5-2017

Design of Logan City's Storm Water Conveyance System

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DESIGN OF LOGAN CITY'S STORM WATER CONVEYANCE SYSTEM

by

Megan Gordon

Thesis submitted in partial fulfillment of the requirements for the degree

of

HONORS IN UNIVERSITY STUDIES AND DEPARTMENTAL HONORS IN CIVIL ENGINEERING

in

Civil Engineering
in the Department of Civil and Environmental Engineering

Approved:

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UTAH STATE UNIVERSITY
Logan, UT
Spring 2017

Final Report for the Design of Logan City's Storm Water Conveyance System

Prepared for
Civil and Environmental Engineering
Senior Design Sequence, Semester 3
CEE 4880, Dr. Peralta
Utah State University

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26 April 2017

Team Member Roles

Table 1. Team Member Roles for 10th West Engineers

Function or specialty on team	Last name	First name
External PE Liaison	Beck	Kade
Faculty Liaison	Weller	Ryan
Financial Planner	Beck	Kade
Geotechnical Engineer	Weller	Ryan
Hydraulic Engineer	Weller	Ryan
Hydrologist	Beck	Kade
Records Keeper	Gordon	Megan
Structural Engineer	Gordon	Megan
Team Leader	Beck	Kade
Technical Writer	Gordon	Megan

Executive Summary

This report summarizes 10th West Engineers' (10WE) storm water conveyance design for Logan City. The implementation of the design mitigates flood risk due to storm water discharge, helps improve local water quality, and uses infrastructure that would otherwise be abandoned. The system collects storm water discharged along 1000 West and transports the water to the holding pond located at approximately 2400 West 2200 North, Logan, Utah (see Figure 1).

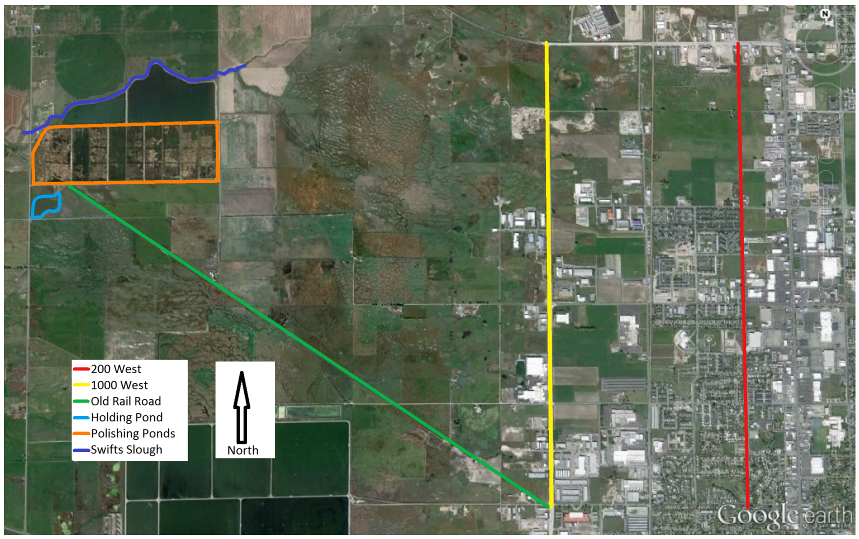

Figure 1. Aerial Photo of the Area of Interest Current Conditions

Logan City is located in northern Utah's Cache County. As development and redevelopment occur, storm water runoff quantities will decrease due to new regulations. However, Logan City's storm water system does not extend beyond 1000 West, which causes localized flooding.

This project had three phases. First, 10WE collected data from both Logan City and through field investigations. Second, 10WE designed an efficient system to convey water from existing discharge locations to the holding pond. Third, 10WE completed this final report to submit to Logan City on the proposed storm water conveyance system.

10WE followed several design methods outlined in government manuals. 10WE's post-construction recommendations for Logan City are: 1) mow banks of each channel annually; 2) conduct a system inspection yearly and after a storm that exceeds the 20-year event to ensure that all channels and diversion structures are operating as designed.

10WE collaborated with the client, Logan City, to ensure the design satisfied all the client's goals. The client had three goals: design a gravity-fed system, minimize effect on wetlands, and produce an economical design. 10WE collaborated with Cutler Engineering, who designed a treatment process for the storm water, and Westside Drainage Solutions, who designed a drainage system for a farm.

Acknowledgements

I would like to thank my team members, Kade Beck and Ryan Weller, for their contribution to this project. I could not have asked for a better team. I would also like to thank Lance Houser, our external Professional Engineer, for his excellent mentorship and for the all of the time he took to assist us with this project. Additionally, I would like to thank Dr. Michael Johnson, our faculty advisor, for his time and assistance with this project. Finally, I would like to thank Dr. Richard Peralta, our professor, for his time teaching us how to become engineers, and grading our reports.

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Problem Statement

Logan City is located in northern Utah's Cache County. The average annual rainfall for Cache Valley is between 15 and 20 inches (PRISM 2016). Several times a year, the incomplete storm water system causes flooding, which risks industrial and agricultural lands. The current system collects storm water between 200 West and 1000 West, and discharges the water directly along 1000 West.

Cutler Reservoir, Swift Slough, and the Lower Bear River in Cache Valley do not comply with water quality regulations. The Clean Water Act of 1972 mandates that all municipal separate storm sewer systems (MS4) comply with EPA regulations, expressed as Total Maximum Daily Loads (TMDLs). Logan City's untreated storm water might contribute to the pollution in these water bodies. The pollution threatens surface water, groundwater, and wildlife in the area.

Logan City plans to implement a new wastewater treatment process. However, the new treatment process is not designed to use the existing polishing ponds. Consequently, Logan City hopes to use these polishing ponds to treat storm water.

The implementation of this design improves storm water management. 10th West Engineers (10WE) had three goals. First, design a system to transport water from the discharge locations to the holding pond. Second, design a system that provides irrigation users access to water during a storm. Third, comply with the goals of the client: design a gravity-fed system, minimize effect on wetlands, and produce an economical design.

Project Description

10WE's objective was to design a storm water conveyance system for the client, Logan City. This design report details a system that collects storm water along 1000 West and transports the water to the holding pond (see Figure 2).

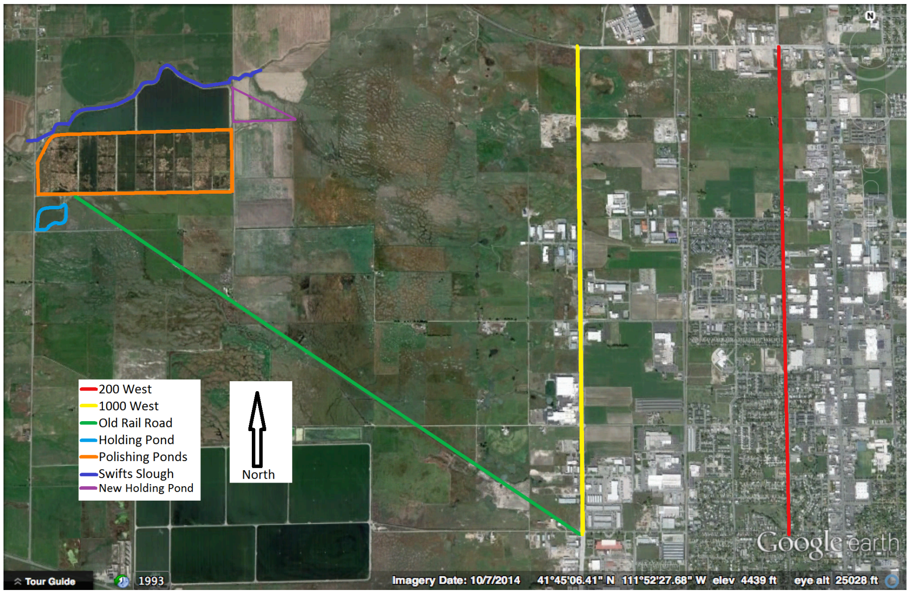

Figure 2. Aerial Photo of the Area of Interest New Holding Pond

The following project description is divided into four sections: tasks, inter-team cooperation, professional ethics, and design sequence.

Tasks

- Completed a field investigation between 1000 West and 2400 West
- Gathered pertinent data from Logan City, Cutler Engineering, and Westside Drainage Solutions
- Identified locations of surface water rights using ArcGIS
- Identified potential flow paths using TauDEM and ArcGIS
- Created design storm using Storm and Sanitary
- Designed and drafted channels and diversion structures using AutoCAD and Microsoft Office
- Selected optimal flow paths
- Completed the final design report using Microsoft Office

Inter-team Cooperation

Lance Houser, PE, Assistant City Engineer, and client representative, served as the External Professional Engineer (EPE) for three related design projects. 10WE designed a system to transport storm water to the holding pond. Cutler Engineering designed a system to treat this

storm water. Westside Drainage Solutions designed a drainage system for a farm located near 1000 West.

10WE, Cutler Engineering, and Westside Drainage Solutions worked together to obtain and process data. Westside Drainage Solutions conducted a Cone Penetration Test (CPT) to identify soil properties (see Appendix I). Due to budget constraints, 10WE did not conduct further CPT's in the area of interest to verify soil conditions. However, Westside Drainage Solutions did not provide a unit weight or friction angle for the soil. Therefore, under the direction of the EPE, 10WE assumed a unit weight and friction angle.

The team leaders held meetings to coordinate assignments and deadlines. Additionally, the teams shared meeting minutes via Google Drive to provide each team access to relevant information.

Professional Ethics

10WE was committed to using the highest level of professional ethics. Therefore, 10WE complied with the American Society of Civil Engineers (ASCE) Code of Ethics (see Special Summary Documentation).

10WE used industry standard design criteria under the direction of the EPE. 10WE used the Natural Resources Conservation Service (NRCS) manual *Urban Hydrology for Small Watersheds* to create the design storm. 10WE used local design standards for open channel design and the United States Bureau of Reclamation (USBR) manual *Design of Small Canal Structures* for the hydraulic structure design. 10WE followed the American Concrete Institute's (ACI) design standards for the design of the diversion structures.10WE complied with additional regulations as needed (see Special Summary Documentation).

10WE used professional conduct in their interactions with the client and mentors. 10WE developed and applied effective methods for overcoming challenges (see Special Summary Documentation). During the design sequence, 10WE met all deadlines they had control over and was punctual to all meetings. Additionally, 10WE communicated professionally within the team, with the external and faculty mentors, and with team leaders from Cutler Engineering and Westside Drainage Solutions. Minutes for meetings conducted since the Interim Report submission are included in Appendix II. Person-hour work reports are included in Appendix III.

Design Sequence

The design sequence had three phases: data collection, system design, and a final report. 10WE produced a final Gantt chart that displays the project timeline (see Figure 3). The design phases were divided into five sections: data collection, design storm, topography, design, and final report. Appendix IV contains the proposed, revised, and final Gantt charts.

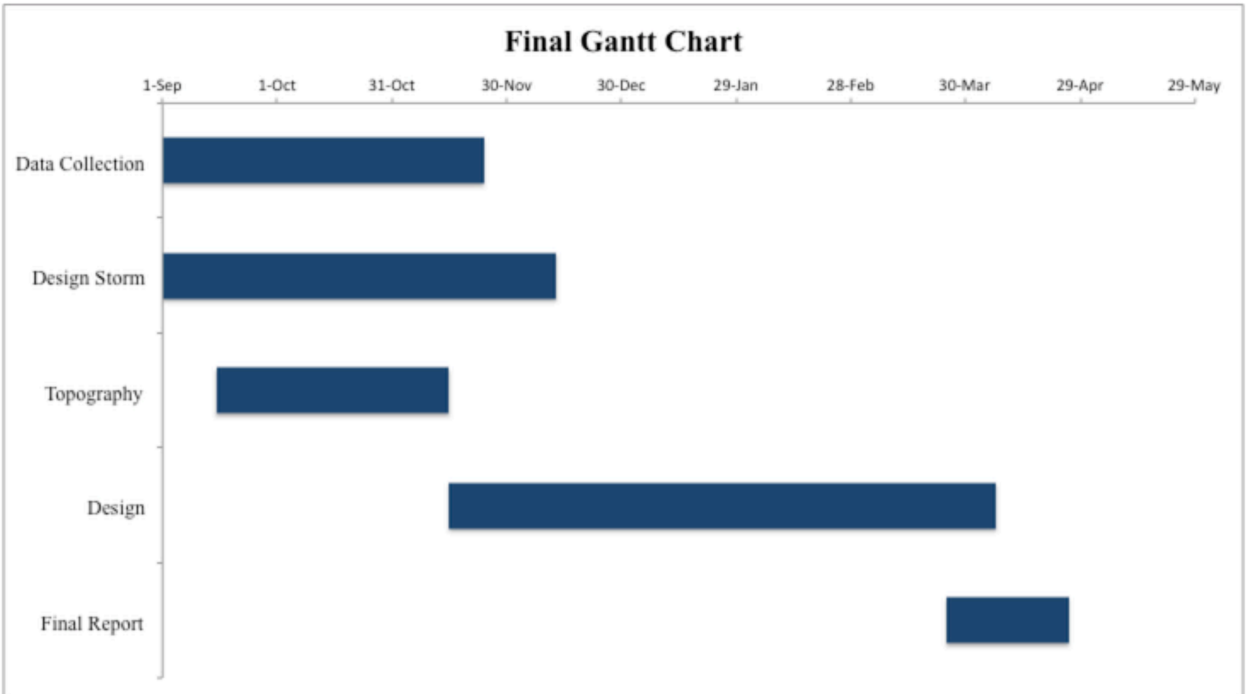

Figure 3. Final Gantt Chart

Data Collection. In May 2016, 10WE completed a field investigation from 1400 North to 2500 North and 200 West to 3200 West (area of interest) (see Figure 4). 10WE drove through the area of interest and identified potential flow paths. 10WE also observed the holding pond, polishing ponds, pump, and outflow from the polishing ponds. The field investigation illustrated the scale of the project and the current conditions in the area of interest.

This field investigation involved driving to, around, and through the area of interest. 10WE mitigated the risks from injury while traveling by wearing seatbelts and obeying all local driving regulations. Photographs from the field investigation are included in Appendix V.

The EPE and Logan City provided essential data for the completion of the design. Data collection began in May 2016. The design process commenced as soon as 10WE received the necessary data.

In addition, 10WE completed field measurements. These measurements established a base flow for various creeks in the area of interest. This process involved taking the water velocity and cross-sectional area measurements in the creeks (see Appendix VI). The creeks measured are lined with fine clay. 10WE carefully evaluated where to take measurements to ensure they did not become trapped in the clay. 10WE completed this investigation in late fall and all team members wore appropriate clothing to diminish the risk of illness.

Design Storm. Logan City's design storm was outdated due to the effect of land developments. Under the direction of the EPE, 10WE created a new design storm. The creation of the new design storm was not anticipated and delayed the project.

Using information from the NRCS, 10WE identified a hydrologic group for each soil type in the drainage basin. With topographical contours overlaid in ArcGIS, 10WE delineated sub basins and assigned a curve number to each sub basin. 10WE decided to create the design storm in Storm and Sanitary, an Autodesk application. The drainage area data is included in Appendix I. The hydrologic group and surface terrain of the sub basins determined the curve number. By determining the total sheet and pipe flow distance, 10WE calculated a time to concentration for each sub basin. The conveyance system design ensures containment of runoff for a 100-year storm. Using the 100-year storm minimizes the risk of flood damage to the area of interest.

The design was created on November 3, 2016, and approved by the EPE on December 13, 2016. The maximum flow of the 100-year storm is 430 cubic feet per second. Consequently, 10WE eliminated the do nothing alternative because of potential damage from the high flows.

Under the supervision of the EPE, 10WE conducted a groundwater analysis to evaluate whether or not on-site treatment was a viable alternative. 10WE used data from the NRCS to determine a representative hydraulic conductivity (k) in the area of interest. To determine elevation of the water table, 10WE researched average well depths in the area of interest using information from the Utah Division of Water Rights. Using this information, 10WE calculated a groundwater velocity of 0.0064 feet per hour (see Table 2 and Appendix VI).

Table 2. Groundwater Analysis

Hydraulic Conductivity k (in/hr)	0.06
Differential Head Δh (ft)	207.13
Length L (ft)	161.00
Darcy Velocity v (ft./hr.)	0.0064

Due to the low permeability of the soil, 10WE determined that on-site treatment of storm water would not be possible. Furthermore, 10WE concluded that groundwater in the area would not be significantly affected by the construction and operation of the storm water conveyance system.

Topography. To understand the topography of the area of interest, 10WE compiled aerial photographs in ArcGIS (see Figure 4A).

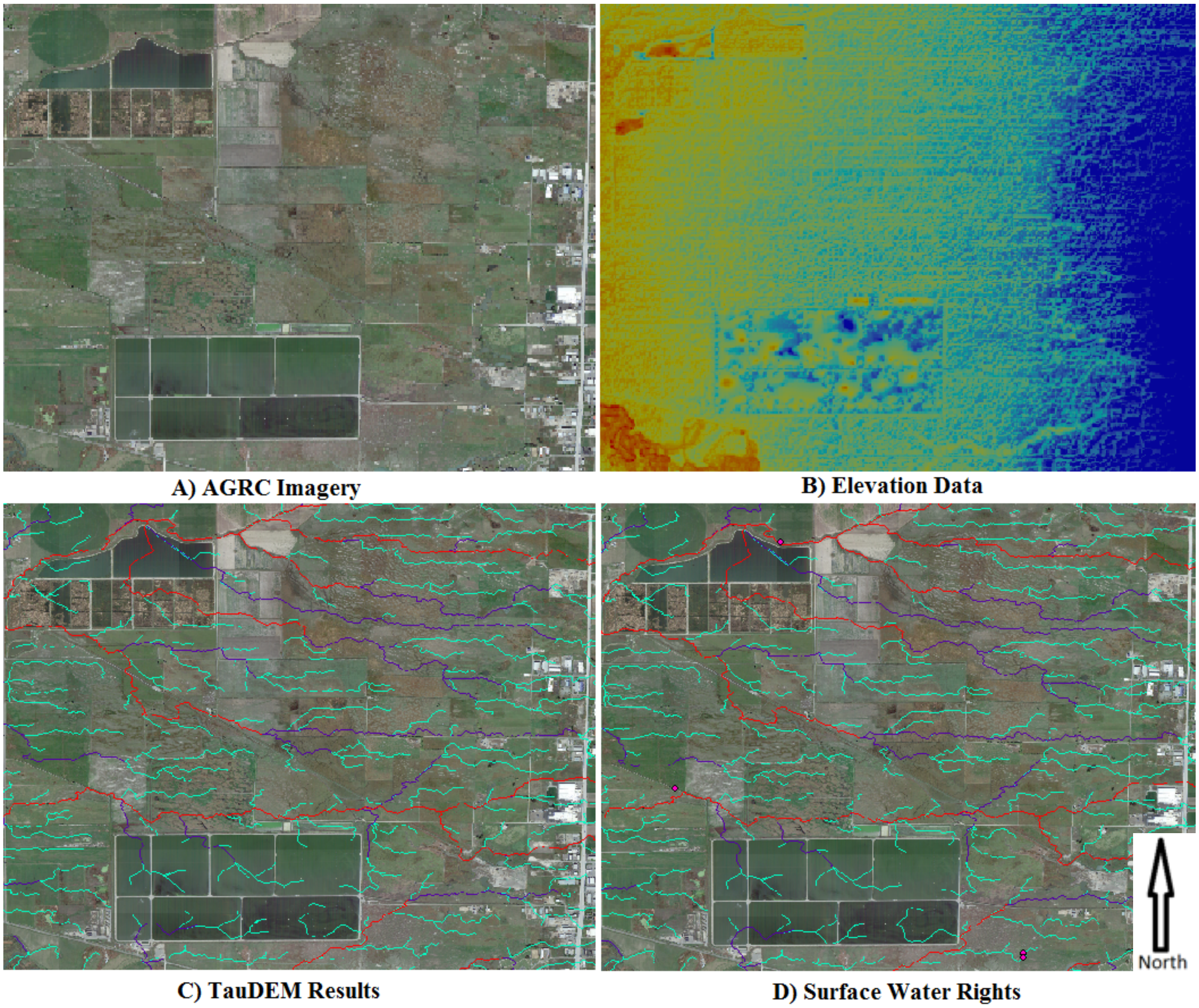

Figure 4. AGRC, Elevation, TauDEM, Surface Water Rights

10WE overlaid elevation data on the aerial photographs (see Figure 4B). Using this information, 10WE ran TauDEM over the area of interest. TauDEM analyzed the elevations in the area and displayed natural flow paths for the area (see Figure 4C). The natural flow paths helped 10WE consider the constraints associated with the design.

Canals in the area supply water to owners of water rights. Surface water rights are signified by pink dots in Figure 4D. This social constraint was addressed in the final design. 10WE ensured that all individuals have access to their water rights by designing diversion structures.

Diversion structure design was a health and safety constraint. Obtaining soil data where structures are built was essential for the safety of the structure (see Appendix I). As previously mentioned, 10WE used representative soil data for the design. 10WE ensured structural integrity by designing for the saturated soil conditions. Structural failure may cause flooding damages.

Wetlands in the area of interest were environmental and economic constraints. As defined by the EPA, wetlands improve water quality, provide wildlife habitat, and regulate surface water flow

(EPA 2016). For these reasons, the design avoided disturbing the wetlands to the extent possible. In addition, the Army Corps of Engineers requires three acres of wetlands be restored for every acre disturbed during construction. This was an economic constraint because the cost of replacing one acre of disturbed wetland is $180,000.

The design of a gravity-operated conveyance system was an economic and constructability constraint. Pumps in the design were outside Logan City's budget. Therefore, natural flow paths identified by TauDEM enabled 10WE to design a gravity-operated system. 10WE conducted a meeting with the faculty advisor (FA) and the EPE to discuss flow paths. Several potential paths were identified.

The existing pipe transporting water from the holding pond to the polishing ponds does not have the required capacity. Two alternative designs were replacing the existing 48-inch pipe with 60-inch pipe or moving the holding pond. These alternatives were economic constraints that required a cost benefit analysis (Appendix VI). 10WE determined that moving the holding pond is more economical than replacing the existing pipe (see Figure 2).

Design. 10WE designed channels and diversion structures for the storm water conveyance system. 10WE used *Design of Small Canal Structures* to design safe and effective structures. A sedimentology specialist may review the design to analyze long-term channel conditions. The channels and diversion structures were constrained by economic, health and safety, and constructability factors.

Economic constraints were a factor in this design. 10WE minimized the size, length, and quantity of hydraulic structures. As the channel length increases, more materials, time, and work are necessary to complete construction. These factors increased the cost of the project. As the size and quantity of diversion structures increased, construction costs also increased.

The health and safety of the public is an important factor to consider. All structures were designed to government standards and with adequate factors of safety. This prevents failure that could risk public health and safety.

Constructability was important to consider. Many constructability factors were related to economic factors. 10WE designed simple and economical channels and diversion structures. 10WE avoided harming wetlands to the extent possible during design. Additionally, saturated soil and slope instability may cause construction equipment to sink or overturn. 10WE considered saturated conditions to ensure the safety of construction workers.

The final channel alignment governed channel design. 10WE designed the channels to avoid wetlands and transport the water to the new holding pond. Mitigating disturbed wetlands is expensive. Therefore, 10WE decided to expand the existing canals to convey the water and avoid the wetlands. 10WE looked at maps of the area to determine what channels could be used to convey the water to the new holding pond location. With the assistance of the EPE, 10WE selected the final channel alignment.

The next step in channel design was to size the existing channels for the 100-year design storm. 10WE used the outflow hydrograph to determine the flow rates for each channel (Figure 5).

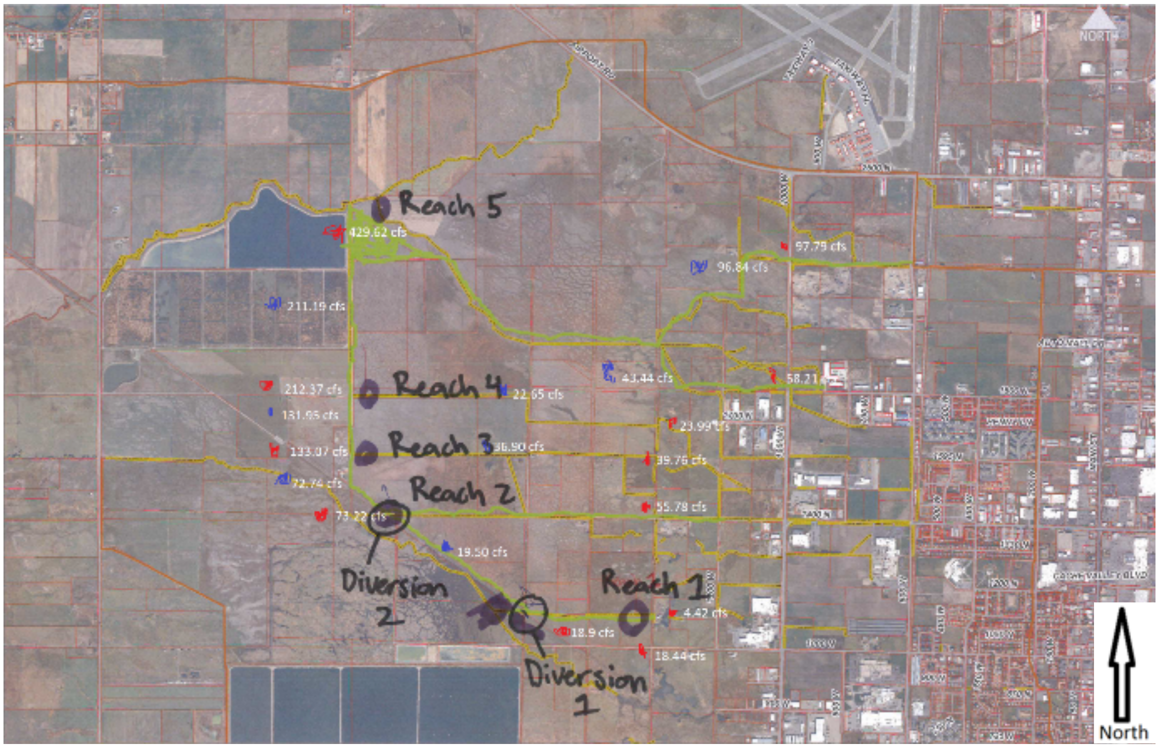

Figure 5. Channel Reaches

10WE used elevation and aerial photography in AutoCAD Civil 3D to plot the existing channels. 10WE created profile plots of the existing ground surface for each channel (Figure 6).

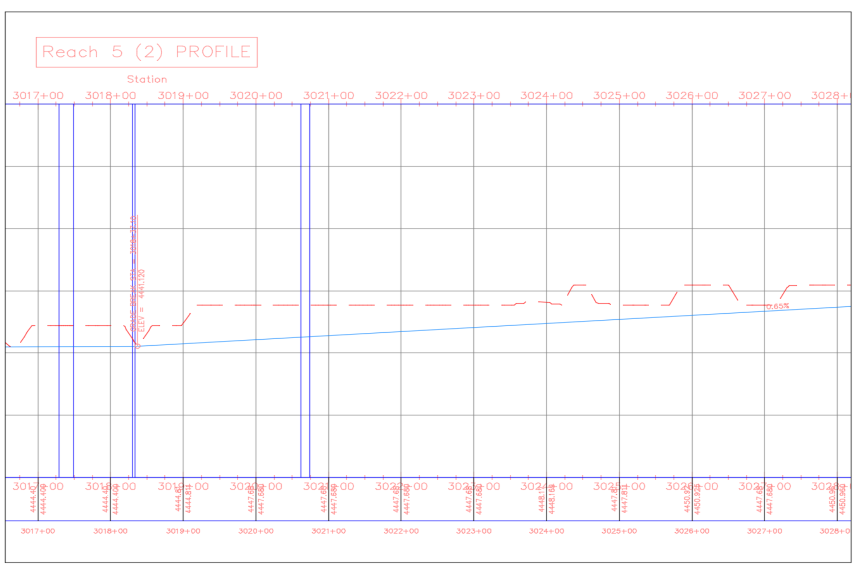

Figure 6. Profile Plot

Using the profile plots, 10WE determined the channel bed slopes. Each time the flow rate or channel bed slope changed, 10WE designed a unique cross section. Under the direction of the EPE and the FA, 10WE used Manning's equation to design each cross section. 10WE ensured channel geometry followed standards from Logan City's *Cache Valley Storm Water Design Standards.* The USBR manual *Design of Small Canal Structures* provided specifications for the freeboard requirements.

Figure 7 shows a map of every cross section. The number and letter for each cross section corresponds to a table displaying the geometry for each cross section. Table 3 contains the geometry of each section on Reach 5(2). Appendix VI contains cross sections and tables for every channel. Detailed calculations for the channel geometry are contained on the flash drive.

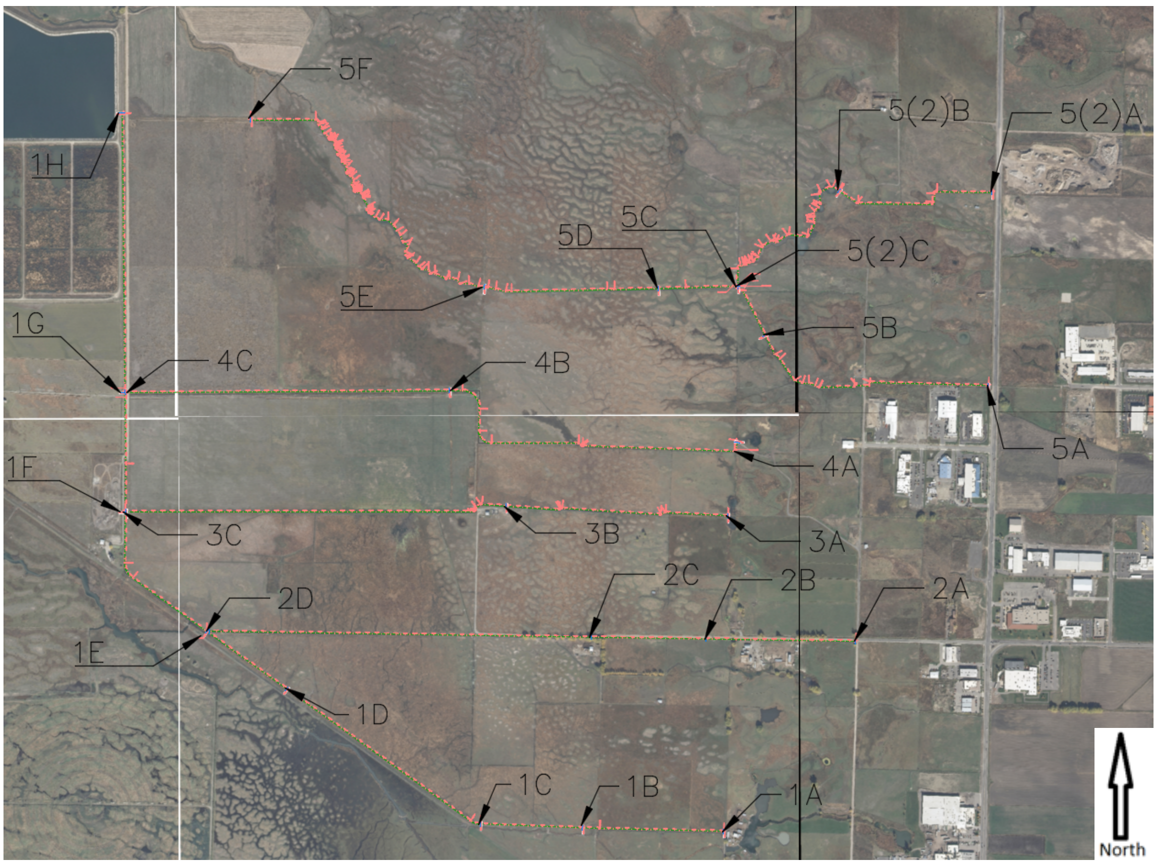

Figure 7. Channel Cross Sections

Table 3. Reach Summary

Reach 5(2)						
Plan View Key	Station	Flow (cfs)	Slope	Base (ft)	Depth (ft)	Side Slope
5(2)A	3036+00	97.79	0.0065	3	3.7	3
5(2)B	3018+37	97.79	0.0006	4	5.0	3
5(2)C	3000+00	97.79	0.0006	f	5.0	3

Using the section lines, 10WE created a plot of the ground surface at every location. 10WE drew cross sections to calculate cut volumes and top scrape areas. 10WE used this data in the economic analysis. Figure 8 shows a section view of station number 3018+37.

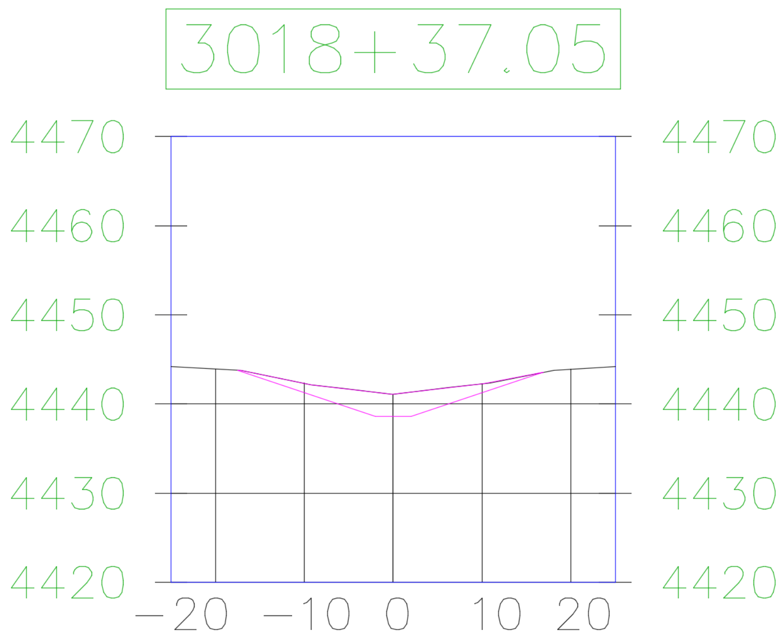

Figure 8. Section View

The bottom axis represents distance in feet from the centerline of the channel. The left and right axes display channel elevation in feet. 10WE created similar section views for every cross section shown in Figure 7. The area between the pink lines represents the soil that must be excavated along the channel. 10WE used the end area method to calculate total cut volumes and scrape areas (Appendix VI).

In the area of interest, there are multiple owners of surface water rights. The owners of surface water rights are legally entitled to have access to the water at any time during the year. 10WE designed two reinforced concrete diversion structures to ensure the owners have access to the water (see Figure 5). 10WE designed the diversion structures under the direction of the EPE in compliance with the ACI Building Code, *Building Code for Requirements for Structural Concrete*. Calculations are shown in Appendix VI. 10WE designed the diversion structures as cantilever retaining walls.

The entire area of interest was assumed to be wetlands for the cost estimate. Local water rights and the layout of the channels governed the location of the diversion structures. Therefore, 10WE did not attempt to avoid wetlands when determining the location of the diversion structures.

10WE began diversion structure design after the width of the channels and flow through the channels were designed. Under the direction of the EPE, twelve-inch diameter head gates were selected to ensure water right owners are provided with three to five cubic feet of water per second. The owners of the water rights will use a Waterman C-10 12-inch Canal Gate, or an equivalent gate, based on specifications provided by the manufacturer (see Appendix I) (Waterman Industries, 2017). 10WE designed a weir to pass the maximum flow to the polishing ponds when the head gate is closed. The top widths of the channel and the existing diversion canal determined the length of the structure (see Figure 9). 10WE designed both diversion structures using the same method. Figures of diversion structure 2 are in Appendix V.

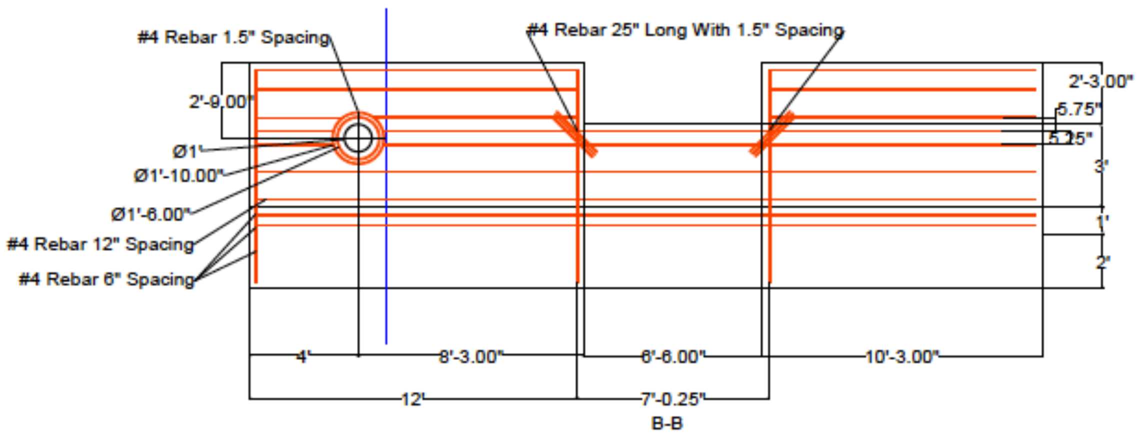

Figure 9. Structure 1 View BB

Once the initial dimensions of the structures were calculated, 10WE determined the base width of the structure through trial and error. 10WE minimized the size of the structure due to economic constraints. 10WE used the following safety factors for design: 1.5 for overturning, 2 for sliding, and 3 for bearing capacity.

To prevent sliding, 10WE could have increased the width of the structure or added a cutoff wall. Adding a cutoff wall was more economical. Additionally, the cutoff wall controls seepage under the structure (see Figure 10). 10WE assumed the specific weight of the soil was 100 pounds per cubic foot, and the friction angle of the soil was 30 degrees.

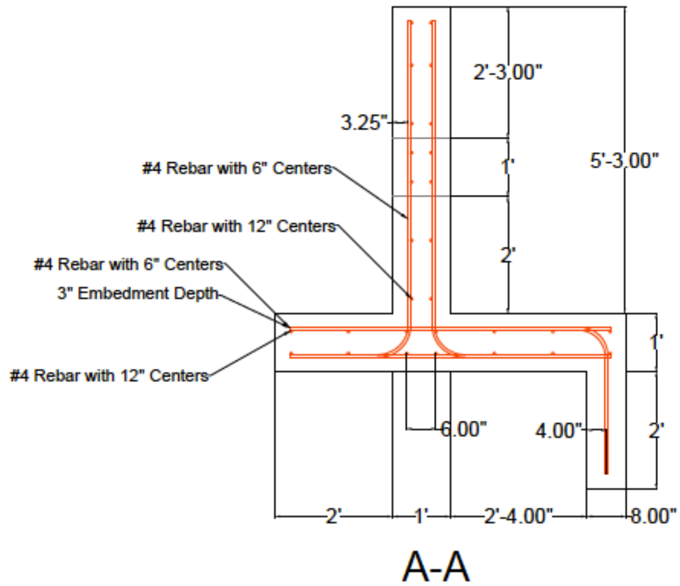

Figure 10. Structure 1 View AA

The structures will have 1.5 feet of soil on top of the foundation. 10WE designed diversion structure 1 to be embedded in 3 feet of soil on each side and diversion structure 2 to be embedded in 5 feet of soil on each side. Using Google Earth, 10WE calculated the angle required for the design of the diversion structures (see Figure 11).

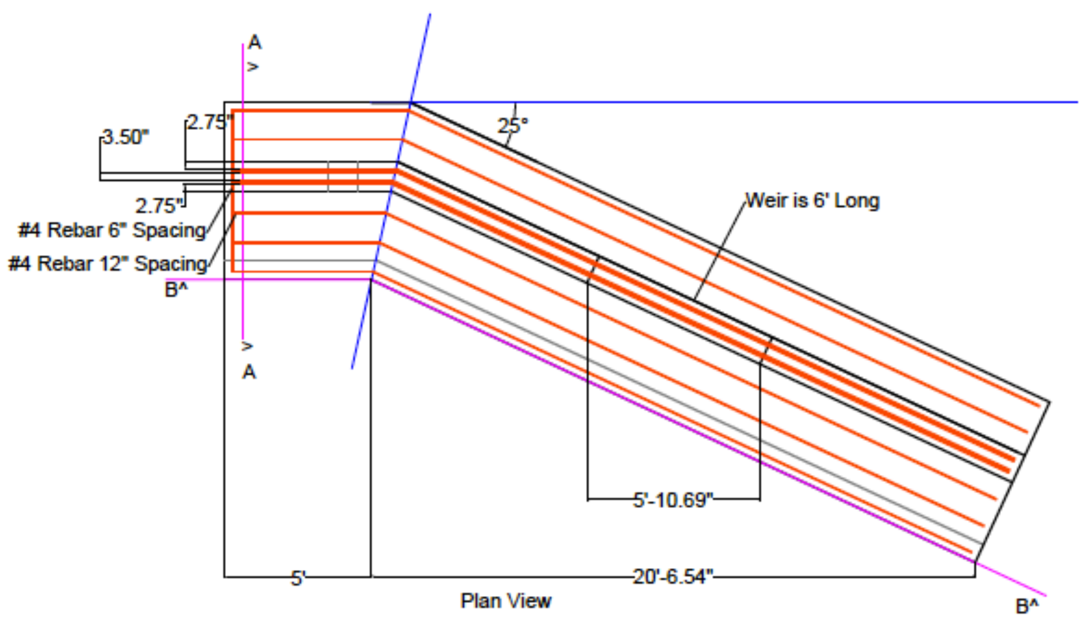

Figure 11. Structure 1 Plan View

10WE calculated the necessary amount of reinforcing steel. The design complies with the ACI Building Code minimum area of reinforcing steel for temperature shrinkage. 10WE designed the reinforcing steel to be embedded in three inches of concrete because the structure is in contact with soil and water.

When the diversion structures are constructed, the contractor will need to stabilize the soil to prevent differential settlement. The contractors must excavate the area to a depth of 18 inches and backfill with 12 inches of 3-inch diameter rock. The contractors will continue to consolidate the soil and add rock until the area stabilizes. Once the area stabilizes, the contractors will add 6 inches of crushed, well-graded aggregate with a maximum particle size of ¾-inch. Contractors will compact the area to 95% of standard proctor. Once this has occurred, the contractors may build the diversion structure.

10WE designed riprap to prevent scour on the downstream side of the structure. Scour could undermine the foundation, causing failure. 10WE calculated the plunge velocity of the water and the appropriate gradation of riprap required to prevent scour. The design specifies that the riprap be 24 inches deep and extend 10 feet downstream (see Table 4 and Table 5).

Table 4. Diversion Structure 1 Riprap

	Lower Range			**Higher Range**		
	ft	**in**	**lbs**	**ft**	**in**	**lbs**
D_{100}	0.91	10.90	64.76	1.23	14.79	161.91
D_{50}	0.72	8.65	32.38	0.77	9.19	38.86
D_{15}	0.49	5.87	10.12	0.61	7.30	19.43

Table 5. Diversion Structure 2 Riprap

	Lower Range			**Higher Range**		
	ft	**in**	**lbs**	**ft**	**in**	**lbs**
D_{100}	1.53	18.31	306.76	2.07	24.85	766.89
D_{50}	1.21	14.53	153.38	1.29	15.44	184.05
D_{15}	0.82	9.86	47.93	1.02	12.26	92.03

10WE's post-construction recommendations for Logan City are: 1) mow banks of each channel annually; 2) conduct a system inspection yearly and after a storm that exceeds the 20-year event to ensure that all channels and diversion structures are operating as designed.

An alternative to this design is to install about 8.6 miles of box culvert instead of expanding the existing canals. The estimated cost of this alternative is $68.3 million dollars. Therefore, 10WE selected the design presented in this report.

Final Report. The objective of this project was to deliver this final report to Logan City on the design of a storm water conveyance system. The FA and EPE approved all final designs, construction drawings, and estimated costs before 10WE submitted this final report. Construction of this design is dependent upon approval by Logan City Council. Contractors will review this design report during the bidding process.

Budget

10WE incurred travel expenses during the field investigation. These expenses and the estimated cost of the project are outlined below.

Team Expenses

Per the Internal Revenue System (IRS 2016), the "standard mileage rates for the use of a car" is reimbursed at 54 cents per mile driven for business purposes. Consequently, the travel reimbursement to date is $24.30 (Appendix VI). However, 10WE is volunteering their time and will not actually be reimbursed by Logan City.

Estimated Cost

The total estimated cost of the project is $12.4 million. This cost includes design, materials, excavation, wetland mitigation, relocating pump stations, and purchasing land (Appendix VI). All construction costs were estimated under the direction of the EPE.

Conclusion

This design focused on transporting storm water from 1000 West to a holding pond. The water is pumped from the holding pond into the polishing ponds for treatment. The treated water is discharged into Swift Slough. Logan City's interest in this project highlights the possibility of implementing this design.

The negative environmental impact of untreated storm water affects water bodies downstream of Logan City. Collecting and treating storm water could prevent pollution, which contributes to removing Cutler Reservoir, Swift Slough, and the Lower Bear River from the EPA's list of impaired waters.

Conveying storm water to the holding ponds and through the polishing ponds has three benefits. First, flood risk is minimized. Second, pollutant discharge is decreased. Third, Logan City uses infrastructure that would otherwise be abandoned.

10WE cooperated with Cutler Engineering and Westside Drainage Solutions to design a storm water conveyance and treatment system. Together, these teams provided a long-term sustainable solution for Logan City's storm water management system.

Reflective Writing (1077 Words)

As part of the requirements to complete a degree in Civil Engineering, students must complete the Civil and Environmental Engineering Design Sequence (CEEDS). My Honors Capstone Project was based on this design project. My design project began in January 2016 and continued through April 2017. We began as a six-member team and split into two groups of three in May 2016. My group consisted of Kade Beck, Ryan Weller, and myself. During this design project, I focused on designing the diversion structure, record keeping, and technical writing.

The CEEDS is designed to prepare students for their future career as engineers. This is accomplished through teaching them the design process, communication skills, and various other skills that will aid them in their future endeavors. The CEEDS has students work closely with both a faculty advisor and external professional engineer (EPE) throughout the entire design process. We began with submitting a proposal and ended with completing a final design report. The CEEDS is also designed as a capstone project for engineers to help them review all they have learned as they learn to apply that knowledge to real situations.

My entire undergraduate career, I have been dreading the completion of the Honors Capstone Project and the CEEDS. While the process has not necessarily been enjoyable, I have learned a lot. I have learned more about how the engineering process works, how to use engineering judgment, and how to effectively communicate.

My project began, like most real world engineering projects, by completing a proposal. During the completion of the proposal, my team worked to understand the scope of the project and began to brainstorm solutions to our problem. Initially our project entailed designing a conveyance and treatment system for the storm water. As we continued to understand the scope of our project, we realized that the two projects were not that closely related and that it would be better to split into two groups.

This led to a unique situation within CEEDS. Our team worked with two other CEEDS design teams to complete a system that will collect, transport, and treat storm water. Working with these other teams simulated how real world engineering projects work, with various teams working toward a common goal.

One of the hardest parts of this project was finding enough information to complete the design. We were limited by the cost and time it would take to complete detailed studies. We had to rely upon data from government websites and Logan City. There were a few instances in which we could not find the appropriate data and we had to assume values with the approval of the EPE. This was a great learning experience for me. In all of my engineering classes up to that point, we had always been given values to use under simplified circumstances. This gave me the opportunity to learn how to find data and to judge whether or not the data are reasonable. I was also able to use my previous knowledge, and engineering judgment, to determine appropriate values to use for the unit weight and friction angle of the soil.

Another skill I learned was how to better use my engineering judgment. Our EPE guided us through the engineering process and taught us when it was necessary to do a full engineering

analysis, or when estimates were sufficient. For example, when designing the diversion structure we knew that, due to the scale of the project, code would govern many of the aspects of design. While it was necessary to show that code governed, it was not necessary to do complete, detailed calculations.

Additionally, since this is an actual project, there is no way to know if we got the correct answer. I had to use my engineering judgment to look at the solutions I got and to decide if they were appropriate solutions. If they were not appropriate solutions, I had to go back and find where I had made a mistake. I also had to make sure I took into account all the appropriate factors. As I designed the diversion structure, there were a few instances in which I had what seemed like an appropriate solution, but when I reviewed my calculations, I found I had forgotten an aspect of the design.

Another important skill I learned was how to be an effective communicator. Our team had to communicate between team members, advisors, and the other CEEDS teams. Through this experience, my team and I learned when it was necessary to hold meetings, and when an email would suffice. This project also required the completion of three major reports and multiple small reports. The completion of all these reports, and the standards to which our reports were held to, helped me improve my writing skills.

An additional challenge my team faced was working with our extremely busy mentors. At times during our project, we struggled to be able to get in contact with our EPE, whom we relied heavily upon for guidance throughout the entire project. At times we would try and contact our EPE multiple times in several ways with no success. From this experience, I learned to be clearer in my expectations, to give myself more time to wait for a response from our EPE, and to be sure to communicate with our EPE early so that he could set aside time in his schedule to help us.

One of the highlights of this project is that it is a project Logan City is actually interested in pursuing. Storm water is really an issue west of 1000 West in Logan City. If our project were to be implemented, it would ensure local landowners could use their land as they want to, and not be periodically overrun with water. However, if this project were to be implemented, it would not be for several years. I really enjoyed working on a project that has the potential to help others.

Overall, this Honors Capstone Project has helped me immensely. Through this project I have developed a greater understanding of what it means to be an engineer. I have learned about how the engineering process works, how to use engineering judgment, and how to be a more effective communicator. This project has made me excited to graduate and become an engineer. I am excited to use the skills and knowledge I have acquired during my time at Utah State University and I am excited to continue to learn throughout my career.

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Appendix I: Data

Soil Testing Data

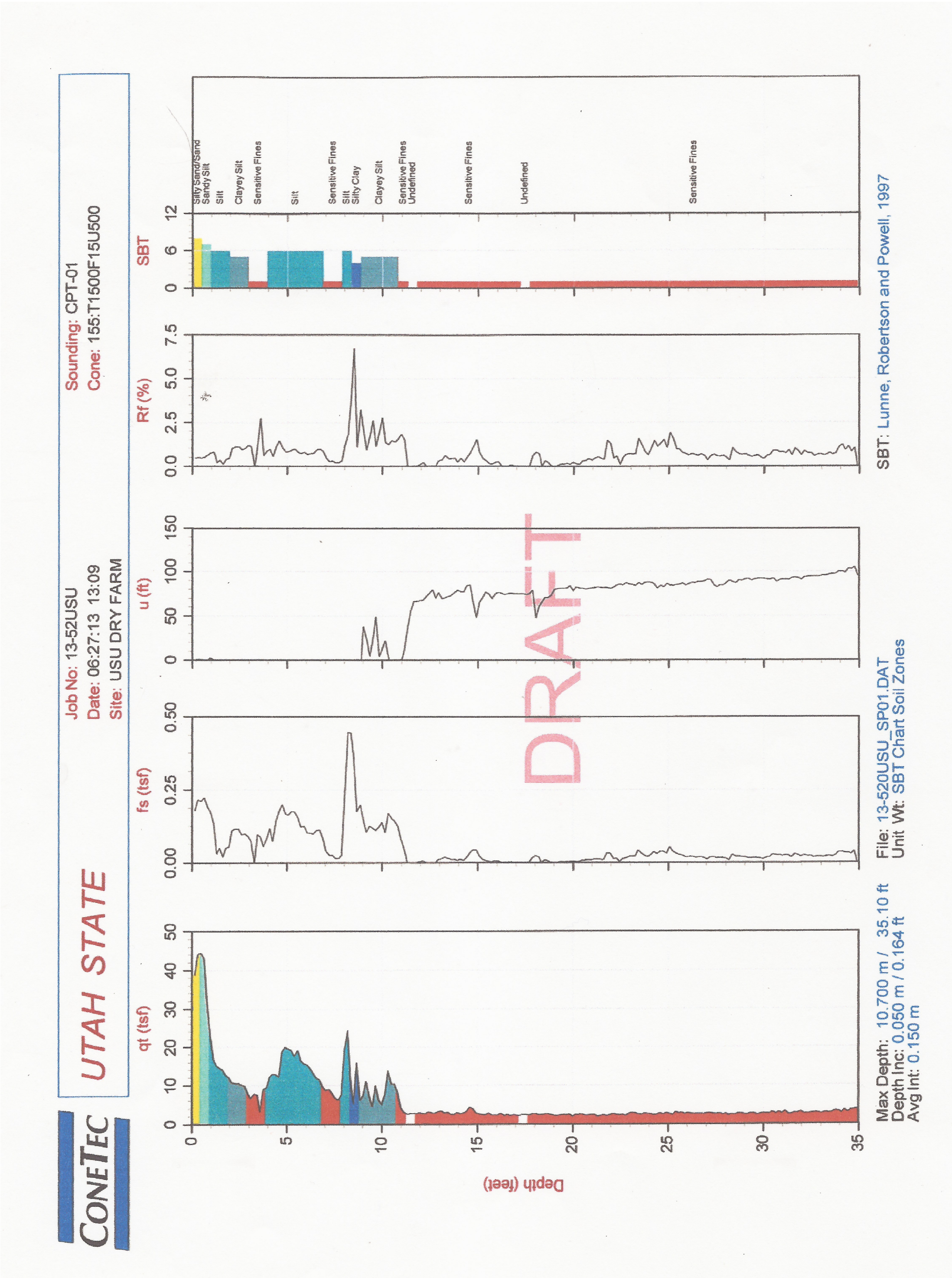


Figure I1. CPT Soil Test

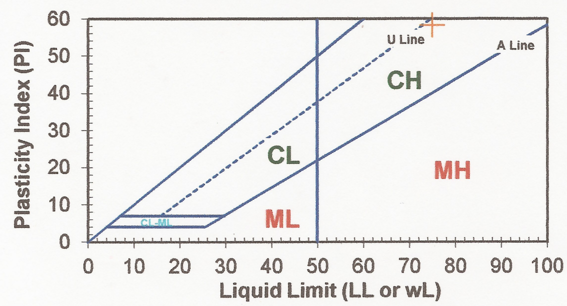
Atterberg Limits Data Sheet
ASTM D4318-10

Project Name:	Boudrero Pond	**Tested By:**	Tyson Glover	**Date:**	10/4/16
Location:	1405 W 1000 N	**Checked By:**	Curtis Bown	**Date:**	10/4/16
Boring No:	#1 at CP1	**Test Number:**	1		
Sample Depth:	12-24 inches	**Gnd Elevation:**			

USCS Soil Classification: Fat Clay (CH)

TEST			PLASTIC LIMIT				LIQUID LIMIT			
Variable	NO Var.	Units	1	2	3	4	1	2	3	4
Number of Blows	N	blows					15	20	26	
Can Number	---	---	210	117			306	204	148	
Mass of Empty Can	M_C	(g)	15.97	15.70			16.06	15.51	16.05	
Mass Can & Soil (Wet)	M_{CMS}	(g)	19.16	41.12			45.13	33.33	39.74	
Mass Can & Soil (Dry)	M_{CDS}	(g)	18.02	31.51			32.08	25.67	30.12	
Mass of Soil	M_S	(g)	2.05	15.81			16.02	10.16	14.07	
Mass of Water	M_W	(g)	1.14	9.61			13.05	7.66	9.62	
Water Content	w	(%)	55.6	60.8			81.5	75.4	68.4	

Liquid Limit (LL or w_L) (%):	75
Plastic Limit (PL or w_P) (%):	58
Plasticity Index (PI) (%):	17
USCS Classification:	CH



PI at "A" Line = 0.73(LL-20)

One Point Liquid Limit Calculation:

$LL = w_n(N/25)^{0.12}$

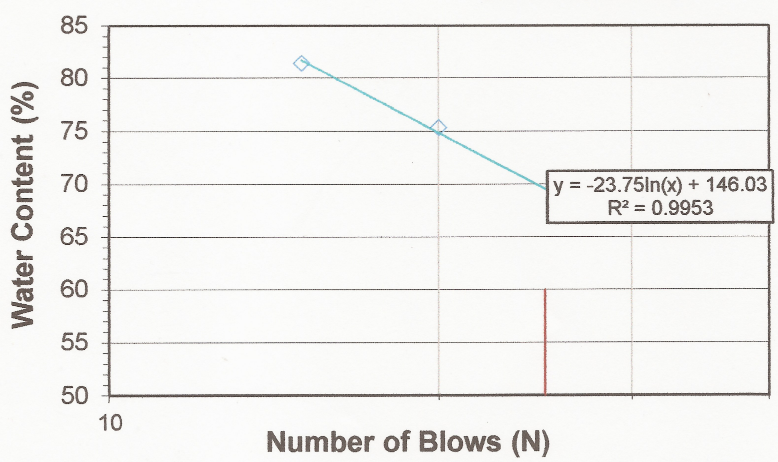
PROCEDURE USED

[X] Wet Preperation Multipoint

[ ] Dry Preperation Multipoint

[ ] Procedure A Multipoint

[ ] Procedure B One-Point



14.333 Atterberg Limits Worksheet Revised 02/13 __ of __

Figure I2. Atterberg Limits Soil Test 1

Atterberg Limits Data Sheet

ASTM D4318-10

Project Name:	Boudrero Pond	**Tested By:**	Tyson Glover	**Date:**	10/4/16
Location:	1405 W 1000 N	**Checked By:**	Curtis Bown	**Date:**	10/4/16
Boring No:	#2 at North End	**Test Number:**	1		
Sample Depth:	12-24 inches	**Gnd Elevation:**			

USCS Soil Classification: Fat Clay (CH)

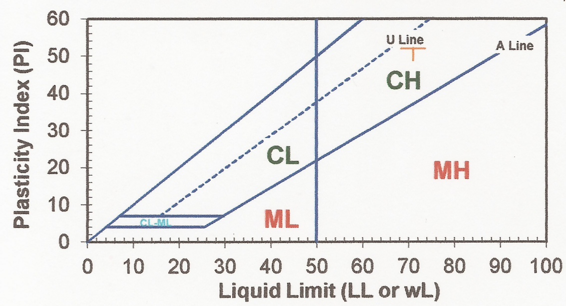
TEST			PLASTIC LIMIT				LIQUID LIMIT			
Variable	NO Var.	Units	1	2	3	4	1	2	3	4
Number of Blows	N	blows					28	18	23	
Can Number	---	---	213	187			208	411	415	
Mass of Empty Can	M_C	(g)	15.87	15.94			15.68	15.48	16.03	
Mass Can & Soil (Wet)	M_{CMS}	(g)	19.34	32.48			51.44	47.46	51.84	
Mass Can & Soil (Dry)	M_{CDS}	(g)	18.17	26.74			37.41	33.58	36.85	
Mass of Soil	M_S	(g)	2.30	10.80			21.73	18.10	20.82	
Mass of Water	M_W	(g)	1.17	5.74			14.03	13.88	14.99	
Water Content	w	(%)	50.9	53.1			64.6	76.7	72.0	

Liquid Limit (LL or w_L) (%):	71
Plastic Limit (PL or w_P) (%):	52
Plasticity Index (PI) (%):	19
USCS Classification:	CH

PI at "A" Line = 0.73(LL-20)

One Point Liquid Limit Calculation:

$LL = w_n(N/25)^{0.12}$



PROCEDURE USED

- [X] Wet Preperation Multipoint
- [ ] Dry Preperation Multipoint
- [ ] Procedure A Multipoint
- [ ] Procedure B One-Point

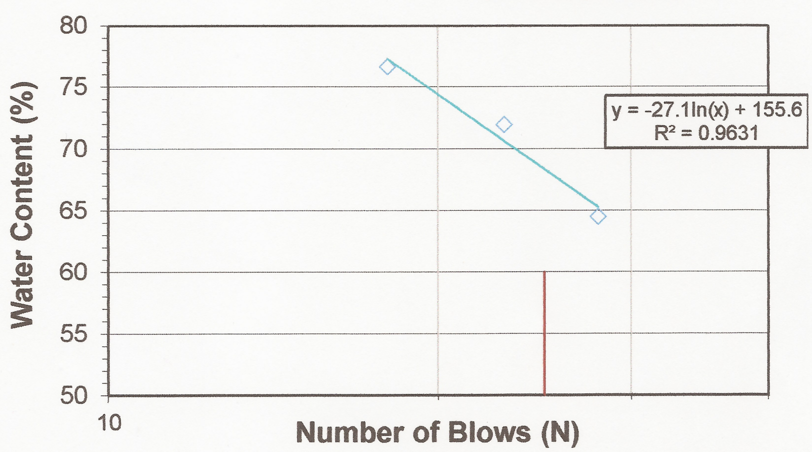


Figure I3. Atterberg Limits Soil Test 2

Drainage Area Characteristics

Table II1. Drainage Basin Characteristics

Basin #	Hydrologic Soil Group Classification	Area (Acres)
1	D	44.27
2	D	28.13
3	D	13.37
4	D	9.02
5	D	35.54
6	D	14.50
7	D	12.65
8	D	56.90
9	D	51.76
10	D	57.69
11	D	458.28
12	D	713.24
13	D	296.66
14	D	208.10
15	D	235.66
16	D	90.63

Canal Gate Specifications

C-10 CANAL GATE

This gate is designed for use on canal and pipeline systems which operate at low "heads" and where a moderately priced gate is desired. Typical installations include: farm turnouts, control of industrial wastes, drainage and for tide control.

Construction is of grey iron with an all-bolted steel frame with ¼" minimum thickness. The standard stem is of a special leaded steel which resists corrosion. The stem is operated at the structural frame top by a heavy cast-bronze lift nut and a cast iron wheel.

Adjustable cast iron wedge blocks, held securely in place by two machine bolts, assure a dependable seating closure with a practical degree of water tightness. The cast iron seats are machined or ground. A solid rim "easy-grip" handwheel is standard.

Optional materials include: bronze seats; stainless steel structural frame and bolts; stainless steel or brass stems; and special epoxy, coal tar or ASTM galvanized coatings.

When desired, design variation in stem diameter, pitch and thread rotation are available to match existing equipment. Extended stems, special lifts, oil seals, stem guides and limit nuts are a few of the optional items available for use with these gates.

Various sizes and options are available.

Special materials available include: "Ni-Resist" iron castings, stainless steel structural frame and assembly bolts; total galvanizing per ASTM A-123; coal tar, and epoxy coatings.

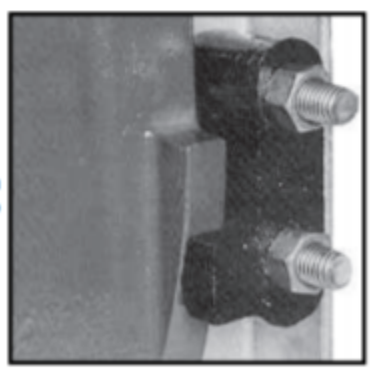
Recommended Maximum Seating Heads	
6" - 24"	23 foot head
30" - 36"	11 foot head
42" - 48"	9 foot head
54" - 72"	6 foot head
Recommended Maximum Unseating Head - 0	

Frame Types for Various Installation Requirements

- F .... Flatback for headwall mounting
- SB .... Spigotback for annular or recor spiral corrugated pipe.
- CIP .... For solvent cement mounting over plastic pipe
- C .... With galvanized steel tapered setting collar for concrete or asbestos cement pipe.
- SA .... Spigotback for annular corrugated pipe.
- TYPE 4 .... For mounting in plastic pipe utilizing special two part epoxy.

Bronze lift nut furnished as standard on all Waterman Canal Gates.

Features ¼" minimum thickness. Compare to competitor's gates.



Waterman Model C-10 wedging system offers two point adjustment and larger wedging surfaces for a more positive contact.

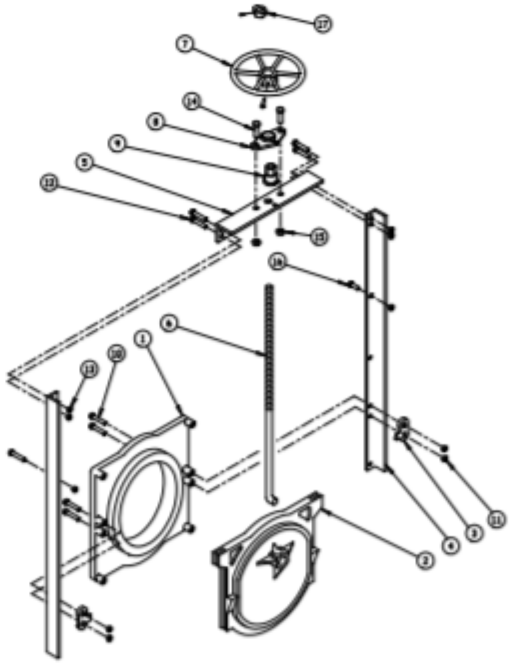
Waterman Industries

1

C-10 CANAL GATE PARTS

PARTS LIST		
No.	Name	Qty.
1	Frame	1
2	Cover	1
3	Wedge (R&L)	2
4	Guide Rail (R&L)	2
5	Headrail	1
6	Stem	1
7	Handwheel	1
8	Thrust Collar	1
9	Lift Nut	1
10	Wedge Bolt	4
11	Wedge Nut	4
12	Frame Bolt	4
13	Frame Nut	4
14	Collar Bolt	2
15	Collar Nut	2
16	Stop Bolt & Nut	1
17	Limit Nut (optional) *	1

* With set screw



CL-10 CANAL GATE

Waterman CL-10 Canal Gates are identical to our model C-10 Gates with the exception of the cast iron cover (slide) which is of a flat plate type construction with ribs reinforcing its face, to withstand the maximum heads as noted for our C-10 gates. This gate cover also features a square bottom design, which allows a more open "clog-free" flow at points of initial opening. The seat being only slightly raised above the cover plate surface helps prevent trash from collecting behind the cover which can cause difficulty in operation.

Available with threaded thrust nut for true NRS application. All parts are interchangeable with our Standard C-10 gate. Available in a variety of sizes.

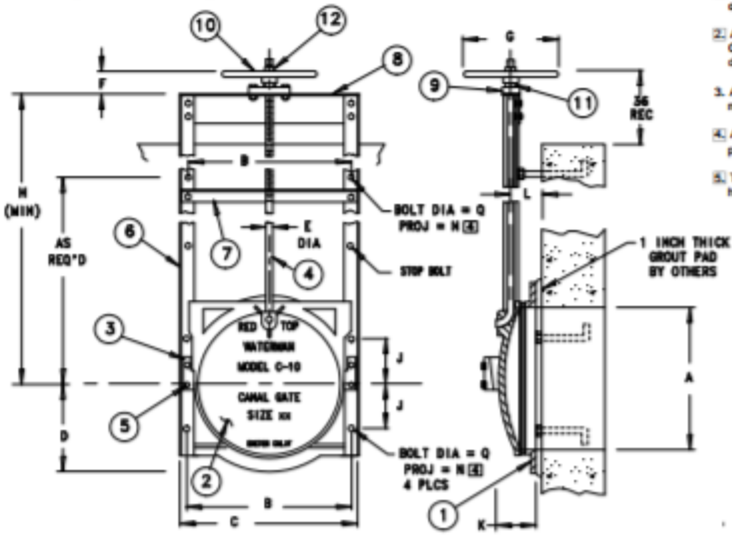
CL-10

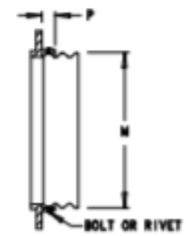
Flat Plate Type, Square Bottom

Shown with optional threaded thrust nut for true non-rising stem operation

C-10 CANAL GATE

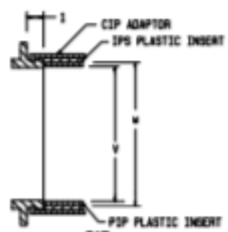
NOTES
1. TYPE 2 lubricated ball bearing lift used on 48" and larger gates.
2. Applies to spigotback gate only. Optional spigot, shown in separate detail.
3. All dimensions are also applicable for model CL-10 & CM-10 gates.
4. Add grout pad thickness to anchor bolt projection.
5. Type 3E 2:1 lift used, mounted to dual headrail.



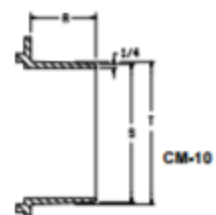


Corrugated Pipe Attached to Spigot Back Frame

PARTS LIST		
No.	Name	Qty.
1	Frame	1
2	Cover	1
3	Wedge (Right & Left)	1 ea.
4	Stem	1
5	Wedge Bolts	4
6	Guide Rail	2
7	Stem Support	A/R
8	Head Rail	1
9	Lift Collar	1
10	Handwheel	1
11	Lift Nut	1
12	Limit Nut	1



CIP



Type 4 Spigot

A	B	C	D	E	F	G	H	J	K	L	M 2	N	P 2	Q	R	S	T	V	W
6	8	9¾	4	⅝	2¾	10	24	3	3½	2⅜	7	3½	2¼	½	-	-	-	6.160	6.645
8	10	12	4⅞	⅝	2¾	10	24	3	3½	2⅜	9	3½	2¼	½	4	7 13/16	8	8.180	8.645
10	12	13¾	6	⅝	2¾	10	24	3½	3½	2⅜	11	3½	2¼	½	3½	9¾	10	10.220	10.770
12	14	15¾	7	⅝	2¾	10	24	4	3½	3	13	4	2¼	½	4	11¾	12	12.270	12.780
14	16	17¾	8	⅝	2¾	10	27	4½	3½	3½	15	4	2¼	½	-	-	-	-	-
15	17	18¾	8¾	⅝	2¾	10	30	5	4½	3½	16	4	2¾	½	4	14¾	15	-	-
16	18½	20¾	9¾	⅝	2¾	10	32	5½	4½	3½	17	4½	2¼	¾	-	-	-	-	-
18	21	22¾	10½	1	3¼	12	34	6	4½	4½	19	4½	2¼	¾	4	17 13/16	18	-	-
20	23½	25¾	11¾	1	3¼	12	38	7	4½	4	21	4½	2¼	¾	-	-	-	-	-
21	24	25¾	12 7/16	1	3¼	12	40	7	4½	4	22	4½	2¼	¾	-	-	-	-	-
24	27½	29¾	13¾	1	3¼	12	44	8	5½	4½	25	4½	2¼	¾	-	-	-	-	-
30	33½	36¾	17¾	1¼	4	15	54	10	6	4½	31	6	2¼	¾	-	-	-	-	-
36	39½	42¾	20¾	1¼	4	15	62	12	6½	5½	37	6	2¾	¾	-	-	-	-	-
42	45½	48¾	23¾	1½	5	18	84	14	7	6	43	6	2¾	¾	-	-	-	-	-
48	51¾	54¾	26¾	1½	6	24 1	90	16	7½	6½	49¾	6	2¾	¾	-	-	-	-	-
54	58¾	61½	30	2	6	30 1	100	18	7½	6½	55¾	7	3	1	-	-	-	-	-
60	65	68	34	2	6	30 1	102	20	8½	7½	61¾	8	3½	1	-	-	-	-	-
72	77½	80½	41	2	13	5	121	25½	10¾	8½	73¾	8	3¾	1	-	-	-	-	-

GATE DIMENSIONS IN INCHES

Waterman Industries

Appendix II: Meeting Minutes

December 13, 2016 Minutes

Tuesday, December 13, 2016; 3:30pm – 5:00pm

Location
UWRL 2nd Floor Conference Room

Meeting Attendees:
Beck, Kade; Houser, Lance; Gordon, Megan; Johnson, Mike; Weller, Ryan

1. **3:55 – Welcome –** Lance Houser
2. **3:57 – Follow-up** – Mike Johnson
    a. Discussion of Interim Report
3. **4:00 – Discussion –** Lance Houser
    a. Channels
        i. Lance and Kade will finalize design storm after the meeting
        ii. Ryan and Lance will size channels over the break
            1. 1ft freeboard required
            2. Vegetated side slope of 2:1 or 3:1
            3. Velocity below 2-3 cfs
            4. Safety factor on flows
            5. Use normal manning's coefficient and excel
    b. Diversion Structures
        i. 2 diversion structures needed for water rights
        ii. Head gate with fixed orifice ($Q = 0.61 * A_0 * \sqrt{2 * g * \Delta h}$)
        iii. Assume gate will be full open
        iv. Bypass weir at 5 cfs per mentor's advice
        v. Concrete
            1. 12in thick walls
            2. 2 mats of steel/rebar
            3. Cantilever/retaining wall design
            4. Size footing for no water downstream
            5. Cutoff wall to prevent seepage
            6. Check for overturning
            7. Assume 4000psi concrete
            8. Waterman head gates, use bolt pattern
            9. Use same structures and worse case
        vi. Culverts as needed
    c. Final Drawings
        i. Plan to overview and cross section at key locations
        ii. Standard cross sections
        iii. Locate and define grade breaks
    d. Groundwater
        i. Aquiclude
        ii. Surface water does not penetrate into groundwater
        iii. Signed memo from Lance approving aquiclude assumption

    e. Cost
        i. Channels
            1. Assume the channel is filled in to begin with for estimating soil to be removed
        ii. Ryan will work on costs and be given standard bid/estimate sheets
        iii. Material, foundation, excavation, grading, excess material to landfill, mobilization, culverts, wetland, pollution
    f. Final Report
        i. Start around Spring Break

4. **1:00 – Timeline/Procedure –** Kade Beck
    a.
5. **4:45 – Task Summary** – Megan Gordon
    a.
6. **4:50 – Next Meeting Time** – Kade Beck, Lance Houser, Megan Gordon, Ryan Weller
    a. Lance Houser and Ryan Weller will meet Monday, December 19, 2016 at 8am to go over channel sizing
    b. Kade Beck, Lance Houser, and Megan Gordon will meet Tuesday, January 10, 2017 at 3:30pm to work on diversion structures
    c. Both meetings will be held at Logan City
    d. Next meeting with both mentors will be to approve economics
7. **5:00 – Adjournment** – Lance Houser

January 20, 2017 Minutes

Friday, January 20, 2017; 9:25am – 10:10am

Location
ASCE Study Room

Meeting Attendees:
Beck, Kade; Gordon, Megan; Weller, Ryan

1. **9:25 – Welcome –** Kade Beck
2. **9:26 – Follow-up and Discussion** – Kade Beck, Megan Gordon, Ryan Weller
    a. Bearing Capacity is still needed from the Westside group
    b. Channels
        i. Could not get the file to work and met with ArcGIS specialists for help
        ii. Received new imagery and DEM files, working to import them into Civil 3D
        iii. Will use all existing channels
            1. Kade had excluded two channels in his analysis and we will edit numbers and not redo design storm
        iv. Ryan will meet with Lance this Tuesday if needed, if not Ryan will meet with Lance next Tuesday for final approval
        v. Channels should be done by February 1, 2017
    c. Economics and Resizing Culverts
        i. Kade will wait to begin until channels and diversion structures are finalized
    d. Diversion Structures
        i. Begin making spreadsheet with tentative values
        ii. Lance will put pressure on Westside for bearing capacity
3. **9:37 – Timeline/Procedure –** Kade Beck
    a. Progress Report 1
        i. Turn in by February 6, 2017 at 5pm
        ii. Need report back by February 9, 2017 at 5pm
    b. Progress Report 2
        i. Turn in by March 3, 2017 at 5pm
        ii. Need report back by March 9, 2017 at 5pm
    c. Final Report
        i. Turn in by April 17, 2017 at 5pm
        ii. Need report back by April 20, 2017 at 5pm
    d. Meeting with Lance, Mike, and all group members
        i. March 14, 2017 at 3:30pm in the UWRL 2^{nd} Floor Conference Room
4. **10:07 – Task Summary** – Megan Gordon
    a. Ryan will work on channel cross sections and slopes
    b. Kade will email Lance and Mike about dates to approve reports and meet
    c. Megan will begin making a spreadsheet for diversion structures
5. **10:08 – Next Meeting Time** – Kade Beck

   a. Friday, January 27, 2017 at 9:30am in the ASCE Study Room
   b. Tuesday, March 14, 2017 at 3:30pm in the UWRL 2nd Floor Conference Room

6. **10:10 – Adjournment** – Kade Beck

February 2, 2017 Minutes

Friday, February 2, 2017; 9:30am - 10:30am

Location
ASCE Study Room

Meeting Attendees:
Beck, Kade; Gordon, Megan; Weller, Ryan

1. **9:30 – Welcome –** Kade Beck
2. **9:30 – Follow-up**
    a. Covered in discussion
3. **9:32 – Discussion –** Kade Beck, Ryan Weller
    a. Progress Report 3
        i. We will not revise the Gantt Chart yet, just discuss changes
        ii. Design will be done February 28th
        iii. Team Mentor Meeting
            1. Expectation for final report
            2. Base flows
            3. Culvert and diversion structures
            4. Groundwater concerns
                a. Need technical memo from Lance
            5. Economics
    b. Design of channels
        i. Difficulty with spatial references in program
        ii. Finish design by February 10th and have the design be approved by Lance in meeting February 14th
    c. Team leader presentation
        i. Discussed presentation
        ii. Practiced presentation
4. **10:25 – Timeline/Procedure –** Kade Beck
    a. Finish design by February 28th
    b. Begin working on the Final Report March 1st
    c. Send progress report to Lance by February 6th at 5pm
5. **10:28 – Task Summary** – Megan Gordon
    a. Megan Gordon will write the progress report and have it finished by February 3rd
    b. Ryan Weller will complete the channel design
    c. Kade Beck will complete the team leader presentation and send the progress report to Lance for approval by February 6th at 5pm
    d. Kade and Ryan will review the progress report
6. **10:29 – Next Meeting Time** – Kade Beck
    a. Monday, February 6, 2017 at 7:45 am in ENLAB 235 B
7. **10:30 – Adjournment** – Kade Beck

March 2, 2017 Minutes

Thursday, March 2, 2017; 3:00 pm-5:00 pm

Location
Lance Houser's Office

Meeting Attendees:

Beck, Kade; Gordon, Megan; Houser, Lance; Weller, Ryan

1. **3:00 – Welcome –** Lance Houser
2. **3:10 – Follow-up** – Lance Houser
    a. See Discussion
3. **3:11 – Discussion –** Lance Houser
    a. Channels
        i. Limited by the quality of data available
        ii. Channel's will not show due to the level of detail (5m DEM)
        iii. Cut vs. cut/fill channels
        iv. Excavation numbers sound appropriate
    b. Structures
        i. One wall will be poured
        ii. Pipe width of channel from field investigation
        iii. Sliding FS=2, Overturn FS=1.5
        iv. Frost depth at 30", have bottom of foundation at 30"
        v. Weir crest at yo+.1ft, 6" freeboard when in use
        vi. Cantilever wall
        vii. 2 steel mats
        viii. Use 1ft sections for typical section in series of independent beams
    c. Cost
        i. Kade was given spreadsheet as basis
        ii. Filled out spreadsheet while discussing, see spreadsheet
        iii. Need rip rap downstream of diversion structures
            1. Ryan given spreadsheet to find gradation of rip rap
        iv. Need total soil excavation amounts
        v. Think of any other potential costs
        vi. Assume entire area is wetland and will be disturbed, $180,000 per acre of wetland destroyed
        vii. Beat $83.2 million
    d. Drawings
        i. Overview and key locations of channel cross sections
        ii. 1:100 scale appropriate for channels
        iii. Draw and send to Lance for red line (Megan and Ryan)
            1. Send by next meeting
    e. Groundwater
        i. Consider to find if it is important
        ii. Find data from the Soil Conservation Service

1. Depth to clay layer, pressure, permeability/hydraulic conductivity

iii. DWR well logs drilled near the area of interest for thickness to clay layer

iv. NRCS for physical properties and pick worst case

v. Darcy's Law to estimate flow up through channel

4. 4:40 – Timeline/Procedure – Kade Beck

a. By next meeting

i. Cost estimate

ii. Diversion structures

iii. Drawings

5. 4:45– Task Summary – Lance Houser

a. Kade Beck will finish cost estimates and look into groundwater

b. Ryan will finish excavation amounts and channel drawings

c. Megan will finish diversion structures and drawings

6. 4:55 – Next Meeting Time – Kade Beck

a. March 14, 2017 at 3:30 pm at the UWRL

7. 5:00 – Adjournment – Lance Houser

March 23, 2017 Minutes

Thursday, March 23, 2017; 4:30pm - 5:05pm

Location

UWRL 2nd Floor Conference Room

Meeting Attendees:

Beck, Kade; Gordon, Megan; Houser, Lance; Johnson, Mike; Weller, Ryan

1. **4:50 – Welcome –** Kade Beck
2. **4:50 – Follow-up**
    a. See Discussion
3. **4:50 – Discussion –** Kade Beck
    a. Channels
        i. Sections and tables need additional formatting
        ii. Check style guide after meeting
        iii. Profile is very long
            1. Tabular data with typical representation
            2. State to see complete file on drive in paper
            3. Overview with key that refers to table
    b. Structures
        i. Calculations are good so far
    c. Cost
        i. About $12.4 million
        ii. Cheaper than box and culvert along NW Field Canal
    d. Final Drawings
        i. Update after meeting
    e. Groundwater
        i. K is 0-0.06 in/hr with one location of 0.2 in/hr
            1. Throw out 0.2 in/hr (Lance Houser)
        ii. Well depth to water is 306ft with 20 psi artesian pressure at surface
    f. Presentation
        i. Invited to presentation on April 12th or 14th
        ii. Cover alternatives and design process
    g. Final Report
        i. Assignments have been made
        ii. Incorporate revisions
        iii. Send to Lance by April 19th
4. **5:00 – Timeline/Procedure –** Kade Beck
    a. Presentation on April 12th or 14th
    b. Report to Lance by April 19th
5. **5:01 – Task Summary** – Megan Gordon
6. **5:02 – Next Meeting Time** – Kade Beck
    a. We have finished with meetings with both mentors
7. **5:03 – Adjournment** – Kade Beck

March 24, 2017 Minutes

Friday, March 24, 2017; 9:25am - 10:20am

Location
ASCE Study Room

Meeting Attendees:
Beck, Kade; Gordon, Megan; Weller, Ryan

1. **9:25 – Welcome –** Kade Beck
2. **9:25 – Follow-up**
   a. See Discussion
3. **9:26 – Discussion –** Kade Beck
   a. Updates
      i. Structures
         1. Meeting with Lance March 29th to finish going over calculations
      ii. Drawing
         1. Issues with elevations
         2. Annotate by hand
         3. Will re-snip profile and work on plan view
            a. Data in table to coordinate with labels on diagrams
      iii. Groundwater
         1. Checked calculations
         2. Report velocity and flow for reach one (as example of scale)
         3. Artesian conditions so the water is flowing upward
   b. Presentation
      i. North arrows
      ii. Costs for alternatives
      iii. Edit Gantt Chart to have finial and projected on same chart
4. **10:10 – Timeline/Procedure –** Kade Beck
   a. Meet Monday, March 27th at 7:30am in the ASCE Study Room
   b. Meet Wednesday, March 29th at 8pm in ENGR 301
   c. Meet Thursday, March 30th at 8pm in ENGR 301
   d. Rough Draft of entire paper completed by April 7th
      i. Kade and Megan will meet on April 7th at 9:30am in the ASCE Study room to begin editing the paper
   e. Kade will finish editing the Interim Report by April 3rd at 5pm
5. **10:20 – Task Summary** – Megan Gordon
   a. Kade
      i. Finish groundwater
      ii. Edit interim report
      iii. Work on slides for presentation
      iv. Work on section for paper
   b. Megan

i. Work on slides for presentation
ii. Work on section for paper
iii. Finish diversion structures
iv. Meet with Lance on March 20th at 3pm
v. Work on final paper

c. Ryan
   i. Update Gantt Chart
   ii. North arrows on pictures in presentation
   iii. Work on slides for presentation
   iv. Work on section for paper

6. **10:20 – Next Meeting Time** – Kade Beck
   a. Monday, March 27th at 7:30am in the ASCE Study Room
7. **10:20 – Adjournment** – Kade Beck

March 27, 2017 Minutes

Monday, March 27, 2017; 7:30pm - 8:20pm

Location
ASCE Study Room

Meeting Attendees:
Beck, Kade; Gordon, Megan; Weller, Ryan

1. **7:30 – Welcome –** Kade Beck
2. **7:30 – Follow-up**
   a. Kade checked other well logs in the area of interest and changed the depth to water to an average value
3. **7:52 – Discussion –** Kade Beck
   a. Worked on compiling the presentation
   b. Assigned roles for presentation
   c. Conclusion: will discuss realistic expectations if we need to fill more time
4. **8:13 – Timeline/Procedure –** Kade Beck
5. **8:15 – Task Summary** – Megan Gordon
   a. Everyone will introduce themselves during the presentation
   b. Everyone will practice individually before the meeting on Wednesday
   c. Kade
      i. Overview, on-site treatment, do nothing alternative, design, conclusion
   d. Megan
      i. Objective, scope, site investigation, design, cost, Gantt chart
   e. Ryan
      i. Design, constraints
6. **8:20 – Next Meeting Time** – Kade Beck
   a. Wednesday, March 29th at 8pm in ENGR 301
   b. Thursday, March 30th at 8pm in ENGR 106
7. **8:20 – Adjournment** – Kade Beck

April 3, 2017 Minutes

Monday, April 3, 2017; 7:45am - 8:20am

Location
ASCE Study Room

Meeting Attendees:
Beck, Kade; Gordon, Megan; Weller, Ryan

1. **7:45 – Welcome –** Kade Beck
2. **7:45 – Follow-up**
3. **7:47 – Discussion –** Kade Beck
    a. Paper
        i. Executive Summary
            1. Design and post-construction
            2. Methods
            3. Possibly re-write
        ii. Description
            1. Post-constructions
            2. Paragraph about how entire project relates before section on design storm
            3. Alternatives, methods, decisions
            4. Table with all alternatives and costs
        iii. Budget
            1. Revise to final estimate
            2. Take out mileage cost
        iv. Conclusion/References
            1. Add necessary information
        v. Appendices
            1. Add relevant calculations, figures, data, tables
            2. Gantt Chart for only 4880 (Ryan)
            3. Minutes for only this semester in paper, all on drive
            4. Total hours
            5. Re-write constraints to ensure it is not in passive voice
            6. Engineering tools
            7. Government regulations (ACI)
            8. Edit post-design risk
            9. Overcoming challenges
4. **8:15 – Timeline/Procedure –** Kade Beck
    a. Rough draft of paper by April 7th at 9:30 am
5. **8:17 – Task Summary** – Megan Gordon
    a. Rough draft of paper – all
        i. Include decisions, logic, and alternatives
    b. Kade:
        i. Edit and add to Interim Report as outlined above

        ii. Talk to Lance about post-construction
    c. Megan:
        i. Box and Culvert alternative
        ii. Finish diversion structure design
        iii. Ask Lance about Box and Culverts
        iv. Minutes for paper and drive
    d. Ryan – Gantt Chart

6. **8:19 – Next Meeting Time** – Kade Beck
7. **8:20 – Adjournment** – Kade Beck

April 12, 2017 Minutes

Wednesday, April 12, 2017; 7:20 am - 8:25 am

Location

ASCE Study Room

Meeting Attendees:

Beck, Kade; Gordon, Megan; Weller, Ryan

1. **7:20 – Welcome:** Kade Beck
2. **7:20 – Follow-up**
3. **7:20 – Discussion:** All
    a. Review respective writing portions
        i. Add North arrows
        ii. Find water rights?
        iii. No alternative table
        iv. Box and Culvert
        v. Add calculations
    b. Discuss submission guideline items left to be done
        i. Formatting appendices
            1. Everyone will add and format their own appendices
        ii. Technical writing review
            1. Kade will take to technical writing lab and complete changes
        iii. Update Lists of Tables and Figures
        iv. Format USB
            1. Everyone will add their own files
        v. Purchase new Binder (maybe new USB?)
            1. Megan will purchase new binder and USB
        vi. Update Special Summary Documentation
            1. Everyone will add code and software used
4. **8:15 – Discuss timeline for remainder of semester-** Kade Beck
    a. Have edits done by Friday
    b. Ryan will add his appendices then give to Megan
5. **8:20 – Task Summary**- Megan Gordon
    a. Kade:
        i. Take to technical writing lab and incorporate changes
        ii. Ask Lance about Box and Culvert
    b. Ryan:
        i. Ask Dr. Peralta about adding calculations from spreadsheet
        ii. Add appendices
    c. Megan:
        i. Buy USB and binder
        ii. Add appendices
    d. All will review the paper
6. **8:25 – Next Meeting Time** – Kade Beck

   a. May meet next week

7. **8:25 – Adjournment** – Kade Beck

Appendix III: Person-hour work reports

Team Member Work Record Summary Table

Table III1. Team Member Work Record Summary

Last Name	First Name	Role(s) on Team	Total work hrs for Fall 2016 & Spring 2017 semesters	Signature (by hand is required)
Beck	Kade	Team Leader, Hydrologist, Financial Planner, External P.E. Liaison	130	
Gordon	Megan	Structural Engineer, Technical Writer, Records Keeper	130	
Weller	Ryan	Faculty Liaison, Hydraulics and Geotechnical Engineer	152	

Individual Team Member Work Logs

Team: 10th West Engineers
Individual (last name, first name): Beck, Kade
Hours worked on team project (including class attendance)

Week #	Start Day	End Day	Su	Mo	Tu	We	Th	Fr	Sa	Week Total	Task(s) (Details can be on another document. Or, there can be multiple rows per week or day.)
i	8-May	14-May						1			Field Trip
ii	22-May	29-May	0	0	1.5	0	0	0	0	1.5	Meeting with Lance
iii	14-Aug	20-Aug	0	0	1	0	0	0	0	1	Contacting Lance
iv	21-Aug	27-Aug	0	0	0	0	0	0	0	0	
1	28-Aug	3-Sep	0	0	0.7	0	2.8	0	0	3.45	Class/meeting with Lance
2	4-Sep	10-Sep	0	0	1.2	0	0.8	0	0	2	Class/team meeting
3	11-Sep	17-Sep	0	0	0.75	0	0.8	1	0	2.55	Class/meeting with Lance and TL's
4	18-Sep	24-Sep	0	0	0.75	0	1.5	0	0	2.25	Class/team meeting
5	25-Sep	1-Oct	0	1.5	0.75	0	0	0	0	2.25	Meeting with Lance/Mentors
6	2-Oct	8-Oct	0	0	0.75	0	0	0	0	0.75	class
7	9-Oct	15-Oct	0	0	0.75	0	0	0	2	2.75	Hydrology/class
8	16-Oct	22-Oct	0	1.5	0.75	0	0.8	0	0	3	Lance/team leader meeting
9	23-Oct	29-Oct	0	0	0.75	0	0	2	2	4.75	Meeting/Hydrology
10	30-Oct	5-Nov	0	3	3	0.75	6	1	0	13.75	Hydrology
11	6-Nov	12-Nov	0	1.25	0	2.5	0	0	0	3.75	
12	13-Nov	19-Nov	0	0.75	3	1	0	0	0	4.75	Lance/class/team meeting
13	20-Nov	26-Nov	0	6	4	0	0	0	2	12	Interim Report
14	27-Nov	3-Dec	0	3	2.5	7	1	0	2.5	16	Interim Report
15	4-Dec	10-Dec	0	1	2.25	0.5	1	0	0	4.75	Interim Report
16	11-Dec	17-Dec	0	0	0	0	0	0	0	0	
						Semester total				81.25	

Certification by Individual
I declare that I worked at least the number of hours I report above for each week during the semester.

Signature

12/7/2016
Date

Certification by Team Leader
I believe that the above-reported hours are accurate.

Team Leader Signature

12/7/2016
Date

KADE BECK
Team Leader Name

Team: 10th West Engineers
Individual (last name, first name): Beck, Kade
Hours worked on team project (including class attendance)

Week #	Start Day	End Day	Su	Mo	Tu	We	Th	Fr	Sa	Week Total	Task(s) (Details can be on another document. Or, there can be multiple rows per week or day.)
i	11-Dec	17-Dec	0	0	3	0	0	0	0	3	Meeting with Mentors
ii	18-Dec	24-Dec	0	0	0	0	0	0	0	0	
iii	25-Dec	31-Dec	0	0	0	0	0	0	0	0	
iv	1-Jan	7-Jan	0	0	0	0	0	0	0	0	
1	8-Jan	14-Jan	0	0	0	0.75	0	0	0	0.75	Class
2	15-Jan	21-Jan	0	0	0	0.75	0	0.5	0	1.25	class, meeting
3	22-Jan	28-Jan	0	0	0	0.75	0	0	0	0.75	class
4	29-Jan	4-Feb	0	0	0	0.5	0	2.5	0	3	Presentation, meeting
5	5-Feb	11-Feb	0	0.5	0	0	0.5	0	0	1	Meeting, Progress Report
6	12-Feb	18-Feb	0	0	0	0	0	0	0	0	
7	19-Feb	25-Feb	0	0	0	0	0	1	0	1	Class
8	26-Feb	4-Mar	0	0	0	0	2	0	0	2	Meeting with Lance
9	5-Mar	11-Mar	0	0	0	0	0.5	0	1	1.5	groundwater/progress report
10	12-Mar	18-Mar	0	0	1.5	0	0	1	0	2.5	Progress Report
11	19-Mar	25-Mar	0	0.3	0	0	2.5	2	0	4.75	Mentor meeting/Presentation
12	26-Mar	1-Apr	0	1	0	2	2	1	0	6	Presentation
13	2-Apr	8-Apr	0	1	1.5	1	0	1.75	2.5	7.75	Meeting/Report
14	9-Apr	15-Apr	0	0	1	2.5	2.8	3.25	4	13.5	Report
15	16-Apr	22-Apr	0	0	0	0	0	0	0	0	
16	23-Apr	29-Apr	0	0	0	0	0	0	0	0	
17	30-Apr	6-May	0	0	0	0	0	0	0	0	
						Semester total				48.75	

Certification by Individual
I declare that I worked at least the number of hours I report above for each week during the semester.

Kade J. Beck
Signature

4/15/2017
Date

Certification by Team Leader
I believe that the above-reported hours are accurate.

Kade J. Beck
Team Leader Signature

4/15/2017
Date

KADE BECK
Team Leader Name

Team: 10th West Engineers
Individual (last name, first name): Gordon, Megan
Hours worked on team project (including class attendance)

Week #	Start Day	End Day	Su	Mo	Tu	We	Th	Fr	Sa	Week Total	Task(s) (Details can be on another document. Or, there can be multiple rows per week or day.)
	8-May	14-May	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	Field Trip
	22-May	28-May	0.00	0.00	1.50	0.00	0.00	0.00	0.00	1.50	Meeting with Lance
i	7-Aug	13-Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
ii	14-Aug	20-Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
iii	21-Aug	27-Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
1	28-Aug	3-Sep	0.00	0.00	0.75	0.00	1.50	0.00	0.00	2.25	Class and meeting with Lance
2	4-Sep	10-Sep	0.00	0.00	1.50	0.00	0.83	0.00	0.00	2.33	Class, group meeting, minutes
3	11-Sep	17-Sep	0.00	0.00	2.00	0.00	0.83	0.00	0.00	2.83	Class and meeting with Lance
4	18-Sep	24-Sep	0.00	0.00	0.83	0.00	3.00	0.00	0.00	3.83	Class, team meeting, wrote progress report 1
5	25-Sep	1-Oct	0.00	0.00	1.50	0.00	0.50	0.00	0.00	2.00	Meeting with mentors, team meeting, minutes
6	2-Oct	8-Oct	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	Class
7	9-Oct	15-Oct	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.75	Class
8	16-Oct	22-Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
9	23-Oct	29-Oct	0.00	0.00	2.00	0.00	0.00	2.00	0.00	4.00	Group meeting, minutes, progress report 2
10	30-Oct	5-Nov	0.00	0.00	1.00	0.00	0.75	1.00	0.00	2.75	Group meeting, minutes
11	6-Nov	12-Nov	0.00	1.00	1.00	0.00	2.50	0.00	0.00	4.50	Class (presentations), meeting, minutes
12	13-Nov	19-Nov	0.00	0.00	0.75	0.00	1.00	0.00	5.50	7.25	Class, meeting, minutes, interim report
13	20-Nov	26-Nov	2.00	7.50	0.00	0.00	0.00	0.00	1.50	11.00	Interim report
14	27-Nov	3-Dec	0.00	0.50	0.00	1.50	0.75	0.00	2.00	4.75	Meting, minutes, interim report, class quiz/survey
15	4-Dec	10-Dec	0.00	0.25	3.00	0.00	0.00	0.00	0.00	3.25	Meeting, interim report, class quiz/survey
16	11-Dec	17-Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
						Semester total				55.00	

Certification by Individual
I declare that I worked at least the number of hours I report above for each week during the semester.

Megan Gordon

Signature

12/6/2016
Date

Certification by Team Leader
I believe that the above-reported hours are accurate.

Kalle Beck

Team Leader Signature

12/6/2016
Date

Kadie Beck

Team Leader Name

Team: 10th West Engineers
Individual (last name, first name): Gordon, Megan
Hours worked on team project (including class attendance)

Week #	Start Day	End Day	Su	Mo	Tu	We	Th	Fr	Sa	Week Total	Task(s) (Details can be on another document. Or, there can be multiple rows per week or day.)
i	18-Dec	24-Dec	0	0	0	0	0	0	0	0	
ii	25-Dec	31-Dec	0	0	0	0	0	0	0	0	
iii	1-Jan	7-Jan	0	0	0	0	0	0	0	0	
1	8-Jan	14-Jan	0	0	1.5	0.75	0	0	0	2.25	Class, meeting with Lance
2	15-Jan	21-Jan	0	0	0	0.75	0	0.75	0	1.5	Class, meeting, minutes
3	22-Jan	28-Jan	0	0	0	0.75	0	0	0	0.75	Class
4	29-Jan	4-Feb	0	0	0	0	0.5	2.5	0	3	Class, meeting, minutes,
5	5-Feb	11-Feb	0	0.5	0	0	0	0	0	0.5	Meeting
6	12-Feb	18-Feb	0	0	0	0	0	0	0	0	
7	19-Feb	25-Feb	0	1	0	0	0	0.5	1	2.5	Diversion Structure
8	26-Feb	4-Mar	0	0	1.5	2	3	0	0	6.5	Diversion Structure, mee
9	5-Mar	11-Mar	0	0	0	6	0	0	0	6	Diversion Structure, minu
10	12-Mar	18-Mar	0	2	0.5	0	0	1.5	0	4	Diversion Structure, mee
11	19-Mar	25-Mar	0	0	0	0	2	2	0	4	Meeting, diversion struct
12	26-Mar	1-Apr	1	1	6	3	2	1.5	4.5	19	Meeting, diversion struct
13	2-Apr	8-Apr	4.5	4.5	5	3.5	2	2	0.5	22	Meeting, diversion struct
14	9-Apr	15-Apr	1	0.5	0	1.5	0	0	0	3	Meeting, diversion struct
15	16-Apr	22-Apr	0	0	0	0	0	0	0	0	
16	23-Apr	29-Apr	0	0	0	0	0	0	0	0	
						Semester total				75	

Certification by Individual

I declare that I worked at least the number of hours I report above for each week during the semester.

Megan Gordon
Signature

15-Apr-17
Date

Certification by Team Leader

I believe that the above-reported hours are accurate.

Kade Beck
Team Leader Signature

15-Apr-17
Date

KADE BECK
Team Leader Name

Team: 10th West Engineers
Individual (last name, first name): **Weller,Ryan**
Hours worked on team project (including class attendance)

Week #	Start Day	End Day	Su	Mo	Tu	We	Th	Fr	Sa	Week Total	Task(s) (Details can be on another document. Or, there can be multiple rows per week or day.)
i	8-May	14-May	0	0	0	0	0	1	0	1	Field Trip
ii	22-May	28-May	0	0	1.5	0	0	0	0	1.5	Meeting w/ Lance
1	28-Aug	3-Sep	0	0	0.75	0	2.75	0	0	3.5	Class. Meeting w/ Lance
2	4-Sep	10-Sep	0	0	1.25	2	2.5	0	0	5.75	Class. Team meeting. ArcGIS
3	11-Sep	17-Sep	0	2	2.5	0	1.5	0.5	0	6.5	Class. Meeting w/ Lance. ArcGIS
4	18-Sep	24-Sep	0	0	1.75	5.5	2.5	0	0	9.75	Class. Team meeting. ArcGIS
5	25-Sep	1-Oct	0	0	0.5	0	1	0	0	1.5	Meeting with P.E. and Faculty
6	2-Oct	8-Oct	0	0	1	0	0	0	0	1	Class
7	9-Oct	15-Oct	0	0	0.75	0	0	0	0	0.75	Class
8	16-Oct	22-Oct	0	0	0	0	0	0	0	0	
9	23-Oct	29-Oct	0	0	0.75	0	1	4	0	5.75	Class, Presentation, Report
10	30-Oct	5-Nov	0	0	0.5	0.5	0	1	0	2	Group Meeting
11	6-Nov	12-Nov	0	0	1.25	0	2.5	0	0	3.75	Class, Group Meeting
12	13-Nov	19-Nov	0	0	1.25	2.75	0.5	0	0	4.5	Class, Report, P.E. Meeting
13	20-Nov	26-Nov	0	8.75	4	0	0	0	0	12.75	Report, Field Work
14	27-Nov	3-Dec	0	2.5	3	0.5	0.5	3	2	11.5	Flows, Team meeting, Class, Report
15	4-Dec	10-Dec	0	4.25	3.5	0	0	0	0	7.75	Report, Team Meeting
16	11-Dec	17-Dec	0	0	0	0	0	0	0	0	
					Semester total					78.25	

Certification by Individual
I declare that I worked at least the number of hours I report above for each week during the semester.

Ryan Weller — 12/6/16
Signature Date

Certification by Team Leader
I believe that the above-reported hours are accurate.

Kadie A Beck — 12/6/16
Team Leader Signature Date

Kadie Beck
Team Leader Name

Team: 10th West Engineers
Individual (last name, first name): Weller,Ryan
Hours worked on team project (including class attendance)

Week #	Start Day	End Day	Su	Mo	Tu	We	Th	Fr	Sa	Week Total	Task(s) (Details can be on another document. Or, there can be multiple rows per week or day.)
i	1-Dec	8-Dec				5				5	
ii	18-Dec	24-Dec	0	1.5	0	0	0	0	0	1.5	Meeting w/ P.E.
iii	25-Dec	31-Dec	0	0	0	0	0	0	0	0	
1	1-Jan	7-Jan	0	0	0	0	0	0	0	0	
2	8-Jan	14-Jan	0	4	2	1.5	0	0	0	7.5	Meeting w/ P.E.,
3	15-Jan	21-Jan	0	0	2	1	0	1.75	0	4.75	Meeting w/ P.E., Class
4	22-Jan	28-Jan	0	2	1.75	2	0	0	0	5.75	Channel Design, Class
5	29-Jan	4-Feb	0	0	2	0	0	1	3	6	Channel Design, Team
6	5-Feb	11-Feb	0	0	0	0	0	1	1	2	Channel Design,
7	12-Feb	18-Feb	0	0	0.5	0	0	0	0	0.5	Channel Design
8	19-Feb	25-Feb	0	0	4.5	0	2	0.5	0	7	Channel Design
9	26-Feb	4-Mar	0	0	0	4.5	2	1.5	0	8	Channel Design,
10	5-Mar	11-Mar	0	0	0	0.5	0	1	0	1.5	Team Meeting
11	12-Mar	18-Mar	0	0	1.5	0	0.75	7	0	9.25	Meeting w/ P.E. and F.A., Channel Design
12	19-Mar	25-Mar	0	1	0	2.75	1.5	2		7.25	Team Meeting,
13	26-Mar	1-Apr	0	1.25	2.25	0	0	0	0	3.5	Team Meeting, Paper
14	2-Apr	8-Apr	0	0	0.5	1.75	1			3.25	Paper, Team Meeting
15	9-Apr	15-Apr						1		1	Team Meeting
16	16-Apr	22-Apr								0	
17	23-Apr	29-Apr								0	
18	30-Apr	6-May								0	
						Semester total				73.75	

Certification by Individual
I declare that I worked at least the number of hours I report above for each week during the semester.

Signature ______ Date 4/15/2017

Certification by Team Leader
I believe that the above-reported hours are accurate.

Team Leader Signature ______ Date 4/15/2017

KADE BECK
Team Leader Name

Appendix IV: Gantt Charts

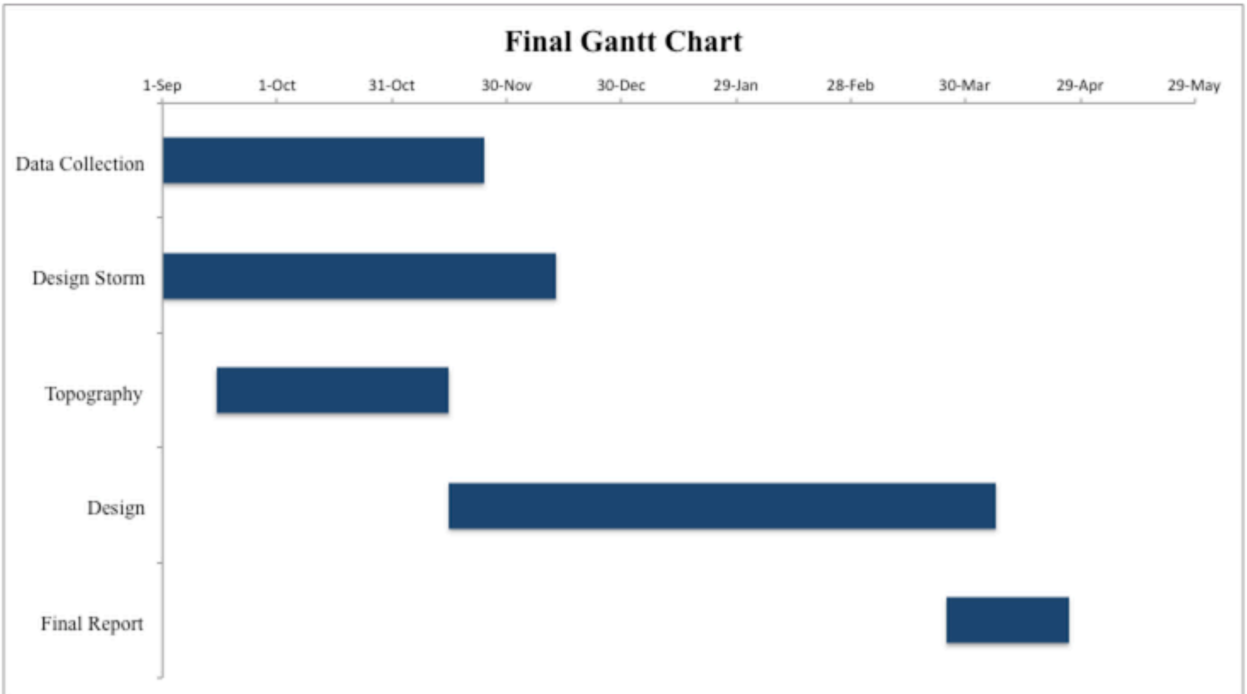


Figure IV1. Final Gantt Chart

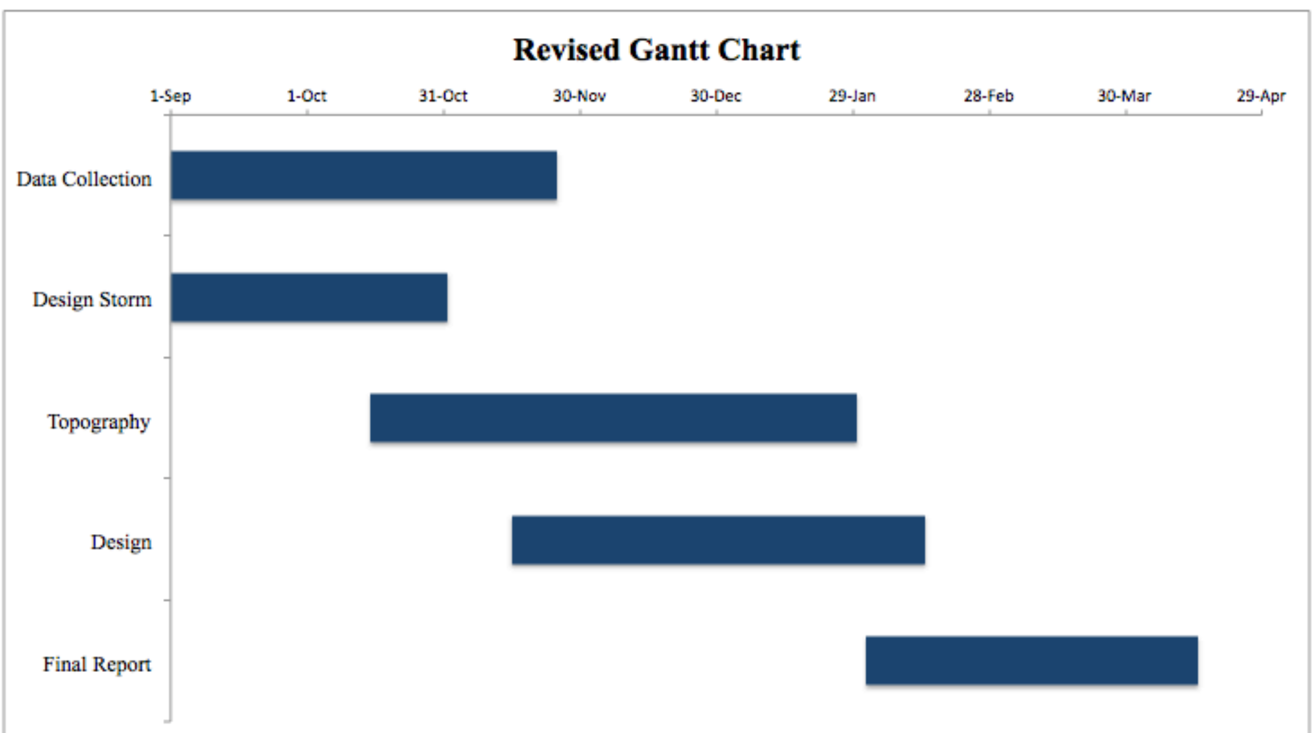


Figure IV2. Revised Gantt Chart 4870

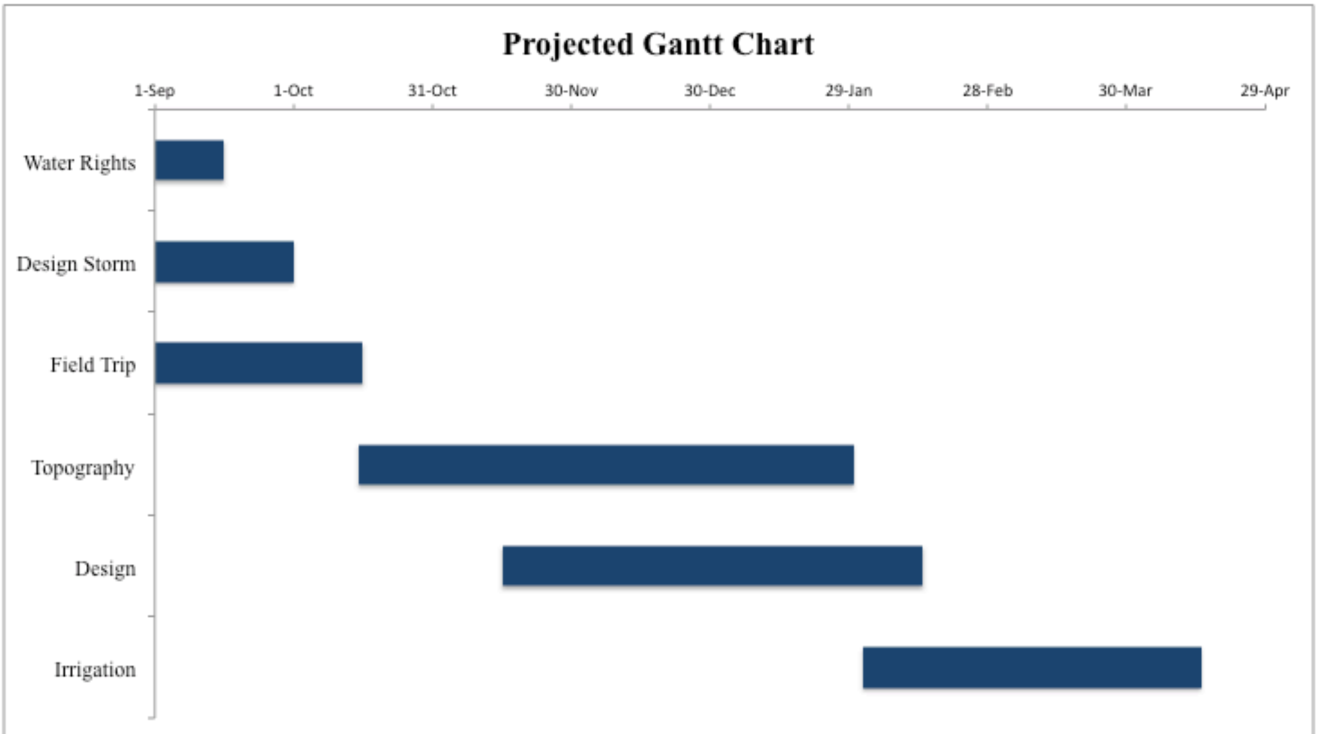


Figure IV3. Projected Gantt Chart

Appendix V: Photos

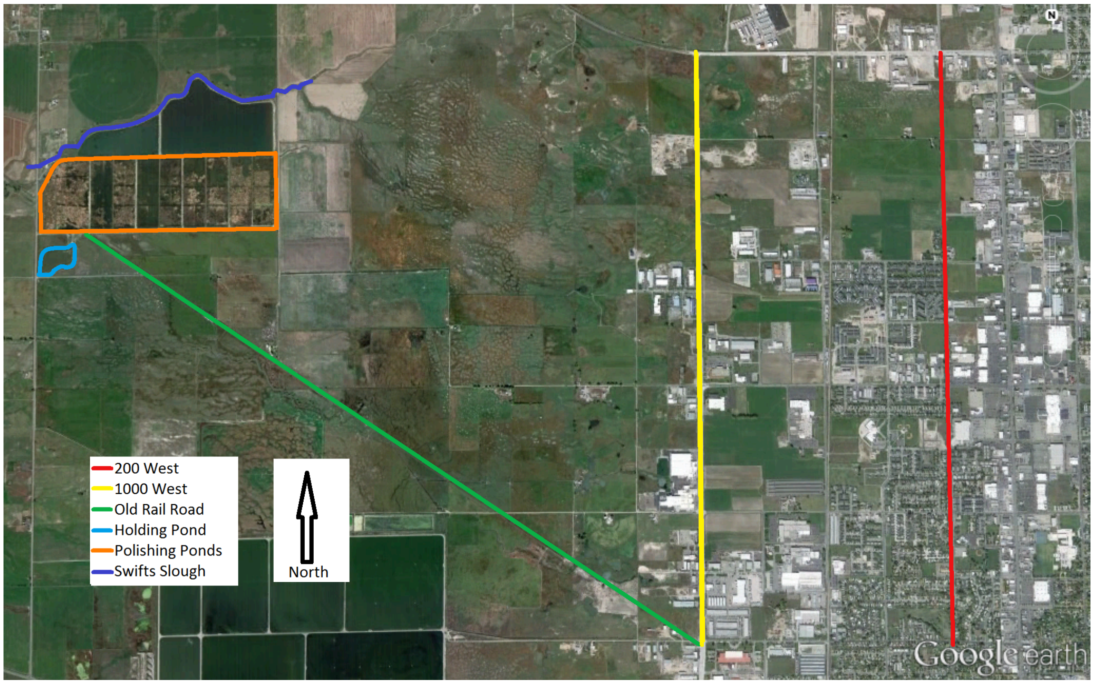


Figure V1. Aerial Photo of Area of Interest Current Conditions

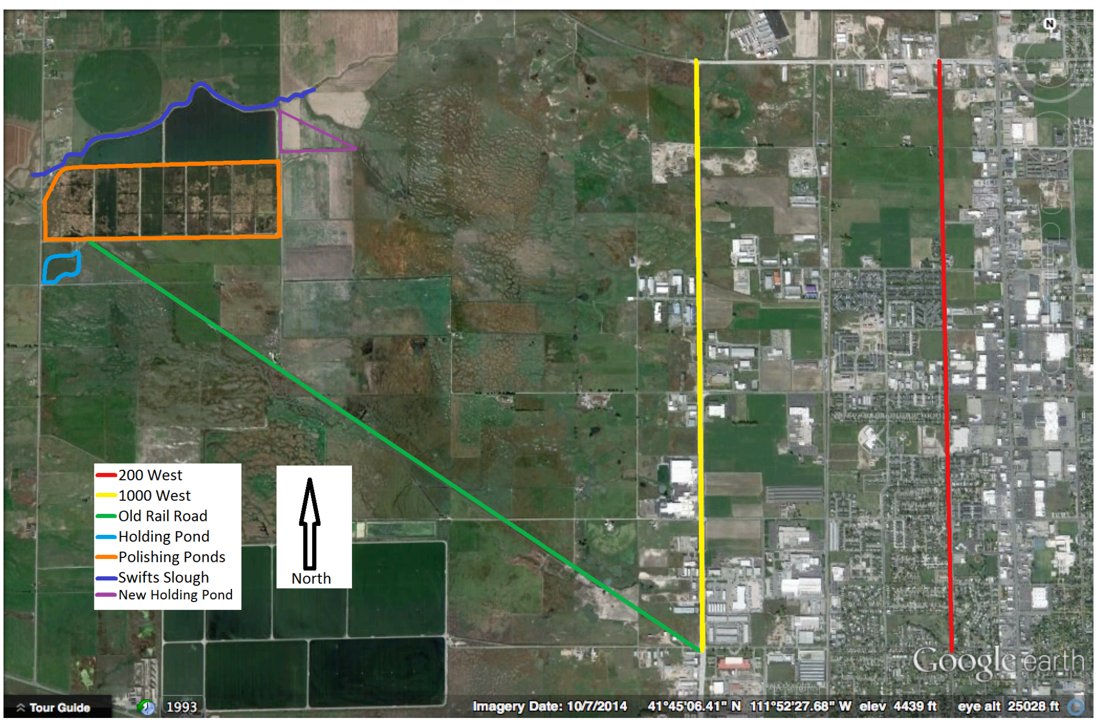


Figure V2. Aerial Photo of Area of Interest New Holding Pond

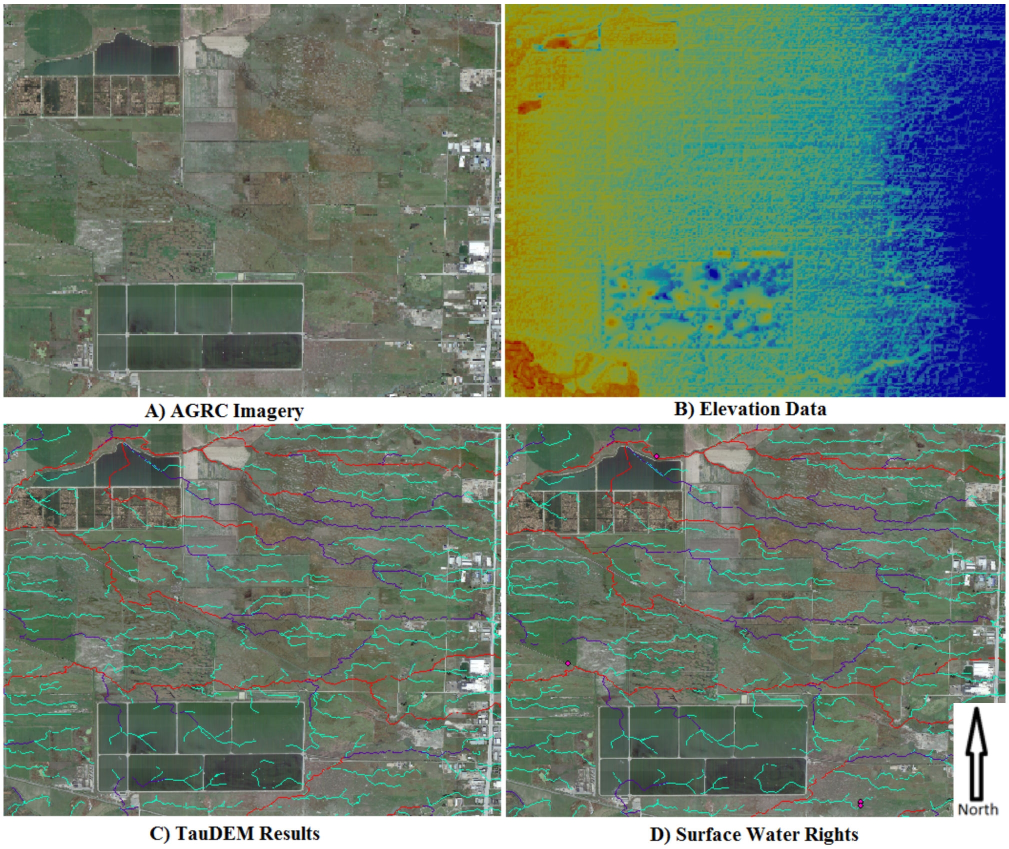


Figure V3. AGRC, Elevation, TauDEM, Surface Water Rights

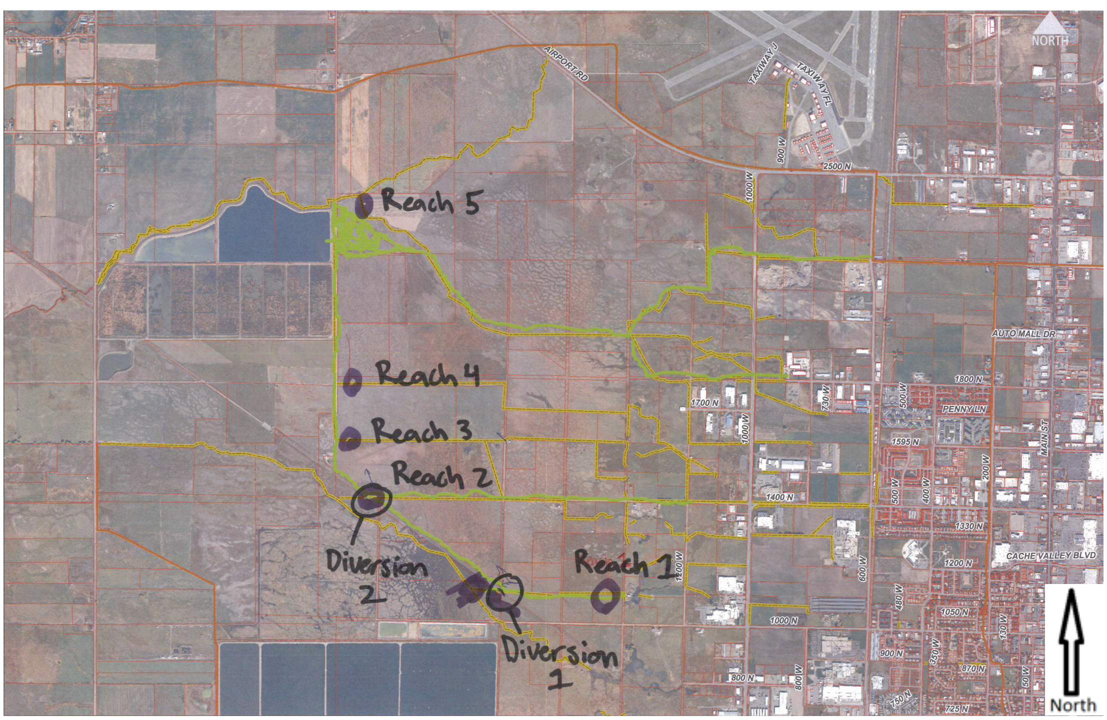


Figure V4. Channel Reaches

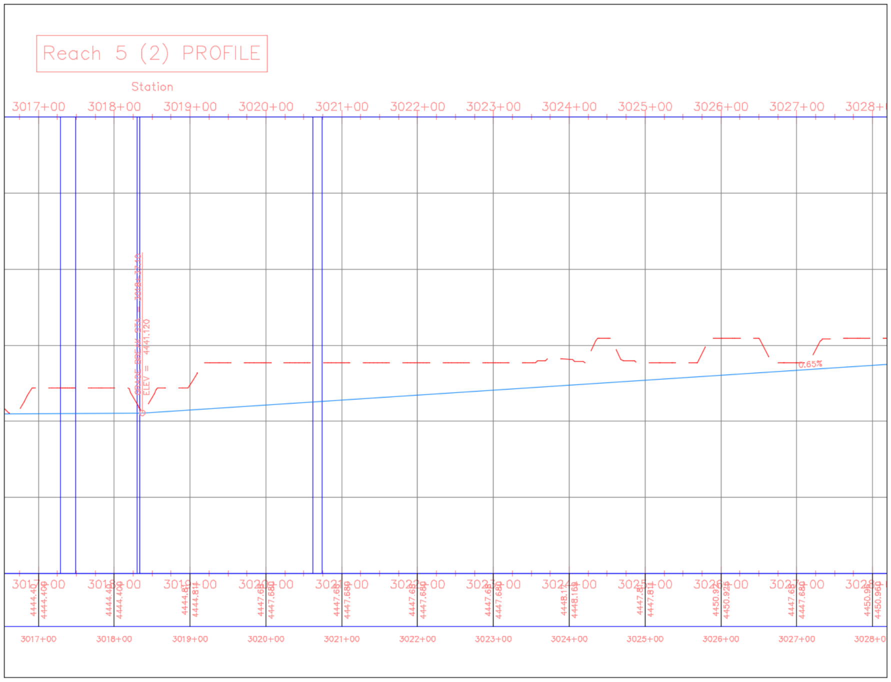


Figure V5. Profile Plot

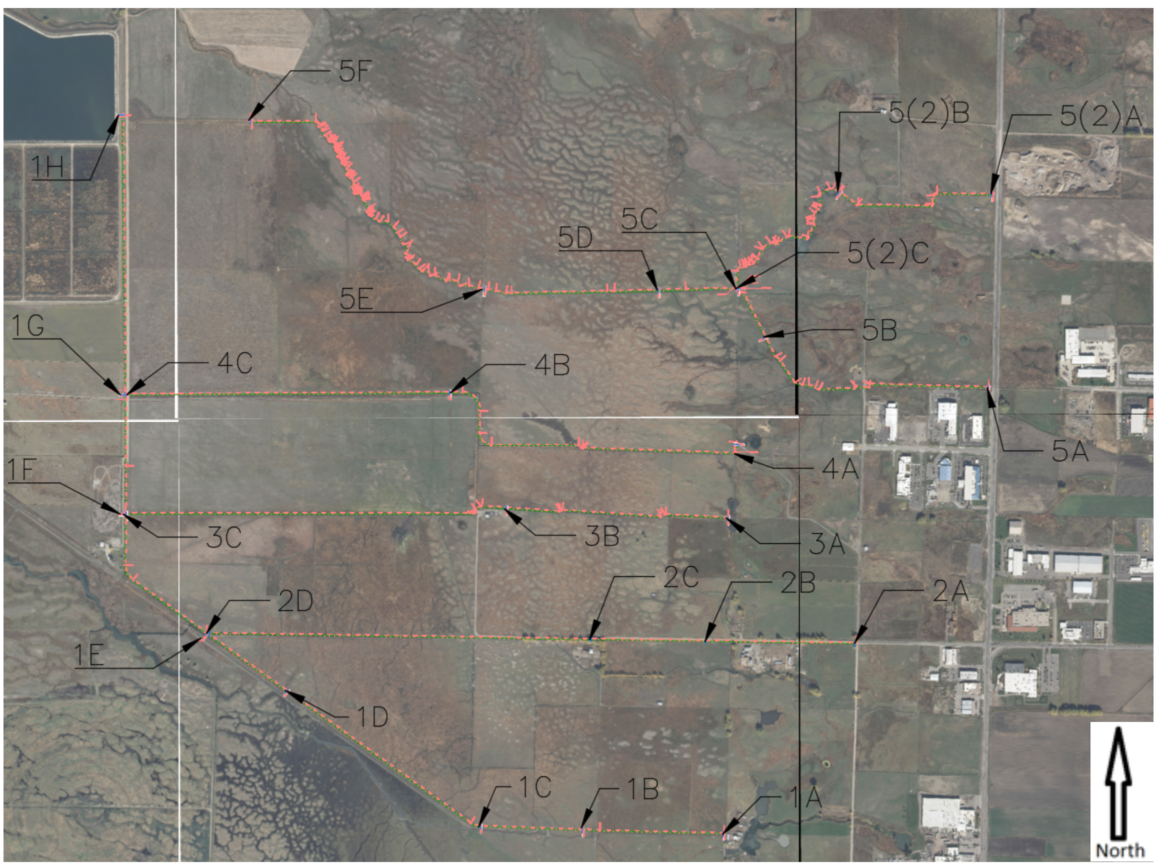


Figure V6. Channel Cross Sections

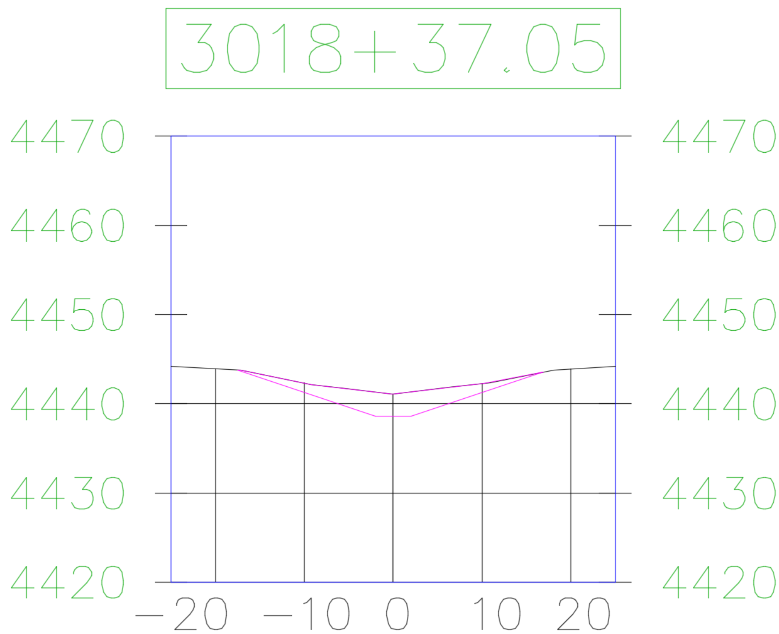


Figure V7. Section View

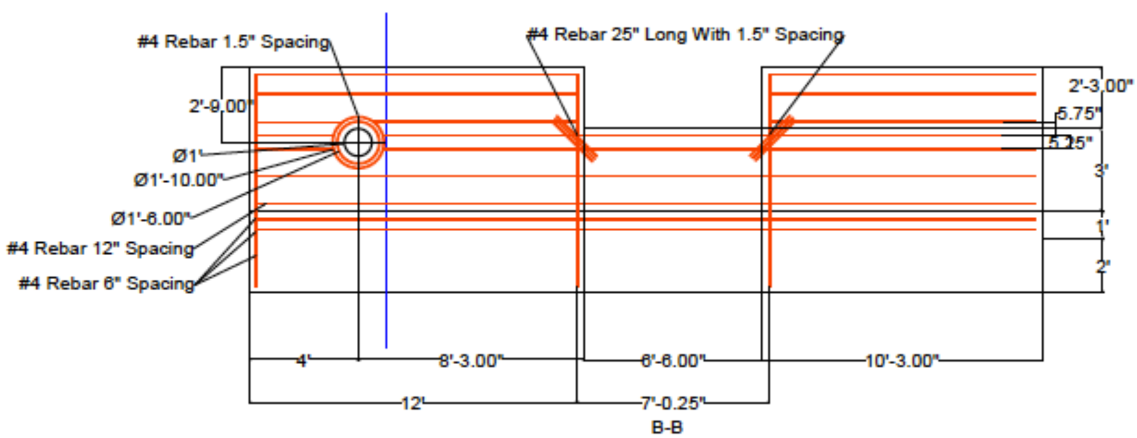


Figure V8. Structure 1 View BB

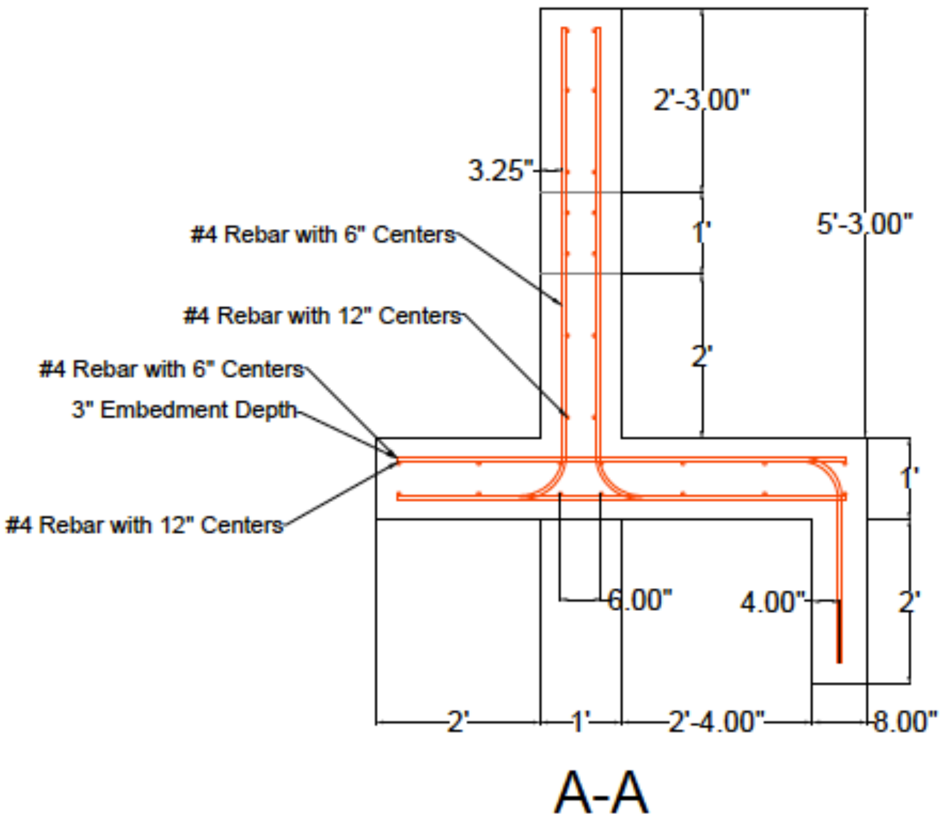


Figure V9. Structure 1 View AA

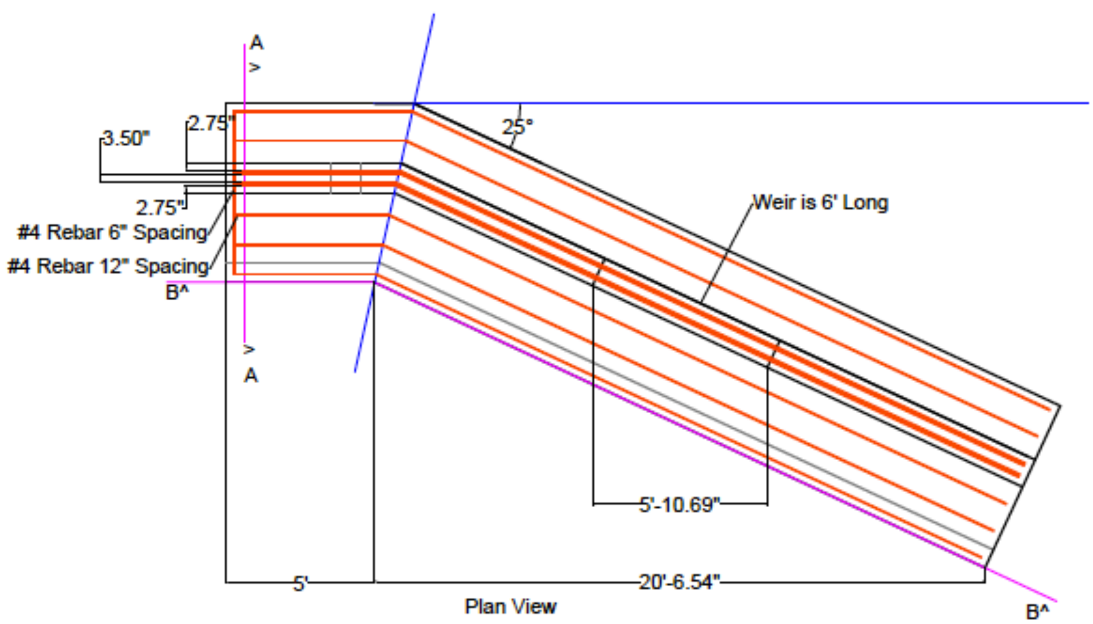


Figure V10. Structure 1 Plan View

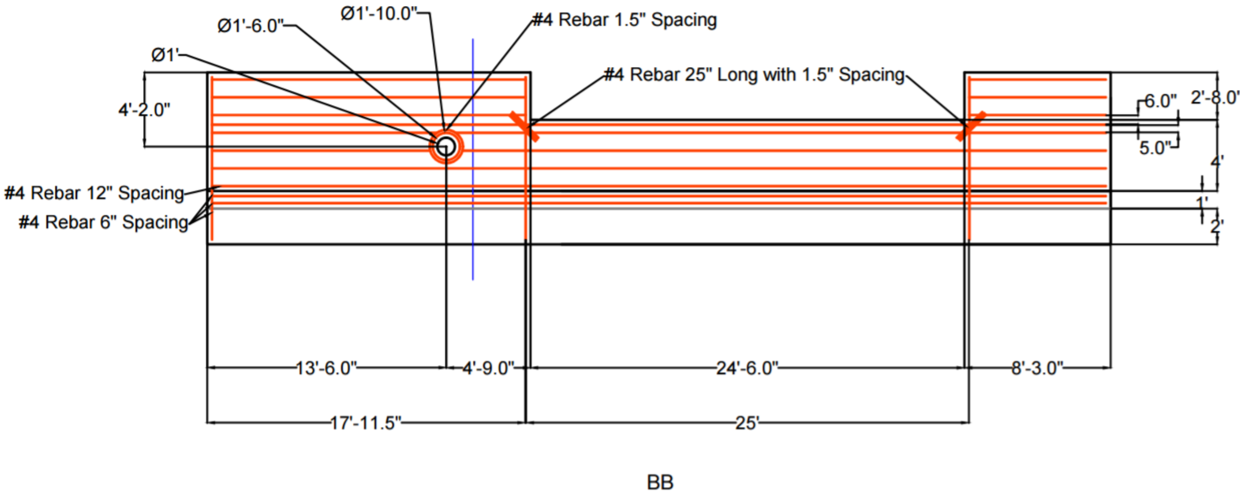


Figure V11. Structure 2 View BB

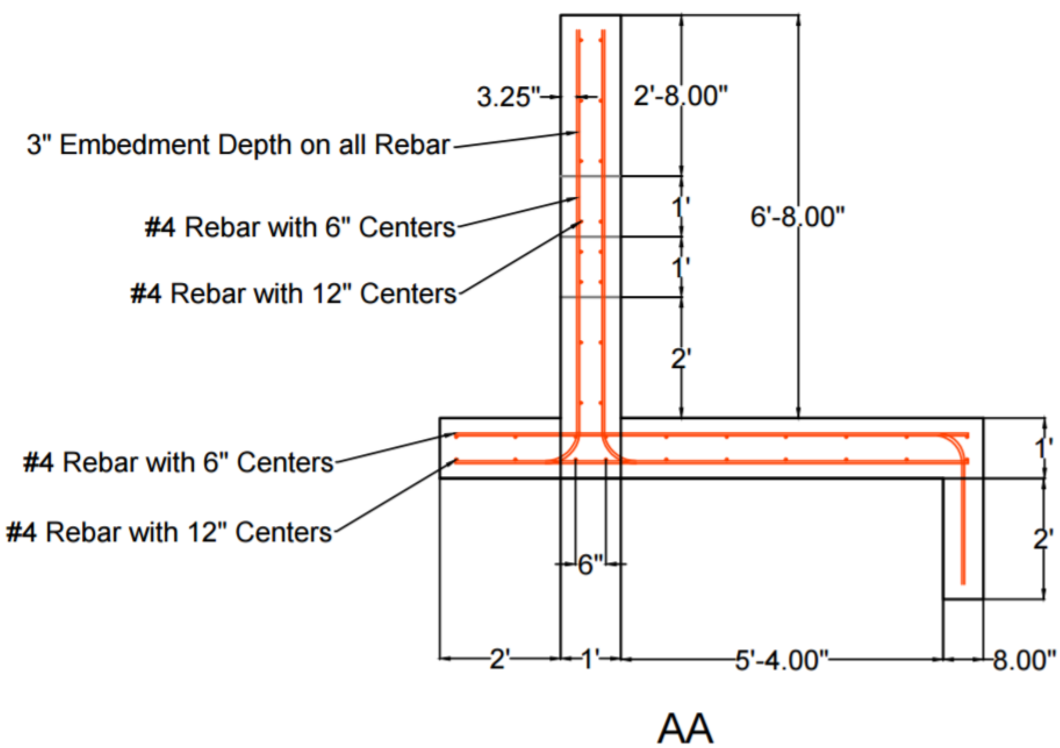


Figure V12. Structure 2 View AA

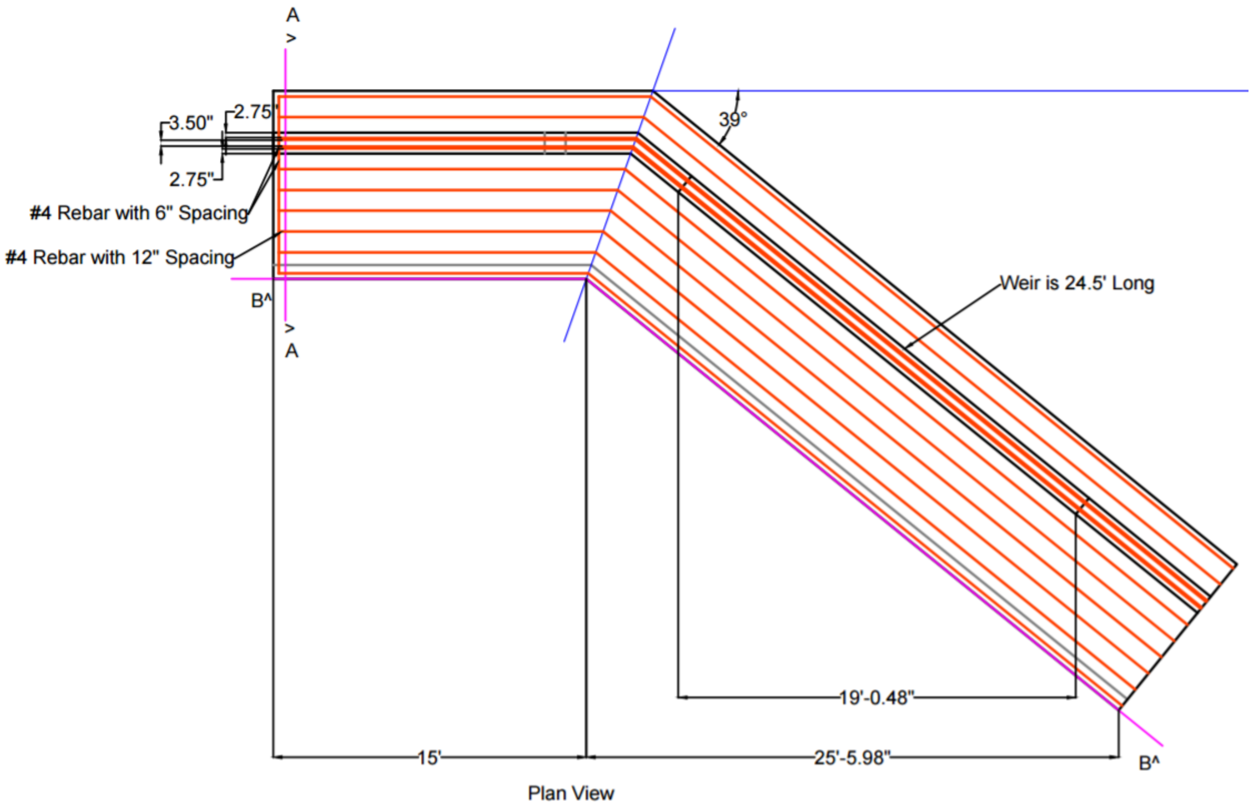


Figure V13. Structure 2 Plan View

Figure V14. Reach 1 Measurement Location

Figure V15. Reach 2 at Diversion Above Measurement Location

Figure V16. Reach 3 Measurement Location


Figure V17. Reach 4 Measurement Location


Figure V18. Reach 5 Measurement Location

Appendix VI: Detailed Calculations

Flow Calculations

Reach 1:

Velocity:

Ping Pong Balls:

$Time_{1A} := 11.8\ s \quad Time_{1B} := 12.8\ s \quad Time_{1C} := 11.3\ s \quad L_1 := 16\ ft$

$$Velocity_{1A} := \frac{L_1}{Time_{1A}} \cdot .8 = 1.0847 \frac{ft}{s}$$

$$Velocity_{1B} := \frac{L_1}{Time_{1B}} \cdot .8 = 1 \frac{ft}{s}$$

$$Velocity_{1C} := \frac{L_1}{Time_{1C}} \cdot .8 = 1.1327 \frac{ft}{s}$$

Cross Sections:

Culvert

$Y_{1A} := 16\ in \quad Y_{1B} := 7\ in \quad D := 24\ in$

$$\theta_{1A} := acos\left(1 - 2 \cdot \frac{Y_{1A}}{D}\right) = 1.9106$$

$$Area_{1A} := \frac{D^2}{4} \cdot \left(\theta_{1A} - sin\left(\theta_{1A}\right) \cdot cos\left(\theta_{1A}\right)\right) = 2.2249\ ft^2$$

$$\theta_{1B} := acos\left(1 - 2 \cdot \frac{Y_{1B}}{D}\right) = 1.141$$

$$Area_{1B} := \frac{D^2}{4} \cdot \left(\theta_{1B} - sin\left(\theta_{1B}\right) \cdot cos\left(\theta_{1B}\right)\right) = 0.7622\ ft^2$$

$$Area_{avg1} := \frac{Area_{1A} + Area_{1B}}{2} = 1.4936\ ft^2$$

Flows:

$$Q_{1A} := Area_{avg1} \cdot Velocity_{1A} = 1.6201 \frac{ft^3}{s}$$

$$Q_{1B} := Area_{avg1} \cdot Velocity_{1B} = 1.4936 \frac{ft^3}{s}$$

$$Q_{1C} := Area_{avg1} \cdot Velocity_{1C} = 1.6918 \frac{ft^3}{s}$$

$$Q_1 := \frac{Q_{1A} + Q_{1B} + Q_{1C}}{3}$$

$$Q_1 = 1.6019 \frac{ft^3}{s}$$

Reach 2:

Velocity:

Dye:

$Plume_{2A} := 60\ s + 33\ s = 93\ s$ $L_2 := 100\ ft$

$Plume_{2B} := 60\ s + 58\ s = 118\ s$

$$Plume_{avg2} := \frac{Plume_{2A} + Plume_{2B}}{2} = 105.5\ s$$

$$Vel_{2A} := \frac{L_2}{Plume_{avg2}} = 0.9479 \frac{ft}{s}$$

Ping Pong Balls:

$Time_{2B} := 60\ s + 44\ s = 104\ s$

$Time_{2C} := 60\ s + 47\ s = 107\ s$

$$Vel_{2B} := \frac{L_2}{Time_{2B}} \cdot .8 = 0.7692 \frac{ft}{s} \qquad Vel_{2C} := \frac{L_2}{Time_{2C}} \cdot .8 = 0.7477 \frac{ft}{s}$$

Cross Section:

$B := 10\ ft$

$Y_{2A} := 6\ in$

Triangular cross section

$$Area_2 := \frac{B \cdot Y_{2A}}{2} = 2.5\ ft^2$$

Flows:

$$Q_{2A} := Area_2 \cdot Vel_{2A} = 2.3697 \frac{ft^3}{s}$$

$$Q_{2B} := Area_2 \cdot Vel_{2B} = 1.9231 \frac{ft^3}{s}$$

$$Q_{2C} := Area_2 \cdot Vel_{2C} = 1.8692 \frac{ft^3}{s}$$

$$Q_2 := \frac{Q_{2A} + Q_{2B} + Q_{2C}}{3}$$

$$Q_2 = 2.054 \frac{ft^3}{s}$$

Reach 3:

Velocity:

$Plume_{3A} := 60\ s + 1\ s = 61\ s$

$L_3 := 26\ ft$

$Plume_{3B} := 60\ s + 34\ s = 94\ s$

$$Plume_{avg3} := \frac{Plume_{3A} + Plume_{3B}}{2} = 77.5\ s$$

$$Vel_{3A} := \frac{L_3}{Plume_{avg3}} = 0.3355 \frac{ft}{s}$$

Cross Section:

$Y_{3A} := 4\ in$

$Y_{3B} := 5\ in$

$$Y_{avg3} := \frac{Y_{3A} + Y_{3B}}{2} = 4.5\ in$$

$B_{3A} := 6\ ft$

$Area_{3A} := B_{3A} \cdot Y_{avg3} = 2.25\ ft^2$

$Y_{3C} := 6\ in$

$B_{3B} := 6\ ft$

$Area_{3B} := Y_{3C} \cdot B_{3B} = 3\ ft^2$

$$Area_{avg3} := \frac{Area_{3A} + Area_{3B}}{2} = 2.625\ ft^2$$

Flows:

$Q_3 := Vel_{3A} \cdot Area_{avg3}$

$$Q_3 = 0.8806 \frac{ft^3}{s}$$

Reach 4:

Velocity:

$Plume_{4A} := 5 \cdot 60\ s + 57\ s = 357\ s$

$L_4 := 50\ ft$

$Plume_{4B} := 8 \cdot 60\ s + 4\ s = 484\ s$

$$Plume_{avg4} := \frac{Plume_{4A} + Plume_{4B}}{2} = 420.5\ s$$

$$Vel_4 := \frac{L_4}{Plume_{avg4}} = 0.1189 \frac{ft}{s}$$

Cross Section:

$Y_{4A} := 2.5\ ft$

$B_{4A} := 14\ ft$

$Area_{4A} := B_{4A} \cdot Y_{4A} = 35\ ft^2$

$Y_{4B} := 2.5\ ft$

$B_{4B} := 14\ ft$

$Area_{4B} := Y_{4B} \cdot B_{4B} = 35\ ft^2$

$$Area_{avg4} := \frac{Area_{4A} + Area_{4B}}{2} = 35\ ft^2$$

Flows:

$Q_4 := Vel_4 \cdot Area_{avg4}$

$$Q_4 = 4.1617 \frac{ft^3}{s}$$

Reach 5:

Velocity:

Dye:

$Plume_{5A} := 60\,s + 37\,s = 97\,s$

$L_5 := 100\,ft$

$Plume_{5B} := 2 \cdot 60\,s + 3\,s = 123\,s$

$$Plume_{avg5} := \frac{Plume_{5A} + Plume_{5B}}{2} = 110\,s$$

$$Vel_{5A} := \frac{L_5}{Plume_{avg5}} = 0.9091\,\frac{ft}{s}$$

Ping Pong:

$Time_{5A} := 60\,s + 38\,s = 98\,s$

$Time_{5B} := 60\,s + 37\,s = 97\,s$

$$Vel_{5B} := \frac{L_5}{Time_{5A}} \cdot .8 = 0.8163\,\frac{ft}{s} \qquad Vel_{5C} := \frac{L_5}{Time_{5B}} \cdot .8 = 0.8247\,\frac{ft}{s}$$

Area:

$B_{5A} := 78\,in$

$Y_{5A} := 6\,in$

$B_{5B} := 84\,in$

$Y_{5B} := 10\,in$

$Area_{5A} := B_{5A} \cdot Y_{5A} = 3.25\,ft^2$

$Area_{5B} := B_{5B} \cdot Y_{5B} = 5.8333\,ft^2$

$$Area_{avg5} := \frac{Area_{5A} + Area_{5B}}{2} = 4.5417\,ft^2$$

Flows:

$$Q_{5A} := Vel_{5A} \cdot Area_{avg5} = 4.1288\,\frac{ft^3}{s}$$

$$Q_{5B} := Vel_{5B} \cdot Area_{avg5} = 3.7075\,\frac{ft^3}{s}$$

$$Q_{5C} := Vel_{5C} \cdot Area_{avg5} = 3.7457\,\frac{ft^3}{s}$$

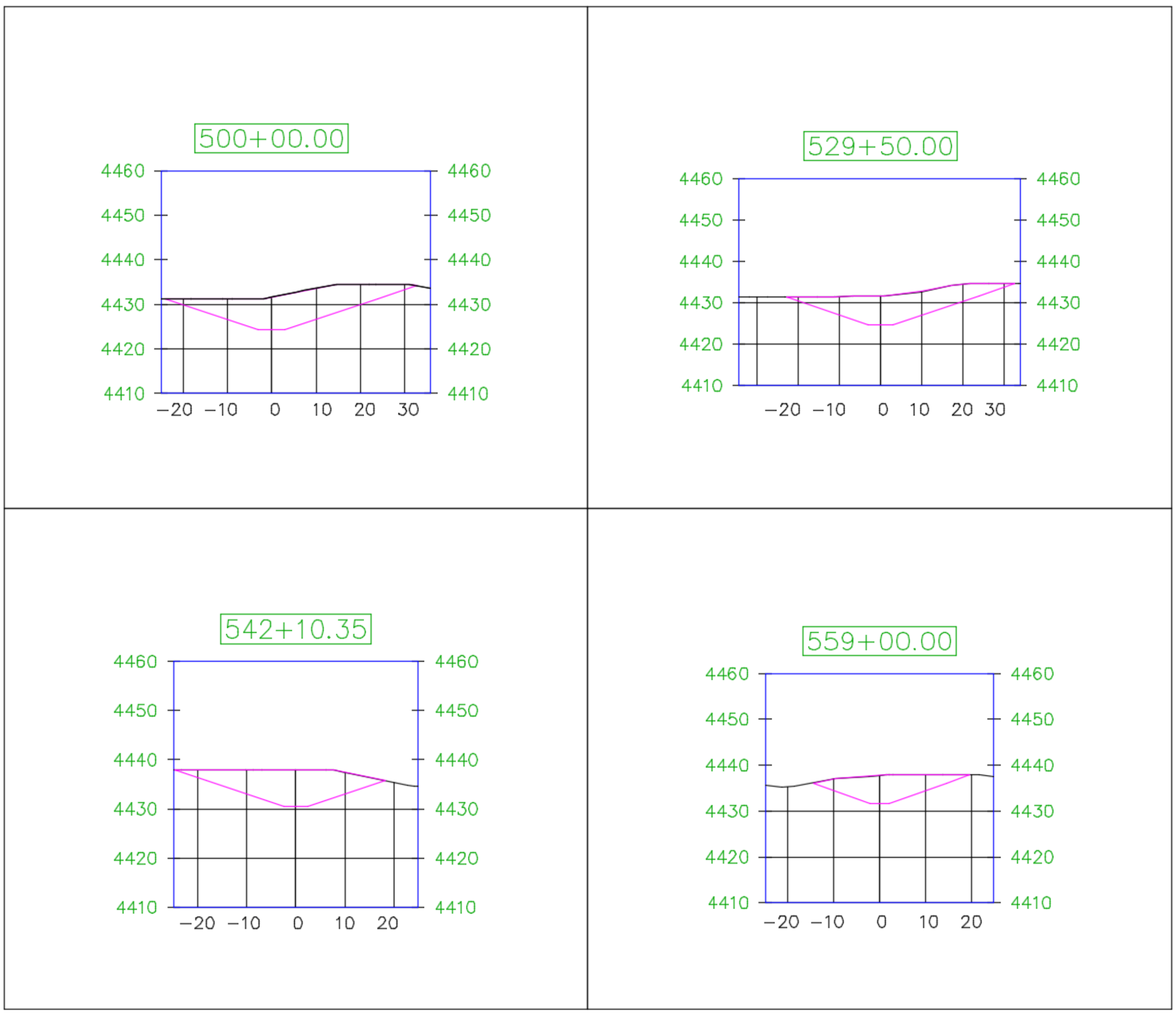
$$Q_5 := \frac{Q_{5A} + Q_{5B} + Q_{5C}}{3}$$

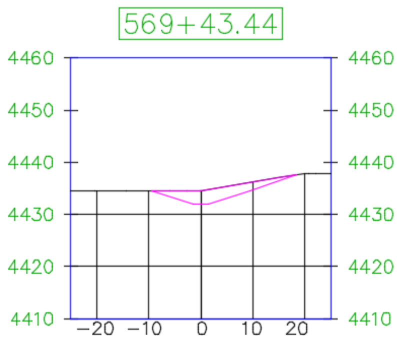
$$Q_5 = 3.8607\,\frac{ft^3}{s}$$

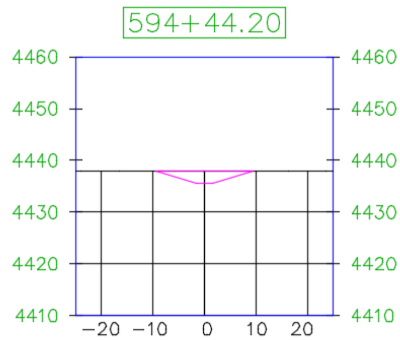
Channel Design Calculations

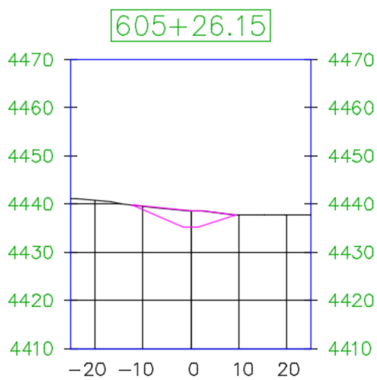
Reach 1:

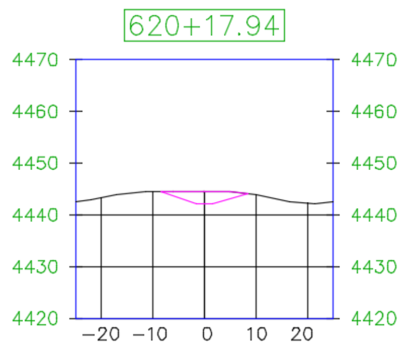
Reach 1						
Plan View Key	Station	Flow (cfs)	Slope	Base (ft)	Depth (ft)	Side Slope
1A	620+18	18.9	0.0022	3	2.3	3
1B	605+26	18.9	0.0009	3	2.6	3
1C	594+44	19.5	0.0009	3	2.6	3
1D	569+43	19.5	0.0008	3	2.7	3
1E	559+00	72.74	0.0008	4	4.2	3
1F	542+00	131.95	0.0008	5	5.3	3
1G	529+50	211.19	0.0003	6	7.0	3
1H	500+00	211.19	0.0003	6	7.0	3




569+43.44
4460
4450
4440
4430
4420
4410
−20 −10 0 10 20


594+44.20
4460
4450
4440
4430
4420
4410
−20 −10 0 10 20


605+26.15
4470
4460
4450
4440
4430
4420
4410
−20 −10 0 10 20

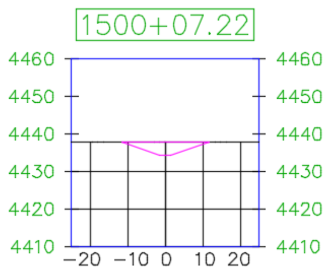

620+17.94
4470
4460
4450
4440
4430
4420
−20 −10 0 10 20

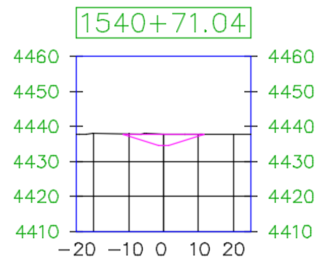
Reach 2:

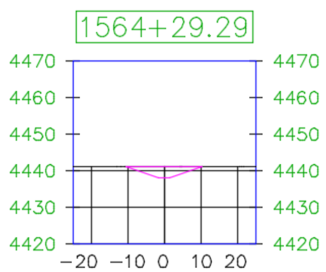
Reach 2						
Plan View Key	Station	Flow (cfs)	Slope	Base (ft)	Depth (ft)	Side Slope
2A	1068+63	55.78	0.0055	3	3.2	3
2B	1052+81	55.78	0.0028	3	3.4	3
2C	1040+67	55.78	0.0008	3	4.0	3
2D	1000+00	55.78	0.0008	3	4.0	3

Reach 3:

Reach 3						
Plan View Key	Station	Flow (cfs)	Slope	Base (ft)	Depth (ft)	Side Slope
3A	1564+29	36.9	0.0014	3	3.0	3
3B	1540+71	36.9	0.0008	3	3.4	3
3C	1500+00	36.9	0.0008	3	3.4	3

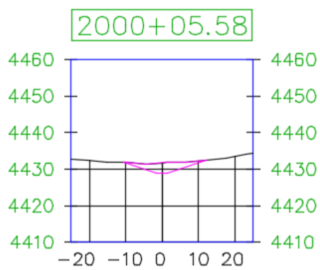


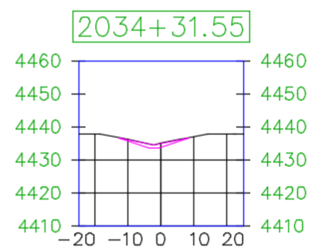


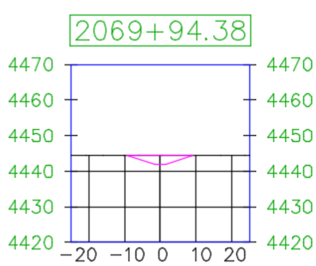


Reach 4:

Reach 4						
Plan View Key	Station	Flow (cfs)	Slope	Base (ft)	Depth (ft)	Side Slope
4A	2069+94	22.65	0.0017	3	2.6	3
4B	2034+31	22.65	0.0005	3	3.0	3
4C	2000+00	22.65	0.0005	3	3.0	3

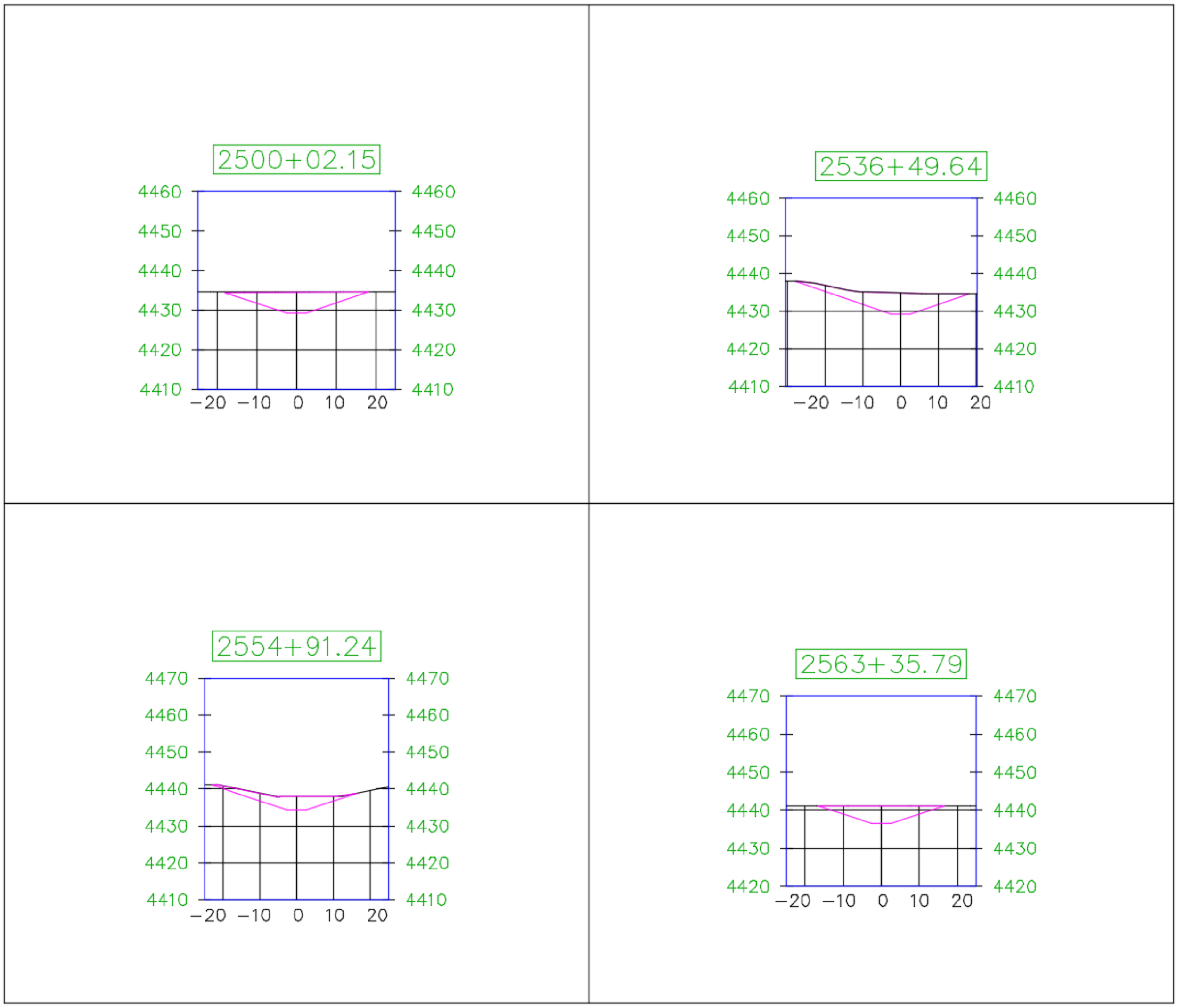


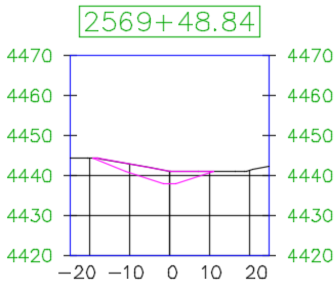




Reach 5:

Reach 5						
Plan View Key	Station	Flow (cfs)	Slope	Base (ft)	Depth (ft)	Side Slope
5A	2596+26	43.44	0.0049	3	2.9	3
5B	2569+48	43.44	0.0023	3	3.2	3
5C	2563+36	140.28	0.0023	5	4.7	3
5D	2554+91	140.28	0.0026	5	4.6	3
5E	2536+49	140.28	0.0009	5	5.2	3
5F	2500+00	140.28	0.0009	5	5.2	3

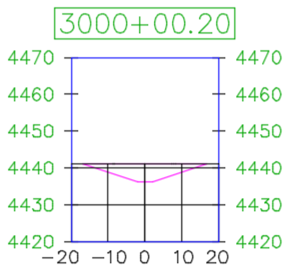


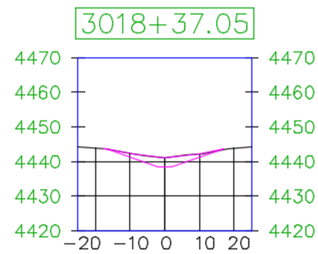

2569+48.84
4470
4460
4450
4440
4430
4420
-20 -10 0 10 20

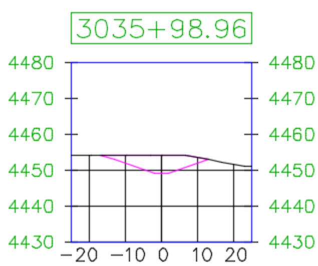

2596+23.42
4480
4470
4460
4450
4440
4430
-20 -10 0 10 20

Reach 5(2):

Reach 5 (2)						
Plan View Key	Station	Flow (cfs)	Slope	Base (ft)	Depth (ft)	Side Slope
5(2)A	3036+00	97.79	0.0065	3	3.7	3
5(2)B	3018+37	97.79	0.0006	4	5.0	3
5(2)C	3000+00	97.79	0.0006	4	5.0	3







Diversion Structure Calculations

Structure 1

Channel Dimensions:

$b := 3\ ft$ $m := 3$ $y_0 := 1.38\ ft$ $FB := 1.25\ ft$ $d_t := 2.63\ ft$ $Q := 19.5\ \frac{ft^3}{sec}$

$s := 0.009$ $y_0 := 1.5\ ft$ $t_w := 18.77\ ft$ $d_t := 3\ ft$ $g := 32.2\ \frac{ft}{sec^2}$

$T_w := b + 2 \cdot (m \cdot d_t) = 21\ ft$ $W_c := 2\ ft$ Width of existing channel

For construction purposes, y0 is assumed to be 1.5 ft and total depth,is 3 ft.

Head Gate:

$D := 1\ ft$ $h_o := \frac{y_0 - .5\ ft}{2} = 0.5\ ft$ Orifice will be 6 inches from the bottom. Head is definded as the head at the midpoint of the orifice. Flow is assumed to fill the orifice.

$Q_o = 0.7 \cdot A_o \cdot \sqrt{2 \cdot g \cdot h}$

$A_o := D^2 \cdot \frac{\pi}{4} = 0.7854\ ft^2$

$Q_o := 0.7 \cdot A_o \cdot \sqrt{2 \cdot g \cdot h_o} = 3.1197\ \frac{ft^3}{sec}$

Weir:

Weir crest wil be at y0. 1 ft of flow is assumed to be going over the weir. The most conservative assumption will be that the head gate is closed and that the weir will need to pass the entire flow.

$Q_w = 3 \cdot L \cdot h_w^{1.5}$ $L = \frac{Q_w}{3 \cdot h_w^{1.5}}$

$Q_w := \frac{Q}{\frac{ft^3}{sec}}$ $h_w := 1$ (ft) Since the weir equation is not homogeneous, the values will need to be unitless.

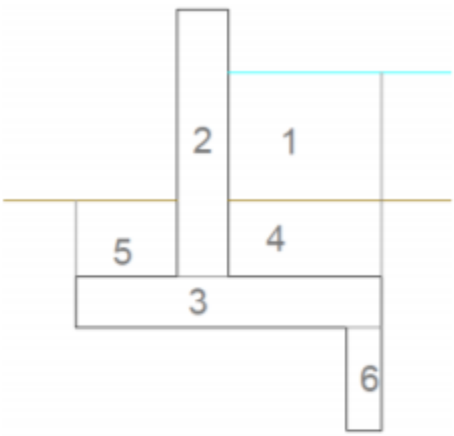
$L := \frac{Q_w}{3 \cdot h_w^{1.5}}\ ft = 6.5\ ft$

Structure:

Assume: $\Phi := 30$ (deg) $\alpha := 0$ (deg) $k_a := 0.33$ $\gamma_{soil} := 100\ \frac{lb}{ft^3}$ $c' := 0\ \frac{lb}{ft^3}$ $k_p := 3$

$\gamma_{water} := 62.4\ \frac{lb}{ft^3}$ $\gamma_{concrete} := 150\ \frac{lb}{ft^3}$

$\gamma_w := \gamma_{water}$ $\gamma_c := \gamma_{concrete}$ $\gamma_s := \gamma_{soil}$



$H := 6.25\ ft$

$H' := 2.5\ ft$

$Width := 6\ ft$

$L_t := 2 \cdot 3\ ft + T_w + W_c = 29\ ft$ $L_t = 29\ ft$

$h_{cutoff} := 2\ ft$

$w_{cutoff} := 8\ in$

$h := 1\ ft$

$b_w := 12\ in$

Overturning:

Area

$A_1 := 3\ ft \cdot 4\ ft = 12\ ft^2$

$A_2 := 1\ ft \cdot 5.25\ ft = 5.25\ ft^2$

$A_3 := 1\ ft \cdot 6\ ft = 6\ ft^2$

$A_4 := 3\ ft \cdot 1.5\ ft = 4.5\ ft^2$

$A_5 := 2\ ft \cdot 1.5\ ft = 3\ ft^2$

$A_6 := 8\ in \cdot 2\ ft = 1.3333\ ft^2$

Weight

$W_1 := A_1 \cdot \gamma_w = 748.8\ \frac{lb}{ft}$

$W_2 := A_2 \cdot \gamma_c = 787.5\ \frac{lb}{ft}$

$W_3 := A_3 \cdot \gamma_c = 900\ \frac{lb}{ft}$

$W_4 := A_4 \cdot \gamma_s = 450\ \frac{lb}{ft}$

$W_5 := A_5 \cdot \gamma_s = 300\ \frac{lb}{ft}$

$W_6 := A_6 \cdot \gamma_c = 200\ \frac{lb}{ft}$

Moment Arm

$MA_1 := 3\ ft + 3 \cdot \frac{ft}{2} = 4.5\ ft$

$MA_2 := 2\ ft + 1 \cdot \frac{ft}{2} = 2.5\ ft$

$MA_3 := 6 \cdot \frac{ft}{2} = 3\ ft$

$MA_4 := 3\ ft + 3 \cdot \frac{ft}{2} = 4.5\ ft$

$MA_5 := \frac{2\ ft}{2} = 1\ ft$

$MA_6 := 5\ ft + 1 \cdot \frac{ft}{2} = 5.5\ ft$

$W := W_1 + W_2 + W_3 + W_4 + W_5 + W_6 = 3386.3\ \frac{lb}{ft}$

Moment

$M_1 := W_1 \cdot MA_1 = 3369.6\ lb$

$M_2 := W_2 \cdot MA_2 = 1968.75\ lb$

$M_3 := W_3 \cdot MA_3 = 2700\ lb$

$M_4 := W_4 \cdot MA_4 = 2025\ lb$

$M_5 := W_5 \cdot MA_5 = 300\ lb$

$M_6 := W_6 \cdot MA_6 = 1100\ lb$

$M_R := M_1 + M_2 + M_3 + M_4 + M_5 + M_6 = 11463.35\ lb$

$P_c := .5 \cdot k_p \cdot h_{cutoff}^2 \cdot \gamma_s = 600\ \frac{lb}{ft}$

$P_h := .5 \cdot k_a \cdot H'^2 \cdot \gamma_s = 103.125\ \frac{lb}{ft}$

$P_w := .5 \cdot (H - 1.25\ ft)^2 \cdot \gamma_w = 780\ \frac{lb}{ft}$

Soil forces cancel out

$M_D := p_w \cdot \frac{H - 1.25\,ft}{3} + \frac{p_c \cdot 2 \cdot h_{cutoff}}{3} = 2100\,lb$

$FS_o := \frac{M_R}{M_D} = 5.4587$ 5.4587>1.5

Sliding:

Assume vertical weight is uniformly distrubuted

$W_s := \frac{W}{Width} = 564.3833\,\frac{lb}{ft^2}$

$W_{cutoff} := \frac{h_{cutoff}^{\;2} \cdot \gamma_s \cdot .5 \cdot k_p}{Width} = 100\,\frac{lb}{ft^2}$

$F_r := k_a \cdot W_s + W_{cutoff} = 286.2465\,\frac{lb}{ft^2}$

$F_s := \frac{p_w}{Width} = 130\,\frac{lb}{ft^2}$

$FS_s := \frac{F_r}{F_s} = 2.2019$ 2.2019>2

Resisting Force is also in the banks

$W_e := 3\,ft$ Width of embedment on each side

$D_e := 5.25\,ft$ Depth of embedment

$p_e := .5 \cdot k_a \cdot D_e^{\;2} \cdot \gamma_s = 454.7813\,\frac{lb}{ft}$

$F_e := 2 \cdot 3\,ft \cdot p_e = 2728.6875\,lb$ Total resisting force from the embedment

$F_{eperfoot} := \frac{F_e}{L_t \cdot Width} = 15.6821\,\frac{lb}{ft^2}$

$F_{rn} := F_r + F_{eperfoot} = 301.9286\,\frac{lb}{ft^2}$

$FS_{sn} := \frac{F_{rn}}{F_s} = 2.3225$

Bearing Capacity:

$M_{net} := M_R - M_D = 9363.35\,lb$

$M_{net} = W \cdot X_{bar}$ $X_{bar} = \frac{M_{net}}{W}$ $e = \frac{B}{2} - X_{bar}$

$q = \frac{W}{A} \pm \frac{M_{net} \cdot y}{I}$ $\left(I = \frac{w \cdot L^3}{12}\right) = \frac{B^3}{12}$ $w = 1\ ft$ $\left(q_{max} = q_{toe}\right) = \frac{W}{B} + \frac{e \cdot W \cdot \frac{B}{2}}{\frac{B^3}{12}}$ $q_{toe} = \frac{W}{B} \cdot \left(1 - \frac{6 \cdot e}{B}\right)$

$X_{bar} := \frac{M_{net}}{W} = 2.7651\ ft$

$e := \frac{Width}{2} - X_{bar} = 0.2349\ ft$

$q_{toe} := \frac{W}{Width} \cdot \left(1 + \frac{6 \cdot e}{Width}\right) = 696.975 \frac{lb}{ft^2}$

$q_{heel} := \frac{W}{Width} \cdot \left(1 - \frac{6 \cdot e}{Width}\right) = 431.7917 \frac{lb}{ft^2}$

$\psi = atan\left(\frac{P_h}{W}\right)$ $P_h := p_w + p_h = 883.125 \frac{lb}{ft}$

$\psi := atan\left(\frac{P_h}{W}\right) = 0.2551$ $\psi_d := \psi \cdot \frac{180}{\pi} = 14.6168$ (deg)

$B' := Width - 2 \cdot e = 5.5301\ ft$

$C' := 0$ Therefore:

$q_u = 0 + q \cdot N_q \cdot F_{qd} \cdot F_{qi} + .5 \cdot \gamma \cdot B' \cdot N_\gamma \cdot F_{\gamma d} \cdot F_{\gamma c}$

$\gamma := \gamma_s - \gamma_w = 37.6 \frac{lb}{ft^3}$

$D_s := 2.5\ ft$ depth of soil

$q := D_s \cdot \gamma = 94 \frac{lb}{ft^2}$

at $\Phi=30$, $N_c := 30.14$ $N_q := 18.4$ $N_\gamma := 22.4$

$F_{\gamma d} := 1$ $F_{qd} := 1$

$F_{qi} := \left(1 - \frac{\psi_d}{90}\right)^2 = 0.7016$

$F_{\gamma i} := \left(1 - \frac{\psi_d}{\Phi}\right)^2 = 0.2629$

$q_u := 0 + q \cdot N_q \cdot F_{qd} \cdot F_{qi} + .5 \cdot \gamma \cdot B' \cdot N_\gamma \cdot F_{\gamma d} \cdot F_{\gamma i} = 1825.7569 \frac{lb}{ft^2}$

$FS_{bc} := \frac{q_u}{q_{heel}} = 4.2283$ 4.2283>3

Steel:

Flexural:

$F_w := .5 \cdot (4\ ft)^2 \cdot \gamma_w = 499.2 \frac{lb}{ft}$

$F_s := .5 \cdot k_a \cdot H'^2 \cdot \gamma_s = 103.125 \frac{lb}{ft}$ Force of soil will cancel

$M_a := F_w \cdot 4 \cdot \frac{ft}{3} = 665.6\ lb$

$d := h - 3.5\ in = 8.5\ in$

$\beta_1 := 0.85$ $f'c := 4000\ psi$ $fy := 60000\ psi$

assume $\Phi := 0.9$

$$3 \cdot \sqrt{\frac{f'c}{psi}} \cdot \frac{b_w}{in} \cdot \frac{\frac{d}{in}}{\frac{fy}{psi}}\ in^2 = 0.3226\ in^2$$

As min is max of:

$$A_{smin} := \frac{200 \cdot \frac{b_w}{in} \cdot \frac{d}{in}}{\frac{fy}{psi}}\ in^2 = 0.34\ in^2$$

$$A_{smin} := 0.34\ in^2$$

$a = \frac{A_s \cdot fy}{0.85 \cdot f'c \cdot b_w}$ $M_a = \Phi \cdot M_n$ $\frac{M_a}{\Phi} = M_n$ $M_n := \frac{M_a}{\Phi} = 739.5556\ lb$

$M_n = A_s \cdot fy \left(d - \frac{a}{2}\right)$ $M_n = A_s \cdot fy \left(d - \frac{A_s \cdot fy}{2 \cdot 0.85 \cdot f'c \cdot b_w}\right)$ $A_s \cdot fy \left(d - \frac{A_s \cdot fy}{2 \cdot 0.85 \cdot f'c \cdot b_w}\right) - M_n = 0$

$A_s := .001450323\ in^2$

$M_n := \frac{M_a}{\Phi} = 739.5556\ lb$

$$\frac{A_s}{in^2} \cdot \frac{fy}{psi} \cdot \left(\frac{d}{in} - \frac{\frac{A_s \cdot fy}{psi\ in^2}}{2 \cdot 0.85^2 \cdot \frac{f'c}{psi} \cdot \frac{b_w}{in}}\right) - \frac{M_n}{lb} = -4.7619 \cdot 10^{-7}$$

As min governs

$A_s := A_{smin} = 0.34\ in^2$

Use 2 no 4 bars

$d_b := 0.5\ in$ $A_b := 0.20\ in^2$

$A_s := 2 \cdot A_b = 0.4\ in^2$

Clear Space: $\frac{(12\ in - 2 \cdot 3\ in - 2 \cdot .375\ in - 2 \cdot d_b)}{1} = 4.25\ in$ >1 in

$d_t := 12\ in - 3\ in - .375\ in - d_b = 8.125\ in$

$a := \frac{A_s \cdot fy}{0.85 \cdot f'c \cdot b_w} = 0.5882\ in$

$c := \frac{a}{\beta_1} = 0.692\ in$

$\frac{c}{d_t} = 0.0852$ < 0.375 Therefore $\Phi := 0.9$

$\Phi M_n := \Phi \cdot A_s \cdot fy \cdot \left(d_t - \frac{a}{2}\right) = 14.0956\ ksi\ in^2\ ft$

$\Phi M_n := \frac{\Phi M_n \cdot 10^3}{ksi\ in^2\ ft}\ lb\ ft = 14095.5882\ lb\ ft$

$M_a := M_a \cdot 1\ ft = 665.6\ lb\ ft$ ΦMn<Ma

Shear:

$V_{max} := F_w + F_s = 602.325\ \frac{lb}{ft}$ $\Phi := 0.75$

$\Phi V_c := \Phi \cdot 2 \cdot \sqrt{\frac{f'c}{psi}} \cdot \frac{b_w}{in} \cdot \frac{d_t}{in}\ lb = 9249.6622\ lb$

$\frac{\Phi V_c}{(2)} = 4624.8311\ lb$

$\frac{\Phi V_c}{2} > V_{max}$ No stirrups requried

Footing: M positive CCW

$q_{toe} = 696.975\ \frac{lb}{ft^2}$

$q_{heel} = 431.7917 \frac{lb}{ft^2}$

$q_{diff} := q_{toe} - q_{heel} = 265.1833 \frac{lb}{ft^2}$

$M_{soilbc} := \frac{Width^2}{2} \cdot q_{heel} + \frac{(Width)^2 \cdot 1}{2 \cdot 3} \cdot q_{diff} = 9363.35\ lb$

$M_{soiltop} := \frac{H'^2 \cdot \gamma_s \cdot k_a}{2} \cdot \left(H' \cdot \frac{1}{3} + h\right) - \frac{H'^2 \cdot \gamma_s \cdot k_a}{2} \cdot \left(H' \cdot \frac{1}{3} + h\right) = 0\ lb$

$M_{water} := F_w \cdot \left(\frac{4\ ft}{3} + h\right) = 1164.8\ lb$

$M_{weight} := -M_R = -11463.35\ lb$

$M_{cutoff} := \frac{h_{cutoff}^3 \cdot \gamma_s \cdot k_p \cdot 2}{3 \cdot 2} = 800\ lb$

$M_{at} := M_{soilbc} + M_{water} + M_{weight} + M_{cutoff} + M_{soiltop}$ Max moment will occur at the toe when moments in one direction are summed

$M_{design} := -1 \cdot (M_{soiltop} + M_{weight}) = 11463.35\ lb$

$d := h - 3.5\ in = 8.5\ in$

$\beta_1 := 0.85$ $f'c := 4000\ psi$ $fy := 60000\ psi$

assume $\Phi := 0.9$

As min is max of:

$$3 \cdot \sqrt{\frac{f'c}{psi}} \cdot \frac{b_w}{in} \cdot \frac{\frac{d}{in}}{\frac{fy}{psi}}\ in^2 = 0.3226\ in^2$$

$$A_{smin} := \frac{200 \cdot \frac{b_w}{in} \cdot \frac{d}{in}}{\frac{fy}{psi}}\ in^2 = 0.34\ in^2$$

$$A_{smin} := 0.34\ in^2$$

$a = \frac{A_s \cdot fy}{0.85 \cdot f'c \cdot b_w}$ $M_{design} = \Phi \cdot M_n$ $\frac{M_{design}}{\Phi} = M_n$ $M_n := \frac{M_{design}}{\Phi} = 12737.0556\ lb$

$M_n = A_s \cdot fy \cdot \left(d - \frac{a}{2}\right)$ $M_n = A_s \cdot fy \cdot \left(d - \frac{A_s \cdot fy}{2 \cdot 0.85 \cdot f'c \cdot b_w}\right)$ $A_s \cdot fy \cdot \left(d - \frac{A_s \cdot fy}{2 \cdot 0.85 \cdot f'c \cdot b_w}\right) - M_n = 0$

$A_s := .02838929363\ in^2$

$$\frac{A_s}{in^2}\cdot\frac{fy}{psi}\cdot\left(\frac{d}{in}-\frac{\frac{A_s\cdot fy}{psi\ in^2}}{2\cdot 0.85^2\cdot\frac{f'c}{psi}\cdot\frac{b_w}{in}}\right)-\frac{M_n}{lb}=1699.6528$$

As min governs

$A_s := A_{smin} = 0.34\ in^2$

Use 2 no 4 bars

$d_b := 0.5\ in$ $\quad A_b := 0.20\ in^2$

$A_s := 2\cdot A_b = 0.4\ in^2$

Clear Space: $\frac{(12\ in-2\cdot 3\ in-2\cdot .375\ in-2\cdot d_b)}{1}=4.25\ in$ $\quad$ >1 in

$d_t := 12\ in-3\ in-.375\ in-d_b = 8.125\ in$

$a := \frac{A_s\cdot fy}{0.85\cdot f'c\cdot b_w}=0.5882\ in$

$c := \frac{a}{\beta_1}=0.692\ in$

$\frac{c}{d_t}=0.0852$ < 0.375 Therefore $\Phi := 0.9$

$\Phi M_n := \Phi\cdot A_s\cdot fy\left(d_t-\frac{a}{2}\right)=14.0956\ ksi\ in^2\ ft$

$\Phi M_n := \frac{\Phi M_n\cdot 10^3}{ksi\ in^2\ ft}\ lb\ ft = 14095.5882\ lb\ ft$

$M_{design} := M_{design}\cdot 1\ ft = 11463.35\ lb\ ft$

ΦMn<Mdesign

Cutoff Wall:

$M_{cutoff} = 800\ lb$

$d := w_{cutoff} - 3.5\ in = 4.5\ in$

$\beta_1 := 0.85 \qquad f'c := 4000\ psi \qquad fy := 60000\ psi$

assume $\quad \Phi := 0.9$

$$3 \cdot \sqrt{\frac{f'c}{psi}} \cdot \frac{b_w}{in} \cdot \frac{\frac{d}{in}}{\frac{fy}{psi}}\ in^2 = 0.1708\ in^2$$

As min is max of:

$$A_{smin} := \frac{200 \cdot \frac{b_w}{in} \cdot \frac{d}{in}}{\frac{fy}{psi}}\ in^2 = 0.18\ in^2$$

$$A_{smin} := 0.18\ in^2$$

$a = \frac{A_s \cdot fy}{0.85 \cdot f'c \cdot b_w} \qquad M_{cutoff} = \Phi \cdot M_n \qquad \frac{M_{cutoff}}{\Phi} = M_n \qquad M_n := \frac{M_{cutoff}}{\Phi} = 888.8889\ lb$

$M_n = A_s \cdot fy \cdot \left(d - \frac{a}{2}\right) \qquad M_n = A_s \cdot fy \cdot \left(d - \frac{A_s \cdot fy}{2 \cdot 0.85 \cdot f'c \cdot b_w}\right) \qquad A_s \cdot fy \cdot \left(d - \frac{A_s \cdot fy}{2 \cdot 0.85 \cdot f'c \cdot b_w}\right) - M_n = 0$

$A_s := .003294267\ in^2$

$$\frac{A_s}{in^2} \cdot \frac{fy}{psi} \cdot \left(\frac{d}{in} - \frac{\frac{A_s \cdot fy}{psi\ in^2}}{2 \cdot 0.85^2 \cdot \frac{f'c}{psi} \cdot \frac{b_w}{in}}\right) - \frac{M_n}{lb} = -6.1609 \cdot 10^{-5}$$

As min governs

$A_s := A_{smin} = 0.18\ in^2$

Use 1 no 4 bars

$d_b := 0.5\ in \qquad A_b := 0.20\ in^2$

$A_s := 1 \cdot A_b = 0.2\ in^2$

$d_t := 8\ in - 3\ in - .375\ in - d_b = 4.125\ in$

$a := \frac{A_s \cdot fy}{0.85 \cdot f'c \cdot b_w} = 0.2941\ in$

$c := \frac{a}{\beta_1} = 0.346\ in$

$\frac{c}{d_t} = 0.0839$ < 0.375 Therefore $\Phi := 0.9$

$\Phi M_n := \Phi \cdot A_s \cdot fy \left(d_t - \frac{a}{2}\right) = 3.5801\ ksi\ in^2\ ft$

$\Phi M_n := \frac{\Phi M_n \cdot 10^3}{ksi\ in^2\ ft}\ lb\ ft = 3580.1471\ lb\ ft$

$M_{cutoff} := M_{cutoff} \cdot 1\ ft = 800\ lb\ ft$ ΦMn<Mcutoff

Volume:

$L_s := T_w + W_e \cdot 2 + 2\ ft = 29\ ft$

$Vol_1 := Width \cdot L_s \cdot h + (H - 1\ ft) \cdot L_s \cdot h + h_{cutoff} \cdot w_{cutoff} \cdot L_s = 13.5154\ yd^3$

$Vol_1 = 13.5154\ yd^3$

Steel (ACI min):

$\rho_{min} := 0.0018$ $D_t := 8.125\ in$

$A_s \equiv \rho \cdot b \cdot d$ $d_t = 4.125\ in$

$A_s := \rho_{min} \cdot b_w \cdot D_t = 0.1755\ in^2$ Foundation

$A_s := \rho_{min} \cdot b_w \cdot d_t = 0.0891\ in^2$ Cutoff wall

For both, use 1 no 4 bar

$l_d \equiv \frac{f_y \cdot \psi_t \cdot \psi_e \cdot d_b}{25 \cdot \lambda \cdot \sqrt{f'c}}$

$f_y := \frac{fy}{psi} = 60000$ $\lambda := 1.0$

$f'c := \frac{f'c}{psi} = 4000$ $\psi_t := 1.0$

$d_b := \frac{d_b}{in} = 0.5$ $\psi_e := 1.0$

$l_d := \frac{f_y \cdot \psi_t \cdot \psi_e \cdot d_b}{25 \cdot \lambda \cdot \sqrt{f'c}} = 18.9737$

$l_s := 1.3 \cdot l_d = 24.6658$

$l_s := 25\ in$

Structure 2

Channel Dimensions:

$b := 4\ ft$ $m := 3$ $y_0 := 2.43\ ft$ $FB := 1.8\ ft$ $d_t := 4.23\ ft$ $Q := 72.74\ \frac{ft^3}{sec}$

$y_0 := 2.5\ ft$ $t_w := 23.391\ ft$ $d_t := 4.5\ ft$ $g := 32.2\ \frac{ft}{sec^2}$

$T_w := b + 2 \cdot (m \cdot d_t) = 31\ ft$ $W_c := 10\ ft$ Width of existing channel

For construction purposes, y0 is assumed to be 1.5 ft and total depth, is 3 ft.

Head Gate:

$D := 1\ ft$ $h_o := y_0 - .5\ ft - \frac{D}{2} = 1.5\ ft$ Orifice will be 6 inches from the bottom. Head is definded as the head at the midpoint of the orifice.

$Q_o \equiv 0.7 \cdot A_o \cdot \sqrt{2 \cdot g \cdot h}$

$A_o := D^2 \cdot \frac{\pi}{4} = 0.7854\ ft^2$

$Q_o := 0.7 \cdot A_o \cdot \sqrt{2 \cdot g \cdot h_o} = 5.4035\ \frac{ft^3}{sec}$

Weir:

Weir crest wil be at y0. 1 ft of flow is assumed to be going over the weir. The most conservative assumption will be that the head gate is closed and that the weir will need to pass the entire flow.

$Q_w \equiv 3 \cdot L \cdot h_w^{1.5}$ $L \equiv \frac{Q_w}{3 \cdot h_w^{1.5}}$

$Q_w := \frac{Q}{\frac{ft^3}{sec}}$ $h_w := 1$ (ft) Since the weir equation is not homogeneous, the values will need to be unitless.

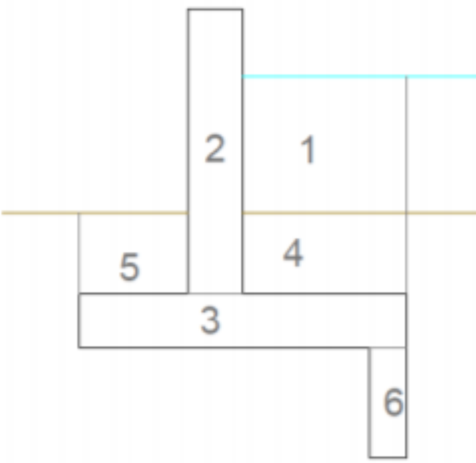
$L := \frac{Q_w}{3 \cdot h_w^{1.5}}\ ft = 24.2467\ ft$

Structure:

Assume: $\Phi := 30$ (deg) $\alpha := 0$ (deg) $k_a := 0.33$ $\gamma_{soil} := 100\ \frac{lb}{ft^3}$ $c' := 0\ \frac{lb}{ft^3}$

$\gamma_{water} := 62.4\ \frac{lb}{ft^3}$ $\gamma_{concrete} := 150\ \frac{lb}{ft^3}$ $k_p := 3$

$\gamma_w := \gamma_{water}$ $\gamma_c := \gamma_{concrete}$ $\gamma_s := \gamma_{soil}$



$H := 7.8\ ft$

$H' := 2.5\ ft$

$Width := 9\ ft$

$L_t := 2 \cdot 5\ ft + T_w + W_c = 51\ ft$ $\quad L_t = 51\ ft$

$h_{cutoff} := 2\ ft$

$w_{cutoff} := 8\ in$

$h := 12\ in$

$b_w := 12\ in$

Overturning:

Area

$A_1 := 6\ ft \cdot 5\ ft = 30\ ft^2$

$A_2 := 1\ ft \cdot 6.8\ ft = 6.8\ ft^2$

$A_3 := 1\ ft \cdot Width = 9\ ft^2$

$A_4 := 6\ ft \cdot 1.5\ ft = 9\ ft^2$

$A_5 := 2\ ft \cdot 1.5\ ft = 3\ ft^2$

$A_6 := 8\ in \cdot h_{cutoff} = 1.3333\ ft^2$

Weight

$W_1 := A_1 \cdot \gamma_w = 1872\ \frac{lb}{ft}$

$W_2 := A_2 \cdot \gamma_c = 1020\ \frac{lb}{ft}$

$W_3 := A_3 \cdot \gamma_c = 1350\ \frac{lb}{ft}$

$W_4 := A_4 \cdot \gamma_s = 900\ \frac{lb}{ft}$

$W_5 := A_5 \cdot \gamma_s = 300\ \frac{lb}{ft}$

$W_6 := A_6 \cdot \gamma_c = 200\ \frac{lb}{ft}$

Moment Arm

$MA_1 := 3\ ft + 6 \cdot \frac{ft}{2} = 6\ ft$

$MA_2 := 2\ ft + 1 \cdot \frac{ft}{2} = 2.5\ ft$

$MA_3 := \frac{Width}{2} = 4.5\ ft$

$MA_4 := MA_1 = 6\ ft$

$MA_5 := \frac{2\ ft}{2} = 1\ ft$

$MA_6 := 8\ ft + 1 \cdot \frac{ft}{2} = 8.5\ ft$

$W := W_1 + W_2 + W_3 + W_4 + W_5 + W_6 = 5642\ \frac{lb}{ft}$

Moment

$M_1 := W_1 \cdot MA_1 = 11232\ lb$

$M_2 := W_2 \cdot MA_2 = 2550\ lb$

$M_3 := W_3 \cdot MA_3 = 6075\ lb$

$M_4 := W_4 \cdot MA_4 = 5400\ lb$

$M_5 := W_5 \cdot MA_5 = 300\ lb$

$M_6 := W_6 \cdot MA_6 = 1700\ lb$

$M_R := M_1 + M_2 + M_3 + M_4 + M_5 + M_6 = 27257\ lb$

$P_c := .5 \cdot k_p \cdot h_{cutoff}^{\ 2} \cdot \gamma_s = 600\ \frac{lb}{ft}$

$P_h := .5 \cdot k_a \cdot H'^{\ 2} \cdot \gamma_s = 103.125\ \frac{lb}{ft}$ Soil forces cancel out

$P_w := .5 \cdot (H - 1.8\ ft)^2 \cdot \gamma_w = 1123.2\ \frac{lb}{ft}$

$M_D := p_w \cdot \frac{H - 1.25\ ft}{3} + \frac{p_c \cdot 2 \cdot h_{cutoff}}{3} = 3252.32\ lb$

$FS_o := \frac{M_R}{M_D} = 8.3808$ 8.3808>1.5

Sliding:

Assume vertical weight is uniformly distrubuted

$W_s := \frac{W}{Width} = 626.8889 \frac{lb}{ft^2}$

$W_{cutoff} := \frac{h_{cutoff}^2 \cdot \gamma_s \cdot .5 \cdot k_p}{Width} = 66.6667 \frac{lb}{ft^2}$

$F_r := k_a \cdot W_s + W_{cutoff} = 273.54 \frac{lb}{ft^2}$

$F_s := \frac{p_w}{Width} = 124.8 \frac{lb}{ft^2}$

$FS_s := \frac{F_r}{F_s} = 2.1918$ 2.1918>2.0

Resisting Force is also in the banks

$W_e := 5\ ft$ Width of embedment on each side

$D_e := 6.8\ ft$ Depth of embedment

$p_e := .5 \cdot k_a \cdot D_e^2 \cdot \gamma_s = 762.96 \frac{lb}{ft}$

$F_e := 2 \cdot 3\ ft \cdot p_e = 4577.76\ lb$ Total resisting force from the embedment

$F_{eperfoot} := \frac{F_e}{L_t \cdot Width} = 9.9733 \frac{lb}{ft^2}$

$F_{rn} := F_r + F_{eperfoot} = 283.5133 \frac{lb}{ft^2}$

$FS_{sn} := \frac{F_{rn}}{F_s} = 2.2717$ 2.3062> 2.0

Bearing Capacity:

$M_{net} := M_R - M_D = 24004.68\ lb$

$M_{net} = W \cdot X_{bar}$ $X_{bar} = \frac{M_{net}}{W}$ $e = \frac{B}{2} - X_{bar}$

$q = \frac{W}{A} \pm \frac{M_{net} \cdot y}{I}$ $\left(I = \frac{w \cdot L^3}{12}\right) = \frac{B^3}{12}$ $w = 1\ ft$ $\left(q_{max} = q_{toe}\right) = \frac{W}{B} + \frac{e \cdot W \cdot \frac{B}{2}}{\frac{B^3}{12}}$ $q_{toe} = \frac{W}{B} \cdot \left(1 - \frac{6 \cdot e}{B}\right)$

$X_{bar} := \frac{M_{net}}{W} = 4.2546\ ft$

$e := \frac{Width}{2} - X_{bar} = 0.2454\ ft$

$q_{toe} := \frac{W}{Width} \cdot \left(1 + \frac{6 \cdot e}{Width}\right) = 729.4311 \frac{lb}{ft^2}$

$q_{heel} := \frac{W}{Width} \cdot \left(1 - \frac{6 \cdot e}{Width}\right) = 524.3467 \frac{lb}{ft^2}$

$\psi = atan\left(\frac{P_h}{W}\right)$ $P_h := p_w + p_h = 1226.325 \frac{lb}{ft}$

$\psi := atan\left(\frac{P_h}{W}\right) = 0.214$ $\psi_d := \psi \cdot \frac{180}{\pi} = 12.2629$ (deg)

$B' := Width - 2 \cdot e = 8.5093\ ft$

$q_u = c' \cdot N_c \cdot F_{cd} \cdot F_{ci} + q \cdot N_q \cdot F_{qd} \cdot F_{qi} + .5 \cdot \gamma \cdot B' \cdot N_\gamma \cdot F_{\gamma d} \cdot F_{\gamma c}$

$C' := 0$ Therefore:

$q_u = 0 + q \cdot N_q \cdot F_{qd} \cdot F_{qi} + .5 \cdot \gamma \cdot B' \cdot N_\gamma \cdot F_{\gamma d} \cdot F_{\gamma c}$

$\gamma := \gamma_s - \gamma_w = 37.6 \frac{lb}{ft^3}$

$D_s := 2.5\ ft$ depth of soil

$q := D_s \cdot \gamma = 94 \frac{lb}{ft^2}$

at $\Phi = 30$, $N_c := 30.14$ $N_q := 18.4$ $N_\gamma := 22.4$

$F_{\gamma d} := 1$ $F_{qd} := 1$

$F_{qi} := \left(1 - \frac{\psi_d}{90}\right)^2 = 0.7461$

$F_{\gamma i} := \left(1 - \frac{\psi_d}{\Phi}\right)^2 = 0.3496$

$q_u := 0 + q \cdot N_q \cdot F_{qd} \cdot F_{qi} + .5 \cdot \gamma \cdot B' \cdot N_\gamma \cdot F_{\gamma d} \cdot F_{\gamma i} = 2543.0111 \frac{lb}{ft^2}$

$FS_{bc} := \frac{q_u}{q_{toe}} = 3.4863$ 3.4836>3.0

Steel:

Flexural:

$F_w := .5 \cdot (5\ ft)^2 \cdot \gamma_w = 780\ \frac{lb}{ft}$

$F_s := .5 \cdot k_a \cdot H'^2 \cdot \gamma_s = 103.125\ \frac{lb}{ft}$ Forces of soil will cancel

$q_{avg} := \frac{q_{heel} + q_{toe}}{2} = 626.8889\ \frac{lb}{ft^2}$

$M_a := F_w \cdot 5 \cdot \frac{ft}{3} = 1300\ lb$

$d := h - 3.5\ in = 8.5\ in$

$\beta_1 := 0.85$ $f'c := 4000\ psi$ $fy := 60000\ psi$

assume $\Phi := 0.9$

$$3 \cdot \sqrt{\frac{f'c}{psi}} \cdot \frac{b_w}{in} \cdot \frac{\frac{d}{in}}{\frac{fy}{psi}}\ in^2 = 0.3226\ in^2$$

As min is max of:

$$A_{smin} := \frac{200 \cdot \frac{b_w}{in} \cdot \frac{d}{in}}{\frac{fy}{psi}}\ in^2 = 0.34\ in^2$$

$$A_{smin} := 0.34\ in^2$$

$a = \frac{A_s \cdot fy}{0.85 \cdot f'c \cdot b_w}$ $M_a = \Phi \cdot M_n$ $\frac{M_a}{\Phi} = M_n$ $M_n := \frac{M_a}{\Phi} = 1444.4444\ lb$

$M_n = A_s \cdot fy \cdot \left(d - \frac{a}{2}\right)$ $M_n = A_s \cdot fy \cdot \left(d - \frac{A_s \cdot fy}{2 \cdot 0.85 \cdot f'c \cdot b_w}\right)$ $A_s \cdot fy \cdot \left(d - \frac{A_s \cdot fy}{2 \cdot 0.85 \cdot f'c \cdot b_w}\right) - M_n = 0$

$A_s := .002\ in^2$

$$\frac{A_s}{in^2} \cdot \frac{fy}{psi} \cdot \left(\frac{d}{in} - \frac{\frac{A_s \cdot fy}{psi\ in^2}}{2 \cdot 0.85^2 \cdot \frac{f'c}{psi} \cdot \frac{b_w}{in}}\right) - \frac{M_n}{lb} = -424.6521$$

As min governs

$A_s := A_{smin} = 0.34\ in^2$

Use 2 no 4 bars

$d_b := 0.5\ in \qquad A_b := 0.20\ in^2$

$A_s := 2 \cdot A_b = 0.4\ in^2$

Clear Space: $\dfrac{(12\ in - 2 \cdot 3\ in - 2 \cdot .375\ in - 2 \cdot d_b)}{1} = 4.25\ in$ >1 in

$d_t := 12\ in - 3\ in - .375\ in - d_b = 8.125\ in$

$a := \dfrac{A_s \cdot fy}{0.85 \cdot f'c \cdot b_w} = 0.5882\ in$

$c := \dfrac{a}{\beta_1} = 0.692\ in$

$\dfrac{c}{d_t} = 0.0852$ < 0.375 Therefore $\Phi := 0.9$

$\Phi M_n := \Phi \cdot A_s \cdot fy \cdot \left(d_t - \dfrac{a}{2}\right) = 14095.5882\ psi\ in^2\ ft$

$\Phi M_n := \dfrac{\Phi M_n}{psi\ in^2\ ft}\ lb\ ft = 14095.5882\ lb\ ft$

$M_a := M_a \cdot 1\ ft = 1300\ lb\ ft$

ΦMn<Ma

Shear:

$V_{max} := F_w + F_s = 883.125\ \dfrac{lb}{ft}$ $\qquad \Phi := 0.75$

$\Phi V_c := \Phi \cdot 2 \cdot \sqrt{\dfrac{f'c}{psi}} \cdot \dfrac{b_w}{in} \cdot \dfrac{d_t}{in}\ lb = 9249.6622\ lb$

$\dfrac{\Phi V_c}{(2)} = 4624.8311\ lb$

$\dfrac{\Phi V_c}{2} > V_{max}$ No stirrups requried

Footing: M positive CCW

$$q_{toe} = 729.4311 \frac{lb}{ft^2}$$

$$q_{heel} = 524.3467 \frac{lb}{ft^2}$$

$$q_{diff} := q_{toe} - q_{heel} = 205.0844 \frac{lb}{ft^2}$$

$$M_{soilbc} := \frac{Width^2}{2} \cdot q_{heel} + \frac{(Width)^2 \cdot 1}{2 \cdot 3} \cdot q_{diff} = 24004.68\ lb$$

$$M_{soiltop} := \frac{H'^2 \cdot \gamma_s \cdot k_a}{2} \cdot \left(H' \cdot \frac{1}{3} + h\right) - \frac{H'^2 \cdot \gamma_s \cdot k_a}{2} \cdot \left(H' \cdot \frac{1}{3} + h\right) = 0\ lb$$

$$M_{water} := F_w \cdot \left(\frac{5\ ft}{3} + h\right) = 2080\ lb$$

$$M_{weight} := -M_R = -27257\ lb$$

$$M_{cutoff} := \frac{h_{cutoff}^{\ 3} \cdot \gamma_s \cdot k_p \cdot 2}{3 \cdot 2} = 800\ lb$$

$$M_{at} := M_{soilbc} + M_{water} + M_{weight} + M_{cutoff} + M_{soiltop}$$

Max moment will occur at the toe when moments in one direction are summed

$$M_{design} := -1 \cdot \left(M_{soiltop} + M_{weight}\right) = 27257\ lb$$

$$d := h - 3.5\ in = 8.5\ in$$

$\beta_1 := 0.85$ $f'c := 4000\ psi$ $fy := 60000\ psi$

assume $\Phi := 0.9$

As min is max of:

$$3 \cdot \sqrt{\frac{f'c}{psi}} \cdot \frac{b_w}{in} \cdot \frac{\frac{d}{in}}{\frac{fy}{psi}}\ in^2 = 0.3226\ in^2$$

$$A_{smin} := \frac{200 \cdot \frac{b_w}{in} \cdot \frac{d}{in}}{\frac{fy}{psi}}\ in^2 = 0.34\ in^2$$

$$A_{smin} := 0.34\ in^2$$

$$a = \frac{A_s \cdot fy}{0.85 \cdot f'c \cdot b_w} \qquad M_{design} = \Phi \cdot M_n \qquad \frac{M_{design}}{\Phi} = M_n \qquad M_n := \frac{M_{design}}{\Phi} = 30285.5556\ lb$$

$$M_n = A_s \cdot fy \cdot \left(d - \frac{a}{2}\right) \qquad M_n = A_s \cdot fy \cdot \left(d - \frac{A_s \cdot fy}{2 \cdot 0.85 \cdot f'c \cdot b_w}\right) \qquad A_s \cdot fy \cdot \left(d - \frac{A_s \cdot fy}{2 \cdot 0.85 \cdot f'c \cdot b_w}\right) - M_n = 0$$

$A_s := .059746729\,in^2$

$$\frac{A_s}{in^2}\cdot\frac{fy}{psi}\cdot\left(\frac{d}{in}-\frac{\frac{A_s\cdot fy}{psi\ in^2}}{2\cdot 0.85^2\cdot\frac{f'c}{psi}\cdot\frac{b_w}{in}}\right)-\frac{M_n}{lb}=-0.0008$$

As min governs

$A_s := A_{smin} = 0.34\,in^2$

Use 2 no 4 bars

$d_b := 0.5\,in$ $\qquad A_b := 0.20\,in^2$

$A_s := 4\cdot A_b = 0.8\,in^2$

Clear Space: $\dfrac{(12\,in - 2\cdot 3\,in - 2\cdot .375\,in - 4\cdot d_b)}{3} = 1.0833\,in > 1\,in$

$d_t := 12\,in - 3\,in - .375\,in - d_b = 8.125\,in$

$a := \dfrac{A_s\cdot fy}{0.85\cdot f'c\cdot b_w} = 1.1765\,in$

$c := \dfrac{a}{\beta_1} = 1.3841\,in$

$\dfrac{c}{d_t} = 0.1703 < 0.375$ Therefore $\Phi := 0.9$

$\Phi M_n := \Phi\cdot A_s\cdot fy\cdot\left(d_t - \dfrac{a}{2}\right) = 27.1324\,ksi\ in^2\ ft$

$\Phi M_n := \dfrac{\Phi M_n\cdot 10^3}{ksi\ in^2\ ft}\ lb\ ft = 27132.3529\,lb\ ft$

$M_{design} := M_{design}\cdot 1\,ft = 27257\,lb\ ft$

ΦMn<Mdesign

Cutoff Wall:

$M_{cutoff} = 800\ lb$

$d := w_{cutoff} - 3.5\ in = 4.5\ in$

$\beta_1 := 0.85 \quad f'c := 4000\ psi \quad fy := 60000\ psi$

assume $\Phi := 0.9$

As min is max of:

$$3 \cdot \sqrt{\frac{f'c}{psi}} \cdot \frac{b_w}{in} \cdot \frac{\frac{d}{in}}{\frac{fy}{psi}}\ in^2 = 0.1708\ in^2$$

$$A_{smin} := \frac{200 \cdot \frac{b_w}{in} \cdot \frac{d}{in}}{\frac{fy}{psi}}\ in^2 = 0.18\ in^2$$

$$A_{smin} := 0.18\ in^2$$

$a = \frac{A_s \cdot fy}{0.85 \cdot f'c \cdot b_w} \qquad M_{cutoff} = \Phi \cdot M_n \qquad \frac{M_{cutoff}}{\Phi} = M_n \qquad M_n := \frac{M_{cutoff}}{\Phi} = 888.8889\ lb$

$M_n = A_s \cdot fy \cdot \left(d - \frac{a}{2}\right) \quad M_n = A_s \cdot fy \cdot \left(d - \frac{A_s \cdot fy}{2 \cdot 0.85 \cdot f'c \cdot b_w}\right) \quad A_s \cdot fy \cdot \left(d - \frac{A_s \cdot fy}{2 \cdot 0.85 \cdot f'c \cdot b_w}\right) - M_n = 0$

$A_s := .003294267\ in^2$

$$\frac{A_s}{in^2} \cdot \frac{fy}{psi} \cdot \left(\frac{d}{in} - \frac{\frac{A_s \cdot fy}{psi\ in^2}}{2 \cdot 0.85^2 \cdot \frac{f'c}{psi} \cdot \frac{b_w}{in}}\right) - \frac{M_n}{lb} = -6.1609 \cdot 10^{-5}$$

As min governs

$A_s := A_{smin} = 0.18\ in^2$

Use 1 no 4 bar

$d_b := 0.5\ in \qquad A_b := 0.20\ in^2$

$A_s := 1 \cdot A_b = 0.2\ in^2$

$d_t := 8\ in - 3\ in - .375\ in - d_b = 4.125\ in$

$a := \frac{A_s \cdot fy}{0.85 \cdot f'c \cdot b_w} = 0.2941\ in$

$c := \frac{a}{\beta_1} = 0.346\ in$

$\frac{c}{d_t} = 0.0839$ < 0.375 Therefore $\Phi := 0.9$

$\Phi M_n := \Phi \cdot A_s \cdot fy \cdot \left(d_t - \frac{a}{2}\right) = 3.5801\ ksi\ in^2\ ft$

$\Phi M_n := \frac{\Phi M_n \cdot 10^3}{ksi\ in^2\ ft}\ lb\ ft = 3580.1471\ lb\ ft$

$M_{cutoff} := M_{cutoff} \cdot 1\ ft = 800\ lb\ ft$ ΦMn<Mcutoff

Volume:

$L_s := T_w + W_e \cdot 2 + 10\ ft = 51\ ft$

$Vol_2 := Width \cdot L_s \cdot h + (H - 1\ ft) \cdot L_s \cdot h + h_{cutoff} \cdot w_{cutoff} \cdot L_s = 32.363\ yd^3$

$Vol_2 = 32.363\ yd^3$ $Vol_1 := 13.5154\ yd^3$

$Vol_t := Vol_1 + Vol_2 = 45.8784\ yd^3$

Steel (ACI min):

$\rho_{min} := 0.0018$ $D_t := 8.125\ in$

$A_s \equiv \rho \cdot b \cdot d$ $d_t = 4.125\ in$

$A_s := \rho_{min} \cdot b_w \cdot D_t = 0.1755\ in^2$ Foundation

$A_s := \rho_{min} \cdot b_w \cdot d_t = 0.0891\ in^2$ Cutoff wall

For both, use 1 no 4 bar

$l_d \equiv \frac{f_y \cdot \psi_t \cdot \psi_e \cdot d_b}{25 \cdot \lambda \cdot \sqrt{f'c}}$

$f_y := \frac{fy}{psi} = 60000$ $\lambda := 1.0$

$f'c := \frac{f'c}{psi} = 4000$ $\psi_t := 1.0$

$d_b := \frac{d_b}{in} = 0.5$ $\psi_e := 1.0$

$l_d := \frac{f_y \cdot \psi_t \cdot \psi_e \cdot d_b}{25 \cdot \lambda \cdot \sqrt{f'c}} = 18.9737$

$l_s := 1.3 \cdot l_d = 24.6658$

$l_s := 25\ in$

Budget

Travel reimbursement

IRS cost per mile = $0.54/mile

Miles to date = 45 miles

Expected total miles = 90 miles

$$Current\ Reimbursement = Cost\ per\ Mile * Miles$$

= $0.54 * 45 = **$24.30**

Estimated Design Costs

PRELIMINARY ESTIMATE

Project: Stormwater Conveyance System for Logan City

Date 4/8/2017

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
1	Mobilization	Lump Sum	1	-	$ 618,966.15
2	Implement SWPPP	Lump Sum	1	-	$ 618,966.15
3	Survey	Lump Sum	1	-	$ 25,000.00
4	Channel Grubbing	Square foot	1447451	$ 0.30	$ 434,235.30
5	Channel Excavation	Cubic Yard	134751	$ 25.00	$ 3,368,775.00
6	Install specialty concrete	Cubic Yard	46	$ 350.00	$ 16,100.00
7	Provide Quality Control Testin	Lump Sum	1	$ 10,000.00	$ 10,000.00
8	Install 18-inch stop gate	Each	1	$ 500.00	$ 500.00
9	Install 12-inch diameter rip rap	Cubic Yard	1106	$ 60.00	$ 66,360.00
10	Silt Fence	Lineal Feet	91060	$ 1.25	$ 113,825.00
11	Wetland Mitigation	Acres	33	$ 180,000.00	$ 5,981,202.48

Total $11,253,930.09

10% ADJUSTMENT (Design and Construction Inspection) $ 1,125,393.01

25% CONTINGENCY (Unexpected Construction Costs) $ 2,658,740.98

TOTAL OF BID $12,379,323.10

Cost Benefit Analysis

Alternative 1—Moving the Polishing Pond

Land purchase for new polishing pond

Land needed = 21.71 acres

Land price = $7596 per acre

$$Land\ Price = Land\ Needed * Land\ Price$$

$$= 21.7 * \$7595 = \mathbf{\$164{,}833}$$

Moving the pump station

Estimated cost = **$1,000,000**

Total Cost

$$Total\ Cost = Land\ Price + Moving\ the\ Pump\ Station$$
$$= \$164{,}833 + \$1{,}000{,}000 = \mathbf{\$1{,}164{,}833}$$

Alternative 2—Upgrading Existing Pipe

Feet of pipe to be replaced = 6200
Cost of 60" concrete pipe installed per foot = $600

$$Cost\ of\ New\ Pipe = Feet\ of\ Pipe * Cost\ per\ Foot$$
$$= 6200 * \$600 = \mathbf{\$3{,}720{,}000}$$

Special Summary Documentation

Constraints Consideration Summary

Health and Safety. The implementation of this project minimizes flood risk to the agricultural and industrial land. During the construction process, equipment may overturn due to slope instability. 10WE considered the safety of the construction crew during the design process. 10WE used saturated soil conditions for design calculation. 10WE also used government design regulations and adequate factors of safety to ensure the integrity of the structures.

Constructability. 10WE designed simple channels and diversion structures. 10WE avoided harming wetlands to the extent possible. In addition, the storm water conveyance system is gravity fed.

Economic. There were many economic constraints for this project: gravity-fed system, channel length, hydraulic structures, wetlands, and moving the holding pond and screw pumps.

- The storm water system is gravity-fed due to the cost of installing and maintaining pumps.
- The channel length was minimized due to the increase in cost as the length increases.
- The size and quantity of hydraulic structures were minimized due to the cost increase as the structures grow in both size and quantity.
- The construction avoided wetlands to the extent possible due to the cost of replacing wetlands.
    - The Army Corps of Engineers requires three acres of wetlands be restored for every acre disturbed during construction.
    - The price of replacing one acre of disturbed wetland is $180,000.
- The holding pond and screw pumps were relocated due to economic constraints.
    - 10WE completed a cost benefit analysis to assist in the decision of whether or not to move the holding pond and screw pumps.

Environmental. As defined by the EPA, wetlands improve water quality, provide wildlife habitat, and regulate surface water flow. The design avoided disturbing the wetlands to the extent possible.

Social. Canals in the area supply water to farmers who own water rights. 10WE ensured all individuals have access to their water rights by designing diversion structures.

Engineering Tools Summary

Table SSD1. 10WE Engineering Tools

Software Name	Version	Manufacturer
ArcGIS	ArcGIS 10.4	Esri
AutoCAD	AutoCAD 2016	AutoDesk
Civil3D	Civil3D 2017	AutoDesk
Google Drive	N/A	Google
Slide	Slide 6.0	Rocscience
Smathstudio	0.98.6179	Andrey Ivashov
Storm and Sanitary	Storm and Sanitary 2015	AutoDesk
TauDEM	5.0	Available from David Tarboton

Government Regulations

Table SSD2. 10WE Government Regulations

Organization	Number	Name
NRCS	TR-55	Urban Hydrology for Small Watersheds
USBR	N/A	Design of Small Canal Structures
Logan City	N/A	Cache Valley Storm Water Design Standards
American Concrete Institute	318 & 10-5-4	Building Code for Requirements for Structural Concrete

Professional Responsibility and Conduct Summary

Table SSD3. Professional Standards

Organization	Number	Name
ASCE	N/A	ASCE Code of Ethics

Risk Considerations

Design process risk considerations. The field investigation risked the health and safety of members of 10WE. The purpose of the field investigation was to gain a better understanding of current conditions in the area of interest. This involved driving and taking velocity and cross-sectional area measurements of canals. The canals of interest are lined with a fine clay. 10WE carefully evaluated where to take measurements to ensure they did not get trapped in the mud. 10WE completed this investigation in late fall and all team members wore appropriate clothing

to diminish the risk of illness. 10WE mitigated risk while driving to the area of interest by wearing seatbelts and obeying all local driving regulations.

Post-design process risk considerations. The implementation of this project minimizes flood risk to the agricultural and industrial land. During the construction process, equipment may overturn due to slope instability. 10WE considered the safety of the construction crew during the design process. 10WE used saturated soil conditions for design calculation.

Potential Additional Reviewers

- Lance Houser PE
- Sedimentologist
- Logan City Council
- Construction Contractors

Methods for Overcoming Challenges

10WE employed several methods to overcome challenges. 10WE focused on communication, comparative advantage, and planning. By designating a "naysayer" for several meetings, 10WE evaluated many different ideas and methods. 10WE avoided confusion among the team and between the client by using the proper method of communication for each task. 10WE reallocated assignments to increase efficiency. For example, Ryan Weller and Megan Gordon changed roles so that Megan is the primary technical writer and Ryan is the geotechnical engineer. Finally, 10WE used planning as method to communicate and coordinate with the client.

Author Biography

Megan Gordon is a Civil Engineering student at Utah State University. Megan will graduate in May 2017 as the Valedictorian of the College of Engineering and with honors in university studies and departmental honors in civil engineering. Megan has obtained three A-Pin awards, which is one the oldest awards at Utah State University for academic achievement. Megan was also selected as the Pre-Professional Civil and Environmental Student of the Year for the 2014-2015 academic year. Megan is planning to pursue a Masters of Engineering at Utah State University.