Tarrytown's Waterfront on the Rise

Climate-adaptive Design Studio

Village of Tarrytown

2022

Acknowledgments

We humbly acknowledge that the original inhabitants of the Tarrytown area were the Weckquasgeek people, who were removed from the land through forced dispossession that caused tremendous hardship. We respect the relationships that exist between indigenous people and the land and waterways. While the Hudson is currently named for a European explorer, the indigenous name is Muhheacannituck, “the waters that are never still”. We understand that this acknowledgement is just a small step in the process of building a more inclusive and equitable space for all.

We would like to express our deep appreciation for the dedication and input from the Village of Tarrytown, especially Deputy Clerk Alissa Fasman, Village Administrator Richard Slingerland and Mayor Karen Brown. The CaD studio would not have been possible without the insights of the Tarrytown stakeholders who participated in the process, providing guidance and feedback to the students.

We gratefully acknowledge the expertise and assistance given to the CaD studio by staff at a variety of Hudson Valley organizations including Scenic Hudson, NYS Department of Environmental Conservation (NYSDEC), and the Hudson River National Estuarine Research Reserve.

We would also like to thank the students who participated in the Fall 2022 LA7010 CaD studio, whose work is displayed here, including: Sangita Bhattacharjee, Xiaomeng Cai, Gengjiaqi Sylvia Chang, Hanrui Freya Fu, Ilana M. Haimes, Keiki Hu, Ziyue Joyce Hu, Maren Louttit Johnsion, Hilary Mulford, Xiaoyun Ren, Aishwarya Shankar, Hang Wang, Brandon Wilson, Xue Xia, Vanessa Dikuyama Zapata, Ying Zhang, and Zinying Nunnally Zhou. Special thanks to Teaching Assistant Hanqi Chai and Research Fellow YuAng Sun.

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Sincerely,

The CaD Team

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Cover Image:
Reconnecting the Connections
Sangita Bhattacharjee

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Getting to Know You

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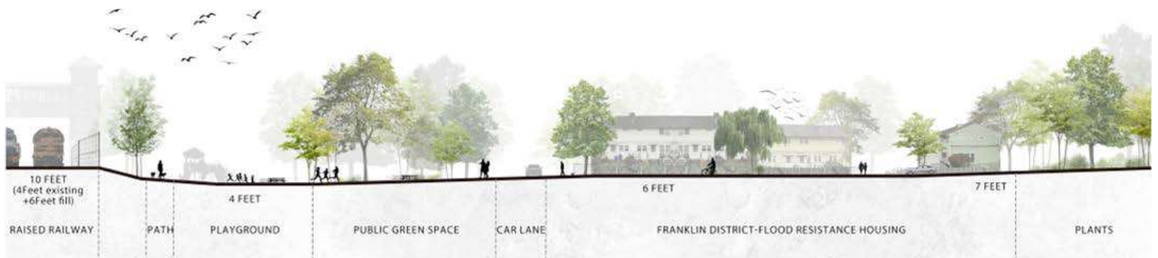


Acclimatizing Hudson
Hanrui Freya Fu
Ziyue Joyce Hu

The Climate-adaptive Design (CaD) studio

Pre-semester meeting
The CaD team meets with key community members

Early in the semester
Students collect and review site information

Back on campus
Student design teams begin developing design concepts

Design development
Key stakeholders participate in on-campus studio reviews

Post-semester meeting
The CaD team meets with stakeholders to review designs and discuss next steps

August | September | October | November | December | January

First site visit
The class visits the host community to meet stakeholders and conduct field visits

Design concept workshop
Students meet with stakeholders to discuss early design ideas

Open house
Students share their final designs with stakeholders

Who We Are

A dynamic public-academic partnership

The Climate-adaptive Design (CaD) studio is an advanced design course led by Cornell University Associate Professor Josh Cerra. The studio links landscape architecture students with Hudson riverfront communities to explore design ideas for more climate resilient and connected waterfront areas.

The CaD studio is an education and research effort made possible by a partnership between the Cornell University Department of Landscape Architecture, the NYSDEC Hudson River Estuary Program, the NYS Water Resources Institute, and host communities in the Hudson Valley.

What We Do

Inspiring change for waterfront communities

The CaD studio is a semester-long landscape architecture studio course that engages a riverfront community in a design process focused on their waterfront.

Students study climate change impacts and use the NYS official sea-level rise projections to propose a variety of design strategies for the waterfront.

During the course of the studio, students meet with stakeholders to understand community issues and interests with respect to the waterfront, and seek feedback on design ideas.

By semester's end, the students have created a set of creative and insightful designs for the host community to access during their ongoing dialogues on waterfront adaptation.

Why We Do It

The CaD team wants to help communities...

- Start the conversation on what change could look like on their waterfront.
- Feel inspired and knowledgeable about adapting to climate change, especially by using natural and nature-based solutions.
- Apply CaD concepts and principles during planning and decision making.
- Access new funding and resources.
- Communicate with regulatory agencies.
- Increase public awareness and support for climate adaptation projects.
- Advance CaD-inspired design projects toward implementation.

The Village of Tarrytown

Making strides toward greater sustainability and resilience

The CaD studio focused on the Village of Tarrytown waterfront during the fall semester of 2022. Tarrytown is approximately 5.7 square miles in area, with a population of around 11,700 people. Approximately 60% of residents identify as white, 3.5% African American, 10% Asian, and over 25% Hispanic or Latinx, according to the U.S. Census. Tarrytown is steeped in history, playing key roles in the Revolutionary War, the Underground Railroad, as well as arts, literature, and culture. Tarrytown is located 25 miles north of mid-town Manhattan and is a stop on the Metro North commuter rail line. The eastern landing of the Tappan Zee (Governor Mario M. Cuomo) Bridge is located in Tarrytown.

The Village of Tarrytown is working toward greater resilience for all residents. The Village is a registered NYS Climate Smart Community, has participated in a Community Resilience Building workshop, and is participating in the Hudson Valley Regional Council's Climate Action Planning Institute. The Village has an active Environmental Advisory Council (TEAC), a Tree Commission, and is currently updating its NYS Department of State Local Waterfront Revitalization Plan.

Hilary Mulford

Climate Risk in Tarrytown

Flooding due to extreme precipitation, stormwater runoff, storm surge, and sea-level rise.

Temperature extremes impacting seasonal conditions and causing dangerous heat waves.

Disrupted precipitation patterns leading to greater likelihood of short-term drought.

Flooding and Sea-level Rise

- The 1% or "100-year" floodplain is defined as a waterfront area that has a 1% chance of flooding in any given year, based on historical data.
- Added up over time, there is a 25% chance of such a flood happening over the span of a 30-year mortgage, making floodplain properties vulnerable to damage.
- These floods are likely to occur more frequently and impact more of the waterfront by the 2050s due to projected sea-level rise and intense precipitation.
- NYS has adopted official projections for sea-level rise that are up to 58" higher than current levels by the 2080s.

Flood risk in Tarrytown. Depths of temporary flooding from the "100-year" or 1% annual chance flood in the 2020s. Green colors indicate depths up to 4 feet. Yellow colors indicate depths up to 6 feet.

Data source: Columbia University Hudson River Flood Impact Decision Support System Version 2

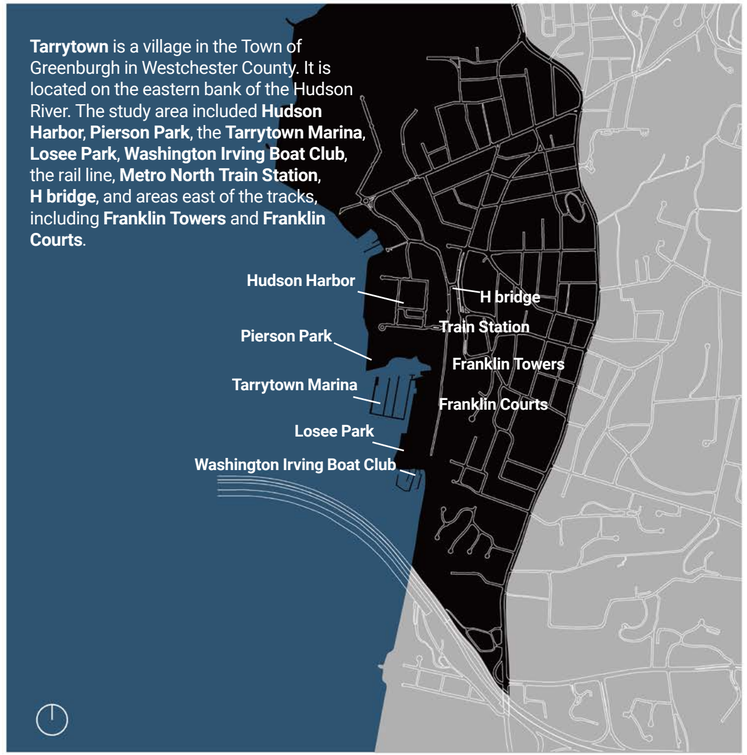
Flood risk in Tarrytown during the "100-year" storm with 60" of projected sea-level rise. According to NYS official projections, 58" of sea-level rise could occur as soon as the 2080s. Green colors indicate depths up to 4 feet. Orange colors indicate depths of up to 8 feet. Some areas may be permanently underwater, even under sunny day conditions.

Project Study Area

Westchester County, New York

Tarrytown is a village in the Town of Greenburgh in Westchester.

The study area is located on the Hudson River waterfront in Tarrytown.



Initial meetings with stakeholders helped student teams identify key themes, challenges and opportunities for the study area:

Key Themes

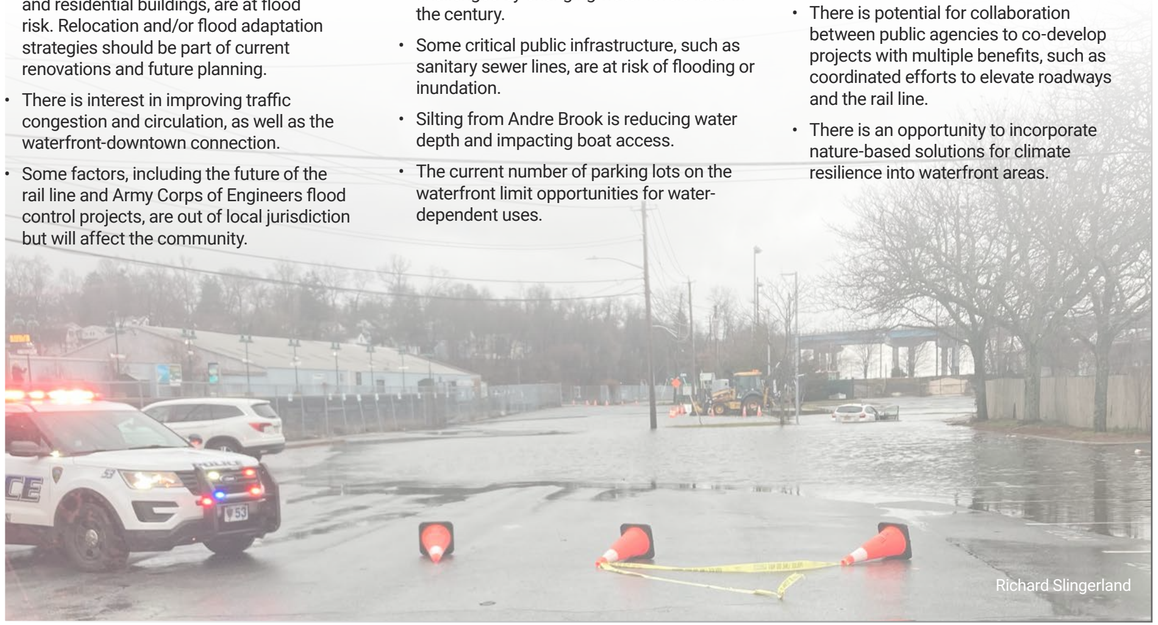
- The waterfront is transitioning from industrial to residential and recreational uses. Decisions about re-development should consider the increasing flood risk and inundation risk due to projected sea level rise.
- Much of downtown, including municipal and residential buildings, are at flood risk. Relocation and/or flood adaptation strategies should be part of current renovations and future planning.
- There is interest in improving traffic congestion and circulation, as well as the waterfront-downtown connection.
- Some factors, including the future of the rail line and Army Corps of Engineers flood control projects, are out of local jurisdiction but will affect the community.

Challenges

- It will be challenging to maintain desired waterfront uses as available land base diminishes due to sea level rise.
- A lack of affordable housing is a challenge that impacts the area.
- Maintaining waterfront access will be challenged by changing water levels later in the century.
- Some critical public infrastructure, such as sanitary sewer lines, are at risk of flooding or inundation.
- Silting from Andre Brook is reducing water depth and impacting boat access.
- The current number of parking lots on the waterfront limit opportunities for water-dependent uses.

Opportunities

- There is an opportunity to incorporate flood resilience into the design of the new portions of the Scenic Hudson Riverwalk.
- The possible re-development of the Washington Irving Boat Club provides an opportunity for a climate resilient approach that benefits all residents.
- There is potential for collaboration between public agencies to co-develop projects with multiple benefits, such as coordinated efforts to elevate roadways and the rail line.
- There is an opportunity to incorporate nature-based solutions for climate resilience into waterfront areas.

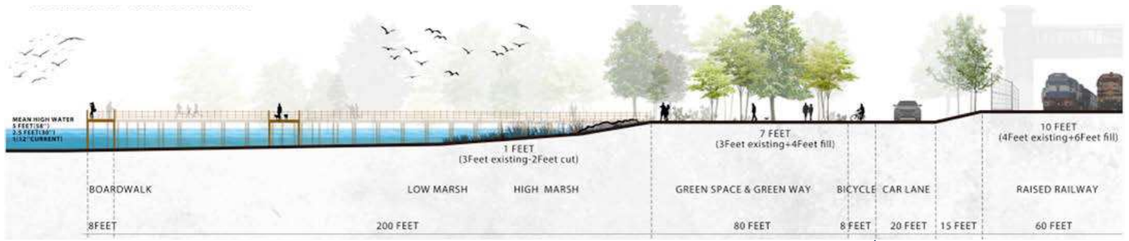

Richard Slingerland

Section 1

Section 2

Design Strategies

Section 3



Acclimatizing Hudson
Hanrui Freya Fu
Ziyue Joyce Hu

CaD Principles

The CaD studio focuses on five key principles in its approach to waterfront design. These principles guide student work and inform the concepts they develop.

Design a Destination
Maximize the value of a waterfront by encouraging water-dependent & water-enhanced uses, like marinas, beaches, & restaurants.

Design for Flooding
Work with water instead of working against it by pursuing strategies such as adaptation, reinforcement, & relocation.

Design with Nature
Preserve & enhance natural areas on the waterfront & use nature-based techniques for erosion control & stormwater management.

Design with Community
Waterfronts that are universally accessible & decidedly memorable can contribute to the well-being & prosperity of the entire community.

Design for Change
Create places that continually provide value under changing conditions. Phase projects over time in ways that are both practical & visionary.

Each CaD studio explored a number of strategies that are based on the CaD principles. The following pages provide brief introductions to the design strategies. Full designs from each studio can be viewed at https://trophic.design/cad/

Before You Turn the Page...

Each strategy comes along with Actions to Take -some that you can do today and others that will take more time and planning to implement.

Each strategy also features student work to visualize possible ways they could be used.

Five icons flag important facts about each strategy. Descriptions about these types of information are detailed here:

+ This section describes how the strategy can create benefits both for people and the ecosystems.

$ Click here or go to page 27 to find sources of funding.

! Important considerations for each strategy are indicated by this icon.

CSC These numbers correspond to Climate Smart Community Actions that can earn points for your city. Click on the icon or visit page 28 to learn more.

? For more information about a strategy, explore the references in this section, located on page 26.

If you are viewing the LookBook on the computer, click the icon to see more information!

Resilient Waterfront Parks

Waterfront parks are an excellent choice for flood-prone areas - they offer recreational opportunities, shoreline access and wildlife habitat, while reducing vulnerability and risk. Waterfront parks should be designed with input from residents to meet the needs of the community and be universally accessible to people of diverse abilities, needs, and resources. The park landscape can accommodate floodwaters and be graded to quickly drain after storm events.

The Tarrytown waterfront includes Pierson and Losee parks, as well as marinas and other assets that are vulnerable to flooding. If the water rises a few feet or more above current levels parts of the parks, including much of Losee Park, may become inundated. Students envisioned a variety of ways to enhance and maintain public use of the waterfront, despite rising seas.

Actions To Take

- ☐ Consult resources such as the *Flood Resilience Handbook for Public Access Sites Along the Hudson River* to analyze the resilience and accessibility of current and planned waterfront parks.
- ☐ When establishing new parks and promenades in future flood-prone areas, identify flood-adapted uses and features that can recover quickly from storm impacts.
- ☐ The design of a floodable park should include recommendations for flood-adapted plants and trees.
- ☐ Review policies and procedures of the parks department and revise as needed to require more climate-adaptive and sustainable practices.
- ☐ Evaluate the feasibility of installation of green infrastructure to capture stormwater when designing or evaluating waterfront parks.

+ Naturalized land cover helps to keep urban areas cooler and allows stormwater to infiltrate while providing habitat for wildlife and health benefits for people.

$ DEC HREP || DEC CSC || EFC GIGP || DOS LWRP || OPRHP || Hudson River Valley Greenway

! Municipalities can protect residents by enacting rent control laws, increasing affordable housing availability and working with a Community Land Trust to promote home ownership.

CSC 7.8 || 7.12 || 7.14 || 7.15 || 7.16

? Flood Resilience Handbook for Access Sites Along the Hudson River
High Performing Landscape Guidelines: 21st Century Parks for NYC
Naturally Resilient Communities

Invitation for Change
Hilary Mulford

Flexible open space can be periodically inundated by flooding without major infrastructure impacts. Flood-tolerant vegetation provides habitat and aesthetic benefits.

Upland Waterfront Connector
Gengjiaqi Chang

Several student designs featured elevated walkways that maintain riverfront access after Losee Park is inundated by rising water levels.

Adaptation in Tarrytown
Xiaoyun Ren

Park spaces can have a flexible program and compatible infrastructure that allows for periodic flooding. This design envisions a floodable building that supports both the Tarrytown marina and a suggested commuter ferry service.

Resilient Roadways and Infrastructure

Roadways and rail lines are often located in close proximity to waterways and may be vulnerable to flooding. Bridges and culverts may contribute to flooding by restricting water flow during heavy precipitation. Infrastructure that is frequently flooded may need to be elevated or relocated to improve safe access under all conditions.

Students envisioned a variety of strategies to reduce flood risk to the rail line, from elevating the tracks and the train station, to moving the rail line inland, to removing the rail entirely and developing water-based transportation for commuters. Ideas to elevate the rail line included opportunities to open up access to the waterfront by siting roadways underneath the rail. Moving the train station north to higher ground near the current H bridge was also proposed. Many student designs included elevated walkways to maintain recreational access to the waterfront.

Actions To Take

- Identify vulnerable roadways and infrastructure.
- Develop an inventory and prioritization plan for infrastructure upgrades.
- Include upgrades in your municipality's capital improvement plan.
- Make sure that infrastructure upgrades are included in your municipality's FEMA Hazard Mitigation Plan.
- Consider use of pervious surfaces when designing roadways, paths, and parking lots.
- Learn more about the Hudson Estuary *Culvert Prioritization Project*, which may provide assistance in identifying culverts that are contributing to flooding and/or pose barriers to aquatic migration.

+ Green street design tools, which integrate stormwater capture and infiltration within the right-of-way, are a critical component of complete street design.

$ DEC HREP, DEC CSC, WQIP (aquatic connectivity restoration), EFC GIGP, FEMA

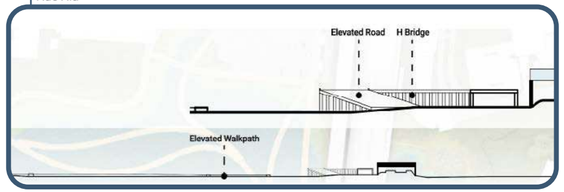
! Communities that identify flood-prone roads and infrastructure in their Hazard Mitigation Plans may be eligible for FEMA funding to mitigate these problems after a declared disaster.

CSC 7.9 || 7.13

? Hudson Estuary Culvert Prioritization Project
U.S. Climate Resilience Toolkit: Rebuilding Roadways to Maximize Resilience
NYSDEC Stream Crossings Best Management Practices

A short-term plan to use the area beneath the current H bridge for recreational activities.

Loops of Resilience
Hang Wang
Xue Xia



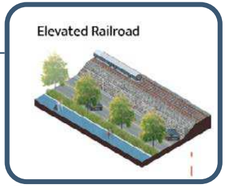
A long-term plan to elevate roads and re-design the H bridge to provide access to the train station, which has been relocated to higher ground.

An elevated walkway offers a spot to enjoy river views as water levels rise.

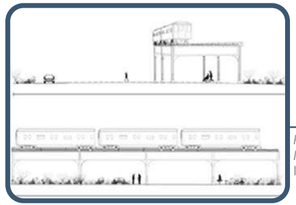
Adaptation in Tarrytown
Xiaoyun Ren

Loops of Resilience
Hang Wang
Xue Xia

Acclimatizing Hudson
Hanrui Freya Fu
Ziyue Joyce Hu



Elevating the tracks on a berm.



Remaking the Inland Waterfront
Ilana L. Haimes

Elevated tracks allow water to flow freely beneath them during flooding, while community uses can take place there during dry periods.

Sculpting the Landscape

According to NYSDEC, about half of the tidal Hudson's shorelines have been altered. Past shoreline alterations have had a negative impact on ecological function, but with careful planning some shoreline sculpting techniques can be used to restore habitats, maintain access, and increase resilience.

Some students focused on strategies such as "cut & fill" to sculpt sites that have been previously altered. For example in low-lying areas, fill can be removed to facilitate marsh habitat creation. Soil can be added in other locations to maintain access amidst flooding and/or projected future inundation. Critically, 'balancing cut & fill' is a major focus of these techniques so that floodplains are not constricted.

Action To Take

- Learn more about the history of shoreline alteration and the value of shallow water habitats in the *Hudson River Estuary Habitat Restoration Plan*.
- Read about NYSDEC permit requirements for waterways, coastlines, and wetlands.
- Learn about FEMA regulations about adding fill in Special Flood Hazard Areas
- Visit Scenic Hudson's *Protecting the Pathways StoryMap* to learn about the potential for marsh migration along the shoreline.
- Visit the *Hudson River Sustainable Shorelines* website to see examples of bulkheaded shoreline area that have been restored to tidal marsh.

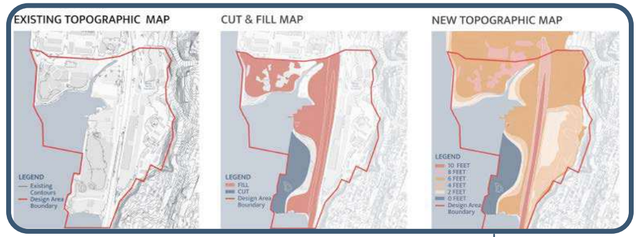
+ It's estimated that 71 miles of natural shoreline in the upper estuary were eliminated during construction of the Hudson's federal navigation channel.

$ DEC HREP || DEC CSC || DOS LWRP || WQIP

! Discussing potential shoreline projects with the NYSDEC Permits Office should be a first step for communities. They will provide advice and guidance to help achieve goals while complying with state regulations.

CSC 7.10 || 7.16

?
Hudson River Habitat Restoration Plan
NYSDEC Environmental Permits
FEMA glossary - Fill
Protecting the Pathways
Sustainable Shorelines Monitoring & Lessons Learned



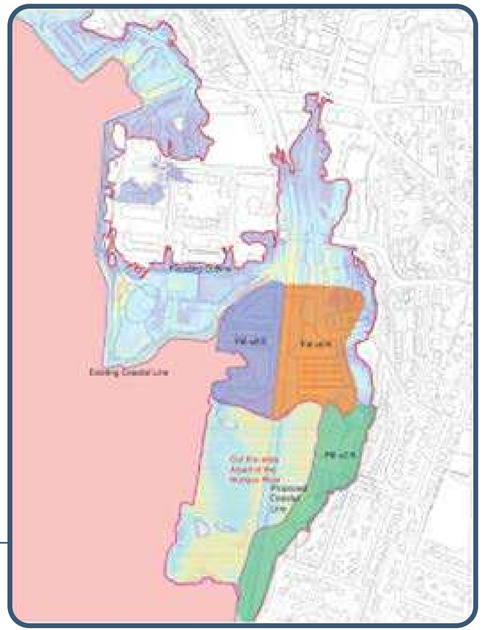
Acclimatizing Hudson
Hanrui Freya Fu
Ziyue Joyce Hu

Students created maps that illustrate strategies to fill some locations with soil cut from others, resulting in a change in topography that does not result in a net addition of fill to the flood plain.

Loops of Resilience
Hang Wang
Xue Xia

A cut & fill strategy proposed to occur in the 2050s elevates portions of Losee Park and combines the marina and boat club to maintain boating access without a net gain of fill in the floodplain.

Tarryrelink
Xiaomeng Cai



Strategic Relocation & Adaptive Reuse

Key municipal, residential, and commercial assets at high risk for damage or permanent loss under current and projected flooding and sea-level rise should be relocated out of the flood zone. If conditions allow, some structures may be repurposed or adapted to reduce flooding and inundation impacts. These kinds of interventions may benefit from enhanced zoning ordinances, policy measures, or incentive programs to facilitate the transition of waterfronts to more flood-adapted and resilient uses and features.

Students considered the relocation of the train station, senior center, and sports facilities to areas outside of the flood plain to maintain use over time. Many students recommended relocating Franklin Courts uphill to remove housing from the floodplain.

Actions To Take

- ☐ Identify municipally-owned, commercial and residential properties assets that are at high risk from flooding.
- ☐ Create a plan for the relocation of municipally-owned assets.
- ☐ Identify partnerships and funding opportunities to relocate key assets, including FEMA Hazard Mitigation and BRIC funding.
- ☐ Read about the Village of Piermont's efforts to foster neighborhood discussions about potential relocation of flood-prone residences.
- ☐ Read Climigration Network's *Lead with Listening: A Guidebook for Community Conversations on Climate Migration.*
- ☐ Explore potential for Transfer of Development Rights (TDR) to steer development toward safe locations.

+ Transitioning residences, businesses, infrastructure, and services out of the flood zone reduces risk. Returning floodplain functions provides benefits to people, wildlife and waterways.

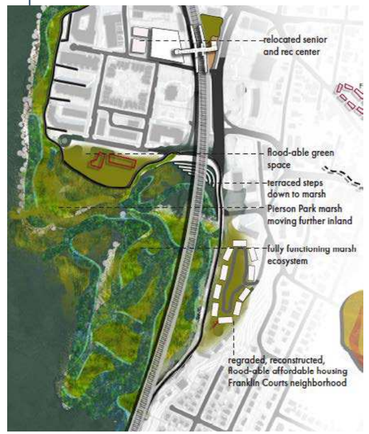
$ DEC HREP || DEC CSC || DOS LWRP || FEMA || HUD CDBG

! A just and equitable approach to strategic relocation is critical to its successful implementation.

CSC 7.15

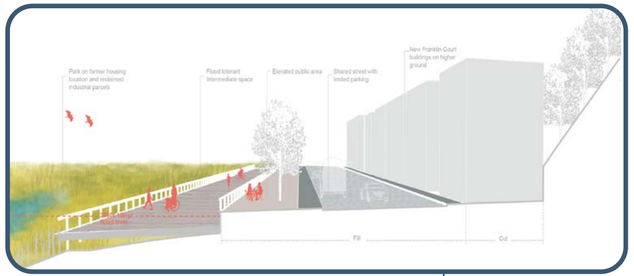
? FEMA BRIC
Adapting to Rising Waters Along the Hudson: Lessons from Piermont , NY
Climigration Network's Lead with Listening Guidebook
NYS Department of State Transfer of Development Rights Technical Bulletin

Invitation for Change
Hilary Mulford



The Senior Center is relocated to higher ground north of its present-day location. A new Franklin Courts is elevated out of the flood plain on a regraded site.

This image depicts Franklin Courts relocated uphill, with a shared street to maintain access, and elevated walkway on the water.



Traces of Change
Vanessa Dikuyama Zapata

Several student designers proposed re-routing and/ or elevating existing roadways, as well as the train tracks.

Acclimatizing Hudson
Hanrui Freya Fu
Ziyue Joyce Hu

Loops of Resilience
Hang Wang
Xue Xia

A vision of a new version of Franklin Courts, relocated away from flood risk.

Sustainable Shorelines

Nature-based shoreline techniques provide erosion control using methods that incorporate living material and limit disturbance of existing habitat. These design techniques often provide ecological benefits, recreational assets, and opportunities for water-dependent businesses. In gently sloped areas with suitable soils, sustainable shorelines can provide pathways for wetland migration as sea-levels rise.

Tarrytown has been included in a federal Army Corps of Engineers study that evaluates strategies to protect communities from storm surge. The choice to use reinforced structures, such as levees, versus relocation and nature-based solutions, such as sustainable shorelines, must be carefully considered.

Actions To Take

- ☐ Visit the *Hudson River Sustainable Shorelines Project Best Management Practices* webpage to learn about shoreline protection methods, including ecologically enhanced structures.
- ☐ Read Hudson River Sustainable Shoreline's *Managing Shore Zones for Ecological Benefits* guide.
- ☐ Visit the NYS Climate Risk and Resiliency Act website to download the *Using Natural Measures to Reduce the Risk of Flooding and Erosion* guide.
- ☐ Consider recommendations in the Waterfront Alliance's *Waterfront Edge Design Guidelines* (WEDG).
- ☐ Download NYSDEC's *Tidal Wetlands Guidance Document.*
- ☐ Contact NYSDEC Regional Permits Program in the early stages of any shoreline project.

+ Sustainable shorelines can provide cost-effective erosion control while enhancing aesthetics, ecological function, and habitat value of a waterfront area.

$ DEC HREP || DOS LWRP || OPRHP || Hudson Valley Greenway

! According to the US National Oceanic and Atmospheric Administration, living shorelines can be more resilient against storms than bulkheads.

CSC 7.8 || 7.14 || 7.16

? Hudson River Sustainable Shorelines Best Management Practices
NYS Climate Risk and Resiliency Act
Waterfront Alliance's WEDG
NYSDEC Tidal Wetlands

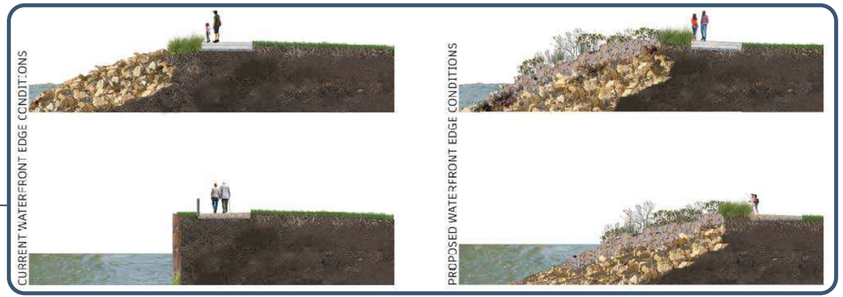
Students proposed using rising water levels as an opportunity to restore natural shorelines and tidal marshes. Tidal marshes provide carbon sequestration, water filtration, and rich habitat that supports biodiversity.

Loops of Resilience
Hang Wang
Xue Xia

Traces of Change
Vanessa Dikuyama Zapata

A long-term student design re-envisions the riverfront as sea level rises to promote wetland function and enhance natural landscapes on the waterfront.

The images on the left show current shoreline conditions in parts of Pierson Park. On the right, bulkheads are replaced with a gently sloped shoreline, and the stone rip rap is vegetated with native plants, which provide erosion control and wildlife habitat.



Remaking the Inland Waterfront
Ilana L. Haimes

Section 2

Section 3

Looking Ahead

Adaptation in Tarrytown
Xiaoyun Ren

Next Steps

- ☐ Share this Look Book with municipal staff, elected officials, planning boards, waterfront stakeholders, and other interested people.
- ☐ Learn more about CaD on the NYS Water Resources Institute website
- ☐ View student designs from all of the CaD studios at https://trophic.design/cad/
- ☐ Consider joining the Hudson River Flood Resilience Network of municipalities.
- ☐ Sign up for the Climate Resilience Newsletter
- ☐ Stay in touch and contact us with ideas, questions, or if you are in need of assistance.
- ☐ When it is available, consider applying for CaD Phase 2 funding to advance preferred design ideas towards implementation on your waterfront.

Keep in Touch!

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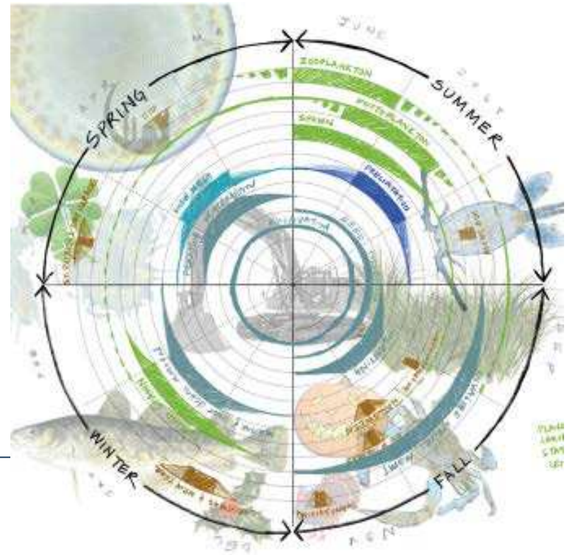
https://trophic.design



Elegies of Futures
Aishwarya Shankar

Protecting The River That Connects Us

The Hudson Estuary

The Hudson flows for 314 miles from the Adirondack Mountains to New York Harbor. For half of its length, the Hudson is an estuary, a place where salt and fresh water mix. Daily tides from the Atlantic Ocean reach over 150 miles from New York Harbor to the Federal Dam in Troy.

Estuaries are nurseries for ocean fish, such as striped bass, American shad, and Atlantic sturgeon, which swim into the river to lay their eggs each spring. In this way, the health of the Hudson is directly connected to the condition of the marine ecosystem in the Atlantic Ocean.

In the past, much of the Hudson shoreline was characterized by shallow water habitats that provided ample food and shelter for fish and wildlife, which also supported the well-being of human inhabitants.

A History of Shoreline Development

The Hudson's natural shorelines have been dramatically altered by human development. According to the Hudson River Comprehensive Restoration Plan, nearly half of the shoreline from the Mario M. Cuomo Bridge to the Troy dam has been altered. The natural shoreline has been converted to bulkheads, riprap, dikes, and other hard structures intended to protect property from erosion or to facilitate industry, transportation, or cultural use.

The images below depict historical views of the Tarrytown shoreline.The 1867 map on the left shows the Hudson River extending east of the train tracks. The aerial photos from 1926, 1940 and 1960 illustrate that much of the Tarrytown waterfront is built on fill. Note that in the 1940 photo, the lighthouse is 1/2 mile offshore, but by 1960, the structure is just a few feet from the shoreline.

Looking to the Future

How communities respond to sea-level rise will affect the health of the Hudson. Protecting against flooding by building hard structures, like sea walls and levees, can lead to unintended consequences. When barriers are overtopped by floodwaters serious damage can occur. Hard structures may increase erosion and flooding in other locations and do not commonly provide habitat value.

If your community has critical infrastructure that may require the protection of hard structures, a good reference to start with is 10 Questions to Ask When Building Defenses to Protect Hudson River Shorelines.

It's important to meet with the NYSDEC Regional Permits Program early in the planning stage of any waterfront project to understand shoreline protection regulations.

1867

1926

1940

1960

David Rumsey Map Collection, Stanford Libraries

Aerial photos courtesy of Westchester County, NY

The Future of Hudson Habitats

Sea-level Rise and Tidal Marshes

The Hudson estuary currently includes over 7,000 acres of tidal wetlands, which protect shorelines, trap greenhouse gases that contribute to climate change, and help keep water clean. Freshwater tidal wetlands, like those in the northern reaches of the estuary, are globally rare and very valuable to young fish and other animals.

Sea-level rise is influencing where tidal wetlands can flourish, with many mudflats and marshes likely to become submerged by rising waters. If sediment accumulation, or accretion, keeps pace with rising waters, wetlands may persist. Marsh plants may be able to migrate inland as water levels rise. But, in many areas existing development and hardened shorelines are at odds with inland marsh migration.

Protecting Marsh Migration Pathways

Scenic Hudson's Protecting the Pathways is a climate change adaptation initiative for tidal wetlands in the Hudson River Estuary. Their interactive map predicts which wetland areas will be gained or lost under different sea-level rise and sediment accretion scenarios. The map also indicates where development could be in conflict with marshes migrating inland to maintain their viability.

We recommend that communities consult the marsh migration mapper when considering development decisions on their waterfronts. This tool can be used to prioritize conservation efforts in areas that currently support wetlands as well as those that are projected to be future marsh due to sea-level rise.

Restoring Hudson's Habitats

Initiatives to protect natural landscapes and restore critical habitats are ongoing. Land use ordinances, dam removals, and efforts to restore vegetated stream banks and wetlands are important to the health of the estuary.

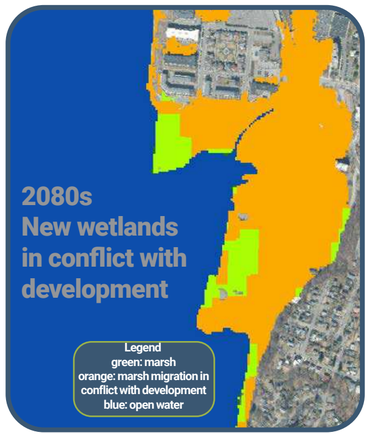
The Hudson River Comprehensive Restoration Plan was produced in 2018 by a consortium of non-profit organizations, public agencies, municipalities, and academic institutions. The plan includes an assessment of current conditions and sets goals for ecosystem restoration and community resilience.

Read the 2020 State of the Hudson for up-to-date information on challenges the river faces and accomplishments in addressing them.

These images from Scenic Hudson's Sea-level Rise and Marsh Migration Mapper depict two different scenarios for future wetlands in Tarrytown.

The map on the left indicates the location and types of tidal wetlands that are projected as likely to exist in the 2080s under a high sea-level rise, medium sediment accretion scenario.

The map on the right indicates the potential area that could be covered in tidal marsh, based on topography, if the area was not developed.



Maps source: Scenic Hudson Sea-level Rise & Marsh Migration Mapper

Design Strategy References

Links to the references cited in the Design Strategy section of this document.

Design Strategy	Source	URL
Sustainable Shorelines	Managing Shore Zones for Ecological Benefits Guide	https://tinyurl.com/shorezones
	Statewide Shoreline Monitoring Framework	https://dos.ny.gov/statewide-shoreline-monitoring-framework
	NYSDEC Tidal Wetlands	https://www.dec.ny.gov/lands/4940.html
	Waterfront Edge Design Guidelines (WEDG)	http://wedg.waterfrontalliance.org/resources/#manual-and-guidelines
Resilient Roadways & Infrastructure	Hudson Estuary Culvert Prioritization Project	https://tinyurl.com/y4kywkok
	U.S. Climate Resilience Toolkit: Rebuilding Roadways to Maximize Resilience	https://toolkit.climate.gov/case-studies/rebuilding-roads-maximize-resilience
	NYSDEC Stream Crossings: Best Management Practices	https://www.dec.ny.gov/permits/49066.html
Resilient Waterfront Parks	Flood Resilience Handbook for Public Access Sites Along the Hudson	https://www.dec.ny.gov/lands/5088.html
	High Performing Landscape Guidelines: 21st Century Parks for NYC	tinyurl.com/NYCParksSustainableDesign
	Naturally Resilient Communities	nrcsolutions.org/
Sculpting the Landscape	Hudson River Habitat Restoration Plan	https://www.dec.ny.gov/lands/89455.html
	NYSDEC Environmental Permits	https://www.dec.ny.gov/permits/6081.html
	FEMA glossary – Fill	https://www.fema.gov/glossary/fill
	Protecting the Pathways	https://tinyurl.com/protectpathways
	Sustainable Shorelines Monitoring & Lessons Learned	https://tinyurl.com/hrnerr
Strategic Relocation & Adaptive Reuse	Climigration Network's Lead with Listening Guidbook	https://www.climigration.org/guidebook
	Adapting to Rising Waters Along the Hudson: Lessons from Piermont	https://www.cbi.org/article/piermont/
	NYS DOS Transfer of Development Rights Technical Bulletin	https://dos.ny.gov/system/files/documents/2023/01/transfer-of-development-rights.pdf
	FEMA BRIC	https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities

Funding Opportunities

State and federal agencies offer financial assistance to municipalities and non-profit organizations for activities building resilience to waterfront flooding, sea-level rise, and other climate risks.

Agency	Assistance Program	Grant amounts, required match	Municipal Planning	Resilient Structures	Emergency Management	Collaboration and Public Outreach	Waterfront Economy	Floodplain protection
Department of Environmental Conservation (DEC)	Hudson River Estuary Program (HREP)	$10,500-$50,000, 15% match	•	•			•	•
	Climate Smart Communities (CSC)	$10,000-$2M, 50% match	•	•				•
	Water Quality Improvements Program (WQIP)	25-60% match		•				•
	Trees for Tribs	N/A						•
Environmental Facilities Corporation (EFC)	Wastewater Infrastructure Engineering Planning	≤$100,000, 20% match	•	•				
	Clean Water Revolving Loan Fund	N/A	•	•				•
	Green Innovation Grant Program (GIGP)	10-60% match						•
Federal Emergency Management Agency (FEMA)	Hazard Mitigation Assistance (HMA)	Over $3M, 25% match	•	•				
	Public Assistance	N/A			•			
	Building Resilient Infrastructure and Communities (BRIC)			•		•		•
	Community Rating System (CRS)	N/A			•	•		
Department of State	Local Waterfront Revitalization Program (LWRP)	15-25% match	•	•		•		
Other	NYSERDA Clean Energy Communities	≤$150,000, no match	•	•		•		
	NYS Office of Parks, Recreation and Historic Preservation (OPRHP)	≤$500,000, 25-50% match					•	•
	US Housing and Urban Development (HUD)	$50,000 - $900,000, 0-5%	•	•			•	
	Empire State Development	80% match for soft costs		•			•	
	Hudson River Greenway	$5,000 - $10,000+					•	•
	NYS Council on the Arts (NYSCA)	N/A				•		

Relevant Climate Smart Community Actions

Get points and funding projects related to CaD concepts through the state's Climate Smart Communities certification program. See related actions below and learn more at: https://climatesmart.ny.gov/

Pledge Element 6: Reduce greenhouse gas emissions through use of climate-smart land-use tools

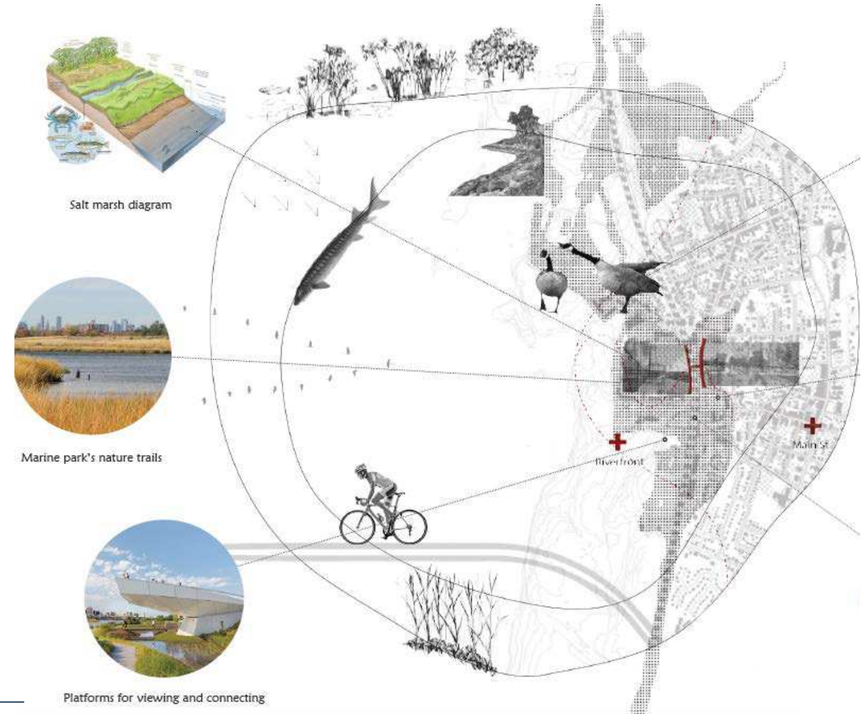
6.1	Develop and adopt a comprehensive plan with sustainability elements
6.2	Incorporate smart growth principles into land-use policies and regulations
6.3	Adopt a renewable energy ordinance
6.4	Implement the energy code building standard
6.5	Establish green building ordinance
6.6	Adopt land-use policies that support or incentivize farmers' markets, community gardens and urban and rural agriculture
6.7	Utilize NYSDOTs GreenLITES voluntary self-certification program for local transportation infrastructure projects
6.8	Adopt green parking lot standards
6.9	Plan strategies that support bicycling and walking
6.10	Implement strategies that support bicycling and walking
6.11	Adopt a complete streets policy
6.12	Install electric-vehicle infrastructure
6.13	Implement strategies that increase public transit ridership and alternative transport modes
6.14	Implement a Safe Routes to School program
6.15	Implement traffic calming measures
6.16	Develop a natural resource inventory
6.17	Develop a local forestry or tree planting project or program
6.18	Preserve natural areas through zoning or other regulations

Pledge Element 7: Plan for adaptation to unavoidable climate change

7.1	Conduct a vulnerability assessment
7.2	Review existing community plans, policies and projects to identify climate adaptation strategies and policies or projects that may decrease vulnerability
7.3	Develop climate adaptation strategies
7.4	Update the multi-hazard mitigation plan to address changing conditions and identify specific actions to reduce vulnerability to natural hazards
7.5	Develop and implement a heat emergency plan
7.6	Require shade structures and features in public spaces
7.7	Open new or expand existing cooling centers
7.8	Conserve natural areas for species migration and ecosystem resilience
7.9	Create or update a watershed assessment to identify flood mitigation priorities
7.10	Design elevation & flood maps
7.11	Freeboard policies
7.12	Use green infrastructure to manage stormwater in developed areas
7.13	Right-size bridges and culverts and remove unnecessary and hazardous dams
7.14	Revegetate riparian buffers
7.15	Facilitate a strategic relocation of uses that are not water dependent from flood prone areas
7.16	Use natural, nature-based or ecologically enhanced shoreline protection
7.17	Promote community flood prevention strategies through the National Flood Insurance Program Community Rating System
7.18	Create a watershed plan to protect water quality
7.19	Implement a source water protection program
7.20	Implement a water conservation and reuse program
7.21	Encourage xeriscaping

More Information on Climate Change in the Hudson River Valley

Websites	URL
Resources for resilience	tinyurl.com/resilienceres
Hudson River Sustainable Shorelines	hrnerr.org/hudson-river-sustainable-shorelines
Hudson Dynamic Shorelines StoryMap Collection	https://seagrant.sunysb.edu/Images/Uploads/PDFs/DynamicShorelines-Hudson.pdf
Adaptation Clearinghouse	adaptationclearinghouse.org/
NY Community Risk and Resiliency Act (CRRA)	www.dec.ny.gov/energy/102559.html
Estuary Program's Climate Resilience webpage	www.dec.ny.gov/lands/39786.html
NYS Climate Impacts Assessment	https://nysclimateimpacts.org/
CaD studio Designs fromr host communites	https://trophic.design/cad/
Interactive Maps	
Hudson River Flood Impact Decision Support System	www.ciesin.columbia.edu/hudson-river-flood-map/
Protecting the Pathways, Scenic Hudson	https://arcg.is/1jbXG4
Sea-level Rise Mapper, Scenic Hudson	scenichudson.org/slr/mapper
NYS Department of State Geographic Information Gateway	http://opdgig.dos.ny.gov/index.html#/map/resilience
Publications	
Financing waterfront resilience fact sheet	https://tinyurl.com/funding-resilience
Revitalizing Hudson Riverfronts, Scenic Hudson	https://scenichudson.org/wp-content/uploads/legacy/u2/revitalizing-hudson-riverfronts.pdf
2020 State of the Hudson Report	https://www.hudsonriver.org/state-of-the-estuary#report
Flood Adaptation Strategies for Hudson Riverfront Communities	www.slideshare.net/hrepclimate/flood-adaptation-strategies
Flood Resilience Handbook for Public Access Sites on the Hudson River	https://www.dec.ny.gov › lands › 5088.html
Hudson River Estuary Habitat Restoration Plan	https://www.dec.ny.gov/lands/89455.html
Hudson River Comprehensive Restoration Plan	http://thehudsonweshare.org/about-the-plan/
Videos	
Sustainable Shorelines	tinyurl.com/CSCvideoSS
Planning for Sea-level Rise	tinyurl.com/CSCvideoSLR
Climate-adaptive Design	tinyurl.com/CSCvideoCAD



Adaptation in Tarrytown
Xiaoyun Ren