Iowa Flood Resilient Communities Cohort: Potential Flood Mitigation Solutions for Tributary A in Manchester, IA

by

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IOWA FLOOD RESILIENT COMMUNITIES COHORT: POTENTIAL FLOOD MITIGATION SOLUTIONS FOR TRIBUTARY A IN MANCHESTER, IOWA

In December 2023, the American Flood Coalition (AFC) launched the Iowa Flood Resilient Communities Cohort, which provides support in accessing federal funding for flood projects. The cohort includes local officials and community partners from four Iowa communities: Columbus Junction, Dubuque, Manchester and Muscatine. AFC partnered with the Iowa Flood Center (IFC) to provide technical support in exploring flood mitigation alternatives and to assist in conceptualizing project designs that could be further pursued.

IFC provided technical assistance to the City of Manchester in its exploration of potential options to – reduce both flood risk and the floodplain footprint of Tributary A. IFC evaluated conceptual daylighting scenarios of Tributary A using a hydraulic model.

1. Background

The City of Manchester is subject to flooding from the Maquoketa River along its west side and smaller tributaries located to the east, as shown in Figure 1-1. The city participates in FEMA's National Flood Insurance Program (NFIP) to allow community members the opportunity to purchase flood insurance as a financial protection against flood losses. In exchange, the city must adopt and enforce floodplain management regulations to reduce future flood risks to new construction and substantially improved structures in Special Flood Hazard Areas (SHFAs).

In 2014, FEMA revised and updated its flood insurance rate maps (FIRMs) delineating the SFHA in Manchester. These changes were based on updates to the hydrology calculations and hydraulic models. One significant update was the estimated watershed area of Tributary A draining to Prospect Ave increased from 2.2 square miles to 3.5 square miles. The 2009 drainage area is shown with the additional drainage area added in 2014 in Figure 1-2. This change in drainage area includes areas to the west that were found to actually drain to Tributary A in the 2014 study. This increase in drainage area directly affects estimates of annual exceedance probability (AEP) flows – increasing the 1-percent AEP flow from 1450 cubic feet per second (cfs) to 2420 cfs, a 67% increase.

The increase in flow along with updated hydraulic modeling is then reflected in an increase in the SFHA in 2014. Figure 1-2 shows the relative change in SFHA footprint in effective FIRMS from 2009 and 2014. These FIRM changes resulted in larger SFHA for Tributary A, Tributary 2, and Tributary 3 that flow through the eastside of Manchester. This increase in SFHA footprint required more homes to hold flood insurance and restricted development within the floodplain and floodway. These mapping updates likely provide a more realistic estimate of flood risk in the community, especially as we begin experiencing changes in our rainfall intensity and frequency due to climate change. However, like most communities, when flooding isn't occurring, having more homes in the SFHA is problematic for homeowners and the community. Like most communities, Manchester would like to reduce the number of homes in the SFHA. This accomplishment would ideally be a result of implementing flood mitigation practices that also reduce flood risk.

Figure 1-1. Study area near Manchester, Iowa. Tributary A has a drainage area of 3.5 square miles at Prospect Avenue. A portion of the Tributary A creek is buried within Manchester.

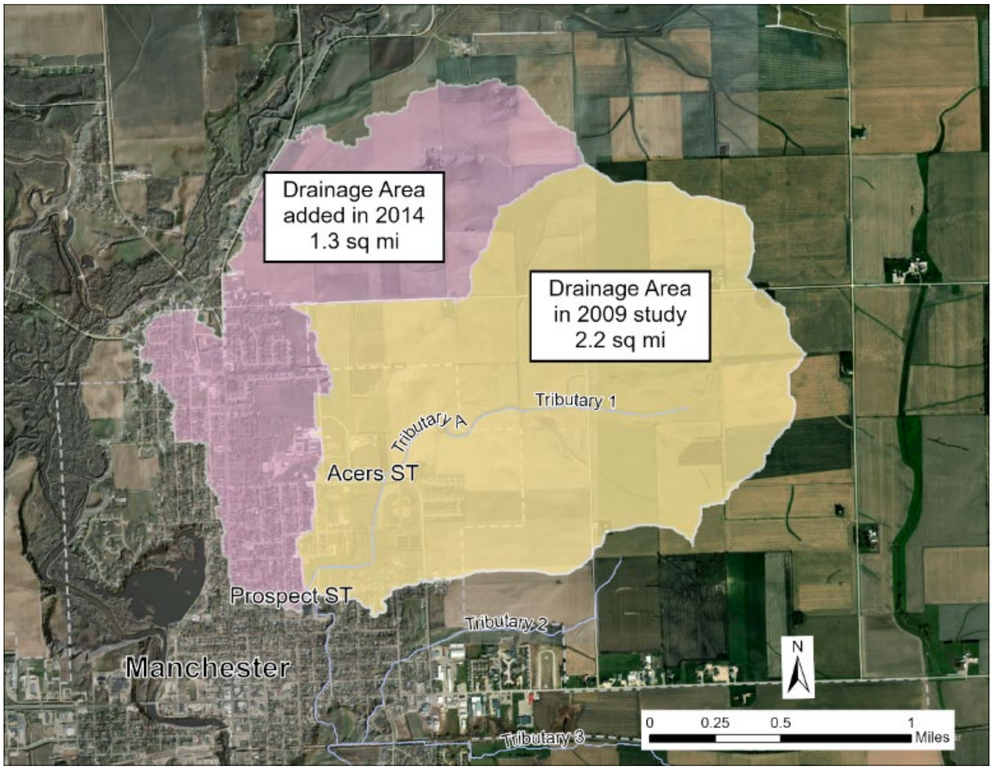

Figure 1-2. Approximate Tributary A drainage area (2.2 sq mi) upstream of Prospect Street in the 2009 FEMA study, along with additional drainage area (1.3 sq mi) added to Tributary A in the 2014 effective study for a total of 3.5 sq mi.

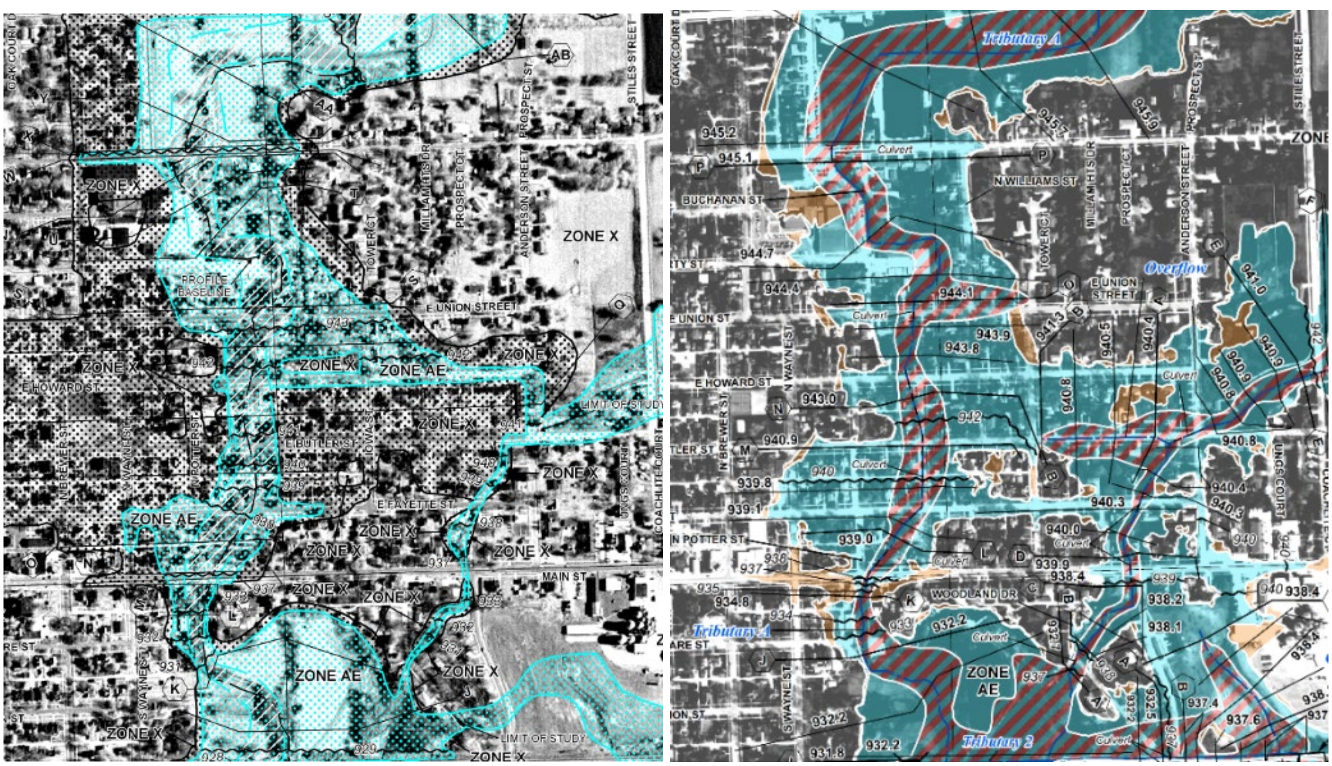

Figure 1-3. Historic FEMA FIRM maps from 2009 (left), and from 2014 (right). The SFHA changed markedly from 2009 to 2014 based on updated hydraulics and hydrology.

One hurdle to reducing the community's flood risk is a 750-foot-long section of Tributary A that was "buried", likely sometime prior to 1900. Figure 1-4 shows locations of buried sections of tunnel that convey flow under two residential blocks between East Howard and East Fayette Streets. Several homes are built right next to or on top of these sections of tunnel. Figure 1-4 also shows the approximate tunnel dimensions measured by Mr. Jason Haight, City Street Superintendent in September 2024. The size of this tunnel is only capable of conveying a fraction of the 1-percent AEP flow. Mr. Haight also observed multiple sanitary sewer pipes from nearby homes running through the tunnel sections. Figure 1-5 shows the approximate alignment of the buried tunnel sections looking south from East Howard Street.

In discussions with representatives from the City of Manchester, one question they needed help in answering is –would daylighting help reduce flood risk? IFC agreed to provide technical assistance in exploring the degree of daylight necessary to reduce the 1-percent AEP flood extents. IFC developed a hydraulic model to help explore different daylighting scenarios and their relative impact on the simulated flood extents.

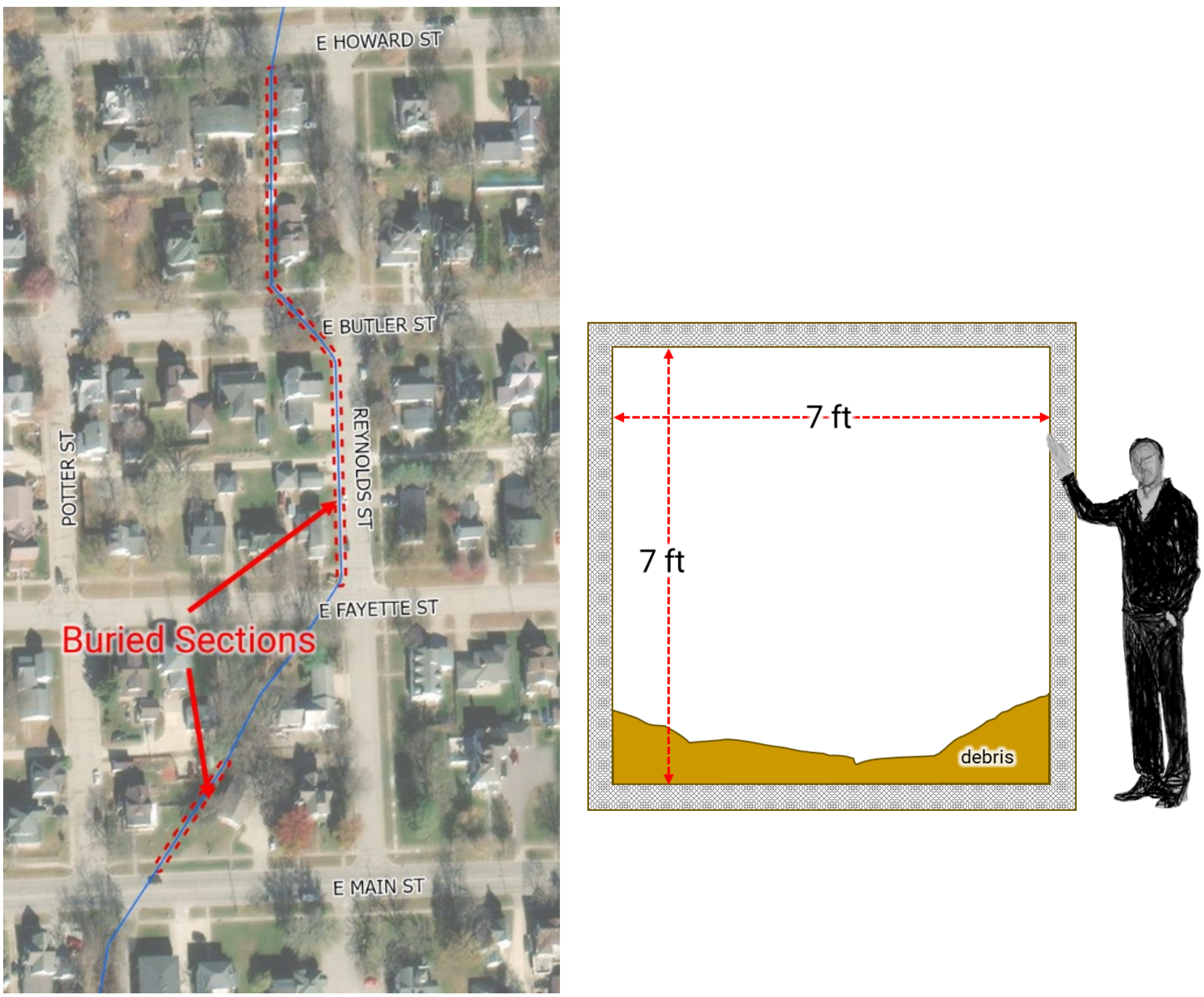

Figure 1-4. (left)Sections of buried creek between Howard Street, East Fayette Street, and Main Street, (right) approximate dimensions of the buried tunnel sections.

Figure 1-5. Street view looking south from Howard Street along the approximate alignment of the buried creek tunnel.

2. Model Development

IFC utilized the U.S. Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS) Version 6.6 software to develop a two-dimensional (2D) model to simulate FEMA AEP flows through the tunnel sections and overland flow processes simultaneously. Development of an existing conditions model provided valuable insight into how flooding occurs along Tributary A and provided a baseline to evaluate additional models of daylighting scenarios.

This model is different than the currently effective one-dimensional (1D) FEMA model for Tributary A. While this 2D model can easily be modified to investigate different scenarios, it likely wouldn't be used to revise the SFHA or the floodway. FEMA has historically used 1D models to delineate the floodway because of their simplicity and standard usage over several decades. Recently, FEMA has developed guidance for creating floodways for 2D model given their growing usage. However, future model updates will likely use the currently effective FEMA 1D model as a starting point.

Hydraulic Modeling

The HEC-RAS 2D model utilizes almost 20,000 grid cells to model surface flow originating from Tributary A, shown in Figure 2-1. The average cell size was 25 feet by 25 feet squares, with smaller cells located along features that require more detail like the Tributary A open channel. Elevations for each grid cell face were extracted from the 1-meter resolution bare-earth 2020 LiDAR statewide dataset (also shown in Figure 2-1). The study domain begins just upstream of East Prospect Street and ends approximately 1,800 feet downstream of the Canadian National Railway.

The 2009 High Resolution Land Cover (HRLC) dataset provided by Iowa Department of Natural Resources (Iowa DNR), shown in Figure 2-2, was used to parameterize using surface roughness values. The corresponding Manning's n values are shown in Table 2-1.

The buried sections of tunnel were modeled using one-dimensional (1D) culvert structures that stretched from the existing inlet location upstream of East Howard Street to East Fayette Street, and another 1D culvert section just upstream of East Main Street. Bridge structures along Tributary A were modeled using the 1D bridge/culvert structure routines within HEC-RAS and were incorporated into the 2D model grid.

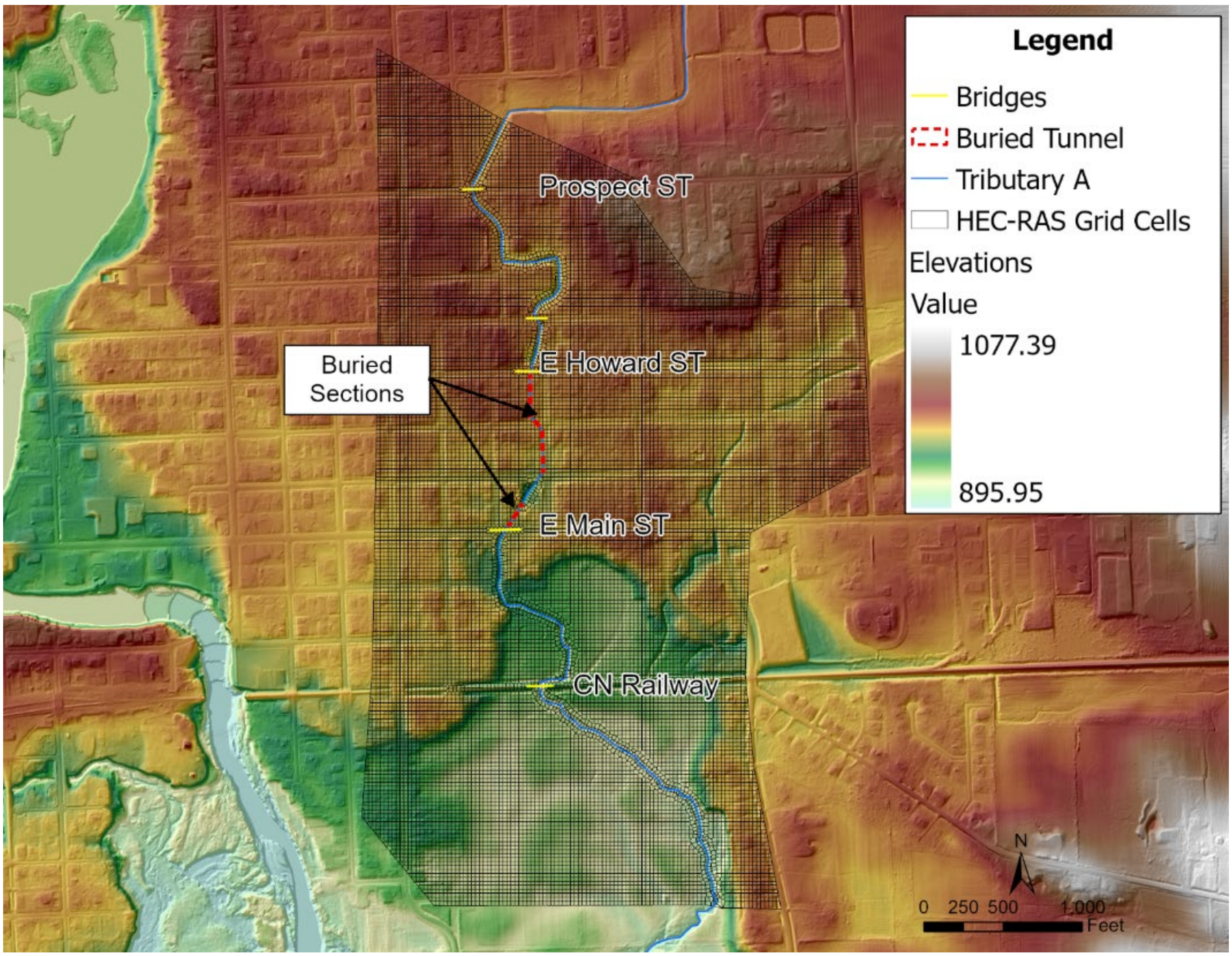

Figure 2-1. HEC-RAS 2D model grid used in simulating Tributary A existing conditions shown with LiDAR terrain elevations.

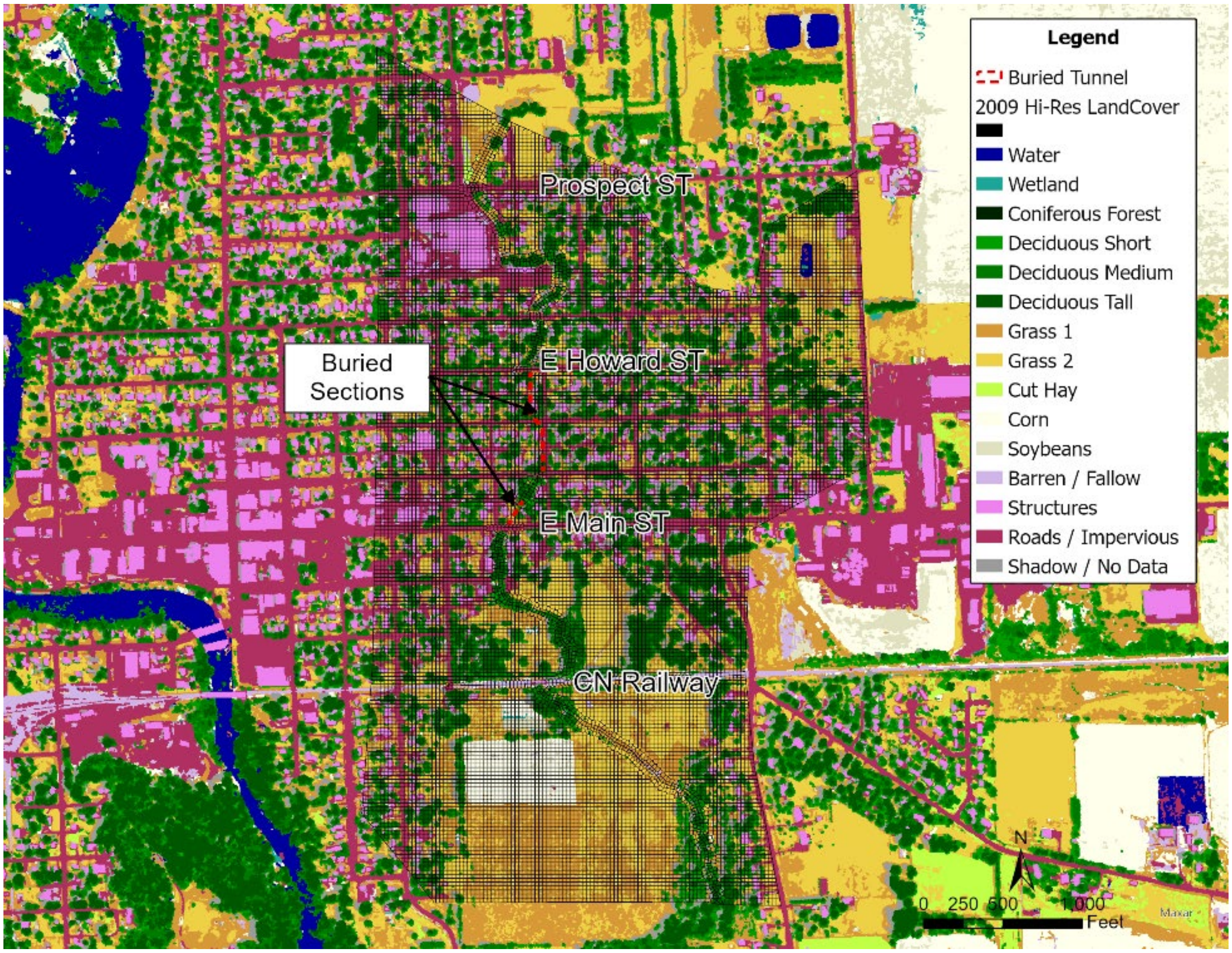

Figure 2-2. 2009 High Resolution Land Cover dataset provided by Iowa DNR used to parameterized surface roughness.

Table 2-1. Manning's n roughness values parameterized by land cover.

Land Cover	Manning's n Roughness
Water	0.032
Wetland	0.075
Coniferous Forest	0.15
Deciduous Short	0.1
Deciduous Medium	0.1
Deciduous Tall	0.1
Grass 1	0.03
Grass 2	0.03
Cut Hay	0.03
Corn	0.035
Soybeans	0.035
Structures	0.3

Hydrology

The HEC-RAS model was used to simulate FEMA 1-percent AEP flows on Tributary A. The boundary conditions used in simulations are shown in Figure 2-2. The upstream inflow was 2,420 cubic feet per second (cfs), additional lateral flow just upstream of the CN Railway increases Tributary A flow to 2,630 cfs. These values mimic 1-percent AEP flows along Tributary A from the currently effective FEMA flood insurance study (FIS). The downstream boundary condition was a steady water level condition of 923.6 ft to match the Tributary A water surface profile in the FIS.

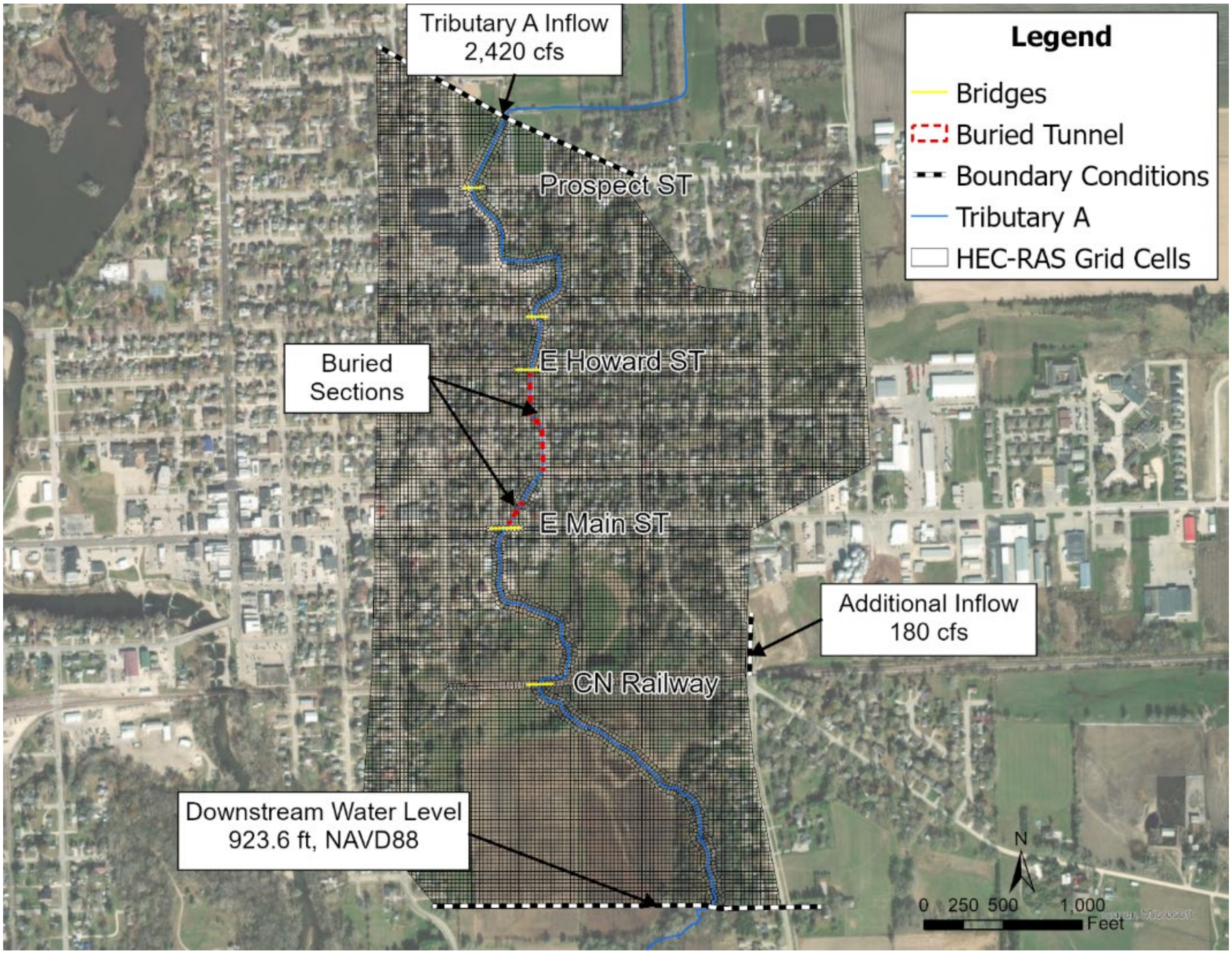

Figure 2-3. HEC-RAS model boundary conditions – FEMA 1-percent AEP inflows and downstream water level.

3. Simulation Results – Existing Conditions

Simulation of the 1-percent AEP produces a flood extent similar to the effective FEMA SFHA, shown in Figure 3-1. The 2D model generally produces a smaller flood extent compared to the FEMA SFHA. This mainly due to the use of different models and methods (FEMA used a 1D model), but also because the FEMA SFHA is more conservative because it includes simulation of the 1-percent AEP events on Tributary 2 and 3. Regardless, these 2D simulation results serve as a convenient baseline to evaluate relative benefits of what-if scenarios on Tributary A.

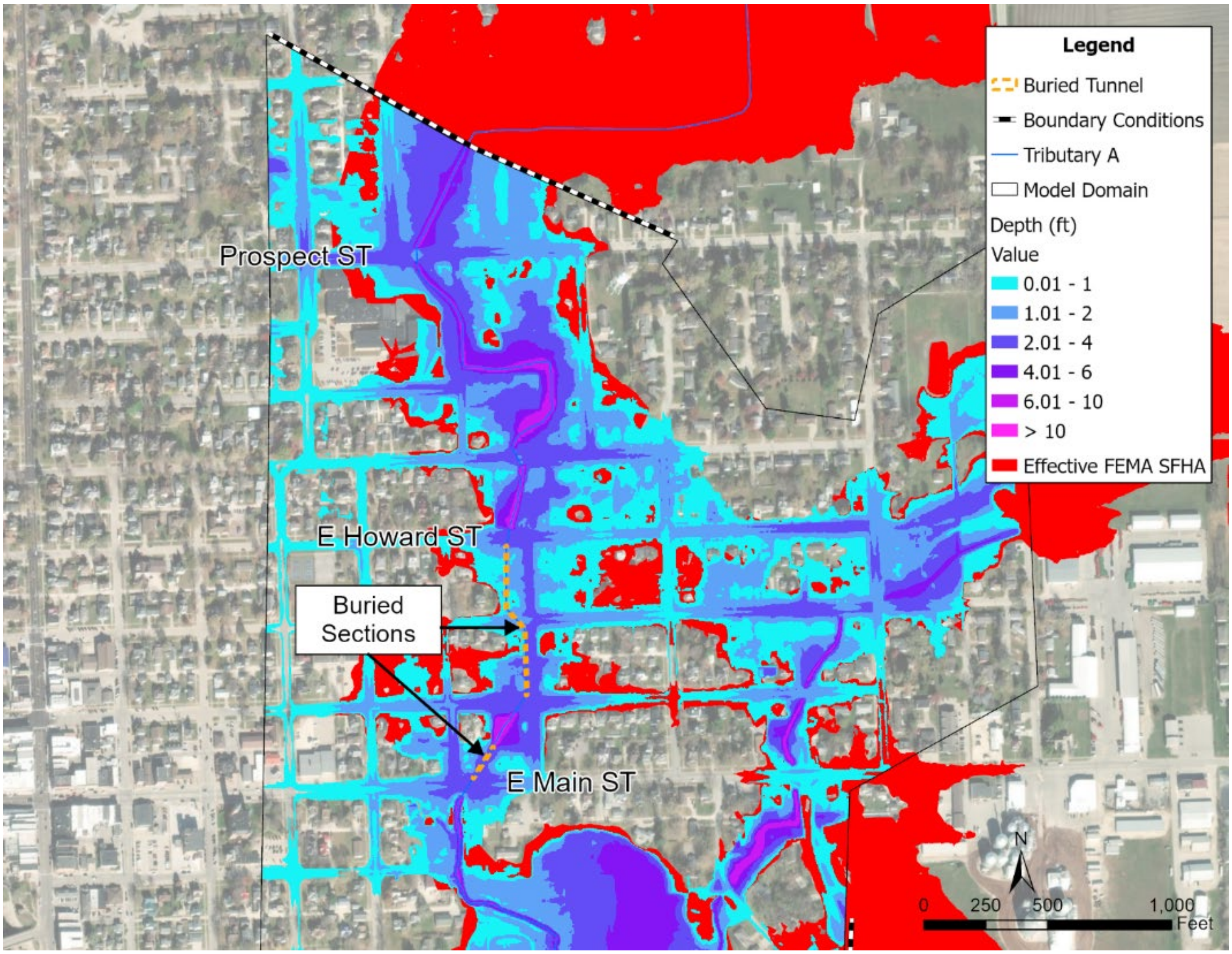

Figure 3-1. Simulated depths with the effective 1-percent AEP flows. Shown with effective FEMA SFHA (in red) for comparison. Note: The 2D simulated flood extents were generated using a different model than the FEMA SFHA, and not simulating flood extents from other tributaries.

Simulation results of existing conditions reveal the complexity of overland flow over the urban landscape. RAS Mapper, the visualization interface available in HEC-RAS, was used to generate particle tracing to visualize flow paths, shown in Figure 3-2. A significant portion of flow leaves the main channel and overtops Prospect Street, outflanking the culvert. This indicates the 10'x5' culvert at this location the is the first upstream bottleneck. Once flow leaves the channel, most doesn't re-enter the main channel. Additional bridges and culverts downstream also appear unable to contain the channel flow, which travels east along east-west streets (Union, Howard, and Butler

Streets) and into Tributary 2's floodplain. The maximum simulated flow through the 7'x7' tunnel section between Howard and Fayette was approximately 315 cfs, nearly eight times less than the 1-percent AEP flow of 2,420 cfs.

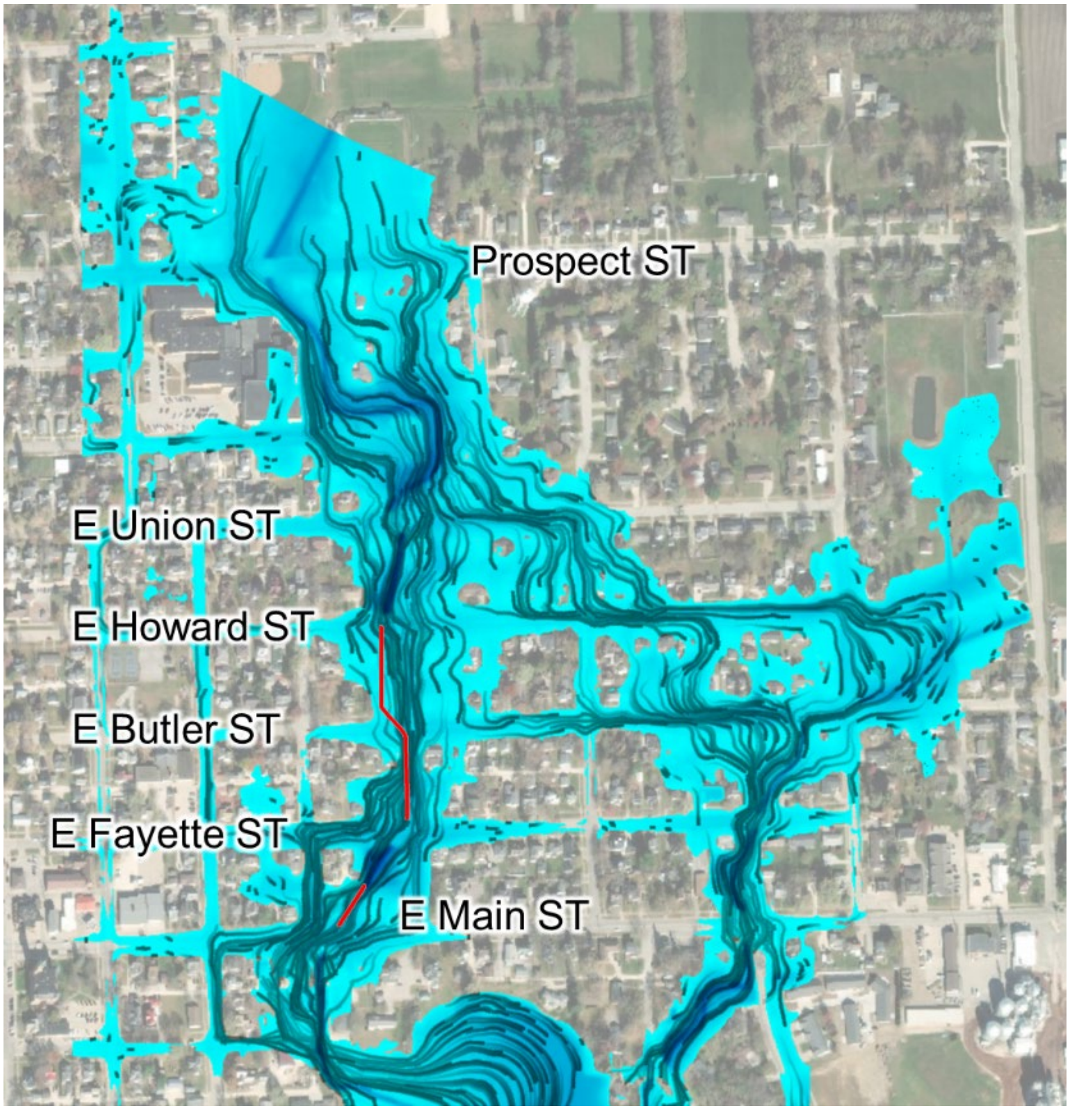

Figure 3-2. Simulated flow paths for existing conditions, 1-percent AEP flow.

4. Minimum Daylighting Scenario

Daylighting the creek could potentially add capacity to the main channel and reduce flood extents. However, due to the proximity to homes and roadways, it is desirable to explore minimum daylighting scenario to minimize impacts to nearby structures. This scenario would involve constructing an open channel with nearly vertical walls to minimize project width. It would require safety railings or fencing for safety along the entire project extents, which are shown in Figure 4-1 While this option would have minimum impacts to nearby structures, it would not add green space or be visually appealing. A typical cross-section along the buried creek alignment is shown in Figure 4-2. This scenario would also require modifying driveways and alleyways along the project extents.

Figure 4-1. Minimum daylighting project extents.

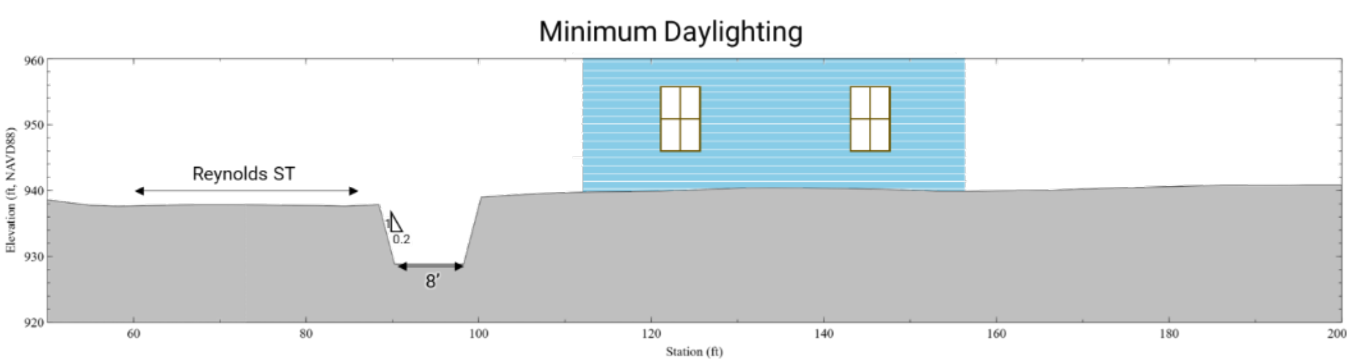

Figure 4-2. Typical cross-section for the minimum daylighting scenario looking south along North Reynolds Street.

5. Medium Daylighting Scenario

While the minimum daylighting scenario minimizes impacts to nearby roadways and homes, it reduces the effectiveness of the improvements through the reach. A medium daylighting scenario was also developed that would add significant capacity to the stream channel and culverts but would require buyouts of some homes. This scenario's project extents are shown in Figure 5-1. Culvert upgrades doubling the existing flow capacity were incorporated from Prospect to Main Street in the model. This was accomplished by duplicating the current culvert openings. This step would be necessary to take advantage of the stream channel upgrades through the project reach. Minimal channel improvements would be completed from Prospect Street to East Howard, with the most significant channel improvements occurring between East Howard and East Fayette Street. The buried sections would be replaced by an 10 foot wide open channel with sloping 2:1 (H:V) sides, and an overall channel width of 50 feet, with a typical cross-section shown in Figure 5-2. This scenario would also require modifying driveways and alleyways along the project extents.

Figure 5-1. Medium daylighting project extents – uncovering buried sections, along with channel and culvert upgrades from Prospect to East Main Streets.

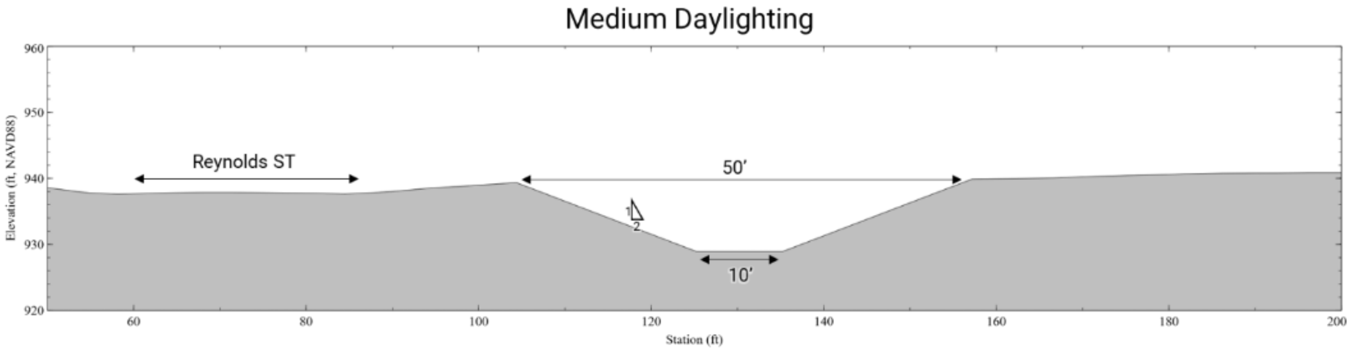

Figure 5-2. Typical cross-section for the medium daylighting scenario between East Howard and East Fayette Streets, looking south along North Reynolds Street. Creates green space and restores the creek floodplain but would affect some private properties and require upgrades at culverts through the project extents.

6. Maximum Daylighting Scenario

A maximum daylighting scenario was developed that maximized the ability of the Tributary A channel to convey flood flows. This scenario would require more buyouts than the medium scenario and would have a much wider project extents, shown in Figure 6-1. This scenario would involve constructing a 10 foot wide low flow channel, approximately 1-2 feet deep with a flat bench approximately 40 feet wide, and an overall channel width of 100 feet. The banks would have sloping 2.5:1 (H:V) sides, a typical cross-section is shown in Figure 6-2. Significant channel upgrades were also extended upstream of Prospect Street and extend past the CN Railway. The significant channel upgrades would also require similar changes to culverts through the reach. All culverts were assumed to be replaced with bridges having a similar cross-section to the upgraded stream channel.

Figure 6-1. Maximum daylighting project extents – uncovering buried sections, along with significant channel upgrades and bridge replacements beginning upstream of Prospect Street to CN Railway.

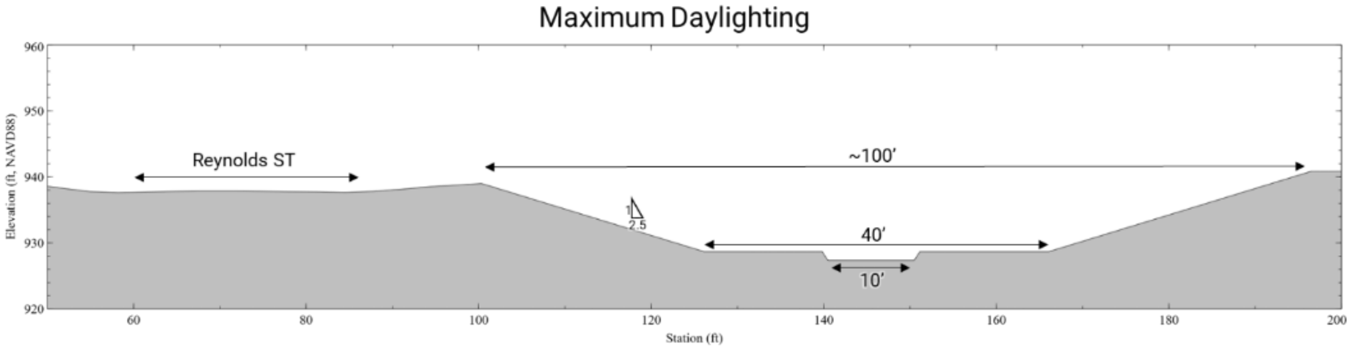

Figure 6-2. Typical cross-section for the maximum daylighting scenario, looking south along North Reynolds Street. This would require more property buyouts and would require bridge replacements along with significant channel upgrades.

7. Simulation Results and Discussion – All Scenarios (1% AEP)

Simulated flood extents for the existing conditions (base), minimum, medium, and maximum daylighting scenarios are shown in Figure 7-1. The minimum daylight scenario had negligible effect on reducing the inundation extents from the baseline. This is likely because bottlenecks at culvert locations upstream are still in place. Flow leaving the channel between Prospect and East Howard Streets doesn't reenter and continues overland. The medium daylighting scenario had some reduction in inundation extents from the baseline. Analysis of the medium daylighting results indicated that although there were channel and culvert upgrades upstream of the buried sections, they need to be more significant to add capacity and contain flows. The maximum daylighting scenario significantly reduced the inundated extents, containing flood flows upstream of East Union Street and conveying through the urban reach and into the low-lying areas upstream of CN Railway.

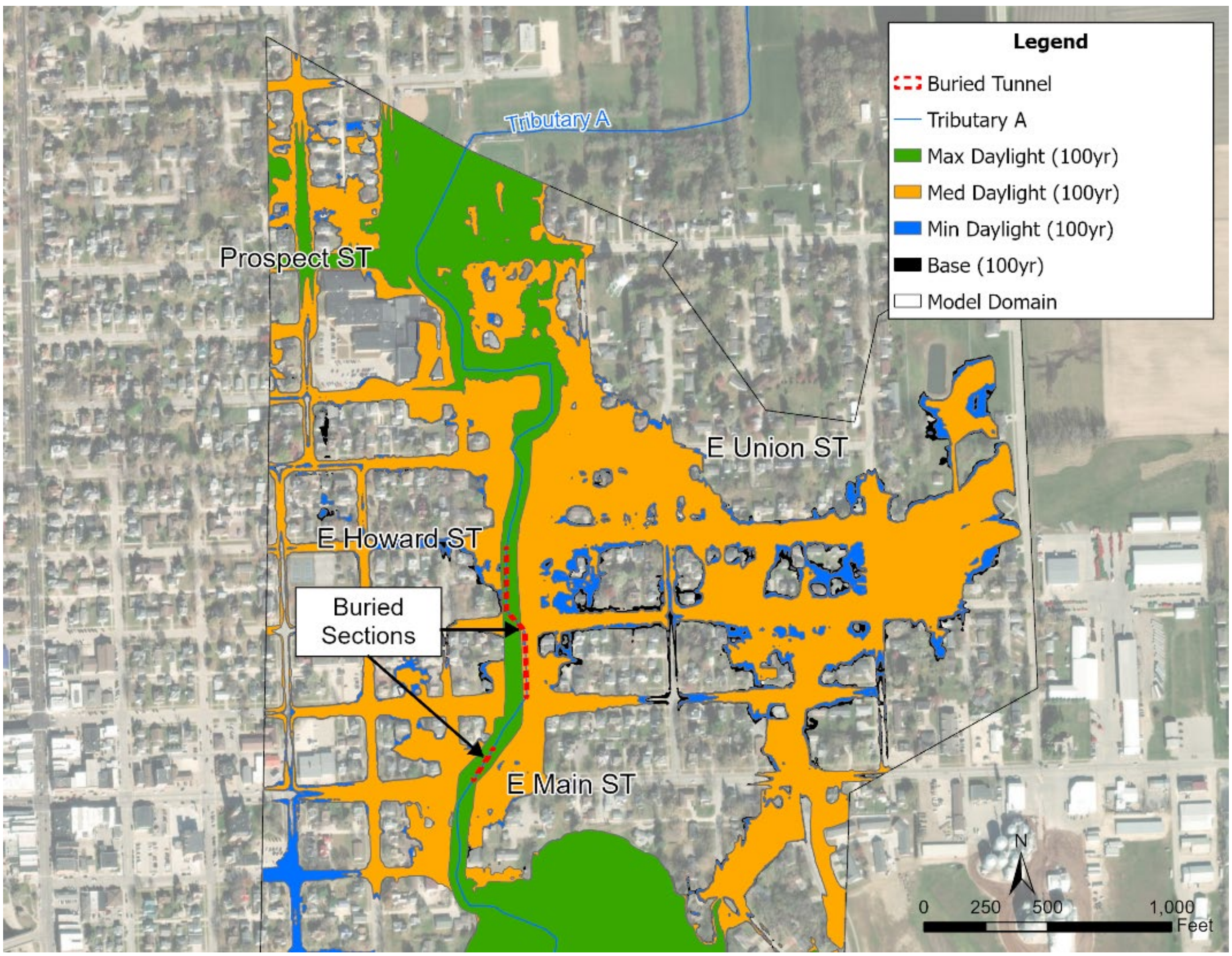

Figure 7-1. Simulation results for all scenarios (base, minimum, medium, and maximum daylight) for the 1-percent AEP flow.

Corresponding water level profiles for each scenario are shown in Figure 7-2. In general, profiles for the base, minimum and medium daylighting scenarios are very similar, hence the similar inundation extents. The maximum daylighting scenario has a significantly lower water level profile due to the significant channel and culvert improvements.

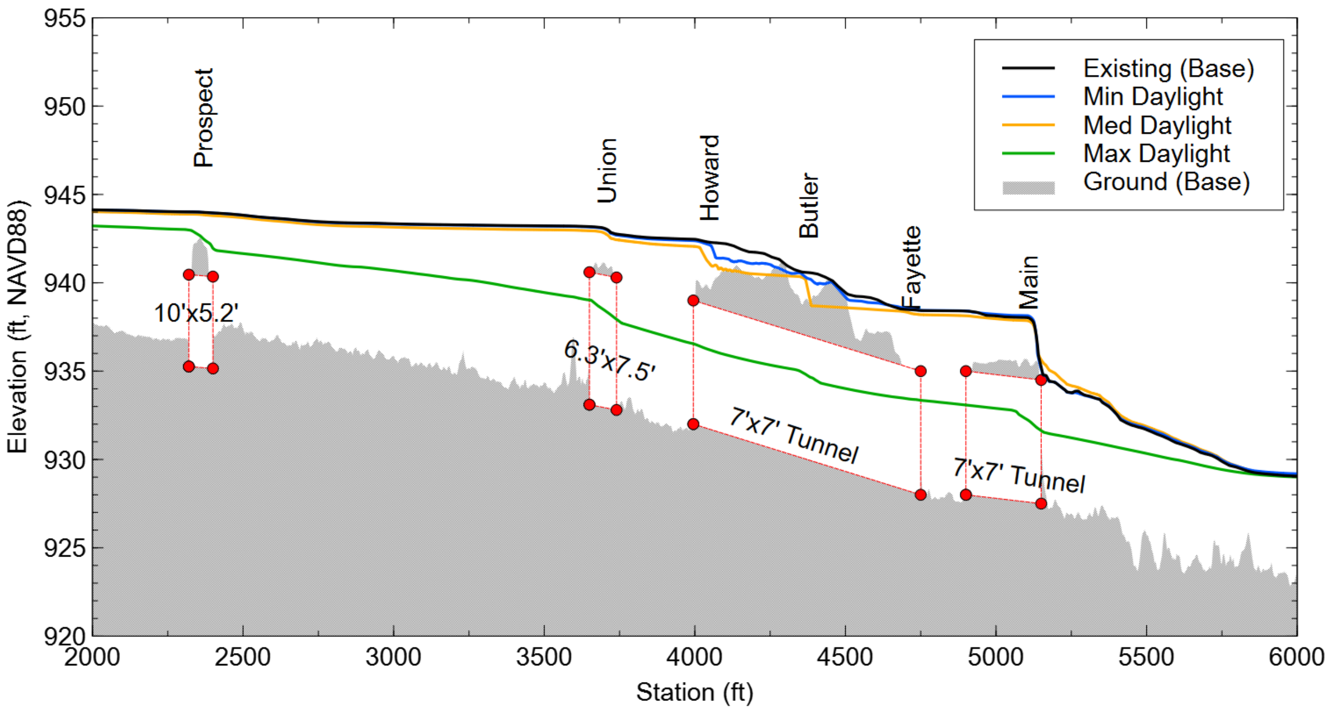

Figure 7-2. Profiles of water level for base, minimum, medium, and maximum daylighting. Existing culverts and ground surface are also shown. Daylighting scenarios have altered culverts and ground profiles (not shown).

The simulation results show that significant improvements to the stream channel and culvert crossings, like the maximum daylighting scenario, are necessary to contain the 1-percent AEP flow and reduce the inundation extents. This would require huge amounts of funding, many buyouts, and would affect several city blocks from Prospect Street to Main Street. Should an investment like this be made by the community it could potentially add some valuable green space to the center of the community and greatly reduce its flood risk. An equivalent project would be the Bee Branch Creek Restoration project in Dubuque, Iowa.

8. Simulation Results – All Scenarios (Reduced 1% AEP)

In addition to conveyance improvements along Tributary A, another potential pathway to reducing the flood extents along Tributary A would be to reduce the 1-percent AEP flow. This could be accomplished by constructing one or more large flood detention projects within the upstream drainage area. These would have to be designed in coordination with FEMA to ensure they would be considered in future hydrologic studies. This would require a change in hydrologic study methods from drainage area-based flow frequency estimates to hydrologic modeling-based analysis. General potential locations that these large flood detention projects could be constructed to have maximum flood attenuation are shown in Figure 8-1. The goal of these projects should be to capture and regulate as much drainage area as possible and provide adequate flood storage to attenuate runoff from the large drainage areas. Projects on Tributary 2 and 3 should also be considered given the floodplain connectivity between Tributary A and Tributary 2. These locations would require landowner willingness to participate and significant funding. Investing upstream of Manchester could potentially provide more flood risk reduction benefit per dollar than downstream improvements alone.

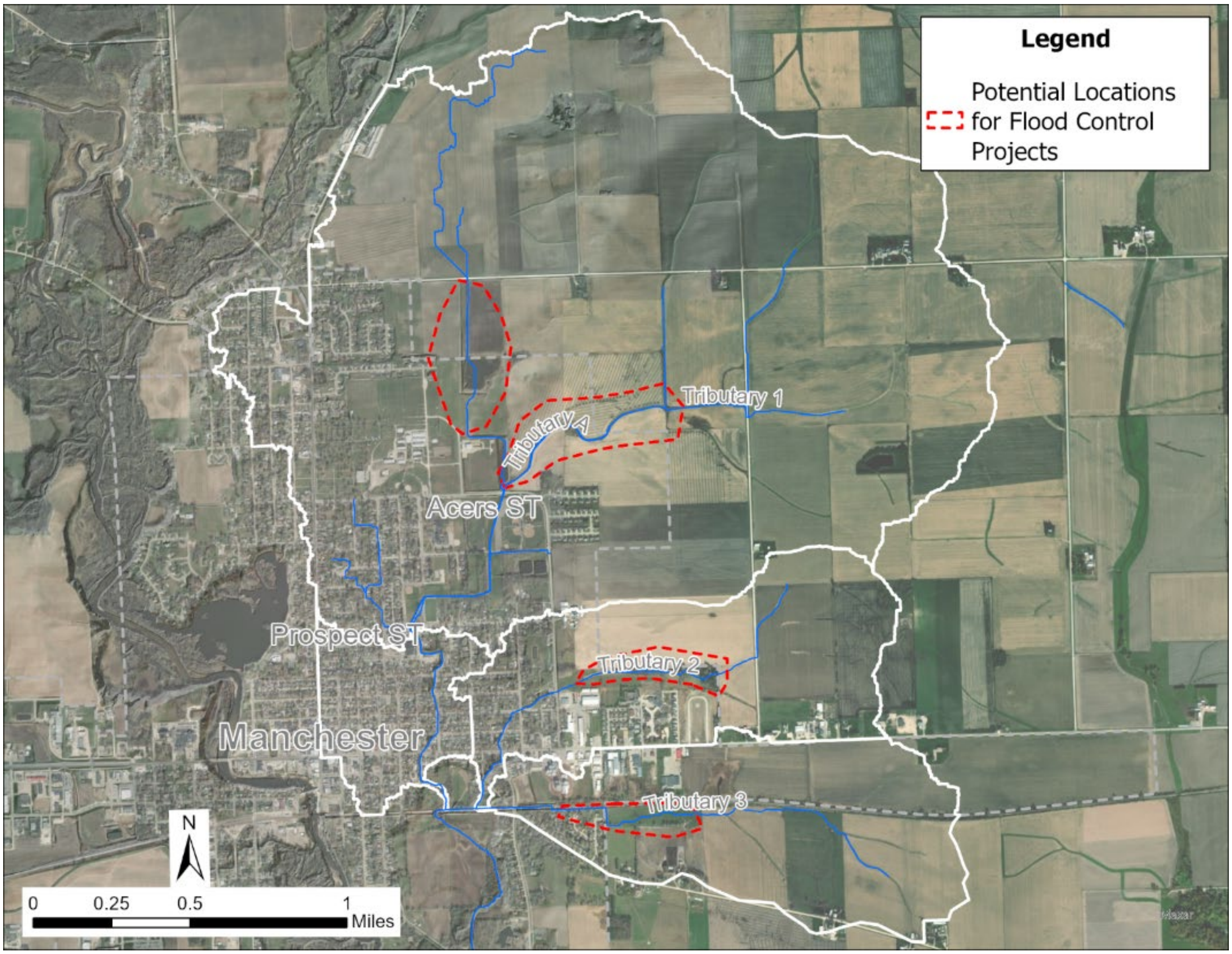

Figure 8-1. General potential locations for large flood control projects to have maximum flood attenuation. Projects would require landowner participation.

Assuming the 1-percent AEP flow could be reduced by 40% by flood control projects, Tributary A daylighting scenarios were simulated with this flow reduction. This would reduce the Tributary A 1-percent AEP flow from 2,420 cfs at Prospect Street to the 2009 FEMA FIS estimate of 1,450 cfs. This would essentially add more capacity to any stream channel improvement projects through this reach. Simulated inundation extents for daylighting scenarios with the reduced flow are shown in Figure 8-2. Overall, the inundation extents are smaller with this reduced 1-percent AEP flow. The maximum daylighting scenario is still the only scenario that contains the flood flow. There is likely an optimum daylighting scenario with stream channel improvements within the range of the medium and maximum daylighting scenarios that would also contain all the flow on Tributary A, potentially saving some costs.

Corresponding water level profiles for each scenario are shown in Figure 8-3. Once again, profiles for the base, minimum and medium daylighting scenarios are very similar. The maximum daylighting scenario has a significantly lower water level profile due to the significant channel and culvert improvements.

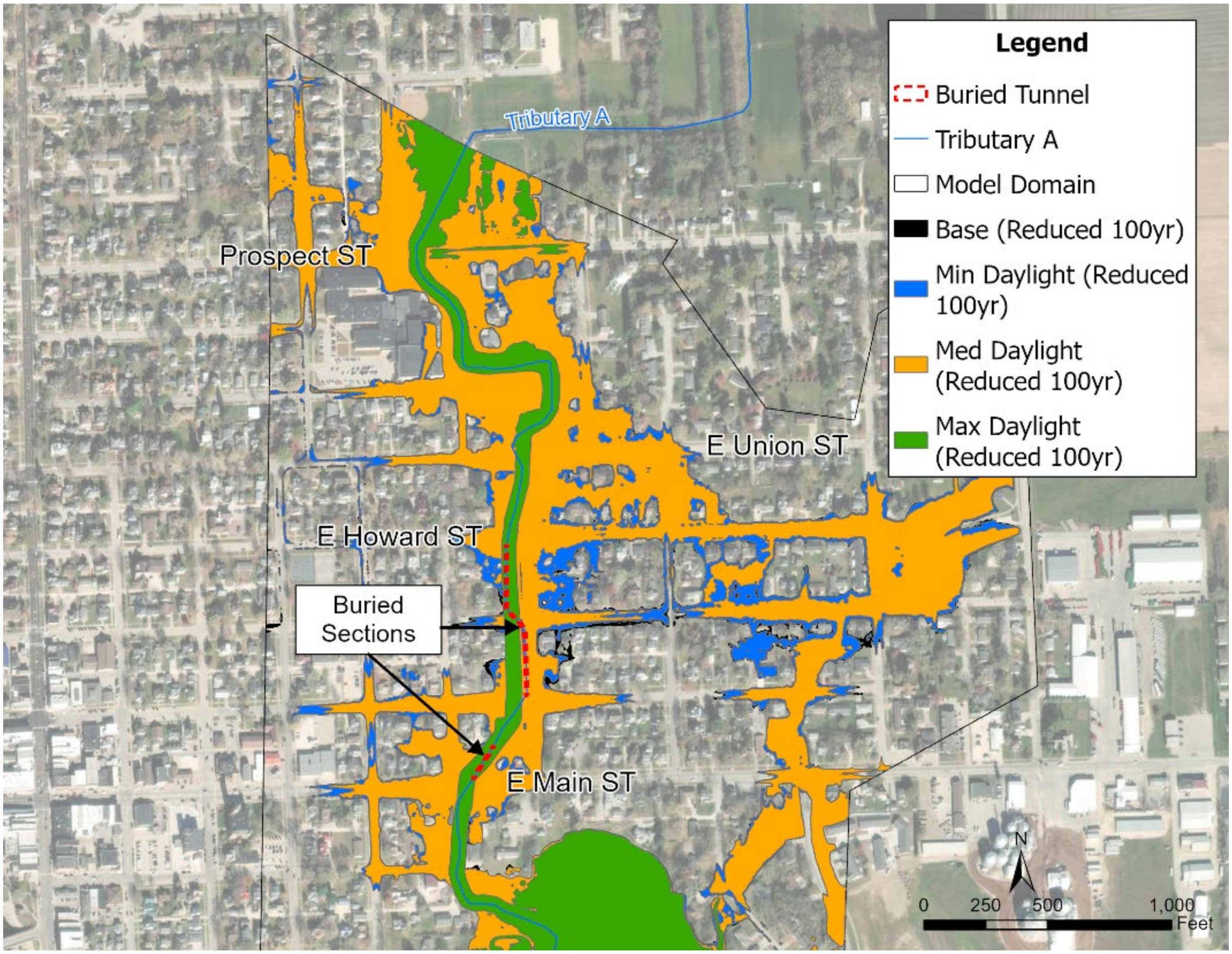

Figure 8-2. Simulation results for all scenarios (base, minimum, medium, and maximum daylight) with a 40% reduction of the 1-percent AEP flow.

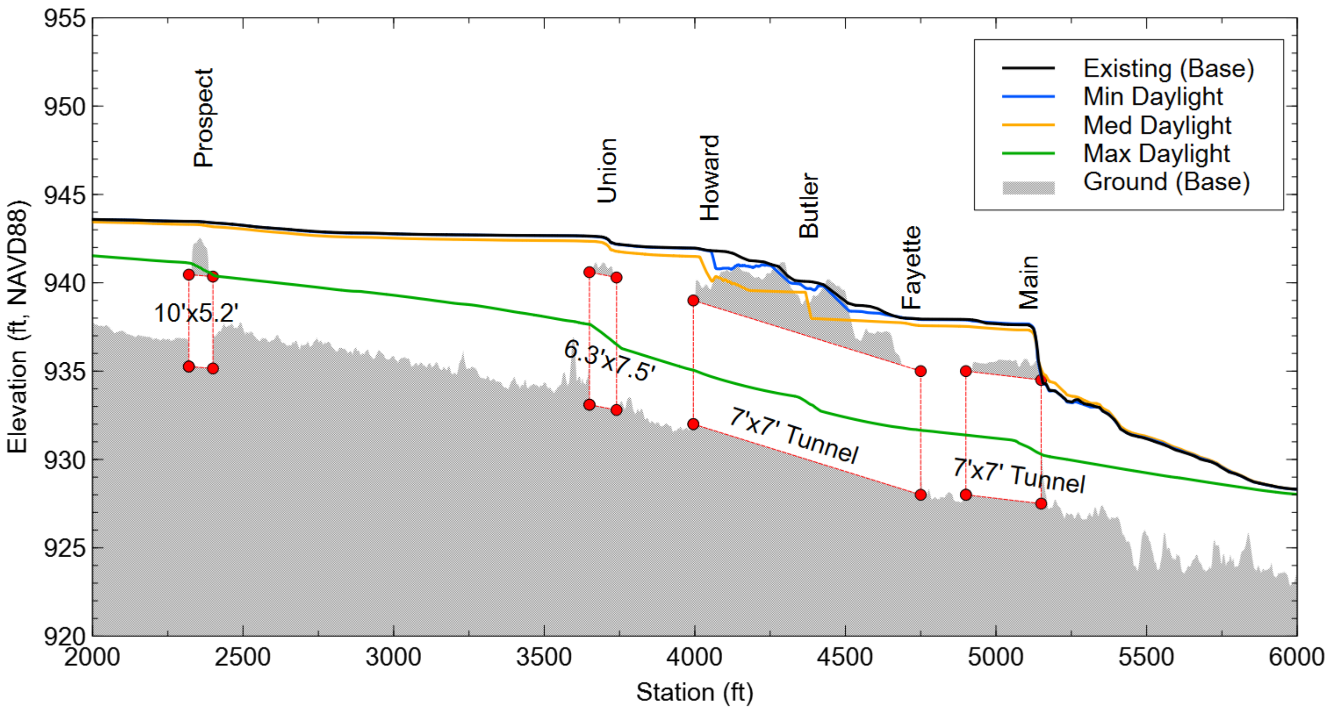

Figure 8-3. Simulated profiles of water level for base, minimum, medium, and maximum daylighting with a 40% reduction in the 1-percent AEP flow at Prospect Street. Existing culverts and ground surface are also shown. Daylighting scenarios have altered culverts and ground profiles (not shown).

9. Summary and Recommendations

Our analysis revealed that significant stream channel and culvert improvements will be required to reduce flood risk along Tributary A. Based on our minimum daylighting scenario, daylighting only the buried tunnel portions of Tributary A do not provide significant reduction in flood extents. While the maximum daylighting scenario was able to contain all the Tributary A flow, it would come at a significant cost – both dollars and displacing residents along multiple blocks. Ideally, large flood control projects in the upstream drainage areas of Tributary A, Tributary 2, and 3 would be constructed to significantly reduce the currently effective FEMA 1-percent AEP flow. This investment upstream would augment any daylighting and stream channel improvements along Tributary A downstream, stretching funding further. Further design and analysis of these conceptual alternatives will be required to focus on potential future projects to reduce flood risk.

We also encourage the city of Manchester to continue its ongoing coordination with the American Flood Coalition and the Iowa Department of Natural Resources' Real Time Technical Assistance (RTTA) program. The study produced by the RTTA partners will provide additional exploration of daylighting Tributary A along with other combinations of upstream flood mitigation projects.

10. References

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