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Understanding Compound Flood Hazards : An Interactive Online Web Application

U.S. Geological Survey New York Water Science Center

Introduction

Compound flooding is flooding that results from a co-occurrence of multiple flood drivers such as precipitation events (pluvial flooding, overland flow of stormwater), incidents of coastal storm surge and tidal flooding (coastal flooding), and flooding that occurs as a shallow water table rises above the land surface or critical infrastructure (groundwater emergence flooding). These flooding hazards have forced communities to reconsider the ways they plan and manage coastal development, as well as when and where they choose to make investments.

In 2021, the U.S. Geological Survey (USGS), in cooperation with U.S. Environmental Protection Agency (EPA) and Long Island Sound Partnership (LISP), began a spatial analysis (herein called the Compound Flood Hazard Study) to assess the compound flood hazard from the combined effects of 1) stormwater and a rising sea level on coastal storm surge, 2) tidal flooding and 3) groundwater flooding. In 2022, the USGS received supplemental funding for studies to "lessen or avert the threat of catastrophe" in New York State counties that had been affected by Hurricane Ida (The White House, 2021). The original study area, which only comprised watersheds in New York State, Connecticut, and Rhode Island that drain to Long Island Sound, was expanded to include New York City (excluding Staten Island) and all of Long Island

Study Objectives

- Develop gridded and high-resolution maps of potential flooding hazards, and factors contributing to rainfall (pluvial), coastal, and shallow groundwater emergence flood hazard
- Analyze frequency of flood driver co-occurrence (compounding), and estimate likelihood of future compound events
- Incorporate study results into a user-friendly interactive online web application that will allow stakeholders to compare the individual and compound flood hazards in areas of interest.

Study Area

Compound Flood Hazard – Hazard Associated with Co-occurrence of Multiple Flood Drivers

Rainfall

https://www.gettyimages.com/detail/news-photo/cars-sit-abandoned-on-the-flooded-major-deegan-expressway-news-photo/1337892826?adppopup=true

Groundwater Emergence Flooding

Groundwater study could reduce floods | | qchron.com

Coastal Storms

Storm brings some coastal flooding to New Jersey shore towns - 6abc Philadelphia

Coastal Nuisance Flooding

JamaicaBay-FloodWatch-streetflooding-1f.jpg (800×488) (suny.edu)

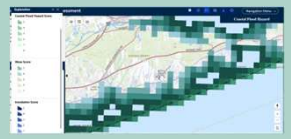
Question: Which type of flooding should I be concerned about in my area?

Overview of Tool

1- Launch page

2- Access Maps of Hazard Ranks and Supplemental Information

3- Search address zoom to location of interest



4- Explore hazard associated with different flood drivers

An interactive web application was developed to explore study results and assessment of compound flood hazard.

Summary

The USGS study explored the potential flooding hazard across the study area associated with coastal storm surge, precipitation events and shallow groundwater emergence. Historical data records were analyzed to evaluate how often these events co-occurred in the past, and how severity of flooding may increase when flood drivers co-occur.

- *Coastal Flood Hazard.* A statistical analysis of current and future flood hazards driven by coastal processes was completed using a combination of observations and global climate model (GCM) projections of water levels. An analysis of regional modeled wave conditions near the shoreline was included to better understand the spatial variability of the potential wave hazard. Results suggest that the future 25-year event (annual exceedance probability of 0.04, meaning there is a 4% chance of the storm occurring in a given year) is comparable to a current 100-year event (annual exceedance probability of 0.01 which has a 1% chance of occurring in a given year) (Cook and Herdman, 2025). This increased frequency in flooding could substantially affect communities and critical infrastructure.
- *Rainfall Flood Hazard.* Seven factors were evaluated for their role in assessing flood onsets from precipitation (curve number, drainage network density, topographic slope, closed depression or ponding fraction, 30-year average rainfall, and 1-hr and 24-hour 100-year return period rainfall accumulation). Curve number, which approximates the percent of rainfall that may runoff due to land cover characteristics, and ponding fraction were identified as being the most important factors in contributing to rainfall flooding. The highest relative exposure to rainfall flood hazards typically occurs in densely populated urban centers. Broader scale flooding is expected in locations where high hazard scores are clustered. Clustered areas of high hazard were identified in the boroughs of New York City, western Long Island, southern central Long Island, the south fork of eastern Long Island and northern New Haven County and southern Hartford County in Connecticut along the Connecticut River (Welk and others, 2025).
- *Groundwater.* Many studies of flood drivers either neglect or only briefly discuss how shallow groundwater conditions may contribute to or exacerbate flood conditions (Bosserelle and others, 2022). This study aimed to understand how groundwater emergence flooding may contribute to compound flood events. The groundwater emergence flood hazard, based on the depth to the water table and hydrologic soils distribution within the study area, is highest in coastal areas and near surface water where the groundwater is close to ground surface (Masterson and others, 2025). Inland areas away from surface water are less susceptible to a groundwater emergence flood hazard. The potential for groundwater emergence flooding is greatest over a large area in Queens County, southern Kings County, and much of coastal Connecticut. Land use in these areas is highly developed, and basements and other infrastructure below ground are susceptible to this type of flooding.
- *Compound, or Co-Occurring Flood Drivers.* An analysis of the co-occurrence of high precipitation, storm surge, and shallow groundwater depths was conducted to examine how compound hazard potential changes across the coastal areas of Long Island Sound and vicinity. This study harnessed daily precipitation, storm surge, and monthly groundwater data from multiple stations using measurements recorded over the past half century from weather stations, tidal gages, and groundwater observation wells. Results show that precipitation and coastal surge events occur together more frequently in the winter months, particularly across the southern portion of Long Island, N.Y., and across interior coastal Connecticut (Glas and others, 2025). The seasonal differences in compound flooding result from a higher frequency of coastal storm surge in the colder months of the year when Nor'easters (extratropical cyclones) are more common, and higher water table altitudes occur. Rainfall, coastal, groundwater emergence and compound flood hazard calculated for each grid cell (0–5, with 5 being highest hazard category).

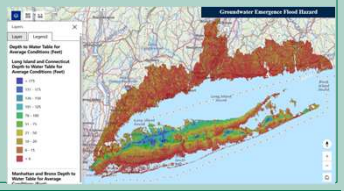
How might this information be applied?

Gridded map of compound flood hazard identifies locations with likelihood of co-occurrence of flood drivers and helps prioritize flood mitigation and management.

High resolution maps of flood influencing variables, such closed surface depressions (shown below), support drainage design and management.

Maps of coastal flood inundation inform planning and management decisions for coastal resiliency projects.

Depth to water table maps inform site selection for green infrastructure flood management projects or identify areas where subsurface infrastructure may be impacted by flooding.



Contact Information

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Related Publications

- Cook, S.E. and Herdman, L.M., 2025. Present and future coastal flooding hazard for Long Island, NY and Long Island Sound (NY/CT), USA. EarthArXiv. https://doi.org/10.31223/X5117Q
- Glas, R., Herdman, L., Cook, S., Howlader, A., and Masterson, K.: Hazard Potential of Compound Flooding from Rainfall, Storm Surge, and Groundwater in Coastal New York and Connecticut, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-5683, 2025.
- Masterson, K.K., Welk, R.J., Barclay J.R., Jahn, K.L.. Herdman, L.M. (2025). A Spatial Analysis of the Groundwater Emergence Flood Hazard in Long Island, New York and near Coastal Areas Surrounding Long Island Sound in New York, Connecticut, and Rhode Island.https://doi.org/10.31223/X5HB28
- Welk, R.J., Jahn, K.L.. Herdman, L.M., Glas, R.L., and Masterson, K.K. (2025). Assessing pluvial flood hazard potential using multi-criteria decision making and iterative ensemble smoothing in Long Island, New York and near coastal areas surrounding Long Island Sound in New York, Connecticut, and Rhode Island. EarthArXiv. https://doi.org/10.31223/X5074B

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