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RESILIENT NEW YORK FLOOD MITIGATION INITIATIVE

RANSOM CREEK, NY

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HIGHLAND PLANNING

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LIST OF ABBREVIATIONS

BIN	Bridge Identification Number
BFE	Base Flood Elevation
BRIC	Building Resilient Infrastructure and Communities
CDGB	Community Development Block Grants
CFA	Consolidated Funding Applications
cfs	Cubic feet per second
CMIP	Coupled Model Intercomparison Project
CRS	Community Rating System
CSC	Climate Smart Communities
DRRA	Disaster Recovery Reform Act of 2018
EWP	Emergency Watershed Protection
FEMA	United States Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FMA	Flood Mitigation Assistance Program
Gomez and Sullivan	Gomez and Sullivan Engineers, D.P.C.
H&H	Hydrologic and Hydraulic
HEC-RAS	USACE Hydrologic Engineering Center’s River Analysis System
Highland Planning	Highland Planning, LLC
HMGP	Hazard Mitigation Grant Program
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
NYSGOSR	New York State Governors Office of Storm Recovery
NYSOEM	New York State Office of Emergency Management
OBG	O’Brien and Gere, Part of Ramboll
PDM	Pre-Disaster Mitigation Grant Program
RCP	Representative Concentration Pathways
RF	Radio Frequency
RL	Repetitive Loss
ROM	Rough Order of Magnitude
SFHA	Special Flood Hazard Area
SRL	Severe Repetitive Loss
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USDHS	United State Department of Homeland Security
USGS	United States Geological Survey
WQIP	Water Quality Improvement Project

Introduction

Historical Initiatives

Flood mitigation has historically been an initiative in western New York and in the Ransom Creek watershed. Ransom Creek flood mitigation efforts date as far back as 1900, when the State of New York cleared the channel within portions of the Town of Amherst, with additional clearing occurring in 1950 (FEMA, 2019a). Although flooding continues to be an issue on Ransom Creek, and various flooding studies have been performed since the 1950's, no information was obtained pertaining to flood mitigation initiatives since the 1950's.

Floodplain Development

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

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

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

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

Resilient NY Initiative

In November 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 (when applicable), extent of previous flood damage, and susceptibility to future flooding and ice jam formations (New York State Governor's Press Office, 2018). The Ransom Creek watershed was chosen as a study site for this initiative.

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

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, and flooding reports. Historical flood reports, newspaper articles, social media posts, community engagement meeting notes, and geographic information system mapping were used to identify stakeholder concerns, produce watershed maps, and identify current high -risk areas. United States Geological Survey (USGS) Future Flow Explorer v1.5 (Burns, Smith, & Freehafer, 2015) and Stream Stats v4.3.1 (Ries et al. 2017) software were used to develop current and future potential discharges and bank-full 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 U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center's River Analysis System (HEC-RAS) program to predict water stage at potential future high risk areas and to 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 September 19, 2019, with representatives of the New York State Department of Environmental Conservation (NYSDEC); Gomez & Sullivan Engineers, D.P.C. (Gomez and Sullivan); Highland Planning, LLC (Highland Planning); the Counties of Erie, Genesee, and Niagara; the Towns of Amherst, Batavia, Clarence, Newstead, and Royalton; the Village of Alexander; and Buffalo Niagara Waterkeeper (Appendix B). Discussions included a variety of topics related to Donner Creek, Gott Creek, Eighteenmile Creek, Tonawanda Creek, and Ransom Creek, including:

- Background and objectives of the Resilient NY Initiative,
- Background of the study areas,
- Firsthand accounts of past flooding events,
- Identification of specific areas that flooded in each community, and the extent and severity of flood damage, and
- 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.

The only specific areas identified along Ransom Creek were at the New Road and Glen Oaks Drive crossings. New Road was noted to have debris removed and rip-rap added at a nearly ninety-degree bend in Ransom Creek, while comments regarding the need to dredge near Glen Oaks Drive were also noted. Additional general comments were received regarding street flooding causing reduced access to houses which were not flooded.

Field Assessment

Gomez and Sullivan completed reconnaissance visits on September 19, 2019 and field assessments of high-risk flood areas at Ransom Creek road crossings on February 17, 2020. Field data were collected on standard data collection sheets (Appendix C).

Information collected during the field assessments included:

- Photo documentation of inspected areas (see Appendix D for photo log),
- Characteristics and measurements of bridges and culverts,
- Notes regarding additional features near the road crossing, such as dams
- Geomorphic classification and assessment, including measurement of bank-full channel width and depth,
- A Wolman pebble count,
- Field identification of potential flood storage areas,
- Characterization of key stream bank failures, head cuts, bed erosion, aggradation areas, and other unstable stream channel features, and
- Preliminary identification of potential flood hazard mitigation alternatives, including those requiring further analysis.

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 Ransom Creek watershed lies primarily within the Towns of Amherst and Clarence, in Erie County, NY, with portions of the headwaters extending into the Towns of Newstead and Lancaster, in Erie County, NY. The creek originates in wetlands, near the intersection of Wehrle Drive and Shisler Road in Clarence, NY, and generally flows from southeast to northwest into Tonawanda Creek in Amherst, NY. The creek has a total drainage area of 61.4 square miles, at its confluence with Tonawanda Creek. At Kraus Road, in the town of Clarence, the watershed has a cumulative drainage area of 10.7 square miles.

Figure 1 depicts the location of the Ransom Creek watershed. Within the watershed, the Towns of Amherst and Clarence were chosen as the target study area due to the history of flooding amount of development along the creek within the towns. Figure 2 depicts the study area within the Towns of Amherst and Clarence and field data collection locations, as well as the study stationing along Ransom Creek.

Watershed Land Use

The National Land Cover Database (USGS, 2016) shows that, within the Ransom Creek watershed, the Woody Wetland land use cover type makes up 23% of the watershed. All developed land cover types total 31% of the watershed and all agriculture cover types total 24%. Further details of the distribution of land cover within the watershed are shown on Table 1 and in Figure 3. The Woody Wetland land use cover type is located mostly in the northern portion of the watershed. Developed land use cover types are dominant in the southwestern portion of the watershed, in the Town of Amherst and western Town of Clarence. Agriculture is present throughout the northern and eastern portions of the watershed.

Table 1. Land Use Cover Types in the Ransom Creek Watershed

Land Use Cover Type	Acres	Percentage
Woody Wetlands	8890.3	22.7%
Developed, Open Space	6260.1	16.0%
Pasture/Hay	6051.1	15.4%
Deciduous Forest	5225.9	13.3%
Developed, Low Intensity	4401.2	11.2%
Cultivated Crops	3408.2	8.7%
Developed, Medium Intensity	1297.9	3.3%
Mixed Forest	1245.7	3.2%
Barren Land (Rock/Sand/Clay)	1072.7	2.7%
Grassland/Herbaceous	361.0	0.9%
Emergent Herbaceous Wetlands	345.5	0.9%
Developed High Intensity	340.7	0.9%
Open Water	241.1	0.6%
Shrub/Scrub	79.2	0.2%
Evergreen Forest	23.1	0.1%
Total	39,243.5	**100%**

Source: (USGS, 2016)

Geomorphology

Ransom Creek resides in the Erie-Ontario Lowland physiographic province. The surficial geology in the headwaters consists of outwash sand and gravel, till, and till moraine. As Ransom creek flows downstream, the surficial geology transitions to lacustrine sand in the central portion of the watershed before transitioning to lacustrine silt and clay in the lower portion of the watershed. The surficial geology suggests the presence of a proglacial lake in the central and lower portions Ransom Creek watershed. This is supported by the topographic relief of the watershed, as the floodplain is narrower in the headwaters, before becoming relatively wide and flat towards the mouth of Ransom Creek. The channel slope similarly transitions with the surficial geology, as the average slope of the upper reach (between Kraus and Stahley Roads) is approximately 11 feet per mile, the slope of the middle reach (between Stahley and Dodge Roads) is approximately 7 feet per mile, and the slope of the lower reach (between Dodge and Tonawanda Creek Roads) is approximately 3 feet per mile. Figure 4 provides a profile of the Ransom Creek channel bottom within the study area, the figure includes the location of all stream crossings within the hydraulic model for reference.

Hydrology

Ransom Creek is approximately 17.1 miles long and its watershed covers approximately 61.4 square miles (39,296 acres) beginning with ground water in the Town of Clarence (Figure 1). The creek generally flows northwest, and empties into Tonawanda Creek. The Tonawanda Creek then flows southwestward to its mouth at the Niagara River. The Ransom Creek watershed includes two named tributaries, which are Gott Creek and Black Creek. Gott Creek is approximately 8.9 miles long with a drainage area of 18.4 square miles, while Black Creek is approximately 7.8 miles long with a drainage area of 15.0 square miles. Together, these two tributaries account for approximately 54% of the total Ransom Creek drainage area.

Characteristic factors were computed from various physical quantities for the drainage basin, these factors are useful in comparing the relative magnitude of flood peaks across similar drainage basins. The three factors which were calculated for the Ransom Creek drainage basin are Form Factor (R_F), Circularity Ratio (R_C) and Elongation Ratio (R_E). Form Factor (R_F) describes the shape of the basin (e.g., circular or elongated) and can be used as a predictor of 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 expected 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.

The physical quantities used in calculating the characteristic factors for the basin are summarized in Table 2, below. Table 3 summarizes the calculation of basin characteristic factors for Ransom Creek.

Table 2. Summary of Ransom Creek Basin Physical Quantities

Characteristic	Quantity
Drainage Area (A, mi^2)	61.4
Basin Length (B_L, mi)	19.4
Basin Perimeter (B_P, mi)	64.8

Table 3. Summary of Calculated Ransom Creek Basin Characteristic Factors

Factor	Formula	Value
Form Factor (R_F)	A/B_L^2	0.16
Circularity Ratio (R_C)	$4\pi A/B_P^2$	0.18
Elongation Ratio (R_E)	$2(A/\pi)^{0.5}/B_L$	0.46

These calculated characteristic factors indicate that the Ransom Creek basin should be categorized as a more elongated basin being more susceptible to erosion, and for which peak discharges would be expected to be lower than less elongated basins; subsequently high flow events would be expected to occur with a longer duration (Parveen, Kumar, & Singh, 2012). The drainage system within the basin would be expected to have appreciable structural controls and have high relief topography (Waikar & Nilawar, 2014).

There are currently no active USGS stream gages on Ransom Creek, and the only records of historic USGS stream measurements for Ransom Creek were related to water quality measurements. The few discharge measurements associated with the water quality records are not sufficient for use in evaluating the frequency of discharges within the watershed.

An effective FEMA Flood Insurance Study (FIS) for Erie County, NY was reissued with corrections on July 19, 2019, and includes computed peak discharges for six locations along Ransom Creek. The study includes approximately 12.8 miles of Ransom Creek from its confluence at Tonawanda Creek to just upstream of the Kraus Road crossing. Table 4 summarizes the FEMA FIS drainage area and peak discharges, in cubic feet per second, for Ransom Creek (FEMA, 2019a).

Table 4. Summary of FEMA FIS Peak Discharges (2019)

Location	Drainage Area (mi^2)	River Station (ft)	Peak Discharge (cfs)			
			10%	2%	1%	0.2%
At confluence with Tonawanda Creek	59.5	62+98	2,500	3,460	3,900	5,340
At Hopkins Road	45.7	187+90	2,300	3,190	5,120	7,910
Upstream of confluence of Black Creek	30.5	248+23	1,640	2,300	2,590	3,270
Upstream of confluence of Gott Creek	18.1	293+44	1,030	1,450	1,630	2,050
At Transit Road	17.0	553+64	971	1,360	1,540	1,930
At Goodrich Road	14.0	674+63	933	1,330	1,510	1,920

Source: (FEMA, 2019a)

According to the FEMA FIS, peak discharge calculations were based on the methods described by the USGS for urban watersheds and the regional regression equations for New York, published in 1991 (Lumia, 1991). The level of urbanization within the drainage basin is expected to have a significant impact on the magnitude of peak flood discharges. For hydrologic purposes, basins are considered to be urbanized if more than 15% of the land use in the drainage area is classified as developed land; including open space, low, medium and high intensity. The regression equations developed by the USGS for both current and potential future conditions are not considered to be directly applicable to urbanized drainage basins. For urbanized drainage basins, the USGS Water-Supply Paper 2207 (*Flood Characteristics of* Urban Watersheds in the United States) (Sauer, Thomas, Stricker, & Wilson, 1983) provides a methodology for estimating peak discharges based on the expected peak discharge for an equivalent rural basin, the amount of development within the basin and other physical characteristics of the basin.

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

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

For ungaged sites, *StreamStats* relies on regional regression equations that were developed by statistically relating the streamflow statistics to the basin characteristics for a group of stream gages within a region. Estimates of streamflow statistics for an ungaged site can then be obtained by measuring its basin characteristics and inserting them into the regression equations (Ries, et al., 2017).

For example, the equation for estimating the 100-year flood for ungaged sites within one hydrologic region in New York is:

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

Where

A is the drainage area in square miles;
SL is the main channel slope in feet per mile; and
P is the mean annual precipitation, in inches (Lumia, R; Freehafer, D A; Smith, M J, 2006).

StreamStats delineates the drainage basin boundary for a selected site by use of an evenly spaced grid of land-surface elevations, known as a Digital Elevation Model (DEM), and a digital representation of the stream network. Using this data, the application calculates multiple basin characteristics, including drainage area, main channel slope, basin slope, basin storage, mean annual runoff, and the percentage of the drainage basin greater than 1,200 feet above sea level. By using these characteristics in the calculation, the peak discharge values have increased accuracy and decreased standard errors by approximately 10% for a 1% annual chance interval (100-year recurrence) discharge when compared to the drainage-area only regression equation (Ries, et al., 2017).

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

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

StreamStats was used to calculate the current peak discharges for Ransom Creek and compared with the effective FIS peak discharges. Table 5 is the summary output of peak discharges calculated by the USGS *StreamStats* software for Ransom Creek at selected FEMA FIS profile locations, while 0 provides the standard error associated with the peak discharge for each recurrence interval. The *Stream Stats* application uses the regional regression equations for New York which were published in 2006, while the FEMA FIS discharge calculations are based on the regional regression equations for New York which were published in 1991. The locations evaluated in *Stream Stats* were chosen based on the description provided in the FEMA FIS, but did not produce the same drainage area as reported in the FEMA FIS. As discussed later in this report, the *Stream Stats* results were only used to evaluate climate change implications, therefore the difference in drainage area was not considered to impact the hydrologic analysis.

Table 5. Summary of Peak Discharges at FEMA FIS Locations from *StreamStats*

Location	Drainage Area (mi2)	River Station (ft)	Peak Discharge (cfs)			
			10%	2%	1%	0.2%
At confluence with Tonawanda Creek	61.4	62+98	2,040	2,710	2,980	3,650
At Hopkins Road	60.6	187+90	2,090	2,780	3,070	3,760
Upstream of confluence of Black Creek	34.7	248+23	1,360	1,790	1,960	2,380
Upstream of confluence of Gott Creek	15.7	293+44	747	970	1,060	1,270
At Transit Road	15.5	553+64	738	959	1,050	1,250
At Goodrich Road	12.3	674+63	614	799	872	1,050

Source: (Lumia, R; Freehafer, D A; Smith, M J, 2006)

Table 6. USGS *StreamStats* Standard Errors for Full-Regression Equations

Standard Error (%)			
10%	2%	1%	0.2%
32.9	35.8	37.2	41.4

Source: (Lumia, R; Freehafer, D A; Smith, M J, 2006)

As the drainage basin has a significant amount of development, with greater than 15% of the drainage area being characterized as being developed, the peak discharges from *Stream Stats* should be revised with the urban flow computations used in the FEMA FIS. The parameters utilized in the urban flow computations for the FEMA FIS were not included in the available supporting documentation for the study.

Stream Stats was used to estimate many of the parameters needed in the urban flow computations, including the rural peak discharges using methods from the FEMA FIS study. Technical Paper 40 (Weather Bureau, 1961) was queried to evaluate the 2-year, 2-hour flow for Ransom Creek. The Basin Development Factor (BDF) was the only parameter for which an estimate could not be readily obtained. Additionally, the available information proved to be insufficient for reasonably estimating the BDF used in the FEMA FIS. Therefore, urban adjustments to the current *StreamStats* values could not be calculated to perform an appropriate comparison with the FIS values.

FEMA FIS peak discharges are greater than *StreamStats* peak discharges. As a result, the FEMA FIS peak discharge values were used in the hydraulic and hydrologic model simulations for this study to maintain consistency between the modeling outputs and the FEMA models.

In addition to peak flows of various recurrence intervals, *Stream Stats* calculates bank-full 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 bank-full discharge and bank-full channel width, depth, and cross-sectional area for streams across New York State. This regionally specific model of calculating bank-full statistics was determined to be more accurate when compared to a statewide (or pooled) model (Mulvihill, Baldigo, Miller, DeKoskie, & DuBois, 2009).

Bank-full discharge is defined as the flow that reaches the transition between the channel and its flood plain. Bank-full discharge is considered to be the most effective flow for moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphological characteristics of channels (Mulvihill et al. 2009). The bank-full width and depth of Ransom 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 & Silvey, 1996). The bank-full discharge is defined as the flow which reaches the transition between the channel and its floodplain (Mulvihill, Baldigo, Miller, DeKoskie, & DuBois, 2009). The bank-full width and depth describe the top width and depth of water at the bank-full discharge, respectively. Table 7 summarizes the estimated bank-full discharge, width, and depth at select locations along Ransom Creek as derived from the USGS *Stream Stats* program (Ries, et al., 2017).

Table 7. Summary of Ransom Creek Bank-Full Discharge Characteristics

Location	Drainage Area (mi^2)	River Station (ft)	Bank-Full Discharge (cfs)	Bank-Full Width (ft)	Bank-Full Depth (ft)
At confluence with Tonawanda Creek	61.4	62+98	929	73.4	3.29
At Hopkins Road	60.6	187+90	921	73	3.28
Upstream of confluence of Black Creek	34.7	248+23	601	56.9	2.92
Upstream of confluence of Gott Creek	15.7	293+44	305	38.1	2.54
At Transit Road	15.5	553+64	302	37.9	2.54
At Goodrich Road	12.3	674+63	255	34.3	2.42

Source: (Ries, et al., 2017)

Infrastructure

Road crossings over Ransom Creek include Tonawanda Creek Road, Hopkins Road, Millersport Highway, New Road, Glen Oaks Drive, Dodge Road, and Transit Road in the Town of Amherst; North French Road, Miles Road, Stahley Road, Heise Road, Clarence Center Road, Goodrich Road, and Kraus Road in the Town of Clarence. The crossing at Glen Oaks Drive consists of three culverts, whereas all other road crossings are bridges. Numerous other structures, such as pedestrian bridges, private drives, and golf course paths, also cross Ransom Creek in both the Town of Amherst and Town of Clarence. Table 8 provides a summary of those bridges which are owned by the New York State Department of Transportation (NYSDOT), while Table 9 summarizes those bridges owned by others. The Bridge Identification Number (BIN), bridge length and surface width information listed in these two tables is from the NYSDOT database (NYSDOT, 2019a). The existing FEMA flood profiles were utilized to estimate the hydraulic capacity was estimated for each of the bridge locations in these tables, based on the highest profile which can pass below the low chord, or does not show a significant rise across the bridge. Although bridges in the lower portions of Ransom Creek are overtopped by floodwaters, they are generally larger in size than the adjacent channel cross section, and are not considered to be overly constrictive because of the low elevations of the adjacent roads which allow large amounts of overbank flow (USACE Buffalo District, 1971). The FEMA FIS notes that the channel in the lower four miles of Ransom Creek is adequate to convey flood runoff from its own watershed areas, but that this area is often inundated by backwater from Tonawanda Creek.

In New York State, hydraulic and hydrologic regulations for bridges were developed by the NYSDOT. The NYSDOT guidelines require a factor of safety for bridges that cross waterways, known as freeboard. Freeboard is the additional capacity, usually expressed as a distance in feet, in a waterway above the calculated capacity required for a specified flood level, usually the base flood elevation. Freeboard compensates for the many unknown factors that could contribute to flood heights being greater than calculated, such as wave action, minor silt and debris deposits, the hydrological effect of urbanization of the watershed, etc. However, freeboard is not intended to compensate for higher floods expected under future climatic conditions, such as those due to sea-level rise or more extreme precipitation events.

According to the NYSDOT bridge manual (2019) for Region 5, which includes Niagara, Erie, Chautauqua, and Cattaraugus Counties, normal bridges are required to maintain the minimum hydraulic design criteria for projects crossing waterways of 2-feet of freeboard over the 2% annual chance flood elevation. For new and replacement bridges, current peak flows shall be increased to account for future projected peak flows based on the USGS *StreamStats* tool where current 2% peak flows shall be increased by 10% in Region 5. For critical bridges, the minimum hydraulic design criteria is 3-feet of freeboard over the 2% annual chance flood elevation. A critical bridge is considered to be vital infrastructure that the incapacity or destruction of such would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters (NYSDOT, 2019b) (United States Department of Homeland Security, 2010).

In the CRRA report (2018), the NYSDEC outlined infrastructure guidelines, most notably that the new freeboard recommendation for normal bridges is 2-feet of freeboard over the elevation of a flood with a 1% chance of being equaled or exceeded in a given year (i.e. base flood elevation) and 3-feet over for a critical structure (NYSDEC, 2018). When compared to current guidelines, the new CRRA climate change recommended freeboard is based on the 1% annual chance flood event water surface elevation, while the previous guidelines were based on the 2% annual chance flood event. This is a higher standard for freeboard. Various bridge crossings were identified as having a high risk for potentially being constriction points based on the FEMA Flood Insurance Rate Maps (FIRMs), community outreach, and site visits. Table 10 displays the 2% and 1% annual chance flood levels and their calculated difference at these potential constriction point bridge locations within the study area.

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 LW, Ameson LA, Hunt JH, Miller AC, 2012). The structures with bank-full widths that are wider than or close to the structures width indicate that water velocities have to slow and contract in order to pass through the structures, which can cause sediment depositional aggradation and the accumulation of sediment and debris. Aggradation can lead to the development of sediment and sand bars, which can cause upstream water surfaces to rise, increasing the potential for overtopping banks or backwater flooding. Since the bank-full discharge required for water surface elevations to reach the bank-full width is low (e.g. 80% ACE), the likelihood of relatively low flow events causing backwater and potential flooding upstream of these structures is fairly high. Table 11 summarizes the hydraulic capacity of potential constriction point bridges as identified by the FEMA Flood Insurance Rate Maps (FIRMs), community outreach, and site visits.

Table 8. NYSDOT Bridges/Culverts Crossing Ransom Creek

Roadway Carried	BIN	River Station (ft)	Bridge Length (ft)	Surface Width (ft)	Bank-full Width (ft)	Hydraulic Capacity (% Annual Chance)
Millersport Highway (Route 263)	1043790	138+00	81	80	73.4	Backwater from Tonawanda Creek
Transit Road (Route 78)	1030310	292+50	59	52	56.9	10

Notes:

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

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

Table 9. Non-NYSDOT Bridges/Culverts Crossing Ransom Creek

Roadway Carried	BIN	River Station (ft)	Owner	Bridge Length (ft)	Surface Width (ft)	Hydraulic Capacity (% Annual Chance)
Pedestrian Bridge	3362230	1+70	Town of Amherst	176	8.2	Backwater from Tonawanda Creek
Tonawanda Creek Road	3326240	1+70	Erie County	152	28	Backwater from Tonawanda Creek
Hopkins Road	3326300	90+80	Erie County	74	32	Backwater from Tonawanda Creek
New Road	3326360	154+20	Erie County	80.5	29.5	Backwater from Tonawanda Creek
Golf Course Path	-	187+10	-	-	-	<10
Golf Course Path	-	192+50	-	-	-	<10
Golf Course Path	-	198+30	-	-	-	<10
Golf Course Path	-	203+35	-	-	-	<10
Golf Course Path	-	210+35	-	-	-	<10
Golf Course Path	-	216+70	-	-	-	<10
Glen Oaks Drive	2267210	220+00	Town of Amherst	69	-	1[a]
Dodge Road	3326330	246+70	Erie County	56.7	34	<10
N. French Road/ County Road	3326670	304+35	Erie County	38	29.6	<10
Miles Road	2213080	335+50	Town of Clarence	40	28.9	2[b]
Private Pedestrian Bridge	-	347+80	-	-	-	1
Private Pedestrian Bridge	-	349+20	-	-	-	<10
Stahley Road	3326340	441+50	Erie County	37	30.4	10
Heise Road	3326690	480+20	Erie County	33	24.5	<10
Nature Lane	-	511+90	-	-	-	<10
Pedestrian Bridge	-	517+60	-	-	-	<10
RailRoad	-	518+75	-	-	-	0.2
Clarence Center Road	3326440	542+80	Erie County	63	31.5	10
Private Road	-	546+50	-	-	-	<10
Pedestrian Bridge	-	550+10	-	-	-	<10
Private Drive	-	553+00	-	-	-	<10
Goodrich Road/ Pedestrian Bridge	3326400	559+90	Erie County	33	26	<10
Pedestrian Bridge	-	570+10	-	-	-	<10
Pedestrian Bridge	-	595+80	-	-	-	10[a]
Pedestrian Bridge	-	626+40	-	-	-	<10
Kraus Road	2213100	673+50	Town of Clarence	25	24	<10

Notes:

a) Roadway embankments overtopped despite additional available hydraulic capacity through the structure opening

b) Bridge has been modified since FIS, and now has a hydraulic capacity greater than the 0.2% annual chance event

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

Table 10. FEMA FIS Profile 2 and 1% Annual Chance Flood Hazard Levels with Differences at Potential Constriction Point Bridges Crossing Ransom Creek

Bridge Crossing	River Station (ft)	2% Water Surface Elevation (ft NAVD88)	1% Water Surface Elevation (ft NAVD88)	Difference in Water Surface Elevations (ft)
New Road	154+20	579.5	580.4	0.9
Glen Oaks Drive	220+00	581.5	582.1	0.6
Miles Road	335+50	591.5	592.4	0.9

Source: (FEMA, 2019a)

Table 11. Hydraulic Capacity of Potential Constriction Point Bridges Crossing Ransom Creek

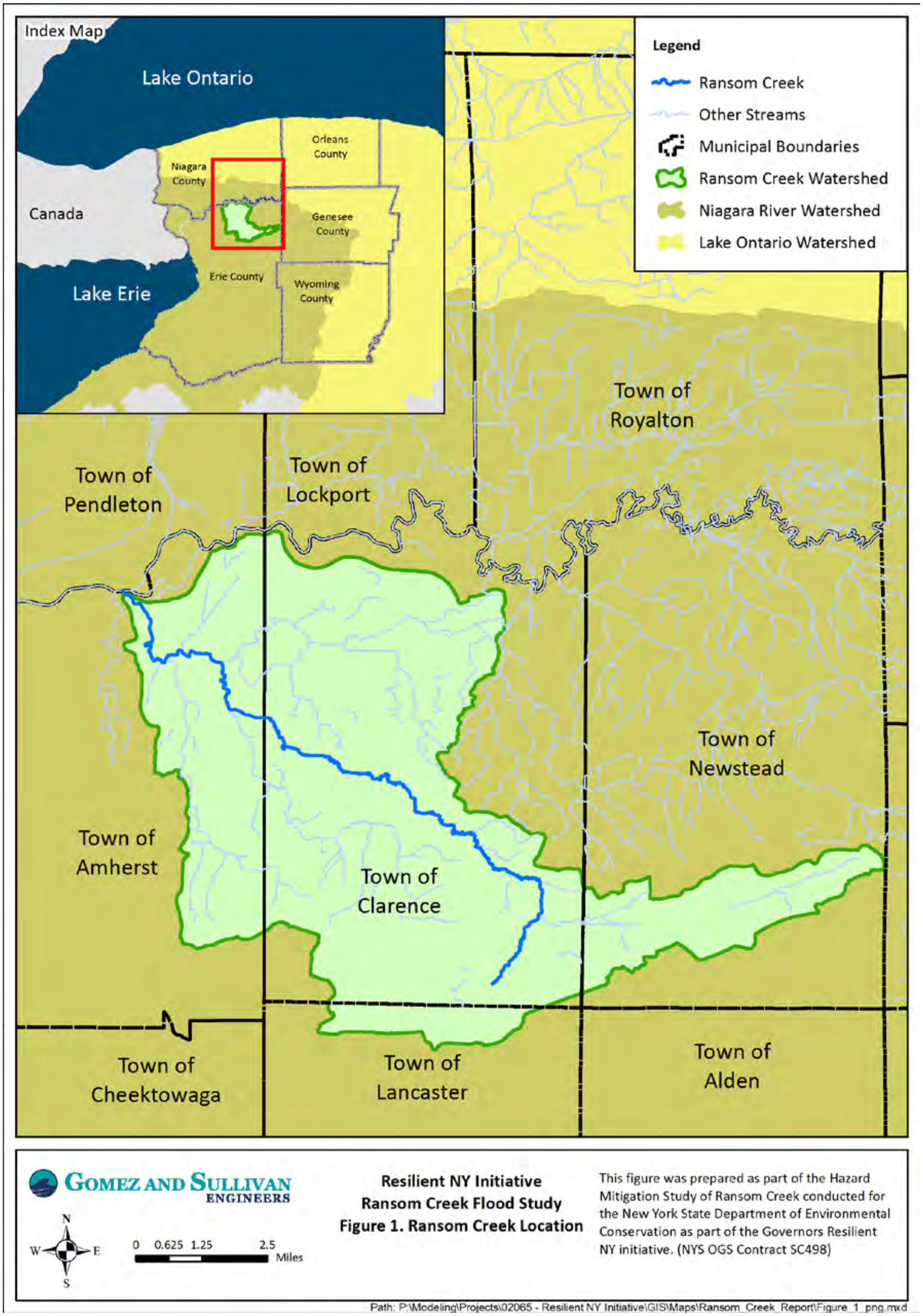
Roadway Carried	Structure Type	River Station (ft)	Structure Width (ft)	Bank-full Width (ft)[1]	Bank-full Discharge (cfs)	Annual Chance Flood Event Equivalent[1]
New Road	Bridge	154+20	80.5	73.0	946	80%
Glen Oaks Drive	Culverts	220+00	69	56.9	626	80%
Miles Road	Bridge	335+50	40	37.9	344	80%

Notes:

1. Annual Chance Flood Event Equivalent describes the equivalent annual chance flood event for the given bankfull discharge as calculated by the USGS *StreamStats* application. The 80% annual chance flood event is equal to a 1.25-year recurrence interval.

Source: (Ries, et al., 2017), (Lumia, R; Freehafer, D A; Smith, M J, 2006)

Figure 1. Ransom Creek Location



Resilient NY Initiative
Ransom Creek Flood Study
Figure 1. Ransom Creek Location

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

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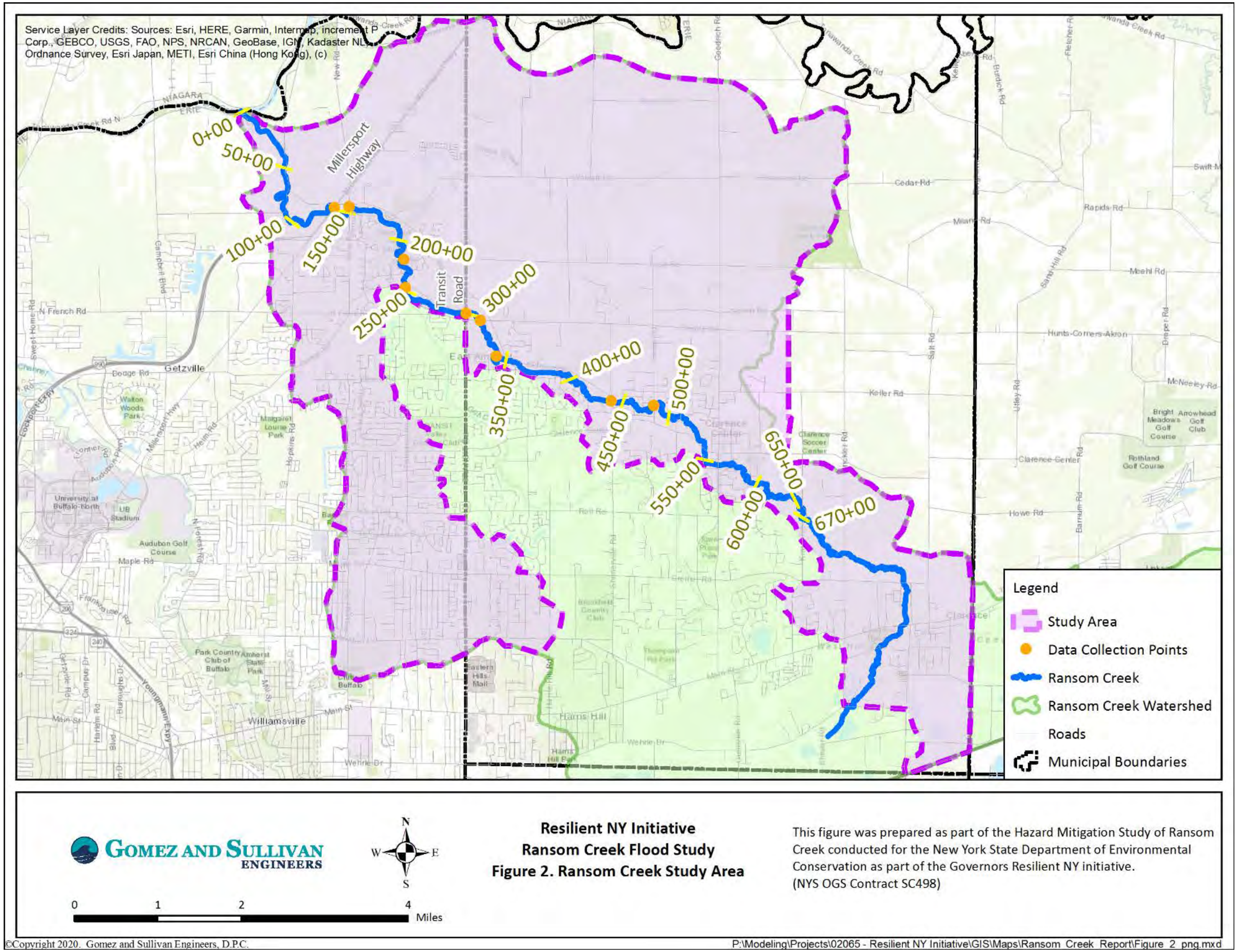
Figure 2. Ransom Creek Study Area



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(NYS OGS Contract SC498)

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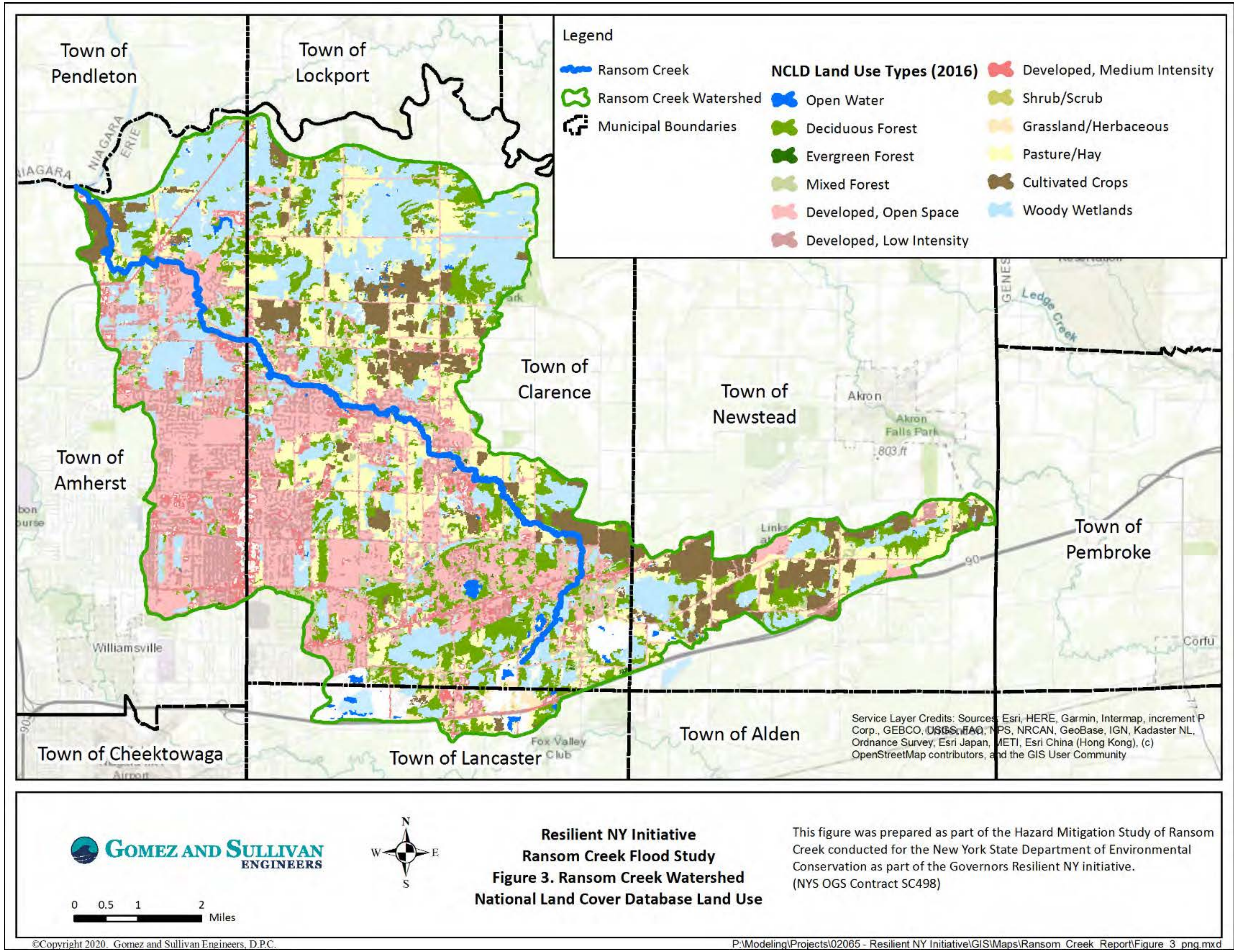
Figure 3. Ransom Creek Watershed National Land Cover Database Land Use



Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

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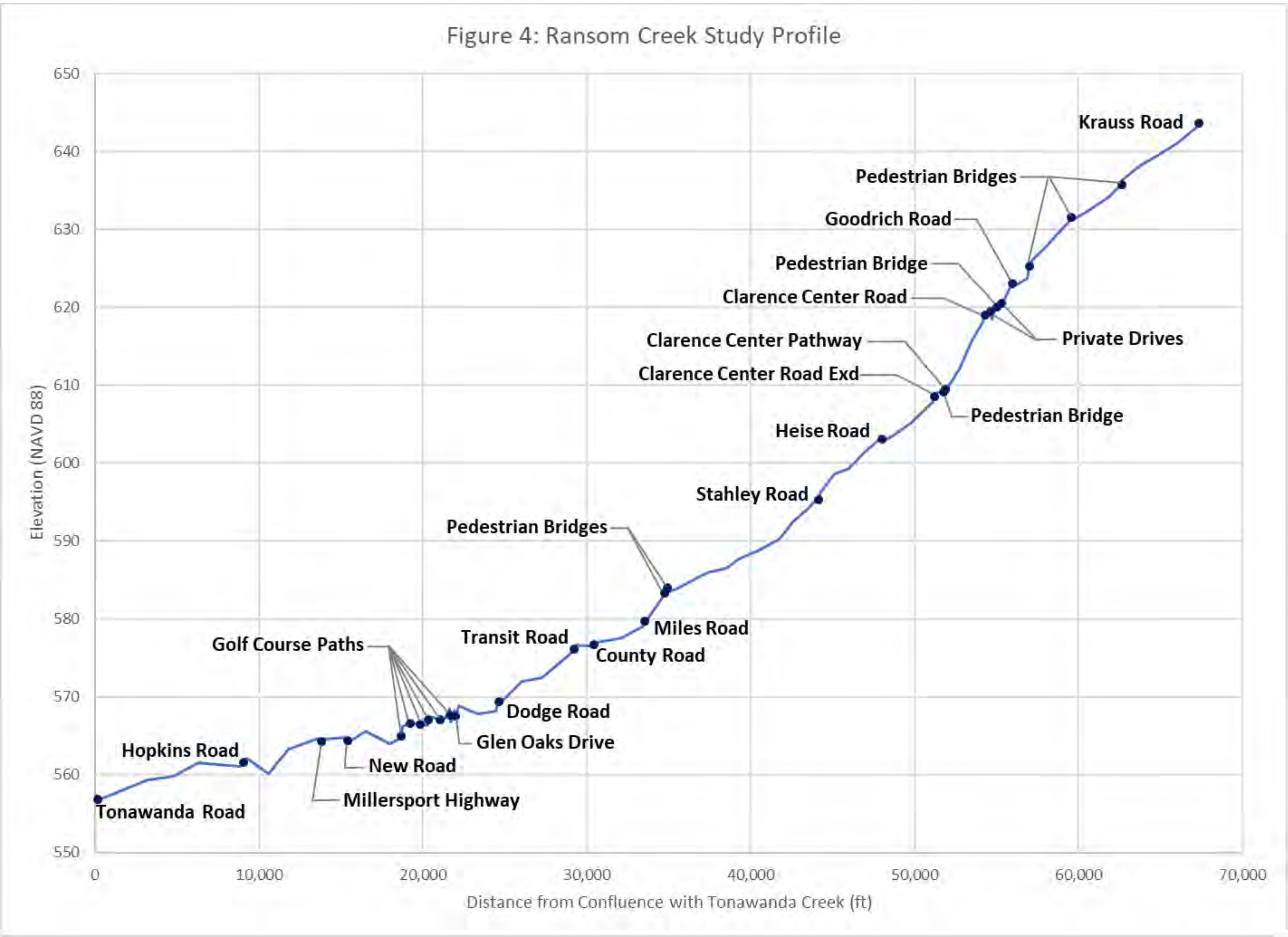
Figure 4. Ransom Creek Channel Profile



Climate Change Implications

Future Projected Discharges

In New York State, climate change is expected to exacerbate flooding due to projected increases of 1-8% in total annual precipitation coupled with increases in the frequency, intensity, and duration of extreme precipitation events (events with more than 1, 2, or 4 inches of rainfall) (Rosenzweig, et al., 2011). In response to these projected changes in climate, New York State passed the Community Risk and Resiliency Act (CRRA) in 2014. In accordance with the guidelines of the CRRA, the NYSDEC released the *New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act* (2018) draft report. In the report, two methods for estimating projected future discharges were discussed: an end of design life multiplier and the USGS *FutureFlow* Explorer map-based web application (NYSDEC, 2018).

The end of design life multiplier is described as an adjustment to current peak flow values by multiplying relevant peak flow parameters by a factor specific to the expected service life of the structure and geographic location of the project to estimate future peak flow conditions. For Western New York, the recommended design-flow multiplier is 10% for an end of design life of 2025-2100 (NYSDEC, 2018).

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

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

Results of the climate models and the RCPs are averaged for three future periods, from 2025 to 2049, 2050 to 2074, and 2075 to 2099. The downscaled climate data for each model and the RCP scenario averaged over these 25-year periods were obtained from the developers of the USGS Climate Change Viewer (https://www.fs.usda.gov/ccrc/tools/ national-climate-change-viewer). 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 & Hostetler, 2017). The predictions of future mean annual runoff, obtained from the USGS *FutureFlow* software were used with the USGS regional regression equations and the computed basin characteristics, described in previous sections, to compute the expected future peak flows. The USGS *FutureFlow* software provides five estimates of the mean annual runoff for each RCP and future time period, one corresponding to each of the five climate models used. Future flows were computed for each of the five models corresponding to RCP 8.5 and the 2075 to 2099 time period, and the mean computed from the five results are displayed. **Error! Reference**

source not found. is a summary of the USGS *FutureFlow* projected peak discharges at the FEMA FIS locations.

Table 12. Summary of Peak Discharges at FEMA FIS Locations from *FutureFlow*

Location	Drainage Area (mi2)	River Station (ft)	Peak Discharge (cfs)			
			10%	2%	1%	0.2%
At confluence with Tonawanda Creek	61.4	62+98	2,139	2,823	3,100	3,780
At Hopkins Road	60.6	187+90	2,186	2,898	3,188	3,901
Upstream of confluence of Black Creek	34.7	248+23	1,431	1,872	2,049	2,478
Upstream of confluence of Gott Creek	15.7	293+44	777	1,005	1,094	1,307
At Transit Road	15.5	553+64	767	993	1,081	1,292
At Goodrich Road	12.3	674+63	636	825	899	1,075

The Ransom Creek drainage basin is considered to be urbanized currently, and development within the basin is likely to increase in the future. Therefore, the future flows should be adjusted to evaluate urban runoff. As previously discussed, insufficient information is available to estimate the BDF used in the urban flow computations for the FEMA FIS. Therefore, this study estimated future urban flows by applying an adjustment to the discharges presented in the FEMA FIS. Table 13 provides a comparison of the current 1% annual change peak stream flows calculated using the USGS *StreamStats* software and the mean predicted future discharge calculated using the USGS *FutureFlow* software at each of the discharge locations included in the effective FIS. The ratio of the discharge from *Stream Stats* and *Future Flow* was averaged across all locations for each recurrence interval. This future discharge ratio was then raised to the exponent applied to rural peak discharges in the urban flow computations to create an adjusted future discharge ratio. Finally, the adjusted future discharge ratio was applied to the FEMA FIS flows (see Table 4). Table 14 provides the ratio and the adjusted ratio, while Table 15 provides the future urban flows. The HEC-RAS model simulation results for the future condition model parameters using the future projected discharge values shown in Table 15 are similar to the base condition model output with the only difference being future projected water surface elevations are up to 0.3 feet higher due to the increased discharges.

Table 13. Comparison of Rural 1% Annual Chance Current and Future Discharges at Ransom Creek

Location	Drainage Area (mi2)	River Station (ft)	Current Stream Stats 1% Annual Chance Discharge (cfs)	Predicted Future Flow 1% Annual Chance Discharge (cfs)	Change (%)
At confluence with Tonawanda Creek	59.5	62+98	2,980	3,100	4.0%
At Hopkins Road	45.7	187+90	3,070	3,188	3.8%
Upstream of confluence of Black Creek	30.5	248+23	1,960	2,049	4.5%
Upstream of confluence of Gott Creek	18.1	293+44	1060	1,094	3.2%
At Transit Road	17.0	553+64	1050	1,081	3.0%
At Goodrich Road	14.0	674+63	872	899	3.1%

Table 14. Summary of Future Peak Discharge Adjustment Factors for Ransom Creek

Parameter	Annual Percent Chance			
	10%	2%	1%	0.2%
Future Discharge Ratio	1.04	1.04	1.04	1.03
Adjusted Future Discharge Ratio	1.03	1.02	1.02	1.02

Table 15. Summary of Estimated Future Peak Discharges for Ransom Creek based on 2019 Effective FEMA FIS Discharges

Location	Drainage Area (mi^2)	River Station (ft)	Peak Discharge (cfs)			
			10%	2%	1%	0.2%
At confluence with Tonawanda Creek	59.5	62+98	2,560	3,540	3,990	5,450
At Hopkins Road	45.7	187+90	2,360	3,270	5,240	8,080
Upstream of confluence of Black Creek	30.5	248+23	1,680	2,360	2,650	3,340
Upstream of confluence of Gott Creek	18.1	293+44	1,060	1,480	1,670	2,090
At Transit Road	17.0	553+64	1,000	1,390	1,570	1,970
At Goodrich Road	14.0	674+63	960	1,360	1,540	1,960

Flooding Characteristics

Flooding History

Flooding occurs along most of the Ransom Creek, but the most widespread flooding is generally in the lower portions of the reach to the west of Transit Road. Ransom Creek is considered to have adequate channel capacity to convey the runoff from its own watershed. However, the drainage divides between the Tonawanda, Ransom, Black and Gott Creeks are low, and their flood flows often merge together. As a result, Ransom Creek experiences extensive flooding in the lower 5.6 miles of the reach (west of Transit Road), as it is tasked with conveying major flood overflows from Tonawanda Creek. The 1960 flood event is generally considered to be the most significant flood along Ransom Creek in the Towns of Amherst and Clarence. The flow corresponded to approximately a 5% annual chance event, and inundated a total of 3,220 acres within the town of Amherst with most flood damage losses being agricultural. More recently in December 2013, heavy rainfall and melting snow caused residential flooding, road closures, and power outages (Jagord, 2013).

Flood Risk Assessment

Flood Mitigation Analysis

Hydraulic analysis of Ransom Creek was conducted using the HEC-RAS program. The HEC-RAS computer program was written by the USACE Hydrologic Engineering Center 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, 2016a).

Hydraulic modeling of Ransom Creek in the Town of Amherst was completed under contract for FEMA as part of the original June 1984 FIS for the Town of Amherst, and revised for the second revision in October 1992 (FEMA, 1992). Hydraulic modeling of Ransom Creek in the Town of Clarence was completed under contract for FEMA as part of the original October 1981 FIS for the Town of Clarence, and restudied from Transit Road to a point approximately 1.3 miles upstream of Goodrich Road for the first revision in March 1996 (FEMA, 1996). Hydraulic modeling of Ransom Creek in the Towns of Amherst and Clarence was completed under contract for FEMA as part of the original September 2008 countywide FIS for Erie County, and restudied for the revised June 2019 countywide FIS (FEMA, 2019a). The hydraulic model for the Towns of Amherst and Clarence for the countywide analysis was produced in a georeferenced HEC-RAS format. The county wide analysis extended the original analysis and flood profile an additional 0.8 miles upstream of Goodrich Road, creating a total model length of approximately 12.8 miles from the mouth of Ransom Creek in the Town of Amherst to the Krauss Road crossing in the Town of Clarence. The hydraulic model covers the majority of the high-risk flood areas along Ransom Creek in the Towns of Amherst and Clarence, and includes fourteen road crossings, and various other pedestrian bridges, private drives, and golf course paths.

A duplicate model was run with the version of HEC-RAS used for the countywide analysis (Version 3.1.3) and results were compared to the FEMA FIS to ensure the correct model files were received. The remainder of this study utilized the most recent version of HEC-RAS (Version 5.0.7). Next, a base condition model was produced, which corrected errors and updated the original H&H data based on field assessments of Ransom Creek, and currently available topographic datasets. The following changes were made in the development of the base condition model:

- Updated the terrain with the most current available bare earth light detection and ranging (LiDAR) digital elevation model from FEMA
- Compared cross-section geometry between the existing hydraulic models and the current terrain data
- Adjusted cross-section geometry, for areas outside of the stream channel throughout the model
- Adjusted ineffective flow areas to account for floodplain expansion and contraction with terrain
- Verified structure geometry including channel characteristics for critical hydraulic structures based on field measurements
- For structures where existing modeling could not be verified, updated structure geometry based on as-built drawings and channel geometry based on survey collection

The base condition model was then compared to the duplicate model, and the effective FEMA FIS elevation profiles to validate the model. After the base condition model was verified, it was then used to develop alternative condition models to simulate potential flood mitigation strategies. The simulation results of the alternative conditions were evaluated based on their reduction in water surface elevations relative to the base condition model. As the potential flood mitigation strategies are, at this point, preliminary, inundation mapping was not developed from the computed water surface profiles for each potential mitigation alternative. Inundation shown on figures within this report reflects that of the effective FEMA FIS for Erie County. The effectiveness of each potential mitigation strategy was evaluated based on reduction in water surface elevations. In addition to reduced water surface elevations at the inundated structures, some structures may be removed from the inundation for a given annual chance exceedance event by implementing the mitigation strategies.

Cost Estimate Analysis

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

Where the mitigation analyses require the acquisition of land to construct, the parcel or parcels where the potential project is to be constructed were assumed to be purchased in their entirety. However, due to the highly variable nature of land costs, the cost of the property was not included in the cost estimate, but the cost estimate does include legal and survey fees associated with acquiring the properties. For the purposes of developing these cost estimates, it was assumed that engineering, legal and administrative costs equal to 25% of the construction cost would be incurred. These costs are intended to account for the cost of performing the final design of the mitigation alternative and provide the appropriate oversight of construction. Due to the preliminary nature of the mitigation alternatives evaluated as part of this study, the cost estimates also include a 30% contingency.

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

High Risk Areas

Based on the FEMA FIS, NCEI storm events database, historical flood reports, and stakeholder input from engagement meetings, three areas along Ransom Creek were identified as high-risk flood areas in the Towns of Amherst and Clarence. Although these do not include all areas of risk along Ransom Creek, they represent the areas with the highest risk of potential damage to structures. Ice jamming was not identified as a primary cause of flooding along Ransom Creek, and therefore was not further evaluated in this study.

High Flood Risk Area #1: New Road (Station 138+64 to 186+98)

High Risk Area #1 is the residential area east of New Road and north of Old Oak Post Road, in the Town of Amherst. The effective FIS and FIRMs indicate that the water surface elevations near New Road bridge are highly influenced by backwater from Tonawanda Creek, with no noticeable rise in water surface elevation at the bridge despite all evaluated flows contacting the low chord of the bridge. During the public outreach it was identified that the nearly ninety-degree bend in the river immediately downstream of this bridge (Photo 1) has required debris management and bank stabilization (rip-rap) in the past. Approximately 100 homes are located in the area immediately upstream of the New Road bridge over Ransom Creek. (Figure 5). The current FIRM indicates that all of the roads in this area would be inundated, but that these homes would not be impacted. The New Road bridge is owned and maintained by Erie County.

Photo 1. Severe Bend in Ransom Creek Downstream of New Road Bridge

Figure 5. Ransom Creek High Flood Risk Area #1: New Road

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

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High Flood Risk Area #2: Glen Oaks Drive (Station 220+82 to 292+04)

High Risk Area #2 is the residential area south of Glen Oaks Drive to the west of Transit Road in the Town of Amherst. A review of the effective FIS profile indicates that the culverts at Glen Oaks Drive are able pass the 1% annual chance flood discharge without completely submerging the culvert inlets (Photo 2). However, the rise in water surface elevation upstream of these culverts ranges from approximately 0.6 feet to 1.1 feet depending on the discharge, suggesting that the culverts cause backwater which could exacerbate flooding upstream of Glen Oaks Drive. A pebble count was performed just upstream of the Glen Oaks Culverts, with silt/sand being the main channel substrate, indicating that flow velocities must be significantly reduced upstream of the culverts. As flow velocities are reduced, the sediments suspended within the flow will start to settle to the channel bottom, with larger sediments falling out first, and smaller sediments falling out last. During the public outreach the need for dredging at Glen Oaks Drive was noted, and the results of the pebble count confirm that sedimentation is an issue in this area. The culverts at Glen Oaks Drive are owned and maintained by the Town of Amherst. Additionally, Dodge road in this area has been closed due to flooding in the past (WGRZ, 2013). The Dodge Road bridge is owned and maintained by Erie County. Approximately 100 homes are located in the area immediately upstream of the Glen Oaks Drive bridge over Ransom Creek, and an additional 50 homes are located along Dodge Road between the Dodge Road/ and Transit Road crossings over Ransom Creek. Many of the homes in this area are shown in the FIRM to be inundated under the 1% annual chance flood. (Figure 6). This risk area includes one repetitive loss property in the Town of Amherst, which has made four claims since 1998 (FEMA, 2019b).

Photo 2. Downstream Face of Glen Oaks Drive Culverts over Ransom Creek

Figure 6. Ransom Creek High Flood Risk Area #2: Glen Oaks Drive

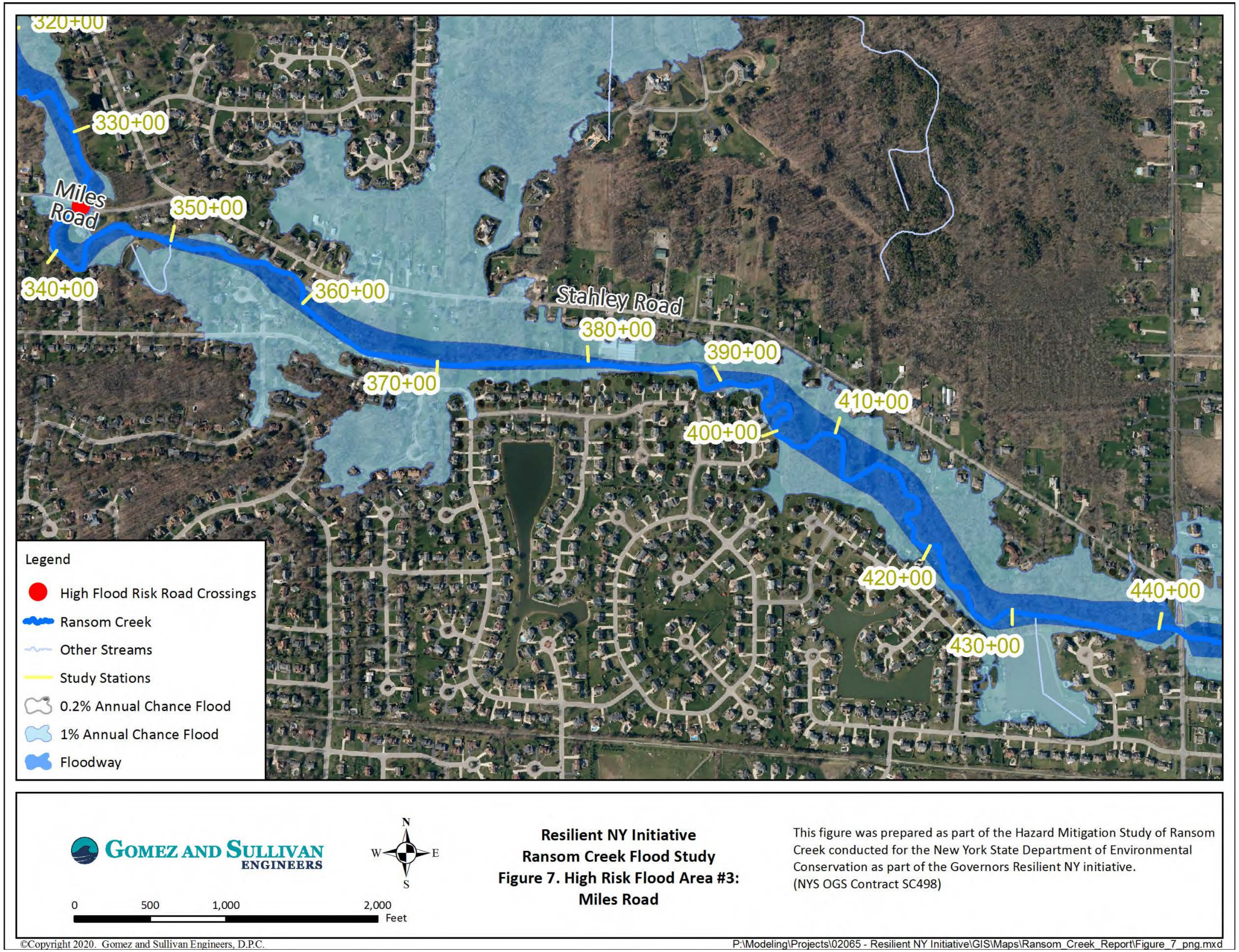
This figure was prepared as part of the Hazard Mitigation Study of Ransom Creek conducted for the New York State Department of Environmental Conservation as part of the Governors Resilient NY initiative. (NYS OGS Contract SC498)

High Flood Risk Area #3: Miles Road (Station 335+98 to 441+14)

High Flood Risk Area #3 is the residential area to the south of Stahley Road between the Miles Road and Stahley Road crossings over Ransom Creek, in the Town of Clarence. A review of the effective FIS profile indicates a rise in water surface elevation upstream of the Miles Road crossing (Photo 3) which ranges from 1.5 feet to 3.1 feet depending on the discharge. Additionally, the effective FIS profile indicates that two footbridges, located approximately 0.2 miles upstream of Miles Road and 150 feet apart, result in a combined rise in water surface elevation upstream ranging from 1.6 feet to 2.2 feet depending on the discharge. The effective FIRM indicates these footbridges span a natural channel constriction, which could contribute to the increased water surface elevations. Approximately 175 homes are located within the inundation area between the Miles Road and Stahley Road. (Figure 7). The Miles Road bridge is owned and maintained by the Town of Clarence, while the two footbridges are privately owned.

Photo 3. Downstream Face of Miles Road Bridge over Ransom Creek

Figure 7. Ransom Creek High Flood Risk Area #3: Miles Road



Resilient NY Initiative
Ransom Creek Flood Study
Figure 7. High Risk Flood Area #3:
Miles Road

This figure was prepared as part of the Hazard Mitigation Study of Ransom Creek conducted for the New York State Department of Environmental Conservation as part of the Governors Resilient NY initiative.
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Mitigation Alternatives

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

High Risk Area #1

Alternative #1-1: Create a High Flow Channel Downstream of New Road (Station 139+68 to 151+63)

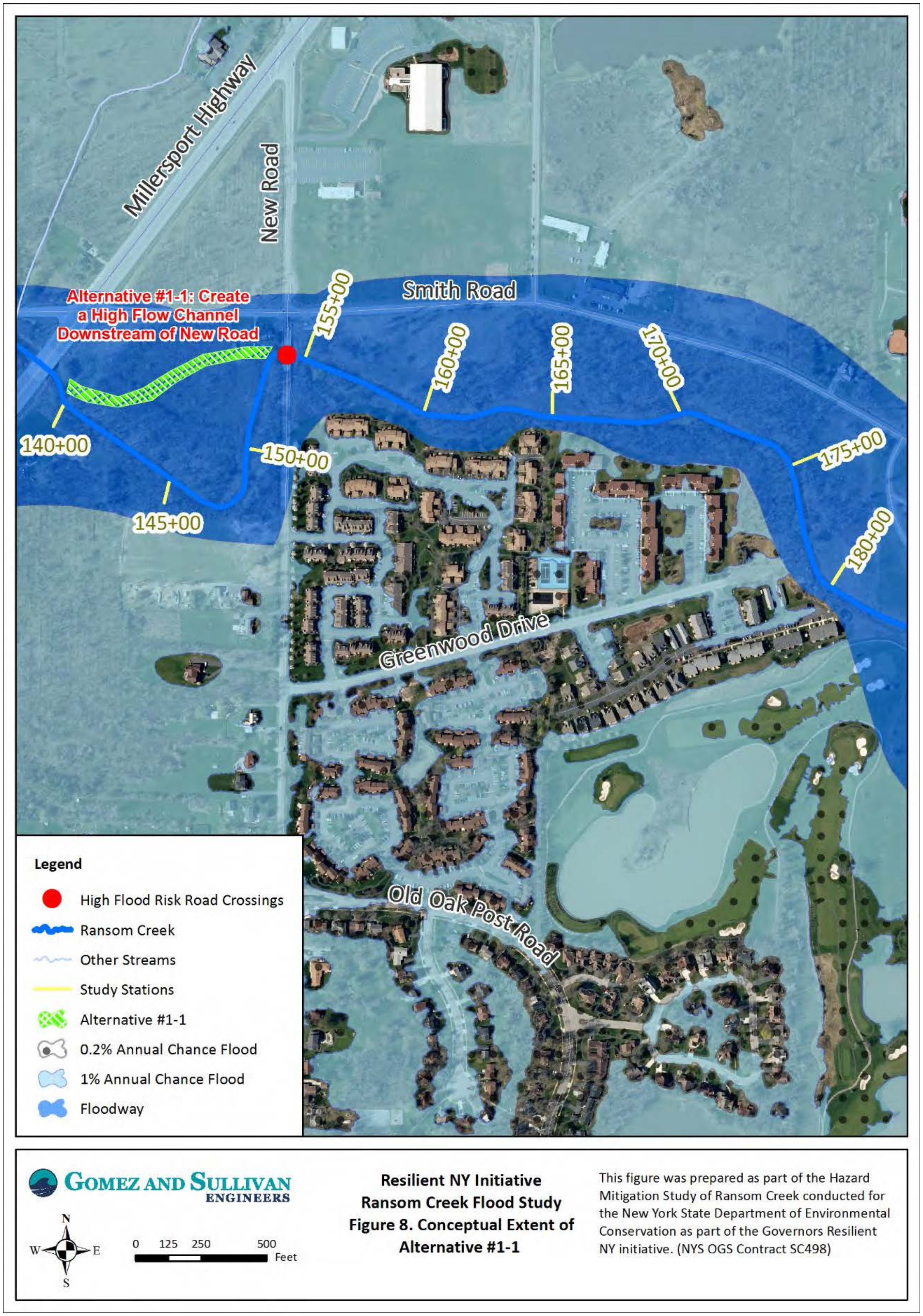
Based on community input the ninety-degree bend in Ransom Creek downstream of New Road causes debris management issues which could be exacerbating flooding in the area. Over time streams migrate within the floodplain, toward more stable and lower energy flow paths, and the need to provide rip-rap for bank stabilization at the bend in Ransom Creek is an indicator that the channel is attempting to form an alternate flow path during high flow events. The effective FIS flood profile and corrected base condition hydraulic model both indicate that residential flooding occurs during the 0.2% annual chance discharge, and that road closures are necessary for the 10% chance annual discharge. Most of the land on the right overbank between New Road and Millersport Highway is undeveloped, except for one residence. This land generally sits at a higher elevation than the bank-full elevation of Ransom Creek.

This alternative is intended to reduce the meander in the stream and associated flooding during high flow events by creating a high flow channel in the right overbank area downstream of the New Road bridge. The high flow channel not intended to convey typical daily flows, but provide improved floodplain access during high flow events. This modification is expected to decrease computed flood elevations in the New Road area. Additionally, this high flow channel would improve hydraulics at the bend downstream of New Road decreasing the need for bank stabilization and debris management.

The modeled alternative consists of creating a high flow channel between New Road and Millersport Highway that is approximately 75 feet wide and whose bottom is approximately 0.5 ft above the normal bank-full elevation, resulting in the excavation of approximately 9,900 cubic yards of material. This conceptual alternative assumed the removal of the residence located immediately downstream of the New Road bridge. The conceptual extent of the high flow channel is shown in Figure 8. Hydraulic modeling of this alternative indicates that creating the high flow channel is expected to provide a minor improvement (less than or equal to approximately 0.1 feet) in water surface elevations for the flood discharge events modeled (existing or estimated future flood discharges), as shown in Figure 9. As such, this alternative is not expected to decrease the number of houses or roadways impacted by flooding. The alternative is expected to have the greatest impact on the 10% annual chance discharge with decreased impact as the discharge increases. This area is highly influenced by backwater from Tonawanda Creek. As such, modeling in this area also considered a scenario where Ransom Creek discharges were not being influenced by significant flows in Tonawanda Creek. While this scenario resulted in more significant water surface elevation reductions due to the creation of a high flow channel, the scenario does not change the conclusions regarding the effectiveness of the alternative with regards to reducing flooding impacts. With that said, the creation of a high flow channel may still decrease the need for bank stabilization and debris management at the bend in Ransom Creek. Relative to all of the evaluated alternatives, this alternative is considered to have insignificant impacts on flooding upstream.

The rough order of magnitude cost for this alternative is $1.9 million, not including the cost to acquire the land required to construct the mitigation alternative. This cost estimate however does include land acquisition costs for survey, appraisal, and engineering coordination for the parcel upon which the high flow channel would be constructed. The majority of the costs for this mitigation alternative relate to the removal and disposal of fill and the creation and planting of wetland within the high flow channel.

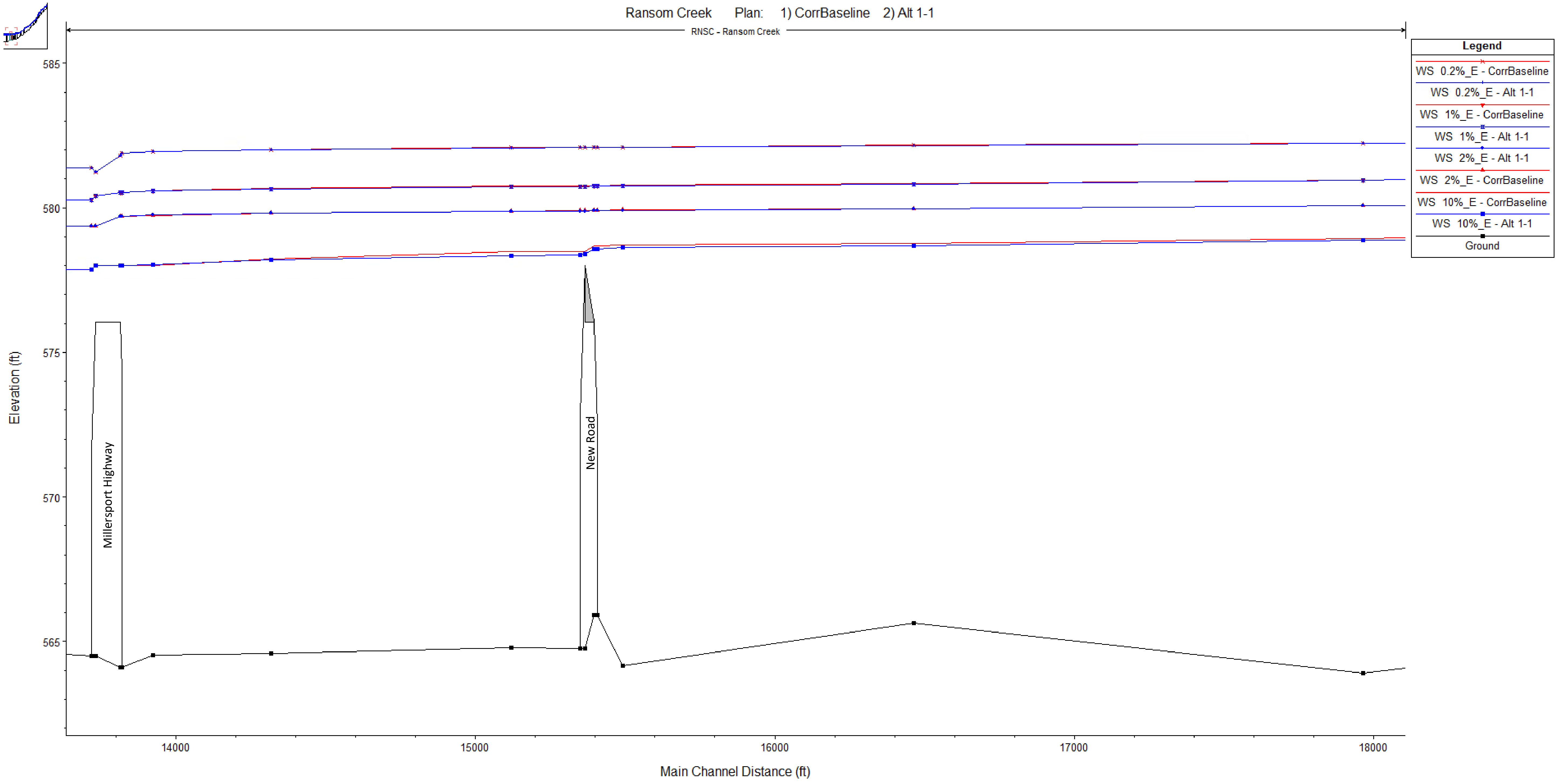
Figure 8. Conceptual Extent of Alternative #1-1



Resilient NY Initiative
Ransom Creek Flood Study
Figure 8. Conceptual Extent of Alternative #1-1

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

Figure 9. Comparison of Computed Water Surface Elevations between Corrected Baseline Conditions and Create a High Flow Channel Downstream of New Road (Alternative #1-1)



Alternative #1-2: Create a Flood Bench Downstream of New Road (Station 139+68 to 151+63)

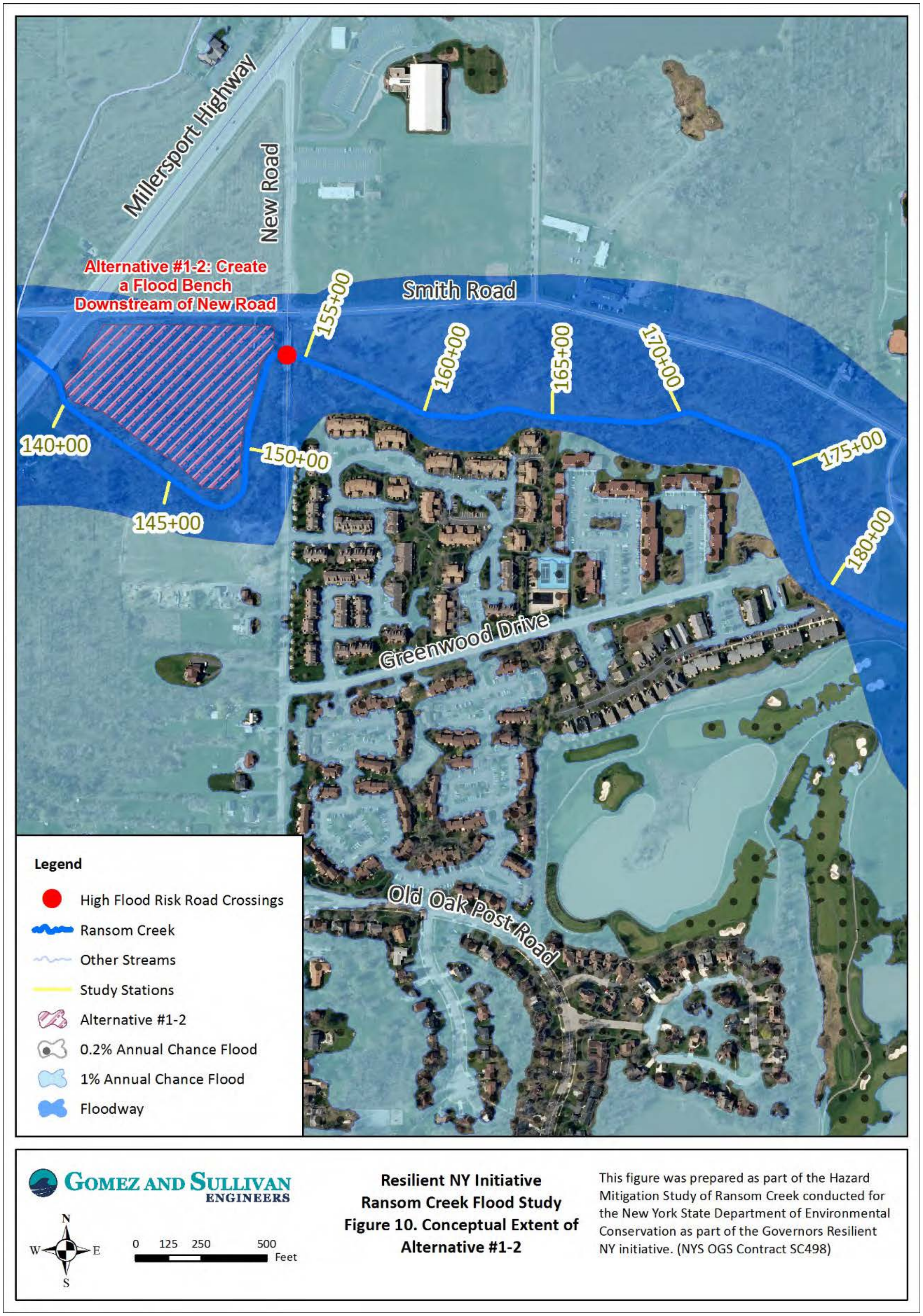
The effective FIS flood profile and corrected base condition hydraulic model both indicate extensive residential and street flooding in the area upstream of New Road. The corrected base condition hydraulic model indicates that a significant portion of the total conveyance is provided in the overbank areas both upstream and downstream of New Road. Most of the land on the right overbank between New Road and Millersport Highway is undeveloped, except for one residence. This land generally sits at a higher elevation than the bank-full elevation of Ransom Creek.

This alternative would increase flow area within the floodplain by lowering the elevation of land in the right overbank downstream of New Road. This modification is intended to decrease computed flood elevations in the New Road area. Additionally, this flood bench would improve hydraulics at the bend downstream of New Road decreasing the need for bank stabilization and debris management.

The modeled alternative consists of removing the residence located immediately downstream of the New Road bridge and lowering the existing topography to an elevation of 573 ft, approximately 0.5 ft above the normal bank-full elevation for the entire right overbank area south of Smith Road between New Road and Millersport Highway. The conceptual extent of the flood bench is shown in Figure 10, and includes excavating approximately 68,000 cubic yards of material over nine acres of land. Hydraulic modeling of this alternative indicates that creating the flood bench is expected to provide a minor improvement (less than or equal to 0.1 feet) in water surface elevations for events equal to or exceeding the 2% annual chance discharge (both existing and estimated future flood discharges). The flood bench is expected to provide an improvement during the 10% annual chance flood event of approximately 0.2 feet in the immediate vicinity of New Road (Figure 11), but the benefit diminishes to 0.1 feet approximately 3,200 feet upstream of New Road under existing and estimated future flood flow conditions. These results are not expected to decrease the number of houses or roadways impacted by flooding. This area is highly influenced by backwater from Tonawanda Creek. As such, modeling in this area also considered a scenario where Ransom Creek discharges were not being influenced by significant flows in Tonawanda Creek. While this scenario resulted in more significant water surface elevation reductions due to the creation of a flood bench, the scenario does not change the conclusions regarding the effectiveness of the alternative with regards to reducing flooding impacts. With that said, the creation of a flood bench may still decrease the need for bank stabilization and debris management at the bend in Ransom Creek. Relative to all of the evaluated alternatives, this alternative is considered to have insignificant impacts on flooding upstream.

The rough order of magnitude cost for this alternative is $5.2 million, not including the cost to acquire the land required to construct the mitigation alternative. This cost estimate however does include land acquisition costs for survey, appraisal, and engineering coordination for the parcel upon which the flood bench would be constructed. The majority of the costs for this mitigation alternative relate to the removal and disposal of fill and the creation and planting of wetland within the floodplain bench.

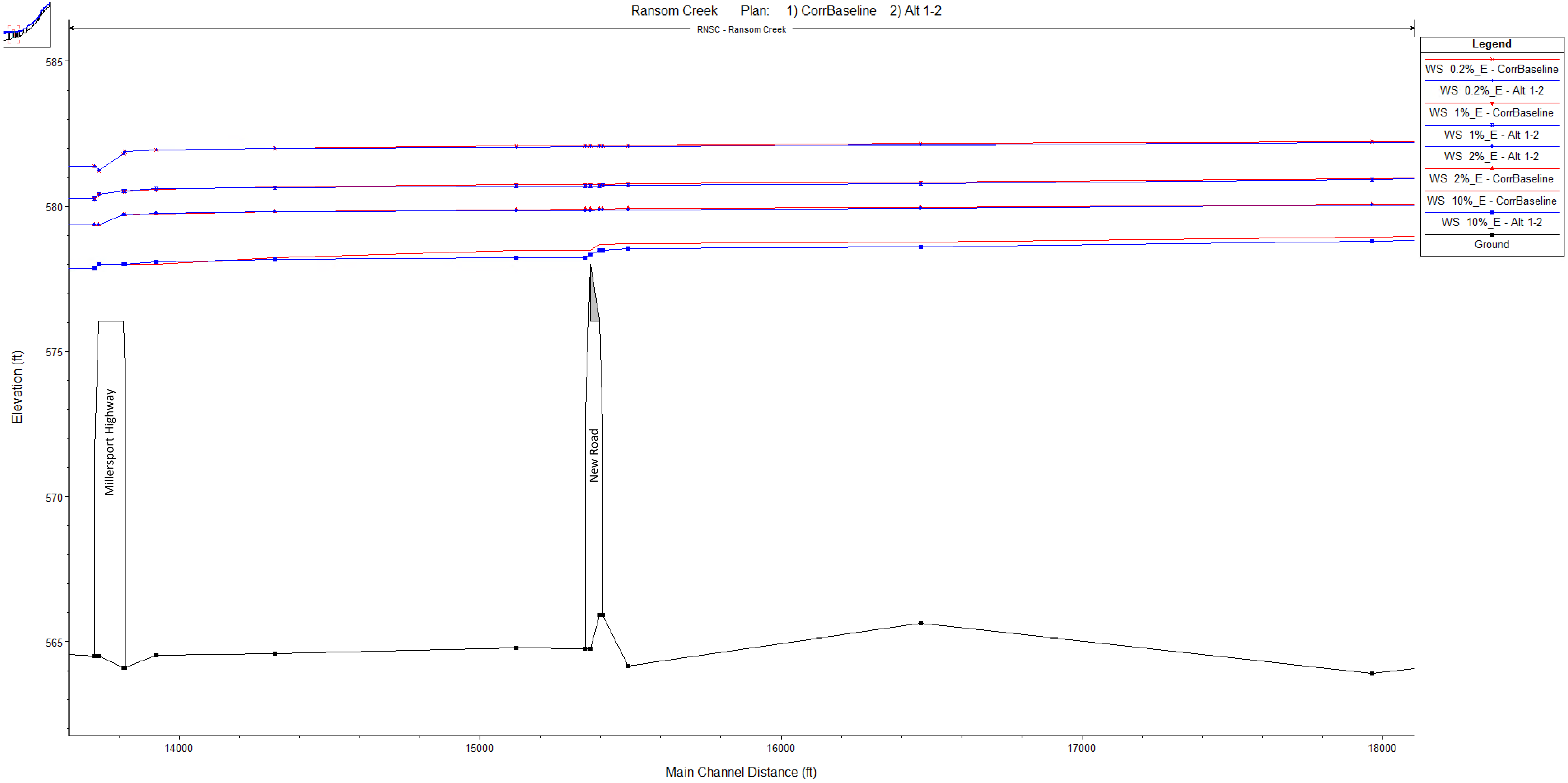
Figure 10. Conceptual Extent of Alternative #1-2



Resilient NY Initiative
Ransom Creek Flood Study
Figure 10. Conceptual Extent of Alternative #1-2

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

Figure 11. Comparison of Computed Water Surface Elevations between Corrected Baseline Conditions and Create a Flood Bench Downstream of New Road (Alternative #1-2)



Alternative #1-3: Modify New Road Bridge (Station 154+20)

The New Road bridge is owned and maintained by Erie County. The corrected base condition hydraulic model indicates that the bridge at New Road causes an increase in water surface elevations upstream of the road of approximately 0.2 feet for the 10% annual chance discharge, but there is no measurable increase in upstream water surface elevations for lower annual chance discharges. Modeling of the current base condition, and the two alternatives discussed above, indicate that water surface elevations downstream of the bridge are at or above the low chord elevation for the New Road bridge for flows corresponding to the 10% annual chance discharge and higher. For higher flows, such as the 2%, 1%, and 0.2% annual chance discharges, the roadway is expected to overtop, with up to approximately 95% of the discharge flowing over the roadway (including in the overbank areas) for the lower frequency discharges. In order to meet the freeboard requirements of either the draft CRRA or the NYSDOT standards, the bridge and its approaches would have to be raised at least six feet. Since most of the discharge at this bridge was due to overtopping of the approaches any increase in bridge height would result in upstream water surface elevation increases unless the bridge span is significantly increased. Such an increase in bridge span is expected to be cost prohibitive. Further, a scenario which only widens the bridge opening without raising the low chord is not expected to significantly reduce water levels since the water level downstream of the bridge is above low chord of the bridge under the 10% annual chance event (backwater from Tonawanda Creek). Similarly, the addition of culverts adjacent to the New Road bridge is not expected to reduce water levels due to the backwater from Tonawanda Creek. Modeling of the corrected base condition which considered a scenario where Ransom Creek discharges were not being influenced by significant flows in Tonawanda Creek was performed. This scenario indicates that the bridge at New Road causes an increase in water surface elevations upstream of the road of approximately 0.4 feet for the 10% annual chance discharge, 0.1 feet for the 2% annual chance discharge, and no increase for higher flows. However, no structures are expected to be impacted as a result of this rise in water surface elevation, and the same stretches of road are expected to be impacted with or without a rise in water surface elevation due to the New Road bridge. Therefore, modification of the New Road bridge was not expected to provide a benefit and modeling of this alternative was not performed.

High Risk Area #2

Alternative #2-1: Replace Culverts at Glen Oaks Drive with a Bridge (Station 220+00)

The culverts at Glen Oaks Drive are owned and maintained by the Town of Amherst. The effective FIS flood profile and corrected base condition hydraulic model both show a rise in water surface elevation of more than 0.5 feet for flow events less than the 1% annual chance discharge at the Glen Oaks Drive crossing. This suggests that greater discharge capacity at this crossing could improve water surface elevations upstream of Glen Oaks Drive. Additionally, the increased discharge capacity could mitigate potential backwater causing sedimentation at this location. This alternative would replace the existing three culverts (Figure 12) with a bridge whose span is 130 feet wide, and whose deck is approximately two feet above the water surface elevation for the estimated future 1% annual chance discharge.

This alternative is computed to have the greatest impact for the 2% annual chance discharge, reducing the water surface elevation immediately upstream of Glen Oaks Drive by approximately 0.7 feet, but has no appreciable impact on the 0.2% annual chance discharge. Computed water surface elevation reductions of approximately 0.5 ft for the 10% annual chance discharge and 0.3 ft for the 1% annual chance discharge were observed. As shown in Figure 13, the mitigation alternative benefit extends beyond the Dodge Road crossing, with benefits only diminishing to less than 0.1 feet approximately 1 mile upstream of Glen Oaks Drive for the 10% and 2% annual chance events; the benefits are diminished approximately 0.5 miles upstream for the 1% annual chance event. The impacts of replacing the culverts with a bridge were also analyzed for the estimated future discharges, and the reductions in water surface elevations and extents of the improvements were computed to be the same as for the existing flood flows. Additionally, this alternative increased average channel velocities from approximately 1.8 feet per second under corrected base conditions for all annual chance discharges to between 2.0 and 2.7 feet per second depending on the annual chance discharge. This has the potential to reduce sedimentation in the area upstream of the Glen Oaks Drive crossing. Relative to all of the evaluated alternatives, this alternative is considered to have moderate impacts on flooding upstream under certain flow conditions.

The rough order of magnitude cost for this alternative $10.1 million.

Figure 12. Conceptual Extent of Alternative #2-1

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

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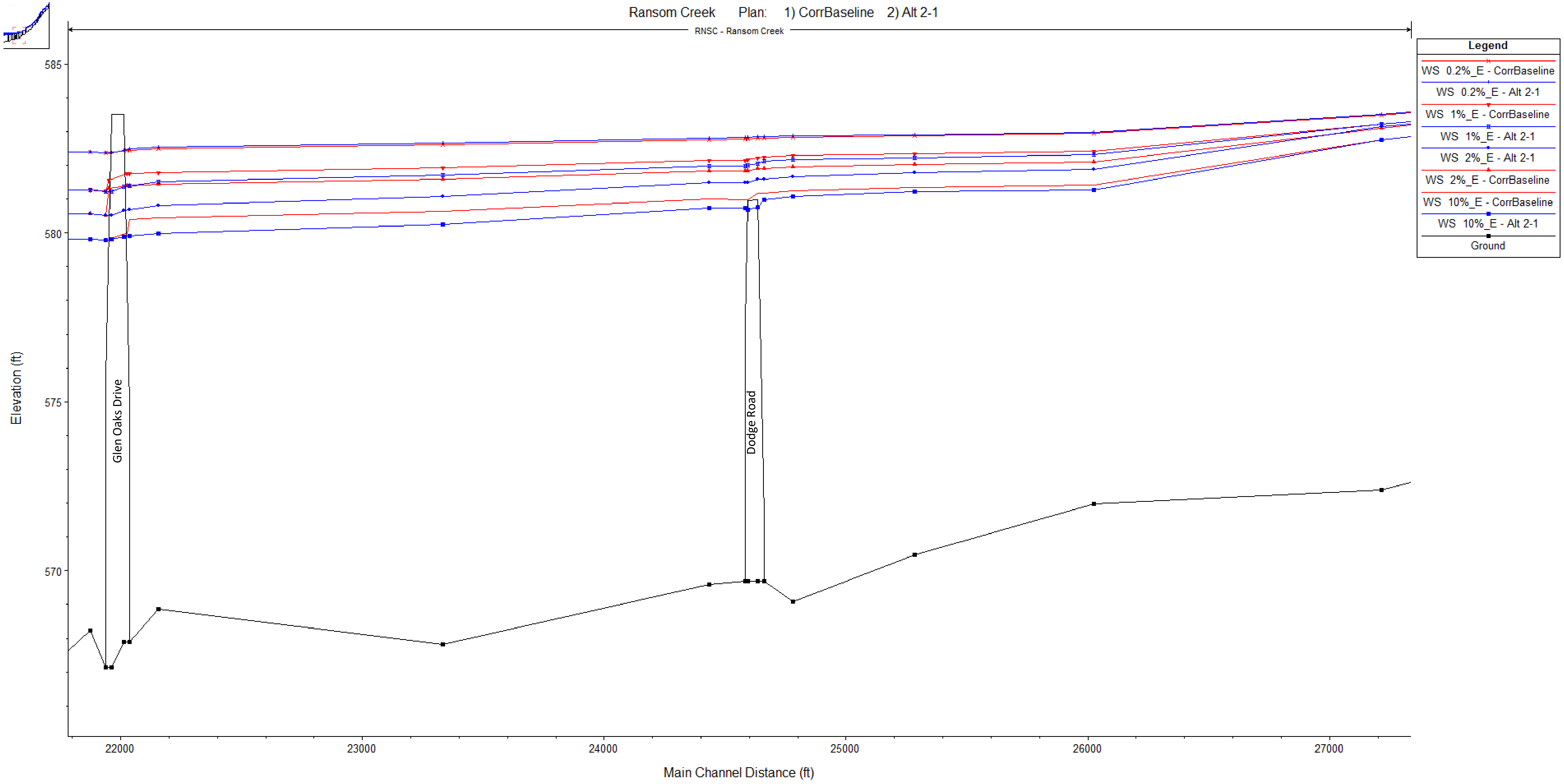
Figure 13. Comparison of Computed Water Surface Elevations between Corrected Baseline Conditions and Replace Culverts at Glen Oaks Drive with Bridge (Alternative #2-1)



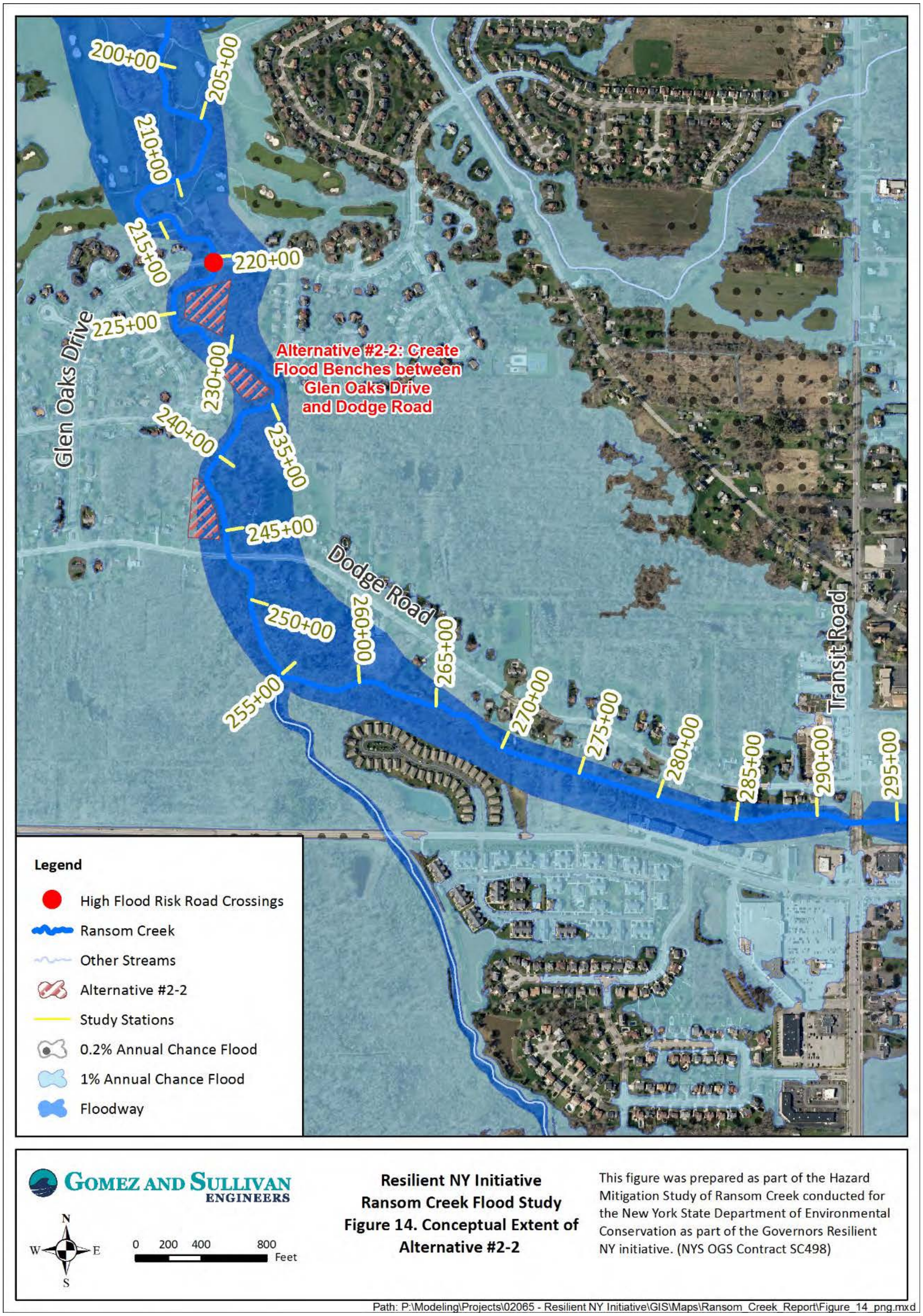
Alternative #2-2: Create Flood Benches Between Glen Oaks Drive and Dodge Road (Station 221+99 to 244+76)

The effective FIS flood profile and corrected base condition hydraulic model both indicate extensive residential and street flooding in the area upstream of Glen Oaks Drive. The area along Ransom Creek between Glen Oaks Drive and Dodge Road is mostly undeveloped and includes a few significant bends in the creek. The existing floodplain on the inside of these bends is generally at a higher elevation than the bank-full elevation of Ransom Creek according to the bank-full depth provided by *StreamStats*. However, the stream does not appear to be entrenched, according to the entrenchment ratio in this area (USDA, 2007).

This potential flood mitigation alternative is intended to increase flow capacity within the floodplain between Glen Oaks Drive and Dodge Road. This would be accomplished through lowering the existing floodplain by one to two feet in three separate areas of the floodplain totaling approximately 11,100 cubic yards of excavated material. The conceptual extent of the flood benches is shown in Figure 14. Hydraulic modeling indicates that the flood bench is expected to provide a reduction in computed water surface elevations during the 10% annual chance flood event of approximately 0.1 feet from 200 ft downstream of Dodge Road to 1,400 ft upstream of Dodge Road, with little benefit for the other recurrence interval events (Figure 15). These results are not expected to decrease the number of houses or roadways impacted by flooding. The same results were computed for the estimated future flood flows. Relative to all of the evaluated alternatives, this alternative is considered to have insignificant impacts on flooding upstream.

The rough order of magnitude cost for this alternative is $1.7 million, not including the cost to acquire the land required to construct the mitigation alternative. This cost estimate however does include land acquisition costs for survey, appraisal, and engineering coordination for the parcel upon which the flood bench would be constructed. The majority of the costs for this mitigation alternative relate to the removal and disposal of fill and the creation and planting of wetland within the floodplain bench.

Figure 14. Conceptual Extent of Alternative #2-2



Resilient NY Initiative
Ransom Creek Flood Study
Figure 14. Conceptual Extent of Alternative #2-2

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

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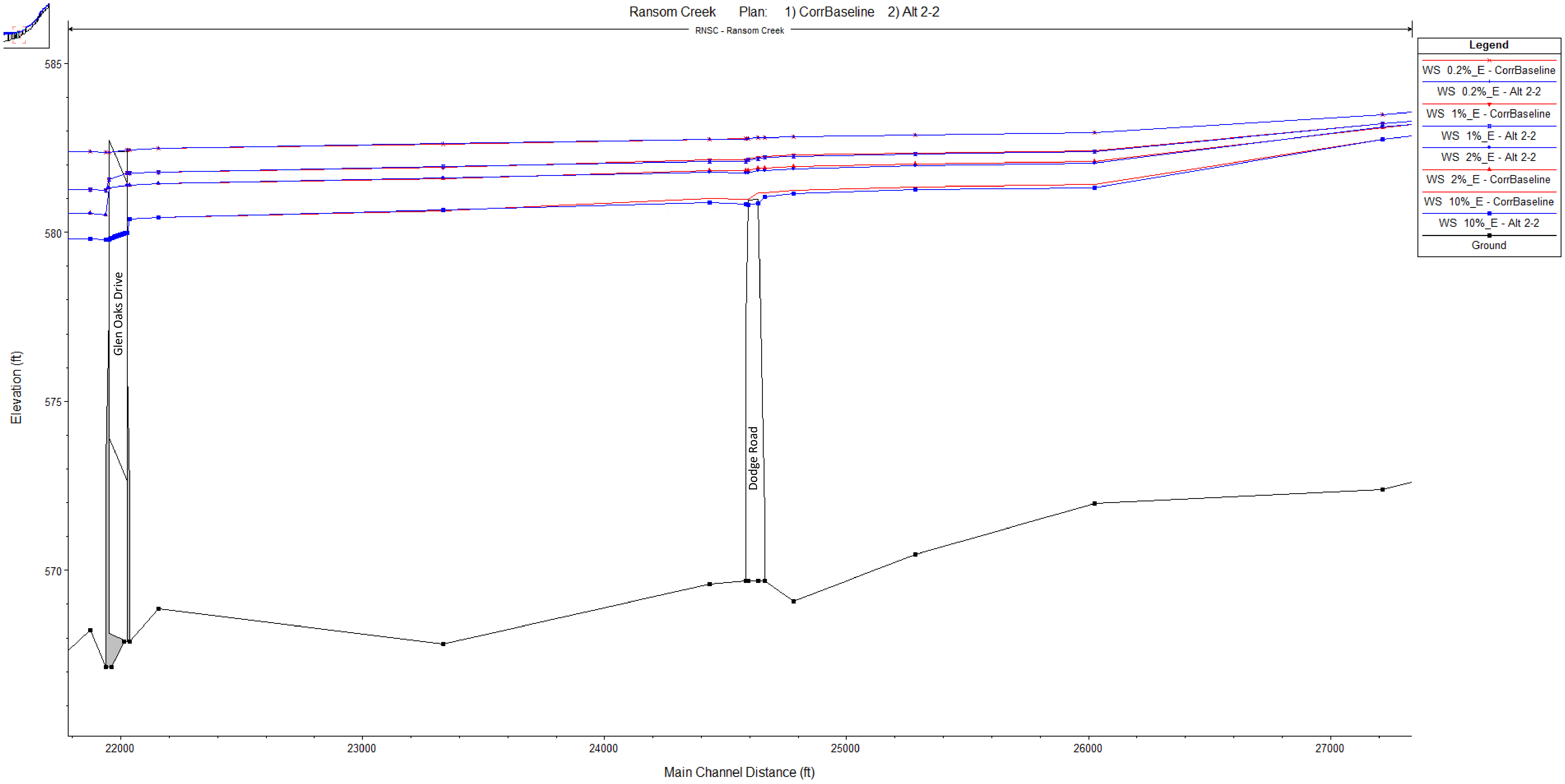
Figure 15. Comparison of Computed Water Surface Elevations between Corrected Baseline Conditions and Create Flood Benches Between Glen Oaks Drive and Dodge Road (Alternative #2-2)



Alternative #2-3: Create a Flood Bench between Dodge Road and Transit Road (Station 260+70 to 283+51)

The effective FIS flood profile indicates that there is extensive flooding on Dodge Road upstream of the Dodge Road crossing. Ransom Creek's floodplain is constricted in this area by residences along Dodge Road on the right (north) overbank as well as development in the left (south) overbank area including the French Oaks Lane development and commercial development along North French Road. Gott Creek also flows into Ransom Creek in this area, compounding flooding issues. The corrected base condition hydraulic model indicates that Dodge Road floods during the 10% annual chance discharge event. Development between the Transit Road crossing and the mouth of Gott Creek has already been established up to the floodway boundaries, with some recent development extending into the floodway.

This modeled alternative addresses flooding by creation of a floodplain bench in the left overbank between the Transit Road crossing and the confluence of Gott Creek with Ransom Creek. A 60- to 190-foot wide flood bench would be created between the left bank and adjacent development to the south of Ransom Creek, by lowering the elevation of the land by 1.5 to 3.5 feet totaling approximately 24,600 cubic yards of excavated material. This would increase flow area within the floodplain. The conceptual extent of the flood bench is shown in Figure 16. Based on field assessments and other sources, it is noted that new apartment complexes have been built between North French Road and Ransom Creek in this area. The flood bench was sized to try to account for these apartment complexes, but they are not shown in current aerial imagery, and their exact location was not surveyed. However, this alternative is not intended to encroach upon the apartment complexes, and may need to be modified if further pursued. Water surface elevations were computed to be reduced by a maximum of 0.6 ft upstream of Transit Road for the 2% annual chance flow. Water surface elevations are expected to be reduced by up to 0.4 ft for the 10% annual chance event, 0.3 ft for the 1% annual chance event, and 0.1 for the 0.2% annual chance flood. Upstream of the flood bench, water surface reductions would be diminished to less than 0.1 feet approximately 50 feet downstream of Transit Road for the 1% annual chance discharge event, but extended upstream of Transit Road for the 10% and 2% annual chance discharge events, as shown in Figure 17 and Figure 18.

For the estimated future flood flows, the water surface elevations are expected to be reduced by up to 0.4 feet for the 10% annual chance event, 0.3 feet for the 1% and 2% annual chance flood, and 0.1 feet for the 0.2% annual chance flood. Upstream of the flood bench, water surface reductions are expected to be diminished to less than 0.1 feet approximately 50 feet downstream of Transit Road for the 1% and 2% annual chance discharge events, but extended upstream of Transit Road for the 10% annual chance discharge event. Relative to all of the evaluated alternatives, this alternative is considered to have moderate impacts on flooding upstream under certain flow conditions.

The rough order of magnitude cost for this alternative is $2.6 million, not including the cost to acquire the land required to construct the mitigation alternative. This cost estimate however does include land acquisition costs for survey, appraisal, and engineering coordination for the parcel upon which the flood bench would be constructed. The majority of the costs for this mitigation alternative relate to the removal and disposal of fill and the creation and planting of wetland within the floodplain bench.

Figure 16. Conceptual Extent of Alternative #2-3

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Ransom Creek Flood Study
Figure 16. Conceptual Extent of Alternative #2-3

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

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Figure 17. Comparison of Computed 10% and 1% Annual Chance Event Water Surface Elevations between Corrected Baseline Conditions and Flood Bench between Dodge Road and Transit Road (Alternative #2-3)

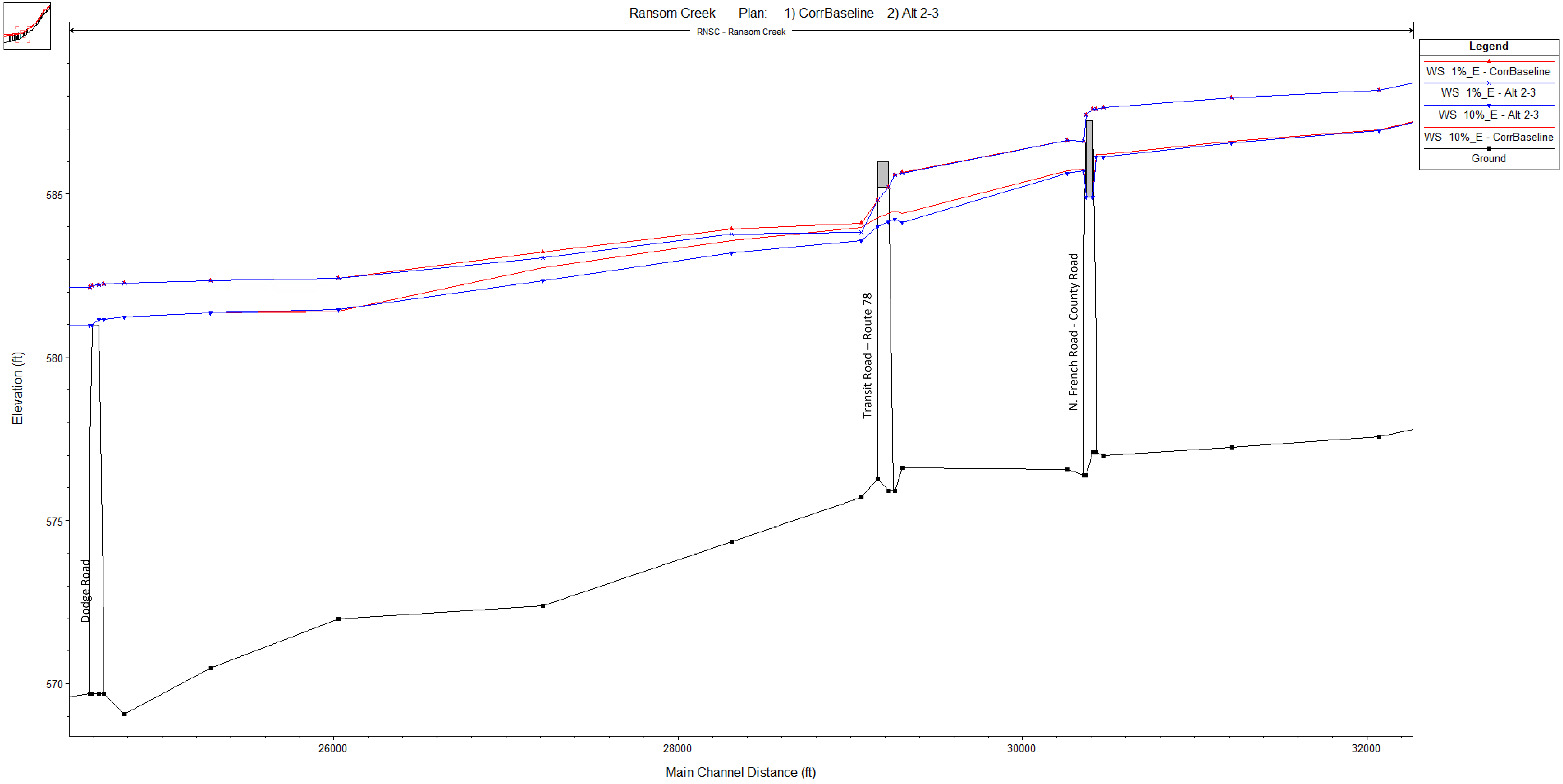
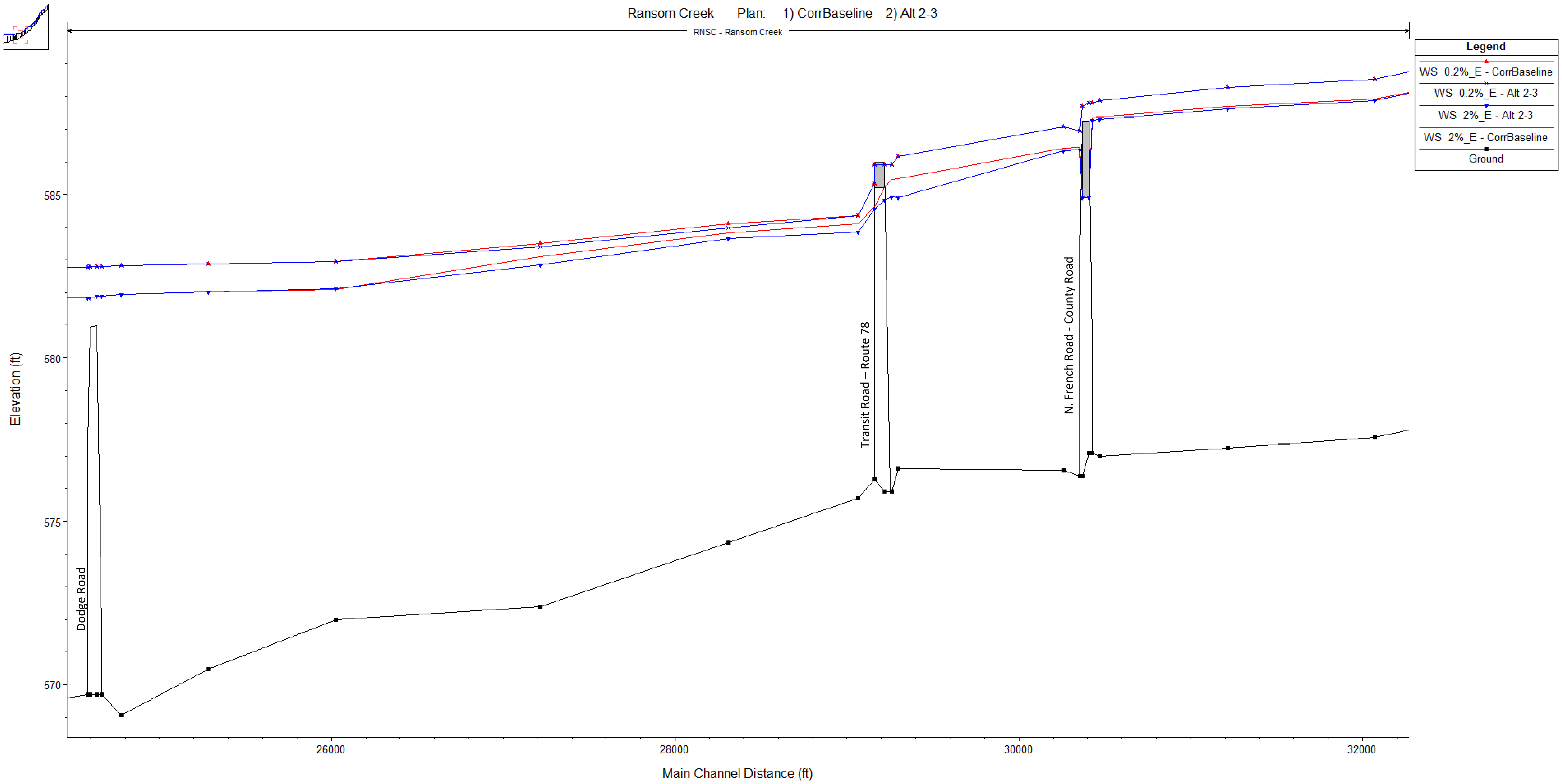


Figure 18. Comparison of Computed 2% and 0.2% Annual Chance Event Water Surface Elevations between Corrected Baseline Conditions and Flood Bench between Dodge Road and Transit Road (Alternative #2-3)



High Risk Area #3

Alternative #3-1: Replace Pedestrian Bridge Upstream of Miles Road (Station 349+20)

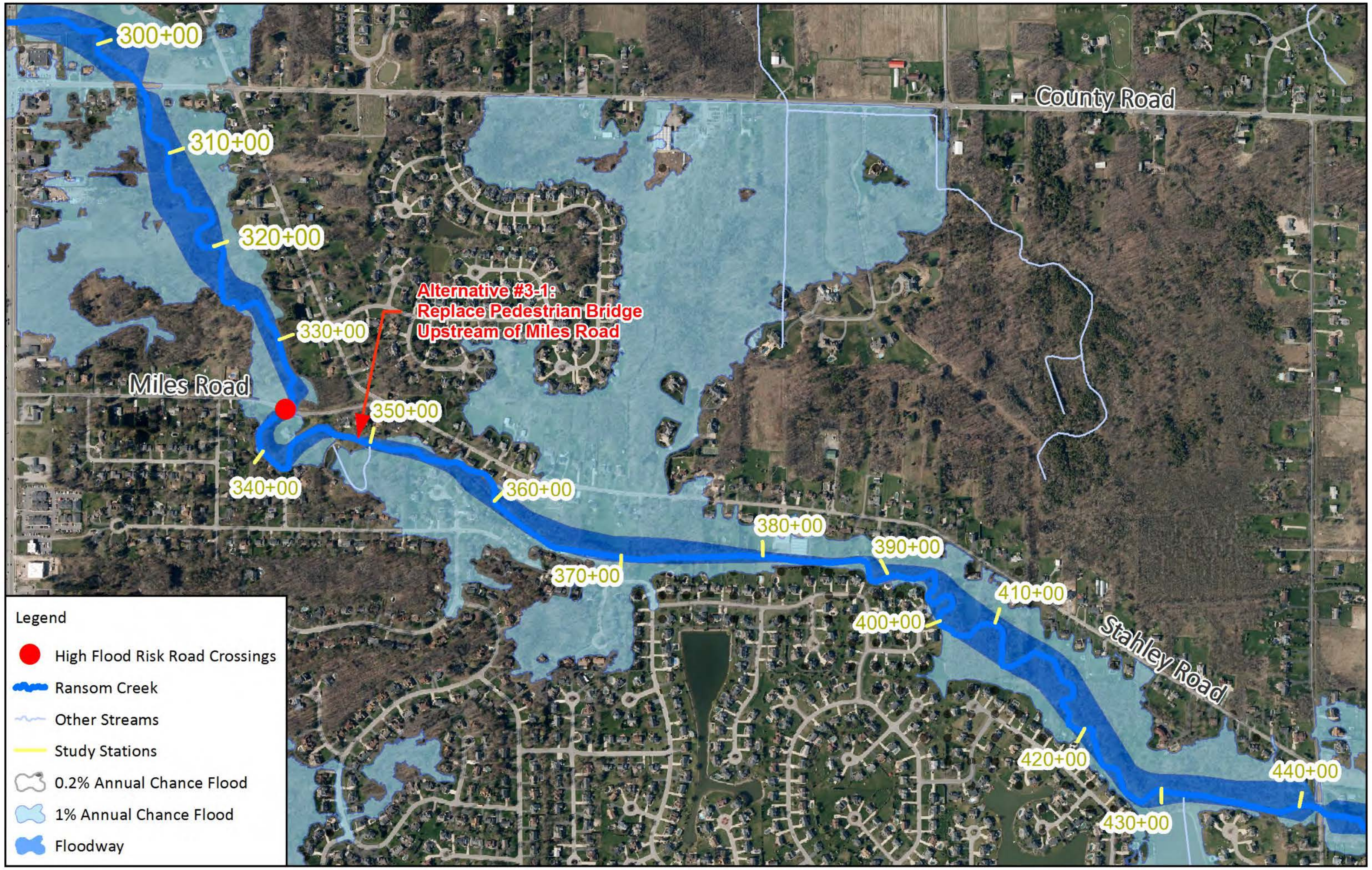
The effective FIS did not incorporate the 2011 bridge replacement at the Miles Road crossing. The corrected base condition model indicates that the replaced Miles Road bridge results in lower water surface elevations immediately upstream of the bridge between 0.8 feet and 2.3 feet as compared to the FIS flood profile, depending on the discharge. The corrected base condition model indicated that the bridge replacement had no impact on computed water surface elevations upstream of two pedestrian bridges located approximately 1,300 feet upstream of the Miles Road crossing. These pedestrian bridges are privately owned and located in a very narrow valley. It is unclear from the FIS profiles whether the bridges or the narrow valley are the main cause of flooding in the residential areas between Miles Road and Stahley Road. The total rise in water surface elevations from downstream to upstream of these two bridges is between 2.2 and 3.7 feet depending on the discharge. The hydraulic capacity of the downstream pedestrian bridge is greater than the 1% annual chance event, while the hydraulic capacity of the upstream pedestrian bridge is less than the 10% annual chance event.

This flood mitigation alternative seeks to reduce flooding through replacement of the upstream pedestrian bridge (Figure 19). The draft CRRA and NYSDOT standards would not apply to the replacement of a private pedestrian bridge. However, raising the low chord at least above the 1% annual chance flood level is needed to achieve significant upstream water surface elevation reductions. Since raising the bridge to meet the draft CRRA standards doesn't have a significant cost impact, this alternative utilized the draft CRRA standards. The bridge was modeled with a span of 50 feet, which is equal to the entire width of channel at this location, and did not include any piers. Implementation of this mitigation alternative resulted in computed water level reductions upstream of the bridge by up to 0.6 ft for the 2% annual chance event. The 1% and 10% annual chance water levels are expected to be reduced by around 0.5 ft. The 0.2% annual chance water level was computed to increase by 0.2 ft. The same results were computed for each of the estimated future flood flows. A sensitivity analysis which removed the pedestrian bridge entirely also showed a rise in water surface elevations under the 0.2% annual chance event when compared to the Corrected Baseline Conditions. Hydraulic models may compute artificially low water surface elevation estimates in the vicinity of bridges under certain flow conditions, including conditions which could potentially create supercritical flow and an associated hydraulic jump. As such, it is expected that the water surface computed for the current conditions is artificially low, it is not expected that implementing this alternative would actually cause a rise in water surface elevations upstream of the bridge under the 0.2% annual chance event.

For both existing and estimated future flood flows, water surface elevation reductions in excess of 0.1 feet were observed as far as 3,600 feet upstream for the 1% chance annual flood event, 2,400 feet upstream for the 2% chance annual flood event, and 900 feet upstream for the 10% and 0.2% chance annual flood events (Figure 20). A sensitivity analysis which evaluated the complete removal of both pedestrian bridges, did not result in additional computed reductions in water surface elevations. The total water surface elevation rise along this 175-foot long section of Ransom Creek with both pedestrian bridges removed is between 1.7 feet for the 10% annual chance discharge and 3.9 feet for the 0.2% annual chance discharge and between 1.7 ft for the 10% annual chance discharge and 4.0 feet for the 0.2% annual chance discharge for Alternative #3-1, the replacement of the upstream pedestrian bridge. This indicates that the channel restriction in this area is a significant contributor to flooding upstream of the pedestrian bridges. Relative to all of the evaluated alternatives, this alternative is considered to have moderate impacts on flooding upstream under certain flow conditions.

The pedestrian bridge is privately owned, and an alternative which replaces this structure may require a unique arrangement to be completed. However, the moderate impacts on flooding upstream suggest that the alternative warrants further evaluation. The rough order of magnitude cost estimate for this mitigation alternative is $160,000.

Figure 19. Conceptual Extent of Alternative #3-1



GOMEZ AND SULLIVAN ENGINEERS

0 500 1,000 2,000 Feet

N W E S

Resilient NY Initiative
Ransom Creek Flood Study
Figure 19. Conceptual Extent of
Alternative #3-1

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

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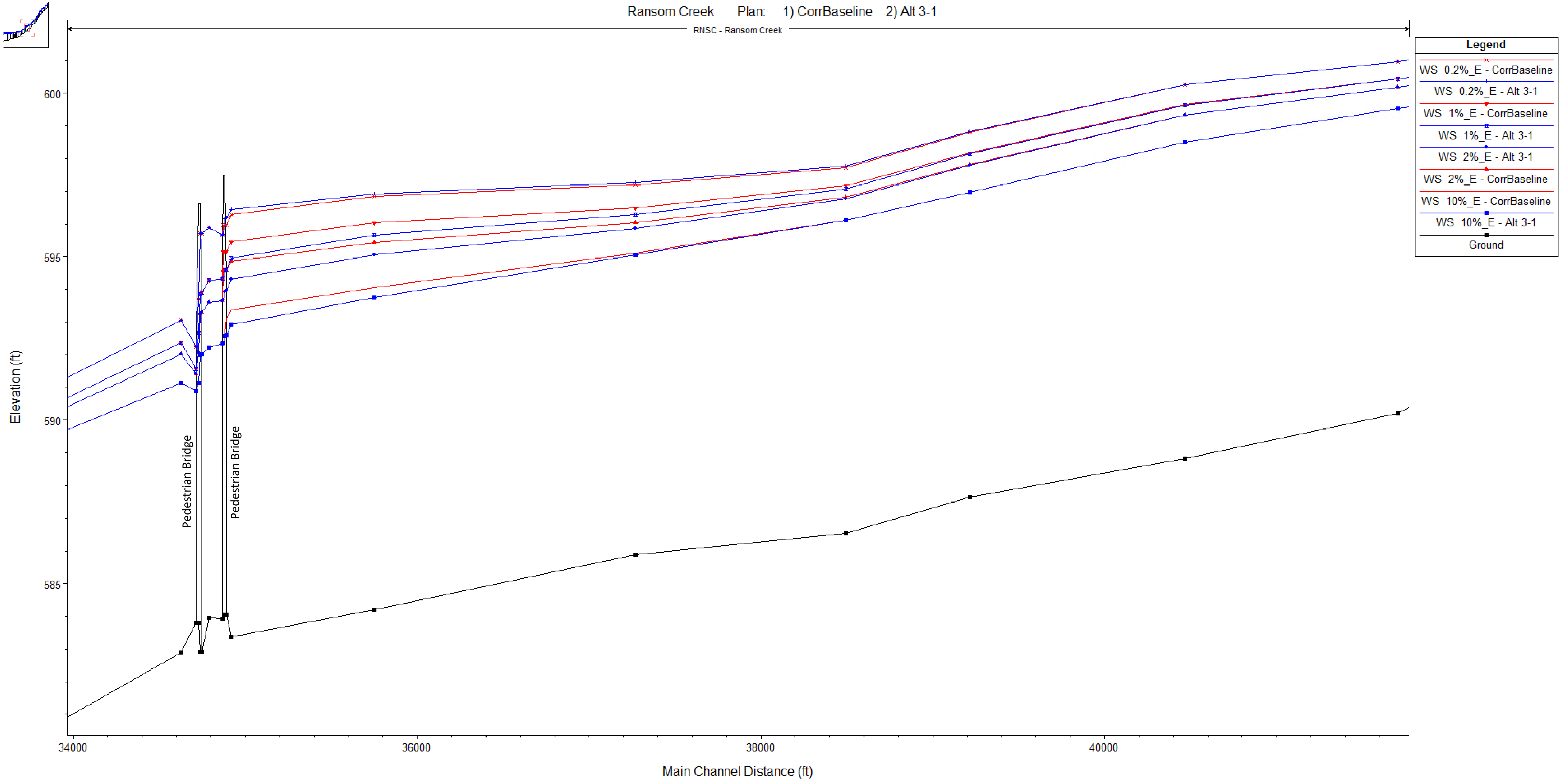
Figure 20. Comparison of Computed Water Surface Elevations between Corrected Baseline Conditions and Replace Pedestrian Bridge Upstream of Miles Road (Alternative #3-1)



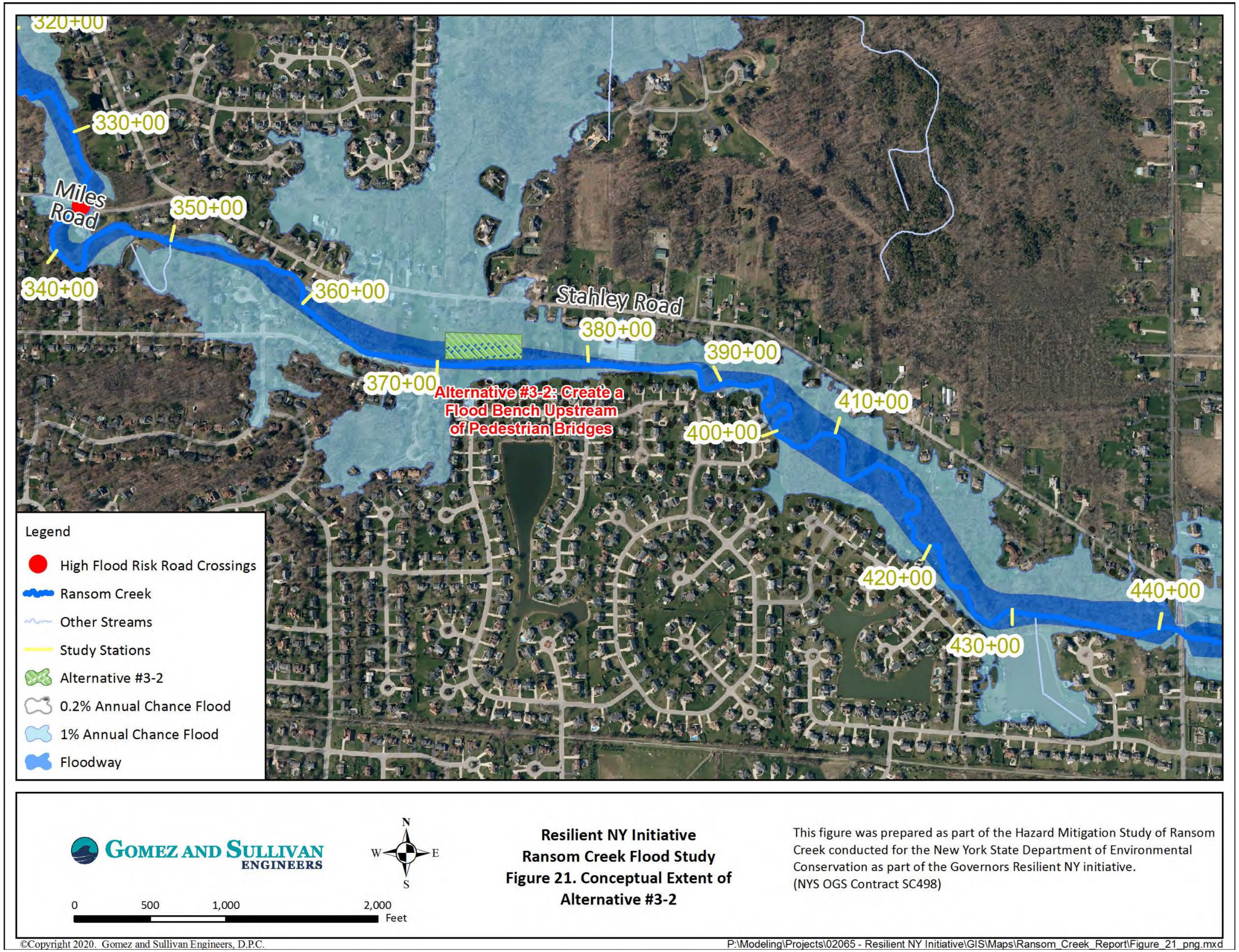
Alternative #3-2: Create a Flood Bench Upstream of Pedestrian Bridges (Station 373+16)

Most of the residential flooding between Miles Road and Stahley Road was found to be upstream of the pedestrian bridges. An area of undeveloped land approximately 2,400 feet upstream of the pedestrian bridges was identified in which the right overbank area was generally higher than the bank-full elevation of Ransom Creek. Part of this undeveloped area is currently owned by the Erie County Sanitation District No. 5.

This alternative is intended to address flooding through the creation of a 500-foot long by 150-foot wide flood bench, which would increase hydraulic capacity in the floodplain by lowering the elevation of this section of land by up to 3 ft. The conceptual extent of the flood bench is shown in Figure 21, and includes the excavation of approximately 5,700 cubic yards of material. Creation of this flood bench is computed to result in lowered water levels in the project area and immediately upstream between 0.2 feet during the 0.2% annual chance event and 0.4 ft during the 10% annual chance event for both current and estimated future flood flows. Water surface elevation reductions in excess of 0.1 feet were computed to extend approximately 1,900 feet along Ransom Creek for the 10%, 2%, and 1% annual chance flows and approximately 1,200 feet along Ransom Creek for the 0.2% annual chance flow, for both current and estimated future flow conditions, as shown in Figure 22. Relative to all of the evaluated alternatives, this alternative is considered to have minimal impacts on flooding upstream.

The rough order of magnitude cost estimate for this mitigation alternative is $790,000, not including the cost to acquire the land required to construct the mitigation alternative. This cost estimate however does include land acquisition costs for survey, appraisal, and engineering coordination for the parcel upon which the flood bench would be constructed. The majority of the costs for this mitigation alternative relate to the removal and disposal of fill and the creation and planting of wetland within the floodplain bench.

Figure 21. Conceptual Extent of Alternative #3-2



Resilient NY Initiative
Ransom Creek Flood Study
Figure 21. Conceptual Extent of Alternative #3-2

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

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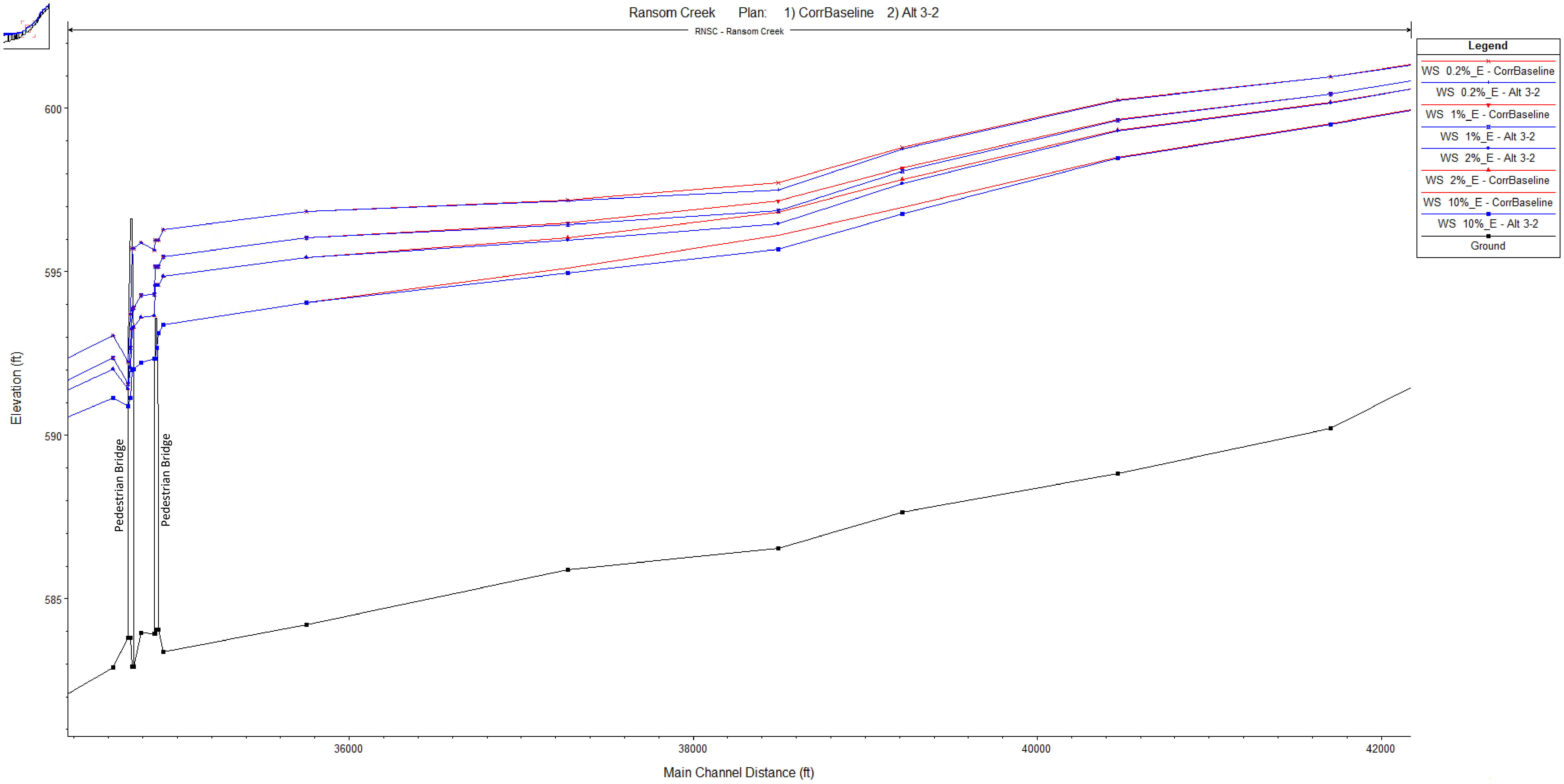
Figure 22. Comparison of Computed Water Surface Elevations between Corrected Baseline Conditions and Create a Flood Bench Upstream of Pedestrian Bridges (Alternative #3-2)

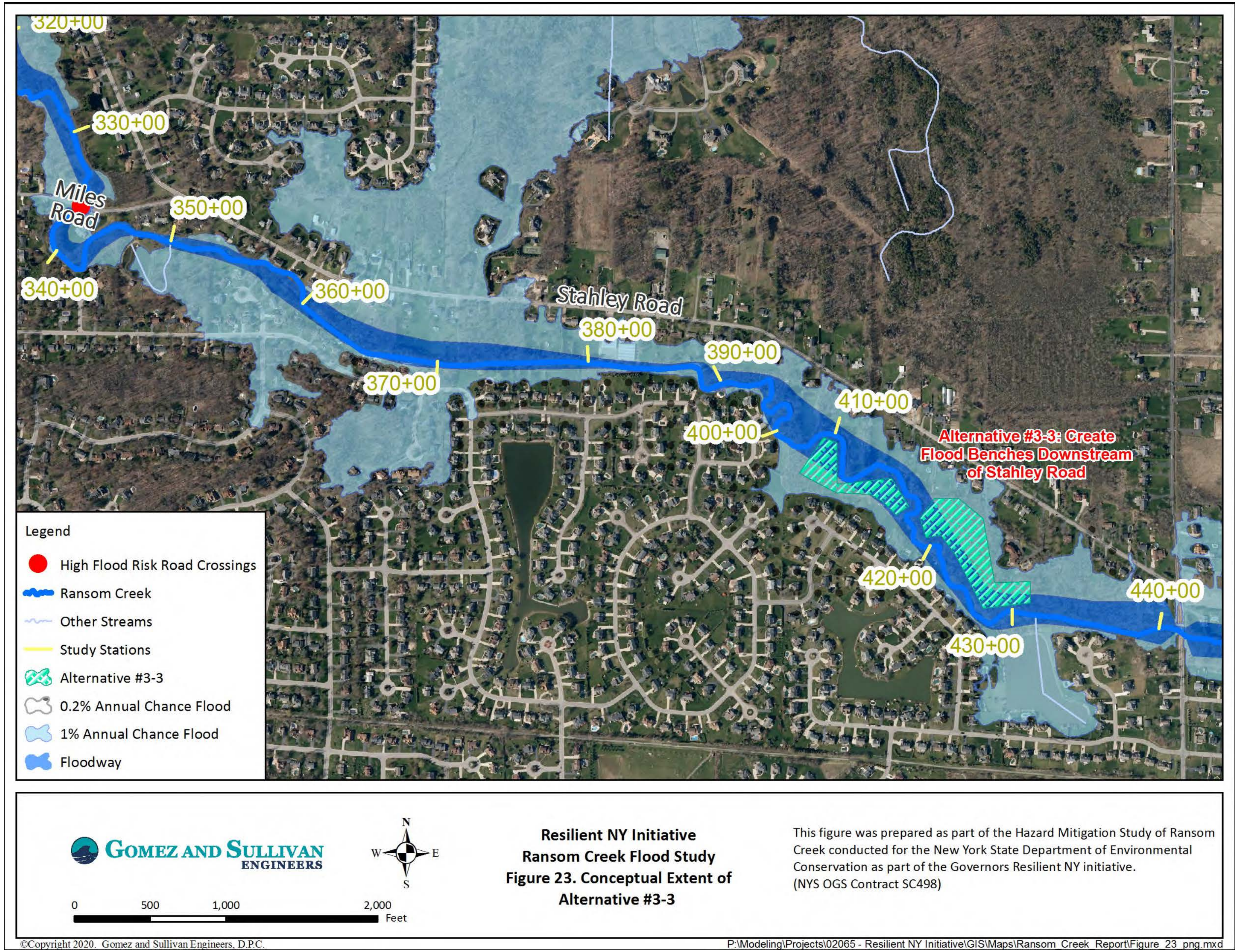


Alternative #3-3: Create Flood Benches Downstream of Stahley Road (Station 405+09 to 425+74)

Approximately 4,900 feet downstream of Stahley Road, the floodplain narrows from 500 feet to 150 feet wide, and the constriction continues for approximately 1,500 feet downstream. Aerial imagery indicates the presence of buildings only 50-feet to 100-feet away from Ransom Creek. The ground elevations between Stahley Road and this floodplain constriction are generally higher than the bank-full elevation of Ransom Creek. This flood mitigation alternative is expected to reduce flooding in adjacent residential areas by lowering a 200-foot to 370-foot wide portion of the existing floodplain bench by up to two feet along approximately 2,100 feet of Ransom Creek. The conceptual extent of this alternative is shown in Figure 23, and includes excavating approximately 16,600 cubic yards of material, which is expected to provide additional hydraulic capacity in the floodplain and help to attenuate flood waters. The conceptual extent of the flood bench is shown in Figure 21. Reductions in water surface elevations were computed to be 0.3 feet during the during the 1% and 0.2% annual chance events and 0.4 feet during the 10% and 2% annual chance events. Reductions in water surface elevations for estimated future flood flows of 0.3 feet during the during the 1% and 0.2% annual chance events and 0.4 feet during the 10% and 2% annual chance events were also computed. Water surface elevation reductions in excess of 0.1 feet are expected along approximately 3,300 feet of Ransom Creek for all modeled flow conditions as shown in Figure 24. Relative to all of the evaluated alternatives, this alternative is considered to have minimal impacts on flooding upstream.

The rough order of magnitude cost estimate for this mitigation alternative is $2.8 million, not including the cost to acquire the land required to construct the mitigation alternative. This cost estimate however does include land acquisition costs for survey, appraisal, and engineering coordination for the parcel upon which the flood bench would be constructed. The majority of the costs for this mitigation alternative relate to the removal and disposal of fill and the creation and planting of wetland within the floodplain bench.

Figure 23. Conceptual Extent of Alternative #3-3



Resilient NY Initiative
Ransom Creek Flood Study
Figure 23. Conceptual Extent of Alternative #3-3

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

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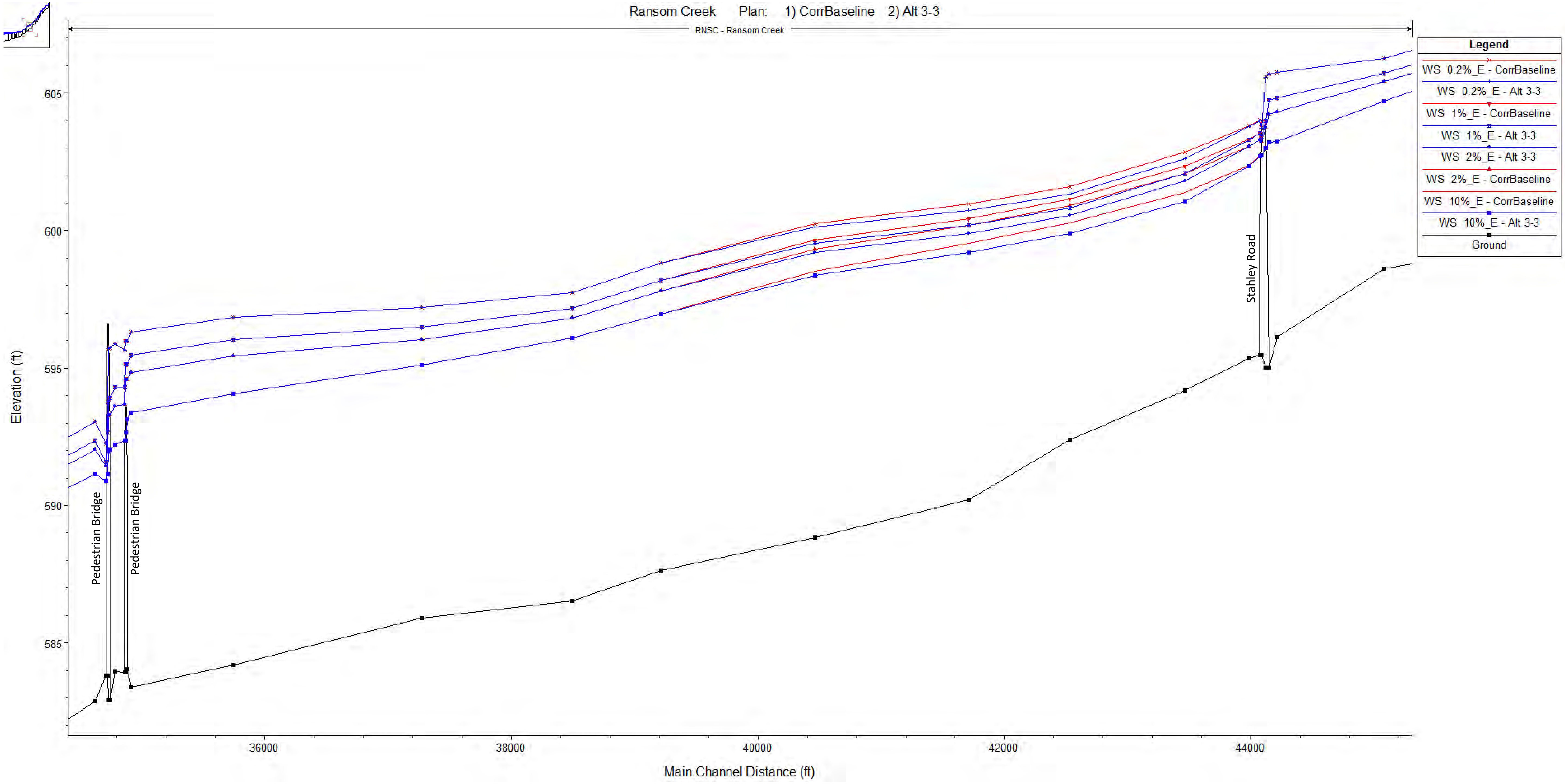
Figure 24. Comparison of Computed Water Surface Elevations between Corrected Baseline Conditions and Create Flood Benches Downstream of Stahley Road (Alternative #3-3)



Basin-Wide Mitigation Alternatives

Alternative #4-1: Add Upstream Detention Basins

Detention ponds constructed in conjunction with new development serve to offset the increases in flood peaks due to the development by slowing the travel of runoff from the development to the receiving stream. While the previous alternatives have dealt with the ability to convey the peak flow rates for floods of given recurrence intervals, the addition of upstream detention basins would lower the computed peak flow rates for each recurrence interval.

Utilizing the regional regression equations from the *StreamStats* software discussed previously, the impact of five acres of new detention storage was evaluated for current flow conditions. Computed reductions for current flow conditions, range from three cfs at the Confluence of Tonawanda Creek for the 10% annual chance flow, to seven cfs for the 0.2% annual chance flow upstream of the confluence of Gott Creek. These flow reductions were applied to the peak flows used in the hydraulic modeling and the hydraulic model was re-run for the current hydraulic conditions in the creek to evaluate the impact of storage on the water surface elevations. With an additional five acres of detention ponds, negligible changes in WSEL are achieved throughout Ransom Creek at all recurrence intervals. More significant reductions are not expected for the estimated future flow conditions. Relative to all of the evaluated alternatives, this alternative is considered to have insignificant impacts on flooding upstream.

The regional regression equations only account for the surface area of the detention pond, not the volume of the pond or the hydraulics of the outlet structure. Appropriate sizing of the detention pond and outlet works would require a more detailed hydrologic analysis of the basin. The rough order of magnitude cost estimate for only the excavation of this mitigation alternative is $1.5 million, assuming the required depth of the detention pond is two feet. The rough order or magnitude cost does not include the cost to acquire the land required to construct the mitigation alternative. This cost estimate however does include land acquisition costs for survey, appraisal, and engineering coordination for the parcel(s) upon which the detention pond(s) would be constructed.

Adding further detention ponds has diminishing returns; increasing the size of the new detention pond to 20 acres causes the flow reduction to increase 3.8 times that at five acres, but the cost increases by nearly four times that at five acres.

Alternative #4-2: Flood Early Warning Detection System

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 (USACE, 2016b).

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

The rough order magnitude cost for this strategy is approximately $100,000.

Alternative #4-3: Flood Buyout Programs

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

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

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

Buyout programs can be funded through a combination of federal, state or local funds, and are generally made available following a nationally recognized disaster. FEMA administers programs to help with buyouts under the Stafford Disaster Act, and the Department of Housing and Urban Development (HUD) administers another program through Community Development Block Grants (CDBG) [(FEMA, 2020), (NYSGOSR, 2019)]. These funding sources can reduce the economic burden on the local community. However, these funds also come with guidelines and regulations that may constrain policy makers' options on whether to pursue a buyout strategy and how to shape their programs. FEMA funds may be used to cover 75% of the expenses, but the remaining 25% must come from another non-federal source. In most cases, the buyout must be a cost-effective measure that will substantially reduce the risk of future flooding damage (Siders, 2013).

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

Within the three high flood risk areas discussed in this report, 1,018 structures were identified as being within the 1% annual chance floodplain. In addition, there is one FEMA Repetitive Loss (RL) and zero Severe Repetitive Loss (SRL) properties located within the Ransom Creek watershed (FEMA, 2019b). For the purposes of this analysis, structures were considered to be within the floodplain if the structure is either shown to be at least partially inundated or mostly surrounded by the inundation area. Due to the methods used to processes the LiDAR data into the elevation model, structures can appear to be elevated above the inundation area without having been placed on fill. Therefore, the structures which appear to be elevated above the 1% annual chance floodplain were conservatively included in this structure count. The overbank areas for High Flood Risk Areas #1 (New Road) and #2 (Glen Oaks Drive) are relatively flat and the flooding from Ransom Creek and neighboring tributaries is not clearly defined. Therefore, only structures within the bounds of the HEC-RAS cross sections were counted for these risk areas. Parcels without structures on them were not included in this assessment, while parcels with multiple structures on them were counted as one structure. Table 16 summarizes the number of structures and their full market value, available from the New York State Tax Parcel database (NYSDTF, 2019).

Table 16. Summary of Potential Property Acquisitions

High Flood Risk Area	Number of Structures	Full Market Value
#1: New Road	456	$ 66,783,600
#2: Glen Oaks Drive	330	$ 108,648,600
#3: Miles Road	232	$ 91,889,300
Total	**1,018**	**$ 267,321,500**

Due to the variable nature of buyout programs, no ROM cost estimate was produced for this study. It is recommended that any buyout program begin with a cost-benefit analysis for each property. After a substantial benefit has been established, a buyout strategy study should be developed that focuses on properties closest to Ransom Creek in the highest risk flood areas and progresses outwards from there to maximize flood damage reductions. In addition, structures located adjacent to flood prone infrastructure (i.e. bridges, culverts, etc.) should also be considered high-risk and prioritized in any buyout program strategy. A potentially negative consequence of buyout programs is the permanent removal of properties from the floodplain, and resulting reduced tax revenue, which would have long-term implications for local governments and should be considered prior to implementing a buyout program.

Alternative #4-4: Flood Proofing

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

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

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

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

Interior Modification/Retrofit Measures

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

Examples include:

- Basement Infill: This measure involves filling a basement located below the BFE to grade (ground level)
- Abandon Lowest Floor: This measure involves abandoning the lowest floor of a two or more story slab-on-grade residential building
- Elevate Lowest Interior Floor: This measure involves elevating the lowest interior floor within a residential building with high ceilings

Dry floodproofing

A combination of measures that results in a structure, including the attendant utilities and equipment, being watertight with all elements substantially impermeable to the entrance of floodwater and with structural components having the capacity to resist flood loads (FEMA, 2015).

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

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

Examples include:

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

Wet floodproofing

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

Examples include:

- Flood Openings: This measure involves installing openings in foundation and enclosure walls located below the BFE that allow automatic entry and exit of floodwaters to prevent collapse from the pressures of standing water
- Elevate Building Utilities: This measure involves elevating all building utility systems and associated equipment (e.g., furnaces, septic tanks, and electric and gas meters) to protect utilities from damage or loss of function from flooding
- Floodproof Building Utilities: This measure involves floodproofing all building utility systems and associated equipment to protect it from damage or loss of function from flooding
- Flood Damage-Resistant Materials: This measure involves the use of flood damage-resistant materials such as non-paper-faced gypsum board and terrazzo tile flooring for building materials and furnishings located below the BFE to reduce structural and nonstructural damage and post-flood event cleanup

Barrier Measures

Barriers, such as floodwalls and levees, can be built around single or multiple residential and non-residential buildings to contain or control floodwaters (FEMA, 2015). Although floodwalls or levees can be used to keep floodwaters away from buildings, implementing these measures will not affect a building's flood insurance rating unless the flood control structure is accredited in accordance with NFIP requirements (44 CFR §65.10) and provides protection from at least the 1% annual chance (100-year) flood. In addition, floodwalls or levees as a retrofit measure will not bring the building into compliance with NFIP requirements for Substantial Improvement/Damage (FEMA, 2013). Barrier measures require ongoing maintenance (i.e. mowing, etc.) which should be factored into any cost analysis. In addition, barrier measures tend to create a false sense of security for the property owners and residents that are protected by them. If a barrier structure is not properly constructed or maintained and fails, catastrophic damages to surrounding areas can occur.

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

hydrostatic pressure caused by the floodwater. The levee without gates is built using vehicle access ramps to avoid the need for passive flood gates.

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

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

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

Alternative #4-5: Area Preservation/Floodplain Ordinances

This alternative proposes that municipalities within the Ransom Creek watershed consider watershed and floodplain management practices such as preservation and/or conservation of areas along with land use ordinances that could minimize future development of sensitive areas such as wetlands, forests, riparian areas, and other open spaces. It could also include areas in the floodplain that are currently free from development and providing floodplain storage.

A watershed approach to planning and management is an important part of water protection and restoration efforts. New York State's watersheds are the basis for management, monitoring, and assessment activities. The New York State Open Space Conservation Plan, NYSDEC's Smart Growth initiative and the Climate Smart Communities Program address land use within a watershed (NYSDEC, Date Unknown).

Natural floodplains provide flood risk reduction benefits by slowing runoff and storing flood water. They also provide other benefits of considerable economic, social, and environmental value that should be considered in local land-use decisions. Floodplains frequently contain wetlands and other important ecological areas which directly affect the quality of the local environment. Floodplain management is the operation of a community program of preventive and corrective measures to reduce the risk of current and future flooding, resulting in a more resilient community. These measures take a variety of forms, are carried out by multiple stakeholders with a vested interest in responsible floodplain management and generally include requirements for zoning, subdivision or building, building codes and special-purpose floodplain ordinances. While FEMA has minimum floodplain management standards for communities participating in the National Flood Insurance Program (NFIP), best practices demonstrate that the adoption of higher standards will lead to safer, stronger, and more resilient communities (FEMA, 2006).

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

In addition, the Community Rating System (CRS) program through FEMA is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. Participating communities are able to get discounted rates on the flood insurance premiums for residents in the community. Adopting these enhanced requirements and preserving open space for floodplain storage earns points in the CRS program, which can lead to discounted flood insurance premiums. For example, the Town of Amherst is already a participating community currently at a Class 8 and could be elevated an entire class through open space preservation.

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

Alternative #4-6: Debris Maintenance Around Bridges/Culverts

Debris, such as trees, branches and stumps, are an important feature of natural and healthy stream systems. In a healthy stream network, woody debris helps to stabilize the stream and its banks, reduce sediment erosion, and slow storm-induced high streamflow events. Fallen trees and brush also form the basis for the entire aquatic ecosystem by providing food, shelter, and other benefits to fish and wildlife. In the headwaters of many streams, woody debris influences flooding events by increasing channel roughness, dissipating energy, and slowing floodwaters, which can potentially reduce flood damages in the downstream reaches. Any woody debris that does not pose a hazard to infrastructure or property should be left in place and undisturbed, thereby saving time and money for more critical work at other locations (NYSDEC, 2013).

However, in some instances, significant sediment and debris can impact flows by blocking bridge and culvert openings and accumulating along the stream path at meanders, contraction / expansion points, etc., which can divert stream flow and cause backwater and bank erosion. When debris poses a risk to infrastructure, such as bridges or homes, it should be removed. Provided fallen trees, limbs, debris and trash can be pulled, cabled or otherwise removed from a stream or stream bank without significant disruption of the stream bed and banks, a permit from the NYSDEC is not required. Woody debris and trash can be removed from a stream without the need for a permit under the following guidelines:

- Fallen trees and debris may be pulled from the stream by vehicles and motorized equipment operating from the top of the streambanks using winches, chains and or cables.
- Hand-held tools, such as chainsaws, axes, handsaws, etc., may be used to cut up the debris into manageable sized pieces.
- Downed trees that are still attached to the banks should be cut off near the stump. Do not grub (pull out) tree stumps from the bank; stumps hold the bank from eroding.
- All trees, brush, and trash that is removed from the channel should not be left on the floodplain. Trash should be properly disposed of at a waste management facility. Trees and brush can be utilized as firewood. To prevent the spread of invasive species, such as Emerald Ash Borer, firewood cannot be moved more than 50 miles from its point of origin.

- Equipment may not be operated in the water, and any increase in stream turbidity from the removal must be avoided (NYSDEC 2013).

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

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

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

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

Next Steps

Additional Data Modeling

The results of hydraulic modeling for mitigation alternatives discussed above, are based on conceptual projects, which have not been designed. 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, based on actual mitigation designs. 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, particularly for those alternatives which include the addition of flood benches which may attenuate flood peaks.

State/Federal Wetlands Investigation

A portion of the land for each alternative with a potential flood bench (Mitigation Alternative #1-2, #2-2, #2-3, #3-2, and #3-3) has been identified as a wetland area by the U.S. Fish and Wildlife Service. Any mitigation strategies which utilize this area need to be evaluated in relation to federal and state wetland criteria before those strategies can be progressed forward. Additionally, the area immediately upstream of Glen Oaks Drive and an area upstream of the pedestrian bridge have also been identified as a wetland by the U.S. Fish and Wildlife Service. Mitigation strategies involving these crossings (Mitigation Alternative #2-1 and #3-1) which could lower the normal water surface elevations, should be reviewed for potential negative impacts to either wetland.

Example Funding Sources

There are numerous potential funding programs and grants for flood mitigation projects that may be used to offset municipal financing, including:

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

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

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

Regional Economic Development Councils/Consolidated Funding Applications (CFA)

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

Water Quality Improvement Project (WQIP) Program

The WQIP Program, administered through the NYSDEC, is a statewide reimbursement grant program to address documented water quality impairments. Eligible parties include local governments and not-for-profit corporations. Funding is available for construction/implementation projects; projects exclusively for planning are not eligible. Match for WQIP is a percentage of the award amount, not the total project cost. Deadlines are in accordance with the CFA application cycle.

Climate Smart Communities (CSC) Grant Program

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

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

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

NRCS Emergency Watershed Protection (EWP) Program

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

FEMA Hazard Mitigation Grant Program (HMGP)

The HMGP, offered by FEMA and administered by the NYSDHSES,, provides funding for creating/updating hazard mitigation plans and implementing hazard mitigation projects. The HMGP program consolidates the application process for FEMA’s annual mitigation grant programs not tied to a State’s Presidential disaster declaration. Funds are available under the Building Resilient Infrastructure and Communities (BRIC) and the Flood Mitigation Assistance (FMA) Programs.

Building Resilient Infrastructure and Communities (BRIC) Program

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

Flood Mitigation Assistance (FMA) Program

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

- Infrastructure protective measures
- Floodwater storage and diversion
- Utility protective measures
- Stormwater management
- Wetland restoration/creation
- Aquifer storage and recovery
- Localized flood control to protect critical facility
- Floodplain and stream restoration
- Water and sanitary sewer system protective measures

Summary & Conclusion

Summary

Flood mitigation efforts along Ransom Creek within the Town of Amherst date back to 1900, and flooding issues along Ransom Creek in the Towns of Amherst and Clarence have increased with development in the watershed. The main areas of flooding concern are the residential neighborhoods near the New Road crossing, between the Glen Oaks Drive and Transit Road crossings, and between the Miles Road and Stahley Road crossings. Feedback collected in the community meeting indicated that channel alignment near New Road and siltation upstream of Glen Oaks Drive were potential causes of flooding issues. In response to these flooding issues, the State of New York in conjunction with the Towns of Amherst and Clarence and Erie County are studying, addressing and comparing potential flood mitigation projects for Ransom Creek as part of the Resilient NY Initiative.

This study included an analysis of available data and new hydraulic models to evaluate the causes of flooding along Ransom Creek. Field observations of the channel substrate upstream of Glen Oaks Drive indicated that sedimentation of the channel is occurring. The effective flood profile and the corrected base condition hydraulic model indicate that significant water surface rises occur across many of the structures, indicating that the structures are unable to pass the computed discharges. Hydrologic and hydraulic data was used to model potential mitigation measures, which have the potential to reduce computed water surface elevations within high flood risk areas along Ransom Creek, and reduce potential flood related damages to properties along the creek. Constructing multiple flood mitigation measures together would increase the overall flood reduction potential along Ransom Creek.

Based on the hydraulic modeling discussed in this report, the mitigation measures that are expected to provide the greatest reductions in computed water surface elevations were the modifying the Glen Oaks Drive crossing and the pedestrian bridge upstream of Miles Road. While modifications to the Glen Oaks Drive crossing can provide substantial benefit, depending on the recurrence interval of the discharge, it is also one of the more costly options. Conversely, while the pedestrian bridge modification is the least costly and has the potential for substantial water surface elevation reductions and water surface elevation reductions in excess of 0.1 feet as far as 3,600 feet upstream of the bridge for the 1% annual chance event, it involves replacement of a private asset on private property. While the replacement of a privately owned structure may require a unique arrangement to be completed, the moderate impacts on flooding upstream and low estimated costs suggest that the alternative warrants further evaluation. The next best alternative with respect to the level of water surface elevation reduction relative to associated costs is the creation of a flood bench upstream of the pedestrian bridge. In addition to reducing water surface elevations, the construction of flood benches would help to reduce the sediment load within flood waters and limit future sedimentation of the channel. However, regulatory constraints regarding wetland areas along Ransom Creek may limit the potential extent of flood bench mitigation measures. Table 17 provides a summary of the flood mitigation alternatives evaluated in this study.

Table 17. Summary of Flood Mitigation Alternatives

Alternative No.	Description	Reduction in Water Surface Elevation (ft) Current Flows	Reduction in Water Surface Elevation (ft) Estimated Future Flows	ROM Cost (U.S. Dollars)
1-1	Create a High Flow Channel Downstream of New Road	0.0 - 0.1	0.0 - 0.1	$1.9 million
1-2	Create a Flood Bench downstream of New Road	0.0 – 0.2	0.0 – 0.2	$5.2 million
1-3	Modify New Road Bridge	Not Modeled		
2-1	Replace Culverts at Glen Oaks Drive with a Bridge	0.0 - 0.7	0.0 - 0.7	$10.1 million
2-2	Create Flood Benches between Glen Oaks Drive and Dodge Road	0.0 - 0.1	0.0 - 0.1	$1.7 million
2-3	Create a Flood Bench between Dodge Road and Transit Road	0.1 - 0.6	0.1 - 0.4	$2.6 million
3-1	Replace Pedestrian Bridge Upstream of Miles Road	0.2 - 0.6	0.2 - 0.6	$160,000
3-2	Create a Flood Bench Upstream of Pedestrian Bridges	0.2 - 0.4	0.2 - 0.4	$790,000
3-3	Create Flood Benches Downstream of Stahley Road	0.3 - 0.4	0.3 - 0.4	$2.8 million
4-1	Add Upstream Detention Basins	0.0	Not Modeled	$1.5 million
4-2	Flood Early Warning Detection System	N/A		$100,000 (not including annual operational costs)
4-3	Flood Buyout Programs	N/A		Variable (case-by-case)
4-4	Flood Proofing	N/A		Variable (case-by-case)
4-5	Area Preservation/Floodplain Ordinances	N/A		Variable (case-by-case)
4-6	Debris Management Around Bridges/Culverts	N/A		$20,000 (not including annual operational costs)

Conclusion

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

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

1. Obtain stakeholder and public input to assess the feasibility and public support of each mitigation strategy presented in this report.
2. 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 potential 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 Ransom Creek based on feasibility, permitting, effectiveness, and available funding.

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Appendix A. Summary of Data and Reports Collected

Year	Type	Document Title	Author	Publisher
1961	Report	Technical Paper No. 40		Weather Bureau
1971	Report	Flood Plain Information: Tonawanda Creek and Its Affected Tributaries	Buffalo District	USACE
1983	Report	Flood Characteristics of Urban Watersheds in the United States	Sauer, V. B., Thomas, W. O., Stricker, V. S., & Wilson, K. V.	USGS
1983	Report	Buffalo Metropolitan Area, N.Y. Water Resources Management Interim Report on Feasibility of Flood Management, Tonawanda Creek Watershed: Final Feasibility Report and Final EIS (2 v.)	Buffalo District	USACE
1991	Report	Regionalization of Flood Discharges for Rural, Unregulated Streams in New York, Excluding Long Island	Lumia, R.	USGS
1992	Report	Flood Insurance Study: Town of Amherst, NY		FEMA
1996	Report	Flood Insurance Study: Town of Clarence, NY		FEMA
1996	Book	Applied River Morphology, 2nd Edition	Rosgen, D. L., & Silvey, H. L.	Wildland Hydrology Books
2000	Report	Title 44: Emergency Management and Assistance, Chapter I - Subchapter B: Insurance and Hazard Mitigation		FEMA
2006	Report	Magnitude and Frequency of Floods in New York	Lumia, R; Freehafer, D A; Smith, M J.	USGS
2007	Report	National Engineering Handbook, Part 654: Stream Restoration Design, Technical Supplement 3E: Rosgen Stream Classification Techniques - Supplemental Materials	Natural Resources Conservation Service	United States Department of Agriculture
2009	Report	Bankfull Discharge and Channel Characteristics of Streams in New York State	Mulvihill, C. I., Baldigo, B. P., Miller, S. J., DeKoskie, D., & DuBois, J.	
2010	Report	DHS Risk Lexicon – 2010 Edition		United States Department of Homeland Security

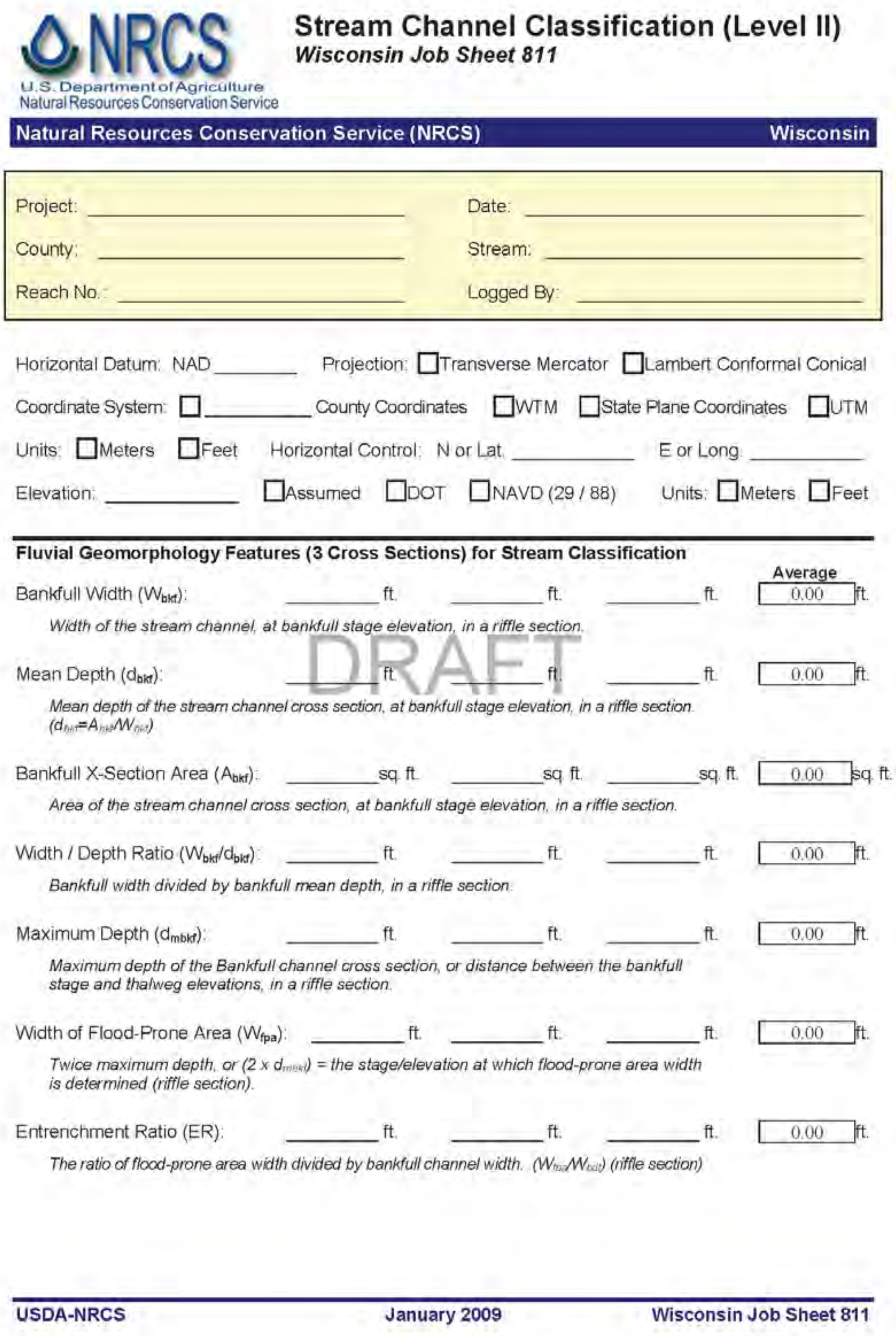
Year	Type	Document Title	Author	Publisher
2011	Article	Responding to Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation	Rosenzweig, C., Solecki, W., DeGaetano, A., O'Grady, M., Hassol, S., & Grabhorn, P.	New York State Energy Research and Development Authority
2011	Article	An Overview of CMIP5 and the Experiment Design	Taylor, K. E., Stouffer, R. J., & Meehl, G. A.	Bulletin of the American Meteorological Society
2012	Report	Federal Highway Administration Report No. FHWA-HIF-12-018, HDS-7: Hydraulic Design of Safe Bridges	Zevenbergen LW, Ameson LA, Hunt JH, Miller AC	United States Department of Transportation
2012	Article	Geomorphometric Characterization of Upper South Koel Basin, Jharkhand: A Remote Sensing & GIS Approach	Parveen, R., Kumar, U., & Singh, V. K.	Journal of Water Resource and Protection
2013	Report	Report No.: FEMA P-936 - Floodproofing Non-Residential Buildings		FEMA
2013	Article	Anatomy of a Buyout Program - New Yor Post-Superstorm Sandy	Siders, A. R.	Vermont Law School
2013	Article	Flooding Forces Some Road Closures		WGRZ
2013	Article	Heavy Flooding, power outages affect town	Jagord, Steven	Clarence Bee
2014	Article	Morphometric Analysis of a Drainage Basin Using Geographical Information System: A Case study	Waikar, M. L., & Nilawar, A. P.	International Journal of Multidisciplinary and Current Research
2015	Report	Report No.: FEMA P-1037 - Reducing Flood Risk to Residential Buildings That Cannot Be Elevated		FEMA
2015	Report	Development of Flood Regressions and Climate Change	Burns, D. A., Smith, M. J., & Freehafer, D. A.	USGS
2016	Report	HEC-RAS River Analysis System User's Manual, Version 5		USACE
2016	Report	Buffalo Creek - Lexington Green CAP 205, Report No. P2#443918		USACE
2016	Data	Multi-Resolution Land Characteristics Consortium National Land Cover Database		USGS

Year	Type	Document Title	Author	Publisher
2017	Data	USGS National Climate Change Viewer	Alder, J. R., & Hostetler, S. W.	USGS
2017	Data	National Oceanic and Atmospheric Administration Atlas 14 Point Precipitation Frequency Estimates	National Weather Service's Hydrometeorological Design Studies Center	National Oceanic and Atmospheric Administration
2017	Data	*StreamStats*, version 4	Ries, K. G., Newson, J. K., Smith, M. J., Steeves, Steeves, P. A., Haluska, T. L., Vraga, H. W.	USGS
2018	Report	DRAFT New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act		NYSDEC
2018	Article	Governor Cuomo Announces $3 Million for Studies to Reduce Community Flood Risk		New York State Governor's Press Office
2019	Report	Flood Insurance Study: Erie County, NY		FEMA
2019	Report	Bridge Manual		NYSDOT
2019	Data	Bridge Point Location & Attributes		NYSDOT
2019	Data	City/Town Boundaries, County Boundaries		New York State Office of Information Technology Services
2019	Data	Dams, Hydrography		NYSDEC
2019	Data	Surficial Geology, Physiographic Map		New York State Museum
2019	Data	New York State Statewide Parcels for Public Use		New York State Department of Taxation and Finance's Office of Real Property Tax Services
2019	Data	RSMeans CostWorks 2019. RSMeans Data Online.		Gordian, Inc.
2020	Data	National Water Information System: Web Interface, Site Inventory for the Nation		USGS
2019	Report	Policy Manual: NY Rising Buyout and Acquisition Program, Version 7.0		NYSGOSR
2020	Website	Hazard Mitigation Grant Program (HMGP)		FEMA

Appendix B. Agency and Stakeholder Meeting Attendees List

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

Appendix C. Field Data Collection Forms



U.S. Department of Agriculture
Natural Resources Conservation Service

Stream Channel Classification (Level II)

Wisconsin Job Sheet 811

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

Project: ______________________ Date: ______________________

County: ______________________ Stream: ______________________

Reach No.: ______________________ Logged By: ______________________

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

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

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

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

Fluvial Geomorphology Features (3 Cross Sections) for Stream Classification

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

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

Reach Characteristics

Channel Materials (Particle Size Index) D50: __________ mm

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

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

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

Channel Sinuosity (K): ________________

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

Distance to Up-Stream Structures: ____________________________.

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

Dominant Channel Soils at an Eroding Bank Location

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

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

Left: ____

____

Right: ____

____

Riparian Vegetation at an Eroding Bank Location

Left Bank: ____________________________ Right Bank: ____________________________

Percent Total Area (Mass): Left: _________________ Right: ____________________

Percent Total Height with Roots: Left: _________________ Right: ____________________

Other Bank Features at an Eroding Bank Location

Actual Bank Height: ______________________ Bankfull Height: ______________________

Bank Slope (Horizontal to Vertical):

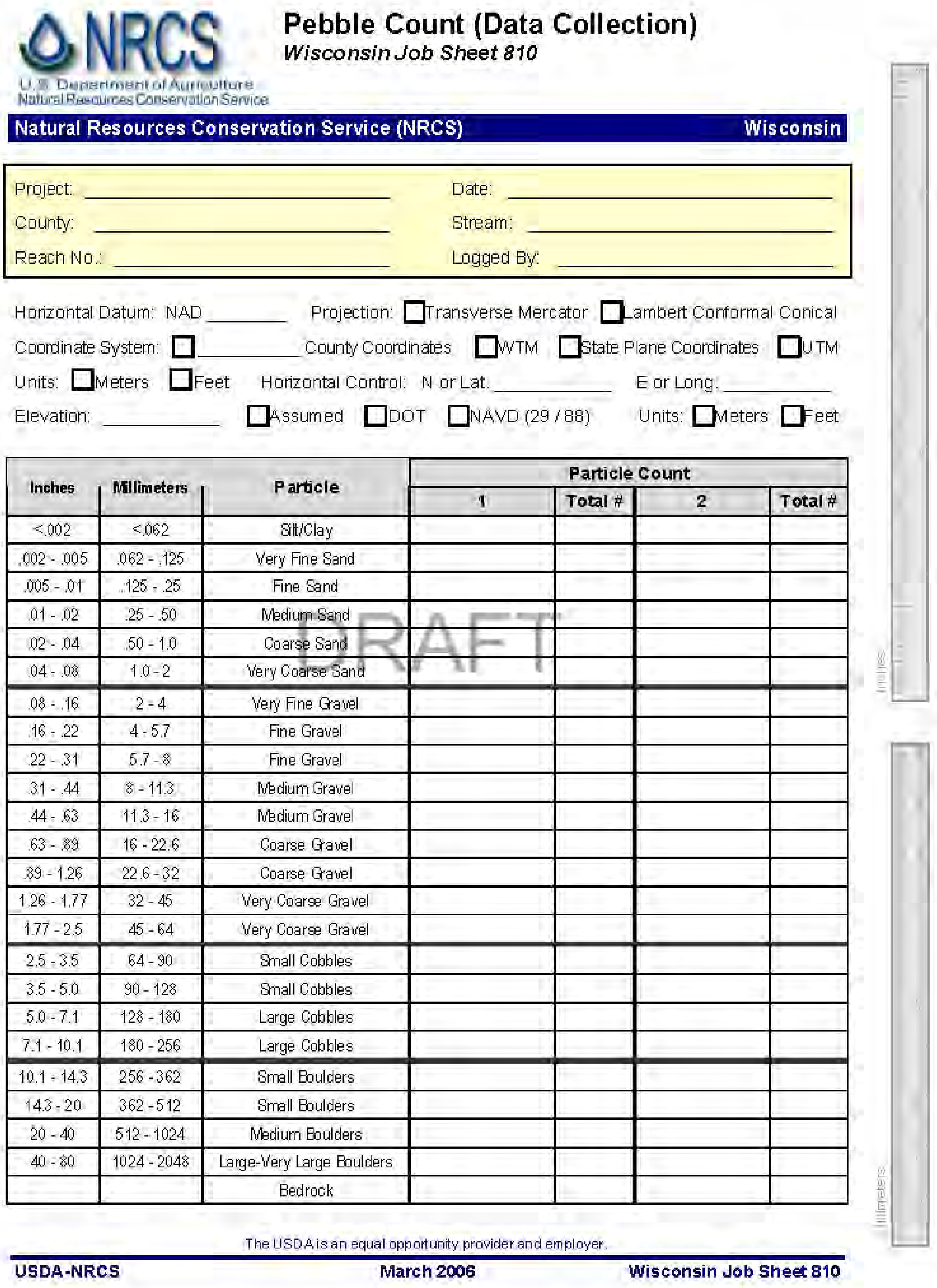
Left:	☐0-20° (flat) ☐21-60° (moderate) ☐61-80° (steep) ☐81-90° (vertical) ☐90°+ (undercut)	Right:	☐0-20° (flat) ☐21-60° (moderate) ☐61-80° (steep) ☐81-90° (vertical) ☐90°+ (undercut)

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

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

The USDA is an equal opportunity provider and employer.

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



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

Pebble Count (Data Collection)

Wisconsin Job Sheet 810

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

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

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

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

USDA-NRCS **March 2006** **Wisconsin Job Sheet 810**

Resilient New York

Date:

Field crew:

Stream:

Road crossing:

Structure data: ☐ Bridge

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

☐ Culvert (see data below)

Length in direction of flow:

Manning value: Top: Bottom:

Deck thickness:

Height of rail:

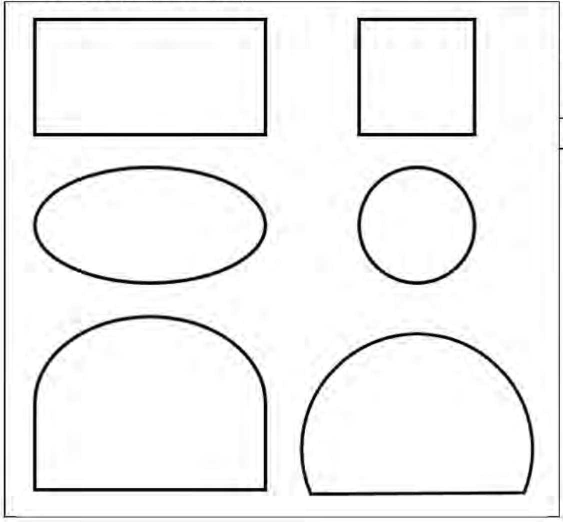
Type of rail:

Structure material:

Bottom substrate:

Description:

Culvert Shape (mark one)



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

Opening width: _____

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[1] All measurements should be taken to 0.1 feet

P:\2065 - Resilient NY Initiative\Field Data Collections\Field_Template.docx

Appendix D. Photo Log

List of Additional Field Photos

Photo D-1. Downstream face of bike path bridge crossing Ransom Creek near confluence with Tonawanda Creek (2/17/2020)
Photo D-2. Upstream face of Tonawanda Creek bridge crossing Ransom Creek near confluence with Tonawanda Creek (2/17/2020)
Photo D-3. Upstream face of Hopkins Road Bridge over Ransom Creek (2/17/2020)
Photo D-4. Downstream face of Millersport Highway bridge over Ransom Creek (2/17/2020)
Photo D-5. Upstream face of New Road bridge over Ransom Creek (2/17/2020)
Photo D-6. Upstream face of Glen Oaks Drive culverts for Ransom Creek (2/17/2020)
Photo D-7. Upstream face of Dodge Road bridge crossing Ransom Creek (3/5/2020)
Photo D-8. Upstream face of Transit Road bridge crossing at Ransom Creek (2/17/2020)
Photo D-9. Upstream face of County Road bridge crossing at Ransom Creek (2/17/2020)
Photo D-10. Downstream face of Miles Road bridge crossing at Ransom Creek (2/17/2020)
Photo D-11. Upstream face of Stahley Road bridge crossing at Ransom Creek (2/17/2020)
Photo D-12. Upstream face of Heise Road bridge crossing at Ransom Creek (2/17/2020)

Photo D-1. *Downstream face of bike path bridge crossing Ransom Creek near confluence with Tonawanda Creek (2/17/2020)*

Photo D-2. *Upstream face of Tonawanda Creek bridge crossing Ransom Creek near confluence with Tonawanda Creek (2/17/2020)*

Photo D-3. *Upstream face of Hopkins Road Bridge over Ransom Creek (2/17/2020)*

Photo D-4. *Downstream face of Millersport Highway bridge over Ransom Creek (2/17/2020)*

Photo D-5. *Upstream face of New Road bridge over Ransom Creek (2/17/2020)*

Photo D-6. *Upstream face of Glen Oaks Drive culverts for Ransom Creek (2/17/2020)*

Photo D-7. *Upstream face of Dodge Road bridge crossing Ransom Creek (3/5/2020)*

Photo D-8. *Upstream face of Transit Road bridge crossing at Ransom Creek (2/17/2020)*

Photo D-9. *Upstream face of County Road bridge crossing at Ransom Creek (2/17/2020)*

Photo D-10. *Downstream face of Miles Road bridge crossing at Ransom Creek (2/17/2020)*

Photo D-11. *Upstream face of Stahley Road bridge crossing at Ransom Creek (2/17/2020)*

Photo D-12. *Upstream face of Heise Road bridge crossing at Ransom Creek (2/17/2020)*