2022-2023 Research Agenda

Bureau of Water Supply

NYC Environmental Protection

Vincent Sapienza, P.E.
Commissioner

Paul V. Rush, P.E.
Deputy Commissioner
Bureau of Water Supply

Sunset at Pepacton Reservoir

As we look toward the future of New York City's water supply system, it is often helpful to learn from the past.

This year marks 180 years since the first parts of our reservoir system were put into service. Across that time, the construction, operation, and protection of New York City's water supply has benefited from an ever-growing body of research and innovation.

That tradition of long-term planning and strategic thinking began long ago, in the early 1800s, when our predecessors designed a system of reservoirs and aqueducts that delivers water by gravity alone. Unique masonry techniques were used to build many of our dams, using equipment that was invented by water supply engineers specifically to quarry and haul large stones. Trees were planted around our reservoirs decades ago to protect them from contamination, and the first wastewater plants were built in the watershed to keep human waste separate from clean water. Our colleagues today have developed new laboratory methods to find and track waterborne pathogens, improved our treatment processes to disinfect water with ultraviolet light, and employed smart rocks and underwater listening devices to analyze the hydrodynamics of our watershed streams.

This work has continued across many generations because of New York City's steadfast belief in long-term planning. Our staff at DEP are always looking to the future while asking a critical question: What comes next?

The answer is reflected in the pages of this report – a rundown of research efforts that DEP employees will focus on over the next several years to ensure our high-quality sources of drinking water are well protected, treated, and monitored. These include efforts to monitor emerging contaminants, study and prepare for the ongoing effects of climate change, aggregate billions of historic and real-time data to improve our predictive analytics, and much more.

Our work might focus on different topics across nearly two centuries, but the mission remains the same. We must act on sound science and apply the best-available technologies to deliver high-quality water that protects the health of our fellow New Yorkers.

Sincerely,

Paul V. Rush, P.E., Deputy Commissioner

Amawalk Reservoir

Table of Contents

Water quality monitoring buoys
at Kensico Reservoir

Introduction

The New York City Department of Environmental Protection (DEP) continues its commitment to remain at the forefront of the water sector by conducting innovative research and implementing best practices to ensure efficient use of resources and optimize investments in technology. The Bureau of Water Supply (BWS) recognizes the need for a flexible research program to meet the ever-changing regulatory landscape and water supply operational challenges. This 2022-2023 BWS Research Agenda provides a framework and context for the bureau's research in the coming years. As we look to the future, there are numerous factors influencing the bureau's near-term research: effects of climate change, implementation of the Lead and Copper Rule Revisions, the Environmental Protection Agency's (EPA) six year review of microbial and disinfection byproduct rules, and the EPA's recent Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) Strategic Roadmap, all of which are directing the bureau's priorities.

Context

The 2020-2021 BWS Research Agenda was predicated on the agency's 2018 Strategic Plan to ensure that DEP stays at the forefront of the water sector by engaging in research, increasing our involvement in peer learning organizations, and influencing regulatory policymaking. In response to this charge, the bureau has led DEP in coordinating an agency-wide research team focused on collaboration while expanding its own research capacity.

Looking ahead, the bureau seeks to build on these principles in order to engage with emerging challenges and federal regulations. New and changing regulatory requirements for lead, microbial and disinfection byproducts, and PFASs – also called "forever chemicals" – are reflected in the bureau's research. Previous studies on these topics provide BWS with a robust body of research to draw conclusions and refine new studies going forward.

Similarly, extreme rainfall events and periods of drought are becoming more frequent in New York City and the watersheds, and increased temperatures are becoming normalized throughout the region. Warming temperatures and extreme rainfall can affect reservoir chemistry and hydrology, and mobilize nutrients and turbidity, resulting in changes to water quality that include taste and odor as well as increased frequency of harmful algal blooms. The variability of our region's climate will also likely result in periods of drought as well. These changes create opportunities for invasive species to proliferate and expand their range. As a result, new data infrastructure and modeling applications are critical to inform how a shifting climate affects daily and long-term operations of the water supply.

Numerous other studies are underway to examine a wide-range of issues including but not limited to stream turbidity studies, treatment at the Croton Filtration Plant, drone applications, unmapped wetlands assessments, acoustic monitoring for endangered bat species, and models to assess nutrient loading in reservoirs. The small investment in our research agenda provides the bureau with the institutional knowledge to collaborate effectively within DEP, and partner with academic institutions and professional organizations to eliminate redundancies and optimize future spending.

Wetlands in the Delaware watershed

Framework

A standardized framework to organize research provides researchers with the ability to build upon previous studies and identify opportunities to collaborate. To that end, an inventory of all research planned, underway, and completed is maintained across several agency bureaus, including BWS. This inventory is updated regularly and catalogues the agency's research by utilizing a flexible framework and hierarchy. Key to the inventory is a clear definition of what is classified as research. As such, all research projects must meet one or more of the following for inclusion in the inventory:

- Answer a specific research question
- Test a hypothesis
- Validate new technology or practice
- Advance knowledge of a particular discipline or issue
- Generate questions for future research

If a research project meets the above criteria, it is classified within four core subject areas that serve as a framework for research priorities moving forward:

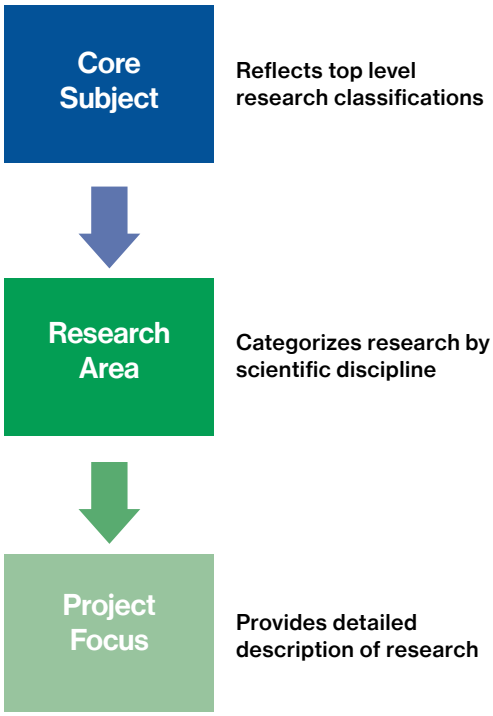
Environment is inclusive of all studies pertaining to the interface of the natural environment with the water supply and includes terrestrial, aquatic, climatological, air, and water resources such as streams, lakes (reservoirs) and wetlands.

Innovation covers all new and emerging technologies, novel methods and strategies to better manage and operate the City's water supply, as well as studies and research pertaining to emerging challenges.

Public Health captures projects committed to ensuring safe, clean water is delivered to all users. It includes research related to water quality, treatment, and regulatory requirements.

Sustainability includes opportunities for the water supply to be self-sustaining in the areas of energy, infrastructure, financing, and hydrology.

Figure 1: Research Framework



As of October 2021, BWS had 52 active or planned research projects. Across the core subjects, the Research Inventory includes 25 research areas (Figure 3). A complete overview of BWS research is reflected in Appendices 1-4. Figures 2 and 3, below, show a high-level summary of the Bureau's existing research inventory.

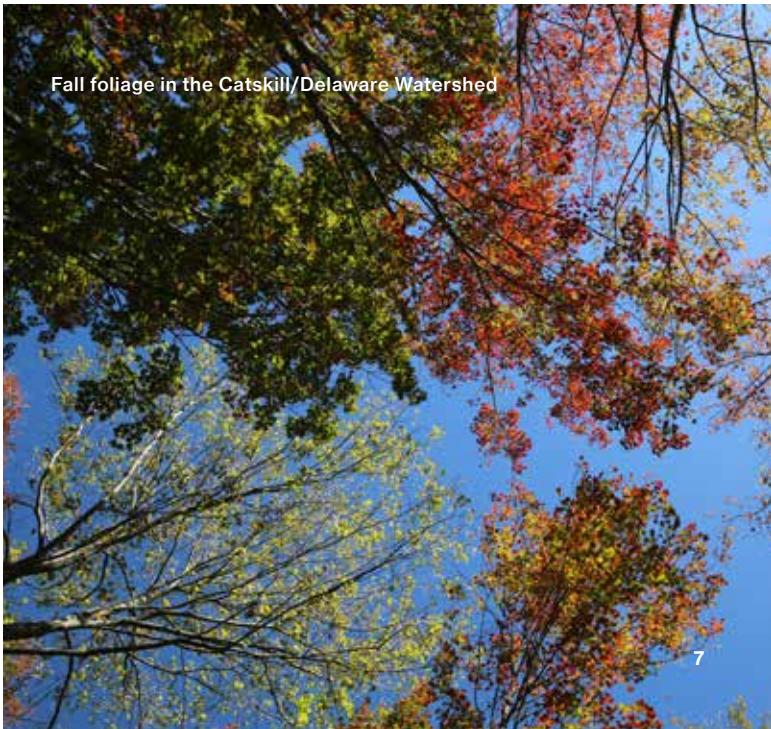
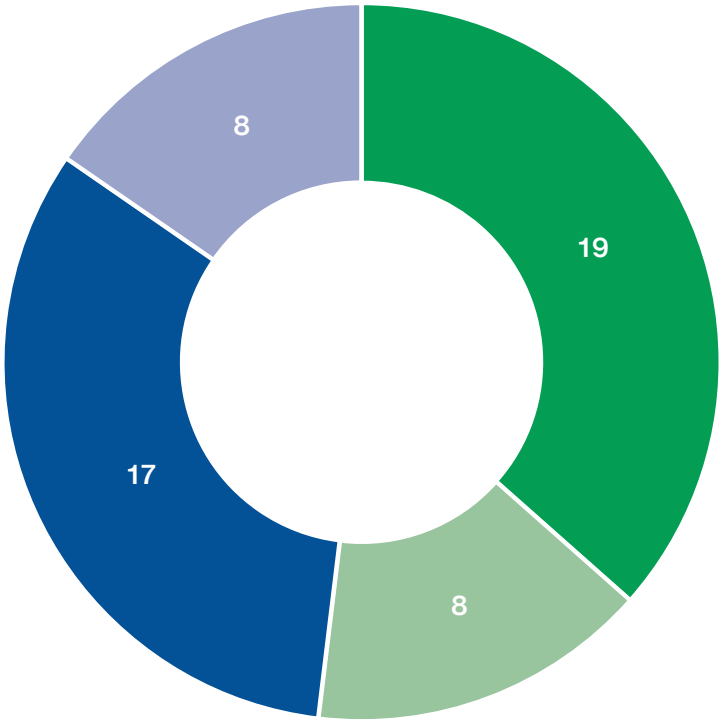

Fall foliage in the Catskill/Delaware Watershed

Figure 2: Research Projects by Core Subject



Environment

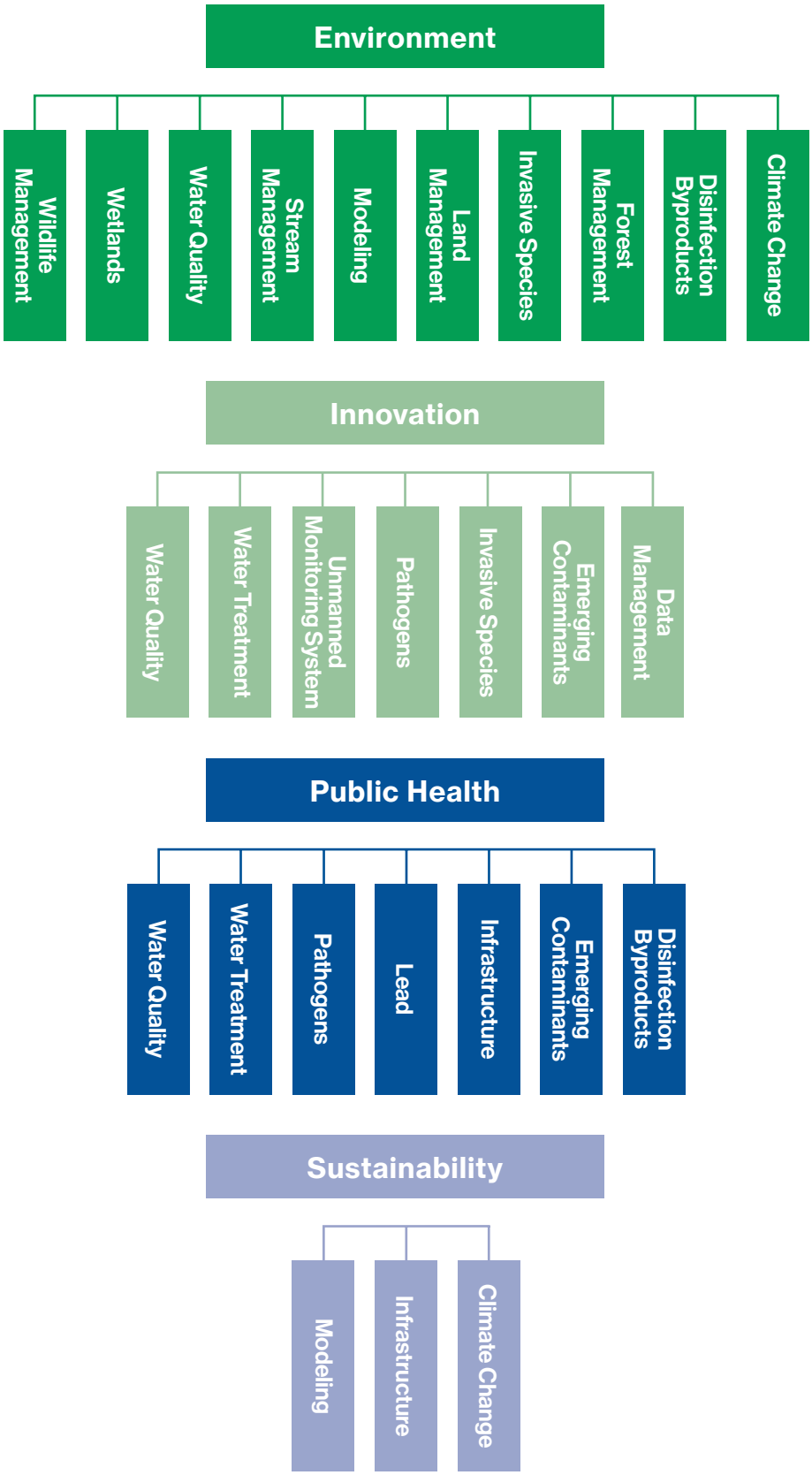
Sustainability

Public Health

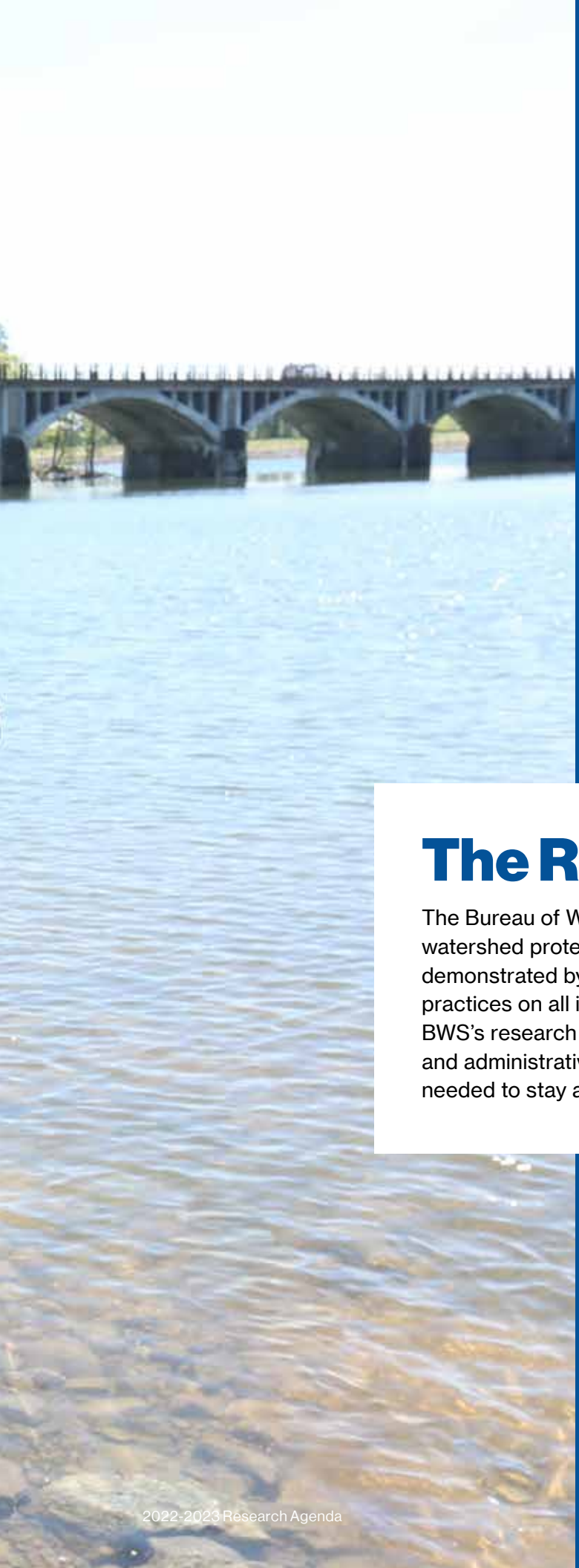
Innovation

Catskill Aqueduct Repair and Rehabilitation

Figure 3: Research Areas by Core Subject



DEP field scientists work on fixing a robotic monitoring buoy



The Research Agenda

The Bureau of Water Supply is committed to excellence in watershed protection, water supply operations, and water quality, demonstrated by engagement in innovative research and best practices on all issues related to water supply management. BWS's research is supported by a wide array of disciplines and administrative support, providing the human infrastructure needed to stay at the forefront of the water sector.

As we consider the inventory of research and challenges anticipated in the coming years, specific themes emerge as a result of climate change and regulatory requirements. Where the research inventory serves as a compendium of all research underway, the research agenda outlines the justification for research based on the most critical regulatory, environmental, and operational challenges that BWS is facing. Those challenges include, but are not limited to the following:

1 Public Health > Lead > Lead and Copper Rule Long-Term Revisions

Lead poisoning can lead to learning and behavior problems in children. Young children are most at risk. Peeling lead paint (and the dust it turns into) is the most common cause of lead poisoning, not lead in water. New York City's source water is lead free, delivered from upstate reservoirs through lead-free aqueducts and water mains. While the use of lead in household plumbing has been banned for decades, some older homes may still have lead pipes and fixtures. To prevent lead from leaching from household plumbing, DEP treats the City's water supply by adjusting the pH and by adding phosphoric acid, a common food additive, which forms a protective barrier on plumbing.

The Lead and Copper Rule Revisions (LCRR) were published in the federal register by the United States Environmental Protection Agency (EPA) in January of 2021. The LCRR has an effective date of December 16, 2021, and a corresponding compliance deadline of October 16, 2024. These multi-faceted revisions impact numerous obligations, requirements, and activities associated with lead for water supplies. Most notably, the revisions call on utilities to comply with a new action level, expand sampling, re-optimize corrosion control, update lead service line inventories, establish requirements and procedures for the replacement of lead service lines, and develop a Lead Service Line Replacement Plan.

DEP scientist collecting biological samples at Schoharie Creek

DEP has been fully engaged in at-the-tap lead monitoring and corrosion control since the 1990's and has been preparing for the implementation of the LCRR. In addition to regular compliance lead and copper monitoring, and the free residential at-the-tap lead testing program, DEP has been conducting a corrosion control optimization study since 2018.

In 2021, DEP's Commissioner formed a multi-bureau Lead Task Force focused on compiling information on corrosion control and lead service line replacement scenarios and strategies, developing accurate inventory methods, analyzing data for compliance forecasting, and formulating a lead management strategy to guide decision-making and resource allocation.

2 Environment and Public Health > Disinfection Byproducts > Stage 2 Disinfectant/Disinfection Byproducts Rule

The EPA has initiated the fourth six-year review of microbial and disinfection byproduct rules, anticipated to be completed in early 2023. Chlorine, one of the disinfectants that DEP uses to treat bacteria and inactivate *Giardia* and viruses, can react with certain natural organic matter in the water to form disinfection byproducts including trihalomethanes, haloacetic acids, chlorite, and bromate. As with all federal regulations, BWS continues to advance research in this field to deliver source water that is low in natural organic matter while optimizing chlorination to meet all disinfection and residual requirements.

BWS continues to use innovative approaches to monitor the watershed reservoirs and streams for the natural organic matter that presages DPB formation. An ongoing bureau priority is to complete a study to select proxy measurements for DBP formation potential and finalize a model that would utilize these proxies to facilitate rapid operational and treatment decisions. More recently, an expert panel convened by the bureau has recommended modifications to the bureau's trend analyses of trihalomethanes and haloacetic acids by focusing on influents from the Catskill and Delaware systems at Kensico Reservoir, including drivers during extreme weather events, and to consider opportunities to optimize disinfection throughout the system. DEP has and will continue to conduct studies, workshops, and data analysis efforts to identify operational, treatment, and watershed management practices to help reduce DBPs and ensure our continued ability to maintain the Filtration Avoidance Determination.

DEP biologist at the Kingston laboratory

3 Environment > Emerging Contaminants > Harmful Algal Blooms

An algae bloom with the potential to harm human health or aquatic ecosystems is referred to as harmful algal bloom (HAB). In freshwater systems, cyanobacteria are the microorganisms that produce HABs that have the potential to produce toxins known as cyanotoxins. The EPA does not currently regulate cyanotoxins. However, EPA encourages public water supplies to consider how likely their water system are to encounter a harmful algal bloom (HAB) in their source water.

BWS routinely monitors for algae and cyanobacteria blooms, and subsequently reports any discovered blooms following the guidance of the New York State Department of Environmental Conservation. Taking into consideration HAB risk factors, as defined by EPA's guidance documents on HABs, DEP reservoirs in the water supply could be vulnerable to potential HABs. BWS is staying abreast of research in this field of study as it pertains to the water supply; for example, BWS is participating in a project to assess the vulnerability of source waters to toxic cyanobacterial outbreaks. The project is a collaboration of water utilities studying the possibility of using new methods of artificial intelligence by incorporating water quality data, weather station data, and satellite imagery to develop risk metrics of a HAB forming in a given waterbody. BWS is also piloting the use of Phytoxigene, an innovative new technology to help detect and characterize cyanobacterial blooms, and the use of drones outfitted with hyperspectral imagery to detect extent of cyanobacterial blooms.

4 Sustainability > Treatment > Croton Taste and Odor

The Croton Water Supply System's source water is treated at the Croton Water Filtration Plant, located underground in the Bronx, and is a critical component of the New York City water supply. As the City undertakes repairs to the Delaware Aqueduct and seeks to meet demand while buffering water availability during droughts, the

The Croton Water Filtration Plant

Croton supply plays a pivotal role to ensure a sustainable water supply for all City residents. Essentially, the Croton system increases the flexibility of the water supply, ensuring the City can respond to evolving effects of climate change and creates redundancy to facilitate infrastructure improvements now, and for decades to come.

As the City utilizes the Croton supply more frequently, emerging challenges, such as changes to taste and odor, must be addressed to ensure a sustainable water supply. The City has experienced episodic taste and odor events annually since the fall of 2018. Research and monitoring has identified two main taste and odor compounds of concern in the Croton supply source water, geosmin and 2-methylisoborneol (MIB). When these compounds are present in the drinking water, they can be detected by consumers at extremely low levels, leading to an increase in customer complaints.

The City is monitoring for these taste and odor compounds on a regular basis to assist in managing the supply and further understand the mechanism(s) causing increased levels in the source water. Research into the source(s) of the production of these taste and odor compounds is on-going and several studies are underway to identify opportunities to optimize Croton Filtration Plant operations. Further study is needed to understand the specific organisms that may be producing these compounds, and why they are producing these compounds at certain times of the year. The bureau is working to convene an expert panel to develop a roadmap for future research and operation of the Croton system.

5 Public Health > Emerging Contaminants > PFAS

The EPA issued a PFAS Strategic Roadmap—laying out a whole-of-agency approach to addressing PFAS. Initiated in the fall of 2021, the approach will enact a wide-ranging set of requirements from setting enforceable limits for public water supplies to limiting PFAS discharges in accordance with changes to NPDES requirements, improving analytical methods to enable monitoring in eight different environmental matrices, and updating methods for drinking-water monitoring and biosolids disposal.

Similarly, BWS will continue to monitor for all required PFAS compounds in addition to the components listed in the fifth Unregulated Contaminant Monitoring Rule, modify analytical methods as directed by the EPA and State agencies, and contribute to the emerging body of data as it pertains to water, aquatic life and biosolids.

There are nearly 1,000 water sampling stations throughout New York City.

6 Environment > Invasive Species

The naturally occurring ecosystems within the watershed provide services that maintain excellent water quality and underpin DEP's watershed protection programs and the Filtration Avoidance Determination. If left unchecked, invasive species threaten to disrupt the ecological balance within the watersheds by damaging water supply infrastructure and ecosystem services provided by the plants, animals, and microorganisms that we rely on for clean water. Climate change is expanding the range of several invasive species and creating more favorable conditions for many other invasive species to become established.

BWS has developed relationships with numerous federal, state, and academic stakeholders and partners on emerging invasive species and is using novel methods to prioritize, detect, and manage their populations. For example, BWS is working in partnership with Cornell University to utilize the introduction of a predator species (i.e., biocontrol) to manage hemlock woolly adelgid, an aphid-like invasive insect that is attacking eastern hemlocks, a critical tree species in the watershed. Further research is needed to optimize establishment and success of these insect predators. Another biocontrol study in partnership with the United States Department of Agriculture targets the emerald ash borer, an invasive beetle that targets native ash trees, causing significant mortality. Finally, in coordination with the State, BWS is actively managing Hydrilla, an invasive plant species, with an approved herbicide. Further research is needed to assess the efficacy of this treatment targeting New Croton Reservoir, and the future of this program as well as its water quality, taste, and odor impacts.

DEP foresters measure trees and prepare to release biocontrols near Neversink Reservoir

Recently identified invasive species in the watershed include zebra mussels and the spotted lanternfly. The zebra mussel was identified in Amawalk Reservoir and poses a significant threat to our water supply infrastructure. The spotted lanternfly is an emerging invasive species that threatens watershed facilities and forest health. An innovative approach to monitoring for new species and tracking existing species is the use of environmental DNA (eDNA). BWS utilizes a contract laboratory to assess the efficacy of this method to identify the presence of invasive species through eDNA extracted from water and soil samples.

7 Innovation > Data Management > Data Lake

BWS monitors and collects millions of data points from all over the water supply and distribution system which are used to assist in the management of the water supply and ensure that the highest quality water is delivered to NYC and outside communities. These data include a wide range of various data sources including sensors that capture data directly in the field in either real-time or near real-time, as well as samples or measurements analyzed in a laboratory. Advancements in technology are creating increases in data volume, data variety, and data velocity. BWS is adapting to these advancements by utilizing state of the art business intelligence tools to retrieve, store, analyze, and display data.

BWS has started a pilot program to utilize cloud technology to explore uses for water supply data. Cloud-based computing improves our existing data infrastructure by breaking down silos and allowing broader access to data and increased opportunities to conduct novel analyses. Initial stages of the pilot program were funded with Microsoft customer investor funding which included one dataset (Early Warning and Remote Monitoring). To validate the advanced capabilities of the cloud, BWS is modeling several operational datasets (delivery and treatment advisories, buoy profilers, lab sampling and additional operations data). The pilot is focused on data modeling, setting up the data pipelines that enable the bureau to push data from its source to the cloud, and establishing baseline dashboards and reports using Power BI. Subsequent stages will introduce testing and review of modern artificial intelligence and machine learning capabilities that cloud based data models offer.

8 Sustainability and Environment > Modeling Efforts > Predictive Models and Forecasts, Climate Change Scenarios

BWS relies on a variety of models to inform daily operations and long-term planning. New and ongoing research is primarily two-fold: developing predictive models and forecasts, and incorporating climate change scenarios.

To refine the bureau's responsiveness to weather conditions and improve its ability to model future conditions, several studies are planned to create and validate models used to forecast streamflow. Collectively, these studies will provide the modeling infrastructure needed to span daily water supply operations in tandem with the long-term forecasting to maintain the water supply for 8.8 million New York City residents.

The Soil and Water Assessment Tool underpins much of this work. This tool is a valuable modeling asset that generates time series data for water quality simulations and reflects downscaled current and future climate conditions. Most importantly, this tool generates future weather conditions that include extreme events (floods and droughts) and considers various levels of greenhouse gas emissions.

BWS is also collaborating with the Bureau of Sustainability on an innovative approach to predicting long-term demand under scenarios of climate change. This dovetails with our drought and Soil and Water Assessment Tool streamflow modeling to understand how drought affects the streamflow that supplies our reservoirs with water.

The nexus among demand and streamflow modeling under drought is the City's Operational Support Tool. The Operational Support Tool emulates the operation of the city's water supply with demand for water and streamflow to the reservoirs driving the system. The Operations Support Tool will be driven by scenarios of streamflow and water demand under drought which will allow the bureau to assess and then adapt to risks imposed by climate change on the City's water supply. This effort will ensure the city has a safe and reliable source of water for decades to come.

Completed Kensico Reservoir shoreline stabilization

East Branch Reservoir

Accomplishments

A retrospective on the past two years demonstrates several accomplishments set forth in the previous research agenda. In particular, the need to develop a process for reviewing proposed research and a gap analysis to identify any new research needs or gaps within existing research were both successfully implemented. In addition, numerous studies evaluating lead in drinking water were completed. A summary of this body of research is highlighted below.

1 Research Proposal Process

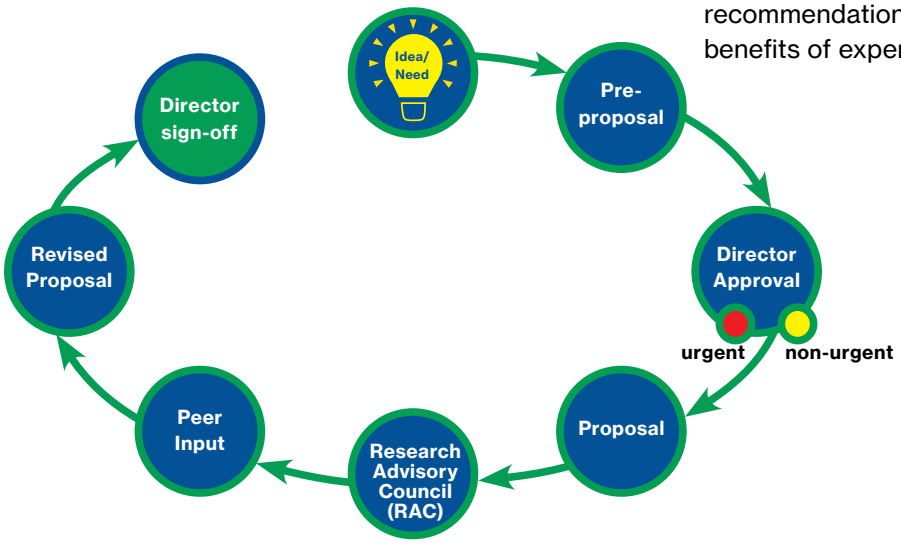
In 2020, the Bureau established its first Research Advisory Council (RAC) to focus on research priorities, establish and manage a research process, and act as a forum to communicate and support research initiatives. The RAC is a staff-level group with representation from all directorates: Executive, Management Services and Budget, Planning, Source Water Operations, Water Quality and Innovation, Water Treatment Operations, Watershed Protection Programs, and Environmental Health and Safety.

The Research Advisory Council prioritized the creation of a research proposal process to streamline and standardize how research projects are initiated in BWS and how they collectively support our Research Agenda.

All new research projects (see Fig. 4) will be initiated with a pre-proposal form to be approved by the appropriate Director. If approved by the Director, the proposal is submitted to the RAC for member review. In addition, a Peer Input Team is assigned to give feedback to the researcher. These reviews are intended to identify opportunities to strengthen the proposed research and ensure a robust and scientifically sound study. Once RAC feedback is incorporated into the research proposal and director approval is finalized, the research can begin. Guidance documents including instructions, process, peer input, and forms were developed by the RAC and are available to all staff in BWS.

Not only does this process improve study design, it also creates opportunities to collaborate on important research efforts by identifying economies of scale or creating synergies within and between agency research. Equally important, it provides the bureau with an opportunity to maximize existing resources to support the most pressing needs of the water supply. The research process is intended to create more transparency in research opportunities and to enhance collaboration within BWS and its research partners.

Figure 4: Research proposal process flow diagram



2 Research Gaps Analysis

The 2020-2021 Research Agenda identified existing research within BWS and noted the need to conduct a gap analysis to align research with the Agency's goals. The gap analysis to identify research to be considered by the bureau was completed in 2021 by the Research Advisory Council. The gap analysis identified research areas for consideration – community vitality, economic impact, emergency management, freshwater salinization, groundwater, restoration, smart technologies, utility management and workforce development. Similarly, the gap analysis identified new research needs in the existing areas of emerging contaminants, invasive species, water treatment, and disinfection byproducts.

3 Others

Additional accomplishments include the National Academies of Sciences, Engineering, and Medicine's evaluation of the City's watershed protection programs, and a two-day workshop convened with subject matter experts to analyze modeling and operational efforts designed to limit DBPs and model their precursors.

A committee of the National Academies reviewed and evaluated the watershed protection program and determined that the current suite of individual programs is appropriate and adequate to comply with the Filtration Avoidance Determination. The final report found that the watershed protection program is generally well-balanced, and made recommendations for ways to optimize incremental benefits of expenditures.

In addition, BWS, under the agency's subscription with The Water Research Foundation, convened a complimentary DBP workshop to advise the bureau on appropriate next steps regarding their DBP initiatives and compliance strategies. Experts from academia, utilities, and regulatory agencies provided recommendations on existing trend analyses, data collection and management, and treatment that will inform the bureau's research in the coming years.

4 Research Spotlight > Lead

While all City-owned water supply aqueducts and water mains are lead free, many homes have privately owned lead service lines (LSLs) and plumbing fixtures that may contain lead. The City has a substantive history of research studying lead exposure within homes and continues to research best management practices for system-wide treatment, elimination of LSLs and at-the-tap treatment until a system-wide solution can be accomplished

For example, DEP is currently conducting a corrosion control study to examine how best to optimize the use of phosphoric acid to help reduce lead levels in water. When water treated with phosphoric acid runs through plumbing, it creates a barrier between the lead pipes and the water. The study seeks to understand the impact of increasing the phosphoric acid dose on lead levels in drinking water by studying changes in lead levels at test sites on City Island, an isolated area of the Bronx. The impact of changing doses is evaluated by collecting samples from two lead pipe loops installed on the Island, and profile samples collected from private homes on City Island. The phosphoric acid dose in the water supplying City Island is being adjusted during the study to evaluate the effects different doses of 2, 3, and 4 mg/L have on corrosion control and subsequent lead levels. Two additional pipe loops in Queens are being used as controls as they do not receive an increased phosphoric acid dose or change in source water. The study is still underway, and various conditions that include the phosphoric acid dose, temperature, pH, chlorine residual and source water all impact the effectiveness of corrosion control.

Another critical study evaluates the impacts of replacing lead service lines on lead concentrations within homes. To establish a study group, DEP identified homes owned by the New York City Housing Authority with lead service lines. Once inspections confirmed the service lines contained lead, the service lines were replaced and flushing was performed. DEP then provided residents with lead test kits to conduct sampling after the lead service line replacements to evaluate the impact of lead levels at-the-tap and the length of time before lead levels were reduced or eliminated. The results of this study demonstrated the effectiveness of lead service line replacement, as a decrease in lead was consistently observed. DEP has continued to study lead levels both before and after lead service line replacement at homes participating in a New York State grant-funded Lead Service Line Replacement Program administered by DEP. To date, almost 250 of these service lines have been replaced.

DEP has also studied the effectiveness of different pitcher filters at removing lead from NYC's drinking water. DEP found that only one of the brands evaluated met the NSF/ANSI standards. As an expansion to DEP's study that has had similar findings and to better understand why NYC water can be a challenge to some pitcher filters, additional research has been ongoing by Jeannie M. Purchase at Virginia Tech. As part of this research, characterization of lead particle charge, size and distribution in spiked NYC water are being evaluated.

DEP scientists collect water samples from an iced-over Rondout Reservoir

Next Steps

The 2022-2023 Research Agenda demonstrates a clear commitment to supporting and advancing research that will allow DEP to provide clean, safe water to City residents even as climate change and regulations create new challenges and requirements. There are opportunities to optimize our internal processes and expand our collaborations within DEP as well as with universities and professional associations.

Moving forward, BWS seeks to expand on our current research by seeking out opportunities to collaborate on research projects across the agency, reducing overall costs and expanding impact. Additional efforts will invest in relationships with universities, foundations, and professional organizations to identify partnerships and leverage our resources to expand our portfolio of projects.

BWS will explore options to migrate the research inventory to a user-friendly interface and staff will work to review and define research areas in order to ensure a logical and consistent categorization for all projects. An accessible interface and clear indexing will aid in creating better collaboration across the agency and will also limit unnecessary redundancies. These efforts will expand the research community within DEP and elevate all research to best in class.

These efforts position the bureau to meet current and future challenges to ensure our priorities are aligned with the following goals:

- Support repair of the Delaware Aqueduct by utilizing operational redundancies, innovative reservoir management, and operation of the Croton Filtration Plant while meeting all State and federal regulatory requirements
- Ensure the quality of NYC's drinking water supply and compliance with all federal and state regulations regarding drinking water quality
- Implement a robust and cost-effective source water protection program that adjusts to evolving conditions
- Effectively operate and maintain water supply infrastructure as we deliver water to NYC and its upstate users while ensuring compliance with the Supreme Court Decree of 1954 and New York State stream release regulations
- Identify and implement opportunities to reduce energy and greenhouse

DEP scientist at the Hawthorne Laboratory

Appendix 1. Environment

Research Areas and Project Focus in the Core Subject of Environment (research pertaining to the interface of the natural environment with the water supply).

Legend

RESEARCH AREA

Project Focus

Climate Change

- Forest Management

Stream Management

- Turbidity and Suspended Sediment Monitoring and Trends
- Stream Regression Relationships
- Sediment Source Characterization
- Sediment Management: Bedload Design
- Turbidity and Suspended Sediment Monitoring and trends

Disinfection Byproducts

- Monitoring for Disinfection Byproduct Precursors

Water Quality

- Delaware River Basin Mass Balance
- Hydrilla Verticillata Impacts on Taste and Odor Compounds in New Croton Reservoir

Invasive Species

- Hemlock Woolly Adelgid Control
- Zebra Mussels

Wetlands

- LiDAR-Based Wetlands Mapping
- Using Indicators to Assess Wetland Condition
- Multivariant and Conditional Comparisons of Shallow, Unmapped Freshwater Wetlands.
- Bog Turtle Habitat in Wetlands

Land Management

- Using a Socio-ecological Approach to Nature-based Solutions for Water Management
- Impacts of Recreation on Watershed Lands

Wildlife Management

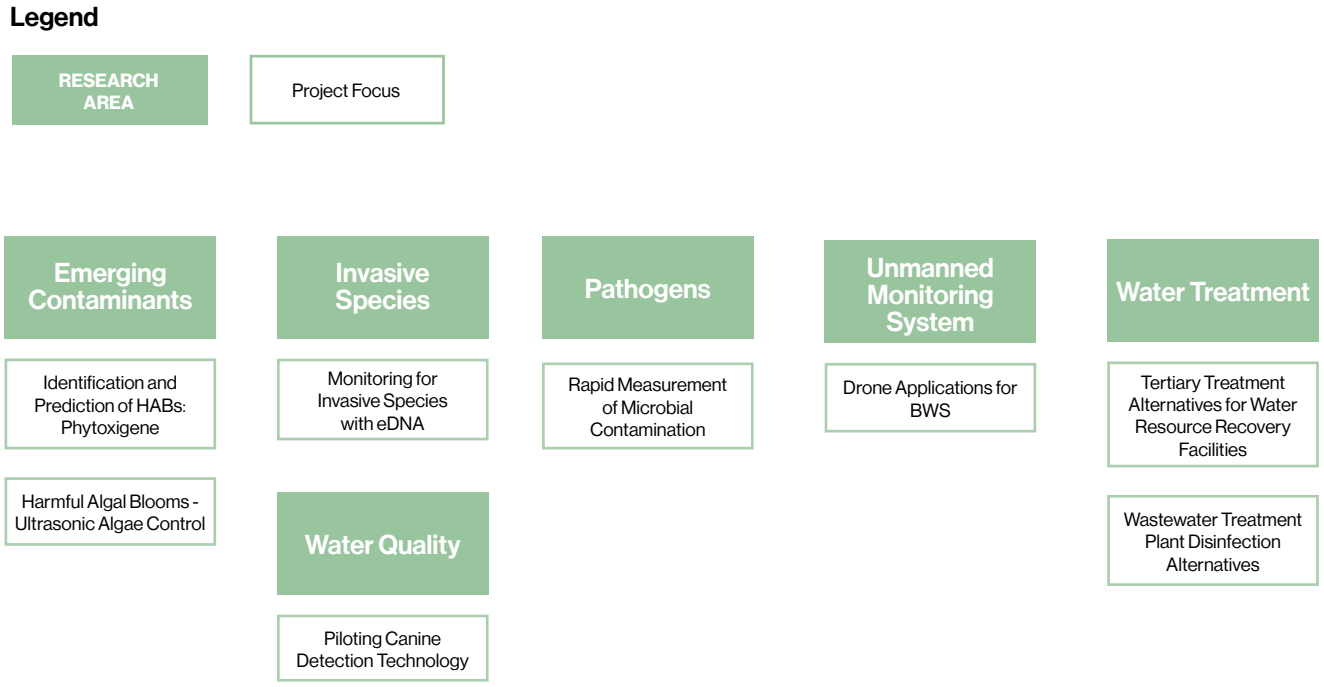
- Acoustic Monitoring

Modeling

- Soil and Water Assessment Tool: Watershed Runoff and Nutrient Modeling

Appendix 2. Innovation

Research Areas and Project Focus in the Core Subject of Innovation (research pertaining to new emerging technologies, novel methods and strategies to better manage the water supply, as well as studies and research pertaining to emerging or unknown challenges).



Appendix 3. Public Health

Research Areas and Project Focus in the Core Subject of Public Health (research pertaining to water quality, treatment, and regulatory requirements).

Legend

RESEARCH AREA

Project Focus

Disinfection Byproducts

- Disinfection Byproduct Precursor Modeling
- DBP Formation Potential in Watershed Sources
- Monitoring for Disinfection Byproduct Precursors

Emerging Contaminants

- Emerging Contaminants Monitoring Project

Water Treatment

- Cyanotoxin and Fluridone Removal
- Granular Activated Carbon: Zeta Potential
- Revision of Calculated Capacity Algorithm in PLCs at the Catskill-Delaware Ultraviolet Filtration Plant

Infrastructure

- Treated Water Delivery into Distribution

Water Quality

- Biologically-Active Carbon
- New Croton Water Quality Index

Lead

- Lead Profiling: Premise Plumbing Study
- Evaluation of Optimizing Corrosion Control in the New York City Water Supply
- Effectiveness of Flushing to Reduce Lead Levels at the Tap
- Compliance with LCRR
- Lead Reduction At the Tap

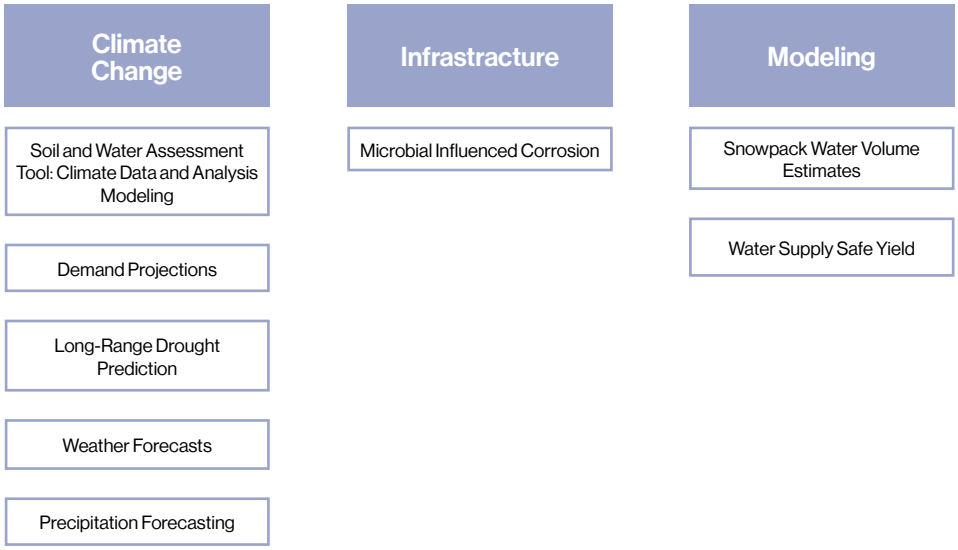
Pathogens

- *Cryptosporidium* and *Giardia* analysis on Wildlife Scat Samples
- Speciation of Oocysts Associated with NYC Resident Cases

Appendix 4. Sustainability

Research Areas and Project Focus in the Core Subject of Sustainability (research pertaining to sustainable energy, infrastructure, financing, and hydrology).

Legend



nyc.gov/dep

Printed on post-consumer recyled paper

Sunset in the Pepacton watershed