Local Flood Analysis

Hamlets of Shandaken and Allaben
Ulster County, New York
February 2018

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Prepared for the Town of Shandaken with funding provided by the Ashokan Watershed Stream Management Program through contract with the New York City Department of Environmental Protection

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ABBREVIATIONS/ACRONYMS

ARWHS	Ashokan Reservoir Watershed Hydrologic Study
AWSMP	Ashokan Watershed Stream Management Program
BCA	Benefit-Cost Analysis
BCR	Benefit-Cost Ratio
BFE	Base Flood Elevation
CCE	Cornell Cooperative Extension
CDBG	Community Development Block Grant
CFS	Cubic Feet per Second
CRS	Community Rating System
CWC	Catskill Watershed Corporation
DEM	Digital Elevation Model
EWP	Emergency Watershed Protection
FEMA	Federal Emergency Management Agency
FHM	Flood Hazard Mitigation
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FMA	Flood Mitigation Assistance
FPMS	Floodplain Management Services Program
HEC-HMS	Hydrologic Engineering Center – *Hydrologic Modeling System*
HEC-RAS	Hydrologic Engineering Center – *River Analysis System*
HMGP	Hazard Mitigation Grant Program
HMP	Hazard Mitigation Plan
LFA	Local Flood Analysis
MMI	Milone & MacBroom, Inc.
NFIP	National Flood Insurance Program
NFIRA	National Flood Insurance Reform Act
NRCS	Natural Resources Conservation Service
NYCDEP	New York City Department of Environmental Protection
NYCFFBO	New York City Funded Flood Buyout Program
NYRCR	New York Rising Community Reconstruction
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
NYSDOT	New York State Department of Transportation
PDM	Pre-Disaster Mitigation
RFC	Repetitive Flood Claims
SAFARI	Shandaken Area Flood Assessment and Remediation Initiative
SFHA	Special Flood Hazard Area
SMIP	Stream Management Implementation Program
SMP	Stream Management Plan
SRL	Severe Repetitive Loss
TS	Trout Spawning
UCSWCD	Ulster County Soil and Water Conservation District
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WSEL	Water Surface Elevation

EXECUTIVE SUMMARY

The Town of Shandaken has retained Milone & MacBroom, Inc. to complete a Local Flood Analysis in the town of Shandaken in the hamlets of Shandaken and Allaben. A Local Flood Analysis is an engineering feasibility analysis that seeks to develop a range of hazard mitigation alternatives. Its primary purpose is to identify flood hazards and mitigation options for the community to implement.

This Local Flood Analysis includes portions of five watercourses: Esopus Creek, Bushnellsville Creek, Fox Hollow Creek, Peck Hollow Creek, and Broadstreet Hollow Creek. Esopus Creek has its headwaters in the Catskill Mountains at Winnisook Lake and discharges to the Ashokan Reservoir, a drinking water supply source for the New York City water system. The other watercourses are tributaries to Esopus Creek.

The Catskill Mountains are subject to large storm events that are often unevenly distributed across watersheds. As a result, local flash floods can occur in one basin while an adjacent basin receives little rainfall. In addition to local flash floods, larger storm events can cause widespread flooding. Major floods have occurred periodically over the last century with at least 11 major floods occurring between 1933 and 2011. Floods can take place any time of the year but are commonly divided into those occurring in winter and spring and those occurring in summer and fall. Floods that take place in summer and fall are typically due to extreme rainfall events caused by hurricanes and tropical storms. Floods in winter and spring are associated with rain on snow events and spring snowmelt.

A public meeting held at the Shandaken town hall was convened at the beginning of the Local Flood Analysis process. Attendees were provided with an overview of the project, the Local Flood Analysis process, and hydraulic modeling techniques. Attendees were provided with large-format maps and asked to point out locations of flooding and flood damages during both Tropical Storm Irene and previous flood events. Information was collected on flood damage and potential flood mitigation alternatives. This information was then used throughout the process to verify flood damages, pinpoint problem areas, and develop flood mitigation alternatives.

Hydraulic assessment was used to evaluate historic and predicted water surface elevations, to identify floodprone areas, and to help develop mitigation strategies to minimize future flood damages and protect water quality. Specific areas were identified within the project area as being prone to flooding during flood events. Alternatives were developed and assessed at each area where flooding is known to have caused extensive damage to homes and properties.

A number of flood mitigation approaches to reduce water surface elevations were evaluated. The following types of analyses were carried out:

1. Bridge analysis
2. Obstruction of the Creekside Drive/County Route 47 bridge due to sediment aggradation
3. Floodplain enhancement and channel alterations
4. Access of Esopus Creek to a secondary channel in the vicinity of the Shandaken Tunnel

A range of floodplain and channel enhancement scenarios were evaluated in the vicinity of the confluence of Esopus Creek and Bushnellsville Creek. These did not result in significant reductions in flooding. Due to relatively narrow valleys and the location of existing roadways and infrastructure as well as dispersed settlement patterns, mitigation alternatives that significantly reduced floodwater elevations were not identified.

A Benefit-Cost Analysis was used to validate the cost effectiveness of proposed hazard mitigation projects, including potential home or business relocations. A Benefit-Cost Analysis is a method by which the future benefits of a project are estimated and compared to its cost. The end result is a Benefit-Cost Ratio, which is derived from a project's total net benefits divided by its total project cost, and represents a numerical expression of the cost effectiveness of a project.

The following is a summary of flood mitigation recommendations. More detailed descriptions of the recommendations are provided in Section 6.0 of this report.

- The relocation of the Town of Shandaken town hall facility is recommended. This includes the town hall, dog pound, and Highway Department garage.

- It is recommended that a full hydraulic assessment be conducted at the Fox Hollow Road bridge over Esopus Creek and at the town-owned bridge over Fox Hollow Creek when these bridges are scheduled for replacement to ensure that the bridge openings are adequately sized and that the new bridges span the channel and floodplain.

- It is recommended that the Creekside Drive (County Route 47) bridge over Bushnellsville Creek be inspected for sediment aggradation at least every 2 years and also immediately following flood events. When removal of sediment at the bridge is necessary, a methodology should be developed to maintain the proper channel dimensions and slope. This is crucial to avoid destabilizing the physical channel, which could have long-term effects.

- Where there is owner interest and programmatic funding available, existing structures should be relocated out of the Federal Emergency Management Agency designated floodway. The floodway is defined as the stream channel and that portion of the adjacent floodplain that must remain open to permit passage of the base flood. Floodwaters are typically deepest and swiftest in the floodway, and anything in this area is in the greatest danger during a flood. Any new development in the floodway should be disallowed, and any new construction within the 100-year flood zone should be required to meet National Flood Insurance Program criteria. Any elevation of existing structures in the floodway should not be allowed.

- It is recommended that the Town of Shandaken work to relocate the most flood-vulnerable properties where there is owner interest and programmatic funding available through flood buyout and relocation programs.

- Some homes in the 100-year flood zone are rarely flooded. Residents and businesses may benefit from minor individual property improvements. Providing landowners with information regarding individual property protection is recommended. In areas where properties are vulnerable to flooding, improvements to individual properties and structures may be appropriate. Potential measures for property protection include the following:

    - Elevation of the structure

  - Construction of property improvements such as barriers, floodwalls, and earthen berms
  - Dry floodproofing of the structure to keep floodwaters from entering
  - Wet floodproofing of the structure to allow floodwaters to pass through the lower area of the structure unimpeded
  - Performing other home improvements to mitigate damage from flooding
  - Encouraging property owners to purchase flood insurance under the National Flood Insurance Program and to make claims when damage occurs

- Floodprone manufactured homes should be elevated on a permanent foundation such that the lowest floor is elevated to or above the base flood elevation and be securely anchored to an adequately anchored foundation system to resist flotation, collapse, and lateral movement.

- The flood control levee that currently lines the left bank of the Bushnellsville Creek and Esopus Creek confluence was breached in 2011, resulting in significant damage. Since repairs were made in 2011, the levee has experienced erosion at the downstream end. Further evaluation of the levee is recommended, and armoring of the levee in the area of the erosion is likely warranted.

- Flooding of roadways during previous flood events has been reported at several locations including Route 28 along Esopus Creek, Fox Hollow Road as it approaches the Fox Hollow Road bridge over Esopus Creek, and the County Route 47 bridge over Bushnellsville Creek. Temporarily closing floodprone roads during flooding events is recommended. This requires effective signage, road closure barriers, and consideration of alternative routes.

- It is recommended that sources of man-made pollution be reduced or eliminated through the relocation or securing of fuel oil and propane tanks.

- It is recommended that drainage ditches and catch basins be maintained and cleaned on a regular basis to reduce localized flooding.

A number of potential funding sources are identified in Section 6.0 of this report. As the recommendations of this Local Flood Analysis are implemented, the Town of Shandaken should work closely with potential funders to ensure that the best combinations of funds are secured for the recommended flood mitigation alternatives. It would be advantageous for the town to identify combinations of funding sources in order to reduce its own requirement to provide matching funds.

1.0 INTRODUCTION

1.1 Project Background

The Town of Shandaken, utilizing funding provided by the New York City Department of Environmental Protection (NYCDEP) through the Ashokan Watershed Stream Management Program (AWSMP), retained Milone & MacBroom, Inc. (MMI) to complete a Local Flood Analysis (LFA) in the town of Shandaken, New York, in the hamlets of Shandaken and Allaben. The town of Shandaken is located on the northern border of Ulster County, northwest of Kingston.

The LFA is a program within the New York City water supply watersheds that was initiated following Tropical Storm Irene. The purposes of the program are to help communities identify and mitigate flood hazards as well as protect water quality in the New York City water supply watersheds. In summary, the LFA is an engineering feasibility analysis that seeks to develop a range of hazard mitigation alternatives with the primary focus of identifying options to reduce flood elevations and the costs of damages associated with inundation. The AWSMP is the lead agency responsible for implementing the LFA program throughout the Ashokan Reservoir watershed communities.

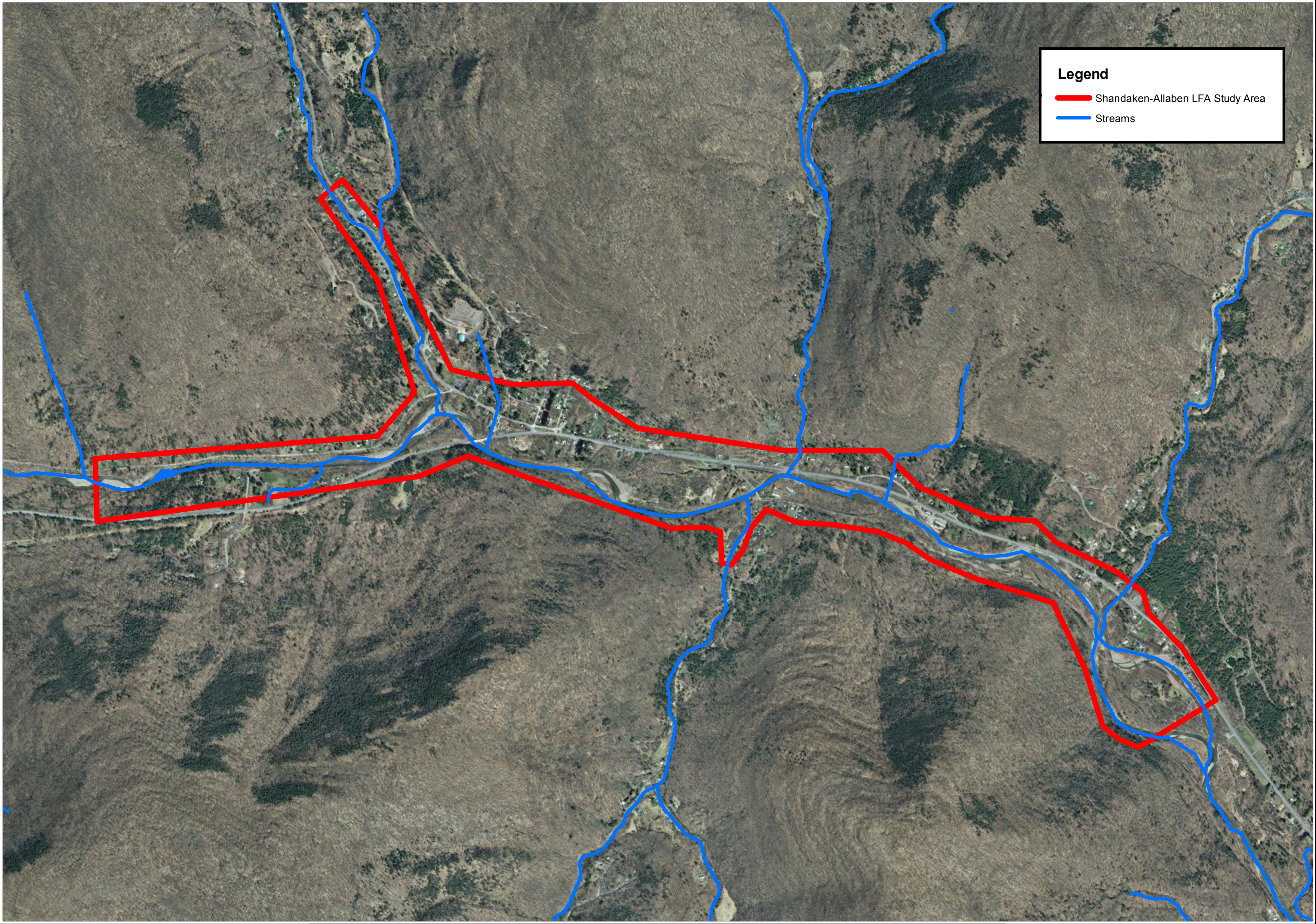
The LFA is the first step of a larger Flood Hazard Mitigation Program. The purpose of the LFA is to identify flood hazards and mitigation options for the community to implement with potential funding assistance from NYCDEP, Catskill Watershed Corporation (CWC), and AWSMP.

1.2 Study Area

The project area is located within the town of Shandaken, New York, and is focused on the hamlets of Shandaken and Allaben. The region was settled around the time of the American Revolution and was established as a town in 1804. The hamlet of Shandaken is located near the center of the town at the confluence of Esopus Creek and Bushnellsville Creek. The hamlet of Allaben lies along Esopus Creek between Fox Hollow and Broadstreet Hollow Creeks. It is home to the Shandaken town hall facility, which includes the town hall, animal shelter, and Highway Department garage. The Shandaken Tunnel (also known as the portal), which carries water from Schoharie Reservoir, empties into Esopus Creek about 0.3 miles downstream of the town hall.

The LFA includes portions of five watercourses: Esopus Creek, Bushnellsville Creek, Fox Hollow Creek, Peck Hollow Creek, and Broadstreet Hollow Creek. Esopus Creek has its headwaters in the Catskill Mountains at Winnisook Lake and discharges to the Ashokan Reservoir, a drinking water supply source for the New York City water system. The other watercourses are tributaries to Esopus Creek.

The project area stretches approximately 4 miles along Esopus Creek. The upstream limit is located 1.2 stream miles above the Esopus Creek-Bushnellsville Creek confluence while the downstream boundary is 0.6 miles downstream of the Esopus Creek-Broadstreet Hollow Creek confluence. The northernmost portion of the project area extends 0.85 stream miles up Bushnellsville Creek. The project area also extends a short distance up Fox Hollow Creek (0.25 miles), Peck Hollow Creek (0.1 miles), and Broadstreet Hollow Creek (0.15 miles). The width of the project area is based roughly on the extent of the 500-year (0.2 percent annual chance) flood. Figure 1-1 shows the boundary of the LFA project area.



SOURCE(S):
http://www.orthos.dhses.ny.gov/arcgis/services, accessed August 2017

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Figure 1-1: Shandaken -Allaben LFA Project Boundary

MXD: Q:\Projects\4615-18 Shandaken-Allaben LFA\GIS\MDX\LFA_Project_Boundary.mxd

Shandaken-Allaben Local Flood Analysis

LOCATION: Shandaken, NY

Map By: EMH
MMI#: 4615-18
Original: 08/28/2017
Revision: 10/30/2017
Scale: 1 in = 2,000 ft

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1.3 Community Involvement

The LFA was undertaken in close consultation with the Shandaken Area Flood Assessment and Remediation Initiative (SAFARI). SAFARI is comprised of individuals with technical and nontechnical backgrounds and is meant to represent various interests and stakeholders at the town and county levels as well as the NYCDEP. SAFARI's mission is to reduce the flood hazard vulnerability in the Shandaken area to ensure that residential and business communities can thrive within a healthy environment. The SAFARI team met regularly with MMI staff over the course of the LFA process to review results and provide input on flood mitigation alternatives. Meeting minutes are included in Appendix B. SAFARI members include representatives from the following organizations:

- Town of Shandaken
- Shandaken Residents and Business Owners
- AWSMP (which includes representatives from the following three organizations):
    - Ulster County Soil and Water Conservation District (UCSWCD)
    - NYCDEP
    - Cornell Cooperative Extension of Ulster County
- CWC
- RCAP Solutions
- Ulster County Department of the Environment
- Ashokan-Pepacton Chapter of Trout Unlimited
- MMI

SAFARI was also the primary pathway for community involvement in the planning process. The public was included and informed throughout the LFA process. The following public outreach events took place or are scheduled:

- On December 20, 2016, an initial presentation was made by MMI at the Shandaken Town Hall. The purpose of this presentation was to kick off the LFA and provide SAFARI members and the public with an overview of the process and timeline. Additionally, information was collected from attendees on flood history and damage.

- A second public meeting will be held at the conclusion of the study. The purpose of this meeting will be to inform the town board and residents on the findings and conclusions of the LFA, including the results of the hydraulic modeling and the benefit-cost analysis (BCA).

1.4 Nomenclature

In order to provide a common standard, the Federal Emergency Management Agency's (FEMA) National Flood Insurance Program (NFIP) has adopted a baseline probability called the base flood. The base flood has a 1 percent (one in 100) chance of occurring in any given year, and the base flood elevation (BFE) is the elevation of this level. For the purpose of this report, the 1 percent annual chance flood is referred to as the ***100-year flood event***. Other reoccurrence probabilities used in this report include the ***2-year flood event*** (50 percent annual chance flood), the ***10-year flood event*** (10 percent annual chance flood), the ***25-year flood event*** (4 percent annual chance flood), the ***50-year flood event*** (2 percent annual chance flood), and the ***500-year flood event*** (0.2 percent annual chance flood). The Special Flood Hazard Area (SFHA) is the area inundated by flooding during the 100-year flood event.

It should be noted that over the time period of a standard 30-year property mortgage, a property located within the SFHA will have a 26 percent chance of experiencing a 100-year flood event. Structures falling within the SFHA may be at an even greater risk of flooding because if a house is low enough, it may be subject to flooding during the 25-year or 10-year flood events. During the period of a 30-year mortgage, the chances of being hit by a 25-year flood event is 71 percent, and the chances of being hit by a 10-year flood event is 96 percent, which is a near certainty.

The FEMA-designated floodway is defined as the stream channel and that portion of the adjacent floodplain that must remain open to permit passage of the base flood. Floodwaters are typically deepest and swiftest in the floodway, and anything in this area is in the greatest danger during a flood. The portion of the floodplain that is outside the floodway is referred to as the flood fringe, and is generally (but not in all cases) associated with less rapidly flowing water. Figure 1-2 illustrates the SFHA, floodway and flood fringe on a typical channel cross section.

I--------------------Special Flood Hazard Area----------------------I
(area inundated by 100-year flood event)

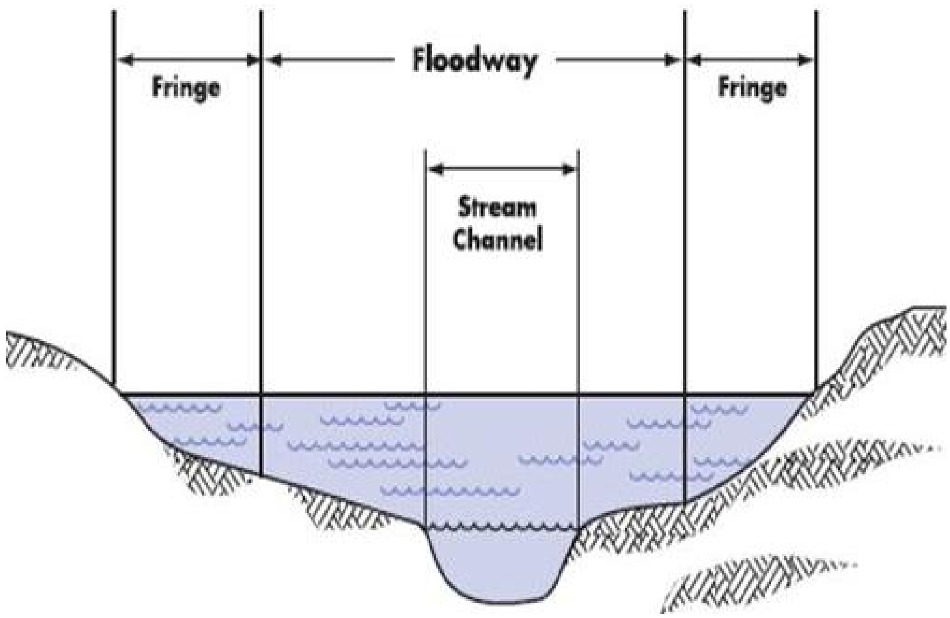


Figure 1-2
Special Flood Hazard Area, Floodway and Flood Fringe

In this report, all references to right bank and left bank refer to "river right" and "river left," meaning the orientation assumes that the reader is standing in the river looking downstream.

2.0 WATERSHED INFORMATION

2.1 Initial Data Collection

Initial data collected for this study and analysis included publicly available data as well as input from SAFARI and from the public meetings held within the hamlets of Shandaken and Allaben. A summary of key documents follows.

Flood Insurance Study (FIS)

FEMA has produced a preliminary FIS dated November 18, 2016, for Ulster County that includes Esopus Creek, Bushnellsville Creek, Fox Hollow Creek, and Broadstreet Hollow Creek. Peck Hollow Creek is not included in the FIS. The purpose of the FEMA study is to determine potential floodwater elevations and delineate existing floodplains in order to identify flood hazards and establish insurance rates. The hydrologic and hydraulic analyses for these streams were completed in April 2013.

An important byproduct of the FIS is a series of Hydrologic Engineering Center – *River Analysis System* (HEC-RAS) computer models that are available for professional use and are a key component of the subject study. The area predicted to be flooded during the 100-year frequency event is known as the SFHA.

Stream Management Plans

Stream Management Plans (SMPs) were completed for three of the five streams in the project area: Esopus Creek, Bushnellsville Creek, and Broadstreet Hollow. A detailed description of the Esopus Creek watershed and channel is contained in the 2007 Upper Esopus Creek Stream Management Plan prepared by the NYCDEP with assistance from the U.S. Army Engineer Research Development Center and the Ulster County Cornell Cooperative Extension (CCE). An SMP was recently completed for Bushnellsville Creek by AWSMP with technical support from the UCSWCD. The Broadstreet Hollow Creek SMP dates from 2003 and was prepared by the UCSWCD and the NYCDEP. The reports present information on the regional setting, climate, physiography, hydrology and flood history, watershed geology, and land use/land cover. Digital copies of the reports are available at http://ashokanstreams.org/publications-resources/stream-management-plans/.

The Upper Esopus Creek SMP consists of three volumes. The first is a summary of findings and recommendations. The second addresses the social and cultural aspects related to stream management, including a history of the watershed and its contribution to the New York City water supply system. The final volume provides a detailed physical description of the watershed. This volume also presents the results of the various assessments that were carried out for the study and used to formulate the recommendations in Volume 1 (NYCDEP, 2007).

The Bushnellsville Creek SMP was completed in 2015. The report is based on fieldwork conducted to assess the physical condition of the stream. The field data were analyzed to determine areas of concern where the stream was unstable or homes and infrastructure were threatened. Bushnellsville Creek was divided into 11 management units based on stream characteristics, valley form, and transportation infrastructure. The report provides a physical description of each management unit along with a narrative of historical conditions and an identification of threats as well as management recommendations. The document is meant to provide landowners and municipalities with information that may be useful in managing their properties in a sustainable manner (AWSMP, 2015).

The Broadstreet Hollow Creek SMP is divided into two volumes. The first volume provides background information on the stream and watershed. It also contains a section on living in proximity to streams, which includes resources for landowners such as permit requirements and agency contacts. The second volume provides descriptions of the 19 management units spread along the length of the stream. This volume also provides reach-by-reach monitoring and management recommendations (UCSWCD, 2003).

United States Geological Survey (USGS) Stream Gauging Network

The USGS operates and maintains two stream flow gauges within the project area. The first gauge (1362200) is located on the Esopus Creek in the hamlet of Allaben. A second gauge (1362230) measures the flow from the Schoharie Reservoir diversion tunnel that is delivered to the Esopus Creek near the downstream end of the project area. Stream flow gauges record daily stream flow, including flood flows that are essential to understanding long-term runoff trends. Gauge data can be utilized to determine flood magnitudes and frequencies. Additionally, real time data is available to monitor water levels and provide flood alerts. Stream flow data and water levels are available at http://waterdata.usgs.gov/ny/nwis/sw.

Hazard Mitigation Plans (HMPs)

The purpose of HMPs is to identify policies and actions that will reduce risk in order to limit losses to property and life. Flood hazard mitigation, in particular, seeks to implement long- and short-term strategies that will successfully limit loss of life, personal injury, and property damage that can occur due to flooding (URS, 2009). Flood mitigation strategies are most successful when private property owners; businesses; and local, state, and federal governments work together to identify hazards and develop strategies for mitigation (Tetra Tech, 2009).

Flood hazard mitigation planning is promoted by various state and federal programs. At the federal level, FEMA administers two programs that provide reduced flood insurance costs for communities meeting minimum requirements – the NFIP and the Community Rating System (CRS) (Tetra Tech, 2013). Flood hazard planning is a necessary step in acquiring eligibility to participate in these programs (URS, 2009).

Ulster County Multijurisdictional Natural HMP

In 2007, Ulster County completed a multijurisdictional natural HMP, which was approved by FEMA in 2009. An updated HMP, released as a draft in May 2017, has been approved by FEMA and the New York State Department of Homeland Security and Emergency Services, and will be adopted by the County Legislature resolution in December 2019. By participating in the plan, jurisdictions within the county comply with the Federal Disaster Mitigation Act of 2000. Compliance with this act allows jurisdictions to apply for federal aid for technical assistance and postdisaster mitigation project funding.

The current HMP identifies flooding as a significant natural hazard in Ulster County. The Town of Shandaken was noted as being especially vulnerable as the majority of development is located in the valley of Esopus Creek and its tributaries, which were identified as High Risk Areas. High Risk Areas are defined as having a 1 percent chance of being flooded in any given year. In other words, a significant portion of the inhabited area of the Town of Shandaken lies within the 100-year floodplain. Additionally, the Town of Shandaken ranks highest in Ulster County for the number of NFIP policies (206 active policies as of August 31, 2017), total losses to date (273, with more than $5.7M in paid claims as of August 31, 2017), and total annual NFIP premiums paid ($256,861).

Town of Shandaken Flood Mitigation Plan

The Town of Shandaken participated in the Ulster County Multijurisdictional Natural Hazard Mitigation Plan. However, based on its flood history, the town decided to develop a flood mitigation plan to more specifically address its needs and aid in reducing vulnerability to floods. The plan, finalized in July 2013, identifies hazards as well as resources, information, and strategies to reduce risk from flood hazards. Additionally, the plan helps guide and coordinate mitigation activities. The plan will also allow Shandaken to participate in the CRS with an improved classification, reducing flood insurance premiums for residents.

New York Rising Community Reconstruction (NYRCR) Plan: NYRCR Towns of Shandaken and Hardenburgh

The New York Community Reconstruction Program was developed to address significant impacts and establish long-term resiliency of the communities impacted by Tropical Storms Irene and Lee. A NYRCR Plan was developed jointly for the Towns of Shandaken and Hardenburgh. It provides a description of the communities and the flood damage that occurred as a result of Tropical Storms Irene and Lee. The plan also provides a risk assessment of economic, health and social services, infrastructure, and cultural assets in the study area. It then explores a number of reconstruction and resiliency strategies:

1. Reducing the impact of flooding on critical facilities and infrastructure
2. Enhancing economic vitality by diversifying the business base and promoting economic growth and tourism
3. Ensuring continuity of critical services before, during, and after a disaster
4. Addressing housing issues related to flood risk, availability, and affordability
5. Protecting, preserving, and improving natural, cultural, and historic resources

The document concludes by presenting projects selected by the committee as candidates for Community Development Block Grant (CDBG) Disaster Recovery funding. One of the proposed projects is the Town of Shandaken Municipal Project, which includes the construction of a new, multiuse municipal facility on Route 28. As proposed, the facility would include the town's administrative offices, the Police Department, emergency operations center, ambulance service, and garages. The facility could be used as a regional evacuation site and community health and human services center. The design of the new facility would include increased capacity for sheltering of vulnerable or high-risk populations and enhanced command center and communications capability during a disaster.

Water Quality Reports

In order to fulfill requirements of the Federal Clean Water Act, the New York State Department of Environmental Conservation (NYSDEC) must provide periodic assessments of the quality of the water resources in the state and their ability to support specific uses. These assessments reflect monitoring and water quality information drawn from a number of programs and sources both within and outside the department. This information has been compiled by the NYSDEC Division of Water and merged into an inventory database of all waterbodies in New York State (NYS). The database is used to record current water quality information, characterize known and/or suspected water quality problems and issues, and track progress toward their resolution.

From the lower end of the project area to Allaben, Esopus Creek is classified by the NYSDEC as a Class A (TS) watercourse. The A classification indicates a best usage for a source of drinking water, swimming and other recreation, and fishing. The additional TS classification denotes that the watercourse may support trout spawning.

This stretch of Esopus Creek is listed as impaired in NYS's 2016 Section 303 (d) inventory. The impairment is due to silt and sediment, which create turbidity that impacts both water supply and recreational uses. The turbidity is attributed to inputs from the Shandaken Tunnel, stream bank erosion, and tributary streams including Broadstreet Hollow Creek. In spite of turbidity, water quality sampling found that conditions are fully supportive of aquatic life.

Above Allaben, the Esopus Creek is classified as a C (TS) stream. Class C waterbodies are suitable for general recreation and support of aquatic life but not as water supply or for public bathing. Esopus Creek upstream of Allaben has no known use impairment. However, of the three sites sampled between Boiceville and Oliverea, the site at Big Indian revealed slight impacts from organic and nutrient inputs. These inputs are attributed to the wastewater treatment plant discharge to Birch Creek in the hamlet of Pine Hill. Nevertheless, aquatic life appears to be fully supported.

The uppermost tributary to Esopus Creek in the project area, Bushnellsville Creek, is classified as a B (TS) stream. Class B denotes that this stream is suitable for swimming and other contact recreation. According to the most current NYCDEC Waterbody Inventory/Priority Waterbodies List, this stream has not been assessed for water quality.

Fox Hollow, Peck Hollow, and Broadstreet Hollow Creeks are all designated as C (TS) streams. Fox Hollow and Peck Hollow Creeks have no major use impairment. Broadstreet Hollow Creek should be considered impaired as it is listed in NYS's 2016 Section 303 (d) inventory and has been identified as contributing excess turbidity to Esopus Creek.

Local Flood Damage Prevention Codes

The Town of Shandaken has adopted a local code for flood damage prevention. The present code was adopted on October 10, 2016, to be consistent with the federal guidelines in order to participate in the NFIP.

The stated purposes of this local law are to do the following:

- Regulate uses that are dangerous to health, safety, and property due to water or erosion hazards or that result in damaging increases in erosion or in flood heights or velocities.
- Require that uses vulnerable to floods, including facilities that serve such uses, be protected against flood damage at the time of initial construction.
- Control the alteration of natural floodplains, stream channels, and natural protective barriers that are involved in the accommodation of floodwaters.

- Control filling, grading, dredging, and other development that may increase erosion or flood damages.
- Regulate the construction of flood barriers that will unnaturally divert floodwaters or that may increase flood hazards to other lands.
- Qualify for and maintain participation in the NFIP.

The stated objectives of the local law are as follows:

- Protect human life and health.
- Minimize the expenditure of public money for costly flood-control projects.
- Minimize the need for rescue and relief efforts associated with flooding and generally undertaken at the expense of the general public.
- Minimize prolonged business interruptions.
- Minimize damage to public facilities and utilities such as water and gas mains; electric, telephone, and sewer lines; streets; and bridges located in areas of special flood hazard.
- Help maintain a stable tax base by providing for the sound use and development of areas of special flood hazard so as to minimize future flood blight areas.
- Provide that developers are notified that property is in an area of special flood hazard.
- Ensure that those who occupy the areas of special flood hazard assume responsibility for their actions.

The Office of the Building Inspector/Zoning and Code Enforcement is empowered as the local administrator for administering and implementing the local Flood Damage Prevention code. It is the duty of the local administrator to grant or deny floodplain development permits in accordance with the code. The local administrator must conduct a permit application review prior to approval and must review the subdivision or new development to determine if the proposed site is reasonably safe from flooding. It is also their responsibility to determine if proposed development in an area of special flood hazard may result in physical damage to other property.

The local law identifies a series of Construction Standards for development in the floodplain, broken down into General Standards, Standards for All Structures, Residential Structures, Non-Residential Structures, and Manufactured Homes and Recreational Vehicles.

The General Standards section is broken down into standards for subdivision proposals and encroachments. All new subdivision proposals and other development proposed in a SFHA must be consistent with the need to minimize flood damage, minimize flood damage to utilities, and provide adequate drainage. When encroaching on zones A1-A30 and AE along streams without a regulatory floodway, development must not increase the BFE by more than 1 foot. Along streams with a regulatory floodway, development must not create any increase in the BFE.

Standards for all structures include provisions for anchoring, construction materials and methods, and utilities. New structures must be anchored so as to prevent flotation, collapse, or lateral movement during the base flood. Construction materials must be resistant to flood damage, and construction methods must minimize flood damage. Enclosed areas below the lowest floor in zones A1-A30, AE, AH, and, in some cases, Zone A must be designed to allow for the entry and exit of floodwaters. Utility equipment such as electrical, HVAC, and plumbing connections must be elevated to or above the base flood height. Water supply and sanitary sewage systems must be designed to minimize or eliminate the infiltration of floodwaters.

The elevation of residential and nonresidential structures is required in areas of special flood hazard. In zones A1-A30, AE, AH, and, in some cases, Zone A, new residential construction and substantial improvements must have their lowest floor (including basement) elevated at or above an elevation that is 2 feet above the BFE. In cases where BFE data is not known for Zone A, new residential construction and substantial improvements must have their lowest floor elevated at or above 3 feet above the highest adjacent grade.

For nonresidential structures in zones A1-A30, AE, AH, and, in some cases, Zone A, developers have the option of either elevating the structures or improvements to or above an elevation that is 2 feet above the BFE or floodproofing the structure so that it is watertight below an elevation that is 2 feet above the BFE. In cases where BFE data is not known for Zone A, new construction and substantial improvements must have their lowest floor elevated at or above 3 feet above the highest adjacent grade.

Recreational vehicles are only allowed in zones A1-A30, AE, and AH if they are on site fewer than 180 consecutive days and are licensed and ready for highway use or meet the construction standards for manufactured homes. Manufactured homes in the A1-A30, AE, and AH zones must be placed on a permanent foundation with the lowest floor elevated at least 2 feet above the BFE. The home should be anchored to the foundation to resist flotation, collapse, or lateral movement. In Zone A where no BFE data are available, such structures must be placed on reinforced piers or similar elements that are at least 3 feet above grade.

2.2 Field Assessment

Following Tropical Storms Irene and Lee, MMI flood specialists and structural engineers conducted on-the-ground flood damage assessment and emergency response within the hamlets of Shandaken and Allaben, working under contract to the NYCDEP. During the Shandaken-Allaben LFA process, MMI staff conducted numerous field visits to the project area. Field visits focused on two areas: (1) the river channel and its banks (bank and channel conditions, sediment bars, and vegetation along the stream corridor); and (2) development in the floodplains.

A field survey of streams in the LFA and their associated floodplains was conducted during winter and spring 2017. This was done to better understand site conditions, inform hydraulic modeling, and gather data for the BCA. The field survey included identification of low-lying structures, observation of bank and channel conditions, and characterization of vegetation along the stream corridor. Channel conditions were photodocumented and are included as a photo log in Appendix A.

2.3 Watershed and Stream Characteristics

Initial European settlement of the watershed occurred in the 1600s. Over the next 200 years, 80 percent to 90 percent of first-growth forest was cleared primarily due to agriculture, tanneries, and forestry. In 1885, the Catskill Forest Preserve was created. In 1907, the Ashokan Reservoir was constructed and was entered into service in 1915. Since the early part of the 20th Century, forest cover has increased with the decline in agriculture, forestry, and the disappearance of the tannery industry. Today, forest cover in the watershed contributing to the Ashokan Reservoir exceeds 95 percent. There is no large-scale agricultural land use within the watershed. This is partly due to historical conditions and present economics but is also due to the fact that the valleys are relatively narrow, and there is little prime agricultural land compared to other parts of the Catskills. Most residential and commercial areas that contribute impervious cover to the watershed are located along river valleys, with most development occurring along the Route 28 corridor (NYCDEP, 2007). The SMPs should be consulted as a resource for detailed information on watershed history, land use, and land cover as well as watershed and stream characteristics.

The watershed of the Esopus Creek that contributes to the project area is 79.7 square miles. The subwatersheds of Bushnellsville Creek, Fox Hollow Creek, Peck Hollow Creek, and Broadstreet Hollow Creek are 11.2 square miles, 4.0 square miles, 5.1 square miles, and 6.0 square miles, respectively. These subwatersheds have a combined area of 26.2 square miles and make up 32.9 percent of the total project area contributing watershed. Figure 2-1 depicts the watersheds as well as the project study area.

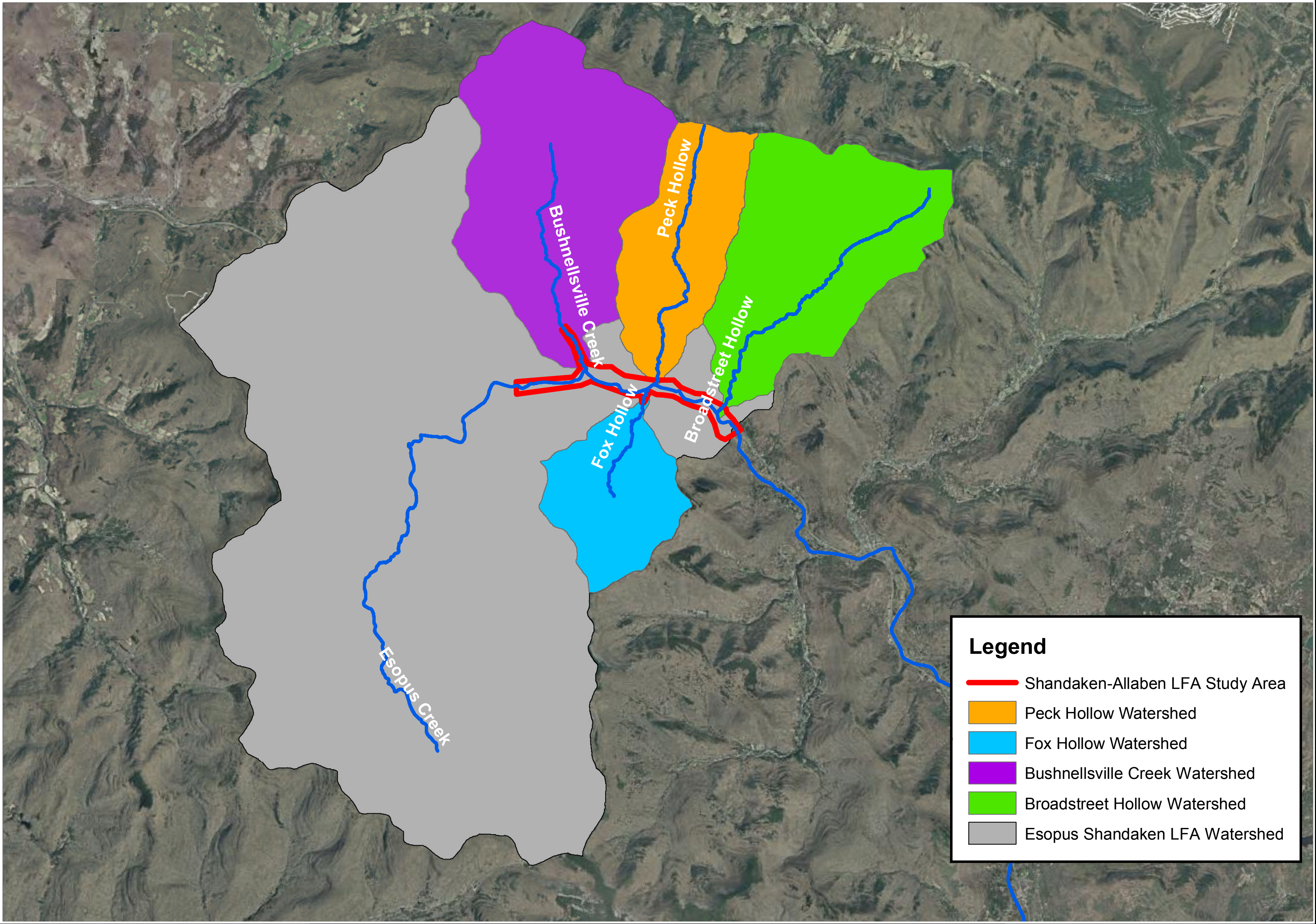
This LFA considers five watercourses: Esopus Creek, Bushnellsville Creek, Fox Hollow Creek, Peck Hollow Creek, and Broadstreet Hollow Creek. The primary watercourse in the study is Esopus Creek, which has its headwaters in the Catskill Mountains near Big Indian. The remaining streams are tributaries that drain to the Esopus Creek within the extent of the project area.

The upper portion of Esopus Creek flows from Lake Winnisook to the Ashokan Reservoir, a distance of approximately 27 miles. From its headwaters, the creek flows in a circular, clockwise manner to the lower boundary of the project area. It then turns in a southeasterly direction until it reaches the hamlet of Mount Tremper. After leaving Mount Tremper, the Esopus Creek flows in a more southerly direction until it reaches the Ashokan Reservoir.

For much of its length, Esopus Creek can be characterized as an alluvial river, meaning its channel is located on sediment previously placed by the river. Alluvial rivers adjust their shape, size, and slope in response to flow rates and sediment loads. Such rivers can naturally be expected to change their course over time as a result of large discharge events.

The underlying bedrock geology of the project area consists of layers of sandstone and siltstone. Streambed particles are typically made up of eroded sedimentary bedrock (NYCDEP, 2007). The surficial material overlying the bedrock consists of ice-age glacial deposits such as till, outwash, and lake sediment, as well as more recent stream deposits. When exposed to the erosive action of the river, silts and clays can become mobilized, resulting in high turbidity and contributing to water quality impairment (NYCDEP, 2007).

The upstreammost section of Esopus Creek extends from its headwaters near Winnisook Lake to the hamlet of Oliverea. This section has a steep slope of 4.2 percent over a distance of 5.5 miles. This upper section of the watercourse is confined within the narrow, forested walls that rise steeply hundreds of feet above the channel along both banks. The watercourse consists of a single channel with low sinuosity. The confining valley walls limit lateral movement of the channel during major flood events.



SOURCE(S):
http://www.orthos.dhses.ny.gov/arcgis/services, accessed August 2017

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Figure 2-1: Esopus Creek Effective Watershed Area

MXD: Q:\Projects\4615-18 Shandaken-Allaben LFA\GIS\MDX\WatershedsAerial.mxd

Shandaken-Allaben Local Flood Analysis

LOCATION: Shandaken, NY

Map By: EMH
MMI#: 4615-18
Original: 08/28/2017
Revision: 11/15/2017
Scale: 1 in = 10,000 ft

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The second section stretches from Oliverea to immediately upstream of the Shandaken Tunnel. The slope in this section is 1.0 percent over a distance of 8.9 miles. The valley bottom begins to broaden out, and the stream becomes braided between Oliverea and Big Indian. Between Big Indian and Allaben, the channel becomes more sinuous with the appearance of gravel point bars. As the creek passes through Allaben, the valley becomes more confined for the entirety of the section. Two notable tributaries entering the Esopus Creek in this section are Birch Creek at Big Indian and Bushnellsville Creek in the hamlet of Shandaken. Two smaller tributaries, Fox Hollow Creek and Peck Hollow Creek, enter into Esopus Creek in the vicinity of Allaben. The majority of the project area is located in this section of Esopus Creek.

The next section includes the length of creek from the Shandaken Tunnel to just downstream of the Woodland Creek confluence. Over a distance of 3.3 miles, the channel slope is 0.7 percent. This section is characterized by an interbasin transfer from the Schoharie Reservoir via the Shandaken Tunnel. The mean yearly flow rate delivered by the tunnel between 1998 and 2015 was 225 cubic feet per second (cfs). The channel in the upstream section is divided by two large islands in the vicinity of Broadstreet Hollow. Below these islands, the channel assumes a single thread form with some occasional gravel point bars.

Figure 2-2 represents a longitudinal profile of Esopus Creek within the project boundaries as well as the location of tributaries included in the study. A longitudinal profile of a river depicts the change in elevation of the channel between two points, thereby showing the rate of change in slope, or gradient, for a certain distance downstream.

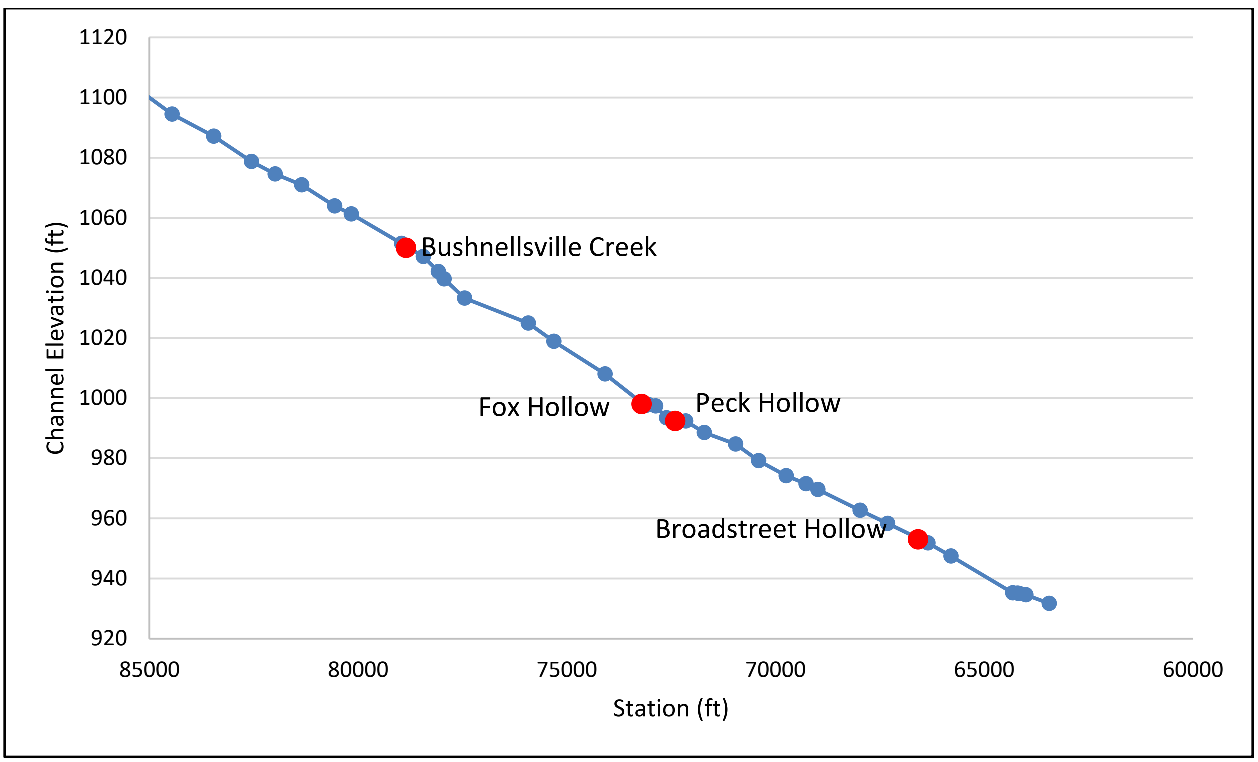


Figure 2-2
Esopus Creek Longitudinal Profile within the Project Area

Bushnellsville Creek is the largest tributary to Esopus Creek within the project area with a watershed area of 11.2 square miles. The creek originates on the eastern slopes of Halcott Mountain and flows 5.8 miles before entering Esopus Creek near the intersection of State Route 42 and Country Route 47. It is confined in a steep, forested valley with minimal floodplain area. For most of its course, it parallels State Route 42, passing under several bridges. As a result, its natural lateral movement across the valley floor is highly confined.

The surficial geology of the watershed is composed of both fluvial (stream) and glacial deposits. Glacial till, lacustrine silt, and clay as well as recently deposited fluvial sediments occur throughout the watershed. The underlying bedrock is composed of grey and green sandstone, red and green shale, and round pebble conglomerates. Compared to unconsolidated fluvial and glacial deposits, this material is resistant to erosion. Locations where the channel is composed of bedrock are referred to as "bedrock control." These areas are extremely stable and limit upstream erosion resulting from disturbances downstream (AWSMP, 2015).

The Bushnellsville Creek watershed is 99.3 percent forested and quite mountainous with four peaks taller than 3,000 feet. Elevations range from 1,050 feet at the confluence with the Esopus Creek to 3,549 feet at the top of the Mount Sherrill. The upper headwaters on Halcott Mountain are extremely steep with slopes above 15 percent. Once the stream reaches the valley floor, the average slope decreases to 2.7 percent (AWSMP, 2015). As a result of steep slopes over most of its length, large volumes of sediment can be transported very quickly downstream during larger discharges. This sediment may accumulate at the confluence with Esopus Creek where the slope of the streambed becomes less steep and the capacity of the stream to move sediment diminishes. Figure 2-3 is a longitudinal profile of Bushnellsville Creek from the upstream end of the project area to its confluence with Esopus Creek.

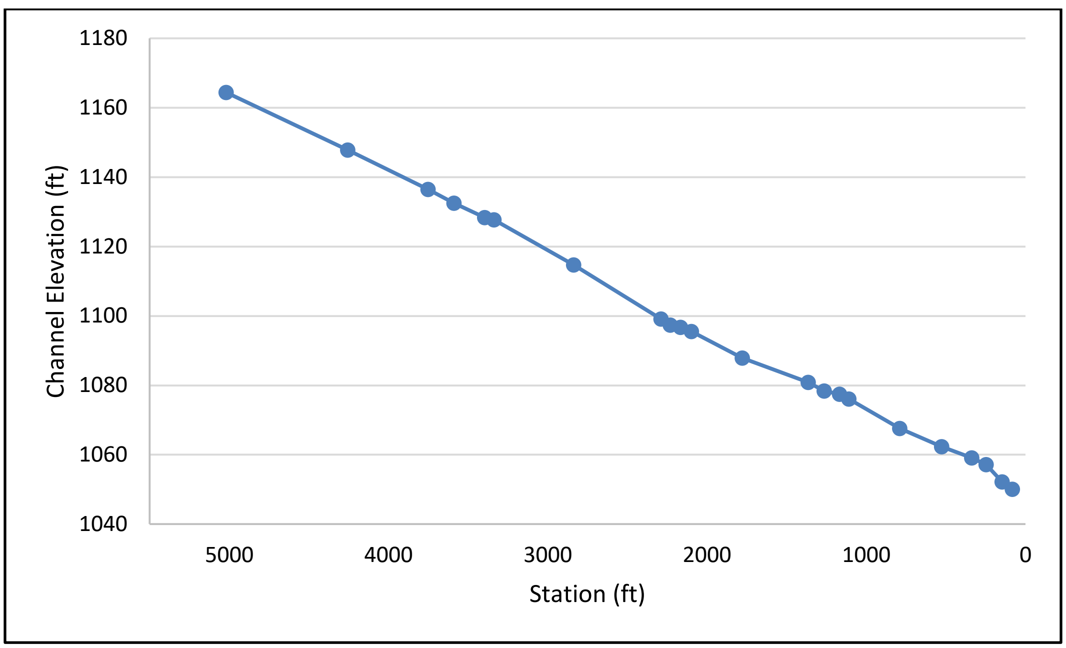


Figure 2-3
Bushnellsville Creek Longitudinal Profile within the Project Area

Broadstreet Hollow Creek is the second largest tributary to Esopus Creek in the project area, with a watershed of 9.2 square miles and a total length of 5.5 miles. The headwaters of Broadstreet Hollow Creek are located on the southern slopes of West Kill Mountain. The stream flows to the southwest for 3.9 miles before turning south and traveling the remainder of its distance to the Esopus Creek. It enters Esopus Creek approximately 1,500 feet downstream of the Shandaken Tunnel outlet.

The geological setting of Broadstreet Hollow Creek is similar to Bushnellsville Creek. The surficial geology consists of glacial and alluvial deposits. The exposed sediments are primarily glacial till and alluvium although lacustrine clay has been observed in the banks and the bed. The bedrock consists of red beds including shales and mudstones as well as grey sandstones and grey shales. However, there is no evidence of bedrock in the valley bottom due to thick deposits of glacial sediment (UCSWCD, 2003).

The watershed is mountainous with steep slopes and a forest cover of 99.5 percent. The valley bottom is narrow with little floodplain area. Broadstreet Hollow Creek runs parallel to Broadstreet Hollow Road along the lower half of its course passing under nine bridges. As a result of the narrow geological setting and transportation infrastructure, the course of the stream is highly constrained. Many residences are located close to the stream. This proximity coupled with little floodplain area suggests that these structures are at risk of flooding during high discharges. The longitudinal profile of Broadstreet Hollow Creek in the project area is illustrated in Figure 2-4.

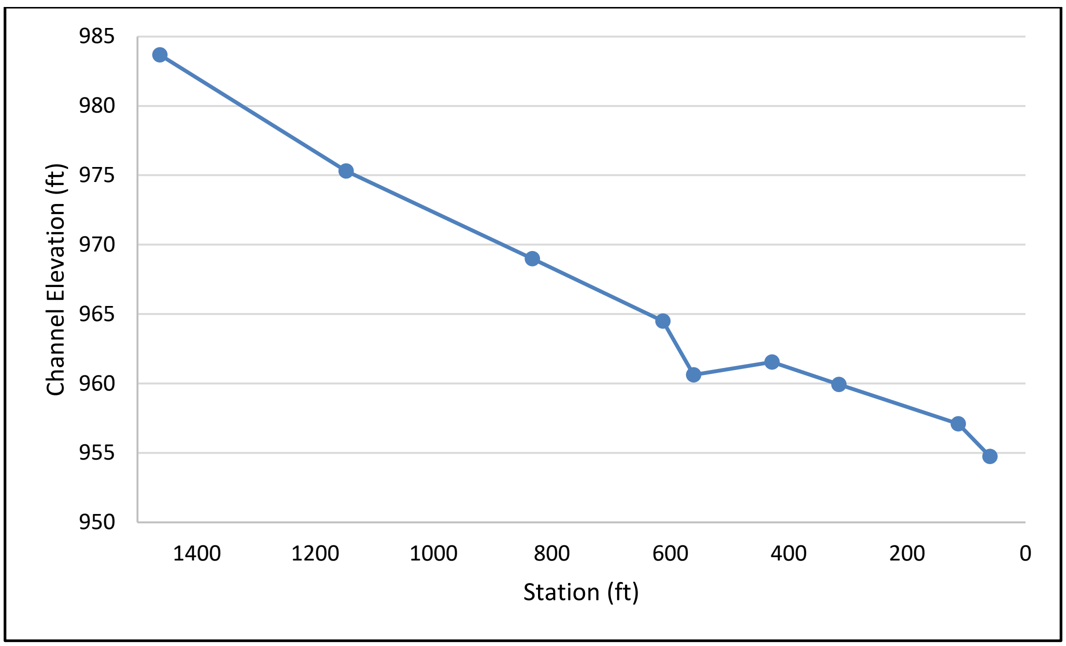


Figure 2-4
Broadstreet Hollow Creek Longitudinal Profile within the Project Area

Peck Hollow Creek is a minor tributary to upper Esopus Creek. The stream begins on the sides of Mount Sherrill and North Dome Mountain in Greene County. The total length of the stream and its watershed area are 4.8 square miles and 5.1 square miles, respectively. From its origin, Peck Hollow Creek flows south 2.9 miles through a steep and narrow valley that is deeply forested before passing under Peck Hollow Road. For the remainder of its course, the stream follows the road before passing under State Route 28 and entering the Esopus Creek. Until it reaches the Esopus Creek, the stream is confined in a narrow valley. It is further constrained by Peck Hollow Road and several bridges. Along Peck Hollow

Road, there are isolated properties that border the stream. Immediately upstream of State Route 28, there are homes on either side of the stream. Those along the left bank are within the 100-year floodplain and are at greater risk of flooding.

The smallest tributary to the Esopus Creek within the project area is Fox Hollow Creek. Fox Hollow Creek originates in the Slide Mountain Wilderness and flows 3.3 miles north before emptying into Esopus Creek. It is typically a riffle-pool form with some step-pool and intermediate forms. The creek is confined in a narrow valley setting that opens up briefly near Herdman Road and again near the confluence with Esopus Creek. For the last 1.3 miles of its course, it runs along Fox Hollow Road. Within this area, it passes under six bridges as well as a railroad trestle at the confluence. The road and bridges inhibit the natural lateral movement of the stream and, in some cases, contribute to channel and bank instability, particularly at the bridge immediately upstream of Panther Mountain Park Road. The longitudinal profile is shown below (Figure 2-5).

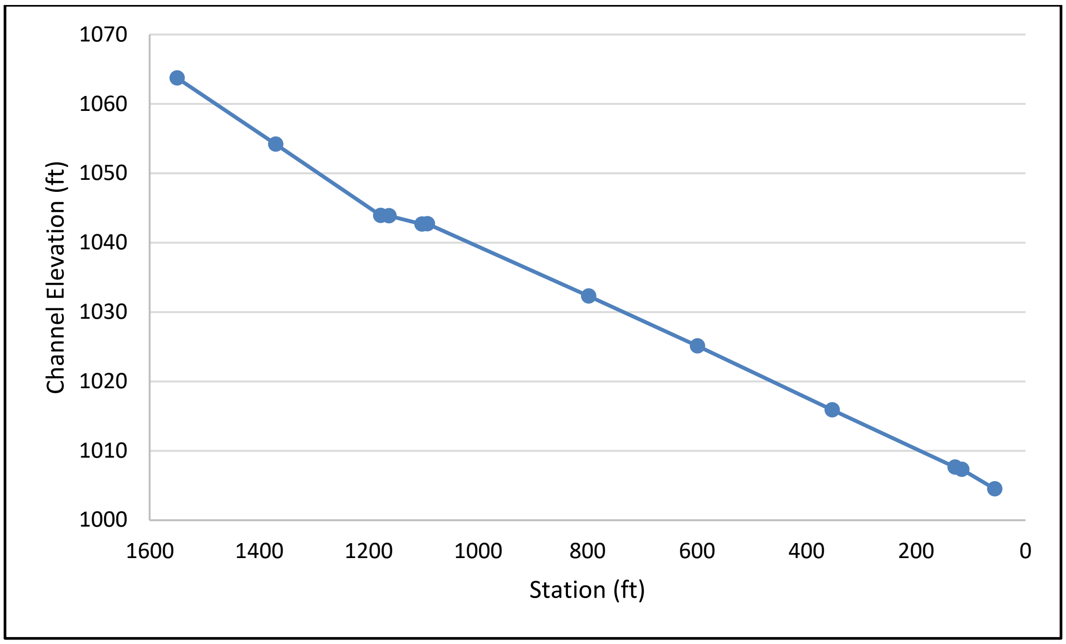


Figure 2-5
Fox Hollow Creek Longitudinal Profile within the Project Area

2.4 <u>Infrastructure and Critical Facilities</u>

There are 11 bridges in the LFA project area. Three bridges span Esopus Creek, four span Bushnellsville Creek, and two bridges cross Fox Hollow Creek. Peck Hollow Creek and Broadstreet Hollow Creek each have a structure that passes flows under State Route 28. There is no FEMA data regarding the State Route 28 bridge at Peck Hollow Creek. This stream is not included in the 2016 Ulster County FIS, and there is no effective FEMA hydraulic model for this watercourse. Additionally, there is one structure that is not hydraulically significant. This is a private footbridge that crosses the Esopus Creek on the property of the Copperhood Retreat and Spa. This structure is a cable footbridge that would not pose a significant hydraulic constriction at any flow. Additionally, this bridge is not critical as it is used to access spa property and has no known effect on emergency evacuation or recovery efforts.

Two of the bridges in the hamlet of Shandaken were replaced in 2016 – the State Route 28 bridge over Esopus Creek and the State Route 42 bridge over Bushnellsville Creek, upstream of Glenbrook Park. Both of these bridges were replaced with larger structures that have greater hydraulic capacity.

Four of the bridges in the LFA study area have the potential to act as significant hydraulic constrictions during flood events. Additionally, overtopping of these structures or their approach roads may impede rescue and recovery efforts. Two of these bridges are located on Bushnellsville Creek, one spans Fox Hollow Creek while the fourth crosses Esopus Creek at Fox Hollow Road. The most upstream of these structures on Bushnellsville Creek is a private bridge that is overtopped by the 10-year flood event. The bridge over Bushnellsville Creek on County Route 47 near the confluence with Esopus Creek does not have sufficient capacity as it is only able to comfortably pass the 10- and 25-year events.

On Fox Hollow Creek, a private bridge near the project area boundary is only able to comfortably pass the 10-year discharge. All flows greater than the 25-year event overtop the bridge.

The final bridge of concern is the Fox Hollow Road bridge over Esopus Creek. The bridge is easily able to pass the 10-year discharge. However, during the 25- and 50-year events, water hits the bridge deck, with flows leaving the left bank of the channel immediately upstream of the bridge, resulting in the inundation of Fox Hollow Road between Esopus Creek and State Route 28. The 100- and 500-year events overtop the bridge. This bridge provides the only access to homes along Fox Hollow Creek and is of critical importance to evacuation and recovery efforts along Fox Hollow Road during natural disasters.

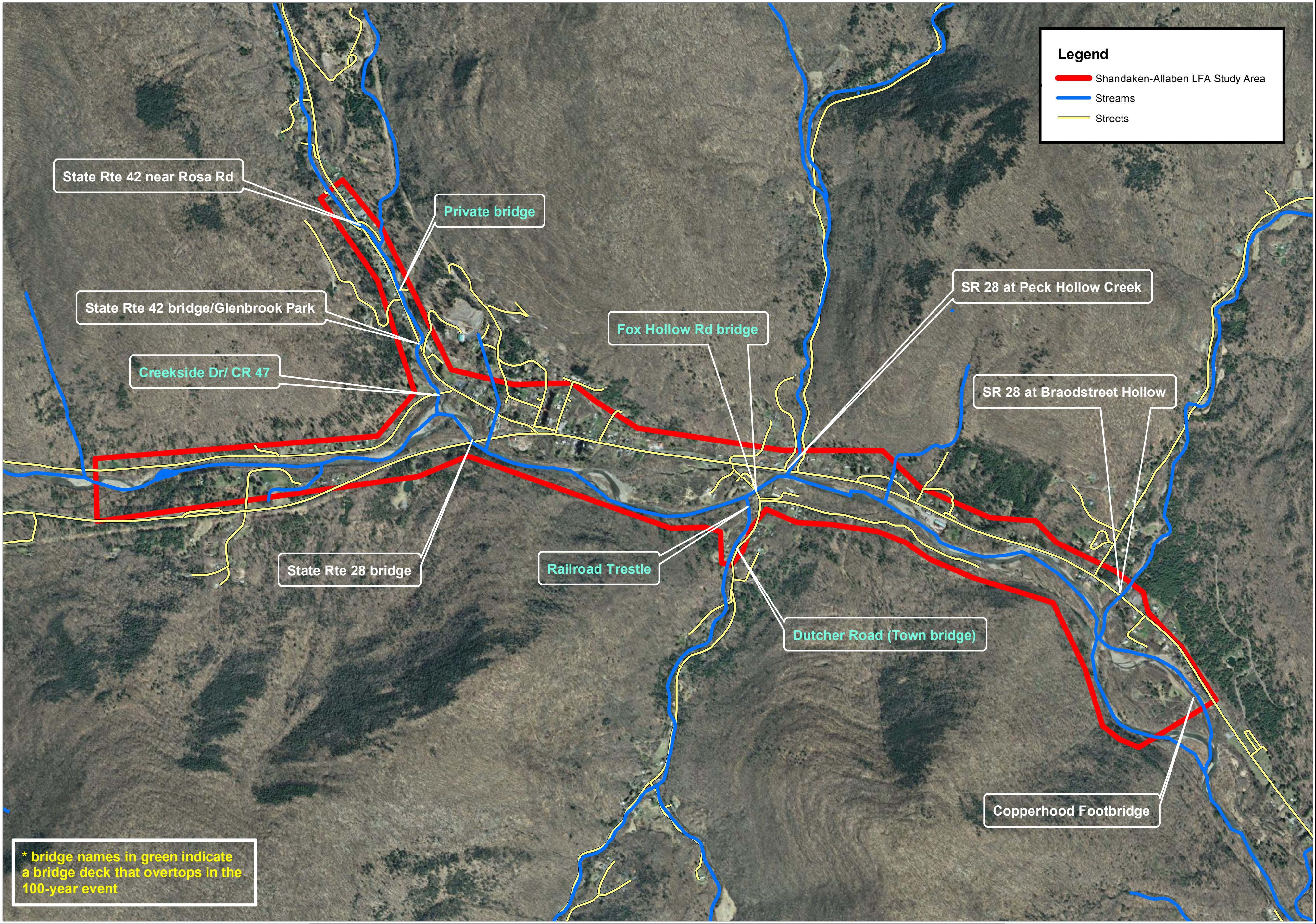
Table 2-1 lists the bridges in the project area from upstream to downstream. Water surface elevations were derived from baseline hydraulic modeling and are in close agreement with elevations in the 2016 FEMA FIS bridge profiles. Figure 2-6 is a map of the LFA project area showing the locations of the 11 bridges evaluated here. The bridges with decks that are overtopped during the 100-year flood event are identified.

TABLE 2-1
Bridges in the Shandaken/Allaben LFA Project Area

Stream	Bridge Crossing	Bridge Deck Elevation	Predicted 100-Year WSEL	Bridge Deck Overtops in 100-Year Event (Y/N)
Esopus Creek	State Route 28	1,061.6	1,056.5	N
Esopus Creek	Fox Hollow Road	1,015.9	1,019.8	Y
Esopus Creek	Copperhood Footbridge	947.6	648.5	N
Bushnellsville Creek	State Route 42 near Rosa Road	1,139.7	1,138.9	N
Bushnellsville Creek	Private Bridge	1,106.0	1,111.4	Y
Bushnellsville Creek	State Route 42/Glenbrook Park	1,092.0	1,092.0	N
Bushnellsville Creek	Creekside Drive/County Route 47	1,065.0	1,068.4	Y
Fox Hollow Creek	Private/Town Bridge	1,053.6	1,056.9	Y
Fox Hollow Creek	Railroad Trestle	1,016.4	1,018.0	Y
Peck Hollow Creek	State Route 28	*	*	Not assessed
Broadstreet Hollow Creek	State Route 28	976.0	976.0	N

*No data available in FEMA 2016 Revised FIS or FEMA HEC-RAS Model
WSEL = Water surface elevation

In the hamlet of Shandaken, a flood control levee lines the left bank of the Bushnellsville Creek and Esopus Creek confluence. The levee begins on Bushnellsville Creek immediately downstream of the County Route 47 bridge. It extends 155 feet along the left bank of Bushnellsville Creek. The levee then turns and runs along the left bank of Esopus Creek for an additional 445 feet (Figure 2-7).



SOURCE(S):
http://www.orthos.dhses.ny.gov/arcgis/services, accessed August 2017

Figure 2-6: Bridges in Project Area

MXD: Q:\Projects\5197-13 Water Street\GIS\BridgesinProjectArea.mxd

Shandaken-Allaben Local Flood Analysis

LOCATION: Shandaken, NY

Map By: EMH
MMI#: 4615-18
Original: 08/28/2017
Revision: 10/30/2017
Scale: 1 in = 2,000 ft

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Figure 2-7
Levee at Bushnellsville Creek and Esopus Creek Confluence Prior to Tropical Storm Irene

The levee was initially constructed in 1954 with federal funds. During Tropical Storm Irene in 2011, the levee was breached, resulting in significant damage to the structure. As part of the repairs to the levee, the stream channel was excavated and cleared to restore it to its previous condition (NYSDEC Website, 2017).

Since the repairs were made in 2011, the levee has experienced erosion at the downstream end. This erosion is due to the change in course of the Esopus Creek. Prior to Tropical Storm Irene, Esopus Creek ran parallel to the lower portion of the levee. However, following Tropical Storm Irene, the channel cut through the floodplain on the right bank, and the course of the stream was diverted directly toward the lower portion of the levee.

Figure 2-8
Erosion along Flood Control Levee in Shandaken

The levee is operated by the State of New York and was reportedly last inspected in 2009 when it received an "Acceptable" rating. The levee is not certified by FEMA, indicating that it does not meet FEMA's standards for design, operation, and maintenance. As a result, flood elevations indicated on the FIS and on Flood Insurance Rate Maps (FIRMs) have been computed as if the levee did not exist.

There are six critical facilities in the project area. The facilities are essential for administration of the town. In some cases, facilities such as the police station, the Volunteer Fire Department, and the Highway Department are vital for disaster response. The town hall, animal shelter, and Highway Department garage are located together on a parcel situated between Esopus Creek and State Route 28. Both the animal shelter and the Highway Department are within FEMA's floodway while the town hall is situated just outside of the floodway boundary. All of the facilities listed are within FEMA's SFHA, with the exception of the Fire Department, which is located within the 500-year flood zone. Critical facilities are listed in Table 2-2.

TABLE 2-2
Critical Facilities in the Project Area

Hamlet	Facility	Address	Stream	Floodway? (Y/N)	SFHA? (Y/N)
Shandaken	Police Department	64 State Route 42	Bushnellsville Creek	N	Y
Shandaken	Post Office	22 State Route 42	Esopus Creek	N	Y
Shandaken	Volunteer Fire Department	7390 State Route 28	Esopus Creek	N	N
Shandaken	Ulster County Dept. of Public Works Yard	7320 State Route 28	Esopus Creek	N	N
Allaben	Town Hall	7209 State Route 28	Esopus Creek	N	Y
Allaben	Animal Shelter	7209 State Route 28	Esopus Creek	Y	Y
Allaben	Town Highway Department Facility	7201 State Route 28	Esopus Creek	Y	Y

Figure 2-9 is a map of the LFA project area showing the locations of critical facilities. Those critical facilities located within the 100-year flood zone (also known as the SFHA) are identified.

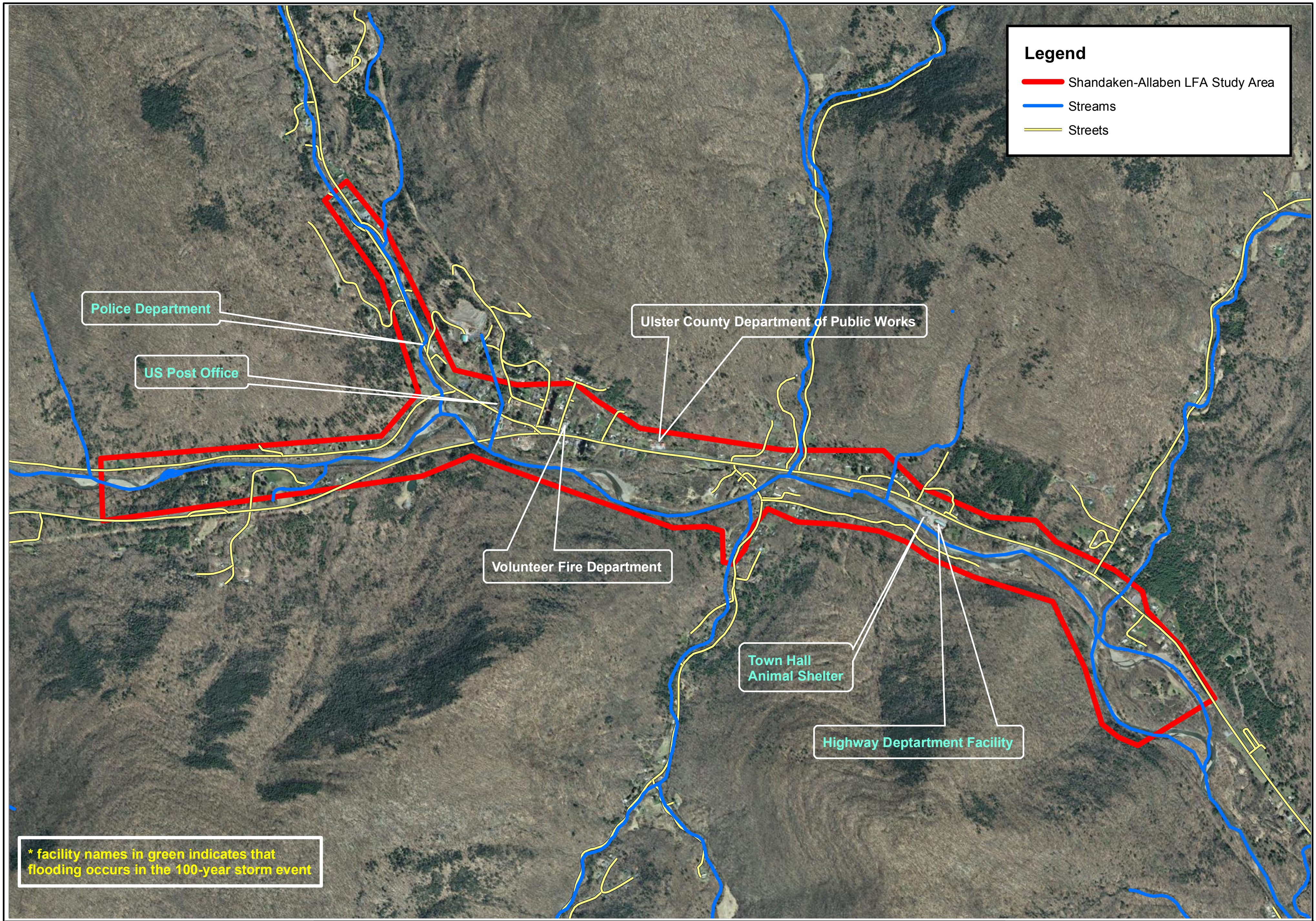
2.5 Potential Impacts on Water Quality due to Flooding

In addition to helping communities identify and mitigate flood hazards, the LFA program mandate includes protecting water quality in the New York City water supply watershed. Flooding is known to cause impaired water quality. Reduction of flooding reduces water quality impairment by reducing the area of land and buildings exposed to floodwaters and by reducing the depth and velocity of floodwaters that mobilize pollutants.

When flooding occurs in the Shandaken-Allaben project area, roads and parking lots are inundated by floodwaters, causing oils, gasoline, and other pollutants to be mobilized. When flooding is severe, vehicles can become inundated; yards, buildings, and storage areas can be flooded; and tanks and fuel drums can be washed into Esopus Creek and its tributaries, severely impacting water quality. Septic systems are also vulnerable to flooding, and potentially to scour, especially when located within the floodway.

One notable potential source of water quality impairment, if it were to be inundated during a flood event, is the Town of Shandaken Highway Department garage. The garage is located within the SFHA along Esopus Creek and is within the FEMA floodway.

The town Highway Department garage property currently stores over 5,000 gallons in combined automotive and industrial chemicals including fuel, oil, antifreeze, and additives. Approximately 3,000 of these 5,000 gallons are stored at a location on the outside western face of the Highway Department garage in three fuel storage tanks containing heating oil and diesel fuel, as seen in Figure 2-11. Other potential pollutants such as old tires, empty fuel drums, and containers (Figure 2-12); paints (Figure 2-13); acetylene torches; and asphalt road patch material are present within and in the immediate vicinity of the garage. Although chemical storage appears to be in compliance with regulations, the best solution to reduce the risk of contamination of Esopus Creek and Ashokan Reservoir during a flood event is to relocate the facility and its contents outside of the floodplain. If the Highway Department garage were to be inundated during a flood event, and floodwaters were to come in contact with and transport any of these pollutants and materials mentioned, significant water quality and environmental damages would likely occur.



SOURCE(S):
http://www.orthos.dhses.ny.gov/arcgis/services, accessed August 2017

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Figure 2-9: Critical Facilities in Project Area

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Shandaken-Allaben Local Flood Analysis

LOCATION: Shandaken, NY

Map By:	EMH
MMI#:	4615-18
Original:	08/28/2017
Revision:	10/30/2017
Scale:	1 in = 2,000 ft

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Figure 2-10
1000-gallon Fuel Storage Tank at Highway Department Garage

Figure 2-11
Old Oil Stored Inside Various Containers at Highway Department Garage

Figure 2-12
Paints and Other Chemicals Stored at Highway Department Garage

2.6 Hydrology

Hydrologic studies are conducted to understand historic and potential future river flow rates. Hydrologic data in terms of stream flow is a critical input for hydraulic models such as HEC-RAS. Stream flow is typically determined from USGS stream gauging stations or from regression equations based on variables such as precipitation and watershed area.

The USGS operates and maintains stream flow gauges that record daily stream flow, including flood flows. These data are essential to understanding long-term trends. Gauge data can be utilized to determine flood magnitudes and frequencies. Table 2-3 is a list of USGS water surface stream gauging stations within the project area.

TABLE 2-3
Active USGS Gauging Stations in Project Area

USGS Gauge Number	Location	Drainage Area (square miles)	Period of Record
1362197	Bushnellsville Creek at Shandaken	11.4	November 1950 to September 2012
1362200	Esopus Creek at Allaben	63.7	October 1963 to Present
1362230	Diversion from Schoharie Reservoir	N/A	February 1924 to Present

FEMA conducted an in-depth hydrologic analysis of the Ashokan Reservoir watershed, which includes upper Esopus Creek and its tributaries (FEMA, 2012). The study was conducted following extensive flooding in 2011 caused by Tropical Storms Irene and Lee. The purpose was to develop current hydrologic analyses for use in other FEMA flood hazard products.

Discharges in the Esopus Creek watershed were developed using Hydrologic Engineering Center – *Hydrologic Modeling System* (HEC-HMS) 3.5, which is a rainfall-runoff model. Where possible, discharges developed using HEC-HMS 3.5 were compared with results developed using USGS stream gauges and USGS *StreamStats* regression equations. The model was calibrated using high water marks documented during Tropical Storm Irene (August 2011) and verified against Tropical Storm Lee (September 2011) and a second storm that occurred in October 2005. Table 2-4 lists peak discharges for the 10-, 25-, 50-, 100-, and 500-year flood events within the study area as determined by FEMA and reported in the Ashokan Reservoir Watershed Hydrologic Study (FEMA, 2012).

TABLE 2-4
FEMA Ashokan Reservoir Hydrologic Study Peak Discharges
(All flow values in cfs)

	Location	Basin Area (mi^2)	10-Year	25-Year	50-Year	100-Year	500-Year
Esopus Creek	Esopus Creek above Bushnellsville Creek	47.60	8,716	13,546	18,444	24,287	45,372
	Esopus Creek above Fox Hollow Creek	59.50	10,769	16,756	22,972	30,211	56,709
	Esopus Creek above Peck Hollow Creek	63.70	11,390	17,664	24,274	31,925	60,210
	Esopus Creek above Broadstreet Hollow Creek	70.00	12,600	19,550	26,827	35,214	66,342
	Esopus Creek above Woodland Creek	84.00	15,173	23,382	31,970	42,159	79,494
Bushnellsville Creek	Bushnellsville Creek above Angle Creek	4.4	1,038	1,587	2,129	2,767	4,944
	Bushnellsville Creek 2,000 feet upstream of Gossoo Road	8.6	1,823	2,810	3,787	4,944	8,930
	Bushnellsville Creek above Confluence with Esopus Creek	11.1	2,200	3,430	4,654	6,114	11,213
Fox Hollow Creek	Fox Hollow Creek at Herdman Road	2.4	691	1,050	1,401	1,814	3,216
	Fox Hollow Creek above Esopus Creek	4.0	1,089	1,649	2,209	2,868	5,114
Broadstreet Hollow Creek	Broadstreet Hollow Creek above Jay Hand Hollow Creek	4.9	1,406	2,145	2,869	3,796	6,741
	Broadstreet Hollow Creek above confluence with Esopus Creek	7.3	1,772	2,715	3,628	4,810	8,598

The flows in the Ashokan Reservoir Hydrologic Study were compared with Steady Flow Data files in the respective FEMA HEC-RAS models. A discrepancy was noted between the Ashokan watershed study and Esopus Creek HEC-RAS model. This is discussed further in Section 4.0 of the report.

Although FEMA documents provide estimations of large flood events (10-year discharge and greater), they do not provide estimates of smaller discharges. These smaller flows are important because they determine the long-term form of the channel. A widely accepted theory is that alluvial channels adjust their width, depth, and slope in response to a natural range of flows that can be represented by a single, equivalent "channel-forming discharge" (Doyle et al., 2007; Richard and Anderson, 2007). Statistical analysis has determined that the frequency of channel-forming discharges typically varies from 1 to 5 years. This frequency can be higher or lower at specific sites. However, the value generally used to represent the channel-forming discharge is 1.5 years. Several surrogates are available to estimate the channel-forming discharge, including the bankfull discharge, effective sediment transport discharge, and frequency analysis. The most commonly used of these methods is bankfull discharge. Along with characterization of the streambed material, measurements associated with the bankfull discharge such as width and depth are useful parameters in the assessment and design of channel and bank restorations.

Table 2-5 lists the bankfull discharges and channel dimensions for locations along Esopus Creek corresponding to those in the Ashokan Reservoir Watershed Hydrologic Study. These values were calculated using USGS *StreamStats,* which is a web implementation of USGS Report SIR 2006-5112. This report provides methods of computing flood discharges in New York based on regression equations. These equations relate discharge to the mean annual precipitation and several other parameters based on watershed basin characteristics within a number of geographically distinct regions in NYS (Mulvihill et al., 2009).

TABLE 2-5
Estimated 2-Year Discharge and Bankfull Discharge,
Width, and Depth for Esopus Creek

Esopus Creek Location	Bankfull Discharge (cfs)	Bankfull Width (feet)	Bankfull Depth (feet)	Bankfull Area (square feet)
Above Bushnellsville Creek	3,560	89.6	3.36	302
Above Fox Hollow Creek	4,240	98.7	3.59	356
Above Peck Hollow Creek	2,450	103.0	3.69	381
Above Broadstreet Hollow Creek	2,700	109.0	3.83	418
Above Woodland Creek	3,240	121.0	4.11	498

Source: USGS *StreamStats*

3.0 EXISTING FLOODING HAZARDS

3.1 Flooding History in Shandaken and Allaben

The Catskill Mountains are subject to large storm events that are often unevenly distributed across watersheds. As a result, local flash floods can occur in one basin while an adjacent basin receives little rainfall. In addition to local flash floods, larger storm events can cause widespread flooding. Notable larger flood events occurred in 1980, 1996, 2005, and most recently during Tropical Storm Irene in August 2011.

An examination of flood history conducted for the 2007 Upper Esopus Creek Management Plan indicates that major floods have occurred periodically over the last century with at least 11 major floods occurring between 1933 and 2011 (NYCDEP, 2007). Floods can take place any time of the year but are commonly divided into those occurring in winter and spring and those occurring in summer and fall. Floods that take place in summer and fall are typically due to extreme rainfall events caused by hurricanes and tropical storms. Floods in winter and spring are associated with rain on snow events and spring snowmelt (Tetra Tech, 2013; NYCDEP, 2007). Table 3-1 provides a summary of the 10 largest flood events on the Esopus Creek as recorded at Allaben, New York.

TABLE 3-1
Historic Peak Discharges in the Upper Esopus Watershed

Rank	Date	Discharge (cfs)
1	August 28, 2011	29,300
2	April 02, 2005	21,700
3	March 30, 1951	20,000
4	April 04, 1987	16,100
5	March 21, 1980	15,900
6	January 19, 1996	15,000
7	April 05, 1984	8,470
8	July 28, 1969	7,870
9	September 18, 2004	6,700
10	February 20, 1981	6,540

(USGS Stream Flow Gauge 1362200)

The USGS has maintained an active gauge on Esopus Creek in Allaben since the early 1960s. During the 1960s and 1970s, there were no floods that exceeded the 10-year discharge event. However, between 1980 and 2011, there have been several major flood events in the Esopus Basin. The first major flood of this period occurred between March 21 and 22, 1980, with a peak discharge of 15,000 cfs. Heavy rains contributed to flooding resulting in an estimated $6 million in damages within the town of Shandaken. Floods of similar discharges occurred again in 1987 (16,100 cfs) and 1996 (15,000 cfs). Figure 3-1 provides an illustration of the extent of flooding that occurred along the Esopus Creek during the 1987 flood.

Figure 3-1
Shandaken Manor on Esopus Creek during the 1987 Flood

On April 2, 2005, a major flood occurred with a discharge of 21,700 cfs at the USGS gauge in Allaben. The recurrence interval for this flood was close to the 50-year discharge event, which is estimated to be 24,274 cfs according to the FEMA Ashokan Reservoir Hydrology Study (FEMA, 2012). This flood resulted in significant damage in the town of Shandaken (Figure 3-2).

Figure 3-2
Fox Hollow Road Washed Out During the 2005 Flood Event

On August 28, 2011, Tropical Storm Irene caused extensive flooding and devastation in eastern New York. Discharge on Esopus Creek at the USGS gauge at Allaben peaked at 29,300 cfs. This discharge exceeded FEMA's projected 50-year flood event of 24,274 cfs but did not exceed the projected 100-year flood event of 31,925 cfs. Figure 3-3 shows annual peak flows recorded at the USGS gauges on Esopus Creek at Allaben. The figure illustrates that Tropical Storm Irene produced the largest discharge ever recorded on Esopus Creek since gauges were first established at this location on Esopus Creek in the early 1950s.

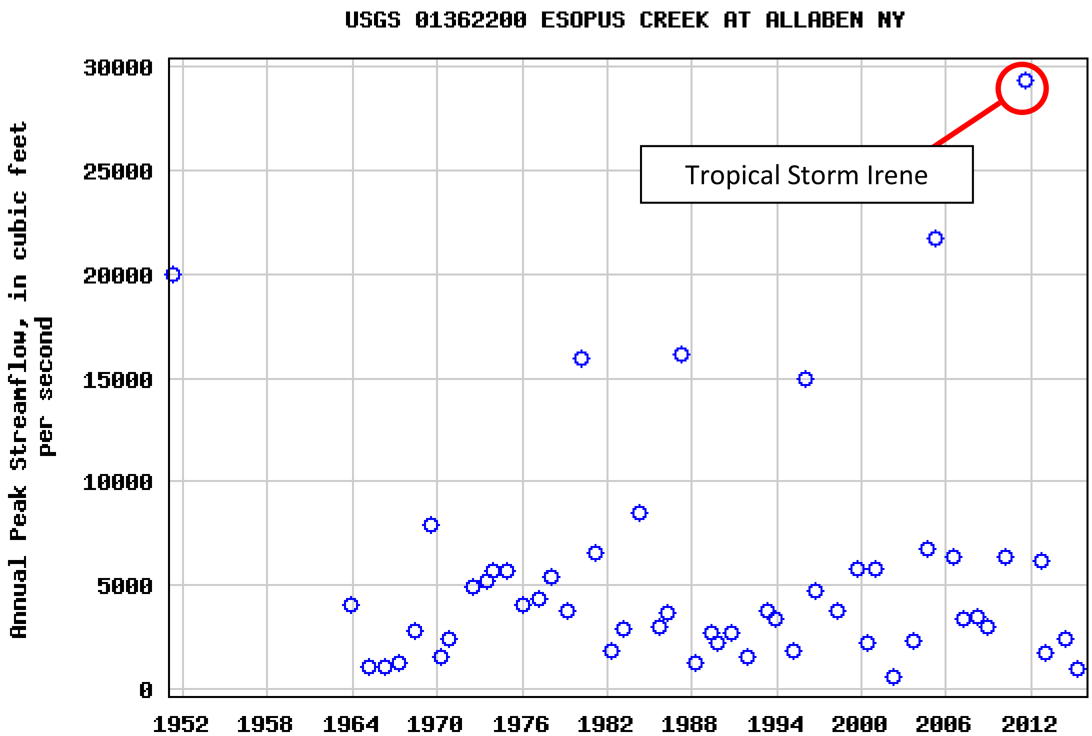


Figure 3-3
Annual Peak Discharge at USGS 1362200 in Allaben, New York

Tropical Storm Irene caused extensive flooding and devastation in the upper Esopus Creek watershed. A week later on September 2, Tropical Storm Lee brought additional rainfall to the area resulting in further flooding. These two events produced the largest and most expensive natural disaster in the history of NYS at that time, with an estimated $1.5 billion in damages (FEMA, 2013). (Hurricane Sandy in 2012 is now the most expensive, with estimated losses in New York of at least $18 billion.)

Photographs, aerial imagery, videos, and news accounts from Tropical Storm Irene paint a vivid picture of the extensive damages that occurred throughout the study area. Numerous roads were flooded or damaged. Within the Oliverea area, six bridges were washed out or compromised. The dam at Winnisook Lake, which is the source of Esopus Creek, began to erode, provoking concerns that another heavy rainfall event could result in failure and lead to catastrophic flooding.

Within the project area, flooding was extensive. In the hamlet of Shandaken, the Esopus Creek nearly overtopped the deck of the State Route 28 bridge as well as the flood control levee that runs along the banks of Bushnellsville and Esopus Creeks. Additionally, numerous houses and businesses suffered extensive damage (Figures 3-4 and 3-5). In the hamlet of Allaben, flooding was severe and resulted in damages to homes and vehicles (Figures 3-6 and 3-7).

Figure 3-4
Esopus Creek Nearly Reaching Deck of State Route 28 Bridge in Shandaken

Figure 3-5
Flooding at Farmer Jones Barns Property in Shandaken, New York

Figure 3-6
Flooding of Homes along Esopus Creek near Confluence with Fox Hollow Creek in Allaben

Figure 3-7
Damage to Trailer along Esopus Creek near Confluence with Fox Hollow Creek in Allaben

Compared with Esopus Creek, there is a lack of information regarding flood discharges and damages on other waterbodies in the project area. However, it is safe to assume that flooding along the upper Esopus Creek is indicative of flooding along tributaries in its upper watershed. There are no current USGS stream flow gauges along any of the streams in the project area besides the Esopus Creek. However, peak stream flow measurements were recorded at a historic USGS gauging station on Bushnellsville Creek discontinuously between 1950 and 2012. The gauge was located approximately 2,000 feet upstream of the confluence with Esopus Creek. Peak discharges were recorded in 1950, 1955, 1976, and then more or less continuously between 1977 and 2012 when measurements were suspended. Table 3-2 provides a summary of the 10 largest flood events recorded at this gauge.

TABLE 3-2
Historic Peak Discharges on Bushnellsville Creek

Rank	Date	Discharge (cfs)
1	August 28, 2011	2,750
2	April 02, 2005	2,700
3	October 15, 1955	1,830
4	November 25, 1950	1,350
5	April 04, 1987	1,000
6	January 19, 1996	996
7	April 05, 1984	896
8	March 21, 1980	848
9	April 16, 2007	700
10	March 30, 1977	683

Major flood events on Bushnellsville Creek roughly correspond to those on Esopus Creek. However, the return period of the major floods on Bushnellsville Creek are markedly smaller than those on Esopus Creek. Only two floods were greater than the 10-year return interval flood, which had an estimated discharge of 2,200 cfs. Though these floods exceeded the 10-year discharge, they were not close to the 25-year return interval discharge of 3,430 cfs (FEMA, 2012).

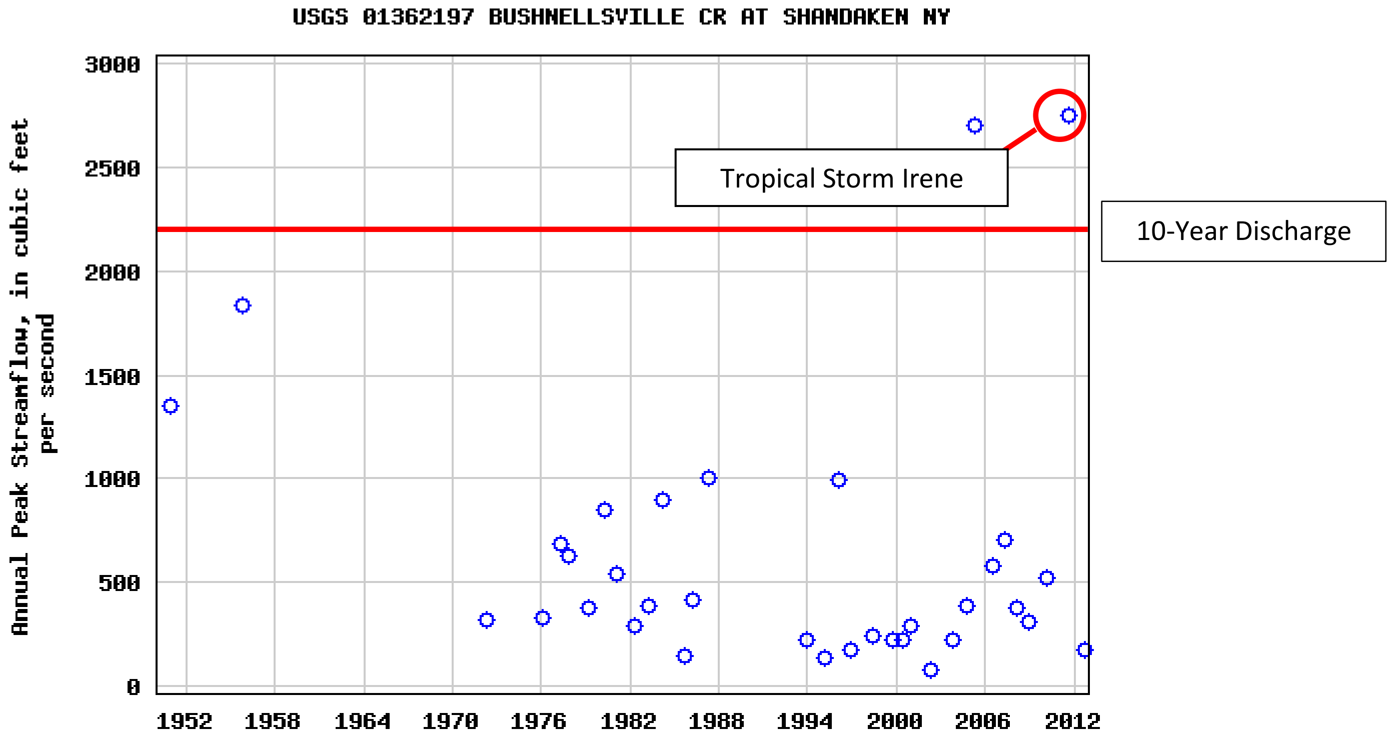


Figure 3-8
Annual Peak Discharge on Bushnellsville Creek

3.2 FEMA Mapping

FEMA FIRMs are available for the study area and depict the SFHA, which is the area inundated by flooding during the statistical 100-year flood event. The maps also depict the FEMA-designated floodway, which is the stream channel and that portion of the adjacent floodplain that must remain open to permit passage of the base flood. Floodwaters are typically deepest and swiftest in the floodway, and anything in this area is in the greatest danger during a flood (FEMA, 2008).

FEMA FIRMs that are relevant to the project area include 36111C0045F, 36111C0210F, and 36111C0230F. These FIRMs all have an effective date of November 18, 2016, and have been adopted by the Town of Shandaken. The maps address the following areas:

- 36111C0045F: Bushnellsville Creek except the confluence with Esopus Creek
- 36111C0210F: The Bushnellsville Creek/Esopus Creek confluence, Esopus Creek at the upper end of the project area, Fox Hollow Creek, and Peck Hollow Creek
- 36111C0230F: Esopus Creek at the lower end of the project area and Broadstreet Hollow Creek

The FIRMs are accessible to the public on the FEMA Flood Map Service Center website (https://msc.fema.gov/portal). A brief description of the SFHA and floodway within the project area is given below.

The SFHA and the floodway are relatively narrow on Esopus Creek from the upper end of the project area to the confluence with Bushnellsville Creek. No homes appear to be at risk though some portions of Creekside Drive/County Route 47 may be flooded during the 100-year discharge.

At the confluence with Bushnellsville Creek, the SFHA and the floodway widen. Properties situated between Esopus Creek, State Route 28, and State Highway 42 are at risk of inundation during the 100-year event. These properties are protected from inundation during lesser events by a levee that is not FEMA certified. Should this levee become compromised or fail, these homes would be at risk from smaller events.

Between the State Route 28 bridge in the hamlet of Shandaken and the downstream end of the project area, the SFHA and the floodway widen considerably. In most locations, the floodway is nearly as wide as the SFHA. In general, State Route 28 is passable during the 100-year event. However, FEMA mapping indicates that it is likely to be inundated at the following locations:

- Between the Ulster County Department of Roads and Bridges facility and Fitchner Terrace
- Peck Hollow Creek
- The diversion from Schoharie Reservoir
- Broadstreet Hollow Creek

Along this stretch of Esopus Creek, there are a few locations where clusters of properties are vulnerable to flooding. These areas include the following:

- The confluence with Fox Hollow Creek where properties on both sides of Esopus Creek are at risk
- The left bank of Esopus Creek between the Shandaken Tunnel outlet and Broadstreet Hollow Road
- The portion of Wettje Road adjacent to Esopus Creek

In addition to these areas, isolated properties, particularly along the left bank of Esopus Creek, are located within the SFHA. The Town of Shandaken town hall building lies just within the SFHA while the Highway Department building is located within the floodway. The Shandaken/Allaben Fire Department structure is safe from flooding as it is located outside of the 500-year flood zone. The parking area for the Fire Department is partially within the 500-year flood zone. Portions of Route 28 both east and west of the Fire Department and portions of Route 42 are subject to flooding during the 100-year flood event, which could potentially prevent fire rescue equipment and personnel from reaching areas of town during a flood event.

All of the tributaries included in the studies are situated in confined valleys with limited floodplains. As a result, the SFHA and the associated floodway areas are rather narrow. Along the length of Bushnellsville Creek, isolated properties on both sides of the stream are vulnerable to the 100-year discharge. A facility of special concern is the Town of Shandaken Police Department located at 64 State Route 42. This building is located in the SFHA. Furthermore, FEMA mapping indicates the roads leading to the facility off State Route 42 are flooded during the 100-year event.

Very few structures in the project area along the remaining tributaries are at risk from inundation. Along Fox Hollow Creek, there are no residential or business structures located in the SFHA. Two parcels located on the left bank of Peck Hollow Creek near State Route 28 are situated in the SFHA. On Broadstreet Hollow Creek, three parcels in proximity to State Route 28 are in the SFHA and are vulnerable to flooding.

Section 5.2 of this report includes mapping of homes, businesses, and other structures located within the SFHA.

3.3 Public Input

On December 20, 2016, an introductory public meeting held at the Shandaken town hall was convened at the beginning of the LFA process. MMI provided attendees with an overview of the project, the LFA process, and hydraulic modeling techniques. Information was collected from attendees on flood damage and potential flood mitigation alternatives. This information was then used throughout the LFA process to verify flood damages, pinpoint problem areas, and develop flood mitigation alternatives.

Attendees were provided with large-format maps and asked to point out locations of flooding and flood damages during both Tropical Storm Irene and previous flood events. A summary of comments is listed below:

- Residents of the hamlet of Shandaken are concerned with active erosion at the lower end of the levee situated at the Esopus Creek/Bushnellsville Creek confluence. Additionally, residents who live between the levee and State Route 42 experience flooding in their basement during high discharge events.

- SAFARI members were concerned that the accumulation of gravel at the Esopus Creek/Bushnellsville Creek confluence had reduced channel capacity and increased flooding.

- Sediment has accumulated under the County Route 47 bridge over Bushnellsville Creek, resulting in a reduced opening area and possibly contributing to flooding upstream.

- Residents noted that downed trees and other debris clogged bridge openings, which worsened flooding.

- SAFARI members and residents were concerned about the accumulation of gravel in certain locations along Esopus Creek and the obstruction of side channels by trees and other debris.

- During high discharges, Esopus Creek accesses the floodplain on the north bank just upstream of the Fox Hollow Road bridge and runs over Fox Hollow Road between State Route 28 and the bridge.

- State Route 28 immediately downstream of the Shandaken Tunnel has washed out during high flows.

- A resident who lives on the Broadstreet Hollow Creek is concerned about potential flooding upstream of the State Route 28 bridge.

4.0 FLOOD MITIGATION ANALYSIS AND ALTERNATIVES

The purpose of a hydraulic assessment is to evaluate historic and predicted water surface elevations, identify floodprone areas, and help develop mitigation strategies to minimize future flood damages and protect water quality. Hydraulic analysis techniques can also help predict flow velocities, sediment transport, scour, and deposition if these outcomes are desired.

Specific areas have been identified as being prone to flooding during severe rain events within the project area. Numerous alternatives were developed and assessed at each area where flooding is known to have caused extensive damage to homes and properties. Alternatives were assessed with hydraulic modeling to determine their effectiveness. The narrative below describes the alternatives and the results of modeling analysis.

4.1 Analysis Approach

Hydraulic analysis of Esopus Creek and its tributaries was conducted using the HEC-RAS hydraulic modeling program. The HEC-RAS software was written by the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center and is considered to be the industry standard for riverine flood analysis. The model is used to compute water surface profiles for one-dimensional, steady-state, or time-varied flows. The system can accommodate a full network of channels, a dendritic system, or a single river reach. HEC-RAS is capable of modeling water surface profiles under subcritical, supercritical, and mixed-flow conditions.

Water surface profiles are computed from one cross section to the next by solving the one-dimensional energy equation with an iterative procedure called the standard step method. Energy losses are evaluated by friction (Manning's Equation) and the contraction/expansion of flow through the channel. The momentum equation is used in situations where the water surface profile is rapidly varied such as hydraulic jumps, mixed-flow regime calculations, hydraulics of dams and bridges, and evaluating profiles at a river confluence.

In order to carry out hydraulic modeling of baseline conditions and alternatives, MMI obtained the effective FEMA HEC-RAS models for Esopus Creek, Bushnellsville Creek, Fox Hollow Creek, and Broadstreet Hollow Creek from the NYCDEP. In addition to the effective models, NYCDEP also provided a noneffective model for Peck Hollow Creek, which was constructed using approximate methods.

The HEC-RAS models furnished by NYCDEP provided the starting point for the current analysis. Duplicate effective models were created for Esopus Creek, Bushnellsville Creek, Fox Hollow Creek, and Broadstreet Hollow Creek. The outputs of the duplicate effective models were compared to those provided by the NYCDEP and found to be identical. Additionally, the water surface elevations of the HEC-RAS models were compared to those published in the FEMA FIS and the online FIRMs and verified for accuracy.

The HEC-RAS models were reviewed to assess variables and coefficients, hydrology, and geometry. An examination of the Steady Flow Data indicated that none of the tributaries were modeled under backwater conditions caused by Esopus Creek. This is relevant as all of the tributaries have bridges in close proximity to their confluence with Esopus Creek. The review also noted that two bridges that had been replaced in 2016 were not included in the effective FEMA models. The first is the State Route 28 bridge over Esopus Creek in the hamlet of Shandaken. The second is the State Route 42 bridge over Bushnellsville Creek upstream of Glenbrook Park.

A review of the Esopus Creek HEC-RAS model noted possible discrepancies between the "Steady Flow" file, the FEMA hydrology documented in Table 4 of the November 18, 2006, FIS, and Table 17 of the Ashokan Reservoir Watershed Hydrologic Study (ARWHS) dated August 12. The ARWHS was taken to be the foundation document as the hydrology of both the 2016 FIS and the HEC-RAS model seems to be based on this report.

The discrepancy initially appears in the length of Esopus Creek between the Fox Hollow and Broadstreet Hollow Creeks tributaries. According to the ARWHS, there should be a flow change point just upstream of the Peck Hollow tributary as well as one just upstream of the Broadstreet Hollow Creek tributary. However, a change point in the HEC-RAS model does not occur until just downstream of the Broadstreet Hollow Creek tributary. As a result, the flows that should occur at a location just above the Peck Hollow Creek tributary occur in the model just downstream of the Broadstreet Hollow Creek tributary.

This discrepancy was brought to the attention of FEMA via a memo dated March 2, 2017. FEMA replied on April 26, 2017. They found that "the hydrology and hydraulic analysis conducted by RAMPP for Esopus Creek and the effective FIRMs and FIS (dated November 2016) are correct, and do not warrant changes to the modeling or mapping."

According to the memo, the discrepancy between hydrologic change points in the ARWHS, the FIS, and the HEC-RAS model was due to a calibration issue. The water surface levels predicted by the hydraulic model did not correlate well to observed data at the USGS stream gauge (0136220) located on Esopus Creek immediately downstream of Fox Hollow Creek. As a result, hydraulic change points in the HEC-RAS model were moved downstream in order to be consistent with observed floodwater surface elevations.

An examination of HEC-RAS geometry files, survey sketches, and photos associated with the HEC-RAS models and aerial imagery was made to determine whether the channel geometry reflected pre-Tropical Storm Irene or post-Tropical Storm Irene conditions. The dates on the channel survey sketches suggest that all of the tributary hydraulic models are pre-Irene. Additionally, aerial imagery and the HEC-RAS model clearly show that Bushnellsville Creek is characteristic of pre-Irene conditions at its confluence with Esopus Creek.

In regard to Esopus Creek, the situation is more complicated. Within the project area, the survey forms are dated between September and October 2011. These dates are after Tropical Storm Irene, which occurred on August 28, 2011. However, the geometry of the model at key locations is consistent with conditions prior to Tropical Storm Irene.

Tropical Storm Irene dramatically altered the stream channels at the Esopus Creek/Bushnellsville Creek confluence (Figure 5-1). The Esopus Creek avulsed toward the south, and as a result, the confluence moved approximately 240 feet downstream of its previous location. Although the survey form is dated October 11, 2011, the HEC-RAS model clearly uses pre-Irene channel geometry. This is clearly shown by the location of the main channel and the bank stations at cross section 78961 in the model relative to their current physical locations.

Figure 4-1
Aerial View of Esopus Creek/Bushnellsville Creek Confluence in 2009 (top) and 2016 (bottom)

Another key location where there appears to be a discrepancy between the date of the survey form and the channel geometry is cross section 70410, which is located immediately upstream of the town hall and Highway Department garage (Figure 4-2). Prior to Tropical Storm Irene, Esopus Creek ran along the base of State Route 28. After Irene, the centerline of the channel shifted approximately 170 feet south, away from the road. The survey form is dated October 2011, which is post-Irene. However, the HEC-RAS cross section and bank stations indicated that the channel runs along State Route 28.

Figure 4-2
Aerial View of Esopus Creek near Shandaken Town Hall in 2009 (top) and 2016 (bottom)

The differences in channel geometry are probably not significant for the purpose of this flood analysis. Once stream flow leaves the channel, the controlling geometry is that of the floodplain and valley and not the stream channel. Therefore, even though the hydraulic model of the Esopus Creek appears to depict pre-Irene channel conditions, this is likely to have only a small effect on modeled water surface elevations at flows that leave the channel.

4.2 Existing Conditions Analysis

Copies of all the duplicate effective models were made to create "corrected effective" or operational models. The corrections included the addition of the new bridges over Esopus Creek and Bushnellsville Creek and running the tributary models with a backwater from Esopus Creek. No such model was created for Peck Hollow Creek as the FEMA HEC-RAS model was only an approximate study.

All baseline models were run under a subcritical flow regime. Modeling in a subcritical flow regime will tend to result in slower water velocities and higher water surface elevations. This provides a worst case scenario for expected flood surface elevations.

Plans for the new bridges on Esopus Creek and Bushnellsville Creek were obtained from the New York State Department of Transportation (NYSDOT). The State Route 28 bridge over Esopus Creek in the hamlet of Shandaken was originally a structure with three piers and a hydraulic opening area of 2,420 square feet. The new bridge has a single, central pier with a much larger hydraulic opening area of 4,064.3 square feet. In the effective FEMA model, the railing on the bridge does not appear to be included. In the corrected model, a 5-foot rail was included as part of the deck/roadway, which significantly increased the total height of the structure.

Based on hydraulic modeling, the replacement bridge reduced water surface levels significantly at the two cross sections just upstream for the 25-, 50-, and 100-year events. The water surface elevation during the 500-year flood event increased upstream of the replacement bridge (Table 4-1, Figure 4-3). The increase in water surface elevation is due to the increased deck height of the new bridge, which results from the addition of the safety railing. However, with a much larger opening area, the new bridge is able to pass larger flows. The previous bridge passed the 25-year event while the 50-year event hit the bridge deck, and the 100-year event overtopped the road. In contrast, modeling indicates that the new bridge comfortably passes the 100-year event.

TABLE 4-1
Water Surface Elevations at the State Route 28 Bridge in the Hamlet of Shandaken

HEC-RAS Cross Section Location	Profile	FEMA Effective Model WSEL (feet)	MMI Corrected Effective Model WSEL (feet)	Change (feet)
2,161 feet upstream of bridge	10-year	1,068.5	1,068.5	0.0
	50-year	1,071.3	1,071.3	0.0
	100-year	1,072.8	1,072.8	0.0
	500-year	1,076.1	1,076.1	0.0
954 feet upstream of bridge	10-year	1,057.4	1,057.4	0.0
	50-year	1,059.4	1,059.8	0.4
	100-year	1,060.7	1,061.2	0.5
	500-year	1,066.0	1,067.5	1.5
437 feet upstream of bridge	10-year	1,054.1	1,054.1	0.0
	50-year	1,057.8	1,056.5	-1.3
	100-year	1,058.8	1,057.6	-1.2
	500-year	1,061.3	1,065.9	4.6
77 feet upstream of bridge	10-year	1,049.6	1,049.6	0.0
	50-year	1,057.1	1,053.6	-3.5
	100-year	1,058.3	1,056.0	-2.3
	500-year	1,059.5	1,065.5	6.0
64 feet downstream of bridge	10-year	1,047.0	1,047.0	0.0
	50-year	1,050.6	1,050.6	0.0
	100-year	1,052.3	1,052.3	0.0
	500-year	1,057.0	1,057.5	0.5

wsel = water surface elevation

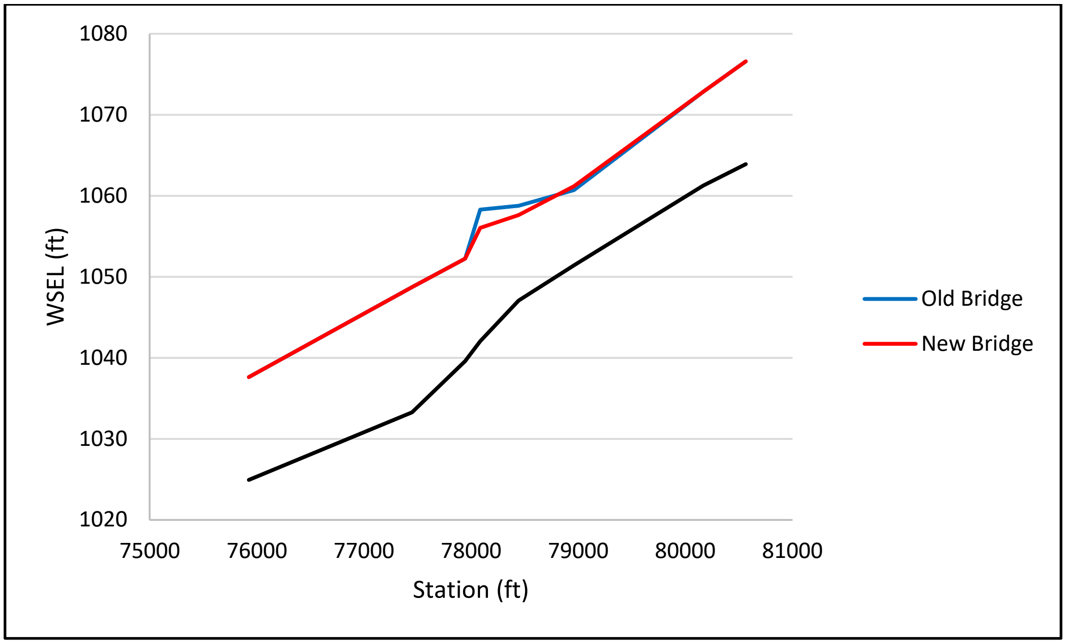


Figure 4-3
Water Surface Elevations at State Route 28 Bridge at 100-Year Discharge

On Bushnellsville Creek, the single-span bridge that had a hydraulic opening area of 353 square feet was replaced with a structure with an opening area of 646 square feet, almost twice as large. Similar to the Esopus Creek bridge, the railing does not appear to be included in the FEMA model and was added to the corrected model.

The effect of the new bridge on water surface levels is inconsistent between cross sections and discharges (Table 4-2). However, the new structure is more hydraulically efficient and able to pass much larger discharges. Hydraulic modeling indicates that the previous bridge was able to pass the 10-year discharge while during the 25-year flood event flows came in contact with the deck of the bridge. The 50-year and greater events overtopped the structure. In comparison, the replacement bridge passes the 50-year discharge while flows during the 100- and 500-year events come in contact with the deck of the bridge.

TABLE 4-2
Water Surface Elevations at the State Route 42 Bridge in the Hamlet of Shandaken

HEC-RAS Cross Section	Profile	FEMA Effective Model WSEL (feet)	MMI Corrected Effective Model WSEL (feet)	Change (feet)
876 feet upstream of bridge	10-year	1,101.5	1,101.5	0.0
	50-year	1,105.3	1,105.3	0.0
	100-year	1,107.4	1,107.4	0.0
	500-year	1,109.1	1,109.1	0.0
556 feet upstream of bridge	10-year	1,094.8	1,094.8	0.0
	50-year	1,096.7	1,097.5	0.8
	100-year	1,097.7	1,097.7	0.0
	500-year	1,102.0	1,102.0	0.0
142 feet upstream of bridge	10-year	1,087.2	1,087.2	0.0
	50-year	1,091.3	1,089.8	-1.5
	100-year	1,092.8	1,093.8	1.0
	500-year	1,095.6	1,095.2	-0.4
42 feet upstream of bridge	10-year	1,085.6	1,087.3	1.6
	50-year	1,091.5	1,090.3	-1.2
	100-year	1,093.0	1,093.9	0.9
	500-year	1,095.1	1,095.5	0.5
53 feet downstream of bridge	10-year	1,082.8	1,082.7	0.0
	50-year	1,085.3	1,085.2	-0.1
	100-year	1,086.1	1,086.2	0.2
	500-year	1,087.9	1,088.6	0.7

wsel = water surface elevation

The hydraulic models of the tributary streams in the project area use normal depth as a downstream boundary condition and do not consider water surface elevations from the Esopus Creek. During high-flow events, water surface elevations from the Esopus Creek may have a significant effect on tributary water surface elevations near the confluence. To account for backwater effects, all of the tributary models were run using known water surface elevations from Esopus Creek as a downstream boundary condition.

Using known backwater elevations from Esopus Creek as a downstream boundary condition could substantially increase water surface levels in the tributaries. However, the increases in water surface elevations did not persist for more than 150 feet upstream of the confluences and will affect five or six properties at most.

4.3 Mitigation Approaches

A number of flood mitigation approaches to reduce water surface elevations were evaluated in the project area. Analyses were carried out along the following lines:

1. Bridge analysis
2. Obstruction of the Creekside Drive/County Route 47 bridge due to sediment aggradation
3. Floodplain enhancement and channel alterations
4. Access of Esopus Creek to a secondary channel in the vicinity of the Shandaken Tunnel

4.3.1 Bridge Analysis

Undersized bridges can act as hydraulic constrictions, exacerbating flooding during high-flow events by increasing water surface elevations upstream of the bridge. Bridges were assessed by removing the bridges from the hydraulic model. This simulates the complete removal of the bridge from the channel. If bridge removal resulted in a significant reduction in water surface elevations and a resulting reduction of the flooding of structures and/or roads in the model, bridge replacement with a more hydraulically adequate structure was evaluated in the model and advanced for consideration.

There are a total of 11 bridges in the project area (see Table 2-1). The State Route 28 bridge over Esopus Creek and the State Route 42 bridge over Bushnellsville Creek were recently replaced and are evaluated as part of the above Existing Conditions Analysis. The State Route 28 bridge over Peck Hollow Creek was not evaluated as it is not included in the FEMA HEC-RAS model. The footbridge over the Esopus Creek at the Copperhood Retreat and Spa was not assessed as it is hydraulically insignificant.

Along Bushnellsville Creek, bridge removal/replacement was modeled at three locations: at the Creekside Drive/County Route 47 bridge, at a private bridge, and at the State Route 42 bridge near Rosa Road.

At the Creekside Drive bridge, hydraulic modeling indicated that removal of the bridge from the model resulted in essentially no reductions in water surface elevations for the 10- and 25-year events (Table 4-3). A 0.7-foot reduction in water surface elevation occurred for the 50-year event at the cross section located 59 feet upstream of the bridge. However, regardless of whether the bridge is removed/replaced or not, hydraulic modeling indicates that floodwaters do not inundate State Route 42 at the 50-year event and smaller. For the 100- and 500-year discharge events, there are significant reductions in water surface levels of similar magnitudes at two cross sections located upstream of the bridge (Figure 4-4). However, even with a reduction in water surface elevation of 2.4 feet for the 100-year event 59 feet upstream of the bridge, the stream still leaves its left bank and inundates State Route 42. Additionally, the decrease in water surface elevations for the 100- and 500-year events does not prevent any homes from flooding. The replacement of the existing bridge with a larger bridge at the Creekside Drive/County Route 47 bridge location would not help to prevent flooding of structures or prevent floodwaters from leaving the channel upstream of the bridge. Section 4.3.2 includes an analysis of sediment aggradation at the Creekside Drive/County Route 47 bridge.

TABLE 4-3
Water Surface Reductions due to Removal/Replacement of Creekside Drive/County Route 47 Bridge

HEC-RAS Cross Section	Profile	WSEL with Bridge (feet)	WSEL without Bridge (feet)	Change (feet)
338 feet upstream of bridge	10-year	1,067.5	1,067.5	0.0
	25-year	1,069.4	1,069.4	0.0
	50-year	1,071.8	1,071.8	0.0
	100-year	1,072.5	1,072.5	0.0
	500-year	1,074.1	1,074.1	0.0
149 feet upstream of bridge	10-year	1,066.4	1,066.4	0.0
	25-year	1,068.5	1,068.5	0.0
	50-year	1,070.2	1,070.2	0.0
	100-year	1,070.9	1,069.7	-1.2
	500-year	1,072.7	1,071.3	-1.4
59 feet upstream of bridge	10-year	1,063.5	1,063.3	-0.2
	25-year	1,064.9	1,064.9	0.0
	50-year	1,067.2	1,066.5	-0.7
	100-year	1,070.4	1,068.0	-2.4
	500-year	1,072.2	1,069.7	-2.5
41 feet downstream of bridge	10-year	1,059.6	1,059.6	0.0
	25-year	1,061.6	1,061.6	0.0
	50-year	1,062.8	1,062.8	0.0
	100-year	1,064.0	1,064.0	0.0
	500-year	1,067.0	1,066.7	-0.3

wsel = water surface elevation

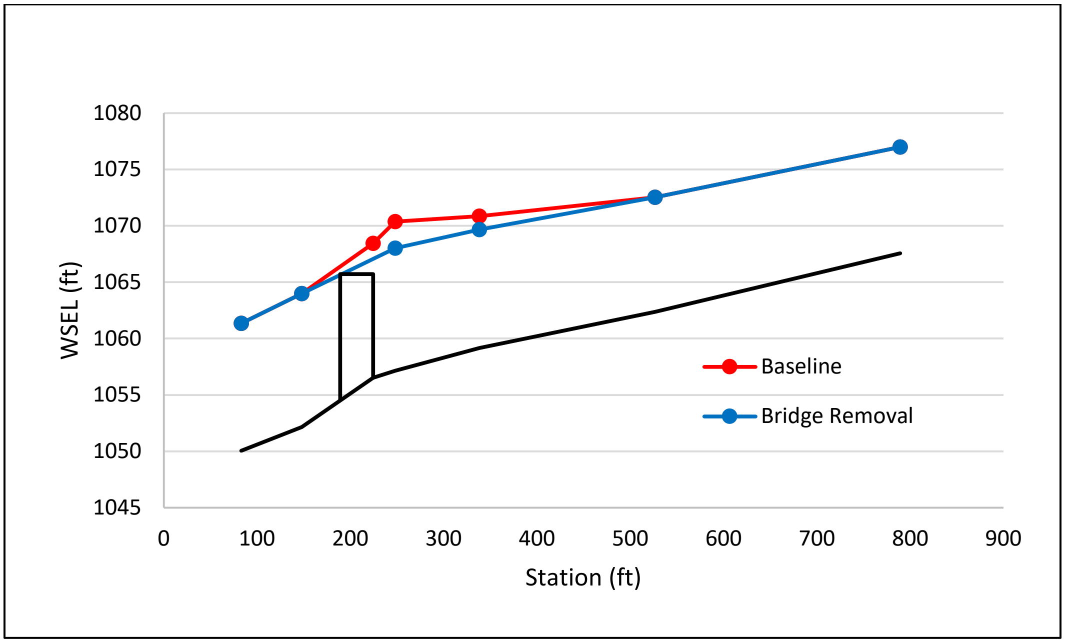


Figure 4-4
Change in Water Surface Elevations at Creekside Drive/County Route 47 Bridge over Bushnellsville Creek at 100-Year Discharge

The private bridge located along Bushnellsville Creek approximately 1,140 feet downstream of Rosa Road appears to be undersized, with a width of approximately 21 feet. When bridge removal/ replacement was evaluated in the hydraulic model, there is a reduction in water surface elevations at all modeled discharges. The reductions occurred in the model at the two cross sections 41 feet and 100 feet upstream of the bridge (Table 4-4). The reduction in water surface elevations is particularly pronounced in smaller floods such as the 10-year event (Figures 4-5 and 4-6). Removal of the bridge from the hydraulic model prevents the creek from flooding State Route 42 at the 25-year event but does not prevent flooding at the larger simulated discharges. At larger flood events, the reduction in water surface levels does not prevent the road from flooding, nor does it prevent the inundation of properties. Therefore, replacement of the bridge is not recommended.

TABLE 4-4
Water Surface Reductions due to Removal of Private Bridge

HEC-RAS Cross Section	Profile	WSEL with Bridge (feet)	WSEL without Bridge (feet)	Change (feet)
648 feet upstream of bridge	10-year	1,119.8	1,119.8	0.0
	25-year	1,120.5	1,120.5	0.0
	50-year	1,122.8	1,122.8	0.0
	100-year	1,123.7	1,123.7	0.0
	500-year	1,124.9	1,124.9	0.0
100 feet upstream of bridge	10-year	1,108.1	1,107.7	-0.4
	25-year	1,110.3	1,109.6	-0.7
	50-year	1,111.3	1,110.3	-1.0
	100-year	1,111.7	1,111.7	0.0
	500-year	1,114.2	1,113.5	-0.7
41 feet upstream of bridge	10-year	1,107.6	1,105.2	-2.4
	25-year	1,110.3	1,109.2	-1.1
	50-year	1,111.4	1,110.2	-1.1
	100-year	1,111.4	1,110.9	-0.5
	500-year	1,114.2	1,112.7	-1.6
24 feet downstream of bridge	10-year	1,103.9	1,103.9	0.0
	25-year	1,106.7	1,105.1	-1.6
	50-year	1,108.5	1,108.5	0.0
	100-year	1,109.4	1,109.3	-0.1
	500-year	1,111.5	1,111.3	-0.2

wsel = water surface elevation

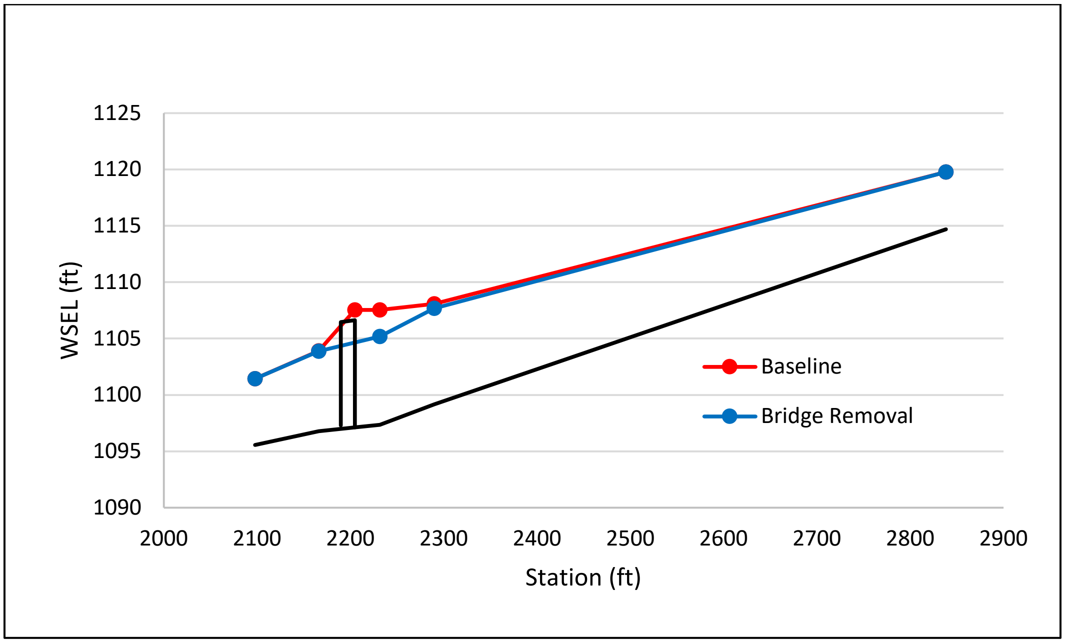


Figure 4-5
Change in Water Surface Elevations at Private Bridge over Bushnellsville Creek at 10-Year Discharge

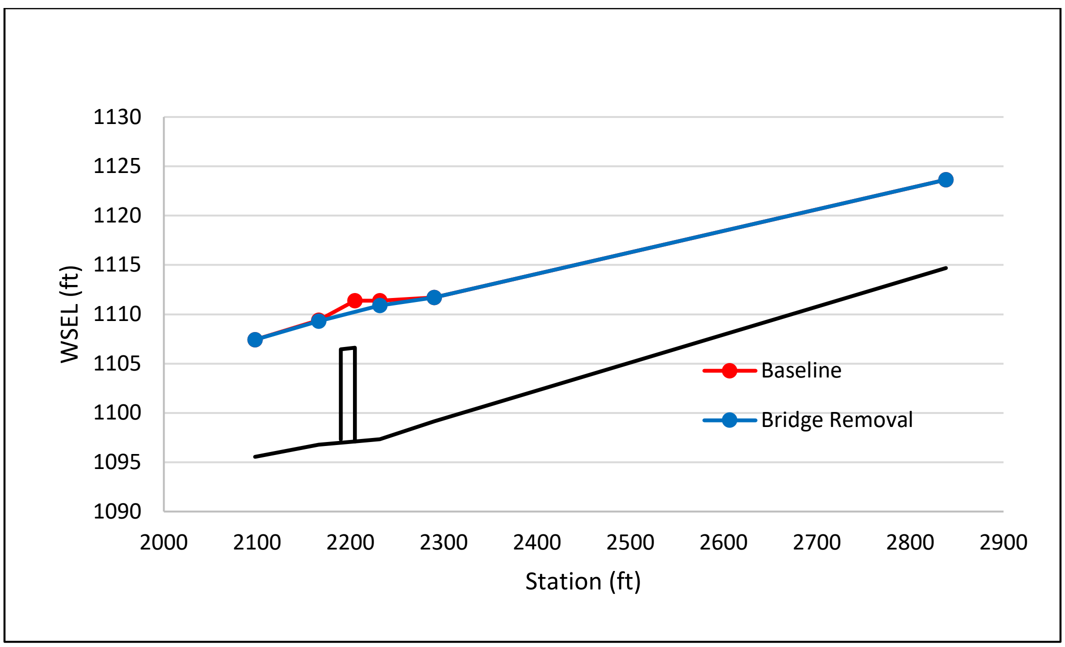


Figure 4-6
Change in Water Surface Elevations at Private Bridge over Bushnellsville Creek at 100-Year Discharge

Modeled removal of the State Route 42 bridge near Rosa Road results in moderate reductions in water surfaces at lower discharges (Table 4-5). However, this does not provide flood reduction benefits at the 10-, 25-, and 50-year flood events. During the 10- and 25-year events, the stream remains in the channel in both the baseline and "no bridge" conditions while at the 50-year event the stream leaves the channel upstream of the bridge and floods State Route 42 under both scenarios.

The "no bridge" condition at the 100-year discharge results in a decrease in water surface elevation of 3.1 feet at a location 100 feet upstream of the bridge (Figure 4-7). This prevents the stream from leaving its right bank and flooding homes along Rosa Road. However, as Bushnellsville Creek leaves its right bank at the next upstream cross section regardless of whether the bridge is in place, there is likely little benefit in removing/replacing the bridge. Removal of the bridge from the hydraulic model does not provide any mitigation benefits during the 500-year discharge. Bridge replacement is not recommended.

TABLE 4-5
Changes in Water Surface Elevations due to Removal of State Route 42 Bridge

HEC-RAS Cross Section	Profile	Water Surface Elevation with Bridge (feet)	Water Surface Elevation without Bridge (feet)	Change (feet)
767 feet upstream of bridge	10-year	1,153.7	1,154.1	0.3
	25-year	1,155.0	1,155.6	0.5
	50-year	1,156.1	1,156.1	0.0
	100-year	1,157.3	1,157.3	0.0
	500-year	1,159.3	1,159.3	0.0
264 feet upstream of bridge	10-year	1,144.3	1,143.3	-1.0
	25-year	1,146.2	1,145.1	-1.1
	50-year	1,148.7	1,148.2	-0.4
	100-year	1,149.6	1,149.6	0.0
	500-year	1,151.3	1,151.3	0.0
100 feet upstream of bridge	10-year	1,140.3	1,139.5	-0.8
	25-year	1,142.6	1,141.4	-1.2
	50-year	1,144.0	1,143.3	-0.6
	100-year	1,147.1	1,144.0	-3.1
	500-year	1,148.7	1,148.1	-0.6
92 feet downstream of bridge	10-year	1,135.5	1,135.5	0.0
	25-year	1,136.8	1,136.2	-0.6
	50-year	1,138.5	1,137.2	-1.3
	100-year	1,139.0	1,137.2	-1.8
	500-year	1,140.6	1,140.0	-0.6

wsel = water surface elevation

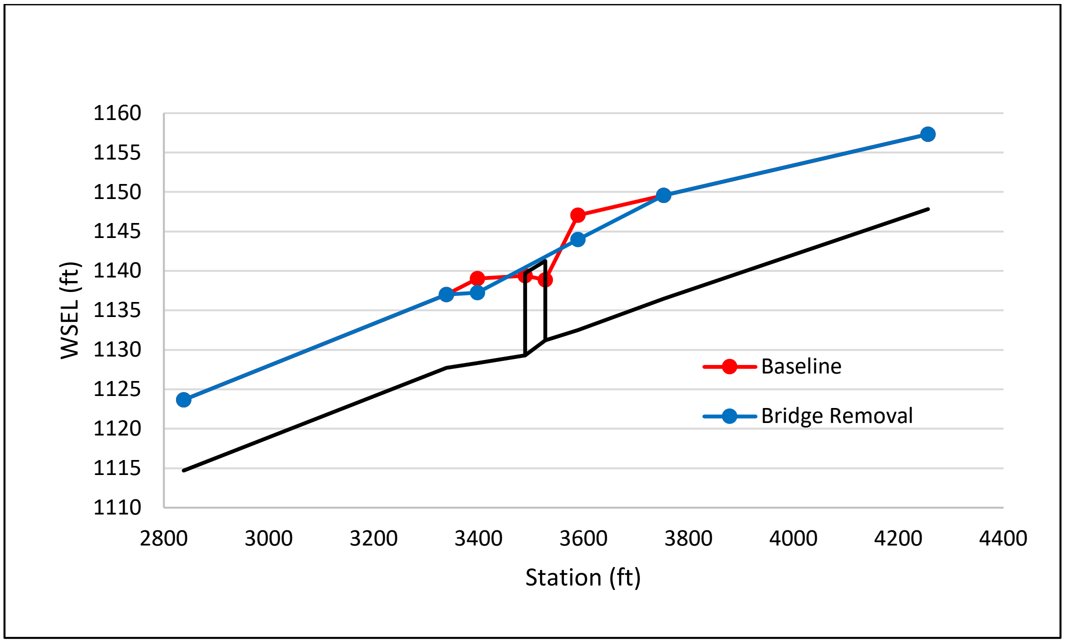


Figure 4-7
Change in Water Surface Elevations at State Route 42 Bridge over Bushnellsville Creek at 100-Year Discharge

On Esopus Creek, the structure at Fox Hollow Road was assessed by removal of the bridge from the hydraulic model. Except for the 25-year discharge, removal of the Fox Hollow Road bridge resulted in relatively modest benefits (Table 4-6). Under baseline conditions, the 25-year discharge leaves the left bank of the channel immediately upstream of the bridge, resulting in the inundation of Fox Hollow Road between Esopus Creek and State Route 28. Removal of the bridge from the model results in Esopus Creek remaining in the channel (Figure 4-8). During larger discharges, there are no tangible benefits despite reductions in water surface elevations (Figure 4-9). Under both scenarios, Esopus Creek leaves the left bank at the three HEC-RAS cross sections upstream of the Fox Hollow Road bridge and floods Fox Hollow Road.

TABLE 4-6
Esopus Creek: Changes in Water Surface Elevation due to Removal of Fox Hollow Road Bridge

HEC-RAS Cross Section	Profile	WSEL with Bridge (feet)	WSEL without Bridge (feet)	Change (feet)
2,227 feet upstream of bridge	10-year	1,028.8	1,028.8	0.0
	25-year	1,031.6	1,031.6	0.0
	50-year	1,032.9	1,032.9	0.0
	100-year	1,034.3	1,034.3	0.0
	500-year	1,037.9	1,037.9	0.0
1,005 feet upstream of bridge	10-year	1,018.2	1,018.2	0.0
	25-year	1,018.8	1,020.0	1.2
	50-year	1,020.9	1,020.9	0.0
	100-year	1,021.8	1,021.8	0.0
	500-year	1,024.9	1,026.0	1.1
40 feet upstream of bridge	10-year	1,012.9	1,011.0	-1.9
	25-year	1,017.4	1,012.4	-5.0
	50-year	1,018.6	1,018.4	-0.2
	100-year	1,019.8	1,020.7	0.9
	500-year	1,024.8	1,025.8	1.0
40 feet downstream of bridge	10-year	1,009.0	1,009.2	0.2
	25-year	1,011.7	1,012.5	0.8
	50-year	1,014.4	1,014.4	0.0
	100-year	1,016.0	1,016.0	0.0
	500-year	1,021.3	1,021.3	0.0

wsel = water surface elevation

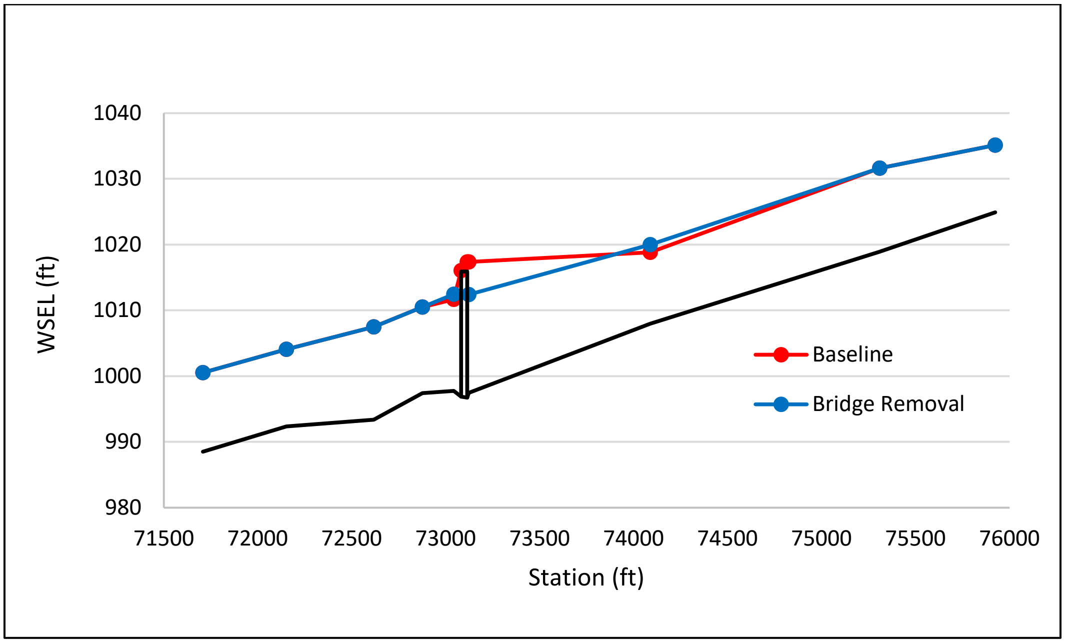


Figure 4-8
Change in Water Surface Elevations at Fox Hollow Road Bridge over Esopus Creek at 25-Year Discharge

On Fox Hollow Creek, both the railroad trestle and the town-owned bridge connecting Fox Hollow Road and a private road (Dutcher Road) were assessed by removing the bridges from the hydraulic model. The resulting water surface elevations were compared to baseline conditions. At the railroad trestle, there were only minor reductions in water surface elevations a short distance upstream of the structure, and there were no flood reduction benefits due to removal of the structure (Table 4-7). Removal of the structure from the model had little effect on water surface elevations due in part to the close proximity of the trestle to the confluence with Esopus Creek and the influence of backwater from Esopus Creek. Its removal or replacement is not recommended.

TABLE 4-7
Fox Hollow Creek: Changes in Water Surface Elevation due to Removal of the Railroad Trestle

HEC-RAS Cross Section	Profile	WSEL with Bridge (feet)	WSEL without Bridge (feet)	Change (feet)
262 feet upstream of bridge	10-year	1,021.7	1,021.7	0.0
	25-year	1,022.1	1,022.1	0.0
	50-year	1,022.8	1,022.8	0.0
	100-year	1,023.3	1,023.3	0.0
	500-year	1,024.4	1,024.4	0.0
38 feet upstream of bridge	10-year	1,013.9	1,013.9	0.0
	25-year	1,018.0	1,017.6	-0.4
	50-year	1,019.4	1,018.9	-0.5
	100-year	1,020.3	1,020.0	-0.3
	500-year	1,024.8	1,024.8	0.0
25 feet upstream of bridge	10-year	1,013.7	1,013.7	0.0
	25-year	1,017.9	1,017.5	-0.4
	50-year	1,019.3	1,018.8	-0.5
	100-year	1,020.3	1,019.9	-0.4
	500-year	1,024.8	1,024.8	0.0
34 feet downstream of bridge	10-year	1,013.4	1,013.4	0.0
	25-year	1,017.5	1,017.5	0.0
	50-year	1,018.8	1,018.8	0.0
	100-year	1,019.9	1,019.9	0.0
	500-year	1,024.8	1,024.8	0.0

wsel = water surface elevation

In contrast to the railroad trestle, significant reductions in water surface elevation occurred at the town bridge (Table 4-8). During the 10-year event, the stream remained in the channel under both scenarios, and the bridge was easily able to pass the discharge. However, the bridge is unable to pass the 25-, 50-, and 100-year events. While no structures are flooded, the bridge is overtopped, and floodwaters inundate Fox Hollow Road. With the bridge removed from the hydraulic model, these discharges remain in the channel (Figures 4-9 and 4-10). The 500-year discharge is only minimally affected by the bridge removal.

The town bridge was recently replaced, and no structures are being flooded as a result of the bridge being undersized. For these reasons, replacement of the town-owned bridge is not recommended at this time. However, if the bridge is damaged in future floods, or when it is scheduled for replacement, it should be replaced with an adequately sized bridge. Replacement of the current bridge with an appropriately sized structure would help to prevent flooding of Fox Hollow Road during large flood events.

TABLE 4-8
Fox Hollow Creek: Changes in Water Surface Elevation due to Removal of the Town Bridge

HEC-RAS Cross Section	Profile	WSEL with Bridge (feet)	WSEL without Bridge (feet)	Change (feet)
243 feet upstream of bridge	10-year	1,058.7	1,058.7	0.0
	25-year	1,059.7	1,059.7	0.0
	50-year	1,060.6	1,060.6	0.0
	100-year	1,061.5	1,061.5	0.0
	500-year	1,063.26	1,063.26	0.0
51 feet upstream of bridge	10-year	1,051.4	1,050.2	-1.2
	25-year	1,055.4	1,051.7	-3.7
	50-year	1,056.4	1,053.0	-3.4
	100-year	1,057.0	1,054.3	-2.7
	500-year	1,059.2	1,061.0	1.8
36 feet upstream of bridge	10-year	1,051.3	1,049.9	-1.4
	25-year	1,055.4	1,051.6	-3.8
	50-year	1,056.3	1,052.8	-3.5
	100-year	1,056.9	1,054.2	-2.7
	500-year	1,059.1	1,056.2	-2.9
24 feet downstream of bridge	10-year	1,048.0	1,048.0	0.0
	25-year	1,048.9	1,048.9	0.0
	50-year	1,050.0	1,050.0	0.0
	100-year	1,051.2	1,051.2	0.0
	500-year	1,056.6	1,056.7	0.1

wsel = water surface elevation

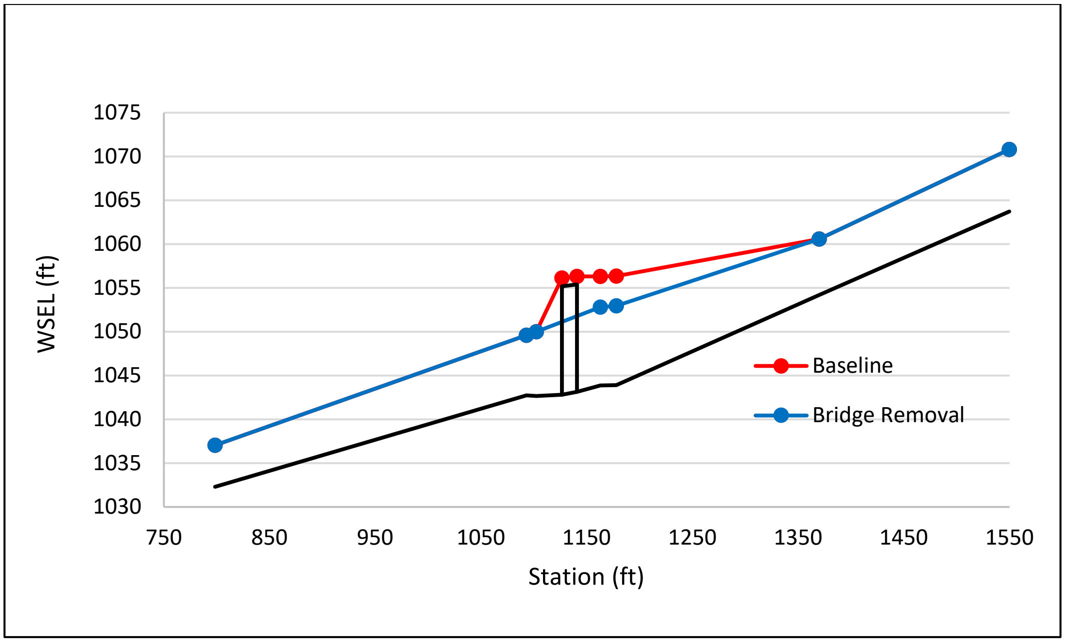


Figure 4-9
Change in Water Surface Elevations at Town Bridge over Fox Hollow Creek at 50-Year Discharge

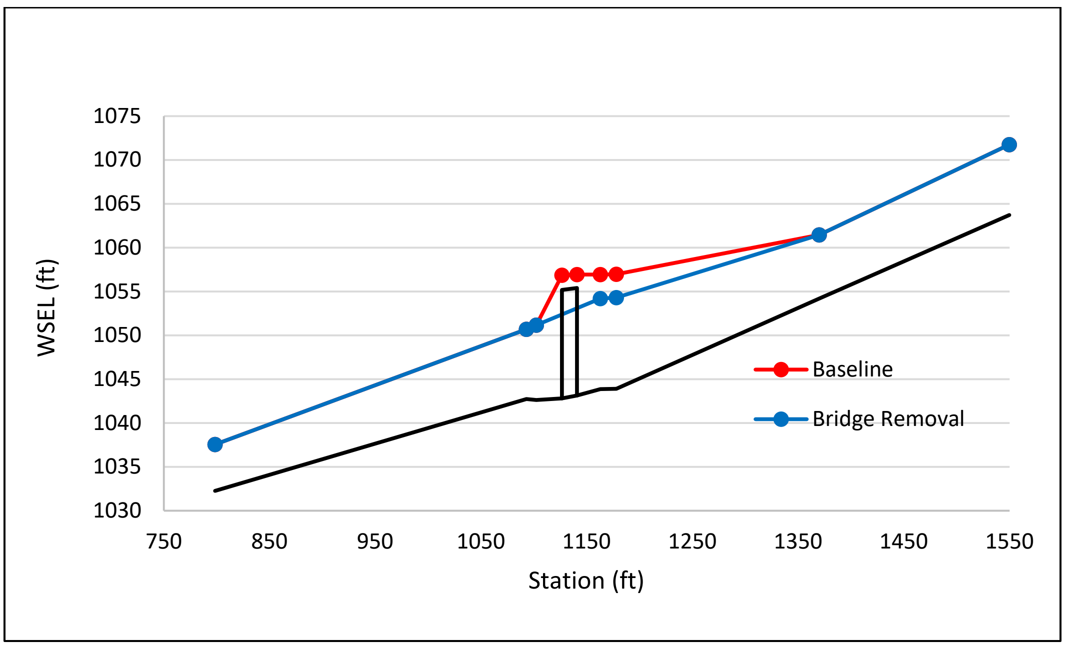


Figure 4-10
Change in Water Surface Elevations at Town Bridge over Fox Hollow Creek at 100-Year Discharge

A single bridge was removed from the Broadstreet Hollow Creek hydraulic model. The State Route 28 bridge is located approximately 440 feet upstream of the confluence with the Esopus Creek and is the main transportation route up and down the Esopus Creek valley. Removal of the bridge resulted in very slight water surface elevation reductions for discharges equal to or smaller than the 50-year return interval (Table 4-9). These flows remained in the channel under both the bridge and no-bridge scenarios. At the 100-year discharge, there were significant reductions in water surface elevations – 5.0

feet at the cross section located 72 feet upstream of the bridge and 2.9 feet at the cross section located 124 feet upstream of the bridge. Removal of the bridge from the model also reduced the flooding of three structures located upstream of the bridge (Figure 4-11). Reductions in water surface elevations were fairly small for the 500-year discharge and provide very little return from a cost-benefit perspective. Figures 4-12 and 4-13 depict the water surface elevations for the 100- and 500-year discharges.

TABLE 4-9
Broadstreet Hollow Creek: Changes in Water Surface Elevation due to Removal of the State Route 28 Bridge

HEC-RAS Cross Section	Profile	WSEL with Bridge (feet)	WSEL without Bridge (feet)	Change (feet)
344 feet upstream of bridge	10-year	974.4	974.4	0.0
	25-year	975.3	975.3	0.0
	50-year	976.3	976.3	0.0
	100-year	977.4	977.4	0.0
	500-year	980.3	979.7	-0.6
124 feet upstream of bridge	10-year	969.6	969.6	0.0
	25-year	971.4	971.3	-0.1
	50-year	973.2	972.8	-0.4
	100-year	977.3	974.4	-2.9
	500-year	980.1	979.1	-1.0
72 feet upstream of bridge	10-year	968.5	968.7	0.2
	25-year	969.7	969.8	0.1
	50-year	972.9	970.7	-2.2
	100-year	976.9	971.9	-5.0
	500-year	980.1	977.1	-3.0
61 feet downstream of bridge	10-year	967.4	967.4	0.0
	25-year	968.3	968.3	0.0
	50-year	968.8	968.8	0.0
	100-year	969.6	970.1	0.5
	500-year	971.8	971.8	0.0

wsel = water surface elevation

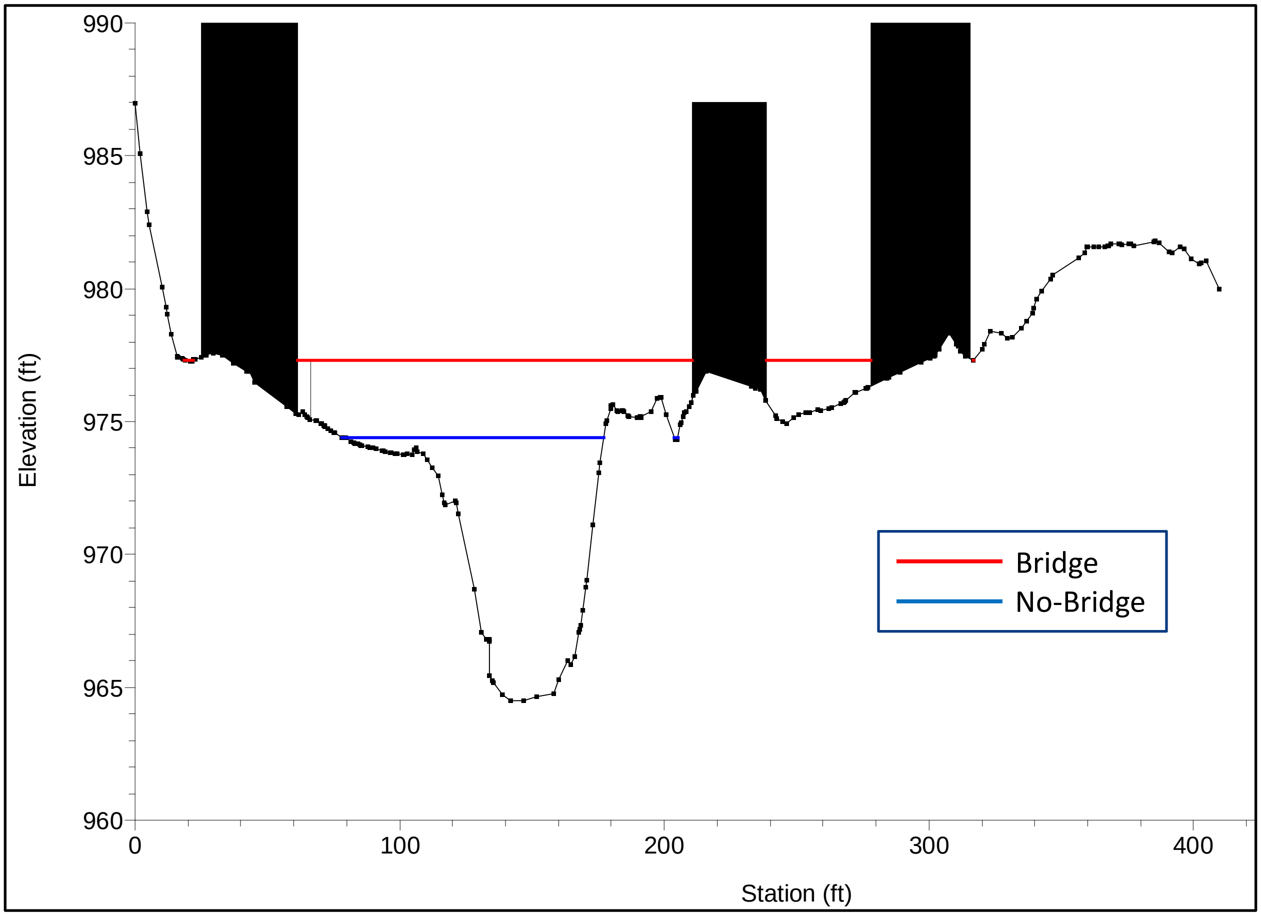


Figure 4-11

100-Year Discharge Water Surface Elevation Reductions at Cross Section 612.5810 Preventing Flooding of Structures along Broadstreet Hollow Creek

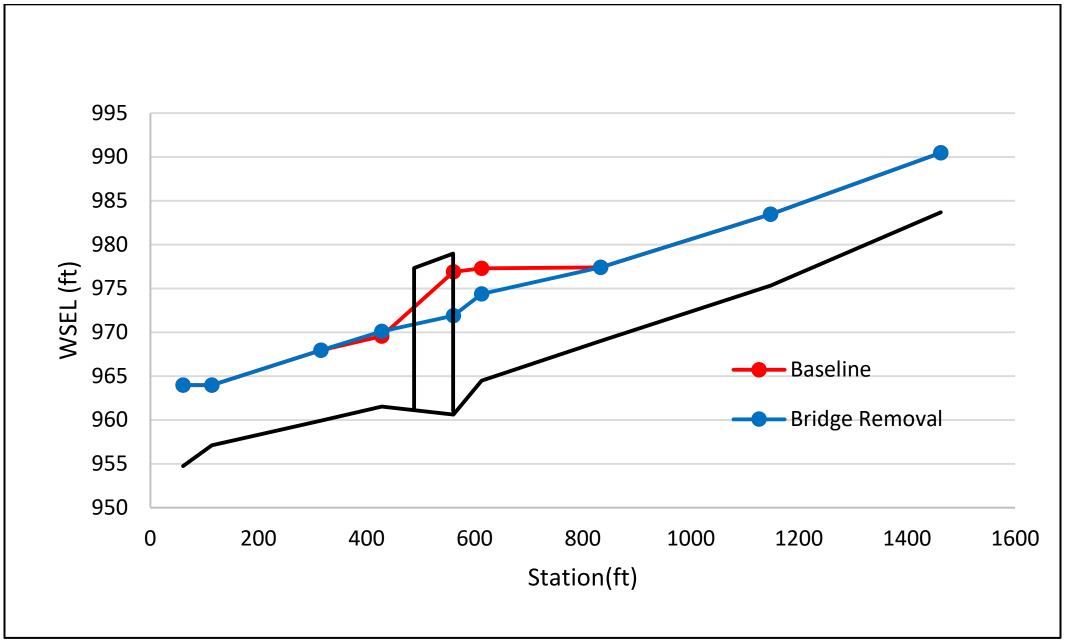


Figure 4-12
Change in Water Surface Elevations at State Route 28 Bridge over Broadstreet Hollow Creek at 100-Year Discharge

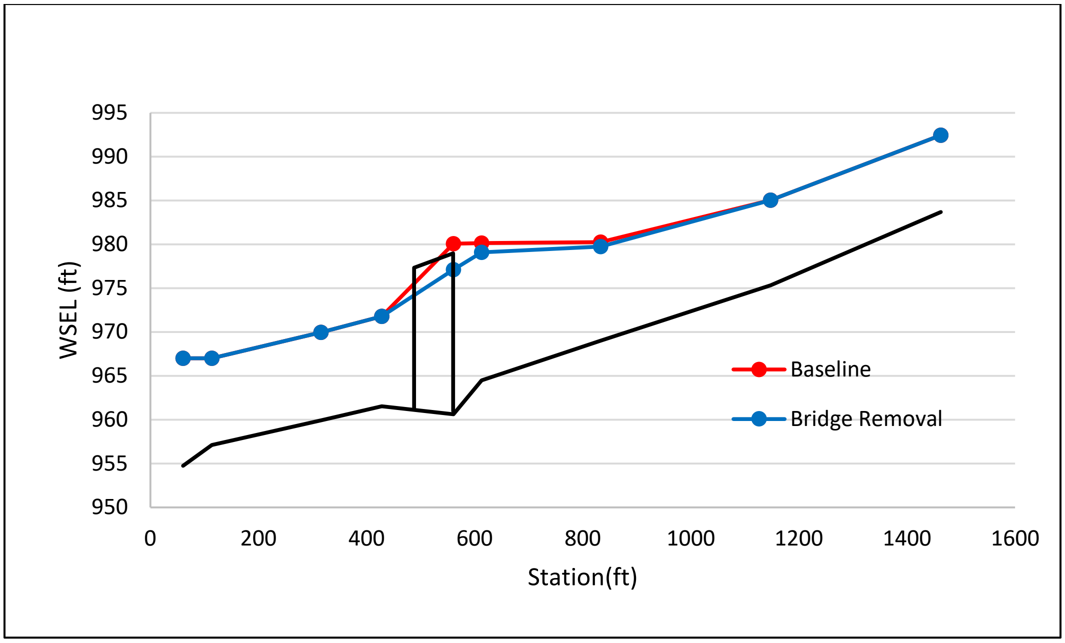


Figure 4-13
Change in Water Surface Elevations at State Route 28 Bridge over Broadstreet Hollow Creek at 500-Year Discharge

4.3.2 Aggradation under the Creekside Drive/County Route 47 Bridge

One of the comments heard during the first public meeting and from SAFARI members was that sediment had accumulated under the County Route 47 bridge, contributing to flooding upstream. To help assess aggradation under the bridge, the UCSWCD provided MMI with NYSDOT bridge inspection reports from 2010, 2012, and 2014. The reports describe the physical condition of the bridge, the roadway, and the channel of Bushnellsville Creek under the bridge. They also contain channel cross-section measurements at the upstream and downstream openings (Figures 4-14 and 4-15) as well as photos of the bridge and channel. The 2010 report contains additional channel measurements from the 2008 inspection.

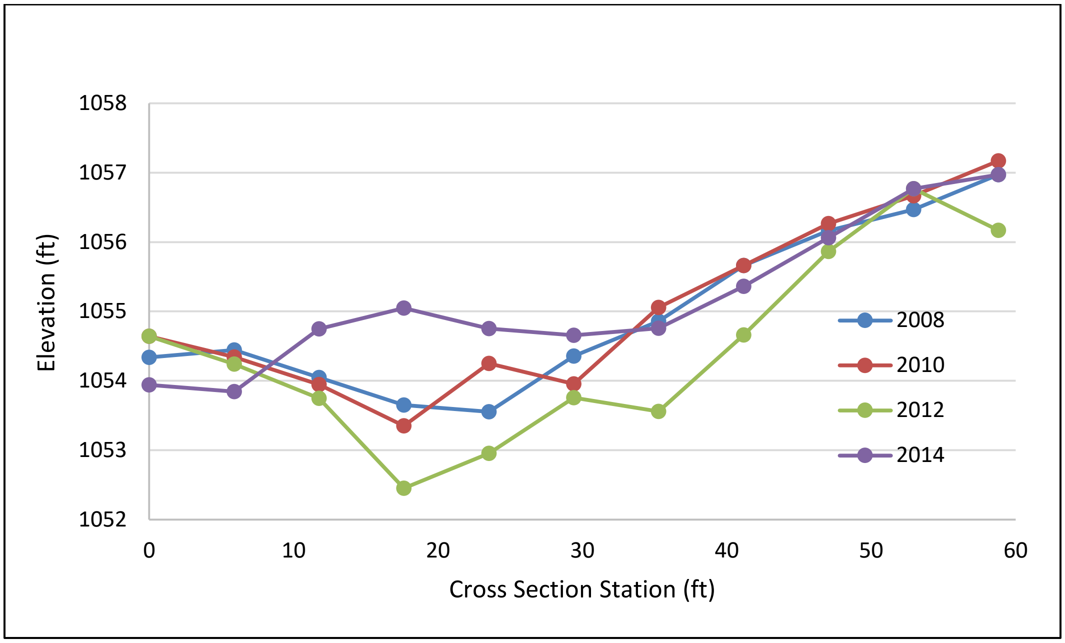


Figure 4-14
NYSDOT Upstream Bridge Opening Measurements 2008-2014

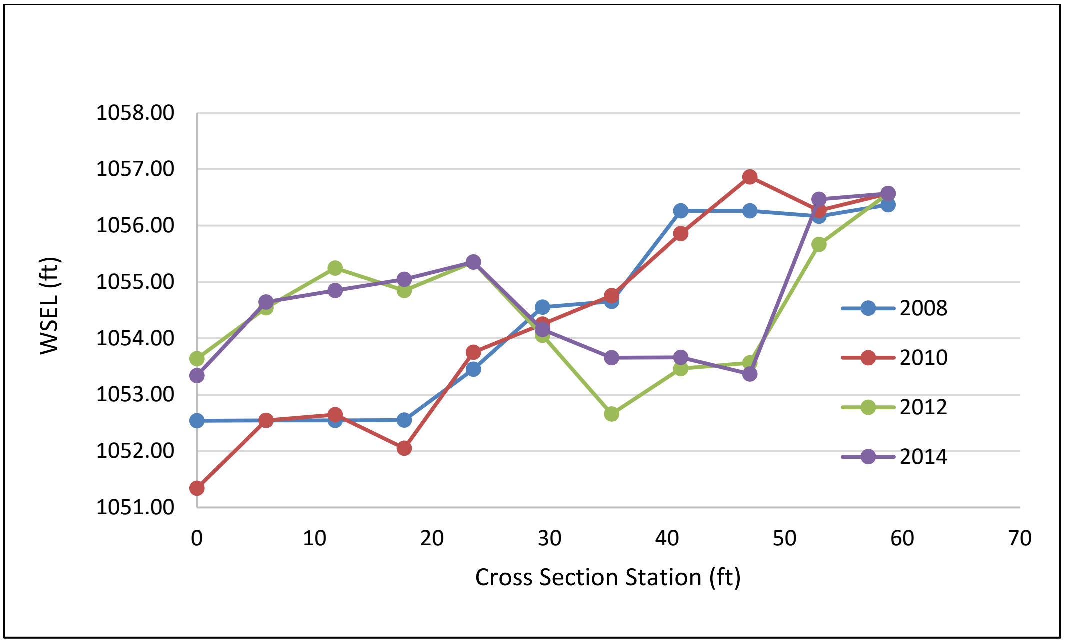


Figure 4-15
NYSDOT Downstream Bridge Opening Measurements 2008-2014

The 2010 inspection report notes that gravel has accumulated along the right abutment, which has narrowed the channel and reduced conveyance. The report also states that no significant changes were identified in the channel under the bridge since the 2008 report (Figures 4-14 and 4-15).

The 2012 report also noted the accumulation of sediment along the right abutment as well as some deposition along the left abutment. Additionally, a pile of woody debris was present on the right bank about 20 feet downstream of the bridge. Woody debris and tree trunks were also present under the bridge along both abutments. The report states that the woody material was most likely deposited by Tropical Storm Irene and that there were significant changes in the channel between 2010 and 2012.

The 2014 report describes significant changes in the Bushnellsville Creek channel. None of the woody debris identified in the previous report was noted. However, a large gravel bar had formed under the bridge and extended about 100 feet downstream (Figures 4-16 and 4-17). This gravel bar was noted by MMI in 2017.

(NYSDOT 2010)

Figure 4-16
2010 Photo of Bushnellsville Creek Downstream of the Creekside Drive Bridge (NYSDOT)

Figure 4-17
2017 Photo of Bushnellsville Creek Downstream of the Creekside Drive Bridge (MMI)

As shown in Figures 4-14 and 4-15, the Bushnellsville Creek channel between the Creekside Drive bridge and Esopus Creek was relatively stable between 2008 and 2010. This stability was perturbed by Tropical Storm Irene in 2011. Following the storm, the channel began a period of active adjustment that is likely ongoing.

As the Bushnellsville Creek hydraulic model predates Tropical Storm Irene, MMI staff measured the bridge opening on March 9, 2017, to assess aggradation under the bridge and incorporate any changes into the model. The bridge opening in the FEMA Effective Model was 934.6 square feet while the exit had an area of 435.9 square feet. The measured bridge opening and exit had respective areas of 342.0 square feet and 382.4 square feet. This corresponds to reductions of approximately 53 square feet at the opening and 54 square feet at the exit (Figures 4-18 and 4-19). Both NYSDOT and MMI measurements indicate that the channel has aggraded since Tropical Storm Irene, resulting in a reduction in the hydraulic opening size.

The new channel elevations at the bridge were modeled in HEC-RAS to assess the effect of water surface elevations in the region of the bridge. Additionally, 1- and 2-foot increases above the measured elevations in the channel were modeled to simulate sediment aggradation as well as bridge blockage due to debris (Figures 4-18 and 4-19).

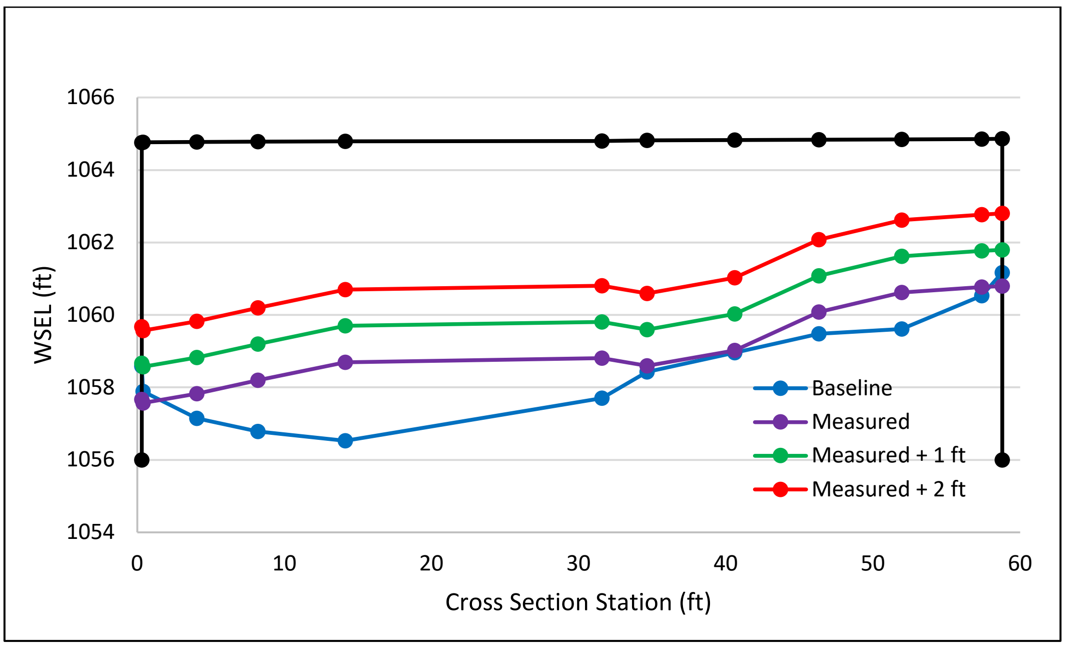


Figure 4-18
Creekside Drive Bridge Opening Conditions Simulated in HEC-RAS

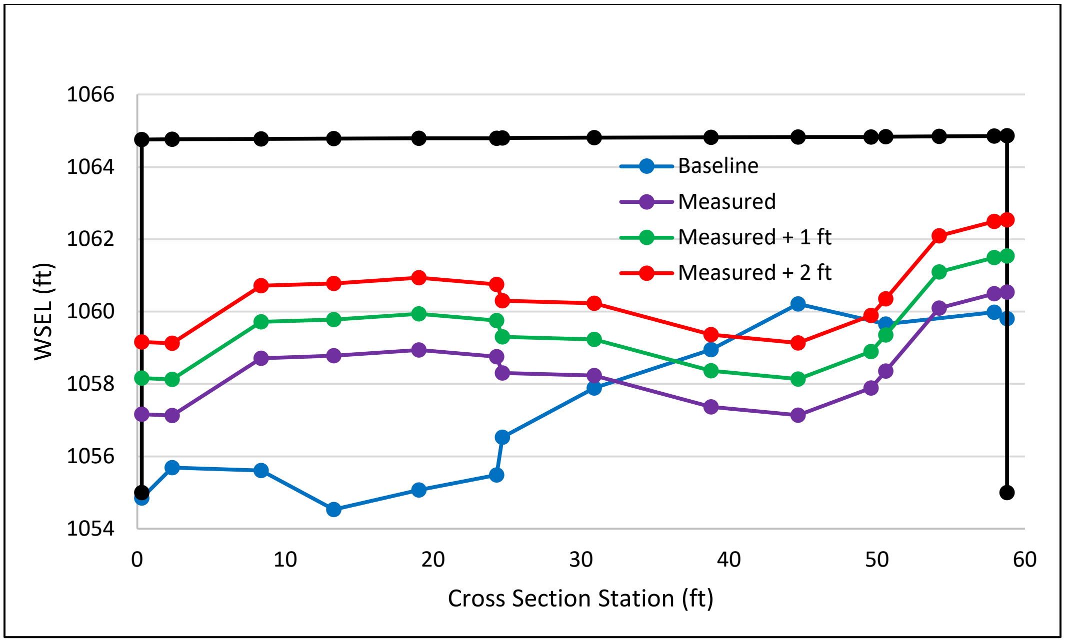


Figure 4-19
Creekside Drive Bridge Exit Conditions Simulated in HEC-RAS

The results of hydraulic modeling indicate that sediment accumulation in the region of the bridge leads to significant increases in water surface elevations at the bridge and the two upstream cross sections (Table 4-10). At baseline conditions in the FEMA Effective Model, the 50-year discharge hits the deck of the bridge while the 100-year event overtops the structure. Under present conditions, the bridge is overtopped at the 50-year event while the 25-year discharge hits the deck. If another 2 feet of aggradation or blockage above present conditions occurred, the 10-year discharge would hit the deck, and the 25-year discharge would overtop the bridge and flood the roadway (Figures 4-20 through 4-22). No homes or other structures in the vicinity of the bridge would be flooded as a result of this blockage.

TABLE 4-10
Water Surface Elevations at Creekside Drive Bridge over Bushnellsville Creek

HEC-RAS Cross Section	Profile	Baseline	Measured	Measured + 1 foot	Measured + 2 feet
149 feet upstream of bridge	10-year	1,066.4	1,066.4	1,066.9	1,068.6
	25-year	1,068.5	1,068.9	1,069.4	1,070.1
	50-year	1,070.2	1,070.2	1,070.6	1,070.9
	100-year	1,070.9	1,071.1	1,071.4	1,071.5
	500-year	1,072.7	1,072.8	1,073.0	1,073.1
59 feet upstream of bridge	10-year	1,063.5	1,064.5	1,065.5	1,068.1
	25-year	1,064.9	1,066.9	1,069.1	1,069.9
	50-year	1,067.2	1,069.8	1,070.3	1,070.6
	100-year	1,070.4	1,070.7	1,071.1	1,071.3
	500-year	1,072.2	1,072.4	1,072.6	1,072.8
Upstream face of bridge	10-year	1,062.8	1,063.7	1,064.7	1,066.0
	25-year	1,064.2	1,065.5	1,066.0	1,068.7
	50-year	1,065.7	1,066.0	1,069.0	1,069.3
	100-year	1,068.4	1,069.3	1,069.4	1,069.8
	500-year	1,070.4	1,070.6	1,070.9	1,071.1

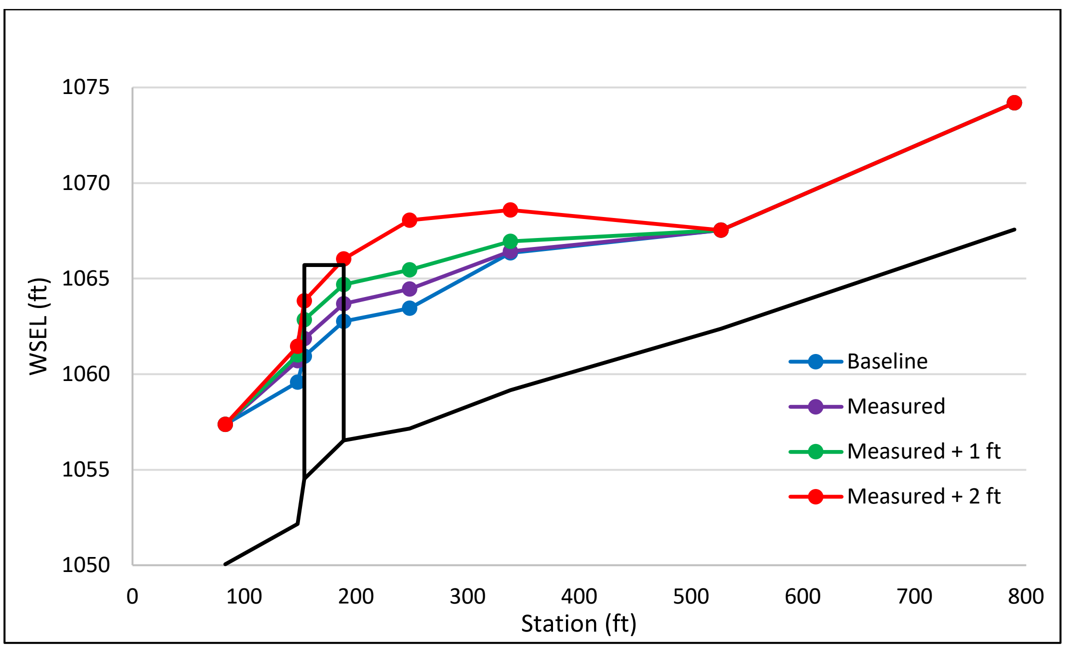


Figure 4-20
Water Surface Elevations for the 10-Year Discharge at Creekside Drive Bridge

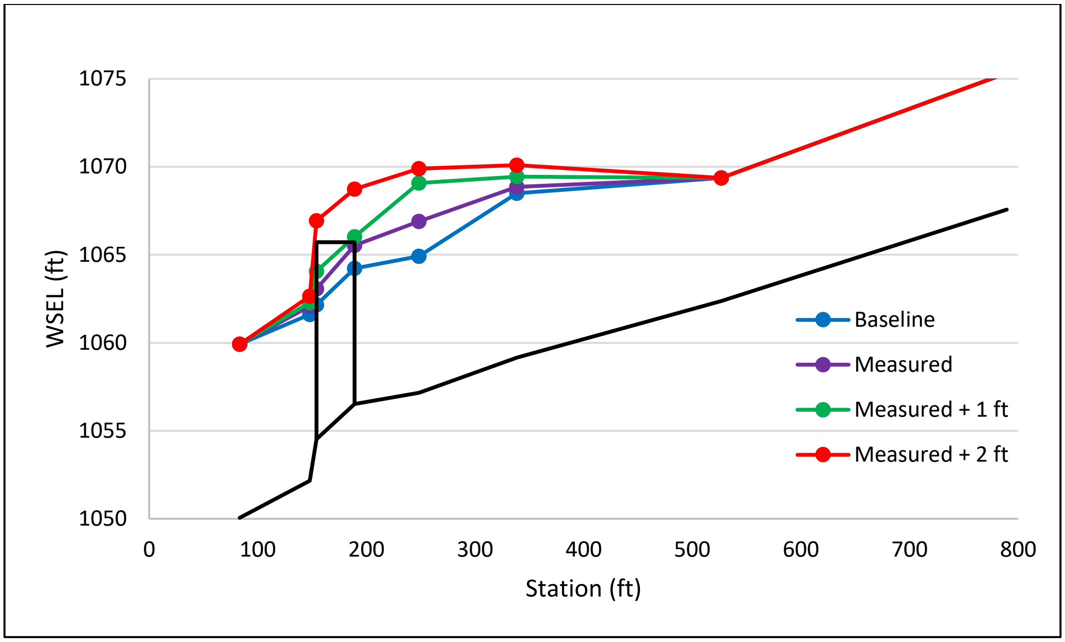


Figure 4-21
Water Surface Elevations for the 25-Year Discharge at Creekside Drive Bridge

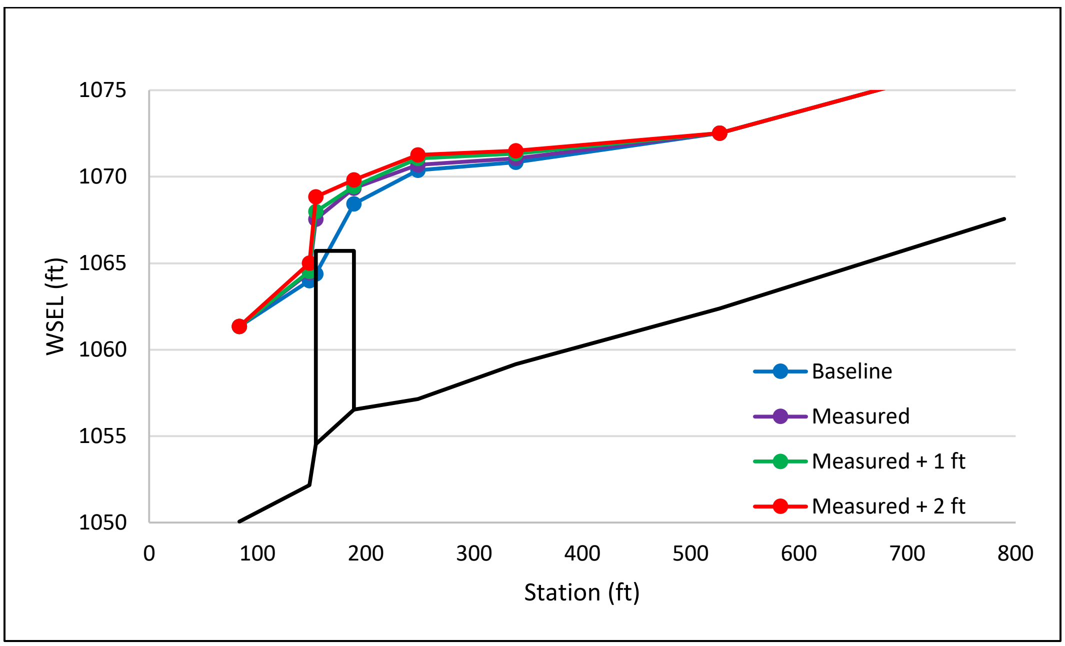


Figure 4-22
Water Surface Elevations for the 100-Year Discharge at Creekside Drive Bridge

Due to the dynamic nature of Bushnellsville Creek near its confluence with the Esopus Creek, the Creekside Drive bridge should be inspected at least every 2 years and also immediately following flood events. Based on MMI hydraulic analyses, maintenance actions may be warranted if 1 foot of aggradation were to occur at the bridge opening. In the event the channel aggrades 2 feet above present conditions, maintenance actions to remove the aggradation would be strongly advised.

4.3.3 Floodplain Enhancement and Removal of Sediment Bars

One of the most floodprone areas in the LFA project area is the confluence of Esopus and Bushnellsville Creeks. Several homes and businesses are located along the left banks of Esopus and Bushnellsville Creeks. This area is bordered by State Route 42 and County Route 47 on the north and by State Route 28 on the south. The homes are protected by a levee that runs along the left banks of the creeks from County Route 47 on Bushnellsville Creek to the State Route 28 bridge over Esopus Creek. Located in this tightly confined area, these homes are subject to overland flooding as well as flooding in basements due to groundwater intrusion.

Mitigation alternatives involving floodplain enhancement and sediment removal were modeled to evaluate their effectiveness at reducing flooding. Floodplain enhancement aims to improve the conveyance of floodwaters. Dense development and placement of fill in the natural floodplain of a river can severely hinder a river's ability to convey flood flows without overtopping its banks and/or causing heavy flood damages. A river in flood stage must convey large amounts of water through a finite floodplain. When a channel is constricted or confined, velocities can become destructively high during a flood, with dramatic erosion and damage. When obstructions are placed in the floodplain, whether they are in the form of structures, infrastructure, or fill, they are vulnerable to flooding and damage.

In certain instances, an existing floodplain can be altered through reclamation, creation, or enhancement to increase flood conveyance capacity. Floodplain reclamation can be accomplished by excavating previously filled areas, removing berms or obstructions from the floodplain, or removal of structures. Floodplain creation can be accomplished by excavating land to create new floodplain where there is none today. Finally, floodplain enhancement can be accomplished by excavating within the existing floodplain adjacent to the river to increase flood flow conveyance.

Figure 4-23 shows a typical cross section of compound channel with excavated floodplain on both banks. The graphic shows enhanced floodplains on both banks; however, floodplain enhancement can occur on either or both banks of a river.

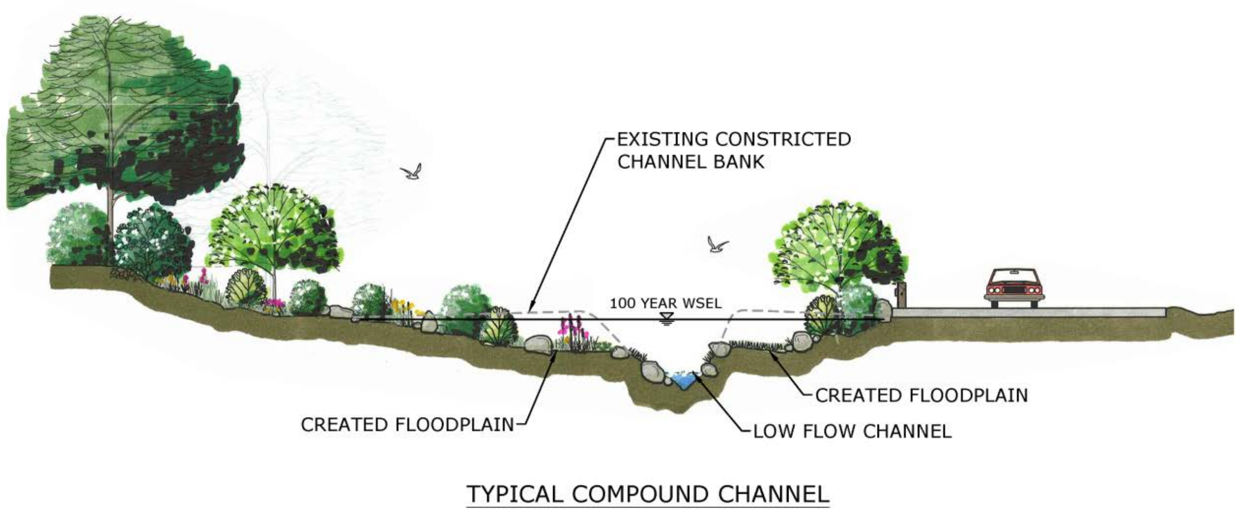


Figure 4-23
Typical Cross Section of a Compound Channel with Floodplains

Five mitigation scenarios were modeled to assess their ability to reduce flood elevations in the vicinity of the confluence of Bushnellsville Creek and Esopus Creek. These scenarios are illustrated on Figure 4-24, along with the extent of the 100-year flood under existing conditions. The five mitigation scenarios are listed below:

- Scenario 1: Removal of gravel bars and enhancement of the floodplain on the right bank upstream of the State Route 28 bridge (Area 1)
- Scenario 2: Removal of the levee on the left bank between Bushnellsville and Esopus Creeks (Area 2)
- Scenario 3: Enhancement of floodplain on the left bank downstream of the State Route 28 bridge (Area 3)
- Scenario 4: This is a combination of Scenarios 1 and 2 (Areas 1 and 2).
- Scenario 5: This is a combination of Scenarios 1, 2, and 3 (Areas 1, 2, and 3).

Figure 4-24
Areas of Floodplain Enhancement at the Confluence of Esopus and Bushnellsville Creeks

These mitigation scenarios would require extensive removal in terms of sediment bars in the channel, banks, construction fill, and the levee. Table 4-11 provides a very rough estimate of the cut volumes for each scenario.

TABLE 4-11
Approximate Volumes of Sediment Removed for Scenarios at the Esopus/Bushnellsville Creeks Confluence

Scenario	Volume (cubic yards)
1	4,000
2	15,000
3	41,000
4	19,000
5	60,000

Scenario 1 involved the removal of extensive gravel bars at the confluence of Bushnellsville Creek and Esopus Creek. In the hydraulic model, the gravel bars were lowered such that the bankfull flow would be able to access the floodplain in the right bank at model cross sections 78961 and 78444 (located 954 and 2,161 feet upstream of the Route 28 bridge, respectively). This alternative did not result in substantial water surface elevation reductions. Very minor reductions (less than half a foot) occurred across all discharges. These reductions only occurred in the immediate vicinity of where the sediment was removed.

Scenario 2 investigated the removal of the flood control levee, which is situated on the left bank between Bushnellsville and Esopus Creeks. The concept behind this alternative was to protect homes north of State Route 42 in the hamlet of Shandaken by enhancing the floodplain on the left banks of Esopus and Bushnellsville Creeks (see Area 2 on Figure 4-22). In addition to the removal of the levee, this alternative would also require the removal of structures situated between State Route 42 and the levee. This alternative resulted in water surface elevation reductions of less than half a foot at cross section 78084 (located 77 feet upstream of the Route 28 bridge). Reductions in water surface elevations were not significant at cross section 78444 (located 437 feet upstream of the Route 28 bridge). A reduction of 1.65 feet occurred at the 100-year discharges, but at the remaining discharges, the water surface levels decreased less than half a foot. At cross section 78961 (located 954 feet upstream of the Route 28 bridge), water surface elevations did not significantly decrease. In summary, removal of the levee and creation of a floodplain did not result in significant decreases in flood elevations for properties located north of State Route 42.

The third scenario involves enhancement of floodplain on the left bank of Esopus Creek, immediately downstream of the State Route 28 bridge. This scenario requires the removal and off-site disposal of a large quantity of earth on which two small structures are currently situated. This alternative resulted in significant reductions in water surfaces at cross section 77448 (located 559 feet downstream of the Route 28 bridge). The 500-year discharge decreased by 7.7 feet, the 100-year discharge by 3.4 feet, the 50-year discharge by 2.4 feet, and the 25-year discharge by 1.4 feet. Water surface elevations at cross section 77943 (located 64 feet downstream of the Route 28 bridge) decreased only slightly. Upstream of the bridge, small reductions occurred at cross section 78084 (located 77 feet upstream of the Route 28 bridge).

In spite of significant reduction in water surfaces at cross section 77448, this scenario does not result in real flood mitigation benefits. Upstream of the Route 28 bridge where most of the problematic flooding occurs, decreases in water surface elevations are small and provide little in the way of flood mitigation that is not currently provided by the levee. Downstream of the State Route 28 bridge, decreases in water surface elevations at cross section 77448 are offset by the low number of structures that would see any flood mitigation benefits.

Scenario 4 is a combination of Scenarios 1 and 2 with floodplain enhancements on the left bank and gravel removal on the right bank in the vicinity of the confluence. The benefits of this alternative are better than Scenarios 1 and 2 but still do not provide worthwhile flood mitigation for properties located between the levee and State Route 42.

Scenario 5 consists of Scenarios 1, 2, and 3. The idea is that a combination floodplain enhancement and gravel removal in the three areas would act synergistically to provide improved flood mitigation in the areas where flooding is most problematic. The following figures provide an illustration of flood relief in the three areas for the 25-, 50-, and 100-year discharges. The 10-year discharge is not shown because the benefits are negligible. The 500-year discharge is also not shown as the level of flooding is so great that mitigation efforts have virtually no impact on reducing vulnerability to flooding.

Figures 4-25 through 4-27 show the changes in water surface elevations in Area 1 at cross section 78961 (located 954 feet upstream of the Route 28 bridge). Under proposed conditions, there is a reduction in water surface elevation of 0.6 feet during the 25-year discharge, 0.9 feet during the 50-year discharge, and 1.2 feet during the 100-year discharge.

The figures illustrate that the largest flows do not inundate County Route 47 and do not overtop the railroad trestle on the right bank of the stream. As no houses are located in the vicinity of this cross section, there are no flood mitigation benefits at this particular location.

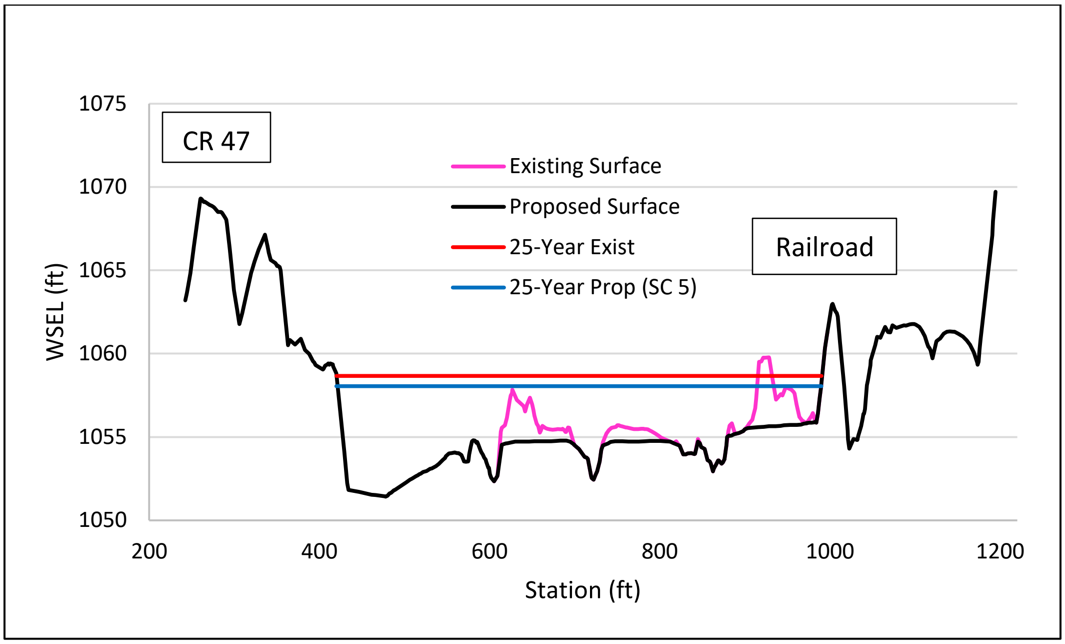


Figure 4-25
XS 78961 Floodplain Enhancement: 25-Year Discharge

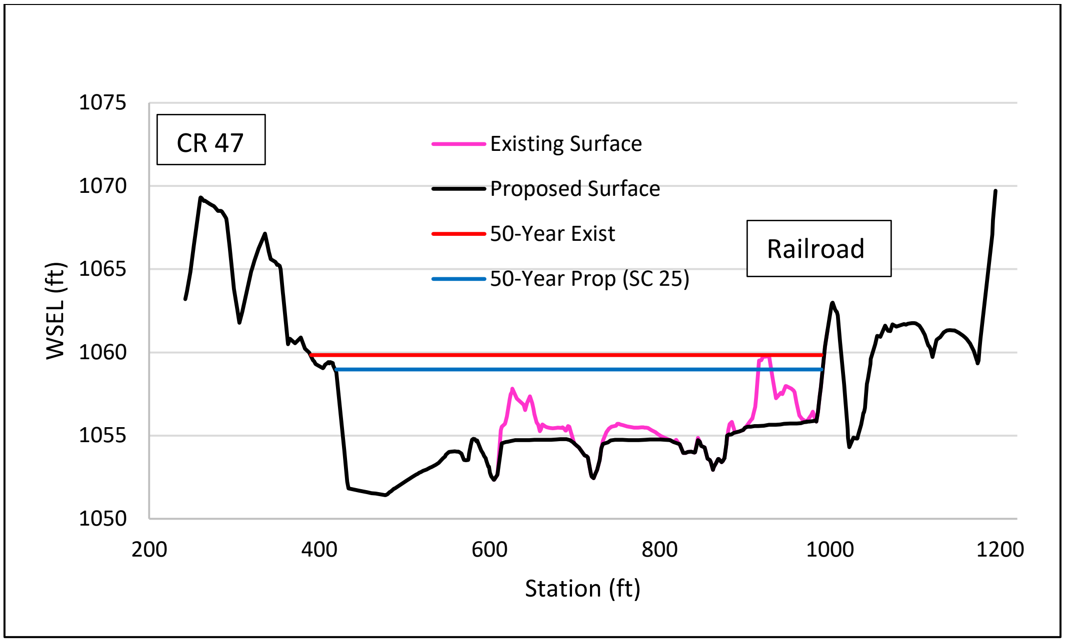


Figure 4-26
XS 78961 Floodplain Enhancement: 50-Year Discharge

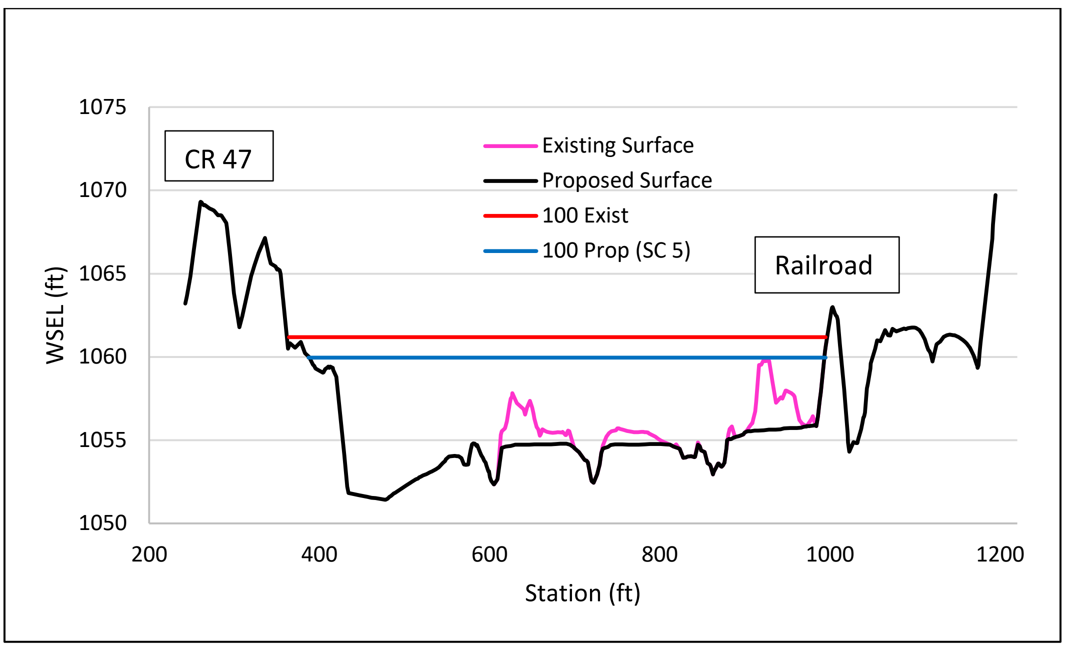


Figure 4-27
XS 78961 Floodplain Enhancement: 100-Year Discharge

Figures 4-28 through 4-33 represent changes in water surface at cross sections 78444 and 78084 in Area 2 (located 437 and 77 feet upstream of the Route 28 bridge, respectively), which is the primary area where flooding is most severe. Under proposed conditions at cross section 78444, there is no change in water surface elevations during the 25-year discharge, an increase of 0.7 feet during the 50-year discharge, and an increase of 1.5 feet during the 100-year discharge. At cross section 78084, there is a reduction in water surface elevation of 0.1 feet during the 25-year discharge, 0.6 feet during the 50-year discharge, and 0.5 feet during the 100-year discharge.

As shown in these figures, Scenario 5 provides little benefit of flood mitigation that is not already provided by the existing levee and, in fact, would result in an increase in water surface elevation in some areas along Esopus Creek. Although this scenario prevents the levee from overtopping during the 100-year event at cross section 78084, water overtops the levee at the upstream cross section resulting in floodwaters reaching properties located behind the levee.

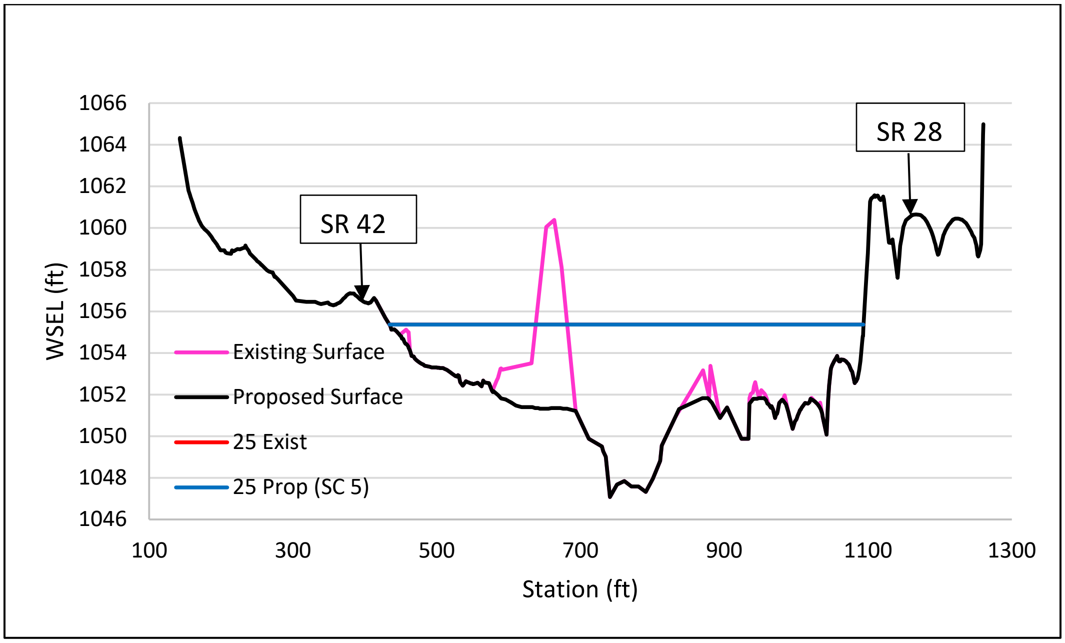


Figure 4-28
XS 78444 Floodplain Enhancement: 25-Year Discharge

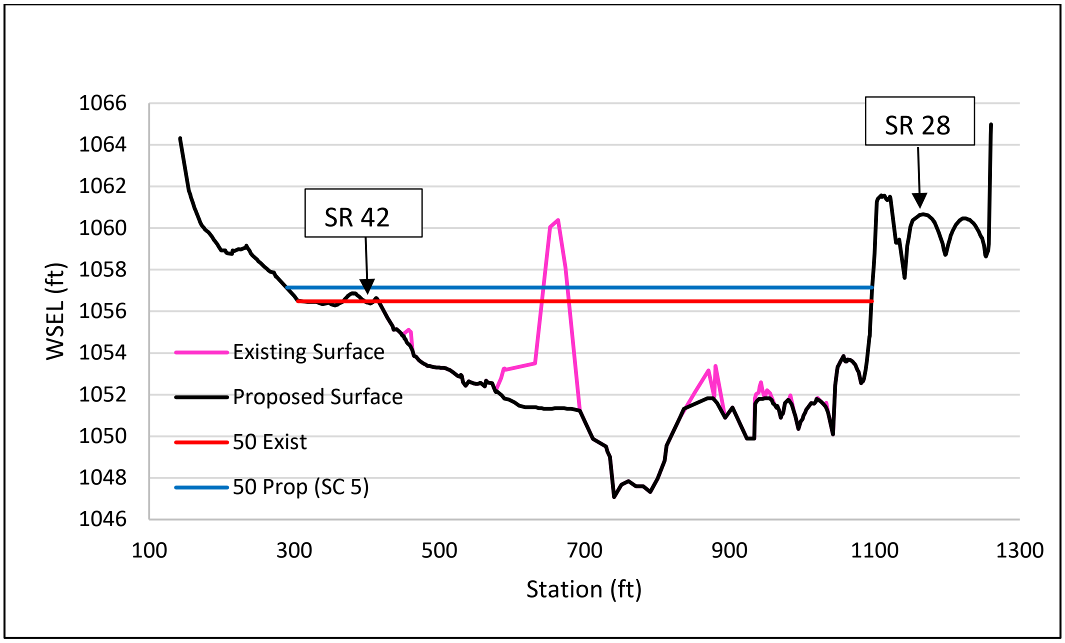


Figure 4-29
XS 78444 Floodplain Enhancement: 50-Year Discharge

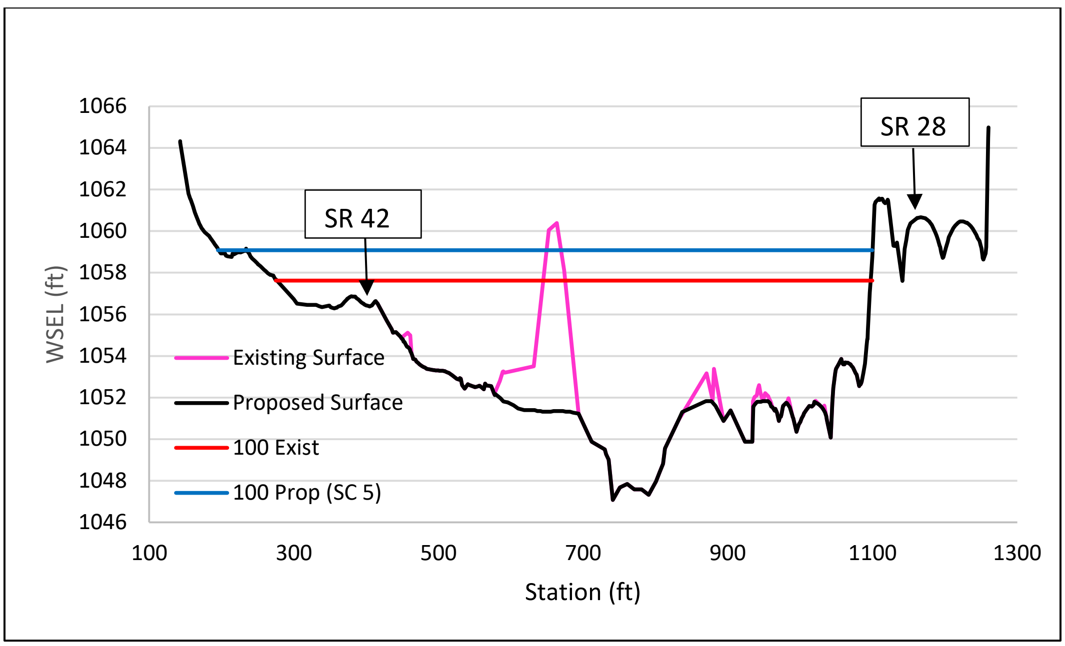


Figure 4-30
XS 78444 Floodplain Enhancement: 100-Year Discharge

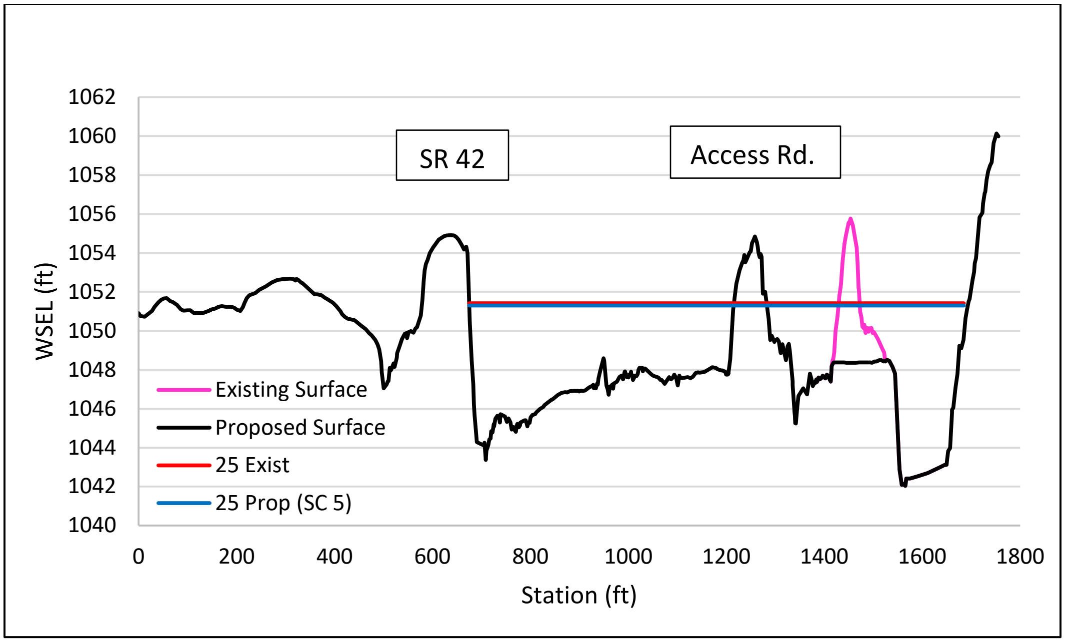


Figure 4-31
XS 78084 Floodplain Enhancement: 25-Year Discharge

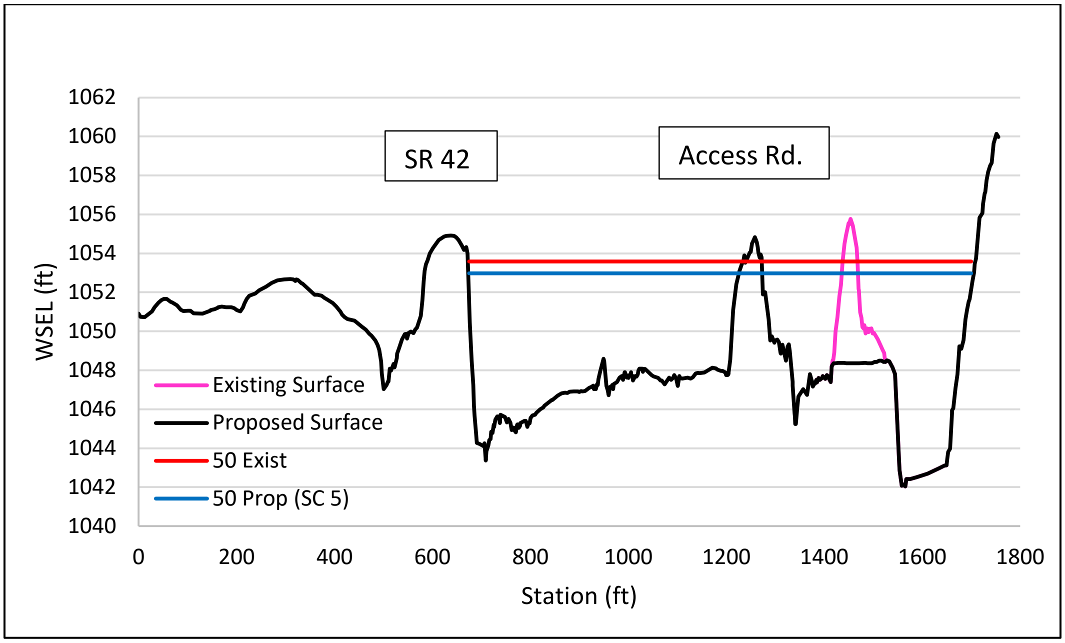


Figure 4-32
XS 78084 Floodplain Enhancement: 50-Year Discharge

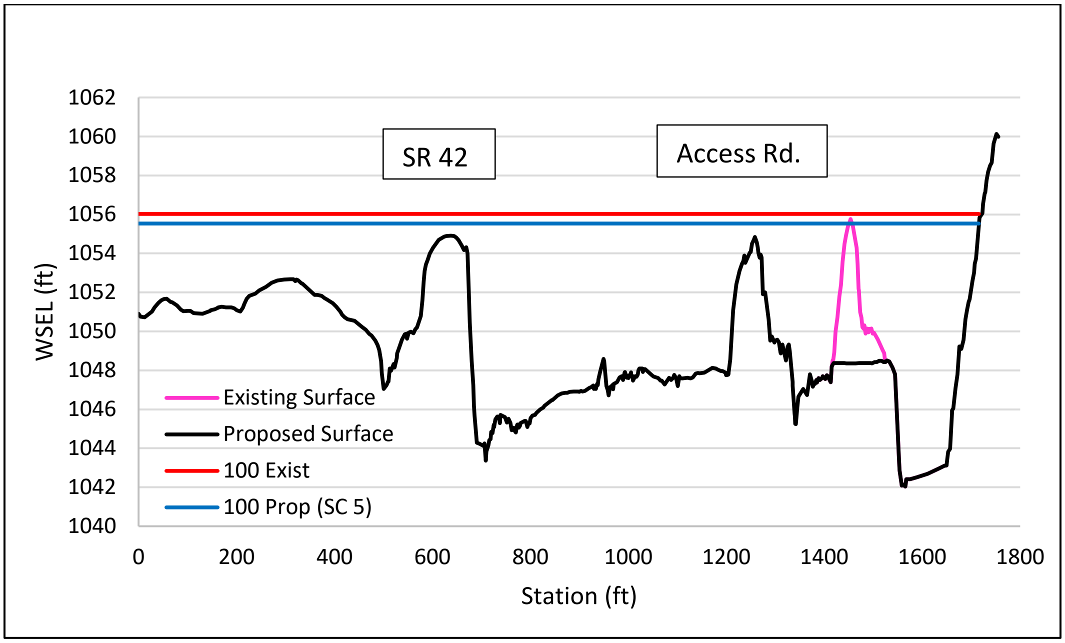


Figure 4-33
XS 78084 Floodplain Enhancement: 100-Year Discharge

Figures 4-34 through 4-36 depict changes in water surface elevations at cross section 77448 (located 559 feet downstream of the Route 28 bridge). Under proposed conditions, there is a reduction in water surface elevation of 1.4 feet during the 25-year discharge, 2.4 feet during the 50-year discharge, and 3.4 feet during the 100-year discharge.

Although significant reductions in water surface elevations occur at cross section 77448 in Area 3, this does not translate into substantial flood mitigation as there are few properties in this area. The figures below illustrate that none of the scenarios modeled at the confluence result in substantial reductions in flooding for properties located between the levee and State Route 42.

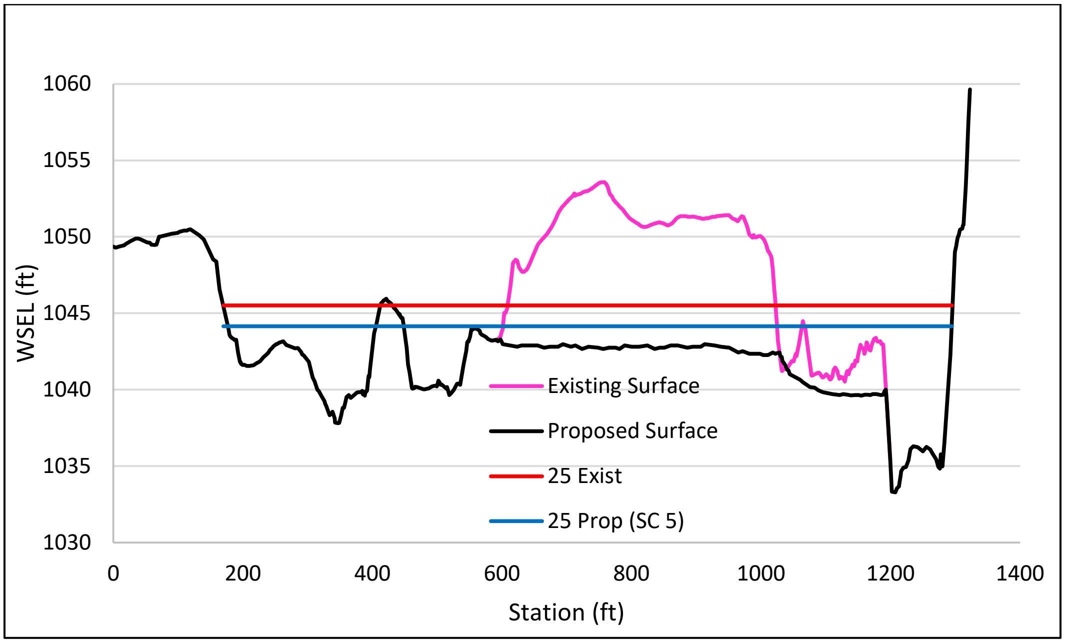


Figure 4-34
XS 77448 Floodplain Enhancement: 25-Year Discharge

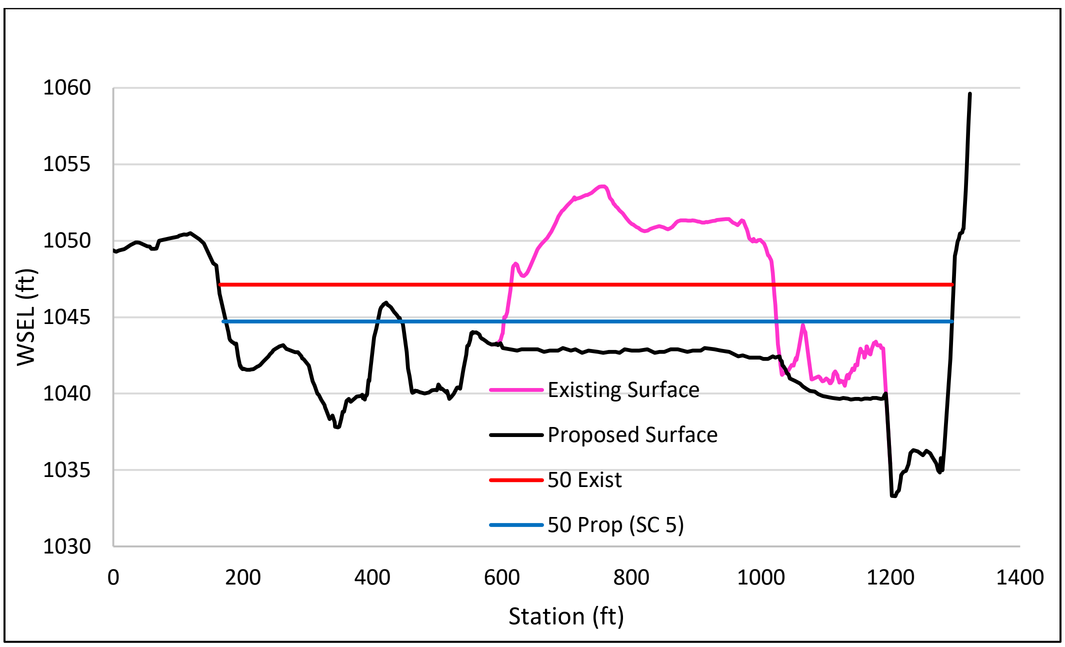


Figure 4-35
XS 77448 Floodplain Enhancement: 50-Year Discharge

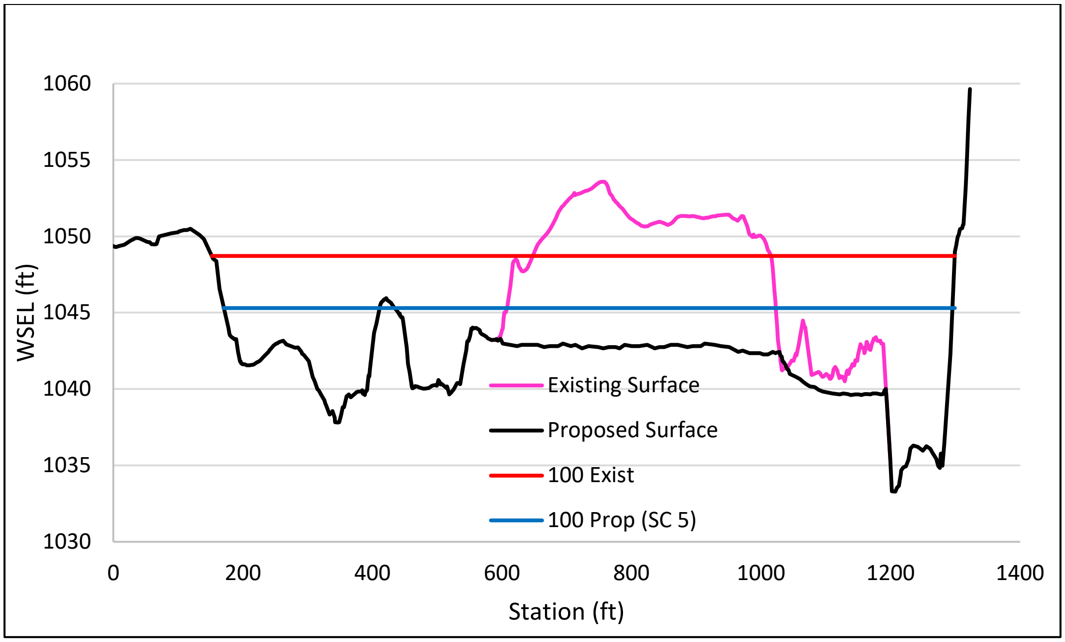


Figure 4-36
XS 77448 Floodplain Enhancement: 100-Year Discharge

4.3.4 Access of Esopus Creek to Secondary Channel in Vicinity of the Shandaken Tunnel

SAFARI members expressed concern regarding erosion of the State Route 28 road embankment immediately downstream where the Shandaken Tunnel empties into Esopus Creek. They were additionally concerned about overtopping of the Route 28 roadway, which could impede evacuation as well as rescue and recovery efforts during floods.

Prior to Tropical Storm Irene, the Esopus Creek consisted of two channels in the vicinity of the Shandaken Tunnel. The main channel ran along State Route 28 while the secondary channel ran along the old railroad trestle on the opposite side of the valley. Pre-Irene imagery indicates that the secondary channel conveyed stream flow during base flow conditions (Figure 4-37).

Figure 4-37
Pre-Irene Channel Conditions in the Vicinity of the Shandaken Tunnel

During the 2011 flood, the State Route 28 roadway embankment immediately downstream of the Shandaken Tunnel was severely eroded requiring emergency action. As part of the emergency in-stream work, the secondary channel was blocked off, and the Esopus was converted to a single-thread stream (Figure 4-38).

Figure 4-38
Post-Irene Channel Conditions in the Vicinity of the Shandaken Tunnel

Hydraulic modeling was undertaken to assess water surface elevations and velocities in the region of the Shandaken Tunnel after the transition of Esopus Creek from a double-thread to a single-thread channel. To characterize this area, a cross section was created at the point where the secondary channel leaves the main stem (cross section 68644). This cross section was created from a Digital Elevation Model (DEM) with one meter resolution. Elevations in the channel were adjusted by using the slope between the upstream and downstream cross sections as reference.

Pre-Irene conditions were simulated by allowing stream flow to access both channels at base flow conditions as in Figure 4-37. Post-Irene conditions were represented by blocking the secondary channel at cross section 68644 in order to depict Esopus Creek as a single-thread stream (Figure 4-38). The models were run, and water surface elevations and channel velocities were compared at cross section 67974 located just downstream of the point where the Shandaken Tunnel outlets into Esopus Creek. Results are shown in Table 4-12.

TABLE 4-12
Pre- and Post-Irene Water Surface Elevations and Velocities in the Vicinity of the Shandaken Tunnel

Return Interval Discharge	Pre-Irene WSEL (feet)	Pre-Irene Channel Velocity (feet/second)	Post-Irene WSEL (feet)	Post-Irene Channel Velocity (feet/second)	Δ WSEL (feet)	Δ Velocity (feet/second)
Bankfull	966.3	7.7	966.2	7.8	0.0	0.1
2-Year	967.2	8.8	967.2	9.3	0.0	0.4
10-Year	969.1	9.4	969.2	10.6	0.1	1.3
25-Year	970.3	9.9	970.4	12.0	0.1	2.2
50-Year	971.2	10.8	971.1	13.1	0.0	2.4
100-Year	972.0	11.7	971.9	14.1	-0.1	2.4
500-Year	974.9	13.9	974.3	16.9	-0.6	3.0

wsel = water surface elevation

The hydraulic modeling results show that blocking the left channel at cross section 68644 to simulate the present, single-thread condition had little effect on water surface elevations. In contrast, velocities increased as discharges increased. This indicates a single-thread channel configuration has greater erosion potential than a double-thread channel. However, before any mitigation actions are taken, further hydraulic modeling of this area is warranted.

5.0 BENEFIT-COST ANALYSIS

5.1 Overview of Benefit-Cost Analysis

A BCA is used to validate the cost effectiveness of a proposed hazard mitigation project. A BCA is a method by which the future benefits of a project are estimated and compared to its cost. The end result is a benefit-cost ratio (BCR), which is derived from a project's total net benefits divided by its total project cost. The BCR is a numerical expression of the cost effectiveness of a project. A project is considered to be cost effective by FEMA when the BCR is 1.0 or greater, indicating the benefits of the project are sufficient to justify the costs.

Due to relatively narrow valleys and the location of existing roadways and infrastructure as well as dispersed settlement patterns, hydraulic analyses did not identify any mitigation alternatives that significantly reduced floodwater elevations. Hydraulic model results, field visits, and FEMA floodplain mapping indicated that relatively few properties in the hamlets of Shandaken and Allaben were at significant risk of inundation.

To facilitate the BCA, a field survey of structures in the FEMA 500-year flood zone was carried out in the project area. The following features were noted and verified against data contained in the Ulster County Parcel Viewer (http://ulstercountyny.gov/maps/parcel-viewer/):

- Is the structure commercial or residential?
- If the structure is commercial, is it a retail establishment, a warehouse, or vacant?
- Does the structure have a basement, crawlspace, or slab foundation?
- What is the number of stories?
- Is the structure split level?
- What is the elevation of the first floor in relation to the grade?

The BCA was conducted to evaluate the economic feasibility of acquiring properties under a buyout program so that their respective structure or structures could be removed from the floodplain. Assumptions for the BCA include the following:

- Benefits for acquired/relocated properties were determined as acquisitions.
- Lost revenue was included only for businesses that provided such information.
- Default depth-damage curves were used in the program.
- HEC-RAS modeling was conducted to develop raster maps (depth grid maps) of water surface elevations for the 10-, 50-, 100-, and 500-year discharge events. These maps were exported to *ArcGIS* and used to determine water surface elevations at individual structures.
- The first-floor elevations of 36 structures were surveyed by MMI on January 25 and 26, 2017.
- For those structures not surveyed, first-floor elevations were estimated using DEM topographic mapping.
- Building information (area, basement, number of stories, etc.) came primarily from the Ulster County Parcel Viewer. Where necessary, this information was supplemented from data collected during a field visit.

- If the area of a structure was not included on the Ulster County Parcel Viewer, it was estimated using aerial imagery and *ArcGIS*.
- Parcel values (full market value) came from assessment data on the Ulster County Parcel Viewer.
- Demolition cost was not included in the calculation of project cost.
- For residential parcels with multiple structures, determination of inundation was based upon the first habitable structure on the property to become flooded.
- For typical commercial parcels with multiple structures, determination of inundation was based upon the first permanent structure on the property to become flooded.

A BCA was run for individual, privately held, potentially floodprone properties within the study area. A separate BCA was run for the Town of Shandaken town hall complex. The BCA analyses do not include benefits that could have been generated for avoiding future street cleanup, avoided detours, avoided emergency response, etc.

5.2 BCA Results – Individual Properties

The Flood Module component of the BCA analyzes proposed mitigation projects based on flood hazard conditions of riverine flood sources. The Flood Module is designed for evaluating individual buildings within a project and is used when flood hazard information and structural data are available. It should be noted that the resulting BCRs were derived from the existing conditions hydraulic models and the county's assessor data. Individual homeowners can voluntarily provide additional damage information from past flood events, which may improve BCA results. BCR scores for individual properties are given in ranges, as shown in Table 5-1, and are displayed with color coding on Figures 5-1 through 5-6.

TABLE 5-1
BCR Score Ranges

BCR Score Range	
> 1.0	Indicates that the property would likely qualify for a voluntary flood buyout or other flood protection measures such as elevation (if not located in the floodway)
0.75 – 1.0	Indicates that the property may potentially qualify for a voluntary flood buyout or other flood protection measures such as elevation (if not located in the floodway)
0.5 – 0.75	Indicates that the property could potentially qualify for a voluntary flood buyout or other flood protection measures such as elevation (if not located in the floodway), with additional information to document flood damages
0.25 – 0.50	Indicates that the property likely would not qualify for a voluntary flood buyout, yet other flood protection measures may be sought out
< 0.25	Indicates that the property would not qualify for a voluntary flood buyout, yet other flood protection measures may be sought out

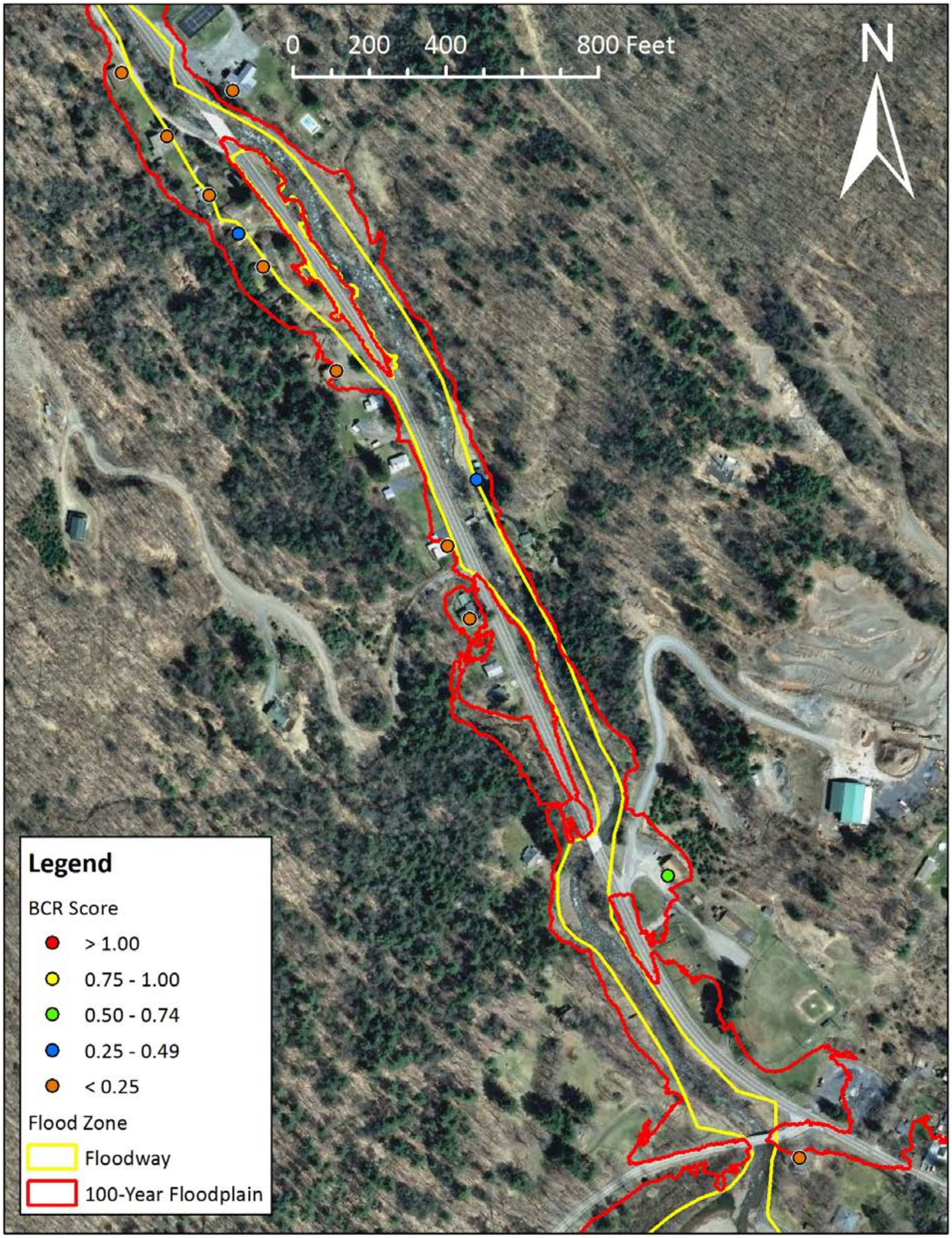


Figure 5-1
BCA Results along Bushnellsville Creek

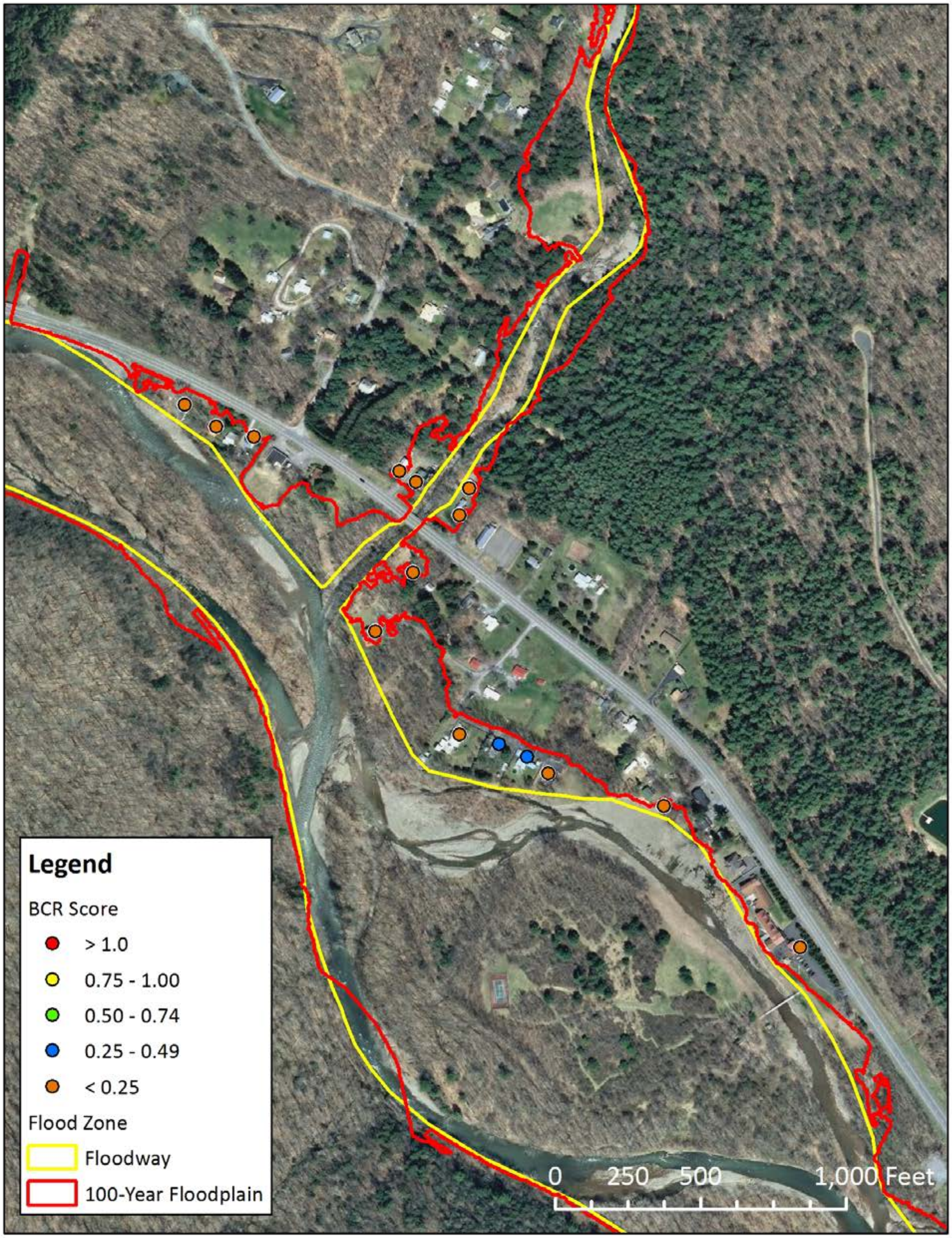


Figure 5-2
BCA Results at Broadstreet Hollow Creek Confluence

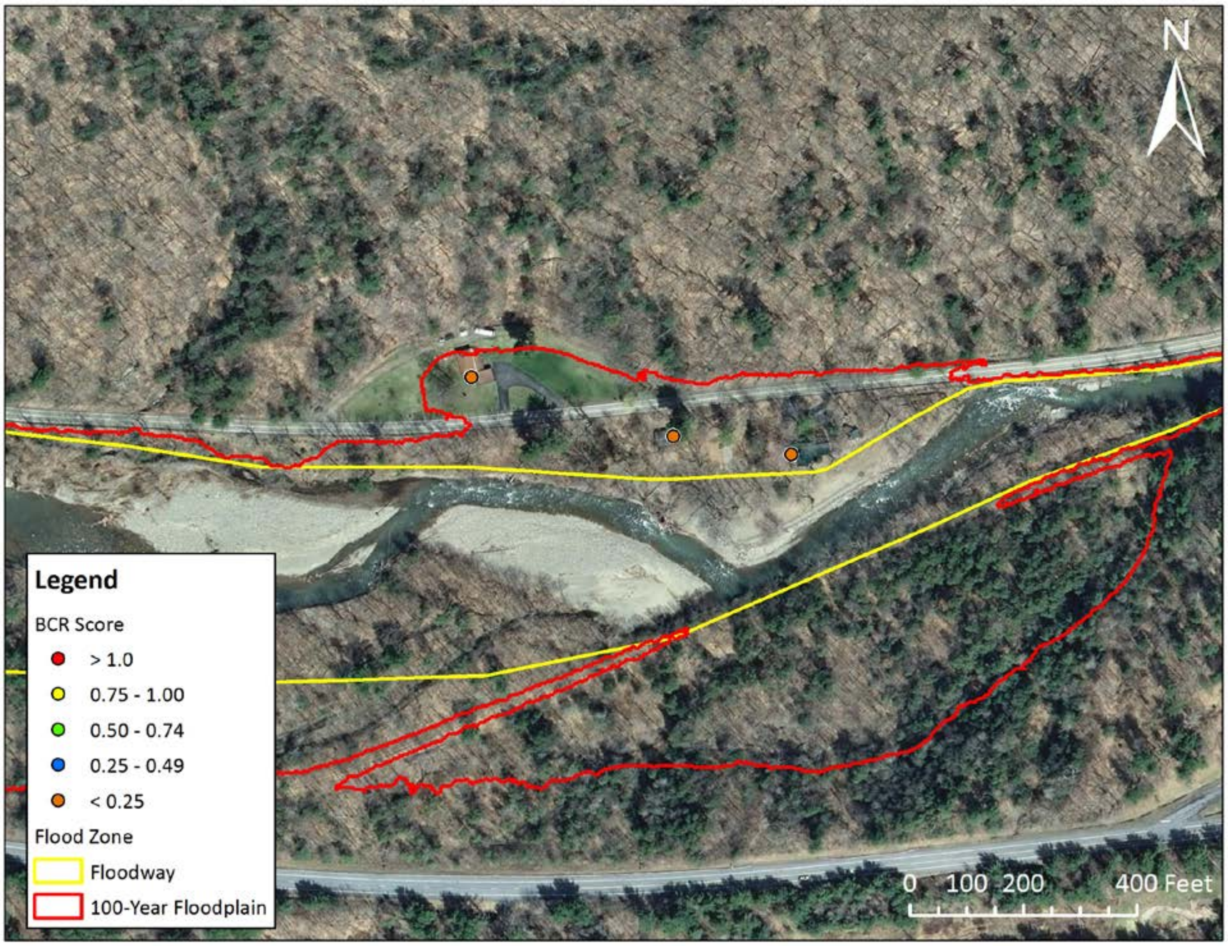


Figure 5-3
BCA Results along Esopus Creek above Shandaken

Figure 5-4
BCA Results along Esopus Creek at Shandaken

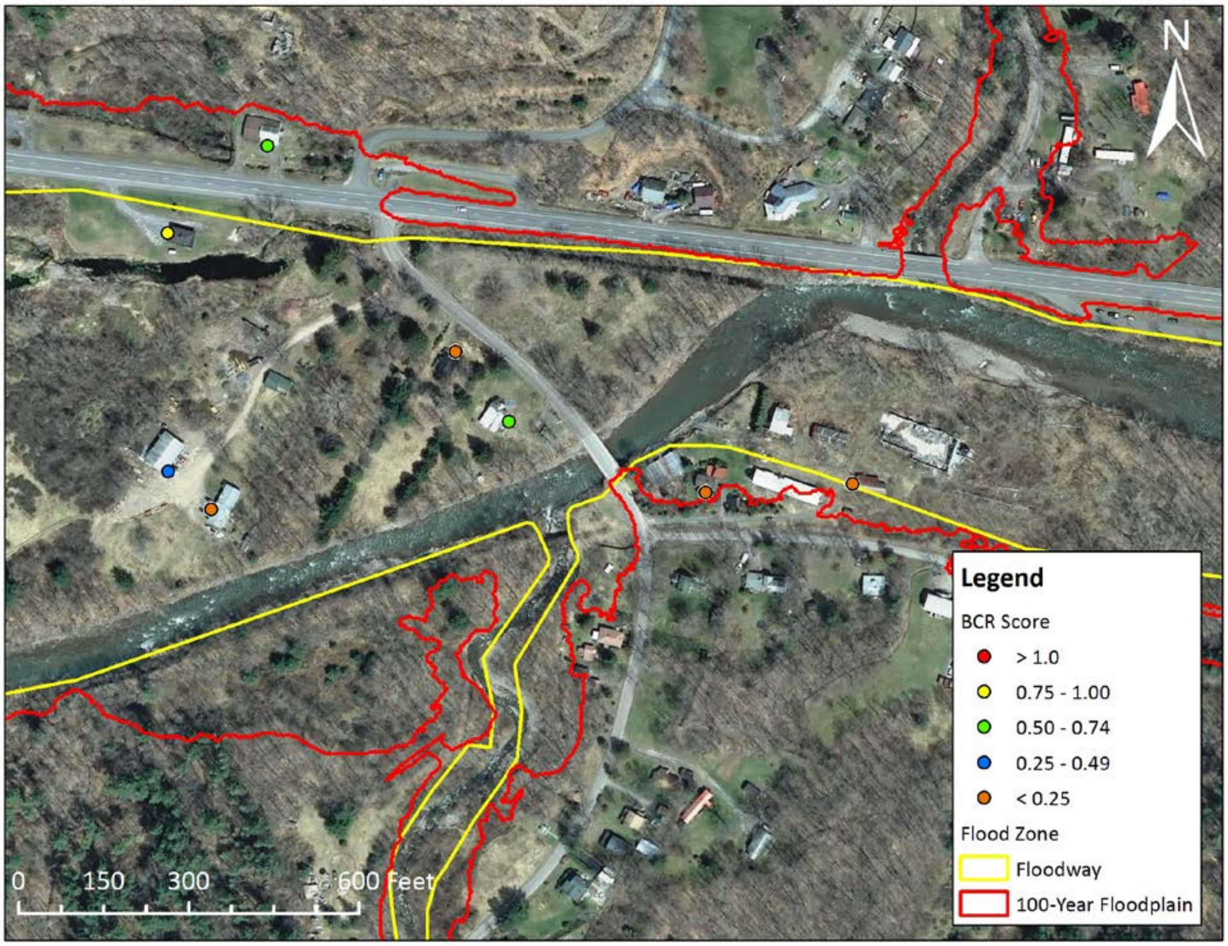


Figure 5-5
BCA Results along Esopus Creek at Fox Hollow Creek

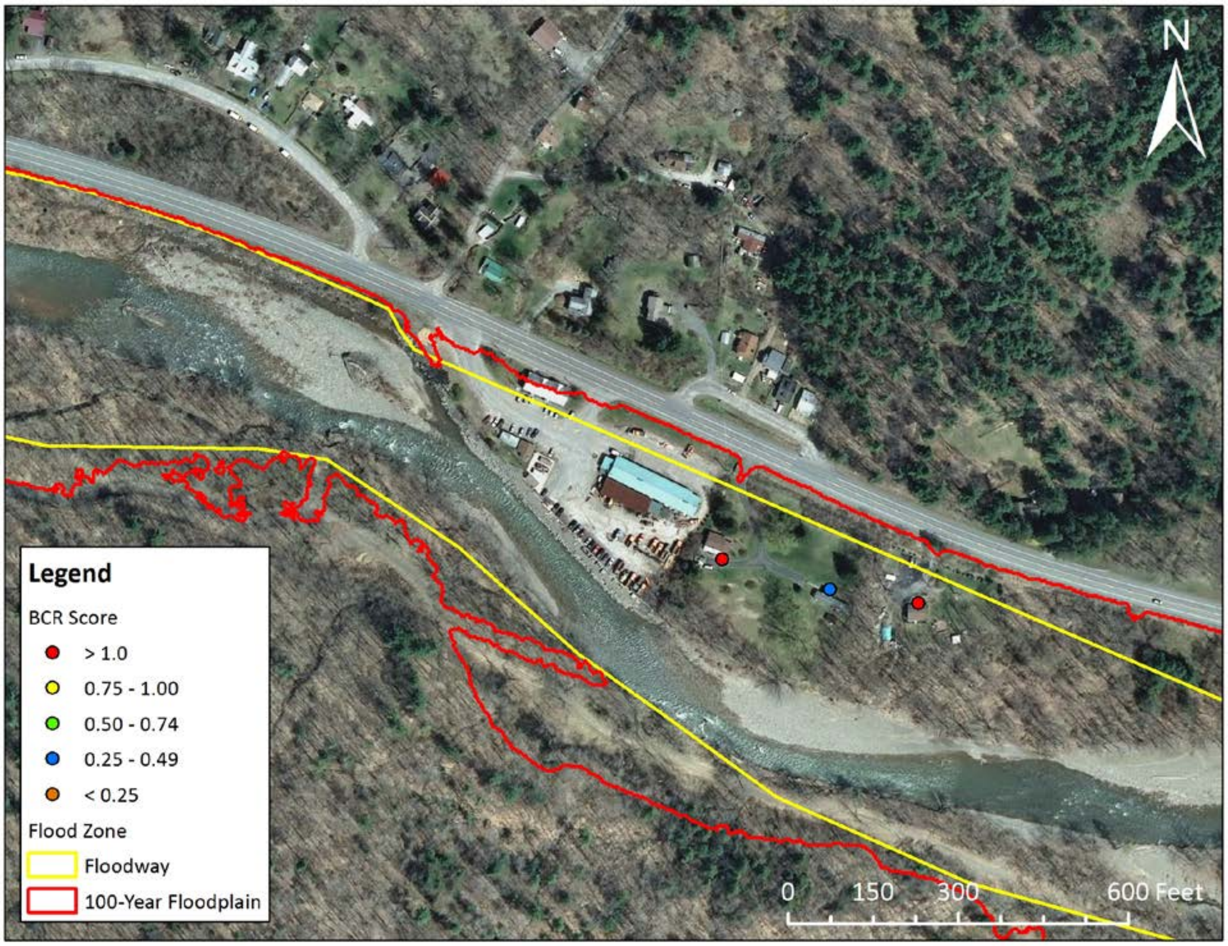


Figure 5-6
BCA Results along Esopus Creek near Town Hall Facility

5.3 Benefits for Relocation of Town Hall Complex

The Flood Module component of the BCA tool was used to determine the benefits for the relocation of the Shandaken town hall facility out of the SFHA. The town hall facility includes the town hall building plus the dog pound and Highway Department garage. The benefits of relocating the town hall facility in its entirety, or relocating some components of the facility, are described below. The cost of relocation of all or portions of the town hall complex is unknown at this time.

5.3.1 Relocation of Town Hall and Dog Pound

The town hall and dog pound buildings are located on a single parcel of land. The town hall comprises approximately 80 percent of the building square footage on this parcel while the dog pound makes up the remaining 20 percent. The dog pound building is located closer to Esopus Creek than the town hall and has a lower first floor elevation and, therefore, floods on a more frequent basis. While both buildings are located within the SFHA, only the dog pound building is located within the FEMA floodway.

Benefits were derived from completely avoided flood damages if the town hall and dog pound were to be relocated out of the SFHA. **Benefits = $200,124**

5.3.2 Relocation of Town Highway Department Garage

The town Highway Department garage is located close to Esopus Creek within the SFHA and within the FEMA floodway. Benefits were derived from completely avoided flood damages if the Highway Department garage were to be relocated out of the SFHA. **Benefits = $209,172**

5.3.3 Relocation of Entire Town Hall Complex

Benefits were derived from completely avoided flood damages if the Town of Shandaken town hall complex, including the town hall, dog pound, and Highway Department garage, were to be relocated out of the SFHA. **Benefits = $409,296**

5.4 Incorporating Open Space and Riparian Benefits into the BCA

The benefits described above were derived from completely avoided flood damages if the Town of Shandaken town hall complex were to be relocated out of the SFHA. Because this alternative would result in a substantial riparian area being made available for public use and enjoyment, benefits could also potentially include land use benefits.

In the FEMA BCA tool, environmental benefits for acquisition projects are incorporated upon achieving a BCR of 0.75 or greater. Land use environmental benefits are based on the size (square footage) of the land and the amount of said land that will be distributed to open green space and/or riparian after the project is finished. Depending on the quantity of land allocated toward environmental restoration efforts, additional environmental benefits can significantly increase project benefits and can result in a 1.00 or greater project BCR.

In the case of relocating the Highway Department garage, if the project were to cost $278,895 or less, environmental benefits would be accounted for and would result in a BCR of 3.99. Table 5-2 contains the maximum allowable total project cost needed to obtain a BCR of 0.75 and the associated additional land use benefits. It is important to note that these calculations assume that 100% of the vacated parcel will be used for riparian benefits after project completion. This would likely entail demolition and removal of the buildings, removal of all pavement, and restoration and replanting of the site using native riparian species.

TABLE 5-2
Town Hall Complex Potential BCA with Additional Land Use Benefits

Structure	Benefits	Maximum Allowable Project Cost	Land Use Benefits	Adjusted Project Benefits	Hypothetical BCR
Highway Department Garage	$209,172	$278,895	$761,769	$970,941	3.48
Town Hall/Dog Pound	$200,124	$266,830	$259,566	$459,690	1.72
Project Total	**$409,296**	**$545,725**	**$1,021,335**	**$1,430,631**	**2.62**

5.5 Incorporating Water Quality Benefits into the BCA

It is important to note that flooding can severely impact water quality, and by reducing flooding and flood-related damages, impacts to water quality can also be reduced. Therefore, water quality impairment is one of the benefits, or "avoided damages," that should be considered as part of a BCA analysis of a flood mitigation scenario. Over the years, FEMA's BCA program has been modified to include other factors that can be quantified and summed with flood inundation benefits such as open space and riparian benefits, mental health, and volunteer costs. As of 2017, a method for quantifying water quality benefits has not been added to the BCA program.

There are many examples within the Shandaken-Allaben LFA project area of potential water quality impairment in the event of a flood and, conversely, potential benefits if that water quality impairment could be avoided through the implementation of a flood mitigation scenario. One example of a potential source of water quality impairment, if it were to be inundated during a flood event, is the Town of Shandaken Highway Department garage. The garage is located within the SFHA along Esopus Creek, is within the FEMA floodway, and is prone to flooding. Sections 5.3 and 5.4 above describe the benefits for the relocation of the Highway Department garage out of the SFHA, which include avoided damages from flooding of the structure as well as open space benefits. In addition, benefits to water quality should be taken into consideration.

As described in more detail in Section 2.5 of this report, the town Highway Department garage currently stores automotive and industrial chemicals including fuel, oil, antifreeze, and additives. Approximately 3,000 gallons of heating oil and diesel fuel are stored at the Highway Department garage. Other potential pollutants include tires, empty fuel drums and containers, paints, acetylene torches, and asphalt road patch material stored within and in the immediate vicinity of the garage. By removing these potential pollutants out of the floodprone SFHA, the relocation of the Town of Shandaken Highway Department garage would provide additional water-quality-related benefits that are not encompassed in the BCA.

Other examples of potential benefits associated with water quality include the following:

- Household chemicals and pollutants associated with home maintenance, lawn care, swimming pools, and backyard barbeques are mobilized when properties get flooded. Flood mitigation scenarios that prevent or reduce flooding of houses and yards will reduce associated impacts to water quality.

- Flooded businesses can be a source of pollution during a flood. Flood mitigation scenarios that prevent or reduce flooding of businesses or industrial areas will reduce associated impacts to water quality.

- Roadways and parking lots contribute pollutants to watercourses when they flood. If flooding is severe, vehicles can be inundated by floodwaters. Flood mitigation scenarios that prevent or reduce flooding of roadways and parking areas, or that result in road closures so that vehicles are not flooded, will reduce impacts to water quality.

- Home and business fuel storage is a potential source of pollution during floods if fuel tanks are not elevated or anchored. Flood mitigation scenarios that encourage elevation or anchoring of fuel storage tanks will reduce impacts to water quality.

6.0 FINDINGS AND RECOMMENDATIONS

The purpose of this LFA is to evaluate potential flood mitigation options within the Town of Shandaken in the hamlets of Shandaken and Allaben. A number of flood mitigation alternatives were considered and evaluated, including the replacement of undersized bridges, channel and floodplain enhancement, removal of sediment bars, and removal of levees. Flood mitigation alternatives were evaluated using hydraulic modeling.

6.1 Flood Mitigation Recommendations

The following flood mitigation recommendations are offered:

6.1.1 Relocation of Town Hall Complex

The relocation of the Town of Shandaken town hall facility out of the SFHA is recommended. This recommendation includes the town hall, dog pound, and Highway Department garage. In its current configuration, the facility is located within the SFHA, with the dog pound and Highway Department garage also located in the FEMA floodway. In addition to eliminating flood risks at the facility, the relocation would also result in benefits to water quality by removing potential pollutants from floodprone areas.

A Proposed Project recommended in the NYRCR Plan for the Towns of Shandaken and Hardenburgh is a new Town of Shandaken Municipal Project, which includes the construction of a new, multiuse municipal facility on Route 28.

The Local Flood Analysis for the Town of Shandaken hamlets of Phoenicia and Mount Tremper, completed in June, 2016, includes the following recommendation: *Relocate floodprone, town-critical facilities to town-owned parcel on Route 28, east of Phoenicia*.

6.1.2 Bridges

1. At the Fox Hollow Road bridge over Esopus Creek, the 25-year discharge exits the channel immediately upstream of the bridge and inundates Fox Hollow Road between Esopus Creek and State Route 28. When the bridge is scheduled for replacement, it is recommended that a full hydraulic assessment be conducted to ensure that the bridge opening is adequately sized and that the new bridge spans the channel and floodplain.

2. The town-owned bridge over Fox Hollow Creek is insufficiently sized to pass the 25-year and larger flood events. While no structures are flooded, the bridge is overtopped during these events, and floodwaters inundate Fox Hollow Road. When this bridge is scheduled for replacement, or if it were to be damaged during a flood, it is recommended that a full hydraulic assessment be conducted to ensure that the replacement bridge is adequately sized.

3. It is recommended that the Creekside Drive (County Route 47) bridge over Bushnellsville Creek be inspected for sediment aggradation at least every 2 years and also immediately following

flood events. Based on hydraulic analyses, maintenance actions may be warranted if 1 foot of aggradation were to occur at the bridge opening. In the event the channel aggrades 2 feet above present conditions, maintenance actions to remove the aggradation are strongly advised. The bridge is noted as an action item in the Ulster County Multi-Jurisdictional Natural Hazard Mitigation Plan and in the Town of Shandaken Flood Mitigation Plan.

When removal of sediment at the bridge is necessary, a methodology should be developed to maintain the proper channel dimensions and slope. This is crucial to avoid destabilizing the physical channel, which could have long-term effects. As a starting point, the following guidelines are recommended:

- Sediment excavation requires regulatory permits. Prior to initiation of any in-stream activities, NYSDEC should be contacted, and appropriate local, state, and federal permitting should be obtained.

- Maintain the original channel slope and do not overly deepen or widen the channel. Excavation should not extend beyond the channel's estimated bankfull width unless it is to match an even wider natural channel.

- Best available practices should be followed to control sedimentation and erosion of the streambed or bank, which may release fine-grain sediments that cause turbidity.

- Disposal of excavated sediments should always occur outside of the floodplain. If such materials are placed on the adjacent bank, they will be vulnerable to remobilization and redeposition during the next large storm event.

- No sediment excavation should be undertaken in areas where aquatic-based rare or endangered species are located.

6.1.3 Floodplain and Channel Enhancement

A range of floodplain and channel enhancement scenarios were evaluated in the vicinity of the confluence of Esopus Creek and Bushnellsville Creek. These did not result in significant reductions in flooding and are not recommended.

6.1.4 Structures within FEMA Floodway

Several structures, some occupied and some abandoned, were identified that are located within the floodway. The floodway designated by FEMA is the stream channel, and that portion of the adjacent floodplain must remain open to permit passage of the base flood. Floodwaters are typically deepest and swiftest in the floodway, and anything in this area is in the greatest danger during a flood (FEMA, 2008). The following recommendations are offered for the FEMA floodway:

- Where there is owner interest and programmatic funding available, move existing structures out of the FEMA-designated floodway. Areas where structures are located within the floodway include the following:

    a. Homes along the left bank of Esopus Creek, just upstream of the Fox Hollow Road bridge

b. Abandoned structures along the right bank of Esopus Creek, just downstream of the Fox Hollow Road bridge
c. At the Shandaken town hall facility along the left bank of Esopus Creek, the Highway Department garage, and dog pound (relocation of critical facilities is noted as an action item in the Ulster County Multi-Jurisdictional Natural Hazard Mitigation Plan)
d. Homes along the left bank of Esopus Creek, just downstream of the town hall facility

- Disallow any new development in the floodway and require new construction within the SFHA to meet NFIP criteria.

- Disallow any elevation of existing structures in the floodway.

6.1.5 Floodprone Structures within FEMA's SFHA

The SFHA is the area inundated by flooding during the 100-year flood event. It is recommended that the Town of Shandaken work to relocate the most flood-vulnerable properties where there is owner interest and programmatic funding available through flood buyout and relocation programs. Figures 5-1 through 5-6 in the BCA section of this report should be used as guidance. The two flowcharts below provides decision-making guidance for nonresidential (Figure 6-1) and residential (Figure 6-2) properties.

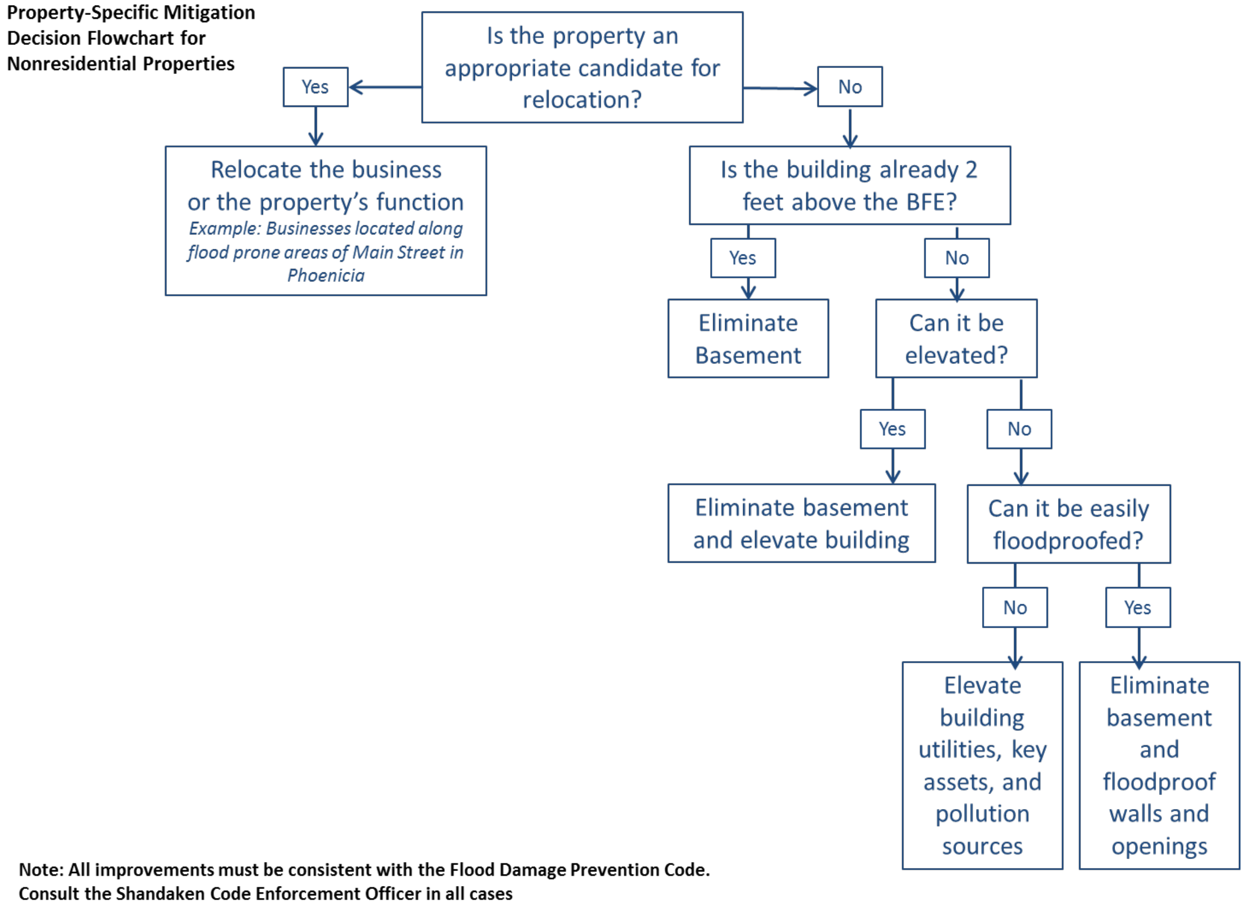
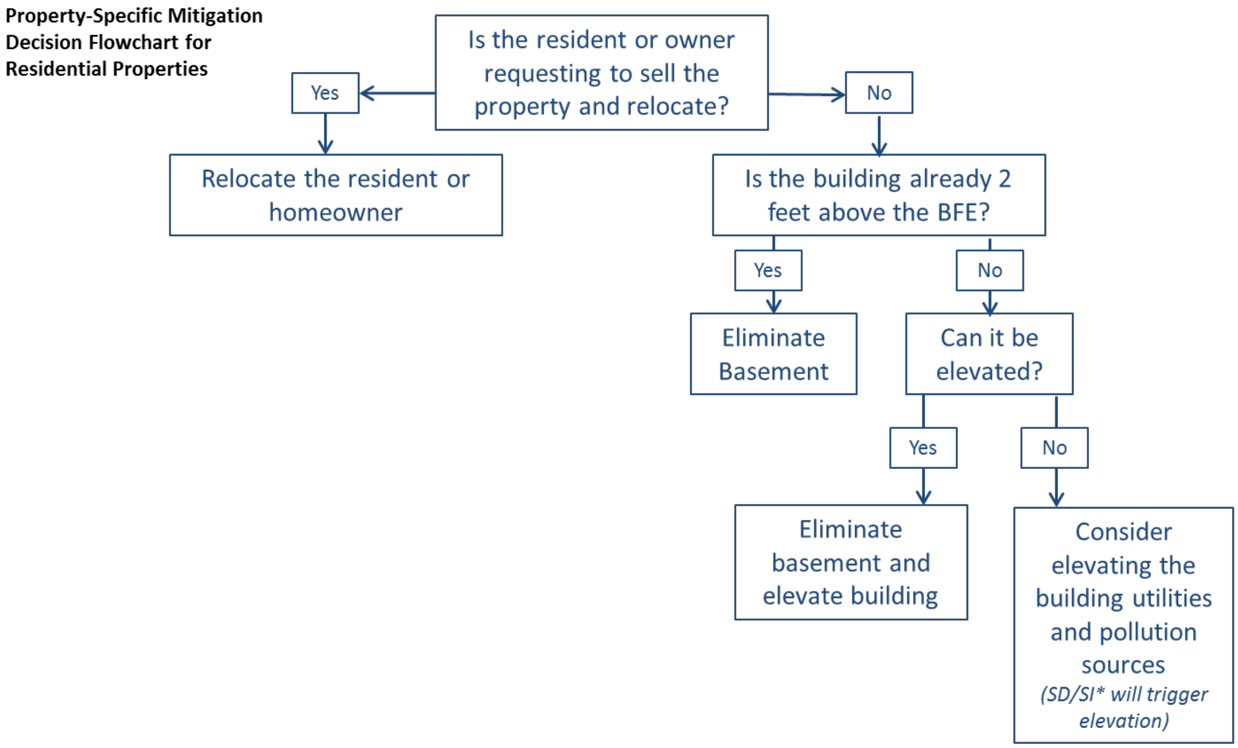


Figure 6-1
Property-Specific Mitigation for Nonresidential Properties



*Substantial Damage/Substantial Improvement
Note: All improvements must be consistent with the Flood Damage Prevention Code. Consult the Shandaken Code Enforcement Officer in all cases

Figure 6-2
Property-Specific Mitigation for Residential Properties

Figure 6-3 below (provided by the NYSDEC) illustrates the relationship between depth of flooding in relation to the first floor and the percent damage to the structure.

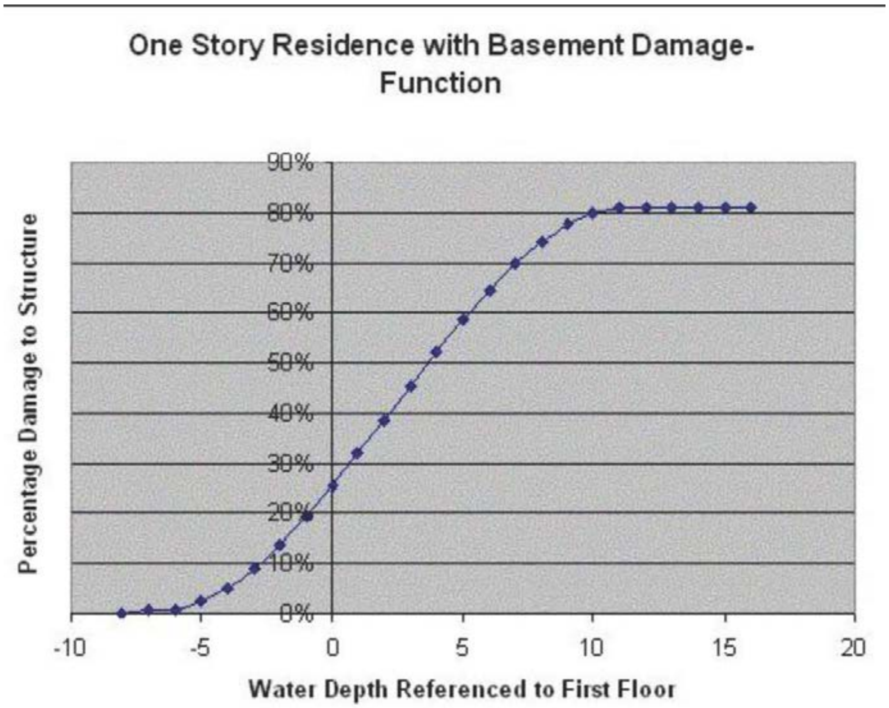


Figure 6-3
How Much Structural Damage Can You Expect?
(graphic provided by NYSDEC)

Some of the homes in the SFHA are rarely flooded. Residents and businesses may benefit from minor individual property improvements. Providing landowners with information regarding individual property protection is recommended.

In areas where properties are vulnerable to flooding, improvements to individual properties and structures may be appropriate. All practices to protect property within a floodplain must comply with local flood law and obtain the approval of the town floodplain administrator or code enforcement officer. Potential measures for property protection include the following:

<u>Elevation of the structure</u> – Home elevation involves the removal of the building structure from the basement and elevating it on piers to a height such that the first floor is located 2 feet above the level of the 100-year flood event. The basement area is abandoned and filled to be no higher than the existing grade. All utilities and appliances located within the basement must be relocated to the first floor level or installed from basement joists or similar mechanism at an elevation no less than 2 feet above the BFE.

<u>Construction of property improvements such as barriers, floodwalls, and earthen berms</u> – Such structural projects can be used to prevent shallow flooding. There may be properties within the town where implementation of such measures will serve to protect structures. Such barriers

must not be permitted unless designed by a qualified engineer and shown to comply with NFIP/local floodplain laws.

Dry floodproofing of the structure to keep floodwaters from entering – Dry floodproofing refers to the act of making areas below the flood level watertight. Walls may be coated with compound or plastic sheathing. Openings such as windows and vents would be either permanently closed or covered with removable shields. Flood protection should extend only 2 to 3 feet above the top of the concrete foundation because building walls and floors cannot withstand the pressure of deeper water.

Wet floodproofing of the structure to allow floodwaters to pass through the lower area of the structure unimpeded – Wet floodproofing refers to intentionally letting floodwater into a building to equalize interior and exterior water pressures. Wet floodproofing should only be used as a last resort. If considered, furniture and electrical appliances should be moved away or elevated above the 100-year flood elevation.

Performing other home improvements to mitigate damage from flooding – The following measures can be undertaken to protect home utilities and belongings:

- Relocate valuable belongings above the 100-year flood elevation to reduce the amount of damage caused during a flood event.
- Relocate or elevate water heaters, heating systems, washers, and dryers to a higher floor or to at least 12 inches above the BFE (if the ceiling permits). A wooden platform of pressure-treated wood can serve as the base.
- Anchor the fuel tank to the wall or floor with noncorrosive metal strapping and lag bolts.
- Install a backflow valve to prevent sewer backup into the home.
- Install a floating floor drain plug at the lowest point of the lowest finished floor.
- Elevate the electrical box or relocate it to a higher floor and elevate electric outlets to at least 12 inches above the high water mark.

Encouraging property owners to purchase flood insurance under the NFIP and to make claims when damage occurs – While having flood insurance will not prevent flood damage, it will help a family or business put things back in order following a flood event. Property owners should be encouraged to submit claims under the NFIP whenever flooding damage occurs in order to increase the eligibility of the property for projects under the various mitigation grant programs.

6.1.6 Manufactured Homes

The potential risk to manufactured homes warrants consideration. According to FEMA guidance, manufactured homes located in the 100-year flood zone should "be elevated on a permanent foundation such that the lowest floor of the manufactured home is elevated to or above the base flood elevation and be securely anchored to an adequately anchored foundation system to resist flotation, collapse and lateral movement (FEMA, 2009)." FEMA recommends that the best way to meet this requirement is to elevate the bottom of the steel frame to the height of the 100-year water surface elevation. An exception to this guidance is given for lots in existing manufactured home parks. In this case, homes must be properly elevated no less than 36 inches above grade unless special conditions apply (FEMA, 2009). For specific guidance, refer to FEMA documentation regarding manufactured homes, which may be found online at https://www.fema.gov/media-library-data/20130726-1502-20490-8377/fema_p85.pdf.

6.1.7 Levee Repair

The flood control levee that currently lines the left bank of the Bushnellsville Creek and Esopus Creek confluence was breached in 2011, resulting in significant damage. Since repairs were made in 2011, the levee has experienced erosion at the downstream end. Further evaluation of the levee is recommended, and armoring of the levee in the area of the erosion is likely warranted. It should be noted that the levee is not certified by FEMA, indicating that it does not meet FEMA's standards for design, operation, and maintenance. The levee does not provide protection of homes located behind the levee during the 100-year flood event.

6.1.8 Road Closures

Flooding of roadways during previous flood events has been reported at several locations including Route 28 along Esopus Creek, Fox Hollow Road as it approaches the Fox Hollow Road bridge over Esopus Creek, and the County Route 47 bridge over Bushnellsville Creek. Approximately 75 percent of all flood fatalities occur in vehicles. Shallow water flowing across a flooded roadway can be deceptively swift and wash a vehicle off the road. Water over a roadway can conceal a washed out section of roadway or bridge. When a roadway is flooded, travelers should not take the chance of attempting to cross the flooded area. It is not possible to tell if a flooded road is safe to cross just by looking at it. It is recommended that risks associated with the flooding of roadways be reduced by temporarily closing floodprone roads during flooding events. This requires effective signage, road closure barriers, and consideration of alternative routes.

6.1.9 Maintenance of Local Drainages

During the public meeting process, flooding was reported associated with undersized culverts and smaller drainageways that are not part of Esopus Creek, Bushnellsville Creek, Fox Hollow Creek, Peck Hollow Creek, or Broadstreet Hollow Creek. While these flooding sources were not evaluated as part of this LFA, they should be investigated and addressed. It is recommended that drainage ditches and catch basins be maintained and cleaned on a regular basis to reduce localized flooding.

6.1.10 Anchoring of Fuel Tanks

It is recommended that sources of man-made pollution be reduced or eliminated through the relocation or securing of fuel oil and propane tanks.

6.1.11 Water Quality Recommendations

In addition to helping communities identify and mitigate flood hazards, the LFA program mandate includes protecting water quality in the New York City water supply watershed. In order to protect water quality during flood events, MMI recommends the following:

- Relocation of the Shandaken Highway Department garage outside the FEMA regulatory floodway in order to prevent chemicals from coming in contact with floodwaters

- Effort should be made to identify additional parcels that could benefit from securing or relocating fuel tanks to eliminate a potential source of man-made pollution and apply for funding through the Catskill Watershed Corporation (http://cwconline.org/fhmi-program-flood-analysis-relocation-assistance-fuel-tank-anchoring).
- Equipment that has the potential to be washed away in a flood (e.g., generators, snowmobiles, ATVs, construction equipment, etc.) should be securely anchored, housed in a shed/garage, or stored outside the 100-year flood boundary.

6.1.12 Procedural Recommendations

- Gather and file flood-related lost revenue information as provided by businesses. This may help improve future BCA determinations.
- During and after future floods, record and compile municipal, county, and state costs related to cleanup and recovery. This may help improve future BCA determinations.
- During and after future floods, record high water marks throughout the hamlets. Track and record flood damage over time for anchor businesses and critical facilities.
- The Town of Shandaken's Flood Hazard Mitigation Plan should continue to be reviewed and updated.

6.2 Funding Sources

Several funding sources may be available to the Town of Shandaken for the implementation of recommendations made in this report.

Stream Management Implementation Program Flood Hazard Mitigation Grants (SMIP-FHM)

FHM is a funding category in the SMIP for LFA communities and those participating in the NY Community Reconstruction Program. Municipalities may apply to implement one or more recommendations contained in their LFA and approved by the municipal board. All projects must have modeled off-site flood reduction benefits. Eligible projects include the following:

- Design/construction of floodplain restoration and reconnection
- Design/construction of naturally stable stream channel dimensions and sediment transport processes
- Design/construction of public infrastructure to reduce water velocity, flow path, and/or elevation
- Correction of hydraulic constrictions

Ineligible projects include construction of floodwalls, berms, or levees; stream dredging; routine annual maintenance; or replacement of privately owned bridges, culverts, or roads. Municipalities must apply to the Stream Management Program in their respective county. Contact information is as follows:

Ulster County Soil and Water Conservation District
Ashokan Watershed Stream Management Program
P.O. Box 667, 3130 Route 28
Shokan, New York 12481
(845) 688-3047

New York City Funded Flood Buyout Program

The New York City Funded Flood Buyout Program (NYCFFBO) is a voluntary program intended to assist property owners who were not eligible for or chose not to participate in the FEMA flood buyout program. It is intended to operate between flood events, not as an immediate response to one. Categories of eligible properties include the following:

1. Properties identified in community LFAs
2. Anchor businesses, critical community facilities, and LFA-identified properties applying to the CWC for relocation assistance
3. Properties needed for a stream project
4. Erosion hazard properties
5. Inundation properties

Risk assessments and BCA are required for these purchases. Municipalities may choose to own and manage the properties after they are purchased and cleared of structures. Conservation easements must be given to NYSDEC, and there are limits to what may be placed on these parcels. Allowed structures are public restrooms served by public sewers or by septic systems whose leach field is located outside the 100-year floodplain or open-sided structures.

The NYCFFBO is governed by the Water Supply Permit and the Property Evaluation and Selection Process document (Process document). Communities work through Outreach and Assessment Leads appointed by the municipality to inform potential applicants about the program and evaluate the eligibility of properties based on the program criteria established in the Process document.

Local Flood Hazard Mitigation Implementation Program

The CWC funds LFA-recommended projects to prevent and mitigate flood damage in the West of Hudson watershed, specifically to remedy situations where an imminent and substantial danger to persons or properties exists or to improve community-scale flood resilience while providing a water quality benefit.

Municipalities and individual property owners may apply directly to the CWC. Municipalities may apply for grants for projects identified in an LFA or New York Rising planning process.

Eligible LFA-derived projects could include the following:

- Alterations to public infrastructure that are expected to reduce/minimize flood damage
- Private property protection measures such as elevation or floodproofing of a structure
- Elimination of sources of man-made pollution such as the relocation or securing of fuel oil/propane tanks
- Stream-related construction (Ineligible projects include construction of floodwalls, berms, or levees; stream dredging; or annual maintenance.)
- Relocation assistance for residence or business recommended by an LFA to a location within the same town

Property owners may apply for the following assistance:

- Funds for relocation assistance of an anchor business or critical community facility. Anchor businesses must be located in a floodplain in a watershed hamlet where an LFA has been conducted though their relocation does NOT have to be recommended in the LFA. They include gas stations, grocery stores, lumberyard/hardware stores, medical offices, or pharmacies, which if damaged or destroyed would immediately impair the health and/or safety of a community.
- Funds for relocation of critical community facilities, such as a firehouse, school, town hall, public drinking water treatment or distribution facility, or wastewater treatment plant or collection system, which if destroyed or damaged would impair the health and/or safety of a community. Facilities must have been substantially damaged by flooding. They do NOT have to be recommended by an LFA but MUST be located in an LFA community.
- Funds for assistance to relocate homes and/or businesses within the same town where the NYCFFBO covers purchase of former property (does NOT have to be in an LFA community)
- Stream debris removal after a serious flood event (does NOT have to be recommended in an LFA)

Sustainable Community Planning Program

This CWC program is for municipalities that have prepared LFAs. It is intended to fund revisions to local zoning codes or zoning maps or to upgrade comprehensive plans in order to identify areas within those municipalities that can serve as new locations for residences and/or businesses to be moved after purchase under the voluntary NYCFFBP. Grants of up to $20,000 are available through this program, part of the CWC's Local Technical Assistance Program.

Emergency Watershed Protection (EWP) Program

Through the EWP program, the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) can help communities address watershed impairments that pose imminent threats to lives and property. Most EWP work is for the protection of threatened infrastructure from continued stream erosion. NRCS may pay up to 75 percent of the construction costs of emergency measures. The remaining costs must come from local sources and can be made in cash or in-kind services. EWP projects must reduce threats to lives and property; be economically, environmentally, and socially defensible; be designed and implemented according to sound technical standards; and conserve natural resources.

FEMA Pre-Disaster Mitigation (PDM) Program

The PDM program was authorized by Part 203 of the Robert T. Stafford Disaster Assistance and Emergency Relief Act (Stafford Act), 42 U.S.C. 5133. The PDM program provides funds to states, territories, tribal governments, communities, and universities for hazard mitigation planning and implementation of mitigation projects prior to disasters, providing an opportunity to reduce the nation's disaster losses through PDM planning and the implementation of feasible, effective, and cost-efficient mitigation measures. Funding of pre-disaster plans and projects is meant to reduce overall risks to populations and facilities. The PDM program is subject to the availability of appropriation funding as well as any program-specific directive or restriction made with respect to such funds.

FEMA Hazard Mitigation Grant Program (HMGP)

The HMGP is authorized under Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act. The HMGP provides grants to states and local governments to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the HMGP is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster. A key purpose of the HMGP is to ensure that any opportunities to take critical mitigation measures to protect life and property from future disasters are not "lost" during the recovery and reconstruction process following a disaster.

The HMGP is one of the FEMA programs with the greatest potential fit to potential projects in this LFA. However, it is available only in the months subsequent to a federal disaster declaration in the State of New York. Because the state administers the HMGP directly, application cycles will need to be closely monitored after disasters are declared in New York.

FEMA Flood Mitigation Assistance (FMA) Program

The FMA program was created as part of the National Flood Insurance Reform Act (NFIRA) of 1994 (42 U.S.C. 4101) with the goal of reducing or eliminating claims under the NFIP. FEMA provides FMA funds to assist states and communities with implementing measures that reduce or eliminate the long-term risk of flood damage to buildings, homes, and other structures insurable under the NFIP. The long-term goal of FMA is to reduce or eliminate claims under the NFIP through mitigation activities.

The Biggert-Waters Flood Insurance Reform Act of 2012 eliminated the Repetitive Flood Claims (RFC) and Severe Repetitive Loss (SRL) programs and made the following significant changes to the FMA program:

- The definitions of repetitive loss and severe repetitive loss properties have been modified.
- Cost-share requirements have changed to allow more federal funds for properties with RFC and SRL properties.

- There is no longer a limit on in-kind contributions for the nonfederal cost share.

One limitation of the FMA program is that it is used to provide mitigation for *structures* that are insured or located in SFHAs. Therefore, the individual property mitigation options described in this LFA are best suited for FMA funds. Like PDM, FMA programs are subject to the availability of appropriation funding as well as any program-specific directive or restriction made with respect to such funds.

NYS Department of State

The Department of State may be able to fund some of the projects described in this report. In order to be eligible, a project should link water quality improvement to economic benefits.

U.S. Army Corps of Engineers (USACE)

The USACE provides 100 percent funding for floodplain management planning and technical assistance to states and local governments under several flood control acts and the Floodplain Management Services Program (FPMS). Specific programs used by the USACE for mitigation are listed below.

- Section 205 – Small Flood Damage Reduction Projects: This section of the 1948 Flood Control Act authorizes the USACE to study, design, and construct small flood control projects in partnership with nonfederal government agencies. Feasibility studies are 100 percent federally funded up to $100,000, with additional costs shared equally. Costs for preparation of plans and construction are funded 65 percent with a 35 percent nonfederal match. In certain cases, the nonfederal share for construction could be as high as 50 percent. The maximum federal expenditure for any project is $7 million.

- Section 14 – Emergency Streambank and Shoreline Protection: This section of the 1946 Flood Control Act authorizes the USACE to construct emergency shoreline and stream bank protection works to protect public facilities such as bridges, roads, public buildings, sewage treatment plants, water wells, and nonprofit public facilities such as churches, hospitals, and schools. Cost sharing is similar to Section 205 projects above. The maximum federal expenditure for any project is $1.5 million.

- Section 208 – Clearing and Snagging Projects: This section of the 1954 Flood Control Act authorizes the USACE to perform channel clearing and excavation with limited embankment construction to reduce nuisance flood damages caused by debris and minor shoaling of rivers. Cost sharing is similar to Section 205 projects above. The maximum federal expenditure for any project is $500,000.

- Section 206 – Floodplain Management Services: This section of the 1960 Flood Control Act, as amended, authorizes the USACE to provide a full range of technical services and planning guidance necessary to support effective floodplain management. General technical assistance efforts include determining the following: site-specific data on obstructions to flood flows, flood formation, and timing; flood depths, stages, or floodwater velocities; the extent, duration, and frequency of flooding; information on natural and cultural floodplain resources; and flood loss potentials before and after the use of floodplain management measures. Types of studies conducted under FPMS include floodplain delineation, dam failure, hurricane evacuation, flood warning, floodway, flood damage reduction, stormwater management, floodproofing, and inventories of floodprone structures. When funding is available, this work is 100 percent federally funded.

In addition, the USACE provides emergency flood assistance (under Public Law 84-99) after local and state funding has been used. This assistance can be used for both flood response and postflood response. USACE assistance is limited to the preservation of life and improved property; direct assistance to individual homeowners or businesses is not permitted. In addition, the USACE can loan or issue supplies and equipment once local sources are exhausted during emergencies.

Other Potential Sources of Funding

New York State Grants – All New York State grants are now announced on the NYS Grants Gateway (a direct link is in the "Links Leaving DEC's Website" section of the right-hand column of this page). The Grants Gateway is designed to allow grant applicants to browse all NYS agency anticipated and available grant opportunities, providing a one-stop location that streamlines the way grants are administered by the State of New York.

Community Development Block Grant (CDBG) – The Office of Community Renewal administers the CDBG program for the State of New York. The NYS CDBG program provides financial assistance to eligible cities, towns, and villages in order to develop viable communities by providing affordable housing and suitable living environments as well as expanding economic opportunities, principally for persons of low and moderate income. It is possible that the CDBG funding program could be applicable for floodproofing and elevating residential and nonresidential buildings, depending on eligibility of those buildings relative to the program requirements.

Empire State Development – The state's Empire State Development program offers loans, grants, and tax credits as well as other financing and technical assistance to support businesses and encourage their growth. It is possible that the program could be applicable for floodproofing, elevating, or relocating nonresidential buildings, depending on eligibility of those businesses relative to the program requirements.

Private Foundations – Private entities such as foundations are potential funding sources in many communities. The Town of Shandaken and SAFARI will need to identify the foundations that are potentially appropriate for some of the actions proposed in this report.

In addition to the funding sources listed above, other resources are available for technical assistance, planning, and information. While the following sources do not provide direct funding, they offer other services that may be useful for proposed flood mitigation projects.

Land Trust and Conservation Groups – These groups play an important role in the protection of watersheds including forests, open space, and water resources.

As the recommendations of this LFA are implemented, the Town of Shandaken will need to work closely with potential funders to ensure that the best combinations of funds are secured for the modeled alternatives and for the property-specific mitigation such as floodproofing, elevations, and relocations. It will be advantageous for the town to identify combinations of funding sources in order to reduce its own requirement to provide matching funds.

REFERENCES

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4615-18-06-f218-rpt.docx

APPENDIX A

MEMORANDA

Memorandum

TO: **Robert Stanley, Supervisor, Town of Shandaken**

FROM: **Vernon Bevan, EIT, MASc, Water Resources Engineer, Milone & MacBroom, Inc.**

DATE: **March 2, 2017**

RE: **Possible Hydrology Discrepancy in FEMA Esopus Creek HEC-RAS Model**
MMI #4615-18-03

While reviewing the Esopus Creek Federal Emergency Management Agency (FEMA) Hydrologic Engineering Center – *River Analysis System* (HEC-RAS) model for the Shandaken-Allaben Local Flood Analysis, Milone & MacBroom, Inc. (MMI) noted possible discrepancies between the "Steady Flow" file and the FEMA hydrology documented in Table 4 of the Flood Insurance Study (FIS), dated November 18, 2016, and Table 17 of the Ashokan Reservoir Watershed Hydrologic Study (ARWHS), dated August 2012. The ARWHS was taken to be the foundation document as the hydrology of both the 2016 FIS and the HEC-RAS model seems to be based on this report.

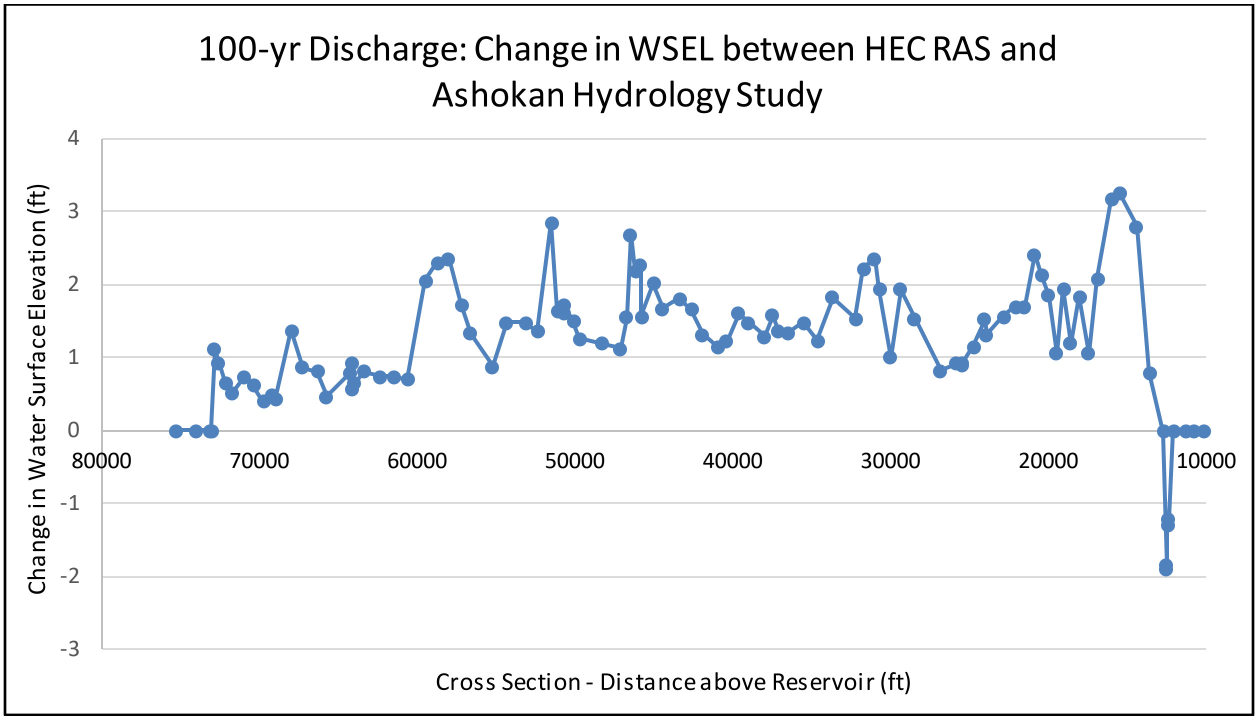
The discrepancy initially appears in the length of the Esopus Creek between the Fox Hollow and Broadstreet Hollow tributaries. According to the ARWHS, there should be a change point just upstream of the Peck Hollow tributary as well as one just upstream of the Broadstreet Hollow tributary. However, a change point in the HEC-RAS model does not occur until just downstream of the Broadstreet Hollow tributary. As a result, the flows that should occur at a location just above the Peck Hollow tributary occur in the model just downstream of the Broadstreet Hollow tributary.

The discrepancies are documented in the attached spreadsheet. The tab titled "Flows" compares the discharges in the HEC-RAS "Steady Flow" file with the discharges in Table 17 of the ARWHS. The hydrology appears to be consistent from Cross Section 123341 to Cross Section 74088. In the ARWHS, the next change point occurs at Cross Section 72617 where the flow rate of the 10-year discharge is 12,600 cubic feet per second. However, the change point in the HEC-RAS model does not occur until Cross Section 66349. This shift in hydrology is propagated to the downstream end of the HEC-RAS model.

This difference in flow has an effect on water surface elevations (Figure 1). The change in water surface elevations for the 100-year discharge is depicted graphically in the tab titled 100-yr. As the graph and accompanying table illustrate, water surface levels in the model are routinely 1 to 2 feet lower than if the hydrology in the ARWHS had been used. Given the situation described above, it is possible that the Flood Insurance Rate Maps underrepresent the 100-year floodplain.

Figure 1

Change in Water Surface Elevation at 100-Year Discharge between Hydrology in HEC-RAS Model and Ashokan Reservoir Watershed Hydrologic Study



We request that you bring this apparent discrepancy in hydrology to FEMA's attention. Our local flood analysis hydraulic modeling of baseline conditions and mitigation alternatives is based on what we believe to be the correct hydrology. We would like to resolve this issue as quickly as possible and look forward to hearing from you regarding the next steps.

Attachment

4615-18-03-mr117-memo

STARR II Strategic Alliance for Risk Reduction

MEMORANDUM

To: **Andrew Martin, FEMA Region II**

From: Curtis Smith

cc: **Alan Springett, Bob Schaefer, Shu Rahman, Olga Gorbunova, Jean Huang, John Hoffman, Prabha Madduri**

Date: 04/26/2017

Subject: Effective hydraulic analysis review for Esopus Creek, Ulster County, NY

Geography impacted by this document: Township of Shandaken, NY

On March 7, 2017, FEMA Region II received a letter submitted by Mr. Robert A. Stanley on behalf of the Township of Shandaken, NY. In this letter, Mr. Stanley expressed concerns regarding the base flood elevations published in the Effective Flood Insurance Rate Maps (FIRMs) for Shandaken; these FIRMs and the companion Flood Insurance Study (FIS) were adopted in November 2016. Specifically, Mr. Stanley challenged the effective hydraulic analysis for Esopus Creek based on findings that the flow change locations utilized in the analysis did not match the location and description listed in either the FIS or the Ashokan Reservoir Watershed Hydrology Report ("Hydrology Report").

Mr. Stanley's letter included supplemental data that consisted of a technical investigation into the matter conducted by the engineering firm Milone & MacBroom, Inc. (MMI). MMI's investigation examined the Hydrology Report against the hydraulic analysis and noted discrepancies in the steady flow file of the analysis. Their findings concluded that such a discrepancy in flow locations could have impacted the base flood elevations by approximately 1 to 2 feet along Esopus Creek.

At the request of FEMA Region II, STARR II reviewed the technical aspects of the proposed discrepancies. Based on this review, *STARR II determined that the hydrologic and hydraulic analyses conducted by RAMPP for Esopus Creek for the effective FIRMs and FIS (dated November 2016) are correct, and do not warrant changes to the modeling or mapping.*

However, although STARR II determined that there was no technical issue with the proposed discrepancies as suggested by Mr. Stanley and MMI, it is worth noting that the hydraulic analysis report and Summary of Discharge (SOD) table found in the FIS do not include adequate information on methodology used, and it was likely this lack of sufficient information that led the original inquiry. To resolve this matter and avoid future such misunderstandings, STARR II makes the following recommendations:

1) That the Region initiate a NTU to add an additional flow change location to the SOD Table (Table 4) of the FIS, and,
2) That the study team add a note to the hydraulic analysis report to clarify the methodology used to apply flow values for an approximately 11 mile reach of Esopus Creek.

In the interim, STARR II proposes that the RSC assist the Region by providing the technical findings contained in this memo to MMI in order to address Mr. Stanley's original inquiry. A summary of these technical findings are described below:

1. The November 2016 effective SOD Table does not include a record for the discharges computed in HEC-HMS for Esopus Creek above the confluence with Fox Hollow. This discharge value is included in the Hydrology Report and is required to accurately model the Esopus Creek floodplain. Please see **Table 1** below which includes the flow change information as extracted from Table 17 of the Hydrology Report.

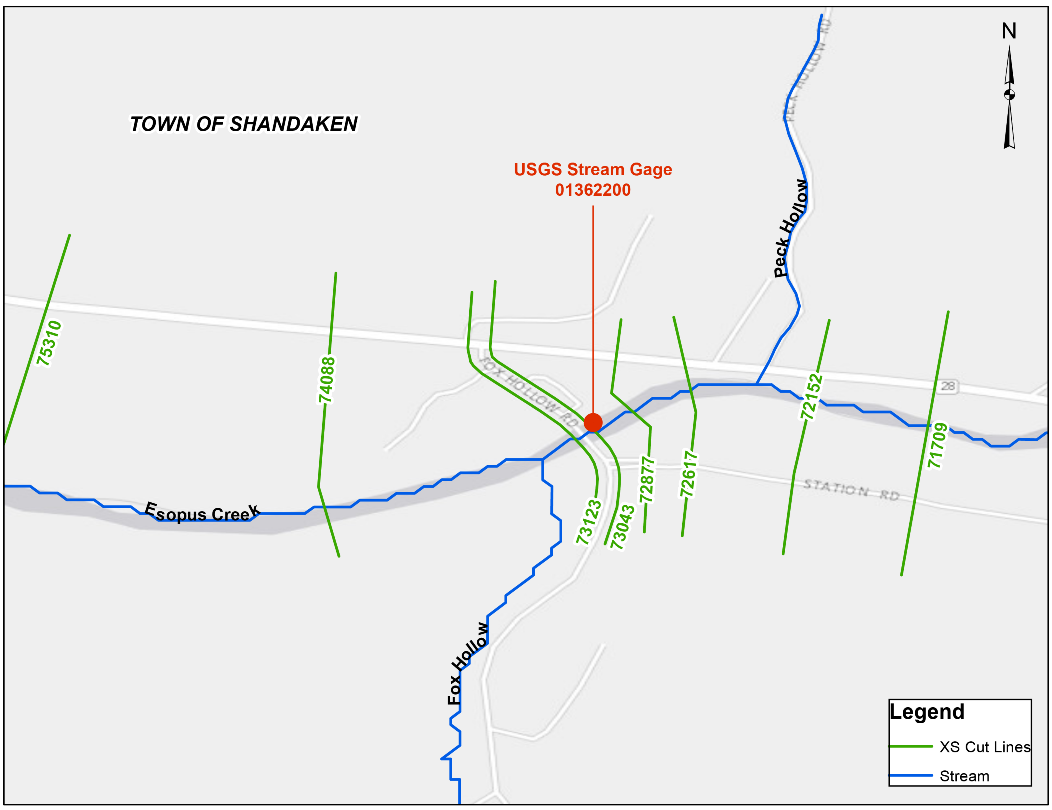
Table 1: Summary of discharges for Esopus Creek reported in Table 17 of the Hydrology Report.

Location	Drainage Area (sq. mi.)	Q10	Q25	Q50	Q100	Q500
Esopus Creek above Elk Bush Kill	11.8	2711	4065	5390	6943	12199
Esopus Creek above McKinley Hollow	16.1	3539	5322	7051	9104	16133
Esopus Creek above Hatchery Hollow	20.7	4393	6696	8919	11611	20869
Esopus Creek above Lost Clove	26.7	5439	8431	11397	15007	27333
Esopus Creek above Birch Creek	30.0	5886	9094	12406	16312	30206
Esopus Creek above Bushnellsville	47.6	8716	13546	18444	24287	45372
Esopus Creek above Fox Hollow	59.5	10769	16756	22972	30211	56709
Esopus Creek above Peck Hollow	63.7	11390	17664	24274	31925	60210
Esopus Creek above Broad Street	70.0	12600	19550	26827	35214	66342
Esopus Creek above Woodland Creek	84.0	15173	23382	31970	42159	79494
Esopus Creek above Stony Clove Creek	105.3	18209	27904	38121	51036	97916

2. Beyond the exclusion of the Fox Hollow flow location in the SOD Table, elements of engineering judgement used to calibrate and select the final flow change locations in the hydraulic model (HEC-RAS) likely led to the misunderstanding and prompted

Mr. Stanley's inquiry and technical memo from MMI. To clarify the application of flow values in the HEC-RAS model, the following information will be added to the hydraulic analysis report:

<u>Update to the Hydraulic Analysis Report</u>
During model production, it was noted that the observed data as published by the USGS did not correlate well to the hydraulic model (HEC-RAS) if the model were to use the direct HEC-HMS output. For example, using the direct HEC-HMS output in the vicinity of Fox Hollow and Peck Hollow, tributaries of Esopus Creek, would have resulted in an overestimation of water surface elevations at USGS stream gage 01362200 (location shown in ***Figure 1****).*



<u>Figure 1</u>. Esopus Creek HEC-RAS model in the vicinity of USGS stream gage 01362200.

In order to be consistent with the observed flood levels, a calibration method was employed for approximately 11 miles of stream reach above the Ashokan Reservoir. This calibration method was based on applying flow values to ***downstream*** *cross sections in HEC-RAS, rather than following the standard practice of applying flow* *values upstream. Applying flow values in the downstream instead of upstream direction effectively shifted the computed flow values to the next downstream flow change location. Doing so resolved the disconnect between the published USGS data and the modeling, and resulted in the final selected flow change locations used in HEC-RAS to be different than the output information generated in HEC-HMS.* ***Figure 2*** *below shows how post-calibration, the HEC-HMS flow values compare reasonably well with the resulting water surface elevations from HEC-RAS in the final location selection.*

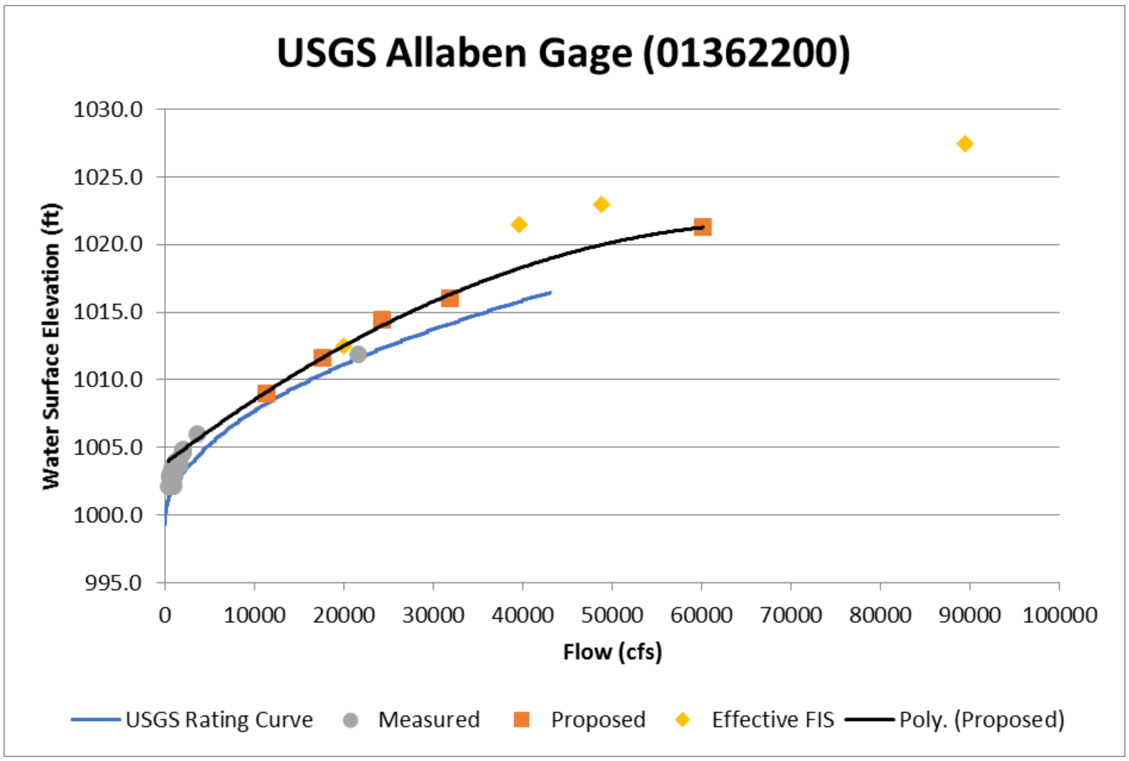


Figure 2. Esopus Creek Proposed HEC-RAS model elevations compared with USGS Rating Curve (Figure 10 of Esopus hydraulic analysis report).

APPENDIX B

SURVEYED FIRST FLOOR ELEVATIONS

First Floor Elevations used in BCA (Surveyed and Measured from DEM)

	Address	First Floor Elevation (ft)		Survey Notes
		Digital Elevation Map	Surveyed	
Bushnellsville Creek	111 State Route 42	1,103.88	-	
	123 State Route 42	1,114.74	-	
	13 Rosa Road	1,150.77	-	
	130 State Route 42	1,109.43	-	
	143 State Route 42	1,125.57	-	
	157 State Route 42	1,131.40	-	
	163 State Route 42	1,134.56	-	
	169 State Route 42	1,140.35	-	
	178-188a State Route 42	1,151.10	-	
	47 State Route 42	-	1,062.40	FIRST FLOOR FRONT DOOR
	48-72 State Route 42	1,086.10	-	
	7 Rosa Road	1,148.50	-	
Broadstreet Hollow	14 Wettje Road	-	972.61	FIRST FLOOR FRONT DOOR
	7096 State Route 28	979.01	-	
	7100 State Route 28	978.01	-	
	7101 State Route 28	-	969.98	FIRST FLOOR RIGHT SIDE DOOR FROM ROAD
	7106a State Route 28	-	979.65	FIRST FLOOR FRONT DOOR
	7106b State Route 28	977.33	-	
	14 Fox Hollow Road	1,014.42	-	
	15 Dutcher Road	-	977.96	FIRST FLOOR FRONT DOOR
	17-21 State Route 42 (WH)	-	1,050.07	GARAGE FLOOR GARAGE FLOOR
	17-21 State Route 42 (Office)	-	1,049.19	GARAGE FLOOR GARAGE FLOOR
	17-21 State Route 42 (19)	-	1,052.93	FIRST FLOOR FRONT RIGHT DOOR
	17-21 State Route 42 (21)	1,053.86	-	
	18 Fox Hollow Rd	1,015.73	-	
	18-20 Wettje Road (18)	-	960.24	FIRST FLOOR FRONT DOOR
	18-20 Wettje Road (20)	957.19	-	
	207 Creek Side Dr	1,103.23	-	
	215 Creek Side Dr	1,103.65	-	

Esopus Creek	22 Wettje Road	-	954.37	GARAGE FLOOR FRONT GARAGE DOOR
	22-24 State Route 42 (House)	1,053.72	-	
	22-24 State Route 42 (PO)	-	1,053.72	FIRST FLOOR POST OFFICE RIGHT FRONT DOOR
	23 State Route 42	-	1,054.42	FIRST FLOOR FRONT DOOR
	230 Creek Side Dr	1,107.21	-	
	24 Wettje Road	953.80	-	
	25 State Route 42	-	1,055.56	FIRST FLOOR FRONT DOOR
	28 Wettje Road	-	955.16	FIRST FLOOR FRONT DOOR
	31 State Route 42	-	1,057.16	FIRST FLOOR FRONT DOOR
	33 State Route 42	-	1,055.09	FIRST FLOOR FRONT DOOR
	38 State Route 42	-	1,058.79	FIRST FLOOR FRONT DOOR
	39 State Route 42	-	1,058.30	FIRST FLOOR FRONT DOOR
	4-15 Warfield Road (a)	1,018.80	-	
	4-15 Warfield Road (b)	1,019.38	-	
	47 State Route 42	-	1,062.40	FIRST FLOOR FRONT DOOR
	49 Creek Side Dr	-	1,069.15	FIRST FLOOR FRONT DOOR
	5 Ruthenbeck Road	1,054.46	-	
	7 Dutcher Road	977.96	-	
	7 State Route 42	-	1,061.52	FIRST FLOOR FRONT DOOR
	7039 State Route 28	-	960.75	FIRST FLOOR FRONT OFFICE DOOR
	7057-7059 (7057) State Route 28	952.08	-	
	7121 State Route 28	-	972.69	FIRST FLOOR FRONT DOOR
	7123 State Route 28	-	969.15	FIRST FLOOR FRONT DOOR
	7131 State Route 28	-	969.36	FIRST FLOOR FRONT DOOR
	7179 State Route 28	-	980.24	FIRST FLOOR BACK DOOR
	7185 State Route 28	-	982.95	FIRST FLOOR BACK DOOR
	7193 State Route 28	-	983.47	FIRST FLOOR BACK DOOR
	7306 State Route 28	1,014.82	-	
	7311 State Route 28	1,013.95	-	
	7339 State Route 28	1,032.00	-	
	7373 State Route 28	1,047.16	-	
	7381 State Route 28	1,048.17	-	
	7386 State Route 28	1,052.28	-	
	7389 State Route 28		1,043.04	FIRST FLOOR BACK BASEMENT DOOR
	7391 State Route 28		1,045.37	FIRST FLOOR FRONT DOOR

APPENDIX C

BCA RESULTS

	Highway Garage	Town Hall	Dog Pound
Tax ID / SBL	5.18-2-32	5.18-2-34	5.18-2-34
First Floor Elevation (ft)	985.14	986.74	987.39
Full Market Value ($)	607,843	823,530	
Land Market Value ($)	37,255	31,373	
Building Value ($)*	570,588	638,409	153,748
Bulding Square Footage (ft^2)	10,314	2,508	604
Building Replacement Value (BRV) [ft^2/$]	55.32	254.5	254.5
Acquisition Benefits ($)	209,172	168,050	32,074

*Value based on percent square footage of structures on parcel.