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RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE

CHITTENANGO CREEK, ONONDAGA & MADISON COUNTIES, NEW YORK

Prepared for:

Project Team

RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE

CHITTENANGO CREEK, ONONDAGA & MADISON COUNTIES, NEW YORK

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IN NOVEMBER 2018, NEW YORK STATE GOVERNOR ANDREW CUOMO COMMITTED FUNDING TO UNDERTAKE ADVANCED MODELING TECHNIQUES AND FIELD ASSESSMENTS OF 48 FLOOD-PRONE STREAMS TO IDENTIFY PRIORITY PROJECTS AND ACTIONS TO REDUCE COMMUNITY FLOOD AND ICE JAM RISKS, WHILE IMPROVING HABITAT. THE OVERALL GOAL OF THE PROGRAM IS TO MAKE NEW YORK STATE MORE RESILIENT TO FUTURE FLOODING.

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ACRONYMS/ABBREVIATIONS

1-, 2-D	1- and 2-Dimensional
ACE	Annual Chance Flood Event
BCA	Benefit Cost Analysis
BCC	Bird of Conservation Concern
BCR	Benefit Cost Ratio
BCR	Bird Conservation Region
BFE	Base Flood Elevation
BRIC	Building Resilient Infrastructure and Communities
CAP	Continuing Authorities Program
CDBG	Community Development Block Grants
CFA	Consolidated Funding Applications
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second (ft3/s)
CON	Continental USA and Alaska

CRISSP	Comprehensive River Ice Simulation System
CRRA	Community Risk and Resiliency Act
CRREL	Cold Regions Research and Engineering Laboratory
CSC	Climate Smart Communities
DEM	Digital Elevation Model
DHS	Department of Homeland Security
DRRA	Disaster Recovery Reform Act of 2018
EWP	Emergency Watershed Protection Program
FCA	Flood Control Act
FCSA	Feasibility Cost Sharing Agreement
FDD	Freezing Degree-Day
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Maps
FIS	Flood Insurance Study
FMA	Flood Mitigation Assistance
GIS	Geographic Information System
GLS	Generalized Least-Squares
GSE	Gomez & Sullivan Engineers
H&H	Hydrologic and Hydraulic
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center River Analysis System
HMA	Hazard Mitigation Assistance
HMGP	Hazard Mitigation Grant Program
HSGP	Homeland Security Grant Program
HUD	United States Department of Housing and Urban Development
I-90	New York State Thruway/Interstate-90
IPaC	Information for Planning and Consultation
IPCC	Intergovernmental Panel on Climate Change
LiDAR	Light Detection and Ranging
LOMR	Letter of Map Revision
LP3	Log-Pearson Type III
MCEM	Madison County Emergency Management
MCSWC	Madison County Soil and Water Conservation District
MSC	Map Service Center
MHWL	Mean High Water Line
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NCEI	National Centers for Environmental Information
NFIP	National Flood Insurance Program
NGVD29	National Geodetic Vertical Datum of 1929
NHD	National Hydrography Dataset
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Services
NWI	National Wetlands Inventory
NYS	New York State
NYSDEC	New York State Department of Environmental Conservations

NYSDHSES	New York State Division of Homeland Security and Emergency Services
NYSDOT	New York State Department of Transportation
NYSOEM	New York State Office of Emergency Management
NYSOGS	New York State Office of General Services
NYSOPRHP	New York State Office of Parks, Recreation, and Historic Places
PDM	Pre-Disaster Mitigation
PPA	Project Partnership agreement
RAMBOLL	Ramboll Americas Engineering Solutions, Inc.
RC	Circularity Ratio
RCP	Representative Concentration Pathway
RE	Elongation Ratio
REHAB	Watershed Rehabilitation Program
RF	Form Factor
RICEN	River Ice Simulation Model
RL	Repetitive Loss
ROM	Rough Order of Magnitude
SCS	Soil Conservation Service
SFHA	Special Flood Hazard Areas
SRL	Severe Repetitive Loss
STORM	Safeguarding Tomorrow through Ongoing Risk Mitigation Act
TOGS	Technical & Operations Guidance Series
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	United States Geologic Service
UTM	Universal Transverse Mercator
VERTCON	Vertical Datum Coordinate Conversion Program
WFPO	Watershed Protection and Flood Prevention Operations Program
WQIP	Water Quality Improvement Project
WRI	Water Resources Investigation
WSEL	Water Surface Elevation
WSP	Water Supply Paper

1. INTRODUCTION

1.1 HISTORICAL INITIATIVES

Flood mitigation has historically been an initiative in central New York and in the Chittenango Creek watershed.

None of the municipalities along Chittenango Creek in Madison County, New York have existing or planned flood protection structures (FEMA 1984a; FEMA 1984b; FEMA 1984c; FEMA 1986b; FEMA 1986c). In the Village of Cazenovia, there is a levee between Chittenango Creek and Carpenter's Pond, however this levee is not recognized by the Federal Emergency Management Agency (FEMA) or the United States Army Corps of Engineers (USACE). The Towns of Sullivan (Madison County), Cicero (Onondaga County), and Manlius (Onondaga County) have participated in a cooperative agreement with Madison County Soil and Water Conservation District (MCSWC) for the removal of log jams from Chittenango Creek between the New York State Thruway and Town of Bridgeport. The Towns of Sullivan and Manlius still currently participate in the log jam removal program along Chittenango Creek (MCEM 2016).

The municipalities along Chittenango Creek in Onondaga County, New York have implemented non-structural measures of flood protection. Historically, the Towns of Cicero and Manlius, in cooperation with the Town of Sullivan in Madison County, participated in a log jam clearing program on Chittenango Creek (Tetra Tech, Inc. 2019). This program has been continued by the Towns of Manlius and Sullivan. The Town of Cicero has employed land use regulations that control construction within high-risk flood areas to aid in the prevention of future flood damage (FEMA 1994). The Town of Manlius has employed some channel dredging, bank stabilization, and other temporary improvements to various streams throughout the Town (FEMA 1992).

1.2 FLOODPLAIN DEVELOPMENT

General recommendations for high-risk floodplain development follow four basic strategies:

1. Remove the flood-prone facilities from the floodplain
2. Adapt the facilities to be flood resilient under repetitive inundation scenarios
3. Develop nature-based mitigation measures (e.g., floodplain benches, constructed wetlands, etc.) to lower flood stages in effected areas
4. Up-size bridges and culverts to be more resilient to ice jams, high-flow events, and projected future flood flows due to climate change in effected areas

In order to effectively mitigate flooding along substantial lengths of a watercourse corridor, floodplain management should restrict the encroachment on natural floodplain areas. Floodplains act to convey floodwaters downstream, mitigate damaging velocities, and provide areas for sediment to accumulate safely. The reduction in floodplain width of one reach of a stream, often leads to the increase in flooding upstream or downstream. During a flood event, a finite amount of water with an unchanging volume must be conveyed and, as certain conveyance areas are encroached upon, floodwaters will often expand into other sensitive areas.

A critical evaluation of existing floodplain law and policies should be undertaken to evaluate the effectiveness of current practices and requirements within this watershed. Local floodplain regulations should be consistent with the National Flood Insurance Program (NFIP) and FEMA regulations since all the municipalities along Chittenango Creek in Onondaga and Madison Counties are participating communities in the NFIP, and should involve a floodplain coordinator and a site plan review process for all proposed developments. This review should be in accordance with local regulations and the NFIP requirements, which require the community to determine if any future proposed development could adversely impact the floodplain or floodway resulting in higher flood stages and sequentially greater economic losses to the community. The communities and their NFIP community IDs along Chittenango Creek are as follows:

- Town of Cicero (Onondaga County) Community ID #360572
- Town of Manlius (Onondaga County) Community ID #360584
- Town of Sullivan (Madison County Community ID #360409
- Town of Cazenovia (Madison County) Community ID #361290
- Town of Fenner (Madison County) Community ID #360399
- Town of Nelson (Madison County) Community ID #361293
- Village of Chittenango (Madison County) Community ID #360395
- Village of Cazenovia (Madison County) Community ID #360394

1.3 RESILIENT NY INITIATIVE

In November of 2018, New York State Governor Andrew Cuomo announced the Resilient NY program in response to devastating flooding in communities across the state in the preceding years. A total of 48 high-priority flood prone watersheds across New York state are being addressed through the Resilient NY program. Flood mitigation studies were commissioned using advanced modeling techniques and field assessments to identify priority projects in these 48 flood-prone watersheds, develop state-of-the-art studies to reduce flooding and ice jams, and to improve ecological habitats in the watersheds (NYSGPO 2018). The Chittenango Creek watershed was chosen as a study site for this initiative.

The New York State Department of Environmental Conservation (NYSDEC) is responsible for implementing the Resilient NY program with contractual assistance from the New York State Office of General Services (NYSOGS). High-priority watersheds were selected based on several factors, such as frequency and severity of flooding and ice jams, extent of previous flood damage, and susceptibility to future flooding and ice-jam formations (NYSGPO 2018).

The Resilient NY flood studies will identify the causes of flooding within each watershed and develop, evaluate, and recommend effective and ecologically sustainable flood and ice-jam hazard mitigation projects. Proposed flood mitigation measures will be identified and evaluated using hydrologic and hydraulic modeling to quantitatively determine flood mitigation recommendations that would result in the greatest flood reduction benefits. In addition, the flood mitigation studies incorporate the latest climate change forecasts and assess ice-jam hazards where jams have been identified as a threat to public health and safety.

This report is not intended to address detailed design considerations for individual flood mitigation alternatives. The mitigation alternatives discussed are conceptual projects that have been initially developed and evaluated to determine their flood mitigation benefits. A more in-depth engineering design study would still be required for any mitigation alternative chosen to further define the engineering project details. However, the information contained within this study can inform such in-depth engineering design studies and be used in the application of state and federal funding and/or grant programs.

The goals of the Resilient NY Program are to:

1. Perform comprehensive flood and ice-jam studies to identify known and potential flood risks in flood prone watersheds
2. Incorporate climate change predictions into future flood models
3. Develop and evaluate flood hazard mitigation alternatives for each flood prone stream area, with a focus on ice-jam hazards

The overarching purpose of the initiative is to recommend a suite of flood and ice-jam mitigation projects that local municipalities can undertake to make their community more resilient to future floods. The projects should be affordable, attainable through grant funding programs, able to be implemented either individually or in combination in phases over the course of several years, achieve measurable improvement at the completion of each phase, and fit with the community way of life.

The flood mitigation and resiliency study for Chittenango Creek began in September of 2021 and a final flood study report was issued June of 2022.

2. DATA COLLECTION

2.1 INITIAL DATA COLLECTION

Hydrological and meteorological data were obtained from readily available state and federal government databases, including ortho-imagery, flood zone maps, streamflow, precipitation, flooding, and ice-jam reports. Historical flood reports, newspaper articles, social media posts, community engagement meeting notes, and geographic information system (GIS) mapping were used to identify stakeholder concerns, produce watershed maps, and identify current high-risk areas. New York State Community Risk and Resiliency Act (NYSDEC 2020b) guidelines, New York State Department of Transportation (NYSDOT) bridge and culvert standards, and United States Geologic Service (USGS) *Future Flow Explorer* v1.5 (USGS 2016) and *StreamStats* v4.3.11 (USGS 2020) software were used to develop current and future potential discharges and bankfull widths and depths at various points along the stream channel.

Hydrologic and hydraulic (H&H) modeling was performed previously, as part of the effective FEMA Flood Insurance Studies (FIS) for each municipality along Chittenango Creek, which includes:

- Town of Cicero (Onondaga County) September 15, 1994
- Town of Manlius (Onondaga County) September 17, 1992
- Town of Sullivan (Madison County) May 15, 1986
- Town of Cazenovia (Madison County) December 19, 1984
- Town of Fenner (Madison County) February 5, 1986
- Village of Chittenango (Madison County) August 1, 1984
- Village of Cazenovia (Madison County) December 19, 1984

FEMA released an updated effective FIS for Onondaga County, which included the Towns of Cicero and Manlius, on November 4, 2016.

Updated H&H modeling was performed in this study using the USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) v6.1.0 (USACE 2021) software to determine water stage at current and potential future levels for high-risk areas, and to evaluate the effectiveness of proposed flood mitigation strategies. These studies and data were obtained and used, all or in part, as part of this effort. Appendix A is a summary listing of data and reports collected.

2.2 PUBLIC OUTREACH

An initial virtual project kickoff meeting was held on October 14, 2021, with representatives of the NYSDEC, NYSOGS, Ramboll Americas Engineering Solutions, Inc. (Ramboll), Gomez & Sullivan Engineers (GSE), Highland Planning, USACE, Town of Manlius, Town of Fenner, Town of Cicero, Syracuse-Onondaga County Planning Agency, and Onondaga County (Appendix B). At the project kickoff meeting, project specifics including background, purpose, funding, roles, and timelines were discussed.

Discussions included a variety of topics, including:

- Firsthand accounts of past flooding events
- Identification of specific areas that flooded in each community, and the extent and severity of flood damage
- Information on post-flood efforts, such as temporary floodwalls

This outreach effort assisted in the identification of current high-risk areas to focus on during the future flood risk assessments.

2.3 FIELD ASSESSMENT

Following the initial data gathering and agency meetings, field staff from Ramboll undertook field data collection efforts with special attention given to high-risk areas in the Towns of Manlius, Cicero, Sullivan, Fenner, and Cazenovia, and Villages of Chittenango and Cazenovia as identified in the initial data collection process. Initial field assessments of Chittenango Creek were conducted in November and December of 2021. Information collected during field investigations included the following:

- Rapid "windshield" river corridor inspection
- Photo documentation of inspected areas
- Measurement and rapid hydraulic assessment of bridges, culverts, and dams
- Geomorphic classification and assessment, including measurement of bankfull channel widths and depths at key cross sections
- Field identification of potential flood storage areas
- Wolman pebble counts
- Characterization of key stream bank failures, head cuts, bed erosion, aggradation areas, and other unstable stream channel features
- Preliminary identification of potential flood hazard mitigation alternatives, including those requiring further analysis

Included in Appendix C is a copy of the Stream Channel Classification Form, Field Observation Form for the inspection of bridges and culverts, and Wolman Pebble Count Form, as well as a location map of where field work was completed. Appendix D is a Photo Log of select locations within the river corridor. The collected field data was categorized, summarized, indexed, and geographically located within a GIS database. This GIS database will be made available to the NYSDEC and NYSOGS upon completion of the project.

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

3. WATERSHED CHARACTERISTICS

3.1 STUDY AREA

The Chittenango Creek watershed lies within both Onondaga and Madison Counties in central New York. The watershed encompasses areas between: the Towns of Cicero and Manlius in Onondaga County; and the Towns of Sullivan, Cazenovia, Nelson, and Fenner, and Villages of Cazenovia and Chittenango in Madison County. The creek flows in a general north-northwest direction with its headwaters in the Town of Fenner, and empties into Oneida Lake at the border of Madison and Onondaga Counties (Figure 3-1).

Within the Chittenango Creek watershed, the areas between the confluence with Oneida Lake and the Village of Cazenovia were chosen as target areas due to their historical and recent flooding issues, and the hydrologic conditions of the creek in these respective reaches. Figures 3-2 and 3-3 depict the stream stationing along Chittenango Creek in Onondaga and Madison Counties, New York, and in the study area of the Towns of Cicero (Onondaga), Manlius (Onondaga), Sullivan (Madison), Fenner (Madison), and Cazenovia (Madison), respectively.

The Town of Sullivan is situated on the southern shoreline of Oneida Lake and is located in northwest Madison County in central New York, approximately 30 miles west of the City of Utica. It is bordered by the Towns of Lenox and Lincoln to the east, the Towns of Fenner and Cazenovia to the south, and the Towns of Manlius and Cicero to the west. Development within Sullivan has been limited. The two main centers are Chittenango Village and Lake Port, which is adjacent to Oneida Lake. The remainder of the town is primarily agricultural, vacant, or wooded. There are large expanses of irrigated fields to the north; the south has large areas of undeveloped land (FEMA 1986c).

The Village of Chittenango is located in northwest Madison County in central New York. The community lies entirely within the Town of Sullivan, and is situated approximately eight miles south of Oneida Lake and ten miles east of the City of Syracuse. Chittenango has a total land area of 1.8 square miles. Approximately 70% of the land area in the community has been developed. The remainder of the land is undeveloped or used for agricultural purposes. Development within the flood plains of the community consists of private businesses and single-family residences. Most of the businesses within the Village of Chittenango lie along State Routes 13 and 5 (FEMA 1984c).

The Town of Cazenovia is located in the western portion of Madison County in central New York, approximately 25 miles southwest of the City of Rome and 29 miles west of the City of Utica. It is bordered by the Town of Sullivan to the north, Town of Fenner to the northeast, Town of Nelson to the east, Town of De Ruyter to the south, Town of Fabius to the southwest, Town of Pompey to the west, and the Town of Manlius to the northwest. Cazenovia is largely agricultural with much undeveloped land. The chief urban center is the Village of Cazenovia. There is also considerable residential development to the north of the town. New Woodstock, which is also a developed community, is located in the southern portion of the town (FEMA 1984a).

The Village of Cazenovia is located in the northwestern portion of Madison County in central New York, approximately 15-miles southeast of the City of Syracuse. It is completely surrounded by the Town of Cazenovia. Approximately 75% of the village has been developed, with the remainder of the land vacant or wooded. The center of the village is primarily occupied by small businesses and the Cazenovia College campus. Most of the businesses are situated adjacent to the Cherry Valley Turnpike, which becomes Main Street in Cazenovia. Single-family residences surround the business area (FEMA 1984b).

The Town of Fenner is located in the western portion of Madison County in central New York. It is bordered by the Town of Cazenovia to the west, Town of Sullivan to the northwest, Town of Lincoln to the northeast, Town of Smithfield to the east, and the Town of Nelson to the south. Chittenango Creek acts as the northwestern boundary between Fenner and Cazenovia (FEMA 1986b).

The Town of Cicero is located in the northeastern corner of Onondaga County in central New York. The town is bordered by the Towns of Manlius, Dewitt, and Salina to the south; Sullivan to the east; Constantia, West Monroe, and Hastings to the north; and Clay to the west. The rapid growth of the town towards the end of the twentieth century has been due to its proximity to the City of Syracuse. The town has a land area of 48 square miles (FEMA 1994).

The Town of Manlius is located in the northeastern portion of Onondaga County in central New York State, approximately eight miles east of the City of Syracuse. It is bordered by the Town of Cicero to the north, DeWitt to the west, Pompey to the south, Sullivan to the east, and Cazenovia to the southeast (FEMA 1992).

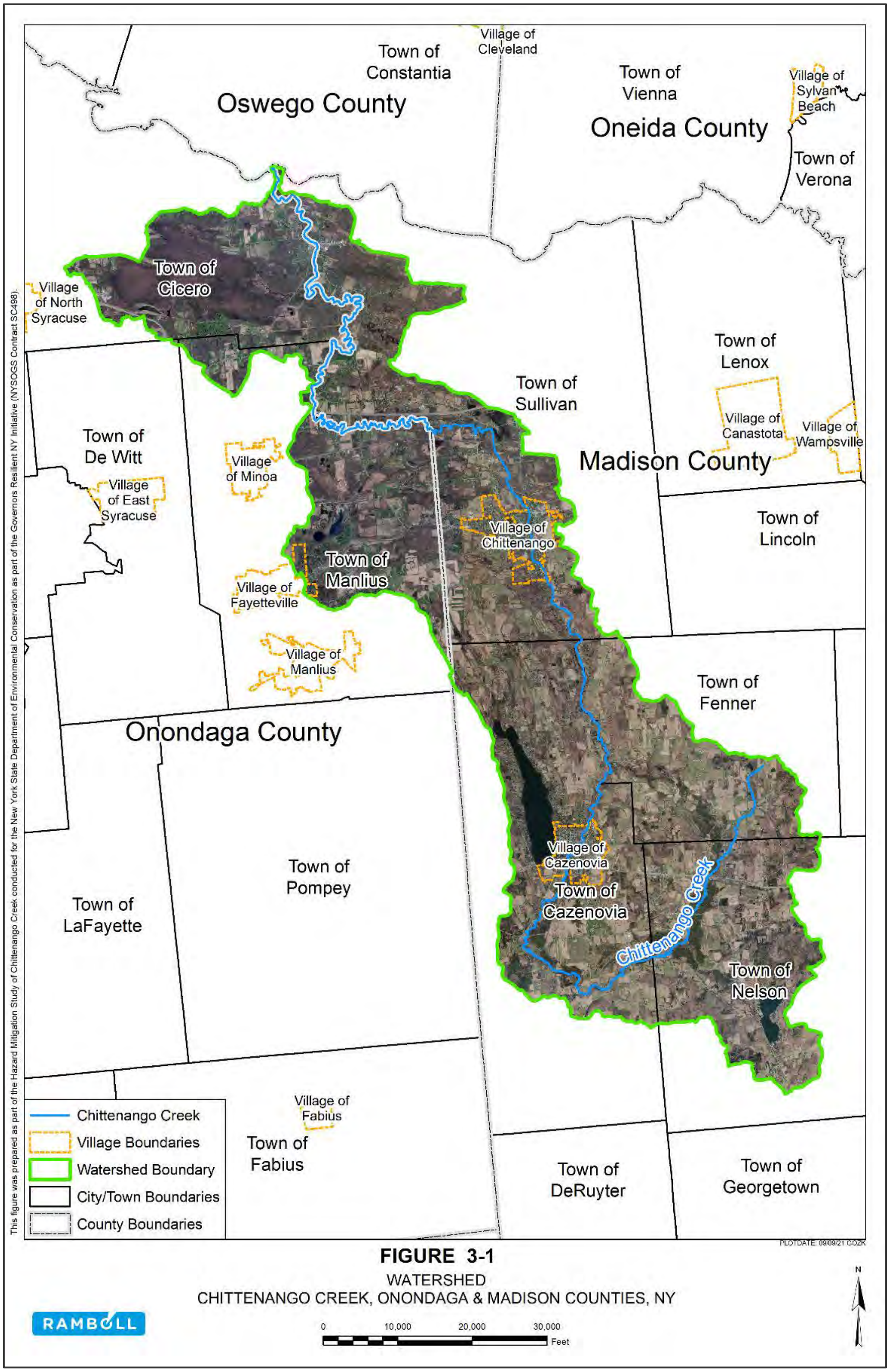

Figure 3-1. Chittenango Creek Watershed, Onondaga and Madison Counties, NY.

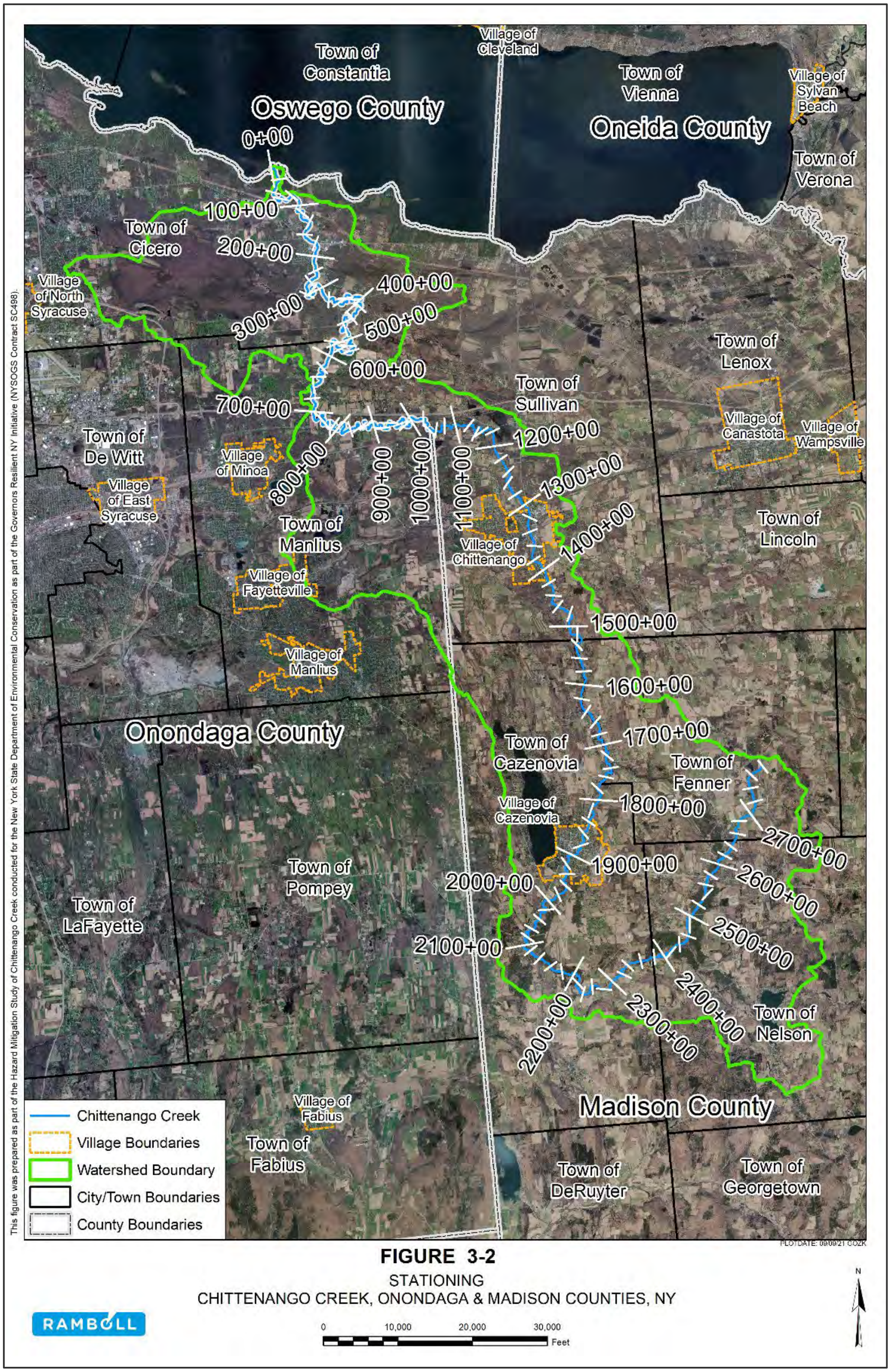

Figure 3-2. Chittenango Creek Stationing, Onondaga and Madison Counties, NY.

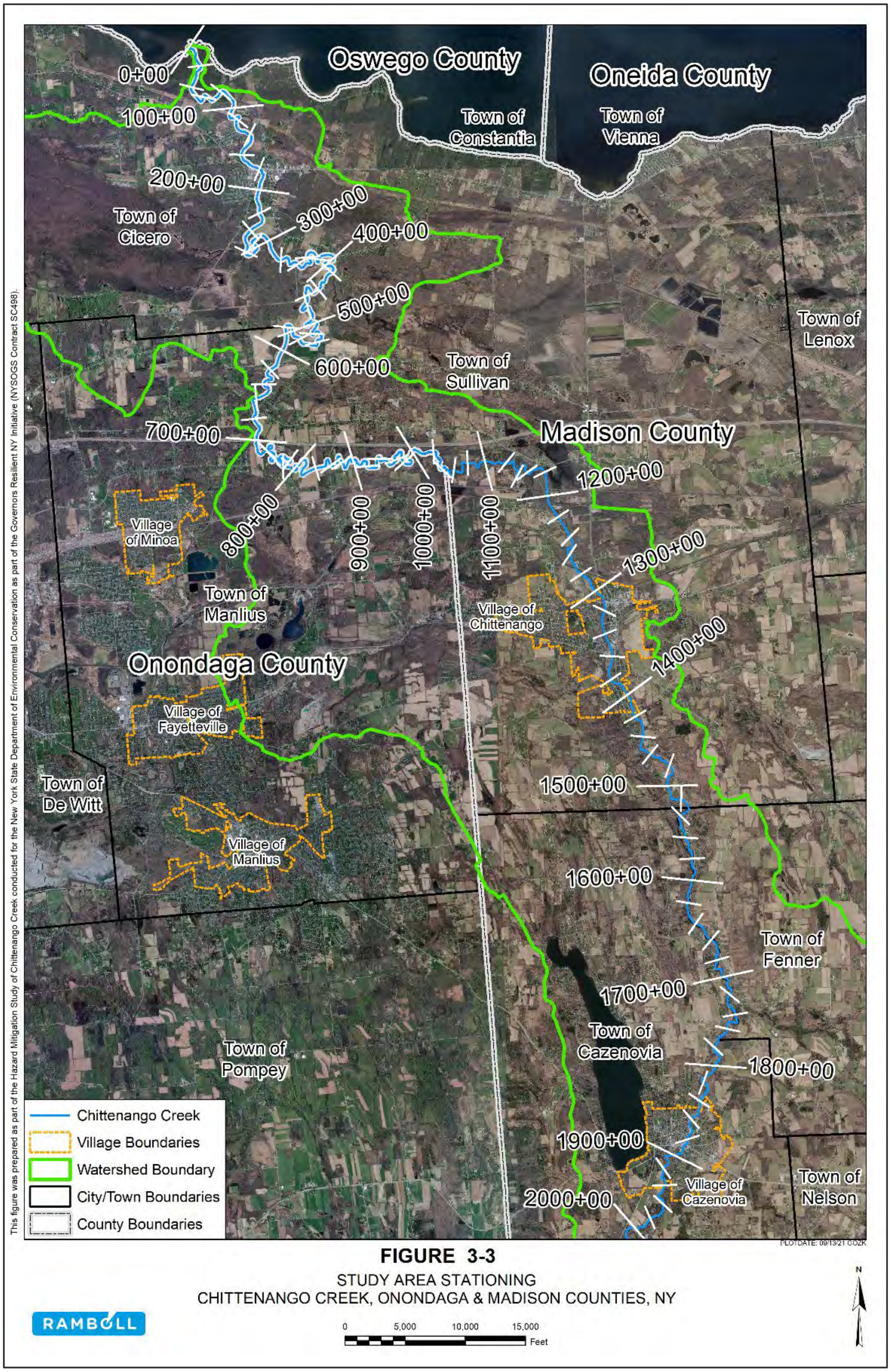

Figure 3-3. Chittenango Creek Study Area Stationing, Onondaga and Madison Counties, NY.

3.2 ENVIRONMENTAL CONDITIONS

An overview of the environmental and cultural resources within the Chittenango Creek watershed was compiled using the following online tools:

- **Environmental Resource Mapper** – The Environmental Resource Mapper is a tool used to identify mapped federal and state wetlands, state designated significant natural communities, and plants and animals identified as endangered or threatened by the NYSDEC (NYSDEC 2021a).
- **National Wetlands Inventory (NWI)** – The NWI is a digital map database available on the Environmental Resource Mapper that provides information on the "status, extent, characteristics and functions of wetlands, riparian, and deep water habitats" (NYSDEC 2021a).
- **Information for Planning and Consultation (IPaC)** – The IPaC database provides information about endangered/threatened species and migratory birds regulated by the U.S. Fish and Wildlife Service (USFWS 2021).
- **Register of Historic Places** – The New York State Historic Sites and Park Boundaries and National Register of Historic Places datasets list historic places worthy of preservation, as authorized by the National Historic Preservation Act of 1966 (NYSOPRHP 2018a; NYSOPRHP 2018b).

3.2.1 Wetlands

The State Regulated Freshwater Wetlands database shows the approximate location of wetlands regulated by New York State. The National Wetlands Inventory was reviewed to identify national wetlands and surface waters (Figure 3-4). The Chittenango Creek watershed includes riverine habitat, freshwater forested/shrub wetlands, freshwater ponds, lakes, and freshwater emergent wetlands (NYSDEC 2021a).

Maps of NYS Regulatory Freshwater Wetlands indicate the approximate boundaries of wetlands. Field investigation is necessary to identify the actual regulated wetland boundaries in the field. The NYSDEC regulates freshwater wetlands that are 12.4 acres (5 hectares) or larger and the 100-ft adjacent area surrounding such wetlands.

3.2.2 Sensitive Natural Resources

Areas designated as significant natural communities by the NYSDEC were mapped in the Chittenango Creek watershed. The significant natural communities identified include the Calcareous talus slope woodland and cliff community in the Uplands ecological system located in Chittenango Falls, and the Northern White Cedar Swamp in the Freshwater Non-tidal Wetlands ecological system located in the Nelson Swamp as mapped by the Environmental Resource Mapper (NYSDEC 2021a) (Figure 3-5).

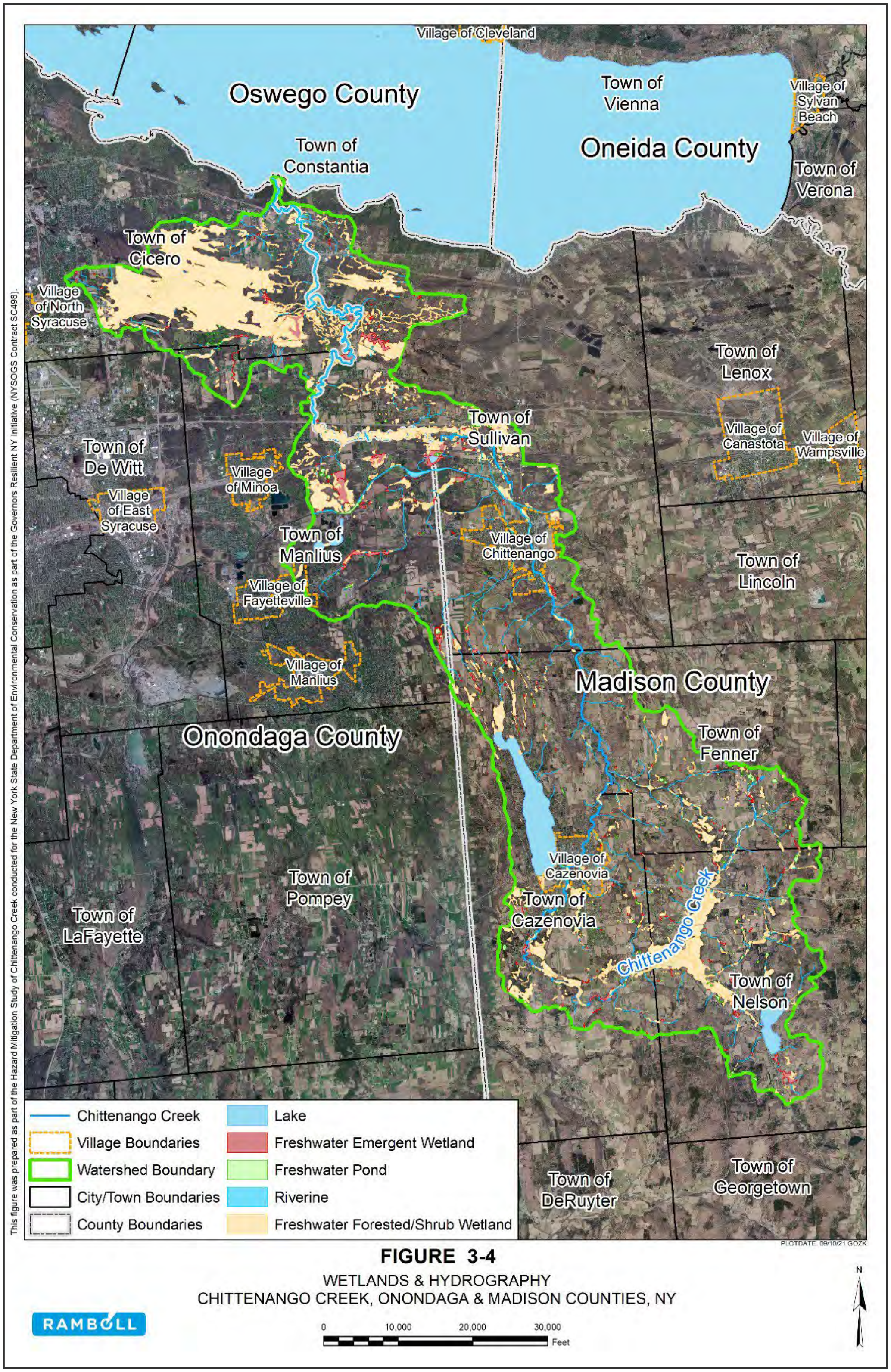

Figure 3-4. Chittenango Creek Wetlands and Hydrography, Onondaga and Madison Counties, NY.

Figure 3-5. Significant Natural Communities and Rare Plants or Animals, Chittenango Creek, Onondaga and Madison Counties, NY.

3.2.3 Endangered or Threatened Species

The Environmental Resource Mapper shows that the Chittenango Creek watershed contains rare plants listed as endangered, threatened, or rare by NYS, and rare animals listed as endangered or threatened; however, the rare plants and animals are not listed by the NYSDEC due to their sensitive nature.

The State's Natural Heritage records include the following additional Threatened and Endangered species along Chittenango Creek and in Oneida Lake:

- Lake Surgeon (threatened) – Town of Sullivan – not likely to be significantly impacted
- Northern Harrier (threatened) – Town of Sullivan and Village of Cazenovia – NYSDEC would recommend bird surveys when evaluating permit applications impacting grasslands
- Upland Sandpiper (threatened) – Village of Cazenovia – surveys would be required for areas north of the Village of Cazenovia and recommended for other reaches of Chittenango Creek
- Chittenango Ovate Amber Snail (endangered) – found throughout the watershed
- Bald Eagle (protected) – found throughout the watershed
- Short-Eared Owl (endangered) – Town of Sullivan – further consultation with NYSDEC specialists required to ascertain if any owl-occupied open terrain habitat area would be impacted
- Pied Billed Grebe (threatened) – Village of Cazenovia – further consultation with NYSDEC specialists required to see if habitat area would be impacted
- Northern Long Eared Bat (threatened) – found throughout the watershed

Opportunities to enhance habitat for some of these species may exist when restoring floodplains or when constructing detention basins or constructed wetlands. Planning should include consideration of habitat requirements of these species; in particular, the NYSDEC would be concerned about the loss of large tracts of open unforested land. The NYSDEC Regional Office should be contacted to determine the potential presence of the species identified (NYSDEC 2021a; NYSDEC 2021b).

The United States Fish and Wildlife Service (USFWS) Information for Planning and Consultation (IPaC) results for the Chittenango Creek watershed lists six endangered species: Indiana Bat (myotis sodalist), Northern Long-eared Bat (myotis septentrionalis), Eastern Massasuga rattlesnake (sistrurus catenatus), Chittenango Ovate Amber Snail (succinea chittenangoensis), Monarch Butterfly (danaus plexippus), and the American Hart's-tongue Fern (asplenium scolopendrium var. Americanum). No critical habitat has been designated for the species at this location (USFWS 2021). The migratory bird species listed in Table 1 are transient species that may pass over, but are not known to nest within the project area.

It should be noted, coordination with the NYSDEC will be critical to fully understand the implications of any flood mitigation alternative on any endangered species and their habitats within the Chittenango Creek watershed.

Table 1. UFWS IPaC Listed Migratory Bird Species

(Source: USFWS 2021)

Common Name	Scientific Name	Level of Concern	Breeding Season
American Golden-plover	*Pluvialis dominica*	BCC Rangewide (CON) [1]	Breeds elsewhere
Bald Eagle	*Haliaeetus leucocephalus*	Non-BCC Vulnerable [2]	Breeds Sep 1 to Aug 31
Black-billed Cuckoo	*Coccyzus erythropthalmus*	BCC Rangewide (CON) [1]	Breeds May 15 to Oct 10
Black-capped Chickadee	*Poecile atricapillus practicus*	BCC-BCR [3]	Breeds April 10 to Jul 31
Blue-winged Warbler	*Vermivora pinus*	BCC-BCR [3]	Breeds May 1 to Jun 30
Bobolink	*Dolichonyx oryzivorus*	BCC Rangewide (CON) [1]	Breeds May 20 to Jul 31
Canada Warbler	*Cardellina canadensis*	BCC Rangewide (CON) [1]	Breeds May 20 to Aug 10
Cerulean Warbler	*Dendroica cerulea*	BCC Rangewide (CON) [1]	Breeds Apr 20 to Jul 20
Evening Grosbeak	*Coccothraustes vespertinus*	BCC Rangewide (CON) [1]	Breeds May 15 to Aug 10
Golden Eagle	*Aquila chrysaetos*	Non-BCC Vulnerable [2]	Breeds Jan 1 to Aug 31
Golden-winged Warbler	*Vermivora chrysoptera*	BCC Rangewide (CON) [1]	Breeds May 1 to Jul 20
Henslow's Sparrow	*Ammodramus henslowii*	BCC Rangewide (CON) [1]	Breeds May 1 to Aug 31
Lesser Yellowlegs	*Tringa flavipes*	BCC Rangewide (CON) [1]	Breeds elsewhere

(Source: USFWS 2021)			
Common Name	**Scientific Name**	**Level of Concern**	**Breeding Season**
Long-eared Owl	*Asio otus*	BCC Rangewide (CON) [1]	Breeds Mar 1 to Jul 15
Northern Saw-whet Owl	*Aegolius acadicus*	BCC-BCR [3]	Breeds Mar 1 to Jul 31
Prairie Warbler	*Dendroica discolor*	BCC Rangewide (CON) [1]	Breeds May 1 to Jul 31
Prothonotary Warbler	*Protonotaria citrea*	BCC Rangewide (CON) [1]	Breeds Apr 1 to Jul 31
Red-headed Woodpecker	*Melanerpes erythrocephalus*	BCC Rangewide (CON) [1]	Breeds May 10 to Sep 10
Ruddy Turnstone	*Arenaria interpres morinella*	BCC-BCR [3]	Breeds elsewhere
Rusty Blackbird	*Euphagus carolinus*	BCC-BCR [3]	Breeds elsewhere
Short-billed Dowitcher	*Limnodromus griseus*	BCC Rangewide (CON) [1]	Breeds elsewhere
Wood Thrush	*Hylocichla mustelina*	BCC Rangewide (CON) [1]	Breeds May 10 to Aug 31

[1] BCC Rangewide (CON): This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska (CON).

[2] Non-BCC Vulnerable: This is not a Bird of Conservation Concern (BCC) in this area but warrants attention because of the Eagle Act or for potential susceptibilities in offshore areas from certain types of development or activities.

[3] BCC-BCR: This is a Bird of Conservation Concern (BCC) only in particular Bird Conservation Regions (BCRs) in the continental USA.

3.2.4 Cultural Resources

According to the National Register of Historic Places, there are 44 registered historic sites and parks within the Chittenango Creek watershed. Consultation with New York State Office of Parks, Recreation, and Historic Places (NYSOPRHP) should be performed to identify the potential presence of archeological resources and the subsequent need to perform a cultural resources investigation (NYSOPRHP 2018a; NYSOPRHP 2018b).

Table 2 lists the New York State Historic Sites and Park Boundaries and National Register of Historic Places sites. Figure 3-6 displays the locations of the historic sites and parks within the Chittenango Creek watershed.

Table 2. New York State Historic Sites and Park Boundaries and National Register of Historic Places Sites

(Source: NYSOPRHP 2018a; NYSOPRHP 2018b)		
Name	**County**	**City**
Abell Farmhouse and Barn	Madison	Cazenovia
Albany Street Historic District	Madison	Cazenovia
Annas Farmhouse	Madison	Cazenovia
Beckwith Farmhouse	Madison	Cazenovia
Brick House	Madison	Cazenovia
Cazenovia Village Historic District	Madison	Cazenovia
Cedar Cove	Madison	Cazenovia
Chappell Farmhouse	Madison	Cazenovia
Chittenango Falls State Park	Madison	Cazenovia
Chittenango Landing Dry Dock Complex	Madison	Sullivan
Chittenango Pottery	Madison	Chittenango
Cobblestone House	Madison	Cazenovia
Comstock/Zephnia Farmhouse	Madison	Cazenovia
Crandall Farm Complex	Madison	Cazenovia
Dorothy Riester House & Studio	Madison	Cazenovia
Evergreen Acres	Madison	Cazenovia
Green Lakes State Park	Onondaga	Manlius
Helen L. McNitt State Park	Madison	Cazenovia
Hillcrest	Madison	Cazenovia
Lehigh Valley Railroad Depot	Madison	Cazenovia
Lehigh Valley State Trail	Madison	Fenner
Lorenzo	Madison	Cazenovia
The Maples	Madison	Cazenovia
Meadows Farm Complex	Madison	Cazenovia
Middle Farmhouse	Madison	Cazenovia
Mycenae Schoolhouse	Onondaga	Manlius
Nelson Methodist Episcopal Church	Madison	Nelson
Nelson Welsh Congregational Church	Madison	Nelson
Niles Farmhouse	Madison	Cazenovia

(Source: NYSOPRHP 2018a; NYSOPRHP 2018b)		
Name	**County**	**City**
Notleymere	Madison	Cazenovia
Old Erie Canal State Historic Park	Onondaga/Madison	Manlius/Sullivan
Old Trees	Madison	Cazenovia
Ormonde	Madison	Cazenovia
Parker Farmhouse	Madison	Cazenovia
Rippleton Schoolhouse	Madison	Cazenovia
Rolling Ridge Farm	Madison	Cazenovia
Shattuck House	Madison	Cazenovia
Shore Acres	Madison	Cazenovia
St. Paul's Church (Episcopal)	Madison	Chittenango
Sweetland Farmhouse	Madison	Cazenovia
Tall Pines	Madison	Cazenovia
The Hickories	Madison	Cazenovia
Upenough	Madison	Cazenovia
York Lodge	Madison	Cazenovia

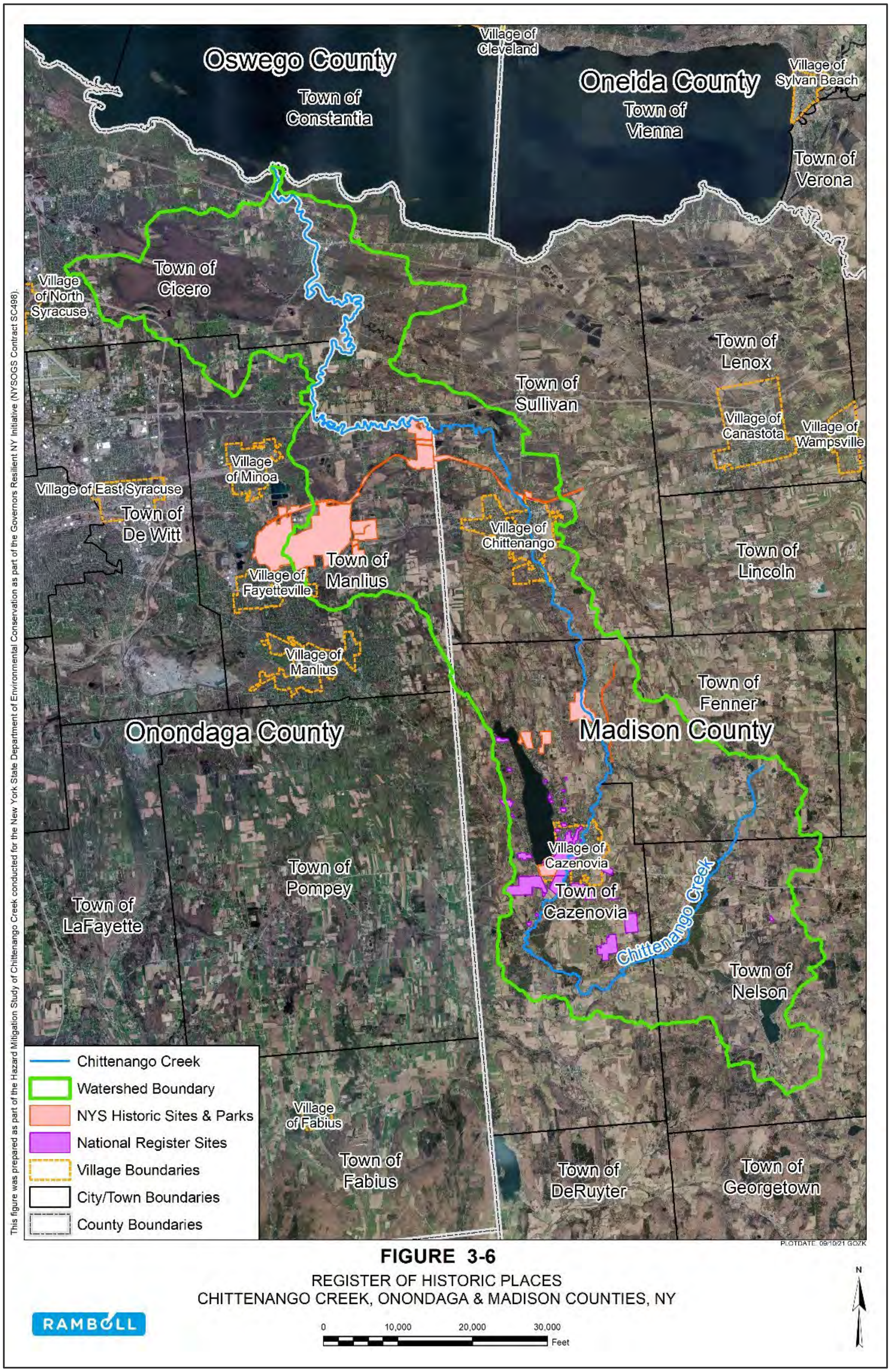

Figure 3-6. Register of Historic Places, Chittenango Creek, Onondaga and Madison Counties, NY.

3.2.5 FEMA Mapping and Flood Zones

The FEMA Flood Map Service Center (MSC) (https://msc.fema.gov/portal/home) is a database that contains FEMA Flood Insurance Rate Maps (FIRMs) for areas that have had FEMA flood insurance studies completed throughout the United States (FEMA 2021). The current effective FEMA FIS reports for the municipalities within the Chittenango Creek watershed are:

- Towns of Cicero and Manlius (Onondaga County) November 4, 2016
- Town of Sullivan (Madison County) May 15, 1986
- Town of Cazenovia (Madison County) December 19, 1984
- Town of Fenner (Madison County) February 5, 1986
- Village of Chittenango (Madison County) August 1, 1984
- Village of Cazenovia (Madison County) December 19, 1984

According to their respective FIS reports, the hydrologic and hydraulic analyses for Chittenango Creek were studied using detailed methods for all the municipalities listed. There is a small portion of Chittenango Creek in the Town of Cazenovia, between East Road and the corporate limits with the Town of Fenner, where only an approximate study exists (FEMA 1984a; FEMA 1984b; FEMA 1984c; FEMA 1986b; FEMA 1986c; FEMA 2016).

For a detailed study, FEMA can perform a limited detailed or detailed study. For both methods, semiautomated hydrologic, hydraulic, and mapping tools, coupled with digital elevation data, are used to predict floodplain limits, especially in lower-risk areas. If the tools are used with some data collected in the field (e.g., sketches of bridges to determine the clear opening) then the study is considered a limited detailed study. Limited detailed analysis sometimes results in the publishing of Base Flood Elevations (BFEs), also referred to as the 100-year flood elevation, on the maps. The decision to place BFEs on a limited detailed study analysis is based on the desire of the community for the BFEs to be shown, plus the accuracy of the elevation data and the data on bridges, dams, and culverts that may impede flow on the flooding source. A study performed using these same tools and the same underlying map, with the addition of field-surveyed cross sections, field surveys of bridges, culverts, and dams, along with a more rigorous analysis including products such as floodways, new calibrations for hydrologic and hydraulic models, and the modeling of additional frequencies, is a detailed study. Detailed studies provide BFE information and flood profiles, and usually a floodway, whereas approximate studies do not (NRC 2007).

For the portions of Chittenango Creek that flow through Onondaga County, a re-delineation study was performed in the updated Onondaga County FIS for 2016. Redelineation is the method of updating effective flood hazard boundaries to match updated topographic data based on the computed water surface elevations (WSELs) from effective models. The results of a redelineation update are more accurate floodplain boundaries when compared to current ground conditions. Redelineation of floodplain boundaries can be applied to both riverine and coastal studies. No new engineering analyses are performed as part of the redelineation methodology; however, redelineation can be paired with new engineering studies as part of a larger update. For riverine studies, effective flood profiles and data tables from the FIS report, BFEs from the FIRMs, and supporting hydrologic and hydraulic analyses are used in conjunction with the updated topographic data to formulate new floodplain boundaries. The coastal redelineation method also typically involves no new analyses. This method combines effective information from the FIRM, FIS report, and the supporting analyses with new, more detailed, or more up to-date topographic data to redelineate coastal high-hazard areas (FEMA 2015a).

Chittenango Creek is a Regulatory Floodway, which is defined as the watercourse channel and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than 1 foot over the 1% annual chance flood hazard (ACE) WSEL (i.e., BFE). In the regulatory floodway, communities must regulate encroachments, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway, and demonstrate through hydrologic and hydraulic analyses performed in accordance with standard engineering practice, that the proposed encroachment would not increase flood levels within the community during the occurrence of the base flood. Development in the portions of the floodplain beyond the floodway, referred to as the floodway fringe, is allowed as long as it does not increase the BFE more than 1.0 foot (FEMA 2000). Figure 3-7 displays the floodway data from the FIS for Chittenango Creek in the Village of Cazenovia, New York (FEMA 1984b).

The FIRMs for all of the municipalities that encompass Chittenango Creek indicate Special Flood Hazard Areas (SFHAs), which are land areas covered by floodwaters during the 1% ACE. The flood zones indicated in the Chittenango Creek study area are Zones A and AE, where mandatory flood insurance purchase requirements apply. A Zones are areas subject to inundation by the 1% ACE. Where detailed hydraulic analyses have not been performed, no BFEs or flood depths are shown. AE Zones are areas that have a 1% annual chance of flooding where BFEs are provided by FEMA (FEMA 1984a; FEMA 1984b; FEMA 1984c; FEMA 1986b; FEMA 1986c; FEMA 2016). Figure 3-8 is a FIRM that includes a portion of Chittenango Creek in the Village of Cazenovia, New York (FEMA 1985a).

For the flood zones within Madison County, New York, digitized Q3 flood zone data derived from FEMA FIRMs was used to produce flood zone maps in this study. Digital Q3 flood data files contain only certain features from the FIRM hardcopy in effect at the time of scanning and do not replace the existing FIRM hardcopy maps. In addition, the process of georeferencing paper maps to digital images can distort certain features over large areas between known points. This process is not recommended to use for detailed flood zone delineation or analysis (FEMA 1996).

The hydraulic analyses performed by FEMA were based on unobstructed flow for all three communities. The flood elevations shown on the profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail. With regards to ice-jam flooding, the effective FEMA FIRMs only reflect flooding related to open-water or free-flow conditions (FEMA 1984a; FEMA 1984b; FEMA 1984c; FEMA 1986b; FEMA 1986c; FEMA 2016).

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY (FEET NGVD)	INCREASE
Chittenango Creek								
A	183,370	49	284	12.0	1,146.7	1,146.7	1,146.8	0.1
B	184,150	105	326	10.5	1,153.6	1,153.6	1,154.2	0.6
C	185,100	71	445	6.7	1,164.7	1,164.7	1,165.7	1.0
D	185,520	50	344	8.7	1,166.4	1,166.4	1,167.3	0.9
E	186,200	125	500	6.0	1,174.8	1,174.8	1,175.2	0.4
F	186,590	46	306	9.8	1,176.0	1,176.0	1,176.7	0.7
G	187,201	160	873	3.4	1,179.7	1,179.7	1,179.8	0.1
H	187,803	302	846	3.5	1,182.0	1,182.0	1,182.1	0.1
I	188,173	229	874	3.4	1,182.3	1,182.3	1,183.1	0.8
J	188,573	48	222	13.5	1,184.0	1,184.0	1,184.0	0.0
K	189,230	147	1,062	2.8	1,189.3	1,189.3	1,189.6	0.3
L	190,048	120	701	4.3	1,195.2	1,195.2	1,195.2	0.0
M	191,258	208	493	6.1	1,195.8	1,195.8	1,196.5	0.7
N	193,028	452	1,740	1.7	1,198.9	1,198.9	1,199.7	0.8
O	193,939	852[2]	2,761	0.9	1,199.1	1,199.1	1,199.9	0.8

[1]Feet above confluence with Oneida Lake

[2]This width extends beyond corporate limits

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

VILLAGE OF CAZENOVIA, NY

(MADISON CO.)

FLOODWAY DATA

CHITTENANGO CREEK

Figure 3-7. Regulatory Floodway Data, Chittenango Creek, Village of Cazenovia, Madison County, NY (FEMA 1984b).

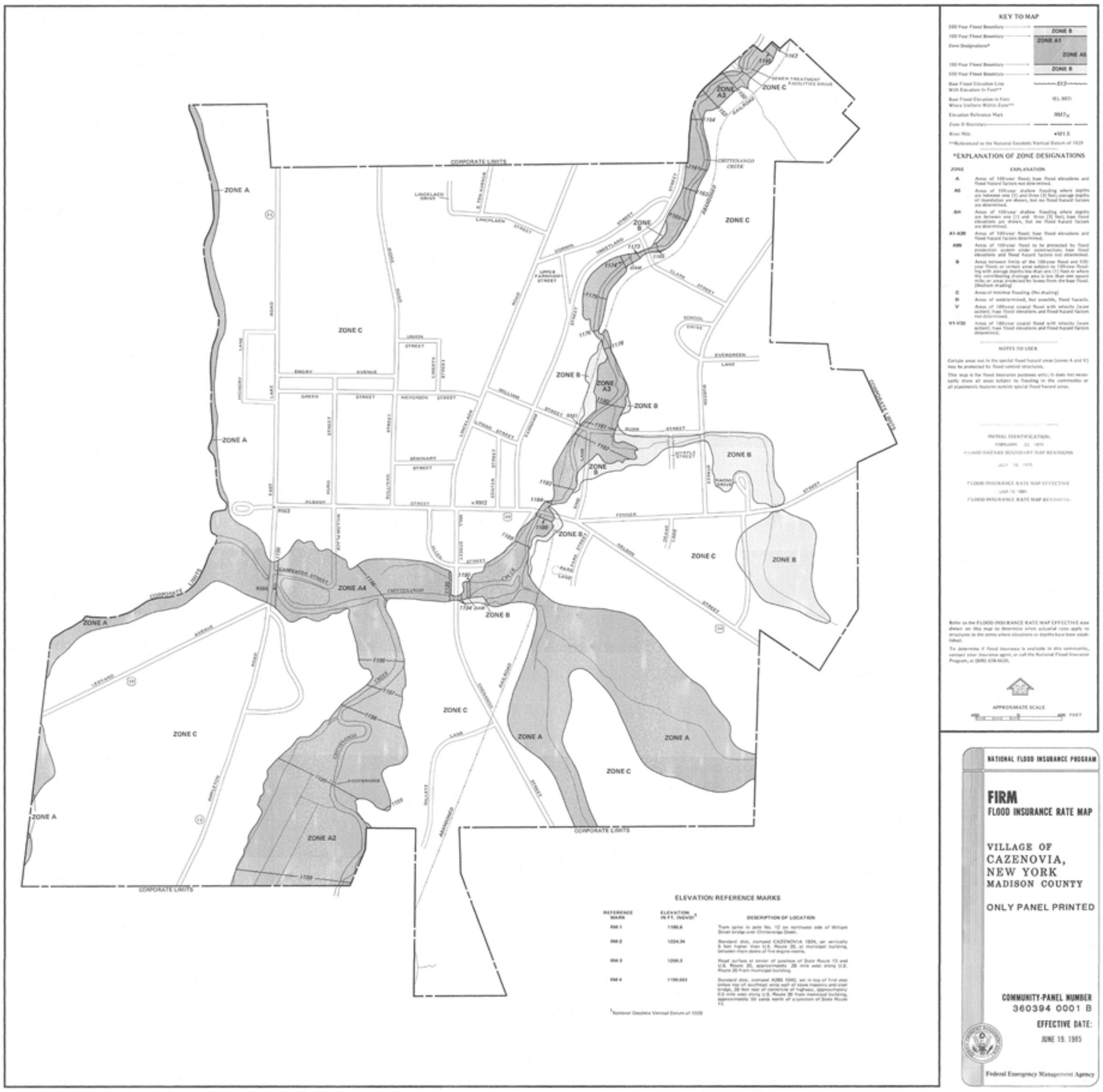

Figure 3-8. FEMA FIRM, Chittenango Creek, Village of Cazenovia, Madison County, NY (FEMA 1985a).

For this study, ice-jam flooding extents were determined using a wide variety of sources, including stakeholder input, news reports, computer models, etc. References to ice-jam flood extents are based solely on these sources and do not reflect the flood zone areas from the effective FEMA FIRMs.

3.3 WATERSHED LAND USE

The Chittenango Creek stream corridor is largely comprised of forested (35%), agricultural (33%), wetlands (17%) and developed (10%) lands within the basin. Of the forested lands, deciduous forests (29%) comprise the largest proportion of the forested lands, while hay/pasture (19%) and cultivated crops (13%) encompass the largest percentages of agricultural lands (USGS 2021a).

The distribution of different land use and cover types varies throughout the Chittenango Creek basin. The upper portions of the basin, in the Towns of Nelson and Fenner, are primarily comprised of cultivated, forested, and wetlands. The middle portions of the basin, in the Town of Cazenovia and the lower portion of the Town of Sullivan, are primarily comprised of cultivated, forested, and wetlands, with the Villages of Cazenovia and Chittenango encompassing large areas of developed land. The lower portions of the basin, in the Towns of Sullivan and Cicero, are primarily cultivated, forested, and wetlands, with the Hamlet of Bridgeport encompassing a small, developed area along Chittenango Creek (USGS 2021a).

3.4 GEOMORPHOLOGY

The Chittenango Creek watershed encompasses large areas of both Onondaga and Madison Counties. Onondaga County is near the geographical center of New York State at the eastern edge of the Finger Lakes region. It is approximately 34 miles long from north to south and 30 miles wide from east to west. The total land area is 507,840 acres or 793.5 square miles. The Onondaga Limestone Escarpment divides the county into two physiographic regions – the Erie-Ontario Plain in the northern half and the Allegheny Plateau in the south. Most of the drainage in the county is north into Lake Ontario. Part of the southern quarter of the county drains south into the Susquehanna River (SCS 1977).

The dominant soils in Onondaga County derived from glacial deposits containing varying amounts of limestone, shale, and sandstone. For the most part these soils are deep, gently sloping to moderately sloping, and medium textured. They are mainly well drained or moderately well drained and are medium to high in content of lime. The dominant soils that formed in glacial till are the well-drained Honeoye and moderately well-drained Lima soils that are high in content of lime on the northern lower foothill edge of the Allegheny Plateau; the well-drained Lansing and moderately well-drained Conesus soils medium in content of lime; and the moderately well-drained Mardin and somewhat poorly-drained Volusia soils that are low in content of lime-to-acid, at the higher elevations on the Allegheny Plateau. On the Erie-Ontario Plain, the dominant soils that formed in glacial till are the well-drained Ontario and moderately well-drained Hilton soils high to medium in content of lime; and well-drained Madrid and moderately well-drained Bombay soils medium to low in content of lime on till plains and drumlins (SCS 1977).

Less common soils, but also important, are those that formed in glacial outwash and in lake-laid material. Dominant among these are the Palmyra and Howard soils. The soils that formed in lacustrine deposits erode easily and generally have slow internal drainage. These soils are mainly on the northeastern part of the Erie-Ontario Plain. Dominant among these are the somewhat poorly-drained Niagara and the moderately well-drained Collamer soils. Large areas of the nearly level Niagara soils mostly are idle or produce only limited amounts of crops. If artificial drainage is properly installed, these soils are productive of most crops. The Ontario and Madrid soils on drumlins are fertile and productive. Because of steep slopes, small field size, and small wet areas, however, these soils are idle and, in places, have reverted to brush. Many of these areas have potential for homesites, especially small estate development. Many of the level, moderately well-drained and somewhat poorly-drained lacustrine soils in the northern half of the county are used for housing and industrial development. Most areas have severe limitations because of drainage and stability (SCS 1977).

All of the drainage from Onondaga County eventually flows into Lake Ontario, except for five small watersheds near the southern edge of the county that drain south to the Susquehanna River (SCS 1977).

Much of the southwestern part of the county drains into Skaneateles or Otisco Lakes. Skaneateles Creek flows north from Skaneateles Lake to the Seneca River, and Nine Mile Creek flows from Otisco Lake into Onondaga Lake, which outlets into the Seneca River. The central part of the county drains into Onondaga Creek which also flows north into Onondaga Lake. East of the Onondaga drainage area to the Madison County line, drainage is into Butternut and Limestone Creeks; they flow to the north. Butternut Creek joins Limestone Creek about 1.5 miles north of Minoa. Limestone Creek joins Chittenango Creek immediately north of North Manlius. Chittenango Creek, which is the northeastern boundary of Onondaga County, drains a narrow area along the creek, including the east end of Cicero Swamp, and then flows into Oneida Lake. The Oneida River is the outlet for Oneida Lake, it flows westerly and forms part of the northern boundary of the county (SCS 1977).

A few minor streams in the northern part of the county drain directly into Oneida Lake or the Seneca, Oneida, and Oswego Rivers. The Oswego River begins at the junction of the Oneida and the Seneca Rivers at Three Rivers and flows north into Lake Ontario. Mud Creek, which drains Peat Swamp and the western half of Cicero Swamp, is a slow, sluggish stream which flows into the Oneida River at Oak Orchard. Ox Creek drains the northwestern part of the county around Beaver Lake and flows north through Oswego County into the Oswego River. Carpenters Brook, White Bottom Creek, and Dead Creek are the major streams that flow directly into the Seneca River. These streams come from springs in the Onondaga Limestone and the Camillus Shale, and have white marl streambeds (SCS 1977).

Madison County is adjacent to the southern shore of Oneida Lake in the central part of New York State. It is bounded on the northeast and east by Oneida and Otsego Counties, on the south by Chenango County, and on the west by Onondaga and Cortland Counties. The county is rural and covers an area of 423,040 acres or 661 square miles. It is roughly triangular in shape, and the northern end is the narrowest dimension. Average width, from east to west, is 22 miles. Average length, from north to south, is approximately 30 miles. Elevation ranges from 368 feet above mean sea level at Oneida Lake to 2,142 feet at a point midway between Georgetown and Erieville in the southwestern part of the county. The steep, north-facing Onondaga Limestone escarpment divides the county into two physiographic provinces: the Appalachian Plateau in the south and the lower-lying Ontario (Oneida) Plain in the north (SCS 1981).

Most of the soils in Madison County formed in parent material that was deposited as a result of glaciation. During the Pleistocene period, the survey area was completely covered by a continental ice sheet several hundred feet thick. Evidence indicates that the ice made at least two or more major advances in the survey area during this period. Before overriding the uplands, advance lobes of ice extended southward through the major valleys. As these advance lobes moved, they deepened, and widened the valleys. Eventually the ice sheet crept into the uplands and covered even the highest hills. Glacial till deposits cover about 60% of the land area in the county (SCS 1981).

Madison County is underlain by bedrock of the Silurian and Devonian Periods. Formations of the Middle to Upper Silurian Period underlie the Oneida Plain in the northern part of the county. The younger Devonian Formations underlie the upland plateau in the southern part of the county. The bedrock of both periods lies nearly flat, except it has a slight regional dip to the south of about 50 feet per mile (SCS 1981).

There are three main types of streams in the county. In the northern third of the county, gradient is low and the streams meander across broad flood plains. In the escarpment area and in the upland areas of the southern two thirds of the county, gradient is very steep, valleys generally are V-shaped, and alignment is relatively straight. In the major valleys in the southern two-thirds of the county, streams flow on mature flood plains, gradient is relatively low, and the alignment meanders over reworked flood plain deposits (SCS 1981).

The principal drainage pattern in the county is dendritic. This pattern is somewhat modified in places by bedrock and by remnant glacial features. The northern half of the county is drained to the north into Oneida Lake. From here, water flows into the Ontario-St. Lawrence Basin. The main north-flowing streams are Chittenango, Oneida, Canastota, and Cowaselon Creeks. The northern part of the town of Madison is drained to the northeast by Oriskany Creek, which joins the Mohawk River. The southern half of the county is drained to the south by the Susquehanna River system. The principal south-flowing streams are the Unadilla, Chenango, and Otselic Rivers and Tioughnioga Creek (SCS 1981).

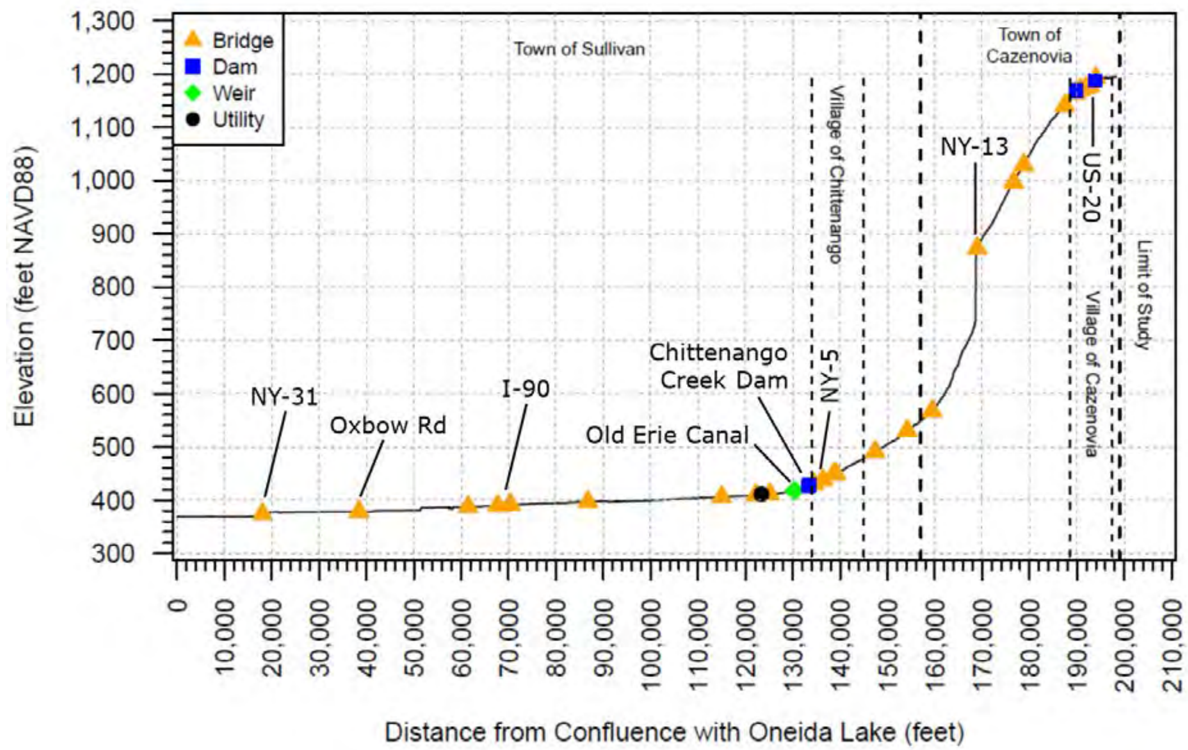

Figure 3-9. Chittenango Creek profile of stream bed elevation and channel distance from the confluence with Oneida Lake.

Figure 3-9 is a profile of stream bed elevation and channel distance from the confluence with Oneida Lake using 1-meter light detection and ranging (LiDAR) data for Chittenango Creek. Chittenango Creek has a steep slope in the upstream reaches primarily in the Town of Cazenovia. Chittenango Falls, located in the Town of Cazenovia downstream of the Village, accounts for a large elevation drop of approximately 170 feet (NYSOITS 2015).

In addition, there are numerous locations where sediment depositional aggradation is occurring within the channel of Chittenango Creek. Aggradation is a natural fluvial process where sediment and other materials are deposited in a stream channel when the supply of sediment is greater than the amount of material that the system is able to transport. Over time, aggradation can lead to the development of sand and sediment bars within the stream channel. These sand and sediment bars may restrict flow by reducing the in-channel flow area and may act as catchpoints for ice pieces during ice breakup events, potentially increasing open-water flood risks and ice-jam formations (Mugade and Sapkale 2015).

3.5 HYDROLOGY

Chittenango Creek drains an area of 135.9 square miles, is approximately 52.7 miles in length, and is located in central New York State south of Oneida Lake, on the eastern edge of Onondaga County, and western edge of Madison County. Chittenango Creek rises in the vicinity of Wyss and Mutton Hill Roads in the Town of Fenner and flows south and west into the Town of Cazenovia before turning and flowing north through the Village of Cazenovia. It then turns and continues its northerly flow into the Town of Sullivan and Village of Chittenango in Madison County before creating the boundary between Madison and Onondaga Counties and emptying into Oneida Lake (USGS 2021c).

There are two main tributaries that flow into Chittenango Creek: Butternut and Limestone Creeks. Butternut Creek rises in the hamlet of Apulia Station (Town of Fabius) and flows north into the Town of LaFayette into the Jamesville Reservoir. Then, continues northward into the Town of DeWitt before meandering northeast/east into the Town of Manlius crossing the New York State Thruway (Interstate-90/I-90) before merging with Limestone Creek. Limestone Creek rises in the Town of DeRuyter near the DeRuyter Reservoir and flows north into Onondaga County and the Towns of Fabius, Pompey, and Manlius and Villages of Manlius and Fayetteville before merging with Butternut Creek north of Interstate-90 and flowing northeast/east and merging into Chittenango Creek (USGS 2021c).

Table 3 is a summary of the basin characteristic formulas and calculated values for the Chittenango Creek watershed, where A is the drainage area of the basin in square miles, B_L is the basin length in miles, and B_P is the basin perimeter in miles (USGS 1978).

Table 3. Chittenango Creek Basin Characteristics Factors

Factor	Formula	Value
Form Factor (R_F)	A / B_L^2	0.18
Circularity Ratio (R_C)	$4*\pi*A / B_P^2$	0.20
Elongation Ratio (R_E)	$2 * (A/\pi)^{0.5} / B_L$	0.49

Form Factor (RF) describes the shape of the basin (e.g., circular or elongated) and the intensity of peak discharges over a given duration of time. Circularity Ratio (RC) gives an indication of topography where the higher the circularity ratio, the lower the relief and less disturbance to drainage systems by structures within the channel. Elongation Ratio (RE) gives an indication of ground slope where values less than 0.7 correlate to steeper ground slopes and elongated basin shapes. Based on the basin characteristics factors, the Chittenango Creek watershed can be characterized as an elongated basin with lower peak discharges of longer durations, high-relief topography with structural controls on drainage, and steep ground slopes (Waikar and Nilawar 2014).

There is one USGS stream gage station on Chittenango Creek, USGS 04244000 Chittenango Creek near Chittenango, New York. The gage has been active since 1950; however, there is no data for the years 1969 to 1971, 1973 to 1977, and 1979 to 2014 so there are only 27 years of data total with only 18 consecutive years of data recorded (USGS 2021b).

As described in Section 3.2.5, there is an effective FEMA FIS for each municipality within the Chittenango Creek watershed in which a detailed analysis was performed for both the hydrologic and hydraulic analyses.

For the Town of Sullivan, hydrologic analyses to determine discharge-frequency relationships and peak discharges for Chittenango Creek were performed using several methods, including the USGS Water Supply Paper (WSP) 1677 and log-Pearson Type III (LP3)/discharge-drainage area ratio statistical analysis techniques (USGS 1965; WRC 1981; FEMA 1986c).

For the Village of Chittenango, hydrologic analyses to determine discharge-frequency relationships and peak discharges for Chittenango Creek were performed using the LP3/discharge-drainage area ratio statistical analysis technique (WRC 1981; FEMA 1984c).

For the Town of Cazenovia, hydrologic analyses to determine discharge-frequency relationships and peak discharges for Chittenango Creek were performed using several methods, including the USGS Water Resources Investigations (WRI) 79-83 and LP3/discharge-drainage area ratio statistical analysis techniques (USGS 1965; USGS 1979; FEMA 1984a).

For the Village of Cazenovia, hydrologic analyses to determine discharge-frequency relationships and peak discharges for Chittenango Creek were performed using the WRI 79-83 technique (USGS 1979; FEMA 1984b).

For the Town of Fenner, hydrologic analyses to determine discharge-frequency relationships and peak discharges for Chittenango Creek were obtained from the FIS for the Town of Cazenovia (FEMA 1986b).

For the Town of Cicero, hydrologic analyses to determine discharge-frequency relationships and peak discharges for Chittenango Creek were performed using the WSP-1677 technique (USGS 1965; FEMA 2016).

For the Town of Manlius, hydrologic analyses to determine discharge-frequency relationships and peak discharges for Chittenango Creek were obtained from the FIS for the Town of Sullivan (FEMA 2016). Table 4 summarizes the peak discharges from the FEMA FIS reports for Chittenango Creek.

Table 4. Chittenango Creek FEMA FIS Peak Discharges

(Source: FEMA 1984a; FEMA 1986c)						
			Peak Discharges (cfs)			
Flooding Source and Location	**Drainage Area (Sq. Miles)**	**River Station (ft)**	**10-Percent**	**2-Percent**	**1-Percent**	**0.2-Percent**
At its confluence with Oneida Lake	288	0+00	12,090	17,160	18,720	24,000
At State Route 31 in Bridgeport	282	182+50	11,860	16,830	18,360	21,500
At the confluence of Limestone Creek	101.4	659+00	4,380	6,350	7,220	9,340
At the downstream corporate limits of Village of Chittenango	74.9	1312+50	3,440	4,980	5,670	7,330
At USGS gage (No. 0424400)	67.7	1446+00	3,170	4,600	5,230	6,760
At the downstream corporate limits of Town of Cazenovia	65	1533+00	3,067	4,447	5,059	6,540
Upstream of Bingley Road	53.3	1730+00	2,129	2,990	3,410	4,350
At the downstream corporate limits of Village of Cazenovia	49.2	1832+00	1,889	2,630	2,990	3,790
At the upstream corporate limits of Village of Cazenovia	34.2	1942+00	1,490	2,129	2,450	3,180

General limitations of the FEMA FIS methodology are the age of the effective FIS H&H analysis, the age of the methodology, and the different methodologies used over the entire reach of Chittenango Creek. The various H&H analyses for Chittenango Creek were completed between 1984 and 1986 using the WSP 1677, WRI 79-83 and LP3/ discharge-drainage area ratio methodologies. At the time of these FIS reports, there were less than 20 years of available gage records, which is insufficient for a hydrologic analysis. In addition, advancements in our understanding of the complex interactions of hydrologic environments, coupled with improvements in hydrologic and hydraulic modeling and technology, has led to increased accuracy and a reduction in possible error in discharge estimations in recent years.

StreamStats v4.6.2 software (https://streamstats.usgs.gov/ss/) is a map-based web application that provides an assortment of analytical tools that are useful for water resources planning and management, and engineering purposes. Developed by the USGS, the primary purpose of *StreamStats* is to provide estimates of streamflow statistics for user selected ungaged sites on streams and for USGS stream gages, which are locations where streamflow data are collected (Ries et al. 2017, USGS 2020).

Methods for computing a peak discharge estimate for a selected recurrence interval at a specific site depend on whether the site is gaged or ungaged, and whether the drainage area lies within a single hydrologic region or crosses into an adjacent hydrologic region or State. Hydrologic regions refer to areas in which streamflow-gaging stations indicate a similarity of peak-discharge response that differs from the peak-discharge response in adjacent regions. These similarities and differences are defined by the regression residuals, which are the differences between the peak discharges calculated from station records and the values computed through the regression equation. There are currently six hydrologic regions in New York State, and Chittenango Creek is located in Region 6 (Lumia 1991; Lumia et al. 2006).

For gaged sites, such as Chittenango Creek, the generalized least-squares (GLS) regional-regression equations are used to improve streamflow-gaging-station estimates (based on LP3 flood-frequency analysis of the gaged annual peak-discharge record) by using a weighted average of the two estimates (regression and gaged). Incorporating the regression estimate into the weighted average tends to decrease time-sampling errors that result for sites with short periods of record. The weighted-average discharges are generally the most reliable and are computed from the equation:

$$Q_{\mathrm{T(W)}} = \frac{Q_{\mathrm{T(g)}}(\mathrm{N}) + Q_{\mathrm{T(r)}}(\mathrm{E})}{\mathrm{N} + \mathrm{E}}$$

where

$Q_{T(w)}$ is weighted peak discharge at the gaged site, in cubic feet per second, for the T-year recurrence interval;

$Q_{T(g)}$ is peak discharge at gage, in cubic feet per second, calculated through log-Pearson Type III frequency analysis of the station’s peak discharge record, for the T-year recurrence interval;

N is number of years of annual peak-discharge record used to calculate $Q_{T(g)}$ at the gaging station;

$Q_{T(r)}$ is regional regression estimate of the peak discharge at the gaged site, in cubic feet per second, for the T-year recurrence interval; and

E is average equivalent years of record associated with the regression equation that was used to calculate $Q_{T(r)}$ (Lumia et al. 2006).

StreamStats delineates the drainage basin boundary for a selected site by use of an evenly spaced grid of land-surface elevations, known as a Digital Elevation Model (DEM), and a digital representation of the stream network. Using this data, the application calculates multiple basin characteristics, including drainage area, main channel slope, and mean annual precipitation. By using these characteristics in the calculation, the peak discharge values have increased accuracy and decreased standard errors by approximately 10% for a 1% annual chance interval (100-yr recurrence) discharge when compared to the drainage-area only regression equation (Lumia et al. 2006; Ries et al. 2017).

When *StreamStats* is used to obtain estimates of streamflow statistics for USGS stream gages, users should be aware that there are errors associated with estimates determined from available data for the stations, as well as estimates determined from regression equations, and some disagreement between the two sets of estimates is expected. If the flows at the stations are affected by human activities, then users should not assume that the differences between the data-based estimates and the regression equation estimates are equivalent to the effects of human activities on streamflow at the stations (Ries et al. 2017).

StreamStats was used to calculate the current peak discharges for Chittenango Creek and compared with the effective FIS peak discharges. Table 4 is the summary output of peak discharges calculated by the USGS *StreamStats* software for Chittenango Creek at select locations, including the same locations as the Village of Fredonia FEMA FIS.

Table 5. USGS *StreamStats* Peak Discharge for Chittenango Creek at the FEMA FIS Locations

(Source: USGS 2020)						
			Peak Discharges (cfs)			
Flooding Source and Location	**Drainage Area (Sq. Miles)**	**River Station (ft)**	**10-Percent**	**2-Percent**	**1-Percent**	**0.2-Percent**
At its confluence with Oneida Lake	308	0+00	7,940	11,400	13,000	17,000
At State Route 31 in Bridgeport	302	185+00	8,000	11,600	13,200	17,300
At the confluence of Limestone Creek	106	660+00	3,970	5,820	6,660	8,790
At the downstream corporate limits of Village of Chittenango	76.8	1309+00	3,390	5,030	5,770	7,680
At USGS gage (No. 0424400)	67.7	1440+00	3,050	4,540	5,220	6,960
At the downstream corporate limits of Town of Cazenovia	64.8	1530+00	2,690	3,960	4,540	6,000
Upstream of Bingley Road	51.5	1730+00	2,060	3,030	3,460	4,560
At the downstream corporate limits of Village of Cazenovia	47	1845+00	1,850	2,720	3,110	4,090
At the upstream corporate limits of Village of Cazenovia	36	1936+00	1,600	2,310	2,630	3,420

Using the standard error calculations from the regression equation analysis in *StreamStats*, an acceptable range at the 95% confidence interval for peak discharge values at the 10, 2, 1, and 0.2% annual chance flood hazards were determined. Standard error gives an indication of how accurate the calculated peak discharges are when compared to the actual peak discharges since approximately two-thirds (68.3%) of the calculated peak discharges would be within one standard error of the actual peak discharge, 95.4% would be within two standard errors, and almost all (99.7%) would be within three standard errors (McDonald 2014). Table 6 is a summary table of the USGS *StreamStats* standard errors at each percent annual chance flood hazard for Region 6 in New York State.

Table 6. USGS *StreamStats* Standard Errors for Full Regression Equations

Source: (Lumia 2006)				
	Peak Discharges (cfs)			
	10-Percent	**2-Percent**	**1-Percent**	**0.2-Percent**
Average Standard Error	32.9	35.8	37.2	41.4

Based on the *StreamStats* standard error calculations, the FEMA FIS peak discharges were determined to be outside of the acceptable range (95% confidence interval). For this study, to maintain consistency in the modeling outputs with the FEMA models and to develop a conservative analysis of flood risk in the Chittenango Creek watershed, the effective FIS peak discharges were used in the HEC-RAS modeling software simulations.

In addition to peak discharges, the *StreamStats* software also calculates bankfull statistics by using stream survey data and discharge records from 281 cross-sections at 82 streamflow-gaging stations in a linear regression analyses to relate drainage area to bankfull discharge and bankfull-channel width, depth, and cross-sectional area for streams across New York State. These equations are intended to serve as a guide for streams in areas of the same hydrologic region, which contain similar hydrologic, climatic, and physiographic conditions (Mulvihill et al. 2009).

Bankfull discharge is defined as the flow that reaches the transition between the channel and its flood plain. Bankfull discharge is considered to be the most effective flow for moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphological characteristics of channels (Mulvihill et al. 2009). The bankfull width and depth of Chittenango Creek is important in understanding the distribution of available energy within the stream channel, and the ability of various discharges occurring within the channel to erode, deposit, and move sediment (Rosgen and Silvey 1996). Table 7 lists the estimated bankfull discharge, width, and depth at select locations along Chittenango Creek as derived from the USGS *StreamStats* program.

Table 7. USGS *StreamStats* Estimated Drainage Area, Bankfull Discharge, Width, and Depth

(Source: USGS 2020)

Flooding Source and Location	Drainage Area (Sq. Miles)	River Station (ft)	Bankfull Depth (ft)	Bankfull Width (ft)	Bankfull Streamflow (cfs)
At its confluence with Oneida Lake	308	0+00	4.7	150	3,100
At State Route 31 in Bridgeport	302	185+00	4.68	149	3,060
At the confluence of Limestone Creek	106	660+00	3.73	91.6	1,320
At the downstream corporate limits of Village of Chittenango	76.8	1309+00	3.5	79.2	1,040
At USGS gage No. 0424400	67.7	1440+00	3.41	74.7	947
At the downstream corporate limits of Town of Cazenovia	64.8	1530+00	3.38	73.3	916
Upstream of Bingley Road	51.5	1730+00	3.23	66	771
At the downstream corporate limits of Village of Cazenovia	47	1845+00	3.17	63.4	720
At the upstream corporate limits of Village of Cazenovia	36	1936+00	3	56.1	598

3.6 INFRASTRUCTURE

According to the NYSDEC Inventory of Dams dataset, there are five dams along Chittenango Creek as identified by the NYSDEC. The dams are purposed as Hydroelectric, Navigation, and/or Water Supply (Secondary). All five dams have a hazard class of A. Class A dams are considered low hazard where a dam failure is unlikely to result in damage to anything more than isolated or unoccupied buildings, undeveloped lands, minor roads such as town or county roads; is unlikely to result in the interruption of important utilities, including water supply, sewage treatment, fuel, power, cable or telephone infrastructure; and/or is otherwise unlikely to pose the threat of personal injury, substantial economic loss or substantial environmental damage (NYSDEC 2021c).

In addition, Chittenango Creek crosses the Erie Canal in the Town of Sullivan downstream of the Village of Chittenango. The crossing is maintained by a constructed weir that controls water levels in both waterways. Table 8 lists the dams and weirs that are along Chittenango Creek, including hazard codes and purpose for the dam (NYSDEC 2021c).

Table 8. Inventory of Dams and Weirs Along Chittenango Creek

(Source: NYSDEC 2021c)

Municipality	State ID	Structure Name	Owner	River Station (ft)	Hazard Code	Purpose
Town of Sullivan	N/A	Old Erie Canal (Weir)	NYS Canal Corp.	1273+50	N/A	N/A
Village of Chittenango	092-0421	Chittenango Creek Dam	New York State	1308+00	A	Hydroelectric, Navigation
Village of Chittenango	092-0430	Chillangua Mill Dam	Private	1383+00	A	Water Supply - Secondary
Village of Cazenovia	093-1533	Cazenovia Electric Company Dam	Private	1847+00	A	Hydroelectric
Village of Cazenovia	093-0493	Cazenovia Lake Outlet Dam	New York State	1893+00	A	Other
Village of Cazenovia	093-0494	Upper State Dam	New York State	1900+00	A	Other

There is one large culvert as identified by the NYSDOT along Chittenango Creek. The culvert is located in the Town of Nelson and carries US-20. A large culvert is defined by the NYSDOT as a structure that has an opening measured perpendicular to its skew that is greater than or equal to five feet, and measured along the centerline of the roadway that is less than or equal to 20 feet (NYSDOT 2020a). In addition to the NYSDOT large culverts, there are a number of county and town-owned culverts that cross Chittenango Creek. Table 9 lists the identification numbers, owners, and structural characteristics of the culverts along Chittenango Creek with bankfull widths from *StreamStats* and hydraulic capacities from FEMA (NYSDOT 2019c; NYSDOT 2021).

Table 9. Culverts Along / Over Chittenango Creek

(Source: NYSDOT 2019c; USGS 2020; NYSDOT 2021)

Roadway Carried	Culvert ID (CIN)	River Station (ft)	Owner	Municipality	Span Length (ft)	Structure Width [1] (ft)	Bankfull Width (ft)	Hydraulic Capacity (% ACE)
US-20	C240028	2575+00	NYSDOT	Nelson	15	78	22	No FIS data
Nelson Road [2]	N/A	2622+00	Madison County	Nelson	18	32	20	No FIS data
Wyss Road [2]	N/A	2714+00	Town of Fenner	Fenner	12	40	11	No FIS data

[1] Structure Width is measured parallel to creek flow and refers to the roadway width, which is the minimum distance between the curbs or the railings (if there are no curbs), to the nearest 30mm or tenth of a foot (NYSDOT 2020b).

[2] Note: Unable to field measure due to safety concerns and no publicly available data for structural measurements. Orthoimagery and GIS spatial analysis tools were used to approximate structural measurements.

Major bridge crossings over Chittenango Creek include NY-31 (Lake Road), Interstate 90, NY-5 (Genesee Street), NY-13 (Gorge Road), and US-20. Bridge lengths and surface widths for NYSDOT bridges and culverts were revised as of 2019. Based on orthographic imagery and field observations of the Chittenango Creek watershed, additional structures crossing Chittenango Creek were identified.

Due to safety concerns and limited access, field staff were unable to perform measurements on some of the waterway crossing structures. For these structures, publicly available structural measurements were obtained from various sources. However, if no public data was available, a combination of orthoimagery and GIS spatial analysis tools were used to approximate structural measurements.

Table 10 summarizes the infrastructure data for structures that cross Chittenango Creek with bankfull widths from *StreamStats* and hydraulic capacities from FEMA. Figure 3-10 displays the locations of the infrastructure along Chittenango Creek.

Table 10. Infrastructure Crossings Over Chittenango Creek

(Source: NYSDOT 2019b; USGS 2020; NYSDEC 2021b; NYSDOT 2021)

Structure Carried	Bridge ID (BIN)	River Station (ft)	Owner	Bridge Length (ft)	Surface Width [1] (ft)	Bankfull Width (ft)	Hydraulic Capacity (% ACE)
Lake Road / NY-31	1021970	184+00	NYSDOT	208	54	149	10
Oxbow Road	3207970	387+00	Onondaga County	124	16	145	< 10
Peck Road	3312780	613+00	Onondaga County	152	40	144	10
Fyler Road	3312770	675+25	Onondaga County	104	37	92	10
I-90 WB	5510021	700+75	NYS Thruway Authority	96	52	91	10
I-90 EB	5510022	701+75	NYS Thruway Authority	96	52	91	10
N Kirkville Road	3312730	854+50	Onondaga County	60	25	90	< 10
Bolivar Road	2309140	1127+00	Madison County	70	35	88	< 10
CSXT Railroad	N/A	1195+00	CSX Transportation, Inc.	85	60	82	< 10
Pipe Crossing	N/A	1206+50	N/A	N/A	N/A	82	< 10
McGraw Road	2309130	1224+00	Madison County	79	30	82	< 10
Tuscarora Road	2309120	1314+00	Madison County	69	28	79	< 10
Russell Street	2309110	1331+50	Madison County	81	35	79	1
Genesee Street / NY-5	1002160	1354+50	NYSDOT	84	52	79	0.2
Madison Street	2309100	1358+75	Madison County	68	42	77	10
Dyke Road	2309090	1440+25	Madison County	64	27	75	0.2
Olmstead Road	2309080	1506+25	Madison County	66	30	74	No FIS data
Access Road (1)	N/A	1556+50	N/A	48	13	73	< 10
Gorge Road / NY-13	1010560	1652+75	NYSDOT	84	47	71	0.2
Bingley Road	2308800	1728+25	Madison County	53	35	66	1

Access Road (2)	N/A	1750+00	N/A	50	15	65	< 10

(Source: NYSDOT 2019b; USGS 2020; NYSDEC 2021b; NYSDOT 2021)

Structure Carried	Bridge ID (BIN)	River Station (ft)	Owner	Bridge Length (ft)	Surface Width [1] (ft)	Bankfull Width (ft)	Hydraulic Capacity (% ACE)
Treatment Plant Road	3367120	1833+50	Madison County	53	23	64	0.2
Clark Street	2308790	1856+00	Village of Cazenovia	44	30	63	0.2
Abandoned Railroad (1)	N/A	1866+25	N/A	51	10	63	10
Burr Street/William Street	2308780	1877+00	Madison County	46	33	63	10
US-20	1010550	1886+00	NYSDOT	79	46	63	10
Mill Street	2308770	1899+75	Madison County	75	42	62	0.2
Abandoned Railroad (2) [2]	N/A	1990+50	N/A	65	26	54	0.2
Rippleton Cross Road	2308760	2002+50	Madison County	73	27	54	0.2
Access Road (3) [2]	N/A	2027+25	N/A	32	12	54	< 10
Ballina Road	2308750	2134+00	Madison County	66	24	52	0.2
Abandoned Railroad (3) [2]	N/A	2143+50	N/A	48	16	52	0.2
East Road/CR-65	3358070	2245+00	Madison County	38	27	50	No FIS data
Access Road (4) [2]	N/A	2335+75	N/A	30	12	48	No FIS data
Constine Bridge Road/CR-50	3308740	2342+25	Madison County	48	27	48	No FIS data
Abandoned Railroad (4) [2]	N/A	2385+50	N/A	44	10	47	No FIS data
Lyon Road	2205200	2472+00	Madison County	27	18	32	No FIS data

[1] Structure Width is measured parallel to creek flow and refers to the curb-to-curb width, which is the minimum distance between the curbs or the bridge railings (if there are no curbs), to the nearest 30mm or tenth of a foot (NYSDOT 2020b).

[2] Note: Unable to field measure due to safety concerns and no publicly available data for structural measurements. Orthoimagery and GIS spatial analysis tools were used to approximate structural measurements.

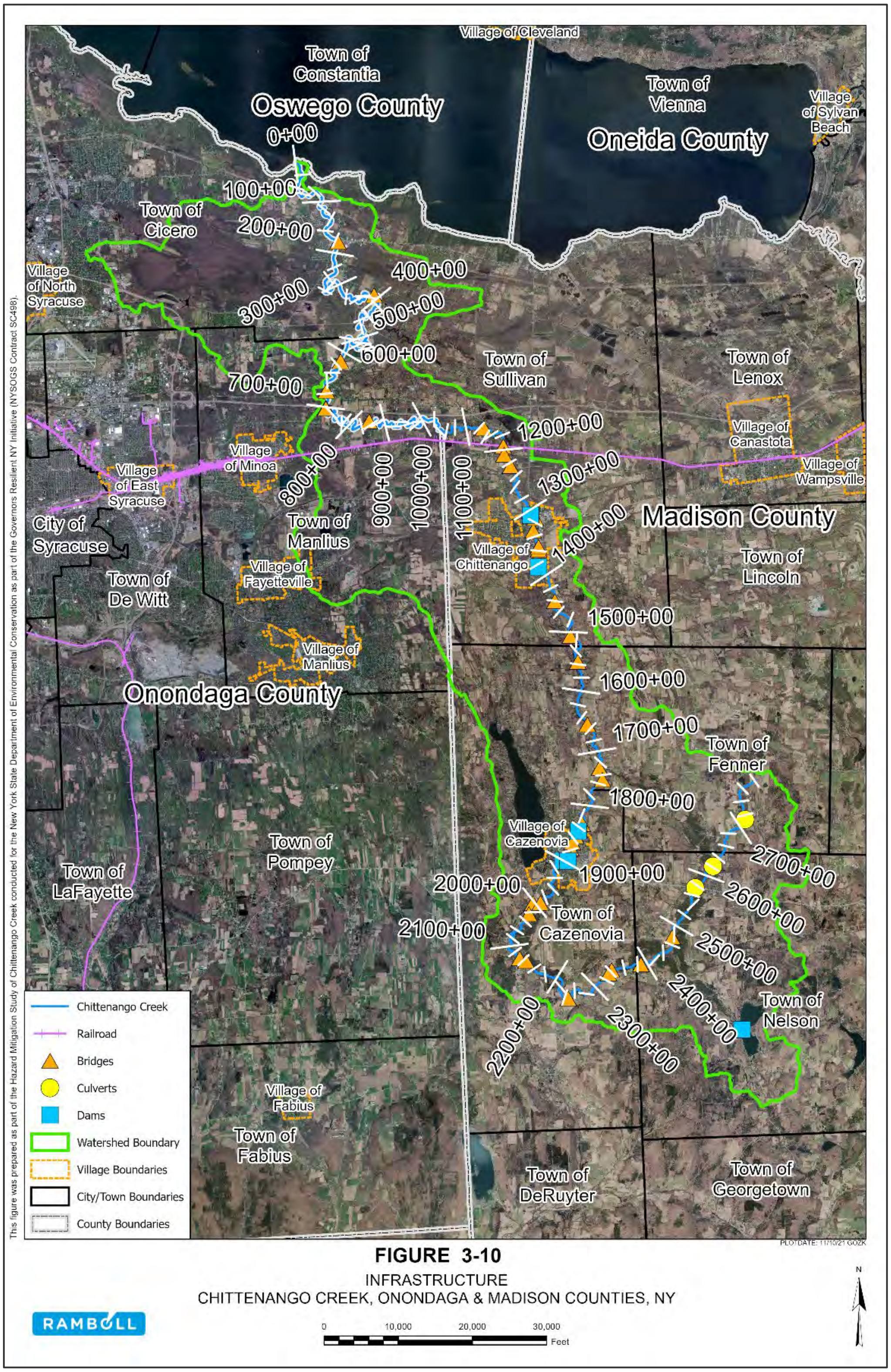

Figure 3-10. Chittenango Creek infrastructure, Onondaga and Madison Counties, NY.

3.7 HYDRAULIC CAPACITY

Hydraulic capacity is the measure of the amount of water that can pass through a structure or watercourse. Hydraulic design is an essential function of structures in watersheds. Exceeding the capacity can result in damages or flooding to surrounding areas and infrastructure (Zevenbergen et al. 2012). In assessing hydraulic capacity of the culverts and bridges along Chittenango Creek, the FEMA FIS profiles in the Towns of Sullivan and Cazenovia were used to determine the lowest annual chance flood elevation to flow under the low chord of a bridge or culvert, without causing an appreciable backwater condition upstream (see Tables 9 and 10).

In New York State, hydraulic and hydrologic regulations for bridges and culverts were developed by the NYSDOT. The NYSDOT guidelines require a factor of safety for bridges that cross waterways, known as freeboard. Freeboard is the additional capacity, usually expressed as a distance in feet, in a waterway above the calculated capacity required for a specified flood level, usually the base flood elevation. Freeboard compensates for the many unknown factors that could contribute to flood heights being greater than calculated, such as wave action, minor silt and debris deposits, the hydrological effect of urbanization of the watershed, etc. However, freeboard is not intended to compensate for higher floods expected under future climatic conditions, such as those due to sea-level rise or more extreme precipitation events (NYSDEC 2020b). Table 11 displays the 1% annual chance flood levels (feet NGVD29) and freeboard height (feet) at FEMA FIS infrastructure locations using the Towns of Sullivan and Cazenovia FIS profiles for Chittenango Creek.

Table 11. FEMA FIS 1% Annual Chance Flood Hazard Levels and Freeboard Values

(Source: FEMA 1984a; FEMA 1986c)

Infrastructure Crossing / Name	River Station (ft)	1-Percent WSEL (ft NGVD)	2-Percent WSEL (ft NGVD)	Freeboard for 2-Percent ACE (ft)
Lake Road / NY-31	184+00	381.5	381.0	1.5
Oxbow Road	387+00	391.0	390.5	— 3.0
Peck Road	613+00	396.0	395.5	— 1.5
Fyler Road	675+25	397.5	397.0	— 2.0
I-90 WB	700+75	400.0	399.5	— 1.0
I-90 EB	701+75	400.0	399.5	— 1.0
N Kirkville Road	854+50	404.0	403.5	— 3.5
Bolivar Road	1127+00	413.5	412.0	— 2.0
CSXT Railroad	1195+00	414.5	414.0	— 0.5
Pipe Crossing	1206+50	417.0	416.5	— 2.5
McGraw Road	1224+00	418.0	417.5	— 2.5
Tuscarora Road	1314+00	439.5	439.0	— 1.5
Russell Street	1331+50	443.5	443.0	2.0

(Source: FEMA 1984a; FEMA 1986c)				
Infrastructure Crossing / Name	**River Station (ft)**	**1-Percent WSEL (ft NGVD)**	**2-Percent WSEL (ft NGVD)**	**Freeboard for 2-Percent ACE (ft)**
Genesee Street / NY-5	1354+50	457.0	456.0	1.5
Madison Street	1358+75	458.5	458.0	0.5
Dyke Road	1440+25	499.0	498.5	3.0
Access Road (1)	1556+50	577.5	577.0	— 3.0
Gorge Road / NY-13	1652+75	880.0	879.5	6.0
Bingley Road	1728+25	1,004.0	1,002.5	2.5
Access Road (2)	1750+00	1,038.0	1,037.5	— 4.0
Treatment Plant Road	1833+50	1,148.5	1,148.0	2.5
Clark Street	1856+00	1,169.5	1,169.0	5.5
Abandoned Railroad (1)	1866+25	1,177.5	1,177.0	0.0
Burr Street / William Street	1877+00	1,180.5	1,180.0	2.0
US-20	1886+00	1,188.5	1,187.5	— 1.0
Mill Street	1899+75	1,194.0	1,194.0	5.5
Abandoned Railroad (2)	1990+50	1,214.0	1,213.5	11.5
Rippleton Cross Road	2002+50	1,218.5	1,218.0	2.5
Access Road (3)	2027+25	1,229.0	1,228.5	3.5
Ballina Road	2134+00	1,253.0	1,252.5	2.0
Abandoned Railroad (3)	2143+50	1,256.5	1,256.5	13.0

* Note: Negative freeboard heights indicate overtopping and are measured from the low chord of a bridge up to the computed water surface elevation.

The term “bridge” shall apply to any structure whether single or multiple span construction with a clear span in excess of 20 feet when measurement is made horizontally along the center line of roadway from face to face of abutments or sidewalls immediately below the copings or fillets; or, if there are no copings or fillets, at six inches below the bridge seats or immediately under the top slab, in the case of frame structures. In the case of arches, the span shall be measured from spring line to spring line. All measurements shall include the widths of intervening piers or division walls, as well as the width of copings or fillets (NYSDOT 2020b).

According to the NYSDOT Bridge Manual (2019) for Onondaga County (Region 3) and Madison County (Region 2), new and replacement bridges are required to meet certain standards, which include (NYSDOT 2019a):

- The structure will not raise the water surface elevations anywhere when compared to the existing conditions for both the 2 and 1% ACE (50- and 100-yr flood) flows.
- The proposed low chord shall not be lower than the existing low chord.
- A minimum of 2'-0" of freeboard for the projected 2% ACE (50-yr flood) is required for the proposed structure. The freeboard shall be measured at the lowest point of the superstructure between the two edges of the bottom angle for all structures.
- The projected 1% ACE (100-yr flood) flow shall pass below the proposed low chord without touching it.
- The maximum skew of the pier to the flow shall not exceed 10 degrees.

For culverts, the NYSDOT guidelines require designs to be based upon an assessment of the likely damage to the highway and adjacent landowners from a given flow, and the costs of the drainage facility. The design flood frequency for drainage structures and channels is typically the 2% (50-yr) annual chance flood hazard for Interstates and other Freeways, Principal Arterials, and Minor Arterials, Collectors, Local Roads, and Streets. If the proposed highway is in an established regulatory floodway or floodplain, then the 1% (100-yr) annual chance flood hazard requirement must be checked (NYSDOT 2018).

The term "culvert" is defined as any structure, whether of single or multiple-span construction, with an interior width of 20 feet or less when the measurement is made horizontally along the center line of the roadway from face-to-face of abutments or sidewalls (NYSDOT 2020b).

In assessing the hydraulic capacity of culverts, NYSDOT highway drainage standards require the determination of a design discharge (e.g., 50-yr flood) through the use of flood frequencies. The design flood frequency is the recurrence interval that is expected to be accommodated without exceeding the design criteria for the culvert. There are four recommended methodologies: The Rational Method, the Modified Soil Cover Complex Method, historical data, and the regression equations. Each method should be assessed and the most appropriate method for the specific site should be used to calculate the design flood frequency and discharge (NYSDOT 2018).

In response to climate change, NYSDOT highway drainage standards require current peak flows shall be increased to account for future projected peak flows for culvert design. Based on the USGS *FutureFlow* software, calculated flows in Onondaga County (Region 3) shall be increased by 10%, and Madison County (Region 2) shall be increased by 20%. These flow increases shall be applied for all methodologies used to determine current flow rates (NYSDOT 2018).

To assess hydraulic capacity for this study, the USGS *StreamStats* tool was used to calculate the bankfull widths and discharge for each structure along Chittenango Creek. Table 12 indicates that the majority of structures crossing Chittenango Creek do not have the appropriate width to successfully pass a bankfull discharge event, including major crossings such as Genesee Street/NY-5 and Madison Street in the Village of Chittenango and Burr Street/William Street in the Village of Cazenovia.

The structures with bankfull widths that are wider than or close to the structures width, such as the CSXT Railroad and Wyss Road, indicate that water velocities have to slow and contract in order to pass through the structures, which can cause sediment depositional aggradation and the accumulation of sediment and debris. Aggradation can lead to the development of sediment and sand bars, which can cause upstream water surfaces to rise, increasing the potential for overtopping banks or backwater flooding. Since the bankfull discharge required for water surface elevations to reach the bankfull width is low (e.g., 80% ACE), the likelihood of relatively low-flow events causing backwater and potential flooding upstream of these structures is fairly high.

Table 12. Hydraulic Capacity of Potential Constriction Point Bridges Crossing Chittenango Creek

(Source: NYSDOT 2019b; NYSDOT 2019c; USGS 2020; NYSDEC 2021b; NYSDOT 2021)

Structure Carried	Type	River Station (ft)	Structure Width [1] (ft)	Bankfull Width (ft)	Bankfull Discharge (cfs)	Annual Chance Flood Event Equivalent [2]
Oxbow Road	Bridge	387+00	124	145	2,940	> 80-percent
N Kirkville Road	Bridge	854+50	60	90	1,280	> 80-percent
Bolivar Road	Bridge	1127+00	70	88	1,240	> 80-percent
CSXT Railroad	Bridge	1195+00	85	82	1,100	> 80-percent
McGraw Road	Bridge	1224+00	79	82	1,090	> 80-percent
Tuscarora Road	Bridge	1314+00	69	79	1,040	> 80-percent
Russell Street	Bridge	1331+50	81	79	1,030	> 80-percent
Genesee Street / NY-5	Bridge	1354+50	84	79	1,030	> 80-percent
Madison Street	Bridge	1358+75	68	77	995	> 80-percent
Dyke Road	Bridge	1440+25	64	75	949	> 80-percent
Olmstead Road	Bridge	1506+25	66	74	929	> 80-percent
Access Road (1)	Bridge	1556+50	48	73	904	80-percent
Bingley Road	Bridge	1728+25	53	66	771	80-percent
Access Road (2)	Bridge	1750+00	50	65	748	> 66.7-percent
Treatment Plant Road	Bridge	1833+50	53	64	728	> 66.7-percent
Clark Street	Bridge	1856+00	44	63	717	> 66.7-percent
Abandoned Railroad (1)	Bridge	1866+25	51	63	717	> 66.7-percent
Burr Street / William Street	Bridge	1877+00	46	63	709	> 66.7-percent
Access Road (3)	Bridge	2027+25	32	54	550	80-percent
Abandoned Railroad (3)	Bridge	2143+50	48	52	516	80-percent

(Source: NYSDOT 2019b; NYSDOT 2019c; USGS 2020; NYSDEC 2021b; NYSDOT 2021)						
Structure Carried	**Type**	**River Station (ft)**	**Structure Width [1] (ft)**	**Bankfull Width (ft)**	**Bankfull Discharge (cfs)**	**Annual Chance Flood Event Equivalent [2]**
East Road/CR-65	Bridge	2245+00	38	50	484	80-percent
Access Road (4)	Bridge	2335+75	30	48	455	80-percent
Constine Bridge Road/CR-50	Bridge	2342+25	48	48	453	80-percent
Abandoned Railroad (4)	Bridge	2385+50	44	47	444	80-percent
Lyon Road	Bridge	2472+00	27	32	223	80-percent
US-20	Culvert	2575+00	15	22	122	80-percent
Nelson Road	Culvert	2622+00	18	20	99.5	> 80-percent
Wyss Road	Culvert	2714+00	12	11	35.7	> 80-percent

[1] Structure Width is measured perpendicular to flow.

[2] Annual Chance Flood Event Equivalent describes the equivalent annual chance flood event for the given bankfull discharge as calculated by the USGS *StreamStats* application. The 80-percent annual chance flood event is equal to a 1.25-yr recurrence interval.

4. CLIMATE CHANGE IMPLICATIONS

4.1 FUTURE PROJECTED STREAM FLOW FOR CHITTENANGO CREEK

In New York State, climate change is expected to exacerbate flooding due to projected increases of 1 to 8% in total annual precipitation coupled with increases in the frequency, intensity, and duration of extreme precipitation events (events with more than 1, 2, or 4 inches of rainfall) (Rosenzweig et al. 2011). In response to these projected changes in climate, NYS passed the Community Risk and Resiliency Act (CRRA) in 2014. In accordance with the guidelines of the CRRA, the NYSDEC released the *New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act* (2020) report. In the report, two methods for estimating projected future discharges were discussed: an end of design life multiplier and the USGS *FutureFlow Explorer* map-based web application (NYSDEC 2020b).

USGS *FutureFlow Explorer* v1.5 is discussed as a potential tool to project peak flows under various climate scenarios into the future (USGS 2016). *FutureFlow* was developed by the USGS in partnership with the NYSDOT. This application is an extension for the USGS *StreamStats* map-based web application and projects future stream flows in New York State. The USGS team examined 33 global climate models and selected five that best predicted past precipitation trends in the region. The results were then downscaled to apply to all six hydrologic regions of New York State. Three time periods can be examined: 2024-2049, 2050-2074 and 2075-2099, as well as two Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathway (RCP) greenhouse gas emission scenarios: RCP 4.5 and RCP 8.5. RCP 4.5 is considered a midrange-emissions scenario, and RCP 8.5 is a high-emissions scenario (Taylor et al. 2011; NYSDEC 2020b).

In general, climate models are better at forecasting temperature than precipitation and contain some level of uncertainty with their calculations and results. The USGS recommends using *FutureFlow* projections as qualitative guidance to see likely trends within any watershed, and as an exploratory tool to inform selection of appropriate design flow. Current future flood projection models will not provide accurate results for basins that extend across more than one hydrologic region in New York (NYSDEC 2020b).

Based on the current future flood projection models, flood magnitudes are expected to increase in nearly all cases in New York State, but the magnitudes vary among regions. While the *FutureFlow* application is still being upgraded, it can be used with appropriate caution. Climate model forecasts are expected to improve and as they do, the existing regression approach will be tested and refined further (NYSDEC 2020b).

In an effort to improve flood resiliency of infrastructure in light of future climate change, the NYSDEC outlined infrastructure guidelines for bridges and culverts (NYSDEC 2020b). For bridges, the minimum hydraulic design criteria are 2 feet of freeboard over the 2% annual chance flood elevation, while still allowing the 1% annual chance event flow to pass under the low chord of the bridge without going into pressure flow. For critical bridges, the minimum hydraulic design criteria are 3 feet of freeboard over the 2% annual chance flood elevation. A critical bridge is considered to be vital infrastructure that the incapacity or destruction of such would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters (NYSDEC 2020b; NYSDOT 2019a; USDHS 2010).

For culverts, the minimum hydraulic design criteria are 2 feet of freeboard over the 2% annual chance flood elevation. For critical culverts, the CRRA guidelines recommend 3 feet of freeboard over the 1% annual chance flood elevation. A critical culvert is considered to be vital infrastructure that the incapacity or destruction of such would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters (NYSDEC 2020b; NYSDOT 2018; USDHS 2010).

The NYSDEC recommends that future peak flow conditions should be adjusted by multiplying relevant peak flow parameters by a factor specific to the expected service life of the structure and geographic location of the project. For Onondaga County, the recommended design-flow multiplier is 10% increased flow for an end of design life of 2025-2100, while in Madison County the recommended design-flow multiplier is 20% increased flow (NYSDEC 2020b). Due to the fact that the Chittenango Creek watershed is predominantly located in Madison County, the design-flow multiplier of 20% increased flow was used in this study. Table 13 provides a summary of the projected future peak stream flows using the FEMA FIS peak discharges and 20% CRRA design multiplier.

Table 13. Chittenango Creek Projected Peak Discharges

(Source: FEMA 1984a; FEMA 1986c)						
			Peak Discharges (cfs)			
Flooding Source and Location	**Drainage Area (Sq. Miles)**	**River Station (ft)**	**10-Percent**	**2-Percent**	**1-Percent**	**0.2-Percent**
Confluence with Oneida Lake	288	0+00	14,508	20,592	22,464	28,800
At State Route 31 in Bridgeport	282	182+50	14,232	20,196	22,032	25,800
Confluence of Limestone Creek	101.4	659+00	5,256	7,620	8,664	11,208
At downstream corporate limits of Village of Chittenango	74.9	1312+50	4,128	5,976	6,804	8,796
At USGS Gage No. 0424400	67.7	1446+00	3,804	5,520	6,276	8,112
At downstream corporate limits of Town of Cazenovia	65	1533+00	3,680	5,336	6,071	7,848
Upstream of Bingley Road	53.3	1730+00	2,555	3,588	4,092	5,220
At downstream corporate limits of Village of Cazenovia	49.2	1832+00	2,267	3,156	3,588	4,548
At upstream corporate limits of Village of Cazenovia	34.2	1942+00	1,788	2,555	2,940	3,816

Appendix H contains the HEC-RAS simulation summary sheets for the proposed and future condition simulations. The HEC-RAS model simulation results for the future condition model parameters using the future projected discharge values are similar to the base-condition model output, with the only difference being future projected water surface elevations are up to 4.2 ft higher at specific locations, generally upstream of bridges or dams due to backwater, as a result of the increased discharges.

Table 14 provides a comparison of HEC-RAS existing condition (using FEMA FIS peak discharges) and future condition (using CRRA 20% design flow multiplier) water surface elevations at select locations along Chittenango Creek.

Table 14. HEC-RAS Base and Future Conditions Water Surface Elevation Comparison

(Source: FEMA 1984a; FEMA 1986c; USACE 2020)						
			Water Surface Elevations (ft NAVD88) [1]			
Flooding Source and Location	**Drainage Area (mi^2)**	**River Station (ft)**	**10-Percent**	**2-Percent**	**1-Percent**	**0.2-Percent**
Confluence with Oneida Lake	288	0+00	+ 0.4	+ 0.5	+ 0.6	+ 0.6
At State Route 31 in Bridgeport	282	182+50	+ 0.8	+ 1.1	+ 1.1	+ 1.3
Confluence of Limestone Creek	101.4	659+00	+ 1.1	+ 3.4	+ 0.2	+ 0.2
At downstream corporate limits of Village of Chittenango	74.9	1312+50	+ 0.2	+ 0.2	+ 0.3	+ 0.3
At USGS Gage No. 0424400	67.7	1446+00	+ 0.7	+ 2.8	+ 1.2	+ 0.6
At downstream corporate limits of Town of Cazenovia	65	1533+00	+ 0.4	+ 0.4	+ 0.4	+ 0.5
Upstream of Bingley Road	53.3	1730+00	0.0	+ 0.5	+ 0.6	+ 0.6
At downstream corporate limits of Village of Cazenovia	49.2	1832+00	+ 0.7	+ 1.0	+ 0.6	+ 0.7
At upstream corporate limits of Village of Cazenovia	34.2	1942+00	+ 0.4	+ 0.5	+ 0.6	+ 0.7

[1] Positive changes in water surface elevation indicate the future conditions water surface elevation is higher than the existing condition.

5. FLOODING CHARACTERISTICS

5.1 FLOODING HISTORY

The history of flooding along Chittenango Creek indicates that flooding can occur during any season of the year. Most major floods have occurred in March, April, and May and are usually the result of spring rains and snowmelt. Storms occurring during the early summer months are often associated with tropical storms moving up the Atlantic coast (FEMA 1986c).

In the Town of Sullivan, including the Village of Chittenango, a number of major flood events occurred in the late nineteenth and early twentieth centuries, including the Great Floods of 1840, 1865, 1897, and 1901, that flooded roads, washed out bridges, and inundated large areas for days. Two benchmark flood events occurred, due to Hurricane Agnes in June of 1972, and a snowmelt and rain event in January of 1996. During both of these events, water overflowed Chittenango Creek inundating roadways, residences, and businesses in both the Town and Village. In 2004, two different heavy rain events in May and August caused Chittenango Creek to overflow its banks causing flooding to roadways and residences, and erosion and soil deposition (MCEM 2016).

In the Town of Cazenovia, including the Village of Cazenovia, flooding has become a significant issue primarily in the twenty-first century. Flash flood events have occurred in 1996, 2000, 2001, 2003, 2005, and 2006. In the Town of Cazenovia, the benchmark flood event occurred during the Spring of 2000 when multiple storms between May and June caused widespread flooding and received a presidential disaster declaration (FEMA 1335 DR-NY). In the Village of Cazenovia, the benchmark flood event was the January 1996 flood, which was a run-off event caused by rain and melting snow and received a presidential disaster declaration (FEMA 1095 DR). Problematic flooding areas were identified near Mill Street from Chittenango Creek into the outlet of Cazenovia Lake, and from the Town & Country Plaza down towards the Burr and Williams Street Bridge in the Village of Cazenovia (MCEM 2016; NCEI 2021; NYSDEC 2021b).

More recently in 2017, a tropical moisture-laden air mass produced numerous showers and thunderstorms which traveled repeatedly over the same areas of the Finger Lakes Region and Upper Mohawk Valley. Widespread flash and urban flooding developed in portions of Cayuga, Onondaga, Madison and Oneida counties. Total rainfall amounts along a narrow corridor from Moravia to Utica generally ranged from 2.5 to 5 inches, most of which fell in less than 1 to 2 hours. In the Town of Sullivan, culverts and roads were washed out in several places while numerous residences experienced flooding, especially along Chittenango Creek (NCEI 2021).

In addition to flooding issues, municipalities along Chittenango Creek experience erosion, sediment aggradation, and tree and debris blockages. There are issues of erosion in the agricultural areas upstream of the Village of Chittenango where bank erosion and overland run-off carries sediments and gravel downstream into the Village. This sediment and gravel can deposit on the upstream face of bridges and culverts restricting flow and causing overflow into nearby structures. Log and debris jams are a known issue within the Chittenango Creek watershed with cooperating municipalities engaged in a log clearing program from the Village of Chittenango downstream to Oneida Lake (MCEM 2016; NYSDEC 2021b).

According to FEMA flood loss data, there has been a total of 21 NFIP claims totaling approximately $336,199 in building and contents payments within the Town of Sullivan and Villages of Chittenango and Cazenovia from 1979 to 2016. Table 15 summarizes the total number of NFIP policies, claims, loss payments, and repetitive loss properties for the Village of Arcade and Towns of Arcade and Freedom.

Table 15. FEMA NFIP Summary Statistics for Madison County, NY from 1979 to 2016

(Source: MCEM 2016)			
Community Name	**No. of Losses**	**Date Of Losses**	**Total Paid ($ USD)**
Cazenovia (Village)	2	10/28/1981 6/5/1979	$14,095
Cazenovia (Village)	3	4/3/2005 1/19/1996 4/11/1993	$9,678
Chittenango (Village)	2	8/6/2003 1/19/1996	$22,642
Chittenango (Village)	2	8/10/2003 1/19/1996	$4,203
Sullivan (Town)	2	6/28/2006 4/2/2005	$32,403
Sullivan (Town)	2	10/29/2012 8/28/2011	$191,580
Sullivan (Town)	2	4/18/1994 4/10/1993	$11,773
Sullivan (Town)	2	10/29/2012 10/14/2005	$32,824
Sullivan (Town)	2	4/18/1994 4/12/1993	$11,031
Sullivan (Town)	2	4/16/1994 4/11/1993	$5,970

A Repetitive Loss (RL) property is any insurable building for which two or more claims of more than $1,000 were paid by the NFIP within any rolling 10-yr period, since 1978. A Severe Repetitive Loss (SRL) property is any insurable building for which four or more claims of more than $5,000 (or cumulative amount exceeding $20,000) were paid by the NFIP, or at least two separate claim payments have been made with the cumulative amount exceeding the fair market value of the insured building on the day before each loss within any rolling 10-yr period, since 1978 (FEMA 2019; FEMA 2020).

It is important to note that the FEMA flood loss data only represents losses for property owners who participate in the NFIP and have flood insurance.

Figures 5-1 through 5-3 display the Zone A (1% ACE) boundaries for Chittenango Creek, as determined by FEMA, for the lower reach in the Town of Sullivan, Village of Chittenango, and Town of Cazenovia, including the Village of Cazenovia, respectively (FEMA 1996). The maps indicate that in the Chittenango Creek watershed, the areas that are considered high flood-risk areas include:

- The reach downstream of the confluence of Limestone and Chittenango Creeks and the Hamlet of Bridgeport in the Town of Sullivan
- The area between the Old Erie Canal and the upstream Village of Chittenango corporate limits
- The area between Clark Street and the upstream Village of Cazenovia corporate limits in the Town of Cazenovia

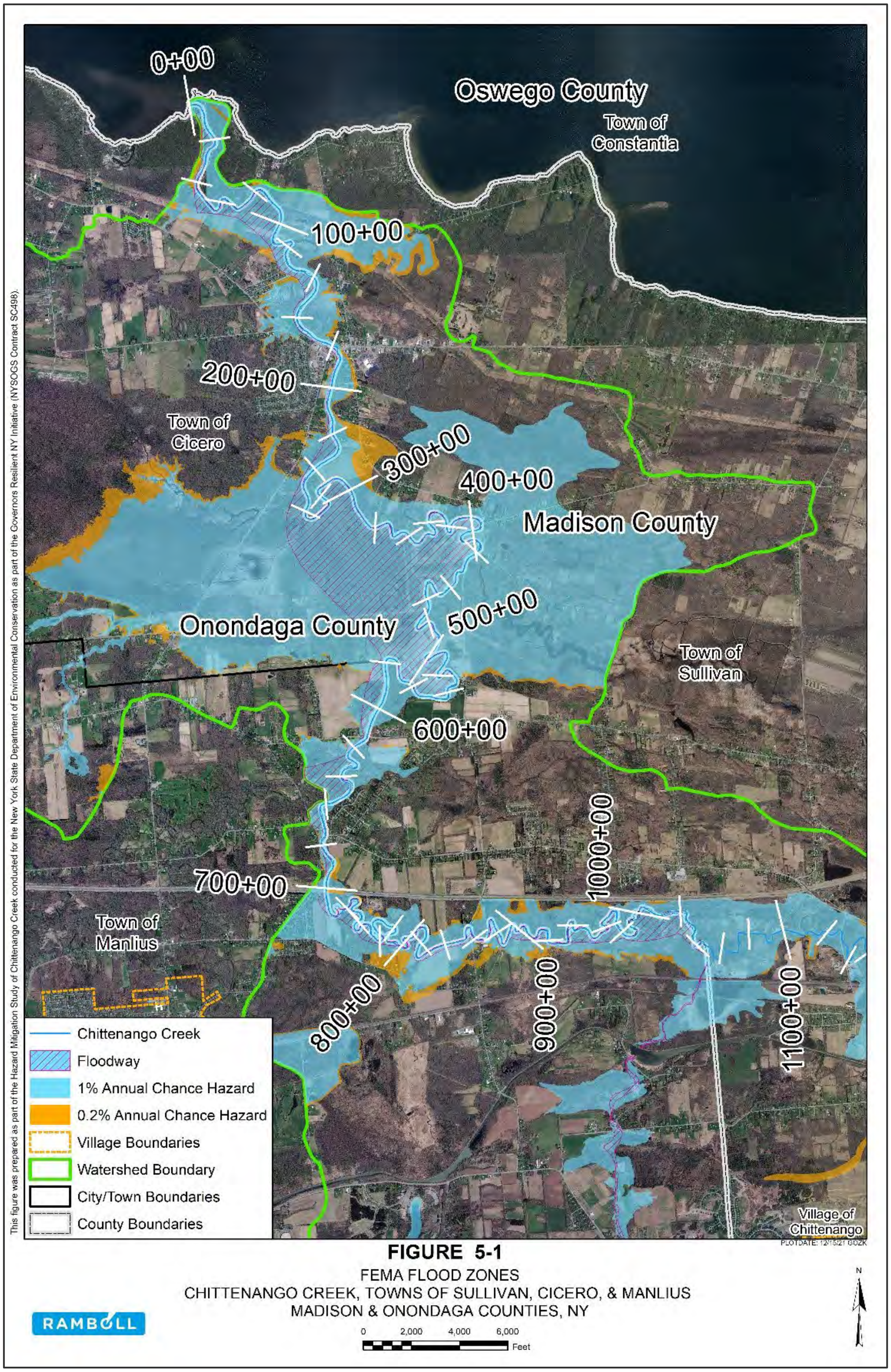

Figure 5-1. Chittenango Creek, FEMA flood zones, Town of Sullivan and Village of Chittenango, Madison County, NY.

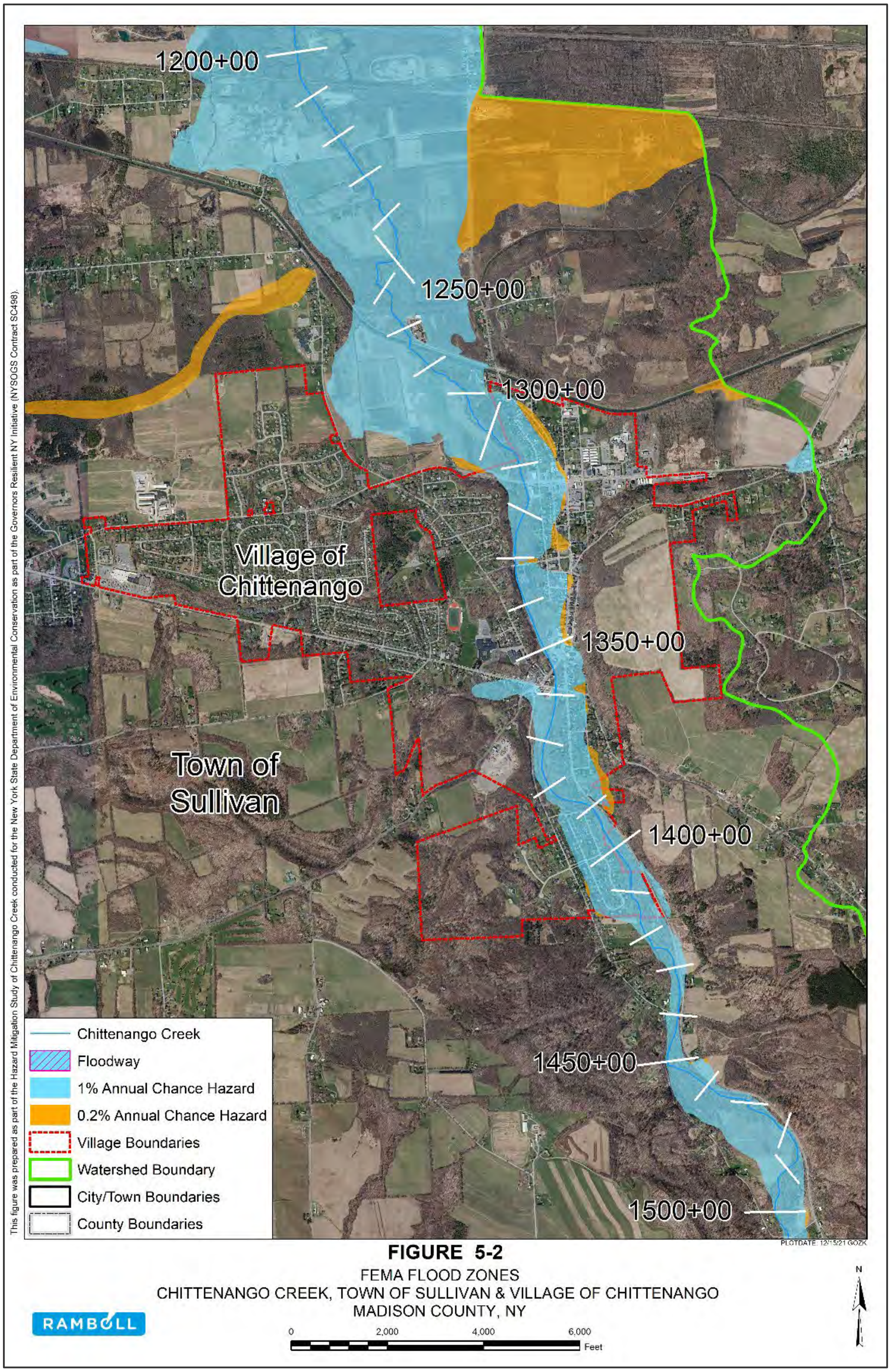

Figure 5-2. Chittenango Creek, FEMA flood zones, Village of Chittenango, Madison County, NY.

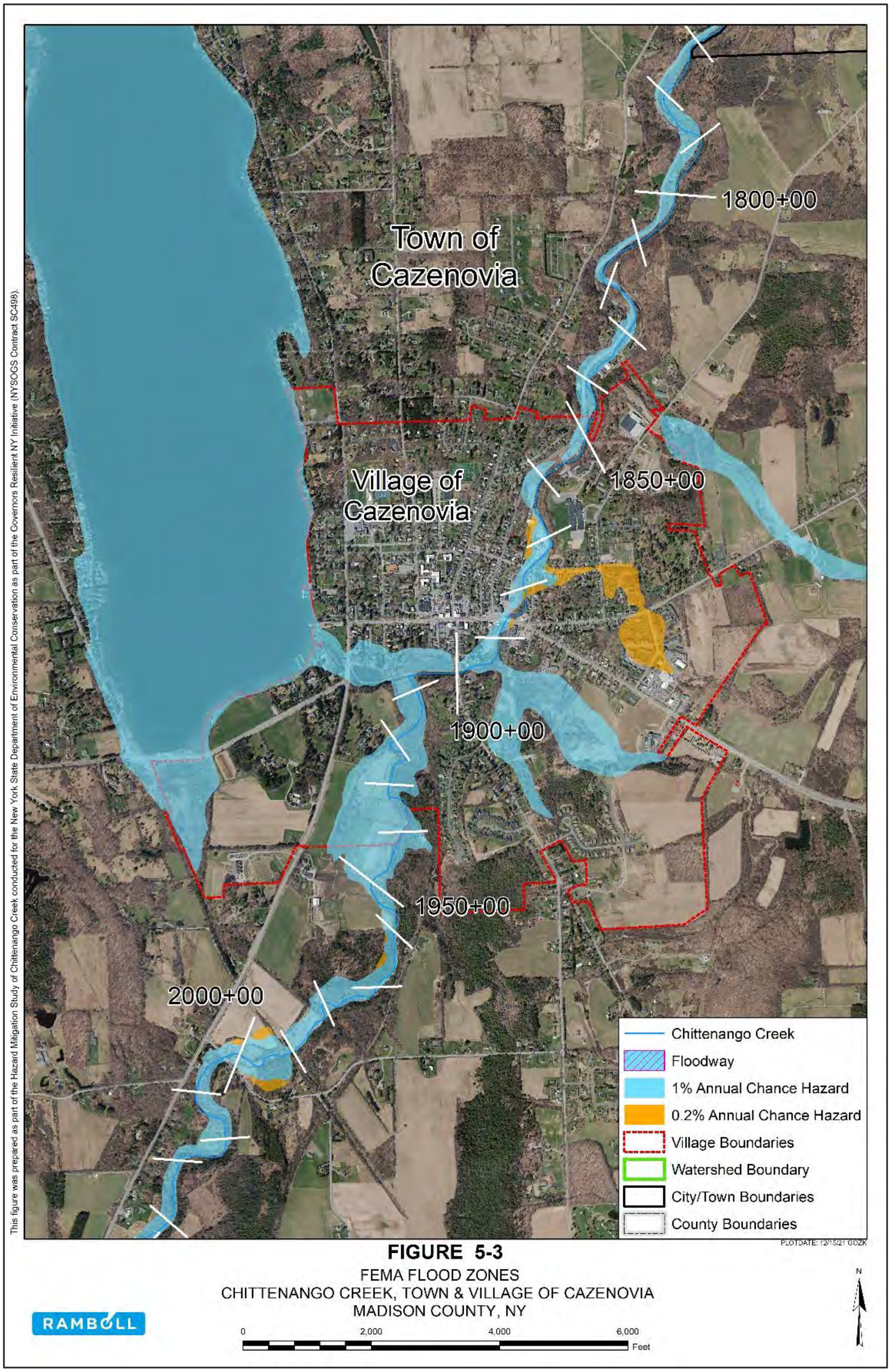

Figure 5-3. Chittenango Creek, FEMA flood zones, Town of Cazenovia and Village of Cazenovia, Madison County, NY.

5.2 ICE-JAM FLOODING

An ice jam typically occurs in the late winter and early spring in ice-covered streams when ice accumulates at man-made (e.g., bridge piers, dams) or natural narrower or shallower sections or meanders of a river slowing down or blocking the incoming ice by bridging the ice across the width of the river (USACE 2006).

As the air temperature drops, the water temperature reaches freezing temperatures and starts to form frazil ice crystals in the water column. These ice crystals travel in the water column (suspended ice) with the river currents, growing in concentration, and losing heat while traveling. They float on the surface (surface ice), and as the crystals grow in size, they form surface frazil ice. As the air temperature continues to drop, temperature losses from the water and frazil ice create more surface ice, and thicken the existing surface frazil ice, increasing the surface ice concentrations on the river as it approaches colder winter temperatures. The presence of surface and suspended frazil ice increases resistance to the flow, thus increasing the water levels of rivers in the wintertime. Increasing concentrations of surface and suspended frazil ice increase the potential for ice jam formation, which can inhibit the flow of water in the channel, affecting both upstream and downstream water levels (USACE 2006).

An existing ice jam can break-up and travel downstream along with larger ice particles with the higher flows of a flash flood and accumulate at a constricted downstream location creating another break-up ice jam, or damage downstream riverbanks or downstream infrastructures severely. Ice-jam flooding presents a complex problem for scientists and engineers since the resulting flood stage can be significantly higher than the flood stage caused from streamflow alone. In other words, a relatively minor discharge of streamflow can result in a major flooding event during an ice jam (USACE 2006).

According to the USACE Cold Regions Research and Engineering Laboratory (CRREL) ice jam database, National Centers for Environmental Information (NCEI) storm events database, and the stakeholder engagement meeting, there have been at least two ice-jam flooding events along Chittenango Creek since 1950 (CRREL 2021; NCEI 2021; NYSDEC 2021b).

On January 20, 2004, the NYS Emergency Management Office reported that the Village of Chittenango was forced to close Tuscarora Road due to the formation of an ice jam immediately upstream of the Old Erie Canal along Chittenango Creek which backed water onto Tuscarora Road and flooded adjacent properties. On February 11, 1962, the USGS reported that the gage on Chittenango Creek near the Village of Chittenango indicated a maximum annual gage height of 5.16 feet due to an ice jam and backwater flooding (CRREL 2021).

Based on the historical ice-jam records and stakeholder input, the area along Chittenango Creek with the highest potential for ice-jam formation is in the Village of Chittenango upstream of the Old Erie Canal. The study area for this report focused on the Towns of Sullivan and Cazenovia and Villages of Chittenango and Cazenovia, and includes an analysis of the effects each flood mitigation measure would have on the aforementioned ice-jam prone area. This area is vulnerable to ice-jam flooding due to a combination of infrastructure, development, and channel characteristics of Chittenango Creek.

In order to determine the most appropriate mitigation measures to address ice-jam flooding along Chittenango Creek, additional hydraulic and hydrologic modeling using ice simulation models and ice-jam specific mitigation measures, as outlined in Appendix E, are recommended for each ice-jam prone area.

6. FLOOD RISK ASSESSMENT

6.1 FLOOD MITIGATION ANALYSIS

For this study of Chittenango Creek, standard hydrologic and hydraulic study methods were used to determine and evaluate flood hazard data. Flood events of a magnitude which are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10-, 2-, 1-, and 0.2% chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than one year are considered. The analyses reported herein reflect flooding potentials based on conditions existing in the county at the time of completion of this study (FEMA 1986c).

Hydraulic analysis of Chittenango Creek was conducted using the HEC-RAS v6.1.0 program (USACE 2021). The HEC-RAS computer program was written by the USACE Hydrologic Engineering Center (HEC) and is considered to be the industry standard for riverine flood analysis. The model is used to compute water surface profiles for 1-Dimensional (1-D) and 2-Dimensional (2-D), steady-state, or time-varied (unsteady) flow. In 1-D solutions, the water surface profiles are computed from one cross section to the next by solving the one-dimensional St. Venant equation with an iterative procedure (i.e., standard step backwater 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 (USACE 2016b).

Hydraulic and Hydrologic modeling of Chittenango Creek was completed by FEMA between 1984 and 1986 in Madison County, and 1992 to 1994 in Onondaga County. Due to the age and format of the FIS studies, an updated 1-D HEC-RAS model was developed using the following data and software:

- Madison County, New York 1-meter LiDAR DEM data with vertical accuracy of 0.143-meters (6 inches) in the North American Vertical Datum of 1988 (NAVD88) (NYSOITS 2015)
- New York State Digital Ortho-Imagery Program imagery (NYSOITS 2017)
- National Land Cover Database (NLCD) data (USGS 2021a)
- RAS Mapper extension in HEC-RAS software (USACE 2021)
- CivilGeo GeoHECRAS version 3.1 software (CivilGeo, Inc. 2021)
- NYSDOT bridge and culvert data (NYSDOT 2019b; NYSDOT 2019c)
- NYSDEC dams data (NYSDEC 2021c)

The hydraulics model was developed for Chittenango Creek beginning at the confluence with Oneida Lake (river station 0+00) and extending to the upstream corporate limits of the Village of Cazenovia (river station 1983+00).

6.1.1 Methodology of HEC-RAS Model Development

Using the LiDAR DEM data, orthoimagery, land cover data, and the RAS Mapper extension in the HEC-RAS software, an existing condition hydraulic model was developed from the effective FEMA hydraulic model using the following methodology:

- LiDAR DEM converted from horizontal North American Datum of 1983 (NAD83) Universal Transverse Mercator (UTM) coordinate system to the New York State Plane Central to convert DEM units from meters to feet;
- Main channel, bank lines, flow paths, and cross-sections, which were drawn along the main channel at stream meanders, contraction/expansion points, and at structures, were digitized in RAS Mapper;
- These features were then imported into the CivilGeo GeoHECRAS software and using the GeoHECRAS software, LiDAR DEM data, and NLCD land cover data, terrain profiles with elevations, cross-section downstream reach lengths, and Manning’s n Values were assigned to each cross-section;
- These features were then imported into HEC-RAS where a 1-D steady flow simulation was performed using USGS *StreamStats* peak discharges.

Downstream boundary conditions for the base and future conditions models were assessed using two different methods: Normal Depth and the FEMA FIS stillwater elevations.

Normal depth was calculated using the friction slope (S_f in Manning's equation), which is the slope of the energy grade line, and can be estimated by measuring the slope of the bed at the downstream reach (USACE 2022). For this model, the slope between the last three cross sections was used and calculated to be 0.000067.

The Oneida Lake stillwater elevations were determined by FEMA in the Town of Sullivan and Onondaga County FIS reports (FEMA 1986c; FEMA 2016). The Town of Sullivan FIS stillwater elevations are reported in the National Geodetic Vertical Datum of 1929 (NGVD29) vertical datum and was converted to the NAVD88 datum using the National Oceanic and Atmospheric Administration (NOAA) Vertical Datum Coordinate Conversion Program (VERTCON) version 3.0 (NOAA 2019). The conversion factor used for Chittenango Creek was -0.627 ft. Table 15 displays the Oneida Lake stillwater elevations from the Town of Sullivan and Onondaga County FIS reports.

Table 16. Oneida Lake Stillwater Elevations

(Source: FEMA 1986c; FEMA 2016)				
	Stillwater Elevation (ft NAVD88)			
FIS Report	**10-Percent**	**2-Percent**	**1-Percent**	**0.2-Percent**
Town of Sullivan	371.2	372.2	372.6	373.6
Onondaga County	372.1	372.9	373.3	374.0

The Normal Depth method was used as the downstream boundary due to the more conservative nature of the values and lack of significant backwater effect from Oneida Lake in both the Onondaga County and Town of Sullivan FEMA FIS profile plots.

The existing condition model water surface elevation results were then compared to the FEMA FIS water surface profiles, past flood events with known water surface elevations, and the effective FEMA FIS elevation profiles to validate the model. After the existing condition model was verified, it was then used to develop proposed condition models to simulate potential flood mitigation strategies. The simulation results of the proposed conditions were evaluated based on their reduction in water surface elevations.

The effectiveness of each potential mitigation strategy was evaluated based on reduction in water surface elevations within the H&H model simulations. The flood mitigation strategies that were modeled were:

- 1-2: Remove Central Piers of Lake Road/NY-31
- 1-3: Remove Central Piers and Increase the Bridge Opening of Lake Road/NY-31
- 1-4: Flood Benches Upstream/Downstream of Lake Road/NY-31
- 2-1: Sediment Removal Analysis in Vicinity of Old Erie Canal Crossing
- 2-2: Channelization of Chittenango Creek in Vicinity of Old Erie Canal Crossing
- 2-3: Flood Benches Upstream of Old Erie Canal Crossing
- 2-4: Increase the Opening of the Tuscarora Road Bridge Crossing
- 2-5: Flood Benches Between Tuscarora Road and Russell Street
- 2-6: Flood Bench Between Russell and Genesee Streets
- 2-7: Streambank Stabilization Between Russell and Genesee Streets
- 2-8: Increase the Opening of the Madison Street Bridge Crossing
- 2-9: Flood Benches Upstream of Madison Street
- 2-10: Flood Benches Upstream of the Valley Acres Neighborhood
- 3-1: Replace Chittenango Gorge Trail Bridge
- 3-2: Increase the Opening of Burr Street Bridge
- 3-3: Increase the Opening of Burr Street Culvert (Unnamed Tributary)
- 3-4: Increase the Opening of the Albany Street/US-20 Bridge Crossing
- 3-5: Flood Benches Upstream of Mill/Chenango Street
- 3-6: Restore Natural Channel Geomorphology to Chittenango Creek/Cazenovia Lake Diversion
- 3-7: Restore Natural Channel Geomorphology to Diversion and Install a Flood Bench

The remaining alternatives were either qualitative in nature or required additional advanced H&H modeling (i.e., 2-D, 3-D, etc.) outside of the scope of this study.

As the flood mitigation strategies discussed in this study are, at this point, preliminary, inundation mapping was not developed from the computed water surface profiles for each potential mitigation alternative. Inundation shown on figures in Section 7 Mitigation Alternatives is based on the computed 1-D water surface elevations statically imposed over a 2-D ground surface by the built-in RAS Mapper extension in the HEC-RAS v6.0 software. The software horizontally distributes the computed WSEL over the cross-section and any ground elevation below the computed WSEL is inundated up to the computed WSEL. As a result, areas that are not hydrologically connected to the floodplain (i.e., overbank areas) may appear inundated.

Note that stationing references for Chittenango Creek for Sections 1 through 6 of this report are based on the USGS National Hydrography Dataset (NHD) for Chittenango Creek (USGS 2021c); however, stationing references for the flood mitigation measures (Section 7) are based on the HEC-RAS model software. While every attempt was made to ensure consistency in the stationing values, the values may differ as a result of the differences in the data sources and methodologies.

6.1.2 1-D Model Limitations

For this study, a 1-D HECRAS model was developed to model the existing conditions and effectiveness of the proposed mitigation alternatives. USACE usually recommends choosing between 1-D and 2-D modeling on a case-by-case basis, but in general there are certain cases where 1-D models can produce results as good as 2-D models with less effort. Those cases include (USACE 2016a):

- Rivers and floodplains in which the dominant flow directions and forces follow the general river flow path.
- Steep streams that are highly gravity driven and have small overbank areas.
- River systems that contain a lot of bridges/culvert crossings, weirs, dams and other gated structures, levees, pump stations, etc. (these structures impact the computed stages and flows within the river system).
- Medium to large river systems, where there is modeling of a large portion of the system (100 or more miles), and it is necessary to run longer time period forecasts (i.e., 2-week to 6-month forecasts).
- Areas in which the basic data does not support the potential gain of using a 2-D model (USACE 2016a).

Based on the topographic and geomorphic features of the Chittenango Creek watershed and the recommendations of the USACE for 1-D versus 2-D modeling, the project team concluded the best model for this study was 1-D. However, after developing the 1-D model for Chittenango Creek, the project team did determine certain limitations in the 1-D model that should be noted. These limitations include:

- Potential overflow areas, which are areas where WSELs exceed the adjacent terrain geometry, were found in a number of locations along Chittenango Creek. These areas were the confluence with Oneida Lake; north Chittenango downstream of the Old Erie Canal; upstream of Interstate-90; and the confluence with Limestone Creek. The overflow areas were primarily caused by inflow areas from large tributaries, such as Limestone Creek, or outflow areas

into other watersheds or large bodies of water, such as Oneida Lake and Canaseraga Creek.
- The portion of the 1-D model that included Chittenango Falls caused supercritical flows due to the steep elevation change in this reach. Since this was the only portion of the model that had supercritical flows, a drop structure at the top of the Falls was used to modify the flow over the Falls and maintain subcritical flow.
- The accuracy of a 1-D model in determining WSELs in the overbank areas outside of the main channel diminishes the further away from the main channel the user defines an overbank area. Portions of the Chittenango Creek watershed, including the downstream reach starting in the Village of Chittenango, have wide and relatively flat floodplains, which led to relatively wide and distant overbank areas in the 1-D model. A more appropriate analysis of overbank areas would require lateral 2-D storage areas in the overbank parallel to the main channel; however, this type of analysis is outside of the scope of this study.
- In general, LiDAR does not capture channel thalweg due to interference and scattering by water of the LiDAR signal. As a result, no bathymetric modifications were done to the existing model to correct for this limitation. However, for this study, some of the flood mitigation strategies that were modeled incorporated modifications to the main channel or in the immediate overbank areas.

The 1-D model results for the existing conditions along Chittenango Creek were compared to both the FEMA FIRM and FIS profile plots and were found to be in agreement with both. Therefore, the results from the proposed flood mitigation alternatives model simulations for this study can be accepted with a high degree of confidence.

6.2 DEBRIS ANALYSIS

According to historical flood reports, stakeholder engagement meetings, and field work, the downstream portion of Chittenango Creek from the Village of Chittenango to the confluence with Oneida Lake was identified as an area susceptible to debris and log jams on the upstream face of infrastructure crossing the creek (MCEM 2016; NYSDEC 2021b).

Along Chittenango Creek in this downstream reach, there are 16 bridge and infrastructure crossings. Of the 16 infrastructure crossings, the locations of highest significance and risk are the four bridge crossings in and downstream of the Village of Chittenango (Tuscarora Road, Russell Street, Genesee Street/NY-5, and Madison Street), the Old Erie Canal structure, and the Lake Road/NY-31 bridge crossing in the hamlet of Bridgeport (MCEM 2016; NYSDEC 2021b).

The debris analysis in this study used the 10% annual chance event (10-year) to develop an existing condition with debris obstruction model simulation using the built-in Floating Pier Debris tool within the HEC-RAS model software (USACE 2021). Manual calibration of the width and height of the debris obstruction in the model was performed to reproduce historical flood levels caused by debris jams at known locations. The calibration determined that a 30% obstruction of the structure's opening reproduced the historical flood levels.

Using the calibrated debris specifications, the existing condition debris simulation model was used to test the effectiveness of the flood mitigation alternatives that influence flow through Chittenango Creek under both present and future conditions.

6.3 ICE JAM ANALYSIS

The ice jam analysis in this study used the 10% annual chance event (10-year) to develop an existing condition with ice cover model simulation at each identified ice-jam susceptible location using the built-in Ice Cover settings within the HEC-RAS model software. Where ice cover was modeled in the vicinity of bridges, the Ice Jam Computation Option under the Bridge/Culvert Data editor was changed to the option "ice remains constant through the bridge" in the HEC-RAS model software (USACE 2021).

Based on historical ice jam data, ice cover lengths and depths were obtained and input into the model. Manual calibration of the length and depth of the ice cover in the model was performed to reproduce historical flood levels caused by ice jam events at known locations. The calibration determined that an ice cover of 1 ft deep by 1,000 ft long followed by an additional ice cover of 0.5 ft by 1,000 ft long upstream of an identified structure's opening reproduced the historical flood levels.

Using the calibrated ice cover specifications, the existing condition ice-cover simulation model was used to test the effectiveness of the flood mitigation alternatives that influence flow through Chittenango Creek under both present and future conditions.

6.4 COST ESTIMATE ANALYSIS

Rough order of magnitude (ROM) cost estimates were prepared for each mitigation alternative. In order to reflect current construction market conditions, a semi-analogous cost estimating procedure was used by considering costs of a recently completed, similar scope construction project performed in Upstate New York. Phase I of the Sauquoit Creek Channel and Floodplain Restoration Project in Whitestown, New York contained many elements similar to those found in the proposed mitigation alternatives.

Where recent construction cost data was not readily available, RSMeans CostWorks 2019 was used to determine accurate and timely information (RSMeans Data Online 2019). Costs were adjusted for inflation and verified against current market conditions and trends.

For mitigation alternatives where increases in bridge sizes were evaluated, bridge size increases were initially analyzed based on 2 feet of freeboard over the base flood elevation for a 1% ACE. For mitigation alternatives where increases in culvert sizes were evaluated, culvert size increases were initially analyzed based on the NYSDOT highway drainage standards of successfully passing the 2% annual chance flood hazard.

For mitigation alternatives where increases in culvert sizes were evaluated, culvert size increases were initially analyzed based on 2 feet of freeboard over the base flood elevation for a 1% ACE. Once these optimal sizes were determined, further analysis was completed including site constraints and constructability. Due to these additional constraints, often the size necessary to meet the freeboard requirement was not feasible. Cost estimates were performed based on projects determined to be constructible and practical.

Once the optimal bridge/culvert size was determined, further analyses were completed, including site constraints and constructability. Due to these additional constraints, for some mitigation measures the size necessary to meet existing and/or CRRA freeboard requirements were not feasible. Cost estimates were only performed for projects determined to be constructible and practical.

Infrastructure and hydrologic modifications will require permits and applications to New York State and/or FEMA, including construction and environmental permits from the state and accreditation, Letter of Map Revision (LOMR), etc. applications to FEMA. Application and permit costs were not incorporated in the ROM costs estimates.

6.5 HIGH-RISK AREAS

Based on the FEMA FIS, NCEI storm events database, CRREL ice jam database, historical flood reports, and stakeholder input from engagement meetings, three areas along Chittenango Creek were identified as high-risk flood areas: the Hamlet of Bridgeport and Village of Chittenango in the Town of Sullivan, and the Village of Cazenovia in the Town of Cazenovia.

6.5.1 High-Risk Area #1: Lake Road/NY-31 Downstream to the Confluence with Oneida Lake, Town of Sullivan, NY

High-risk Area #1 is the downstream reach of Chittenango Creek from the bridge crossing at Lake Road/NY-31 in the Hamlet of Bridgeport at river station 184+00 to the confluence with Oneida Lake at river station 0+00 (Figure 6-1). Flooding in this area poses a threat to numerous residential and commercial properties near the confluence and Lake Road/NY-31.

There is a substantial number of houses located along Chittenango Creek near its confluence with Oneida Lake. These properties are located within the 1% (100-yr) floodplain and are influenced by high lake levels, especially during spring runoff. Some houses are located within the actual floodway for Chittenango Creek. Houses in this area are not allowed to build fences or other structures that will obstruct the creek's flow (NYSDEC 2021b).

According to the FEMA FIS and FIRM for the Town of Sullivan, there is significant backwater upstream of the confluence with Oneida Lake and at the Lake Road/NY-31 bridge crossing (Figure 6-2). In addition, the Lake Road/NY-31 bridge crossing does not provide the NYSDOT required 2 feet of freeboard over the 2% (50-year) annual chance event (FEMA 1986a; FEMA 1986c).

This reach is also susceptible to sediment aggradation, and tree and debris buildup from upstream sources. Aggradation and tree/debris buildup restrict the channel flow area, which can cause water surfaces to rise and potentially overtop banks or back water upstream of structures and/or meanders.

High-risk Area #1 is a protected imperiled mussel stream section. For any proposed mitigation project that would disturb the streambed below the Mean High Water Line (MHWL), the NYSDEC requires freshwater mussel surveys and the possible re-location of mussels depending on the type, scale, and timeline of the proposed work. This has implications for both construction and also for continued maintenance. The timeline for conducting the survey would need to be taken into consideration as well as budgeting for it. For example, if threatened or endangered mussels are found and moved, the applicant has minimized disruption and complied with one aspect of the Part 182 regulations. But the applicant still has a responsibility to ensure that the species is better off after the action than it was before the project occurred per regulations. Typically, the NYSDEC requires mitigation in the form of habitat replacement or enhancement.

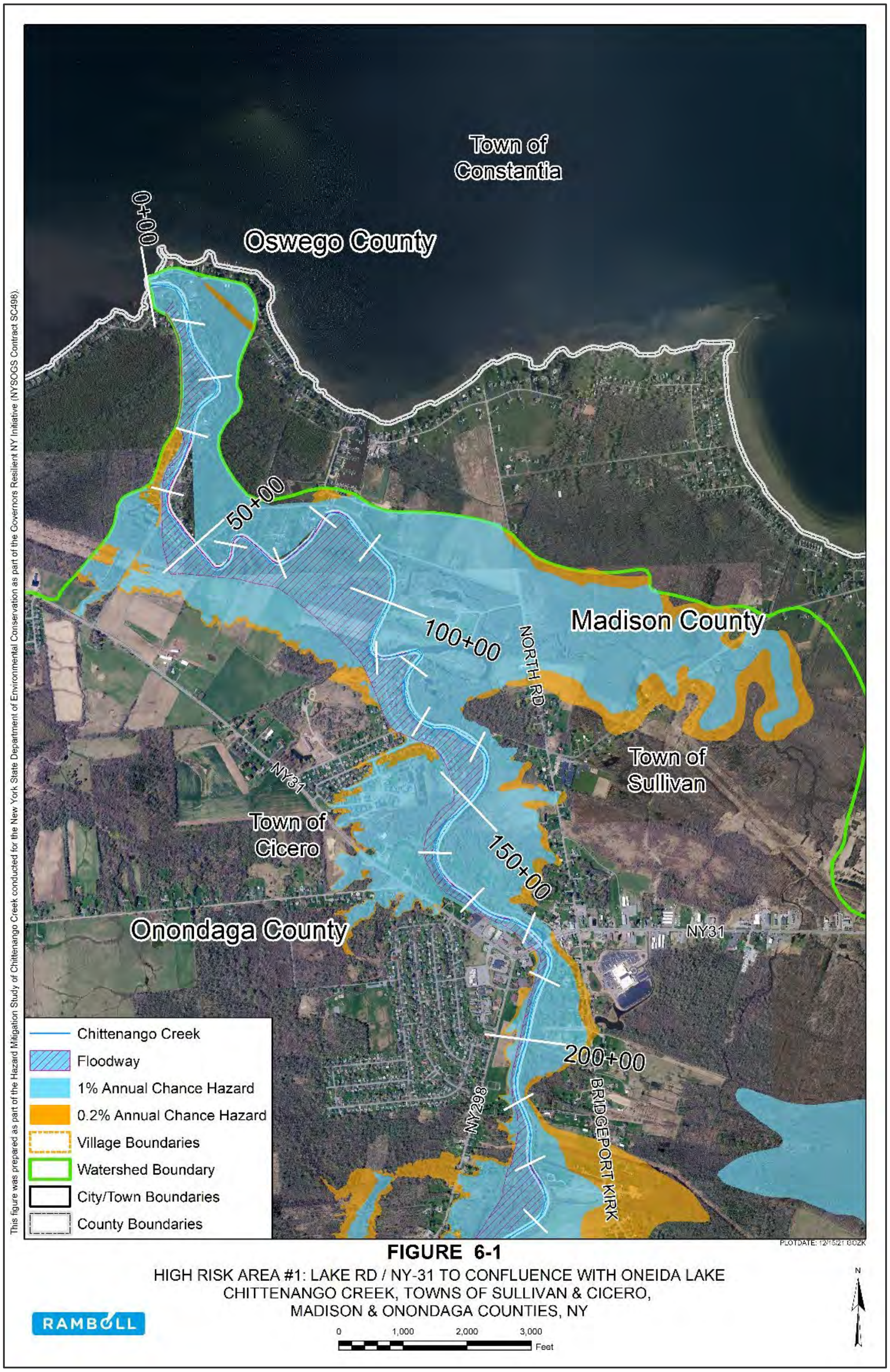

Figure 6-1. High-risk Area #1: Lake Road / NY-31 downstream to the confluence with Oneida Lake, Town of Sullivan, NY.

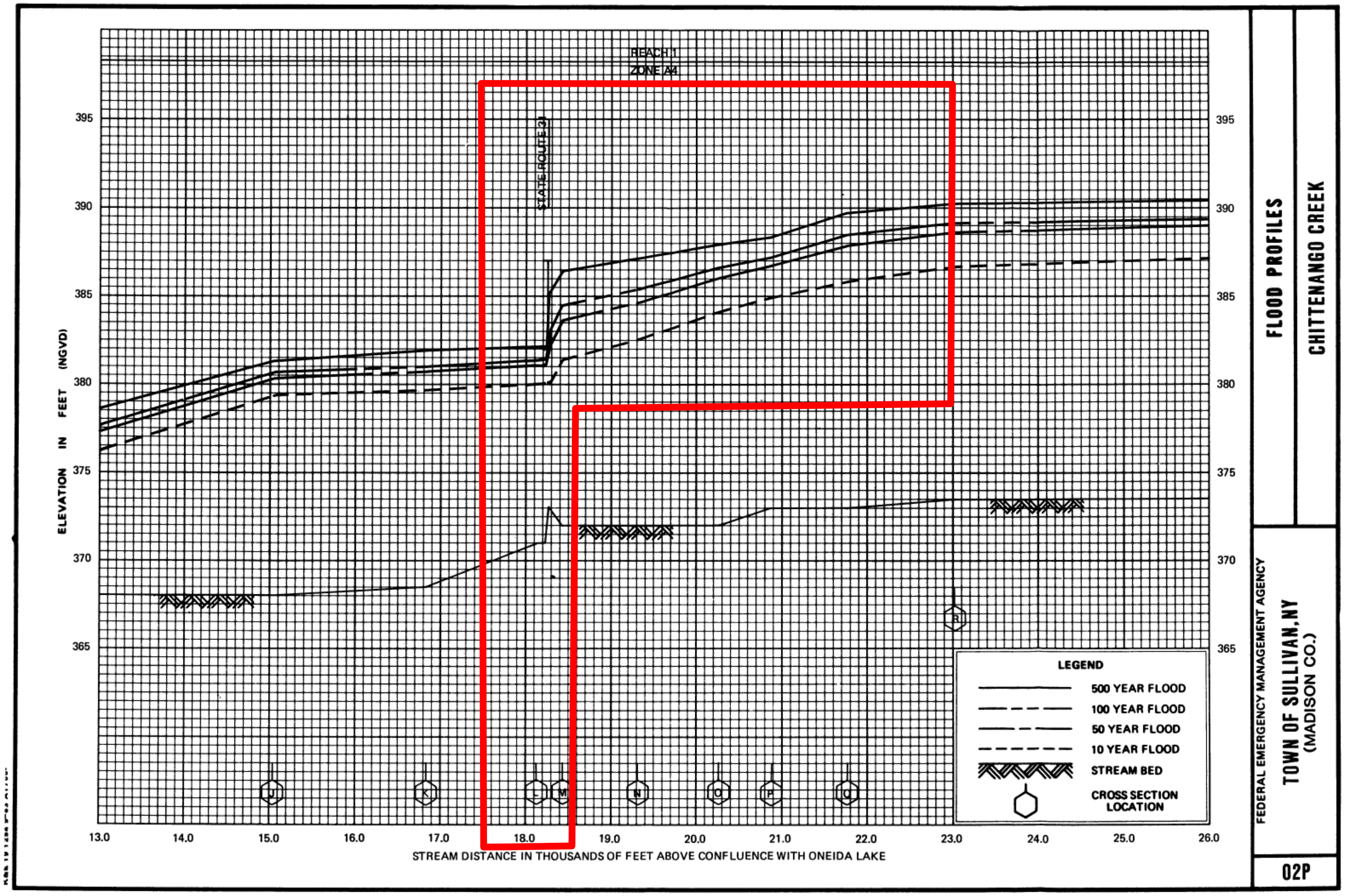

Figure 6-2. FEMA FIS profile for Chittenango Creek in the vicinity of Lake Road / NY-31 in the Town of Sullivan, NY (FEMA 1986c).

Note: Lake Road/NY-31 is located at river station 184+00 on the FEMA FIS profile.

6.5.2 High-risk Area #2: Village of Chittenango Upstream of Corporate Limits, Downstream to the Old Erie Canal Crossing, Village of Chittenango, NY

High-risk Area #2 is the area from the upstream of the corporate limits of the Village of Chittenango at river station 1420+00, downstream to the Old Erie Canal crossing over Chittenango Creek in the Village of Chittenango at river station 1273+50 (Figure 6-3). Large portions of downtown Chittenango reside within the 1% and 0.2% annual chance flood areas. Numerous residential and commercial properties, including both public and privately owned areas, are within the FEMA flood zones. In addition, Genesee Street and Falls Boulevard/NY-13 are important thoroughfares in the Village where businesses and residences that reside along or adjacent to them depend on the traffic and access.

According to the NYSDOT Functional Class, Genesee Street is classified as a Principal Arterial Other (Urban), which is defined as a roadway at the major centers of activity of a metropolitan area and/or the highest traffic volume corridors and carry a high proportion of the total urban area travel on a minimum mileage. The principal arterial system should carry the major portion of trips entering and leaving the urban area, as well as the majority of through movements desiring to bypass the central city. Almost all fully and partially controlled access facilities will be part of this functional system. Falls Blvd/NY-13 is classified as a Major Collector (Urban), which is defined as roadways that provide both land access service and traffic circulation within residential neighborhoods, commercial and industrial areas. An urban collector may penetrate residential neighborhoods, distributing trips from the arterials through the area to the ultimate destination. The collector street also collects traffic from local streets in residential neighborhoods and channels it into the arterial system. In the central business district, and in other areas of like development and traffic density, the collector system may include the street grid which forms a logical entity for traffic circulation (NYSDOT 2017).

According to the FEMA FIS and FIRM for the Village of Chittenango, there is significant backwater upstream of Tuscarora Road, Russell Street, and Madison Street (Perryville Road) (Figure 6-4). In addition, the Tuscarora Road, Genesee Street/NY-5, and Madison Street (Perryville Road) bridge crossings do not provide the NYSDOT required 2 feet of freeboard over the 2% (50-year) annual chance event (FEMA 1984c; FEMA 1985b).

This reach is also susceptible to sediment aggradation, tree and debris buildup from upstream sources, and ice jams at the Old Erie Canal crossing. Aggradation, tree/debris buildup, and ice jams can restrict the channel flow area, which can cause water surfaces to rise and potentially overtop banks or backwater upstream of structures and/or meanders.

The Old Erie Canal structure, including the two piers in the channel, acts as a flow restrictor and catchpoints for debris and ice floes in Chittenango Creek, which can cause backwater flooding in upstream areas. The Chittenango Feeder Canal weir upstream of the Old Erie Canal has been identified as currently damaged, unmaintained, and silted at the upstream face (NYSDEC 2021b).

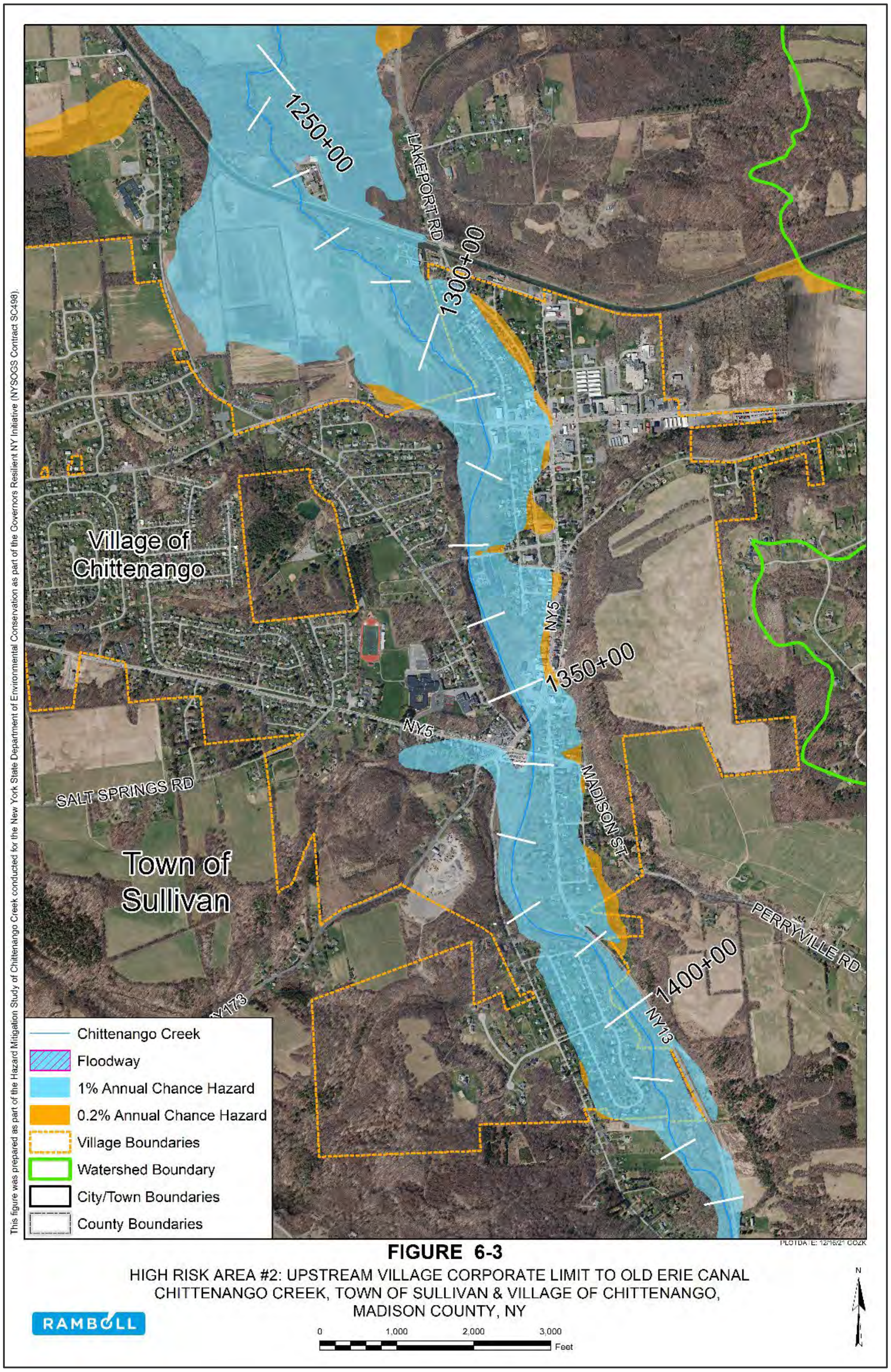

Figure 6-3. High-risk Area #2: Village of Chittenango upstream of corporate limits downstream to the Old Erie Canal Crossing, Village of Chittenango, NY.

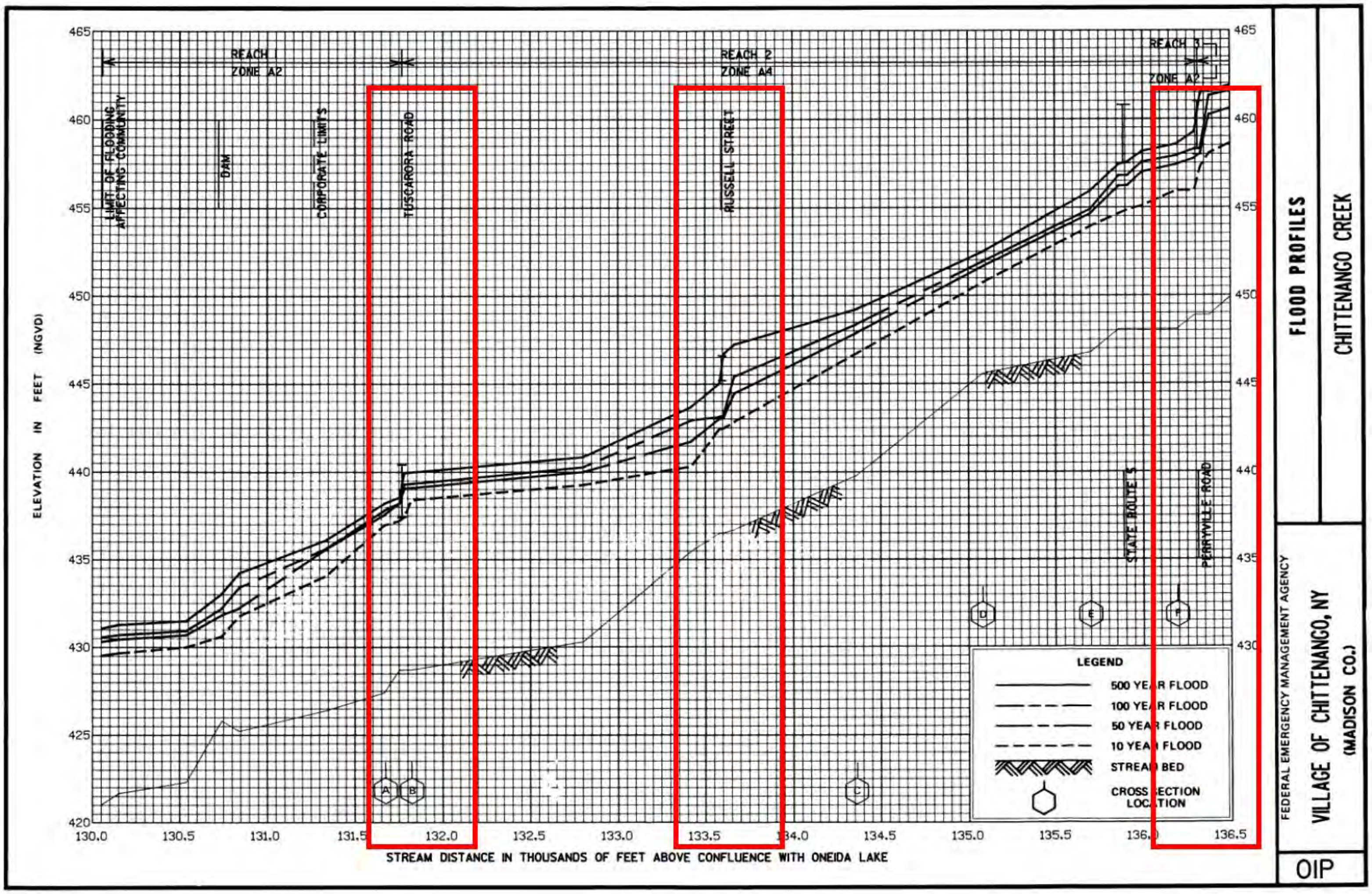

Figure 6-4. FEMA FIS profile for Chittenango Creek in the Village of Chittenango, NY (FEMA 1984c).

Note: Tuscarora Road, Russell Street, and Madison Street (Perryville Road) bridges are located at river stations 1314+00, 1331+50, and 1358+75, respectively, on the FEMA FIS profile.

6.5.3 High-risk Area #3: Mill Street Downstream to Clark Street, Village of Cazenovia, NY

High-risk Area #3 is the area between Mill Street and Clark Street in the Village of Cazenovia starting at river station 1900+00 and extending downstream to river station 1856+00 (Figure 6-5). Flooding in this area affects numerous residential and commercial properties, including both public and privately owned areas, that are within the FEMA 1% and 0.2% annual chance flood areas. In addition, Albany Street/US-20 is an important thoroughfare in the Village where businesses and residences that reside along or adjacent to it depend on the traffic and access.

According to the NYSDOT Functional Class, Albany Street/US-20 is classified as a Principal Arterial Other (Rural), which is defined as a roadway that consists of a connected rural network of continuous routes that either serve corridor movement having trip length and travel density characteristics indicative of substantial statewide or interstate travel, and/or provide an integrated network without stub connections except where unusual geographic or traffic flow conditions dictate otherwise (e.g. international boundary connections and connections to coastal cities) (NYSDOT 2017).

According to the FEMA FIS and FIRM for the Village of Cazenovia, there is significant backwater upstream of the abandoned railroad, Burr Street/William Street, and Albany Street/US-20 bridge crossings (Figure 6-6). In addition, the abandoned railroad and Albany Street/US-20 bridge crossings do not provide the NYSDOT required 2 feet of freeboard over the 2% (50-yr) annual chance event (FEMA 1984b; FEMA 1985a).

There are two unnamed tributaries, and the Chittenango Creek diversion into Cazenovia Lake, that contribute to the flood risk within the Village. The downstream unnamed tributary originates near the Towne & Country Plaza on Nelson Street and flows west/north-west crossing Fenner, Burton, Myrtle, and Burr Streets. The Burr Street culvert has been identified as a source of backwater flooding and is prone to sediment and debris blockage (NYSDEC 2021b).

The downstream unnamed tributary originates near Stone Quarry Road and flows west/north-west crossing South Village Drive, Link Trail Trailhead, Water Lane, and the Old Lehigh Valley Railroad.

The Chittenango Creek diversion feeds Cazenovia Lake by diverting flow from the main stem of Chittenango Creek into a small diversion channel that empties into the Lake. The diversion occurs upstream of the Mill Street/Chenango Street bridge crossing and is an abrupt 90 degree bend in the channel creating a “T” shaped meander.

This reach is also susceptible to sediment aggradation, and tree and debris buildup from upstream sources. Aggradation and tree/debris buildup restrict the channel flow area, which can cause water surfaces to rise and potentially overtop banks or back water upstream of structures and/or meanders.

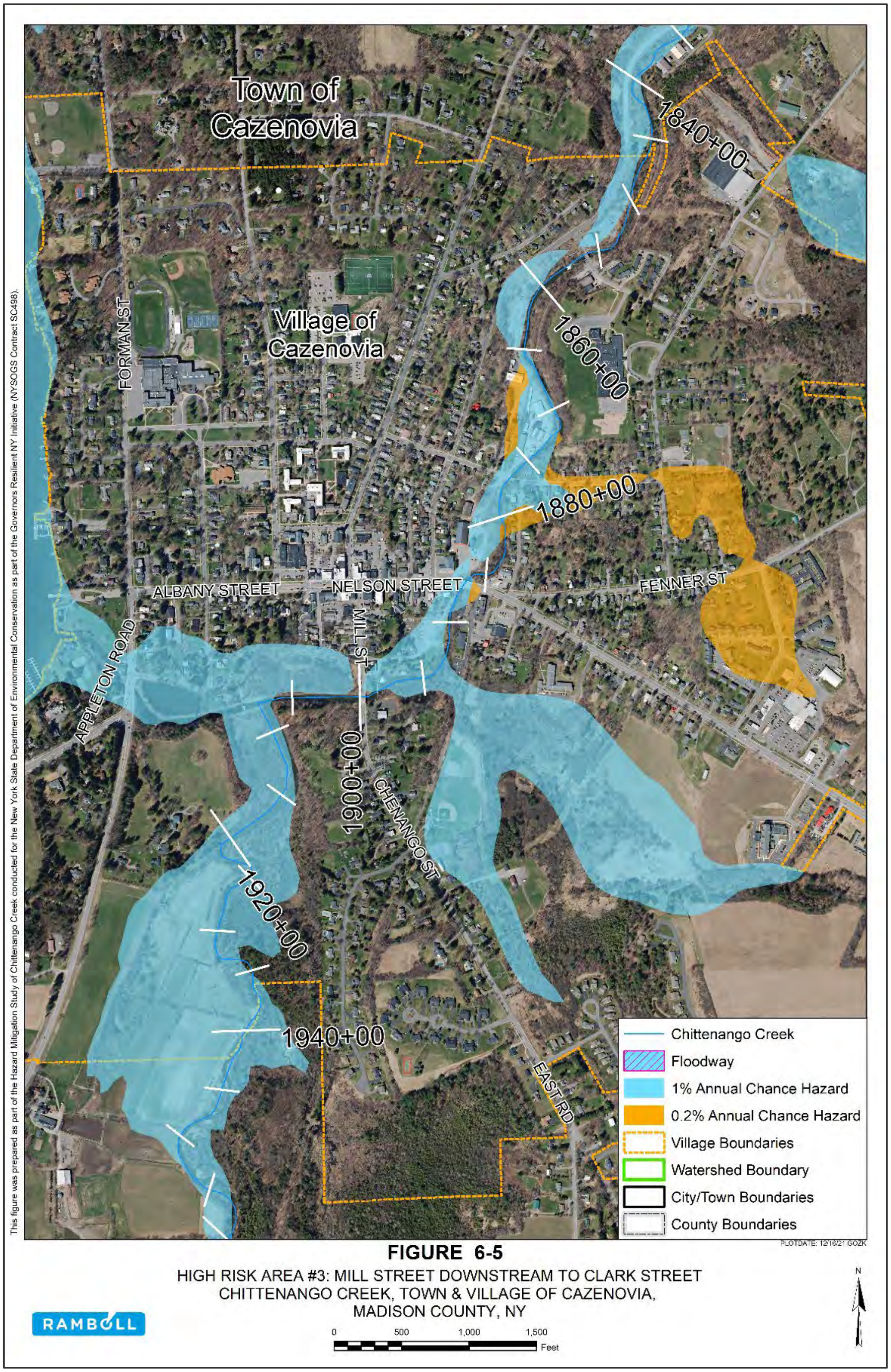

Figure 6-5. High-risk Area #3: Mill Street downstream to Clark Street, Village of Cazenovia, NY.

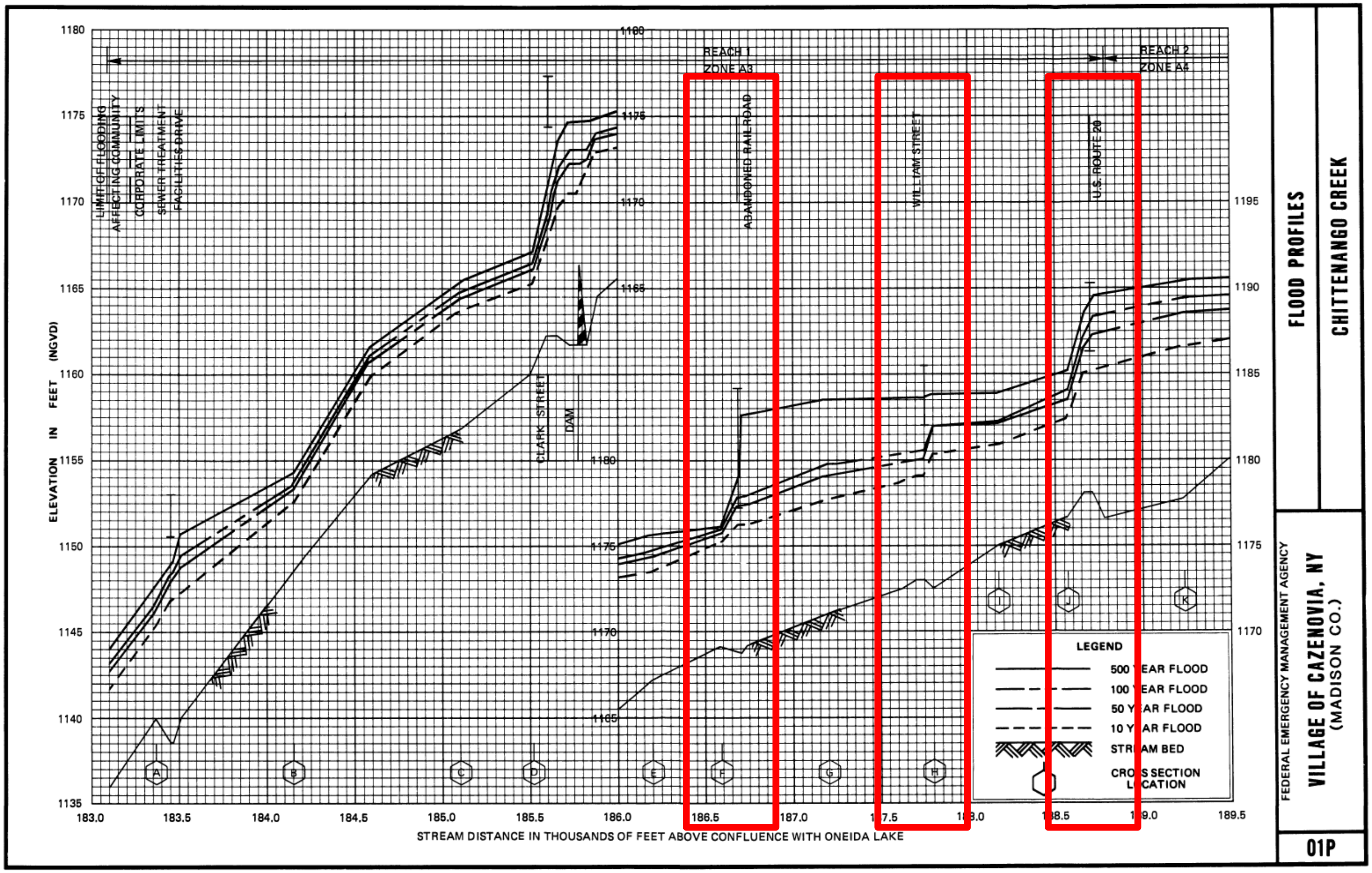

Figure 6-6. FEMA FIS profile for Chittenango Creek in the Village of Cazenovia, NY (FEMA 1984b).

Note: The Abandoned Railroad, Burr/William Street, and Albany Street/US-20 bridges are located at river stations 1866+25, 1877+00, and 1886+00, respectively, on the FEMA FIS profile.

7. MITIGATION ALTERNATIVES

The following are flood mitigation alternatives that have the potential to reduce water surface elevations along high-risk areas of Chittenango Creek. These alternatives could potentially reduce flood-related damages in areas adjacent to the creek. The Towns of Sullivan and Cazenovia, Villages of Chittenango and Cazenovia, Onondaga and Madison Counties, and associated state agencies and stakeholders should evaluate each alternative and consider the potential effects to the community, and the level of community buy-in for each before pursuing them further.

7.1 HIGH-RISK AREA #1

7.1.1 Alternative #1-1: Sediment Management at Mouth with Oneida Lake

This measure is intended to the remove deposited sediment at the outlet of Chittenango Creek with Oneida Lake that has aggraded the creek channel (Figure 7-1). Sediment sources at the outlet are driven by riverine processes, which occurs due to the natural sediment transport and streambank erosion that happens along Chittenango Creek. As the sediment aggrades at the outlet, the channel geometry is altered, and the in-channel flow area is reduced. This, in turn, reduces the volume of water that can be transported safely within the channel without overtopping the banks. In addition, if large portions of sediment are transported downstream to the outlet from upstream sources then sediment management and reduction measures should be considered and employed first to reduce sediment loads at the outlet.

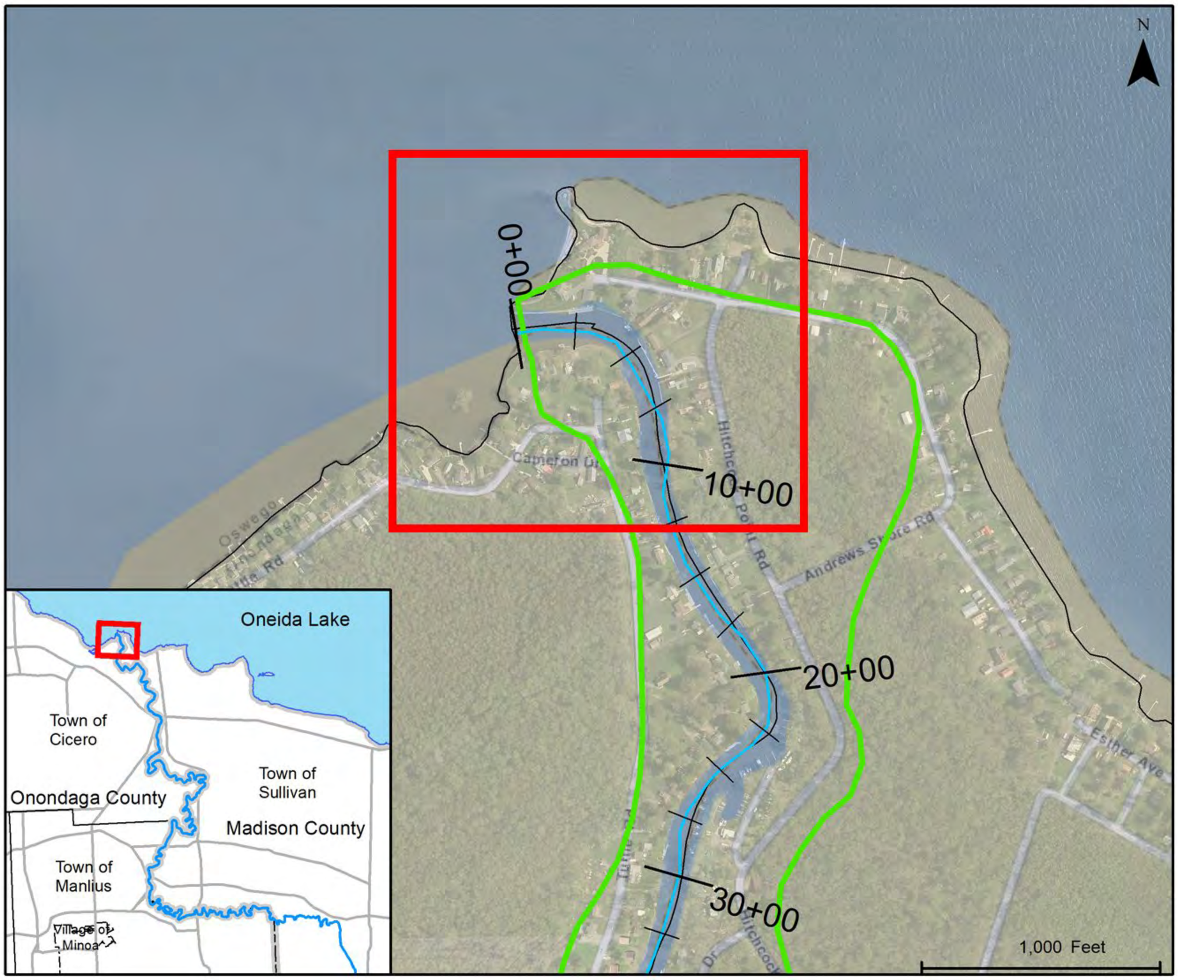

Figure 7-1. Location map for Alternative #1-1.

A sediment management strategy that involves removing sediment from the channel, such as dredging, requires extensive environmental and modeling studies, application, sampling, testing, certification, permitting, operational and maintenance plans with proof of financial viability, and a significant proposal justification, including only viable alternative and greatest benefit with least amount of impact. The NYSDEC *Technical & Operations Guidance Series (TOGS) 5.1.9 In-Water and Riparian Management of Sediment and Dredged Material* (2004) should be used to determine the procedure and necessary steps in order to develop a sediment removal strategy.

There are a number of federal, state, and local regulatory controls in place which apply to in-water and riparian sediment management projects. The applicability of these controls to each project depends on the particular circumstances of each case, such as the sediment classification and the intended use or management of the removed material (NYSDEC 2004).

Some or all of the following New York State and Federal Permits may be required: Use and Protection of Waters Permit; Freshwater Wetlands Permit; Tidal Wetlands Permit;

State Pollutant Discharge Elimination System Permit; Clean Water Act § 401 Water Quality Certification and § 404 Permit and Rivers and Harbors Act § 10 Permits, issued by the USACE. An antidegradation review and Wild, Scenic and Recreational Rivers Program permits may also be required (NYSDEC 2004).

The basic steps involved in the application process and technical review of a sediment assessment and management plan involves the following:

1. A pre-application meeting with the NYSDEC to discuss all application, permitting, and information needs
2. A sampling plan to determine sampling requirements for proper characterization of proposed sediments and material to be removed
3. Laboratory analysis of sampled material
4. Evaluation of laboratory results
5. Determination of appropriate management options based on sediment class
6. Development of permit conditions for the process of removing sediments and materials, and the management of the removed materials
7. Maintenance and monitoring of operations for the management plan (NYSDEC 2004)

Due to the complex nature of sediment transport during riverine processes, no modeling simulations were performed for this alternative. However, it is recommended that any sediment/debris management plan return and/or maintain the natural channel width and area so that the channel can successfully pass the bankfull discharge. According to the USGS *StreamStats* software, the bankfull width and area of Chittenango Creek at the confluence with Oneida Lake is 150 ft and 705 ft^2, respectively (USGS 2020).

Sediment management at the outlet can improve water quality and in-channel flow area of Chittenango Creek, thereby, reducing flood risk for areas in the vicinity of the outlet. However, the process of removing sediment can also fundamentally change the composition of aquatic habitats and potentially release pollutants into the water column that were previously secured in the channel sediments.

The USACE has the authority to construct small flood risk reduction projects that are engineeringly feasibly, structurally sound and cost efficient through the authority provided under Section 205 of the 1948 Flood Control Act (FCA), as amended. Coordination should also occur with the NYSDEC as they need to be the non-Federal sponsor on these types of projects.

In addition, a FEMA Benefit-Cost Analysis (BCA) would need to be performed to determine the cost-effectiveness of the alternative prior to applying for FEMA mitigation grant programs funding. The BCA is the method by which the future benefits of a mitigation project are determined 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 when the BCR is 1.0 or greater.

It should be noted that utmost consideration should be given to habitat protection when discussing deltas, such as the outlet of Chittenango Creek to Oneida Lake. Deltas are among the most highly productive regions of rivers and lakes and dredging them does constitute a loss of important habitat. That habitat loss may or may not be justifiable when weighed against the benefit of protecting property and businesses from floods.

The ROM cost for this measure is $320,000, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

7.1.2 Alternative #1-2: Remove Central Piers of Lake Road/NY-31

This measure is intended to increase the cross-sectional flow area of the channel and remove any potential impediments or catch points for sediment and debris by removing the central pier of the Lake Road/NY-31 bridge located at river station 184+00 (Figure 7-2).

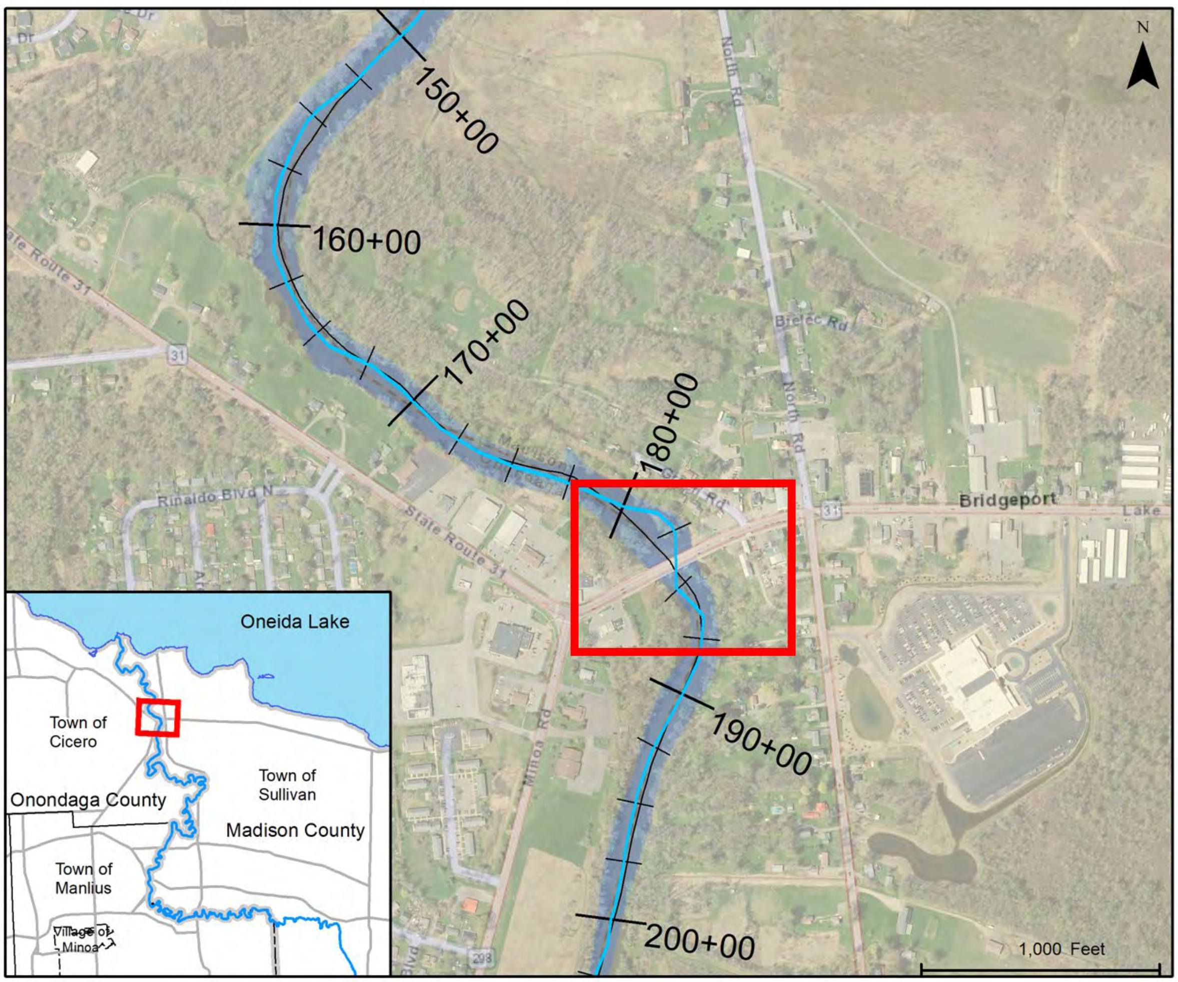

Figure 7-2. Location map for Alternative #1-2.

The existing bridge structure has an opening of 208 ft, a width of 51 ft, and two piers in the creek channel that are approximately 5 ft wide and spaced approximately 80 ft apart. The Lake Road/NY-31 bridge is owned and maintained by the NYSDOT (Figure 7-3).

Figure 7-3. Lake Road/NY-31 bridge, Bridgeport, NY.

Based on orthoimagery of the area, the meander in the creek channel upstream of the bridge crossing coupled with the in-channel piers act as impediments to flow, reducing water velocities and allowing sediment and debris to aggregate and restrict flow in this area (NYSOITS 2017).

As previously displayed in Figure 6-2, the FEMA FIS for the Lake Road/NY-31 bridge is unable to successfully pass the 10-, 2-, 1-, or 0.2% annual chance event without significant backwater upstream of the bridge (FEMA 1986b). In addition, the FEMA FIRM displays significant backwater upstream of the Lake Road/NY-31 bridge crossing (FEMA 1986a).

By removing the central piers, the cross-sectional flow area of the channel would increase and the potential for sediment, debris, and ice to accumulate or catch on the upstream face of the bridge would be reduced, thereby reducing flood risk to areas adajcent to and immediately upstream of the bridge.

According to historical flood reports, stakeholder engagement meetings, and field work, the Lake Road/NY-31 bridge was identified as a hydraulic structure that experiences debris blockage and ice jams resulting in backwater flooding during higher peak flow events (FEMA 1986b; NYSDEC 2021b). For this alternative, open-water, debris obstruction, and ice-jam simulations were performed to test the effectiveness of the alternative at reducing water surface elevations. Table 17 outlines the results of the existing conditions model simulations for each initial condition scenario. Figures 7-4 through 7-6 display the profile plots for each initial condition scenario for the pier removal alternative. Full model outputs for this alternative can be found in Appendix H.

Table 17. Summary Table for Alternative #1-2 Existing Conditions Results Based on Open-water, Debris Obstruction, and Ice-jam Conditions

Existing Conditions	Reductions in Water Surface Elevations (feet)
Open-Water	Up to 0.5 ft
Total Length of Benefited Area	2,600-ft
River Stations	179+50 to 205+50
Debris Obstruction	Up to 0.1-ft
Total Length of Benefited Area	3,425-ft
River Stations	179+50 to 213+75
Ice Jam	Up to 0.5-ft
Total Length of Benefited Area	4,350-ft
River Stations	179+50 to 223+00

Table 18 outlines the results of the future conditions model simulations for each initial condition scenario.

Table 18. Summary Table for Alternative #1-2 Future Conditions Results Based on Open-water, Debris-obstruction, and Ice-jam Conditions

Future Conditions	Reductions in Water Surface Elevations (feet)
Open-Water	Up to 0.5-ft
Total Length of Benefited Area	4,350-ft
River Stations	179+50 to 223+00
Debris Obstruction	Up to 0.1-ft
Total Length of Benefited Area	2,600-ft
River Stations	179+50 to 225+50
Ice Jam	Up to 0.5-ft
Total Length of Benefited Area	4,350-ft
River Stations	179+50 to 223+00

The potential benefits of this strategy are limited to immediately upstream of the Lake Road/NY-31 bridge. Since the piers account for a small portion of the channel area, the effects of removing the piers on WSELs is not significant. However, the primary benefit of removing the two piers would be to reduce the potential of debris and ice from catching on a pier and creating obstructions/jams upstream of the bridge.

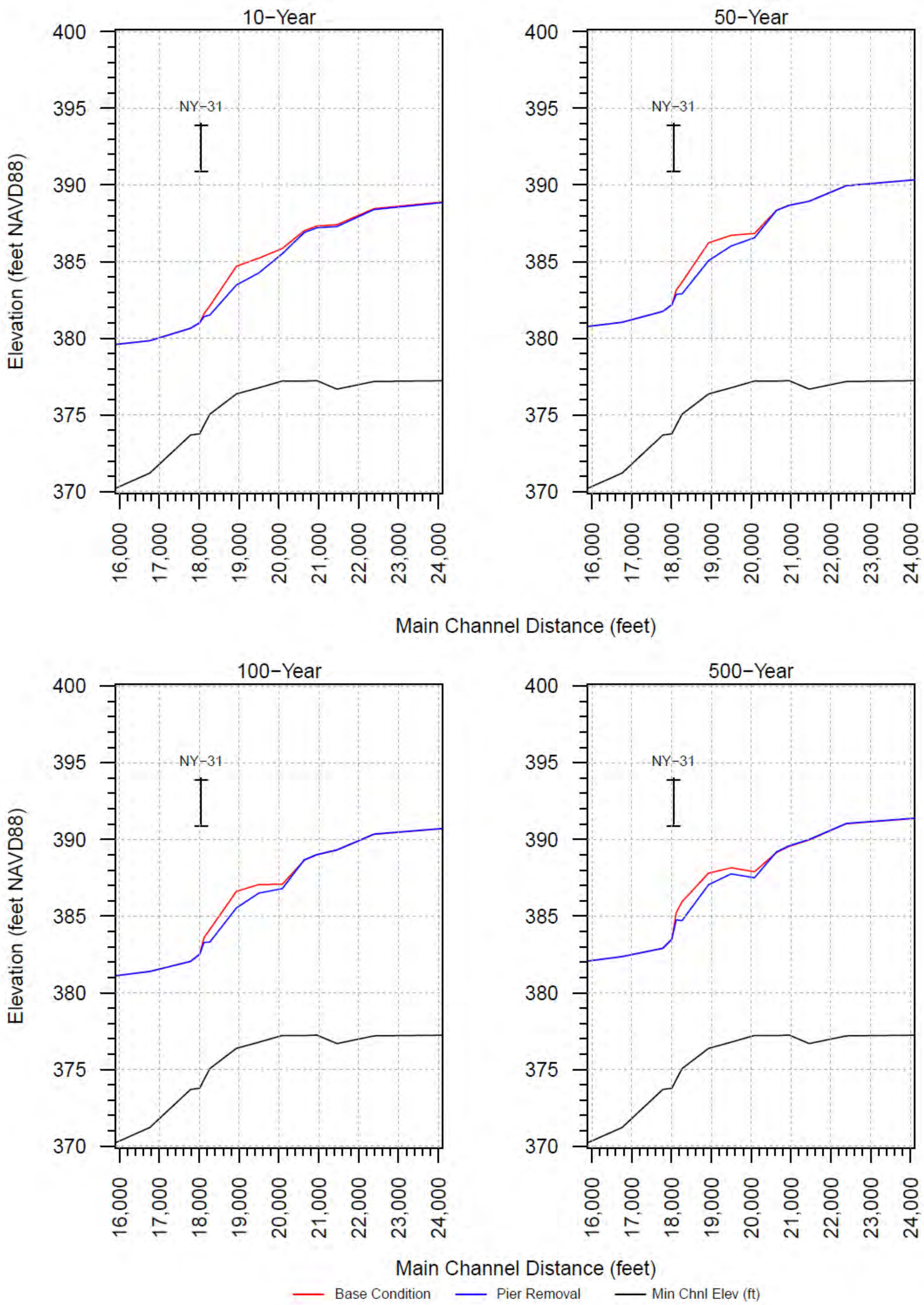

Figure 7-4. HEC-RAS model simulation output results for Alternative #1-2 for the existing condition (red) and pier removal (blue) scenarios.

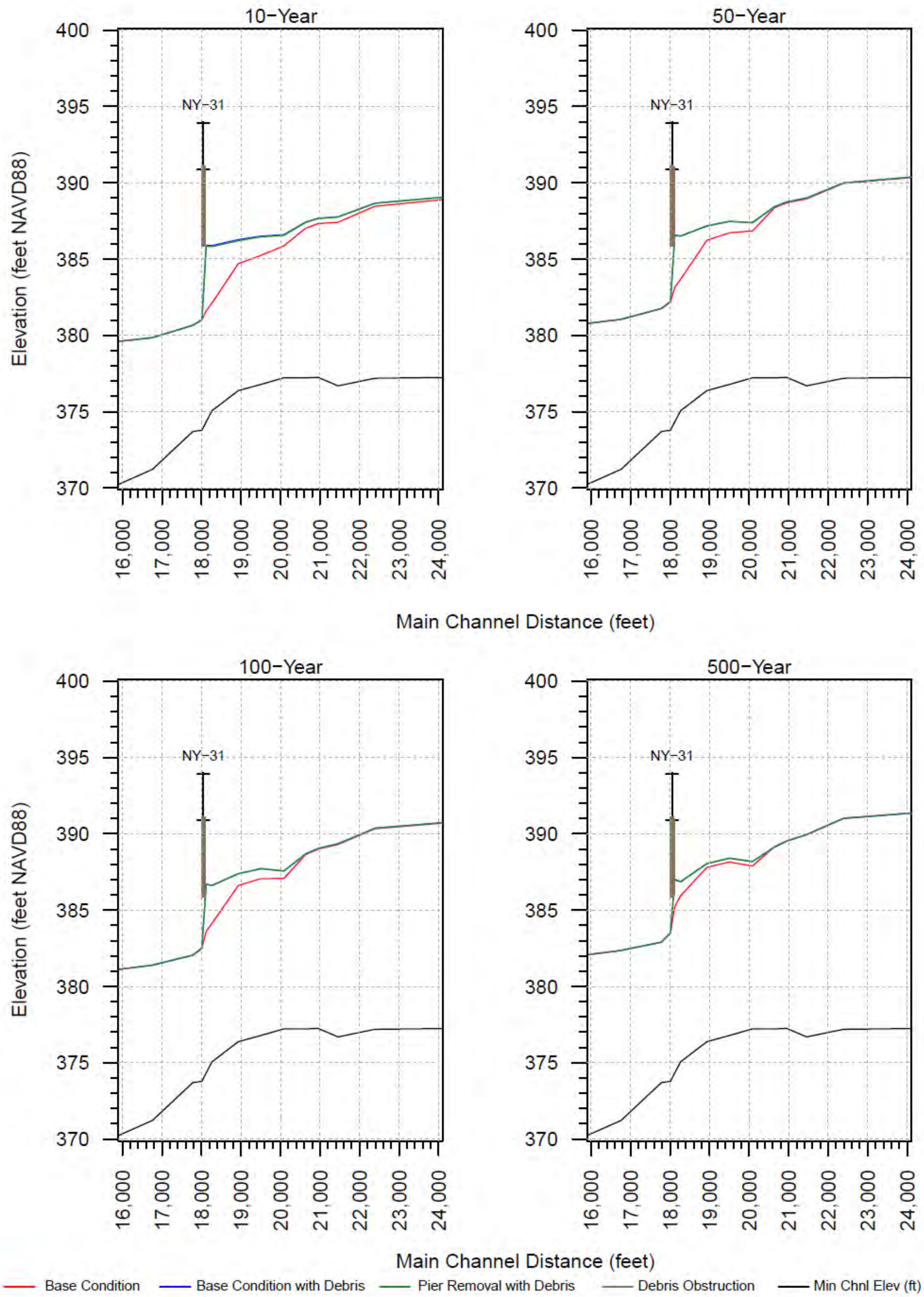

Figure 7-5. HEC-RAS debris obstruction model simulation output results for Alternative #1-2 for the existing condition (red), existing condition with debris (blue), and pier removal with debris (green) scenarios.

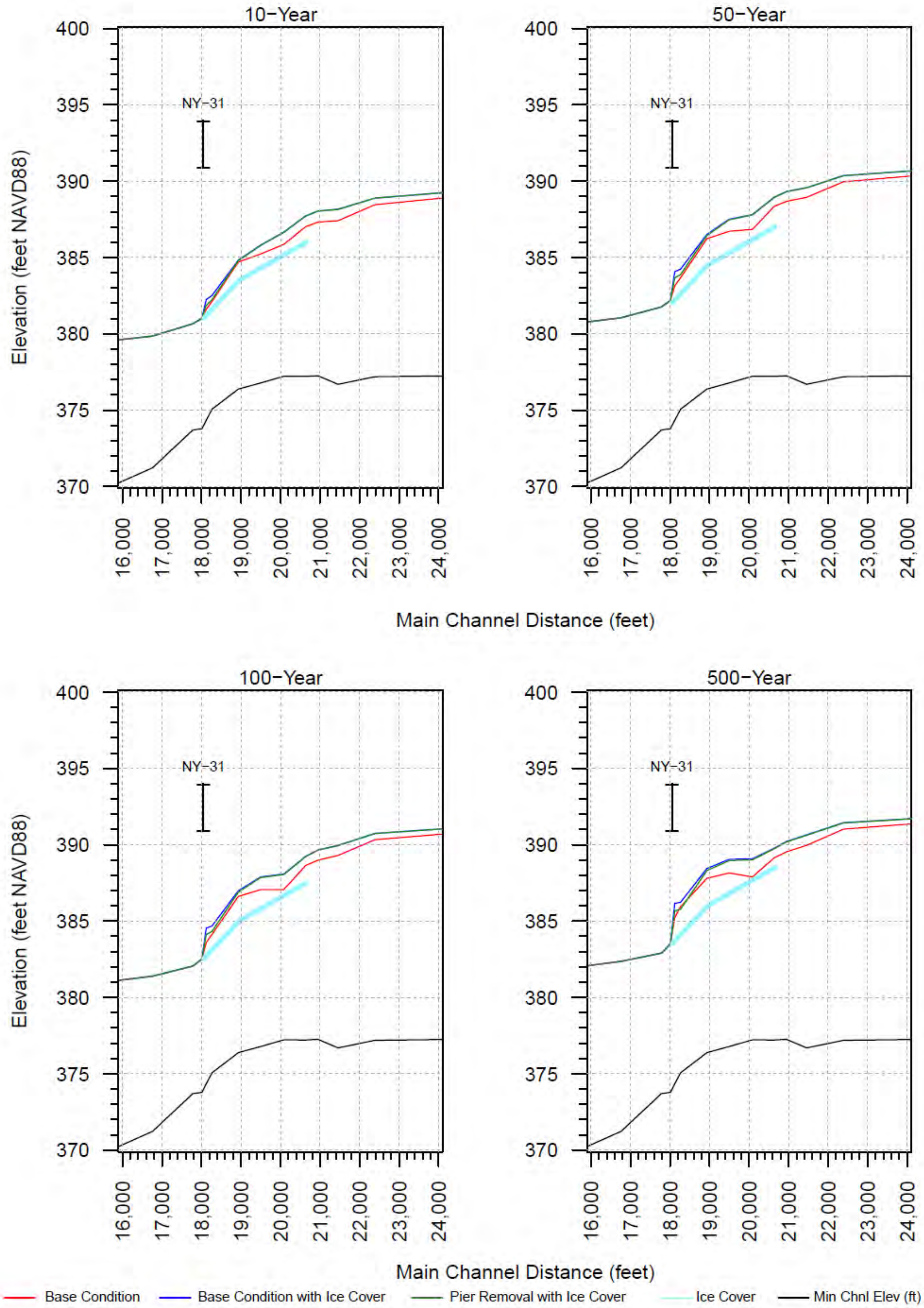

Figure 7-6. HEC-RAS ice cover model simulation output results for Alternative #1-2 for the existing condition (red), existing condition with ice cover (blue), and pier removal with ice cover (green) scenarios.

To evaluate the effectiveness of the flood mitigation impacts, the project team analyzed this alternative independent of any other proposed mitigation alternative. However, there is the potential for added benefits (i.e., reduction in WSELs, less flooding, reduced erosion, etc.) when multiple flood mitigation projects are built in conjunction. For areas that experience significant flood damages or chronic flooding, it is recommended that multiple flood mitigation strategies in conjunction be considered and evaluated by affected communities.

The ROM cost for this strategy is approximately $7.1 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination. Additional engineering consideration would also be required to determine if removing the two piers would alter the structural integrity of the bridge in any way.

7.1.3 Alternative #1-3: Remove Central Piers and Increase the Bridge Opening of Lake Road/NY-31

This measure is intended to address issues within High-risk Area #1 by increasing the opening of the Lake Road/NY-31 bridge and removing the two central piers, which are located at river station 184+00 (Figure 7-2).

By increasing the opening of the bridge structure and removing the two central piers, the cross-sectional flow area of the channel would increase and the potential for sediment, debris, and ice to accumulate or catch on the upstream face of the bridge would be reduced, thereby reducing flood risk to areas adajcent to and immediately upstream of the bridge.

The bridge upsizing design selected for this proposed condition model simulation was selected to ensure that the 1% annual chance event WSEL could successfully pass under the Lake Road/NY-31 bridge. To achieve the desired result, the bridge upsizing design increased the opening of the bridge by 20 ft on each bank for a total increase of 40 ft. This measure would potentially reduce the flood risk and benefit the properties adjacent to and immediately upstream of Lake Road/NY-31.

For this alternative, open-water, debris obstruction, and ice-jam simulations were performed to test the effectiveness of the alternative at reducing water surface elevations. Table 19 outlines the results of the existing conditions model simulations for each initial condition scenario. Figures 7-7 through 7-9 display the profile plots for each initial condition scenario for the pier removal alternative. Full model outputs for this alternative can be found in Appendix H.

Table 19. Summary Table for Alternative #1-3 Existing Conditions Results Based on Open-water, Debris-obstruction, and Ice-jam Conditions

Existing Conditions	Reductions in Water Surface Elevations (feet)
Open-Water	Up to 1.6-ft
Total Length of Benefited Area	3,150-ft
River Stations	177+00 to 208+50
Debris Obstruction	Up to 1.4-ft
Total Length of Benefited Area	4,600-ft
River Stations	177+00 to 223+00
Ice Jam	Up to 2.3-ft
Total Length of Benefited Area	4,600-ft
River Stations	177+00 to 223+00

Table 20 outlines the results of the future conditions model simulations for each initial condition scenario.

Table 20. Summary Table for Alternative #1-3 Future Conditions Results Based on Open-water, Debris-obstruction, and Ice-jam Conditions

Future Conditions	Reductions in Water Surface Elevations (feet)
Open-Water	Up to 2.4-ft
Total Length of Benefited Area	4,600-ft
River Stations	177+00 to 223+00
Debris Obstruction	Up to 1.2-ft
Total Length of Benefited Area	4,600-ft
River Stations	177+00 to 223+00
Ice Jam	Up to 3.0-ft
Total Length of Benefited Area	4,600-ft
River Stations	177+00 to 223+00

The potential benefits of this strategy are limited to immediately upstream of the Lake Road/NY-31 bridge. The primary benefits of increasing the bridge opening would be to increase the flow capacity of the bridge structure, reduce the potential of backwater from high-flow events, and help prevent debris and ice from catching on the structure and creating obstructions/jams upstream of the bridge.

The ROM cost for this strategy is approximately $8.9 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination. Additional engineering consideration would also be required to determine if increasing the bridge opening and/or removing the two piers would alter the structural integrity of the bridge in any way.

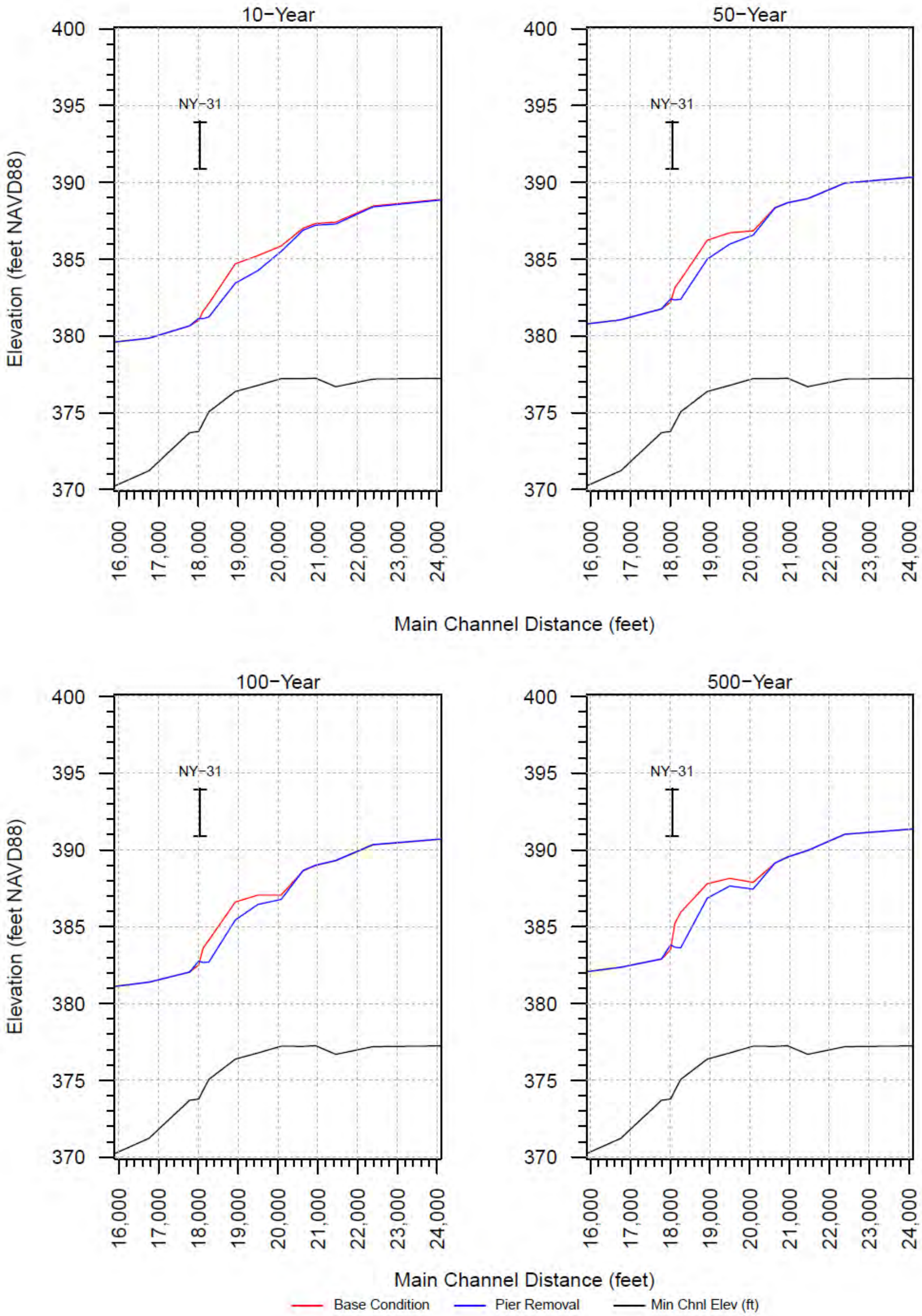

Figure 7-7. HEC-RAS model simulation output results for Alternative #1-3 for the existing condition (red) and bridge widening/pier removal (blue) scenarios.

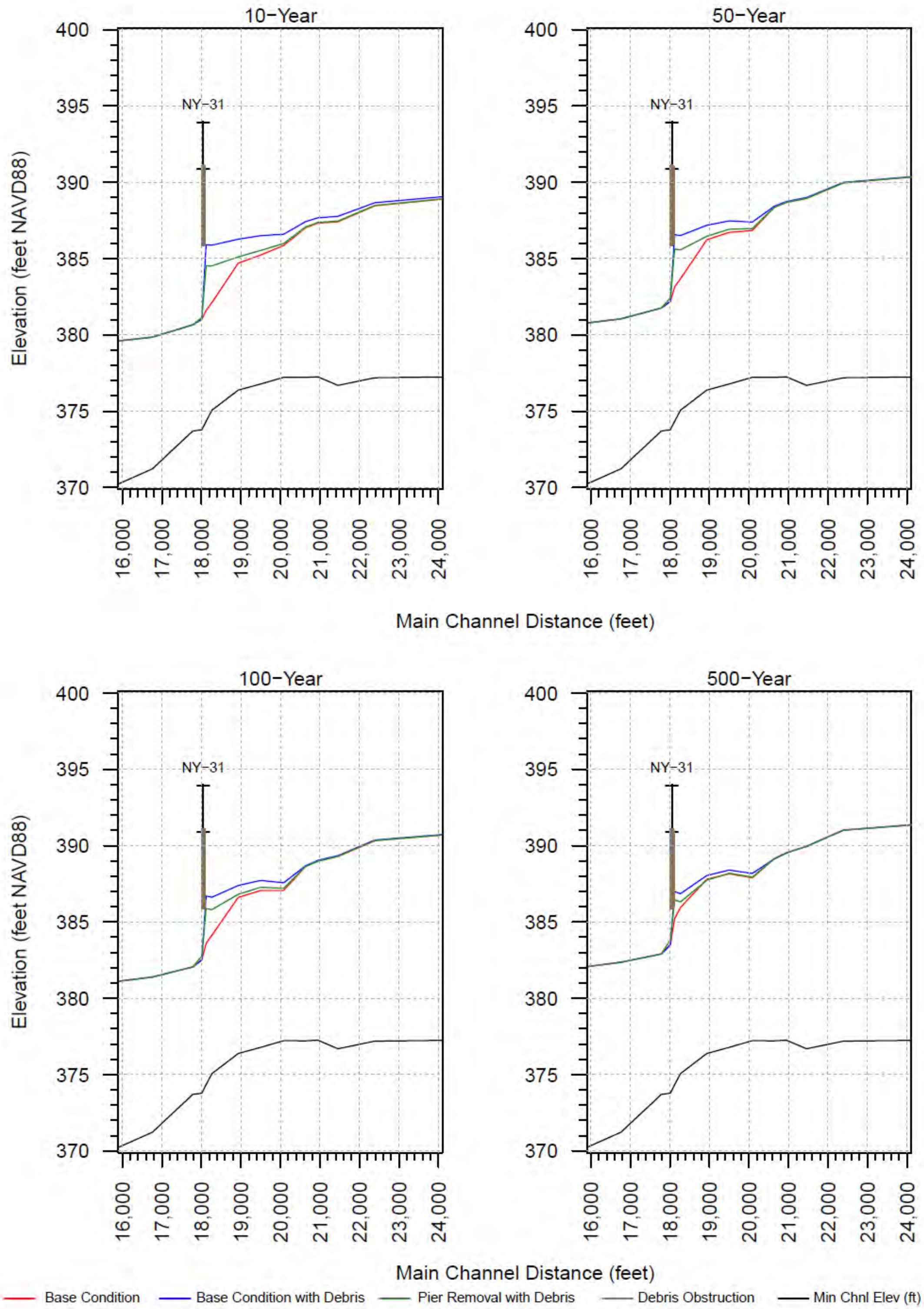

Figure 7-8. HEC-RAS debris obstruction model simulation output results for Alternative #1-3 for the existing condition (red), existing condition with debris (blue), and bridge widening/pier removal with debris (green) scenarios.

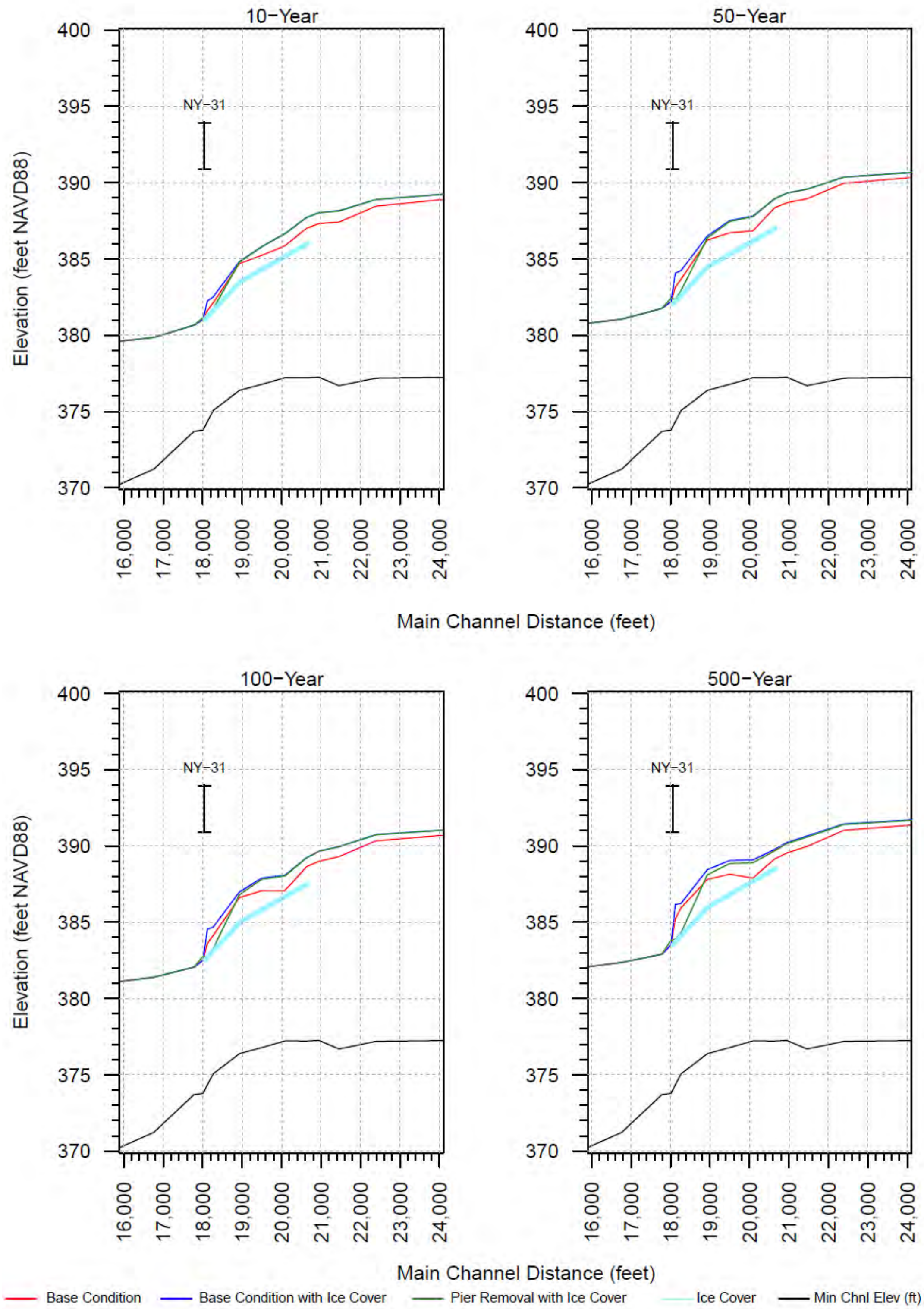

Figure 7-9. HEC-RAS ice cover model simulation output results for Alternative #1-3 for the existing condition (red), existing condition with ice cover (blue), and bridge widening/pier removal with ice cover (green) scenarios.

7.1.4 Alternative #1-4: Flood Benches Upstream / Downstream of Lake Road / NY-31

Installing a flood bench would provide additional storage and floodplain width over and above the current storage and width provided by the adjacent agricultural and undeveloped lands, which could potentially reduce damages in the event of flooding and address issues within High-risk Area #1. Two potential flood benches were modeled in the vicinity of Lake Road/NY-31 in the Hamlet of Bridgeport (Figure 7-10):

- Flood Bench A is approximately 7 acres in size and located between river stations 160+00 to 175+00
- Flood Bench B is approximately 22 acres in size and located between river stations 190+00 to 210+00

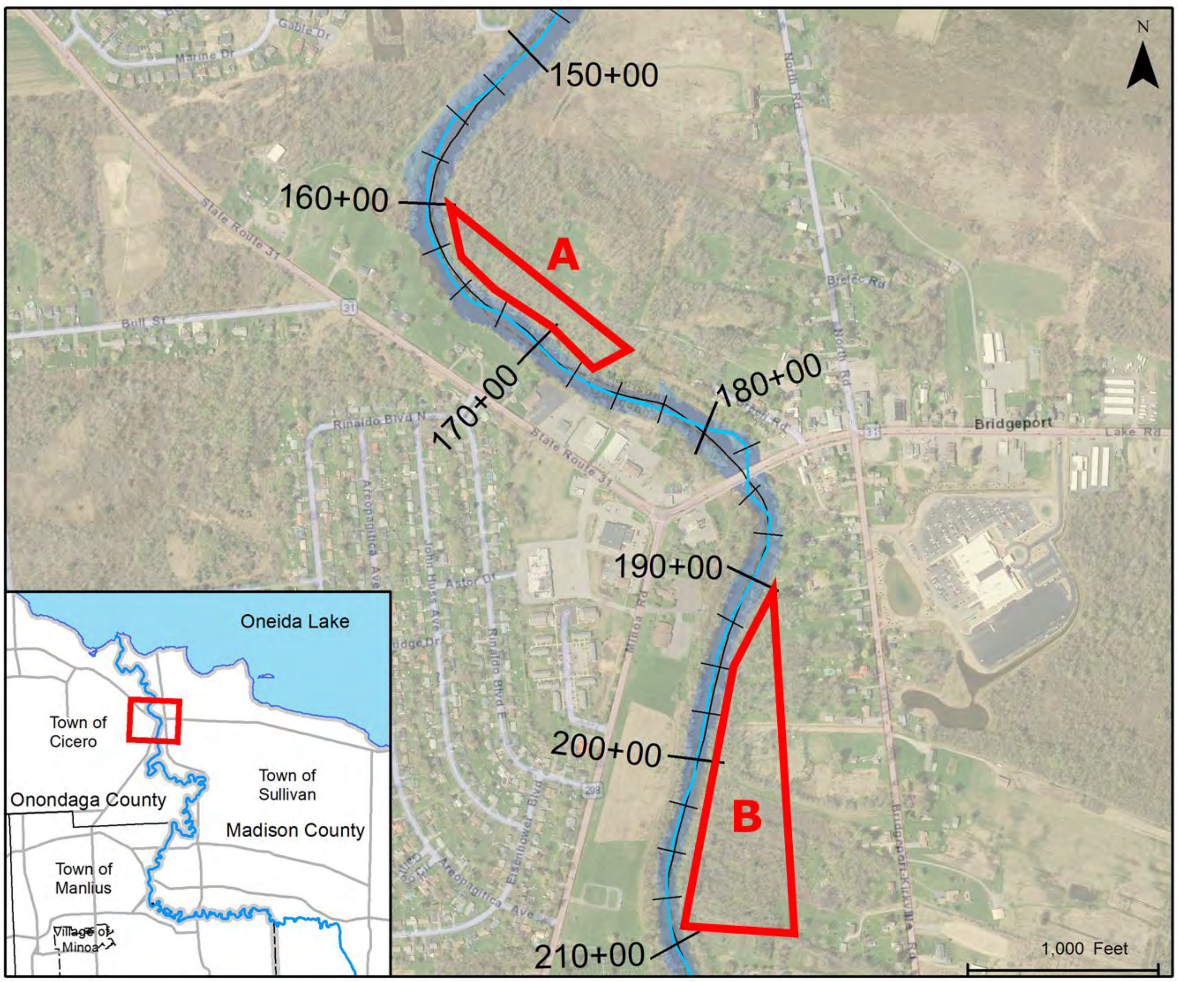

Figure 7-10. Location map for Alternative #1-4.

The flood bench designs used for the proposed condition model simulation set the minimum bench elevation approximately equal to the bankfull elevation, which was an average depth of 2 ft for both benches.

The flood benches are within the FEMA designated SFHA or Zone A, which are areas subject to inundation by the 1% ACE, but where base flood elevations and flood hazard factors were not determined, and where mandatory flood insurance purchase requirements and floodplain management standards apply (FEMA 1986b). Appendix F depicts a flood mitigation rendering of a flood bench illustrating before and after landscape features.

For this alternative, open-water, debris-obstruction, and ice-jam simulations were performed to test the effectiveness of the alternative at reducing water surface elevations for Flood Bench B only. Flood Bench A is downstream of the bridge and would have minimal influence on water surface elevations upstream of the bridge crossing.

Table 21 outlines the results of the existing conditions model simulations for each initial condition scenario. Figures 7-11 through 7-14 display the profile plots for each initial condition scenario for the flood bench alternative. Full model outputs for this alternative can be found in Appendix H.

Table 21. Summary Table for Alternative #1-4 Existing Conditions Results Based on Open-water, Debris-obstruction, and Ice-jam Conditions

Existing Conditions	**Reductions in Water Surface Elevations (feet)**	
	Flood Bench A	**Flood Bench B**
Open-water	Up to 1.5-ft	Up to 3.0-ft
Total Length of Benefited Area	2,700-ft	3,450-ft
River Stations	153+50 to 180+50	188+50 to 223+00
Debris Obstruction	N/A	Up to 1.6-ft
Total Length of Benefited Area	N/A	2,300-ft
River Stations	N/A	200+00 to 223+00
Ice Jam	N/A	Up to 2.4-ft
Total Length of Benefited Area	N/A	3,450-ft
River Stations	N/A	188+50 to 223+00

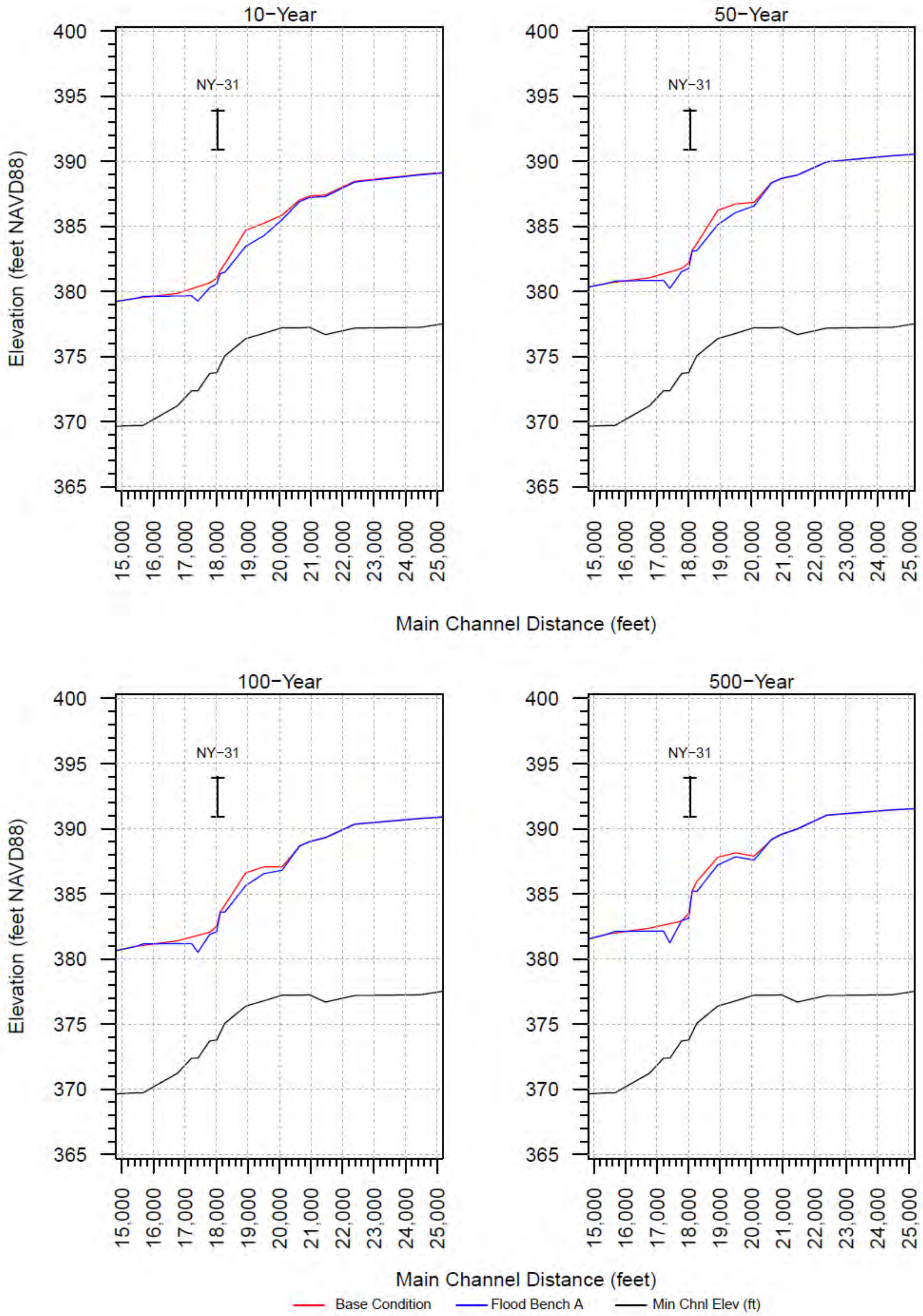

Figure 7-11. HEC-RAS model simulation output results for Alternative #1-4 for the existing condition (red) and Flood Bench A (blue) scenarios.

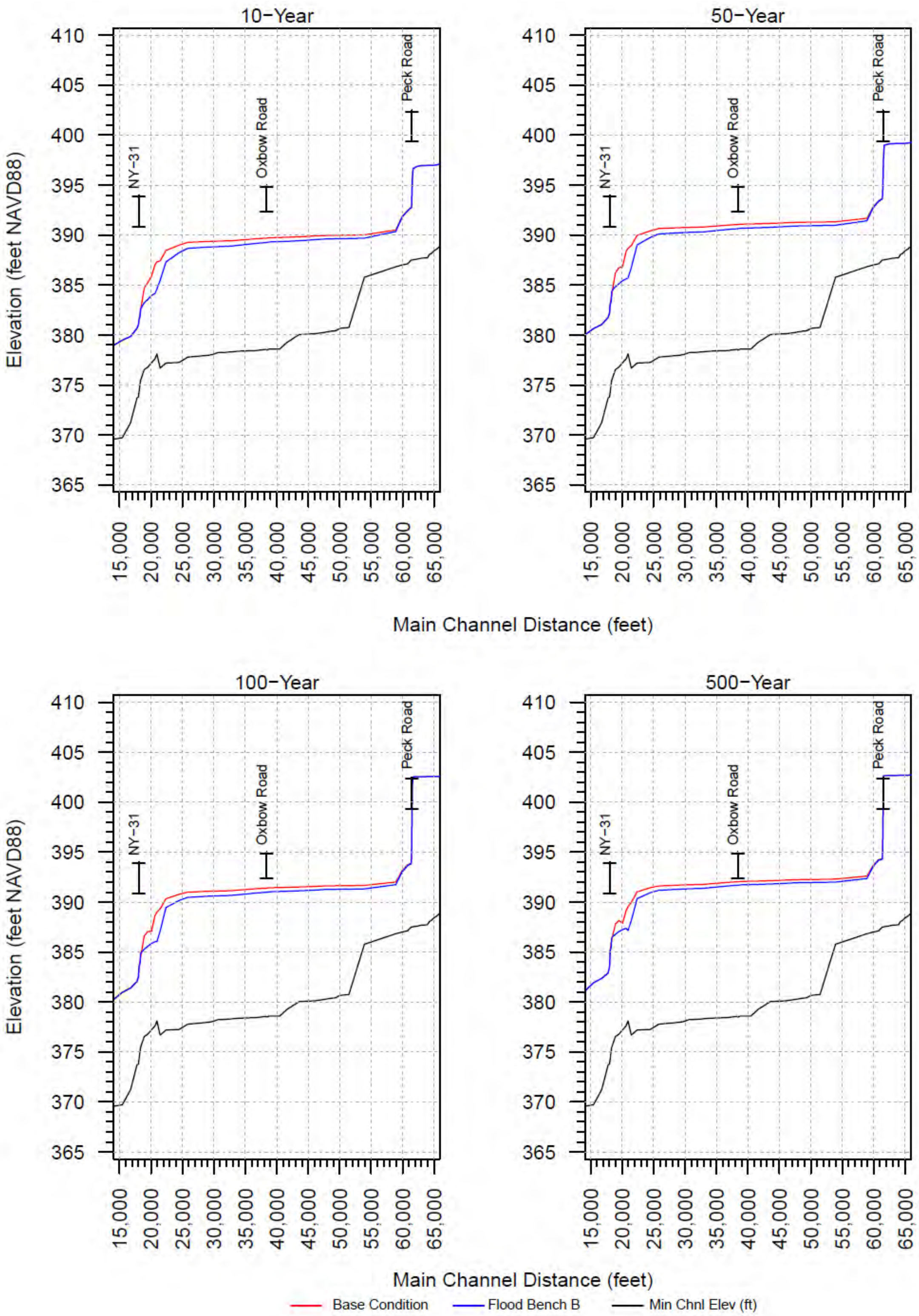

Figure 7-12. HEC-RAS model simulation output results for Alternative #1-4 for the existing condition (red) and Flood Bench B (blue) scenarios.

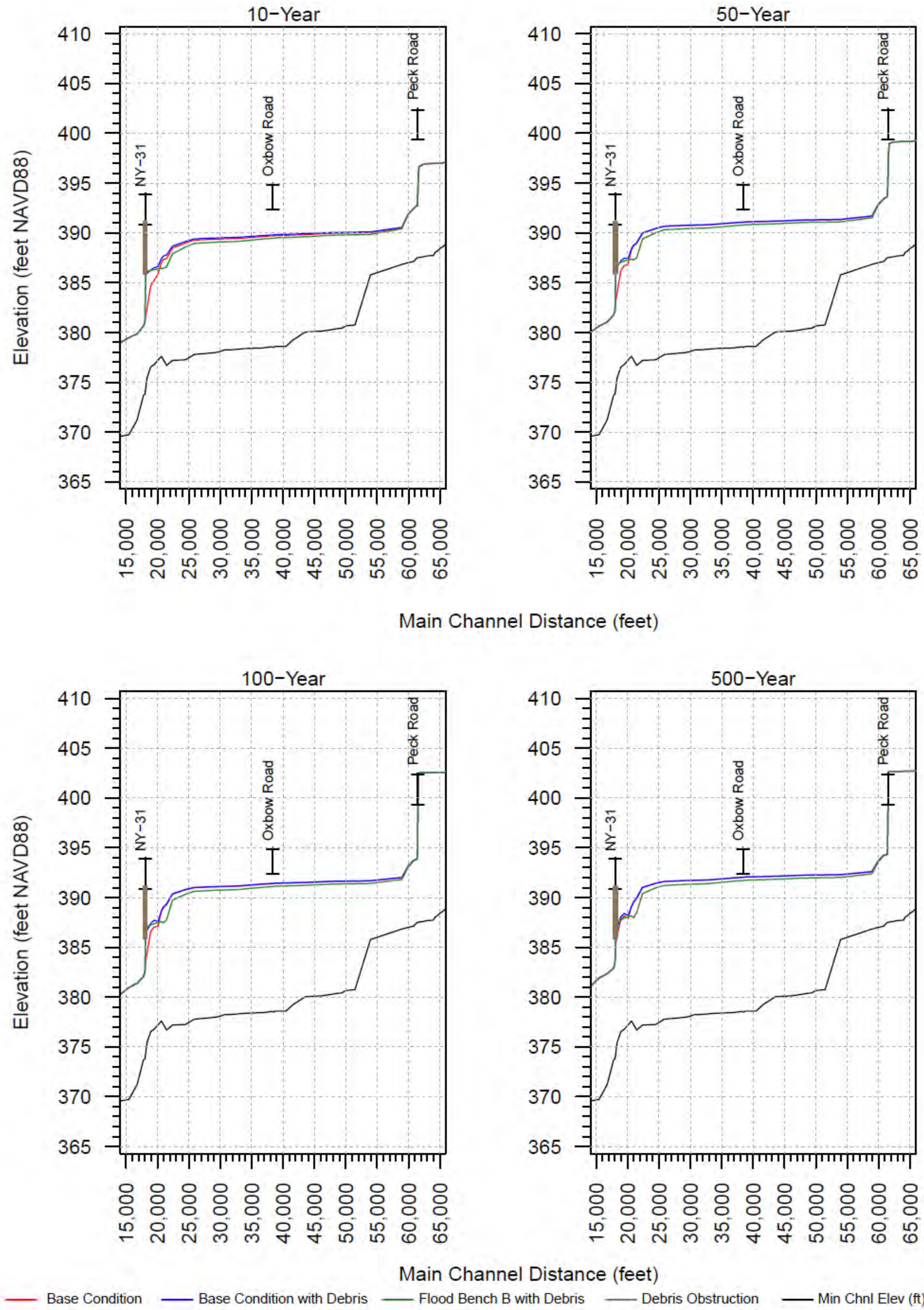

Figure 7-13. HEC-RAS debris obstruction model simulation output results for Alternative #1-4 for the existing condition (red), existing condition with debris (blue), and Flood Bench B with debris (green) scenarios.

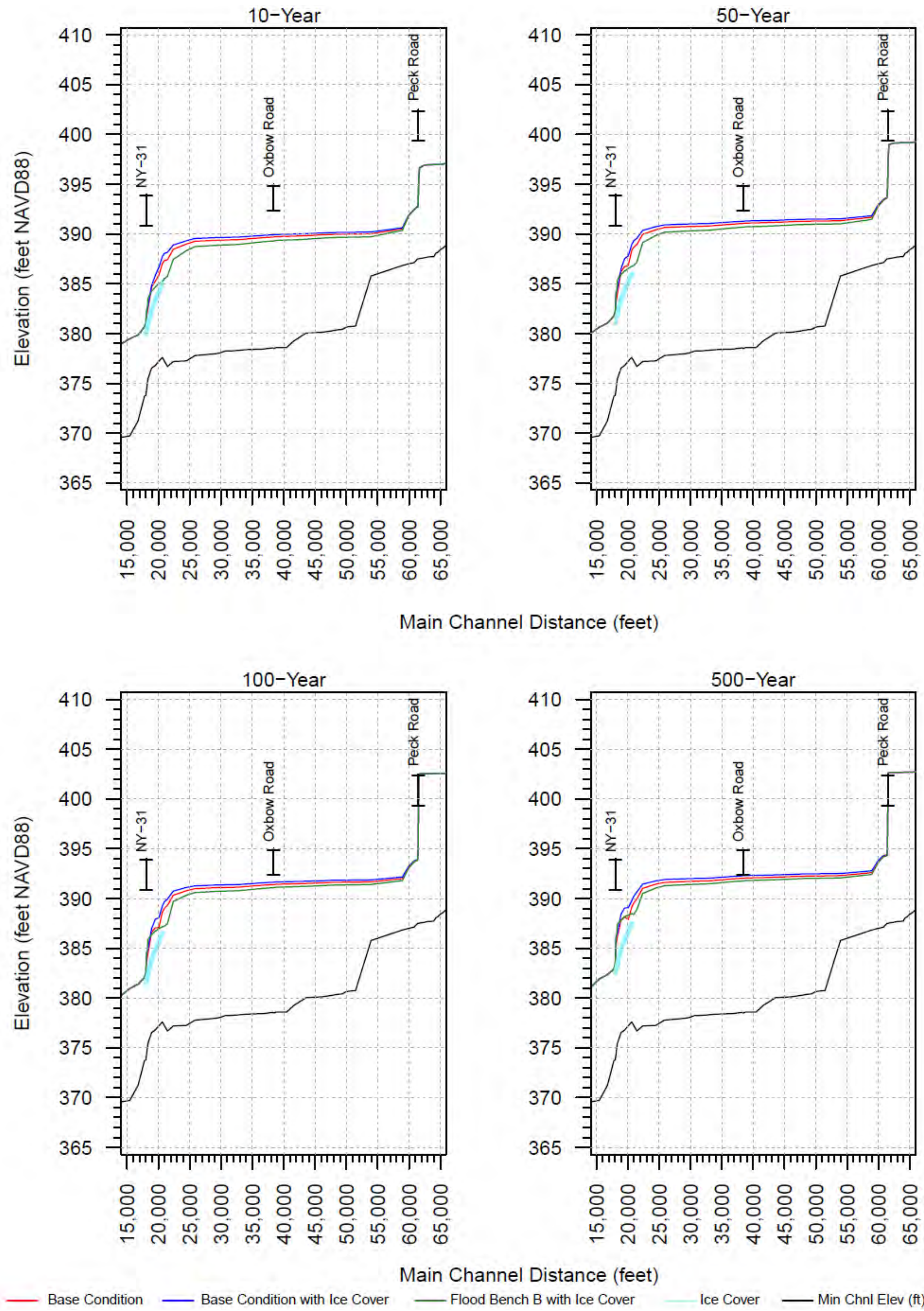

Figure 7-14. HEC-RAS ice cover model simulation output results for Alternative #1-4 for the existing condition (red), existing condition with ice cover (blue), and Flood Bench B with ice cover (green) scenarios.

Table 22 outlines the results of the future conditions model simulations for each initial condition scenario.

Table 22. Summary Table for Alternative #1-4 Future Conditions Results Based on Open-water, Debris-obstruction, and Ice-jam Conditions

Future Conditions	Reductions in Water Surface Elevations (feet)	
	Flood Bench A	Flood Bench B
Open-Water	Up to 1.8-ft	Up to 2.9-ft
Total Length of Benefited Area	2,575-ft	4,250-ft
River Stations	153+75 to 179+50	180+50 to 223+00
Debris Obstruction	N/A	Up to 1.8-ft
Total Length of Benefited Area	N/A	3,450-ft
River Stations	N/A	188+50 to 223+00
Ice Jam	N/A	Up to 2.6-ft
Total Length of Benefited Area	N/A	3,450-ft
River Stations	N/A	188+50 to 223+00

Flood benches generally provide flood protection for localized areas in the vicinity of and immediately upstream and/or downstream of the bench. Based on the analysis of high-risk areas, flood benches located both upstream and downstream of Lake Road/NY-31 would provide significant flood protection in this reach from open-water flooding. In addition, a flood bench upstream of the bridge would provide significant flood protection from debris buildup and ice-jam flooding.

To evaluate the effectiveness of the flood mitigation impacts, the project team analyzed each flood bench independently. However, there is the potential for added benefits (i.e., reduction in WSELs, less flooding, reduced erosion, etc.) when multiple flood mitigation projects are built in conjunction. For areas that experience significant flood damages or chronic flooding, it is recommended that multiple flood mitigation strategies in conjunction be considered and evaluated by affected communities.

The ROM cost for each flood bench alternative is:

- Flood Bench A: $2.0 million
- Flood Bench B: $5.6 million

These ROM cost estimates do not include land acquisition costs for survey, appraisal, and engineering coordination. In addition, the NYSDEC will require wetland delineations, an analysis for any endangered and/or threatened species within the proposed project area, and information regarding access during construction of any flood bench mitigation alternative.

7.1.5 Alternative #1-5: Flood Control Detention Basin Upstream of Bridgeport

The construction of small flood-control detention structures in the headwaters and tributaries of flood-prone streams has proven successful at preventing flood damage in small towns throughout the United States (Helms 1986). These structures are traditionally located in rural areas in agricultural fields and undeveloped land. They maintain little to no permanent pool and are designed to detain water during larger flow events, decreasing peak-flow water surface elevations and minimizing flooding further downstream in developed areas. The area between river stations 220+00 and 310+00 downstream of the Hamlet of Bridgeport in the Town of Sullivan would be the best location for a flood-control structure in the downstream reach (Figure 7-15).

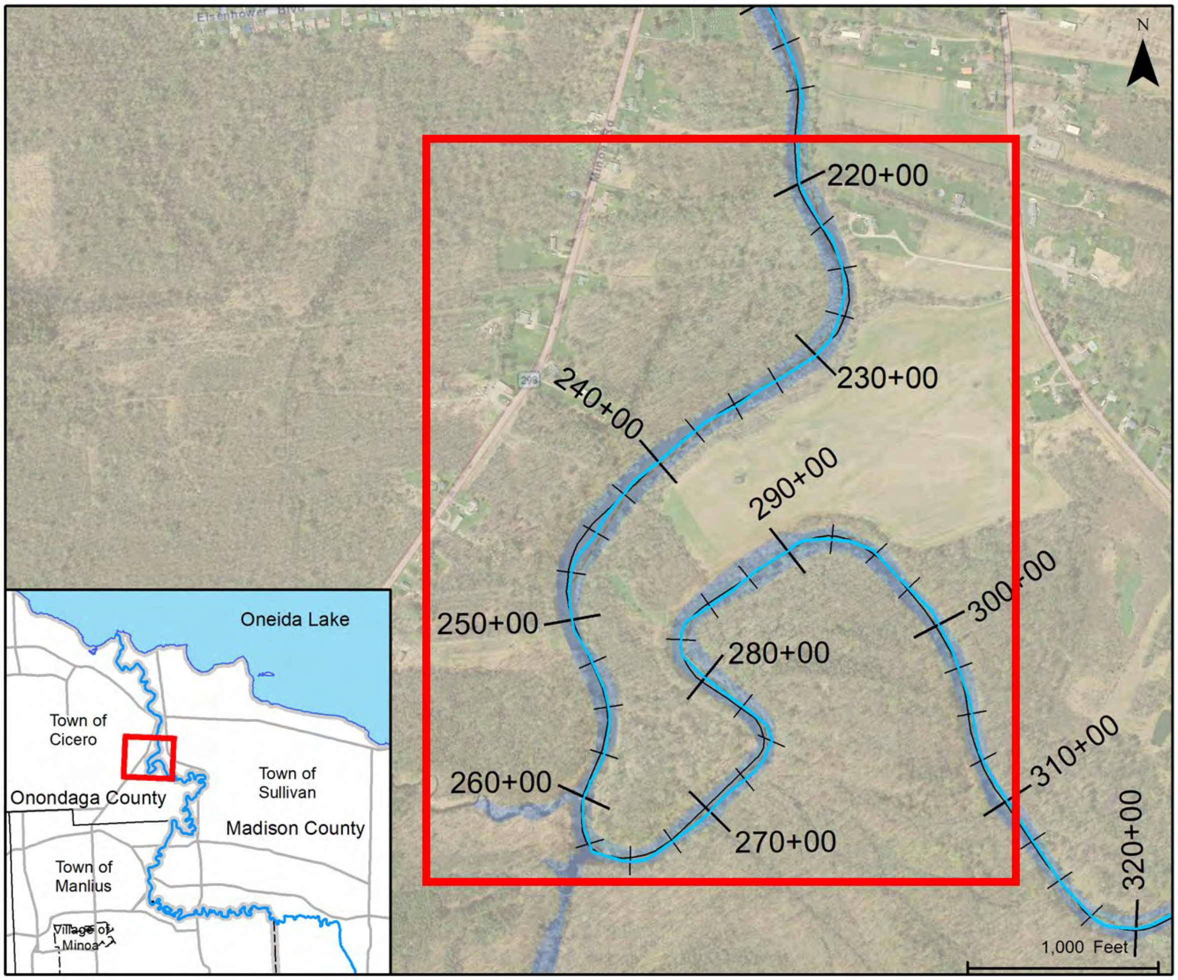

Figure 7-15. Location map for Alternative #1-5.

In New York State, a joint permit application from the NYSDEC and USACE may be required in order to construct, reconstruct, or repair a dam or other impoundment. The NYSDEC is entrusted with the regulatory power to oversee dam safety, which encompasses flood detention structures. To protect people from the loss of life and property due to flooding and/or dam failure, the NYSDEC Dam Safety Section, in cooperation with the USACE, reviews proposed dam construction and/or modifications, conducts dam safety inspections, and monitors projects for compliance with dam safety criteria.

The USACE has the authority to construct small flood risk reduction projects that are engineeringly feasibly, structurally sound, and cost efficient through the authority provided under Section 205 of the 1948 FCA, as amended. Coordination should also occur with the NYSDEC as they need to be the non-Federal sponsor on these types of projects.

In addition, a FEMA BCA would need to be performed to determine the cost-effectiveness of the alternative prior to applying for FEMA mitigation grant programs funding. The BCR must be greater than or equal to 1.0 in order for the project to be considered cost effective.

Due to the conceptual nature of this measure, and significant amount of data required to produce a reasonable rough-order-of-magnitude cost, it is not feasible to quantify the costs of this measure without further engineering analysis and modeling. However, the cost of designing, permitting, constructing, and maintaining one or more flood-control dams in the headwaters of the Chittenango Creek watershed are expected to be significant.

7.2 HIGH-RISK AREA #2

7.2.1 Alternative #2-1: Sediment Removal Analysis in Vicinity of Old Erie Canal Crossing

This measure is intended to address issues within High-risk Area #2 by increasing the flow capacity of Chittenango Creek by removing the accumulated sediment and/or debris at the Old Erie Canal located at river station 1274+00 (Figure 7-16). The flooding upstream of the Old Erie Canal crossing poses a flood risk threat to nearby residential and commercial properties, and state- and county-owned infrastructure.

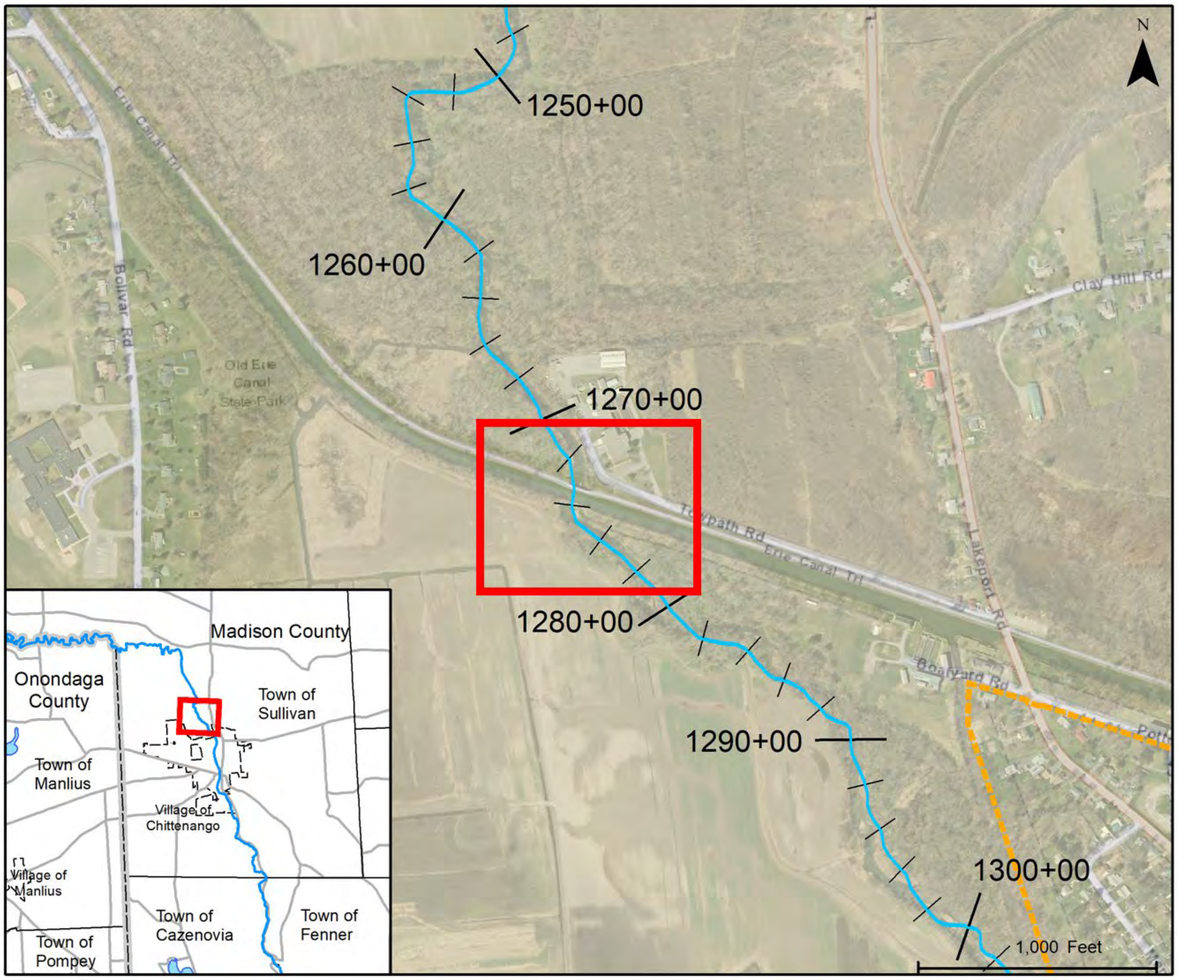

Figure 7-16. Location map for Alternative #2-1.

The canal structure is owned and maintained by the NYS Canal Corporation. The existing structure has a length of 80 ft, width of 80 ft, and two piers in the channel that are approximately 5 ft wide and spaced approximately 20 ft apart. The canal structure is raised approximately 3 ft from the Chittenango Creek channel bed to allow flow from the creek to pass underneath the structure. In addition, the canal structure has three separate overflow openings that allow water to flow from the Old Erie Canal into Chittenango Creek during high flow events along the Old Erie Canal (Figure 7-17).

Figure 7-17. Northside (downstream) facing south (upstream) at the Old Erie Canal crossing over Chittenango Creek, Sullivan, NY.

Based on orthoimagery of the area, the meander in the creek channel upstream of the canal structure coupled with the large, rectangular stone piers in the channel, and the canal structure itself being only a few feet above the creek bed, all act as impediments to flow, reducing water velocities and allowing sediment and debris to aggregate and restrict flow in this area (NYSOITS 2017).

The FEMA FIS profile plot for the Old Erie Canal structure indicates the structure is unable to successfully pass the 10-, 2-, 1-, or 0.2% annual chance event without significant backwater upstream and overtopping of the structure (FEMA 1986b). In addition, the FEMA FIRM displays significant backwater upstream of the Old Erie Canal crossing (FEMA 1986a).

By removing sediment from approximately 1,000 ft both upstream and downstream within the Chittenango Creek channel, the flow capacity of the creek can be increased allowing more volume of water to flow through the Old Erie Canal underpass, and potentially reducing flood risk and/or backwater effects from the structure during high flow events.

In addition, according to historical flood reports, stakeholder engagement meetings, and field work, the Old Erie Canal weir structure was identified as a hydraulic structure that experiences debris blockage and ice jams resulting in backwater flooding during higher peak flow events (FEMA 1986b; NYSDEC 2021b). For this alternative, open-water, debris-obstruction, and ice-jam simulations were performed to test the effectiveness of the alternative at reducing water surface elevations. Table 23 outlines the results of the existing conditions model simulations for each initial condition scenario. Figures 7-18 through 7-20 display the profile plots for each initial condition scenario for the pier removal alternative. Full model outputs for this alternative can be found in Appendix H.

Table 23. Summary Table for Alternative #2-1 Existing Conditions Results Based on Open-water, Debris-obstruction, and Ice-jam Conditions

Existing Conditions	Reductions in Water Surface Elevations (feet)
Open-Water	Up to 3.5-ft
Total Length of Benefited Area	4,625-ft
River Stations	1304+00 to 1350+25
Debris Obstruction	Up to 1.8-ft
Total Length of Benefited Area	3,450-ft
River Stations	1304+50 to 1339+00
Ice Jam	Up to 2.1-ft
Total Length of Benefited Area	3,450-ft
River Stations	1304+50 to 1339+00

Table 24 outlines the results of the future conditions model simulations for each initial condition scenario.

Table 24. Summary Table for Alternative #2-1 Future Conditions Results Based on Open-water, Debris-obstruction, and Ice-jam Conditions

Future Conditions	Reductions in Water Surface Elevations (feet)
Open-Water	Up to 2.3-ft
Total Length of Benefited Area	4,525-ft
River Stations	1293+75 to 1339+00
Debris Obstruction	Up to 2.3-ft
Total Length of Benefited Area	3,450-ft
River Stations	1304+50 to 1339+00
Ice Jam	Up to 2.3-ft
Total Length of Benefited Area	3,450-ft
River Stations	1304+50 to 1339+00

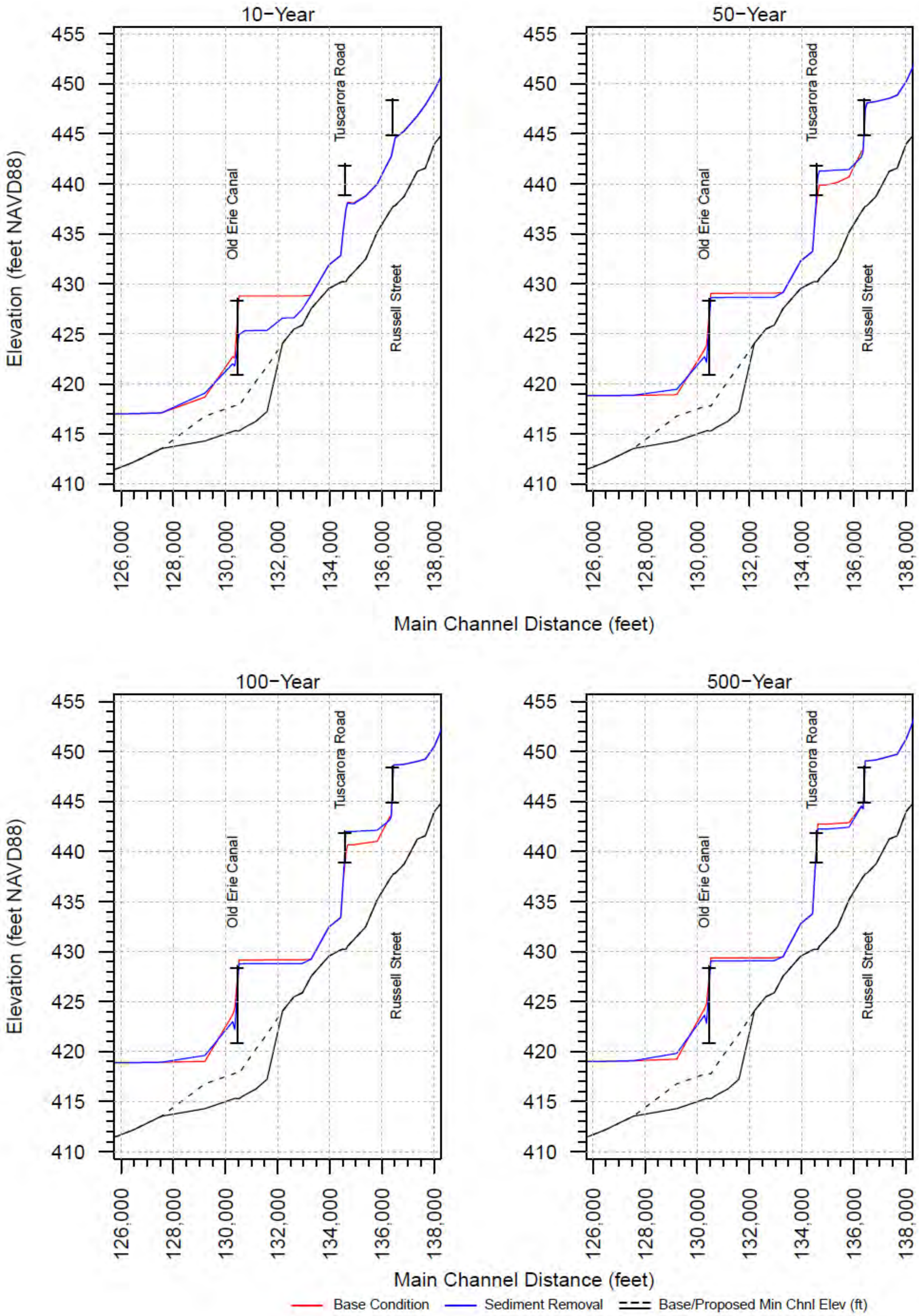

Figure 7-18. HEC-RAS model simulation output results for Alternative #2-1 for the existing condition (red) and sediment removal (blue) scenarios.

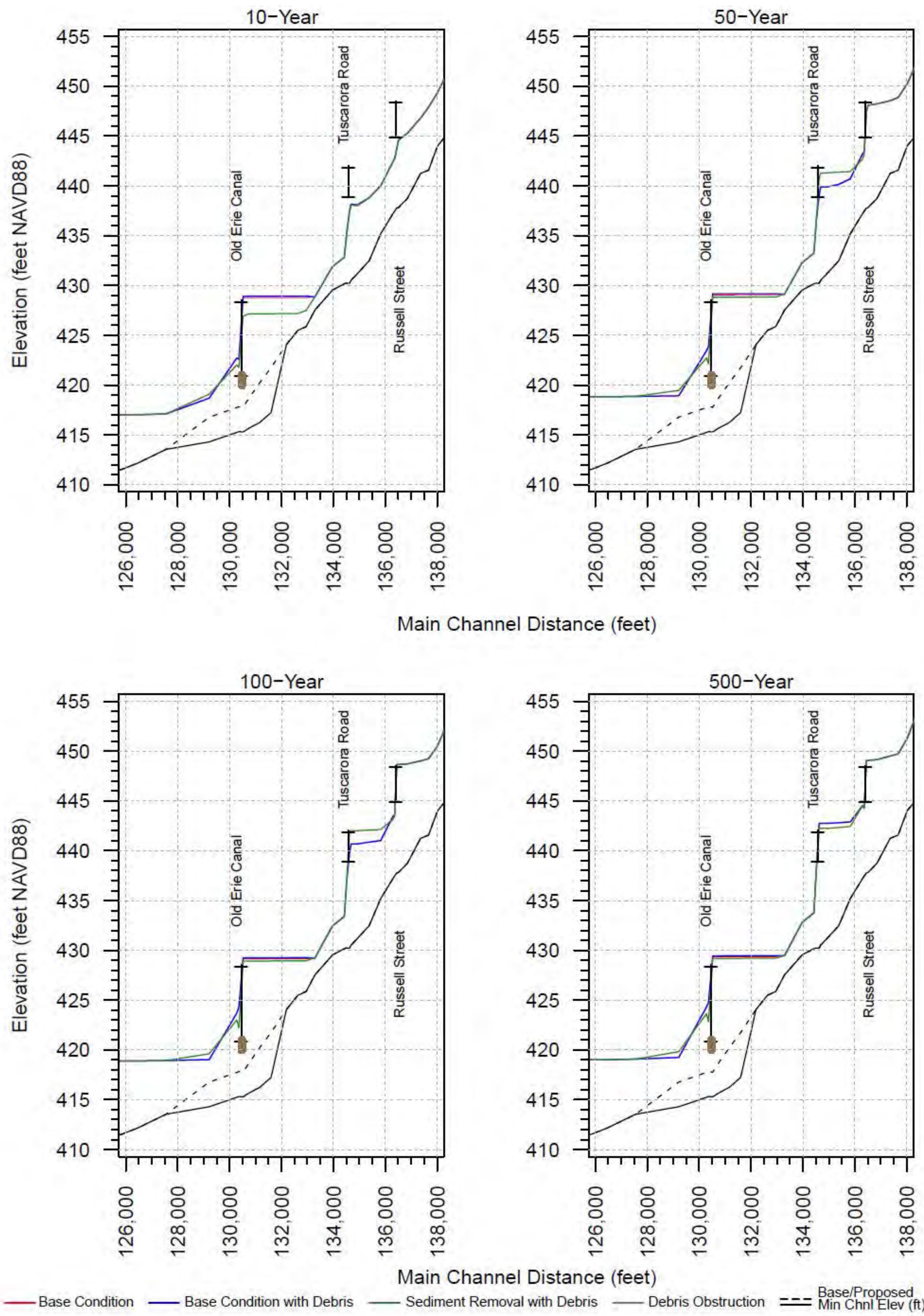

Figure 7-19. HEC-RAS debris obstruction model simulation output results for Alternative #2-1 for the existing condition (red), existing condition with debris (blue), and sediment removal with debris (green) scenarios.

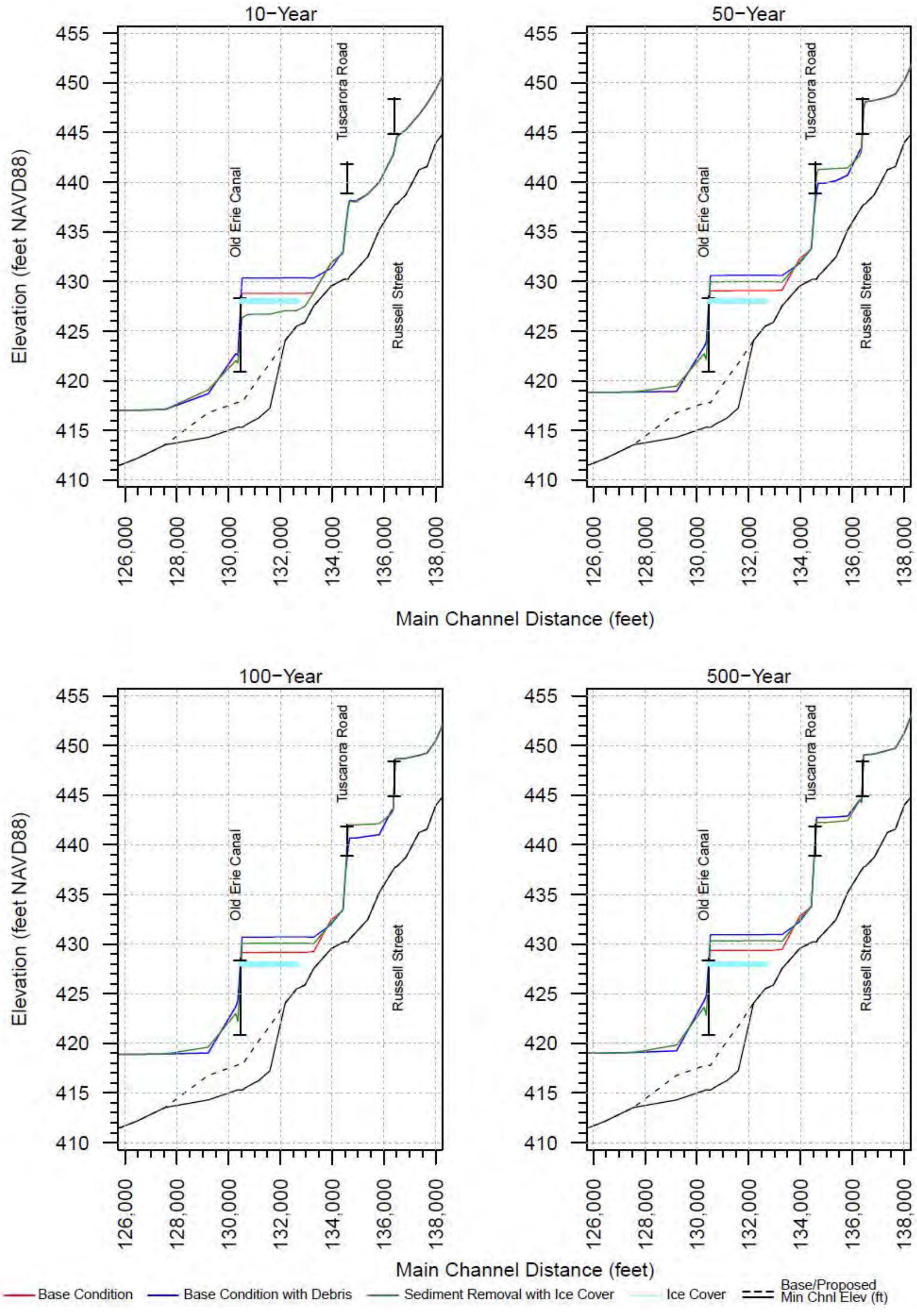

Figure 7-20. HEC-RAS ice cover model simulation output results for Alternative #2-1 for the existing condition (red), existing condition with ice cover (blue), and sediment removal with ice cover (green) scenarios.

A sediment management strategy that involves removing sediment from the channel, such as dredging, requires extensive environmental and modeling studies, application, sampling, testing, certification, permitting, operational and maintenance plans with proof of financial viability, and a significant proposal justification, including only viable alternatives and greatest benefit with least amount of impact. The NYSDEC *Technical & Operations Guidance Series (TOGS) 5.1.9 In-Water and Riparian Management of Sediment and Dredged Material* (2004) should be used to determine the procedure and necessary steps in order to develop a sediment removal strategy.

There are a number of federal, state, and local regulatory controls in place which apply to in-water and riparian sediment management projects. The applicability of these controls to each project depends on the particular circumstances of each case, such as the sediment classification and the intended use or management of the removed material (NYSDEC 2004).

Some or all of the following New York State and Federal Permits may be required: Use and Protection of Waters Permit; Freshwater Wetlands Permit; Tidal Wetlands Permit; State Pollutant Discharge Elimination System Permit; Clean Water Act § 401 Water Quality Certification and § 404 Permit and Rivers and Harbors Act § 10 Permits, issued by the USACE. An antidegradation review and Wild, Scenic and Recreational Rivers Program permits may also be required (NYSDEC 2004).

The Old Erie Canal is also a NYS Historic Site, which would require any construction or work in the vicinity of the canal to follow NYS Historic Site guidelines, requirements, permitting, etc. (NYSOPRHP 2018b).

In addition, the process of removing sediment can have negative effects on aquatic ecosystems, including:

- Fundamentally changing the composition of aquatic habitats
- Potentially releasing pollutants into the water column that were previously secured in the channel sediments
- Directly or indirectly leading to the loss of plants and animals that live in sediments
- Reducing sediment supply downstream
- Removing larger gravels and cobbles can destabilize the channel bed substrate, exposing smaller sized sediments and making them easier to move downstream
- Increasing flood risk downstream by increasing the volume of water carried
- Triggering erosion of the bed and banks by altering flow velocities and volumes (SEPA 2010)

The potential benefits of this strategy are limited to the vicinity of the Old Erie Canal structure. The primary benefit of removing sediment would be to increase the flow capacity through the structure and reduce the potential of debris and ice catching on a pier and creating obstructions/jams upstream of the structure.

The ROM cost for this strategy is approximately $1.5 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination, and any removal and/or disposal costs associated with the removed sediment.

7.2.2 Alternative #2-2: Channelization of Chittenango Creek in Vicinity of Old Erie Canal Crossing

This measure is intended to address issues within High-risk Area #2 by increasing the flow velocity of Chittenango Creek by channelizing this reach as it passes underneath the Old Erie Canal located at river station 1274+00 (Figure 7-16). The flooding upstream of the Old Erie Canal crossing poses a flood risk threat to nearby residential and commercial properties, and state- and county-owned infrastructure.

Channelization and channel modification describe river and stream channel engineering undertaken for flood control, navigation, drainage improvement, and reduction of channel migration potential. Activities that fall into this category include straightening, widening, deepening, or relocating existing stream channels, and clearing or snagging operations. These forms of hydromodification typically result in more uniform channel cross-sections, steeper stream gradients, and reduced average pool depths (USEPA 2007).

Channelization in this reach would include deepening by removing sediment from approximately 1,000 ft both upstream and downstream within the channel, and installing concrete armoring along the channel bed and banks underneath the Old Erie Canal structure.

According to historical flood reports, stakeholder engagement meetings, and field work, the Old Erie Canal structure was identified as a hydraulic structure that experiences debris blockage and ice jams resulting in backwater flooding during higher peak flow events (FEMA 1986b; NYSDEC 2021b). For this alternative, open-water, debris-obstruction, and ice-jam simulations were performed to test the effectiveness of the alternative at reducing water surface elevations. Table 25 outlines the results of the existing conditions model simulations for each initial condition scenario. Figures 7-21 through 7-23 display the profile plots for each initial condition scenario for the pier removal alternative. Full model outputs for this alternative can be found in Appendix H.

Table 25. Summary Table for Alternative #2-2 Existing Conditions Results Based on Open-water, Debris-obstruction, and Ice-jam Conditions

Existing Conditions	Reductions in Water Surface Elevations (feet)
Open-Water	Up to 3.2-ft
Total Length of Benefited Area	3,450-ft
River Stations	1304+50 to 1339+00
Debris Obstruction	Up to 3.2-ft
Total Length of Benefited Area	3,450-ft
River Stations	1304+50 to 1339+00
Ice Jam	Up to 4.0-ft
Total Length of Benefited Area	5,650-ft
River Stations	1293+75 to 1350+25

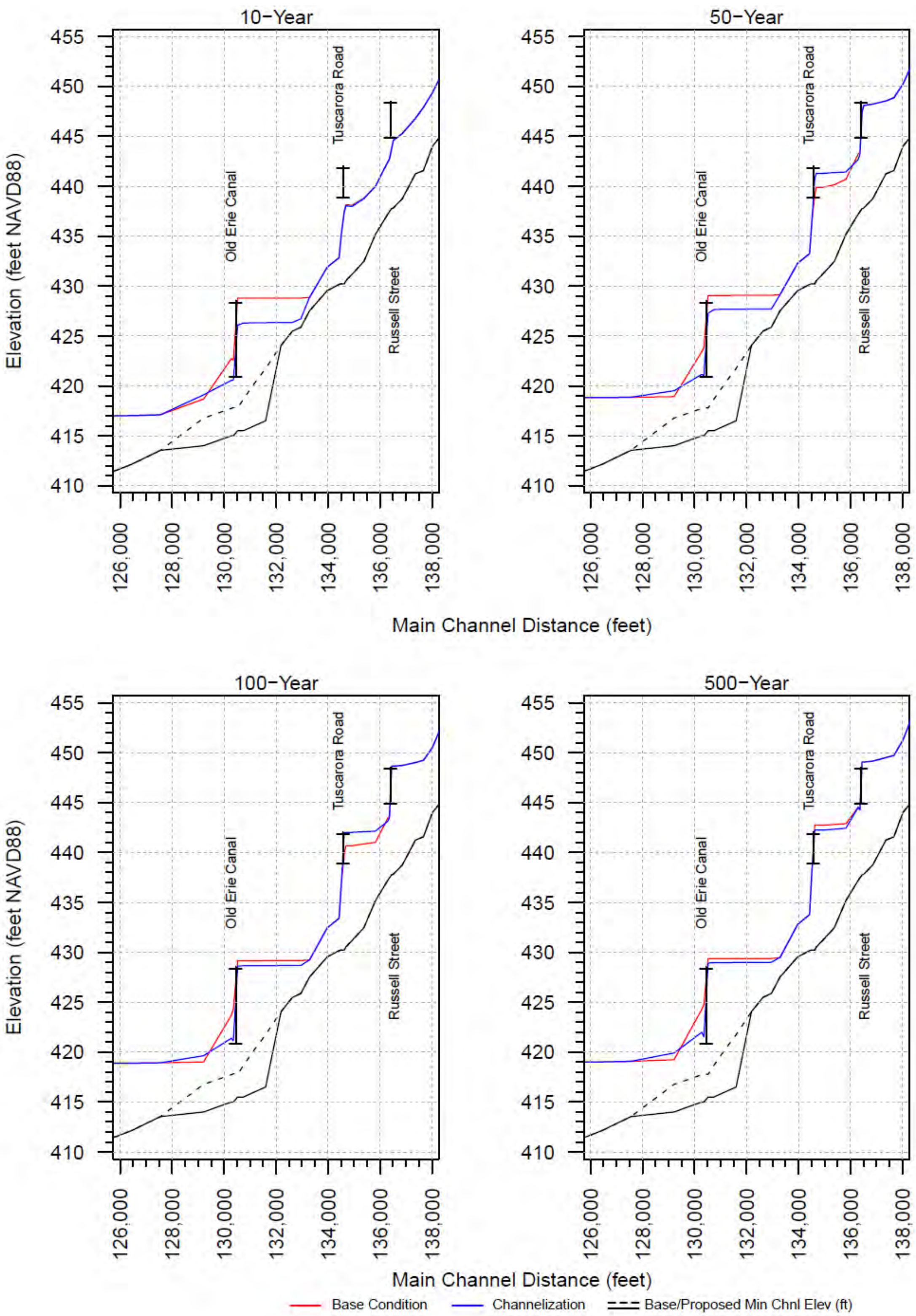

Figure 7-21. HEC-RAS model simulation output results for Alternative #2-2 for the existing condition (red) and channelization (blue) scenarios.

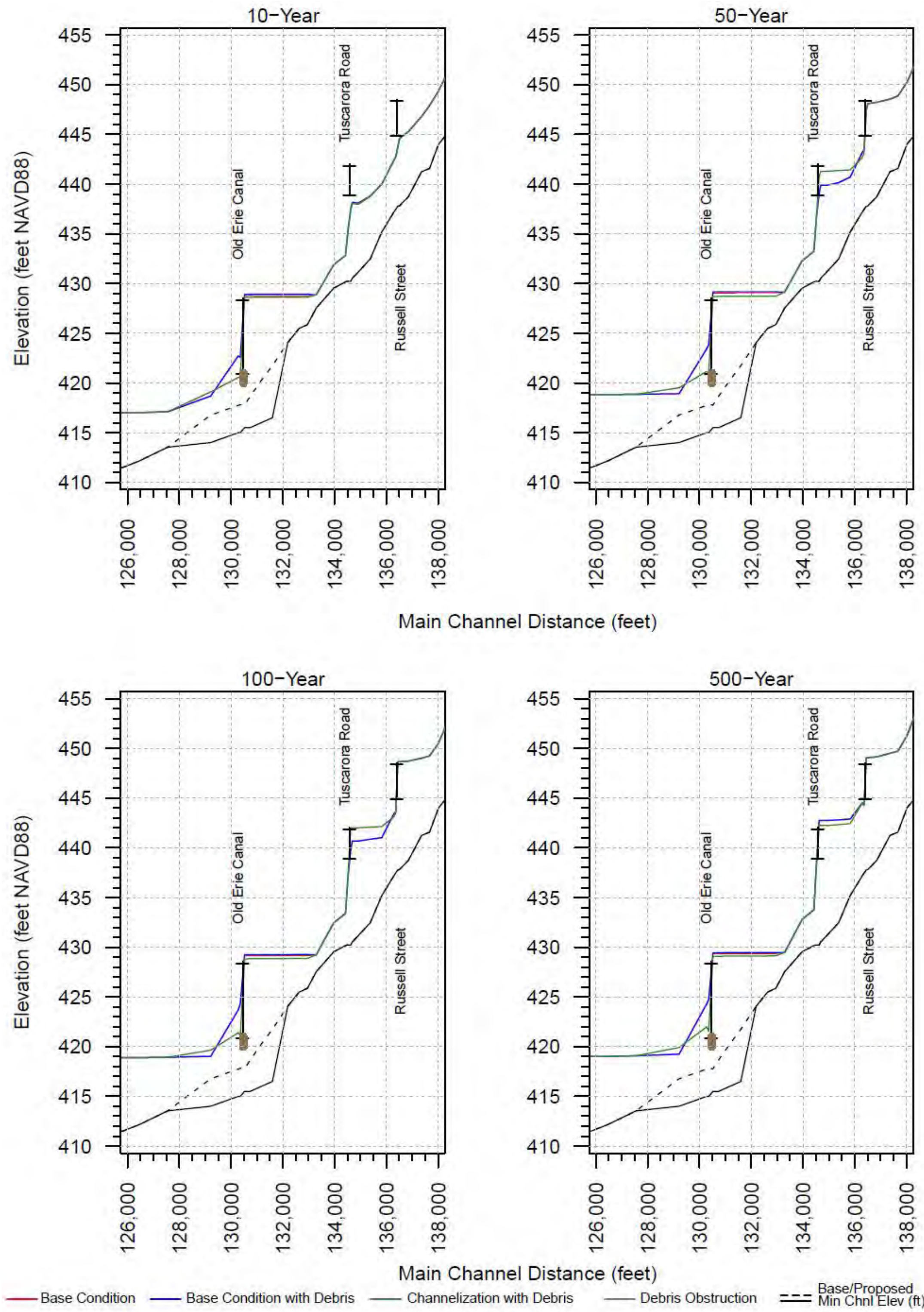

Figure 7-22. HEC-RAS debris obstruction model simulation output results for Alternative #2-2 for the existing condition (red), existing condition with debris (blue), and channelization with debris (green) scenarios.

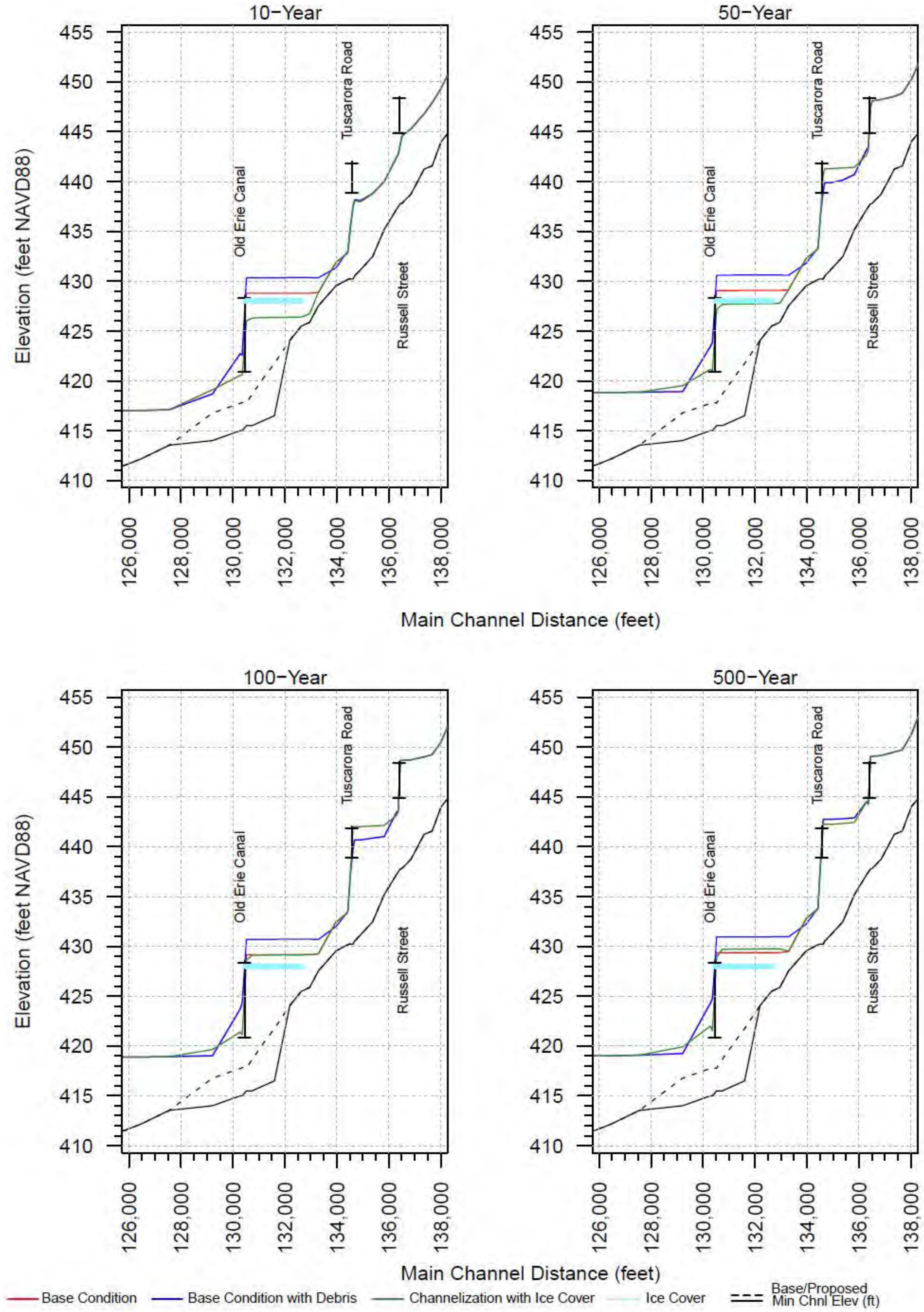

Figure 7-23. HEC-RAS ice cover model simulation output results for Alternative #2-2 for the existing condition (red), existing condition with ice cover (blue), and channelization with ice cover (green) scenarios.

Table 26 outlines the results of the future conditions model simulations for each initial condition scenario.

Table 26. Summary Table for Alternative #2-2 Future Conditions Results Based on Open-water, Debris-obstruction, and Ice-jam Conditions

Future Conditions	Reductions in Water Surface Elevations (feet)
Open-Water	Up to 2.6-ft
Total Length of Benefited Area	3,450-ft
River Stations	1304+50 to 1339+00
Debris Obstruction	Up to 2.6-ft
Total Length of Benefited Area	3,450-ft
River Stations	1304+50 to 1339+00
Ice Jam	Up to 2.6-ft
Total Length of Benefited Area	3,450-ft
River Stations	1304+50 to 1339+00

Channelization and channel modification activities can play a critical role in nonpoint source pollution by increasing the downstream delivery of pollutants and sediment that enter the water. Some channelization and channel modification activities can also cause higher flows, which increase the risk of downstream flooding (USEPA 2007).

Channelization and channel modification can (USEPA 2007):

- Disturb stream equilibrium
- Disrupt riffle and pool habitats
- Create changes in stream velocities
- Eliminate the function of floods to control channel-forming properties
- Alter the base level of a stream (streambed elevation)
- Increase erosion and sediment load

Many of these impacts are related. For example, straightening a stream channel can increase stream velocities and destroy downstream pool and riffle habitats. As a result of less structure in the stream to retard velocities, downstream velocities may continue to increase and lead to more frequent and severe erosion (USEPA 2007).

In addition, the Old Erie Canal is a NYS Historic Site, which would require any construction or work in the vicinity of the canal to follow NYS Historic Site guidelines, requirements, permitting, etc. (NYSOPRHP 2018b).

The potential benefits of this strategy are limited to immediately upstream of the Old Erie Canal weir structure. The primary benefit of increasing the weir openings would be to increase the flow capacity through the structure and reduce the potential of debris and ice catching on a pier and creating obstructions/jams upstream of the structure.

The ROM cost for this strategy is approximately $1.5 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination and any removal and/or disposal costs associated with the removed sediment.

7.2.3 Alternative #2-3: Flood Benches Upstream of the Old Erie Canal Crossing

Installing a flood bench would provide additional storage and floodplain width over and above the current storage and width provided by the adjacent agricultural and undeveloped lands, which could potentially reduce damages in the event of flooding and address issues within High-risk Area #2. Four potential flood benches were modeled in the vicinity of the Old Erie Canal and Tuscarora Road in the Town of Sullivan (Figure 7-24):

- Flood Bench A is approximately 10 acres in size with average depth of 1.5 ft and located between river stations 1275+00 to 1286+00
- Flood Bench B is approximately 8 acres in size with average depth of 1.5 ft and located between river stations 1286+00 and 1300+00
- Flood Bench C is approximately 8 acres in size with average depth of 1.0 ft and located between river stations 1300+00 to 1312+50
- Flood Bench D is approximately 5 acres in size with average depth of 1.5 ft and located between river stations 1292+00 to 1304+00

Flood Benches A, B, and C were analyzed to address flooding issues along the left bank of Chittenango Creek, including adjacent properties and Bolivar and Tuscarora Roads. Flood Bench D was analyzed to address flooding issues along the right bank of Chittenango Creek, including adjacent properties and Manor Drive and Lakeport Road. The flood bench designs used for the proposed condition model simulation set the minimum bench elevation approximately equal to the bankfull elevation.

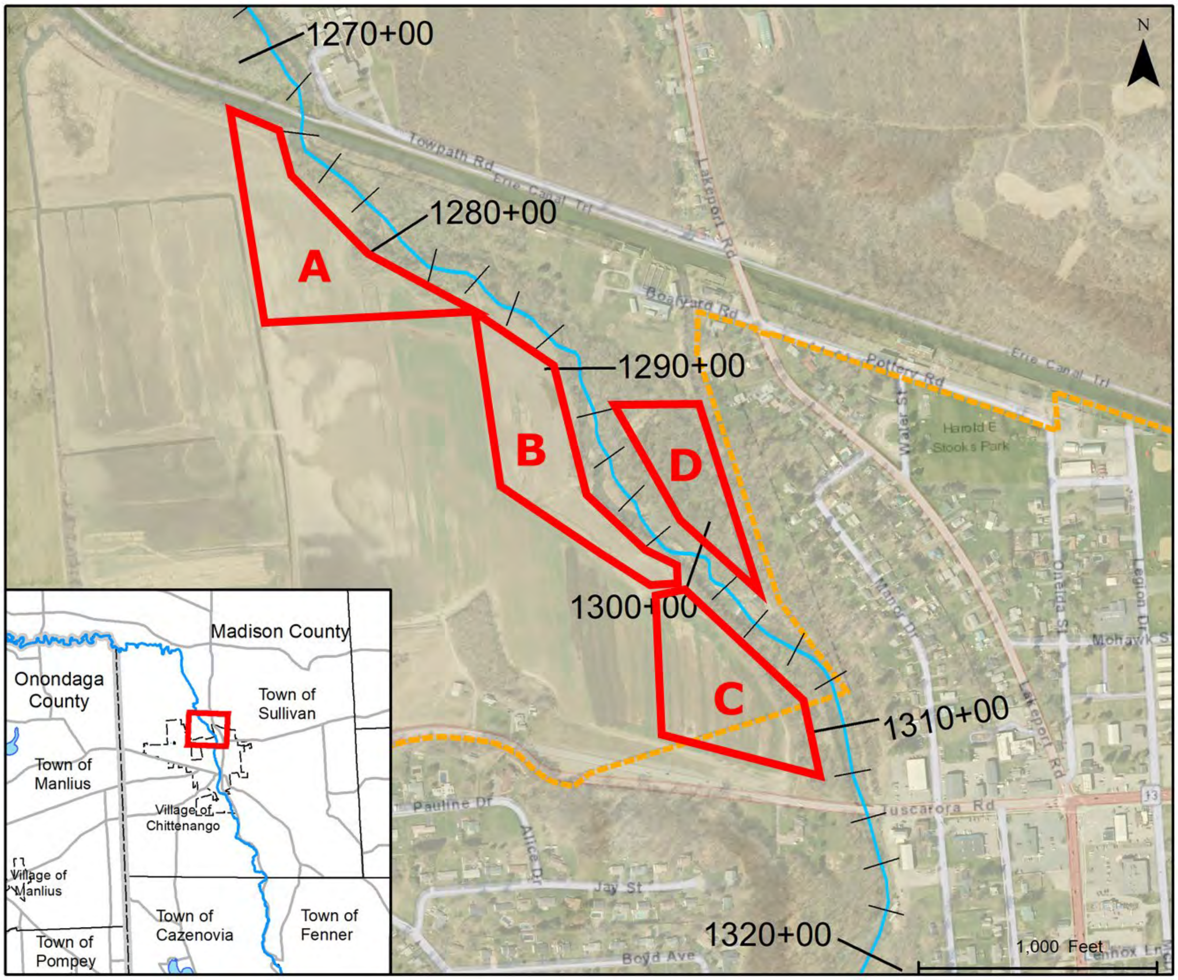

Figure 7-24. Location map for Alternative #2-3.

The flood benches are within the FEMA designated SFHA or Zone A, which are areas subject to inundation by the 1% ACE, but where base flood elevations and flood hazard factors were not determined, and where mandatory flood insurance purchase requirements and floodplain management standards apply (FEMA 1986b). Appendix F depicts a flood mitigation rendering of a flood bench illustrating before and after landscape features.

For this alternative, open-water, debris-obstruction, and ice-jam simulations were performed to test the effectiveness of the alternative at reducing water surface elevations. However, the debris-obstruction and ice-jam simulation results indicated no significant influence of any flood bench on water surface elevations in the vicinity of the Old Erie Canal crossing. This is most likely a result of the low topography in the overbank areas immediately upstream of the Old Erie Canal crossing, and that overtopping of the weir structure occurs for the 2-, 1-, and 0.2% ACE hazards.

Table 27 outlines the results of the existing conditions model simulations for each initial condition scenario. Full model outputs for this alternative can be found in Appendix H. Figures 7-25 through 7-28 display the profile plots for each flood bench alternative.

Table 27. Summary Table for Alternative #2-3 Existing Conditions Results Based on Open-water Conditions for Each Flood Bench Alternative

Existing Conditions	Reductions in Water Surface Elevations (feet)			
	Flood Bench A	Flood Bench B	Flood Bench C	Flood Bench D
Open-Water	Up to 0.8-ft	Up to 0.8-ft	Up to 0.7-ft	Up to 0.8-ft
Total Length of Benefited Area	1,200-ft	1,200-ft	1,200-ft	1,200-ft
River Stations	1332+50 to 1344+50	1332+50 to 1344+50	1332+50 to 1344+50	1332+50 to 1344+50

Table 28 outlines the results of the future conditions model simulations for each initial condition scenario.

Table 28. Summary Table for Alternative #2-3 Future Conditions Results Based on Open-water Conditions for Each Flood Bench Alternative

Future Conditions	Reductions in Water Surface Elevations (feet)			
	Flood Bench A	Flood Bench B	Flood Bench C	Flood Bench D
Open-Water	Up to 0.6-ft	Up to 0.6-ft	Up to 0.8-ft	Up to 0.6-ft
Total Length of Benefited Area	1,200-ft	1,200-ft	1,200-ft	1,200-ft
River Stations	1332+50 to 1344+50	1332+50 to 1344+50	1332+50 to 1344+50	1332+50 to 1344+50

Flood benches generally provide flood protection for localized areas in the vicinity of and immediately upstream and/or downstream of the bench. Based on the analysis of high-risk areas, a flood bench located upstream of the Old Erie Canal would not provide significant flood protection in this reach from open-water, debris-obstruction, and/or ice-jam flooding. This is most likely a result of the morphological features of the channel in this area (i.e., the significant meanders in the channel flow path immediately upstream of the bridge), the weir structure’s gate openings, and the low topography in the overbank areas immediately upstream of the weir structure.

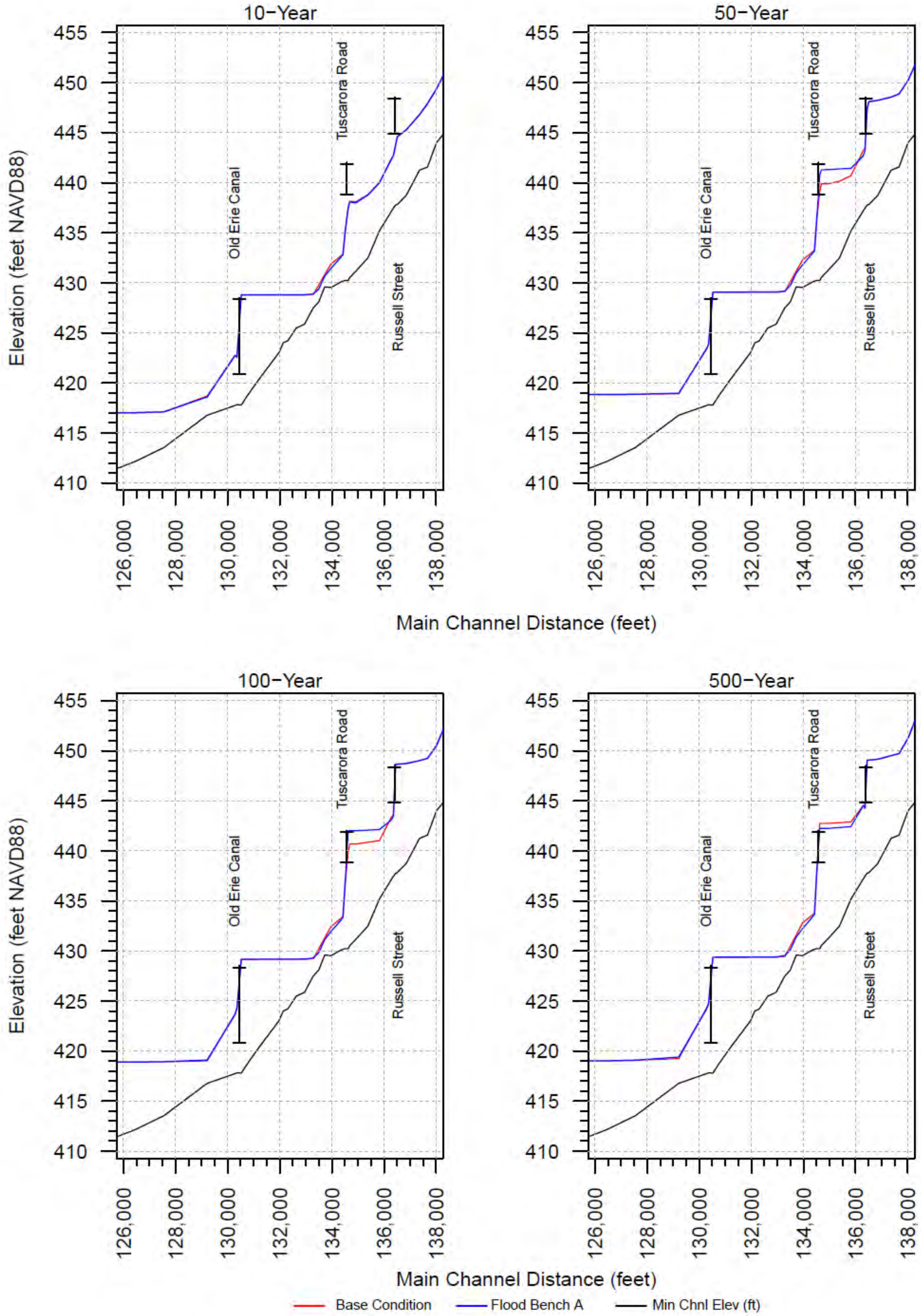

Figure 7-25. HEC-RAS model simulation output results for Alternative #2-3 for the existing condition (red) and Flood Bench A (blue) scenarios.

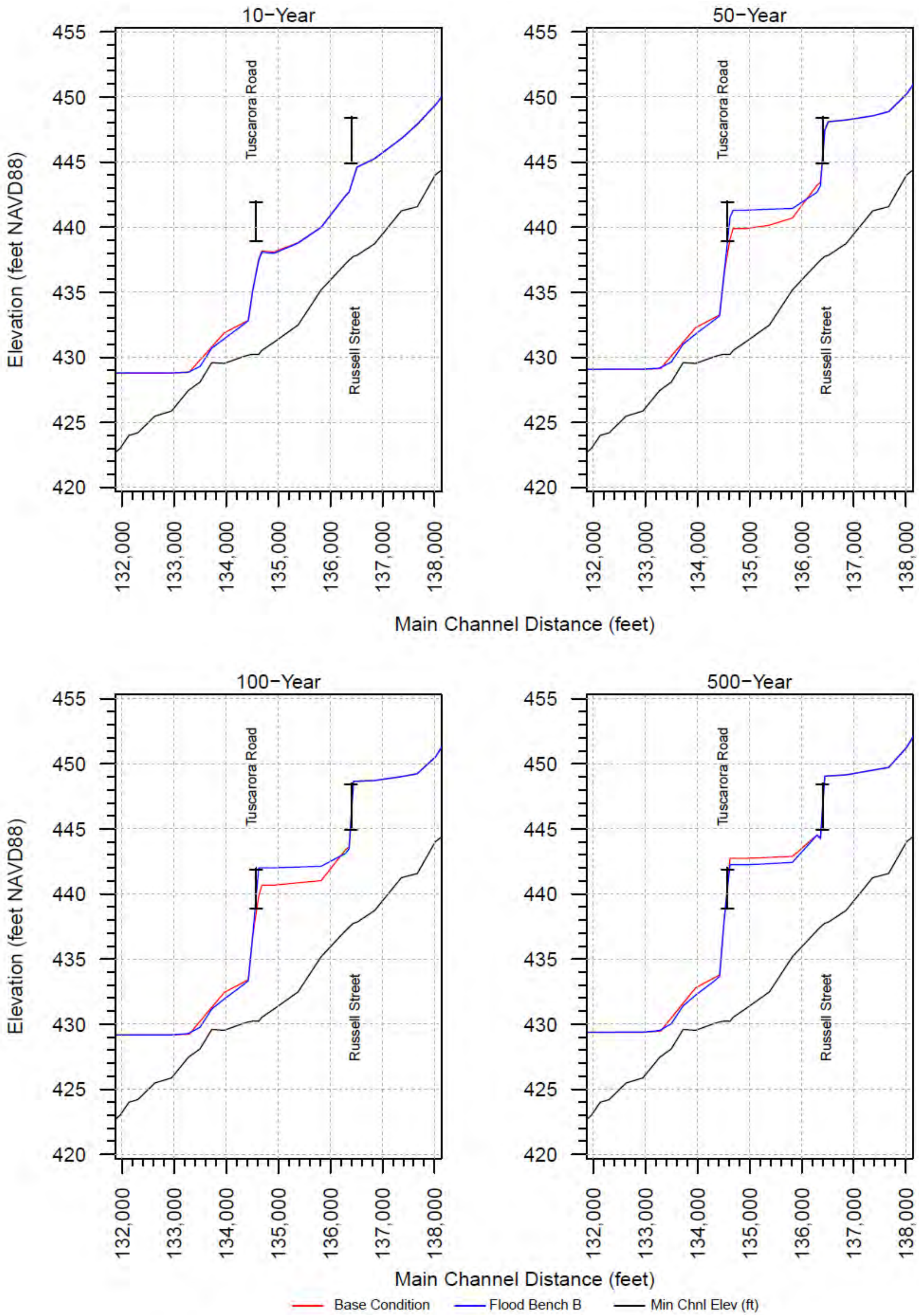

Figure 7-26. HEC-RAS model simulation output results for Alternative #2-3 for the existing condition (red) and Flood Bench B (blue) scenarios.

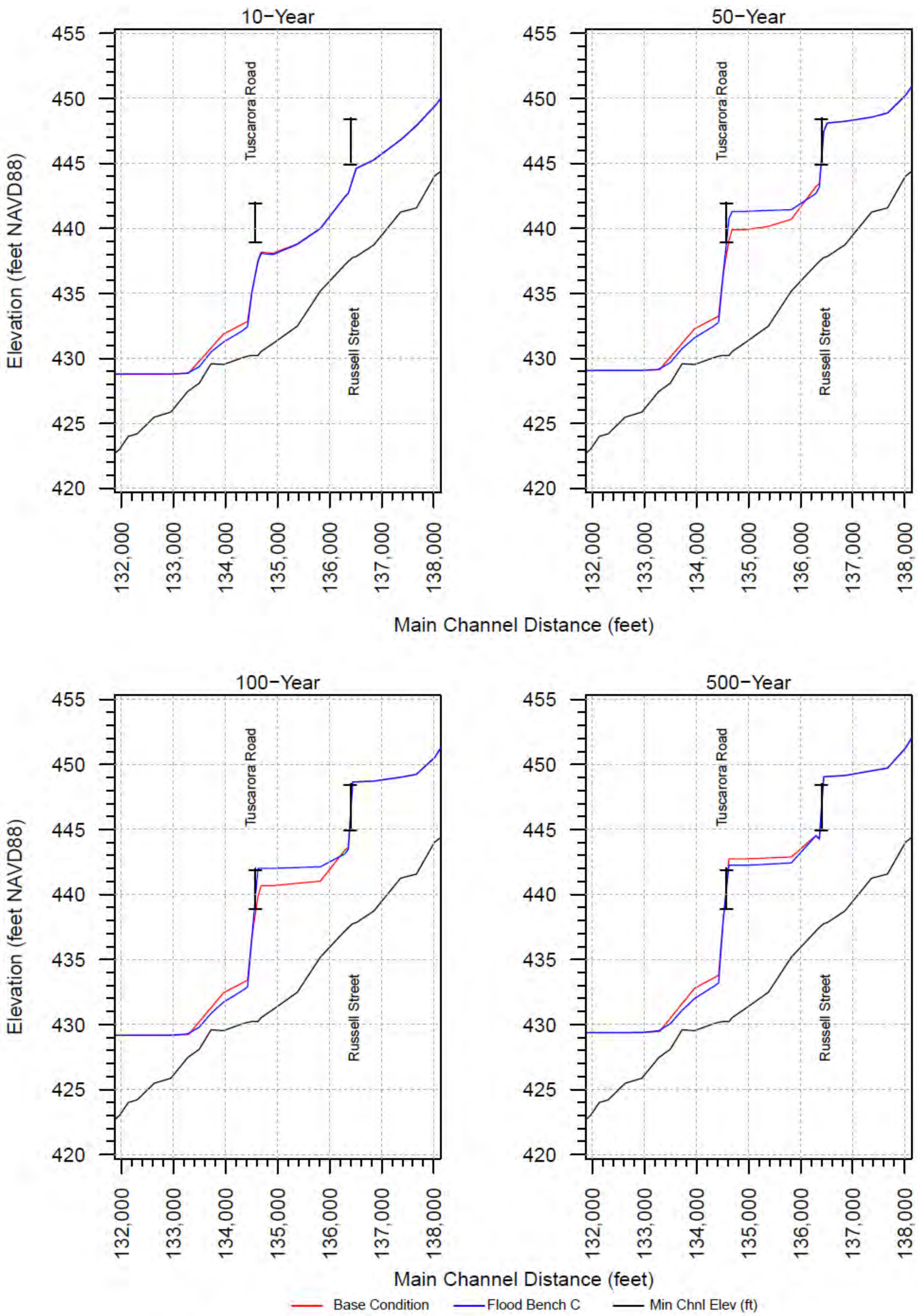

Figure 7-27. HEC-RAS model simulation output results for Alternative #2-3 for the existing condition (red) and Flood Bench C (blue) scenarios.

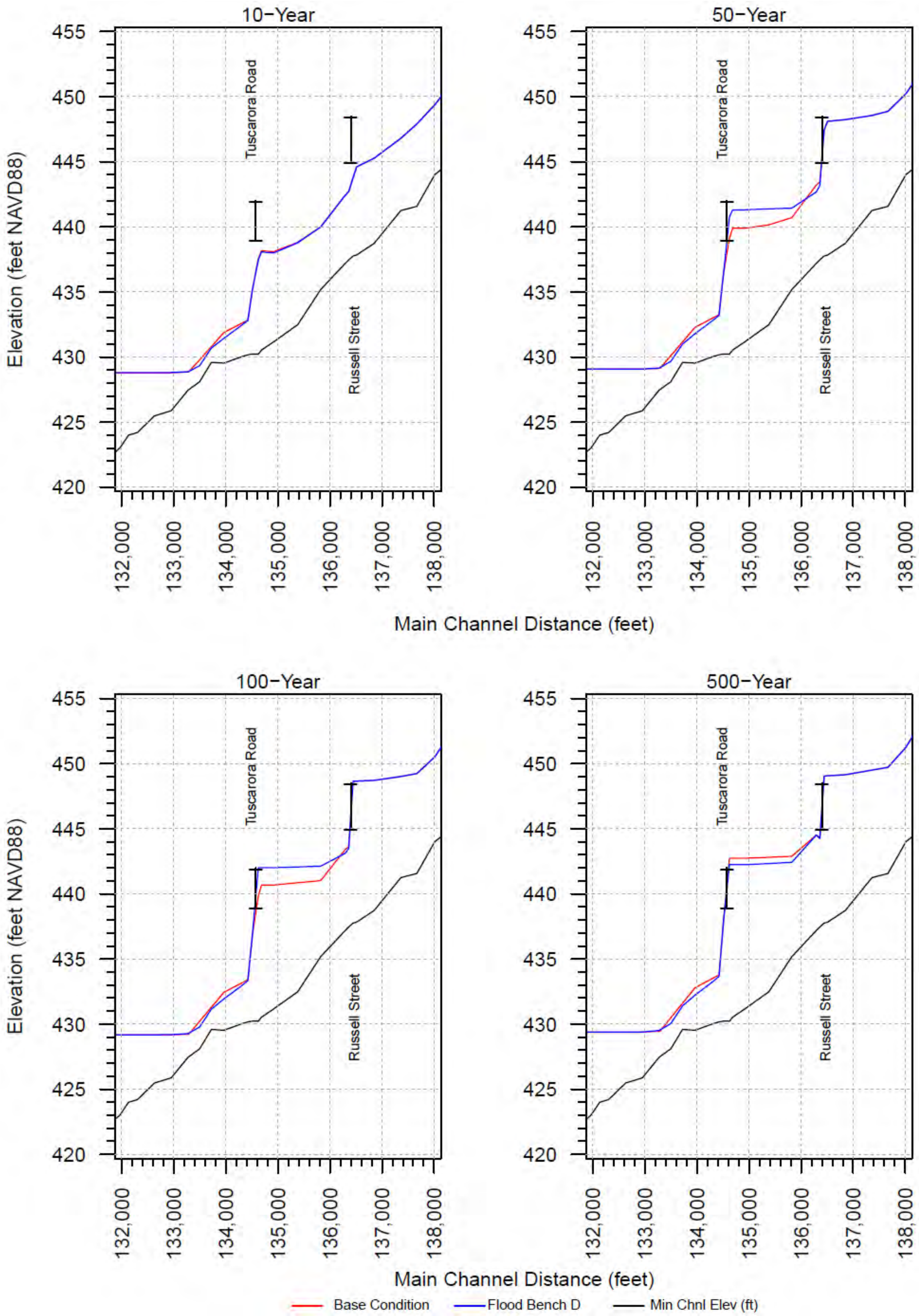

Figure 7-28. HEC-RAS model simulation output results for Alternative #2-3 for the existing condition (red) and Flood Bench D (blue) scenarios.

To evaluate the effectiveness of the flood mitigation impacts, the project team analyzed each flood bench independently. However, there is the potential for added benefits (i.e., reduction in WSELs, less flooding, reduced erosion, etc.) when multiple flood mitigation projects are built in conjunction. For areas that experience significant flood damages or chronic flooding, it is recommended that multiple flood mitigation strategies in conjunction be considered and evaluated by affected communities.

Based on the analysis of the flood bench simulation, this measure is not recommended due to the ineffectiveness of the measure to provide adequate flood protection to areas upstream of the Old Erie Canal structure where the at-risk properties are located, and the additional costs associated with constructing a flood bench.

The ROM cost for each flood bench alternative is:

- Flood Bench A: $2.5 million
- Flood Bench B: $2.0 million
- Flood Bench C: $1.5 million
- Flood Bench D: $1.5 million

These ROM cost estimates do not include land acquisition costs for survey, appraisal, and engineering coordination. In addition, the NYSDEC will require wetland delineations, an analysis for any endangered and/or threatened species within the proposed project area, and information regarding access during construction of any flood bench mitigation alternative.

7.2.4 Alternative #2-4: Increase the Opening of the Tuscarora Road Bridge Crossing

This measure is intended to address issues within High-risk Area #2 by increasing the width of the Tuscarora Road bridge opening, which would increase the cross-sectional flow area of the channel located at river station 1315+00 (Figure 7-29).

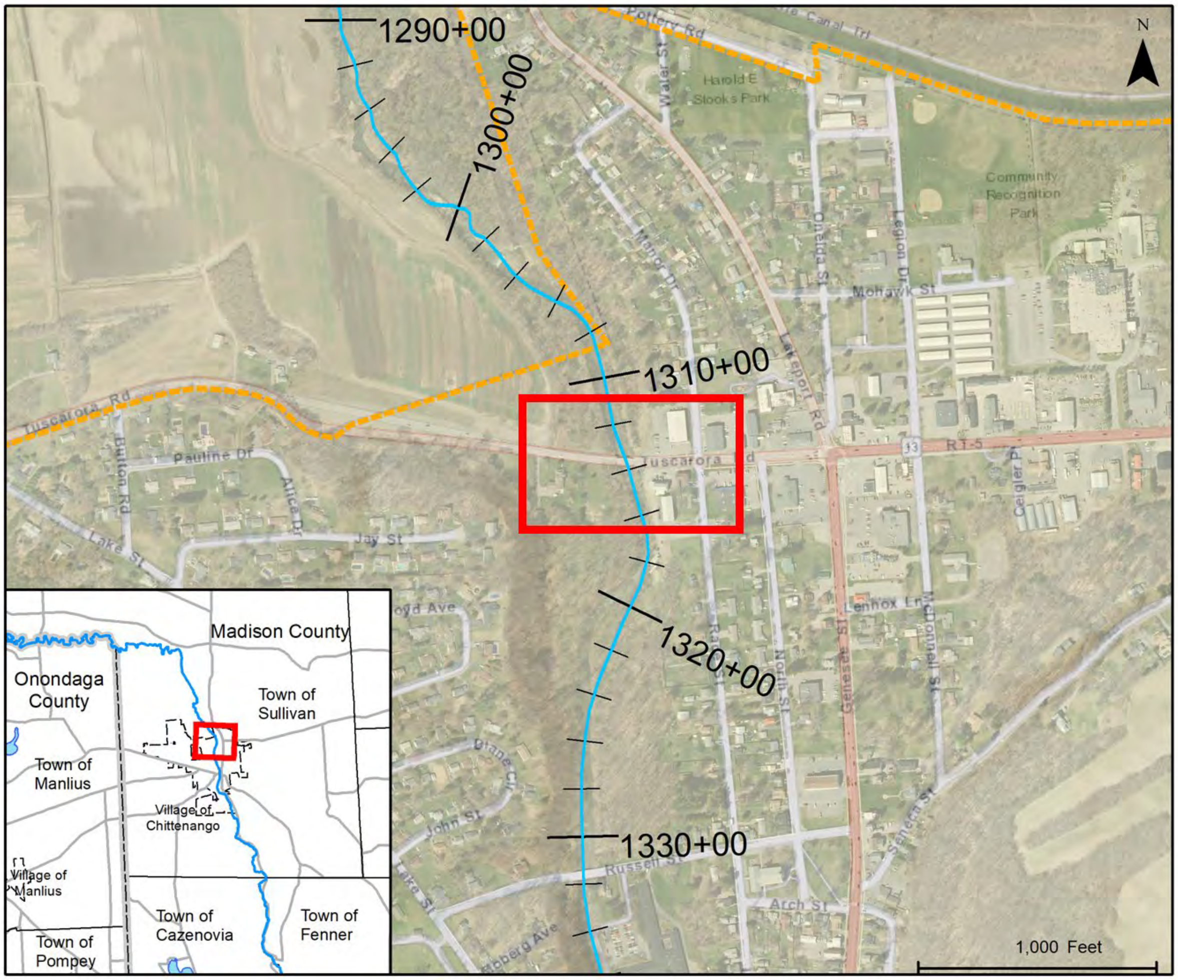

Figure 7-29. Location map for Alternative #2-4.

The bridge is owned by Madison County and has no pier in the channel. The existing bridge structure has a bridge span of 69 ft and a width of 28 ft (Figure 7-30). The flooding in the vicinity of the Tuscarora Road bridge poses a flood-risk threat to nearby residential and commercial properties, and county-owned infrastructure. Appendix F depicts a flood mitigation rendering of a bridge widening scenario.

Figure 7-30. Tuscarora Road bridge, Chittenango, NY.

Based on orthoimagery of the area, the meander in the creek channel upstream of the bridge crossing acts as an impediment to flow, reducing water velocities and allowing sediment and debris to aggregate and restrict flow in this area (NYSOITS 2017).

As previously displayed in Figure 6-4, the FEMA FIS for the Tuscarora Road bridge is unable to successfully pass the 10-, 2-, 1-, or 0.2% annual chance event without significant backwater upstream the of the bridge (FEMA 1984b). In addition, the FEMA FIRM displays significant backwater upstream of the Tuscarora Road bridge crossing (FEMA 1985b).

By increasing the opening span of the bridge structure, the cross-sectional flow area of the channel would increase and the potential for sediment, debris, and ice to accumulate or catch on the upstream face of the bridge would be reduced, thereby reducing flood risk to areas adajcent to and immediately upstream of the bridge.

The bridge widening design selected for this proposed condition model simulation was selected to ensure that the 1% annual chance event WSEL could successfully pass under the Tuscarora Road bridge. To achieve the desired result, the bridge widening design increased the width of the bridge opening from 69 ft to 84 ft by widening the bridge on the left bank by 15 ft. This measure would potentially reduce the flood risk and benefit the properties adjacent to and immediately upstream of Tuscarora Road.

The proposed condition modeling confirmed that the Tuscarora Road bridge is a constriction point along Chittenango Creek. The modeling simulation results indicated water surface reductions of up to 1.9 ft in areas approximately 1,900 ft immediately upstream of the bridge extending up to the Russell Street bridge crossing, specifically along river stations 1346+50 to 1365+50 (Figure 7-31). The modeling output for future conditions displayed similar results with water surface reductions of up to 1.7 ft. Full model outputs for this alternative can be found in Appendix H.

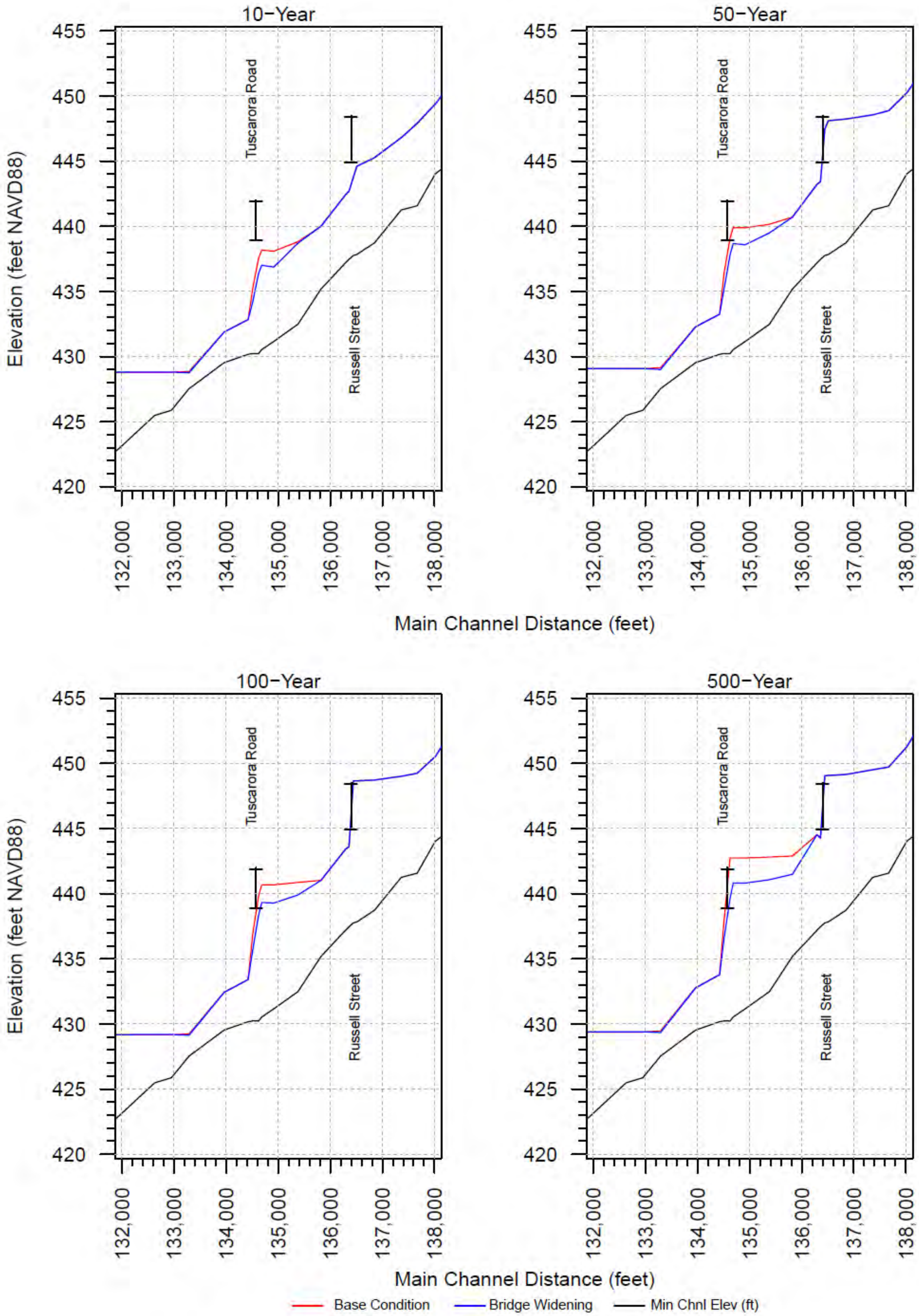

Figure 7-31. HEC-RAS model simulation output results for Alternative #2-4 for the existing condition (red) and bridge widening (blue) scenarios.

The potential benefits of this strategy are limited to immediately upstream of the Tuscarora Road bridge. The primary benefits of increasing the bridge opening would be to increase the flow capacity of the bridge structure, reduce the potential of backwater from high-flow events, and help prevent debris and ice from catching on the structure and creating obstructions/jams upstream of the bridge.

The ROM cost for this strategy is approximately $1.4 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination. Additional engineering consideration would also be required to determine if increasing the bridge opening would alter the structural integrity of the bridge in any way.

7.2.5 Alternative #2-5: Flood Benches Between Tuscarora Road and Russell Street

Installing a flood bench would provide additional storage and floodplain width over and above the current storage and width provided by the adjacent developed floodplain in this reach of Chittenango Creek, which could potentially reduce damages in the event of flooding and address issues within High-risk Area #2. Two potential flood benches were modeled in the vicinity of Tuscarora Road and Russell Street in the Village of Chittenango (Figure 7-32):

- Flood Bench A is approximately 4 acres in size and located between river stations 1314+00 to 1324+00
- Flood Bench B is approximately 6 acres in size and located between river stations 1320+00 to 1330+00

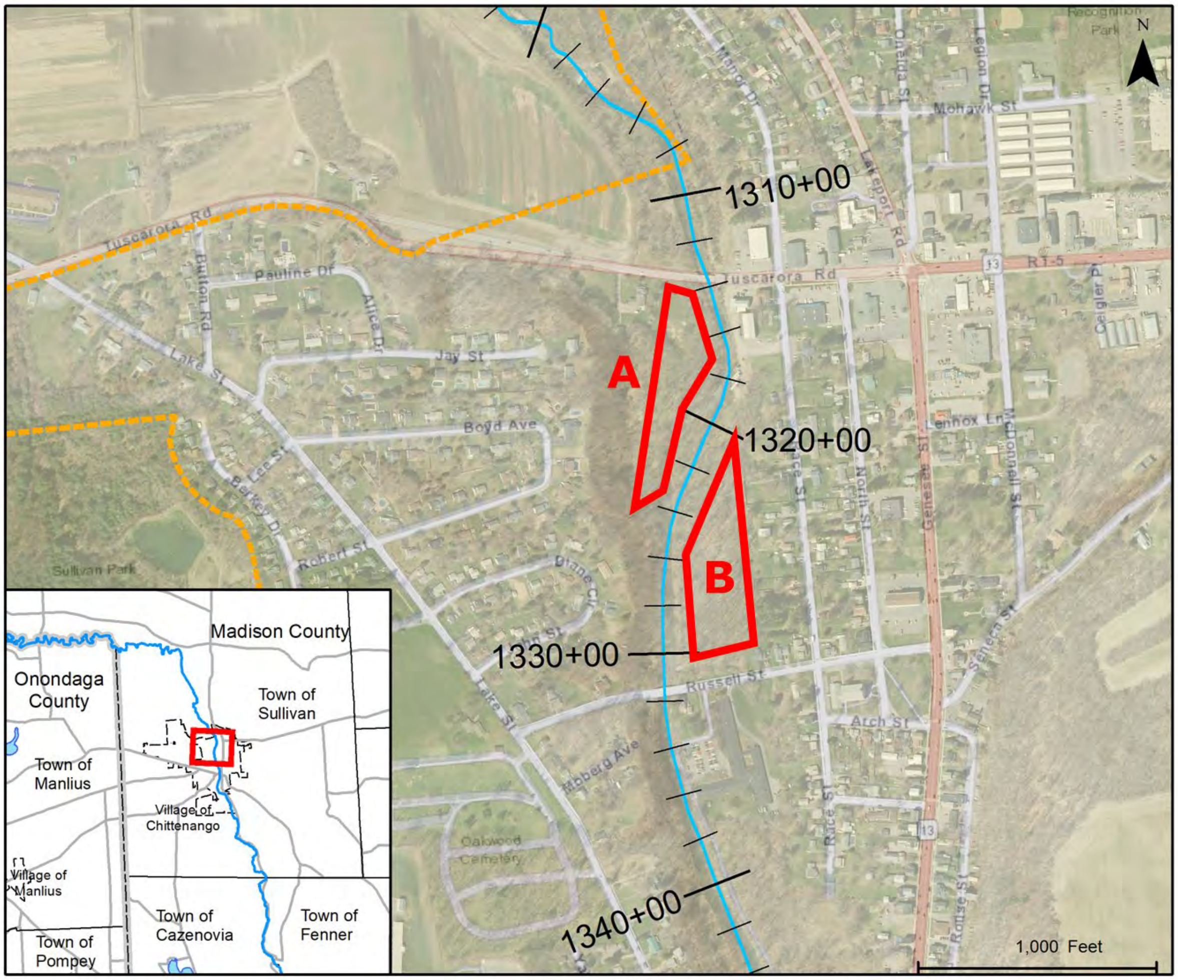

Figure 7-32. Location map for Alternative #2-5.

The flood bench designs used for the proposed condition model simulation set the minimum bench elevation approximately equal to the bankfull elevation, which was an average depth of 2 ft for both benches.

The flood benches are within the FEMA designated SFHA or Zone A, which are areas subject to inundation by the 1% ACE, but where base flood elevations and flood hazard factors were not determined, and where mandatory flood insurance purchase requirements and floodplain management standards apply (FEMA 1984b). Appendix F depicts a flood mitigation rendering of a flood bench illustrating before and after landscape features.

Table 29 outlines the results of the existing and future conditions model simulations for each flood bench. Full model outputs for this alternative can be found in Appendix H. Figures 7-33 and 7-34 display the profile plots for each flood bench alternative.

Table 29. Summary Table for Alternative #2-5 Existing and Future Conditions for Each Flood Bench Alternative

	Reductions in Water Surface Elevations (feet)	
	Flood Bench A	**Flood Bench B**
Existing Conditions	Up to 0.9-ft	Up to 2.1-ft
Total Length of Benefited Area	1,750-ft	1,625-ft
River Stations	1349+50 to 1367+00	1351+50 to 1367+75
Future Conditions	Up to 0.7-ft	Up to 1.8-ft

Flood benches generally provide flood protection for localized areas in the vicinity of and immediately upstream and/or downstream of the bench. Based on the analysis of high-risk areas, a flood bench located between Tuscarora Road and Russel Street would provide significant flood protection in this reach from open-water flooding.

To evaluate the effectiveness of the flood mitigation impacts, the project team analyzed this alternative and each flood bench independently of other alternatives. However, there is the potential for added benefits (i.e., reduction in WSELs, less flooding, reduced erosion, etc.) when multiple flood mitigation projects are built in conjunction. For areas that experience significant flood damages or chronic flooding, it is recommended that multiple flood mitigation strategies in conjunction be considered and evaluated by affected communities.

The ROM cost for each flood bench alternative is:

- Flood Bench A: $1.1 million
- Flood Bench B: $1.6 million

These ROM cost estimates do not include land acquisition costs for survey, appraisal, and engineering coordination. In addition, the NYSDEC will require wetland delineations, an analysis for any endangered and/or threatened species within the proposed project area, and information regarding access during construction of any flood bench mitigation alternative.

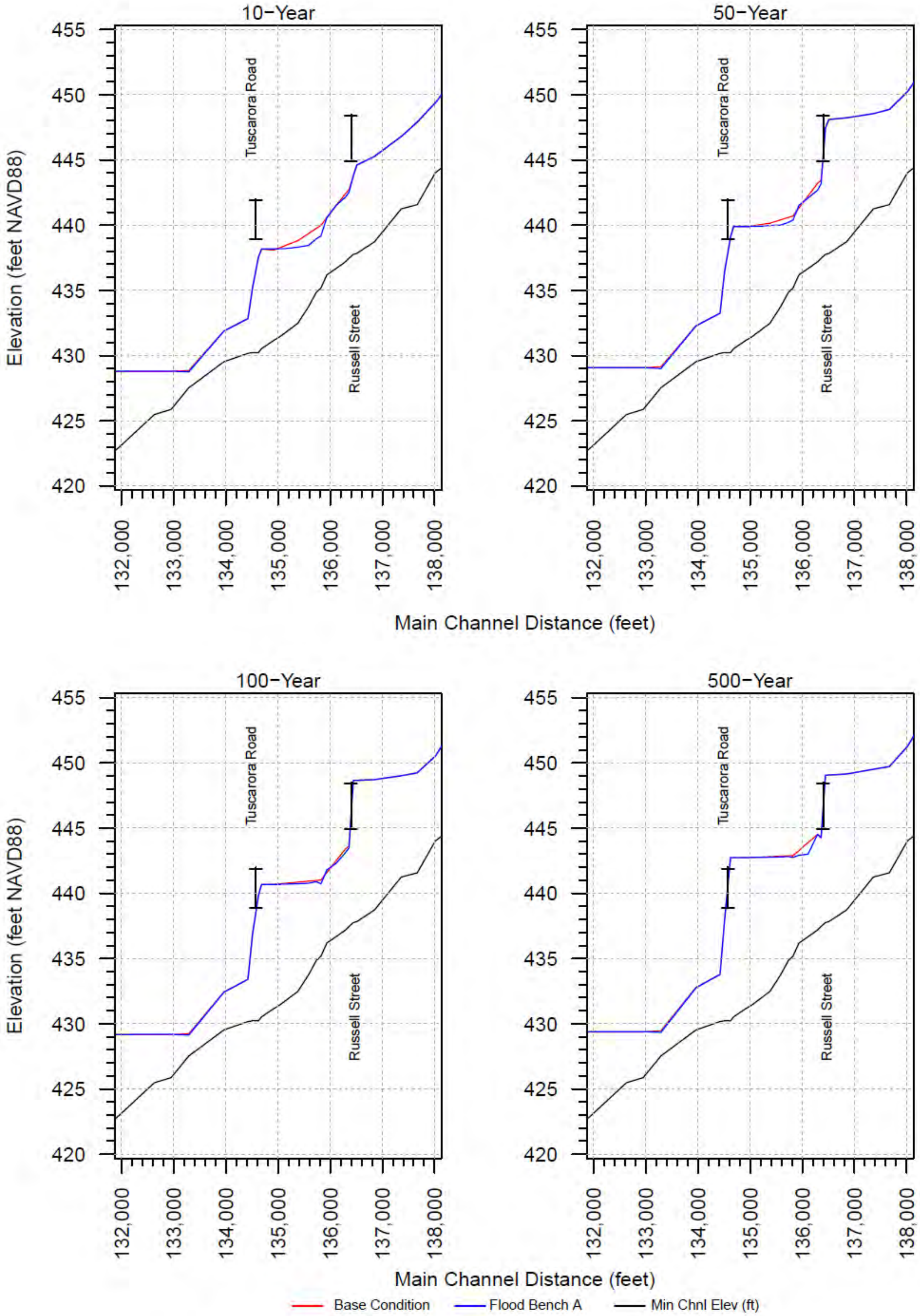

Figure 7-33. HEC-RAS model simulation output results for Alternative #2-5 for the existing condition (red) and Flood Bench A (blue) scenarios.

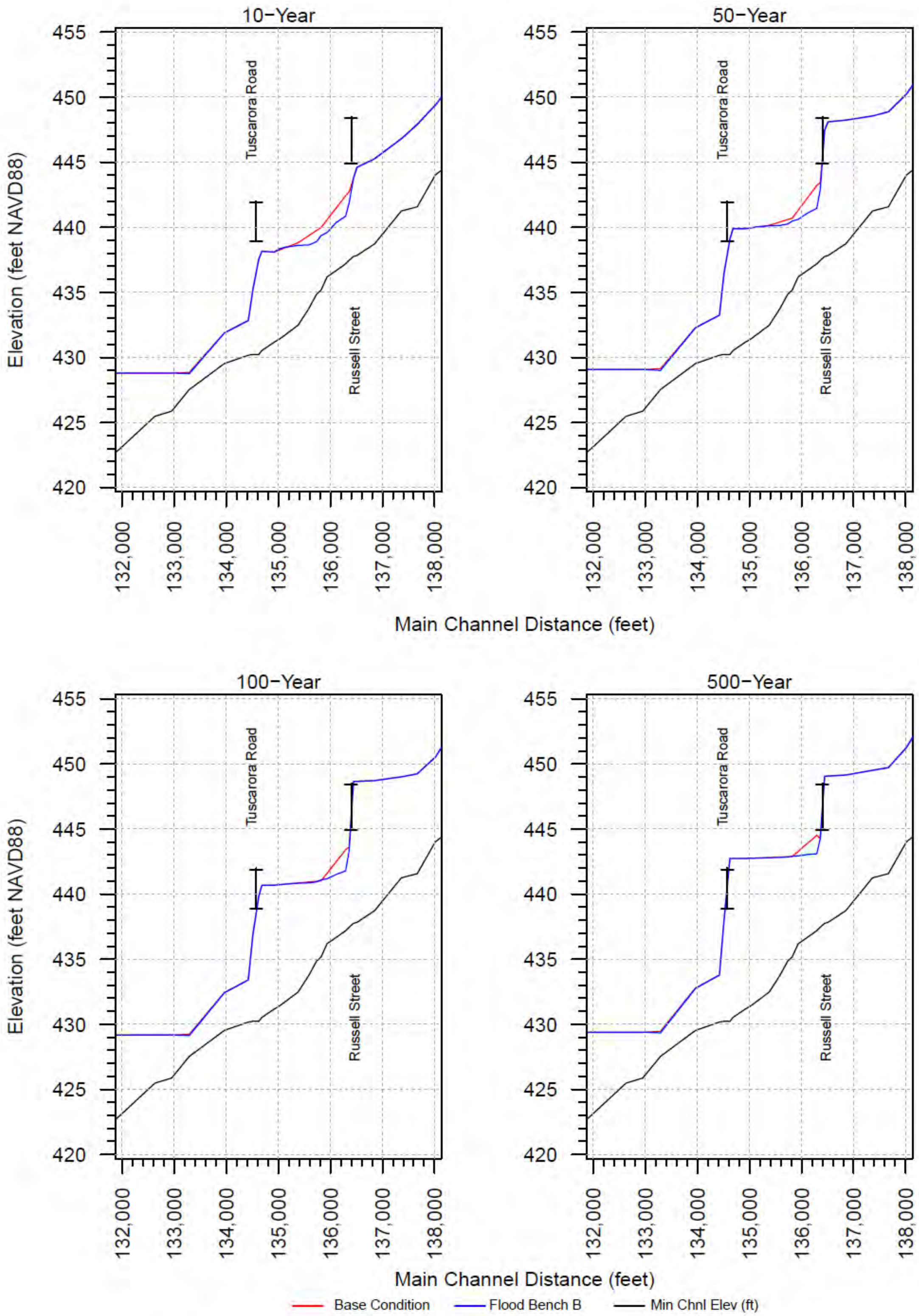

Figure 7-34. HEC-RAS model simulation output results for Alternative #2-5 for the existing condition (red) and Flood Bench B (blue) scenarios.

7.2.6 Alternative #2-6: Flood Bench Between Russell and Genesee Streets

Installing a flood bench would provide additional storage and floodplain width over and above the current storage and width provided by the adjacent developed floodplain in this reach of Chittenango Creek, which could potentially reduce damages in the event of flooding and address issues within High-risk Area #2. One potential flood bench was modeled in the vicinity of Russell and Genesee Streets in the Village of Chittenango that is approximately 5 acres in size at river stations 1338+00 to 1348+00 (Figure 7-35).

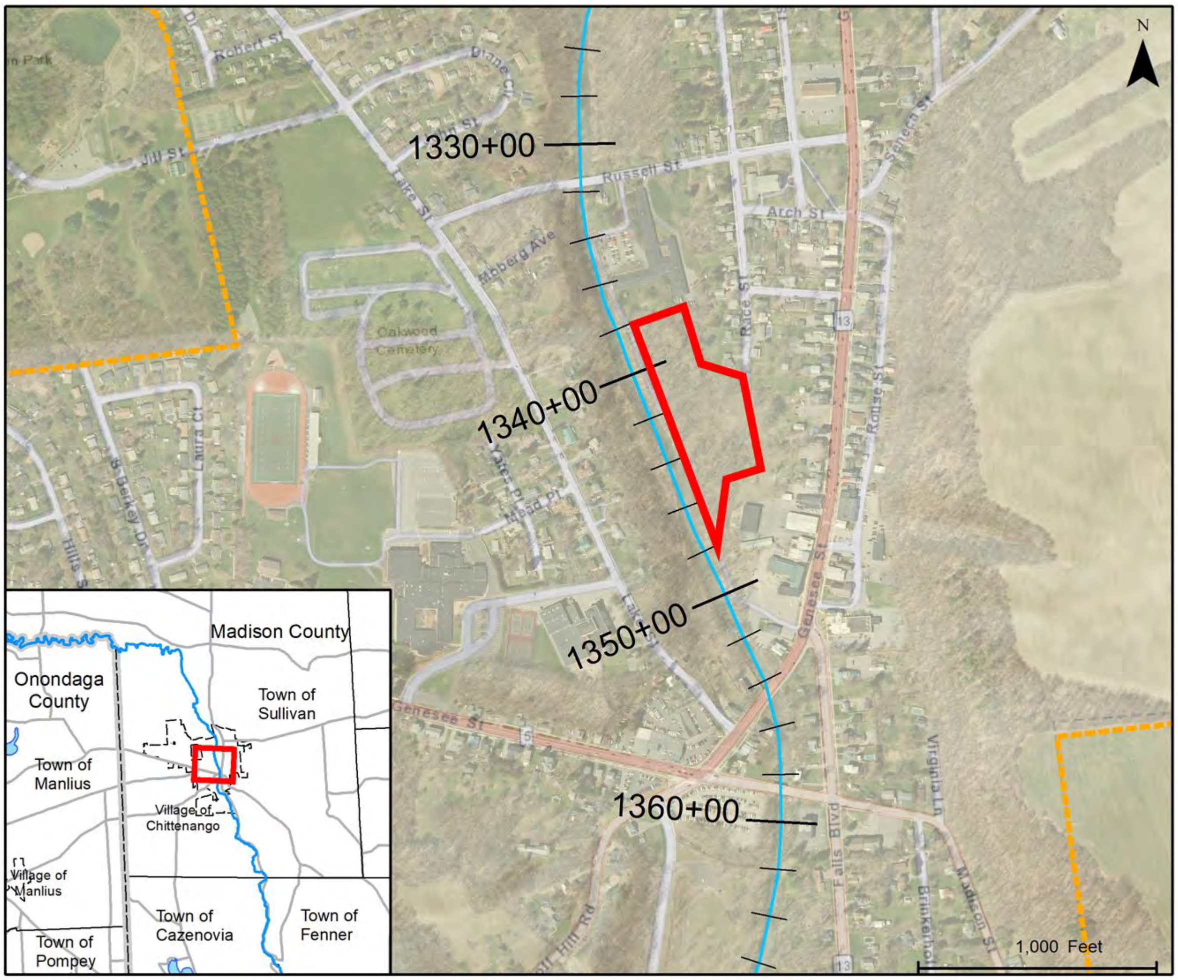

Figure 7-35. Location map for Alternative #2-6.

This measure would potentially reduce the flood risk for, and benefit the properties adjacent to and immediately upstream of the flood bench. The flood bench design used for the proposed condition model simulation set the minimum bench elevation approximately equal to the bankfull elevation, which was an average depth of 3 ft.

The flood benches are within the FEMA designated SFHA or Zone A, which are areas subject to inundation by the 1% ACE, but where base flood elevations and flood hazard factors were not determined, and where mandatory flood insurance purchase requirements and floodplain management standards apply (FEMA 1984b). Appendix F depicts a flood mitigation rendering of a flood bench illustrating before and after landscape features.

Table 30 outlines the results of the existing and future conditions model simulations for the flood bench. Full model outputs for this alternative can be found in Appendix H. Figure 7-36 displays the profile plot for this flood bench alternative.

Table 30. Summary Table for Alternative #2-6 Existing and Future Conditions

	Reductions in Water Surface Elevations (feet)
Existing Conditions	Up to 1.8-ft
Total Length of Benefited Area	2,350-ft
River Stations	1367+00 to 1390+50
Future Conditions	Up to 1.7-ft

Flood benches generally provide flood protection for localized areas in the vicinity of and immediately upstream and/or downstream of the bench. Based on the analysis of high-risk areas, a flood bench located between Russel and Genesee Streets would provide significant flood protection in this reach from open-water flooding.

The ROM cost this alternative is $1.6 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination. In addition, the NYSDEC will require wetland delineations, an analysis for any endangered and/or threatened species within the proposed project area, and information regarding access during construction of any flood bench mitigation alternative.

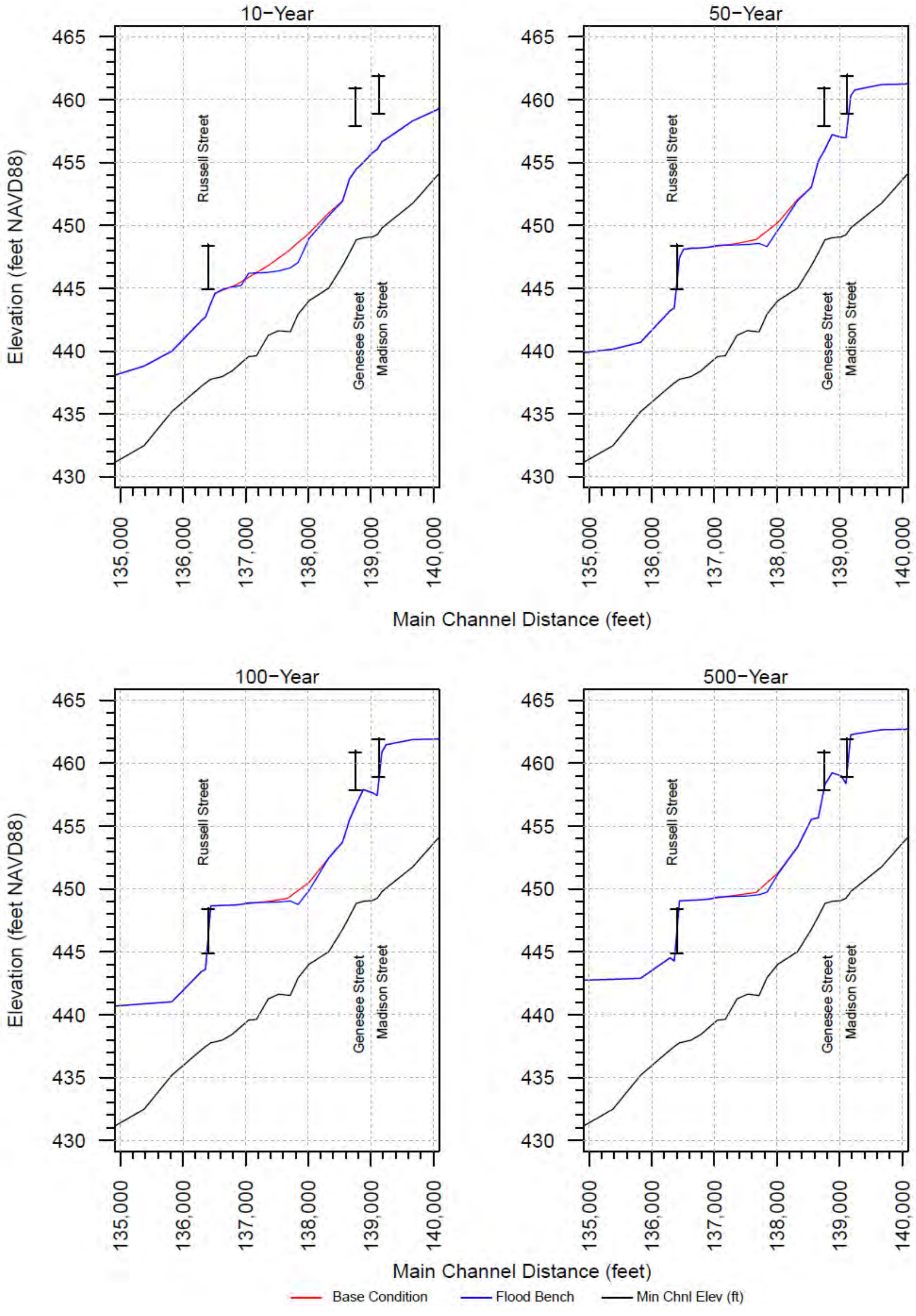

Figure 7-36. HEC-RAS model simulation output results for Alternative #2-6 for the existing condition (red) and the flood bench (blue) scenarios.

7.2.7 Alternative #2-7: Streambank Stabilization Between Russell and Genesee Streets

Streambank erosion is a natural process that occurs when the forces of flowing water exceed the ability of the soil and vegetation to hold the banks in place. The forces that cause erosion increase during flood events, and most erosion occurs at these times. Human disturbances to watersheds that increase frequency and magnitude of runoff events also increase streambank erosion. Human disturbances include logging, mining, agriculture, and urbanization. Typical urban or suburban developments which may impact a stream include houses, garages, parking lots, and walkways, including areas cleared of forest and replaced by tailored lawns (GSWCC 2000).

Loss of streambank and streamside vegetation reduces the resisting forces and makes streambanks more susceptible to erosion. This is often the single greatest contributing factor to harmful or accelerated erosion on small and medium-size streams. Streambank vegetation may be removed intentionally for various reasons, or its loss may be inadvertent due to trampling by animals or humans (GSWCC 2000).

Streambank stabilization measures work either by reducing the force of flowing water, by increasing the resistance of the bank to erosion, or by some combination of both. Generally speaking, there are four approaches to streambank protection: 1) the use of vegetation; 2) soil bioengineering; 3) the use of rock work in conjunction with plants; and 4) conventional bank armoring. Re-vegetation includes seeding and sodding of grasses, seeding in combination with erosion control fabrics, and the planting of woody vegetation (shrubs and trees). Soil bioengineering systems use woody vegetation installed in specific configurations that offer immediate erosion protection, reinforcement of the soils, and in time a woody vegetative surface cover and root network. The use of rock work in conjunction with plants is a technique which combines vegetation with rock work. Over time, the plants grow and the area appears and functions more naturally. Conventional armoring is a fourth technique which includes the use of rock, known as riprap, to protect eroding streambanks (GSWCC 2000).

Streambank stabilization can also play a vital role in flood risk management in areas located in flood-prone areas. The magnitude of that risk is a function of the flood hazard, the characteristics of a particular location (i.e., elevation, proximity to the waterway, susceptibility to fast-moving flows, etc.), measures that have been taken to mitigate the potential impact of flooding, the vulnerability of people and property, and the consequences that result from a particular flood event. A flood risk management strategy identifies and implements measures that reduce the overall risk, and what remains is the residual risk. In developing the strategy, those responsible judge the costs and benefits of each measure taken and their overall impact in reducing the risk (NRC 2013).

Through historical flood reports, stakeholder engagement meetings, and/or field work, numerous areas along Chittenango Creek in the Village of Chittenango have been identified as areas for potential streambank stabilization strategies. These areas have been outlined in Figure 7-37.

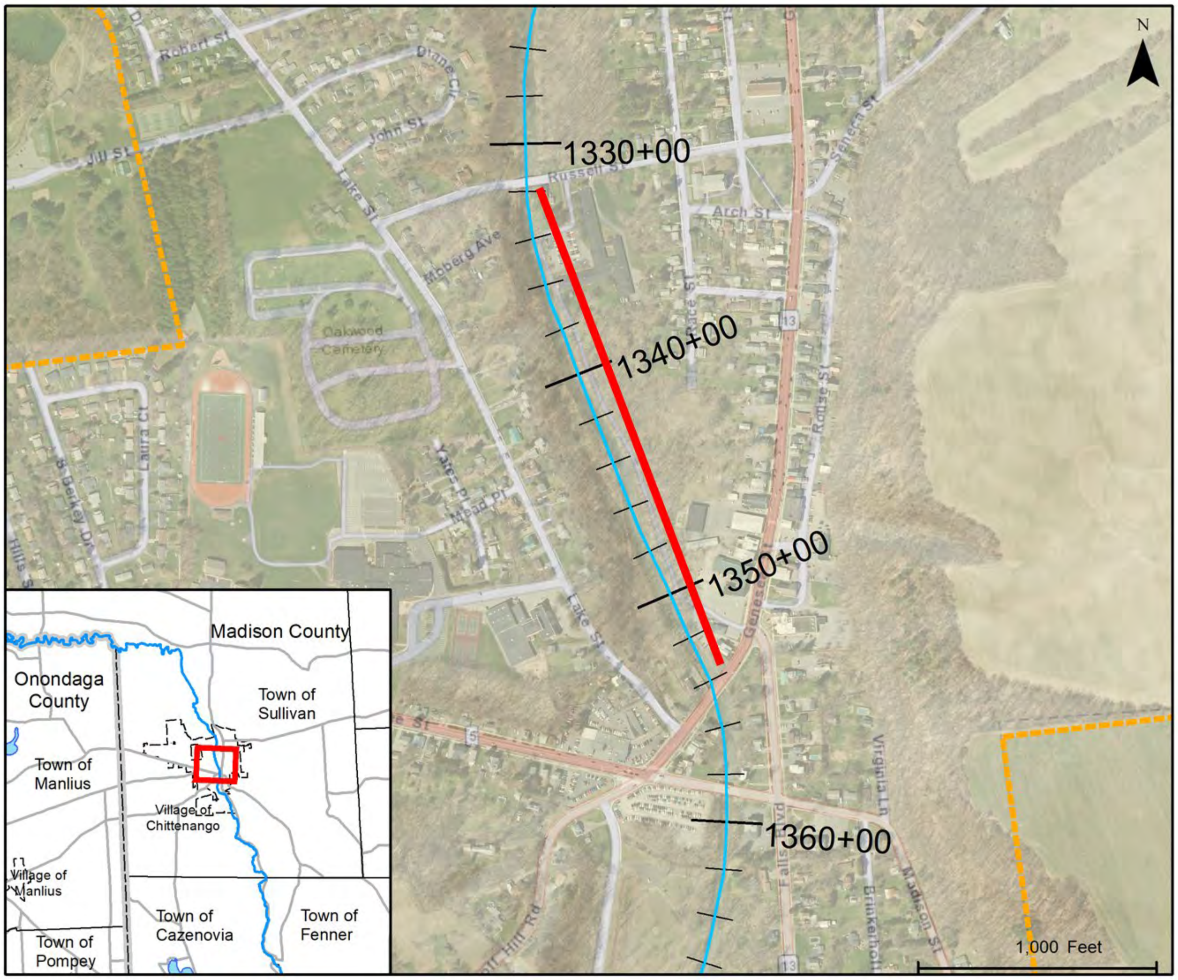

Figure 7-37. Location map for Alternative #2-7.

Appendix G contains detailed discussion of various streambank stabilization strategies, including drawings, definitions, ideal locations, design and construction considerations, maintenance, and ROM costs.

Transport of sediment and debris in streams is predominantly controlled by stream transport capacity, sediment physiochemical characteristics and supply rate. Several hydraulic and geomorphologic factors determine stream transport capacity including channel width, flow depth and cross-sectional geometry, bed slope and roughness, and discharge velocity and volume. In general, the more turbulent energy available for suspension and mobilization of sediment, the greater the sediment transport capacity per unit of stream width, and the larger the size of sediment particles that can be moved (USEPA 2009a).

Larger sediments and debris generally experience more episodic movement over longer time scales through watersheds. Smaller sediments generally move more continuously and within a shorter time scale. This difference is due to the fact that larger sediments and debris rely on larger, more powerful flows for transport, which occur episodically and less frequently than flows able to move smaller particles, such as the bankfull discharge (USEPA 2009a).

To assess the applicability of different streambank stabilization strategies under higher frequency lower-flow conditions, channel velocity (feet per second) and shear stress (pounds per square foot) were calculated using the HEC-RAS software for the existing conditions model at the 10% annual chance event; the results are summarized in Table 31.

Table 31. HECRAS Existing Condition Model Output of Channel Velocity (ft/s) and Shear Stress (lb/sq ft) at the 10% Annual Chance Event for Alternative #2-7

Source: USACE 2021		
River Station	**Channel Velocity (ft/s)**	**Channel Shear Stress (lb/sq ft)**
138660	8.15	1.45
138549	10.84	2.53
138329	8.58	1.49
138014	8.07	2.03
137668	7.23	1.17
137362	7.26	1.08
136850	6.71	0.89
136510	6.04	0.72
136444	8.15	1.35

Based on the existing conditions model output for channel velocity and shear stress, Table 32 summarizes the applicability of potential streambank strategies for this proposed alternative.

Table 32. Potential Streambank Stabilization Strategies for Alternative #2-7

Source: NRCS 2009	
Type of Treatment	**Type of Sub-Treatment**
Brush Mattresses	Staked only with rock riprap toe (grown)
Coir Geotextile Roll	Roll with Polypropylene rope mesh staked and with rock riprap toe
Gravel/Cobble	12-inch
Soil Bioengineering	Live brush mattress (grown)
	Brush layering (initial/grown)
Boulder Clusters	Boulder - Very large (>80-inch diameter)
	Boulder - Large (>40-in diameter)
	Boulder - Medium (>20-inch diameter)

Due to the variable, conceptual, and site specific nature of streambank stabilization strategies, no ROM Cost Estimates were determined for this measure. Additional geomorphic and engineering analyses, including additional modeling, would be necessary in order to determine the most appropriate streambank stabilization strategy and its associated costs.

7.2.8 Alternative #2-8: Increase the Opening of the Madison Street Bridge Crossing

This measure is intended to address issues within High-risk Area #2 by increasing the width of the Madison Street bridge opening, which would increase the cross-sectional flow area of the channel located at river station 1368+50 (Figure 7-38).

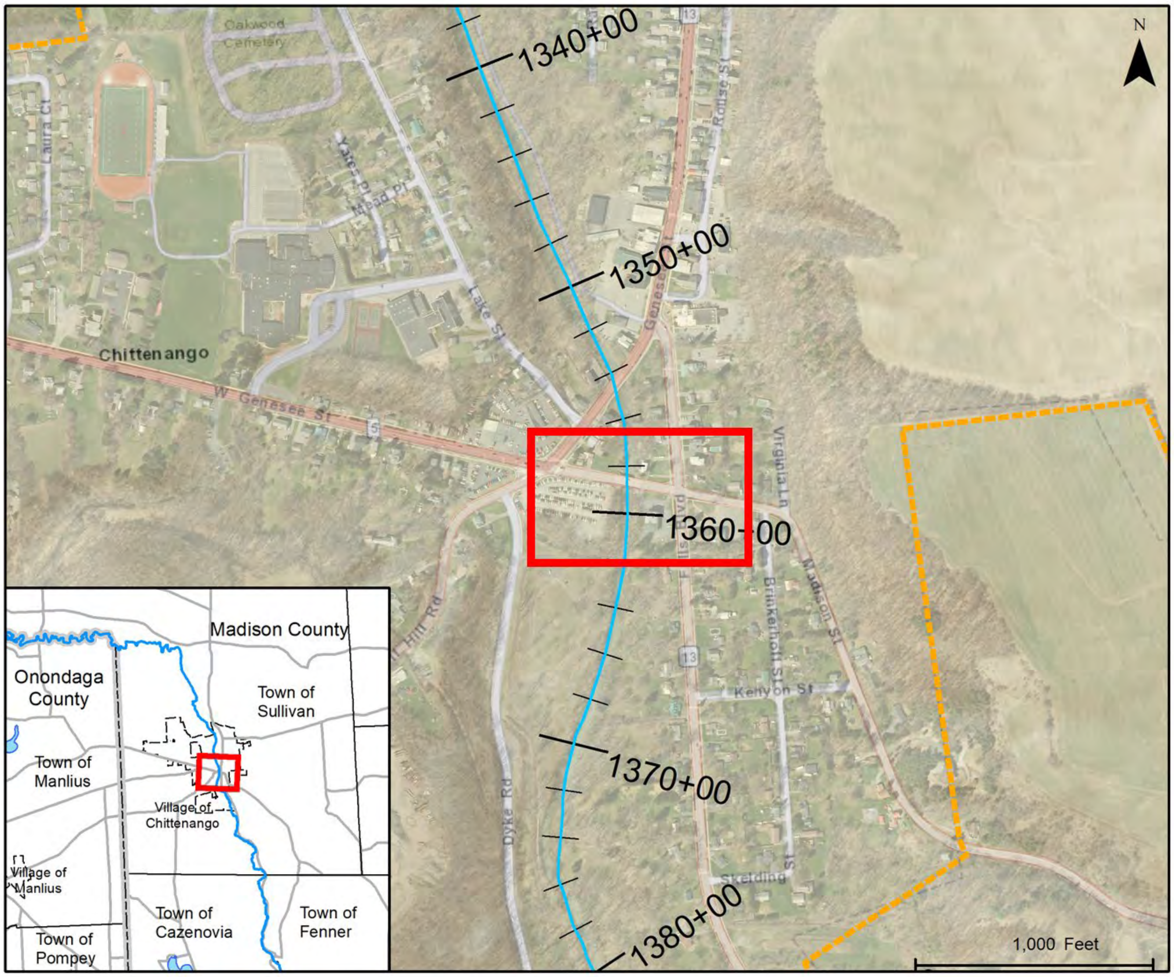

Figure 7-38. Location map for Alternative #2-8.

The bridge is owned by Madison County and has no pier in the channel. The existing bridge structure has a bridge span of 68 ft and a width of 42 ft (Figure 7-39). The flooding in the vicinity of the Madison Street bridge poses a flood-risk threat to nearby residential and commercial properties, and county-owned infrastructure. Appendix F depicts a flood mitigation rendering of a bridge widening scenario.

Figure 7-39. Madison Street bridge, Chittenango, NY.

Based on orthoimagery of the area, the meander in the creek channel in the vicinity, and downstream of the bridge crossing coupled with the close proximity of the Genesee Street/NY-5 bridge act as impediments to flow, reducing water velocities and allowing sediment and debris to aggregate and restrict flow in this area (NYSOITS 2017).

As previously displayed in Figure 6-4, the FEMA FIS for the Madison Street (Perryville Road) bridge is unable to successfully pass the 10-, 2-, 1-, or 0.2% annual chance event without significant backwater upstream the of the bridge (FEMA 1984b). In addition, the FEMA FIRM displays significant backwater upstream of the Madison Street bridge crossing (FEMA 1985b).

By increasing the opening span of the bridge structure, the cross-sectional flow area of the channel would increase and the potential for sediment, debris, and ice to accumulate or catch on the upstream face of the bridge would be reduced, thereby reducing flood risk to areas adajcent to and immediately upstream of the bridge.

The bridge widening design selected for this proposed condition model simulation was selected to ensure that the 1% annual chance event WSEL could successfully pass under the Madison Street bridge. To achieve the desired result, the bridge widening design increased the width of the bridge opening from 68 ft to 11 ft by widening the bridge on the left bank for a total bridge opening of 79 ft. This measure would potentially reduce the flood risk and benefit the properties adjacent to and immediately upstream of Tuscarora Road.

The proposed condition modeling confirmed that the Madison Street bridge is a constriction point along Chittenango Creek. The modeling simulation results indicated water surface reductions of up to 3.0 ft in areas approximately 1,650 ft immediately upstream of the bridge extending from river stations 1392+50 to 1409+00 (Figure 7-

40). The modeling output for future conditions displayed similar results with water surface reductions of up to 1.0 ft. Full model outputs for this alternative can be found in Appendix H.

The potential benefits of this strategy are limited to immediately upstream of the Madison Street bridge. The primary benefits of increasing the bridge opening would be to increase the flow capacity of the bridge structure, reduce the potential of backwater from high-flow events, and help prevent debris and ice from catching on the structure and creating obstructions/jams upstream of the bridge.

The ROM cost for this strategy is approximately $1.7 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination. Additional engineering consideration would also be required to determine if increasing the bridge opening would alter the structural integrity of the bridge in any way.

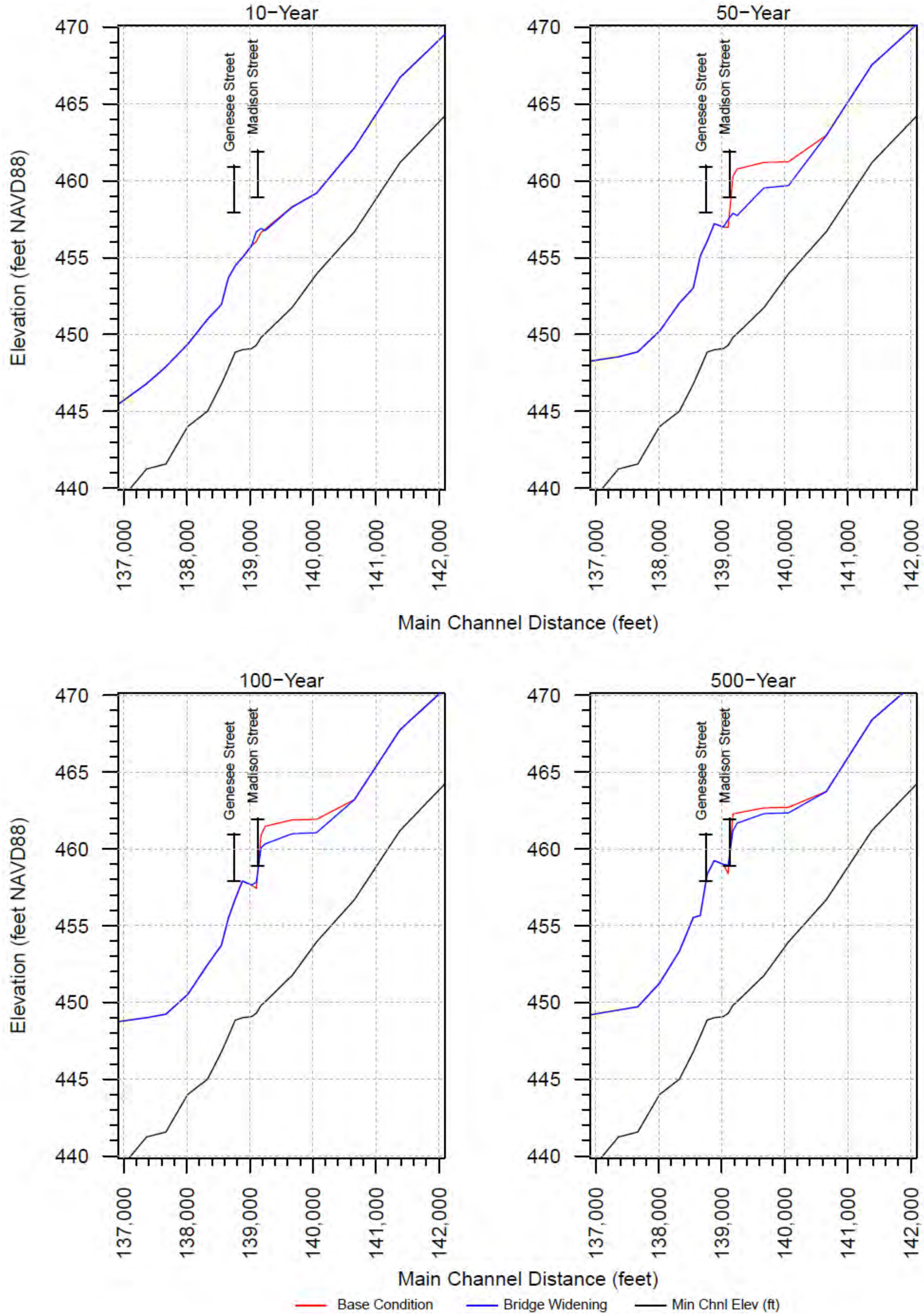

Figure 7-40. HEC-RAS model simulation output results for Alternative #2-8 for the existing condition (red) and the bridge widening (blue) scenarios.

7.2.9 Alternative #2-9: Flood Benches Upstream of Madison Street

Installing a flood bench would provide additional storage and floodplain width over and above the current storage and width provided by the adjacent developed floodplain in this reach of Chittenango Creek, which could potentially reduce damages in the event of flooding and address issues within High-risk Area #2. Two potential flood benches were modeled upstream of Madison Street in the Village of Chittenango (Figure 7-41):

- Flood Bench A is approximately 4.5 acres in size and located between river stations 1361+50 to 1370+00
- Flood Bench B is approximately 6.5 acres in size and located between river stations 1368+00 to 1384+00

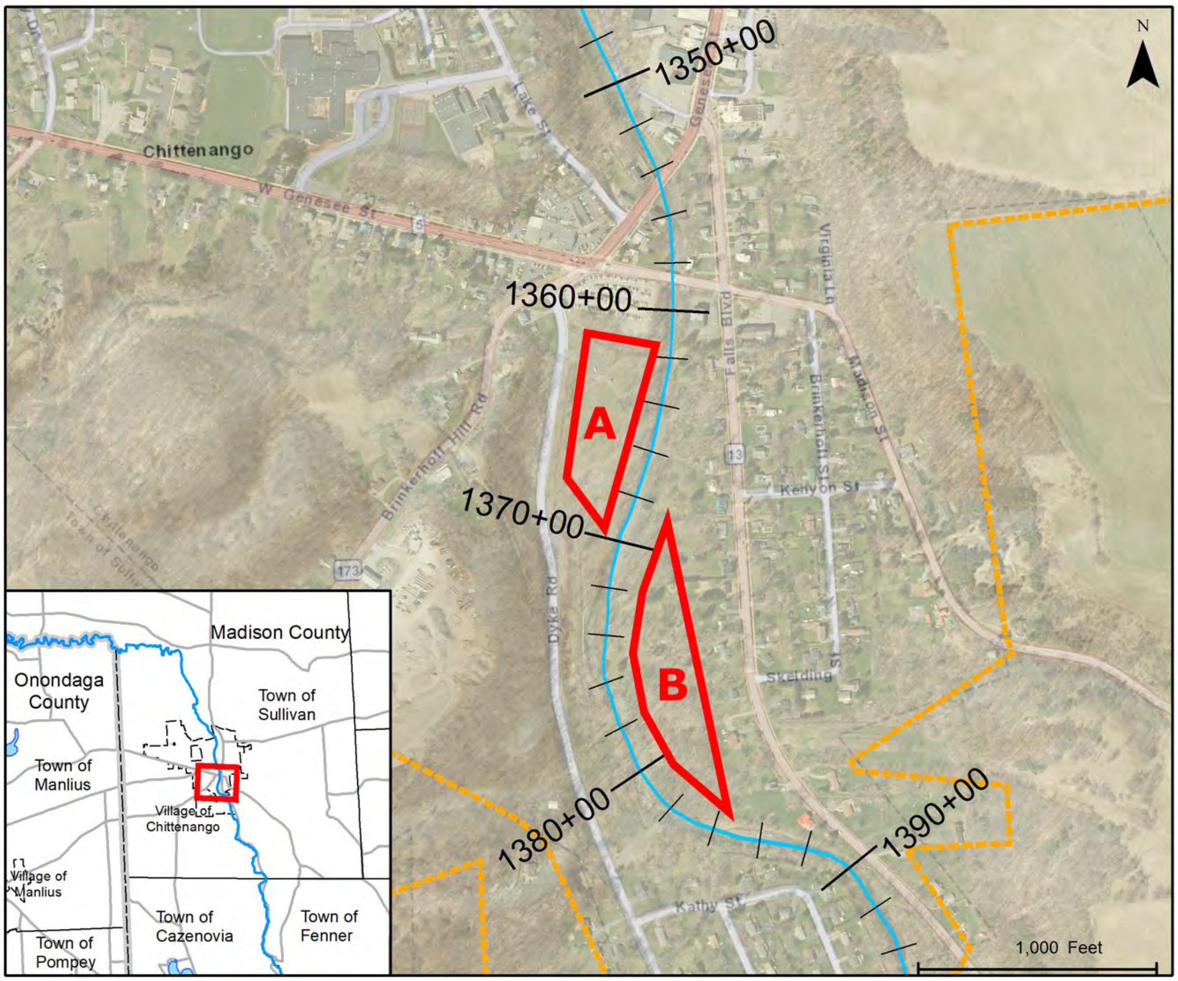

Figure 7-41. Location map for Alternative #2-9.

This measure would potentially reduce the flood risk for, and benefit the properties adjacent to and immediately upstream of, the flood bench. The flood bench designs used for the proposed condition model simulation set the minimum bench elevation approximately equal to the bankfull elevation at each cross section, which was an average depth of 2.5 ft for the two benches.

The flood benches are within the FEMA designated SFHA or Zone A, which are areas subject to inundation by the 1% ACE, but where base flood elevations and flood hazard factors were not determined, and where mandatory flood insurance purchase requirements and floodplain management standards apply (FEMA 1984b). Appendix F depicts a flood mitigation rendering of a flood bench illustrating before and after landscape features.

Table 33 outlines the results of the existing and future conditions model simulations for each flood bench. Full model outputs for this alternative can be found in Appendix H. Figures 7-42 and 7-43 display the profile plots for each flood bench alternative.

Table 33. Summary Table for Alternative #2-9 Existing and Future Conditions for Each Flood Bench Alternative

	Reductions in Water Surface Elevations (feet)	
	Flood Bench A	**Flood Bench B**
Existing Conditions	Up to 1.0-ft	Up to 2.3-ft
Total Length of Benefited Area	1,500-ft	3,050-ft
River Stations	1399+50 to 1414+50	1403+00 to 1433+50
Future Conditions	Up to 1.2-ft	Up to 2.5-ft

Flood benches generally provide flood protection for localized areas in the vicinity of and immediately upstream and/or downstream of the bench. Based on the analysis of high-risk areas, a flood bench located upstream of Madison Street would provide significant flood protection in this reach from open-water flooding.

To evaluate the effectiveness of the flood mitigation impacts, the project team analyzed this alternative and each flood bench independently of other alternatives. However, there is the potential for added benefits (i.e., reduction in WSELs, less flooding, reduced erosion, etc.) when multiple flood mitigation projects are built in conjunction. For areas that experience significant flood damages or chronic flooding, it is recommended that multiple flood mitigation strategies in conjunction be considered and evaluated by affected communities.

The ROM cost for each flood bench alternative is:

- Flood Bench A: $1.3 million
- Flood Bench B: $2.0 million

These ROM cost estimates do not include land acquisition costs for survey, appraisal, and engineering coordination. In addition, the NYSDEC will require wetland delineations, an analysis for any endangered and/or threatened species within the proposed project area, and information regarding access during construction of any flood bench mitigation alternative.

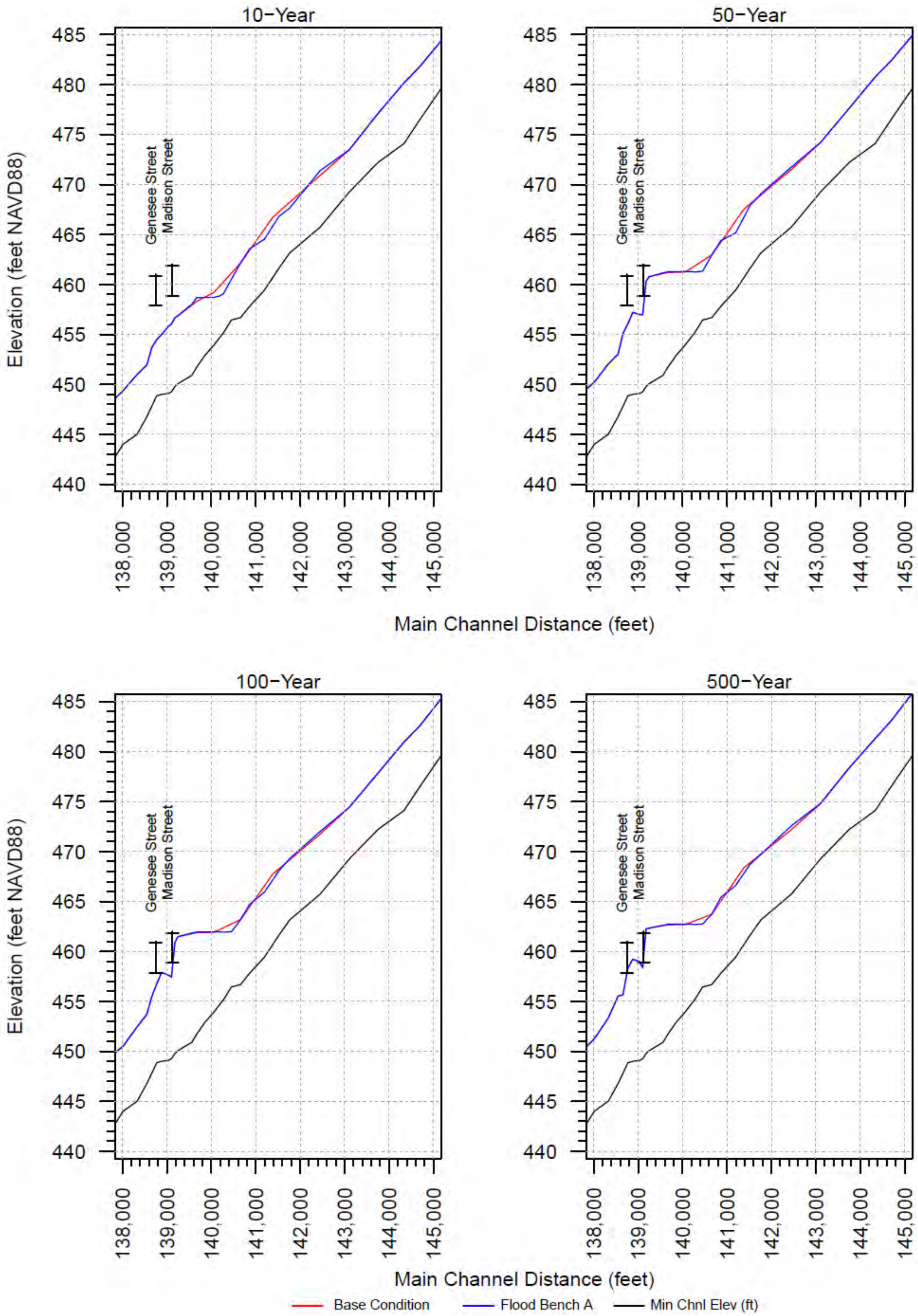

Figure 7-42. HEC-RAS model simulation output results for Alternative #2-9 for the existing condition (red) and Flood Bench A (blue) scenarios.

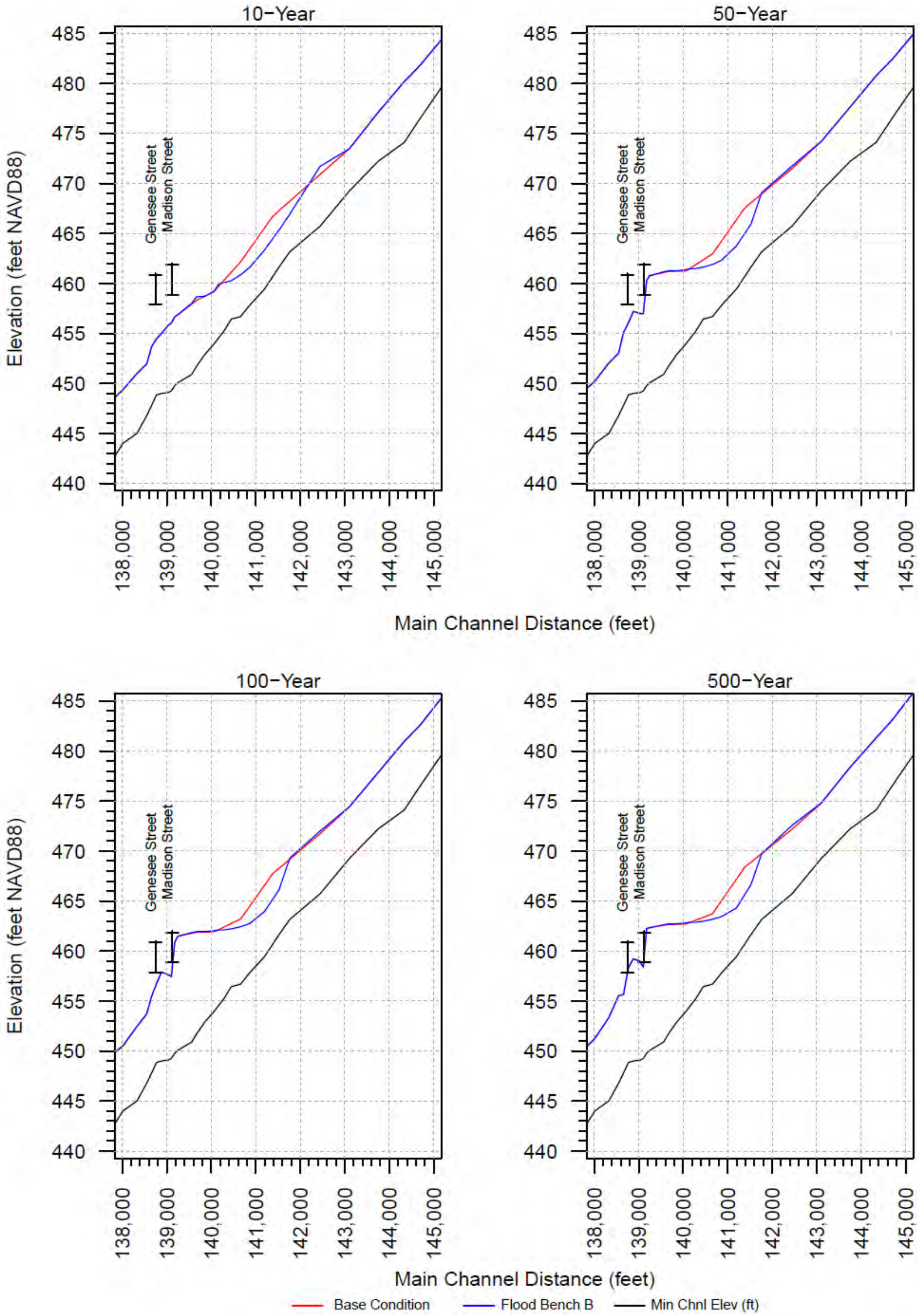

Figure 7-43. HEC-RAS model simulation output results for Alternative #2-9 for the existing condition (red) and Flood Bench B (blue) scenarios.

7.2.10 Alternative #2-10: Flood Benches Upstream of Valley Acres Neighborhood

Installing a flood bench would provide additional storage and floodplain width over and above the current storage and width provided by the adjacent developed floodplain in this reach of Chittenango Creek, which could potentially reduce damages in the event of flooding and address issues within High-risk Area #2. Two potential flood benches were modeled upstream of the Valley Acres neighborhood in the Village of Chittenango (Figure 7-44):

- Flood Bench A is approximately 12 acres in size and located between river stations 1404+00 to 1426+00
- Flood Bench B is approximately 4 acres in size and located between river stations 1419+00 to 1436+00

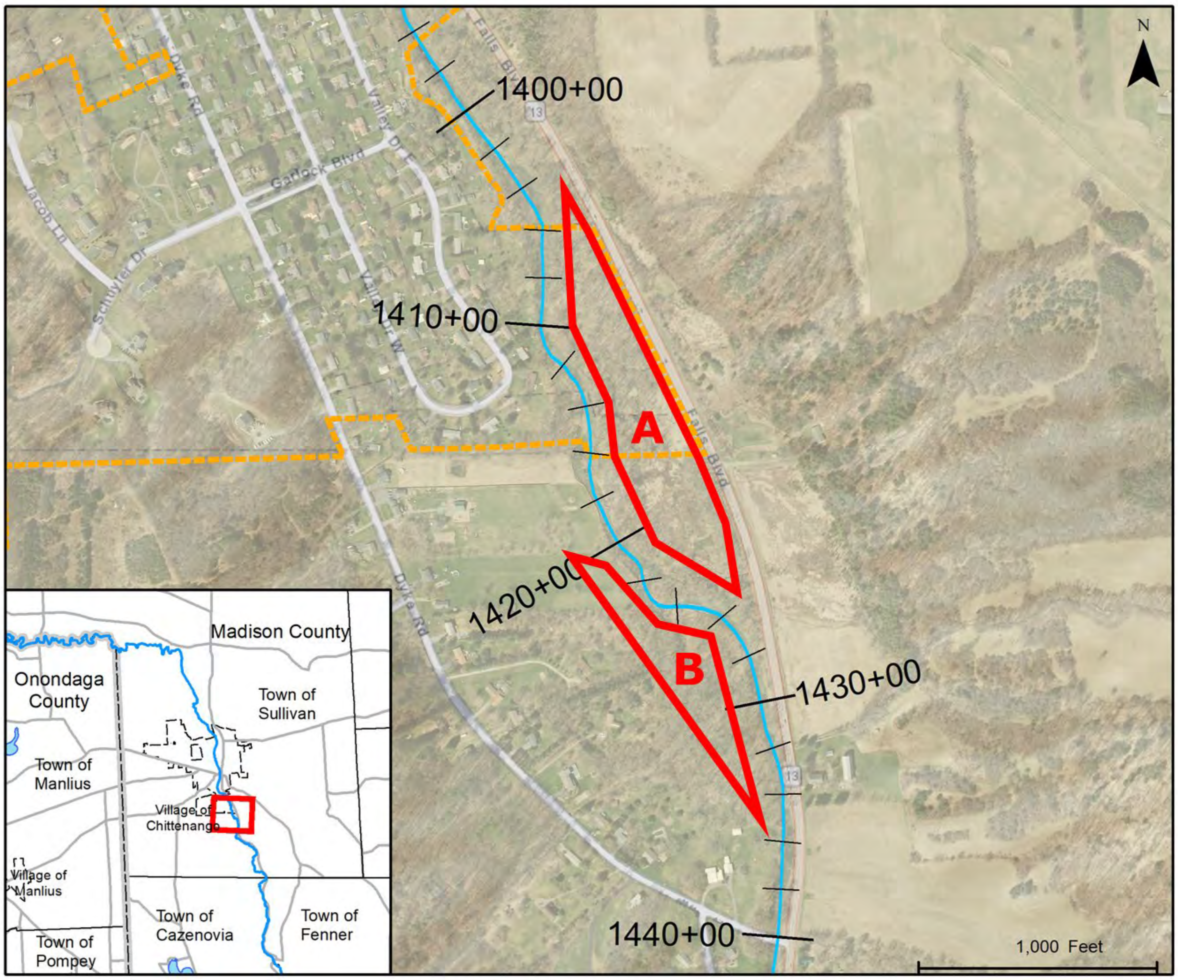

Figure 7-44. Location map for Alternative #2-10.

This measure would potentially reduce the flood risk for, and benefit the properties adjacent to and immediately upstream of, the flood bench. The flood bench designs used for the proposed condition model simulation set the minimum bench elevation approximately equal to the bankfull elevation at each cross section, which was an average depth of 2 ft for Flood Bench A and 2.5 ft for Flood Bench B.

The flood benches are within the FEMA designated SFHA or Zone A, which are areas subject to inundation by the 1% ACE, but where base flood elevations and flood hazard factors were not determined, and where mandatory flood insurance purchase requirements and floodplain management standards apply (FEMA 1984b). Appendix F depicts a flood mitigation rendering of a flood bench illustrating before and after landscape features.

Table 34 outlines the results of the existing and future conditions model simulations for each flood bench. Full model outputs for this alternative can be found in Appendix H. Figures 7-45 and 7-46 display the profile plots for each flood bench alternative.

Table 34. Summary Table for Alternative #2-10 Existing and Future Conditions for Each Flood Bench Alternative

	Reductions in Water Surface Elevations (feet)	
	Flood Bench A	**Flood Bench B**
Existing Conditions	Up to 2.6-ft	Up to 4.2-ft
Total Length of Benefited Area	2,450-ft	2,100-ft
River Stations	1440+00 to 1464+50	1455+00 to 1476+00
Future Conditions	Up to 2.6-ft	Up to 4.1-ft

Flood benches generally provide flood protection for localized areas in the vicinity of and immediately upstream and/or downstream of the bench. Based on the analysis of high-risk areas, a flood bench located upstream of Madison Street would provide significant flood protection in this reach from open-water flooding.

To evaluate the effectiveness of the flood mitigation impacts, the project team analyzed this alternative and each flood bench independently of other alternatives. However, there is the potential for added benefits (i.e., reduction in WSELs, less flooding, reduced erosion, etc.) when multiple flood mitigation projects are built in conjunction. For areas that experience significant flood damages or chronic flooding, it is recommended that multiple flood mitigation strategies in conjunction be considered and evaluated by affected communities.

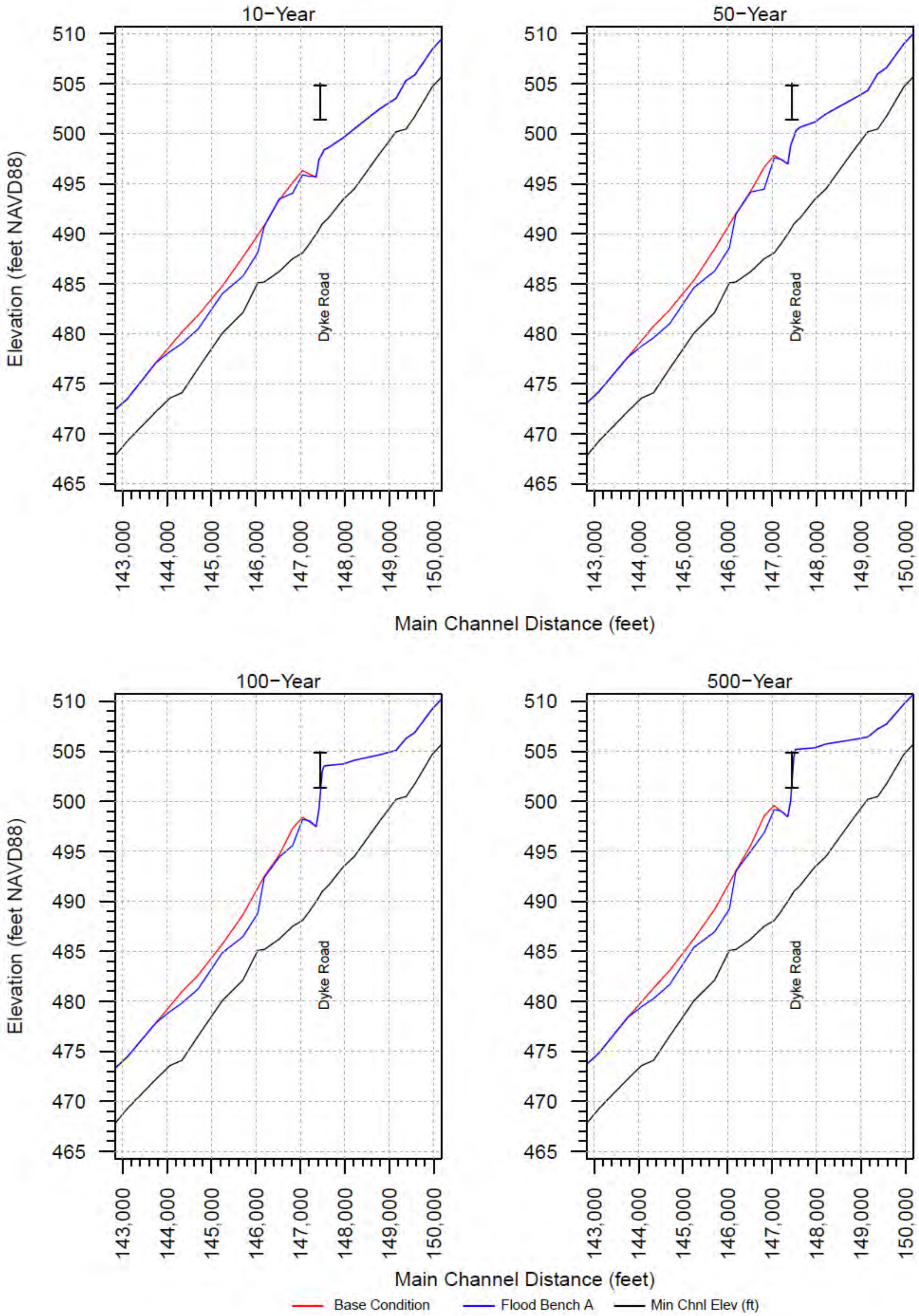

Figure 7-45. HEC-RAS model simulation output results for Alternative #2-10 for the existing condition (red) and Flood Bench A (blue) scenarios.

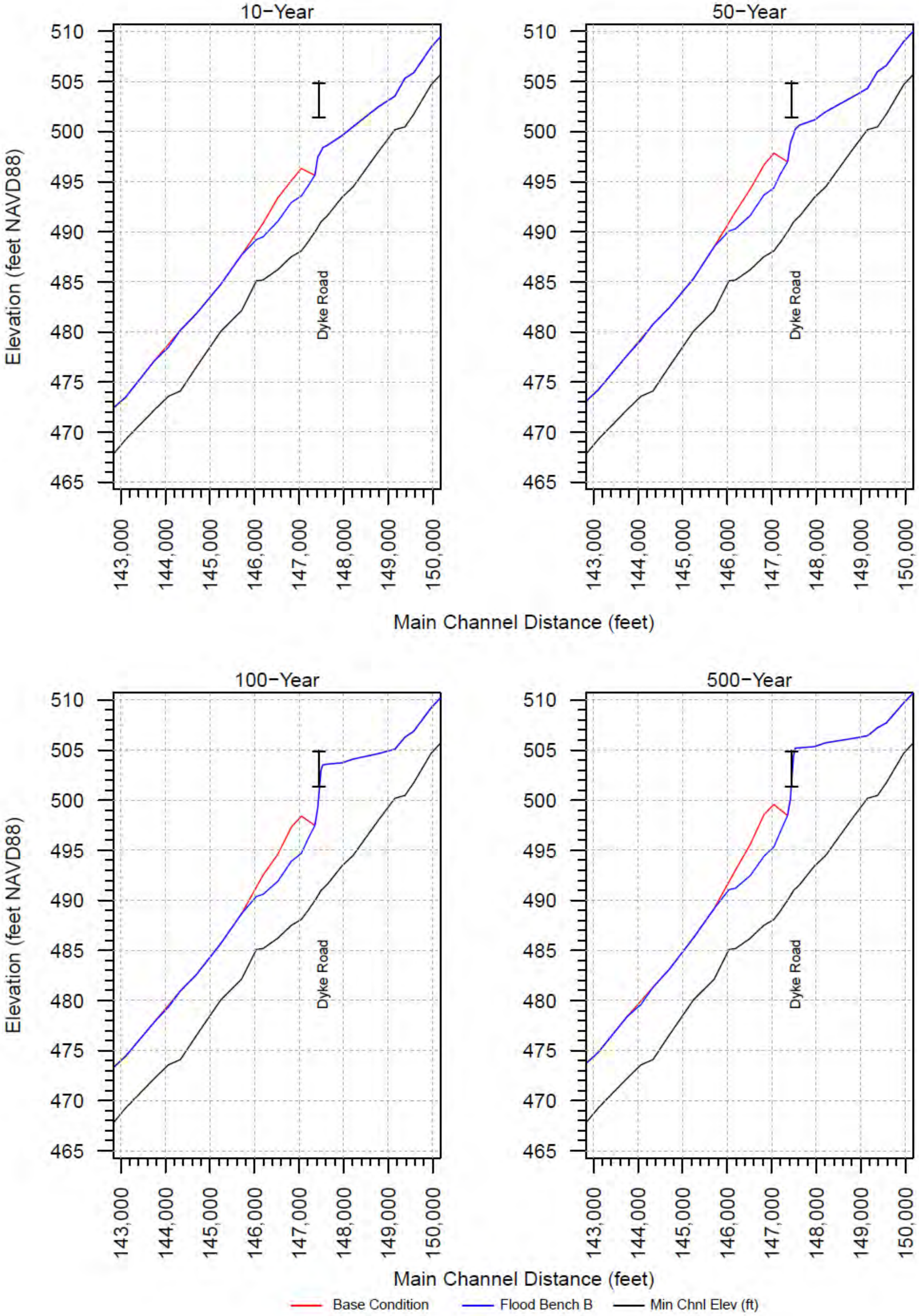

Figure 7-46. HEC-RAS model simulation output results for Alternative #2-10 for the existing condition (red) and Flood Bench B (blue) scenarios.

The ROM cost for each flood bench alternative is:

- Flood Bench A: $3.2 million
- Flood Bench B: $1.3 million

These ROM cost estimates do not include land acquisition costs for survey, appraisal, and engineering coordination. In addition, the NYSDEC will require wetland delineations, an analysis for any endangered and/or threatened species within the proposed project area, and information regarding access during construction of any flood bench mitigation alternative.

7.2.11 Alternative #2-11: Flood Control/Sediment Detention Basin Upstream of Village of Chittenango

The construction of small flood-control detention structures in the headwaters and tributaries of flood-prone streams has proven successful at preventing flood damage in small towns throughout the United States (Helms 1986). These structures are traditionally located in rural areas in agricultural fields and undeveloped land. They maintain little to no permanent pool and are designed to detain water during larger flow events, decreasing peak-flow water surface elevations and minimizing flooding further downstream in developed areas. The area between river stations 1450+00 and 1498+00 downstream of the Village of Chittenango in the Town of Sullivan would be the best location for a flood-control structure in the downstream reach (Figure 7-47).

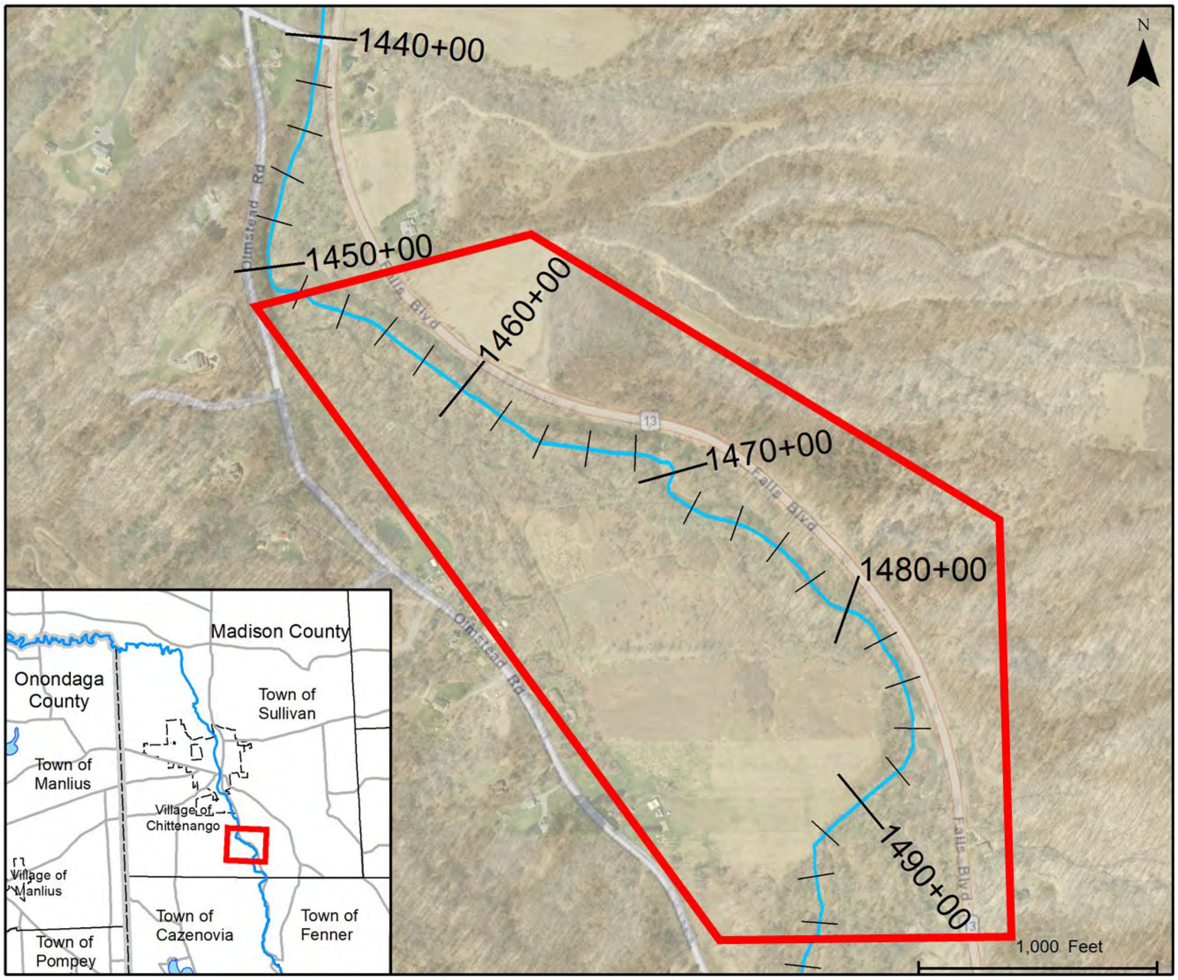

Figure 7-47. Location map for Alternative #2-11.

In addition, the detention structure could be designed to reduce watercourse and gully erosion, trap sediment, reduce and manage runoff near and downstream of the basin, and to improve downstream water quality. Figure 7-48 depicts a representative in-stream sediment detention pond design.

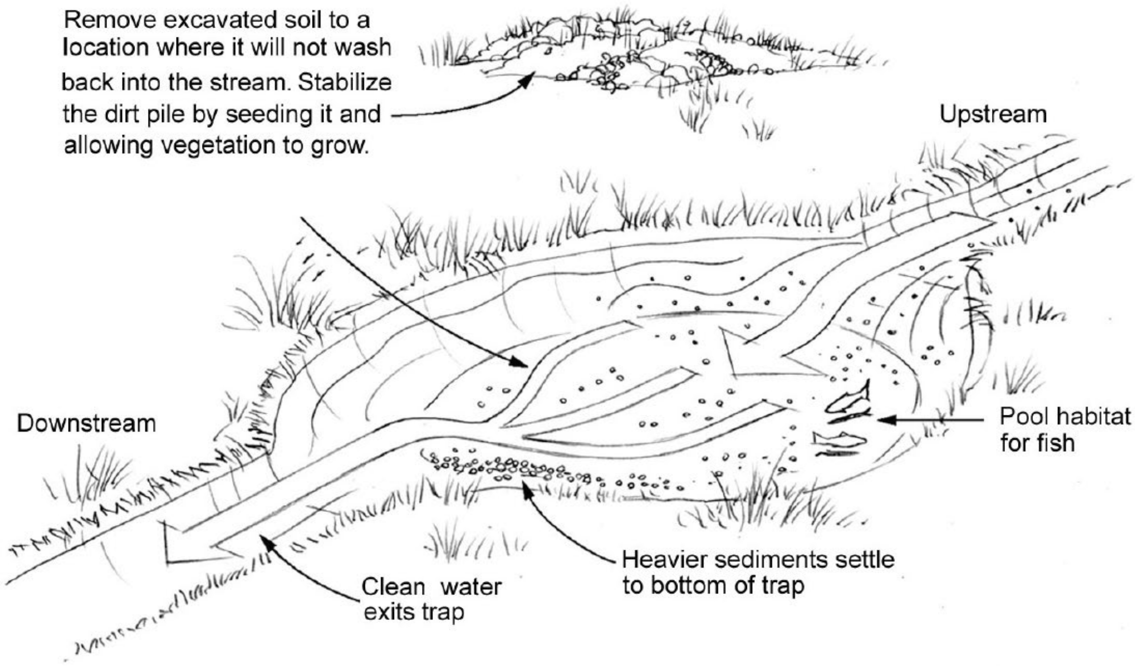

Figure 7-48. Representative diagram of an in-stream sediment detention pond (WCD 2009).

Sediment basin maintenance (i.e., removal of accumulated sediment) is necessary to ensure proper function. A well-functioning sediment basin allows for the trapping and removal of sediments regularly from one location rather than having to maintain an entire watercourse reach, saving money and reducing negative impacts to aquatic life and water quality. However, sediment traps are not naturally occurring features of a watercourse. Sediment traps can have both benefits and drawbacks to fish and other aquatic life (WCD 2009).

Sediment detention basins should be considered on a site-by-site basis where there are large open land areas and where downstream areas, which have historically experienced sediment issues, would benefit the most from the construction of a sediment detention basin (WCD 2009).

In New York State, a joint permit application from the NYSDEC and USACE may be required in order to construct, reconstruct, or repair a dam or other impoundment. The NYSDEC is entrusted with the regulatory power to oversee dam safety, which encompasses flood detention structures. To protect people from the loss of life and property due to flooding and/or dam failure, the NYSDEC Dam Safety Section, in cooperation with the USACE, reviews proposed dam construction and/or modifications, conducts dam safety inspections, and monitors projects for compliance with dam safety criteria.

The USACE has the authority to construct small flood risk reduction projects that are engineeringly feasibly, structurally sound and cost efficient through the authority provided under Section 205 of the 1948 FCA, as amended. Coordination should also occur with the NYSDEC as they need to be the non-Federal sponsor on these types of projects.

In addition, a FEMA BCA would need to be performed to determine the cost-effectiveness of the alternative prior to applying for FEMA mitigation grant programs funding. The BCR must be greater than or equal to 1.0 in order for the project to be considered cost effective.

Due to the conceptual nature of this measure, and significant amount of data required to produce a reasonable rough-order-of-magnitude cost, it is not feasible to quantify the costs of this measure without further engineering analysis and modeling. However, the cost of designing, permitting, constructing, and maintaining one or more flood-control dams in the headwaters of the Chittenango Creek watershed are expected to be significant. In addition, operation and maintenance costs to maintain the embankment, design capacity, vegetative cover, and outlet of the basin and periodic removal of any materials should be considered (NRCS 2002).

7.3 HIGH-RISK AREA #3

7.3.1 Alternative #3-1: Replace Chittenango Gorge Trail Bridge

This measure is intended to address issues within High-risk Area #3 by replacing the Chittenango Gorge Trail bridge with a bridge specifically designed for trails. Removing the existing railroad bridge features and replacing the current Trail bridge with a pedestrian walkway would increase the cross-sectional flow area of the channel located at river station 1867+50 (Figure 7-49).

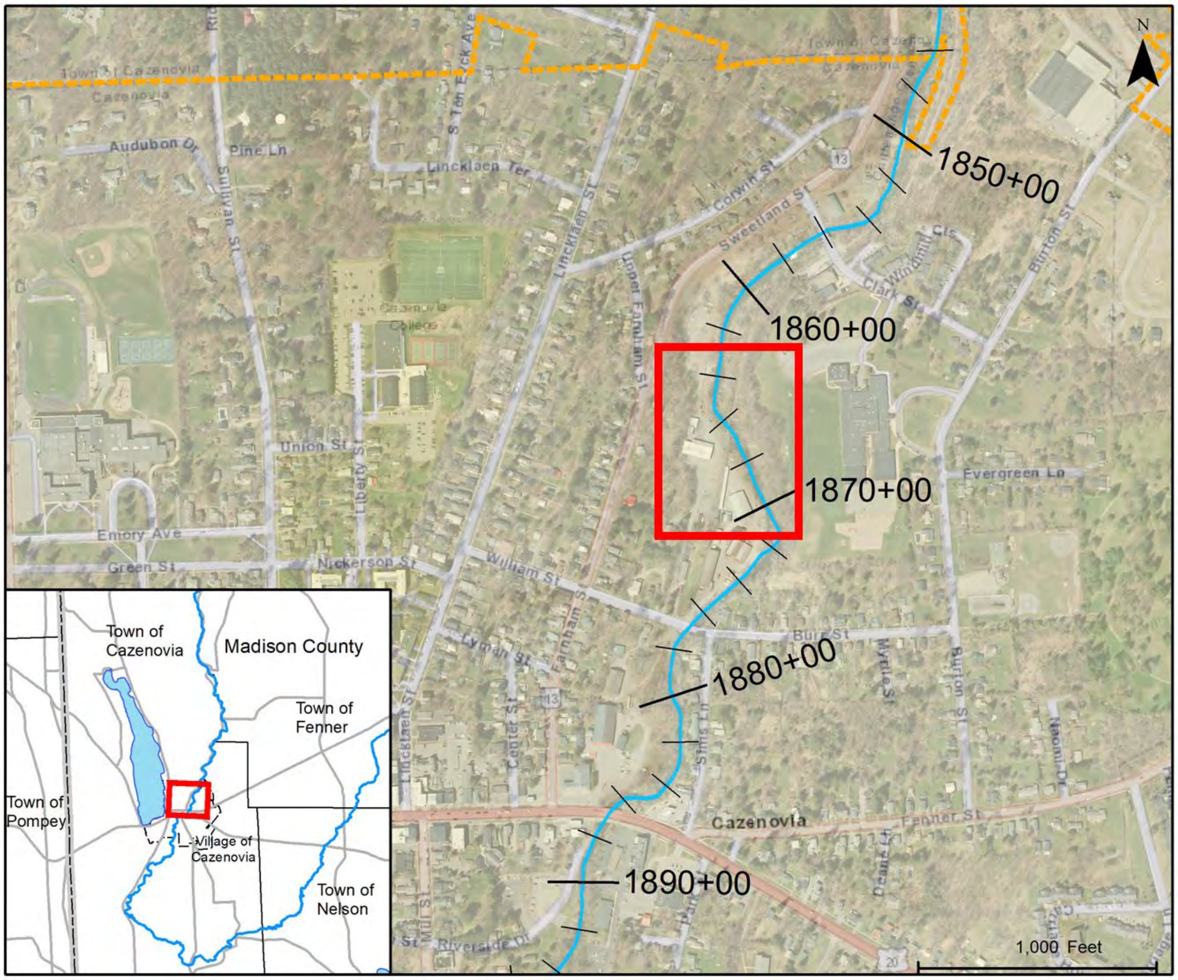

Figure 7-49. Location map for Alternative #3-1.

The current trail bridge is the remnants of an abandoned railroad bridge with a flat, closed top deck which allows for pedestrian traffic. The base of the current bridge retains the railroad support abutments, which are approximately 6 ft in height and extend below the top deck of the trail bridge. This extension reduces the flow capacity of the channel in this reach (Figure 7-50).

Figure 7-50. Chittenango Gorge Trail bridge, Cazenovia, NY.

Based on orthoimagery of the area, the meanders in the creek channel both upstream and downstream of the bridge crossing coupled with the existing bridge structure and Cazenovia Electric Company Dam immediately downstream, all act as impediments to flow, reducing water velocities and allowing sediment and debris to aggregate and restrict flow in this area (NYSOITS 2017).

As previously displayed in Figure 6-6, the FEMA FIS for the Chittenango Gorge Trail (Abandoned Railroad) bridge is unable to successfully pass the 2-, 1-, and 0.2% annual chance event without significant backwater upstream the of the bridge (FEMA 1984d). In addition, the FEMA FIRM displays significant backwater upstream of the trail bridge crossing (FEMA 1985a).

By replacing the existing structure with a pedestrian walkway, the cross-sectional flow area of the channel would increase and the potential for sediment, debris, and ice to accumulate or catch on the upstream face of the bridge would be reduced, thereby reducing flood risk to areas adajcent to and immediately upstream of the bridge.

The bridge replacement design selected for this proposed condition model simulation removed the railroad abutments and reduced the bridge structure height from 7 ft to 3 ft. This height reduction represents the structure necessary for a pedestrian walkway. This measure would potentially reduce the flood risk and benefit the properties adjacent to and immediately upstream of the trail bridge.

The proposed condition modeling confirmed that the trail bridge is a constriction point along Chittenango Creek. The modeling simulation results indicated water surface reductions of up to 0.9 ft in areas approximately 1,400 ft immediately upstream of the bridge extending from river stations 1909+00 to 1923+00 (Figure 7-51). The modeling output for future conditions displayed similar results with water surface reductions of up to 1.5 ft. Full model outputs for this alternative can be found in Appendix H.

The potential benefits of this strategy are limited to immediately upstream of the trail bridge. The primary benefits of increasing the bridge opening would be to increase the flow capacity of the bridge structure, reduce the potential of backwater from high-flow events, and help prevent debris and ice from catching on the structure and creating obstructions/jams upstream of the bridge.

The ROM cost for this strategy is approximately $310,000, which includes removal of the existing bridge structure, but does not include land acquisition costs for survey, appraisal, and engineering coordination. Additional engineering consideration would also be required to determine the appropriate size and structure of the new pedestrian walkway.

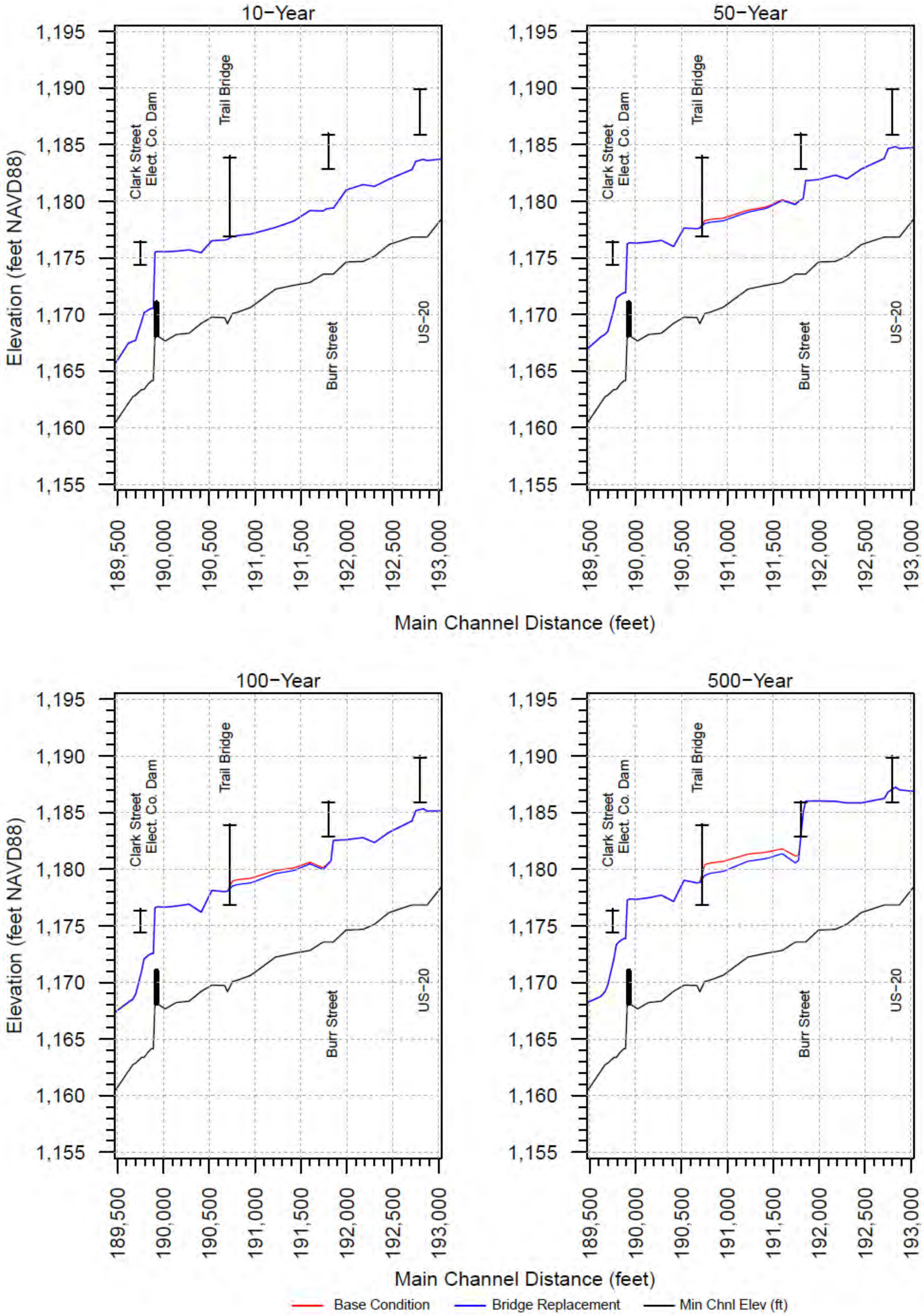

Figure 7-51. HEC-RAS model simulation output results for Alternative #3-1 for the existing condition (red) and bridge replacement (blue) scenarios.

7.3.2 Alternative #3-2: Increase the Opening of Burr Street Bridge

This measure is intended to address issues within High-risk Area #3 by increasing the width of the Burr Street bridge opening, which would increase the cross-sectional flow area of the channel located at river station 1877+50 (Figure 7-52).

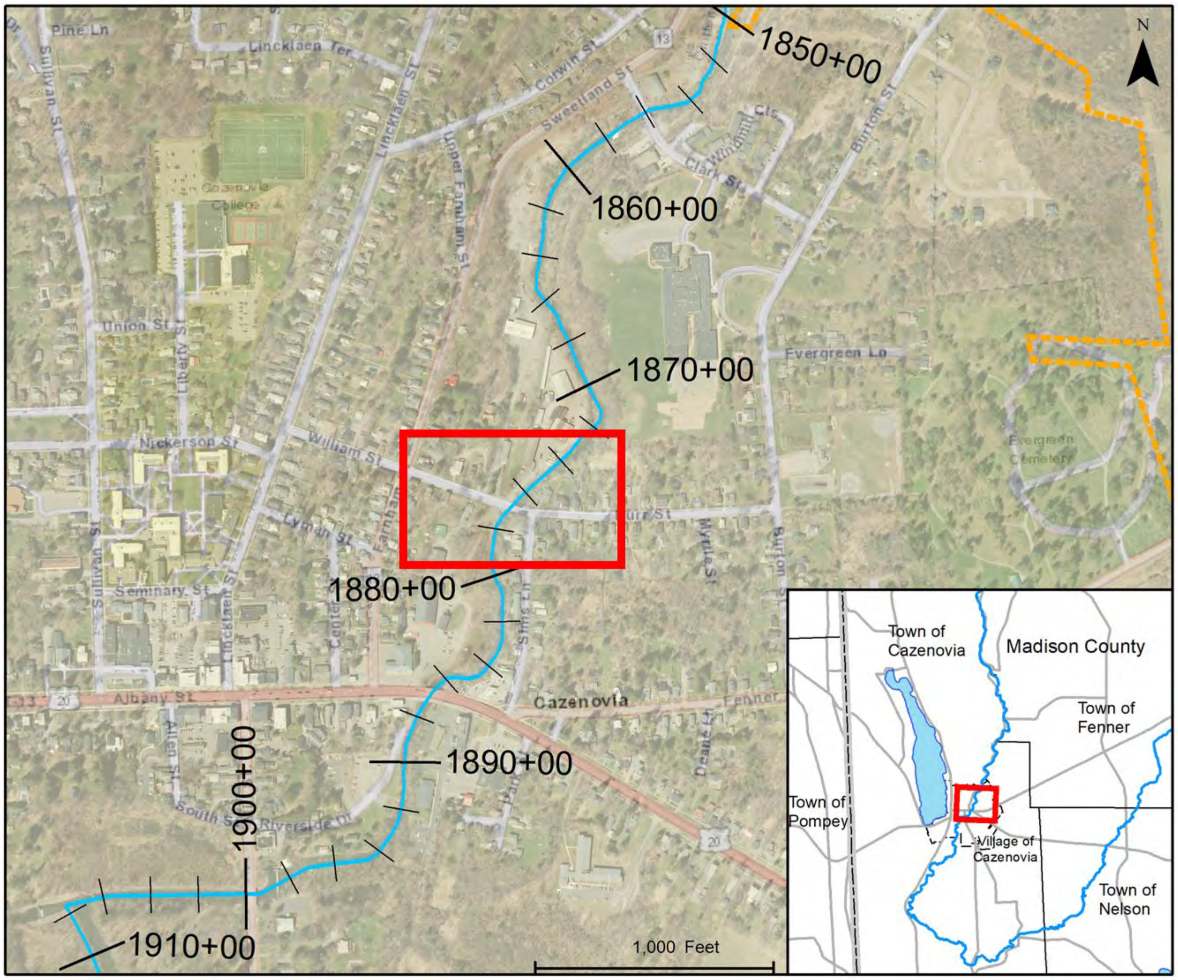

Figure 7-52. Location map for Alternative #3-2.

The bridge is owned by Madison County and has no pier in the channel. The existing bridge structure has a bridge span of 46 ft and a width of 33 ft (Figure 7-53). The flooding in the vicinity of the Burr Street bridge poses a flood risk threat to nearby residential and commercial properties, and county-owned infrastructure. Appendix F depicts a flood mitigation rendering of a bridge-widening scenario.

Figure 7-53. Burr Street bridge, Cazenovia, NY.

Based on orthoimagery of the area, the meanders in the creek channel both upstream and downstream of the bridge crossing act as impediments to flow, reducing water velocities and allowing sediment and debris to aggregate and restrict flow in this area (NYSOITS 2017).

As previously displayed in Figure 6-6, the FEMA FIS for the Burr Street (William Street) bridge is able to successfully pass the 10-, 2-, and 1% annual chance event; however, the FIS profile indicates significant backwater upstream the of the bridge (FEMA 1984d). In addition, the FEMA FIRM displays significant backwater upstream of the Madison Street bridge crossing (FEMA 1985a).

By increasing the opening span of the bridge structure, the cross-sectional flow area of the channel would increase and the potential for sediment, debris, and ice to accumulate or catch on the upstream face of the bridge would be reduced, thereby reducing flood risk to areas adajcent to and immediately upstream of the bridge.

The bridge widening design selected for this proposed condition model simulation was selected to ensure that the 1% annual chance event WSEL could successfully pass under the Burr Street bridge without significant backwater upstream of the bridge. To achieve the desired result, the bridge widening design increased the width of the bridge opening from 46 ft to 56 ft by widening the bridge on the left bank by 10 ft. This measure would potentially reduce the flood risk and benefit the properties adjacent to and immediately upstream of Burr Street.

The proposed condition modeling confirmed that the Burr Street bridge is a constriction point along Chittenango Creek. The modeling simulation results indicated water surface reductions of up to 1.5 ft in areas approximately 1,600 ft immediately upstream of the bridge extending from river stations 1922+50 to 1938+50 (Figure 7-54). The modeling output for future conditions displayed similar results with water surface reductions of up to 2.9 ft. Full model outputs for this alternative can be found in Appendix H.

The potential benefits of this strategy are limited to immediately upstream of the Burr Street bridge. The primary benefits of increasing the bridge opening would be to increase the flow capacity of the bridge structure, reduce the potential of backwater from high-flow events, and help prevent debris and ice from catching on the structure and creating obstructions/jams upstream of the bridge.

The ROM cost for this strategy is approximately $1.1 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination. Additional engineering consideration would also be required to determine if increasing the bridge opening would alter the structural integrity of the bridge in any way.

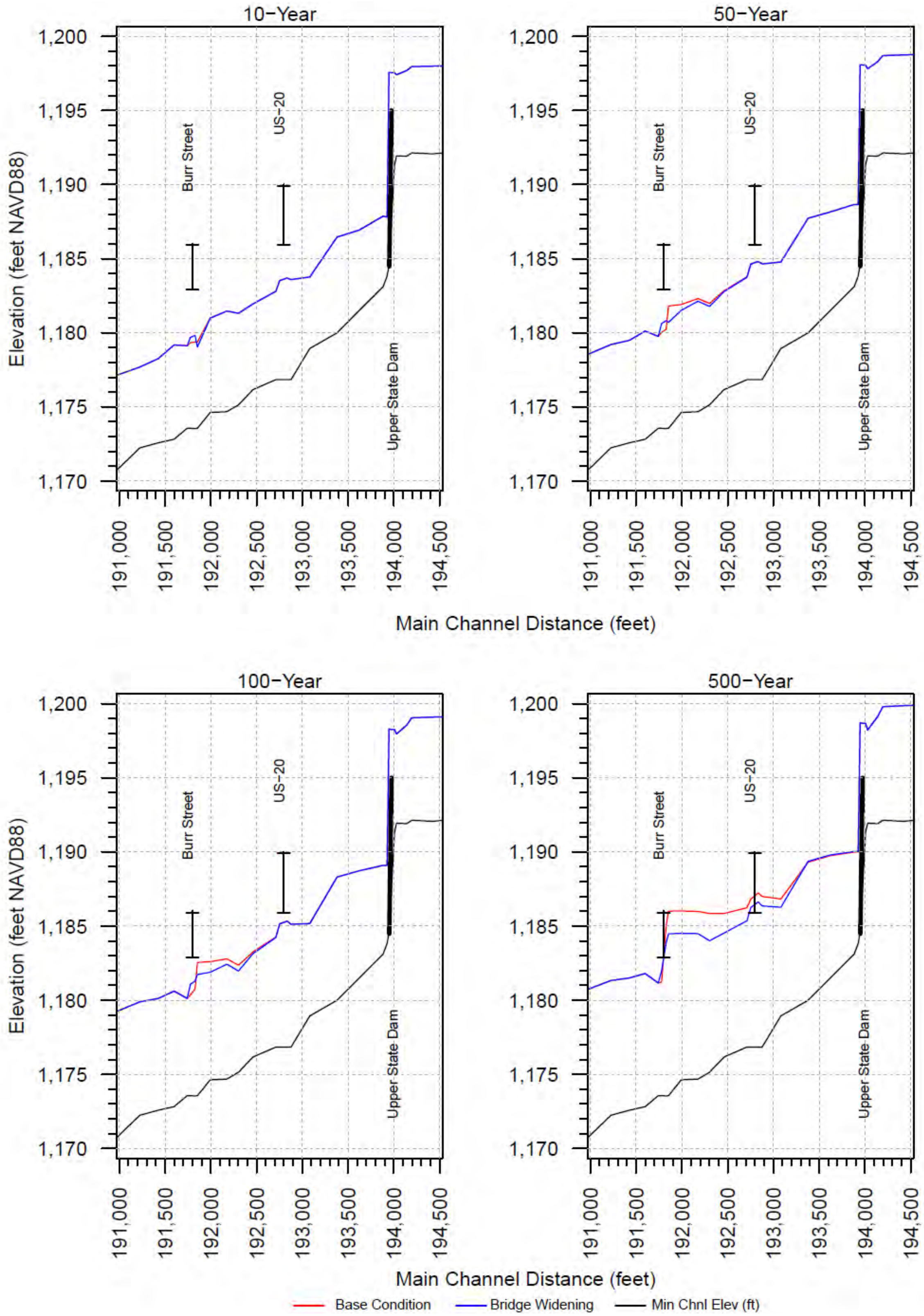

Figure 7-54. HEC-RAS model simulation output results for Alternative #3-2 for the existing condition (red) and bridge upsizing (blue) scenarios.

7.3.3 Alternative #3-3: Hydrologic and Hydraulic Analysis of Unnamed Tributary

This measure is intended to address issues within High-risk Area #3 in the vicinity of the confluence with Chittenango Creek and the Unnamed Tributary in the Village of Cazenovia, New York. The Unnamed Tributary is located at river station 1874+50 along Chittenango Creek (Figure 7-55).

The Burr Street culvert has been identified as a significant source of flooding in the Village along the Unnamed Tributary. Residences along Burr Street have been flooded three times in ten years including January 1996, April 2001, and August 8, 2003. All of the houses on both sides of the street have had some degree of basement flooding. The Village of Cazenovia Public Works Department has reduced some of the inflow to the Burr Street area by diverting half of the flow from a Fenner Street storm drain into the detention basin west of the Town and Country Shopping Center. Additionally, an orifice plate was placed on the detention basin discharge to reduce peak flows to Burr Street (MCEM 2016).

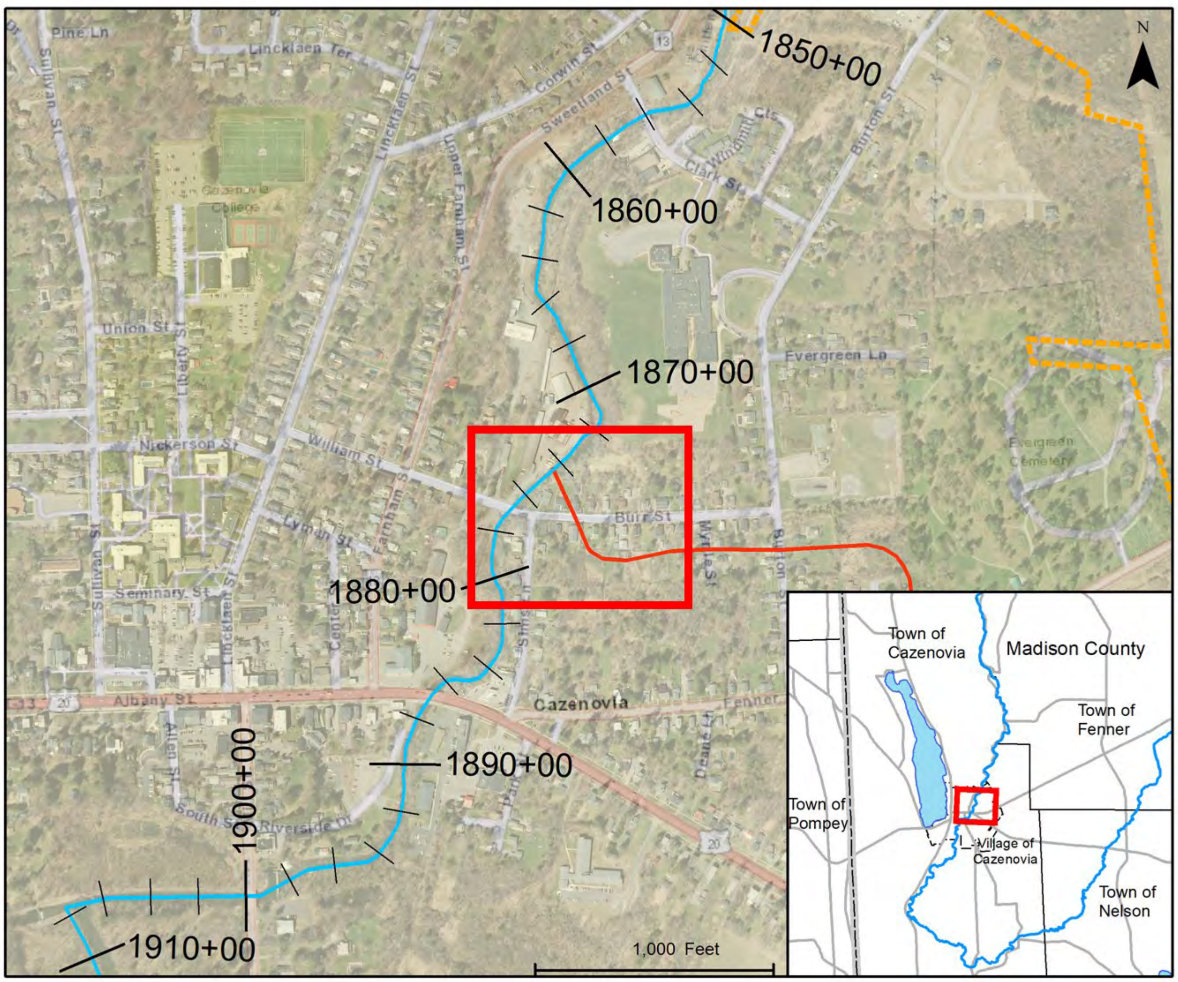

Figure 7-55. Location map for Alternative #3-3.

The Unnamed Tributary flows westward behind the houses on the south side of Burr Street before turning north and flowing through an approximately 45 ft long by 36-in diameter culvert under Burr Street (Figure 7-56). This small stream has a 380 acre watershed that covers the northeast corner of the Village and parts of the Town of Fenner.

Figure 7-56. Burr Street culvert (Unnamed Tributary), Cazenovia, NY (MCEM 2016).

The FEMA FIRM displays significant backwater upstream of the Burr Street culvert which, due to its close proximity to Chittenango Creek, exacerbates the backwater flooding from the Burr Street bridge crossing on Chittenango Creek (FEMA 1985a).

By increasing the opening of the culvert structure, the cross-sectional flow area of the tributary would increase, and the potential for sediment, debris, and ice to accumulate or catch on the upstream face of the culvert would be reduced, thereby reducing flood risk to areas adajcent to and immediately upstream of the bridge. Appendix F depicts a flood mitigation rendering of a culvert widening scenario.

Due to the lack of hydrologic data and access to the culvert (i.e., field conditions and private property access), the project team was unable to develop an H&H model of the unnamed tributary to analyze flood mitigation alternatives. However, the culvert has been identified as a potential source of flooding by the community.

The potential benefits of this strategy are limited to immediately upstream of the Burr Street culvert. The primary benefits of increasing the culvert opening would be to increase the flow capacity of the structure, reduce the potential of backwater from high-flow events, and help prevent debris and ice from catching on the structure and creating obstructions/jams upstream of the culvert.

An H&H analysis of the Unnamed Tributary would provide the community and stakeholders with the necessary background and supporting information to begin to address flooding issues along the Unnamed Tributary, which in turn would benefit Chittenango Creek and the properties along Burr Street. An approach similar to the one performed in this study would discuss known flooding-related issues and develop strategies to address those flooding issues. The ROM cost for this measure is $60,000.

7.3.4 Alternative #3-4: Increase the Opening of the Albany Street/US-20 Bridge Crossing

This measure is intended to address issues within High-risk Area #3 by increasing the width of the Albany Street/US-20 bridge opening, which would increase the cross-sectional flow area of the channel located at river station 1887+00 (Figure 7-57).

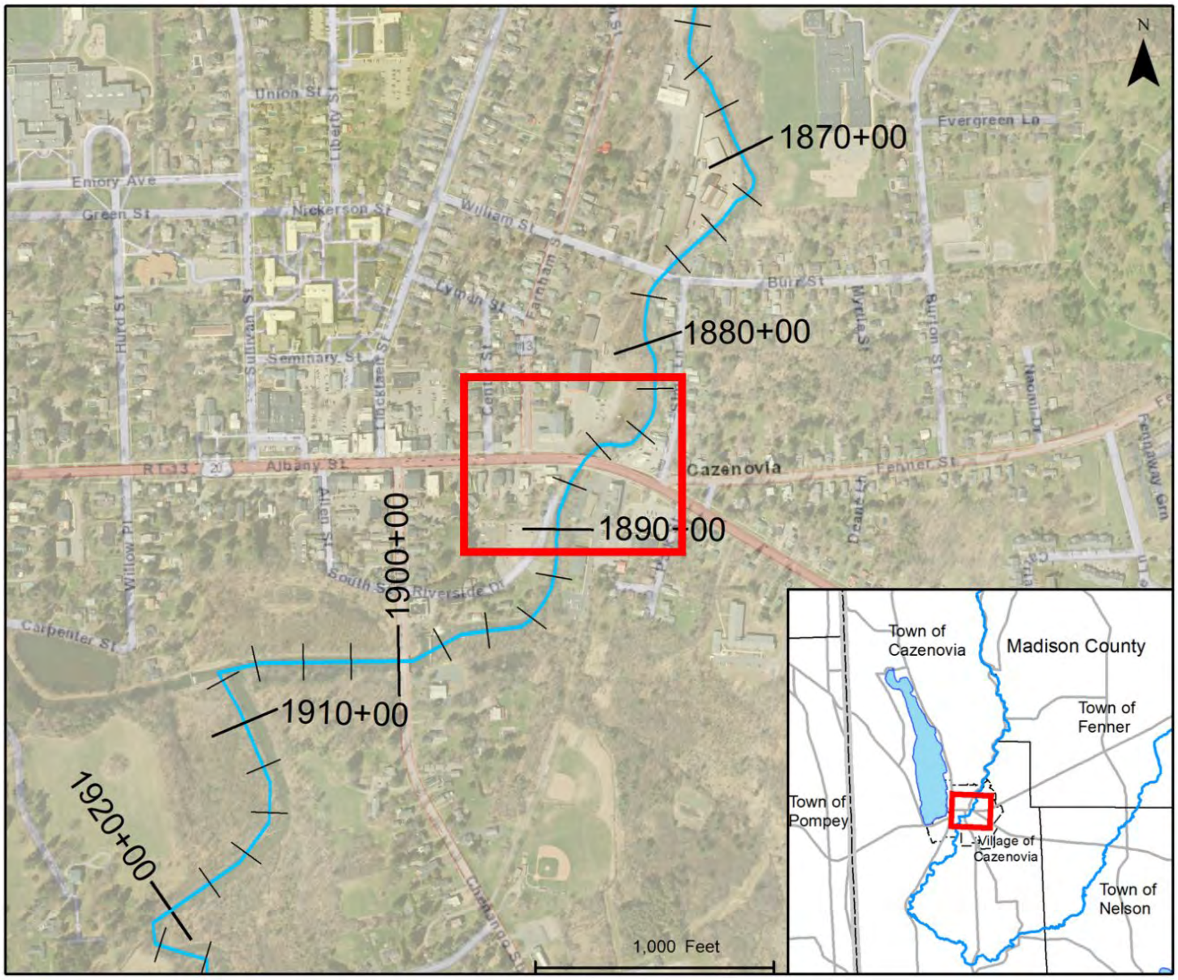

Figure 7-57. Location map for Alternative #3-4.

The bridge is owned by the NYSDOT and has no pier in the channel. The existing bridge structure has a bridge span of 79 ft and a width of 46 ft (Figure 7-58). The flooding in the vicinity of the Albany Street/US-20 bridge poses a flood risk threat to nearby residential and commercial properties, and county-owned infrastructure. Appendix F depicts a flood mitigation rendering of a bridge widening scenario.

Figure 7-58. Albany Street/US-20 bridge, Cazenovia, NY.

Based on orthoimagery of the area, the meanders in the creek channel both upstream and downstream of the bridge crossing act as impediments to flow, reducing water velocities and allowing sediment and debris to aggregate and restrict flow in this area (NYSOITS 2017).

As previously displayed in Figure 6-6, the FEMA FIS for the Albany Street/US-20 bridge is unable to successfully pass the 2-, 1-, and 0.2% annual chance event without significant backwater upstream of the bridge (FEMA 1984d). In addition, the FEMA FIRM displays significant backwater upstream of the Albany Street/US-20 bridge crossing (FEMA 1985a).

By increasing the opening span of the bridge structure, the cross-sectional flow area of the channel would increase and the potential for sediment, debris, and ice to accumulate or catch on the upstream face of the bridge would be reduced, thereby reducing flood risk to areas adajcent to and immediately upstream of the bridge.

The bridge widening design selected for this proposed condition model simulation was selected to ensure that the 1% annual chance event WSEL could successfully pass under the Albany Street/US-20 bridge without significant backwater upstream of the bridge. To achieve the desired result, different combinations of bridge widening and heightening designs were modeled. Bridge width increases of 5, 10, 15, and 20 ft and increasing the low chord elevation by up to 3 ft were all modeled. The model simulation results indicated no significant impact on water surface elevations (Figure 7-59). The modeling output for future conditions displayed similar results. Full model outputs for this alternative can be found in Appendix H.

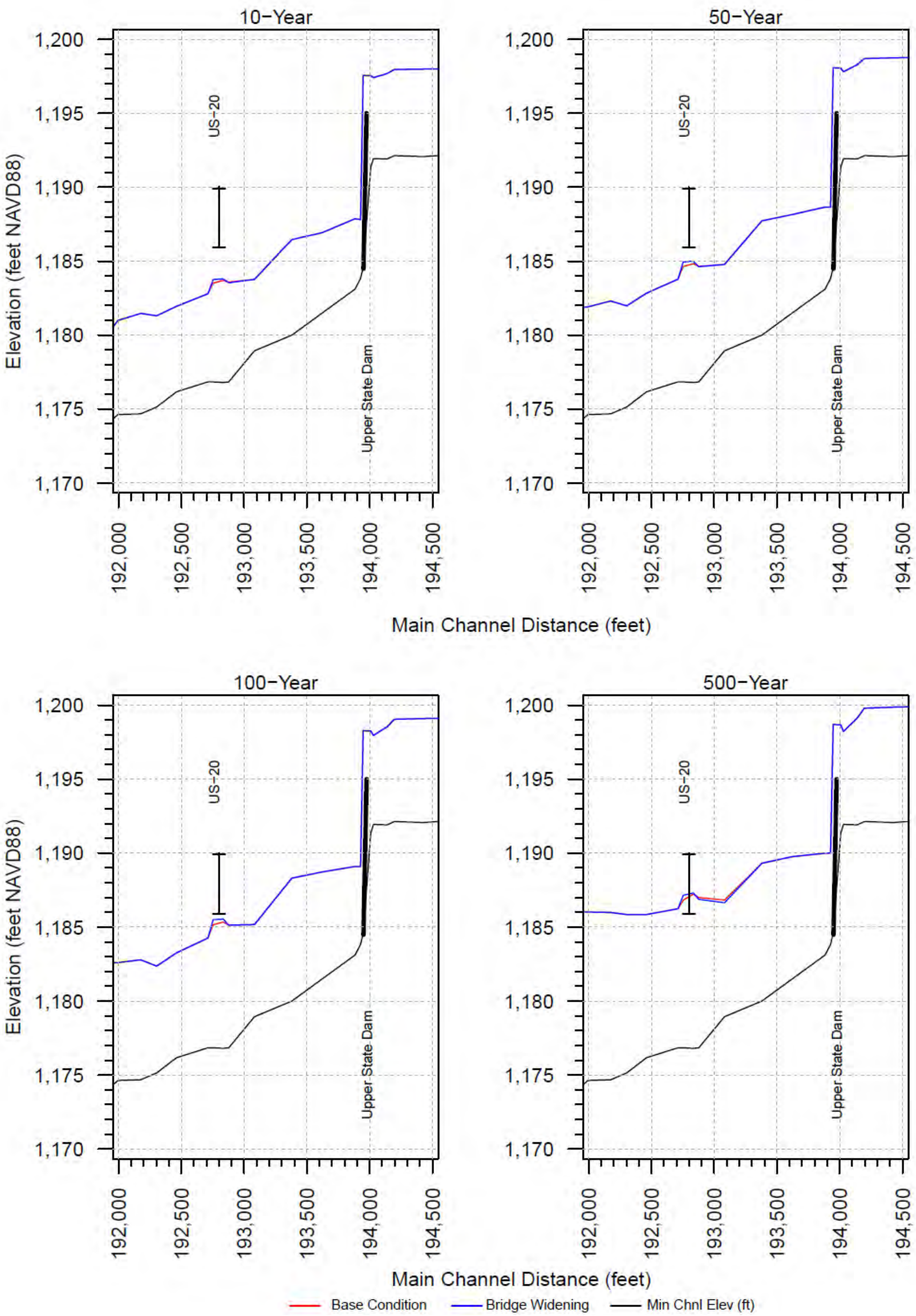

Figure 7-59. HEC-RAS model simulation output results for Alternative #3-4 for the existing condition (red) and bridge upsizing (blue) scenarios.

The ineffectiveness of the bridge widening simulations are most likely a result of the morphological features of the channel in this area (i.e., the significant meanders in the channel flow path immediately downstream of the bridge), and the close proximity of the Upper State Dam upstream and the Burr Street bridge crossing downstream of Albany Street/US-20.

Based on the analysis of the bridge upsizing, this measure is not recommended due to the ineffectiveness of the measure to provide adequate flood protection to areas within the vicinity of the Albany Street/US-20 bridge crossing, where the at-risk properties are located and the additional costs associated with replacing the bridge.

The ROM cost for this strategy is approximately $1.9 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination. Additional engineering consideration would also be required to determine if increasing the bridge opening would alter the structural integrity of the bridge in any way.

7.3.5 Alternative #3-5: Flood Benches Upstream of Mill/Chenango Street

Installing a flood bench would provide additional storage and floodplain width over and above the current storage and width provided by the adjacent developed floodplain in this reach of Chittenango Creek, which could potentially reduce damages in the event of flooding and address issues within High-risk Area #3. Three potential flood benches were modeled upstream of Mill/Chenango Streets in the Village of Cazenovia (Figure 7-60):

- Flood Bench A is approximately 4 acres in size with an average depth of 2 ft and located between river stations 1900+00 to 1908+00
- Flood Bench B is approximately 5.5 acres in size with an average depth of 1 ft and located between river stations 1908+00 to 1918+00
- Flood Bench C is approximately 2.5 acres in size with an average depth of 3 ft and located between river stations 1900+00 to 1912+00

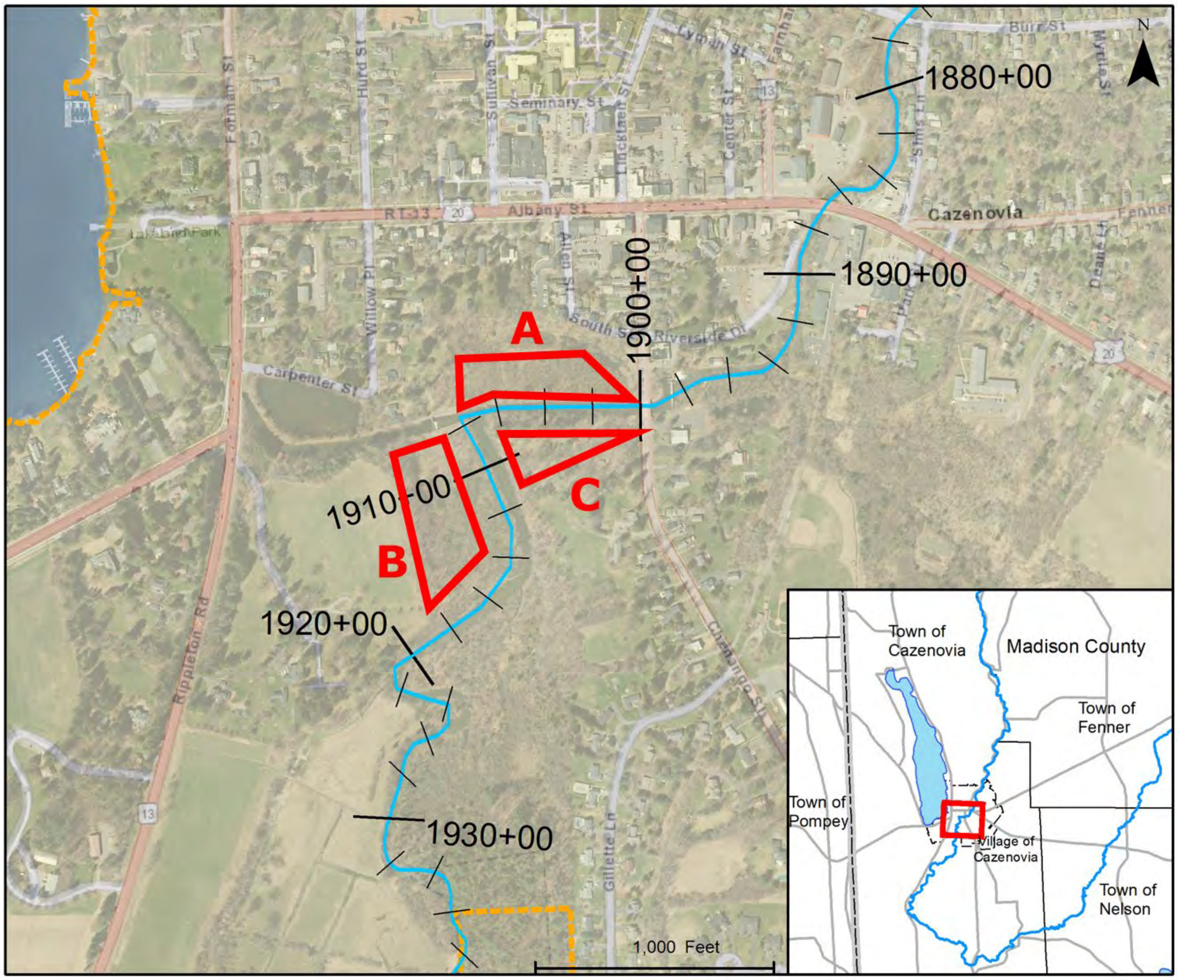

Figure 7-60. Location map for Alternative #3-5.

The flood benches are within the FEMA designated SFHA or Zone A, which are areas subject to inundation by the 1% ACE, but where base flood elevations and flood hazard factors were not determined, and where mandatory flood insurance purchase requirements and floodplain management standards apply (FEMA 1984d). Appendix F depicts a flood mitigation rendering of a flood bench illustrating before and after landscape features.

Flood benches generally provide flood protection for localized areas in the vicinity of and immediately upstream and/or downstream of the bench. Based on the analysis of high-risk areas, all three flood benches located upstream of the Mill/Chenango Street bridge crossing would not provide significant flood protection in this reach from open-water flooding. The modeling output for future conditions displayed similar results. Figures 7-61 through 7-63 display the profile plots for each flood bench alternative. Full model outputs for this alternative can be found in Appendix H.

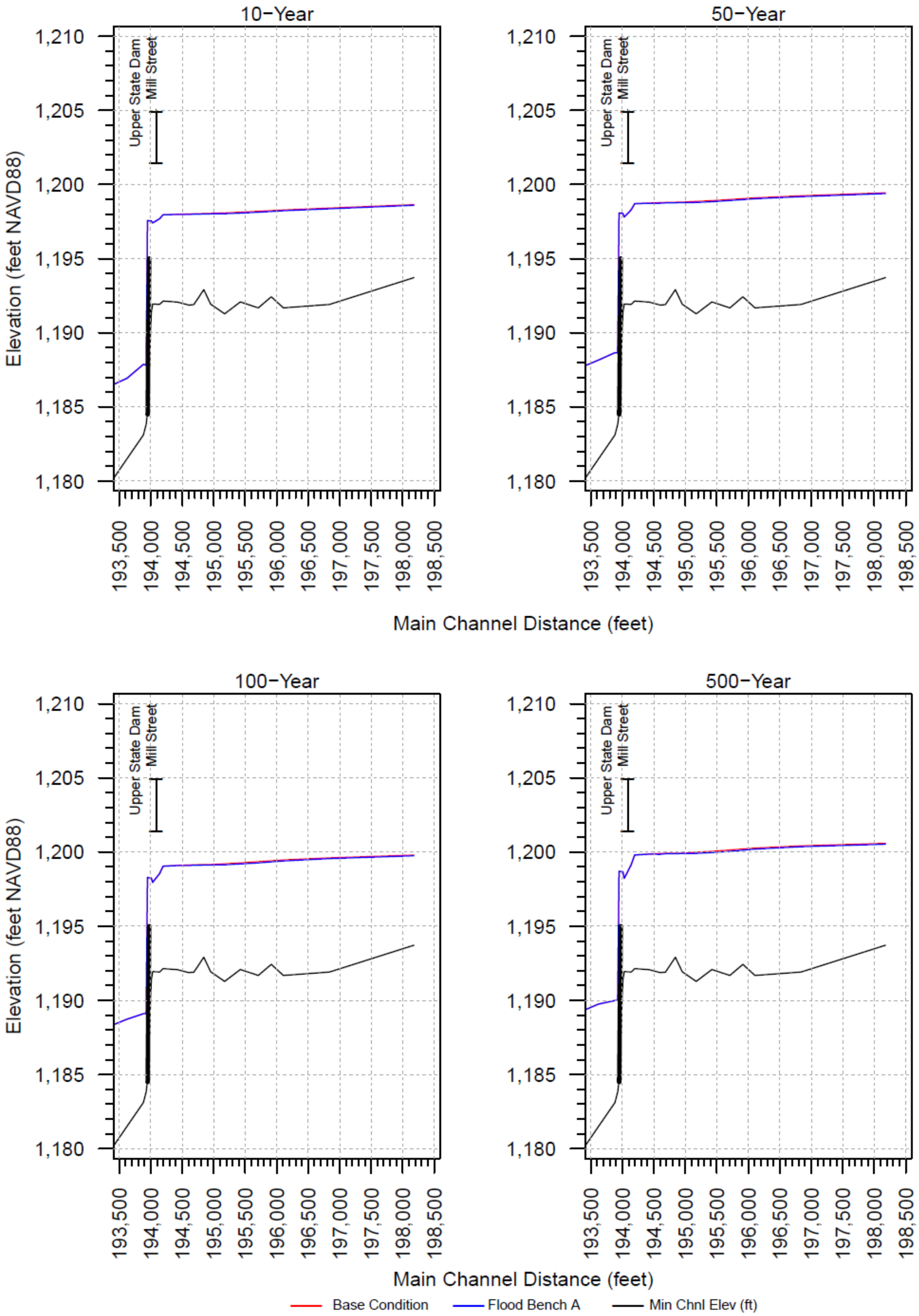

Figure 7-61. HEC-RAS model simulation output results for Alternative #3-5 for the existing condition (red) and Flood Bench A (blue) scenarios.

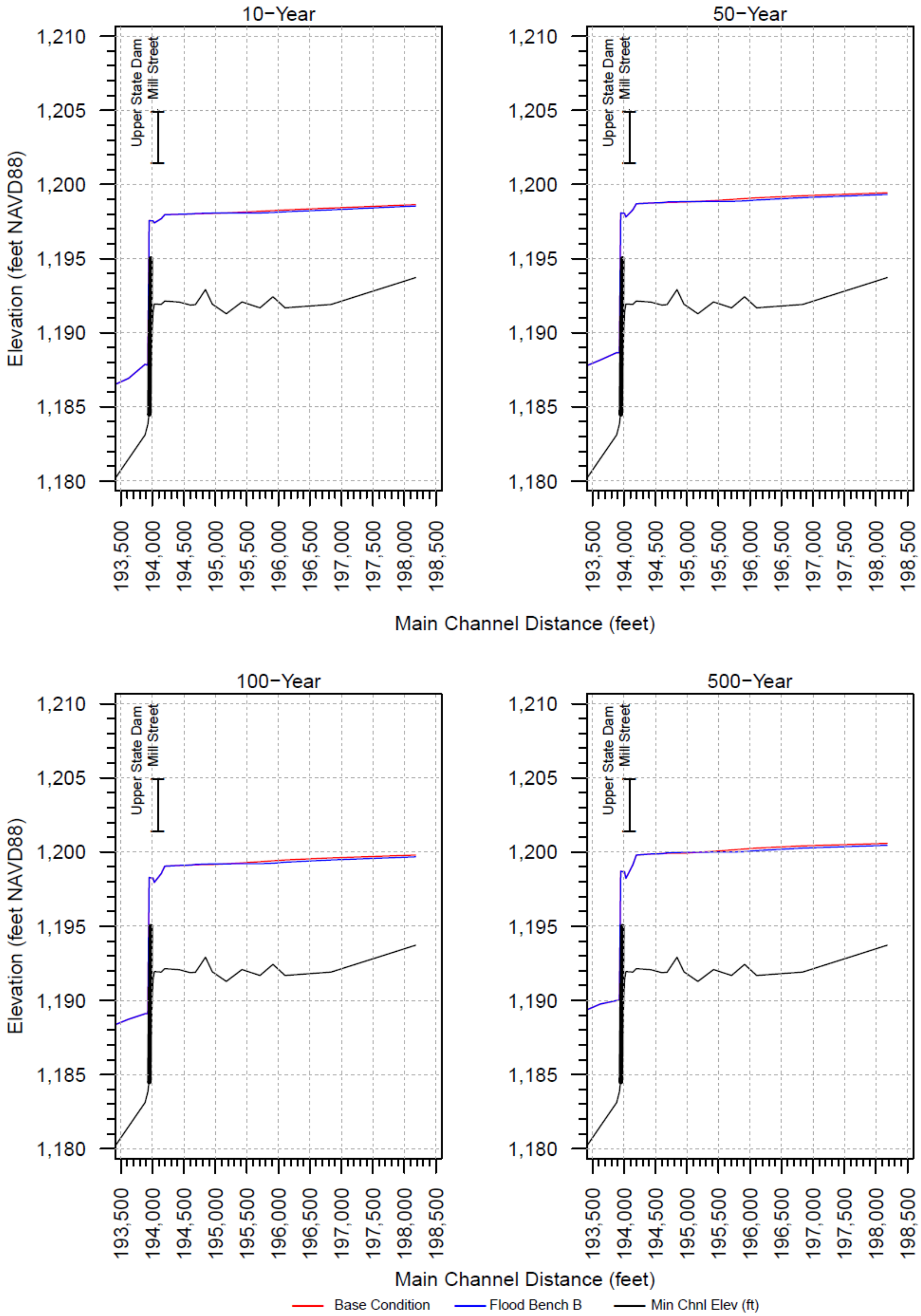

Figure 7-62. HEC-RAS model simulation output results for Alternative #3-5 for the existing condition (red) and Flood Bench B (blue) scenarios.

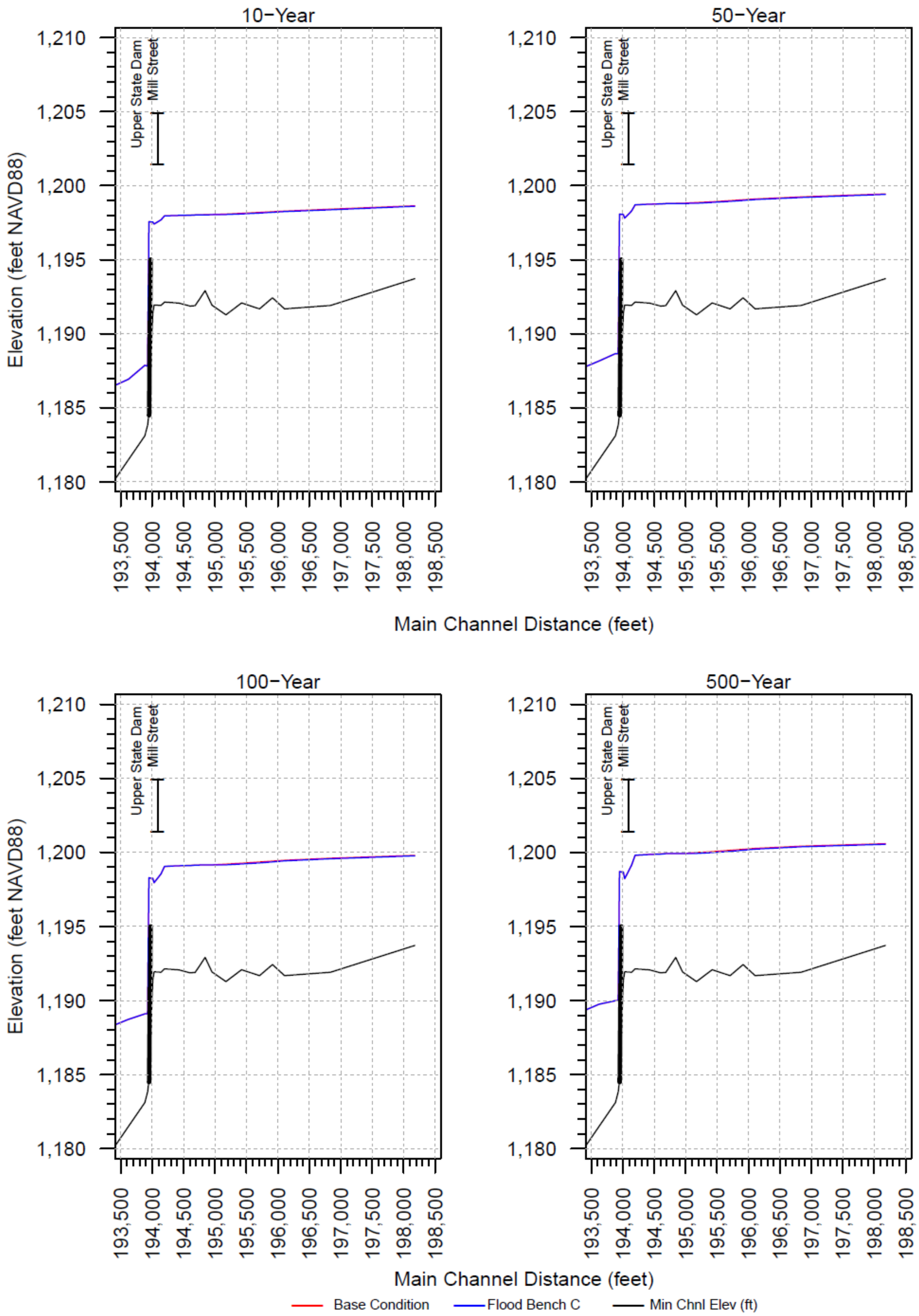

Figure 7-63. HEC-RAS model simulation output results for Alternative #3-5 for the existing condition (red) and Flood Bench C (blue) scenarios.

The ineffectiveness of the flood bench simulations is most likely a result of the morphological features of the channel in this area (i.e., Cazenovia Lake diversion channel) and the close proximity of the Albany Street/US-20 bridge crossing and Upper State Dam downstream of the benches.

Based on the analysis of the flood bench simulations, this measure is not recommended due to the ineffectiveness of the measure to provide adequate flood protection to areas upstream of the Mill/Chenango Street crossing where the at-risk properties are located, and the additional costs associated with constructing a flood bench.

To evaluate the effectiveness of the flood mitigation impacts, the project team analyzed this alternative and each flood bench independently of other alternatives. However, there is the potential for added benefits (i.e., reduction in WSELs, less flooding, reduced erosion, etc.) when multiple flood mitigation projects are built in conjunction. For areas that experience significant flood damages or chronic flooding, it is recommended that multiple flood mitigation strategies in conjunction be considered and evaluated by affected communities.

The ROM cost for each flood bench alternative is:

- Flood Bench A: $1.0 million
- Flood Bench B: $1.3 million
- Flood Bench C: $1.0 million

These ROM cost estimates do not include land acquisition costs for survey, appraisal, and engineering coordination. In addition, the NYSDEC will require wetland delineations, an analysis for any endangered and/or threatened species within the proposed project area, and information regarding access during construction of any flood bench mitigation alternative.

7.3.6 Alternative #3-6: Restore Natural Channel Geomorphology to Chittenango Creek/Cazenovia Lake Diversion

Restoring the natural channel geomorphology to Chittenango Creek in the vicinity of the Cazenovia Lake Diversion in the Village of Cazenovia would improve channel flow, which would reduce the erosion, sediment aggradation, and the potential for backwater flooding within High-risk Area #3. Two natural meanders were modeled to represent the Cazenovia Lake Diversion and Chittenango Creek (Figure 7-64).

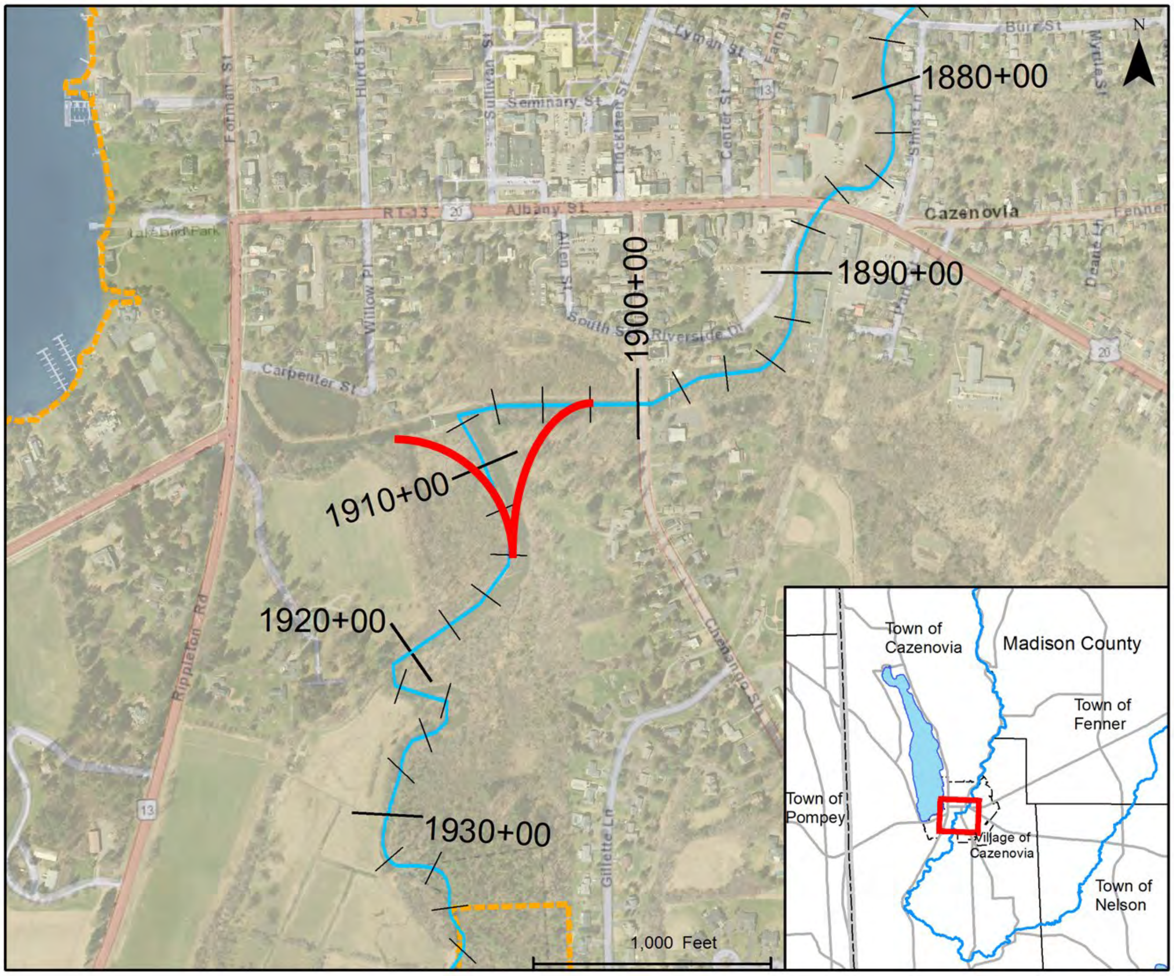

Figure 7-64. Location map for Alternative #3-6.

The channel design used for the proposed condition model simulation set the minimum channel elevation to match the upstream to downstream tie-in elevation for both the Cazenovia Lake Diversion and Chittenango Creek. The new Cazenovia Lake Diversion channel is approximately 500 ft long with a minimum channel elevation of 1192 ft NAVD88. The new Chittenango Creek channel is approximately 400 ft long with a minimum channel elevation of 1192 ft NAVD88. The former channel and overbank terrain was filled to match the elevation of the most adjacent overbank area, which was 1195 ft NAVD88. Channel bank elevations for both the Diversion channel and Chittenango Creek were set to 1200 ft NAVD88 (Figure7-65).

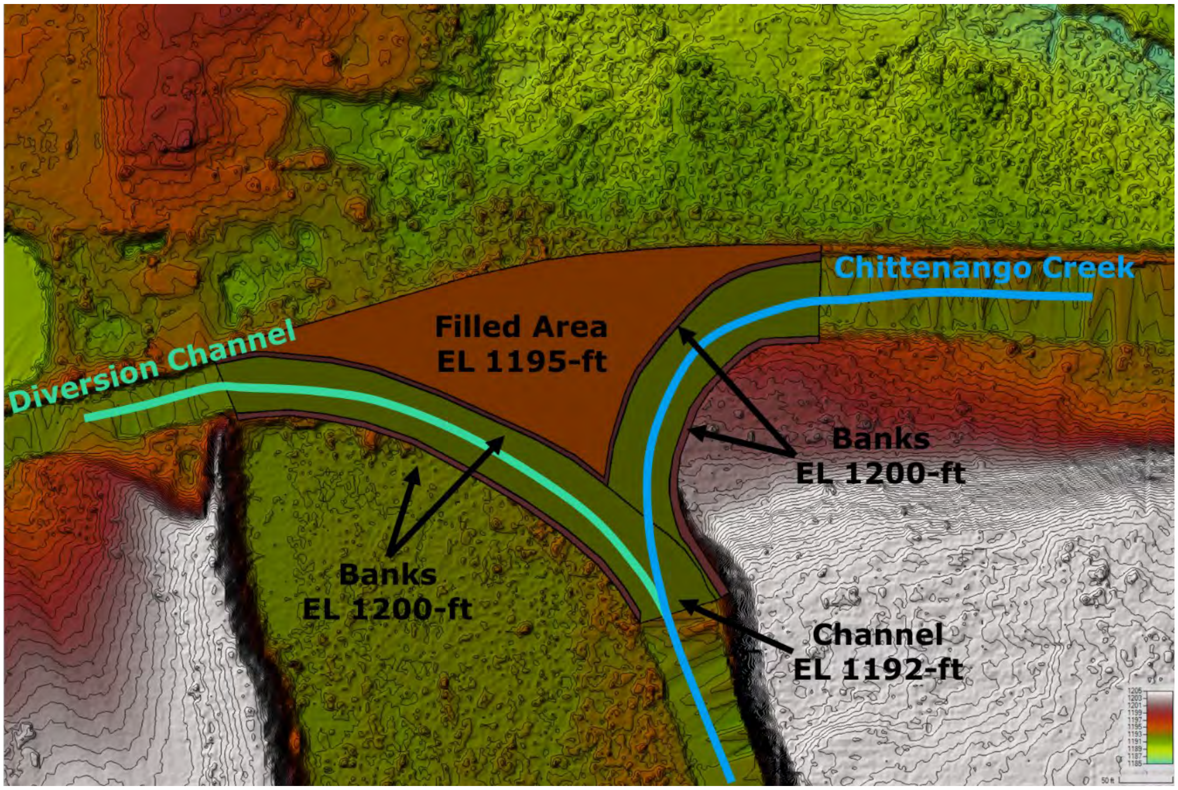

Figure 7-65. HEC-RAS terrain data for Alternative #3-6.

The new channel reaches are within the FEMA designated SFHA or Zone AE, which are areas subject to inundation by the 1% ACE with base flood elevations determined and where mandatory flood insurance purchase requirements and floodplain management standards apply (FEMA1984d).

Based on the analysis of high-risk areas, the new channel geomorphology would not provide significant flood protection in this reach from open-water flooding. The modeling output for future conditions displayed similar results. Figure 7-66 displays the profile plot for this alternative. Full model outputs for this alternative can be found in Appendix H.

The ineffectiveness of the new channel geomorphology simulation is most likely a result of the topographic features of the channel and overbank areas in this reach (i.e., low relief topography at or close to the minimum channel elevation) and the close proximity of the Albany Street/US-20 bridge crossing and Upper State Dam downstream of the new channel.

To evaluate the effectiveness of the flood mitigation impacts, the project team analyzed this alternative independently of other alternatives. However, there is the potential for added benefits (i.e., reduction in WSELs, less flooding, reduced erosion, etc.) when multiple flood mitigation projects are built in conjunction. For areas that experience significant flood damages or chronic flooding, it is recommended that multiple flood mitigation strategies in conjunction be considered and evaluated by affected communities.

The ROM cost for this measure is $540,000, which does not include land acquisition costs for survey, appraisal, and engineering coordination and acquisition or disposal of any fill or dredged materials. In addition, the NYSDEC will require wetland delineations, an analysis for any endangered and/or threatened species within the proposed project area, and information regarding access during construction for this mitigation alternative.

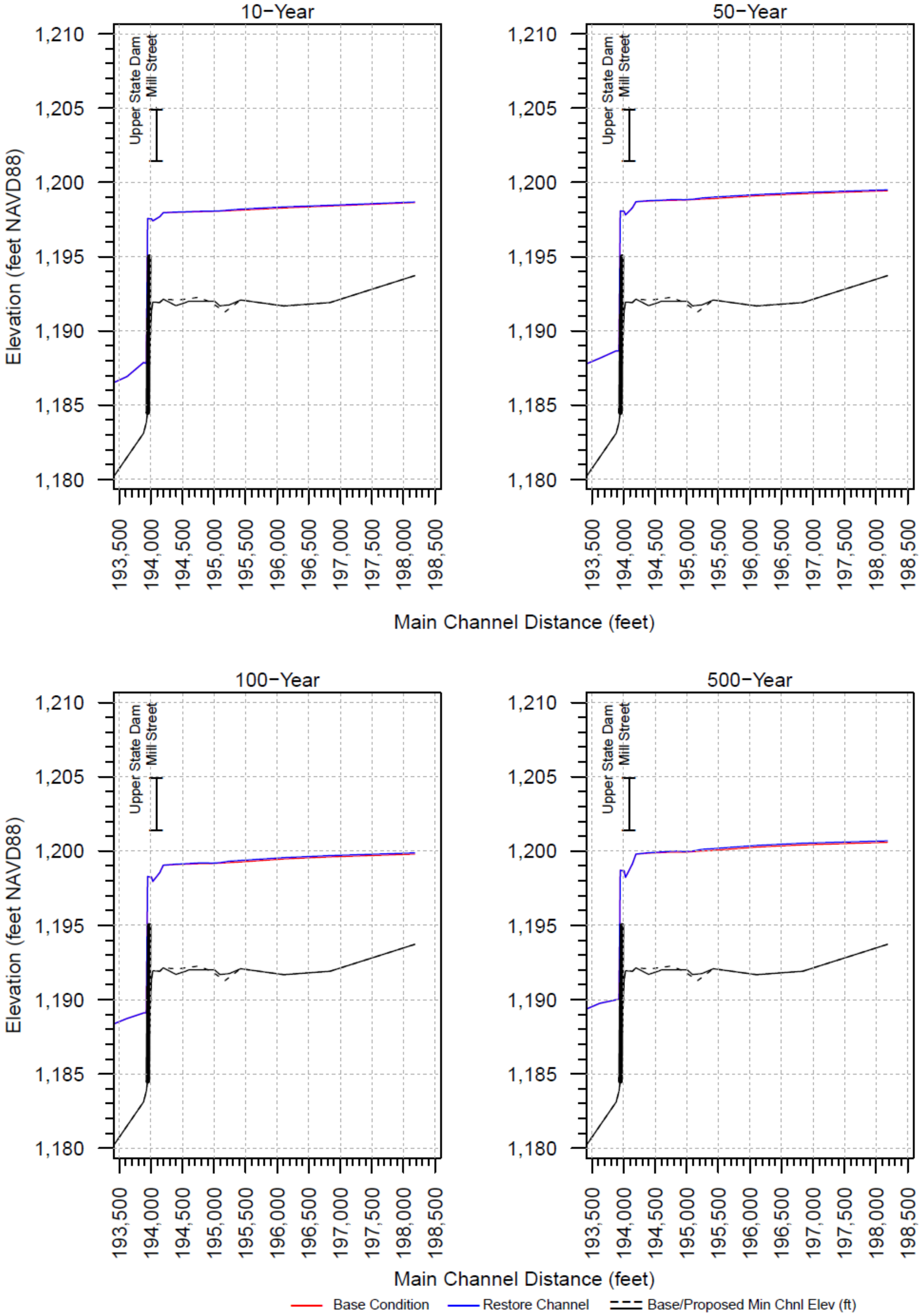

Figure 7-66. HEC-RAS model simulation output results for Alternative #3-6 for the existing condition (red) and new channel reach (blue) scenarios.

7.3.7 Alternative #3-7: Restore Natural Channel Geomorphology to Diversion and Install a Flood Bench

Restoring the natural channel geomorphology to Chittenango Creek in the vicinity of the Cazenovia Lake Diversion in the Village of Cazenovia would improve channel flow, which would reduce the erosion, sediment aggradation, and the potential for backwater flooding within High-risk Area #3. Installing a flood bench would provide additional storage and floodplain width, which could potentially reduce damages in the event of flooding. Two natural meanders were modeled to represent the Cazenovia Lake Diversion and Chittenango Creek with a flood bench approximately four acres in size and located between river stations 1903+00 to 1910+00 (Figure 7-67).

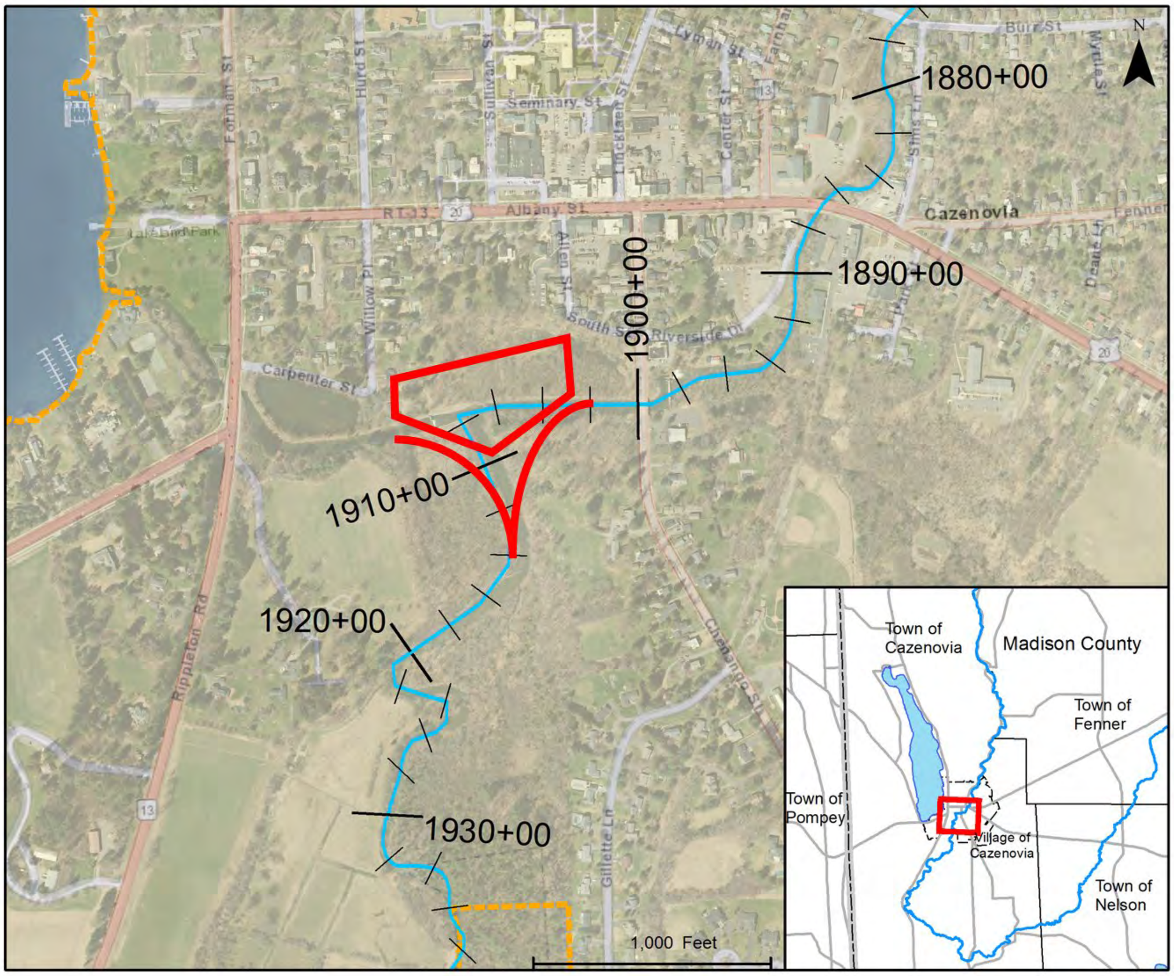

Figure 7-67. Location map for Alternative #3-7.

The channel design used for the proposed condition model simulation set the minimum channel elevation to match the upstream to downstream tie-in elevation for both the Cazenovia Lake Diversion and Chittenango Creek. The new Cazenovia Lake Diversion channel is approximately 500 ft long with a minimum channel elevation of 1192 ft NAVD88. The new Chittenango Creek channel is approximately 400 ft long with a minimum channel elevation of 1192 ft NAVD88. The former channel and overbank terrain was filled to match the elevation of the most adjacent overbank area, which was 1195 ft NAVD88. Channel bank elevations for both the Diversion channel and Chittenango Creek were set to 1200 ft NAVD88 (Figure 7-65).

The flood bench designs used for the proposed condition model simulation set the minimum bench elevation approximately equal to the bankfull elevation, which was an average depth of 2.5 ft.

The new channel reaches and flood bench are within the FEMA designated SFHA or Zone AE, which are areas subject to inundation by the 1% ACE with base flood elevations determined and where mandatory flood insurance purchase requirements and floodplain management standards apply (FEMA 1984d). Appendix F depicts a flood mitigation rendering of a flood bench illustrating before and after landscape features.

Based on the analysis of high-risk areas, the new channel geomorphology and flood bench would not provide significant flood protection in this reach from open-water flooding. The modeling output for future conditions displayed similar results. Figure 7-68 displays the profile plot for this alternative. Full model outputs for this alternative can be found in Appendix H.

The ineffectiveness of this alternative is most likely a result of the topographic features of the channel and overbank areas in this reach (i.e., low-relief topography at or close to the minimum channel elevation) and the close proximity of the Albany Street/US-20 bridge crossing and Upper State Dam downstream of the new channel and bench.

To evaluate the effectiveness of the flood mitigation impacts, the project team analyzed this alternative independently of other alternatives. However, there is the potential for added benefits (i.e., reduction in WSELs, less flooding, reduced erosion, etc.) when multiple flood mitigation projects are built in conjunction. For areas that experience significant flood damages or chronic flooding, it is recommended that multiple flood mitigation strategies in conjunction be considered and evaluated by affected communities.

The ROM cost for this measure is $1.8 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination and acquisition or disposal of any fill or dredged materials. In addition, the NYSDEC will require wetland delineations, an analysis for any endangered and/or threatened species within the proposed project area, and information regarding access during construction of any flood bench mitigation alternative.

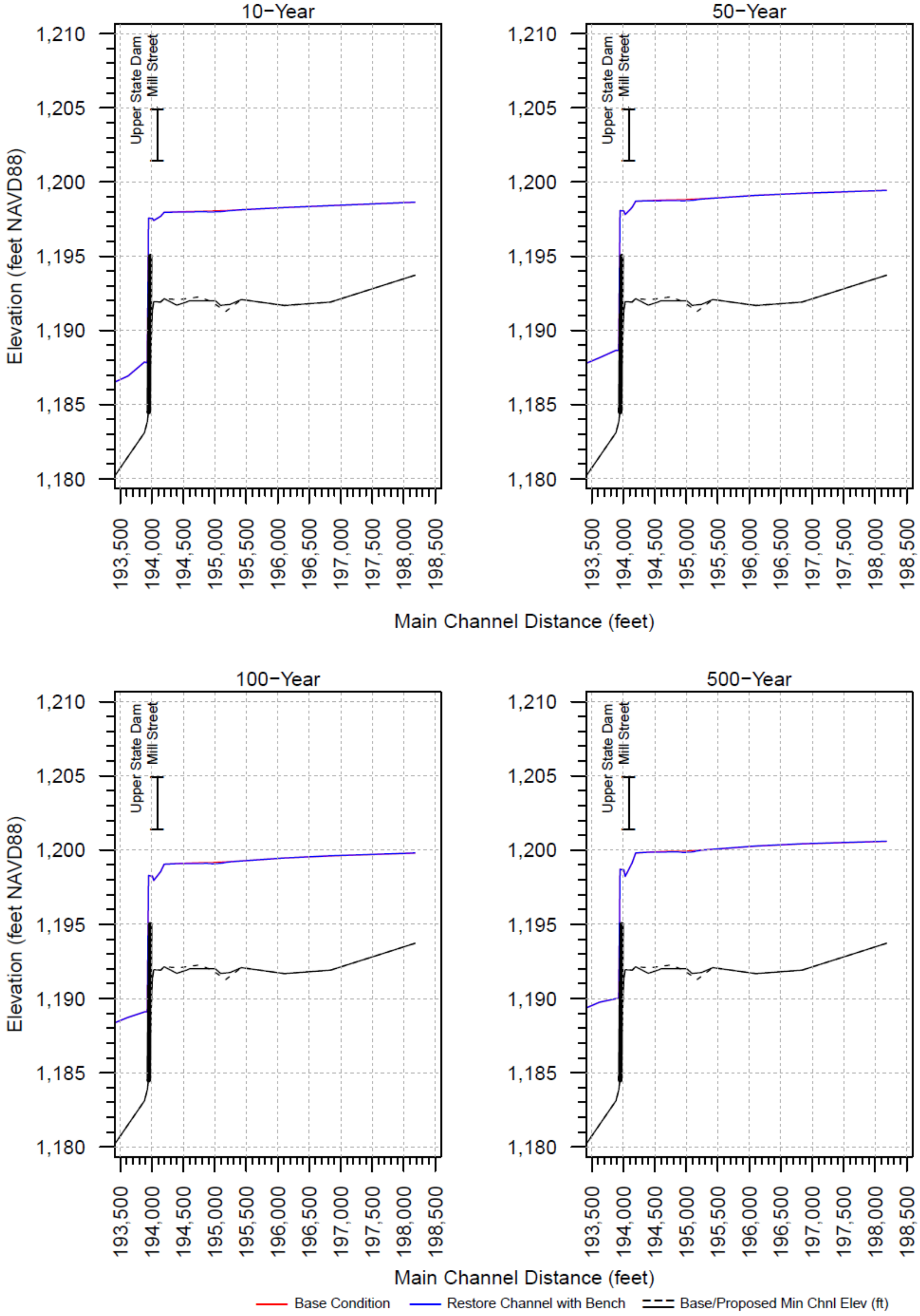

Figure 7-68. HEC-RAS model simulation output results for Alternative #3-7 for the existing condition (red) and new channel reach/flood bench (blue) scenarios.

7.3.8 Alternative #3-8: Flood Control Detention Basin Upstream of Village of Cazenovia

The construction of small flood-control detention structures in the headwaters and tributaries of flood-prone streams has proven successful at preventing flood damage in small towns throughout the United States (Helms 1986). These structures are traditionally located in rural areas in agricultural fields and undeveloped land. They maintain little to no permanent pool and are designed to detain water during larger flow events, decreasing peak-flow water surface elevations and minimizing flooding further downstream in developed areas. The area between river stations 1920+00 and 1966+00 downstream of the Village of Cazenovia and in the Town of Cazenovia would be the best location for a flood-control structure in the downstream reach (Figure 7-69).

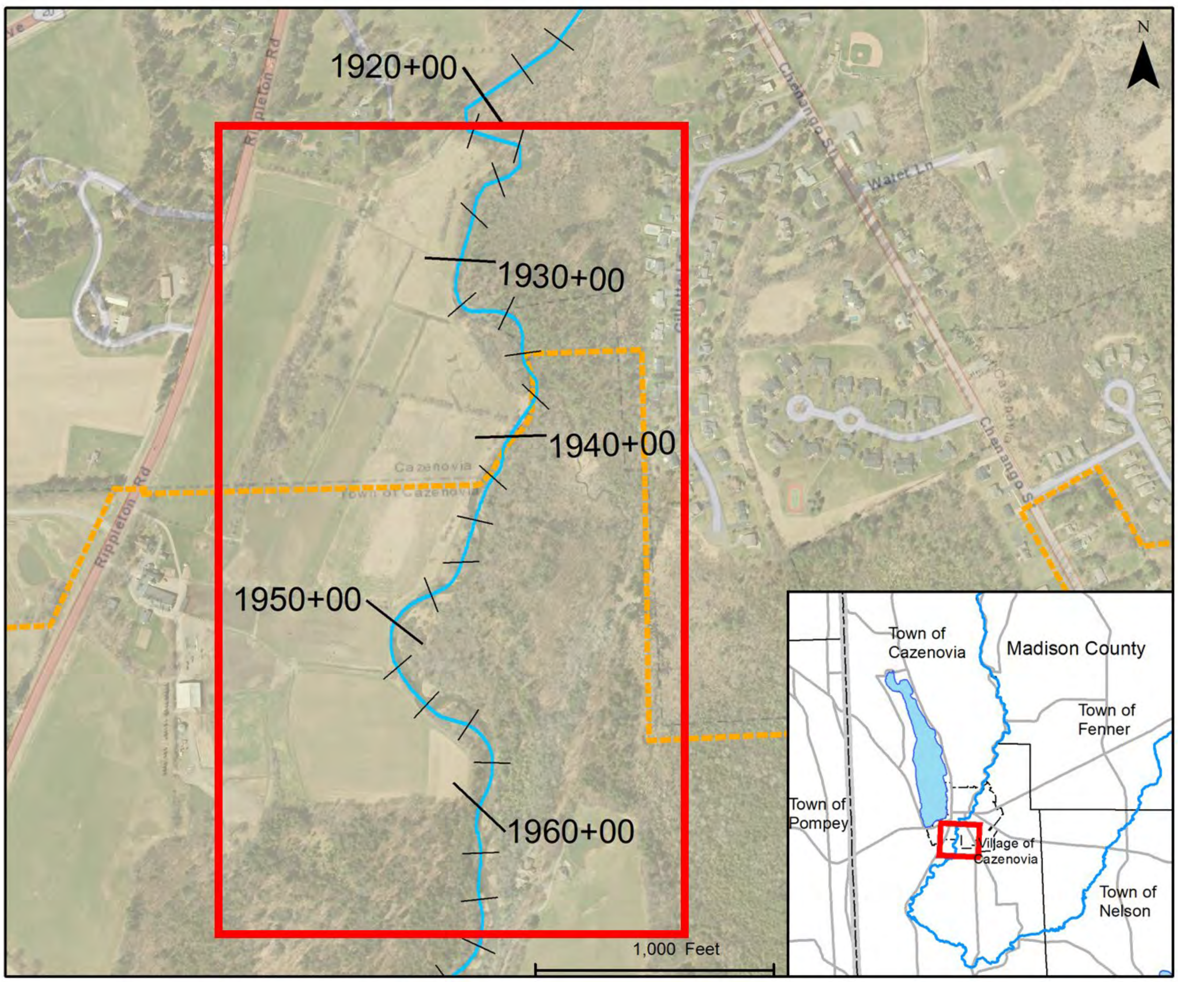

Figure 7-69. Location map for Alternative #3-8.

In New York State, a joint permit application from the NYSDEC and USACE may be required in order to construct, reconstruct, or repair a dam or other impoundment. The NYSDEC is entrusted with the regulatory power to oversee dam safety, which encompasses flood detention structures. To protect people from the loss of life and property due to flooding and/or dam failure, the NYSDEC Dam Safety Section, in cooperation with the USACE, reviews proposed dam construction and/or modifications, conducts dam safety inspections, and monitors projects for compliance with dam safety criteria.

The USACE has the authority to construct small flood risk reduction projects that are engineeringly feasibly, structurally sound and cost efficient through the authority provided under Section 205 of the 1948 FCA, as amended. Coordination should also occur with the NYSDEC as they need to be the non-federal sponsor on these types of projects.

In addition, a FEMA BCA would need to be performed to determine the cost-effectiveness of the alternative prior to applying for FEMA mitigation grant programs funding. The BCR must be greater than or equal to 1.0 in order for the project to be considered cost effective.

Due to the conceptual nature of this measure, and significant amount of data required to produce a reasonable ROM cost, it is not feasible to quantify the costs of this measure without further engineering analysis and modeling. However, the cost of designing, permitting, constructing, and maintaining one or more flood-control dams in the headwaters of the Chittenango Creek watershed are expected to be significant.

8. BASIN-WIDE MITIGATION ALTERNATIVES

Non-structural measures attempt to avoid flood damages by modifying or removing properties currently located within flood-prone areas. These measures do not affect the frequency or level of flooding within the floodplain; rather, they affect floodplain activities. In considering the range of non-structural measures, the community needs to assess the type of flooding which occurs (depth of water, velocity, duration) prior to determining which measure best suits its needs (USACE 2016c).

8.1 ALTERNATIVE #4-1: EARLY-WARNING FLOOD DETECTION SYSTEM

Early-warning flood detection systems can be implemented, which can provide communities with more advanced warning of potential flood conditions. Early forecast and warning involve the identification of imminent flooding, implementation of a plan to warn the public, and assistance in evacuating persons and some personal property. A typical low cost early-warning flood detection system consists of commercially available off-the-shelf-components. The major components of an early-warning flood detection system are a sensor connected to a data acquisition device with built-in power supply or backup, some type of notification or warning equipment, and a means of communication.

For ice-jam warning systems, condition is generally monitored using a pressure transducer. The data acquisition system performs two functions: it collects and stores real-time flood stage data from the pressure transducer, and initiates the notification process once predetermined flood-stage conditions are met (USACE 2016c).

This method can also be supplemented by an ice-jam predicting calculation procedure using the freezing degree-day (FDD) method to forecast the ice thickness at critical locations to inform early action to control ice (Shen and Yapa 2011). The method involves a small computer tool that goes through all the ice calculations and gives the output in a graphical format of the predicted ice thickness with time. This can be quickly implemented and can be a very good solution due to its low cost, and low labor and maintenance requirements. The method needs only the forecasted air temperature and current water level at the critical location. During severe winter conditions, the ice thickness prediction can be used to help prepare and coordinate resources needed for a potential ice-jam event and consequential flooding. For regular winter conditions, the tool can be used as a quick ice-thickness monitoring mechanism.

The pressure transducer system can be powered from an alternating current source via landline, or by batteries that are recharged by solar panels. The notification process can incorporate standard telephone or cellular telephone. Transfer of data from the system can be achieved using standard or cellular telephone, radio frequency (RF) telemetry, wireless internet, or satellite transceivers. Emergency management notification techniques can be implemented through the use of radio, siren, individual notification, or a reverse 911 system. More elaborate means include remote sensors that detect water levels and automatically warn residents. These measures normally serve to reduce flood hazards to life, and damage to portable personal property (USACE 2016c).

The ROM cost for this strategy is approximately $120,000, not including annual maintenance and operational costs.

8.2 ALTERNATIVE #4-2: RIPARIAN RESTORATION

Riparian ecosystems support many critically important ecological functions, but most riparian areas have been severely degraded by a variety of human disturbances within the Chittenango Creek watershed. Restoration, which is defined as the process of re-establishing historical ecosystem structures and processes, is being used more often to mitigate some of the past degradation of these ecosystems (Goodwin et al. 1997).

Adoption of a process-based approach for riparian restoration is key to a successful restoration plan, and in riparian systems, flooding disturbance is a key process to consider. Successful restoration depends on understanding the physical and biological processes that influence natural riparian ecosystems, and the types of disturbances to anthropogenic modifications that cause damage to riparian areas. In this case, alteration of historical flooding processes has caused degradation of the riparian system.

Riparian ecosystems generally consist of two flooding zones: Zone I occupies the active floodplain and is frequently inundated, and Zone II extends from the active floodplain to the valley wall. Successful restoration depends on understanding the physical and biological processes that influence natural riparian ecosystems and the types of disturbance that have degraded riparian areas. Adoption of a process-based approach for riparian restoration is key to a successful restoration plan. Disturbances to riparian ecosystems in the Chittenango Creek watershed have resulted from streamflow modifications by dams, reservoirs, and diversions; stream channelization; direct modification of the riparian ecosystem; and watershed disturbances (Goodwin et al. 1997).

With ecological processes in mind, a successful riparian restoration plan should focus on four key areas: (1) interdisciplinary approaches, (2) a unified framework, (3) a better understanding of fundamental riparian ecosystem processes, and (4) restoration potential more closely related to disturbance type (Goodwin et al. 1997).

Three issues should be considered regarding the cause of the degraded environment: (1) the location of the anthropogenic modification with respect to the degraded riparian area, (2) whether the anthropogenic modification is ongoing or can be eliminated, and (3) whether or not recovery will occur naturally if the anthropogenic modification is removed (Goodwin et al. 1997).

Riparian restoration requires a deep understanding of physical and ecological conditions that exist and that are desired at a restoration site. These conditions must be naturally sustainable given a set of water, sediment, and energy fluxes. If the conditions cannot be naturally sustained, the restoration will fail to meet the original goals (Goodwin et al. 1997).

8.3 ALTERNATIVE #4-3: DEBRIS MAINTENANCE AROUND INFRASTRUCTURE

Multiple areas along Chittenango Creek were identified as catchpoints for debris and sediment. Areas where debris maintenance should be employed or continued to be employed are:

- The downstream reach of Chittenango Creek from the NYS Thruway (Interstate-90) downstream to Lake Road/NY-31 in the Hamlet of Bridgeport, which is maintained by the Towns of Sullivan and Manlius
- The Chittenango Creek Feeder Canal into the Old Erie Canal, which is maintained by the NYS Canal Corporation

Debris, such as trees, branches, and stumps, are an important feature of natural and healthy stream systems. In a healthy stream network, woody debris helps to stabilize the stream and its banks, reduce sediment erosion, and slow storm-induced high streamflow events. Fallen trees and brush also form the basis for the entire aquatic ecosystem by providing food, shelter, and other benefits to fish and wildlife. In the headwaters of many streams, woody debris influences flooding events by increasing channel roughness, dissipating energy, and slowing floodwaters, which can potentially reduce flood damages in the downstream reaches. Any woody debris that does not pose a hazard to infrastructure or property should be left in place and undisturbed, thereby saving time and money for more critical work at other locations (NYSDEC 2013).

However, in some instances, significant sediment and debris can impact flows by blocking bridge and culvert openings and accumulating along the stream path at meanders, contraction/expansion points, etc., which can divert stream flow and cause backwater and bank erosion. When debris poses a risk to infrastructure, such as bridges or homes, it should be removed. Provided fallen trees, limbs, debris and trash can be pulled, cabled or otherwise removed from a stream or stream bank without significant disruption of the stream bed and banks, a permit from the NYSDEC is not required. Woody debris and trash can be removed from a stream without the need for a permit under the following guidelines:

- Fallen trees and debris may be pulled from the stream by vehicles and motorized equipment operating from the top of the streambanks using winches, chains and or cables.
- Hand-held tools, such as chainsaws, axes, handsaws, etc., may be used to cut up the debris into manageable-sized pieces.
- Downed trees that are still attached to the banks should be cut off near the stump. Do not grub (pull out) tree stumps from the bank; stumps hold the bank from eroding.
- All trees, brush, and trash that is removed from the channel should not be left on the floodplain. Trash should be properly disposed of at a waste management facility. Trees and brush can be utilized as firewood. To prevent the spread of invasive species, such as Emerald Ash Borer, firewood cannot be moved more than 50 miles from its point of origin.

- Equipment may not be operated in the water, and any increase in stream turbidity from the removal must be avoided (NYSDEC 2013).

Any work that will disturb the bed or banks of a protected stream (gravel removal, stream restoration, bank stabilization, installation, repair, replacements of culverts or bridges, objects embedded in the stream that require digging out, etc.) will require an Article 15 permit from the NYSDEC. Projects that will require disturbance of the stream bed or banks, such as excavating sand and gravel, digging embedded debris from the streambed or the use of motorized, vehicular equipment, such as a tractor, backhoe, bulldozer, log skidder, four-wheel drive truck, etc. (any heavy equipment), in the stream channel, or anywhere below the top of banks, will require either a Protection of Waters, or Excavation or Placement of Fill in Navigable Waters Permit (NYSDEC 2013).

In addition, sediment control basins along Chittenango Creek could be established to reduce watercourse and gully erosion, trap sediment, reduce and manage runoff near and downstream of the basin, and to improve downstream water quality. A sediment-control detention basin is an earth embankment or a combination ridge and channel generally constructed across the slope of minor watercourses to form a sediment trap and water detention basin. The basin should be configured to enhance sediment deposition by using flow deflectors, inlet and outlet selection, or by adjusting the length-to-width ratio of the creek channel. Additional hydrologic and hydraulic studies should be performed to identify the optimal locations for the sediment control basins. Operation and maintenance costs to maintain the embankment, design capacity, vegetative cover, and outlet of the basin should be considered (NRCS 2002).

Consultation with the NYSDEC can help determine if, when and how sediment and debris should be managed and whether a permit will be required.

The ROM cost for this strategy is up to $20,000 annually, not including additional maintenance and operational costs.

8.4 ALTERNATIVE #4-4: DETENTION BASIN AND WETLAND MANAGEMENT

Stormwater detention basins and wetlands are designed and constructed to contain and/or filter pollutants that flush off of the landscape. Without proper maintenance, nutrients such as nitrogen and phosphorus that are typically found in stormwater runoff can accumulate in the basin and/or wetlands leading to degraded conditions such as low dissolved oxygen, algae blooms, unsightly conditions, and odors. Excess sediment from the watershed upstream can also accumulate in the basins and wetlands. This sediment can smother the vegetation and clog any filtering structures or outlets. In addition, standing water in basins can heat up during the summer months. This warmer water is later released into neighboring waters, which can have negative impacts on aquatic life (USEPA 2009b).

Without proper maintenance, excess pollutants in ponds and wetlands may actually become sources of water quality issues such as poor water color/clarity/odor, low dissolved oxygen leading to plant die-off, and prevalence of algal blooms. When these basins and wetlands are “flushed” during a large rain event, the excess nutrients causing these problems may be transferred to the receiving waterbody (USEPA 2009b).

Maintenance is necessary for detention basins and wetlands to operate as designed on a long-term basis. The pollutant removal, channel protection, and flood control capabilities of basins and wetlands will decrease if any of the following occur (USEPA 2009b):

- Sediment accumulates reducing the storage volume
- Debris blocks the outlet structure
- Pipes or the riser are damaged
- Invasive plants take over the planted vegetation
- Slope stabilizing vegetation is lost
- The structural integrity of the embankment, weir, or riser is compromised

Detention basin and wetland maintenance activities range in terms of the level of effort and expertise required to perform them. Routine basin and wetland maintenance, such as mowing and removing debris or trash, is needed multiple times each year, but can be performed by citizen volunteers. More significant maintenance such as removing accumulated sediment is needed less frequently, but requires more skilled labor and special equipment. Inspection and repair of critical structural features such as embankments and risers, needs to be performed by a qualified professional (e.g., structural engineer) who has experience in the construction, inspection, and repair of these features (USEPA 2009b). Water level management, if control structures are available, can be an effective tool to meet a range of pond and wetland habitat and process management objectives.

Program managers and responsible parties need to recognize and understand that neglecting routine maintenance and inspection can lead to more serious problems that threaten public safety, impact water quality, and require more expensive corrective actions (USEPA 2009b).

It should be noted that the NYSDEC would not approve sediment detention ponds below mean high water. However, consideration would be given to plans for such structures that were part of a flood mitigation project, such as a floodplain bench.

8.5 ALTERNATIVE #4-5: FLOOD BUYOUT PROGRAMS

Buyouts allow state and municipal agencies the ability to purchase developed properties within areas vulnerable to flooding from willing owners. Buyouts are effective management tools in response to natural disasters to reduce or eliminate future losses of vulnerable or repetitive loss properties. Buyout programs include the acquisition of private property, demolition of existing structures, and conversion of land into public space or natural buffers. The land is maintained in an undeveloped state for public use in perpetuity. Buyout programs not only assist individual homeowners, but are also intended to improve the resiliency of the entire community in the following ways (Siders 2013):

- Reduce exposure by limiting the people and infrastructure located in vulnerable areas
- Reduce future disaster response costs and flood insurance payments
- Restore natural buffers such as wetlands in order to reduce future flooding levels

- Reduce or eliminate the need to maintain and repair flood control structures
- Reduce or eliminate the need for public expenditures on emergency response, garbage collection and other municipal services in the area
- Provide open space for the community

Resilience achieved through buyouts can have real economic consequences in addition to improved social resilience. According to FEMA, voluntary buyouts cost $1 for every $2 saved in future insurance claims, an estimate which does not include money saved on flood recovery and response actions, such as local flood fighting, evacuation and rescue, and recovery expenses that will not be incurred in the future. In order to achieve these goals, buyouts need to acquire a continuous swatch of land, rather than individual homes in isolated areas, or only some of the homes within flood-prone areas (Siders 2013).

Buyout programs can be funded through a combination of federal, state, or local funds and are generally made available following a nationally recognized disaster. FEMA administers programs to help with buyouts under the Stafford Disaster Act, and the Department of Housing and Urban Development (HUD) administers another program through Community Development Block Grants (CDBG). These funding sources can reduce the economic burden on the local community. However, these funds also come with guidelines and regulations that may constrain policy makers' options on whether to pursue a buyout strategy, and how to shape their programs. FEMA funds may be used to cover 75% of the expenses, but the remaining 25% must come from another non-federal source. In most cases, the buyout must be a cost-effective measure that will substantially reduce the risk of future flooding damage (Siders 2013).

For homes in the Special Flood Hazard Area (SFHA), FEMA has developed precalculated benefits for property acquisition and structure elevation of buildings. Based on a national analysis that derived the average benefits for acquisition and elevation projects, FEMA has determined that acquisition projects that cost $276,000 or less, or elevation projects that costs $175,000 or less, and which are located in the 1% annual chance event (i.e., 100-yr recurrence interval) floodplain are considered cost-effective and do not require a separate benefit-cost analysis. For projects that contain multiple structures, the average cost of all structures in the project must meet the stated criteria. If the cost to acquire or elevate a structure exceeds the amount of benefits listed above, then a traditional FEMA approved benefits-cost analysis must be completed (FEMA 2015b).

In the Chittenango Creek watershed, there are approximately 1,715 tax parcels within the FEMA 1% annual chance event (100-yr) and 0.2% annual chance event (500-yr) hazard zones. Of the 1,715 tax parcels, 1,131 are classified as residential with a total full market value of $154.7 million, and 88 are classified as commercial with a total full market value of $24 million. Table 35 summarizes the number of parcels and their full market value within the three high-risk flood areas (NYSGPO 2021). Figure 8-1 displays the tax parcels that intersect the FEMA flood zones, including generalized locations of FEMA repetitive loss properties.

Table 35. Summary Table for Tax Parcels within FEMA Flood Zones in High-risk Areas along Chittenango Creek

Source: NYSGPO 2021		
High-risk Flood Area	**Number of Parcels**	**Full Market Value**
#1: Lake Road/NY-31 downstream to the confluence with Oneida Lake, Town of Sullivan, NY	460	$58.7 million
#2: Village of Chittenango upstream of corporate limits downstream to the Old Erie Canal Crossing, Village of Chittenango, NY	485	$55 million
#3: Mill Street downstream to Clark Street, Village of Cazenovia, NY	150	$24.5 million
Total	**1,095**	**$138.2 million**

In addition, there are seven FEMA repetitive loss properties within the Chittenango Creek watershed (Figure 8-1). There are three RL properties in the Hamlet of Bridgeport in High-risk Area #1, one RL property in the Town of Sullivan, one RL property in the Village of Chittenango, and two RL properties in the Village of Cazenovia (FEMA 2019).

Due to the variable nature of buyout programs, no ROM cost estimate was produced for this study. It is recommended that any buyout program begin with a cost-benefit analysis for each property. After a substantial benefit has been established, a buyout strategy study should be developed that focuses on properties closest to Chittenango Creek in the highest-risk flood areas and progresses outwards from there to maximize flood damage reductions. In addition, structures located adjacent to flood-prone infrastructure (i.e., bridges, culverts, etc.) should also be considered high-risk and prioritized in any buyout program strategy. A potential negative consequence of buyout programs is the permanent removal of properties from the floodplain, and resulting tax revenue, which would have long-term implications for local governments, and should be considered prior to implementing a buyout program.

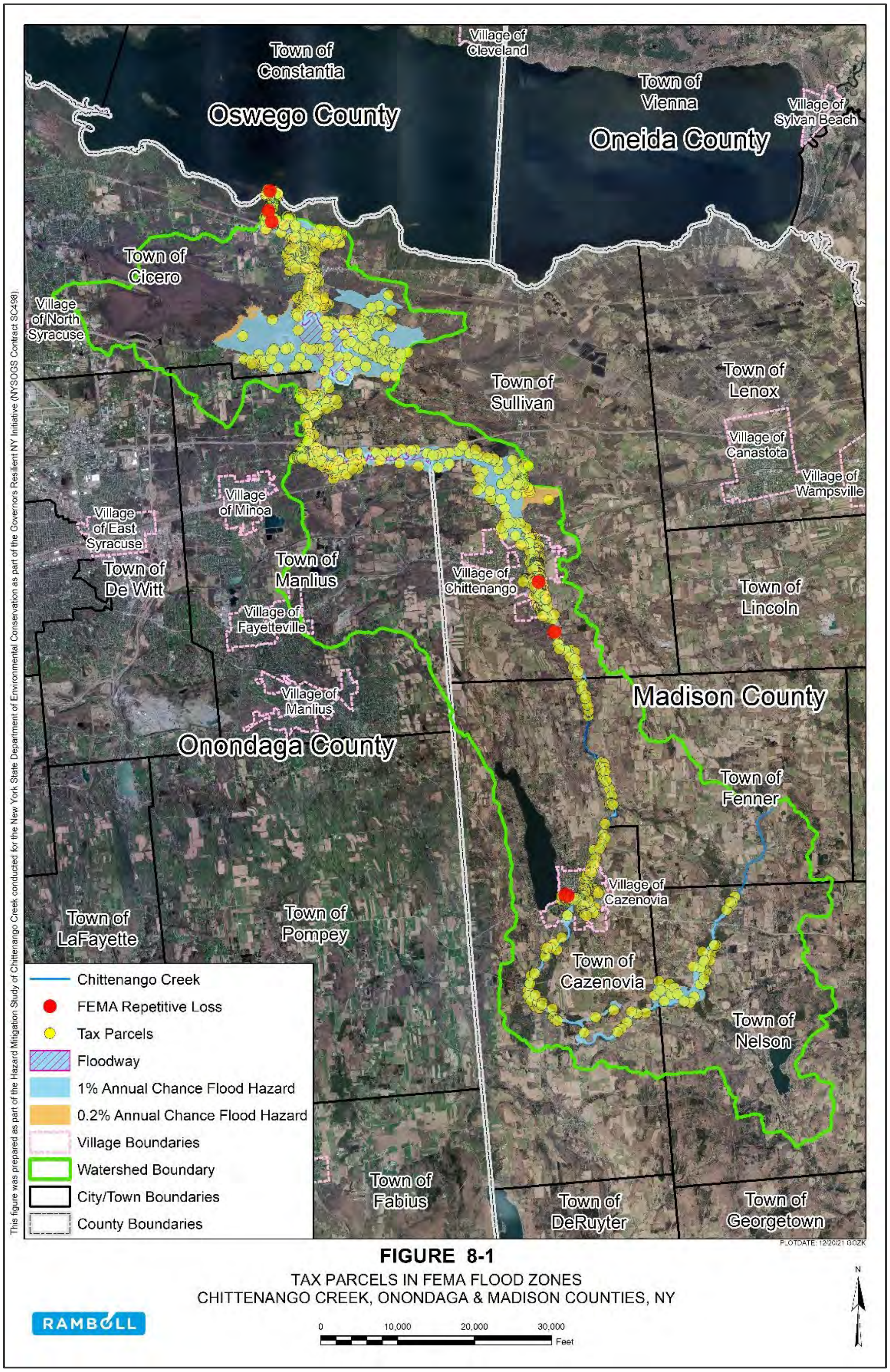

Figure 8-1. Tax parcels within FEMA flood zones, Chittenango Creek, Onondaga and Madison Counties, NY.

8.6 ALTERNATIVE #4-6: FLOODPROOFING

Floodproofing is defined as any combination of structural or nonstructural adjustments, changes, or actions that reduce or eliminate flood damage to a building, contents, and attendant utilities and equipment (FEMA 2000). Floodproofing can prevent damage to existing buildings and can be used to meet compliance requirements for new construction of residential and non-residential buildings.

The most effective flood mitigation methods are relocation (i.e., moving a home to higher ground outside of a high-risk flood area) and elevation (i.e., raising the entire structure above BFE). The relationship between the BFE and a structure's elevation determines the flood insurance premium. Buildings that are situated at or above the level of the BFE have lower flood risk than buildings below BFE, and tend to have lower insurance premiums than buildings situated below the BFE (FEMA 2015b).

In some communities, where non-structural flood mitigation alternatives are not feasible, structural alternatives such as flood proofing may be a viable alternative. The National Flood Insurance Program has specific rules related to flood proofing for residential and non-residential structures. These can be found in the Code of Federal Regulations (CFR) 44 CFR 60.3 (FEMA 2000).

For communities that have been provided an exception by FEMA, the CFR allows for the floodproofing of residential basements as outlined in 44 CFR 60.6 (c) “a permit can be obtained to floodproof a residential building basement, if it can demonstrate an adequate warning time under a flood depth less than 5 feet and a velocity less than 5 fps.” Floodproofing residential basements should be considered during the design phase of a structure prior to construction. For existing structures, floodproofing residential basements can be a difficult, complex, and expensive measure to achieve. Instead, residential structures should be raised above the BFE in accordance with local regulations. Floodproofing is allowed for non-residential structures, with design guidelines outlined in FEMA P-936 – Floodproofing Non-Residential Structures (FEMA 2000; FEMA 2013). The local floodplain administrator should carefully review local ordinances, the CFR and available design guidelines before issuing a permit for structural flood proofing. Floodproofing strategies include:

Interior Modification/Retrofit Measures

Interior modification and retrofitting involve making changes to an existing building to protect it from flood damage. When the mitigation is properly completed in accordance with NFIP floodplain management requirements, interior modification/retrofit measures could achieve the somewhat similar results as elevating a home above the BFE. Keep in mind, in areas where expected base flood depths are high, the flood protection techniques below may not provide protection on their own to the BFE or, where applicable, the locally required freeboard elevation (FEMA 2015b).

Examples include:

- *<u>Basement Infill</u>:* This measure involves filling a basement located below the BFE to grade (ground level).

- *Abandon Lowest Floor:* This measure involves abandoning the lowest floor of a two or more story slab-on-grade residential building.
- *Elevate Lowest Interior Floor:* This measure involves elevating the lowest interior floor within a residential building with high ceilings.

Dry floodproofing:

A combination of measures that results in a structure, including the attendant utilities and equipment, being watertight with all elements substantially impermeable to the entrance of floodwater and with structural components having the capacity to resist flood loads (FEMA 2015b).

Although NFIP regulations require non-residential buildings to be watertight and protected only to the BFE for floodplain management purposes (to meet NFIP regulations), protection to a higher level is necessary for dry floodproofing measures to be considered for NFIP flood insurance rating purposes. Because of the additional risk associated with dry floodproofed buildings, to receive an insurance rating based on 1% annual chance (100-yr) flood protection, a building must be dry floodproofed to an elevation at least 1 ft above the BFE (FEMA 2013).

Examples include:

- *Passive Dry Floodproofing System*: This measure involves installing a passive (works automatically without human assistance) dry floodproofing system around a home to protect the building from flood damage.
- *Elevation*: This measure involves raising an entire residential or non-residential building structure above BFE.

Wet floodproofing:

The use of flood-damage-resistant materials and construction techniques to minimize flood damage to areas below the flood protection level of a structure, which is intentionally allowed to flood (FEMA 2015b).

Examples include:

- *Flood Openings*: This measure involves installing openings in foundation and enclosure walls located below the BFE that allow automatic entry and exit of floodwaters to prevent collapse from the pressures of standing water.
- *Elevate Building Utilities*: This measure involves elevating all building utility systems and associated equipment (e.g., furnaces, septic tanks, and electric and gas meters) to protect utilities from damage or loss of function from flooding.
- *Floodproof Building Utilities*: This measure involves floodproofing all building utility systems and associated equipment to protect it from damage or loss of function from flooding.
- *Flood Damage-Resistant Materials*: This measure involves the use of flood damage-resistant materials such as non-paper-faced gypsum board and terrazzo tile flooring for building materials and furnishings located below the BFE to reduce structural and nonstructural damage and post-flood event cleanup.

Barrier Measures

Barriers, such as floodwalls and levees, can be built around single or multiple residential and non-residential buildings to contain or control floodwaters (FEMA 2015b). Although floodwalls or levees can be used to keep floodwaters away from buildings, implementing these measures will not affect a building's flood insurance rating unless the flood control structure is accredited in accordance with NFIP requirements (44 CFR §65.10) and provides protection from at least the 1% annual chance (100-yr) flood. Furthermore, floodwalls or levees as a retrofit measure will not bring the building into compliance with NFIP requirements for Substantial Improvement/Damage (FEMA 2013). Barrier measures require ongoing maintenance (i.e., mowing, etc.) which should be factored into any cost analysis. In addition, barrier measures tend to create a false sense of security for the property owners and residents that are protected by them. If a barrier structure is not properly constructed or maintained and fails, catastrophic damages to surrounding areas can occur.

- *Floodwall with Gates and Floodwall without Gates*: These two measures involve installing a reinforced concrete floodwall, which works automatically without human assistance, constructed to a maximum of four feet above grade (ground level). The floodwall with gates is built with passive flood gates that are designed to open or close automatically due to the hydrostatic pressure caused by the floodwater. The floodwall without gates is built using vehicle ramps or pedestrian stairs to avoid the need for passive flood gates.
- *Levee with Gates and Levee without Gates*: These two measures involve installing an earthen levee around a home, which works automatically without human assistance, with a clay or concrete core constructed to a maximum of six feet above grade (ground level). The levee with gates is built with passive flood gates that are designed to open or close automatically due to hydrostatic pressure caused by the floodwater. The levee without gates is built using vehicle access ramps to avoid the need for passive flood gates.

Modifying a residential or non-residential building to protect it from flood damage requires extreme care, will require permits, and may also require complex, engineered designs. Therefore, the following process is recommended to ensure proper and timely completing of any floodproofing project (FEMA 2015b):

- Consult a registered design professional (i.e., architect or engineer) who is qualified to deal with the specifics of a flood mitigation project
- Check your community's floodplain management ordinances
- Contact your insurance agent to find out how your flood insurance premium may be affected
- Check what financial assistance might be available
- Hire a qualified contractor
- Contact the local building department to learn about development and permit requirements and to obtain a building permit

- Determine whether the mitigation project will trigger a Substantial Improvement declaration
- See the project through to completion
- Obtain an elevation certificate and an engineering certificate (if necessary)

No cost estimates were prepared for this alternative due to the variable and case-by-case nature of the flood mitigation strategy. Local municipal leaders should contact residential and non-residential building owners that are currently at a high flood risk to inform them about floodproofing measures, the recommended process to complete a floodproofing project, and the associated costs and benefits.

8.7 ALTERNATIVE #4-7: AREA PRESERVATION/FLOODPLAIN ORDINANCES

This alternative proposes municipalities within the Chittenango Creek watershed consider watershed and floodplain management practices such as preservation and/or conservation of areas along with land use ordinances that could minimize future development of sensitive areas such as wetlands, forests, riparian areas, and other open spaces. It could also include areas in the floodplain that are currently free from development and providing floodplain storage.

A watershed approach to planning and management is an important part of water protection and restoration efforts. New York State's watersheds are the basis for management, monitoring, and assessment activities. The NYS Open Space Conservation Plan, NYSDEC Smart Growth initiative and the Climate Smart Communities Program address land use within a watershed (NYSDEC 2014). Land use planning should be incorporated into a municipalities comprehensive plan or, if a comprehensive plan does not exist, passed as a series of ordinances that consider more restrictive floodplain development regulations besides the New York State minimum requirements.

Natural floodplains provide flood risk reduction benefits by slowing runoff and storing flood water. They also provide other benefits of considerable economic, social, and environmental value that should be considered in local land-use decisions. Floodplains frequently contain wetlands and other important ecological areas which directly affect the quality of the local environment. Floodplain management is the operation of a community program of preventive and corrective measures to reduce the risk of current and future flooding, resulting in a more resilient community. These measures take a variety of forms, are carried out by multiple stakeholders with a vested interest in responsible floodplain management, and generally include requirements for zoning, subdivision or building, building codes and special-purpose floodplain ordinances. While FEMA has minimum floodplain management standards for communities participating in the National Flood Insurance Program (NFIP), best practices demonstrate the adoption of higher standards which will lead to safer, stronger, and more resilient communities (FEMA 2006).

Further hydrology and hydraulic model scenarios could be performed to illustrate how future watershed and floodplain management techniques could benefit the communities within the Chittenango Creek watershed.

8.8 ALTERNATIVE #4-8: COMMUNITY FLOOD AWARENESS AND PREPAREDNESS PROGRAMS/EDUCATION

Disaster resilience encompasses both the principles of preparedness and reaction within the dynamic systems and focuses responses on bridging the gap between pre-disaster activities and post-disaster intervention, and among structural/non-structural mitigation. Integral to these concepts is the role of the community itself, and how the community adapts to being prepared for disasters and, ultimately, how the community takes on the effort of disaster risk reduction. By consulting the community at risk, the local stakeholder concerns can be taken into consideration, and thus be addressed accordingly in the post-disaster recovery stage (Nifa et al. 2017).

Community flood awareness programs should focus on a multi-scale, holistic strategy of preparedness and resilience, and in this way attempt to achieve a substantial reduction of disaster losses, in lives, and in the social, economic, and environmental assets of the community. This approach should incorporate four functions of flood education (Dufty 2008):

1. Preparedness conversion: learning related to commencing and maintaining preparations for flooding.
2. Mitigation behaviors: learning and putting into practice the appropriate actions for before, during and after a flood.
3. Adaptive capability: learning how to change and maintain adaptive systems (e.g., warning systems) and build community competencies to help minimize the impacts of flooding.
4. Post-flood learnings: learning how to improve preparedness levels, mitigation behaviors and adaptive capability after a flood.

In developing a program, community leaders should consider a commitment to community participation in the design, implementation, and evaluation of flood education programs. A more participatory approach to community flood and other hazards can enhance community resilience to adversity by stimulating participation and collaboration of stakeholders and decision makers in building its capability for preparedness, response, and recovery. In addition, community flood-education programs should be ongoing as it is unsure when a flood event will occur (Dufty 2008).

8.9 ALTERNATIVE #4-9: DEVELOPMENT/UPDATING OF A COMPREHENSIVE PLAN

Local governments are responsible for planning in a number of areas, including housing, transportation, water, open space, waste management, energy, and disaster preparedness. In New York State, these planning efforts can be combined into a comprehensive plan that steers investments by local governments and guides future development through zoning regulations. A comprehensive plan will guide the development of government structure as well as natural and built environment.

Significant features of comprehensive planning in most communities include its foundations for land use controls for the purpose of protecting the health, safety, and general welfare of the community’s citizens. The plan will focus on immediate and long-range protection, enhancement, growth, and development of a community’s assets.

Materials included in the comprehensive plan will include text and graphics, including but not limited to maps, charts, studies, resolutions, reports, and other descriptive materials. Once the comprehensive plan is completed, the governing board motions to adopt it (i.e., town or village board) (EFC 2015).

Development of a comprehensive plan in general is optional, as is the development of a plan in accordance with state comprehensive plan statutes. However, statutes can guide plan developers through the process. Comprehensive plans provide the following benefits to municipal leaders and community members (EFC 2015):

- Provide a legal defense for regulations
- Provide a basis for other actions affecting the development of the community (i.e., land use planning and zoning)
- Help to establish policies regarding creation and enhancement of community assets

All communities within the watershed should develop or update their respective comprehensive plans in an effort to coordinate and manage any and all land use changes and development within the Chittenango Creek floodplain.

In addition, any comprehensive plan developed for communities within the watershed should include future climate change and NYS Smart Growth practices. Local governments should incorporate sustainability elements throughout the comprehensive plan. “Future-proofing” management and mitigation strategies by taking climate change into consideration would ensure that any strategy pursued would have the greatest possible chance for success. NYS Smart Growth practices would maximize the social, economic, and environmental benefits from public infrastructure development, while minimizing unnecessary environmental degradation, and disinvestment in urban and suburban communities caused by the development of new or expanded infrastructure.

8.10 ALTERNATIVE #4-10: ICE MANAGEMENT

This strategy is intended to control ice-jam formation by maintaining ice coverage in high-risk sections of Chittenango Creek. Ice management strategies include various methods of preventing ice jams by breaking ice using various ice cutting patterns and techniques, as well as various equipment and personnel. Ice-jam mitigation strategies are very much site dependent. A strategy that works for a certain reach of a river may not work for another reach in the same river due to river morphology and hydrodynamics. Therefore, each of these strategies need to be analyzed with numerical modeling and simulations to check if they work for a considered area/reach of a river before implementing or recommending with the previous observational experience alone. Suggested locations for ice cutting operations would be provided based on anticipated effectiveness, site accessibility, and historical occurrences of ice jams. Criteria and scheduling would be provided by county and/or state agencies and determined based on environmental conditions (e.g., temperature, ice thickness, weather forecast) (USACE 2016c).

The standard strategies that are widely accepted and practiced in cold-region engineering, such as in central New York, are listed below with greater detail provided in Appendix E:

- Ice breaking – either through the use of explosives or ice-breaker ferries and cutters that either cut ice free from the banks or cross-cut ice to hasten the release of ice in order to prevent ice-jam formations
- Trenchers and special design trenching equipment – used to dig ditches customarily, but can be used to cut ice to hasten release downstream
- Channeling plow – plow mounted to a sledge drawn by a tractor that breaks and clears ice from channel
- Water jet and thermal cutting – supersonic water streams and thermal cutting tools to separate ice and move it downstream
- Hole cutting – drill large holes into the ice to reduce the integrity of the ice cover and curtail ice formation
- Air bubbler and flow systems – release air bubbles and mix heated effluent into the cold water to suppress ice growth
- Ice forecasting systems – systems designed to monitor ice cover on waterways and alert local communities when there is the potential for an ice jam
- Ice retention structures – such as ice booms or inflatable dams designed to force ice floes into or stop ice floes at a specific area
- Removal of bridge piers, heated bridge piers, or heated riverbank dikes (USACE 2006)

Generally, the FDD method, as previously discussed, is a good technique to first predict the ice thickness at critical locations, such as bridges or any flow constriction structures using the forecasted air temperature. This method will let the community officers know the severity of any possible ice jams based on future air temperature, allowing for time to get equipment and labor ready for the forthcoming ice jam. A small computer program could be used to do the iterative calculations faster, so that any non-technical user can use it to foresee the ice jam (Shen and Yapa 2011).

Another technique is maintaining a calibrated ice model to predict possible ice jam locations using forecasted air temperature and flow. This will be a comprehensive 2-D river ice simulation model (RICEN) (Shen et al. 1995) or Comprehensive River Ice Simulation System (CRISSP 2D) (CEATI 2005) that predicts the fate of ice evolution from fall to spring.

Ramboll suggests performing a freeze-up or a break-up ice model simulation study prior to implementing any of the above discussed strategies. The basic data needs and steps involved in an ice simulation analysis are also outlined in Appendix E.

Due to the variable nature of ice jam occurrence and severity, no cost estimates were prepared for this alternative.

9. NEXT STEPS

Before selecting a flood mitigation strategy, securing funding or commencing an engineering design phase, Ramboll recommends that additional modeling simulations and wetland investigations be performed.

9.1 ADDITIONAL DATA MODELING

Additional data collection and modeling would be necessary to more precisely model water surface elevations and the extent of potential flooding in overbank areas and the floodplain. 2-D unsteady flow modeling using the HEC-RAS program, would incorporate additional spatial information in model simulations producing more robust results with a higher degree of confidence than the currently modeled 1-D steady flow simulations. 2-D ice simulations are highly recommended to access the wintery condition with the suggested alternatives to evaluate the water level rises due to presence of ice, ice-jam or break-up ice jam conditions.

9.2 STATE AND LOCAL REGULATIONS

Prior to implementation of any mitigation alternative, pertinent local municipalities' Flood Damage Prevention laws, NYSDEC Part 502 regulations (for state-related facilities), and any other applicable state and local laws or regulations should be determined and appropriate steps taken to ensure compliance. These laws and regulations should also reflect the FEMA requirements for work within the regulated floodplain.

9.3 STATE/FEDERAL WETLANDS INVESTIGATION

Any flood mitigation strategy that proposes using wetlands in any capacity, needs to be evaluated based on federal and state wetland criteria before that mitigation strategy can be recommended for final consideration.

None of the proposed mitigation alternatives involved any jurisdictional NYSDEC wetlands; however, several alternatives are on lands that historically were designated wetlands. The NYSDEC require wetland delineations where mapped NYSDEC wetlands have historically existed or are in close proximity, such as near the outlet of Chittenango Creek into Oneida Lake, and any flood bench mitigation project. Wetland delineations will verify whether the NYSDEC would require an Article 24 Wetland Permit for any mitigation project.

9.4 NYSDEC PROTECTION OF WATERS PROGRAM

Chittenango Creek is protected under Article 15 of Title 6 of the New York Codes, Rules, and Regulations (6NYCRR) Part 608, which refers to the “Use and Protection of Waters.” Chittenango Creek has a designation as classification C (T), which indicates the waterway is best used for fishing and is designated trout waters. From its headwaters to the area south of the Thruway just north of Kirkville Road, Chittenango Creek supports trout. Any permits for in-stream work will most likely be issued with trout timing, where work is prohibited between October 1st to May 15th. To maximize benefit, planning for floodplain restoration projects should include preserving tree and shrub cover along banks of trout streams.

In addition, Chittenango Creek contains imperiled mussels (S1 and S2 freshwater mussels) that are rare, endangered, or threatened in New York. Any changes to the bed or bank of Chittenango Creek would need to be reviewed and approved by the NYSDEC (NYSDEC 2020a; NYSDEC 2021a).

9.5 ENDANGERED AND THREATENED SPECIES OF FISH AND WILDLIFE

Chittenango Creek is protected under Article 15 of Title 6 of the New York Codes, Rules, and Regulations (6NYCRR) Part 182, which refers to the "Endangered and Threatened Species of Fish and Wildlife." For any flood mitigation alternative that has a proposed project area that includes an endangered and threatened species, the NYSDEC will require an analysis for any endangered and/or threatened species within the proposed project area.

9.6 ICE EVALUATION

Due to the complex interaction of ice formation and water flow through a river, it is difficult to draw conclusions regarding proposed flood mitigation strategies and ice-jam formations based on observational data alone. The river bathymetry and channel meanders can complicate the ice dynamics and freeze-up jams. Spring runoff is affected by multiple environmental factors, including:

- Air temperature
- Water temperature
- Snow and ice melt intensity
- Upstream flow
- Upstream ice concentration
- Land cover
- Precipitation

Therefore, river reaches with possible or potential ice jams should be analyzed using more comprehensive ice studies, possibly a 2-D ice dynamic study, to better understand the nature of the flooding, and the necessary mitigation. Ice-jam flooding is very different compared to regular flooding due to the presence of solid and frazil ice. The transportation of frazil ice and solid ice in a river constantly changes the hydrodynamics of the flow, and even at low flows can still raise water levels high enough to cause flooding. The growth of single-layer ice jams can create conditions that change low flood hazards, to high flood hazards, even at low flow conditions.

The impact of these factors will be amplified by climate change. Projected increases in precipitation across New York State indicates the potential for increases in spring runoff, which in turn would increase water levels and velocities in nearby streams and rivers (Rosenzweig et al. 2011). In theory, the increased velocities would move solid ice and frazil ice down the river channel quicker, possibly preventing ice-jam formations. However, due to the limited available research in this area, additional data collection and modeling needs to be performed before a recommendation can be made regarding a flood mitigation strategy, and its specific influence on ice-jam formations.

9.7 EXAMPLE FUNDING SOURCES

There are numerous potential funding programs and grants for flood mitigation projects that may be used to offset municipal financing, including:

- New York State Office of Emergency Management (NYSOEM)
- New York State Department of Transportation Bridge NY Program
- Regional Economic Development Councils/Consolidated Funding Applications (CFA)
- Natural Resources Conservation Services (NRCS) Watershed Funding Programs
- FEMA Unified Hazard Mitigation Assistance (HMA) Program
- FEMA Safeguarding Tomorrow through Ongoing Risk Mitigation (STORM) Act
- USACE Continuing Authorities Program (CAP)

9.7.1 NYS Office of Emergency Management (NYSOEM)

The NYSOEM, through the U.S. Department of Homeland Security (DHS), offers several funding opportunities under the Homeland Security Grant Program (HSGP). The priority for these programs is to provide resources to strengthen national preparedness for catastrophic events. These include improvements to cybersecurity, economic recovery, housing, infrastructure systems, natural and cultural resources, and supply chain integrity and security. In 2018, there was no cost share or match requirement.

9.7.2 NYSDOT Bridge NY Program

The NYSDOT, in accordance with Governor Andrew Cuomo’s infrastructure initiatives, announced the creation of the Bridge NY program. The Bridge NY program provides enhanced assistance for local governments to rehabilitate and replace bridges and culverts. Particular emphasis will be provided for projects that address poor structural conditions; mitigate weight restrictions or detours; facilitate economic development or increase competitiveness; improve resiliency and/or reduce the risk of flooding.

The program is currently open and accepting applications from local municipalities through the State Fiscal Years 2020-21 and 2021-22. A minimum of $200 million was made available for awards in enhanced funding under the Bridge NY program for local system projects during the two-year period. More funding may be added to either the bridge or culvert program if it becomes available after the announcement of the solicitation.

9.7.3 Regional Economic Development Councils/Consolidated Funding Applications (CFA)

The Consolidated Funding Application is a single application for state economic development resources from numerous state agencies. The ninth round of the CFA was offered in 2019.

9.7.3.1 Water Quality Improvement Project (WQIP) Program

The Water Quality Improvement Project Program, administered through the Department of Environmental Conservation, is a statewide reimbursement grant program to address documented water quality impairments. Eligible parties include local governments and not-for-profit corporations. Funding is available for construction/implementation projects; projects exclusively for planning are not eligible. Match for WQIP is a percentage of the award amount, not the total project cost. Deadlines are in accordance with the CFA application cycle.

9.7.3.2 Climate Smart Communities (CSC) Grant Program

The Climate Smart Communities (CSC) Grant Program is a 50/50 matching grant program for municipalities under the New York State Environmental Protection Fund, offered through the CFA by the NYS Office of Climate Change. The purpose of the program is to fund climate change adaptation and mitigation projects, and includes support for projects that are part of a strategy to become a Certified Climate Smart Community. The eligible project types that may be relevant include the following:

- The construction of natural resiliency measures, conservation or restoration of riparian areas and tidal marsh migration areas
- Nature-based solutions such as wetland protections to address physical climate risk due to water level rise, and/or storm surges and/or flooding
- Relocation or retrofit of facilities to address physical climate risk due to water level rise, and/or storm surges and/or flooding
- Flood risk reduction
- Climate change adaptation planning and supporting studies

Eligible projects include implementation and certification projects. Deadlines are in accordance with the CFA cycle.

9.7.4 Natural Resources Conservation Services (NRCS) Watershed Funding Programs

The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) administers three separate funding programs to promote landscape planning, flood prevention, and rehabilitation projects in communities throughout the country.

9.7.4.1 Emergency Watershed Protection (EWP) Program

The NRCS administers the Emergency Watershed Protection (EWP) Program, which responds to emergencies created by natural disasters. It is not necessary for a national emergency to be declared for an area to be eligible for assistance. The EWP Program is a recovery effort aimed at relieving imminent hazards to life and property caused by floods, fires, windstorms, and other natural disasters.

All projects must have a project sponsor. Sponsors include legal subdivisions of the state, such as a city, county, general improvement district, conservation district, or any Native American tribe or tribal organization.

The NRCS may bear up to 75% of the eligible construction cost of emergency measures (90% within limited-resource areas as identified by the U.S. Census data). The remaining costs must come from local sources and can be in the form of cash or in-kind services.

Public and private landowners are eligible for assistance but must be represented by a project sponsor.

Eligible projects include, but are not limited to, debris-clogged stream channels, undermined and unstable streambanks, and jeopardized water control structures and public infrastructures.

9.7.4.2 Watershed and Flood Prevention Operations (WFPO) Program

The Watershed Protection and Flood Prevention Operations (WFPO) Program includes the Flood Prevention Operations Program (Watershed Operations) authorized by the Flood Control Act of 1944 (P.L. 78-534) and the provisions of the Watershed Protection and Flood Prevention Act of 1954 (P.L. 83- 566). It provides for cooperation between the federal government, and the states and their political subdivisions, to address resource concerns due to erosion, floodwater, and sediment and provide for improved utilization of the land and water resources.

The WFPO Program provides technical and financial assistance to states, local governments and tribes to plan and implement authorized watershed project plans for the purpose of:

- Flood prevention
- Watershed protection
- Public recreation
- Public fish and wildlife
- Agricultural water management
- Municipal and industrial water supply
- Water quality management
- Watershed structure rehabilitation (there is a separate program that manages rehabilitation projects)

9.7.4.3 Watershed Rehabilitation (REHAB) Program

The Watershed Rehabilitation (REHAB) Program helps project sponsors rehabilitate aging dams that are reaching the end of their design life and/or no longer meet federal or state standards. Watershed Rehabilitation addresses critical public health and safety concerns. Since 1948, NRCS has assisted local sponsors in constructing 11,850 project dams. Rehabilitation of watershed project dams is authorized for dams originally constructed as part of a watershed project carried out under any of the following four authorities—Public Law 83-566, Public Law 78-534, the Pilot Watershed Program authorized under the Department of Agriculture Appropriation Act of 1954, or the Resource Conservation and Development Program authorized by the Agriculture and Food Act of 1981.

Watershed project sponsors represent interests of the local community in federally-assisted watershed projects. Sponsors request assistance from NRCS. When funding is allocated, the sponsor and NRCS enter into an agreement that defines the roles and responsibilities of each party to complete the rehabilitation.

Many aging dams no longer meet current state and NRCS design and safety criteria and performance standards, and may pose a potential hazard to lives and property if dam failure would occur. The NRCS provides technical and financial assistance to local project sponsors to rehabilitate aging dams that protect lives and property, and infrastructure. Local sponsors who are interested in rehabilitating their aging dam may request technical and financial assistance from the NRCS. The NRCS prioritizes dams for rehabilitation based on the risks to life and property if a dam failure would occur.

9.7.5 FEMA Hazard Mitigation Grant Program (HMGP)

The Federal Emergency Management Agency's Hazard Mitigation Grant Program (HMGP), offered by the New York State Division of Homeland Security and Emergency Services (NYSDHSES), provides funding for creating/updating hazard mitigation plans and implementing hazard mitigation projects. The HMA program consolidates the application process for FEMA's annual mitigation grant programs not tied to a state's Presidential disaster declaration. Funds are available under the Building Resilient Infrastructure and Communities (BRIC) and the Flood Mitigation Assistance (FMA) Programs.

For flood mitigation measures that are being considered for funding through FEMA grant programs, a benefit-to-cost analysis will be required. In order to qualify for FEMA grants and/or funding, the benefit-to-cost ratio must be greater than one.

9.7.5.1 Building Resilient Infrastructure and Communities (BRIC)

Beginning in 2020, the Building Resilient Infrastructure and Communities grant program, which was created as part of the Disaster Recovery Reform Act of 2018 (DRRA), replaced the existing Pre-Disaster Mitigation (PDM) program and is funded by a 6% set-aside from federal post-disaster grant expenditures. BRIC will support states, local communities, tribes and territories as they undertake hazard mitigation projects, reducing the risks they face from disasters and natural hazards. BRIC aims to categorically shift the federal focus away from reactive disaster spending and toward research-supported, proactive investment in community resilience. Through BRIC, FEMA will invest in a wide variety of mitigation activities, including community-wide public infrastructure projects. Moreover, FEMA anticipates BRIC will fund projects that demonstrate innovative approaches to partnerships, such as shared funding mechanisms and/or project design.

9.7.5.2 Flood Mitigation Assistance (FMA) Program

The Flood Mitigation Assistance Program provides resources to reduce or eliminate long-term risk of flood damage to structures insured under the National Flood Insurance Program. The FMA project funding categories include Community Flood Mitigation – Advance Assistance (up to $200,000 total federal share funding) and Community Flood Mitigation Projects (up to $10 million total). Federal funding is available for up to 75% of the eligible activity costs. FEMA may contribute up to 100%

federal cost share for severe repetitive loss properties, and up to 90% cost share for repetitive loss properties. Eligible project activities include the following:

- Infrastructure protective measures
- Floodwater storage and diversion
- Utility protective measures
- Stormwater management
- Wetland restoration/creation
- Aquifer storage and recovery
- Localized flood control to protect critical facility
- Floodplain and stream restoration
- Water and sanitary sewer system protective measures

9.7.6 FEMA Safeguarding Tomorrow through Ongoing Risk Mitigation (STORM) Act

The STORM Act provides capitalization grants to participating states and tribes in order to loan money to local governments for hazard mitigation projects to reduce risks from disasters and natural hazards. The act states that $100 million would be authorized for fiscal years 2022 and 2023. As loans are repaid, the funds are available for other mitigation project loans.

This “resilience revolving loan fund” will be eligible for projects intended to protect against wildfires, earthquakes, flooding, storm surges, chemical spills, seepage resulting from chemical spills and floods, and any other event deemed catastrophic by FEMA. These low-interest funds will allow for cities and states to repay the loan with savings from mitigation projects. It also gives states and localities the flexibility to respond to oncoming disasters without paying high interest rates so they can invest in their communities.

9.7.7 USACE Continuing Authorities Program (CAP)

The USACE Continuing Authorities Program (CAP) is a group of nine legislative authorities under which the Corps of Engineers can plan, design, and implement certain types of water resources projects without additional project-specific congressional authorization. The purpose of the CAP is to plan and implement projects of limited size, cost, scope and complexity. Table 36 lists the CAP authorities and their project purposes (USACE 2019).

Table 36. USACE Continuing Authorities Program (CAP) Authorities and Project Purposes

(Source: USACE 2019)

Authority	Project Purpose
Section 14, Flood Control Act of 1946, as amended	Streambank and shoreline erosion protection of public works and non-profit public services
Section 103, River and Harbor Act of 1962, as amended (amends Public Law 79-727)	Beach erosion and hurricane and storm damage reduction
Section 107, River and Harbor Act of 1960, as amended	Navigation improvements
Section 111, River and Harbor Act of 1968, as amended	Shore damage prevention or mitigation caused by federal navigation projects
Section 204, Water Resources Development Act of 1992, as amended	Beneficial uses of dredged material
Section 205, Flood Control Act of 1948, as amended	Flood control
Section 206, Water Resources Development Act of 1996, as amended	Aquatic ecosystem restoration
Section 208, Flood Control Act of 1954, as amended (amends Section 2, Flood Control Act of August 28, 1937)	Removal of obstructions, clearing channels for flood control
Section 1135, Water Resources Development Act of 1986, as amended	Project modifications for improvement of the environment

All projects in this program include a feasibility phase and an implementation phase. Planning activities, such as development of alternative plans to achieve the project goals, initial design and cost estimating, environmental analyses, and real estate evaluations, are performed during the feasibility phase to develop enough information to decide whether to implement the project. The feasibility phase is initially federally funded up to $100,000. Any remaining feasibility phase costs are shared 50/50 with the non-federal sponsor after executing a feasibility cost sharing agreement (FCSA). The final design, preparation of contract plans and specifications, permitting, real estate acquisition, project contracting and construction, and any other activities required to construct or implement the approved project are completed during the implementation phase. The USACE and the non-federal sponsor sign a project partnership agreement (PPA) near the beginning of the implementation phase. Costs beyond the feasibility phase are shared as specified in the authorizing legislation for that section (USACE 2019).

10. SUMMARY

The Towns of Sullivan and Cazenovia, including the Villages of Chittenango and Cazenovia, have had a history of flooding events along Chittenango Creek. Flooding in the Towns can occur during any season of the year and are usually the result of spring rains and snowmelt, heavy rains by convective systems, and ice jams caused by above freezing temperatures allowing ice breakups in waterways. In response to persistent flooding, the State of New York in conjunction with the Towns of Sullivan and Cazenovia, Villages of Chittenango and Cazenovia, and Onondaga and Madison Counties, are studying, addressing, and recommending potential flood mitigation projects for Chittenango Creek as part of the Resilient NY Initiative.

This report analyzed the historical and present day causes of flooding in the Chittenango Creek watershed. Hydraulic and hydrologic data was used to model potential flood mitigation measures. The model simulation results indicated that there are flood mitigation measures that have the potential to reduce water surface elevations along high-risk areas of Chittenango Creek, which could potentially reduce flood related damages in areas adjacent to the creek. Constructing multiple flood mitigation measures would increase the overall flood reduction potential by combining the reduction potential of the mitigation measures being constructed. For example, building multiple flood benches along a single reach would compound the flood mitigation benefits of each bench.

Based on the flood mitigation analyses performed in this report, the mitigation measures that provided the greatest reductions in water surface elevations were Flood Bench Upstream of Lake Road/NY-31, Sediment Removal in the Vicinity of the Old Erie Canal, Flood Bench between Tuscarora Road and Russell Street, Increasing the Opening of the Madison Street Bridge, and Flood Benches Upstream of the Valley Acres Neighborhood.

Based on the analysis of the bridge widening simulations, the Tuscarora Road and Madison and Burr Streets’ crossings benefited from increased structural openings. However, the bridge widening measures are the costliest of the discussed flood mitigation measures. The benefits of the measures in their respective reaches should be balanced with the associated costs of each widening measure to determine if it would be feasible to move a widening measure forward. In addition, other complications, such as traffic re-routing, should be taken into account when considering any of the bridge widening measures.

The flood bench measures discussed for Chittenango Creek would provide significant flood mitigation benefits in their respective reaches. Flood benches, however, generally only benefit the areas immediately adjacent to and upstream of the constructed bench. Due to the heavily developed nature of the floodplain in the Villages of Chittenango and Cazenovia, very few areas were found to be adequate for large scale flood benches that could potentially provide greater flood mitigation protection to historically vulnerable areas in High-risk Areas #2 and #3. In addition, flood bench measures generally tend to be the costliest of flood mitigation projects when compared to other measures discussed in this report. The benefits of these measures in their respective reaches should be balanced with the associated costs of each flood bench measure to determine if it would be feasible to move a flood bench project forward.

The debris maintenance around waterway crossing infrastructure, riparian restoration, and detention basin and wetland management measures would maintain the flow channel area in Chittenango Creek, help to reduce and/or manage runoff into the waterway during precipitation events, trap and/or reduce sediment entering the waterway, and improve overall water quality. Sediment and debris that enters the waterway reduces the channel flow area, which over time can reduce the flow capacity of the channel and potentially lead to greater occurrences of, and more damaging flooding.

The sediment removal alternative in the vicinity of the Old Erie Canal provided significant flood mitigation benefits; however, sediment removal can cause irreparable damages to aquatic ecosystems, release contaminants in sediments and creek beds, and increase flood risk to downstream areas. In addition, the Old Erie Canal structure is protected under the NYS historic site register. Any modifications or construction in the vicinity of the canal would need to consult and adhere to NYS historic site guidelines and requirements.

Streambank stabilization measures can potentially reduce flood risk in small and medium-size watersheds by re-establishing or reinforcing streamside vegetation, which in turn can increase streambank resistance to erosion and reduce the force of flowing water in the channel. Reducing streambank erosion has multiple benefits, including reducing the amount of available sediment in the channel, reducing loss of land, and maintaining flow or storage capacity. It is important to note that streams and rivers are dynamic systems, and erosion is a natural process. As such, not all eroding banks should be stabilized. Prior to pursuing a streambank stabilization measure, the cause of erosion should be determined and addressed on a site-specific basis. For example, if the banks are eroding due to a natural meander, then it may be best to leave the bank alone as long as there is little to no threat to surrounding infrastructure or buildings.

Ice management to control ice buildup at critical points along Chittenango Creek would be highly recommended for areas upstream of known flood-prone zones. An ice prediction method using the FDD would be a good starting point to monitor and mitigate any ice-related flooding before it actually occurs. For example, planning, preparation, equipment and labor management for ice break-up using amphibious excavators is highly effective at preventing ice jams and potential flooding at key infrastructure points. Therefore, good prediction of possible ice jams enables municipalities to have the appropriate equipment available at the right time and place. This will reduce indirect costs and inconvenience. To alleviate costs of equipment purchase, operation, and maintenance, the county and local townships could share ownership. Recurring maintenance and staffing required in order to operate the equipment should be factored into any cost analysis.

For flood mitigation measures that are being considered for funding through FEMA grant programs, a benefit-to-cost analysis will be required. In order to qualify for FEMA grants and/or funding, the benefit-to-cost ratio must be greater than one. Flood buyouts/property acquisitions can qualify for FEMA grant programs with a 75% match of funds. The remaining 25% of funds is the responsibility of state, county, and local governments. The case-by-case nature of buyouts and acquisitions requires widespread property owner participation to maximize flood risk reductions. An unintended consequence of buyout programs is the permanent removal of properties from the floodplain, including tax revenue, which would have long-term implications for local governments and should be considered prior to implementing a buyout program.

Floodproofing is an effective mitigation measure but requires a large financial investment in individual residential and non-residential buildings. Floodproofing can reduce the future risk and flood damage, but leaves buildings in flood-risk areas so that future flood damages remain. A benefit to floodproofing versus buyouts is that property and structures remain intact, thereby maintaining the tax base for the local municipality.

In general, there would be an overall greater effect in water surface elevations if multiple alternatives were built in different phases, rather than a single mitigation project. For example, building multiple flood benches along a single reach would compound the flood mitigation benefits of each bench. Table 37 is a summary of the proposed flood mitigation measures, including modeled water surface elevation reductions and estimated ROM costs.

Table 37. Summary of Flood Mitigation Measures

Alternative No.	Description	Benefits Related to Alternative	ROM cost ($U.S. dollars)
1-1	Sediment Management at Mouth with Oneida Lake	Reduce watercourse and gully erosion, trap sediment, reduce and manage runoff, and improve downstream water quality	$320,000 [v]
1-2	Remove Central Piers of Lake Road/NY-31	Model simulated WSEL reductions of up to 0.5-ft	$7.1 million [i]
1-3	Remove Central Piers and Increase the Bridge Opening of Lake Road/NY-31	Model simulated WSEL reductions of up to 1.6-ft	$7.9 million [i]
1-4	Flood Benches Upstream/Downstream of Lake Road/NY-31	Model simulated WSEL reductions of Flood Bench A: up to 1.5-ft Flood Bench B: up to 3.0-ft	Flood Bench A: $2.0 million i Flood Bench B: $5.6 million [i]
1-5	Flood Control Detention Basin Upstream of Bridgeport	Limits flood extents and depths downstream and helps with sediment transport	Variable [iiii]
2-1	Sediment Removal Analysis in Vicinity of Old Erie Canal Crossing	Model simulated WSEL reductions of up to 3.5-ft	$1.5 million [v]
2-2	Channelization of Chittenango Creek in Vicinity of Old Erie Canal Crossing	Model simulated WSEL reductions of up to 3.2-ft	$1.5 million [i]
2-3	Flood Benches Upstream of Old Erie Canal Crossing	Model simulated WSEL reductions of Flood Bench A: up to 0.8-ft Flood Bench B: up to 0.8-ft Flood Bench C: up to 0.7-ft Flood Bench D: up to 0.8-ft	Flood Bench A: $2.5 million [i] Flood Bench B: $2.0 million [i] Flood Bench C: $1.5 million [i] Flood Bench D: $1.5 million [i]
2-4	Increase the Opening of the Tuscarora Road Bridge Crossing	Model simulated WSEL reductions of up to 1.9-ft	$1.4 million [i]

Alternative No.	Description	Benefits Related to Alternative	ROM cost ($U.S. dollars)
2-5	Flood Benches Between Tuscarora Road and Russell Street	Model simulated WSEL reductions of Flood Bench A: up to 0.9-ft Flood Bench B: up to 2.1-ft	Flood Bench A: $1.1 million [i] Flood Bench B: $1.6 million [i]
2-6	Flood Bench Between Russell and Genesee Streets	Model simulated WSEL reductions of up to 1.8-ft	$1.6 million [i]
2-7	Streambank Stabilization Between Russell and Genesee Streets	Reduce force of flowing water and/or increase resistance of the bank to erosion	Variable [iii]
2-8	Increase the Opening of the Madison Street Bridge Crossing	Model simulated WSEL reductions of up to 3.0-ft	$1.7 million [i]
2-9	Flood Benches Upstream of Madison Street	Model simulated WSEL reductions of Flood Bench A: up to 1.0-ft Flood Bench B: up to 2.3-ft	Flood Bench A: $1.3 million [i] Flood Bench B: $2.0 million [i]
2-10	Flood Benches Upstream of Valley Acres Neighborhood	Model simulated WSEL reductions of Flood Bench A: up to 2.6-ft Flood Bench B: up to 4.2-ft	Flood Bench A: $3.2 million [i] Flood Bench B: $1.3 million [i]
2-11	Flood Control/Sediment Detention Basin Upstream of Village of Chittenango	Limits flood extents and depths downstream and helps with sediment transport	Variable [iiii]
3-1	Replace Chittenango Gorge Trail Bridge	Model simulated WSEL reductions of up to 0.9-ft	$310,000 [i]
3-2	Increase the Opening of Burr Street Bridge	Model simulated WSEL reductions of up to 1.5-ft	$1.1 million [i]
3-3	Hydrologic and Hydraulic Analysis of Unnamed Tributary	Provide community/stakeholders with necessary background and supporting information to begin addressing flooding issues	$60,000

Alternative No.	Description	Benefits Related to Alternative	ROM cost ($U.S. dollars)
3-4	Increase the Opening of the Albany Street/US-20 Bridge Crossing	No model simulated WSEL reductions	$1.9 million [i]
3-5	Flood Benches Upstream of Mill/Chenango Street	No model simulated WSEL reductions	Flood Bench A: $1.0 million i Flood Bench B: $1.3 million i Flood Bench B: $1.0 million i
3-6	Restore Natural Channel Geomorphology to Chittenango Creek/Cazenovia Lake Diversion	No model simulated WSEL reductions	$540,000 [i]
3-7	Restore Natural Channel Geomorphology to Diversion and Install a Flood Bench	No model simulated WSEL reductions	$1.8 million [i]
3-8	Flood Control Detention Basin Upstream of Village of Cazenovia	Limits flood extents and depths downstream and helps with sediment transport	Variable [iiii]
4-1	Early-warning Flood Detection System	Early-warning for open-water and ice-jam events	$120,000 [v] (not including annual operational costs)
4-2	Riparian Restoration	Restores natural habitats, reduces/manages runoff, and improves water quality	Variable [iiii] (case-by-case)
4-3	Debris Maintenance Around Culverts/Bridges	Maintains channel flow area and reduces flood risk	$20,000 [v] (not including annual operational costs)
4-4	Detention Basin and Wetland Management	Reduces erosion, traps sediments, reduces/manages runoff, and improves water quality	Variable [iiii] (case-by-case)

Alternative No.	Description	Benefits Related to Alternative	ROM cost ($U.S. dollars)
4-5	Flood Buyouts/Property Acquisitions	Reduces and/or eliminates future losses	Variable (case-by-case)
4-6	Floodproofing	Reduces and/or eliminates future damages	Variable (case-by-case)
4-7	Area Preservation/Floodplain Ordinances	Reduces and/or eliminates future losses	Variable [iiii] (case-by-case)
4-8	Community Flood Awareness and Preparedness Programs/Education	Engages the community to actively participate in flood mitigation and better understand flood risks	Variable (case-by-case)
4-9	Development of a Comprehensive Plan	Guides future development, provides legal defense for regulations, and helps establish policies related to community assets	Variable (case-by-case)
4-10	Ice Management	Control/prevent ice-jam formation by maintaining ice coverage	$40,000 [v] (not including annual operational costs)

[i] Note: ROM cost does not include land acquisition costs for survey, appraisal, and engineering coordination.

[ii] Note: Due to the variable nature of identifying, designing, and constructing a sediment detention basin, no ROM costs were determined for this alternative.

[iii] Note: Due to the variable, conceptual, and site specific nature of streambank stabilization strategies, no ROM costs were determined for this measure.

[iiii] Note: Due to the conceptual nature of this measure, and significant amount of data required to produce a reasonable rough-order-of-magnitude cost, it is not feasible to quantify the costs of this measure without further engineering analysis and modeling.

[v] Note: ROM cost does not include annual maintenance or land acquisition costs for survey, appraisal, and engineering coordination.

11. CONCLUSION

Municipalities affected by flooding along Chittenango Creek can use this report to support flood mitigation initiatives within their communities. This report is intended to be a high-level overview of proposed flood mitigation strategies and their potential impacts on water surface elevations in Chittenango Creek. The research and analysis that went into each proposed strategy should be considered preliminary, and additional research, field observations, and modeling are recommended before final mitigation strategies are chosen.

In order to implement the flood mitigation strategies proposed in this report, communities should engage in a process that follows the following steps:

1. Obtain stakeholder and public input to assess the feasibility and public support of each mitigation strategy presented in this report.
2. Complete additional data collection and modeling efforts to assess the effectiveness of the proposed flood mitigation strategies.
3. Develop a list of final flood mitigation strategies based on the additional data collection and modeling results.
4. Select a final flood mitigation strategy or series of strategies to be completed for Chittenango Creek based on feasibility, permitting, effectiveness, and available funding.
5. Develop a preliminary engineering design report and cost estimate for each selected mitigation strategy.
6. Assess funding sources for the selected flood mitigation strategy.

Once funding has been secured and the engineering design has been completed for the final mitigation strategy, construction and/or implementation of the measure should begin.

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