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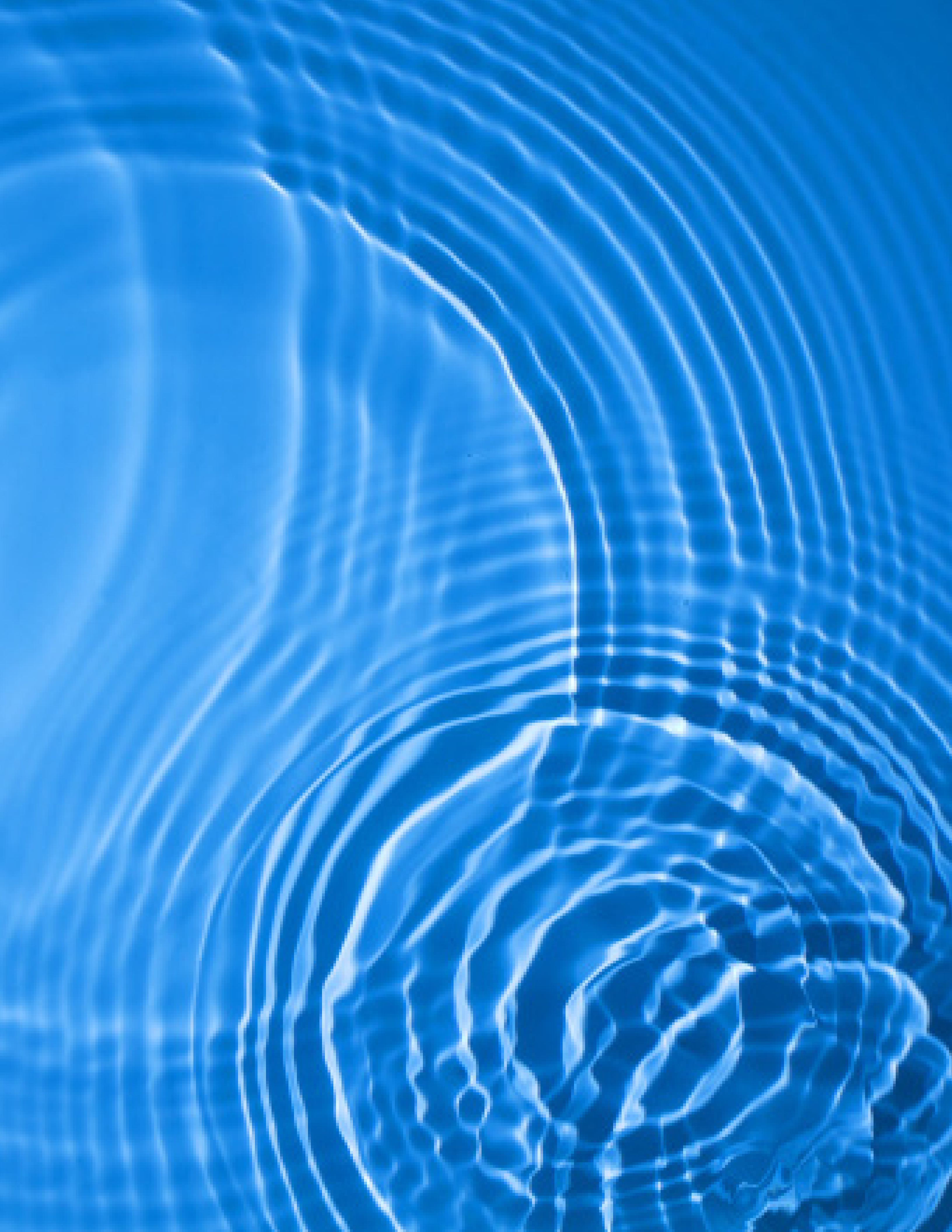
WATEREUSE

Water Reuse in the Hudson River Valley: Current Practices, Challenges, and Opportunities



Workshop Graduate Course In Brief

Columbia University's Master in Public Administration in Environmental Science and Policy degree program (MPA-ESP) was created in 2002 and is jointly administered by the School of International and Public Affairs (SIPA) and Columbia's Earth Institute. This intensive one-year program prepares students to become environmental sustainability leaders by developing the interdisciplinary skills required to address the most pressing environmental issues facing the world today, including climate change, global water shortages, food security, and pollution.

The Spring Workshop in Applied Earth Systems Policy Analysis is the capstone requirement of the MPA-ESP Program. In the Workshop, graduate students undertake analytic projects for real-world clients in government and nonprofit organizations in project teams. These teams research and analyze environmental policies or management problems faced by their clients under the supervision of a faculty member. The Workshop Team produces oral briefings, memos, and a report with project recommendations.

This report is the product of the Team's investigation of water reuse for the Hudson River Valley, conducted over the 2021 spring semester. It describes findings from the intensive primary and secondary research which included an in-depth literature review, Expert Interviews, case study comparisons, and subsequent analyses of the data.

For this report on water reuse in the Hudson River Valley, our client is the WateReuse Association, and Carrie Capuco, their Director of Strategic Operations.

Acknowledgements

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Ryan Martens from Grassroots Farm

Paula Kehoe from the San Francisco Public Utilities Commission

Heather Magnan and Nate Townsend from the Watershed Agricultural Council

Jack Algiere, Elijah Goodwin, and Shane Hardy from Stone Barns Center for Food and Agriculture

Authors

Danna Creager
Project Manager, Primary Research

Katherine Lin
Deputy Project Manager, Secondary Research

Michael Bannon
Primary Research

Leanne Burns
Editor

Abigail Edwards
Secondary Research

Louiza Molohides
Analytics

Carson Ross
Secondary Research, Report Layout

Zhiyao Wang
Analytics

ACRONYMS

CAFOs	Concentrated Animal Feeding Operation
CNMPs	Comprehensive Nutrient Management Plans
CSO	Combined Sewage Overflow
CSA	Community Supported Agriculture
CWA	Clean Water Act
EFC	Environmental Facilities Corporation
EPA	Environmental Protection Agency
IMG program	Intermunicipal Water Infrastructure Grant program
MPA ESP	Masters of Public Administration in Environmental Science and Policy
NPDES	National Pollution Discharge Elimination System
NYC DEC	New York City Department of Environmental Conservation
NYC DEP	New York City Department of Environmental Protection
SIP	Sustainability in Practice
SIPA	School of International and Public affairs
SPDES	State Pollutant Discharge Elimination System
SWOT analysis	Strengths, Weaknesses, Opportunities, and Threats analysis
USDA NRCS	United States Department of Agriculture Natural Resources Conservation Service
WIIA	New York Water Infrastructure Improvement Act
WRL	New York Water Resources Law
WPCL	New York Water Pollution Control Law

Contents

Executive Summary

The WateReuse Association has been working since 1990 to advance efforts in water recycling and water reuse to ensure that communities have a safe, reliable and cost-effective supply of water, necessary to sustain a high standard of living, public health and wellbeing, and a robust economy. In order to do so, the Association takes a three-pronged approach which involves: working to to advance public acceptance and support for recycled water; engaging with federal and state agencies to increase water infrastructure investment programs; and, likewise working with the agencies to facilitate water recycling pilot projects as a demonstration of safety and environmental and economic sustainability. The Association's membership includes water utilities, businesses, government agencies and not-for-profit organizations in 38 states in the US and in 11 countries around the world. The WateReuse Association envisions a culture that embraces water reuse and recycled water as a sustainable solution for water quality and supply that benefits the environment, economy and society for future generations.

From January through April 2021, a team of graduate students from the Environmental Science and Policy MPA Program, a joint program of the School of International and Public Affairs (SIPA) and Columbia's Earth Institute engaged in a research project on behalf of the WateReuse Association. The project addresses the Association's goal to advance its understanding of the current state and the future potential for recycled water use among farmers, vintners and other food producers in the Hudson River Valley, New York.

Carrie Capuco, the Director of Strategic Operations at the WateReuse Association, asked that the Workshop Team produce a report and recommendations to be used by the Association in its efforts to advance legislation for water reuse in water-rich areas in the US. The report is intended to inform the Association's efforts at both the state and national levels.

Ms. Capuco asked the Workshop Team to:

(1) Determine how and under what circumstances Hudson River Valley farms and vineyards or other sectors are using recycled water in their processes, and what might be barriers to adopting water-reuse technologies in the area,

(2) Investigate support for water-reuse within the Hudson River Valley in terms of current policies and agencies/cooperatives/funders involvement, and identify where opportunities exist to expand support,

(3) Assess whether concerns around climate resiliency and watershed management drive—or have the potential to drive—any use of recycled water in the Hudson River Valley and other water abundant regions.

The Team was organized into three sub-teams and initially used four pillars to structure primary and secondary research and analytic processes, including: (1) Policy, (2) Food & Wine Production, (3) Technology, and (4) Key Actors. The Secondary Research Team reviewed publicly available data to inform foundational knowledge and contextualize the report.The Primary Research Team conducted 15 Expert Interviews to gather information around water reuse policy and implementation within the Hudson River Valley. From there, both sub-teams aggregated and assessed the data, working with the Analytic Team to formulate analyses that informed recommendations in this report. Through the process of collecting and analyzing information, and through discussions with the client, the value in considering water reuse opportunities more broadly across the Hudson River Valley became apparent. Therefore, the Findings section of the report expands the second pillar to include additional economic sectors that hold promise for water reuse: (1) Agriculture & Livestock, (2) Wineries, Cideries, Breweries, and (3) Recreation. The Team provides recommendations under each pillar, identifies areas for further research within each sector, and provides a toolset to guide the WateReuse Association's approach to future work in the Hudson River Valley.

While the full list can be found within the Recommendations Section of this report, several key recommendations are summarized here:

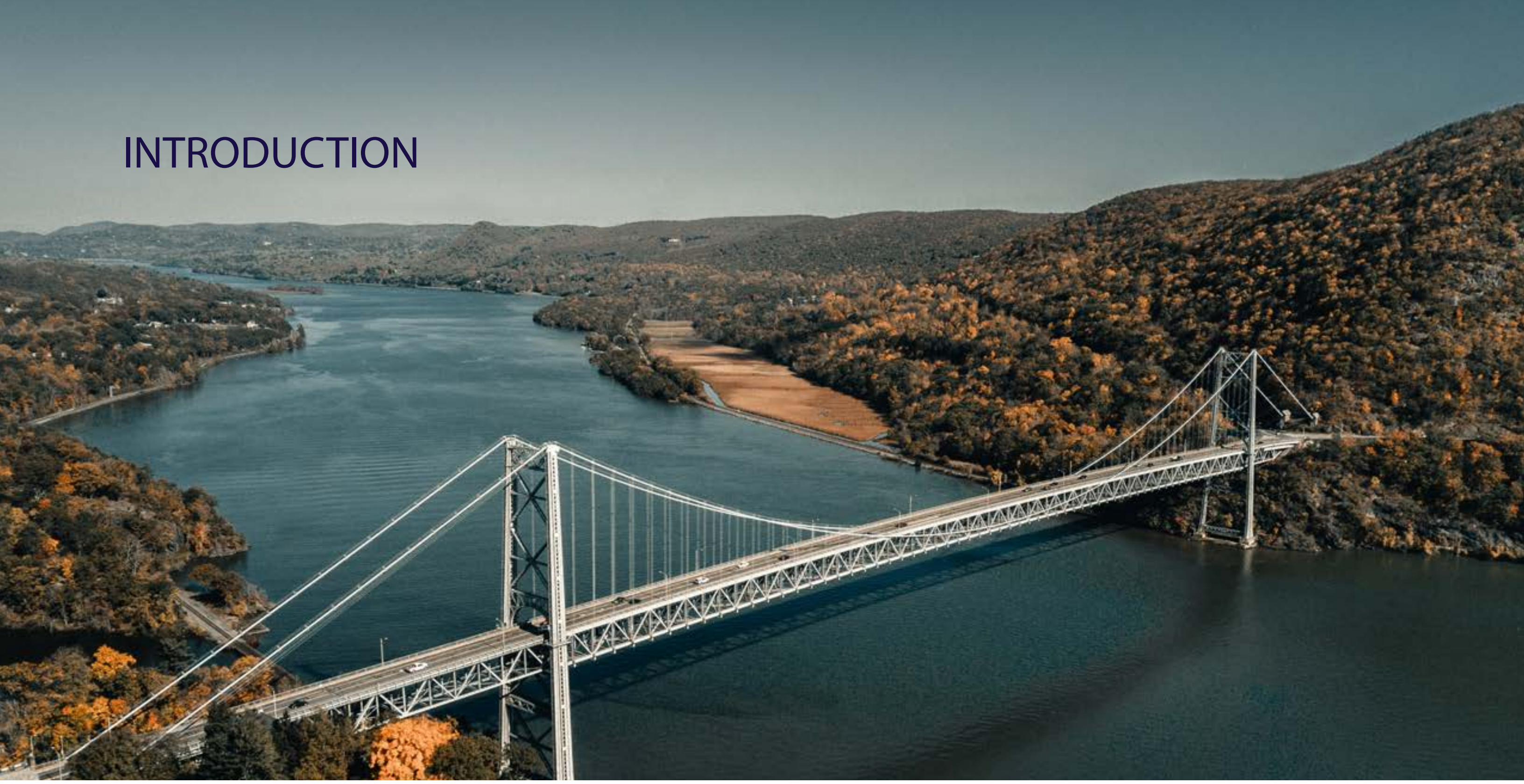
(1) Explicitly define the language surrounding the definition of water reuse and utilize it for outreach to regional stakeholders and community members as it is apparent that different understandings around what water reuse encompasses can inhibit its adoption and/or the perceived recognition of its use or value within the Hudson River Valley.

(2) Prioritize relationship-building with communities and influential stakeholders in the region to broaden understanding, support, and adoption of water reuse within the Hudson River Valley. This will not only promote education around water reuse and its value for improving resilience to climate variability in water rich areas, but will also continue to inform the WateReuse Association's understanding of current practices and potential in the region.

(3) Advance water reuse by implementing pilot programs within the Hudson River Valley to inform pertinent legislation, highlight applicability of reuse in water-abundant areas, and demonstrate the feasibility of various potential technologies and their costs.

(4) Expand the focus beyond food and wine production to capture other areas with water reuse potential including recreation and stormwater management.

INTRODUCTION



What is water reuse?

Water reuse, also known as water recycling, encompasses multiple practices for capturing various types of wastewater and treating it as needed for an intended end use (Environmental Protection Agency, n.d.). Sources of water for reuse include industrial or commercial wastewater, rain and stormwater, domestic grey and blackwater, saltwater, and tailwater, which refers to runoff from fields after irrigation (Environmental Protection Agency, 2019; WateReuse, n.d.-a; WateReuse, n.d.-b). Reclamation requirements for these "wastewaters" vary from strict standards for drinking or indirect potable reuse like groundwater recharge or reservoir augmentation, to lower standards for "fit for purpose" use such as agricultural irrigation, industrial processes, groundwater recharge, and wetland restoration (Peckham, 2016; Environmental Protection Agency, n.d.). To ensure public health, recycled water that is non-potable is often differentiated visually from drinking water by either adding dye to the water itself or color-coding the pipes (Connecticut DEEP, 2015; Peckham, 2016). By making the most of every drop, water reuse not only conserves water, but can also save money, turning wastewater into an asset that enhances water security, sustainability, and resilience in the face of limited resources and climate change (Fluence, 2018).

Water reuse can offer solutions to pressing water management issues (WateReuse, n.d.-a) and is increasingly being adopted to address water supply challenges in arid regions of the western and southern US (WateReuse, n.d.-c; WateReuse, 2017). Declining freshwater resources can threaten nearly every aspect of life, including food production, community drinking water, and industrial growth. Water reuse provides a way to mitigate current and anticipated water shortages. For instance, in water-stressed areas, recycled water can help stretch the supply available for demands like landscape and agricultural irrigation, industrial and commercial purposes, and fire protection (Western Resource Advocates, 2018).

At the same time, water-rich areas in the Pacific Northwest, the northeast, and the Great Lakes Region, are increasingly recognizing the benefits of water recycling for resiliency and sustainability. Water availability is becoming more variable due to climate change, and population growth, pollution, and changes in land use can adversely affect water quality. In response, certain states and cities in water abundant regions are incorporating water reuse strategies to help manage stormwater, protect sensitive waterways, restore ecosystems, and safeguard against future uncertainties (Peckham, 2016; WateReuse, n.d.-c; Maryland Department of the Environment, n.d.; New York Department of Environmental Conservation, n.d.-a).

Hudson River Valley Bioregion

The Hudson River Valley is located within the eastern portion of New York State, roughly 150 miles above New York City to slightly north of Albany (Bplant.org, n.d.; HVNY, n.d.). The region has a complex geologic history. During the Pleistocene Epoch, glacial floodwaters carved the underlying bedrock comprised of shale, limestone, and siltstone, shaping the topography into a wide, irregular valley broken up by hills and terraces (Bplant.org, n.d.; Bryce et al., 2010). These waters deposited rich sediments, diverse in both texture and nutrient levels, and as they receded created an estuary with tidal influence that extends as far north as Troy which today is known as the Hudson River (Bplant.org, n.d.). The Munsee and Lenape tribes first occupied this land and took advantage of the fertile soil, cultivating a variety of crops prior to colonization (Turton, 2018).

Today, the agricultural tradition continues, with nearly 3500 individual farms and orchards covering more than 500,000 acres that produce livestock and poultry, dairy products like cheese and milk, and a variety of crops including wheat, vegetables, and apples (Litton, 2010; Neilsen, D, 2015). The Hudson River Valley is also home to at least 34 wineries and a growing craft beer industry (American Winery Guide; n.d.; Edick & Willcox, 2017; Gordon, 2019). It is known for a culture of sustainability and awareness of environmental issues, with many farmers integrating climate change resiliency initiatives into their production practices (Legnick, 2019; Hudson Food and Travel, n.d.). The diverse sectors of agriculture support a strong farm-to-table movement that—along with ample recreational activities like hiking, skiing, and golfing—help to drive tourism in the region.

Designated as a Natural Heritage Area in 1996 (Maurice D. Hinchey Hudson River Valley National Heritage Area, n.d.-a), the Hudson River Valley Bioregion is typically defined as ten counties that are commonly divided into three regions: The Upper Hudson Valley, Middle Hudson Valley, and Lower Hudson Valley (Maurice D. Hinchey Hudson River Valley National Heritage Area, n.d.-b; Figure 1). These regions roughly follow the same boundaries as the Hudson River Estuary Watershed which is also referred to as the Lower Hudson Watershed (New York Department of Environmental Conservation, n.d.-b; Hudson River Estuary Program, n.d.-a).

The Upper Hudson Valley includes Greene, Columbia, Albany, and Rensselaer counties and is dominated by the Catskill Mountains, farms, and orchards (Maurice D. Hinchey Hudson River Valley National Heritage Area, n.d.-b). The Middle Hudson Valley includes Putnam, Orange, Dutchess, and Ulster counties featuring the Hudson Highlands (Maurice D. Hinchey Hudson River Valley National Heritage Area, n.d.-b). The Lower Hudson Valley includes Rockland and Westchester counties, and shifts from urban areas to marshes and rolling hills (Maurice D. Hinchey Hudson River Valley National Heritage Area, n.d.-b).

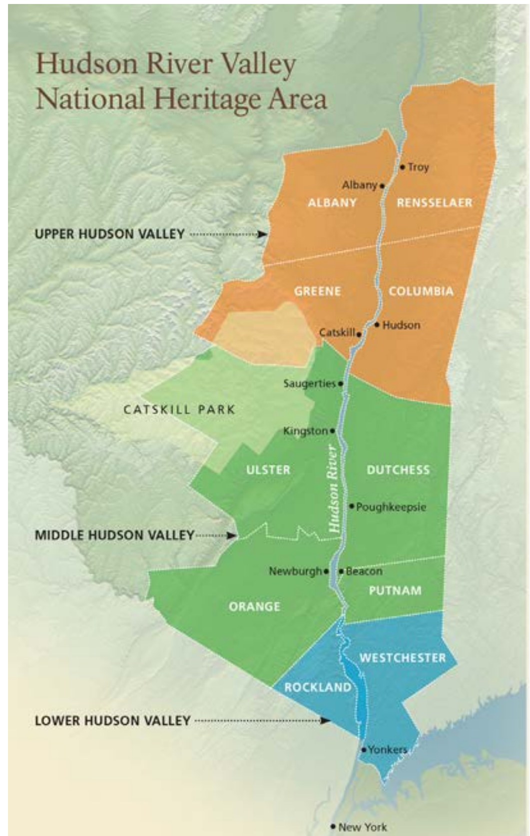


Figure 1: Counties of the Upper, Middle and Lower Hudson River Valley

Though these three areas are most frequently defined as the Hudson River Valley Bioregion, other geographical boundaries exist and vary based upon natural, political and economic considerations. The Team, with guidance from Carrie Capuco, has determined that the aforementioned ten counties define the Hudson River Valley Bioregion for the purposes of this project.

Why might the Hudson River Valley benefit from a water reuse strategy?

Currently, the Hudson River Valley is typified by a continental climate of warm and humid summers and cold, wet winters. The Atlantic Ocean, Hudson River, and Catskill Mountains all contribute to a variety of microclimates that allow for the diverse agriculture of the Hudson Valley (Hudson Valley, 2009). The warm Atlantic breezes and short growing season are particularly suited to growing wine (Gordon, 2019). These microclimates, together with the Hudson River and its watershed, the proximity of the Atlantic, and significant rainfall, contribute to this bioregion being considered water-abundant (Cuppett & Urban-Mead, 2010; New York Department of Environmental Conservation, n.d.-c). Although average precipitation is not readily available for the Hudson River Valley, New York State averages over 40 inches annually. Total annual precipitation varies regionally with mountainous regions receiving over 50 inches a year (Melillo et al., 2014).

Climate change is predicted to increasingly affect freshwater resources across the globe (Fecht, 2019; U.S. Forest Service, n.d.). The impacts on the hydrologic cycle are already altering the quantity, quality, timing, and distribution of water (U.S. Forest Service, n.d.). While the effects on future availability may be difficult to assess given geographic and regional variability, they are unlikely to be limited to water-scarce areas alone. As precipitation patterns change, and floods, droughts, and severe weather disturbances become more common, the water-rich region of the Hudson River Valley may also face substantial challenges around the impacts of climate variability on a monthly, seasonal or annual basis.

For instance, while extreme precipitation is an expectation of climate change in the region, an assessment by Cornell University indicates that the annual rainfall across New York State—including in much of the Hudson Valley—has been lower than average recently (New York State Water Resources Institute, n.d.). An overall decrease in precipitation creates challenges for keeping crops hydrated in fast-draining, sandy soils (Solomon, 2021). When precipitation does come, it increasingly falls in downpours, which can lead to flooding, agricultural run-off, erosion of topsoil, and crop damage (Solomon, 2021; Gilson, 2018). These trends likely reflect the increasing variability growers and producers will contend with as a result of the effects of a changing climate. In addition to an increase of heavy precipitation events interspersed with prolonged periods of drought, longer-term climate change models for the Hudson River Valley also predict rising temperatures with less predictable frosts and thaws, flooding and saltwater intrusion along the Hudson River due to sea level rise, and an increase in pests as ranges expand (Gilson, 2018; Hudson River Estuary Program, n.d.-b; Solomon, 2021).

The uncertainties associated with climate change and climate change variability are likely to present major challenges for local farmers, producers, and vintners of the Hudson River Valley. Utilizing reused water in food and wine production could be one way to increase the resilience of regions heavily dependent on agriculture like the Hudson River Valley. By employing water recycling practices there may be opportunities to better manage stormwater runoff during heavy rain events, capturing or redirecting it to be less damaging (Hunter et al., 2019). Water reuse may also offer solutions during periods of extreme heat and drought. At times when precipitation is less dependable, captured, recycled water could be used to irrigate crops or cool livestock (Hunter et al., 2019; NYCCSC, n.d.).

Thus, as the climate becomes more unpredictable, all areas—even those currently considered "water-abundant"—may benefit from a comprehensive approach to climate change resiliency that considers the principles of water reuse. Aiming to inform and advance national legislation that supports water reuse, this report will determine the current status of water reuse technologies and processes in the Hudson River Valley and identify the potential for and impact of water recycling practices and retrofits for the area's food and wine production, along with possible opportunities that may also exist within the recreational sector.

Research Approach

- SECONDARY RESEARCH
- PRIMARY RESEARCH
- ANALYTICAL RESEARCH

Secondary Research

Secondary research for this project focused on defining the Hudson River Valley Bioregion, assessing the agricultural landscape, New York State policies and regulations, irrigation considerations, key actors, and water recycling practices and systems for various reuse purposes. Underlying this research was the consideration of how climate change and increasing climate variability will impact food and wine production and other economic activities in the region with respect to changing water resources.

This research was originally divided into four key categories, or "pillars" to organize guiding questions, findings, and analyses. These original pillars included (1) Policy, (2) Food & Wine Production, (3) Technology, and (4) Key Actors. The pillars are used to inform the analytical strategies and recommendations section of this report, however, through information gathered through preliminary research and conversations with the client and stakeholders, it became clear that additional economic sectors should be included, and so the Findings section of the report is organized as an expansion of the second pillar to include three broad economic sectors of importance, as well as recommendations to the client for further research within each: (1) Agriculture & Livestock, (2) Wineries, Cideries, Breweries, and (3) Recreation.

Although secondary research may be traditionally conducted by exclusively reviewing academic and gray literature, there is little available that specifically pertains to the Hudson River Valley and water reuse. As such, the Team determined that it would be strategic to utilize all sources of information, including case studies, local news and websites, anecdotal information from blogs written about the area, and government websites, in addition to peer-reviewed publications.

While the research is focused mainly on current practices in the Hudson River Valley, it is supplemented with case studies of best practices in agricultural water reuse, water recycling in wine production, and successful water recycling projects in both water abundant and water-scarce regions.

Primary Research

The Primary Research Team identified a qualitative approach to conduct empirical data collection through Expert Interviews. To conduct these Expert Interviews, the Team identified important stakeholders including those in government agencies, community coalitions, other regional organizations, and academia. For government officials, the Team located the individuals leading the agency's work with farms, vineyards, and/or water reuse by exploring each agency's website. In addition to various municipal and state agencies, there are a number of well-established organizations and coalitions that are influential in progressing sustainable and resilient environmental techniques in the region. By connecting with farm organizations and specific land stewards within them, we gained critical information from leaders in the food, agriculture, and water sustainability and resilience sectors.

The Primary Research Team's next steps involved creating a brief script describing the project and Team to facilitate initial outreach to stakeholders of interest for approval by the client, Carrie Capuco (Appendix A). In this way, the Team and Ms. Capuco ensured the accurate portrayal of the relationship between the WateReuse Association and the MPA Environmental Science and Policy Program for the research that is being conducted.

The Primary Research Team then developed a baseline set of questions for every organization, agency, and stakeholder to be interviewed, along with two sets of additional questions specifically targeted at certain types of stakeholders: one for agencies and organizations and the other for farmers, vintners, and food producers, which were sent to a member of the Analytics Team and the Secondary Research Team for feedback. Following the feedback and approval from the internal teams, the set of questions were sent on to the Faculty Advisor for feedback, and finally back to Ms. Capuco for final edits. The set of approved guiding interview questions can be found in Appendix B of this report.

Once the script and interview questions were approved, the Primary Research Team began the first round of outreach I in February 2021. The Primary Research Team amended a spreadsheet the Secondary Research Team had compiled to identify stakeholders to keep track of stakeholder outreach and interview status and to store information of identified contacts in the region.

The Primary Research Team also used this document to categorize the priority level of outreach for each stakeholder and to distinguish what type of organization each stakeholder represented. At the time of this report, the Team has interviewed 15 experts, stakeholders and food producers.

While the Primary Research Team hoped to send a survey to farming and vinting contacts during the duration of the project, we were limited by time and thus unable to gather this data from farmers, vintners, and food producers. However, the Primary Research Team was able to draft a survey instrument which is included within the Recommendations Section of this report and also identified well-connected stakeholders and regional coalitions who may be able to send out the survey to farming and vinting contacts to gather additional information in the future.

Analytic Research

The Analytic Research Team was responsible for identifying evaluation strategies and tools for qualitative and quantitative data assessment. The Team reviewed the literature with two primary objectives in mind: 1) What strategies could best be used to concretize data into useful information; and, 2) How could these strategies also align with and inform the design and development of questions for expert interviews. In conjunction with the research strategies, the Team came to a consensus on the following tools:

Stakeholder Analysis

A Stakeholder Analysis is an effective way of identifying individuals or groups who would need to be actively involved in a water reuse program, or whose interests may be affected by water reuse. The intentionality of this analysis focuses on the interests of different groups to harness the support of those in favor of water reuse, to understand those who would oppose water reuse, and to manage risks posed by either group and/or either perspective. As a consequence, a Stakeholder Analysis is essential to exploring the possible adoption and practice of water reuse within the Hudson River Valley Bioregion. By identifying high-ranking stakeholders, the long-term concerns of stakeholders can be examined. There are limitations associated with this analytic approach, as not all stakeholders can feasibly be included, but ultimately, this tool provides the client with potential champions of water reuse in the area and offers critical information regarding why some groups may oppose water reuse (Department for International Development, 2003).

SWOT Analysis

The stakeholder analysis was then used to create a SWOT analysis. SWOT is a qualitative tool that is commonly used as a means to systematically analyze the internal and external environments of an organization. Through categorizing and comparing the internal and external factors, a SWOT analysis offers insights for converting threats into opportunities and off-setting the weaknesses against the strengths. Critics contend that SWOT is not effective enough to be accepted as an analysis technique because it may be prone to bias, making conclusions drawn arguably less robust. Additionally, SWOT is limited to identifying the priorities of factors, it may still be useful in solving for the developments and conflicts in different dimensions, and providing comprehensive suggestions on different data (Gürel, 2017). The Analytic Research Team analyzed the internal strengths, weaknesses, and external opportunities, and threats in order to recommend the best strategies for the client.

The Stakeholder Analysis and SWOT used a multi-pronged approach to analyze the stakeholders in the region based on the data collected. While each analysis has its limitations, creating an amalgamation of the key stakeholders in the region can be used by the client to further engage with the community and expand upon water reuse in the region.

The Analytic Research Team also looked into a few quantitative strategies that could not be completed due to time-constraints and restricted data and resources. Instead, the Team recommends that the client consider these strategies, which include a cost matrix for technology and an ecological analysis.

Findings

- The Current State of Water Reuse
- Sector 1: Food & Agriculture
- Sector 2: Wineries, Breweries, Cideries
- Sector 3: Recreation
- Analytical Findings

CURRENT STATUS OF WATER REUSE IN THE HUDSON RIVER VALLEY

Based on the Team's research, large scale water reuse does not appear to be a widespread practice in the Hudson River Valley Bioregion. This is likely due to the abundant water resources, including snow and rainfall, plentiful aquifers, and the Hudson River which all contribute to keeping the cost of water low for the area.

Residents of the Hudson Valley source drinking water and potable water used for other purposes from a combination of private wells and municipal systems, which in turn obtain water from aquifers, the Hudson River, and smaller creeks and tributaries. Used water, or wastewater is disposed of in both private septic systems and larger wastewater treatment facilities, many of which discharge directly into the Hudson River and its tributaries (Cuppett & Urban-Mead, 2010).

Unlike certain states and sub-regions within New York, the state of New York does not have explicit water reuse guidelines or standards, but there are policies within the existing regulatory framework governing water usage for various sectors, water quality standards, and discharge of water from different sources, which merit consideration in identifying opportunities for water recycling in the Hudson Valley:

Relevant New York State Policies and Regulations

The New York Water Resources Law (WRL) is the principal water quality law in the state. It requires statewide registration of existing agricultural withdrawals and inter-basin diversions of water or wastewater above a set threshold (Rincker, 2013).

The New York Water Pollution Control Law (WPCL) impacts water quality by regulating nonpoint source pollution such as excess fertilizers, herbicides, and insecticides from agricultural lands within the state. The WPCL makes it illegal to throw, drain, run, or discharge pollutants into water bodies (Rincker, 2013).

State Pollutant Discharge Elimination System (SPDES) permits are issued by the New York State Department of Environmental Conservation (NY DEC) to regulate point source pollution from industrial, municipal, agricultural, private and commercial discharges, including wastewater and stormwater runoff, to protect groundwater or water bodies (New York Department of Environmental Conservation, n.d.-d). All discharges must meet NY DEC water quality standards and effluent limitations (Town of Cortlandt, 2011).

The New York Water Infrastructure Improvement Act (WIIA) authorizes the state's Environmental Facilities Corporation (EFC) to fund municipal water projects, including for drinking water and sewage treatment, through the $3 billion Intermunicipal Water Infrastructure Grant (IMG) program (New York Environmental Facilities Corporation, n.d.). In 2018, $49 million in IMGs went to the Hudson Valley region, including nearly $8 million to upgrade the Kingston Water Treatment Plant in order to decrease the nitrogen content of its effluent (Kirby, 2018).

Concentrated animal feeding operations (CAFOs) which are densely populated large scale livestock facilities, are regulated by the federal Clean Water Act (CWA) under the National Pollution Discharge Elimination System (NPDES) permitting program. State and local governments can establish additional regulations to further limit CAFO practices by requiring certification of comprehensive nutrient management plans (CNMPs) for instance. There are roughly 500 CAFOs in New York State. The majority are dairy farms with 300 or more cows and associated livestock operations (Concentrated Animal Feeding Operations, n.d.)

Water Recycling Practices and Systems

Technologies used to capture and treat water for reuse vary greatly by method and capital costs (See Figure 2). They range from state-of-the-art systems to clean and disinfect sewage or industrial wastewater, to simple, low-tech capture and storage of non-potable water to use for cleaning or other purposes.

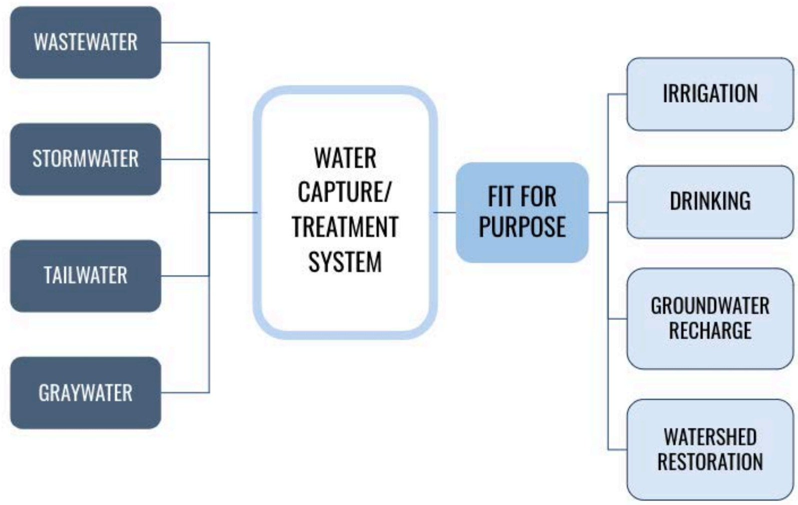


Figure 2: *Sources and End Uses for Recycled Water*

Municipal Wastewater Recycling

Due to the presence of pathogens and potentially harmful chemicals in municipal wastewater, a series of several treatments are needed before the water can be reused. This generally begins by removing solids and oils, with subsequent steps to remove smaller particles, nutrients, and pathogens. For example, some combination of filtration, coagulation and flocculation, biological reactors, and disinfection with chlorine or ultraviolet radiation may be used (Watereuse, 2015).

The large-scale municipal water treatment facilities of the Hudson Valley, which are regulated under stringent NY DEC effluent standards, are located in densely populated towns and cities throughout the region. The Poughkeepsie Water Treatment Facility sources their drinking water from the Hudson River using a multi-step filtration and disinfection process, while discharging wastewater effluent—also referred to as "sanitary sewage"—into the Hudson River downstream. The plant's effluent is compliant with SPDES permits, but major rain storms or snow melts can cause combined sewage overflow (CSO) events, overwhelming the sewage system and causing raw sewage that is diluted by stormwater to flow directly into the Hudson River. For this reason, towns like Poughkeepsie and Kingston, whose wastewater treatment plants discharge into Rondout Creek to eventually flow into the Hudson River, are exploring ways to separate their stormwater and wastewater infrastructure and promote groundwater recharge to protect the water quality in the river (City of Poughkeepsie, n.d.; Kirby, 2018).

Stormwater Capture

Although stormwater can pick up contaminants from surfaces where it falls, it is generally quite clean in comparison to wastewater, so fewer steps are needed to treat it for non-potable uses. There are varying systems to capture, store, and redirect stormwater, the most popular being rooftop systems, subsurface systems, or some combination of the two (Bloomberg and Strickland, 2012). Rooftop systems may be either green roofs, which have layers of growing media and plants on top of the roof to absorb rainwater and reduce runoff, or blue roofs, which control the flow of roof drains and regulate runoff by storing water on the roof or directing it into containers. Subsurface systems include gravel bed systems, vault systems, perforated pipe systems, and stormwater chambers, among others. These systems represent varying approaches to temporarily store stormwater runoff underground in either closed or open bottom reservoirs to allow for infiltration (Bloomberg and Strickland, 2012).

Redirecting stormwater or the reduction of impermeable surfaces in densely populated areas can protect water bodies by reducing contaminated runoff or CSOs, and promoting groundwater recharge. Recycling stormwater may also be of interest to Hudson River Valley producers or industries as an alternative to purchasing costly discharge permits, due to the relatively low installation costs of many stormwater capture systems. Particularly if captured through a rooftop system, stormwater is cleaner and easier to treat than other recycled water sources, making it a viable option for irrigation or other production processes.

Tailwater Capture

Tailwater reuse tends to refer either to controlled drainage, also known as drainage water management, or tailwater recovery systems. Controlled drainage involves adjusting groundwater levels through the use of stop logs at different points in the growing season to make water more or less available to crops (United States Department of Agriculture NRCS, n.d.). Recovery systems capture rain and irrigation runoff in ditches and use a pipeline and pumping system to redistribute the water throughout the field. Tailwater capture and reuse systems are highly dependent on the size and topography of the land being cultivated (United States Department of Agriculture NRCS, n.d.). The level of treatment necessary for tailwater depends on the style of farming from which the water is captured. The presence of livestock and chemical inputs is particularly important to note, as these can affect nutrient levels in runoff.

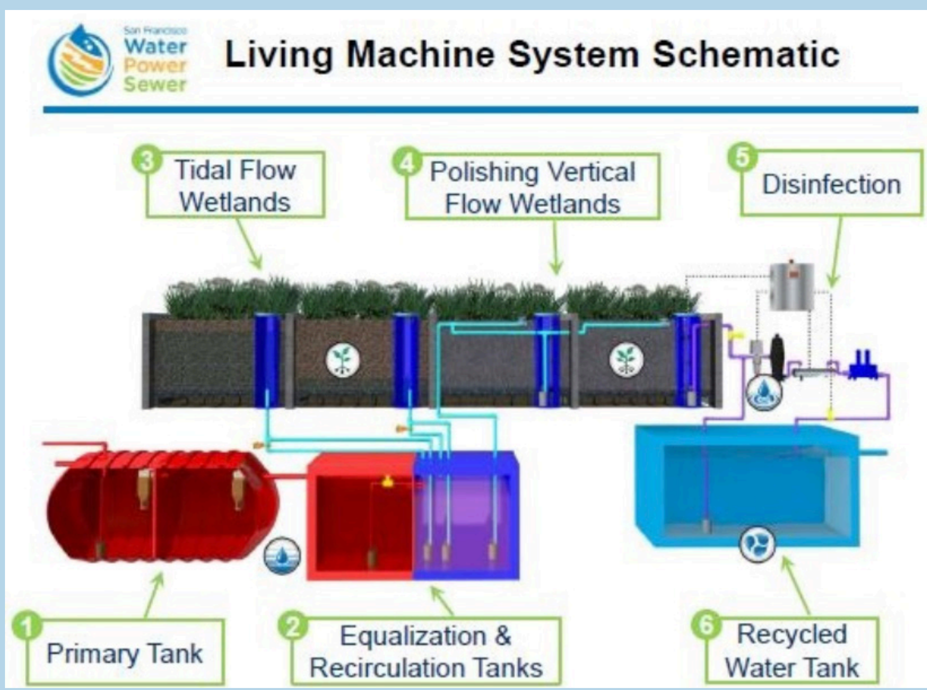
Determining the viability for tailwater capture and reuse in the Hudson Valley will include examining existing irrigation infrastructure, soil water holding capacity of sub-regions, and evaluating the economic impacts on farmers and producers for installing these systems.

Greywater Capture

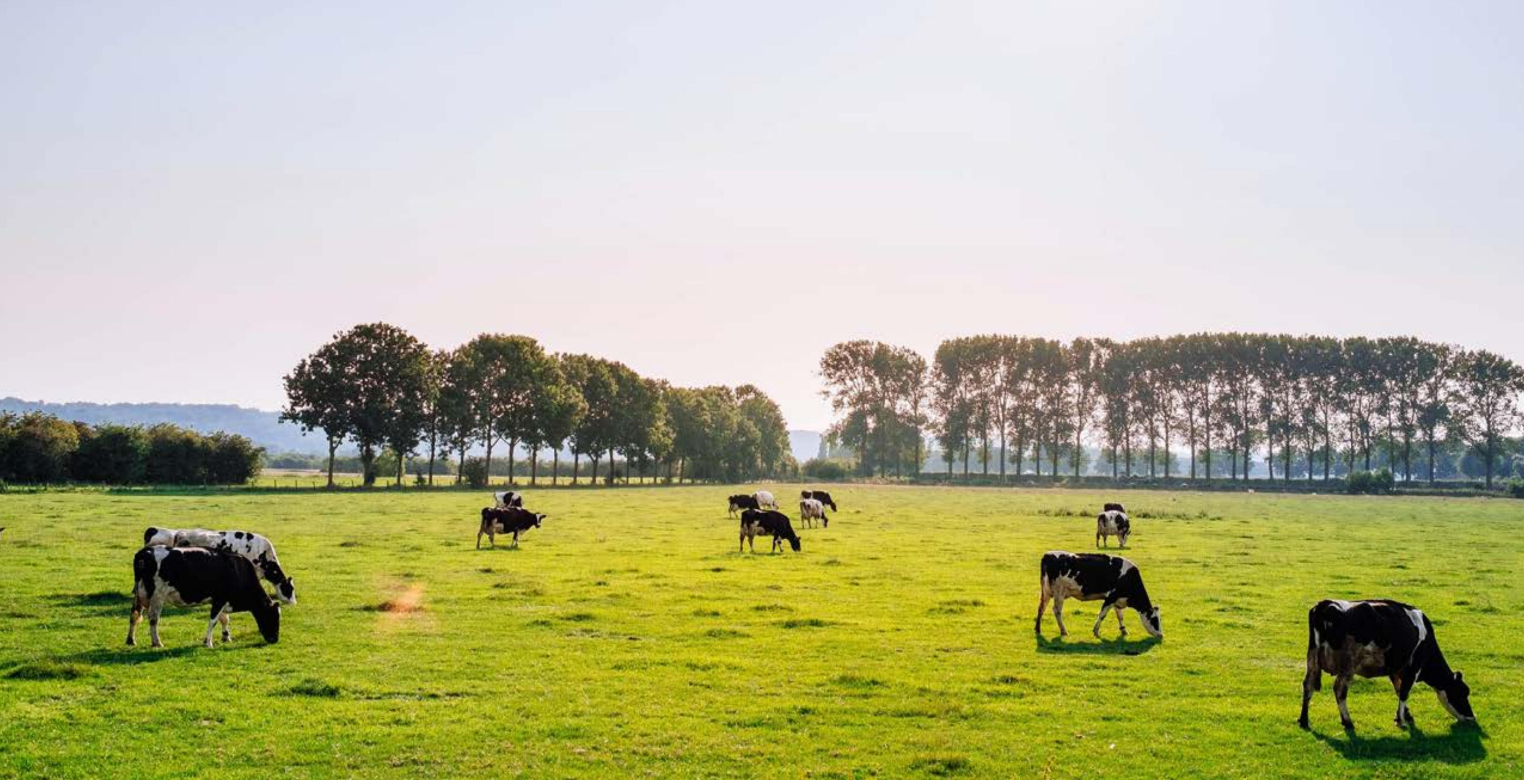
Greywater includes water used for various domestic purposes that is separated from sewage, thus avoiding contamination from harmful substances, to be reused on site. This is the least defined source of reused water, with systems varying broadly, as a large proportion of greywater is captured and reused at the household or property level through individually designed mechanisms (Environmental Protection Agency, 2012).

Water Reuse in Action: The Living Machine San Francisco, CA

Located in San Francisco, California, the Living Machine system is one of the first buildings in the nation with onsite treatment and reuse of its wastewater, including both greywater and sewage wastewater. The Living Machine system treats the building's wastewater through an engineered wetland system and then distributes the treated water through the building to use for toilet and urinal flushing (The Living Machine, n.d.). The system is responsible for approximately 5,000 gallons of recycled water per weekday, reducing total water use by about 65%, which ultimately saves 800,000 gallons of drinking water annually (The Living Machine, n.d.).



Sector 1: Farms & Livestock



According to the 2017 United States Department of Agriculture (USDA) Census, of the ten counties included in the Hudson River Valley Bioregion, there are 3466 individual farms comprising 533,585 total acres of farmland (United States Department of Agriculture, 2017). The average farm size in these ten counties ranges from 41 acres to 191 acres (United States Department of Agriculture, 2017). Four of the ten counties in the Hudson River Valley have orchard crops (e.g., apples) listed as the top five crops by acre, which is significant as orchards commonly utilize irrigation (United States Department of Agriculture, 2017).

Anecdotal evidence from stakeholder interviews has indicated that water reuse is not a widespread practice, and when it occurs, it often is not formally labeled or categorized as water reuse. In some cases, low-cost circumstances of water reuse have occurred on livestock farms without being recognized as such. For example, many dairy farm facilities' pipes and storage tanks must be regularly cleaned, and the water used to flush these systems is often then pumped into the dairy's manure management systems. The flush-water is not allowed to be dumped directly into streams due to high nutrient levels and manure management systems require additional liquid for the purpose of pumping and moving manure. By reusing the flush-water to augment the water needed for manure management, less water is used overall. While this one example of water reuse currently employed on farms was identified via conversations with experts and stakeholders in the Hudson Valley, we recognize that there may be other water reuse practices taking place in the region that also may not be broadly recognized as "reuse" or "water recycling".

Total Farmland	533,585 acres
Total Irrigated	11,818 acres
Percent Irrigated	2.21%

Harvest Water
Sacramento, CA

California has been using recycled water crop irrigation for years. The Harvest Water program conducted by the California Section of the WateReuse Association is one of the largest water recycling projects in the state. Located in Sacramento county, it has the capacity to deliver up to 50,000 acre-feet per year of tertiary-treated recycled water, irrigating more than 16,000 acres of farmland (Regional San, 2020). This program increases groundwater levels and groundwater storage capacity, supports habitat improvement efforts, and advances regional water sustainability (Regional San, 2020).

Water Reuse is not a widespread practice, and when it occurs, it often is not formally labeled or categorized as water reuse.

Areas for further research

- Connecting with dairy farmers in particular would contribute to the record of existing water reuse techniques for manure management utilized in the region. There may be further examples of practical water reuse around other farms, including dairies, that is unrecognized as such due to a lack of understanding of the broad applications of water reuse systems.

- Relationships must be built with regional dairies and other farmers to educate them around what "counts" as water reuse and how water reuse can be adopted for their benefit.

Sector 2: Wineries, Breweries, Cideries

Winery wastewater has very different characteristics than other wastewater sources. Winery wastewater is defined as any water used throughout the winemaking process from grape to bottle. This means that winery wastewater has many more pollutants to treat compared to municipal wastewater (Cassano et al., 2015). In a 2015 study, the University of California, Davis, assessed the possibility of utilizing treated winery wastewater to irrigate vineyards (Kerlin, 2015). Although one of the greatest challenges when irrigating with treated winery wastewater is high salinity, the total salinity of the treated winery wastewater was below the thresholds for common grape varieties and soil salinity conditions (Buelow et al., 2015). It should be noted however that soil mineralogy may impact the safety of winery wastewater utilization, and therefore must be monitored (Buelow et al., 2015). Ultimately, the study found that current data and risk assessment tools suggest that reuse of treated winery wastewater is possible; however, further research and regular monitoring is needed for widespread use (Buelow et al., 2015). For vineyards that already have irrigation infrastructure, this might be a strategic way to introduce water reuse into the Hudson Valley.

A number of companies offer winery wastewater treatment technologies such as Hydro International, ClearBlu Environmental, and Orenco Systems (Hydro International, n.d., ClearBlu Environmental, n.d., Orenco Systems, n.d.). In addition, Sustainable Winegrowing British Columbia published a handbook for winery wastewater management that serves as an excellent resource for wineries interested in converting to a wastewater treatment system (Sustainable Winegrowing British Columbia, 2018).

Waterfire Vineyards
Traverse, MI

Waterfire Vineyards is located on an isthmus between Lake Michigan and Torch Lake in Michigan, a region that receives a comparable amount of annual rain to the Hudson Valley. Waterfire Vineyards was the first winery outside of California to receive a Sustainability in Practice (SIP) Certification. SIP certification is extremely rigorous, requiring high standards around habitat, water, energy, soil, recycling, air quality, packaging, pest management, social equity, and business management practices that must be verified frequently. The winery pumped in water for irrigation during the first five years of production, as juvenile plants are extremely susceptible to climatic variations. Since then, the grapes have only needed rainfall to grow, so the winery has moved toward other sustainable practices to maintain their SIP Certification.

The irrigation infrastructure remains in place, however, and the winery recognizes that it may become useful in the future as climatic variability becomes more common, particularly if paired with reused water.

The biggest climate variability-related concern that Waterfire Vineyards and other farmers, vintners, and food producers in the Great Lakes region are currently facing is that of pests and disease. As the climate is changing there is evidence that insect populations—some quite detrimental to grape crops—are migrating further north as these regions become more hospitable. Changes in rainfall patterns and rising humidity are also easing the spread and intensity of fungal diseases, while the increased use of control measures are leading to fungicide resistance.

Another pressing concern with climate variability involves the effect of changing temperatures on the physiological development of vines throughout the season. Photosynthesis—the rate at which carbon is converted to sugar—is optimal between 50-68 degrees Fahrenheit. If this window is impacted by a shortened spring and increasingly higher summer temperatures, successful grape development will likely require additional care and water supply, dramatically changing the industry as it exists today. Certain grape varieties that currently thrive in this region will no longer be suitable, leaving farmers to make the difficult choice of whether to shift to more appropriate varieties, or not—both of which come with a large price tag. These are critical factors to consider when looking into potential drivers for water reuse in what appears, on the surface, to be a water-rich region.

Areas for further research

- Further research should include contacting vineyard owners to gauge interest in water reuse technologies, along with any potential places where water is being reused that is not specifically recognized as water reuse technology.
- Cideries, breweries and microbreweries are prevalent across the Hudson River Valley and are growing throughout the region. In other states, there have been some successes in utilizing small-scale water reuse in the brewing process, so this could be an excellent opportunity for further research into water reuse potential in the Hudson River Valley.

Sector 3: Recreation

Recreational reuse accounts for only 7% of total water reuse in the US (Kadeli et al., 2012). It is a very small portion of the reuse category compared to agriculture irrigation (29%), energy production (18%), and others nationally (Kadeli et al., 2012). Impounding reuse, which refers to reclaimed water for maintenance of contact (fishing/ boating) and non-contact (swimming), is a main practice of water reuse within 7% accounted for by recreational purposes nationally (Kadeli et al., 2012).

However, the distribution of national reuse categories may not be a reflection of regional characteristics and needs. There appears to be no evidence of recreational reuse occurring within the Hudson River Valley currently, but with the ample recreational activities and areas, there may be opportunities for water recycling to be integrated into this sector.

Recreational Reuse	7%
Agricultural Irrigation	29%
Energy Production	18%

Lake of Isles Golf Course North Stonington, CT

An average American golf course uses 312,000 gallons of water per day (Deford, 2008). Two traditional sources for golf course irrigation are municipal potable water systems and use of on-site water bodies like lakes, ponds, and streams. The Lake of Isles Golf course, located in North Stonington, Connecticut is renowned for its high-quality greens. To maintain them, the golf course utilizes highly treated effluent from a nearby wastewater treatment plant. The Lake of Isles Golf Course currently reuses close to 1 million gallons of water per day to irrigate the greens during its peak season, and from 2010 to 2015, approximately 228 million gallons of reclaimed water were used (CT Department of Energy & Environmental Protection, 2015). Irrigating with recycled water provides a beneficial use for the treated effluent, reduces discharges to the rapid infiltration beds, and eliminates the impacts of using potable water. Treated wastewater or captured stormwater may similarly provide other sustainable means for maintaining productive greens on golf courses in the Hudson River Valley and is worth further investigation.

Areas for further research

Ski Resorts

Making snow from reclaimed water for the purpose of prolonging and avoiding interruption of recreational sledding and skiing is becoming more popular in the US, and may offer sustainable solutions to Hudson Valley ski resorts as climate variability leads to unreliable snowpack. Several resorts in New England already use treated effluent during the winter to support their snowmaking (Kadeli et al., 2012), so this is an area that warrants additional consideration for water reuse potential in the Hudson River Valley.

Recreational Fields

With active, healthy communities, the Hudson River Valley is home to numerous athletic fields and parks with green space (Hudson Valley Tourism, 2021; Stateparks, 2021). The 2012 EPA Water Reuse Guidelines cite the important role water reuse can play for irrigation of public parks and recreation centers, athletic fields, school yards and playing fields, and landscaped areas surrounding public buildings and facilities, and note how considerations for irrigating these areas are similar to those of golf courses (Environmental Protection Agency, 2012). Therefore, these green spaces may present another opportunity for integrating water reuse practices within the Hudson River Valley.

Equine Industry

Horse culture in the Hudson Valley is diverse and includes both outdoor and indoor competitions, as well as therapeutic and recreational horseback riding. Horse farms depend on water for many purposes in their daily operations including water for livestock consumption, grounds maintenance, grooming, general cleaning, applying fertilizer to and irrigating hay and other crops, in addition to water needed for human uses (Marshall & O'Meara, 2013). There are clear opportunities to conserve water within the horse industry, with some practices of reuse already in place although they have not been recognized as such. Expert interviews conducted by the Primary Research Team indicate that equine farms and equestrian centers commonly collect and store wash-water used to bathe horses in tanks. This water is later used to reduce dust in both indoor and outdoor arenas. Reusing wash-water is an accessible and effective way to reduce the frequency and amount of draws from well-water that can be easily adopted by more farms within the industry, and this type of reuse should be actively promoted going forward.

ANALYTICAL FINDINGS

Stakeholder Analysis

The Primary Research Team identified a total of 51 stakeholders. However, 10 stakeholders were excluded from the analysis because of insufficient contact information, or lack of response to the Team's inquiries. The remaining 41 stakeholders were grouped into four categories: (1) Regulators, (2) Owners/Users, (3) Implementers, and, (4) Influencers, to align with the "Literature Review: Implementation of a Decentralized Alternative Water Systems in the US," (Hayek, 2021).

- Regulators set requirements and controls for water reuse strategies; they mainly consist of government agencies.
- Influencers educate on the topic of water reuse and practice; they mainly consist of institutions and universities.
- Implementers design, consult, or help with installation of water reuse; they mainly consist of non-profit organizations or for-profit firms.
- Owners/Users choose to both invest in and implement water reuse infrastructure and pay for ongoing maintenance and insurance; they are farms, vineyards, and wine producers, combined as one category.

To begin, the Analytic Research Team conducted a baseline analysis of all potential stakeholders for each category based on secondary research. Of the 41 potential stakeholders, 15 were interviewed by the Primary Research Team. Interview transcripts were reviewed and used to conduct a refined analysis focused solely on stakeholders who were interviewed (Figure 3e).

Then, the Analytic Research Team used Schmeer's "Influence vs Importance Matrix" (Schmeer 2001) to refine the baseline stakeholder assessment:

Influence is the combined measure of the amount of resources available to the stakeholder, and the actual capacity to engage and mobilize those resources.

- Types of resources include: Scale of operations informed by the amount of land and business growth in a cost-effective manner, existing infrastructure such as equipment and buildings, and strategic plans for current or potential water management.
- Indicators of capacity to engage are dependent upon the stakeholders' relationships with Hudson River Valley such as existing partnerships and local associations.

Each stakeholder was assigned an Influence ranking of 0-3:

- 3: stakeholders with sufficient resources or high capacity to engage; including stakeholders with large scales of operations or significant knowledge and research conducted on water reuse.
- 2: stakeholders with medium amounts of resources or engagement; including stakeholders with smaller scale of operations, or limited funding for the Hudson Valley.
- 1: stakeholders with limited resources and capacity to engage.
- 0: stakeholders with neither resources nor capacity to engage.

The Analytic Research Team averaged scores for resources and capacity to engage for each stakeholder, resulting in an Influence Index between three and one, specifically: 3 = High Influence, 2 = Medium Influence, and 1 = Low Influence.

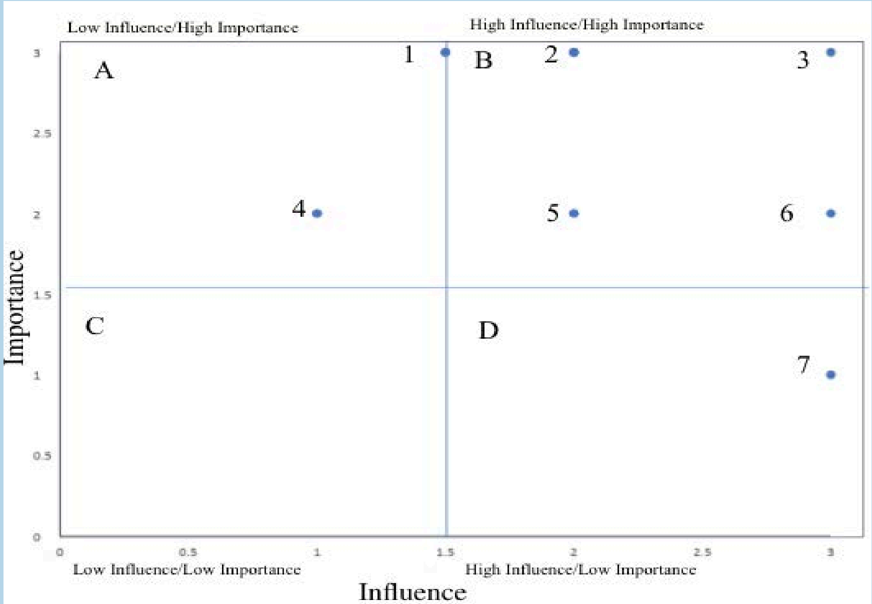
Likewise, the Analytic Research Team created an Importance Index for each stakeholder. Importance is defined as the proximity of a stakeholder to the Hudson River Valley, their engagement with water management, and their interest in water reuse. Specifically, if the stakeholder was:

- Located within Hudson River Valley, they were given one point, whereas if they were located outside the Hudson River Valley, they were given zero points.
- Engaged with water management through planned or current water strategies, they were given one point. If stakeholder engagement was determined to be limited, they were given 0.5 or zero points.
- Interested in water reuse as indicated through verbal confirmation from the interview, they were given one point, whereas if interest was limited, they were given 0.5 or zero points.

These three variables were then summed, resulting in an Importance Index between three and one, specifically: 3 = High Importance, 2 = Medium Importance, and 1 = Low Importance.

The resulting Stakeholder Analysis can be found in Figures 3a to 3e. Each matrix has four boxes labeled A, B, C, and D, respectively. Stakeholders included in Box B were identified as key stakeholders who can significantly influence water reuse in the region (Department for International Development, 2003). Specifically:

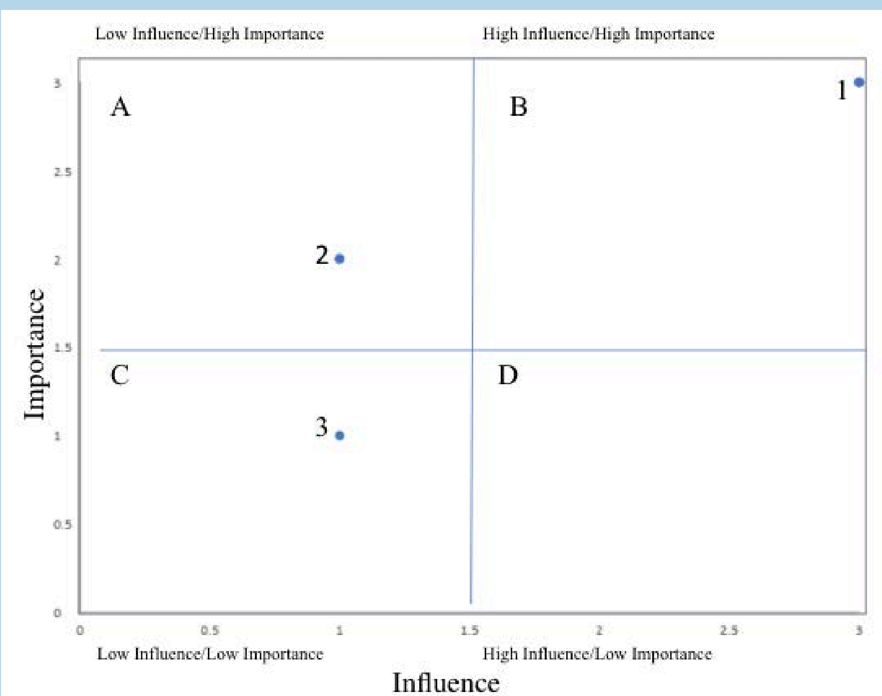
- Box A includes stakeholders of high importance to the activity, but with low influence. These stakeholders require special initiatives if their interests are to be protected. Thus, effort should be made to keep these stakeholders satisfied.
- Box B shows stakeholders of high importance who can also significantly influence water reuse in the region. These stakeholders should be managed closely as developing a good working relationship with these stakeholders will help to ensure their support for water reuse.
- Box C identifies stakeholders who are of low priority and only need limited monitoring.
- Box D shows stakeholders with high influence who can affect the outcome of water reuse in the region whose interests are unaligned with the target of this project. These stakeholders may be able to block water reuse planning and activities. Therefore, while they are unlikely to be partners in these efforts, there may be opportunities to strategically engage with them on the topic.



1- Hudson Valley Fresh
1-Hudson Valley CSA Coalition
2-Glynwood
2-Hudson Valley Farm hub
2-HVADC
2-Scenic Hudson
3-Riverkeeper
4-Hudson Valley Wine and Grape Association
4- Roundout Valley Growers
5-Northeast Sustainable Agriculture
5-Northeast Organic Farming
6-Watershed Agriculture Council
7-Hazen and Sawyer

Figure 3a: *Implementers Baseline Matrix Analysis*

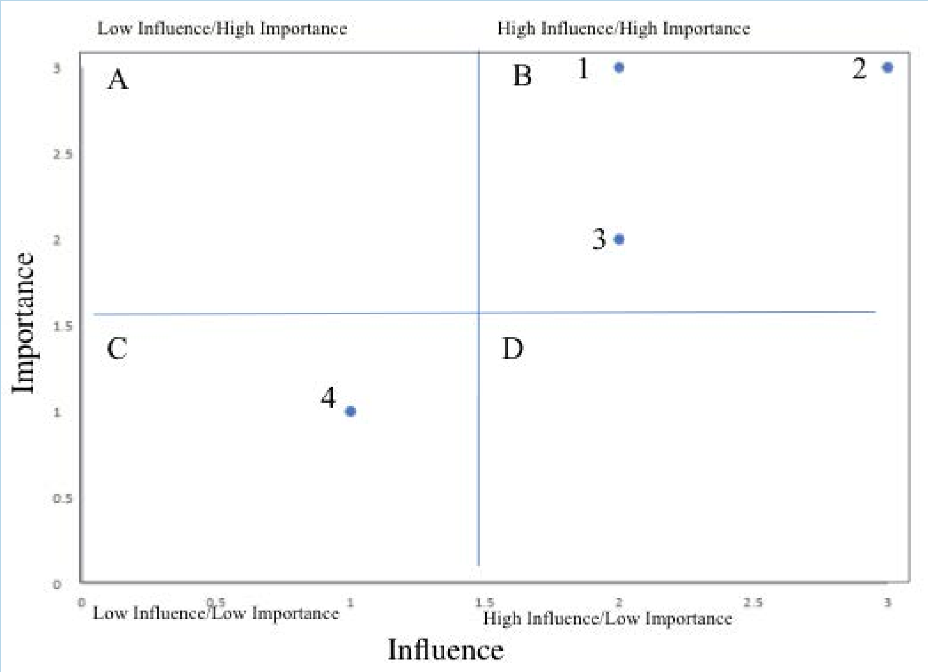
Overall, there are 13 implementers, 11 owners/users, 10 regulators, and 7 influencers that were identified and analyzed through the baseline stakeholder analysis. Eight implementers are located in Box B as high influence/high importance. These implementers are Glynwood Center for Regional Food and Farming, Hudson Valley Farm Hub, Hudson Valley Agribusiness Development Corporation, Scenic Hudson, Riverkeeper, Northeast Sustainable Agriculture Working Group, Northeast Organic Farming Association of NY, and Watershed Agricultural Council.



1-Fishkill Farms
1-Eight Mile Creek Farm
1-Brotherhood Winery
1- Hawthorne Winery
2-Threshold Farm
2-Tousey Winery
2-Common Goods Farm
2-Indoor Garden Microgreens
3-WaterFire Vineyard
3-Grassroots Farm
3-Harlem Valley Homestead

Figure 3b: *Owners/Users Baseline Matrix Analysis*

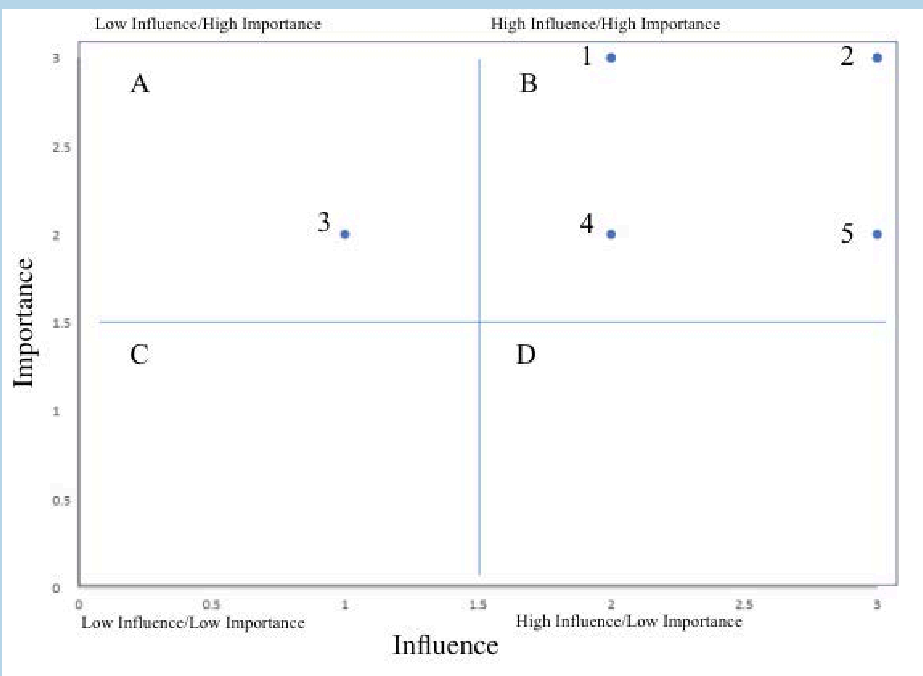
In the Baseline Stakeholder Analysis of Owners/Users, four owners/users are in Box B which are: Fishkill Farms, Eight Mile Creek Farm, Brotherhood Winery, and Hawthorne Valley Farm. These owners are of high importance and high influence due to their location in the Hudson Valley, their years of experience, and large scale of operations.



1-NY Department of Agriculture Land and Water Resources
1- EPA region 2
1-Ulster County Soil and Water
2- NY Department of Environmental Conservation
2-NYC Department of Environmental Protection
2- NYS Soil and Water
3- NY Department of Agriculture- Milk and Dairy
3- NRCS-USDA NY State
4- Colorado Department of Public Health and Environment
4- San Francisco Public Utilities

Figure 3c: *Regulators Baseline Matrix Analysis*

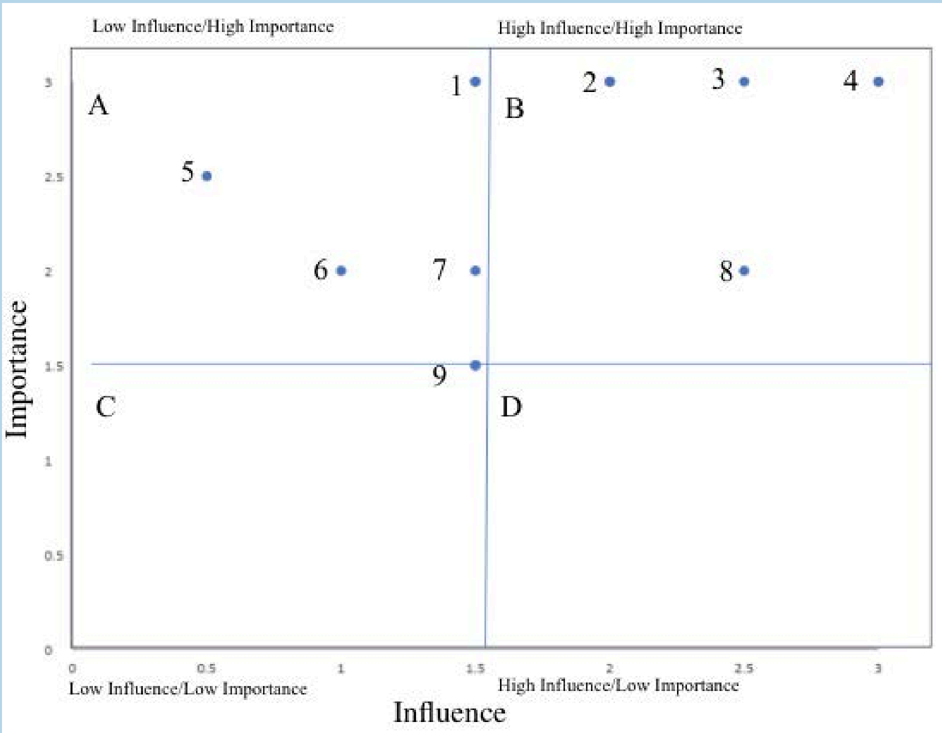
In the Baseline Stakeholder Analysis of Regulators, eight regulators are in Box B which are: NY Department of Land Agriculture and Water Resources, EPA Region 2, Ulster County Department of Soil and Water, New York Department of Environmental Conservation, New York Department of Environmental Protection (NYC DEP), NYC Soil and Water Conservation, NY Department of Agriculture Division of Milk and Dairy Services, and Natural Resources Conservation Service from the US Department of Agriculture (USDA NRCS).



1-Cornell Cooperative Extension
1-Rich Earth Institute
2-Roxbury Agriculture Institute
2-Bard Water Lab
2-Hudson Valley Research Lab
3-Green Building Council
3-Cary Institute
4-Columbia
5- Stone Barns Center for Food and Agriculture

Figure 3d: *Influencers Baseline Matrix Analysis*

In the Baseline Stakeholder Analysis of Influencers, there were six influencers in Box B which are: Rich Earth Institute, Cornell Cooperative Extension, Roxbury Agriculture Institute, Bard Water Lab, Columbia, and Stone Barns Center for Food and Agriculture. These stakeholders should be managed closely as developing a good working relationship will help ensure their support for water reuse for the region.



1-Rich Earth Institute
1-Stone Barns Center for Food and Agriculture
2-Columbia
2-Grassroots Farm
2-NYDEP
3-Watershed Agriculture Council
4-Cornell Cooperative Extension
4-NRCS-USDA
5-Cary Institute
6-Colorado Department of Public Health and Environment
7-Riverkeeper
8-Hazen and Sawyer
9-San Francisco Public Utilities
9-WaterFire Vineyards

Figure 3e: *Stakeholders Interviewed Baseline Matrix Analysis*

Of the interviewed stakeholders in the Refined Stakeholder Analysis there are four influencers, two regulators, one owner/user and three implementers that are considered high influence and high importance. These stakeholders should be considered by the WateReuse Association for future engagement due to their participation, influence, and knowledge of water management in the Hudson River Valley.

SWOT Analysis

A SWOT analysis was undertaken to guide our findings about decision-making, as this type of analysis informs the WateReuse Association's organizational strengths (internal) and weaknesses (internal), as well as community and regional opportunities (external) and threats (external). The Analytic Research Team compiled data for the SWOT analysis using a combination of information gleaned from expert interviews around concerns with respect to water use in the region, and the Stakeholder Analysis around how influential stakeholders are for implementing water reuse strategies.

A SWOT analysis was conducted using the stakeholders that were placed in Box B, (i.e., stakeholders of high importance who can also significantly influence water reuse in the region) from the Stakeholder Analysis, whom the Team considers to be of potential interest for the client. The Analytic Team then conducted an analysis of the client's strengths and weaknesses related to implementing water recycling practices and legislation in this region. The results can be seen in Figure 4a.

External threats and opportunities to the project were also examined from the perspective of the client, and the results can be seen in Figure 4b. The external threats and opportunities were grouped based on three of the original four pillars. The Key Actors pillar was not included, as it was the sole focus of the previous analytic tool, the Stakeholder Analysis. However, stakeholder considerations are in many ways embedded within the Policy, Food and Wine Production, and Technology pillars, since people and organizations are essential to realizing the threats and opportunities for our client. From the SWOT analysis, the Team developed recommendations for our client based on the pillars which are outlined in the final section of this report.

Figure 4a: SWOT Internal Strengths and Weaknesses

Strengths (internal)	Weaknesses (internal)
• Experience working on water scarcity issues Relationships with experts in climate variability for water scarce areas • Membership network with national and international reach (38 states and 11 countries) • Proven capacity to build and sustain partnerships • Relationships with water utilities and private consultants focused on water issues • Opportunity to leverage ESP student report and analytical framework	• Moderate size of staff may limit capacity • Water rich projects are not fully formulated • Water rich areas have different climate variability parameters • Lack of clarity around existing Hudson River Valley stakeholder representation • May distract from current membership building efforts

Figure 4b: SWOT External Opportunities and Threats

	Opportunities (external)	Threats (external)
Food & Wine Production	• Influencers have existing knowledge on water-food-energy nexus, sustainability, growing practices, and impacts of climate change on water abundant region • Key owners/users have interest in learning about water reuse practices for their region • Many influencers are interested in the dynamic between climate variability, water retention and their impact on the Hudson River Valley • Many influencers have existing infrastructure for education programs that can be used and expanded to meet Association needs • Influencers have experience building partnerships through their networks and relationships with regulators	• Lack of clarity on water reuse and how climate variability impacts water abundant areas can potentially foster mistrust with WateReuse Association • Narrow water reuse definition/understanding does not highlight reuse-potential in climate variable conditions and results in some owners being unaware that they are engaged in water reuse • Unaligned influencer missions (e.g., Riverkeeper) may limit effectiveness of WateReuse efforts to find synergies within leadership goals and objectives
Policy	• Regulator's interest in dealing with agricultural runoff can incentivize water reuse policy • Water policies in other states can inform WateReuse Association efforts	• The existing water reuse guidelines are limited and primarily focus on stormwater. The lack of water quality standards for reused water poses potential health risks • Local governments may be reluctant to implement water reuse due to water abundance in Hudson River Valley region • Unfunded mandates (however important) have placed burdens on owners and users • Mistrust among land owners, users, and regulators can undermine water reuse policy and implementation in region
Technology	• Potential to leverage influencer knowledge on water reuse implementation and cost-benefit examples • Influencers working in the Hudson River Valley could potentially create pilot projects to examine the types of technology to be used in the region • Cost effective technologies could be used to manage excess wastewater at vineyards	• Lack of information on water reuse costs and technology causes opaqueness on the type of technology that would qualify for water reuse • Current use of rainwater rather than irrigation by most farmers in the region is likely to make implementing water reuse infrastructure costly and may be a potential barrier • Most water reuse technologies focus on water scarce areas and would need to be modified for water abundant areas

Recommendations

- Current Opportunities
- Toolbox for Future Research

CURRENT OPPORTUNITIES

The Workshop Team developed multiple recommendations to inform the WateReuse Association's next steps for implementing water reuse practices within the Hudson River Valley and other water-rich areas. These recommendations are organized into the four research pillars that guided the Team's research. The Team also provides a toolbox of analytic strategies and approaches to guide future research for the WateReuse Association.

Policy

Although no statewide policies specifically exist for regulating water reuse in New York, policies currently focused on pollution and discharge control hold potential to impact large scale water reuse in the region. These policies can be viewed on pg. 15. Eachshould be reexamined based on the following three considerations:

- How such regulations impact specific industries
- How regulations might be repurposed for water reuse
- What incentives might motivate stakeholders to recycle water for irrigation or nutrient capture

Opportunities may exist for capture and reuse of stormwater as a means to reduce pressure on municipal systems, especially in the face of increasing heavy precipitation events mixed with periods of drought.

- We suggest an expansion of research into the relationship between municipal wastewater treatment facilities, combined sewage overflow (CSO) discharge into the Hudson River, and drinking water sourced from the Hudson River as a water reuse focus.

New or future water reuse policy design and implementation will require the support of industry, producers, and water resource stewards.

- To effectively implement water reuse in the region, we recommend that policies promoting water reuse be developed through collaboration with engineers, academics and private-sector researchers, farmers, foresters, land stewards, and the greater Hudson River Valley community.

Policy, regulation, and governance will need to occur on a local and/or state level to address regional conditions and challenges.

- We suggest direct engagement with regulators (i.e., stakeholders who set requirements and controls for water reuse strategies and mainly consist of government agencies like the NRCS and NYC DEP; see pgs. 27 and Appendix C), who have both the capacity for impacting water reuse capabilities and the flexibility to meet needs as they arise.

Farmers, vintners, and food producers in the region already feel strained by regulation, so any new regulation for the purpose of water reuse must take funding into consideration.

- To be successful, water reuse mandates should avoid being "unfunded" or underfunded. Policy needs to identify and target sources of funding or grants, such as the IMG program (see pg. 15), associated with the potential to promote source water protection and/or reuse.

In the short term, the Team highly recommends the implementation of pilot programs to inform pertinent legislation, and advance regional awareness of how water reuse can be successfully integrated in water-abundant areas.

Food and Wine Production

To broaden its impact within the Hudson River Valley, the WateReuse Association should focus on building relationships with influential stakeholders in the region for information gathering and sharing, and education and outreach.

- Setting up focus groups with influencers (i.e., stakeholders who educate on the topic of water reuse and mainly consist of institutions and universities like Columbia University and Cornell Cooperative Extension; see pg. 27 and Appendix C), who can advance: (a) an understanding of potential barriers and incentives for the individual producer and community members; (b) knowledge about the scale of work and effective practices for purposes of investment, insurance and maintenance costs for water reuse in the region; (c) the actual adoption of appropriate water reuse practices; and, (d) inform the design of education, training and outreach of water reuse programs for food and wine producers.

Our conversations with experts elucidated the necessity of pilot programs.

- We encourage the Association to partner with regulators to grant temporary permits allowing unregulated water activities to be part of pilot projects.
- Pilot programs increase trust, and can build support for amending laws or designing new legislation.
- Pilot programs, when effective, facilitate interest in, and investment by farmers, vintners, community members, and regional associations, and financial institutions.

The Teams also recommends that the Association expand its focus beyond food and wine production to support recreational industries like golf, skiing, and the equine sector.   While not the emphasis of this report, the Team believes these areas have a great potential to implement water recycling practices.

Cornell Cooperative Extension Regional Agriculture Programs

Technology

- Our research has indicated that the costs of water reuse technology vary widely due to the substantial range in scope and scale to which this technology can be applied. In effect, the true costs can be opaque to end users which may serve as a barrier to adoption.

- The team recommends that conversations with potential owners and users of water reuse technology be continued and expanded upon to gain a greater understanding of (a) existing water infrastructure, and (b) thought processes and drivers for water reuse in the Hudson River Valley.

- Conversations with implementers, who have fundamental information regarding the costs of different water reuse technologies, should be expanded to improve understanding on how the costs will impact owners/users within the Hudson River Valley in both the short and long term.

- Pilot programs should be implemented to introduce different forms of water reuse technology to owners/users in the region, as well as to inform best-use technologies for different economic sectors and implications for their investment.

Key Actors

As different understandings of water reuse may inhibit its widespread adoption and/or the perceived recognition of its current use within the Hudson River Valley, the Team recommends that the language surrounding the definition of water reuse should be explicitly defined and utilized in outreach to key actors or stakeholders.

The widespread adoption of water reuse practices within the Hudson River Valley will require the support of the many stakeholders within the region.

- To effectively implement water reuse in the region, we recommend that the Association begin by building strong relationships with the Hudson River Valley community, including coalitions and farmer organizations, individual growers and food producers, vintners, brewers, local agencies, academics and private-sector researchers, and the recreational industry.

SURVEY | COST MATRIX | ECOLOGICAL ANALYSIS

We recommend that the WateReuse Association conduct a survey of farmers, vintners, and food producers in the Hudson Valley region for the purposes of building trust and incorporating local needs and insights into pilot programs, policy proposals, and/or educational initiatives for water reuse. By soliciting specific input from individual producers in the Hudson Valley, a more in-depth understanding of the potential and capacity for water reuse in the region is possible. The survey instrument questions and metrics were developed through feedback collected through 15 Expert Interviews conducted for this report.

The Team identified a list of potential contacts as being well-connected throughout the Hudson River Valley via secondary research and Expert Interviewee recommendations. We recommend the WateReuse Association partner with these organizations to send the survey to their members and/or constituencies. These organizations are: The Hudson Valley Community Supported Agriculture Coalition, Hudson Valley Agribusiness Development Corporation, Glynwood Center for Regional Food and Farming, the Hudson Valley Farm Hub, state or local agencies, and Cornell Cooperative Extension. All of these organizations were identified as those having high importance and high influence within our stakeholder analysis.

Survey Questions

Where is your farm located?

Survey taker chooses from 10 counties in the included map (Figure 1)

What is your farm's acreage? *(Include range options, TBD)*

What does your farm grow or produce? (can select more than one)

Dairy   *Wine*

Fruits/vegetables   *Other food product (fill in box)*

Does your farm irrigate?

Yes   *No*   *Sometimes (fill in explanation)*

What are obstacles that farmers have faced in implementing water reuse processes? Why have/haven't they incorporated water reuse? *(Fill in blank)*

How aware are you of the interaction between climate change and water?

Scale of 1-5 with 1 being not at all aware and 5 being extremely aware

What is your knowledge of/perspective on water reuse? *(Fill in blank)*

How do you think consumers/buyers of your products will react to a shift towards water reuse practices and technologies?

Positive reaction   *Negative reaction*   *No reaction*   *Unsure*

If your farm practices water reuse practices/technology: approximately how much money did you invest in water reuse? *(Fill in blank)*

How much energy does your current water management utilize?

Low amount of energy   *Moderate amount*   *High amount*   *Unsure*

Toolbox for Future Research

SURVEY | COST MATRIX | ECOLOGICAL ANALYSIS

Because cost has been identified as a potential barrier to water reuse, we recommend the WateReuse Association build out a cost matrix of the various types of water reuse systems and technologies. A cost matrix of the different water recycling technologies can:

- Inform the initial investment required to implement water reuse in the Hudson River Valley, and,
- Be used to create a future cost-benefit analysis that can provide insight on how water reuse may be most economically feasible for the region.

To aid in the development of a cost-matrix, the Team first recommends that the source of the water to be recycled, the scale of operations, and the end use be examined to determine the type of water reuse system, and thus the technology needed.

- The Team has identified four main sources of water with the potential for reuse in the Hudson River Valley including (1) Greywater, (2) Wastewater, (3) Tailwater, and (4) Stormwater.
- The scale of operations can be viewed in three categories, including: (1) Individual, (2) Coalitions, and (3) Municipal, and is dependent on how much water enters the system, and the distance it is traveling.
- The end uses are varied, ranging from potable water to irrigation, groundwater recharge, and on-site industrial repurposing, among others.
- Once the technology needed is determined, the subsequent cost for implementing that system should be calculated and analyzed through the cost matrix. This cost can include insurance, ongoing electricity charges, maintenance and personnel training, among other factors.

Toolbox for Future Research

SURVEY | COST MATRIX | ECOLOGICAL ANALYSIS

The Team also recommends that the WateReuse Association conduct an ecological analysis of the impact of water reuse systems on the soil ecology in the Hudson River Valley.

- An ecological impact analysis would help to identify, quantify and evaluate the potential effects of water reuse on the environment. A deeper understanding of the implications of water reuse at the ecosystem level would be beneficial for informing policy decisions.

First, a baseline should be created for the soil mineralogy and water retention for subregions of the Hudson Valley in order to account for variability.

- Information can be gathered from local farmers and vitners in the region, along with data from soil surveys from the USDA. Information on the water recharge and retention should also be gathered to create a model for speed of the water cycle in the region.

Once information is collected, watershed modeling can be conducted with spatial analysis software like ArcGIS that enables soil and water to be analyzed through various timescales and projections.

- ArcGIS, and similar software, have tools that assess how weather, soil, land use, and land management can impact watersheds. In this case, land management will be changed based on the type of water reuse systems, and software modeling can reflect those changes.

- Depending on the tool used, two sets of projections should be made:

  The first, being a control or baseline, would include no changes to land, soil, or future weather.

  The second projection would include land changes made depending on the scale of water reuse the Association assumes could be implemented. Examining how the second projection differs from the first can provide insight on the potential watershed changes that would occur should water reuse be used in the Hudson River Valley.

Conclusion

Water has been central to the Hudson River Valley's robust agricultural traditions, and protecting, conserving, and managing this resource is likely to become increasingly important as the climate continues to change. The need for climate resiliency necessitates looking forward toward more innovative water conservation practices than those currently employed within the region.

Our findings and research around water reuse in the Hudson River Valley provide novel insight for the WateReuse Association to build upon for its integration within water-rich areas. While the Team's work was limited by time, resources, and scope, we were able to make key recommendations and identify areas of further research for agriculture, wineries and breweries, and recreation in the region. Our research process and analytic strategy not only informed the potential for water-reuse in water-rich areas like the Hudson River Valley, but also identified key gaps in the understanding of and benefits around water reuse, and the capacity that exists for legislation to support its adoption. Continuing to identify where water reuse may already be in practice—especially in instances where it has not been widely recognized as such—while exploring the untapped opportunities uncovered through the Team's research is the first step.

Going forward, we recommend that the WateReuse Association conduct a survey of farmers, vintners, and food producers in the Hudson River Valley region, along with a cost matrix and ecological analysis to gain a more comprehensive understanding of the capacity of water reuse, its economic feasibility, and environmental impact for the Bioregion. Relationship building and the implementation of water recycling pilot programs will also be essential to continue to inform the potential for water-reuse and facilitate stakeholder education and support in the region. The Team's findings and recommendations can hopefully be expanded in order for water reuse to become a viable option to address climate variability within the Hudson River Valley and other water abundant communities throughout the US. We believe an informed and integrated water reuse strategy can help forge the Hudson River Valley's path toward resiliency and inform best practices for other water-rich areas like it.

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Appendix A: Finalized Script

We are a group of graduate students from Columbia University in the Environmental Science & Policy MPA program researching the current state of and future potential for water reuse in Hudson Valley agriculture and viticulture on behalf of the WateReuse Association. The WateReuse Association has worked in a variety of states in the past, but this will be their first project assessing water reuse in the Hudson Valley. We hope to gain more understanding of the difference in perceptions and access to information in the Hudson Valley through informal discussions with stakeholders. As a [INSERT ROLE] in the region, we are reaching out to ask if you have time for a quick and informational conversation to guide our research. Any information you could offer about [INSERT SPECIFIC TOPIC RELATED TO THEIR ROLE] would be incredibly helpful!

Appendix B: Guiding Interview Questions

1. Do you see challenges with water in the Hudson Valley region? What would you say are those challenges or concerns?
    a) Does climate variability concern you with water availability/quality?
2. How would you or your agency/organization define water reuse?
3. What is your perspective on water reuse?
4. Do you directly engage with water reuse or are you partnered with organizations who do water reuse?
    a) ***If they/their partner organizations already implement or have programming around water reuse:***
        i. What is the reused water primarily used for?
        ii. What led to your adoption of these practices?
        iii. Have the benefits of water reuse overcome the initial costs of implementing? What were the costs (economic nature like capital investment costs, disruption of growing capacity, increased human resource management needs to effectively manage the wastewater, etc)?
    b) ***If they do or do not implement water reuse:***
        i. What are the obstacles to implementing water reuse practices from the perspective of your agency/ organization?
5. ***(If they don't talk about this in 4)*** What do you know about water reuse technologies? Do you use any of them in your water management practices?
6. How knowledgeable do you feel about different water reuse technologies?
    a) Optional depending on answer: What kind of water reuse educational program do you think would work for your organization/constituency?

Additional Questions for Agencies

1. Are there any major policies, regulations, and/or outreach programs relating to water reuse that you believe we should research or be aware of?
    a) What policy changes and regulations would make water reuse technology implementation more widespread and effective?
2. ***(If we don't feel like this was addressed in the baseline discussion)*** Are there any partner organizations that you/your organization often work with regarding water use?
3. Do you have suggestions as to what other research topics we should look into or organizations we should reach out to related to water reuse and/or the Hudson Valley?

Additional Questions for Organizations of Farmers/Food Producers/Vintners

1. Has your organization/your constituents considered the potential impacts of climate change and variability [in the Hudson Valley]?
    a) If yes, which aspects of climate change?
2. What does collaboration between member organizations look like for your coalition/organization?
    a) ***Doesn't have to be a direct question but want to get at:*** Do you share any technology/practices/integration around stormwater management or irrigation (infrastructure and practices that the infrastructure meant for)
3. Do you have suggestions as to what other topics to research or organizations we should reach out to related to agricultural/viniculture in the Hudson Valley?

Appendix C: Baseline Analysis Table

Stakeholders	Importance Index	Influence Index
Bard Water Lab	3	3
Brotherhood Winery	3	3
Cary Institute	2	1
Colorado Department of Public Health and Environment	1	1
Columbia	2	2
Common Ground Farm	2	1
Cornell Cooperative Extension	3	2
Eight Mile Creek Farm	3	3
EPA Region 2	3	2
Fishkill Farms	3	3
Glynwood Center for Regional Food and Farming	3	2
Grassroots Farm	2	1
Harlem Valley Homestead	3	3
Hawthorne Valley Farm	2	1
Hazen and Sawyer	1	3
Hudson Valley Agribusiness Development Corporation	3	2
Hudson Valley CSA Coalition	3	1.5
Hudson Valley Fresh	3	1.5
Hudson Valley Farmhub	3	2
Hudson Valley Wine and Grape Association	2	1
Indoor Gardens Microgreens	2	1
Natural Resources Conservation Service - USDA - New York State	2	2
New York Department of Environmental Conservation	3	3
New York Department of Agriculture - Milk and Dairy Division	2	2
New York Department of Agriculture - Land and Water Resources	3	2
New York State Soil and Water Conservation	3	3
New York City Department of Environmental Protection	3	3
Northeast Sustainable Agriculture Working Group	2	2
Northeast Organic Farming Association of NY	2	2
Rich Earth Institute	3	2
Riverkeeper	3	3
Roundout Valley Growers Association	3	2
Roxbury Agriculture Institute	3	3
San Francisco Public Utilities	1	1
Scenic Hudson	2	1
Stone Barns Center for Food and Agriculture	2	3
Threshold Farm	2	1
Tousey Winery	2	1
Ulster County Soil and Water	3	2
Waterfire Vineyards	1	1
Watershed Agriculture Council	2	3

Appendix D: Refined Analysis for Interviewed Stakeholders

Stakeholders	Importance Index	Influence Index
Cary Institute	2.5	0.5
Colorado Department of Public Health and Environment	2	1
Columbia	3	2
Cornell	3	2
Grassroots Farm	3	2
Hazen and Sawyer	2	2.5
New York Department of Environmental Protection	3	2
NRCS - USDA	3	3
Riverkeeper	2	1.5
Rich Earth Institute	3	1.5
San Francisco Public Utilities	1.5	1.5
Stone Barns Center for Food and Agriculture	3	1.5
WaterFire Vineyards	1.5	1.5
Watershed Agricultural Council	3	2.5

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Water Reuse in the Hudson Valley: Current Practices, Challenges, and Opportunities.