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RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE

CAYUGA CREEK, NIAGARA COUNTY, NEW YORK

Prepared for:

Project Team:

RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE
CAYUGA CREEK, NIAGARA 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-D	1-Dimensional
2-D	2-Dimensional
AC	Acres
ACE	Annual Chance Flood Event
BFE	Base Flood Elevation
BPR	Bureau of Public Roads
BRIC	Building Resilient Infrastructure and Communities
RC	Circularity Ratio
CSC	Climate Smart Communities
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second (ft3/s)
CRREL	Cold Regions Research and Engineering Laboratory
CDBG	Community Development Block Grants
CRRA	Community Risk and Resiliency Act
CRS	Community Rating System

CFA	Consolidated Funding Applications
DEM	Digital Elevation Model
DHS	United States Department of Homeland Security
DRRA	Disaster Recovery Reform Act of 2018
RE	Elongation Ratio
EWP	Emergency Watershed Protection
ESRI	Environmental Systems Research Institute
FEMA	Federal Emergency Management Agency
FT	Feet
FIRM	Flood Insurance Rate Maps
FIS	Flood Insurance Study
FMA	Flood Mitigation Assistance
RF	Form Factor
FDD	Freezing Degree-Day
GIS	Geographic Information System
HMA	Hazard Mitigation Assistance
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	Department of Housing and Urban Development
IPaC	Information for Planning and Consultation
IPCC	Intergovernmental Panel on Climate Change
LOMR	Letter of Map Revision
NCEI	National Centers for Environmental Information
NFIP	National Flood Insurance Program
NRCS	Natural Resources Conservation Services
NWI	National Wetlands Inventory
NAVD88	North American Vertical Datum of 1988
NYPA	New York Power Authority
NYS	New York State
NYSDEC	New York State Department of Environmental Conservations
NYSDHSES	New York State Division of Homeland Security and Emergency Services
NYSDOT	New York State Department of Transportation
NYSOEM	New York State Office of Emergency Management
NYSOGS	New York State Office of General Services
NYSOPRHP	New York State Office of Parks, Recreation, and Historic Places
PDM	Pre-Disaster Mitigation
RAMBOLL	Ramboll Americas Engineering Solutions, Inc.
ROM	Rough Order of Magnitude
STORM	Safeguarding Tomorrow through Ongoing Risk Mitigation
SFHA	Special Flood Hazard Areas
HMA	Unified Hazard Mitigation Assistance
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USSCS	United States Soil Conservation Service
USGS	United States Geologic Service
WQIP	Water Quality Improvement Project
WSEL	Water Surface Elevation

1. INTRODUCTION

1.1 HISTORICAL INITIATIVES

Flood mitigation has been an initiative in western New York and in the Cayuga Creek watershed. Historically, the most severe flooding in the watershed occurs in early spring as a result of snowmelt, heavy rains, and ice jams. Shallow flooding in low-lying areas of the City of Niagara Falls during heavy rain events also occurs (FEMA 1990). Based on high-water marks in Cayuga Creek, severe flooding occurred in April 1976 (FEMA 1983). More recently, during high-precipitation events in January and March of 1998, the Cayuga Village Trailer Park experienced severe flooding (NYPA 2006). In the upstream portion of the Cayuga Creek watershed, the Town of Wheatfield has historically experienced flooding after major storms or snow melt events due to inadequate grade, low stream banks, and debris and sediment deposits along Cayuga Creek (FEMA 1992). At the downstream end of the Cayuga Creek watershed, Cayuga Island has historically experienced flooding due to ice jams in the Niagara River and long duration storms over Lake Erie (FEMA 1990).

Flooding in the watershed associated with ice jams in the upper Niagara River has been somewhat mitigated with the annual installation of the Lake Erie-Niagara River Ice Boom at the head of the Niagara River, and floodplain management regulations have been instituted in the communities along Cayuga Creek due to inclusion in the National Flood Insurance Program (NFIP). The Town of Wheatfield performs annual maintenance reviews of waterways in the town to ensure unrestricted flow in areas susceptible to flooding (NYPA 2006). The Town of Niagara acquired 30 acres of land along Cayuga Creek adjacent to the Niagara International Airport in 2018, intended for a wetland restoration project to mitigate flooding and water pollution (Joe 2018).

Multiple studies have been performed on the Cayuga Creek watershed including an effective Federal Emergency Management Agency (FEMA) Flood Insurance Studies (FIS) released in 2010 for the entirety of Niagara County, a United States Army Corps of Engineers (USACE) Analysis Reconnaissance Report released in 2002, and a New York Power Authority (NYPA) Watershed Assessment released in 2006.

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 affected areas
4. Up-size bridges and culverts to be more resilient to ice jams, high flow events, and projected future flood flows due to climate change in affected 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 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 City of Niagara Falls (NFIP Community #360506) is a participating community 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 Cayuga Creek watershed was chosen as a study site for this initiative.

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

The Resilient NY flood studies will identify the causes of flooding within each watershed and develop effective and ecologically sustainable flood and ice-jam hazard mitigation projects. Proposed flood mitigation measures will be identified and evaluated using hydrologic and hydraulic modeling to quantitatively determine flood mitigation strategies that would result in the greatest flood reduction benefits. In addition, the flood mitigation studies incorporate the latest climate change forecasts and assess open-water and ice-jam hazards where future flood risks have been identified.

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

The goals of the Resilient NY Program are to:

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

The overarching purpose of the initiative is to evaluate a suite of flood and ice-jam mitigation projects that local municipalities can undertake to make their community more resilient to future floods. The projects should be affordable, attainable through grant funding programs, able to be implemented either individually or in combination in phases over the course of several years, achieve measurable improvement at the completion of each phase, and fit with the community way of life. The information developed under this initiative is intended to provide the community with a basis for assessing and selecting flood mitigation strategies to pursue; no recommendations are made as to which strategies the community should pursue.

The flood mitigation and resiliency study for Cayuga Creek began in February of 2021, and a final flood study report was issued in August 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* v4.5.3 (USGS 2021) 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 2010 FEMA Flood Insurance Study (FIS) for the City of Niagara Falls.

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 2019) software to determine water stage at current and potential future levels for high-risk areas and to evaluate the effectiveness of proposed flood mitigation strategies. These studies and data were obtained and used, all or in part, as part of this effort. Appendix A is a summary listing of data and reports collected.

2.2 PUBLIC OUTREACH

An initial virtual project kickoff meeting was held on March 16, 2021, with representatives of the NYSDEC, NYSOGS, Ramboll, Highland Planning, USACE, Town of Niagara, Town of Lewiston, Niagara County Soil and Water Conservation District, Buffalo Niagara Waterkeeper, Niagara County Department of Public Works, Lake Erie Watershed Protection Alliance, and Niagara Falls Air Reserve Station (Appendix C). At the project kickoff meeting, project specifics, including background, purpose, funding, roles, and timelines, were discussed. Discussions included a variety of topics, including:

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

This outreach effort assisted in the identification of current high-risk areas to focus on during 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 City of Niagara Falls, Town of Niagara, Town of Wheatfield, and Town of Lewiston as identified in the initial data collection process. Field assessments of Cayuga Creek were conducted on May 23, 2021. Information collected during the field investigation included the following:

- Photo documentation of inspected bridges and culverts
- Structural measurement of bridges and culverts

Appendix B is a photo log of select infrastructure 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 Cayuga Creek watershed study area lies entirely within Niagara County, New York. Cayuga Creek originates in the Town of Lewistown, flows southwest through the Tuscarora Indian Reservation and into the Town of Wheatfield before flowing south through the Niagara Falls International Airport and into the Town of Niagara. The creek flows south through the City of Niagara Falls to its confluence with the Niagara River (Figure 3-1). Within the Cayuga Creek watershed, the Town of Niagara and the Town of Wheatfield were chosen as the study area due to historical flooding issues and the hydrologic conditions of the creek. Figure 3-2 and Figure 3-3 depict the stream stationing along Cayuga Creek and the study area, respectively. The stationing Ramboll developed may differ from stationing shown in the FEMA Flood Insurance Studies (FIS) developed for Cayuga Creek due to differences in data sources and methodologies. The stationing used in this report was calculated using the Environmental Systems Research Institute's (ESRI) ArcMap version 10.8 software package (ESRI 2020).

The Town of Niagara and the City of Niagara Falls occupies approximately 26.3 square miles in the southeastern portion of Niagara County in western New York State. The area is bounded by the Town of Lewiston to the north, the Town of Wheatfield and City of North Tonawanda to the east, and the Niagara River to the south.

The Cayuga Village Trailer Park in the Town of Niagara has historically experienced flooding associated with the 1969 diversion of Cayuga Creek from its natural channel through an artificial channel upstream of the trailer park (NYPA 2006). Additionally, the City of Niagara Falls has experienced flooding at the downstream end of Cayuga Creek due to ice jams in the upper Niagara River and long-duration storms over Lake Erie (FEMA 1990). Prolonged spring thaws and heavy summer rainfall create the most severe flooding conditions in the watershed (FEMA 2010b).

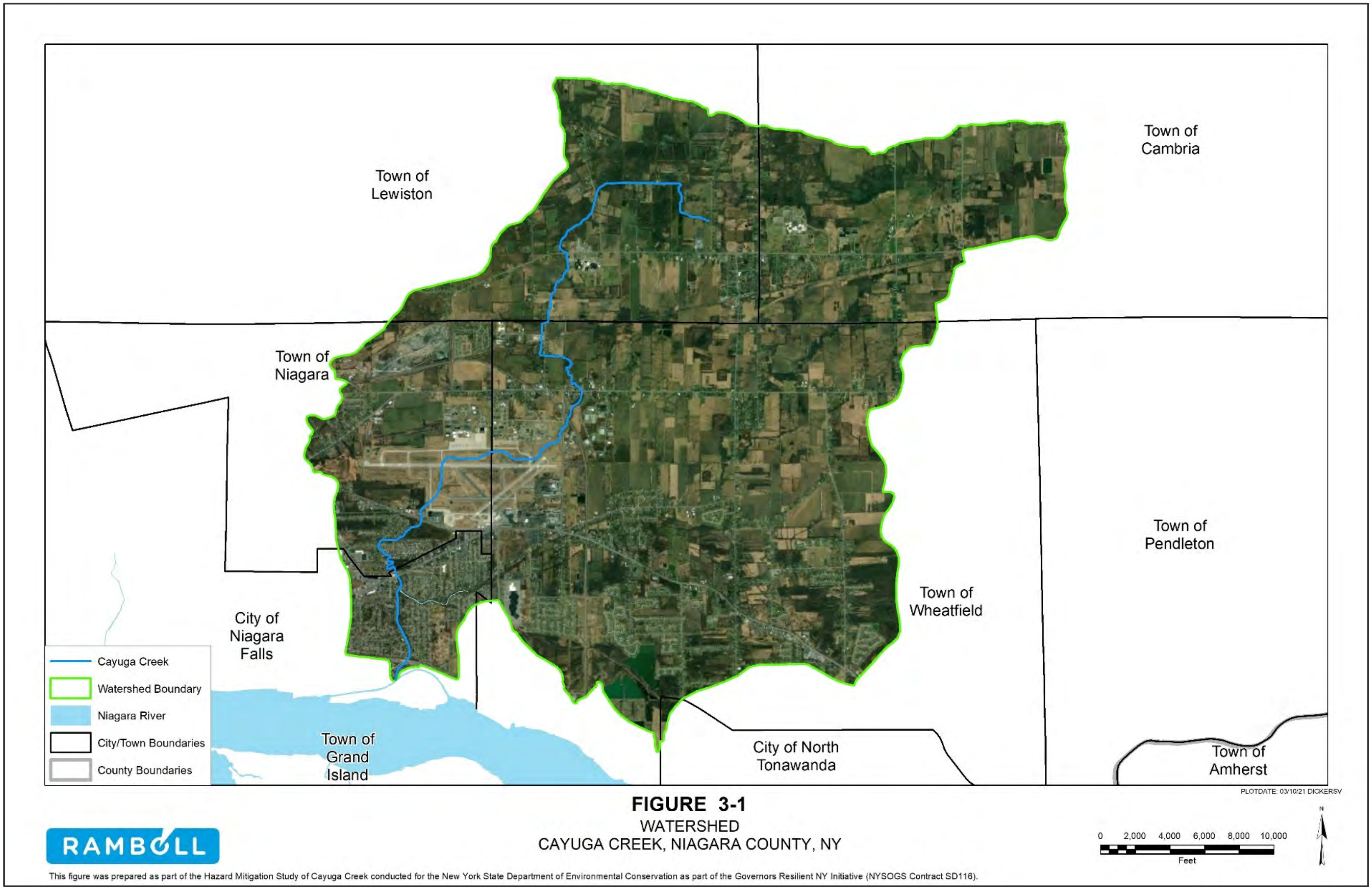

Figure 3-1. Cayuga Creek Watershed, Niagara County, NY.

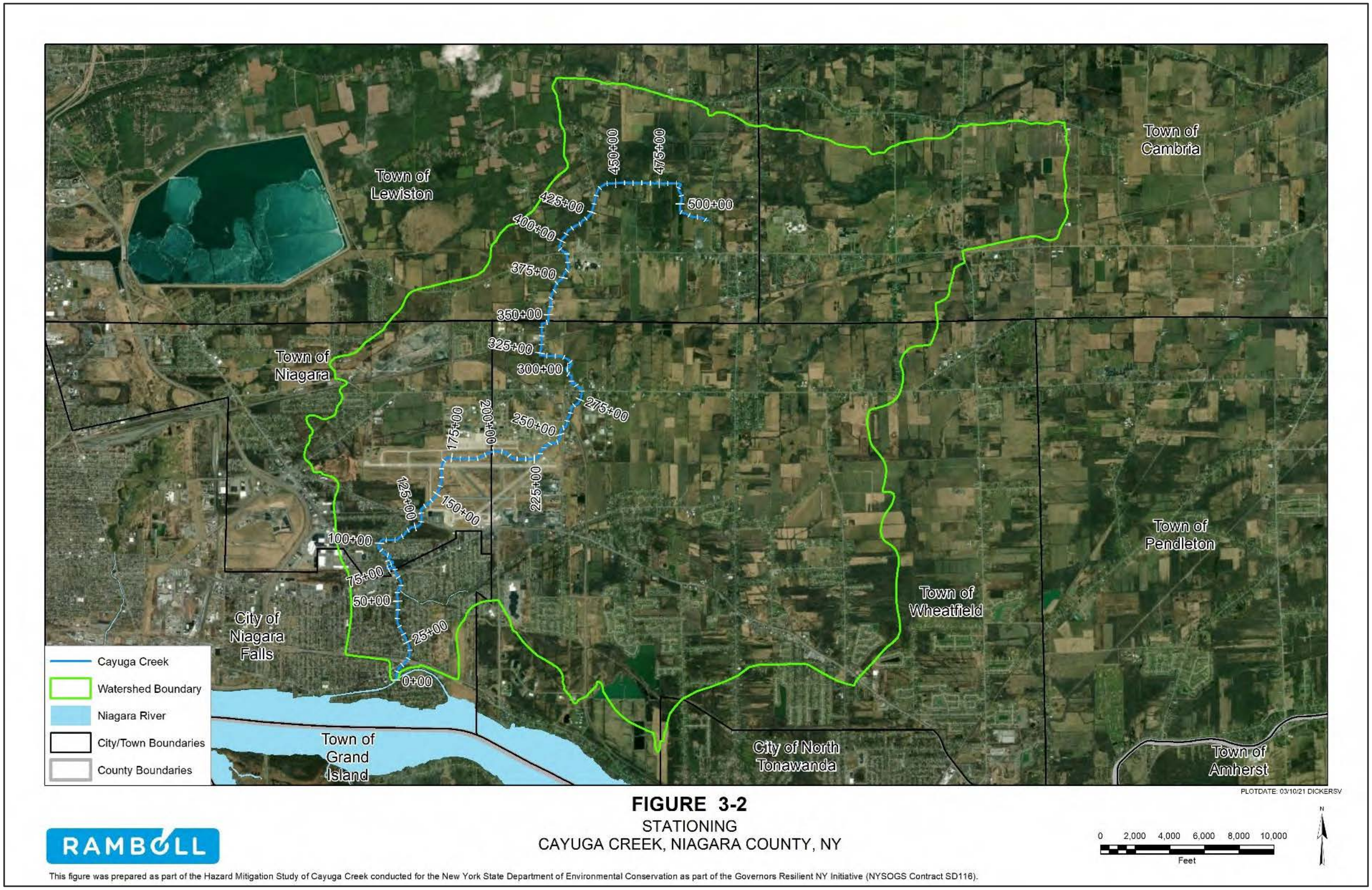

Figure 3-2. Cayuga Creek Stationing, Niagara County, NY.

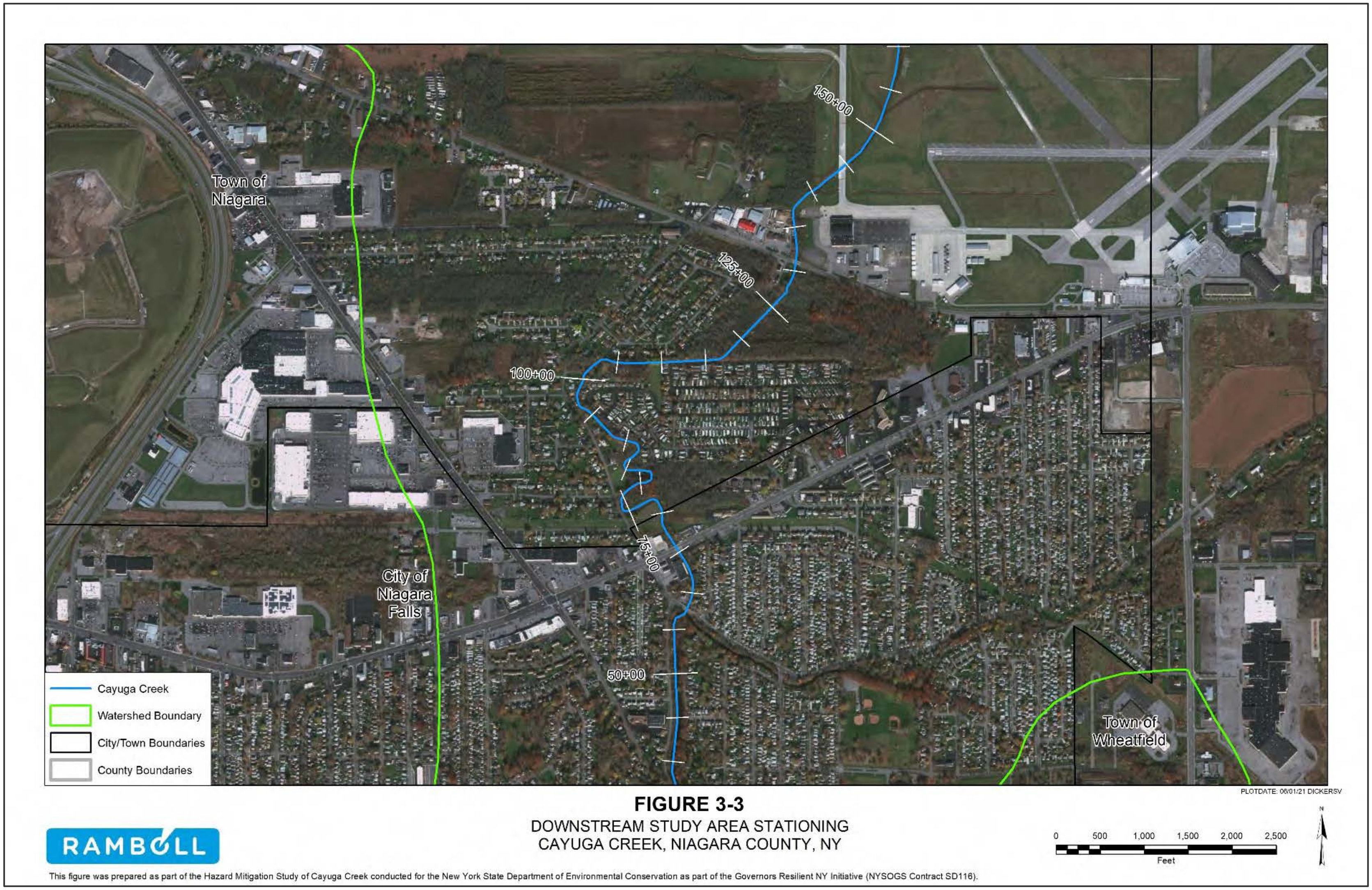

Figure 3-3. Cayuga Creek Downstream Study Area Stationing, Niagara County, NY.

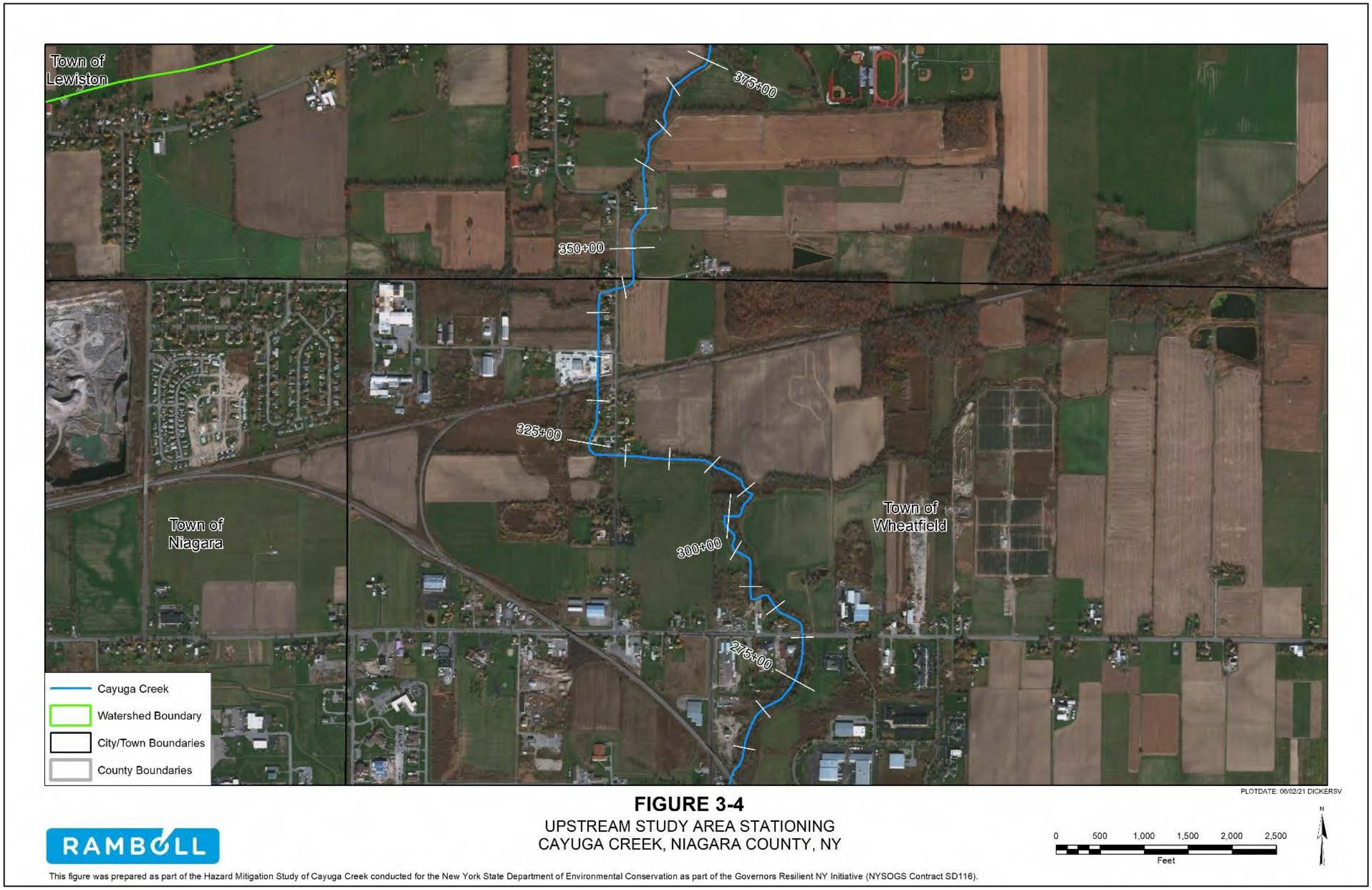

Figure 3-4. Cayuga Creek Upstream Study Area Stationing, Niagara County, NY.

3.2 ENVIRONMENTAL CONDITIONS

An overview of the environmental and cultural resources within the Cayuga 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 deep-water 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)

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 Cayuga Creek watershed (NYSDEC 2021).

The National Wetlands Inventory (NWI) was reviewed to identify national wetlands and surface waters (Figure 3-4). The Cayuga Creek watershed includes riverine habitats, freshwater emergent wetlands, and freshwater forested / shrub wetlands (NYSDEC 2021).

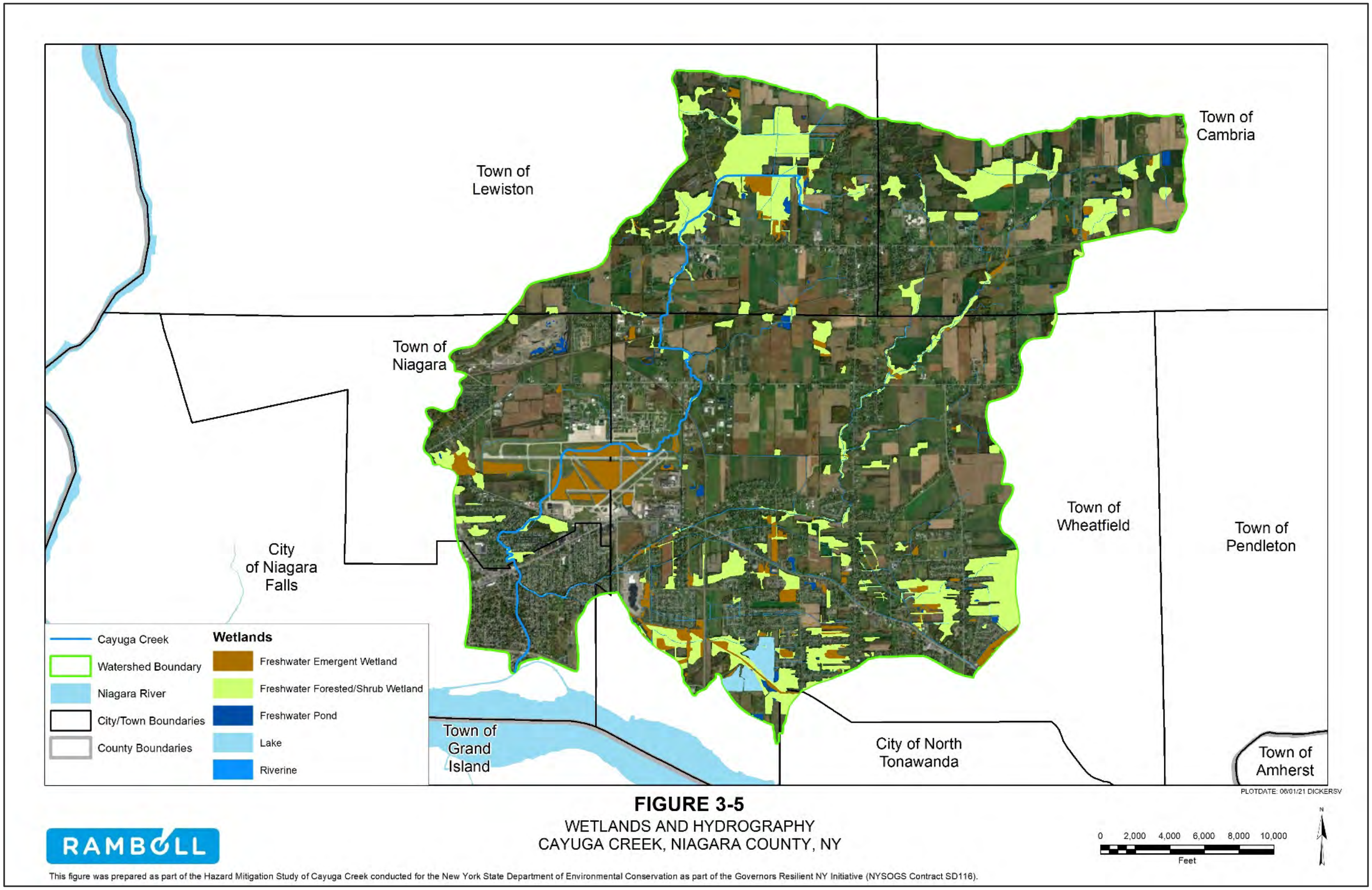

Figure 3-5. Cayuga Creek Wetlands and Hydrography, Niagara County, NY.

3.2.2 Sensitive Natural Resources

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

3.2.3 Endangered or Threatened Species

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

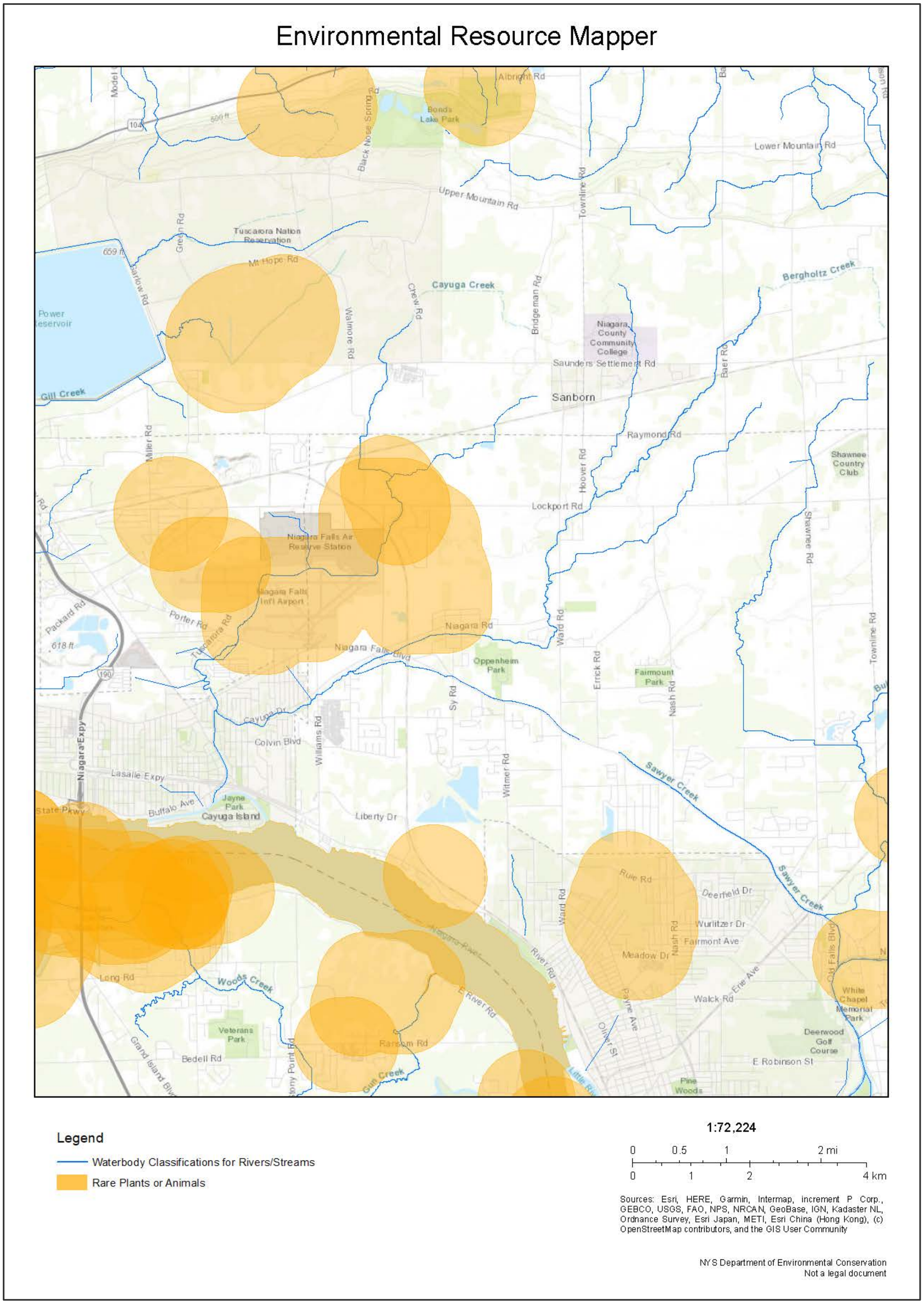

Figure 3-6. Rare Plants or Animals, Cayuga Creek, Niagara County, NY.

The USFWS Information for Planning and Consultation (IPaC) results for the project area list no threatened or endangered species. No critical habitat has been designated for the species at this location (USFWS 2021). The migratory bird species listed in Table 1 are transient species that may pass over but are not known to nest within the project area.

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	Breeds Dec 1 to Aug 31
Black-billed Cuckoo	*Coccyzus erythropthalmus*	BCC Rangewide (CON)	Breeds May 15 to Oct 10
Bobolink	*Dolichonyx oryzivorus*	BCC Rangewide (CON)	Breeds May 20 to Jul 31
Canada Warbler	*Cardellina canadensis*	BCC Rangewide (CON)	Breeds May 20 to Aug 10
Dunlin	*Calidris alpina arcticola*	BCC – BCR	Breeds elsewhere
Lesser Yellowlegs	*Tringa flavipes*	BCC Rangewide (CON)	Breeds elsewhere
Red-headed Woodpecker	*Melanerpes erythrocephalus*	BCC Rangewide (CON)	Breeds May 10 to Sep 10
Semipalmated Sandpiper	*Calidris pusilla*	BCC Rangewide (CON)	Breeds elsewhere
Short-billed Dowitcher	*Limnodromus griseus*	BCC Rangewide (CON)	Breeds elsewhere
Snowy Owl	*Bubo scandiacus*	BCC Rangewide (CON)	Breeds elsewhere
Wood Thrush	*Hylocichla mustelina*	BCC Rangewide (CON)	Breeds May 10 to Aug 31

3.2.4 Cultural Resources

According to the National Register of Historic Places, Cayuga Creek is located near the Town of Niagara District School No. 2 (9670 Lockport Road) and the Johann Williams Farm (10831 Cayuga Drive); the location of these resources are shown in Figure 3-6 below. 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).

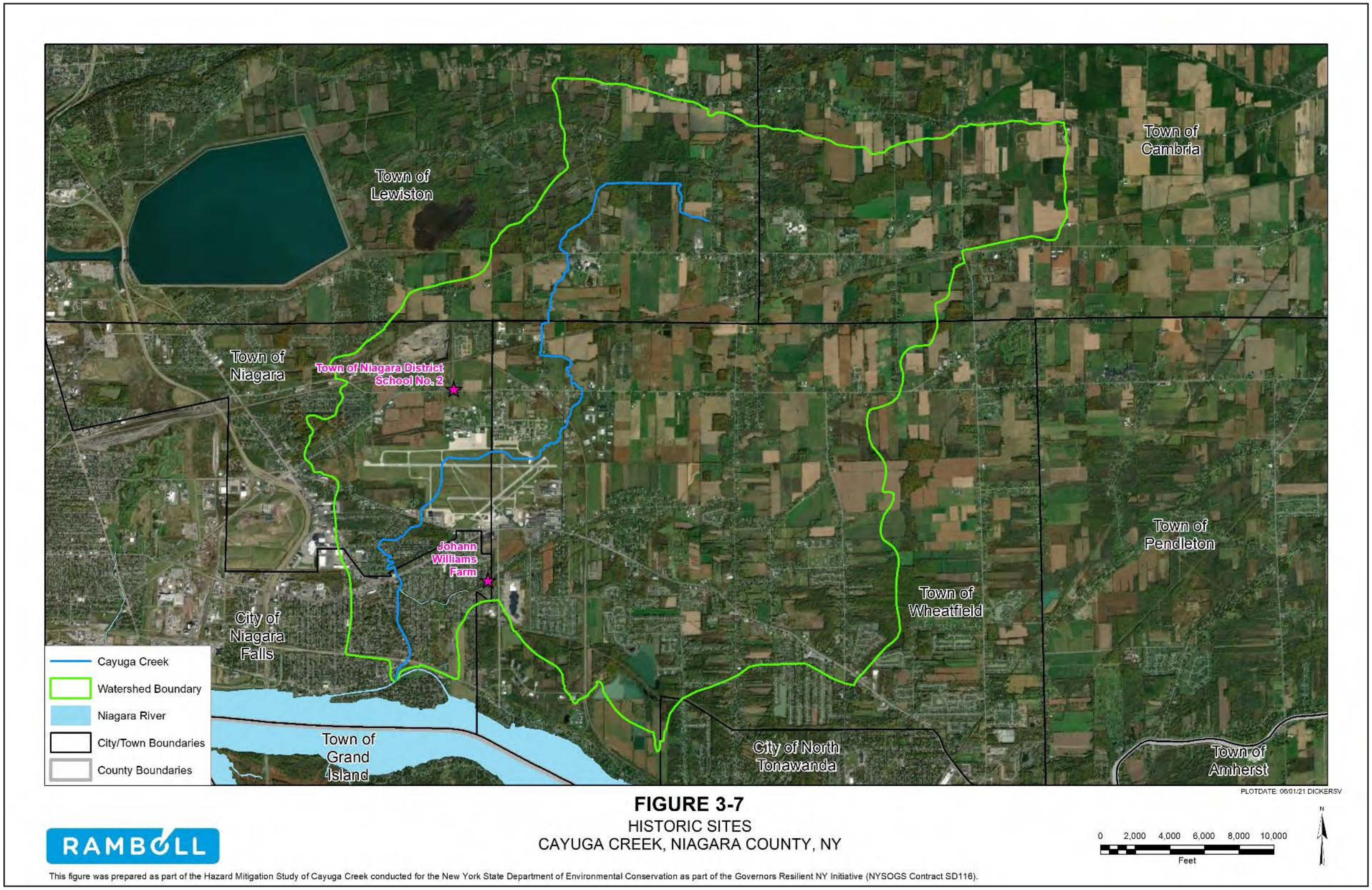

Figure 3-7. National Register of Historic Places, Cayuga Creek, Niagara County, NY.

3.2.5 Floodplain Location

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. For the County of Niagara, the current effective FEMA FIS was completed on September 17, 2010. According to the FIS, the hydrologic and hydraulic analysis completed was an updated new detailed study based on the original FEMA H&H studies for all communities within Niagara County. The FEMA FIS included Cayuga Creek in the new detailed study (FEMA 2010b).

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

The FIRMs for the Town of Niagara and City of Niagara Falls indicate Special Flood Hazard Areas (SFHAs), which are land areas covered by floodwaters during the 1% annual chance flood event (ACE), along the banks of the creek, for almost the entire length of the creek (FEMA 2019). Cayuga Creek is a Regulatory Floodway, which is defined as the watercourse channel and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than 1-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 (FEMA 2000).

For 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. The flood zones indicated in the Cayuga Creek study area are Zones A and AE, where mandatory flood insurance purchase requirements apply. A Zones are areas subject to inundation by the 1% annual chance flood event. Where detailed hydraulic analyses have not been performed, no BFEs or flood depths are shown. AE Zones are areas that have a 1% annual chance of flooding where BFEs are provided by FEMA (FEMA 2000). Figure 3-7 is a FIRM that includes a portion of Cayuga Creek in the Town of Niagara, New York (FEMA 2010a).

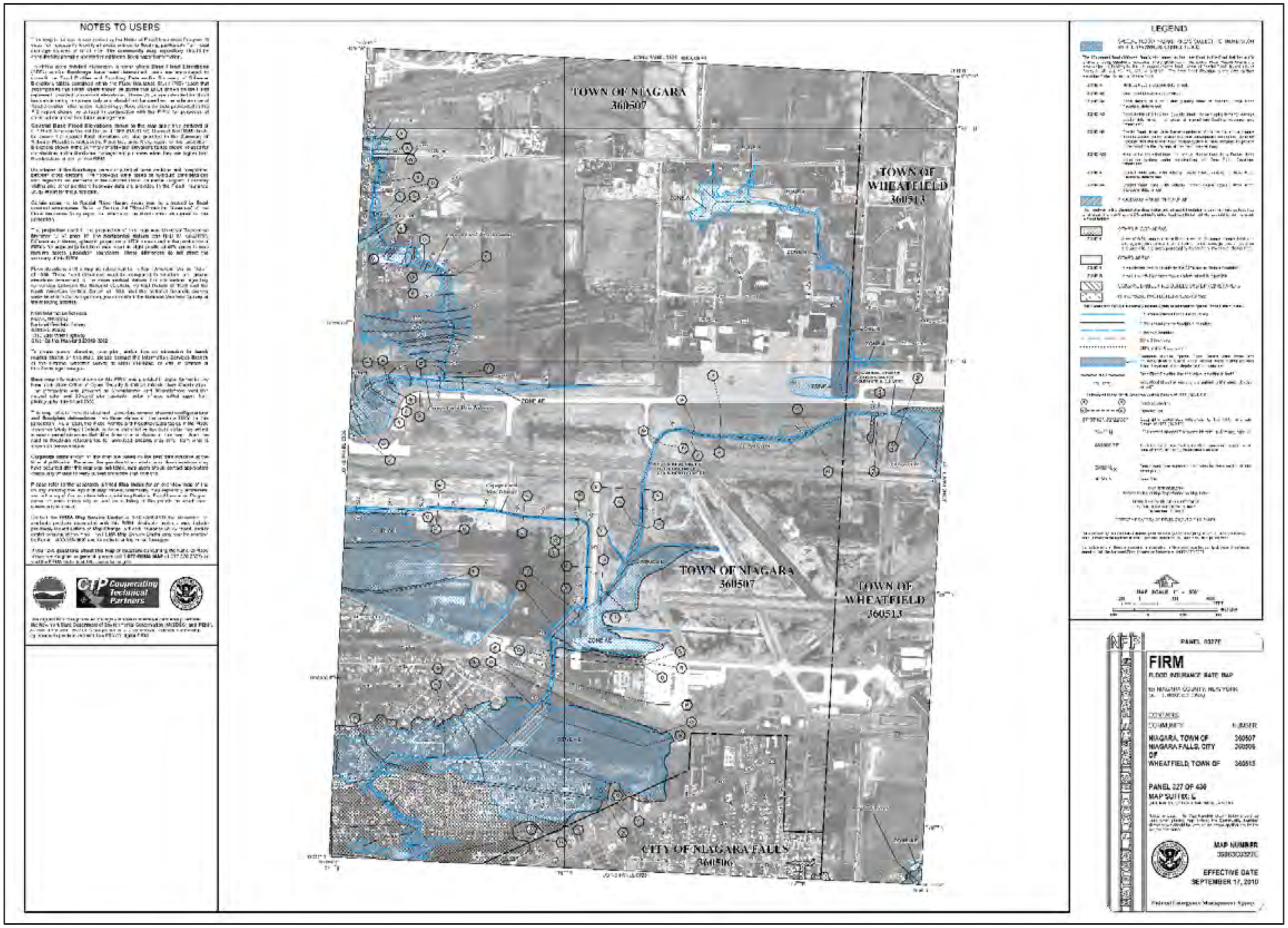

Figure 3-8. FEMA FIRM, Cayuga Creek, Town of Niagara, Niagara County, NY.

3.3 WATERSHED LAND USE

The Cayuga Creek watershed is largely comprised of cultivated / hay (43%), developed (29%), forested (10%), and wetland (10%) land types. Alfalfa (11%) and soybeans (9%) comprise the largest portion of cultivated land, while open space (11%) and low intensity development (12%) comprise the largest portion of developed land (NASS 2021).

In the Towns of Lewiston and Wheatfield, the floodplain development is primarily agricultural or forested (FEMA 1992). Downstream of the Niagara Falls International Airport, the Cayuga Creek floodplain is primarily developed (FEMA 1983).

3.4 GEOMORPHOLOGY

The soils of Niagara County formed in glacial till that was deposited during and shortly after the Pleistocene ice age, approximately 300,000 years ago. Glacial till occupies a large part of the surface area in Niagara County and underlies most areas of lake sediments. Four types of glacial till deposits occur in the county – ground morains, drumlins, elongated till ridges, and terminal moraines (USSCS 1972).

The principal bedrock formations in Niagara County are Queenston shale, Lockport dolomitic limestone, and Rochester shale. Queenston shale is well exposed in the Niagara River Gorge and near the banks of many of the smaller streams in the county. The Lockport dolomitic limestone is exposed along the Niagara Escarpment and Barge Canal, and in the limestone quarries in the county. The Rochester shale is exposed in a road cut south of the Village of Gasport (USSCS 1972).

Within the Cayuga Creek watershed basin, the most predominant soil types are Odessa silty clay loam (OdB), Lakemont silty clay loam (Lc), and Ovid silt loam (OvA). OdB makes up the largest proportion of soil type by total acreage within the Cayuga Creek basin (26.5%). It is gently sloping, deep, and somewhat poorly drained, and is located on footslopes of lake plains and valley terraces. Lc makes up the second largest proportion of soil type by acreage within the Cayuga Creek watershed (15.2%). It is gently sloping, deep, and poorly drained, and is located on nearly level parts and slight depressions of lake plains. OvA makes up the third largest proportion of soil type by acreage within the Cayuga Creek basin (8.2%). It is gently sloping, deep, and somewhat poorly drained, and is located on till plains (NRCS 2021).

Figure 3-9 is a stream bed elevation and channel distance from the confluence with Niagara River profile using light detection and ranging (LiDAR) data from the NYSDEC for Cayuga Creek. The creek's stream bed lowers approximately 77 vertical feet over this reach from an elevation of approximately 640-ft above sea level (NAVD88) at the upstream end in the Town of Lewiston, to 613-ft above sea level (NAVD88) at the confluence with Niagara River in the City of Niagara Falls (NYSDEC 2007).

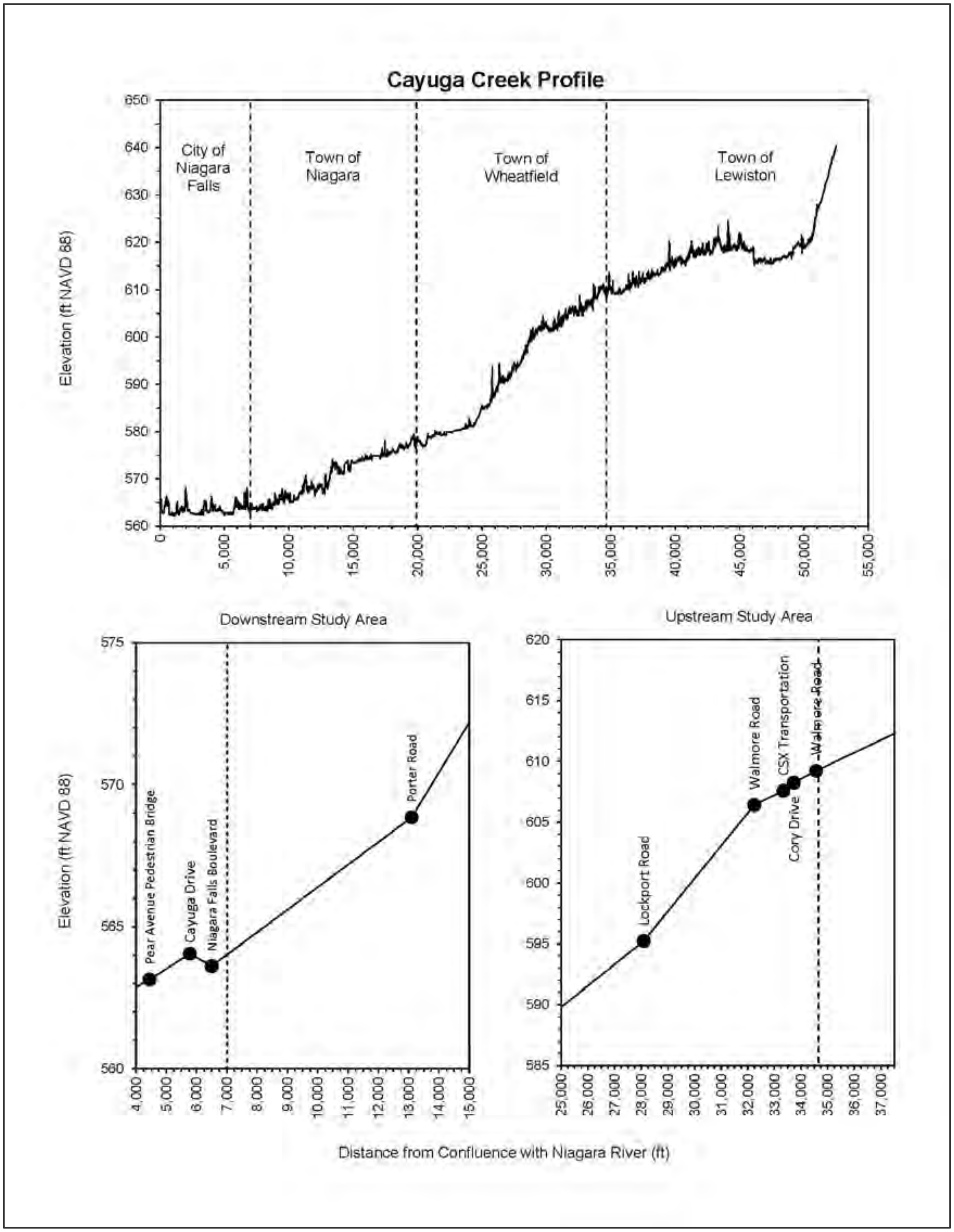

Figure 3-9. Cayuga Creek profile of stream bed elevation and channel distance from the confluence with Niagara River.

3.5 HYDROLOGY

Cayuga Creek is approximately 10 miles long and has a drainage area of 35.5 square miles, which includes Bergholtz Creek. Cayuga Creek is located in southwestern Niagara County in western New York State. Excluding the Bergholtz Creek watershed, Cayuga Creek has a drainage area of 14 square miles. Cayuga Creek and Bergholtz Creek both discharge into the Niagara River downstream of the Niagara Falls (FEMA 1983; FEMA 1990).

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

Factor	Formula	Value
Form Factor (R_F)	A / B_L^2	0.26
Circularity Ratio (R_C)	$4*\pi*A / B_P^2$	0.35
Elongation Ratio (R_E)	$2 * (A/\pi)^{0.5} / B_L$	0.57

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, Cayuga 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 are currently no USGS stream gaging stations on Cayuga Creek.

An effective FEMA Flood Insurance Study (FIS) for Niagara County was issued on September 17, 2010, which was a new detailed study and included drainage area and discharge information for Cayuga Creek. Table 3 summarizes the FEMA FIS drainage area and peak discharges, in cubic feet per second, for Cayuga Creek (FEMA 2010b).

Table 3. Cayuga Creek FEMA FIS Peak Discharges

(Source: FEMA 2010b)						
			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 Little Niagara River	28.2	0+00	1,650	2,650	3,050	3,800
Upstream corporate limits, City of Niagara Falls	14.3	57+50	950	1,450	1,650	2,100
Upstream of confluence of Bergholtz Creek	14.0	63+55	642	894	1,000	1,250
Downstream of confluence of Western Tributary	12.7	136+70	584	814	914	1,130

In the original FIS reports, peak discharges were established by applying a standard log-Pearson Type III analysis on the discharge-frequency relationships of nine USGS gaging stations in Niagara County. A regional skew value of 0.0 was a computed weighted average considering the natural skews and years of record for each gage considered. Regional curves were then determined correlating peak discharge and drainage area for the selected return periods, and that data was extended. These regional curves were extended to cover watersheds less than 15 square miles in area. Methods outlined in the Bureau of Public Roads (BPR) Circular No. 4 were also used and were found to closely match the regional curves (USDC 1963).

For the revised 2010 analysis, due to the lack of USGS gaging stations within the streams of interest, two sets of regression equations, outlined in the USGS WRI 90-4197 and SIR 2006-5112 reports, respectively, were evaluated for the best peak flow estimates for the selected return periods (USGS 1991; USGS 2006). Based on comparisons of published peak flow occurrences, previous FIS reports, and neighboring gage locations, the WRI 90-4197 regression equations were ultimately used.

General limitations of the FEMA FIS methodology are the age of the effective FIS H&H analysis and methodology, which can introduce a large degree of uncertainty and errors into the calculations due to more recent advances in H&H computations and modeling, and the limited regional discharge-frequency relationships used to calculate the flood frequency curves.

StreamStats v4.4.0 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 2021).

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

For ungaged sites, *StreamStats* relies on regional regression equations that were developed by statistically relating the streamflow statistics to the basin characteristics for a group of stream gages within a region. Estimates of streamflow statistics for an ungaged site can then be obtained by measuring its basin characteristics and inserting them into the regression equations (Ries et al. 2017). For example, the equation for estimating the 100-yr flood for ungaged sites within Hydrologic Region 6 in New York is:

$$Q_{100} = 46.0 * (A)^{0.823} * (ST+0.5)^{-0.177} * (RUNF)^{0.505} * (EL12+1)^{0.166} * (SR)^{0.318}$$

Where

A is the drainage area in square miles;

ST is the percentage of the drainage area acting as basin storage;

RUNF is the mean annual runoff in inches;

EL12 is the percentage of the drainage area at or above an elevation of 1200 feet; and

SR is the slope ratio (Lumia et al. 2006).

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

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

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

StreamStats was used to calculate the current peak discharges for Cayuga 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 Cayuga Creek at the same locations as the FEMA FIS peak discharges.

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

(Source: USGS 2021)						
			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 Little Niagara River	31.5	0+00	1,010	1,330	1,460	1,760
Upstream corporate limits, City of Niagara Falls	13.4	57+50	496	656	720	870
Upstream of confluence of Bergholtz Creek	13.3	63+55	492	651	715	863
Downstream of confluence of Western Tributary	12.1	136+70	450	596	654	791

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 6 in New York State.

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

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

At the more downstream locations, the FEMA FIS values were determined to be outside of the acceptable range based on the *StreamStats* standard error calculator. As the FEMA FIS peak discharge values are greater than the *StreamStats* values at all locations, the FEMA FIS peak discharge values were used in the hydraulic and hydrologic simulations for this study to maintain consistency between the modeling outputs and the FEMA models.

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 Cayuga Creek is important in understanding the distribution of available energy within the stream channel and the ability of various discharges occurring within the channel to erode, deposit, and move sediment (Rosgen and Silvey 1996). Table 6 lists the estimated drainage area, bankfull discharge, width, and depth at select locations along Cayuga Creek as derived from the USGS *StreamStats* program.

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

(Source: USGS 2021)				
Flooding Source and Location	**Drainage Area (Sq. Miles)**	**Bankfull Depth (ft)**	**Bankfull Width (ft)**	**Bankfull Streamflow (cfs)**
Confluence with Little Niagara River	31.5	2.41	71.7	877
Upstream corporate limits, City of Niagara Falls	13.4	1.96	50.1	427
Upstream of confluence of Bergholtz Creek	13.3	1.96	50.0	424
Downstream of confluence of Western Tributary	12.1	1.91	48.0	392

3.6 INFRASTRUCTURE

Numerous infrastructure crossings exist along Cayuga Creek, including bridges and culverts. Major NYSDOT bridge crossings over Cayuga Creek include LaSalle Expressway and Niagara Falls Boulevard (US-62) in the City of Niagara Falls. Table 7 lists a summary of all infrastructure crossing Cayuga Creek that is a part of the NYSDOT bridge inspection program. Bridge and culvert lengths and surface widths for NYSDOT bridges were revised as of February 2019. There are no dams along Cayuga Creek (NYSDOT 2016a; NYSDEC 2019).

Table 7. NYSDOT Bridges / Culverts Crossing Cayuga Creek

(Source: NYSDOT 2016a)							
Type	**Roadway Carried or Structure Name**	**NYSDOT BIN / CIN**	**River Station (ft)**	**Length[1] (ft)**	**Width[2] (ft)**	**Bankfull Width[3] (ft)**	**Hydraulic Capacity (% Annual Chance)**
Bridge	**Buffalo Avenue (NY-384)**	2047320	11+60	116	37	71.7	0.2
Bridge	**LaSalle Expressway**	1064959	13+55	472	112.2	71.7	10
Bridge	**South Military Road**	2043870	19+80	94	30	71.6	0.2
Bridge	**Lindbergh Avenue**	2260900	33+90	89	30	71.4	2
Pedestrian Bridge	**Pear Avenue Pedestrian Bridge**	2260910	45+00	100	13.3	71.2	1
Bridge	**Cayuga Drive**	2260930	57+90	75	34	50.1	10
Bridge	**Niagara Falls Boulevard (US-62)**	1028560	65+50	76	72.1	50.1	10
Bridge	**Porter Road (NY-182)**	1039580	130+75	65	40	48.2	0.2
Culvert	**Saunders Settlement Road (NY-31)**	C550022	390+20	12	64	30.1	No FEMA FIS Data
Culvert	**Chew Road**	C103989	436+00	12	70 [4]	27.2	No FEMA FIS Data

[1] Length is measured perpendicular to flow. For culverts, length refers to the total span, which is the sum of the culvert's span lengths and the horizontal distances of any separation between spans (NYSDOT 2006).
[2] For bridges, width is measured parallel to creek flow and refers to the curb-to-curb width, which is the minimum distance between the curbs or the bridge railings (if there are no curbs), to the nearest 30mm or tenth of a foot. For culverts, width refers to the out to out length of the culvert to the nearest tenth of a foot (NYSDOT 2006).
[3] Estimated using the USGS *StreamStats* program.
[4] Estimated using ESRI basemap imagery.

In addition to the NYSDOT infrastructure, Cayuga Creek has several infrastructure crossings not included in the NYSDOT bridge inspection program, including the CSX Transportation railroad crossings in the Town of Wheatfield and several culverts at the Niagara Falls International Airport in the Town of Niagara. Table 8 lists a summary of all non-NYSDOT infrastructure crossing Cayuga Creek. Figure 3-8 displays the locations of all bridges and culverts, NYSDOT and non-NYSDOT, that cross Cayuga Creek.

Table 8. Non-NYSDOT Bridges / Culverts Crossing Cayuga Creek

Type	Roadway Carried or Structure Name	River Station (ft)	Length[1] (ft)	Width[2] (ft)	Bankfull Width[3] (ft)	Hydraulic Capacity (% Annual Chance)
Culvert	**Niagara Falls International Airport Taxiway G Bridge**	144+20	70	235	45.1	10
Culvert	**Niagara Falls International Airport Runway**	166+85	70	600	44.5	0.2
Culvert	**Niagara Falls International Airport Overpass**	204+60	55	160	41.2	0.2
Culvert	**Niagara Falls International Airport Overpass**	223+10	50	300	41.0	10
Culvert	**Walmore Road**	255+05	20	40	40.3	Less than 10
Railroad Bridge	**CSX Transportation**	260+80	50	65	40.2	0.2
Bridge	**Lockport Road**	280+20	25	55	39.5	2
Culvert	**Walmore Road**	320+95	20	35	34.9	Less than 10
Railroad Bridge	**CSX Transportation**	331+70	50	65	34.2	Less than 10
Culvert	**Cory Drive**	335+40	20	25	33.9	Less than 10
Culvert	**Walmore Road**	343+95	20	20	32.0	Less than 10

[1] Length is measured perpendicular to flow. Estimated using ESRI basemap imagery.
[2] For bridges, width is measured parallel to creek flow and refers to the curb-to-curb width, which is the minimum distance between the curbs or the bridge railings (if there are no curbs). For culverts, width refers to the out to out length of the culvert (NYSDOT 2006). Estimated using ESRI basemap imagery.
[3] Estimated using the USGS *StreamStats* program.

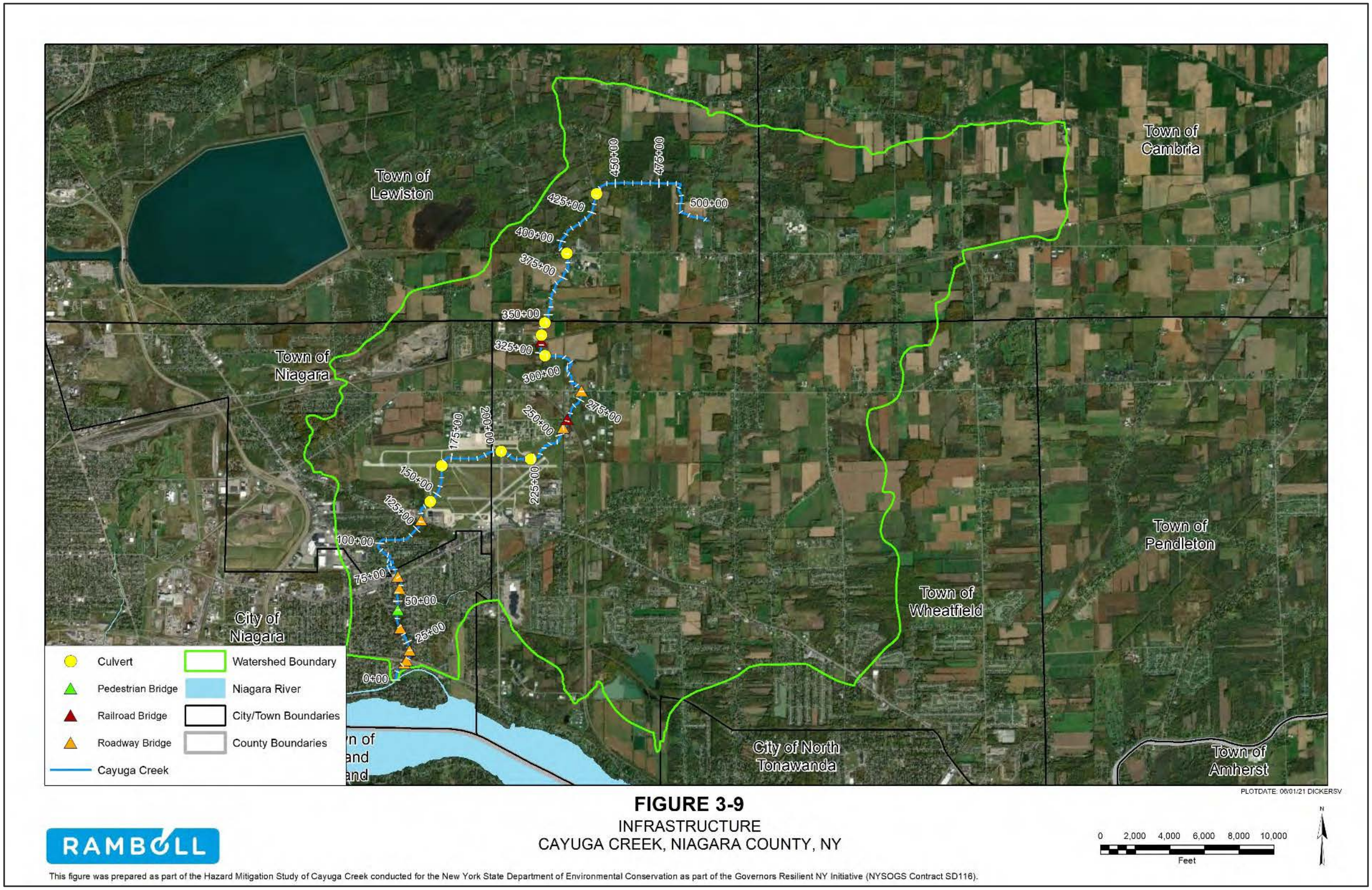

Figure 3-10. Cayuga Creek Infrastructure, Niagara County, NY.

3.7 HYDRAULIC CAPACITY

Hydraulic capacity is the measure of the amount of water that can pass through a structure or watercourse. Hydraulic design is an essential function of structures in watersheds. Exceeding the capacity can result in damages or flooding to surrounding areas and infrastructure (Zevenbergen et al. 2012). In assessing hydraulic capacity of the high-risk constriction point culverts and bridges along Cayuga Creek, the FEMA FIS profile of Cayuga Creek was used to determine the lowest annual chance flood elevation to flow under a culvert or the low chord of a bridge without causing an appreciable backwater condition upstream (Tables 7 and 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 2018).

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-in 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 current 1% annual chance event (100-yr flood), based on peak streamflow from the USGS *StreamStats* plus a 10% increase in flow, shall pass below the proposed low chord without touching it.
- The maximum skew of the pier to the flow shall not exceed 10 degrees.

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

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

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

In an effort to improve flood resiliency of infrastructure in light of future climate change, New York state passed the Community Risk and Resiliency Act (CRRA) in 2014. In accordance with the guidelines of the CRRA, the NYSDEC released the *New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act* (2020) report. In the report, the NYSDEC outlined infrastructure guidelines for bridges and culverts (NYSDEC 2020). In general, current peak flows shall be increased to account for future projected peak flows based on the USGS *StreamStats* tool where current 2% annual chance event peak flows shall be increased by 10% in Hydrologic Region 6.

For bridges, the minimum hydraulic design criteria is 2-ft of freeboard over the 2% annual chance flood elevation, while still allowing the 1% annual chance event flow to pass under the low chord of the bridge without going into pressure flow. For critical bridges, the minimum hydraulic design criteria is 3-ft of freeboard over the 2% annual chance flood elevation. A critical bridge is considered to be vital infrastructure that the incapacity or destruction of such would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters (NYSDEC 2020; NYSDOT 2019; USDHS 2010).

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

Table 9 displays the 2% and 1% annual chance flood levels and their calculated difference at FEMA FIS infrastructure locations using the FIS profile for Cayuga Creek. In the FEMA FIS for Niagara County, Niagara Falls Boulevard (US-62) is referred to as Pine Avenue, and Cory Drive as Blank Road.

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

Source: (FEMA 2010b)				
Roadway Carried or Structure Name	**River Station (ft)**	**2% Water Surface Elevation (ft NAVD88)**	**1% Water Surface Elevation (ft NAVD88)**	**Difference in Water Surface Elevations (ft NAVD88)**
Buffalo Avenue (NY-384)	11+60	567.50	568.00	0.50
LaSalle Expressway	13+55	567.50	568.00	0.50
South Military Road	19+80	567.50	568.00	0.50
Lindbergh Avenue	35+90	567.75	568.75	1.00
Pear Avenue Pedestrian Bridge	45+00	567.75	568.75	1.00
Cayuga Drive	57+90	567.75	568.75	1.00
Niagara Falls Boulevard (US-62)	65+50	569.75	570.50	0.75
Porter Road (NY-182)	130+75	574.25	574.50	0.25
Niagara Falls International Airport Taxiway G Bridge	144+20	578.50	578.75	0.25
Niagara Falls International Airport Runway	166+85	581.25	281.50	0.25
Niagara Falls International Airport Overpass	204+60	585.25	585.75	0.50
Niagara Falls International Airport Overpass	223+10	587.75	588.00	0.25
Walmore Road	255+05	594.75	595.00	0.25
CSX Transportation	260+80	596.75	597.50	0.75

Source: (FEMA 2010b)				
Roadway Carried or Structure Name	**River Station (ft)**	**2% Water Surface Elevation (ft NAVD88)**	**1% Water Surface Elevation (ft NAVD88)**	**Difference in Water Surface Elevations (ft NAVD88)**
Lockport Road	280+20	604.50	608.25	3.75
Walmore Road	320+95	611.00	611.50	0.50
CSX Transportation	331+70	614.50	615.00	0.50
Cory Drive	335+40	614.75	615.00	0.25
Walmore Road	343+95	615.00	615.25	0.25

In assessing hydraulic capacity of the bridges and culverts located in the identified high-risk areas along Cayuga Creek, the FEMA FIS profile was used to determine the lowest annual chance flood elevation to flow under a culvert or the low chord of a bridge (Table 8). According to the FEMA FIS profiles, the LaSalle Expressway, Lindbergh Avenue, Cayuga Drive, Niagara Falls Boulevard, Niagara Falls Airport Taxiway G, Niagara Falls Airport Overpass (Station 223+10), Lockport Road, Walmore Road (Stations 255+05, 320+95, and 343+95), CSX Transportation (Station 331+70), and Cory Drive infrastructure crossings do not meet the NYSDOT guidelines for 2-ft of freeboard over the 2% annual chance flood. In addition, these structures do not meet the new CRRA climate change infrastructure guidelines as described above. The LaSalle Expressway, Cayuga Drive, Niagara Falls Boulevard, Niagara Falls Airport Taxiway G, Niagara Falls Airport Overpass (Station 223+10), Walmore Road (Station 255+05, 320+95, and 343+95), CSX Transportation (Station 331+70), and Cory Drive infrastructure crossings have low chord elevations below the 2% annual chance flood event. The Lindbergh Avenue and Lockport Road bridges have low chord elevations above the 2% annual chance flood event but do not meet the 2-ft of freeboard requirement (FEMA 2010b). Even though these structures may have hydraulic capacity restraints, the NYSDOT has to balance both physical constraints along with cost versus benefit of replacing existing bridges to meet the new CRRA guidelines.

In addition, the USGS *StreamStats* tool was used to calculate the bankfull widths and discharge for each structure along Cayuga Creek. Table 10 indicates that in Niagara County, New York, there is one bridge and six culverts that cross Cayuga Creek with openings that are smaller than the bankfull widths: Lockport Road bridge, and Walmore Road (Station 255+05, 320+95, and 343+95), Cory Drive, Saunders Settlement Road, and Chew Road culverts.

The structures with bankfull widths that are wider than the structures width indicate that water velocities have to slow and contract in order to pass through the structures, which can cause sediment depositional aggradation and the accumulation of sediment and debris. Aggradation can lead to the development of sediment and sand bars, which can cause upstream water surfaces to rise, increasing the potential for overtopping banks or backwater flooding.

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

Source: (NYSDOT 2016a; OBG 2020; USGS 2021; FEMA 2010b)					
Roadway Carried	**Structure Type**	**River Station (ft)**	**Structure Width (ft)**	**Bankfull Width (ft)**	**Bankfull Discharge (cfs)**
Walmore Road	Culvert	255+05	20	40.3	275
Lockport Road	Bridge	280+20	25	39.5	265
Walmore Road	Culvert	320+95	20	34.9	206
Cory Drive	Culvert	335+40	20	33.9	195
Walmore Road	Culvert	343+95	20	32.0	173
Saunders Settlement Road (NY-31)	Culvert	390+20	12	30.1	153
Chew Road	Culvert	436+00	12	27.2	125

4. CLIMATE CHANGE IMPLICATIONS

4.1 FUTURE PROJECTED STREAM FLOW IN CAYUGA CREEK

In New York State, climate change is expected to exacerbate flooding due to projected increases of 1-8% 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 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* (2018) draft report. In the report, two methods for estimating projected future discharges were discussed: an end of design life multiplier and the USGS *FutureFlow Explorer* map-based web application (NYSDEC 2018).

USGS *FutureFlow Explorer* v1.5 (https://ny.water.usgs.gov/maps/floodfreq-climate/) is discussed as a potential tool to project peak flows under various climate scenarios into the future. *FutureFlow* was developed by the USGS in partnership with the New York State Department of Transportation. This application is an extension for the USGS *StreamStats* map-based web application and projects future stream flows in New York state. The USGS team examined 33 global climate models and selected five that best predicted past precipitation trends in the region. The results were then downscaled to apply to all six hydrologic regions of New York state. Three time periods can be examined: 2024-2049, 2050-2074 and 2075-2099, as well as two Intergovernmental Panel on Climate Change (IPCC) greenhouse gas emission scenarios: RCP 4.5 and RCP 8.5. RCP 4.5 is considered a midrange-emissions scenario, and RCP 8.5 is a high-emissions scenario (Taylor et al. 2011; NYSDEC 2018).

In general, climate models are better at forecasting temperature than precipitation and contain some level of uncertainty with their calculations and results. The USGS recommends using *FutureFlow* projections as qualitative guidance to see likely trends within any watershed, and as an exploratory tool to inform selection of appropriate design flow. Current future flood projection models will not provide accurate results for basins that extend across more than one hydrologic region in New York (NYSDEC 2018).

Based on the current future flood projection models, flood magnitudes are expected to increase in nearly all cases in New York state, but the magnitudes vary among regions. While the *FutureFlow* application is still being upgraded, it can be used with appropriate caution. Climate model forecasts are expected to improve and as they do, the existing regression approach will be tested and refined further (NYSDEC 2018).

The NYSDEC recommends that future peak-flow conditions should be adjusted by multiplying relevant peak-flow parameters by a factor specific to the expected service life of the structure and geographic location of the project. For Western New York, the recommended design-flow multiplier is 10% increased flow for an end of design life of 2025-2100 (NYSDEC 2018). Table 11 provides a summary of the projected future peak stream flows using the FEMA FIS peak discharges and 10% CRRA design multiplier.

Table 11. Cayuga Creek Projected Peak Discharges

(Source: FEMA 2010b, NYSDEC 2018)						
			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 Little Niagara River	28.20	0+00	1,815	2,915	3,355	4,180
Upstream corporate limits, City of Niagara Falls	14.30	57+50	1,045	1,595	1,815	2,310
Upstream of confluence of Bergholtz Creek	14.02	63+55	706	983	1,100	1,375
Downstream of confluence of Western Tributary	12.74	136+70	642	895	1,005	1,243

Appendix D 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 0.6-ft higher at specific locations, generally upstream of bridges due to backwater, as a result of the increased discharges.

Table 12 provides a comparison of HEC-RAS base condition modeled water surface elevations at the FIS discharge locations, using the FEMA FIS peak discharge values, and future condition, using the FEMA FIS peak discharges and 10% CRRA design multiplier.

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

(Source: FEMA 2010b; NYSCEC 2018, USACE 2016a)						
			Water Surface Elevations (ft NAVD88) [1]			
Flooding Source and Location	Drainage Area (mi^2)	River Station (ft)	10-Percent	2-Percent	1-Percent	0.2-Percent
Upstream corporate limits, City of Niagara Falls	14.30	57+50	+0.3	+0.3	+0.4	+0.4
Upstream of confluence of Bergholtz Creek	14.02	63+55	+0.3	+0.3	+0.4	+0.4
Upstream corporate limits, Town of Niagara	12.74	346+50	+0.0	+0.6	+0.6	+0.0

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

5. FLOODING CHARACTERISTICS

5.1 FLOODING HISTORY

In the City of Niagara Falls, annual flooding in the lower Cayuga Creek watershed has historically been an issue in early spring due to snowmelt, heavy rains, and ice jams in the Upper Niagara River. Backwater effect created by ice jams in the Niagara River above Niagara Falls and long-duration storms over Lake Erie has caused flooding of Cayuga Island (FEMA 2010b). The annual installation of the Lake Erie-Niagara River Ice Boom at the head of the Niagara River has somewhat mitigated flooding associated with these ice jams (NYPA 2006). According to the effective FEMA FIS, in the City of Niagara Falls, low-lying areas are prone to flooding caused by the overflow of Cayuga Creek; prolonged spring thaws and heavy summer rainfall create the most severe flooding conditions.

Flooding in the Cayuga Village Trailer Park in the Town of Niagara has consistently been a problem. Melting snow in conjunction with moderate amounts of precipitation has been the primary cause of floods in the area. Existing flood control measures in the Cayuga Village Trailer Park consist of a private earthen berm built along Cayuga Creek, constructed to control floodwaters and protect structures in and around the Cayuga Village Trailer Park. While the berms do work to contain the flow in Cayuga Creek, the resulting higher velocities have previously caused the berm to breach in areas (NYPA 2006).

In the Town of Wheatfield, flooding may occur during peak storm events adjacent to Cayuga Creek due to inadequate grades, low stream banks, restricting culvert sizes, and debris and sediment deposits. Recent residential development in the Town of Wheatfield could increase potential flood-related damage. The Town of Wheatfield's drainage program, which performs annual maintenance and clearing of all of the main drainage ways in the Town of Wheatfield, has somewhat addressed the reoccurring flooding of Walmore Road

According to the effective FEMA FIS, flooding of note due to severe storm events occurred in February 1985, January 1996, January 1998, March 2003, April 2005, and March 2007.

FEMA FIRMs are available for Cayuga Creek from FEMA. Figures 5-1 and 5-2 display the floodway and 1 and 0.2% annual chance flood event boundaries for Cayuga Creek as determined by FIRM for Niagara County (FEMA 2010a).

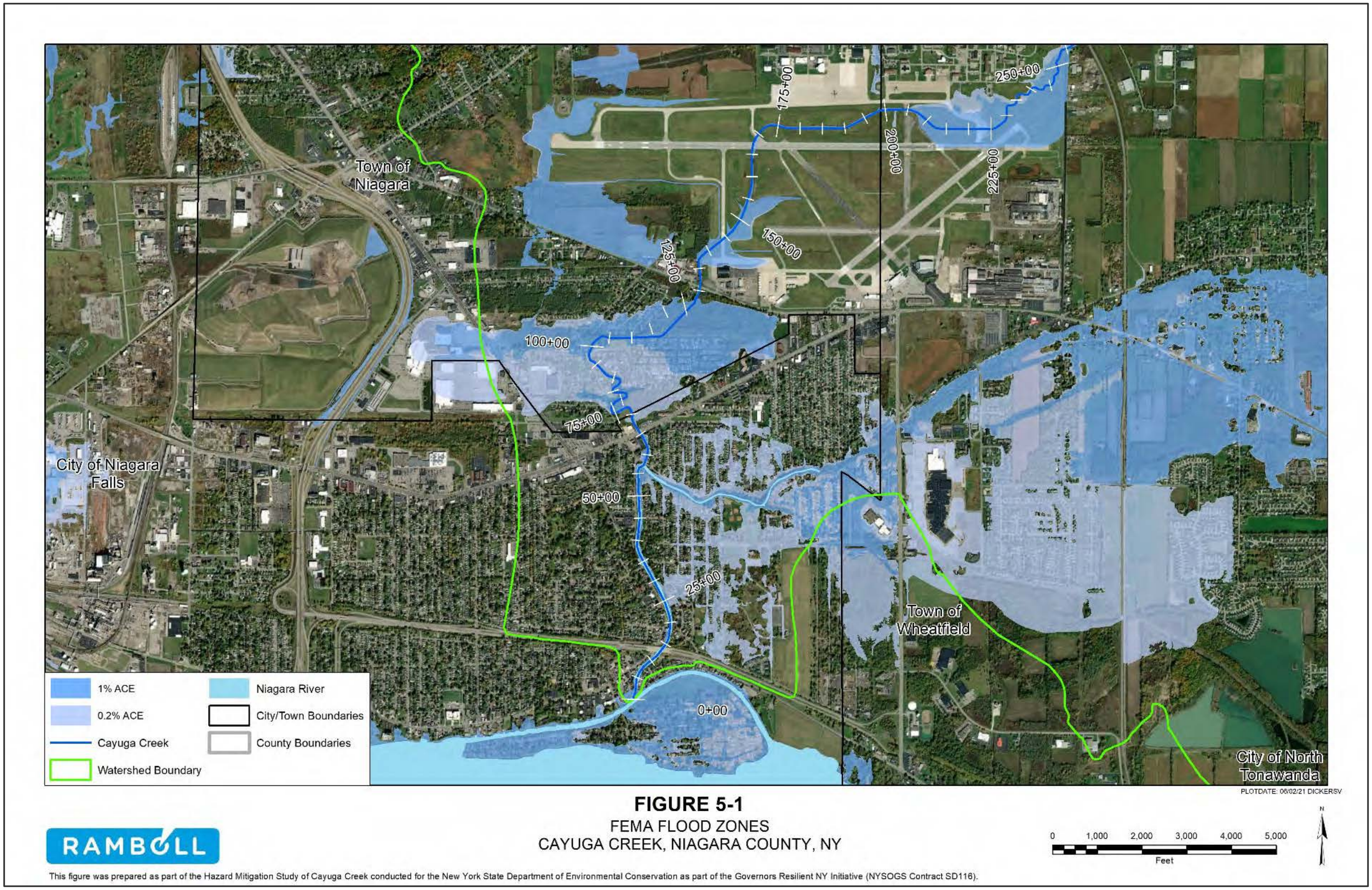

Figure 5-1. Cayuga Creek FEMA Flood Zones, City of Niagara Falls and Town of Niagara, Niagara County, NY.

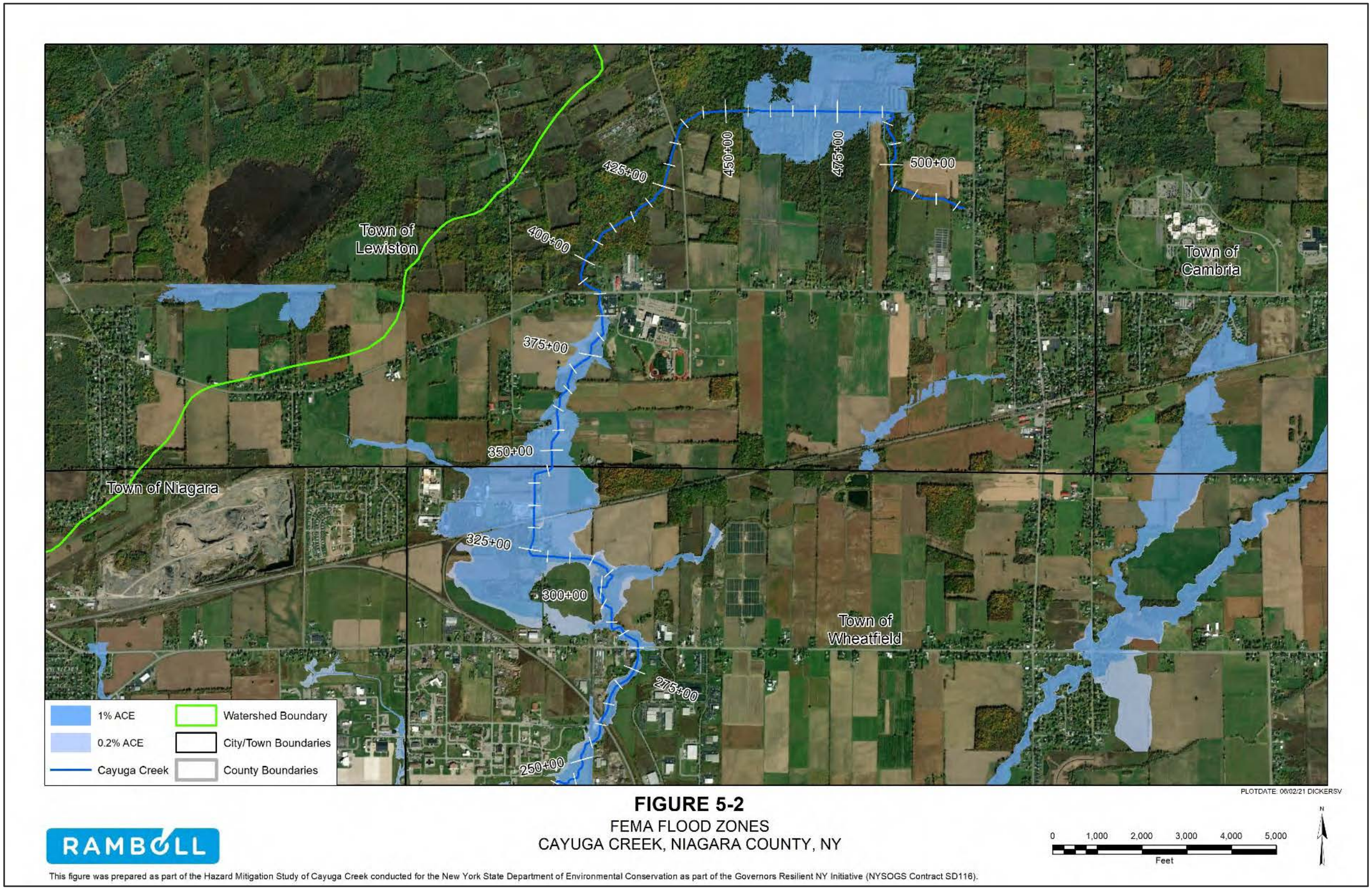

Figure 5-2. Cayuga Creek FEMA flood zones, Town of Wheatfield and Town of Lewiston, Niagara County, NY.

6. FLOOD RISK ASSESSMENT

6.1 FLOOD MITIGATION ANALYSIS

For this study of Cayuga 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-yr 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-yr floods, have a 10, 2, 1, and 0.2% chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than one year are considered. The analyses reported herein reflect flooding potentials based on conditions existing in the county at the time of completion of this study (FEMA 2021).

Hydraulic analysis of Cayuga Creek was conducted using the HEC-RAS v5.0.7 program (USACE 2019). 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 Cayuga Creek in Niagara County was completed by FEMA in 2010. 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:

- Niagara County, New York LiDAR DEM data (NYSDEC 2007)
- New York State Digital Ortho-imagery Program imagery for Niagara County (NYSOITS 2017)
- National Land Cover Database (NLCD) data (USGS 2019)
- FEMA FIS peak discharge data (FEMA 2010b)
- 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 Cayuga Creek beginning downstream of LaSalle Expressway (river station 3+00) and extending upstream of Porter Road (river station 136+25) and downstream of Lockport Road (river station 270+00) and extending upstream of Saunders Settlement Road (river station 400+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 hydraulic model was developed from the effective FEMA hydraulic model 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 10.7, LiDAR DEM data, and NLCD land cover data, terrain profiles with elevations, cross-section downstream reach lengths, and Manning's n values were assigned to each cross-section
- These features were then imported into HEC-RAS, where the overland topographic data was combined with the channel bathymetry from the effective hydraulic model and a 1-D steady flow simulation was performed using FEMA FIS peak discharges

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. The simulation results of the proposed conditions were evaluated based on their reduction in water surface elevations. As the potential flood mitigation strategies are, at this point, preliminary, inundation mapping was not developed from the computed water surface profiles for each potential mitigation alternative. Inundation shown on figures within this report reflects that of the effective FEMA FIS for Niagara County. The effectiveness of each potential mitigation strategy was evaluated based on reduction in water surface elevations. In addition to reduced water surface elevations at the inundated structures, some structures may be removed from the inundation for a given annual chance exceedance event by implementing the mitigation strategies.

The flood mitigation strategies that were modeled were:

- 1-1: Flood Bench Downstream of Porter Road
- 1-2: Flood Bench Upstream of Niagara Falls Boulevard
- 1-3: Flood Control Detention Structure Downstream of Porter Road
- 1-4: Levee Upstream of Elderberry Place
- 2-1: Replace Upstream Walmore Road Circular Culverts with Box Culvert
- 2-2: Replace Cory Drive Circular Culverts with Box Culvert
- 2-3: Replace Downstream Walmore Road Circular Culvert with Box Culvert
- 2-4: Increase Size of CSX Transportation Railroad Bridge Crossing
- 2-5: Install Crossing Pipes into CSX Transportation Railroad Bridge Embankment

- 2-6: Flood Bench Upstream of Cory Drive
- 2-7: Flood Bench Upstream of Walmore Road

Stationing references for the flood mitigation measures are based on the NYSDEC hydrography GIS data for Cayuga Creek, which differs from the FEMA FIS stationing values.

6.2 COST ESTIMATE ANALYSIS

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

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

For mitigation alternatives where increases in bridge sizes were evaluated, bridge size increases were initially analyzed based on 2-ft 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 only performed for projects determined to be constructible and practical.

For mitigation alternatives where increases in culvert sizes were evaluated, culvert size increases were initially analyzed based on the NYSDOT highway drainage standards of successfully passing the 2% annual chance flood hazard. If the NYSDOT standard was achieved, then the CRRA recommended guideline of 2-ft of freeboard (3-ft for a critical structure) was analyzed. 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 only performed for 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.

6.3 ICE JAM FORMATION

According to the USACE Cold Regions Research and Engineering Laboratory (CRREL) ice jam database, National Centers for Environmental Information (NCEI) storm events database, the FEMA FIS, and the stakeholder engagement meeting, there have been no reported or observed ice-jam events on Cayuga Creek (CRREL 2021, NCEI 2021, FEMA 2010b). Therefore, ice-jam flooding was determined not to be a driving factor of flood risk along Cayuga Creek.

6.4 HIGH-RISK AREAS

Based on the FEMA FIS, NCEI storm events database, historical flood reports, and stakeholder input from engagement meetings, two areas along Cayuga Creek were identified as high-risk flood areas in the Town of Niagara, Town of Wheatfield, and Town of Lewiston.

6.4.1 High-risk Area #1: Niagara Falls Boulevard to Porter Road, Town of Niagara, New York

High-risk Area #1 is the area along Cayuga Creek in the Town of Niagara beginning upstream of Niagara Falls Boulevard and extending immediately downstream of Porter Road, as shown in Figure 6-1 below. The flooding in this area poses a flood risk threat to residential and commercial properties within the 1% and 0.2% annual chance event flooding extents.

According to the NYSDOT Functional Class Viewer, Niagara Falls Boulevard and Porter Road are both classified as Urban Principal Arterial, which is defined as a roadway that serves the major centers of activity of a metropolitan area as the highest traffic volume corridors and carries a high proportion of the total urban area travel on a minimum mileage (NYSDOT 2016b).

In this reach, residential neighborhoods adjacent to Cayuga Creek are at a higher risk of flood damages due to their proximity to the creek channel and the current lack of flood protection measures. Figure 6-2 is the FEMA FIS profile for High-risk Area #1; in the FEMA FIS for Niagara County, Niagara Falls Boulevard (US-62) is referred to as Pine Avenue. According to the FIS, Niagara Falls Boulevard's low chord elevation is able to pass the 10% annual chance event. However, the 2, 1, and 0.2% annual chance event WSEL exceed the low chord elevation. Porter Road bridge is able to pass all storm events considered in the FEMA FIS (FEMA 2010b).

As of July 2021, Buffalo Niagara Waterkeeper is implementing a stream restoration project along Cayuga Creek between Elderberry Place and Porter Road. The restoration design creates a new meandering channel to restore fish and wildlife habitat within the Cayuga Creek floodplain and reconnect Cayuga Creek to its natural floodplain. All proposed alternatives for High-risk Area #1 can be implemented in conjunction with the Buffalo Niagara Waterkeeper project.

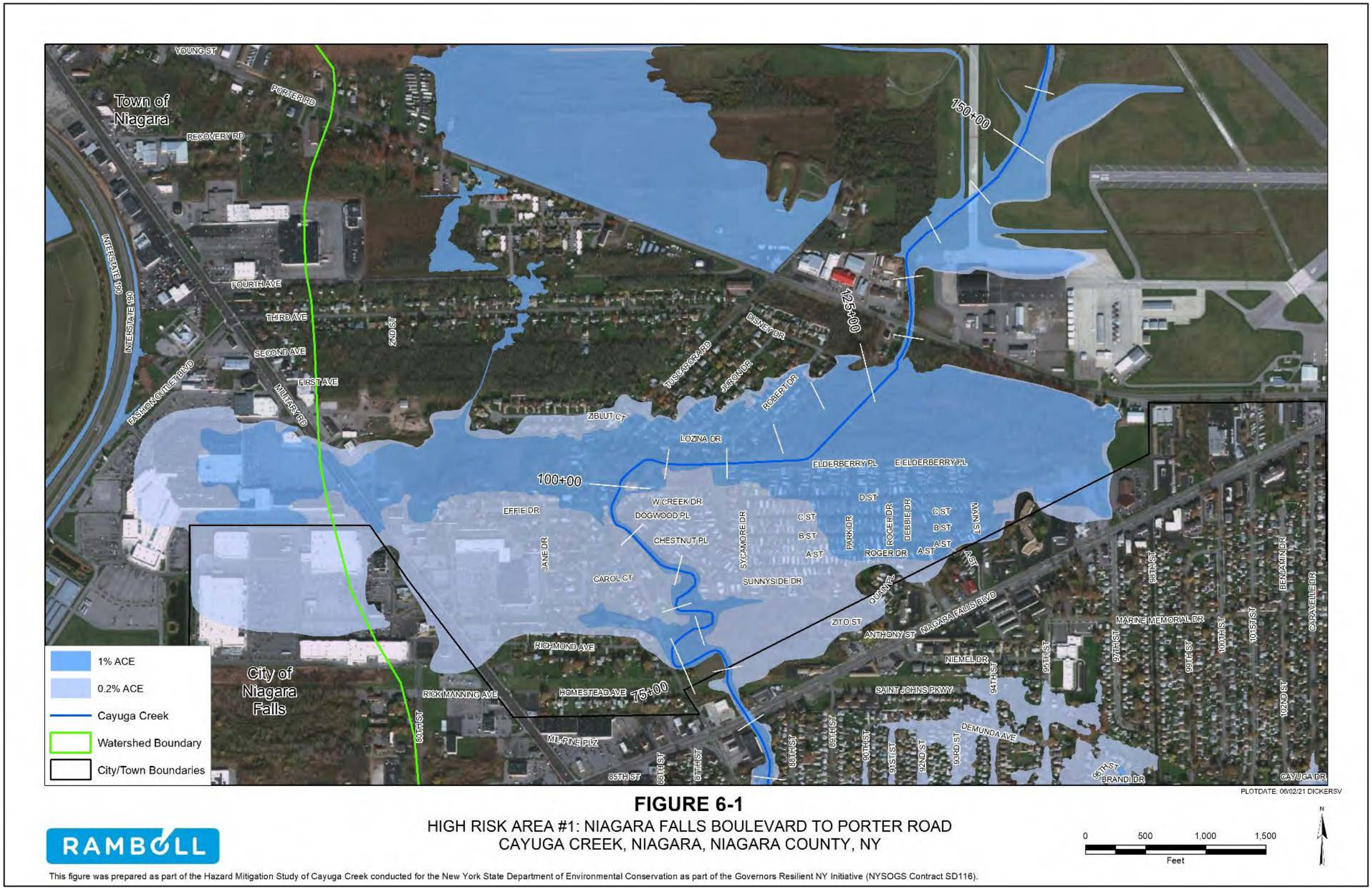

Figure 6-1. High-risk Area #1: Niagara Falls Boulevard to Porter Road, Town of Niagara, NY.

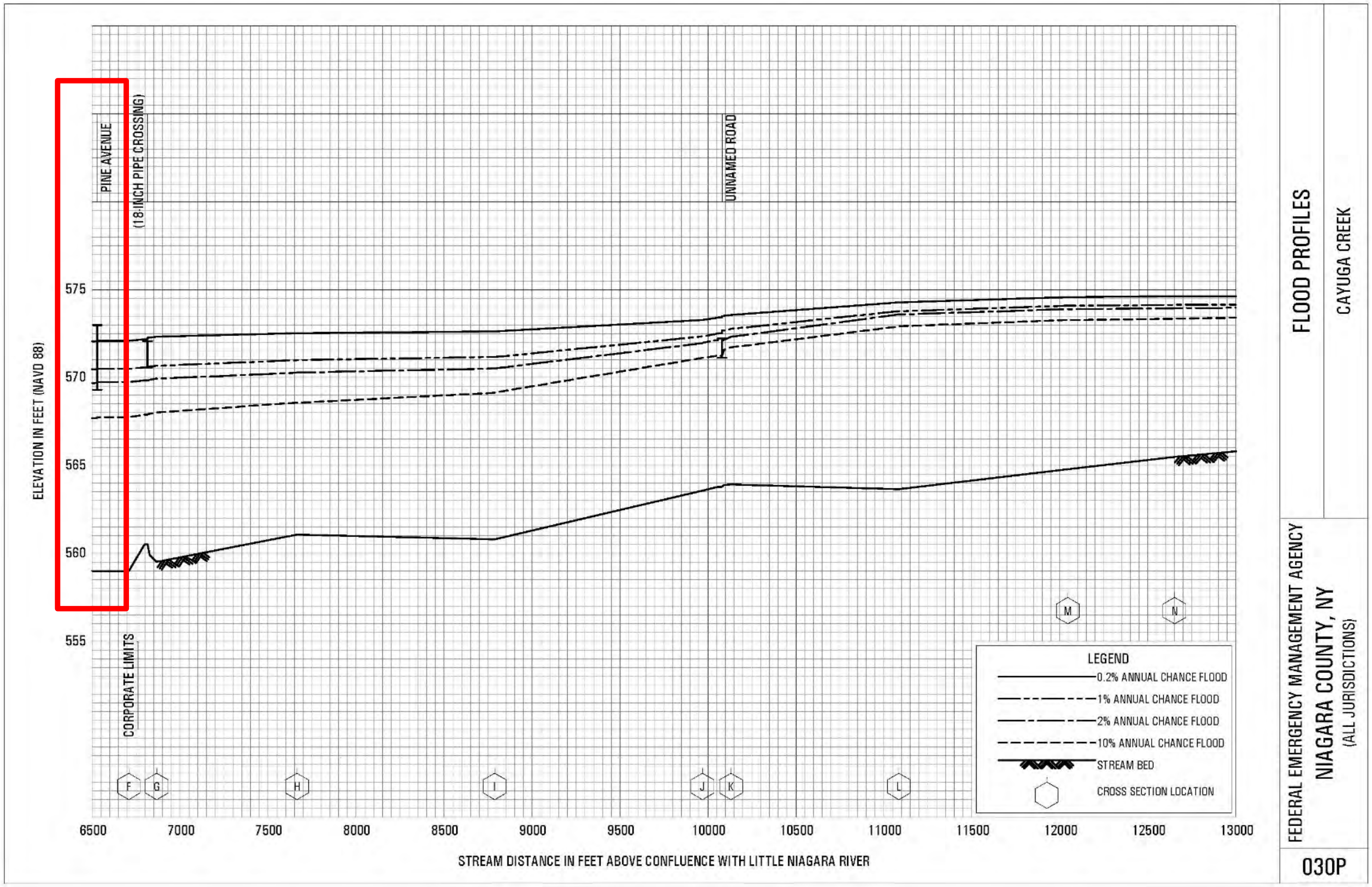

Figure 6-2. FEMA FIS profile for Cayuga Creek in the vicinity of Niagara Falls Boulevard, Town of Niagara, NY.

Note: Located at river station 65+50 on the FEMA FIS profile.

6.4.2 High-risk Area #2: Walmore Road in the Vicinity of Niagara Falls International Airport

High-risk Area #2 is the area along Cayuga Creek in the Towns of Wheatfield and Lewiston in the vicinity of Walmore Road upstream of Niagara Falls International Airport, as shown in Figure 6-3 below. The flooding in this area poses a flood risk threat to commercial properties and cropland within the 1% and 0.2% annual chance event flooding extents. According to the NYSDOT functional classifications, Walmore Road is classified as an Urban Local Street, which provides direct access to abutting land and access to higher order systems (NYSDOT 2016b).

Cayuga Creek in the vicinity of Walmore Road is suspectable to open-water flooding due to multiple factors, including sediment aggradation restricting the in-channel flow area along Cayuga Creek through this reach, and inadequate hydraulic capacity at the Walmore Road bridge crossing. Figure 6-4 is the FEMA FIS profile for High-risk Area #2 (FEMA 2010). Walmore Road's low chord elevation at both bridge crossings with Cayuga Creek is unable to pass any flood events considered in the FEMA FIS. The inability of this bridge to pass high flow events increases the chance for backwater flooding and potential flood damages to areas and properties both downstream and upstream of the bridge crossing.

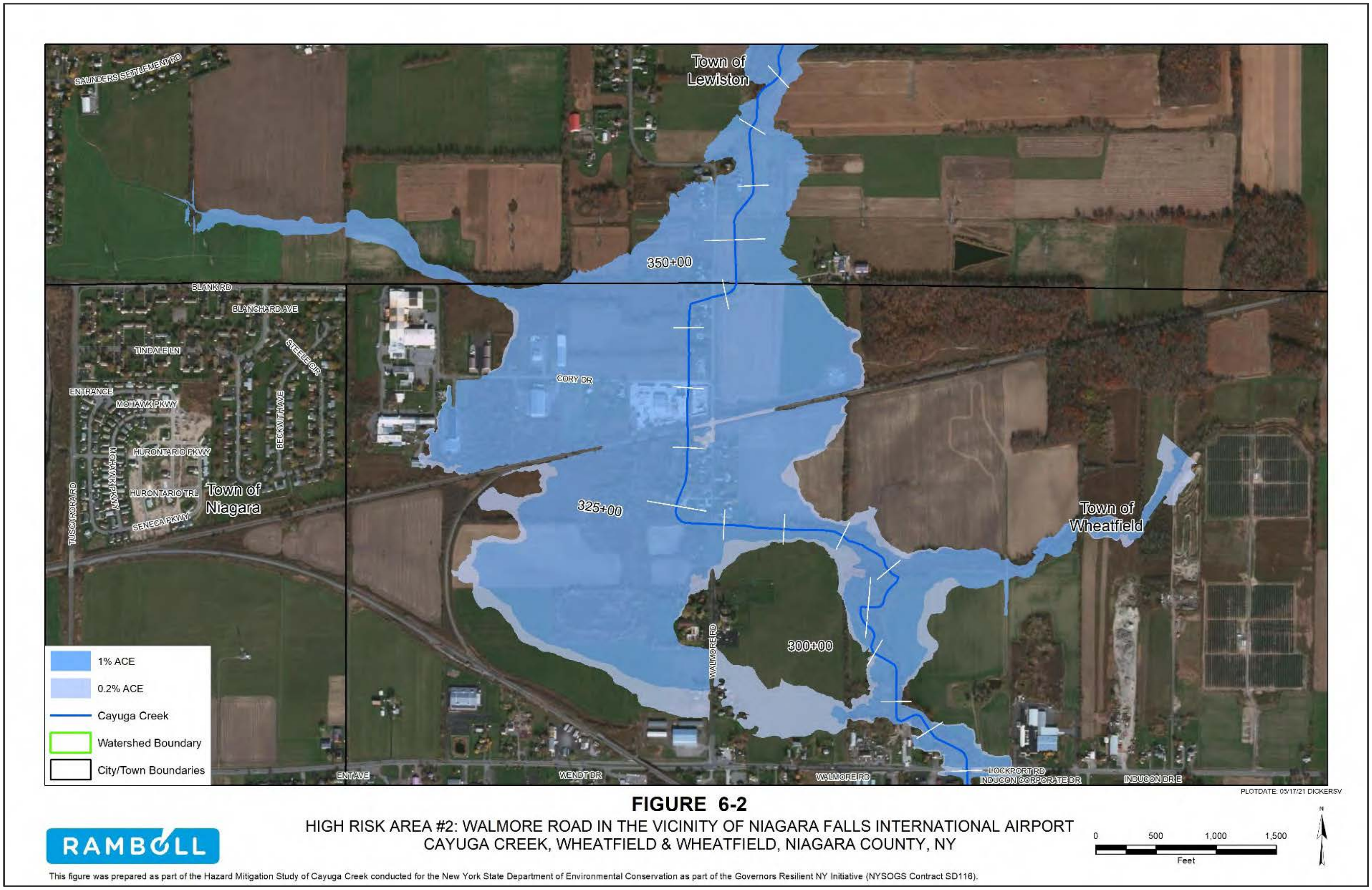

Figure 6-3. High-risk Area #2: Walmore Road in the vicinity of Niagara Falls International Airport.

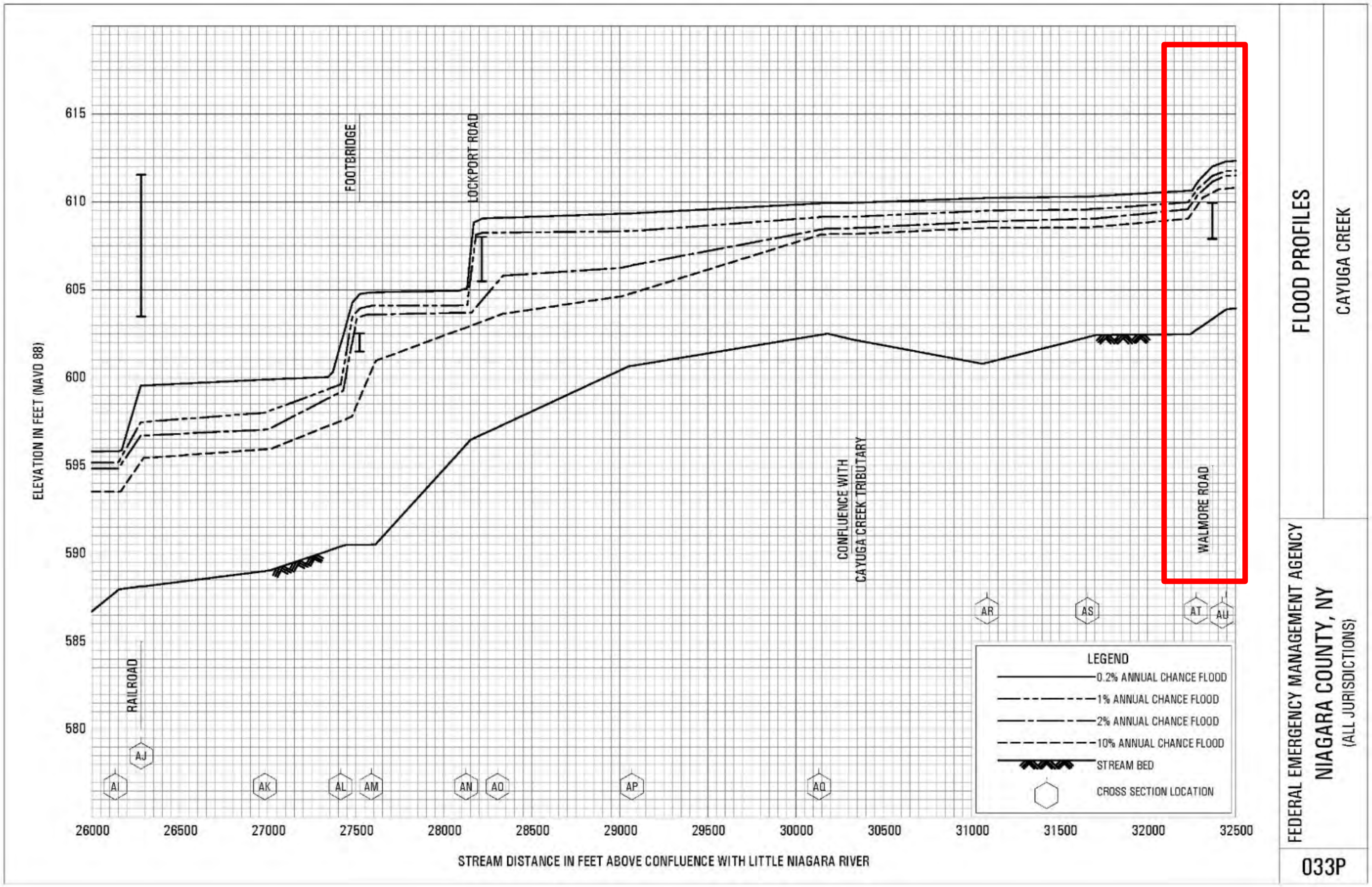

Figure 6-4. FEMA FIS profile for Cayuga Creek in the vicinity of Walmore Road.

Note: Located at river station 323+50 on the FEMA FIS profile.

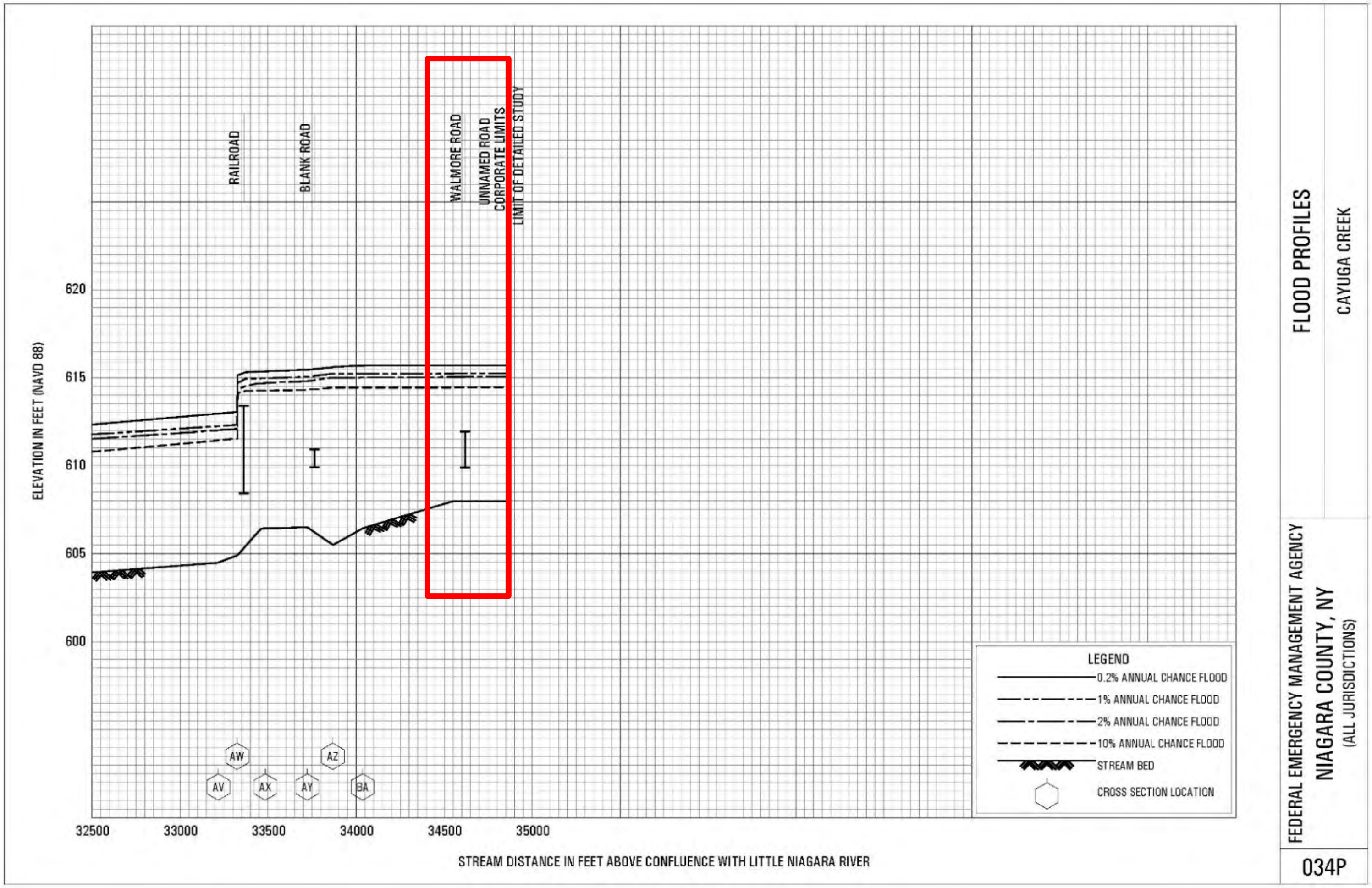

Figure 6-5. FEMA FIS profile for Cayuga Creek in the vicinity of Walmore Road.

Note: Located at river station 346+00 on the FEMA FIS profile.

7. MITIGATION ALTERNATIVES

The following are flood mitigation alternatives that have the potential to reduce water surface elevations along high-risk areas of Cayuga Creek. These alternatives could potentially reduce flood related damages in areas adjacent to the creek. The Town of Niagara, Town of Wheatfield, and Town of Lewiston should evaluate each alternative and consider the potential effects to the community and the level of community buy-in for each before pursuing them further.

7.1 HIGH-RISK AREA #1

7.1.1 Alternative #1-1: Flood Bench Downstream of Porter Road

Installing a flood bench provides additional storage and floodplain width, potentially reducing flood damages in the event of flooding and addressing issues within High-risk Area #1. The flood benches are within FEMA's designated Regulatory Floodway and Zone AE. The Regulatory Floodway is defined as the channel of a river or other watercourse and the adjacent land areas that must be reserved 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. Zone AE includes areas with a 1% annual chance of flooding where BFEs are provided by FEMA (FEMA 2000, FEMA 2010a).

The flood benches would potentially benefit and reduce the flood risk for the properties adjacent to Cayuga Creek downstream of Porter Road. The proposed flood bench is located on the left bank of Cayuga Creek immediately downstream of Porter Road between river stations 125+00 and 130+00 (Figure 7-1, next page). The total acreage of the flood bench is approximately 11 acres with a minimum elevation of 569 feet NAVD88.

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

The proposed condition modeling simulation confirmed that the area between Niagara Falls Boulevard and Porter Road is in a high-risk flood area. The model results simulated a maximum water surface reduction of approximately 0.4 feet in the area adjacent to the flood bench (Figure 7-2, next page).

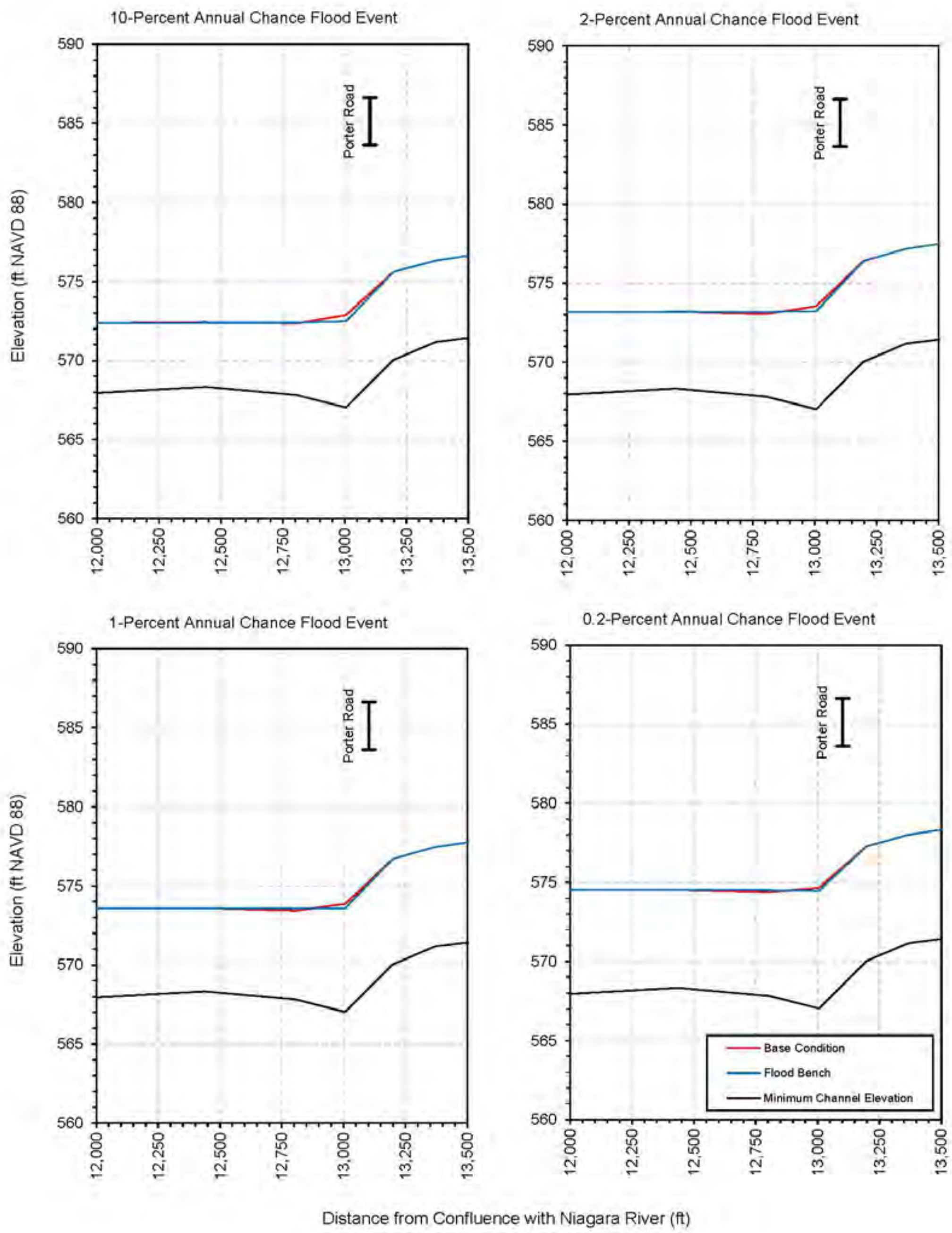

Figure 7-2. HEC-RAS model simulation output results for Alternative #1-1.

The potential benefits of this strategy are limited to the areas in the vicinity of the flood bench, specifically between river stations 125+00 and 130+00.

The Rough Order Magnitude cost is $3.71 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

7.1.2 Alternative #1-2: Flood Benches Upstream of Niagara Falls Boulevard

Installing a flood bench provides additional storage and floodplain width, potentially reducing flood damages in the event of flooding and addressing issues within High-risk Area #1. Three flood benches were modeled upstream of the Niagara Falls Boulevard bridge crossing (Figure 7-3). All three flood benches are within the FEMA Regulatory Floodway or Zone AE (FEMA 2000, FEMA 2010a). The flood benches would potentially benefit and reduce the flood risk for the properties along Cayuga Creek upstream of Niagara Falls Boulevard.

Figure 7-3. Location map for Alternative #1-2.

A summary of the input data for the proposed flood benches is presented in Table 13.

Table 13. Alternative #1-2 HEC-RAS Input

Simulation ID	River Station (ft)	Area (ac)	Flood Bench Elevation (ft NAVD88)
Bench A	85+50 to 91+00	0.98	566
Bench B	77+50 to 85+00	1.56	566
Bench C	72+00 to 82+50	0.68	566

When all three flood benches are considered simultaneously, the model results simulated a maximum water surface reduction of approximately 0.3 feet in the area adjacent to the flood bench (Figure 7-4, next page). Based on the analysis of the HEC-RAS model simulation results, when considered individually, installing a flood bench upstream of Niagara Falls Boulevard would not provide significant flood protection in this reach from open-water flooding.

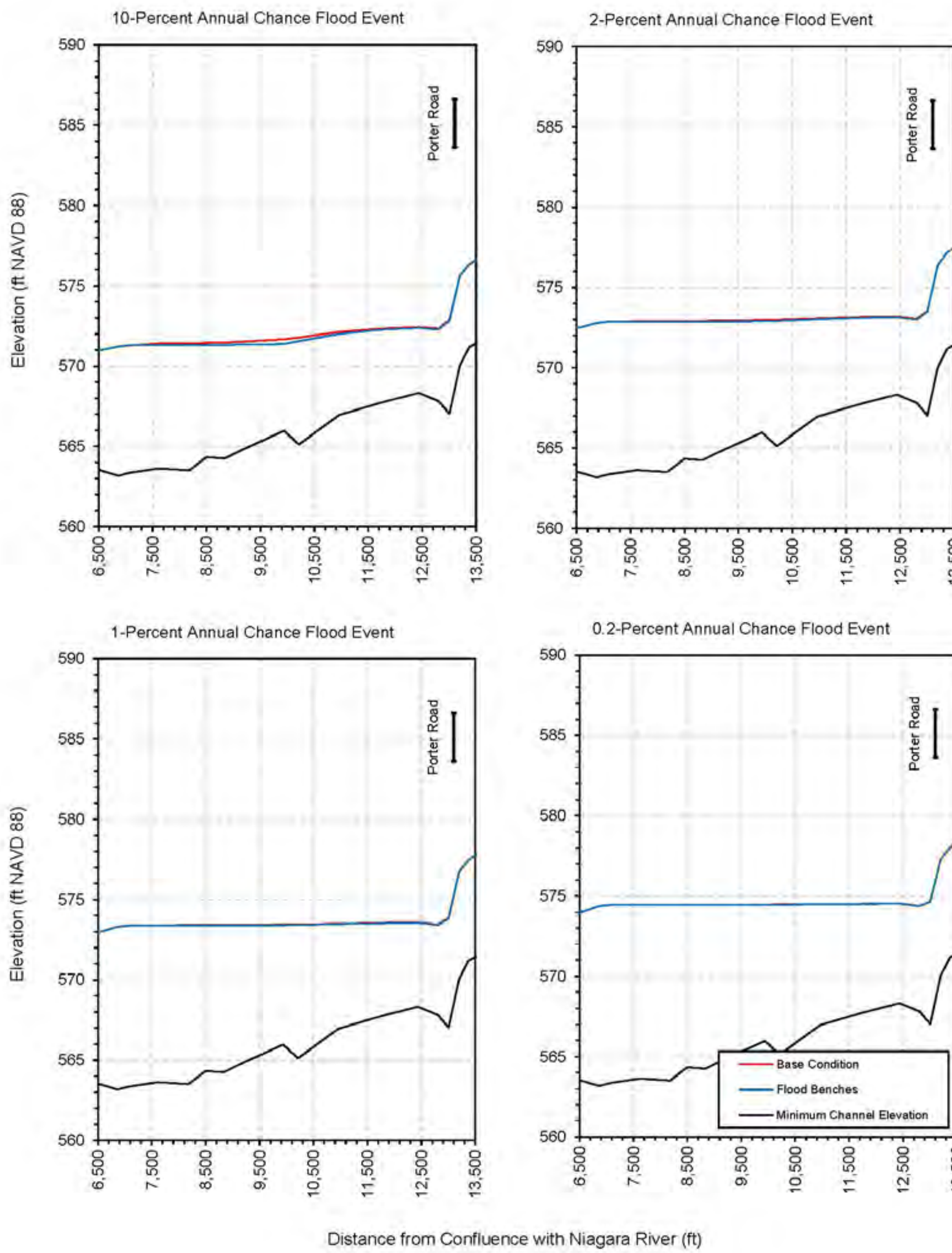

Figure 7-4. HEC-RAS model simulation output results for Alternative #1-2.

The potential benefits of this strategy are limited to the areas in the vicinity and directly upstream of the flood bench, specifically between river stations 72+00 and 115+00. Installing only one of the proposed flood benches is not recommended due to the ineffectiveness to provide adequate flood protection to the areas immediately upstream of Niagara Falls Boulevard, and the additional costs associated with installing a flood bench.

The Rough Order Magnitude cost is $1.97 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

7.1.3 Alternative #1-3: Flood Control Detention Structure Downstream of Porter Road

The construction of small flood-control detention structures in the headwaters of flood-prone streams has proven successful at preventing flood damage in small towns throughout the United States (Helms 1986). The structures are traditionally located in agricultural fields or undeveloped land. They maintain little to no permanent pool and are designed to detain water during larger flow events, decrease peak-flow water surface elevations, and minimize flood further downstream in developed areas. The area between Elderberry Place and Porter Road along Cayuga Creek would be the best location for a flood control structure in High-risk Area #1 (Figure 7-5, next page).

Figure 7-5. Location map for Alternative #1-3.

In New York State, a joint permit application from the NYSDEC and USACE may be required 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 flood 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.

To acquire a permit for the construction, reconstruction, or repair of a dam or other impoundment, a developer must submit an application to the NYSDEC for an Article 15 dam Construction Permit, along with the USACE Joint Application Form that, if approved, would allow activities affect waters within the state.

The USACE has the authority to construct small flood-risk reduction projects that are engineeringly feasible, structurally sound, and cost-efficient through the authority provided under Section 205 of the 1948 FCA, as amended. Coordination should also occur with the NYSDEC as they need to be the non-federal sponsor on these projects. In addition, a FEMA BCA would need to be performed to determine the cost-effectiveness of the alternative before applying for the FEMA mitigation grant programs funding. The BCA is used to determine the BCR for the project, where a project is considered cost-effective when the BCR is 1.0 or greater.

Due to the conceptual nature of this measure and the 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 Cayuga Creek watershed are expected to be significant.

7.1.4 Alternative #1-4: Levee along Elderberry Place

Installing a levee along Elderberry Place is intended to address flooding experienced at the mobile park home located on the left bank of Cayuga Creek between Niagara Falls Boulevard and Porter Road. An approximately 1,350-ft long and 2-ft high levee along Elderberry Place would help prevent the flooding of Cayuga Creek from impacting the mobile park home during flood events up to and including the 1% annual chance event (Figure 7-6, next page). The proposed levee begins at approximately river station 117+50 as there is not enough room along the Cayuga Creek left stream bank to construct a levee along Elderberry Place before this point.

Figure 7-6. Location map for Alternative #1-4.

Any levee constructed in the Cayuga Creek watershed would need to follow the USACE *Design and Construction of Levees* EM 110-2-1913 guidelines, including obtaining the required individual, regional, and nationwide permits for design, construction, and maintenance of a levee (USACE 2000). USACE has the authority to construct small flood-risk reduction projects that are engineeringly feasible, structurally sound, and cost-efficient through the authority provided under Section 205 of the 1948 FCA, as amended. Coordination should also occur with the NYSDEC as they need to be the non-federal sponsor on these projects. In addition, a FEMA BCA would need to be performed to determine the cost-effectiveness of the alternative before applying for FEMA mitigation grant programs funding.

A levee would require significant engineering, construction, and maintenance efforts throughout its lifespan, resulting in a relatively high cost burden. Levees should be placed as far away from the creek channel as possible to maximize the capacity of the natural floodplain to convey floodwaters and designed and constructed in a manner that does not cause flooding downstream of the structure. In addition, strict requirements would need to be met to comply with NFIP requirements (44 CFS §65.10) to affect a building's flood insurance rating.

The proposed model results simulated a maximum water surface reduction of approximately 0.5 feet in the area of the mobile park home (Figure 7-7, next page).

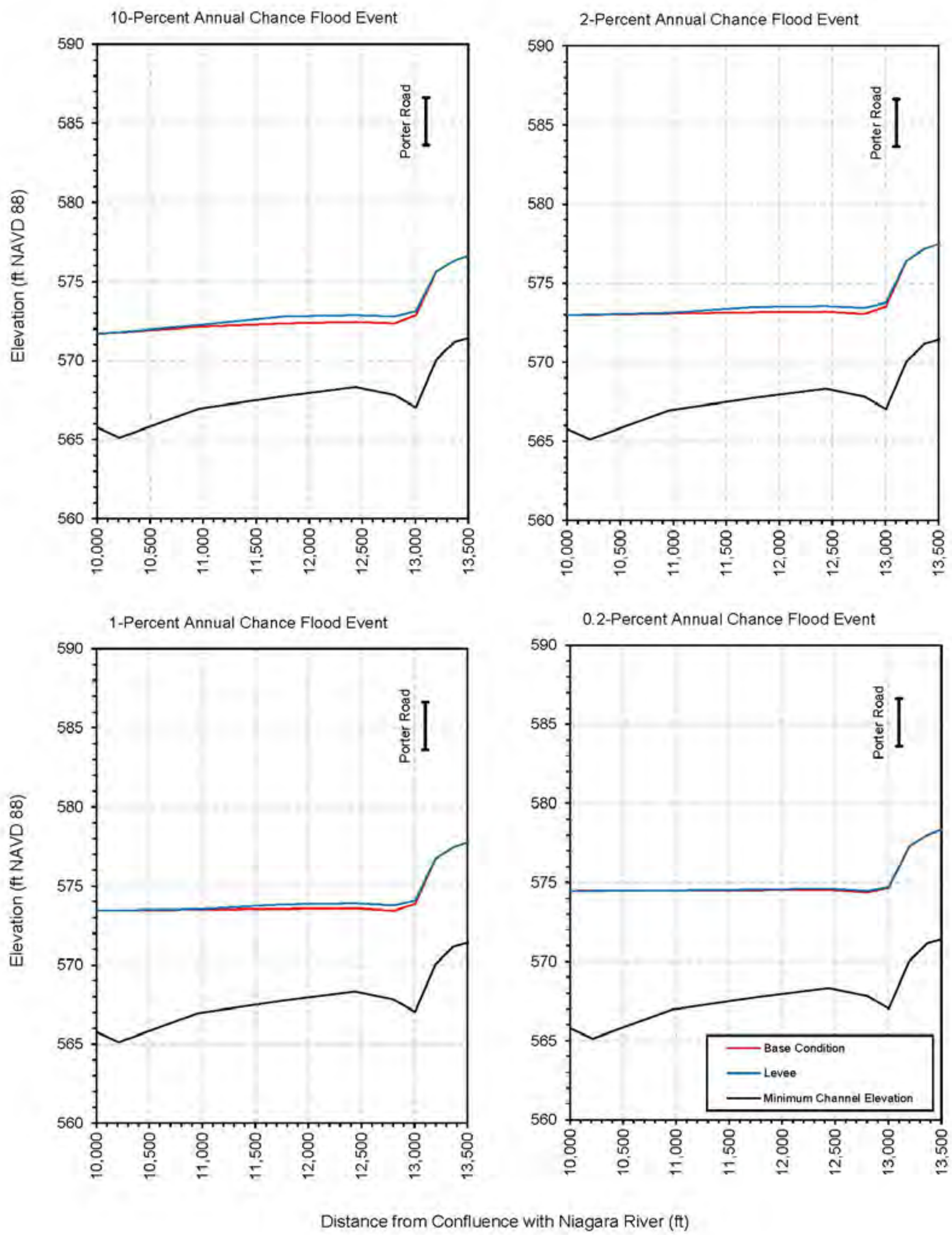

Figure 7-7. HEC-RAS model simulation output results for Alternative #1-4.

The Routh Order Magnitude cost is $230,000, which does not include permitting, annual maintenance, or land acquisition costs for survey, appraisal, and engineering coordination. This ROM estimate assumes suitable clay material for levee fill that meets USACE requirements is readily available and nearby the Town of Niagara.

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

7.2 HIGH-RISK AREA #2

7.2.1 Alternative #2-1: Replace Upstream Walmore Road Circular Culverts with Box Culvert

This measure increases the cross-sectional flow area of the channel by replacing the existing circular culverts with a single box culvert at the Walmore Road crossing located at river station 343+95 (Figure 7-8). The Town of Wheatfield owns this culvert crossing.

Figure 7-8. Location map for Alternative #2-1.

The existing culvert structure has three 48-inch circular culverts (Figure 7-9). The flooding in the vicinity of the culvert poses a flood risk threat to the roadway and the nearby commercial and agricultural properties both upstream and downstream of the culvert crossing.

Figure 7-9. Upstream Walore Road circular culverts, Wheatfield, NY.

According to the HEC-RAS base condition model and FEMA FIS, the upstream Walmore Road crossing does not allow discharges at the 10, 2, 1, and 0.2% annual chance flood water surface elevation to pass, which causes water surface elevations to exceed the low chord elevation and cause backwater upstream of the culvert (FEMA 2010b). In addition, the culverts do not provide the NYSDOT recommended drainage for a culvert in a regulatory floodway, which is the 1% annual chance flood hazard.

This measure would potentially reduce the flood risk and benefit the properties adjacent to and immediately upstream of the Walmore Road culvert. The box culvert replacement increased the cross-sectional flow area of the bridge by replacing the existing three 48-inch circular culverts with a single 20-ft wide by 6-ft high box culvert. The proposed condition modeling simulation indicated water surface reductions of up to 2.4 feet immediately upstream of the Walmore Road crossing extending up to the Saunders Settlement Road culvert (Figure 7-10, next page).

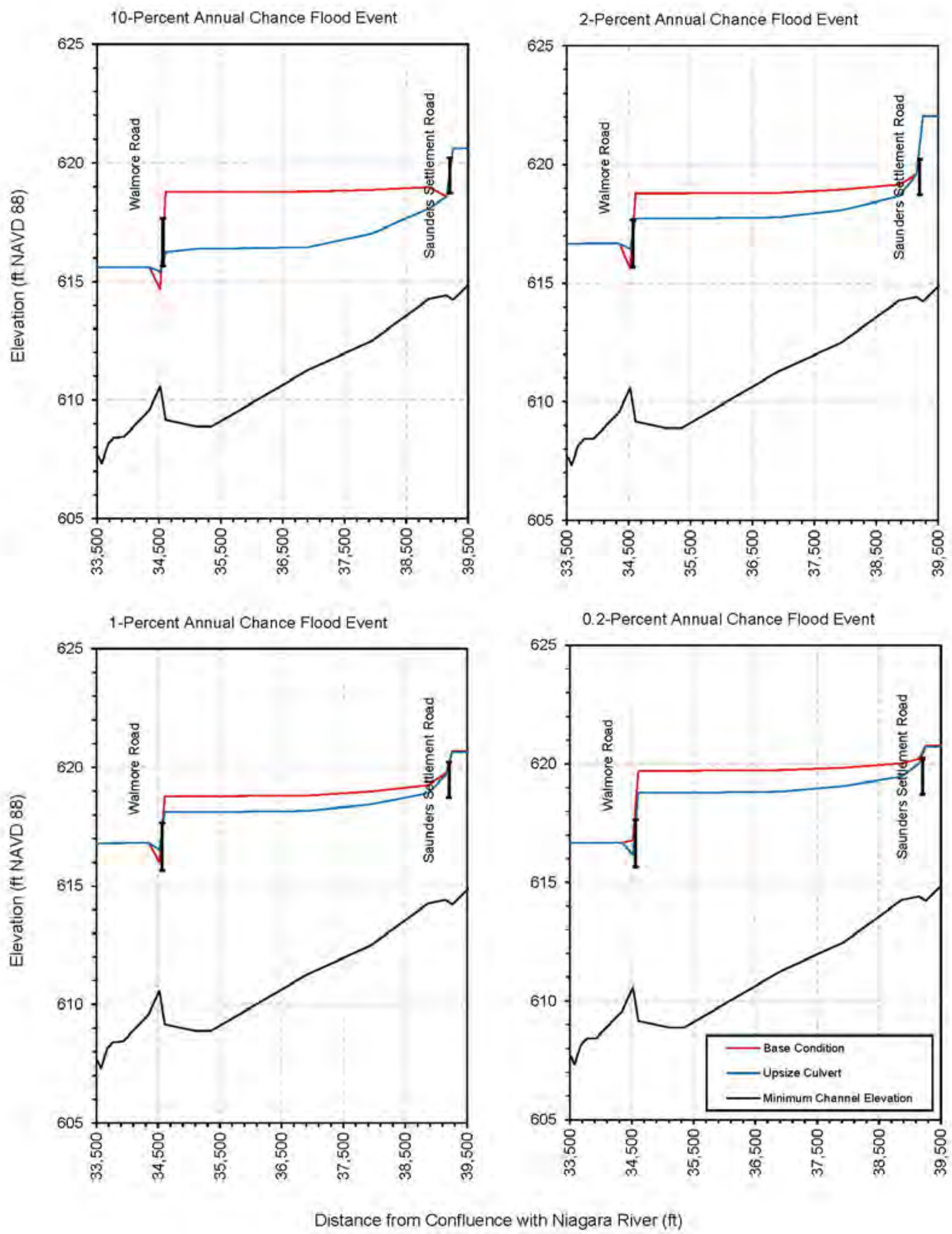

Figure 7-10. HEC-RAS model simulation output results for Alternative #2-1.

The potential water surface elevation reduction benefits of this alternative would extend approximately 4,500-ft upstream to the Saunders Settlement Road culvert.

The Rough Order Magnitude cost is $410,000, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

7.2.2 Alternative #2-2: Replace Cory Drive Circular Culverts with Box Culvert

This measure increases the cross-sectional flow area of the channel by replacing the existing circular culverts with a single box culvert at the Cory Drive crossing located at river station 335+40 (Figure 7-11). The Town of Wheatfield owns this culvert crossing.

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

The existing culvert structure has three 48-inch circular culverts (Figure 7-12, next page). The flooding in the vicinity of the culvert poses a flood risk threat to the roadway and the nearby commercial and agricultural properties both upstream and downstream of the culvert crossing.

Figure 7-12. Cory Drive circular culverts, Wheatfield, NY.

According to the HEC-RAS base condition model and FEMA FIS, the upstream Walmore Road crossing does not allow discharges at the 10, 2, 1, and 0.2% annual chance flood water surface elevation to pass, which causes water surface elevations to exceed the low chord elevation and cause backwater upstream of the culvert (FEMA 2010b). In addition, the culverts do not provide the NYSDOT recommended drainage for a culvert in a regulatory floodway, which is the 1% annual chance flood hazard.

This measure would potentially reduce the flood risk for and benefit the properties adjacent to and immediately upstream of the Cory Drive culvert. The box culvert replacement increased the cross-sectional flow area of the bridge by replacing the existing three 48-inch circular culverts with a single 30-ft wide by 5-ft high box culvert. The proposed condition modeling simulation indicated no significant water surface reductions in the vicinity of the Cory Drive culvert (Figure 7-13, next page).

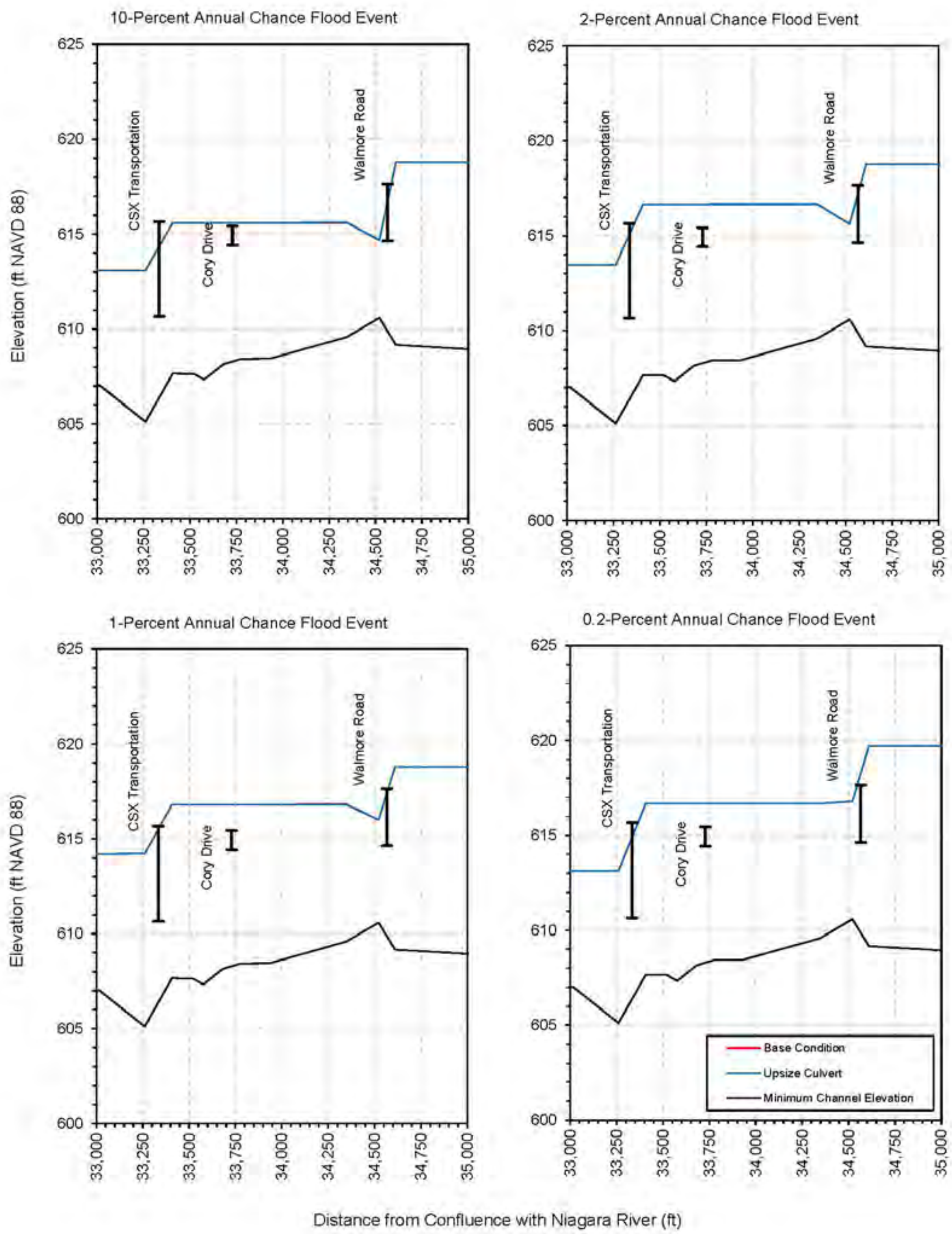

Figure 7-13. HEC-RAS model simulation output results for Alternative #2-2.

Based on the analysis of the HEC-RAS model simulation results, replacing the circular culverts under Cory Drive with a box culvert would not provide significant flood protection in this reach from open-water flooding. This measure is not recommended due to the ineffectiveness of providing adequate flood protection to the areas immediately upstream and downstream of Cory Drive and the additional costs associated with replacing the circular culverts. According to the FIS, the primary cause of flooding in the vicinity of Cory Drive is backwater from the CSX Transportation Railroad bridge crossing. Therefore, this measure is not recommended unless a mitigation alternative at the CSX Transportation Railroad bridge crossing is also implemented.

The Rough Order Magnitude cost is $490,000, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

7.2.3 Alternative #2-3: Replace Downstream Walmore Road Pipe Culvert with Box Culvert

This measure increases the cross-sectional flow area of the channel by replacing the existing pipe culvert with a box culvert at the Walmore Road crossing located at river station 320+95 (Figure 7-14, next page). The Town of Wheatfield owns this culvert crossing.

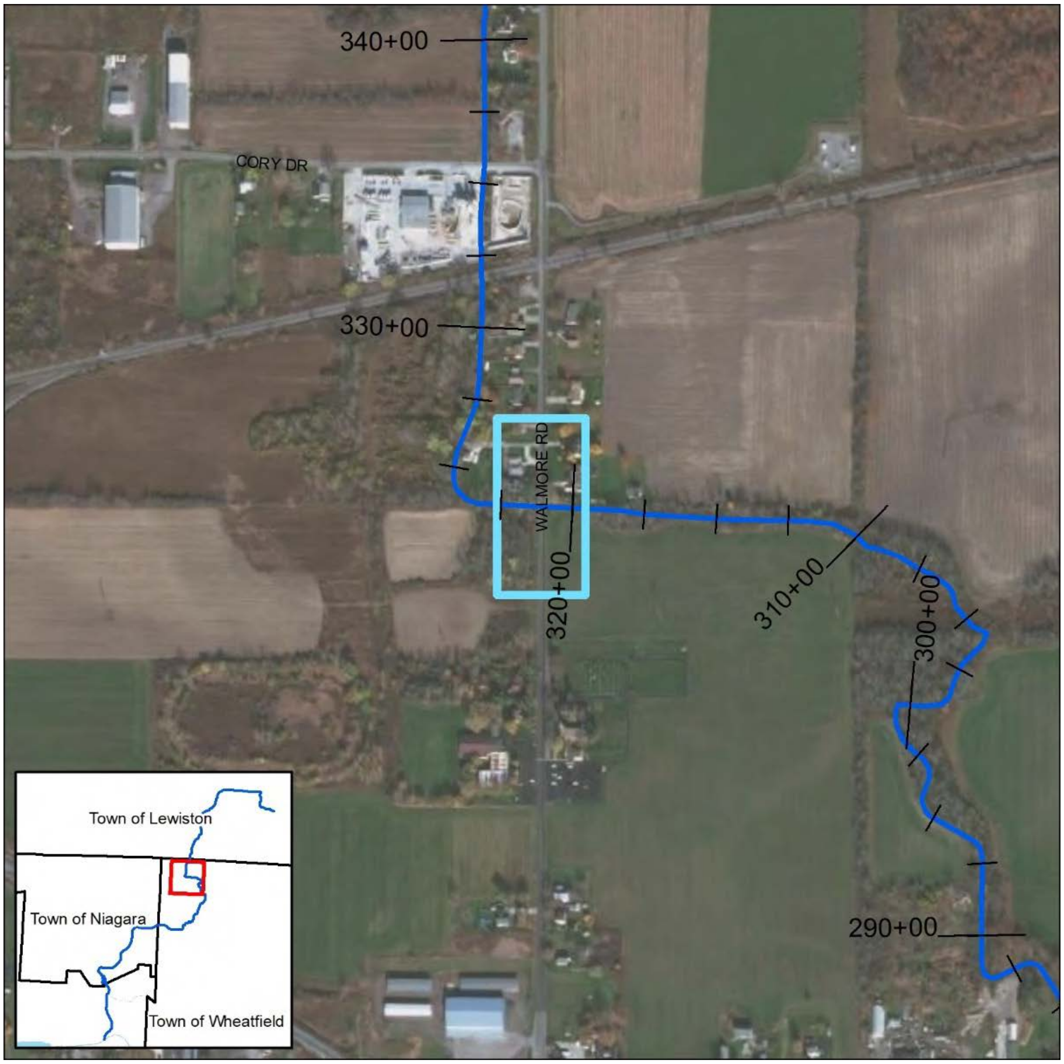

Figure 7-14. Location map for Alternative #2-3.

The existing culvert structure has a single 10-ft span by 6.25-ft rise pipe culverts (Figure 7-15, next page). The flooding in the vicinity of the culvert poses a flood risk threat to the roadway and the nearby commercial and agricultural properties both upstream and downstream of the culvert crossing.

Figure 7-15. Downstream Walmore Road pipe culvert, Wheatfield, NY.

According to the HEC-RAS base condition model and FEMA FIS, the downstream Walmore Road crossing does not allow discharges at the 10, 2, 1, and 0.2% annual chance flood water surface elevation to pass, which causes water surface elevations to exceed the low chord elevation and cause backwater upstream of the culvert (FEMA 2010b). In addition, the culverts do not provide the NYSDOT recommended drainage for a culvert in a regulatory floodway, which is the 1% annual chance flood hazard.

This measure would potentially reduce the flood risk for and benefit the properties adjacent to and immediately upstream of the Walmore Road culvert. The box culvert replacement increased the cross-sectional flow area of the bridge by replacing the existing 10-ft span by 6.25-ft rise pipe culvert with a single 30-ft wide by 6-ft high box culvert. The proposed condition modeling simulation indicated water surface reductions of up to 2.5-ft immediately upstream of the downstream Walmore Road crossing extending up to the CSX Transportation railroad crossing (Figure 7-16, next page).

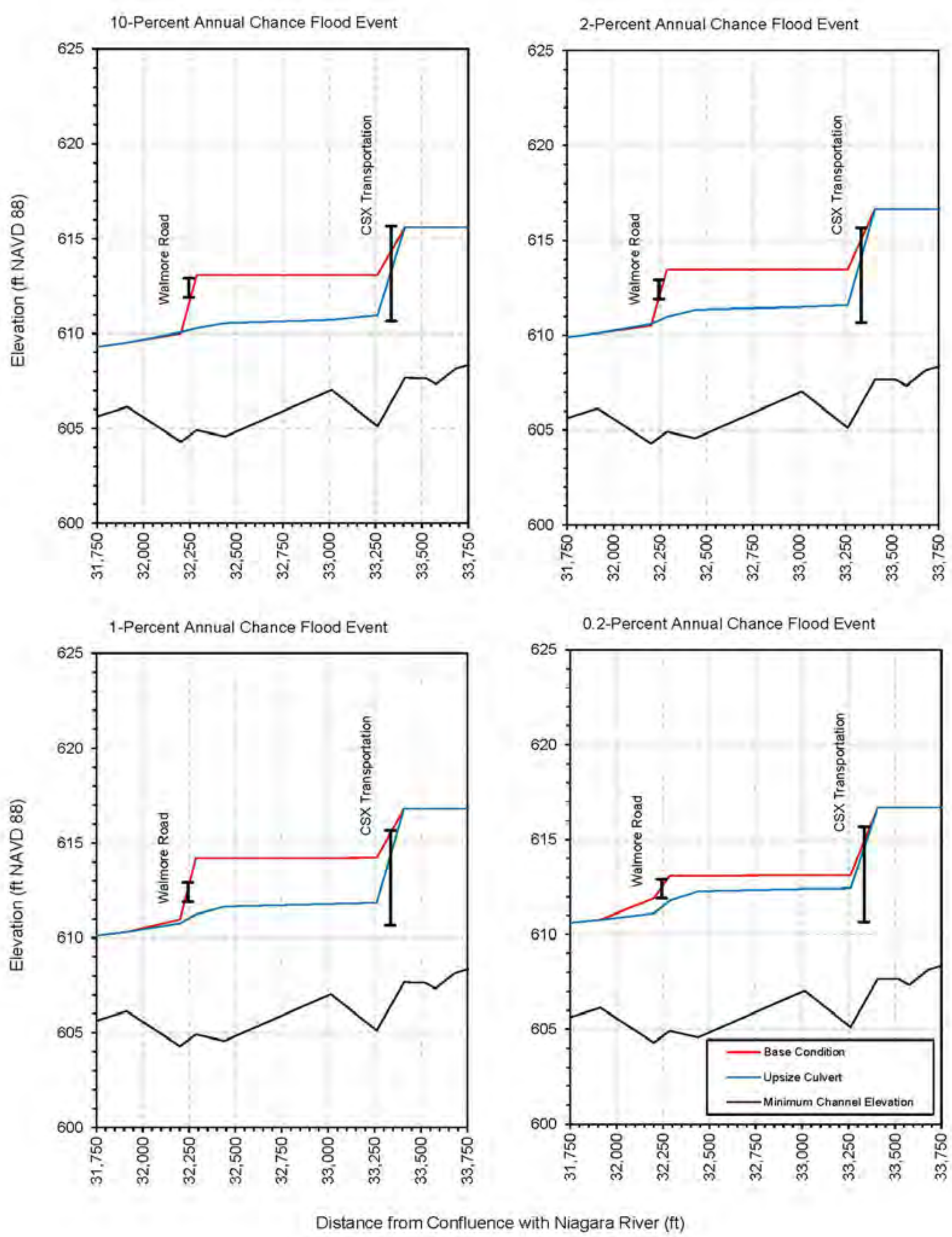

Figure 7-16. HEC-RAS model simulation output results for Alternative #2-3.

The potential water surface elevation reduction benefits of this alternative would extend approximately 1,250-ft upstream to the CSX Transportation railroad crossing.

The Rough Order Magnitude cost is $550,000, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

7.2.4 Alternative #2-4: Increase Size of CSX Transportation Railroad Bridge Crossing

This measure increases the cross-sectional flow area of the channel by increasing the width of the CSX Transportation railroad bridge opening at river station 331+70 (Figure 7-17). CSX Transportation owns this bridge crossing in the Town of Wheatfield.

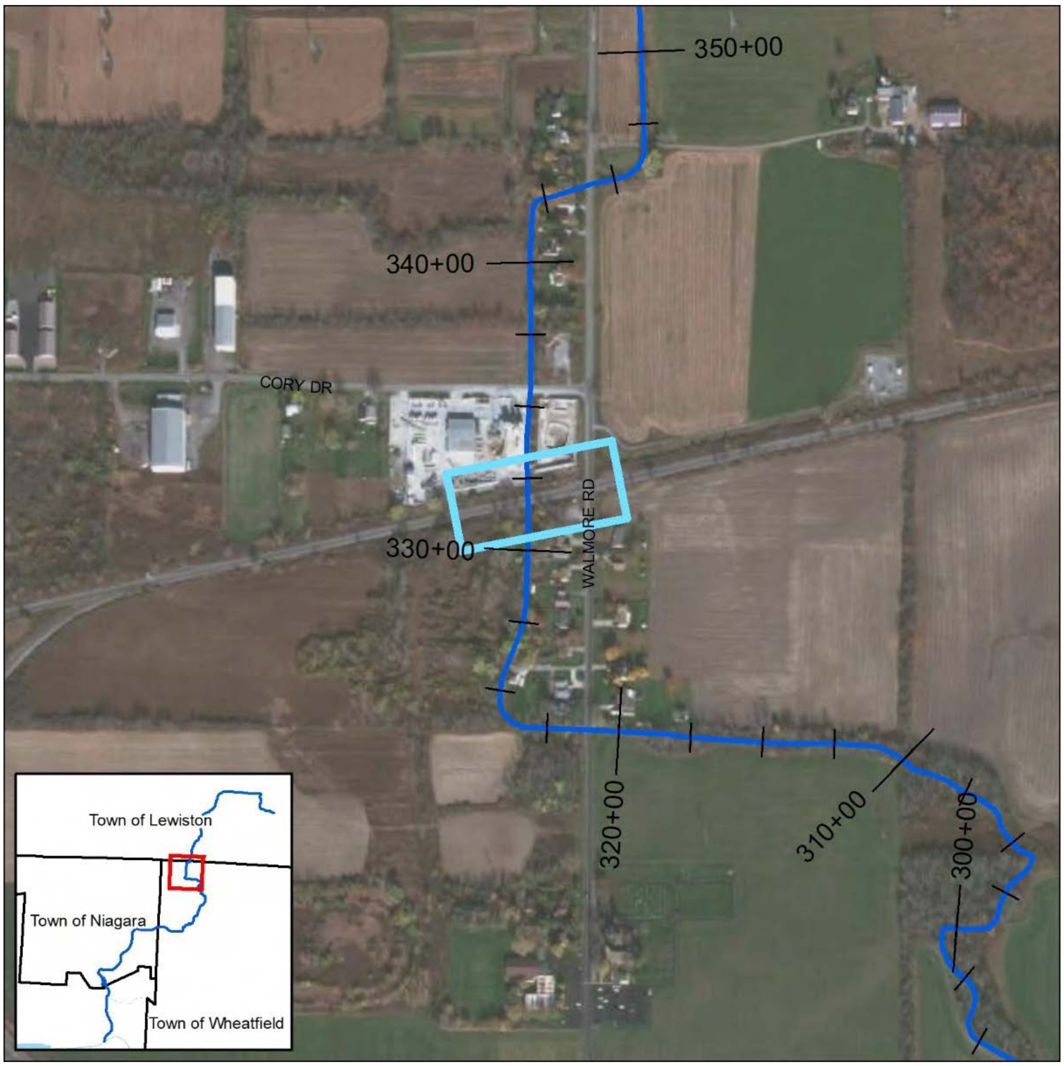

Figure 7-17. Location map for Alternative #2-4.

The existing bridge opening is approximately 20-ft wide by 4-ft high (Figure 7-18). The flooding in the vicinity of the culvert poses a flood risk threat to the roadway and the nearby commercial and agricultural properties both upstream and downstream of the culvert crossing.

Figure 7-18. CSX Transportation railroad bridge crossing, Wheatfield, NY.

According to the HEC-RAS base condition model and FEMA FIS, the downstream Walmore Road crossing does not allow discharges at the 10, 2, 1, and 0.2% annual chance flood water surface elevation to pass, which causes water surface elevations to exceed the low chord elevation and cause backwater upstream of the culvert (FEMA 2010b). In addition, the culverts do not provide the NYSDOT recommended drainage for a culvert in a regulatory floodway, which is the 1% annual chance flood hazard.

This measure would potentially reduce the flood risk for, and benefit the properties adjacent to and immediately upstream of, the CSX Transportation railroad bridge. The bridge widening scenario doubled the cross-sectional flow area of the bridge by increasing the bridge span from 20 feet to 40 feet. The proposed condition modeling simulation indicated water surface reductions of up to 2-ft immediately upstream of the CSX Transportation railroad bridge crossing extending up to the upstream Walmore Road crossing (Figure 7-19, next page).

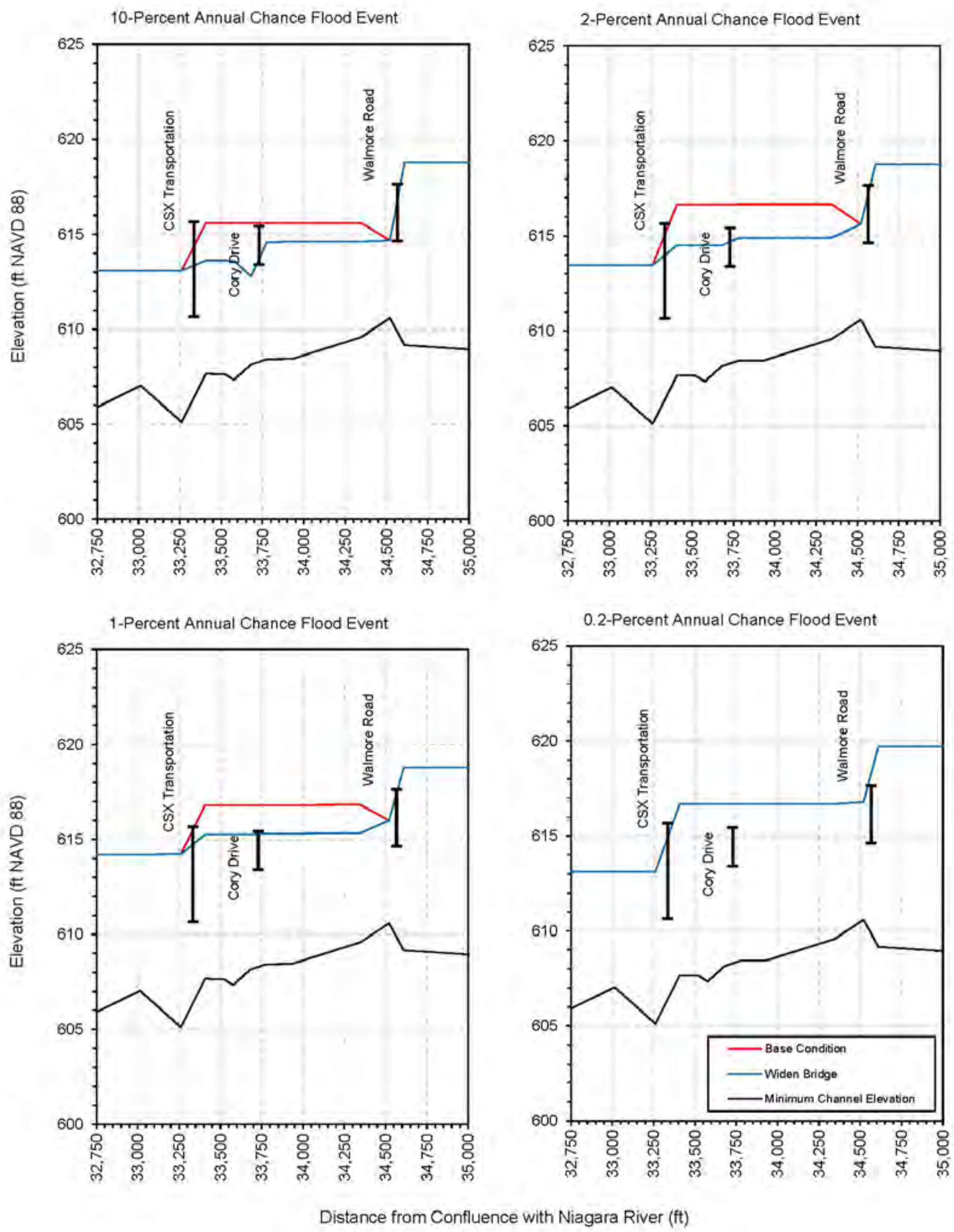

Figure 7-19. HEC-RAS model simulation output results for Alternative #2-4.

The potential water surface elevation reduction benefits of this alternative would extend approximately 1,250-ft upstream to the upstream Walmore Road crossing for low flow events (i.e. the 10, 2, and 1% annual chance flood hazard). For high flow events (i.e. the 0.2% annual chance flood hazard), Alternative #2-4 has no impact, and resulting water surface elevations match those of existing conditions.

The Rough Order Magnitude cost is $940,000, which does not include land acquisition costs for survey and appraisal, permitting, additional engineering and coordination, and / or special inspection requirements.

7.2.5 Alternative #2-5: Install Crossing Pipes into CSX Transportation Railroad Bridge Embankment

This measure increases the cross-sectional flow area of the channel by installing two circular culverts on the left bank of the bridge opening of the railroad crossing located at river station 331+70 (Figure 7-20). CSX Transportation owns this bridge crossing in the Town of Wheatfield.

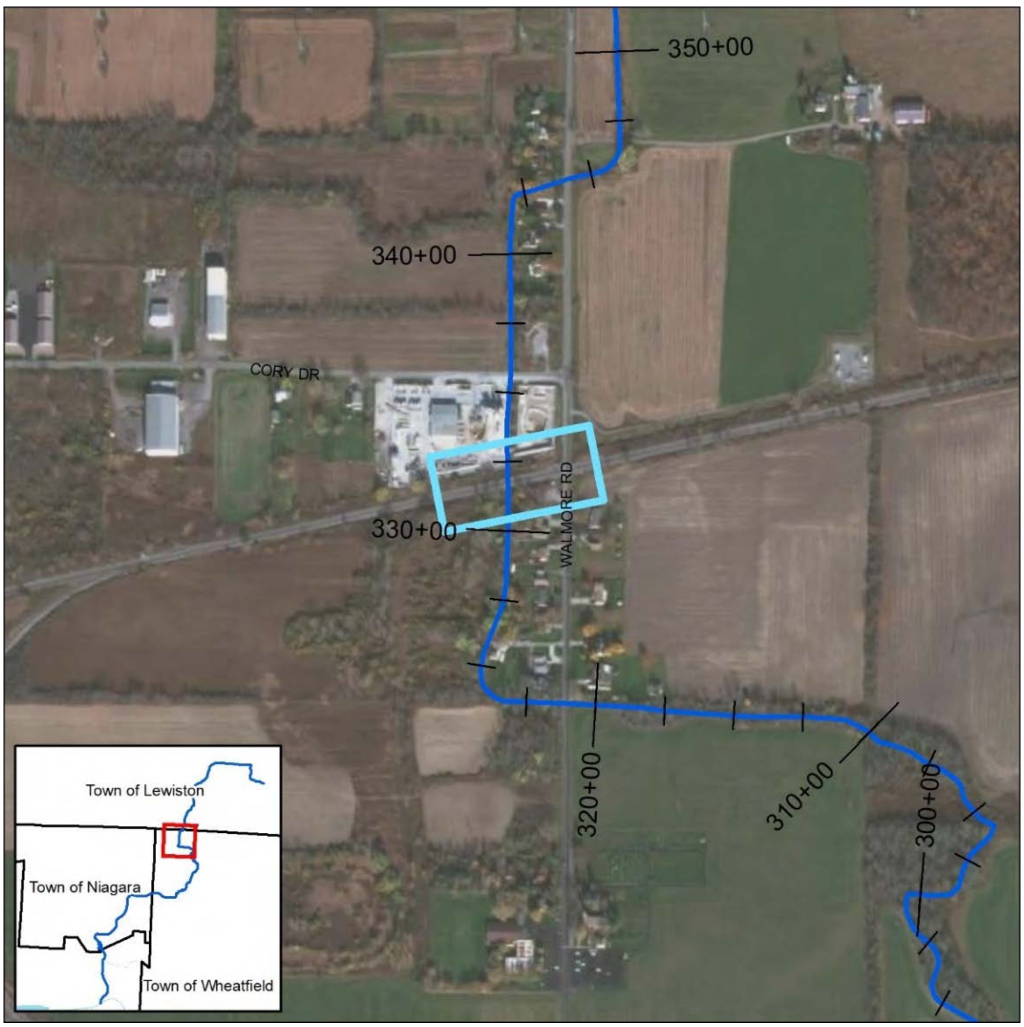

Figure 7-20. Location map for Alternative #2-5.

The existing bridge opening is approximately 20-ft wide by 4-ft high (Figure 7-21). The flooding in the vicinity of the culvert poses a flood risk threat to the roadway and the nearby commercial and agricultural properties both upstream and downstream of the culvert crossing.

Figure 7-21. CSX Transportation railroad bridge crossing, Wheatfield, NY.

According to the HEC-RAS base condition model and FEMA FIS, the downstream Walmore Road crossing does not allow discharges at the 10, 2, 1, and 0.2% annual chance flood water surface elevation to pass, which causes water surface elevations to exceed the low chord elevation and cause backwater upstream of the culvert (FEMA 2010b). In addition, the culverts do not provide the NYSDOT recommended drainage for a culvert in a regulatory floodway, which is the 1% annual chance flood hazard.

This measure would potentially reduce the flood risk for and benefit the properties adjacent to and immediately upstream of the CSX Transportation railroad bridge. The crossing pipes scenario increased the cross-sectional flow area by including two 5-ft diameter circular culverts placed above bankfull elevation on the left channel bank. The proposed condition modeling simulation indicated water surface reductions of up to 2.0-ft immediately upstream of the CSX Transportation railroad bridge crossing extending up to the upstream Walmore Road crossing (Figure 7-22, next page).

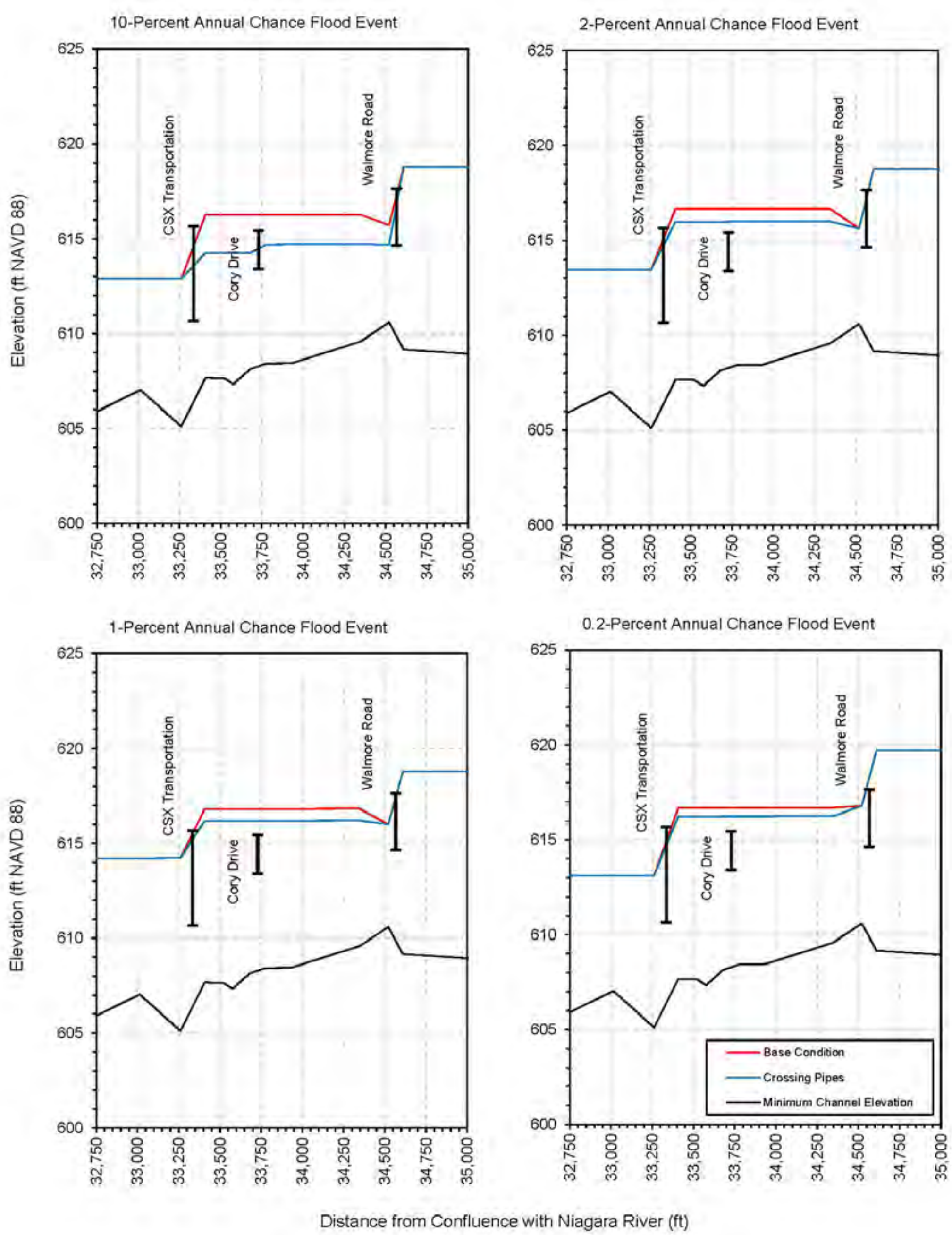

Figure 7-22. HEC-RAS model simulation output results for Alternative #2-5.

The potential water surface elevation reduction benefits of this alternative would extend approximately 1,250-ft upstream to the upstream Walmore Road crossing.

The Rough Order Magnitude cost is $400,000, which does not include land acquisition costs for survey and appraisal, permitting, additional engineering and coordination, and / or special inspection requirements.

7.2.6 Alternative #2-6: Flood Bench Upstream of Cory Drive

Installing a flood bench provides additional storage and floodplain width, potentially reducing flood damages in the event of flooding and addressing issues within High-risk Area #2. The flood benches are located within FEMA's designated Regulatory Floodway and Zone AE. The Regulatory Floodway is defined as the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than one foot over the 1% annual chance flood hazard water surface elevation. Zone AE includes areas that have a 1% annual chance of flooding where BFEs are provided by FEMA (FEMA 2000, FEMA 2010a).

The flood benches would potentially benefit and reduce the flood risk for the properties adjacent to Cayuga Creek in the vicinity of Cory Drive. The proposed flood bench is located on the right bank of Cayuga Creek immediately upstream of Cory Drive between river stations 335+00 and 342+50 (Figure 7-23, next page). The total acreage of the flood bench is approximately 11 acres with a minimum elevation of 609 feet NAVD88.

Figure 7-23. Location map for Alternative #2-6.

The proposed condition modeling simulation confirmed that the area upstream of Cory Drive is in a high-risk flood area. The proposed condition modeling simulation indicated no significant water surface reductions in the vicinity of the flood bench (Figure 7-24, next page).

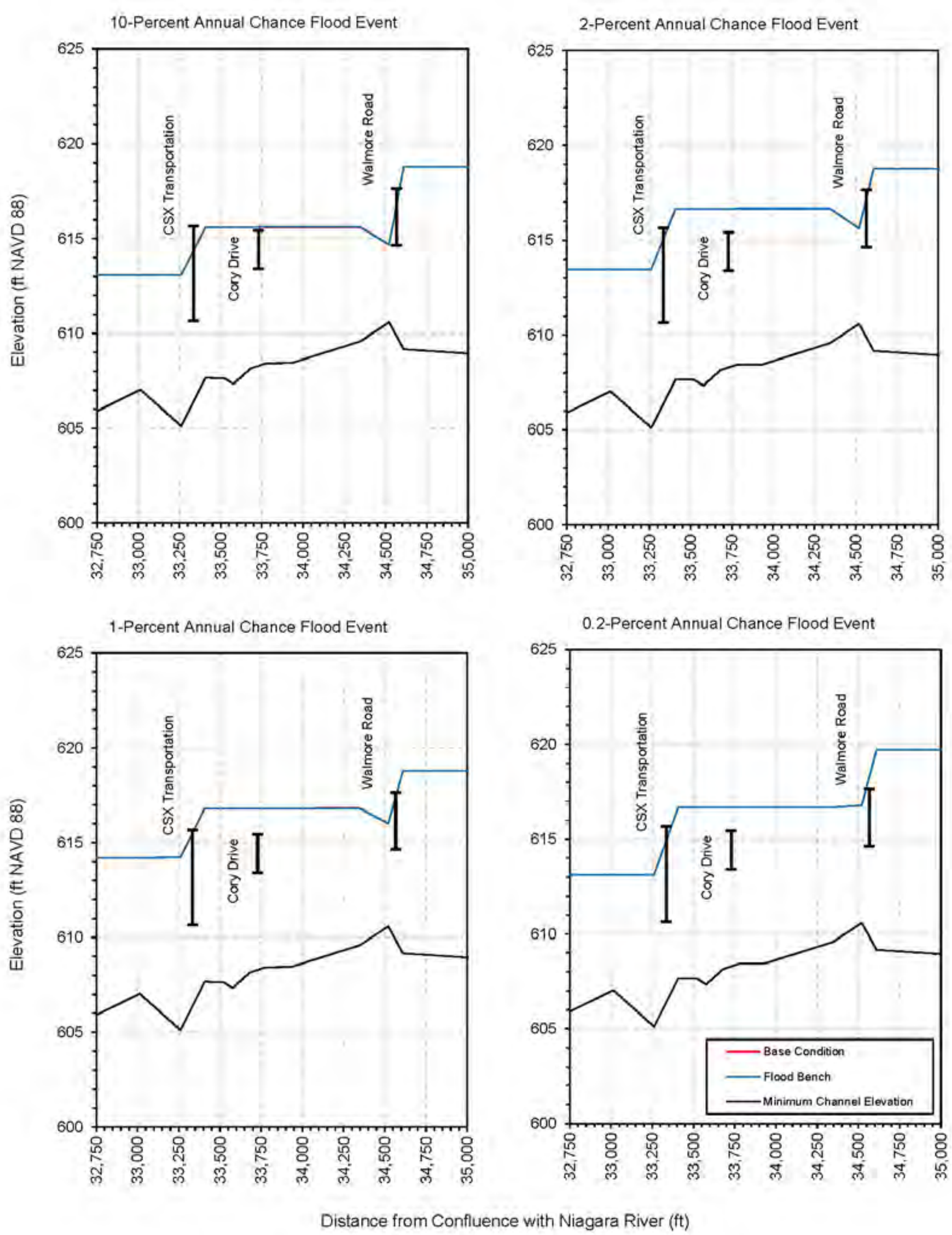

Figure 7-24. HEC-RAS model simulation output results for Alternative #2-6.

Based on the analysis of the HEC-RAS model simulation results, installing a flood bench upstream of Cory Drive would not provide significant flood protection in this reach from open-water flooding. This measure is not recommended due to the ineffectiveness to provide adequate flood protection to the areas immediately upstream and downstream of Cory Drive and the additional costs associated with installing a flood bench. According to the FIS, the primary cause of flooding in the vicinity of Cory Drive is backwater from the CSX Transportation Railroad bridge crossing. Therefore, this measure is not recommended unless a mitigation alternative at the CSX Transportation Railroad bridge crossing is also implemented.

The Rough Order Magnitude cost is $2.48 million, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

7.2.7 Alternative #2-7: Flood Bench Upstream of Walmore Road

Installing a flood bench provides additional storage and floodplain width, potentially reducing flood damages in the event of flooding and addressing issues within High-risk Area #2. The flood benches are located within FEMA's designated Regulatory Floodway and Zone AE. The Regulatory Floodway is defined as the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than one foot over the 1% annual chance flood hazard water surface elevation. Zone AE includes areas that have a 1% annual chance of flooding where BFEs are provided by FEMA (FEMA 2000, FEMA 2010a).

The flood benches would potentially benefit and reduce the flood risk for the properties adjacent to Cayuga Creek in the vicinity of Walmore Road. The proposed flood bench is located on the right bank of Cayuga Creek immediately upstream of Cory Drive between river stations 347+00 and 352+50 (Figure 7-25, next page). The total acreage of the flood bench is approximately 1.6 acres with a minimum elevation of 609 feet NAVD88.

Figure 7-25. Location map for Alternative #2-7.

The proposed condition modeling simulation confirmed that the area upstream of Walmore Road is in a high-risk flood area. The proposed condition modeling simulation indicated no significant water surface reductions in the vicinity of the flood bench (Figure 7-26, next page).

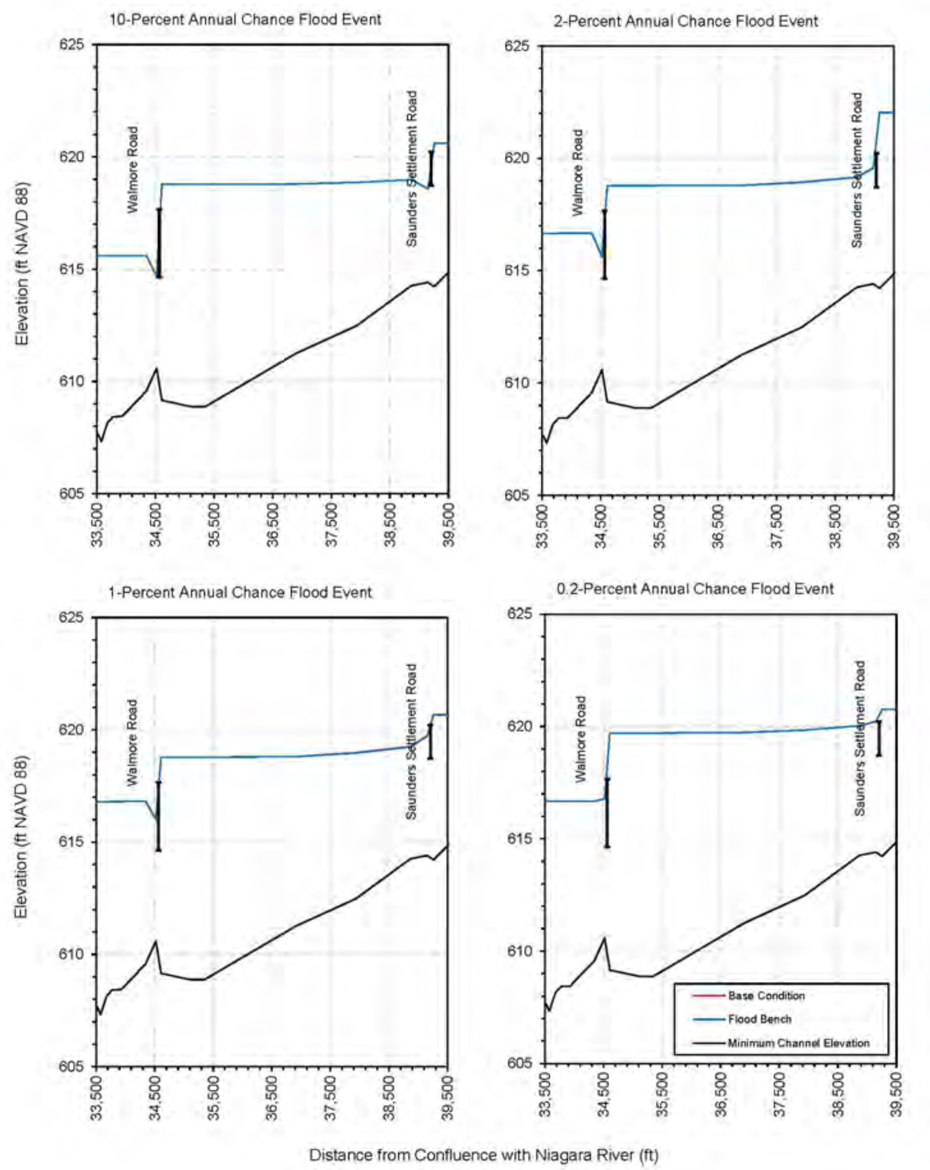

Figure 7-26. HEC-RAS model simulation output results for Alternative #2-7.

Based on the analysis of the HEC-RAS model simulation results, installing a flood bench upstream of Walmore Road would not provide significant flood protection in this reach from open-water flooding. This measure is not recommended due to the ineffectiveness to provide adequate flood protection to the areas immediately upstream and downstream of Walmore Road and the additional costs associated with installing a flood bench.

The Rough Order Magnitude cost is $370,000, which does not include land acquisition costs for survey, appraisal, and engineering coordination.

7.3 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).

7.3.1 Alternative #3-1: Early-warning Flood Detection System

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

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

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

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

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

7.3.2 Alternative #3-2: 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 a protected stream (gravel removal, stream restoration, bank stabilization, installation, repair, replacements of culverts or bridges, objects embedded in the stream that require digging out, etc.) will require an Article 15 permit from the NYSDEC. Projects that will require disturbance of the stream bed or banks, such as excavating sand and gravel, digging embedded debris from the streambed or the use of motorized, vehicular equipment, such as a tractor, backhoe, bulldozer, log skidder, four-wheel drive truck, etc. (any heavy equipment), in the stream channel, or anywhere below the top of banks, will require either a Protection of Waters or Excavation or Fill in Navigable Waters Permit (NYSDEC 2013).

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

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

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

7.3.3 Alternative #3-3: Flood Buyout Program

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

- Reduce exposure by limiting the people and infrastructure located in vulnerable areas
- Reduce future disaster response costs and flood insurance payments
- Restore natural buffers such as wetlands in order to reduce future flooding levels
- Reduce or eliminate the need to maintain and repair flood control structures
- Reduce or eliminate the need for public expenditures on emergency response, garbage collection and other municipal services in the area
- Provide open space for the community

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

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

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

In the Town of Niagara, the entirety of the Cayuga Village Mobile Home Park and approximately 153 residential and 15 commercial properties are within the FEMA 1% and 0.2% annual chance flood hazard zones of Cayuga Creek in the residential neighborhood located between Niagara Falls Boulevard and Porter Road (FEMA 2010a). These properties have a combined full market value of approximately $82.1 million with residential and commercial parcels accounting for $43 million and $39.1 million, respectively. Figure 7-27 displays the tax parcels in the Town of Niagara that intersect the FEMA flood zones.

According to FEMA severe repetitive loss and repetitive loss data, there are three properties classified as repetitive loss properties in the Cayuga Creek watershed which are all located within High-risk Area #1. There are no severe repetitive loss properties in the Cayuga Creek watershed (FEMA 2019). A repetitive loss 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 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 2019).

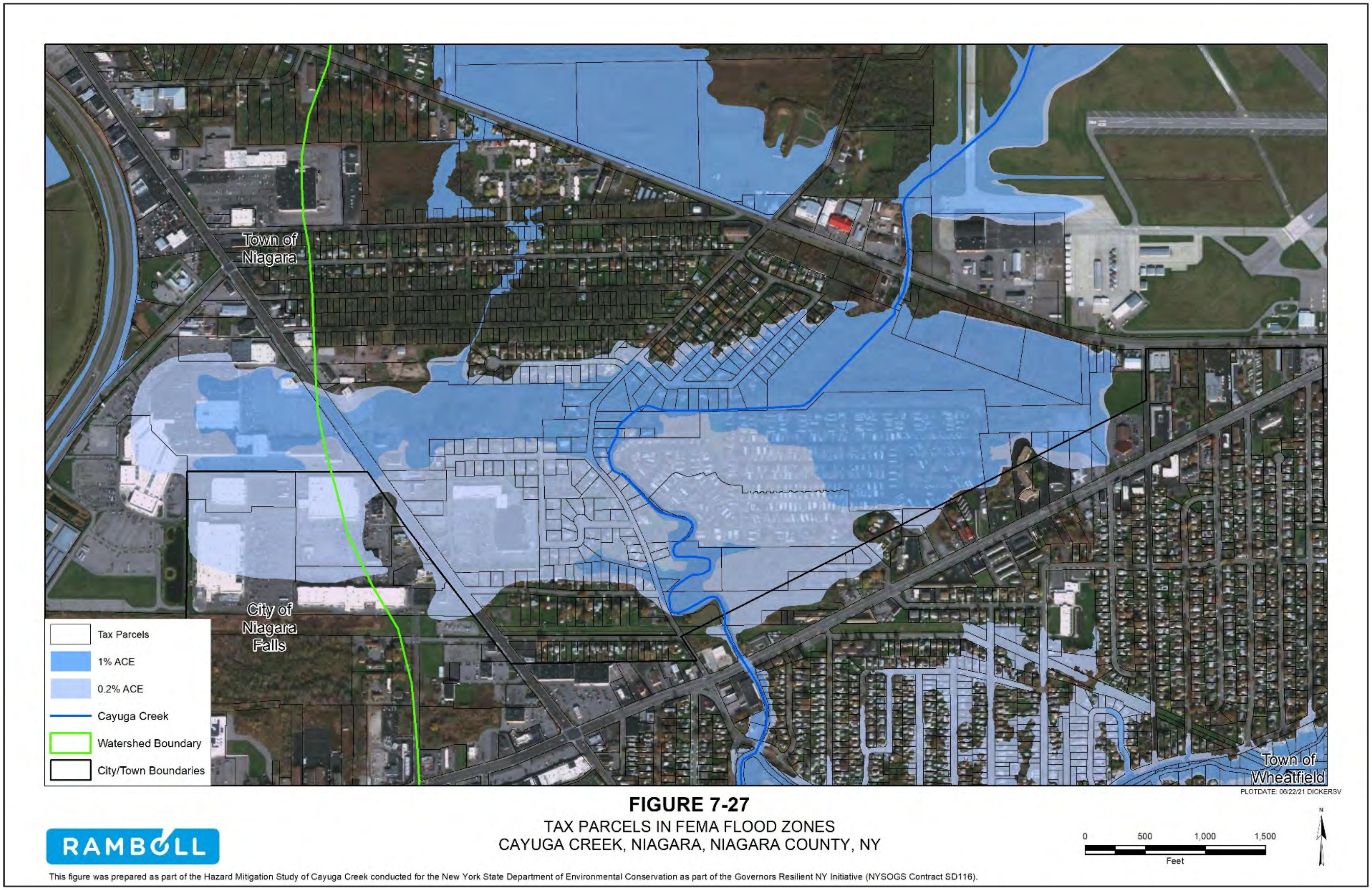

Figure 7-27. Tax parcels within FEMA flood zones, Cayuga Creek, Niagara Falls, Niagara County, NY.

Due to the variable nature of buyout programs, no ROM cost estimate was produced for this study. It is recommended that any buyout program begin with a cost-benefit analysis for each property. After a substantial benefit has been established, a buyout strategy study should be developed that focuses on properties closest to Cayuga 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.

7.3.4 Alternative #3-4: Floodproofing

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

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

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

For existing residential structures, structures should be raised above the BFE in accordance with local regulations. Floodproofing is allowed for non-residential structures, with design guidelines outlined in FEMA P-936 – Floodproofing Non-Residential Structures (FEMA 2000; FEMA 2013). The local floodplain administrator should carefully review local ordinances, the CFR and available design guidelines before issuing a permit for structural flood proofing. Floodproofing strategies include:

Interior Modification / Retrofit Measures

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

Examples include:

- *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 2015b).

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

In New York State, only non-residential buildings are allowed to be dry floodproofed and the building must be dry floodproofed to an elevation of at least 2-ft above the BFE. New York State has higher freeboard standards than federal regulations at 44 CFR Part 60.3. Care must be taken to check the NYS Building Code for more stringent guidelines.

Examples include:

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

Wet floodproofing

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

Examples include:

- *Flood Openings*: This measure involves installing openings in foundation and enclosure walls located below the BFE that allow automatic entry and exit of floodwaters to prevent collapse from the pressures of standing water.

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

Barrier Measures

Barriers, such as floodwalls and levees, can be built around single or multiple residential and non-residential buildings to contain or control floodwaters (FEMA 2015b). Although floodwalls or levees can be used to keep floodwaters away from buildings, implementing these measures will not affect a building's flood insurance rating unless the flood control structure is accredited in accordance 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 4-ft 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 6-ft above grade (ground level). The levee with gates is built with passive flood gates that are designed to open or close automatically due to hydrostatic pressure caused by the floodwater. The levee without gates is built using vehicle access ramps to avoid the need for passive flood gates.

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

- Consult a registered design professional (i.e. architect or engineer) who is qualified to deal with the specifics of a flood mitigation project
- Check your community's floodplain management ordinances
- Contact your insurance agent to find out how your flood insurance premium may be affected
- Check what financial assistance might be available
- Hire a qualified contractor
- Contact the local building department to learn about development and permit requirements and to obtain a building permit
- Determine whether the mitigation project will trigger a Substantial Improvement declaration
- See the project through to completion
- Obtain an elevation certificate and an engineering certificate (if necessary)

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

7.3.5 Alternative #3-5: Area Preservation / Floodplain Ordinances

This alternative proposes municipalities within the Cayuga 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 [date unknown]).

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).

For floodplain ordinances, the NYSDEC has a sample of regulatory requirements for floodplain management that a community can adopt within their local flood damage prevention ordinance. If a community is interested in updating their local law to include regulatory language promoting floodplain management, it is recommended that they reach out to the NYSDEC through floodplain@dec.ny.gov or (518) 402-8185 for more information.

In addition, the Community Rating System (CRS) program through FEMA is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. Participating communities are able to get discounted rates on the flood insurance premiums for residents in the community. Adopting these enhanced requirements and preserving open space for floodplain storage earns points in the CRS program, which can lead to discounted flood insurance premiums.

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

7.3.6 Alternative #3-6: 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 Cayuga Creek watershed. Restoration, which is defined as the process of re-establishing historical ecosystem structures and processes, is being used more often to mitigate some of the past degradation of these ecosystems (Goodwin et al. 1997).

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

Riparian ecosystems generally consist of two flooding zones: Zone I occupies the active floodplain and is frequently inundated, and Zone II extends from the active floodplain to the valley wall. Successful restoration depends on understanding the physical and biological processes that influence natural riparian ecosystems and the types of disturbance that have degraded riparian areas. Adoption of a process-based approach for riparian restoration is key to a successful restoration plan. Disturbances to riparian ecosystems in the Cayuga 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).

7.3.7 Alternative #3-7: 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).

7.3.8 Alternative #3-8: Community Flood Awareness and Preparedness Programs / Education

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

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

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

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

7.3.9 Alternative #3-9: Development of a Comprehensive Plan

Local governments are responsible for planning in a number of areas, including housing, transportation, water, open space, waste management, energy, and disaster preparedness. In New York State, these planning efforts can be combined into a comprehensive plan that steers investments by local governments and guides future development through zoning regulations. A comprehensive plan will guide the development of government structure as well as natural and built environment. Significant features of comprehensive planning in most communities include its foundations for land use controls for the purpose of protecting the health, safety, and general welfare of the community's citizens. The plan will focus on immediate and long-range protection, enhancement, growth, and development of a community's assets. Materials included in the comprehensive plan will include text and graphics, including but not limited to maps, charts, studies, resolutions, reports, and other descriptive materials. Once the comprehensive plan is completed, the governing board motions to adopt it, i.e. town or village board (EFC 2015).

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

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

7.3.10 Alternative #3-10: Drainage System Strategies

The causes of ponding or flooding of excess water include land topography, high water table levels, or poor subsurface drainage. Regular ponding or flooding of excess water can impact plant growth and restrict land use and management goals. Plant growth is essential for improving soil quality and increasing soil organic matter, and saturated soils increase the likelihood of diseases and denitrification. Ponding or flooding of excess water can affect nearby infrastructure and slope stability, and prevent access (NRCS 2012).

Planned drainage system strategies can be implemented to address excess water. Possible solutions to mitigate ponding or flooding of excess water include (NRCS 2012):

- Drainage management structures, such as surface drains or raised beds and ridges
- Water and sediment control basins/farm ponds
- Roof runoff structures and capture for reuse methods
- Floodplain management
- Wetland restoration
- Windbreak placement
- Pumping stations/plants

Several strategies can be used in conjunction to optimize drainage systems.

On agricultural land, implemented drainage systems should be designed in a site-specific manner and incorporate the following principles (SCS 1971):

1. Fit the farming system (i.e., compatible crops, field layouts, cultural practices, etc.)
2. Cause water to flow readily from land to ditch without harmful erosion or deposition of silt
3. Have adequate capacity to carry the flow
4. Be designed for construction and maintenance with appropriate equipment locally available

In addition, seeps and high water tables must be accounted for during drainage system planning and evaluating sites for construction.

Drainage systems require regular maintenance and inspection to function properly. 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).

Municipalities with stakeholders and / or residents that are experiencing persistent ponding or flooding of excess water should consult with the NYSDEC to determine the appropriate course of action to address the issues.

8. 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.

8.1 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.

8.2 STATE / FEDERAL WETLANDS INVESTIGATION

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

8.3 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)
- 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

8.3.1 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.

8.3.2 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

8.3.3 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.

8.3.3.1 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.

8.3.3.2 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.

8.3.4 NRCS Emergency Watershed Protection (EWP) Program

Through the Emergency Watershed Protection (EWP) Program, the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) can assist communities in addressing watershed impairments that pose imminent threats to lives and property. Most EWP projects involve the protection of threatened infrastructure from continued stream erosion. Projects must have a project sponsor, defined as a legal subdivision of the State, such as a city, county, general improvement district, or conservation district, or an Indian Tribe or Tribal organization. Sponsors are responsible for providing land rights to do repair work, securing the necessary permits, furnishing the local cost share (25%), and performing any necessary operation and maintenance for a 10-yr period. Through EWP, the NRCS may pay up to 75% of the construction costs of emergency measures, with up to 90% paid for projects in limited-resource areas. The remaining costs must come from local services. Eligible projects include, but are not limited to, debris-clogged stream channels, undermined and unstable streambanks, and jeopardized water control structures and public infrastructures.

8.3.5 FEMA Hazard Mitigation Grant Program (HMGP)

The HMGP, offered by FEMA and administered by the NYSDHSES, provides funding for creating / updating hazard mitigation plans and implementing hazard mitigation projects. The HMGP 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 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.

8.3.5.1 Building Resilient Infrastructure and Communities (BRIC)

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

8.3.5.2 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 (NFIP). 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

8.3.6 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. SUMMARY

The Towns of Niagara Falls and Wheatfield have had a history of flooding events along Cayuga Creek. Flooding in these areas primarily occurs during the summer and winters months due to heavy rains by convective systems and snow melt. In response to persistent flooding, the State of New York in conjunction with the Towns of Niagara Falls and Wheatfield, and Niagara County, are studying and evaluating potential flood mitigation projects for Cayuga Creek as part of the Resilient NY Initiative.

This report analyzed the historical and present-day causes of flooding in the Cayuga 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 Cayuga 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 Cayuga 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 the culvert replacement and bridge widening alternatives. In the Town of Wheatfield, the upsizing measures associated with the Walmore Road and CSX Transportation railroad crossing provided the most significant reductions in water surface elevations according to the HEC-RAS model simulation results.

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

However, structural upsizing is a generally costly flood mitigation measure. The benefits of the measures in their respective reaches should be balanced with the associated costs of each upsizing widening 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 bridge widening measures.

The debris maintenance alternatives around culverts / bridges would maintain the flow channel area in Cayuga Creek. As sediment and debris build up at the openings of bridges and culverts, the channel flow area is reduced. This can lead to potential backwater and flooding due to the inability of the creek channel to pass stream flows of the same annual chance event.

The flood bench measures discussed for Cayuga Creek in the Town of Niagara 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 Cayuga Creek floodplain in the Town of Niagara, very few areas were found to be adequate for large scale benches that could potentially provide greater flood mitigation protections to historically vulnerable areas along Cayuga Creek. Additionally, flood bench measures 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.

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

Floodproofing is an effective mitigation measure but requires a large financial investment in individual residential and non-residential buildings. Floodproofing can reduce the future risk and flood damage potential but leaves buildings in flood risk areas so that the potential for future flood damages remain. A benefit to floodproofing versus buyouts is that properties remain in the community and the tax base for the local municipality remains intact. Table 14 is a summary of the proposed flood mitigation measures, including modeled water surface elevation reductions and estimated ROM costs.

Table 14. Summary of Flood Mitigation Measures

Alternative No.	Description	Benefits Related to Alternative	ROM cost ($U.S. dollars)
1-1	Flood Bench Downstream of Porter Road	Model simulated WSEL reduction of up to 0.4 feet	$3.71 million
1-2	Flood Bench Upstream of Niagara Falls Boulevard	Model simulated WSEL reduction of up to 0.3 feet	$1.97 million
1-3	Flood Control Detention Structure Downstream of Porter Road	Limits flood extents and depths downstream and helps with sediment transport	N/A
1-4	Levee Upstream of Elderberry Place	Model simulated WSEL reduction of up to 0.5 feet	$230,000
2-1	Replace Upstream Walmore Road Circular Culverts with Box Culvert	Model simulated WSEL reduction of up to 2.4 feet	$410,000

Alternative No.	Description	Benefits Related to Alternative	ROM cost ($U.S. dollars)
2-2	Replace Cory Drive Circular Culverts with Box Culvert	No significant reduction in model simulated WSEL	$490,000
2-3	Replace Downstream Walmore Road Circular Culvert with Box Culvert	Model simulated WSEL reduction of up to 2.5 feet	$550,000
2-4	Increase Size of CSX Transportation Railroad Bridge Crossing	Model simulated WSEL reduction of up to 2 feet	$940,000
2-5	Install Crossing Pipes into CSX Transportation Railroad Bridge Embankment	Model simulated WSEL reduction of up to 2 feet	$400,000
2-6	Flood Bench Upstream of Cory Drive	No significant reduction in model simulated WSEL	$2.48 million
2-7	Flood Bench Upstream of Walmore Road	No significant reduction in model simulated WSEL	$370,000
3-1	Early-warning Flood Detection System	Early flood warning for open water events	$120,000 (not including annual operational costs)
3-2	Debris Maintenance Around Culverts / Bridges	Maintains channel flow area and reduces flood risk	$20,000 (not including annual operational costs)
3-3	Flood Buyouts Program	Reduces and / or eliminates future losses	Variable (case-by-case)
3-4	Floodproofing	Reduces and / or eliminates future damages	Variable (case-by-case)
3-5	Area Preservation / Floodplain Ordinances	Reduces and / or eliminates future losses	Variable (case-by-case)
3-6	Riparian Restoration	Restores natural habitats, reduces / manages runoff, and improves water quality	Variable (case-by-case)

Alternative No.	Description	Benefits Related to Alternative	ROM cost ($U.S. dollars)
3-7	Retention Basin and Wetland Management	Reduces erosion, traps sediments, reduces / manages runoff, and improves water quality	Variable (case-by-case)
3-8	Community Flood Awareness and Preparedness Programs / Education	Engages the community to actively participate in flood mitigation and better understand flood risks	Variable (case-by-case)
3-9	Development of a Comprehensive Plan	Guides future development, provides legal defense for regulations, and helps establish policies related to community assets	Variable (case-by-case)
3-10	Drainage System Strategies	Reduces and / or eliminates ponding or flooding of excess water and improves soil quality	Variable (case-by-case)

10. CONCLUSION

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

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

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