RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE

Buffalo Creek, NY

This document was prepared for the New York State Department of Environmental Conservation, in cooperation with the New York State Office of General Services, Highland Planning, LLC, and Gomez & Sullivan Engineers, DPC.

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

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

NOTICE

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ABBREVIATIONS/ACRONYMS

1-D	1-Dimensional
2-D	2-Dimensional
ACE	Annual Chance Exceedance
CFA	Consolidated Funding Applications
CFS	Cubic Feet per Second (ft^3/s)
CMIP5	5th Phase of the Coupled Model Intercomparison Project
CRISSP	Comprehensive River Ice Simulation System
CRRA	Community Risk and Resiliency Act
CSC	Climate Smart Communities
CWSRF	Clean Water State Revolving Fund
DEM	Digital Elevation Model
DHS	Department of Homeland Security
ECSWCD	Erie County Soil and Water Conservation District
EPA	Environmental Protection Agency
EPG	Engineering Planning Grant
ESD	Empire State Development Corporation
EWP	Emergency Watershed Protection
FDD	Freezing Degree-Day
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FMA	Flood Mitigation Assistance
FT	Feet
GIS	Geographic Information System
H&H	Hydrologic and Hydraulic
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HMA	Hazard Mitigation Assistance
HSGP	Homeland Security Grant Program
LiDAR	Light Detection and Ranging
NAD 27	North American Datum of 1927
NAVD 88	North American Vertical Datum of 1988
NFIP	National Flood Insurance Program
NRCS	Natural Resources Conservation Service

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
NYSEFC	New York State Environmental Facilities Corporation
NYSOEM	New York State Office of Emergency Management
NYSOGS	New York State Office of General Services
OBG	OBG, Part of Ramboll
PDM	Pre-Disaster Mitigation
R_C	Circularity Ratio
RCP	Representative Concentration Pathways
R_E	Elongation Ratio
R_F	Form Factor
RF	Radio Frequency
RL	Repetitive Loss
ROM	Rough Order of Magnitude
SQ MI	Square Miles (mi^2)
SMS	Surface Modeling System
SRL	Severe Repetitive Loss
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Service
USSCS	United States Soil Conservation Service
WCRP	World Climate Research Programme
WGCM	Working Group Coupled Modelling
WQIP	Water Quality Improvement Project
WRI	Water Resources Investigations

INTRODUCTION

HISTORICAL INITIATIVES

Flood mitigation has historically been an initiative in western New York and in the Buffalo Creek watershed. In response to periodic and repetitive flood losses along Buffalo Creek, the U.S. Congress authorized a program of farmland treatment, retirement, and reforestation of sub-marginal land for the Buffalo Creek watershed. The program was in effect from 1946 to 1963 and was designed to reduce runoff and erosion from farms and stabilize channel banks. The principal conservation measures applied to the channel banks were bank protection, channel improvement, levees, and water control structures in the Towns of Elma and West Seneca. This also included bank protection by the United States Soil Conservation Service (USSCS) on both banks of Buffalo Creek beginning upstream of the Lexington Green neighborhood and extending to the confluence with Cayuga Creek.

In the summer of 1963, Erie County excavated a channel in the rock channel bottom of Buffalo Creek upstream of the Winspear Road bridge. The excavated channel was approximately 18-feet wide, 800-feet long, and varied in depth from 1.5 to 6 feet. The excavated channel was designed to concentrate flow into the narrow channel and reduce the amount of ice that can form (USACE 1966). Numerous studies were conducted from 1966 to 1992 to assess the feasibility of flood control projects in Buffalo Creek in the Town of West Seneca. Each assessment concluded either that the proposed project did not warrant federal participation or that the economic benefit to the community did not outweigh the project cost (USACE 2016a).

In response to recent flooding in 2014, residents and homeowners petitioned local leaders and state/federal agencies for assistance. In the Lexington Green neighborhood in West Seneca, for example, homeowners used sandbags along the channel banks in an effort to prevent flood waters from reaching their homes. Additionally, local interest groups constructed a temporary levee (using recycled concrete) downstream of another levee in the upstream portion of the neighborhood to prevent future flood losses. Neither of the levees are accredited by the Federal Emergency Management Agency (FEMA), meaning flood insurance is still required for homes that reside within the FEMA 100-year flood zone. As a result of the flood issues in this area, the United States Army Corps of Engineers (USACE) completed an initial determination report that evaluated the eligibility with proceeding to a feasibility study investigation for the Lexington Green neighborhood in February of 2016, which would have recommended a cost-effective flood mitigation plan. It was concluded in the initial determination report that project costs would be greater than the economic benefits achieved, and the study was never pursued (USACE 2016a).

FLOODPLAIN DEVELOPMENT

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

1. Remove the flood prone facilities from the floodplain.
2. Adapt the facilities to be flood resilient under repetitive inundation scenarios.
3. Develop nature-based mitigation measures (e.g., floodplain benches, constructed wetlands, etc.) and right size bridges and culverts to lower flood stages 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. Local floodplain regulations should be consistent with the National Flood Insurance Program (NFIP) and FEMA regulations and should involve a floodplain coordinator and a site plan review process for all proposed developments. This review should determine if the proposed development could impact the floodplain or floodway and should not allow any fill in the floodplain or floodway of any watercourse.

RESILIENT NY INITIATIVE

In November of 2018, New York State Governor Andrew Cuomo announced the Resilient NY Initiative in response to devastating flooding in communities across the State in the preceding years. 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 Buffalo Creek watershed was chosen as a study site for this initiative.

The New York State Department of Environmental Conservation and Office of General Services implemented the studies. 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 identified the causes of flooding within each watershed and developed, evaluated, and recommended effective and ecologically sustainable flood and ice-jam hazard mitigation projects. Proposed flood mitigation measures were identified and evaluated using hydrologic and hydraulic modeling to quantitatively determine flood mitigation recommendations that would result in the greatest flood reductions benefits. In addition, the flood mitigation studies incorporated the latest climate change forecasts and assessed ice jam hazards where jams have been identified as a threat to public health and safety.

The goals of the Resilient NY Initiative are to:

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

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

The flood mitigation and resiliency study for Buffalo Creek began in March of 2019 and is planned to be completed in early 2020.

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. United States Geologic Service (USGS) *FutureFlow* Explorer v1.5 (Burns et al. 2015) and *StreamStats* v4.3.1 (Ries et al. 2017) software were used to develop current and future potential discharges and bankfull widths and depths at various points along the stream channel. Hydrologic and hydraulic (H&H) modeling was performed previously, as part of a FEMA Flood Insurance Study (FIS) using USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) to predict water stage at potential future high-risk areas and evaluate the effectiveness of flood mitigation strategies. These studies were obtained and used, all or in part, as part of this effort. Appendix A is a summary listing of data and reports collected.

PUBLIC OUTREACH

An initial project kickoff meeting was held on May 1, 2019, with representatives of the New York State Department of Environmental Conservation (NYSDEC), New York State Office of General Services (NYSOGS), OBG, Part of Ramboll (OBG), Gomez & Sullivan Engineers, Highland Planning, LLC, Town of West Seneca, Town of Elma, Erie County Soil and Water Conservation District (SWCD), USACE, Buffalo-Niagara Waterkeepers, and applicable local residents (Appendix D). Discussions included a variety of topics, including:

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

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

FIELD ASSESSMENT

Following the initial data gathering and agency meetings, field staff from OBG and Gomez and Sullivan undertook field data collection efforts with special attention given to high-risk areas in the Towns of West Seneca and Elma as identified in the initial data collection process. Initial field assessments of Buffalo Creek were conducted in May 2019. Information collected during field investigations included the following:

- Rapid "windshield" river corridor inspection
- Photo documentation of inspected areas
- Measurement and rapid hydraulic assessment of bridges, culverts, and dams
- Geomorphic classification and assessment, including measurement of bankfull channel widths and depths at key cross sections
- Field identification of potential flood storage areas

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

Included in Appendix B is a copy of the Stream Channel Classification Form, Field Observation Form for the inspection of bridges and culverts, and Wolman Pebble Count Form, as well as a location map of where field work was completed. Appendix C 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 Buffalo Creek watershed lies primarily within Erie County, NY, but a portion of the upper basin is located in Wyoming County as well (Figure 1). The creek flows in a general west/northwest direction. The headwaters are in the Town of Sardinia, then the creek flows through the Towns of Holland, Java, Shelden, Wales, Marilla, Elma, and West Seneca until it reaches the confluence of Cayuga Creek. Of the tributaries that form the Buffalo River watershed, Buffalo Creek has the largest drainage area, with the other two major tributaries being Cayuga and Cazenovia Creeks (USACE 1966). Within the Buffalo Creek watershed, the Towns of Elma to West Seneca were chosen as target areas due to their historical flood records and the hydrologic conditions of the creek in these areas. Figures 2-1 and 2-2 depict the stream stationing along Buffalo Creek in Erie County, NY, and the study area in the Towns of Elma to West Seneca, NY, respectively.

WATERSHED LAND USE

The Buffalo Creek stream corridor is largely comprised of cultivated (44%) and forested lands (39%) within the upper basin, and similarly through the middle reaches. As the creek approaches the confluence with Cayuga Creek, the corridor is comprised of developed land, with heavily developed land in the lower reaches due to the close proximity of the study area to the City of Buffalo (Yang et al. 2018).

GEOMORPHOLOGY

The floodplain is relatively narrow and well defined with shale outcrops in several locations in the steep valley walls which run along the creek for almost its entire length. There are exposed rock formations in the channel bottom at several of the bridges crossing the creek. Through the study area, Buffalo Creek has a relatively steep average slope of 14 feet per mile (USACE 1966).

Figure 3 is a profile of the Buffalo Creek streambed elevation versus channel distance from the confluence with Cayuga Creek to its headwaters developed by interpolating values from the FEMA FIS flood profile data (FEMA 2019b). Buffalo Creek has an average slope of 0.27% over the profile stream length of 18.7 miles. The slope is relatively consistent and flat through this reach of Buffalo Creek. The creeks streambed lowers approximately 262 vertical feet over this reach from an elevation of 835 feet above sea level (NAVD 88) at the limit of the detailed study (near the border of East Aurora, NY), to 573 feet above sea level at the confluence of Buffalo Creek and Cayuga Creek (in West Seneca, NY).

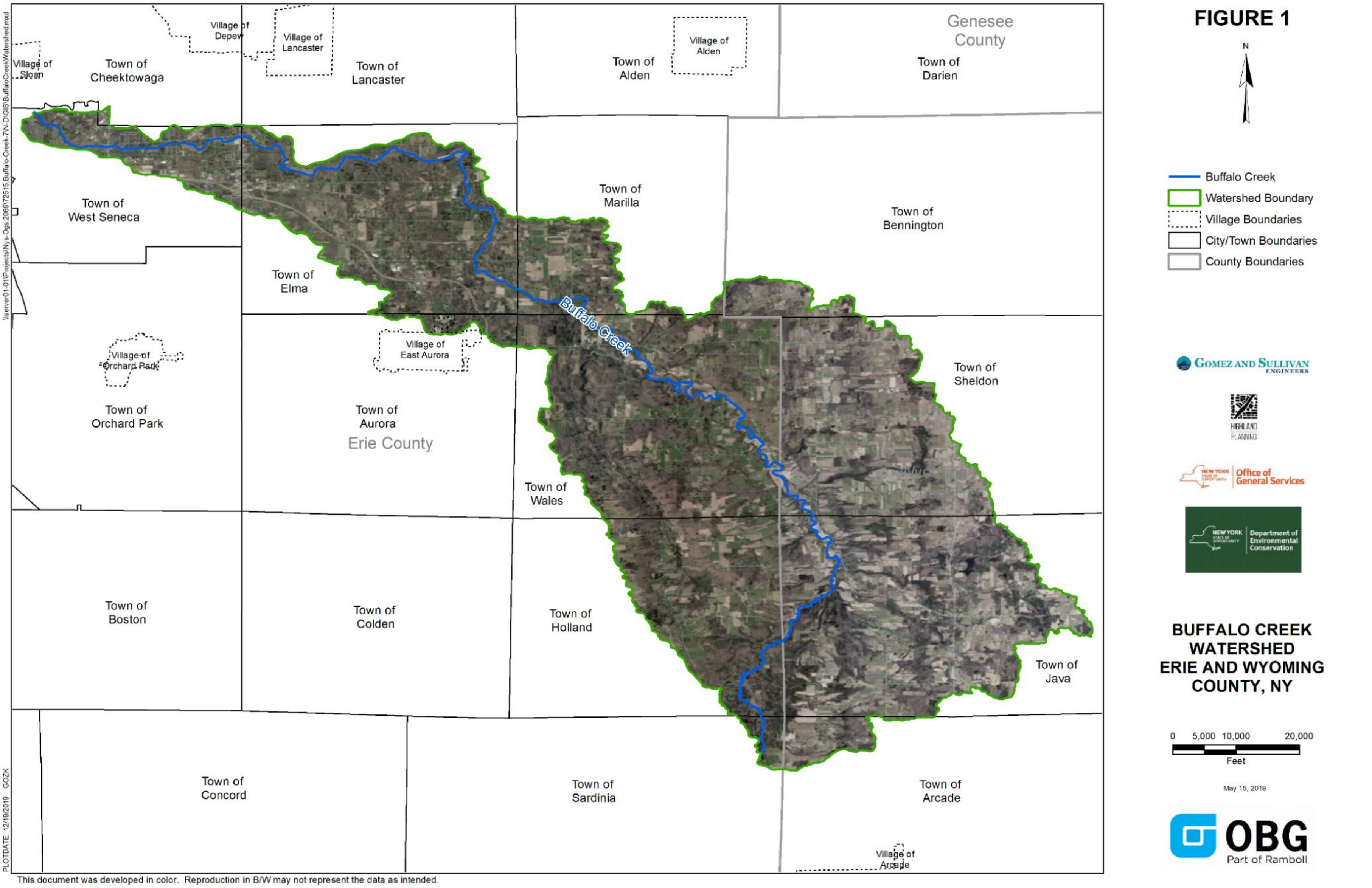
FIGURE 1
N
Buffalo Creek
Watershed Boundary
Village Boundaries
City/Town Boundaries
County Boundaries
BUFFALO CREEK WATERSHED ERIE AND WYOMING COUNTY, NY
0 5,000 10,000 20,000
Feet
May 15, 2019
Genesee County
Erie County
Village of Sloan
Town of Cheektowaga
Village of Depew
Village of Lancaster
Town of Lancaster
Town of Alden
Village of Alden
Town of Darien
Town of West Seneca
Town of Elma
Town of Marilla
Town of Bennington
Buffalo Creek
Village of Orchard Park
Town of Orchard Park
Village of East Aurora
Town of Aurora
Town of Wales
Town of Sheldon
Town of Boston
Town of Colden
Town of Holland
Town of Java
Town of Concord
Town of Sardinia
Town of Arcade
Village of Arcade
This document was developed in color. Reproduction in B/W may not represent the data as intended.


FIGURE 2-1
N
Buffalo Creek
Village Boundaries
City/Town Boundaries
County Boundaries
BUFFALO CREEK STATIONING
ERIE COUNTY, NY
0 3,750 7,500 15,000
Feet
May 15, 2019
Erie County
Village of Depew
Village of Lancaster
Village of Alden
Village of Sloan
Town of Cheektowaga
Town of Lancaster
Town of Alden
Town of West Seneca
Town of Marilla
Town of Elma
Town of Orchard Park
Village of East Aurora
Village of Orchard Park
Town of Aurora
Town of Wales
Buffalo Creek
0+00
50+00
100+00
150+00
200+00
250+00
300+00
350+00
400+00
450+00
500+00
550+00
600+00
650+00
700+00
750+00
800+00
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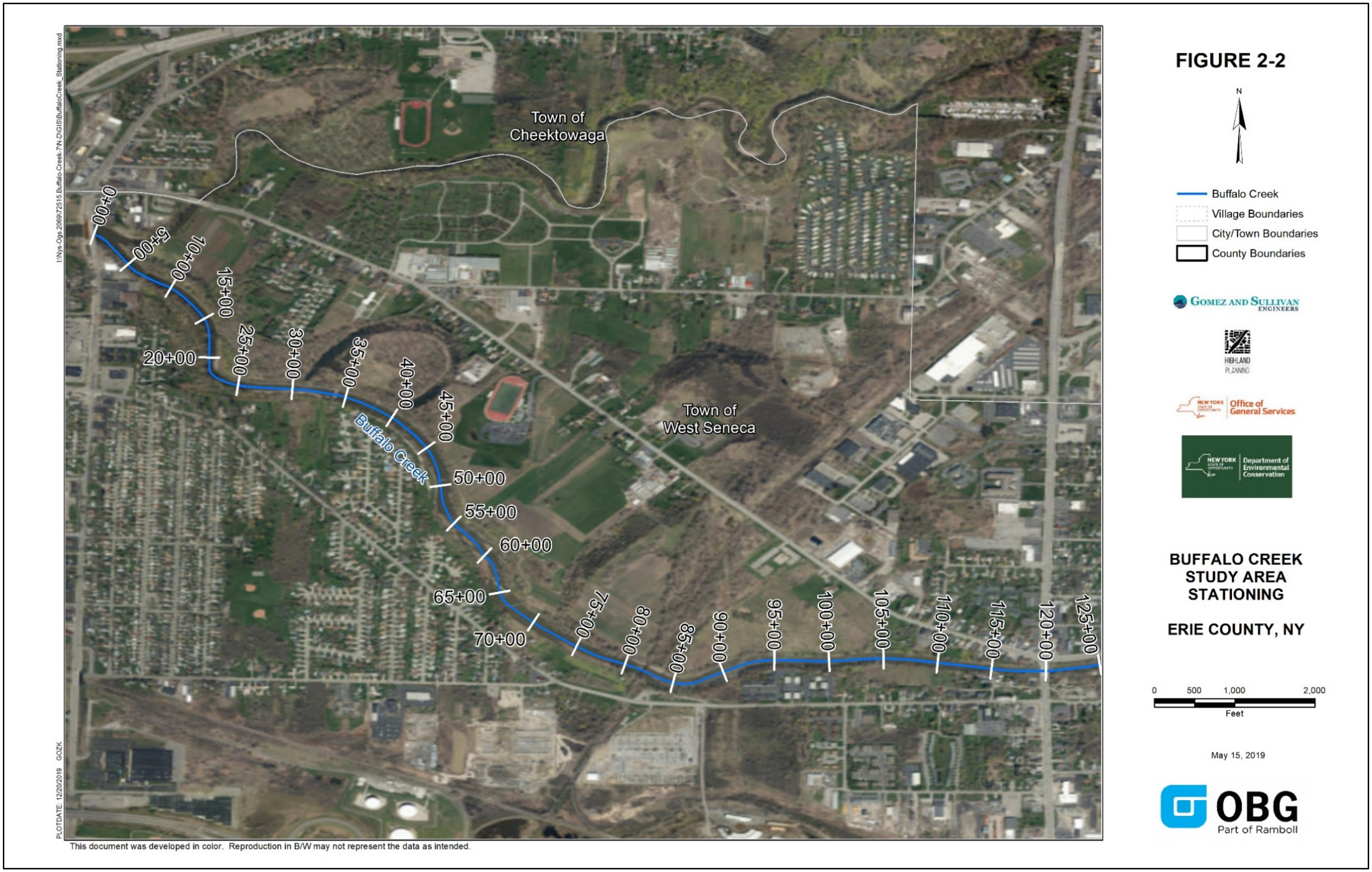
FIGURE 2-2
N
Buffalo Creek
Village Boundaries
City/Town Boundaries
County Boundaries
Town of Cheektowaga
Town of West Seneca
Buffalo Creek
0+00
5+00
10+00
15+00
20+00
25+00
30+00
35+00
40+00
45+00
50+00
55+00
60+00
65+00
70+00
75+00
80+00
85+00
90+00
95+00
100+00
105+00
110+00
115+00
120+00
125+00
BUFFALO CREEK STUDY AREA STATIONING
ERIE COUNTY, NY
0 500 1,000 2,000
Feet
May 15, 2019
OBG Part of Ramboll
This document was developed in color. Reproduction in B/W may not represent the data as intended.
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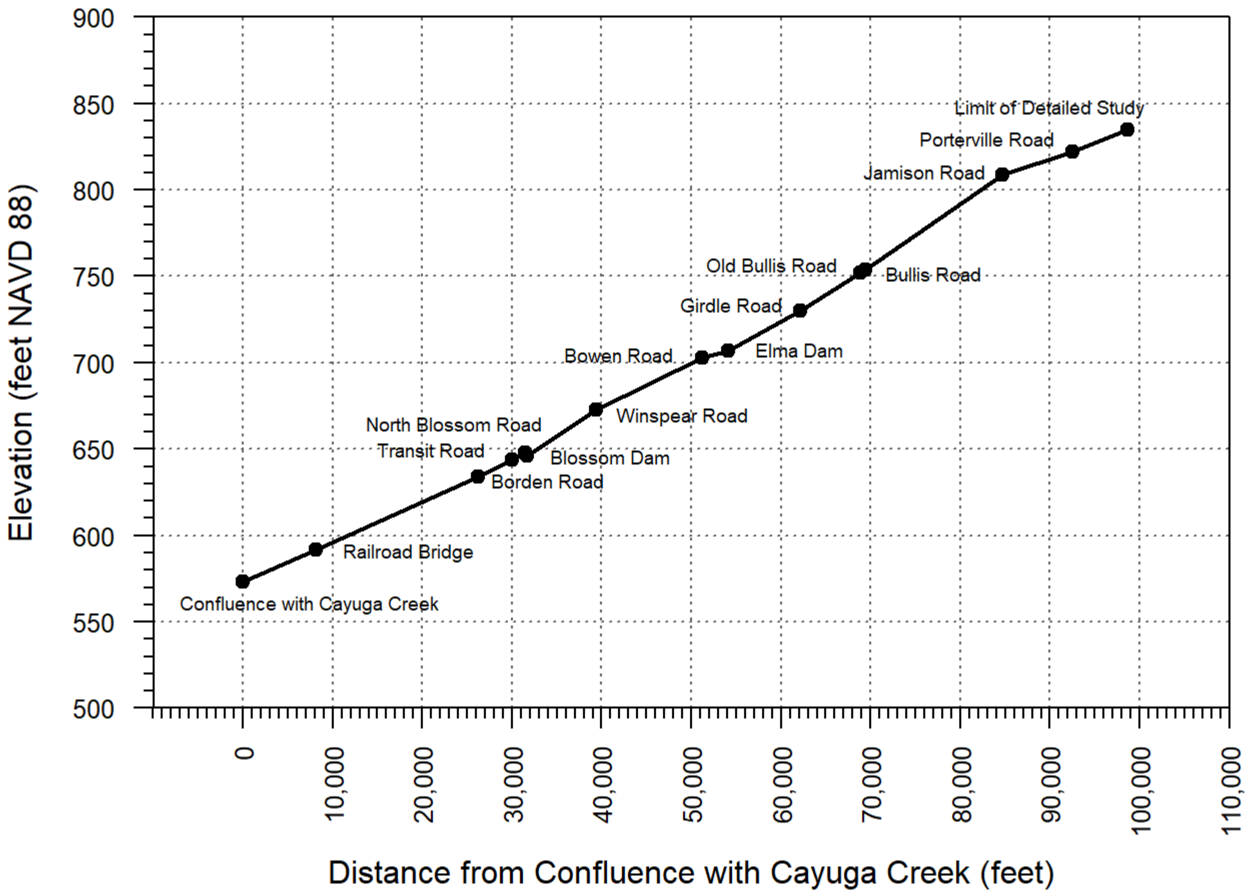

Figure 4. Buffalo Creek profile. River stationing and elevation data were interpolated from the FEMA FIS flood profiles (FEMA 2019b).

HYDROLOGY

Buffalo Creek forms a fan-shaped tributary area in Wyoming County near the Town of Java on the north slope of the Alleghany Plateau. Numerous source tributaries join the main stream channel as the creek flows in a general northwest direction to the confluence with Cayuga Creek. The largest tributary of Buffalo Creek is Hunter Creek, which joins the creek from the southwest at Wales Center, NY (USACE 1966).

The watershed is long and narrow with a total drainage area of approximately 150 square miles along a 43-mile stream length from the source to the confluence with Cayuga Creek. After the confluence with Cayuga Creek, Buffalo Creek continues to flow westward another two miles to the confluence with Cazenovia Creek, and an additional six miles as the Buffalo River to its mouth at Lake Erie (USACE 1966).

Table 1 is a summary of the basin characteristic formulas and calculated values for the Buffalo Creek watershed, where A is the drainage area of the basin in square miles, B_L is the basin length in miles, and B_P is the basin parameter in miles.

Table 1. Buffalo Creek Basin Characteristics Factors

(Source: USGS 1978)

Factor	Formula	Value
Form Factor (R_F)	A / B_L^2	0.17
Circularity Ratio (R_C)	$4*\pi*A / B_P^2$	0.14
Elongation Ratio (R_E)	$2 * (A/\pi)^{0.5} / B_L$	0.47

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

There are two USGS stream gaging stations on Buffalo Creek, USGS 04214500 at Gardenville, NY and USGS 04214400 near Wales Hollow, NY (Figure 4). The USGS Gage 04214500 at Gardenville, NY was used as the representative hydrologic dataset due to the robustness of the data collected at this site, and the extended time period over which the data was collected. The gage station at Gardenville provided the hydrologic data used by FEMA to develop regional drainage area/mean annual discharge curves for areas along Buffalo Creek (USGS 2019). An effective FEMA FIS for Erie County was issued on June 7, 2019 and included drainage area and discharge information for Buffalo Creek. Table 2 lists the FEMA FIS drainage area and peak discharges, in cubic feet per second, for various locations along Buffalo Creek (FEMA 2019b).

Table 2. Buffalo Creek FEMA FIS Peak Discharges

(Source: FEMA 2019b)

Location	Drainage Area (sq. mi.)	River Station (ft)	Peak Discharges (cfs) 10-Percent	2-Percent	1-Percent	0.2-Percent
Upstream of Confluence of Cayuga Creek	146.0	0+00	*	*	16,000	*
Approximately 100 ft downstream of towns of Elma, Marilla corporate limit	106.0	952+00	9,200	12,000	13,100	15,800
Approximately 1,300 ft upstream of towns of Elma, Marilla corporate limit	104.0	966+00	9,000	11,700	12,800	15,400
Approximately 5,050 ft upstream of towns of Elma, Marilla corporate limit	102.0	1003+50	8,900	11,500	12,600	15,200
Approximately 400 ft upstream of towns of Marilla, Wales corporate limit	100.0	1079+00	8,700	11,400	12,400	14,900
At Strykersville Road	81.0	1209+00	7,300	9,600	10,500	12,700
Approximately 300 ft upstream of confluence with Stony Bottom Creek	74.0	1214+00	6,800	8,900	9,800	11,800
Upstream limit of study	57.0	1595+00	5,500	7,200	8,000	9,700

* Data not available

The FEMA FIS peak discharges were determined in accordance with Water Resources Investigations (WRI) 79-83 methodology using the Buffalo River ungaged sites on gaged streams equation:

$$Q = K(DA)^{X}(ST + 10)^{-Y}$$

where Q is the stream discharge;
DA is the drainage area;
ST is the percent of total drainage area stored in lakes, ponds and swamps; and
K, x and y are variables associated with frequency.

For Buffalo Creek, a value of 49,900 was used for K; a value of 0.733 was used for x; and a value of 2.03 was used for y. Calculated peak discharges were then adjusted using regression equations calculated at the gage station at Gardenville (FEMA 2019b).

For this study, the USGS *StreamStats* software was used to calculate the peak discharges for Buffalo Creek. The *StreamStats* application was selected due to the fact that the program uses regionally specific full regression equations developed by the USGS to estimate streamflow statistics that take into account multiple basin characteristics, including drainage area, main channel slope, and mean annual precipitation. These additional characteristics increase accuracy and decrease standard errors by approximately 10% for a 100-year recurrence interval discharge when compared to the drainage-area only regression equation (Lumia et al. 2006; Ries et al. 2017).

The *StreamStats* application uses a more modern approach with site specific data to calculated peak discharges, while the FEMA FIS discharge calculations use equations developed in the 1970's for ungaged streams on the Buffalo River. Buffalo Creek has had a USGS gage collecting streamflow data continuously since 1939 (USGS 2019). Table 3 is the summary output of peak discharges calculated by the USGS *StreamStats* software for Buffalo Creek at the same locations as the FEMA FIS peak discharges.

In addition, *StreamStats* calculates bankfull statistics by using stream survey data and discharge records from 281 cross-sections at 82 streamflow-gaging stations in a linear regression analyses to relate drainage area to bankfull discharge and bankfull-channel width, depth, and cross-sectional area for streams across New York State. This regionally specific model of calculating bankfull statistics was determined to be more accurate when compared to a statewide (or pooled) model (Mulvihill et al. 2009).

Table 3. USGS StreamStats Peak Discharge for Buffalo Creek at the FEMA FIS Locations

Source: (Ries et al. 2017)

			Peak Discharges (cfs)			
Location	Drainage Area (sq. mi.)	River Station (ft)	10-Percent	2-Percent	1-Percent	0.2-Percent
Upstream of Confluence of Cayuga Creek	146.0	0+00	7,990	11,800	13,600	18,000
Approximately 100 ft downstream of towns of Elma, Marilla corporate limit	111.0	952+00	7,130	10,700	12,400	16,500
Approximately 1,300 ft upstream of towns of Elma, Marilla corporate limit	110.0	966+00	7,060	10,600	12,300	16,400
Approximately 5,050 ft upstream of towns of Elma, Marilla corporate limit	107.0	1003+50	6,980	10,500	12,100	16,200
Approximately 400 ft upstream of towns of Marilla, Wales corporate limit	106.0	1079+00	6,990	10,600	12,200	16,300
At Strykersville Road	85.7	1209+00	6,100	9,300	10,800	14,500
Approximately 300 ft upstream of confluence with Stony Bottom Creek	78.7	1214+00	5,630	8,580	9,920	13,400
Upstream limit of study	55.6	1595+00	5,200	8,160	9,530	13,100

The bankfull width and depth of Buffalo Creek is important in understanding the distribution of available energy within the channel and the ability of various discharges occurring within the channel to erode, deposit, and move sediment (Rosgen and Silvey 1996). Table 4 lists the estimated bankfull discharge, width, and depth at select locations along Buffalo Creek as derived from the USGS *StreamStats* program (Ries et al. 2017).

Table 4. Estimated Bankfull Discharge, Width, and Depth

(Source: Ries et al. 2017)

Location	River Station (ft)	Watershed Area (sq. mi.)	Discharge (cfs)	Bankfull Width (ft)	Bankfull Depth (ft)
Railroad	81+50	146	3,190	136	3.51
USGS Gage 04214500	110+00	142	3,120	135	3.48
Transit Road	300+00	137	3,020	133	3.45
Bowen Rd Bridge	512+00	130	2,890	130	3.41
Girdle Road Bridge	621+00	121	2,720	126	3.35
Porterville Rd Bridge	924+00	111	2,530	122	3.28

INFRASTRUCTURE

There are numerous dams along Buffalo Creek and its tributaries that interact with the flow of the creek. Of the seven dams along Buffalo Creek, four are purposed as "other," while two are irrigation dams, and one dam is hydroelectric. Only the Rowley Dam, located in the Town of Elma upstream of the Elma Village Green, has a hazard rating of Class A or "low hazard" dam. The remaining dams along Buffalo Creek are classified as "negligible or no hazard" dams (NYSDEC 2019b).

Major bridge crossings over Buffalo Creek include Routes 20, 20A, 78, and 277 in the Towns of Wales, Marilla, Elma, and West Seneca. In the Town of West Seneca, an abandoned railroad bridge (downstream of Union Road), and its associated topography restricts the stream channel and creates an impediment to flow, especially during the winter months, leading to numerous reported ice jams. Bridge lengths and surface widths for New York State Department of Transportation (NYSDOT) bridges were revised as of February 2019. Table 5 summarizes the NYSDOT bridge data for bridges that cross Buffalo Creek in both Erie and Wyoming Counties with bankfull widths from the USGS *StreamStats* program (NYSDOT 2016; Ries et al. 2017).

Table 5. Summary of NYSDOT Bridges Crossing Buffalo Creek

Source: (NYSDOT 2016; Ries et al. 2017, FEMA 2019b)

County Name	Roadway Carried	River Station (ft)	NYSDOT Bin	Bridge Length (ft)	Width (ft)	Bankfull Width (ft)	Hydraulic Capacity (% Annual Chance)
Erie	Route 277	119+00	1044250	127	68.2	135	1 *only available data
Erie	Borden Road	262+00	3327020	162	40.4	133	1 *only available data
Erie	Route 20	300+00	1015540	198	68.9	133	Insufficient for all storms
Erie	North Blossom Road	314+00	3327240	148	24	132	1
Erie	Winspear Road	394+00	3327250	134	28	132	0.2
Erie	Bowen Road	512+00	3327100	124	34	130	0.2
Erie	Girdle Road	621+00	3327310	220	30	126	0.2
Erie	Bullis Road	689+00	3327260	524	28	126	0.2
Erie	Old Bullis Road	694+00	2260680	128	21.4	126	1
Erie	Jamison Road	847+00	1048310	174	28.7	123	0.2
Erie	Porterville Road	924+00	3327900	225	41	122	2
Erie	Two Rod Road	997+00	3328290	300	29.5	120	Not included in 2019 Erie County FEMA FIS
Erie	Route 20a	1064+00	1016100	106	44	119	0.2
Erie	Route 78	1111+00	1030180	163	40	109	0.2
Erie	Merlau Road	1187+00	3328150	155	29	104	0.2
Erie	East Creek Road	1304+00	3328210	155	30	102	0.2
Erie	Centerline Road	1349+00	3328200	100	28.1	101	Not included in 2019 Erie County FEMA FIS

Table 5. Summary of NYSDOT Bridges Crossing Buffalo Creek

Source: (NYSDOT 2016; Ries et al. 2017, FEMA 2019b)

County Name	Roadway Carried	River Station (ft)	NYSDOT Bin	Bridge Length (ft)	Width (ft)	Bankfull Width (ft)	Hydraulic Capacity (% Annual Chance)
Erie	Chester Road	1565+00	3328160	97	13.7	91	Not included in 2019 Erie County FEMA FIS
Wyoming	Factory Road	1654+00	3320180	97	23	86	Not included in 2019 Erie County FEMA FIS
Wyoming	Sanders Road	1695+00	3320190	83	28	84	Not included in 2019 Erie County FEMA FIS
Wyoming	Holland Road	1815+00	3319930	84	38	79	Not included in 2019 Erie County FEMA FIS
Wyoming	Sheehe Road	1883+00	3319900	40	22.3	47	Not included in 2019 Erie County FEMA FIS

Bankfull widths were derived from the USGS *StreamStats* software for bridge crossing locations that were considered high risk for potentially being constriction points based on the FEMA Flood Insurance Rate Maps (FIRMs). Table 5 indicates that in Erie County, NY, the Bowen Road, Route 277 (Union Road), Route 20a, and Centerline Road bridges in the Towns of Elma, West Seneca, and Wales respectively, are not wide enough to span the bankfull width of Buffalo Creek. According to the USACE Flood Plain Information, Buffalo Creek, NY report, in March of 1962, flooding occurred causing property damages to twelve residential, three commercial, and four public units along Bowen Road after high discharges from the Elma Dam combined with an ice jam on Buffalo Creek in the vicinity of Bowen Road (USACE 1966). Figure 4 displays the locations of the high and low-risk constriction point bridges that cross Buffalo Creek in Erie County, NY.

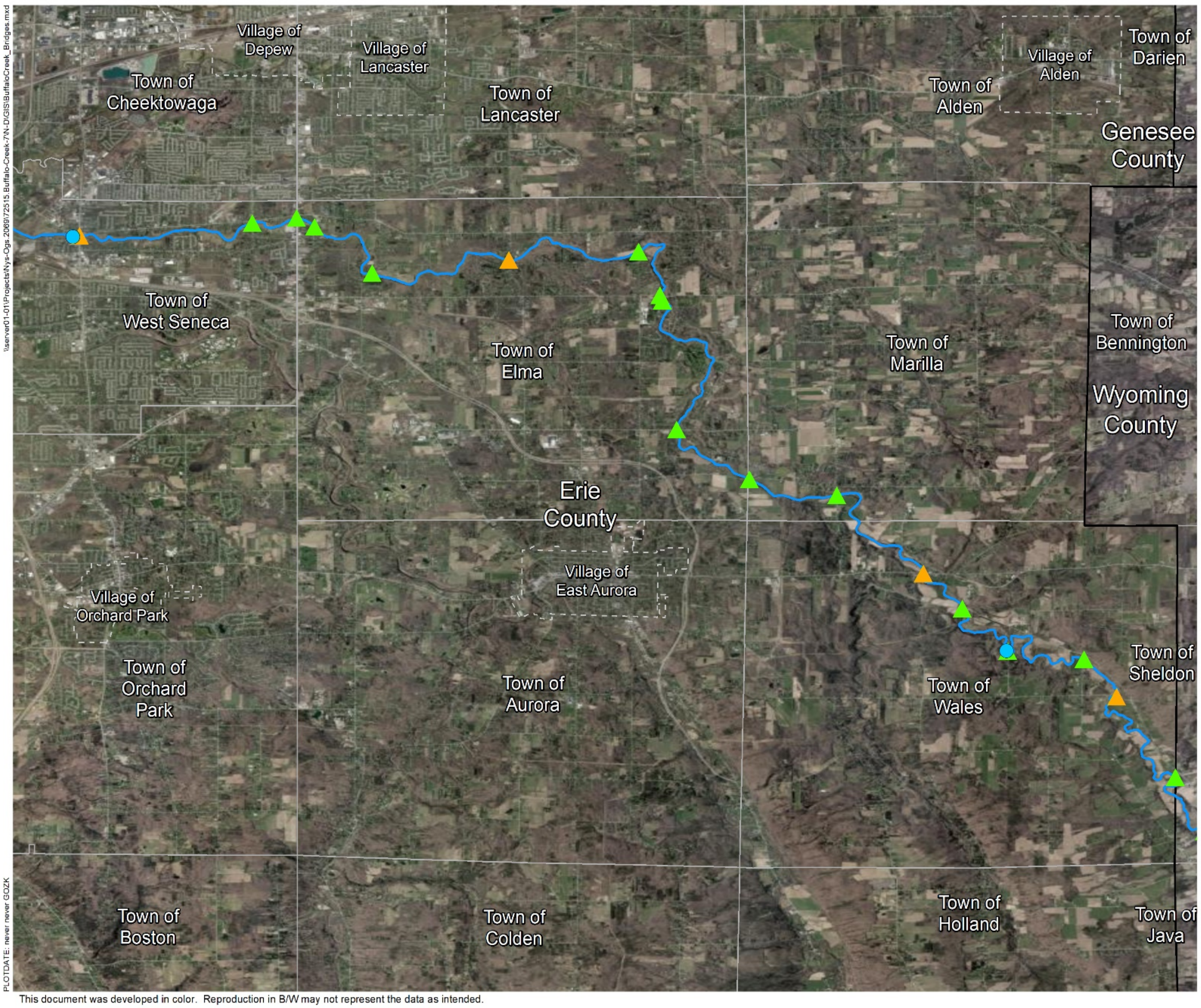

FIGURE 4

N

- Buffalo Creek
- High-Risk Constriction Point Bridges
- Low-Risk Constriction Point Bridges
- USGS Gages
- Village Boundaries
- City/Town Boundaries
- County Boundaries

GOMEZ AND SULLIVAN ENGINEERS

HIGHLAND PLANNING

NEW YORK STATE OF OPPORTUNITY | Office of General Services

NEW YORK STATE OF OPPORTUNITY | Department of Environmental Conservation

BUFFALO CREEK BRIDGE CONSTRICTION POINTS

ERIE COUNTY, NY

0 5,000 10,000
Feet

May 16, 2019

OBG Part of Ramboll

Hydraulic capacity is the measure of the amount of water that can pass through a structure or watercourse. Hydraulic design is an essential function of structures in watersheds. Exceeding the capacity can result in damages or flooding to surrounding areas and infrastructure (Zevenbergen et al. 2012). In New York State, the hydraulic and hydrologic regulations for bridge low chord elevations is 2-feet over the 2-percent annual chance flood elevation for normal bridges, and 3-feet for critical bridges according to the NYSDOT.

In assessing hydraulic capacity of the high-risk constriction point bridges along Buffalo Creek, the FEMA FIS profile of Buffalo Creek was used to determine the highest annual chance flood elevation to flow under the low chord of a bridge (Table 5) (FEMA 2019b). In addition, USGS *StreamStats* was used to calculate the bankfull discharge and then compared to the annual chance flood event discharges to determine the potential for backwater and flooding at these bridges. Table 6 summarizes the results from USGS *StreamStats* for the bankfull discharge required for the water surface to reach the bankfull width of the high-risk constriction point bridges along Buffalo Creek. Since the high-risk bridges' bankfull widths exceed their lengths, which when coupled with the fact that the bankfull discharges for each bridge is equivalent to a 67-percent annual chance flood event or greater, the likelihood that relatively low to moderate flows potentially causing backwater and flooding at these bridges is fairly high.

Table 6. Bankfull Discharge of High-Risk Constriction Point Bridges Using USGS StreamStats

Source: (Ries et al. 2017)

Roadway Carried	River Station (ft)	Bankfull Discharge (cfs)	Annual Chance Flood Event Equivalent
Route 277	119+00	3,120	67-Percent
Bowen Road	512+00	2,890	80-Percent
Route 20a	1064+00	2,420	80-Percent
Centerline Road	1349+00	1,760	80-Percent

CLIMATE CHANGE IMPLICATIONS

FUTURE PROJECTED DISCHARGE IN BUFFALO CREEK

In New York State, climate change is expected to exacerbate flooding due to projected increases of 1-8% in total annual precipitation coupled with increases in the frequency, intensity, and duration of extreme precipitation events (events with more than 1, 2, or 4 inches of rainfall) (Rosenzweig et al. 2011). In response to these projected changes in climate, NYS passed the Community Risk and Resiliency Act (CRRA) in 2014. In accordance with the guidelines of the CRRA, the NYSDEC released the *New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act* (2018) draft report. In this report, the NYSDEC outlined infrastructure guidelines, most notably that the new low chord elevation recommendation for normal bridges is 2-feet freeboard over the base flood elevation for a 1-percent annual chance flood event and 3-feet over for a critical structure (NYSDEC 2018).

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

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

Results are averaged for three future periods, from 2025 to 2049, 2050 to 2074, and 2075 to 2099. The downscaled climate data for each model and the RCP scenario averaged over these 25-year periods were obtained from the developers of the USGS Climate Change Viewer. The USGS *FutureFlow* software calculates results based on all five climate models for any of the two greenhouse-gas scenarios, and the three time periods. These available results are meant to reflect a range of variation predicted from among the five models, and two greenhouse-gas scenarios (Alder and Hostetler 2017). Table 7 provides the current peak stream flows calculated using the USGS *StreamStats* software and the mean predicted future discharge calculated using the USGS *FutureFlow* software at the USGS Gage 04214500 at Gardenville, NY.

Table 7. Current and Projected Discharge with Percent Difference and Change in Water Surface Elevations at the Confluence with Cayuga Creek

(Source: Ries et al. 2017; Burns et al. 2015)

Annual Chance Flood Event	Current Discharge (cfs)	Mean Predicted Future Discharge (cfs)	Percent Difference (%)	Change in Water Surface Elevation (ft)
80-Percent	3,030	3,743	+ 23.5%	+ 0.6
50-Percent	4,340	5,142	+ 18.5%	+ 0.8
20-Percent	6,450	7,337	+ 13.8%	+ 0.7
10-Percent	7,990	8,922	+ 11.7%	+ 0.7
2-Percent	11,800	12,887	+ 9.2%	+ 0.6
1-Percent	13,600	14,648	+ 7.7%	+ 0.6
0.2-Percent	18,000	19,099	+ 6.1%	+ 0.5

Climate change is projected to increase peak discharges in Buffalo Creek in all reaches, and at all recurrence intervals; however, low-flow peak discharges at higher annual chance flood events are expected to be significantly influenced by climate change. In addition, these higher annual chance flood events are predicted to have the highest increases in water surface elevations in Buffalo Creek at the confluence with Cayuga Creek as well.

Appendix F contains the HEC-RAS simulation summary sheets for the proposed and future condition simulations. The HEC-RAS model simulation results for the future condition model parameters using the future projected discharge values are similar to the base condition model output, with the only difference being future projected water surface elevations are 0.2 to 0.6-feet higher due to the increased discharges.

FLOODING CHARACTERISTICS

FLOODING HISTORY

Flooding along Buffalo Creek generally occurs in the late winter and early spring due to rapid snowmelt and spring rains. The situation is compounded by restrictive bridges, which cause ice jams along the stream channel, and continued development in the floodplain, exposing greater numbers of assets to potential flood damages.

Most major floods have historically occurred during the months of January to March. The greatest flood of historical record occurred in June 1937, while other damaging discharges occurred in the summer of 1928, March 1942, March 1955, March 1956, January 1959, March 1962, January 1996, December 2008, and January 2014. Minor flooding events also occurred in March 2004, February 2014, and February 2019. The June 1937 flood is generally considered to be the maximum flood of record and is the only major flooding event to have occurred during the summer months. Heavy rainfall was recorded throughout western New York on June 17, and again during June 20-21. The rainfall of June 20-21 was centered in the eastern suburbs of Buffalo and fell on wet, saturated ground in a period of around six hours. The maximum recorded rainfall was 3.00 inches at the Buffalo Airport, 2.06 inches at the downtown Buffalo station, and 1.50 inches at South Wales. There were no observations of rainfall available for the Buffalo Creek watershed; however, the few high-water marks obtained indicate that the storm caused the highest water levels along the creek for open channel conditions. Damages were primarily agricultural and largely due to erosion along the creek (USACE 1966; URS 2015).

More recently on January 18, 1996, a rapid snowmelt of 8 to 12 inches, heavy rainfall of around one inch, and unseasonably warm temperatures combined to produce a major ice jam on Buffalo Creek between Borden and Transit Streets in the Town of West Seneca, NY. The nearly 1-mile long ice jam caused numerous road closures and water damage to nearly two hundred homes. In total, reported damages exceeded $2.2 million with $1.7 million in property damages, and $500,000 in crop damages (URS 2015). On February 4, 2019, rapid temperature warming occurred across the Buffalo, NY area resulting in record high temperatures. As a consequence, rapid snowmelt occurred resulting in high volumes of meltwater and ice breakups on local waterways. Ice jams formed on Cazenovia and Buffalo Creek near the Town of West Seneca causing roads, businesses, and residences to flood, and resulting in approximately $13,000 in reported property damages (NCEI 2019).

FEMA FIRMs are available for Buffalo Creek from FEMA. Figures 5-1, 5-2, and 5-3 display the floodway and 1- and 0.2-percent annual chance flood event boundaries for Buffalo Creek as determined by FEMA for the Towns of West Seneca, Elma, and Wales, respectively. The maps indicate that flooding generally occurs in the downstream portions of Buffalo Creek, primarily in the Towns of West Seneca and Elma in Erie, County, NY. The Town of West Seneca has experienced the largest impacts from flooding along Buffalo Creek, with Gardenville and Lexington Green neighborhoods experiencing repetitive losses due to flood damages from ice jams along the creek (FEMA 2019a).

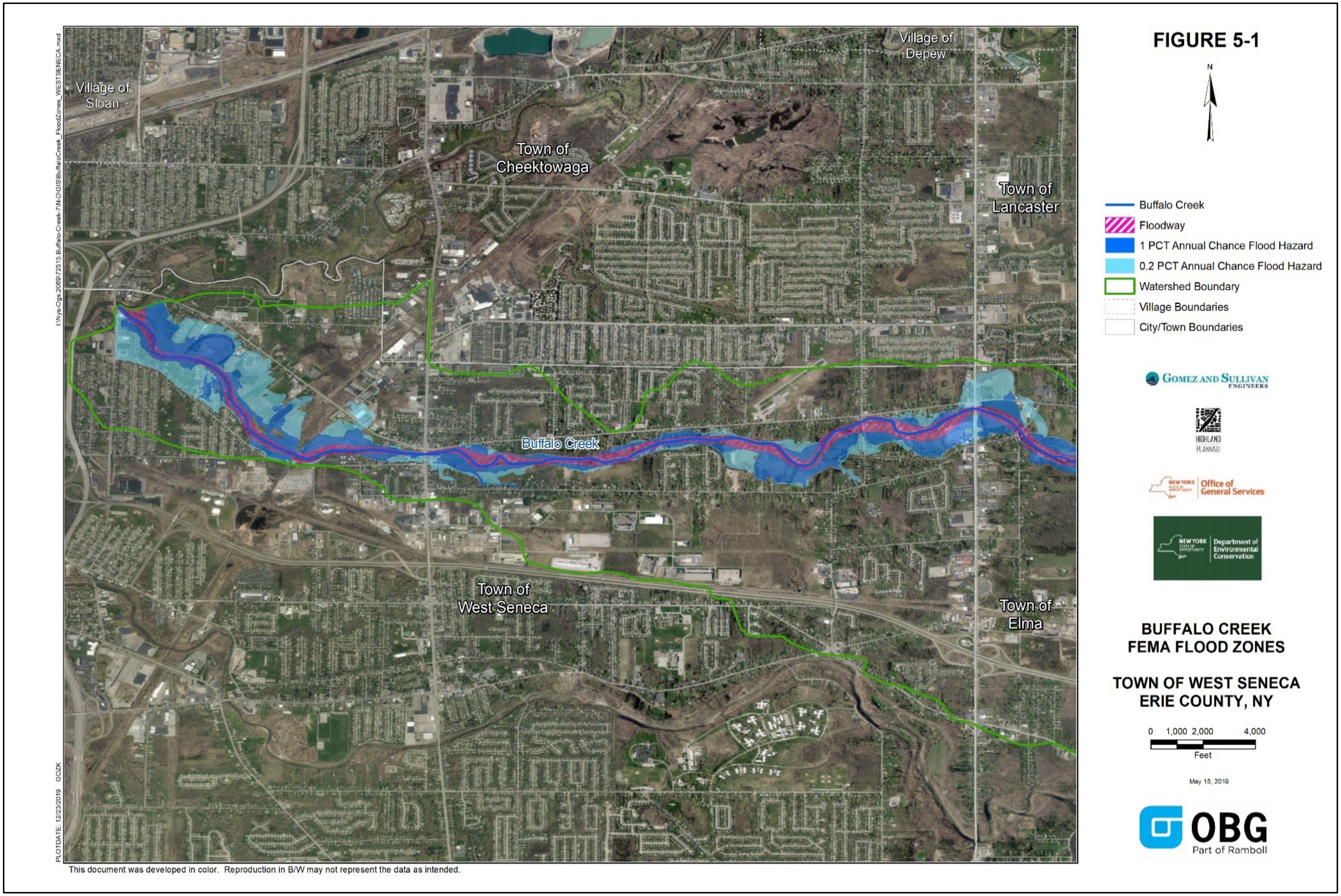
FIGURE 5-1
N
Village of Depew
Village of Sloan
Town of Cheektowaga
Town of Lancaster
Buffalo Creek
Town of West Seneca
Town of Elma
Buffalo Creek
Floodway
1 PCT Annual Chance Flood Hazard
0.2 PCT Annual Chance Flood Hazard
Watershed Boundary
Village Boundaries
City/Town Boundaries
GOMEZ AND SULLIVAN ENGINEERS
HIGHLAND PLANNING
Office of General Services
Department of Environmental Conservation
BUFFALO CREEK
FEMA FLOOD ZONES
TOWN OF WEST SENECA
ERIE COUNTY, NY
0 1,000 2,000 4,000
Feet
May 15, 2019
OBG
Part of Ramboll
PLOTDATE: 12/23/2019 GCZK
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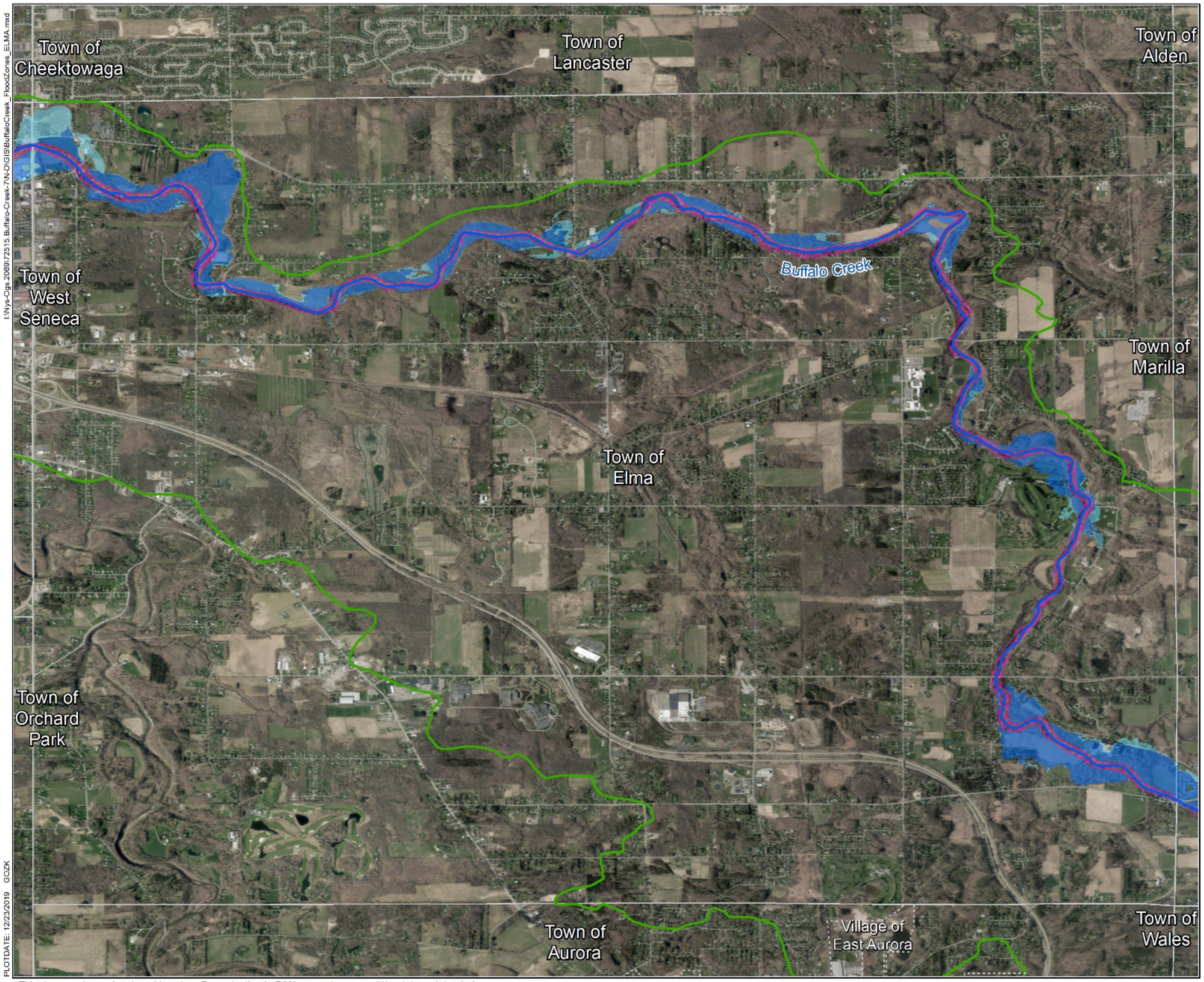
FIGURE 5-2



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N

- Buffalo Creek
- Floodway
- 1 PCT Annual Chance Flood Hazard
- 0.2 PCT Annual Chance Flood Hazard
- Watershed Boundary
- Village Boundaries
- City/Town Boundaries

Gomez and Sullivan Engineers

Highland Planning

New York State of Opportunity | Office of General Services

New York State of Opportunity | Department of Environmental Conservation

BUFFALO CREEK FEMA FLOOD ZONES

TOWN OF ELMA ERIE COUNTY, NY

0 1,250 2,500 5,000 Feet

May 15, 2019

OBG Part of Ramboll

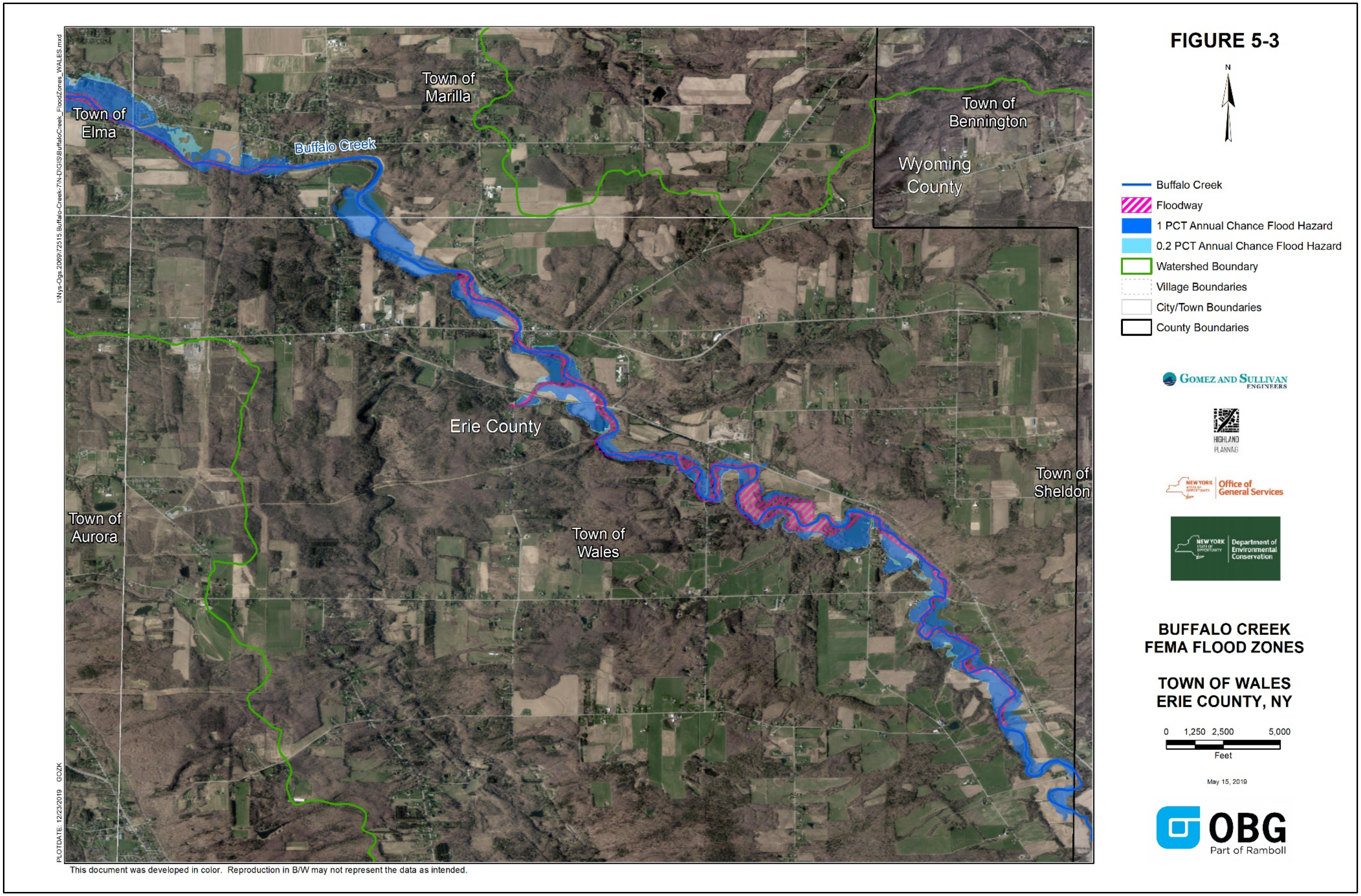
FIGURE 5-3
N
Town of Elma
Town of Marilla
Town of Bennington
Wyoming County
Buffalo Creek
Erie County
Town of Sheldon
Town of Aurora
Town of Wales
Buffalo Creek
Floodway
1 PCT Annual Chance Flood Hazard
0.2 PCT Annual Chance Flood Hazard
Watershed Boundary
Village Boundaries
City/Town Boundaries
County Boundaries
BUFFALO CREEK FEMA FLOOD ZONES
TOWN OF WALES ERIE COUNTY, NY
0 1,250 2,500 5,000
Feet
May 15, 2019
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FLOOD MITIGATION ANALYSIS

Hydraulic analysis of Buffalo Creek was conducted using the HEC-RAS program. The HEC-RAS computer program was written by the USACE Hydrologic Engineering Center (HEC) and is considered to be the industry standard for riverine flood analysis. The model is used to compute water surface profiles for one-dimensional, steady-state, or time-varied flow. Water surface profiles are computed from one cross section to the next by solving the one-dimensional energy equation with an iterative procedure (i.e. standard step backwater method). Energy losses are evaluated by friction (Manning's Equation) and the contraction/expansion of flow through the channel. The momentum equation is used in situations where the water surface profile is rapidly varied, such as hydraulic jumps, mixed-flow regime calculations, hydraulics of dams and bridges, and evaluating profiles at a river confluence (USACE 2016b).

Hydraulic modeling of Buffalo Creek in the Towns of Elma and West Seneca were completed by FEMA in 1976. The effective FEMA H&H data was produced in a non-georeferenced HEC-2 format and began at the confluence of Buffalo Creek with Cayuga Creek (river station 0+00), and extended upstream to the Pleasant View Lane neighborhood in the Town of West Seneca (river station 203+99), which included the target study area. Included within this reach is the Route 277 (Union Road) bridge hydraulic obstruction. Hydraulic obstructions outside of the target area were not evaluated as part of this report.

In order to use the data in the more advanced HEC-RAS program, the data was formatted into a HEC-RAS input format, then geo-referenced using GIS and ortho-imagery of the Buffalo Creek watershed. Using the updated HEC-RAS input data, a duplicate model was developed without any changes to the original H&H data and run in HEC-RAS. Next, a base condition model was produced, which corrected errors and updated the original H&H data based on field assessments of Buffalo Creek. The following changes were made in the development of the base condition model:

- Updated the vertical datum of the H&H data from NAD 27 to NAVD 88
- Updated the terrain with the most current available 2-meter light detection and ranging (LiDAR) digital elevation model (DEM) from the NYSDEC
- Adjusted cross-section geometry for areas outside of the stream channel using the updated terrain
- Adjusted left and right bank stations to match the 2-yr annual chance flood event water surface elevations
- Updated Manning n-values to better reflect channel, bank, and floodplain roughness
- Identified and added ineffective flow areas to cross section geometry

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

COST ESTIMATE ANALYSIS

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

Where recent construction cost data was not readily available, *RSMeans CostWorks 2019* was used to determine accurate and timely information (RSMeans Data Online 2019). Additionally, a 2016 USACE report focused on flood mitigation measures in the Lexington Green area (USACE 2016a) was used for pricing information for some of the mitigation alternatives. Costs were adjusted for inflation and verified against current market conditions and trends.

HIGH RISK AREA #1: ABANDONED RAILROAD BRIDGE, WEST SENECA, NY

High Risk Area #1 is the abandoned railroad bridge crossing Buffalo Creek in Gardenville (a hamlet of the Town of West Seneca), and the topographic features that support the railroad on the northern (right) bank. The railroad bridge is located approximately three-quarters of a mile east of the Indian Church Road and Route 277 (Union Road) junction (Figure 6).

The effective FEMA FIRMs show the abandoned railroad and its topography constricting flow, which results in backwater upstream. During winter and early spring, ice flowing along the creek is constricted by the large piers of the railroad bridge and the topography supporting the bridge on both channel banks, which causes the ice to collect at the base of the piers. As the ice builds, water flow in the creek channel is restricted and rises, which causes backwater to overflow the creek banks onto nearby streets, properties, etc. (NYSDEC 2019a).

HIGH RISK AREA #2: LEXINGTON GREEN NEIGHBORHOOD, WEST SENECA, NY

High Risk Area #2 is the neighborhood of Lexington Green in the Town of West Seneca. The residential community of Lexington Green (approximately 71 residences) is located on the south side (left bank) of Buffalo Creek a short distance downstream from the abandoned railroad bridge (Figure 6). The neighborhood sits atop the old creek channel, which was filled with gravel and excavated material by the USSCS in the 1960s. As a result, precipitation driven overbank flooding can occur at the 2 percent Annual Chance Exceedance (ACE - 50-year recurrence interval flow) level, and ice-jam flooding can occur at much lower flows during periods of ice and snow melt in the late winter to early spring (USACE 2016a).

In addition to runoff and ice-jam flooding, the old channels under the neighborhood are thought to have a high groundwater conductivity and connection to the existing creek, potentially providing for a significant flux of water from the creek to the groundwater beneath the neighborhood. These groundwater fluxes, combined with sanitary sewer surcharges due to malfunction or improper operation of the gate during highly wet weather and high flow periods, contribute to localized flooding on roadways. The sewer outlet from the neighborhood has been identified as one of the main potential causes of flooding from malfunction or improper operation of the gate on the sewer outlet to Buffalo Creek (USACE 2016a).

HIGH RISK AREA #3: OXBOW LAKE, WEST SENECA, NY

High Risk Area #3 is Oxbow Lake, located downstream of the Lexington Green neighborhood in the Town of West Seneca (Figure 6). Oxbow Lake was originally part of the natural channel path of Buffalo Creek. In the 1950s, the USSCS, now known as the Natural Resources Conservation Service (NRCS), implemented a sediment control project aimed at addressing potential sediment load contributions to the commercial navigation channels of the lower Buffalo River and Lake Erie (USACE 1979). This project included the straightening of Buffalo Creek and removing the meander near the Lexington Green neighborhood. The project included creating the oxbow lake, constructing a soil berm to separate the oxbow from normal high-water recharge of Buffalo Creek, and installing an outfall pipe from the oxbow into Buffalo Creek. At the time, the channel re-alignment of the creek and grade controls were seen as a means to alleviate seasonal ice jam flooding and soil erosion along Buffalo Creek in this reach. Since the creation of the oxbow lake, nature has reclaimed the area and it has developed into a wetland habitat for many varieties of fish and wildlife (Ecology and Environment Inc. 2010). In 2012, the NYSDEC passed an amendment in Erie County designating approximately 50% of the oxbow lake area as a Class 2 Freshwater Wetland. A Class 2 wetland is defined by the NYSDEC as a wetland that provides important wildlife habitat and open space benefits in an urbanized area. The significance of Class 2 wetlands is substantially enhanced by their urban locations due to the important natural, recreational, educational, scientific, open space, and aesthetic benefits provided by such wetlands (NYSDEC 2012).

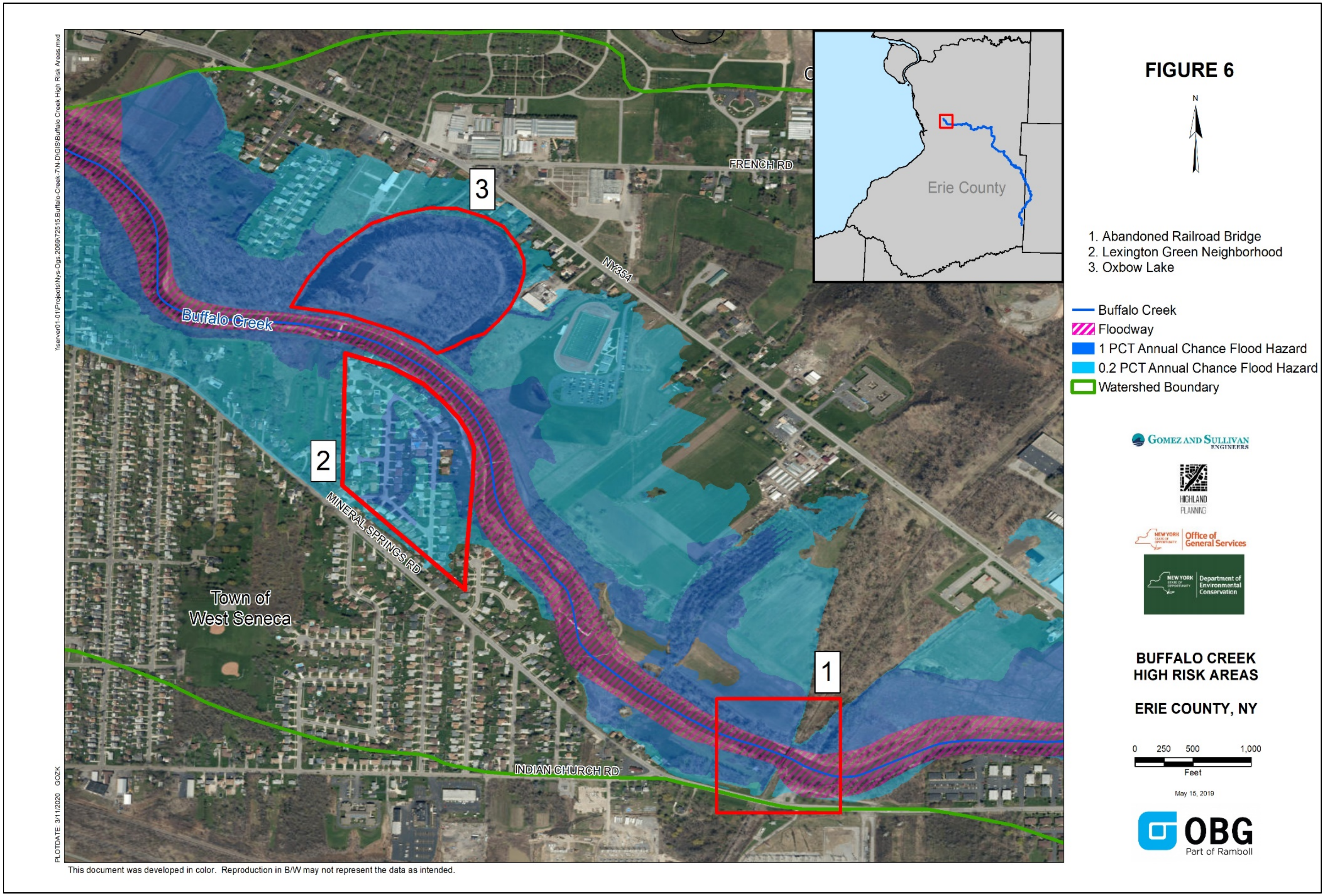
FIGURE 6
N
1. Abandoned Railroad Bridge
2. Lexington Green Neighborhood
3. Oxbow Lake
Buffalo Creek
Floodway
1 PCT Annual Chance Flood Hazard
0.2 PCT Annual Chance Flood Hazard
Watershed Boundary
BUFFALO CREEK
HIGH RISK AREAS
ERIE COUNTY, NY
0 250 500 1,000
Feet
May 15, 2019
Erie County
FRENCH RD
NY354
Buffalo Creek
MINERAL SPRINGS RD
INDIAN CHURCH RD
Town of
West Seneca
1
2
3
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ICE JAM ANALYSIS

ICE JAM FORMATION

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

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

When an ice jam first forms it starts form a single layer inter blocking of small surface ice called a juxtaposed ice cover. With time and increased incoming surface ice volumes, a single layer ice cover grows into a thick ice jam, which is referred to as a freeze-up ice jam. A single layer ice jam can grow in length and at some point, the incoming ice will overturn at the leading edge of the ice cover and pass under the juxtapose cover to form multi-layered ice jams. These ice jams are often called as hanging ice jams and they tend to reduce the area of the river cross section thus reducing the flow. This creates significant backwater effects and causes upstream flooding. With the thickening of the ice jam the local water level also rises and suddenly breaks the ice jam. This ice jam break-up is called a mechanical break-up. This will release larger flows in downstream, which occurs usually during the springtime. The higher water temperatures during the springtime or direct sunlight can weaken the ice cover deteriorates and melt in place without significant movement of ice tend to break up the jam, which is called a thermal break-up.

A thermal or mechanical breakup can happen during the cold wintertime while the water levels of the river increase due to rain or high flows from upstream or locally breaking the existing ice cover which makes break-up ice jam flooding in winter unique from other flooding during the summertime.

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

ICE JAM FLOODING MITIGATION ALTERNATIVES

There are several widely accepted and practiced standards for ice jam controls to mitigate the ice jam related flooding. These are referred to as ice jam mitigation strategies and each strategy is very much site dependent. A strategy that works for a certain reach of a river wouldn't work for another reach in the same river due to river morphology and hydrodynamics. Therefore, each of these strategies need to be analyzed with numerical modeling and simulations to check if they work for a considered area/reach of a river before implementing or recommending with the previous observational experience alone. The standard strategies that are widely accepted and practiced in cold region engineering are described below;

Ice booms

Ice booms are the most widely used ice jam control strategy to control ice movement and minimizes surface ice transport. They can be both permanent and temporary structures depending on the emergency measure in high-risk situations. They mainly consist of a series of timber beams or pontoons connected and strung across a river. Once the ice disappears, the booms can be removed if needed and transported elsewhere for storage during the summer months. Ice booms are flexible and can be designed to release ice gradually when overloaded. They can be a relatively cost-effective intervention and can be placed seasonally to reduce potential negative environmental impacts. Ice booms can also be deployed relatively rapidly, rendering them effective as an emergency response measure.

However, the removal of ice booms can be costly since the components of each boom must be disconnected, cleaned, transported and stored until their next deployment. Ice booms can also be ineffective given that ice jams have the potential to circumvent the booms by moving underneath them. Ice booms do not suit all river environments and require low river flow velocity and adequate upstream ice storage capacity.

Ice breaking using explosives

Thermally grown ice is relatively easy to break up by blasting, while frazil ice is more difficult because it absorbs much of the blast energy. Ice blasting using dynamite is being widely used in rivers where very thick ice jams are formed. It is a very efficient method that can be performed within minutes. It is easily transported to remote locations and does not require any maintenance. Holes are drilled in the ice and dynamite is inserted to blow the ice apart. The most effective results can be achieved by placing the charges underneath the ice surface.

Using dynamite to clear ice can, however, be harmful to the environment. It is also a dangerous method to employ with potentially fatal consequences. Dynamite is not a sustainable solution and can require multiple treatments during extreme cold. It also requires the containment of large areas, which might have to be repeated several times.

Ice breaking using ice-breaker ferries and Cutters

Ice breakers are specialized vessels designed to break ice jams in wide rivers. They represent a non-structural ice jam mitigation method that is used internationally, in lakes, wide rivers, and oceans. Ice breakers are generally operated when temperatures start to rise, before it reaches the peak cold. They are most suitable for ice sheet breaking (juxtaposed type ice jams), as there are limitations for the ice thickness that they are capable of breaking.

Cutting thick ice covers can also mechanically weaken the ice jams and help relive the internal pressure of an ice-covered channel due to the thick ice cover. A thick ice cover increases the resistance to flow and slowdown the discharge under the ice covers and increase the backwater effects upstream. By cutting the ice cover this pressure can be relieved and the backwater effects can be minimized to reduce upstream flooding potentials. This can also help to control the ice jam breakup and control large ice pieces release from the break-up.

Ice breakers can typically break thick ice covers of up to three to ten feet. Ice breakers have proven to be effective tools for breaking up ice cover on rivers. There are multiple types of ice breakers and, being a mobile solution, they can be flexibly targeted at areas with the most need. Operating ice breakers requires a highly skilled command and crew and are not suitable in all environments. Transporting ice breakers is also relatively difficult, making it a time-consuming and potentially cost-intensive solution.

Installing inflatable dams (Obermeyer Spillways)

Removing permanent run-of-river low head dams that are prone to ice jams and replacing then with floatable dams can be a good solution for flow control for all seasons. Since the crest elevation can altered, they allow for a control release of incoming ice, allowing it to spillover without jamming. Also, in case of a sudden freeze-up jam that lead to an overnight thick jam can also be broken by frequent or oscillatory movement of lowering and raising the crest to break or weaken the ice jam.

Obermeyer Spillway gates are recommended in areas where it is more prone to ice accumulation and flow control is still essential during all seasons. Obermeyer Spillway Gates consist of a row of steel gate panels installed either at the top of dams or as free-standing structures. The system utilizes a combination of metal flap-gate panels supported by multiple small inflatable “bladders” that adjust the panels’ angle and elevation. By controlling the pressure in the bladders, the water flow can be infinitely adjusted within the system control range. Panels can also be designed to include heated abutment plates to prevent ice formation.

Mixing heated effluent to the cold water

The release of warm water waves into a river from a nearby treatment plants or additions of heated water mixing can help mitigate ice jam formations where the above mentioned alternatives won’t work. Provided that the effluent is added to the river prior to ice jam formation, the additional water volume can increase the river flow velocities and prevent ice jam creation in the first place. The wastewater can also be used for the thermal control of ice, as the released warm water can melt or thin ice jams.

Removal of Bridge Piers or Heated bridge piers or heated riverbank dikes

Bridge piers are a hotspot for capturing surface and suspended frazil ice. When surface ice floes are adhered to the bridge piers and abutments the lateral growth of ice rapidly increase thus snagging more ice on the surface creating an ice bridge across the river. When there are more piers across the river the potential of ice bridging between piers increase due to a series of small ice bridging between two piers can be rapidly form than between longer between the longer pier spans.

Removing bridge piers can lead to high cost construction projects with inconvenience to the daily traffic through the bridge and the structural integrity. Therefore, heated bridge piers can be a good alternative to the existing piers that are prone to more ice cohesion and that can lead to high cost of removing the piers. This will limit the ice adhesion to the bridge and pass through the surface and suspended ice without encouraging snagging, capturing and flocculation of surface ice at bridge piers avoiding the possible ice jams.

Also, the heating of piers can heat the surrounding water and mix with the ambient cold water that will lead to the melt existing surface and suspended ice in the water. This reduces any extra ice generation in the water column.

However, heating bridge piers involves carful installation of the wiring and maintenance of the heating elements and energy costs. More frequent inspections of the bridge piers are also needed since the temperature can affect the concrete composition or special treatment for the concrete is needed.

Ice retention Structures

Ice retention structures are used to control ice jams by actively initiating jams in more suitable locations where they are less damaging. Ice is captured and retained upstream of residential areas.

Ice retention structures are cost-effective, installation methods are simple, however the design is highly customizable according to the site. A retention structure can be associated with a flood bench so that increased water levels due to ice accumulation can be compromised be allowing more storage in the flood bench. The retention structures don't increase the water level during normal flows.

However, the structures do require ongoing maintenance to remove debris. Channel bed scour is a concern for these structures, therefore, a scour analysis needed to perform in the vicinity of the structure to make sure the ice mitigation strategy will not adversely affect the normal river flow.

Ice Forecasting Systems and Ice Management

Visual monitoring of the ice formation, and ice cover progressions and water levels are good elements of monitoring the ice conditions of a river during the wintertime, but not sufficient to accurately predict the upstream back water effects or ice jam formations or ice jam break-ups. Ice condition and ice jam monitoring system is a useful tool for emergency ice management but limited in ice forecasting ability.

Ice long-term forecasting and short-term freeze-up and ice jam breakup predictions is a complicated process and challenging due to several reasons. Ice forecasting needs geomorphological, meteorological, coupled thermodynamics and hydrodynamics to identify the factors effecting an ice jam condition. Therefore, an ice forecasting simulation will not be able to carried out in a timely manner to help making emergency decisions.

Therefore, a good forecasting system that will recommend an ice management plan would and customized ice monitoring strategy would be the most appropriate alternative to follow. An annual ice jam simulation with that accounts for forecasted meteorological and hydrological conditions and simulated ice control strategy that is suitable for the upcoming winter can identify the flood prone areas and enable to calculate the associate risk beforehand. These annual studies can also suggest the type of monitoring that is needed in different reaches or areas. For example, if an area needed to visually monitor the ice formation and ice transport through web-cams or need to perform a calculation procedure such as "Freezing-Degree-Day" (FDD) method to predict the thickness of an ice jam to break to make decision when to start breaking. This will help officials to manager the resources and order the equipment and staff available before an emergency occur.

Ramboll suggests that to perform a freeze-up or a break-up ice simulation study before implement or recommend any of the above discussed strategies. The basic data needs and steps involved in an ice simulation analysis is also outlined below.

ICE FORECASTING MODEL SIMULATIONS

Freeze-up ice simulation is a complex simulation carried out to predict ice generation, movement and coagulation with the change of air temperature, water temperature and water flow over a period of time. Usually these simulations and carried out for a two to three-month time period. A calibration and validation is also needed to ensure accuracy. A freeze-up or ice jam simulation needs the following input data:

- Accurate river bathymetry created from LiDAR survey or hydro-corrected bathymetric data from the state agencies.
- Weather data such as air temperature, wind condition, cloud cover, snowfall and precipitation data.
- Flow conditions, from gauge data or measured data. (e.g. upstream discharge and downstream water level data).
- Ice conditions data, such as water temperature data, incoming ice concentration, and initial ice cover thickness or initial ice floe concertation's and ice floe thickness.
- Visual observation data that are useful to calibrate the model, such as ice cover leading edge propagation locations, water temperature and ice thickness measurements.

The results of such a simulation, when the results are in agreement with observational data, can lead to a better understanding of ice behavior and associated ice jam flooding in the simulated areas that will aid officials and emergency responders in developing better ice management plans.

ICE JAM PRONE AREAS

The Buffalo Creek watershed is highly susceptible to ice jam formation and backwater flooding. Since 1939, there have been 42 reported ice jam events on Buffalo Creek (CRREL 2019). Since 2014, there have been 4 ice jam flooding events on Buffalo Creek, which has resulted in approximately $820,000 in reported property damages (NCEI 2019). Based on historical flood reports and public outreach, the Town of Elma to West Seneca were identified to be the most adversely affected communities by ice jam flooding in the Buffalo Creek basin. Ice jam flooding on Buffalo Creek occurs primarily in the following locations:

- City of Buffalo and Town of West Seneca downstream the Interstate-90 bridge crossing after Buffalo Creek becomes the Buffalo River;
- Town of West Seneca downstream of the Union Road Bridge in the vicinity of the Lexington Green neighborhood, the Transit Road/US-20 bridge, and the confluence with Cayuga Creek; and
- Town of Elma upstream of the Winspear Road Bridge and in the vicinity of Centennial Park (NYSDEC 2019a).

The HEC-RAS model data available for this report focused on the Town of West Seneca and, more specifically, the areas downstream the Union Road bridge towards the confluence of Buffalo Creek with Cayuga Creek. This area is highly vulnerable to flooding, and in particular ice jam flooding, as a result of urban development and prior channelization projects of Buffalo Creek in this reach. The recent flooding of 2014 and 2019 in the neighborhood of Lexington Green, which is located in between the oxbow lake and Union Road bridge, highlights the vulnerability of this reach of Buffalo Creek to flooding.

DOWNSTREAM OF INTERSTATE-90 BRIDGE CROSSING

Buffalo Creek converged with Cayuga Creek to form the headwaters of the Buffalo River in the Town of West Seneca, NY. Downstream the confluence is the Interstate-90 bridge crossing of the Buffalo River. Buffalo River continues downstream, converging with Cazenovia Creek, before emptying into the Lake

Erie. This reach of Buffalo River flows through the City of Buffalo where the river has been channelized and meanders greatly and often. This meandering causes water velocity slowdowns and the river bends become hotspots to capture and accumulate ice, which increases the potential of ice jam formations along the Buffalo River (Figure 7).

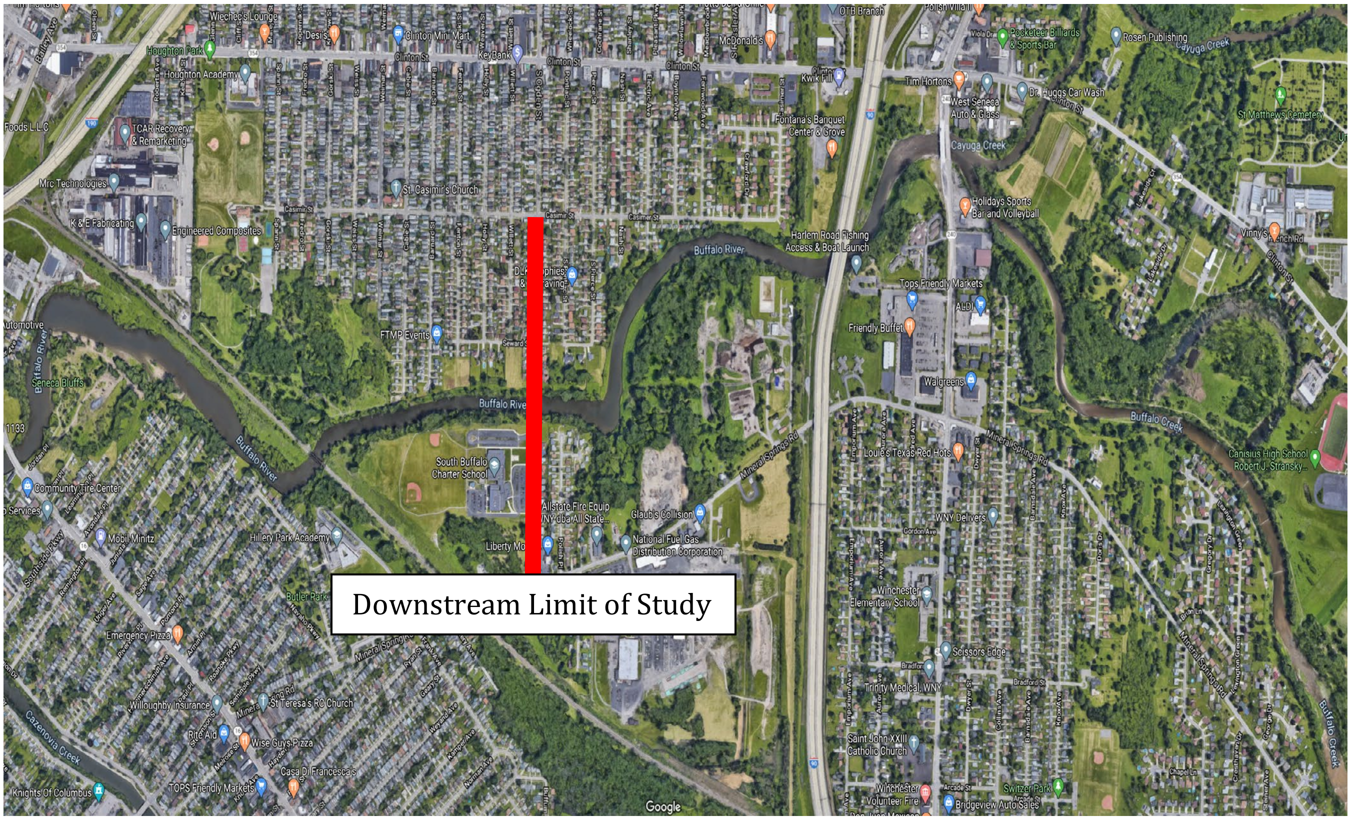

Figure 2. Buffalo River meanders downstream the Interstate-90 bridge crossing in the Town of West Seneca and City of Buffalo, NY.

During the early winter months Lake Erie will start freezing up and producing more ice, which is pushed by the winds over the lake towards the mouth of the Buffalo River. This causes an increase of ice concentration at the mouth of the Buffalo River. The increased ice concentrations at the mouth of the Buffalo River affects the overall ice transport in the river and initiates more frazil ice generation from downstream to upstream of the river. The wider river width also increases the potential of ice generation due to larger surface area enabling more heat transfer between water and cold air. The combination of these two actions decreases the water temperature downstream and through mixing cools the upstream warmer water making it colder and generating more ice. The generation of more ice in the downstream reach of Buffalo River changes the flow hydrodynamics and affects the upstream flow through backwater effects. These changes in the upstream of Buffalo River affect the hydraulic conditions of Buffalo Creek at the confluence with Cayuga Creek and the downstream boundary limit of this study.

It is evident that the ice conditions and geomorphology of the Buffalo River affects ice jam formation and associated flooding within the vicinity of the Buffalo Creek and Cayuga Creek confluence. Therefore, Ramboll recommends a freeze-up 2-D ice simulation using the Comprehensive River Ice Simulation System (CRISSP2D) to evaluate and understand the existing ice dynamics and associated hydrodynamic changes due to presence of ice during the winter versus open water conditions during the summer. Ramboll recommends following the modeling approach outlined in the aforementioned section regarding ice modeling. Ramboll suggests including the downstream mouth of the Buffalo River to upstream of Buffalo Creek and Cayuga Creeks confluence including Cayuga creek as an auxiliary input to the model domain. Depending on the ice simulation results, ice mitigation strategies can be evaluated to determine the more appropriate ice control plan to mitigate the ice jam related flooding in this highly residential area.

CONFLUENCE WITH CAYUGA CREEK, WEST SENECA, NY

In the Town of West Seneca, the reach between the oxbow lake and confluence of Buffalo Creek with Cayuga Creek was identified as a potential ice jam location. A preliminary ice jam analysis was performed on this location using available FIS profiles and spatial GIS data.

According to the FEMA FIS profile, the Harlem Road and Interstate 90 bridges' low chord is above the 10, 1, and 0.2-percent annual chance flood water surface elevations, which is immediately in the vicinity of the confluence (FEMA 2019b). In 2017, the Harlem Road bridge was re-designed and had two of the three bridge piers removed. Since the re-design, there have been no reported ice jam formations in this reach. However, ice jams have formed between the oxbow lake and Harlem Road bridge. This is most likely caused by the meanders in the creek channel in this reach and slowed down water velocities. The meanders cause water flow to decrease and deposition to occur, evidenced by the sand bar (Figure 8). During an ice breakup event upstream, ice pieces flowing through this reach have a higher probability of getting caught on the sand bars as they travel downstream. These ice pieces will continue to get caught at the meander and eventually form an ice jam, obstructing the flow of water downstream, which increases the chances of backwater flooding.

Figure 3. Sand Bar formation downstream the oxbow lake in Town of West Seneca, NY.

Possible ice jam mitigation measures for the Harlem Road bridge would include: ice management and ice break-up at the confluence and upstream Buffalo Creek at a very early stage; or straightening the reach from the oxbow lake to the Harlem Road bridge at the confluence with Cayuga Creek. Further analysis, including the collection of detailed topographic and bathymetric survey data, would be required to quantify the benefit of any project.

Additional field observations, data collection, and H&H modeling is required before any possible ice jam mitigation measure should be pursued for the Winspear Road bridge.

UNION ROAD BRIDGE, WEST SENECA, NY

The Union Road Bridge was identified as a potential ice jam location along Buffalo Creek. Using the H&H model data from FEMA, ice jam scenarios were simulated in the HEC-RAS modeling software to evaluate the ice jam potential of the Union Road bridge. Using the HEC-RAS modeling software, an ice cover simulation of 1-foot thick was initiated with 0.3 ice porosity, about 2,000-feet downstream of the abandoned railroad with 80-percent annual chance flood conditions (1.25-year return period). The Ice cover was extended to the upstream face of the Union Street bridge, while using the dynamic ice cover computation options for the bridges in HEC-RAS model allowing HEC-RAS to compute the dynamic ice cover thickness at each cross section within the specified length, depending on hydrodynamics conditions at each cross section. The simulation indicated that the back water generated from an ice jam with an 80-percent annual chance flood condition initiated at Lexington Green area can raise the water level at upstream of the Union Street bridge (616.1 ft NAVD 88) close to an open water 10-percent annual chance flood conditions (617.8 ft NAVD 88) water level. This shows the significance of ice jamming at the Lexington Green Area to the upstream flooding (Figure 9).

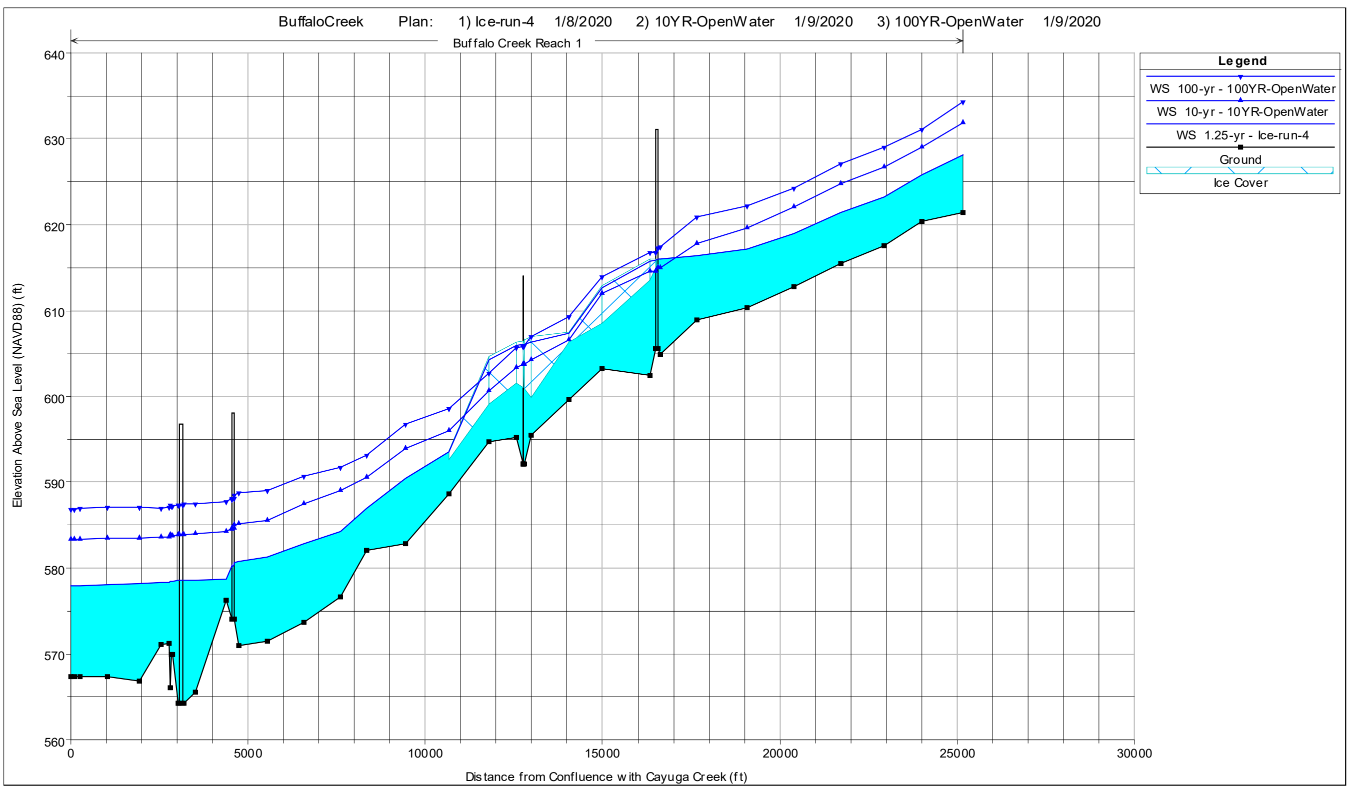

Figure 4. HEC-RAS dynamic ice cover model simulation output for the Union Road bridge. Water surface elevations (feet) for 80, 10, and 1-percent annual chance flood conditions near the abandoned railroad bridge in the Town of West Seneca, NY.

The existence of the sand bars upstream and downstream of the railroad bridge are good evidence of slowed down flow in this area (Figure 10) due to the railroad bridge. The railroad bridge opening and the center pier act as flow constrictions to the flow, so the backwater effects from that slow down the inflow of water passing the bridge. The abrupt flatness of this area also is a factor for the slowed down flow making this location an ideal point for ice jam initiation as a freeze-up or break-up jam. The combination of existing sand bars with the slowed down flows increases the potential to accumulate incoming ice flows and form an ice jam.

By removing the abandoned railroad bridge, the flow restriction can be reduced, decreasing the potential of flocculation of ice flows near the bridge piers and abutments. Also, by removing the sand bars, grading the bathymetry to natural slope, and widening the flow areas between Lexington Green and the abandoned railroad bridge, the probability of incoming ice flows passing downstream without jamming can be increased. Ice control structures and flood benches can also help this process by directing ice pieces out of the channel and providing additional storage area for water and ice during ice breakup events, respectively. These recommendations will reduce the potential for ice jam flooding in the vicinity of the Union Road bridge.

Figure 5. Sand Bar formation at the abandoned railroad bridge in the Town of West Seneca, NY.

TRANSIT ROAD/US-20 BRIDGE, WEST SENECA, NY

The Transit Road/US-20 bridge was also identified as a potential ice jam location in the Town of West Seneca. A preliminary ice jam analysis was performed on this area using available FIS profiles and spatial GIS data.

According to the FEMA FIS profile, the Transit Road bridge low chord is below the 10, 1, and 0.2-percent annual chance flood water surface elevations (FEMA 2019b). The bridge is well below the required 2-feet of freeboard over the 1-percent annual chance flood elevation, recommended by the CRRA. In addition, the North Blossom Road bridge and dam are in close proximity to the Transit Road bridge. The North Blossom Road bridge low chord is only 1-foot above the 1-percent annual chance flood elevation, which is also below the required 2-feet of freeboard. The Blossom Dam is located approximately 1,700-feet upstream of the Transit Road bridge. The dam is engineered to slow water flows of up to the 0.2-percent annual chance flood elevation (Figure 11). Slowing water flow with structures increases the chances of ice accumulation and formation of freeze-up jams. If an ice cover forms, the ice break-up increases the potential for downstream break-up ice jam potential. The North Blossom and Transit Road bridges are the two most immediate downstream bridges, so they have the highest probability of initiating an ice jam.

Possible ice jam mitigation measures for the Transit Road bridge would include: ice management and ice break-up at the Blossom Dam and/or the North Blossom and Transit Road bridges at a very early stage; widening and/or raising the bridge; or installing a flood bench with an ice control structure on the right bank of Buffalo Creek upstream the Blossom Dam. Further analysis, including the collection of detailed topographic and bathymetric survey would be required to quantify the benefit of any project.

Additional field observations, data collection, and H&H modeling is required before any possible ice jam mitigation measure should be pursued for the Transit Road/US-20 bridge.

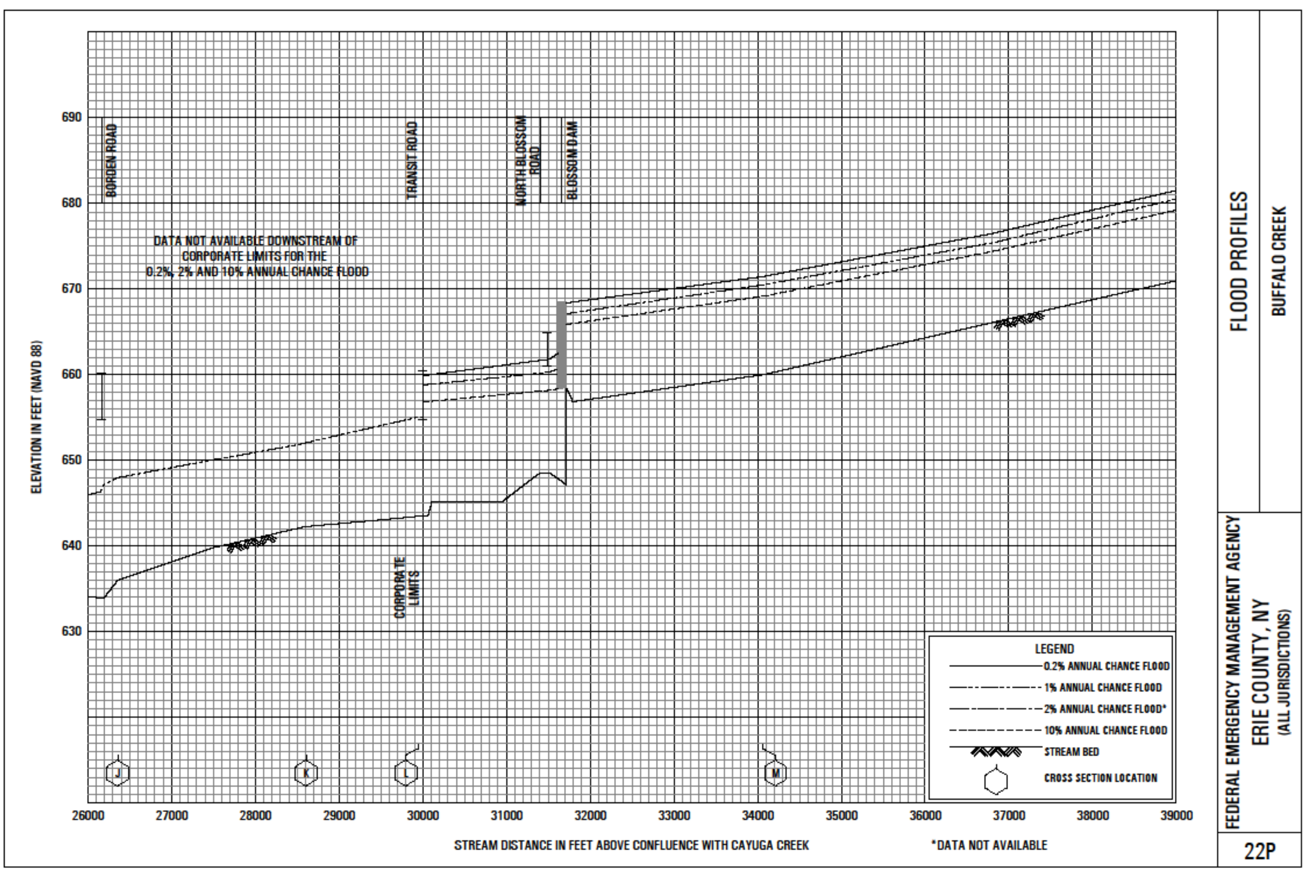

Figure 6. FEMA FIS profile of Buffalo Creek at the Transit Road/US-20 bridge (FEMA 2019b).

WINSPEAR ROAD BRIDGE, ELMA, NY

In the Town of Elma, the Winspear Road Bridge was identified as potential ice jam location along Buffalo Creek. A preliminary ice jam analysis was performed on this location using available FIS profiles and spatial GIS data.

According to the FEMA FIS profile, the Winspear Road bridge is above the required 2-feet of freeboard over the 1-percent annual chance flood elevation (FEMA 2019b). The Winspear Road bridge is located in a relatively stable reach of Buffalo Creek with no major topographic features in the vicinity of the bridge. The most probable cause of ice jam formation in and around the bridge is the creek channel on the left bank along the bridge abutment. There is a small but pronounced meander in the channel as water flows downstream under the bridge. Recent ortho-imagery of the area displays the formation of a sandbar on the right bank of the channel (Figure 12). This meander causes water flow to decrease and deposition to occur, evidenced by the sand bar. During an ice breakup event upstream, ice pieces flowing through the meander have a higher probability of getting caught on the left bank of the creek as it meanders around the bridge abutment. These ice pieces will continue to get caught at the meander and eventually form an ice jam, obstructing the flow of water downstream, which increases the chances of backwater flooding.

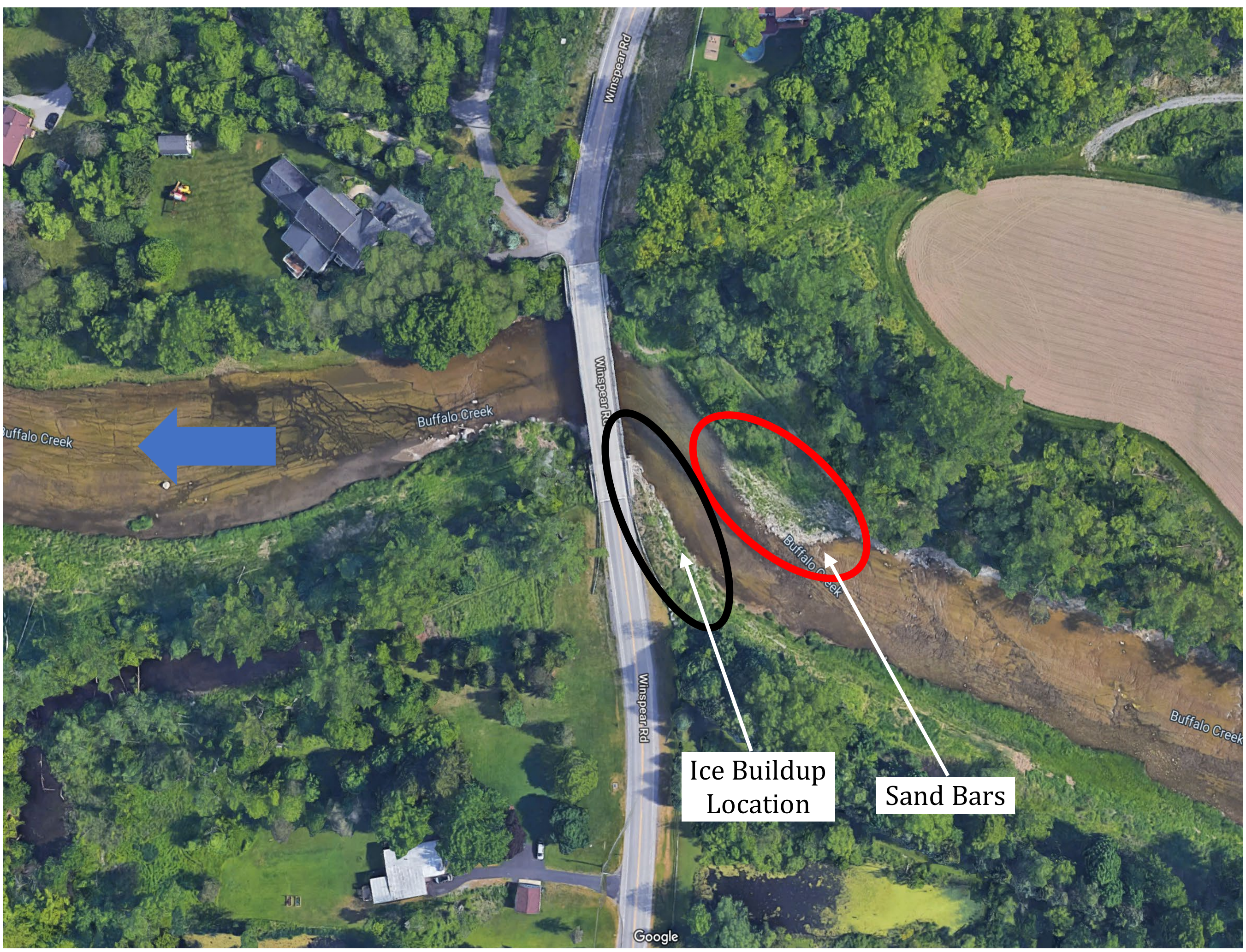

Figure 7. Ice buildup and sand bar locations upstream the Winspear Road bridge in the Town of Elma, NY.

Potential ice jam mitigation measures in the Winspear Road bridge area would include: ice management and breakup on the upstream reach of the bridge; installing a flood bench with an ice control structure on the left bank of Buffalo Creek upstream of the bridge. There is area, on both the left and right over bank upstream of the bridge, to construct a floodplain bench. Further analysis, including the collection of detailed topographic and bathymetric survey, would be required to quantify the benefit of any project.

Additional field observations, data collection, and H&H modeling is required before any possible ice jam mitigation measure should be pursued for the Winspear Road bridge.

CENTENNIAL PARK, ELMA, NY

The Centennial Park area in the hamlet of Elma Center, NY was also identified as a potential ice jam location along Buffalo Creek. A preliminary ice jam analysis was performed on this location using available FIS profiles and spatial GIS data.

According to the FEMA FIS, the Centennial Park area is located in a relatively stable reach of Buffalo Creek with no major topographic features in the vicinity of the bridge (FEMA 2019b). The most probable cause of ice jam formation in and around the park area is the near 90^{o} meander in the creek channel downstream of the park. The meander causes water flow to slow, as evidenced by the large sand bars that have developed in the middle of the channel (Figure 13). When an ice breakup event occurs upstream, the ice pieces will get caught on the sand bars and outside (right) bank of the meander. This buildup of ice pieces will initiate an ice jam and obstruct the flow of water downstream increasing the chances of backwater flooding.

Potential ice jam mitigation measures in the Centennial Park area would include: ice management and removal around the sand bar island; dredging and deepening the creek channel to remove sediment deposits and increase the cross-sectional area of the channel; installing a flood bench with an ice control structure on the right bank upstream of the park; and straighten the channel downstream of the park to remove the meander. Further analysis, including the collection of detailed topographic and bathymetric survey would be required to quantify the benefit of any project.

Additional field observations, data collection, and H&H modeling is required before any possible ice jam mitigation measure should be pursued for the Winspear Road bridge.

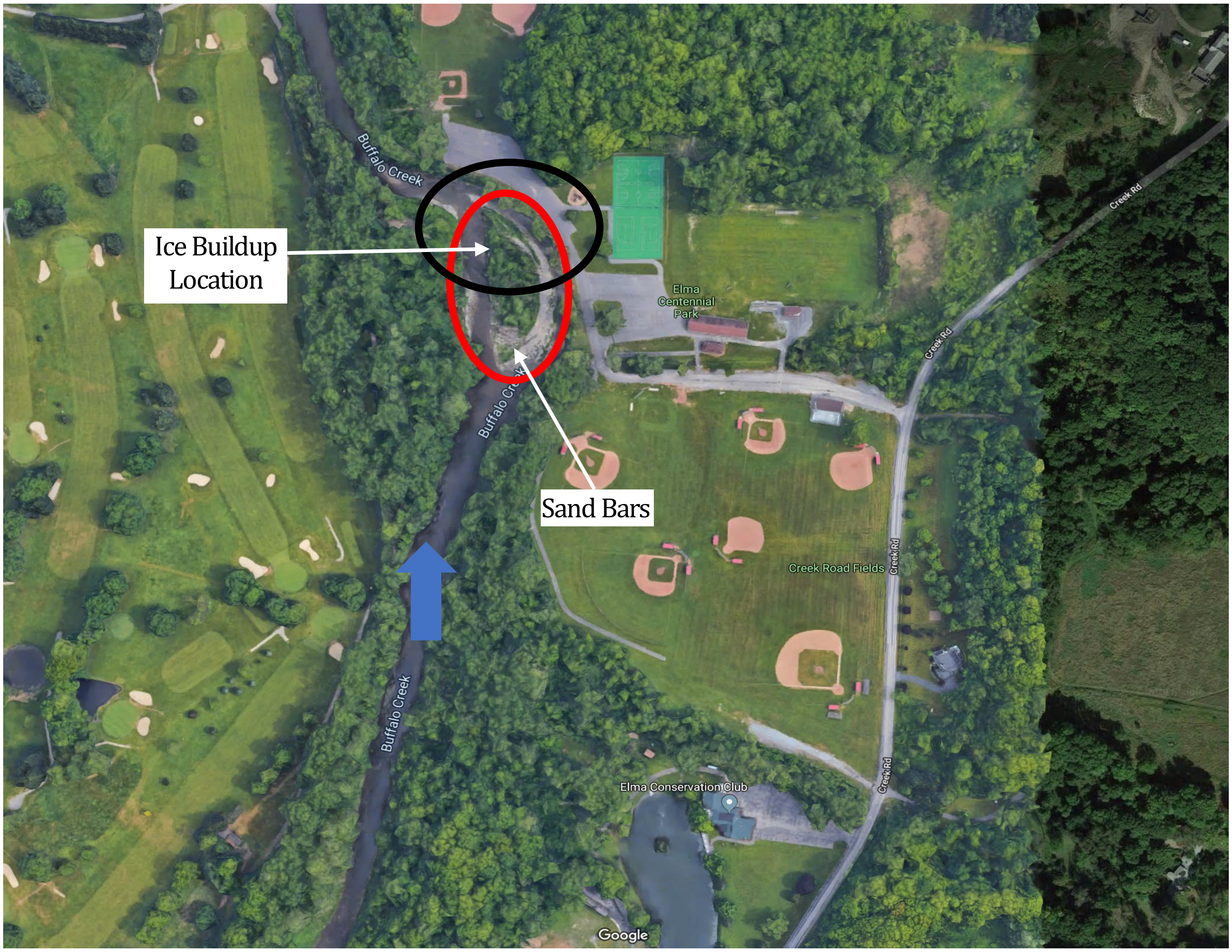

Figure 8. Ice buildup and sand bar locations downstream the Centennial Park area in the Town of Elma, NY.

MITIGATION RECOMMENDATIONS

ALTERNATIVE #1: REMOVE ABANDONED RAILROAD BRIDGE

This measure is intended to increase the channel flow area by removing the abandoned railroad bridge located approximately three-quarters of a mile west of the Indian Church Road and Route 277 (Union Road) junction. Removing the railroad bridge, approach abutments, and associated piers that support the bridge would remove in-channel impediments to flow of water, sediment, debris, and ice. Removal of these impediments would reduce constriction at the railroad bridge, which has historically caused ice jam floods in this area (Figure 6).

The proposed condition modeling confirmed that the abandoned railroad bridge is a constriction point along Buffalo Creek. The simulation output results indicate the railroad bridge and its piers restricts flow causing the water to contract and flow downstream under the bridge. At higher flows, this causes backwater and increased water surface elevations of up to 0.5 ft immediately upstream of the bridge. Without the railroad bridge and its piers, the backwater effect is removed, and water surface elevations are reduced in this reach (Figure 14). Uniformity of flow also has the potential to reduce for the chances of ice jam formation.

To assess the influence of ice jams on the railroad bridge and its piers, a blocked obstruction simulation with varying ice cover thicknesses was performed. This simulation was intended to mimic the effects of ice formations on the banks and piers in the event of an ice jam upstream of the railroad bridge, which would reduce the cross-sectional area of the channel for water to flow. The simulation results indicated for a 10-year flood event with approximately 8,000 cfs and a 1.5-ft thick ice cover, water surface elevations would increase 1-2 feet immediately upstream of the railroad bridge compared to non-ice jam water surface elevations for a 10-year flood event discharge (Figure 15). This would be the case if the railroad were removed or left in place for flows below the 1-percent annual chance flood; however, at flows greater than the 1-percent annual chance flood levels, the removal of the railroad bridge reduced water surface elevations from the resulting ice jam when compared to water surface elevations if the railroad bridge was not removed.

The railroad bridge has a large pier near the center of the stream channel. When ice forms in the creek and reaches the railroad bridge, this pier acts as a barrier to and restricts flow in the channel increasing the potential for ice jam formation and flooding. Therefore, by removing the railroad bridge, and its piers, the potential for ice jamming and associated water level rises in the area can be reduced. The potential benefits of removing the railroad would affect water surface elevations only in the vicinity of the bridge at river stations 75+00 and 95+00.

The Rough Order Magnitude cost for this measure is $480,000.

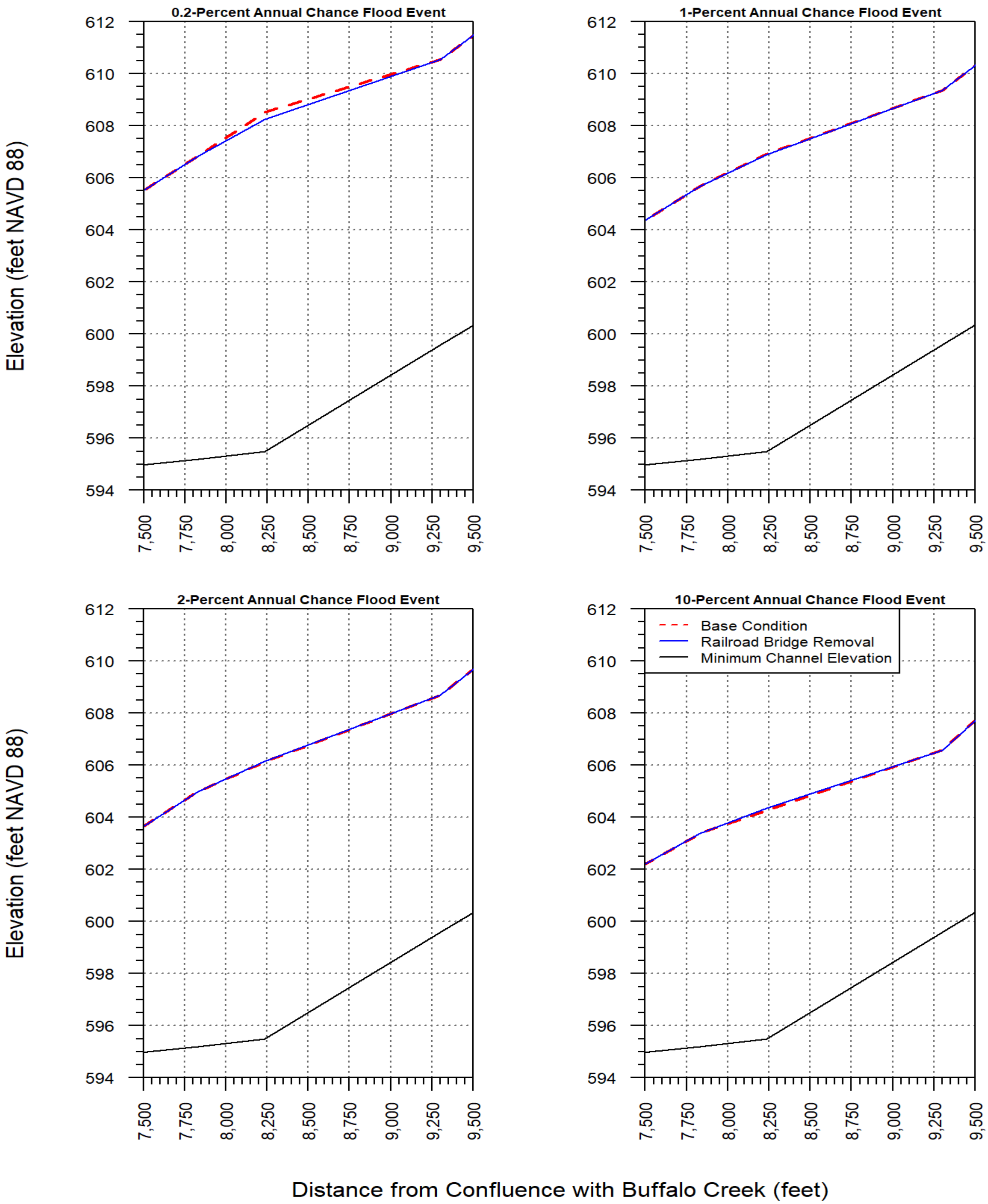

Figure 9. Alternative #1 HEC-RAS proposed condition model output results for the 10, 2, 1, and 0.2-Percent annual chance flood events for the railroad removal (blue) and base condition (red) simulations.

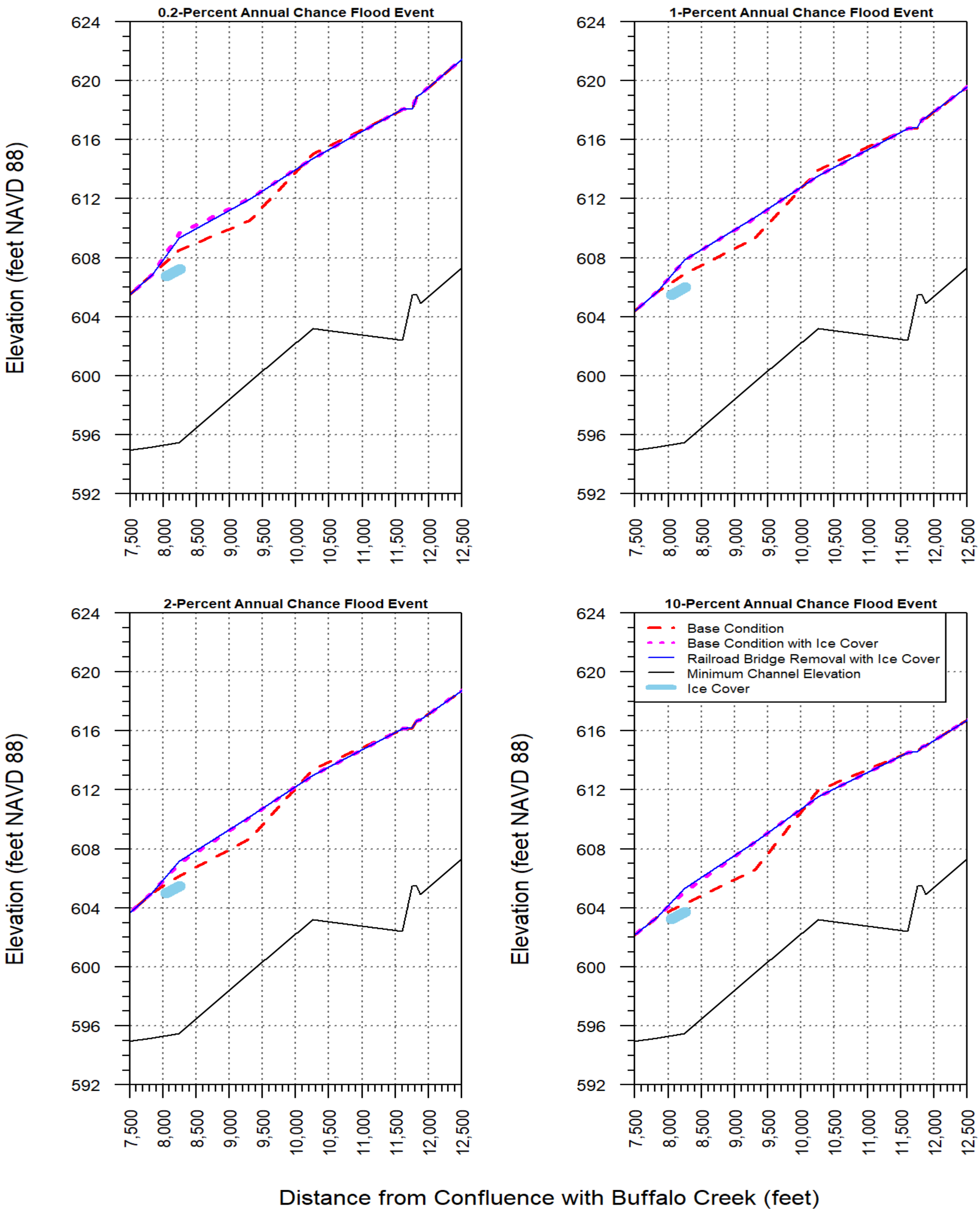

Figure 10. Alternative #1 HEC-RAS ice cover model output results for the 10, 2, 1, and 0.2-Percent annual chance flood events for the railroad bridge removal with ice cover (blue), base condition with ice cover (red dashed), and base condition (red) simulations.

ALTERNATIVE #2: REMOVE ABANDONED RAILROAD BRIDGE AND ASSOCIATED TOPOGRAPHY

This measure is intended to increase the channel flow area by removing the abandoned railroad bridge and the topography supporting the railroad bridge. The elevated landscape that was built on both banks of the creek to support the railroad bridge crossing, constrict water as it flows downstream under the bridge. During high flow and ice jam events, this compressing causes backwater, which increases water surface elevations upstream and the potential for backwater and/or ice jam flooding. By removing the railroad bridge and the associated support topography and returning the landscape to a more natural and subdued elevation, the bankfull and overbank widths in this reach can be increased, providing additional storage and floodplain width. In addition, this alternative would include the benefits of alternative #1 since the railroad bridge removal would be included in this alternative (Figure 16).

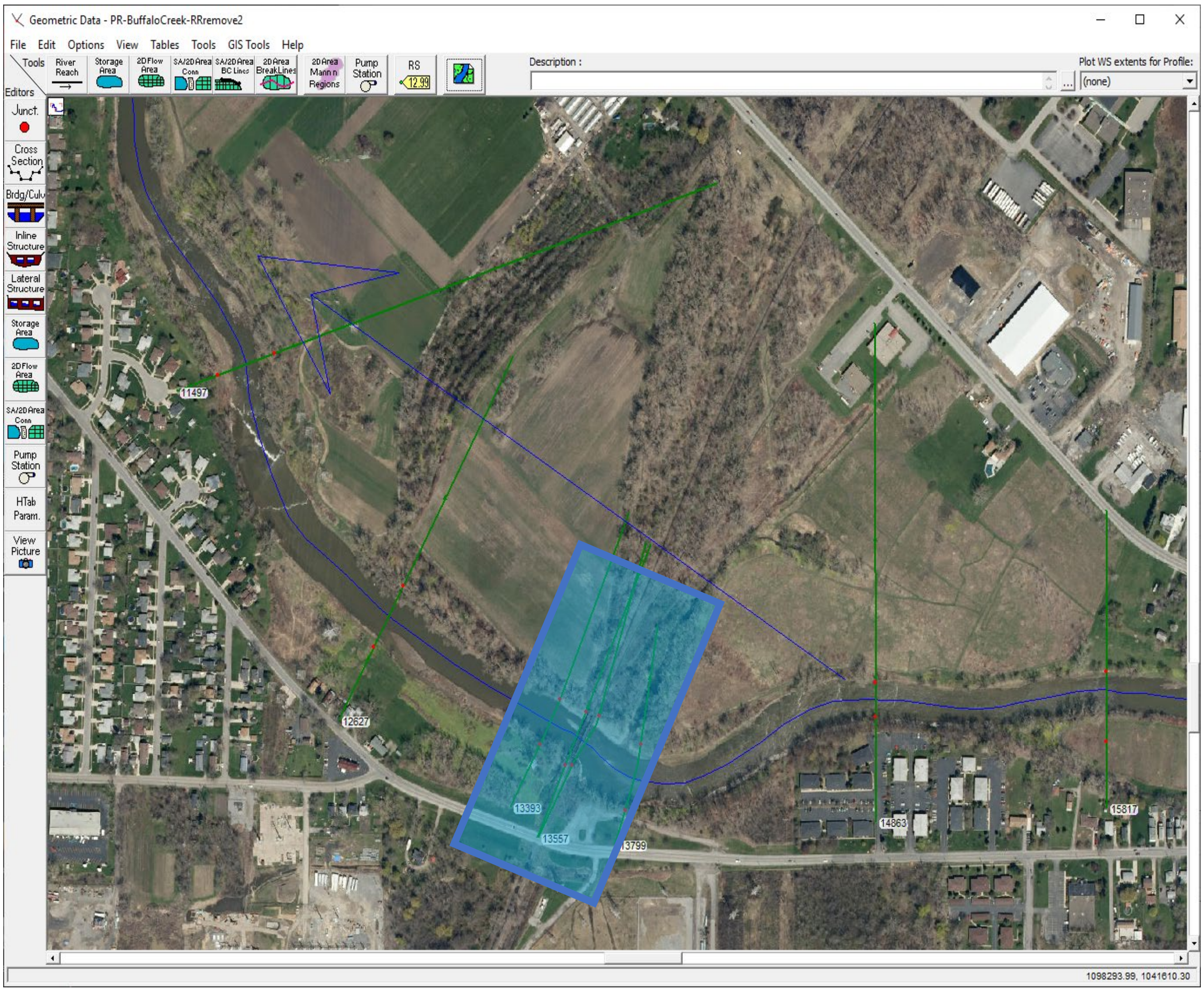

Figure 11. Alternative #2 location map. Railroad bridge removal and associated topography are located between river stations 70+00 and 85+00.

The proposed condition modeling confirmed that the abandoned railroad bridge and its topographic features are a constriction point along Buffalo Creek. The proposed condition simulation results indicate that the railroad bridge topography constricts flow but does not have a large influence on flooding within the reach. The simulation determined water surface elevation increases of up to 0.3-ft immediately upstream of the railroad bridge with a small decrease of up to 0.1-ft further upstream of the bridge for low flow events. However, for high flow events above the 1-percent annual chance flood levels, the model results indicated decreased water surface elevations of up to 1-ft. The future conditions modeling displayed similar results with starting water surface elevations 0.1-0.5 ft higher due to the increased discharges associated with predicted future flows (Figure 17).

To assess the influence of ice jams on the railroad bridge and its embankment, a blocked obstruction simulation with a 1-foot ice cover thickness was performed. This simulation was intended to mimic the effects of ice formations on the banks and piers in the event of an ice jam in the vicinity of the railroad bridge, which would reduce the cross-sectional area of the channel for water to flow. The simulation results indicated for a 10-year flood event with approximately 8,000 cfs and a 1.5-ft thick ice cover, water surface elevations would increase up to 6-feet compared to non-ice jam water surface elevations for a 10-year flood event discharge (Figure 18). The increases in water surface elevation varied for the proposed condition simulation and base condition with ice cover. The proposed condition water surface increase occurs upstream of the railroad bridge then water levels decrease as they approach the Lexington Green neighborhood almost returning to non-ice cover water surface elevations. The base condition with ice cover water surface elevations peak downstream of the railroad bridge and then return to near non-ice cover water levels as they approach the neighborhood.

Water surface elevations increased in the reach after removing the topography due to the narrow topography of Buffalo Creek in this reach as a whole. Upstream of the railroad bridge, the topography of the creek is narrow with steep banks. Water is constricted as it moves through this reach until it passes the railroad bridge, then the channel banks flatten and widen causing water to expand, slow down, and increase water depth. Although removing the railroad topography does not simulate a significant reduction in water surface elevations, there are important benefits of removing the railroad bridge and associated topography with regards to reducing ice jam flooding potential. The potential benefits of removing the railroad bridge and associated topography would affect the areas in the vicinity of the railroad bridge at river stations 60+00 and 120+00.

The Rough Order Magnitude cost for this measure is $3.5 Million.

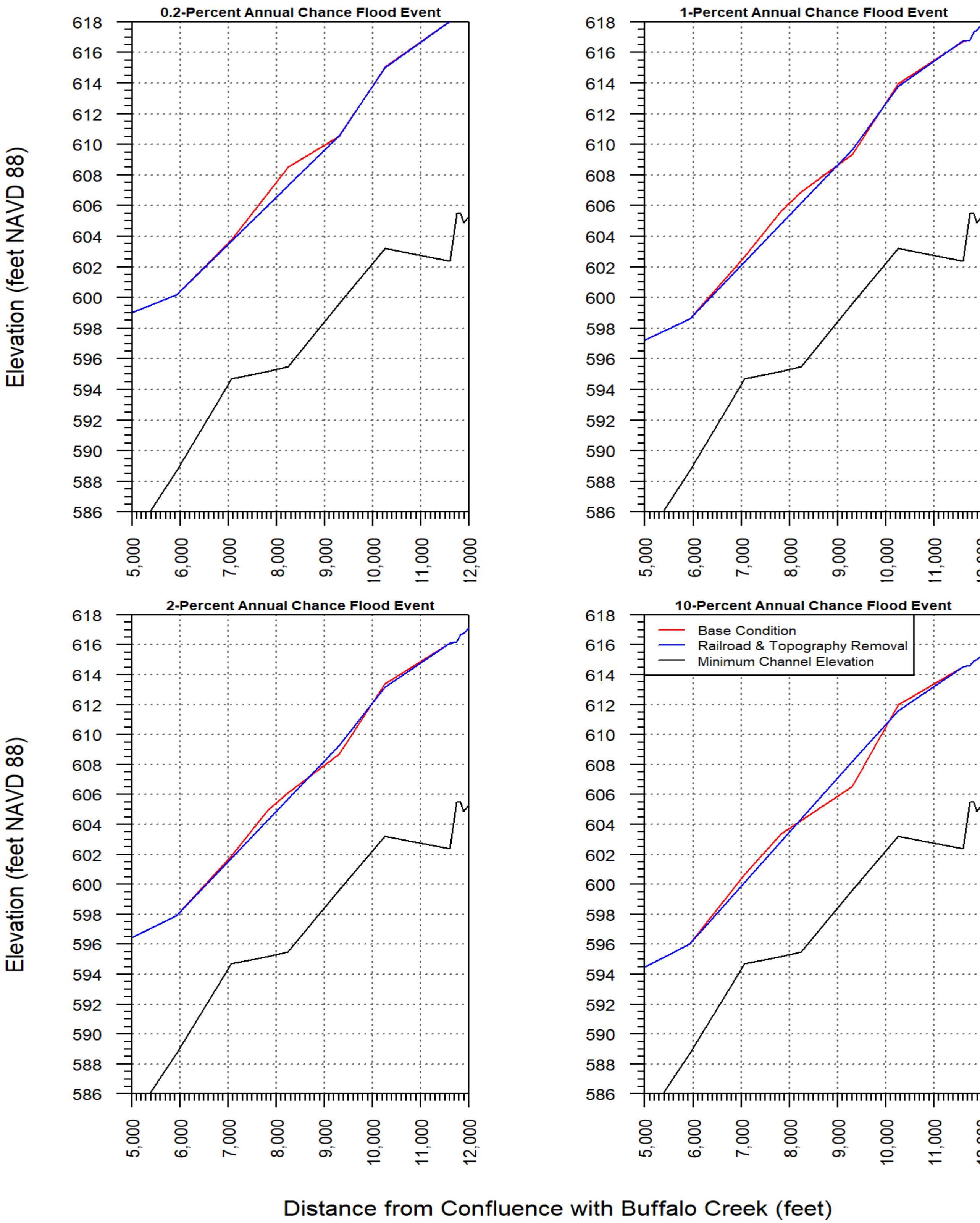

Figure 12. Alternative #2 HEC-RAS proposed condition model output results for the 10, 2, 1, and 0.2-Percent annual chance flood events for the railroad bridge and associated topography removal (blue) and base condition (red) simulations.

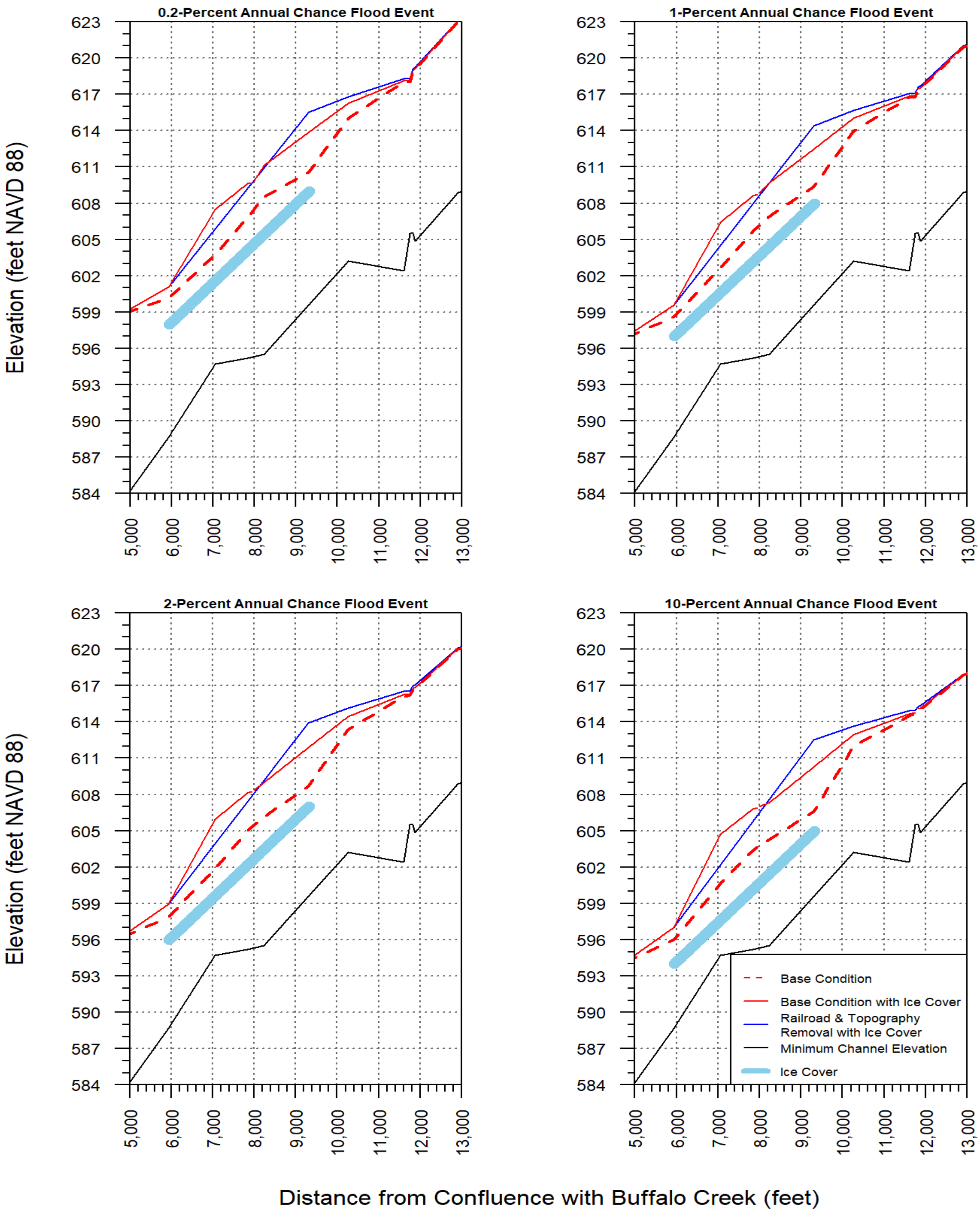

Figure 13. Alternative #2 HEC-RAS ice cover model output results for the 10, 2, 1, and 0.2-Percent annual chance flood events for the railroad bridge and topography removal with ice cover (blue), base condition with ice cover (red dashed), and base condition (red) simulations.

ALTERNATIVE #3: REPLACE RAILROAD BRIDGE AND ASSOCIATED TOPOGRAPHY WITH FLOOD BENCH

This measure is intended to increase the channel flow area by removing the abandoned railroad bridge and the topography supporting the railroad bridge and replacing these features with a flood bench, which would increase the cross-sectional area of the floodplain. By building a flood bench, additional storage and floodplain width can be achieved, which could potentially reduce even more damages in the event of flooding when compared to alternatives #1 and #2, while still achieving the same benefits of alternatives #1 and #2 (Figure 19).

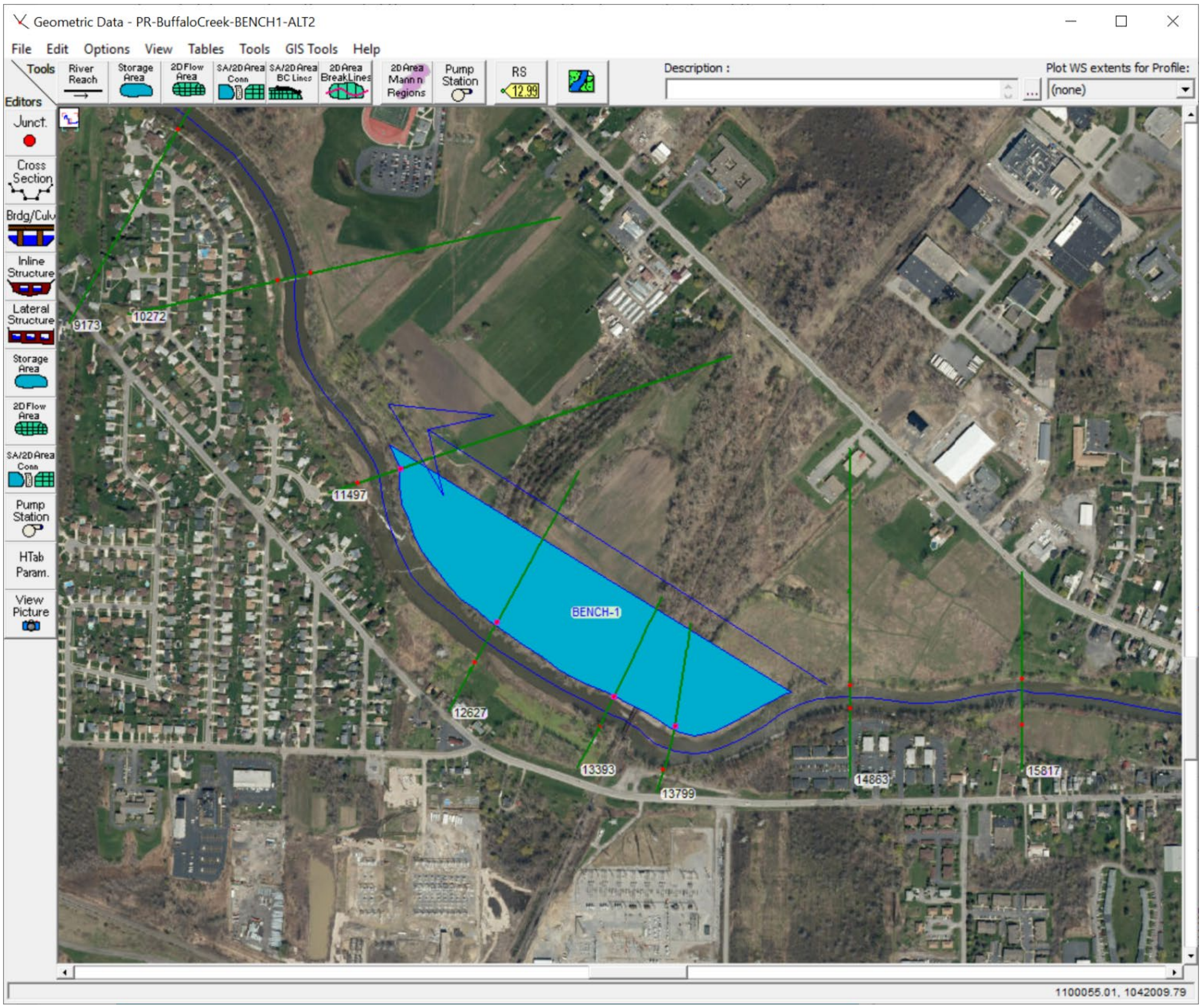

Figure 14. Alternative #3 location map. Flood bench (blue) would be location between river stations 55+00 and 95+00.

In the proposed condition simulation when a flood bench with varying depths was added in place of the railroad topography, there was a measurable reduction in the water surface elevation. When flood benches of 3-6 feet were simulated, the potential reduction in water surface elevations were 2-3 feet according to the model results (Figure20). The modeling output for future conditions predict slightly smaller reductions (1.5 to 2.5 ft) due to the increased discharges associated with predicted future flows in Buffalo Creek.

By removing the railroad bridge, its piers, and incorporating a flood bench, the potential for flooding and ice jams in the area can be reduced. The potential benefits of a flood bench are limited to the areas immediately upstream and downstream of the bridge, specifically between river stations 55+00 to 95+00.

The Rough Order Magnitude cost for this measure is $12.6 Million.

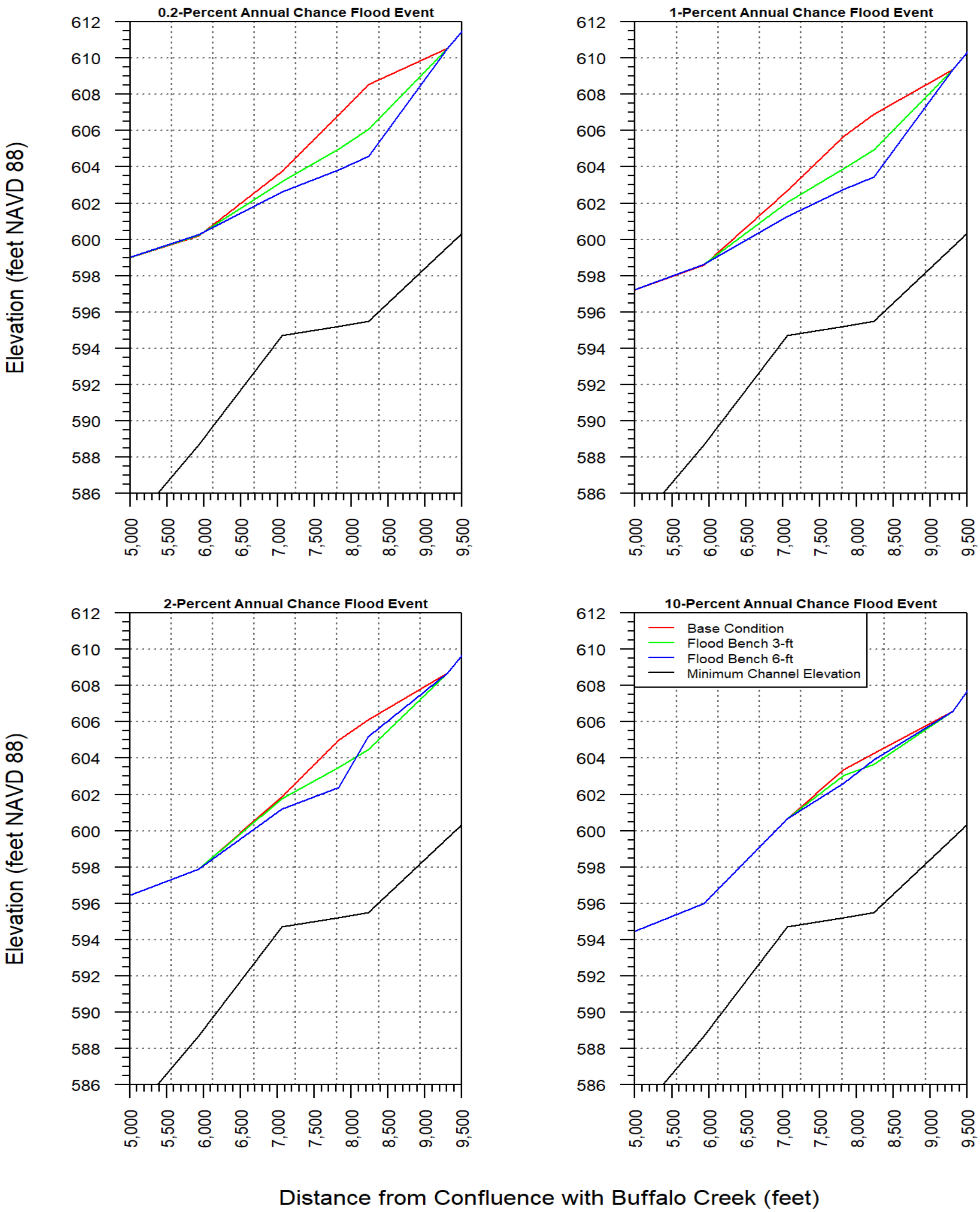

Figure 15. Alternative #3 HEC-RAS proposed condition model output results for the 10, 2, 1, and 0.2-Percent annual chance flood events for the 3-ft (green) and 6-ft (blue) flood bench and base condition (red) simulations.

ALTERNATIVE #4: RECONNECT THE OXBOW LAKE

This measure is intended to increase the cross-sectional flow and potential storage area for high flows by reconnecting a portion of Buffalo Creek with the oxbow lake. The need for and function of the sills would need to be analyzed, including the possibility of worsening submerged hydraulic jump conditions. The oxbow lake could provide valuable additional acreage for water during high flows and ice jam overflows. Reconnecting the oxbow would reduce the need for large construction projects, while maintaining the natural habitats and aesthetics the oxbow wetlands provide to the community (Figure 121).

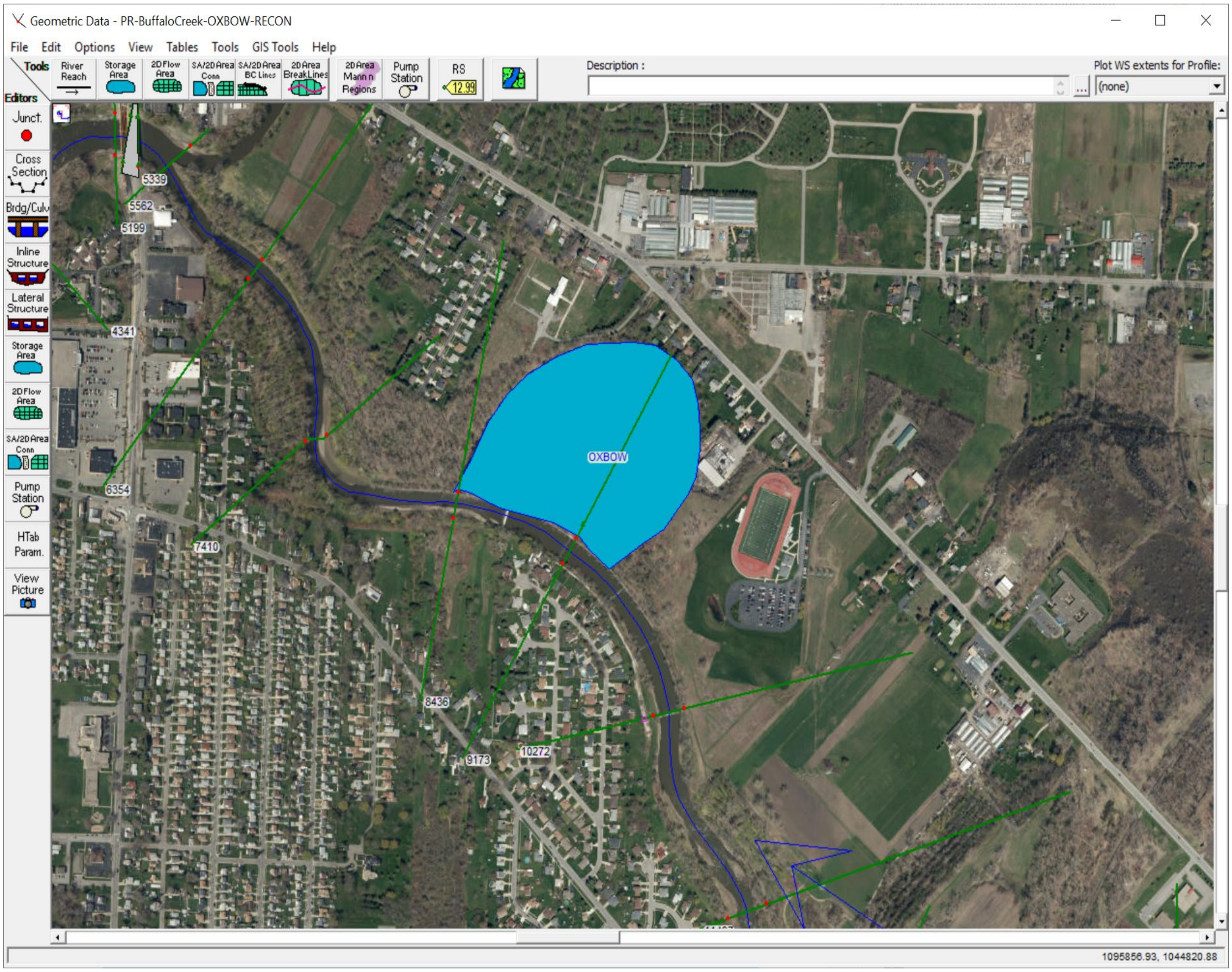

Figure 16. Alternative #4 location map. The oxbow lake (blue) is located between river stations 30+00 and 50+00.

The topography between Buffalo Creek's main channel and the oxbow lake has been built up with sediment so high flows currently do not engage the oxbow lake's additional storage area. The topography between the creek and the oxbow would need to be reduced to below the 1-percent annual chance flood event water surface elevation in order to utilize the additional storage area of the oxbow lake for high flow events.

The proposed hydraulic modeling confirmed that reconnecting the oxbow provides additional storage during high flow events in Buffalo Creek. Potential water surface reductions of up to 1.6-ft was simulated. The future conditions modeling predict slightly smaller reductions, due to the increased discharges associated with predicted future flows (Figure 22).

The simulation output results indicate that reconnecting the oxbow lake to Buffalo Creek would provide valuable additional water storage area during high flow events. Since the oxbow lake is designated as a freshwater wetland, construction of any kind would present numerous regulatory challenges in addition to temporarily displacing many natural habitats. In addition, for any changes or tie-ins to the oxbow lake, permission must be sought from the NRCS and Erie-Wyoming Joint Conservation Board prior to construction. The potential benefits of reconnecting the oxbow lake are limited to areas immediately upstream of the oxbow, specifically between river stations 35+00 to 70+00.

The Rough Order Magnitude cost for this measure is $6.4 Million.

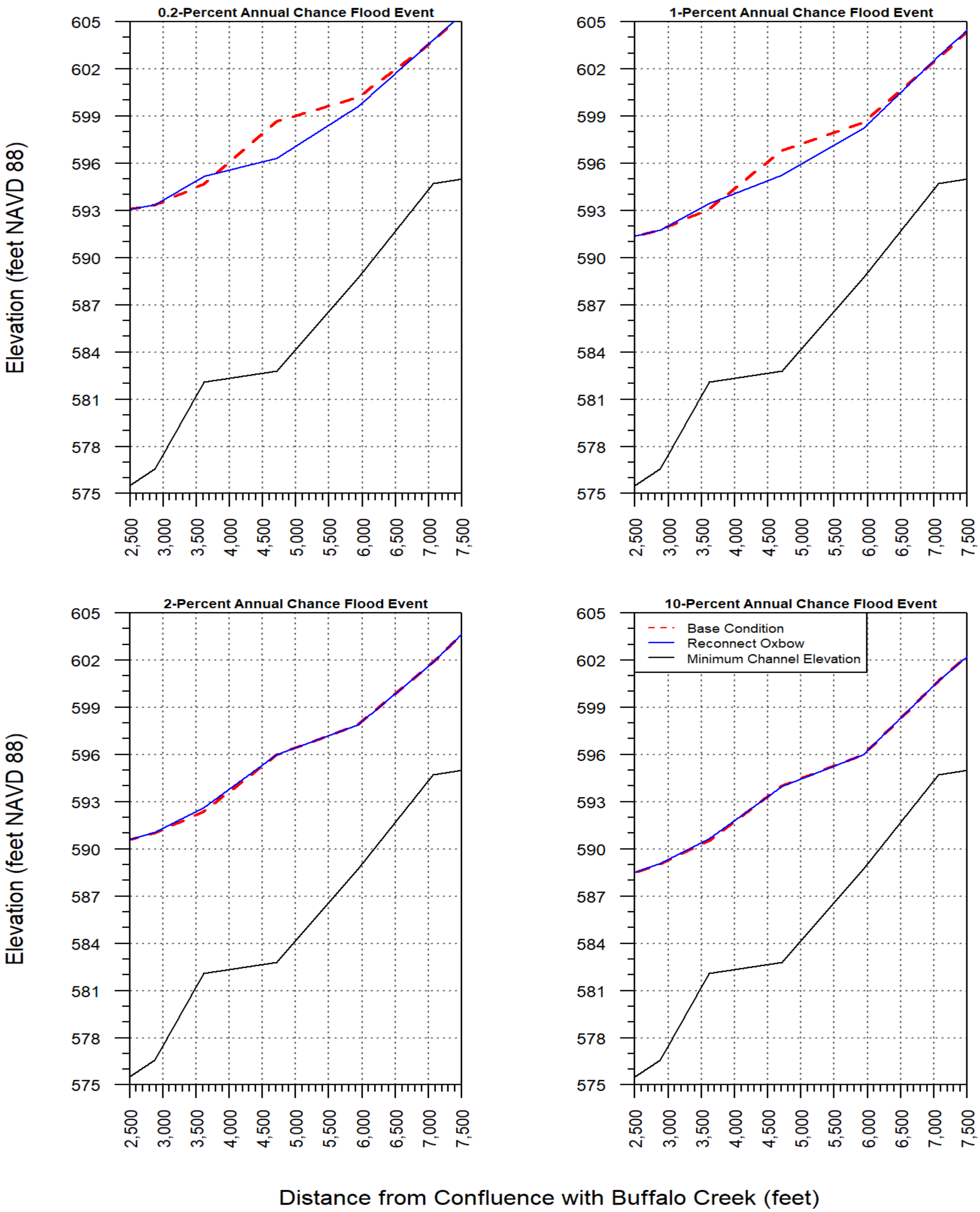

Figure 17. Alternative #4 HEC-RAS proposed condition model output results for the 10, 2, 1, and 0.2-Percent annual chance flood events for the oxbow reconnection (blue) and base condition (red) simulations.

ALTERNATIVE #5: RECONNECT THE OXBOW LAKE AND INSTALL FLOOD BENCH

This measure is intended to increase the cross-sectional flow and potential storage area for high flows by reconnecting a portion of Buffalo Creek with the oxbow lake and installing flood benches in the oxbow lake. The oxbow lake could provide valuable additional acreage for water during high flows and ice jam overflows. Reconnecting the oxbow and installing flood benches would reduce the need for large construction projects, while maintaining the natural habitats and aesthetics the oxbow wetlands provide to the community since the flood benches would allow the natural habitats to reclaim the area after construction. This project would include the benefits of alternative #4 and would be located in the same reach along Buffalo Creek between river stations 30+00 and 50+00 (Figure 21).

The proposed hydraulic modeling confirmed that reconnecting the oxbow provides additional storage during high flow events in Buffalo Creek. The proposed condition simulation considered scenarios of reconnecting the oxbow and then adding a 3-9-foot flood bench. Potential water surface reductions of 2-4 feet were simulated. The future conditions modeling predict slightly smaller reductions, due to the increased discharges associated with predicted future flows (Figure 23).

The simulation output results indicate that reconnecting the oxbow lake to Buffalo Creek and installing flood benches would provide valuable additional water storage area during high flow events. Since the oxbow lake is designated as a freshwater wetland, construction of a flood bench would present numerous regulatory challenges in addition to temporarily displacing many natural habitats. The potential benefits of reconnecting the oxbow lake are limited to areas immediately upstream of the oxbow, specifically between river stations 35+00 to 70+00.

The Rough Order Magnitude cost for this measure is $22.1 Million.

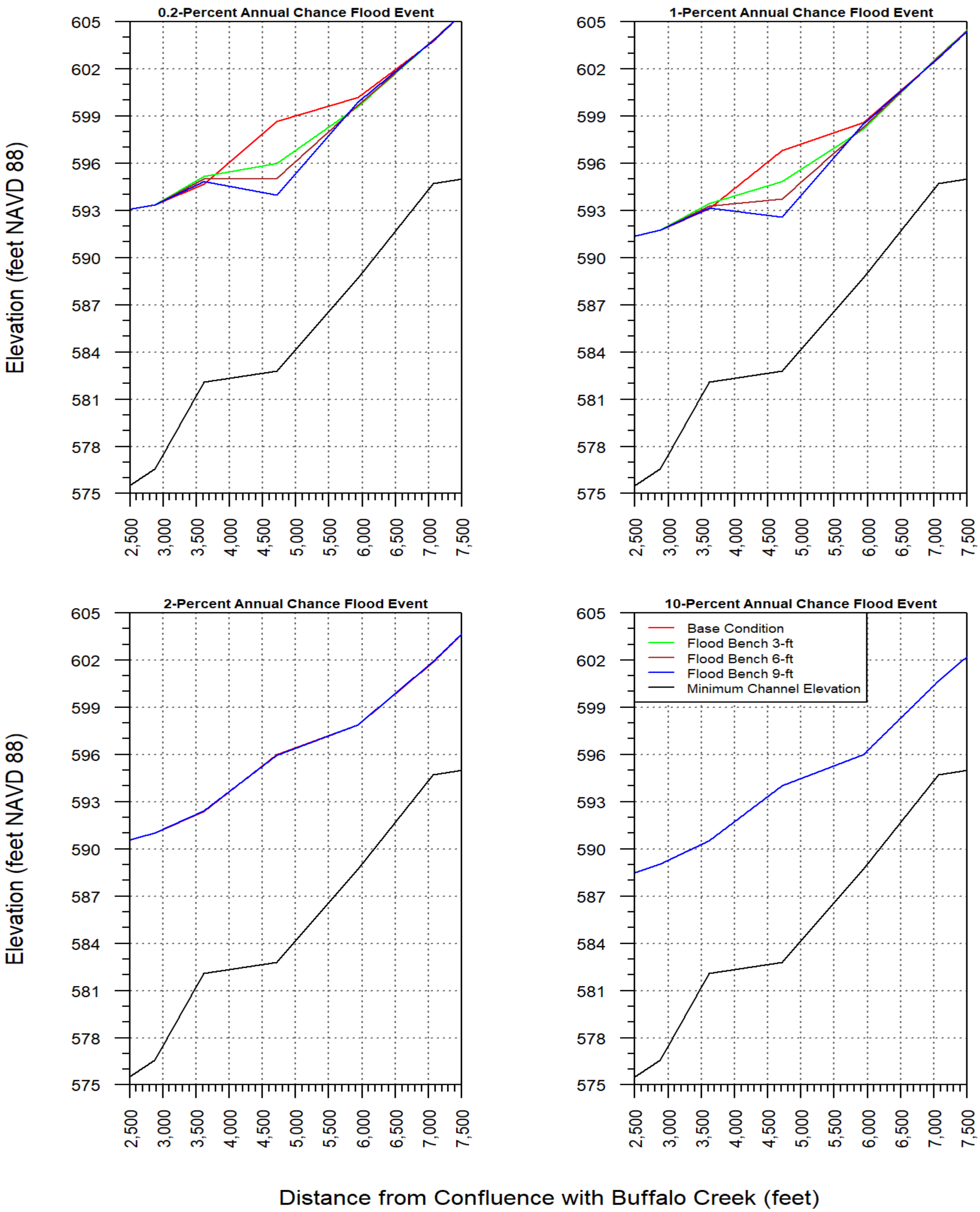

Figure 18. Alternative #5 HEC-RAS proposed condition model output results for the 10, 2, 1, and 0.2-Percent annual chance flood events for the 3-ft (green), 6-ft (brown), and 9-ft (blue) flood benches and base condition (red) simulations.

ALTERNATIVE #6: FLOOD BENCH

This strategy is intended to increase the cross-sectional flow and potential storage area for high flows by constructing flood benches along the right bank of Buffalo Creek downstream of the abandoned railroad bridge and extending to the oxbow lake. This strategy would require excavating approximately 4,000 linear feet of channel banks (Figure 24).

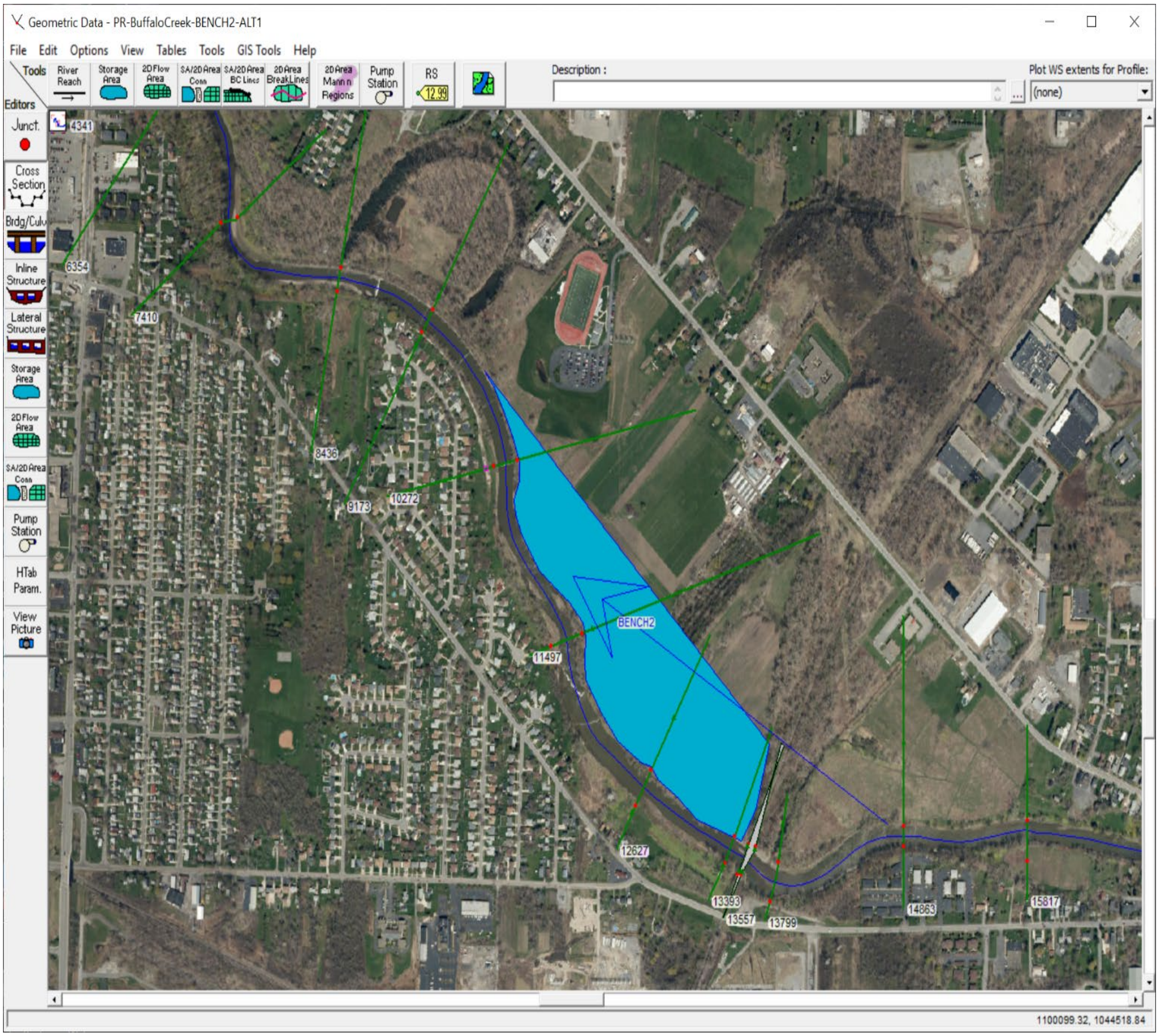

Figure 19. Alternative #6 location map. The flood bench (blue) is located between river stations 42+00 and 80+00.

The proposed condition simulation resulted in measurable reductions in water surface elevations along the 4,000 ft long reach of Buffalo Creek. Water surface reductions for a 3-6-foot bench were modeled to be 1-2 feet. The future conditions modeling output predict slightly smaller reductions in water surface elevations due to discharges associated with predicted future flows (Figure 25).

The model results indicate this strategy would provide a reduction in water surface elevations across a longer portion of Buffalo Creek, including upstream of the railroad bridge. The potential benefits of the flood bench are immediately upstream and in the vicinity of the bench at river stations 60+00 and 90+00.

The Rough Order Magnitude cost for this measure is $16.2 Million.

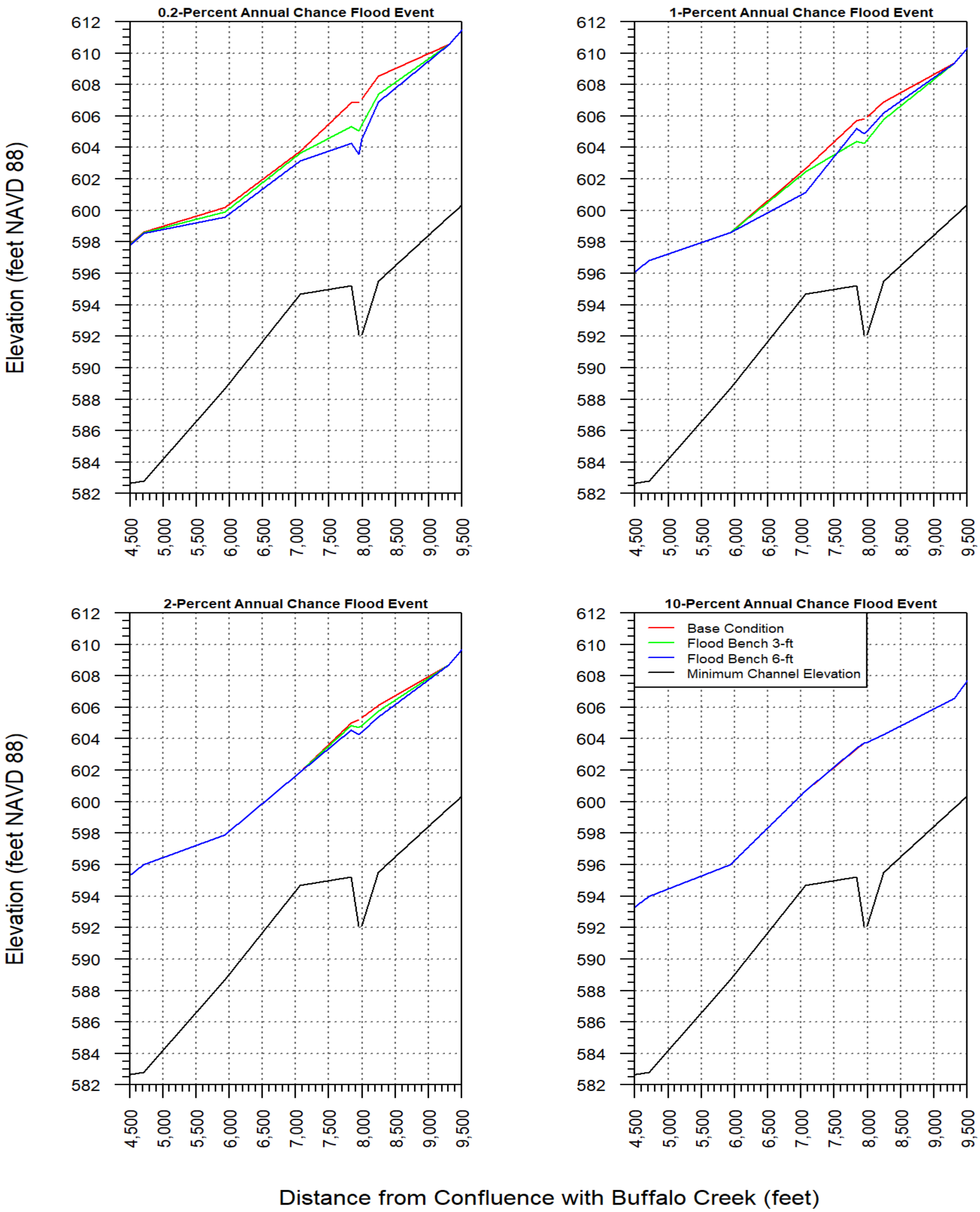

Figure 20. Alternative #6 HEC-RAS proposed condition model output results for the 10, 2, 1, and 0.2-Percent annual chance flood events for the 3-ft (green) and 6-ft (blue) flood benches and base condition (red) simulations.

ALTERNATIVE #7: ICE CONTROL STRUCTURE

The addition of a flood bench increases the water storage volume to the river, making it more susceptible to capture and generating ice during the winter time. Therefore, ice cover break-up is needed to avoid freeze-up jams. Some ice control structures should also be considered downstream of the bench and across or on either side of the river to capture or divert incoming ice flows or broken ice pieces flowing downstream. Ice control structures are constructed within the stream channel at a sufficient height where ice blocks within the channel are captured while still allowing for water to flow around the structures and captured ice blocks (Lever et al. 2000). The structures direct ice into a flood bench that provides the required area to accommodate increased flows during an ice jam event. The flood bench would be located on the right bank of Buffalo Creek opposite the Lexington Green neighbor (Figure 26).

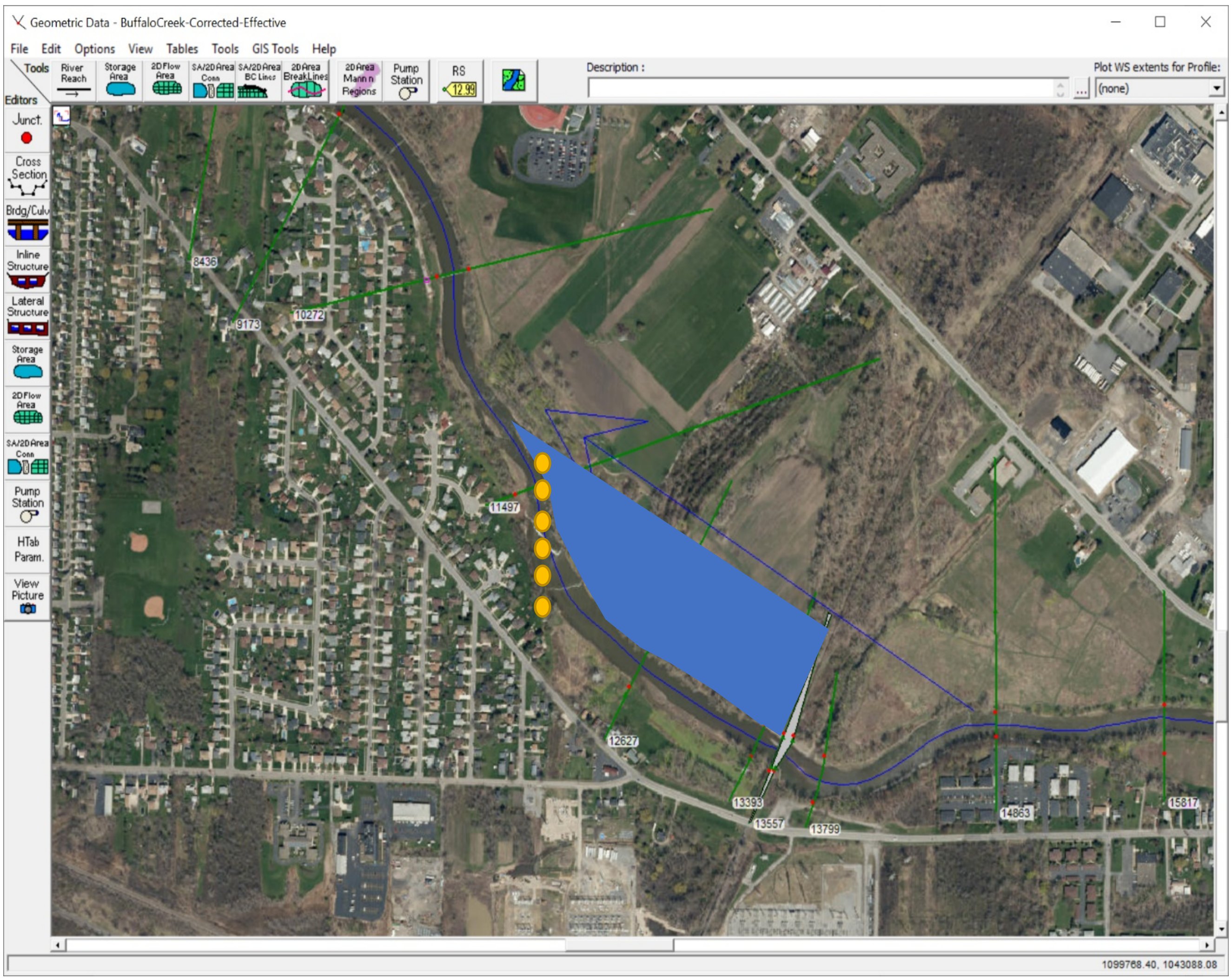

Figure 21. Alternative #7 location map. Flood bench (blue) and ice control structure (orange circles) would be located between river stations 55+00 and 80+00.

Due to the complexity of ice jam modeling and the limited scope of this study, hydraulic modeling was not performed to assess the impact of this strategy. The frazil ice and surface ice flow are complicated due to the number of variables such water depths, surface area, air temperature, flow velocity, etc.

Therefore, any suggested ice control structure in the river or in flood benches would need to go through a dynamic ice freeze-up and break-up computer modeling (2-dimensional River ice dynamic simulation) simulation to understand the ice transport and ice generation mechanism with and without the structures to support the proposed design. Poorly designed structures may result in worsening the flooding potential instead of mitigating the ice jam related flooding (USACE 2016a).

The Rough Order cost for this measure is approximately $11.2 Million, including construction costs for a flood bench.

ALTERNATIVE #8: LEVEE

This strategy is intended to restrict high flow events from overtopping channel banks and flooding homes, properties, etc. in the high-risk area of the Lexington Green neighborhood by constructing a permanent levee along the neighborhood. The levee would be approximately 2,300-5,100 feet long and a height of 2 feet above the future flood flow stage for the projected 1-percent annual chance flood elevation (596-608 ft NAVD 88). Compaction and the possibility of using cut material as fill has not been accounted for at this point. Downstream and opposite bank effects of the levee were modelled, and the levee was determined to have no measurable effects on upstream or downstream water surface elevations (Figure 27).

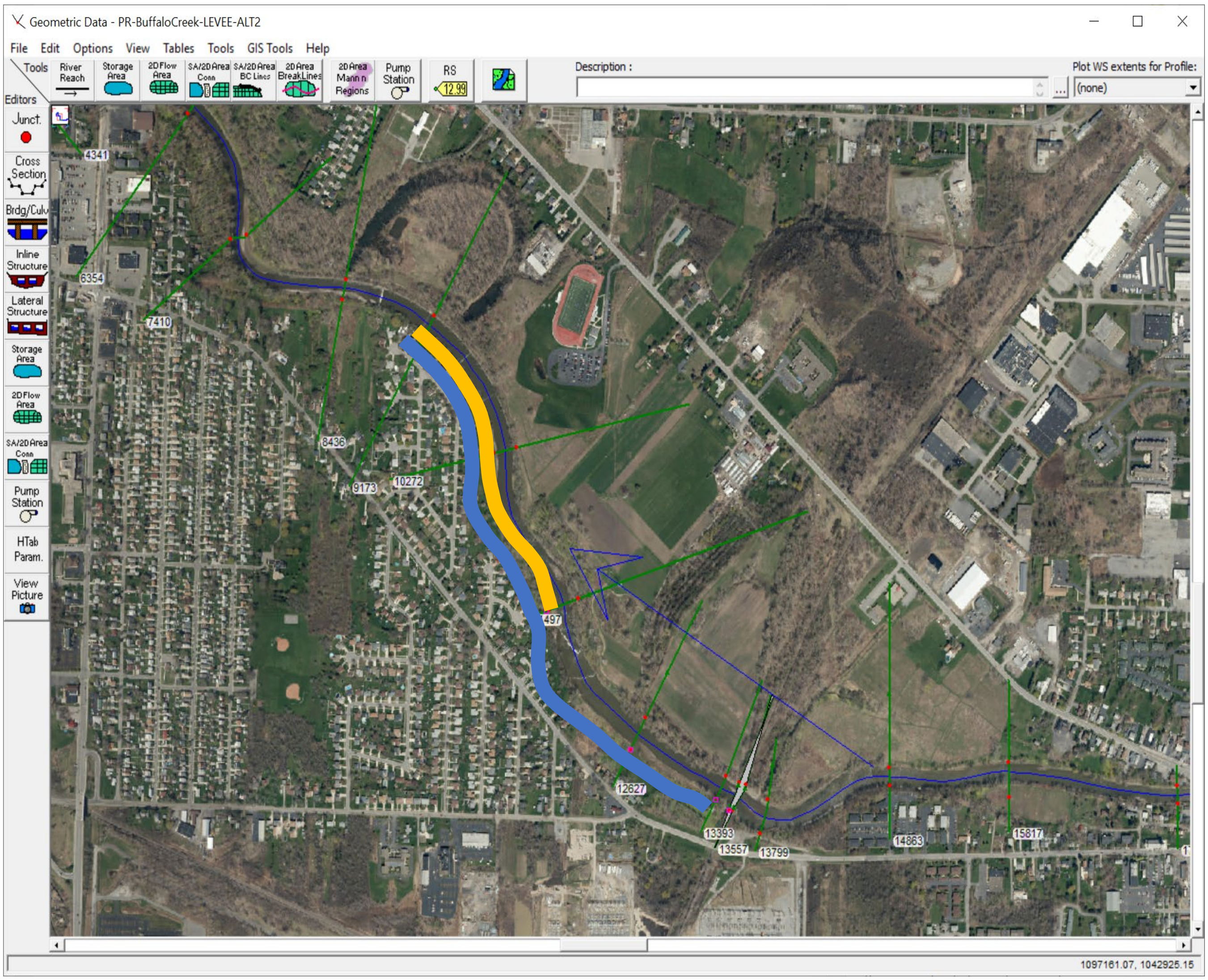

Figure 22. Alternative #8 location map. Two different levee lengths, 2,300 ft (orange) and 5,100 ft (blue) were simulated along the left bank of Buffalo Creek from river station 35+00 to 60+00 and 35+00 to 115+00, respectively.

The proposed and future hydraulic modeling confirmed that constructing a levee along Buffalo Creek in the reach adjacent to the Lexington Green neighborhood would decrease the flood risk of the neighborhood, while leaving the flood potential of downstream and opposite bank areas unaffected (Figure 28).

Both levee structures provide protection to the Lexington Green neighborhood. The 5,100 ft levee structure provides additional protection to residences and businesses on the left bank immediately downstream the railroad bridge along Mineral Springs and Indian Church Roads. A cost-benefit analysis would be recommended to determine which levee structure would best for this alternative. The potential benefits of the flood benches are immediately upstream and in the vicinity of the levees at river stations 30+00 and 75+00.

The Rough Order Magnitude cost for this strategy is approximately $5.5 Million for the 2,300 ft levee.

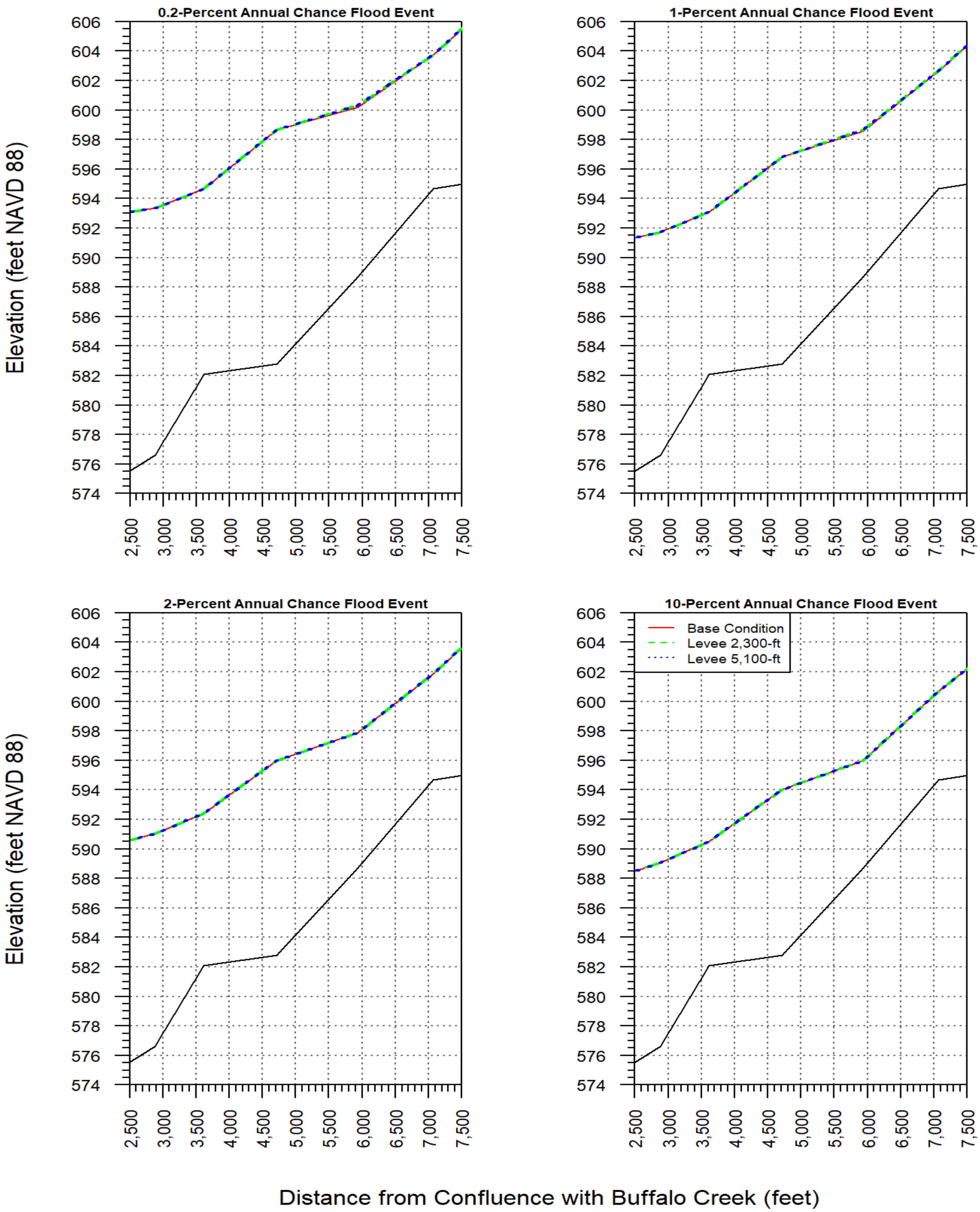

Figure 23. Alternative #8 HEC-RAS proposed condition model output results for the 10, 2, 1, and 0.2-Percent annual chance flood events for the 2,300 ft (green), 5,100 ft (blue), and base condition (red) simulations.

ALTERNATIVE #9: PILOT CHANNEL

This strategy is intended to divert high flow events from the main channel of Buffalo Creek into a pilot channel, which would flow parallel to the creek and outflow into the oxbow lake. The pilot channel would begin diverting flow immediately downstream of the railroad bridge and would require using the oxbow as additional storage and construction of a connection between the oxbow lake and the main channel of Buffalo Creek. This measure would also require the acquisition of private lands bordering the right bank of Buffalo Creek in this reach in order to construct the pilot channel (Figure 29).

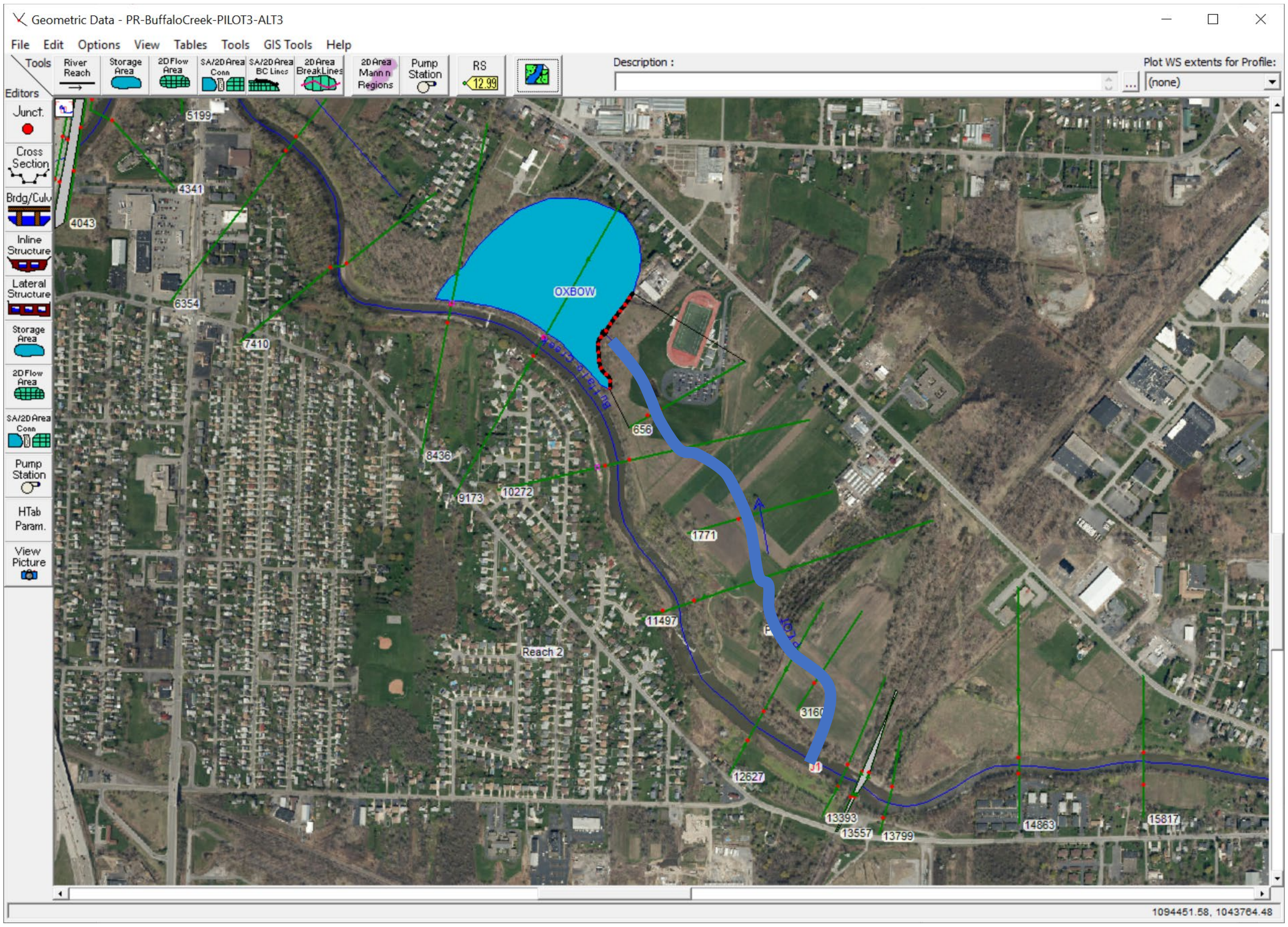

Figure 24. Alternative #9 location map. The pilot channel would be location at river station 75+00 and flow parallel to the main channel of Buffalo Creek into the oxbow lake at 40+00.

Due to the complex multi-directional flow that would occur with the addition of a pilot channel to Buffalo Creek, the 1-dimensional (1-D) HEC-RAS model output results are not the definitive results. In order to more accurately simulate the impact of a pilot channel, a high resolution 2-dimensional (2-D) HEC-RAS model should be performed before recommending this measure as a mitigation strategy.

The proposed and future hydraulic modeling results for a pilot channel indicate that diverting high flows through the pilot channel would reduce water surface elevations in this portion of Buffalo Creek. Various channel width and minimum channel elevations were used to assess the optimal channel width to depth ratio. Channel widths of 100-200 feet and minimum channel elevations of 586-590 ft NAVD 88 were simulated. Predicted resultant reductions in water surface were 1-4 feet in the main channel of Buffalo Creek, while pilot channel water surface elevations ranged from 590-603 feet NAVD 88. The future conditions modeling output displayed similar results only with water surface elevations being 0.1-0.4 feet higher than proposed condition results (Figures 30 and 31). The potential benefits of the flood benches are immediately upstream and in the vicinity of the pilot channel at river stations 30+00 and 95+00.

The introduction of another shallow channel does not increase the freeze-up conditions in the main channel. In fact, the pilot channel itself will freeze-up prior to the main channel. Therefore, flow diversion to the pilot channel will not occur as anticipated during the winter time. Therefore, observation and early detection of any freeze-up jams within the pilot channel is necessary. Breaking up the ice covers, if possible, would help control the ice jamming issues and blockage in the pilot channel during the winter time. A hot air curtain bubbling from the pilot channel bottom can also keep the pilot channel from freezing and generating more frazil ice (USACE 2006). A freeze-up dynamic 2-D ice simulation is necessary to understand the freeze-up flow condition if this alternative is considered.

The pilot channel simulation results indicate that this measure would reduce main channel water surface elevations, while maintaining high flows within the pilot channel banks. This measure presents numerous challenges that would need to be overcome before being considered as a viable mitigation strategy, including reconnecting and using the oxbow lake as additional storage, acquiring lands to build the pilot channel, and additional 2-D hydraulic modeling to determine the optimal channel width and depth for the pilot channel.

The Rough Order Magnitude cost for this measure is $8.3 Million.

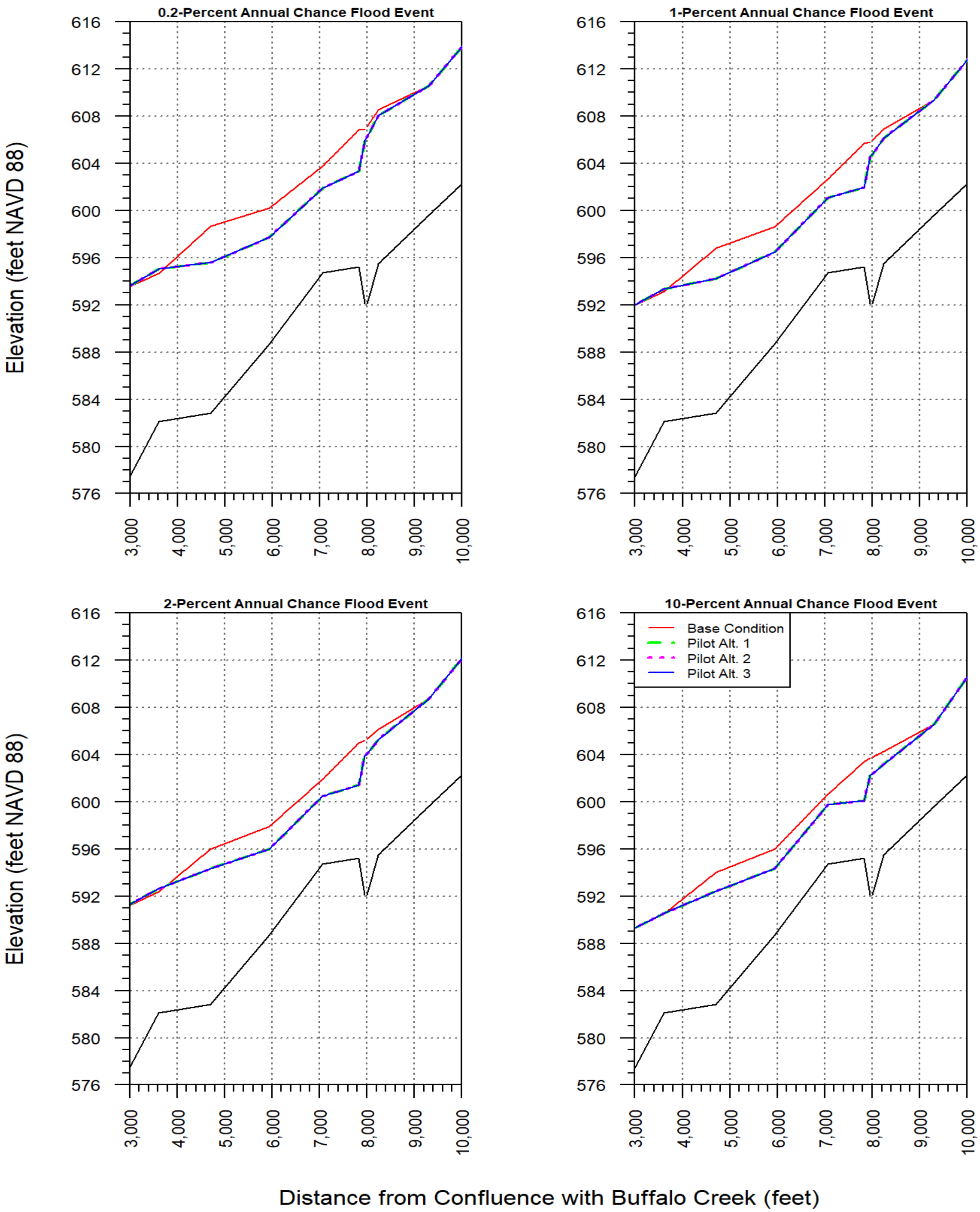

Figure 25. Alternative #9 HEC-RAS proposed condition model output results for the 10, 2, 1, and 0.2-Percent annual chance flood events for the main reach of Buffalo Creek for the pilot alternative #1 (green), pilot alternative #2 (magenta), and pilot alternative #3 (blue) and the base condition (red) simulations.

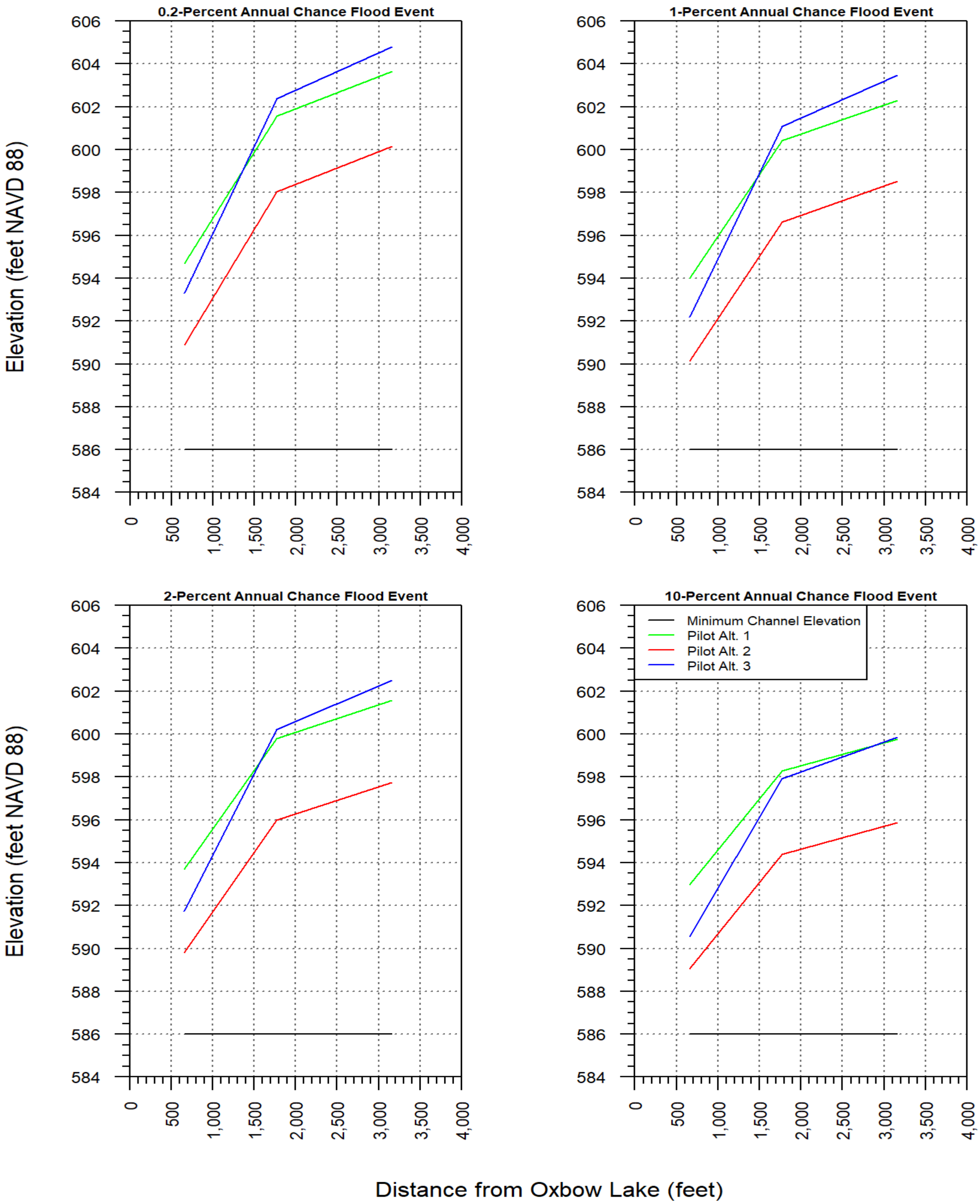

Figure 26. Alternative #9 HEC-RAS proposed condition model output results for the 10, 2, 1, and 0.2-Percent annual chance flood events for the pilot channel reach of Buffalo Creek for the pilot alternative #1 (green), pilot alternative #2 (magenta), and pilot alternative #3 (blue) and the base condition (red) simulations.

ALTERNATIVE #10: FLOOD EARLY WARNING DETECTION SYSTEM

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 2016a).

Flood early warning detection systems can be implemented which can provide communities with more advance 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 flood early warning system consists of commercially available off-the-shelf-components. The major components of a flood early warning system are a sensor connected to a data acquisition device with built-in power supply or backup, some type of notification or warning equipment, and a means of communication. For ice jam warning systems, condition is generally monitored using a pressure transducer. The data acquisition system performs two functions: it collects and stores real-time flood stage data from the pressure transducer and initiates the notification process once predetermined flood stage conditions are met (USACE 2016a). This method can also be supplemented by the freezing degree-day (FDD) method to forecast the ice thickness at critical locations to inform early action to control ice.

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 2016a).

The Rough Order Magnitude cost for this strategy is approximately $100,000.

ALTERNATIVE #11: ICE MANAGEMENT

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

Possible ice management strategies would include:

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

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

Another technique is maintaining a calibrated ice model to predict possible ice jam locations using forecasted air temperature and flow. This will be a comprehensive 1-D or 2-D ice dynamics coupled hydrodynamic model that predicts the freeze-up location, ice cover thicknesses and water levels (Su et al. 1997).

The Rough Order Magnitude cost for this measure ranges from $20,000 to $1.83 Million, not including annual operational costs.

NEXT STEPS

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

ADDITIONAL DATA MODELING

Additional data 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

The oxbow lake is identified by both the NYSDEC and the U.S Fish & Wildlife Service (USFWS) as a freshwater wetland. Any flood mitigation strategy that proposes using the oxbow lake in any capacity needs to be evaluated based on federal and state wetland criteria before that mitigation strategy can be recommended for final consideration.

ICE EVALUATION

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

- Available moisture
- Air temperature
- Land cover
- Precipitation
- Snowmelt intensity

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

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 Revolving Funds
- NYS Office of Emergency Management (OEM)
- Regional Economic Development Councils/Consolidated Funding Applications (CFA)
- Natural Resources Conservation Service Emergency Watershed Protection (EWP) Program

- U.S. Federal Emergency Management Agency Unified Hazard Mitigation Assistance (HMA) Program

New York State Revolving Funds

The Clean Water State Revolving Fund (CWSRF) provides interest-free or low-interest rate financing for water quality improvement projects to municipalities throughout New York State. The Federal Environmental Protection Agency (EPA) annually provides the state with a grant to capitalize the CWSRF program. EFC uses this federal money, along with the required State match to fund projects for the purpose of preserving, protecting, or improving water quality.

NYS Office of Emergency Management

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

Regional Economic Development Councils/Consolidated Funding Applications

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

Water Quality Improvement Project (WQIP) Program

The Water Quality Improvement Project 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.

Wastewater Infrastructure Engineering Planning Grant (EPG) Program

The Wastewater Infrastructure Engineering Planning Grant program is offered by the NYSDEC in conjunction with the New York State Environmental Facilities Corporation (EFC). The EPG program is available to municipalities to help fund initial planning of eligible CWSRF water quality projects. Grants of up to $100,000 are available to finance engineering and planning services for the production of an engineering report. The goal is to advance water quality projects to construction, which will allow successful applicants to use the engineering report to seek financing through the CWSRF program, Water Quality Improvement Project program, or other funding entities to further pursue the identified solution.

The eligible activities under the EPG program include planning activities to determine the scope of water quality issues, evaluation of alternatives, and the recommendation of a capital improvement project. The costs to conduct an environmental review for the recommended alternative are eligible. Design and construction costs are not eligible. All grants require a local match equal to 20 percent of the requested grant amount. The grant will be disbursed in two or more payments based on the municipality's progress toward completion of an acceptable engineering report, with the first disbursement sent as an advance payment once the grant agreement is executed and the final disbursement made once the engineering report has been completed and accepted by the DEC and EFC. Deadlines are in accordance with the CFA cycle.

Climate Smart Communities (CSC) Grant Program

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

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

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

NRCS Emergency Watershed Protection Program

The Emergency Watershed Protection Program is allocated through the Hurricane Irene and Tropical Storm Lee Flood Mitigation Grant Program, administered by the Empire State Development Corporation (ESD) in collaboration with the NYSDEC. Through the EWP, the U.S. Department of Agriculture's Natural Resources Conservation Service 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 necessary permits, furnishing the local cost share (25 percent), and performing any necessary operation and maintenance for a ten-year period. Through EWP, the NRCS may pay up to 75 percent of the construction costs of emergency measures, with up to 90 percent paid for projects in limited-resource areas. The remaining costs must come from local services. Eligible projects include, but are not limited to, debris-clogged stream channels, undermined and unstable streambanks, and jeopardized water control structures and public infrastructures.

FEMA Unified Hazard Mitigation Assistance Program

The FEMA Unified Hazard Mitigation Program, offered by the New York State Division of Homeland Security and Emergency Services (NYSDHSES), provides funding for creating/updating hazard mitigation plans and implementing hazard mitigation projects. The HMA program consolidates the application process for FEMA's annual mitigation grant programs not tied to a State's Presidential disaster declaration. Funds are available under the Pre-Disaster Mitigation (PDM) Program and the Flood Mitigation Assistance (FMA) Program.

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.

Pre-Disaster Mitigation Program

The Pre-Disaster Mitigation Grant Program provides resources to reduce overall risk to the population and structures from future hazard events, while also reducing reliance on federal funding from future disasters. Federal funding is available for up to 75 percent of eligible activity costs. The PDM project funding categories include Advance Assistance (up to $200,000 total of federal share funding), Resilient Infrastructure (up to $10 million total of federal share funding), and Projects (up to $4 million per project).

Flood Mitigation Assistance Program

The Flood Mitigation Assistance Program provides resources to reduce or eliminate long-term risk of flood damage to structures insured under the National Flood Insurance Program. The FMA project funding categories include Community Flood Mitigation – Advance Assistance (up to $200,000 total federal share funding) and Community Flood Mitigation Projects (up to $10 million total). Federal funding is available for up to 75 percent of the eligible activity costs. FEMA may contribute up to 100 percent federal cost share for severe repetitive loss (SRL) properties, and up to 90 percent cost share for repetitive loss (RL) 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

SUMMARY & CONCLUSION

SUMMARY

The Town of West Seneca, NY has had a long history of flooding events along Buffalo Creek. Flooding in the Town primarily occurs during the late winter and early spring months and is exacerbated by ice jams. In response to persistent flooding, the State of New York in conjunction with the Town of West Seneca and Erie County are studying, addressing, and recommending potential flood mitigation projects for Buffalo Creek as part of the Resilient NY Initiative.

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

Based on the flood mitigation analyses performed in this report, the mitigation measures that provided the greatest reductions in water surface elevations were the flood bench and pilot channel alternatives. The most cost effective of these alternatives would be the pilot channel; however, there would be an overall greater effect in water surface elevations if multiple flood bench alternatives were built along Buffalo Creek in different phases, rather than a single pilot channel project.

Other alternatives that should be considered are reconnecting the oxbow lake to the main channel of Buffalo Creek and constructing a levee along the Lexington Green neighborhood. Regulatory constraints regarding the oxbow lake and its wetland status may prohibit the application of this alternative, but the benefits of reconnecting the oxbow lake for high flow events are evident, and the possibility of using the oxbow should be explored further. The levee along the left bank of Buffalo Creek would protect the residences along the Lexington Green neighborhood, which have suffered from flood damages for many years, while minimally impacting water surface elevations downstream. However, the levees do not reduce water surface elevations or provide any additional benefits other than protecting the assets behind them.

The ice control structure would address both flooding from high flows and potential ice jam flooding along Buffalo Creek. An ice control structure and associated flood bench would provide the greatest protection from both types of flooding that occur on Buffalo Creek by combining the benefits of a flood bench with the ice management of the ice control structures.

Ice management to control ice buildup at critical points along Buffalo Creek would be recommended for areas upstream of known flood prone zones. For example, ice breakup using amphibious excavators, such as the Amphibex 400 by Normrock Industries, Inc., is highly effective at preventing ice jams and potential flooding at key infrastructure points by separating ice pack and moving ice pieces downstream. In addition, these types of equipment can provide a wide variety of functions for all seasons, including: restoration and cleaning of contaminated rivers; placements of water conduits, pipelines, and underwater cables; cleaning waste water treatment basins; vegetation control; creation of animal habitats; and recovery and dredging of mining waste, coal ash, and tailings (Normrock Industries, Inc. 2019). To alleviate costs, the County and local Townships could share ownership of the equipment. Recurring maintenance and staffing required in order to operate the equipment should be factored into any cost analysis.

For flood mitigation measures that are being considered for funding through FEMA grant programs, a benefit-to-cost analysis will be required. In order to qualify for FEMA grants and/or funding, the benefit to cost ratio must be greater than one. Table 8 provides a summary of the flood mitigation alternatives, their modeled influence on water surface elevations, and associated ROM costs.

Table 8. Summary of Flood Mitigation Measures

Alternative No.	Description	Change in Water Surface Elevation (ft)	Potential Benefited Area by River Station	ROM cost (U.S. dollars)
1	Remove Abandoned Railroad Bridge	Up to – 2.0 ft	75+00 - 95+00	$480,000
2	Remove Abandoned Railroad Bridge and Associated Topography	Up to – 0.5 ft	60+00 - 120+00	$3.5 Million
3	Replace Railroad Bridge and Associated Topography with Flood Bench	Up to – 3.0 ft	55+00 - 95+00	$12.6 Million
4	Reconnect the Oxbow Lake	Up to – 1.5 ft	35+00 - 70+00	$6.4 Million
5	Reconnect the Oxbow Lake and Install Flood Bench	Up to – 4.0 ft	35+00 - 70+00	$22.1 Million
6	Flood Bench	Up to – 2.0 ft	60+00 - 95+00	$16.2 Million
7	Ice Control Structure	N/A	N/A	$11.2 Million
8	Levee	Up to + 0.4 ft	30+00 - 75+00	$5.5 Million
9	Pilot Channel	Up to – 4.0 ft	30+00 - 95+00	$8.3 Million
10	Flood Early Warning Detection System	N/A	N/A	$100,000
11	Ice Management	N/A	N/A	Up to $1.83 Million (not including annual operational costs)

CONCLUSION

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

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

1. Obtain stakeholder and public input to assess the feasibility and public support of each mitigation strategy presented in this report.
2. Identify any additional mitigation strategies based on stakeholder and public input.
3. Complete additional data collection and modeling efforts to assess the effectiveness of the proposed flood mitigation strategies.
4. Develop a list of final flood mitigation strategies based on the additional data collection and modeling results.
5. Select a final flood mitigation strategy or series of strategies to be completed for Buffalo Creek based on feasibility, permitting, effectiveness, and available funding.
6. Develop a preliminary engineering design report and cost estimate for each selected mitigation strategy.
7. 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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