 5 percent of the time within a 24-hour period; and • No sample shall exceed 10 NTU at any time. For membrane filter: • The maximum shall not exceed 0.2 NTU more than 5 percent of the time within a 24-hour period; and • No sample shall exceed 0.5 NTU at any time.	Continuously
Chlorine Residual	Over any 24-hour period, the average chlorine residual shall be within the range 0.5 – 2.5 mg/L.	Continuously
pH	At all times, the pH shall be between 6 and 9.	Weekly
Odor	The system shall not emit offensive odors.	n/a
Flow	At least one flow meter must be installed.	Continuously

Notes:

1. Systems shall be sampled weekly for BOD and TSS during the Conditional Startup Mode period, after which monthly sampling shall be performed. Based on the results, the Director may reduce the frequency of sampling as described in Section 11 of these rules and regulations.
2. Pathogenic microorganism control for bacteria is achieved by complying with water quality limits for total coliform. Total coliform sampling shall be conducted daily during the Conditional Startup Mode. Based on the results, the Director may reduce the frequency of total coliform sampling during Final Use Mode or may allow surrogate parameter monitoring for systems that can meet the specified log reduction targets as described in Section 11 of these rules and regulations. If total coliform testing sampling frequency is reduced to weekly or less, the maximum number shall not exceed an MPN of 2.2 /100 mL or additional sampling will be required.

Table 2: Example continuous monitoring methods used for the different treatment processes (SFDPH, 2017).

Treatment Process	Example Continuous Monitoring Methods
Microfiltration or Ultrafiltration	• Daily pressure decay test • Effluent Turbidity
Membrane Biological Reactor (MBR)	• Effluent Turbidity
Reverse Osmosis	• Influent and Effluent Total Organic Carbon (TOC) • Influent and Effluent Electrical Conductivity
Ultraviolet Light Disinfection	• Influent UV transmittance • Influent turbidity • UV intensity • Flow rate
Chlorine Disinfection	• Free chlorine residual • Flow rate
Ozone Disinfection	• Ozone residual • Flow rate
Notes: 1. The information presented herein is for informational purposes. Specific requirements will be approved by SFDPH-EH based on details provided by the Project Applicant in the Engineering Report.	

Table 3: Reporting frequency for each type of Alternate Water Source System (SFDPH, 2017).

Alternate Water Source	Routine Reporting Frequency[1]
Blackwater	Monthly
Graywater	Monthly during Conditional Startup Mode, Annually thereafter[2]
Foundation Drainage	Monthly during Conditional Startup Mode, Annually thereafter[2]
Stormwater	Monthly during Conditional Startup Mode, Annually thereafter[2]
Rainwater[3]	Monthly during Conditional Startup Mode, Annually thereafter[2]
Notes: 1. Operational changes, system malfunctions, and/or monitoring results which are outside of the applicable water quality limits shall be reported within 24 hours. 2. Reduced reporting frequency after Conditional Startup Mode is contingent on the Director's approval. 3. Rainwater systems that are used for subsurface irrigation, drip irrigation, or non-spray surface irrigation and, at a minimum, include a first flush diverter, and a 100 µm filter, do not require water quality monitoring or reporting.	

Table 4: Training and Education Resources found in the Permitting of Alternate Water Source Systems Application Packet (SFDPH-EH, 2019).

City and County of San Francisco
DEPARTMENT OF PUBLIC HEALTH
ENVIRONMENTAL HEALTH

Training and Education Resources for Treatment System Managers of Alternate Water Source Systems in San Francisco for compliance with Article 12C of the San Francisco Health Code

Alternate Water Source Systems permitted under Article 12C are required to comply with all requirements in the Rules and Regulations located at: http://www.sfdph.org/dph/files/EHSdocs/ehsWaterdocs/NonPotable/SFHC_12C_Rules.pdf

Depending on the design and components, operating an alternate water source treatment system may require basic or specialized knowledge about water chemistry, plumbing, mechanical and electrical systems and public health.

All Treatment System Managers are required to sign and date an affidavit attesting to their qualifications and abilities to operate the system for which they are responsible. The Rules and Regulations governing Article 12C are explicit about what qualifications are required to operate a blackwater or graywater treatment system, whereas Treatment System Managers for other types of Alternate Water Source Systems must note the relevant training, certifications, education and/or experience that qualifies them to safely operate a compliant on-site alternate water source treatment system.

The California State Water Resources Board offers a certification for Water Treatment Operators that contains material relevant to managing an onsite alternate water system: http://www.waterboards.ca.gov/drinking_water/certlic/occupations/DWopcert.shtml

Other training and education resources are also available. San Francisco Department of Public Health Environmental Health Branch does not recommend specific training or education resources, however we are aware of the following entities that may offer relevant training and education for Alternate Water Source System Treatment System Managers to consider:

- Architectural Record Continuing Education Center
- American Society of Civil Engineers
- American Society of Plumbing Engineers
- American Institutes of Architects
- American Public Works Association
- American Rainwater Catchment Systems Association
- Build It Green
- Greywater Action
- Irrigation Association
- National Onsite Wastewater Recycling Academy (NOWRA)
- United States Green Building Council
- Texas A&M University TEEX

SFDPH will update this list upon learning of additional providers of relevant educational and training opportunities for Treatment System Managers.

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