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RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE

CLEAR CREEK, WYOMING AND CATTARAUGUS COUNTIES, NEW YORK

Prepared for:

Project Team:

RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE

CLEAR CREEK, WYOMING AND CATTARAUGUS COUNTIES, NEW YORK

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Prepared by	**Kadir Goz, Sarah Dickert**
Approved by	**Shaun B. Gannon, P.E., D.WRE, P.H., CFM**

Ramboll

101 First Street
4th Floor
Utica, NY 13501
USA

T 315-956-6950

F 315-790-5434

https://ramboll.com

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-, 3-D	1-, 2-, and 3-Dimensional
AC	Acres
ACE	Annual Chance Flood Event
BCA	Benefit Cost Analysis
BCR	Benefit Cost Ratio
BFE	Base Flood Elevation
BRIC	Building Resilient Infrastructure and Communities
CAP	Continuing Authorities Program
CCSWCD	Cattaraugus County Soil and Water Conservation District
CDBG	Community Development Block Grants
CFA	Consolidated Funding Applications
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second (ft^3/s)
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
ECDEP	Erie County Department of Environment & Planning
EPF	Environmental Protection Fund
EWP	Emergency Watershed Protection
FCA	Flood Control Act
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Maps
FIS	Flood Insurance Study
FMA	Flood Mitigation Assistance
FT	Feet
GIS	Geographic Information System
HMGP	Hazard Mitigation Grant Program
HSGP	Homeland Security Grant Program
H&H	Hydrologic and Hydraulic
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HUD	United States Department of Housing and Urban Development
IPaC	Information for Planning and Consultation
LF	Linear Feet
LiDAR	Light Detection and Ranging
LOMR	Letter of Map Revision
MSC	Map Service Center
NAVD88	North American Vertical Datum of 1988
NCEI	National Centers for Environmental Information
NFHL	National Flood Hazard Layer
NFIP	National Flood Insurance Program

NHD	National Hydrography Dataset
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
NYSDOS	New York State Department of State
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
RAMBOLL	Ramboll Americas Engineering Solutions, Inc.
RC	Circularity Ratio
RE	Elongation Ratio
RF	Form Factor
RL	Repetitive Loss
ROM	Rough Order of Magnitude
SFHA	Special Flood Hazard Areas
SQ MI	Square Miles (mi^2)
SRL	Severe Repetitive Loss
STORM	Safeguarding Tomorrow through Ongoing Risk Mitigation Act
USACE	United States Army Corps of Engineers
USSCS	United States Soil Conservation Service
USGS	United States Geologic Service
WCSWCD	Wyoming County Soil and Water Conservation District
WQIP	Water Quality Improvement Project

1. INTRODUCTION

1.1 HISTORICAL INITIATIVES

Flood mitigation has historically been an initiative in western New York and in the Clear Creek watershed. The watershed has historically been a source of flooding events and sediment and erosion issues along the channel banks in Wyoming and Cattaraugus Counties, New York.

In the Town and Village of Arcade, non-structural measures of flood protection have been utilized to aid in the prevention of flood damage. These measures are in the form of land use regulations that control building within areas that have a high risk of flooding (FEMA 1992b; FEMA 1992d).

In the Town of Freedom, there have been no known flood protection measures instituted (FEMA 1991b). In response to sediment and erosion issues along Clear Creek, the Cattaraugus County Soil and Water Conservation District (CCSWCD) corrected two roadside ditches in the Town of Freedom with significant erosion concerns that outlet into Clear Creek to reduce the amount of sediment entering the creek and moving downstream (ECDEP 2021).

Multiple studies have been performed on the Clear Creek watershed including effective Federal Emergency Management Agency (FEMA) Flood Insurance Studies (FIS) released in 1991 for the Town of Freedom and in 1992 for the Village and Town of Arcade, a United States Army Corps of Engineers (USACE) Special Flood Hazard Evaluation Report released in 1989, and a Genesee / Finger Lakes Regional Planning Council Flood Mitigation Action Plan for the Town of Arcade released in 1999.

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 the Village of Arcade (Community ID #361555) and Towns of Arcade (Community ID #360939) and Freedom (Community ID #360074) 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.

1.3 RESILIENT NY INITIATIVE

In November of 2018, New York State (NYS) 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 Clear 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 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 strategies that would result in the greatest flood reduction benefits. In addition, the flood mitigation studies incorporate the latest climate change forecasts and assess open-water and ice-jam hazards where future flood risks have been identified.

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 evaluate 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 information developed under this initiative is intended to provide the community with a basis for assessing and selecting flood mitigation strategies to pursue; no recommendations are made as to which strategies the community should pursue.

The flood mitigation and resiliency study for Clear Creek began in May of 2021, and a final flood study report was issued in October of 2021.

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 2020a) guidelines, New York State Department of Transportation (NYSDOT) bridge and culvert standards, and United States Geologic Service (USGS) *FutureFlow Explorer* v1.5 (USGS 2016) and *StreamStats* v4.5.3 (USGS 2017) 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 1991 FEMA Flood Insurance Study (FIS) for the Town of Freedom and 1992 FIS for the Town and Village of Arcade. Flood Insurance Rate Maps (FIRMs) were also developed and distributed by FEMA based on the H&H analyses performed in the FIS reports for each respective community (FEMA 1991b; FEMA 1992b; FEMA 1992d).

Updated H&H modeling was performed in this study using the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center's River Analysis System (HEC-RAS) v5.0.7 (USACE 2019b) 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.

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. The stationing used in this report was calculated using the Environmental Systems Research Institute’s (ESRI) ArcMap version 10.8 software package (ESRI 2020).

2.2 PUBLIC OUTREACH

Initial project kickoff meetings were held virtually on March 25th, 2021, with representatives of the NYSDEC, NYSOGS, Ramboll Americas Engineering Solutions, Inc. (Ramboll), Highland Planning, NYSDOT, USACE, CCSWCD, Wyoming County, including Soil and Water Conservation District (WCSWCD) and Fire and Emergency Management, Allegany County (Emergency Services), Village of Arcade (Power and Water), Seneca Nation Emergency Manager, and Lake Erie Watershed Protection Alliance (Appendix B). During these meetings, 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 Village of Arcade, and Towns of Arcade and Freedom as identified in the initial data collection process. Initial field assessments of Clear Creek were conducted in May 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.

3. WATERSHED CHARACTERISTICS

3.1 STUDY AREA

The Clear Creek watershed encompasses areas within three counties (Wyoming, Cattaraugus, and Allegany Counties) in western New York. The creek flows in a general north-northwest direction with its headwaters in the Town of Centerville in Allegany County, and passes through the Towns of Freedom in Cattaraugus County, and Arcade in Wyoming County, before emptying into Cattaraugus Creek in the Village of Arcade (Figure 3-1).

Within the Clear Creek watershed, the area between the confluence with Cattaraugus Creek and the hamlet of Sandusky along NY-98 was chosen as the target area due to the historical and recent flooding and erosion issues, and the hydrologic conditions of the creek in this reach. Figures 3-2 and 3-3 depict the stream stationing: along Clear Creek in Wyoming, Cattaraugus, and Allegany Counties, New York; in the Village of Arcade and the Towns of Arcade, Freedom, and Centerville; and in the study area of the Village of Arcade and Towns of Arcade and Freedom, respectively.

The Village of Arcade is located in the southwest corner of Wyoming County in western New York. The village is bordered by the Town of Arcade to the north, east and west; and Freedom to the south (FEMA 1992d). Cattaraugus Creek flows southward through the Town of Arcade, to the Village of Arcade. Clear Creek similarly flows southeast through the town into the Village of Arcade. The topography of the village, like the town, is described as rolling and hilly upland. Additionally, the village is entirely situated within the Upper Cattaraugus Creek watershed. The village has an area of 2.5 square miles (Tetra Tech 2021).

The Town of Arcade is located in the southwest corner of Wyoming County in western New York. The town is bordered by the towns of Java to the north; Wethersfield to the northeast; Eagle to the east; Freedom to the south; Yorkshire to the southwest; Sardina to the west; and Holland to the northwest (FEMA 1992b). Cattaraugus Creek flows southward through the town to the Village of Arcade. Clear Creek similarly flows southeast through the town into the Village of Arcade. The topography of the town is described as rolling and hilly upland. Additionally, the town lies within the Upper Cattaraugus Creek watershed, though the northwest corner of the town sits on the Buffalo Creek watershed, while the southeastern corner is slightly situated along the Wiscoy Creek watershed. The town has an area of 47.1 square miles (Tetra Tech 2021).

The Town of Freedom is located in Cattaraugus County in western New York, approximately 40 miles southeast of Buffalo. It is bordered by the Town of Arcade to the north, Town of Centerville to the east, Town of Farmersville to the south, and the Towns of Machias and Yorkshire to the west (FEMA 1991b). There are four hamlets located within the Town of Freedom. The four hamlets are Elton, Fairview, Freedom, and Sandusky. The Town of Freedom has a total area of 40.7 square miles (Tetra Tech 2020).

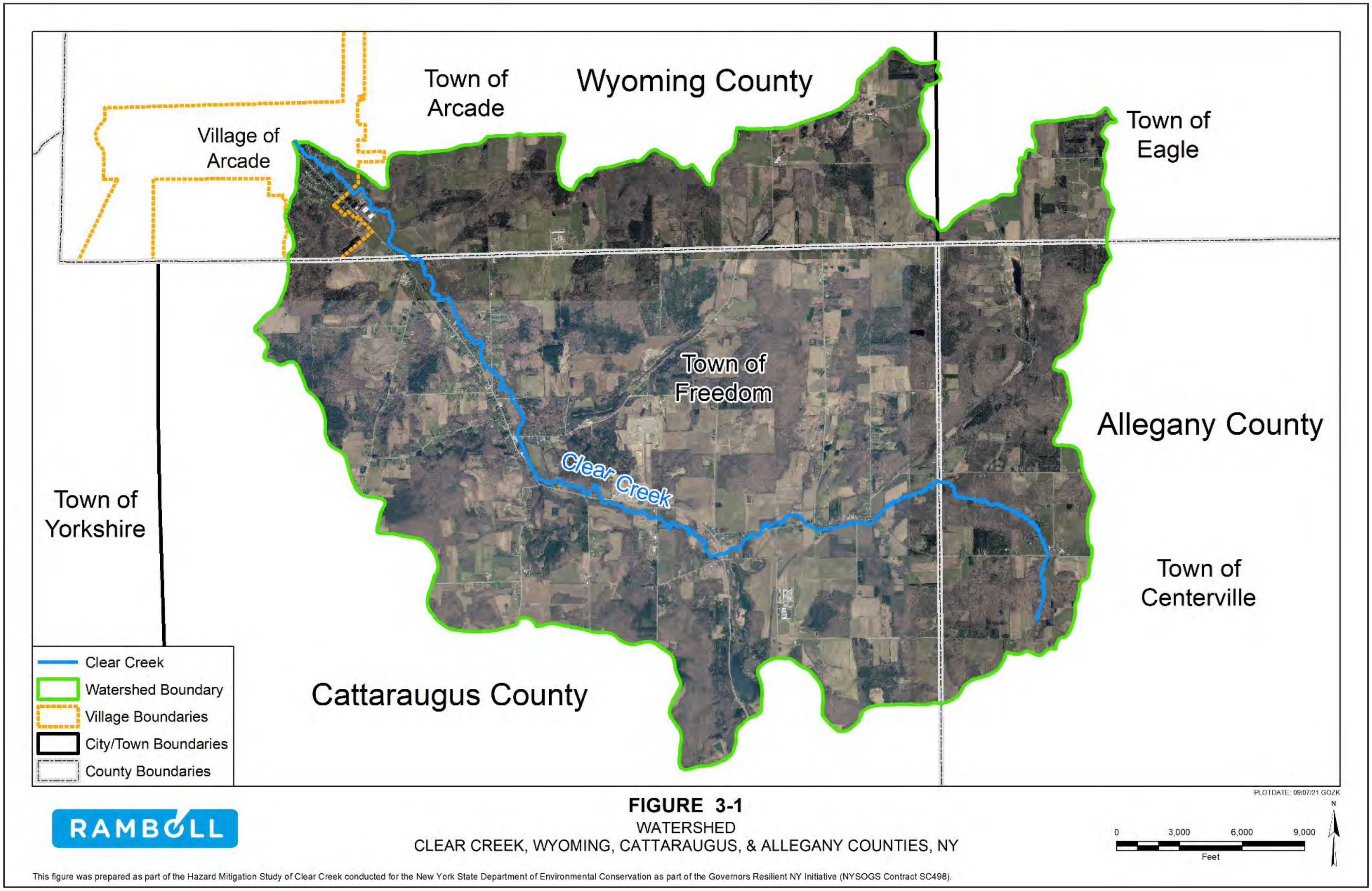

Figure 3-1. Clear Creek Watershed, Wyoming, Cattaraugus, and Allegany Counties, NY.

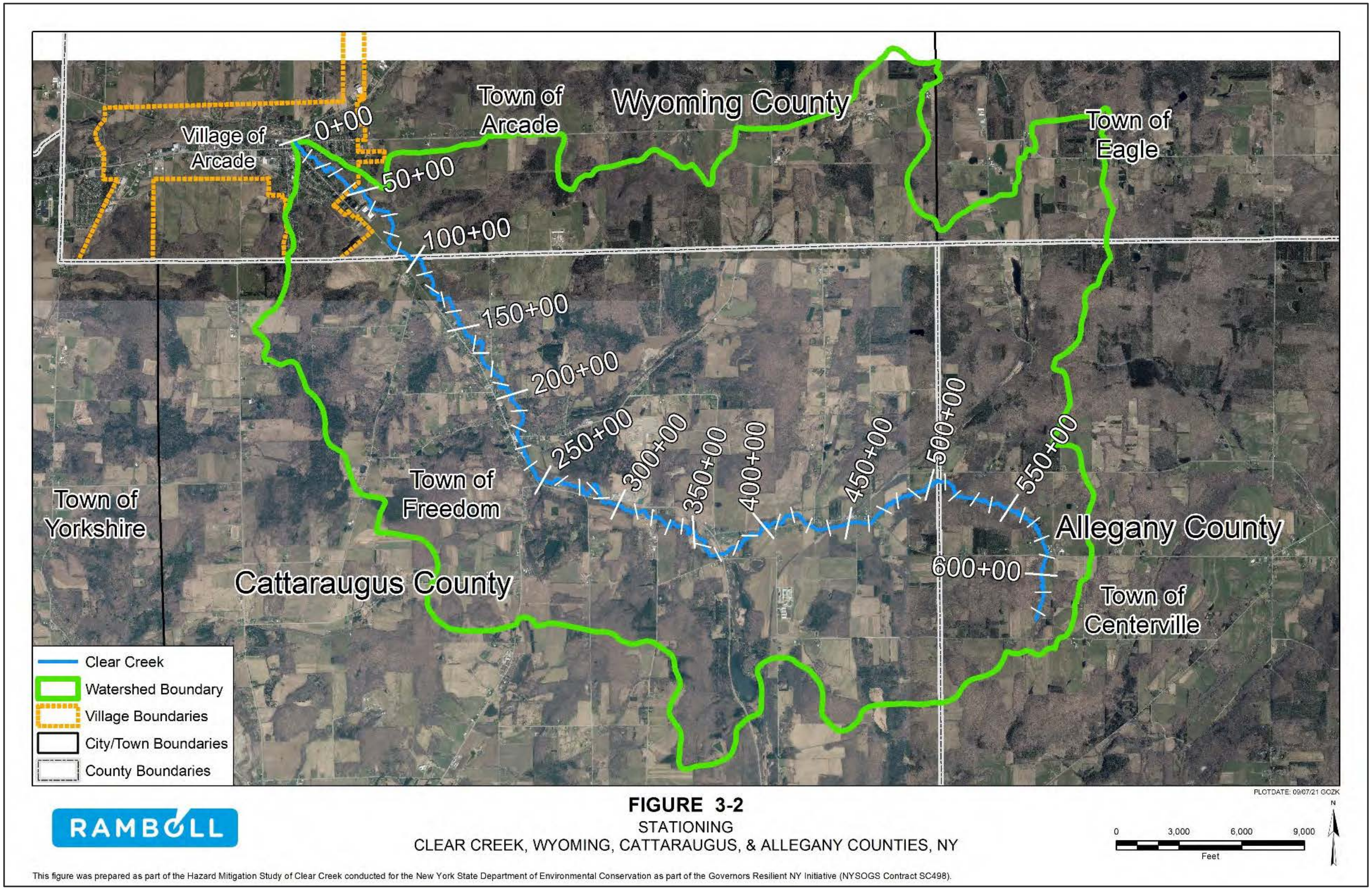

Figure 3-2. Clear Creek Stationing, Wyoming, Cattaraugus, and Allegany Counties, NY.

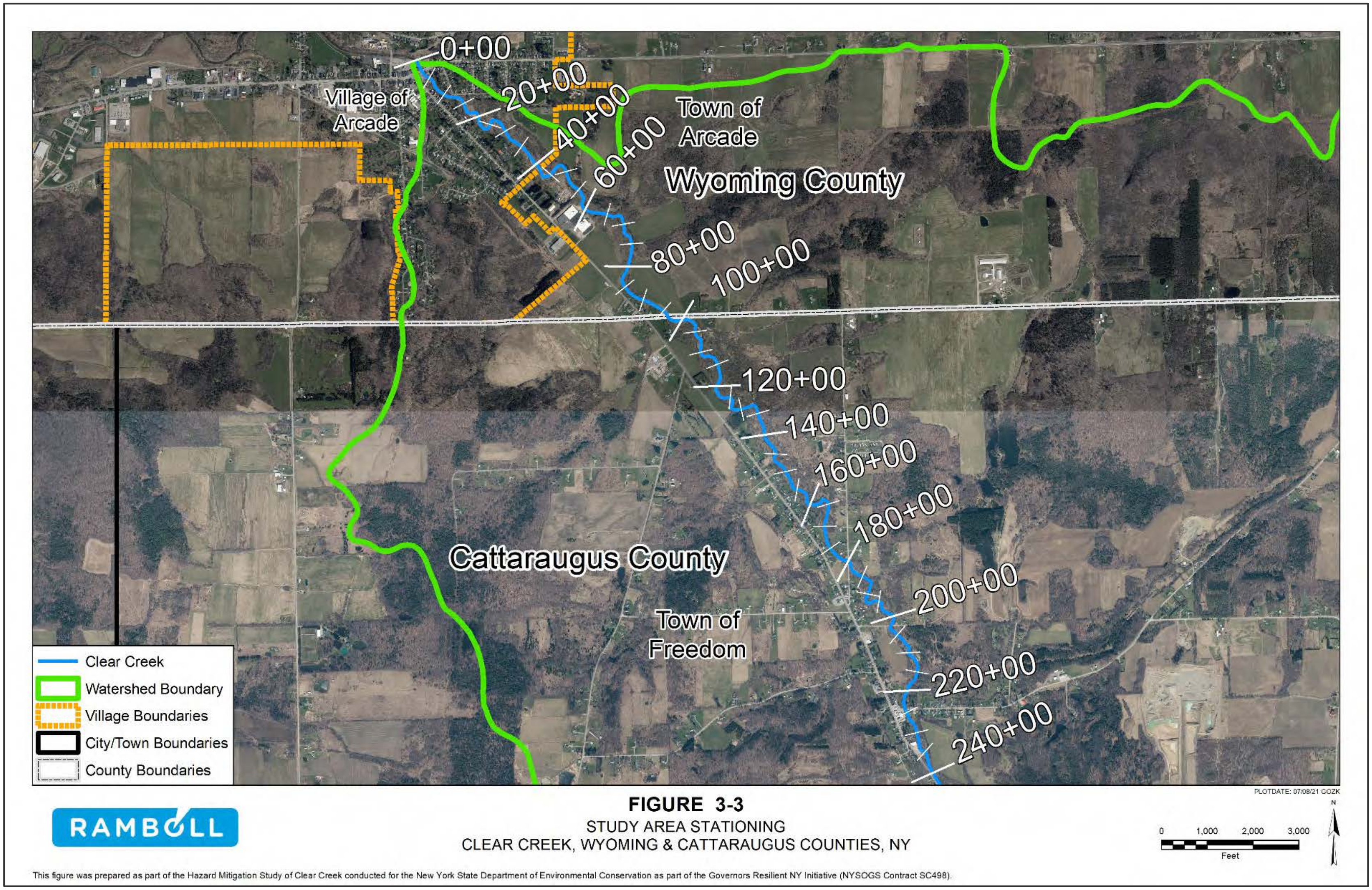

Figure 3-3. Clear Creek Study Area Stationing, Wyoming and Cattaraugus Counties, NY.

3.2 ENVIRONMENTAL CONDITIONS

An overview of the environmental and cultural resources within the Clear 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).
- **National Register of Historic Places** – The National Register of Historic Places lists historic places worthy of preservation, as authorized by the National Historic Preservation Act of 1966 (NPS 2014).

3.2.1 Wetlands

The State Regulated Freshwater Wetlands database shows the approximate location of wetlands regulated by New York State. The check zone is a 100-ft buffer zone around the wetland in which the actual wetland may occur. The USFWS National Wetlands Inventory was reviewed to identify national wetlands and surface waters (Figure 3-4). The Clear Creek watershed includes riverine habitats, freshwater emergent wetlands, and freshwater forested / shrub wetlands (NYSDEC 2021a).

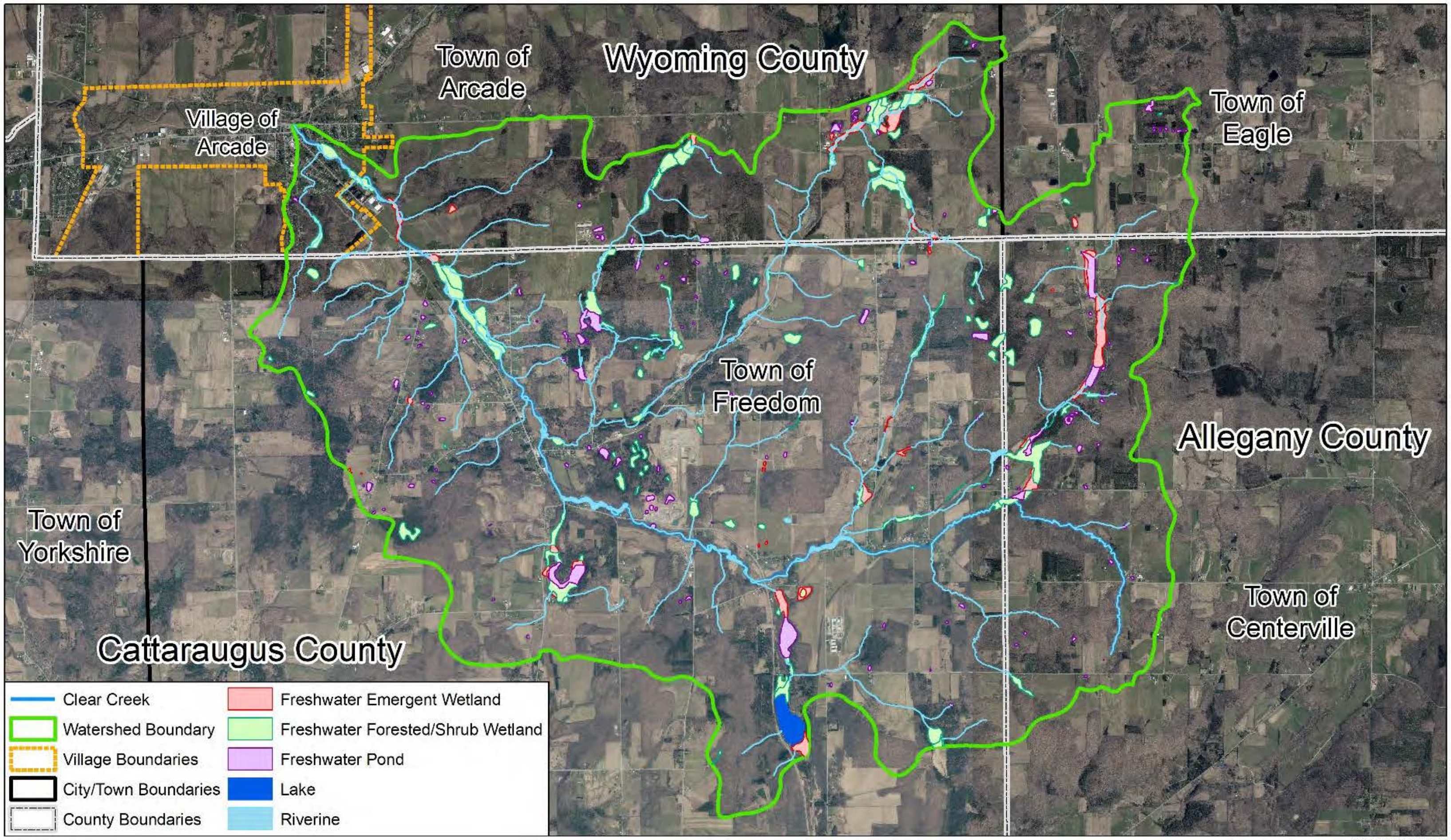

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FIGURE 3-4

WETLANDS AND HYDROGRAPHY

CLEAR CREEK, WYOMING, CATTARAUGUS, & ALLEGANY COUNTIES, NY

This figure was prepared as part of the Hazard Mitigation Study of Clear Creek conducted for the New York State Department of Environmental Conservation as part of the Governors Resilient NY Initiative (NYSOGS Contract SC498).

Figure 3-4. Clear Creek Wetlands and Hydrography, Wyoming, Cattaraugus, and Allegany Counties, NY.

3.2.2 Sensitive Natural Resources

No areas designated as significant natural communities by the NYSDEC were mapped by the Environmental Resource Mapper in the Clear Creek watershed (NYSDEC 2021a).

3.2.3 Endangered or Threatened Species

The Environmental Resource Mapper shows that the watershed basin is within the vicinity of rare plants and animals, including Bats listed as endangered or threatened (Figure 3-5). The NYSDEC Regional Office should be contacted to determine the potential presence of the species identified (NYSDEC 2021a).

The USFWS Information for Planning and Consultation (IPaC) results for the project area list one threatened species, the Northern Long-eared Bat (Myotis septentrionalis). According to the IPaC database, there are no critical habitat designations, National Wildlife Refuge lands, or fish hatcheries within the Clear Creek watershed (UWFWS 2021). The migratory bird species listed in Table 2 are transient species that may pass over, but are not known to nest within the project area.

Table 1. UFWS IPaC Listed Migratory Bird Species

(Source: USFWS 2020)			
Common Name	**Scientific Name**	**Level of Concern**	**Breeding Season**
Bald Eagle	*Haliaeetus leucocephalus*	Non-BCC Vulnerable [1]	Breeds Sep 1 to Aug 31
Black-billed Cuckoo	*Coccyzus erythropthalmus*	BCC Rangewide (CON) [2]	Breeds May 15 to Oct 10
Black-capped Chickadee	*Poecile atricapillus practicus*	BCC-BCR [3]	Breeds Apr 10 to Jul 31
Bobolink	*Dolichonyx oryzivorus*	BCC Rangewide (CON) [2]	Breeds May 20 to Jul 31
Long-eared Owl	*Asio otus*	BCC Rangewide (CON) [2]	Breeds Mar 1 to Jul 15
Prairie Warbler	*Dendroica discolor*	BCC Rangewide (CON) [2]	Breeds May 1 to Jul 31
Wood Thrush	*Hylocichla mustelina*	BCC Rangewide (CON) [2]	Breeds May 10 to Aug 31
Yellow-bellied Sapsucker	*Sphyrapicus varius*	BCC-BCR [3]	Breeds May 10 to Jul 15

[1] 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.

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

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

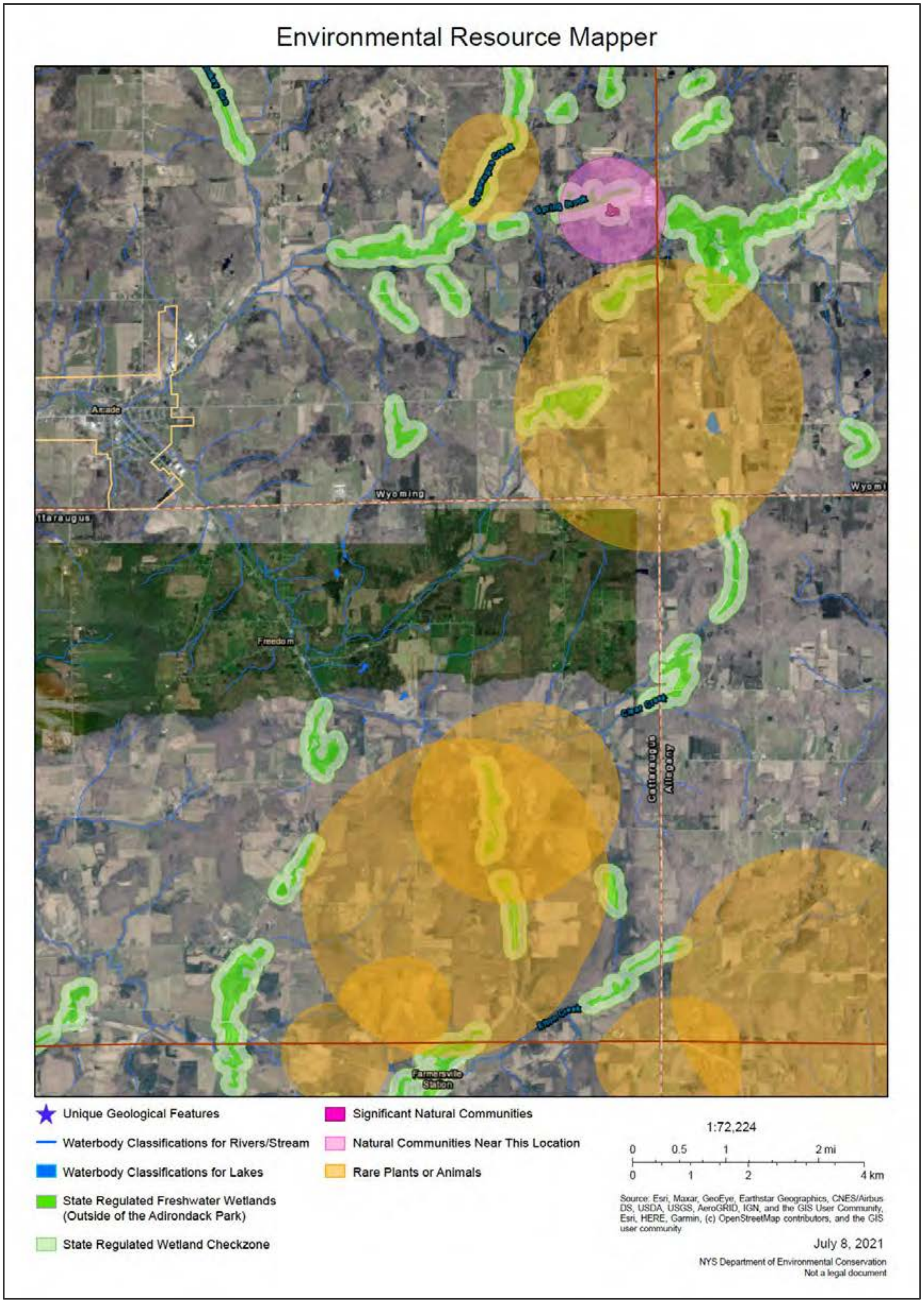


Figure 3-5. Significant Natural Communities and Rare Plants or Animals, Clear Creek, Cattaraugus and Wyoming County, NY.

3.2.4 Cultural Resources

According to the National Register of Historic Places, Clear Creek is located near two historic sites: the Salem Welsh Church in the Town of Freedom and the Arcade and Attica Railroad in the Village of Arcade. The location of these sites are shown in Figure 3-6.

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 (NPS 2014).

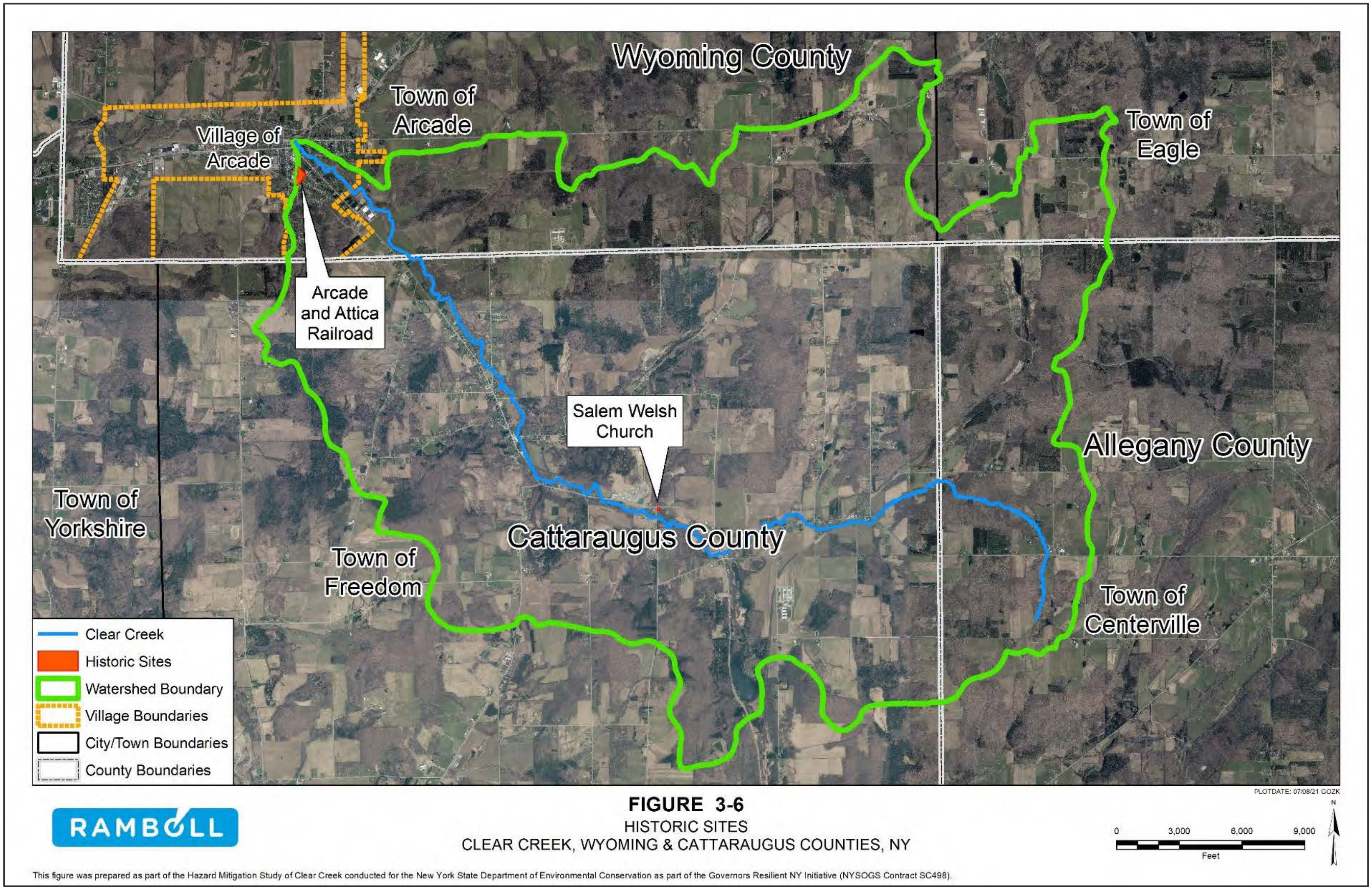


Figure 3-6. National Register of Historic Places, Clear Creek, Wyoming and Cattaraugus Counties, NY.

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). For the Village and Town of Arcade, the current effective FEMA FIS reports were completed on March 3, 1992. For the Town of Freedom, the current effective FEMA FIS was completed on August 19, 1991. According to the FIS reports for all three communities, the hydrologic and hydraulic analyses were completed using detailed methods, and Clear Creek was included in the detailed studies (FEMA 1991b; FEMA 1992b; FEMA 1992d).

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 the BFEs 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).

Clear 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 one foot over the 1% annual chance flood hazard water surface elevation, referred to as the Base Flood Elevation (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 Clear Creek in the Town of Freedom, NY (FEMA 1991b).

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
Clear Creek								
A	9,900	450	1,113	4.8	1,534.7	1,534.7	1,534.8	0.1
B	11,800	354	800	6.6	1,549.1	1,549.1	1,549.2	0.1
C	14,110	380	1,586	3.3	1,573.0	1,573.0	1,573.5	0.5
D	16,653	521	973	5.4	1,591.3	1,591.3	1,591.3	0.0
E	18,620	400	1,094	4.8	1,609.2	1,609.2	1,609.2	0.0
F	20,167	83	295	11.2	1,623.6	1,623.6	1,623.6	0.0
G	22,560	74	384	8.6	1,646.5	1,646.5	1,646.5	0.0
H	25,210	140	533	4.7	1,677.4	1,677.4	1,677.5	0.1
I	26,715	69	258	9.7	1,694.3	1,694.3	1,694.3	0.0
J	28,820	234	479	5.2	1,718.9	1,718.9	1,718.9	0.0
K	31,710	180	594	4.2	1,744.7	1,744.7	1,744.8	0.1
L	33,227	189	400	5.2	1,756.5	1,756.5	1,756.6	0.1

[1]Feet above confluence with Cattaraugus Creek

TABLE 2	FEDERAL EMERGENCY MANAGEMENT AGENCY **TOWN OF FREEDOM, NY** **(CATTARAUGUS CO.)**	**FLOODWAY DATA** **CLEAR CREEK**

Figure 3-7. Regulatory Floodway Data, Town of Freedom, Cattaraugus County, NY.

The FIRMs for the Village, and Towns of Arcade and Freedom, indicate Special Flood Hazard Areas (SFHAs), which are land areas covered by floodwaters during the 1% annual chance flood event (ACE). The flood zones indicated in the Clear 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% annual chance flood event. 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 1991a; FEMA 1992a; FEMA 1992c). Figure 3-8 is a FIRM that includes a portion of Clear Creek in the Town of Freedom, 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 1991b; FEMA 1992b; FEMA 1992d).

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.

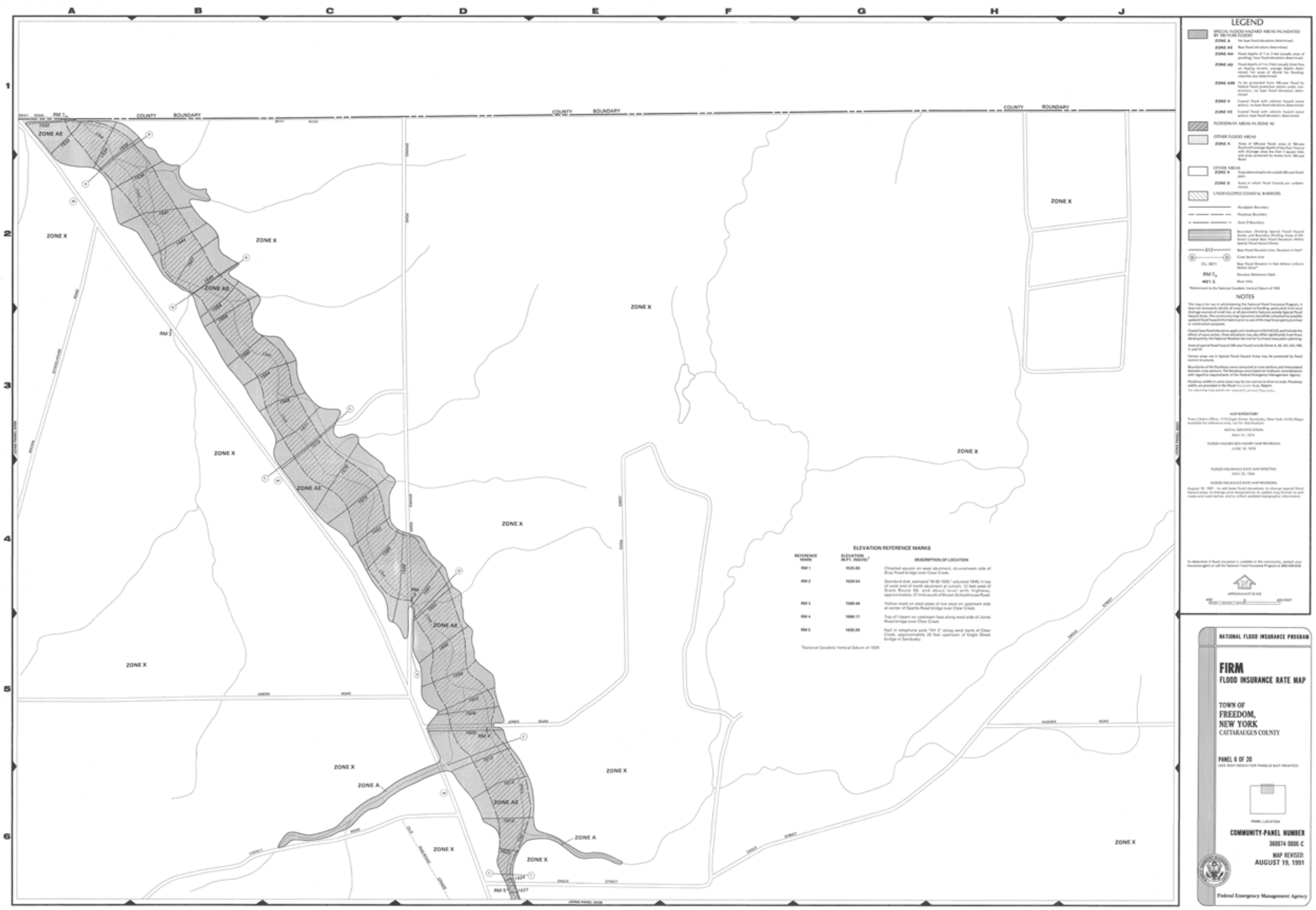


Figure 3-8. FEMA FIRM, Clear Creek, Town of Freedom, Cattaraugus County, NY.

3.3 WATERSHED LAND USE

The Clear Creek stream corridor is largely comprised of forested (52%), agricultural (36%), and developed (7%) lands within the basin. Of the forested lands, deciduous forest (38%) and mixed forest (10%) comprise the largest proportion of the forested lands, while hay / pasture (20%) and cultivated crops (16%) encompass the largest percentages of agricultural lands (USGS 2021).

The distribution of different land use and cover types varies throughout the Clear Creek basin. The upper and middle portions of the basin, in the Town of Freedom, is primarily comprised of cultivated and forested lands, while the lower portion, in the Village and Town of Arcade, is primarily developed lands of varying intensities (high, medium, low, or open space) (USGS 2021).

3.4 GEOMORPHOLOGY

The Clear Creek watershed encompasses areas in Wyoming, Cattaraugus, and Allegany Counties; however, the watershed is predominately within Cattaraugus County. Cattaraugus County includes both glaciated and unglaciated landscapes. Within the borders of Cattaraugus County there are three physiography provinces: the Erie-Ontario Plain province, the glaciated Allegheny Plateau province, and the unglaciated Allegheny Plateau province. The Erie-Ontario Plain province is a small area of lowland in the northwest corner of the county which occupies less than 5% of the county. It is characterized with low relief, gently terraced by wave action in former pre-glacial lakes, with a series of very narrow ravines cut across by a number of streams. The lowest elevation in Cattaraugus County is just over 600 feet where Cattaraugus Creek leaves the county at the extreme northwest corner (NRCS 2002a).

The glaciated Allegheny Plateau province occupies about 75% of the county. The plateau is characterized by steep valley walls, wide ridge tops and flat-topped hills between drainageways. The Allegheny Plateau in Cattaraugus County is intersected by a number of broad, flat-bottomed valleys, presently occupied by sluggish, meandering streams. The topography is strongly influenced by the underlying bedrock, which is nearly level bedded. The Allegheny Plateau extends south from Cattaraugus Creek to just north of the Allegheny River. On the glaciated Allegheny Plateau, the elevation rises from about 1,400 feet in the major valleys to 2,200 feet. The greater part of the upland plateau lies between elevations of 1,600 to 2,000 feet (NRCS 2002a).

The unglaciated Allegheny Plateau province occupies the lower 20% of the county, following the general course of the Allegheny River. This crudely triangular area of New York, the so called Salamanca Re-entrant, escaped glaciation and is the most northerly region of unglaciated landscapes in eastern North America (Muller 1977). The contrast in relief between the glaciated and unglaciated parts of the county are striking. This area has more rugged topography, longer and steeper slopes, deeply incised and V-shaped valleys, and does not have the irregular, hilly characteristics typical of much of the glaciated areas. The elevation rises from 1,284 feet, at the point where the Allegheny River enters Pennsylvania, to about 2,400 feet at the top of the plateau. The maximum recorded elevation, 2,430 feet, occurs at Claire benchmark in the Town of Allegany (NRCS 2002a).

From the unglaciated summits south of Olean to the floodplain of Cattaraugus Creek northwest of Gowanda, the total relief in Cattaraugus County is 1,825 feet, a range of elevation greater than any other western New York county (NRCS 2002a). Figure 3-9 is the Clear Creek profile of stream bed elevation and channel distance from the confluence with Cattaraugus Creek using 1-meter light detection and ranging (LiDAR) data (NYSOITS 2017b).

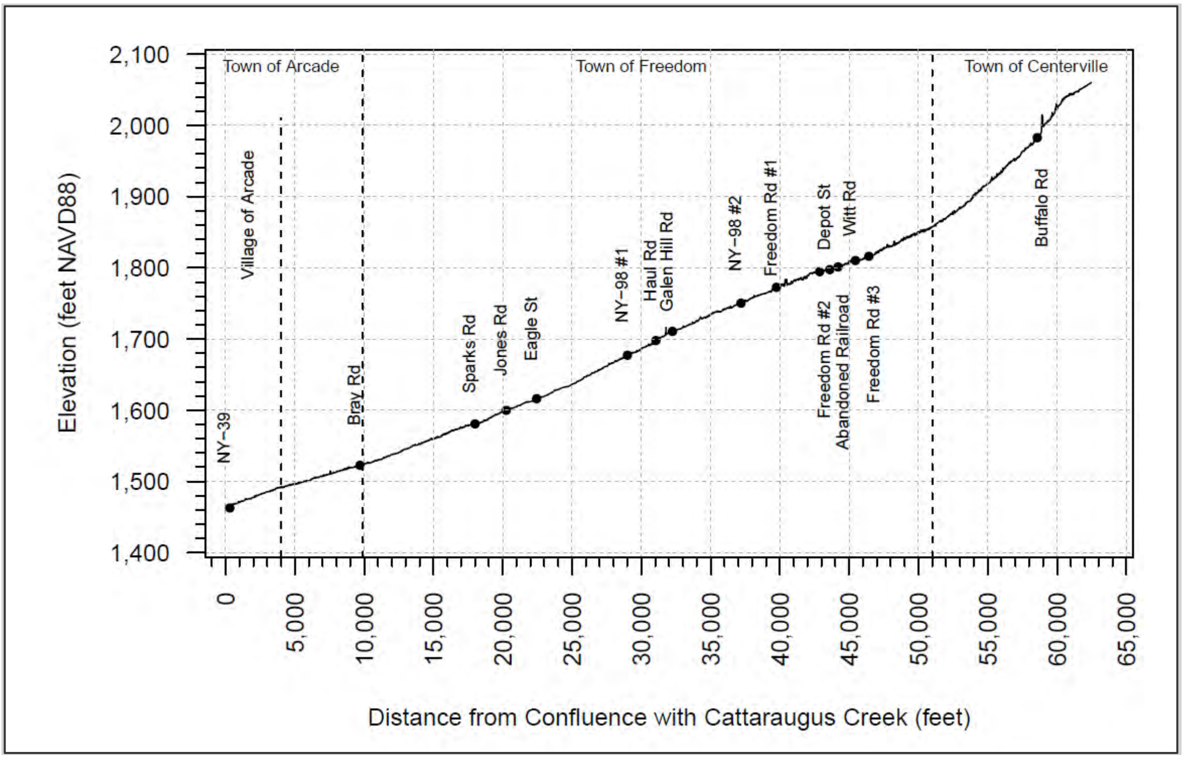


Figure 3-9. Clear Creek profile of stream bed elevation and channel distance from the confluence with Cattaraugus Creek.

Cattaraugus County contains bedrock that dates back 300 to 400 million years to the Devonian, Mississippian, and Pennsylvanian periods of the Paleozoic Era (Tesmer 1975). Many of these rocks contain the remains of typical shallow-water marine invertebrates of that time. Formations of the Upper Devonian are at the lower elevations, while those of the Pennsylvanian are at the higher elevations. In general, the older rock strata occur in northern Cattaraugus County while the younger rocks are found to the south near the Pennsylvania state line, capping the tops of the highest hills. The stratum of bedrock is generally horizontal but has a slight dip to the south or south-southwest, of approximately 40-ft per mile (Flint 1947; NRCS 2002a).

The oldest bedrock formation is of the Devonian period. In Cattaraugus County it is the Hanover Shale, which is of the Java Group. The succession of bedrock from oldest to youngest in the County is: Hanover Shale (Java Group), Dunkirk Shale (Canadaway Group), South Wales Shale (Canadaway Group), Laona Member (Canadaway Group), Westfield Member (Canadaway Group), Shumla Member (Canadaway Group), Northeast Member (Canadaway Group), Chadakoin Formation (Conneaut Group), Venango Formation (Conewango Group), Oswayo Formation (Conewango Group), Knapp Formation (Pocono Group), Olean Conglomerate (Pottsville Group), and Sharon Slate (Pottsville Group) (NRCS 2002a).

Cattaraugus County experienced several advances and retreats of glacial ice during the Pleistocene ice age. The ice age began about 300,000 years ago and ended during the late Wisconsin glaciation, about 12,000 to 17,000 years ago. In Cattaraugus County, the earlier glaciation was covered or destroyed by two later Wisconsin glacial advances, an earlier advance by the Altonian substage from the northeast, and the later Woodfordian substage from the northwest (Muller 1977).

As the glacial ice melted and receded, further exposing valley areas, large quantities of melt water discharging from the glacial front carried rock and soil debris, which was deposited as valley train terraces, kames, and eskers. Nearly level or undulating valley train terrace deposits occupy the floors of many valleys. All of these postglacial fluvial deposits generally are referred to as outwash or glaciofluvial deposits, and consist mainly of stratified sand and gravel. Erosion and sedimentation have been taking place continually since the ice retreated. Steep, fan-shaped alluvial deposits have accumulated at the mouth of the lateral streams, where the velocity of the water slowed and the sand and gravel dropped out of suspension (NRCS 2002a).

The drainage system of Cattaraugus County is separated into two systems: the Lake Erie-St. Lawrence River system and the Allegheny-Ohio-Mississippi River system. The drainage from the northern one-third of the county flows northward and then west into the Lake Erie-St. Lawrence system, and the southern two-thirds of the county flows southward into the Allegheny-Ohio-Mississippi River system. In the northern part of the county, the principal drainage system for the upland plateau is Cattaraugus Creek and its tributaries. Cattaraugus Creek forms the boundary line between the counties of Cattaraugus and Erie. Numerous tributaries, rising in the county, enter Cattaraugus Creek from the south. Of these are the Connoisarauley, which flows into Cattaraugus Creek near the center of the county, and the South Branch of Cattaraugus Creek, which enters several miles downstream. Other major streams which flow into Cattaraugus Creek include Mansfield Creek, Buttermilk Creek, Elton Creek, and Clear Creek (NRCS 2002a).

In addition, there are numerous locations where sediment depositional aggradation is occurring within the channel of Clear 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

Clear Creek drains an area of 32.1 square miles, is approximately 12 miles in length, and is located in northwestern Allegany County, northeastern Cattaraugus County, and southwestern Wyoming County. Clear Creek rises in the vicinity of Buffalo Road (CR-3) in the Town of Centerville and flows north / northwest into the Town of Freedom where the creek flows parallel to NY-98 through Freedom into the Town, then Village of Arcade before emptying into Cattaraugus Creek. Clear Creek has one named tributary, Haskell Creek in the Village and Town of Arcade, and many small, unnamed tributaries throughout the watershed in the Town of Freedom (USGS 2018).

Table 2 is a summary of the basin characteristic formulas and calculated values for the Clear 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 2. Clear Creek Basin Characteristics Factors

Factor	Formula	Value
Form Factor (R_F)	A / B_L^2	0.40
Circularity Ratio (R_C)	$4*\pi*A / B_P^2$	0.41
Elongation Ratio (R_E)	$2 * (A/\pi)^{0.5} / B_L$	0.71

Form Factor (R_F) 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 (R_C) 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 (R_E) 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 Clear Creek watershed basin can be characterized as fern shaped (more circular than elongated) with lower peak discharges of longer durations, moderate-relief topography with limited structural controls on drainage and moderate ground slopes (Waikar and Nilawar 2014).

According to the USGS National Water Information System, there are currently no USGS stream gaging stations on Clear Creek (USGS 2021).

An effective FEMA Flood Insurance Study (FIS) for the Village and Town of Arcade was issued on March 3, 1992, and for the Town of Freedom on August 19, 1991. These FEMA FIS were new detailed studies and included drainage area and discharge information for Clear Creek. Table 3 summarizes the FEMA FIS drainage area and peak discharges, in cubic feet per second, for Clear Creek (FEMA 1991b; FEMA 1991d; FEMA 1992b). In the effective FEMA FIS, only the 1% annual chance flood (100-yr storm) event was computed.

Table 3. Clear Creek FEMA FIS Peak Discharges

(Source: FEMA 1991b; FEMA 1991d; FEMA 1992b)			
Flooding Source and Location	**Drainage Area (Sq. Miles)**	**River Station (ft)**	**Peak Discharges (cfs)**
			1-Percent
Above confluence with Cattaraugus Creek	33.0	0+00	5,900 *
At a point approximately 3,900-ft upstream of confluence with Cattaraugus Creek	32.8	39+00	7,000 **
Approximately 3,375-ft upstream of Main Street at confluence of Clear Creek Tributary	30.0	40+00	5,900 ***
At Bray Road bridge	26.1	90+00	5,300 **
At a point approximately 0.3- mi upstream of Eagle Street bridge	17.8	218+50	3,300 **
At a point approximately 0.17-mi east of Maple Grove Road	12.6	226+00	2,500 **
At a point approximately 0.15-mi upstream of Galen Hill Road bridge	9.5	299+00	2,100 **

* Note: This peak discharge value was obtained from the Village of Arcade FIS (FEMA 1992d).

** Note: These peak discharge values were obtained from the Town of Freedom FIS (FEMA 1991b).

*** Note: These peak discharge values were obtained from the Town of Arcade FIS (FEMA 1992b).

The FEMA FIS peak discharges for Clear Creek in the downstream reach displays a lack of hydrologic consistency due to the different hydrologic calculation methods used by the different FIS studies. According to the effective FEMA FIS for the Village and Town of Arcade, peak discharges were determined using the statistical analyses of stream flow records available for the watershed, and analyses of rainfall and runoff characteristics in the general region of the watershed, as carried out by the USACE Buffalo District (FEMA 1992b; FEMA 1992d). For the Town of Freedom, peak discharges were established using the Kinematic Wave Method of the HEC-1 computer program. Clear Creek was divided into five sub-reaches to increase accuracy (FEMA 1991b).

General limitations of the FEMA FIS methodology include: the age of the effective FIS H&H analysis and the age of the methodology; the limited regional flood frequency curves used to calculate discharge-frequency relationships; and the extrapolation of regional curves to ungaged streams. These limitations represent outdated methodologies for determining discharge-frequency relationships and introduce error at multiple stages in the calculations, which can lead to over or under estimations of peak discharges.

USGS *StreamStats* v4.5.3 software 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 2017).

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 (Lumia 1991; Lumia et al. 2006).

For ungaged sites, such as Clear Creek in hydrologic Region 5 of New York State, *StreamStats* relies on regional regression equations that were developed by statistically relating the streamflow statistics to the basin characteristics for a group of stream gages within a region. Estimates of streamflow statistics for an ungaged site can then be obtained by measuring its basin characteristics and inserting them into the regression equations (Ries et al. 2017). For example, the full-regression equation for estimating the 100-yr flood for ungaged sites within hydrologic Region 5 in New York is:

$$Q_{100} = 1.91 * (A)^{0.980} * (SL)^{0.636} * (P)^{0.590}$$

Where

A is the drainage area in square miles;

SL is the main channel slope in feet per mile; and

P is the mean annual precipitation, in inches (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 (Ries et al. 2017).

However, when one or more of the basin characteristics for an ungaged site are outside the given ranges, then the estimates are extrapolated. *StreamStats* provides warnings when extrapolation occurs. Although StreamStats does provide estimates of streamflow statistics in these circumstances, no error indicators are provided with them, as the errors associated with these estimates are unknown and may be very large (Ries et al. 2017).

In addition, estimates of streamflow statistics that are obtained from regression equations are based on the assumption of natural flow conditions at the ungaged site unless the reports that document the equations state otherwise. If human activities such as dam regulation and water withdrawals substantially affect the timing, magnitude, or duration of flows at a selected site, the regression-equation estimates provided by *StreamStats* should be adjusted by the user to account for those activities (Ries et al. 2017). Table 4 is the summary output of peak discharges calculated by the USGS *StreamStats* software for Clear Creek at the same locations as the FEMA FIS peak discharges.

Table 4. USGS *StreamStats* Peak Discharge for Clear Creek at the FEMA FIS Locations

(Source: USGS 2017)						
Flooding Source and Location	**Drainage Area (Sq. Miles)**	**River Station (ft)**	**Peak Discharges (cfs)**			
			10-Percent	**2-Percent**	**1-Percent**	**0.2-Percent**
Above confluence with Cattaraugus Creek	32.1	0+00	2,880	4,440	5,150	6,990
At a point approximately 3,900-ft upstream of confluence with Cattaraugus Creek	31.5	39+00	2,860	4,400	5,110	6,930
Approximately 3,375-ft upstream of Main Street at confluence of Clear Creek Tributary	31.2	40+00	2,820	4,340	5,040	6,830
At Bray Road bridge	29.0	90+00	2,590	3,990	4,620	6,260
At a point approximately 0.3-mi upstream of Eagle Street bridge	17.2	218+50	1,430	2,170	2,500	3,350
At a point approximately 0.17-mi east of Maple Grove Road	15.2	226+00	1,230	1,860	2,140	2,850
At a point approximately 0.15-mi upstream of Galen Hill Road bridge	13.8	299+00	1,070	1,610	1,840	2,440

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 5 is a summary table of the USGS *StreamStats* standard errors at each percent annual chance flood hazard for Region 5 in New York State.

Table 5. USGS *StreamStats* Standard Errors for Full Regression Equations

Source: (Lumia 2006)				
	Peak Discharges (cfs)			
	10-Percent	**2-Percent**	**1-Percent**	**0.2-Percent**
Standard Error	36.1	37.5	38.7	42.6

The FEMA FIS peak discharges were determined to be outside of the acceptable range (95% confidence interval) based on the *StreamStats* standard error calculations. In addition, only the 1% annual chance flood event (100-yr) peak discharges were computed for the FEMA hydrologic analyses for all three communities. As a result, the *StreamStats* peak discharge values were used in the hydraulic and hydrologic model simulations for this study to improve the accuracy of the H&H modeling results and provide a more robust analysis of potential mitigation strategies by evaluating different annual chance flood events (i.e., 10, 2, and 0.2% annual chance event or the 10, 50, and 500-yr storm events).

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 Clear 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 6 lists the estimated drainage area, bankfull discharge, width, and depth at select locations along Clear Creek as derived from the *StreamStats* program.

Table 6. USGS *StreamStats* Estimated Drainage Area, Bankfull Discharge, Width, and Depth

(Source: USGS 2017)					
Flooding Source and Location	**Drainage Area (Sq. Mi.)**	**River Station (ft)**	**Bankfull Depth (ft)**	**Bankfull Width (ft)**	**Bankfull Streamflow (cfs)**
Above confluence with Cattaraugus Creek	32.1	0+00	2.42	72.3	891
At a point approximately 3,900-ft upstream of confluence with Cattaraugus Creek	31.5	39+00	2.41	71.7	877
Approximately 3,375-ft upstream of Main Street at confluence of Clear Creek Tributary	31.2	40+00	2.41	71.4	870
At Bray Road bridge	29.0	90+00	2.37	69.3	818
At a point approximately 0.3-mi upstream of Eagle Street bridge	17.2	218+50	2.08	55.7	527
At a point approximately 0.17-mi east of Maple Grove Road	15.2	226+00	2.02	52.9	475
At a point approximately 0.15-mi upstream of Galen Hill Road bridge	13.8	299+00	1.97	50.8	438

3.6 INFRASTRUCTURE

According to the NYSDEC Inventory of Dams dataset (2019), there is one dam along Clear Creek that interacts with the flow of the creek. The dam is classified as a Class D dam. Class D dams are also referred to as “negligible or no hazard” dams. Class D dams have been breached or removed, have failed or otherwise no longer materially impound waters, or were planned but never constructed and are now considered to be defunct dams posing negligible or no hazard. Table 7 lists the dam along Clear Creek, including hazard codes and purpose for the dam (NYSDEC 2019).

Table 7. Inventory of Dams Along Clear Creek

(Source: NYSDEC 2019)				
Municipality	**Dam Name**	**River Station (ft)**	**Hazard Code**	**Purpose**
Town of Freedom	Arcade Village Reservoir #1 Dam	245+00	D	Other

Major waterway crossings over Clear Creek include East Main Street (NY-39) in the Village of Arcade, Bray Road in the Town of Arcade, and NY-98 and multiple Freedom Road crossings in the Town of Freedom. Table 8 lists a summary of all infrastructure crossing Clear Creek. Bridge lengths and widths for NYSDOT structures were revised as of February 2019 (NYSDOT 2019b).

Table 8. Infrastructure Inventory Summary Table

(Source: NYSDOT 2014; NYSDOT 2019b; Ramboll 2021)

Roadway Carried	River Station (ft)	Type	NYSDOT BIN	Owner	Length [1] (ft)	Width [2] (ft)	Bankfull Width [3] (ft)	Hydraulic Capacity (% Annual Chance)
East Main Street (NY-39)	2+80	Bridge	1024560	NYSDOT	43.5	44	72.3	Unable to pass 1% due to backwater from Cattaraugus Creek
Bray Road	96+60	Bridge	3321620	Cattaraugus County	94	24.1	69.3	1%
Sparks Road	180+00	Bridge	3321640	Cattaraugus County	72	25.8	66.5	Unable to pass 1% *
Jones Road	202+30	Bridge	3321630	Cattaraugus County	60	18	65.5	Unable to pass 1% *
Eagle Street	224+15	Bridge	3321650	Cattaraugus County	54	25.7	55.9	1%
NY-98 (1)	290+00	Bridge	1035610	NYSDOT	93	32.8	52.6	1%
Haul road (Unnamed road near Auto Yard)	310+00	Culvert	N/A	N/A	29	22		Unable to pass 1% *
Galen Hill Road	322+50	Bridge	3321660	Cattaraugus County	55	25.7	50.8	1%
NY-98 (2)	371+70	Bridge	1035600	NYSDOT	74	40	44	1%
Freedom Road (CR-23) (1)	397+85	Bridge	3321590	Cattaraugus County	66	28	43.7	No FIS Data
Freedom Road (CR-23) (2)	428+50	Bridge	3321580	Cattaraugus County	46	25.1	29.1	No FIS Data

(Source: NYSDOT 2014; NYSDOT 2019b; Ramboll 2021)

Roadway Carried	River Station (ft)	Type	NYSDOT BIN	Owner	Length [1] (ft)	Width [2] (ft)	Bankfull Width [3] (ft)	Hydraulic Capacity (% Annual Chance)
Depot Street	435+70	Bridge	3323360	Cattaraugus County	46	16.3	28.7	No FIS Data
CSX Transportation (Abandoned)	443+35	Railroad Bridge	N/A	CSX Transportation	35	27	28.6	No FIS Data
Witt Road	454+15	Bridge	3321680	Cattaraugus County	30	23.7	28.3	No FIS Data
Freedom Road (CR-23) (3)	464+05	Bridge	3321570	Cattaraugus County	40	30.3	22.1	No FIS Data
Buffalo Rd (CR-3)	589+40	Culvert	N/A	Cattaraugus County	12	35	12.1	No FIS Data

[1] Length is measured perpendicular to flow.
[2] For bridges, 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. For culverts, width refers to the out to out length of the culvert to the nearest tenth of a foot (NYSDOT 2006).
[3] Estimated using the USGS *StreamStats* program.
* Note: The FIS reports for the Village of Arcade and Towns of Arcade and Freedom only calculated the 1% ACE (100-year) peak discharge. No data was available for any other recurrence interval.

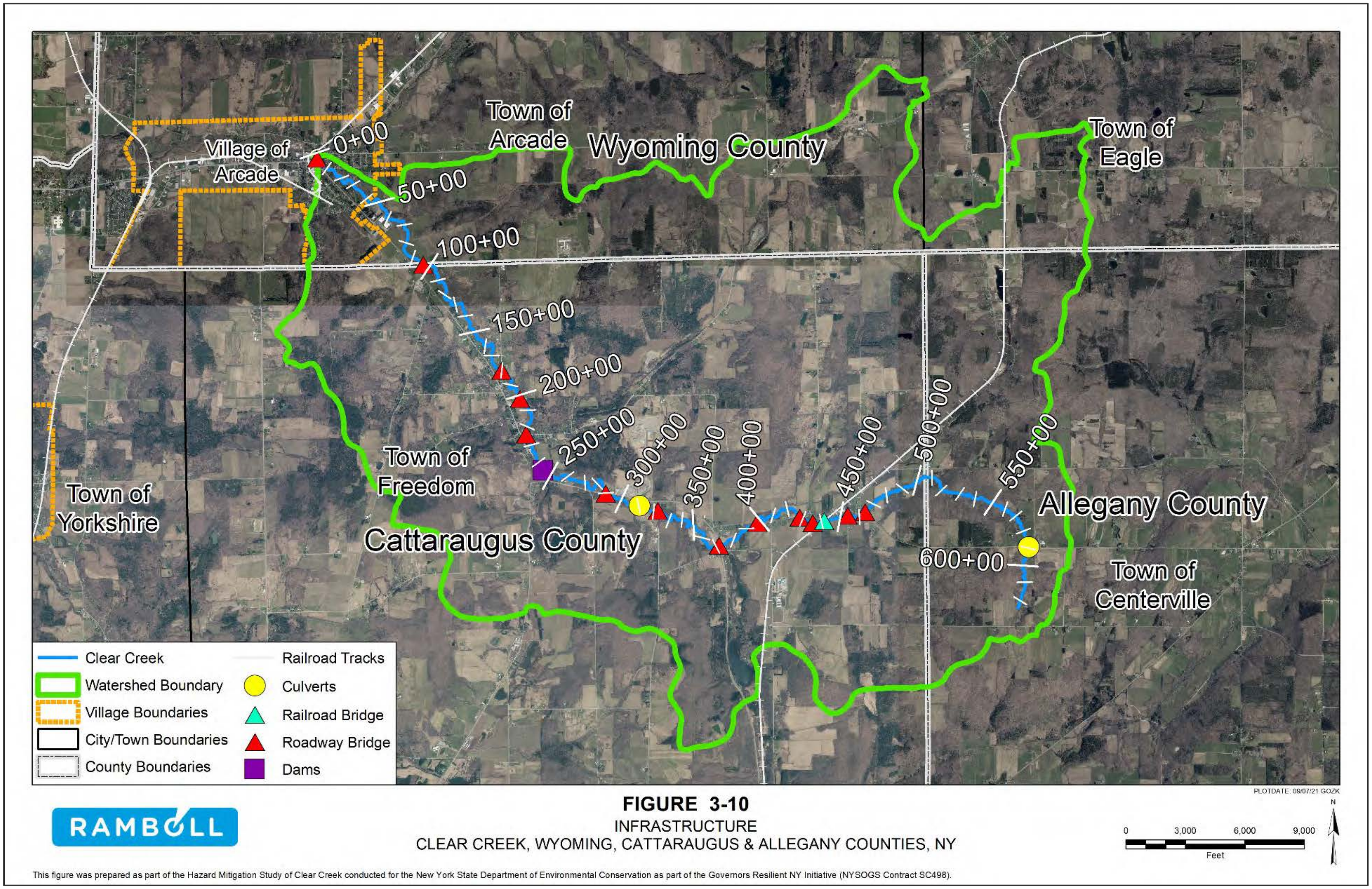


Figure 3-10. Clear Creek Infrastructure, Wyoming, Cattaraugus, and Allegany Counties, NY.

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 high-risk constriction point culverts and bridges along Clear Creek, the FEMA FIS profile of Clear Creek was used to determine the lowest annual chance flood elevation to flow under a culvert or the low chord of a bridge, without causing an appreciable backwater condition upstream (Table 8).

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 2020a).

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 2020).

According to the NYSDOT bridge manual (2019) for Region 5, which includes Niagara, Erie, Chautauqua, and Cattaraugus Counties, 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% annual chance event (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% annual chance event (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% annual chance event (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 2020).

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 an effort to improve flood resiliency of infrastructure in light of future climate change, New York state 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, the NYSDEC outlined infrastructure guidelines for bridges and culverts. In general, current peak flows shall be increased to account for future projected peak flows based on the USGS *StreamStats* tool where current 2% annual chance event peak flows shall be increased by 10% in Hydrologic Region 5 (NYSDEC 2020a).

For bridges, the minimum hydraulic design criteria is 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 is 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 2020a; NYSDOT 2019a; USDHS 2010).

For culverts, the minimum hydraulic design criteria is 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 2020a; NYSDOT 2018; USDHS 2010).

When compared to current guidelines, the CRRA climate change recommendation of freeboard for bridges and culverts encourages building more flood resilient infrastructure. Table 9 displays the 1% annual chance flood levels and freeboard at FEMA FIS infrastructure locations using the FIS profile for Clear Creek. In the effective FEMA FIS, only the 1% annual chance event (100-yr storm) was computed.

Table 9. FEMA FIS Profile 1% Annual Chance Flood Hazard Levels at Infrastructure Locations

Source: (FEMA 1991b; FEMA 1992b; FEMA 1992d)			
Roadway Carried	**River Station (ft)**	**1% Water Surface Elevation (ft NAVD88)**	**Freeboard (ft)**
East Main Street (NY-39)	2+80	1479	0 – due to backwater from Cattaraugus Creek
Bray Road	96+60	1531.5	1.5 - Town of Arcade FIS 11 - Town of Freedom FIS
Sparks Road	180+00	1590.5	0
Jones Road	202+30	1608	0
Eagle Street	224+15	1625	2
NY-98	290+00	1691	2
Haul road (Unnamed road near Auto Yard)	310+00	1717	0
Galen Hill Road	322+50	1722	3
NY-98	371+70	1759	4

According to the FEMA FIS profiles, the Sparks Road and Jones Road bridges do not meet the NYSDOT guidelines for 2 feet of freeboard over the 2% annual chance flood. In addition, these structures do not meet the CRRA climate change infrastructure guidelines as described above. Their low chord elevations are below the 1% annual chance flood event and they do not provide the recommended hydraulic capacity (FEMA 1991b). Even though these structures may have hydraulic capacity restraints, the NYSDOT has to balance both physical constraints along with cost versus benefit of replacing existing bridges to meet the CRRA guidelines.

In addition, the USGS *StreamStats* tool was used to calculate the bankfull widths and discharge for each structure along Clear Creek. The structures with bankfull widths that are wider than or close to the structures width, 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.

Table 10 indicates that there are four bridges and one culvert that cross Clear Creek with openings that are smaller than the bankfull widths: East Main Street (NY-39), Jones Road, Eagle Street, NY-98 (Station 371+70), and County Road 3. In addition, there are two bridges with openings that are very close (within five feet) of bankfull width: Galen Hill Road and Witt Road.

Table 10. Hydraulic Capacity of Potential Constriction Point Bridges Crossing Clear Creek

Source: (USGS 2017; NYSDOT 2019b; Ramboll 2021)

Roadway Carried	Structure Type	River Station (ft)	Structure Width (ft)	Bankfull Width (ft)	Bankfull Discharge (cfs)	Annual Chance Flood Event Equivalent [1]
East Main Street (NY-39)	Bridge	2+80	43.5	72.3	891	80-percent
Bray Road	Bridge	96+60	94	69.3	818	80-percent
Sparks Road	Bridge	180+00	72	66.5	753	80-percent
Jones Road	Bridge	202+30	60	65.5	731	80-percent
Eagle Street	Bridge	224+15	54	55.9	532	80-percent
NY-98 (1)	Bridge	290+00	93	52.6	469	66.7-percent
Haul Road (Unnamed Road near Auto Yard)	Culvert	310+00	29	52.4	467	66.7-percent
Galen Hill Road	Bridge	322+50	55	50.8	438	66.7-percent
NY-98 (2)	Bridge	371+70	40	44	329	66.7-percent
Freedom Road (CR-23) (1)	Bridge	397+85	66	43.7	323	66.7-percent
Freedom Road (CR-23) (2)	Bridge	428+50	46	29.1	143	80-percent
Depot Street	Bridge	435+70	46	28.7	139	80-percent
CSX Transportation (Abandoned)	Railroad Bridge	443+35	35	28.6	138	80-percent
Witt Road	Bridge	454+15	30	28.2	134	80-percent
Freedom Road (CR-23) (3)	Bridge	464+05	40	22.1	82.4	80-percent
Buffalo Road (CR-3)	Culvert	589+40	12	12.1	24.5	80-percent

[1] 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% annual chance flood event is equal to a 1.25-yr recurrence interval, while the 66.7% annual chance flood event is equal to a 1.5-yr recurrence interval.

4. CLIMATE CHANGE IMPLICATIONS

4.1 FUTURE PROJECTED STREAM FLOW IN CLEAR 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, New York State passed the CRRA in 2014 and provided guidelines for estimating projected future discharges in their 2020 report. In the report, two methods were discussed: an “end of design life multiplier”, and the USGS *FutureFlow Explorer* map-based web application (NYSDEC 2020a).

The “end of design life multiplier” is described as an adjustment to current peak flow values by multiplying relevant peak flow parameters by a factor specific to the expected service life of the structure and geographic location of the project to estimate future peak flow conditions. For Western New York, the recommended design-flow multiplier is 10% for an end of design life of 2025-2100 (NYSDEC 2020a).

USGS *FutureFlow Explorer* v1.5 (https://ny.water.usgs.gov/maps/floodfreq-climate/) is discussed as a potential tool to project peak flows under various climate scenarios into the future. *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) 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 2020a).

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 state (NYSDEC 2020a).

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 2020a).

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 western New York, the recommended design-flow multiplier is 10% increased flow for an end of design life of 2025-2100 (NYSDEC 2020a). Table 11 is a summary of the USGS *FutureFlow* projected peak discharges at the FEMA FIS locations along Clear Creek.

Table 11. USGS *FutureFlow* Projected Peak Discharges Along Clear Creek

(Source: USGS 2016)						
			Peak Discharges (cfs)			
Flooding Source and Location	**Drainage Area (mi^2)**	**River Station (ft)**	**10-Percent**	**2-Percent**	**1-Percent**	**0.2-Percent**
Above confluence with Cattaraugus Creek	32.1	0+00	3,190	4,800	5,520	7,390
At a point approximately 3,900-ft upstream of confluence with Cattaraugus Creek	31.5	39+00	3,160	4,750	5,480	7,330
Approximately 3,375-ft upstream of Main Street at confluence of Clear Creek Tributary	31.2	40+00	3,110	4,680	5,390	7,210
At Bray Road bridge	29.0	90+00	2,860	4,300	4,950	6,610
At a point approximately 0.3-mi upstream of Eagle Street bridge	17.2	218+50	1,570	2,330	2,670	3,520
At a point approximately 0.17-mi east of Maple Grove Road	15.2	226+00	1,340	1,970	2,250	2,950
At a point approximately 0.15-mi upstream of Galen Hill Road bridge	13.8	299+00	1,180	1,730	1,970	2,580

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 0.5-ft higher at specific locations, generally upstream of bridges due to backwater, as a result of the increased discharges.

Table 12 provides a comparison of the percent change in peak stream flows between the USGS *StreamStat* and *FutureFlow* software at FEMA FIS locations along Clear Creek.

Table 12. Percent Change Comparison of Current and Future Discharges

(Source: USGS 2016; USGS 2017)

Flooding Source and Location	Drainage Area (mi²)	River Station (ft)	Percent Change (%)			
			10-Percent	2-Percent	1-Percent	0.2-Percent
Above confluence with Cattaraugus Creek	32.1	0+00	11	8	7	6
At a point approximately 3,900-ft upstream of confluence with Cattaraugus Creek	31.5	39+00	10	8	7	6
Approximately 3,375-ft upstream of Main Street at confluence of Clear Creek Tributary	31.2	40+00	10	8	7	6
At Bray Road bridge	29.0	90+00	10	8	7	5
At a point approximately 0.3-mi upstream of Eagle Street bridge	17.2	218+50	10	7	7	5
At a point approximately 0.17-mi east of Maple Grove Road	15.2	226+00	11	8	8	6
At a point approximately 0.15-mi upstream of Galen Hill Road bridge	13.8	299+00	10	7	7	6

Due to the fact that the percent change comparison for the current and future peak discharges are less than the NYSDEC recommended design-flow multiplier of 10%, the current peak discharges from *StreamStats* were increased by 10% for each annual chance flood event for this study. Table 13 is a summary of the future projected peak discharges using the 10% design-flow multiplier at the FEMA FIS locations along Clear Creek.

Table 13. Future Projected Peak Discharges Along Clear Creek Using the NYSDEC 10% Design-Flow Multiplier

(Source: USGS 2016; NYSDEC 2020a)						
			Peak Discharges (cfs)			
Flooding Source and Location	**Drainage Area (mi^2)**	**River Station (ft)**	**10-Percent**	**2-Percent**	**1-Percent**	**0.2-Percent**
Above confluence with Cattaraugus Creek	32.1	0+00	3,170	4,880	5,670	7,690
At a point approximately 3,900-ft upstream of confluence with Cattaraugus Creek	31.5	39+00	3,150	4,840	5,620	7,620
Approximately 3,375-ft upstream of Main Street at confluence of Clear Creek Tributary	31.2	40+00	3,100	4,770	5,540	7,510
At Bray Road bridge	29.0	90+00	2,860	4,390	5,090	6,900
At a point approximately 0.3-mi upstream of Eagle Street bridge	17.2	218+50	1,570	2,390	2,750	3,690
At a point approximately 0.17-mi east of Maple Grove Road	15.2	226+00	1,330	2,000	2,300	3,060
At a point approximately 0.15-mi upstream of Galen Hill Road bridge	13.8	299+00	1,180	1,770	2,020	2,680

Table 14 provides a comparison of HEC-RAS base condition, using USGS *StreamStats*, and future condition, using the NYSDEC 10% design-flow multiplier, water surface elevations at select locations along Clear Creek.

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

(Source: USGS 2016, USGS 2017, USACE 2016a)

			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**
Above confluence with Cattaraugus Creek	32.1	0+00	+ 0.5	+ 0.3	+ 0.4	+ 0.3
At a point approximately 3,900-ft upstream of confluence with Cattaraugus Creek	31.5	39+00	+0.3	+ 0.3	+ 0.3	+ 0.2
Approximately 3,375-ft upstream of Main Street at confluence of Clear Creek Tributary	31.2	40+00	+ 0.2	+ 0.4	+ 0.3	+ 0.3
At Bray Road bridge	29.0	90+00	+ 0.1	+ 0.2	+ 0.3	+ 0.2
At a point approximately 0.3-mi upstream of Eagle Street bridge	17.2	218+50	+ 0.4	+ 0.5	0.0	+ 0.1
At a point approximately 0.17-mi east of Maple Grove Road	15.2	226+00	+ 0.1	+ 0.3	+ 0.3	+ 0.3
At a point approximately 0.15-mi upstream of Galen Hill Road bridge	13.8	299+00	+ 0.2	+ 0.3	+ 0.3	+ 0.3

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

5. FLOODING CHARACTERISTICS

5.1 FLOODING HISTORY

Flooding along Clear Creek generally occurs in the summer and early winter months due to heavy rain, or rain on saturated soil events. Flooding has also occurred in the winter from a combination of snow melt and rainfall. The situation is compounded at the confluence with Cattaraugus Creek due to backwater and the low relief topography in the area.

In the Village and Town of Arcade, low-lying areas are subject to periodic flooding caused by the overflow of Cattaraugus and Clear Creeks at their confluence, where the Water Street and Main Street bridges on the respective creeks are subject to frequent clogging by trees and debris. The floodwater from both areas backs up and flows down Pearl Street and along the south side of Main Street. Other frequent flooding areas are Park and Prospect Streets, and the Arcade Elementary School. The runoff coming down the hill at the end of Park and Prospect Streets, and the overflow diversion area from Haskell Creek, are the main sources of flooding in this area (FEMA 1992b; FEMA 1992d).

The greatest recorded flood in the Village and Town occurred on July 6, 1902. The estimated peak discharge was 27,000 cubic feet per second (cfs) at the former USGS gage site. That flood is estimated to have had a recurrence interval of greater than 200 years (USACE 1968). The flood on September 28, 1967 was estimated to have had a 40-yr recurrence interval, with a peak discharge of 9,820 cfs at the former USGS gage site. Other significant floods occurred in 1908; March 1942; March 1956; March 1957; March 1971; June 1972 (Hurricane Agnes); June 18, 1984; and June 11, 1986 (FEMA 1992b; FEMA 1992d). More recently, there have been reported flood events in the Village and Town on November 17-26, 2014; May 20, 2015; and June 14, 2015. Although the county was impacted from these flooding events, the Town did not report any damages, and the Village only reported snow removal costs for the November 2014 event (Tetra Tech 2021).

In addition to flooding issues, the Village and Town of Arcade experience erosion, sediment aggradation, and tree and debris blockages along Clear Creek. There are issues of erosion along the roadside embankment near Clearview Drive on Bray Road. During heavy rain events, the creek overtops its banks as it approaches Bray Road (which separates Wyoming and Cattaraugus County) on the Cattaraugus County side. This spillover leads to streambank erosion and loss of bank every year (NYSDEC 2021b).

In the Town of Freedom, local newspaper articles indicate that flooding on Clear Creek occurred in 1902, 1971, 1972, 1984, 1985, and 1986 (Reference 2). Frequency interval for these floods is not known since no data are available. Local officials report that some bridges were destroyed in the 1986 flood (FEMA 1991b). More recently, there have been reported flood events in the Town on October 27-November 9, 2012 (Hurricane Sandy); May 13-22, 2014; November 17-26, 2014; and July 14, 2015. Although the county was impacted from these flooding events, the Town did not report any damages (Tetra Tech 2020).

The Town of Freedom also experiences erosion, sediment aggradation, and tree and debris blockages along Clear Creek. Along the reach between Sparks Road and Jones Road in the Town, changes in the grading of the stream bed (most likely a result of sediment aggradation from upstream materials) has led to localized flooding issues. Cattaraugus County has identified this area as requiring streambank stabilization to prevent further aggradation and flooding issues (NYSDEC 2021b).

According to FEMA flood loss data, there has been a total of 35 NFIP claims totaling approximately $588,848 building and contents payments within the Village of Arcade, and Towns of Arcade and Freedom since 1979. In addition, there are 37 properties identified as repetitive loss and no severe repetitive loss properties within the Village of Arcade, and Towns of Arcade and Freedom. Of the 37 repetitive loss properties, there are 3 properties within the Clear Creek watershed, all of which are in the Village of Arcade (FEMA 2019; Tetra Tech 2020; Tetra Tech 2021). 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.

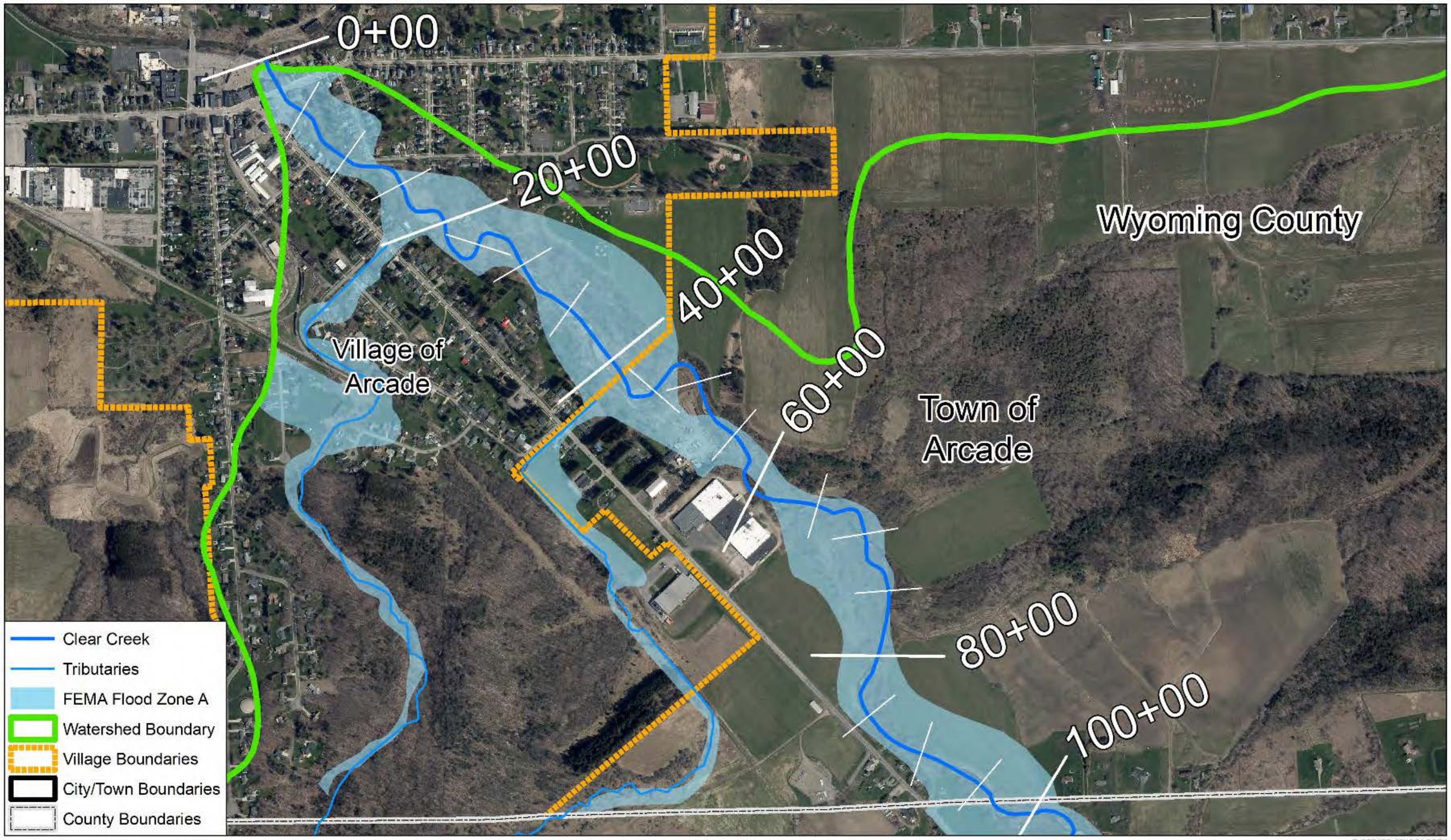
Table 15. FEMA NFIP Statistics Summary

Source: (Tetra Tech 2020; Tetra Tech 2021)

Municipality	No. of Policies	No. of Claims (Losses)	Total Loss Payments ($ USD)	No. of RL Properties
Village of Arcade	39	26	$500,464	32
Town of Arcade	4	5	$7,378	2
Town of Freedom	7	4	$81,006	3
Total	50	35	$588,848	37

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 claims payments have been made with the cumulative amount of 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.

FEMA FIRMs are available for Clear Creek from FEMA. Figures 5-1 and 5-2 display the Zone A (1% annual-chance flood event) boundaries for Clear Creek as determined by FEMA for the Village and Town of Arcade, and the Town of Freedom, respectively. The maps indicate that in the Clear Creek watershed, flooding generally occurs upstream of the confluence of Cattaraugus and Clear Creeks in the Village and Town of Arcade and in the hamlet of Sandusky in the Town of Freedom (FEMA 1996).



RAMBOLL

FIGURE 5-1
FEMA FLOOD ZONES
CLEAR CREEK, VILLAGE & TOWN OF ARCADE, WYOMING COUNTY, NY

This figure was prepared as part of the Hazard Mitigation Study of Clear Creek conducted for the New York State Department of Environmental Conservation as part of the Governors Resilient NY Initiative (NYSOGS Contract SC498).

Figure 5-1. Clear Creek, FEMA flood zones, Village and Town of Arcade, Wyoming County, NY.

*Note: This map was created using FIRMs georeferenced to the earth's surface. This figure is not official and may not be used for regulatory purposes.

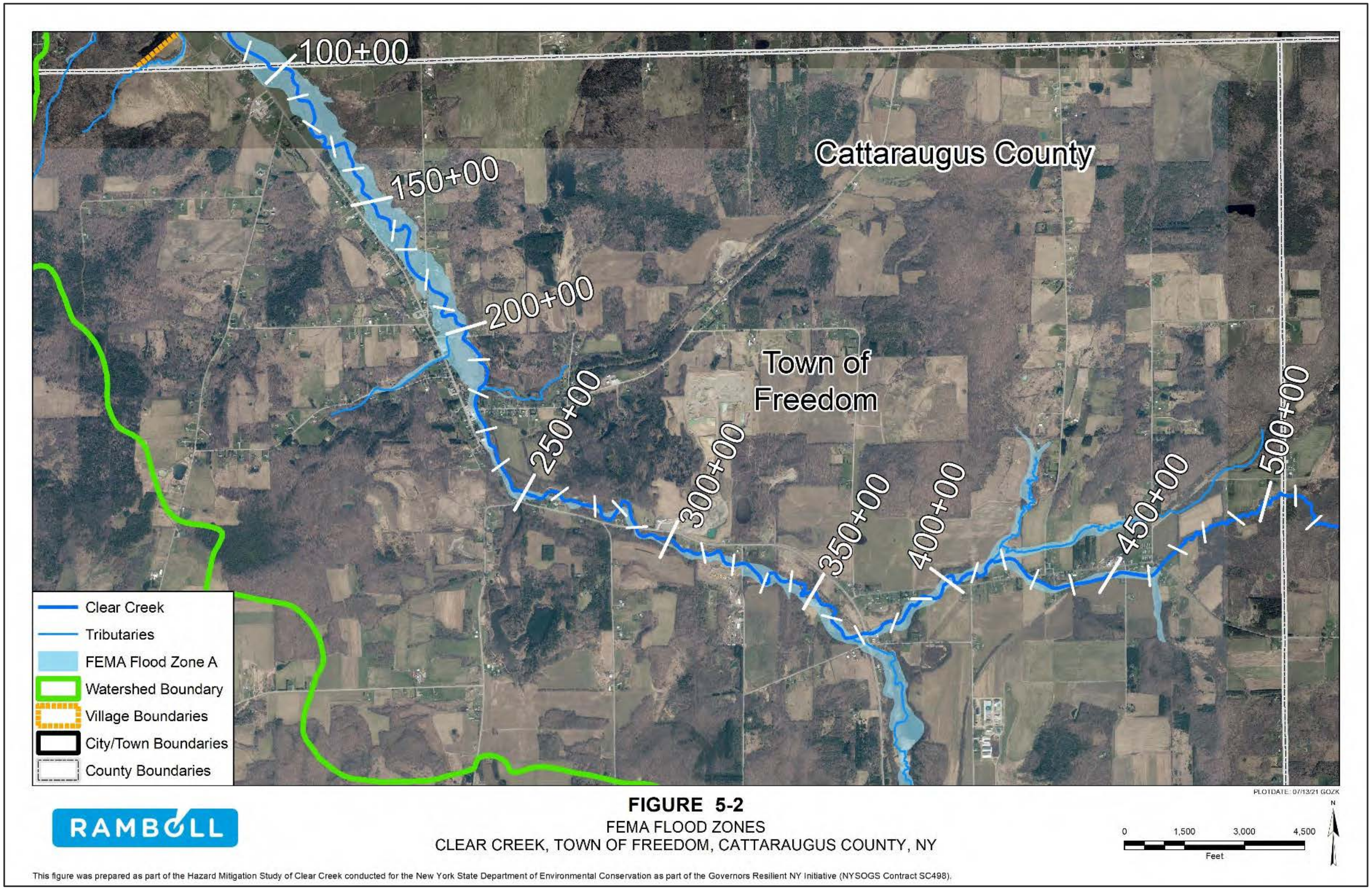


Figure 5-2. Clear Creek, FEMA flood zones, Town of Freedom, Cattaraugus County, NY.

*Note: This map was created using FIRMs georeferenced to the earth's surface. This figure is not official and may not be used for regulatory purposes.

6. FLOOD RISK ASSESSMENT

6.1 FLOOD MITIGATION ANALYSIS

Flood events of a magnitude which are expected to be equaled or exceeded on the average during any 10, 50, 100, or 500-yr period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance premium rates. These events, commonly termed the 10, 50, 100, and 500-yr 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 (FEMA 1991b). The analyses reported here reflect flooding potentials based on conditions existing in the community at the time of completion of this study.

Hydraulic analysis of Clear Creek was conducted using the HEC-RAS v5.0.7 program. 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 and 2-Dimensional (2-D), steady-state, or time-varied (unsteady) flow. In 1-Dimensional (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 2016a).

Hydraulic and Hydrologic modeling of Clear Creek was completed by FEMA for the Village and Town of Arcade in 1992, and for the Town of Freedom in 1991. Due to the age and format of the FIS study, an updated 1-D HEC-RAS model was developed using the following data and software:

- New York State Digital Ortho-imagery Program imagery for Wyoming and Cattaraugus Counties (NYSOITS 2016; NYSOITS 2020)
- New York Southwest 1-meter LiDAR DEM data with a vertical accuracy of 0.7-ft (NYSOITS 2017)
- National Land Cover Database (NLCD) data (USGS 2021)
- RAS Mapper extension in HEC-RAS software
- ESRI ArcMap 10.7 with the HEC-GeoRAS extension GIS software (ESRI 2019)

The hydraulics model was developed for Clear Creek beginning at the confluence with Cattaraugus Creek (river station 0+00) and extending upstream to the NY-98 (2) waterway crossing in the vicinity of Phillippi and Moore Road (river station 0+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, a base condition model was developed using the following methodology:

- 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 exported to the ESRI ArcMap 10.7 GIS software
- Using the HEC-GeoRAS extension in ArcMap, LiDAR DEM and NLCD land cover data were obtained and used to develop updated terrain profiles for overbank areas, stream centerline and cross-section downstream reach lengths for the channel and left and right overbanks, flow paths and Manning's n values for land use were assigned
- The stream centerline, cross-sections, bank lines, flow paths, and land use data were then imported back into HEC-RAS where a 1-D steady flow simulation was performed using the effective FEMA FIS peak discharges

Downstream boundary conditions for the base and future conditions models were based on the slope of the downstream reach, also referred to as Normal Depth, of Cattaraugus Creek in the vicinity of the confluence with Clear Creek. Due to the proximity of the East Main Street (NY-39) bridge crossing to the confluence of Clear and Cattaraugus Creeks, the H&H model did not have the required downstream length to properly resolve the water surface elevations after the influence of the bridge was taken into account. Also, the slope of Cattaraugus Creek in this area is the control of water surface elevations at the confluence with Clear Creek due to the size and discharge volume of Cattaraugus Creek compared to Clear Creek. Therefore, the Normal Depth for Cattaraugus Creek in the vicinity of the confluence with Clear Creek was used as the downstream boundary condition for the H&H model.

In addition, the 1% annual chance event (100-yr) water surface elevation for the confluence of Clear and Cattaraugus Creek is provided within the FIS for the Village of Arcade; however, FEMA incorporates the backwater influence of Cattaraugus Creek into the profile plots. This does not give an accurate representation of the flood risk due solely to Clear Creek in the downstream reach.

The base condition model water surface elevation results were then compared to the FEMA FIRM and FIS profile 1% annual chance event water surface profiles and past flood events with known water surface elevations to validate the model.

After the base 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.

As the potential flood mitigation strategies 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 within this report reflects that of the effective FEMA FIRMs for the Village of Arcade and the Towns of Arcade and Freedom.

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:

- Flood benches upstream of confluence with Unnamed Tributary
- Flood benches upstream of the Village corporate limits
- Flood benches downstream of Sparks Road
- Levee along NY-98 downstream of Sparks Road
- Flood benches upstream of Sparks Road
- Increase size of Sparks Road bridge opening
- Flood benches upstream of Jones Road
- Increase size of Jones Road bridge opening

Streambank stabilization alternatives were evaluated using the base condition model results of channel velocity and shear stress. The remaining alternatives were either qualitative in nature or required additional advanced 3-D modeling outside of the scope of this study.

Note that stationing references for Clear Creek for Sections 1 through 6 of this report are based on the USGS National Hydrography Dataset (NHD) for Clear Creek (USGS 2020); 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.

6.2 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% annual chance flood event. 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% annual chance flood event. 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.

6.3 ICE-JAM FORMATION

According to the USACE Cold Regions Research and Engineering Laboratory (CRREL) ice-jam database, NCEI storm events database, and the stakeholder engagement meeting, there have been no reported or observed ice-jam events on Clear Creek (NYSDEC 2021b; CRREL 2021; NCEI 2021).

Based on the available data, ice-jam flooding was determined not to be a driving factor of flood risk in the Village of Arcade and Towns of Arcade and Freedom. Instead, restrictive infrastructure, sediment / debris, and erosion were identified to be the primary drivers of flood risk within the watershed.

6.4 HIGH-RISK AREAS

Based on the FEMA FIS, NCEI storm events database, historical flood reports, and stakeholder input from engagement meetings, three areas along Clear Creek were identified as high-risk flood areas in Wyoming and Cattaraugus Counties, New York.

6.4.1 High-Risk Area #1: Confluence of Cattaraugus and Clear Creeks, Village of Arcade, Wyoming County, New York

High-risk Area #1 is the area upstream of the confluence of Cattaraugus and Clear Creeks in the Village of Arcade starting at river station 0+00 and extending upstream to river station 40+00. Flooding in this area poses a threat to numerous residential and commercial properties along East Main (NY-39), Liberty, Grove, and Pearl Streets. In addition, NYSDOT and Village-owned infrastructure, including the East Main Street (NY-39) bridge crossing, are within the FEMA flood Zone A and are at risk of flooding during high-flow or backwater events on Clear Creek (Figure 6-1).

According to the FEMA FIS for the Village of Arcade, the East Main Street (NY-39) bridge crossing is unable to pass a 1% annual chance flood hazard (Figure 6-2). Indicated on the FIS profile plot, backwater from Cattaraugus Creek causes water surface elevations to overtop the bridge during high flow events (FEMA 1992c; FEMA 1992d).

This reach is also susceptible to sediment aggradation and trees 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 backwater upstream of structures and / or meanders.

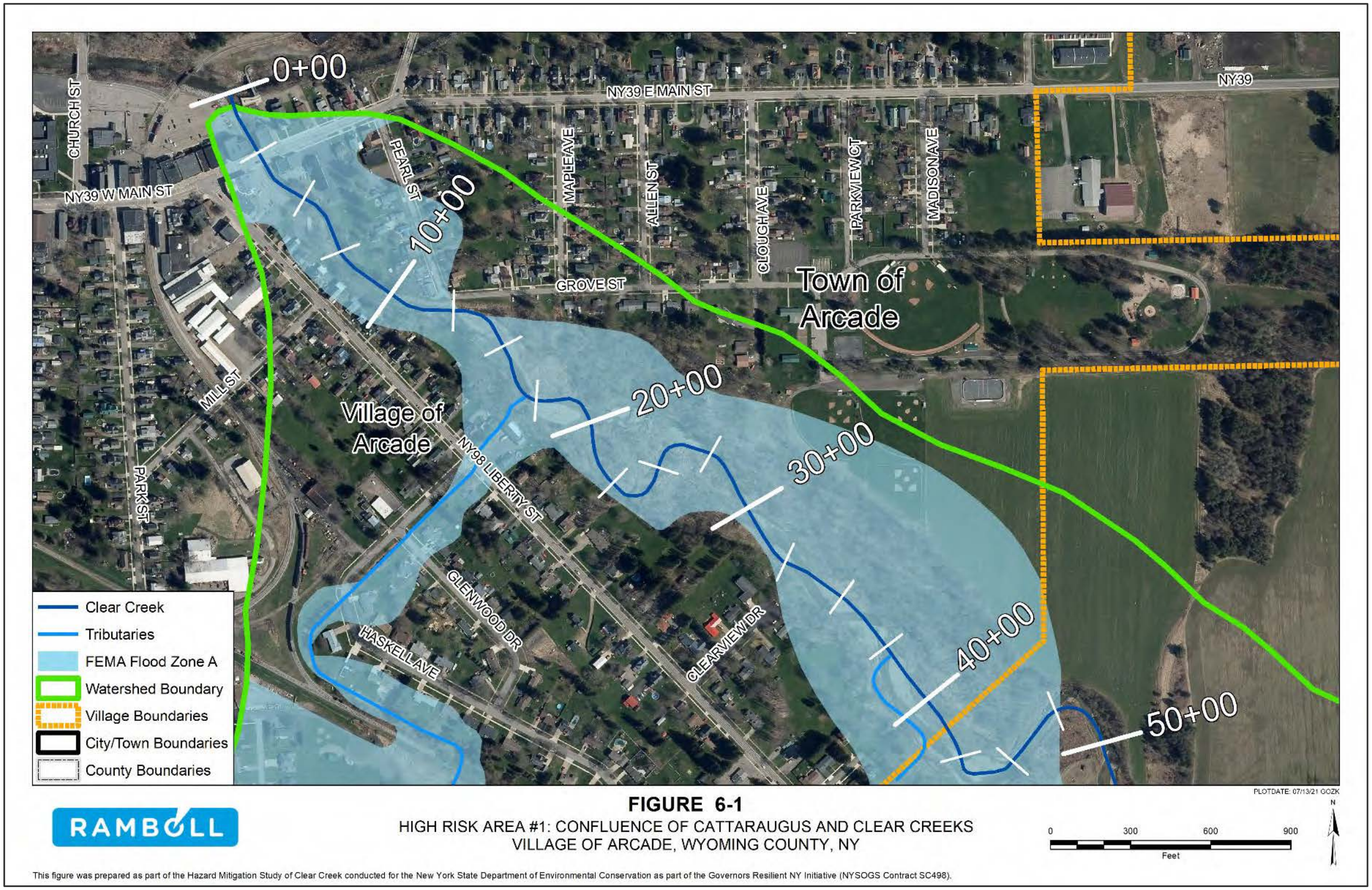


Figure 6-1. High-risk Area #1: Confluence of Cattaraugus and Clear Creeks, Village of Arcade, Wyoming County, NY.

*Note: This map was created using FIRMs georeferenced to the earth's surface. This figure is not official and may not be used for regulatory purposes.

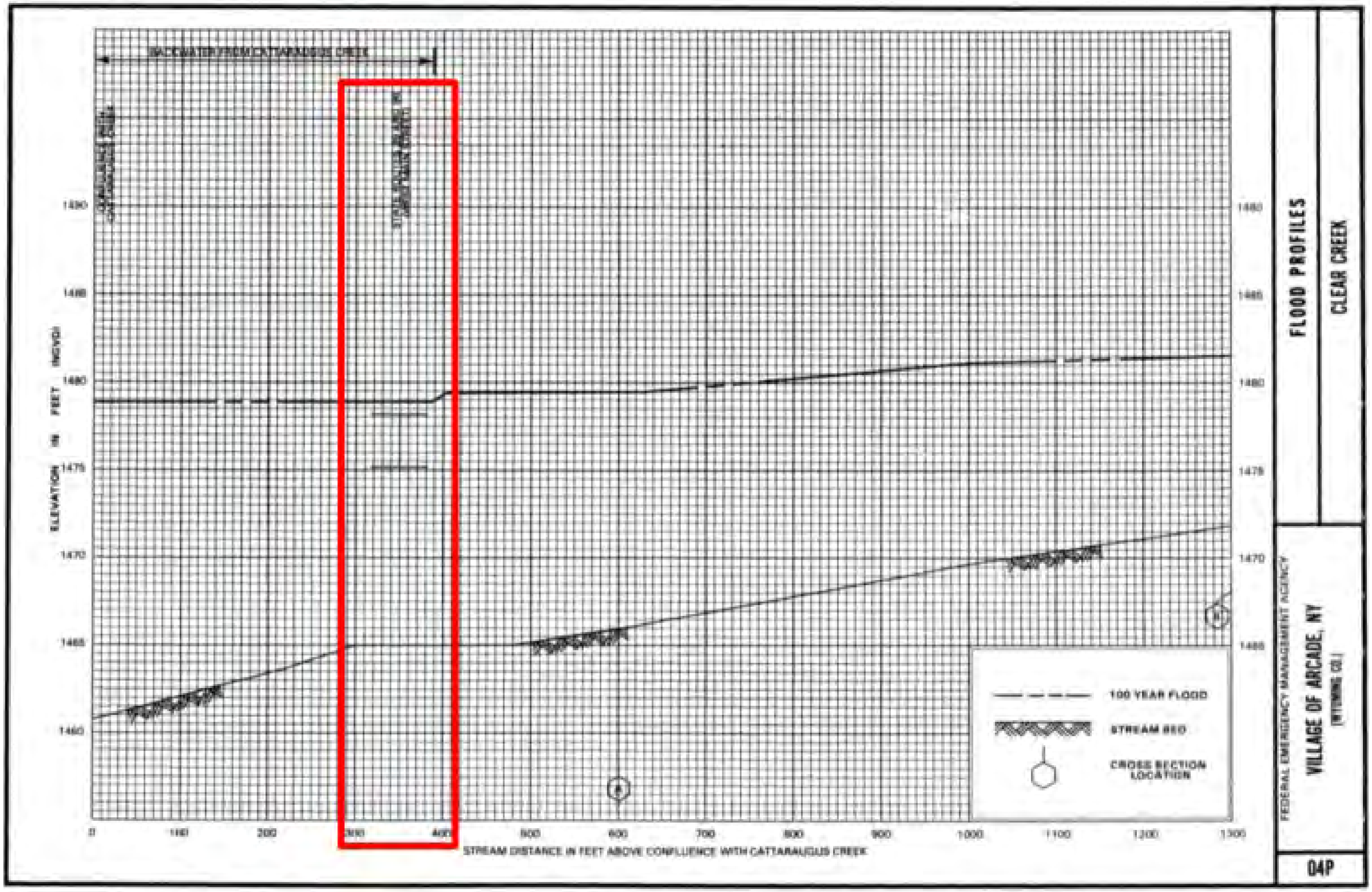


Figure 6-2. FEMA FIS profile for Clear Creek at the confluence with Cattaraugus Creek in the Village of Arcade, NY.

Note: The East Main Street (NY-39) bridge is located at river station 3+50 on the FEMA FIS profile.

6.4.2 High-Risk Area #2: Stuart Avenue to Bray Road Corridor, Town of Arcade, Wyoming County, New York

High-risk Area #2 is the area between Stuart Avenue and Bray Road in the Town of Arcade, starting at river station 40+00 and extending upstream to river station 97+00 (Figure 6-3). The flooding in this area occurs primarily over undeveloped land; however, a large commercial warehouse and multiple commercial properties are within the FEMA Zone A flood area. In addition, there is an unnamed tributary that empties into Clear Creek adjacent to the Stuart Avenue neighborhood near river station 40+00. This tributary contributes to the flood risk in this area by creating a flood risk for numerous residential properties and the Liberty Street (NY-98) bridge crossing from high-flow events.

According to the FEMA FIS for the Town of Arcade, the Liberty Street (NY-98) bridge crossing is unable to pass the 1% annual chance flood hazard (Figure 6-4). This is most likely a result of the hydrologic characteristics of the unnamed tributary and backwater effects from Clear Creek (FEMA 1992a; FEMA 1992b).

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 backwater upstream of structures and / or meanders.

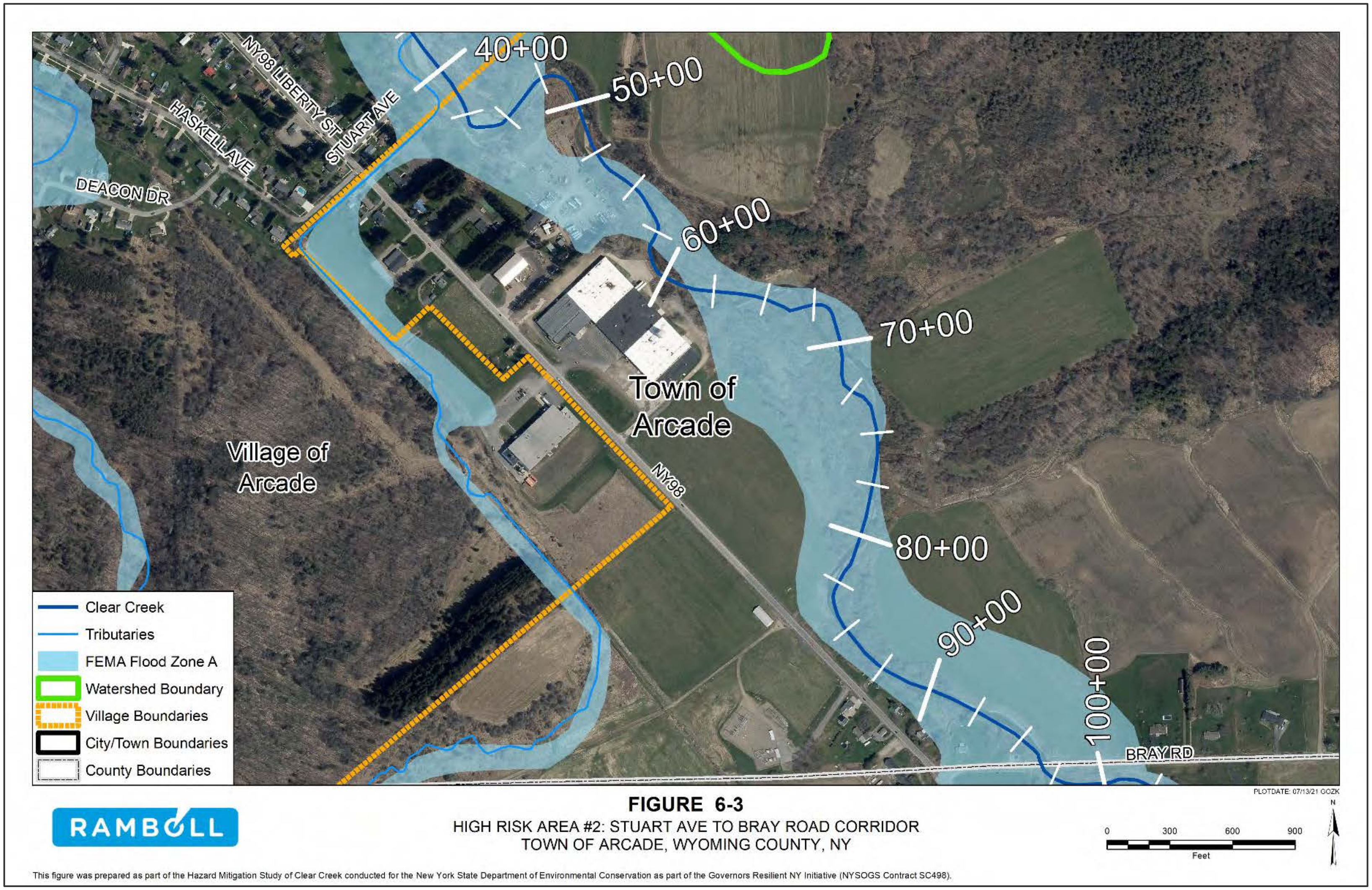


Figure 6-3. High-risk Area #2: Stuart Avenue to Bray Road Corridor, Town of Arcade, Wyoming County, NY.

*Note: This map was created using FIRMs georeferenced to the earth's surface. This figure is not official and may not be used for regulatory purposes.

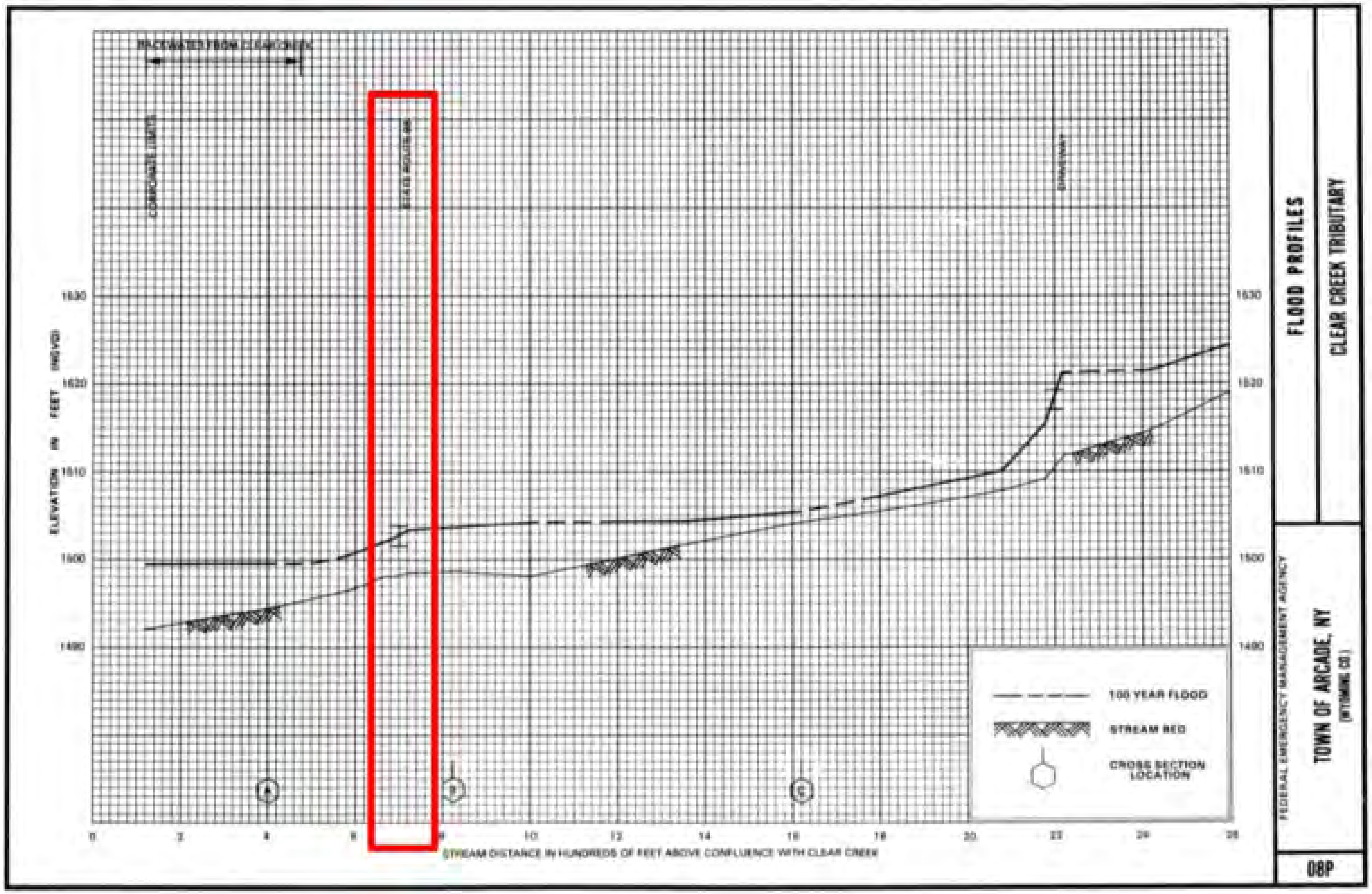


Figure 6-4. FEMA FIS profile for Clear Creek Tributary at the confluence with Clear Creek in the Town of Arcade, NY.

Note: The Liberty Street (NY-98) bridge crossing is located at river station 7+00 on the FEMA FIS profile.

6.4.3 High-risk Area #3: Sparks Road to Eagle Street Corridor, Town of Freedom, Cattaraugus County, New York

High-risk Area #3 is the area between Sparks Road and Eagle Street in the Town of Freedom starting at river station 180+00 and extending upstream to river station 220+00 (Figure 6-5). The flooding in this area occurs primarily over undeveloped land; however, there are sections of residential and commercial properties adjacent to Clear Creek that are within the FEMA Zone A flood zones, specifically between Sparks and Jones Roads. Both Sparks and Jones Roads are owned and maintained by the Town of Freedom, while NY-98 is owned and maintained by the NYSDOT. There are three unnamed tributaries that empty into Clear Creek, which are located at river stations 217+50, 192+50, and 181+00.

According to the FEMA FIS for the Town of Freedom, the Sparks and Jones Roads bridge crossings are unable to pass the 1% annual chance flood hazard (Figure 6-6). The flooding in this reach occurs most likely as a result of increased flow from tributaries, channel meanders, and undersized infrastructure (FEMA 1991a; FEMA 1991b).

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 backwater upstream of structures and / or meanders. In addition, the reach between Sparks and Jones Roads was identified as an area susceptible to flooding issues as a result of aggradation and destabilized banks, according to local stakeholders (NYSDEC 2021b).

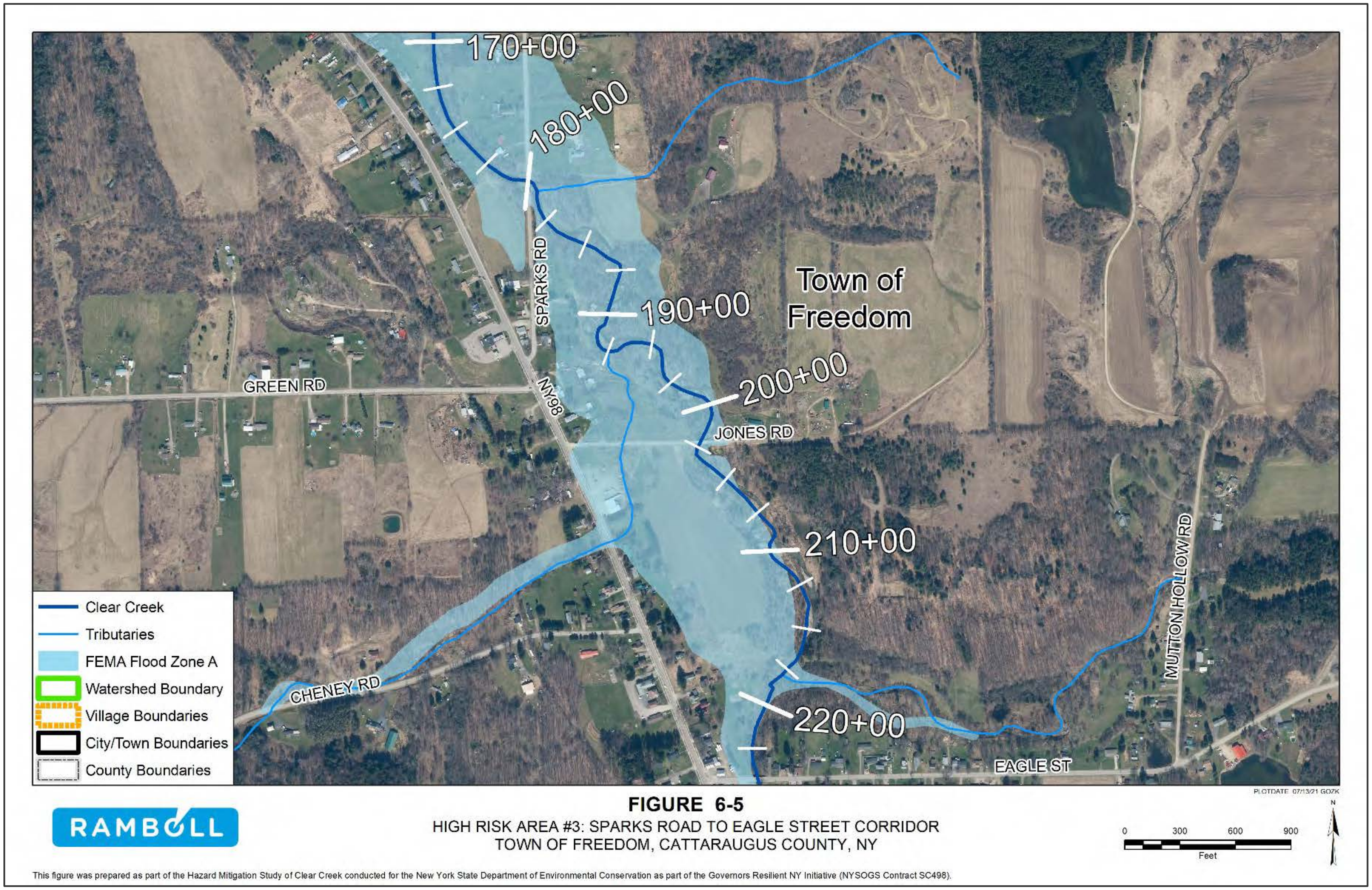


Figure 6-5. High-risk Area #3: Sparks Road to Eagle Street Corridor, Town of Freedom, Cattaraugus County, NY.

*Note: This map was created using FIRMs georeferenced to the earth's surface. This figure is not official and may not be used for regulatory purposes.

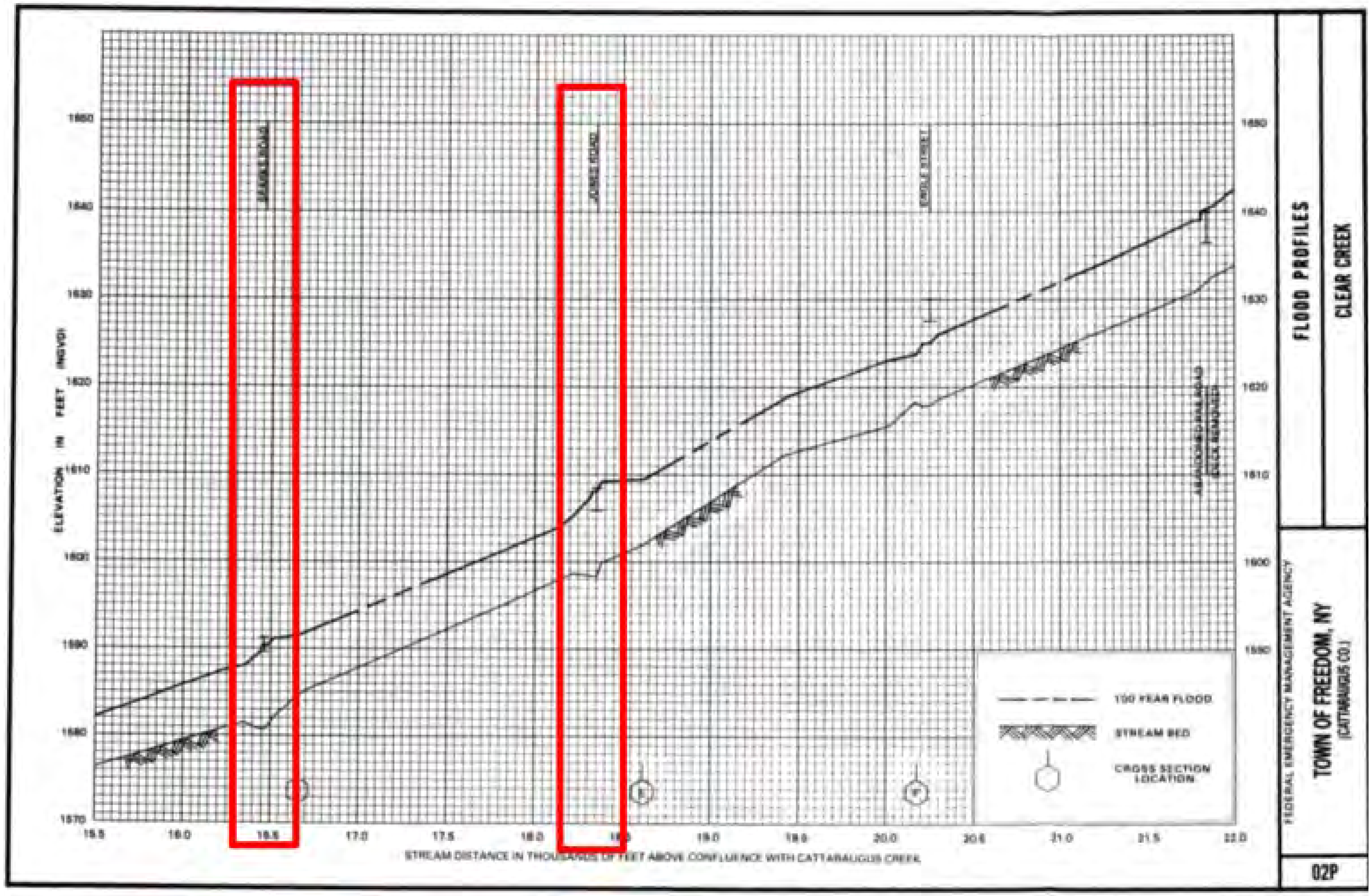


Figure 6-6. FEMA FIS profile for Clear Creek in the reach between Sparks Road and Eagle Street, Town of Freedom, NY.

Note: Sparks Rd is located at river station 164+50; Jones Rd is located at river station 183+50; and Eagle St is located at river station 202+50 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 Clear Creek. These alternatives could potentially reduce flood-related damages in areas adjacent to the creek. Local and State officials 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 / Debris Management at Mouth

This measure is intended to the remove deposited sediment at the outlet of Clear Creek with Cattaraugus Creek 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 occurs along Clear 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.

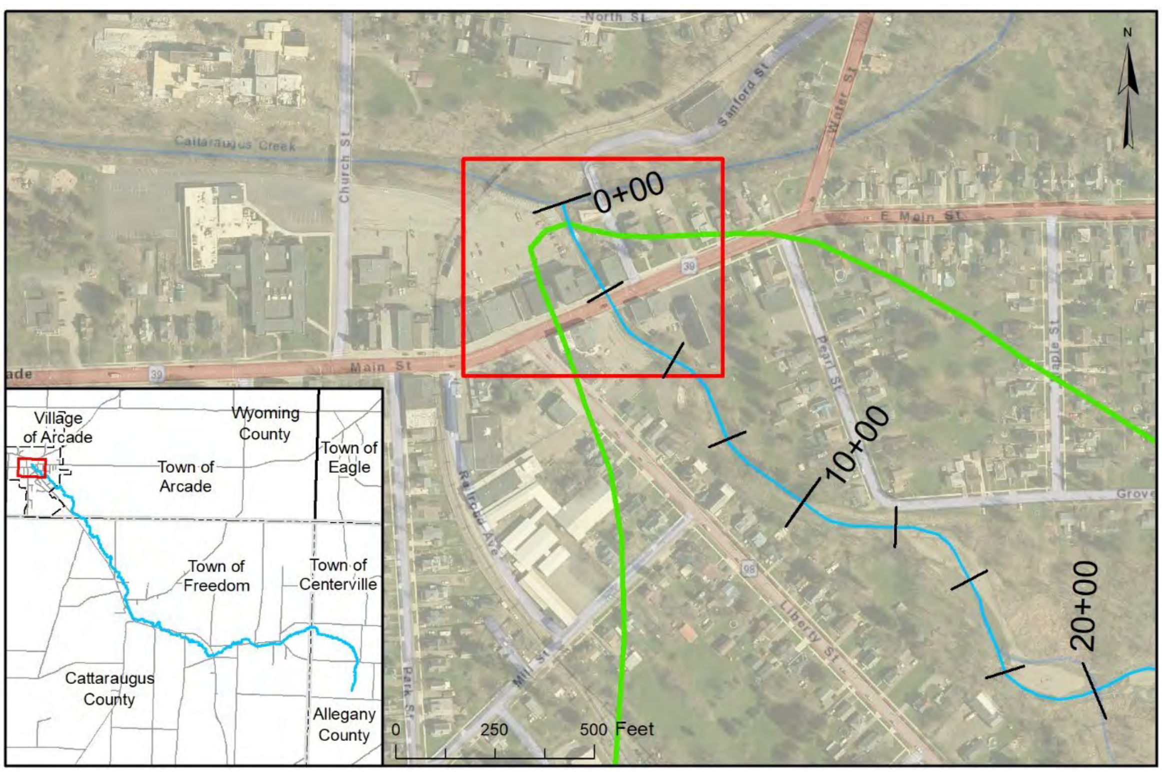


Figure 7-1. Location map for Alternative #1-1.

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 Clear Creek at the confluence with Cattaraugus Creek is 72.3-ft and 175-ft^2, respectively (USGS 2017).

Sediment management at the outlet can improve water quality of both Clear and Cattaraugus Creeks, and in-channel flow area and, thereby, reduce 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.

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 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.

The Rough Order Magnitude cost for this measure is $120,000, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

7.1.2 Alternative #1-2: Flood Benches Upstream of Confluence with Unnamed Tributary

Installing a flood bench would provide additional storage and floodplain width, 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 Liberty Street and Clearview Drive upstream of the East Main Street (NY-39) bridge crossing (Figure 7-2).

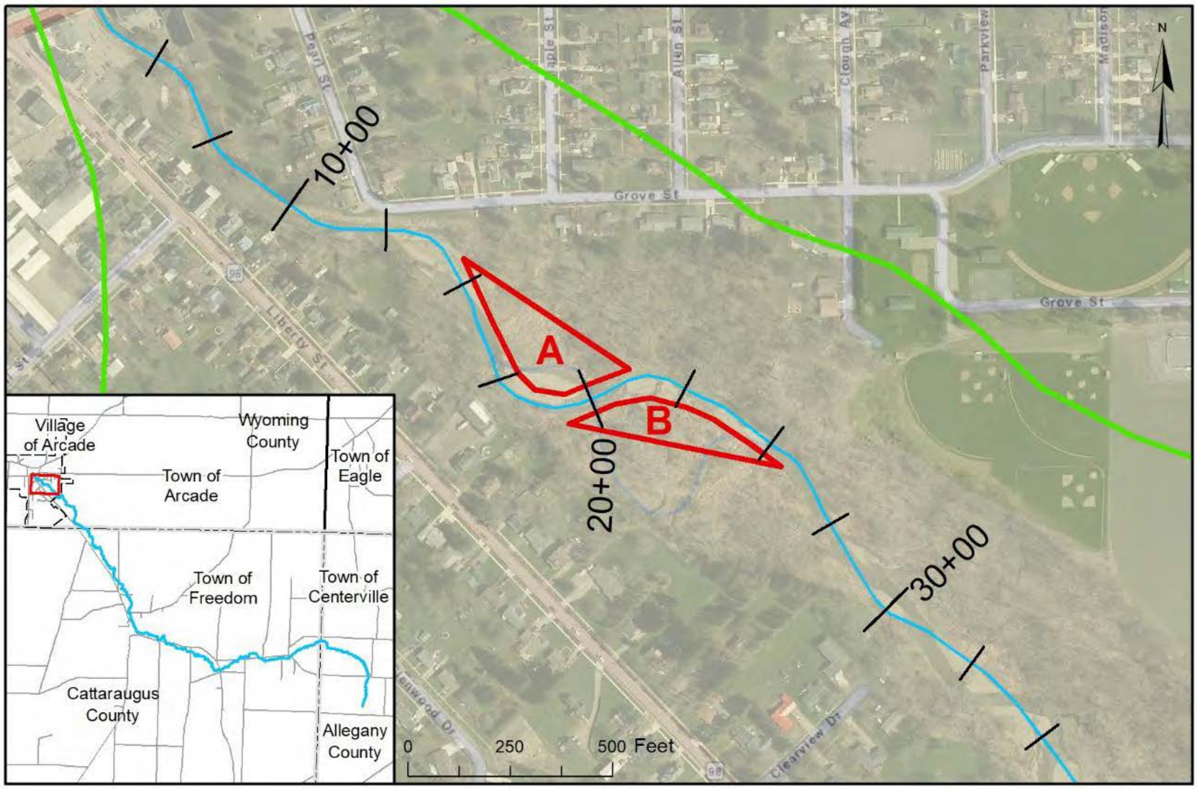


Figure 7-2. Location map for Alternative #1-2.

The flood bench designs used for the proposed condition model simulation set the minimum bench elevation approximately equal to the bankfull elevation. The flood bench river stationing, area, and average depths are summarized in Table 16.

Table 16. Alternative #1-2 Flood Bench Design Summary

Flood Bench	River Stationing	Area (acres)	Average Depth (ft)
Bench A	15+00 to 21+50	1.1	1.0
Bench B	19+50 to 25+50	0.8	2.0

The flood benches are within the FEMA designated SFHA or Zone AE, which are areas subject to inundation by the 1% annual chance flood event with base flood elevations determined and where mandatory flood insurance purchase requirements and floodplain management standards apply (FEMA 1992a). Appendix E depicts a flood mitigation rendering of a flood bench illustrating before and after landscape features.

Table 17 outlines the results of the existing and future conditions model simulations for the flood bench alternatives (Appendix G). Figures 7-3 and 7-4 display the profile plots for each flood bench alternative.

Table 17. Summary Table for Alternative #1-2 Existing and Future Conditions for Each Flood Bench

	Reductions in Water Surface Elevations (feet)	
	Flood Bench A	**Flood Bench B**
Existing Conditions	Up to 1.0-ft	Up to 1.6-ft
Total Length of Benefited Area	2,150-ft	1,500-ft
River Stations	17+50 to 39+00	13+50 to 28+50
Future Conditions	Up to 1.0-ft	Up to 1.6-ft

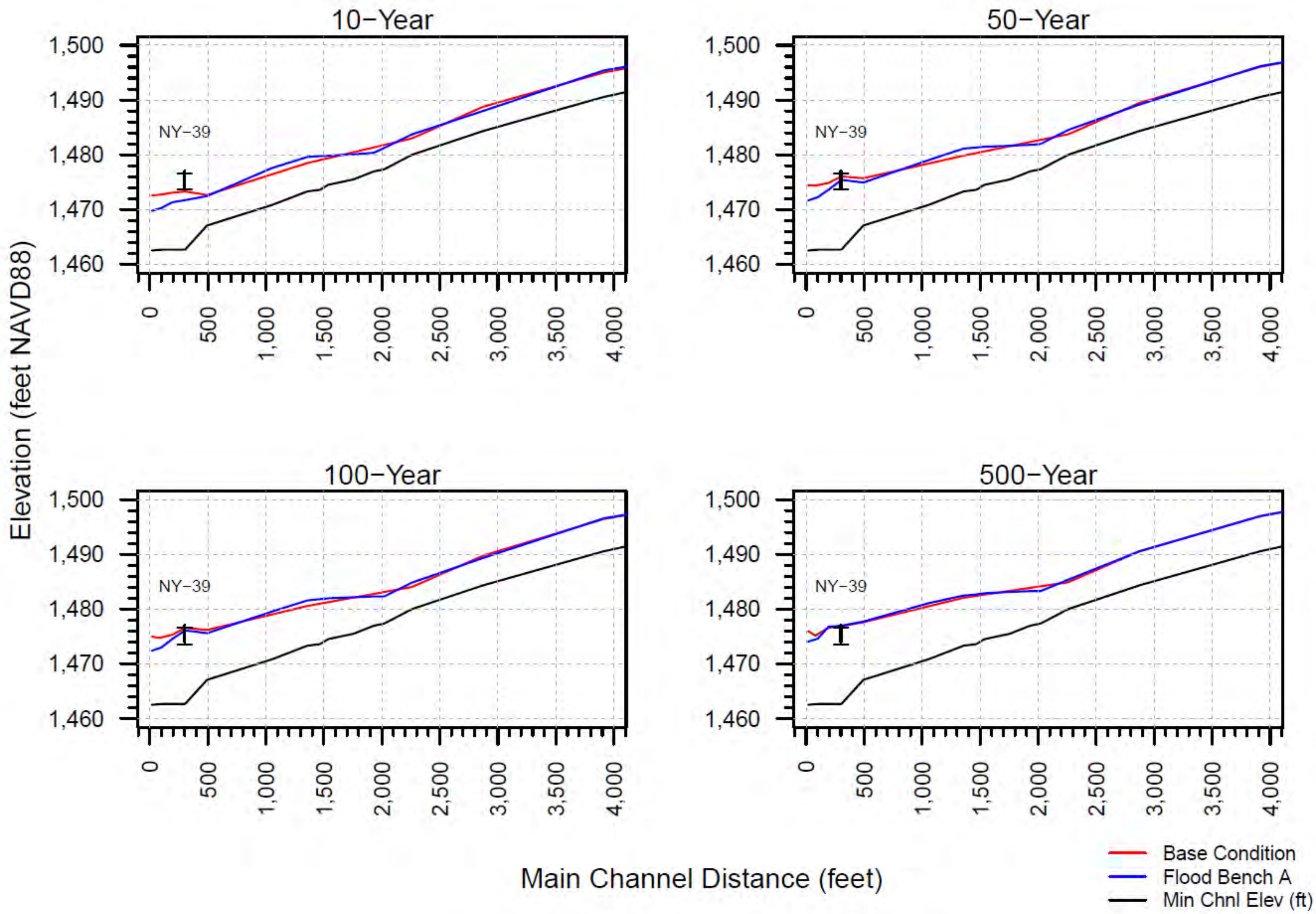


Figure 7-3. HEC-RAS model simulation output results for Alternative #1-2 Flood Bench A.

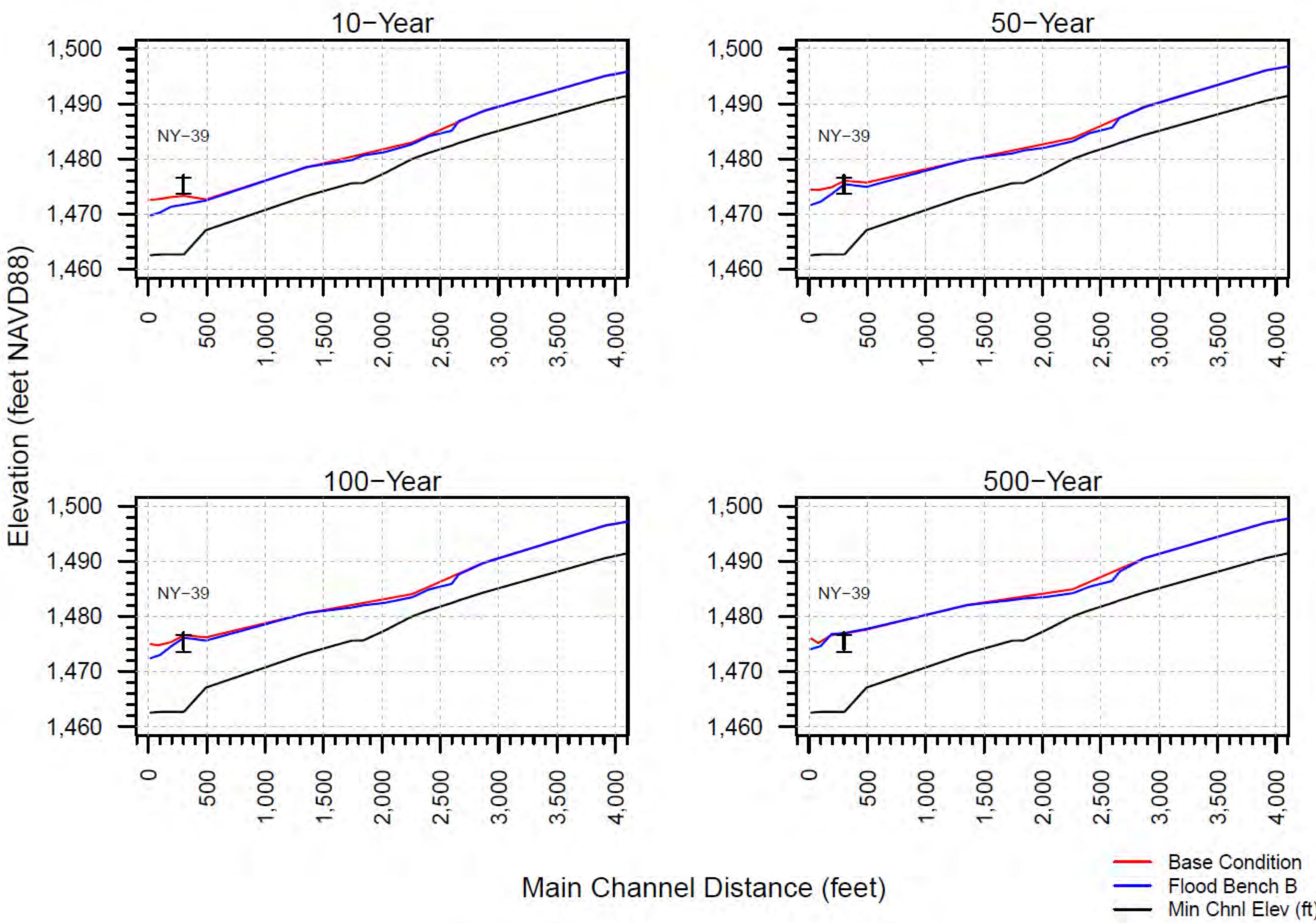


Figure 7-4. HEC-RAS model simulation output results for Alternative #1-2 Flood Bench B.

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 East Main Street (NY-39) bridge crossing would provide flood protection in this reach from open-water flooding, but this benefit is limited when analyzing the model results for Flood Bench A. Flood Bench A had mixed results with both water surface reductions and increases in this reach. This is most likely a result of the morphological features of the channel in this area (i.e., the significant meander in the channel flow path upstream of Flood Bench A) and the distance of the flood bench upstream of the bridge crossing (Flood Bench A is closer to the bridge and is influenced by backwater effects upstream of the bridge).

The Rough Order Magnitude cost for each flood bench alternative is:

- Flood Bench A: $320,000
- Flood Bench B: $320,000

These cost estimates do not include land acquisition costs for survey, appraisal, and engineering coordination. Based on the model simulations results, Flood Bench A is not recommended due to the limited benefit compared to cost for the flood bench.

7.1.3 Alternative #1-3: Sediment / Debris Retention Basin Downstream of the Village Corporate Limits

Sediment retention basins 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 basin is an earth embankment or a combination ridge and channel generally constructed across the slope and minor watercourses to form a sediment trap and water detention basin (Figure 7-5).

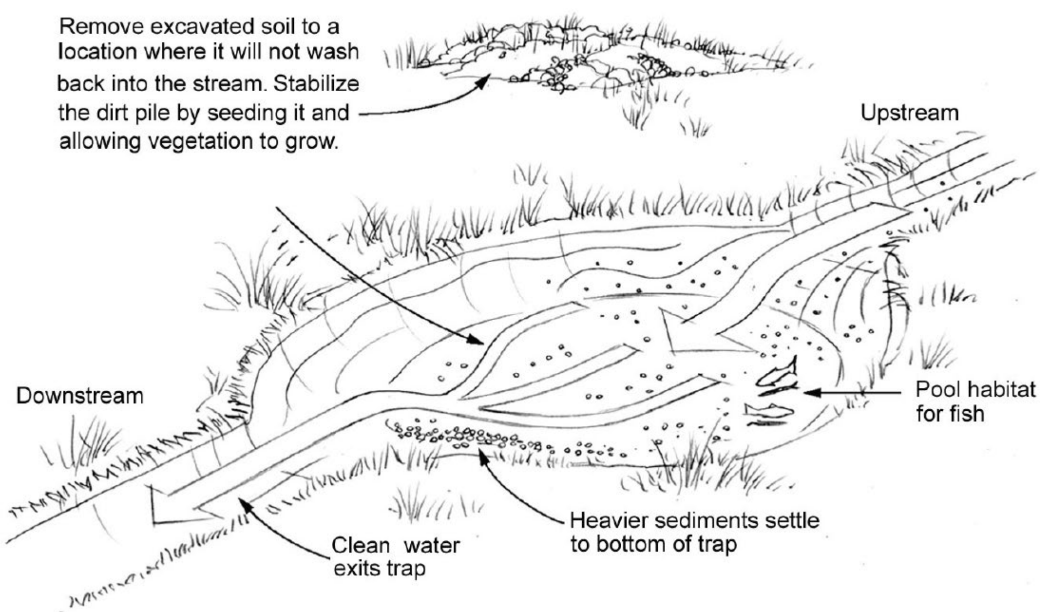


Figure 7-5. Representative diagram of an in-stream sediment retention pond (WCD 2009).

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; however, based on a preliminary analysis of the Clear Creek watershed, the area identified in Figure 7-6 in the Village of Arcade could be a potential location for a sediment retention basin.

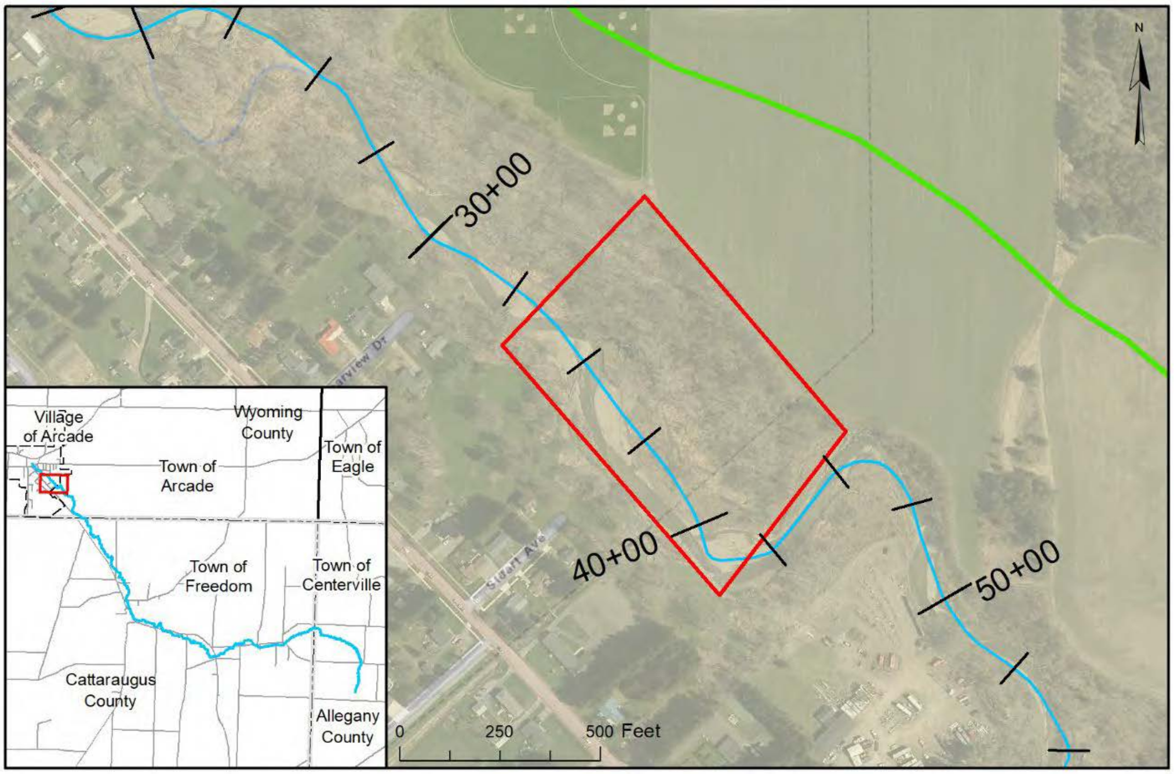


Figure 7-6. Location map for Alternative #1-3.

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).

Best maintenance practices include removing accumulated sediments periodically (i.e., every 1 to 10 years) depending upon sediment load; clearing the basin when the sediment load is at half capacity to avoid sediment build up and potential overflows, which can accumulate sediment downstream; and clearing sediments in the late summer or early fall when the water is the lowest (or when dry, if possible) (WCD 2009).

Sediment retention 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 retention basin. Advanced H&H modeling should be conducted prior to pursuing this strategy due to the complex nature of sediment transport modeling.

Due to the variable nature of identifying, designing, and constructing a sediment retention basin, no ROM costs were determined for this alternative. 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).

7.1.4 Alternative #1-4: Streambank Stabilization in the Vicinity of Pearl and Grove 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 Clear Creek in the Village of Arcade have been identified as areas for potential streambank stabilization strategies. These areas have been outlined in Figure 7-7.

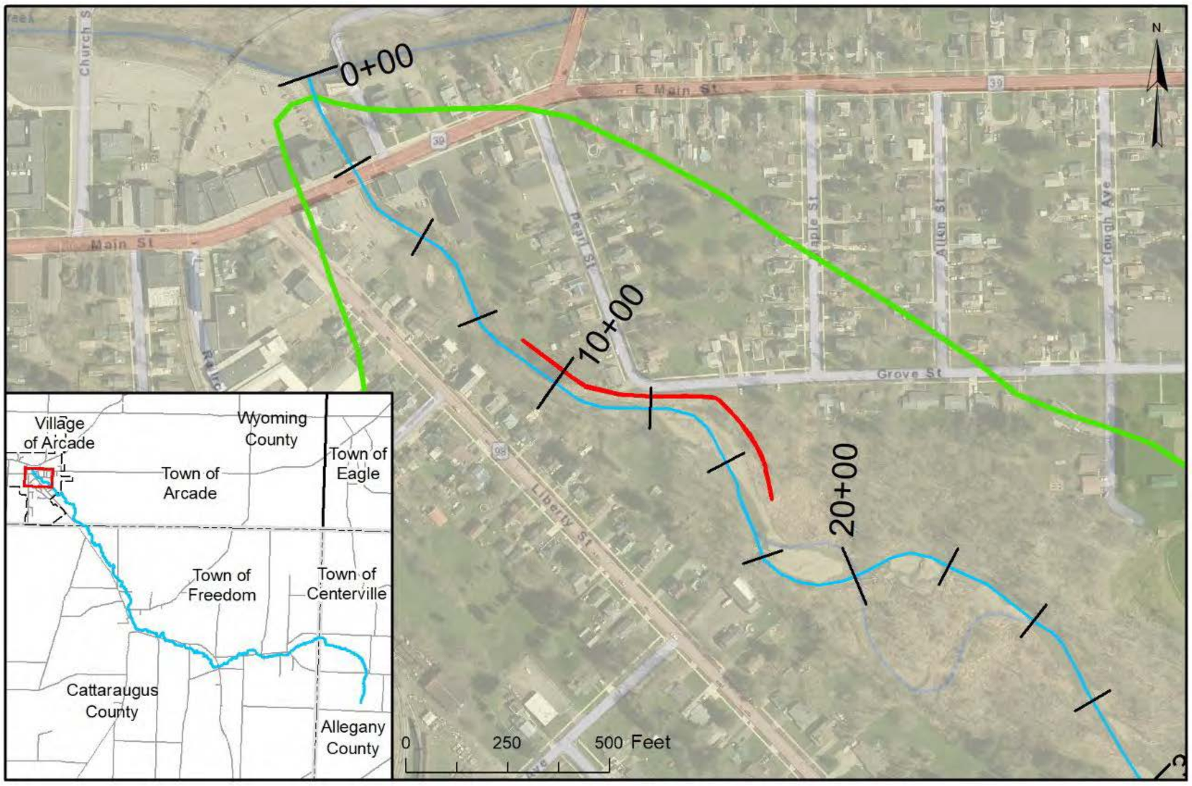


Figure 7-7. Location map for Alternative #1-4.

Appendix F contains detailed discussion of various streambank stabilization strategies, including drawings, definitions, ideal locations, design and construction considerations, maintenance, and Rough Order of Magnitude 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 base conditions model at the 10% annual chance event and the results are summarized in Table 18.

Table 18. HECRAS Base Condition Model Output of Channel Velocity (ft/s) and Shear Stress (lb/sq ft) at the 10% Annual Chance Event for Alternative #1-4

(Source: USACE 2019b)		
River Station	**Channel Velocity (ft/s)**	**Channel Shear Stress (lb/sq ft)**
22+60	9.06	2.2
13+56	5.62	0.67
4+93	12.07	3.08

Based on the base conditions model output for channel velocity and shear stress, Table 19 summarizes the applicability of potential streambank strategies for this proposed alternative.

Table 19. Potential Streambank Stabilization Strategies for Alternative #1-4

(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 costs 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.

7.1.5 Alternative #1-5: Hydrologic and Hydraulic Analysis of Haskell Creek

This measure is intended to address flooding issues within High-risk Area #1 in the vicinity of the confluence of Haskell and Clear Creeks in the Village of Arcade, New York (Figure 7-8). Haskell Creek is a source of flooding in the Village in two ways: when water overtops its banks during high-flow events, and by contributing additional flow to Clear Creek during high-flow events causing Clear Creek to overtop its banks. In addition, Haskell Creek contributes sediment and debris to the downstream reach of Clear Creek, which can restrict water flow and cause potential backwater flooding.

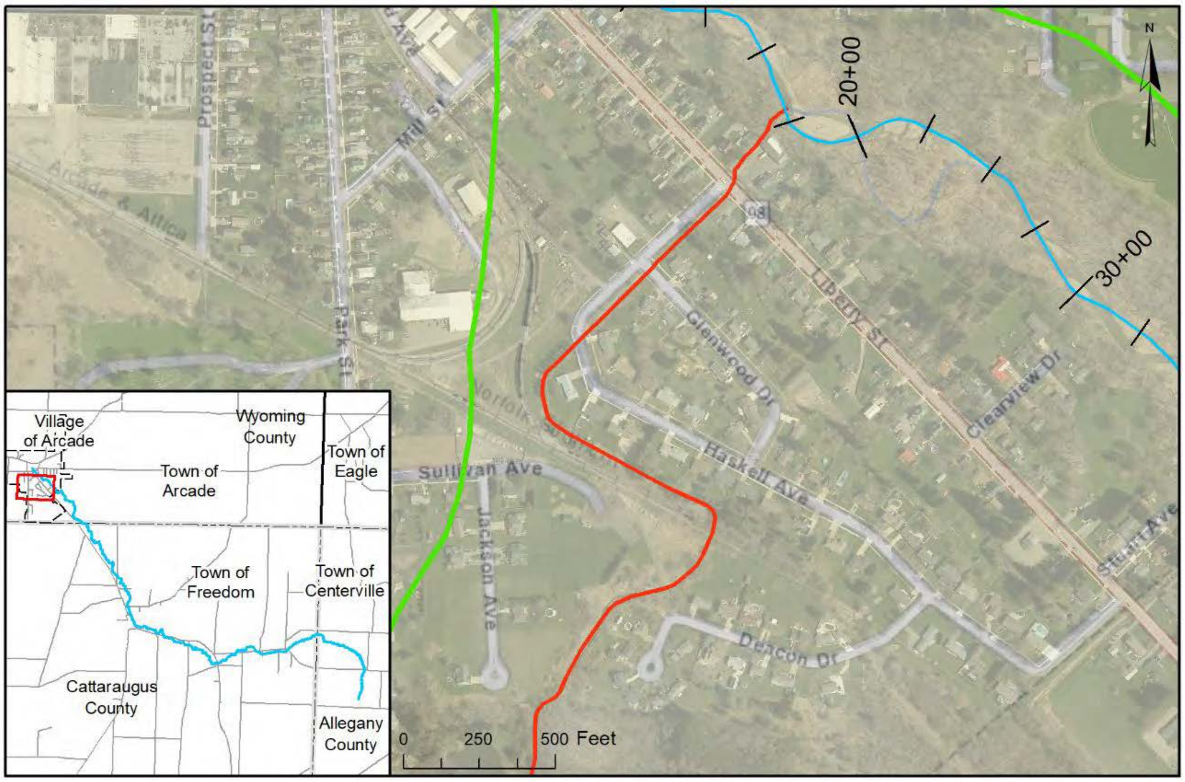


Figure 7-8. Location map for Alternative #1-5.

According to the FEMA FIS, there are multiple structures along Haskell Creek that cannot successfully pass the 1% annual chance flood event, including Liberty Street (NY-98), Glenwood Drive, and Haskell Avenue (Figure 7-9). Due to the inability of these structures to successfully pass the 1% annual chance event, backwater flooding occurs upstream of each structure, as evidenced in the FEMA FIRM for the Village of Arcade, New York (Figure 7-10).

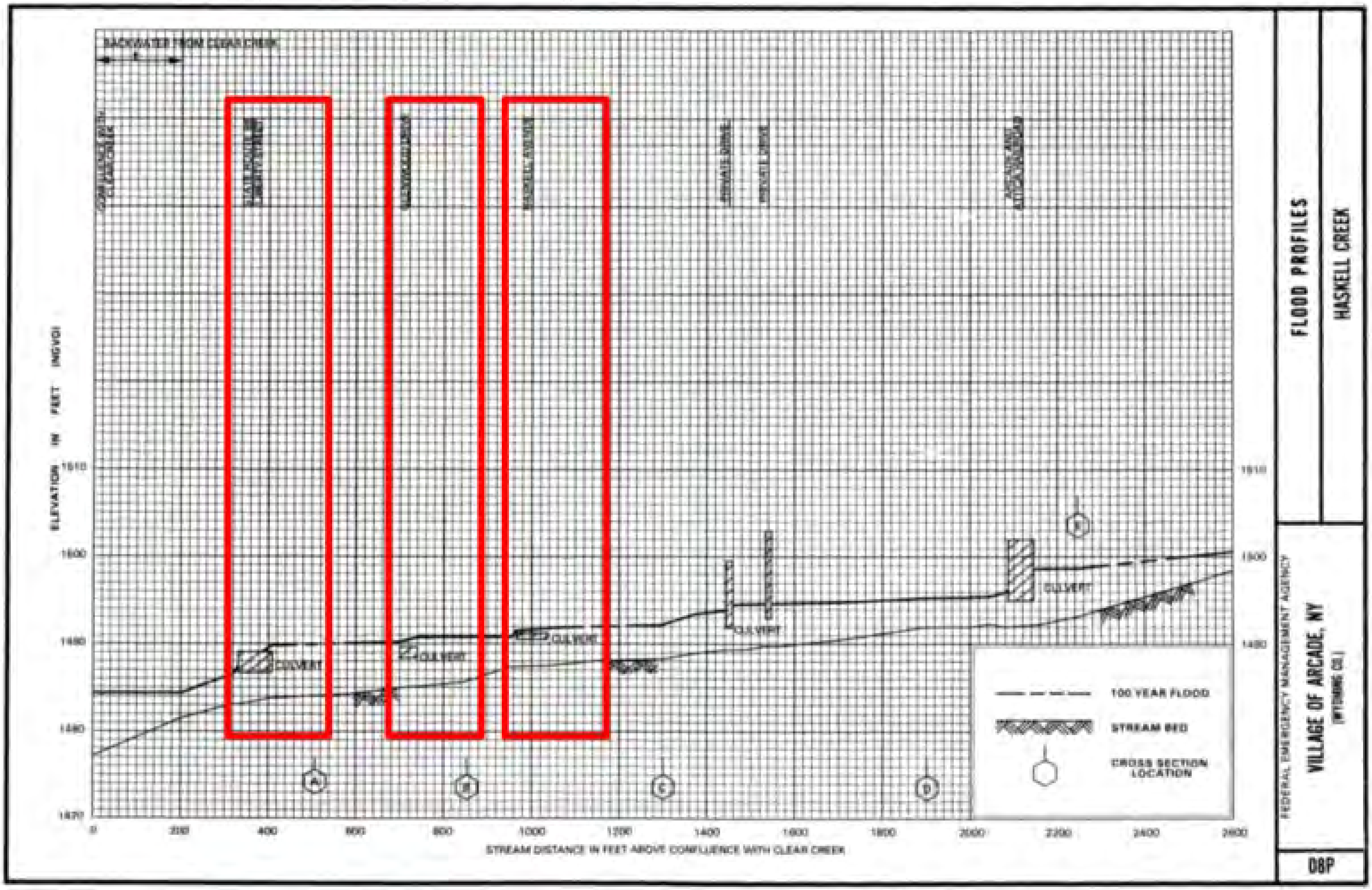


Figure 7-9. FEMA FIS flood profiles for Haskell Creek, Village of Arcade, Wyoming County, NY (FEMA 1992b).

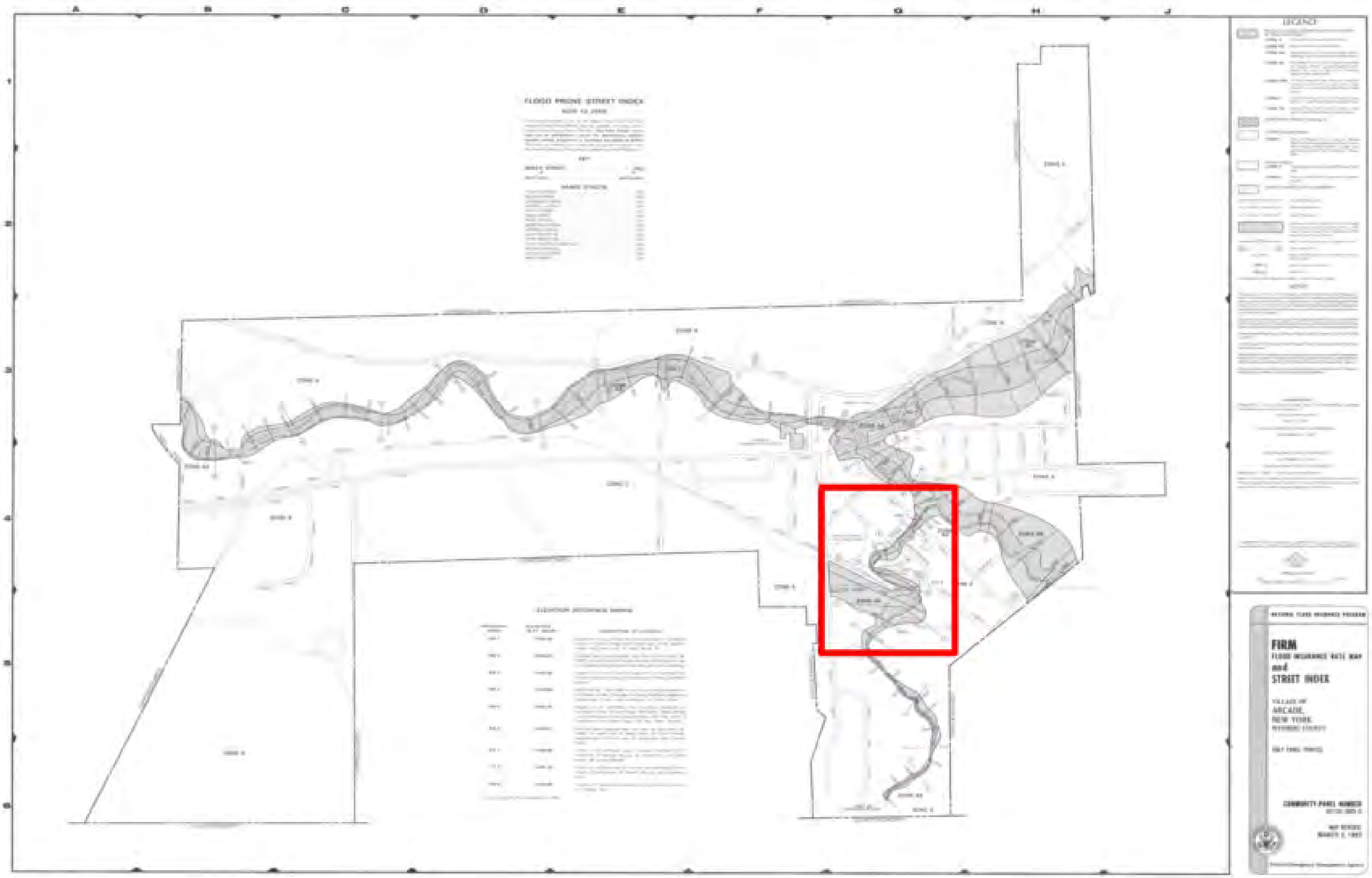


Figure 7-10. FEMA FIRM for the Village of Arcade, NY (FEMA 1992a).

A hydrologic and hydraulic analysis of Haskell Creek would provide the community and stakeholders with the necessary background and supporting information to begin to address flooding issues along Haskell Creek, which in turn would benefit Clear Creek. 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 Rough Order Magnitude cost for this measure is $60,000**.**

7.2 HIGH-RISK AREA #2

7.2.1 Alternative #2-1: Flood Benches Upstream of the Village Corporate Limits

Installing a flood bench would provide additional storage and floodplain width, 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 Liberty Street (NY-98) and the Penn Turf Products, Inc. property (Figure 7-11).

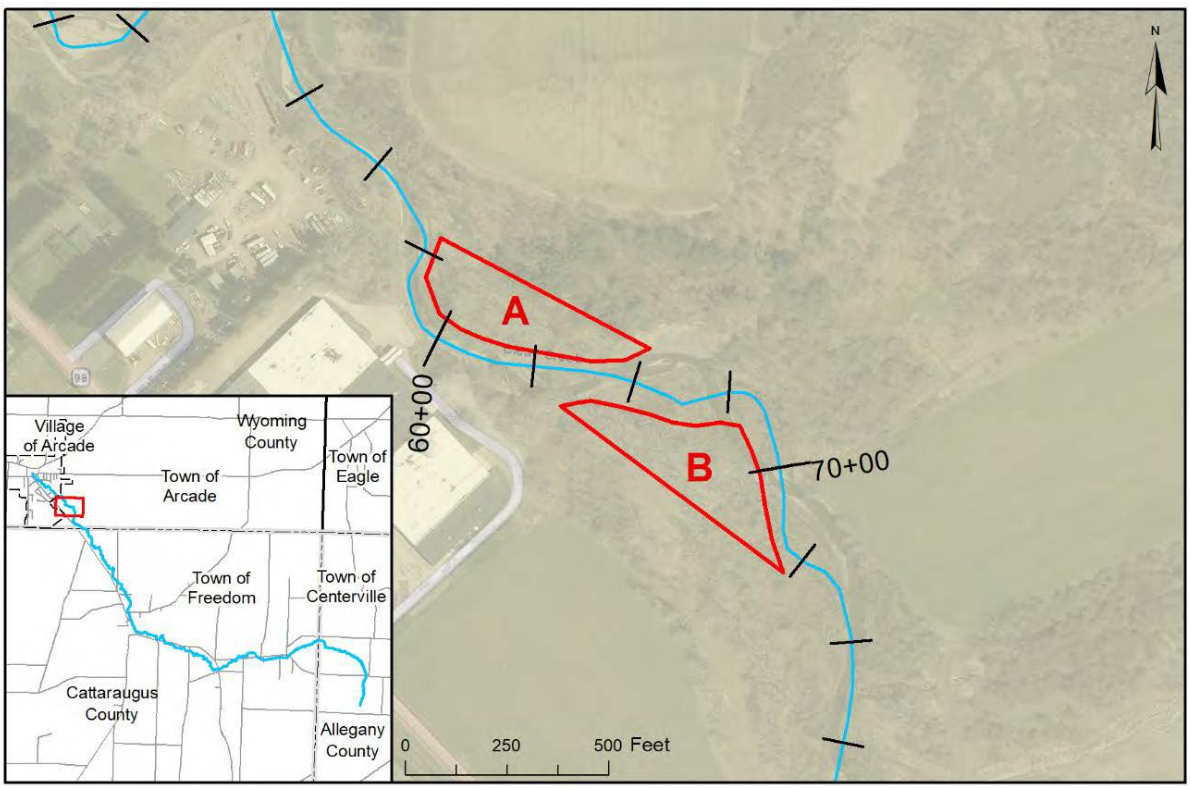


Figure 7-11. Location map for Alternative #2-1.

The flood bench designs used for the proposed condition model simulation set the minimum bench elevation approximately equal to the bankfull elevation. The flood bench river stationing, area, and average depths are summarized in Table 20.

Table 20. Alternative #2-1 Flood Bench Design Summary

Flood Bench	River Stationing	Area (acres)	Average Depth (ft)
Bench A	57+50 to 65+00	1.7	2.0
Bench B	63+00 to 72+50	1.9	1.5

The flood benches are within the FEMA designated SFHA or Zone AE, which are areas subject to inundation by the 1% annual chance flood event with base flood elevations determined and where mandatory flood insurance purchase requirements and floodplain management standards apply (FEMA 1992c). Appendix E depicts a flood mitigation rendering of a flood bench illustrating before and after landscape features.

Table 21 outlines the results of the existing and future conditions model simulations for flood bench alternative (Appendix G). Figures 7-12 and 7-13 display the profile plots for each flood bench alternatives.

Table 21. Summary Table for Alternative #2-1 Existing and Future Conditions for Each Flood Bench

	Reductions in Water Surface Elevations (feet)	
	Flood Bench A	**Flood Bench B**
Existing Conditions	Up to 2.3-ft	Up to 2.5-ft
Total Length of Benefited Area	1,400-ft	1,150-ft
River Stations	55+00 to 69+00	68+50 to 80+00
Future Conditions	Up to 2.2-ft	Up to 2.5-ft

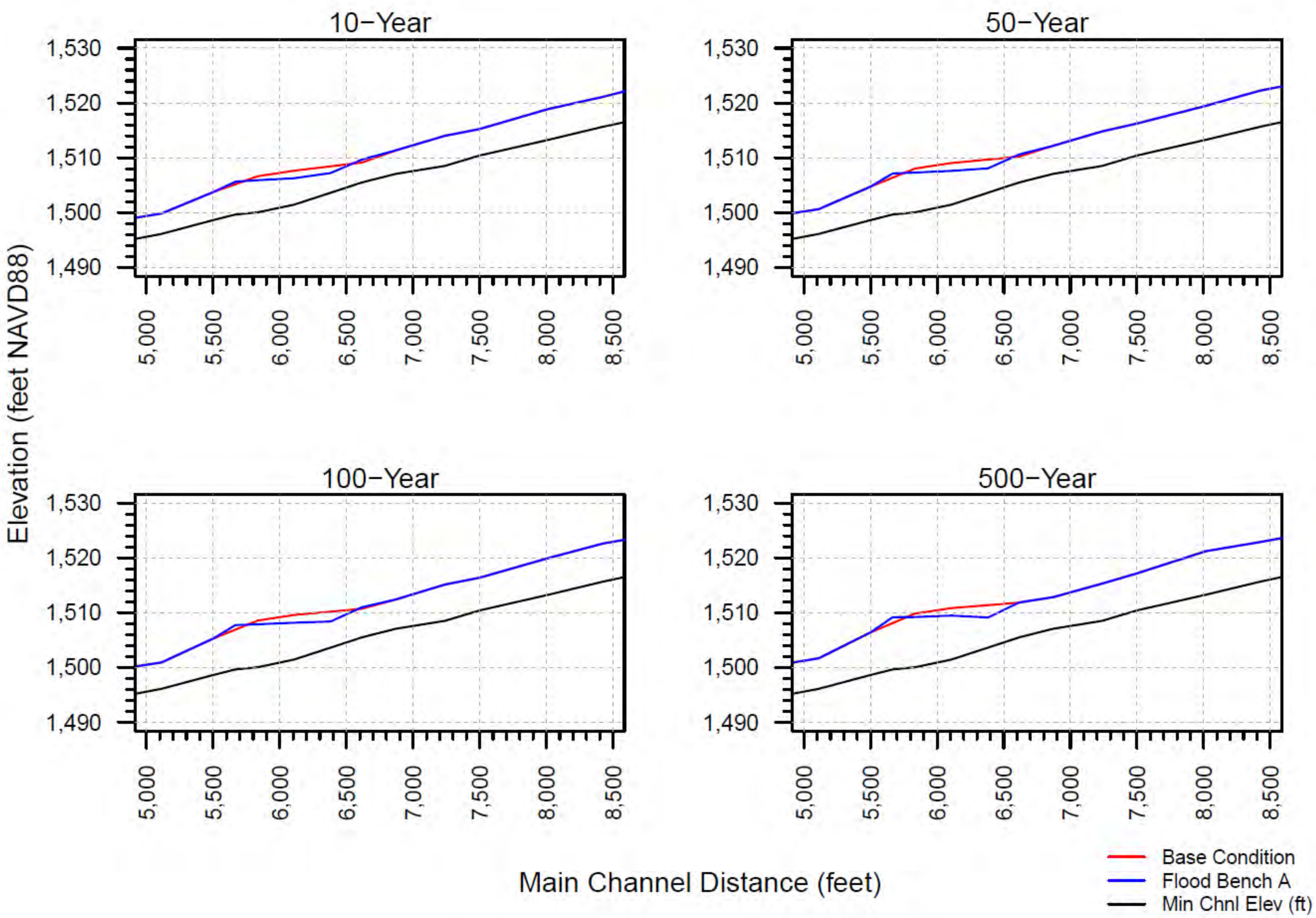


Figure 7-12. HEC-RAS model simulation output results for Alternative #2-1 Flood Bench A.

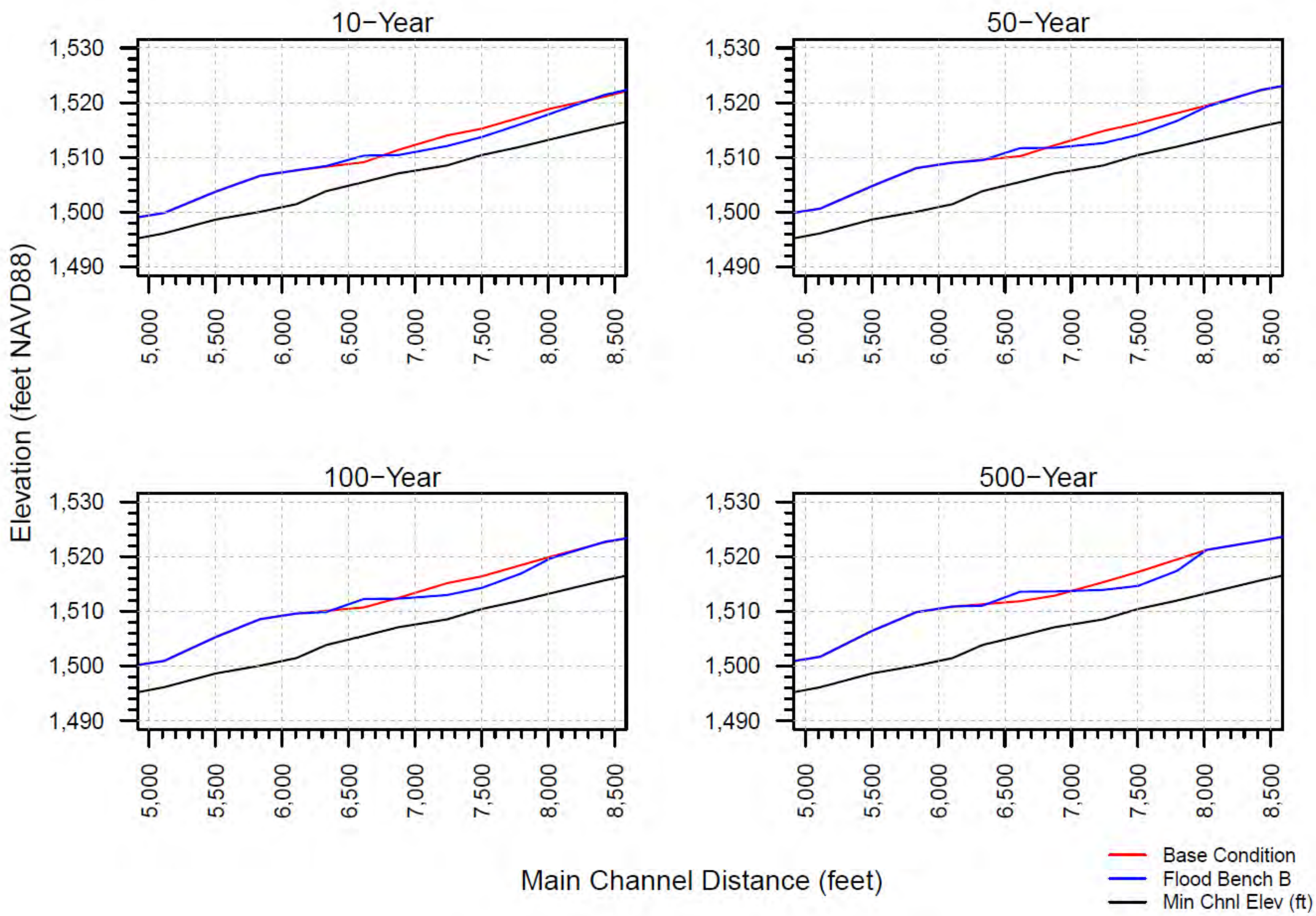


Figure 7-13. HEC-RAS model simulation output results for Alternative #2-1 Flood Bench B.

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 in the vicinity of Liberty Street (NY-98) and the Penn Turk Products, Inc. property would provide flood protection in this reach from open-water flooding, but this benefit is limited when analyzing the model results for Flood Bench B. Flood Bench B had modeled WSEL reductions of up to 2.5-ft, but the reductions occurred primarily over agricultural land with no structures. Flood Bench A provided WSEL reductions that would benefit the commercial properties and structures along Liberty Street (NY-98), including the Penn Turf Products, Inc. and Steel & O'Brien Manufacturing facility.

The Rough Order Magnitude cost for each flood bench alternative is:

- Flood Bench A: $580,000
- Flood Bench B: $610,000

These cost estimates do not include land acquisition costs for survey, appraisal, and engineering coordination. Flood Bench B would not be recommended due to the limited benefit compared to cost for the flood bench.

7.2.2 Alternative #2-2: Streambank Stabilization Upstream of the Village Corporate Limits

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. Human disturbances to watersheds that increase frequency and magnitude of runoff events also increase streambank erosion. 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. Streambank stabilization can also play a vital role in flood risk management in areas located in flood prone areas (GSWCC 2000; NRC 2013).

Through historical flood reports, stakeholder engagement meetings, and / or field work, areas along Clear Creek in the Town of Arcade have been identified as areas for potential streambank stabilization strategies. These areas have been outlined in Figure 7-14.

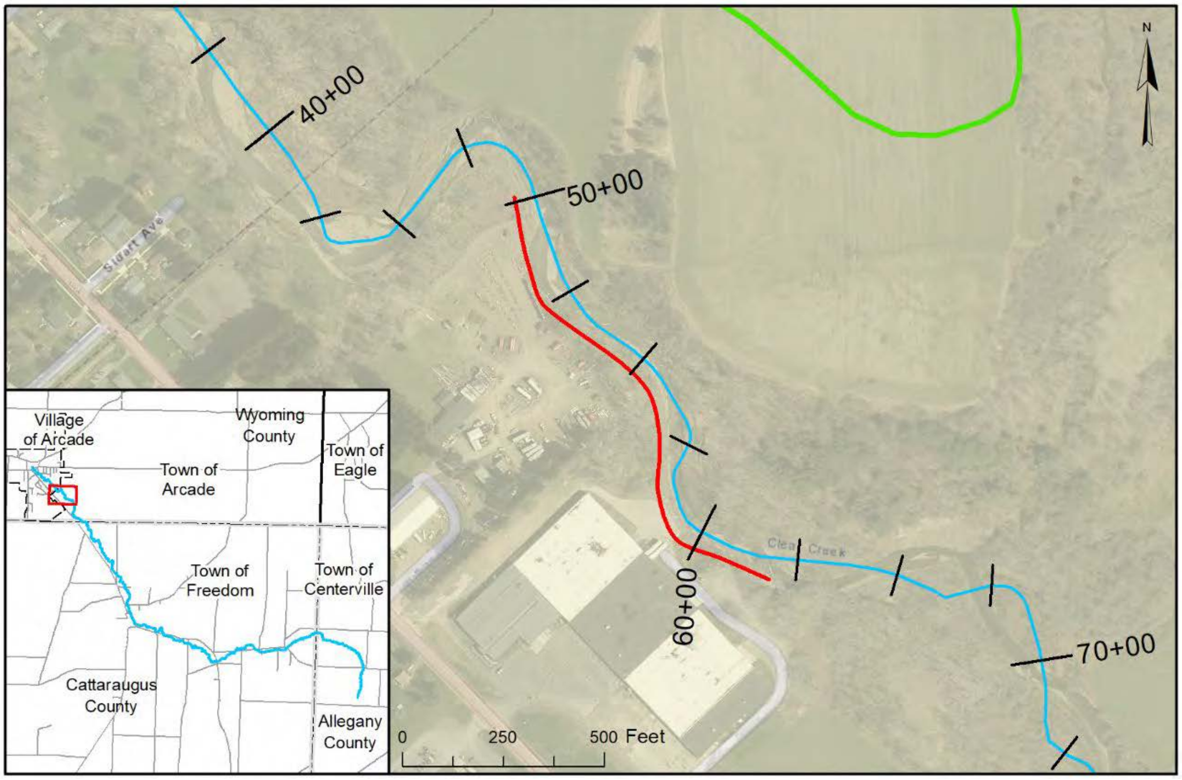


Figure 7-14. Location map for Alternative #2-2.

Appendix F contains detailed discussion of various streambank stabilization strategies, including drawings, definitions, ideal locations, design and construction considerations, maintenance, and Rough Order of Magnitude 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).

To assess the applicability of different streambank stabilization strategies under higher frequency-lower flow conditions, channel velocity (ft/s) and shear stress (lb/sq ft) were calculated using the HEC-RAS software for the base conditions model at the 10% annual chance event, and the results are summarized in Table 22.

Table 22. HECRAS Base Condition Model Output of Channel Velocity (ft/s) and Shear Stress (lb/sq ft) at the 10% Annual Chance Event for Alternative #2-2

(Source: USACE 2019b)		
River Station	**Channel Velocity (ft/s)**	**Channel Shear Stress (lb/sq ft)**
6616	8.29	1.64
6108	5.42	0.58
5835	7.91	1.24
5502	10.7	2.48
5112	4.42	0.48
3914	7.13	1.17

Based on the base conditions model output for channel velocity and shear stress, Table 23 summarizes the applicability of potential streambank strategies for this proposed alternative.

Table 23. Potential Streambank Stabilization Strategies for Alternative #2-2

(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 costs 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.

7.2.3 Alternative #2-3: Flood Control Structure Downstream of the Town Corporate Limits

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 70+00 and 90+00 downstream of the Town of Arcade corporate limits would be the best location for a flood-control structure in the downstream reach.

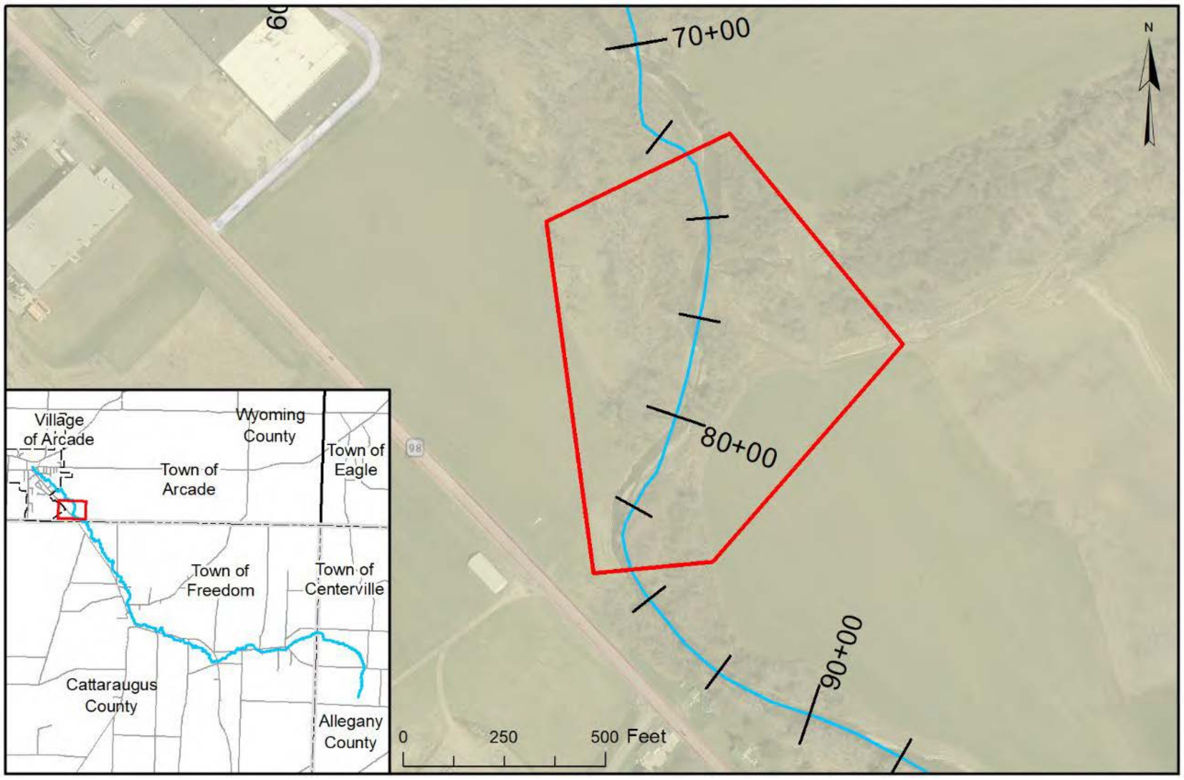


Figure 7-15. Location map for Alternative #2-3.

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 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 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 Clear Creek watershed are expected to be significant.

7.2.4 Alternative #2-4: Hydrologic and Hydraulic Analysis of Clear Creek Tributary

This measure is intended to address flooding issues within High-risk Area #1 in the vicinity of the confluence of Clear Creek and the Unnamed Tributary in the Town of Arcade, New York (Figure 7-16). The Unnamed Tributary is a source of flooding in the Town in two ways: when water overtops its banks during high-flow events, and by contributing additional flow to Clear Creek during high-flow events causing Clear Creek to overtop its banks. In addition, the Unnamed Tributary contributes sediment and debris to the downstream reach of Clear Creek, which can restrict water flow and cause potential backwater flooding.

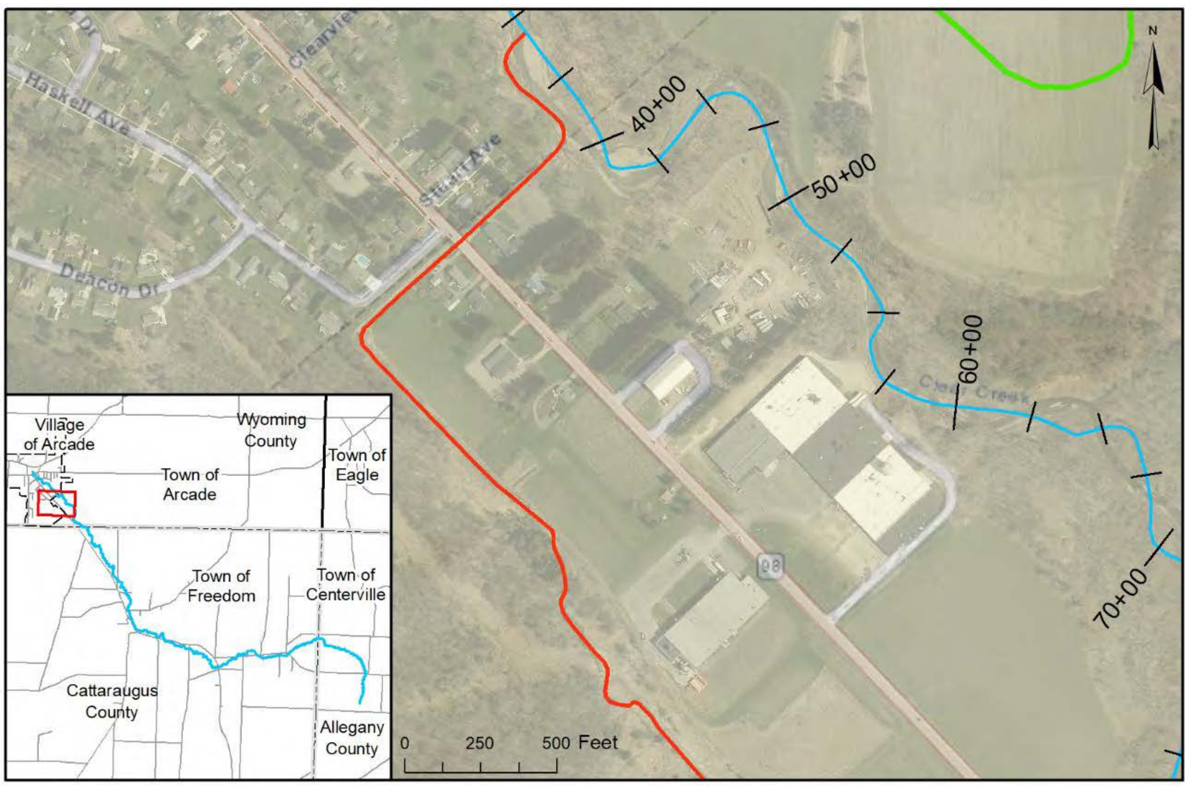


Figure 7-16. Location map for Alternative #2-4.

According to the FEMA FIS, there is one structure along the Unnamed Tributary that cannot successfully pass the 1% annual chance flood event: Liberty Street (NY-98)

(Figure 7-17). Due to the inability of this structure to successfully pass the 1% annual chance event, backwater flooding occurs upstream of the structure, as evidenced in the FEMA FIRM for the Town of Arcade, New York (Figure 7-18).

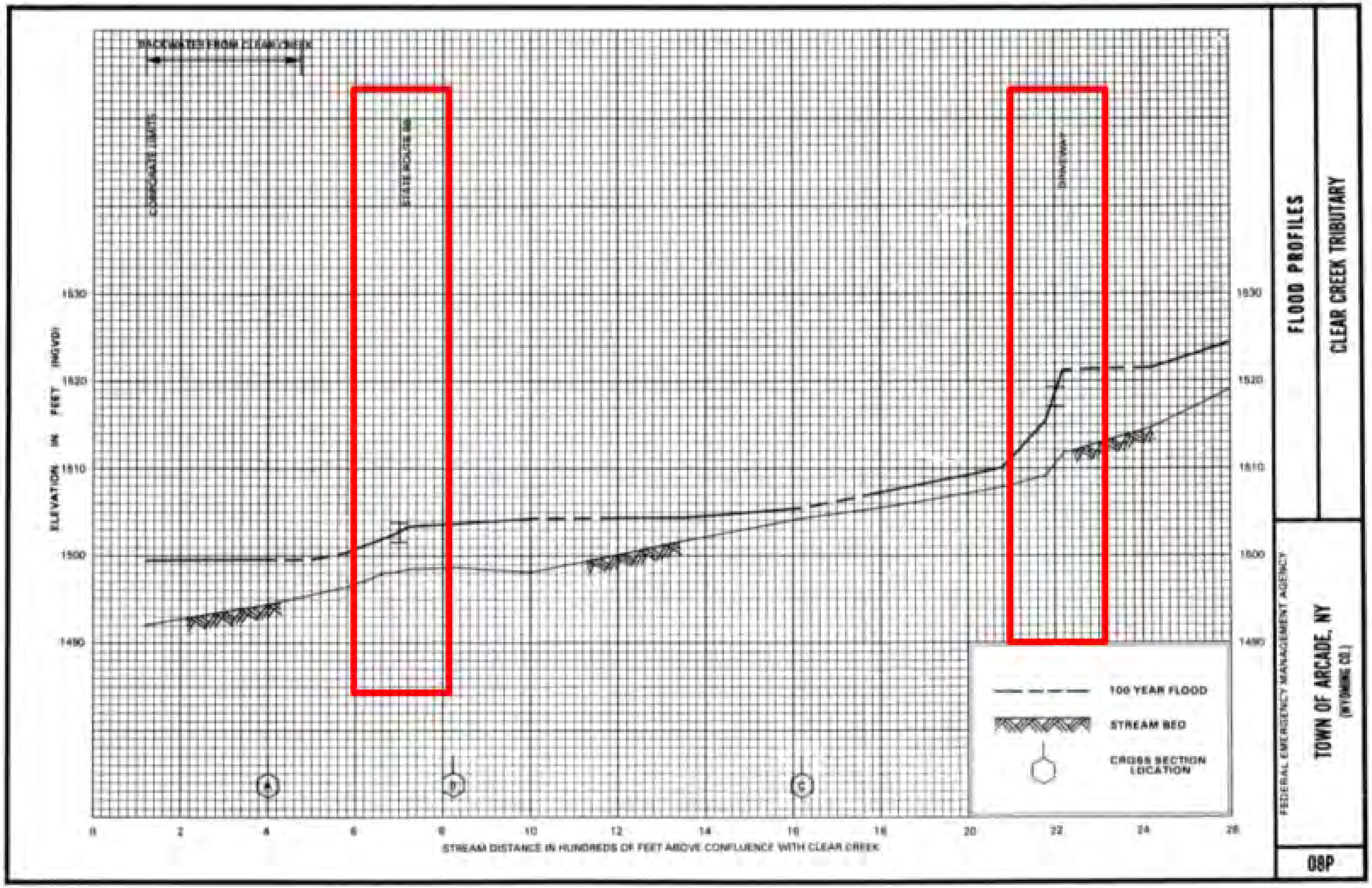


Figure 7-17. FEMA FIS flood profiles for the Unnamed Tributary, Town of Arcade, Wyoming County, NY (FEMA 1992d).

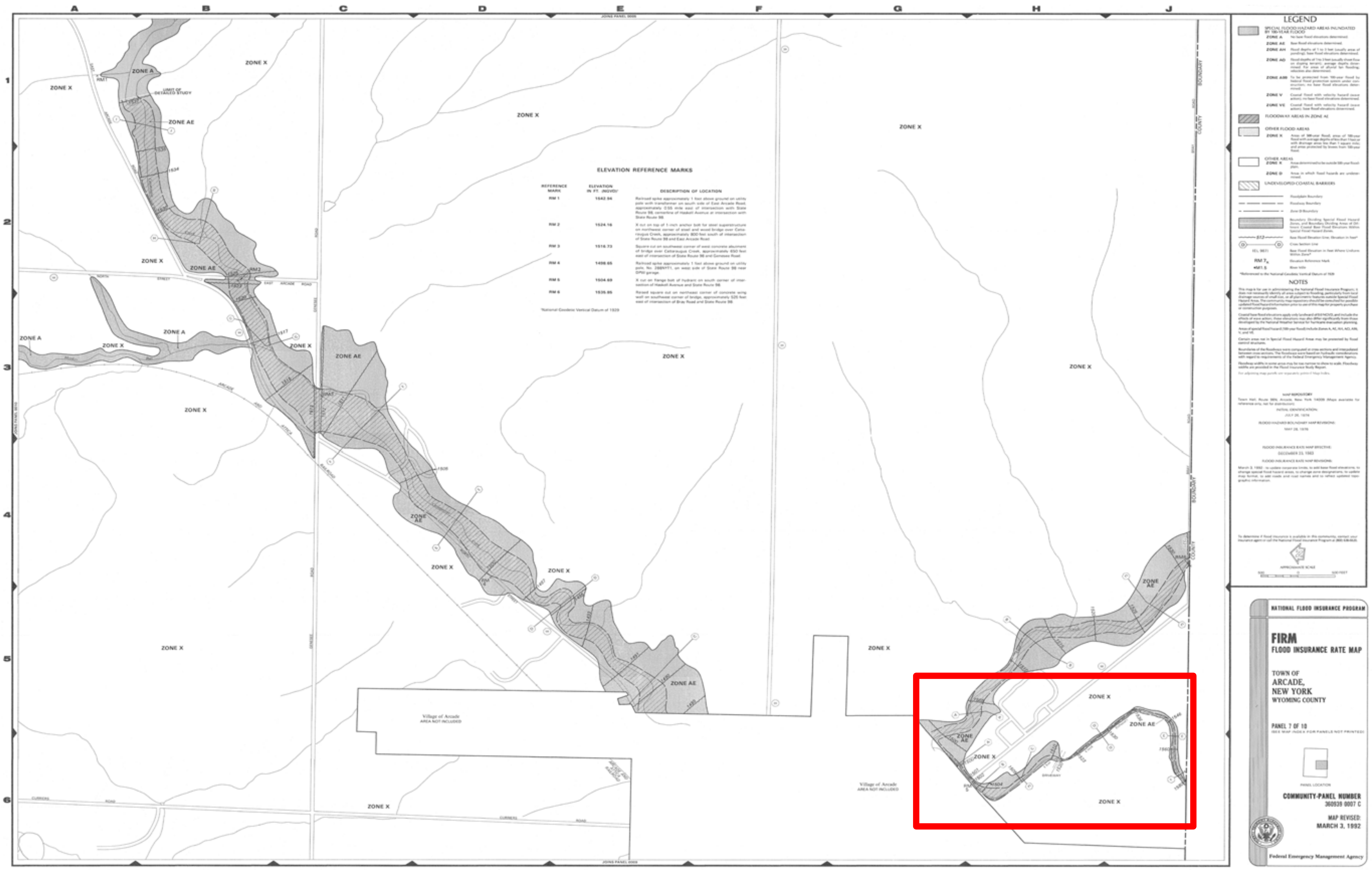


Figure 7-18. FEMA FIRM for the Unnamed Tributary, Town of Arcade, Wyoming County, NY (FEMA 1992c).

A hydrologic and hydraulic analysis of the Unnamed Tributary to Clear Creek 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 Clear Creek. 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 Rough Order Magnitude cost for this measure is $60,000.

7.2.5 Alternative #2-5: Streambank Stabilization Upstream of Bray Road

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. Human disturbances to watersheds that increase frequency and magnitude of runoff events also increase streambank erosion. 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. Streambank stabilization can also play a vital role in flood risk management in areas located in flood prone areas (GSWCC 2000; NRC 2013).

Through historical flood reports, stakeholder engagement meetings, and / or field work, areas along Clear Creek in the Town of Freedom have been identified as areas for potential streambank stabilization strategies. These areas have been outlined in Figure 7-19.

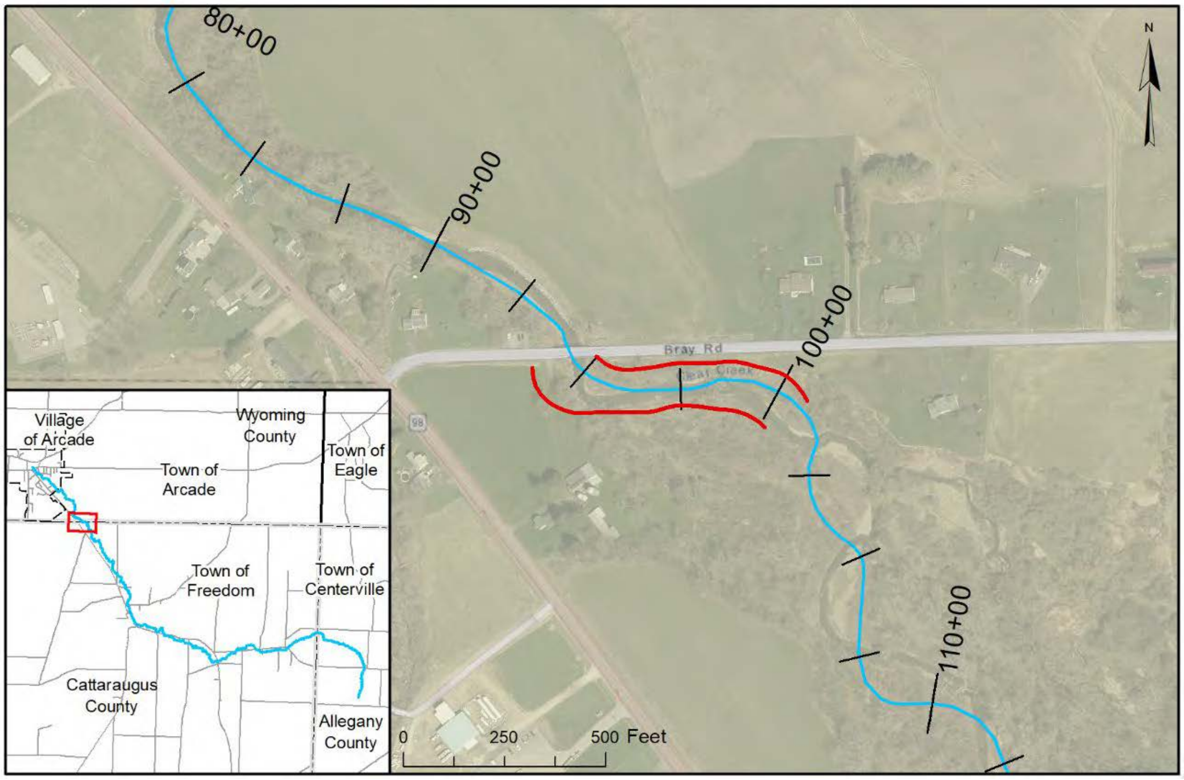


Figure 7-19. Location map for Alternative #2-5.

Appendix F contains detailed discussion of various streambank stabilization strategies, including drawings, definitions, ideal locations, design and construction considerations, maintenance, and Rough Order of Magnitude 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).

To assess the applicability of different streambank stabilization strategies under higher frequency-lower flow conditions, channel velocity (ft/s) and shear stress (lb/sq ft) were calculated using the HEC-RAS software for the base conditions model at the 10% annual chance event and the results are summarized in Table 24.

Table 24. HECRAS Base Condition Model Output of Channel Velocity (ft/s) and Shear Stress (lb/sq ft) at the 10% Annual Chance Event for Alternative #2-5

(Source: USACE 2019b)		
River Station	**Channel Velocity (ft/s)**	**Channel Shear Stress (lb/sq ft)**
11230	9.39	1.82
9938	5.75	0.73
9766	4.81	0.47
9720	Bray Road	

Based on the base conditions model output for channel velocity and shear stress, Table 25 summarizes the applicability of potential streambank strategies for this proposed alternative.

Table 25. Potential Streambank Stabilization Strategies for Alternative #2-5

(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)
	Vegetated coir mat
	Live willow stakes
Boulder Clusters	Boulder - Very large (>80-inch diameter)
	Boulder - Large (>40-in diameter)
	Boulder - Medium (>20-inch diameter)
	Boulder - Small (>10-inch diameter)

Due to the variable, conceptual, and site specific nature of streambank stabilization strategies, no ROM costs 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.

7.3 HIGH-RISK AREA #3

7.3.1 Alternative #3-1: Flood Benches Downstream of Sparks Road

Installing a flood bench would provide additional storage and floodplain width, which could potentially reduce damages in the event of flooding and address issues within

High-risk Area #3. Two potential flood benches were modeled downstream of the Sparks Road bridge crossing where numerous residential and commercial properties are at flood risk (Figure 7-20).

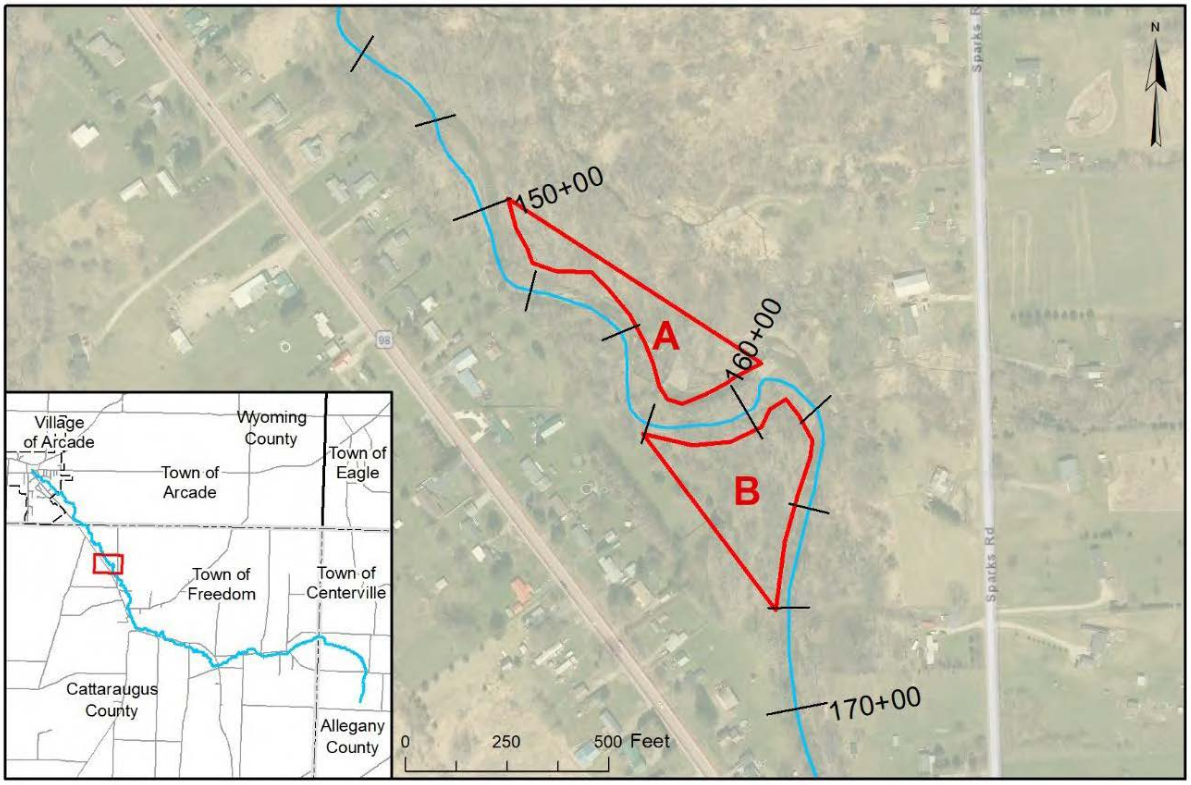


Figure 7-20. Location map for Alternative #3-1.

The flood bench designs used for the proposed condition model simulation set the minimum bench elevation approximately equal to the bankfull elevation. The flood bench river stationing, area, and average depths are summarized in Table 26.

Table 26. Alternative #3-1 Flood Bench Design Summary

Flood Bench	River Stationing	Area (acres)	Average Depth (ft)
Bench A	150+00 to 161+00	1.6	2.0
Bench B	157+50 to 167+50	2.1	1.5

The flood benches are within the FEMA designated SFHA or Zone AE, which are areas subject to inundation by the 1% annual chance flood event with base flood elevations determined and where mandatory flood insurance purchase requirements and floodplain management standards apply (FEMA 1992c). Appendix E depicts a flood mitigation rendering of a flood bench illustrating before and after landscape features.

Table 27 outlines the results of the existing and future conditions model simulations for flood bench alternative (Appendix G). Figures 7-21 and 7-22 display the profile plots for each flood bench alternatives.

Table 27. Summary Table for Alternative #3-1 Existing and Future Conditions for Each Flood Bench

	Reductions in Water Surface Elevations (feet)	
	Flood Bench A	**Flood Bench B**
Existing Conditions	Up to 1.5-ft	Up to 1.1-ft
Total Length of Benefited Area	2,550-ft	2,700-ft
River Stations	150+00 to 175+50	155+00 to 182+00
Future Conditions	Up to 1.4-ft	Up to 1.2-ft

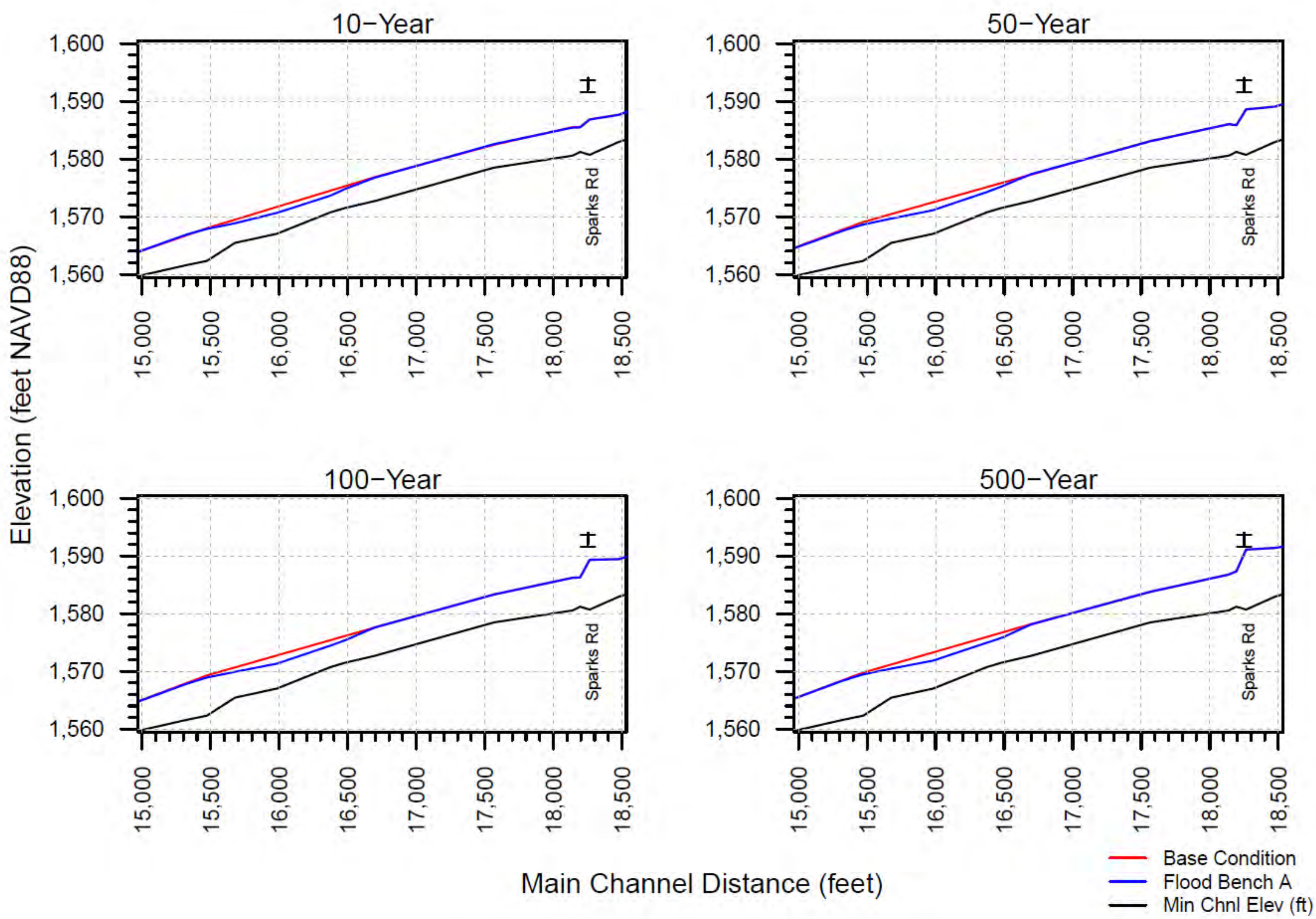


Figure 7-21. HEC-RAS model simulation output results for Alternative #3-1 Flood Bench A.

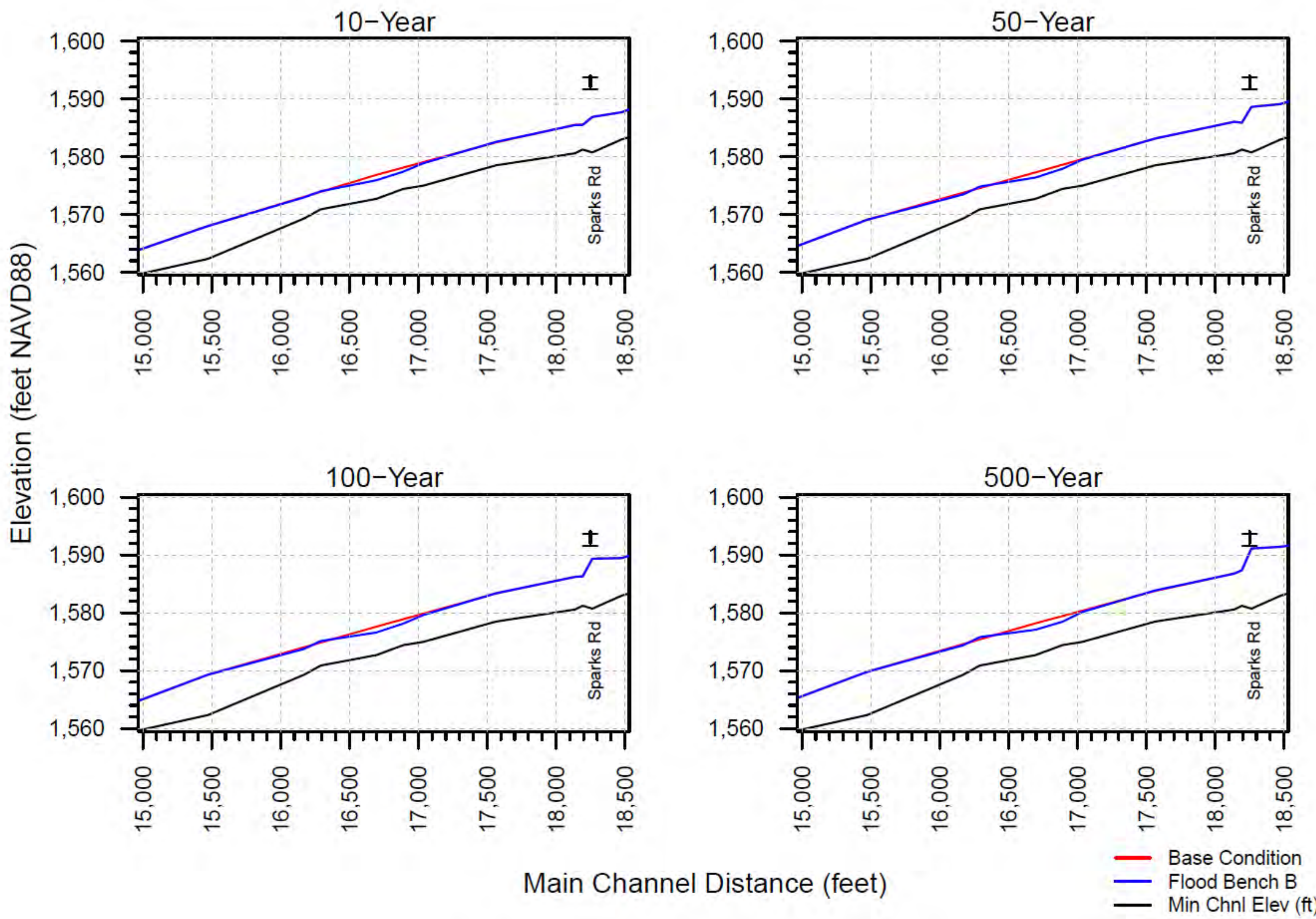


Figure 7-22. HEC-RAS model simulation output results for Alternative #3-1 Flood Bench B.

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 downstream of Sparks Road would provide flood protection from open-water flooding to the residences and businesses in this reach.

The Rough Order Magnitude cost for each flood bench alternative is:

- Flood Bench A: $630,000
- Flood Bench B: $660,000

These cost estimates do not include land acquisition costs for survey, appraisal, and engineering coordination.

7.3.2 Alternative #3-2: Levee Along NY-98 Downstream of Sparks Road

This strategy is intended to restrict high-flow events from overtopping channel banks and flooding homes, properties, etc. in the high-risk area of the NY-98 residences downstream of Sparks Road by constructing a permanent levee along the left bank of Clear Creek adjacent to the community. The levee would be approximately 2,750 linear feet (LF) with a height of 2-ft above the flood stage for the 1% annual chance flood elevation (1,579.75-1,559.5 ft NAVD 88) and located along river stations 135+00 to 162+50 (Figure 7-23). Compaction and the possibility of using cut material as fill was not accounted for this alternative. Downstream and opposite bank effects of the levee were modelled to determine if the levee would have any measurable effects on upstream or downstream water surface elevations.

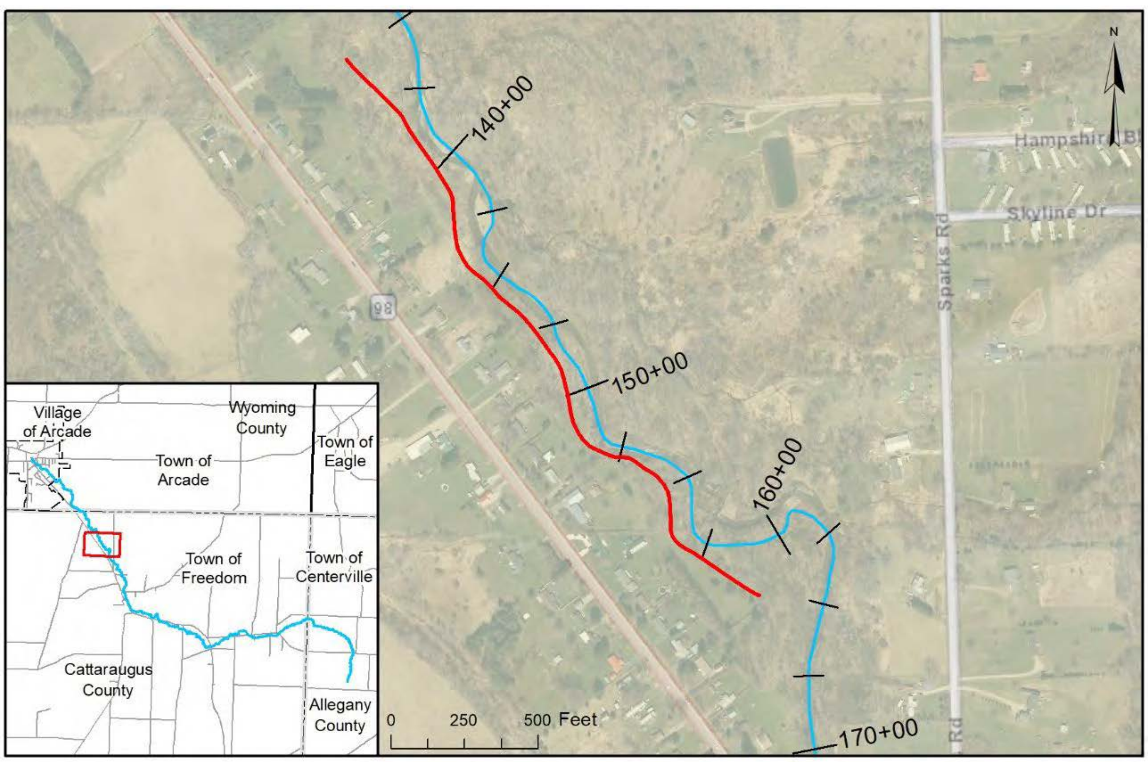


Figure 7-23. Location map for Alternative #3-2.

The proposed and future hydraulic modeling confirmed that constructing a levee along Clear Creek in the reach adjacent to NY-98 would decrease the flood risk of the neighborhood, while leaving the flood potential of downstream and opposite bank areas unaffected (Figure 7-24).

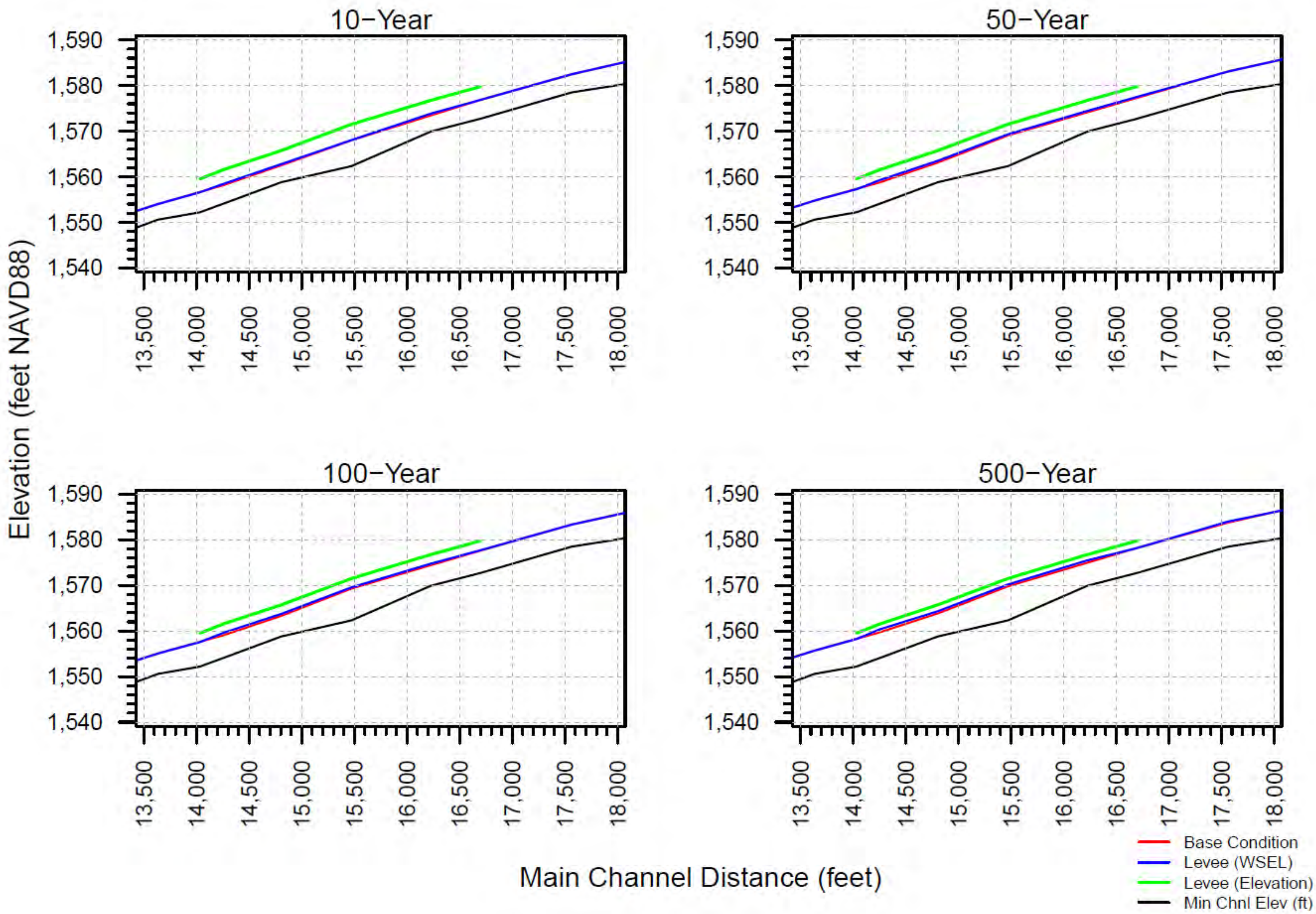


Figure 7-24. HEC-RAS model simulation output results for Alternative #3-2.

Without the levee, a 1% annual chance flood event would overtop the channel banks downstream of the Sparks Road bridge and near river station 170+00, inundating the residences and properties along NY-98 along this reach. With the levee, model simulation results indicated this water would remain in the channel and flow downstream causing water surface elevations to increase without impairing the adjacent properties. The potential benefits of this alternative are immediately upstream and in the vicinity of the levees at river stations 140+00 to 170+00.

Any levee constructed in the Clear Creek watershed would need to follow the USACE *Design and Construction of Levees* (EM 1110-2-1913) guidelines, including obtaining the required individual, regional, and nationwide permits for design, construction, and maintenance of a levee (USACE 2000).

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 BCA would need to be performed to determine the cost-effectiveness of the alternative prior to applying for FEMA mitigation grant programs funding.

A levee would require significant engineering, construction, and maintenance efforts throughout its lifespan, resulting in a relatively high cost burden. Levees should be placed as far away from the creek channel as possible to maximize the capacity of the natural floodplain to convey floodwaters, and designed and constructed in a manner that does not cause flooding downstream of the structure. In addition, strict requirements would need to be met to comply with NFIP requirements (44 CFR §65.10) to affect a building's flood insurance rating. However, it must be noted that a levee would not remove areas from the FEMA mapped floodplain. A levee would only provide additional flood protection for a certain level of annual chance flood event. Homeowners and businesses behind the levee would still be required to purchase flood insurance if they are within any FEMA designated flood zones (FEMA 2000).

The Rough Order Magnitude cost for this strategy is approximately $1.4 million, which does not include permitting, annual maintenance or land acquisition costs for survey, appraisal, and engineering coordination. This estimate also assumes suitable clay material for levee fill that meets USACE requirements is readily available and nearby the Town of Freedom.

In addition, closure structures, tie-ins and pump stations were not discussed as these structures should be considered on an as needed basis to address interior drainage. As such, the cost estimate for this alternative did not include the associated costs for these structures.

7.3.3 Alternative #3-3: Flood Benches Upstream of Sparks Road

Installing a flood bench would provide additional storage and floodplain width, which could potentially reduce damages in the event of flooding and address issues within High-risk Area #3. Four potential flood benches were modeled upstream of the Sparks

Road bridge crossing where numerous residential and commercial properties are at flood risk (Figure 7-25).

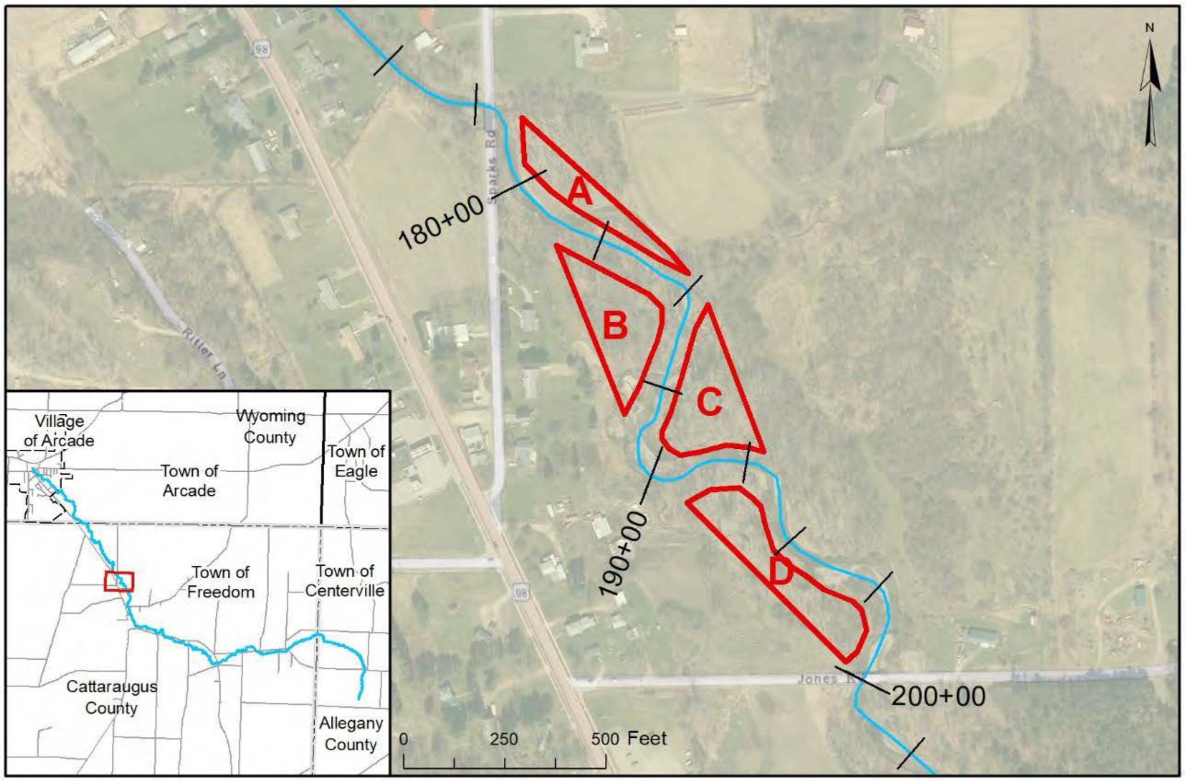


Figure 7-25. Location map for Alternative #3-3.

The flood bench designs used for the proposed condition model simulation set the minimum bench elevation approximately equal to the bankfull elevation. The flood bench river stationing, area, and average depths are summarized in Table 28.

Table 28. Alternative #3-3 Flood Bench Design Summary

Flood Bench	River Stationing	Area (acres)	Average Depth (ft)
Bench A	178+00 to 185+00	0.8	1.5
Bench B	182+00 to 188+00	1.1	1.5
Bench C	185+00 to 192+75	1.1	1.0
Bench D	191+00 to 200+00	1.2	1.0

The flood benches are within the FEMA designated SFHA or Zone AE, which are areas subject to inundation by the 1% annual chance flood event with base flood elevations determined and where mandatory flood insurance purchase requirements and floodplain management standards apply (FEMA 1992c). Appendix E 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 flood bench alternatives (Appendix G). Figures 7-26 through 7-29 display the profile plots for each of the flood bench alternatives.

Table 29. Summary Table for Alternative #3-3 Existing and Future Conditions for Each Flood Bench

	Reductions in Water Surface Elevations (feet)			
	Flood Bench A	**Flood Bench B**	**Flood Bench C**	**Flood Bench D**
Existing Conditions	Up to 1.0-ft	Up to 1.1-ft	Up to 1.3-ft	Up to 1.0-ft
Total Length of Benefited Area	2,250-ft	1,975-ft	1,550-ft	1,025-ft
River Stations	181+75 to 204+25	184+50 to 204+25	188+75 to 204+25	194+00 to 204+25
Future Conditions	Up to 0.7-ft	Up to 1.1-ft	Up to 1.3-ft	Up to 1.0-ft

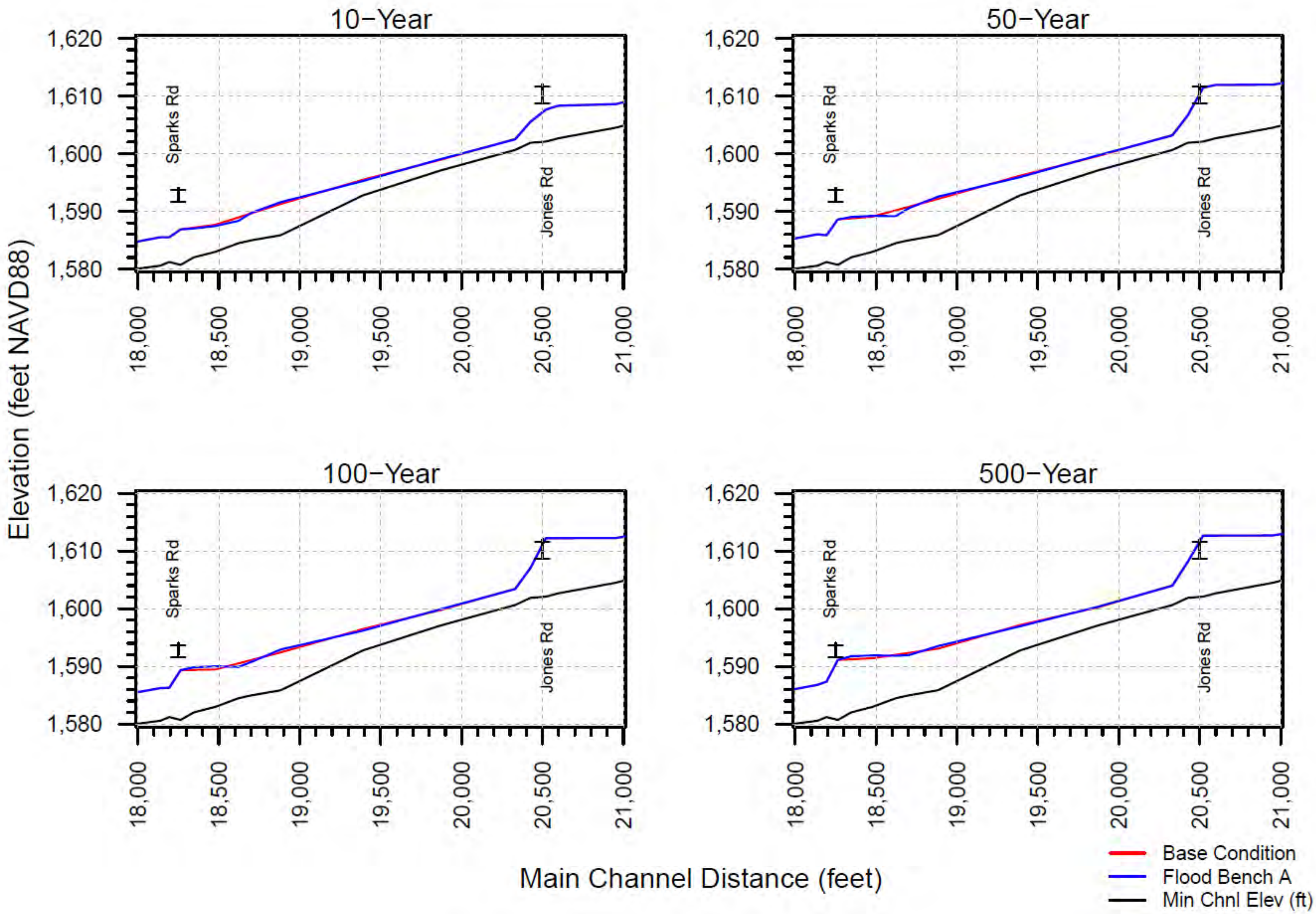


Figure 7-26. HEC-RAS model simulation output results for Alternative #3-3 Flood Bench A.

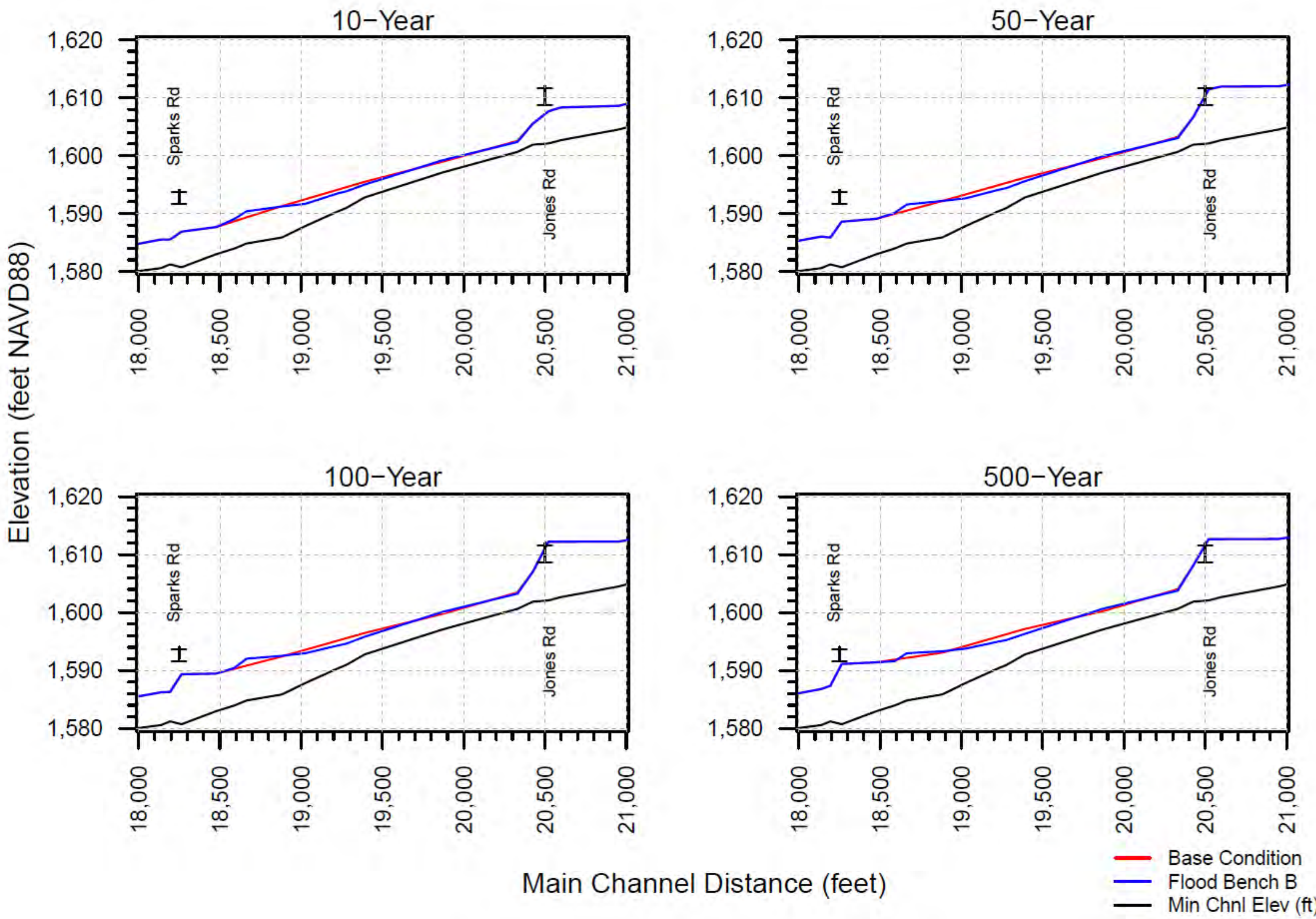


Figure 7-27. HEC-RAS model simulation output results for Alternative #3-3 Flood Bench B.

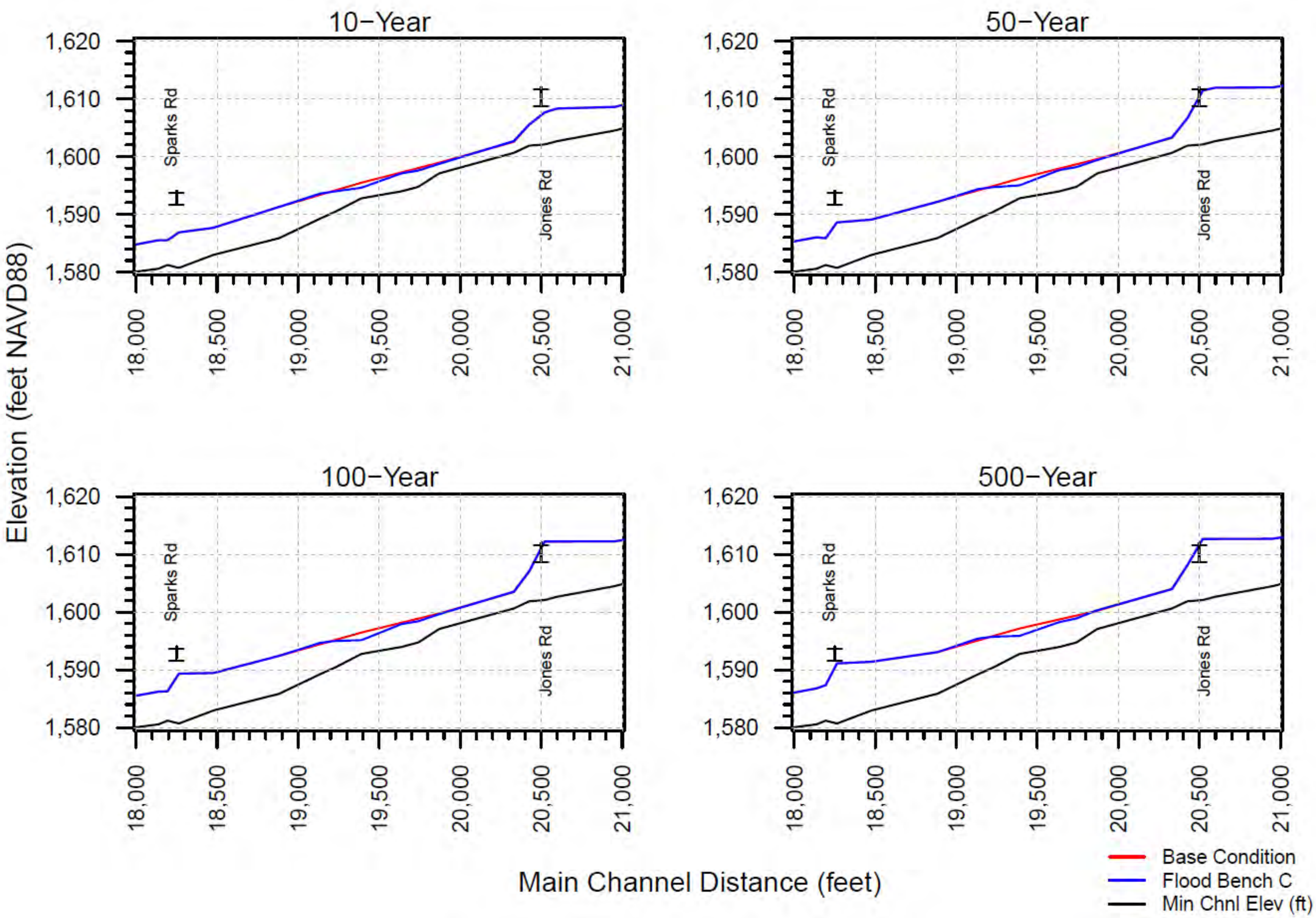


Figure 7-28. HEC-RAS model simulation output results for Alternative #3-3 Flood Bench C.

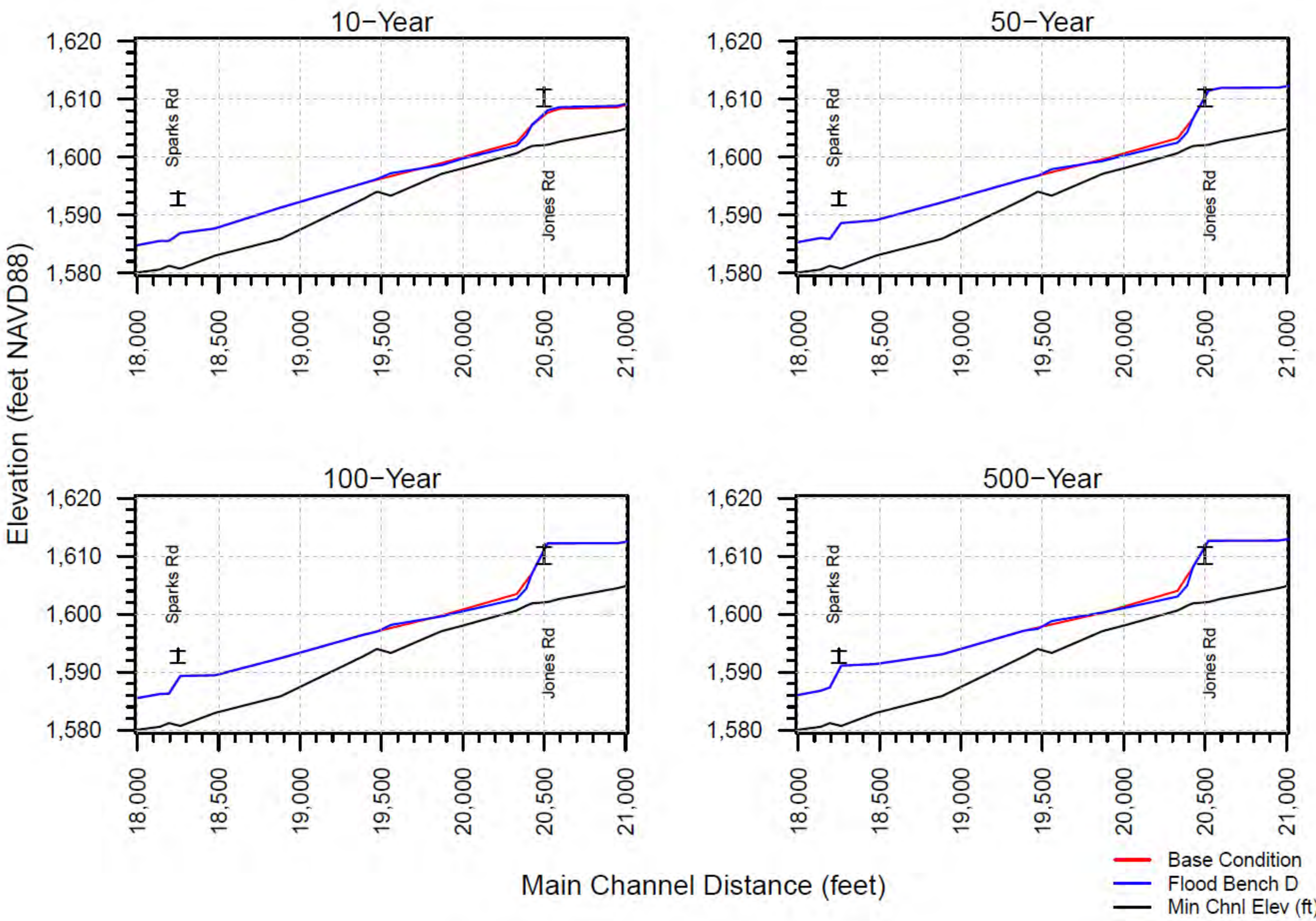


Figure 7-29. HEC-RAS model simulation output results for Alternative #3-3 Flood Bench D.

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 Sparks Road would provide flood protection from open-water flooding to the residences and businesses in this reach, but this benefit is limited when analyzing the model results for Flood Benches A and D. Flood Benches A and D have modeled WSEL reductions of up to 1.0-ft and 0.9-ft, respectively, but there were also WSEL increases both down and upstream of the benches according to the model simulation results. 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) and the distance of the flood benches from the Sparks Road and Jones Road bridge crossings (Flood Bench A is closer to the Sparks Road bridge and is influenced by backwater effects upstream of the bridge, while Flood Bench D is downstream of the Jones Road bridge and is influenced by the compression / expansion / overtopping of channel flow as it passes under / over the undersized bridge).

The Rough Order Magnitude cost for each flood bench alternative is:

- Flood Bench A: $300,000
- Flood Bench B: $360,000
- Flood Bench C: $340,000
- Flood Bench D: $340,000

These cost estimates do not include land acquisition costs for survey, appraisal, and engineering coordination. Flood Benches A and D would not be recommended due to influences of the Sparks and Jones Road bridges and the limited benefit compared to cost for these flood benches.

7.3.4 Alternative #3-4: Increase Size of Sparks Road Bridge Opening

This measure is intended to address issues within High-risk Area #3 by increasing the width of the Sparks Road bridge opening, which would increase the cross-sectional flow area of the channel located at river station 178+00 (Figure 7-30).

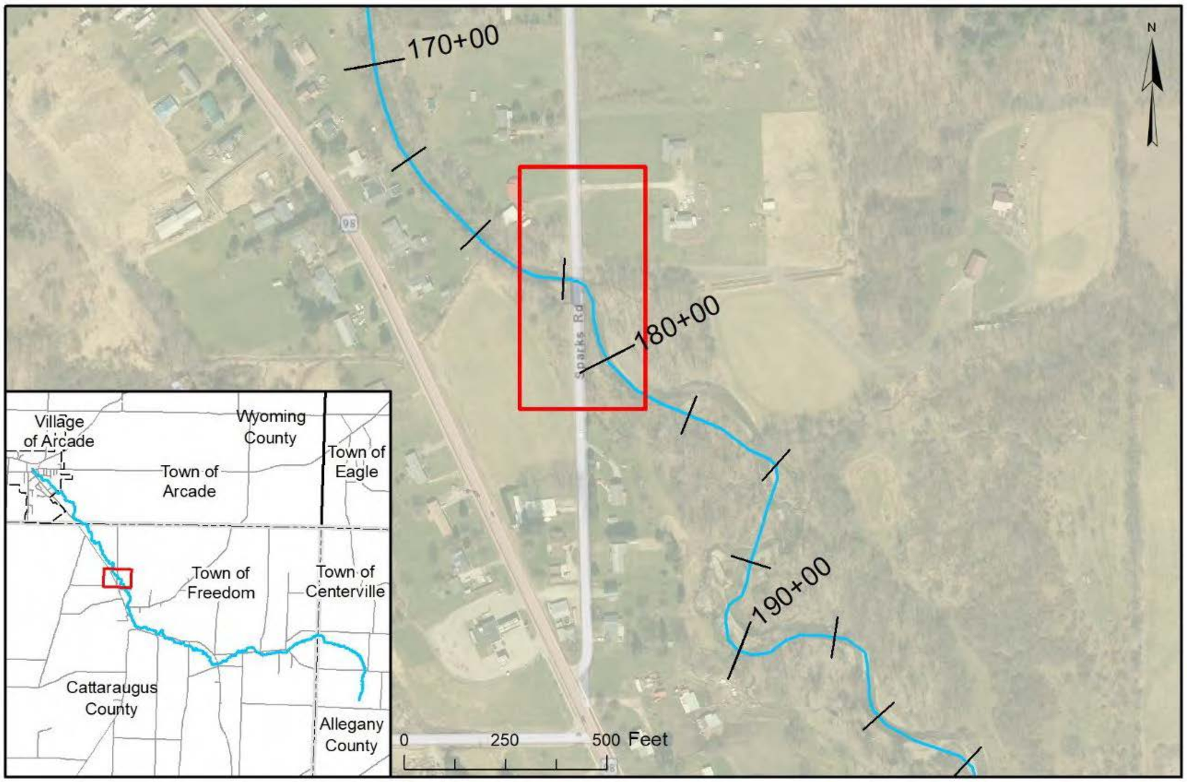


Figure 7-30. Location map for Alternative #3-4.

According to the FEMA FIRM, there is backwater upstream of the Sparks Road bridge at the 1% annual chance event (FEMA 1991a). The bridge is owned by Cattaraugus County and the existing bridge structure has a bridge span of 72-ft, one central pier, and a maximum low chord to channel bottom height of 10.5-ft (Figure 7-31). The flooding in the vicinity of the Sparks Road bridge poses a flood risk threat to nearby residential and commercial properties (Ramboll 2021). Appendix F depicts a flood mitigation rendering of a bridge widening scenario.

Figure 7-31. Sparks Road Bridge, Town of Freedom, NY.

The optimal bridge width to successfully pass the 1% annual chance event was determined through manual selection and multiple simulation runs. The bridge widening design used for the proposed condition model simulation increased the width of the bridge opening from 72-ft to 87-ft by widening the bridge on the left bank by 15-ft. Two separate model scenarios were simulated: widening with a central pier and widening without a central pier.

The proposed condition model results indicated water surface reductions of up to 1.5-ft for the widening with a central pier and 1.8-ft for the widening without a central pier in areas approximately 400-ft upstream of the bridge, specifically along river stations 181+00 to 185+00 (Figure 7-32). The modeling output for future conditions displayed similar results with water surface reductions of up to 1.6-ft for the widening with a central pier and 1.9-ft for the widening without a central pier (Appendix H).

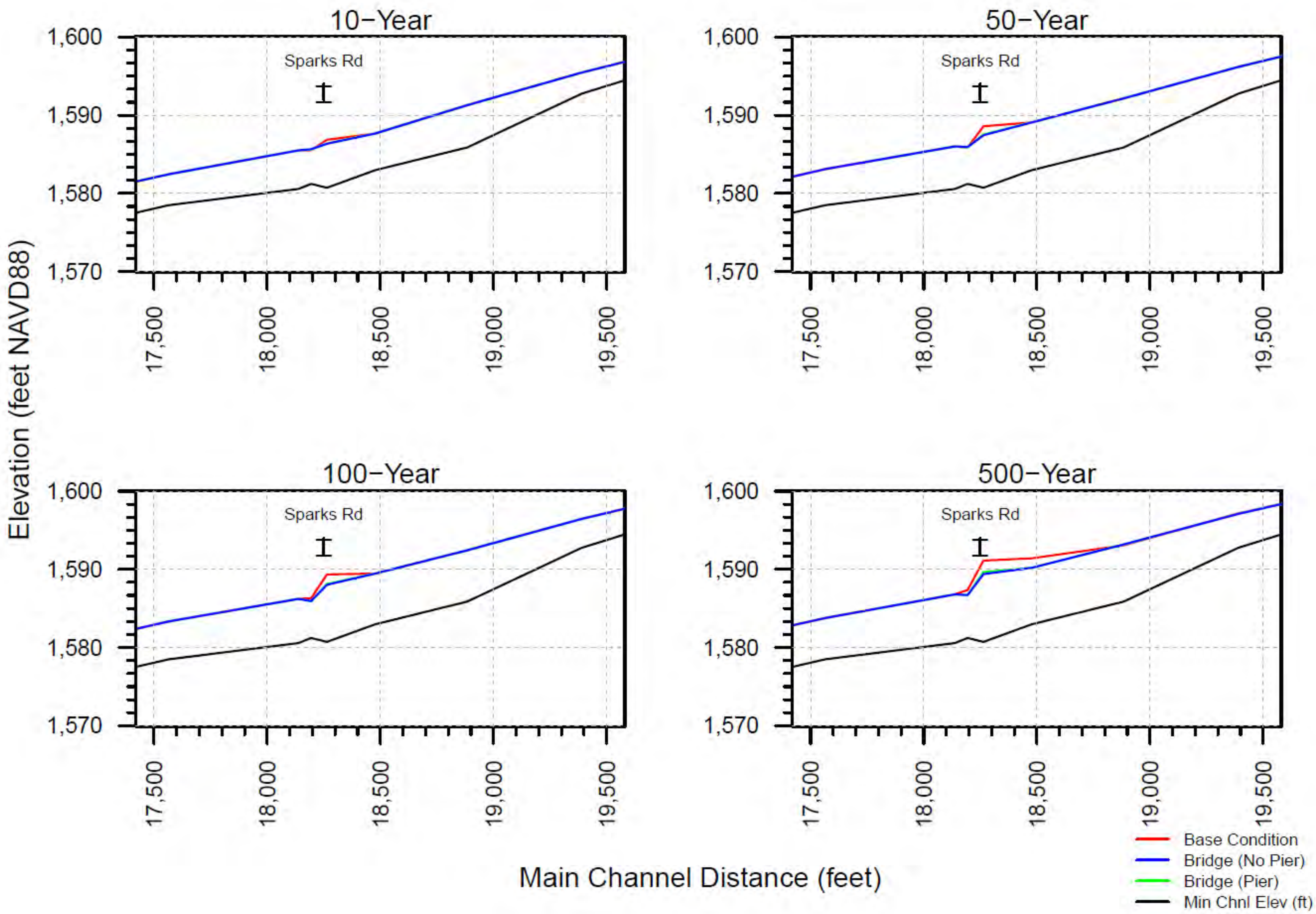


Figure 7-32. HEC-RAS model simulation output results for Alternative #3-4.

The Rough Order Magnitude cost for this measure is $720,000 for the widening with a central pier and $1.2 million for the widening without a central pier, 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 central pier would alter the structural integrity of the bridge in any way.

7.3.5 Alternative #3-5: Flood Benches Upstream of Jones Road

Installing a flood bench would provide additional storage and floodplain width, which could potentially reduce damages in the event of flooding and address issues within High-risk Area #3. Two potential flood benches were modeled upstream of the Jones Road bridge crossing where numerous residential properties are at flood risk (Figure 7-33).

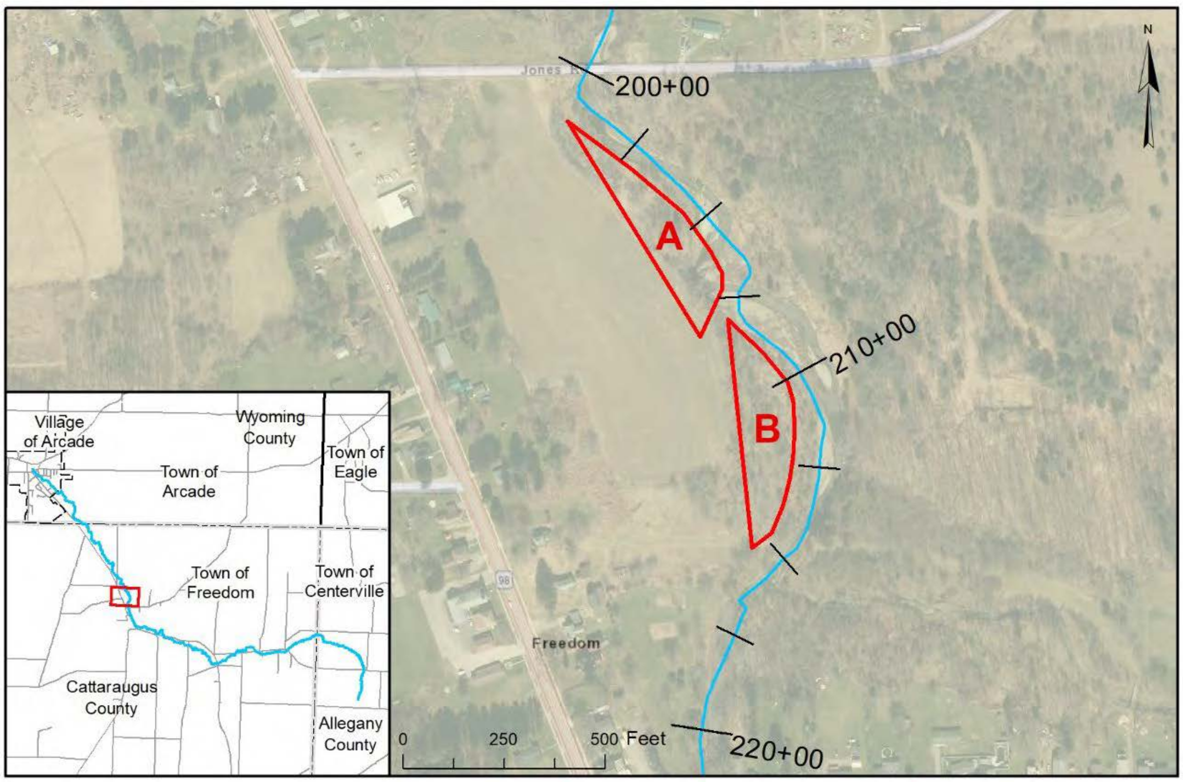


Figure 7-33. Location map for Alternative #3-5.

The flood bench designs used for the proposed condition model simulation set the minimum bench elevation approximately equal to the bankfull elevation. The flood bench river stationing, area, and average depths are summarized in Table 30.

Table 30. Alternative #3-5 Flood Bench Design Summary

Flood Bench	River Stationing	Area (acres)	Average Depth (ft)
Bench A	201+00 to 208+00	1.3	1.5
Bench B	208+00 to 215+50	1.3	1.5

The flood benches are within the FEMA designated SFHA or Zone AE, which are areas subject to inundation by the 1% annual chance flood event with base flood elevations determined and where mandatory flood insurance purchase requirements and floodplain management standards apply (FEMA 1992c). Appendix E depicts a flood mitigation rendering of a flood bench illustrating before and after landscape features.

Table 31 outlines the results of the existing and future conditions model simulations for flood bench alternatives (Appendix G). Figures 7-34 and 7-35 display the profile plots for each of the flood bench alternatives.

Table 31. Summary Table for Alternative #3-5 Existing and Future Conditions for Each Flood Bench

	Reductions in Water Surface Elevations (feet)	
	Flood Bench A	**Flood Bench B**
Existing Conditions	Up to 2.4-ft	Up to 2.5-ft
Total Length of Benefited Area	1,950-ft	1,700-ft
River Stations	207+00 to 226+50	209+50 to 226+50
Future Conditions	Up to 2.4-ft	Up to 2.6-ft

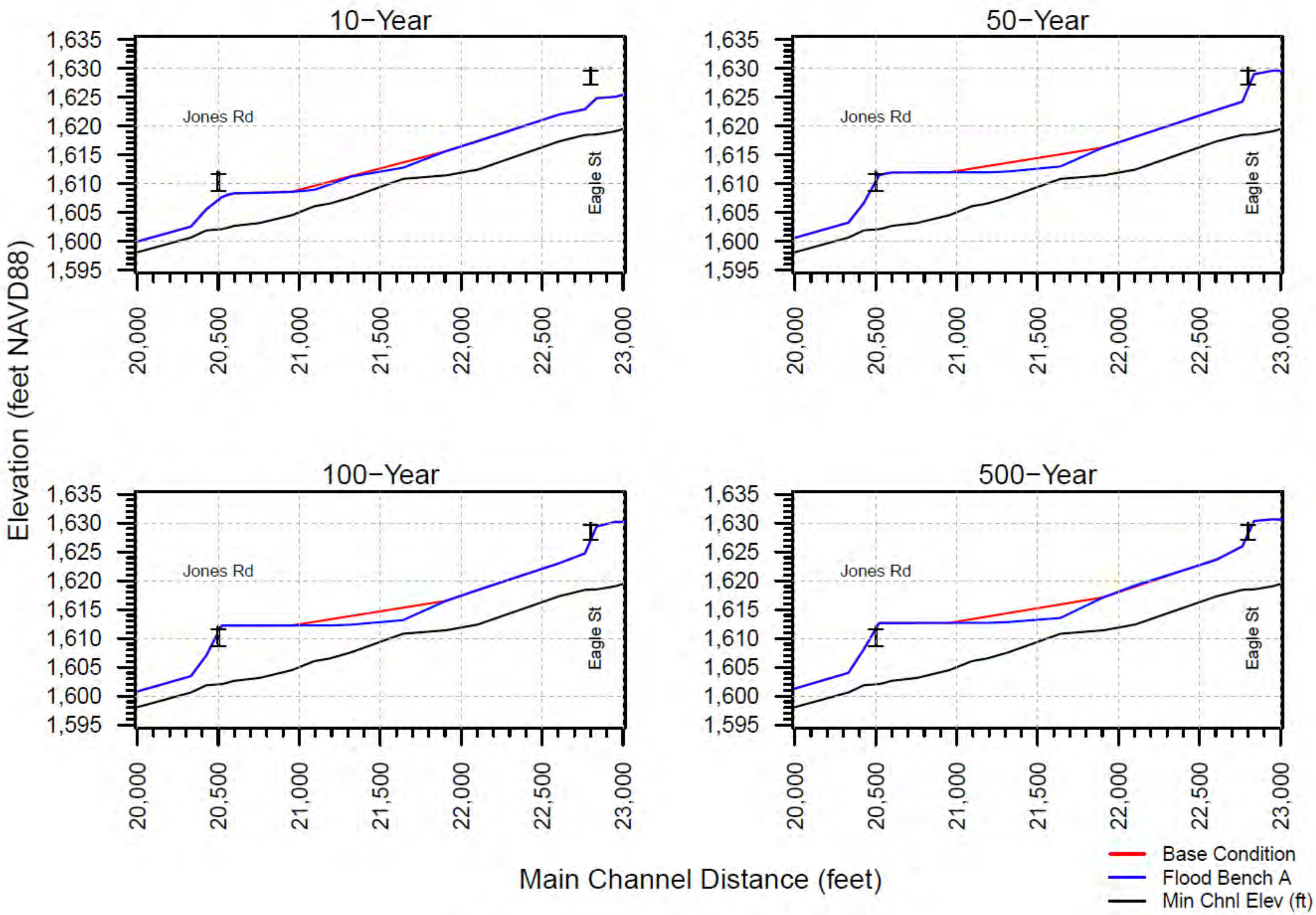


Figure 7-34. HEC-RAS model simulation output results for Alternative #3-5 Flood Bench A.

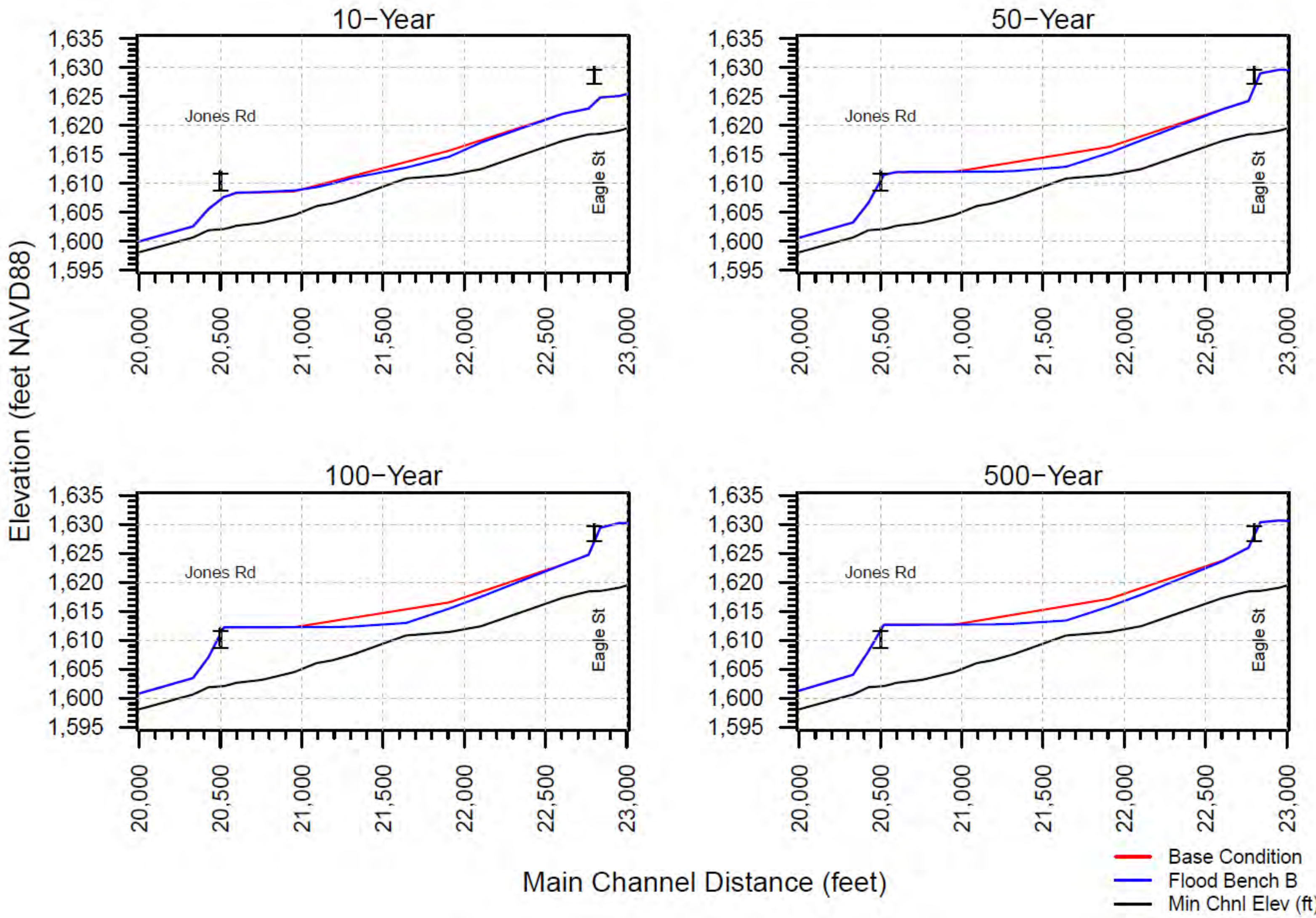


Figure 7-35. HEC-RAS model simulation output results for Alternative #3-5 Flood Bench B.

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 Jones Road would provide flood protection from open-water flooding to the residences in this reach.

The Rough Order Magnitude cost for each flood bench alternative is:

- Flood Bench A: $420,000
- Flood Bench B: $460,000

These cost estimates do not include land acquisition costs for survey, appraisal, and engineering coordination.

7.3.6 Alternative #3-6: Increase Size of Jones Road Bridge Opening

This measure is intended to address issues within High-risk Area #3 by increasing the width of the Jones Road bridge opening, which would increase the cross-sectional flow area of the channel located at river station 200+00 (Figure 7-36).

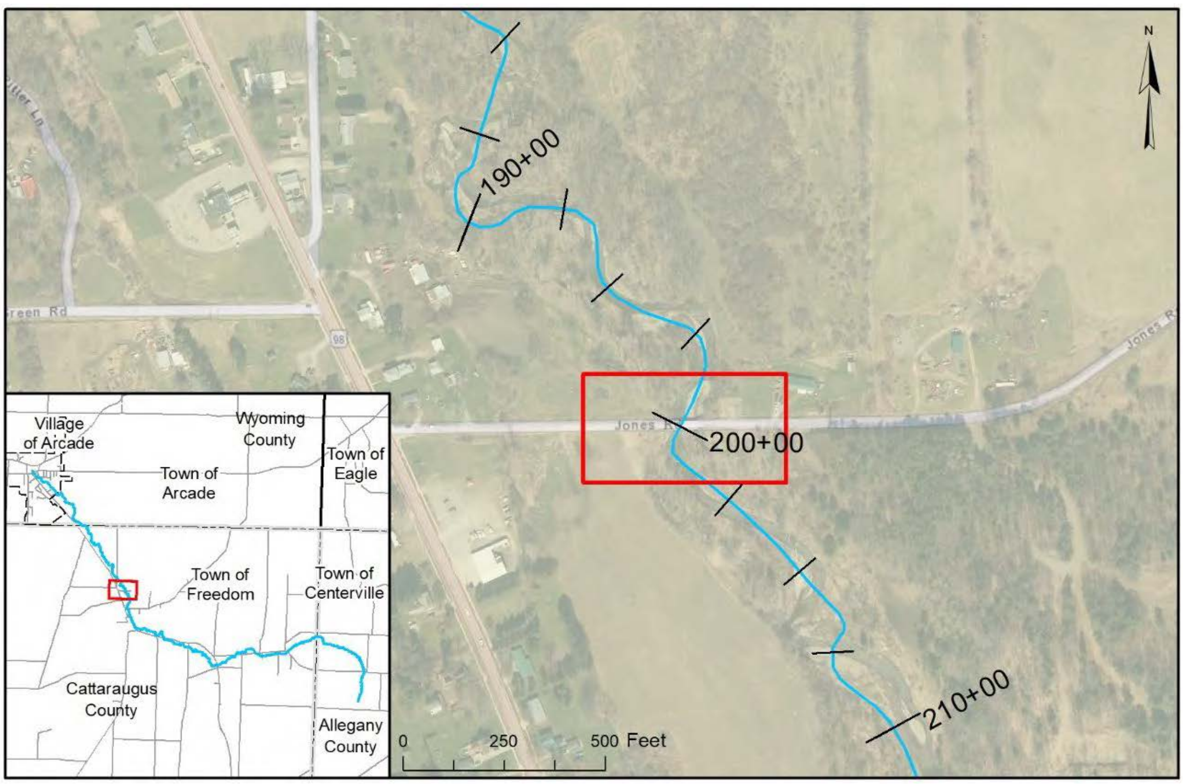


Figure 7-36. Location map for Alternative #3-6.

According to the FEMA FIRM, there is backwater upstream of the Jones Road bridge at the 1% annual chance event (FEMA 1991a). The bridge is owned by Cattaraugus County and the existing bridge structure has a bridge span of 60-ft and a maximum low-chord-to-channel bottom height of 7-ft (Figure 7-37). The flooding in the vicinity of the Jones Road bridge poses a flood risk threat to nearby residential and commercial properties (Ramboll 2021). Appendix F depicts a flood mitigation rendering of a bridge widening scenario.

Figure 7-37. Jones Road bridge, Town of Freedom, NY.

The optimal bridge width to successfully pass the 1% annual chance event was determined through manual selection and multiple simulation runs. The bridge widening design used for the proposed condition model simulation increased the width of the bridge opening from 60-ft to 75-ft by widening the bridge on both banks by 7.5-ft, and increasing the height of the bridge by 1-ft from 7-ft to 8-ft.

The proposed condition model results indicated water surface reductions of up to 2.6-ft in areas approximately 1,550-ft upstream of the bridge, specifically along river stations 203+50 to 219+00 (Figure 7-38). The modeling output for future conditions displayed similar results with water surface reductions of up to 2.4-ft (Appendix H).

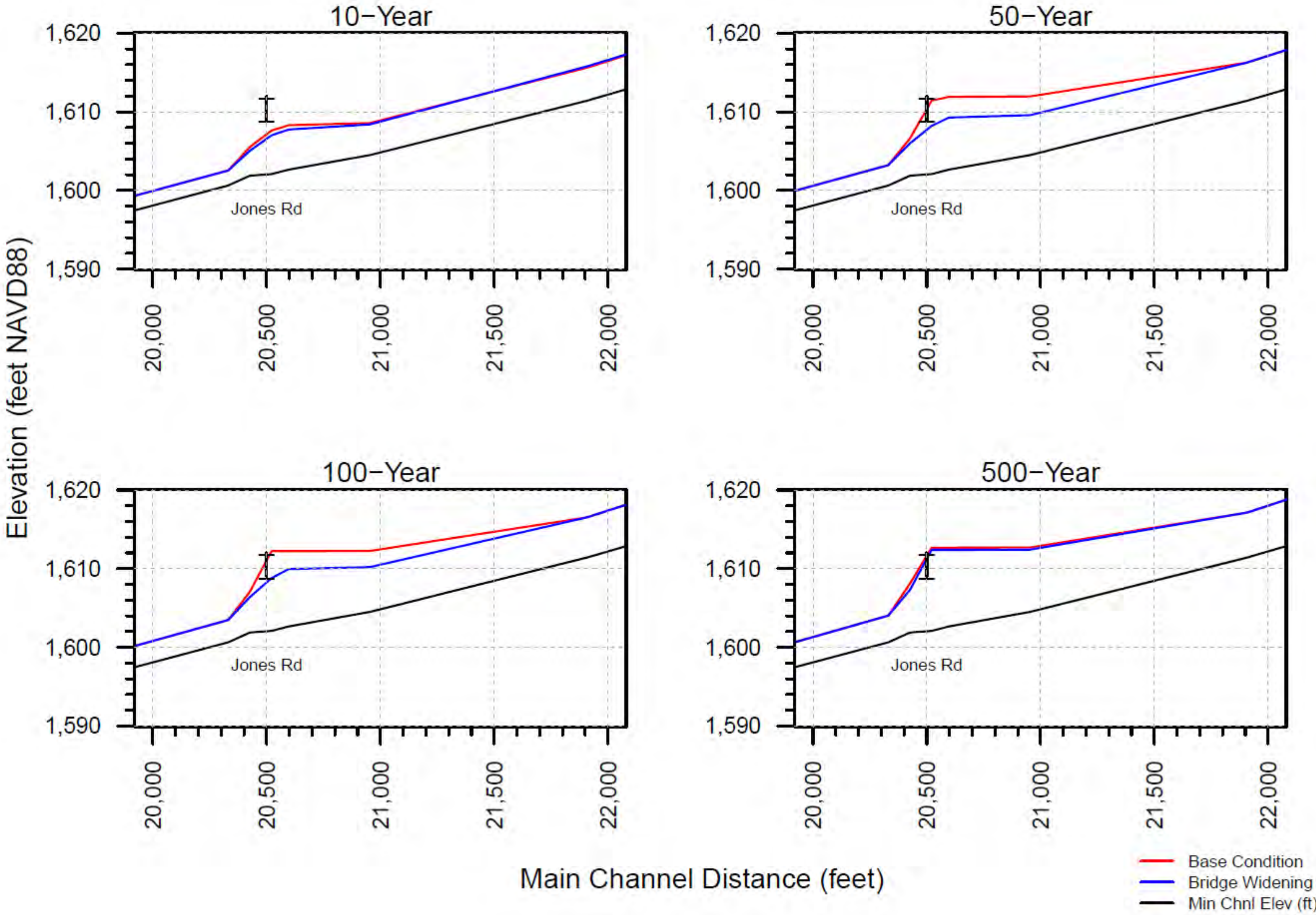


Figure 7-38. HEC-RAS model simulation output results for Alternative #3-6.

An additional modeling simulation was performed for this alternative. The additional model simulation evaluated Flood Bench A from Alternative #3-5 in conjunction with the Jones Road bridge widening strategy.

The proposed condition model results indicated water surface reductions of up to 2.6-ft in areas approximately 1,550-ft upstream of the bridge, specifically along river stations 203+50 to 219+00 (Figure 7-39). The modeling output for future conditions displayed similar results with water surface reductions of up to 2.4-ft (Appendix H).

The bridge widening in conjunction with a flood bench upstream Jones Road lowered WSELs to similar levels immediately upstream of the Jones Road bridge when compared to the bridge widening scenario alone; however, the WSEL reductions extended further upstream with the addition of a flood bench then compared to the bridge wideneing scenario alone, specifically from river stations 210+00 to 219+00.

The Rough Order Magnitude cost for the bridge widening measure is $1.2 million, while the cost estimate for the bridge widening in conjunction with a flood bench measure is $1.6 million**.** These cost estimate do not include land acquisition costs for survey, appraisal, and engineering coordination.

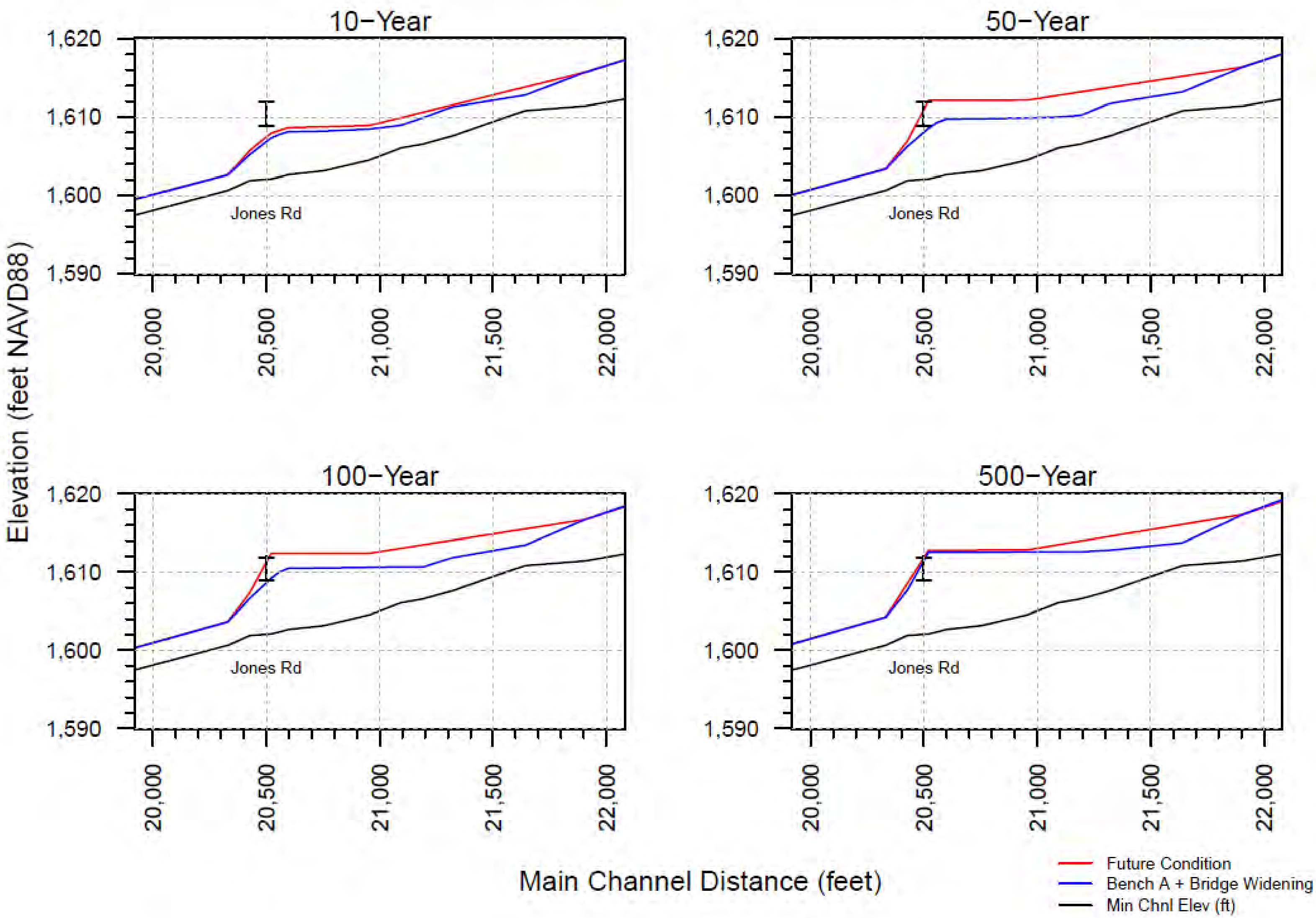


Figure 7-39. HEC-RAS model simulation output results for Alternative #3-6 in conjunction with a flood bench.

7.3.7 Alternative #3-7: Streambank Stabilization Between Sparks and Jones Roads

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. Human disturbances to watersheds that increase frequency and magnitude of runoff events also increase streambank erosion. 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, increasing the resistance of the bank to erosion, or by some combination of both. Streambank stabilization can also play a vital role in flood risk management in areas located in flood prone areas (GSWCC 2000; NRC 2013).

Through historical flood reports, stakeholder engagement meetings, and / or field work, areas along Clear Creek in the Town of Freedom have been identified as areas for potential streambank stabilization strategies. These areas have been outlined in Figure 7-40.

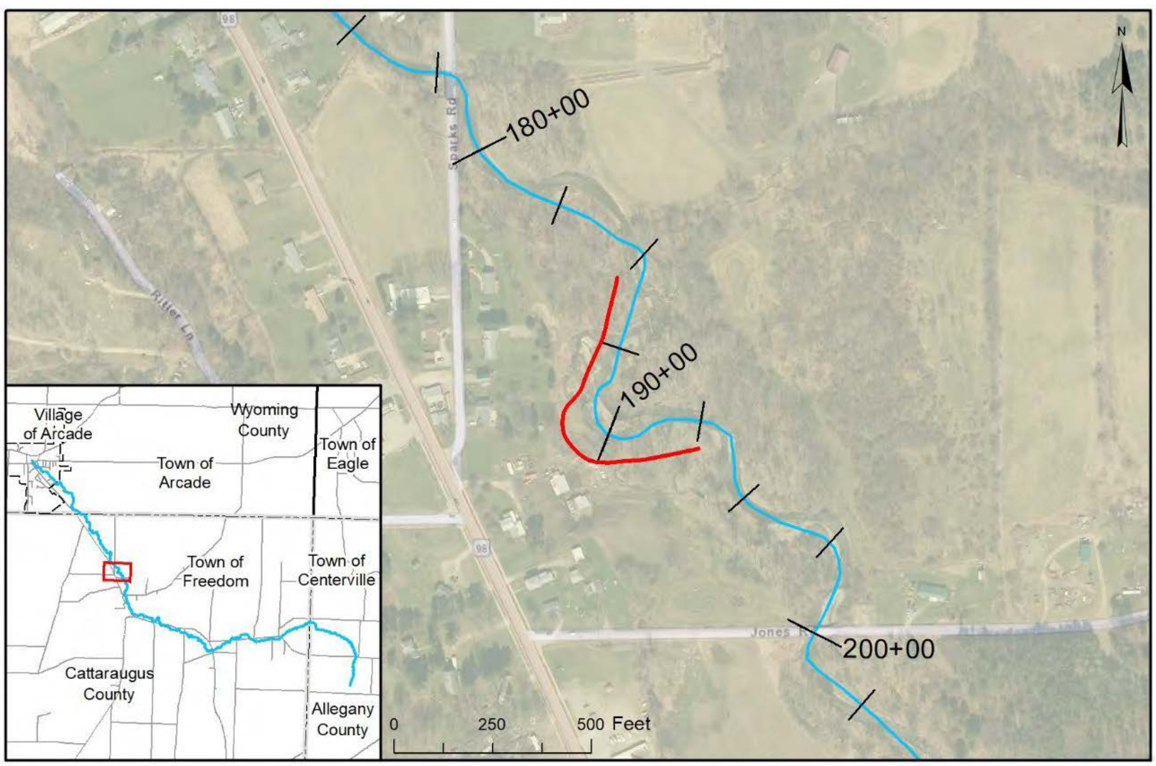


Figure 7-40. Location map for Alternative #3-7.

Appendix F contains detailed discussion of various streambank stabilization strategies, including drawings, definitions, ideal locations, design and construction considerations, maintenance, and Rough Order of Magnitude 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).

To assess the applicability of different streambank stabilization strategies under higher frequency-lower flow conditions, channel velocity (ft/s) and shear stress (lb/sq ft) were calculated using the HEC-RAS software for the base conditions model at the 10% annual chance event and the results are summarized in Table 32.

Table 32. HECRAS Base Condition Model Output of Channel Velocity (ft/s) and Shear Stress (lb/sq ft) at the 10% Annual Chance Event for Alternative #3-7

(Source: USACE 2019b)		
River Station	**Channel Velocity (ft/s)**	**Channel Shear Stress (lb/sq ft)**
198+70	4.3	0.56
193+90	6.3	1.04
188+83	9.31	1.83
184+77	10.42	2.36

Based on the base conditions model output for channel velocity and shear stress, Table 33 summarizes the applicability of potential streambank strategies for this proposed alternative.

Table 33. Potential Streambank Stabilization Strategies for Alternative #3-7

(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 costs 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.

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 2016b).

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, conditions are 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 2016b).

This method can also be supplemented by an ice-jam prediction 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 2016b).

The Rough Order Magnitude 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 Clear Creek watershed. Restoration, which is defined as the process of reestablishing 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 Clear 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

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 Fill in Navigable Waters Permit (NYSDEC 2013).

In addition, sediment control basins along Clear 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 basin is an earth embankment or a combination ridge and channel generally constructed across the slope and 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 2002b).

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 Rough Order Magnitude cost for this strategy is up to $20,000, not including annual maintenance and operational costs.

8.4 Alternative #4-4: Retention Basin and Wetland Management

Stormwater ponds 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 stormwater ponds and 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 wet ponds and wetlands. This sediment can smother the vegetation and clog any filtering structures or outlets. In addition, standing water in ponds 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 ponds 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 a stormwater pond or wetland to operate as designed on a long-term basis. The pollutant removal, channel protection, and flood control capabilities of ponds and wetlands will decrease if (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

Pond and wetland maintenance activities range in terms of the level of effort and expertise required to perform them. Routine pond 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).

8.5 Alternative #4-5: Flood Buyout Program

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 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 2015).

In the Village of Arcade and Towns of Arcade and Freedom along Clear Creek, there are approximately 272 parcels within the FEMA Zone A (1% annual chance flood / 100-yr) hazard zones (Figure 8-1). Of the 272 parcels, 163 parcels are classified as residential, while 39 parcels are classified as commercial. These parcels have a combined full market value of $18.8 million, with residential and commercial parcels accounting for $14.3 million and $4.5 million, respectively. Table 34 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 34. Summary Table for Tax Parcels within FEMA Flood Zones in High-risk Areas along Connoisarauley Creek

Source: NYSGPO 2021		
High-risk Flood Area	**Number of Parcels**	**Full Market Value**
#1: Confluence of Cattaraugus and Clear Creeks, Village of Arcade, Wyoming County, NY	93	$8.64 million
#2: Stuart Avenue to Bray Road Corridor, Town of Arcade, Wyoming County, NY	14	$3.59 million
#3: Sparks Road to Eagle Street Corridor, Town of Freedom, Cattaraugus County, NY	86	$ 6.55 million
Total	**193**	**$18.8 million**

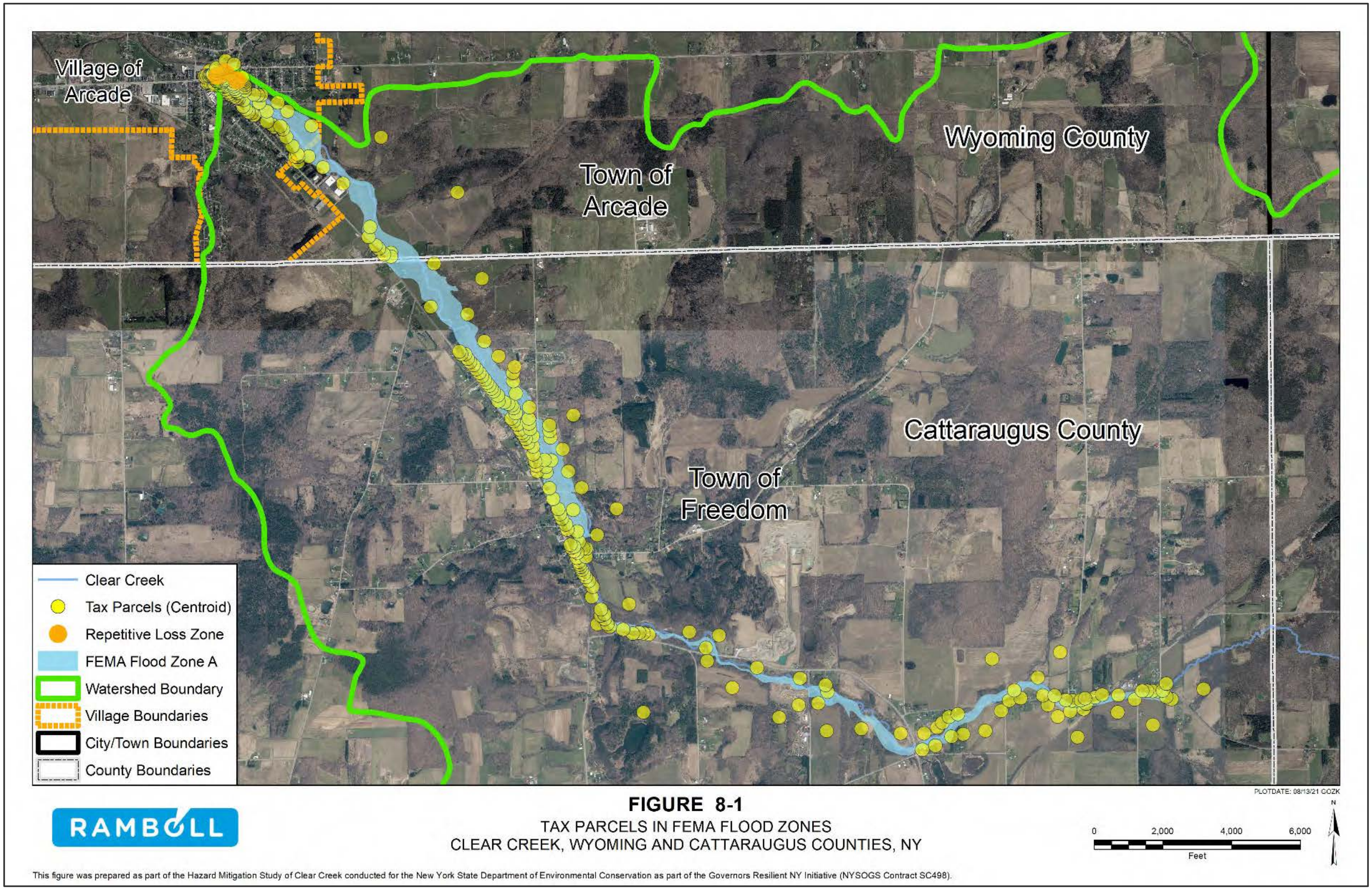


Figure 8-1. Tax parcels within FEMA flood zones, Clear Creek, Wyoming and Cattaraugus Counties, NY.

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 Clear 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.

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 2015).

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 2015).

Examples include:

- *Basement Infill:* 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 2015).

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 one foot above the BFE (FEMA 2013).

In New York State, only non-residential buildings are allowed to be dry floodproofed and the building must be dry floodproofed to an elevation of at least two feet above the BFE. New York State has higher freeboard standards than federal regulations at 44 CFR Part 60.3. Care must be taken to check the NYS Building Code for more stringent guidelines.

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 2015).

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 2015). 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 2015):

- 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 Clear 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's 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 Clear 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 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):

- Provides a legal defense for regulations
- Provides a basis for other actions affecting the development of the community (i.e., land use planning and zoning)
- Helps 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 Clear 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.

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 assess 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 / 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 pursued for consideration.

9.3 NYSDEC PROTECTION OF WATERS PROGRAM

Clear Creek is protected under Article 15 of Title 6 of the New York Codes, Rules, and Regulations (6NYCRR Part 608). Clear Creek has a designation as classification C (TS), which indicates the waterway supports fisheries, is suitable for non-contact activities, and has the potential to support trout populations and spawning. Any changes to the bed or bank of Clear Creek would need to be reviewed and approved by the NYSDEC (NYSDEC 2020b; NYSDEC 2021a).

9.4 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) Emergency Watershed Protection (EWP) Program
- FEMA's Unified Hazard Mitigation Assistance (HMA) Program
- FEMA's Safeguarding Tomorrow through Ongoing Risk Mitigation (STORM) Act
- USACE Continuing Authorities Program (CAP)

9.4.1 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.

9.4.2 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

Current program draft application submittals for pre-review must be received by April 14, 2021 for culvert applications, and May 5, 2021 for bridge applications.

9.4.3 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.

9.4.3.1 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.

9.4.3.2 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.

9.4.4 NRCS Emergency Watershed Protection (EWP) Program

Through the Emergency Watershed Protection (EWP) Program, the U.S. Department of Agriculture’s Natural Resources Conservation Service (NRCS) can assist communities in addressing watershed impairments that pose imminent threats to lives and property. Most EWP projects involve the protection of threatened infrastructure from continued stream erosion. Projects must have a project sponsor, defined as a legal subdivision of the state, such as a city, county, general improvement district, or conservation district, or an Indian Tribe or Tribal organization. Sponsors are responsible for providing land rights to do repair work, securing the necessary permits, furnishing the local cost share (25%), and performing any necessary operation and maintenance for a ten-year period. Through EWP, the NRCS may pay up to 75% of the construction costs of emergency measures, with up to 90% paid for projects in limited-resource areas. The remaining costs must come from local services. Eligible projects include, but are not limited to, debris-clogged stream channels, undermined and unstable streambanks, and jeopardized water-control structures and public infrastructures.

9.4.5 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.

9.4.5.1 Building Resilient Infrastructure and Communities (BRIC)

Beginning in 2020, the Building Resilient Infrastructure and Communities grant program, which was created as part of 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.

9.4.5.2 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

9.4.6 FEMA's 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.

9.4.7 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 35 lists the CAP authorities and their project purposes (USACE 2019a).

Table 35. USACE Continuing Authorities Program (CAP) Authorities and Project Purposes

(Source: USACE 2019a)

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 2019a).

10. SUMMARY

The Towns of Arcade and Freedom, including the Village of Arcade, have had a history of flooding events along Clear Creek. Flooding in the Towns primarily occurs during the summer months due to heavy rains by convective systems, and during winter months due to rain-on-snow and snowmelt events. In response to persistent flooding, the State of New York in conjunction with the Towns of Arcade and Freedom, Village of Arcade, and Wyoming and Cattaraugus Counties, are studying and evaluating potential flood mitigation projects for Clear Creek as part of the Resilient NY Initiative.

This report analyzed the historical and present day causes of flooding in the Clear 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 Clear 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.

Based on the flood mitigation analyses performed in this report, the mitigation alternatives that provided the greatest reductions in water surface elevations for High-risk Area #2 were the flood benches upstream of the Village of Arcade corporate limits, and for High-risk Area #3 were the flood benches upstream of Jones Road and increasing the size of both Sparks and Jones Road's bridge openings.

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.

The flood bench measures discussed for Clear 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 Village of Arcade, very few areas were found to be adequate for large scale flood benches that could potentially provide greater flood mitigation protections to historically vulnerable areas in High-risk Area #1. 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.

Based on the analysis of the bridge widening simulations, the Sparks and Jones Road bridge crossings benefited from increased bridge 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 bridge widening measure to determine if it would be feasible to move a bridge 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 debris maintenance around waterway crossing infrastructure, riparian restoration, and retention basin and wetland management measures would maintain the flow channel area in Clear 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.

Streambank stabilization measures can potentially reduce flood risk in small and medium-size watersheds by reestablishing 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.

Levees are effective at managing flood risk within a watershed when properly designed, constructed, and maintained. However, levees do not remove properties from flood zones, so flood insurance would still be required for any property behind a levee. In addition, regulatory and permitting requirements for constructing and maintaining levees must be considered for any levee measure.

Floodproofing and flood buyout programs are effective mitigation measures but require large financial investments in individual residential and non-residential buildings. Floodproofing can reduce the future risk and flood damage potential but leaves buildings in flood-risk areas so that the potential for future flood damages remains. Flood buyout programs eventually lead to the removal of buildings from the floodplain. A benefit to floodproofing versus buyouts is that properties remain in the Village, and the tax base for the local municipality remains intact. Floodproofing versus flood buyouts should be considered on a case-by-case basis with all associated benefits and drawbacks.

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.

Table 36 is a summary of the proposed flood mitigation measures, including modeled water surface elevation reductions and estimated ROM costs.

Table 36. Summary of Flood Mitigation Measures

Alternative No.	Description	Benefits Related to Alternative	ROM cost ($U.S. dollars)
1-1	Sediment / Debris Management at Mouth	Improves water quality and increases channel flow area	$120,000 [i]
1-2	Flood Benches Upstream of Confluence with Unnamed Tributary	Model simulated WSEL reductions of: Flood Bench A: Up to 1.0-ft Flood Bench B: Up to 1.6-ft	Flood Bench A: $320,000 Flood Bench B: $320,000 [i]
1-3	Sediment / Debris Retention Basin Downstream of the Village Corporate Limits	Reduce watercourse and gully erosion, trap sediment, reduce and manage runoff, and improve downstream water quality	N/A [ii]
1-4	Streambank Stabilization in the Vicinity of Pearl and Grove Streets	Reduce force of flowing water and / or increase resistance of the bank to erosion	N/A [iii]
1-5	Hydrologic and Hydraulic Analysis of Haskell Creek	Provide community / stakeholders with necessary background and supporting information to begin addressing flooding issues	$60,000
2-1	Flood Benches Upstream of the Village Corporate Limits	Model simulated WSEL reductions of: Flood Bench A: Up to 2.3-ft Flood Bench B: Up to 2.5-ft	Flood Bench A: $580,000 Flood Bench B: $610,000 [i]
2-2	Streambank Stabilization Upstream of the Village Corporate Limits	Reduce force of flowing water and / or increase resistance of the bank to erosion	N/A [iii]
2-3	Flood Control Structure Downstream of the Town Corporate Limits	Limits flood extents and depths downstream and helps with sediment transport	N/A [iiii]
2-4	Hydrologic and Hydraulic Analysis of Clear Creek Tributary	Provide community / stakeholders with necessary background and supporting information to begin addressing flooding issues	$60,000
2-5	Streambank Stabilization Upstream of Bray Road	Reduce force of flowing water and / or increase resistance of the bank to erosion	N/A [iii]

Alternative No.	Description	Benefits Related to Alternative	ROM cost ($U.S. dollars)
3-1	Flood Benches Downstream of Sparks Road	Model simulated WSEL reductions of: Flood Bench A: Up to 1.5-ft Flood Bench B: Up to 1.0-ft	Flood Bench A: $630,000 Flood Bench B: $660,000 [i]
3-2	Levee Along NY-98 Downstream of Sparks Road	No model simulated upstream or downstream effects	$1.4 million [v]
3-3	Flood Benches Upstream of Sparks Road	Model simulated WSEL reductions of: Flood Bench A: Up to 1.0-ft Flood Bench B: Up to 1.1-ft Flood Bench C: Up to 1.3-ft Flood Bench D: Up to 1.0-ft	Flood Bench A: $300,000 Flood Bench B: $360,000 Flood Bench C: $340,000 Flood Bench D: $340,000 [i]
3-4	Increase Size of Sparks Road Bridge Opening	Model simulated WSEL reductions of: With Pier: Up to 1.5-ft Without Pier: Up to 1.8-ft	With Pier: $720,000 Without Pier: $1.2 million [i]
3-5	Flood Benches Upstream of Jones Road	Model simulated WSEL reductions of: Flood Bench A: Up to 2.6-ft Flood Bench B: Up to 2.5-ft	Flood Bench A: $420,000 Flood Bench B: $460,000 [i]
3-6	Increase Size of Jones Road Bridge Opening	Model simulated WSEL reductions of up to 2.3-ft	$1.2 million [i]
	Increase Size of Jones Road Bridge Opening in Conjunction with a Flood Bench	Model simulated WSEL reductions of up to 2.6-ft	$1.6 million [i]
3-7	Streambank Stabilization Between Sparks and Jones Roads	Reduce force of flowing water and / or increase resistance of the bank to erosion	N/A iii
4-1	Early-warning Flood Detection System	Early flood warning for open-water and ice-jam events	$120,000 (not including annual operational costs)

Alternative No.	Description	Benefits Related to Alternative	ROM cost ($U.S. dollars)
4-2	Riparian Restoration	Restores natural habitats, reduces / manages runoff, and improves water quality	Variable (case-by-case)
4-3	Debris Maintenance Around Culverts / Bridges	Maintains channel flow area and reduces flood risk	$20,000 (not including annual operational costs)
4-4	Retention Basin and Wetland Management	Reduces erosion, traps sediments, reduces / manages runoff, and improves water quality	Variable (case-by-case)
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 (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)

[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 retention 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 Clear Creek can use this report to support flood mitigation initiatives within their communities. This report is intended to be a high-level overview of potential flood mitigation strategies, their impacts on water surface elevations, and the associated ROM cost for each mitigation strategy. The research and analysis that went into each mitigation 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 discussed 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 Clear 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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