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RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE

CANADAWAY CREEK, CHAUTAUQUA COUNTY, NEW YORK

Prepared for:

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NEW YORK STATE OF OPPORTUNITY. Department of Environmental Conservation

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RAMBOLL

HIGHLAND PLANNING

GOMEZ AND SULLIVAN ENGINEERS

RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE
CANADAWAY CREEK, CHAUTAUQUA COUNTY, NEW YORK

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

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ACRONYMS / ABBREVIATIONS

1-, 2-, 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
CCSWCD	Chautauqua County Soil and Water Conservation District
CDBG	Community Development Block Grants
CEHA	Coastal Erosion Hazard Area
CFA	Consolidated Funding Applications
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second (ft3/s)
CRRA	Community Risk and Resiliency Act
CRREL	Cold Regions Research and Engineering Laboratory
CRISSP	Comprehensive River Ice Simulation System
CSC	Climate Smart Communities
DEM	Digital Elevation Model
DHS	Department of Homeland Security
DRRA	Disaster Recovery Reform Act of 2018
EPF	Environmental Protection Fund
EWP	Emergency Watershed Protection
FCA	Flood Control Act
FEMA	Federal Emergency Management Agency
FDD	Freezing Degree-Day
FHA	Federal Highway Administration
FHF	Flood Hazard Factor
FIA	Federal Insurance Agency
FIRM	Flood Insurance Rate Maps
FIS	Flood Insurance Study
FMA	Flood Mitigation Assistance
FT	Feet

GLS	Generalized Least-Squares
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
LP3	Log-Pearson III
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
RICEN	River Ice Simulation Model
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
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 Canadaway Creek watershed. In response to periodic and repetitive flood losses in the watershed, local and state agencies have engaged in flood mitigation efforts along Canadaway Creek.

Within the Canadaway Creek watershed, there are no major flood control structures in the Towns of Dunkirk and Pomfret, and the Village of Fredonia. Due to the high channel velocities through the middle reaches of the creek, much of the channel has been lined with concrete walls to control stream bank erosion through the Village of Fredonia. Near the downstream corporate limits of the Village, gravel bar material is periodically removed due to sediment depositional aggradation.

In the Town of Dunkirk, the Fredonia Sewage Treatment Plant sewer line is located along Canadaway Creek in the vicinity of West Lake Road (Hwy 5) and Temple Road. The streambank erosion protection project consisted of a stone revetment, approximately 400-ft long, with a 36-in layer of stone riprap on a 4-in layer of bedding stone over filter fabric which is keyed into the bedrock at the toe. Construction of the project was completed in August 1993 at a cost of approximately $194,000 (NYSDEC 2012).

1.2 FLOODPLAIN DEVELOPMENT

General recommendations for high-risk floodplain development follow three 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 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 Federal Emergency Management Agency (FEMA) regulations since the Towns of Dunkirk, Pomfret, and Arkwright, and Village of Fredonia 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 Canadaway 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 evaluated using hydrologic and hydraulic modeling to quantitatively determine flood mitigation strategies that would result in the greatest flood reductions 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 Initiative 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 Canadaway Creek began in May of 2020 and a final flood study report was issued in May 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 2020) 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* v4.3.11 (USGS 2019b) 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 1984 and 1989 FEMA Flood Insurance Study's (FIS) for the Town of Pomfret and Village of Fredonia, respectively. 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.

2.2 PUBLIC OUTREACH

Initial project kickoff meetings were held virtually between June 22nd and 29th, 2020, with representatives of the NYSDEC, NYSOGS, Ramboll Americas Engineering Solutions, Inc. (Ramboll), Highland Planning, NYSDOT, Town of Pomfret, Village of Fredonia, Chautauqua County, and Chautauqua County Soil and Water Conservation District (CCSWCD) (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 Towns of Dunkirk and Pomfret, and Village of Fredonia as identified in the initial data collection process. Initial field assessments of Canadaway Creek were conducted in March 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

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

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

3. WATERSHED CHARACTERISTICS

3.1 STUDY AREA

The Canadaway Creek watershed lies entirely within Chautauqua County, New York. The creek flows in a north / northwesterly direction with its headwaters in the Town of Charlotte traveling through the Towns of Arkwright and Pomfret, and the Village of Fredonia before emptying into Lake Erie in the Town of Dunkirk (Figure 3-1).

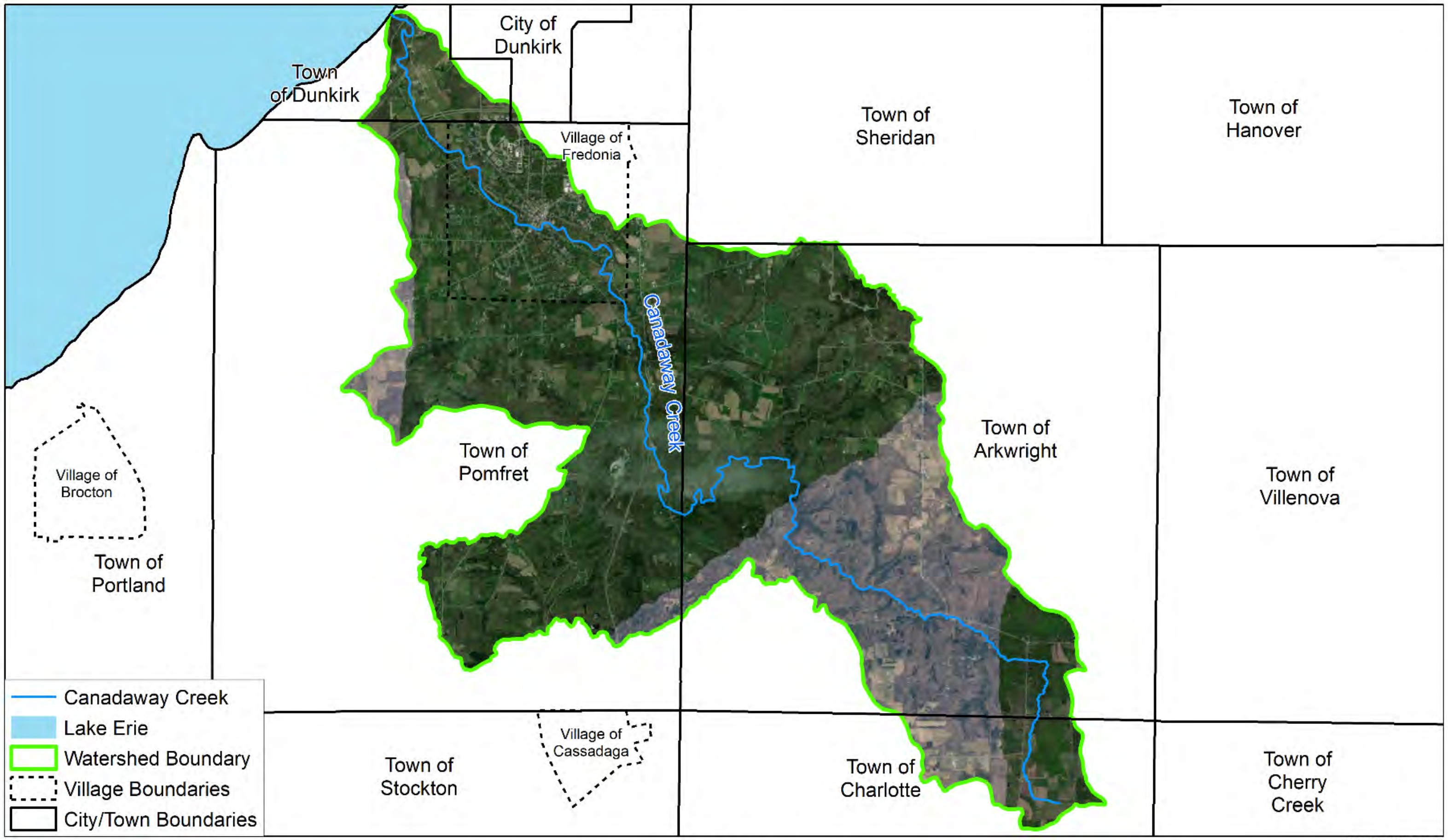
The Canadaway Creek basin is the major basin that runs through the Towns of Arkwright and Pomfret, and the Village of Fredonia. In addition to many small, unnamed tributaries, Canadaway Creek receives flow from Ackles, Clinton, and Markum Brooks in the Town of Arkwright and Beaver Creek in the Town of Dunkirk. Canadaway Creek is the primary contributor to local flood problems for the Village of Fredonia and Town of Pomfret in Chautauqua County, NY (FEMA 1984; FEMA 1989b).

Within the Canadaway Creek watershed, the Village of Fredonia and Town of Dunkirk was chosen as the target area due to historical flood records and the hydrologic conditions of the creek in this area. Figures 3-2 and 3-3 depict the stream stationing along Canadaway Creek in Chautauqua County, NY, and the study area in the Village of Fredonia and Town of Dunkirk, NY, respectively.

3.2 ENVIRONMENTAL CONDITIONS

An overview of the environmental and cultural resources within the Canadaway 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 2021) (https://gisservices.dec.ny.gov/gis/erm/)
- **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 deepwater habitats" (NYSDEC 2021)
- **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) (https://ecos.fws.gov/ipac/)
- **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) (https://www.nps.gov/maps/full.html?mapId=7ad17cc9-b808-4ff8-a2f9-a99909164466)



PLOTDATE: 03/05/21 GOZK

FIGURE 3-1

WATERSHED
CANADAWAY CREEK, CHAUTAUQUA COUNTY, NY

0 3,000 6,000 9,000
Feet
N

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

Figure 3-1. Canadaway Creek Watershed, Chautauqua County, NY.

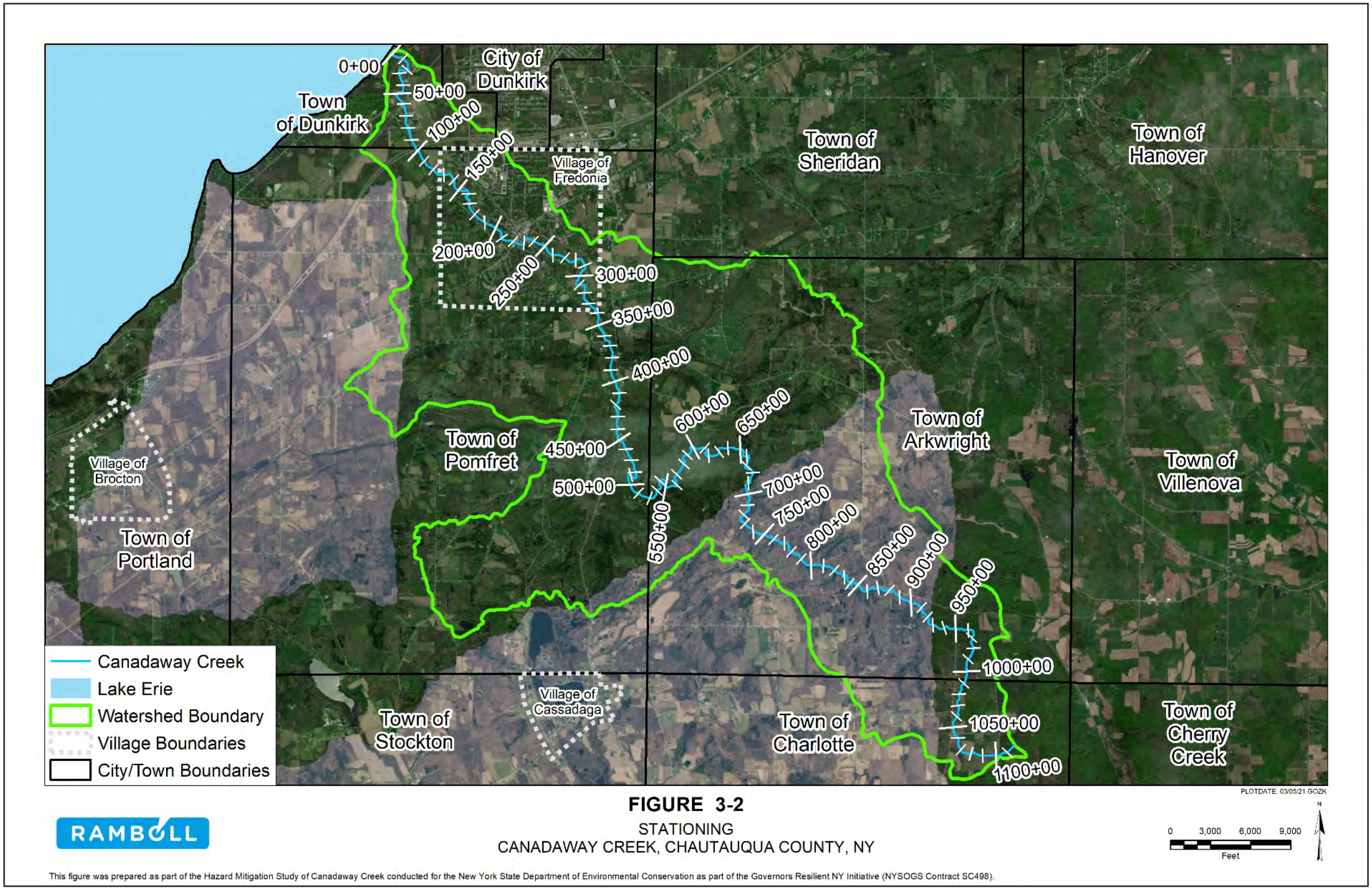


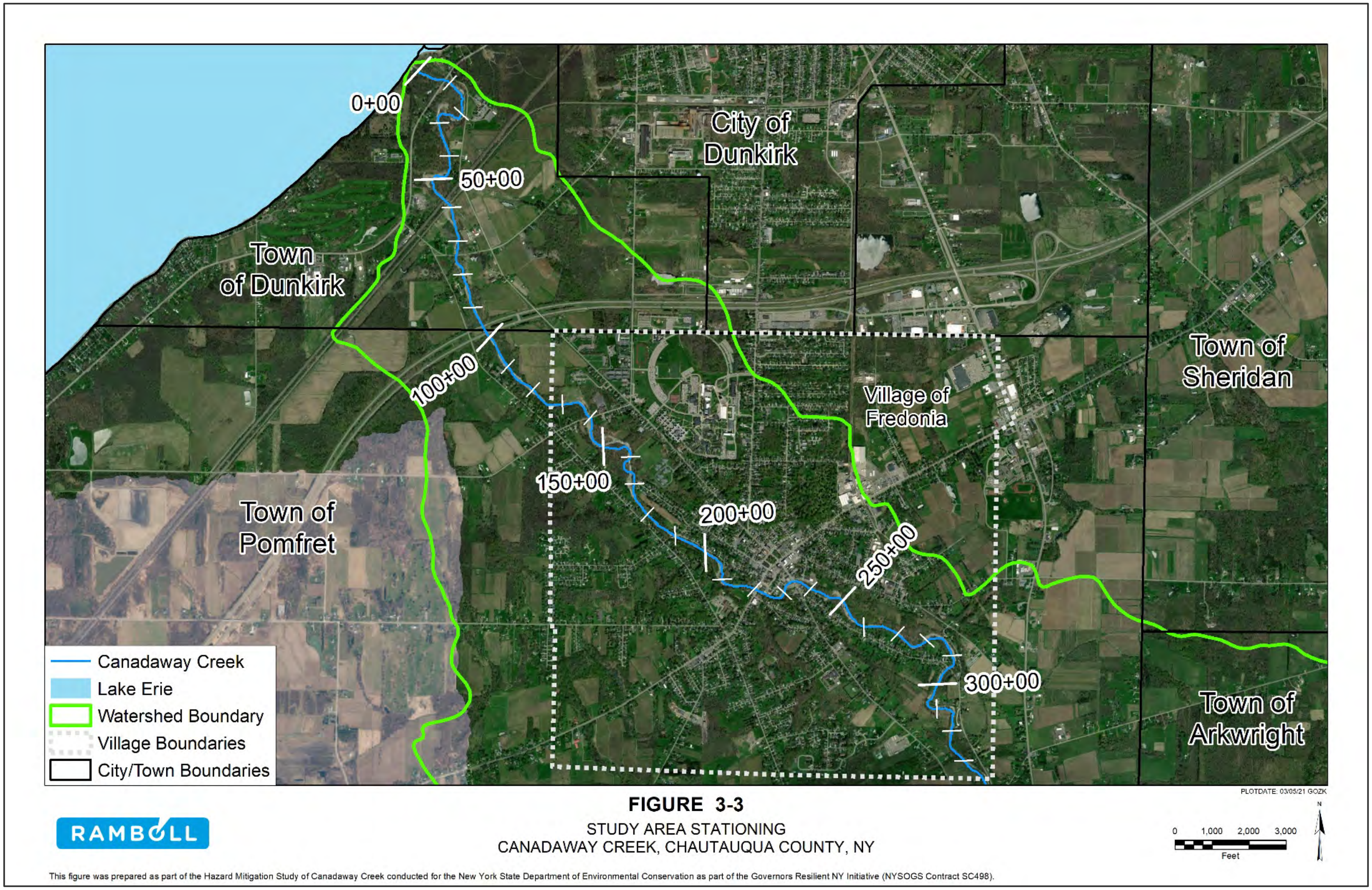
FIGURE 3-2

STATIONING

CANADAWAY CREEK, CHAUTAUQUA COUNTY, NY

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

Figure 3-2. Canadaway Creek Stationing, Chautauqua County, NY.



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

Figure 3-3. Canadaway Creek Study Area Stationing, Chautauqua County, NY.

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. According to the Environmental Resource Mapper, several state-regulated freshwater wetlands are located within the Canadaway Creek watershed. The National Wetlands Inventory was reviewed to identify national wetlands and surface waters (Figure 3-4). The Canadaway Creek watershed includes riverine, freshwater pond, and lake habitats, freshwater emergent wetlands, and freshwater forested / shrub wetlands (NYSDEC 2021).

3.2.2 Sensitive Natural Resources

The Canadaway Creek watershed contains areas designated as significant natural communities as mapped by the Environmental Resource Mapper. The significant natural community identified included a sand beach, which is within the Uplands Ecological System at Point Gratiot in the Town of Dunkirk, NY along the Lake Erie shoreline (NYSDEC 2021).

3.2.3 Endangered or Threatened Species

The Environmental Resource Mapper shows that the watershed basin contains several areas identified as containing rare plants and / or animals listed as endangered, threatened, or rare by New York State, including the Red-headed Woodpecker, which is listed as a Special Concern species (Figure 3-5). The NYSDEC Regional Office should be contacted to determine the potential presence of the species identified, if any permits are required, or if an environmental impact assessment needs to be performed prior to any project or action (NYSDEC 2021).

The USFWS Information for Planning and Consultation (IPaC) results for the project area list five endangered or threatened species: Northern Long-eared Bat, Clubshell clam, Longsolid clam, Northern Riffleshell clam, and Rayed Bean clam. There are no critical habitat designations for any species at this location (USFWS 2021) (https://ecos.fws.gov/ipac/). The migratory bird species listed in Table 1 are transient species that may pass over, but are not known to nest within the project area.

Table 1. UFWS IPaC Listed Migratory Bird Species

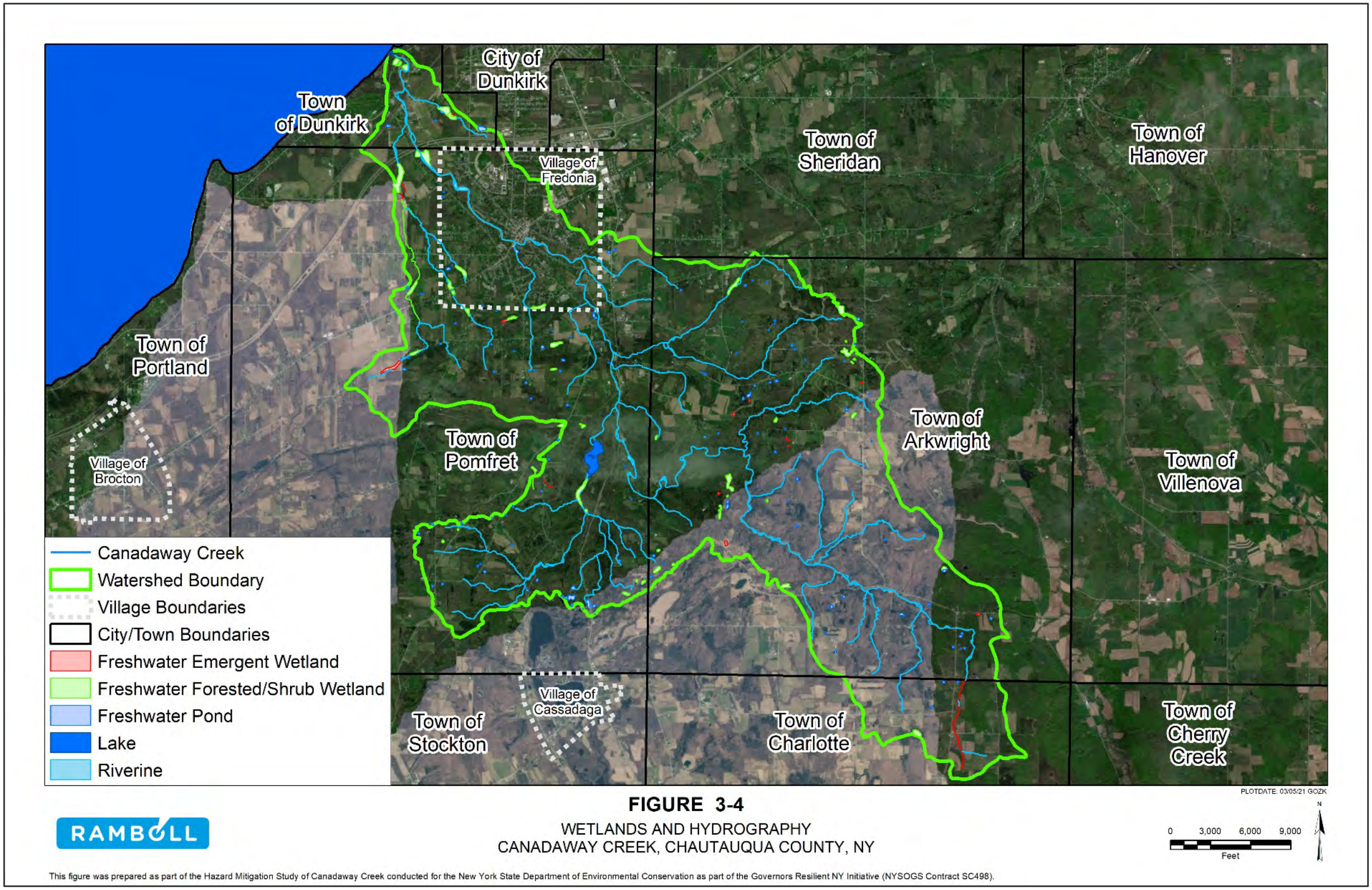
(Source: USFWS 2021)

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
Bobolink	*Dolichonyx oryzivorus*	BCC Rangewide (CON)[2]	Breeds May 20 to Jul 31
Canada Warbler	*Cardellina canadensis*	BCC Rangewide (CON)[2]	Breeds May 20 to Aug 10
Dunlin	*Calidris alpina arcticola*	BCC-BCR[3]	Breeds elsewhere
Lesser Yellowlegs	*Tringa flavipes*	BCC Rangewide (CON)[2]	Breeds elsewhere
Prairie Warbler	*Dendroica discolor*	BCC Rangewide (CON)[2]	Breeds May 1 to Jul 31
Red-headed Woodpecker	*Melanerpes erythrocephalus*	BCC Rangewide (CON)[2]	Breeds May 10 to Sep 10
Ruddy Turnstone	*Arenaria interpres morinella*	BCC-BCR[3]	Breeds elsewhere
Semipalmated Sandpiper	*Calidris pusilla*	BCC Rangewide (CON)[2]	Breeds elsewhere
Snowy Owl	*Bubo scandiacus*	BCC Rangewide (CON)[2]	Breeds elsewhere
Wood Thrush	*Hylocichla mustelina*	BCC Rangewide (CON)[2]	Breeds May 10 to Aug 31

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.



This figure was prepared as part of the Hazard Mitigation Study of Canadaway 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. Canadaway Creek Wetlands and Hydrography, Chautauqua County, NY.

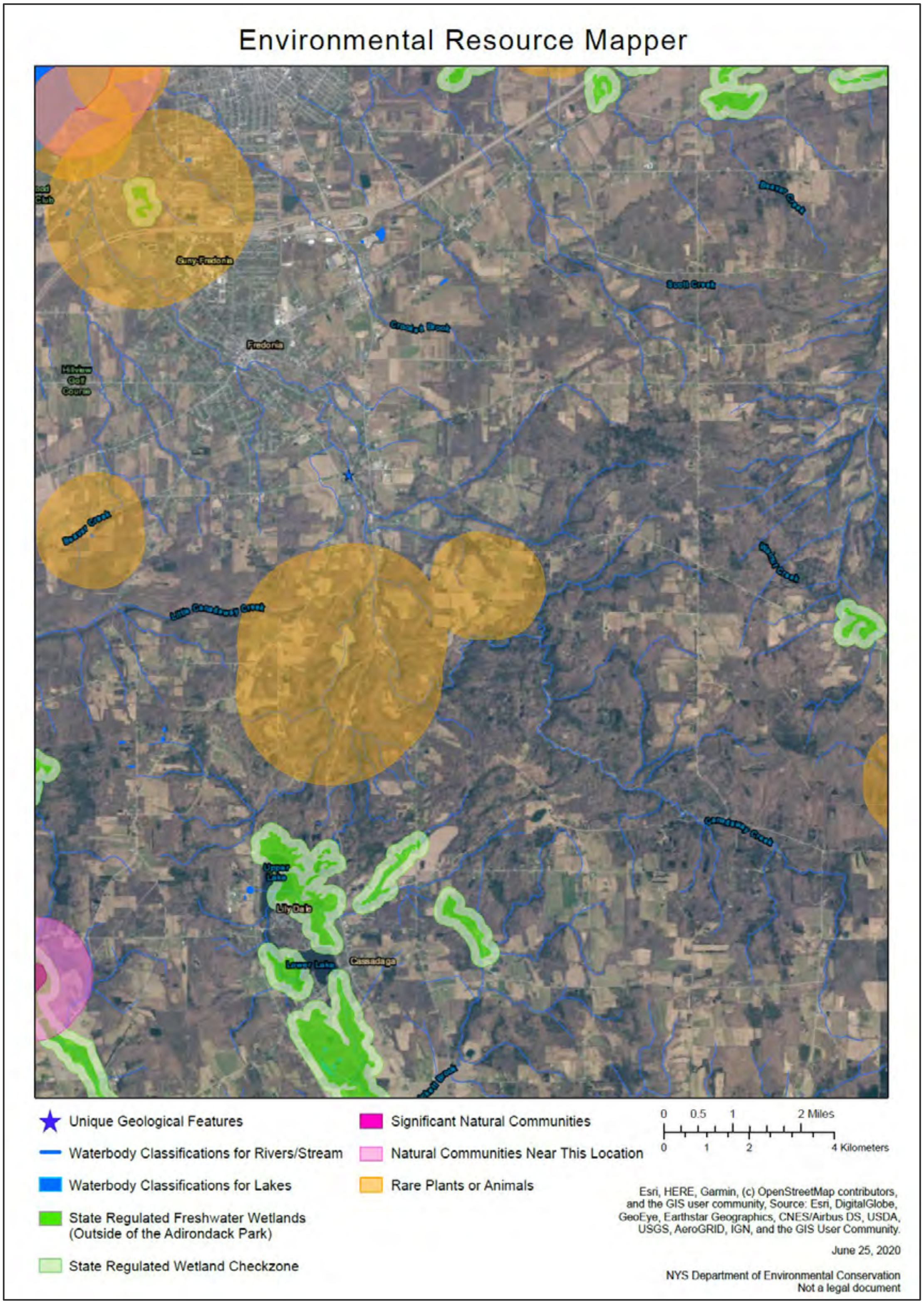


Figure 3-5. Significant Natural Communities and Rare Plants or Animals, Canadaway Creek, Chautauqua County, NY.

3.2.4 Cultural Resources

According to the National Register of Historic Places, Canadaway Creek is located near the United States Post Office and the Fredonia Commons Historic District in the Village of Fredonia, NY. Figure 3-6 displays the boundaries of these historic sites.

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).

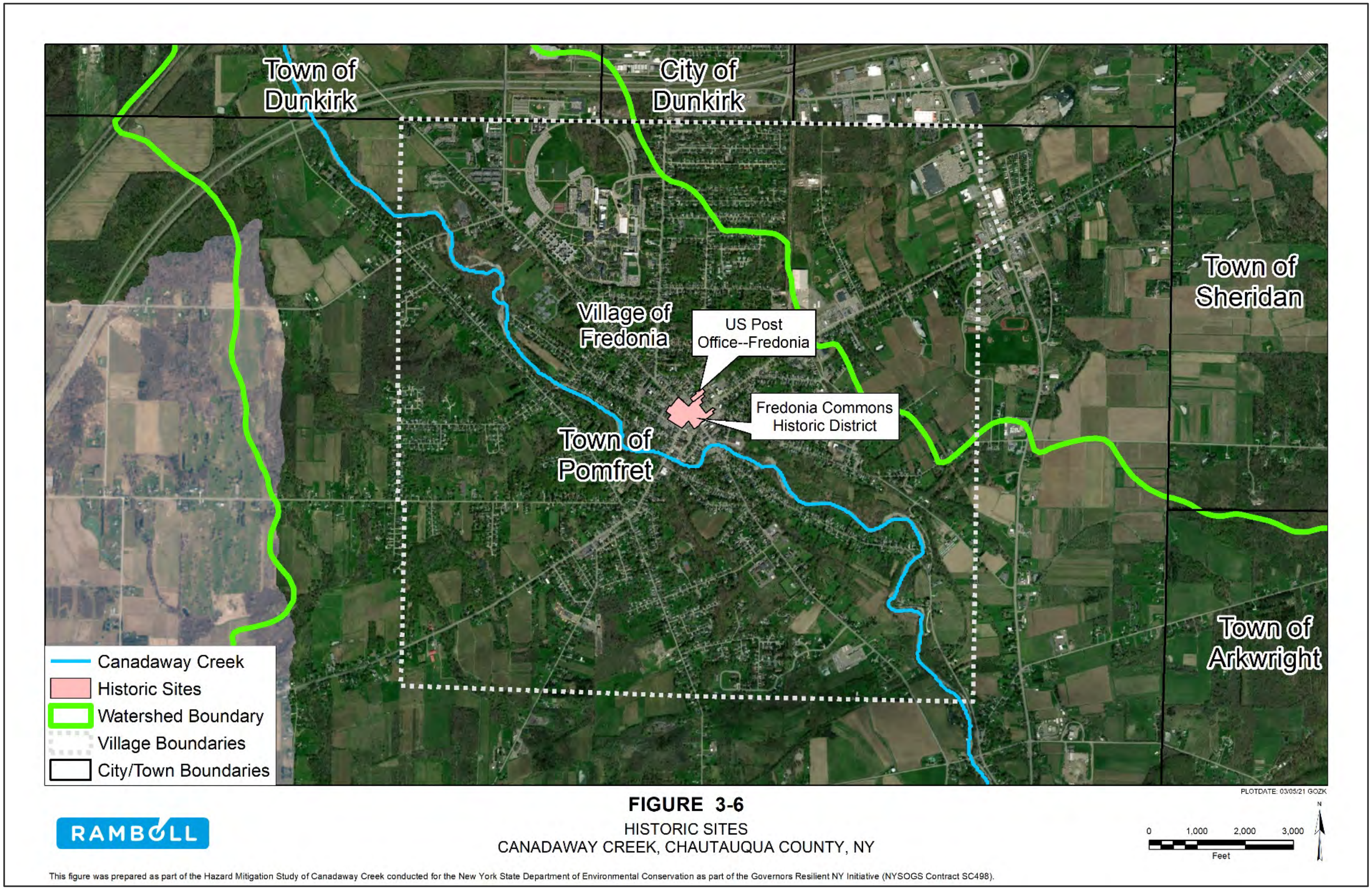


FIGURE 3-6

HISTORIC SITES

CANADAWAY CREEK, CHAUTAUQUA COUNTY, NY

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

Figure 3-6. National Register of Historic Places, Canadaway Creek, Chautauqua County, NY.

3.3 FEMA Mapping and Flood Zones

The Federal Insurance Administration (FIA) was created by the National Flood Insurance Act of 1968 and administered by the United States Department of Housing and Urban Development (USHUD). The FIA was absorbed into FEMA through an executive order by President Jimmy Carter on April 1, 1979.

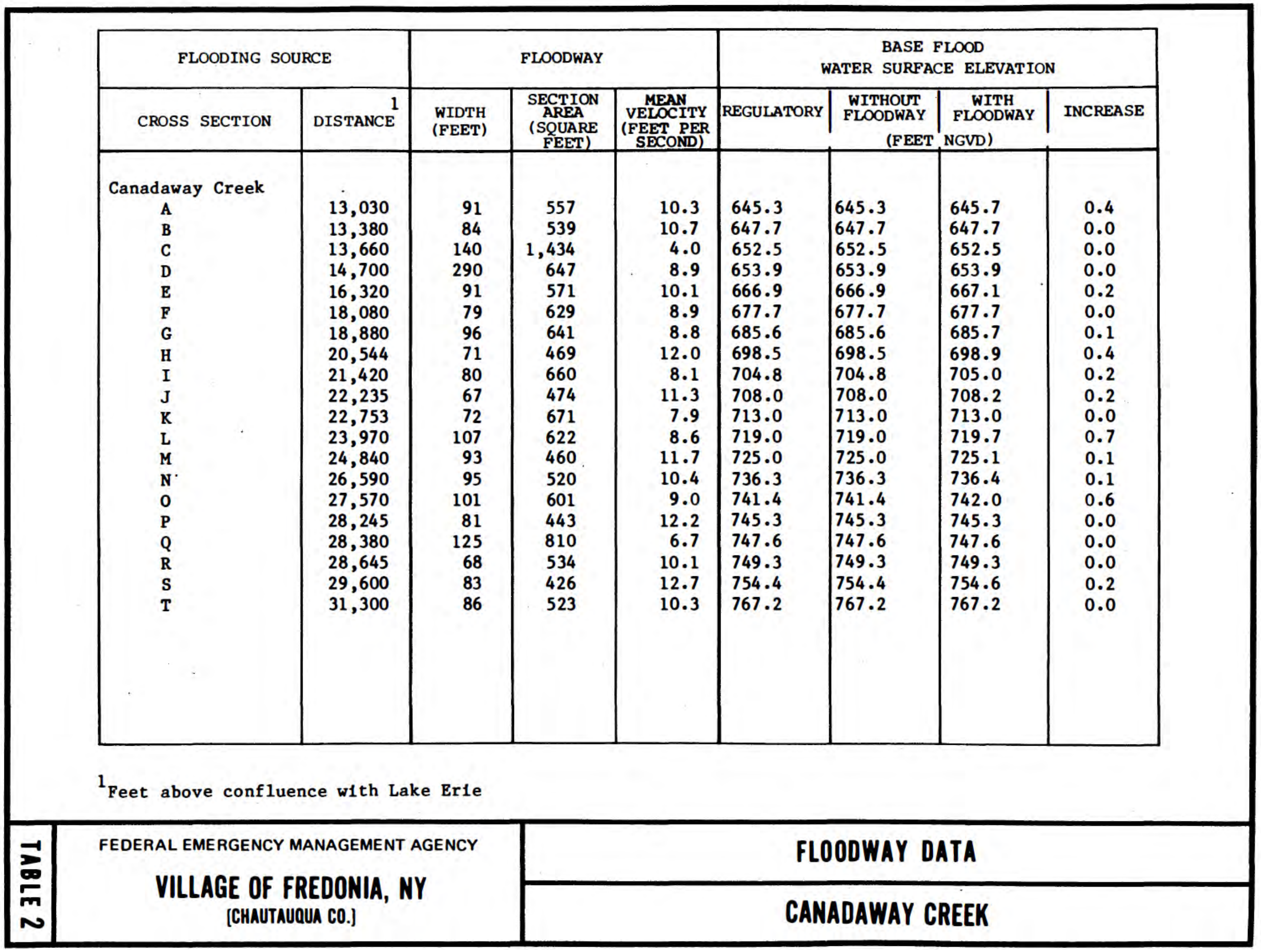
The FEMA Flood Map Service Center (MSC) (https://msc.fema.gov/portal/home) is a database that contains FEMA Flood Insurance Rate Maps (FIRMs) for areas that have had FEMA flood insurance studies completed throughout the United States (FEMA 2021). For the Town of Pomfret and Village of Fredonia, the current effective FEMA FIS reports were completed in 1984 and 1989, respectively. According to their respective FIS reports, the hydrologic and hydraulic analyses completed for Canadaway Creek in the Village of Fredonia was done using detailed methods for its entire length through the Village, while the Town of Pomfret used approximate methods (FEMA 1984; FEMA 1989b). No updated FIS reports, H&H analyses, or preliminary products have been produced since the original studies for both the Town of Pomfret and Village of Fredonia were completed in 1984 and 1989, respectively.

The H&H analyses performed for Canadaway Creek in the Village of Fredonia was a detailed study, which included a revisional analysis performed from Risley Street upstream to Liberty Street based on the August 1979 storm and subsequent flooding at the Water Street bridge due to debris blockage (FEMA 1989b). The FIS reports for the Towns of Pomfret and Dunkirk do not provide any H&H data for Canadaway Creek.

For Canadaway Creek in the 1989 Village of Fredonia FIS, hydrologic analyses were performed to establish the peak discharge-frequency and elevation-frequency relationships for floods of the selected recurrence intervals. Detailed analyses of the hydrologic characteristics were carried out originally using the USGS Water Resources Investigations 79-83 method (USGS 1979) and, for the revised portion of Canadaway Creek, a regional frequency analysis developed for the Buffalo Metro Study by the USACE Buffalo District (USACE [date unknown]; (FEMA 1989b).

For the hydraulic analysis, cross sections for the backwater analyses of Canadaway Creek were obtained from topographic maps compiled from aerial photographs. Below-water sections and overbank areas adjacent to the channel were obtained by field measurement. All bridges and culverts were field checked to obtain elevation data and structural geometry. For the 1989 revision, all cross-sectional data were obtained from field surveys. Channel roughness factors used in the hydraulic computations were chosen by engineering judgment and field observation of the streams and floodplain areas. Water-surface elevations of floods of the selected recurrence intervals were computed using the USACE HEC-2 step-backwater computer program (USACE 1973). For the 1989 revision, a water-surface profile depicting the "100-year flood profile with Water Street Bridge blocked by debris" was added to the flood profiles (FEMA 1989b).

In addition, Canadaway Creek in the Village of Fredonia is a Regulatory Floodway, which is defined as the watercourse channel and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than 1 ft 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 ft. Figure 3-7 displays the floodway data from the FIS for the Village of Fredonia, NY (FEMA 1989b; FEMA 2000).



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
Canadaway Creek								
A	13,030	91	557	10.3	645.3	645.3	645.7	0.4
B	13,380	84	539	10.7	647.7	647.7	647.7	0.0
C	13,660	140	1,434	4.0	652.5	652.5	652.5	0.0
D	14,700	290	647	8.9	653.9	653.9	653.9	0.0
E	16,320	91	571	10.1	666.9	666.9	667.1	0.2
F	18,080	79	629	8.9	677.7	677.7	677.7	0.0
G	18,880	96	641	8.8	685.6	685.6	685.7	0.1
H	20,544	71	469	12.0	698.5	698.5	698.9	0.4
I	21,420	80	660	8.1	704.8	704.8	705.0	0.2
J	22,235	67	474	11.3	708.0	708.0	708.2	0.2
K	22,753	72	671	7.9	713.0	713.0	713.0	0.0
L	23,970	107	622	8.6	719.0	719.0	719.7	0.7
M	24,840	93	460	11.7	725.0	725.0	725.1	0.1
N	26,590	95	520	10.4	736.3	736.3	736.4	0.1
O	27,570	101	601	9.0	741.4	741.4	742.0	0.6
P	28,245	81	443	12.2	745.3	745.3	745.3	0.0
Q	28,380	125	810	6.7	747.6	747.6	747.6	0.0
R	28,645	68	534	10.1	749.3	749.3	749.3	0.0
S	29,600	83	426	12.7	754.4	754.4	754.6	0.2
T	31,300	86	523	10.3	767.2	767.2	767.2	0.0

[1] Feet above confluence with Lake Erie

TABLE 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

VILLAGE OF FREDONIA, NY
(CHAUTAUQUA CO.)

FLOODWAY DATA

CANADAWAY CREEK

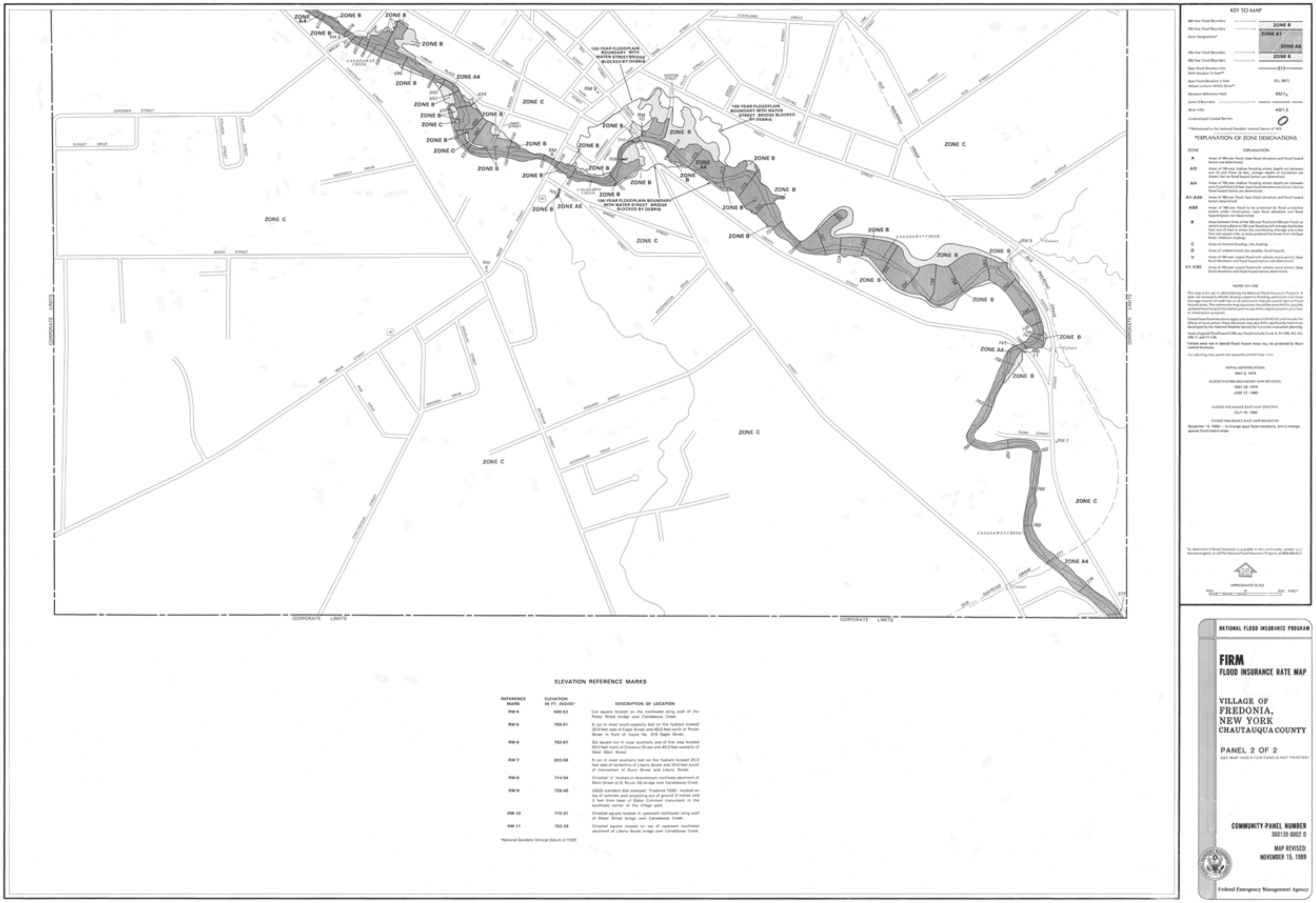
Figure 3-7. Regulatory Floodway Data, Canadaway Creek, Village of Fredonia, Chautauqua County, NY.

The FIRMs along Canadaway Creek indicate Special Flood Hazard Areas (SFHAs), which are land areas covered by floodwaters during the 1% annual chance flood event (ACE) (FEMA 1989a). In the Village of Fredonia and Town of Pomfret FIS reports, Flood Hazard Factors (FHFs) were used by the FIA to correlate flood information with insurance rate tables. The FHF for a reach is the average weighted difference between the 10 and 1% annual chance flood hazard (10- and 100-year flood) water-surface elevations expressed rounded to the nearest 0.5 ft, multiplied by 10, and shown as a three-digit code (FEMA 1989b). The flood zones indicated in the Canadaway Creek study area are Zones A, A3-4, B, and C. A Zones are SFHAs subject to inundation by the 1% annual chance flood event, determined by approximate methods, where no BFEs are shown or FHFs were determined. Zones A3-4 are SFHAs subject to inundation by the 1% annual chance flood event determined by detailed methods with BFEs shown and zones subdivided according to FHF. B Zones are areas between the SFHAs and the limits of the 0.2% annual chance event (500-year) flood, including areas of the 0.2% flood plain that are protected from the 1% flood by dike, levee, or other water control structure. B Zones also include areas subject to certain types of 1% annual chance event shallow flooding where depths are less than 1.0 ft; and areas subject to 1% annual chance event flooding from sources with drainage areas less than one square mile. Zone B have no BFEs and are not subdivided by FHF. C Zones are areas of minimal flooding (FEMA 1984; FEMA 1989b).

For streams and other watercourses where FEMA has provided BFEs, but no floodway has been designated, or where FEMA has not provided BFEs, the community must review floodplain development on a case-by-case basis to ensure that increases in water surface elevations do not occur, or identify the need to adopt a floodway if adequate information is available (FEMA 2000). Figure 3-8 is a FIRM that includes a portion of Canadaway Creek in the Village of Fredonia, NY (FEMA 1989a).

Digitized Q3 flood zone data derived from FEMA FIRMs were 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).

With regards to ice-jam flooding, the effective FEMA FIRMs only reflect flooding related to open-water or free-flow conditions. 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.



ELEVATION REFERENCE MARKS

REFERENCE MARK	ELEVATION IN FT. (NGVD)*	DESCRIPTION OF LOCATION
RM 4	690.53	Cut square located on the northwest wing wall of the Risley Street bridge over Canadaway Creek.
RM 5	755.91	X cut in most south-westerly bolt on fire hydrant located 20.0 feet east of Eagle Street and 40.0 feet north of Porter Street in front of house No. 316 Eagle Street.
RM 6	783.87	Set square cut in most southerly end of first step located 50.0 feet north of Chestnut Street and 45.0 feet westerly of West Main Street.
RM 7	803.08	X cut in most southerly bolt on fire hydrant located 25.0 feet east of centerline of Liberty Street and 20.0 feet south of intersection of Dunn Street and Liberty Street.
RM 8	714.94	Chiseled "x" located on downstream northeast abutment of Main Street (U.S. Route 20) bridge over Canadaway Creek.
RM 9	729.48	USGS standard disk stamped "Fredonia 1935" located on top of concrete post projecting out of ground 3 inches and 2 feet from base of Baker Common monument in the southeast corner of the village park.
RM 10	715.91	Chiseled square located in upstream northeast wing wall of Water Street bridge over Canadaway Creek.
RM 11	762.29	Chiseled square located on top of upstream southeast abutment of Liberty Street bridge over Canadaway Creek.

*National Geodetic Vertical Datum of 1929

Figure 3-8. FEMA FIRM, Canadaway Creek, Village of Fredonia, Chautauqua County, NY.

3.4 WATERSHED LAND USE

The Canadaway Creek stream corridor is largely comprised of forested lands (64%) and cultivated crops (18%) within the basin. Of the forested lands, deciduous forests (61%) comprise the largest proportion of forest type, while other hay / non-alfalfa (9%) and grapes (7%) comprise the largest percentages of cultivated land (NASS 2019).

The upper and middle reaches of the basin, from the headwaters in the Town of Charlotte to the corporate limits of the Village of Fredonia, are primarily forested and cultivated lands. Developed lands (9%) within the basin are primarily located in the lower reaches of the Canadaway Creek within the Village of Fredonia downstream to the outlet to Lake Erie (NASS 2019).

3.5 GEOMORPHOLOGY

Chautauqua County is in two physiographic provinces: the Erie-Ontario Plain province and the Allegheny Plateau province. The Erie-Ontario Plain province is a lowland belt along the shores of Lake Erie. This belt is 2 to 6-miles wide and has topography typical of that of an abandoned lakebed. It has little relief except for a series of very narrow ravines cut across it by a number of streams. It ranges in elevation from 572 ft at Lake Erie to about 850 ft at the base of the bordering escarpment. The alignment of the escarpment parallels Lake Erie and ranges in elevation from 1,400 ft in the eastern part of the county to 1,600 ft in the western part (USSCS 1994).

The base of the escarpment constitutes the northern boundary of the Allegheny Plateau province, which occupies about 80% of the county. The plateau is characterized by steep valley walls, wide ridgetops, and flat-topped hills between drainageways. The part of the Allegheny Plateau in Chautauqua 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 (USSCS 1994).

On the Allegheny Plateau, the elevation rises from about 1,300 ft in the major valleys to 2,100 ft. The greater part of the upland portion of the plateau lies between elevations of 1,600 and 1,800 ft. The maximum elevation, 2,190 ft, occurs on Gurnsey Hill in the southeast corner of the county. Because it was never glaciated, this area has more rugged topography, has longer and steeper slopes, has deeply incised and V-shaped valleys, and does not have the irregular, hilly characteristics typical of much of the glaciated areas (USSCS 1994).

The bedrock geology in the area consists mostly of the Canadaway Group, which is composed primarily of shales, sandstones, and siltstones. The Canadaway Group is a succession of black and gray shales that include some thin siltstone layers and occurs above the Java Group. In Chautauqua County, the Canadaway Group averages about 1,050 ft in thickness and is subdivided into seven members. The oldest of these is the black Dunkirk Shale, which is about 85-ft thick and is exposed in the lake cliffs at Dunkirk (USSCS 1994; NYSGS 1999).

Prehistoric advances and retreats of glacial ice during the last ice age, beginning approximately 300,000 years ago and ending 14,000 years ago, affected the bedrock and soil composition of Chautauqua County, NY. Soil material and pieces of bedrock would be carried and redeposited by moving glacial sheets creating unconsolidated materials of various sizes, shapes, and mineral content. Because the deposited materials were variable, different soils formed in them. Erosion and sedimentation have been at work since the ice retreated and, as a result, steep, fan-shaped alluvial deposits accumulated at the mouths of streams where the velocity of the water slowed, and the sand and gravel dropped out of suspension. A striking topographic feature called the Beach Ridge runs parallel to Lake Erie and across the county. This feature represents the shore line of the former glacial lake, which developed during many years of wave action and erosion (USSCS 1994).

The drainage of Chautauqua County is separated into two systems: the Allegheny-Ohio-Mississippi River system and the Lake Erie-St. Lawrence River system. Along the northwestern part of the county, the drainage of the northern slope of the escarpment and lake plain flows north into Lake Erie through numerous small waterways and several major creeks, which includes Canadaway Creek, and comprises the Lake Erie-St. Lawrence River system (USSCS 1994).

Within the Canadaway Creek watershed basin, the most predominant soil types are Busti silt loam (BsB) (10%) and Chautauqua silt loam (CkC) (7%) (NRCS 2019). Busti silt loam makes up the largest proportion of soil type by total acreage within the Canadaway Creek basin. This soil is gently sloping, very deep, and somewhat poorly drained. It is in convex areas on uplands, on side slopes, and in concave areas on foot slopes that receive runoff from the higher adjacent soils. Chautauqua silt loam makes up the second largest proportion of soil type within the basin and is sloping, very deep, and moderately well drained. It is on hillsides and side slopes that receive runoff from the higher adjacent soils (USSCS 1994).

Figure 3-9 is a profile of stream bed elevation and channel distance from the confluence with Lake Erie using 1-meter light detection and ranging (LiDAR) data for Canadaway Creek. Canadaway Creek has an average slope of 1.3% over the profile stream length. The creek's streambed lowers approximately 1,451 vertical feet over this reach from an elevation of 2,025-ft above sea level (NAVD 88) at the headwaters in the Town of Charlotte to 573-ft above sea level at the confluence of Lake Erie in the Town of Dunkirk, NY (NYSOITS 2017b).

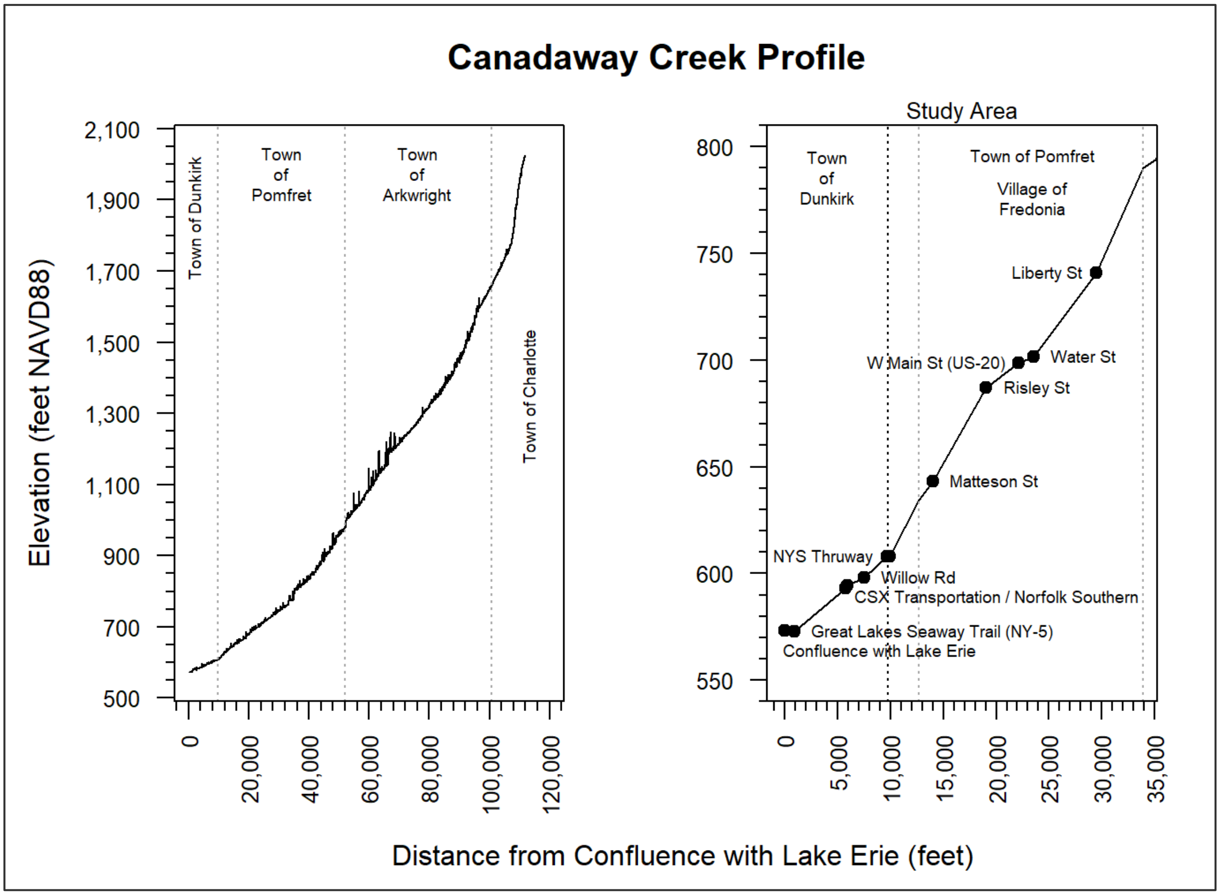


Figure 3-9. Canadaway Creek profile of stream bed elevation and channel distance.

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

3.6 HYDROLOGY

Canadaway Creek drains an area of 40.3 square miles (sq. mi.), is approximately 20.6 miles in length, and is located in the southwestern portion of New York State and in the northern portion of Chautauqua County. Canadaway Creek rises in the vicinity of Lewis and Cook Roads in the Town of Charlotte and flows north / northwest through the Towns of Arkwright and Pomfret, and the Village of Fredonia before entering the Town of Dunkirk from the south and emptying into Lake Erie.

In the Town of Pomfret, most floods result from heavy winter or early spring rainfall, usually augmented by melting snow. Occasionally, intense rainfall associated with cyclonic disturbances produce flooding (FEMA 1984).

In the Village of Fredonia, Canadaway Creek has an extensive history of flood problems. Flooding can occur at almost any time of the year due to high intensity precipitation, a rapid spring thaw, or a combination of the two. Flooding is frequently aggravated by ice jams or blockage from debris (FEMA 1989b).

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

Factor	Formula	Value
Form Factor (R_F)	A / B_L^2	0.21
Circularity Ratio (R_C)	$4*π*A / B_P^2$	0.26
Elongation Ratio (R_E)	$2 * (A/π)^{0.5} / B_L$	0.52

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 Canadaway Creek watershed can be characterized as an elongated basin with lower peak discharges of longer durations, high relief topography with structural controls on drainage, and steep ground slopes (Waikar and Nilawar 2014).

There is one USGS stream gage station on Canadaway Creek in Chautauqua County, USGS gage 04213376 Canadaway Creek at Fredonia, NY. The period of record for this gage is from 1979 to 2018, as of the writing of this report. An effective FEMS FIS for the Town of Pomfret and Village of Dunkirk was issued on November 19, 1984 and November 15, 1989, respectively; however, only the Village of Fredonia's FIS report included drainage area and peak discharge information for Canadaway Creek. The methodology used in the H&H analyses differed for each municipality: the Town of Pomfret used approximate methods, while the Village of Fredonia performed a detailed study. Table 3 summarizes the FEMA FIS drainage area and peak discharges, in cubic feet per second, for Canadaway Creek (FEMA 1984; FEMA 1989b).

According to the effective FEMA FIS for the Village of Fredonia, peak discharges for Canadaway Creek were developed using the USGS Water Resources Investigations (WRI) 79-83 method (USGS 1979). This method computes flows corresponding to a given drainage area and percent storage for a drainage basin. The equations were developed from a regression analysis based on data from stream gaging stations in western New York. This method was selected because it reflects the high discharges experienced in this area due to the small amount of storage area. Peak discharges for the revised portions of Canadaway Creek were determined using a regional frequency analysis developed for the Buffalo Metro Study by the Buffalo District COE (USACE [date unknown]). This method computes flows corresponding to drainage areas and slopes of given drainage basins. These equations were based on the log-Pearson Type III distribution (LP3) equations. No H&H analyses information was provided in the Town of Pomfret FEMA FIS for Canadaway Creek (FEMA 1984; FEMA 1989b).

General limitations of the FEMA FIS methodology are the age of the effective FIS H&H analysis and the age of the methodology. The H&H analysis for Canadaway Creek was completed in 1989 using the WRI 79-83 and LP3 methodology. At the time of the FIS report, there were less than 10 years of available gage records, which is insufficient for hydrologic analysis. In addition, advancements in our understanding of the complex interactions of hydrologic environments, coupled with improvements in hydrologic and hydraulic modeling and technology, has led to increased accuracy and a reduction in possible error in discharge estimations in recent years.

StreamStats v4.3.11 software (https://streamstats.usgs.gov/ss/) is a map-based web application that provides an assortment of analytical tools that are useful for water-resources planning and management, and engineering purposes. Developed by the USGS, the primary purpose of *StreamStats* is to provide estimates of streamflow statistics for user selected ungaged sites on streams and for USGS stream gages, which are locations where streamflow data are collected (Ries et al. 2017, USGS 2019b).

Table 3. Canadaway Creek FEMA FIS Peak Discharges for the Village of Fredonia

(Source: FEMA 1989b)

			Peak Discharge (cfs)			
Flooding Source and Location	**Drainage Area (Sq. Miles)**	**River Station (ft)**	**10-percent**	**2-percent**	**1-percent**	**0.2-percent**
At downstream corporate limits	33.5	123+00	3,040	4,830	5,760	7,900
Approximately 0.3-mile downstream of Risley Street	32.5	180+75	*	*	5,620	7,180
Approximately 150-ft upstream of Main Street (U.S. Route 20)	30.6	214+00	*	*	5,330	6,820
At the upstream corporate limits	27.4	304+00	2,570	4,100	4,890	6,800

*Discharges not computed for 1989 revision

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

$$Q_{T(W)} = Q_{T(g)}(N) + Q_{T(r)}(E) \; / \; N + E$$

where

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

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

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

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

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

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

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

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

Table 4. USGS *StreamStats* Peak Discharge for Canadaway Creek

(Source: USGS 2019b)

			Peak Discharges (cfs)			
Flooding Source and Location	**Drainage Area (Sq. Miles)**	**River Station (ft)**	**10-percent**	**2-percent**	**1-percent**	**0.2-percent**
Confluence with Lake Erie	40.4	0+00	4,410	7,120	8,410	11,800
Confluence with Beaver Creek	38.6	76+00	4,320	7,000	8,270	11,600
At downstream corporate limits – Fredonia / Pomfret *	33.1	127+00	3,820	6,180	7,300	10,300
Approximately 0.3-mile downstream of Risley Street *	32.5	172+00	3,810	6,180	7,300	10,300
Approximately 150-ft upstream of Main Street (US-20) *	30.5	222+50	3,660	5,960	7,050	9,930
At the upstream corporate limits – Fredonia / Pomfret *	27.2	338+00	3,390	5,510	6,520	9,190
Approximately 250-ft downstream of Spoden Road	15.9	419+00	2,050	3,320	3,910	5,480

* Note: These locations are the same as the Village of Fredonia FEMA FIS.

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

FEMA FIS peak discharges were determined to be outside an acceptable range (95% confidence interval) based on the *StreamStats* standard error calculations, and the *StreamStats* peak discharges are higher. For this study, the USGS *StreamStats* peak discharges were used in the HEC-RAS model simulations due to the fact that the *StreamStats* program offers a more robust and modern methodology, a more conservative analysis of flood risk in the Canadaway Creek watershed, and is not affected by the general limitations of the FEMA FIS discharge methodology (e.g. insufficient peak discharge data sample size for LP3, outdated methodology and technology).

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 Canadaway 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 bankfull discharge, width, and depth at select locations along Canadaway Creek as derived from the USGS *StreamStats* program.

Table 6. USGS *StreamStats* Peak Discharge for Canadaway Creek

(Source: USGS 2019b)

			Peak Discharges (cfs)		
Flooding Source and Location	**Drainage Area (Sq. Miles)**	**River Station (ft)**	**Bankfull Depth (ft)**	**Bankfull Width (ft)**	**Bankfull Streamflow (cfs)**
Confluence with Lake Erie	40.4	0+00	2.56	79.6	1,080
Confluence with Beaver Creek	38.6	76+00	2.54	78.1	1,040
At downstream corporate limits – Fredonia / Pomfret	33.1	127+00	2.44	73.2	914
Approximately 0.3-mile downstream of Risley Street	32.5	172+00	2.43	72.7	900
Approximately 150-ft upstream of Main Street (US-20)	30.5	222+50	2.39	70.8	853
At the upstream corporate limits – Fredonia / Pomfret	27.2	338+00	2.33	67.4	775
Approximately 250-ft downstream of Spoden Road	15.9	419+00	2.04	53.9	493

3.7 INFRASTRUCTURE

There are numerous dams along Canadaway Creek and its tributaries that interact with the flow of the creek. Of the eight dams within the Canadaway Creek watershed, only four dams are identified as being located on Canadaway Creek, while the remaining four are located on tributaries within the watershed. The purpose for which the dams are used varies with three irrigation, two recreation, two other, and one primary water supply dams. The dams are classified as a Class A, C, or D. Class A dams are considered low hazard where a dam failure is unlikely to result in damage to anything more than isolated or unoccupied buildings, undeveloped lands, minor roads such as town or county roads; is unlikely to result in the interruption of important utilities, including water supply, sewage treatment, fuel, power, cable or telephone infrastructure; and / or is otherwise unlikely to pose the threat of personal injury, substantial economic loss or substantial environmental damage. Class C dams are considered high hazard dams, where a dam failure may result in widespread or serious damage to home(s); damage to main highways, industrial or commercial buildings, railroads, and / or important utilities, including water supply, sewage treatment, fuel, power, cable or telephone infrastructure; or substantial environmental damage; such that the loss of human life or widespread substantial economic loss is likely. Class D dams are also referred to as “negligible or no hazard” dams, which are defined as dams that have been breached or removed, or have failed or otherwise no longer materially impound waters, or dams that were planned but never constructed and are considered to be defunct dams posing negligible or no hazard. Table 7 is a summary table of dams that are within the Canadaway Creek watershed (NYSDEC 2009).

Table 7. Inventory of Dams within Canadaway Creek Watershed

(Source: NYSDEC 2009)

Municipality	State ID	Dam Name	Owner	Waterway	Hazard Code	Purpose
Town of Arkwright	003-3459	Robert Dobbins Dam	Private	Dutch Hollow Creek	D	Recreation
Town of Pomfret	003-0578	Cook Brothers Mill Dam	Private	Canadaway Creek	D	Irrigation
Town of Pomfret	003-0579	Ingham & Derly Co. Dam	Private	Canadaway Creek	D	Irrigation
Town of Pomfret	003-0585	Laona Dam	Private	Canadaway Creek	A	Irrigation
Town of Pomfret	003-1102	Fredonia Reservoir Dam	Village of Fredonia	Canadaway Creek	C	Water Supply – Primary
Town of Pomfret	003-4247	Fredonia Parks & Recreation Dam	Village of Fredonia	Wiley Creek	D	Recreation
Town of Pomfret	003-3304	Hill View Golf Course Dam	Private	Beaver Creek	A	Other
Town of Pomfret	003-0608	Dam #003-0608	N/A	Unnamed Tributary	D	Other

According to the NYSDOT, there are no large culverts along Canadaway Creek; however, there are three small culverts along the creeks path in the Town of Charlotte: Ruttenbur, Cook, and Lewis Roads. Major bridge crossings over Canadaway Creek include the Great Lakes Seaway Trail (NY-5) and Interstate 90 in the Town of Dunkirk, West Main Street (US-20) in the Village of Fredonia, NY-60 in the Town of Pomfret, and Bard Road (CR-72) and Rood Road (CR-77) in the Town of Arkwright.

Table 8 summarizes the infrastructure data for bridges and culverts that cross Canadaway Creek in Chautauqua County, NY with bankfull widths from the USGS *StreamStats* program. Figure 3-9 displays the locations of the bridges and dams that cross Canadaway Creek in Chautauqua County, NY. Bridge lengths and surface widths for NYSDOT bridges were revised as of February 2019 (NYSDOT 2014; NYSDOT 2016a; NYSOITS 2017a; USGS 2019b).

Table 8. Infrastructure Crossing Canadaway Creek

(Source: FEMA 1989b; NYSDOT 2014; NYSDOT 2016a; NYSOIT S 2017a; USGS 2019b)

Roadway Carried	BIN/CIN	River Station (ft)	Primary Owner	Structure Opening [1] (ft)	Structure Width [2] (ft)	Bankfull Width (ft)	Hydraulic Capacity (% ACE)
Great Lakes Seaway Trail (NY-5)	1001240	8+00	NYSDOT	102	41	79.5	No FEMA FIS Data
CSX Transportation	N/A	57+50	Railroad	N/A *	N/A *	78.4	No FEMA FIS Data
Norfolk Southern Railway Co	N/A	58+00	Railroad	N/A *	N/A *	78.4	No FEMA FIS Data
West Willow Road	3324240	74+00	Chautauqua County	69	26	78.1	No FEMA FIS Data
Interstate 90 (WB)	5511321	96+00	NYS Thruway Authority	80	53.5	73.7	No FEMA FIS Data
Interstate 90 (EB)	5511322	98+50	NYS Thruway Authority	80	49	73.7	No FEMA FIS Data
Matteson Street	3326080	140+00	Chautauqua County	87	35.5	73	0.2
Risley Street	3326090	189+50	Chautauqua County	91	44.7	72.6	0.2
West Main Street (US-20)	1015400	220+50	NYSDOT	69	57.8	72.1	0.2
Water Street	1050600	234+50	Chautauqua County	77	44.5	70.9	10
Liberty Street	1050590	294+00	Chautauqua County	94.5	39.7	68.5	0.2
Webster Road	3325400	350+50	Chautauqua County	79	34	67.3	No FEMA FIS Data
Spoden Road	3325440	421+50	Chautauqua County	41	26	53.9	No FEMA FIS Data
NY-60	1027870	451+00	NYSDOT	165	48	53.4	No FEMA FIS Data
Shumla Road	3325410	488+00	Chautauqua County	134	34	52.9	No FEMA FIS Data
Shumla Road	2212730	510+50	Chautauqua County	41.3	25.8	52.6	No FEMA FIS Data
Bard Road (CR-72)	3323440	854+50	Chautauqua County	57	32	35.1	No FEMA FIS Data
Griswold Road	3323400	885+00	Chautauqua County	84	24	31.3	No FEMA FIS Data

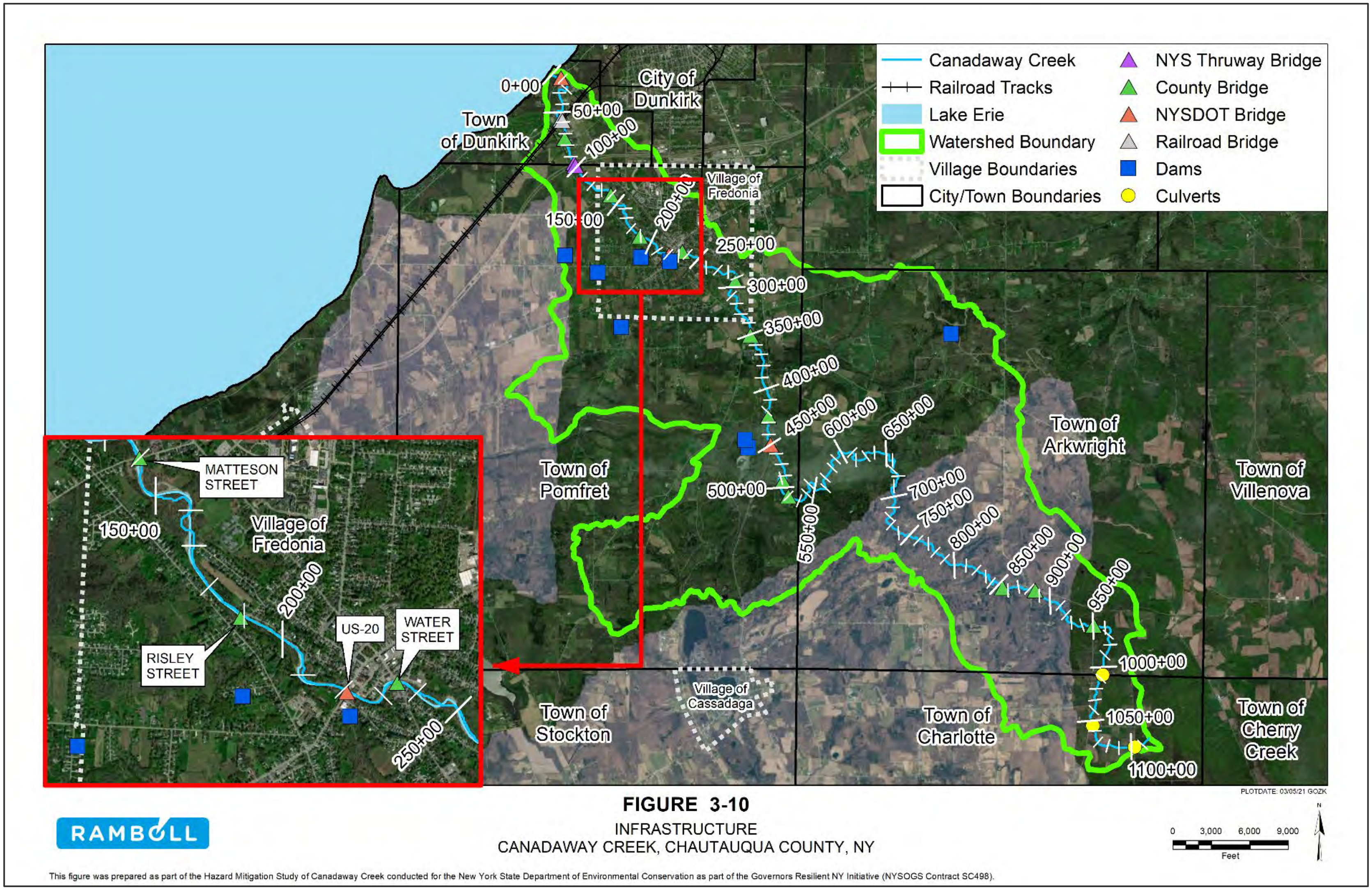
(Source: FEMA 1989b; NYSDOT 2014; NYSDOT 2016a; NYSOIT S 2017a; USGS 2019b)

Roadway Carried	BIN/CIN	River Station (ft)	Primary Owner	Structure Opening [1] (ft)	Structure Width [2] (ft)	Bankfull Width (ft)	Hydraulic Capacity (% ACE)
Rood Road (CR-77)	3323450	950+50	Chautauqua County	40	35	23.6	No FEMA FIS Data
Ruttenbur Road	N/A	1007+00	Town of Charlotte	9	65	19.3	No FEMA FIS Data
Cook Road	N/A	1055+00	Town of Charlotte	5	40.5	13.5	No FEMA FIS Data
Lewis Road	N/A	1102+00	Town of Charlotte	N/A	N/A	4.7	No FEMA FIS Data

* Note: Field measurements were taken in early March of 2021. Field conditions were not ideal and some structures were inaccessible. In addition, multiple structures passed through or were within private premises where field staff could not enter.

[1] Structure opening is measured perpendicular to stream flow and represents the opening width of the structure for water to flow through.

[2] Structure width is measured parallel to creek flow and refers to the curb-to-curb width, which is the minimum distance between the curbs or the bridge railings (if there are no curbs), to the nearest 30mm or tenth of a foot or the length of a culvert (NYSDOT 2006).



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

Figure 3-10. Canadaway Creek Infrastructure, Chautauqua County, NY.

3.8 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 Canadaway Creek, the FEMA FIS surface elevation profiles of Canadaway Creek were used to determine the lowest annual chance flood elevation to flow under either 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 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 2020).

The term “bridge” shall apply to any structure whether single or multiple span construction with a clear span in excess of 20 ft 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 6 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 2019):

- 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.

To account for future projected peak flows in H&H analyses for bridges, the NYSDOT requires current peak flows be increased based on the USGS *StreamStats* tool where current 2% peak flows shall be increased by 10% in Region 5. 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 (NYSDOT 2019; USDHS 2010).

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, most notably that the new freeboard recommendation for normal bridges is 2-feet of freeboard over the elevation of a flood with a 1% chance of being equaled or exceeded in a given year (i.e. base flood elevation) and 3-feet over for a critical structure (NYSDEC 2020a). When compared to current guidelines, the new CRRA climate change recommended freeboard is based on the 1% annual chance flood event water surface elevation, while the previous guidelines were based on the 2% annual chance flood event. This is a higher standard for freeboard. Table 8 displays the 2% and 1% annual chance flood levels and their calculated difference at FEMA FIS infrastructure locations using the Village of Fredonia FIS profiles for Canadaway Creek.

Table 9. FEMA FIS profile 2 and 1% Annual Chance Flood Hazard Levels with Differences at Infrastructure Locations

Source: (FEMA 1989b)

Bridge Crossing	River Station (ft)	2-percent Water Surface Elevation (ft NAVD88)	1-percent Water Surface Elevation (ft NAVD88)	Difference in Water Surface Elevations (ft NAVD88)
Matteson Street	135+60	650.5	652.0	1.5
Risley Street	182+25	*	685	N/A
West Main Street (US-20)	212+50	*	705	N/A
Water Street	230+25	*	713	N/A
Liberty Street	286+00	748.0	749.0	1.0

* Not computed for 1989 revision

According to the FEMA FIS water surface elevation profiles for the Village of Fredonia, only the West Main Street (US-20) bridge crossing does not meet the NYSDOT guidelines for 2-feet of freeboard for bridges. In addition, West Main Street (US-20) bridge crossing also does not meet the new CRRA climate change infrastructure guidelines as described above. The low chord elevation is below the 2% annual chance flood event and the bridge does not provide the recommended hydraulic capacity (FEMA 1989b; NYSDOT 2016a; NYSDEC 2020a). Even though this structure 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 new draft CRRA guidelines.

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 Canadaway 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 10 lists the estimated drainage area, bankfull discharge, width, and depth at potential constriction point locations along Canadaway Creek as derived from the USGS *StreamStats* program.

Based on the *StreamStats* bankfull statistics, there are five bridges that cross Canadaway Creek that have bridge openings that are smaller than the bankfull widths: West Willow Road in the Town of Dunkirk, Matteson Road and West Main Street in the Village of Fredonia, and Spoden and Shumla Roads in the Town of Pomfret. In addition, there is one bridge with an opening that is very close to bankfull width: Water Street in the Village of Fredonia. This bridge with an opening close to bankfull is an area of concern since it has been identified as a location with known historical and present flooding issues due to debris blockage and sediment depositional aggradation at the upstream face of the bridge (FEMA 1989b; NYSDEC 2020b).

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. Since the bankfull discharge required for water surface elevations to reach the bankfull width is low (e.g. 80% annual chance event), the likelihood of relatively low flow events causing backwater and potential flooding upstream of these structures is fairly high.

Table 10. Hydraulic Capacity of Potential Constriction Point Locations Along Canadaway Creek

Source: (NYSDOT 2016a; Ramboll 2021; USGS 2003; FEMA 1989b)

Roadway Carried	BIN	River Station (ft)	Structure Opening (ft)	Bankfull Width (ft)	Bankfull Discharge (cfs)	Annual Chance Flood Event Equivalent[1]
CSX Transportation	N/A	57+50	N/A	78.4	1,050	> 80%
Norfolk Southern Railway Co.	N/A	58+00	N/A	78.4	1,050	> 80%
West Willow Road	3324240	74+00	69	78.1	1,040	> 80%
West Main Street (US-20)	1015400	220+50	69	72.1	886	> 80%
Water Street	1050600	234+50	77	70.9	855	> 80%
Spoden Road	3325440	421+50	41	53.9	493	> 80%
Shumla Road	2212730	510+50	41.3	52.6	469	> 80%

[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-year recurrence interval.

4. CLIMATE CHANGE IMPLICATIONS

4.1 FUTURE PROJECTED STREAM FLOW IN CANADAWAY 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).

The USGS *FutureFlow* software is an extension of the *StreamStats* software where regionally specific peak flow regression equations are used to estimate the magnitude of future floods for any stream or river in New York State (excluding Long Island) and the Lake Champlain basin in Vermont. The *FutureFlow* software substitutes a new climate variable (either precipitation or runoff) to the peak flow regression equations. This climate variable is obtained from five climate models that were reviewed by the World Climate Research Programme’s (WCRP) Working Group Coupled Modelling (WGCM) team during the 5th Phase of the Coupled Model Intercomparison Project (CMIP5). These five climate models were chosen because they best represent past trends in precipitation for the region (Burns et al. 2015).

With the USGS *FutureFlow* software, climate variable data is evaluated under two future scenarios, termed “Representative Concentration Pathways” (RCP) in CMIP5, that provide estimates of the extent to which greenhouse-gas concentrations in the atmosphere are likely to change through the 21st century. RCP refers to potential future emissions trajectories of greenhouse gases, such as carbon dioxide. Two scenarios, RCP 4.5 and RCP 8.5, were evaluated for each climate model in CMIP5. RCP 4.5 is considered a midrange-emissions scenario, and RCP 8.5 is a high-emissions scenario (Taylor et al. 2011).

Results of the climate models and the RCPs are averaged for three future periods, from 2025 to 2049, 2050 to 2074, and 2075 to 2099. The downscaled climate data for each model and the RCP scenario averaged over these 25-year periods were obtained from the developers of the USGS Climate Change Viewer (https://www.fs.usda.gov/ccrc/tools/national-climate-change-viewer) (USGS 2013). The USGS *FutureFlow* software calculates results based on all five climate models for any of the two greenhouse-gas scenarios, and the three time periods. These available results are meant to reflect a range of variations predicted from among the five models, and two greenhouse-gas scenarios. The predictions of future mean annual runoff, obtained from the USGS *FutureFlow* software were used with the USGS regional regression equations and the computed basin characteristics, described in previous sections, to compute the expected future peak flows. The USGS *FutureFlow* software provides five estimates of the mean annual runoff for each RCP and future time period, one corresponding to each of the five climate models used. Future flows were computed for each of the five models corresponding to RCP 8.5 and the 2075 to 2099 time period, and the mean computed from the five results are displayed (Burns et al. 2015). Table 11 is a summary of the USGS *FutureFlow* projected peak discharges at the FEMA FIS locations.

Table 11. Canadaway Creek Projected Peak Discharges

(Source: USGS 2016)

			Peak Discharges (cfs)			
Flooding Source and Location	**Drainage Area (Sq. Miles)**	**River Station (ft)**	**10-percent**	**2-percent**	**1-percent**	**0.2-percent**
Confluence with Lake Erie	40.4	0+00	5,312	8,212	9,558	13,060
Confluence with Beaver Creek	38.6	76+00	5,244	8,112	9,450	12,920
At downstream corporate limits – Fredonia / Pomfret	33.1	127+00	4,750	7,306	8,496	11,580
Approximately 0.3-mi downstream of Risley Street	32.5	172+00	4,732	7,290	8,486	11,580
Approximately 150-ft upstream of Main Street (U.S. Route 20)	30.5	222+50	4,582	7,062	8,214	11,220
At the upstream corporate limits – Fredonia / Pomfret	27.2	338+00	4,216	6,524	7,602	10,400
Approximately 250-ft downstream of Spoden Road	15.9	419+00	3,486	5,346	6,212	8,452

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 0.7-ft higher in open-flow areas and up to 3-ft higher upstream of constriction points, such as bridges and / or meanders, as a result of the increased discharges and backwater.

Table 12 provides a comparison of HEC-RAS base condition, using USGS *StreamStats*, and future condition, using USGS *FutureFlow*, water surface elevations at the FEMA FIS discharge locations.

Table 12. HEC-RAS Base and Future Conditions Water Surface Elevation Comparison

(Source: USGS 2016; USGS 2019b)

			Water Surface Elevation (feet NAVD88) [1]			
Flooding Source and Location	**Drainage Area (Sq. Miles)**	**River Station (ft)**	**10-percent**	**2-percent**	**1-percent**	**0.2-percent**
Confluence with Lake Erie	40.4	0+00	+ 4.7	+ 3.2	+ 2.4	+ 2.5
Confluence with Beaver Creek	38.6	76+00	+ 1.0	+ 3.4	+ 0.9	+ 0.1
At downstream corporate limits	33.1	127+00	+ 0.6	+ 0.6	+ 0.6	+ 0.7
Approximately 0.3-mi downstream of Risley Street	32.5	172+00	+ 0.5	+ 0.7	+ 0.7	+ 0.6
Approximately 150-ft upstream of Main Street (U.S. Route 20)	30.5	222+50	+ 1.2	+ 1.2	+ 1.2	+ 1.4
At the upstream corporate limits	27.2	338+00	+ 0.9	+ 0.9	+ 0.8	+ 0.8
Approximately 250-ft downstream of Spoden Road	15.9	419+00	+ 0.6	+ 0.2	+ 0.3	+ 0.2

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

Table 13 provides a comparison of the current 1% annual change peak stream flows calculated using the USGS *StreamStats* software and the mean predicted future discharge calculated using the USGS *FutureFlow* at each of the discharge locations included in the effective FIS.

Table 13. Comparison of 1% Annual Chance Current and Future Discharges

(Source: USGS 2016; USGS 2019b)

Location	Drainage Area (Sq. Miles)	River Station (ft)	Current *StreamStats* Discharge (cfs)	Predicted *FutureFlow* Discharge (cfs)	Change (%)
Confluence with Lake Erie	40.4	0+00	8,410	9,558	13.7
Confluence with Beaver Creek	38.6	76+00	8,270	9,450	14.3
At downstream corporate limits	33.1	127+00	7,300	8,496	16.4
Approximately 0.3-mi downstream of Risley Street	32.5	172+00	7,300	8,486	16.2
Approximately 150-ft upstream of Main Street (U.S. Route 20)	30.5	222+50	7,050	8,214	16.5
At the upstream corporate limits	27.2	338+00	6,520	7,602	16.6
Approximately 250-ft downstream of Spoden Road	15.9	419+00	3,910	4,656	19.1

5. FLOODING CHARACTERISTICS

5.1 FLOODING HISTORY

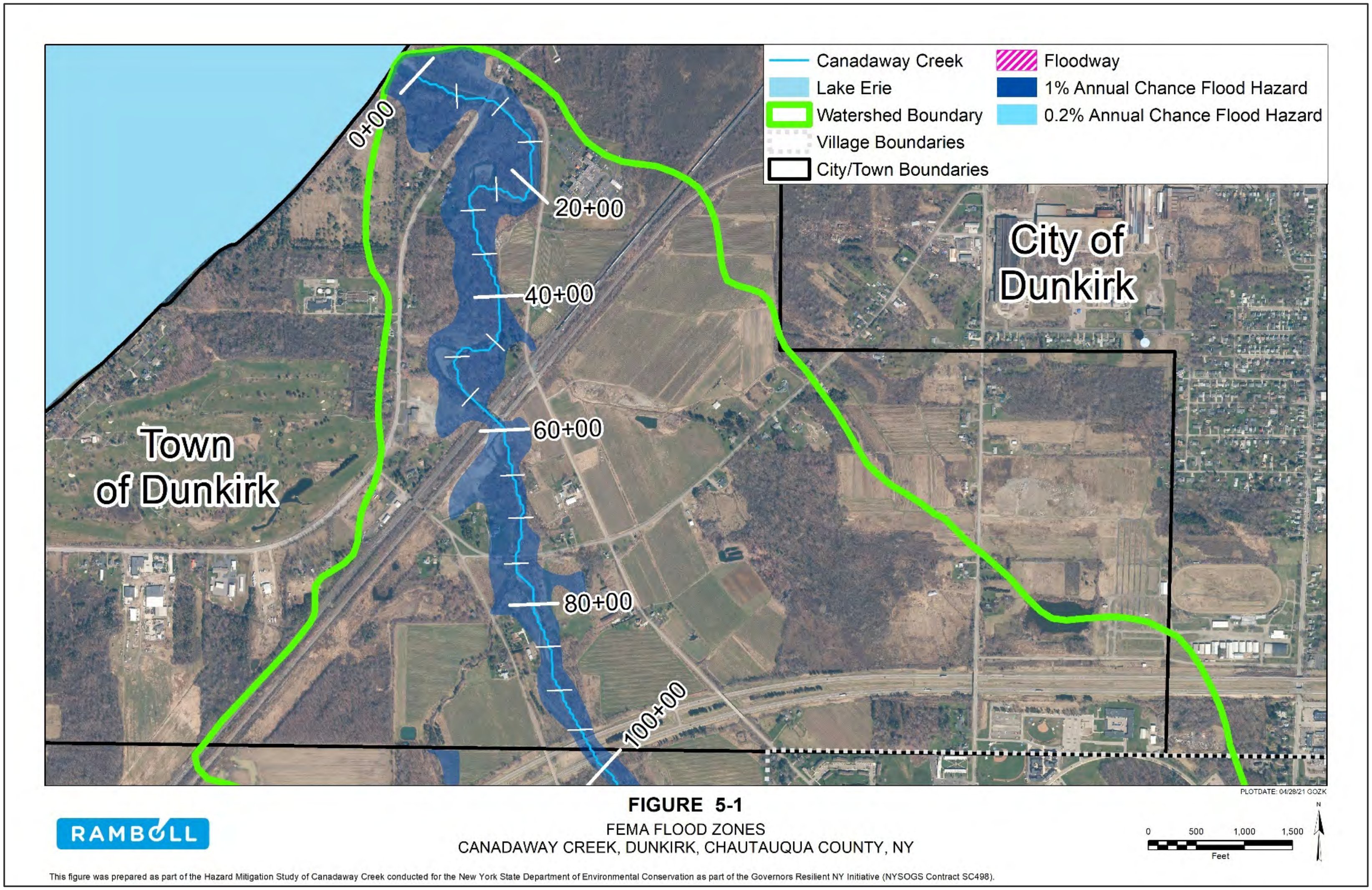
Flooding along Canadaway Creek generally occurs in the summer to early winter months due to heavy rain and rain-on-snow events. The situation is compounded by snowmelt, debris accumulation at the upstream face of bridges and culverts, and sediment depositional aggradation within the creek channel. The heavily forested areas upstream of the Village of Fredonia release large wooded debris into the creek during heavy rain and high flow events, which can accumulate at bridge and culvert openings, restricting flow and causing backwater, which could potentially cause flooding. In addition, during high flow events, streambank erosion releases sediment into the creek channel, which then deposit downstream at meanders, bridges, and culverts where water velocities slow and lose the required energy to suspend the sediments in the water column. The Village of Fredonia is at considerable risk of flood damages due to the close proximity of residential and commercial properties to the creek banks.

According to FEMA severe repetitive loss and repetitive loss data, there are 10 properties identified as repetitive loss and one severe repetitive loss property within the Village of Fredonia. All of the repetitive and severe repetitive loss properties are located within the Canadaway Creek watershed. 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 ten-year 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 exceeding the fair market value of the insured building on the day before each loss within any rolling ten-year period, since 1978 (FEMA 2019d; FEMA 2021).

The three largest storms of record for Canadaway Creek occurred on August 7, 1979, September 14, 1979, and August 1, 1986. These storms were the result of cloudburst-type rainfall over the relatively small drainage basin and caused extensive damage through a combination of flooding of residential and commercial structures, and extensive erosion and structural damage due to the extremely high velocities present. At the height of the August 1979 storm, the largest of the three, a substantial portion of the Water Street bridge was blocked by fallen trees and other debris. It is estimated that the recurrence interval of the August 1979 storm was considerably greater than the 500-year flood (USGS 1984; FEMA 1989b).

More recently, Canadaway Creek has experienced minor flooding events on July 25, 2010, July 24, 2018, and October 6, 2018, and ice-jam related flooding on January 11, 2014. The minor flooding events were all classified as flash floods caused by heavy rain events, while the ice-jam event was caused by warming temperatures and rainfall on snow leading to ice breakups on local waterways. All of these events caused minor property damages with the ice-jam event of 2014 attributed with the most damages at $12,000 (NCEI 2021).

FEMA FIRMs are available for Canadaway Creek from FEMA. Figures 5-1, 5-2, and 5-3 display the floodway and 1 and 0.2% annual chance flood event boundaries for Canadaway Creek as determined by FEMA for the Town of Dunkirk, Village of Fredonia, and Towns of Pomfret, Arkwright, and Charlotte, respectively (FEMA 1996). The maps indicate that flooding generally occurs in the downstream portions of Canadaway Creek, primarily in the neighborhoods adjacent to Norton, Water, Canadaway, and Hart Streets and Forest Place in the Village of Fredonia.



This figure was prepared as part of the Hazard Mitigation Study of Canadaway 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. Canadaway Creek, FEMA flood zones, Dunkirk, Chautauqua 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.

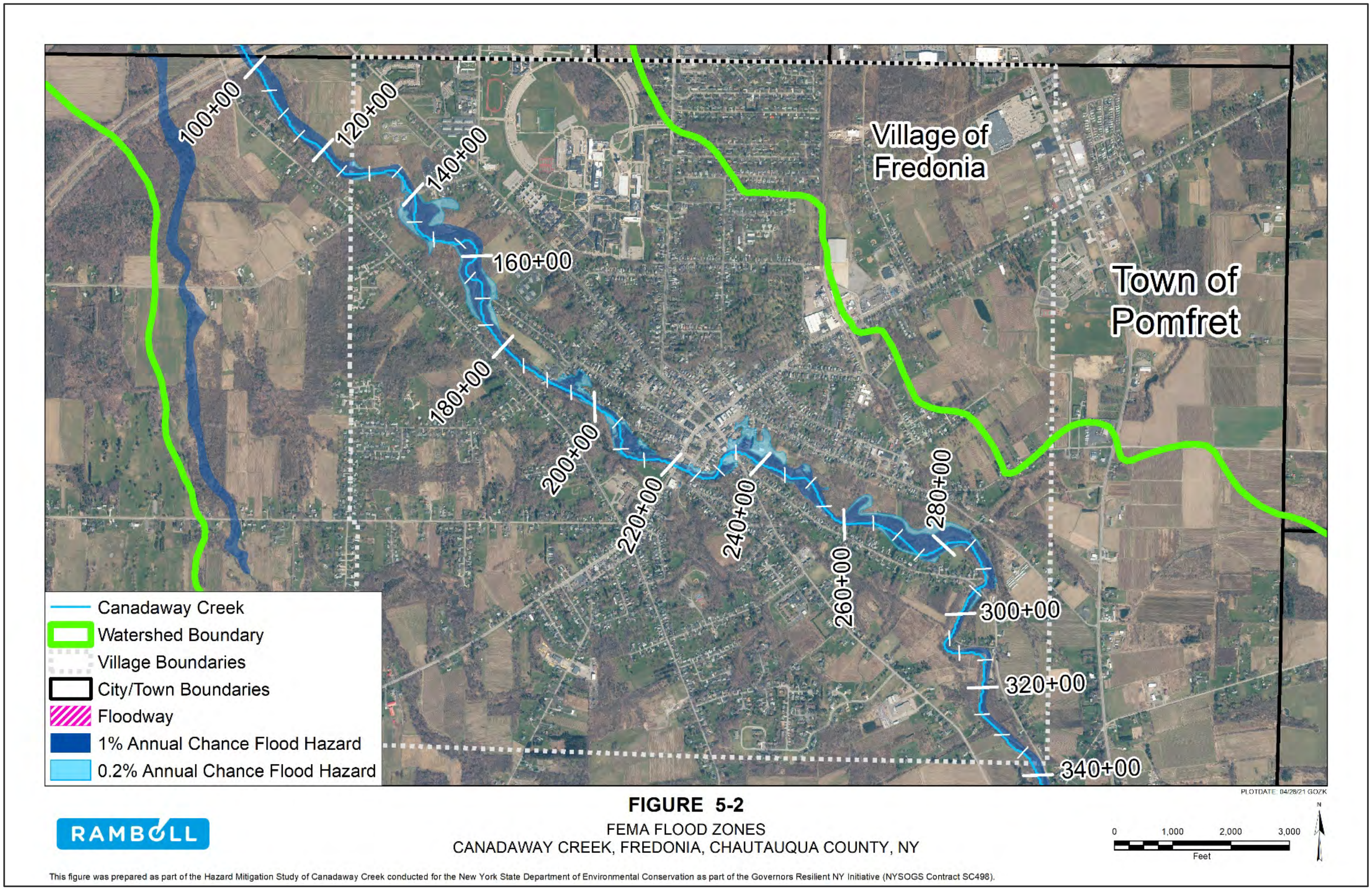
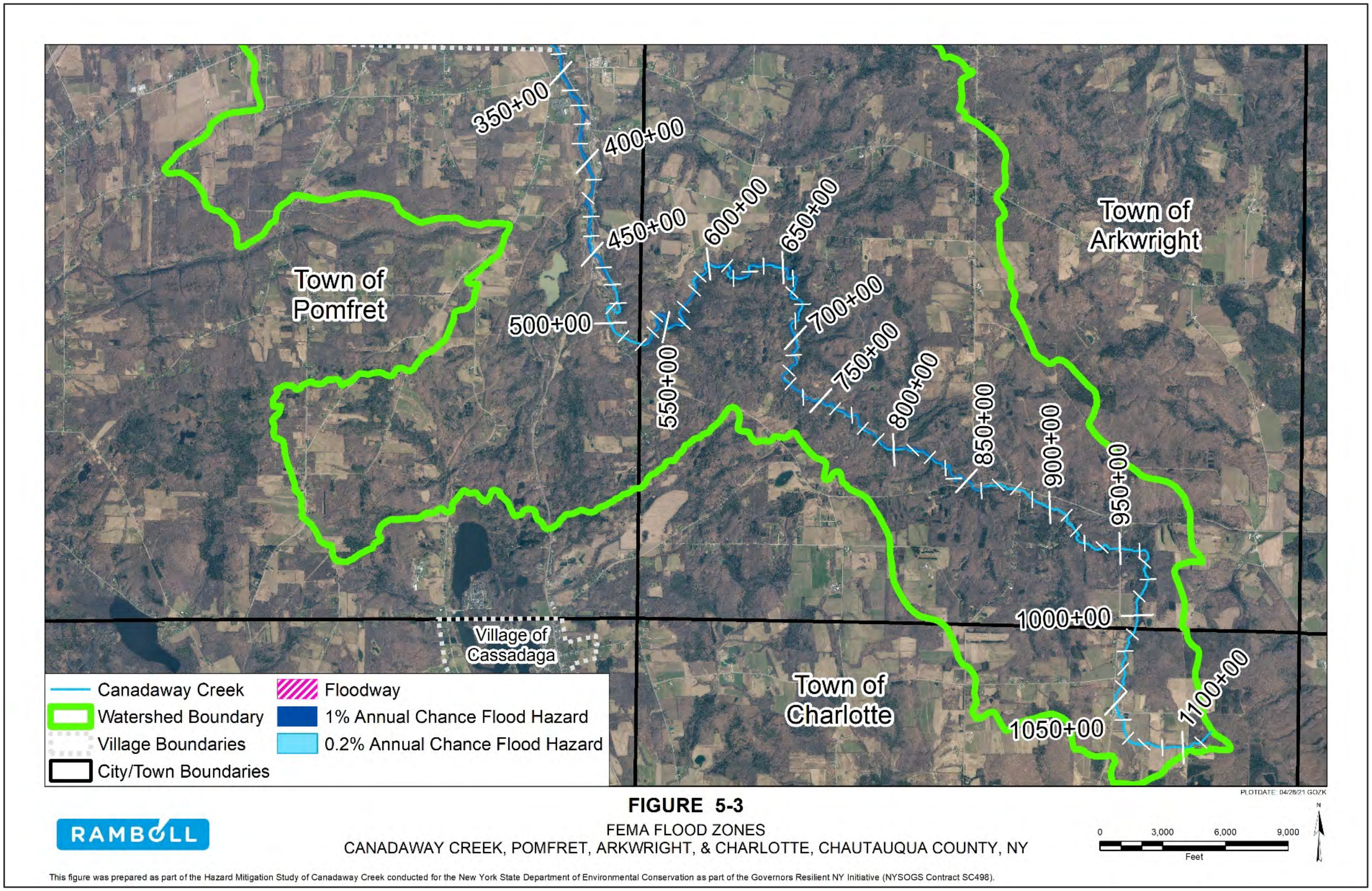


FIGURE 5-2
FEMA FLOOD ZONES
CANADAWAY CREEK, FREDONIA, CHAUTAUQUA COUNTY, NY

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

Figure 5-2. Canadaway Creek, FEMA flood zones, Fredonia, Chautauqua 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.



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

Figure 5-3. Canadaway Creek, FEMA flood zones, Pomfret, Arkwright, and Charlotte, Chautauqua 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

For this study of Canadaway Creek, standard hydrologic and hydraulic study methods were used to determine and evaluate flood hazard data. Flood events of a magnitude which are expected to be equaled or exceeded once on the average during any 10, 50, 100, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10, 50, 100, and 500-year floods, have a 10, 2, 1, and 0.2% chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than one year are considered. The analyses reported herein reflect flooding potentials based on conditions existing in the county at the time of completion of this study (FEMA 1989b).

Hydraulic analysis of Canadaway Creek was conducted using the HEC-RAS v5.0.7 program (USACE 2019b). 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 Canadaway Creek in the Village of Fredonia was completed by FEMA in 1983 and revised in 1988. 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 Chautauqua County (NYSOITS 2017a)
- Chautauqua County, NY 1-meter LiDAR DEM data with a vertical accuracy of 0.7-ft (NYSOITS 2017b)
- National Land Cover Database (NLCD) data (USGS 2019a)
- USGS *StreamStats* peak discharge data (USGS 2019b)
- 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 Canadaway Creek beginning at the confluence with Lake Erie (river station 0+00) and extending upstream of the Village of Fredonia limits into the Town of Pomfret (river station 417+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 USGS *StreamStats* and *FutureFlows* peak discharges to simulate current and future conditions

Downstream boundary conditions for the base and future conditions models were based on the FEMA FIS Lake Erie stillwater elevations. For the base condition model, the Lake Erie stillwater elevations from the City of Dunkirk effective FEMA FIS (1980) were obtained and converted to NAVD88 for use in the model.

For the future conditions model, Lake Erie stillwater elevations were obtained from the preliminary 2021 Erie County, NY FEMA FIS. In the preliminary FIS, FEMA completed an Updated Coastal Analysis for the entire shoreline of Erie County. The southernmost transect studied for the coastal analysis was at the Erie and Chautauqua County boundary. Since the City of Dunkirk is approximately 15 miles from the county boundary, the stillwater elevations at the southernmost transect were reasonably assumed to be coincidental and acceptable to use (FEMA 2021a). Table 14 displays the Lake Erie stillwater elevations for the City of Dunkirk, NY effective and Erie County, NY preliminary FEMA FIS reports.

Table 14. City of Dunkirk, NY (effective 1980) and Erie County, NY (Preliminary 2021) FEMA FIS Lake Erie Stillwater Elevations Comparison

(Source: FIA 1980; FEMA 2021a)

	Water Surface Elevations (ft NAVD88)			
Flooding Source and Location	**10-Percent**	**2-Percent**	**1-Percent**	**0.2-Percent**
City of Dunkirk, NY FEMA FIS (effective 1980)	575.9	577.1	577.5	578.3
Erie County, NY FEMA FIS (preliminary 2021)	578.6	579.1*	579.5*	580.0

* Note: These values differ from the 2- and 1-percent ACE WSELs in the Erie County, NY FEMA FIS (preliminary 2021). These values were adjusted based on reasonable scientific understanding that lower ACEs contain higher discharges, which would increase WSELs, and in an effort to produce a hydraulically correct model.

The stillwater values in the preliminary 2021 FIS were used for the future conditions downstream boundary condition for the following reasons:

- These values are significantly higher (up to 2.7-ft) than the effective 1980 FIS for the City of Dunkirk;
- According to the Great Lakes Environmental Research laboratory (GLERL), the lake-wide period of record (1918 to 2020) average water level for Lake Erie is EL 571.4-ft IGLD85 (EL 571.5-ft NAVD88), which is significantly lower than the 10% annual chance event of both the 1980 and 2021 FEMA FIS reports (GLERL 2020); and
- Based on current research, there is disagreement over the projected water levels for the Great Lakes with different models projecting both modest decreases or increases in Lake Erie water levels (Angel and Kunkel 2010; Hayhoe et al. 2010; MacKay and Seglenieks 2012; Lofgren et al. 2011).

The base condition model water surface elevation results were then compared to the FEMA FIS water surface profiles, past flood events with known water surface elevations, and the effective FEMA FIS elevation profiles to validate the model. After the base condition model was verified, it was then used to develop proposed condition models to simulate potential flood mitigation strategies.

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 FIS for the Towns of Dunkirk and Pomfret and Village of Fredonia.

The effectiveness of each potential mitigation strategy was evaluated based on reduction in water surface elevations. The flood mitigation strategies that were modeled were:

- 1-1: Remove Central Pier from CSX Railroad Bridge Crossing
- 1-2: Install Crossing Pipe into Railroad Embankments
- 1-3: Flood Benches in Vicinity of Railroad
- 1-4: Increase Size of West Willow Road Bridge
- 2-1: Flood Bench Adjacent to Hart Street Neighborhood
- 2-2: Levee Adjacent to Hart Street Neighborhood
- 2-3: Remove Central Pier from Water Street Bridge Crossing
- 2-4: Increase Opening Size of Water Street Bridge Crossing
- 2-5: Flood Benches in Vicinity of Liberty Street

The remaining alternatives were either qualitative in nature or required additional advanced 3-D modeling outside of the scope of this study.

Stationing references for the flood mitigation measures are based on the USGS National Hydrography Dataset (NHD) for Canadaway Creek, which differs from the FEMA FIS stationing values (USGS 2020).

6.2 DEBRIS ANALYSIS

According to historical flood reports, stakeholder engagement meetings, and field work, the Water Street bridge in the Village of Fredonia was identified as a hydraulic structure that experiences debris blockage at the upstream opening resulting in backwater flooding during higher peak flow events (FEMA 1989b; NYSDEC 2020b).

Based on the FEMA FIS H&H analysis discussion and profile plots, the effective FIS contains water surface elevation profile lines for the 1 and 0.2% annual chance event with the Water Street bridge fully obstructed. When fully obstructed, the FIS indicates that the 1- and 0.2% annual chance event WSELs over the Water Street bridge. In this study, the flood mitigation alternatives for the Water Street bridge area included a debris simulation.

In an effort to simulate real-world events more closely, the H&H analysis in this study used November 2017 storm data to determine the most appropriate degree of obstruction. Using flood images and news reports from the November 5, 2017 rain event in Western NY, it was determined that approximately 3-inches of rainfall occurred over a 24-hour period. This rainfall, coupled with debris, led to high water levels in Canadaway Creek, specifically at the Water Street bridge where debris and water were measured to reach the high chord of the bridge. The 3-in / 24-hr rain event equated to a 10-year recurrence interval (Kuczkowski 2017; NRCC 2021).

Using the 10% annual chance event (10-year recurrence interval), a base condition debris simulation was performed using the built-in Floating Pier Debris tool within the HEC-RAS model software. Manual calibration of the width and height of the debris obstruction in the model was performed to reproduce the November 5, 2017 event. The calibration determined that a 40% obstruction of the structure opening reproduced the November 5, 2017 event. Using the calibrated debris specifications, the base condition debris simulation model was used to test the effectiveness of the flood mitigation alternatives that influence flow through the Water Street bridge under both current and future conditions.

6.3 ICE JAM ANALYSIS

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

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

An existing ice jam can break-up and travel downstream along with larger ice particles with the higher flows of a flash flood and accumulate at a constricted downstream location creating another break-up ice jam, or damage downstream riverbanks or downstream infrastructures severely. Ice-jam flooding presents a complex problem for scientists and engineers since the resulting flood stage can be significantly higher than the flood stage caused from streamflow alone. In other words, a relatively minor discharge of streamflow can result in a major flooding event during an ice jam (USACE 1966).

6.3.1 Ice-Jam Flooding Mitigation Alternatives

There are several widely accepted and practiced standards for ice-jam controls to mitigate the ice-jam related flooding. These are referred to as ice-jam mitigation strategies, and each strategy is very much site dependent. A strategy that works for a certain reach of a river may not work for another reach in the same river due to river morphology and hydrodynamics. Therefore, each of these strategies need to be analyzed with numerical modeling and simulations to check if they work for a considered area or reach of a river before implementing or pursuing with the previous observational experience alone. The standard strategies that are widely accepted and practiced in cold-region engineering, such as in Western New York, are listed below with greater detail provided in Appendix E:

- Ice booms
- Ice breaking using explosives
- Ice breaking using ice-breaker ferries and cutters
- Installing inflatable dams (Obermeyer Spillways)
- Mixing heated effluent into the cold water
- Removal of bridge piers, heated bridge piers, or heated riverbank dikes
- Ice retention structures
- Ice forecasting systems and ice management

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

6.3.2 Ice-Jam Prone Areas

According to the USACE Cold Regions Research and Engineering Laboratory (CRREL) ice jam database, National Centers for Environmental Information (NCEI) storm events database, and the stakeholder engagement meeting for Canadaway Creek, there have been at least two ice-jam flooding events along Canadaway Creek since 1950 (CRREL 2021; NCEI 2021; NYSDEC 2020b).

On January 1, 1959, there was a reported ice-jam event that occurred along Canadaway Creek in the Village of Fredonia. No other information about the event was provided (CRREL 2021). More recently, on January 11, 2014, rainfall and warm temperatures resulted in an ice jam event on Canadaway Creek near NY-60 in the Hamlet of Laona and Town of Pomfret. As a result of the flooding, there were reported property damages of approximately $10,000 in the Hamlet (NCEI 2021).

Based on the historical ice-jam records and stakeholder input, the areas along Canadaway Creek with the highest potential for ice-jam formation are the Water Street bridge in the Village of Fredonia, and in the vicinity of NY-60 in the Hamlet of Laona and Town of Pomfret.

The study area for this report focused on the Town of Dunkirk and Village of Fredonia and includes an analysis of the effects each flood mitigation measure would have on the aforementioned ice-jam prone areas. These areas are vulnerable to ice-jam flooding due to a combination of infrastructure, development, and channel characteristics in their respective reaches of Canadaway Creek. The recent ice-jam flooding event of 2014 highlights the vulnerability of certain areas along Canadaway Creek to ice-jam flooding. In order to determine the most appropriate mitigation measures to address ice-jam flooding along Canadaway Creek, additional hydraulic and hydrologic modeling using ice simulation models and ice-jam specific mitigation measures, as outlined in Appendix E, are recommended for each ice-jam prone area.

6.4 COST ESTIMATE ANALYSIS

Rough order of magnitude (ROM) cost estimates were prepared for each mitigation alternative. In order to reflect current construction market conditions, a semi-analogous cost estimating procedure was used by considering costs of a recently completed, similar scope construction project performed in Upstate New York. Phase I of the Sauquoit Creek Channel and Floodplain Restoration Project in Whitestown, NY 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 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, for some mitigation measures the size necessary to meet the freeboard requirement was not feasible. Cost estimates were performed based on projects determined to be constructible and practical.

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

6.5 HIGH-RISK AREAS

Based on the FEMA FIS, NCEI storm events database, historical flood reports, and stakeholder input from engagement meetings, three areas along Canadaway Creek were identified as high-risk flood areas in the Towns of Dunkirk and Pomfret, including the Village of Fredonia.

6.5.1 High-risk Area #1: Railroad Bridges Upstream to West Willow Road Bridge, Town of Dunkirk, NY

High-risk Area #1 is the railroad bridge crossing over Canadaway Creek upstream to the West Willow Road in the Town of Dunkirk. There are two railway lines in this area that are owned by CSX Transportation (river station 57+00) and Norfolk Southern Railway Company (river station 59+00), and the West Willow Road bridge (river station 74+00) which is owned by Chautauqua County (Figure 6-1). According to the FEMA MSC, there is no effective FEMA FIS, so no water surface elevation profile data is available from FEMA regarding the hydraulic capacity of the bridges in this area. However, according to the FEMA FIRM, there is backwater flooding upstream of the railroad bridges at the 1% annual chance flood hazard, which continues upstream past West Willow Road (Figure 6-2).

The primary driver of flood risk in this area is the sharp, near 90º bends in the creek channel upstream of the railroad bridges. The meanders cause water velocities to slow and lose the required energy to maintain suspended sediments within the water column. As a result, sediment depositional aggradation occurs at the apex of the meanders as evidenced by the sand bars that have developed upstream of the railroad bridges. In addition, erosion along the railroad tracks bank has reduced the stability of the railroad track supports, and recently required a streambank stabilization project to repair the damages caused by erosion (NYSDEC 2020b). There is also backwater upstream of the West Willow Road bridge; however, it is unclear based on current available data and the lack of FEMA FIS data whether the bridge contributes to the flood risk in this area.

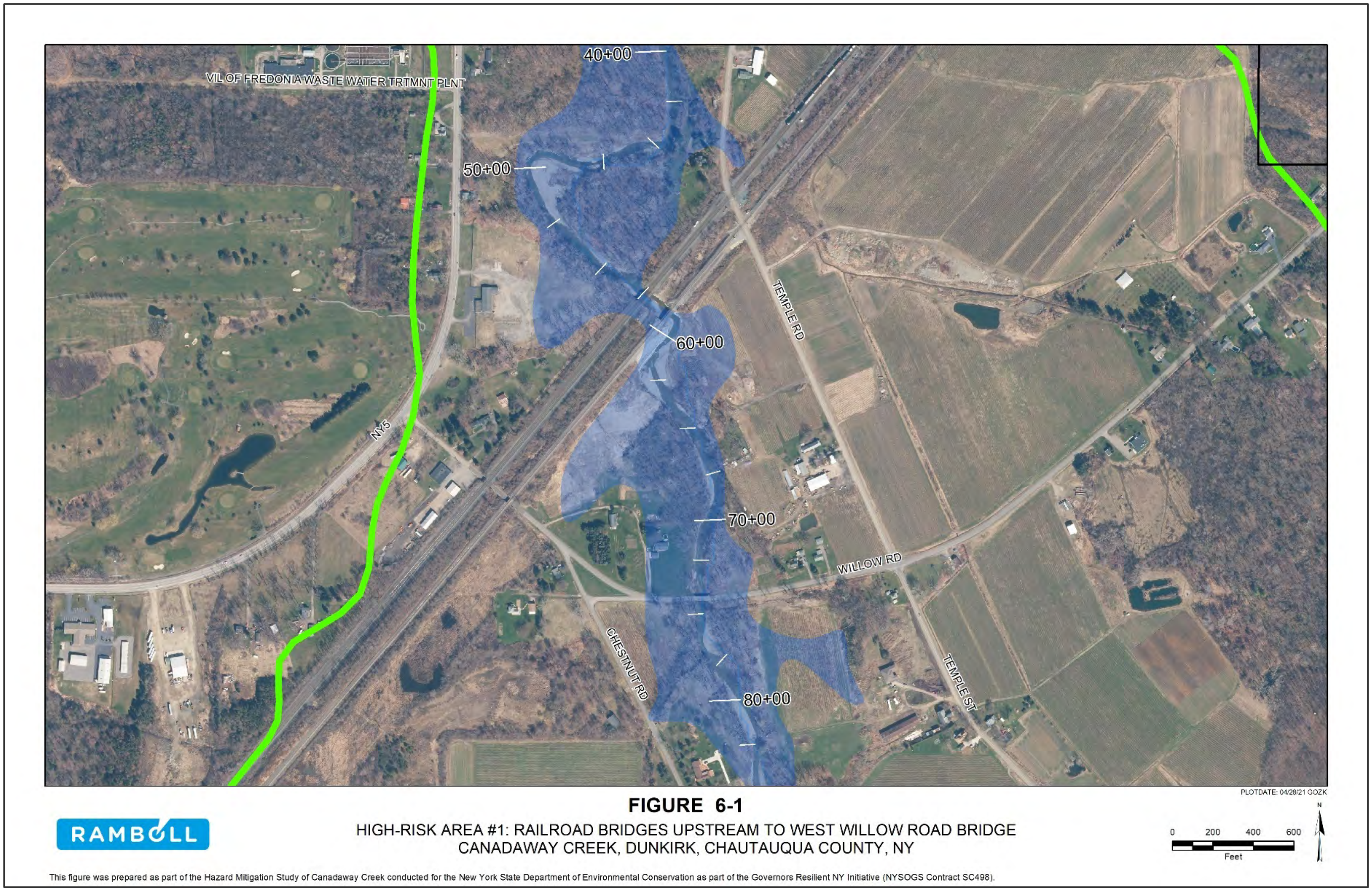


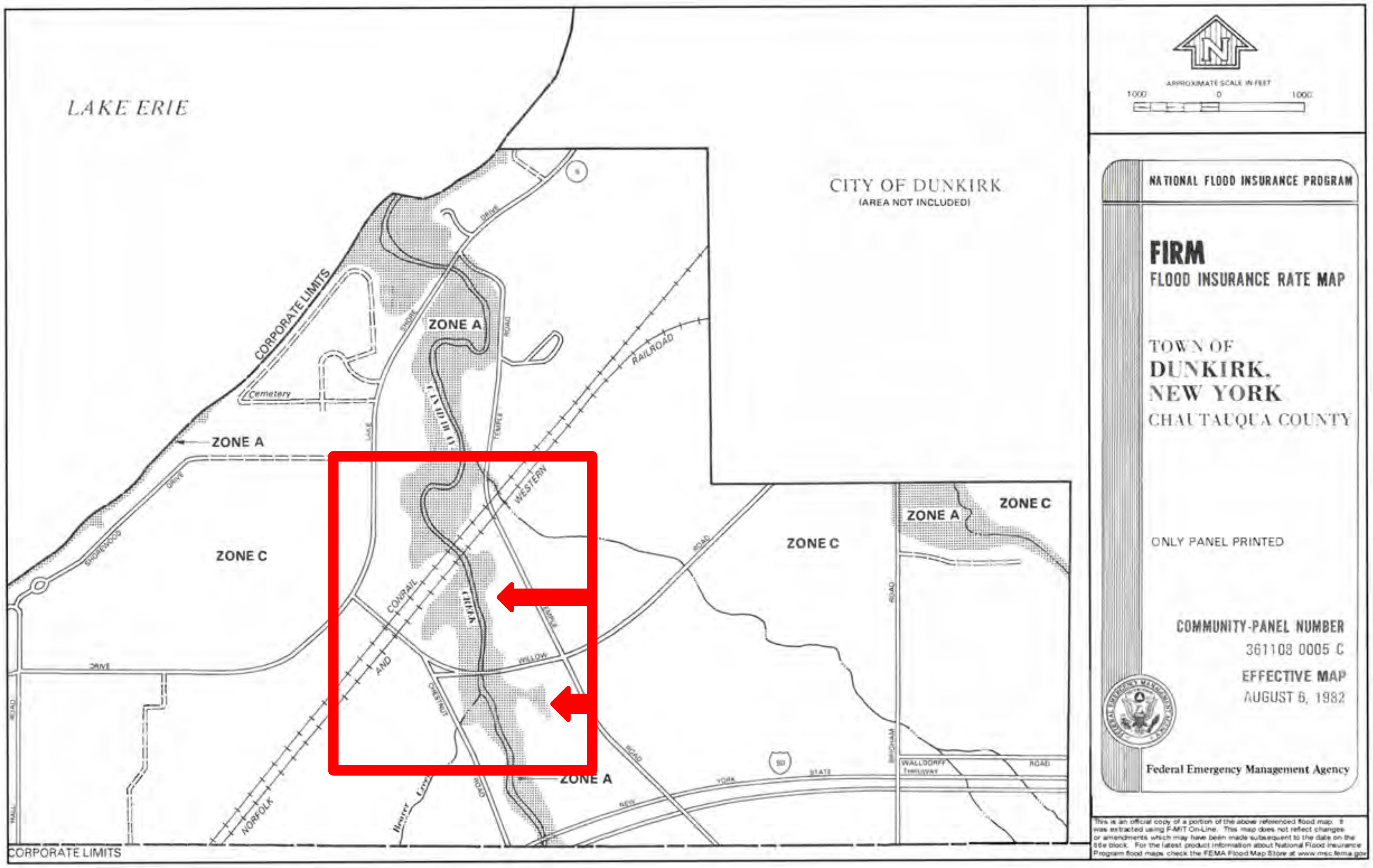
FIGURE 6-1

HIGH-RISK AREA #1: RAILROAD BRIDGES UPSTREAM TO WEST WILLOW ROAD BRIDGE
CANADAWAY CREEK, DUNKIRK, CHAUTAUQUA COUNTY, NY

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

Figure 6-1. High-risk Area #1: Railroad Bridges upstream to West Willow Road Bridge, Town of Dunkirk, 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.



This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov

Figure 6-2. FEMA FIRM for Canadaway Creek in the Town of Dunkirk, NY.

6.5.2 High-risk Area #2: Hart Street Upstream to Water Street Bridge, Village of Fredonia, NY

High-risk Area #2 is the area from Hart Street (river station 207+50) upstream to the Water Street bridge crossing over Canadaway Creek (river station 234+50) (Figure 6-3). The Hart Street area is within the 1 and 0.2% annual chance event areas with multiple residences in the flood zones. The Water Street bridge (BIN #1050600) is owned and maintained by Chautauqua County, NY. The effective FEMA FIRM shows that the bridge is able to pass a 1% annual chance flood event, but not the 0.2% annual chance event. In addition, the FIS includes an analysis for when the Water Street bridge is blocked by debris. In these scenarios, the Water Street bridge is unable to pass the 1% or 0.2% annual chance event (FEMA 1989b). The susceptibility of the Water Street bridge crossing to flooding is an important issue not only for nearby residential and commercial properties, but also for infrastructure and emergency response since Water Street is an important route into and out of the Village of Fredonia.

Water Street is an important thoroughfare in the Village of Fredonia. Numerous businesses and residences reside along Water Street and depend on its traffic and access for property owners and businesses. According to the NYSDOT Functional Class viewer (https://gis.dot.ny.gov/html5viewer/?viewer=FC), Water Street is classified as a Urban Minor Arterial, which is defined as a roadway that interconnects with and augments the urban principal arterial system and provides service to trips of moderate length at somewhat lower of travel mobility than principal arterials; ideally, they should not penetrate identifiable neighborhoods; the spacing of minor arterial streets should normally be not more than one mile in fully developed areas (NYSDOT 2016b).

The Water Street bridge crossing is susceptible to both open water flooding and ice-jam formations due to the central pier of the bridge and sediment depositional aggradation at the upstream face of the bridge opening. The central pier is a catchpoint along Canadaway Creek for wooded debris, which restricts the cross-sectional flow area of the channel. When enough debris accumulates, backwater can occur with flooding in upstream areas. Sediment depositional aggradation occurs as a result of the meander of the creek as it passes under Water Street and the abutments of the bridge structure, reducing water velocities within the channel causing the water column to lose the required energy to maintain suspended sediments. This is evidenced by the sand bars that have developed on the outside bend of the meander as Canadaway Creek passes under Water Street (NYSDEC 2020b).

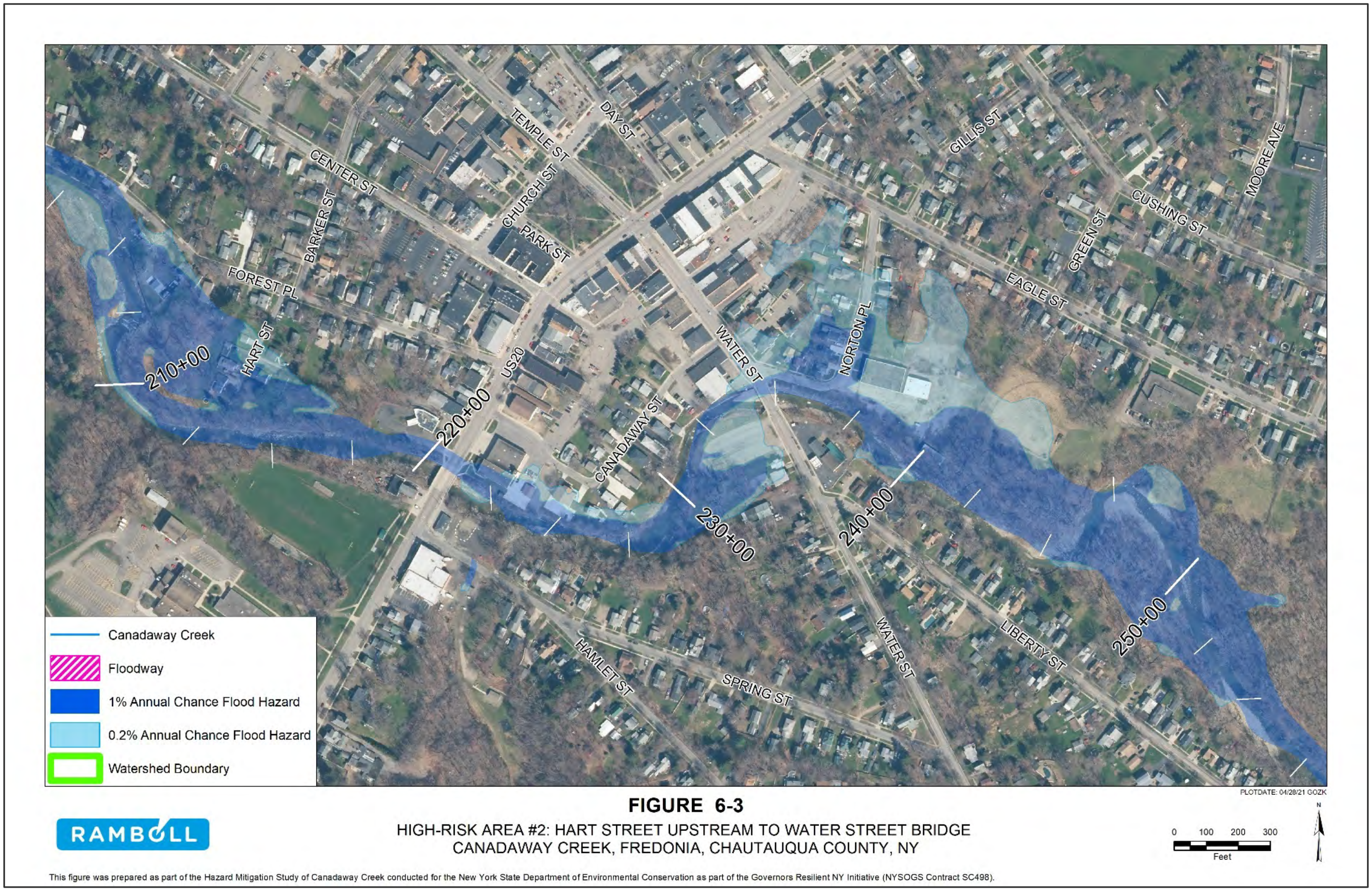


Figure 6-3. High-risk Area #2: Hart Street upstream to Water Street Bridge, Village of Fredonia, NY.

*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.

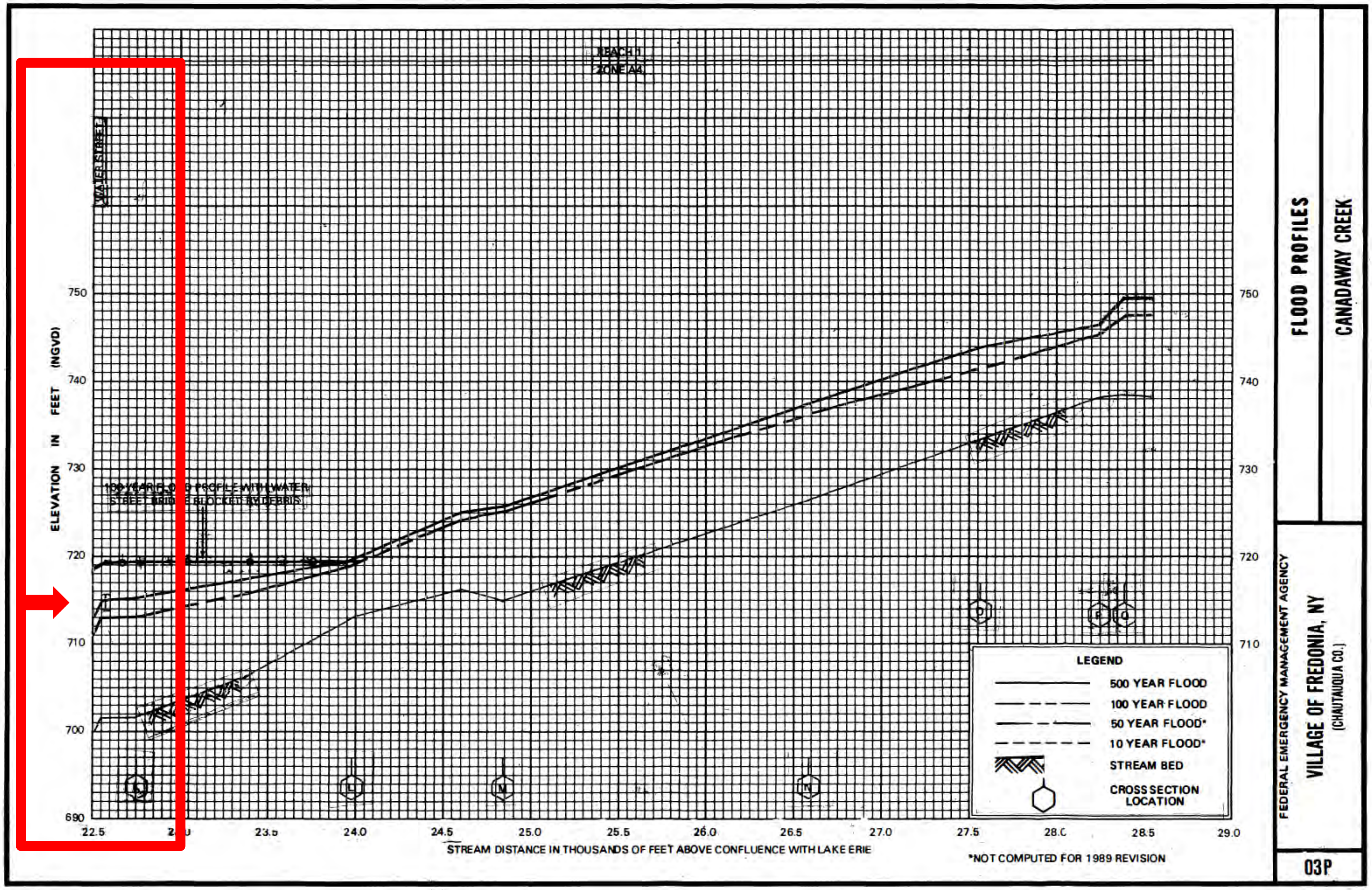


Figure 6-4. FEMA FIS profile for Canadaway Creek in the vicinity of the Water Street bridge crossing.

*Note: Located at river station 225+75 on the FEMA FIS profile.

6.5.3 High-risk Area #3: Areas Adjacent to Porter Avenue / Road, Town of Pomfret, NY

High-risk Area #3 is along Porter Avenue, which becomes Porter Road outside the Village of Fredonia, in the Town of Pomfret, beginning at the Liberty Street bridge crossing (river station 294+00) and extending upstream approximately 8,200-feet upstream of the confluence of Canadaway Creek and the unnamed tributary in the Hamlet of Laona (river station 376+00) (Figure 6-5). Canadaway Creek runs parallel with Porter Road starting near the intersection with NY-60 and continues downstream until reaching the Dunn Street neighborhood.

Porter Avenue / Road is owned and maintained by Chautauqua County. According to the NYSDOT Functional Class viewer, Porter Avenue / Road is classified as a Urban Major Collector, which is defined as a roadway that provides both land access service and traffic circulation within residential neighborhoods, commercial and industrial areas; may penetrate residential neighborhoods, distributing trips from the arterials through the area to the ultimate destination; collects traffic from local streets in residential neighborhoods and channels it into the arterial system; and in the central business district, and in other areas of like development and traffic density, the collector system may include the street grid which forms a logical entity for traffic circulation (NYSDOT 2016b).

Canadaway Creek near Porter Avenue / Road is susceptible to both open-water flooding and ice-jam formations due to multiple factors, including steep terrain, a primarily bedrock creek channel in this reach, and a sinuous creek path. The steep terrain and primarily bedrock creek channel increase water velocities, while the many natural meanders experience deposition and erosion, increasing sediment depositional aggradation downstream and de-stabilization of the channel banks. In addition to sediment erosion, wooded debris during heavy rain events enter Canadaway Creek primarily in this reach and are carried downstream contributing to potential flooding in downstream areas along the creek. All of these factors contribute to flood risk in this reach and further downstream along Canadaway Creek (NYSDEC 2020b). The confluence of Canadaway Creek and the unnamed tributary in the Hamlet of Laona was also the site of the January 11, 2014 ice jam that caused approximately $10,000 in property damages in Laona, New York (NCEI 2021).

FIGURE 6-5

HIGH-RISK AREA #3: AREAS ADJACENT TO PORTER AVE/ROAD
CANADAWAY CREEK, POMFRET, CHAUTAUQUA COUNTY, NY

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

Figure 6-5. High-risk Area #3: Areas adjacent to Porter Avenue / Road, Town of Pomfret, 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.

7. MITIGATION ALTERNATIVES

The following are flood mitigation alternatives that have the potential to reduce water surface elevations along high-risk areas of Canadaway 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 before pursuing them further.

7.1 HIGH-RISK AREA #1

7.1.1 Alternative #1-1: Remove Central Pier from CSX Railroad Bridge Crossing

This measure is intended to increase the cross-sectional flow area of the channel and remove any potential impediments or catch points for sediment and debris by removing the central pier of the CSX Transportation, Inc. railroad crossing located at river station 60+00 (Figure 7-1). The railroad crossing has one pier in the center of the creek channel that is approximately 15-ft in width. Based on orthoimagery of the area, meanders in the creek channel coupled with the in-channel pier act as impediments to flow, reducing water velocities and allowing sediment and debris to aggregate and restrict flow in this area. This is evidenced by the large sediment bars upstream of the railroad bridge and by historical flood reports in the area (NYSOITS 2017a; NYSDEC 2020b).

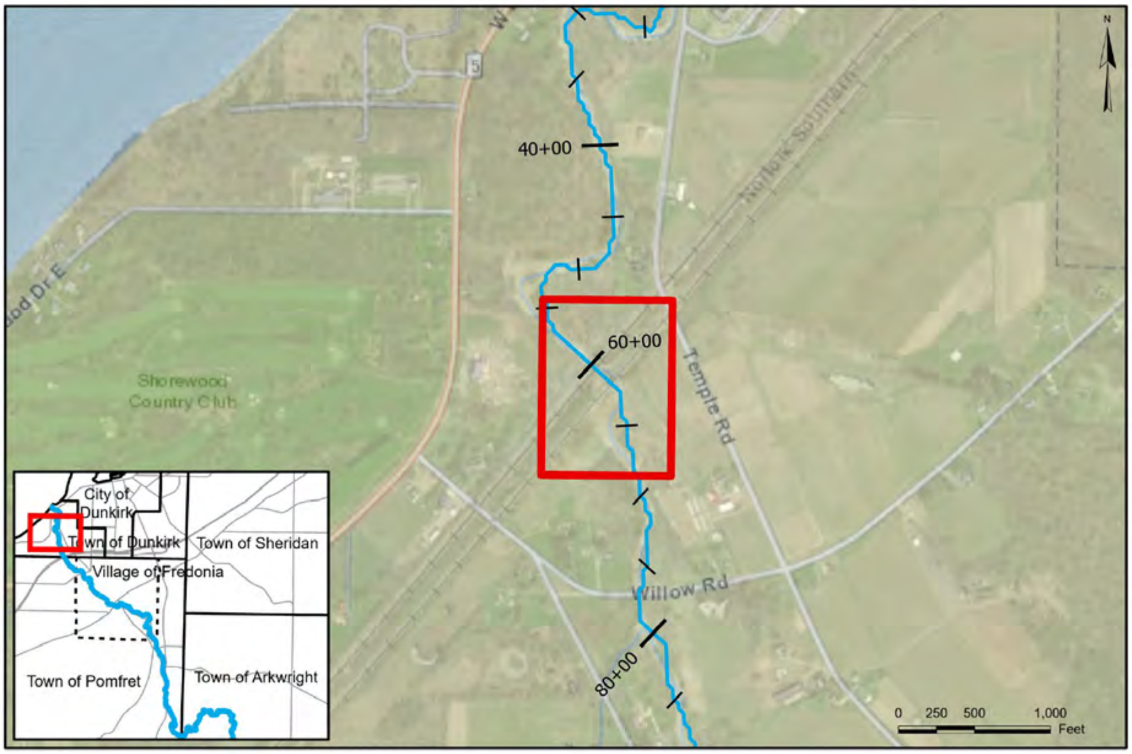


Figure 7-1. Location map for Alternative #1-1.

According to the HEC-RAS base condition model, the CSX railroad bridge is able to successfully pass the 0.2% annual chance event WSELs; however, due to the close proximity of the Norfolk Southern railroad bridge and sharp meander of Canadaway Creek immediately upstream of the Norfolk Southern railroad bridge, significant backwater occurs upstream of the railroad bridges and a hydraulic jump is present between the two railroad bridges (Figure 7-2).

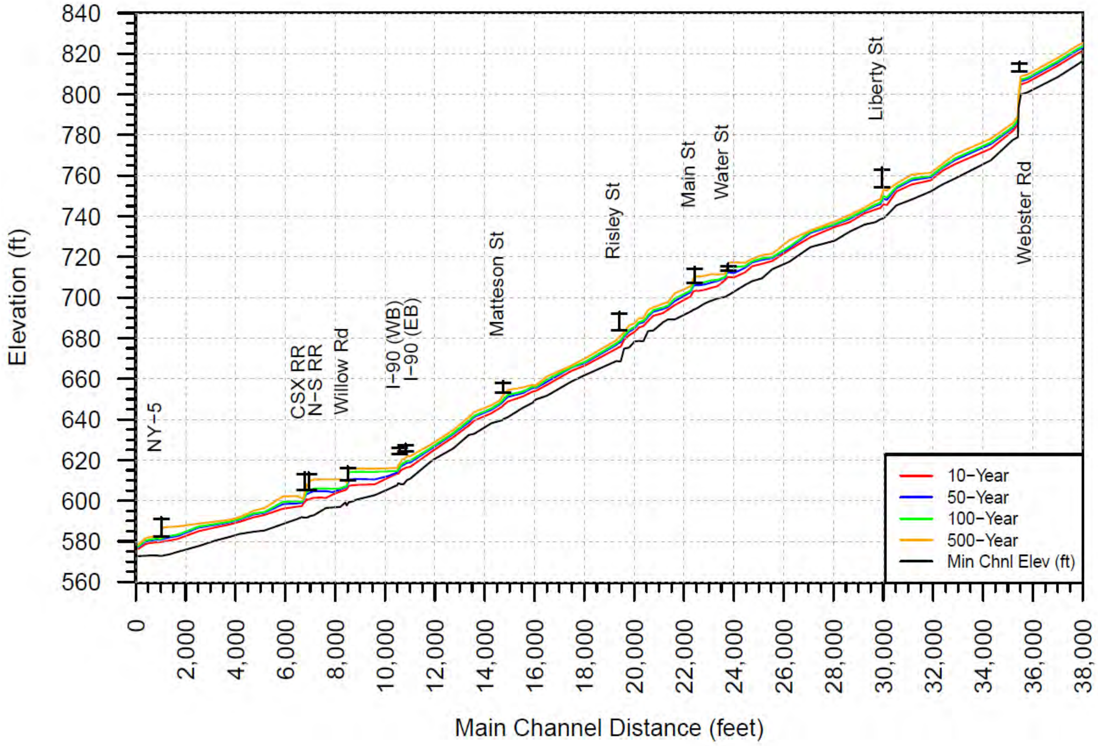


Figure 7-2. HEC-RAS base condition model simulation output results.

This measure would potentially reduce the flood risk and benefit the properties adajcent to and immediately upstream of the railroad bridges. The pier removal scenario increased the cross-sectional flow area of the channel by removing the 15-ft wide pier in the center of the channel. The proposed condition modeling simulation results indicated water surface reductions of up to 2.9 ft in areas approximately 1,650-ft upstream of the bridge extending to the West Willow Road bridge, specifically between river stations 67+50 to 84+00 (Figure 7-3). The modeling output for future conditions displayed similar results with water surface reductions of up to 2.5 ft (Appendix H).

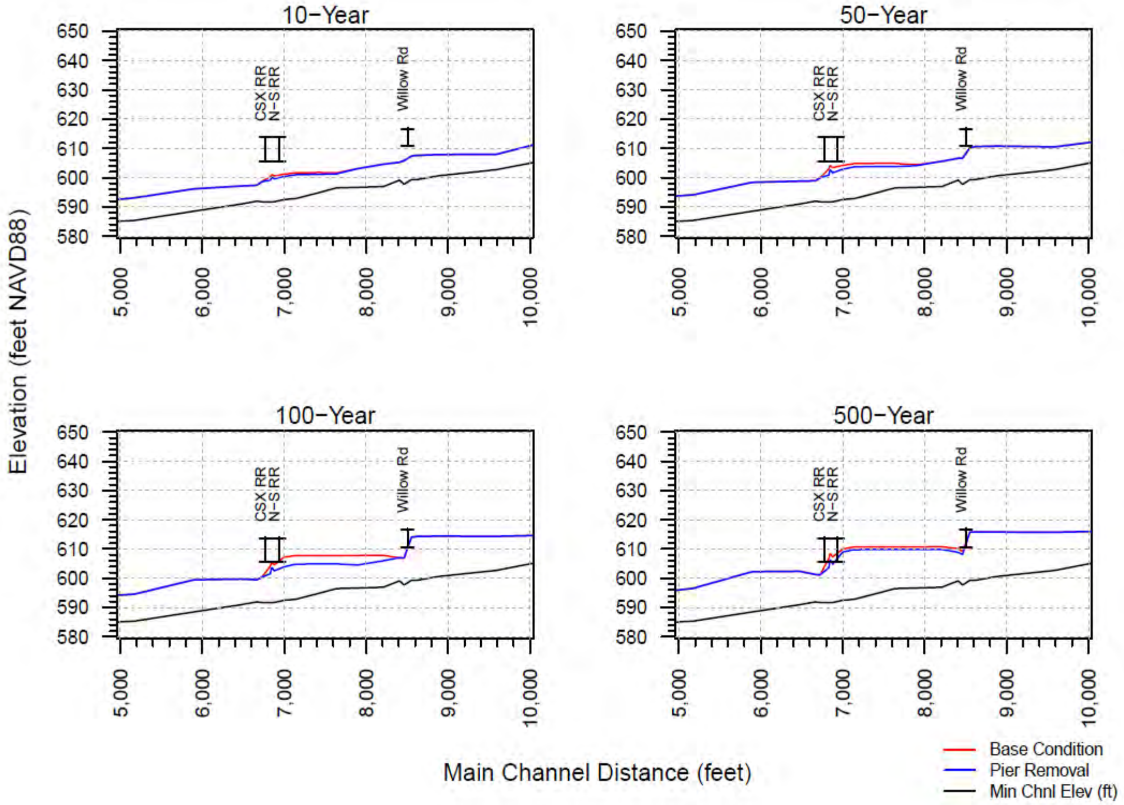


Figure 7-3. HEC-RAS model simulation output results for Alternative #1-1.

Due to the economic and political considerations of any mitigation alternative that involves railroad crossings and / or property, the feasibility of this alternative is relatively low.

The Rough Order Magnitude cost for this measure is $110,000, which does not include land acquisition costs for survey, appraisal, and engineering and railroad company coordination. Additional engineering consideration would also be required to determine if removing the central pier of the railroad bridge would alter the structural integrity of the bridge in any way.

7.1.2 Alternative #1-2: Install Crossing Pipes into Railroad Embankments

This measure is intended to increase the cross-sectional flow area of the channel by installing one additional pipe culvert on the left bank of both of the railroad bridge embankments located at river stations 60+00 and 61+00. The railroad bridge located at river station 60+00 is owned by CSX Transportation, Inc. and the railroad bridge located at 61+00 is owned by Norfolk Southern Railway in the Town of Dunkirk, NY (Figure 7-4). The flooding in the vicinity of the railroad bridges pose a flood risk threat to nearby residential properties upstream of the railroad crossings.

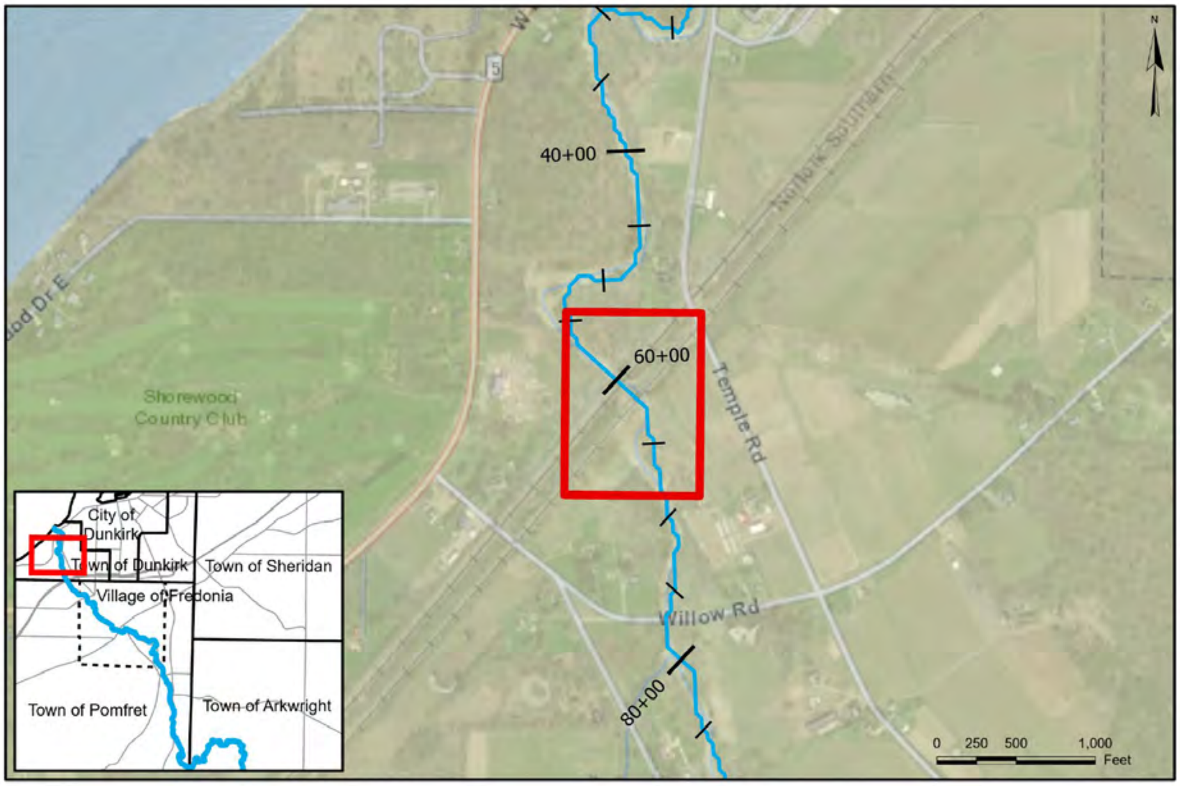


Figure 7-4. Location map for Alternative #1-2.

According to the HEC-RAS base condition model, the CSX railroad bridge is able to successfully pass the 0.2% annual chance event WSELs, while the Norfolk Southern railroad bridge is unable to pass the 0.2% annual chance event. However, due to the close proximity of the two railroad bridges and sharp meander of Canadaway Creek immediately upstream of the bridges, significant backwater occurs upstream of the Norfolk Southern railroad bridge, and a hydraulic jump is present between the two railroad bridges.

This measure would potentially reduce the flood risk for and benefit the properties adjacent to and immediately upstream of the railroad bridge. The crossing pipe scenario increased the cross-sectional flow area of the bridge on the left channel bank by including one 8-ft diameter pipe culvert placed above the bankfull elevation. The proposed condition modeling simulation results indicated water surface reductions of up to 1.8 ft in areas approximately 1,475-ft upstream of the bridge, specifically along river stations 70+00 to 84+75 (Figure 7-5). The modeling output for future conditions displayed similar results with water surface reductions of up to 1.1 ft (Appendix H).

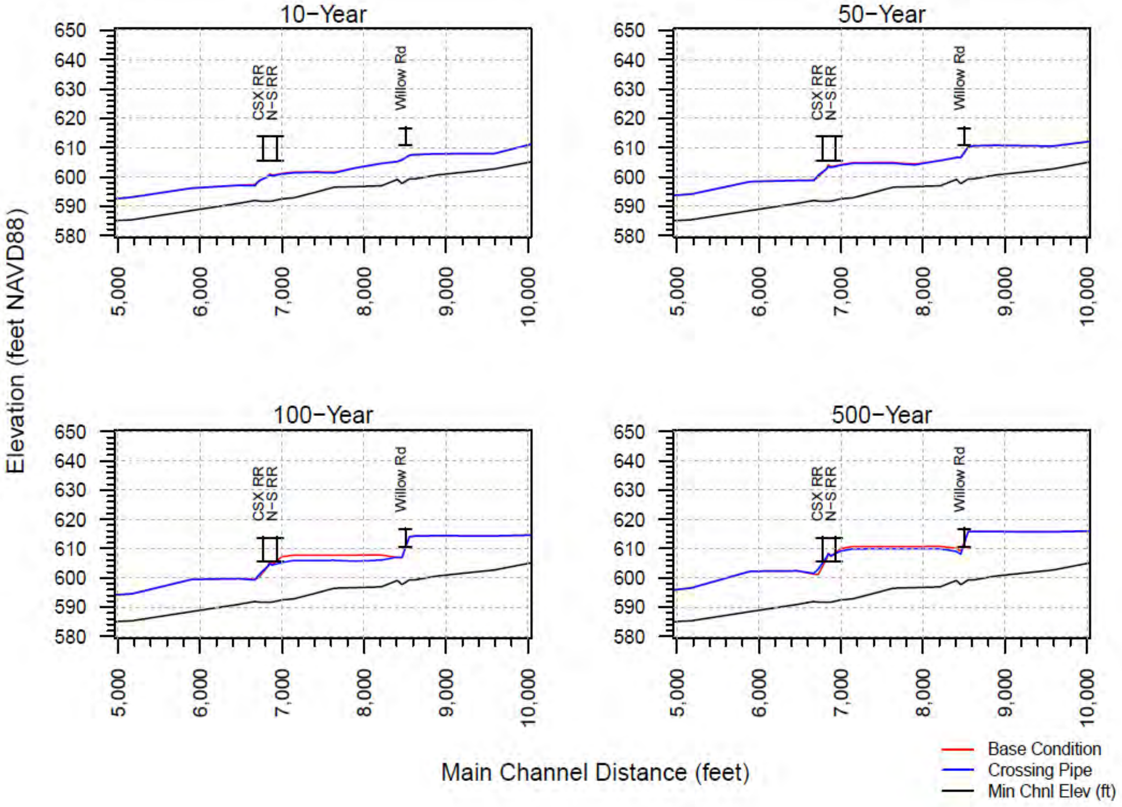


Figure 7-5. HEC-RAS model simulation output results for Alternative #1-2.

Due to the economic and political considerations of any mitigation alternative that involves railroad crossings and / or property, the feasibility of this alternative is relatively low.

The Rough Order Magnitude cost for this measure is $1.1 million, which does not include land acquisition costs for survey, appraisal, and engineering and railroad company coordination.

7.1.3 Alternative #1-3: Flood Benches in the Vicinity of the Railroad Crossings

Installing a flood bench would provide additional storage and floodplain width over and above the current storage and width provided by the adjacent agricultural and undeveloped lands, which could potentially reduce damages in the event of flooding and address issues within High-risk Area #1. Two potential flood benches were modeled in the vicinity of the railroad bridge crossings in the Town of Dunkirk: one flood bench downstream approximately 3.8 acres in size at river stations 53+00 to 67+00, and one flood bench upstream approximately 6.8 acres in size at river stations 71+00 to 78+00 (Figure 7-6). The flood bench designs used for the proposed condition model simulation set the minimum bench elevation approximately equal to the bankfull elevation, which was an average depth of 3.5 ft.

The flood benches are within the FEMA designated SFHA or Zone A, which are areas subject to inundation by the 1% annual chance flood event, but where base flood elevations and flood hazard factors were not determined, and where mandatory flood insurance purchase requirements and floodplain management standards apply (FIA 1980; FEMA 1982). Appendix F depicts a flood mitigation rendering of a flood bench illustrating before and after landscape features.

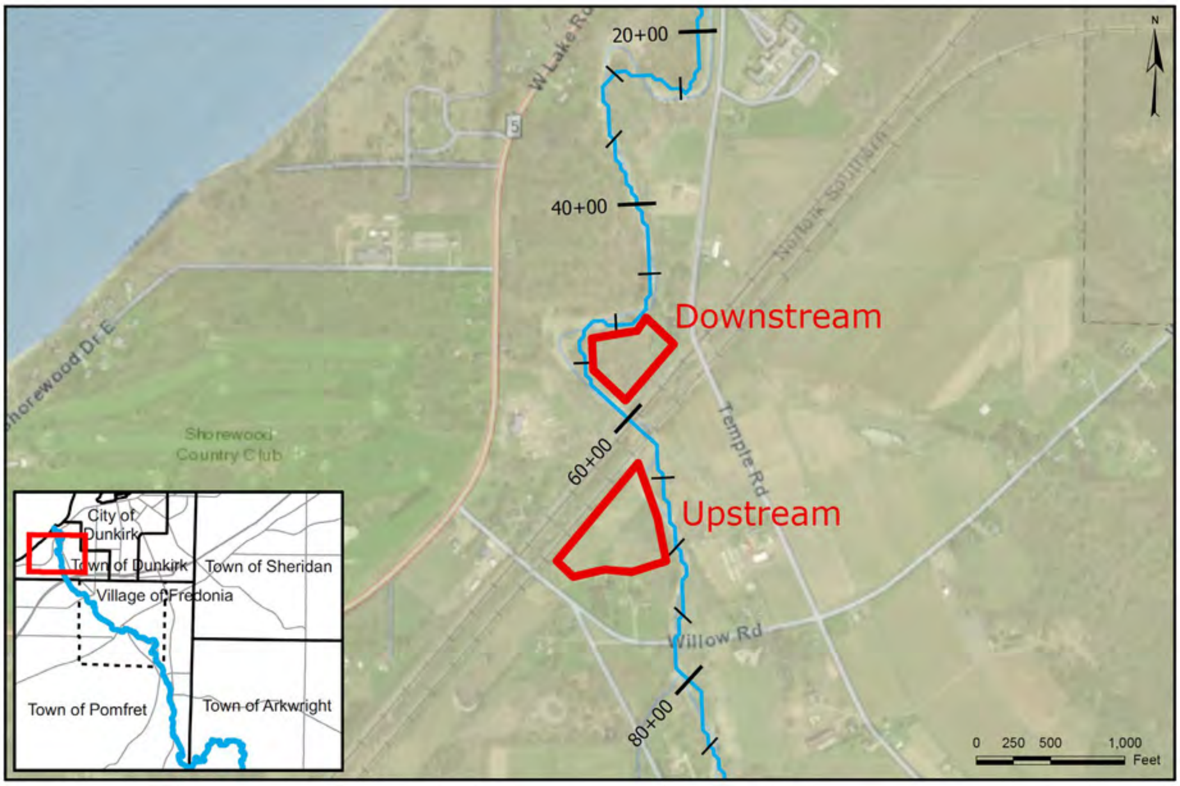


Figure 7-6. Location map for Alternative #1-3.

The proposed condition model results indicated that a flood bench downstream of the railroad bridges reduced water surface depths by up to 2.5 ft in areas approximately 1,200-ft downstream of the bridge, specifically along river stations 56+00 to 68+00; while a flood bench upstream of the railroad bridges indicated no significant change in water surface elevations (Figure 7-7). The modeling output for future conditions displayed similar results with water surface reductions of up to 1.9 ft for the downstream flood bench, while the upstream flood bench indicated no significant change under future conditions (Appendix H).

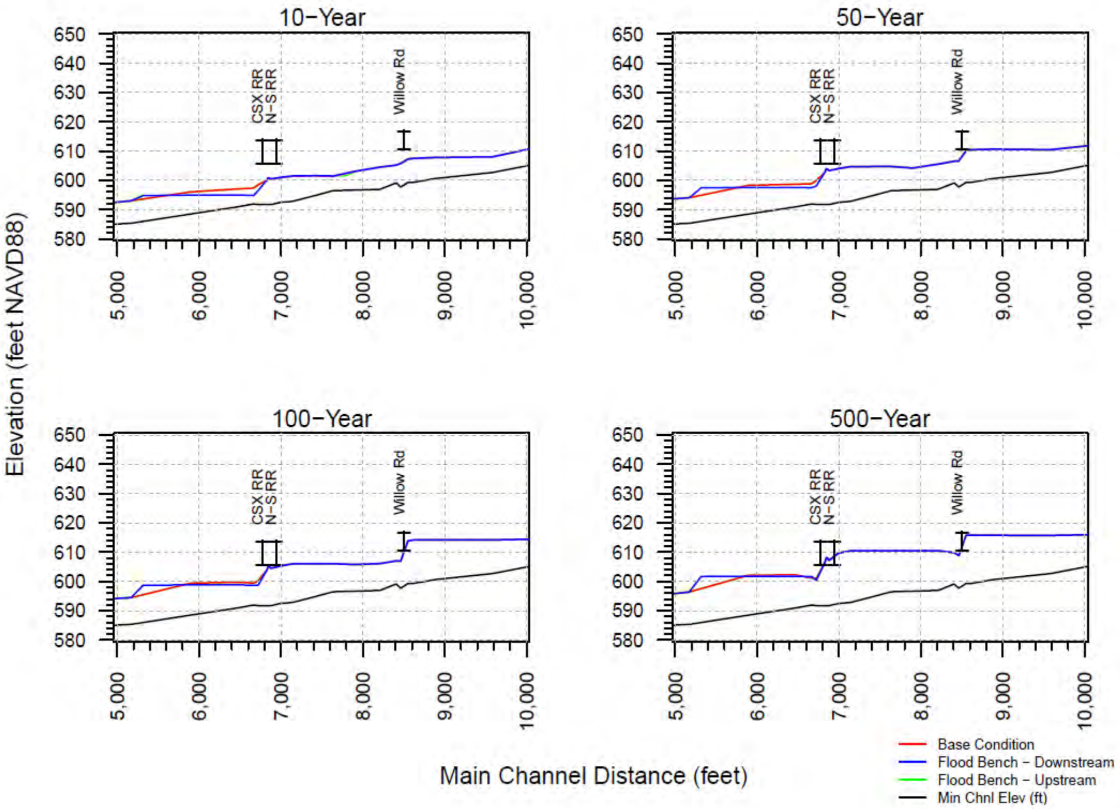


Figure 7-7. HEC-RAS model simulation output results for Alternative #1-3.

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 railroad crossings would not provide significant flood protection in this reach from open-water flooding. 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 immediately upstream of the railroad bridges).

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

The Rough Order Magnitude cost for the upstream flood bench is $2.4 million and the downstream flood bench is $1.4 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

7.1.4 Alternative #1-4: Increase Size of West Willow Road Bridge

This measure is intended to address issues within High-risk Area #1 by increasing the width of the West Willow Road bridge opening, which would increase the cross-sectional flow area of the channel located at river station 77+50 (Figure 7-8).

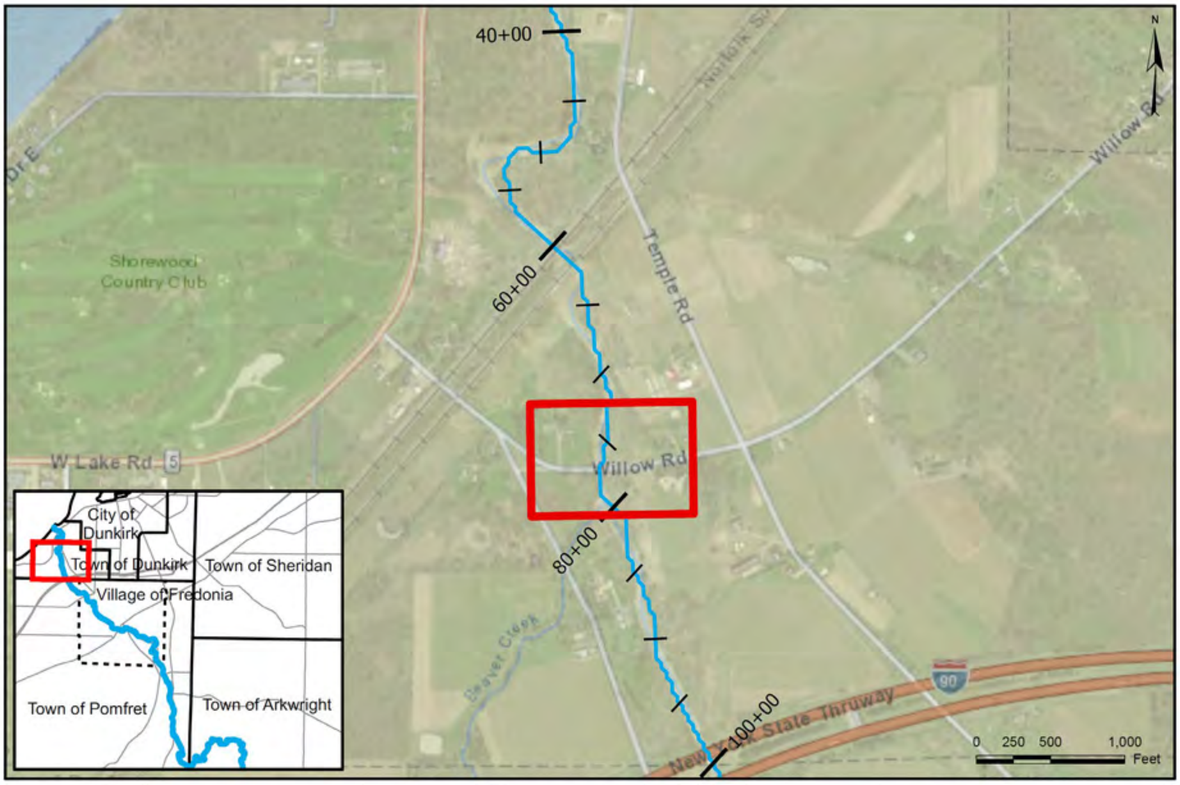


Figure 7-8. Location map for Alternative #1-4.

The bridge is owned by Chautauqua County and the existing bridge structure has a bridge span of 65 ft, and a maximum low chord to channel bottom height of 12 ft (Figure 7-9). The flooding in the vicinity of the West Willow Road bridge poses a flood risk threat to nearby residential properties (Ramboll 2021). Appendix F depicts a flood mitigation rendering of a bridge widening scenario.

Figure 7-9. West Willow Road bridge, Dunkirk, NY.

According to the FEMA FIRM, there is backwater upstream of the West Willow Road bridge at the 1 and 0.2% annual chance event WSELs (FEMA 1989a). This measure would potentially reduce the flood risk and benefit the properties adjacent to and immediately upstream of West Willow Road.

The bridge widening design used for the proposed condition model simulation increased the width of the bridge opening from 65 ft to 85 ft by widening each side of the bridge by 10 ft. This measure would potentially reduce the flood risk and benefit the properties adjacent to and immediately upstream of the bridge crossing.

The proposed condition model results indicated water surface reductions of up to 4.1 ft in areas approximately 1,500-ft upstream of the bridge, specifically along river stations 85+00 to 100+00 (Figure 7-10). The modeling output for future conditions displayed similar results with water surface reductions of up to 4.1 ft for the bridge widening alternative (Appendix H).

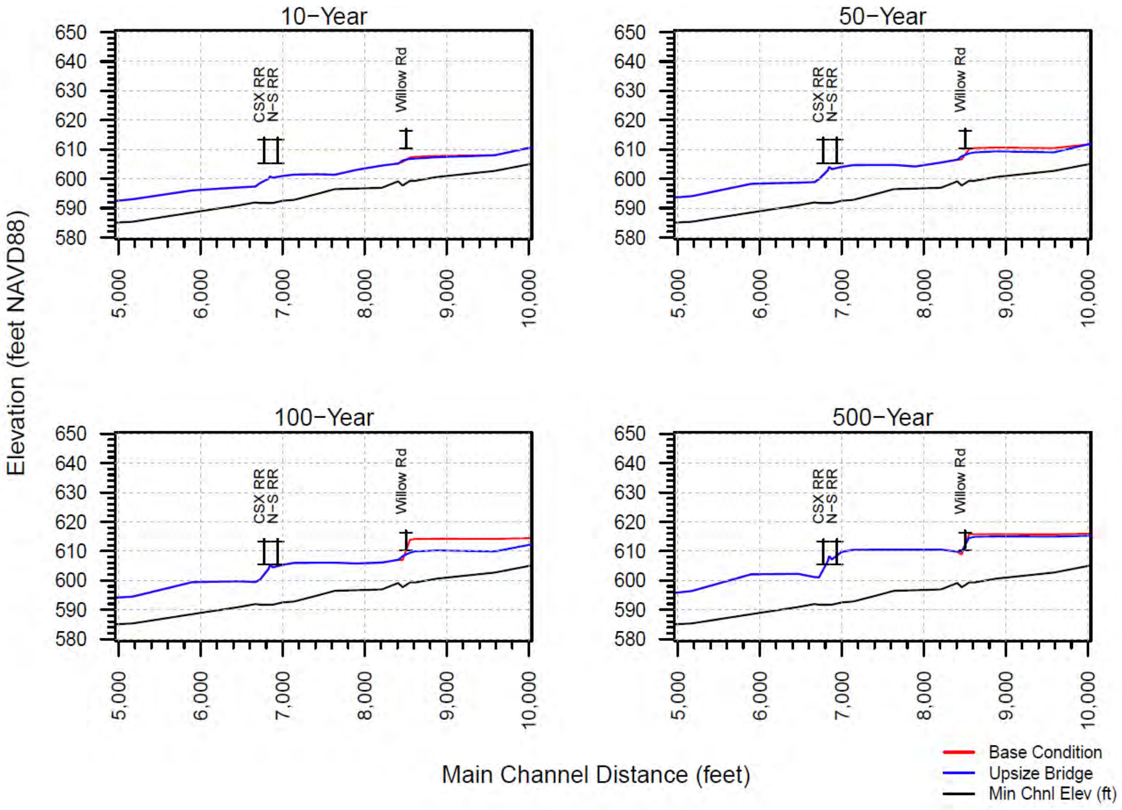


Figure 7-10. HEC-RAS model simulation output results for Alternative #1-4.

The Rough Order Magnitude cost for this measure is $1.8 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

7.2 HIGH-RISK AREA #2

7.2.1 Alternative #2-1: Flood Bench Adjacent to Hart Street Neighborhood

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. The flood bench would be in the vicinity of the Hart Street Neighborhood in the Village of Fredonia, approximately 1.9 acres in size and located between river stations 209+00 to 216+00 (Figure 7-11). The flood bench designs used for the proposed condition model simulation set the minimum bench elevation approximately equal to the bankfull elevation, which was an average depth of 2.5 ft.

The flood bench is within the FEMA designated SFHA or Zone A, which are areas subject to inundation by the 1% annual chance flood event, but where base flood elevations and flood hazard factors were not determined, and where mandatory flood insurance purchase requirements and floodplain management standards apply (FIA 1980; FEMA 1982). Appendix F depicts a flood mitigation rendering of a flood bench illustrating before and after landscape features.

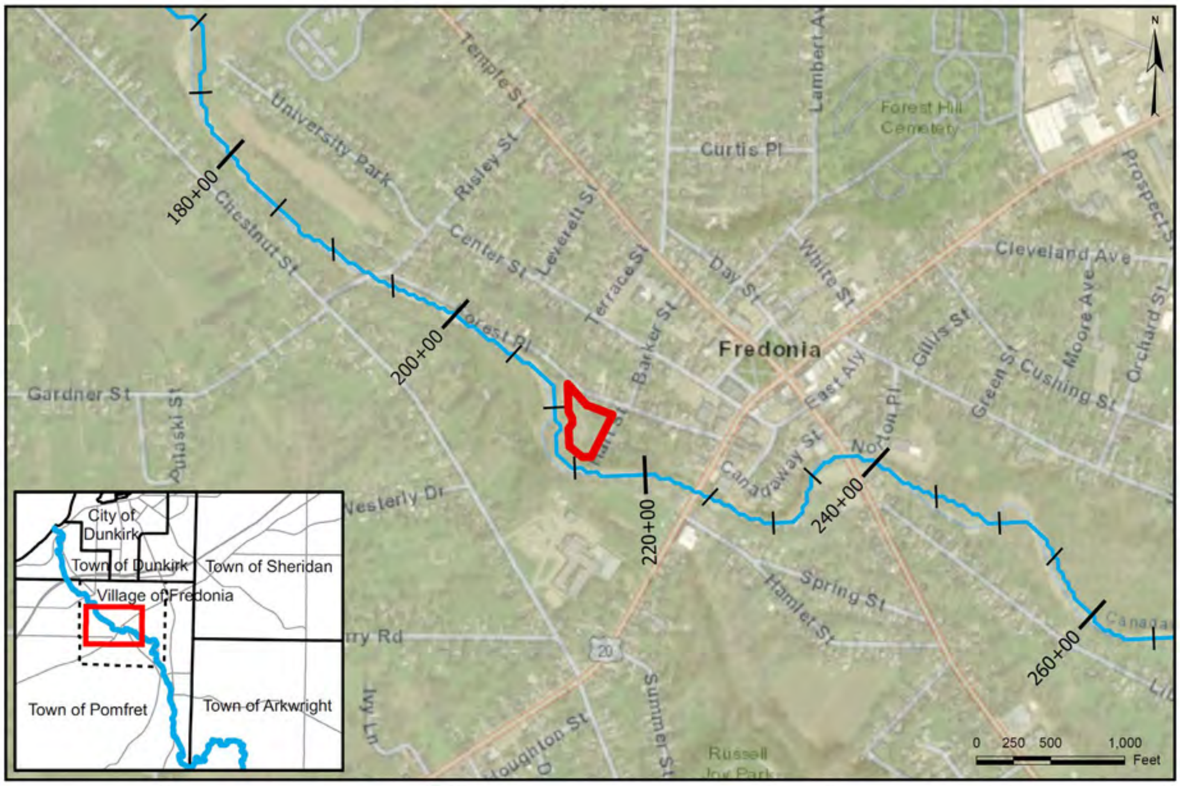


Figure 7-11. Location map for Alternative #2-1.

The flood bench design used for the proposed condition model simulation set the bench elevation approximately equal to the bankfull elevation. This measure would potentially reduce the flood risk for and benefit the properties adjacent to and immediately upstream of the flood bench. The proposed condition model results indicated water surface reductions of up to 2.5 ft in areas approximately 1,000-ft upstream of the flood bench, specifically along river station 212+00 to 222+00 (Figure 7-12). The modeling output for future conditions displayed similar results with water surface reductions of up to 3.3 ft for the flood bench alternative (Appendix H).

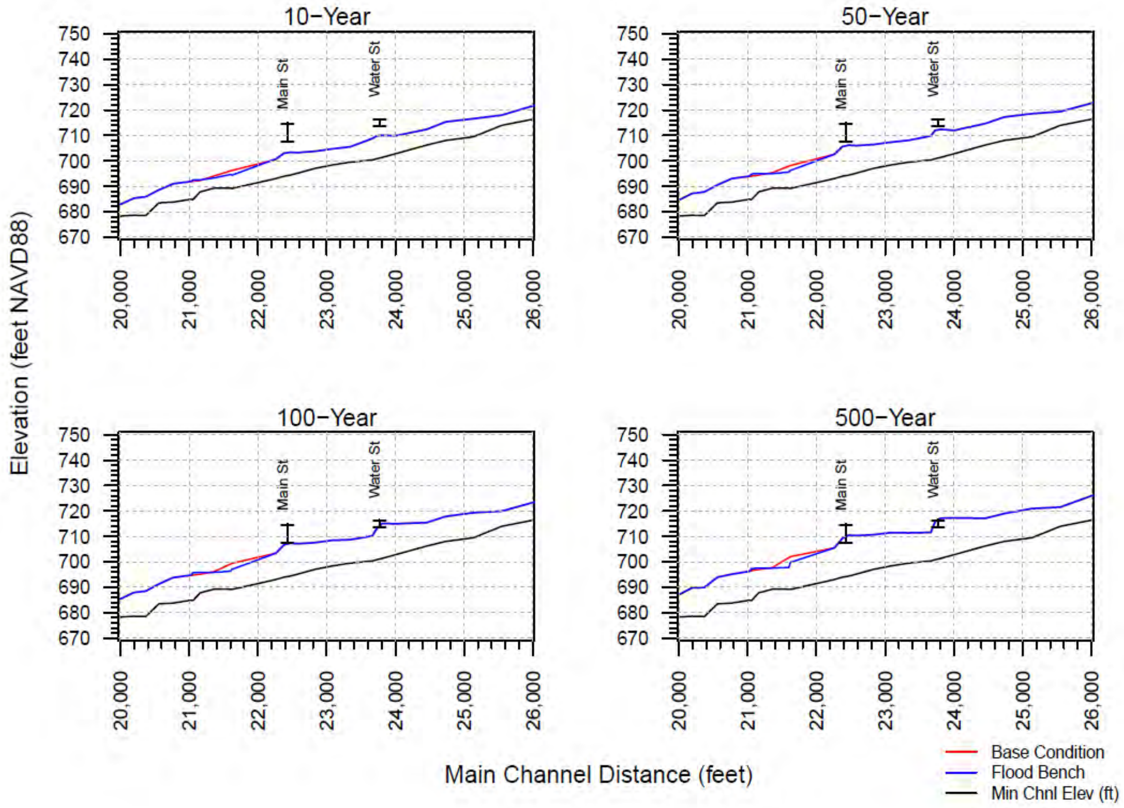


Figure 7-12. HEC-RAS model simulation output results for Alternative #2-1.

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 adjacent to the Hart Street neighborhood would provide flood protection in this reach from open-water flooding.

The Rough Order Magnitude cost for this measure is $680,000, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

7.2.2 Alternative #2-2: Levee Adjacent to Hart Street Neighborhood

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 Hart Street neighborhood by constructing a permanent levee along the right bank of Canadaway Creek adjacent to the community. The levee would be approximately 1,500-ft long with a height of two feet above the future flood flow stage for the projected 1% annual chance flood elevation (696 - 705 ft NAVD 88) and located along river stations 205+50 to 220+50. Compaction and the possibility of using cut material as fill has not been accounted for at this point. Downstream and opposite bank effects of the levee were modelled, and the levee was determined to have no measurable effects on upstream or downstream water surface elevations (Figure 7-13).

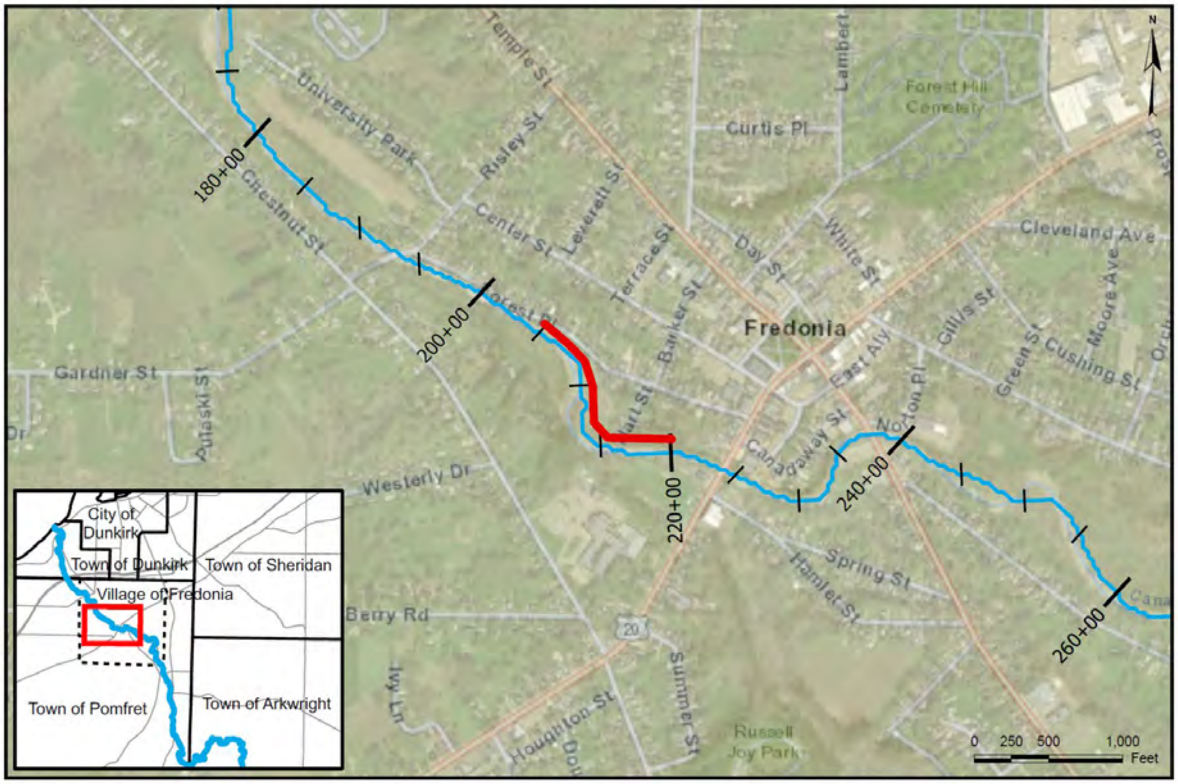


Figure 7-13. Location map for Alternative #2-2.

The proposed and future hydraulic modeling confirmed that constructing a levee along Canadaway Creek in the reach adjacent to the Hart Street neighborhood would decrease the flood risk of the neighborhood, while leaving the flood potential of downstream and opposite bank areas unaffected (Figure 7-14).

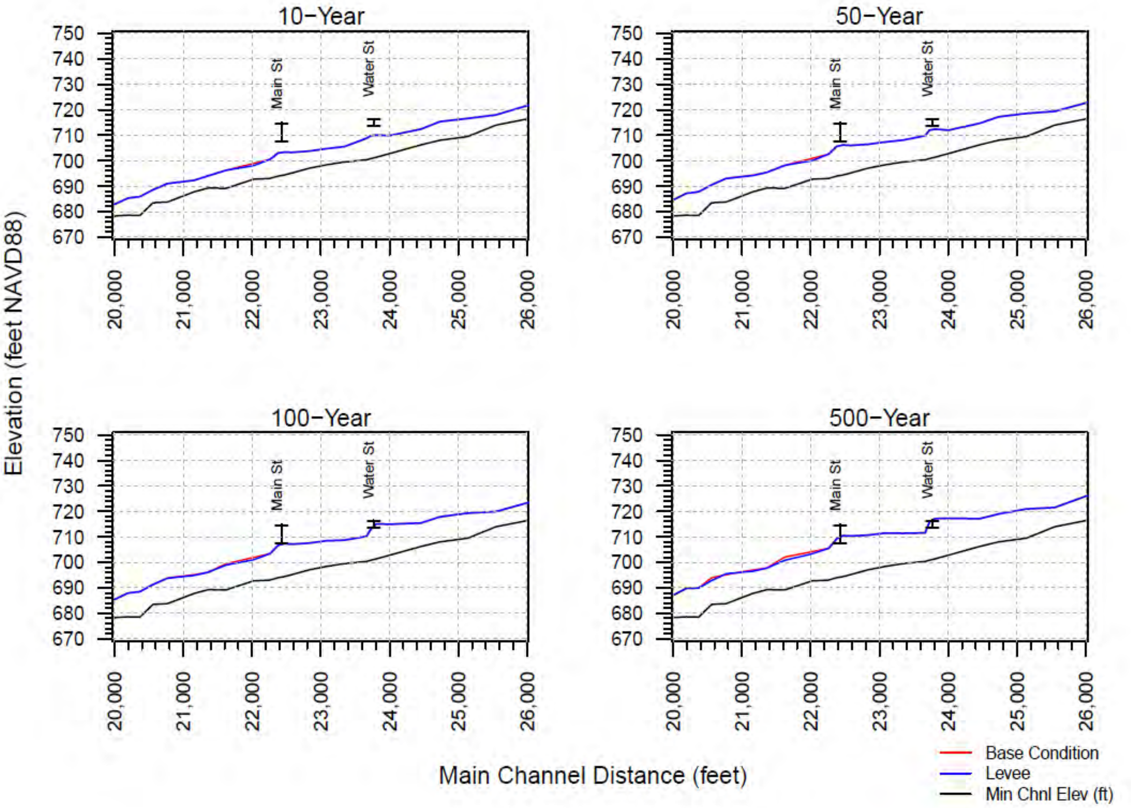


Figure 7-14. HEC-RAS model simulation output results for Alternative #2-2.

The proposed condition model simulation results indicated that water surface elevations for the levee adjacent to Hart Street would increase due to the greater volume of water being passed through the creek channel. Without the levee, a 1% annual chance flood event would overtop the channel banks downstream of the US-20 / Main Street bridge and near river station 220+50 inundating the Hart Street neighborhood, impacting numerous buildings and properties.

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 neighborhood. The potential benefits of this alternative are immediately upstream and in the vicinity of the levees at river stations 205+50 to 220+50.

Additional hydrologic and hydraulic modeling, coupled with an engineering review, would be necessary to determine the full scale, design criteria, and costs associated with a large-scale levee system throughout the Village that complies with FEMA flood plain management criteria. In addition, the levee would not remove areas from the FEMA mapped floodplain, but 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 $2.1 million, which does not include annual maintenance or land acquisition costs for survey, appraisal, and engineering coordination.

7.2.3 Alternative #2-3: Remove Central Pier from Water Street Bridge Crossing

This measure is intended to increase the cross-sectional flow area of the channel and remove any potential impediments or catch points for sediment and debris by removing the central pier of the Water Street bridge located at river station 239+00 (Figure 7-15).

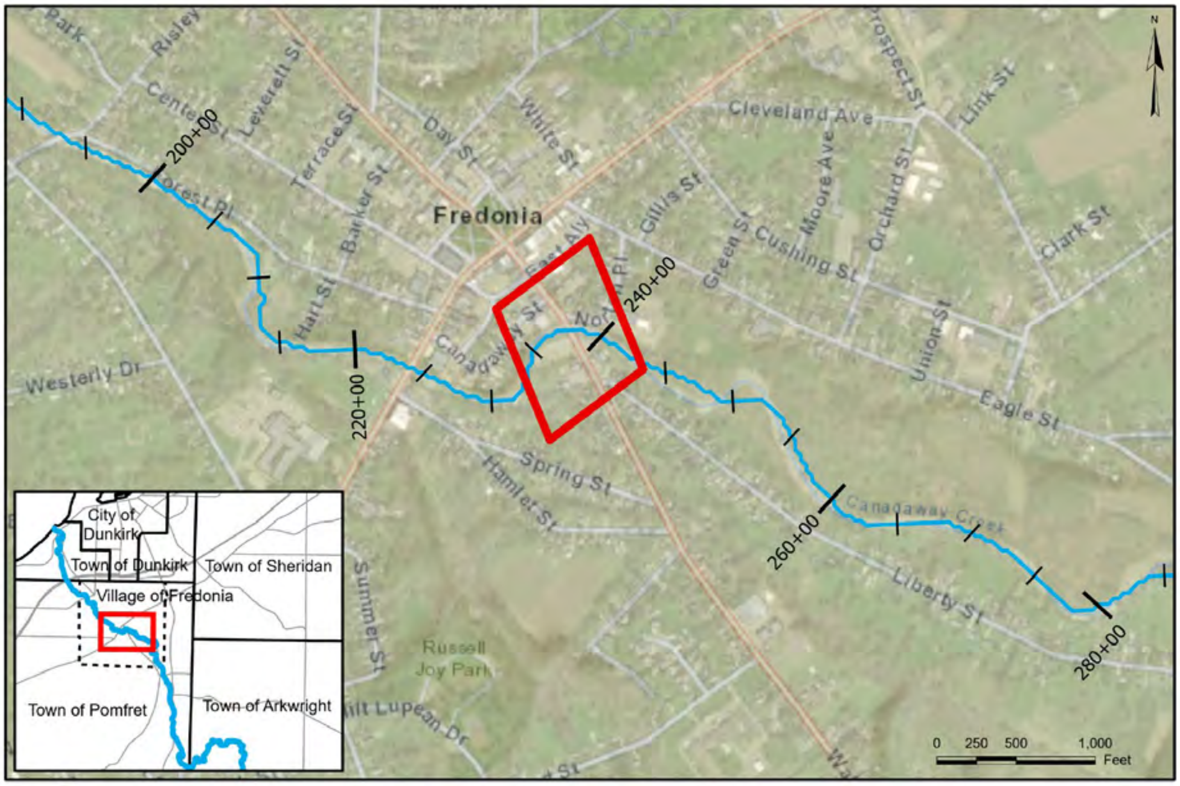


Figure 7-15. Location map for Alternative #2-3.

The existing bridge structure has an opening of 77 ft, a width of 44.5 ft, and a maximum height from low chord to bottom of channel of 15.2 ft. The Water Street bridge is owned and maintained by Chautauqua County, NY (Figure 7-16).

Figure 7-16. Water Street bridge, Fredonia, NY.

According to the FEMA FIS for the Village of Fredonia effective 1989, the Water Street bridge is able to sufficiently pass the 1% annual chance event WSELs and provides the NYSDOT recommended 2-ft of freeboard over the 2% annual chance flood water surface elevation. However, the flood elevations and profiles provided by FEMA are only valid if the Water Street bridge remains unobstructed, operates properly, and does not fail. When the Water Street bridge opening is obstructed with debris, the FEMA FIS profiles indicate that the 1 and 0.2% annual chance event WSELs overtop the high chord of the bridge (FEMA 1989b). According to historical flood reports, stakeholder engagement meetings, and field work, the Water Street bridge was identified as a hydraulic structure that experiences debris blockage and ice jams resulting in backwater flooding during higher peak flow events (FEMA 1989b; NYSDEC 2020b). For this alternative, open-water, debris obstruction, and ice-jam simulations were performed to test the effectiveness of the alternative at reducing water surface elevations. Table 15 outlines the results of the existing conditions model simulations for each initial condition scenario. Figures 7-17 through 7-19 display the profile plots for each initial condition scenario for the pier removal alternative.

Table 15. Summary Table for Alternative #2-3 Existing Conditions Results Based on Open-water, Debris Obstruction, and Ice-jam Conditions.

Initial Condition	Reduction in Water Surface Elevations from Base Initial Condition
Open-Water	Up to 0.4-ft
Debris Obstruction	Up to 0.3-ft
Ice Jam	Up to 0.4-ft

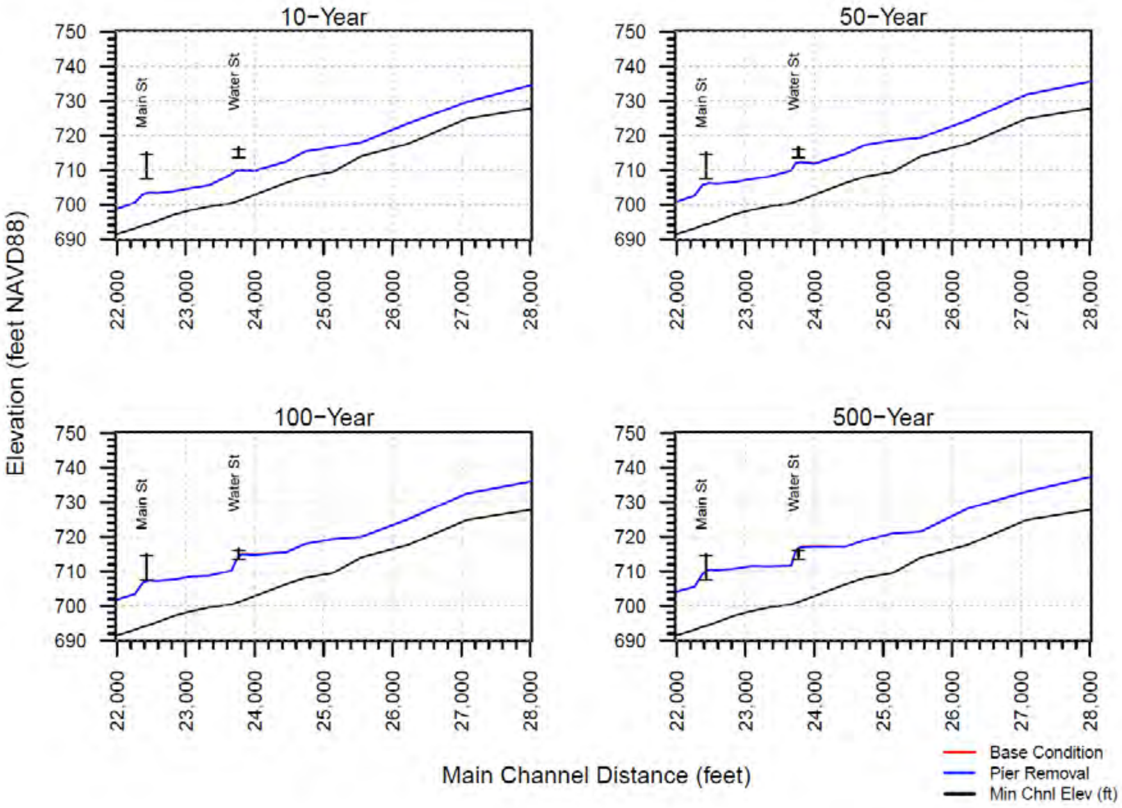


Figure 7-17. HEC-RAS open-water model simulation output results for Alternative #2-3.

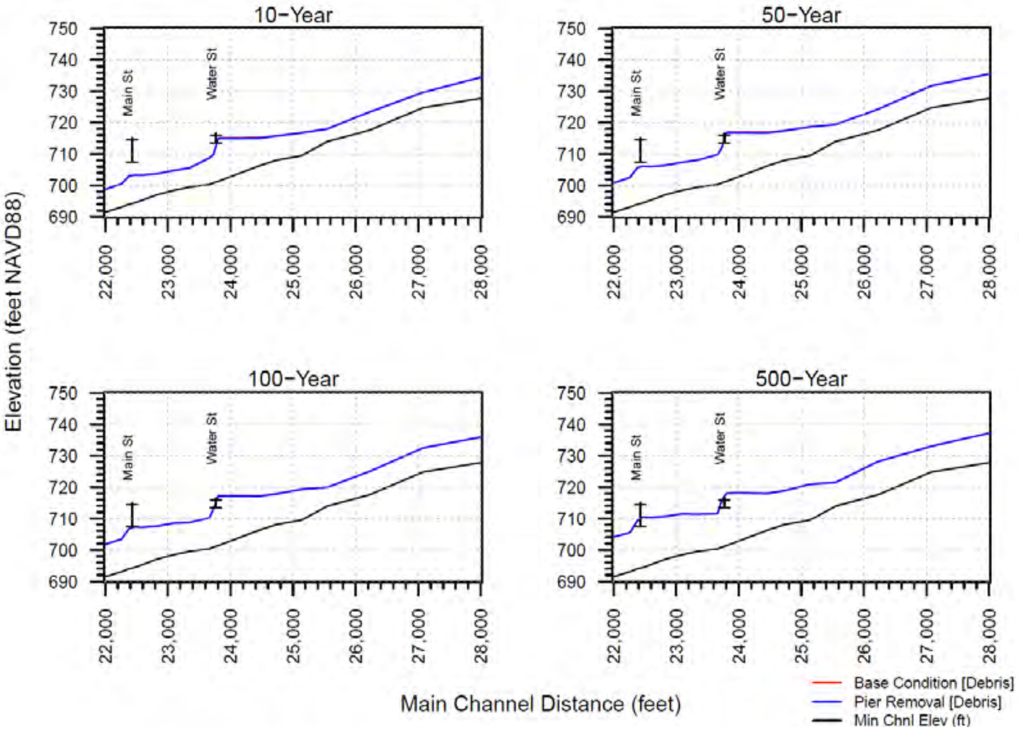


Figure 7-18. HEC-RAS debris obstruction model simulation output results for Alternative #2-3.

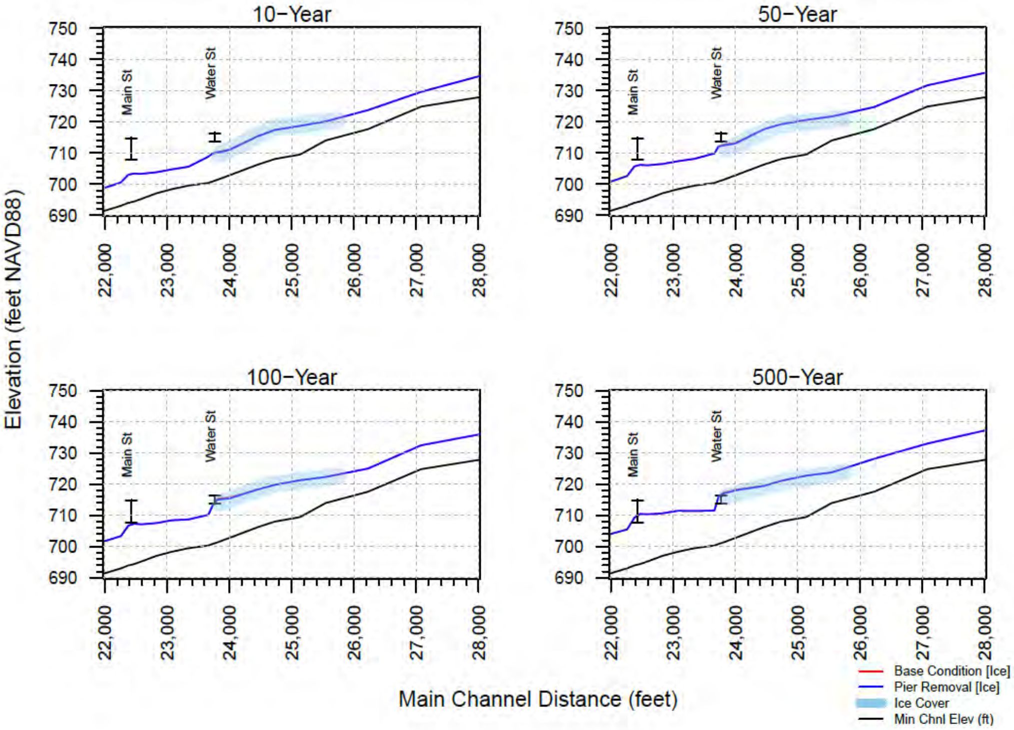


Figure 7-19. HEC-RAS ice cover model simulation output results for Alternative #2-3.

Table 16 outlines the results of the future conditions model simulations for each initial condition scenario.

Table 16. Summary Table for Alternative #2-4 Future Conditions Results Based on Open-water, Debris Obstruction, and Ice-jam Conditions.

Initial Condition	Reduction in Water Surface Elevations from Base Initial Condition
Open-Water	Up to 0.6-ft
Debris Obstruction	Up to 0.4-ft
Ice Jam	Up to 0.4-ft

The potential benefits of this strategy are limited to immediately upstream of the Water Street bridge. The primary benefit of removing the central pier would be to reduce the potential of debris and ice catching on the pier, and creating obstructions or jams upstream of the bridge.

The Rough Order Magnitude cost for this strategy is approximately $100,000, 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 of the roadway bridge would alter the structural integrity of the bridge in any way.

7.2.4 Alternative #2-4: Increase Opening Size of Water Street Bridge Crossing

This measure is intended to address issues within High-risk Area #2 by increasing the width of the Water Street bridge opening, which would increase the cross-sectional flow area of the channel located at river station 239+00 (Figure 7-20). The bridge is owned by Chautauqua County and has one central pier in the channel. The existing bridge structure has a bridge span of 77 ft, a width of 44.5 ft, and a maximum height from low chord to bottom of channel of 15.2 ft (Ramboll 2021). The flooding in the vicinity of the Water Street bridge poses a flood risk threat to nearby residential properties and City and County owned infrastructure. Appendix F depicts a flood mitigation rendering of a bridge widening scenario.

According to the FEMA FIS, there is backwater upstream of the Water Street bridge at the 1 and 0.2% annual chance event WSELs (the 2 and 10% were not included in the 1989 FIS profiles). The bridge widening design used for the proposed condition model simulation increased the width of the bridge opening from 77 ft to 92 ft by widening the left bank of the bridge by 15 ft and removing the central pier. This measure would potentially reduce the flood risk and benefit the properties adjacent to and immediately upstream of Water Street.

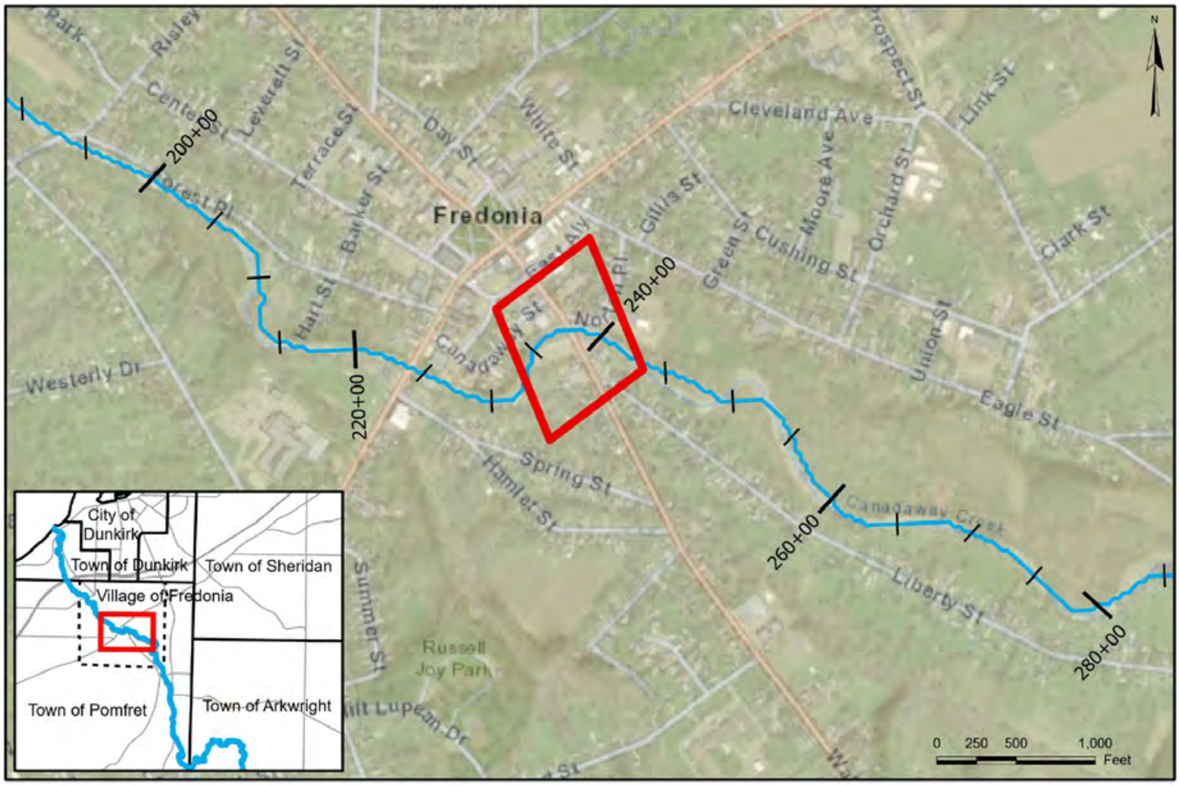


Figure 7-20. Location map for Alternative #2-4.

According to historical flood reports, stakeholder engagement meetings, and field work, the Water Street bridge was identified as a hydraulic structure that experiences debris blockage and ice jams resulting in backwater flooding during higher peak flow events (FEMA 1989b; NYSDEC 2020b). For this alternative, open-water, debris-obstruction, and ice-jam simulations were performed to test the effectiveness of the alternative at reducing water surface elevations. Table 17 outlines the results of the existing conditions model simulations for each initial condition scenario. Figures 7-21 through 7-23 display the profile plots for each initial condition scenario for the bridge widening alternative.

Table 17. Summary Table for Alternative #2-4 Existing Conditions Results Based on Open-water, Debris Obstruction, and Ice-jam Conditions

Initial Condition	Reduction in Water Surface Elevations from Base Initial Condition
Open-Water	Up to 2.3-ft
Debris Obstruction	Up to 3.5-ft
Ice Jam	Up to 1.3-ft

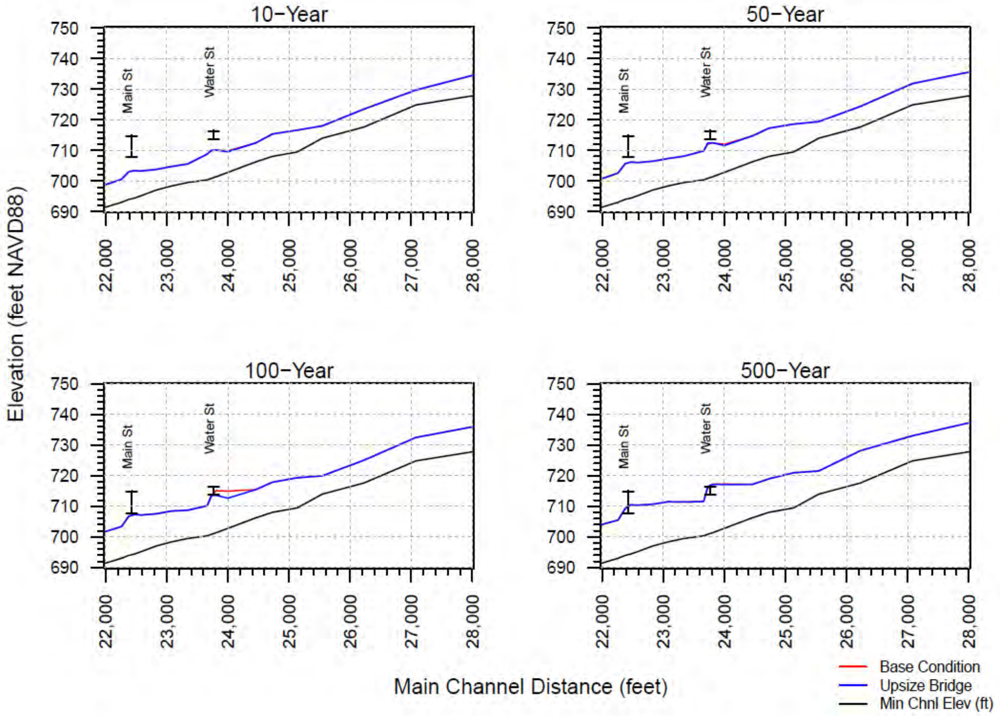


Figure 7-21. HEC-RAS open-water model simulation output results for Alternative #2-4.

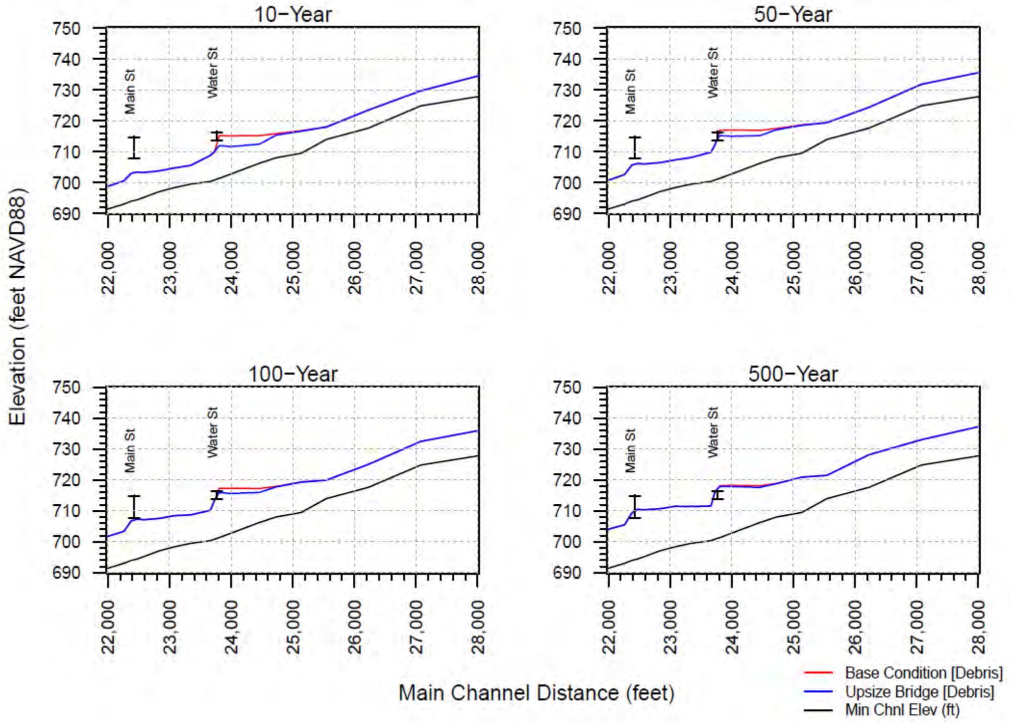


Figure 7-22. HEC-RAS debris obstruction model simulation output results for Alternative #2-4.

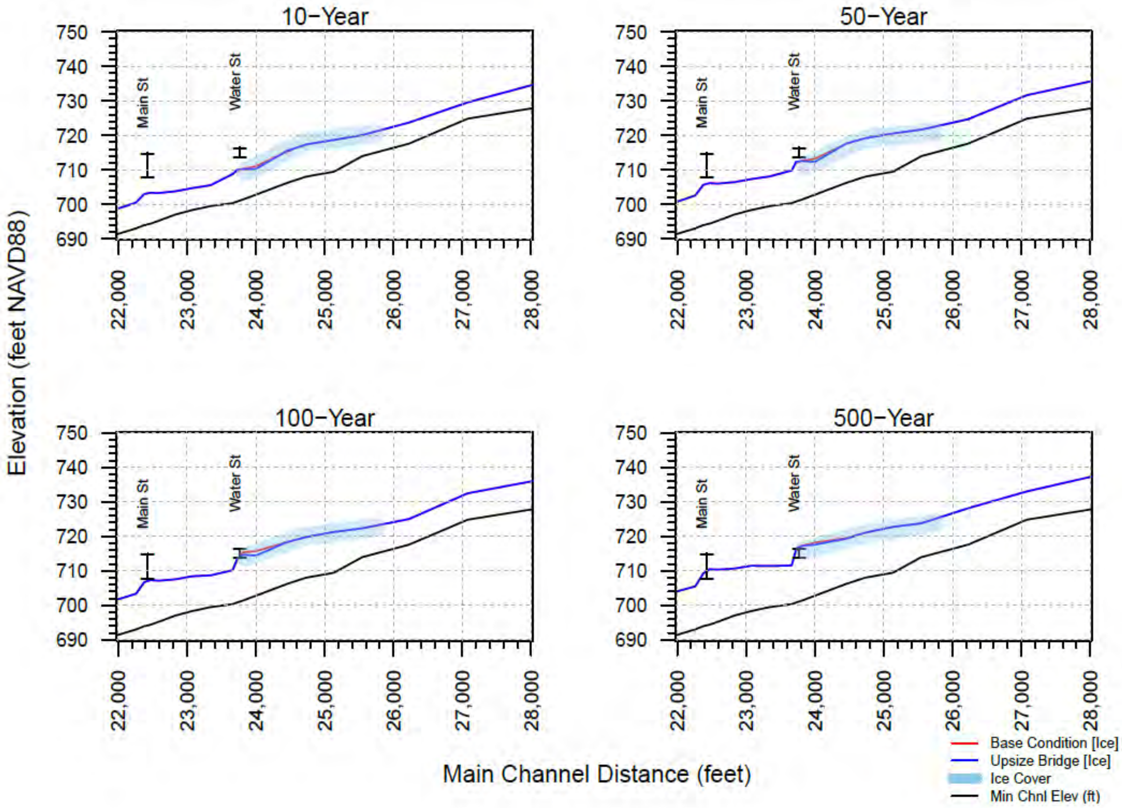


Figure 7-23. HEC-RAS ice cover model simulation output results for Alternative #2-4.

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

Table 18. Summary Table for Alternative #2-4 Future Conditions Results Based on Open-water, Debris Obstruction, and Ice-jam Conditions

Initial Condition	Reduction in Water Surface Elevations from Base Initial Condition
Open-Water	Up to 1.3-ft
Debris Obstruction	Up to 3.9-ft
Ice Jam	Up to 1.6-ft

The potential benefits of this strategy are limited to areas approximately 1,000-ft upstream of the Water Street bridge, specifically along river stations 238+00 to 248+00. The primary benefit of widening the bridge opening would be to increase the cross-sectional flow area of the bridge, which would allow a higher volume of water to flow underneath the bridge without overtopping the banks and causing flooding. Increasing the size of the Water Street bridge would reduce potential flood risk under each modeled initial condition (open-water, debris obstruction, and ice jams) for both existing and future conditions.

The Rough Order Magnitude cost for this strategy is approximately $2.7 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

7.2.5 Alternative #2-5: Flood Benches Adjacent to the Liberty Street Neighborhood

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. Three potential flood benches were modeled in the vicinity of Liberty Street upstream of the Water Street bridge in the Village of Fredonia: Flood Bench A located between river stations 244+50 and 252+00 on the right bank, which is approximately 2.3 acres; Flood Bench B located between river stations 247+00 and 256+00 on the left bank which is approximately 2.1 acres; and Flood Bench C located between river stations 280+00 and 292+50 on the left bank, which is approximately 3.8 acres (Figure 7-24). The flood bench designs used for the proposed condition model simulation set the minimum bench elevation approximately equal to the bankfull elevation at each cross section, which was an average depth of 3 ft.

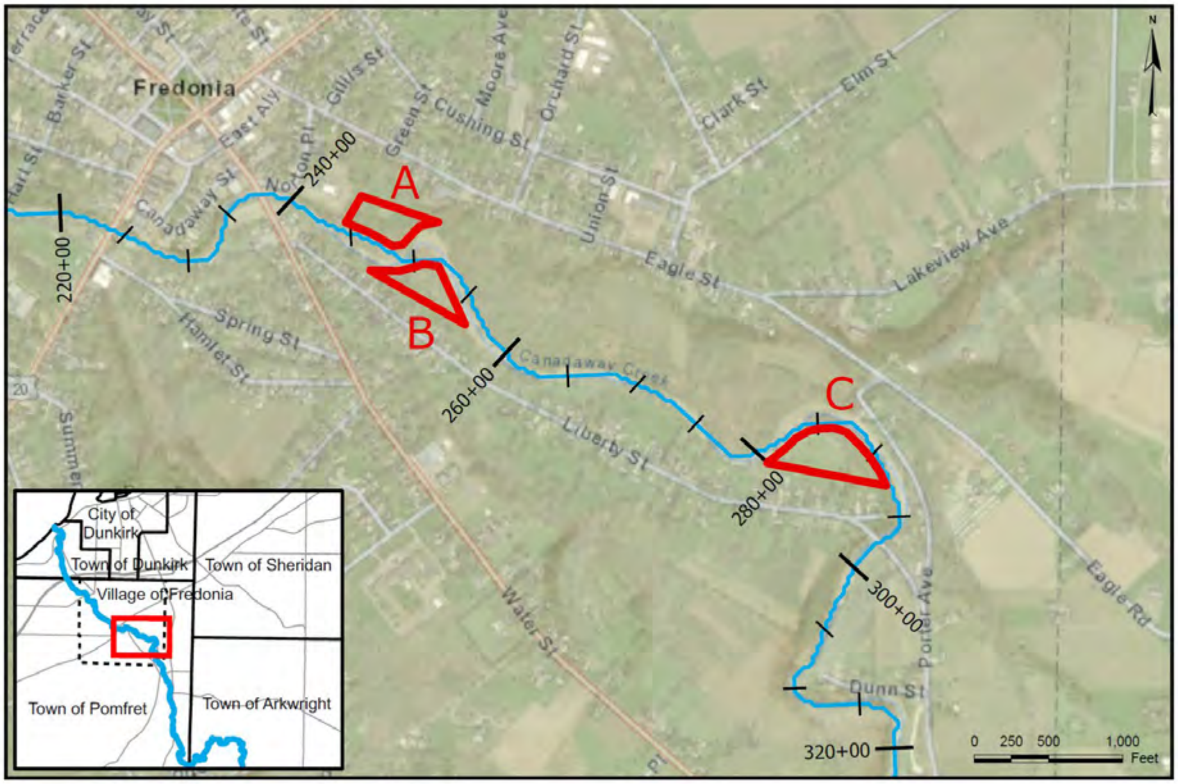


Figure 7-24. Location map for Alternative #2-5.

The flood benches are within the FEMA designated SFHA or Zone A, which are areas subject to inundation by the 1% annual chance flood event, but where base flood elevations and flood hazard factors were not determined, and where mandatory flood insurance purchase requirements and floodplain management standards apply (FIA

1980; FEMA 1982). Appendix F depicts a flood mitigation rendering of a flood bench illustrating before and after landscape features.

According to historical flood reports, stakeholder engagement meetings, and field work, the Water Street bridge was identified as a hydraulic structure that experiences debris blockage and ice jams resulting in backwater flooding during higher peak flow events (FEMA 1989b; NYSDEC 2020b). For this alternative, open-water and ice-jam simulations were performed to test the effectiveness of the alternative at reducing water surface elevations. Table 19 outlines the results of the existing conditions model simulations for each initial condition scenario (Appendix H). Figures 7-25 and 7-27 display the profile plots for each initial condition scenario for the flood bench alternatives.

Table 19. Summary Table for Alternative #2-5 Existing Conditions Results Based on Open-water, Debris Obstruction, and Ice-jam Conditions

Initial Condition	Reduction in Water Surface Elevations from Base Initial Condition		
	Flood Bench A	**Flood Bench B**	**Flood Bench C**
Open-Water	Up to 2.7-ft	Up to 0.7-ft	Up to 3.5-ft
Debris Obstruction	Up to 2.7-ft	Up to 0.7-ft	N/A
Ice Jam	Up to 2.3-ft	Up to 1.3-ft	N/A

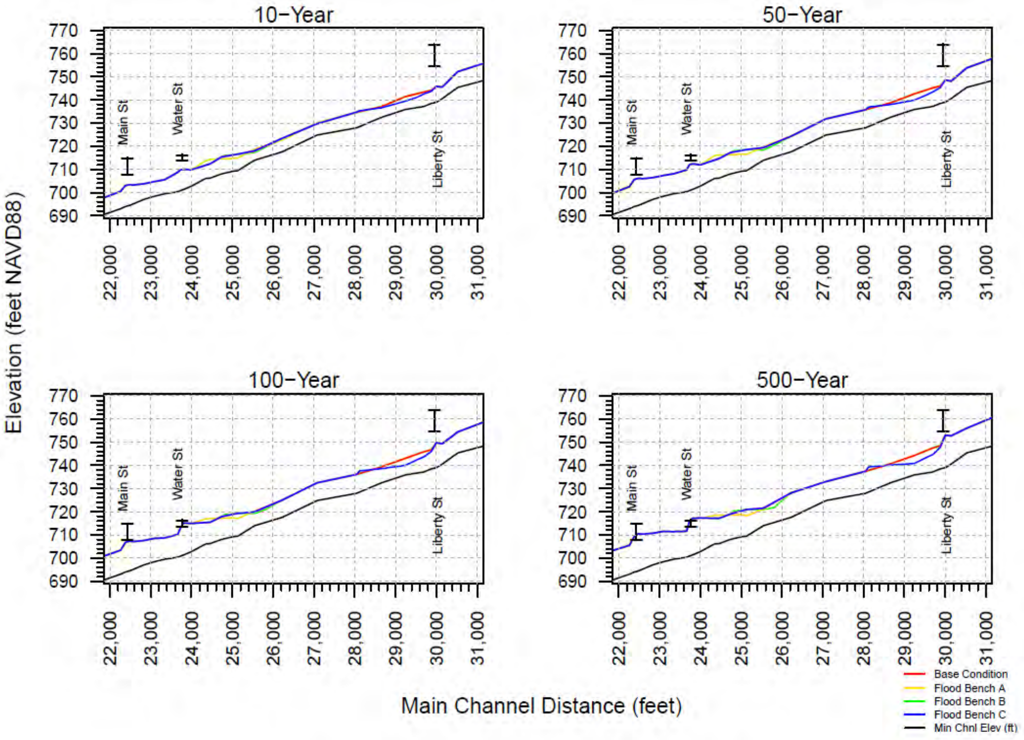


Figure 7-25. HEC-RAS open-water model simulation output results for Alternative #2-5.

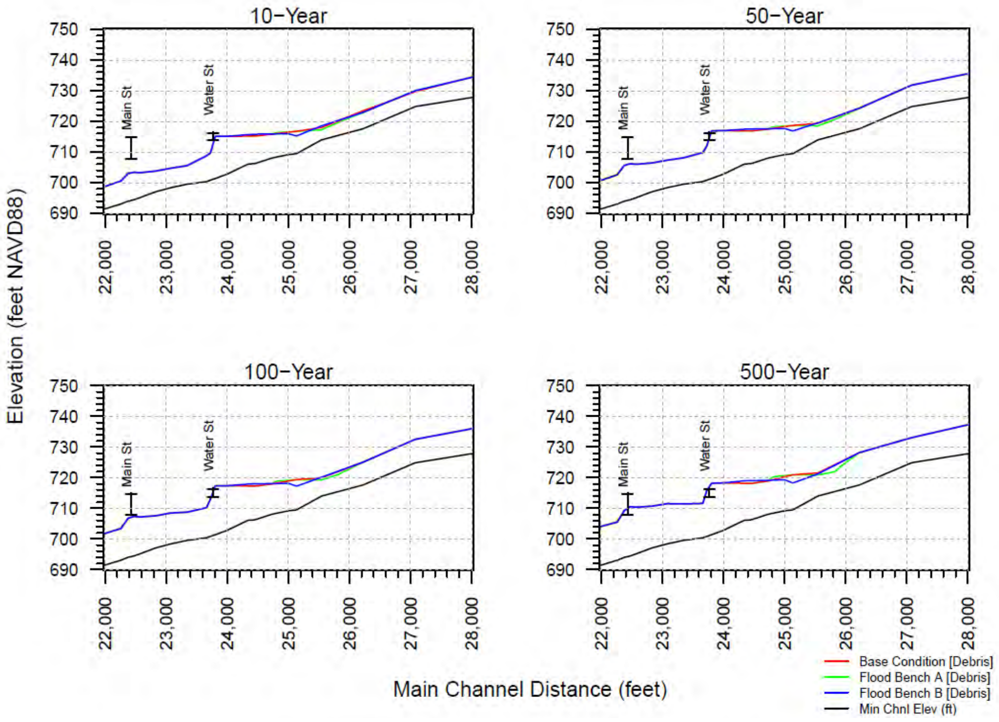


Figure 7-26. HEC-RAS debris obstruction model simulation output results for Alternative #2-5.

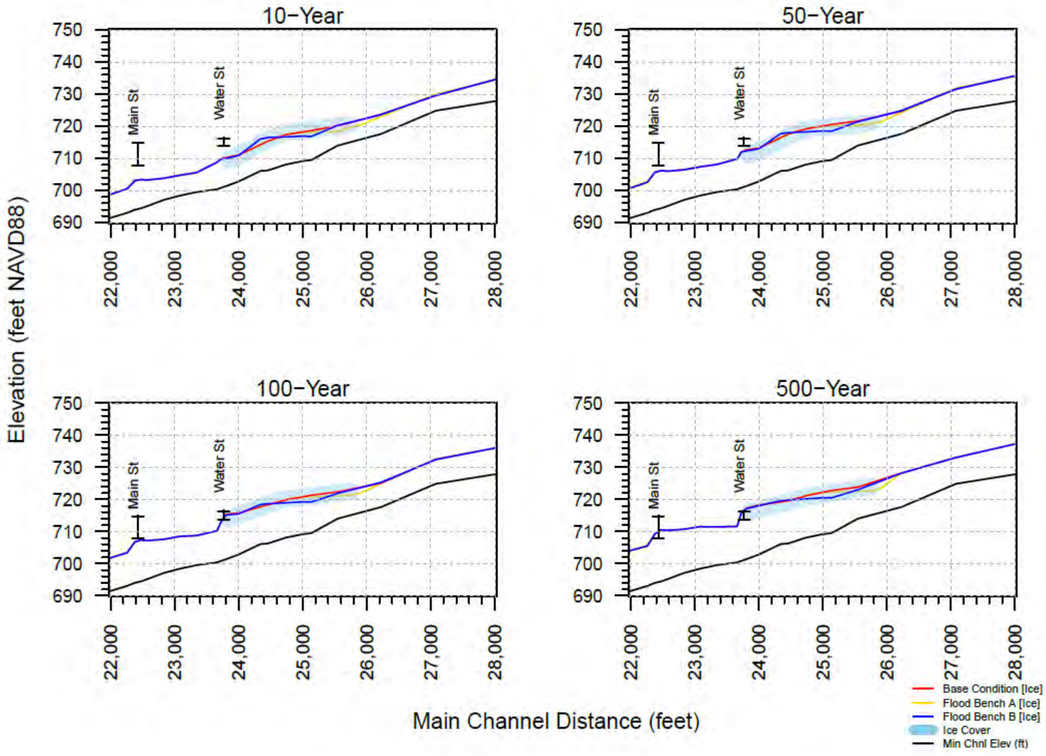


Figure 7-27. HEC-RAS ice cover model simulation output results for Alternative #2-5.

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

Table 20. Summary Table for Alternative #2-5 Future Conditions Results Based on Open-water, Debris Obstruction, and Ice-jam Conditions

Initial Condition	Reduction in Water Surface Elevations from Base Initial Condition		
	Flood Bench A	Flood Bench B	Flood Bench C
Open-Water	Up to 3.1-ft	Up to 2.7-ft	Up to 3.3-ft
Debris Obstruction	Up to 2.9-ft	Up to 2.8-ft	N/A
Ice Jam	Up to 2.3-ft	Up to 2.8-ft	N/A

Flood Bench A water surface reductions extended approximately 1,550-ft upstream of the Water Street bridge, specifically along river stations 247+00 to 262+50. Flood Bench B water surface reductions extended approximately 1,100-ft upstream of the Water Street bridge, specifically along river stations 251+50 to 262+50. Flood Bench C water surface reductions extended approximately 1,250-ft downstream of the Liberty Street bridge, specifically along river stations 286+50 to 299+00.

Flood benches generally provide flood protection for localized areas in the vicinity of and immediately upstream and / or downstream of the bench. Based on the analysis of high-risk areas, a flood bench located adjacent to the Liberty Street neighborhood would provide flood protection in this reach to adjacent properties and infrastructure, but they would not reduce the flood risk for the Water Street bridge due to the distance downstream to the bridge and the limited impact of the flood benches.

The Rough Order Magnitude cost for this measure is $710,000 for Flood Bench A, $630,000 for Flood Bench B, and $1.1 million for Flood Bench C, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

7.2.6 Alternative #2-6: Flood Control Dam / Reservoir in the Village of Fredonia

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 Water Street and Liberty Street would be the best location for a flood-control structure in the Village of Fredonia (Figure 7-28).

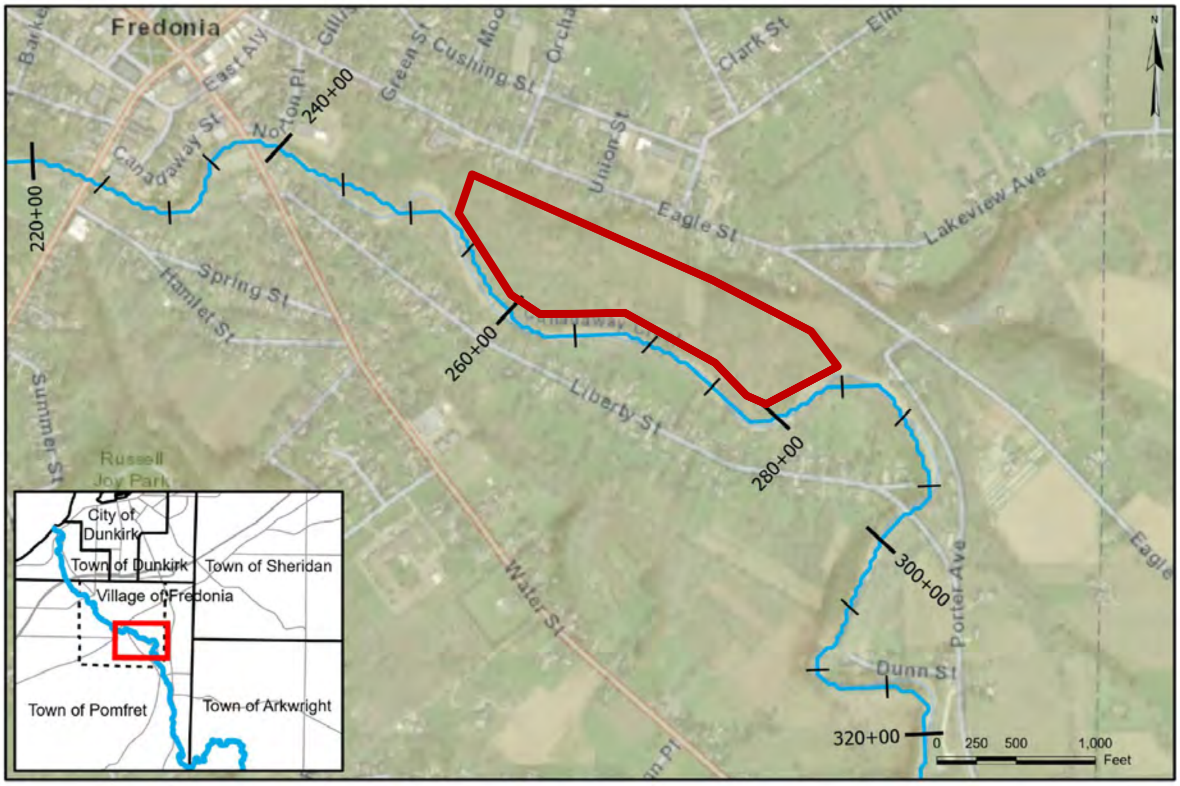


Figure 7-28. Location map for Alternative #2-6.

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 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.

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 Canadaway Creek watershed are expected to be significant.

7.2.7 Alternative #2-7: Streambank Stabilization Adjacent to Liberty Street and Porter Avenue

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 (GASWCC 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 (GASWCC 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 (GASWCC 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 Canadaway Creek in the Village of Fredonia have been identified as areas for potential streambank stabilization strategies. These areas have been outlined in Figure 7-29.

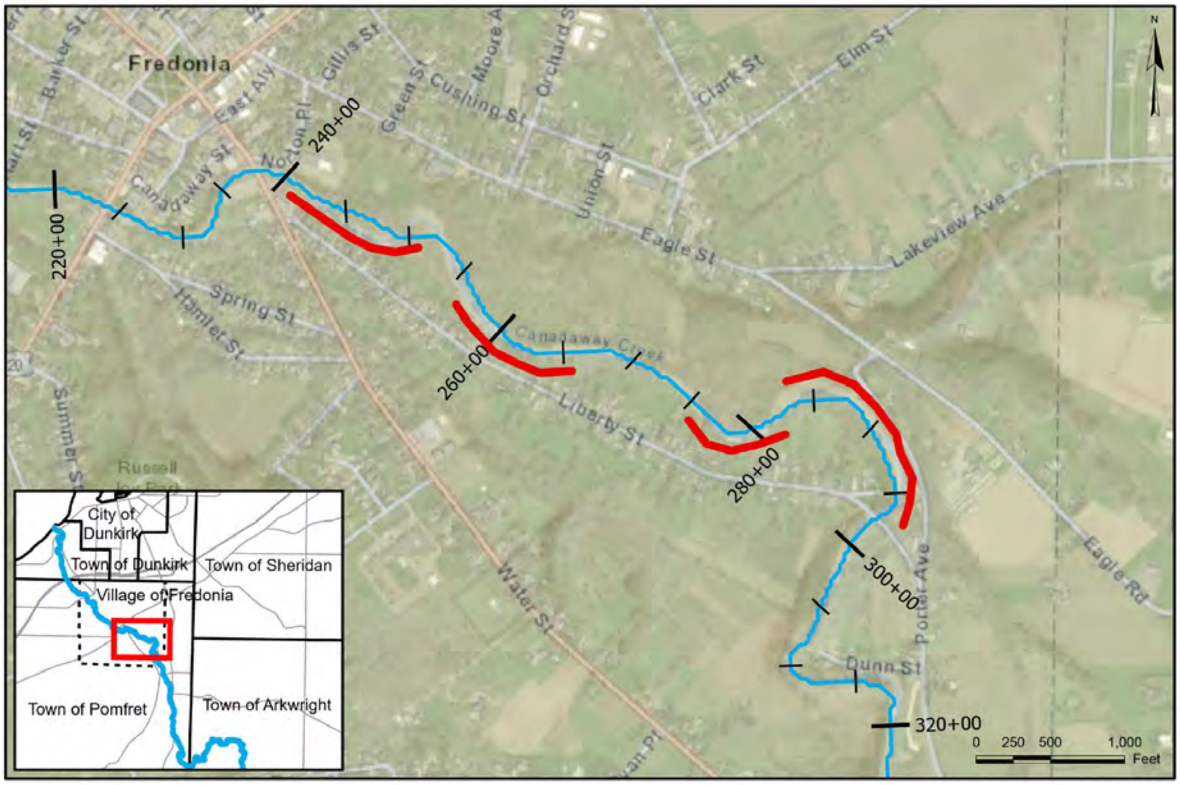


Figure 7-29. Location map for Alternative #2-7.

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

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: Streambank Stabilization Adjacent to Dunn Street and Porter 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 (GASWCC 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 (GASWCC 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 (GASWCC 2000; NRC 2013).

Through historical flood reports, stakeholder engagement meetings, and / or field work, numerous areas along Canadaway Creek in the Village of Fredonia and Town of Pomfret have been identified as areas for potential streambank stabilization strategies. These areas have been outlined in Figure 7-30.

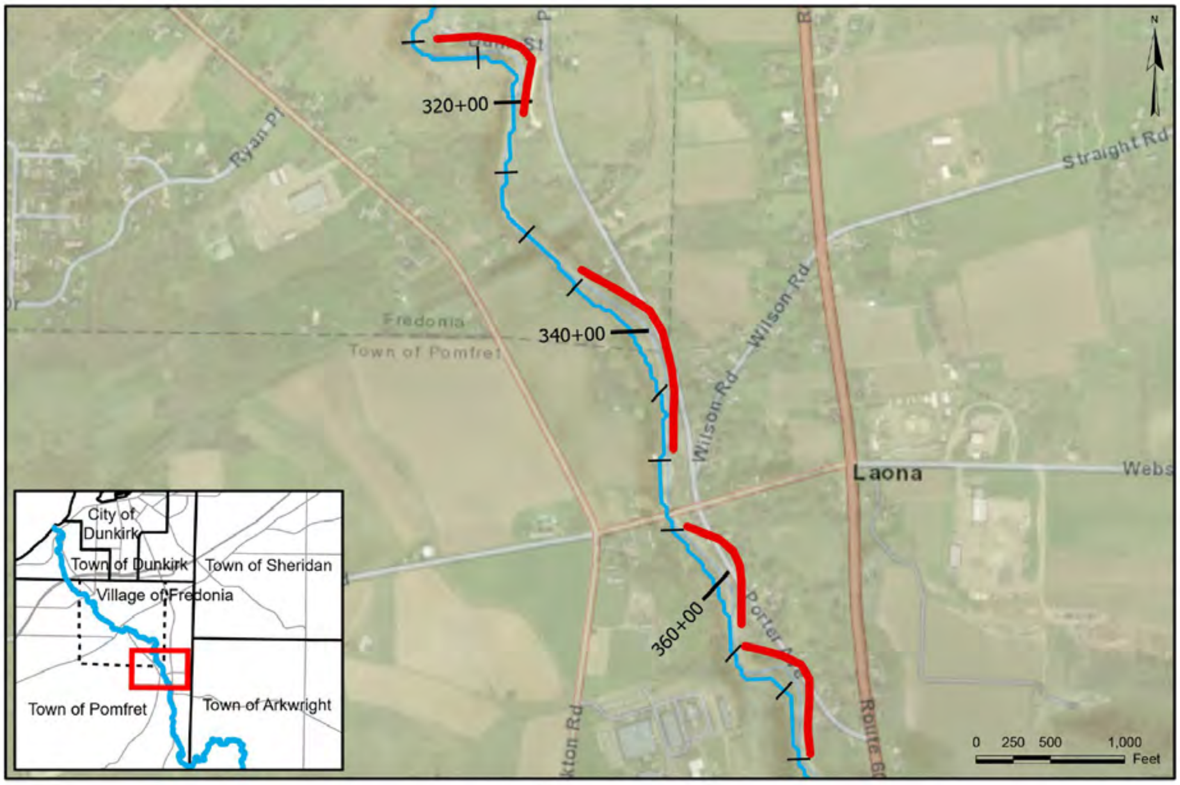


Figure 7-30. Location map for Alternative #3-1.

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

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.

7.3.2 Alternative #3-2: Sediment / Debris Retention Pond in the Village of Fredonia

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 7-31).

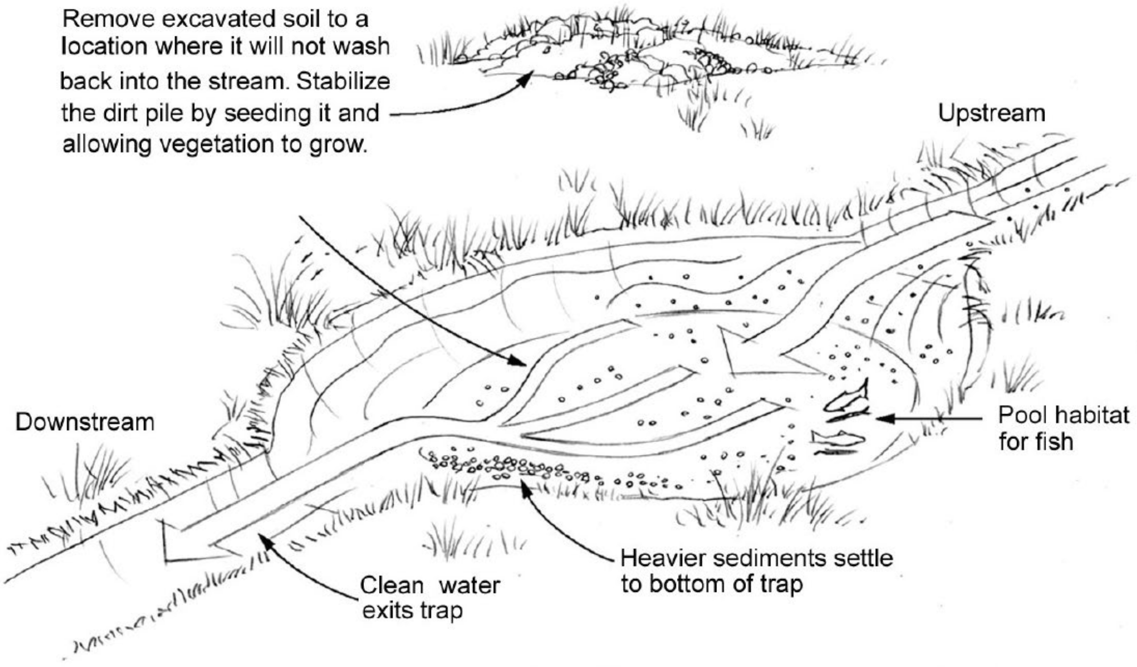


Figure 7-31. Representative diagram of an in-stream sediment retention pond (WCD 2009).

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 Canadaway Creek watershed, the areas identified in Figure 7-32 in the Village of Fredonia could be potential locations for a sediment retention basin.

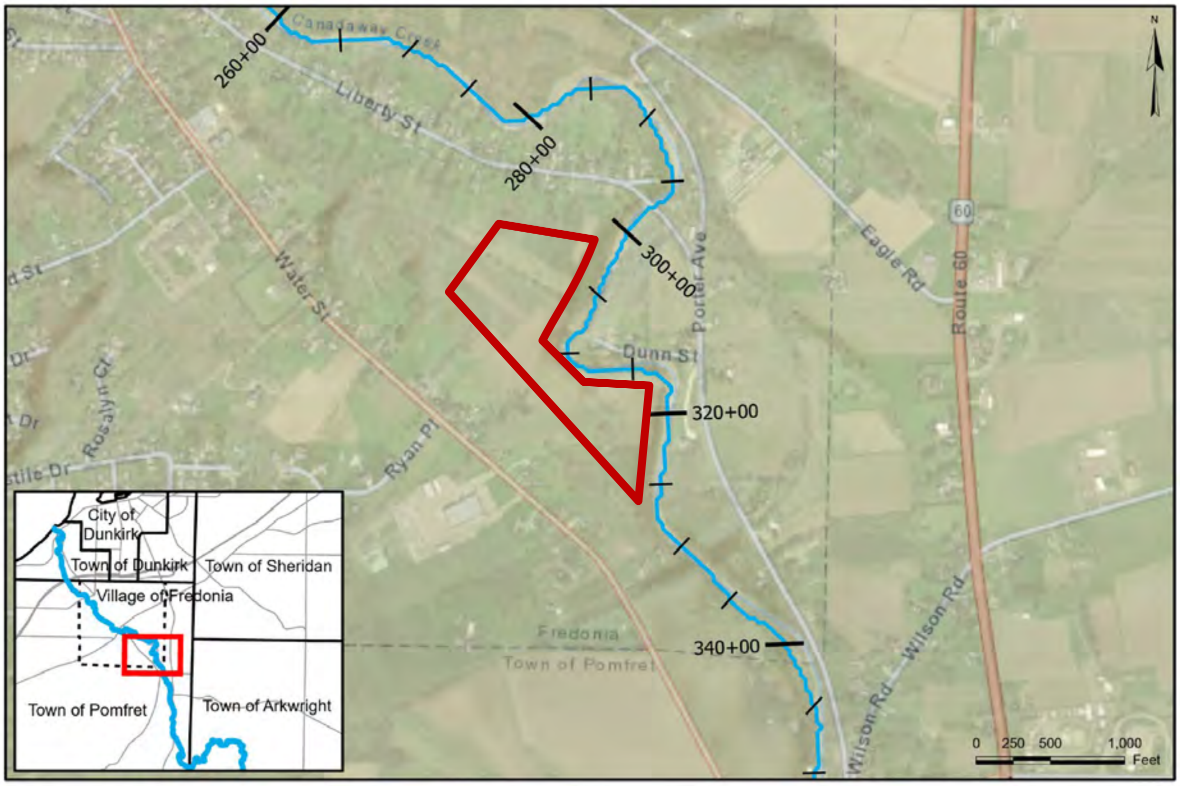


Figure 7-32. Location map for Alternative #3-2.

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).

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

This method can also be supplemented by an ice-jam predicting calculation procedure using the freezing degree-day (FDD) method to forecast the ice thickness at critical locations to inform early action to control ice (Shen and Yapa 2011). The method involves a small computer tool that goes through all the ice calculations and gives the output in a graphical format of the predicted ice thickness with time. This can be quickly implemented and can be a very good solution due to its low cost, and low labor and maintenance requirements. The method needs only the forecasted air temperature and current water level at the critical location. During severe winter conditions, the ice thickness prediction can be used to prepare ice, and plan regarding resources needed for the upcoming ice jam and consequential flooding. And 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 Canadaway Creek watershed. Restoration, which is defined as the process of re-establishing historical ecosystem structures and processes, is being used more often to mitigate some of the past degradation of these ecosystems (Goodwin et al. 1997).

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 Canadaway 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 BRIDGES / CULVERTS

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 Canadaway Creek (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 Canadaway 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 and any long-term effects to fish populations should be considered (NRCS 2002).

Consultation with the NYSDEC can help determine if, when and how sediment and debris should be managed and whether a permit will be required. Any sediment and / or large debris removal should be limited to the mouths of bridges and culverts to minimize the impact on fish and aquatic habitats.

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 2009).

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 2009).

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 2009):

- 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 2009). 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 2009).

8.5 ALTERNATIVE #4-5: ICE MANAGEMENT

This strategy is intended to control ice-jam formation by maintaining ice coverage in high-risk sections of Canadaway Creek. Ice management strategies include various methods of preventing ice jams by breaking ice using various ice cutting patterns and techniques, as well as various equipment and personnel. Suggested locations for ice cutting operations would be provided based on anticipated effectiveness, site accessibility, and historical occurrences of ice jams. Criteria and scheduling would be provided by county and / or state agencies and determined based on environmental conditions (e.g. temperature, ice thickness, weather forecast) (USACE 2016b).

Possible ice management strategies would include:

- Ice cutting – cut ice free from banks or cross-cut ice to hasten the release of ice in order to prevent ice-jam formations
- Trenchers and special design trenching equipment – used to dig ditches customarily, but can be used to cut ice to hasten release downstream
- Channeling plow – plow mounted to a sledge drawn by a tractor that breaks and clears ice from channel
- Water jet and thermal cutting – supersonic water streams and thermal cutting tools to separate ice and move it downstream
- Hole cutting – drill large holes into the ice to reduce the integrity of the ice cover and curtail ice formation
- Ice breakers – ships, hovercrafts, amphibious hydraulic excavators, construction equipment, and blasting techniques designed to breakup ice and move ice downstream
- Air bubbler and flow systems – release air bubbles and warm water from the water bottom to suppress ice growth (USACE 2006)

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

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

The Rough Order Magnitude cost for this measure is $40,000, not including annual maintenance and operational costs.

8.6 ALTERNATIVE #4-6: FLOOD BUYOUTS / PROPERTY ACQUISITION

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 Canadaway Creek watershed, there are approximately 369 parcels within the FEMA Zone A (1% annual chance event / 100-yr) flood hazard area. Of the 369 parcels, 212 parcels are classified as residential, while 15 parcels are classified as commercial. These parcels have a combined full market value of $63.8 million with residential and commercial parcels accounting for $29.7 million and $4.5 million, respectively. Table 21 summarizes the number of parcels and their full market value within the three high-risk flood areas (NYSGPO 2021).

Table 21. Summary Table for Tax Parcels within FEMA Flood Zones in High-risk Areas along Canadaway Creek

Source: NYSGPO 2021

High-risk Flood Area	Number of Parcels	Full Market Value
#1: Railroad Bridges Upstream to West Willow Road Bridge	47	$6.8 million
#2: Hart Street Upstream to Water Street Bridge	115	$21.6 million
#3: Areas Adjacent to Porter Avenue / Road	35	$15.8 million
Total	**197**	**$44.2 million**

According to FEMA severe repetitive loss and repetitive loss data, there are 10 properties identified as repetitive loss and one severe repetitive loss properties within the Canadaway Creek watershed, all of which are located in the Village of Fredonia (FEMA 2019). Figure 8-1 displays the tax parcels that intersect the FEMA flood zones, including generalized locations of FEMA repetitive and severe repetitive loss properties. 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 ten-year 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 ten-year period, since 1978 (FEMA 2019; FEMA 2020).

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 Canadaway Creek in the highest-risk flood areas and progresses outwards from there to maximize flood damage reductions. In addition, structures located adjacent to flood prone infrastructure (i.e. bridges, culverts, etc.) should also be considered high-risk and prioritized in any buyout program strategy. A potential negative consequence of buyout programs is the permanent removal of properties from the floodplain, and resulting tax revenue, which would have long-term implications for local governments, and should be considered prior to implementing a buyout program.

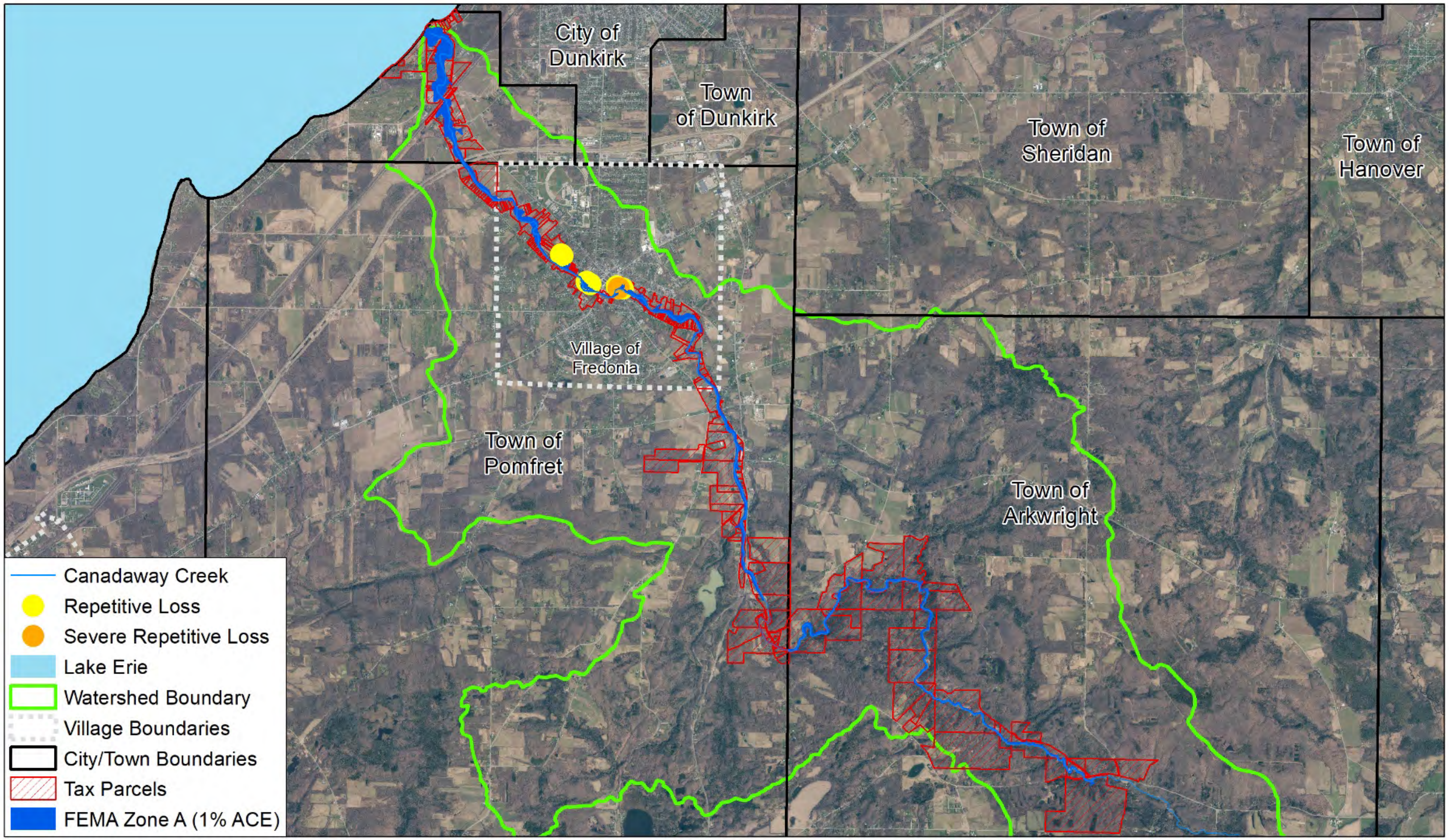


FIGURE 8-1

TAX PARCELS
CANADAWAY CREEK, DUNKIRK, POMFRET, & ARKWRIGHT, CHAUTAUQUA COUNTY, NY

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

Figure 8-1. Tax parcels within FEMA flood zones, Canadaway Creek, Town of Dunkirk and Village of Fredonia, Chautauqua County, NY.

8.7 ALTERNATIVE #4-7: 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 perform 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 1-ft above the BFE (FEMA 2013).

Examples include:

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

Wet floodproofing

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

8.8 ALTERNATIVE #4-8: AREA PRESERVATION / FLOODPLAIN ORDINANCES

This alternative proposes municipalities within the Canadaway 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 Canadaway Creek watershed.

8.9 ALTERNATIVE #4-9: COMMUNITY FLOOD AWARENESS AND PREPARDNESS 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).

8.10 ALTERNATIVE #4-10: 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 relating to the 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 Canadaway 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 access the wintery condition with the suggested alternatives to evaluate the water level rises due to presence of ice, ice-jam or break-up ice jam conditions.

9.2 STATE / FEDERAL WETLANDS INVESTIGATION

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

9.3 NYSDEC PROTECTION OF WATERS PROGRAM

Canadaway Creek is protected under Article 15 of Title 6 of the New York Codes, Rules, and Regulations (6NYCRR Part 608). Canadaway Creek has a designation as classification B (TS), which indicates the waterway is best used for swimming and other contact recreation, but not for drinking water and has the potential to support trout populations and spawning. Any changes to the bed or bank of Canadaway Creek would need to be reviewed and approved by the NYSDEC (NYSDEC 2020c; NYSDEC 2021).

9.4 ICE EVALUATION

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

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

- Land cover
- Precipitation

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

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

9.5 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)
- Chautauqua County 2% Occupancy Tax Grant Program for Lakes and Waterways

9.5.1 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.

9.5.2 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.

9.5.3 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.

9.5.3.1 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.

9.5.3.2 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.

9.5.4 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 percent), and performing any necessary operation and maintenance for a ten-year period. Through EWP, the NRCS may pay up to 75 percent of the construction costs of emergency measures, with up to 90 percent 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.

9.5.5 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.

9.5.5.1 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 six percent 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.

9.5.5.2 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

9.5.6 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.

9.5.7 USACE Continuing Authorities Program (CAP)

The Corps' 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 22 lists the CAP authorities and their project purposes (USACE 2019a).

Table 22. 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 Corps 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).

9.5.8 Chautauqua County 2% Occupancy Tax Grant Program for Lakes and Waterways

Chautauqua County collects a 2% occupancy tax to collect revenue to fund projects in the county which provide water quality benefits. Grants are available in amounts ranging from $500 to $40,000. Grant funding has been used for roadway drainage, agriculture, stormwater, streambank, and lakeshore projects. An application for an erosion control project along Village Park in the village of Silver Creek is currently under review, with construction scheduled to begin in 2021 (Chautauqua County 2019).

10. SUMMARY

The Towns of Dunkirk and Pomfret, including the Village of Fredonia, have had a history of flooding events along Canadaway Creek. Flooding in the Town primarily occurs during the summer and winter months due to heavy rains by convective systems and ice jams caused by above freezing temperatures allowing ice breakups in waterways. In response to persistent flooding, the State of New York in conjunction with the Towns of Dunkirk and Pomfret, Village of Fredonia, and Chautauqua County, are studying and evaluating potential flood mitigation projects for Canadaway Creek as part of the Resilient NY Initiative.

This report analyzed the historical and present day causes of flooding in the Canadaway 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 Canadaway 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 along Canadaway Creek by combining the reduction potential of the mitigation measures being constructed.

Based on the flood mitigation analyses performed in this report, the mitigation measures that provided the greatest reductions in water surface elevations were increasing the size of the West Willow Road bridge and flood benches adjacent to the Liberty Street neighborhood. The West Willow Road mitigation alternative would potentially reduce flood risk in High-risk Area #1; however, the flood benches adjacent to the Liberty Street neighborhood would not provide flood risk benefits to the Water Street area of High-risk Area #2.

There would be an overall greater effect in water surface elevations if multiple alternatives were built along Canadaway Creek 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.

Based on the analysis of the bridge widening simulations, the West Willow Road and Water Street bridge crossings would benefit from increased bridge openings. However, structural upsizing measures generally are costly flood mitigation measures. The benefits of these measures in their respective reaches should be balanced with the associated costs of each upsizing measure to determine if it would be feasible to move an upsizing measure forward. In addition, other complications, such as traffic re-routing, should be taken into account when considering any of the structural upsizing measures.

The flood bench measures discussed for Canadaway Creek would provide moderate 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 Fredonia, 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 #2. In addition, flood bench measures generally tend to be the costliest of flood mitigation projects when compared to other measures discussed in this report. The benefits of these measures in their respective reaches should be balanced with the associated costs of each flood bench measure to determine if it would be feasible to move a flood bench project forward.

The debris maintenance around waterway crossing infrastructure, riparian restoration, and retention basin and wetland management measures would maintain the flow channel area in Canadaway 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.

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

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 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 23 is a summary of the proposed flood mitigation measures, including benefits related to the mitigation alternative, and estimated ROM costs.

Table 23. Summary of Flood Mitigation Measures

Alternative No.	Description	Benefits Related to Alternative	ROM cost ($U.S. dollars)
1-1	Remove Central Pier from CSX Railroad Bridge Crossing	Model simulated WSEL reductions of up to 2.5-ft	$110,000 [i]
1-2	Install Crossing Pipe into Railroad Embankments	Model simulated WSEL reductions of up to 1.8-ft	$1.1 million [ii]
1-3	Flood Benches in the Vicinity of the Railroad Crossings	Model simulated WSEL reductions of up to 2.5-ft (Downstream Bench only)	$1.4 million [iii] (Downstream Bench only)
1-4	Increase Size of West Willow Road Bridge	Model simulated WSEL reductions of up to 4.1-ft	$1.8 million [iii]
2-1	Flood Bench Adjacent to Hart Street Neighborhood	Model simulated WSEL reductions of up to 2.5-ft	$680,000 [iii]
2-2	Levee Adjacent to Hart Street Neighborhood	No model simulated upstream or downstream effects	$2.1 million [iv]
2-3	Remove Central Pier from Water Street Bridge Crossing	Model simulated WSEL reductions of up to 0.4-ft	$100,000 [v]
2-4	Increase Opening Size of Water Street Bridge Crossing	Model simulated WSEL reductions of up to 2.3-ft	$2.7 million [iii]
2-5	Flood Benches Adjacent to the Liberty Street Neighborhood	Model simulated WSEL reductions of up to 2.7-ft (Bench A), 0.7-ft (Bench B), and 3.5-ft (Bench C)	Flood Bench A: $710,000 Flood Bench B: $630,000 Flood Bench C: $1.1 million [iii]
2-6	Flood Control Dam / Reservoir in the Village of Fredonia	Limits flood extents and depths downstream and helps with sediment transport	N/A [vi]
2-7	Streambank Stabilization Adjacent to Liberty Street and Porter Avenue	Reduce force of flowing water and / or increase resistance of the bank to erosion	N/A [vii]

Alternative No.	Description	Benefits Related to Alternative	ROM cost ($U.S. dollars)
3-1	Streambank Stabilization Adjacent to Dunn Street and Porter Road	Reduce force of flowing water and / or increase resistance of the bank to erosion	N/A [vii]
3-2	Sediment / Debris Retention Pond in the Village of Fredonia	Reduce watercourse and gully erosion, trap sediment, reduce and manage runoff, and improve downstream water quality	N/A [viii]
4-1	Early Warning Flood Detection System	Early flood warning for open water and ice-jam events	$120,000 (not including annual operational costs)
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	Ice Management	Controls ice buildup around vulnerable structures crossing the waterway and potentially reduces flood risk	$40,000 (not including annual operational costs)
4-6	Flood Buyouts / Property Acquisitions	Reduces and / or eliminates future losses	Variable (case-by-case)
4-7	Floodproofing	Reduces and / or eliminates future damages	Variable (case-by-case)

Alternative No.	Description	Benefits Related to Alternative	ROM cost ($U.S. dollars)
4-8	Area Preservation / Floodplain Ordinances	Reduces and / or eliminates future losses	Variable (case-by-case)
4-9	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)
4-10	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 and railroad company coordination. Additional engineering consideration would also be required to determine if removing the central pier of the railroad bridge would alter the structural integrity of the bridge in any way.

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

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

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

[v] Note: ROM cost 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 of the roadway bridge would alter the structural integrity of the bridge in any way.

[vi] 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.

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

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

11. CONCLUSION

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

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

1. Obtain stakeholder and public input to assess the feasibility and public support of each mitigation strategy presented in this report.
2. Complete additional data collection and modeling efforts to assess the effectiveness of the proposed flood mitigation strategies.
3. Develop a list of final flood mitigation strategies based on the additional data collection and modeling results.
4. Select a final flood mitigation strategy or series of strategies to be completed for Canadaway 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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