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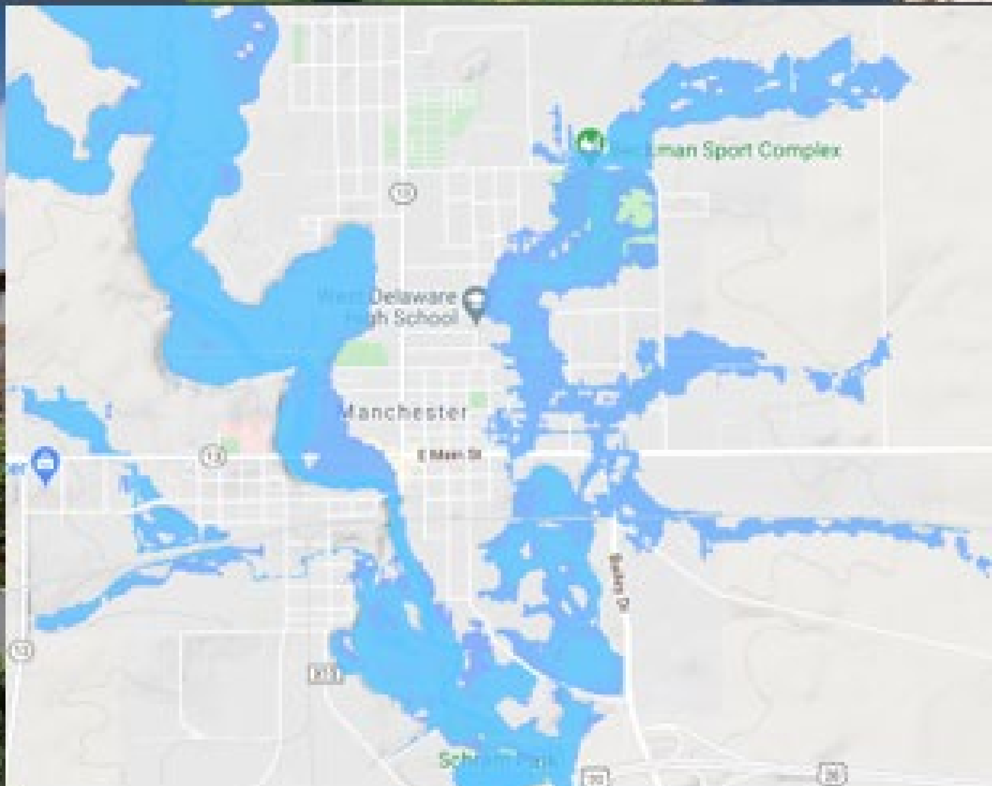
Waterway Redevelopment Project

City of Manchester

Report – May 7, 2021



Waterway Redevelopment Report

Manchester, IA

Prepared for:

The City of Manchester through the University of Iowa Department of Civil & Environmental Engineering

Prepared by:

Vance Davis, Connor Johnson, Luke Lesnik, and Kendall Wobig

Executive Summary

The goal of this project was to minimize flood risk and cost to the residents of Manchester, Iowa. Updated FEMA flood maps show that sections of the town are now at elevated flood risk relative to previous assessments. Increased flood risk impacts the community both directly (flooded structures) and indirectly (elevated flood insurance or reduced home values). Additionally, the impacted area is a relatively low-cost residential area, so displaced community members could be unable to relocate. To ensure public safety and minimize financial burden, our team worked with Manchester officials and engineers at Fehr Graham to reduce flood peaks and update storm infrastructure.

Before pursuing a design, we performed an accounting of current conditions to determine where our efforts would be most effective and impactful. We prioritized areas experiencing the greatest flood peaks and increases in cost while keeping social impact in mind. The areas of concern are impacted by two tributaries—Tributary A, which runs from the northeast corner of town, past West Delaware High School, through residential areas to the south side of Main Street at Potter Street; and Tributary 2, which runs roughly parallel to Main Street on the north before crossing to the south side at Bailey Drive and meeting Tributary A.

Tributary A drains roughly 1,380 acres, while Tributary 2 drains 420 acres. The peak flows that result from Tributary A's floods are greater, and stretches of Tributary A are conveyed in a box culvert system underneath three residential blocks between Howard Street and Main Street. These factors result in increased impact along Tributary A, and our design prioritized reductions along this waterway.

Our thought process for this project was founded on a variety of reputable approaches to flood protection. Engineering design standards (the Iowa Stormwater Management Manual, or ISWMM) and the Manchester Code of Ordinances served as touchstones for our design.

The primary aspect of our approach was creating detention basins to provide storage. This helped decrease flood peaks downstream by delaying the movement of water, creating more uniform flows. This approach required a large footprint, but it also minimized concerns for downstream impact and delayed the need for future upgrades. Since the project site is in the heart of Manchester, minimizing disruption to the area and finding land for stormwater management structures were substantive challenges as well. However, our team was able to identify suitable parcels of land for our design without significantly interrupting residential life. By building two detention basins along Tributary A and one detention basin along Tributary 2, we expect to significantly reduce flood peaks along Tributary A while achieving some peak reduction along Tributary 2. A basin with 63 acre-feet of storage is designed at the Krogmann Site, north of Acers Street along Tributary A, at the northeast corner of town. A 27 acre-ft basin is designed on the Bunting Site, just south of Harris Street along Tributary A. The third detention basin has 15 acre-ft of storage and is located on the east side of Stiles Street, across from Joseph J. Baum Memorial Park. A breakdown of the reduction percentages can be found in Tables 6 and 7, in Appendix A.

Beyond the detention basins, we have included several recommendations for further investigation. Another aspect of our approach was to delay the concentration of smaller engineered components. Our design included bioswales along Main Street and in city parks. These essentially perform the same tasks as detention basins at a smaller scale. Along with these devices, we suggested native vegetation along a

significant stretch of Tributary A. This would slow the movement of water through the area and increase natural uptake of water while increasing habitat and biodiversity along the waterway.

Our design also included a green roof on West Delaware High School. A green roof would serve to reduce runoff from the considerable impermeable area created by the building. Though this would require a structural analysis of the building, we have included it as a hypothetical design alternative.

The final aspect of our design was bringing the underground section of Tributary A back to the surface, or "daylighting" the channel. By doing so, we removed a choke point along the tributary, which would otherwise cause significant flooding. This aspect of our design had the greatest direct impact on residents, as several buildings would be removed to make way for the resurfaced channel, but the resulting flood protection made this alternative worthy of consideration.

The final package includes the locations and specifications for all relevant structural and hydrologic elements. These are delivered using modeling in HEC-RAS and AutoCAD Civil3D.

Designing this project came with its challenges, including the COVID-19 pandemic and harsh Iowa weather. That being said, our team successfully collaborated with the Manchester team, and members of our team were able to conduct in-person sites visits throughout the duration of the project.

Major constraints included our limited design timeline, project financial considerations, and bounds of community disruption. Our design resulted in a well-curated overview of alternatives that simultaneously protect residents from flooding without greatly impacting existing communities. While certain parcels of land would need to be acquired, the reduction in risk more than justifies the alternatives selected.

The total expected cost for this project includes property acquisition and construction of the three detention basins. The total expected cost for the Krogmann Site is $1,340,800; the Bunting Site is $179,210; and the Hutchison Site is $133,620. Altogether, the expected total design cost for this project amounts to approximately $1,654,000. The combined impact of the detention ponds is exponential, so we recommend simultaneous construction for the greatest impact. If the city decides to implement our other recommended elements, there will be additional costs associated with them.

Using property values and insurance data, we estimated that community flood costs would total around $35,000,000. As such, our alternatives would be well-worth the city's investment. Should the city choose to implement only certain elements of our design, effects would not be as pronounced, but some reduction can still be expected.

Qualifications and Experience

The engineering design group is comprised of four University of Iowa students enrolled in Project Design & Management (CEE:4850). This is their capstone project. The point of contact for the team is Vance Davis.

Luke Lesnik is an environmental engineering student focusing on water resources and water/wastewater treatment. He worked on report production, making editing and formatting decisions for reports and presentations.

His contributions included assessing and defining initial conditions by examining site plans and studies provided by Fehr Graham; carrying out design and modeling of the Bunting Property detention basin; and assisting with plan drawings.

Vance Davis is an environmental engineering student focused on environmental education and climate effects on human systems. They served as the project manager, coordinating tasks and communication. They also assisted in model production, site selection, and alternative analysis.

Some of Vance's specific contributions in this project were the design and modeling of the Krogmann Property detention basin, bioswales, and green roofs; conducting site visits; and creating flood hydrographs. Their work also included modeling in Civil3D and NRCS WinTR-55.

Kendall Wobig is a civil engineering student focusing on water resources. She will serve as one of the report production representatives. Alongside assembling a final report, she will assist in technical modeling and project analyses.

Some of Kendall's specific contributions to this project include assisting with preliminary CAD design in Civil3D, setting up a workmap in GIS of the project area, and modelling the two tributaries of interest as well as existing structures along the channels in HEC-RAS.

Connor Johnson is an environmental engineering student focused on water resources and sustainability. He has served as the Technical Specialist of the group; assisting with any questions about software programs and helping resolve any problems that arise.

Some of Connor's specific contributions to this project include the modeling of the Hutchison Property detention basin, the cost estimate of flooding on affected properties, and the initial assessment of the constructed wetlands. Additionally, he has assisted with creating model designs and producing reports and presentations.

Design Services

With the updated 100-year floodplain from FEMA, flood risks loom large over the residents of Manchester. A HEC-RAS model has been developed for hydrologic analysis of Tributaries A and 2. Initial conditions were defined by numerous cross-sections, culverts, and flow data from USGS StreamStats and WinTR-55. A piecewise approach was used to reduce flooding throughout the drainage area of Tributaries A and 2. Three detention basins have been designed to store runoff and decrease flood peaks. Site grading and outlet structures have been designed for optimal storage and peak reduction in each basin. Recommendations have been provided for additional stormwater management elements, including bioswales, a green roof, constructed wetlands, stream restoration, and channel daylighting.

This design project demanded modeling flows with HEC-RAS, mapping the site layout and relevant boundaries with GIS, and drawing construction plans with AutoCAD Civil3D. Design specifications follow guidelines in the Iowa Statewide Urban Design and Specifications (SUDAS). All proposed changes meet the Manchester Code of Ordinances. Additionally, plan drawings using AutoDesk software will meet American National Standards Institute (ANSI) and National CAD/CIFM guidelines.

The final product of this design included:

- Flood cost analysis
- Design cost analysis
- HEC-RAS models of existing conditions and conditions following alternative implementation
    - Hydrologic analysis of Tributary A and Tributary 2
    - Impact of proposed detention ponds
- Three detention pond designs; includes:
    - Storage volume
    - Stage-storage-discharge relationships
    - Inlet and outlet structures
    - All applicable dimensions and design criteria
    - Existing and final grading
    - Construction boundaries
- Recommendations for:
    - Two bioswale locations & concepts
    - West Delaware High School green roof design:
        - Applicable dimensions and design criteria
    - Constructed wetland design
        - Basic site identification
        - Design recommendations
    - Stream restoration:
        - Maintenance of Tributary A
        - Restoring native vegetation to Tributary A following Bunting Property Detention Basin
    - Preliminary recommendations for Tributary A daylighting; includes:
        - Property removal discussion
        - Aspects of design to consider
        - Identification of associated costs

The specific locations of these designs can be found in Figure 3 in Appendix A.

The timeline for work on this project, as well as the team member responsible for each design element, can be found in Figure 1. The figure shows completed tasks in shades of blue and future tasks in shades of orange.

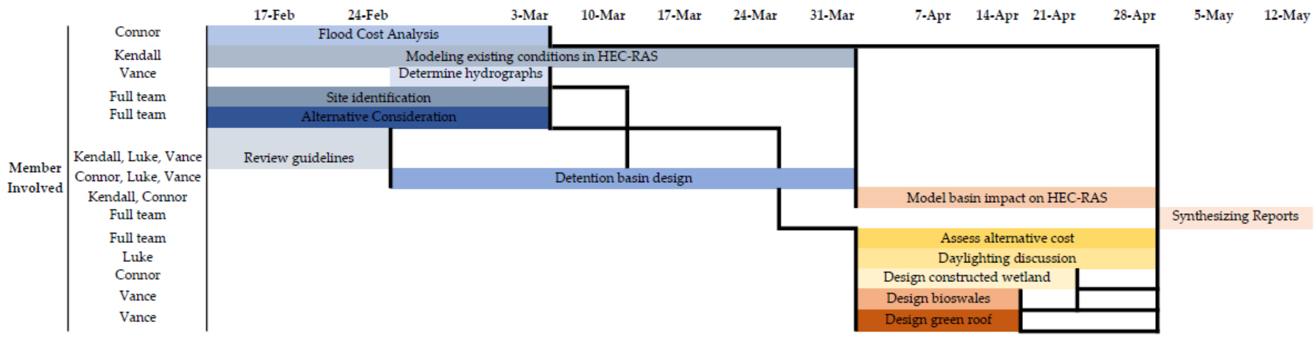


Figure 1: Gantt chart and member assignment for design process.

As will be expanded upon later in this report, our design focuses on addressing flooding hydrologically. As such, changes to the stormwater system play a minor role in our design, though some recommendations are still included.

Constraints, Challenges, and Impacts

For our purposes, challenges refer to aspects of the project which required special consideration or attention. Perhaps the most glaring is that of the COVID-19 pandemic, which forced work to be performed remotely and limits visitation. Beyond this, the inclement weather of Iowan winters and springs further limited our team's ability to travel or perform site visits. Logistical challenges such as these are not trivial, but, as we have experienced this past year, neither are they insurmountable. Our team has successfully navigated virtual collaboration, and we were able to complete two site visits over the course of the project which greatly informed our process.

Further challenges were centered on the project sites. The area in question runs through the heart of Manchester, and minimizing disruption to the area was top of mind as we navigated our design. This was of particular importance considering portions of the waterway are buried underground, winding through residential areas. Additionally, land needed to be selected for detention basins, bioswales, and wetlands. While our hope was that city-owned land or otherwise public areas would be sufficient for the project, the most ideal locations for our alternatives were on private land. That being said, the selected sites (with the exception of channel daylighting) do not require significant structure removal, and we expect that landowners will be obliging to our design given their broad positive impacts. Finally, Manchester has fairly minimal elevation change, which forced us to rethink the traditional construction of our detention basins.

Beyond the challenges of the project, constraints further focused our design. For our purposes, constraints are technical requirements or limits that define the boundaries of the project. Our design timeline was limited by our team's graduation, as well as our demands as full-time students. While this occasionally made workflow less uniform, it also held us to strict deadlines, resulting in what we believe to be a coherent and well-compiled final design. Another constraint was the cost of the project. Manchester is a relatively small city, and as it is working in the public domain, we worked to make the relative cost and benefit of the project as clear as possible. This is evidenced by the flood cost and design cost comparison, which identifies the quantitative benefit of the project. Finally, legal constraints were provided via SUDAS, ISWMM, and the City of Manchester Code of Ordinances.

The societal impacts of this project were at the forefront of our process. The project location encompasses the eastern part of Manchester, with about 100 residential properties affected. These properties are generally lower cost housing, meaning relocation could be a significant issue for affected community members. The efficacy of our project is determined by its sustainability and equity. Our solutions were grounded in best practice and addressed the specific hydrologic processes contributing to flooding, and some aspects of our design (notably the constructed wetland, bioswales, and stream restoration initiatives) have notably positive environmental impacts.

The daylighting of Tributary A requires structural removal and impact transit across the waterway. This cost is made clear in our analysis, and specific structural removal is identified. We have included these recommendations for the City of Manchester's consideration alongside other alternatives which require lower relative levels of community disruption.

The majority of our designs do not require substantial structure removal or community relocation. By implementing solutions in undeveloped areas and selecting designs with continuous impact, our design minimized individual cost to community members. Additionally, by creating a comparison of initial and final conditions, as well as a well-founded cost analysis, we make the costs and benefits to the city and community clear.

Our societal impact assessments would be incomplete without a revisiting of the goals of this project. Upon completion of this waterway redevelopment project, the intended impact was to reduce risk for the residents of the City of Manchester, minimize flooding in the land surrounding the waterway, and limit cost (direct and indirect) for residents. Should the City of Manchester follow our design, we firmly believe these goals will be met.

Alternative Solutions Considered

A stretch of Tributary A is buried underground, specifically in a 3-block residential area from E Howard Street to E Main Street between N Potter Street and N Reynolds Street. The City of Manchester requested that we explore the possibility of daylighting the channel to reduce flow restrictions through the neighborhood. In theory, this alternative would eliminate the underground culvert system, lowering the local flood risk due to flow restriction. Through our HEC-RAS analysis, we determined that the 8 x 8-foot concrete conduit through this area is not the main choke point on Tributary A. Several residences would need to be removed for this design due to its location and larger footprint, forcing homeowners to relocate. We anticipate a relatively high cost to construct this alternative due to property acquisition, structure removal, necessary topographic changes, and other components of the design. Given the complexity of this task relative to our time constraints, we decided to prioritize other solutions over this initiative. However, this alternative may bring great economic rewards to the community by lowering risk of flood damage, lowering flood insurance, and boosting property values. We have included recommendations on how to approach this alternative, should the city decide to move forward with it.

Another approach was to upsize the underground stormwater drainage system through the City of Manchester. By fitting the waterway with larger pipes, peak flows could be discharged more quickly, decreasing the risk of flooding in critical areas. However, while local flood risk could be decreased by this alternative, attention must be paid to peak flows that may propagate downstream. Given that this alternative does not minimize flood peaks overall (rather it passes that peak downstream) and that it would require extensive reworking of the storm sewer system, we did not pursue this alternative considering other options. However, we did identify bottlenecking points along the waterway through our HEC-RAS model, and we have included recommendations on resizing these elements. One such element we found to constrict flow the most was the culvert at Harris Street, along Tributary A. If possible, our team would recommend increasing the allowable volume of the culvert to accommodate additional discharge. Another possible choke point in Tributary A is the culvert at Prospect Street, whose volume could potentially be increased to allow for more flow.

The option we most dedicatedly pursued was to implement detention basins upstream, which store storm runoff, reduce peak flows, and improve water quality. These structures will be used for recreation, support native plant and animal species, and enhance the beauty of the City of Manchester. Though this alternative required us to utilize private parcels of land, the land selected required minimal community relocation. The ponds significantly reduce flood peaks, yielding flood protection to downstream communities. As mentioned previously, the siting for these ponds was the most significant concern, but our team was able to locate suitable sites with the guidance of the City of Manchester team.

Other options considered included stream restoration and maintenance efforts, constructed wetlands, green roofs, bioswales and raingardens, and permeable pavers. The stream restoration efforts have lower flood impacts relative to some of the larger design elements, but they are simple to implement and require little maintenance. These efforts include planting native vegetation and periodically cleaning out debris from runoff. Additionally, this option improves water quality and has a very small footprint. Therefore, we decided it would be worth Manchester’s consideration.

Similarly, a bioswale within Joseph J. Baum Memorial Park and raingardens/swales along Main Street would increase water quality and reduce runoff, and are included in our recommendations. However, the infiltration characteristics of these sites would need to be determined before any design are implemented, and as such, we have included these alternatives as recommendations of further interest.

Constructed wetlands—another alternative—would serve dual purposes of water quality improvement and flood protection, and they would naturally extend from ongoing projects in Manchester. Additionally, they provide habitat and natural beauty to the design area, which will be of particular interest to landowners of the site, the Good Neighbor Society. That being said, the primary objective of the project was to reduce flood risk, and so this reduced the priority of the wetlands relative to higher-impact designs, such as the detention ponds.

Green roofs were also considered for this design. However, green roofs create significant loads on roofing structures, and so retrofitting older structures can prove difficult due to the deteriorating strength of the supports in the building. Additionally, retrofitting residential buildings would present significant disruption to the community. The best option for a green roof was West Delaware High School, which is squarely situated in the Tributary A watershed. While we noted that significant structural analysis of the school would be necessary to ensure this alternatives viability, we decided to move forward with this design to provide another possible option and an example of possible green infrastructure for any future development in the area.

Final Design Details

Modeling the Waterway

There are two waterways of concern in this project's area of study. The first one, called Tributary A, flows to the south near the east side of Manchester. The other, Tributary 2, flows to the southwest and joins Tributary A from the east. A visual from a map of the area constructed in ArcMap version 10.8 can be found in Appendix A. These tributaries were modeled using the Hydrologic Engineering Center's River Analysis System (HEC-RAS), version 5.0.7. Much of the existing geometry data modeled in HEC-RAS was outsourced from the GIS workmap. LiDAR was used in part to determine the stations and elevations of cross-section data points along each tributary. These elevation data were acquired from the Iowa Department of Natural Resources' Geodata Server. Reach lengths and boundary cross-section stations were determined using ArcMap's Measuring Tool. Additionally, the structural data for the culverts existing within each tributary was provided by Fehr Graham and was then modeled using HEC-RAS' Bridge/Culvert Editor. Flow data was determined using NRCS WinTr-55, which is often used in small watershed hydrology. Cross-section locations were downloaded from the Federal Emergency Management Agency (FEMA). Tributary discharges were modeled one-dimensionally, and steady flow was assumed in the modelling process. References to the NRCS WinTR-55 data, ArcMap, FEMA cross-section locations, and structural data provided by Fehr Graham can be found in Appendix A.

Within HEC-RAS, eight distinct flow profiles were modeled, varying from the 2-year flood all the way up to the 500-year flood. Once all the existing geometry data was modeled in HEC-RAS' Geometric Data editor and the program was successfully run assuming steady flow, HEC-RAS created an output table showing hydrologic data for each of the cross-sections on both tributaries. This output table can be found in Appendix A. These data include channel velocities, Froude numbers, water surface elevations, and more. After the program ran successfully, HEC-RAS also created a series of tables displaying culvert output data such as culvert velocities, exit losses, and minimum weir flow elevations. HEC-RAS models culverts, bridges, and other structures separately from regular cross-sections on a tributary, so the output tables for all the culverts is shown in separate tables located in Appendix A.

The flow data that was modeled in HEC-RAS was then used by the LVCK design team to model a detention basin to mitigate some of the discharge in case the area experiences flooding.

Flood Cost Determination

Data was gathered for all the properties that lie within the 100-year floodplain. The list of affected properties was detailed by the City of Manchester. Each property was assessed for its building value and its additional land value, which were included in the list, and then it was compared against the values found on Beacon. There were over 200 properties that were included in this assessment. We were conservative in our estimates in that we didn't assess expected property value increases. Furthermore, our cost determination does not account for lost and damaged personal belongings. Insurance costs were investigated, and according to typical values for the state of Iowa, it would be expected that the typical resident would be paying around $900, annually, according to government statistics. These values could vary depending on the specific location of a property; the deeper within a floodplain a property is, the more expensive insurance will be. However, the expected cost of insurance was not included in our final cost determination. The current estimate of the flood cost comes out to roughly $35 million, if all of the

200 properties were impacted. This value could be higher depending on the severity of the flooding and how much personal property is damaged.

Hydrographs

Our initial approach to creating the necessary hydrographs for this project was to refer to the USGS analysis tool StreamStats. However, the complicated routing of the waterway far from a metropolitan center led to difficulties with the service, and we were instead forced to calculate the hydrographs ourselves. What information we could gain from StreamStats was used to supplement our starting point in later steps.

To do this, we delineated the relevant watersheds by hand using a topographic map of the area. These watersheds include that for Tributary A, Tributary B, and each of the detention pond sites. We then determined the composite curve number of each watershed by finding the acreage of different land uses and inputting this data into the NRCS WinTR-55 program. We used the same map and the NRCS Lag Method to determine the time of concentration for each watershed.

We then referred to ISWMM Chapter 3 Section 2 for 24-hour storm rainfall depths. Using the appropriate values for Delaware County and the values for curve number, acreage, and time of concentration from previous steps, we were then able to calculate flood peaks for the 24-hour design storms for each watershed.

Example calculations for the Tributary A watershed and designs inputs for NRCS WinTR-55 are included in Appendix B and Appendix A, respectively.

Detention Ponds

The locations of the detention ponds were selected for their potential impact on the watershed and their perceived availability for use. The locations and approximate boundaries of the basins are included in Figure 2 below. Using the NRCS WinTR-55 method for storage volume calculations, we determined the total storage volume required in each of the tributaries' watersheds to reduce flood peaks by various percentages. Seeing as we were unable to perform our own tests on soil quality or groundwater depth, we referred to an engineering report on a nearby detention/infiltration pond provided to us by Mr. Wicks with Fehr Graham. This provided a maximum depth from which to work and helped to outline some specific challenges we might face in our designs.

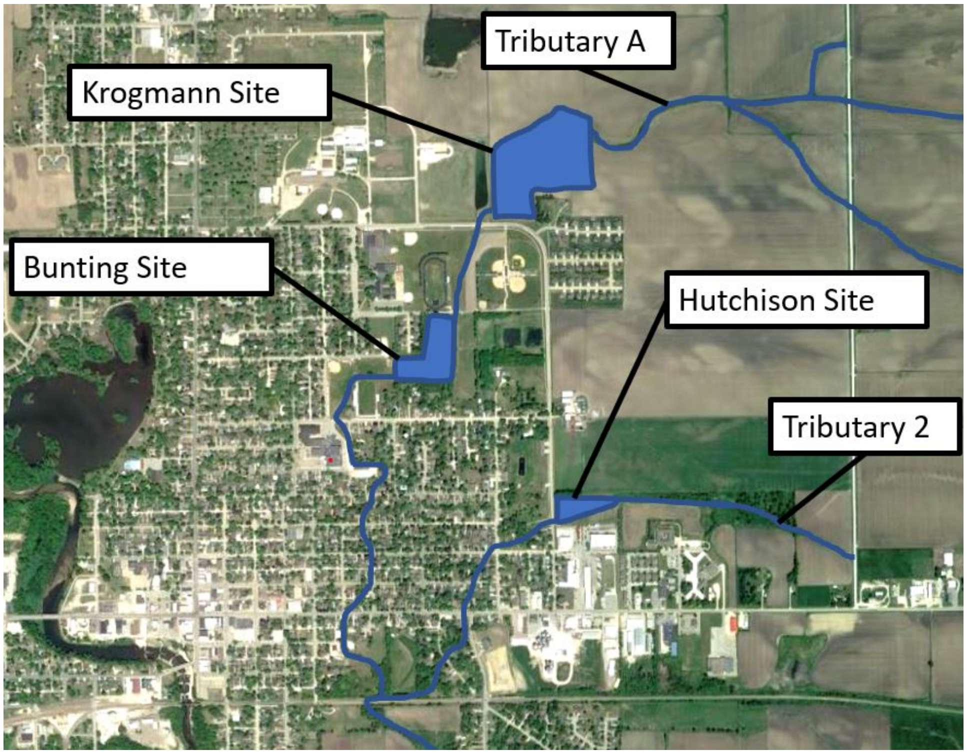


Figure 2: The locations of the three detention basins and their positions along Tributary A and Tributary 2

Before beginning our designs, we reviewed ISWMM Chapter 7 and Chapter 3. All designs are set at least 10 feet from property lines. For our design purposes, designs are assumed to be at least 250 feet from low depth wells and 50 feet from any septic tanks.

Following some initial brainstorming by hand, we designed each of the ponds using AutoCAD Civil3D. The files of our work will be included in the deliverables.

We began by situating our designs using topographic data from ArcGIS and aligning it with the aerial view of each site. For each of the sites, the landscape does not have a great deal of elevation change. To expand the amount of storage available in each pond, we created embankments surrounding each of the ponds. These embankments are not significant in size and do not designate the structures as dams as regulated by IDNR Bulletin 16 or ISWMM Chapter 3.

The Krogmann detention pond covers roughly 18 acres of farmland just north from the corner of Acers and Stiles Streets. It drains approximately 1015 acres on Tributary A. The basin is designed to allow for some northward expansion of the existing subdivision to the south. The embankment surrounding the site is situated at 950.00 feet AMSL. The site consists of a sediment forebay and dry detention pond. The sediment forebay was designed based on ten percent of the storage volume, for a total of nearly 5 acre-ft of storage. The forebay discharges via a rip-rap protected outlet back into the channel at an elevation of 948.00 feet AMSL and has a bottom elevation of 942.00 feet AMSL. The forebay bottom will consist of a concrete pad with a fixed meter to measure sediment accumulation. The undeveloped nature of the surrounding area means an access road can be created as needed for access to the forebay, which will need to be cleared of sediment as it fills over time.

The channel itself was left intact, while the surrounding land was excavated to create two sub-basins, which will both drain to the same outlet structure. A 0.2% bottom slope was used to provide maximum storage. Though the slight slope means the basins serve to infiltrate more than drain, the intact channel prevents small events from creating standing water in the basin.

The compound outlet structure consists of a 4 x 1-foot rectangular orifice combined with a 6 x 13-foot drop inlet. The orifice allows for transmission of low flows in the original channel, while the drop inlet conveys flows from 2-year up to the 100-year flood event. At this point, an emergency secondary spillway of elevation 949.00 feet AMSL activates, protecting the integrity of the embankment. Design calculations for outlet flows are included in Appendix B.

The Bunting property is about 10 acres of land on Tributary A, downstream of the Krogmann site but upstream of West Delaware High School and most residences at elevated flood risk. Most of the property acreage will be used for the detention basin, with offsets exceeding 10 feet from all property lines. The basin boundary is set ~30 feet from existing structures on the southern edge of the property.

A dry detention basin will be implemented on the Bunting property to maximize the available storage volume. The stage-storage relationship was determined using 1-foot contours in Civil3D, which is represented in Table 11 in Appendix A. An embankment at 944.00 feet AMSL will encompass the detention basin on the north, west, and south sides. A low-flow channel will be maintained across the basin, where the existing streambed lies. A 12" orifice inlet will transmit low flows and allow extended storage of 1-year runoff volumes. Native vegetation may be planted in the basin to improve water quality. Wetland flora improve the visible quality of water by minimizing sediment transport, and also sequester nitrogen loads from agricultural runoff. Native vegetation would especially thrive in the low-lying areas of the basin below 941.00 feet AMSL.

For 2-year to 50-year events, a rectangular 14 x 3-foot drop inlet will be activated. The low flow inlet and drop inlet convey stormwater to a three 36" pipes, which provide an outlet through the basin embankment to the existing channel downstream of the Bunting property. An emergency spillway will be activated in more extreme events, protecting the integrity of the embankment. The stage-discharge relationship was determined using weir and orifice equations, included in Appendix A. The relevant equations and sample calculations can be found in Appendix B. During dry weather, the team envisions the more elevated northern leg of the basin space as a dog park, soccer field, or similar recreational area for the community.

The Hutchison property detention basin covers about 3 acres of land on the east side of Manchester and will detain flows from Tributary 2. A smaller, permanent wet basin is located within the boundaries of the larger, encompassing basin that will provide extra storage for larger storms. There is available space within the larger basin that could be used for recreational use, if desired. The embankment surrounding the property lies at an elevation of 945 feet AMSL. The base of the basin will follow a 0.3% slope towards the SW corner, where the wet pond is located. The current design accounts for the implementation of the constructed wetland to the east of the basin, which will deal with the sediment load of the flow. If the expected sediment load exceeds the capacities of the wetland, a sediment forebay will be added to the design, prior to the wet pond.

The low flow inlet consists of a 4 x 2-foot opening at the base of the drop inlet. A square 8 x 8-foot drop inlet will then be activated and help convey flows for the 2-year to 25-year, 24-hour storm events. The two-stage inlet allows the water to flow into a 4.5 x 7 foot culvert, which will convey the water downstream to the existing channel. An emergency spillway will be activated for larger rain events and protect the overall structure of the basin. The design drawings can be found in Appendix D and the stage-discharge relationship are located in Appendix A.

Constructed Wetlands

The constructed wetlands have been included here as a recommendation for further projects. The City of Manchester currently has a water quality initiative ongoing in the upstream area of Tributary 2, and the wetlands would be a natural extension of this initiative further downstream. The wetlands could be situated on the northern edge of an open lot behind the Good Neighbor Society complex "The Meadows". The roughly 10 acres of land directly precedes the Hutchison site detention pond. If the wetlands were constructed, they would provide increased water quality benefits in tandem with the pond's flood protection. The wetlands would be constructed according to standard practices in ISWMM Chapter 8.

Bioswales

The bioswales/raingardens have been included here as a recommendation for further projects. Bioswales for this project were selected to be placed along Main Street and in one location in Joseph J. Baum Memorial Park. Roadside plots on Main Street are privately maintained at the moment. It is our recommendation that these owners could "opt-in" to maintenance of these designs; otherwise, maintenance could be turned over to the city. This being said, bioswales would bring vibrance to a prominent part of town while increasing flood resiliency.

The memorial park was selected as a significant drainage ditch exists within the park already, and converting this element into a bioswale or small basin would be relatively simple while bringing native vegetation and beauty to a public space.

The swales would then be designed according to ISWMM Chapter 9 as vegetated swales or using the Iowa DNR's guidelines for rain gardens.

Finally, native revegetation along Tributary A for the 1200 ft directly following the Bunting property is included as a recommendation here. Revegetation would increase water quality, stabilize banks, slow floodwater concentration, and provide natural habitat. Cost is dependent on developmental stage of plants when installed, as well as by species selected.

Green Roof

The green roof for this project was designed according to ISWMM Chapter 17. The roof of West Delaware High School was selected for this alternative as it is situated within the drainage area of Tributary A and has a large continuous surface area. As mentioned above, the structural requirements of a green roof of this scale would be significant, and while it is possible the existing structure is not capable of housing this design, its inclusion in this report serves as a reference should the project or something similar be undertaken in the future.

With West Delaware High School as the example, the design is as follows. Assuming 90% coverage of the school's non-sloped roof areas, roughly 1.8 acres of green roof could be created. This could be further sub-divided and accomplished in smaller sections, but this design includes the entirety of the roof. The delineation of the roof is found in Appendix A, Figure 18. In this example, we used the most minimal form of green roof, the extensive green roof, which has roughly 4 inches of soil. In this case, the design used modular soil and plant installation, using LiveRoof Standard Design modules as the reference. In order from bottom to top, the layers of the roof are as follows: roof deck, 4" expanded polystyrene roof insulation, 80-mil PVC waterproofing layer, 215-mil fluid applied rubber membrane slip-sheet, and LiveRoof Standard Design soil and plant module. Figure 19 in Appendix A, provided by LiveRoof, LLC, shows the cross-section view of this design.

Assuming standard densities for the non-soil elements and a saturated weight of 28 lb/ft^2 for the soil modules, the roof would weigh in at roughly 29.2 lb/ft^2. Assuming a porosity of 0.2 for the soil and 0.25 for the drainage layer, the green roof would store 0.147 acre-ft of water. The water quality volume, using methods from ISWMM's updated Chapter 3, was found to be 0.198 acre-ft—the roof would hold roughly 74% of the WQv. This storage could be increased with greater depth (bearing in mind that increased depth increases weight, and structural integrity would already be a concern).

Using the RSMeans Online calculator, this green roof would cost $1,813,000, which serves to remove it from our final design on cost considerations. This cost estimation can be found in Appendix B, Table 21. As it would not contribute as significantly as the detention ponds to water quantity solutions, it is only included here as a reference for future projects.

Recommendations for Channel Daylighting

Daylighting the channel in the zone between E Howard Street and E Main Street is a complicated task, but the rewards may be great. Much care must be paid to protect existing utility lines and reroute, where necessary. For example, sanitary sewer lines often coincide with the underground waterway, running just below or even straight through the box culverts. This is the case at Howard Street and potentially at the alley between Butler Street and Fayette Street. Additionally, sanitary sewer lines are exposed crossing the tributary in alleys to the north and south of Main Street.

To assess the feasibility of daylighting Tributary A, a cost-benefit analysis must be performed. The cost of acquiring properties along the new channel as well as relocating the displaced families is critical. Costs are associated with rerouting utility lines, which may have to cross the new channel. Other costs include structure removal, earthwork, channel stabilization materials, and vegetation. Since daylighting the channel will interfere with the existing road network, a traffic study will need to be conducted to determine which roads will be removed on the site and if any bridges will need to be constructed across the new channel. These costs will be compared to the benefit the open channel will have in reducing flood costs for the community and providing a new green space through town.

Engineer's Cost Estimate

Costs were calculated according to individual design element and summed for total project cost. Costs to be included in our estimation include construction equipment and labor for each of the design elements, property acquisition for detention pond sites and channel daylighting, structural materials for each site, contingency funds, and administrative costs.

For the detention ponds, construction costs were primarily determined by the cut and fill requirements of each site, as well as by the concrete pad necessary for the Krogmann sediment forebay. For the Krogmann site, property acquisition played a significant role as well, as the area is currently productive farmland.

These values were determined using RSMeans Online Cost Handbook. The assumed line items and construction costs from the Handbook are shown in Appendix B, Tables 22-23. Property values for Bunting and Hutchison Pond were found using a 10% increase of the Beacon Property values, while a price of $15,000/acre was assumed for the Krogmann property as an estimate from the informed experience of Ryan Wicks, P.E., Fehr Graham Consulting.

Beyond construction, we assumed contingency costs of 10% of construction costs and administrative cost of 20%. A table showing tabulation of final values can be found below in Table 1. The final design cost of the three detention basins is $1,653,630.

Table 1: Design Cost Estimation

Design Item	**Cost of Construction**	**Property Acquisition**	**Contingency**	**Admin. Cost**	**Total**
Krogmann Pond	$843,000	$270,000	$111,300	$116,500	$1,340,800
Bunting Pond	$123,000	$13,310	$14,300	$28,600	$179,210
Hutchison Pond	$94,000	$9,020	$10,200	$20,400	$133,620
					$1,653,630

To determine the exact benefits of the flood peak reductions, a 2D watershed model could be created to expand upon the HEC-RAS model created for this project. This being said, our estimate for total flood impact cost was found to be $35,000,000. This impact was determined by assessing the cost of structures in the floodway and estimated insurance increases for property owners. Clearly, relative to the cost of preventative measures, this design serves to mitigate significant damage to affected areas and cost to residents.

Appendices

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Appendix A—Figures & Tables

Figure 3: Design Sites—(1) Krogmann detention pond; (2) Bunting detention pond; (3) Native vegetation; (4) West Delaware High School Green Roof; (5) Joseph J. Baum Memorial Park bioswale; (6) Hutchison detention pond; (7) Constructed wetland; (8) Main Street bioswales

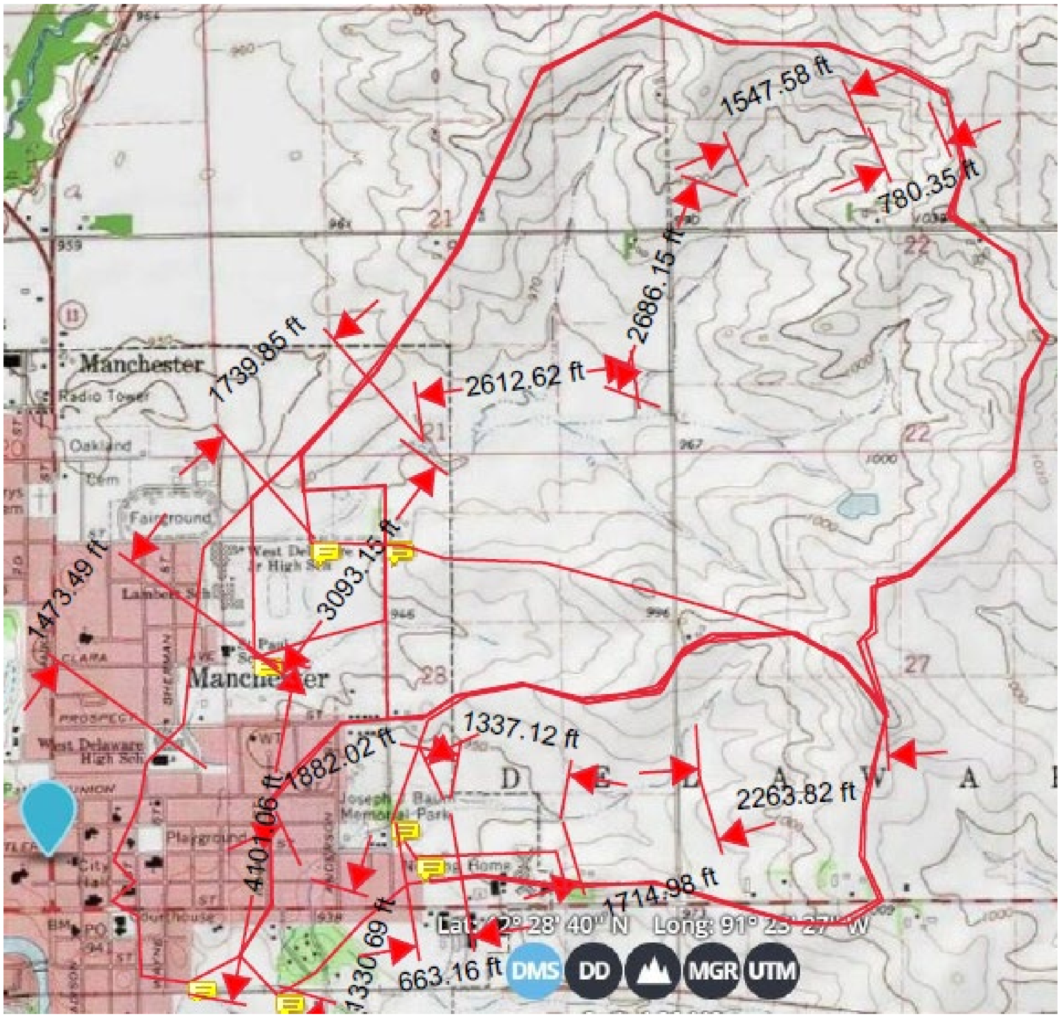

Figure 4: Watershed delineations and hydraulic flow lengths

Table 2: NRCS WinTR-55 Hydrograph Inputs & Assumptions

Watershed	Total Area (acres)	Open Space; Good Condition (acres)	1/4-Acre Residential (acres)	Industrial (acres)	SR+Crop Residue; Good Condition (acres)	Curve Number	Flow Length (ft)	Tc (hrs)
Tributary A	1385.26	67.27	185.07	--	1132.92	72	14820.91	3.798
Tributary 2	428.43	--	132.25	12.13	284.05	75	8544.34	2.246
Krogmann Site	1015.38	--	--	--	1015.38	73	9366.55	1.653
Bunting Site	1291.75	66.97	91.57	--	1132.92	72	12193.25	2.099
Hutchinson Site	333.17	--	--	12.13	321.038	73	5979.08	1.155

Assumed 18.5% HSG A, 81.5% HSG B (from StreamStats)
Assumed average land slope of 2.32% (from StreamStats)

Table 3: 24-hour Design Storm Rainfall Depths (in)

24-hour Rainfall Depths (in)	
1-yr	2.63
2-yr	3.04
5-yr	3.78
10-yr	4.48
25-yr	5.56
50-yr	6.48
100-yr	7.48

Table 4: Storage Volume Requirements, Tributary A

Return Period (yr)	P (in)	α	Rv	V Runoff (in)	V Storage (acre-ft)
100	7.48	0.50	0.28	4.24	135.31
50	6.48	0.50	0.28	3.39	108.16
25	5.56	0.50	0.28	2.64	84.15
10	4.48	0.50	0.28	1.81	57.61
5	3.78	0.50	0.28	1.31	41.73
2	3.04	0.50	0.28	0.83	26.54
1	2.63	0.50	0.28	0.60	19.07
100	7.48	0.67	0.22	4.24	107.24
50	6.48	0.67	0.22	3.39	85.72
25	5.56	0.67	0.22	2.64	66.69
10	4.48	0.67	0.22	1.81	45.65
5	3.78	0.67	0.22	1.31	33.07
2	3.04	0.67	0.22	0.83	21.04
1	2.63	0.67	0.22	0.60	15.11
100	7.48	0.75	0.19	4.24	94.20
50	6.48	0.75	0.19	3.39	75.29
25	5.56	0.75	0.19	2.64	58.58
10	4.48	0.75	0.19	1.81	40.10
5	3.78	0.75	0.19	1.31	29.05
2	3.04	0.75	0.19	0.83	18.48
1	2.63	0.75	0.19	0.60	13.27

Table 5: Storage Volume Requirements, Tributary 2

Return Period (yr)	P (in)	α	Rv	V Runoff (in)	V Storage (acre-ft)
100	7.48	0.50	0.28	4.58	45.14
50	6.48	0.50	0.28	3.69	36.46
25	5.56	0.50	0.28	2.91	28.72
10	4.48	0.50	0.28	2.03	20.08
5	3.78	0.50	0.28	1.50	14.84
2	3.04	0.50	0.28	0.99	9.74
1	2.63	0.50	0.28	0.73	7.18
100	7.48	0.67	0.22	4.58	35.78
50	6.48	0.67	0.22	3.69	28.89
25	5.56	0.67	0.22	2.91	22.76
10	4.48	0.67	0.22	2.03	15.91
5	3.78	0.67	0.22	1.50	11.76
2	3.04	0.67	0.22	0.99	7.72
1	2.63	0.67	0.22	0.73	5.69
100	7.48	0.75	0.19	4.58	31.43
50	6.48	0.75	0.19	3.69	25.38
25	5.56	0.75	0.19	2.91	19.99
10	4.48	0.75	0.19	2.03	13.98
5	3.78	0.75	0.19	1.50	10.33
2	3.04	0.75	0.19	0.99	6.78
1	2.63	0.75	0.19	0.73	5.00

Table 6: Peak flow reduction percentages, Tributary A (Note: 1 and 2-year event floods completely contained)

Peak Flow Reduction Percentages	
1-year	--
2-year	--
5-year	94%
10-year	77%
25-year	55%
50-year	37%
100-year	22%

Table 7: Peak flow reduction percentages, Tributary 2

Peak Flow Reduction Percentages	
1-year	92%
2-year	76%
5-year	51%
10-year	29%
25-year	12%
50-year	5%
100-year	1%

Table 8: Stage-discharge values, Krogmann detention pond (green section shows flow control)

Stage	Weir 1 (cfs)	Orifice 1 (cfs)	Weir 2 (cfs)	Orifice 2 (cfs)	Outlet Pipe (cfs)	Emergency Spillway (cfs)	Total Outflow (cfs)
946.0	0.0	--	--	--	--	--	0.0
946.1	0.3	--	--	--	--	--	0.3
946.2	1.0	--	--	--	--	--	1.0
946.3	1.8	--	--	--	--	--	1.8
946.4	2.7	--	--	--	--	--	2.7
946.5	3.8	0.0	--	--	--	--	3.8
946.6	5.0	6.1	--	--	--	--	5.0
946.7	6.3	8.6	--	--	--	--	6.3
946.8	7.7	10.5	--	--	--	--	7.7
946.9	9.2	12.2	--	--	--	--	9.2
947.0	10.8	13.6	--	--	--	--	10.8
947.1	12.5	14.9	--	--	--	--	12.5
947.2	14.2	16.1	--	--	--	--	14.2
947.3	16.0	17.2	--	--	--	--	16.0
947.4	17.9	18.3	--	--	--	--	17.9
947.5	19.8	19.3	0.0	0.0	62.5	--	19.3
947.6	21.9	20.2	2.1	118.8	67.5	--	22.3
947.7	23.9	21.1	6.0	168.0	75.0	--	27.1
947.8	26.1	22.0	11.1	205.7	80.0	--	33.1
947.9	28.3	22.8	17.1	237.5	87.5	--	39.9
948.0	30.5	23.6	23.9	265.6	92.5	--	47.5
948.1	32.9	24.4	31.4	290.9	100.0	--	55.7
948.2	35.2	25.1	39.5	314.2	101.3	--	64.6
948.3	37.7	25.8	48.3	335.9	107.5	--	74.1
948.4	40.2	26.5	57.6	356.3	115.0	--	84.2
948.5	42.7	27.2	67.5	375.6	121.3	--	94.7
948.6	45.3	27.9	77.9	393.9	127.5	--	105.8
948.7	47.9	28.6	88.7	411.4	134.4	--	117.3

948.8	50.6	29.2	100.1	428.2	140.0	--	129.3
948.9	53.3	29.8	111.8	444.4	146.0	--	141.7
949.0	56.1	30.5	124.0	460.0	151.5	0.0	154.5
949.1	58.9	31.1	136.6	475.1	157.0	3.0	160.0
949.2	61.8	31.6	149.6	489.7	162.2	8.5	170.7
949.3	64.7	32.2	163.0	503.9	167.1	15.5	182.6
949.4	67.7	32.8	176.8	517.7	172.2	23.9	196.1
949.5	70.7	33.4	190.9	531.1	176.8	33.4	210.2
949.6	73.8	33.9	205.4	544.2	181.3	43.9	225.3
949.7	76.9	34.5	220.3	557.1	185.9	55.3	241.2
949.8	80.0	35.0	235.4	569.6	190.4	67.6	258.0
949.9	83.2	35.5	251.0	581.8	194.6	80.7	275.3
950.0	86.4	36.0	266.8	593.8	198.8	94.5	293.3

Table 9: Stage storage values, Krogmann detention pond

Stage (ft)	Storage (acre-ft)
942.0	0.00
944.0	2.79
946.0	14.23
948.0	31.36
950.0	63.45

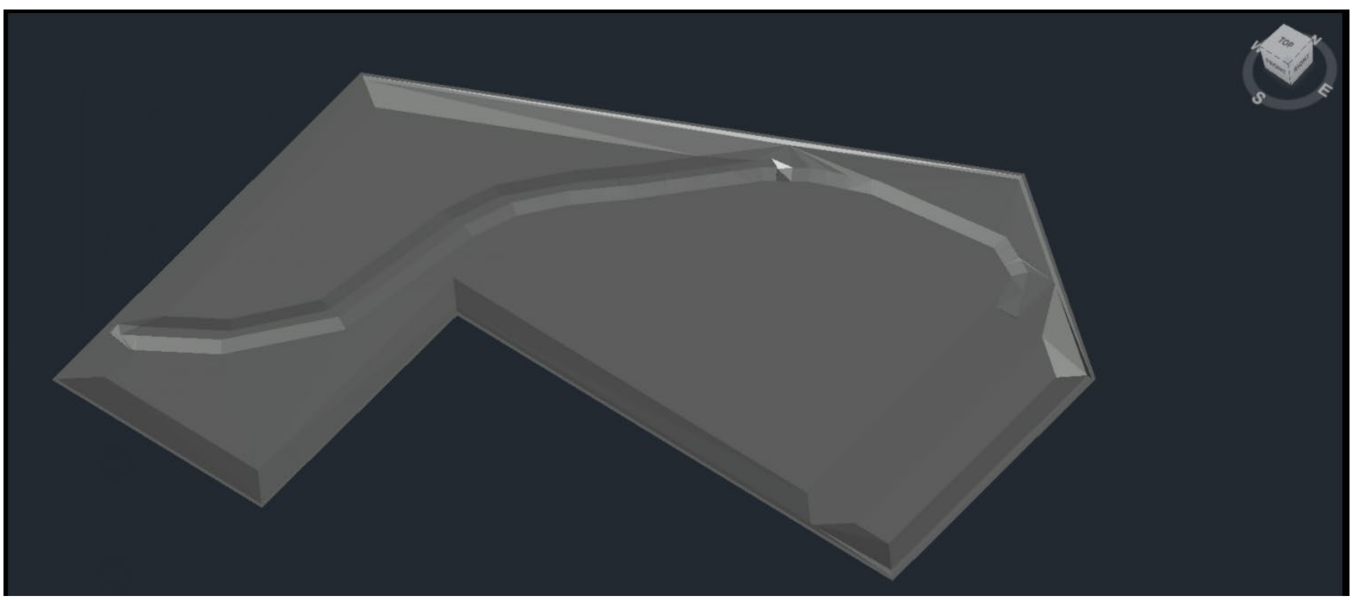

Figure 5: Krogmann Pond SE Isometric View, Civil3D

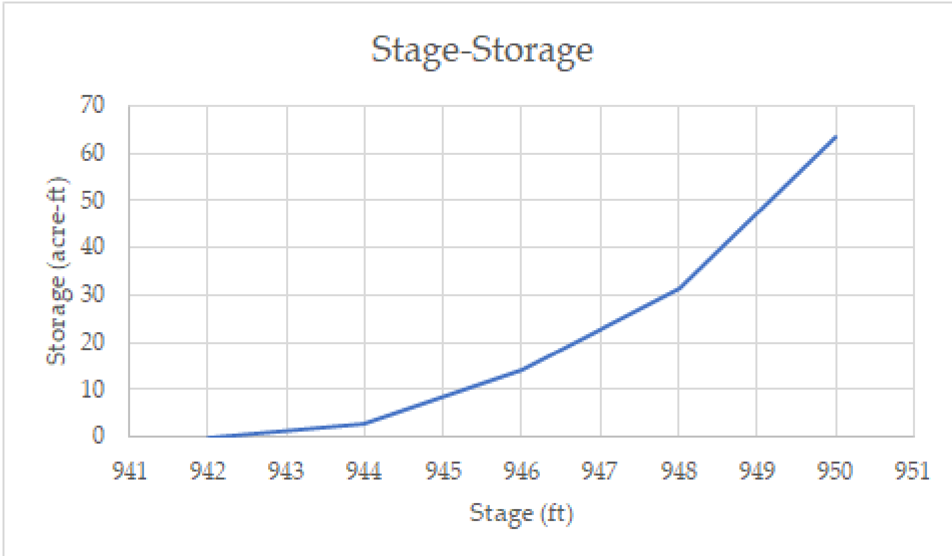

Figure 6: Stage-storage curves, Krogmann detention basin

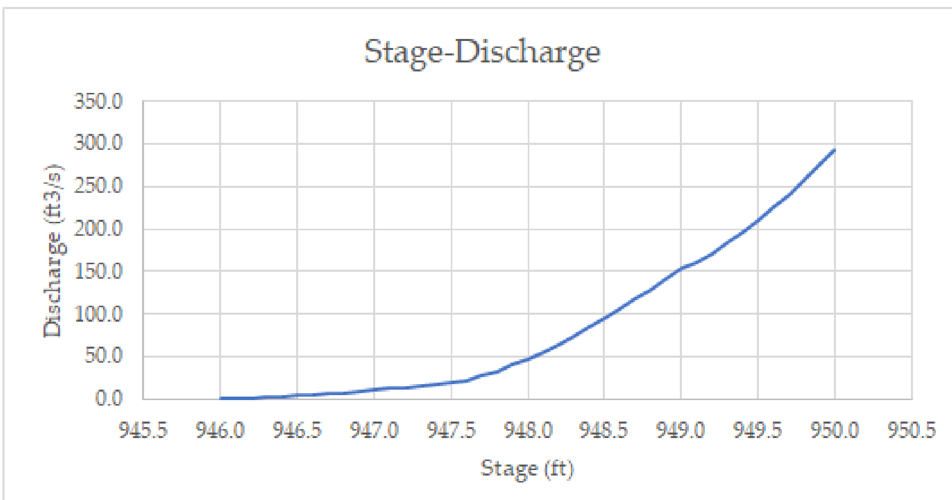

Figure 7: Stage-discharge curve, Krogmann detention basin

Table 10: Stage-discharge values, Bunting detention basin

	Low flow inlet (12 in. orifice)		Rectangle Drop inlet (14x3 ft)				Emergency Spillway		3 x 36" RCP outlet		**Overall Structure**
	Low flow orifice		Drop inlet- weir control		Drop inlet- orifice control		Spillway weir		Outlet orifice		
	centerline (ft)	940.5	elevation (ft)	942	centerline (ft)	942	elevation (ft)	943	centerline (ft)	941	
	Cd	0.6	Cw	2.7	Cd	0.6	Cw	2.7	Cd	0.6	
	area (ft2)	0.785398163	width (ft)	21	area (ft2)	48	width (ft)	15	area (ft2)	21.20575041	
Stage (ft)	Head (ft)	Discharge (cfs)	Head (ft)	Discharge (cfs)	Head (ft)	Discharge (cfs)	Head (ft)	Discharge (cfs)	Head (ft)	Discharge (cfs)	**Discharge (cfs)**
940.5	0	0									**0**
940.6	0.1	1.19587026									**1.19587026**
940.7	0.2	1.69121594									**1.69121594**
940.8	0.3	2.071308049									**2.071308049**
940.9	0.4	2.391740519									**2.391740519**
941	0.5	2.674047193							0	0	**2.674047193**
941.1	0.6	2.929271935							0.1	32.28849701	**2.929271935**
941.2	0.7	3.163975307							0.2	45.66283038	**3.163975307**
941.3	0.8	3.38243188							0.3	55.92531732	**3.38243188**
941.4	0.9	3.587610779							0.4	64.57699402	**3.587610779**
941.5	1	3.781673806							0.5	72.1992742	**3.781673806**
941.6	1.1	3.966252949							0.6	79.09034223	**3.966252949**
941.7	1.2	4.142616098							0.7	85.42733329	**4.142616098**
941.8	1.3	4.31177154							0.8	91.32566076	**4.31177154**
941.9	1.4	4.47453679							0.9	96.86549102	**4.47453679**
942	1.5	4.6315856	0	0	0	0			1	102.1051928	**4.6315856**
942.1	1.6	4.783481038	0.1	1.793011433	0.1	73.08620663			1.1	107.0888296	**6.576492472**
942.2	1.7	4.930699395	0.2	5.071402173	0.2	103.3595046			1.2	111.8506346	**10.00210157**
942.3	1.8	5.07364782	0.3	9.316760703	0.3	126.5890232			1.3	116.4178316	**14.39040852**
942.4	1.9	5.212677611	0.4	14.34409147	0.4	146.1724133			1.4	120.8124933	**19.55676908**
942.5	2	5.348094385	0.5	20.04647725	0.5	163.4257262			1.5	125.0528112	**25.39457163**
942.6	2.1	5.480165986	0.6	26.35177869	0.6	179.0239135			1.6	129.153988	**31.83194467**
942.7	2.2	5.609128712	0.7	33.20703645	0.7	193.367927			1.7	133.1288837	**38.81616517**
942.8	2.3	5.735192289	0.8	40.57121738	0.8	206.7190093			1.8	136.9884911	**46.30640967**
942.9	2.4	5.858543869	0.9	48.4113087	0.9	219.2586199			1.9	140.7422955	**54.26985257**
943	2.5	5.979351298	1	56.7	1	231.1188785	0	0	2	144.3985484	**62.6793513**
943.1	2.6	6.097765789	1.1	65.41420786	1.1	242.3995248	0.1	1.280722452	2.1	147.9644816	**72.7926961**
943.2	2.7	6.213924146	1.2	74.53408563	1.2	253.1780464	0.2	3.622430124	2.2	151.4464752	**84.3704399**
943.3	2.8	6.327950614	1.3	84.04233058	1.3	263.5160655	0.3	6.654829074	2.3	154.8501918	**97.02511027**
943.4	2.9	6.439958436	1.4	93.92368264	1.4	273.4635449	0.4	10.24577962	2.4	158.1806845	**110.6094207**
943.5	3	6.55005117	1.5	104.1645513	1.5	283.0616611	0.5	14.31891232	2.5	161.442485	**125.0335148**
943.6	3.1	6.658323814	1.6	114.7527317	1.6	292.3448265	0.6	18.82269906	2.6	164.6396763	**140.2337546**
943.7	3.2	6.76486376	1.7	125.677184	1.7	301.3421497	0.7	23.71931175	2.7	167.775952	**156.1613595**
943.8	3.3	6.869751623	1.8	136.9278587	1.8	310.0785139	0.8	28.97944099	2.8	170.8546666	**172.7770513**
943.9	3.4	6.973061956	1.9	148.4955572	1.9	318.5753889	0.9	34.57950621	2.9	173.8788778	**190.0481254**
944	3.5	7.074863866	2	160.371818	2	326.8514525	1	40.5	3	176.8513816	**207.9466818**

Table 11: Stage-storage relationship, Bunting detention basin

Stage (ft)	Surface Area (ft^2)	Volume (ft^3)	Volume (ac-ft)
940	0	0	0
941	160,000	80,200	1.84
942	260,000	290,000	6.66
943	402,000	621,000	14.3
944	706,000	1,170,000	27.0

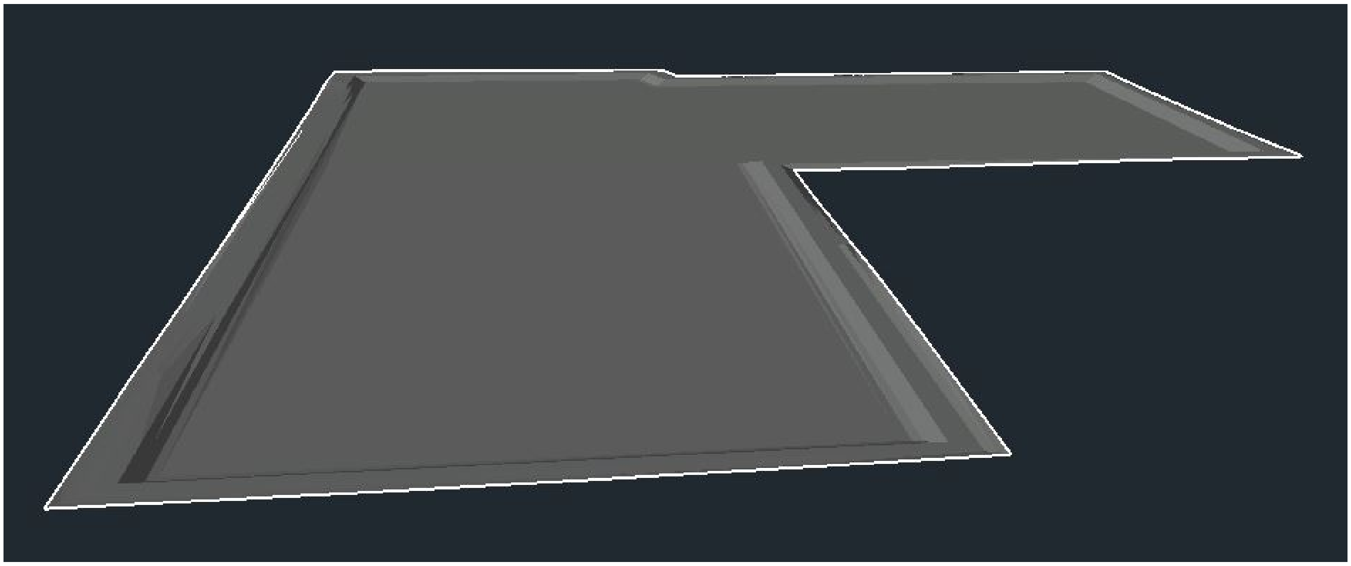

Figure 8: Bunting Basin SE Isometric View, Civil3D

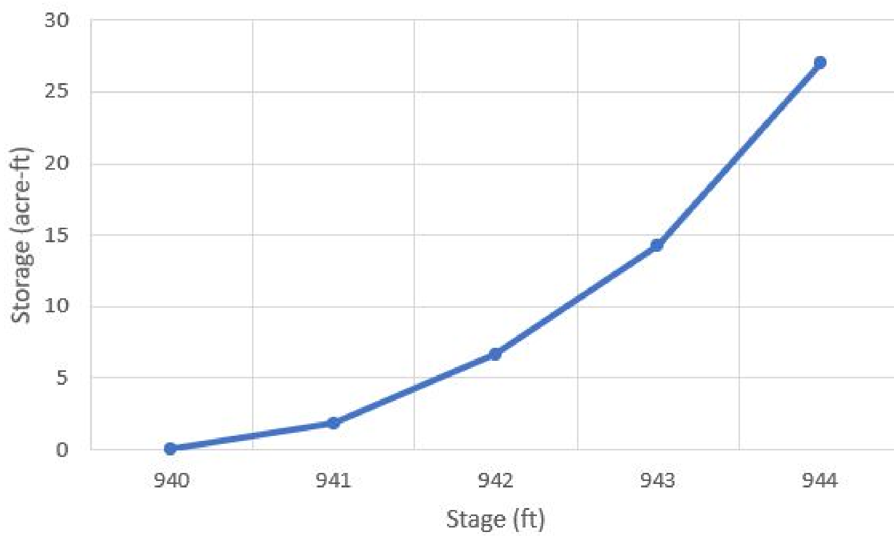

Figure 9: Stage-storage curve, Bunting detention basin

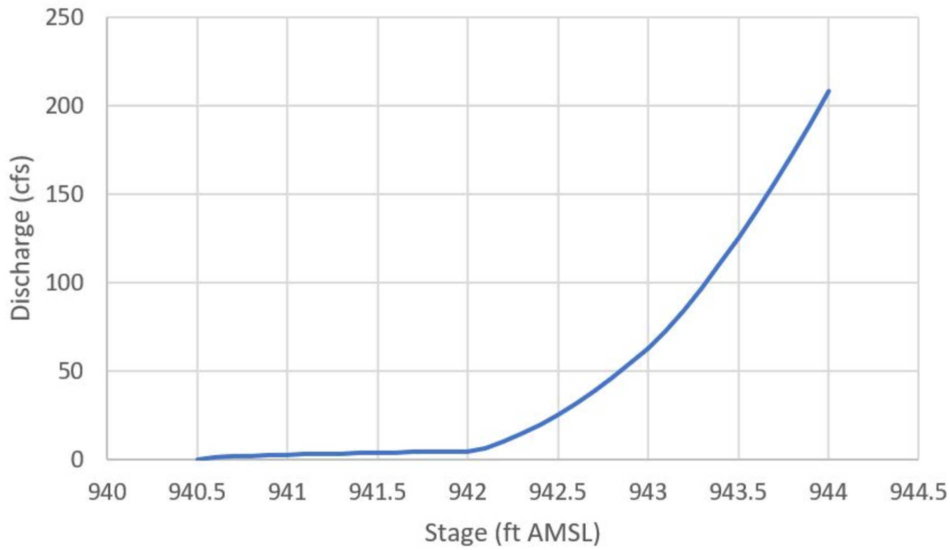

Figure 10: Stage-discharge curve, Bunting detention basin

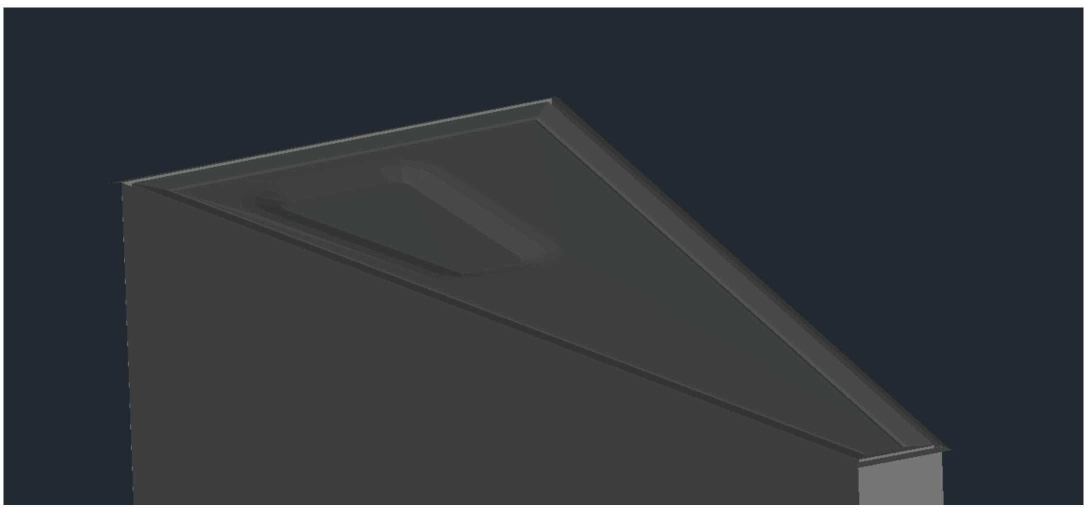

Figure 11: Hutchison Basin Isometric View, Civil3D

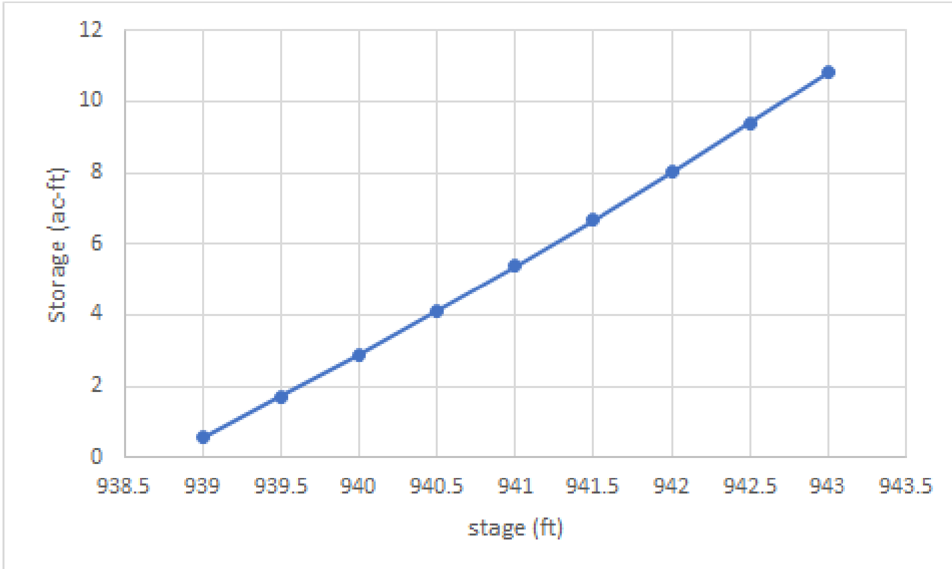

Figure 12: Hutchison Stage-Storage Graph

Table 12: Hutchison Stage-Discharge Values

Stage	Lower Inlet Weir	Lower Inlet Orifice	Drop Inlet Weir	Drop Inlet Orifice	Spillway Weir	Total Discharge (cfs)
938	0.0	0.0				0.0
938.5	0.0	0.0				0.0
939	0.8	2.7				2.7
939.5	2.4	3.8				3.8
940	4.3	4.6	0.0	0.0		4.6
940.5	6.7	5.3	38.2	122.6		43.5
941	9.3	6.0	108.0	173.3		114.0
941.5	12.2	6.5	198.4	212.3		205.0
942	15.4	7.1	305.5	245.1		252.2
942.5	18.8	7.6	426.9	274.1		281.6
943	22.5	8.0	561.2	300.2		308.3
943.5	26.3	8.5	707.2	324.3		332.7
944	30.4	8.9	864.0	346.7	0.0	355.5
944.5	34.6	9.3	1031.0	367.7	11.3	388.2
945	39.0	9.6	1207.5	387.6	90.0	487.2

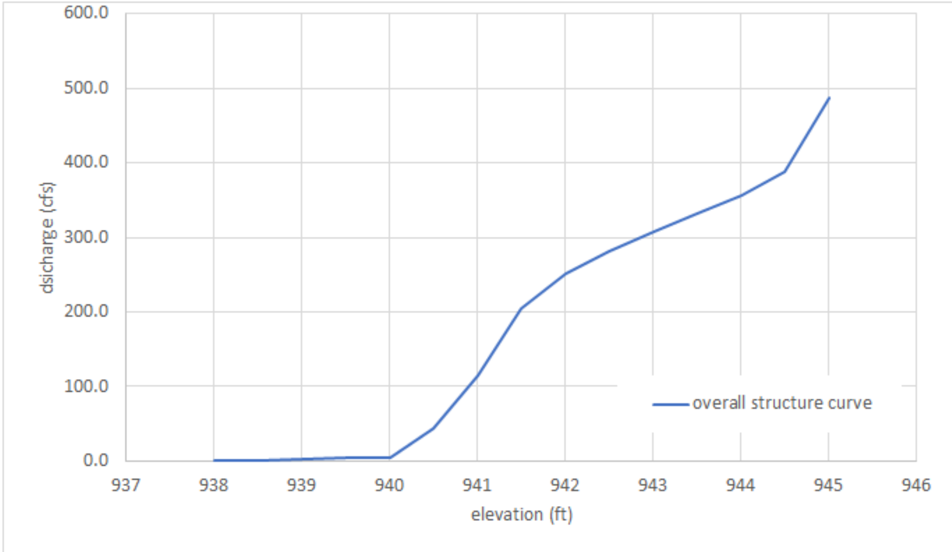

Figure 13: Hutchison Stage-Discharge Curve

Table 13: Tributary A Profile Output

HEC-RAS Plan: existing_conditions River: Tributary A Reach: Tributary A Profile: 100-yr

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Tributary A	16381.73	100-yr	1180.34	955.99	957.49		957.51	0.000987	1.22	967.15	904.23	0.21
Tributary A	15913.17	100-yr	1180.34	955.65	956.85		956.89	0.001886	1.46	805.90	931.55	0.28
Tributary A	15538.53	100-yr	1180.34	953.98	955.26		955.46	0.011158	3.38	333.49	422.49	0.67
Tributary A	15196.61	100-yr	1180.34	951.95	953.57		953.63	0.003026	2.02	585.02	596.28	0.36
Tributary A	14879.82	100-yr	1180.34	950.00	952.60		952.65	0.003152	1.71	691.28	933.12	0.35
Tributary A	14533.81	100-yr	1180.34	949.92	951.70		951.74	0.002195	1.77	691.81	826.54	0.31
Tributary A	14314.09	100-yr	1180.34	949.80	951.35		951.38	0.001279	1.35	872.15	848.29	0.24
Tributary A	13925.32	100-yr	1180.34	948.00	951.03		951.04	0.000629	1.07	1106.80	903.51	0.17
Tributary A	13519.48	100-yr	1180.34	947.95	950.66		950.69	0.001294	1.31	897.96	920.23	0.23
Tributary A	12921.76	100-yr	1180.34	946.01	950.54		950.55	0.000090	0.68	1805.07	821.26	0.07
Tributary A	12413.64	100-yr	1180.34	946.00	950.53		950.53	0.000021	0.42	3009.72	1069.37	0.04
Tributary A	12161.13	100-yr	1180.34	946.00	950.52		950.52	0.000015	0.35	3419.57	997.80	0.03
Tributary A	12014.5	100-yr	1180.34	946.00	950.52	946.74	950.52	0.000015	0.35	3414.94	997.74	0.03
Tributary A	11912		Culvert									
Tributary A	11871	100-yr	1180.34	946.00	950.32		950.32	0.000004	0.18	6308.71	2064.83	0.02
Tributary A	11851.43	100-yr	1180.34	946.00	950.32		950.32	0.000004	0.18	6308.58	2064.82	0.02
Tributary A	11665.06	100-yr	1180.34	943.97	950.32		950.32	0.000003	0.18	6564.05	1595.60	0.02
Tributary A	11274.74	100-yr	1180.34	943.78	950.32		950.32	0.000001	0.14	8244.23	1716.05	0.01
Tributary A	11062.73	100-yr	1180.34	942.00	950.32		950.32	0.000001	0.12	10163.04	2310.69	0.01
Tributary A	10977.25	100-yr	1180.34	942.00	950.32	944.05	950.32	0.000001	0.12	10162.48	2310.69	0.01
Tributary A	10951		Culvert									
Tributary A	10940.5	100-yr	1180.34	942.84	948.49		948.49	0.000004	0.18	6349.03	2059.27	0.02
Tributary A	10828.92	100-yr	1180.34	942.84	948.49		948.49	0.000004	0.18	6348.15	2059.27	0.02
Tributary A	10716.6	100-yr	1180.34	943.29	948.49		948.49	0.000001	0.11	10545.49	3164.02	0.01
Tributary A	10396.18	100-yr	1180.34	942.00	948.49		948.49	0.000001	0.09	13095.17	3194.70	0.01
Tributary A	10029.35	100-yr	1180.34	941.98	948.49		948.49	0.000001	0.14	8863.34	2238.89	0.01
Tributary A	9481.21	100-yr	1180.34	941.34	948.49		948.49	0.000002	0.16	7783.69	2021.01	0.01
Tributary A	8917.03	100-yr	1180.34	939.96	948.49		948.49	0.000002	0.17	7147.67	1487.46	0.01
Tributary A	8728.5	100-yr	1180.34	939.96	948.49	941.79	948.49	0.000002	0.17	7146.49	1487.46	0.01
Tributary A	8651		Culvert									
Tributary A	8620	100-yr	1180.34	938.00	948.43		948.43	0.000001	0.15	8258.22	1584.86	0.01
Tributary A	8486.47	100-yr	1180.34	938.00	948.43		948.43	0.000001	0.14	8258.03	1584.86	0.01
Tributary A	8382.51	100-yr	1180.34	939.15	948.43		948.43	0.000002	0.16	7075.53	1381.09	0.01
Tributary A	7936.43	100-yr	1180.34	937.99	948.43		948.43	0.000001	0.13	8528.09	1496.10	0.01
Tributary A	7606.25	100-yr	1180.34	937.99	948.43	940.33	948.43	0.000001	0.13	8527.36	1496.09	0.01
Tributary A	7360		Culvert									
Tributary A	7261.5	100-yr	1180.34	936.00	948.26	938.90	948.26	0.000001	0.15	8478.43	1530.91	0.01
Tributary A	6331		Culvert									
Tributary A	6111	100-yr	1180.34	930.00	943.24	933.59	943.24	0.000002	0.18	6715.64	1262.48	0.01
Tributary A	6033		Culvert									

Tributary A	5940	100-yr	1180.34	930.00	937.76		937.79	0.000461	1.43	824.27	341.70	0.16
Tributary A	5914.4	100-yr	1180.34	930.00	937.74		937.78	0.000388	1.57	751.98	238.07	0.16
Tributary A	5561.16	100-yr	1180.34	933.85	936.42	936.42	936.90	0.024100	5.51	214.27	229.39	1.00
Tributary A	5264.73	100-yr	1180.34	925.92	928.07		928.12	0.001219	1.74	665.06	428.87	0.25
Tributary A	4868.72	100-yr	1180.34	925.68	927.35		927.43	0.002697	2.24	527.21	421.64	0.35
Tributary A	4493.12	100-yr	1180.34	923.92	926.97		926.99	0.000605	1.04	1135.10	934.23	0.17
Tributary A	4319.15	100-yr	1180.34	922.00	926.18	926.18	926.63	0.025952	5.39	218.91	255.39	1.03
Tributary A	4229	100-yr	1180.34	924.00	924.66	924.66	924.91	0.008240	2.45	366.42	534.71	0.55
Tributary A	3894.74	100-yr	1180.34	922.00	923.79		923.85	0.001110	1.04	648.62	553.30	0.21
Tributary A	3461.76	100-yr	1180.34	921.60	923.34		923.37	0.001078	1.30	888.74	858.07	0.22
Tributary A	3061.56	100-yr	1180.34	919.90	922.76		922.82	0.001842	2.15	593.29	530.24	0.30
Tributary A	2562.27	100-yr	1180.34	917.65	921.99		922.08	0.001251	2.38	500.42	360.30	0.27
Tributary A	2264.83	100-yr	1180.34	918.42	921.57		921.64	0.001735	2.23	553.74	432.34	0.30
Tributary A	1904.46	100-yr	1180.34	915.99	919.25	919.25	920.15	0.019825	7.64	154.51	87.09	1.01
Tributary A	1355.48	100-yr	1180.34	914.00	918.13		918.13	0.000022	0.38	3080.40	1004.27	0.04
Tributary A	1131.65	100-yr	1180.34	914.00	918.12		918.13	0.000016	0.32	3645.16	1142.31	0.03
Tributary A	852.92	100-yr	1180.34	915.41	917.64	917.64	918.07	0.018637	5.48	228.54	269.63	0.91
Tributary A	738.19	100-yr	1180.34	910.00	912.98	912.84	914.03	0.015214	8.22	143.59	58.93	0.93
Tributary A	377.37	100-yr	1180.34	909.96	912.09		912.17	0.002015	2.35	501.82	299.12	0.32
Tributary A	0	100-yr	1180.34	908.04	909.76	909.76	910.32	0.022976	5.96	197.93	181.54	1.01

Table 14: Tributary 2 Profile Output

HEC-RAS Plan: existing_conditions River: Tributary 2 Reach: Tributary 2 Profile: 100-yr

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Tributary 2	7357.73	100-yr	946.00	923.91	972.78		972.78	0.000107	0.31	3064.63	66.01	0.01
Tributary 2	7117.77	100-yr	946.00	925.75	972.77		972.77	0.000164	0.33	2553.75	58.01	0.01
Tributary 2	6909.31	100-yr	946.00	927.26	972.74		972.74	0.000104	0.47	2659.41	60.04	0.01
Tributary 2	6783.64	100-yr	946.00	924.00	972.74		972.74	0.000001	0.03	25484.56	537.11	0.00
Tributary 2	6574.57	100-yr	946.00	927.95	972.74		972.74	0.000000	0.03	26327.61	595.27	0.00
Tributary 2	6416.25	100-yr	946.00	927.95	972.74	926.47	972.74	0.000000	0.03	26327.50	595.27	0.00
Tributary 2	6320		Culvert									
Tributary 2	6281.5	100-yr	946.00	930.00	972.74		972.74	0.000004	0.08	12120.80	331.31	0.00
Tributary 2	6243	100-yr	946.00	930.00	972.74		972.74	0.000003	0.08	12120.76	331.31	0.00
Tributary 2	6105.07	100-yr	946.00	931.90	972.74		972.74	0.000004	0.09	11306.48	314.47	0.00
Tributary 2	5831.15	100-yr	946.00	931.90	972.74	934.46	972.74	0.000004	0.09	11305.73	314.47	0.00
Tributary 2	5701.15		Culvert									
Tributary 2	5649.15	100-yr	946.00	934.00	972.73		972.73	0.000000	0.03	30021.87	930.21	0.00
Tributary 2	5610.37	100-yr	946.00	934.00	972.73		972.73	0.000000	0.03	30021.87	930.21	0.00
Tributary 2	5508.81	100-yr	946.00	934.00	972.73		972.73	0.000006	0.10	9372.44	266.89	0.00
Tributary 2	5375	100-yr	946.00	934.00	972.73	936.52	972.73	0.000008	0.10	9371.88	266.89	0.00
Tributary 2	5310		Culvert									
Tributary 2	5284	100-yr	946.00	936.00	972.73		972.73	0.000001	0.04	22440.22	686.55	0.00
Tributary 2	5271.84	100-yr	946.00	936.00	972.73		972.73	0.000001	0.04	22440.22	686.55	0.00
Tributary 2	5158.46	100-yr	946.00	936.00	972.73		972.73	0.000012	0.14	6638.14	192.74	0.00
Tributary 2	5009.75	100-yr	946.00	936.00	972.72	938.47	972.72	0.000015	0.12	6636.95	192.74	0.00
Tributary 2	4816		Culvert									
Tributary 2	4740.55	100-yr	946.00	936.00	972.72		972.72	0.000000	0.03	34745.15	1050.98	0.00
Tributary 2	4612.6	100-yr	946.00	936.00	972.72		972.72	0.000001	0.03	30885.95	943.36	0.00
Tributary 2	4499.41	100-yr	946.00	936.00	972.72		972.72	0.000001	0.05	19186.63	581.48	0.00
Tributary 2	4351.79	100-yr	946.00	937.73	972.72		972.72	0.000001	0.05	19263.06	585.61	0.00
Tributary 2	4223.09	100-yr	946.00	937.93	972.72		972.72	0.000000	0.03	32090.06	1010.96	0.00
Tributary 2	4212	100-yr	946.00	937.93	972.72	939.57	972.72	0.000000	0.03	32089.94	1010.96	0.00
Tributary 2	4107		Culvert									
Tributary 2	4065	100-yr	946.00	940.00	972.71		972.71	0.000000	0.02	41942.41	1355.47	0.00
Tributary 2	4006.33	100-yr	946.00	940.00	972.71		972.71	0.000000	0.02	41942.41	1355.47	0.00
Tributary 2	3928.18	100-yr	946.00	940.00	972.71		972.71	0.000000	0.02	44907.63	1469.64	0.00
Tributary 2	3766.56	100-yr	946.00	940.00	972.71		972.71	0.000000	0.02	44985.61	1504.95	0.00
Tributary 2	3587.45	100-yr	946.00	940.00	972.71		972.71	0.000000	0.02	43386.73	1477.68	0.00
Tributary 2	3447.14	100-yr	946.00	941.08	972.71		972.71	0.000000	0.02	43150.44	1477.08	0.00
Tributary 2	3239.24	100-yr	946.00	941.64	972.71		972.71	0.000001	0.03	32187.93	1081.13	0.00
Tributary 2	3077.4	100-yr	946.00	941.84	972.71		972.71	0.000000	0.02	40195.48	1458.19	0.00
Tributary 2	2912.18	100-yr	946.00	943.17	972.71		972.71	0.000001	0.03	36477.76	1417.62	0.00
Tributary 2	2747.71	100-yr	946.00	944.00	972.71		972.71	0.000001	0.03	26732.50	1010.18	0.00
Tributary 2	2544.97	100-yr	946.00	945.93	972.71		972.71	0.000005	0.08	11252.57	440.95	0.00
Tributary 2	2321	100-yr	946.00	946.01	972.71		972.71	0.000001	0.04	22267.22	978.90	0.00
Tributary 2	2147.59	100-yr	946.00	949.63	972.71		972.71	0.000002	0.04	21202.29	1034.47	0.00
Tributary 2	1922.22	100-yr	946.00	951.95	972.71		972.71	0.000002	0.04	22077.04	1231.19	0.00
Tributary 2	1695.09	100-yr	946.00	952.65	972.71		972.71	0.000005	0.06	15089.22	849.56	0.00
Tributary 2	1435.55	100-yr	946.00	953.98	972.71		972.71	0.000009	0.08	11583.29	730.27	0.00
Tributary 2	1282.73	100-yr	946.00	955.98	972.70		972.70	0.000007	0.06	15566.86	1170.66	0.00
Tributary 2	1033.36	100-yr	946.00	956.70	972.70		972.70	0.000011	0.07	12611.74	911.95	0.00
Tributary 2	672.62	100-yr	946.00	961.83	972.70		972.70	0.000018	0.07	12025.87	1475.05	0.00
Tributary 2	525.29	100-yr	946.00	963.77	972.69		972.69	0.000072	0.11	8309.08	1380.13	0.01
Tributary 2	371.81	100-yr	946.00	965.91	972.67		972.67	0.000450	0.26	3789.58	767.40	0.02
Tributary 2	293.48	100-yr	946.00	968.01	972.54		972.54	0.001903	0.40	2369.06	676.52	0.04
Tributary 2	212.87	100-yr	946.00	968.00	972.34		972.35	0.003291	0.47	2031.63	671.65	0.05
Tributary 2	0	100-yr	946.00	969.46	970.90	970.90	971.31	2.627420	5.09	185.76	237.87	1.02

Table 15: Tributary A Cross-Sections*

Plan: existing_conditions Tributary A Tributary A RS: 16381.73 Profile: 100-yr

E.G. Elev (ft)	957.51	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.02	Wt. n-Val.		0.040	
W.S. Elev (ft)	957.49	Reach Len. (ft)	468.12	468.56	460.99
Crit W.S. (ft)		Flow Area (sq ft)		967.15	
E.G. Slope (ft/ft)	0.000987	Area (sq ft)		967.15	
Q Total (cfs)	1180.34	Flow (cfs)		1180.34	
Top Width (ft)	904.23	Top Width (ft)		904.23	
Vel Total (ft/s)	1.22	Avg. Vel. (ft/s)		1.22	
Max Chl Dpth (ft)	1.50	Hydr. Depth (ft)		1.07	
Conv. Total (cfs)	37574.4	Conv. (cfs)		37574.4	
Length Wtd. (ft)	468.56	Wetted Per. (ft)		904.26	
Min Ch El (ft)	955.99	Shear (lb/sq ft)		0.07	
Alpha	1.00	Stream Power (lb/ft s)		0.08	
Frctn Loss (ft)	0.62	Cum Volume (acre-ft)	198.71	782.37	288.35
C & E Loss (ft)	0.00	Cum SA (acres)	145.87	231.27	259.58

Plan: existing_conditions Tributary A Tributary A RS: 14879.82 Profile: 100-yr

E.G. Elev (ft)	952.65	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.05	Wt. n-Val.		0.040	
W.S. Elev (ft)	952.60	Reach Len. (ft)	333.96	346.01	357.71
Crit W.S. (ft)		Flow Area (sq ft)		691.28	
E.G. Slope (ft/ft)	0.003152	Area (sq ft)		691.28	
Q Total (cfs)	1180.34	Flow (cfs)		1180.34	
Top Width (ft)	933.12	Top Width (ft)		933.12	
Vel Total (ft/s)	1.71	Avg. Vel. (ft/s)		1.71	
Max Chl Dpth (ft)	2.60	Hydr. Depth (ft)		0.74	
Conv. Total (cfs)	21024.0	Conv. (cfs)		21024.0	
Length Wtd. (ft)	344.81	Wetted Per. (ft)		933.19	
Min Ch El (ft)	950.00	Shear (lb/sq ft)		0.15	
Alpha	1.00	Stream Power (lb/ft s)		0.25	
Frctn Loss (ft)	0.90	Cum Volume (acre-ft)	198.71	760.17	287.88
C & E Loss (ft)	0.00	Cum SA (acres)	145.87	206.66	258.95

Plan: existing_conditions Tributary A Tributary A RS: 12921.76 Profile: 100-yr

E.G. Elev (ft)	950.55	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.01	Wt. n-Val.	0.030	0.040	0.030
W.S. Elev (ft)	950.54	Reach Len. (ft)	499.42	508.12	504.97
Crit W.S. (ft)		Flow Area (sq ft)	121.73	1634.93	48.42
E.G. Slope (ft/ft)	0.000090	Area (sq ft)	121.73	1634.93	48.42
Q Total (cfs)	1180.34	Flow (cfs)	57.22	1107.35	15.77
Top Width (ft)	821.26	Top Width (ft)	121.98	615.16	84.13
Vel Total (ft/s)	0.65	Avg. Vel. (ft/s)	0.47	0.68	0.33
Max Chl Dpth (ft)	4.53	Hydr. Depth (ft)	1.00	2.66	0.58
Conv. Total (cfs)	124204.7	Conv. (cfs)	6020.7	116524.6	1659.4
Length Wtd. (ft)	507.59	Wetted Per. (ft)	121.99	615.21	84.13
Min Ch El (ft)	946.01	Shear (lb/sq ft)	0.01	0.01	0.00
Alpha	1.03	Stream Power (lb/ft s)	0.00	0.01	0.00
Frctn Loss (ft)	0.02	Cum Volume (acre-ft)	196.96	716.21	287.53
C & E Loss (ft)	0.00	Cum SA (acres)	143.24	170.58	258.34

Plan: existing_conditions Tributary A Tributary A RS: 11851.43 Profile: 100-yr

E.G. Elev (ft)	950.32	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.	0.030	0.040	0.030
W.S. Elev (ft)	950.32	Reach Len. (ft)	184.70	186.37	181.38
Crit W.S. (ft)		Flow Area (sq ft)	1972.80	2543.43	1792.36
E.G. Slope (ft/ft)	0.000004	Area (sq ft)	1972.80	2543.43	1792.36
Q Total (cfs)	1180.34	Flow (cfs)	422.44	450.57	307.33

Plan: existing_conditions Tributary A Tributary A RS: 11851.43 Profile: 100-yr (Continued)

Top Width (ft)	2064.82	Top Width (ft)	612.78	679.79	772.25
Vel Total (ft/s)	0.19	Avg. Vel. (ft/s)	0.21	0.18	0.17
Max Chl Dpth (ft)	4.32	Hydr. Depth (ft)	3.22	3.74	2.32
Conv. Total (cfs)	596499.2	Conv. (cfs)	213484.5	227701.5	155313.2
Length Wtd. (ft)	185.36	Wetted Per. (ft)	612.87	679.83	774.57
Min Ch El (ft)	946.00	Shear (lb/sq ft)	0.00	0.00	0.00
Alpha	1.03	Stream Power (lb/ft s)	0.00	0.00	0.00
Frctn Loss (ft)	0.00	Cum Volume (acre-ft)	192.46	649.20	280.31
C & E Loss (ft)	0.00	Cum SA (acres)	139.14	150.99	251.96

Plan: existing_conditions Tributary A Tributary A RS: 10977.25 Profile: 100-yr

E.G. Elev (ft)	950.32	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.	0.030	0.040	0.030
W.S. Elev (ft)	950.32	Reach Len. (ft)	35.90	36.75	37.10
Crit W.S. (ft)	944.05	Flow Area (sq ft)	2890.27	4489.46	2782.75
E.G. Slope (ft/ft)	0.000001	Area (sq ft)	2890.27	4489.46	2782.75
Q Total (cfs)	1180.34	Flow (cfs)	318.68	531.56	330.11
Top Width (ft)	2310.69	Top Width (ft)	835.48	757.91	717.30
Vel Total (ft/s)	0.12	Avg. Vel. (ft/s)	0.11	0.12	0.12
Max Chl Dpth (ft)	8.32	Hydr. Depth (ft)	3.46	5.92	3.88
Conv. Total (cfs)	1212313.0	Conv. (cfs)	327308.4	545957.3	339047.3
Length Wtd. (ft)	36.75	Wetted Per. (ft)	836.03	757.97	721.29
Min Ch El (ft)	942.00	Shear (lb/sq ft)	0.00	0.00	0.00
Alpha	1.00	Stream Power (lb/ft s)	0.00	0.00	0.00
Frctn Loss (ft)		Cum Volume (acre-ft)	144.97	534.65	249.47
C & E Loss (ft)		Cum SA (acres)	125.88	128.21	243.26

Alpha	1.02	Stream Power (lb/ft s)	0.00	0.00	0.00
Frctn Loss (ft)	0.00	Cum Volume (acre-ft)	75.19	276.79	54.85
C & E Loss (ft)	0.00	Cum SA (acres)	101.82	81.40	181.92

Plan: existing_conditions Tributary A Tributary A RS: 7261.5 Profile: 100-yr

E.G. Elev (ft)	948.26	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.	0.030	0.040	0.030
W.S. Elev (ft)	948.26	Reach Len. (ft)	10031.30	1265.19	9668.00
Crit W.S. (ft)	938.90	Flow Area (sq ft)	2560.12	2941.74	2976.57
E.G. Slope (ft/ft)	0.000001	Area (sq ft)	2560.12	2941.74	2976.57
Q Total (cfs)	1180.34	Flow (cfs)	362.97	443.05	374.32
Top Width (ft)	1530.91	Top Width (ft)	498.10	340.50	692.31
Vel Total (ft/s)	0.14	Avg. Vel. (ft/s)	0.14	0.15	0.13
Max Chl Dpth (ft)	12.26	Hydr. Depth (ft)	5.14	8.64	4.30
Conv. Total (cfs)	1224145.0	Conv. (cfs)	376441.8	459491.4	388211.9
Length Wtd. (ft)	1265.19	Wetted Per. (ft)	500.51	341.19	696.62
Min Ch El (ft)	936.00	Shear (lb/sq ft)	0.00	0.00	0.00
Alpha	1.02	Stream Power (lb/ft s)	0.00	0.00	0.00
Frctn Loss (ft)		Cum Volume (acre-ft)	0.22	168.12	12.80
C & E Loss (ft)		Cum SA (acres)	83.15	65.38	168.27

Plan: existing_conditions   Tributary A   Tributary A RS: 10029.35   Profile: 100-yr

E.G. Elev (ft)	948.49	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.	0.030	0.040	0.030
W.S. Elev (ft)	948.49	Reach Len. (ft)	564.08	548.14	525.75
Crit W.S. (ft)		Flow Area (sq ft)	219.04	4654.10	3990.19
E.G. Slope (ft/ft)	0.000001	Area (sq ft)	219.04	4654.10	3990.19
Q Total (cfs)	1180.34	Flow (cfs)	18.17	648.97	513.20
Top Width (ft)	2238.89	Top Width (ft)	133.74	846.88	1258.26
Vel Total (ft/s)	0.13	Avg. Vel. (ft/s)	0.08	0.14	0.13
Max Chl Dpth (ft)	6.51	Hydr. Depth (ft)	1.64	5.50	3.17
Conv. Total (cfs)	979138.6	Conv. (cfs)	15071.4	538348.3	425718.8
Length Wtd. (ft)	539.49	Wetted Per. (ft)	133.78	847.03	1262.15
Min Ch El (ft)	941.98	Shear (lb/sq ft)	0.00	0.00	0.00
Alpha	1.01	Stream Power (lb/ft s)	0.00	0.00	0.00
Frctn Loss (ft)	0.00	Cum Volume (acre-ft)	99.79	450.65	159.70
C & E Loss (ft)	0.00	Cum SA (acres)	112.40	110.80	214.53

Plan: existing_conditions   Tributary A   Tributary A RS: 8486.47   Profile: 100-yr

E.G. Elev (ft)	948.43	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.	0.030	0.040	0.030
W.S. Elev (ft)	948.43	Reach Len. (ft)	110.27	103.96	106.56
Crit W.S. (ft)		Flow Area (sq ft)	891.09	5602.77	1764.17
E.G. Slope (ft/ft)	0.000001	Area (sq ft)	891.09	5602.77	1764.17
Q Total (cfs)	1180.34	Flow (cfs)	99.76	804.05	276.53
Top Width (ft)	1584.86	Top Width (ft)	317.06	892.93	374.87
Vel Total (ft/s)	0.14	Avg. Vel. (ft/s)	0.11	0.14	0.16
Max Chl Dpth (ft)	10.43	Hydr. Depth (ft)	2.81	6.27	4.71
Conv. Total (cfs)	1039013.0	Conv. (cfs)	87815.4	707779.8	243418.1
Length Wtd. (ft)	105.91	Wetted Per. (ft)	317.51	893.44	379.43
Min Ch El (ft)	938.00	Shear (lb/sq ft)	0.00	0.00	0.00

Plan: existing_conditions Tributary A Tributary A RS: 4868.72 Profile: 100-yr

E.G. Elev (ft)	927.43	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.08	Wt. n-Val.		0.040	
W.S. Elev (ft)	927.35	Reach Len. (ft)	404.22	375.60	338.88
Crit W.S. (ft)		Flow Area (sq ft)		527.21	
E.G. Slope (ft/ft)	0.002697	Area (sq ft)		527.21	
Q Total (cfs)	1180.34	Flow (cfs)		1180.34	
Top Width (ft)	421.64	Top Width (ft)		421.64	
Vel Total (ft/s)	2.24	Avg. Vel. (ft/s)		2.24	
Max Chl Dpth (ft)	1.67	Hydr. Depth (ft)		1.25	
Conv. Total (cfs)	22727.8	Conv. (cfs)		22727.8	
Length Wtd. (ft)	375.60	Wetted Per. (ft)		421.73	
Min Ch El (ft)	925.68	Shear (lb/sq ft)		0.21	
Alpha	1.00	Stream Power (lb/ft s)		0.47	
Frctn Loss (ft)	0.42	Cum Volume (acre-ft)	0.22	84.82	12.43
C & E Loss (ft)	0.02	Cum SA (acres)	0.50	44.10	12.17

Plan: existing_conditions Tributary A Tributary A RS: 3461.76 Profile: 100-yr

E.G. Elev (ft)	923.37	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.03	Wt. n-Val.		0.040	0.030
W.S. Elev (ft)	923.34	Reach Len. (ft)	374.45	400.20	379.22
Crit W.S. (ft)		Flow Area (sq ft)		714.82	173.93
E.G. Slope (ft/ft)	0.001078	Area (sq ft)		714.82	173.93
Q Total (cfs)	1180.34	Flow (cfs)		932.06	248.28
Top Width (ft)	858.07	Top Width (ft)		646.63	211.45
Vel Total (ft/s)	1.33	Avg. Vel. (ft/s)		1.30	1.43
Max Chl Dpth (ft)	1.74	Hydr. Depth (ft)		1.11	0.82
Conv. Total (cfs)	35950.3	Conv. (cfs)		28388.2	7562.1
Length Wtd. (ft)	395.94	Wetted Per. (ft)		646.68	211.47
Min Ch El (ft)	921.60	Shear (lb/sq ft)		0.07	0.06
Alpha	1.00	Stream Power (lb/ft s)		0.10	0.08
Frctn Loss (ft)	0.55	Cum Volume (acre-ft)	0.22	68.46	6.74
C & E Loss (ft)	0.00	Cum SA (acres)	0.50	28.47	7.54

Plan: existing_conditions   Tributary A   Tributary A RS: 1355.48   Profile: 100-yr

E.G. Elev (ft)	918.13	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.		0.040	0.030
W.S. Elev (ft)	918.13	Reach Len. (ft)	226.59	223.83	229.08
Crit W.S. (ft)		Flow Area (sq ft)		2743.53	336.87
E.G. Slope (ft/ft)	0.000022	Area (sq ft)		2743.53	336.87
Q Total (cfs)	1180.34	Flow (cfs)		1052.35	127.99
Top Width (ft)	1004.27	Top Width (ft)		842.99	161.28
Vel Total (ft/s)	0.38	Avg. Vel. (ft/s)		0.38	0.38
Max Chl Dpth (ft)	4.13	Hydr. Depth (ft)		3.25	2.09
Conv. Total (cfs)	251004.3	Conv. (cfs)		223786.3	27218.0
Length Wtd. (ft)	224.11	Wetted Per. (ft)		843.19	161.69
Min Ch El (ft)	914.00	Shear (lb/sq ft)		0.00	0.00
Alpha	1.00	Stream Power (lb/ft s)		0.00	0.00
Frctn Loss (ft)	0.00	Cum Volume (acre-ft)	0.22	34.78	0.89
C & E Loss (ft)	0.00	Cum SA (acres)	0.50	13.12	0.42

Plan: existing_conditions   Tributary A   Tributary A RS: 0   Profile: 100-yr

E.G. Elev (ft)	910.32	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.55	Wt. n-Val.		0.040	
W.S. Elev (ft)	909.76	Reach Len. (ft)			
Crit W.S. (ft)	909.76	Flow Area (sq ft)		197.93	
E.G. Slope (ft/ft)	0.022976	Area (sq ft)		197.93	
Q Total (cfs)	1180.34	Flow (cfs)		1180.34	
Top Width (ft)	181.54	Top Width (ft)		181.54	
Vel Total (ft/s)	5.96	Avg. Vel. (ft/s)		5.96	
Max Chl Dpth (ft)	1.72	Hydr. Depth (ft)		1.09	
Conv. Total (cfs)	7786.9	Conv. (cfs)		7786.9	
Length Wtd. (ft)		Wetted Per. (ft)		181.62	
Min Ch El (ft)	908.04	Shear (lb/sq ft)		1.56	
Alpha	1.00	Stream Power (lb/ft s)		9.32	
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

*A full list of cross sections with all flow profiles would have been over 100 pages long. For this table, as well as in **Table 16** below, only a few distinct cross-sections were selected to showcase outputs at various locations along the streamline. The design 100-year profile was selected for these tables. A complete list of cross-sections with all profile outputs will be included with the final deliverables.

Table 16: Tributary 2 Cross Sections*

Plan: existing_conditions   Tributary 2   Tributary 2 RS: 7117.77   Profile: 100-yr

E.G. Elev (ft)	972.77	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.		0.400	0.300
W.S. Elev (ft)	972.77	Reach Len. (ft)	236.37	239.96	238.39
Crit W.S. (ft)		Flow Area (sq ft)		1387.92	1165.83
E.G. Slope (ft/ft)	0.000164	Area (sq ft)		1387.92	1165.83
Q Total (cfs)	946.00	Flow (cfs)		454.91	491.09
Top Width (ft)	58.01	Top Width (ft)		29.67	28.34
Vel Total (ft/s)	0.37	Avg. Vel. (ft/s)		0.33	0.42
Max Chl Dpth (ft)	47.02	Hydr. Depth (ft)		46.78	41.14
Conv. Total (cfs)	73763.2	Conv. (cfs)		35471.2	38292.0
Length Wtd. (ft)	238.50	Wetted Per. (ft)		76.91	68.27
Min Ch El (ft)	925.75	Shear (lb/sq ft)		0.19	0.18
Alpha	1.05	Stream Power (lb/ft s)		0.06	0.07
Frctn Loss (ft)	0.03	Cum Volume (acre-ft)	785.31	2029.63	723.08
C & E Loss (ft)	0.00	Cum SA (acres)	36.56	77.54	32.90

Plan: existing_conditions   Tributary 2   Tributary 2 RS: 6281.5   Profile: 100-yr

E.G. Elev (ft)	972.74	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.	0.300	0.400	0.300
W.S. Elev (ft)	972.74	Reach Len. (ft)	38.50	38.50	38.50
Crit W.S. (ft)		Flow Area (sq ft)	3501.04	7210.01	1409.75
E.G. Slope (ft/ft)	0.000004	Area (sq ft)	3501.04	7210.01	1409.75
Q Total (cfs)	946.00	Flow (cfs)	284.59	568.81	92.59
Top Width (ft)	331.31	Top Width (ft)	101.32	187.92	42.07
Vel Total (ft/s)	0.08	Avg. Vel. (ft/s)	0.08	0.08	0.07
Max Chl Dpth (ft)	42.74	Hydr. Depth (ft)	34.55	38.37	33.51
Conv. Total (cfs)	504872.0	Conv. (cfs)	151885.1	303571.2	49415.7
Length Wtd. (ft)	38.50	Wetted Per. (ft)	135.06	188.95	74.88
Min Ch El (ft)	930.00	Shear (lb/sq ft)	0.01	0.01	0.00
Alpha	1.01	Stream Power (lb/ft s)	0.00	0.00	0.00
Frctn Loss (ft)	0.00	Cum Volume (acre-ft)	593.42	1816.98	613.98
C & E Loss (ft)	0.00	Cum SA (acres)	31.79	74.01	29.97

Plan: existing_conditions   Tributary 2   Tributary 2 RS: 5508.81   Profile: 100-yr

E.G. Elev (ft)	972.73	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.	0.300	0.400	0.300
W.S. Elev (ft)	972.73	Reach Len. (ft)	297.02	303.78	307.47
Crit W.S. (ft)		Flow Area (sq ft)	562.44	4706.85	4103.14
E.G. Slope (ft/ft)	0.000006	Area (sq ft)	562.44	4706.85	4103.14
Q Total (cfs)	946.00	Flow (cfs)	34.22	472.94	438.84
Top Width (ft)	266.89	Top Width (ft)	16.71	127.07	123.11
Vel Total (ft/s)	0.10	Avg. Vel. (ft/s)	0.06	0.10	0.11
Max Chl Dpth (ft)	38.73	Hydr. Depth (ft)	33.66	37.04	33.33
Conv. Total (cfs)	387681.9	Conv. (cfs)	14024.1	193815.5	179842.4
Length Wtd. (ft)	304.84	Wetted Per. (ft)	49.80	127.54	155.87
Min Ch El (ft)	934.00	Shear (lb/sq ft)	0.00	0.01	0.01
Alpha	1.03	Stream Power (lb/ft s)	0.00	0.00	0.00
Frctn Loss (ft)	0.00	Cum Volume (acre-ft)	543.12	1653.73	552.28
C & E Loss (ft)	0.00	Cum SA (acres)	29.38	70.00	27.24

Plan: existing_conditions   Tributary 2   Tributary 2 RS: 5009.75   Profile: 100-yr

E.G. Elev (ft)	972.72	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.		0.400	0.300
W.S. Elev (ft)	972.72	Reach Len. (ft)	268.60	269.20	267.40
Crit W.S. (ft)	938.47	Flow Area (sq ft)		3399.45	3237.50
E.G. Slope (ft/ft)	0.000015	Area (sq ft)		3399.45	3237.50
Q Total (cfs)	946.00	Flow (cfs)		424.64	521.36

Plan: existing_conditions Tributary 2 Tributary 2 RS: 5009.75 Profile: 100-yr (Continued)

Top Width (ft)	192.74	Top Width (ft)		95.16	97.58
Vel Total (ft/s)	0.14	Avg. Vel. (ft/s)		0.12	0.16
Max Chl Dpth (ft)	36.72	Hydr. Depth (ft)		35.72	33.18
Conv. Total (cfs)	247721.2	Conv. (cfs)		111197.3	136523.9
Length Wtd. (ft)	269.20	Wetted Per. (ft)		130.10	130.32
Min Ch El (ft)	936.00	Shear (lb/sq ft)		0.02	0.02
Alpha	1.05	Stream Power (lb/ft s)		0.00	0.00
Frctn Loss (ft)		Cum Volume (acre-ft)	538.44	1549.84	486.95
C & E Loss (ft)		Cum SA (acres)	29.15	67.28	24.73

Plan: existing_conditions Tributary 2 Tributary 2 RS: 4223.09 Profile: 100-yr

E.G. Elev (ft)	972.72	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.	0.300	0.400	0.300
W.S. Elev (ft)	972.72	Reach Len. (ft)	288.65	285.60	281.58
Crit W.S. (ft)		Flow Area (sq ft)	12586.61	12948.19	6555.27
E.G. Slope (ft/ft)	0.000000	Area (sq ft)	12586.61	12948.19	6555.27
Q Total (cfs)	946.00	Flow (cfs)	409.68	341.43	194.89
Top Width (ft)	1010.96	Top Width (ft)	395.97	389.85	225.14
Vel Total (ft/s)	0.03	Avg. Vel. (ft/s)	0.03	0.03	0.03
Max Chl Dpth (ft)	34.79	Hydr. Depth (ft)	31.79	33.21	29.12
Conv. Total (cfs)	1375973.0	Conv. (cfs)	595884.4	496621.6	283466.6
Length Wtd. (ft)	286.09	Wetted Per. (ft)	425.93	390.29	254.12
Min Ch El (ft)	937.93	Shear (lb/sq ft)	0.00	0.00	0.00
Alpha	1.03	Stream Power (lb/ft s)	0.00	0.00	0.00
Frctn Loss (ft)	0.00	Cum Volume (acre-ft)	483.89	1361.01	433.09
C & E Loss (ft)	0.00	Cum SA (acres)	26.59	60.66	22.22

Plan: existing_conditions Tributary 2 Tributary 2 RS: 3587.45 Profile: 100-yr

E.G. Elev (ft)	972.71	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.	0.300	0.400	0.300
W.S. Elev (ft)	972.71	Reach Len. (ft)	177.48	179.11	180.98
Crit W.S. (ft)		Flow Area (sq ft)	14147.61	15940.29	13298.82
E.G. Slope (ft/ft)	0.000000	Area (sq ft)	14147.61	15940.29	13298.82
Q Total (cfs)	946.00	Flow (cfs)	325.87	309.91	310.22
Top Width (ft)	1477.68	Top Width (ft)	511.70	503.01	462.97
Vel Total (ft/s)	0.02	Avg. Vel. (ft/s)	0.02	0.02	0.02
Max Chl Dpth (ft)	32.71	Hydr. Depth (ft)	27.65	31.69	28.73
Conv. Total (cfs)	1809838.0	Conv. (cfs)	623437.5	592896.8	593503.4
Length Wtd. (ft)	179.35	Wetted Per. (ft)	533.13	503.12	491.71
Min Ch El (ft)	940.00	Shear (lb/sq ft)	0.00	0.00	0.00
Alpha	1.02	Stream Power (lb/ft s)	0.00	0.00	0.00
Frctn Loss (ft)	0.00	Cum Volume (acre-ft)	280.96	1013.45	295.19
C & E Loss (ft)	0.00	Cum SA (acres)	18.53	51.58	16.50

Plan: existing_conditions Tributary 2 Tributary 2 RS: 2747.71 Profile: 100-yr

E.G. Elev (ft)	972.71	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.	0.300	0.400	0.300
W.S. Elev (ft)	972.71	Reach Len. (ft)	163.36	164.47	164.79
Crit W.S. (ft)		Flow Area (sq ft)	3223.34	21049.87	2459.30
E.G. Slope (ft/ft)	0.000001	Area (sq ft)	3223.34	21049.87	2459.30
Q Total (cfs)	946.00	Flow (cfs)	125.53	733.86	86.61
Top Width (ft)	1010.18	Top Width (ft)	129.15	766.19	114.84
Vel Total (ft/s)	0.04	Avg. Vel. (ft/s)	0.04	0.03	0.04
Max Chl Dpth (ft)	28.71	Hydr. Depth (ft)	24.96	27.47	21.41
Conv. Total (cfs)	917742.2	Conv. (cfs)	121781.0	711937.8	84023.4
Length Wtd. (ft)	164.48	Wetted Per. (ft)	153.01	766.24	135.75
Min Ch El (ft)	944.00	Shear (lb/sq ft)	0.00	0.00	0.00

Plan: existing_conditions Tributary 2 Tributary 2 RS: 2747.71 Profile: 100-yr (Continued)

Alpha	1.00	Stream Power (lb/ft s)	0.00	0.00	0.00
Frctn Loss (ft)	0.00	Cum Volume (acre-ft)	184.47	530.22	139.41
C & E Loss (ft)	0.00	Cum SA (acres)	14.69	34.97	10.72

Plan: existing_conditions Tributary 2 Tributary 2 RS: 1695.09 Profile: 100-yr

E.G. Elev (ft)	972.71	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.	0.300	0.400	0.300
W.S. Elev (ft)	972.71	Reach Len. (ft)	248.94	227.13	227.77
Crit W.S. (ft)		Flow Area (sq ft)	3270.46	10085.22	1733.54
E.G. Slope (ft/ft)	0.000005	Area (sq ft)	3270.46	10085.22	1733.54
Q Total (cfs)	946.00	Flow (cfs)	226.78	608.06	111.17
Top Width (ft)	849.56	Top Width (ft)	200.92	533.45	115.19
Vel Total (ft/s)	0.06	Avg. Vel. (ft/s)	0.07	0.06	0.06
Max Chl Dpth (ft)	20.06	Hydr. Depth (ft)	16.28	18.91	15.05
Conv. Total (cfs)	413615.8	Conv. (cfs)	99153.0	265857.5	48605.3
Length Wtd. (ft)	235.82	Wetted Per. (ft)	215.96	533.51	128.71
Min Ch El (ft)	952.65	Shear (lb/sq ft)	0.00	0.01	0.00
Alpha	1.01	Stream Power (lb/ft s)	0.00	0.00	0.00
Frctn Loss (ft)	0.00	Cum Volume (acre-ft)	92.18	261.97	56.20
C & E Loss (ft)	0.00	Cum SA (acres)	9.97	22.93	6.37

Plan: existing_conditions Tributary 2 Tributary 2 RS: 672.62 Profile: 100-yr

E.G. Elev (ft)	972.70	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.00	Wt. n-Val.	0.300	0.400	0.300
W.S. Elev (ft)	972.70	Reach Len. (ft)	165.10	167.60	163.74
Crit W.S. (ft)		Flow Area (sq ft)	1773.91	4646.65	5605.32
E.G. Slope (ft/ft)	0.000018	Area (sq ft)	1773.91	4646.65	5605.32
Q Total (cfs)	946.00	Flow (cfs)	99.40	341.34	505.27
Top Width (ft)	1475.05	Top Width (ft)	402.42	456.39	616.24
Vel Total (ft/s)	0.08	Avg. Vel. (ft/s)	0.06	0.07	0.09
Max Chl Dpth (ft)	10.87	Hydr. Depth (ft)	4.41	10.18	9.10
Conv. Total (cfs)	224714.1	Conv. (cfs)	23610.5	81081.8	120021.8
Length Wtd. (ft)	166.06	Wetted Per. (ft)	402.70	456.42	623.62
Min Ch El (ft)	961.83	Shear (lb/sq ft)	0.00	0.01	0.01
Alpha	1.07	Stream Power (lb/ft s)	0.00	0.00	0.00
Frctn Loss (ft)	0.01	Cum Volume (acre-ft)	6.62	53.10	16.42
C & E Loss (ft)	0.00	Cum SA (acres)	2.32	8.88	2.48

Plan: existing_conditions Tributary 2 Tributary 2 RS: 0 Profile: 100-yr

E.G. Elev (ft)	971.31	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.40	Wt. n-Val.		0.400	
W.S. Elev (ft)	970.90	Reach Len. (ft)			
Crit W.S. (ft)	970.90	Flow Area (sq ft)		185.76	
E.G. Slope (ft/ft)	2.627420	Area (sq ft)		185.76	
Q Total (cfs)	946.00	Flow (cfs)		946.00	
Top Width (ft)	237.87	Top Width (ft)		237.87	
Vel Total (ft/s)	5.09	Avg. Vel. (ft/s)		5.09	
Max Chl Dpth (ft)	1.44	Hydr. Depth (ft)		0.78	
Conv. Total (cfs)	583.6	Conv. (cfs)		583.6	
Length Wtd. (ft)		Wetted Per. (ft)		238.85	
Min Ch El (ft)	969.46	Shear (lb/sq ft)		127.58	
Alpha	1.00	Stream Power (lb/ft s)		649.67	
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

*This table has been edited for length and clarity. See the side note in **Table 15** above.

Table 17: Tributary A Culverts

Plan: existing_conditions Tributary A Tributary A RS: 11912 Culv Group: Acers St Profile: 100-yr

Q Culv Group (cfs)	239.24	Culv Full Len (ft)	
# Barrels	1	Culv Vel US (ft/s)	2.82
Q Barrel (cfs)	239.24	Culv Vel DS (ft/s)	2.73
E.G. US. (ft)	950.52	Culv Inv El Up (ft)	943.02
W.S. US. (ft)	950.52	Culv Inv El Dn (ft)	942.70
E.G. DS (ft)	950.32	Culv Frctn Ls (ft)	0.01
W.S. DS (ft)	950.32	Culv Exit Loss (ft)	0.12
Delta EG (ft)	0.20	Culv Entr Loss (ft)	0.07
Delta WS (ft)	0.20	Q Weir (cfs)	941.10
E.G. IC (ft)	950.35	Weir Sta Lft (ft)	52.60
E.G. OC (ft)	950.52	Weir Sta Rgt (ft)	1050.24
Culvert Control	Outlet	Weir Submerg	0.62
Culv WS Inlet (ft)	950.32	Weir Max Depth (ft)	0.51
Culv WS Outlet (ft)	950.32	Weir Avg Depth (ft)	0.51
Culv Nml Depth (ft)	2.20	Weir Flow Area (sq ft)	507.25
Culv Crt Depth (ft)	2.49	Min El Weir Flow (ft)	950.01

Plan: existing_conditions Tributary A Tributary A RS: 10951 Culv Group: Harris St Profile: 100-yr

Q Culv Group (cfs)	114.65	Culv Full Len (ft)	21.00
# Barrels	1	Culv Vel US (ft/s)	8.12
Q Barrel (cfs)	114.65	Culv Vel DS (ft/s)	8.12
E.G. US. (ft)	950.32	Culv Inv El Up (ft)	943.02
W.S. US. (ft)	950.32	Culv Inv El Dn (ft)	942.70
E.G. DS (ft)	948.49	Culv Frctn Ls (ft)	0.08
W.S. DS (ft)	948.49	Culv Exit Loss (ft)	1.02
Delta EG (ft)	1.83	Culv Entr Loss (ft)	0.72
Delta WS (ft)	1.83	Q Weir (cfs)	1071.43
E.G. IC (ft)	950.30	Weir Sta Lft (ft)	0.00
E.G. OC (ft)	950.32	Weir Sta Rgt (ft)	2310.69
Culvert Control	Outlet	Weir Submerg	0.00
Culv WS Inlet (ft)	947.26	Weir Max Depth (ft)	0.32
Culv WS Outlet (ft)	946.94	Weir Avg Depth (ft)	0.32
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	732.10
Culv Crt Depth (ft)	3.20	Min El Weir Flow (ft)	950.01

Plan: existing_conditions Tributary A Tributary A RS: 8651 Culv Group: Prospect St Profile: 100-yr

Q Culv Group (cfs)	74.04	Culv Full Len (ft)	62.00
# Barrels	1	Culv Vel US (ft/s)	1.48
Q Barrel (cfs)	74.04	Culv Vel DS (ft/s)	1.48
E.G. US. (ft)	948.49	Culv Inv El Up (ft)	938.00
W.S. US. (ft)	948.49	Culv Inv El Dn (ft)	938.00
E.G. DS (ft)	948.43	Culv Frctn Ls (ft)	0.01
W.S. DS (ft)	948.43	Culv Exit Loss (ft)	0.03
Delta EG (ft)	0.06	Culv Entr Loss (ft)	0.02
Delta WS (ft)	0.06	Q Weir (cfs)	1106.31
E.G. IC (ft)	948.43	Weir Sta Lft (ft)	0.00
E.G. OC (ft)	948.49	Weir Sta Rgt (ft)	1487.46
Culvert Control	Outlet	Weir Submerg	0.91
Culv WS Inlet (ft)	943.00	Weir Max Depth (ft)	0.47
Culv WS Outlet (ft)	943.00	Weir Avg Depth (ft)	0.47
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	695.89
Culv Crt Depth (ft)	1.19	Min El Weir Flow (ft)	948.01

Plan: existing_conditions   Tributary A   Tributary A RS: 7360   Culv Group: Union St   Profile: 100-yr

Q Culv Group (cfs)	89.39	Culv Full Len (ft)	197.00
# Barrels	1	Culv Vel US (ft/s)	2.32
Q Barrel (cfs)	89.39	Culv Vel DS (ft/s)	2.32
E.G. US. (ft)	948.43	Culv Inv El Up (ft)	936.00
W.S. US. (ft)	948.43	Culv Inv El Dn (ft)	934.00
E.G. DS (ft)	948.26	Culv Frctn Ls (ft)	0.05
W.S. DS (ft)	948.26	Culv Exit Loss (ft)	0.08
Delta EG (ft)	0.17	Culv Entr Loss (ft)	0.04
Delta WS (ft)	0.17	Q Weir (cfs)	1090.95
E.G. IC (ft)	948.30	Weir Sta Lft (ft)	80.39
E.G. OC (ft)	948.43	Weir Sta Rgt (ft)	1576.53
Culvert Control	Outlet	Weir Submerg	0.59
Culv WS Inlet (ft)	941.50	Weir Max Depth (ft)	0.43
Culv WS Outlet (ft)	939.50	Weir Avg Depth (ft)	0.43
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	640.69
Culv Crt Depth (ft)	1.72	Min El Weir Flow (ft)	948.01

Plan: existing_conditions   Tributary A   Tributary A RS: 6331   Culv Group: Culvert #1   Profile: 100-yr

Q Culv Group (cfs)	631.10	Culv Full Len (ft)	880.00
# Barrels	1	Culv Vel US (ft/s)	9.86
Q Barrel (cfs)	631.10	Culv Vel DS (ft/s)	9.86
E.G. US. (ft)	948.26	Culv Inv El Up (ft)	933.50
W.S. US. (ft)	948.26	Culv Inv El Dn (ft)	928.00
E.G. DS (ft)	943.24	Culv Frctn Ls (ft)	2.60
W.S. DS (ft)	943.24	Culv Exit Loss (ft)	1.51
Delta EG (ft)	5.02	Culv Entr Loss (ft)	0.91
Delta WS (ft)	5.02	Q Weir (cfs)	549.24
E.G. IC (ft)	948.13	Weir Sta Lft (ft)	0.00
E.G. OC (ft)	948.26	Weir Sta Rgt (ft)	1530.91
Culvert Control	Outlet	Weir Submerg	0.00
Culv WS Inlet (ft)	941.50	Weir Max Depth (ft)	0.27
Culv WS Outlet (ft)	936.00	Weir Avg Depth (ft)	0.27
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	408.80
Culv Crt Depth (ft)	5.78	Min El Weir Flow (ft)	948.01

Plan: existing_conditions   Tributary A   Tributary A RS: 6033   Culv Group: Main St   Profile: 100-yr

Q Culv Group (cfs)	769.28	Culv Full Len (ft)	125.00
# Barrels	1	Culv Vel US (ft/s)	13.74
Q Barrel (cfs)	769.28	Culv Vel DS (ft/s)	13.74
E.G. US. (ft)	943.24	Culv Inv El Up (ft)	927.40
W.S. US. (ft)	943.24	Culv Inv El Dn (ft)	925.50
E.G. DS (ft)	937.79	Culv Frctn Ls (ft)	0.79
W.S. DS (ft)	937.76	Culv Exit Loss (ft)	2.90
Delta EG (ft)	5.45	Culv Entr Loss (ft)	1.76
Delta WS (ft)	5.48	Q Weir (cfs)	411.06
E.G. IC (ft)	943.17	Weir Sta Lft (ft)	0.00
E.G. OC (ft)	943.24	Weir Sta Rgt (ft)	1262.48
Culvert Control	Outlet	Weir Submerg	0.00
Culv WS Inlet (ft)	934.40	Weir Max Depth (ft)	0.25
Culv WS Outlet (ft)	932.50	Weir Avg Depth (ft)	0.25
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	316.01
Culv Crt Depth (ft)	6.60	Min El Weir Flow (ft)	943.01

Table 18: Tributary 2 Culverts

Plan: existing_conditions   Tributary 2   Tributary 2 RS: 6320   Culv Group: Woodland St   Profile: 100-yr

Q Culv Group (cfs)	6.80	Culv Full Len (ft)	77.00
# Barrels	1	Culv Vel US (ft/s)	0.27
Q Barrel (cfs)	6.80	Culv Vel DS (ft/s)	0.27
E.G. US. (ft)	972.74	Culv Inv El Up (ft)	927.41
W.S. US. (ft)	972.74	Culv Inv El Dn (ft)	926.67
E.G. DS (ft)	972.74	Culv Frctn Ls (ft)	0.00
W.S. DS (ft)	972.74	Culv Exit Loss (ft)	0.00
Delta EG (ft)	0.00	Culv Entr Loss (ft)	0.00
Delta WS (ft)	0.00	Q Weir (cfs)	0.00
E.G. IC (ft)	927.97	Weir Sta Lft (ft)	0.00
E.G. OC (ft)	972.74	Weir Sta Rgt (ft)	595.27
Culvert Control	Outlet	Weir Submerg	1.00
Culv WS Inlet (ft)	932.41	Weir Max Depth (ft)	31.74
Culv WS Outlet (ft)	931.67	Weir Avg Depth (ft)	31.74
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	18894.23
Culv Crt Depth (ft)	0.39	Min El Weir Flow (ft)	941.01

Plan: existing_conditions   Tributary 2   Tributary 2 RS: 5701.15   Culv Group: Main St   Profile: 100-yr

Q Culv Group (cfs)	10.87	Culv Full Len (ft)	104.00
# Barrels	1	Culv Vel US (ft/s)	0.36
Q Barrel (cfs)	10.87	Culv Vel DS (ft/s)	0.36
E.G. US. (ft)	972.74	Culv Inv El Up (ft)	930.72
W.S. US. (ft)	972.74	Culv Inv El Dn (ft)	929.86
E.G. DS (ft)	972.73	Culv Frctn Ls (ft)	0.00
W.S. DS (ft)	972.73	Culv Exit Loss (ft)	0.00
Delta EG (ft)	0.00	Culv Entr Loss (ft)	0.00
Delta WS (ft)	0.00	Q Weir (cfs)	1195.92
E.G. IC (ft)	969.50	Weir Sta Lft (ft)	0.00
E.G. OC (ft)	972.74	Weir Sta Rgt (ft)	314.47
Culvert Control	Outlet	Weir Submerg	1.00
Culv WS Inlet (ft)	935.72	Weir Max Depth (ft)	27.74
Culv WS Outlet (ft)	934.86	Weir Avg Depth (ft)	27.74
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	8722.07
Culv Crt Depth (ft)	0.47	Min El Weir Flow (ft)	945.01

Plan: existing_conditions   Tributary 2   Tributary 2 RS: 5310   Culv Group: Fayette St   Profile: 100-yr

Q Culv Group (cfs)	14.49	Culv Full Len (ft)	52.00
# Barrels	1	Culv Vel US (ft/s)	0.36
Q Barrel (cfs)	14.49	Culv Vel DS (ft/s)	0.36
E.G. US. (ft)	972.73	Culv Inv El Up (ft)	932.45
W.S. US. (ft)	972.73	Culv Inv El Dn (ft)	932.19
E.G. DS (ft)	972.73	Culv Frctn Ls (ft)	0.00
W.S. DS (ft)	972.73	Culv Exit Loss (ft)	0.00
Delta EG (ft)	0.00	Culv Entr Loss (ft)	0.00
Delta WS (ft)	0.00	Q Weir (cfs)	953.66
E.G. IC (ft)	956.40	Weir Sta Lft (ft)	0.00
E.G. OC (ft)	972.73	Weir Sta Rgt (ft)	266.89
Culvert Control	Outlet	Weir Submerg	1.00
Culv WS Inlet (ft)	936.45	Weir Max Depth (ft)	29.73
Culv WS Outlet (ft)	936.19	Weir Avg Depth (ft)	29.73
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	7934.55
Culv Crt Depth (ft)	0.40	Min El Weir Flow (ft)	943.01

Plan: existing_conditions Tributary 2 Tributary 2 RS: 4816 Culv Group: Butler St Profile: 100-yr

Q Culv Group (cfs)	6.65	Culv Full Len (ft)	155.00
# Barrels	1	Culv Vel US (ft/s)	0.35
Q Barrel (cfs)	6.65	Culv Vel DS (ft/s)	0.35
E.G. US. (ft)	972.72	Culv Inv El Up (ft)	934.14
W.S. US. (ft)	972.72	Culv Inv El Dn (ft)	933.73
E.G. DS (ft)	972.72	Culv Frctn Ls (ft)	0.00
W.S. DS (ft)	972.72	Culv Exit Loss (ft)	0.00
Delta EG (ft)	0.00	Culv Entr Loss (ft)	0.00
Delta WS (ft)	0.00	Q Weir (cfs)	734.37
E.G. IC (ft)	935.08	Weir Sta Lft (ft)	0.00
E.G. OC (ft)	972.72	Weir Sta Rgt (ft)	192.74
Culvert Control	Outlet	Weir Submerg	1.00
Culv WS Inlet (ft)	939.09	Weir Max Depth (ft)	28.72
Culv WS Outlet (ft)	938.68	Weir Avg Depth (ft)	28.72
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	5535.46
Culv Crt Depth (ft)	0.71	Min El Weir Flow (ft)	944.01

Plan: existing_conditions Tributary 2 Tributary 2 RS: 4107 Culv Group: Stiles St Profile: 100-yr

Q Culv Group (cfs)	6.65	Culv Full Len (ft)	84.00
# Barrels	1	Culv Vel US (ft/s)	0.42
Q Barrel (cfs)	6.65	Culv Vel DS (ft/s)	0.42
E.G. US. (ft)	972.72	Culv Inv El Up (ft)	934.55
W.S. US. (ft)	972.72	Culv Inv El Dn (ft)	934.39
E.G. DS (ft)	972.71	Culv Frctn Ls (ft)	0.00
W.S. DS (ft)	972.71	Culv Exit Loss (ft)	0.00
Delta EG (ft)	0.01	Culv Entr Loss (ft)	0.00
Delta WS (ft)	0.01	Q Weir (cfs)	5107.93
E.G. IC (ft)	935.52	Weir Sta Lft (ft)	0.00
E.G. OC (ft)	972.72	Weir Sta Rgt (ft)	1010.96
Culvert Control	Outlet	Weir Submerg	1.00
Culv WS Inlet (ft)	939.05	Weir Max Depth (ft)	26.72
Culv WS Outlet (ft)	938.89	Weir Avg Depth (ft)	26.72
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	27008.20
Culv Crt Depth (ft)	0.72	Min El Weir Flow (ft)	946.01

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                        Delaware County, Iowa

                   Hydrograph Peak/Peak Time Table

 Sub-Area       Peak Flow and Peak Time (hr) by Rainfall Return Period
 or Reach        2-Yr      5-Yr      10-Yr     25-Yr     50-Yr    100-Yr      1-Yr
Identifier      (cfs)     (cfs)     (cfs)     (cfs)     (cfs)     (cfs)     (cfs)
            (hr)      (hr)      (hr)      (hr)      (hr)      (hr)      (hr)
---------------------------------------------------------------------------------
SUBAREAS
TributaryA    204.43    338.52    481.57    719.07    935.03   1180.34    140.49
           14.61     14.37     14.37     14.29     14.48     14.44     14.67


REACHES

OUTLET        204.43    338.52    481.57    719.07    935.03   1180.34    140.49
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Figure 14: Tributary A Hydrograph Peak

vrdavs

Waterway Redevelopment
Initial Hydrographs
Delaware County, Iowa

Hydrograph Peak/Peak Time Table

Sub-Area or Reach Identifier	Peak Flow and Peak Time (hr) by Rainfall Return Period 2-Yr (cfs) (hr)	5-Yr (cfs) (hr)	10-Yr (cfs) (hr)	25-Yr (cfs) (hr)	50-Yr (cfs) (hr)	100-Yr (cfs) (hr)	1-Yr (cfs) (hr)
SUBAREAS							
Tributary2	116.62	185.58	257.37	373.64	479.02	595.34	82.53
	13.46	13.43	13.31	13.39	13.29	13.30	13.49
REACHES							
OUTLET	116.62	185.58	257.37	373.64	479.02	595.34	82.53

Figure 15: Tributary 2 Hydrograph Peak

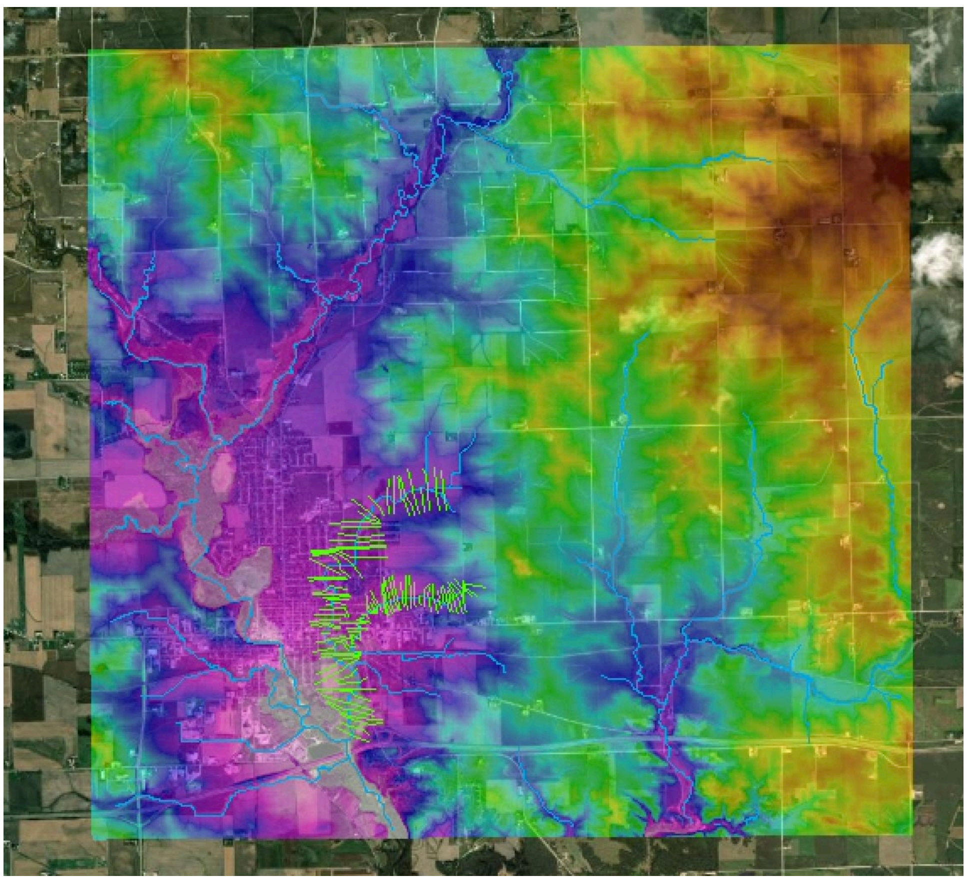


Figure 16: Design location modeled in ArcMap

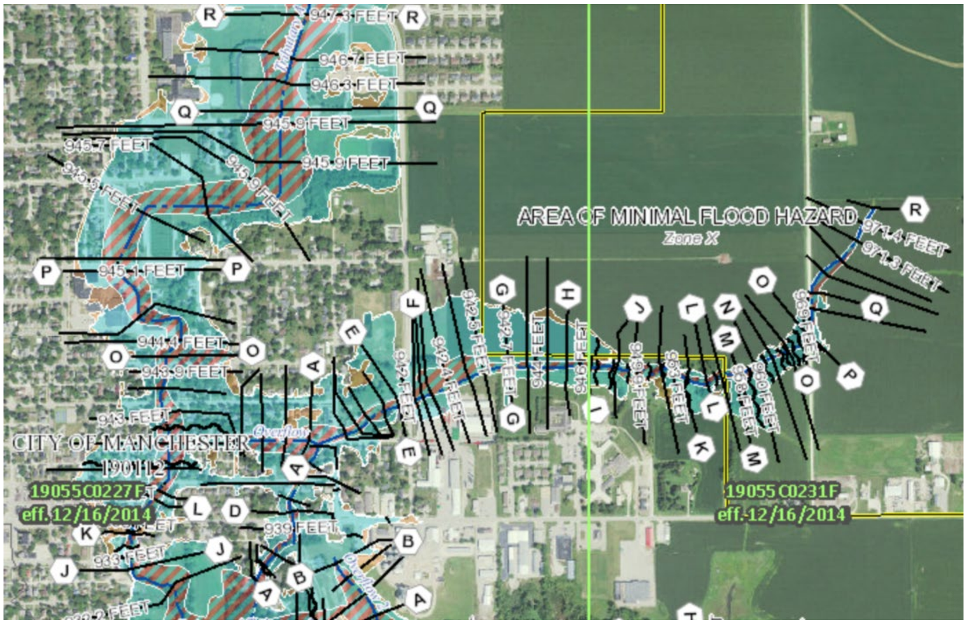


Figure 17: FEMA's National Flood Hazard Layer

Table 19: Culvert Data from Fehr Graham

Tributary	Location	Type/size	X-section area (sq ft)	Inlet elev. (ft)	Outlet elev. (ft)	Elev. change (ft)
2	Stiles St	54" RCP	15.9	934.55	934.39	0.16
2	Butler St	Twin 42" RCP	19.2	934.14	933.73	0.41
2	Fayette St	RCB 10'x 4'	40	932.45	932.19	0.26
2	E Main	RCB 6' x 5'	30	930.72	929.86	0.86
2	Woodland Dr	RCB 5' x 5'	25	927.41	926.67	0.74
A	Acers St	3 – 73" by 45" arch p	58.9	943.2	942.3	0.9
A	Harris St	Twin 36" RCP	14.1	943.02	942.7	0.32
A	Prospect St	RCB 10' x 5'	50	938	938	0
A	Union St	RCB 7' x 5.5'	38.5	936	934	2
A	Howard to Fayette	RCB 8' x 8'	64	933.5	928	5.5
A	Alley to Main St	PCC box 8' x 7'	56	927.4	926.5	0.9
A	Main St	stone box 8' x 7'	56	926.5	925.5	1

Elev. change (ft)	Length (ft)	slope	Overtop elev. (ft) (estim.)	Max. flow (cfs?)	Head above culvert (ft)
0.16	84	0.19%	941.7	155	2.5
0.41	155	0.26%	939	140	1.25
0.26	52	0.50%	939	400	2
0.86	104	0.83%	938.5	320	2.5
0.74	77	0.96%	935	240	2.5
0.9	82	1.10%	947.4		
0.32	21	1.52%	944		
0	62	0.00%	941.5		
2	197	1.02%	940.5		
5.5	880	0.63%	940		
0.9	125	0.72%	936		
1	103	0.97%	936		

Figure 18: Green Roof Delineation

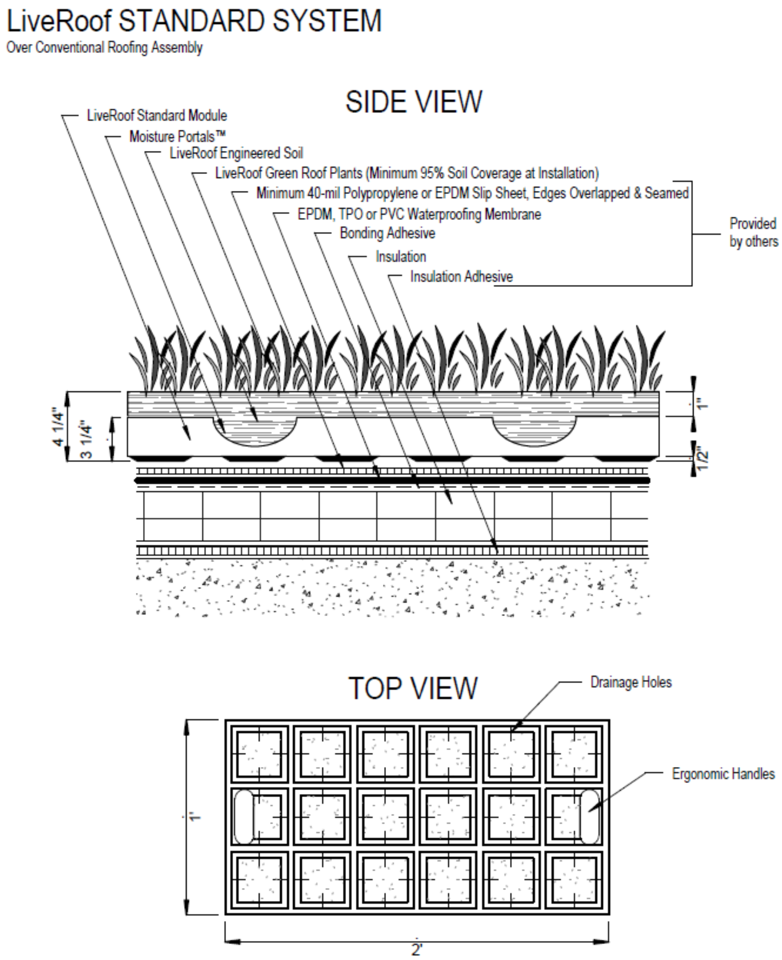


Figure 19: LiveRoof Standard Design cross-sections

Appendix B—Design Calculations

$$T_c = \frac{1}{0.6}\left(\frac{l^{0.8}(S+1)^{0.7}}{1900\,Y^{0.5}}\right) = \frac{1}{0.6}\left(\frac{14820.91^{0.8}(3.\bar{8}+1)^{0.7}}{1900\,(2.32)^{0.5}}\right) = 3.798485$$

$$S = 1000/CN - 10 = 1000/72 - 10 = 3.\bar{8}$$

WHERE:

T_c: TIME OF CONCENTRATION, HR

l: HYDRAULIC LENGTH OF WATERSHED, FT

CN: NRCS CURVE NUMBER

Y: AVERAGE WATERSHED LAND SLOPE, %

Figure 20: Example calculation, time of concentration, NRCS lag method, Tributary A

$$R_V = 0.682 - 1.43\alpha + 1.64\alpha^2 - 0.805\alpha^3 = 0.682 - 1.43(0.5) + 1.64(0.5)^2 - 0.805(0.5)^3 = 0.28$$

$$S = 1000/CN - 10 = 1000/72 - 10 = 3.\bar{8}\text{ IN}$$

$$V_R = \frac{(P - 0.2S)^2}{P + 0.8S} = \frac{(7.48\text{ IN} - 0.2(3.\bar{8}\text{ IN}))^2}{7.48\text{ IN} - 0.8(3.\bar{8}\text{ IN})} = 4.24\text{ IN}$$

$$R_V = V_S / V_R, \quad V_S = 1.19\text{ IN} \quad \therefore \quad \forall_S = V_S \cdot A = \frac{1.19\text{ IN} \cdot 1385.26\text{ ACRE}}{12\text{ IN/FT}} = 135.31\text{ ACRE-FT}$$

WHERE:

R_V: RATIO OF STORAGE VOLUME TO RUNOFF (IN/IN)

α: RATIO OF LOW TO HIGH FLOOD PEAK

S: POTENTIAL MAXIMUM RETENTION AFTER RUNOFF BEGINS (IN)

CN: NRCS CURVE NUMBER

V_R: RUNOFF VOLUME (IN)

V_S: STORAGE VOLUME (IN)

A: WATERSHED AREA (ACRES)

$\forall_S$: STORAGE VOLUME (ACRE-FT)

P: PRECIPITATION (IN)

Figure 21: Example calculation, required storage volume for 50% peak flow reduction of 100-year event, NRCS TR-55 method, Tributary A

$$Q = C_w \cdot L \cdot h^{3/2} = 3.5 \cdot 4\,\text{FT}\,(0.5\,\text{FT})^{3/2} = 4.95\ \text{FT}^3/\text{s}$$

WHERE:

- C_w: WEIR COEFFICIENT, ASSUMED 3.5
- L: WEIR LENGTH (FT)
- h: HEAD ABOVE WEIR CREST (FT)
- Q: DISCHARGE (FT^3/s)

Figure 22: Example calculation, weir discharge, Krogmann Site

$$Q = C \cdot A \cdot (2gh)^{1/2} = 0.5 \cdot 36\,\text{FT}^2 \cdot (2 \cdot 32.2\,\text{FT}/\text{s}^2 \cdot 2\,\text{FT})^{1/2} = 204.3\ \text{FT}^3/\text{s}$$

WHERE:

- C: ORIFICE COEFFICIENT, ASSUMED 0.5
- A: AREA, (FT^2)
- g: ACCELARATION OF GRAVITY, 32.2 FT/s^2
- h: HEAD ABOVE CENTER OF ORIFICE (FT)
- Q: DISCHARGE (FT^3/s)

Figure 23: Example calculation, orifice discharge, Krogmann Site

$$Q = C_w L h^{3/2} = (2.7)(24\,\text{ft})(2\,\text{ft})^{3/2} = 183\ \text{ft}^3/\text{s}$$

Where:

- C_w: weir coefficient, assumed 2.7 based on Table C3-S12-1 in ISWMM Chapter 3.
- L: weir length (perimeter of 6×6 ft drop inlet), ft
- h: head above weir crest, ft
- Q: discharge, cfs

Figure 24: Example calculation, weir discharge, Bunting Site

$$Q = C_d A (2gh)^{1/2} = (0.6)\left(\tfrac{\pi}{4}(1\,ft)^2\right)\left(2 \cdot 32.2\,ft/s^2 \cdot 0.5\,ft\right)^{1/2} = 2.67\,ft^3/s$$

Where:

- C_d: orifice coefficient, assumed 0.6 based on ISWMM Chapter 3 for square-edge uniform entrance condition.
- A: orifice area (1-ft pipe), ft^2
- g: acceleration of gravity, ft/s^2
- h: head above orifice centerline, ft
- Q: discharge, cfs

Figure 25: Example calculation, orifice discharge, Bunting Site

Table 20: Green Roof RSMeans Calculation

Qty	Line Num			T	Description	Unit	Extended Total	Extended Total O&P
78564.82	0733631				Green roof systems, fluid applied rubber membrane, 215 mil thick, reinforced, not including in	S.F.	$355,898.63	$559,381.52
78564.82	0733631				Green roof systems, moisture retention barrier and reservoir, not including insulation	S.F.	$263,192.15	$318,187.52
78564.82	0733631				Green roof systems, installation sedum mat system (no soil required), per SF, 4000 SF minimu	S.F.	$610,448.65	$681,156.99
78564.82	0722161				Roof Deck Insulation, extruded polystyrene, 4" thick, R20, 25 PSI compressive strength	S.F.	$219,195.85	$254,550.02
							$1,448,735.28	$1,813,276.05

Table 21: Krogmann Basin RSMeans Calculation

Qty	Line Nu			T	Description	Unit	Extended Total	Extended Total O&P
96289.63	31231				Excavating, bulk, dozer, open site, bank measure, common earth, 700 H.P. dozer, 300' haul	B.C.Y.	$473,744.98	$535,370.34
737.00	03305				Structural concrete, in place, equipment pad (3000 psi), 6' x 6' x 8", includes forms, reinforcing steel, concr	Ea.	$219,368.05	$288,034.34
77.78	31371				Rip-rap and rock lining, random, broken stone, 3/8 to 1/4 C.Y. pieces, machine placed for slope protection,	S.Y.	$7,144.09	$8,656.91
5082.24	31232				Backfill, structural, common earth, 300 H.P. dozer, 300' haul	L.C.Y.	$7,115.14	$8,385.70
613.50	03305				Structural concrete, in place, elevated slab (4000 psi), 6" slab, includes finishing, excl forms, reinforcing	S.F.	$1,883.45	$2,276.09
							$709,255.71	$842,723.38

Table 22: Bunting Basin RSMeans Calculation

Qty	Line N			T	Description	Unit	Extended Total	Extended Total O&P
15201.65	3123				Excavating, bulk, dozer, open site, bank measure, common earth, 700 H.P. dozer, 300' haul	B.C.Y.	$74,792.12	$84,521.17
270.00	3341				Public Storm Utility Drainage Piping, reinforced concrete pipe (RCP) with gaskets, 36" diameter, 8' lengths, class 3, excl	L.F.	$28,593.00	$34,681.50
1168.78	3123				Backfill, structural, common earth, 300 H.P. dozer, 300' haul	L.C.Y.	$1,636.29	$1,928.49
14.22	3137				Rip-rap and rock lining, random, broken stone, 3/8 to 1/4 C.Y. pieces, machine placed for slope protection, grouted	S.Y.	$1,434.09	$1,739.11
133.00	0330				Structural concrete, in place, elevated slab (4000 psi), 6" slab, includes finishing, excl forms, reinforcing	S.F.	$408.31	$493.43
							$106,863.81	$123,363.70

Table 23: Hutchison Basin RSMeans Calculation

Qty	Line Nu			T	Description	Unit	Extended Total	Extended Total O&P
14551.10	312316				Excavating, bulk, dozer, open site, bank measure, common earth, 700 H.P. dozer, 300' haul	B.C.Y.	$75,229.19	$85,705.98
2489.11	312323				Backfill, structural, common earth, 300 H.P. dozer, 300' haul	L.C.Y.	$3,883.01	$4,654.64
16.67	313713				Rip-rap and rock lining, random, broken stone, 3/8 to 1/4 C.Y. pieces, machine placed for slope protection, grouted	S.Y.	$1,681.17	$2,038.74
433.50	033053				Structural concrete, in place, elevated slab (4000 psi), 6" slab, includes finishing, excl forms, reinforcing	S.F.	$1,330.85	$1,608.29
							$82,124.22	$94,007.65

Appendix C—Bibliography

Federal Emergency Management Agency. (2020). *FEMA's national flood hazard layer (NFHL)*. FEMA's National Flood Hazard Layer (NFHL) - ArcGIS. Retrieved April 9, 2021, from https://hazards-fema.maps.arcgis.com/apps/webappviewer/index.html?id=8b0adb51996444d4879338b5529aa9cd&extent=-90.46477205322262,42.24326980975105,-90.38168794677739,42.27503191553417

Gordian. (2011). *RSMeans Online*. RSMeans Online. Retrieved May 7, 2021, from https://www.rsmeansonline.com/ManageEstimate/

Iowa Department of Agriculture and Land Stewardship-Division of Soil Conservation (IDALS-DSC). (2008). *Iowa Rain Garden Design and Installation Manual*. Iowa DNR. https://www.iowadnr.gov/portals/idnr/uploads/water/watershed/files/raingardens.pdf

Iowa Department of Natural Resources. (1990). *Design criteria and guidelines for Iowa dams* (Technical Bulletin No. 16). https://www.iowadnr.gov/portals/idnr/uploads/water/dams_design.pdf

Iowa Department of Natural Resources. (2009, October 28). *Iowa stormwater management manual*. iowadnr.gov. Retrieved April 9, 2021, from https://www.iowadnr.gov/Environmental-Protection/Water-Quality/NPDES-Storm-Water/Storm-Water-Manual

LiveRoof Global, LLC. (2020, November 10). *Detail drawings*. LiveRoof. Retrieved May 7, 2021, from https://liveroof.com/technical/detail-drawings/

Schneider Geospatial. (2021). *Beacon*. Beacon. Retrieved April 9, 2021, from https://beacon.schneidercorp.com/Application.aspx?AppID=72&LayerID=474&PageTypeID=1&PageID=924

State of Iowa. (2020). *Two-foot contours county downloads*. Iowa Geospatial Data. Retrieved April 9, 2021, from https://geodata.iowa.gov/pages/two-foot-contours-county-downloads

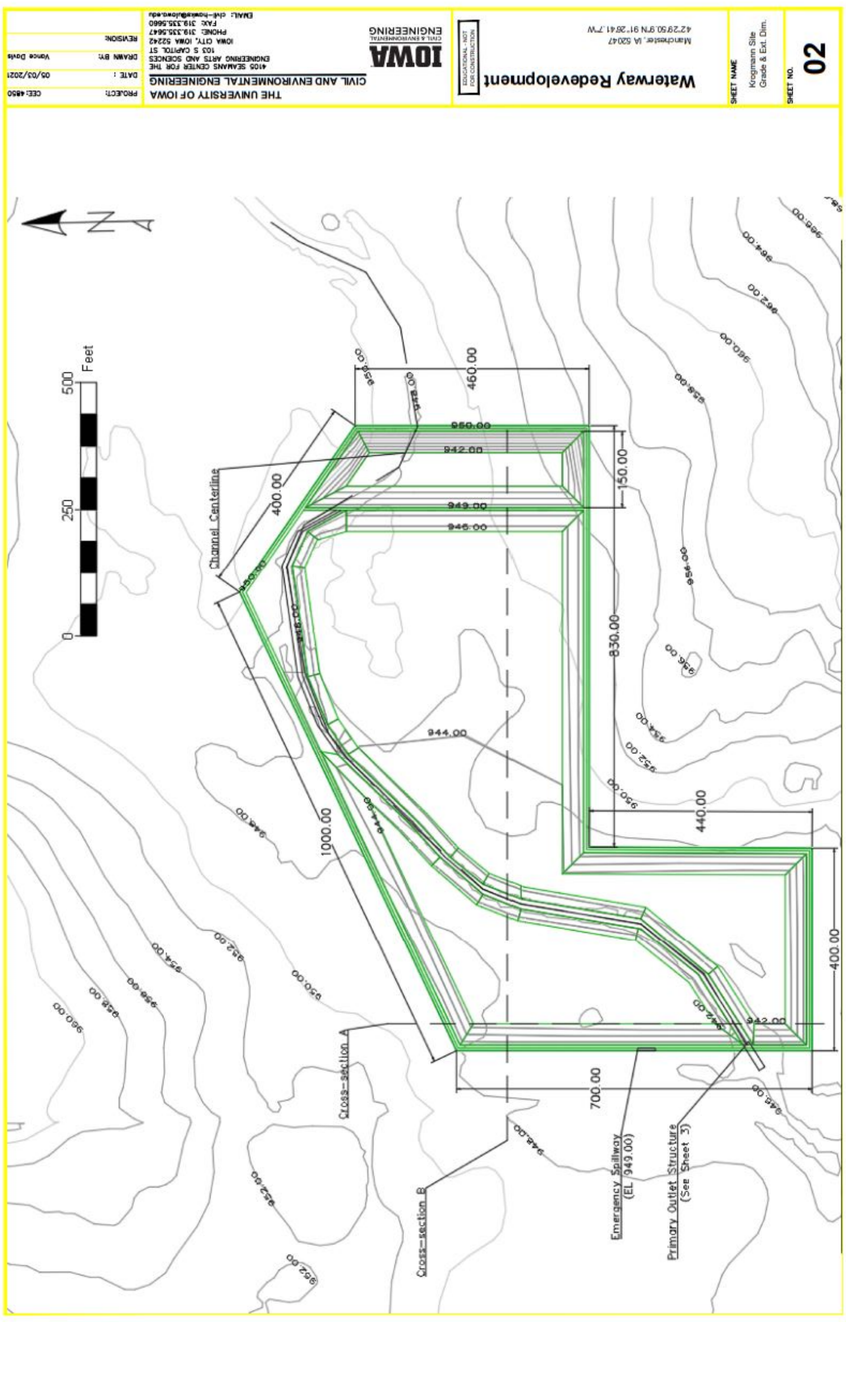
State of Iowa. (2020, December 2). *Three-meter digital elevation model of Iowa*. Iowa Geospatial Data. Retrieved April 9, 2021, from https://geodata.iowa.gov/datasets/iowadnr::three-meter-digital-elevation-model-of-iowa

State of Iowa. (2020, December 17). *Stream centerlines of Iowa*. Iowa Geospatial Data. Retrieved April 9, 2021, from https://geodata.iowa.gov/datasets/iowadnr::stream-centerlines-of-iowa

United States Geological Survey. (2021). *USGS StreamStats*. StreamStats. Retrieved April 9, 2021, from https://streamstats.usgs.gov/ss/

United States Geological Survey. (2021). *National geologic map database*. USGS National Geologic Map Database. Retrieved April 9, 2021, from https://ngmdb.usgs.gov/topoview/viewer/#15/42.4899/-91.4502

Appendix D—Design Drawings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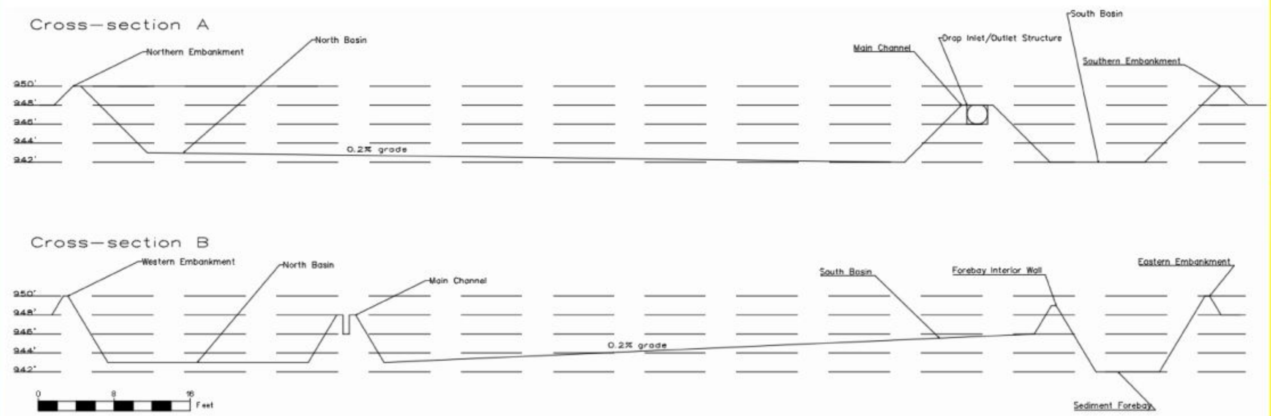
IOWA
Waterway Redevelopment
Krogmann Site Grade & Ext. Dim.
SHEET NO.
02
Feet
0
250
500
Channel Centerline
460.00
150.00
830.00
440.00
400.00
700.00
1000.00
400.00
950.00
942.00
949.00
946.00
944.00
Cross-section A
Cross-section B
Emergency Spillway (EL 949.00)
Primary Outlet Structure (See Sheet 3)

Note:

1. Horizontal dimensions are reduced by a factor of 6 for Cross-section A, and by a factor of 10 for Cross-section B.
2. Lines show proposed grading of basins and embankments unless otherwise specified.
3. Maximum embankment slopes are 6:1 H:V.



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IOWA CIVIL & ENVIRONMENTAL ENGINEERING

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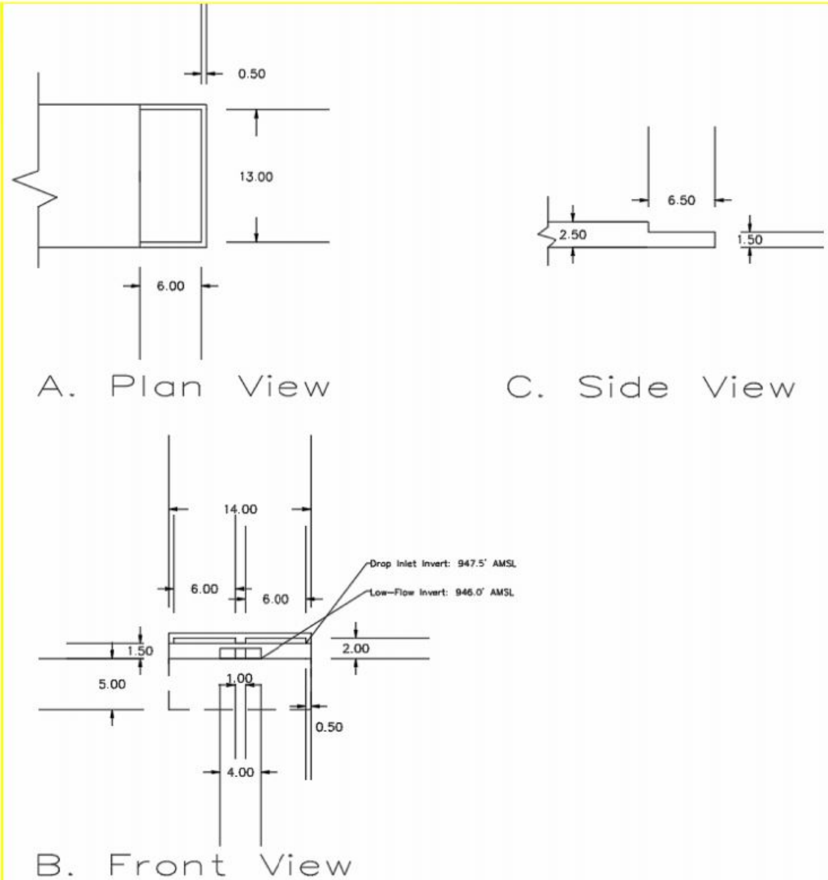
PROJECT: CEE:4850
DATE: 05/03/2021
DRAWN BY: Vance Davis
REVISION:

Waterway Redevelopment

Manchester, IA 52047
42°29'50.9"N 91°28'41.7"W

SHEET NAME: Krogmann Site Cross-sections

SHEET NO. **03**



Note:

1. 4'x1' orifice (H:V) is for average low flow.
2. 13'x6' drop inlet acts as a weir for larger storm events. The structure is composed of 6" thick concrete.Its structure is also partially underground for stability, as shown by the dashed lines in the front view.
3. 2 6'x2' box culverts at 0.4% grade transmit water downstream.
4. A 35'-wide emergency spillway activates at 949.0' AMSL.

PROJECT: CEE:4850
DATE : 05/03/2021
DRAWN BY: Vance Davis
REVISION:

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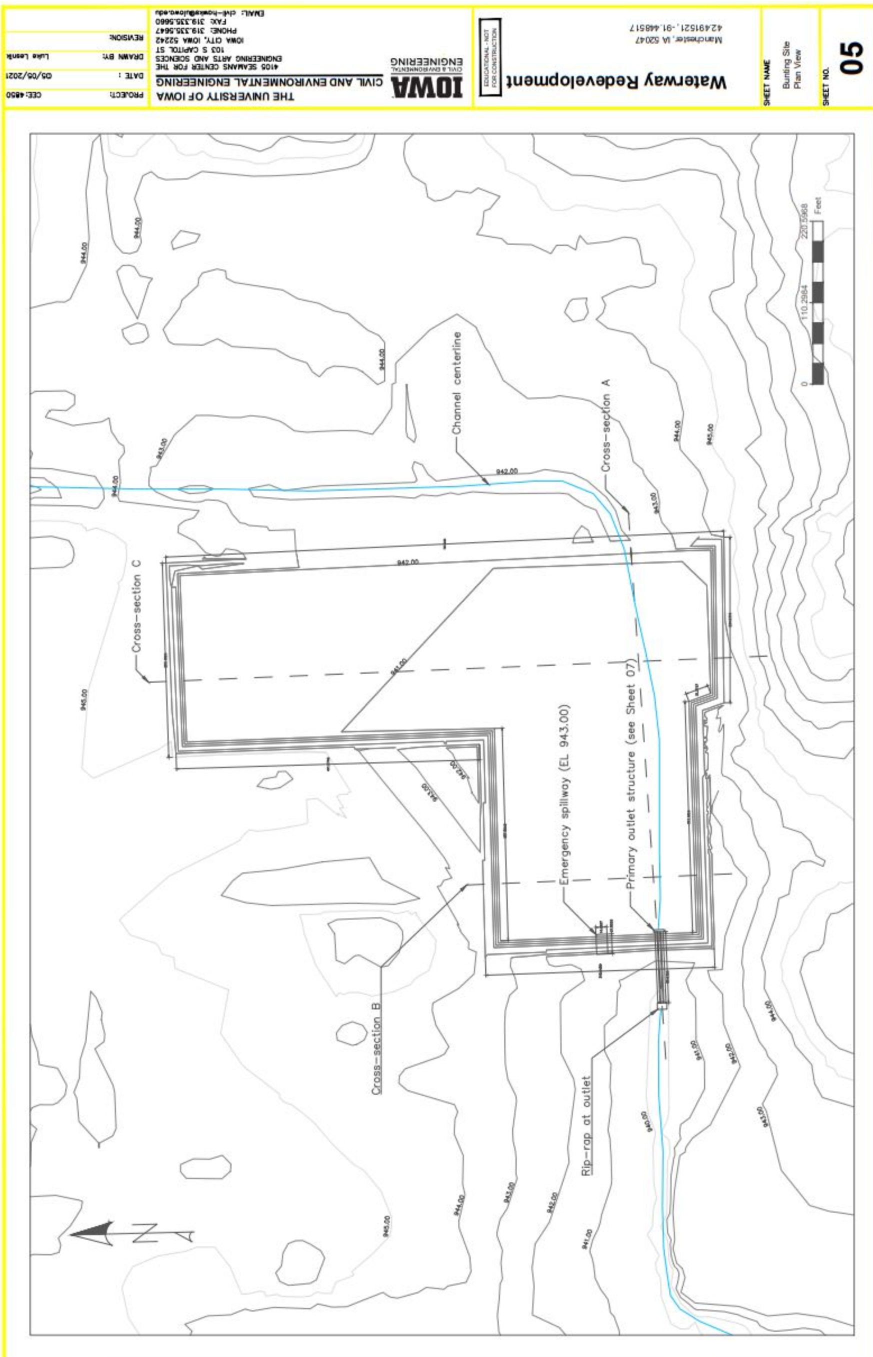
42°29'50.9"N 91°26'41.7"W

SHEET NAME
Krogmann Site Outlet Dimensions

SHEET NO.
04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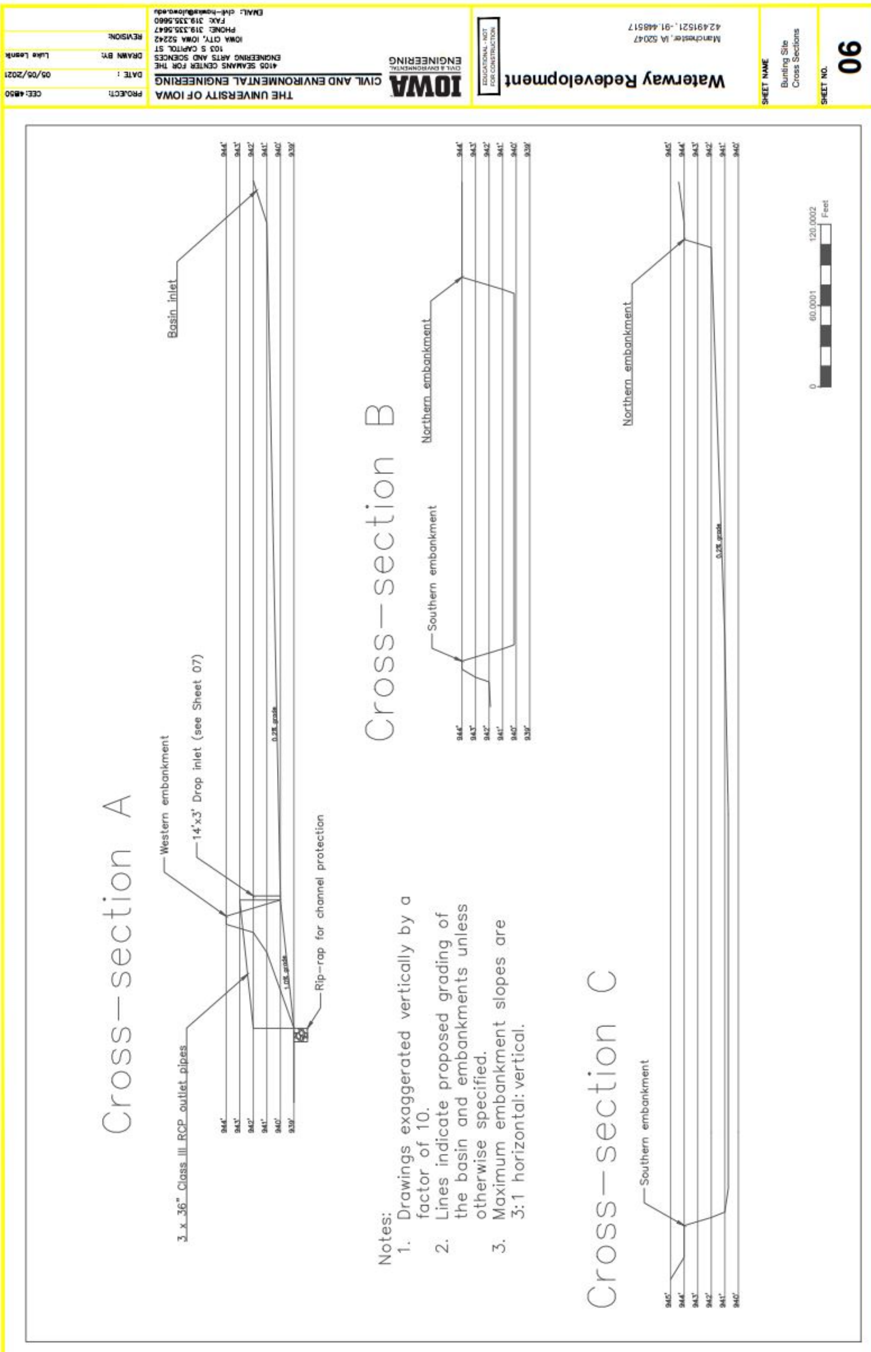
IOWA
Waterway Redevelopment
SHEET NAME
Bunting Site
Plan View
SHEET NO.
05
Channel centerline
Cross-section A
Cross-section B
Cross-section C
Emergency spillway (EL 943.00)
Primary outlet structure (see Sheet 07)
Rip-rap at outlet
Feet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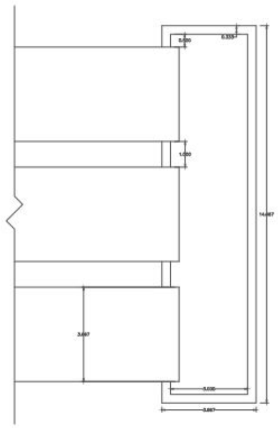
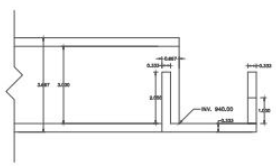
CIVIL AND ENVIRONMENTAL ENGINEERING
IOWA
Waterway Redevelopment
Manchester, IA 52047
SHEET NAME
Bunting Site Cross Sections
SHEET NO.
06
Cross-section A
3 x 36" Class III RCP outlet pipes
Western embankment
14'x3' Drop inlet (see Sheet 07)
Rip-rap for channel protection
Basin inlet
Cross-section B
Southern embankment
Northern embankment
Cross-section C
Southern embankment
Northern embankment
Notes:
1. Drawings exaggerated vertically by a factor of 10.
2. Lines indicate proposed grading of the basin and embankments unless otherwise specified.
3. Maximum embankment slopes are 3:1 horizontal: vertical.
0
60.0001
120.0002
Feet



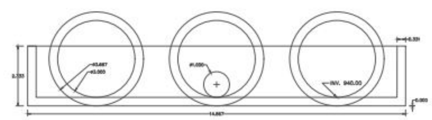
A. Plan View



B. Profile View

Notes:

1. Round 12” low flow orifice for average flow conditions.
2. 14’x3’ drop inlet operates as a weir for larger storm events. The structure is composed of 4’” thick concrete.
3. 3 x 36” Class III RCP outlet pipes at a 1.0% grade transmit water downstream.



C. Front View

PROJECT:	CEE: 4850
DATE :	05/05/2021
DRAWN BY:	Luke Lesnik
REVISION:	

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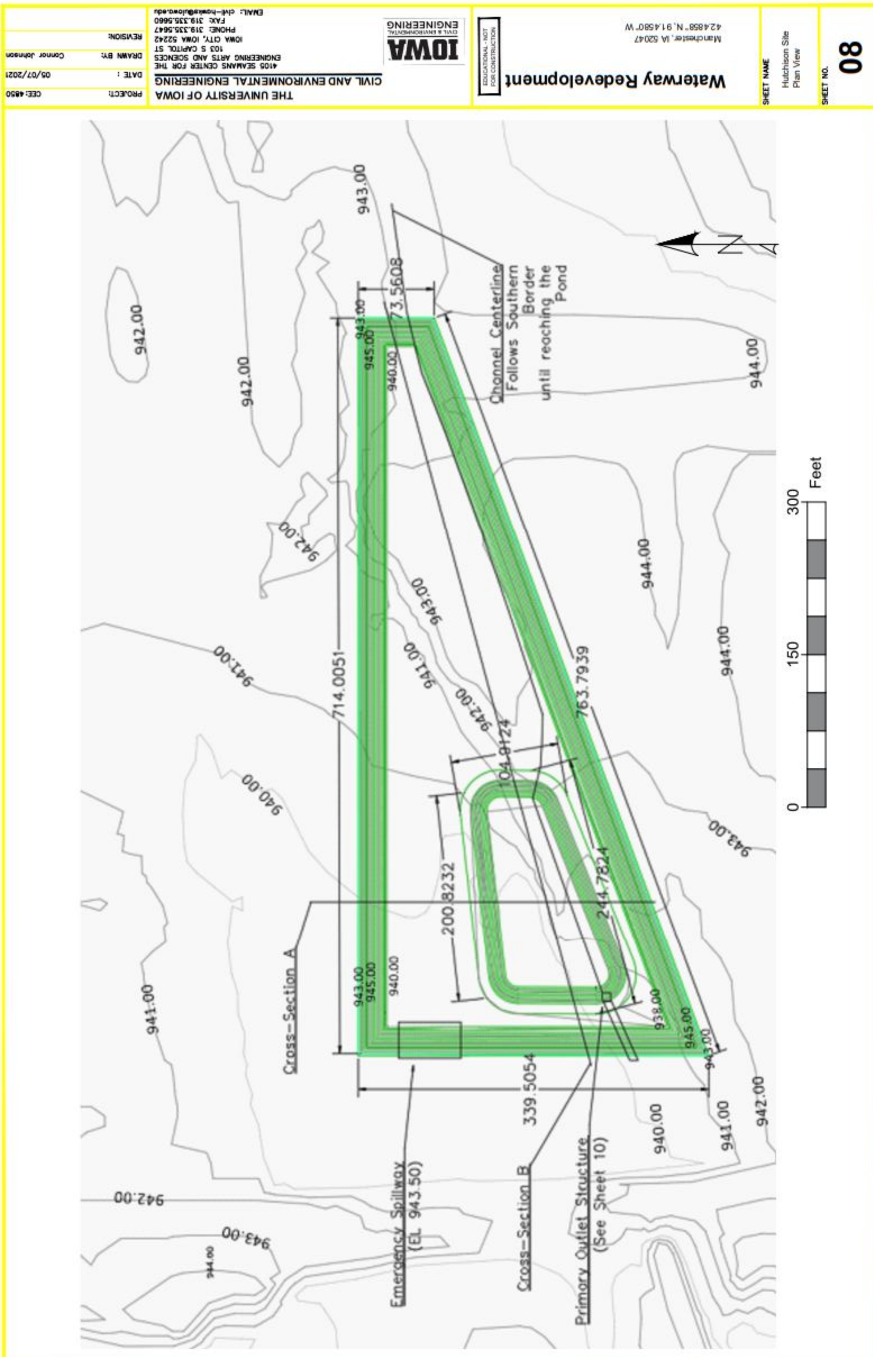
42.491521, -91.448517

SHEET NAME
Bunting Site Outlet Dimensions

SHEET NO.
07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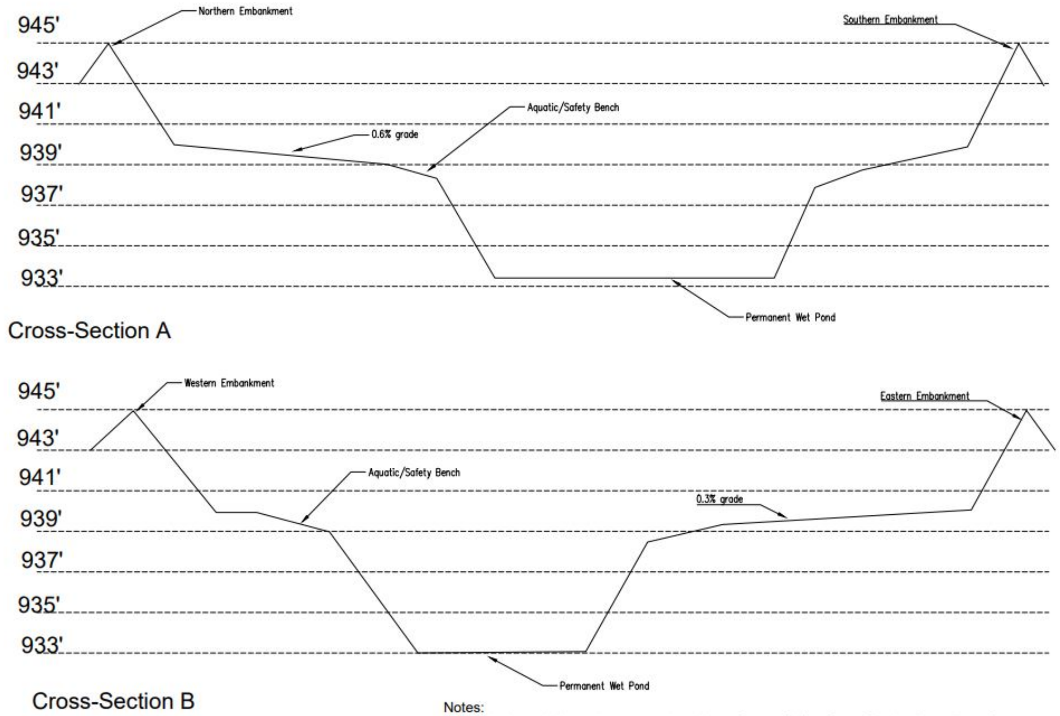
Waterway Redevelopment
Manchester, IA 52047
42.4858° N, 91.4580° W
SHEET NAME
Hutchison Site Plan View
SHEET NO.
08
Channel Centerline Follows Southern Border until reaching the Pond
73.5608
714.0051
763.7939
104.9124
200.8232
244.7824
339.5054
Cross-Section A
Cross-Section B
Emergency Spillway (EL 943.50)
Primary Outlet Structure (See Sheet 10)
0
150
300
Feet
N
943.00
945.00
940.00
942.00
941.00
944.00
938.00



Notes:

1: Horizontal dimensions are reduced by a factor of 3 for Cross-Section A and by a factor of 7 for Cross-Section B.

2: Embankment slopes are at a 4:1 (H:V) ratio - this includes the embankments of the pond.

3: The Aquatic/Safety Bench has a 20:1 (H:V) slope

4: The grade specified for each cross-section is the overall slope from the base of the outer embankments to the base of the other outer embankment.

PROJECT: CEE:4850
DATE: 05/07/2021
DRAWN BY: Connor Johnson
REVISION:

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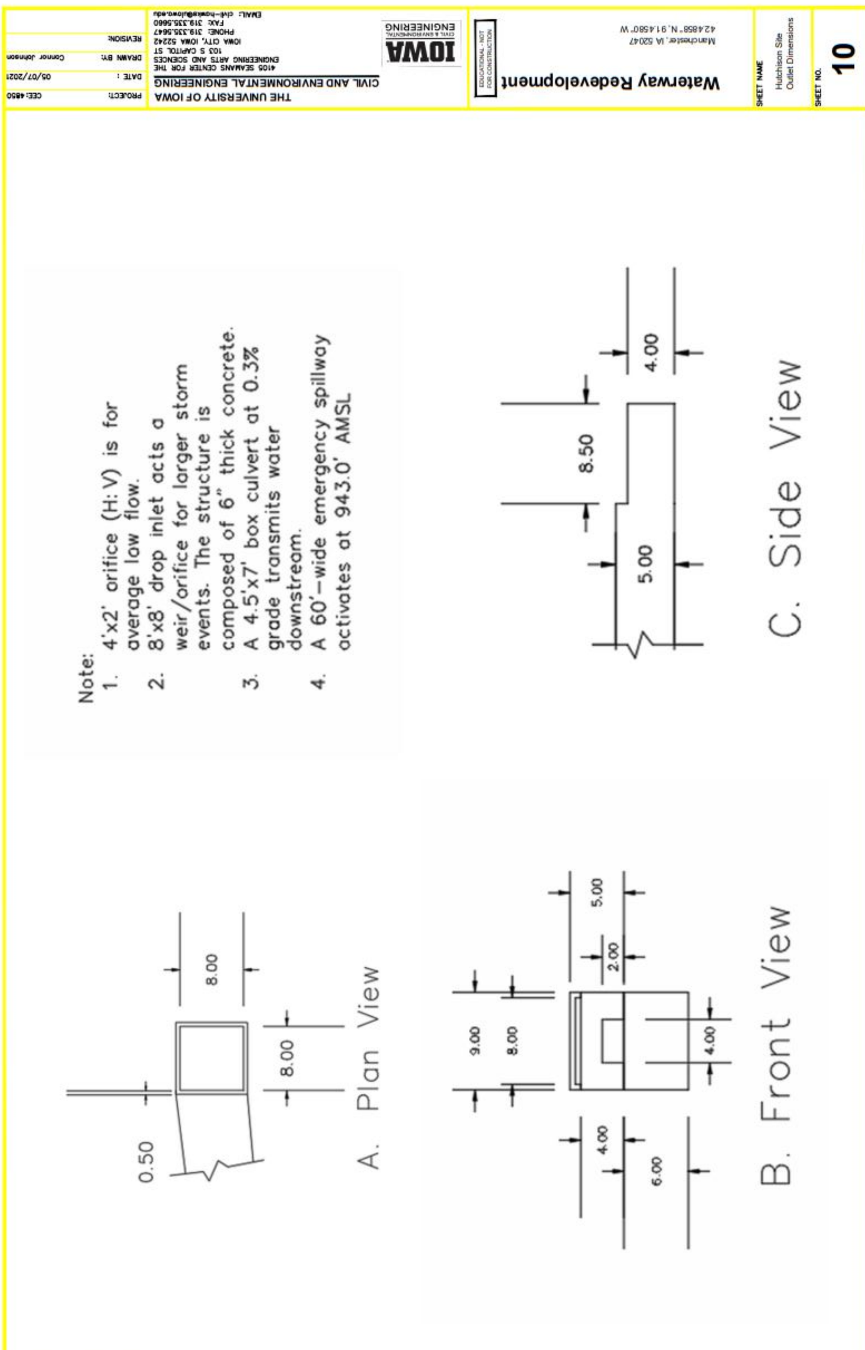
42.4858° N, 91.4580° W

SHEET NAME: Hutchison Site Cross Sections

SHEET NO. **09**


THE UNIVERSITY OF IOWA
CIVIL AND ENVIRONMENTAL ENGINEERING
IOWA
PROJECT: CEE:4850
DATE: 05/07/2021
DRAWN BY: Connor Johnson
REVISION:
Waterway Redevelopment
Manchester, IA 52047
42.4858°N, 91.4580°W
SHEET NAME
Hutchison Site Outlet Dimensions
SHEET NO.
10
Note:
1. 4'x2' orifice (H:V) is for average low flow.
2. 8'x8' drop inlet acts a weir/orifice for larger storm events. The structure is composed of 6" thick concrete.
3. A 4.5'x7' box culvert at 0.3% grade transmits water downstream.
4. A 60'-wide emergency spillway activates at 943.0' AMSL
0.50
8.00
8.00
A. Plan View
9.00
8.00
4.00
6.00
2.00
5.00
4.00
B. Front View
8.50
5.00
4.00
C. Side View