# Final Appendix H

# Geotechnical

# Rahway River Basin (Fluvial), New Jersey
# Flood Risk Management Findings Report

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**New Jersey Department of Environmental Protection**

**U.S. Army Corps of Engineers New York District**

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## 1.0 INTRODUCTION

This Feasibility Study is the second phase of the U.S. Army Corps of Engineers planning process, and as part of this study, geologic research was conducted to determine the subsurface conditions of each project location. Bedrock and surficial geology maps from the New Jersey Geological and Water Survey were reviewed and based on this information; preliminary recommendations were developed. This appendix presents the results of the study.

## 2.0 WATERSHED DESCRIPTION

The Rahway River is located within portions of Essex, Union and Middlesex Counties in New Jersey. Its headwaters are located in West Orange and its mouth is between Carteret and Linden, where it terminates at the Arthur Kill. A map of the Rahway River basin is shown in Figure 1.


**Figure 1. Municipalities within the Rahway River Basin**

The bedrock geology underlying the Rahway River generally consists of red shales and sandstones of the Brunswick formation. Surficial soils generally consist of material deposited during the Wisconsin glacial epoch. The thickness of the surficial soils ranges from 0 to over 70 feet with an average of approximately 30 feet.

## 3.0 PROJECT AREA

The project addresses the following locations along the Rahway River:

- Existing Dam in Mountain Reservation, Millburn
- Essex Street Bridge, Millburn
- Oakland Road Bridge, Maplewood
- West Branch Channel, Millburn
- East Branch Channel, Millburn
- Nomahegan Park, Cranford

Project locations toward the north and south are shown in Figure 2A and Figure 2B, respectively. Figure 2C shows all proposed features within the Rahway Fluvial project area for Alternative 3 – Combination Plan.

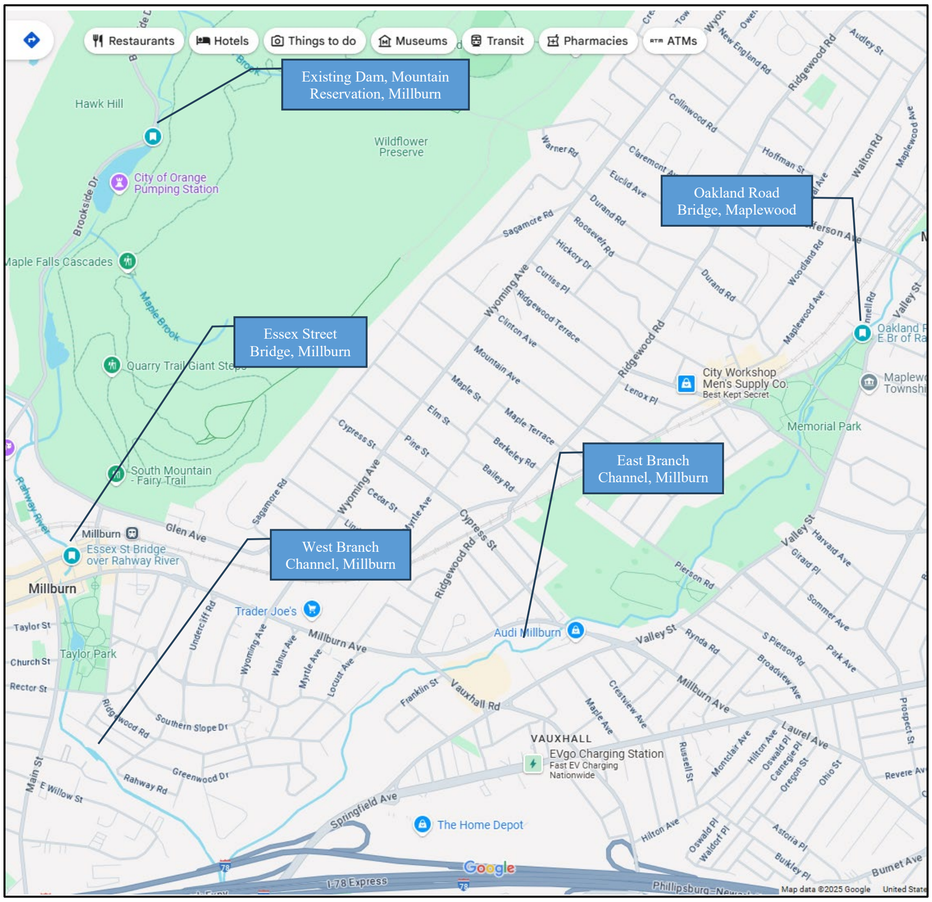


**Figure 2A. Northern Project Locations, Milburn and Maplewood, NJ**

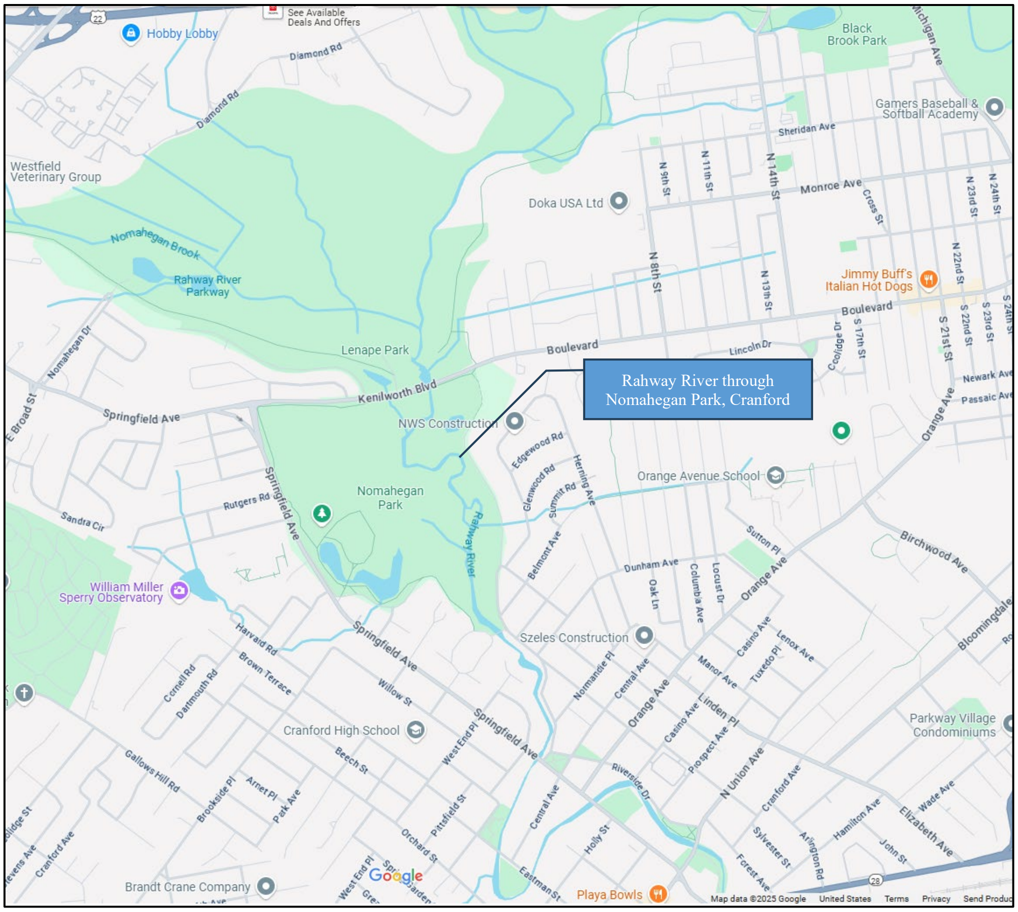


**Figure 2B. Southern Project Location, Cranford, NJ**

# 4.0 PRELIMINARY PROJECT LOCATION RECOMMENDATIONS

## 4.1 Dam in South Mountain Reservation, Millburn

The surficial geology in this area is mapped as be a thin Rahway till (Qt or Qtt) with scattered rock outcrops (r), Alluvium (Qal), and Till of the Terminal Moraine (Qtm) as shown in Figure 3. The Rahway till consists of silty sand, sandy silt, and sand with some gravel, cobbles, and boulders. The Alluvium consist mainly of silt, sand, clay and minor pebble-to-cobble gravel with variable amounts of organic matter. The Till of the Terminal Moraine consist mainly of the same material as the Rahway Till, but generally thicker and with discontinuous beds of sand and gravel. The bedrock geology is mapped primarily as Basalt (Jo) with the Feltville formation nearby. The Feltville formation consists of sedimentary rocks ranging from coarse grained sandstone to silty mudstone. An excerpt of the bedrock geology map is presented in Figure 4.

At this location, we understand an earthen embankment dam with a spillway to the east and a box culvert through the center is planned. Because of the geological conditions, it is likely that the spillway could be constructed directly on basalt bedrock with a bearing capacity of at least 8 tons per square foot (tsf), assuming highly weathered rock is not encountered. Based on the geometry provided, it is likely that some amount of rock excavation will be required.

The dam itself will also likely be able to be supported directly on bedrock from the east side up to about mid-channel. Further the west, the geology changes – the bedrock becomes deeper and softer (sedimentary rock instead of basalt) and the soil more permeable and less dense. Considering that, it will likely be infeasible to construct the dam's foundation directly on bedrock. Instead, it will probably be necessary to support the dam on a deep foundation with some sort of a cutoff mechanism (secant pile wall, slurry wall, etc.). It may also be possible to perform some sort of ground improvement (e.g., jet grouting, deep soil mixing, etc.), in lieu of deep foundations, on the west side of the dam to increase bearing capacity and reduce permeability.

If the culvert is positioned strategically, to account for the depth to rock, it too may be able to be supported directly on bedrock. If it is not possible to position the culvert strategically, rock excavation would likely be needed if positioned toward the east. Over excavation of soil would likely be necessary to reach bedrock if positioned slightly toward the west. If positioned further west, a deep foundation with cutoff wall or soil improvement may be needed.

## 4.2 Essex Street Bridge Modification/Reconstruction in Millburn

The mapped surficial material, as shown in Figure 5, consists of "Rahway Outwash" (Qrw) which is a Glacial River deposit associated with the draining of Glacial Lake Woodbridge. This material consists of stratified layers of sand, gravely sand and gravel and cobble mixtures and is mapped to be as much as 20 ft thick. A cross section in the surficial geology map near the site shows the Qrw material overly one or more of several other formations (Qwblb, Qwbf, Qt, and Qwb) which range in composition from stratified silt, fine sand, and clay to sand and gravel, to glacial till comprised of sandy silt or silty sand with some gravel and cobbles and a smaller number of boulders with occasional beds of sand or gravel. Considering the cross section and the fact that the depth to bedrock is greater than the thickness of the Qrw material, it is likely that there are intermediate materials similar to those shown in the cross section at the site.

The mapped bedrock at the site, as shown in Figure 6, consists of Orange Mountain Basalt near the border with the Passaic Formation, which consists of interbedded sedimentary rock grading from sandstone to mudstone. Sandstone is generally harder than mudstone, but in this formation, the sandstone layers are relatively thin while the finer grained layers (siltstone, mudstone, etc.) tend to be thicker. A cross section in the bedrock geology map near the site shows the basalt as a thinning layer overlying the Passaic formation as it approaches the boundary with it, so it is possible there is only a relatively thin layer of basalt. The mapped depth to bedrock is approximately 30 ft +/- 10 ft.

Based on the above, it is likely that a new bridge constructed on a shallow foundation may experience some degree of consolidation settlement, if significant amounts of the Qwblb material is found beneath the Qrw material. It is also possible that the Qrw material may be susceptible to scour, depending on the relative proportions of sand, gravel, and cobbles as well as the river velocity in the area. Because of these facts, any new bridge foundation would most likely need to be pile supported.

We would likely recommend that bridge support piles be driven to bedrock since bedrock is relatively shallow. If piles need to be installed adjacent to existing structures, we would likely recommend drilled-in instead of driven piles such as drilled shafts or micropiles. A thorough geotechnical investigation, including soil borings, laboratory tests, and in-situ tests should be performed prior to making a decision of the pile foundations instead of shallow foundation.

### 4.3 Oakland Road Bridge Modification/Reconstruction in Maplewood

As shown in Figure 7, the mapped surficial material consists of "East Branch Outwash" (Qeb) which is a Glacial River deposit associated with the draining of Glacial Lake Woodbridge. This material consists of stratified layers of sand and gravel and cobble mixtures and is mapped to be as much as 40 ft thick. Considering the likely depth to bedrock and the mapped thickness of this material, it is possible or even likely that it extends to, or nearly to, bedrock. Unfortunately, there are no nearby cross sections on the surficial geology map to confirm this.

The bedrock, as shown in Figure 8, consists of the Passaic Formation, which is comprised of interbedded sedimentary rock grading from sandstone to mudstone. Sandstone is generally harder than mudstone, but in this formation, the sandstone layers are relatively thin while the finer grained layers (siltstone, mudstone, etc.) tend to be thicker. Because the site bedrock is mapped in a bedrock valley, there is some uncertainty associated with the bedrock elevation. It is likely the depth to bedrock is 20 ft +/- 10 ft., but it is possible that rock may be as deep as 60 ft.

Based on the above, the Qeb material may be susceptible to scour, depending on the relative proportions of sand, gravel, and cobbles as well as the river velocity in the area. Because of this, new bridge foundations may need to be pile supported. If bedrock is within the shallowest end of the range of depths discussed above, it is possible that the bridge foundations could be constructed as shallow foundations bearing directly on bedrock. If this is the case, the bearing capacity of the rock would likely be in the range of 8 to 20 tsf, depending on the type and quality of rock present.

If the bridge requires pile support, we would likely recommend that the piles be driven to bedrock, since bedrock is relatively shallow. If piles need to be installed adjacent to existing structures, we would likely recommend drilled-in piles, instead of driven piles, such as drilled shafts or micropiles.

### 4.4 West Branch Channel Modification in Millburn

As shown in Figure 9, the mapped, surficial material consists mostly of "Rahway Outwash" (Qrw) with smaller portions of the project areas consisting of Glacial Lake Woodbridge Deltaic Sand

(Qwb). The Qrw material is a Glacial River deposit associated with the draining of Glacial Lake Woodbridge which consists of stratified layers of sand, gravel and sand, and gravel and cobble mixtures and is mapped to be as much as 40 ft thick. The Qwb material also consists of sand, sand and gravel, and gravel and cobble mixtures and is mapped to be as much as 90 ft thick. A nearby cross section in the surficial geology map near the site shows both of these materials overly one or more of several other formations which range in composition from stratified silt, fine sand, and clay (Qwblb), to sand and gravel (Qwbf), to glacial till (Qt) comprised of sandy silt or silty sand with some gravel and cobbles and a smaller number of boulders with occasional beds of sand or gravel. Considering the variable depth to bedrock and variable conditions in the cross section, it is likely that intermediate materials, similar to those shown in the cross section, are present at some portions of the project area, but not at others.

As shown in Figure 10, bedrock conditions consist of Orange Mountain Basalt to the north and the Passaic Formation to the south. The Passaic Formation consists of interbedded sedimentary rock grading from sandstone to mudstone. Sandstone is generally harder than mudstone, but in this formation, the sandstone layers are relatively thin while the finer grained layers (siltstone, mudstone, etc.) tend to be thicker. The mapped depth to bedrock at the norther and southern ends of the project area are approximately 15 ft and 60 ft respectively, both about +/- 10 ft. The bedrock appears to be sloping fairly evenly from north to south.

Based on the above, the Qrw and Qwb materials may be susceptible to scour, depending on the relative proportions of sand, gravel, and cobbles as well as the river velocity in the area. Because of this, scour countermeasures may be necessary. However, if the coarser proportions of these materials are encountered at the proposed riverbed elevation, it is possible that the naturally occurring gravel and cobbles may provide natural scour protection. Once the composition of the actual soils present at the site has been determined, a scour assessment must be conducted to determine scour susceptibility.

### 4.5 East Branch Channel Modification

As shown in Figure 11, the mapped surficial material along the northern two thirds of the project area consists of "East Branch Outwash" (Qeb) with the remainder consisting of Alluvium (Qal). The Qeb material consists of sand, gravel, and cobbles mapped to be as much as 40 ft thick. The

Qal material consists of silt, sand, and clay with small amounts of gravel and cobbles and is mapped to be generally less than 10 ft thick. A nearby cross section in the surficial geology map near the site shows the both of these materials overly one or more of several other formations which range in composition from stratified silt, fine sand, and clay (Qwblb), to sand and gravel (Qwbf), to glacial till (Qt) comprised of sandy silt or silty sand with some gravel and cobbles and a smaller number of boulders with occasional beds of sand or gravel. Considering the depth to bedrock is greater than the mapped thicknesses of both of these materials, it is likely that intermediate materials, similar to those shown in the cross section, are present throughout most of the project area.

The bedrock, as shown in Figure 12, at the project area is comprised of the Passaic Formation which consists of interbedded sedimentary rock grading from sandstone to mudstone. Sandstone is generally harder than mudstone, but in this formation, the sandstone layers are relatively thin while the finer grained layers (siltstone, mudstone, etc.) tend to be thicker. The mapped depth to bedrock at the norther and southern ends of the project area are approximately 50 ft and 65 ft respectively, both about +/- 10 ft. The depth to bedrock appears to be fairly consistent in the northern half of the project, then slopes toward the southern end.

Based on the above, the Qrw and Qal materials may be susceptible to scour, depending on the relative proportions of sand, silt, clay, gravel, and cobbles as well as the river velocity in the area. If this is the case, scour countermeasures may be necessary. However, if the coarser proportions of the Qeb materials or a substantial layer of clay of the Qal are encountered at the proposed riverbed elevation, it is possible there could be some natural scour protection.

### 4.6 Levees and possible floodwalls in the area of Nomahegan Park in Cranford

The mapped bedrock materials are uniform throughout the area while the surficial conditions vary. The most common surficial material present in this area, as shown in Figure 13, consists of glacial lake bottom soils associated with Glacial Lake Woodbridge (Qwblb). This material consists of silt, fine sand, and clay and is mapped to be as much as 90 ft thick. It is present from the northern terminus of the proposed east levee for about two thirds to three quarters of its alignment. It is also present along the proposed west levee for roughly the center third of the alignment. From our experience, materials such as this tend to be soft and have a very low bearing capacity; however, it may have a somewhat low permeability because of its finer grained composition.

The second most prevalent material in the project area is Rahway till (Qt). The thickness of the till is mapped to vary from approximately 10 ft to 70 ft thick. The till is comprised of sandy silt or silty sand with some gravel and cobbles and a smaller number of boulders with occasional beds of sand or gravel. This soil is present along the southern one third to one quarter of the alignments of both the east and west levees. These soils are likely fairly dense, but also somewhat permeable because of the sand and gravel content and beds.

The third most common soil present at the site is the Cranford deposit (Qcr) which is a deltaic deposit associated with Glacial Lake Ashbrook. This formation consists of sand and is mapped to be as much as 30 ft thick. This material is present along the northernmost quarter of the west levee. From our experience, materials such as these tend to be generally loose and have a relatively low bearing capacity for sand. They also tend to have relatively high permeability due to their sandy composition.

Also of note is the presence of alluvium (Qal) immediately adjacent to all of the soils discussed above. Since the alignment shown in the drawings and the mapped geology is not of very high precision, it is possible such soils may be encountered along the alignment of the proposed levees. This soil is generally deposited by flowing water associated with the river and can consist of some combination of sand, silt, and clay, with minor inclusions of gravel and cobbles. This soil is generally loose and, as such, will generally have a low bearing capacity. The permeability of this soil will likely vary greatly, depending on its composition at any given location.

The bedrock conditions, as shown in Figure 14, consist of the Passaic Formation, which consists of interbedded sedimentary rock grading from sandstone to mudstone. Sandstone is generally harder than mudstone, but in this formation, the sandstone layers are relatively thin while the finer grained layers (siltstone, mudstone, etc.) tend to be thicker. The mapped depth to bedrock varies from approximately 80 ft in the northwest corner of the site, to about 30 ft at the southern terminus of the east levee.

Based on the above, it is likely that the portions of the levees constructed on the Qwblb soils will experience some degree of consolidation related settlement, due to the weight of the levees. This can be prevented or mitigated by one or more approaches such as surcharging, soil improvement, or building the levee higher than needed by an amount at least equal to the estimated settlement. Because of the expected relatively high clay content of this material, it is possible that a cutoff wall will not be needed. If floodwalls need to be constructed in areas with this soil, they would most likely need to be pile supported.

For the portions of the levees constructed on the Qt soils settlement is not expected to be a significant issue. However, a cutoff wall or some similar cutoff mechanism may be needed, depending on the composition and permeability of this soil and whether sand or gravel beds are present. If floodwalls need to be constructed in this area, they would most likely be able to be supported by a shallow foundation, assuming there will not be a requirement for uplift.

For the portions of the levees constructed on the "Qcr" soils, elastic settlement during construction may be an issue, but is not expected that this will be of concern in the long term. However, it is likely that a cutoff wall or some similar cutoff mechanism will be needed, because of the sandy composition and likely loose nature of this soil. If floodwalls need to be constructed in this area, they would likely need to be pile supported.

For pile supported floodwalls, we would likely recommend that the piles be driven to bedrock since bedrock is relatively shallow. In areas where sensitive adjacent structures are present, we typically recommend drilled-in piles such as drilled shafts or micropiles. A thorough geotechnical investigation, including soil borings, laboratory tests, and in-situ tests should be performed prior to making a decision of the pile foundations instead of shallow foundation.

## 5.0 LIMITATIONS

Recommendations stated herein must be considered preliminary as they are based on mapped geology of the area, not borings drilled at the site. Although the maps utilized are of relatively high resolution and quality, it is possible that the information presented is not exactly accurate. Further, although the maps provide a good general overview of the soils and bedrock present, engineering parameters such as permeability, bearing capacity, etc., are difficult to determine.

Prior to any construction taking place, an extensive geotechnical subsurface investigation program shall be conducted in accordance with USACE, AASHTO, and general engineering standards, as applicable. Such a program should consist of borings and test pits as well as in-situ and laboratory testing. Borings and other field tests for bridges should be located at the proposed bridge abutment and pier locations as well as the proposed locations of other ancillary structures associated with the bridge and any channel improvements in the area. Borings and other field tests for levees, floodwalls, and channel improvements should be drilled along the alignment of the levees, floodwalls, and channel improvements as well as other elements of these systems. Borings should be spaced uniformly and in accordance with USACE and AASHTO standards and should be drilled into bedrock to a depth sufficient for all loads to be dissipated.