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

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Abstract

Long Island, New York and near coastal areas surrounding Long Island Sound are densely populated and, like other coastal areas, are susceptible to flooding from several potential sources, including stormwater from precipitation events, tidal flooding and storm surge, and groundwater inundation or groundwater emergence flooding. The latter refers to the intersection of a rising water table with land surface or critical infrastructure. Many studies of flood drivers either neglect or only briefly discuss how shallow groundwater conditions may contribute to or exacerbate flood conditions. As part of a comprehensive study of compound flood hazards in the near coastal areas surrounding Long Island and Long Island Sound, a spatial analysis was completed, in cooperation with the Environmental Protection Agency's Long Island Sound Study, using available regional datasets to characterize the potential hazard for groundwater emergence flooding.

The approximately 3,100 square mile study area was subdivided into 11,407 900-meter by 900-meter (approximately 3,000-feet by 3,000-feet) grid cells, for the purposes of integrating the spatial datasets to calculate and map the groundwater emergence flood hazard. The depth to the water table, hydrologic soil groups, and National Land Cover Database were harmonized to the common grid. A groundwater emergence flood hazard rank was calculated for each grid cell for current average conditions following a set of rules accounting for the depth to the water table and the percent of area within each cell with slow infiltrating soils. A higher sea level position scenario was also calculated for the Long Island part of the study area. The calculated groundwater emergence flood hazard rank was reviewed in concert with the National Land Cover Data Base to identify developed areas and associated infrastructure that may be at risk to groundwater emergence flooding.

Study results indicate that the groundwater emergence flood hazard is highest in coastal areas and near surface water where the water table is close to ground surface. Inland areas away from surface water bodies are not likely to be exposed to groundwater emergence flooding. For Long Island, under a scenario with higher sea level position, a greater groundwater emergence flood hazard is calculated in some locations closer to the coast and where land is submerged. Away from the coast and surface-water drainage, the groundwater emergence flood hazard is similar between the current average sea level condition and a higher sea level position scenario.

Introduction

There are over 23 million people living within 50 miles of Long Island Sound, which has about 600 miles of coastline. In 1985, the U.S. Congress created the Long Island Sound Study (LISS) in response to water-quality concerns and nitrogen contamination issues. LISS is a partnership of federal, state, and local government agencies, private organizations and educational institutions working together to restore and protect the Sound (LISS, 2025).

Historically, the focus of LISS has been on water-quality issues, but in 2015, a "Sustainable and Resilient Communities" theme was included as part of the revision of the Comprehensive Conservation and Management Plan (LISS, 2015). The goal of this theme is to "support vibrant, informed and engaged communities that use, appreciate and help protect the Sound." This theme reflects new challenges stemming from changing environmental and hydrologic conditions, such as flooding exacerbated by a rise in sea level and compound flooding. Compound flooding is flooding that results from a co-occurrence of multiple flood drivers: 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. Yet, many studies of flood drivers do not fully explore the effects of compound flooding, and either neglect or only briefly discuss how shallow groundwater conditions may contribute to or exacerbate flood conditions (Bosserelle and others, 2022).

In 2021, the U.S. Geological Survey (USGS), in cooperation with U.S. Environmental Protection Agency (EPA) and LISS, 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 U.S. Geological Survey 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. (Figure 1).

Purpose and Scope

The purpose of this report is to document a spatial analysis that was completed using selected regional datasets to evaluate where there is the potential for groundwater emergence flood hazard to occur or to exacerbate surface-flooding conditions. The U.S. Geological Survey describes a "hazard" as the physical process or condition that can do harm to things we care about as a society, as opposed to "risk" which is the potential loss of those things caused by the hazard (U.S. Geological Survey, 2024a).

The report provides a general overview of the hydrogeology within the study area and depth to the water table for average groundwater recharge and current average groundwater pumping conditions. Factors contributing to a groundwater emergence flood hazard, and regional spatial datasets that were used to evaluate this hazard, are described. Specifically, these datasets are depth to the water table and hydrologic soils maps. Once the groundwater emergence flood hazard was computed, the National Land Cover Database (NLCD) land cover product (Dewitz and U.S. Geological Survey, 2021) was used to identify developed locations that may be particularly susceptible to groundwater emergence flooding damage to basements and increased groundwater interaction with subsurface infrastructure.

The study area was subdivided into 11,407 900-meter by 900-meter (approximately 3,000-feet by 3,000-feet) grid cells for the purpose of integrating the spatial datasets to calculate and map the groundwater emergence flood hazard. The spacing of the grid (900-meters) was selected to accommodate harmonization of multiple datasets of different spatial resolution that were used in the Compound Flood Hazard Study to calculate the hazard ranks associated with groundwater emergence. Procedures for harmonizing the depth to the water table, hydrologic soil groups, and NLCD datasets to the common grid are presented, and rules for calculating a groundwater emergence flood hazard rank for each grid cell are described. Maps of the regional and gridded datasets, and the calculated groundwater emergence flood hazard ranks are presented. The report also includes a discussion of the limitations associated with the datasets used and the hazard rank calculation.

Hydrogeology

Watersheds located in the northern and western part of the study area in Rhode Island, Connecticut, and Westchester, Bronx and New York Counties in New York have a distinctly different hydrogeologic setting than the southern part of the study area (Long Island, New York, including Kings, Queens, Nassau, and Suffolk Counties). In the northern and western parts, unconsolidated glacial sediments that include both till and stratified drift overlie bedrock. Principal aquifers include valley-fill glacial aquifers, and crystalline and sandstone bedrock aquifers (Olcott, 1995). The unconsolidated glacial sediments overlying bedrock range in thickness from less than 5 feet to over 300 feet with thinner sediments in upland areas and thicker sediments in river valleys (Long Island Sound Resource Center and U.S. Geological Survey, 2004; Yager and others, 2018). Best available estimates of water withdrawals for drinking water, both public and private, and industrial uses from wells on the north shore of Long Island Sound (coastal Connecticut and adjacent areas of New York and Rhode Island) total about 60 million gallons per day (Mgal/d) from more than 150 public water and industrial well fields and thousands of private wells (Barclay and others, 2024a). In New York County and Bronx County, bedrock is generally close to land surface and overlain by till and stratified drift (DeMott and others, 2023). These deposits yield little water to wells and are not considered to be productive aquifers (Perlmutter and Arnow, 1953).

Unconsolidated deposits reach a maximum thickness of more than 2,000 feet beneath the south-central part of Long Island, New York (Stumm and others, 2024). These deposits comprise an aquifer system that is the sole source of drinking water to Long Island residents living in Nassau and Suffolk Counties. In 2019, about 390 Mgal/d of groundwater were withdrawn from 1,115 wells in these two counties (Walter and others, 2024).

Recharge from precipitation is the primary source of water to the aquifer systems in the study area (Barclay and others, 2024a; Walter and others, 2024). Groundwater in these aquifer systems discharges either to pumped wells or to fresh or saline surface waters. Groundwater levels vary spatially and temporally across the study area in response to precipitation patterns, groundwater withdrawals, and local hydrogeologic conditions which can include topography, sediment and bedrock properties, and hydrologic interactions with natural discharge points (streams and coastal waters) as well as subsurface infrastructure. The depth to the water table tends to be shallower in flat areas near surface-water bodies, and deeper in areas with locally higher land surface altitudes particularly where unconsolidated sediments are thicker and more permeable.

The U.S. Geological Survey, in cooperation with New York State and local agencies, systematically collects groundwater data at varying measurement frequencies to monitor the hydrologic conditions on Long Island, New York. Annual synoptic monitoring events have been used to developed maps for all or part of Long Island depicting depth to water table and potentiometric surface contours for 2006 (Monti and Busciolano, 2009), 2010 (Figure 1, Monti and others, 2013), 2013 (Como and others, 2015) and 2016 (Como and others, 2018).

The configuration of the water table on Long Island includes two east-west elongated groundwater mounds in central Nassau and Suffolk Counties that generally coincide with regions of higher land surface altitude and the glacial moraine deposits along the center of the island (Figure 1). Areas with localized high water table conditions also are present in northwestern Nassau County (Stumm and others, 2002) and the central part of the southern peninsula (south fork) of eastern Suffolk County (Schubert and others, 2004). Depth to saturated conditions is computed by subtracting the water table altitude from the land surface altitude. The most recent Long Island-wide synoptic groundwater level monitoring event was published in 2015 (Como and others, 2015) based on data collected in 2013. The depth to the water table from this survey ranged from 0 to greater than 250 feet below land surface.

In the northern part of the study area (Rhode Island; Connecticut; and Westchester Bronx, and New York Counties in New York), the depth to the water table ranges from 0 feet near wetlands to more than 30 feet in upland areas (Barclay and others, 2024a). Regional maps of water table altitude and depth to the water table derived from measurements at monitoring wells were not available for the northern and western part of the study area at the time of this publication.

Data Compilation and Analysis of Factors Contributing to Groundwater Emergence Flood Hazard

Groundwater emergence occurs when the water table rises above land surface. The Federal Emergency Management Agency (FEMA) Multi-Hazard Identification and Risk Assessment identified high water tables as a potential flooding hazard even if no surface flooding occurs (FEMA, 1997). For instance, shallow depths to the water table are a concern in both suburban residential settings and in highly developed urban areas with extensive subsurface infrastructure because of potential flooding damage to basements and increased groundwater interaction with subsurface infrastructure. Soils that infiltrate rainwater slowly (such as silt and clay) can exacerbate flooding in high water table areas because these areas may drain more slowly following a groundwater emergence flooding event as a result of reduced hydraulic conductivities under saturated conditions (Susilo and others, 2009).

Regional spatially continuous datasets were either created or extracted from existing data sources and mapped for the study area. The datasets were then integrated into the 11,407 900-meter by 900-meter (approximately 3,000-feet by 3,000-feet) grid cells to calculate and map the groundwater emergence flood hazard. A groundwater emergence flood hazard score or "rank" was calculated for each grid cell by considering the depth to groundwater and the presence of hydrologic soil groups that infiltrate more slowly (silt and clay).

Depth to Water Table

A single map of the depth to the water table is not available for the entire study area; therefore, a regional map of current average depth to the water table was assembled using the results of the following studies and data collection efforts:

- Simulated water table altitudes for average hydrologic conditions from the groundwater flow model developed for the Connecticut watersheds on the north shore of Long Island Sound (Barclay and others, 2024a,b); hereafter, referenced as the "Connecticut groundwater flow model." The model used average monthly recharge from water years 2005 through 2022, as estimated from a Soil-Water Balance model (Holland and Barclay, 2024) and was calibrated to average monthly conditions from water years 1993 through 2022. A water year is a 12-month period from October 1 through the following September 30 and is named for the calendar year in which it ends. The model output dataset was used to map the depth to the water table for study watersheds in Rhode Island, Connecticut, and Westchester County and part of Bronx County watersheds in New York. In the Connecticut groundwater flow model, current average conditions are represented using long term (2005-2022) average groundwater recharge and 2020 industrial and public water supply pumping rates.

- Simulated water table altitudes for average annual 2010-2019 pumping and groundwater recharge conditions were obtained from the Long Island regional aquifer system groundwater flow model (Walter and others, 2024; Jahn and others, 2024). The model output dataset was used to map the depth to groundwater for Kings, Queens, Nassau, and Suffolk Counties of Long Island, New York. For the Long Island regional aquifer system, current average conditions are represented using average groundwater recharge and groundwater pumping for the period 2010-19.
- Groundwater level records for the period 2004 – 2015 obtained from the U.S. Geological Survey National Water Information System (NWIS) database (U.S. Geological Survey, 2024b) for wells in New York and Bronx Counties, an area that is not included in the domains of the groundwater flow models referenced above.

Although the model simulations and datasets described above represent average conditions for different periods, there is sufficient overlap in the periods (years) such that the combination of these datasets can be used to develop a reasonable regional representation of depth to water for current average conditions.

A geographic information system (GIS) was used to create a map of the water table altitude using the results of the Connecticut groundwater flow model (Barclay and others, 2024a) and the Long Island Regional aquifer system groundwater flow model (Walter and others, 2024). Both models were constructed using a horizontal grid resolution of 500 feet per side, and the vertical coordinate information for both groundwater flow models is referenced to the North American Vertical Datum of 1988 (NAVD 88). The water table altitude map was constructed from the model simulation results through linear interpolation between model grid centroids.

The land-surface altitude was obtained from U.S. Geological Survey National Map 3DEP Downloadable Data Collection 1/3rd arc-second Digital Elevation Model (DEM; U.S. Geological Survey, 2023). The DEM was derived primarily from 7.5-minute elevation data for the conterminous United States and supplemented with lidar (Light Detection and Ranging) and aerial photography (U.S. Geological Survey, 2023). The datum for land-surface altitude is NAVD 88 with one-third arc-second, approximately 10-meter, resolution. The interpolated surface of water table altitude developed from the Connecticut groundwater flow model (Barclay and others, 2024a) and the Long Island Regional aquifer system groundwater flow model (Walter and others, 2024) was subtracted from the topographic altitude at the same location to create a map of depth to the water table (Figure 2a).

Water level data from groundwater monitoring wells in New York and Bronx Counties were used to supplement the depth to water table contours for the part of the study area outside the Connecticut groundwater flow model and the Long Island Regional aquifer system groundwater flow model domains. The U.S. Geological Survey NWIS database (U.S. Geological Survey, 2024b) was filtered to identify shallow wells (up to 100 feet depth) in New York and Bronx Counties that had more than 10 measurements with periods of record spanning more than one year. Twelve wells screened in unconsolidated deposits or shallow bedrock under assumed unconfined conditions in New York and Bronx Counties (Figure 1) were identified as meeting these criteria with measurements spanning years 2004 through 2015. Average depth to water level was calculated for each well based on its respective record (Table 1). Water table altitude contours were not drawn given the range of well depths and different periods of record; instead, zones representing depth to water ranges in New York and southern Bronx counties were included in a map of the depth to water table (Figure 2a).

An additional depth to water table map was created for the Long Island regional aquifer system (Kings, Queens, Nassau and Suffolk Counties) using simulated water table altitudes for a scenario with average annual 2010-2019 pumping and groundwater recharge and a sea level position of 6 ft above NAVD 88 as an alternative to the baseline sea level of 0.34 ft above NAVD 88 (Walter and others, 2024). The depth to water table was calculated and mapped (Figure 3a) following the methods described above for the Connecticut groundwater flow model and the Long Island regional aquifer system groundwater flow model. Some coastal areas, particularly along the south shore of Long Island, are predicted to be submerged (shown as pink in Figure 3a) because of the higher simulated sea level position; therefore, a depth to the water table is not presented for these locations.

The depth to the water table under current average conditions ranges from less than 6 feet to greater than 200 feet. The depth to the water table on Long Island is less than 10 feet along the coast and near surface-water bodies (Figure 2a). The depth to the water table away from the coastline generally increases and is deepest in the northwestern part of Long Island. Shallower depths (less than 10 feet) to the water table are present along the coastline and surface-water bodies in the study area north of Long Island Sound (Westchester County, New York; Connecticut; and Rhode Island). The depth to the water table increases to approximately 20 feet in parts of these watersheds north of Long Island Sound. The average depth to water table in 2010 of New York County and Bronx County outside the Long Island Sound watershed, estimated from well records in New York County, ranges between about 7 to 27 feet below land surface (Table 1).

The depth to the water table for a Long Island scenario with an alternate sea level position of 6 feet above NAVD 88 (Figure 3a) is similar to current average conditions (Figure 2a) in locations adjacent to the coast in areas with surface water drainages. These coastal areas are characterized by a dense network of streams and wetlands that receive groundwater discharge and therefore constrain increases in the water table altitudes (Walter and others, 2024). However, model simulation results indicate that groundwater discharge to streams in these locations is greater in the higher sea level scenario than under current average conditions (Bayraktar and others, 2024), potentially exacerbating flood conditions in these areas.

A shallow depth to the water table is a concern in both suburban residential settings and in highly developed urban areas with extensive subsurface infrastructure because of potential flooding damage to basements as well as increased likelihood of groundwater interaction with subsurface infrastructure such as sewer, septic, and water distribution systems. The depth of residential and urban infrastructure can vary depending on location and nature of infrastructure as indicated by these examples:

- Typical residential basement depths can range from about 6 to 10 feet (Conestoga-Rovers and Associates, 2007; New Jersey Department of Environmental Protection, 2021).
- In New York State, typical onsite residential septic tanks are designed at depths 6 to 7 feet below ground surface (New York State Department of Health Bureau of Water Supply Protection, 2012).
- National average sewer depths are 3 to 6.5 feet below land surface (U.S. Environmental Protection Agency, 2002), and in New York City, sewers were typically constructed at depths of about 13 feet below land surface (New York State Chamber of Commerce, 2012).

- The minimum depth for the excavation for a subway tunnel was 18 feet (New York State Chamber of Commerce, 2012). The deepest subway stations in New York City are constructed at depths greater than 100 feet (Young, 2013).

Hydrologic Soil Groups

Soils are classified by the Natural Resource Conservation Service into hydrologic soil groups based on the soil infiltration rate and stormwater runoff potential (Peaslee, 2020). A regional hydrologic soil group dataset made available through the Natural Resources Conservation Service Soil Data Development Toolbox extension in ArcMap (Peaslee, 2020) was used to identify areas in the study area where fine-grained soils are present. These areas may drain more slowly during precipitation events (Westenbroek and others, 2010) and under groundwater emergence flooding conditions, which can potentially extend periods of flooding.

Soils in group A have the highest infiltration rate (greater than 0.30 inches per hour) and consist mostly of sandy soils, whereas soils in group D have the lowest infiltration rate (less than 0.05 inches per hour) and consist mostly of clayey soil (Natural Resources Conservation Service, 2019). Wet soils, whether saturated from antecedent conditions or where the water table is close to land surface, may also infiltrate more slowly. Soils under these conditions may be assigned a combined category such as A/D, B/D, C/D or D/D where the infiltration potential is low unless soils are drained (Ross and others, 2018).

Soils in group A, which are sandy soils, are most common on Long Island in Nassau and Suffolk Counties, whereas soils in group B, loamy till soils with 10-20% clay, are most common in Kings and Queens Counties (Finkelstein and others, 2022) (Figure 4a). In the northern part of the study area (Rhode Island; Connecticut; and Westchester, Bronx, and New York Counties in New York), loamy till soils of group B are most common (Figure 4a). Western Connecticut and Westchester County have substantial secondary areas of groups C, which are clay till soils, and D, which are fine silt and clay soils; eastern Connecticut and Rhode Island have substantial secondary areas of group A soils (Soil Survey Staff, 2022). The dual categories A/D, B/D, C/D or D/D are classified in areas in Rhode Island, Connecticut, and Westchester and Bronx Counties in New York.

National Land Cover Database

Land use categories, as defined in the 2019 NLCD (Dewitz and U.S. Geological Survey, 2021) were mapped for the study area (Figure 5a). Areas classified as "developed" in the study area grid include NLCD classifications of "Developed, Low Intensity", "Developed, Medium Intensity", and "Developed, High Intensity" and likely have basements and/or subterranean urban infrastructure that are susceptible to flooding if the depth to groundwater is shallow. The percentage of developed area in each grid cell (Figure 5b) was calculated by overlying the study area grid on the map of NLCD land use and determining the percent of each cell as any of the three developed NLCD classifications.

Calculation of Groundwater Emergence Flood Hazard Rank

The depth to water table, hydrologic soil groups, and NLCD dataset were harmonized to the common 900-meter by 900-meter grid as follows:

- The grid was overlain on the depth to water table maps presented in Figure 2a and 3a, and the minimum depth to water table value within each cell was identified and selected for the cell

(Figures 2b and 3b). Using the minimum depth to water table provides a more sensitive indicator of potential groundwater emergence flood hazard than the mean or median depth.

- The grid was overlain on the map of hydrologic soil groups (Figure 4a) and the percent of the grid cell area comprised of hydrologic soil groups B (moderately low runoff potential, 10-20 percent clay), C (moderately high runoff potential, 20-40 percent clay), and D (high runoff potential, greater than 40 percent clay) was calculated for each grid cell (Figure 4b). The presence of hydrologic soil group B was included because of the clay content which could contribute to slower drainage.

Once the regional datasets described above were harmonized to the grid, groundwater emergence flood hazard ranks were calculated for the study area for current average conditions (Figure 6) and for the Long Island regional aquifer system under a simulated sea level scenario 6 feet above NAVD 88 (Figure 7) following the rules presented in Table 2. Locations with depths to the water table less than 6 feet were deemed to be most susceptible to a groundwater emergence flood hazard, especially in areas where slowly infiltrating soils are present. These locations were assigned the highest groundwater emergence flood hazard ranks (rank = 5). The occurrence of a groundwater emergence flood hazard is less likely in locations where the depth to the water table is greater than 15 feet.

The groundwater emergence flood hazard under current average conditions (Figure 6) is highest in coastal areas, and near surface water where the water table is close to the land surface. Inland areas, away from surface water bodies have little or no exposure to groundwater emergence flooding hazard. A large part of the study area is comprised of land cover classified as developed (Figure 5b). The highest groundwater emergence hazard ranks were calculated for developed urban areas in Kings and Queens County in New York and New Haven and New London in Connecticut. These developed areas are likely to have a higher density of basements and subsurface urban infrastructure; as such, the risk of groundwater flooding is greater in more highly developed areas.

The high groundwater emergence flood hazard ranks calculated for western Kings County indicate that previous concerns about a rising water table causing damage to building foundations and flooding basements (Rosenzweig and others, 2024; Soren, 1976) are warranted. High groundwater emergence flood hazard ranks were also calculated for inland areas located close to surface water bodies, such as the Nissequogue River, Lake Ronkonkoma and the Peconic River on Long Island, New York. An elevated water table and residential basement flooding have been reported in neighborhoods near Nissequogue River and Lake Ronkonkoma (Suffolk County, 2023). In the Peconic River watershed in eastern Long Island, areas adjacent to stream channels are subject to groundwater emergence conditions and become flooded during high-stage conditions as the water table rises above the streambanks (Schubert and others, 2006). In New Haven, CT, Yale University has indicated concerns that alternate coastal water level altitudes and increased precipitation, and concurrent rising groundwater levels may result in increased flooding of basements, and seepage into underground sewer pipes, utility corridors, and other subsurface infrastructure (Bjerklie and others, 2012).

The hazard ranks along the northern coastline of Long Island, New York tend to be lower than those calculated along the southern Connecticut coast or the southern Long Island coast. Coastal areas along the north shore of Long Island generally are characterized by steep topography and greater depths to the water table. Topography generally is flatter along the south shore of Long Island, and the water table is closer to land surface. The presence of hydrologic soil groups B, C and D in Connecticut and western Long

Island also contribute to higher groundwater emergence flood hazard ranks because these soils drain more slowly.

A second calculation of groundwater emergence flood hazard was performed for Long Island for a simulated sea level position of 6 feet above NAVD 88 following the same set of rules (Figure 7). As a result of the higher simulated sea level position, some of the coastal areas, particularly along the south shore of Long Island, are submerged (shown as pink in Figure 7). A minimum depth to the water table was not assigned to grid cells in these areas, and a groundwater emergence flood hazard rank was not calculated. Groundwater emergence flood hazard ranks are similar between the current average condition and higher sea level position scenario away from the coast; however, the hazard rank is higher in some areas adjacent to the submerged cells for the higher sea level position scenario.

Limitations of Analysis

Several limitations and potential uncertainties should be considered when using the results of this spatial analysis of groundwater emergence flood hazard. Use of regional datasets and a uniform grid ensures consistent foundational data and methods for estimating the potential groundwater emergence flood hazard. A limitation of this analysis approach, however, is that local-scale features and characteristics are not well represented when aggregated to a larger 900-meter by 900-meter area. As such, the potential groundwater emergence flood hazard may be misrepresented where local characteristics play a large role in groundwater emergence flooding.

A single depth to water table map is not available for the entire study area; therefore, a map of depth to the water table for the study area was assembled using the results of separate groundwater modeling studies in Connecticut and New York. The groundwater model simulations in these studies represent average conditions over different periods of time that are assumed to represent current average conditions, and do not represent the full range of potential water table fluctuations that occur in response to monthly and seasonal variations in groundwater recharge and pumping. In areas with shallow depths to the water table, such as near the coast or surface waters, the potential groundwater emergence hazard may be underestimated if the seasonal high-water table is very different from the average condition.

In Bronx and New York Counties outside the respective groundwater flow model domains, the depth to groundwater was estimated by taking the average of water level measurements at a limited number of wells, which may not fully represent conditions in intervening areas between well locations. Finally, the analysis does not consider the potential effect of perched water zones, locally saturated sediments located above the regional water table, on groundwater emergence flooding.

Summary

The U.S. Geological Survey, in cooperation with U.S. Environmental Protection Agency and Long Island Sound Study, began a study in 2021 to assess compound flood hazard from the combined effects of stormwater and changing coastal water level altitudes on coastal storm surge, tidal and groundwater emergence flooding in the Long Island Sound watershed in Connecticut and New York. In 2022, the U.S. Geological Survey 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). With the additional funding, the project study area was expanded to include New York City (excluding Staten Island) and all of Long Island. Regional spatially continuous datasets were either created or extracted from existing data sources and mapped for the study area. The land area within study area was subdivided into 11,407 900-meter by 900-meter (approximately 3,000-feet by 3,000-feet) grid cells for the purposes of integrating spatial datasets to calculate and map groundwater emergence flood hazard and harmonizing the spatial datasets to the common grid. Groundwater emergence flood hazard ranks were calculated for each grid cell for current average conditions and for the Long Island regional aquifer system under a simulated sea level scenario 6 feet above NAVD 88, taking into account the depth to water table and the presence of soils such as silt and clay which infiltrate more slowly. The calculated groundwater emergence flood hazard rank was reviewed in concert with the National Land Cover Data Base to identify developed areas that may be particularly susceptible to groundwater emergence flooding damage to basements and increased groundwater interaction with subsurface infrastructure.

The groundwater emergence flood hazard within the study area is highest in coastal areas and near surface water where the groundwater is close to ground surface. Inland areas away from surface water are less susceptible to a groundwater emergence flood hazard. The highest hazard ranks were calculated over a large area in Queens County, southern Kings County, and much of coastal Connecticut. These areas are also highly developed. On Long Island, New York, groundwater emergence flood hazard ranks are similar between the current average condition and higher sea level position scenario away from the coast; however, in some areas adjacent to the submerged cells, the groundwater emergence flood hazard rank for the higher sea level position scenario is higher.

Several limitations and potential uncertainty should be considered when using the results of this analysis of groundwater emergence flood hazard. Nonetheless, because many studies of flood drivers either neglect or only briefly discuss how shallow groundwater conditions may contribute to or exacerbate flood conditions during compound flood events, the analysis presented herein provides a reasonable approximation of locations in the study area that may experience a groundwater emergence flood hazard.

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Figures

Figure 1. Map showing study area, regional water table altitude contours for Long Island, New York (Monti and others, 2013), and selected monitoring well locations in New York and Bronx Counties, New York (U.S. Geological Survey, 2024b). Contours shown are referenced to the National Geodetic Vertical Datum of 1929. On Long Island, NAVD 88 is approximately 1 foot higher than NGVD 29 (Como and others, 2018).

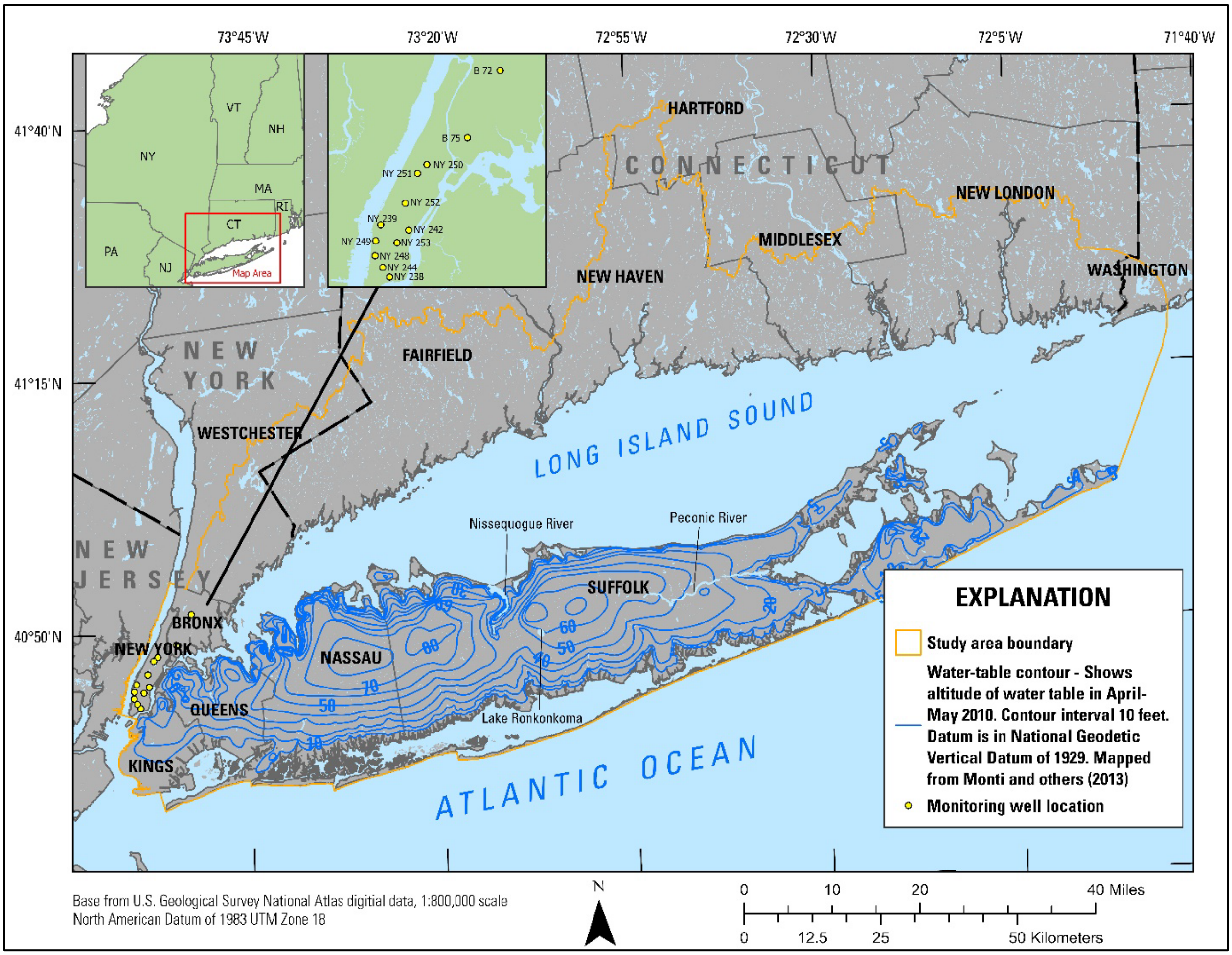


Figure 2a. Map showing depth to the water table in the study area as a digital elevation model of the depth to water table (Welk and others, 2025) developed from results presented in Walter and others (2024) and Barclay and others (2024a) and measurements at wells in New York and Bronx Counties.

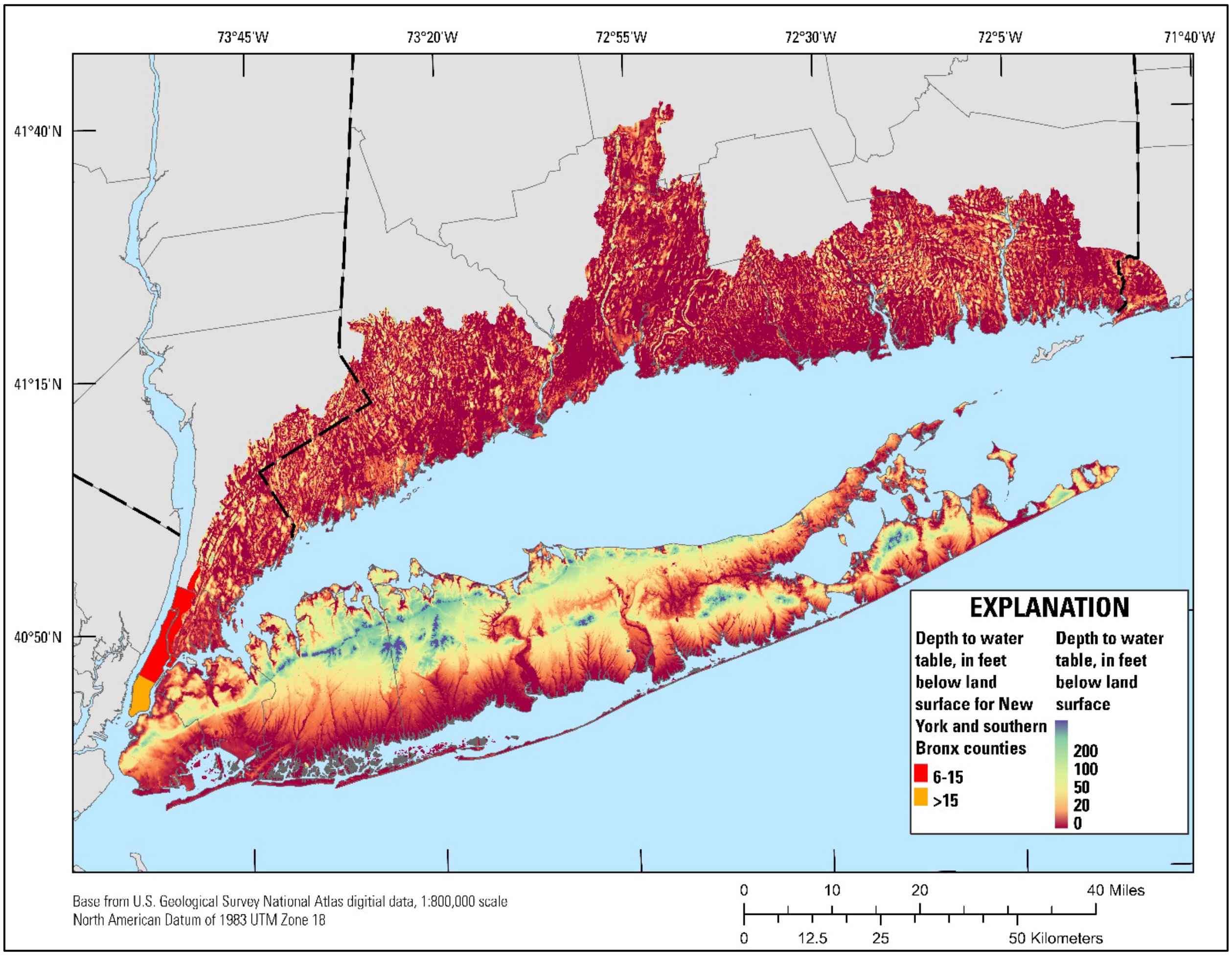


Figure 2b. Map showing depth to the water table in the study area aggregated to 900-meter by 900-meter grid cells (Welk and others, 2025).

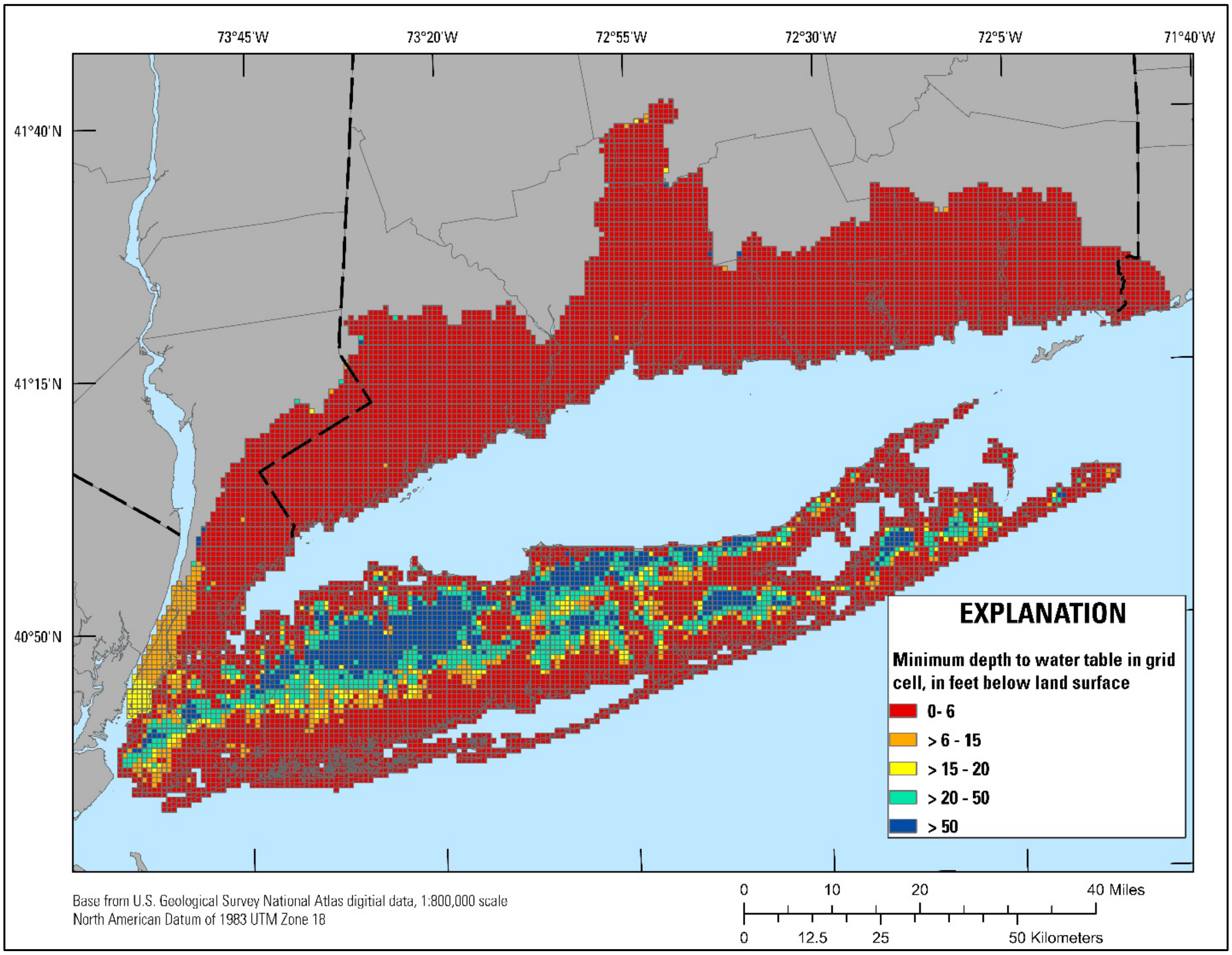


Figure 3a. Maps showing depth to the water table for Kings, Queens, Nassau and Suffolk Counties, New York for an alternate sea level position 6 feet above NAVD 88 based on groundwater flow model output as a digital elevation model of the depth to water table (Welk and others, 2025) developed from results presented in Walter and others (2024).

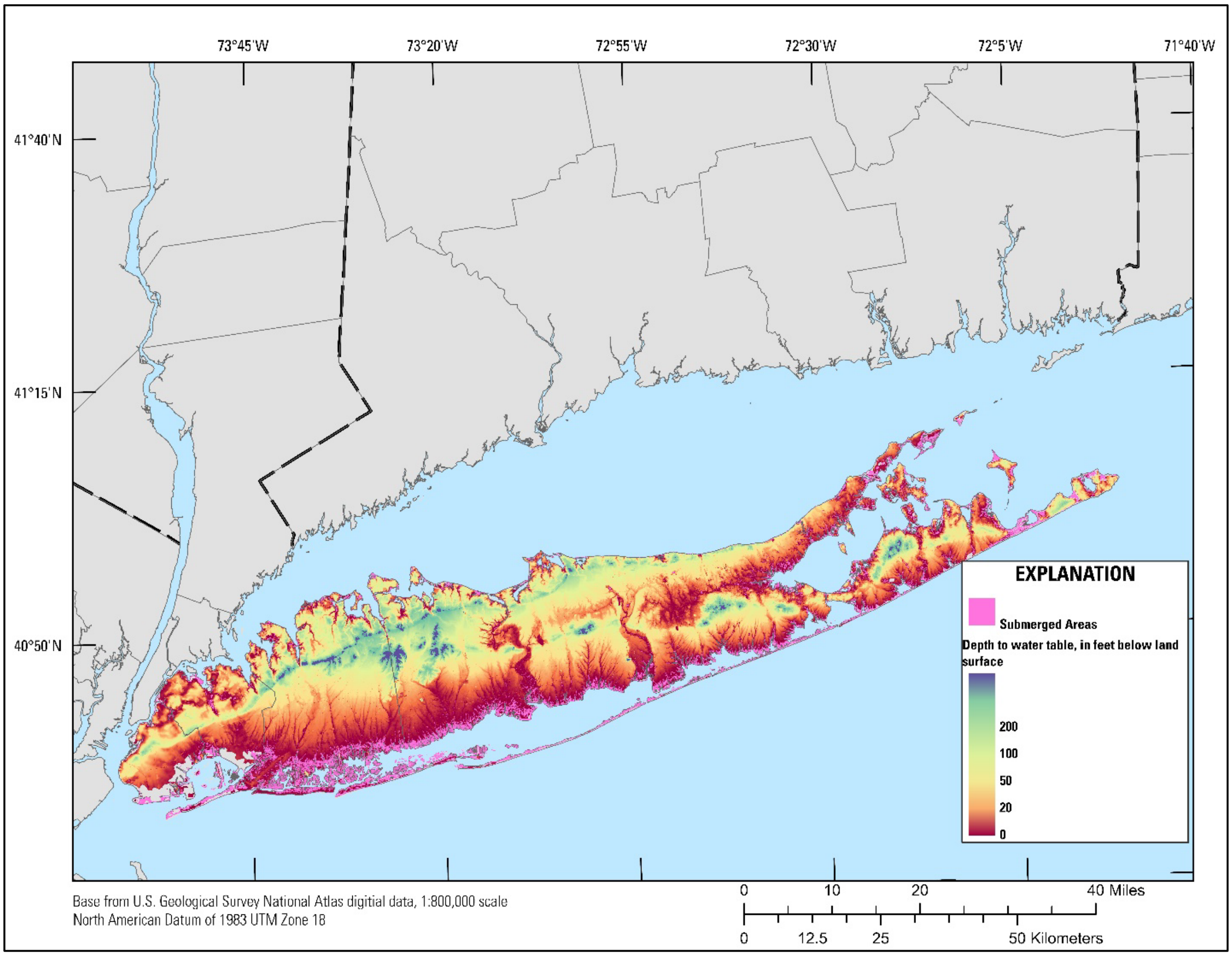


Figure 3b. Map showing depth to the water table for Kings, Queens, Nassau and Suffolk Counties, New York for an alternate sea level position 6 feet above NAVD 88 based on groundwater flow model output aggregated to 900-meter by 900-meter grid cells (Welk and others, 2025).

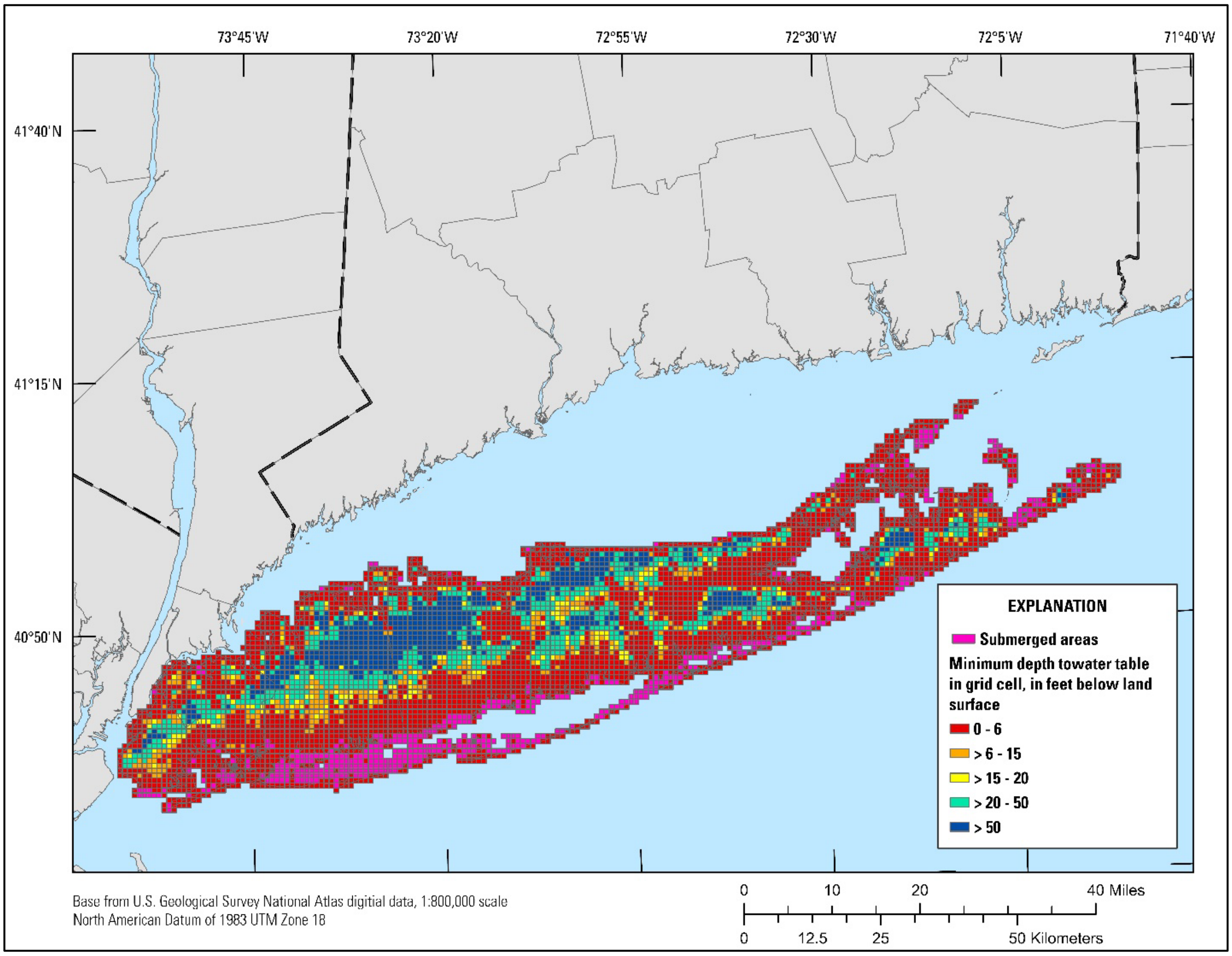


Figure 4a. Map showing Hydrologic Soil Groups in Long Island, New York and near coastal areas surrounding Long Island Sound in New York, Connecticut, and Rhode Island (Finkelstein 2022; Soil Survey Staff, 2022).

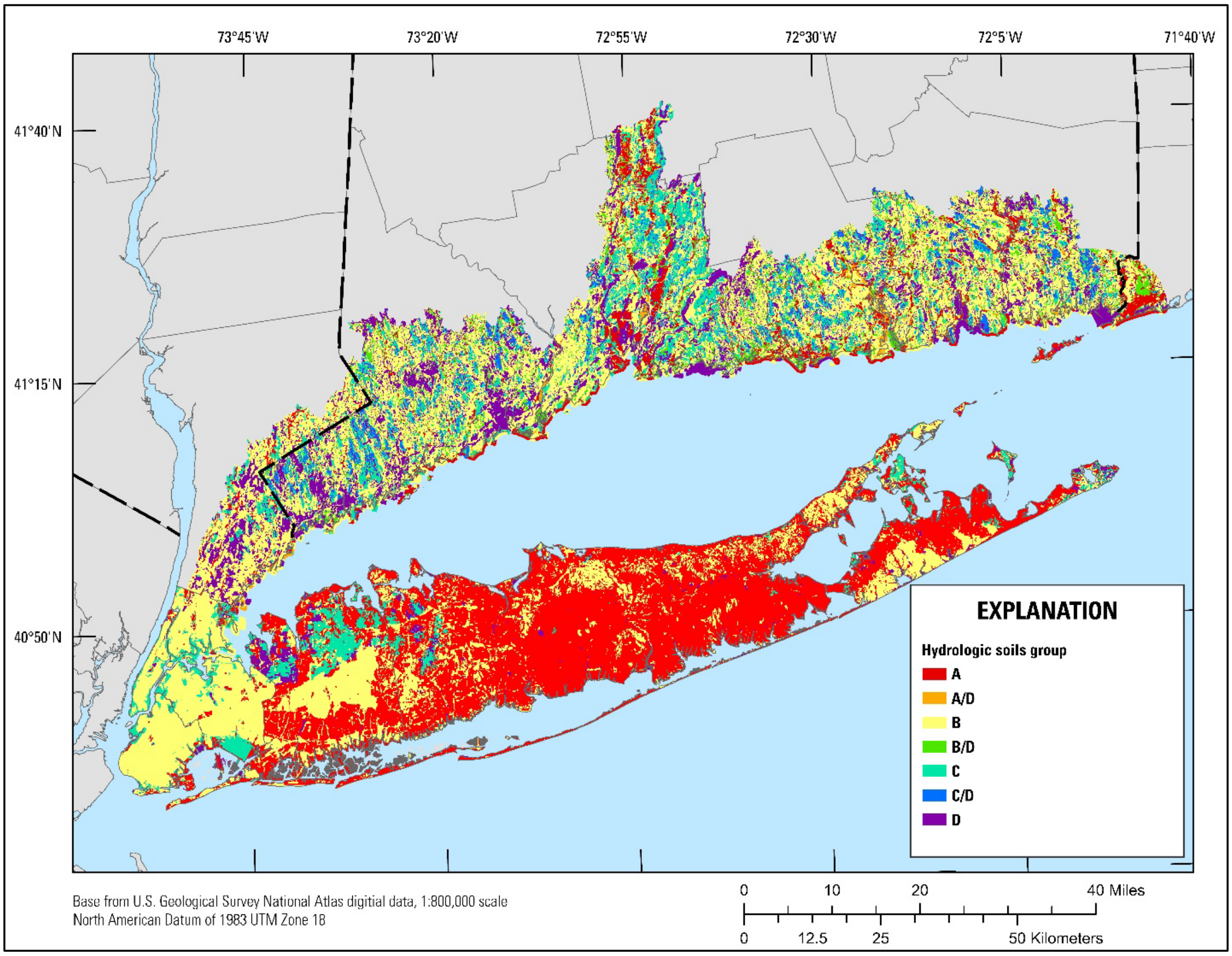


Figure 4b.	Map showing percent of 900-meter by 900-meter grid cell area containing hydrologic soil groups B, C and D (Welk and others, 2025).

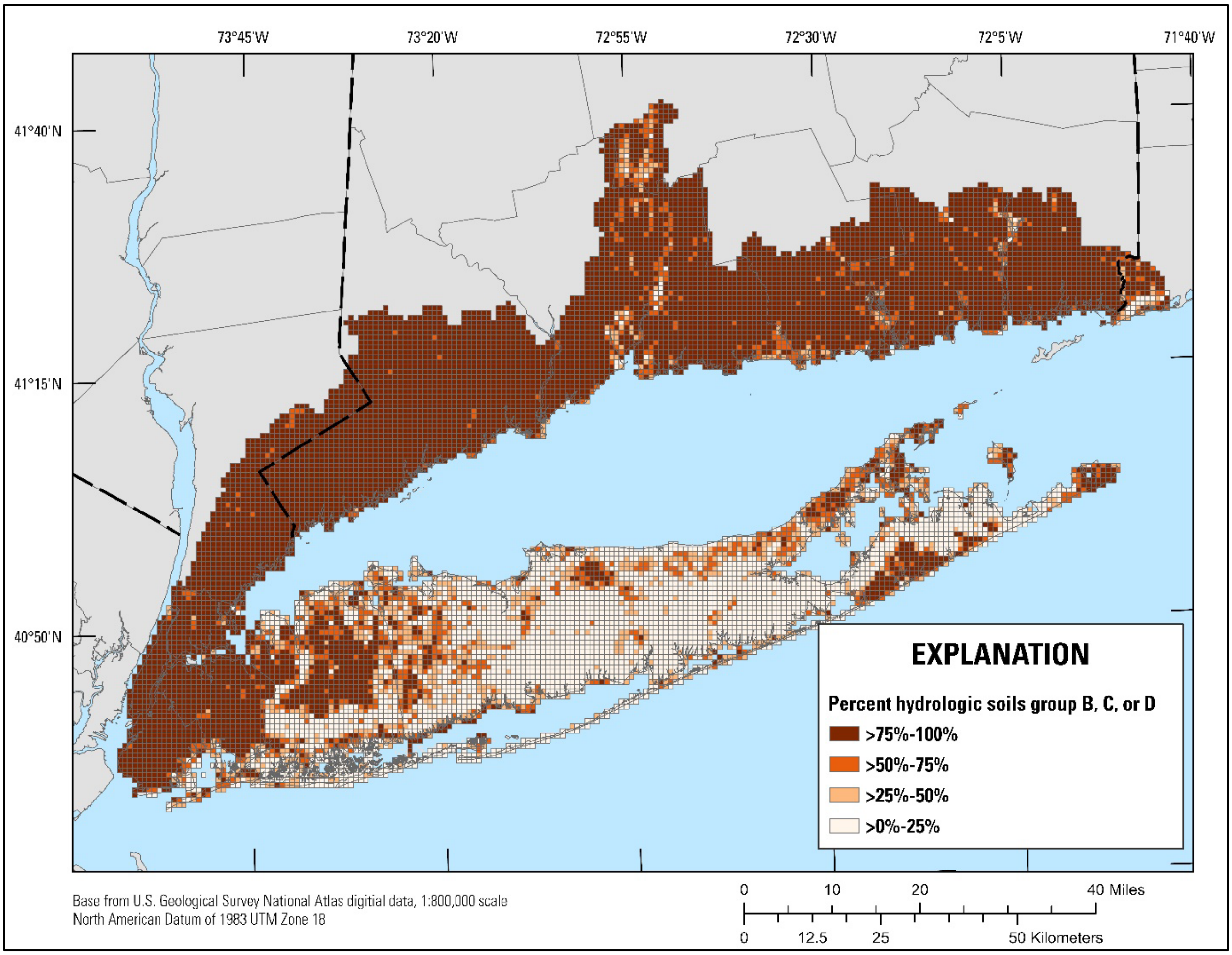


Figure 5a. Map showing 2019 National Land Cover Data (NLCD) classification descriptions for study area (Dewitz and U.S. Geological Survey, 2021).

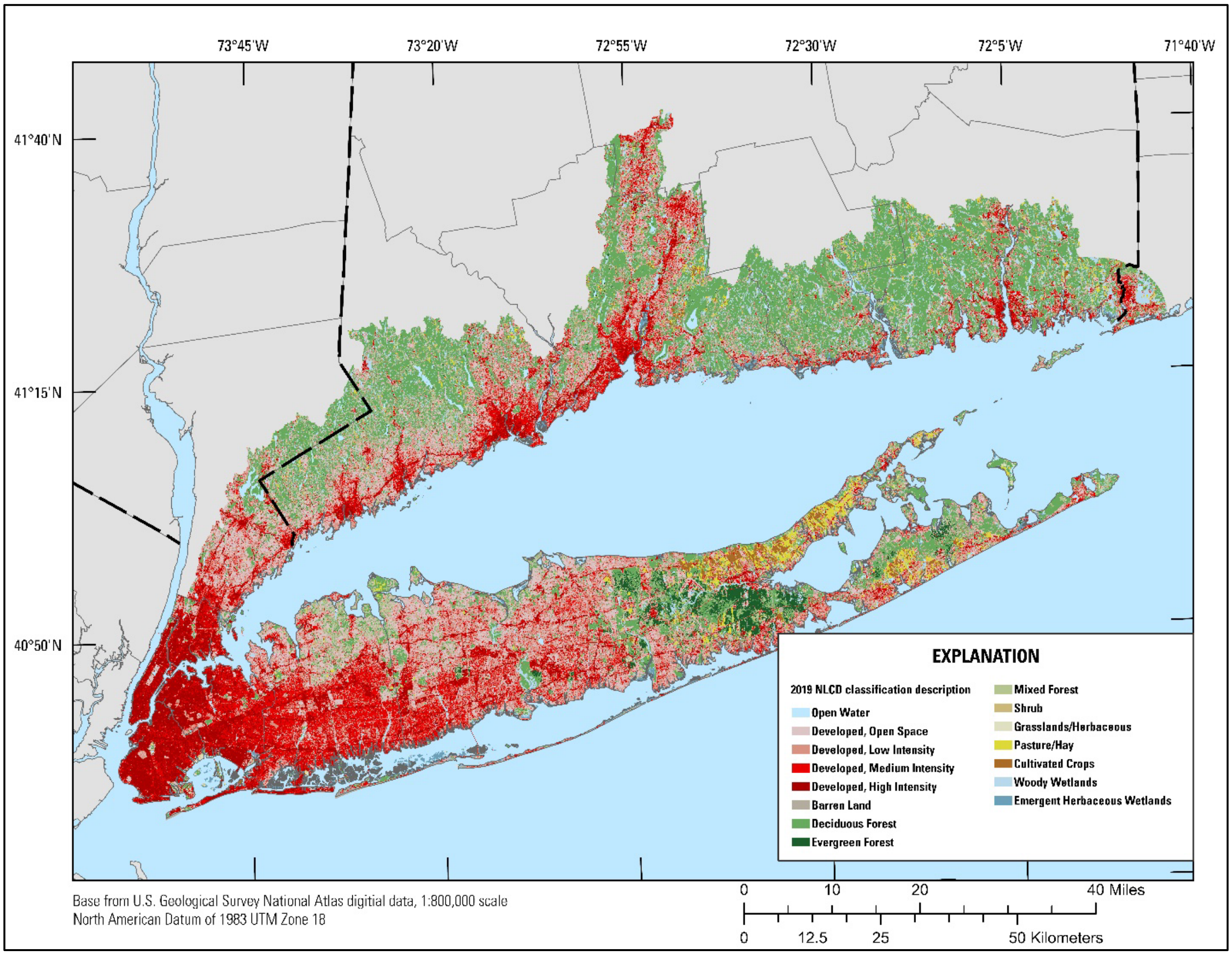


Figure 5b. Map showing percent of 900-meter by 900-meter grid cell area containing developed land cover (Welk and others, 2025).

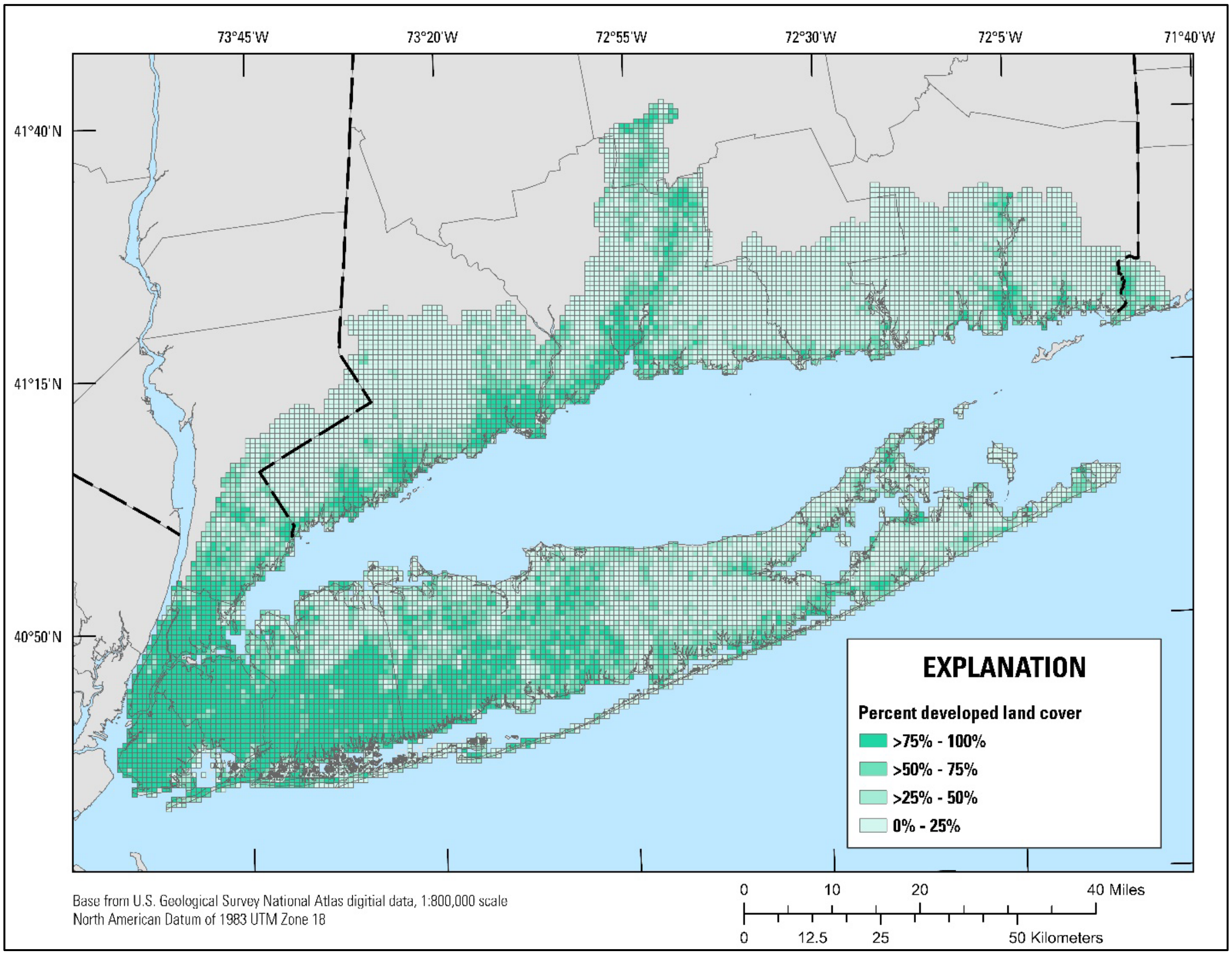


Figure 6. Map showing groundwater emergence flood hazard ranks for current average groundwater conditions for Long Island, New York and near coastal areas surrounding Long Island Sound in New York, Connecticut, and Rhode Island (Welk and others, 2025).

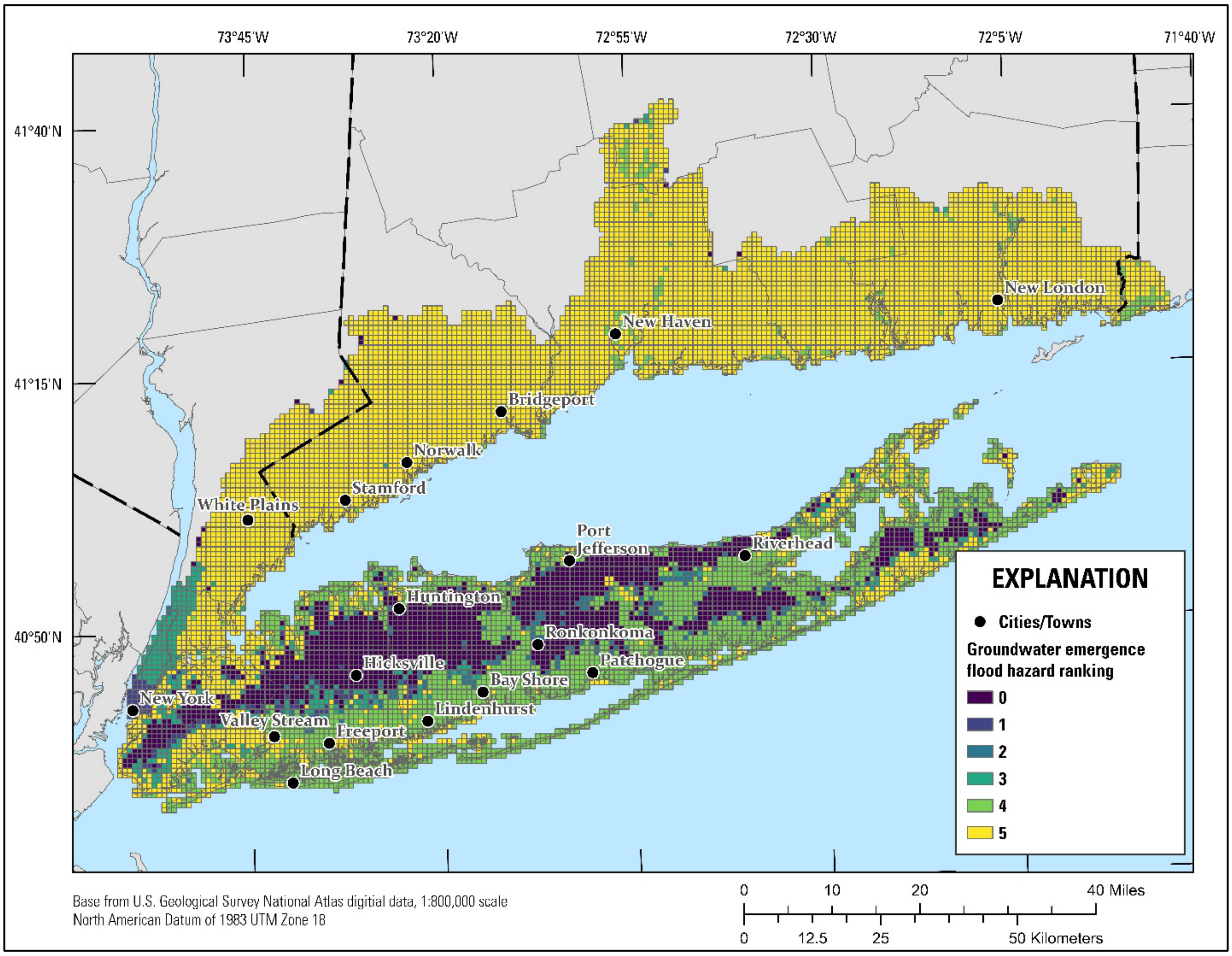
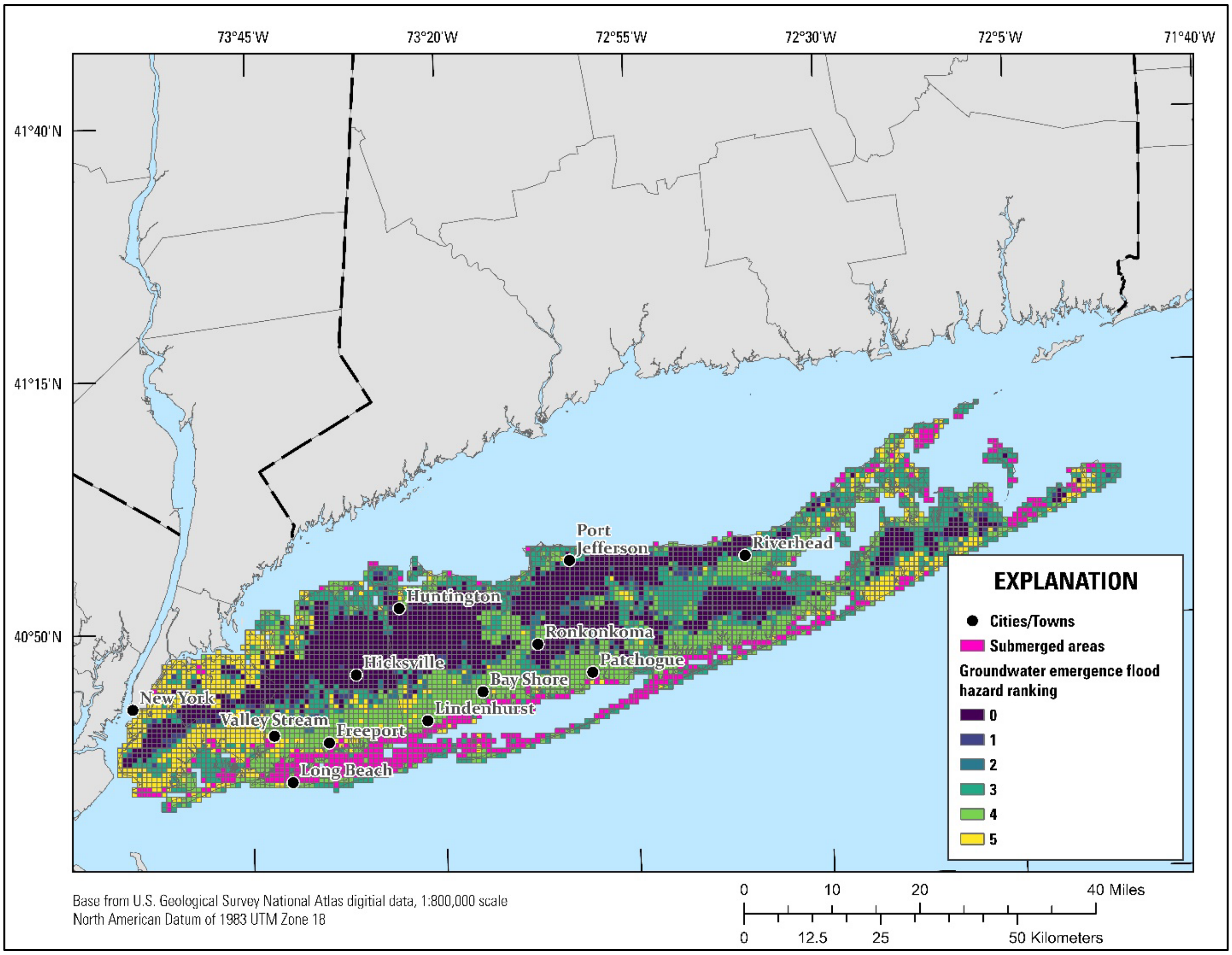


Figure 7. Map showing groundwater emergence flood hazard ranks for groundwater conditions with a sea level position of 6 feet above NAVD 88 for Long Island, New York (Welk and others, 2025).



Tables

Table 1. Details and average depth to water level at selected wells in New York and Bronx Counties, New York. Data are from U.S. Geological Survey (2024b).

Site Number	Station Name	Well Depth (feet)	Geology	Period of Record Start	Period of Record End	Number of Observations	Average Depth to water level, in feet below land surface
404606073583701	B 75. 1	25	Overburden	8/15/2006	4/14/2015	67	14.9
404419073590801	B 72. 1	39	Overburden	8/14/2006	4/14/2015	69	13.5
404246073593502	NY 238. 1	35	Overburden	10/13/2004	11/9/2007	22	27.4
404508074000501	NY 239. 1	42	Overburden	2/15/2004	4/22/2009	32	15.3
404452073582502	NY 242. 1	65	Overburden	1/7/2004	4/25/2013	76	20.3
404312073595902	NY 244. 1	67	Overburden	10/18/2004	4/25/2013	75	26.0
404344074002601	NY 248. 1	100	Overburden	10/27/2004	8/3/2012	59	19.1
404424074002301	NY 249. 1	30	Overburden	10/19/2004	4/18/2011	54	15.8
404750073571801	NY 250. 1	75	Bedrock	10/19/2005	4/25/2013	69	7.7
404727073575101	NY 251. 1	32	Bedrock	10/19/2005	4/25/2013	73	7.2
404606073583701	NY 252. 1	73	Bedrock	11/21/2005	4/25/2013	51	7.5
404419073590801	NY 253. 1	45	Overburden	7/10/2006	4/25/2013	56	18.6

Table 2. Rules for calculating groundwater emergence flood hazard ranks.

Groundwater Emergence Flood Hazard Rank	Depth to Groundwater (Feet)	Hydrologic Soil Group B C D Occurrence in Grid Cell
5	≤6	> 50%
4	≤6	≤ 50%
3	> 6 to 15	> 50%
2	> 6 to 15	≤ 50%
1	> 15	> 50%
0	> 15	≤ 50%