Flooding and Erosion Basics

THE TIDAL HUDSON

The Hudson River is an estuary with two daily tides. Waterfront communities often sit at the lowest point of the watershed and are vulnerable to costly flood hazards from different sources that impact infrastructure, private property, and environmental health. The Hudson Valley will continue to experience more frequent and intense rain events as global temperatures rise and more moisture is available in the atmosphere. This, plus sea level rise, results in growing flood hazards for many waterfront communities.

Coastal flooding due to storm surge on December 23, 2022 inundates the Poughkeepsie waterfront at high tide. Credit: Europa McGovern via MyCoast NY.

FLOODS AND FLOODPLAINS

Flood: When water overflows onto land that is normally dry.

Floodplain: An area of land next to a river, stream, or estuary that is prone to flooding when the water levels are higher than normal.

Floodplains provide many benefits when preserved in their natural state or are restored to it. Land use practices that cover the land with **impervious materials**, such as buildings or asphalt, contribute to extra runoff by preventing infiltration into wetlands, underlying soils, and aquifers. Runoff is a major source of **water pollution** when it runs along the ground and picks up sediment, litter, petroleum, chemicals, fertilizers, and other toxic substances that can eventually end up in the Hudson River Estuary.

Natural floodplains can slow down water, reduce the number and severity of floods, minimize pollution by filtering runoff, and contribute to groundwater recharge by promoting infiltration.

MAIN CAUSES OF FLOODING

Flooding can occur anytime. The severity of a flood is influenced by factors such as weather conditions (e.g. rainfall intensity, storm track, the direction and intensity of wind), soil moisture, stream flow, elevated groundwater levels, soil frost depth, and snowpack before the event. Other factors include local topography, land cover, hydrology, and the way water is managed through urban drainage

MAIN CAUSES OF FLOODING, CONTINUED

systems, dams, berms, flood walls, and levees. Common drivers of flooding in waterfront communities are described below.

River flooding (aka fluvial flooding): Results from precipitation (rain or snowmelt) that can range from intense over a short amount of time to longer in duration. River flooding can occur along the Hudson or any of its tributaries, and can also occur when traditional flood-control structures, such as levees and dikes, are overtopped.

Surface flooding (aka runoff, sheet flow, or pluvial flooding): Occurs when water from a heavy precipitation event (rain or snowmelt) flows over the ground faster than it can infiltrate and/or overwhelms a stormwater management system.

Coastal flooding: Occurs in tidal waters from three main causes. All are increasing in frequency and severity due to sea level rise:

- High-tide flooding (aka sunny day flooding or nuisance flooding): Localized flooding that occurs in low-lying areas along the shoreline during a full or new moon at certain times of the year.
- Storm surge: When strong winds drive water onshore during severe storms such as hurricanes and nor'easters.
- Strong local winds create waves that drive water onshore.

Compound flooding (Figure 1) is when two or more flood drivers occur at the same time and amplify each other. Compound flooding is becoming more common as precipitation increases in frequency and intensity, sea level rises, and shorelines are developed. For example, communities that sit at the confluence of the Hudson River and a tributary may experience flooding driven from river, surface, and coastal flooding at the same time when storms that bring heavy rain, winds, and surge that coincide with high tide. For example, communities that sit at the confluence of the Hudson River and a tributary may experience flooding driven from river, surface, and coastal flooding at the same time when storms bring heavy rain, winds, and storm surge that coincides with high tide.

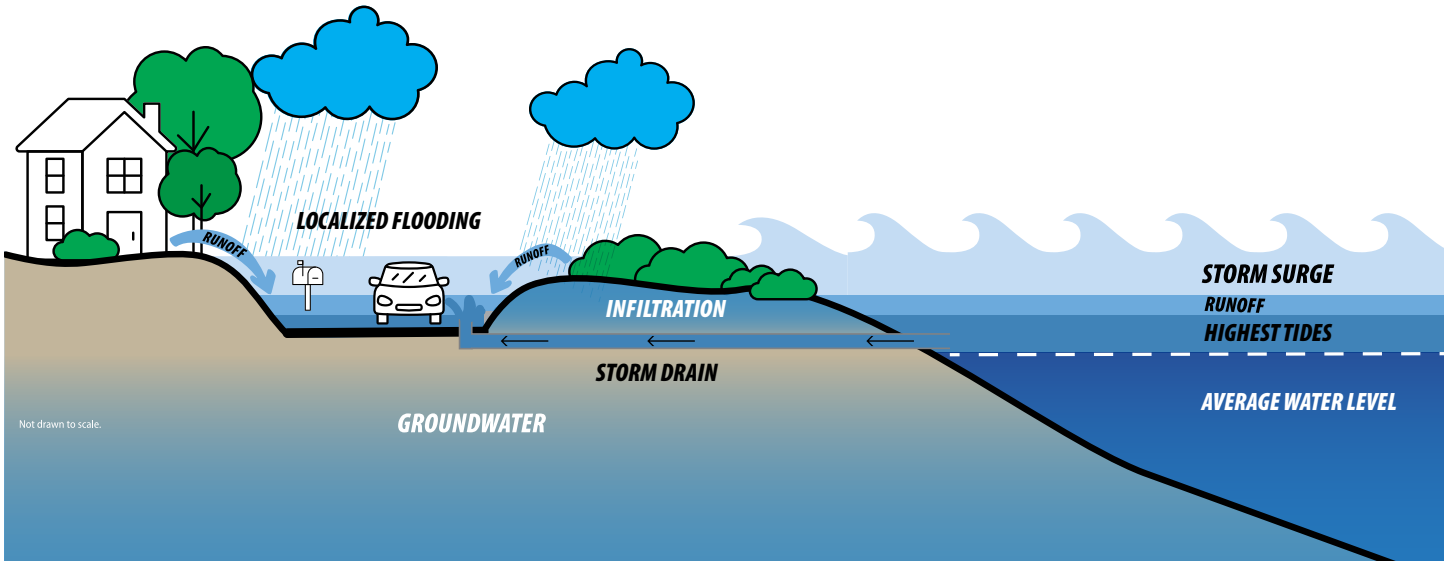

Figure 1: Compound Flooding. *In this example higher than average tides, runoff, and storm surge combine and compound to increase localized flooding. Other factors can amplify these main drivers: Coastal storm surge can flow up standard storm drain systems, preventing runoff from draining to the river or ocean and even allowing backflow from the surge to encroach further inland. This high tide backflow can even happen without rain, which are called nuisance or sunny day flood events. Impervious surface leads to increased runoff. High groundwater levels can reduce infiltration and contribute to runoff. Sea level rise is increasing the average water level over time, and climate change is contributing to more frequent and intense storms.*

EROSION

Sediment is always moving. If more sediment is removed from a shoreline by water, waves, and/or wind than is being deposited, erosion occurs. Hudson waterfront shorelines are shaped by (Figure 2):

Tidal and river currents: Currents running parallel to the shore, both from the ebb and flood of tides and downstream river flow can erode the shoreline. The floating debris it carries can also increase erosion. Fast-moving water has more energy that can move sediment more easily.

Waves: Local waves are dependent on local winds. A boat traveling through the water can also generate a wake, especially along navigation channels. High winds, typically from the south, in opposition to tidal and river currents, can also produce steep waves that cause erosion.

Ice: During the winter, typically December to March, rotating ice blocks can grind against the shoreline, impact the stability, and damage structures in the water, such as docks and bulkheads.

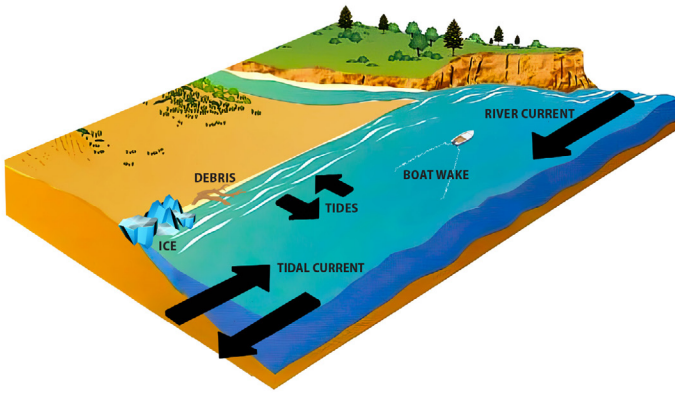

Figure 2: Erosive Forces: *There are several dynamic forces acting on the Hudson River estuary shoreline: tidal currents, river current, waves from wind and boat wake, and ice and debris grinding against the shoreline. This list is not exhaustive.*

Adjacent structures: Severe erosion can take place where a built structure meets the natural shoreline, such as at the end of a bulkhead. The reflection of the waves on the structure can cause erosion at both ends of the structure.

Storms & high tides: Storms and Sea Level Rise: Increased frequency of high water levels due to storms and higher high tides increases erosive forces along shorelines.

CHANGING WATERS

New York's climate is changing faster than national and global averages. River, surface, and coastal flooding are all increasing with changing precipitation patterns and sea level rise.

Precipitation: Warmer temperatures lead to more evaporation and precipitation. At the equator, this is the reason for the development of more frequent and intense hurricanes. Locally, in New York, this leads to heavier downpours that can overwhelm our storm water and drinking water infrastructure. Precipitation patterns are also becoming more variable, meaning not as predictable, and more extreme. There may be periods of intense rain followed by periods of drought.

Shifting Seasons: In New York, winters have warmed three times faster than summers. Warmer winter temperatures, with fewer days below freezing, are bringing more winter precipitation to New York as rain, less snow, reduced snow cover, and earlier spring snowmelt. The dynamic and complex nature of flooding will likely change in unexpected ways as shifting seasons impact wetlands, forests, native species, and soil function.

Flooding after heavy rain in Mamaroneck. Credit: Tadej Znidarcic via MyCoast NY.

Sea Level Rise: Sea level around the Hudson River Estuary has been rising since the end of the last Ice Age. Since the Industrial Revolution and the onset of increased burning of fossil fuels, sea levels have been rising at an accelerated pace. Sea level rise is both a natural process and is influenced by the actions of people, including increased greenhouse gas emissions. The main causes for global sea level rise (SLR) are melting ice sheets and glaciers and thermal expansion (molecules of warmer water take up more space). Regional factors that contribute to SLR in the Northeast and Hudson River Estuary are changing ocean circulation from a slowing of the Gulf Stream and land subsidence from rock type and soil compaction.

The water level at The Battery in Manhattan has risen more than 1 foot since 1900 and is accelerating.

- In the next 30 years, the Hudson River Estuary is expected to rise 1 - 2 ft.
- By 2100, the Hudson River Estuary is expected to rise 2 - 5 ft.

As sea level rises, more land will be inundated. In the next 30 years, low-lying Hudson River waterfront communities will experience **65 - 80 days** of high tide flooding per year.

FURTHER READING

Current and Changing Conditions

- "Chapter 2: Estuary Conditions: Understanding Tides, Salinity, Waves, Wakes, Ice, and Sea Level Rise." Flood Resilience Handbook for Public Access Sites Along the Hudson River (NYS DEC & NIEWPCC): bit.ly/FloodResilienceAccessHudson
- High Tide Flooding (NOAA): https://coast.noaa.gov/states/fast-facts/recurrent-tidal-flooding.html
- Ask the scientist: Extreme rainfall, why it happens and how we predict it (NOAA): https://www.noaa.gov/stories/ask-scientist-extreme-rainfall-why-it-happens-and-how-we-predict-it

Stormwater

- "Understanding Stormwater Inundation." Adapting Stormwater Management for Coast Floods website (NOAA): https://coast.noaa.gov/stormwater-floods/understand/
- Urban Flood Hazards: Challenges and Opportunities - Discussion Paper (ASFPM): bit.ly/ASFPMUrbanFloodHazardsPaper

Erosion Along the Tidal Hudson

- "When to Implement Sustainable Shorelines." Hudson River Sustainable Shorelines website: https://hrnerr.org/sustainable-shorelines/when-to-implement-sustainable-shorelines/

This fact sheet is a product resulting from Fiscal Years 2021-2022 Cooperative Technical Partners Program – Region 2 funded under award EMN-2021-CA-00012-S01 from the Federal Emergency Management Agency of the U.S. Department of Homeland Security to Cornell University on behalf of New York Sea Grant.

New York Sea Grant is part of a nationwide network of 34 university-based programs working with coastal communities through the National Oceanic Atmospheric Administration (NOAA). Sea Grant research and outreach programs promote better understanding, conservation, and use of America's coastal resources. Sea Grant is funded in New York through SUNY and Cornell University and federally through NOAA.

Jessica Kuonen
Hudson Estuary Resilience Specialist
jak546@cornell.edu

Sea Grant NEW YORK