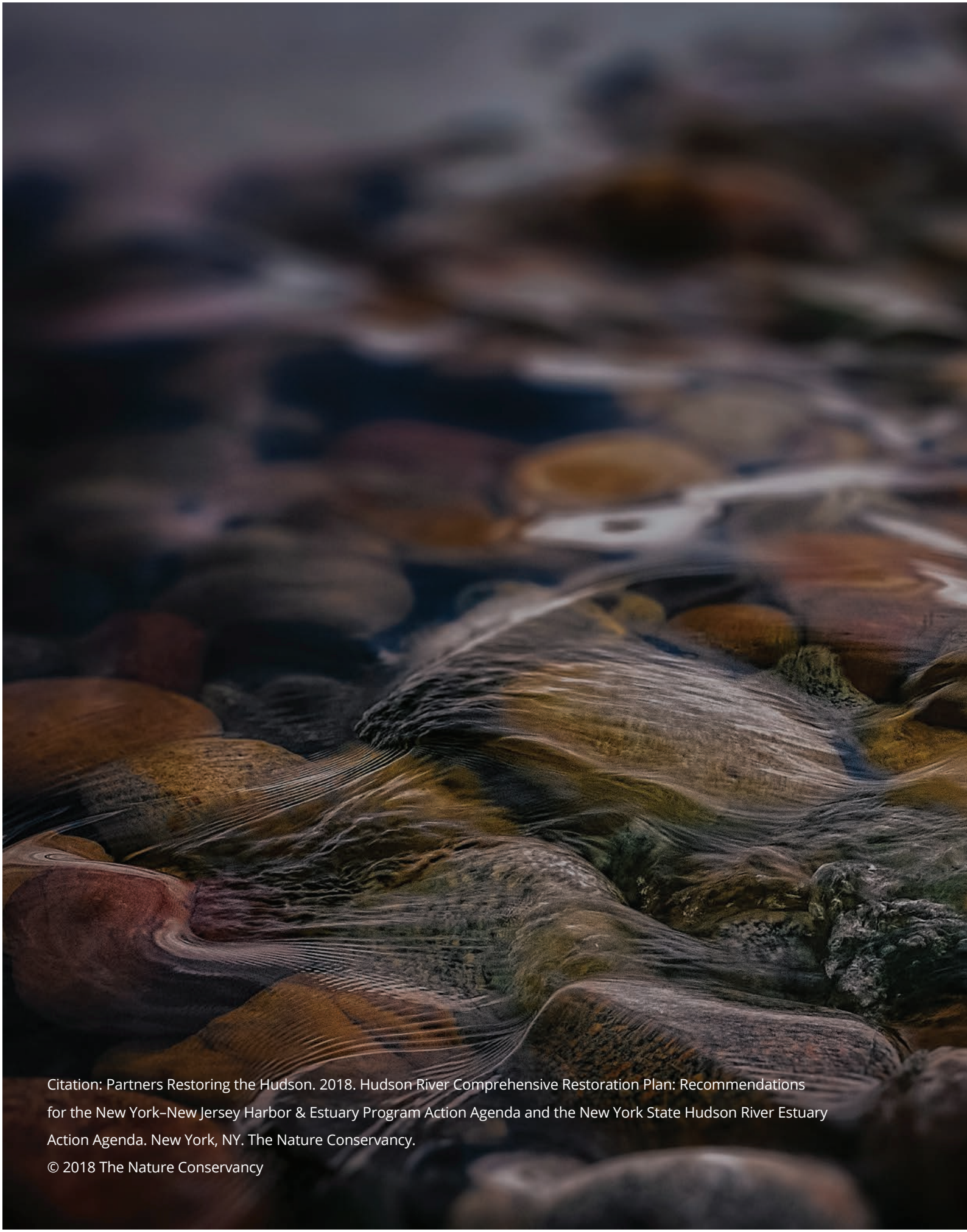
Hudson River Comprehensive Restoration Plan

Recommendations for the New York–New Jersey Harbor & Estuary Program Action Agenda and the New York State Hudson River Estuary Action Agenda

AUGUST 2018

the HUDSON we SHARE



Citation: Partners Restoring the Hudson. 2018. Hudson River Comprehensive Restoration Plan: Recommendations for the New York–New Jersey Harbor & Estuary Program Action Agenda and the New York State Hudson River Estuary Action Agenda. New York, NY. The Nature Conservancy.

Table of Contents

List of Tables and Maps

Acknowledgments

PARTNERS RESTORING THE HUDSON

Non-Profit Organizations

Beacon Institute for Rivers and Estuaries, Clarkson University

Cornell Cooperative Extension Columbia and Greene Counties

Cornell Cooperative Extension of Dutchess County

Historic Hudson River Towns

Hudson River Boat & Yacht Club Association

Hudson River Foundation

Hudson River Sloop Clearwater

Hudson River Watershed Alliance

Hudson River Watertrail Association

Lower Hudson Valley Coalition of Conservation Districts

Riverkeeper

Scenic Hudson

The Nature Conservancy

Public Agencies

State and federal agencies include:

Hudson River Estuary Program, New York State Department of Environmental Conservation

Hudson River National Estuarine Research Reserve

Hudson River Valley Greenway

NOAA Restoration Center

New York State Department of State

New York State Department of Health

New York–New Jersey Harbor and Estuary Program

New York State Energy Research and Development Authority

New York State Thruway Authority

U.S. Army Corps of Engineers

U.S. Environmental Protection Agency

U.S. Fish & Wildlife Service

Academia and Research Institutions

Center for International Earth Science Information Network, Columbia University

Cary Institute of Ecosystem Studies

Marist College

CONTRIBUTORS TO THE CANDIDATE PROJECT OPPORTUNITIES

Local Governments

Albany County

Albany County Office of Natural Resource Conservation

Albany County Planning Department

Capital District Regional Planning Commission

City of Albany

City of Cohoes

City of Newburgh

City of Newburgh Conservation Advisory Council

City of Peekskill

City of Troy

Columbia County Environmental Management Council

Columbia County Planning Department

Cornwall CAC

Dutchess County Planning Department

Green County Planning Department

Kingston Conservation Advisory Council

Orange County Planning Department

Putnam County Planning

Rensselaer County

Rensselaer County Planning Department

Rockland County Conservation District

Rockland County Waterfront Intermunicipal Council

Stormwater Coalition Albany County

Tivoli Waterfront Committee

Town of Bethlehem

Town of Colonie

Town of Cortlandt

Town of Germantown

Town of Marlborough

Town of Orangetown

Town of Ossining

Town of Stockport

Village of Athens

Village of Buchanan

Village of Catskill

Village of Croton-on-Hudson

Village of Dobbs Ferry

Village of Hastings-on-Hudson

Village of Nyack

Village of Wappinger Falls

Village of Wappinger Falls Planning & Development

Westchester County Department of Planning

Other Non-Profit Organizations

Columbia Land Trust

Esopus Creek Conservancy

Flow Chart Foundation

Hudson Sloop Club

Kingston Land Trust

North River Friends of Clearwater

Nurse-Family Partnership

Quassaick Creek Watershed Alliance

Saw Mill River Audubon

Shakespeare on the Hudson

The Care of Trees

Water Action Compliance Assistance and Planning LLC

Other Academia and Research Institutions

Bard College

CUNY Institute for Sustainable Cities

Pace University

Siena College

Other

AVST

Crawford & Associates Engineering & Land Surveying, PC

Edward S. Butler, P.E., Consulting Engineer

James West Consulting

Land Stewardship Design

Schodack Island State Park

Cady Design & Build

The Stewart House

GRANT SUPPORT

Made possible, in part, with support from:

New York State Energy Research and Development Authority: Grant #46952

NYS Hudson River Estuary Program Stewardship Grant Program: DEC01-T00056GG-3350000

NYS Thruway Authority: Prime Agreement D214187

Matching funds from The Nature Conservancy

List of Acronyms

ADA	Americans with Disabilities Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIESIN	Center for International Earth Science Information Network
CSO	Combined Sewage Overflow
EPA	Environmental Protection Agency
HHRT	Historic Hudson River Towns
HRNERR	Hudson River National Estuarine Research Reserve
HRWA	Hudson River Watershed Alliance
LIDAR	Light Detection and Ranging
LTCP	Long-Term Control Plan
NAWCA	North American Wetlands Conservation Act
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NSCD	Natural Stream Channel Design
NY-NJ HEP	New York–New Jersey Harbor & Estuary Program
NYS CFA	New York State Consolidated Funding Application
NYSDEC	New York State Department of Environmental Conservation
NYSDOS	New York State Department of State
NYSERDA	New York State Energy Research and Development Authority
NYSOGS	New York State Office of General Services
NYSOPRHP	New York State Office of Parks, Recreation, and Historical Preservation
NYSTA	New York State Thruway Authority
PCB	Polychlorinated Biphenyls
SAV	Submerged Aquatic Vegetation
SWCD	Soil and Water Conservation District
TEC(s)	Target Ecosystem Characteristic(s)
USACE	U.S. Army Corps of Engineers
WRDA	Water Resources Development Act
WWTP	Wastewater Treatment Plant

Executive Summary

For most of the past four decades, the Hudson Valley region has protected remaining high quality natural resources and open space while working earnestly through an array of community engagement and restoration activities to repair or replace lost elements. A long and storied history of advocacy, community engagement and on-the-ground activities contributes to the regional characteristics of today. These impressive strides produced a transformational shift in the way communities, residents and tourists interact with the Hudson River estuary (the estuary). Because of these efforts, communities now embrace the Hudson River as an asset; most K-12 students have exposure to the estuary through curriculum and/or hands-on experiences; thousands of acres of state, county and municipal parks exist which include swimming beaches, boat launches, and fishing piers; and we may even be witnessing the initial phases of recovery for the Atlantic Sturgeon.

Despite all the success, legacy impacts of aging infrastructure, degraded water quality, contamination, overfishing, habitat loss and ever-increasing development remain evident. Meanwhile, over the past decade, the implications of sea level rise, storm surge, flooding and drought are being felt in both subtle and dramatic ways. These new realities are expected to further alter already compromised natural processes, biological communities, human communities and infrastructure present in the Hudson River estuary. These environmental changes are expected to influence natural habitats and processes as well as where and how people interact with the estuary. These changes are expected to alter how these resources and interactions are managed.

Addressing this combination of legacy impacts and changing future conditions is more than a natural resource management issue. The relationships between natural resources, the economy, infrastructure and social components of the region are strong and highly related. Elements of a successful effort to address legacy impacts and adapt to these new conditions will require the development and application of innovative tools and techniques, enhanced collective action of a diverse network of traditional and non-traditional partners, strengthened community engagement and new funding streams and financing tools. A comprehensive approach that evaluates not only the individual attributes of interest but also addresses the interaction among them is necessary to meet the challenges. Through the significant efforts over several decades, much has been learned.

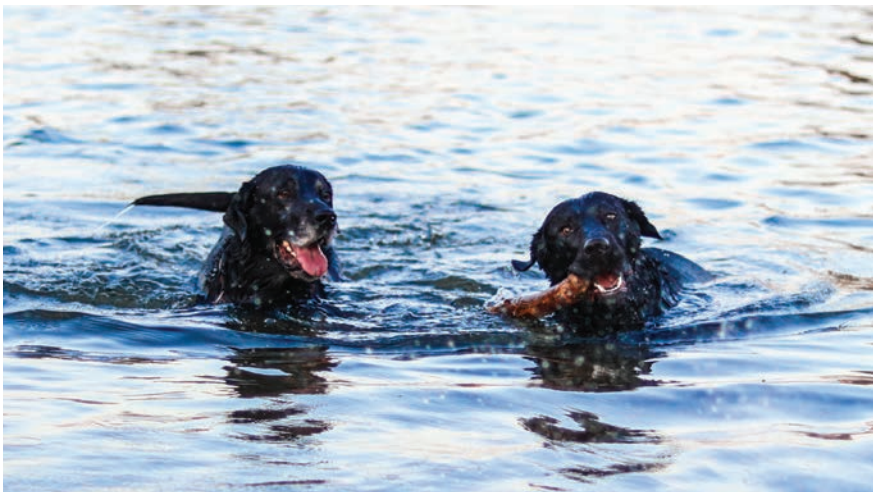
The Hudson River Comprehensive Restoration Plan synthesizes and applies scientific knowledge within a framework that establishes quantifiable desired future conditions. In the pursuit of setting and achieving goals, innovative partnership approaches are expected to emerge or develop that enhance collective action to resolve the challenges and shape the future of the Hudson River estuary from the Federal Lock and Dam at Troy, NY to the new Gov. Mario M. Cuomo Bridge.

This effort produced integrated mapping tools that depict where different habitats are currently expected to be found. This led to a limited evaluation of how and to what degree those habitats may have been influenced by different activities and yields a snapshot of projected current conditions within the study area. An array of critical estuary attributes and ecological characteristics, were identified and characterized relative to their role in and importance to the natural and human communities within the system. The evaluations also produced initial recommendations to improve, enhance and/or optimize their condition; although the objective was to identify quantifiable targets, this was not possible or pragmatic in all cases. To achieve the desired "place-based" elements of the Hudson River Comprehensive Restoration Plan (Hudson River CRP), a mapping tool was created that highlighted locations for which more than 1,800 "Candidate Project Opportunities" were submitted by 20+ riverfront communities and several contributing agencies and partner organizations. Although most projects are far from shovel ready, they do provide a context to consider where implementation might be viable pending further consideration of additional stakeholders, including landowners and municipalities. This combination of current conditions, desired future conditions of critical elements, and potential project opportunities

can augment and inform future New York State Hudson River Estuary Program and New York–New Jersey Harbor & Estuary Program Action Agendas by linking programmatic activity to a place-based plan.

Other elements of the Hudson River CRP include recommendations to improve the engagement and coordination of implementation capacity. To enhance coordination and engagement around the Action Agenda, the NYS Hudson River Estuary Program and the federal NY-NJ Harbor & Estuary Program will utilize working groups comprising experts, practitioners, and managers, responsible for revising goals and objectives as necessary. Both estuary programs will use the Hudson River CRP to inform their engagement in the region as well. Both state and federal estuary management agencies will be further supported by Partners Restoring the Hudson (PRH) which will provide the support and services the agencies may not able to fulfill, such as securing private grant funds, evaluating market-based financing tools, enhancing approaches to community engagement and developing new relationships with non-traditional partners.

The region underwent several turning points over the past century and the evidence suggests we are amid yet another pivotal moment that will significantly influence the region's future. While many of the traditional conservation measures (e.g., protection, restoration, etc.) will still prove to be valuable tools, they will need to be applied in the context of changing environmental and social conditions, and new tools and resources will be necessary. The Hudson River CRP is intended to inform how the region responds to the challenges being faced by benchmarking current conditions, using a science-based approach to propose attainable goals capable of framing new dialogue, providing reference to place-based opportunities, and recommending additional forums to catalyze and support collective action. The Hudson River CRP is meant to be an adaptively managed tool that is responsive to continued dialogue, realized future conditions, new knowledge and experiences. This initiative represents an adaptable starting point, not an end.



Introduction

After a half century of activism, scientific inquiry, protection and restoration—and a sea change in the cultural attitude toward the Hudson River estuary—we have reached a threshold moment when we can actively plan for the next half century.

The Hudson River Comprehensive Restoration Plan (Hudson River CRP) is the first attempt to benchmark restoration progress to date in the Hudson, and set long-term goals for its future. However, "restoration" means to return to a previous state of being, which assumes the circumstances allowing that condition to exist are stable in very long-time horizons. In the Hudson River estuary (the estuary), we know environmental conditions are not stable. This is evidenced by a clear trajectory of rising sea levels, more intense storm events, extensive flood events and more pronounced drought periods. How we interact with the river is also changing; more cargo is being shipped along its shores and on the water, more recreational opportunities exist today than ever before, and, although incomplete, attempts are being made to correct legacy impacts to the river. In the context of this work, we do not propose a return to some previous, unattainable condition. Rather, we offer a pathway forward that recognizes likely future conditions and contributes to a more productive natural system, vibrant economy, strengthened sense of community, and a safe, clean natural resource available for recreation, tourism and education.

The Hudson River CRP builds on the vision established through decades of activism by visionary environmentalists, research conducted by world-class scientists, and the engagement of every day citizens as expressed in the Hudson River Estuary Program Action Agenda, which calls for healthy and resilient communities that mutually reinforce healthy and resilient ecosystems. It sets the first quantifiable targets for restoration activities over the coming decades, developed by bringing together leading scientists and other experts in 12 distinct disciplines with a collective experience of hundreds of years. It identifies opportunity areas for specific restoration activities, with a first-of-its-kind mapping tool that combines essential natural resource and human use data with project ideas suggested by a diverse set of regional stakeholders. The Hudson River CRP is intended to inspire and guide collaborative actions by many entities, and to secure and leverage the resources needed to achieve a shared vision.

The collective vision of those contributing to this effort is that the Hudson River CRP will provide a strategic, activity-oriented, place-based approach to implementation that recommends quantifiable goals that strengthen and complement the NYS Hudson River Estuary Program and federal NY-NJ Harbor & Estuary Program Action Agendas; contributes to enhanced recovery trends; improves the overall resilience of Hudson River estuary human and biological communities; ultimately yields abundant fish, clean water, diverse habitats, thriving compatible economic activity and waterfront communities that are adapting to the significant consequences of climate change. Implementation strategies and activities need to be based upon sound science, be executed through effective partnerships with shared goals, access more diversified funding sources and further enhance a robust stakeholder community.

Many attributes of the Hudson River need protection, improvement, enhancement or re-imagining, including aspects of our natural resources, community infrastructure, transportation systems, social networks, and cultural contributions. There are currently regional economic development, sustainability, transportation, and open space plans at the local, county and regional levels which are all focused on ensuring a vibrant future. There are also habitat restoration plans aiming to repair the implications of past decision-making, while community resilience plans are beginning to emerge with the goal of preparing for an uncertain future relative to precipitation, sea levels, flooding and drought. Although not exhaustive, the Hudson River CRP provides a framework to establish the principal restoration needs of the river, identifies critical thresholds of action and recommends a platform to have the natural resource

Clockwise from top left: © unsplash/Ray Hennessy, © iStock/Boogich, © unsplash/Jeremy Perkins, © iStock/huePhotography

needs better integrated with economic and social planning and implementation activity. The Hudson River CRP also proposes a forum to enhance consensus building, issue evaluation and stakeholder engagement.

PARTNERS RESTORING THE HUDSON

In 2013, The Nature Conservancy convened a diverse group of stakeholders including non-government organizations, state and federal agencies, and research institutes to informally begin to organize around the development of a comprehensive restoration plan to supplement the NYS Hudson River Estuary Action Agenda and dovetail with other regional planning initiatives. Partners Restoring the Hudson (PRH) emerged from this early dialogue and is the principal, yet largely informal, group behind the development and completion of the Hudson River CRP.

PLAN COMPONENTS

The Hudson River CRP comprises four central components that provide a robust context for collaborative action:

01 Current Condition Assessment: The assessment produced an updated physical habitat model and provides insight into present day conditions throughout the geographic scope of the Hudson River CRP.

02 Target Ecosystem Characteristics (TECs): A TEC is a specific feature of the estuary that is related to a restoration goal. Detailed TEC descriptions in the report articulate past and present conditions, establish attainable goals and propose a pathway to achieving those goals through quantifiable objectives and actions.

03 Candidate Project Opportunities: A collection of stakeholder and partner generated project ideas and needs that can contribute in some way to habitat restoration, more resilient community infrastructure or improved public access and recreation.

04 Management Strategy: A management strategy developed by PRH to support continued implementation and maintain relevance to the region and stakeholders.

Top © unsplash/Alex Iby, bottom: Bear Mountain © NYSDEC/Steve Stanne

INTENDED USE AND OUTCOMES

While the opportunities to use and apply the information developed for this effort are wide-ranging, the primary aim of the Hudson River CRP is to catalyze greater collective action to address the complex and multi-faceted challenges and opportunities present in the Hudson River estuary. Five principal uses for the Hudson River CRP include:

01 Catalyze innovative collaboration in support of project planning and implementation.
02 Integrate natural resource management opportunities into regional planning and implementation.
03 Leverage increasingly diverse sources of capacity, expertise and funding.
04 Provide a platform for adaptive management.
05 Enable comprehensive reporting on progress.

PRH recognizes that not all recommendations outlined below will be fully adopted or aligned with each participating entity. The intent is to highlight where overlap and alignment exist and catalyze this capacity to more effectively yield a higher rate of successful implementation. While there may be perceived conflicts among recommendations and participants, execution of the Hudson River CRP is intended to provide a platform to work through these challenges to arrive at workable solutions, where and when possible. Although a willingness to change organizational strategic plans and visions is not a requisite requirement, the expectation is that participating entities will identify activities or locations aligned with their respective vision and volunteer to provide a leadership role or, at least, provide insight or consultation if requested. As organizations develop strategic and operational plans, the Hudson River CRP can serve as guidance in those processes, but may also be wholly or in-part adopted by any entity.

The Hudson River CRP, when coupled with the past successes of the individual partners, will be a powerful tool in the ongoing effort to achieve the stated purpose, attract more investment and establish new relationships. It also provides a framework to consider, for example, how existing stakeholders within a geographic focus can develop collaborative relationships or how new participants can augment or replicate existing efforts. Implementation of a strategic approach based on sound science, shared goals, strong and effective partnerships and more diverse resource streams is critical to achieving the recommendations of the Hudson River CRP.

The potential for misuse and misinterpretation of the Hudson River CRP does exist and is a challenge. The following disclaimers are intended to limit this potential:

01 The following map products are estimates of location, quantity and boundary; further field verification is warranted and likely to yield different results as the scale of interest is reduced.
02 Candidate project opportunities or actions identified within the TECs have not undergone feasibility analysis or completed a conceptual design. Their inclusion in the Hudson River CRP in no way conveys universal support by PRH nor any individual entity nor does it fulfill any regulatory obligation. These opportunities are provided to promote further exploration and development of proposed concepts and opportunities.
03 Identification of specific actions or candidate project opportunities does not convey any special regulatory privileges and no ranking or prioritization hierarchy has been conducted. This activity is best left to individual entities for their own programmatic purposes.

04 Participating partners retain the right to execute, support, endorse or challenge any individual element or elements of the Hudson River CRP according to their own interests without rejecting or refuting it entirely.

05 All recommended actions and candidate project opportunities are subject to all local, state and federal guidance, rules and regulations.

06 Actions or project opportunities identified on private land are not expected to receive further evaluation without current landowner dialogue, agreement and consent and appropriate local home rule decision-making.

IDENTIFIED CONFLICTS, DISPUTE RESOLUTION AND CONSISTENCY CLAIMS

Several challenges are identified not only within components of this plan but also among other intra- and inter-regional plans. This is not surprising, nor should it be discouraging. The challenge with those issues is that their resolution will require difficult conversations with a broad spectrum of stakeholders and there is not likely one "right" answer; there could be many or none. A significant element of implementing activities identified in the Hudson River CRP will be stakeholder buy-in, engagement and dialogue. These dialogue and relationship-building processes can uncover win-win scenarios, but they may also identify winners and losers, as not all circumstances are conducive to win-win or compromised outcomes. The Hudson River CRP and the individual organizations and agencies involved with its implementation have an obligation to engage in honest dialogue with stakeholders to find common ground where and when possible, and the management and implementation structure should support this process. However, not all issues may be resolvable within this framework and each individual entity reserves the right to act independently and of its own accord should dialogue not identify viable solutions.

It is important to note that delaying assessment of identified challenges and/or decision-making on some of the most challenging conflicts until some watershed moment or boiling point occurs is not likely to reveal the best outcome. Rather, delaying issue evaluation will more likely further entrench the "us versus them" battles and stymie any opportunity to develop and implement innovative solutions. A more proactive approach to identified challenges and conflicts is recommended.

Another important consideration will be to validate claims of consistency with the Hudson River CRP. As existing or new projects are nominated and developed, their design may contain features or elements that are inconsistent with the goals of the Hudson River CRP. To ensure alignment, eligibility criteria can be established (e.g., Hudson River Sustainable Shorelines) to validate the claims of contribution or consistency.

RELATIONSHIPS TO EXISTING REGIONAL PLANS

Encompassing many, but not all, issues receiving attention throughout the region, the Hudson River Comprehensive Restoration Plan is intended to augment existing plans by characterizing current conditions, establishing quantifiable targets and identifying specific places where action can be considered. How integration and/or augmentation occurs will likely be different for each planning product. Recognizing there are many regional planning products, we highlight five highly related documents as examples of how integration and relationships are likely to develop.

Hudson River Estuary Program Action Agenda

The Hudson River Estuary Program Action Agenda, a principal guidance document in the region since 2001, continues to serve as a central regional planning document relative to natural resource, water and recreation management. The NYS Hudson River Estuary Program's geography ranges from the Federal Lock and Dam at Troy, NY, south to the Verrazano Narrows, which separate Staten Island from Long Island. The Hudson River Comprehensive Restoration Plan is intended to augment and inform

the development and execution of the Action Agenda for the northern range of the programmatic area by providing additional assessments of baseline conditions, establishing quantifiable ecosystem targets and building a catalogue of potential project opportunities.

The Action Agenda has historically been produced in five-year increments, on average. Updates and revisions to the Hudson River Comprehensive Restoration Plan are expected to occur "as needed," but at greater than five-year intervals. The Action Agenda will continue to characterize the desired five-year outcomes of the NYS Hudson River Estuary Program but has the potential to serve as the single, five-year implementation strategy that captures goals from the Hudson River Comprehensive Restoration Plan going forward, assuming the target statements are adopted by the Estuary Program.

The Hudson River Comprehensive Restoration Plan is also intended to strengthen and innovate four principal aspects of estuary management.

01 Inspire and Guide Action

- Catalogue place-based opportunities and activities, developed through a participatory process, that will enhance the condition of the Hudson River system.
- Provide as a shared reference and driver of restoration actions for implementing organizations, and that guide decision-making.

02 Enhance Collaboration

- Provide a shared vision and vehicle to support and enhance existing efforts and develop new collaborative relationships around place-based opportunities to achieve restoration goals across agencies and organizations in the region.
- Complement and support the Action Agenda and other plans in the region.

03 Expand Support

- Frame goals on both intermediate (2030) and long-term (2050) time-scales to garner public and private sector support.

04 Secure and Leverage Resources

- Use existing capacity and resources, across organizations, to leverage transformative support for plan implementation

Hudson River Estuary Habitat Restoration Plan

In 2013, the New York State Hudson River Estuary Program released the Hudson River Estuary Habitat Restoration Plan. This report identifies the critical habitat attributes of the estuary, their functional role, a rationale for restoration and served as a foundational element for the development of the habitat-related Target Ecosystem Characteristics (TECs). The Hudson River Comprehensive Restoration Plan augments this report byhighlighting specific opportunities for implementation activity, pending rigorous feasibility assessments and stakeholderengagement. The combination of New York State guidance on which habitats should be protected or restored, combined with the elements of the Hudson River Comprehensive Restoration Plan, create a powerful, transparent tool to catalyze strong cross-organizational partnerships to propose, plan, fund and execute implementation activity.

Hudson-Raritan Estuary Comprehensive Restoration Plan

The NY&NJ Port Authority, the US Army Corps of Engineers, and the NY–NJ Harbor & Estuary Program (NY–NJ HEP) are working to implement a Hudson–Raritan Estuary Comprehensive Restoration Plan (Hudson Raritan Estuary CRP) for the area south of the Gov. Mario M. Cuomo Bridge (formerly the Tappan Zee Bridge). The Hudson River Comprehensive Restoration Plan begins where the Hudson Raritan Estuary CRP leaves off, 25 miles north of the Statue of Liberty. The nature of habitats in the Hudson Raritan Estuary is different than those encountered in the Hudson Valley, with a greater tidal range, more saline waters, and a watershed dominated by urban land uses. While each plan has different target attributes and designated actions, there are several areas of common interest and activity which serve as points of interaction between the plans and their implementation. Common elements of both regional plans, in terms relative to the Hudson-Raritan Estuary CRP, include shorelines and shallows, tributary connections, sediment contamination, and public access. Although the characterization of these elements differs between the two plans, they are related and connected by flowing water, sediment, migratory fish, and invasive species.

New York–New Jersey Harbor & Estuary Program Action Agenda

The draft 2017–2022 NY–NJ HEP Action Agenda contains 17 objectives and 39 actions, many of which will help advance progress on the Hudson River Comprehensive Restoration Plan. HEP's Restoration Work Group serves to help implement and track progress on the TECs in the Hudson Raritan Estuary CRP. Although the NY–NJ HEP Program area was recently expanded to include the upper Hudson River estuary, a strategy for engagement has not been developed. However, the Hudson River CRP provides a platform to evaluate mutual interests and partnership development around restoration of shorelines and shallows, tributary connections, sediment movement and fish habitat. Coordination has been accomplished through reciprocal advisory board participation between the Hudson River Estuary Program and NY–NJ HEP.

Hudson River Habitat Restoration Feasibility Study

In 2013, the NYSDEC Commissioner requested that the Corps of Engineers' Hudson River Habitat Restoration Feasibility Study be resumed following its suspension in 2004. Following extensive coordination with the PRH and the New York District USACE, the Feasibility Study was successfully resumed in 2016 with non-federal sponsors, NYSDEC and NYSDOS. The purpose of the Feasibility Study is to identify the water resource problems and propose associated solutions within the 125 miles of the Upper Hudson River between the Gov. Mario M. Cuomo Bridge and the Federal Lock and Dam at Troy, NY.

The Hudson River Comprehensive Restoration Plan provides valuable information on existing current conditions, impacted areas, regional goals and targets and potential restoration opportunities. As part of the feasibility study, these restoration opportunities were screened and a subset of sites were evaluated in greater detail. These sites advance the overall goals of the Hudson River Comprehensive Restoration Plan including restoring side channels, wetlands, shorelines and tributary connections. Specific restoration projects will be recommended in the Draft Hudson River Habitat Restoration Feasibility Report and Environmental Assessment (FR/EA) for near-term construction and future feasibility study.

OPPORTUNITY FOR ADDITIONAL COLLABORATION AND PLANNING

Many of the Hudson River CRP's recommendations contribute to the social or economic needs of the region including efficient and effective waste and stormwater management, tourist and recreational opportunities, safe and resilient transportation networks, and resilient waterfront revitalization. Deepening relationships with other active sectors in the Hudson Valley, particularly the Regional Councils and Regional Economic Development Councils through thoughtful integration of the goals and objectives, coupled with the strategic sharing of information, expertise and capacity is one example of how to catalyze implementation and requires more intentional and thoughtful consideration.

Other opportunities exist to resolve estuary issues which may have their source outside of the region. For example, the Mohawk River Watershed Coalition recently completed a conservation plan which will have implications for the estuary as the Hudson's largest tributary, entering just above the Federal Lock and Dam at Troy, NY. The Mohawk River is a significant source of sediment to the estuary as well as a key destination for recreational boaters originating in the Hudson but could also serve as an invasion pathway for invasive species. Collaboration with this coalition to establish restoration priorities consistent with the needs of both geographies can be a significant step toward achieving the established targets for the estuary. Other collaboration opportunities exist, such as the Atlantic Coast Fish Habitat Partnership and the North Atlantic Landscape Conservation Cooperative, which have the potential to inform or support implementation activities.

The focus on the estuary and its valley floor was intentional and necessary for a variety of reasons including scope and scale of challenges, programmatic constraints and geographical differences in biological, social and economic aspects.

The vision is to have the full Hudson River Watershed covered by several specific, yet dovetailing plans that contribute to and inform the management of the entire watershed.

New York Harbor and the Hudson River estuary are now complete, and the Mohawk River is starting to develop planning tools. Similar efforts, rooted in science and greater community engagement, to develop dovetailing plans for tributaries of the estuary and the non-tidal Hudson River should be a focus of future efforts. This additional evaluation and planning recommendation represents an aspirational goal and does not commit any entity or entities to undertaking this effort.

West Point © Scenic Hudson/Jeff Anzevino

Assessment of Current Conditions

A fundamental element of any restoration plan is knowledge of the types of habitats known to exist and their distribution, and some effort to assess their current condition. In most cases, such efforts are constrained by the availability of digital data sources. Although limitations do exist, the geospatial datasets available for the estuary are an incredible asset to characterize present-day conditions.

The assessment of current conditions was completed through a two-phase modeling process that mimics current conditions:

01 Consolidate and update existing physical habitat information to more accurately simulate thetypes of habitat available and their distribution throughout the estuary.

02 Assess the extent impacts or alterations to the habitats are likely to occur, support remote project site characterization and inform initial stages of project development and design.

In the spring of 2013, following Superstorm Sandy, new information became available in the form of high resolution aerial imagery (Light Detection and Ranging data [LIDAR]) with support from the National Oceanic and Atmospheric Administration and the New York State Department of Environmental Conservation (NYSDEC). This new resource, along with existing bathymetric surveys led by NYSDEC, provided an opportunity to create a single, continuous habitat model for the entire estuary.

The purpose of this assessment was to identify where physical habitat had been altered to help inform the application of management actions. Identification of where existing impacts are located is expected to inform project development processes by identifying existing constraints, challenges and opportunities. As new restoration and development projects are routinely being proposed, the results of this analysis can provide initial insight to help in determining appropriate locations for future development projects. Similar to other aspects of the Hudson River CRP, the intent is to revisit and update this assessment as new information becomes available.

STUDY AREA

The area of interest was limited to the main channel, floodplains and riparian areas of the Hudson River between the Gov. Mario M. Cuomo Bridge and the Federal Lock and Dam at Troy, NY. More specifically, it is the area from the bottom of the channel through to the projected boundary of the 500-year floodplain under a sea level rise scenario of 72 inches. Mouths of tributaries falling in this zone were also included but only to the extent of 200 meters upstream of the previously referenced boundary or 200 meters upstream of the first barrier or, whichever occurred first. This model-generated line was only used to demarcate the boundary of the study area; all analyses were conducted using present-day mean sea level conditions.

PHYSICAL HABITAT MODEL

Columbia University's Center for International Earth Science and Information Network (CIESIN), with funding from The Nature Conservancy, began assimilating spatial datasets in 2015 including the LIDAR dataset to develop a seamless physical habitat model or simulation of the estuary from the Federal Lock and Dam at Troy, NY to the Gov. Mario M. Cuomo

Bridge near Tarrytown and Nyack, NY. A fundamental aspect of developing this habitat model was the creation of a composite bathymetry (i.e., depth) surface for the entire estuary. This effort incorporated a total of five data sources including products of the Hudson River Estuary Program's Benthic Mapping Project (1998–2003; 2007 update) and three different LIDAR products. This produced a digital elevation model (e.g., topographic map) for the entire estuary ranging from one meter above the mean high high water (MHHW) mark to 20 meters below mean sea level. In addition to this bathymetric model, additional data sources including sediment type, slope, and sediment environment were applied to further characterize habitat types.

Summary of Results

Analysis of aquatic habitats (1m above sea level or less) revealed a significant amount of diversity, with relatively few dominating habitat types:

01 136 unique habitat types range in individual total coverage from 0.25 acres to 8,885 acres and most are organized into narrow, linear features that run parallel to the shoreline.

02 59 habitat types have total coverage areas equal to or greater than 247 acres.

03 37 habitat types have a total coverage area between 24 and 247 acres.

04 40 habitat types have a total coverage area of less than 24 acres.

05 Of the 10 largest habitat types:

- Five are characterized as flat, muddy or sandy areas with depths between 2 to 10 meters and dominate the estuary; when combined, these five habitat types comprise 20,937 acres or 31.7% of the estuary.
- Three are flat, muddy or sandy areas 10-20m below sea level, which together comprise12,992 acres or 19.7% of the estuary.
- Two are flat, muddy or sandy areas 0-2m below mean sea level (shallow subtidal zone)which together cover 7,981 acres or 12.1% of the estuary.

The aquatic habitat model was later expanded to capture the full width of the floodplain and riparian areas one meter above MHHW inland to the projected boundary of the 500-year floodplain under a sea level rise scenario of 72 inches. These and other results are available at thehudsonweshare.org.

ECOLOGICAL ASSESSMENT

Depending on their condition, a wide assortment of habitat types is generally expected to support a significant diversity of insects, fish, plants, birds and mammals. The CIESIN team, in consultation with a team of ecological experts, assessed the quality of the identified physical habitat types using existing data sources only. The aim of characterizing the physical habitat units was to identify habitat types or larger areas exposed to factors that could alter the anticipated habitat type or condition. First, they identified geospatial datasets that were available for the entire study and were likely to influence physical habitat quality. They then mapped occurrences of all the known impacts and/or activities in the study area to determine which habitat types are likely to have been influenced by the most impacts or activities and document where the alteration is likely to have occurred.

Only 23 impact types were identified with complete coverage throughout the study area (Table 1). Metadata were developed for each of these identified layers and collected into a single database viewable at thehudsonweshare.org. The 23 datasets (Table 1) were used within a GIS framework to identify which habitats are most influenced by individual variables and to identify areas where concentrations of impacts are likely to co-occur. A 90 m "zone of influence" buffer was applied to each occurrence, regardless of impact type, indicating the area reasonably expected to be influenced by the impact. This buffer yields a fixed impact area of nearly 6.3 acres for each impact occurrence, an overestimation for some impacts and an underestimation for others.

Table 1 Data Sets Used in the Ecological Assessment

Bulk Storage Facilities	Marinas	Hudson River Submerged Aquatic Vegetation (2007): *Trapa natans*
Boat Launches	Mined Land Permit	Hudson River Estuary Shoreline Type: Soft Engineered
Boat Docks and Piers, not associated with Ports, Marinas, or Boat Launches	Natural Gas Interstate and Intrastate Pipelines	State Pollutant Discharge Elimination System
Inventory of Dams	Oil, Gas and Other Regulated Wells	Agency for Toxic Substances and Disease Registry (ATSDR) Hazardous Waste Site Polygon Data with CIESIN Modifications, Ver. 2
Coastal Maintained Channels in U.S. Waters	Phosphorus Load Model	Stream Crossings and Culverts
Electric Transmission Lines	Hudson River Estuary Tidal Wetlands 2007: *Phragmites australis*	Stormwater Outfalls
Hudson River Areas of Fill: Historically Open Water	Port Facilities and Anchorages	New York State Water Withdrawals
Hudson River Estuary Shoreline Type: Hard Engineered	Environmental Remediation Sites	

Summary of Results

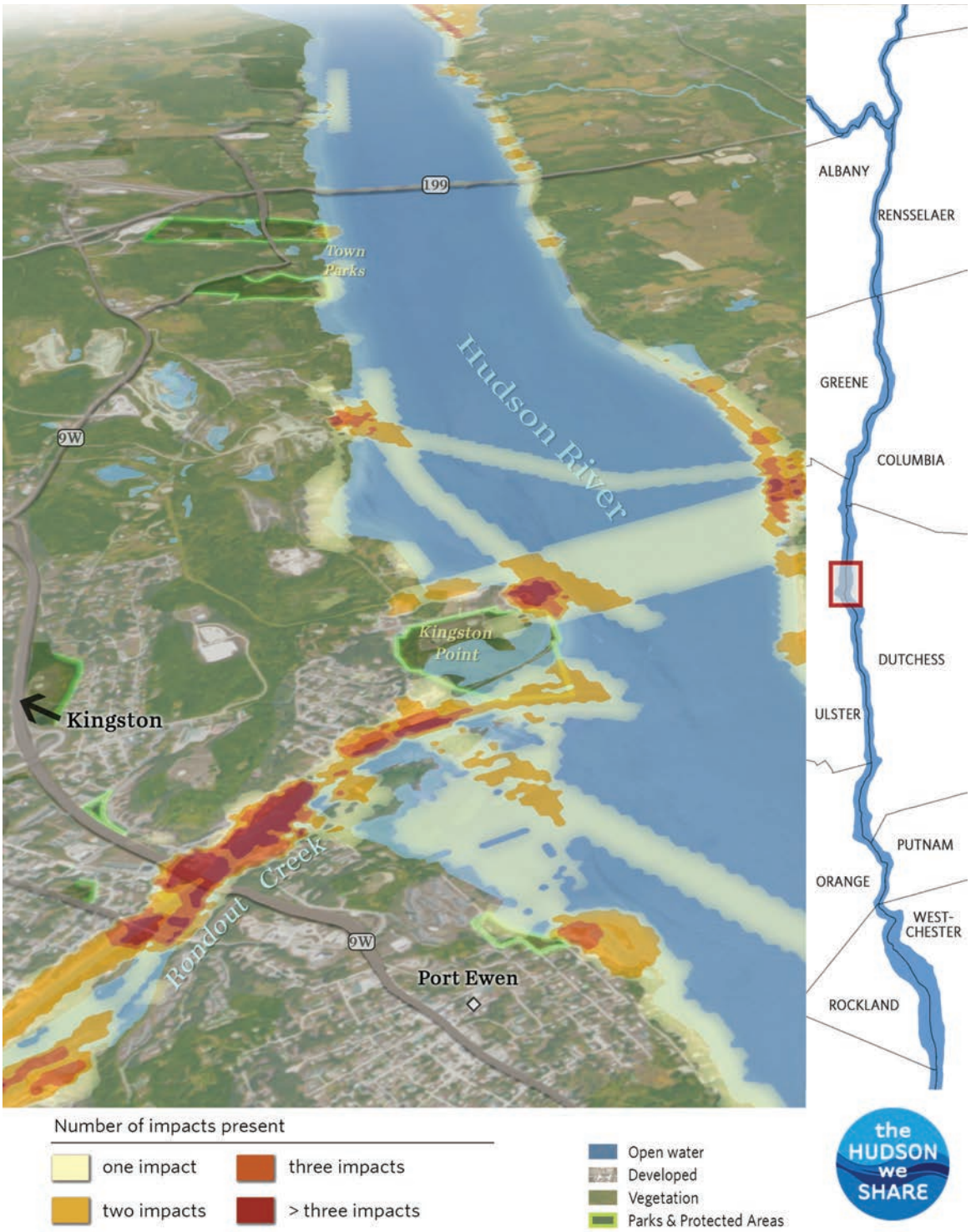
The size of the study area covered a total of 94,382 acres. The total area influenced by individual variables across the physical habitats varies widely, but cumulative impacts (e.g., areas where multiple impacts occur in proximity to each other or at the same location) influence about one-third of the study area. Most of the impacts to estuary habitat appear to occur near the shoreline and near confluences with significant tributaries, particularly in more developed areas. These areas are where the social and economic interface with water is most pronounced. That observation does not discount the significance of impacts generated by historical fill activities and on-going maintenance dredging associated with the shipping channel in the northern reaches of the estuary (Table 2). The areas with the highest cumulative impacts are closely associated with urban waterfronts; two communities had hot spots exhibiting seven co-occurring impacts, the maximum observed, while a total of nine additional communities had hot spots exhibiting six co-occurring impacts.

Table 2 Most Common Impacts, and the Respective Extent of Impact, identified in the Hudson River CRP Assessment of Current Conditions

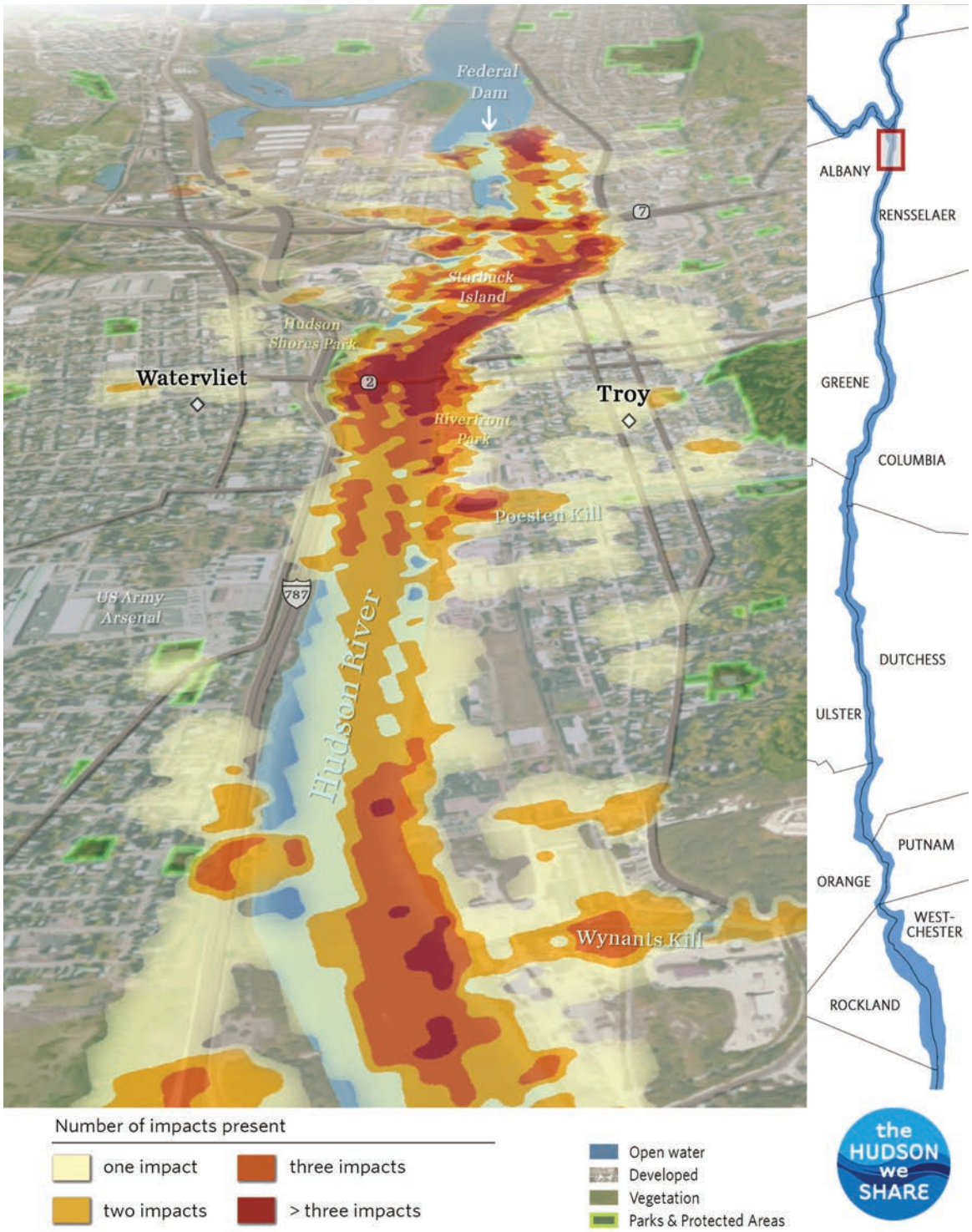
Impact Type	Estimated Total Acres Impacted	Estimated % of Study Area Impacted
Hard Engineered Shoreline	10,109	10.7%
Coastal Maintained Channel + Hudson River Areas of Fill	9,283	9.4%
Invasive Water Chestnut *(Trapa natans)*	1,971	2.1%

To be clear, areas identified as having an impact(s) are not intended to convey or imply dirty, "unhealthy" or unsafe conditions, rather they simply indicate where physical habitat conditions are likely to have changed from what would naturally occur in the area. It is worth reiterating that the impacted physical habitat areas identified are only associated with the impacts of the 23 variables listed above; there are additional known impacts but they are not consistently mapped throughout the watershed and are not included in the analysis. In total, this analysis indicates that 33.6% of the 94,382 acres of physical habitat in the study area are impacted by significant human activity. The distribution of total impact indicates that the northern third of the estuary may be disproportionately impacted:

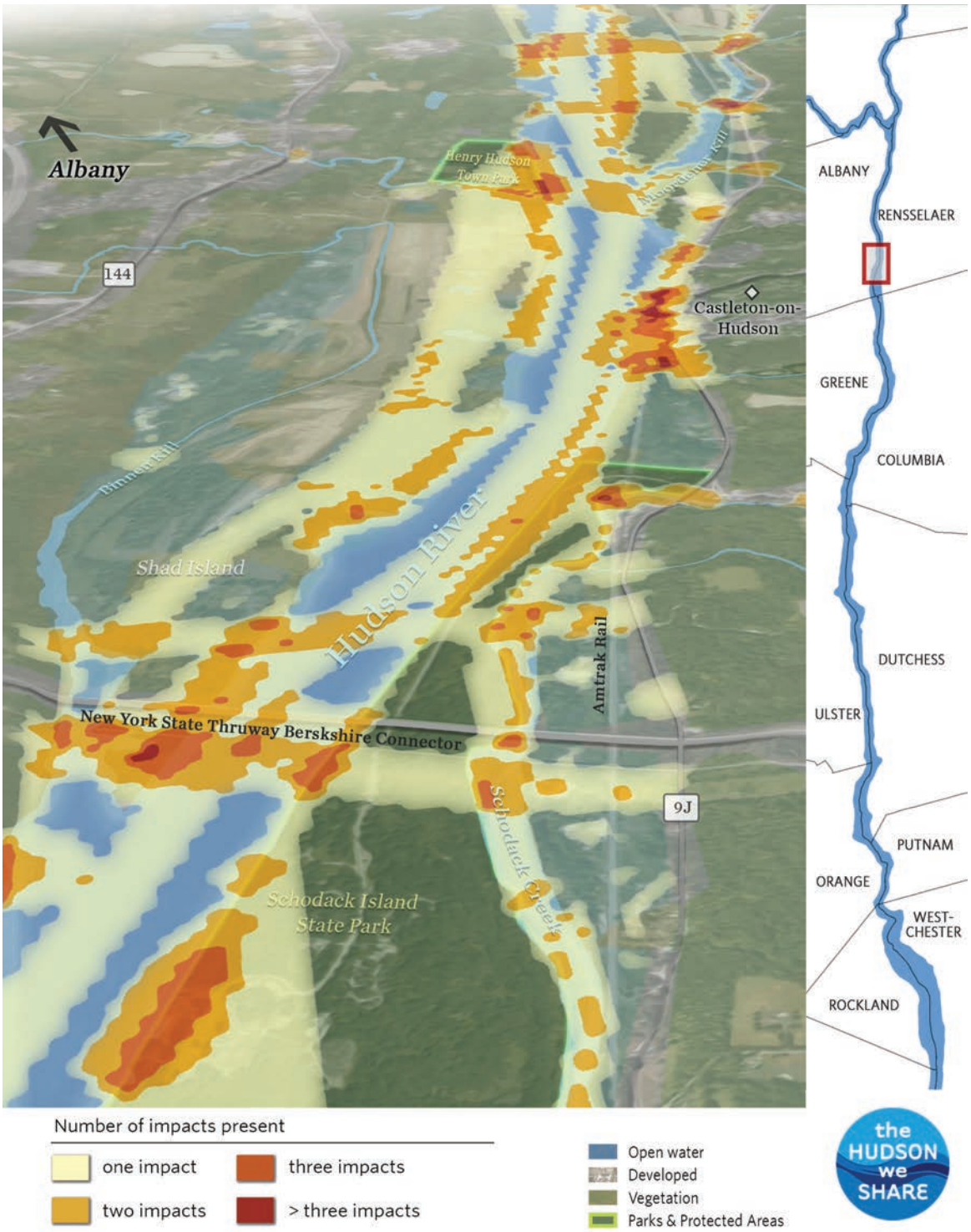
Upper reach (Albany, Rensselaer, Greene and Columbia Counties):
14,159 acres impacted habitat (50% of 28,249 total acres)
Mid-reach (Ulster, Dutchess and northern Orange Counties):
9,178 acres of impact (31% of 28,795 acres)
Lower reach (northern Orange and Putnam Counties south to the Governor Mario M. CuomoBridge):
8,357 acres of impacted habitat (22% of 37,332 acres)



Map 1 *Cumulative physical habitat impact characterization from the Kingston-Rhinecliff Bridge south to the Kingston waterfront. The shaded areas capture the impact point itself along with a 90 m (295 foot) "zone of influence." Areas identified as having an impact(s) are not intended to convey or imply dirty, "unhealthy," or unsafe conditions, rather they simply indicate where physical habitat conditions are likely to have changed from what would naturally occur in the area.*



Map 2 *Cumulative physical habitat impact characterization of the waterfront south of the Federal Lock and Dam at Troy, NY. The shaded areas capture the impact point itself along with a 90 m "zone of influence." Areas identified as having an impact(s) are not intended to convey or imply dirty, "unhealthy," or unsafe conditions, rather they simply indicate where physical habitat conditions are likely to have changed from what would naturally occur in the area.*



Map 3 *Cumulative physical habitat impact characterization of the Hudson River from the Henry Hudson Town Park south to Schodack Island State Park. The shaded areas capture the impact point itself along with a 90 m "zone of influence." Areas identified as having an impact(s) are not intended to convey or imply dirty, "unhealthy," or unsafe conditions, rather they simply indicate where physical habitat conditions are likely to have changed from what would naturally occur in the area.*

Map 4 *Cumulative physical habitat impact characterization from Croton Point south to the new Gov. Mario M. Cuomo Bridge. Areas identified as having an impact(s) are not intended to convey or imply dirty, "unhealthy," or unsafe conditions, rather they simply indicate where physical habitat conditions are likely to have changed from what would naturally occur in the area.*

Target Ecosystem Characteristics (TECs)

INTRODUCTION

In any restoration plan, there is a need to clearly describe what elements are being considered, why they merit such attention and how they inform recommendations. In the case of the Hudson River CRP, the parts of the system being explicitly considered for protection, restoration or re-imagining are called ecosystem characteristics, and restoration objectives are called targets. Together, these form Target Ecosystem Characteristics (TECs). An ecosystem characteristic is an attribute of the estuary which is considered to have significant ecological or societal value. To develop a TEC, it is necessary to first describe what the attribute is, what ecological or social function it serves in the system, and establish a justification for management activity. Once an ecosystem characteristic is described, the current condition is quantified along with a description of what forces or factors might be placing this attribute at risk either now or in the future. With knowledge of what might cause further deterioration of the ecosystem characteristic, it should be possible to lay out actions that may mitigate potential loss, enhance the current condition, or expand the amount present in the system. This sequence from identification to action/research must be evidence-based and well-documented so that any questions that arise may be addressed and adaptive management strategies may be carried out. An essential component of the analysis is development of a target, or desired condition, for each ecosystem characteristic to guide restoration actions over both the short term and the long term.

TEC SELECTION

To determine which estuary attributes were most important, we consulted more than 30 different planning documents including place-based, taxon-based, economic development and sustainability plans. This process identified 12 significant and consistently referenced system attributes. The 12 attributes were categorized by three attribute types and include:

Habitats and Biological Communities:

Characteristics directly affiliated with natural resource attributes

01 Shallow Water and Intertidal Habitats
02 Hudson River Shorelines and Riparian Areas
03 Tributary Connectivity and Barriers
04 Resilient Plant and Animal Communities
05 Fisheries

Drivers of Condition:

Critical elements that strongly influence natural resource attributes

06 Sediment
07 Contaminants
08 Storm and Wastewater

People and Shoreline Communities:

Elements that support and inform human interactions with the estuary

09 Public Access
10 Navigation Safety and Natural Resource Interactions
11 Estuary Education
12 Resilient Waterfronts and Community Shorelines

Twelve expert teams were established, consisting of a non-governmental team lead and three to eight volunteer team members, and tasked with completing a narrative for each TEC. Abstract-style summaries of each report follow, while a more complete TEC development process description along with the full TEC narratives are available at thehudsonweshare.org. The following target statements are ambitious but considered to be attainable for the 2030 and 2050 timeframes.

STUDY BOUNDARY FOR TARGET ECOSYSTEM CHARACTERISTICS

The same study area used to assess the current condition of the estuary was initially established to characterize and quantify each TEC. Due to the inherent, natural relationships to factors outside of this boundary for three TECs, their study areas were expanded to better reflect the scope and scale of the attributes as follows:

01 The tributary expert team incorporated all barriers along the entire length of tributaries entering the estuary between the Federal Lock and Dam at Troy, New York and the Gov. Mario M. Cuomo Bridge.
02 The expert sediment team evaluated all sediment management challenges and opportunities for this same footprint.
03 The expert storm and wastewater team expanded their study of water resources south to the Yonkers wastewater treatment plant, which collects and treats household sewage as far north as Tarrytown, NY, south of the Gov. Mario M. Cuomo Bridge.

HABITAT AND BIOLOGICAL COMMUNITY TECs

01 Shallow Water and Intertidal Habitats

Target Statement

By 2050, vital shallow water and intertidal habitats measure at least 12,000 acres, including 7,500 acres of tidal wetlands and 4,500 acres of native submerged aquatic vegetation. These habitats provide essential life-support for the native fish, birds and other wildlife of the estuary. By 2030, 10 conservation or restoration projects for such habitats are underway or complete.

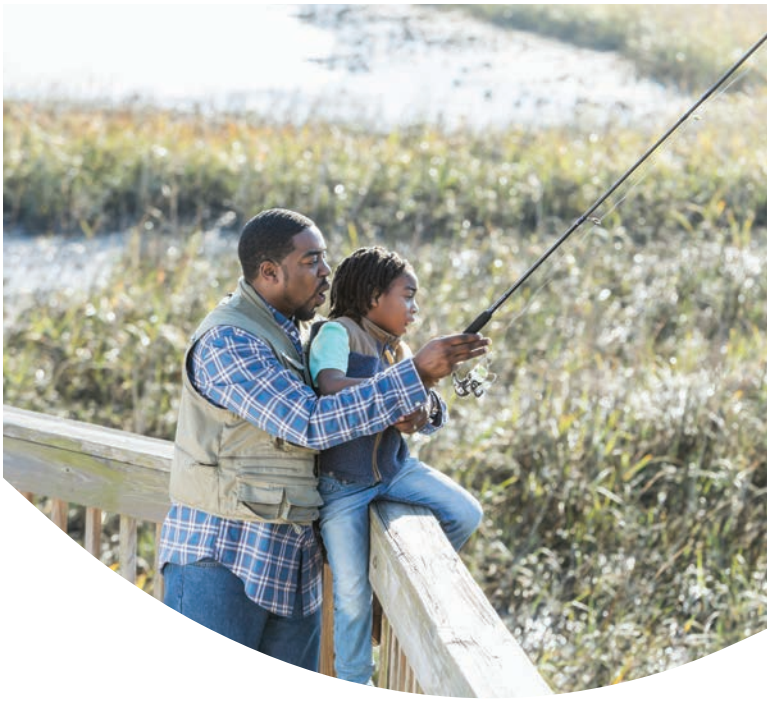
Summary

Shallow water habitats of the estuary are generally characterized as the area of the river that is always inundated between the low tide line and six feet deep (at low tide). For the purposes of this plan, we expand this characterization to also include the tidally influenced transition zone (intertidal zone) between Mean Low Low Water (MLLW) and Mean High High Water (MHHW). These areas include specific habitat types such as submerged aquatic vegetation (SAV), intertidal wetlands, and mud flats. Generally, these habitats are most common in the brackish to freshwater reaches north of Haverstraw, NY, due to the natural variations in the shape of the river, landscape and lower development activity in the lower estuary. These habitats, particularly the vegetated portions, provide critical nursery areas for small fishes, contribute significant dissolved oxygen to the entire estuarine system, and store sediments being delivered by both the main stem and tributaries.

In total, this habitat type covers approximately 12,000 acres which includes an estimated 6,750 acres of intertidal wetlands, 3,250 acres capable of hosting annually-variable submerged aquatic vegetation and 2,000 acres of the floating invasive water chestnut (*Trapa natans*). In general, these habitat types are well understood. Some of these habitat sites have been especially well studied such as Tivoli Bays and some areas associated with the native submerged aquatic water celery (*Vallisneria americana*). The results of habitat studies highlight critical linkages to resident and migratory fish, a wide variety of birds and a significant role in maintaining/improving water quality. These habitats are also considered naturally protective features capable of providing risk reduction to adjacent uplands, be it natural habitat or infrastructure, from storm surge and flooding impacts. Research has also identified significant challenges to their persistence from changes to water quality, existing and potential invasive species, sea level rise, and incompatible recreational use.

A principal management objective to ensure the continued presence and function of shallow water and intertidal habitats in the estuary is to ensure these features can migrate and occupy new locations as the sea level rises. The migration pathways will require protection, and, in many cases, additional action may be necessary to accommodate this shift to new areas. (See also Hudson River Shoreline and Riparian Areas for further target details.)

Another active management strategy to be evaluated for feasibility is artificial application of supplemental sediments or active augmentation. The first step, is to assess the viability of all major shallow water complexes for vertical accretion and migration to determine which are likely to likely to persist, shift or disappear with rising sea levels. Second, for those areas not expected



to persist, methodologies to achieve accretion through active management should be explored, developed, tested and, if appropriate, accepted. Accretion assessments should continue in parallel with the development of effective and feasible active management methodologies. These alternative strategies should commence by 2020 with a completion goal of 2030 and, if proven and accepted as a viable management action, active augmentation could be considered to become an on-going management technique through 2070 where appropriate and feasible.

Because of past wetland-filling activities, many shallow water and natural side-channel areas were lost. Successful restoration of these filled habitats would restore not only their function, but could be expected to support and encourage wetland migration. In short, side-channel restoration not only increases the mosaic of available in-river habitat coverage and availability, and if designed appropriately, may facilitate and potentially accelerate the process of wetland migration. One such restoration effort was completed in the estuary in 2017, and additional efforts in other appropriate areas are recommended.

Invasive species, both current and potential, remain a constant challenge to maintaining shallow water habitat form and function. Characterizing and mitigating the impacts of *Phragmities australis* on Hudson River tidal wetlands has been a primary focus of recent work resulting in the publication of a guide to better manage this invasive species. Potential future invaders also need to be addressed by identifying which species are most problematic and their most likely invasion routes, and then beginning to develop suitable prevention and management plans.

02 Hudson River Shorelines and Riparian Areas

Target Statement

By 2050, 700 acres of riparian areas are protected to accommodate future wetland expansion caused by sea level rise, and 20 miles of hardened Hudson River shorelines north of the Gov. Mario M. Cuomo Bridge are softened or otherwise restored to improve habitat values. The shorelines and riparian areas provide vital habitats as well as important resources along migration routes for birds and other wildlife. They improve climate resiliency and provide scenic and recreational opportunities for the public. By 2030, one major hard shoreline habitat restoration project has been completed, additional habitat protection opportunities have been prioritized, and 400 acres of riparian area suitable for wetland migration have been protected.

Summary

Riparian areas are located immediately inland and contiguous to shallow water and intertidal habitats, including tidal wetlands. Floodplains are a specific type of riparian area which are subject to inundation under flood conditions and, for regulatory purposes, are typically delineated by return frequencies (e.g., 100-year or 500-year floodplains). For the purposes of this report, riparian areas, including floodplains, of the Hudson River estuary are the same as the study area detailed under the Assessment of Current Conditions.

© Tulus Simatupang

These critical areas host near-river processes that directly influence riverine habitat conditions, and represent transition zones and connections between aquatic and upland habitats. Shorelines are the most immediate and intense points of interaction between the water in the river and adjacent terrestrial habitats and features.

The character and inland extent of riparian areas are highly variable throughout the estuary for a variety of reasons including topography and land use. These diverse places provide habitat for a wide variety of plants, animals and birds; contribute to significant natural processes such as nutrient cycling, flood water storage, carbon sequestration and sediment trapping; and host recreational access to the river. The lowest lying riparian areas, including floodplains, are expected to be transformed by the rising sea levels over time, and have the potential to host significant inland intertidal wetland migration as referenced in Shallow Water and Intertidal Habitats. It has been estimated that about 40% (+/- 100 miles) of 100-year floodplain is undeveloped (~9,000 acres) in the Hudson River estuary. Floodplain areas (including the undeveloped areas) are more common in the northern most reaches of the estuary due to natural variations in the shape of the river and surrounding landscape. Approximately 44% of the estuary's shoreline is engineered (e.g., vertical sheet piling, rip-rap revetments along railroad tracks and causeways), while the remainder is a combination of soft (e.g., sand or sediment) and hard (e.g., rock or boulder) natural substrate that may or may not coexist. Activities in riparian areas such as resource extraction (e.g., rock and gravel mining), development (e.g., roads and buildings), construction of water and sediment control structures (e.g., dikes and ditches), and implementation of shoreline hardening tactics all reduce the ability to store floodwaters. This reduction in storage capacity likely exacerbates impacts to transportation, community infrastructure and private property during periods of flooding.

Over time, rising sea levels are expected to dramatically change the current location and nature of floodplains. Some areas of the existing floodplains are expected to become occupied by migrating intertidal wetlands, some will become permanently inundated by shallow water, and still other areas could become open water habitat due to the nature of the valley walls. To support intertidal wetland migration to new areas, we recommend the protection, and, if necessary, habitat restoration, of 400 acres of floodplain and necessary adjacent uplands by 2030 and an additional 300 acres by 2050.

To ensure that the ecological functions of Hudson River riparian areas are sustained for as long as possible, three primary objectives have been identified. First, at least 700 acres of riparian area providing tidal wetland migration pathways are protected through fee acquisition, easement or title transfer by 2050. Second, 20 miles of currently hardened Hudson River shoreline are identified and "softened" using sustainable, nature-based techniques. Third, Hudson River riparian areas are further evaluated for their migration potential, protected, and where needed, restored to promote their full range of ecological functions relative to their landscape context. Target setting and prioritization for these activities should be based on a complete inventory and evaluation of the estuary's riparian areas.

03 Tributary Connectivity and Barriers

Target Statement

By 2050, dams are removed and culverts are replaced at priority locations to allow free movement of fish and other animals in Hudson River tributaries. Removing dams and replacing barrier culverts supports healthy populations of recreational, commercial, and resident fish species, and helps restore clean water and native habitats. By 2030, 20 tributary dams will be removed, and 30 barrier culverts will be replaced to allow upstream movement of fish and other animals.

Summary

More than 90 tributaries deliver freshwater, sediment, nutrients and other organic material to the estuary in substantial quantities from the surrounding watershed. Historically, many of these same tributaries also provided habitat to a wide array of native, resident fish species but also spawning, nursery and adult habitat to several species of migratory fish species. Although there are several migratory fish species in the Hudson River, notably Atlantic and Short-nosed Sturgeon, Striped Bass and American Shad, access to tributaries is most critical to the life cycles of River Herring (Alewife and Blueback Herring) and American Eel. River Herring use tributaries for spawning areas while Eel reside in tributaries and out-migrate to the sea to spawn. Ensuring passage for these species from the estuary up to the first natural barrier is critical. There are more than 1600 dams, in various sizes and condition, and thousands of culverts scattered across all 90 Hudson River tributaries which significantly reduce available habitat for American Eel and other migratory species. Resident species, such as Brook Trout as well as other fish and wildlife, would also benefit from greater connectivity within tributary systems to improve habitat conditions, access to cold-water refugia, and genetic diversity.

However, with more intense precipitation events and the advancing age of dam infrastructure, the risk of dam failure and hazard potential for downstream residents and infrastructure are reasons to consider removal of obsolete dams. Undersized culverts also pose a danger for public safety. When flood waters are unable to pass through the road crossing, flow conditions can quickly undermine ("blow out") the roadway or lead to upstream flooding. Right-sized culverts allow flood waters and debris to flow under the crossing, increasing the resilience of the roadway and improving public safety.

Constraints to improving the connectivity of Hudson River tributaries are numerous, but two significant factors have been identified. Although resources are starting to organize around removals and retrofits, there isn't much precedent for dam removal activity in the region, and building the organizational expertise and capacity to execute these projects, at a meaningful scale, will take some time. A second factor is the possible presence of contaminants in the sediment deposited in the pools immediately upstream of the dams which contributes to uncertainty associated with the removal process, project costs and post-removal conditions. Leaving barriers in place should not be considered a long-term solution to controlling contamination, as these dams are often at increasing risk of failure with age, and have negative impacts on stream processes related to water quality, sediment transport, and habitat provisions.

Given the numerous dams and culverts, the challenge of restoring tributary connectivity is daunting, but certainly not insurmountable. To achieve desired outcomes, a clearly defined and engaged "community of practice" will need continued training and implementation resources. A removal strategy targeting significant barriers in tributaries with the best stream habitat could provide the best benefits for fish populations. Effectively addressing smaller opportunities as they arise is also not only prudent, but necessary. Additional considerations and expertise will need to be focused on the regulatory environment surrounding dam removal and retrofits as well as understanding and addressing the social challenges that such projects may experience in highly populated areas.

04 Resilient Plant and Animal Communities

Target Statement

By 2050, ecologically-significant natural plant and animal communities are more resilient to a variety of stressors, including climate change and invasion by non-native species. Such natural communities support ecosystem function and provide significant benefits to people. By 2030, existing occurrences and known pathways for harmful species invasions are mapped, prioritized, treated and monitored for success while critical habitats whose loss could perpetuate cascading effects are identified and prioritized for protection and restoration.

Summary

The biological communities of the Hudson River estuary—the assemblages of organisms that co-occur in space and time—include a diverse array of species ranging from microscopic to enormous, plant to animal, terrestrial to aquatic, freshwater to saltwater, obscure to iconic, and everywhere in between. Different communities can be distinguished in different major habitats of the river, such as in freshwater and brackish-water main channels, vegetated shallows, wetlands, tributary mouths, sandflats, mudflats and so forth. Although demarcation lines between habitats are useful, the movement of water, materials and organisms between these habitats blurs any sharp boundaries that we might draw between or among them. This collection of communities drive ecosystem function in the estuary, and are central to almost every way in which humans interact with the river—indeed, to a large extent they determine the value of the river to people. They influence nutrient cycles and energy flow, play a role in improving water quality, provide aesthetic, recreational and food benefits, and have intrinsic value that is closely tied to the scenic and cultural heritage of the Hudson Valley.

The biological communities of the estuary have varied appreciably over the past several decades, with large changes in the abundance and even the presence of some species. For instance, zebra mussels have fundamentally reshaped the estuary since they first appeared in 1991; Atlantic sturgeon populations have slowly begun to recover following substantial decreases, a fishing moratorium, and listing as a federally endangered species; and non-native genotypes of common reed have slowly been replacing native cattail and other high marsh species in the estuaries' wetlands. We know the most about the status and trends of species that are most directly important or interesting to people. For these high-profile species, data is often fragmented, with very little information before ~1980, and inadequate data on many groups remain a management challenge. For more obscure species, data is scarce or absent.

The overall picture is dynamic—with some species increasing and others decreasing, some by an order of magnitude or more—because of natural and anthropogenic forces. The most important stressors from an ecological perspective are probably those that limit or challenge the resilience and adaptability of natural communities, like habitat loss, fragmentation and degradation; toxic contaminants; shoreline hardening; high rates of biological invasions; and rapid climate change and sea level rise. Several additional stressors have significant effects on the ways that people interact with the biological communities of the estuary or with species. These include overharvest, pollution and the establishment of some non-native species.

There are several ways to ensure resilient plant and animal communities persist in the estuary. First, minimize the risk of future non-native species establishment through strengthening and enforcement of existing policy, infrastructure implementation and decision-making to align social and ecological interests. Second, invest in the development, feasibility and desirability of prudent controls (e.g., biological barriers), with limited side effects, to manage arriving or already present species. Third, protect and restore existing habitats, pathways to future habitats, and the anticipated locations of future habitats for common, rare and important species. Fourth, design and secure long-term funding to complete basic research around connectivity and modes of migration and monitor the status of species and status of habitats to inform adaptive management of these resources going forward. Fifth, enhance education of the public to improve their interactions with existing biological communities of interest and increase awareness of the values and services these communities provide; the general public is also an asset to the protection of existing resources as well as the detection of new invaders which can only improve with additional training.

05 Fisheries

Target Statement

By 2050, populations of signature Hudson River fisheries are robust and sustainable and contaminant levels are declining in all targeted species. These conditions will support both ecologic and economic vitality while restoring historic fishing traditions. By 2030, both populations and contaminants are effectively monitored and managed, and key habitats needed to support American Shad, River Herring, Striped Bass, Black Bass, American Eel, Blue Crab, and Sturgeon populations during critical life stages and seasons are identified and protected or beginning to be restored.

Summary

Through the actions outlined in the Hudson River CRP, the estuary Action Agenda, interstate plans and endangered species recovery plans, we aim to restore and sustain important fish and fisheries in the Hudson River estuary. A fishery is generally affiliated with places or regions that, naturally or artificially, produce and manage fish for consumption purposes and is not representative of all the species found in each area. Historically, the Hudson River has had a robust and naturally productive commercial fishery. The iconic species associated with this once remarkably productive mid-Atlantic fishery include Short-nose and Atlantic Sturgeon, American Shad, River Herring, Striped Bass and American Eel. While the diverse habitats of the estuary and direct connection to the Atlantic Ocean support more than 200 species of fish, it was the migratory fishes that once supported a vibrant fishing industry from Manhattan to Troy. Due to a combination of legacy contamination, overfishing, and habitat loss, most fisheries of the estuary have been modified or closed completely. Commercial fishing for Striped Bass ended in 1976; the last Atlantic Sturgeon was harvested in 1995; American Shad fishing closed in 2010. However, small commercial fisheries for Blue Crab and River Herring remain. Recreational fishing is still strong, particularly for Striped Bass, Smallmouth and Largemouth Bass, despite the establishment of human consumption advisories due to PCB and other contaminants. The implementation of these restoration actions will allow for these species to recover to the point where the species are effectively playing their ecological role at abundance levels high enough to sustain appropriate-sized recreational and commercial fisheries.

The commercial fishes frequenting the estuary are all native and are mostly diadromous (e.g., migratory), spending time during various life stages in either salt or freshwater. The diadromous fishes of the estuary are the most difficult to manage and have been the most overfished along their Atlantic coastal migration route and in the estuary, particularly Atlantic Sturgeon and American Shad. Neither of these species may now be fished in the Hudson River. Most adult migratory fishes are found in freshwater during the spring when they spawn. Their young spend varying times in the estuary until they leave to mature at sea, returning later to their natal water to spawn. Because many of the above species mature at sea, they represent a vital component of the oceanic food web but are also susceptible to harvest, both intended and accidental, by ocean fisheries. American Eels have an opposite life history, spawning in the Sargasso Sea but maturing for a considerable time in brackish and freshwater water of the estuary and its tributaries. Species such as Sturgeon may not reach reproductive maturity until they reach 20 years old. These in-estuary and out-of-estuary variables, combined with an altered mosaic of habitat availability, the implications of climate change and a complex management structure, make managing the iconic Hudson River fisheries a challenging proposition.

Although circumstances continue to be challenging, a management success story may be unfolding related to Atlantic Sturgeon. In recent years, data indicates that the abundance of juvenile Atlantic Sturgeon has shown an increasing trend. Although it is too early to declare a success, the observations are certainly encouraging.

The likelihood of recovery success for many of these species hinges on our ability to address three key challenges. First, effective management of the fishes and fisheries of the estuary, and beyond, should be enhanced through adaptive management, and informed by expanded research and monitoring, of regulatory structures and regulations in collaboration with other Atlantic coastal states and Canada. Second, critical estuary habitats should be managed at least in proportion to what currently exists as the effects of climate change are realized, but they should be managed for equal or higher quality. It should also be recognized that additional habitat gains can be made through efforts to restore side-channel habitats (see also Hudson River Shorelines and Riparian Areas and Shallow Water and Intertidal Wetlands) and re-establish tributary connectivity (see Tributary Connectivity and Barriers) by mitigating the effects of stream barriers and past dredging and filling practices. Finally, the realized and potential proliferation of invasive aquatic biota, both species and extent of coverage, should be slowed or eliminated with attention to connectivity with sources of invasive species from other water ways (e.g., New York Harbor and the Great Lakes), and this should be coupled with effective implementation of the New York State Aquatic Invasive Species Management Plan.

06 Sediment

Target Statement

By 2050, we understand more about the contribution and movement of sediment from the watershed into the Hudson River estuary which is reflected in both management actions and monitoring data trends. This knowledge will support the planning and appropriate actions in the watershed to improve tributary habitats and water quality, as well as robust shallow water estuary habitats. By 2030, 25 projects are underway to either reduce sediment in tributaries where excess sediment is a documented impairment, or deliver more sediment to shallow estuary habitats needing more sediment to sustain levels with sea level rise.

Summary

Sediment is a fundamental component of any aquatic system as it influences light penetration, carries/hosts pollutants, supplies nutrients, supports wetland maintenance and provides habitat for plants and macroinvertebrates and can help reduce risk of flooding and erosion. The Hudson River estuary has been characterized as a naturally turbid system with significant capacity to both store and transport sediments, but a challenging paradox exists between tributaries and the estuary. Currently, many tributaries are impaired by too much sediment deposition from storm water run-off, eroding streambanks and stream channels adjusting to higher peak flows. Conversely, several tidal wetlands in the estuary are vulnerable to sea level rise because sediment accretion rates may not be able to keep pace. If sediment accretion rates in these wetlands are not able to keep pace with sea level rise, they are likely to shift to an open water habitat and significant wetland functions would be lost. Thus, tidal wetlands may require more sediment to maintain their function. There are other challenges in the estuary affected by sediment transport including maintenance dredging for commercial ports, recreational marinas and the navigation channel (see Navigation), and where to put historic fill material removed for aquatic restoration purposes. Sediment stored behind both large and small tributary dams also warrants consideration when scoping dam removal opportunities.

The amounts of sediment entering the estuary vary greatly from year to year as a function of precipitation and streamflow. Human activities associated with navigation channel development and management, shoreline hardening, historical logging and agricultural practices along with intensifying land-use conversion and development in the watershed have likely altered the rate, patterns, and composition of sediment delivered to and transported through the estuary. These changes likely influence both tributary and main stem processes and conditions. Although sediment delivery and transport are very difficult and expensive to quantify, estimates suggest that contemporary delivery rates are eight times higher than at the time of pre-European settlement but half as much as experienced during the peak of animal-powered agriculture and logging practices at the end of the 19th century. Since then our intentional interaction with and management of sediments in the river has greatly intensified as evidenced by the development and maintenance of a navigation channel and the establishment of commercial ports and recreational facilities. Another complicating factor is that most sediment core samples, although sparse relative to the area of the estuary, indicate PCB contamination levels of about 0.1 ppm and above. These levels are common, but certainly not universal. Concentrations above this threshold can complicate meeting the standards typically associated with “beneficial use” opportunities (e.g., beach nourishment, wetland restoration, strip mine reclaimation, etc.); a “beneficial use detemination” can be the significant element in project feasibility. Additionally, the intensity and frequency of significant precipitation events are expected to increase, which could lead to a related increase of sediment delivery events. A common and documented source of chronic water quality

impairment in tributaries is excess sediment. Yet, in the estuary, periodic sediment delivery events can have long-term implications. For example, Tropical Storm Irene resulted in high loads of sediment to the estuary that smothered estuarine aquatic vegetation, resulting in near total loss of submerged aquatic vegetation following the storms. By 2017, approximately 2/3 of the known submerged aquatic vegetation coverage has recovered. To overcome these challenges, an improved understanding of sediment dynamics and characteristics both within individual tributary watersheds and between all tributaries and the estuary itself are needed to improve our ability to identify and implement management objectives, strategies and actions.

Excluding the significant sediment delivery from the Mohawk River, run-off induced erosion from uplands and in-channel erosion within tributaries to the Hudson are a primary sediment source. These sources support maintenance, and possibly accretion, in some of the shallow water habitats typically found at the confluence with the estuary. However, a lack of monitoring data precludes the prioritization of stream segments to be more appropriately managed to allow for natural adjustments to increased peak stream flows. Strategic prioritization, likely through modeling exercises, is a critical step as restoration experience from the Catskills suggests costs between $200 and $285 per linear foot. A tributary watershed approach that prioritizes specific reaches within tributaries for restoration and provides nature-based restoration guidance is necessary. This guidance should include elements of wetland protection, stream channel, floodplain and riparian area restoration, dam removal, culvert right-sizing, and improved urban, suburban, and agricultural stormwater management. Other nature-based restoration actions capable of reducing peak discharge rates and enhancing the safe passage of sediment and debris flows should also be considered.

In the estuary, a sediment management strategy based on an improved understanding of sediment source/fate dynamics is necessary to meet both natural and social demands. This will require additional research into the estuary sediment transport dynamics, a management framework that quantifies the trade-offs among management activities, stakeholder coordination and implementation resources. Through an improved understanding of existing sources, supply/discharge rates, concentration, and transport patterns, finding a balanced solution to both challenges will likely become more attainable. Although complex and time consuming, a strengthened, comprehensive approach to sediment management is an imperative, fundamental step to achieving many of the restoration and resilience goals identified in this plan.

07 Contaminants

Target Statement

By 2050, identify and reduce contaminants entering the Hudson River, and remove or remediate river sediments contaminated by long-term pollutants, so that food webs of the river are supported, people can safely eat Hudson River fish, and harbors are free of the contaminants that constrain their operation. These efforts decrease direct and indirect toxic risks to human communities and improve ecosystem health and resilience. By 2030, priority contaminants of greatest concern are identified, the respective transport mechanisms and fluxes are well understood, and their sources and distribution are mapped and monitored, while at least 10 priority source sites are being prepared for remediation in direct consultation with affected communities.

Summary

The presence of a variety of chemical contaminants has been a primary driver in the use and management of the Hudson River estuary for decades. Although contaminants are present at elevated levels in all environmental attributes of the Hudson River estuary (sediments, soil, water, air and biota), their highest concentrations are generally in the organic sediments. Chemical contamination of the estuary from persistent legacy pollutants such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), dioxins, pesticides and metals is a long-standing problem and is now combined with an ever-increasing suite of contaminants of emerging concern. These contaminants are known to enter the system through industrial point sources,

wastewater treatment facilities, and non-point sources including atmospheric deposition, municipal runoff, agricultural runoff, combined sewer overflows and septic systems. Their presence has, and continues, to impair ecosystem function, threaten human health, and limit managers' options for use of the system's valuable resources, particularly its fish community and recreational opportunities. Furthermore, the Hudson River corridor is known to contain many brownfields, therefore former industrial properties targeted for redevelopment or reuse may be constrained by the presence of contaminants.

There are 120 contaminated sites within 400 meters of the Hudson River estuary according to the New York State Registry of Inactive Hazardous Waste Sites. An additional 25 sites have been issued Certificates of Completion of Cleanup. In fact, 200 miles of the Hudson River, including the tidal estuary is classified as a Superfund Site by USEPA under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). The chemical contaminants of greatest concern are PCBs, a class of man-made synthetic compounds manufactured for a variety of 20th century industrial uses and now banned in many countries worldwide. Beyond their exceptionally slow rate of decomposition, perhaps the most disturbing properties of PCBs are their ability to accumulate in the tissues of macroinvertebrates, fish and other wildlife and their adverse health effects to humans which limit consumption.

Although the flow of legacy contaminants to the estuary, PCBs in particular, may have been somewhat curtailed by recent efforts above Troy, there continues to be little assessment effort spent evaluating the ramifications of their continued presence in the estuary. The continued input, distribution and movement of PCBs in the estuary ecosystem remains a significant void of understanding which requires further monitoring and research. Understanding the results of remediation efforts would likely inform, if not compel, remedial actions in both the tidal and non-tidal reaches of the Hudson.

Metals, including mercury (Hg), cadmium (Cd), chromium (Cr) and lead (Pb) have been of concern in the estuary but are not as widely recognized as PCB's. Knowledge of the distribution of metals in the estuary sediments is incomplete; focusing initial efforts to more fully understand the implications of primary heavy metal sources and associated source control actions is recommended.

Contaminants of emerging concern include pharmaceuticals, personal care products, pesticides, industrial chemicals and microplastics. These contaminants are problematic because of their ability to produce profound biophysical changes and alter natural processes (e.g., photosynthesis) even at very low concentrations. Microplastics are also alarming because they attract organic toxicants (e.g. PCBs and dioxins) and there is not a definitive characterization of the full ramifications when they are consumed by fish or other organisms; although behavioral changes and/or death have been identified.

The contaminants of emerging concern are also entering the system with poorly understood ramifications. Generally, we know little about the levels and toxicities of some metals and many contaminants of emerging concern making remediation prioritization difficult. The absence of actionable information on the source, distribution and movement of contaminants in tidal estuary limits our ability to evaluate impacts of past remedial efforts and prioritize those that should be implemented in the future. Extensive research into the toxicities and ecological implications of contaminants of emerging concern and microplastics is needed to not only gain a better understanding of their implications, but to also develop, evaluate and implement effective treatment options where and when possible.

08 Storm and Wastewater

Target Statement

By 2050, Long Term Control Plans (LTCP) will be fully implemented in all combined sewer systems that discharge to the Hudson River, and wastewater treatment plants throughout the watershed will no longer regularly discharge untreated sewage. Clean water is vital to all aspects of life in the Hudson Valley, from drinking water for communities, to infrastructure for economic growth, to clean headwater streams and estuary waters supporting robust fisheries and recreation. By 2030, 25 projects likely to measurably improve conditions within whole tributaries or entire municipalities have been implemented in priority locations to improve wastewater infrastructure or stormwater management.

Summary

The Hudson River Valley is designated a National Heritage Area, with a growing recreation and tourism economy centered on the Hudson River estuary itself and the towns and villages along its shores. However, both the perception, and reality, of continued poor water quality in the estuary limit opportunities for expanding attractive uses of the estuary and its community waterfronts. Wastewater is water that has been used in homes, businesses or for agricultural purposes. During use, the water can pick up contaminants such as pathogens, organic matter, nutrients, industrial chemicals, pharmaceuticals and sediment. Stormwater is runoff generated from rain or snowmelt that flows over land or impervious surfaces, such as paved streets and building rooftops, and does not soak into the ground before reaching a waterway. During travel over surfaces, or through infrastructure pipes, stormwater picks up contaminants like trash, metals, road salt, pesticides, oil, nutrients, animal waste and sediment. Unless properly treated, the various contaminants picked up by waste and stormwater are discharged to the estuary or its tributaries and contribute to both the perception and reality of less than optimal water quality conditions.

The Hudson River estuary receives waste and stormwater from communities that house nearly 1% of the US population (roughly 2.8 million people), either through direct discharges, or indirectly through tributaries. Despite long-term positive trends in treatment capacity and estuary water quality, these wastes and stormwater discharges continue to be major sources of multiple pollutants that threaten public health, impede recreational use, depress economic activity related to recreation and waterfront revitalization, and degrade environmental functions of the estuary.

The sheer volume of waste and stormwater generated in the region is challenging existing collection and treatment capabilities. There are currently 45 wastewater treatment facilities including 11 combined sewer overflow communities, discharging into the estuary north of Yonkers. These facilities are served by over 1500 miles of sewer pipe some of which may date back 100 years or more. Maintaining and upgrading waste and stormwater infrastructure will be expensive and take considerable time and resources to achieve measurable results. This existing infrastructure is further challenged by climate change. Current projections of more frequent extreme storms imply a need to handle increased stormwater flows, as well as flooding damage to infrastructure from storm surges (as occurred during Tropical Storm Irene and Superstorm Sandy). Rising sea levels pose a long-term threat to waste and stormwater infrastructure in estuary communities, because much of the infrastructure is in the floodplain. Prioritization of necessary upgrades is very straightforward as about 25 % of the treatment facilities discharging directly to the estuary are in the 100-year floodplain and most likely to be impacted by present-day flood events or the first to be impacted by sea level rise. These at-risk facilities, and those currently not meeting treatment standards, should be the first to receive upgrade support.

The immediate challenge in reducing waste and stormwater impacts in the Hudson River estuary is to decrease storm-water flows and combined sewer overflows while improving waste and stormwater treatment where necessary. Considering the complexity and age of the infrastructure, the number of communities and expense involved, careful study and planning is essential to ensure that actions are appropriately prioritized. Improved monitoring, assessment and public reporting activities can begin immediately and will significantly inform the strategic deployment of resources. Upgrading treatment facilities and associated assets and eliminating sources of contamination carried by storm and wastewater is under way in the Capital District (e.g., "Albany Pool"), and long-term control plans are underway for all combined sewer systems. Finally, adapting to new standards as health and ecosystem thresholds of existing and emerging contaminants become better understood, responding appropriately to climate change and planning for eventual reinvestment are long-term priorities that must also be addressed to maintain high water quality.

09 Public Access

Target Statement

By 2050, public river access sites supporting boating, kayaking, swimming, fishing and riverside wildlife viewing enable residents and visitors to have rich and diverse river experiences. These facilities provide educational opportunities, contribute to ecological management goals, improve quality of life, and support economic development and tourism. By 2030, the impacts of sea level rise on the future amount and condition of river access sites have been evaluated, ecologically sound adaptation plans have been developed for sites in need, and existing access site managers continue to improve accessibility, where feasible, for everyone, including people with disabilities, older adults and families with small children.

Summary

The Hudson River estuary is recognized, both regionally and nationally, as an important recreational resource. Because of its significance, Congress has recognized the Hudson as an Estuary of National Significance and established the Hudson River Estuary National Research Reserve. The river and its valley have received many state and federal designations including: A) Hudson River Valley Greenway and Greenway Trail (State, 1991); B) Hudson River Valley National Heritage Area (Federal, 1996); C) American Heritage River (Federal, 1998); D) Hudson River Greenway Water Trail (State, 2001); and E) National Water Trail (Federal, 2012). These designations support connectivity between the river and upland trails along the portions of the waterfront, which then connect into 3,000 miles of regional trails in the Hudson Valley, including the Appalachian Trail, which crosses over the river at the Bear Mountain Bridge. The recently announced Empire State Trail, when completed in 2020, will be a continuous 750-mile route spanning the state from New York City to Canada and Buffalo to Albany, creating the longest multi-use state trail in the nation. The Hudson River estuary is bookended by New York State's two most populous metropolitan areas, the greater New York City Region and the greater Albany Capital Region, and the study area includes 10 New York counties and the waterfronts of 21 villages, 41 towns and 10 cities.

The region's love affair with the Hudson River estuary has dramatically increased over the past several decades due in no small measure to pollution clean-ups spurred by state and federal policies such as the Clean Water Act and the Comprehensive Environmental Response, Compensation and Liability Act ("Superfund Act"). Local and regional waterfront restoration plans and programs that identify opportunities for public access have also been established through programs such as the NYS Hudson River Estuary Program, the Hudson River Valley Greenway and the NYSDOS Local Waterfront Revitalization Program (LWRP). A vibrant community of conservation and environmental advocacy organizations, and a staunch citizen stakeholder community have assured that these programs and policies are well developed and well applied. Implementation of restoration and clean-up efforts under federal, state and local regulations and programs has been largely responsible for communities and citizens re-engaging with the jewel found in their backyard. The renewed relationship with the Hudson has led to the emergence of world-class recreational opportunities including: blue way trails, waterfront pedestrian trails and parks that connect recreational and educational, art and nature opportunities. Historical sites which, in some cases, pre-date the Revolutionary War are attracting new visitors. The region's 256-mile Hudson River Greenway trail connects with the Walkway Over the Hudson, the world's longest and highest pedestrian bridge, and the Hudson River Skywalk connecting the Thomas Cole and Olana historic sites via the Rip Van Winkle bridge. Every riverfront community now has some form of public access to the river.

Although all the public access infrastructure is a critical contributor to the regional economy, and the region's quality of life, it does require regular maintenance, is vulnerable to climate change and requires users to be educated about how to safely use the resource. New public access facilities are desired in some areas but feasibility is limited by available public land and/or safety concerns (e.g. adjacent rail lines to be crossed). However, existing facilities are well used by the public which requires regular maintenance and repair budgets, and, to accommodate more users, upgrades to facilities to meet the Standards for Accessible Design need to be accelerated. These facilities are also, generally, located along the dynamic shoreline of the Hudson River which makes them vulnerable to ice floes, sediment deposition, flooding and sea level rise. As a result, facility managers and state agencies are beginning to think about resilient design and implementation techniques. These facilities also provide proving grounds for improved, ecologically-sound, shoreline and infrastructure measures that meet the needs of users but also provide ecological benefits for fish, birds and plants. Users of these facilities and the open waters of the estuary also need to be informed and educated of the risks and challenges associated with recreational activities on federally managed and maintained shipping channels. They should have a better understanding of the impact of their activities on critical aquatic habitats; such as shallow water habitats inhabited by submerged aquatic vegetation.

10 Navigation Safety and Natural Resource Interactions

Target Statement

By 2050, state-of-the-art navigational safety aids, emergency response capacities and river maintenance dredging plans are in place to protect and sustain ecosystems while also supporting operational and safety needs for recreational and commercial navigation. These conditions ensure the safe on-river interaction of commercial and recreational user groups, prevent accidents and spills and protect or restore critical natural resources. By 2030, an active, diverse and collaborative Navigation Safety Committee has identified opportunities to reduce risk and has achieved early success by installing remotely accessed distance to water surface technology on all bridge infrastructure and additional state-of-the-art safety measures and resources, while DEC, USACE and port agencies on the Hudson are coordinating plans for dredging and dredged material management to assure win-win solutions that sustain navigation and restore ecosystems.*

Summary

The Hudson River estuary is used as a nationally significant commerce corridor, requiring that ecological and transportation goals come into alignment. In 2014, for example, nearly 18 million tons of cargo were shipped on the Hudson with 15.8 million tons bound for domestic ports and nearly 2 million tons shipped abroad; the Troy Lock and Dam alone provides safe passage of more $6 billion of commerce annually. Commercial cargo being shipped on the river today includes raw materials (e.g., sand and gravel), iron ore, scrap metal, chemicals, cement, food products, large turbines, sewage sludge, wastewater and petroleum products. The Hudson remains a vital "working" river, and the potential for ecological and safety conflicts is important to recognize. Historically, extensive habitat loss accompanied the development and maintenance of the navigation channel. Oil spills and shipping accidents occur on a regular but infrequent basis. These impacts can be better managed.

Recent estimates identified more than 90 documented boat launches, marinas and port facilities in the region. This infrastructure supports recreation, tourism, public access and commercial shipping. While some significant facilities are being upgraded, such as the Port of Albany, others have routine maintenance needs and activities, while others could be expected to undergo upgrades in the foreseeable future. Sediment management is a significant challenge for these facilities as well as natural resource management. A calibrated and coordinated approach to facility upgrades and maintenance represents an area of activity capable of not only improving the safety and condition of these facilities but also making contributions to natural resource management objectives.

** Note: This TEC did not benefit from a focused working group as it was established as a standalone topic following the completion of the original TEC development process. No detailed description exists and we recommend working with the U.S. Coast Guard working group, as warranted and appropriate, to develop a summary of the topic and revise the goal statement and associated description as necessary.*

Co-existing with this increasing commercial use is a vibrant recreational boating community which includes kayaks, jet skis, sailboats, small fishing vessels, cabin cruisers and yachts. With more than 60 yacht/boat clubs throughout the estuary recreational boaters are another significant stakeholder in future management objectives in the region. The infrastructure necessary to support this community already exists in the form of public marinas and launches as well as private clubs, but this infrastructure also requires maintenance and risk management activities which need investment.

Sediment management is a principal concern of commercial and recreational navigation users, as well as natural resource managers. As identified in other components of the Hudson River CRP, sediment management is a fundamental necessity to ensure the long-term viability of both commercial and recreational uses on the river and ensure habitats and ecological functions are conserved. For example, Sediment-related turbidity is a beneficial factor in preventing algae blooms in the Hudson, and a certain amount of sediment may be necessary to sustain wetlands and ecosystems in the face of sea level rise.

Dredging activities in and adjacent to the 32-foot deep commercial shipping channel is largely managed through the U.S. Army Corps of Engineers while much of the navigational aid and emergency response infrastructure is managed by the U.S. Coast Guard. In the early 1900's, construction and early management of the navigation channel resulted in the estimated loss of more than 9000 acres of habitat, with most of the loss occurring in the upper estuary. Future investments in port development have the potential to further damage habitats of the river unless properly designed and managed to incorporate new design elements and current knowledge of river ecology; ideally such future investments will incorporate restoration of habitats that were formerly destroyed.

Proper disposal of dredged material is a significant challenge to management and restoration that needs to be addressed. Although current dredging operations and material storage facilities do exist on the river, only one storage facility remains open. There is not sufficient capacity to accommodate the additional material generated by channel maintenance. Lack of disposal facilities has the potential to limit proposed habitat restoration activities as well.

Along with a much-improved understanding of sediment dynamics in the Hudson River Watershed, an improved, comprehensive sediment management strategy is necessary to sustain the viability of navigation and to effectively manage the habitats and ecology of the river. Nourishment of marshes with sediment may be needed in the context of sea level rise, and may present an opportunity for ecologically-sound placement of clean dredged material. Management of sediments, discussed under Sediments, is a key strategy that can support both recreational and commercial navigation if properly designed to also support ecological needs.

In addition, dredging options for the recreational marinas and clubs along the Hudson, especially in the lower reaches of the estuary, are severely constrained by the cost of testing for contaminants and the cost of disposal options triggered by the presence of contaminants. These facilities provide significant recreational access to the river, but they have few options to maintain their harbors and basins, which are now silting in. Similarly, contaminated sediments increase the cost of navigational dredging of the channel. Reduction of legacy contamination in sediments, discussed under Contaminants, is a key strategy that will support both recreational and commercial navigation by reducing the cost of dredged material disposal.

Safety is another principal concern for both commercial and recreational users. Increased commercial traffic, attributable, in part, to increased use of the Hudson as a fossil fuel shipping corridor, simply increases the odds of interactions with recreational users and the risk of spill-related accidents. Recreational users of all types would benefit from better understanding and appreciation of how to react to an encounter with a cargo ship, and ecologically sensitive areas to avoid. Commercial captains would benefit from improved, real-time information transfer, particularly associated with bridge clearance information as sea levels rise in the future. Resource managers and municipalities will benefit from continued upgrades to emergency response plans and capacities.

Coordination between navigation management and natural resource stakeholders is necessary to enhance safety on the river and reduce the impacts to sensitive natural resources. This coordination should extend to the development of ports and the conditions of use for anchorages. Currently, port expansion is not well coordinated and one of only two approved anchorages on the river is located over the most important spawning habitat for Atlantic Sturgeon; anchor scarring is currently evident in underwater imaging. River bottom conditions are crucial habitat factors for Sturgeon spawning success. Managing the use of existing anchorages to avoid such habitats would be a desirable outcome of enhanced coordination of ecological and navigation needs. The issue of establishing new anchorages has recently been a significant topic of concern in the region, with natural resource implications being one significant element of the debate. This topic is one of several examples of conflict identified in this initiative that will likely require further evaluation and dialogue over the near-term and may not produce an equitable or negotiated solution.

The U.S. Coast Guard has established a working group to address navigation related issues and challenges. "The Hudson River Safety, Navigation and Operation Committee" provides a seat for the Estuary Program, Riverkeeper, Hudson Valley Land Trusts, and a riverfront community representative. This is a significant milestone with the potential to improve the safety, coordination and collaboration of the vested stakeholders related to navigational management in the estuary, and beyond. We expect current and future safety concerns referenced above will be addressed swiftly and provide a solid foundation for future endeavors, particularly related to sediment management.

11 Estuary Education

Target Statement

By 2050, every K–12 student in the Hudson Valley receives meaningful classroom and hands-on education regarding the Hudson River and its watershed, ample research and training opportunities are available for citizen scientists and post-graduate students, and all communities have designated access points and programming for interested stakeholders and residents. This will expand science-based knowledge of the estuary and of the actions needed to conserve it. By 2030, at least five river education sites offer effective place-based programs, 80% of school districts are using river or watershed curricula at elementary, middle and high school levels, and decision-makers learn about key challenges and success stories related to watershed management. Those engaged represent a diverse audience which reflects the demographics of the region.

Summary

A Hudson River CRP begins with an improved understanding by the public, and decision makers, of the naturally occurring ecological features and values of the system. Accomplishing this requires Hudson River education and stewardship programs for the public, municipalities, waterfront businesses and all riverfront partners. Meaningful education programs are multidisciplinary, multimodal and multi-cultural allowing them to connect to a range of learners, learning styles and cultures. At the core of these education programs are field experiences that bring participants into direct contact with the estuary; there is no virtual substitute

for direct personal experience with the water, and no better way to build an understanding of the river, its benefits and its current condition. Along with public education, we also need to build and reinforce an understanding among our local adult decision makers that the river is an asset and a resource to their communities.

Providing education on and about the river requires access. Currently public waterfront access to the Hudson is present at all riverside communities except where it is not feasible. The sites vary in management structure and include state, county, municipal and non-profit facilities. Many, but not all, of these sites serve varied education and training audiences that include adults interested in the natural world, boaters needing water education, and teachers seeking professional development opportunities. Student groups include K-12 and undergraduate audiences learning about the estuary, research science students hoping to find a project about the estuary system and college students participating in service learning projects as they give back to the community.

Training opportunities for estuary residents are also important for education. They include sessions for planning and zoning board members on watershed protection, and sessions for workforce members looking for technical training on restoration or sustainable practices. To establish 'reach' and breadth in education offerings, partnerships will continue to be crucial. Many workshops and teacher training programs are offered through the collaborative partnership efforts of two or more groups that include the estuary program, other state or national agencies, universities and colleges, and research groups. Service providers and business partners are a growing sector in these partnerships, and, in some instances, will be best suited to provide the technical content and training. An evolving focus on sustainable planning, resilient shorelines, waterfront planning for sea level rise and green infrastructure projects has opened the door for new technical training and job force education. This growing need will continue to provide a unique opportunity for industry/research/education partnerships.

The environmental education community has been unwavering in its pursuit to ensure that every K-12 student in the Hudson River Watershed receives meaningful education experiences related to the Hudson River ecosystem and its watershed, and it has an on-going commitment to establishing that this objective is warranted and recognized as a long-term priority. This includes a need to evaluate and develop specific curricula and lesson plans, including materials, for specific access locations along the river that cater to not only conditions of the site, but the anticipated users of the site. There is also a need to enrich research opportunities across the estuary to deepen our collective knowledge and understanding of the river while supporting locally developed scientists and cultivating highly engaged citizens. New information, applications and techniques are anticipated to emerge from this research and developing an effective curriculum that transfers this knowledge and expertise to practitioners, managers, and decision-makers may stimulate new solutions or approaches to long-standing problems.

12 Resilient Waterfronts and Community Shorelines

Target Statement

By 2050, Hudson River shoreline communities have dramatically reduced their vulnerability to chronic and catastrophic impacts of climate change, while sustaining a healthy river ecosystem. Strong economies and recreational opportunities create vibrant waterfronts; homes, businesses and infrastructure are resilient to variable and extreme conditions and natural areas and waterfront parks slow and store floodwaters. By 2030, all riverfront communities with significant vulnerability to sea level rise, flooding and drought have, with the active participation of residents and businesses, completed a resilience plan, proactively updated municipal law, zoning and building codes and taken steps to reduce their vulnerability, using ecological principles where appropriate.

Summary

The Hudson River estuary is tidally influenced up to the Troy Lock and Dam, 153 miles from the Battery in Manhattan. More than 40% of the shoreline in the study area is considered "engineered" through a wide variety of measures and methods. These engineered shorelines are often, but not always, associated with urban centers, transportation and/or community infrastructure. The proximity of this infrastructure to the waters of the estuary makes them susceptible to sea level rise, storm surge and flooding.

Within the Hudson River CRP study area 21 villages, 41 towns and 10 cities directly front the Hudson River, with a total population of 1.3 million and close to 600,000 jobs (based on 2010 Census data). Approximately 178,000 residents live within ½ mile of the waterfront in about 76,000 units of housing, 3% of which are public housing. Over 105,000 jobs are located within ½ mile of the shoreline. The Hudson River shoreline is also heavily influenced by transportation-related infrastructure, including 12 Metro-North stations and 2 additional Amtrak stations on the eastern shore and a significant freight line along the western shore south of Esopus. Within a ½ mile of the shoreline there are 24 wastewater treatment plants, 10 hospitals, 9 power plants, 6 ports, 7,500 acres of parkland and 68 identified Superfund sites. There are also significant, but unquantified, miles of flood-vulnerable roadway infrastructure. Although the risks, challenges and ramifications of sea level rise, storm surge and flooding are not equal among these areas or types of infrastructure, the potential for disruptive impacts is both real and significant and requires proactive strategies to reduce this risk and improve resilience.

Resilience can be defined as the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to and recover rapidly from disruptions. If the communities of the Hudson are to be thriving places that minimize their impacts on natural resources and strive to reduce their risk to climate change, steps will need to be taken to ensure that they become resilient to drought, rising seas and more frequent and more intense storms. Resilient communities are also more likely to be self-equipped to respond and recover from damaging events and are less reliant on external disaster aid and assistance.

A socially and economically equitable approach to improved policies, practices and activities, rooted in both science and engineering, is necessary to ensure that high and consistent levels of resilience are realized throughout the estuary. This will require not only the issuance of state guidance, but also recognition and adoption of improved policies and practices into

municipal law. State agencies are currently undertaking a vulnerability assessment for their operations and assets, as directed by Governor Cuomo in the 2015 Opportunity Agenda Climate Smart NY initiative. Many communities are also now conducting vulnerability assessments, and the culminating recommendations will need to be implemented in a prioritized way that allows for a variety of strategies including fortification, accommodation and relocation. Many communities are also embracing their waterfronts as key assets; however, current and future visions will need to account for ways to improve both the ecological and resilience values of these dynamic areas. The incorporation of natural or nature-based features and flood-safe infrastructure will be important. Finally, many challenges are likely to be common across many communities while the approach to solutions is likely to vary widely. Platforms to share these varied approaches and lessons learned are likely to spur action and accelerate implementation.

Conflicts within TEC Recommendations

With an area as large and as complex as the Hudson River estuary, recommendations are likely going to be made that are contradictory, not mutually supportive or in direct conflict with other recommendations developed within the same planning effort or framework. In the example instances identified below, there is confidence that each of the conflicting recommendations is individually valid for the specific challenges it seeks to address. The conflict comes to light when all recommendations are considered at once.

We recommend diverse working groups be established to consider and provide recommendations for the conflicts that become evident.

As discussed previously, starting to evaluate trade-offs and provide meaningful guidance to decision makers is a process that should begin before there is a poignant moment generating intense scrutiny or requiring swift action.

Robust and complex challenges were identified by the TEC expert teams; the most prominent and time-sensitive include:

01 Actions to conserve tidal and intertidal wetlands can reduce available shallow water habitat, and vice versa.
02 Increasing stringency of water quality or other standards, can mean a change in permitting regime and performance requirements for municipalities and other entities, with possible changes in costs to those entities.
03 Human activities and development in riparian areas, flood-plain, and along the shoreline (e.g., shoreline hardening) can impact or reduce available habitat and vice versa (e.g., wetland migration affecting built structures or human use areas).
04 Hydroseeding to reduce sediment transport can exacerbate invasive species concerns.
05 Dredging activities can impact habitats and natural communities but are necessary to maintain commercial and recreational access and navigation.
06 Elimination of *Phragmites* can exacerbate problems with contaminants and increase exposure to flooding.

Research Agenda

The Hudson River estuary is arguably the most studied natural resource in the world; however, there is much we do not yet know or understand relative to current conditions and processes, let alone how these might shift with climate change and continued development. Each TEC team developed a research agenda for their respective attribute. A full list of research questions and topics is found within the original TEC document on **thehudsonweshare.org**. Below is a summary of those needs.

Foundational Research

- Empirically identify the quantity and distribution of contaminants in the estuary.
- Quantify the current sediment transport regime and characteristics.
- Identify species composition and associated functions of newly forming wetlands in the estuary.
- Compile high resolution, impervious surface data for the estuary's floodplain and riparian areas.
- Complete inventory of NYS Office of Government Services-owned lands in the current and future floodplain.
- Complete inventory of locations and conditions of hardened/engineered shorelines not protecting critical facilities or infrastructure and prioritize restoration using natural or nature-based features.
- Improve understanding of independent and cumulative effects of the main stem floodplain and riparian area ecological functions and prioritize areas for protection or restoration action.
- Develop an improved, comprehensive database of contemporary and planned uses, condition and longevity of all watershed dams.
- Assess identities and distributions of fish and other species occurring in tributaries.
- Create basic documentation of identity, distribution, concentrations and consequences of most contaminants, particularly emerging contaminants such as personal care and pharmaceutical products.
- Identify source, levels, distributions and toxicities of microplastics in both tributaries and the estuary.
- Demonstrate significant toxicities of contaminants in natural environments.
- Determine sediment trapping capacity of 25 dams exceeding 20,000 acre-feet of design storage.
- Update knowledge of American Shad population dynamics relative to competition for food, predation by invasive species, navigation lock operation and salt front migration with changing flows.
- Conduct nutritional studies of estuary aquatic biota to determine effect of diet change on reproductive capacity in the herring family.
- Map the seasonal habitat use and needs of estuary fishes.
- Continuation of long river aquatic surveys by utilities beyond closing of Indian Point to project recovery rates.
- Perform more fundamental research on poorly-known habitats and communities including tidal swamps and the supratidal zone.
- Conduct biological inventories and site-specific maps of Hudson River estuary floodplains and other riparian habitats.

Experimental Research

- Devise methods to incorporate habitat for uncommon and rare species into planning and design of flood and storm protection infrastructure.
- Experimental development and evaluation of habitat restoration projects for achieving biological objectives.
- Evaluate and quantify the toxicities and ecological effects of contaminants in combination with other non-chemical conditions and stressors (e.g., increased ambient temperatures, low dissolved oxygen, etc.).
- Develop the relationship between laboratory induced toxicities and the compromised health of natural populations in contaminated natural settings.

- Determine if heavy metals will adhere to microplastics in natural environments and, if so, identify implications for larval Hudson River fishes.
- Develop improved understanding of interactive toxic and ecological effects of contaminants found in the estuary.
- Innovate fish passage structures for low flow drainages.
- Evaluate benefit of improved fish passage into estuary tributaries as well as north of the Troy Lock and Dam.
- Develop and evaluate non-chemical techniques capable of blocking non-native animal and fish movements into the Hudson River Basin from neighboring basins without blocking commercial or recreational boat traffic.

Applied Research

- Identify the maximum pace of horizontal wetland migration in the estuary.
- Identify the estuary implications of potential storm surge barrier installation in the harbor under the NY–NJ Harbor and Tributaries Study.
- Identify areas, by cost-effectiveness, for strategic relocation in the long-term.
- Identify which shoreline areas can help support wetland migration as sea levels rise.
- Evaluate trade-offs of improved connectivity throughout the Hudson River Watershed, including north of the Troy Lock and Dam.
- Identify and summarize best practices for adaptation to inform actions of municipalities.
- Identify which developed waterfronts are best suited to accommodate restored and natural shorelines that benefit the river.

Monitoring

- Monitor sediment regime characteristics to identify pattern shifts, and likely cause.
- Establish sediment transport modeling stations at Waterford, NY and the Gov. Mario M. Cuomo Bridge.
- Monitor outcomes of connectivity remediation projects using “Before-After, Control-Impact” study designs.
- Evaluate potential impacts of flood and storm protection engineering on biota.
- Long-term evaluation of habitat restoration projects.
- Long-term monitoring of natural and nature-based features to identify functions, characterize performance, and track ecological response and structural integrity.

Candidate Project Opportunities

Over 1800 project opportunities (Map 5) were submitted for consideration from a diverse group of regional stakeholders related to restoration activities, community infrastructure and access/education projects. Very few of these projects are shovel ready as most have not gone through a feasibility, vetting or permitting process, however, they do represent elements of a future vision for stakeholders and therefore deserve consideration. Many of these projects could provide multiple benefits, if considered, designed and implemented appropriately, particularly those in close proximity to each other. These project opportunities were gathered from stakeholders who participated in a series of regional workshops that were held in 2015 and led by The Nature Conservancy, Scenic Hudson, Hudson River Watershed Alliance, and Historic Hudson River Towns. With funding from the New York State Energy Research and Development Authority and the Hudson River Estuary Program, five workshops drawing participants from 25 riverfront communities and all 10 estuary planning offices were held. In 2017, additional opportunities were submitted by government agencies and not-for-profits participating in PRH.

These opportunities underscore that there is a significant array of needs within the estuary ranging from shoreline softening and wetland protection, to developing flood tolerant transportation networks and updating, reinforcing and relocating wastewater treatment facilities. When considering these opportunities in combination with the ecological assessment and desired future conditions (i.e., TECs), it is apparent that a diversified approach is necessary to correct the multitude of challenges in the estuary.

The candidate project opportunity list serves as a "living document." Through ongoing stakeholder engagement and an online submission form (available at thehudsonweshare.org), new and emerging opportunities can be identified and progress can be tracked. As environmental and community realities change, the list will adjust and as it does, stakeholders, with variable capacity, skill sets and interests, can more effectively recognize natural collaboration opportunities.

There is a significant array of needs within the estuary ranging from shoreline softening and wetland protection, to developing flood tolerant transportation networks and updating, reinforcing, and relocating wastewater treatment facilities.

The Hudson River estuary includes most land-use types on the spectrum of rural forest and agricultural to densely urbanized, each influencing the estuary in different ways and requiring different strategies. In the visual examples that follow, four representative areas (Maps 6–9) of the estuary show candidate project opportunities identified by regional stakeholders. These areas illustrate the relationships at a scale where a roadmap to local success can be envisioned. Not all opportunities as currently envisioned are likely to pass viability criteria, but these examples and those in the database are not considered all-inclusive or completely scoped.

In the highly developed reach from the Federal Lock and Dam at Troy, south to the Wynants Kill (Map 6) there are a suite of actions, if planned and implemented accordingly, that can improve community resilience and improve habitat conditions (current or emerging development proposals excluded). Stakeholder recommendations include:

01 Stabilize the northern shore of Starbuck Island (Map 6) vulnerable to erosion particularly from ice floes, which contains an emergency boat ramp and back-up drinking water wells for the Village of Green Island.

02 Soften the western shoreline along the Hudson to the west of Starbuck Island to protect the side channel which acts as a tidally-influenced mud flat supporting a variety of aquatic vegetation (Map 6, area between Points 7 and 6); this feature also connects to the Watervliet shoreline project (Map 6, Point 6).

03 Relocate a road salt storage facility along the eastern Hudson shoreline and the south bank of the Poesten Kill.

04 Remove or mitigate multiple tributary barriers along both the Poesten Kill and Wynants Kill.

05 Remediate contaminants, such as heavy metals, pharmaceuticals and micro-plastics if found to exist beyond harmful thresholds.

06 Implement the Albany Pool Combined Sewer Long-Term Control Plan (LTCP).

Consider the multiple benefits of simultaneously, or at least incrementally, resolving the Starbuck Island and Watervliet erosion issues (improved community resilience and habitat conditions), a public boat launch at the northern end of the Troy bulkhead (access and recreation), relocating a salt storage facility along Troy's Poesten Kill and Hudson shoreline (improve community resilience and water quality), and implementation of green space along the channelized Poesten Kill and Wynants Kill through bank naturalization and barrier removal (tributary connectivity and community resilience). These collective actions, combined with benefits of the Albany Pool LTCP (water quality) and likely contaminant remediation (biological and human health), will have profound implications that enhance community resilience, fish and wildlife habitat, public access and recreation and tourism opportunities.

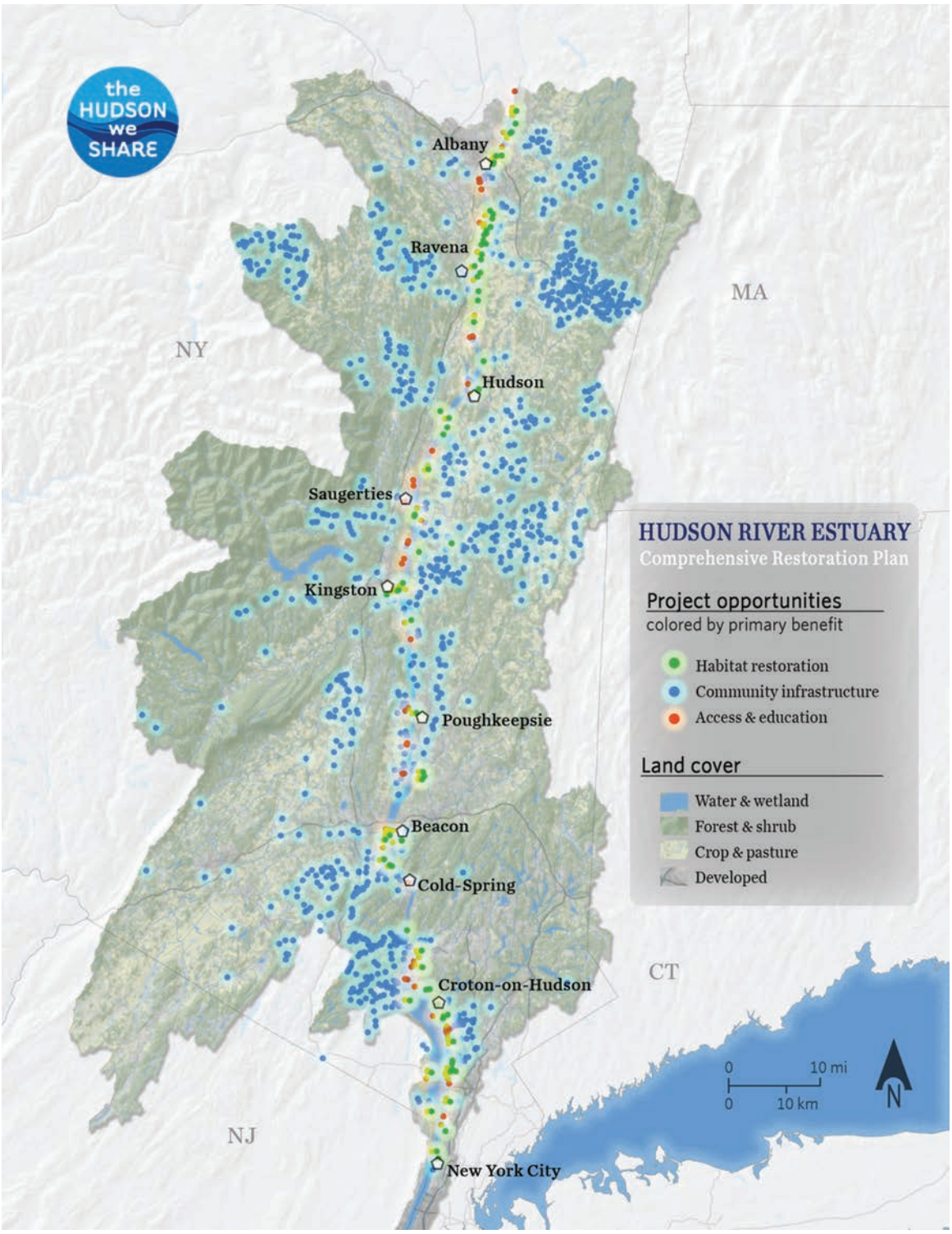
Map 7 The Kingston-Rhinecliff Bridge south to the Kingston Waterfront and Hudson River/Rondout Creek confluence represent challenges of a moderately-sized community facing coastal flooding concerns, invasive species management and brownfield remediation.

Map 8 The southern end of Campbell Island and the northern portion of Schodack Island State Park illustrate areas of wetland migration, side-channel restoration and nature-based shoreline treatments.

Map 9 The area just north of the Gov. Mario M. Cuomo Bridge around Sleepy Hollow, Tarrytown and Upper Nyack represents a heavily urbanized area with recommendations including culvert right-sizing, brownfield remediation, wetland protection, and nature-based shoreline softening.

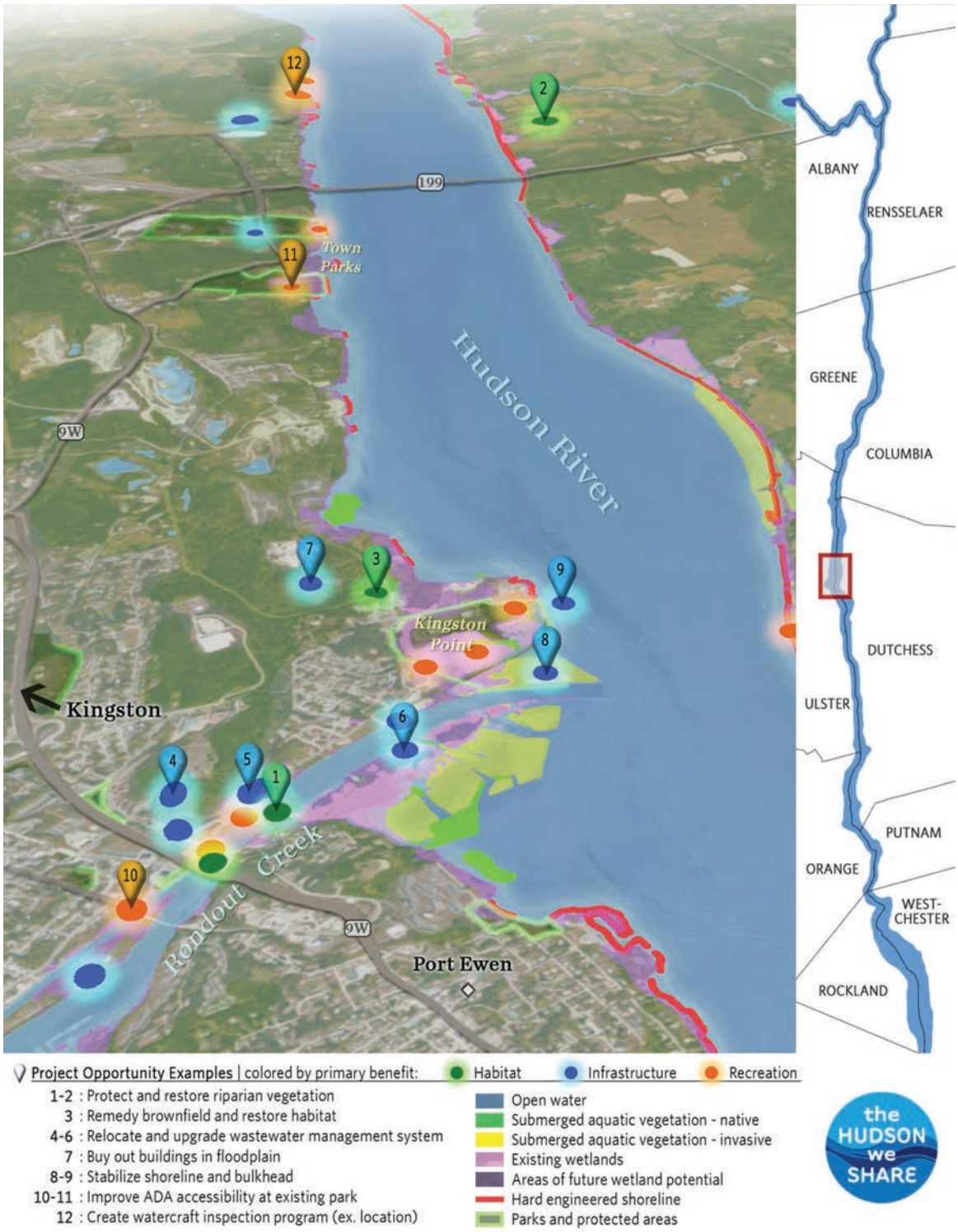
When the project opportunities are sorted into manageable geographic clusters as described above, the overwhelming challenge of restoring the estuary is more approachable. Exploring opportunities at a cluster scale allows for improved understanding of the interactive nature of existing challenges but also begins to reveal the potential of implementation efforts to produce compounding benefits. Compounding benefits assumes that a cluster of single, multiple-objective implementation efforts occurring closer to each other are likely to yield more pronounced benefits than single, multiple-objective projects occurring at a distance from each other. The replication of this approach among several related clusters begins to build a network of locations that collectively contribute to regional improvement trends. Recognizing that circumstances will not always allow for several nearby projects to be designed and implemented simultaneously, a phased design and construction approach can be employed and sequenced over a period until desired outcomes are achieved.

The full database of project opportunities is available at thehudsonweshare.org. The absence of a prioritization for these opportunities is intentional as there is a compelling body of support (see TECs section) indicating they all should be more fully considered, developed and pursued in parallel. The task of prioritization will be left to the individual entities implementing the Hudson River CRP. The recommendation is that those entities, organizations and/or partnerships embarking on project implementation should be encouraged to adopt comprehensive approaches addressing multiple challenges at many locations within a given area. Meanwhile, individual project initiatives should be designed in ways that effectively incorporate a variety of project attributes and are likely to yield multiple benefits to both communities and natural habitat.

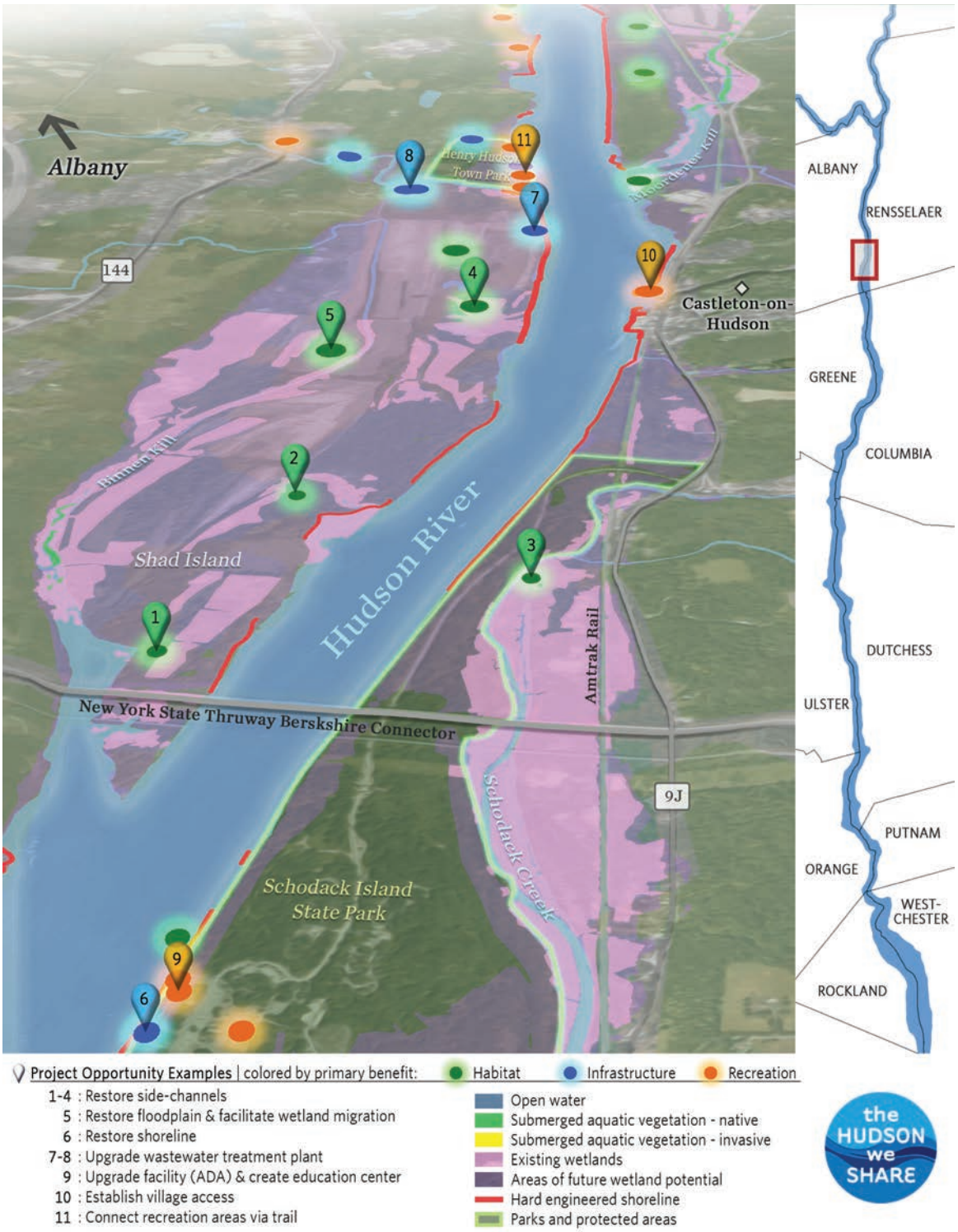


Map 5 *Regional map depicts the approximate locations of nearly 300 candidate project opportunities. This is not an all-inclusive list, nor are these projects shovel ready. The Community Infrastructure projects identified away from the estuary are comprised of barriers (dams and culverts) along tributaries. Implementation efforts should not be advanced without local government and private ownership support and engagement.*

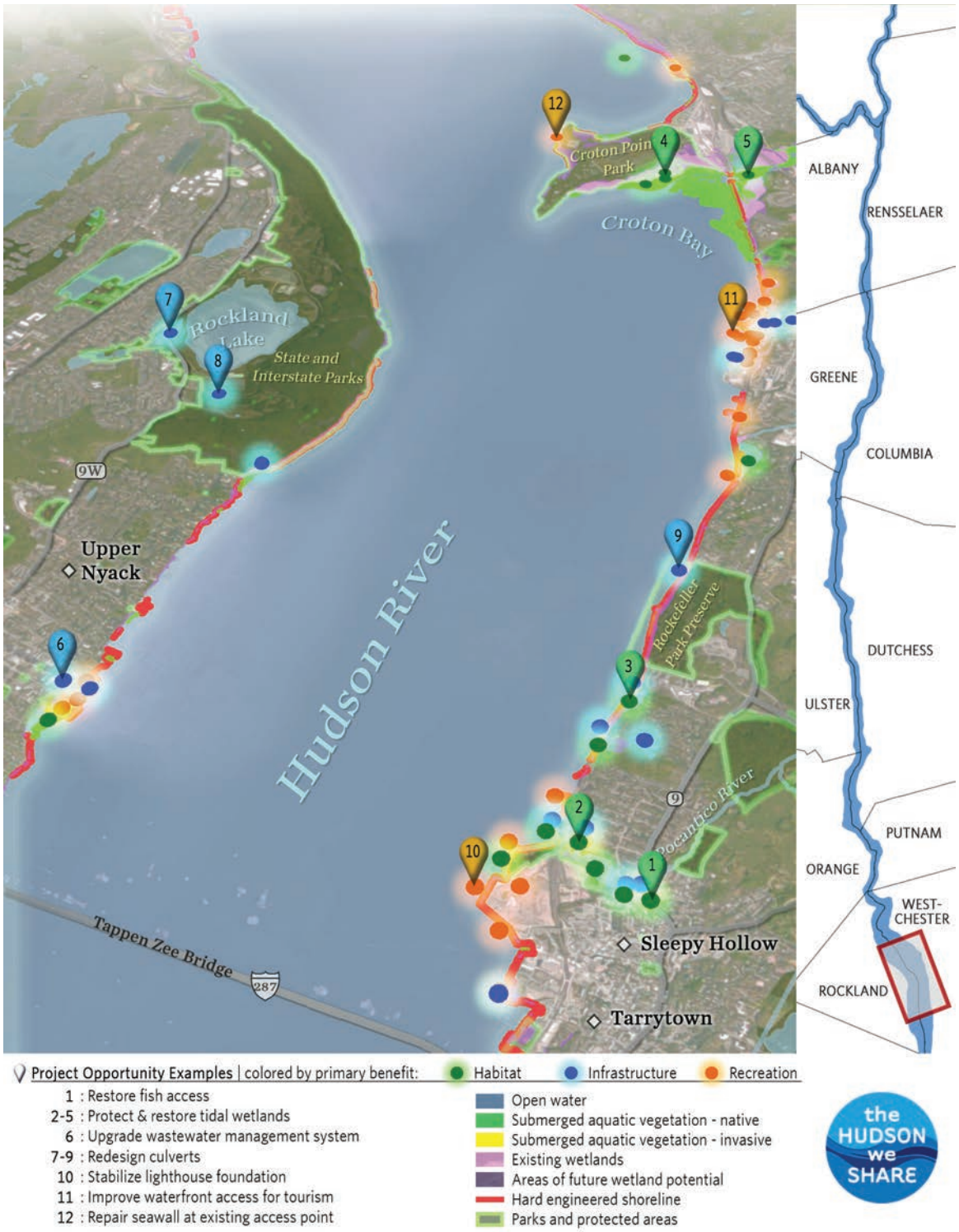
Map 6 *Candidate project opportunities in relation to existing features along a northern estuary reach from the Federal Lock and Dam at Troy to the southern boundary of Troy, NY. This reach is heavily developed and has significant amounts of hardened shoreline yet is very important from a recreational and biological perspective. Implementation efforts should not be advanced without local government and private ownership support and engagement.*



Map 7 *A mid-Hudson reach from the Kingston-Rhinecliff Bridge south to Port Ewen, NY. This area is particularly susceptible to flooding and sea level rise around Kingston Point and along Rondout Creek. This is a significant tourism destination, surrounded by residential housing and community infrastructure. The City of Kingston is aggressively pursuing climate adaptation strategies here and incorporating an array of green and grey infrastructure to bolster community resilience. Other needs include remediation of contaminants, improving sediment management practices, and upgrading public access facilities. Implementation efforts should not be advanced without local government and private ownership support and engagement.*



Map 8 *A more rural reach of the Hudson River estuary between the southern end of Campbell Island and the northern portion of Schodack Island State Park. This reach is expected to experience significant wetland migration due to sea level rise. Other habitat restoration opportunities include side-channel restoration, shoreline softening, and public access projects that incorporate nature-based engineering solutions. Implementation efforts should not be advanced without local government and private ownership support and engagement.*



Map 9 *A decidedly more developed area of the southern Hudson River estuary, just north of the Gov. Mario M. Cuomo Bridge around Sleepy Hollow, Tarrytown and Upper Nyack. Although many community infrastructure opportunities exist in this reach, including wastewater treatment upgrades and contaminant remediation, several habitat restoration and access opportunities were also identified. Much of the shoreline here has been hardened, with some areas being considered for softening, while management of invasive species around Croton Bay are identified as possible opportunities. Implementation efforts should not be advanced without local government and private ownership support and engagement.*

Execution and Management

The Hudson River Valley is one of the most studied waterways on the planet. It has a strong tradition of engaged community groups that collaborate to support its recovery in a variety of ways. The region is also a beneficiary of well-defined state and federal programs that were created at the request of local stakeholders. These programs have a proven track record of coordinating governmental and local action to achieve strong outcomes. This multi-stakeholder approach offers the Hudson River CRP many resources to draw upon to ensure its success. It also necessitates a principled approach that acknowledges the existing partnerships and opportunities in the region.

DESIRED MANAGEMENT ELEMENTS

The Hudson River CRP vision, goals and objectives were developed by a broad network of stakeholders. Those stakeholders were engaged to not only identify what needs to be accomplished but also how we might increase the rate of implementation and ensure the flexibility to adapt to changing natural and social conditions. Several desirable elements of an implementation structure are identified which can be characterized as immediate while others are more aspirational.

Immediate desirable elements of a management platform include:

01 A forum where everyone can have a seat at the table and all participants are considered equals.

02 A platform for stakeholders to administer, adaptively manage and implement the Hudson River CRP, including but not limited to:

- Produce periodic reports of collective implementation activity
- Establish working groups around some combination of the TECs focused on vetting candidate project opportunity proposals; catalyzing collaborative implementation; communicating innovative discoveries; tracking progress; adaptively managing plan content at critical milestones, as new information becomes available or circumstances warrant.

03 Stakeholders that represent a wide range of authorities (e.g., federal, state, county, local) and capacities (governmental, for-profit, non-profit, academic) can capitalize on opportunities as they emerge.

04 Engage and attract a broader array of new or non-traditional participants and partners focusing on other important attributes of the region.

05 A platform for open dialogue and conflict resolution to address discrepancies and contradictions within this plan and among other regional implementation plans and proposals, recognizing that compromise may not always be possible, desirable or appropriate.

06 Accelerate capacity development to better meet demand.

07 This initiative should have a forward leaning approach that strives to reimagine roles and responsibilities going forward, with a focus on adapting existing platforms as much as possible.

The estuary is confronted with many diverse and complex challenges. These challenges, coupled with fluctuations in available funding, suggest the increased importance of strengthening collaboration and creative problem solving, as well as leveraging the region's strong tradition of public participation and civic organizations. Local government also plays a critical role in the Hudson River Valley, and New York, as a home-rule state, defers many decisions to the local level. The success of the Hudson River CRP—and the restoration of the estuary, now more than ever—requires coordination and cooperation across multiple governmental jurisdictions: federal, state, county and municipal.

Implementation of the Hudson River CRP will require three primary activities:

01 Communication and collaboration among stakeholders who are advancing projects and initiatives identified in the plan.

02 Improving the connection of funding and technical support opportunities for partners who can apply for and administer the resources to achieve implementation.

03 Inclusion of Hudson River CRP recommendations into the implementation plans of the state and federal management programs: the NY-NJ Harbor & Estuary Program and the Hudson River Estuary Program.

These activities will require the identification of enhanced social networks, additional organizational capacity, and new relationships to carry out the work.

PROPOSED MANAGEMENT VEHICLE

It is recommended that, beginning with the next updates for both the federal NY–NJ Harbor Estuary & Program and the Hudson River Estuary Program Action Agendas, appropriate and aligned elements of the Hudson River CRP, including the TECs, target statements and research agenda, be incorporated as feasible and appropriate. Nesting the implementation structure under the existing federal and state estuary management programs effectively ensures the recommendations provided through the Hudson River CRP reside with those entities most likely to advance coordination and implementation.

Both state and federal estuary management programs will be further supported by PRH which will provide support and services the agencies may not be able to fulfill, such as securing private grant funds, evaluating market-based financing tools, enhancing approaches to community engagement and developing new relationships with non-traditional partners.

To enhance coordination and engagement around the Action Agenda, it is recommended that the Hudson River Estuary Program and the federal NY-NJ Harbor & Estuary Program utilize working groups comprising experts, practitioners and managers, responsible for not only revising goals and objectives as necessary, but also reporting collective progress toward implementation goals.

TRACKING AND REPORTING PROGRESS

One principal outcome identified at the onset of developing the Hudson River CRP is the ability to produce a progress report that highlights all the activity of all the groups working on and in the estuary. The purpose for this is four-fold. First, there is a need to better communicate the scope and scale of the work that must be undertaken. Second, by reporting collective progress toward goals and objectives, stakeholders can celebrate their contributions and show the regional community there is hope for a better future. Third, this celebration of progress can be used to establish a track record of success that attracts the attention of and investment by new prospective partners to further support and catalyze implementation. Fourth, a cyclical, comprehensive reporting process also provides a necessary tool in the adaptive management process that allows for the identification of gaps and recognition of what approaches are successful, and highlights when an alternative approach may be necessary. The recommendation is for this reporting to occur on a three- to five-year cycle so that progress is not encumbered by constant reporting and to account for the time necessary to make progress. It is also recommended that progress toward this objective be made incrementally by adapting existing reporting mechanisms and improving their efficiency. An immediate, sweeping change is likely not feasible.

MAINTAINING RELEVANCE

To keep pace with unknown future realities, the elements and priorities identified in the Hudson River CRP should be modified as needed. New attributes or challenges (e.g., TECs) should be considered for adoption so long as they are significant, pervasive and a clear approach to resolution can be developed, vetted and adopted by those implementing this plan. More broadly, the Hudson River CRP Plan should be reconsidered and revised as warranted, but at least on a 10-year cycle or on a cycle with longer time horizons than the respective Action Agendas the Hudson River CRP is intended to inform.

Top © Kent Mason, bottom © NYSDEC/Steve Stanne

GENERATING SUPPORT AND ENGAGING A BROAD CONSTITUENCY

The Hudson River itself is a major driver of the region's $5.7 billion tourism economy, a significant portion of which is water-based, and the region is within a short day-trip of 15 million Americans. Countless citizens gather at the river's edge annually for large public events and informal recreation opportunities, and commercial use of the river is integral to several major industries. The foundation of all this activity and potential is the integrity of the estuary's natural systems. Preservation, maintenance and improvement of ecological conditions is necessary to promote the well-being of the people and communities who rely on them.

Public support for this natural resource is strong. The region is home to many well-organized citizen groups, and scientific and conservation organizations with established records of strong performance. Annually, thousands of citizen volunteers turn out for river cleanups, citizen science and stewardship programs. Local government is an active partner. Thousands of municipal officials participate in trainings on topics related to climate change, sea level rise, water resources, habitat conservation and land use strategies. The next generation of ecological stewards is alive and well. More than 10,000 students learn about the river through regional citizen science events, field trips and classroom visits annually.

Because of its significance, Congress recognized the Hudson as an Estuary of National Significance and established the Hudson River Estuary National Research Reserve. Similarly, cultural heritage resources are addressed through the Hudson Valley's National Heritage Area Program. Federal legislation has been introduced to support regional collaboration and create a source of federal funding to support ecological outcomes through the proposed Hudson–Mohawk Basin Act. New York State has codified its commitment to protecting and managing the Hudson River through the Hudson River Estuary Program and has maintained a solid commitment to the program for over 30 years. Dozens of county and local governments have also prioritized stewardship of the river and related environmental resources.

The momentum of these successes positions the many public and private stakeholders in the region to advance strategies, projects and initiatives identified in the Hudson River CRP. Together, federal, state and local governments, in partnerships with non-governmental organizations and community groups, have an opportunity to transform ecological conditions on the river for the better. Collaboration, coupled with new levels of funding, is necessary to address the many challenges and opportunities that have been identified.

An important consideration in identifying a path forward to enhance coordination and resources available for ecological restoration is recognition that the water resources of the Hudson River estuary are functionally interrelated and interdependent with resources in the upper Hudson and Mohawk Rivers, as well as the New York–New Jersey Harbor. Dedicated programs that address needs in the estuary and related systems such as the NYS Hudson River Estuary Program and the NYS Coastal Management Program are essential to provide effective communication, coordination and cooperation among federal, state and local governments, non-governmental organizations and the private sector. The Estuary Program and the federal NY–NJ HEP are two such examples already at work in the watershed.

Successful implementation of the Hudson River CRP, in cooperation with other regional planning initiatives, will hinge on thriving public-private partnerships. Championing the ideas, progress and outcomes of implementation is an incredibly necessary aspect to sustaining support and recognition of the estuary, and will continue to require a broad network of support. There is a long history of such complementary activities in the region that have proven very effective. To successfully implement the Hudson River CRP, past partners and new collaborators are necessary.

Project Support and Implementation Resources

Funding needs to execute the actions of this plan are significant. Research needs, project implementation, community engagement, vulnerability assessments, engineering designs, permit applications, etc., are all necessary elements of implementing the recommendations of the Hudson River CRP. New York State has historically been a primary investor in the region, particularly regarding natural resource management. Relying on state funding is simply not enough.

Resources external to state government will need to be accessed, capable of leveraging local and state investments and the available sources include federal grants, philanthropic, traditional financing and innovative financing opportunities.

FEDERAL RESOURCES

A federal nexus with the estuary has long been established through navigation infrastructure, railways, fisheries management, endangered species recovery and numerous programmatic designations. New federal interests are emerging, such as community infrastructure adaptation, infrastructure placement and habitat restoration. Congressional appropriations provided in a future Water Resource Development Act (WRDA) resulting from approval of the Hudson River Habitat Restoration Feasibility Report could also be a source of federal funding and a mechanism for implementation. The North American Wetlands Conservation Act (NAWCA) wetlands program, for example, is a significant funding source that has not been successfully utilized for the Hudson River in recent history. There are other funding sources such as the Federal Highway and Works Administration (FHWA) that can fund research and/or experimental design processes. There are also federal opportunities that only state agencies can apply for, which suggests new collaboration opportunities with the eligible agencies, usually outside of NYSDEC, as another avenue for leveraging state resources, particularly if the issue is a critical thematic one or is prevalent across a large geography.

STATE RESOURCES

New York State provides a tremendous amount of funding for a very wide array of activities through the Consolidated Funding Application (CFA) program, which is where NYSDOS LWRP funds are accessed along with Office of Parks, Recreation and Historic Preservation (ORPHP) funds. Other sources include the multitude of grant opportunities delivered by the Estuary Program, with resources appropriated in the NYS Environmental Protection Fund (EPF). The range of funds available are variable, but many of them require some form of a matching fund by the applicant, which can be a barrier to application. Other entities, such as the Environmental Facilities Corporation, offer financing options for large infrastructure projects, generally drinking or wastewater facilities. State funding is available from a wide array of sources to support many elements of the Hudson River CRP and many of the sources, though not all, are eligible to leverage other federal or private resources.

Aspirational Project Support and Implementation Resources

While traditional implementation resources are expected to remain as the principal execution resources for the recommendations of the Hudson River CRP, they have proven insufficient to tackle the scope and scale of all the needs in the region. Therefore, augmenting resources that increase the collective implementation capacity will be needed to achieve the desired outcomes.

There are successful examples of emerging tools capable of providing dedicated, long-term implementation support resources, but they require specific circumstances to become realistic options. The existing circumstances of the Hudson Valley have not been assessed to determine if the requisite conditions exist to support their application in the region nor has a core of expertise to undertake these activities been identified or created. In addition, there have been capacity gaps identified within the stakeholder community that, if addressed, can enhance the pace of implementation. Collectively, these support elements are aspirational objectives recommended to be evaluated, developed and implemented in parallel with the recommendations identified in the TECs.

INNOVATIVE FINANCING AND MARKET-BASED FUNDING

Given the constraints in public funding, and the growing interest from investors seeking triple bottom line (social, environmental and financial) benefits, it is worthwhile exploring innovative financing alternatives to scale up and accelerate the rate of implementation. Many of these emerging tools have been developed outside the U.S. but have the potential to be applied in the Hudson Valley. For example, green bonds have been issued to support climate and environmental projects nationally and internationally, including municipal green bonds. Water funds have been set up to generate cash flow from downstream water users to pay for upstream conservation work that ensures water quality and quantity. Governments have leveraged the private sector's efficiency in delivering stormwater green infrastructure projects through community-based public private partnerships. Factors to consider when evaluating the suitability of projects for innovative financing include but are not limited to scale of the project (larger projects tend to attract investors/service providers more easily and have the efficiency of scale) and existence and certainty of cash flows from utilities or other services.

Rather than thinking of a process that secures funding and then builds a project, stakeholders should consider whether there is a market-based tool to accomplish an outcome. For example, The Nature Conservancy is working to re-open a recently closed saw mill in rural Washington State to process timber harvested from forest stands to reduce forest fire risk. Other market-based revenue streams can be associated with regulatory process such as in-lieu-fee mitigation, such as the model that Ducks Unlimited has recently unveiled in the upper Susquehanna River Basin of Central New York.

Some of these innovative funding approaches are new twists on traditional tools, while others are entirely new and still being developed and refined. Deepening the regional understanding and exposure to these market-based tools through a formal evaluation and feasibility assessment relative to the circumstances and opportunities of the Hudson Valley is warranted, provided the requisite expertise is engaged.

FACILITATING ORGANIZATIONAL CAPACITY DEVELOPMENT

As evidenced by the Hudson River CRP, there is no shortage of ideas, opportunities or needs in the study area. There likely is a shortage of matching fund sources, proposal development capacity, grant administrators and, potentially, staff capacity to execute the proposed work.

Competitive Match Fund

A significant hurdle for many grant applicants is the availability of non-federal and non-state matching funds, particularly for large grants. In many cases, in-kind contributions are used to meet these requirements but this has a limited effect for larger proposals. Further, organizations active in grant proposals can become limited in both the size and number of proposals pursued at any given time as they must avoid being over-leveraged. To overcome these hurdles, development of a pool of matching funds, privately sourced and managed, should be seriously evaluated and considered. This has the potential to not only attract new, private revenue to the implementation of the Hudson River CRP, but also to encourage the development of new partnerships and capacity.

Proposal Writing Capacity

Another limiting factor, particularly associated with the NYS Consolidated Funding Application, is that both municipalities and non-government organizations are limited in the number of proposals that can be developed due to the complexity and timing of the proposal submission process. This bottleneck could be significantly reduced with enhanced proposal development capacity. There are a number of ways to overcome this limitation, including development of short-term contract staff positions within participating organizations, a regional or county level proposal development center, or in some cases, short-term internship opportunities with academic or non-governmental institutions. If developed, this capacity should not be limited to state funding opportunities; it can also focus on more complex federal opportunities as well as private grant sources.

Grant Administration Capacity

The accounting and reporting requirements, particularly for state and federal funds, can be cumbersome for already stretched municipalities and some civic groups. Successful management of grant awards is critical to secure future resources and viable service providers in this arena can be difficult to identify. Developing a network or central service provider for this type of administrative support can significantly enhance regional grant capacity and accelerate implementation of the plan. An evaluation of need and viable service provider options should occur and, based on findings and recommendations, additional grant administration capacity should be developed.

Summary of Findings

01 The Hudson River CRP was developed by a partnership of stakeholders to further inform the federal and state management entities responsible for managing the natural resources of the Hudson River estuary and propose pathways to enhance implementation.

02 The elements of the Hudson River CRP serve as recommendations to be considered by the respective management entities and in no way commit those entities to sole implementation responsibilities. The Hudson River CRP is intended to serve as a catalyst for coordinated, collective action.

03 While restoration is required to ensure necessary features are available throughout the study area, these projects will need to be undertaken with greater consideration of future conditions, not just past or current conditions.

04 The scope and scale of the Hudson River CRP is limited to open waters of the estuary and the riparian areas, including floodplains. This initiative intentionally omitted a full analysis of estuary tributaries and non-tidal tributaries above the Federal Lock and Dam at Troy. Similar planning efforts should be undertaken for these areas to ensure the entire Hudson River Watershed is covered by quantitative planning guidance.

05 The upper, middle and lower reaches of the study area do not appear to be impacted equally. The upper region of the estuary appears to have been impacted more than the middle and lower reaches. The nature of impacts also varies by region.

06 The TECs were developed to establish an informed benchmark for achieving desired future conditions and are intended to be dynamic and adaptively managed based on new information, experiences, conditions and circumstances.

07 Perceived and real conflicts within and among the TECs were identified whose solutions require careful consideration and evaluation *before* a polarizing event occurs, further complicating resolution.

08 Proposed project opportunities were developed through stakeholder engagement to identify possible implementation locations and conceptual activities. This database does not contain the entire universe of possible opportunities while some of those identified may not prove to be feasible or practical as described. Implementation efforts should not be advanced without local government and private ownership support and engagement and with other stakeholders.

09 Candidate project opportunities or actions identified within the TECs have not undergone feasibility analysis or completed a conceptual design. Their inclusion in the Hudson River CRP in no way conveys universal support by PRH nor any individual entity nor does it fulfill any regulatory obligation. These opportunities are provided to promote further exploration and development of proposed concepts and opportunities.

10 Consideration and implementation of the Hudson River CRP is recommended to be managed by the NYS Hudson River Estuary Program and associated Hudson River Estuary Management Advisory Committee through the establishment of working groups and by the NY–NJ Harbor & Estuary Program.

11 PRH should continue to exist but transition to a support and implementation role that also conducts activities the government agencies are not able to perform.

12 Traditional funding sources are not sufficient to meet the challenges identified in this plan; therefore, new and innovative financing and funding solutions are worthy of evaluation and eventual implementation.

Conclusion

The Hudson River Estuary has an intriguing ecological and social history. Change has been a primary theme woven into these storylines and will most certainly be perpetuated well into the future. Another theme in the estuary's history has been the people and institutions developed to protect what has been afforded and improve what has been damaged. There is more than a 50-year history of improvement and success. Over this period of five decades, the needs, strategies, tactics and actions have had to evolve or change entirely due to emerging natural or social circumstances.

With sea level rise concerns and legacy impacts requiring action, the region finds itself in the midst of yet another pivotal moment. No longer can we afford to work to replace what has been lost, we must look to make these improvements in the context of future conditions.

The Hudson River CRP is intended to inform how the region prepares for this uncertain future. This dynamic effort identifies key natural resource attributes, influential drivers of conditions and principal social attributes, and establishes a benchmark upon which progress can be measured. The Hudson River CRP also builds upon more than five decades of collective vision for how these attributes could be managed to ensure an irreplaceable natural resource persists in a way that is resilient to environmental changes while meeting the increasing social demands. As the science indicates, there are thresholds that, if crossed, are likely to result in cascading implications which can further limit the estuary's potential along with management options. Collective stakeholder action focused on evaluating these trade-offs, developing innovative, at-scale solutions and more adequately resourcing implementation activities are fundamental requirements to enhance the region's future. The Hudson River CRP provides a dynamic framework to consider and inform the management of the region's principal natural resource and success will require fundamental and meaningful integration into other regional planning elements and the development of new, even more impactful implementation partnerships.