Intended for

New York State Department of Environmental Conservation
625 Broadway
Albany, New York 12233

Document type

Interim Final Report

Date

July, 2021

RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE

TONAWANDA CREEK, NEW YORK

Prepared for:

NEW YORK STATE OF OPPORTUNITY. Office of General Services

NEW YORK STATE OF OPPORTUNITY. Department of Environmental Conservation

Project Team:

OBG Part of Ramboll

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HIGHLAND PLANNING

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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LIST OF ABBREVIATIONS

1-D	one-dimensional
2-D	two-dimensional
ACE	annual chance flood event
BFE	base flood elevation
BIN	Bridge Identification Number
BRIC	Building Resilient Infrastructure and Communities
CDBG	Community Development Block Grants
CFA	Consolidated Funding Applications
CFR	Code of Federal Regulations
cfs	cubic feet per second
CIN	Culvert Identification Number
CMIP	Coupled Model Intercomparison Project
CRRA	Community Risk and Resiliency Act
CRS	Community Rating System
CSC	Climate Smart Communities
DEM	Digital Elevation Model
EWP	Emergency Watershed Protection
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FMA	Flood Mitigation Assistance
ft	feet
GIS	Geographic Information Systems
GLS	Generalized Least-Squares
GSE	Gomez and Sullivan Engineers, D.P.C.
H&H	Hydrologic and Hydraulic
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center's River Analysis System
Highland Planning	Highland Planning, LLC
HMGP	Hazard Mitigation Grant Program
IPaC	Information for Planning and Consultation
LiDAR	Light Detection and Ranging
LOMR	Letter of Map Revision
LP3	Log-Pearson III
mi^2	square miles
MSC	Map Service Center
NAVD88	North American Vertical Datum of 1988
NCEI	National Centers for Environmental Information
NFIP	National Flood Insurance Program
NLCD	National Land Cover Database
NRCS	Natural Resources Conservation Service
NWI	National Wetlands Inventory
NYSDEC	New York State Department of Environmental Conservation
NYSDHSES	New York State Division of Homeland Security and Emergency Services
NYSDOT	New York State Department of Transportation

NYSERDA	New York State Energy Research and Development Authority
NYSGOSR	New York State Governors Office of Storm Recovery
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
OBG	O'Brien and Gere, Part of Ramboll
PDM	Pre-Disaster Mitigation
RCP	Representative Concentration Pathways
RAMBOLL	OBG, Part of Ramboll
R_C	Circularity Ratio
R_E	Elongation Ratio
R_F	Form Factor
RF	Radio Frequency
RL	Repetitive Loss
ROM	Rough Order of Magnitude
SFHA	Special Flood Hazard Area
SRL	Severe Repetitive Loss
USACE	United States Army Corps of Engineers
USDHS	United States Department of Homeland Security
USDOT	United States Department of Transportation
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WCRP	World Climate Research Programme
WGCM	Working Group Coupled Modelling
WQIP	Water Quality Improvement Project

Introduction

Historical Initiatives

Flood mitigation has historically been an initiative in western New York and in the Tonawanda Creek watershed. Efforts to improve Tonawanda Creek and its tributaries date back to at least 1825, with work perfomed along with the construction of the Erie Canal, studies by the USACE on the creek date to 1887 and the majority of studies address flooding concerns. Historical approaches to reduce flooding have included clearing and snagging, removal of debris jams, straightening channels, and constructing levees and flood walls (USACE, Buffalo District, 1983).

Specific to the study area in the City of Batavia and the Village of Attica, a project was performed between November 1954 and November 1955 that included clearing and improvement of approximately 3.5 miles of channel in Batavia, along with bank protection (NYSDEC). Floodwalls have been built within the Village of Attica, that were subsequently re-built after they were damaged during Tropical Storm Agnes in June of 1972 (USACE, Buffalo District, 1983). More recently, streambank stabilization was performed in Attica to protect key infrastructure (Genesee/Finger Lakes Regional Planning Council and Lu Engineers, 2003)

Floodplain Development

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

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

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

A critical evaluation of existing floodplain law and policies should be undertaken to evaluate the effectiveness of current practices and requirements within this watershed. Local floodplain regulations should be consistent with the National Flood Insurance Program (NFIP) and Federal Emergency Management Agency (FEMA) regulations since the City of Batavia and Village of Attica are participating communities in the NFIP and should involve a floodplain coordinator and a site plan review process for all proposed developments. This review should be in accordance with local regulations and the NFIP requirements, which require the community to determine if any future proposed development could adversely impact the floodplain or floodway resulting in higher flood stages and sequentially greater economic losses to the community.

Resilient NY Initiative

In November of 2018, New York State Governor Andrew Cuomo announced the Resilient NY program in response to devastating flooding in communities across the State in the preceding years. A total of 48 high-priority flood prone watersheds across New York State are being addressed through the Resilient NY program. Flood mitigation studies were commissioned using advanced modeling techniques and field assessments to identify priority projects in these 48 flood-prone watersheds, develop state-of-the-art studies to reduce flooding and ice jams, and improve ecological habitats in the watersheds (NYSGPO, 2018). The Tonawanda 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. Potential flood mitigation measures will be evaluated using hydrologic and hydraulic (H&H) 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 for 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 Tonawanda Creek began in September of 2019 and a final flood study report is expected to be issued in the summer of 2021.

Data Collection

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, 2018) draft 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, 2021a) software were used to develop current and future potential discharges and bankfull widths and depths at various points along the stream channel. H&H modeling was performed previously, as part of the 1982 FEMA Flood Insurance Study (FIS) for the City of Batavia and the 1986 FEMA Flood Insurance Study (FIS) for the Village of Attica.

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 compute water stage at current and potential future levels for high risk areas and to evaluate the effectiveness of potential 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 for this study.

Public Outreach

An initial project kickoff meeting was held on September 19, 2019, with representatives of the NYSDEC, NYSOGS, OBG, Part of Ramboll (Ramboll), Gomez & Sullivan Engineers, D.P.C. (GSE), Highland Planning, USACE, the Counties of Erie, Genesee, and Niagara; the Towns of Amherst, Batavia, Clarence, Newstead, and Royalton; the Village of Alexander; and Buffalo Niagara Waterkeeper (Appendix B). At the project kickoff meeting, project specifics including background, purpose, funding, roles, and timelines were discussed. Discussions included a variety of topics, including:

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

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

Field Assessment

Following the initial data gathering and agency meetings, field staff from GSE undertook field data collection efforts with special attention given to high risk areas in the City of Batavia and Village of Attica, as identified in the initial data collection process. Initial field assessments of Tonawanda Creek were conducted in September, 2019. Information collected during field investigations included the following:

- Rapid "windshield" river corridor inspection
- Photo documentation of inspected areas
- Field identification of potential flood storage areas

- Characterization of key stream bank failures, head cuts, bed erosion, aggradation areas, and other unstable stream channel features
- Preliminary identification of potential flood hazard mitigation alternatives, including those requiring further analysis

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

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

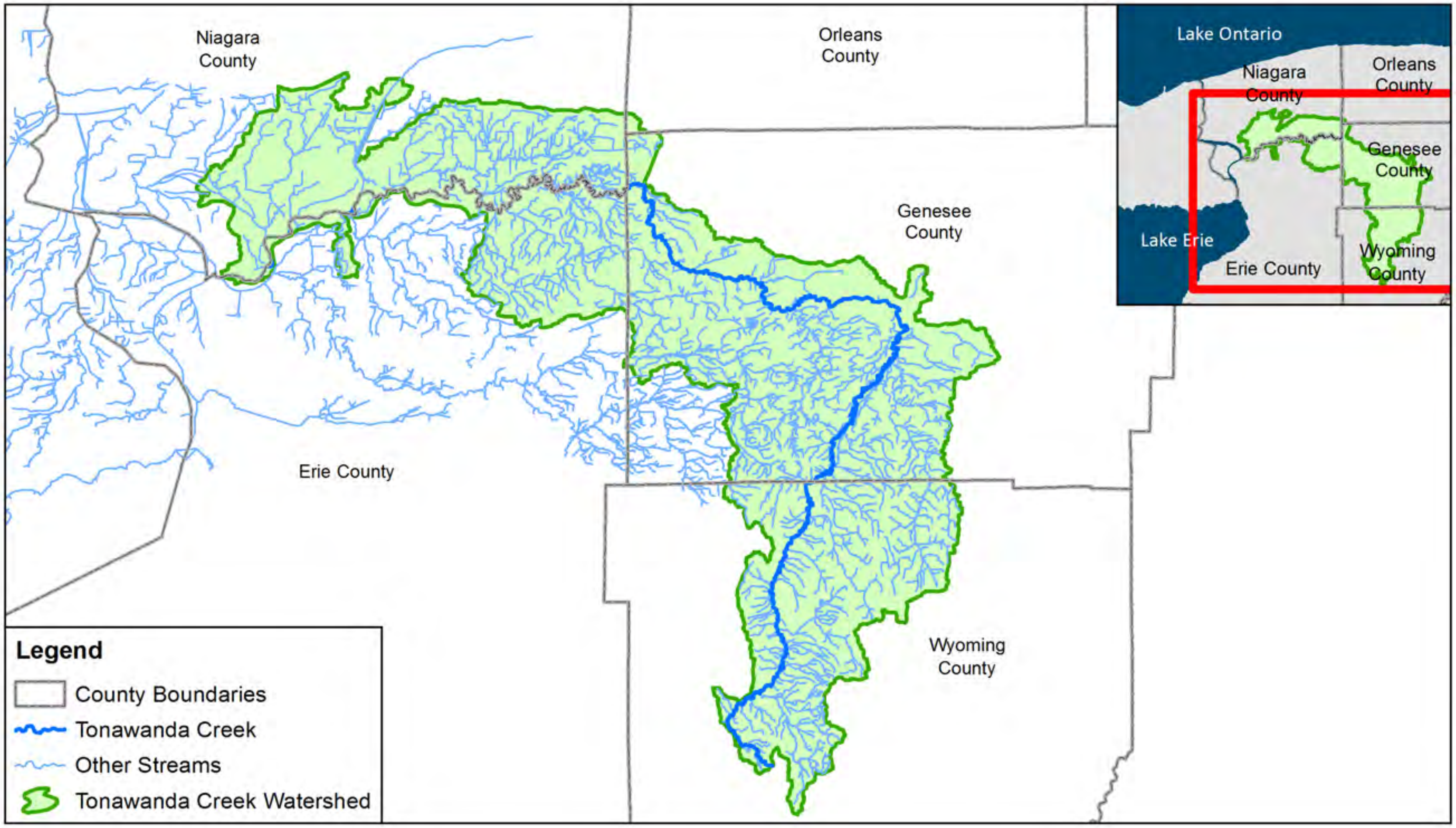
Watershed Characteristics

Study Area

The Tonawanda Creek watershed encompasses an area of 455 square miles, within Erie, Genesee, Niagara and Wyoming Counties in western New York, prior to its confluence with Ellicott Creek just upstream of the Niagara River. Tonawanda Creek flows from its source in the Cattaraugus Hills in Wyoming County, through deep valleys with steep slopes, northward for approximately 22 miles to Attica. From there, the creek passes through flat bottom land, with limited channel capacity, to Batavia. Turning westward at Batavia, the creek winds through more level terrain. The channel capacity is often insufficient; the creek flows sluggishly and often flood extensively during periods of high flow. Ledge-Murder Creek is the principal tributary emptying into Tonawanda Creek between Batavia and Rapids, NY. Below river mile 11.2, Tonawanda Creek forms a portion of the Erie Canal and continues to the Niagara River (USACE, Buffalo District, 1983).

Figure 1 depicts the location of the Tonawanda Creek watershed. Within the watershed, the City of Batavia and Village of Attica were chosen as the target study area due to the history of flooding in and along the creek and the amount of development along the creek. Figure 2 depicts the stationing of the creek for the watershed and identifies the study area. Figure 3 depicts the stationing along Tonawanda Creek within the City of Batavia and Village of Attica, as well as the locations where field data was collected for this study.

Figure 1. Tonawanda Creek Watershed, Niagara, Erie, Genesee and Wyoming Counties, NY



Resilient NY Initiative
Tonawanda Creek Flood Study
Figure 1. Tonawanda Creek Watershed, Niagara, Erie, Genessee, and Wyoming Counties, NY

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

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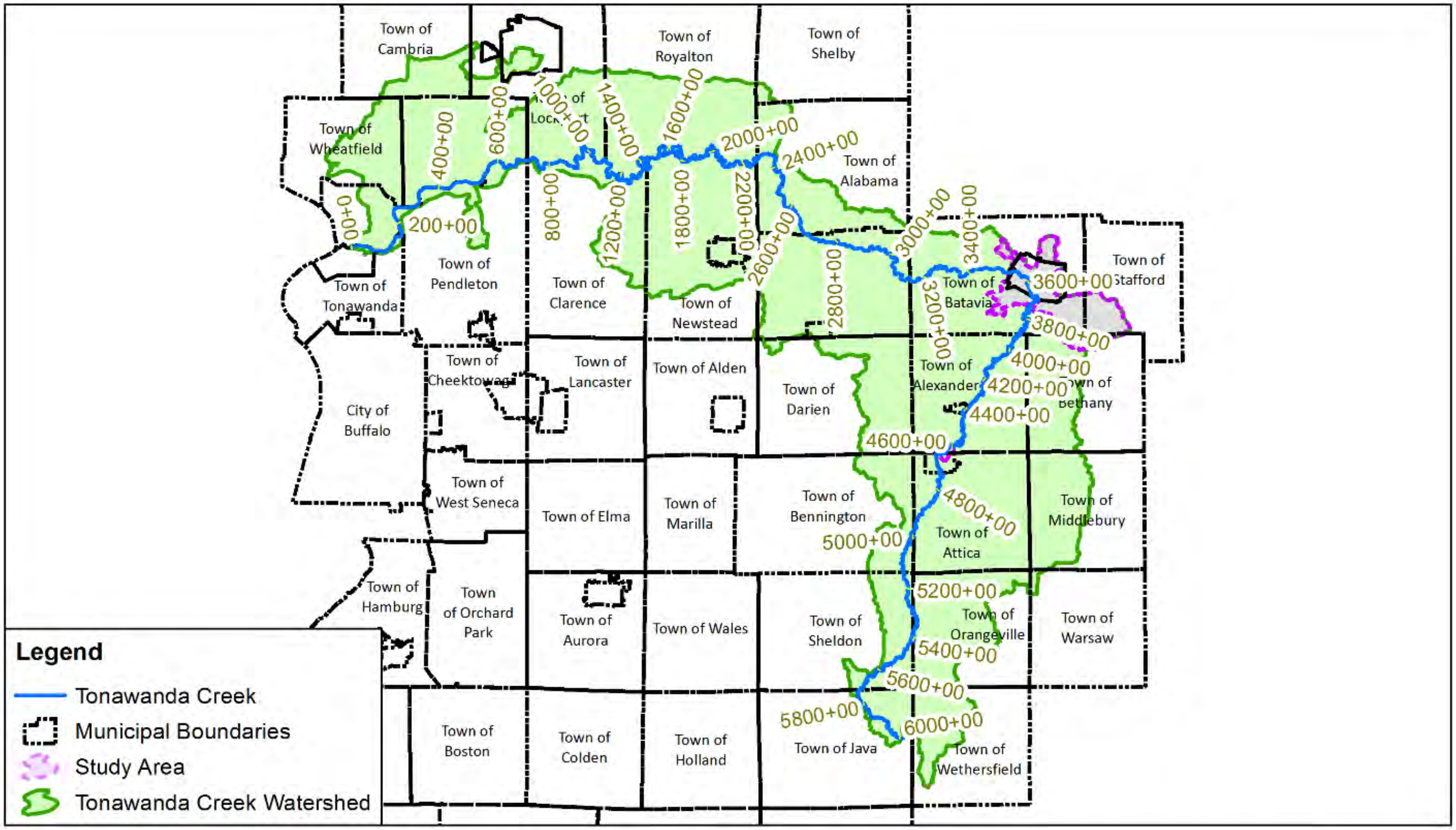
Figure 2. Tonawanda Creek Stationing, Niagara, Erie, Genesee, and Wyoming Counties, NY



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N W E S

0 2.5 5 10 Miles

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Figure 3. Tonawanda Creek Batavia Study Area Stationing, Genesee County, NY

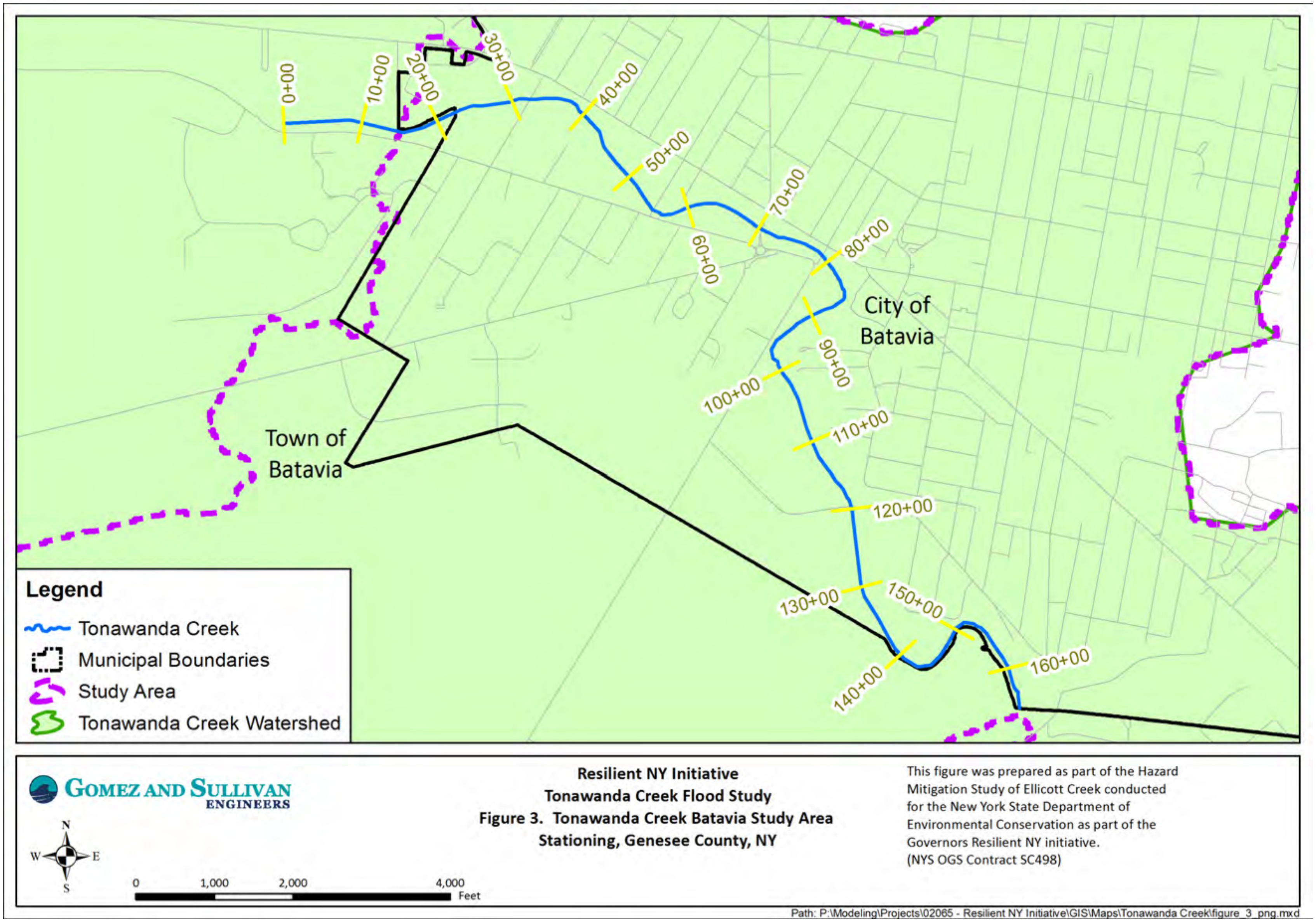
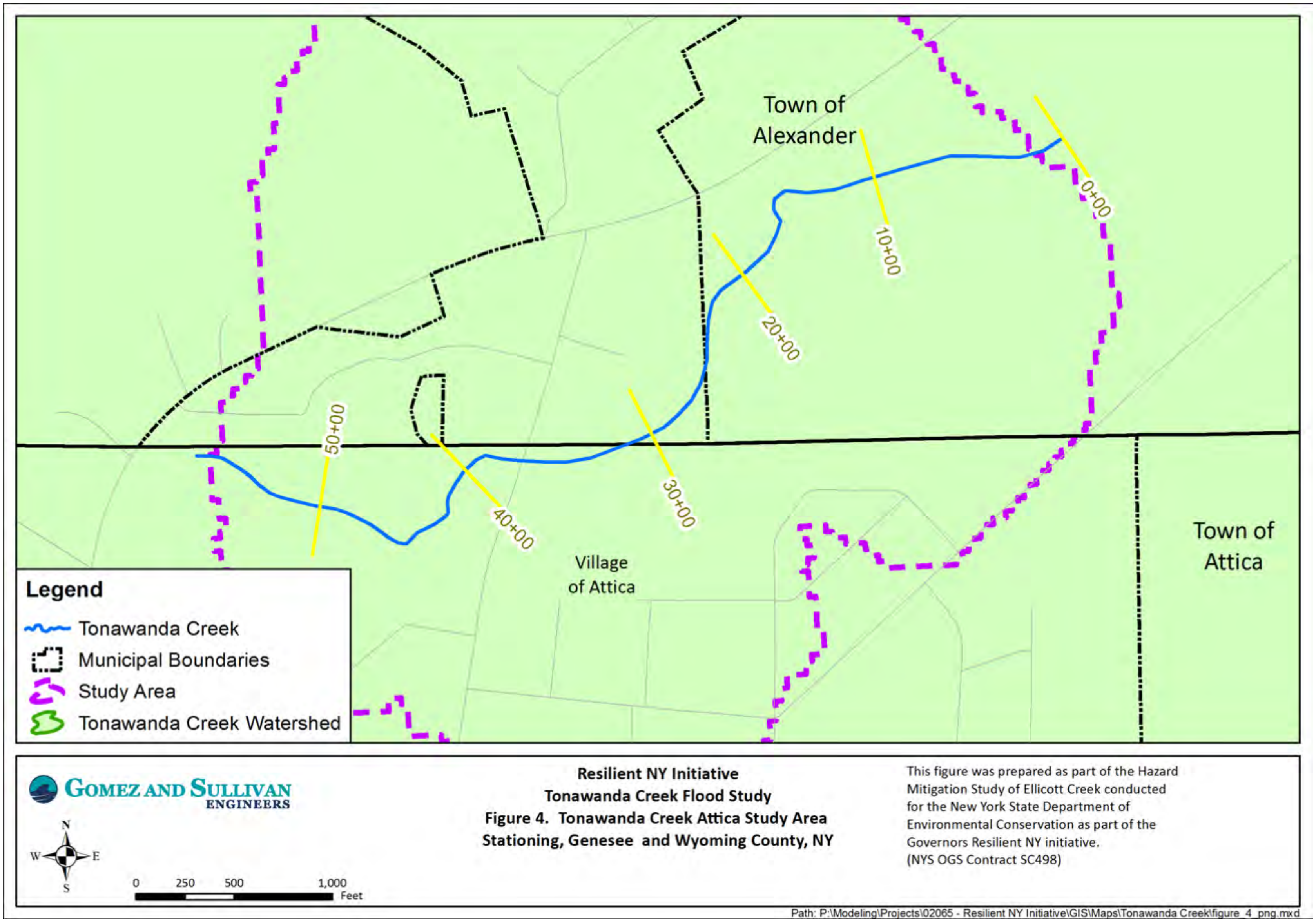


Figure 4. Tonawanda Creek Attica Study Area Stationing,Genesee and Wyoming County, NY



Environmental Conditions

An overview of the environmental and cultural resources within the Tonawanda Creek study area 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, 2020a) (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, 2020a)
Information for Planning and Consultation (IPaC): The IPaC database provides information about endangered/threatened species and migratory birds regulated by the United States Fish and Wildlife Service (USFWS, 2020) (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)

Wetlands

The State-Regulated Freshwater Wetlands database shows the approximate location of wetlands regulated by New York State. The check zone is a 100-foot buffer zone around the wetland in which the actual wetland may occur. According to the Environmental Resource Mapper, 30 NYSDEC-regulated wetlands within the Batavia study area, there are no NYSDEC-regulated wetlands within the Attica study area (NYSDEC, 2020a).

The NWI was reviewed to identify national wetlands and surface waters (Figure 5, Figure 6). The Tonawanda Creek Batavia study area includes 279 wetlands, separate from Tonawanda Creek. Within this study area, there are 55 freshwater emergent wetlands, 112 freshwater forested/shrub wetlands, 47 freshwater ponds, four lakes and 61 riverine wetlands. The Tonawanda Creek Attica study area includes 11 wetlands separate from Tonawanda Creek. Within this study area, there are two freshwater forested/shrub wetlands, two freshwater ponds and seven riverine wetlands (NYSDEC, 2020a).

Sensitive Natural Resources

No areas designated as significant natural communities by the NYSDEC were mapped in the Tonawanda Creek study area (Figure 7) (NYSDEC, 2020a).

Endangered or Threatened Species

The Environmental Resource Mapper shows that rare plants and animals included freshwater mussels in the Batavia study area and bigmouth shiner in the Attica study area, have beed documented in the vicinity of the study area as mapped by the Environmental Resource Mapper (Figure 7). The NYSDEC Regional Office should be contacted to determine the potential presence of the species identified (NYSDEC, 2020a).

The USFWS Information for Planning and Consultation (IPaC) results for the study area list no endangered species within the Batavia study area. Within the the Attica study area, the northern long-eared bat was listed.No critical habitat has been designated for the species within the study area (USFWS, 2020).

The migratory bird species listed in Table 1 are transient species that may pass over but are not known to nest within the study area.

Table 1. USFWS IPaC Listed Migratory Bird Species

Common Name	Scientific Name	Level of Concern	Breeding Season
American Golden-plover	*Pluvialis dominica*	BCC Rangewide (CON)	Breeds elsewhere
Bald Eagle	*Haliaeetus leucocephalus*	Non-BCC Vulnerable	Dec 1 to Aug 31
Black-billed Cuckoo	*Coccyzus erythropthalmus*	BCC Rangewide (CON)	May 15 to Oct 10
Bobolink	*Dolichonyx oryzivorus*	BCC Rangewide (CON)	May 20 to Jul 31
Buff-breasted Sandpiper	*Calidris subruficollis*	BCC Rangewide (CON)	Breeds elsewhere
Canada Warbler	*Cardellina canadensis*	BCC Rangewide (CON)	May 20 to Aug 10
Cerulean Warbler	*Dendroica cerulea*	BCC Rangewide (CON)	Apr 20 to Jul 20
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)	May 10 to Sep 10
Ruddy Turnstone	*Arenaria interpres morinella*	BCC - BCR	Breeds elsewhere
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)	May 10 to Aug 31

Source: (USFWS, 2020)

Cultural Resources

According to the National Register of Historic Places, there are eight historic places within the Batavia study area; Batavia Veterans Administrtion Hospital, Holland Land Office, Genesee County Courthouse Historic District, Genesee County Courthouse, Batavia Club, First Presbyterian Church, Richmond Memorial Library, and Saint James' Episcopal Church. Within the Attica study area, there are no locations included on the National Register of Historic Places. 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 5. Tonawanda Creek Study Batavia Area Wetlands and Hydrography, Genesee County, NY

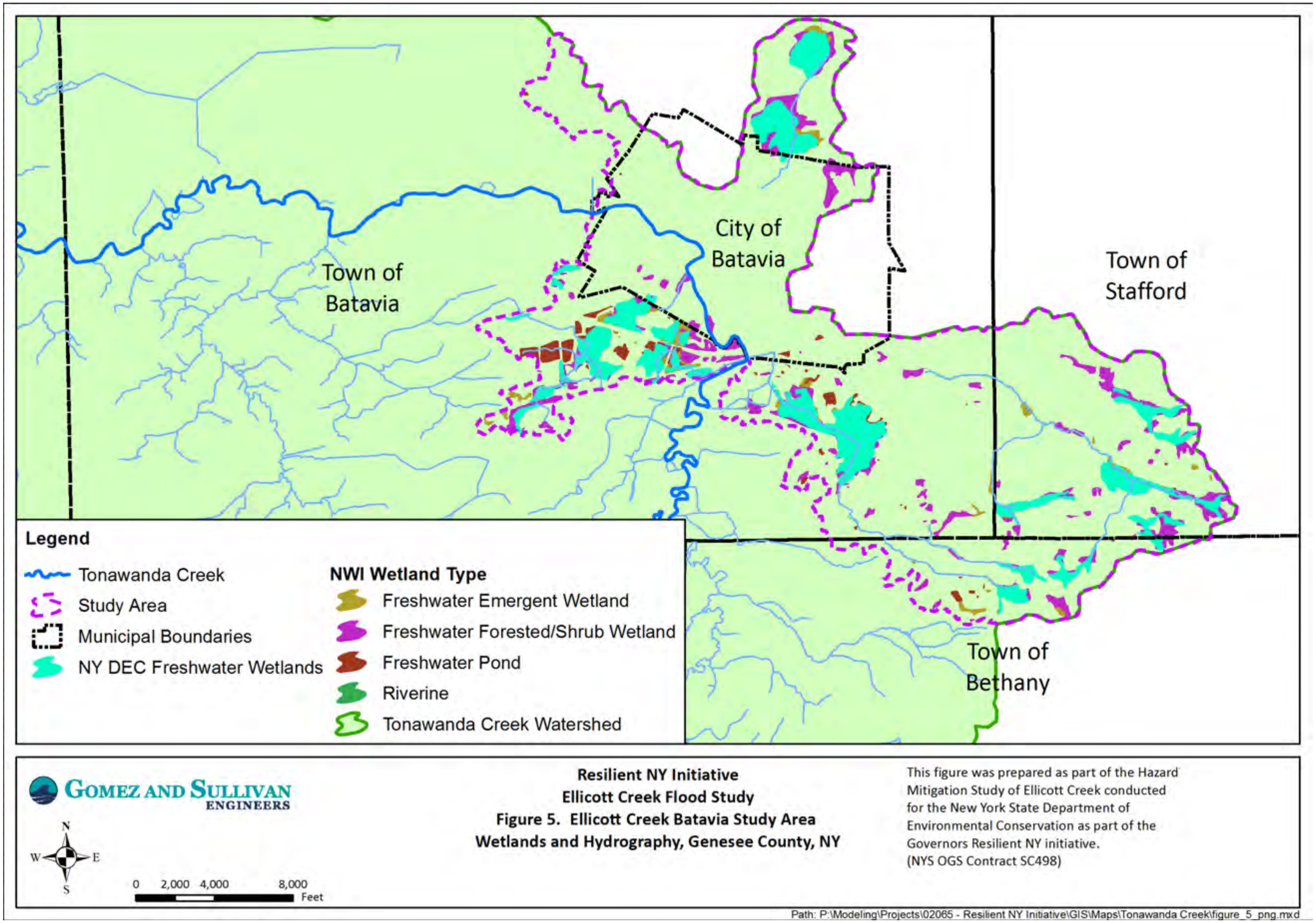


Figure 6. Tonawanda Creek Study Attica Area Wetlands and Hydrography, Genesee and Wyoming County, NY

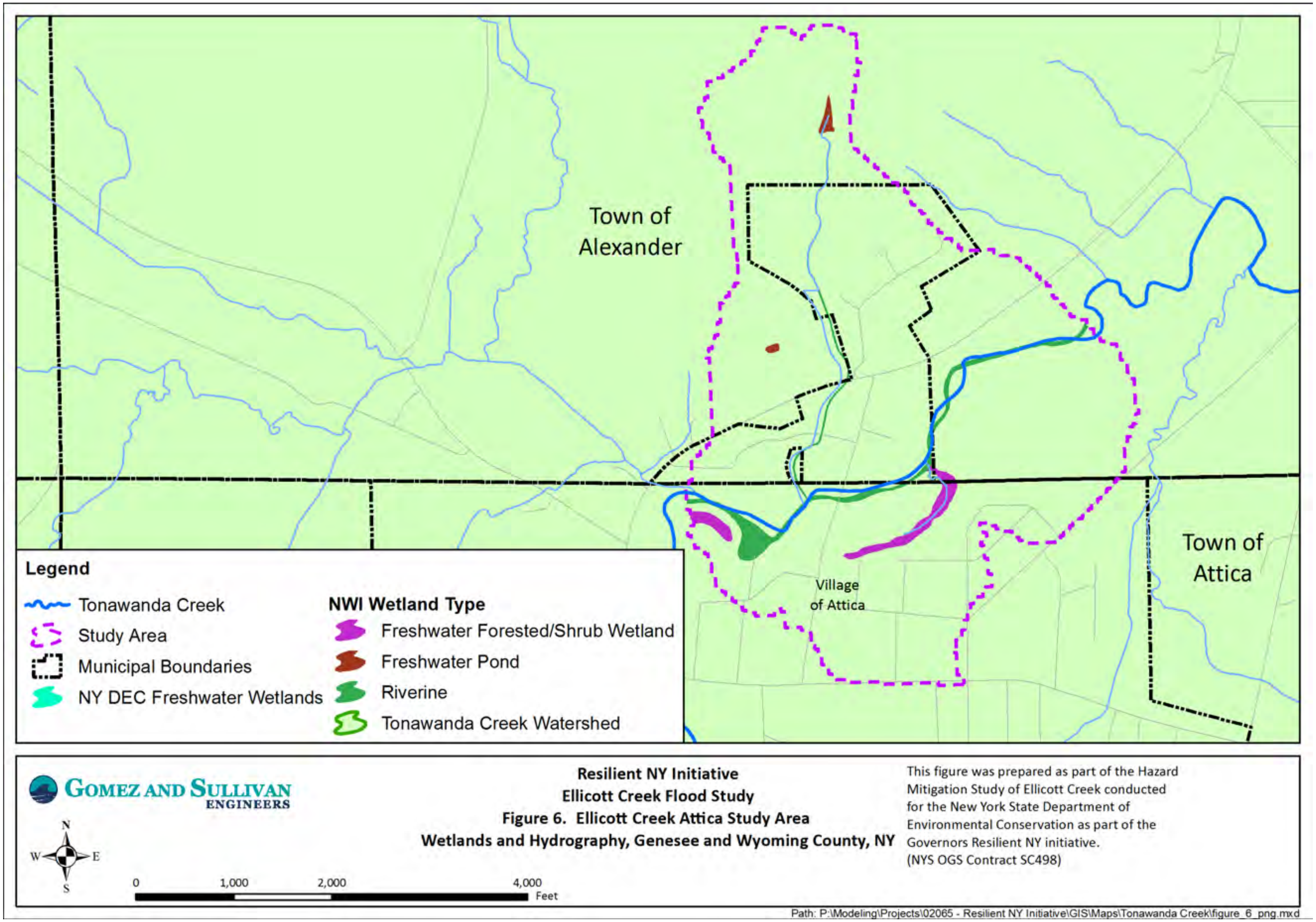


Figure 7. Significant Natural Communities and Rare Plants or Animals, Tonawanda Creek Batavia Study Area, Genesee County, NY

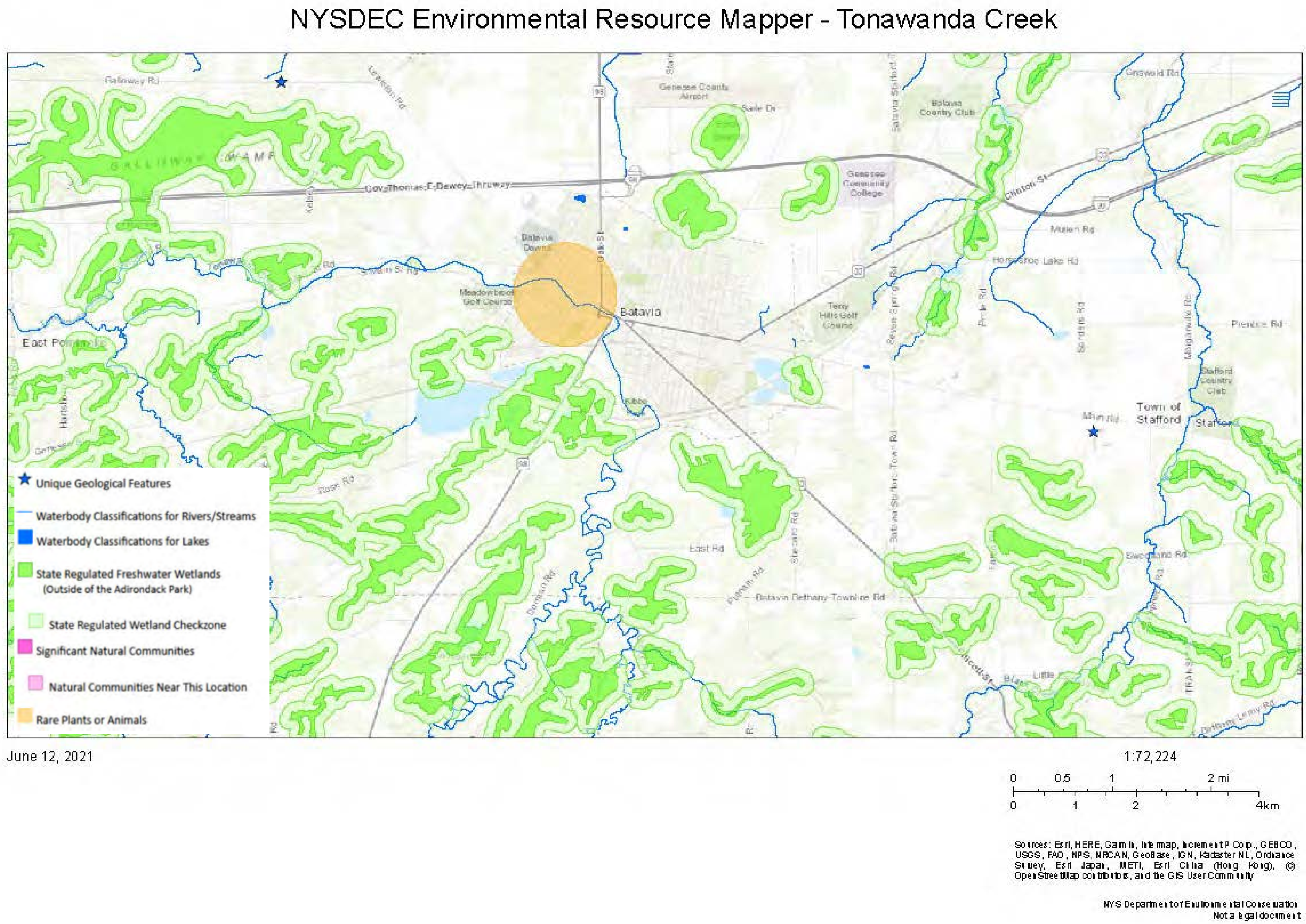
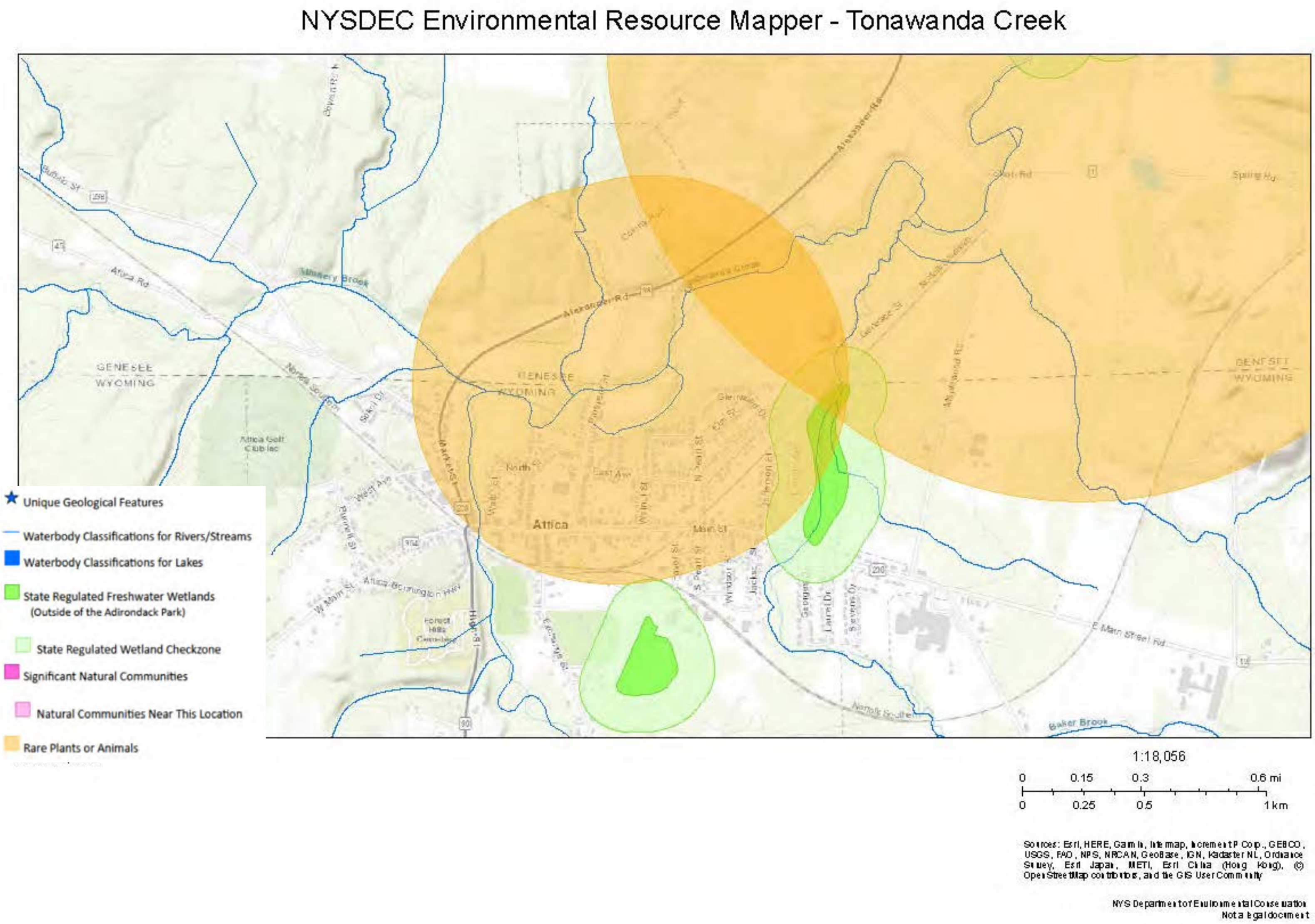


Figure 8. Significant Natural Communities and Rare Plants or Animals, Tonawanda Creek Attica Study Area, Genesee and Wyoming County, NY



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 City of Batavia, the current effective FEMA FIS was completed on March 16, 1982; for the Village of Attica, the current effective FIS was completed on July 3, 1986. According to the FIS reports, the hydrologic and hydraulic analyses completed included new detailed analyses. The FEMA FIS included Tonawanda Creek in the new detailed study (FEMA, 1986; FEMA, 1982).

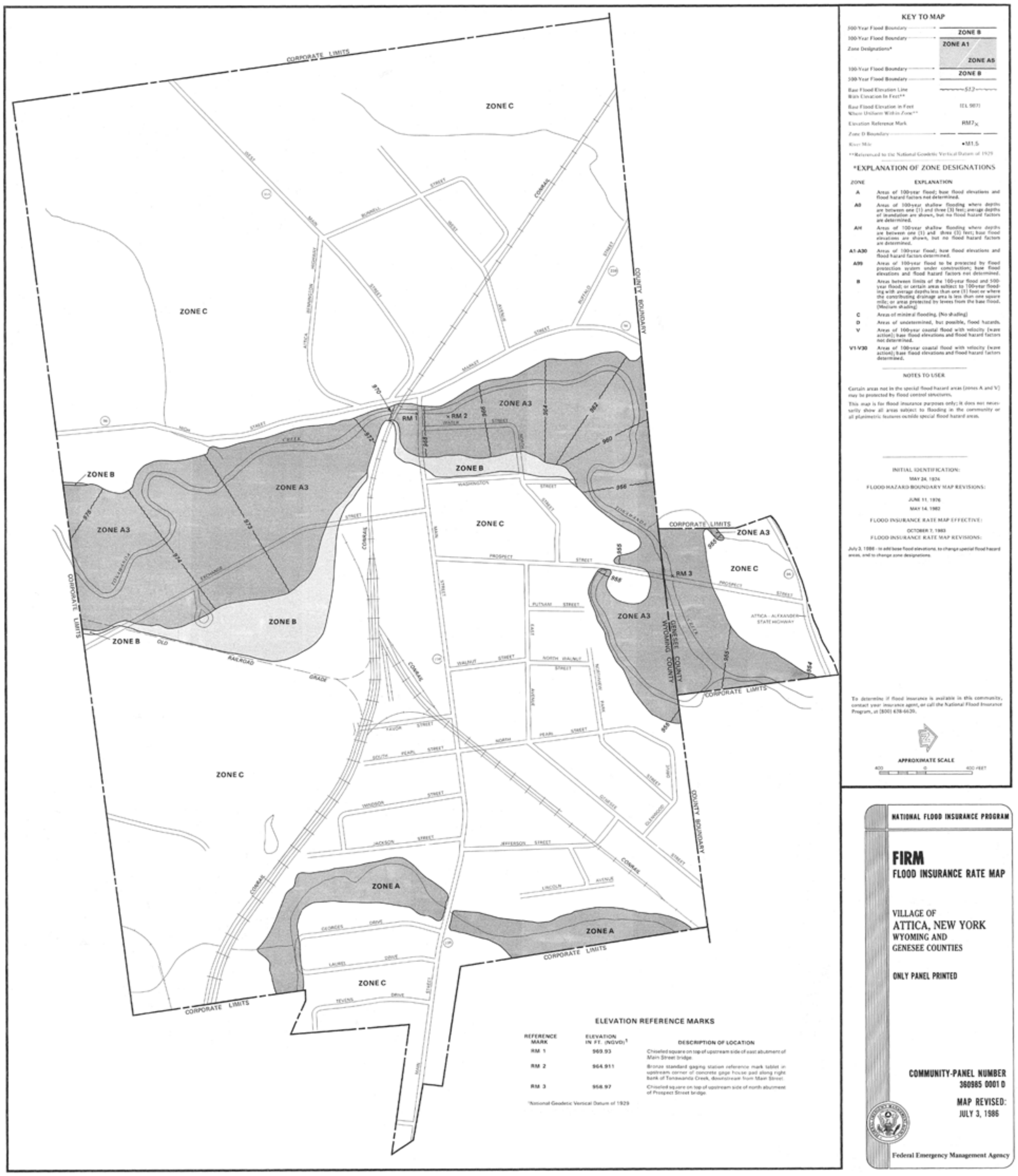
For a new detailed study, FEMA can perform a limited detailed or detailed study. For both methods, semiautomated hydrologic, hydraulic, and mapping tools, coupled with digital elevation data, are used to predict floodplain limits, especially in lower-risk areas. If the tools are used with some data collected 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 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 FIRM for Tonawanda Creek indicates 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, 1982; FEMA, 1986). Within the City of Batavia, Tonawanda Creek is a Regulatory Floodway, which is defined as the watercourse channel and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than 1-foot over the 1% annual chance flood hazard water surface elevation, referred to as the Base Flood Elevation (BFE). In the regulatory floodway, communities must regulate encroachments, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway and demonstrate through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not increase flood levels within the community during the occurrence of the base flood. Development in the portions of the floodplain beyond the floodway, referred to as the floodway fringe, is allowed as long as it does not increase the BFE more than 1.0 foot (FEMA, 2000).

In the Village of Attica, no floodway has been computed. 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 Tonawanda Creek study area are Zones AE, AH and AO, where mandatory flood insurance purchase requirements apply. AE Zones are areas that have a 1% annual chance of flooding where BFEs are provided by FEMA. AH zones are shallow flooding areas where BFEs are provided by FEMA. AO zones are shallow flooding areas where FEMA provides a base flood depth, which indicates the depth of water above highest adjacent grade resulting from a flood that has a 1% annual chance of equaling or exceeding that level. FEMA does not provide a BFE for Zone AO (FEMA 2000). Figure 9 is a FIRM that includes a portion of Tonawanda Creek in the City of Batavia, NY (FEMA, 1982).

Figure 9. FEMA FIRM, Tonawanda Creek, City of Batavia, Genesee County, NY

Figure 10. FEMA FIRM, Tonawanda Creek, Village of Attica, Wyoming and Genesee Counties, NY



Study Area Land Use

The National Land Cover Database (MRLC, 2019) shows that, within the study area, the Woody and Emergent Herbaceuous Wetland land use cover types make up 16.7% of the study area. All developed land cover types total 25.1% of the study area and all agriculture cover types total 41.3%. Further details of the distribution of land cover within the watershed are shown in Table 2. Within the Batavia study area, cultivated crops and pasture/hay fields are mainly located in the western and northern portions of the study area; the central portion of the study area is mainly developed area, and there is a significant amount of wetland areas in the southeastern portion of the study area. Within the Attica study area, the areas of forest and cultivated lands are located mainly along the stream corridors, with the remainder ot the study area made up mainly of developed areas.

Table 2. Land Use Cover Types in the Tonawanda Creek Study Area

Land Use Cover Type	Batavia		Attica	
	Acres	Percentage	Acres	Percentage
Woody Wetlands	1656.71	15.6%	4.93	1.2%
Developed, Open Space	761.86	7.2%	42.73	10.2%
Pasture/Hay	1266.03	11.9%	60.51	14.4%
Deciduous Forest	1050.63	9.9%	126.49	30.0%
Developed, Low Intensity	1006.27	9.5%	54.59	13.0%
Cultivated Crops	3179.82	29.9%	60.32	14.3%
Developed, Medium Intensity	565.72	5.3%	20.03	4.8%
Mixed Forest	212.77	2.0%	36.01	8.6%
Barren Land (Rock/Sand/Clay)	39.62	0.4%	1.88	0.4%
Grassland/Herbaceous	24.45	0.2%	0.22	0.1%
Emergent Herbaceous Wetlands	188.15	1.8%	0.00	0.0%
Developed High Intensity	322.83	3.0%	4.52	1.1%
Open Water	305.02	2.9%	0.44	0.1%
Shrub/Scrub	46.44	0.4%	0.44	0.1%
Evergreen Forest	9.54	0.1%	7.82	1.9%
Total	10635.86	**100%**	420.93	**100%**

Source: (MRLC, 2019)

Geomorphology

Upstream of Batavia to the Town of Alexander, the Tonawanda Creek valley is largely filled with stratified gravel, sand and silt; poorly drained low-lying areas are generally filled with organic silty alluvium, with some deposits exceeding three feet in thickness and likely were deposited as a result of glacial outwash. The valley north of Alexander generally has low topography, with the exception of several knobby ridges consisting of stratified, well-sorted sand and gravel deposited by glacial ice. The low areas adjacent to the ridges are also composed of sand and gravel consisting of glacial outwash, inwash to glacial Great Lakes and alluvium (USACE, Buffalo District, 1983).

Figure 11 is a profile of stream bed elevation and channel distance within the study area based on the hydraulic model used for this study. The figure includes the location of all stream crossings included within the hydraulic model.

Figure 11. Tonawanda Creek Batavia Study Area Profile of Stream Bed Elevation and Channel Distance

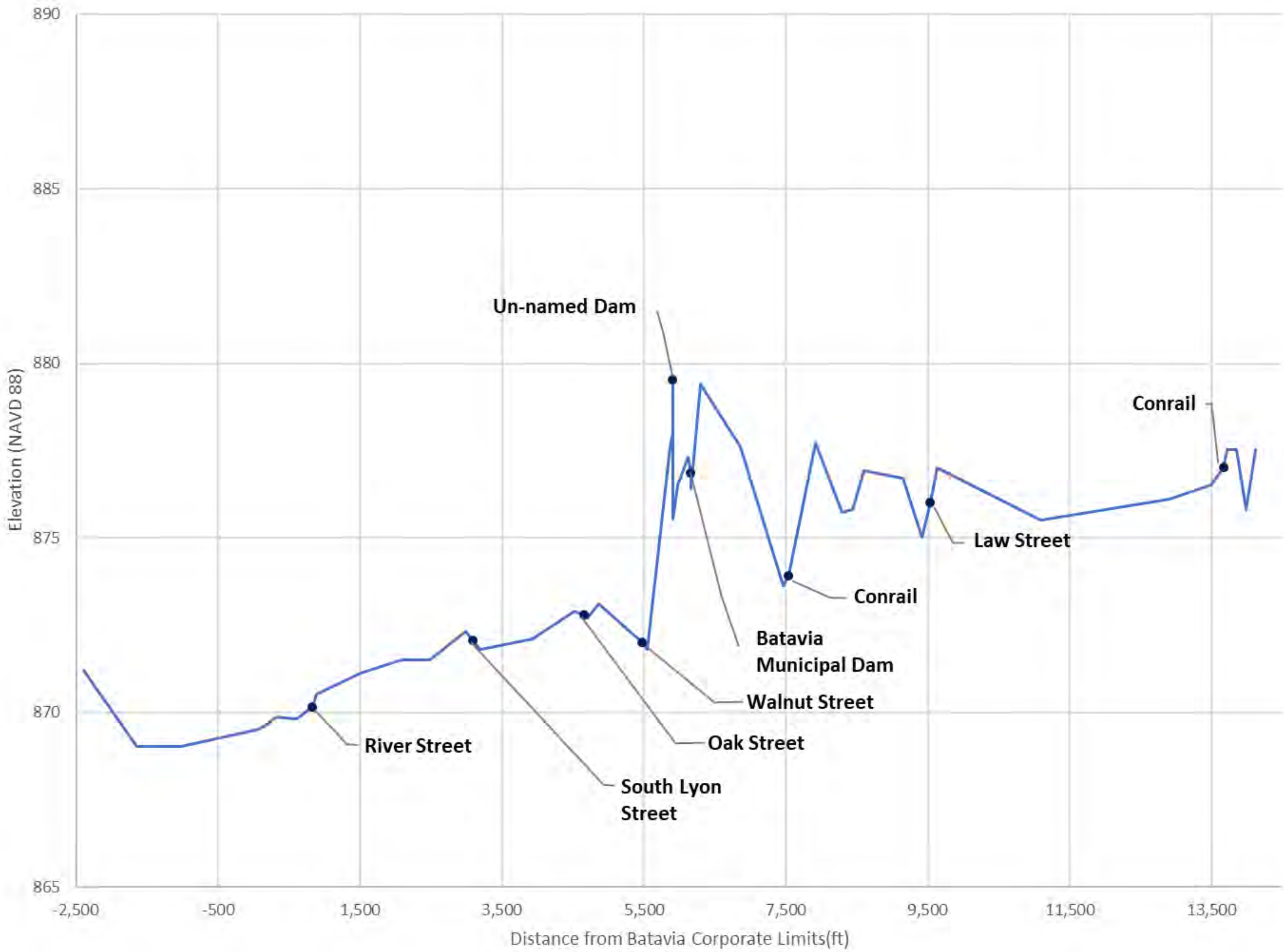
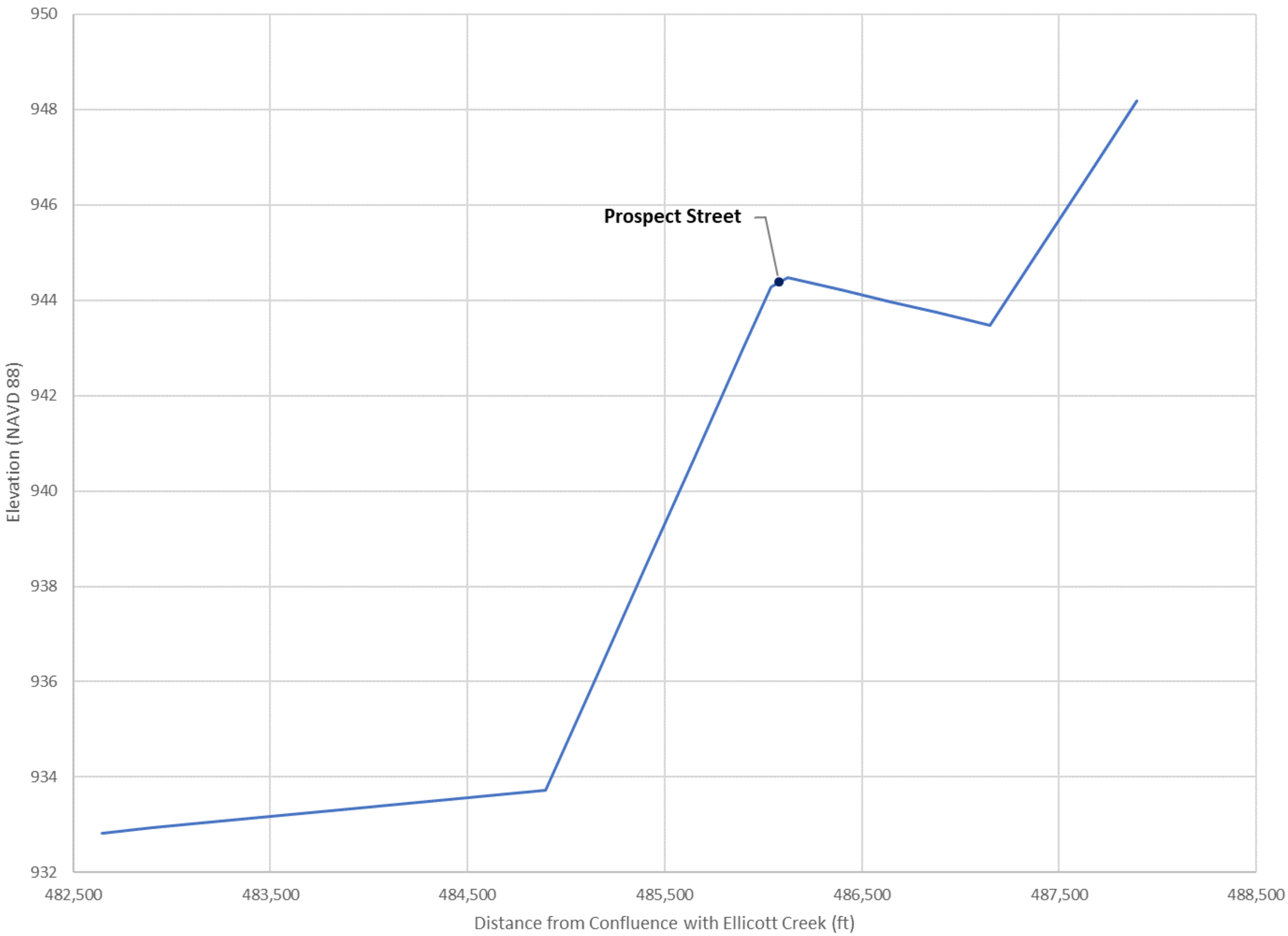


Figure 12. Tonawanda Creek Attica Study Area Profile of Stream Bed Elevation and Channel Distance



Hydrology

Tonawanda Creek at the Village of Attica, NY is approximately 26.3 miles long and the watershed covers approximately 82.7 square miles (53,000 acres). Tonawanda Creek at the City of Batavia, NY is approximately 46.8 miles long and the watershed covers approximately 174.6 square miles (111,750 acres). Tonawanda Creek begins in the Cattaraugus Hills upstream of Faun Lake in the Town of Bliss. The creek generally flows in a northerly direction from the source to the Village of Attica. Tonawanda Creek continues to flow generally north to the City of Batavia at which point the creek turns west and eventually joins with the Niagara River near the City of Tonawanda.

The only significant tributary within the drainage area of the Attica project area is the East Fork of Tonawanda Creek which joins the main stem in the Town of Sheldon after passing under NY State Route 98. Little Tonawanda Creek is a significant tributary which joins the main stem of Tonawanda Creek approximately 3.5 miles south of the City of Batavia city limits.

Table 3 is a summary of the basin characteristic formulas and calculated values for the Tonawanda Creek watershed at both project locations, Village of Attica and the City of Batavia, where A is the drainage area of the basin in square miles (mi^2), B_L is the basin length in miles, and B_P is the basin perimeter in miles (USGS, 1978).

Village of Attica
A = 82.7 square miles
B_L = 26.3 miles
B_P = 78.4 miles

City of Batavia
A = 174.6 square miles
B_L = 46.8 miles
B_P = 132.1 miles

Table 3. Tonawanda Creek Basin Characteristics Factors

Factor	Formula	Attica Value	Batavia Value
Form Factor (R_F)	A/B_L^2	0.12	0.08
Circularity Ratio (R_C)	$4\pi A/B_P^2$	0.17	0.13
Elongation Ratio (R_E)	$2(A/\pi)^{0.5}/B_L$	0.39	0.32

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 characteristic factors, the Tonawanda Creek basin would be categorized as more elongated with lower peak but longer duration high flows expected (Parveen, Kumar, & Singh, 2012). The drainage system within the basin would be expected to be steep with large impacts caused by structural disturbances in the drainage system (Waikar & Nilawar, 2014).

There are three (3) USGS stream gaging stations on Tonawanda Creek within the drainage area of the project locations. The most upstream gage is located in Johnsonburg, NY (USGS Gage ID 04216400). This historic gage has 25 years of recorded data ranging from 1962 to 1985. The highest recorded peak flow was 1,850 cubic feet per second on June 23, 1972. The second gage is located within the Village of Attica (USGS Gage ID 04216418). This gage is currently active with 44 years of record beginning in 1972, with a continuous period of record beginning in 1978. The annual peak flows recorded at this gage range from

1,430 cubic feet per second to 9,400 cubic feet per second. The third gage is located within the City of Batavia (USGS Gage ID 04217000). This gage is also currently active with 77 years of record beginning in 1942, and a continuous period of record beginning in 1945. The annual peak flows recorded at this gage range from 1,470 cubic feet per second to an estimated historic discharge of 10,000 cubic feet per second.

An effective FEMA Flood Insurance Study (FIS) for the City of Batavia was issued on March 16, 1982 and for the Village of Attica, issued on July 3, 1986. Both of the FIS reports included a new detailed study for Tonawanda Creek and included drainage area and discharge information for the portions of Tonawanda Creek included in these studies. Table 4 summarizes the FEMA FIS drainage areas and peak discharges, in cubic feet per second (cfs), for Tonawanda Creek within the study areas (FEMA, 1982) (FEMA, 1986). The river station presented in the table below is calculated from the confluence with Elicott Creek. The stations presented in the FIS reports for the City of Batavia and Village of Attica are 5580 and 5500, calculated from each corporate limit respectively.

Table 4. Tonawanda Creek FEMA FIS Peak Discharges

Flooding Source and Location		Drainage Area (mi^2)	River Station (ft)	Peak Discharge (cfs)			
				10%	2%	1%	0.2%
City of Batavia	TONAWANDA CREEK At USGS Gaging Station No. 04217000	171	383520	6,000	7,600	8,200	9,400
Village of Attica	TONAWANDA CREEK At USGS Gaging Station No. 04216418	77.1	490240	6,900	N/A	10,100	12,500

Source: (FEMA, 1982); (FEMA, 1986)

According to the effective FEMA FIS, the hydrology estimates for the City of Batavia and the Village of Attica were obtained from the USACE report, *Interim Report on Feasibility of Flood Management, Tonawanda Creek Watershed* (USACE, Buffalo District, 1983)[1]. This report utilized a peak discharge-frequency analyses to develop peak discharge frequency curves for a range of drainage areas based data collected from six (6) locations between Batavia and the confluence with the Niagara River. No further details regarding the hydrologic analyses is provided in either the FIS or the 1983 USACE report.

General limitations of the FEMA FIS methodology are the age of the effective FIS H&H analysis and the age of the methodology. The H&H analysis for Tonawanda Creek was completed in 1983 using the USACE methodology stated above.

The FIS studies were completed in 1982 and 1986, with the peak flow estimates derived in 1983 by the USACE. The flows within the Attica FIS study, are reported at the USGS streamflow gage location in the Village of Attica, NY. The 1983 USACE report did not utilize this gage information in determining flows or developing the peak- discharge-frequency curves for the six (6) locations. Presumably the Attica gage was not included due to the project location the report was prepared for (the Batavia Reservoir Compound-

[1] The 1983 USACE report is an updated version of the report referenced in the City of Batavia FIS. This previous report, dated December 1980, was unable to be located. Within the other versions found of the 1980 report (November 1981, July 1983, and April 1991), the methodology for the hydrologic analysis remained consistent throughout.

Modified Plan), the relative newness of the gage (five (5) years), or both. Due to this, there is no direct estimate for the flow change location reported in the FIS, presented in the 1983 USACE report.

Additionally, reviewing the 1983 USACE report, values for the 10%, 2%, 1% and 0.2% can be estimated from the peak discharge-frequency curves developed and presented on Plate 6 of the report. These are included in Table 5, below. Comparing these values to those reported in the Village of Attica FIS shows a substantial discrepancy in the flows estimated for Attica, as the FIS flows are greater than those estimated from the peak discharge-frequency curves. As Attica is upstream of Batavia, the flows in the FIS are expected to be less than those in Batavia, following the trend depicted in the curves. It is noted that the discharges estimated from the 1983 USACE Report are fairly consistent with the reported flows in the FIS for the City of Batavia.

Table 5. Tonawanda Creek USACE 1983 Peak Discharges at Batavia

Flooding Source and Location		Drainage Area (mi^2)	Peak Discharge (cfs)			
			10%	2%	1%	0.2%
City of Batavia	TONAWANDA CREEK At USGS Gaging Station No. 04217000	171	6,100	7,600	8,300	9,600

Source: (USACE, Buffalo District, 1983)

StreamStats v4.5.3 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 [(USGS, 2017); (USGS, 2021a)].

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 [(USGS, 1991); (USGS, 2006)].

For gaged sites, such as Tonawanda Creek in hydrologic region six (6) of New York State, the generalized least-squares (GLS) regional-regression equations are used to improve streamflow-gaging-station estimates (based on log-Pearson type III (LP3) flood-frequency analysis of the gaged annual peak-discharge record) by using a weighted average of the two estimates (regression and gaged). Incorporating the regression estimate into the weighted average tends to decrease time sampling errors that result for sites with short periods of record. The weighted-average discharges are generally the most reliable and are computed from the equation:

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

Where,

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

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

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

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

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

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

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

StreamStats was used to calculate the current peak discharges for Tonawanda Creek and compared with the effective FIS peak discharges. Table 6 is the summary output of peak discharges calculated by the USGS *StreamStats* software for Tonawanda Creek at the same locations as the FEMA FIS peak discharges. The values in Table 6 below represent the variable, $Q_{T(r)}$ as defined above. The river station presented in the table below is calculated from the confluence with Elicott Creek.

Table 6. USGS StreamStats Peak Discharge for Tonawanda Creek at the FEMA FIS Locations

Flooding Source and Location		Drainage Area (mi²)	River Station (ft)	Peak Discharge (cfs)			
				10%	2%	1%	0.2%
City of Batavia	TONAWANDA CREEK At USGS Gaging Station No. 04217000	170	383520	5,550	7,870	8,880	11,400
Village of Attica	TONAWANDA CREEK At USGS Gaging Station No. 04216418	76.5	490240	4,030	5,850	6,660	8,690

Source: (USGS, 2021a)

USGS PeakFQ (USGS, 2021c) program implements Bulletin 17C procedures for flood-frequency analysis of streamflow records, providing estimates of flood magnitudes and their corresponding variance for a range of annual exceedance probabilities. The values in Table 7 below represent the variable, $Q_{T(g)}$ as defined above. The river station presented in the table below is calculated from the confluence with Elicott Creek. The gage in Johnsonburg was not analyzed as the gage is no longer active and the data is greater than (ten) 10 years old and is therefore no longer statistically significant. Additionally, the drainage area at the Johnsonburg gage (23.7 square miles) is significantly less than the drainage area at the Attica gage and therefore would not be statistically relevant for inclusion in the analysis.

Table 7. Bulletin 17C Gage Peak Discharge for Tonawanda Creek at the FEMA FIS Locations

Flooding Source and Location		Drainage Area (mi²)	River Station (ft)	Peak Discharge (cfs)			
				10%	2%	1%	0.2%
City of Batavia	TONAWANDA CREEK At USGS Gaging Station No. 04217000	171	383520	5,704	7,339	8,002	9,492
Village of Attica	TONAWANDA CREEK At USGS Gaging Station No. 04216418	76.9	490240	4,929	7,160	8,268	11,290

Source: (USGS, 2021c)

The USGS National Streamflow Statistics (USGS, 2021b) utilizes the gage weighted flow estimate equation, as outlined in (USGS, 2006) and above in this report. The values presented in Table 8 below are the calculated weighted averages of the gage record data and the regional regression estimates for the specific exceedance probabilities. From the equation above, these values shown here are the $Q_{T(W)}$ variable. The river station presented in the table below is calculated from the confluence with Elicott Creek.

Table 8. Gage Weighted Peak Discharge for Tonawanda Creek at the FEMA FIS Locations

Flooding Source and Location		Drainage Area (mi²)	River Station (ft)	Peak Discharge (cfs)			
				10%	2%	1%	0.2%
City of Batavia	TONAWANDA CREEK At USGS Gaging Station No. 04217000	171	383520	5,700	7,370	8,050	9,610
Village of Attica	TONAWANDA CREEK At USGS Gaging Station No. 04216418	76.9	490240	4,860	7,020	8,090	11,000

Source: (USGS, 2021b)

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 was 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 9 is a summary table of the USGS *StreamStats* standard errors at each percent annual chance flood hazard for Region six (6) in New York State.

Table 9. USGS StreamStats Standard Errors for Full Regression Equations

Parameter	Annual Chance of Exceedance (%)			
	10%	2%	1%	0.2%
Standard Error of Peak Discharge (%)	32.9	35.8	37.2	41.4

Source: (USGS, 2006)

Based on the peak flow estimates presented in Table 4 and Table 6 it has been determined that for the Village of Attica, the FEMA FIS values fall outside 95% Confidence Interval for the USGS Regional Regression Equations. In addition, the FEMA FIS values are greater than USGS Regional Regression Equations values**.** Typically, this would indicate the use of the FEMA FIS peak discharge values in the hydraulic model simulations to maintain consistency between modeling outputs and the FEMA models.

However, as previous noted, the values reported in the FIS do not appear to be consistent with the methodology outlined in the 1983 USACE report, referenced in the FIS. Also, there is an active gage with a relatively robust record of data located at the flow change location identified in the FIS. Due to these factors, the gage record data (44 current years) weighted with the USGS Regional Regression Equations estimates of the peak discharges (Table 8) were used in the evaluation of mitigation alternatives in the Attica study area.

For the City of Batavia, FEMA FIS peak discharges (Table 4) were determined to be within an acceptable range (95% confidence interval) of the USGS Regional Regression Equations (Table 6) based on the *StreamStats* standard error calculations. It is also noted that the gage weighted analysis (Table 8) also falls within the acceptable range. However, the FEMA FIS peak discharge values were used in the hydraulic model simulations (Table 4) 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 analysis 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 (USGS, 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 (USGS, 2009). The bankfull width and depth of Tonawanda 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 & Silvey, 1996). Table 10 lists the estimated drainage area, bankfull discharge, width, and depth at select locations along Tonawanda Creek as derived from the USGS *StreamStats* program.

Table 10. USGS StreamStats Estimated Drainage Area, Bankfull Discharge, Width, and Depth

Flooding Source and Location		Drainage Area (mi²)	River Station (ft)	Bankfull Depth (ft)	Bankfull Width (ft)	Bankfull Streamflow (cfs)
City of Batavia	TONAWANDA CREEK At USGS Gaging Station No. 04217000	171	383520	3.67	142	3,480
Village of Attica	TONAWANDA CREEK At USGS Gaging Station No. 04216418	76.5	490240	3	104	1,850

Source: (USGS, 2021a)

Infrastructure

There are two dams located on Tonawanda Creek within the study area, Table 11 includes a summary of the dams located on Tonawanada Creek within the study area. There is one (1) NYSDOT owned bridge crossing Tonawanda Creek within the study area of the City of Batavia, NY, as summarized in Table 12. Tonawanda Creek is crossed by one (1) structure within the Village of Attica study area, which is owned and maintained by Wyoming County and three (3) structures within the City of Batavia study area, which are owned and maintained by Genesee County, as summarized in Table 13. 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 (USDOT, 2012). In assessing hydraulic capacity of the culverts and bridges along Tonawanda Creek, the FEMA FIS profile of Tonawanda Creek was used to determine the lowest annual chance flood elevation to flow under the low chord of a bridge, without causing an appreciable backwater condition upstream ((FEMA, 1986), Table 12). Figure 13 depicts the location of the infrastructure crossing Tonawanda Creek within the study area.

Table 11. Inventory of Dams along Tonawanda Creek

Municipality	Dam Name	FIS River Station (ft)	Hazard Code	Purpose
City of Batavia	Unknown	5890	Unknown	Unknown
City of Batavia	Batavia Municipal Dam	6140	A	Water Supply

Source: (NYSDEC, 2020b)

Table 12. NYSDOT Bridges/Culverts Crossing Tonawanda Creek

Roadway Carried (NY/US Route)	NYSDOT BIN/CIN	FIS River Station (ft)	Bridge Length (ft)	Surface Width[1] (ft)	Hydraulic Capacity (% Annual Chance)
NYS Route 98/33 (Oak Street)	1022969	4620	154	54	10%
Notes: 1. Surface 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 30 mm or tenth of a foot (NYSDOT, 2006).					

Source: (NYSDOT, 2019a); (FEMA, 1986)

Table 13. Non-NYSDOT Bridges/Culverts Crossing Tonawanda Creek

Roadway Carried	BIN/CIN	FIS River Station (ft)	Owner	Bridge Length (ft)	Surface Width (ft)	Hydraulic Capacity (% Annual Chance)
River Street	2210810	830	Genesee County	145	34	10%
South Lyon Street	2210820	3070	Genesee County	133	13.2	1%
Law Street	2210840	9500	Genesee County	124	25.6	1%
Prospect Street	3319560	1400	Wyoming County	109	29.3	10%

Source: (NYSDOT, 2019a); (FEMA, 1986)

Figure 13. Tonawanda Creek Batavia Study Area Infrastructure, Genesee County, NY

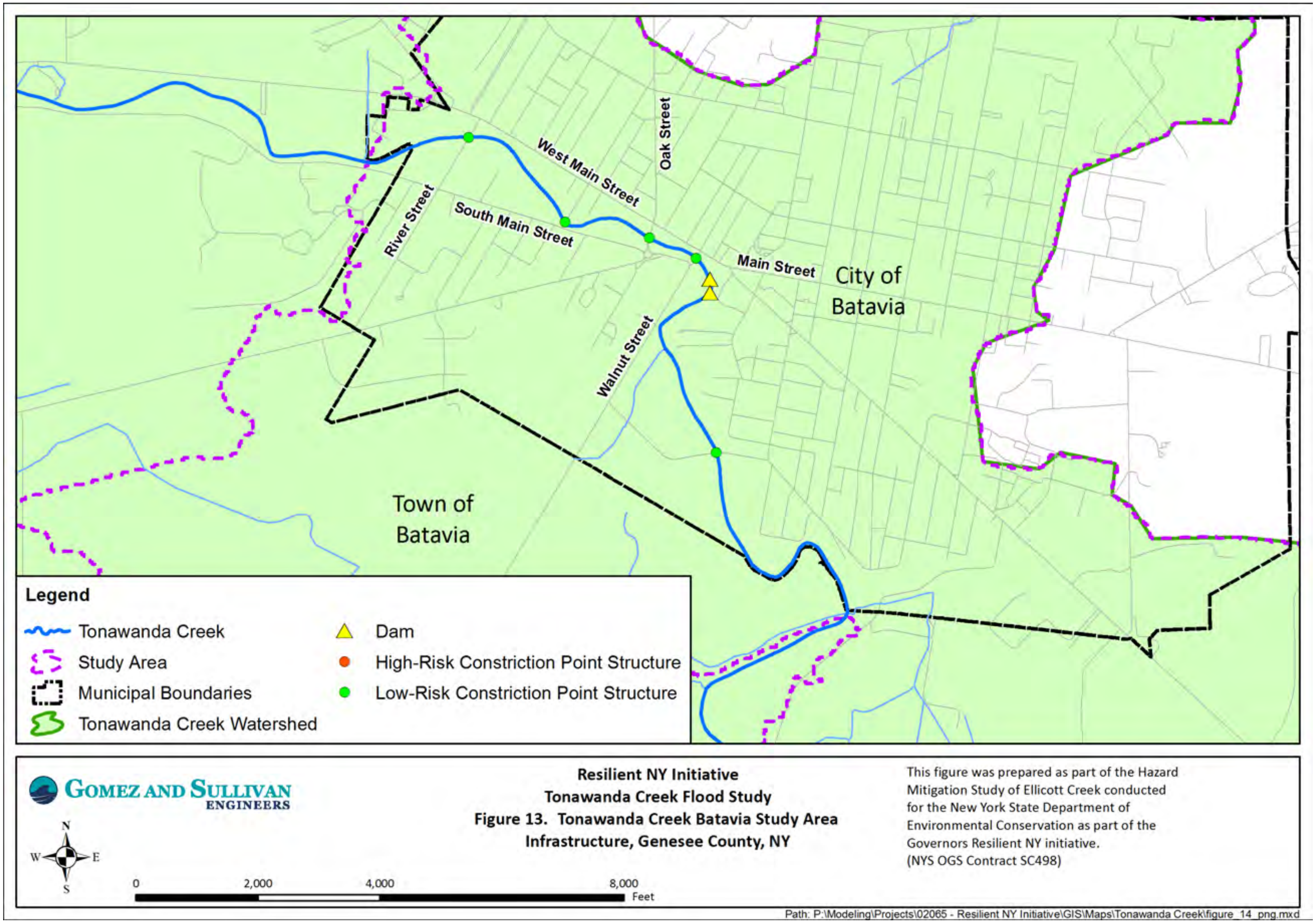
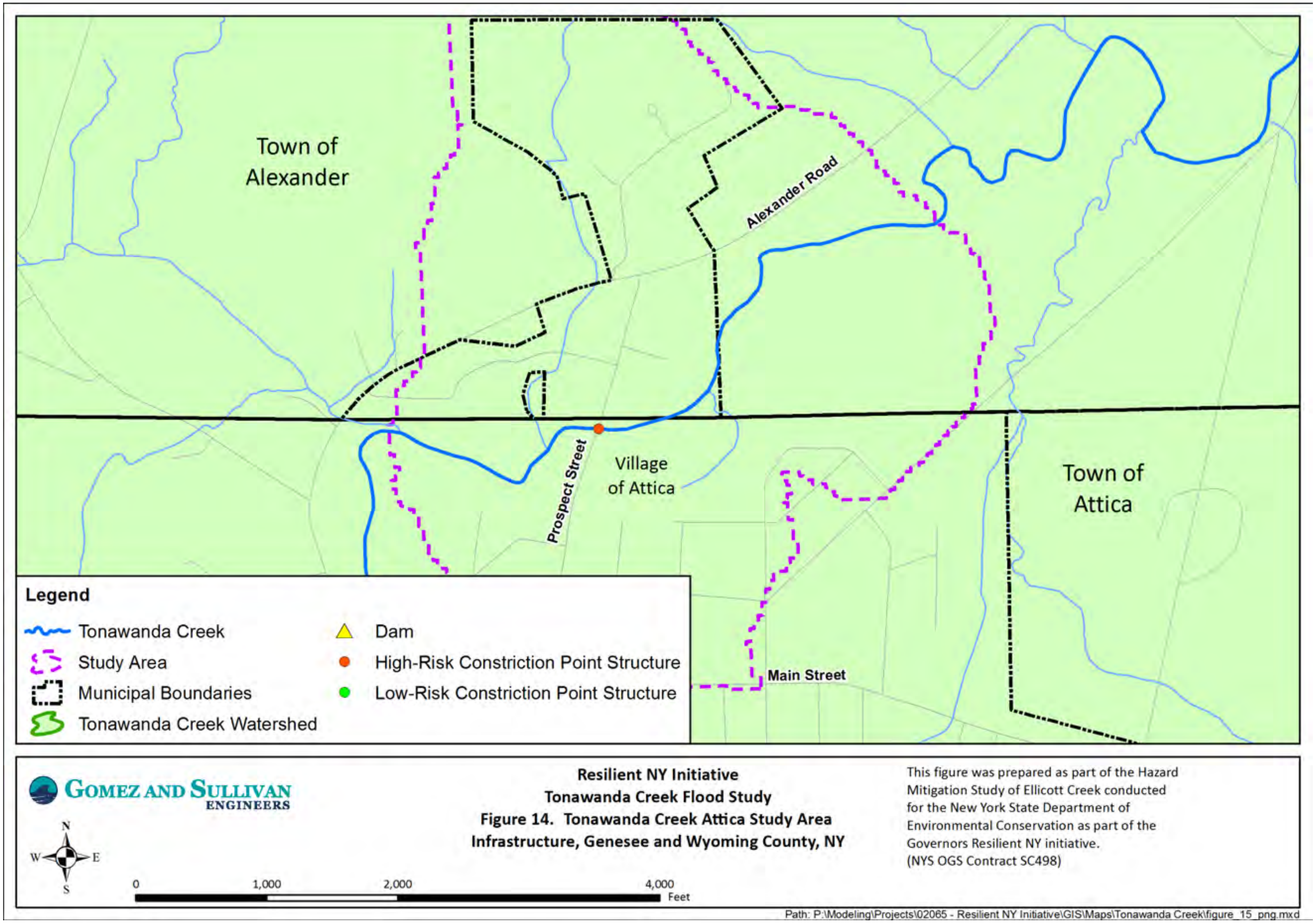


Figure 14. Tonawanda Creek Attica Study Area Infrastructure, Genesee and Wyoming County, NY



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 feet when measurement is made horizontally along the center line of roadway from face to face of abutments or sidewalls immediately below the copings or fillets; or, if there are no copings or fillets, at 6 inches below the bridge seats or immediately under the top slab, in the case of frame structures. In the case of arches, the span shall be measured from spring line to spring line. All measurements shall include the widths of intervening piers or division walls, as well as the width of copings or fillets (NYSDOT, 2020).

According to the NYSDOT bridge manual (2019) for Region 4, which includes Orleans, Genesee, Wyoming, Monroe, Livingston, Wayne and Ontario Counties, new and replacement bridges are required to meet certain standards, which include (NYSDOT, 2019b):

- The structure will not raise the water surface elevations anywhere when compared to the existing conditions for both the 2 and 1% ACE (50- and 100-year flood) flows.
- The proposed low chord shall not be lower than the existing low chord.
- A minimum of 2'-0" of freeboard for the projected 2% ACE (50-year 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% ACE (100-year 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.

In addition, current peak flows shall be increased to account for future projected peak flows based on the USGS *StreamStats* tool where current 2% ACE peak flows shall be increased by 10% in Region 5. For critical bridges, the minimum hydraulic design criteria is 3-feet of freeboard over the 2% annual chance flood elevation. A critical bridge is considered to be vital infrastructure that the incapacity or destruction of such would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters [(NYSDOT, 2019b); (USDHS, 2010)].

In an effort to improve flood resiliency of infrastructure in light of future climate change, New York State passed the Community Risk and Resiliency Act (CRRA) in 2014. In accordance with the guidelines of the CRRA, the NYSDEC released the *New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act* (2018) report. In the report, the NYSDEC outlined infrastructure guidelines, most notably that the new freeboard recommendation for normal bridges is 2-feet of freeboard over the elevation of a flood with a 1% chance of being equaled or exceeded in a given year (i.e. base flood elevation) and 3-feet for a critical structure (NYSDEC, 2018). When compared to current guidelines, the new CRRA climate change recommended freeboard is based on the 1% ACE water surface elevation, while the previous guidelines were based on the 2% ACE. This is a higher standard for freeboard.

Table 14 displays the 2% and 1% annual chance flood levels and their calculated difference at FEMA FIS infrastructure locations using the FIS profile for Tonawanda Creek. As mentioned previously, the FEMA FIS for the Village of Attica does not provide a flow or profile for the 2% (50-year) annual chance flood event.

Table 14. FEMA FIS Profile 2 and 1% Annual Chance Flood Hazard Levels with Differences at Infrastructure Locations

Bridge Crossing	River Station (ft)	2% Water Surface Elevation (ft NAVD88)	1% Water Surface Elevation (ft NAVD88)	Difference in Water Surface Elevations (ft NAVD88)
River Street	830	887.52	887.02	0.50
South Lyon Street	3070	887.27	887.92	0.65
NYS Route 98/33 (Oak Street)	4620	888.22	889.02	0.80
Law Street	9500	892.22	892.72	0.50
Prospect Street	1400	N/A	954.78	N/A

Source: (FEMA, 1986; FEMA, 1982)

The elevations presented in Table 14 are corrected from the NGVD 1929 (NGVD29) vertical datum used in both the FEMA FIS reports for the Village of Attica and the City of Batavia to the current NAVD 1988 (NAVD88) vertical datum. The vertical correction factors or datum shifts are -0.522 feet and -0.482 feet respectively. The datum shift is calculated as the difference between the NAVD88 and NGVD29 heights (NAVD88 – NGVD29) at a given location. The datum shift was calculated using the National Geodetic Survey (NGS) Height Conversion Methodology embedded within the NOAA VertCon web application (NOAA, 2021).

In assessing hydraulic capacity of the bridges located in the identified high-risk areas along Tonawanda Creek, the FEMA FIS profile was used to determine the lowest annual chance flood elevation to flow under a culvert/the low chord of a bridge), without causing a significant backwater condition upstream ((FEMA, 1986), Table 12). According to the FEMA FIS profiles, four structures within the identified high-risk areas do not meet the NYSDOT guidelines for 2-feet of freeboard for bridges: NYS Route 98/33, River Street, and South Lyon Street in the City of Batavia, and Prospect Street in the Village of Attica. In addition, these structures do not meet the new CRRA climate change infrastructure guidelines as described above. Their low chord elevations are below the 2% ACE (for NYS Route 98/33 and River Street), the 0.2% ACE (for South Lyon Street), and 1% ACE (for Prospect Street) and they do not provide the recommended hydraulic capacity (FEMA, 1986; FEMA, 1982). 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 draft CRRA guidelines.

In addition to comparing the annual chance flood elevations and low chords for bridges that cross Tonawanda Creek, the structure width and bankfull width were compared for each of these structures. The USGS *StreamStats* tool was used to calculate the bankfull widths and discharge for each structure along Tonawanda Creek. Table 13 indicates that in Genesee County, NY, there are two (2) bridges within the study area that cross Tonawanda Creek that have bridge openings that are smaller than the bankfull widths: South Lyon Street and Law Street, and none in Wyoming County, NY. In addition, there are two (2) bridges with openings that are very close (within 5 feet) of bankfull width: River Street and Prospect

Street. Of the bridges listed in Table 15, two are within the identified high risk areas: South Lyon Street and Prospect Street.

The structures with bankfull widths that are wider than or close to the structures width indicate that water velocities have to slow and contract in order to pass through the structures, which can cause sediment depositional aggradation and the accumulation of sediment and debris. Aggradation can lead to the development of sediment and sand bars, which can cause upstream water surfaces to rise, increasing the potential for overtopping banks or backwater flooding. Since the bankfull discharge required for water surface elevations to reach the bankfull width is low (e.g. 50% ACE +/-), the likelihood of relatively low flow events causing backwater and potential flooding upstream of these structures is fairly high. Therefore, structures with widths less than or within five feet of the bankfull width are considered high-risk constriction point structures, as depicted in Figure 13.

Table 15. Hydraulic Capacity of Potential Constriction Point Bridges Crossing Tonawanda Creek

Roadway Carried	Structure Type	FIS River Station (ft)	Structure Width (ft)	Bankfull Width (ft)	Bankfull Discharge (cfs)	ACE Equivalent[1]
River Street	Bridge	830	145	142	3,480	50% < ACE < 20%
South Lyon Street	Bridge	3070	133	142	3,480	50% < ACE < 20%
Law Street	Bridge	9500	124	142	3,480	50% < ACE < 20%
Prospect Street	Bridge	1400	109	104	1,850	66.7% < ACE < 50%

Notes:
1. ACE Equivalent describes the equivalent ACE for the given bankfull discharge as calculated by the USGS *StreamStats* application. The 50% ACE is equal to a 2-year recurrence interval.

Source: (NYSDOT, 2019a); (USGS, 2021a); (FEMA, 1986)

Climate Change Implications

Future Projected Stream Flow in Tonawanda 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) (NYSERDA, 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) 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* Explorer was developed by the USGS in partnership with the NYSDOT. This application is an extension for the USGS *StreamStats* map-based web application and projects future stream flows in New York State. The USGS team examined 33 global climate models and selected five that best predicted past precipitation trends in the region. The results were then downscaled to apply to all six hydrologic regions of New York State. Three time periods can be examined: 2024-2049, 2050-2074 and 2075-2099, as well as two Intergovernmental Panel on Climate Change (IPCC) greenhouse gas emission scenarios: RCP 4.5 and RCP 8.5. RCP 4.5 is considered a midrange-emissions scenario, and RCP 8.5 is a high-emissions scenario [(Taylor, Stouffer, & Meehi, 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 16 provides a summary of the projected future peak stream flows using the FEMA FIS peak discharges and 10% CRRA design multiplier.

Table 16. Tonawanda Creek Projected Peak Discharges

Flooding Source and Location		Drainage Area (mi^2)	River Station (ft)	Peak Discharge (cfs)			
				10%	2%	1%	0.2%
City of Batavia	TONAWANDA CREEK At USGS Gaging Station No. 04217000	171	383520	6,600	8,360	9,020	10,340
Village of Attica	TONAWANDA CREEK At USGS Gaging Station No. 04216418	76.9	490240	5,350	7,720	8,900	12,100

Source: (NYSDEC, 2018)

Appendix E contains the HEC-RAS simulation summary sheets for the current and projected future flow 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 2.0-feet and 0.8-feet higher at specific locations in the Village of Attica and City of Batavia respectively, generally upstream of bridges due to backwater, as a result of the increased discharges.

Table 17 provides a comparison of HEC-RAS base condition modeled water surface elevations at the FIS discharge locations, using the selected flows as identified in the Hydrology section above for the two project areas, City of Batavia and Village of Attifca, and future condition, using the 10% CRRA design multiplier flows.

Table 17. HEC-RAS Current and Projected Future Flow Water Surface Elevation Comparison

Flooding Source and Location		Drainage Area (mi^2)	HEC-RAS River Station (ft)	Water Surface Elevation Change (ft)[1]			
				10%	2%	1%	0.2%
City of Batavia	TONAWANDA CREEK At USGS Gaging Station No. 04217000	170	8329	0.44	0.71	0.42	0.59
Village of Attica	Prospect Street[2]	82.4	486081	0.35	0.31	0.75	2.04

Notes:

1. Positive changes in water surface elevation indicate the future conditions water surface elevation is higher than the base condition.
2. USGS Gaging Station No. 04216418 is located upstream of the project model limits. Prospect Street is provided here as it has been designated a High Risk Area.

Source: : (NYSDEC, 2018)

Flooding Characteristics

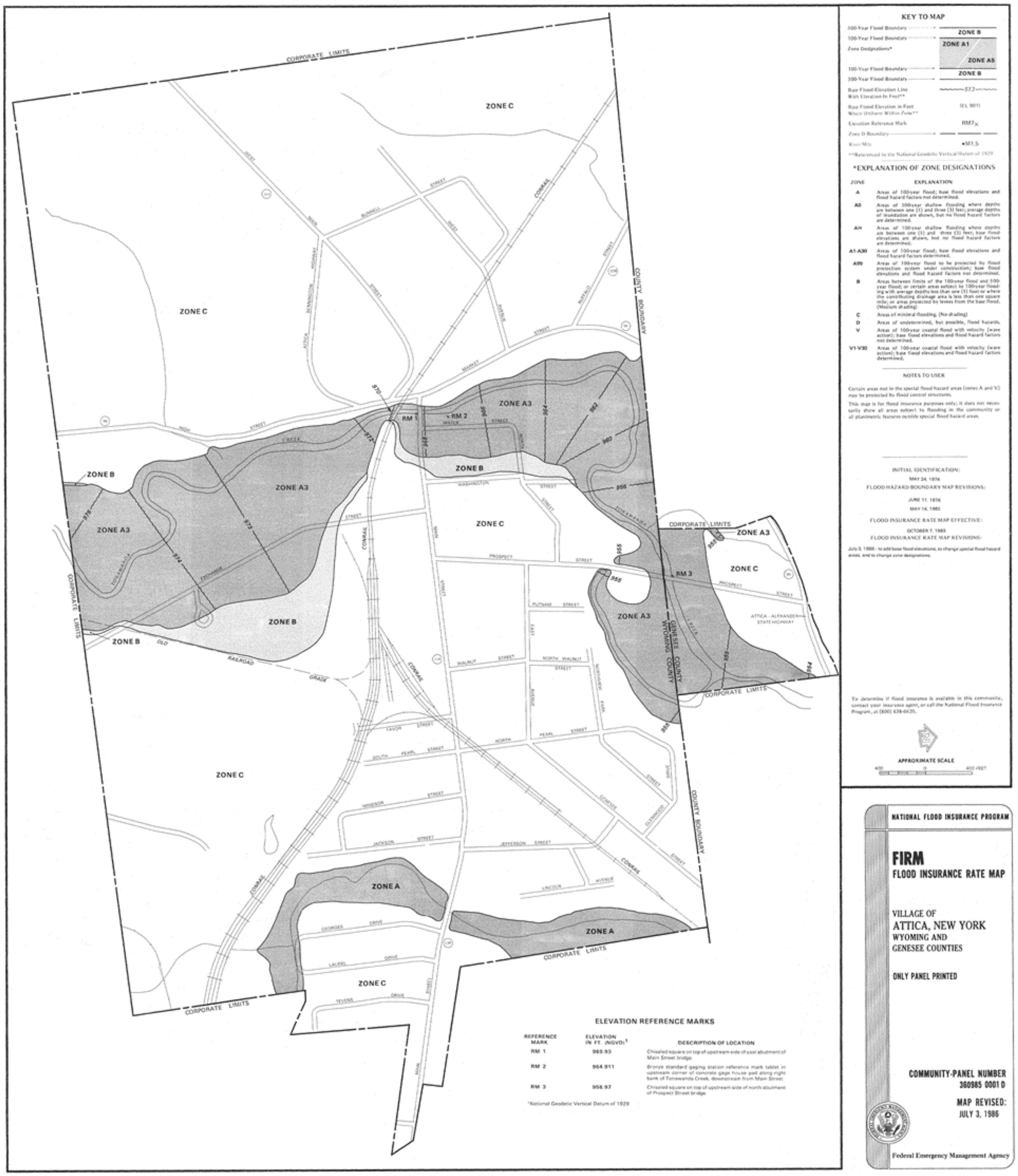
Flooding History

Along Tonawanda Creek, flooding tends to occur due to heavy spring rains or during the spring thaw. As of 1986, major floods had occurred on Tonawanda Creek in March 1865, July 1902, March 1904, March 1916, June 1928, April 1940, March 1942, March 1956, January 1957, January 1959, March 1960, June 1972, September 1977 and March 1970 (FEMA, 1986). Severe floods also occurred in June 1989, January 1998 and July 1998 (Genesee/Finger Lakes Regional Planning Council and Lu Engineers, 2003). Gage records at the USGS gage at Alabama (downstream of Batavia) have indicated 84 flows in a 56 year period which exceeded the bankfull stage. A flood which occurred in 1960 was estimated to have caused $5.64 million (1975 dollars) in damages, not including agricultural damages. In 1983, annual flood damages along Tonawanda Creek were estimated to $3 million (USACE, Buffalo District, 1983). Within the City of Batavia, the maximum measured stage occurred in March 1942, corresponding to an estimated discharge of 6,000 cfs. Prior to the improvements which were completed in 1955, spring floods were common in Batavia. Although those improvements have decreased the frequency and severity of flooding, spring runoff caused the creek to overflow onto Walnut, Law and South Main Streets in 1961 (FEMA, 1982). In the Village of Attica, severe flooding occurred during July 1902 and was exacerbated by the failure of an upstream dam. Flooding caused by Tropical Storm Agnes in June 1972 caused damages to floodwalls which were previously constructed to protect infrastructure in the Village of Attica (USACE, Buffalo District, 1983).

FEMA FIRMs are available for Tonawanda Creek, depicting the extent of the expected floodplain. Figure 15 and Figure 16 display the floodway and 1% and 0.2% ACE boundaries for Tonawanda Creek as determined by FEMA for the City of Batavia and Village of Attica, respectively (FEMA, 1982).

Figure 15. Tonawanda Creek, FEMA Flood Zones, City of Batavia, Genesee County, NY

Figure 16. Tonawanda Creek, FEMA Flood Zones, City of Batavia, Genesee County, NY



Flood Mitigation Analysis

For this study of Tonawanda Creek, standard hydrologic and hydraulic study methods were used to determine and evaluate flood hazard data. Flood events of a magnitude which are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10%, 2%, 1%, and 0.2% chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. The analyses reported herein reflect flooding potentials based on conditions existing in the county at the time of completion of the effective FIS (FEMA, 1986; FEMA, 1982).

Hydraulic analysis of Tonawanda 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 one- and two-Dimensional (2-D), steady-state, or time-varied (unsteady) flow. In one-dimensional (1-D) solutions, the water surface profiles are computed from one cross section to the next by solving the one-dimensional St. Venant equations 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 Tonawanda Creek in the City of Batavia was completed by FEMA in 1982, and in the Village of Attica in 1986. Due to the age and format of the City of Batavia FIS study, and the unavailability of the FIS model for the the Village of Attica, updated 1-D HEC-RAS models were developed using the following data and software:

- Wyoming and Genesee Counties, NY 1-meter LiDAR DEM data
- New York State Digital Ortho-imagery Program imagery for Wyoming and Genesee Counties (NYSOITS, 2020)
- National Land Cover Database (NLCD) data (MRLC, 2019)
- USGS *StreamStats* peak discharge data (USGS, 2021a)
- RAS Mapper extension in HEC-RAS software
- ESRI ArcMap 10.7.1 (ESRI, 2019)

The hydraulic model was developed for Tonawanda Creek in Attica, NY beginning approximately 3,400 feet downstream of the Prospect Street Bridge (river station 4826+47) and extending approximately 1,800 feet upstream of the Prospect Street Bridge (river station 4878+95).

The hydraulic model was developed for Tonawanda Creek in Batavia, NY beginning approximately 3,250 feet downstream of River Street (river station 3743+14) and extending upstream to approximately 445 feet upstream of the conrail bridge (river station 3908+50).

Methodology of HEC-RAS Model Development

For the new model created for the Village of Attica, LiDAR DEM data, orthoimagery, land cover data, and the RAS Mapper extension in the HEC-RAS software were used to develop a base condition hydraulic model using the following methodology:

- LiDAR DEM data, the NYS Hydrography line type shapefile, and orthoimagery were uploaded to the RAS Mapper interface.
- The NYS Hydrography was corrected to follow both the thalweg identified in the DEM as well as the channel from the orthoimagery.
- Cross Sections were developed at an appropriate interval to adequately detail the project parameters. The station and elevation information was extracted from the DEM using the RAS Mapper tool.
- Manning's n-values were selected based on the reported values in the effective FIS for the Village of Attica and validated with both the NLCD and orthoimagery data.
- Channel inverts were estimated based on the FIS profile of Tonawanda Creek for the Village of Attica. Cross sections were edited assuming a simple trapezoidal channel section between the DEM surface and the assumed channel invert from the FIS profile.
- Bridge geometry was input from design documents obtained from the Wyoming County Department of Transportation for the Prospect Street Bridge.
- Flows for the 10%, 2%, 1%, and 0.2% and the Projected Future Floods were developed as previously mentioned in this report.
- Normal depth boundary conditions were used for all flows and set based on an interative model simulation.
- The model was run using a 1-dimensional steady flow analysis under subcritical conditions.

For the City of Batavia, the effective model was obtained in HEC-2 format, and redeveloped into a HEC-RAS model using the following similar methodology:

- The HEC-2 input data was manually entered into the ArcMap 10.7.1 program to create 3-dimensional shapefiles for the river, cross sections, and structures.
- These shapefiles were then imported in the RAS Mapper tool and verified for correct orientation and values.
- Bridge geometry was derived from the HEC-2 input data and updated as necessary with field measurements.
- Additional cross sections were added as needed throughout the model to adequately detail the project parameters. The station and elevation information was extracted from the DEM using the RAS Mapper tool.
- Manning's n-values were selected based on the reported values in the effective FIS for the Village of Attica and validated with both the NLCD and orthoimagery data.
- Flows for the 10%, 2%, 1%, and 0.2% and the Projected Future Floods were developed as previously mentioned in this report.
- Normal depth boundary conditions were used for all flows and set based on an interative model simulation.
- The model was run using a 1-dimensional steady flow analysis under subcritical conditions.

The base condition model water surface elevation results were then compared to the FEMA FIS water surface profiles, and the effective FEMA FIS streambed elevation profiles to validate the model.

The HEC-RAS model developed for the Village of Attica was unable to validate against the FIS profile. The WSELs upstream of the bridge are approximately 2-feet higher in the model than in the FIS, and about 1-foot lower downstream of the bridge. This is most likely due to the reconstruction of Prospect Street Bridge after the FIS was created. The bridge reconstruction resulted in higher approaches that are reflected in the DEM terrain data. It is unclear what the channel and overbank geometry was at the time the effective FIS was developed. Applying the bridge geometry data available in the FIS into the model confirms the increase in elevation of both the bridge deck and the approaches. The current model developed for this study was created using the best available data (terrain, flows, modeling, etc.). The model could further be refined with bathymetric and hydraulic survey of the channel and bridge geometries. It is anticipated that these refinements, and possibly others, will be accomplished in the subsequent phases of this project.

After the base condition model was verified, it was then used to develop alternative condition models to simulate potential flood mitigation strategies. Generic renderings of various potential flood mitigation strategies are provided in Appendix F. The simulation results of the alternative 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 the Village of Attica and City of Batavia respectively. 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 area for a given annual chance exceedance (ACE) event by implementing the mitigation strategies.

The flood mitigation strategies that were modeled were:

- Alternative #1-1: Flood Bench Creation at South Main Street Bridge
- Alternative #2-1: Flood Bench Creation at Walnut Street Bridge
- Alternative #3-1: Flood Bench Creation Downstream of Prospect Street Bridge, 1000' (Station 485+897 to 484+896)
- Alternative #3-2: Modify Prospect Street Bridge (Station 486+081)
- Alternative #3-3: Flood Bench Creation Downstream of Prospect Street Bridge and Modify Prospect Street Bridge
- Alternative #4-1: Early Warning Flood Detection System
- Alternative #4-2: Debris Maintenance Around Bridges/Culverts
- Alternative #4-3: Flood Buyout Programs
- Alternative #4-4: Floodproofing
- Alternative #4-5: Area Preservation / Floodplain Ordinances

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

Cost Estimate Analysis

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

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

For mitigation alternatives where increases in bridge sizes were evaluated, bridge size increases were initially analyzed based on 2-feet freeboard over the base flood elevation for a 1% ACE. 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 New York State and / or FEMA, including construction and environmental permits from the State and accreditation, Letter of Map Revision (LOMR), etc. applications to FEMA. Application and permit costs were not incorporated in the ROM costs estimates.

High Risk Areas

Based on the FEMA FIS, NCEI storm events database, historical flood reports, and stakeholder input from engagement meetings, two areas along Tonawanda Creek were identified as high-risk flood areas in the City of Batavia; one along Tonawanada Creek was identified as a high-risk flood area in the Village of Attica.

High Risk Area #1: South Main Street in the City of Batavia (Sta 32+52 to 70+78)

High Risk Area #1 extends along Tonawanda Creek from River Street to Oak Street in the City of Batavia. A review of the effective FIRM for this area indicates that significant structure and street flooding occurs in this area. The stream channel throughout this High Risk Area was included in the channel improvements which were performed in 1954 and 1955. Flood issues are most pronounced along South Main Street to the south of Tonawanda Creek, however some flooding also occurs along West Main Street to the north of the creek. Within this High Risk Area, flooding affects mostly residential areas to the south of the creek and commercial areas to the north, as well as the wastewater treatment plant to the south of the creek. A review of the FEMA flood profile does not indicate that the structures crossing the creek in this area contribute significantly to flooding issues. No repetitive loss or severe repetitive loss structures are located within this High Risk Area. Figure 17 depicts the extent of flooding within the risk area and approximate extent of the historical flood control project, while Figure 18 shows the water surface profiles within the risk area.

Figure 17. High Risk Area #1: South Main Street in the City of Batavia (Sta 32+52 -70+78)

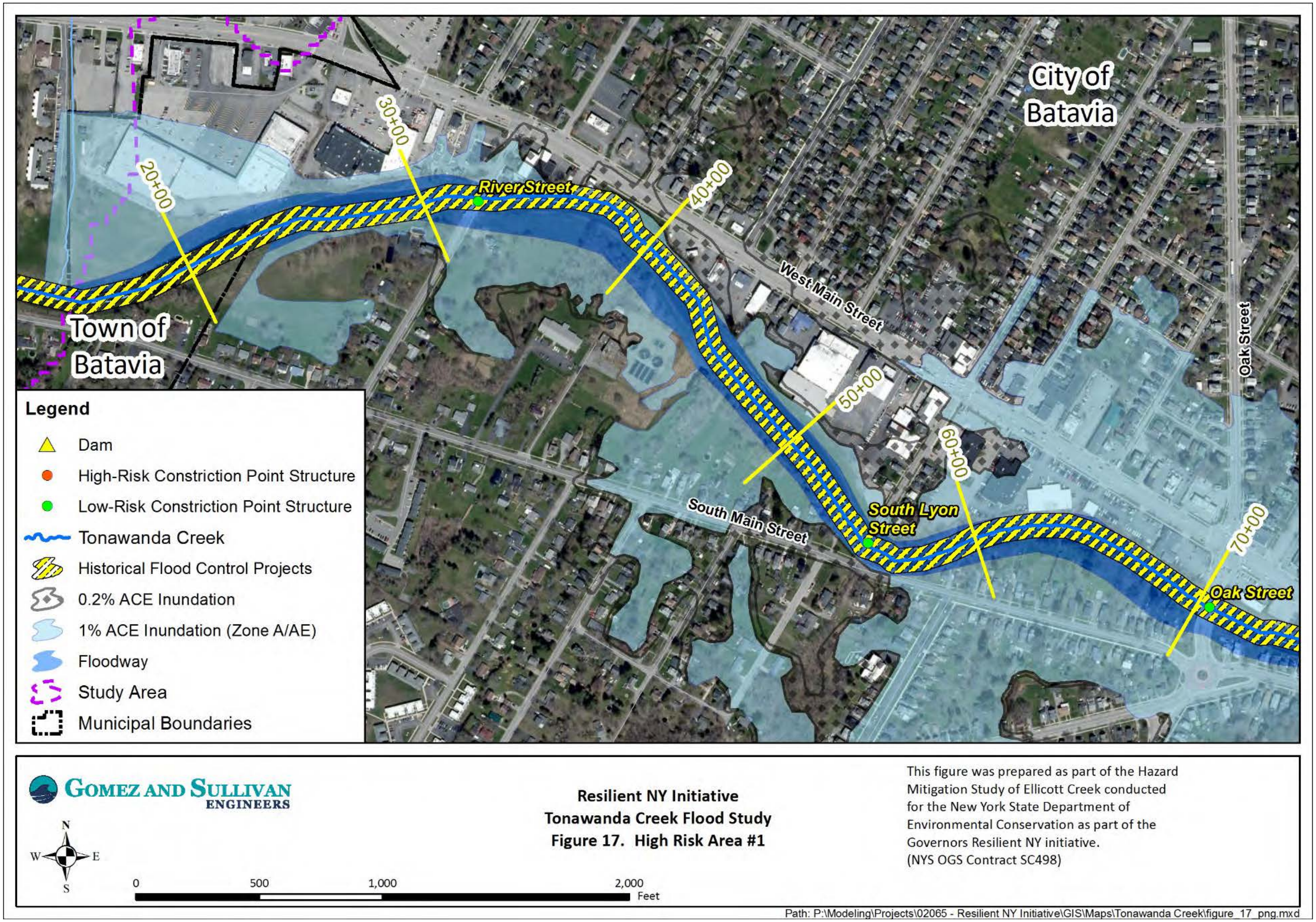
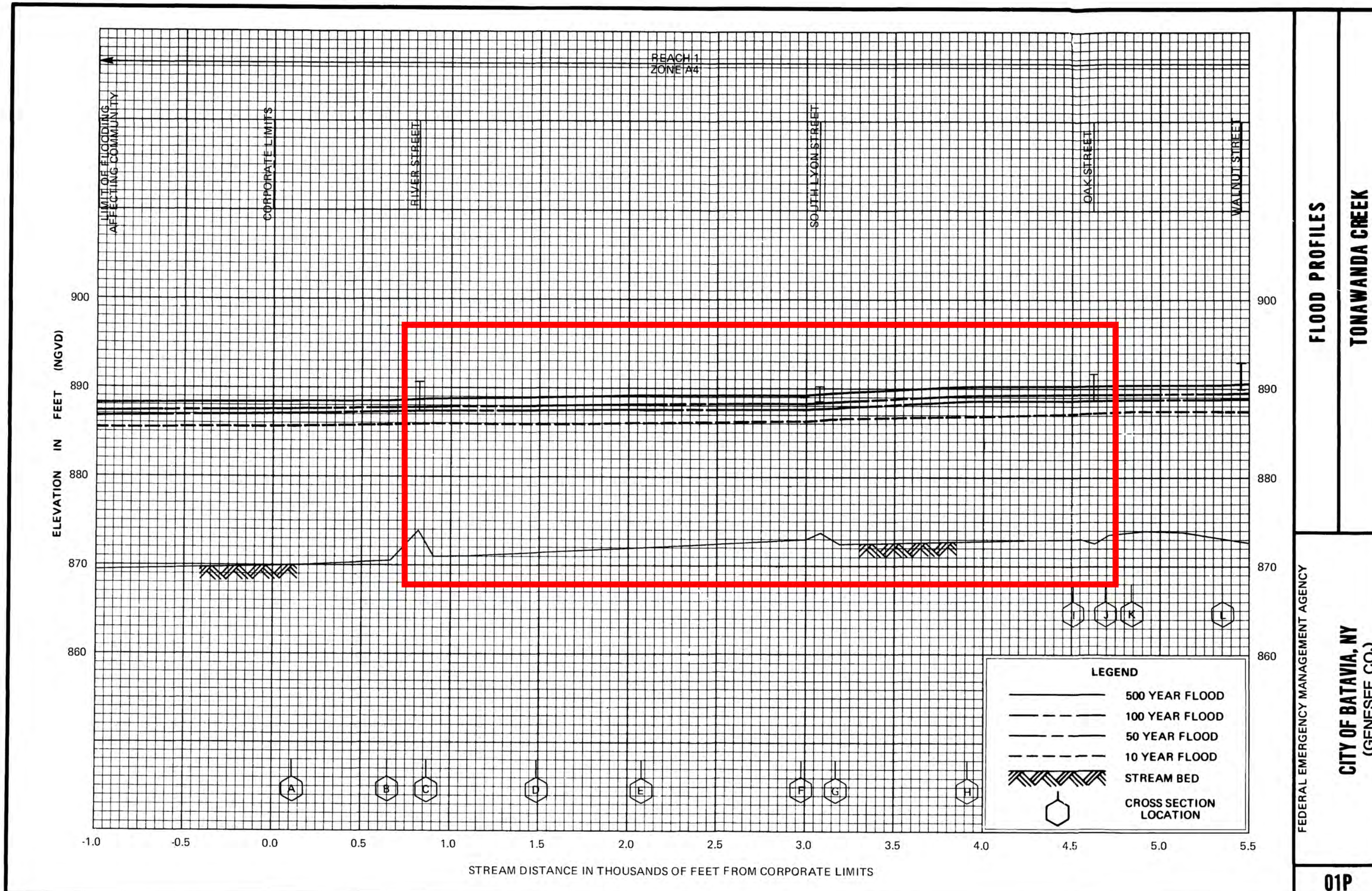


Figure 18. FEMA FIS Profile for Tonawanda Creek in the Vicinity of High Risk Area #1 South Main Street in the City of Batavia (Sta 32+52 -70+78)



High Risk Area #2: Walnut Street in the City of Batavia (Sta 79+01 to 99+61)

High Risk Area #2 extends along Tonawanda Creek from the Walnut Street footbridge to the Conrail Bridge in the City of Batavia. A review of the effective FIRM for this area indicates that significant structure and street flooding occurs in this area. The stream channel in the downstream portion of this High Risk Area was included in the channel improvements performed in 1954 and 1955. Within this High Risk Area, flooding affects mostly residential areas to the west of the creek and commercial areas to the east. A review of the FEMA flood profile does not indicate that the structures crossing the creek in this area contribute significantly to flooding issues. No repetitive loss or severe repetitive loss structures are located within this High Risk Area. Figure 19 depicts the extent of flooding within the risk area and approximate extent of the historical flood control project, while Figure 20 shows the water surface profiles within the risk area.

Figure 19. High Risk Area #2: Walnut Street in the City of Batavia (Sta 79+01 – 99+61)

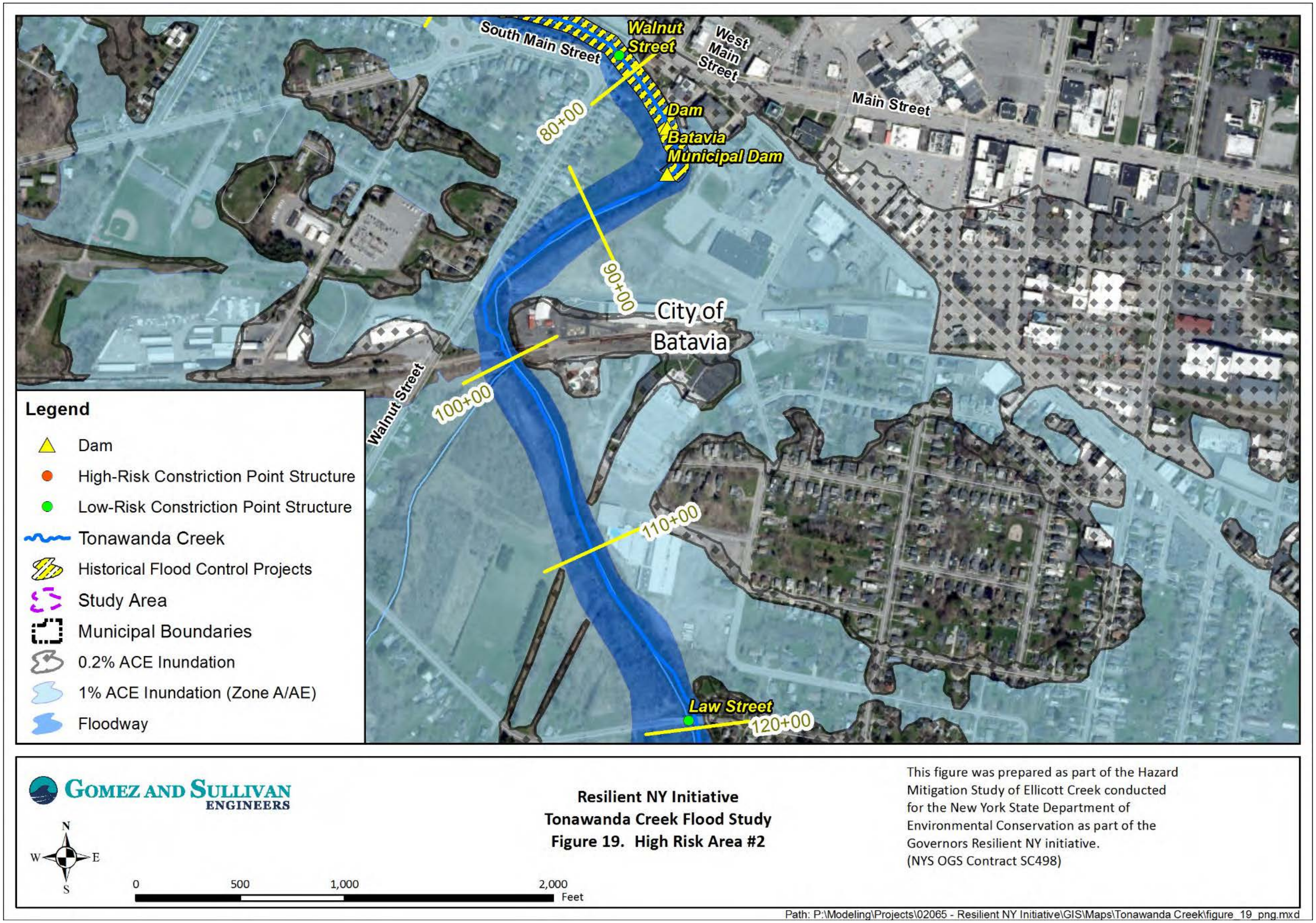
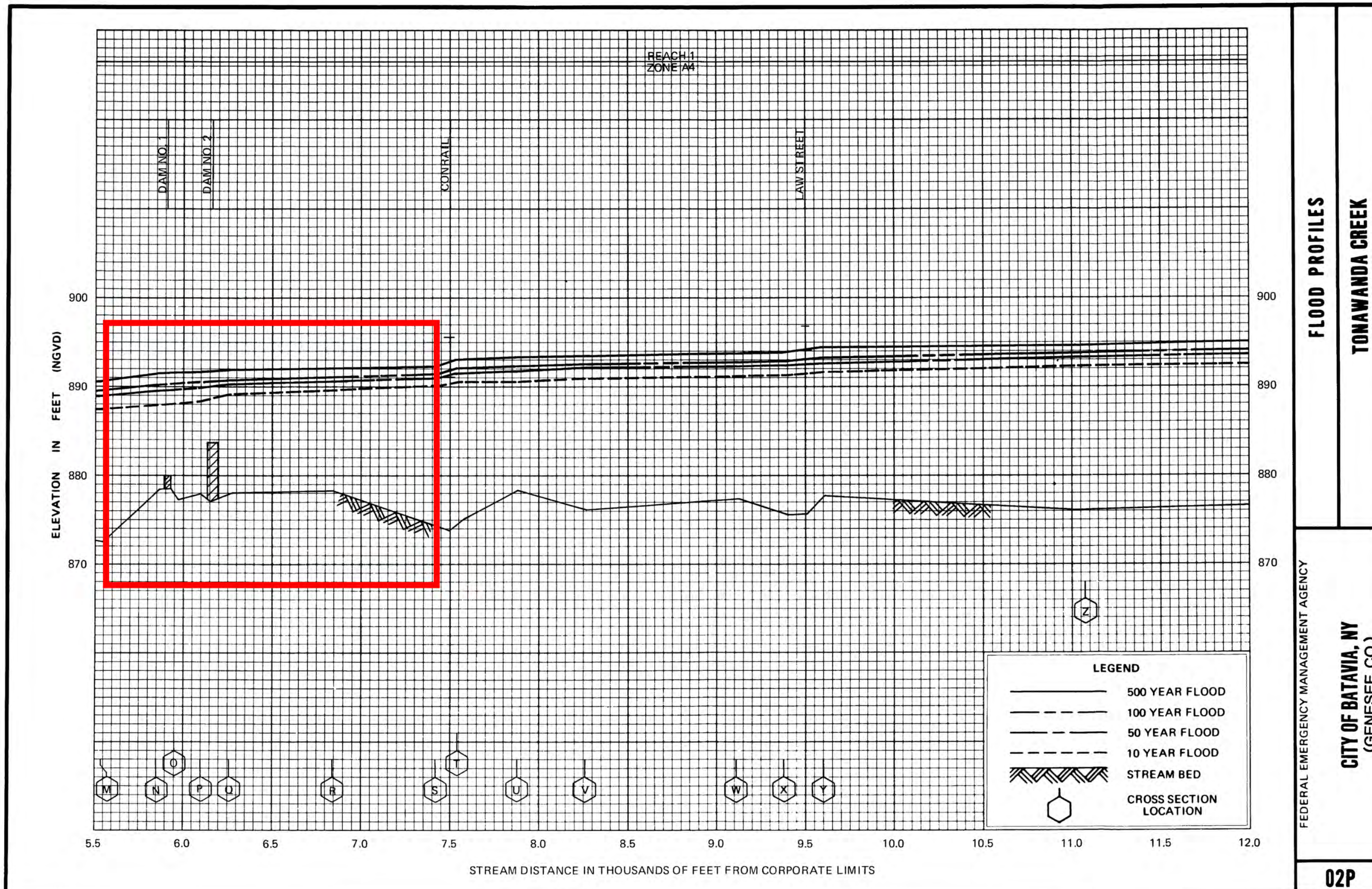


Figure 20. FEMA FIS Profile for Tonawanda Creek in the Vicinity of High Risk Area #2 Walnut Street in the City of Batavia (Sta 79+01 – 99+61)



High Risk Area #3: Prospect Street in the Village of Attica (Sta 486+081 to 484+896)

High Risk Area #3 includes the areas along Tonawanda Creek in the vicinity of the Prospect Street bridge in the Village of Attica. A review of the effective FIRM for this area indicates that significant structure and street flooding occurs in this area. Flood issues are most pronounced along Prospect Street to the north of Tonawanda Creek. Within this High Risk Area, flooding affects mostly commercial areas to the north of the creek, as well as the wastewater treatment plant to the north of the creek, downstream of the Prospect Street bridge. The Prospect Street bridge was identified as a High-Risk Potential Constriction Point Structure and does not meet the NYSDOT or draft CRRA guidelines for 2 feet of freeboard above the 2% abd 1% ACE, respectively. The Prospect Street bridge is owned and maintained by Wyoming County (BIN 3319560). Two repetitive loss and no severe repetitive loss structures are located within this High Risk Area. Figure 21 depicts the extent of flooding within the risk area, while Figure 22 shows the water surface profiles within the risk area.

Figure 21. High Risk Area #3: Prospect Street in the Village of Attica (Sta 20+00 – 40+00)

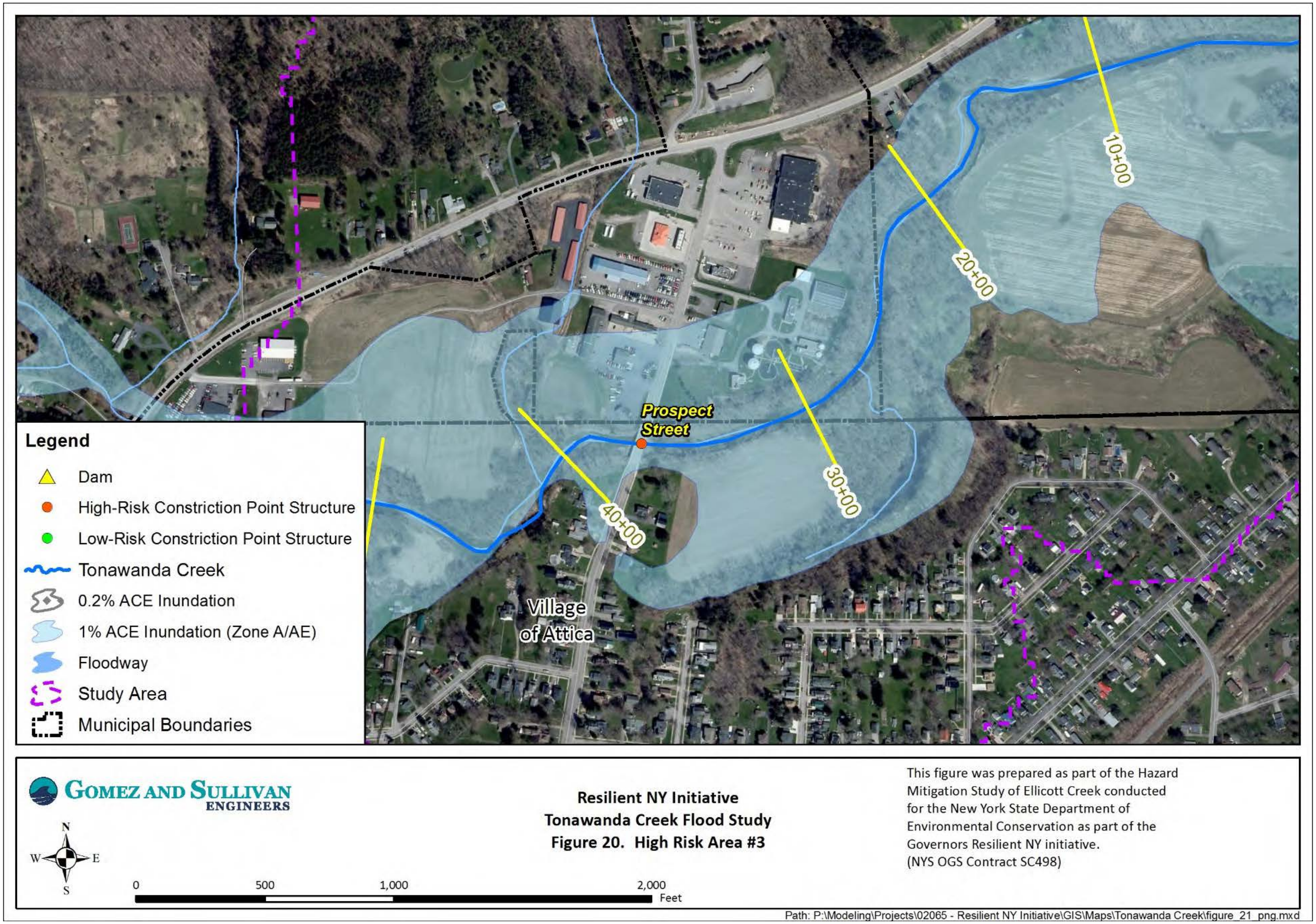
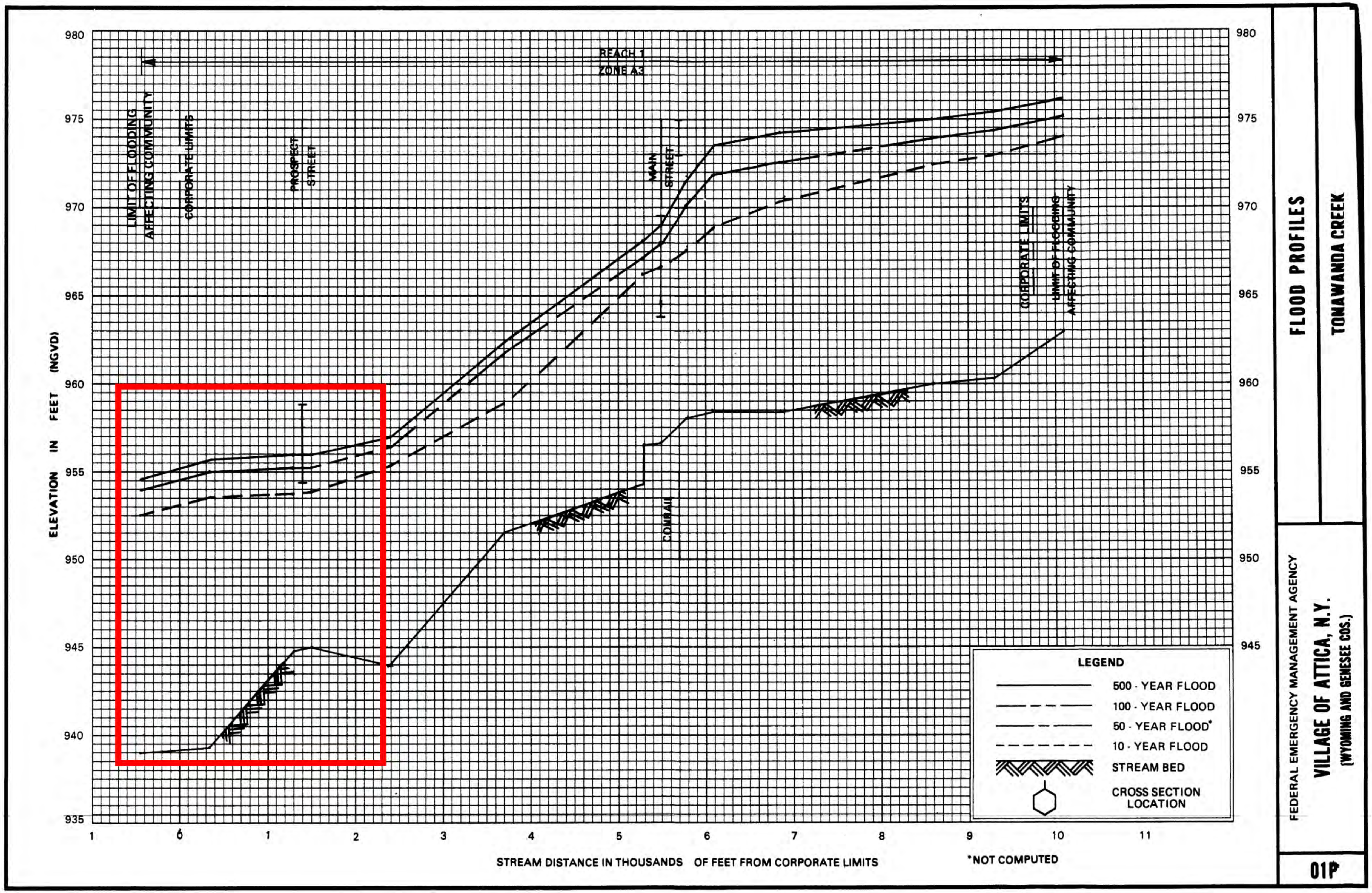


Figure 22. FEMA FIS Profile for Tonawanda Creek in the Vicinity of High Risk Area #3: Prospect Street in the Village of Attica (Sta 20+00 – 40+00)



Mitigation Alternatives

The following flood mitigation alternatives that have the potential to reduce water surface elevations were evaluated for the identified high-risk areas along Tonawanda Creek. These alternatives could potentially reduce flood related damages in areas adjacent to the creek. The City of Batavia and Village of Attica 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.

High Risk Area #1:

Alternative #1-1: Flood Bench Creation Between River Street and South Lyon Street (Sta 32+52 to 55+12)

The water surface profiles for the effective FEMA FIS and existing conditions model indicate extensive residential and street flooding upstream of the River Street bridge for all of the modeled discharges. The floodplain corridor through this area has been encroached upon by urban development, with many overbank areas higher than the bankfull depth, which has reduced the capacity of the floodplain to contain flood waters.

This potential flood mitigation alternative is intended to provide additional flow area through construction of a flood bench extending approximately 2100 feet upstream of the South Main Street bridge. The left overbank existing topography was lowered by approximately 2-4 feet for this alternative to an elevation of 884.5, resulting in the removal of approximately 16,500 cubic yards of material. Figure 23 depicts the conceptual extents of this alternative.

Figure 24 depicts the difference in modeled water surface elevations for existing flood conditions under the base condition and Alternative #1-1 conditions in the vicinity of this alternative. The hydraulic analysis shows that this alternative results in no appreciable decrease in the water surface elevation.

This strategy is not recommended because the modeled water surface elevations did not appreciably decrease for any modeled discharges. Therefore a Rough Order of Magnitude cost estimate was not developed for this alternative.

Figure 23. Location Map for Alternative #1-1

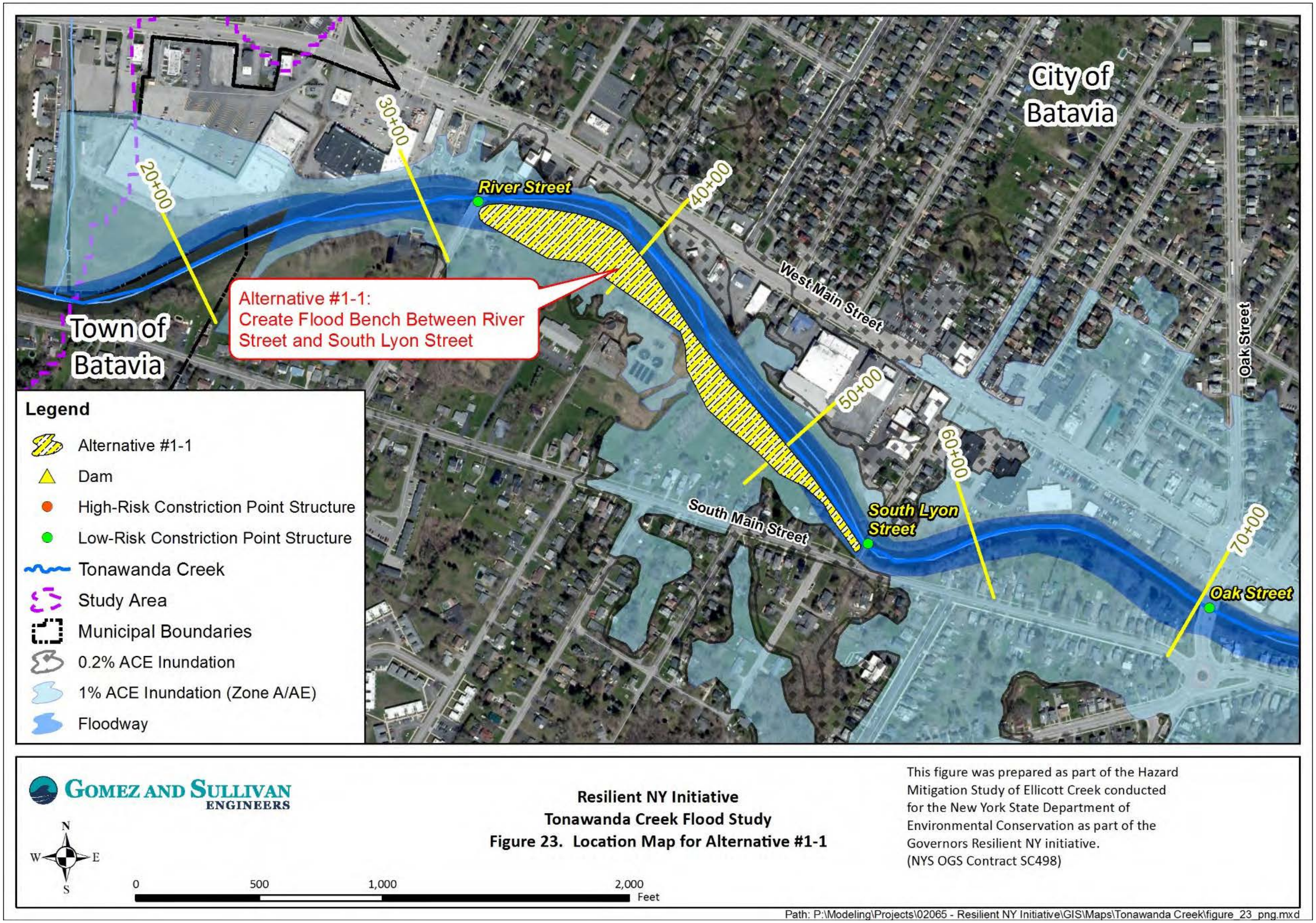
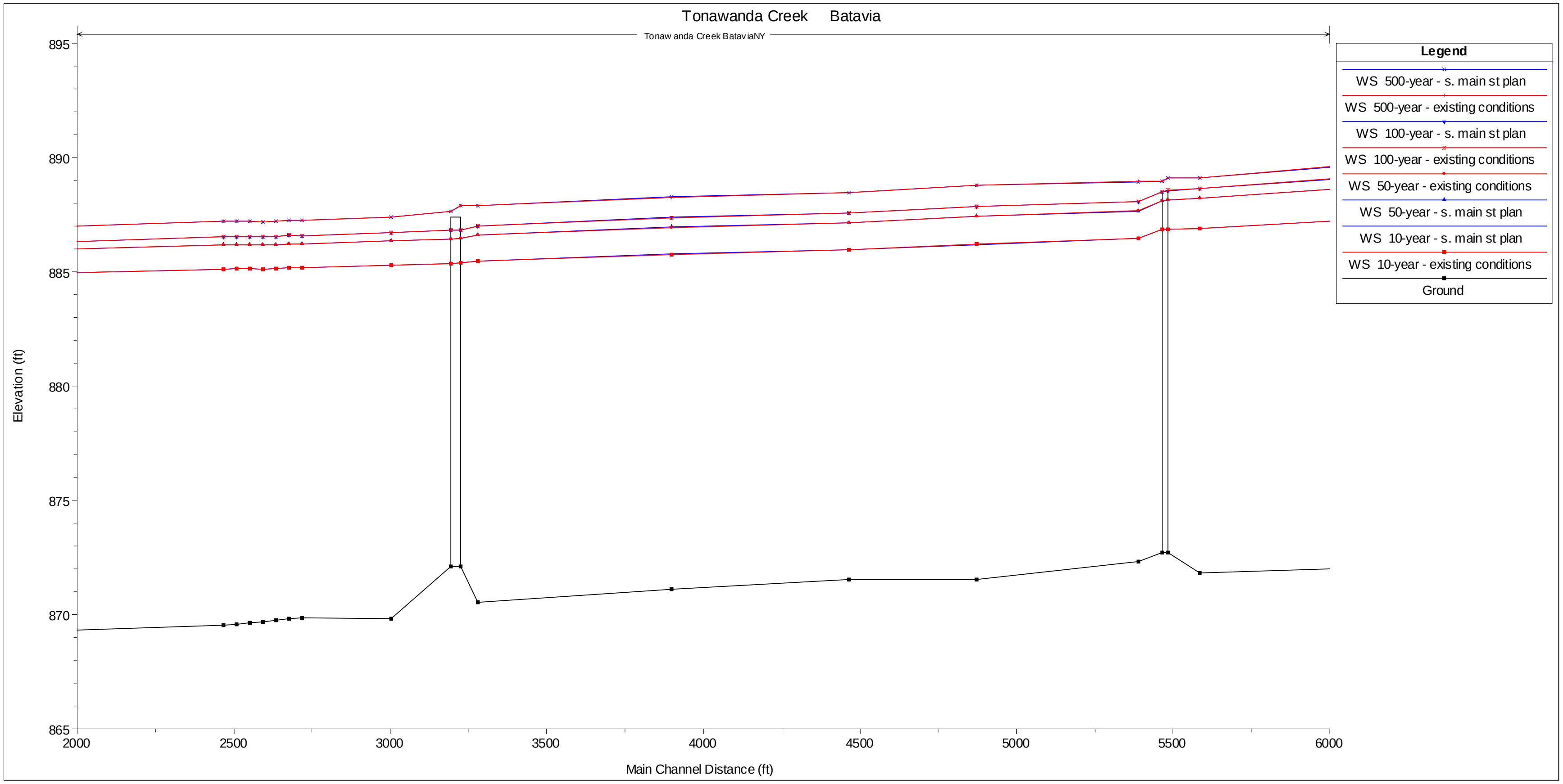


Figure 24. HEC-RAS Model Simulation Output Results for Alternative #1-1



High Risk Area #2:

Alternative #2-1: Flood Bench Creation along Walnut Street Bridge (Sta 81+26 – 90+02)

The water surface profiles for the effective FEMA FIS and existing conditions model indicate extensive residential and street flooding along Walnut Street for all the modeled discharges. The floodplain corridor through this area has been encroached upon by urban development, with many overbank areas higher than the bankfull depth, which has reduced the capacity of the floodplain to contain flood waters.

This potential flood mitigation alternative is intended to provide additional flow area in the left overbank, through construction of a flood bench extending approximately 800 feet beginning approximately 200 feet upstream of the Walnut Street bridge. The existing topography of the left overbank was lowered by approximately 2 feet to an elevation of 885.5 for a width of up to 150 feet and a length of approximately 850 feet for this alternative. The elevation of this flood bench is above the weir elevation for the Batavia Municipal Dam, therefore the flood bench is not expected to impact the operation of the dam. Flood bench creation for this alternative would result in the removal of approximately 5,000 cubic yards of material. Figure 25 depicts the conceptual extents of this alternative.

Figure 26 depicts the difference in modeled water surface elevations for existing flood conditions under the base condition and Alternative #2-1 conditions in the vicinity of this alternative. The hydraulic analysis shows that this alternative results in water surface elevation reductions extending from approximately 400 feet upstream of the Walnut Street bridge to the Batavia corporate limits. Water surface elevation reductions under current discharges are computed to be as much as 0.2 ft for the 10 % ACE discharge and 0.1 ft for the 1 %,2%, and 0.2 % ACE discharges. Similar results, relative to the extent and magnitude of water surface elevation reductions, were found under this alternative for the projected future discharges. Reductions under projected future discharges are computed to be as much as 0.2 ft for the 10 % ACE discharge, 0.1 ft for the 2 %, 1 %, and 0.2 % ACE discharges.

The Rough Order Magnitude cost $650,000, which does not include land acquisition costs other than survey, appraisal, and engineering coordination.

Figure 25. Location Map for Alternative #2-1

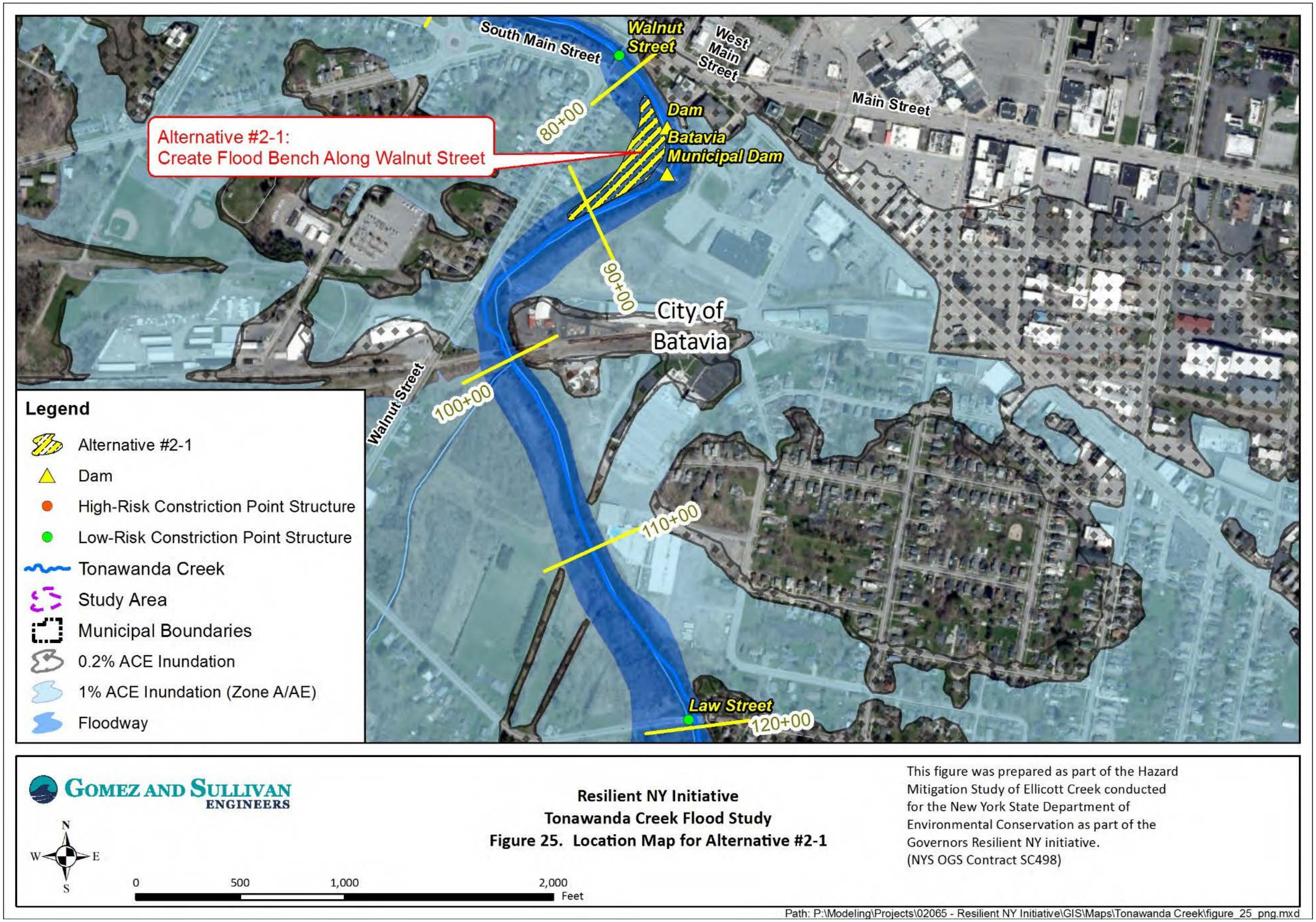
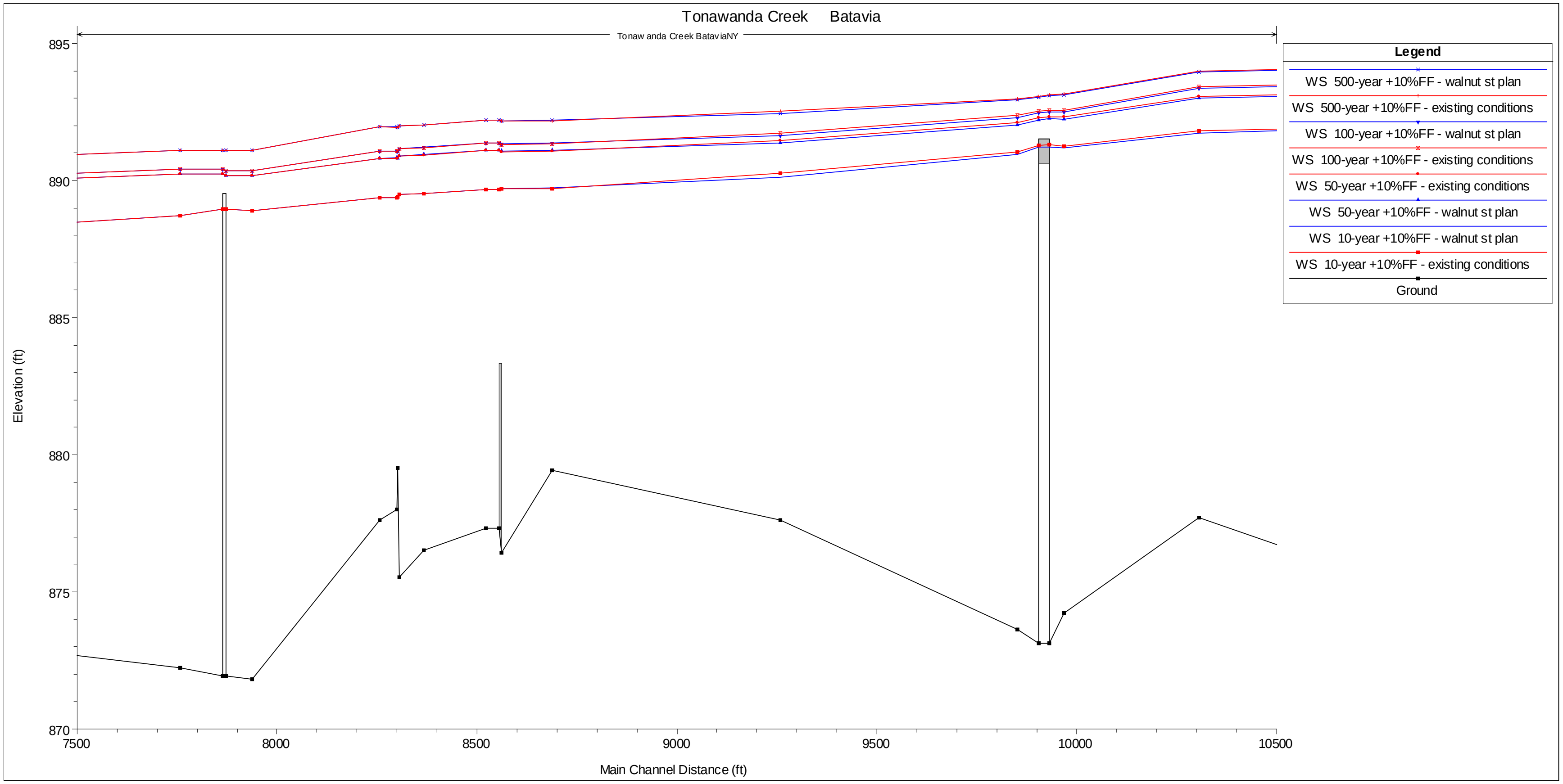


Figure 26. HEC-RAS Model Simulation Output Results for Alternative #2-1



High Risk Area #3:

Alternative #3-1: Flood Bench Creation Downstream of Prospect Street Bridge (Sta 485+897 to 484+896)

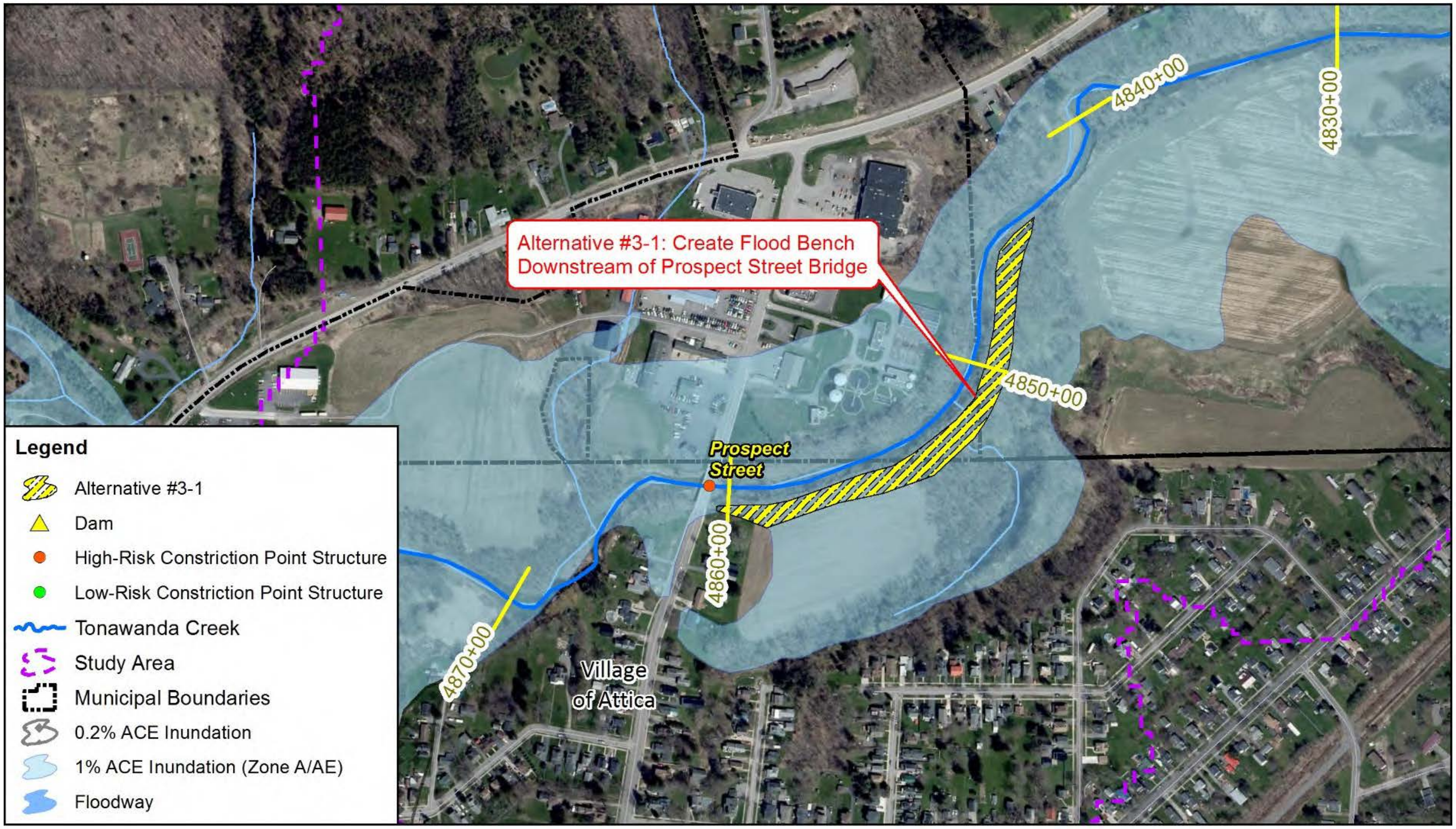
The water surface profiles for the effective FEMA FIS and the base condition model for the Village of Attica project area indicates that the Prospect Street bridge causes an increase in water surface elevations upstream of the road for all the modeled discharges, causing extensive commercial and street flooding. The overbank elevation is generally higher than the bankfull depth which prevents the flood flows from accessing the floodplain sooner. Additionally, the bridge span is within 5 feet of the bankfull width according to the StreamStats estimation, indicating a constriction of flow at the bridge.

This potential flood mitigation alternative provides additional flow area in the right overbank downstream of the Prospect Street Bridge through construction of a 1,000 foot long by approximately 100 foot wide flood bench. The existing topography was lowered by approximately 4 feet for this alternative to an elevation between the approximate bankfull and 10% annual chance water surface elevations, resulting in the removal of approximately 27,400 cubic yards of material. Figure 27 depicts the conceptual extents of this alternative.

Figure 28 depicts the difference in modeled water surface elevations for existing flood conditions under the base condition and Alternative #3-1 conditions in the vicinity of this alternative. The hydraulic analysis shows that this alternative results in water surface elevation reductions extending from the upstream limits of the study downstream through the bridge to about the location of the clarifiers of the wastewater treatment plant (Sta 485+395), approximately 700 feet downstream of the bridge. Water surface elevation reductions under current discharges are computed to be as much as 1.0 ft for the 10.0% and 2% ACE discharges, 0.9 ft for the 1.0 % ACE discharge and 1.3 ft for the 0.2% ACE discharge. Similar results, relative to the extent and magnitude of water surface elevation reductions, were found under this alternative for the projected future discharges. Reductions under projected future discharges are computed to be as much as 1.1 ft for the 10.0% ACE discharge, 0.9 ft for the 2.0% ACE discharge, 1.2 ft for the 1.0 % ACE discharge and 2.7 ft for the 0.2% ACE discharge.

The Rough Order Magnitude cost is $2 million, which does not include land acquisition costs other than survey, appraisal, and engineering coordination.

Figure 27. Location Map for Alternative #3-1



GOMEZ AND SULLIVAN ENGINEERS

N W E S

0 500 1,000 2,000 Feet

Resilient NY Initiative
Tonawanda Creek Flood Study
Figure 27. Location Map for Alternative #3-1

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

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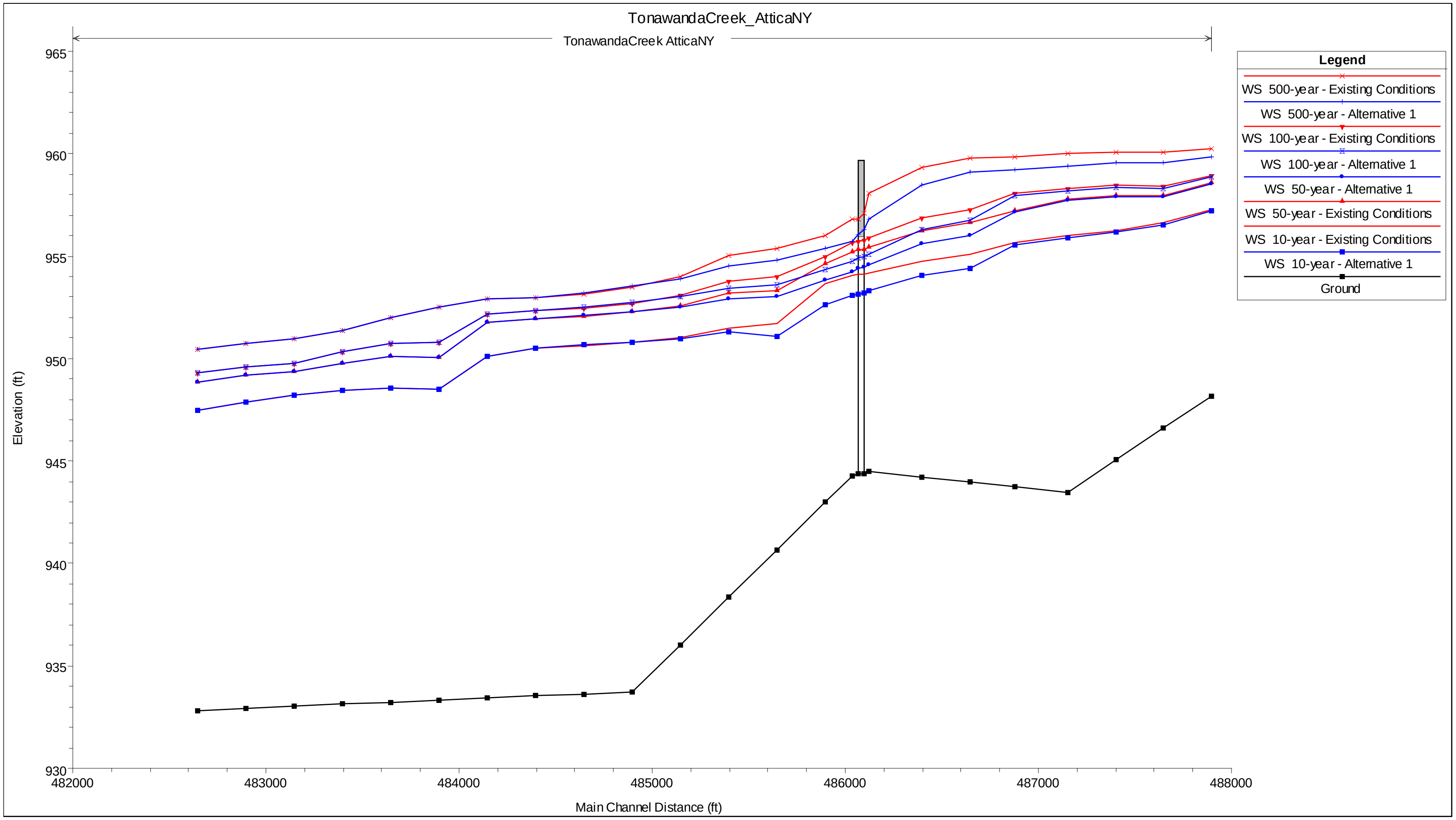
Figure 28. HEC-RAS Model Simulation Output Results for Alternative #3-1



Alternative #3-2: Modify Prospect Street Bridge (Sta 486+081)

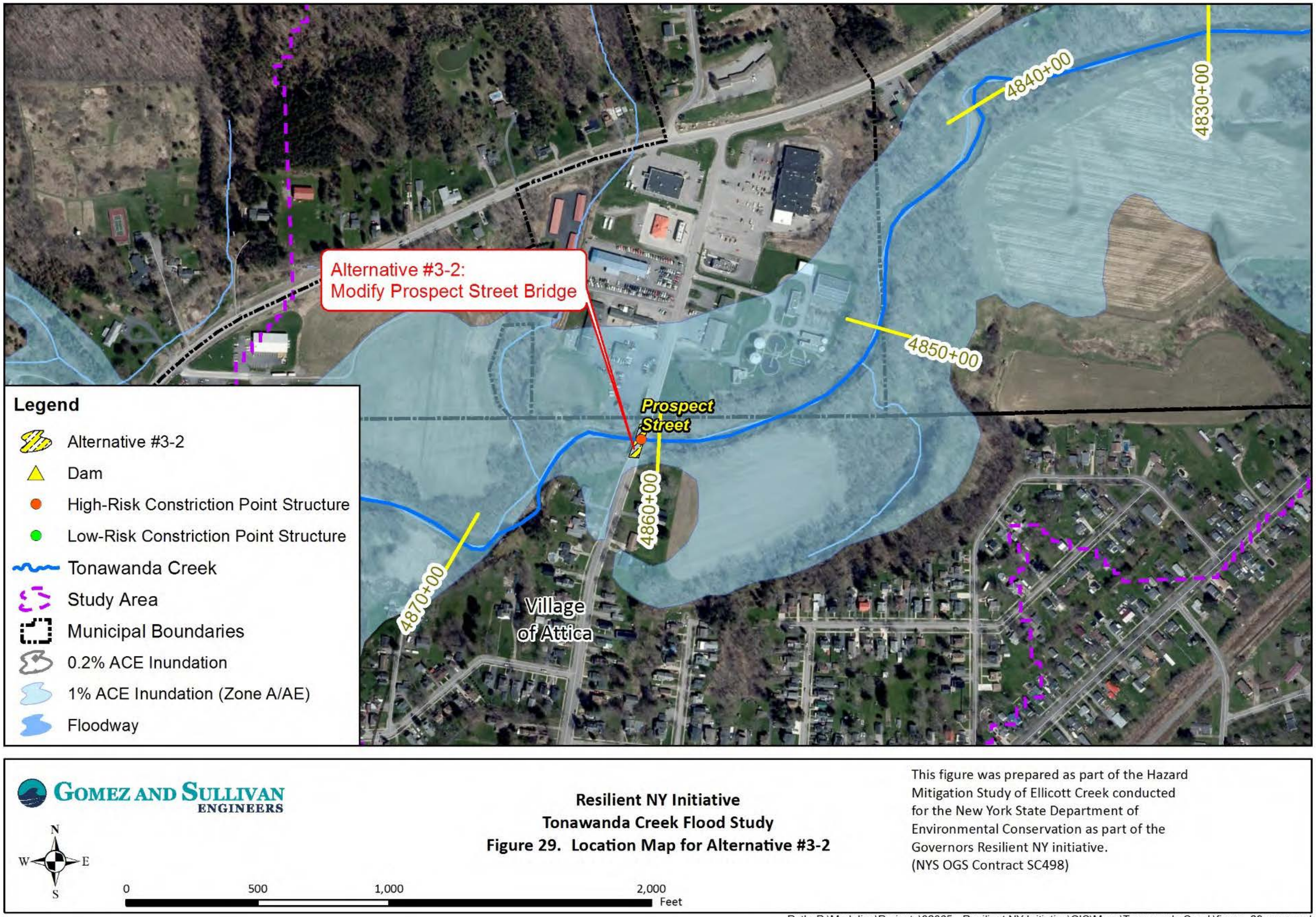
The water surface profiles for the effective FEMA FIS and the base condition model for the Village of Attica project area indicates that the Prospect Street bridge causes an increase in water surface elevations upstream of the road for all the modeled discharges, causing extensive commercial and street flooding. The overbank elevation is generally higher than the bankfull depth which prevents the flood flows from accessing the floodplain sooner. Additionally, the bridge span is within 5 feet of the bankfull width according to the StreamStats estimation, indicating a constriction of flow at the bridge.

This potential flood mitigation alternative provides additional flow area through the bridge by increasing the bridge span and raising the low chord, to meet current NYSDOT bridge hydraulic design standards. The span was increased from 109 feet to 130 feet and the low chord was raised to meet the 2-foot freeboard requirement of the 50-year +10% for the Project Future Flood WSEL. The low chord was raised from an elevation of 955.94 to 957.86 (+1.92 feet) with the top of road rising to match the change. Figure 29 depicts the conceptual extents of this alternative.

Figure 30 depicts the difference in modeled water surface elevations for existing flood conditions under the base condition and Alternative #3-2 conditions in the vicinity of this alternative. The hydraulic analysis shows that this alternative results in water surface elevation reductions extending from the upstream limits of the study downstream through the bridge. Water surface elevation reductions under current discharges are computed to be as much as 0.4 ft for the 10.0% ACE discharge, 0.6 ft for the 2.0% ACE discharge, 0.7 ft for the 1.0 % ACE discharge and 1.7 ft for the 0.2% ACE discharge. Similar results, relative to the extent and magnitude of water surface elevation reductions, were found under this alternative for the projected future discharges. Reductions under projected future discharges are computed to be as much as 0.4 ft for the 10.0% ACE discharge, 0.6 ft for the 2.0% ACE discharge, 1.2 ft for the 1.0 % ACE discharge and 2.3 ft for the 0.2% ACE discharge.

The Rough Order Magnitude cost is $3.5 million, which does not include land acquisition costs other than survey, appraisal, and engineering coordination.

Figure 29. Location Map for Alternative #3-2



Resilient NY Initiative
Tonawanda Creek Flood Study
Figure 29. Location Map for Alternative #3-2

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

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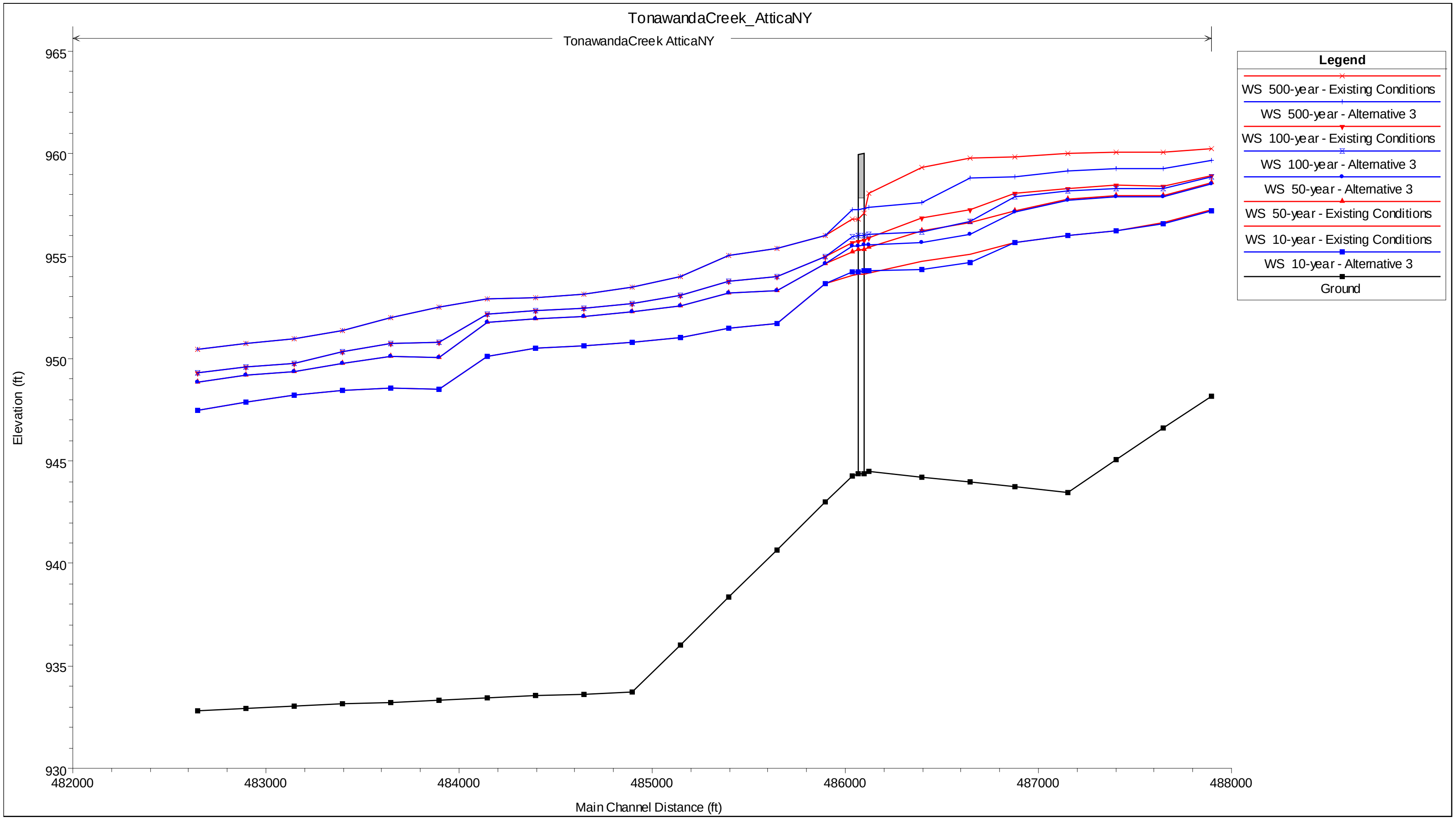
Figure 30. HEC-RAS Model Simulation Output Results for Alternative #3-2



Alternative #3-3: Flood Bench Creation Downstream of Prospect Street Bridge and Modify Prospect Street Bridge (Sta 486+081 to 484+896)

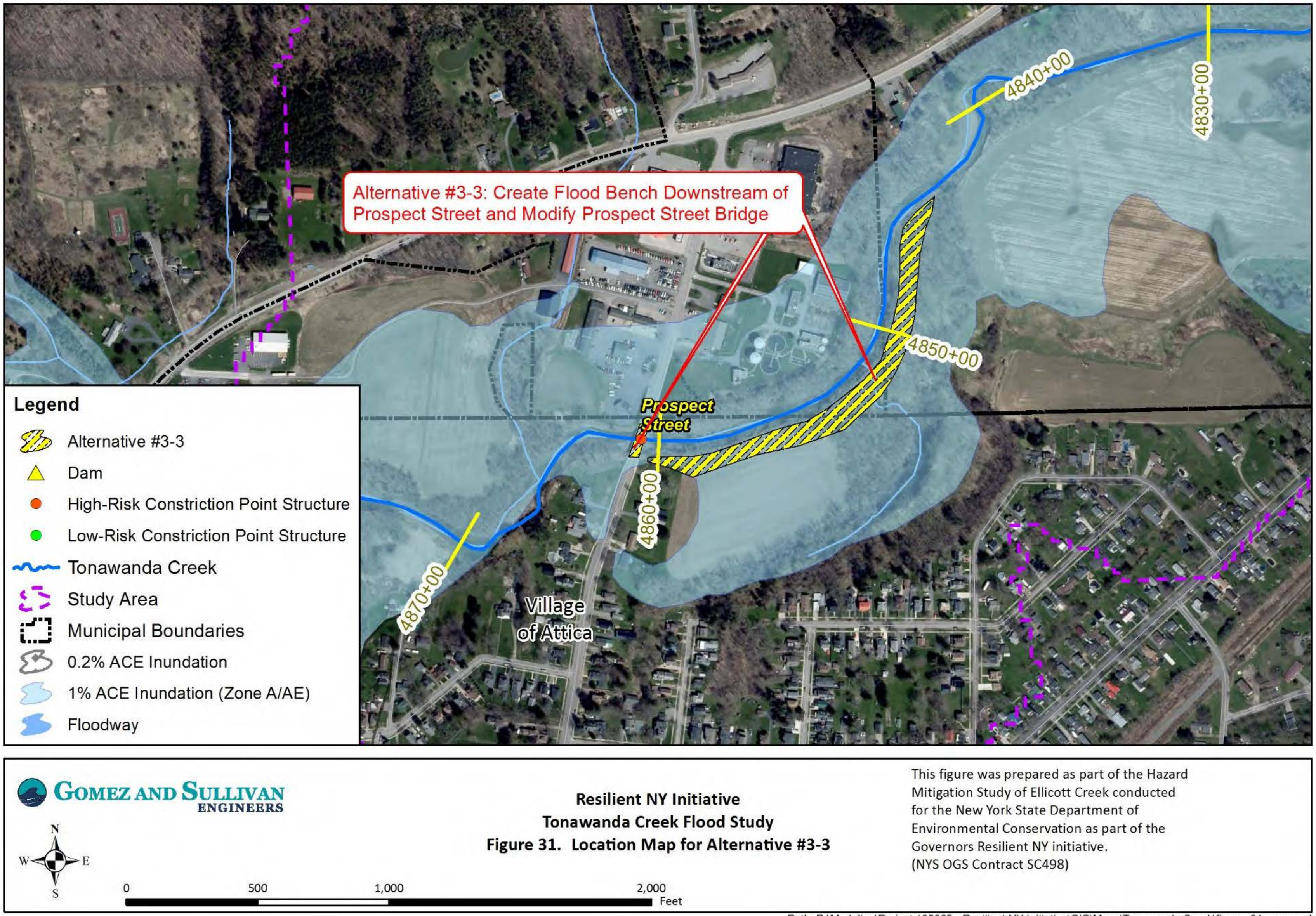
The water surface profiles for the effective FEMA FIS and the base condition model for the Village of Attica project area indicates that the Prospect Street bridge causes an increase in water surface elevations upstream of the road for all the modeled discharges, causing extensive commercial and street flooding. The overbank elevation is generally higher than the bankfull depth which prevents the flood flows from accessing the floodplain sooner. Additionally, the bridge span is within 5 feet of the bankfull width according to the StreamStats estimation, indicating a constriction of flow at the bridge.

This potential flood mitigation alternative provides the benefits of both Alternatives 3-1 and 3-2 together; providing additional flow area flow area in the right overbank downstream of the Prospect Street Bridge through construction of a 1,000 feet long by 100 feet wide flood bench. As well as providing additional flow area through the bridge by increasing the bridge span and raising the low chord, to meet current NYSDOT bridge hydraulic design standards. Figure 31 depicts the conceptual extents of this alternative.

Figure 32 depicts the difference in modeled water surface elevations for existing flood conditions under the base condition and Alternative #3-3 conditions in the vicinity of this alternative. The hydraulic analysis shows that this alternative results in similar water surface elevation reductions as Alternative #3-1, extending from the upstream limits of the study downstream through the bridge to about the location of the clarifiers of the wastewater treatment plant (Sta 485+395), approximately 700 feet downstream of the bridge. Water surface elevation reductions under current discharges are computed to be as much as 1.2 ft for the 10.0% ACE discharge, 1.3 ft for the 2.0% ACE discharge, 1.4 ft for the 1.0 % ACE discharge and 2.5 ft for the 0.2% ACE discharge. Similar results, relative to the extent and magnitude of water surface elevation reductions, were found under this alternative for the projected future discharges. Reductions under projected future discharges are computed to be as much as 1.3 ft for the 10.0% ACE discharge, 1.3 ft for the 2.0% ACE discharge, 1.8 ft for the 1.0 % ACE discharge and 3.2 ft for the 0.2% ACE discharge.

The Rough Order Magnitude cost is $5.1 million, which does not include land acquisition costs other than survey, appraisal, and engineering coordination.

Figure 31. Location Map for Alternative #3-3



Resilient NY Initiative
Tonawanda Creek Flood Study
Figure 31. Location Map for Alternative #3-3

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

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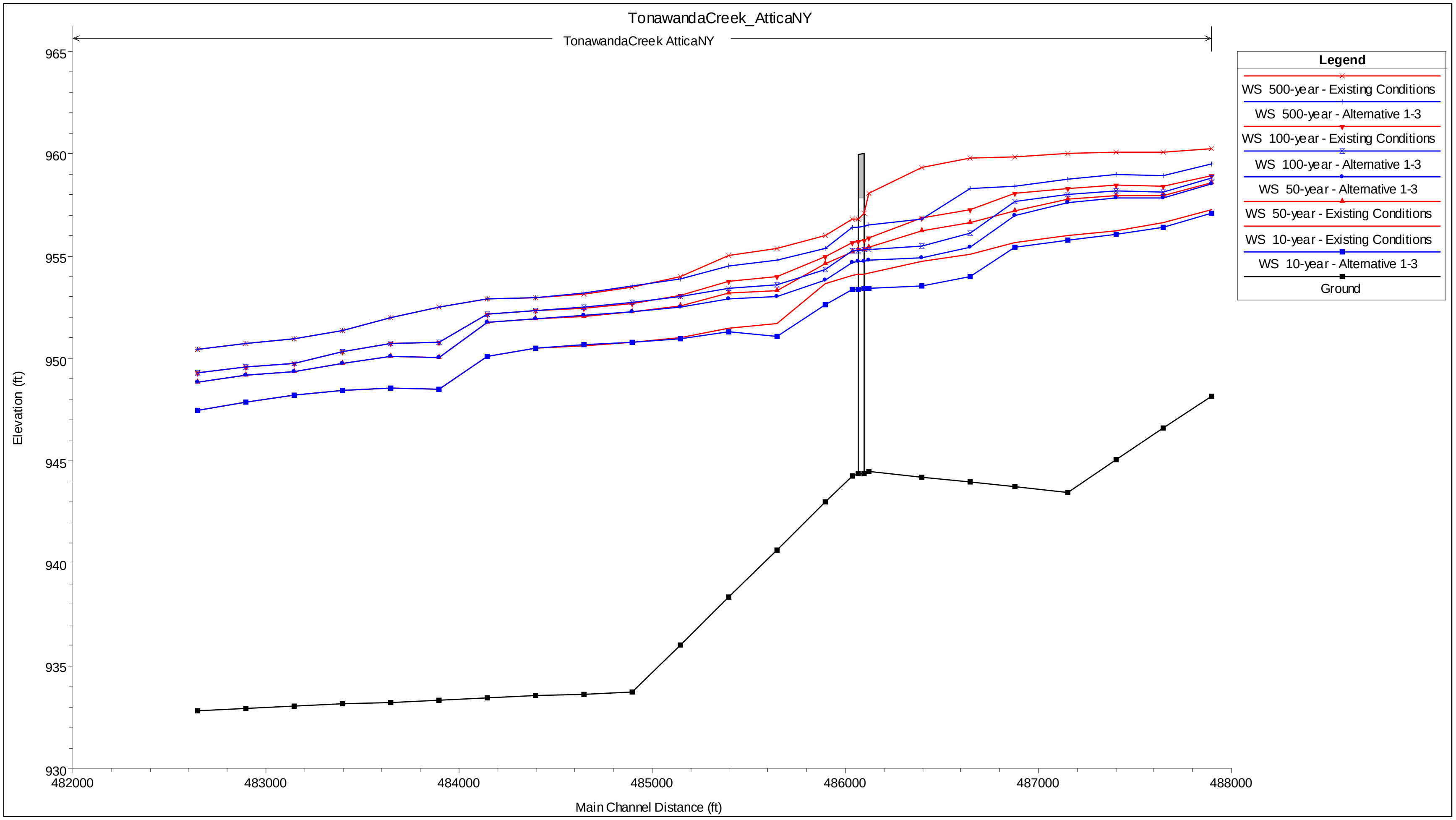
Figure 32. HEC-RAS Model Simulation Output Results for Alternative #3-3



Other Alternatives

Another alternative that was considered was a floodplain bench upstream of the Prospect Street Bridge. This floodplain bench was similarly designed to be 100 feet wide and approximately 1,250 feet long (Sta 487+648 to 486+396). The existing topography was lowered by approximately 2.5 feet for this alternative to an elevation between the approximate bankfull and 10% annual chance water surface elevations, resulting in the removal of approximately 11,740 cubic yards of material.

This alternative was not progressed further as the preliminary results yielded a negligible impact to the water surface elevation through the area of interest. The constriction of the flow through the bridge and the disconnection of the downstream floodplain created the adverse water surface elevations in the current conditions. Increasing the floodplain connection and storage upstream of the bridge yielded little to no reduction due to those constraints remaining downstream. Adding the upstream floodplain bench to any of the three (3) alternatives presented for the High Risk Area #3 also only provides minimal additional reduction in the water surface elevations.

The upstream floodplain bench is not a recommended alternative and is only presented here to provide confirmation that all options were considered for mitigation at the High Risk Area #3 location. As such, no figures or results are provided in this report.

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).

Alternative #4-1: Early Warning Flood Detection System

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

The 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.

Alternative #4-2: 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 Tonawanda 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.

Alternative #4-3: Flood Buyout Programs

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

- Reduce exposure by limiting the people and infrastructure located in vulnerable areas

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

Resilience achieved through buyouts can have real economic consequences in addition to improved social resilience. According to FEMA, voluntary buyouts cost $1 for every $2 saved in future insurance claims, an estimate which does not include money saved on flood recovery and response actions, such as local flood fighting, evacuation, and rescue, and recovery expenses that will not be incurred in the future. In order to achieve these goals, buyouts need to acquire a continuous swath 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) [(FEMA, 2020), (NYSGOSR, 2019)]. These funding sources can reduce the economic burden on the local community. However, these funds also come with guidelines and regulations that may constrain policy makers' options on whether to pursue a buyout strategy and how to shape their programs. FEMA funds may be used to cover 75% of the expenses, but the remaining 25% must come from another non-federal source. In most cases, the buyout must be a cost-effective measure that will substantially reduce the risk of future flooding damage (Siders, 2013).

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

In the Tonawanda Creek Batavia study area, there are approximately 1381 residences within the FEMA 1% and 0.2% annual chance flood hazard zones (Figure 33); in the Attica study area there are approximately eight residences within the FEMA 1% and 0.2% annual chance flood hazard zones (Figure 34). In addition, there are two FEMA Repetitive Loss (RL) and Severe Repetitive Loss (SRL) properties located within the Tonawanda Creek Batavia study area, both of which is a residential property and there are three FEMA Repetitive Loss (RL) and Severe Repetitive Loss (SRL) properties located within the Tonawanda Creek Attica study area, one of which is a residential property.

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

Figure 33. Tax Parcels within FEMA Flood Zones, Tonawanda Creek Batavia Study Area, City of Batavia, Genesee County, NY

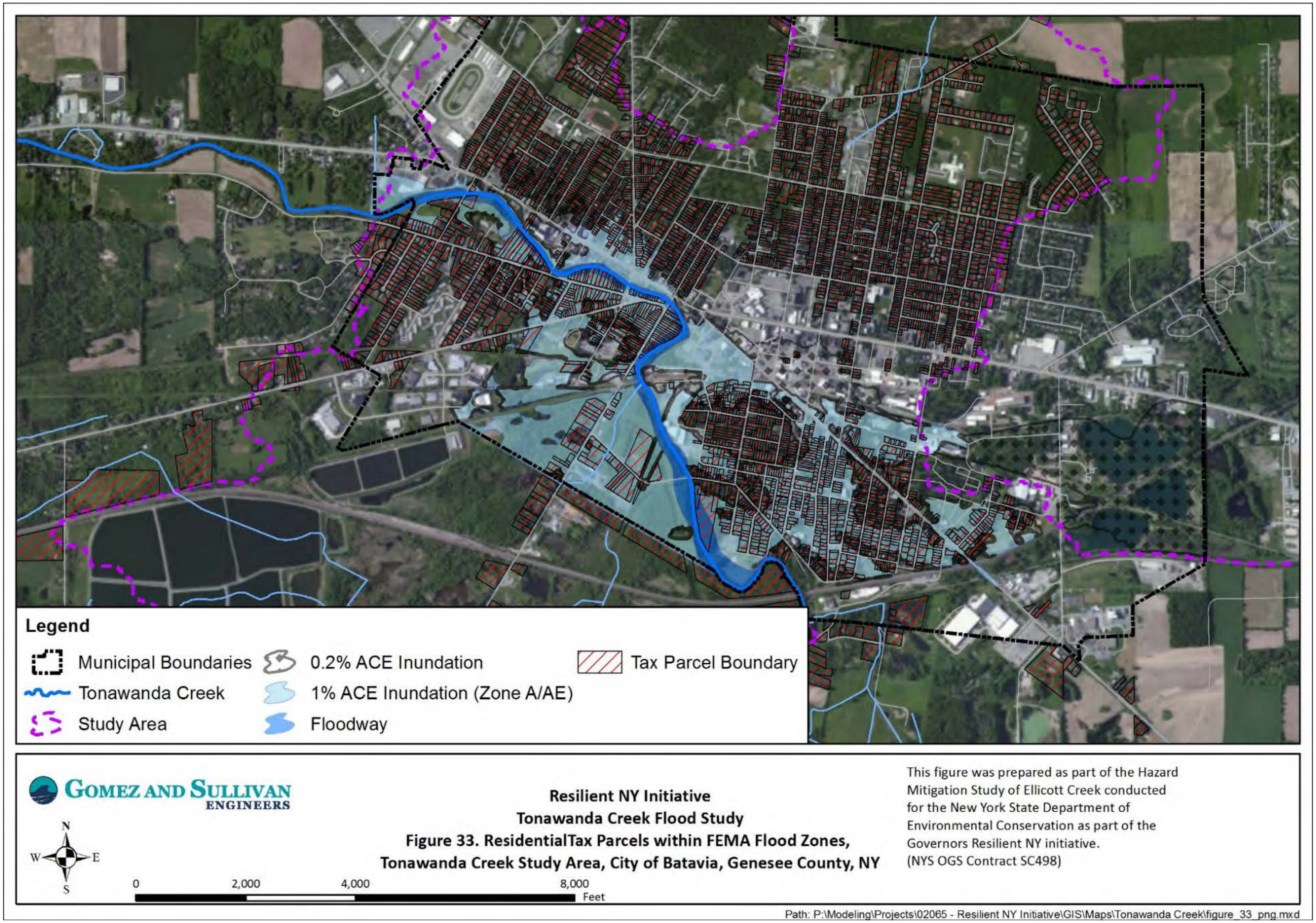
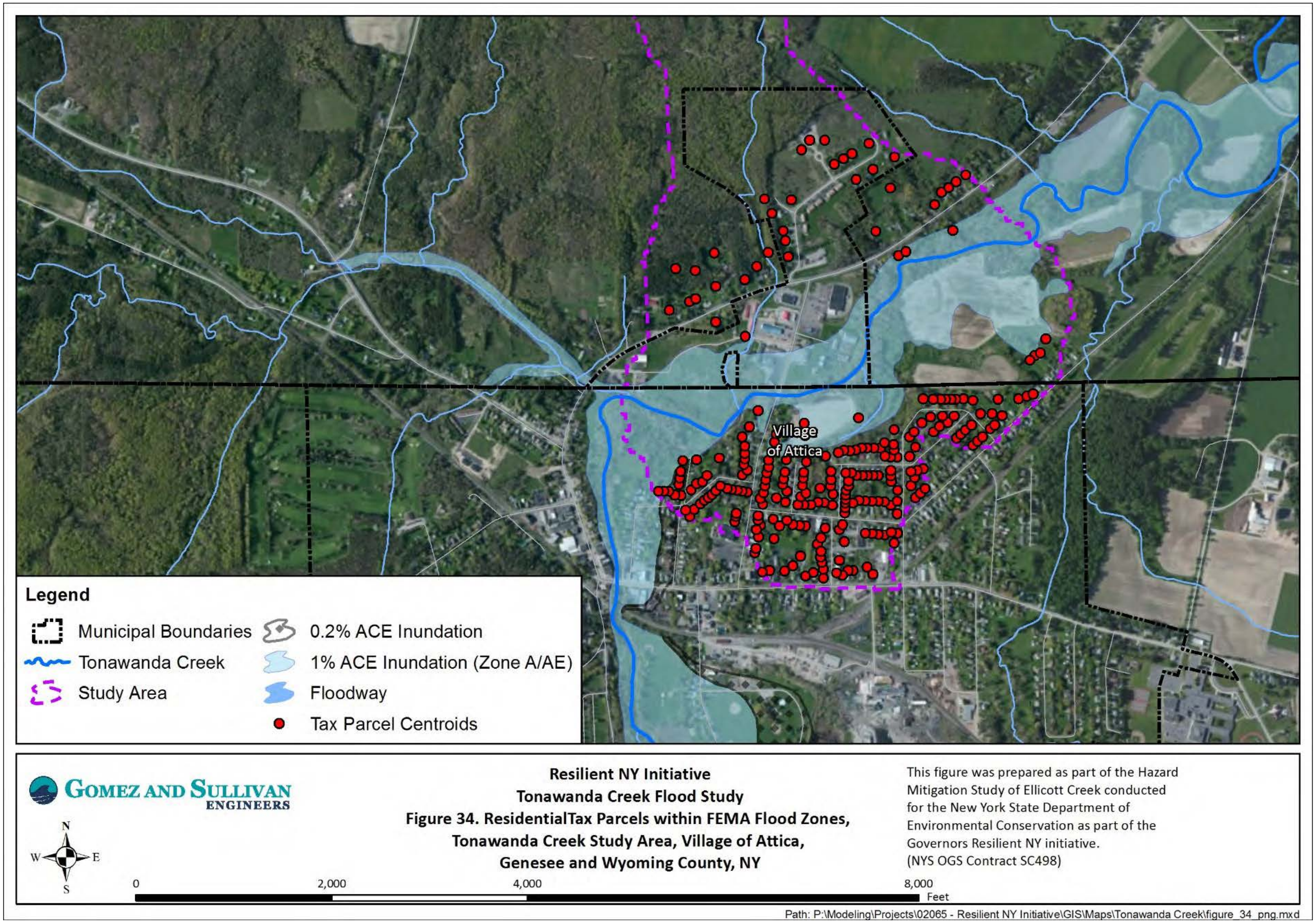


Figure 34. Tax Parcels within FEMA Flood Zones, Tonawanda Creek BataviaStudy Area, Village of Attica, Genesee and Wyoming County, NY



Alternative #4-4: 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, 2015c).

In some communities, where non-structural flood mitigation alternatives are not feasible, structural alternatives such as flood proofing may be a viable alternative. The NFIP 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 or above the freeboard required by 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 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, 2015c).

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, 2015c).

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-year) flood protection, a building must be dry floodproofed to an elevation at least 1-foot above the BFE (FEMA, 2013).

In New York State, only non-residential buildings are allowed to be dry floodproofed and the building must be dry floodproofed to an elevation of at least 2 feet above the BFE. New York State has higher freeboard standards than federal regulations at 44 CFR Part 60.3. Care must be taken to check the New York State 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 the BFE or above the freeboard required by local regulations.

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, 2015c).

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, 2015c). Although floodwalls or levees can be used to keep floodwaters away from buildings, implementing these measures will not affect a building's flood insurance rating unless the flood control structure is accredited in accordance with NFIP requirements (44 CFR §65.10) and provides protection from at least the 1% annual chance (100-year) 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. Within areas protected by floodwalls, or otherwise topographically isolated from the floodplain, flooding can occur due to backflow of flood waters through storm drainage systems. These systems should include backflow prevention devices.

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

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

- 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.

Alternative #4-5: Area Preservation / Floodplain Ordinances

This alternative proposes that municipalities within the Tonawanda 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 are 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 New York State 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 NFIP, best practices demonstrate that the adoption of higher standards 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 Tonawanda Creek watershed.

Next Steps

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

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.

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.

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 Division of Homeland Security and Emergency Services (NYSDHSES)
- Regional Economic Development Councils/Consolidated Funding Applications (CFA)
- Natural Resources Conservation Services (NRCS) Emergency Watershed Protection (EWP) Program
- FEMA Hazard Mitigation Grant Program (HMGP)

New York State Division of Homeland Security and Emergency Services (NYSDHSES)

The New York State Office of Emergency Management (NYSOEM), which is a part of the NYSDHSES, in conjunction with the United States Department of Homeland Security (USDHS) and FEMA, offers several funding opportunities through federal grant programs. Two primary programs are available through FEMA's Hazard Mitigation Grant Program (HMGP): Public Assistance, which includes post-disaster recovery grants enabled by Presidential declaration to reimburse for the emergency protective measures and the repair of eligible public facilities and infrastructure; and Hazard Mitigation, which includes pre-disaster project grants to eligible government sub-applicants to avoid or reduce the loss of life and property in future events. The NYSOEM would be the primary point of contact for all aspects of these programs.

Regional Economic Development Councils/Consolidated Funding Applications (CFA)

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

Water Quality Improvement Project (WQIP) Program

The WQIP Program, administered through the NYSDEC, 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.

Climate Smart Communities (CSC) Grant Program

The 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 New York State 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.

NRCS Emergency Watershed Protection (EWP) Program

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

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.

Building Resilient Infrastructure and Communities (BRIC) Program

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.

Flood Mitigation Assistance (FMA) Program

The FMA Program provides resources to reduce or eliminate long-term risk of flood damage to structures insured under the 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

New York State Department of Transportation (NYSDOT) BRIDGE NY Program

The BRIDGE NY program from the NYSDOT is intended to provide assistance to local governments for rehabilitation and replacement of bridges and culverts, that otyherwise would not be completed. At least $200 million in funding is expected to be awarded for fiscal years 2020-21 and 2021-22, with awards considered for projects costing as little as $250,000 and a maximum award amount of $5.0 million. The program is specifically intended for locally owned structures on public roadways. The program can cover up to 95% of the authorized project costs, and can cover all project costs including design/engineering, right-or-way, construction and inspection. The ranking criteria to be used in selecting projects includes risk and resiliency; this report can support the application to support the necessity of increasing the structure opening size.

Summary

The City of Batavia and Village of Attica had a history of flooding events along Tonawanda Creek. Flooding in the City and Village primarily occurs during the spring and winter months due to heavy rains by convective systems and snowmelt. In response to persistent flooding, the State of New York in conjunction with the City of Batavia and Village of Attica, and Genesee and Wyoming Counties, are studying and evaluating potential flood mitigation projects for Tonawanda Creek as part of the Resilient NY Initiative.

This study analyzed the historical and present day causes of flooding in the Tonawanda 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 Tonawanda 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 Tonawanda 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 included a flood bench along Walnut Street in the City of Batavia, a flood bench downstream of the Prospect Street bridge and modification of the Prospect Street bridge in the Village of Attica. There would be an overall greater effect in water surface elevations if multiple alternatives were built along Tonawanda Creek in different phases, rather than a single mitigation project. For example, building multiple flood benches along a single reach would compound the flood mitigation benefits of each bench.

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

The debris maintenance alternatives around culverts / bridges would maintain the flow channel area in Tonawanda 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.

No feasible alternatives resulted in appreciable reductions in water surface elevations in the vicinity of South Main Street. Therefore, basin-wide mitigation alternatives such as flood buyout programs, floodproofing and area preservation/floodplain ordinances may be the most desirable alternatives in this area. Additionally, an early flood-warning detection system may be helpful in reducing danger to the public and the costs of flood damages by allowing residents to evacuate and move possessions out of harm's way prior to the onset of flooding.

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

Table 18. Summary of Flood Mitigation Measures

Alternative No.	Description	Change in Water Surface Elevation (ft)		ROM cost ($U.S. dollars)
		Current Flows	Projected Flows	
1-1	South Main Street Flood Bench	negligible	negligible	N/A
2-1	Walnut Street Flood Bench	0.1 - 0.2	0.1 - 0.2	$650,000
3-1	Prospect Street Downstream Flood Bench	0.9 – 1.3	0.9 – 2.7	$2.0 million
3-2	Prospect Street Bridge Replacement	0.4 – 1.7	0.4 – 2.3	$3.5 million
3-3	Prospect Street Combination	1.2 – 2.5	1.3 – 3.2	$5.1 million
4-1	Early Flood Warning Detection System	N/A	N/A	$120,000 (not including annual operational costs)
4-2	Debris Maintenance Around Bridges/Culverts	N/A	N/A	$20,000 (not including annual operational costs)
4-3	Flood Buyouts Program	N/A	N/A	Variable (case-by-case)
4-4	Floodproofing	N/A	N/A	Variable (case-by-case)
4-5	Area Preservation/Floodplain Ordinances	N/A	N/A	Variable (case-by-case)

Conclusion

Municipalities affected by flooding along Tonawanda 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 potential 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 presented 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 potential 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 Tonawanda 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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Appendix A. Summary of Data and Reports Collected

Year	Type	Document Title	Author	Publisher
1978	Report	National Handbook of Recommended Methods for Water-Data Acquisition	Office of Water Data Coordination	USGS
1983	Report	Interim Report on Feasibility of Flood Management Tonawanda Creek Watershed		USACE
1991	Report	Regionalization of Flood Discharges for Rural, Unregulated Streams in New York, Excluding Long Island	Richard Lumia	USGS
1996	Book	Applied River Morphology, 2nd Edition	D. L. Rosgen and H. L. Silvey	Wildland Hydrology Books
2000	Code	Title 44: Emergency Management and Assistance, Chapter 1		FEMA
2002	Standard	National Conservation Practice Standard No. 638: Water and Sediment Control Basin		NRCS
2003	Report	Draft Genesee & Wyoming Counties Joint Flood Mitigation Plan - Village of Attica	Genesee/Finger Lakes Regional Planning Council and Lu Engineers	
2006	Report	Floodplain Management Requirements: A Study Guide and Desk Reference for Local Officials		FEMA
2006	Report	Bridge Inventory Manual		NYSDOT
2006	Report	Magnitude and Frequency of Floods in New York	Richard Lumia, Douglas A. Freehafer, and Martyn J. Smith	USGS
2007	Book	Elevation Data for Floodplain Mapping		NRC

Year	Type	Document Title	Author	Publisher
2009	Report	Bankfull Discharge and Channel Characteristics of Streams in New York State	Christiane I. Mulvihill, Barry P. Baldigo, Sarah J. Miller, Douglas DeKoskie, and Joel DuBois	USGS
2010	Report	DHS Risk Lexicon		USDHS
2011	Report	Responding to Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation in New York State, Final Report		NYSERDA
2011	Article	An Overview of CMIP5 and the Experiment Design	K. E. Taylor, R. J. Stouffer, and G. A. Meehi	Bulletin of the American Meteorological Society
2012	Report	Hydraulic Design of Safe Bridges	L. W. Zevenbergen, L. A. Arneson, J.H. Hunt, and A.C. Miller	USDOT
2012	Article	Geomorphic Characterization of Upper South Koel Basin, Jharkhand: A Remove Sensing and GIS Approach	R. Parveen, U. Kumar, and V. K. Singh	Journal of Water Resource and Protection, 1042-1050
2013	Report	Floodproofing Non-Residential Buildings		FEMA
2013	Report	Removal of Woody Debris and Trash from Rivers and Streams		NYSDEC
2013	Article	Anatomy of a Buyout Program – New York Post-Superstorm Sandy	A. R. Siders	Vermont Law School
2014	Book	Handbook of Biological Statistics, 3rd Edition	J. H. McDonald	Sparky House Publishing
2014	Report	National Register of Historical Places and National Historic Landmarks Program Records for New York State		NPS

Year	Type	Document Title	Author	Publisher
2014	Article	Morphometric Analysis of a Drainage Basin Using Geographical Information System: A Case Study	M. L. Waikar and A. P. Nilawar	International Journal of Multidisciplinary and Current Research
2015	Report	Guidance for Flood Risk Analysis and Mapping: Redelineation Guidance		FEMA
2015	Report	Hazard Mitigation Assistance Program Digest, September 2015		FEMA
2015	Report	Reducing Flood Risk to Residential Buildings That Cannot Be Elevated		FEMA
2015	Article	Influence of Aggradation and Degradation on River Channels: A Review	U. R. Mugade and J. B. Sapkale	International Journal of Engineering and Technical Research
2015	Report	Development of Flood Regressions and Climate Change Scenarios to Explore Estimates of Future Peak Flows	Douglas A. Burns, Martyn J. Smith, and Douglas A. Freehafer	USGS
2016	Report	HEC-RAS: River Analysis System User's Manual, Version 5.0	HEC	USACE
2016	Software	Application of Flood Regressions and Climate Change Scenarios to Explore Estimates of Future Peak Flows, Version 1.5 Web Application		USGS
2020	Data	New York State Digital Ortho-Imagery Program	GIS Program Office	NYSOITS

Year	Type	Document Title	Author	Publisher
2017	Report	Fact Sheet 2017-3046: *StreamStats*, Version 4	Kernell G. Ries III, Jeremy K. Newsom, Martyn J. Smith, John D. Guthrie, Peter A. Steeves, Tiana L Haluska, Katharine R. Kolb, Ryan F. Thompson, Richard D. Santoro, and Hans W. Vraga	USGS
2018	Report	DRAFT New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act		NYSDEC
2018	Report	Highway Design Manual	Engineering Division, Office of Design	NYSDOT
2018	Article	Governor Cuomo Announces $3 Million for Studies to Reduce Community Flood Risk		NYSGPO
2019	Software	ArcGIS for Desktop 10		ESRI
2019	Data	2016 Land Cover: Conterminous United States	NLCD	MRLC
2019	Data	Bridge Point Locations and Select Attributes	Structures Division	NYSDOT
2019	Report	Bridge Manual	Structures Division	NYSDOT
2019	Data	CostsWorks 2019	RS Means Data Online	Gordian, Inc.
2019	Software	Hydrologic Engineering Center's River Analysis System, Version 5.0.7	HEC	USACE
2019	Report	Policy Manual: NY Rising Buyout and Acquisition Program, Version 7.0		NYSGOSR
2020	Data	Storm Events Database	NCEI	NOAA
2020	Software	Environmental Resource Mapper Web Application		NYSDEC

Year	Type	Document Title	Author	Publisher
2020	Data	Inventory of Dams – New York State		NYSDEC
2020	Standard	Standard Specifications (US Customary Units), Volume 1	Engineering Division	NYSDOT
2020	Software	Information for Planning and Consultation Web Application	ECOS	USFWS
2020	Software	*StreamStats*, Version 4.4.0 Web Application		USGS
2020	Website	Hazard Mitigation Grant Program (HMGP)		FEMA
Unk	Article	Watershed Management		NYSDEC
Unk	Article	Batavia Flood Damage Reduction Project		NYSDEC

Appendix B. Agency and Stakeholder Meeting Attendees List

Initial Project Kickoff Meeting: September 19, 2019

Attendees	Affiliation
Thomas Lowe	Alexander, Village of
William Wagner	Alexander, Village of
Tim Lucey	Amherst, Town of
Paul Rubins	Amherst, Town of
Jeff Szatkowski	Amherst, Town of
Jim Zymanek	Amherst, Town of
Tom Lichtenthal	Batavia, Town of
Steve Mountain	Batavia, Town of
Katherine Winkler	Buffalo Niagara Waterkeeper
James Dussing	Clarence, Town of
Paul Englert	Clarence, Town of
Gregory Butcher	Erie County
Mark Gaston	Erie County
Joanna Panawiewicz	Erie County
J.T. Glass	Erie County
Molly Cassatt	Genesee County
Derik Kae	Genesee County
Bradley Mudrzynski	Genesee County
Damian Gomez	Gomez & Sullivan
Erin Redding	Gomez & Sullivan
Charvi Gupta	Highland Planning
Jen Topa	Highland Planning
Susan Hopkins	Highland Planning
Gary Baehr	Newstead, Town of
Norman Allen	Niagara County
Scott Collins	Niagara County
Stephany Antonov	NYSDEC
David Clarke	NYSDEC
Ted Myers	NYSDEC
Kerrie O'keeffe	NYSDEC
Thomas R. Snow Jr.	NYSDEC
Chad Staniszewski	NYSDEC
Ryan Tomko	NYSDEC
Kadir Goz	OBG
James Sparks	Royalton, Town of

Appendix C. Field Data Collection Forms

NRCS
U.S. Department of Agriculture
Natural Resources Conservation Service

Stream Channel Classification (Level II)

Wisconsin Job Sheet 811

Natural Resources Conservation Service (NRCS) **Wisconsin**

Project: ______________________ Date: ______________________

County: ______________________ Stream: ______________________

Reach No.: ______________________ Logged By: ______________________

Horizontal Datum: NAD ________ Projection: ☐Transverse Mercator ☐Lambert Conformal Conical

Coordinate System: ☐ __________ County Coordinates ☐WTM ☐State Plane Coordinates ☐UTM

Units: ☐Meters ☐Feet Horizontal Control: N or Lat ___________ E or Long ___________

Elevation: ___________ ☐Assumed ☐DOT ☐NAVD (29 / 88) Units: ☐Meters ☐Feet

Fluvial Geomorphology Features (3 Cross Sections) for Stream Classification

				Average
Bankfull Width (W_{bkf}):	________ ft.	________ ft.	________ ft.	0.00 ft.
Width of the stream channel, at bankfull stage elevation, in a riffle section.				
Mean Depth (d_{bkf}):	________ ft.	________ ft.	________ ft.	0.00 ft.
Mean depth of the stream channel cross section, at bankfull stage elevation, in a riffle section. ($d_{bkf}=A_{bkf}/W_{bkf}$)				
Bankfull X-Section Area (A_{bkf}):	________ sq. ft.	________ sq. ft.	________ sq. ft.	0.00 sq. ft.
Area of the stream channel cross section, at bankfull stage elevation, in a riffle section.				
Width / Depth Ratio (W_{bkf}/d_{bkf}):	________ ft.	________ ft.	________ ft.	0.00 ft.
Bankfull width divided by bankfull mean depth, in a riffle section.				
Maximum Depth (d_{mbkf}):	________ ft.	________ ft.	________ ft.	0.00 ft.
Maximum depth of the Bankfull channel cross section, or distance between the bankfull stage and thalweg elevations, in a riffle section.				
Width of Flood-Prone Area (W_{fpa}):	________ ft.	________ ft.	________ ft.	0.00 ft.
Twice maximum depth, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area width is determined (riffle section).				
Entrenchment Ratio (ER):	________ ft.	________ ft.	________ ft.	0.00 ft.
The ratio of flood-prone area width divided by bankfull channel width. (W_{fpa}/W_{bkf}) (riffle section)				

USDA-NRCS **January 2009** **Wisconsin Job Sheet 811**

Reach Characteristics

Channel Materials (Particle Size Index) D50: _________ mm

The D50 particle size index represents the median diameter of channel materials, as sampled from the channel surface, between the bankfull stage and thalweg elevations.

Water Surface Slope (S): ________________ ft./ft.

Channel slope = "rise" over "run" for a reach approximately 20-30 bankfull channel widths in length, with the "riffle to riffle" water surface slope representing the gradient at bankfull stage.

Channel Sinuosity (K): ________________.

Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL/VL); or estimated from a ratio of valley slope divided by channel slope (VS/S).

Distance to Up-Stream Structures: ______________________________.

Stream Type: _____________________ (For reference, note Stream Type Chart and Classification Key)

Dominant Channel Soils at an Eroding Bank Location

Bed Material: __________________________ Left Bank: ___________ Right Bank: ___________

Description of Soil Profiles (from base of bank to top):

Left: ____

____

Right: ____

____

Riparian Vegetation at an Eroding Bank Location

Left Bank: _____________________________ Right Bank: _____________________________

Percent Total Area (Mass): Left: __________________ Right: ___________________________

Percent Total Height with Roots: Left: __________________ Right: ______________________

Other Bank Features at an Eroding Bank Location

Actual Bank Height: _______________________ Bankfull Height: __________________________

Bank Slope (Horizontal to Vertical):

Left:
- ☐ 0-20° (flat)
- ☐ 21-60° (moderate)
- ☐ 61-80° (steep)
- ☐ 81-90° (vertical)
- ☐ 90°+ (undercut)

Right:
- ☐ 0-20° (flat)
- ☐ 21-60° (moderate)
- ☐ 61-80° (steep)
- ☐ 81-90° (vertical)
- ☐ 90°+ (undercut)

Visible Seepage in Bank? ☐ Yes ☐ No Where? ______________________________

Thalweg Location: ☐ Near 1/3 ☐ Mid 1/3 ☐ Far 1/3

NRCS
U.S. Department of Agriculture
Natural Resources Conservation Service

Pebble Count (Data Collection)

Wisconsin Job Sheet 810

Natural Resources Conservation Service (NRCS) **Wisconsin**

Project: ____________________ Date: ____________________
County: ____________________ Stream: ____________________
Reach No.: ____________________ Logged By: ____________________

Horizontal Datum: NAD ________ Projection: ☐ Transverse Mercator ☐ Lambert Conformal Conical
Coordinate System: ☐ ________ County Coordinates ☐ WTM ☐ State Plane Coordinates ☐ UTM
Units: ☐ Meters ☐ Feet Horizontal Control: N or Lat. __________ E or Long. __________
Elevation: __________ ☐ Assumed ☐ DOT ☐ NAVD (29 / 88) Units: ☐ Meters ☐ Feet

Inches	Millimeters	Particle	Particle Count			
			1	Total #	2	Total #
<.002	<.062	Silt/Clay				
.002 - .005	.062 - .125	Very Fine Sand				
.005 - .01	.125 - .25	Fine Sand				
.01 - .02	.25 - .50	Medium Sand				
.02 - .04	.50 - 1.0	Coarse Sand				
.04 - .08	1.0 - 2	Very Coarse Sand				
.08 - .16	2 - 4	Very Fine Gravel				
.16 - .22	4 - 5.7	Fine Gravel				
.22 - .31	5.7 - 8	Fine Gravel				
.31 - .44	8 - 11.3	Medium Gravel				
.44 - .63	11.3 - 16	Medium Gravel				
.63 - .89	16 - 22.6	Coarse Gravel				
.89 - 1.26	22.6 - 32	Coarse Gravel				
1.26 - 1.77	32 - 45	Very Coarse Gravel				
1.77 - 2.5	45 - 64	Very Coarse Gravel				
2.5 - 3.5	64 - 90	Small Cobbles				
3.5 - 5.0	90 - 128	Small Cobbles				
5.0 - 7.1	128 - 180	Large Cobbles				
7.1 - 10.1	180 - 256	Large Cobbles				
10.1 - 14.3	256 - 362	Small Boulders				
14.3 - 20	362 - 512	Small Boulders				
20 - 40	512 - 1024	Medium Boulders				
40 - 80	1024 - 2048	Large-Very Large Boulders				
		Bedrock				

GOMEZ AND SULLIVAN ENGINEERS

Resilient New York

Date:

Field crew:

Stream:

Road crossing:

Structure data: ☐ Bridge

Height at edge[1]: _____ Width at top of opening: _____
Height at deepest point: _____ Bank slope: Rise: _____ Run: _____
Piers _____ Pier shape: round triangle square
Span between piers: _____ Width of piers: _____

☐ Culvert (see data below)

Length in direction of flow:

Manning value: Top: Bottom:

Deck thickness:

Height of rail:

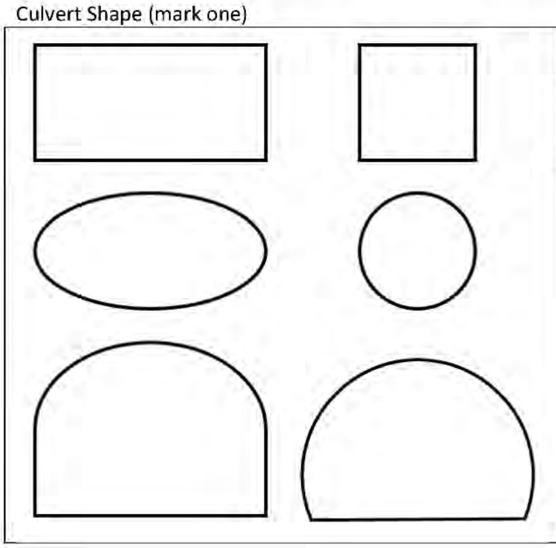
Type of rail:

Structure material:

Bottom substrate:

Description:

Culvert Shape (mark one)



Depth from top of opening to bottom of stream
at edge: _____
at deepest location: _____

Opening width: _____

[1] All measurements should be taken to 0.1 feet

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Appendix D. Photo Log

List of Additional Field Photos

Photo D-1. *Downstream face of pedestrian bridge at Walnut Street*

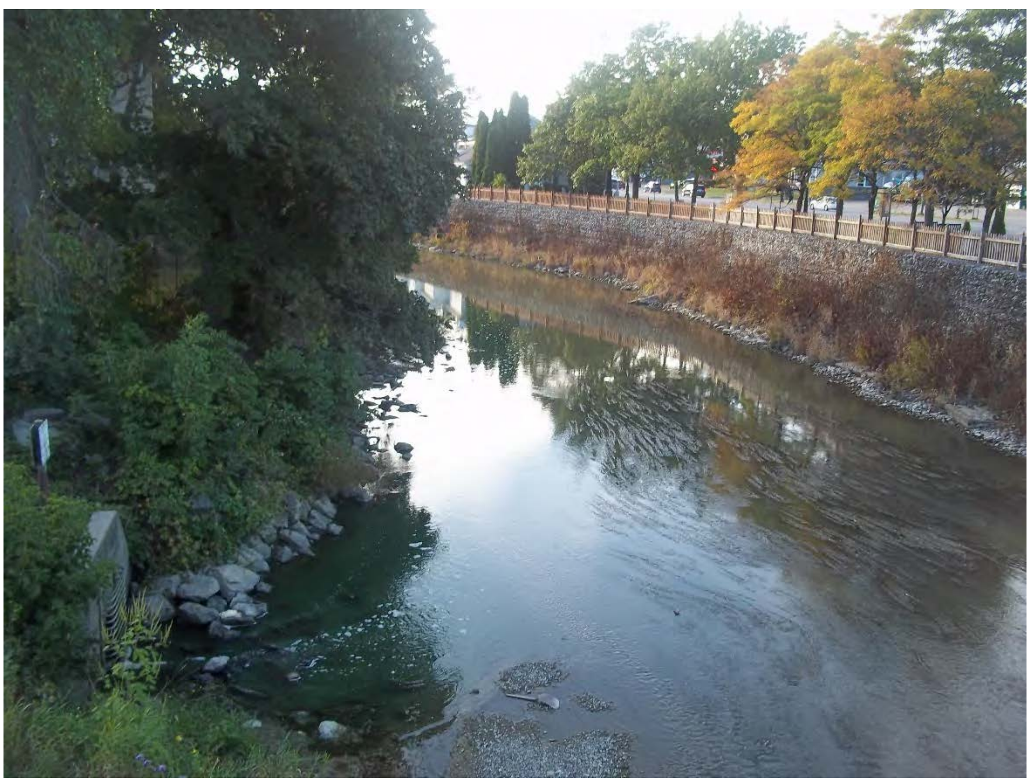
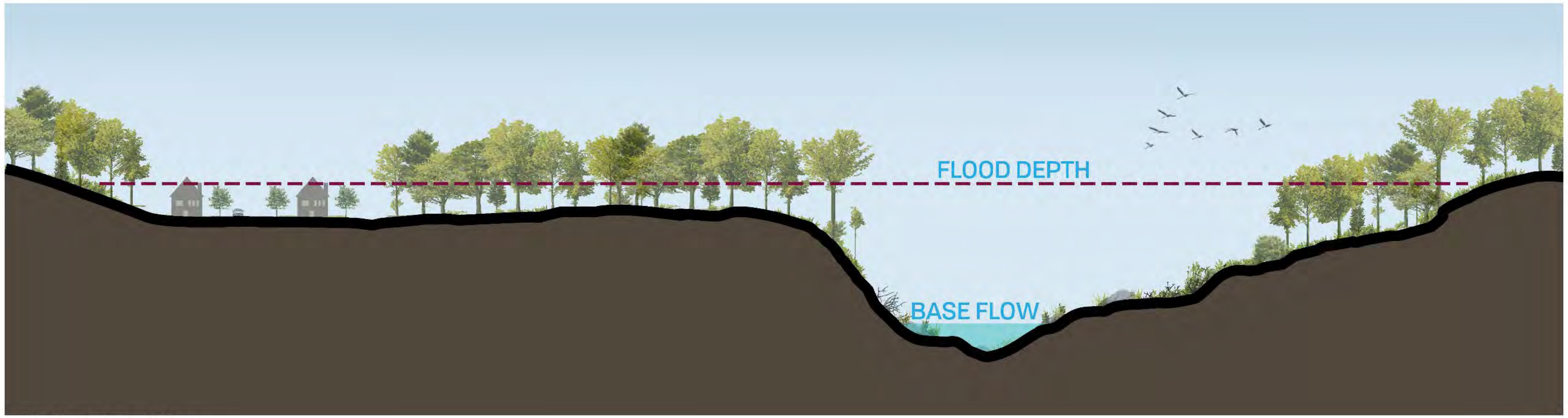


Photo D-2. *Channel downstream from pedestrian bridge at Walnut Street*

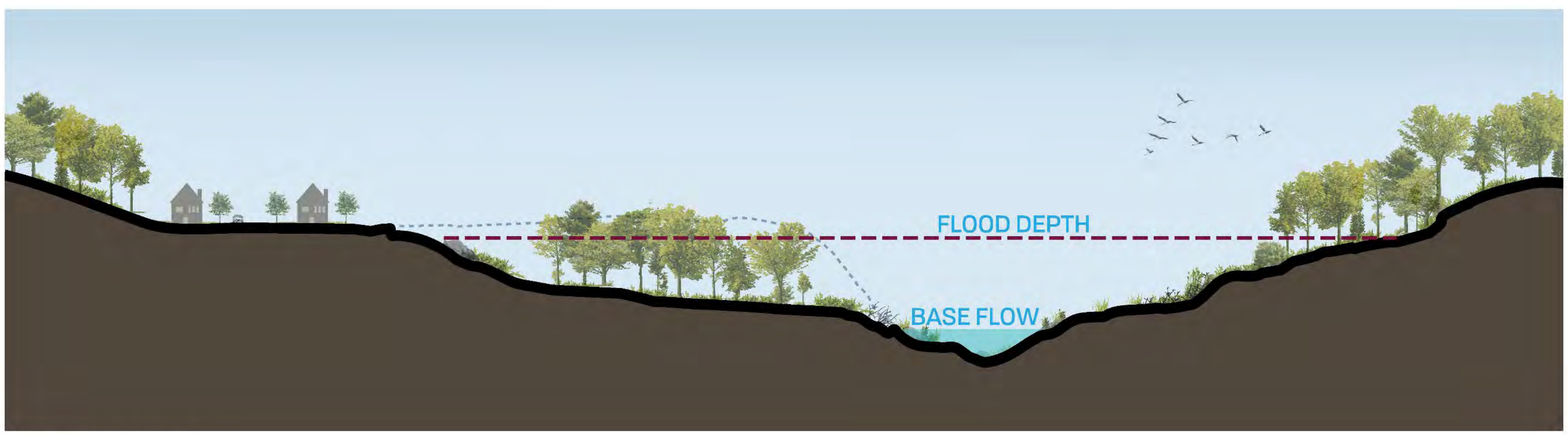
Photo D-3. *Channel upstream from pedestrian bridge at Walnut Street*

Photo D-4. *Small dam upstream from pedestrian bridge at Walnut Street*

Appendix E. HEC-RAS Simulation Output

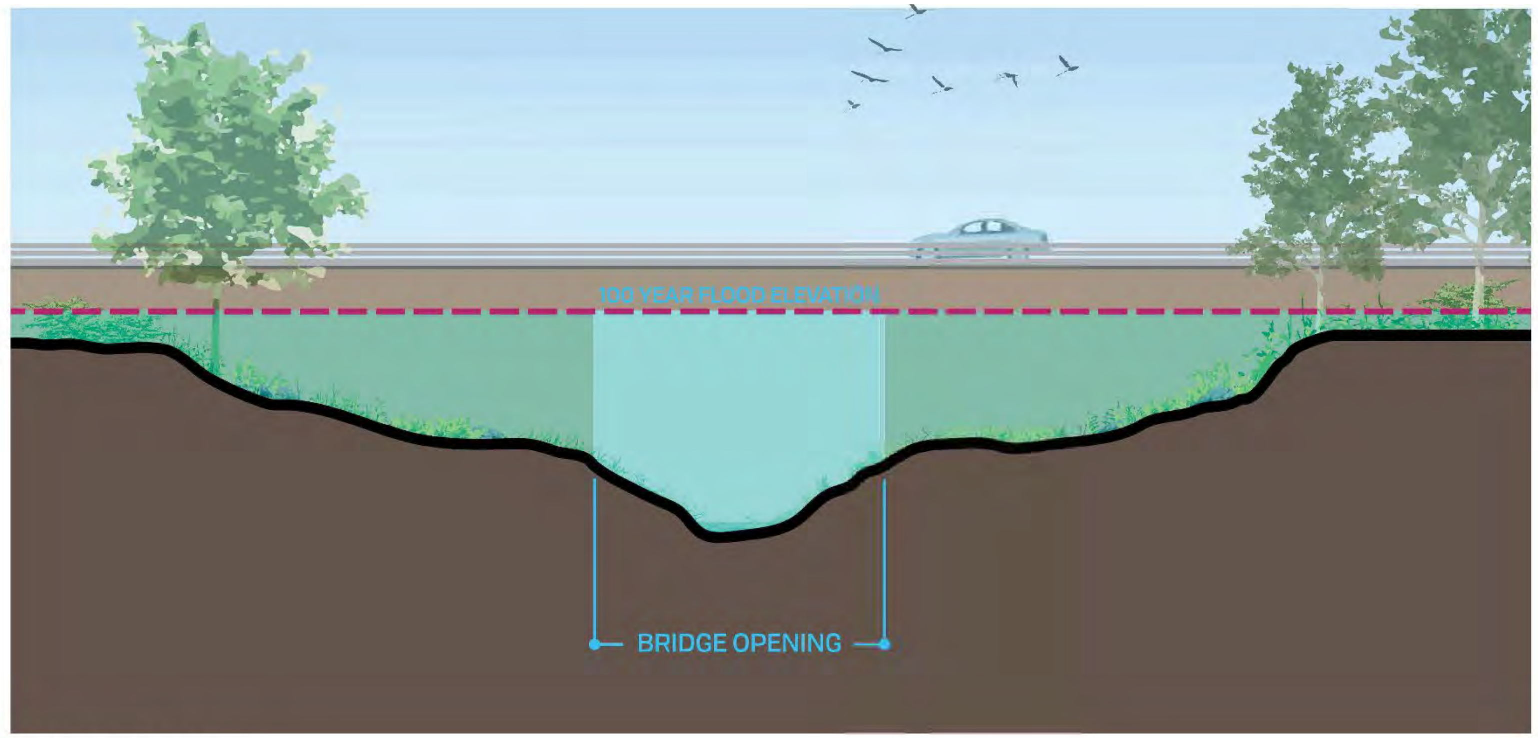


Existing Condition

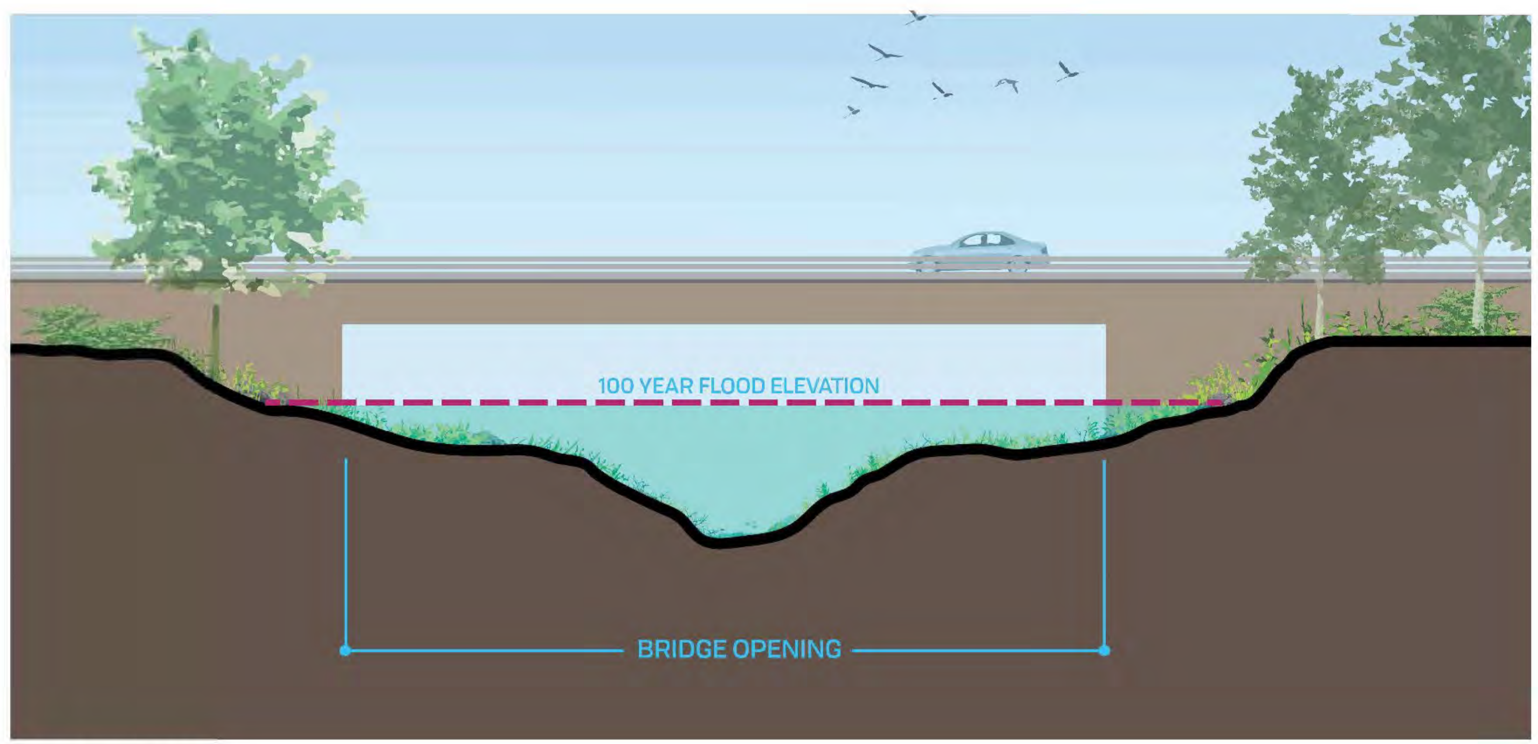


Future Condition

FLOODPLAIN BENCH

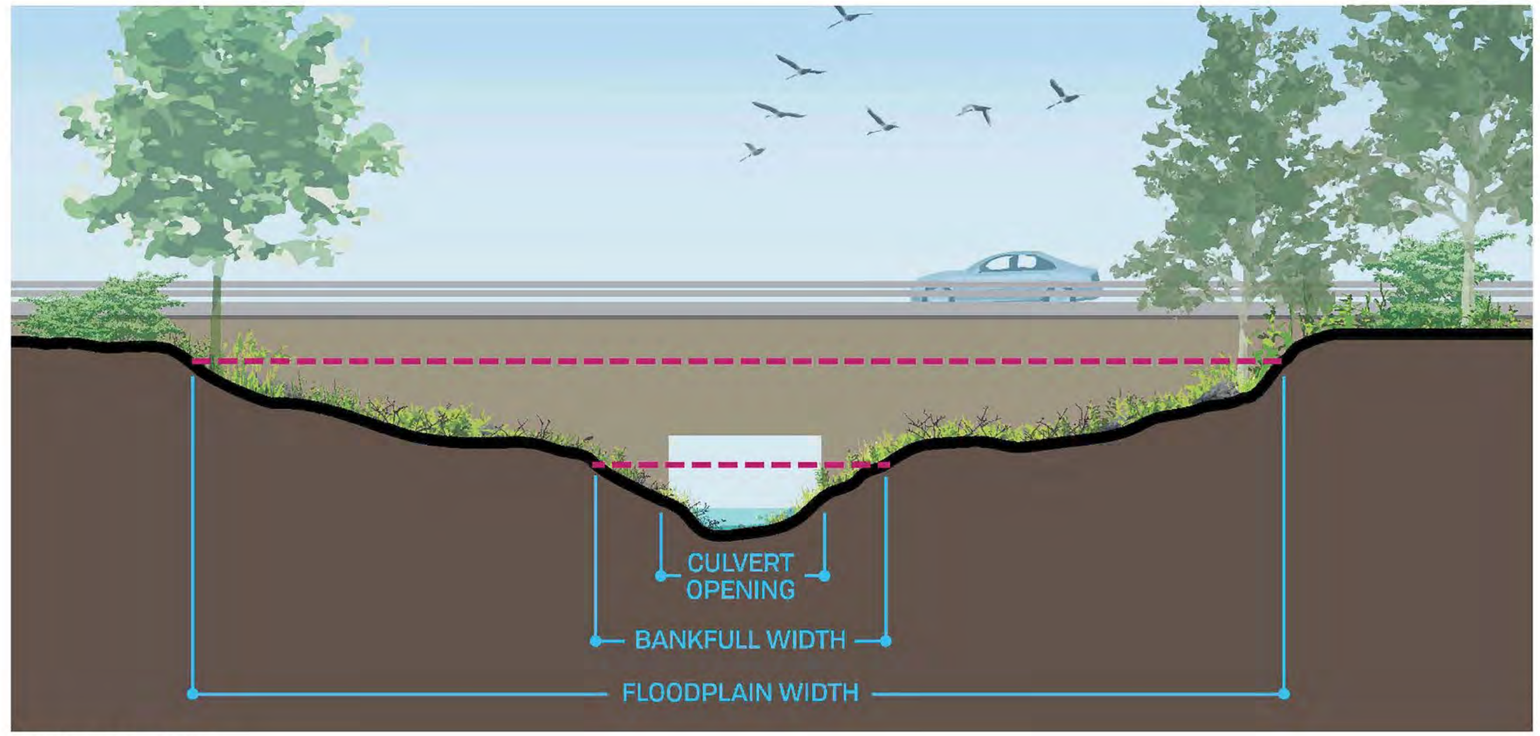


Existing Condition

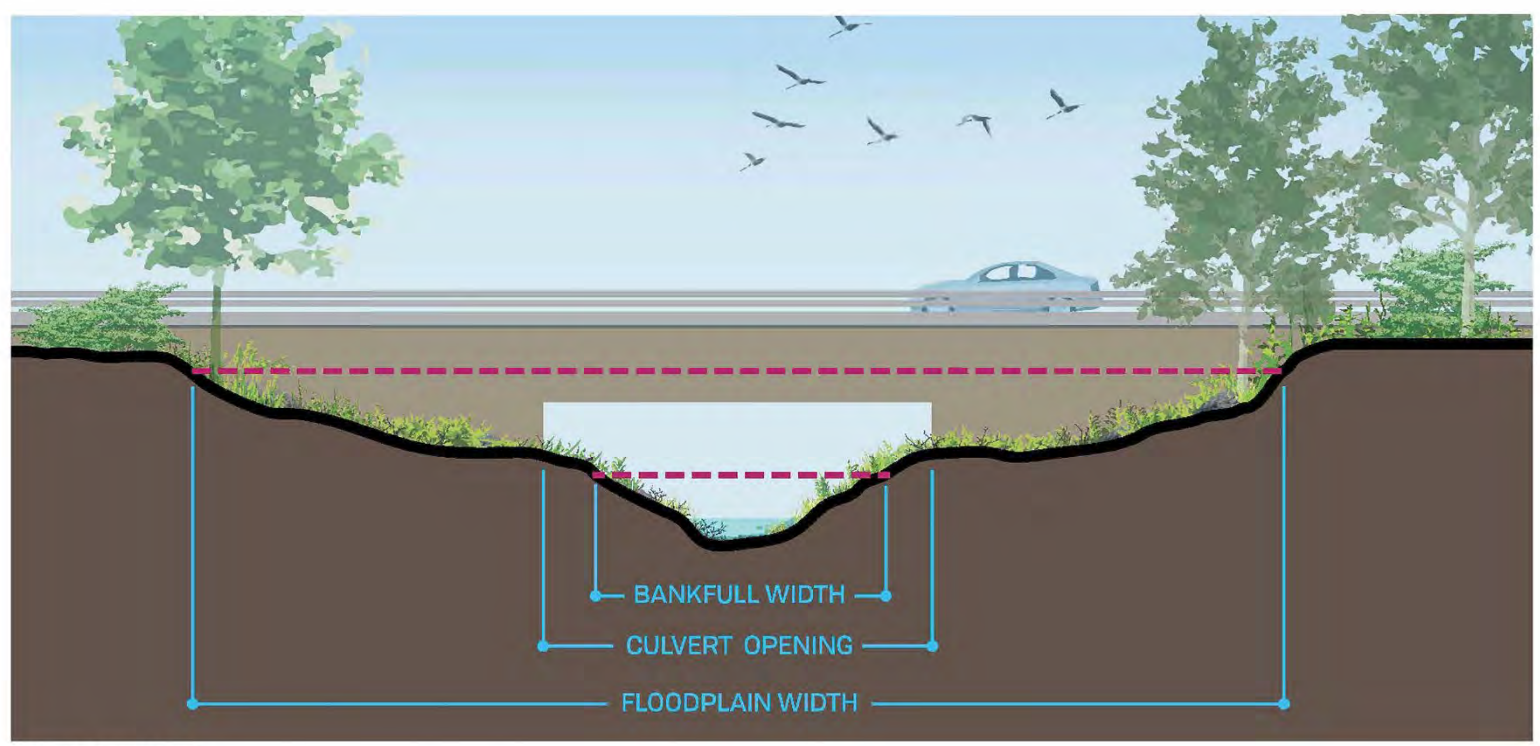


Future Condition

EXPANDED BRIDGE OPENING

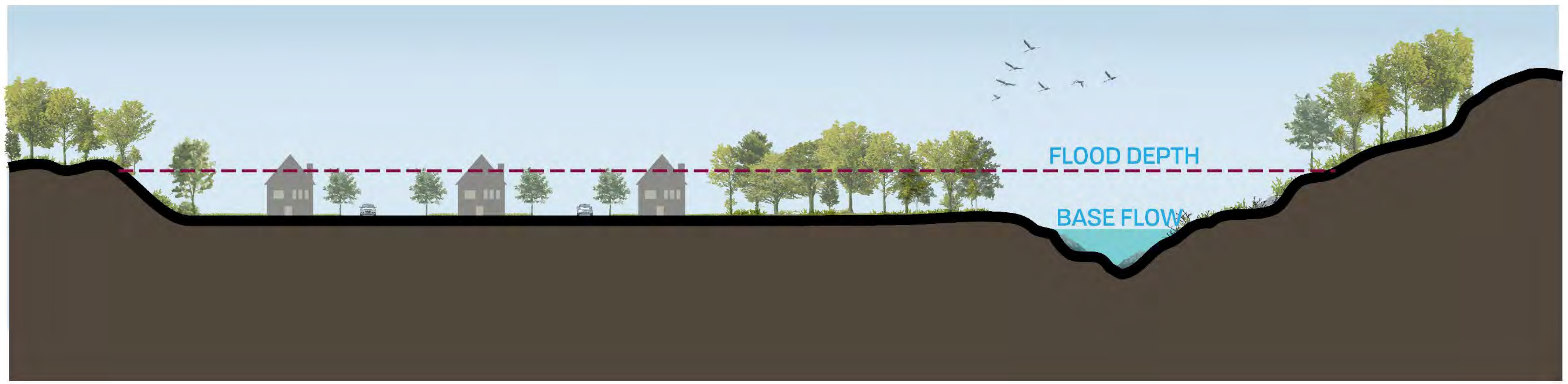


Existing Condition

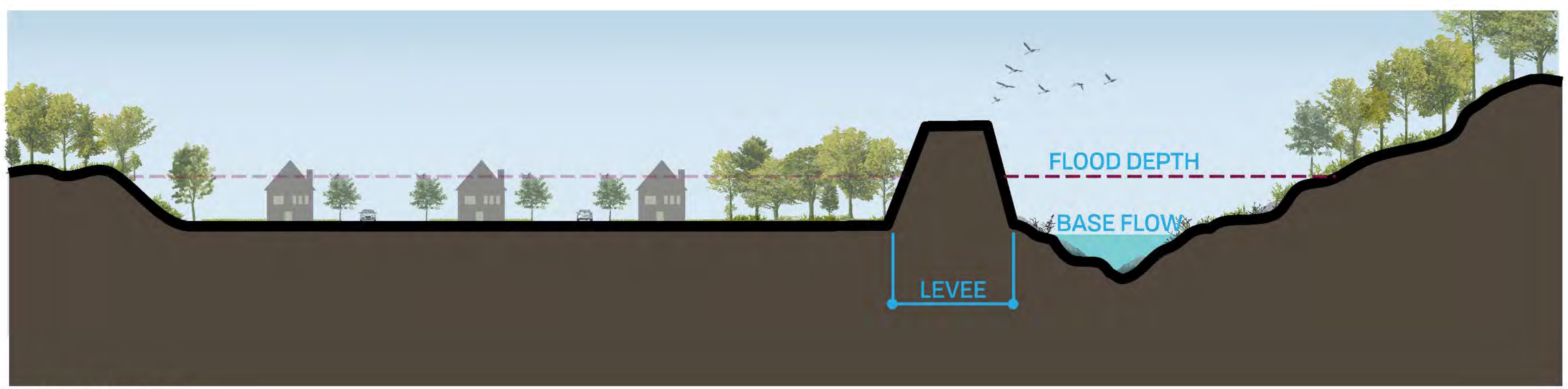


Future Condition

EXPANDED CULVERT OPENING



Existing Condition



Future Condition

PROTECTIVE LEVEE