Weathering Waste: Combined Sewer Overflows, Community Impacts, and Climate Change in New York's Capital Region

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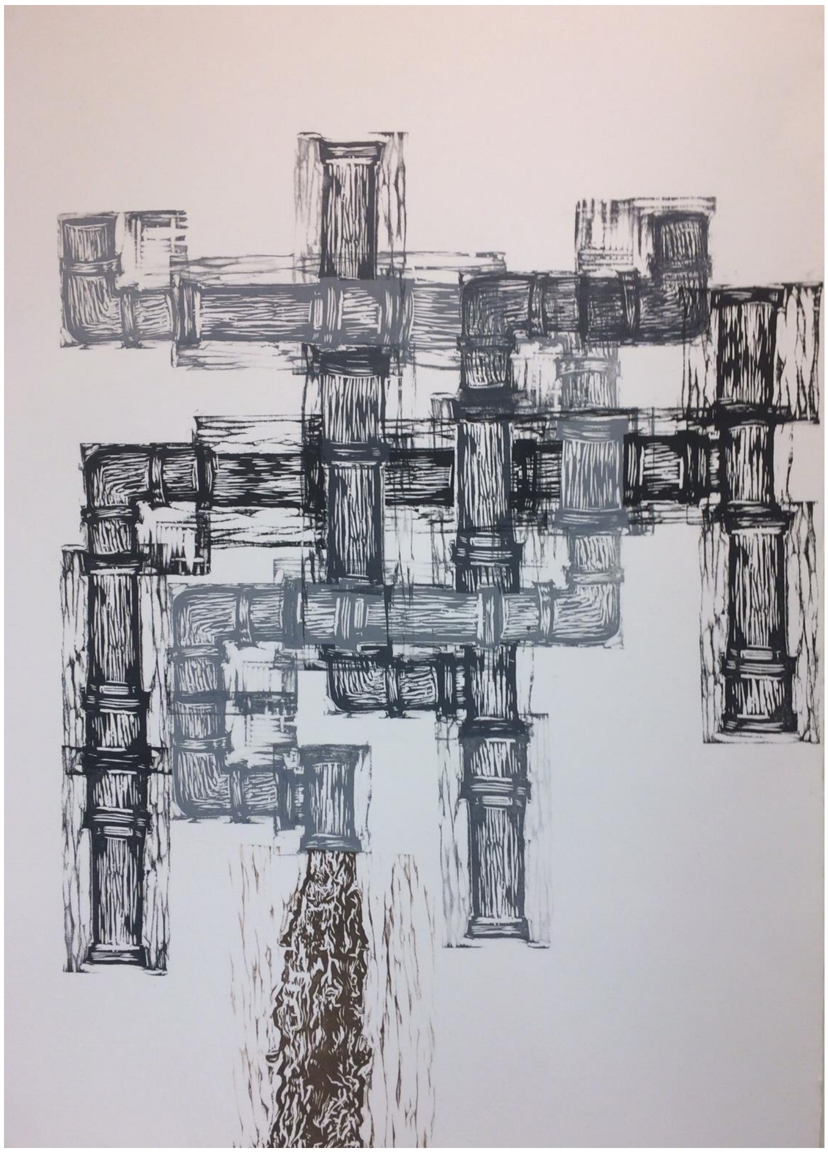

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Abstracts

Overview

Combined Sewer Overflows (CSOs) have major impacts on water quality and communities. Our research took an interdisciplinary look at the impacts of CSOs in the Capital Region. The quantitative research focused on the water quality impacts of CSOs as well as the potential future impacts of climate change on these events while the qualitative research focused on community knowledge, engagement, and mitigation efforts. Collectively, we came up with recommendations for addressing the Capital Regions CSO issues.

Quantitative Abstract

Currently, little to no data exists on the impacts of CSOs on winter water quality. Additionally, the impacts of climate change on these events is not well understood at a local level. In this study we investigated the impacts of CSOs on water quality from November to March through monthly water sampling as well as explored the potential impacts of climate change on CSO events in the Capital Region. Nutrient levels for nitrate and phosphate were relatively similar between months, however concentrations for ammonium were higher in dry weather months and were statistically significant. As seen in previous research, we found higher levels of bacteria (*Escherichia coli* and *Enterococcus*) and turbidity following CSO events, however there was only a slightly higher rate of failing the EPA Bacteria Beach Action Values in wet weather than in dry weather. When comparing our results to previously collected data in this section of the river, we also found that water quality, at least from a bacterial standpoint, seems to be worse during the winter months, which may be attributed to the lack of discharge disinfection in the winter in this area. We did not find *E.coli* and *Enterrococcus* to be equal measures of water quality, as while some of our samples passed the *Enterrococcus* EPA Beach Action Value standards, none of our samples passed the *E.coli* standard. We found a statistically significant link between precipitation and the number of CSO events, so with increases in precipitation due to climate change, it's likely that the number of CSO events will increase as well.

Qualitative Abstract

New York's Capital District is caught in the convergence of aging infrastructure and climate change. Communities and their governments struggle to contend with and address the impacts of combined sewer system overflows on both locals and the environment. As an infrastructure intended to obscure these material flows between ourselves and our environments, today the sewers themselves are largely invisible. The lack of political will to mitigate CSOs is also an infrastructural issue, as the success of waste management invisibility has led to a general lack of public concern for the sewer system. Education and outreach efforts by regulatory bodies have been minimal and no previous studies have been carried out to assess their relative effectiveness. Speaking with stakeholders at various levels and distributing public surveys, we explored the effectiveness and methods of current efforts, finding that constituents were largely unknowledgeable of CSOs and the surrounding concerns, despite being increasingly engaged in

Hudson water and riverfront activities. Boundaries between different approaches to CSO mitigation are discussed in the context of the implementation and equity of green infrastructure and outreach efforts. There is noticeable gap in project collaboration and coalitions between alternative and official adaptation, mitigation, and management initiatives. In conclusion, we suggest a more holistic approach to combined sewer management that accounts for greater socio-ecological equity, increases collaboration between all stakeholders, and considers alternatives to traditional sewage management practices.

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Introduction

Each year, waterways in the United States are contaminated with 850 billion gallons of raw, untreated sewage. The vast majority of this discharge is legal, in the form of Combined Sewer Overflows (CSOs), a result of the widespread use of outdated and inadequate sewer systems across the nation. This accepted discharge of pollution into rivers and streams across the country significantly impacts water quality, thus harming the health of both aquatic ecosystems and humans who live, work, and play in these environments (EPA, 2017).

In combined sewer systems (CSSs), as opposed to separated systems, rainwater, household sewage, and industrial wastewater are all gathered into a single network of pipes. Under dry conditions, this wastewater flows to a sewage treatment plant, where it is sanitized before being discharged into a local water body. However, when the water volume in the pipe exceeds the plant's capacity--whether due to snowmelt, rainfall, or other wet weather events--the wastewater in the pipe is discharged directly into the local water bodies without being treated (Figure 1). Thus CSOs discharge raw sewage, industrial waste, toxic materials, and debris into our waterways (EPA, 2017). It does not take a significant amount of rain to overwhelm a CSO system and cause a discharge event; on average, only 0.1 inch an hour or 0.4 inches a day are needed to trigger an event (Riverkeeper, 2017). There is therefore a high likelihood of river contamination during rain events in communities with combined sewer systems.

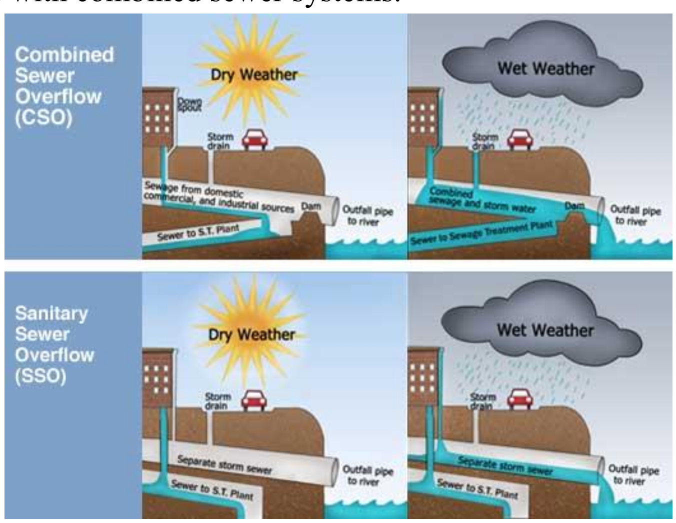


Figure 1: Combined Sewer System compared with a Separate (Sanitary) Sewer System. Photo courtesy of the EPA.

In the U.S., there are approximately 860 communities with CSSs (Figure 2). Commonly, CSOs are located in older cities, where the population size has outgrown the original infrastructure (Figure 2). The majority of CSSs are found in the northeastern U.S., with ten percent of all CSOs located in New York (EPA, 2017). Within New York, the Capital Region has one of the highest concentrations of CSOs on the Hudson River, second only to New York City. As one the oldest colonial cities in America, the Capital Region is especially afflicted with decrepit waste infrastructure (Opalka, 2018). While the health of the Hudson River Estuary has improved in recent years, CSOs remain a major challenge. As these upper Hudson cities experienced massive industrial growth in the twentieth century, they struggled to provide adequate infrastructure to match in the rapid urban expansion. It is the legacy of these old pipes with which these communities must now contend.

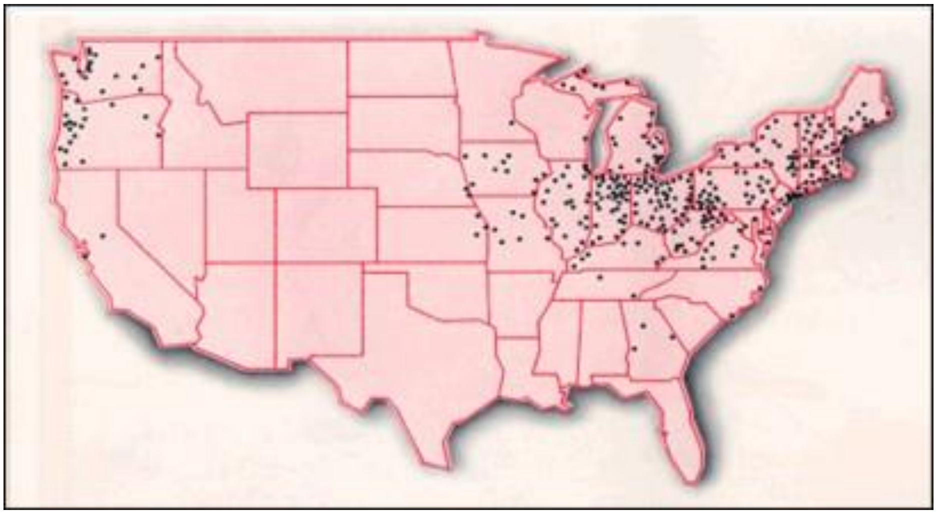


Figure 2: Locations of the U.S.'s CSO communities. Photo courtesy of the EPA.

Water Quality Impacts

CSOs have been listed as the number one water quality concern in many communities (DEC, 2017). They not only decrease the recreational and municipal value of the water bodies where discharge occurs, but they also present a public health issue. Several studies have shown that CSO events significantly increase concentrations of *Escherichia coli (E. coli)* and *Enterococcus*, both of which are fecal coliform indicator bacteria (Patz et al., 1996; Field, Curtis, & Bowden, 1976). Additionally, CSOs have been shown to increase levels of giardia and cryptosporidium (Morris et al., 1996). These bacteria can cause gastrointestinal problems for people who are exposed to contaminated water bodies either through recreation or drinking. Studies have shown increased rates of hospitalization for cases of gastrointestinal diseases following heavy rainfall in CSO communities (Jagai et al., 2015). Research on such diseases also emphasize the high costs of providing medical care to individuals who become ill from waterborne contamination; costing the United States between $2.1 billion and $13.8 billion per year (Gaffield et al, 2003). An additional concern for the public health impacts of CSOs is that many people do not associate these health problems with being exposed to contaminated water, but rather as a result of food they have eaten; cases of CSO related diseases are thus vastly underreported and the full impact of contaminated water on human health is unclear (Field, Curtis, & Bowden, 1976).

In addition to public health impacts, the effect on water quality due to CSO events also impacts the ecosystem as a whole. Elevated sediment loads in the discharge can bury benthic communities and make it hard for aquatic organisms to navigate in the cloudy water. Studies have shown that water bodies receiving CSO discharge have a low density of benthic organisms and a high saprobic index, an indicator of organic pollution (Kominkova et al., 2005).

While nitrate, ammonium, and phosphate are all nutrients naturally found in ecosystems, their concentrations can also be increased due to human activities such as agriculture or CSOs. High levels of nitrate in surface water, specifically water used for drinking and cooking can have negative human health impacts, such as blue baby syndrome. In addition to having adverse health impacts in humans, aquatic life can also be impacted at high concentrations of nitrate in the water. Aquatic animals living in water with high concentrations of nitrate and having long exposure times to this water can be adversely impacted as oxygen becomes unavailable to them (Camargo et al., 2003). Large concentrations of phosphate in surface water can cause algal blooms and speed up eutrophication which creates anoxic conditions for aquatic life in the impacted water body which can lead to fish kills (EPA, 2017). Furthermore, toxins discharged from CSOs can also build up in local fish populations and make them inedible (Wang, 2014). Little is known about the impacts of CSOs on water bodies from November to April, the time period outside of the "CSO season."

All of these impacts are not only felt in the CSO communities, but can also have profound effects on downstream water bodies and their ecosystems. These downstream communities often may not have CSOs in their own communities but are still faced with their impacts.

Community Impacts

How different communities, both upstream and downstream, relate to the CSO water bodies plays a major role in determining their exposure to CSO events. In addition to a community's relation to the water, knowledge of CSOs, or lack thereof, can impact how residents in CSO communities interact with their waterbodies. Sadly, due to lack of proper education and outreach, CSO community members are often unaware of the dangers of swimming in these water bodies, or even understand what a CSO is, much less that they live in a CSO community. Specifically, throughout the Hudson watershed, questions of access to knowledge regarding environmental contamination remain a primary concern. Environmental justice on the Hudson includes not only considerations of exposure and toxicity, but of information access and education as well (Hird et al, 2014). Environmental data justice is defined as "the public accessibility and continuity of environmental data and research, supported by networked open-source data infrastructure that can be modified, adapted, and supported by local communities" (Dillon et al, 2017). Attending to community impacts of CSOs thus entails moving beyond mere education and outreach consider what kinds of data are collected about these events, and whose interests they serve.

The impact of these waste infrastructures on urban inhabitants is often uneven, shaped by the legacies of racialized urban planning (Bullard et al., 2000). In particular, government and planning boards have placed sewage treatment facilities in low-income communities of color (Perreault et al, 2012). In addition to wastewater impacts, both income and race are correlated with exposure to stormwater flows (Brown, 2010). Thus, certain communities are not only in closer proximity to urban water infrastructures, but are also more vulnerable as exposure poses a higher public health risk for some.

As discussed above, both fecal pathogens and emerging contaminants are a dire public health concern for these communities, and their collective impacts are not fully understood. Due to the emerging nature of these contaminants, the distribution and severity of the health impacts of CSOs thus remains largely unknown. Following the impacts of CSOs downstream, we see that waste is “not only our problem, but...entangled with the lives of nonhuman creatures and the future of the planet we share” (Reno, 2013). Further, climate change may exacerbate these environmental disparities as increased precipitation, combined with the flashiness of urban hydrology, threatens to both increase and intensify future CSO events. While climate change has become a central subject of global political concern, climate justice is rarely discussed at the urban scale (Bulkeley et al, 2013). Work towards ecologically resilient urban futures must also include careful consideration of the ways in which the changing climate is manifested in urban water flows. In contrast to the dominant climate change imaginary, where climate is abstracted from everyday experiences, the rising contamination of CSOs may force us to reconsider the intimacy and nearness of the changing climate (Giggs et al, 2016).

Climate Change Impacts

Published research, international, and national institutions have recognized the reality of climate change and the threat it poses to ecological, social, and economic systems (IPCC, 2007). However, the impacts from climate change that will be seen and felt across the globe will vary from region to region. Between 1880 and 2012 the IPCC reported an average 1.53^{o}F increase in temperature global, while New York state experienced 2.4^{o}F warming between 1970 and 2014 (IPCC, 2013; NY DEC, 2014). Not only do different regions experience varying degrees of warming and cooling, but these changes also have widely divergent implications for precipitation patterns, biodiversity, air quality, and other aspects of local ecosystems. With the effects of climate change varying significantly across regions, localized studies are needed to adequately predict the effects of climate change.

In regards to CSOs, specific attention is needed for addressing increasing and flashier precipitation, drainage, and runoff events in urban areas (Bi et al., 2014). As temperature and precipitation regimes change, areas may experience increases in flood or drought conditions. Such changes could potentially affect water flow into receiving water bodies, alter sediment morphology and transport, and change the mobility and dilution of pollutants that are discharged from wastewater systems and storm drains in urban areas (Bi et al., 2014). If precipitation increases in a region, both in quantity and intensity, local sewage systems must be capable of handling greater amounts of water. Locations with CSOs that are predicted to receive more intense rain events are likely to have more CSOs events if no climate change adaptation measures are implemented.

Multiple studies across Canada, Europe, and the United States have explored climate change impacts on CSO frequency and water quality impacts, and give insight to the possible effects that would be seen in the Hudson River. An Environmental Protection Agency (EPA) Report that focused on the average of multiple locations in New England, including upstate New York, predicted between a -24% and 14% shift in CSO events from 2025-2050, with most locations seeing increases in CSOs under the Hadley Model climate projection. The decrease in CSO events considered the effectiveness of mitigation measures, should they be implemented. In general, the great variability of precipitation trends across New England points to more localized studies being used to predict possible trends. A study observing the impact of climate change on CSOs in Southern Quebec found that despite a 40% decrease in mean flow of the St. Lawrence River, a 20% increase in maximum intensity of rainfall events was projected. Increases in intensity predicted a mean 54% increase in peak flow, thereby leading to a 3-148% increase in the number of CSO events in 2050 compared to 2013. Decreased flow, coupled with an increasing number of CSOs, projects that ecotoxicological risk indices will increase by more than 100%, doubling of the risk associated with pollutants discharged during CSO events (Bi et al, 2014).

While these studies have begun to look at how worsening climate change will impact CSO rates, most of these models are still based on historical hydrologic data. Although changes in infrastructure may currently suffice or address current problems, the short-term predictions fail to account for increases in the number of extreme events (Ashley et. Al., 2008). Current climate scenarios point to increasing number of extreme rain events across North America and Northern Europe, but with longer spans of time between events. Overall, however, there is currently a lack of studies observing the impact of climate change on CSOs, in part due to the significant variation across regions (Jalliffier-Verne et al., 2015).

This lack of knowledge has profound implications for the management of urban waterways; urban environmental policies are formed and implemented without a clear understanding of the underlying dynamics of changing hydrological systems, and the associated risks for those reliant on these water sources for recreation, drinking, and food. The EPA requires that communities develop nine minimum controls and Long Term Control Plans (LTCPs) for mitigating and resolving CSOs (EPA, 2008). However, if the plans are based upon short-term models or historical data, they may be insufficient for helping communities cope with precipitation changes. With water quantity and quality being greatly affected by regional hydrology and local contamination sources, localized projections and tailored resilience planning can predict and address potential future increases of CSOs and water quality trends.

Mitigation & Adaptation

In addition to the unequal impacts of urban water contamination, inequalities may be produced through attempts to address the causes of CSO events. Efforts to both mitigate and adapt to the effects of climate change on CSOs are also tied to issues of environmental injustice and the uneven forms of power in the production of urban environmental policy. As many cities with outdated sewage systems are engaging in a variety of urban environmental management practices intended to reduce the occurrence and mitigate the effects of CSO events, the burdens of these new policies are often unevenly distributed.

The most effective ways to reduce CSO occurence are through sewage pipe separation and increased wastewater treatment capacity. These changes in urban design often become environmental justice issues, with new wastewater treatment plants often sited in low-income communities of color (Christian-Smith, 2012; Perreault, 2012). However, due to the high cost of these large-scale infrastructural changes, alternative approaches to dealing with CSOs are increasingly considered. The more common tactic to address increased urban water flows is the implementation of green infrastructure projects, such as rain gardens, vegetated swales, green roofs, and porous pavements. These green spaces increase rainwater infiltration and slow the movement of water through the urban landscape, thereby helping to reduce runoff and thus CSO events ("Green Infrastructure Examples").

It is important to analyze the different communities that are impacted by these CSO mitigation sites, and consider their varying social (in)accessibilities. Where green infrastructure is placed, and the new kinds of relationships that form as a result, impacts both its mitigation effectiveness and persistence. Placement considerations should include both ecological effectiveness and social relevance. To implement this dual goal, both political will and social capital are necessary to maintain the ecological benefits of green infrastructure over time (Davis, 2011). Long-term commitment is also necessary to ensure that the production of new environmental amenities does not produce ecological gentrification through the displacement and exclusion of certain populations from urban green spaces (Dooling, 2009).

The agency of the nonhuman components of water management schemes is also a vital aspect of understanding CSO mitigation. Rewilding outside of human efforts may play a key role in increasing rainwater retention, as new kinds of plants move into the vacant lots and abandoned sites of post-industrial urban landscapes (Lorimer, 2008). Through the interaction between human political interests and nonhuman agencies that new "environmental knowledge controversies" are produced, altering the forms of risk that are monitored and managed (Jones et al, 2014). The forms of knowledge at stake result from the "emerging copropower assemblages of agricultural and municipal laborers, engineers, nongovernmental organizations (NGOs), state regulatory agencies, bacteria, and plants" (Webel, 2016). The diverse agencies that that congeal around urban sewage systems shape how they are known and managed.

In response to uneven governmental involvement in mitigating CSOs, and the uncertain effectiveness of these interventions, many communities are organizing on a more local level. Forms of community involvement range from rainwater retention techniques to citizen science water quality monitoring efforts. These efforts represent the possibility for a new "reparative approach to human waste" (Webel, 2016). Another avenue towards diversifying knowledge practices of urban environmental management is through the use of participatory risk assessments to build a better picture of community vulnerabilities to climate change (Aalst et al., 2008). However, this approach has primarily focused on developing countries and disaster relief, without adequately addressing the ways in which many communities are already impacted by the effects of climate change through urban flooding. In response to a lack of academic or governmental support, citizen science campaigns can be an effective way to monitor local water quality (Farnham et al., 2017). Urban environmental management is increasingly incorporating such forms of participatory involvement, for both environmental monitoring and governance (Certomà et al., 2015; Gabrys et al., 2016a; Gabrys, 2016b; Fedra, 1999). Community involvement in both monitoring and managing urban environmental change presents a critical form of citizen involvement in the face of dominant models of top-down governance. Participatory environmental monitoring projects "have been critiqued for potentially passing the burden of monitoring onto communities." However, "when connected with research and public health organizations" they "can both empower individuals by increasing their perceived and actual agency and build collective knowledge by producing novel scientific findings" (Kriesky et al., 2017).

History of Wastewater Management in the Capital Region

The modern predicament of CSOs stems from the ways in which ideas about centralized waste management were embedded in the city's infrastructure centuries ago. The attempt to tame wild urban streams is interlinked with the displacement of indigenous peoples living along the Upper Hudson. The Mahican and Mohawk peoples' traditional uses of these tributaries were precluded when the streams were piped, buried underground, and integrated into water infrastructure. Water pipes were installed as an engineering solution to both rampant urban fires the public health crisis of cholera. Several national outbreaks of cholera, most notably in 1832, 1849, and 1866 also severely impacted the Upper Hudson region. New understandings of disease transmission meant that human waste was newly pathologized, and sewer pipes became the solution to a previously unidentified problem. As industrial growth in the Capital Region lead to rapid population growth, the problem of sewage waste management became more pressing. A major snowstorm in the Capital Region in 1888 resulted in minor waste management crisis; the City of Troy placed a classified ad in the Troy Daily Times stating: "100 able bodied men wanted immediately to work opening the streets, cesspools and gutters" (Moore, 1991). The combination of increasing urbanization, disease transmission, and the inception of the water closet overwhelmed the privy vaults and cesspools. By the end of the 19th century, there was growing public demand for centralized wastewater systems (Burian et al., 1999).

While the dire need for improved sewage management became increasingly evident, what form that system would take was not yet determined. During this time, "city councils, sanitary engineers, and health groups agreed, *although not without dissent,* that water-carriage systems of sewerage provided the most benefit and the lowest costs compared to other disposal options" (Burian et al., 1999, emphasis mine). There was an ongoing debate for several years between the combined and separated systems. Yet while neighboring cities such as Lenox, Massachusetts opted for separated sewer systems, the municipalities in the Capital Region opted for combined system for its economic efficiency. But what seemed to be cost-saving at the time ended up costing those city governments millions in the long-term.

With the inception of this new system came the permitted discharge of human sanitary wastes into the sewer pipes, which had formerly only carried streams and stormwater. In a society where the wastewater as a concept had just been created, an understanding of wastewater contamination had yet to be formed. Once wastewater was legally created, it could be managed in a new arena of regulation. The new sewage infrastructure transformed private effluence into publically manageable substance (Reno, 2015). If infrastructure is matter that enables the flows of other matter, waste infrastructure is designed to make these flows disappear (Larkin, 2013). The sewers not only cleanses the city of pathogens but also makes its own intervention invisible in a kind of imaginary sanitation. Once venerated as an engineering solution, the sewer system slowly morphed into obscurity. The Capital Region cities continue to rely on many of those original pipes laid in the late 19th and early 20th centuries.

With this more general public amnesia for waste infrastructures comes a lack of funding for maintenance and repair. As a result, these inherited pipes fall into disrepair and the large-scale changes needed for growing cities were never made. Thus while centralized waste management was intended to promote new standards of cleanliness, it also inadvertently resulted in more diffuse, insidious forms of contamination. City residents are alienated from the ways their waste flows into environments elsewhere, and waste contamination becomes an unseen business-as-usual aspect of everyday life. CSOs illuminate this hidden issue; they hold the potential to disrupt the sanitizing imaginary that waste infrastructures produce. In overflowing the system, they reveal the normative state of rupture underlying the city's infrastructure. This became increasingly visible with the rise of the environmental movement, when the Hudson was frequently described as an "open sewer."

Eventually, environmental organizing led to new federal and state regulations and the enforcement of the Clean Water Act of 1972--first through the creation of sewer districts and the construction of wastewater treatment plants and then through CSO consent orders in particular. In the 1970s, Albany County and Rensselaer County both began to implement new plans for sewage management in response to this new federal and state legislation--and their attending financial programs to assist with the high costs of implementation. Mandates from the State of New York that ordered known polluters to cease their current waste disposal methods spurred both Albany and Rensselaer counties to establish County Sewer Districts for the treatment of industrial and domestic waste (Rensselaer County Planning Board, 1968). Establishing these districts enabled them to share the high costs of construction and operation and laid the groundwork for future inter-municipal collaboration.

Albany Pool

In 2007, the communities of Albany, Troy, Rensselaer, Cohoes, Watervliet, and Green Island in New York came together with the Capital District Regional Planning Commission, a state agency, to address the Capital Region's CSO problem (Pool, 2011). Each municipality has a State Pollution Discharge Elimination System (SPDES) permit, which authorizes the discharge of wastewater into into the Hudson and tributaries from a "properly operating CSS" (Albany Pool, 2017). The collaboration was formed in order to meet the requirements stipulated under the Wet Weather Water Quality Act of 2000, an amendment to the federal Clean Water Act (CWA) of 1972, 33 U.S.C. §125. The amendment required that all communities holding permits to operate CSOs comply with the *CSO Control Policy*. This inter-municipal cooperative, known as the Albany Pool, contains the six communities that are dispersed throughout two sewer districts, the Albany County Sewer District and the Rensselaer County Sewer District. In total, the six communities contain 92 CSO outfall locations, with an annual discharge of 1.2 billion gallons of untreated wastewater. In the event of an overflow, a mixture of stormwater and wastewater in these communities is released into either the Hudson River or the Mohawk River (Pool, 2011). Since the Albany Pool program is under the management of multiple parties, the communities established the Albany Pool Communities Corporation; a nonprofit that takes some pressure off the government to fund large infrastructure projects as the communities can split the cost of planning and maintaining new structures (Communities Corporation, 2017). The corporation additionally facilitates communication between each of the six municipalities.

In 2011, the DEC determined each of the Albany Pool communities to be in violation of the CWA, and the state's Environmental Conservation Law§ 17-1743 based on their failure to submit an LTCP that conformed to the *CSO Control Policy* and was "approvable" by the DEC, which "determined that the draft LTCP was missing material elements of an LTCP, including the evaluation of a slate of CSO control alternatives, as distinct from non-CSO controls, along with the data and rationale supporting the recommendation of one CSO control alternative over the other alternatives." As a result, the Albany Pool communities agreed to enter into an Order on Consent, including paying a civil penalty, submitting a revised LTCP, and implement the Compliance Schedule.

Later in 2011, the Pool communities passed the revised 15-Year Long Term Control Plan (LTCP), approved by the New York Department of Conservation (DEC), to manage their failing combined sewer systems. Although this section of the Hudson River is classified by the DEC as a Class C waterbody, suitable for recreational fishing (not for consumption) and non- contact recreation (such as boating), the plan aims to achieve swimmable, fishable waters by 2028. Numerous organizations have pointed out that while the river is not classified for swimming, it doesn't stop people from swimming and there have been many documentations of this occurring in this area of the river (Riverkeeper, 2017). The control plan seeks to examine the health of the Hudson River, to identify cost effective methods for mitigating CSO events, and to model the potential impacts of these projects. The types of projects included in the Long-Term Control Plan (LTCP) range from rain gardens and rain barrel installations to sewer separation where necessary (Pool, 2011). Sewer separation and stormwater storage are expected to make up the highest expenditure in the Long-Term Plan. The second most costly component of the LTCP is the floating control stations, which monitor sewer outflows and extract floating materials from the water. Other projects under the LTCP include implementing seasonal disinfection of water, improvements in wastewater treatment, maximizing the capacity of existing infrastructure, and tributary enhancement. The DEC will assist in the construction and organization of these projects. The combined cost of all the projects in the LTCP is estimated to be $109.7 million.

Another aspect of the Albany Pool collaboration is the Combined Sewer Notification System. This program is a web-based alert system that allows community residents to ascertain the likelihood of a CSO event at a given time (Notification System, 2017). This was created in compliance with the Sewage Pollution Right to Know Law, enacted in 2013, which requires that the DEC is notified within two hours and that general public is notified within four hours from when untreated or partially treated wastewater is released from public sewer systems (DEC, 2013). Through this system a user can look at a map that displays the likelihood that a CSO event is occuring at a given outfall location. However, the map is based on modeling projections generated with Geographic Information Systems and does not display a completely accurate picture of which outfalls are currently overflowing. Information about CSO events is also disseminated to the public through the NY-Alert System. Community members can sign up for NY sewage spill alerts through this state-wide emergency system that sends out CSO alerts over text and email.

Purpose Statement

This interdisciplinary research seeks to analyze the preparations of the Albany Pool Long Term Control Plan for their CSOs in the era of climate change and to examine the effectiveness and equity of these preparations. We hope to accomplish this by assessing quantitative and qualitative components of CSOs in the Capital Region.

Questions Guiding this Research

1. *Water Quality*: What is the water quality in the Albany Pool region from November to March?
2. *Exploration into Climate Change:* What are the predicted changes for precipitation in the Capital Region and how will these changes impact CSOs?
3. *Knowledge:* What are local stakeholders' understanding/awareness of combined sewer overflows and their effects on their local environment?
    a. How are locals and stakeholders using the Hudson River?
    b. How do officials and corporate actors perceive the effects of climate change on CSO frequency and intensity?
4. *Engagement:* How does grassroots pressure on municipalities affect officials responding to CSO legislation and preparation?
    a. What is the role of non-human agency in potentially mitigating CSO events?
5. *Mitigation:* How effective are current efforts to raise awareness about CSO events?
    b. Are there differences in preparedness and awareness of CSOs in communities of differing incomes or minorities?
    c. How can communities and municipalities realistically better prepare for and inform locals about CSOs?
    d. How are these potential solutions distributed within communities?

Methods

Setting

Case Study of Upper Hudson River

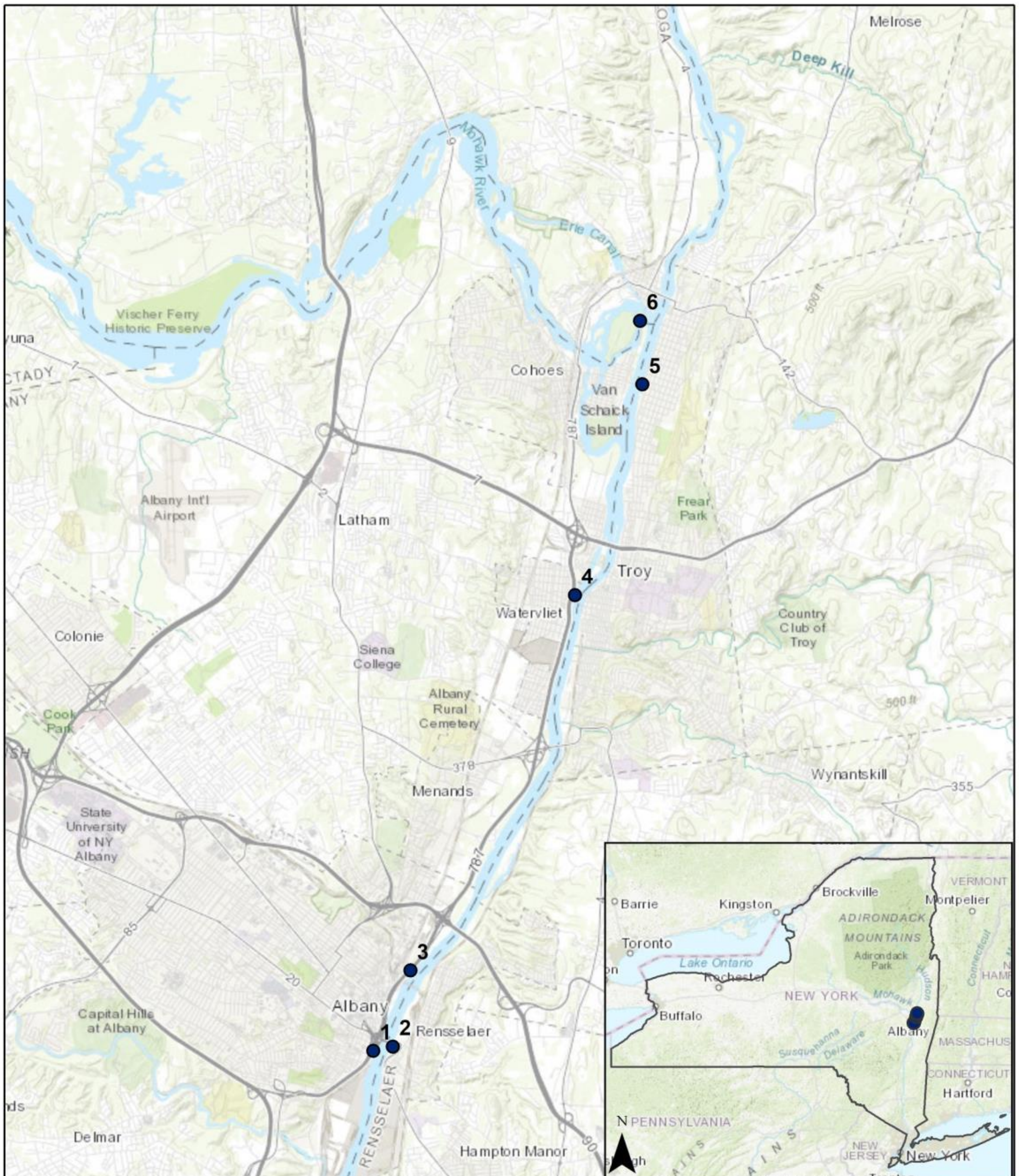
This mixed methods study focuses on CSO events occurring in the Capital Region of the New York, within the six communities that make up the Albany Pool: Green Island, Cohoes, Watervliet, Albany, Troy, and Rensselaer. This region was chosen for our study due the unique collaborative system that these municipalities have developed in response to the ubiquity of outdated combined sewers in the area.

As a case study, our research revolved around the "study of a case within a real life contemporary context or setting" (Creswell, 2013). We gained an in-depth understanding of the research area through data triangulation, including water quality measurements, precipitation modeling, semi-structured interviews, online surveys, site visits, participant observation, and archival research.

<u>Quantitative Instrumentation and Data Analysis</u>

Water Collection

In order to assess the water quality of the Albany Pool section of the Hudson River during this period in which there is no previously collected data, we conducted once a month water testing from November to April. Additional water testing was conducted following CSO events. Grab samples were taken using an eight foot water sampling pole and water samples stored in hydrogen chloride (5% HCl) washed 125 mL plastic bottles for nutrient analysis, and 250 mL glass bottles that had been autoclaved at 121°C for 15 minutes for bacterial analysis. During transport, samples were kept in a dark, ice filled cooler to prevent changes in the samples from time of collection to time of analysis. Samples were taken at six locations on the Hudson River, at five locations analogous to Riverkeeper sites and an additional site downstream of the largest CSO, "the Big-C" (Figure 3). Riverkeeper sites were chosen as their organization has collected some of the only data on this stretch of the Hudson, though only for May to October, and will allow for comparison with our results in our analysis. Dissolved oxygen, turbidity, temperature, and conductivity were measured at each location on each sampling day. Temperature and dissolved oxygen were measured using a YSI 550A dissolved oxygen meter, conductivity was measured using a YSI 30 conductivity meter, and turbidity was measured using a Hach 2100P turbidimeter. pH was taken for each of the samples in lab using an Accumet basic AB15 pH meter. These results will be compared with DEC water quality standards for Class C water bodies.



Site Number	Site Name	Latitude	Longitude
1	The Big "C"	42.64131	-73.7516
2	Dunn Memorial Bridge (via Riverfront Park)	42.64217	-73.7464
3	Albany Rowing Center Boathouse	42.65706	-73.7417
4	Congress St. Bridge (via Hudson Shores Park)	42.73041	-73.6979
5	Above Troy Lock (via Troy 9/11 Memorial Park)	42.77156	-73.6801
6	Hudson at the Mohawk (via Peebels Island State Park)	42.78398	-73.6807

Figure 3: Map of water sampling locations, with site names and GPS coordinates.

Bacterial Analysis

In the lab, we followed EPA protocols, Methods 1600 and 1603, with guidance from Sylvia F. McDevitt, Ph.D for quantifying *Enterococcus* and *E.coli* levels in the water samples using membrane filtration in order to asses the "swimmability" of the site (see appendix II for full membrane filtration methods). The mTEC *E.coli* agar was prepared prior to sampling from an agar powder mix. We followed standard agar instructions for the preparation and 4 mL of the liquid agar was pipetted into 9 x 50 mm pre-sterilized petri dishes. The mEI *Enterococcus* agar was purchased premade. Sterile membrane filters with grids were placed on the base of the Nalgene Polysulfone Filter Holder and the funnel was attached. Sample bottles were shaken in order to ensure even distribution of bacteria. Six filtrations were run per water sample, three for *E.coli* at 1, 10, and 100 mL volumes and three for *Enterococcus* at 1, 10, and 100 mL volumes. Sterile forceps were used to remove the membrane filters from the filter base and place the filters on the agar. Plates were then sealed with parafilm, inverted, and incubated at 35 °C +/- 0.5°C for 24 +/- 2 hours. After the allotted incubation time, "most readable" (ideally 20-60 colonies on the plate) out of the three plates for both types of bacteria per location was chosen and counted. The observed number of colonies were then compared with EPA Beach Action Values for safe swimming standards (190 cells/100mL for *E.coli*; 60 cells/100 mL for *Enterococcus*) to see if the water sample passed or failed these standards.

Nitrate

Nitrate was measured using an IC Dionex 2100 ion chromatograph in the Skidmore SAIL lab to detect the concentration of nitrate in each sample. Samples were placed in polyvials that had been rinsed three times with double- deionized water then taken to the SAIL lab for analysis. Our standards ranged from 0 to 10 ppm and were mixed using a nitrate stock solution and DI water.

Ammonium

For ammonium, we created an ammonium assay using a 0.2 M citrate reagent, a 0.2 M 2-phenylphenol nitroprusside reagent, and a 0.07 M buffered hypochlorite reagent. The citrate reagent was made using 5g of trisodium citrate salt and 80 mL of nanopure water. The pH of the solution was then adjusted to 7.0 using 1M HCl. The 2-phenylphenol reagent was made using 3.22 g of solid 2-phenylphenol salt 15 mg of sodium nitroprusside dihydrate dissolved in nanopure water. The buffered hypochlorite reagent was made using 2.32 g tribasic sodium phosphate dissolved in 80 mL of nanopure water. This solution then had 10 mL of sodium hypochlorite solution and 10 mL of 2M NaOH added to it to reach a pH of 13. These reagents were then compared to a 200 ppm N standard and a 20 ppm N standard. 70 µL of sample or standard were added to each to well followed by 50µL citrate reagent, 50µL of 2-phenylphenol nitroprusside reagent, 25µL of hypochlorite reagent, and 50µL of nanopure. Plates were read at 600 nm using a BioTek synergy HTX multi mode reader. Standards ranged from 0 to 5 ppm and were mixed using the ammonium stock solution and DI water.

Phosphate

To test for phosphate, the ascorbic acid method was used. A 10 ppm standard phosphate solution was made using DI water and potassium phosphate, and a standard curve was created. Then a potassium antimonyl tartrate solution was mixed with 1.3715g of potassium antimonyl tartrate and DI water. An ammonium molybdate solution was mixed using 20g of ammonium molybdate and 400ml of DI water. Finally a 0.01M ascorbic acid solution was made using 1.76g of ascorbic acid and DI water. A combined reagent was made by mixing 50 ml of 5M H_2SO_4 , 5ml of potassium antimonyl tartrate solution, 15 ml of ammonium molybdate solution, and 30 ml of ascorbic acid solution. 50 ml of sample or solution was mixed with 8 ml of the combined reagent in an erlenmeyer flask. After 20 minutes the sample was transferred to a spec cell and read using a spectrophotometer at 880nm. Standards ranged from 0 to 0.5 ug/L and were mixed using a phosphate stock solution and DI water.

Exploration into Climate Change

Data on climate change in the Capital Region was gathered from a variety of sources and compared. Additionally, previously collected precipitation data was gathered from NOAA, and data on CSO events was collected from the NYSDEC. The number of CSO events per month was counted and compared to the number of precipitation events that occurred that month. To determine precipitation the number of rain events in the 72 hours prior to a CSO event were tallied. Then the total number of precipitation events for each month were counted.

<u>Qualitative Instrumentation and Data Analysis</u>

Semi-structured Interviews

We conducted interviews with key stakeholders involved at every stage in the urban ecology of sewage, following the lifecycle from production, treatment, contamination, prevention, and remediation. These interviews were gathered using key informant sampling and snowball sampling techniques utilizing other the internet and other key informants depending on the interview group. The main interview groups included wastewater treatment plant employees, state-level actors, grassroots organizers, and community members.

The name of each interviewee, length of the interview, and what subcategory (see subheadings below) the interviewee fell under was compiled into a stakeholder chart for reference. From the responses data was coded to identify emerging themes that were noticed. These themes were organized to capture issues surrounding CSO management at every stage, from community infrastructure, to sewage facilities, to community organizations, remediation efforts, and health outcomes.

I. Wastewater Treatment Plant Employees

These interviews provided a lens into the ongoing effects of climate change on CSO events. Speaking with employees who have worked at the plant for long periods of time also helped build a better understanding of the historical changes in waste and runoff, water inputs, and CSO event increases, their opinions about what should happen in the future, and the infrastructural challenges to altering the sewer system.

II. State-led Initiatives and Local Government

Interviews with individuals involved with state-led initiates will include the Capital District Regional Planning Commission, Albany Pool (including Martin Daley, Director or Water Quality Programs and Regional Planner), officials from the Department of Environmental Conservation (Hudson River Estuary Program), and local government officials. In order to compare and contrast the approaches, agenda setting, and initiatives implemented in communities, interviews were conducted with local officials from the Albany Pool Communities and were focused on addressing CSO mitigation and adaptation. Across the communities there are differences of number of CSOs, population, industry, diversity, and income.

III. Grassroots Adaptation and Remediation Efforts

Key informants for community-led efforts included NGO activists such as Riverkeeper staff, organizers of citizen science projects such NATURE (North Troy Art, Technology and Urban Research in Ecology***)*** Lab affiliates (Kathy High and Guy Schaffer), urban bioremediation efforts (Scott Kellogg), and public art projects (Matej Vakula, Jillian Hirsch).

Qualtrics Online Surveys

I. Community Members

The online survey component of our study was intended to provide a snapshot of constituent CSO knowledge and positions. The first portion of the survey inquired into how community members use the river and engage with CSOs. The second section addresses knowledge and opinion on frequency, current initiatives, adaptation, and mitigation. We distributed online survey links during public events and in public spaces such as local parks, coffee shops, libraries, other centers in communities where we conducted water quality testing. In addition, we shared the survey online through social media, including local NGO facebook pages and community facebook groups, such as the "Troy NY Bulletin Board." The survey was distributed in Albany, Troy, Cohoes, Watervliet, and Menands. Cross-tabulations and Chi squared analysis of the coded response allowed us to identify meaningful findings on community stances, knowledge, and awareness, while discarding results that may be due to chance (Silverman, 2006). See Appendix II for survey questions.

Archival Research

Our research also relied on archival research to investigate the historical and geographical contingencies that produce this issue and affect the dynamics of how CSOs continue to play out. For this approach, we compared water management policies between the Albany Pool communities, as well as examined federal and state policies around water quality.

Comparing primary documents from these multiple sources, we analyzed the changing representations of waste and water over time and across different sectors. Considering these various social constructions provided a lens into the diverse forms of hydro-relationality at play in the production, use, and dispersal of wastewater through CSSs. Looking at both the representations of both the Hudson River and waste, we considered their roles in the formation of urban waste regime (Gille, 2010). Ultimately, this opened our research to investigating the impact these constructions have on what kinds of knowledge are considered valuable, and what types of mitigative or adaptive action are subsequently taken.

Site Visits and Participant Observation

The completed site visits to various urban environments provided a lens into the ongoing negotiations of meaning as well as the human and nonhuman relationships taking shape around CSO events and management. To gather our observations for later analysis, we took field notes, and collected audio recordings and photos. Visiting "green infrastructure" sites, we were particularly attuned to the potential discrepancies between the different discourses surrounding these sites and actual community uses. Additional field locations include Albany Pool meetings, community workshops, and public areas situated on the Hudson River waterfront.

Action Research

Our study involved action research, a collaborative method of research that incorporates stakeholder participation. Action research confronts environmental and social issues on a systematic level to remedy these issues and to ensure reciprocity for the stakeholders (Schneller & Irizarry, 2014). In order to facilitate a relationship of greater reciprocity with the communities in which our research was situated, we shared our research findings through a variety of outlets and media forms. We presented our data to a group of stakeholders, including community organizers and members of the public to facilitate interorganizational collaboration. We also collaborated with the NATURE Lab in Troy to design and carryout a workshop that brought together panelists with expertise from the watershed, sewershed, and grassroots perspectives of CSO management. We developed the workshop in order to gain a better understanding of how coalitions could be built between organizations and to gage whether community groups and governing bodies would be receptive to collaboration over CSO management. The workshop also sought to determine local opinion and knowledge of CSOs.

Limitations

Despite triangulating our methods to create a representative case study of CSO awareness, practices, mitigation and adaptation measures, and potential solutions, our research rested heavily on the willingness of participants. Our results were contingent on both our access to participants and the varying capacities of different community members to share their time and perspectives. Some of community members do not own computers, which limited their ability to access the survey and could have skewed the results of our data. Additionally, a longer engagement with the community and a more collaborative approach to our research design, while not feasible for the short duration of this study, would have improved our efforts to integrate our findings with ongoing community adaptation and mitigation efforts.

Quantitative Results

Over the course of this study, we conducted five rounds of water samples, capturing 3 CSO events and 2 non-CSO samples. Water temperatures ranged from a low of 0.4 to 6.3 C. DO ranged from 11.9 to 15.5 mg/L, and no samples fell below the DEC limit of 4.5 mg/L (Appendix 1). Conductivity fluctuated greatly, ranging from a low of 87.9 to a high of 269.4 uS. There is no numerical standard conductivity, but the DEC states that conductivity values at a site should remain relatively constant, which did not occur at any of our sites. There were not significant differences in temperature, DO, and conductivity between CSO and non-CSO samples (Appendix 2).

pH ranged from 6.22 to 7.64, and all of our November samples, two January samples, and one March sample fell below the DEC limit of 6.5. With the exception of the March sample, pH values were, on average, lower in CSO samples than in non-CSO samples. Turbidity values varied greatly, ranging from a low of 3 to a high of 126 NTU, all sites except for one in February and three in March exceeded the DEC standard of 50 NTU. The Troy 9/11 Memorial was the only sampling site that did not have at least one sample fail the turbidity standard. Turbidity was higher overall in CSO samples than in non-CSO samples, and samples with higher turbidity had higher bacteria levels ($p=0.00$, $F= 9.293$, $df=29$).

<u>Bacterial Analysis</u>

Bacteria colony counts were significantly higher following CSO events (*E.coli*: $p=0.004$, $F=5.217$, $df=27$; *Enterococcus*: $p=0.000$, $F=14.337$, $df=27$). However, on average, all of our months, except for *Enterococcus* in December, failed the EPA Beach Action Value Standards. Additionally, CSO samples only had a slightly higher rate of failing, 66%, than dry samples, 59%. Our worst results came following a large CSO event that was caused by two days of combined snowmelt and heavy rain in late February. Every sample from this event failed both standards and had the highest *Enterro* levels we saw in our study. Our highest E.coli levels were seen following a CSO event in November (See Appendix 1). No samples passed the EPA water quality limits for *E.coli*.

The Big C and Riverfront consistently had the highest bacteria levels, failing both the *E.coli* and *Enterro* limits in every sample. The Troy 9/11 Memorial had the best results out of our sites, only failing the *Enterro* limit twice (Figure 4). There were no significant differences in results between the west and east sides of the river.

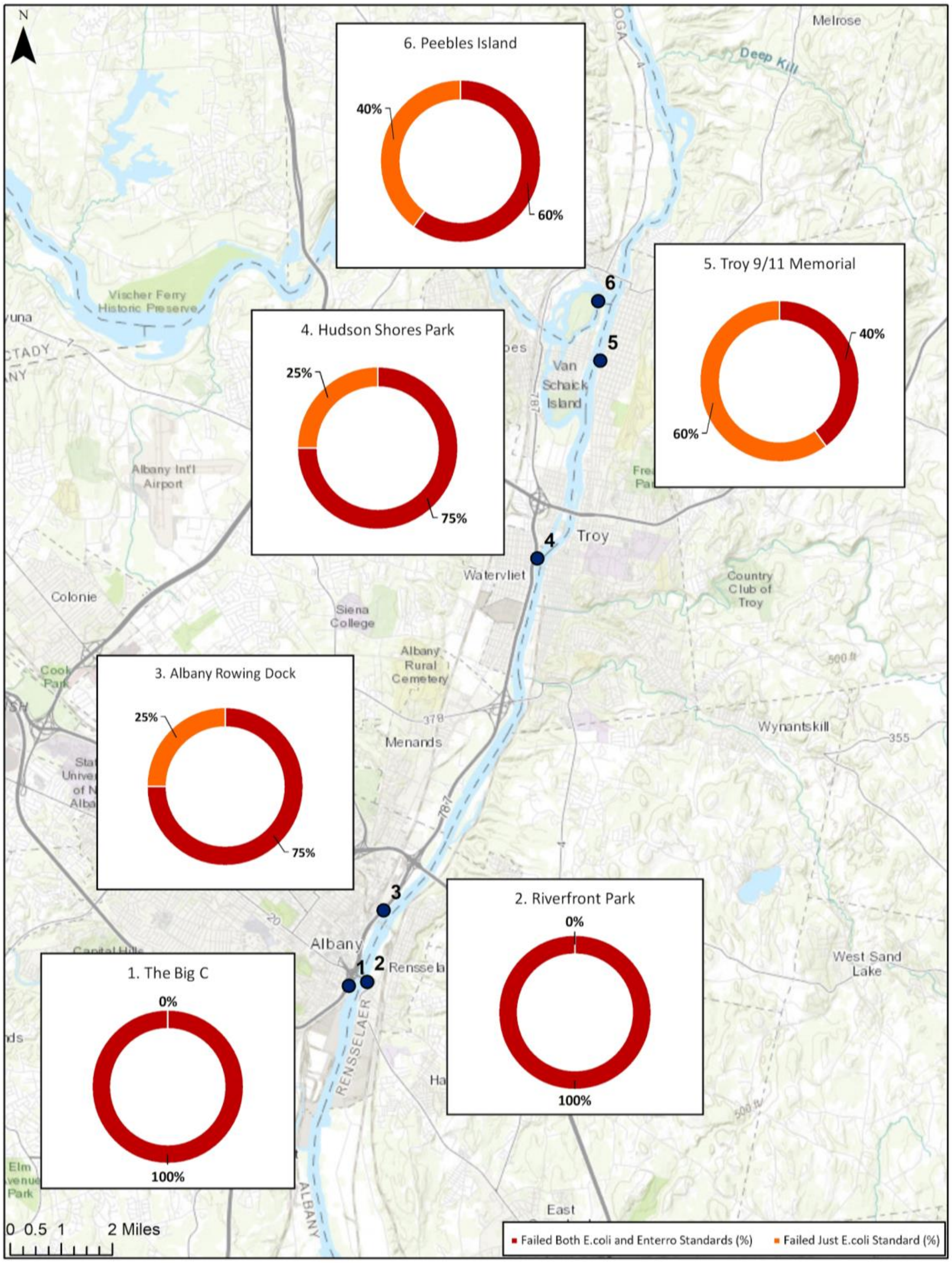


Figure 4: Bacterial results by site, by total percentage of samples. Red represents samples that failed both the *E.coli* and *Enterrococcus* EPA Beach Action Value Standards while orange represents samples that only failed the *E.coli* standard. March data was not included for sites 1, 2, 3, and 4 due to a lack of E.coli data, see appendix.

Nutrient Analysis

Nitrate concentrations were between 0.56 and 1.36 ppm. Concentrations were relatively similar between sites and months. The month with the highest average nitrate levels overall was January, and the month with the lowest average nitrate levels was December (Figure 5).

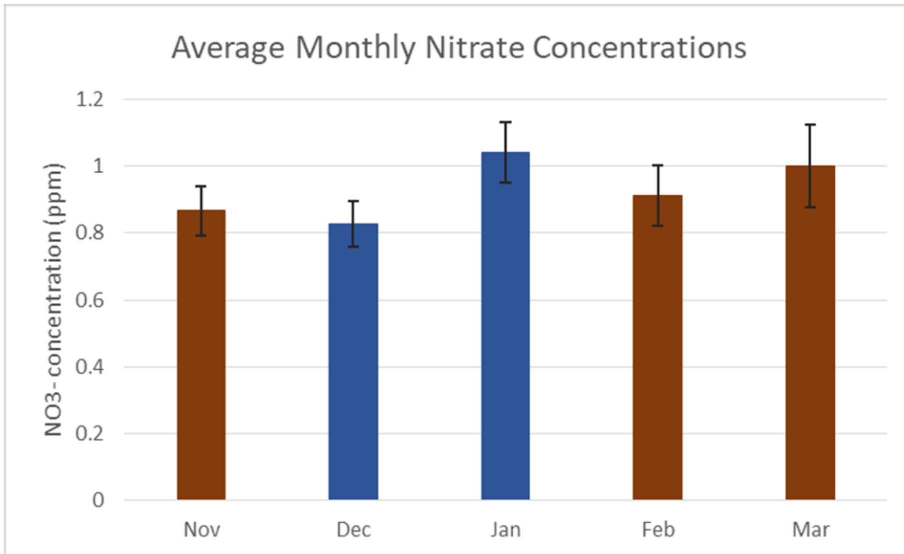


Figure 5. This graph shows average ammonium concentrations for all sampling dates. Blue bars show dry weather and brown bars show wet weather. The r^2 from the standard curve was 0.95, p=0.449, F=0.955, df=29.

Ammonium levels were between 0.46 and 0.80ppm. There was no month that had higher ammonium levels than other months overall, however there was variation between sites from month to month. The month with the highest average ammonium concentration was December, and the month with the lowest average ammonium concentration was March. There was also a large drop in ammonium levels between January and February (Figure 6).

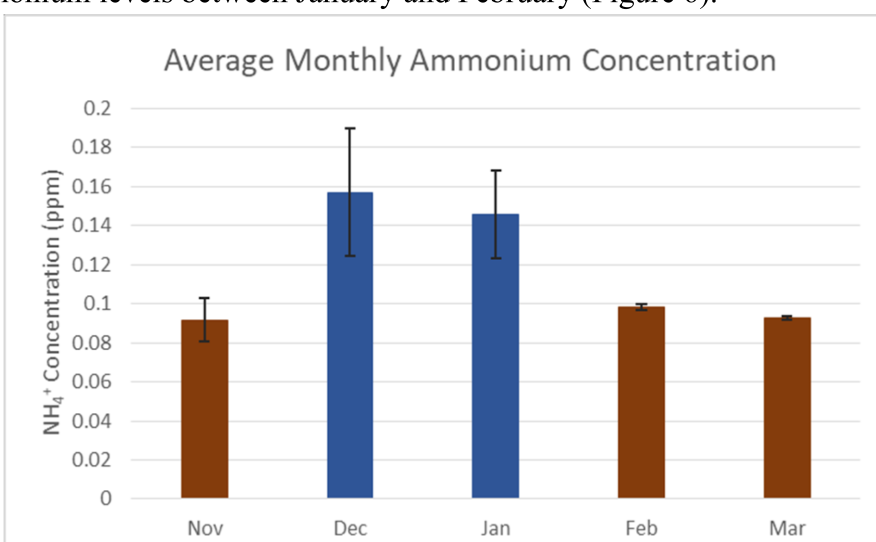


Figure 6. Graph showing average ammonium concentration for all sampling dates. The r^2 for the standard curve was 0.99, p= 0.04, F=2.94, df=29.

Phosphate levels were between 0.143 and 0.267 ppm. There is variation between all the locations sampled, as well as dates sampled meaning that there is no one site that is always higher or lower than the other locations we sampled at. The month with the highest phosphate concentration was January (Figure 7).

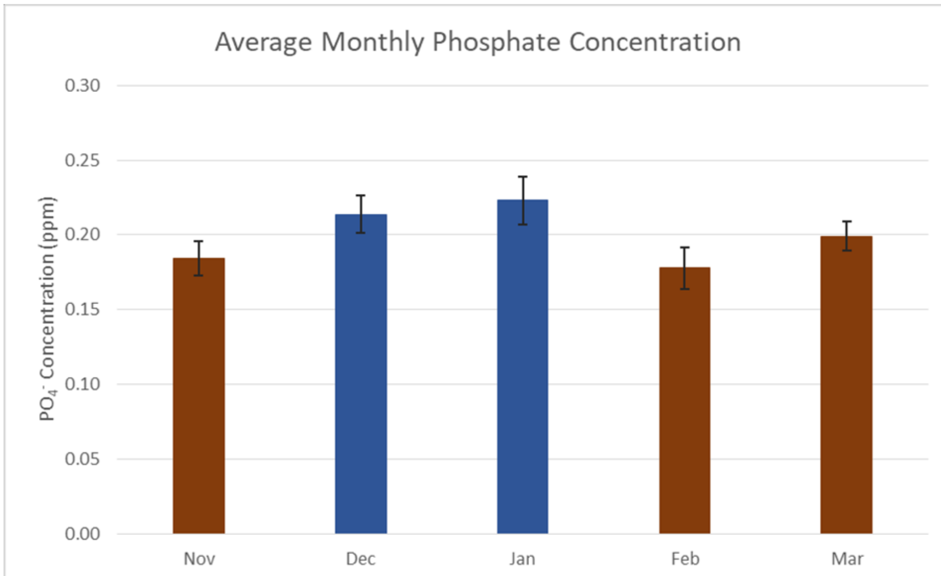


Figure 7. Graph showing the average phosphate concentration for all sampling dates. The r^2 for the standard curve was 0.99, p=0.1, F=2.185, df=29.

<u>Exploration into Climate Change</u>

Data collected from the National Oceanic and Atmospheric Administration (NOAA) shows that there has been an overall increase in precipitation of 0.82 inches per decade in Albany since 1895 (Figure 8). Data from the NY ClimAID report shows an increase in extreme rain events over time as well (Figure 9). The report also predicts an overall increase in precipitation for the Capital Region as well as an increase in extreme precipitation events (Figure 10).

CSO data collected from the New York DEC dating back to 2013 was compared to monthly precipitation data spanning the same time period gathered from NOAA to determine a correlation between CSO events and precipitation events. When counting the number of precipitation events that occurred in the three days prior to a CSO event on a monthly basis, a correlation coefficient of 0.9 was obtained (Figure 8).

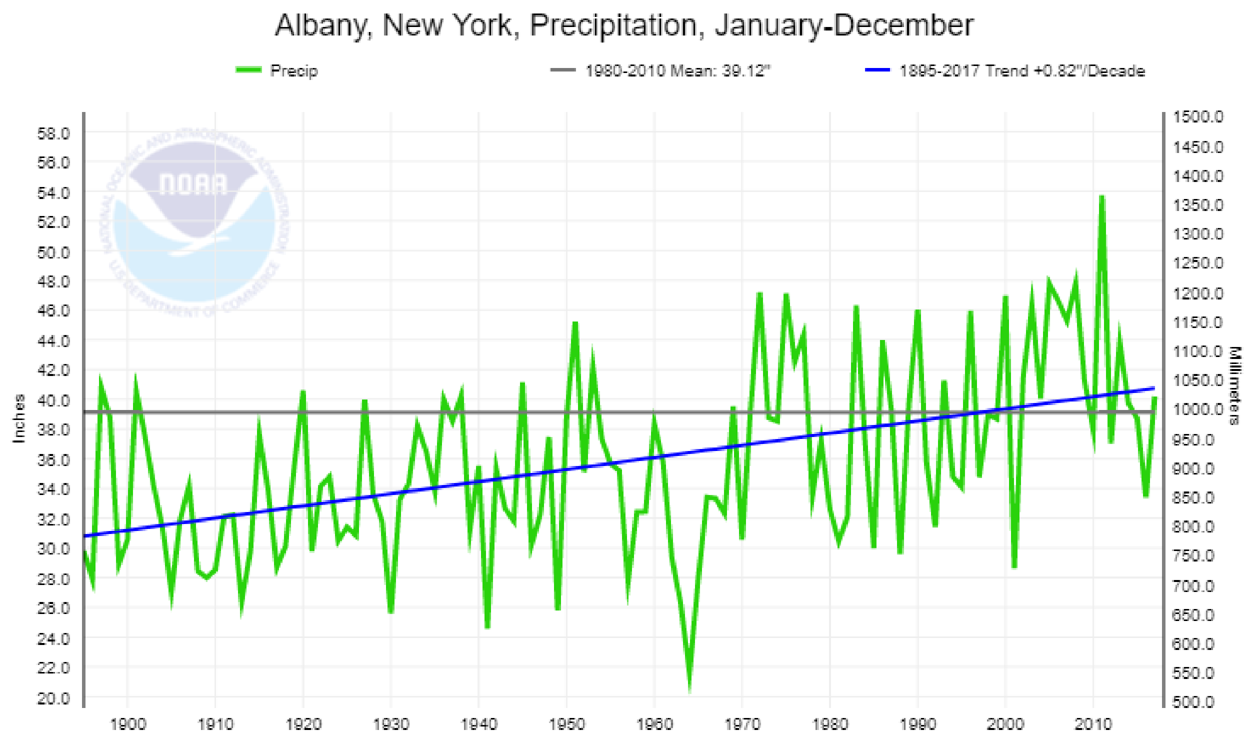


Figure 8. Precipitation data since 1895 from NOAA. The green line shows annual precipitation, the grey line shows the average precipitation between 1980 and 2010, and the blue line shows the trend of increasing precipitation since 1895.

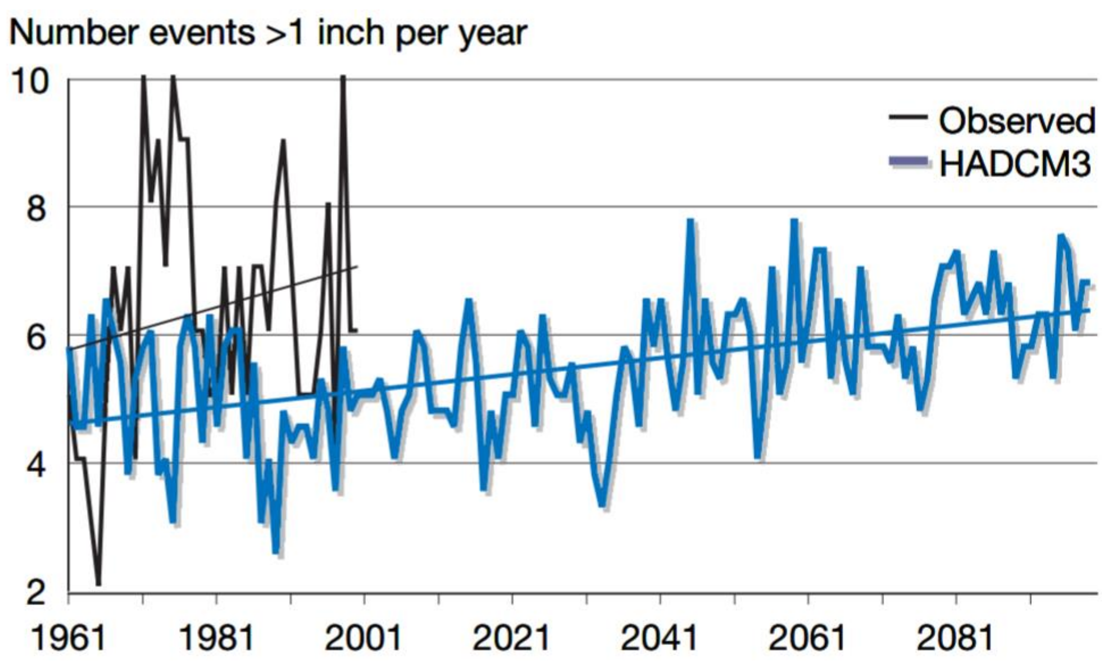


Figure 9. Observed and projected (using HADCM3) number of extreme rainfall events (>1in) from 1960 to 2100, averaged from four weather stations in NYS, from the NY ClimAID Report.

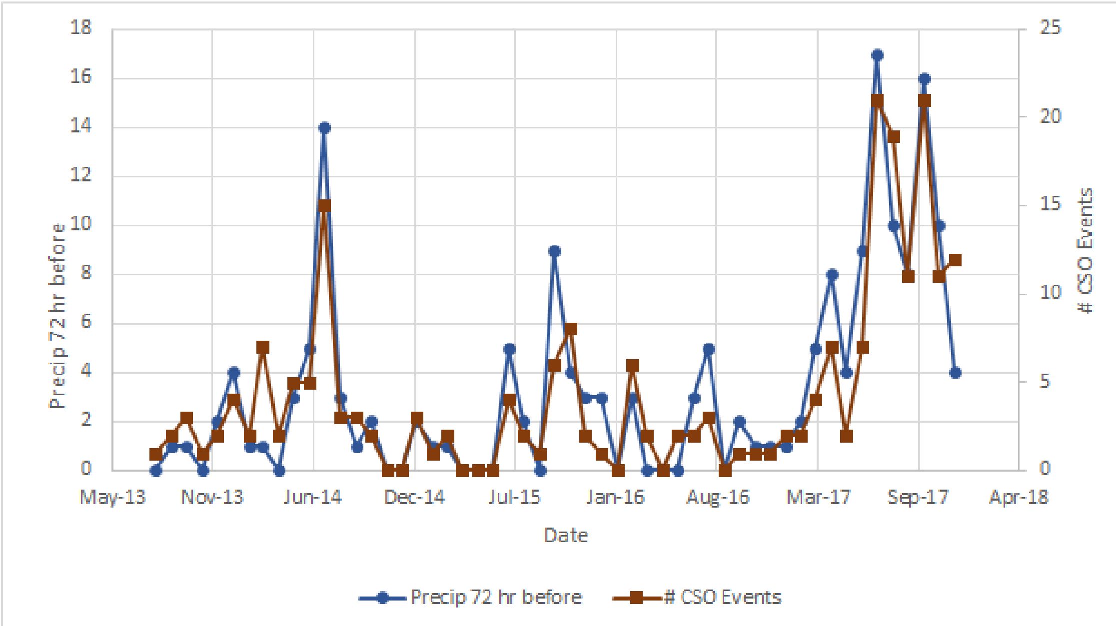


Figure 10. This graph shows number of CSO events per month in orange, and number of precipitation events 72 hours prior to a CSO event per month in blue (p= 0.000, df=52).

Quantitative Discussion

Overall, the decrease in water quality following CSO events found in our study is consistent with numerous studies on this topic (Mulliss et al. 1997; Rechenburg and Koch, 2006). Unlike previous studies, we did not find major differences between DO levels in CSO vs dry samples and our slight differences in DO are more likely due to changes in temperature of the water than the CSO events.

Concentrations for all three nutrients were generally higher on dry sampling days, despite the expectation that these concentrations would be higher following an event. This was true for all nutrients and all months except for nitrate concentrations in December. In addition to this November, December, and January have higher nutrient concentrations overall than February and March. Nitrate concentrations were relatively similar between all months with no significant difference between months. Ammonium concentrations were higher on dry weather months and were much lower following an event. Phosphate levels were also relatively similar between months and were not statistically significant.

The EPA standard for nitrate levels in water is 10 mg/L, however none of our samples were greater than this amount. Therefore the levels of nitrate in the Hudson River, even following a CSO event are not high enough to cause human health impacts such as blue baby syndrome or have significant negative impacts on aquatic life in the river. Ammonium levels were higher during dry weather months and were statistically significant, however this could be due to natural variation between water samples. This could also be due to a flooding of the system with organic nitrogen which would impact the mineralization process of the nitrogen cycle. Without testing for total nitrogen it is difficult to determine the true reason for why ammonium levels were higher in December and January. Determining acceptable levels of ammonium and phosphate proved difficult because neither the EPA nor New York DEC has any numerical criteria on levels for these nutrients. The DEC website states that currently "nutrients are regulated in New York State waters by a narrative water quality standard rather than a numeric standard." The narrative standard for phosphorus and nitrogen is thus, "none in amounts that result in the growths of algae, weeds, and slimes that will impair the waters for their best uses" (DEC, n.d.). This makes drawing a comparison between the levels of nutrients that we detected in our water samples difficult because of the lack of a numeric standard to compare to, and because while the Hudson is often cited as being nutrient loaded, it's low water residence time and high turbidity levels don't allow for algal blooms to occur (Howarth, 2016). Despite this however, ammonium and phosphorus are listed as reasons for impairment for this section of the Hudson, so although no specific limits were listed, the EPA still recognizes that this is a problem for the area. Both EPA and DEC are in the process of determining specific nutrient criteria for ammonium and phosphate, which can be used in future studies to determine the impact that these nutrients are having on water quality.

The USGS has estimated background nutrient levels for freshwater streams such as the Hudson. Based on these estimates they say that "waters with concentrations of nutrients greater than the national background concentrations are considered to have been affected by human activities in a variety of land-use settings" (USGS, n.d.). Their estimates are 0.6 mg/L of nitrate and 0.1 mg/L of ammonium. Our data show that for all months of sampling, the average nitrate concentration was greater than 0.6 mg/L even on dry weather sampling days. When examining individual data points, only two locations had nitrate levels below background conditions, however they were not much lower as these concentrations were 0.56 and 0.59 ppm. Ammonium follows a similar trend for November, December, and January where the average concentration was much higher than the background conditions. For these three months concentrations were between 0.6 and 0.7 ppm. However February and March saw a large decrease in ammonium concentrations and the average concentrations for these two months actually fell below background conditions at 0.09 ppm for both months. The USGS estimate is 0.1 mg/L for total phosphorus in streams. Our average monthly phosphate results are all greater than this estimate, however it should be noted that the USGS estimate is for total phosphorus and we tested for phosphate, which is only one component of total phosphate.

Our high turbidity levels following CSO events are consistent with the findings of previous studies (Heinz et al. 2008; Gibson et al. 1998). Our findings also are consistent with EPA findings of excess sedimentation/turbidity as a reason for impairment for this section of the Hudson (EPA, 2012). Many of these studies note that high turbidity levels were recorded in tandem with high bacteria levels, and while we did see this trend in our data, it is important to note that low turbidity did not necessarily indicate safe bacteria levels. Many of our samples had low turbidity levels while still failing the EPA bacteria standards for *E.coli* and *Enterococcus*.

In comparison to local data, our data were consistent with Riverkeeper's findings of the Capital District having very poor water quality. Overall, Riverkeeper found the Capital District had the poorest water quality of the entire Hudson, with many of these sites sampled by Riverkeeper in the Capital District having the poorest water quality out of all of the sites sampled by them throughout the Hudson (Riverkeeper, 2017). Our site by site comparison within the Capital District, we overall saw worse failure rates and thus poorer water quality than Riverkeeper. The extremely poor bacteria results from our Riverfront Park and Big C samples were not surprising given their proximity to the largest outfall pipe in the district.

However, unlike Riverkeeper, and many other studies, we did not find large differences in the failure rates of CSO vs dry samples. While samples following CSO events had higher bacteria levels than dry samples, they only failed the EPA standards slightly more than dry samples, and over 50% of dry samples failed the EPA standard. This increase in failing rates is not surprising given that sewage treatment plants in the Capital District only disinfect sewage discharge in the summer. It is also important to note that in a comparison between sampling sites across a channel (ie: shore vs mid channel), Riverkeeper often found worse water quality along the shore, which is where we saw the majority of recreation on the river while sampling (Riverkeeper, 2017).

Unlike the EPA and many other organizations, we did not find *Enterococcus* and *E.coli* to be equal measures of water quality and safety. Of our samples that passed the *Enterococcus* limits, they all consequently failed the *E.coli* standards. This calls into question the reliability of *Enterococcus* as a single parameter indicator of swimmable water, as while swimmers may be safe from *Enterococcus* contamination, they may still be at risk of *E.coli* contamination. *E.coli* tests are not conducted in the Hudson River as it is brackish water and *E.coli* growth has been shown to be inhibited by salt. However, our results indicate that E.coli are thriving in this section of the river and thus the low salt levels this far up the Hudson seem to not be having a major impact on the E.coli colonies. Additionally, newer studies on this topic show that while salt may inhibit *E.coli* growth, they are still able to persist at dangerous levels in salt contents higher than most of the world's oceans and thus even in salt water still pose a risk (Stahl et al. 2016). Further studies on this topic have shown that E.coli grown in salty environments can adapt to the salty conditions (How et al 2012). 2014 was the last year in which the EPA updated its water quality standards for bacteria, and in this version they continue to only use *E.coli* as an indicator in freshwater.

It is important to note that we could not find any studies that were conducted during the months we sampled in (Nov-March) with which to compare our data. However based on the poor water quality results that we saw, there is a current need for more sampling in winter because CSO events still impact on water quality even in the "off-season" and these impacts on winter water quality are most likely only going to get worse as climate change brings more, non-snow precipitation in the winter months, and thus triggering more winter CSO events. Additionally, as noted above, Albany Pool, like many other CSO mitigation organizations, is only focusing on mitigating the summer events, while water quality is being impacted year round by CSO events and these impacts are likely to get worse.

The predicted changes in precipitation discussed above pose a serious threat to water quality and CSO communities. Despite this, Albany Pool is basing its plan off of historical climate and precipitation data, and is not including climate change in the plan (Pool, 2011). The Albany region is expected to see a 5-10% increase in precipitation, with an increase in intense rainfall events, over the next 60 years. Additionally, the increase in precipitation will disproportionately affect winter precipitation, as winter non-snow precipitation is expected to significantly increase in the region (VHB, 2016). Based on our findings that CSOs and precipitation are so closely linked, as precipitation increases due to climate change, CSOs will also probably increase so it is important for all short and long term CSO control plans to take climate change predictions into account. The severity of not looking at the impacts of climate change on CSOs was best summed up in a document about climate change in Albany:

> "*An increase in precipitation coupled with a rising Hudson, could significantly compromise Albany's sewer and stormwater system and lead to more CSOs, more sewage backups, and a decrease in water quality in the Hudson.*" (Albany Climate)

Qualitative Results and Discussion

<u>Overview</u>

Semi-structured interviews were conducted with 18 key stakeholders within the Capital Region and New York State. Four stakeholders held a position in municipal government, six stakeholders held public positions at the county level, one worked for the Capital District Regional Planning Commission, and two worked for New York State. We also interviewed two community organizers, one long-time local fisherman, and two stakeholders affiliated with universities that have been impacted by CSOs.

A total of 150 individuals took part in the online survey, focusing on local uses of the Hudson River and knowledge of CSOs. Some respondents did not answer all 24 survey questions and only completed a portion of the survey. The respondents hail from 21 different communities across the Capital District. The survey was primarily distributed to residents throughout the six Albany Pool communities, namely Albany, Rensselaer, Troy, Watervliet, Green Island, and Cohoes. The highest percentage of respondents (34.6%) were from Troy, followed by Albany (28.9%). Additionally, 20.5% of respondents resided outside the Albany Pool communities (Figure 11).

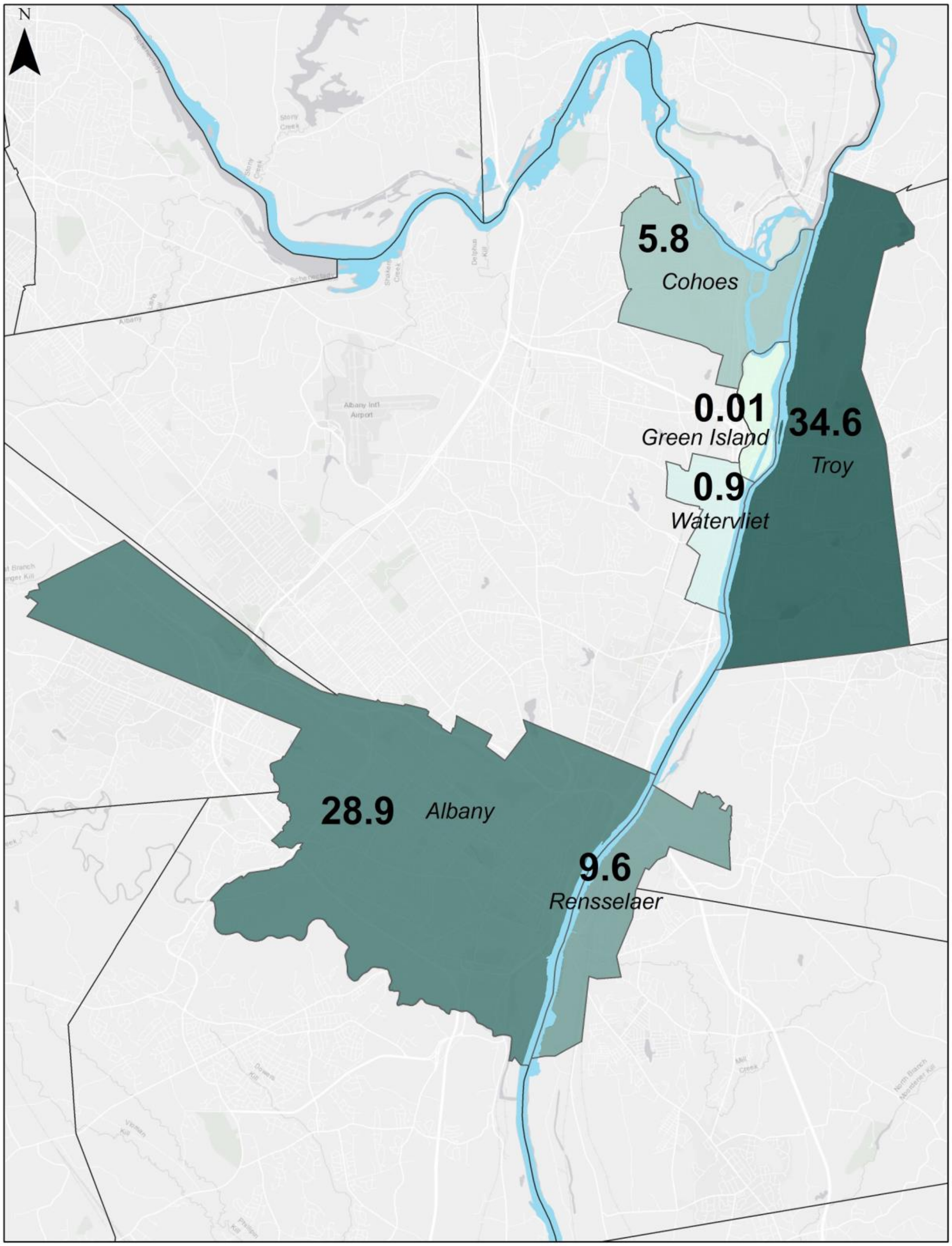


Figure 11: Survey respondent distribution in Albany Pool communities - Percent response to: which community are you a part of or reside in? (n=117)

Sewer Management: The Political Structures

Engineering Expertise

In the Capital Region, wastewater management decisions have been made based on both institutional and experiential knowledge. Prior to the formation of the Albany Pool, these different municipalities often operated in isolation. This disunion is ingrained in governmental memory, as public officials recall that the Hudson River "was like the Berlin wall" (Coffey, personal communication, 2018). While the separate Sewer Districts in Rensselaer County and Albany County had been formed in the late 1960s, there was little communication or collaboration between them until they were brought together through Albany Pool. Yet while the political structures governing these sewers across the river were disunited, the workers and managers involved in the management of the wastewater itself had developed social networks that laid the foundation for Albany Pool's creation. Wastewater treatment plant managers had already developed a cross-river relationship which became useful once they were required to collaborate to fulfill the consent order. Likewise, the DEC's assistance in instigating the Albany Pool corporation was facilitated by the fact that the DEC employee at the time was a former college classmate of the plant operator. Conversations between former college classmates, between parallel positions across the river, in comradery at wastewater conferences—all became part of the social networks that mapped on top of sewer networks and informed how new kinds of collaborations took shape.

The successes of the Albany Pool negotiations--both between federal, state, and city level governing bodies as well as inter-municipal collaboration--were partly due to the ways in which the technical expertise of City Engineers and sewage treatment plant managers were prioritized. Through their lived experience with the complexities of the wastewater system, these technical experts bring additional kinds of knowledge beyond the regulatory and legal knowledge of the political figures involved in the process. As a result of the priority given to the sewage treatment plants, Albany Pool was able to significantly reduce the cost of compliance. Upgrades at the plants meant that they were able to treat more water at a high standard and reduce the number of violations. Albany Pool was able to significantly reduce the cost of compliance with the consent order by encouraging improvements to sewage treatment plants, which were funded by external grants and increase in tax contributions from wastewater customers.

This framework for knowledge sharing is especially important where some communities have more resources, longer-term experience, and new technologies that are changing how the sewers are understood and managed. The high cost of maintaining and updating waste management infrastructure has been a primary concern from the outset. From the decision to install combined, rather than separated, sewer systems in the first place, to their subsequent neglect and disrepair, lack of funding has been a primary challenge. Through sharing funding, the formation of Albany Pool enabled more equitable distribution of infrastructural knowledge and management. The collaborative structure of Albany Pool has facilitated shared knowledge by familiarizing each of the community officials with public officials from the surrounding Pool communities. The Albany Pool Board consists of officials from many different professional backgrounds, including engineering, law, code enforcement, administration, and planning (CDRPC, 2018). Sean Ward, the Executive Assistant to the Mayor of Green Island noted, "We are a very small community. We rely on their expertise and we give expertise on a lot of this stuff" (personal communication, 2018). Further, he explains, "we have expertise that they don't: our administrative background, engineers, planners, legal team...through Albany Pool these are shared with less affluent communities." These shared systems of knowledge help minimize the need for additional resources and increase the efficiency of CSO mitigation efforts.

In a region where economic status is unevenly distributed, engineering expertise pools in particular places. While each of the Pool communities receives funding from the DEC as part of the Long-Term Control Plan, they also fund their own independent projects to improve CSO management. The way in which CSO mitigation funding is allocated at the community level may vary based on who is mandating the project. Projects stipulated in the LTCP receive differential prioritization from projects that are instigated by the municipality itself, or by the Sewer District.

The Village of Green Island, while one of the smaller communities, and with far fewer CSO locations, has a large town budget, and has allocated funding to an additional alert system outside of the mandated NY alert system to ensure that their community members receive information about CSO events.

The City of Albany's Water Board has significant assets outside of the Pool budget. Albany Water Board Commissioner Joe Coffey recognizes this privilege, explaining: "Some of the other communities might not have the same where-with-all to [establish additional reserves] but we're kind of blessed in that regard" (personal communication, 2018). As a result of this supplemental funding, they were able to invest in smart-cover technology which reports CSO events in real time. Joe Coffey explains that Albany Pool has enabled him to share this new knowledge; "Troy is looking at the smart covers now for one or more of their overflows…We have shared this with other pool communities, and the state likes it" (personal communication, 2018). Coffey mentioned that if Albany notices overflow on the smart cover system, they will notify other communities to check for CSO outfalls. This speeds up the dispersal of CSO alerts and thus, while the other communities do not have smart covers, they are at least able to benefit from the technology of other communities. In the process, Coffey describes he has become intimately integrated into this new information technology system. Every time it rains and the sewers overflow, these smart covers communicate alerts directly to his phone, which dings and vibrates until he sends the proper notification. In the rain, Coffey is in constant communication with the sewers, receiving and transmitting the sewer's fecal message to the state.

While the Albany Pool funding has led to more intimate knowledge of the sewers, some aspects of the system remain unknown. The Albany Stormwater Coalition has undertaken the task of mapping the sewershed of Albany County. They are beginning to see how the infrastructures: of wastewater flows shape urban hydrology, connected seemingly disparate locations and altering the watershed. Their mapping projects also reveal the deeply intertwined nature of combined separated sewer systems. The city is continuously accreting new infrastructure on top of old designs. Information on where the pipes are located, how they connect and where they flow is incomplete, and dependent on the expertise of long-time employees who take this knowledge with them when they retire. (Moscinski, 2018).

One response to the complexity of this matrix is to simply decide to implement GI regardless of which state mandate applies. Coffey expresses: “The projects we’ve done—it’s really the same thing. Sometimes I think we try to separate things too much, we get too nuanced with this” (personal communication, 2018). Amidst broader political and financial negotiations, Albany Pool members are constantly navigating the distinctions between the particular intention of the original mandate, the source of the funding, and ultimately, the projects that take shape on the ground.

Spatial Approaches

The process has also involved coordinating between departments. Sewer management is divided between separated systems, with the stormwater coalition, and combined systems, under the consent order. This has been challenging because so much remains unknown about the ways combined and separated pipes are entangled together in the same landscape. As Tim Murphy emphasized, even though many of the communities within the Stormwater Coalition have both combined sewer systems and separated systems,“in the past Stormwater and CSOs weren’t linked in governance” (personal communication, 2018). Both separated and combined system mitigation efforts often overlap, as both are operating within the sewershed framework.

However, other urban water initiatives in the Capital region approach the issue with a watershed, rather than sewershed, spatial lens. Where the sewershed approach is grounded in infrastructural design and politics, a watershed approach prioritizes principles of ecological connectedness and urban hydrology more holistically. The Hudson Estuary Watershed Resiliency Project, for example, promotes urban watershed planning to build community resilience for climate change. The project is a partnership between Cornell University and Cornell Cooperative Extension, DEC’s Hudson River Estuary Program, and NY Water Resources Institute. These groups are contending with overflow from the opposite direction of the sewershed; rather than dealing with how the city floods the river with sewage waste, they are concerned with how the river floods back. The Hudson will begin to inundate the city as sea level rise causes the river to encroach upon the 100-year floodplain. Unsustainable urban development both increases runoff and sewage waste, leading to CSOs, and contributes to the climate change which is exacerbating sea level rise, as the Hudson floods the city back.

Additionally, local environmental organizations help to both engage the local community and illuminate the impacts of development outside of the city’s bounds on these urban streams. The Arbor Hill Environmental Justice Corporation received a grant for a Community Monitoring Urban Watershed Project in the Arbor Hill community, which consists of five predominantly African American neighborhoods (EPA, 1999). This project included a water quality sensor for Patroon Creek, a Hudson River tributary which contains several CSS outfall locations (EPA, 2018). The sensors sent live data feeds to kiosks in the Albany Public Library and the Albany High School. While the gage was originally funded by an EMPACT grant by Haywood Burns through

NYS DEC, it was discontinued due to lack of ongoing financial support (USGS, Personal Communication, 2018). This is emblematic of the disparity between more effective longer-term educational projects, which require ongoing maintenance and sustained investment and the shorter-term funding available through governmental programs. The Stockbridge Creek Watershed Alliance coordinated citizen science efforts to gather water quality data on the tributaries leading into the Hudson River, focusing on locations identified as environmental justice neighborhoods by the EPA's environmental justice mapper. This project not only provided localized data on nutrient and bacteria levels but also revealed new issues not yet identified by the government, such as the discovery of leaky pipes and illicit connections discharging sewage directly into the creeks. The NATURE Lab in North Central Troy has also sought to address environmental justice concerns through citizen science. However, rather than sampling in locations determined by a spatial algorithm, they brought local low-income youth into the process of data collection itself. With bioartist Oliver Kellhammer, participants in the Uptown Summer Youth Program collected and analyzed samples from the Hudson River (Media Sanctuary, 2018). Not only were their neighborhoods receiving newfound attention after decades of neglect, but they were actively involved in the process, empowered to become curious about their local ecologies and forge new relationships with these contaminated sites. Citizen science as a means of community outreach provides an opportunity for communication not only through information dissemination but also through experiential engagement. Providing local residents with the tools to understand their local water bodies themselves enables them to develop a deeper relationship with the river.

The watershed approach to urban ecology is thus not only a different way of structuring and understanding urban space, but a mode of relating with that place through longer-term engagement and experiential education. Collaboration between watershed and sewershed approaches might thus entail both cross-pollinating different management frames and integrating the experiential knowledge of engineering experts and citizen scientists. Thinking with both watershed and sewershed frameworks might not only help to bridge these horizontal boundaries between governing bodies, but also between governments and communities.

Case Study: Beaver Creek Clean River Project

The Beaver Creek Clean River Project exemplifies how the gap between public knowledge and engineering expertise has created challenges for CSO mitigation projects, and the insufficiency of Albany Pool outreach efforts in bridging this gap. The Beaver Creek Sewer line accounts for 45% of all capital region combined sewer discharge (Albany Pool, 2017). As one of the largest Albany Pool initiatives, the proposed project is a floatables collection facility that will redirect and filter solid waste from the submerged creek (public meeting, 2018). The facility will be located on a public park near an elementary school in the South End of Albany because it had to be along the Beaver Creek line but also outside of the Hudson's 100-year floodplain.

Local community members demonstrated concern that the project was deliberately cited in this South End of Albany because it is a low-income neighborhood. Aware of the long history of environmental injustice, where environmental disamenities such as sewage treatment plants have been sited in low-income neighborhoods of color, many view the Albany Pool's rhetoric surrounding the project as an attempt to green-wash a dirty project. In a social media post, a member of the local neighborhood association expressed her dismay that the treatment facility will be sited in the park near the school, noting that "the name given to this project and the water facility...requires reading between the lines. This water facility is in fact a SEWAGE treatment plant" (Hille, 2018). While from an engineering perspective the facility does not qualify as a sewage treatment plant, the project managers have dealt inadequately with the undifferentiated public perception of waste infrastructure.

This knowledge controversy also represents public amnesia about both the pre-existing creek and the sewage already leaking from the pipe into the park. The misconception that "with this plan, the South End becomes the dumping ground for treatment of other neighborhoods' sewage" suggests a lack of public understanding of sewage infrastructure more broadly (Hille, 2018). The South End had already been this "dumping ground" for many years; the aged Beaver Creek pipe currently seeps sewage into the park's ravine. The project was intended to not only mitigate the problem of CSOs more broadly but also to improve the conditions of this particular neighborhood park specifically; in addition to removing solid waste from the wastewater stream, the facility will also reduce the odors on site, replacing contaminated soil with a garden designed for educational and recreational use. But by re-branding the project as "clean" and "green" rather than directly addressing this history of injustice, the Albany Pool failed to bridge the knowledge gap. The Beaver Creek Clean River Project is intended to be a solution to this environmental justice issue, but without the necessary educational outreach required to convey the embedded injustices of pre-existing infrastructure—as upstream wastes flow into this downstream South End neighborhood—both past infrastructural injustices and present waste flows remain obscured to the local community, who then perceive the project as a new imposition of waste infrastructure into their neighborhood.

In addition to these misunderstandings about the project's origins and intent, the community was not meaningfully engaged in its implementation. While the Albany Pool held several public meetings about this project, the community felt this outreach was largely symbolic, and that meetings were too infrequent, poorly advertised, and in inconvenient locations. One social media commenter expressed their opinion that the facade of community outreach was merely a "patronizing sham" (Johnson, 2018). The community was not presented with alternatives, such as actually daylighting Beaver Creek, separating it from the sewage lines and reinstating its original hydrology. These alternatives suggest additional artificially-imposed limitations to the project in addition to the geographical constraints of the sewage line and the floodplain; the need to meet the demands of regulatory deadlines and the lack of funding precluded a discussion of more creative solutions. Without being presented with alternatives, or the opportunity to propose them, the community was left with little room for opposition. Additionally, the community engagement came late in the process of designing the facility, partially as a result of local activist pushback. As a result, while the framework for community engagement was in place, the process and context did not support the full diversity of voices on the issue. The disparity between local concerns and official outreach efforts remains an ongoing challenge to Albany Pool efforts to engage the public about CSOs.

Education & Outreach Efforts

As the public opposition to the Beaver Creek Project exemplifies, education and outreach has remained a continuous struggle for those working within the water quality field and on occasion even provides barriers to implementing projects. As our survey results showed, 57 % of respondents were not familiar with the term "combined sewer system" and 64% of respondents were not familiar with "combined sewer overflow." Even of respondents familiar with the term "combined sewer systems," 19.6% of those respondents were not familiar with the term "combined sewer overflow" or "CSO." While the survey respondents reflect a small subset of the population, a number of respondents engage in water activities, such as rowing, fishing, and swimming. As contact with the water increased, knowledge of CSOs decreased. Even when speaking with individuals attending an environmental symposium, the percentage of panel attendees familiar with CSOs reflected our survey, with roughly two-thirds being unfamiliar with the term.

Education on water quality can be sporadic depending on the agent, and those leading education and outreach efforts do not often come together to form coalitions to maximize their reach and pool resources. In conversations with employees of the Albany County Stormwater Coalition, NYSDEC Hudson River Estuary Program (HRE), and Albany POOL, there were multiple outreach and education projects over the years; however, joint projects were infrequent despite rare cases. For example, during apparent overlap in jurisdiction, as when the Stormwater Coalition and Radix work in an area that was initially thought to have separate sewer systems, or when coming from similar areas of work, as when NYS DEC and the Albany Pool paneled together (the Long-Term Control Plans are created by the DEC and implemented by Albany Pool) (Heinzen, personal communication, 2018; Vail, personal communication, 2018). There are fewer instances of regulatory and governmental bodies working in tandem with citizen science, non-profit/non-governmental, and community led watershed groups in the region.

The overall lack in consistency of education and outreach efforts by established agencies can be traced to how outreach is prompted. Much of the community interaction and education occurred during regulatory enforcement/work or when the agencies were invited into the communities:

> We get invited in often. There might be places where we would say, 'Oh, this place is really well-suited for something.' But we don't necessarily look at the map and say, 'that's the place we should work.' We really go with the people who are passionate, who are invested, and that's a way that I prioritize my work. That's different from how other programs operate. We really want to build local capacity, we want to support these groups, as they grow and develop so they can take action effective locally. (Emily Vail, personal communication, 2018)

While this is an effective way to target and build local capacity, especially in proactive communities, the approach may miss communities that are less informed about stormwater and therefore not seeking assistance. The Stormwater Coalition has in the past provided brochures and targeted education, but as their work has shifted to "sewershed" mapping, education has primarily reverted to educating problem areas via informational pamphlets or relying on action from the municipality governments (N. Heinzen, personal communication, 2018).

Municipalities have used a variety of means to spread information regarding important developments, including those about water quality. Multiple communities have local Facebook pages to spread information, a mechanism that agencies such as the Stormwater Coalition have yet to take advantage of (N. Heinzen, personal communication, 2018). Other communities, such as Green Island distribute newsletters:

> Our village newsletter goes out to every resident in Green Island with an electric account, but every unit has an electric bill and in that electric bill is a newsletter, we try to put any imperative information in that newsletter on a monthly basis… so we do alert our residents about CSOs, about the Pool communities, about stormwater, about best practices. That is our strongest way of reaching the entire population of Green Island. (M. Alix, personal communication, 2018)

Making use of the Everbridge Alert System, village website, social media, CDRPC's website, and the Stormwater Coalition's website, the Village of Green Island has developed multiple pathways to reach out and inform citizens not only on developments, but also education and best practices.

However, the effectiveness of more extensive methods are questionable as other distributors have had minimal success in community responses and increased knowledge. County Sewer District Director Gerard Moscinski expressed his frustration at the public response:

> One of the issues in the consent order is public education… I had 7,000 made, we sent to every customer in the sewer district. Guess how many phone calls I had about that? Zero, zero. Not a one. Not a one. I was very disappointed. A person would call… and I would ask 'did you see the insert I sent with the bill?' and they would say 'What? What are you talking about? I don't look at inserts.' That was part of the public education process to let them know what was going on… It was disappointing... What can I tell you? You start sending them a bill for more money, and believe me they call. (personal communication, 2018)

Such experiences indicate that education and outreach that occurs face-to-face, with visible river users, may be the most effective and long-lasting teaching and outreach method.

This approach is currently used by the NYS Department of Health's (NYS DOH) Hudson River Fish Advisory Outreach Project, which educates on fish consumption, by attending community events, creating educational material, and partnering with a wide variety of local organizations, including nutrition and environmental educators, health care providers, food banks and faith organizations, social service providers, municipal parks and recreation staff. As 33% of people on the Hudson between Troy and Catskill were aware of the advice, yet continued to eat fish, outreach efforts must not only convey what is happening in the Hudson, but what it means to individuals consuming the fish (NYS Department of Health, 2016). The educational approach must be culturally relevant and sufficiently urgent for individuals who are more vulnerable to potential negative health effects. The NYS DOH has partnered with organizations that provide services to newcomers, such as Latinos Unidos of the Hudson Valley, the U.S. Committee for Refugees and Immigrants, and the Chinese-American Planning Council. Through these partnerships, they have restructured their educational approach to be culturally relevant to the diverse audiences they are trying to reach. These approaches exemplify coalition building and community integrated approaches to create more effective education and outreach programs.

Government and regulatory agencies working with CSOs have not embraced these partnership or coalition education/outreach programs as they have with Fish Advisory Outreach Project. Regulatory agency education is often focused on the top-down approach on how individuals should interact with the river following a CSO event and how they prevent causing more harm (i.e. best practices), rather than building reciprocal relationships with community, watershed, research, advocacy, and educational groups.

Case Studies: The Lower Hudson and Community Workshop

Groups in the Lower Hudson have started to take the initiative in coalition building and outreach that connects government, regulatory, education, science, advocacy, and community organizations. Ryan Palmer of the Center for the Urban River at BECZAK, which is partnered with Sarah Lawrence College, worked with municipalities, organizations such as Riverkeeper, and other local watershed organizations in the first Lower Hudson Urban Water Summit on March 1, 2018. With over 125 people in attendance and excited responses, the Summit seems promising for future engagement and communication between citizen and regulatory groups. Already there is talk of the formation of new watershed groups (Palmer, personal communication, 2018). However, Palmer also outlined both the importance and difficulty in building these bridges:

> To start something fresh is hard… when you're sort of going in blind to a new community it always almost never works. People maybe show up to one meeting, but in terms of really getting the people engaged is hard… They need to know that their time will be well spent and that something will actually happen. (personal communication, 2018)
>
> You know some of the groups were not that accessible to everyday people. It seems like have at least realized, even if they haven't had success at it that, people are the solution to all these problems… You have to try hard to get young people, to get a diverse audience, to get the community involved because they're the ones that really matter, not that PhDs aren't important, but you can't just sit around in a room full of scientists and solve what is more of a people issue… (personal communication, 2018)

To see if community/sewershed/watershed/etc. members in the upper Hudson would be receptive to coalition building workshops and summits. In the panel “Watershed, Sewershed, Seedshed,” at the *Ruderal Ecologies: Grounds for Change* symposium, findings from archival, quantitative, and qualitative research in the context of Troy was presented to an audience of community members and organizers, artists, academics, activists, and city council members. Paneling to represent different areas of knowledge and expertise on CSOs, and relating the phenomenon to their own work was Emily Vail, Gerry Moscinski, and Scott Kellogg.

While the majority of attendees simply listened to the panel, one young male professional, engaged in Troy's local government, expressed great interest in knowing more about sewage treatment, educational efforts, and activist opportunities. Hearing about upcoming projects, such as Scott Kellogg's bio-remediation islands, people asked how they could become involved, and Emily Vail expressed the desire to work further with NATURE Lab and other organizations. The receptiveness of the panelists to working with one another in addition to the attendees' positive responses shows promise for potential future multi-partner and stakeholder education/outreach efforts in the Upper Hudson and Capital District.

<u>Access to Information</u>

Each of the Pool communities is required to report CSO events to the public through the NY-Alert System within 4 hours of a CSO event (DEC, 2017). Although the alert system is open to the public, only 3 out of 123 respondents reported receiving the sewage spill notifications from NY-Alert System (Figure 12.).

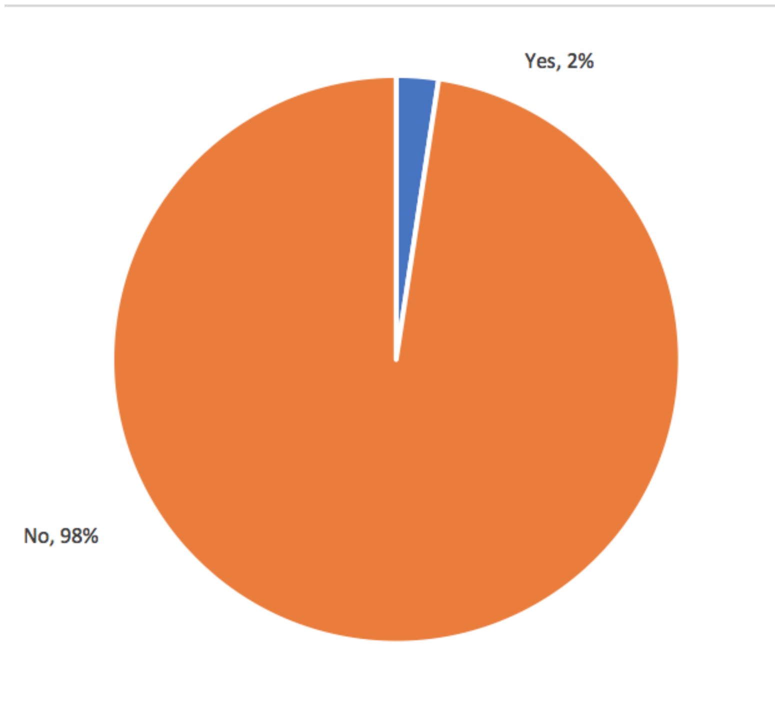


Figure 12: Do you receive the NY-Alert sewage spill notifications? (n=123)

It is important to note that the majority of respondents were not familiar with the term CSO, thus it is unlikely that they signed up for NY Sewage Spill Alerts. Additionally, the sign up process is complex, requiring multiple steps, which deters even more individuals from obtaining the alerts.

This lack of awareness about the alert system was echoed by the Director of Radix, Scott Kellogg. He reported:

> I only heard about it [NY-Alert] at the Vacant Lots Working Groups recap when the Water Board was talking about it. I believe that now it is state law that CSOs need to be reported and notifications need to be sent out, which is why the Water Board got in trouble this summer...Some of them [referring to NY Alerts]…ok…look at this one. I don't even know what that means (personal communication, 2018).

In his statement, Kellogg also indicated the lack of clarity within the notifications. For example, one of the NY-Alert notifications reads "3 House Laterals are directly tied into Dry River Conveyance System" (NYS ITS, 2018). While this alert was supposedly issued by Watervliet CSOs, it is unclear if this actually refers to a CSO event. Therefore, even if individuals receive the NY Sewage Spill Alerts, they may not understand the terminology utilized. All together these factors contribute to the lack in public knowledge surrounding CSOs.

In addition, two other key stakeholders reported that the NY-Alert System has shortcomings. These discrepancies have caused some of the Pool communities, such as Green Island to create their own alert systems. The Village of Green Island Code Enforcement Officer, Maggie Alix, noted that "we [Green Island] do have the NY-Alert system as well, which is an option, but we don't feel that it is heavily utilized" (personal communication, 2018). This highlights both the ineffectiveness of NY-Alert and the inconsistencies in data access between the Albany Pool communities. While Green Island's Everbridge Alert System is accessible to members of other communities, it is not actively distributed beyond Green Island and many of the aspects of Everbridge are specific to Green Island. This also brings up larger environmental justice questions about how the wealth and resources of a community shapes the ability to invest in particular outreach mechanisms, such as a separate alert system, and the ability of the public to have access to this digital data, and understand its implications. The challenges to public knowledge of CSOs remain even when distribution errors and lack in clarity do not occur. What people know (or do not know) about Hudson contamination changes how they engage with the river.

<u>Public Access and Use of the Hudson River</u>

Walking along the Hudson, there are stark contrasts in use and access to the river. Some stretches remain easily accessible to the public, while others are blocked by physical barriers. Yet, some locals and residents of the surrounding communities continue to use the river for a variety of activities. As it flows through the Capital Region, the Hudson is dotted by parks, rowing and boat clubs, bike paths, and numerous docks. Questions of who has and lacks access to the river, and how the river is utilized speaks to community-human-river relationships that reflect not only access to natural resources, but also information, culture, and socioeconomic status.

Past development created physical barriers to the river, such as in the City of Albany, where the interstate separates the city from the riverfront (Figure 13). Accessing the river requires knowledge of specific access points, which are in themselves still limited to small stretches, which continues to alienate residents (S. Kellogg, personal communication 2018). Improvements, though slow, have been made, both in Albany and other communities. Starbuck Island provides a large open green space on Green Island that many locals use, and the number of pedestrian bridges and paths have increased partially due to the implementation waterfront revitalization initiatives. Albany now has the Corning Preserve that serves as dock point, park and path connection. The Commissioner of the Albany Department of Planning and Development, Chris Spencer, mentioned tackling the barriers between communities and the Hudson River through lighting, innovative design, and sculpture, which try to naturally reconnect people to the waterfront (personal communication, 2018). Some of these actions have been successful, as a long-time fisherman noted the increased usage over the years as the water's quality has seemed to improve (personal communication, 2018).

Figure 13: New York Interstate 787 creates a physical barrier separating people from the river in many areas and providing only limited number of access points.

These physical barriers limit and promote the types of interactions and relations that people have with the river. The previous, though slowly eroding, physical separation of people from the water impacts perceptions and to some degree knowledge about the river's concerns and pollution. The lack of effective and educational outreach by informational bodies, such as the Stormwater Coalition, Albany Pool, and various municipalities, mean that individuals are often not considering pollution concerns when interacting with the water or understand how they are impacting the river.

Our online survey posed questions on what river usage activities were most common, with the option to select swimming, boating, water sports, fishing, recreation at parks and paths alongside the Hudson, other, and "I choose not to respond" (Figure 14) While our respondents are primarily taking advantage of parks and paths, activities such as boating, water sports, fishing, and swimming drew our attention. People engaging in activities that put them in direct contact with the water are at much higher risk from the negative health implication of CSO events.

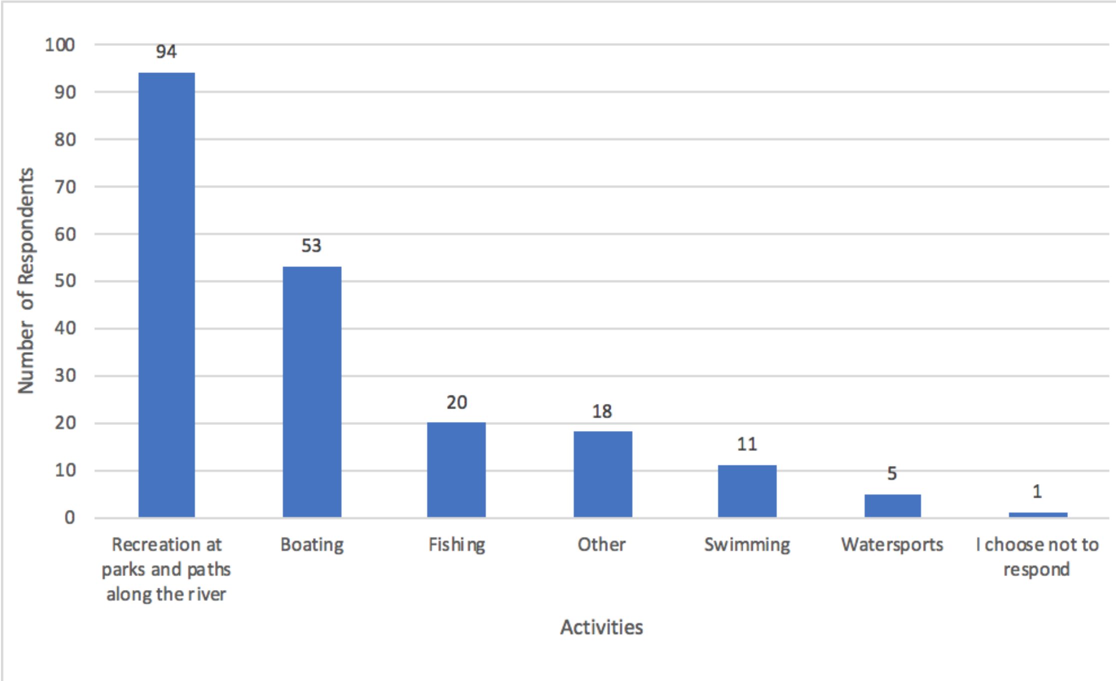


Figure 14: Select any and all activities that you do on the Hudson River. (n=150)

While 64% of respondents surveyed were unfamiliar with CSOs, there is general concern regarding overall water quality. In ranking Hudson River water quality, 61.42% of respondents ranked perceived pollution between 6 and 10 (0 being no pollution and 10 being extremely polluted). No respondents gave perceived water quality a ranking of 1 or 2.

A trend in our data showed that people most directly engaged/in direct contact with the water were less likely to know of combined sewer systems or CSOs. Analyzing the survey results showed that only 18% swimmers were familiar with CSOs. Fishers, which made up 13.25% of respondents including 20% of which fished for consumption, fared only slightly better. All respondents who fished for consumption were not familiar with CSOs. In total only 25% of fishers were familiar to CSOs. The lack of knowledge by those closely interacting with the river reinforced when speaking with a long-time catch and release fisher on the Hudson, who takes people on fishing excursions, noted that he was unfamiliar with CSOs and, while aware of different sources with water quality information, does not utilize them before going on the water (personal communication, 2018). The awareness of CSOs by these two groups is markedly lower than that of the respondents taken together, where 36% were familiar with CSOs.

Further, education sessions with recent immigrants and refugees fishing in the Hudson illustrated unexplored gaps in knowledge, access to information, and differing relationships to the river. As a result of NYSDOH's local research, they have found that newcomers to the area, including immigrants and refugees, are often in close contact with the Hudson, yet know less of its superfund/pollution status (NYS Department of Health, 2016). Because our survey does not account for the potential differing levels of awareness of CSOs and pollution in immigrant/refugee/non-native English-speaking communities, knowledge may be even markedly lower, putting these groups at increased risk.

Despite water quality improvements since the 1960s and the PCB dredging projects in recent years, there may be some perceptions of improving or safer water conditions. However, as the quantitative research illustrated, no samples passed the EPA water quality limits for both *E.coli* and *Enterro* levels, with levels and bacteria colony counts peaking after CSO events and failing 66% of the time in comparison with 59% of non-CSO samples. Perception and knowledge of the river's cleanliness seems to impact the relation and activities that one engages in, whether it is for leisure, subsistence, or activism. Therefore, analyzing local perception and knowledge is of great importance to understanding how to create coalitions to improve water conditions, educate people how to engage with the water, and provide better access to information during times of high pollutant discharge and overflows.

Mitigation in Policy and Practice: Hurdles and Opportunities

Many stakeholders mentioned specific mitigation strategies that were being undertaken by their organizations. Amongst these interviews, *funding* and *administrative challenges* were common themes. There are a wide range of mitigation tactics and many of them are not overly complex. Some of the technologies have been around for several centuries. As Ryan Palmer of the Center for the Urban River Beczak stated:

> It's [Combined Sewer Overflow] not an engineering feat, we know how to fix it, it's just talking about pipes, water, and poop; we're not talking about putting someone on the moon. It's really just a will thing; a political will thing. Getting people elected to office, getting people engaged, getting funding for departments to fix these problems. (personal communication, 2018)

Thus, effective mitigation does not necessarily require the implementation of groundbreaking technology, but rather efficient management, coordination, implementation, and improvement of existing technologies and systems.

Since wastewater infrastructure is managed by counties and municipalities, CSOs are in competition with many other initiatives for public funding. Although CSOs have a variety of environmental and social repercussions, governing bodies are also faced with other pressing public issues. Martin Daley, the Director of Water Quality Programs at CDRPC, mentioned that the Albany Pool projects "are all new projects and they are in addition to the capital backlog that these communities have of infrastructure projects that are no less important to protect their systems… and to protect their public health" (personal communication, 2018). Not only do these communities have to deal with issues within other governmental departments, but they also are facing aging wastewater infrastructure that was built in the 1960s, costing both time and money. As Daley acknowledged:

> We are at the end of the useful life of a lot of these facilities and so it's a real critical time moving forward for these systems and so you'll find a lot of the communities are eager to address these, but they just don't have the financial mechanisms in place to do all of the things on that wishlist. (personal communication, 2018)

Thus, funding and attention are, at times, directed towards maintenance needs of current infrastructure and alternative public health projects, rather than new CSO mitigation initiatives and infrastructure. For example, water treatment improvements account for $15.8 million of the total $109.7 million (Pool, 2011).

Beyond the Sewer: Green Infrastructure

Meanwhile, ongoing development continues to increase impervious surfaces. In this environment of suburbanization undeveloped land is automatically deemed as "wasted space." As the landscape is continually remade in the image of a sanitized suburban utopia, the result is the movement of waste elsewhere—the creation of new spaces of waste on downstream beaches, aquatic habitats, and fishing piers. Designing these developed landscapes to increase rainwater retention is a way to mitigate this displacement of waste elsewhere.

As a result of both widespread development and the high expense of more large-scale infrastructural changes, green infrastructure (GI) has become one of the main low-cost tactics utilized to combat CSOs in the Capital Region. While the increased implementation of GI within the Capital Region has been proven to effectively manage CSOs, it contains similar challenges of maintenance. Nancy Heinzen noted that "most contractors don't come at green infrastructure with a deep knowledge of native plants. But now we're asking them to know all about native plants. They can learn it, but it will taking a while to understand the function," (N. Heinzen, personal communication, 2018). Since many contractors have an unfamility with practices required for green infrastructure implementation, these projects may be poorly-designed and less effective. Additional resources would need to be directed towards professional development trainings, where local contractors can learn environmentally mindful practices to use in these projects. However, this would require willingness and support on the part of the municipalities and contractors.

In order to expand the possibilities of green infrastructure implementation, the CDRPC conducted a feasibility study for creating a green infrastructure banking system. If an organization were unable to meet the required amount of green infrastructure on a given site, then they could develop green infrastructure projects on an alternate location with higher permeability (M. Daley, personal communication, 2018). This would give organizations alternatives to fulfill the necessary stormwater retention requirements (Mastraccchio & Miller, 2017). A credit banking system has not yet been rolled out in the Capital Region, but it has been proven to be an effective method in cities, such as Washington D.C. and San Antonio, Texas, for engaging a wider range of community stakeholders in practices that mitigate CSO events. However, under this system, the siting of GI is primarily guided by economic considerations.

In addition to acting as a buffer and filter for stormwater runoff, stakeholders listed a number of co-benefits that come with the implementation of GI. It was reported that GI has a great potential as an educational tool (M. Daley, personal communication, 2018, C. Spencer, personal communication, 2018, N. Heinzen, personal communication, 2018), possibly because it has the potential to strengthen residents' engagement in a place (Anguelovski, 2013). Stakeholders also mentioned that GI reduces heat island effects and contributes to community aesthetics (M. Daley, personal communication, 2018). The fact that green infrastructure can be used to tackle multiple facets of environmental and social issues, makes it incredibly appealing to public officials. The director of the The City of Albany Department of Water and Water Supply, Joe Coffey, noted that:

> Some projects we designed to be a green infrastructure project. Quail Street was designed, and it worked. Others go along with project…GI is another tool in the toolkit. The project is here, what green infrastructure are we going to use as part of the project. Do it everywhere you go, it's part of who we are. Our mission is to incorporate GI wherever we can. (personal communication, 2018)

This philosophy of incorporating green infrastructure into all possible development projects was a common response amongst many other key stakeholders as well. It shows that municipalities are looking at CSOs holistically and systematically and are not just using it to fill a quota. Rather than using another expensive piece of artificial technology, the use of green infrastructure promotes the rehabilitation and regeneration of natural ecosystems. However, while government agencies recognize that green infrastructure has the potential to rehabilitate ecosystems and strengthen community ties, its environmental remediation and community building potential has been largely an afterthought. Developing green infrastructure as part of larger construction projects cuts costs, but it also fails to address other more systematic challenges, such as habitat fragmentation and inequitable distribution of environmental services. Therefore, it is important to incorporate these social and environmental understandings of green infrastructure into design and siting, rather than considering them as an added bonus (Jerome, Mell, & Shaw, 2017). While this multifaceted approach of green infrastructure design has high potential, it requires strong coordination amongst multiple governmental bodies (Schifman et al., 2017), which has proven to be a difficult for Capital Region municipalities thus far (C. Spencer, personal communication, 2018).

The Quail Street Green Infrastructure Project included a "collaborative educational component to be performed in conjunction with the College of St. Rose and the University of Albany's Downtown Campus." (Pool, 2017, p 5). Under this framing, the signs "perform" education on the street by serving as evidence of this governmental-higher education collaboration. After the originary engagement of their creation, the signs have become static objects on the street, and little attention has been payed to the actual reception and influence of the information they depict. On a given balmy Sunday, few passersby pause to read the signs, or contemplate the relation between the scrawny saplings, the sewers, and the Hudson. The emphasis on signage reflects the pedagogical orientation of the Albany Pool project towards fulfilling the requirements of the consent order.

Government agencies are often reluctant to partner with citizen groups, both due to a political imperative for rapid, single-issue response and concerns around liability were something to go wrong (Kellogg, 2013). Consequently, governmental agencies are commonly unfamiliar with community concerns surrounding green infrastructure practices and alternative approaches. The construction of a GI site in Watervliet entailed the removal of several mature trees. These trees had long been cared for by the local residents, as one tree grew older, the community moved sidewalk slabs to allow its roots to expand. The younger GI trees are aimed to grow into power lines overhead. Mature trees decrease runoff exponentially more than smaller trees through as their leaves intercept rainfall and root networks store water in the soil (MacDonagh, Smiley, and Bloniarz, 2012). Additionally, the project created a significant disruption in the community; the new sidewalk retains snow cover for longer, becoming a challenge for older residents in the winter and the construction disturbance in the street caused one resident to lose a tenant and local businesses to lose customers.

Treating green infrastructure simply as an extension of sewer infrastructure ignores the diversity between sites in the city; it ignores the complexity and history of local, pre-existing ecologies. This prioritization is spurred by the political mandate for implementing new GI practices and the 'smart city' imperative for green technologies. Focus on protecting these older trees should determine the placement and types of GI practices that are installed on site (US EPA, 2014).

Rather than relying on the logic of economics, GI might be sited in order to maximize communal value, access to the river, and what sites might have the largest watershed impact from an urban ecology perspective. GI should "become less about stormwater detention and more about community access, creating resilient habitats, and providing flood protection for the community" (Davis, 2015). The more piecemeal approach of interchangeable GI sites, rather than building connectivity that would also encourage multi-species habitat. While the infrastructural system itself may not be imminently overturned, novel mitigation efforts are part of a merging mosaic of practices that are both local in effect and regional in scope. Efforts for creating systemic change must be sustainable in the long-run; they become expand and extend through a cumulative process of experimenting and through the reciprocal sharing of practices.

Alternative Mitigation Efforts

There are some communities organizations that go beyond the conventional conceptions of green infrastructure. These alternative mitigation approaches are underutilized by municipalities. The Radix Ecological Sustainability Center is taking a unique approach to CSO mitigation. Due to its strength and size, the daikon radish is used as a natural tool to aerate and add nutrients to compacted soil. As described by Scott Kellogg the radishes, "rot and create this conduit for air and moisture and they feed the worms and microbiology in the soil and overtime can be used to improve the absorptive capacity of the soil" (personal communication, 2018). Thus, the daikon radish can be used to increase the permeability of soil and in doing so, creates more storage space for water during high intensity rainfall events (Cover Crops, 2010). This both improves the health of the soil and can be utilized to mitigate CSOs.

Radix has also created a floating island in the Hudson River used for bioremediation and incorporated the construction of these island into its summer youth program. The island is made up a series of water plants that provide habitat to aquatic-dwelling species, uptake excess nutrients, and filter river water (S. Kellogg, personal communication, 2018). Kellogg mentioned that the most impactful aspect of the islands was the hands-on educational component, which has the potential to reconnect urban communities with the nature embedded in their neighborhoods (S. Kellogg, personal communication, 2018). Thus, these islands show a lot of promise as a method for sparking public interest and increasing CSO awareness amongst the local communities. Radix is in the process of expanding the bioremediation islands with a $5000 grant from the Albany Water Board (J.Coffey, personal communication 2018). This grant was given in lieu of paying a fine for failing to notify the public of a CSO event. CSO mitigation and education efforts could be even more effective if community efforts were supported from the onset, rather than implemented as the result of a fine.

Valuing other forms of urban green space--such as community gardens and public parks--as green infrastructure can be done through building partnerships with local organizations to increase both ecological and social connectivity between sites. Additionally, there has been interest in transforming vacant lots into informal green space. Often perceived as derelict spaces associated with poverty and crime, these by-products of disinvestment and developmental sprawl can become sites of ecological and social resilience. Independent of human facilitation, these sites are already undergoing a process of urban rewilding. The interconnection urban ecologies and sewer hydrologies provides an opportunity to revaluing ruderal species and low-income urban farmers alike.

Group Recommendations

<u>Year Round Mitigation Efforts</u>

CSO mitigation efforts should be expanded year round**,** rather than during the "wet" spring and summer months, as our study shows that CSOs are having detrimental effects to the river, especially in this "off season". In order to mitigate the water quality impacts due to CSOs year round sanitation efforts should be implemented instead of only from May to October. In addition to this there should also be year round water quality testing to measure bacterial levels, nutrient concentrations, and other water quality parameters to increase the amount of water quality data for this section of the Hudson River which will increase knowledge of how CSO events impact the Hudson.

<u>Addressing Climate Change</u>

As climate change continues to alter regional seasonal weather patterns in the Capital Region, it will become increasingly important to for municipalities to take climate change into account in their planning and mitigation efforts. If they do not address climate change, the success of their efforts will be compromised as they are negated by the increases and changes in precipitation.

Improved Outreach

The general lack of knowledge surrounding CSOs alone indicates governmental failure to effectively communicate with the public. The public deserves to know what is going on in their own communities and how environmental health and human health will be impacted. It is important for outreach efforts to consider ways to improve access to the alert systems, what form that communication takes, and who has access to resources to make these improvements.

Collaborations should be utilized to create community outreach events, where public officials across departments can join together with members of the community to discuss management of CSOs and progress in mitigation, while encouraging connections between people and the river. For example, a Hudson River Fest in one of the Capital Region parks along the river could be utilized to engage more members of the public. As noted above, there are a variety of opportunities to collaborate with local communities. In fact, many innovative initiatives that focus on issues related to CSOs already exist in the Capital Region.

Either the current CSO alert system needs to be better distributed amongst the public or that an improved alert system is needed (Figure 12). A user-friendly and informative Pool-wide CSO alert system with clear notifications could help to increase public awareness. This new alert system could combine the Pool-wide notification map and the NY-Alert model (Notification System, 2017). While increasing distribution of CSO alert systems communities need to be mindful to prevent notification fatigue. Otherwise some members of the public does may become overwhelmed with notifications and start to accept CSOs as fact (M. Daley, personal communication, 2018).

An alert system alone cannot solve the lack of public knowledge surrounding CSOs and access to technology is inconsistent, outreach efforts should also emphasize greater on-site signage and notification methods. There should be clear signage at all parks in close proximity to a CSO outfall, not just directly above an outfall location. Since the discharge moves, it will impact on public spaces downstream. However, people do not always take the time to read or even look at park signage. Another clear and striking method of notification may be CSO notification lights, such as the two installed in Washington D.C. on the Potomac and Anacostia Rivers (McPolin, 2016). In the Capital Region, efforts to create locative water quality sensors have struggled due to a lack of ongoing maintenance support, such as the Arbor Hill Environmental Justice Corporation's discontinued water gage. Additionally, expanding on local citizen science efforts can also be framed as a form of CSO communication, engaging community members in the process of learning about their local water quality as a form of experiential education.

Improvements to the Implementation of Green Infrastructure

In addition, future mitigation efforts include implementing changes in both traditional conveyance and end-of-pipe infrastructure. Through integrated planning approaches around combined and separated systems, green infrastructure has taken a central position in mitigation efforts. However, beyond integration between governmental departments, it is also important to consider ways to integrate wastewater management throughout a neighborhood. More decentralized methods can enable communities to manage stormwater for both everyday use and the more extreme, unpredictable events that will continue to increase with climate change. The distribution of these "green infrastructure" amenities within a community require careful consideration regarding access and accessibility to different members of that community. New city planning efforts have sought to foreground the implementation of GI throughout the city (Troy Comprehensive Plan Draft, 2018). Further, we re-emphasize the initial vision of the City of Albany's Comprehensive Plan which suggested that the LTCP--in addition to implementing traditional stormwater management practices--would also restore wetlands and improve riparian corridors (Albany 2030, 2012, p. 117).

However, these interventions must be integrated into the socio-ecological contexts of the urban landscape. This imperative for a more holistic approach has long been a challenge for sewage management in the Capital Region; in 1968, when the sewer districts were first being established, an RPI professor warned of "attempting the solution of single problems without regard to the effects of that action upon either other aspects of the environmental conditions or the conditions created for contiguous communities" (Kilcawley, 1968). Today, this imperative still stands, as rainwater retention technologies must also serve the human and nonhuman communities in which they are embedded.

Outside of cost, the largest barriers to implementing GI in Hudson River Estuary counties are pre-existing constraints built into the site and a lack of local knowledge and experience (Meyer and Vail, 2012, p. 4). Recognizing the both the historical and spatial context of the CSO issue will help guide approaches to GI in the future. Due to the prevalence of historical buildings in the Capital region, it may be beneficial to assist community members with retrofitting GI into existing development. Additionally, by acknowledging CSOs as a shared national inheritance, disparate CSO communities might establish networks for the trans-boundary sharing of best management practices and resources.

Coalition Building and Collaboration

The Albany Pool coalition represents a model for inter-municipal collaboration which might be copied in other CSO communities. Rather than replicating the Albany Pool model, we propose that the DEC promote an even more expansive vision for departmental and community collaboration by drawing on the lessons learned through the process of implementing the LTCP in the Capital Region. Integrated planning approaches should drive collaboration between the management structures for both separated and combined sewer systems. Collaboration between the Stormwater coalition and Albany pool efforts would be more economically and ecologically efficient. While the Albany Pool has largely been a successful collaboration between CSO communities in the Capital Region, increasing interdepartmental collaboration between municipalities could foster greater communication between departments and bolster public knowledge of CSOs. Stormwater retention and CSO education spearheaded by the DEP, where they partner with Departments of Education or Parks and Recreation to implement GI projects, exemplifies intragovernmental collaboration that contributes to a centralized mission, and expands the reach and efficiency of mitigation efforts (DEP, 2016). A similar program in the Capital Region would be an excellent opportunity for outreach.

Coalitions between community and non-governmental agencies with political/governmental and planning bodies as well. Community integrated groups and citizen science initiatives take on environmental stewardship projects that already have deeper connections with locals and communities within the Capital Region. Having regulatory bodies and local government work alongside and utilize their connections opens the possibility for more effective education and outreach, as well as take on more sociologically just and community relevant projects, which would potentially decrease resistance as seen with the Beaver Creek project.

The Lower Hudson Urban Waters Summit provides an example as to how these coalitions and conversations could begin their formation in the Upper Hudson. Bringing together stakeholders from community watershed/sewershed groups, non-governmental/non-profit organizations, state and local officials, planning bodies, and academics, the summit created a platform where new relationships and discussions could take place. Unlike in the lower Hudson whose communities have much more autonomy in deciding their sewer management approach, the municipalities connected under Albany Pool already are working together to implement the long term control plan (Palmer, personal communication, 2018). The presence of numerous watershed, community, and academic bodies, such as Stockport Creek Watershed Alliance, Arbor Hill Environmental Justice Corporation, NATURE Lab, Radix, Rensselaer Polytechnic Institute, SUNY Albany, etc. create suitable conditions to instituting robust inter-organizational coalitions between stakeholders at different levels.

Conclusion

Our research shows that CSOs are having major impacts on water quality year round and are disproportionately negatively affecting winter water quality likely due to a lack of sanitation efforts during winter months. Due to the close relationship between precipitation and CSO events These negative effects are only likely going to get worse with increases in precipitation due to climate change, especially in winter. These negative impacts will have increased adverse impacts on aquatic ecosystems.

The combined sewer system obscures the material flows between ourselves and our environments in multiple ways, making both the movement of our own wastes and the historical paths of buried creeks and streams largely invisible in everyday life. CSOs threaten to rupture tis invisibility by confronting us with the reality of the sewer's perpetual state of malfunction. Yet without adequate outreach, even this more spectacular form of pollution remains largely unknown and unseen in urban communities. The sewer's own achievement of invisibility makes it hard to gain public support for seemingly simple infrastructural solutions. Knowledge gaps remain both in the public more broadly and within Albany Pool, as the LTCP fails to incorporate the longer-term processes of climate change with the more immediate considerations of regulatory demands.

As sewage overflow continues to pollute the Hudson and Mohawk Rivers, it is important that clear and candid information be disseminated amongst the affected communities. The challenge is to ensure that individuals understand the public health risks posed by CSOs, while working to cultivate feelings of care and concern for the riverine systems. The current requirements for CSO mitigation are not enough to meet the needs of the Albany Pool communities. Thus, municipalities must reach beyond these policy provisions and develop more holistic mitigation. Our results illustrate the failure of current education and outreach efforts and show the need for new approaches and initiatives, with some focusing on revamping current notification systems and building collaboration and coalitions both inter-departmentally, at the district planning level, and inter-organizationally, between stakeholders from the grassroots to governing bodies. These new education and outreach efforts have the opportunity to inform and inspire, rather than push people to avoid contact with the river, and create a more robust and vibrant community surrounding riverfront and outdoor activities.

Moving forward, CSO mitigation should reconsider the distribution of resources, in a way that is based on both ecological value and social need. We hope that these management bodies, and other CSO organizations, seriously consider our recommendations and take them into account in their plans, as we do not believe that CSO mitigation plans can truly succeed without taking them into account.

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Appendices

Appendix I: Interview Questions:

Wastewater Treatment Plant Manager/Employee:

- How have CSOs frequency and/or intensity changed over the course of your work at this plant?
- Have you already seen impacts from climate change? How so in your opinion?
- What impact have you seen from recently created green infrastructure on CSOs?
- What mitigation effort/policy change do you think would have the greatest impact/be the most beneficial?

Community and State-led Initiatives:

- How do you determine where to place green infrastructure? Who determines this?
- What forms of community engagement do you conduct? In what ways are locals able to voice their opinions or provide input?
- To what extent have the effects of climate change been incorporated into the Long Term Control Plan? Is the Long Term Control Plan subject to alterations?
- Do you believe that the Notifications System in place is adequate? Do you think that the public is aware of CSO events?

Grassroots Adaptation and Remediation Efforts:

- What motivated you to begin this project?
- Who do you hope will engage with your project?
- What is your perception of the pros and cons of Albany POOL funded projects?
- How do you view your project in relation to these state-funded initiatives? How does it supplement, counter, or oppose these projects?

Community Members:

- Have you ever heard the term CSO before? If so what does it stand for?
- Are you aware when CSO events are occurring?/Do you know how to find out when CSO events are occur?
- Could you describe how you first became aware of CSOs in your community?
- Do you know how close you live to a CSO outflow pipe?
- Could you describe your relationship to the Hudson river? Do you use it for recreational or other purposes? How present is the river in your daily life?
- Do you ever go to meetings about CSO management and mitigation, or submit written/online comments?

Appendix II: Qualtrics Survey Questions:

Other than the consent form and submission questions, all can be left unanswered as an option

1. By selecting “yes,” completing, and submitting the survey you agree to have your anonymous responses used for CSO research in the Capital Region. By doing so, you understand that the cumulative responses of all survey takers and research findings will be used in: a public presentation of the research, the creation of a local public radio broadcast/podcast, brought to the attention of local community, stakeholders, officials and influentials in order to facilitate discussion, and posted publicly online and in public community spaces.
    1. Yes, I agree and consent to the terms
    2. No, I do not give my consent
2. Select any and all waterfront activities that you partake in:

    1. Utilizing adjacent parks and paths, boating, watersports, swimming, fishing, other

3. On a scale of 1 (very clean) to 10 (very polluted) would you rank the Upper Hudson in the Capital Region?
4. In the case of a pollution event, on a scale of 0 (no information) to 10 (very well informed and clear information), how well do you feel informed?
5. What are your primary sources for this information? Check all that apply
    1. Local community leaders, the state government, local government, community organizations, state or nationwide non-governmental organizations, other
6. Are you familiar with the term: combined sewer system?
7. Are you familiar with the term: combined sewer overflow, or its abbreviation, CSO?
8. If so, where have you heard the term “combined sewer overflow” (CSO) used?
9. [definition of CSO provided for survey takers]
10. Are you aware of any CSO events in the Capital Region’s stretch of the Hudson River?
11. [if yes]
    1. How were you made aware of this CSO event?
12. Does any knowledge of CSOs affect your frequency of contact with the Hudson River’s water?
    1. No change, it increases contact, it limits contact, I don’t know, other
13. How many CSO events do you estimate occur in 1 year within the Capital Region’s stretch of the Hudson River?
14. Are you aware of any city, state, or national action to combat CSO events in the Capital Region?
15. On a scale of 1 (very low priority) to 10 (top priority) would you place CSO adaptation and mitigation on the agenda of local and state government officials?
16. How do you envision the frequency of CSO events changing in the future?
    1. Remains the same, events increase in frequency, events decrease in frequency, I don’t know
17. Select what you think may potentially affect changes in frequency in the oncoming years
    1. Increases in rainfall intensity, decreases in rainfall intensity, increases in rain events, decreases in rain events, community infrastructure and environmental adaptation, other
18. Select, if any, which local adaptation measures you would support:
    1. Green infrastructure, replacing the combined sewer system with a separate sewer system, climate change mitigation strategies, construction of new wastewater treatment plants, other
19. Which Capital Region community do you live or primarily reside in?
    1. Green Island, Cohoes, Watervliet, Albany, Troy, Rensselaer, Menands, I prefer not to answer
20. Submit answers now or cancel. By submitting you are confirming and consenting to your participation in the study.
    1. Submit, Cancel

Appendix 3: Water Quality Parameters By Site

Albany Rowing	DO (mg/L)	Temperature (C)	Turbidity (NTU)	Conductivity (uS)	pH	Ammonuim (ppm)	Nitrate(ppm)	Phosphate(ppm)	E.coli (colonies/ 100mL)	(colonies / 100 mL)
Nov (**CSO**)	12.1	6.1	9	269.4	**6.34**	0.61	0.64	0.156	**9500**	**270**
Dec	13.7	3	5	217.9	7.1	0.8	0.59	0.242	**2200**	41
Jan	16.57	0.4	41	87.9	**6.34**	0.69	1.07	0.244	**3100**	**61**
Feb (**CSO**)	15.08	1.3	**106**	173.9	**5.83**	0.1	1.12	0.205	**7700**	**830**
Mar (**CSO**)	13.87	4.5	38	258.3	7.38	0.1	1.25	0.207	-	**330**

Riverfront Park	DO (mg/L)	Temperature (C)	Turbidity (NTU)	Conductivity (uS)	pH	Ammonuim (ppm)	Nitrate(ppm)	Phosphate(ppm)	E.coli (colonies/ 100mL)	Enterococcus (colonies / 100 mL)
Nov (**CSO**)	11.91	5.9	23	168.4	**6.36**	0.67	0.67	0.217	**7400**	**85**
Dec	13.31	2.5	5	173.5	6.71	0.65	0.98	0.217	**2200**	**83**
Jan	14.54	0.6	8	190.3	**6.38**	0.76	1.16	0.267	**1600**	**130**
Feb (**CSO**)	15.3	1.7	**73**	126	6.61	0.1	1.1	0.173	**5200**	**1030**
Mar (**CSO**)	14.16	4.5	**58**	330.2	6.51	0.1	0.76	0.2	-	**220**

Big C	DO (mg/L)	Temperature (C)	Turbidity (NTU)	Conductivity (uS)	pH	Ammonuim (ppm)	Nitrate(ppm)	Phosphate(ppm)	E.coli (colonies/ 100mL)	(colonies / 100 mL)
Nov (**CSO**)	11.71	6.3	49	98.6	**6.22**	0.13	1.03	0.201	**26400**	**180**
Dec	12.98	3.5	5	182.3	6.87	0.15	0.71	0.205	**2400**	**80**
Jan	14.93	0.8	8	214.7	7.03	0.71	1.19	0.238	**3600**	**220**
Feb (**CSO**)	16.75	2.1	**113**	141.6	6.69	0.09	0.65	0.188	**7800**	**1310**
Mar (**CSO**)	13.2	5.7	49	319.6	**6.24**	0.09	1.14	0.183	-	**143**

Hudson Shores	DO (mg/L)	Temperature (C)	Turbidity (NTU)	Conductivity (uS)	pH	Ammonuim (ppm)	Nitrate(ppm)	Phosphate(ppm)	E.coli (colonies/ 100mL)	Enterococcus (colonies / 100 mL)
Nov (***CSO*** *)*	11.67	6.1	28	245.1	**6.27**	0.61	1.01	0.198	**6400**	35
Dec	13.9	3.1	4	196.1	6.69	0.67	0.77	0.248	**890**	**65**
Jan	14.22	0.6	74	291.7	6.64	0.76	1.29	0.161	**3700**	**109**
Feb (***CSO*** *)*	15.5	1.3	**126**	281.6	6.59	0.1	0.74	0.123	**6500**	**1470**
Mar (***CSO*** *)*	13.59	5.2	**111**	330.7	7.51	0.09	1.37	0.181	-	**90**

Troy 9/11	DO (mg/L)	Temperature (C)	Turbidity (NTU)	Conductivity (uS)	pH	Ammonuim (ppm)	Nitrate(ppm)	Phosphate(ppm)	E.coli (colonies/ 100mL)	Enterococcus (colonies / 100 mL)
Nov (***CSO*** *)*	11.84	6.3	4	114.9	**6.32**	0.65	0.83	0.143	**3200**	38
Dec	13.12	3.3	3	108.4	6.63	0.71	0.88	0.204	**1100**	26
Jan	15.01	0.4	6	121.6	6.84	0.61	0.72	0.237	**1900**	39
Feb (***CSO*** *)*	14.64	2.1	18	158.9	6.74	0.1	0.75	0.218	**4100**	**165**
Mar (***CSO*** *)*	13.35	4.6	33	180.1	7.56	0.1	0.56	0.181	**1300**	**97**

Peebles	DO (mg/L)	Temperature (C)	Turbidity (NTU)	Conductivity (uS)	pH	Ammonuim (ppm)	Nitrate(ppm)	Phosphate(ppm)	E.coli (colonies/ 100mL)	Enterococcus (colonies / 100 mL)
Nov (***CSO*** *)*	12.16	7.1	18	219.3	**6.34**	0.6	1.02	0.191	**16000**	**82**
Dec	14.3	4.5	3	244.8	6.76	0.56	1.04	0.165	**820**	15
Jan	14.01	0.4	27	169.7	6.71	0.64	0.82	0.19	**1100**	55
Feb (***CSO*** *)*	15.71	1.2	**124**	246.1	6.7	0.09	0.75	0.16	**5500**	**540**
Mar (***CSO*** *)*	14.12	4.8	**133**	297.3	7.64	0.09	0.92	0.183	**3700**	**150**

Appendix 4: Key Stakeholders who participated in Semi-structured Interviews

Stakeholder	**Position Title**	**Organization**	**Interview Date**
Martin Daley*	Director of Water and Water Quality	Capital District Regional Planning Commission	January 8th, 2018
Tim Murphy*	Executive Director	Albany County Water Purification District	January 23rd, 2018
Kathy High	NATURE Lab Coordinator	The Sanctuary for Independent Media	January 15th, 2018
Scott Kellogg	Educational Director	Radix Ecological Sustainability Center	January 30th, 2018
Nancy Heinzen	Program Director	Albany County Stormwater Coalition	February 2nd, 2018
Jared Flagler	Advocate	Albany County Stormwater Coalition	February 2nd, 2018
Joe Cleveland	Technician Assistant	Albany County Stormwater Coalition	February 2nd, 2018
Joe Coffey*	Commissioner	City of Albany Department of Water and Water Supply	February 9th, 2018
Regina Keenan	Hudson River Fish Advisory Outreach Coordinator	New York State Department of Public Health	February 26th, 2018
Kathy Sheehan	Registrar, County and City Historian	Rensselaer County Historical Society	March 3rd, 2018
Paul Naumann	President	Rensselaer Polytechnic Institute Rowing	March 5th, 2018
Emily Vail	Watershed Outreach Specialist	Department of Environmental Conservation, Hudson River Estuary Program	March 8th, 2018
Chris Spencer	Commissioner	City of Albany Department of Planning and Development	March 13th, 2018
Ryan Palmer	Head of Center for the Urban River Beczak	Sarah Lawrence University	March 13th, 2018

Sean Ward*	Executive Assistant to the Mayor	Village of Green Island	March 21st, 2018
Maggie Alix*	Building Inspector and Code Enforcement Officer Director of Parks and Recreation	Village of Green Island	March 21st, 2018
Gerry Moscinski*	Administrative Director	Rensselaer County Sewer District	March 29th, 2018
Anonymous	Long-time fisherman and excursion leader on the Hudson River	Private Citizen	April 9, 2018

**indicates member of Albany Pool Board*

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