

Department of Civil Engineering

Senior Design Project

Fall 2013

Final Report

The University of Toledo Ottawa River Restoration

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Department of Civil Engineering Senior Project

Executive Summary Report

Fall Semester 2013

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University of Toledo Ottawa River Restoration

Problem Statement

The recent Ottawa River restoration work on main campus of the University of Toledo has revealed erosion issues near five storm water outfalls along the North side of the river. The current Chair of the UT President's Commission on the River has requested a plan for repairing these five outfalls as well as for increased access to the river. Erosion issues under the numerous bridges that cross the Ottawa River have also been considered.

Objectives

- To provide a plan to repair the outfalls that have been damaged by erosion and weathering.
- To prepare a design for the outfalls that is aesthetically pleasing.
- To promote functionality and longevity of the outfalls.
- To reduce the possibility of erosion in the future near outfalls and under bridges.
- To provide additional access points to the river through piers and/or overlooks.
- To create access points and platforms which are appealing to the faculty/staff and student body.
- To address safety concerns that arise with the design process.

Solution Approach

The designs presented in this project address outfall and erosion issues along the Ottawa River and underneath two pedestrian bridges. The outfalls and bridges were analyzed independently to examine their individual problems. From there, cost effective and innovative solutions were presented to resolve the outfall and bridge erosion issues. Lastly, two overlooks near two of the outfalls were conceptually designed to add additional access points to the river.

Schedule and Person Loading

- Approximately 800 hours total has been spent on the design of this project
- 160 hours per person (5 member team) – approximately 10 hours per week per member

Constraints

- Available space between the existing road and the outfalls limited design options
- Elevation differences between the outfalls and the edge of the river
- The design cannot negatively impact the flow of the river
- Cost of the project
- Existing infrastructure (above and below ground)
- Environmental footprint
- Innovation
- Aesthetics

Economics

No budget was provided for this project. We have prioritized by identifying major concerns first, followed by additional design alternatives. A material cost analysis has been determined for each of the alternatives selected.

Implementation Potential

The recent construction that has occurred in the Ottawa River has exposed the need for these issues to be addressed. The probability that this project will actually take place is very likely. This is especially true with the interest of making the river more attractive to the University.

Deliverables

- Current site condition pictures showing damage and erosion issues
- Conceptual drawings for proposed overlooks with location map showing proposed locations
- Visuals of alternative designs
- Maps showing location of each outfall
- Cost analysis of the each location covered in the project including a total material cost estimate for project
- Final comprehensive report

Conclusions and Recommendations

In addressing the issues at the outfall channels and two pedestrian bridges, it was determined that cost effective, innovative and effective protection methods are the best solution to eradicate erosion issues. In order to correct the problems with the current headwalls, it was concluded that they would either have to be replaced or repaired.

Problem Statement

The section of the Ottawa River that runs through the University of Toledo is a main focal point for the campus community. In 1960, the 3700 foot long section of the river that runs through campus was diked and straightened. As a result, much of the natural habitats of native fish and other species were destroyed (Gamble, 2013). It is in the best interest of the University of Toledo to showcase the beauty of the Ottawa River and plan projects that will improve the river as a whole. In order to do this, the UT President's Commission on the River was formed in 2005 by President Dan Johnson. The objective of the Commission is to involve students, faculty, staff, and the community in the development and implementation of projects related to the improvement of the Ottawa River. One project that the Commission has successfully implemented is the use of a rain garden to treat storm water runoff. The University also secured a grant from the EPA to perform several in-stream modifications to improve the habitat for native wildlife. In order to do this, a series of logs, large rocks, and hydraulic structures were strategically placed into the river. Also, many non-native plant species were removed and replaced with native trees and vegetation. This project was completed in August of 2013 (Lawrence, 2013).

In the process of restoring the river and removing the plants, many of the existing storm water outfalls on the North side of the river were exposed. It was realized that many of these outfalls had been damaged over the years due to erosion and weathering. There are five outfalls in particular that specifically need to be addressed. The problems range from erosion around the back side of the headwalls to damaged pipes and splash pads at the entrance to the river.

Another main issue associated with the river is the erosion that is taking place under several of the existing bridges. Under the bridges, very little vegetation can grow due to the lack of light. Since a root base is not present under the bridges, the soil is very susceptible to erosion from the river and water that drains down next to the bridge abutments. The objective is to provide slope protection that will increase longevity and protect the bridges from damage caused by erosion, while maintaining an aesthetically appealing appearance.

Figure 1 shows the project location on the University's campus along the Ottawa River. Figure 2 identifies the outfall and bridge locations associated with the project, which are contained within 3 reaches of the Ottawa River on campus. Reach 1 and 2 are not depicted in Figure 1 since they are outside the scope of this project. Reach 1 is located from Secor Road to the West Rocket Drive Traffic Bridge. Reach 2 is located from the West Rocket Drive Traffic Bridge to the Center for Performing Arts Pedestrian Bridge. Reach 3 is located from the Center for Performing Arts Pedestrian Bridge to the Carlson Library Pedestrian Bridge. Reach 4 is located from the Carlson Library Pedestrian Bridge to the David Root Bridge. Finally, Reach 5 is located from the David Root Bridge to the East Ramp Pedestrian Bridge.

Many people view the Ottawa River as a dirty waterway due to its past history of contamination (Gamble, 2013). It is in the best interest of the University to increase the ease of access to the river so that this negative misconception can be changed for the better by improving its popularity. In order to achieve this, two overlooks have been designed on the Ottawa River.

[illegible]

The map displays the following features:

- Reaches:** Five orange-outlined areas labeled REACH #1 through REACH #5.
- Outfalls:** Five red squares labeled OUTFALL #1 through OUTFALL #5.
- Buildings:** Labeled with abbreviations: FH (top left), SM (top center), CL (center left), SV (center right), and FC (bottom right).
- Pedestrian Bridges:** CARLSON PEDESTRIAN BRIDGE (bottom left) and EAST RAMP PEDESTRIAN BRIDGE (top right).
- North Arrow:** A white arrow pointing upwards with the letter 'N' next to it.
- Other Features:** A large parking lot is visible in the center, and a red running track is in the bottom right.

Constraints

There are several constraints that must be considered in completing this project. The first of these issues is that there are currently no funds earmarked for this project. The money for this project will hopefully be allocated by the University or acquired through grant applications after the design stages have been completed. Space has also be a relevant constraint because many of the outfalls are very close to the existing infrastructure - both above and below ground. In particular, Towerview Boulevard is very close to two of the outfalls in question. Elevation differences between the outfalls and the edge of the river also played a factor in the decision of what channel protection to utilize. Environmental factors must also be taken into account. The ideas involved with this project must have a minimal impact on the plant life surrounding the outfalls, bridges, and pier locations, while effort is put forth to include innovative designs. Furthermore, the alterations made to the river must not change or interrupt the flow pattern of the river so that erosion is not created in other locations on the river bank or that the elevation of the river changes. Native plants should be used if there is any planting involved with the final design. A low-profile headwall design would be ideal for this project so that the changes are aesthetically pleasing. Finally, the piers/overlooks must complement the current architecture of the campus, while being sure that safety is maintained with their implementation.

Outfall #1

Outfall #1 is located in Reach 3 on the North side of the Ottawa River, between the pedestrian bridges by the Center for Performing Arts and the Carlson Library, just off the access path. There is no vegetation where this outfall is located. There is little damage to the headwall itself, but soil has eroded from underneath the headwall structure on its western side. Also, the splash pad has broken off on the westernmost side of the outfall. The erosion has caused some of the toe of the headwall to break away (Figure 3). Outfall #1 has steep banks that lack stability resulting in the erosion. The outfall does not have a very lengthy channel run. There is rip-rap at the base of the outfall, but there is little protection of the banks around the outfall. Dimensions of the current headwall are 67” tall, 82” wide, and 36” deep. This outfall utilizes a 14” diameter pipe.

Figure 3 – Outfall #1 Channel



Alternatives to Outfall #1

Repair Headwall

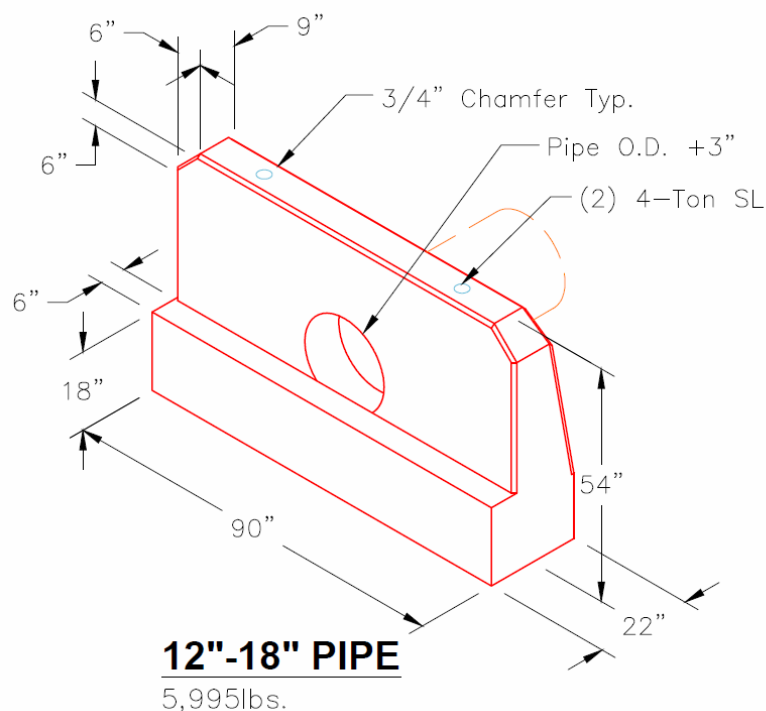
At Outfall #1, a proposed alternative and recommended solution is to repair the headwall of the structure. To repair the erosion from the structure, first the broken splash pad should be removed from the outfall. Some of the loose soil and any obstructions should be removed from around the area where the erosion concern is an issue. Next, rip rap should be placed and compacted to shore up the headwall structure. A new concrete splash pad should be poured at the

base of the headwall structure. This is a very cost effective way to ensure erosion protection from around the outfall structure. The new splash pad dimensions would be 82" wide, 24" deep, and 6" thick. The total volume of concrete needed would be 0.253 cubic yards.

Remove and Replace Headwall

Another proposed alternative is to remove and replace the entire headwall structure at Outfall #1. This option eliminates the damaged areas to the headwall. Many headwalls are precast concrete structures, so they can be purchased at reasonable cost. The pipe associated with this headwall is 14" in diameter. The cost of the new precast headwall needed for this size of pipe is \$495.00 as priced from Oldcastle Precast Headwalls. Figure 4 depicts the new headwall.

Figure 4 – Sample Replacement Headwall



Overlook Addition

An overlook, in the form of a pier, constructed over Outfall #1 will provide an area where students can enjoy the Ottawa River. This overlook will be a platform where people can sit and enjoy the view or catch fish. The overlook will cover the outfall, which will make the area more aesthetically pleasing. The pier will be 12' deep by 18' wide with a total area of 216 square feet. Composite wood will be used in the construction of the overlook, making it an affordable, durable, and long lasting platform. Figure 5 shows a sample conceptual design of the proposed overlook. The overlook will have a concrete walkway connecting it to the access road that runs along the North bank of the river. The platform will have a ramp to provide easy access to all individuals. Railing will be constructed around the platform to provide fall protection. Along the

railing on the side of the overlook, benches will be made to offer a place to sit. The deck of the overlook will be placed on support columns in the front, while additional columns will support the back section. The platform will be elevated to accommodate the flood levels of the river. The design dead weight for the pier will be 25 pounds per square foot (psf). The design live load will be 20 psf for the snow load and 100 psf calculated from the capacity of people that the pier can hold. The factored design ultimate load was calculated to be 222 psf. In speaking with a local contractor, Gary Dahl, it is estimated that a deck of this size and weight bearing capacity will cost anywhere from \$10,000-12,000. This cost includes all estimated materials and labor. Picture 1 in Appendix B shows a more site specific layout of this proposed overlook.

Figure 5- Sample Composite Deck for Overlook



Outfall #2

Outfall #2 is located on the North side of the Ottawa River in Reach 4, near the Carlson Library. When walking across the small pedestrian bridge to the Carlson Library the outfall can be observed on the right hand side. The headwall of the outfall is sized at 48” tall, 134” wide, and 12” deep. The headwall currently sits approximately five feet from the dry weather water level. The current pipe coming from the outfall is a 24” corrugated steel pipe. The outfall consists of a steep slope with extreme erosion issues (Figure 6). There is also a short channel that funnels the water into the river.

Figure 6 – Outfall #2 Erosion



The concrete headwall seems to be in working condition. It is serving its purpose of holding back the earth around it. The corrugated metal pipe has been damaged, presumably from recent construction work performed during the river restoration (Figure 6). The channel consists of eroded soil on the banks with various sizes of rocks in the middle of the channel to help dissipate the flow with the large elevation difference between the outfall and the water level.

The existing erosion issues are due to the steep slope around the outfall. Removal of vegetation around the outfall also has increased the erosion concerns. The channel is in need of reconstruction due to the dangerous erosion issues and the absence of efficient bank stabilization. More details on channel alternatives will be addressed in a separate section of the scope.

Alternatives to Headwall at Outfall #2

Repair Headwall

A proposed alternative to address this headwall is to modify the damaged section of pipe. To do this, the damaged section of the pipe that extends out of the headwall should be cut off. The pipe will then be flush with the headwall. This approach will keep the headwall as is, without a need to replace or move the headwall. A replacement alternative was not implemented since the headwall is in relevantly good condition.

Overlook Addition

A key element when considering the outfalls is to make them aesthetically pleasing. To achieve this, an overlook that is placed over top of the outfall is proposed. The location of the overlook will be from the existing sidewalk that runs East and West along the river to the concrete headwall of the outfall. The clear opening that currently exists behind the outfall will be a good location for this overlook (Figure 7). It will provide an additional access point for the campus community to enjoy the river. The overlook will be 12' deep by 20' wide with a total area of 240 square feet. Concrete will be used as the main material for this overlook to tie into the existing sidewalk. Concrete will allow for the superior strength and longevity of the overlook. The overlook will be designed to cantilever out into the river. Railings will be built around the overlook for safety. Seating in the form of picnic tables will be implemented into the overlook. The design dead weight for the pier due to the weight of the concrete is 150 pounds per square foot (psf). The design live load will be 20 psf for the snow load and 100 psf calculated from the capacity of people that the pier can hold. The factored design ultimate load was calculated to be 372 psf. The entire overlook will tie into the existing outdoor study area along the East side of Carlson Library known as the Student Garden Plaza. A conceptual idea for a possible overlook design is shown in Figure 8. Picture 2 and 3 in Appendix B shows a more site specific layout of this proposed overlook. Due to the complex design and uncertainties associated with this overlook, it is difficult to provide an accurate estimate of a price for this overlook. Rather, we provided a conceptual design.

Figure 7 – Proposed Location for Overlook at Outfall #2



Figure 8 – Concrete Overlook Concept



Outfall #3

Outfall #3 is located on the North side of the Ottawa River in Reach 4, near the Health and Human Services Building (Figure 9). It is observable when driving East on North Towerview Boulevard to the right on the bank of the river. The headwall of the outfall is sized at 134" tall, 80" wide, and 12" deep. The headwall currently sits approximately 25 feet from the dry weather water level. The headwall also is located approximately eight feet from North Towerview Blvd. The current pipe coming from the outfall is a 21" concrete pipe. The bank around the outfall consists of a moderate slope with hazardous erosion issues on each side of the outfall.

The concrete pipe in the headwall has no damage and has accessible flow into the channel. The channel consists of a small path worn into the soil from the small flow of water. The concrete headwall is in relatively good shape. The headwall extends out of the ground significantly due to erosion caused by the removal of the various trees and bushes that were originally around the outfall (Figure 9). The massive headwall is no longer needed due to the erosion issues. The headwall is also currently leaning forward. There is no form of channel stabilization to restrict the flow path of the water.

The existing erosion issues are the most significant on outfall #3. Removal of vegetation around the outfall increased the erosion concerns. The channel is in need of reconstruction due to the erosion issues and the absence of efficient bank stabilization.

Alternatives to Headwall at Outfall #3

Repair Headwall

One of the proposed alternatives for correcting this headwall is to modify the headwall so that it is less noticeable. Since a headwall of this size is no longer needed, a portion of the headwall can be cut off to eliminate the unappealing site. The bottom portion of the headwall that is still in the ground will serve its purpose for the outfall. To deal with the significant erosion issues, the bank around the outfall will need to be backfilled. The backfilled material will level out the erosion issues allowing bank stabilization and erosion methods to be installed. The average cost associated with concrete wall sawing of this nature is \$35.00/linear foot. At this rate, the total cutting cost for this headwall (80" wide) is \$233.33.

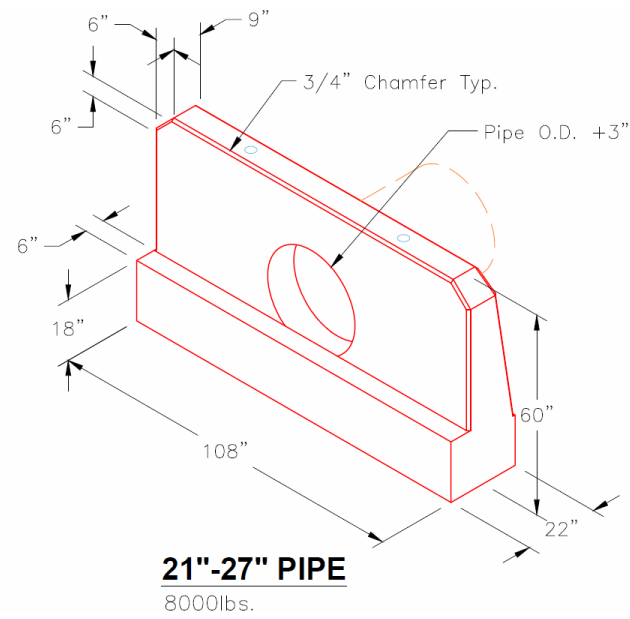
Figure 9 – Erosion around Headwall #3



Remove and Replace Headwall

Another proposed alternative to address the enormous, unappealing headwall is by removing and replacing it with a new one. This will allow for more opportunity to deal with the erosion issues. A smaller, more appropriately sized headwall could then be installed for the outfall, while incorporating the existing concrete pipe in the headwall itself. A new headwall would also eliminate the forward lean of the existing headwall. Though this lean is minimal, the headwall could continue to settle; therefore, amplifying the lean. The pipe associated with this headwall is 21” in diameter. The cost of the new precast headwall needed for this size of pipe is \$605.00 as priced from Oldcastle Precast Headwalls. Figure 10 depicts the new headwall.

Figure 10 – Sample Replacement Headwall



Outfall #4

Outfall #4 is located in Reach 5 on the North side of the Ottawa River, South of the Health and Human Services Building. This outfall sits 8 feet south of the curb along North Towerview Boulevard. Outfall #4 is in poor condition. Inside the headwall, the pipe had settled, disconnecting itself from the headwall. As a result, the pipe no longer lines up with the headwall's outlet as shown in Figure 11. Soil on the top side of the headwall has, overtime washed out due to the separated pipe carrying the earth away and exposed the back side of the headwall. There is severe erosion along the side of the headwall as well, due to poor bank stabilization as seen in Figure 12. Outfall #4 does have a long channel, compared to other outfalls, that has a relatively flat slope as it approaches the main flow area of the river. The channel could also use protection from erosion, since the channel walls have little vegetation to control the erosion. The current headwall is a U-shaped structure with the dimensions of 70" tall, 60" wide and 35" deep. The pipe inside the structure has a 12" diameter

Figure 11 – Settled Pipe Inside Headwall #4



Figure 12- Erosion around Outfall #4

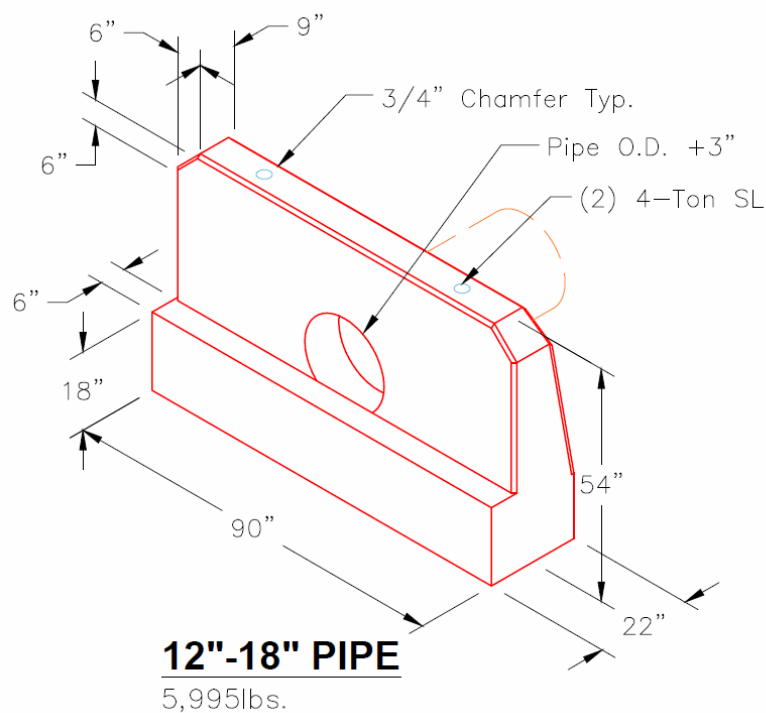


Alternatives to Headwall at Outfall #4

Remove and Replace Headwall

A proposed alternative for Outfall #4 is to remove and replace the existing headwall. Currently, water exiting the pipe cannot flow freely from the outfall. The 12" pipe inside the headwall will need to be replaced. A section of guardrail from North Towerview Boulevard may need to be removed to access the damaged pipe. Soil will have to be excavated from the outfall to the location where there is a non-damaged section of existing pipe. A new headwall and pipe could then be installed. The replacement of the headwall is the only way to properly remediate the problems at this outfall. The pipe associated with this headwall is 12" in diameter. The cost of the new precast headwall needed for this size of pipe is \$495.00 as priced from Oldcastle Precast Headwalls. Figure 13 depicts the new headwall.

Figure 13 – Sample Replacement Headwall



Outfall #5

Outfall #5 is located in Reach 5. This outfall has a 21" pipe and a 37.5" tall headwall. The headwall and splash pad to the outfall are in good shape, but there are erosion issues due to poor bank stability in the channel. This head wall also contains a flap gate which prevents the river water to backflow into the pipe. Soil on each side of the headwall is loose and is eroding into the channel as shown in Figure 14. Outfall #5 has a relatively long flow channel that will also require erosion protection. Figure 15 shows the channel at Outfall #5. The eroding issues with this outfall are simple to correct.

Alternatives to Headwall at Outfall #5

The existing headwall at Outfall #5 is still in very good condition. There are no noticeable issues that would justify any repairs or the replacement for this headwall. The only concerns for this outfall reside in the channel erosion.

Figure 14 – Outfall #5



Figure 15 – Channel at Outfall#5



Channel Erosion Alternatives

Rock Check Dams

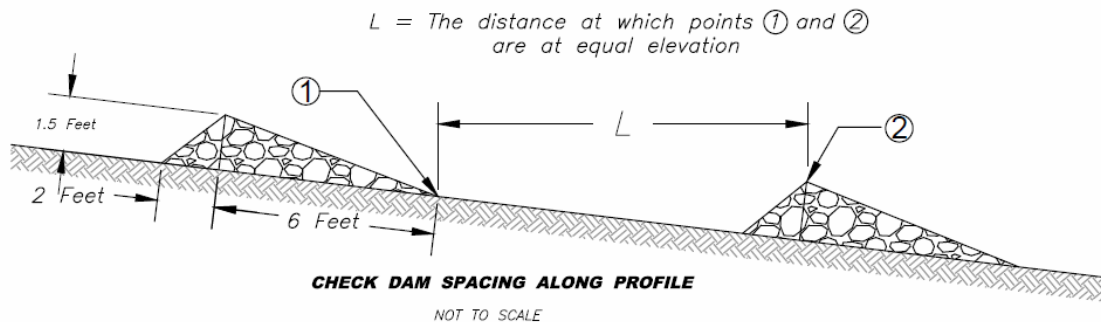
Rock check dams are a BMP (best management practice) that are used to slow the flow of water down in a specific channel. When the water is slowed down, it reduces the possibility of further erosion and scouring of the channel. Rock check dams are constructed perpendicular to the flow of the channel so that ponding can occur behind the check, as seen in (Figure 16). When this ponding occurs, it not only slows the flow of the water down, it also allows some of the sediment particles present in the water to settle out. Check dams are also very beneficial in areas where it is not possible to redirect the water to another location. Steep channels are also good applications for rock check dams.

Figure 16 – Example of Rock Check Dams



As stated previously, rock check dams are constructed perpendicular to the direction of water flow. They also must entirely span the width of the channel so that erosion does not occur around the edges. When installing these devices, it is important to keep the center of the dam a bit lower than the sides so that water can continue to flow over the dam. Each dam should be placed a distance down the slope so that the top of the downstream dam is level with the bottom of the upstream dam. This can be seen in Figure 17.

Figure 17 – Downstream Spacing



Maintenance of these rock check dams can vary depending on how much loose material is washed downstream. If the depth of the sediment in the ponds reaches about half of the original ponding depth it is necessary to physically remove the sediment so that the rock check dams can still serve their intended purpose. It is also necessary to check the integrity of the dams after high capacity flows to make sure that they are still intact.

The best location for these rock check dams to be used would be Outfall #3 and Outfall #4. The reason for this is that these outfalls have a relatively long channel, as compared to the other outfalls, extending from the headwall to the edge of the river. The channels for Outfalls #3 and #4 can be seen in Figure 18 and Figure 19 respectively. This would provide enough room for check dams to be installed for each outfall so that there is no further erosion of the existing bank due to these storm water outlets. Picture 4 in Appendix B shows how rock check dams could be implemented in these channels.

Figure 18 – Outfall #3 Channel



Figure 19- Outfall #4 Channel



The size of the rip rap for each channel is based on the discharge velocity of the pipe feeding the channel. These discharge velocities were calculated from Manning's equation for full pipe flow. Once the velocity was known, the size and type of the rip rap was chosen, based on a reference chart taken from the Ohio Department of Transportation's Location and Design Manual. For both channel #3 and #4 it was determined that Type C rip rap would be appropriate to use. In Type C rip rap, 85% of the material, by weight, is larger than a 6 inch square opening and at least 50% of the material, by weight, is larger than a 12 inch square opening. In order to calculate the volume of rip rap needed, standard cross sections were taken from the Urban Drainage and Flood Control District's Urban Storm Drainage Criteria Manual. Table 1 shows the volume and price per ton of Type C rip rap. The price of Type C rip rap is \$18 per ton as obtained from Hanson Aggregates. It can be seen from the table that for the channel of Outfall #3, the material price would be \$164.59, and for the channel of Outfall #4, the material price would be \$214.72. Channel #3 only has enough elevation difference between the headwall and the edge of the river for one check dam to be put into place, but Channel #4 will have enough elevation difference for two.

Table 1 – Rock Check Dam Pricing

Rock Check Dam/ Channel Rip Rap Alternative								
	Channel Rip-Rap	Check Dam Rip-Rap	Total	Total	Price/Ton	Geo-textile	Geo-textile Price	Total Price
Channel	(yd^3)	(yd^3)	(yd^3)	(Tons)	(\$/Ton)	(Price/sq ft)	(\$)	(\$)
#3	3.70	0.89	4.59	8.03	18.00	0.20	20.00	164.59
#4	4.30	1.78	6.08	10.64	18.00	0.20	23.20	214.72
							Total =	379.31

A-Jacks

A new and innovative erosion control method is the concept of concrete objects known as A-Jacks. The A-Jack units are high-stability concrete armor units that interlock into a flexible, permeable matrix. They are designed to dissipate energy and resist the forces of flowing water, while preventing scour and erosion. The units are installed either randomly or in a uniform pattern and the voids formed within the matrix provide about 40% open space. The voids created actually provide habitat for aquatic life when used as a reef, revetment, or soil support system in river applications. Biologists believe the A-Jacks create partly submerged structures where fish and wildlife can hide, while also diverting the stream to protect vegetation and banks from erosion. The voids also may be backfilled with suitable soils and planted with vegetation above the normal base flow. Contractors can install the units by hand, reducing construction time (Figure 20). A-Jack units are typically configured in three rows stacked in a two-and-one configuration, two aligned A-Jacks comprise a first and second row near the waterline, and a third row is staggered relative to the other two rows (Figure 21) (Armortec, 1999).

The A-Jack approach can be used to address the erosion issues around the outfalls, along with the erosion issues in the channels. A main benefit for the A-Jack approach is that they can be used in areas where there are short channel lengths, unlike rock check dams. For these reasons, the A-Jacks could be used as channel protection in Outfall #1, Outfall #2, and

Outfall #5. Figures 22, 23, and 24 depict these outfall channels. Picture 5 in Appendix B shows how A-Jacks could be implemented in these smaller channels.

Figure 20 – Installation of A-Jacks



Figure 21 – A-Jacks along Channel



Figure 22 – Outfall #1 Channel



Figure 23- Outfall #2 Channel



Figure 24 – Outfall #5 Channel



The size of the A-Jack Concrete Units for each channel is based on various parameters of the Ottawa River. These parameters consist of the 100-year design discharge, channel bottom width, channel side slope, and required factor of safety. Using these factors the actual shear stress and actual velocity could be determined. The recommended shear stress and recommended velocity based on the bed slope were then obtained from the charts provided from the A-Jacks Concrete Armor Units Design Manual of Ayres Associates. Comparing the actual and recommended values a factor of safety was calculated. The AJ-24 Concrete Unit was chosen since the calculated factor of safety exceeded the required factor of safety. Two A-Jack Concrete Units linked together can cover a length or width of three feet. Depending on the length and the width of the channel the quantity of A-Jack units could be calculated. Table 2 shows the quantity and price per A-Jack. It can be seen from the table that for channel of Outfall #1, the material price would be \$4290.00, for the channel of Outfall #2, the material price would be \$4590.00, and for the channel of Outfall #5, the material price would be \$3780.00.

Table 2 – A-Jack Pricing

A-Jack Concrete Units Alternative						
Channel	Length (ft)	Width (ft)	Rows	Total (A-Jacks)	Price/A-Jack (\$/A-Jack)	Total Price (\$)
#1	13.00	9.00	11.00	143.00	30.00	4290.00
#2	15.00	6.00	13.00	153.00	30.00	4590.00
#5	20.00	6.00	9.00	126.00	30.00	3780.00
					Total =	12660.00

Articulating Concrete Block Mats

Articulating Concrete Block mats provide practical erosion control to outfall channels. An interlocking matrix of concrete blocks make up these block mats. Galvanized steel, stainless steel, or polyester revetment cable run through the blocks, connecting them in a mat that can be simply laid down in sections. Since the blocks are placed in mats, they are flexible making it an excellent choice for lining channel bottoms.

The blocks can be designed for specific hydraulic situations. Blocks of different sizes and shapes will give channel protection at different flows. There are blocks that are tapered to slow down and dissipate high flow rates. These are also beneficial in channels where there are great hydraulic jumps.

There is an option for open-celled and close-celled blocks. Close-celled blocks are standard plate blocks that offer no void spaces in their design (Figure 25). Open-celled blocks provide void spaces in the blocks that allow for vegetation to grow through (Figure 26). Therefore, open-celled blocks are a form of erosion protection that has a low impact on plant life.

Figure 25 – Close-celled Block

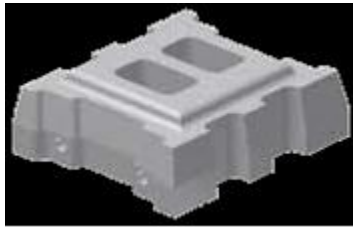
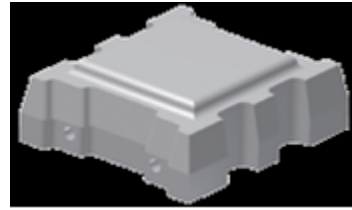


Figure 26 – Open-celled Block



The installation of articulating concrete block mats does not require any more than conventional construction equipment and is simple to place. First, geotextile fabric will be placed on the prepared channel (Figure 27). The concrete block mats are available in various configurations; therefore, they will come from the factory ready to be placed (Figure 28 & 29). Moving the mats will require a spreader bar to be placed on a crane. At least two rows of blocks will need to be buried to offer an acceptable anchor to hold the block mats in place (Figure 30).

Figure 27 – Channel Preparation

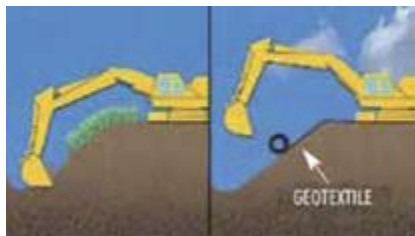


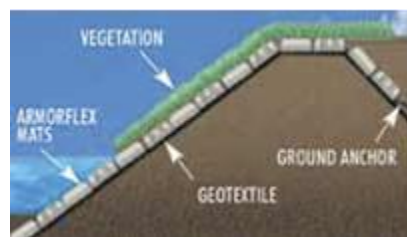
Figure 28 – Mat Rigging



Figure 29 – Mat Placement



Figure 30 – Backfilled



Articulating concrete blocks are a proven and effective way to stabilize channels and prevent erosion. It is an excellent alternative that is visually appealing with the use of open-celled blocks. Figure 31 shows the blocks after installation before they are back filled. Figure 32 shows the blocks after being back filled and with established plant life on top of them. This alternative will work well where there are outfall channels with longer runs; so, Outfall #3, #4, and #5 will benefit from this option. Refer back to Figures 18, 19, and 24, respectively, for these

outfalls channels. The block matting is simple, durable, cost effective, and easy to install; thus, making it an option that needs to be considered. Picture 6 in Appendix B shows how articulating concrete blocks could be implemented in these channels (Armortec, 1999).

Figure 31 – Installed Open-celled Blocks



Figure 32 – Open-celled Blocks After Established Vegetation



Selecting the type of articulating block for Channels #3, #4, and #5 is largely based on various hydraulic conditions of the river, the slope of the river bank, and the geometry and weight of the block. Initially, a target factor of safety will have to be selected to which the block will have to meet. According to the Federal Highway Administration, articulating block utilized for a channel bed must have a target factor of safety of 1.4. Design shear stress for the channel was calculated based on river data. For the channels, open-celled blocks will be used. SHORETEC Articulated Concrete Revetment Mat Systems provided a table of their open-celled block units with block dimensions, weight, moment arms, and critical shear stress. The smallest block that was available by SHORETEC was the SD-400 OC. This was the block first chosen to see if it would meet our target factor of safety. The factor of safety calculated for the SD-400 OC block was calculated to be 2.29. Since the factor of safety exceeded the target, there was no need for a larger block and the SD-400 OC block was selected for the channel stabilization for each channel (SHORETEC, 2013).

The total area of the block was found for each channel by multiplying the length of the channel by the sum of the width of the channel floor and the length of block that would needed

to be buried to form the anchors. Geo-textile will be placed under the concrete block mat, so the same areas will be used. In Table 3, the area was multiplied by the price per foot to find the total price for both the block mats and the geo-textile. SHORETEC provided a price of \$4.00 per square foot for the SD-400 OC block and Agriculture Solutions provided a price of \$0.20 per square foot for the geo-textile fabric. The material cost for Channel #3 is \$1,680.00, \$1,948.80 for Channel #4, and \$1,512.00 for Channel #5.

Table 3 – Articulating Concrete Block Mats Pricing

Articulating Concrete Block Mats								
	Mat Length	Mat Width	Mat Area	Block Mat	Block Mat Price	Geotextile	Geotextile Price	Total Price
Channel	(ft.)	(ft.)	(ft^2)	Price / sq. ft.	(\$)	Price / sq. ft.	(\$)	(\$)
#3	25	16	400	4.00	1600.00	0.20	80.00	1680.00
#4	29	16	464	4.00	1856.00	0.20	92.80	1948.80
#5	20	18	360	4.00	1440.00	0.20	72.00	1512.00
							Total =	5140.80

Bridge Erosion

East Ramp Pedestrian Bridge

The East Ramp Pedestrian Bridge spanning the Ottawa River, located by Savage Hall, has moderate erosion occurring around the abutments and piers. The banks on each side of the bridge have plentiful vegetation which creates stabilization and serves as natural erosion control. There is little concern with bank stabilization and erosion at these locations. However, directly under the bridge there is little to no vegetation. As a result of this, the river has cut steep banks into the center portions of the river and higher up on the banks. The steeper the banks become, the faster the erosion will occur. With steeper banks there will be less bank stabilization as well. As these banks erode, they will begin to encroach upon the bridge piers. Additionally, these steep banks could break off exposing much more of the bridge's piers; especially at times with high water flows and high velocities. If the erosion reaches the piers it could cause stability and structural problems for the bridge. Since this bridge already has structural issues which is an area of concern, a problem at the piers could noticeably affect the bridge's structural integrity.

The erosion at the East Ramp Bridge has been neglected for years. The main areas of focus are to control the erosion just below the abutments and around the piers. This is a concern for both the North and South side of the bridge. Since the piers extend into the river, they are typically surrounded with water during and after wet weather events. The need to control the erosion around the piers is more critical since the erosion is already threatening the bridge's structural integrity. As the water flow under the bridge gets parted by the piers, the water velocities around the piers increases. This means that the area around the piers will erode away faster than other parts of the river like the banks, river bottom, and even the area around the bridge abutments.

The stabilization of the bank beneath this bridge has two areas of concern. The first area of concern is mainly on the North side of the river. The location of the river at lower flows has eroded the river side just before the piers. This has left a ledge that could shear off of the bank and fall into the river. As erosion around the piers continues, this threat will grow because it will weaken the back side of the ledge; therefore, increasing the possibility of it shearing. If this occurs, it will greatly expose the piers and promote further erosion and decreased bank stabilization. The second area of concern is around the bridge abutments on both the North and South side. In this area, there is no vegetation to serve as natural bank stabilization, there is only soil. As erosion occurs in this unprotected area, it weakens the banks. It is clear that something needs done to prevent erosion and increase bank stabilization under this bridge. For this, several alternatives have been determined. The erosion and bank stabilization issues for the East Ramp Bridge on the North and South side of the river can be seen in Figure 33 and Figure 34, respectively.

Figure 33- North Side of East Ramp Bridge



Figure 34-South Side of East Ramp Bridge



Carlson Pedestrian Bridge Erosion Control

Currently, the area beneath the Carlson Pedestrian Bridge appears to be undergoing significant erosion. An analysis of the area yielded the following concerns. As a result of the erosion there is limited bank stabilization. The North Slope is very steep, which amplifies the problem of erosion. On the bridge embankments, there is little to no vegetation growth to help stabilize the banks. This can be attributed to the steepness of the slopes and tough growing conditions under the bridge. As a result of erosion, small flow channels have formed on the embankments running into the river (Figure 35). The flow channels are carving away at the bridge slopes and washing away valuable soil that is needed to keep the structure in place. These small channels cause water to enter the river at an increased velocity. Because of this, the water entering the river is carrying the soil to the river. This also negatively impacts the water quality.

Figure 35-South Side of Carlson Bridge



The erosion under the Carlson pedestrian bridge is very significant. In the past and during previous construction, it appears that there has been a minimal effort made towards reducing the amount of erosion that takes place under the bridge. In addition, the erosion appears to have been occurring for a considerable amount of time since water has etched out a few significant pathways. The etching of these pathways is a process that takes years to accomplish. There are also many smaller, erosion formed flow channels in the soil that can be seen on both the North and South side of the bridge (Figure 36).

Figure 36-North Side of Carlson Bridge



Bank stabilization is the process of holding the soil of a bank in place so it does not wash away or slide. Bank stabilization is a very important aspect to any bank, especially on banks that serve as structural support. In the case of the Carlson pedestrian bridge, bank stabilization is very important. Due to the lack of stabilization under the bridge, much erosion has occurred over the years (Figure 37). The implementation of erosion control alternatives can be used to help stabilize steep bank slopes such as the North side of this bridge (Figure 36). Because the erosion that has occurred under the Carlson Pedestrian Bridge is determined to be repairable and preventable, it is a great candidate for a bank restoration.

Figure 37-North Abutment of Carlson Bridge



Bridge Erosion Alternatives

Rip Rap

The first alternative that was determined was the use of rip rap for the erosion control and bank stabilization. This is a commonly used alternative that is easy to install and is usually very cost effective. Rip rap is an assortment of larger sized rocks which are placed in a layer on a bank or slope to help limit the erosion. Figure 38 depicts an example of what the use of rip rap can look like. The rock size needs to be determined based on the water velocity of the river, such that the rocks will not be swept away with the water's current. Rip rap essentially puts weight on the soil and banks to hold it into place. Rip rap can also help to stabilize the bank not just by limiting erosion but also by helping to hold the side slopes in place just by the added material. It also slows down water runoff, again limiting erosion. Rip rap can look aesthetically pleasing to most people if it is used correctly. This alternative could be used at both the Carlson Pedestrian Bridge as well as the East Ramp Pedestrian Bridge. Picture 7 in Appendix B shows a visual representation of rip rap used under these bridges.

Figure 38- Application of Rip Rap



The size of the rip rap for underneath each bridge is based on the discharge velocity and depth of flow of the Ottawa River. The discharge velocity and depth of flow were obtained from the HEC-RAS model provided by Dr. Patrick Lawrence, Chair of the UT President's Commission of the River. Using the design guideline for rip rap from the U.S. Department of Transportation, the d_{50} size of riprap was obtained. For both bridges it was determined that Type C rip rap would be appropriate to use. This rip rap can be used on a bank up to a 1 to 1.5 slope which will work for all applications on this project. In Type C rip rap, 85% of the material, by weight, is larger than a 6 inch square opening and at least 50% of the material, by weight, is larger than a 12 inch square opening, as stated previously. In order to calculate the volume of rip rap needed, the areas underneath each side of the bridges were used. Table 4 shows the volume

and price per ton of Type C rip rap. It can be seen from the table that for the East Ramp Pedestrian Bridge, the material price (including geo-textile fabric) would be \$852.12, and for the Carlson Pedestrian Bridge, the material price would be \$655.48.

Table 4 – Rip Rap Pricing

Under Bridge Rip Rap Alternative						
Bridge	Under Bridge Rip-Rap (yd³)	Geotextile (Price/sq ft)	Geotextile Price (\$)	Total (Tons)	Price/Ton (\$/Ton)	Total Price (\$)
East Ramp Pedestrian Bridge	22.10	0.20	155.97	38.68	18.00	852.12
Carlson Pedestrian Bridge	17.00	0.20	119.98	29.75	18.00	655.48
					Total =	1507.60

Articulating Concrete Blocks

The use of articulating concrete blocks have proven to be a very reliable and effective way to reduce erosion around structures such as bridge abutments and piers. This alternative will also positively impact bank stabilization when used in the correct application. There is an assortment of these blocks that vary in size, geometry, weight, etc. The differences in the blocks will allow the best result for each unique application. Some of the blocks are close-celled, like those seen in Figure 39. Other articulating blocks are open-celled to allow plant life to grow through. This style block can be seen in Figure 40. The additional plant life growth will add additional bank stabilization and erosion control. The use of these will be aesthetically pleasing and can promote the growth of native species. This alternative could successfully be applied at either of the two bridge locations. Picture 8 in Appendix B shows a visual representation of articulating concrete blocks used under these bridges.

Figure 39- Close-Celled Articulating Concrete Block

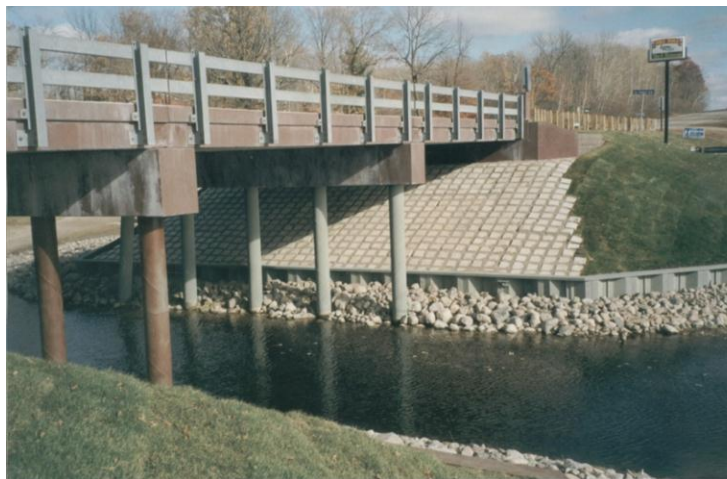


Figure 40- Open-Celled Articulating Concrete Block



The selection of the articulating concrete block mats for bank stabilization under East Ramp Pedestrian Bridge and Carlson Library Bridge underwent the same calculations as were mentioned for the outfall channels. This alternative is best suited for 2 to 1 slopes which works best for the East Ramp Bridge. The target factor of safety as mentioned by the Federal Highway Administration for bank stabilization was also 1.4, so it was still met by the SD-400 OC block. As seen in Table 5, the area that was needed stabilized under each bridge was calculated. The price for material is found by multiplying the area by the price per square foot. As mentioned before, SHORETEC provided a price of \$4.00 per square foot for the SD-400 OC block and Agriculture Solutions provided a price of \$0.20 per square foot for the geo-textile fabric. The material cost for the Carlson Library Bridge is \$7,560 and \$9,072 for East Ramp Pedestrian Bridge.

Table 5 – Articulating Concrete Block Mats Pricing

Bridge (Bank)	Articulating Concrete Block Mats							
	Mat Length (ft.)	Mat Width (ft.)	Mat Area (ft ²)	Block Mat Price / sq. ft.	Block Mat Price (\$)	Geotextile Price / sq. ft.	Geotextile Price (\$)	Total Price (\$)
East Ramp (N.)	30	36	1080	4.00	4320.00	0.20	216.00	4536.00
East Ramp (S.)	30	36	1080	4.00	4320.00	0.20	216.00	4536.00
Carlson (N.)	30	30	900	4.00	3600.00	0.20	180.00	3780.00
Carlson (S.)	30	30	900	4.00	3600.00	0.20	180.00	3780.00
							Total =	16632.00

Geo-mat

The third and final proposed alternative is the use of a geo-mat, or geo textile. There is a wide variety of geo-mats that can be used for erosion control along river banks and other areas where erosion is of concern. There are different means to install these mats simply from staking them to the ground to boring holes and installing anchors. When anchors are used, they aid in the stabilization of the bank as well as serving to fix the geo mat to the riverside. Figure 41 shows one method for the installation for the geo-mat. Since plant life can easily grow through the mats,

the added vegetation will allow further erosion control and bank stabilization. This alternative could be used for the East Ramp Pedestrian Bridge and the Carlson Library Pedestrian Bridge. Picture 9 in Appendix B shows a visual representation of geo-matting used under these bridges.

Figure 41- Installation of Geo-Mat



The selection of the type of geo-matting for use under the East Ramp Pedestrian Bridge and Carlson Library Pedestrian Bridge was based on the slope of the bank and the lowest angle of repose for the infill material. Using those factors, the EGA 30 geo-mat with 6 inch cells was chosen from the recommendation table from Geo Products, LLC. The next factor in the design was anchoring the geo-mat. A net sliding factor was determined to ensure that there was enough friction to hold the geo-mat on the bank. Anchoring methods include toeing the mat using an anchor trench and staking the mat to the bank. Tendons will connect to each anchoring point and increase stability.

Table 6 displays the number of geo-mat panels that will cover the area under each bridge to stabilize the bank. Price calculation is determined by multiplying the mat area by the price per foot. The cost of the tendons and stakes used to hold the geo-mat in place were also determined. Geo Products provided a price of \$168.02 for each panel, \$125 per coil of tendon, and \$0.80 per stake. There is also the cost of #57 stone used to fill the cells in the Geo-mat. The volume of stone was calculated from the geo-mat volume and converted into tonnage as seen in Table 7. Hanson Aggregate provided the price of \$11.50 per ton for #57 stone. The material cost for the geo-mat and stone for Carlson Library Bridge is \$2,571.87, and \$3,152.34 for East Ramp Pedestrian Bridge.

Table 6 – Geo-mat Pricing

Geo-mat / Geo-grid								
	Number of Panels (27.4' x 8.4')	Price/ Panels	Panel cost (\$)	Tendon Cost (\$)	Total Number of Stakes	Price/ Stake	Stake Cost (\$)	Total Price (\$)
East Ramp	10	168.02	1680.20	250.00	300	0.80	240.00	2170.20
Carlson	8	168.02	1344.16	250.00	240	0.80	192.00	1786.16
							Total =	3956.36

Table 7 - #57 Stone for Geo-mat Pricing

#57 Stone for Geo-mat								
	Panel Area (yd^2)	Stone Depth (yd)	Stone Volume (yd^3)	Number of Panels	Total Volume (yd^3)	Total Tons	Price / Ton (\$)	Total Price (\$)
East Ramp	25.57	0.17	4.27	10.00	42.70	85.4	11.50	982.14
Carlson	25.57	0.17	4.27	8.00	34.16	68.3	11.50	785.71
							Total =	1767.86

Conclusion

For this project, our recommended solutions were based largely on price, and innovation, while being sure to keep negative environmental impact to a minimum. Available space at each outfall was also a limiting factor. For Outfall #1, it is recommended that the splash pad of the headwall be replaced, and that A-Jacks be installed in the channel and on the banks on both side of the headwall. This would result in a material price of \$4315.30 for Outfall #1. For Outfall #2, it is proposed that the damaged end of the corrugated metal pipe be cut off flush with the surface of the headwall and that A-Jacks be placed in the channel and on both sides of the headwall. This would result in a material price of \$4590.00. The recommended solution for Outfall #3 would be to cut the upper portion of the headwall down and to install a rock check dam in the channel. This would result in a material price of \$397.92. Outfall #4 would benefit the most by replacing the headwall, and installing two rock check dams in the channel. This would result in a material price of \$709.72. Since the headwall of Outfall #5 is in good condition, the only work necessary would be to install articulating concrete blocks in the channel. This would result in a material price of \$1512.00 for the articulating concrete blocks.

In order to address the erosion issues under the Carlson Pedestrian Bridge and the East Ramp Pedestrian Bridge, the geo-mat is the recommended solution. Although, this is not the most cost effective solution, it is very innovative when compared to rip rap and articulating concrete blocks. Plants are also able to grow in the geo-matting, making this alternative even more attractive when compared to rip rap. According to plant expert, Tim Walters, a possible seed that could be planted under these bridges would be Virginia wild-rye. Violet or wild ginger could also be planted as plugs. These species tend to be able to grow in shade and are able to survive high flow events on the river. The estimated material price for the geo-matting under the Carlson Pedestrian Bridge is \$2571.87. The estimated material price for the geo-matting under the East Ramp Pedestrian Bridge is \$3152.34. With all of the recommended solutions taken into account (including outfalls and bridges), the estimated total material cost is \$17249.15. Cost summary for the project can be seen in Table 7. This price does not include the cost of labor or

equipment. Refer to Appendix B which contains CAD drawings for specific dimensions for check dams, A-Jacks, articulating concrete block, geo-mat, and headwalls (Drawings 1-6).

Table 7 – Project Cost Summary

<u>Project Cost Summary</u>			
Outfall	Recommended Repair	Recommended Channel Protection	Cost
#1	Repair Splash Pad	A-Jacks	\$4,315.30
#2	Cut Off Damaged Pipe	A-Jacks	\$4,590.00
#3	Cut Down Headwall	One Rock Check Dam	\$397.92
#4	Replace Headwall	Two Rock Check Dams	\$709.72
#5	No Headwall Modification	Articulating Concrete Block	\$1,512.00
		Total Outfall Cost =	\$11,524.94
	Bridge	Recommended Erosion Control	Cost
	Carlson Pedestrian	Geo-mat	\$3,152.35
	Savage Pedestrian	Geo-mat	\$2,571.87
		Total Bridge Cost =	\$5,724.22
		Total Project Cost =	\$17,249.16

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Statement of Qualifications

Biographies and Resumes



Kyle Bucher is a senior at The University of Toledo currently pursuing a degree in Civil Engineering. He has completed four co-op rotations with two different companies. His first term was with The City of Sylvania Utilities Department. Kyle obtained valuable field experience by inspecting sewer installations, performing repairs on sewer systems, and maintaining waterways and watersheds. His final three co-op rotations were with the alloy metal manufacturing company, Materion. Here he worked in the Facilities Engineering Department where he provided engineering assistance plant wide. Kyle also managed equipment installation, building repair, and steel structure construction projects with his time there. Upon graduation, Kyle plans to take a full time position with Materion as Civil Facilities Engineer.



Joseph Hanely is a senior at The University of Toledo with an anticipated degree in Civil Engineering. During Joseph's time in the Civil Engineering program, he has completed 3 co-op terms with The Village of Dundee, Michigan, a local municipality. Joseph gained experience ranging from skills of water, storm, and sewer systems, along with surveying, AutoCAD, to name a few. He was involved in surveying, estimating, inspecting projects, and design work. Joseph plans to find a full time position in Civil Engineering after graduation this December.



Benjamin Hodges is a senior in his final semester at The University of Toledo in the Civil Engineering program. Benjamin has completed five co-op terms with the E.S. Wagner Company, working in heavy highway construction on road reconstruction project and the I-475 rehabilitation project. He has gained a wide variety of experience and skills from his time as a laborer working on various crews, site layout using GPS, grade checking for roadway undercuts, quantity tracking during the project, and field supervision of small crews. After his anticipated graduation in December 2013, Benjamin plans on taking a full time position with the E.S. Wagner Company.



Benjamin Wetherill is a senior at the University of Toledo where he is in his final semester in the Civil Engineering program. Ben has completed three co-op terms with Ulliman Schutte Construction, a wastewater and water supply construction firm with headquarters in Dayton, OH. During his co-op terms, Ben had the opportunity to work in Virginia, Maryland, and Washington D.C. Ben gained experience working as an Assistant Project Engineer during his first co-op where he obtained submittal material along with priced, purchased, and distributed project materials. During his second co-op as a Project Estimator, Ben was able to gain experience in the take-off and estimating side of the construction process. In Ben's third and final co-op as an Assistant Project Engineer he gained a lot more responsibility and performed small portions of the project on his own in conjunction with the Project Manager. Planning to graduate in December of 2013, Ben plans to acquire a position as a Project Engineer for a construction company in Ohio or nearby state.



Mark Wolf is a senior in the Civil Engineering program at the University of Toledo. While pursuing his degree in Civil Engineering, Mark has completed four co-op experiences. The first two co-op positions that Mark held were for the City of Perrysburg Engineering Department. During his time at the City of Perrysburg, Mark was able to utilize GPS equipment to locate items for the water division, and upload the data. Mark's next two co-op experiences were with the Geo. Gradel Company. While working for the Geo. Gradel Company, Mark gained experience assisting in the management of projects, recording revenue for their scrap program, preparing bid take-off, and estimating. After his graduation in December 2013, Mark's goal is to securing a position in Civil Engineering.

KYLE D. BUCHER

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OBJECTIVE

To secure a position in Civil Engineering where my knowledge, mechanical and structural aptitude, and commitment to safety can effectively contribute to the successful operation of the company.

EDUCATION

August 2009-Present

The University of Toledo, Toledo, Ohio
Bachelor of Science, Civil Engineering

- Anticipated Graduation Date: December 2013

COMPUTER SKILLS

Microsoft Office Suite
Microsoft Access
AutoCAD 2012

EXPERIENCE

August 2012 - Present

January 2012 - May 2012

Materion, Elmore, Ohio
Civil Engineering Co-op

- Managed capital projects
- Restructured document filing database
- Designed steel structures
- Provided engineering assistance

May 2011- August 2011

City of Sylvania Utilities, Sylvania, Ohio
Civil Engineering Co-op

- Inspected sewer and water line replacement projects
- Inspected sewer lines for problems and repairs
- Repaired storm sewer lines

May 2010- August 2010

City of Sylvania Parks and Forestry, Sylvania, Ohio
General Temporary Laborer

- Operated landscape and other equipment
- Performed equipment maintenance and repair
- Maintained parks and cemetery
- Assisted with composting operations

ADDITIONAL TRAINING

Leadership Initiatives - Project Management Fundamentals Course
Trane - Air to Air Energy Recovery Seminar
Safe Start - Unit 1 Training

REFERENCES

Available upon request

JOSEPH M. HANELY

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OBJECTIVE	To secure a full time position in the field of Civil Engineering to utilize my skills and experience in the work field.
EDUCATION August 2009 – Present	The University of Toledo, Toledo, Ohio <i>Bachelor of Science, Civil Engineering</i> <ul style="list-style-type: none">• Expected Graduation Date: December 2013
EXPERIENCE August 2013 - Present	E.S. Wagner Company Oregon, Ohio Shop Mechanic <ul style="list-style-type: none">• General Labor• Vehicle and Machinery Maintenance• General Shop Projects
May 2010 - May 2013	Village of Dundee, Michigan Dundee, Michigan <i>Co-op</i> <ul style="list-style-type: none">• Aided in Village Engineering Operations• Oversaw New Construction Projects• General Office Work
Summer of May 2009 - July 2013	Xanterra Parks and Resorts (Maumee Bay State Park) Oregon, Ohio <i>Maintenance Department and Banquet Server</i> <ul style="list-style-type: none">• Maintained Property• Ensure Customer Service• Maintained Equipment
August 2008 - May 2010	Gordon Food Services, Oregon, Ohio <i>Sales Associate</i> <ul style="list-style-type: none">• Stock Shelves• Help Maximize Sales• Customer Service
COMPUTER SKILLS	<ul style="list-style-type: none">• Microsoft Office Suite• Microsoft Internet Explorer• AutoCAD
HONORS & AWARDS	<ul style="list-style-type: none">• Dean's List• Scholarship Awards• National Honors Society High School Graduate
REFERENCES	Available upon request.

BENJAMIN EDWARD HODGES

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OBJECTIVE

To secure a full time position in the Civil Engineering field that will complement my academic endeavors with hands-on experience.

EDUCATION

The University of Toledo, Toledo, Ohio

August 2009-Present

Bachelor of Science, Civil Engineering

- Anticipated Graduation Date: December 2013
- Grade Point Average: 3.997

COMPUTER SKILLS

Microsoft Office Suite

AutoCAD 2009

EXPERIENCE

E.S. Wagner Company, Oregon, OH

June 2009-Present

Project Engineer Co-op/ Equipment Distribution Personnel

- Administer parts, materials, equipment, etc. to construction sites
- Perform engine/ mechanic work
- Prepare equipment and material orders for field job sites
- Organize construction materials
- Repair various tools used in the field
- Obtain inventory of various supplies
- Maintain a clean work environment
- Manage work force, enter quantities and employee/ equipment time
- Detail the interior and exterior of semi-trucks and pick-up trucks
- Utilize a global positioning system to check grade, install storm sewers, and survey roadway pavement layout
- Reconcile payment quantities with project owner

HONORS &

University of Toledo Rocket Scholar Award

AWARDS

National Honor Society

SPECIAL SKILLS

& INTERESTS

- Take tremendous pride in my work
- Excellent ability to learn new skills quickly
- Possess a very logical thought process
- Display a great organizational ability

REFERENCES

Available upon request

BENJAMIN J. WETHERILL

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Forrest, OH 45843
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OBJECTIVE

To obtain a position as a Civil Engineer encompassing a hands-on capacity that will enhance and enrich my Civil Engineering knowledge and assist in achieving my PE license.

EDUCATION

August 2009 – Present

The University of Toledo, Toledo, Ohio
Bachelor of Science, Civil Engineering

- Anticipated Graduation Date: Dec. 2013
- Grade Point Average: 3.72
- Business Minor

COMPUTER SKILLS

Microsoft Office Suite and AutoCAD
ICE: MC² Estimating Computer Software and Digitizing

EXPERIENCE

January 2013 – May 2013

Ulliman Schutte Construction, Dayton, Ohio
Co-op Engineer for project in Lorton, VA

- Head coordinator for all below ground yard piping
- Lead Engineer/Designer for change orders and as-built projects
- Performed start-up and testing for mechanical components

May 2012 – August 2012

Ulliman Schutte Construction, Dayton, Ohio
Co-op Estimator/Engineer for estimating office in Rockville, MD

- Performed takeoff and estimated architectural section of all bids
- Configured prices from vendors and organized bid proposals

August 2011 – December 2011

Ulliman Schutte Construction, Dayton, Ohio
Co-op Engineer for project in Lorton, VA

- Obtained submittal material and secured purchase orders
- Priced, purchased, and organized deliveries for project materials
- Coordinated distribution and implementation of job components

August 2008 – May 2009

Marathon Petroleum Company, Findlay, Ohio
Engineering Explorers (In conjunction with Ohio Northern University)

- Job Shadowed Lucas R. DeGarmo, Project Engineer I

HONORS & AWARDS

Rocket Scholar Award
MOSSER Construction: Robert H. Moyer Scholarship
Central Ohio Associated General Contractors Scholarship
William D. Squires Scholarship
Golden Key International Honour Society
LEVIS Leadership Scholarship
Engineering Department Dean's List Recognition

COLLEGIATE ACTIVITIES

UT LEVIS Leadership Program and Rocket 2 Rocket Peer Mentorship
Civil Engineering Department Mentorship Program for Freshman
ASCE – American Society of Civil Engineers
UTSPE – University of Toledo Society of Professional Engineers
Office – Secretary and Survey Committee
Intramural Sports

REFERENCES:

Available upon request

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Oregon, OH 43616
(419) 836-2402
Mark.Wolf@rockets.utoledo.edu

OBJECTIVE	To obtain a career in the field of Civil Engineering that will allow me to grow professionally and utilize my knowledge and skills.
EDUCATION August 2009-Present	The University of Toledo , Toledo, Ohio <i>Bachelor of Science, Civil Engineering</i> <ul style="list-style-type: none">• Anticipated Graduation Date: May 2013
EXPERIENCE May 2006-Present	Wolf Farms , Oregon, Ohio <ul style="list-style-type: none">• Cultivated farm land to prepare for planting.• Participated in the operation of planting and harvesting of the grain crop.• Transported grain to the elevator.• Provided help in the repairing of equipment.• Assisted with water drainage and tiling of farm land.
June-August 2008	Maumee Bay State Park Nature Center , Oregon, Ohio <ul style="list-style-type: none">• Volunteered at the Nature Center, which involved various maintenance duties.• Controlled invasive plant species.
May-August 2011	City of Perrysburg Engineering Division , Perrysburg, Ohio <ul style="list-style-type: none">• Utilized hand-held GPS units to mark locations of curb boxes, pull boxes, etc.• Repaired any broken curb boxes.
January-May 2012	<ul style="list-style-type: none">• Uploaded data from GPS and sent it out to be post processed.• Organized and recorded plans.• Checked Sight distances at intersections.
August-December 2012 May-August 2013	Geo. Gradel Company , Toledo, Ohio <ul style="list-style-type: none">• Worked on site, and assisted in management of projects.• Calculated and recorded revenues from scrap management projects.• Dissected project plans and prepared bid take-offs.
HONORS & AWARDS	<ul style="list-style-type: none">• Rocket Gold Scholarship• Dr. & Mrs. Riza Scholarship• H. Peter Carstensen Scholarship• Top 10% while attending Clay High School• National Honor Society member
ACTIVITIES	<ul style="list-style-type: none">• Participated in the football program at Clay High School• 4-H involvement in the Livestock Unlimited 4-H Club, where I served as vice president.
REFERENCES	Available upon request

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Appendix A-Design Calculations

Channel Flow and Velocity Calculations

Outfall #1

$$\text{Pipe Diameter} = 14''$$

$$\text{Pipe Radius} = 7'' \text{ or } 1.167'$$

$$A = \pi r^2 = \pi(1.167)^2 = 1.069 \text{ ft}^2$$

$$R_H = \frac{A}{P_w} = \frac{A}{2\pi r} = \frac{1.069}{2\pi(1.167)} = 0.292'$$

$$S = 0.02$$

$$K = 1.486$$

$$n = 0.013$$

$$Q = \frac{K}{n} A R_H^{2/3} S^{1/2} = \frac{1.486}{0.013} (1.069)(0.292)^{2/3} (0.02)^{1/2}$$

$$Q = 7.600 \text{ ft}^3/\text{s}$$

$$V = \frac{Q}{A} = \frac{7.600}{1.069} = 7.110 \text{ ft/s}$$

$$V = 7.110 \text{ ft / s}$$

Outfall #2

$$\text{Pipe Diameter} = 24''$$

$$\text{Pipe Radius} = 12'' \text{ or } 1.000'$$

$$A = \pi r^2 = \pi(1.000)^2 = 3.142 \text{ ft}^2$$

$$R_H = \frac{A}{P_w} = \frac{A}{2\pi r} = \frac{\pi}{2\pi(1.000)} = 0.500'$$

$$S = 0.02$$

$$K = 1.486$$

$$n = 0.013$$

$$Q = \frac{K}{n} A R_H^{2/3} S^{1/2} = \frac{1.486}{0.013} (\pi)(0.500)^{2/3} (0.02)^{1/2}$$

$$Q = 31.993 \text{ ft}^3/\text{s}$$

$$V = \frac{Q}{A} = \frac{31.993}{\pi} = 10.184 \text{ ft/s}$$

$$V = 10.184 \text{ ft} / \text{s}$$

Outfall #3

$$\text{Pipe Diameter} = 21"$$

$$\text{Pipe Radius} = 10.5" \text{ or } 0.875'$$

$$A = \pi r^2 = \pi(0.875)^2 = 2.405 \text{ ft}^2$$

$$R_H = \frac{A}{P_w} = \frac{A}{2\pi r} = \frac{2.405}{2\pi(0.875)} = 0.4375'$$

$$S = 0.02$$

$$K = 1.486$$

$$n = 0.013$$

$$Q = \frac{K}{n} A R_H^{2/3} S^{1/2} = \frac{1.486}{0.013} (2.405)(0.4375)^{2/3} (0.02)^{1/2}$$

$$Q = 22.408 \text{ ft}^3 / \text{s}$$

$$V = \frac{Q}{A} = \frac{22.408}{2.405} = 9.316 \text{ ft/s}$$

$$V = 9.316 \text{ ft} / \text{s}$$

Outfall #4

$$\text{Pipe Diameter} = 12"$$

$$\text{Pipe Radius} = 6" \text{ or } 0.500'$$

$$A = \pi r^2 = \pi(0.500)^2 = 0.783 \text{ ft}^2$$

$$R_H = \frac{A}{P_w} = \frac{A}{2\pi r} = \frac{0.783}{2\pi(0.500)} = 0.249'$$

$$S = 0.02$$

$$K = 1.486$$

$$n = 0.013$$

$$Q = \frac{K}{n} A R_H^{2/3} S^{1/2} = \frac{1.486}{0.013} (0.783)(0.249)^{2/3} (0.02)^{1/2}$$

$$Q = 5.018 \text{ ft}^3 / \text{s}$$

$$V = \frac{Q}{A} = \frac{5.018}{0.783} = 6.405 \text{ ft/s}$$

$$V = 6.405 \text{ ft} / \text{s}$$

Outfall #5

$$\text{Pipe Diameter} = 21"$$

$$\text{Pipe Radius} = 10.5" \text{ or } 0.875'$$

$$A = \pi r^2 = \pi(0.875)^2 = 2.405 \text{ ft}^2$$

$$R_H = \frac{A}{P_w} = \frac{A}{2\pi r} = \frac{2.405}{2\pi(0.875)} = 0.4375'$$

$$S = 0.02$$

$$K = 1.486$$

$$n = 0.013$$

$$Q = \frac{K}{n} A R_H^{2/3} S^{1/2} = \frac{1.486}{0.013} (2.405)(0.4375)^{2/3} (0.02)^{1/2}$$

$$Q = 22.408 \text{ ft}^3/\text{s}$$

$$V = \frac{Q}{A} = \frac{22.408}{2.405} = 9.316 \text{ ft/s}$$

$$V = 9.316 \text{ ft} / \text{s}$$

Channel Alternative Design Calculations

Rip Rap/Check Dam Volume Calculations:

Channel #3: (Outlet velocity = 9.316 ft/s, From ODOT – Type C Rip-Rap)

Channel Rip Rap: (1 ft thick, 25 ft long, 4 ft wide)

$$Volume_{Channel} = (25ft)(4ft)(1ft)$$

$$Volume_{Channel} = 100ft^3 \times \frac{1yd^3}{27ft^3} = 3.70yd^3$$

Check Dam: (4 ft wide)

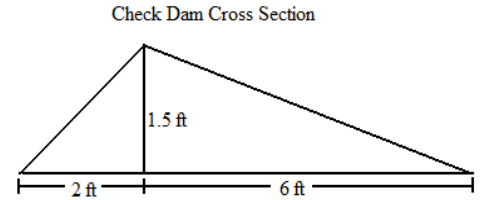
$$Area_{cross-section} = \frac{1}{2}(2ft)(1.5ft) + \frac{1}{2}(6ft)(1.5ft)$$

$$Area_{cross-section} = 6ft^2$$

$$Volume_{Dam} = (6ft^2)(4ft)$$

$$Volume_{Dam} = 24ft^3 \times \frac{1yd^3}{27ft^3} = 0.89yd^3$$

Total Channel #3 Volume = 4.59yd³ of Type C 6 inch Rock



Channel #4: (Outlet velocity = 6.405 ft/s, From ODOT – Type C Rip-Rap)

Channel Rip Rap: (1 ft thick, 29 ft long, 4 ft wide)

$$Volume_{Channel} = (29ft)(4ft)(1ft)$$

$$Volume_{Channel} = 116ft^3 \times \frac{1yd^3}{27ft^3} = 4.30yd^3$$

Check Dams: (4 ft wide, 2 dams)

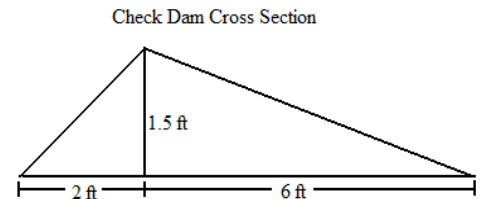
$$Area_{cross-section} = \frac{1}{2}(2ft)(1.5ft) + \frac{1}{2}(6ft)(1.5ft)$$

$$Area_{cross-section} = 6ft^2$$

$$Volume_{Dams} = (6ft^2)(4ft)(2 \text{ dams})$$

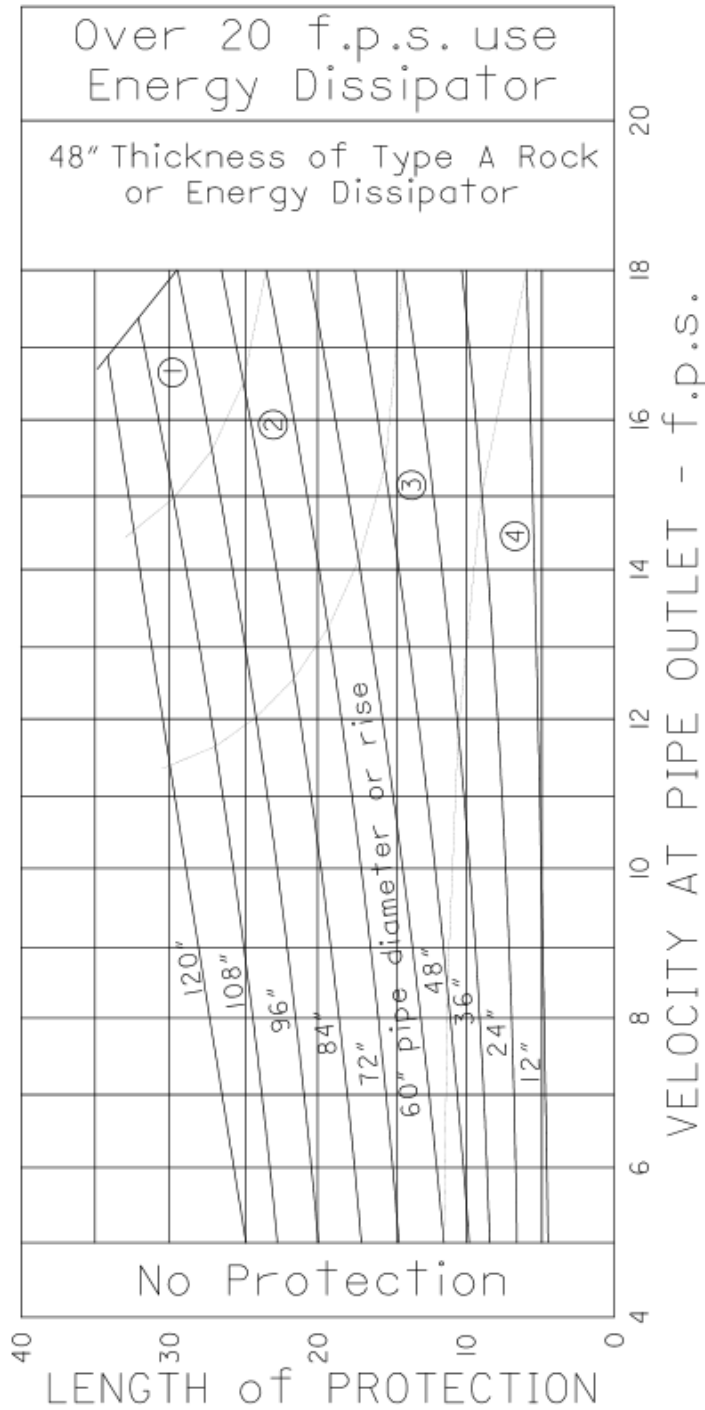
$$Volume_{Dams} = 48ft^3 \times \frac{1yd^3}{27ft^3} = 1.78yd^3$$

Total Channel #4 Volume = 6.08yd³ of Type C 6 inch Rock



ODOT Chart Used to Size Rip-Rap

ROCK CHANNEL PROTECTION AT CULVERT AND STORM SEWER OUTLETS	1107-1
	REFERENCE SECTION 1107.2



ROCK TYPE	LEGEND	NOTES
①	48" of 18" rock	Rock size (6", 12", 18") indicates the square opening on which 85% of the material, by weight, will be retained. The width of protection shall be the width of the headwall, with 4' being the minimum. (Where a stream bed will withstand the calculated velocity without erosion, no rock channel protection will be required.)
②	36" of 18" rock	
③	30" of 12" rock	
④	18" of 6" rock	

A-Jacks Design Calculations:

River Details:

$$100\text{-year Design Discharge: } Q = 4235 \frac{ft^3}{sec}$$

$$\text{Bed Slope: } S_o = 0.012 \frac{ft}{ft} (1.2\%)$$

$$\text{Channel Bottom Width: } b = 54ft$$

$$\text{Channel Side Slope: } Z = 2H:1V$$

$$\text{Required Factor of Safety: } F.S. = 1.5$$

$$\text{Manning's Coefficient: } n = (n_0 + n_1 + n_2 + n_3 + n_4)(m_5)$$

$$n = (0.02 + .01 + .005 + .013 + .02)(1) = 0.068$$

Step 1

The determination of hydraulic conditions will be straightforward, since the roughness of the A-Jacks along the banks will not appreciably affect the flow conditions of the soft-bottom channel. The solution procedure will evaluate the AJ-24 armor units and determine their factor of safety under the given conditions.

- $Qn = 4235 \times 0.068 = 288 \frac{ft^3}{sec}$
- From Nomograph determine $\frac{y_o}{b} = 0.15$
- Calculate $y_o = 0.15 \times 54ft = 8.55ft$

Step 2

Determine velocity and bed shear stress:

- Velocity: $V = \frac{Q}{A} = \frac{Q}{y_o(b + Zy_o)} = \frac{4235}{8.55[57 + 2(8.55)]} = 6.68 \frac{ft}{sec}$
- Bend Coefficient: $K_b = 1$
- Max Shear Stress: $\tau_0 = K_b \gamma y_o S_f = 1 \times 62.4 \times 8.55 \times 0.012 = 6.45 \frac{lbs}{ft^2}$

Step 3

Determine the limiting values of shear stress and velocity for AJ-24 armor units on the channel bed from Figures 2.9 and 2.10 at a bed slope of 0.012 ft/ft (1.2%):

$$\tau_p(\text{bed}) = 44 \frac{lbs}{ft^2}$$

$$V_p(\text{bed}) = 23.5 \frac{ft}{sec}$$

Multiply the limiting values of shear stress and velocity for the bed by the side slope correction fact from Figures 2.11 with a 2H:1V slope:

$$\tau_p (\text{side slope}) = 44 \times 0.45 = 19.8 \frac{\text{lbs}}{\text{ft}^2}$$

$$V_p (\text{side slope}) = 23.5 \times 0.67 = 15.7 \frac{\text{ft}}{\text{sec}}$$

Step 4

Determine the safety factors associated with shear stress and velocity:

$$F.S. (\text{shear stress}) = \frac{\tau_p}{\tau_{\text{actual}}} = \frac{19.8}{6.45} = 3.06 \approx 3$$

$$F.S. (\text{velocity}) = \frac{V_p}{V_{\text{actual}}} = \frac{15.7}{6.68} = 2.35 \approx 2.5$$

Conclude that safety factors for both shear and velocity criteria exceed the required value of 1.5 for this particular application, using A-Jacks AJ-24 armor units.

Step 5

Summarize Results for the A-Jacks AJ-24 system:

100-year discharge, Q	4235
Bed slope, percent	1.2
Bottom width, b	57
Side Slope Z	2H:1V
Manning's Coeff., n	0.068
Depth, y	8.55
Velocity, V	6.68
Shear Stress	6.45
Safety Factor (shear stress)	3.06
Safety Factor (velocity)	2.35

Roughness Coefficient Equation

$$n=(n_0+n_1+n_2+n_3+n_4)(m_5)$$

Channel conditions		Values	
Material involved	Earth	n_0	0.020
	Rock cut		0.025
	Fine gravel		0.024
	Coarse gravel		0.028
Degree of irregularity	Smooth	n_1	0.000
	Minor		0.005
	Moderate		0.010
	Severe		0.020
Variations of channel cross section	Gradual	n_2	0.000
	Alternating occasionally		0.005
	Alternating frequently		0.010–0.015
Relative effect of obstructions	Negligible	n_3	0.000
	Minor		0.010–0.015
	Appreciable		0.020–0.030
	Severe		0.040–0.060
Vegetation	Low	n_4	0.005–0.010
	Medium		0.010–0.025
	High		0.025–0.050
	Very high		0.050–0.100
Degree of meandering	Minor	m_5	1.000
	Appreciable		1.150
	Severe		1.300

Figure 2.9

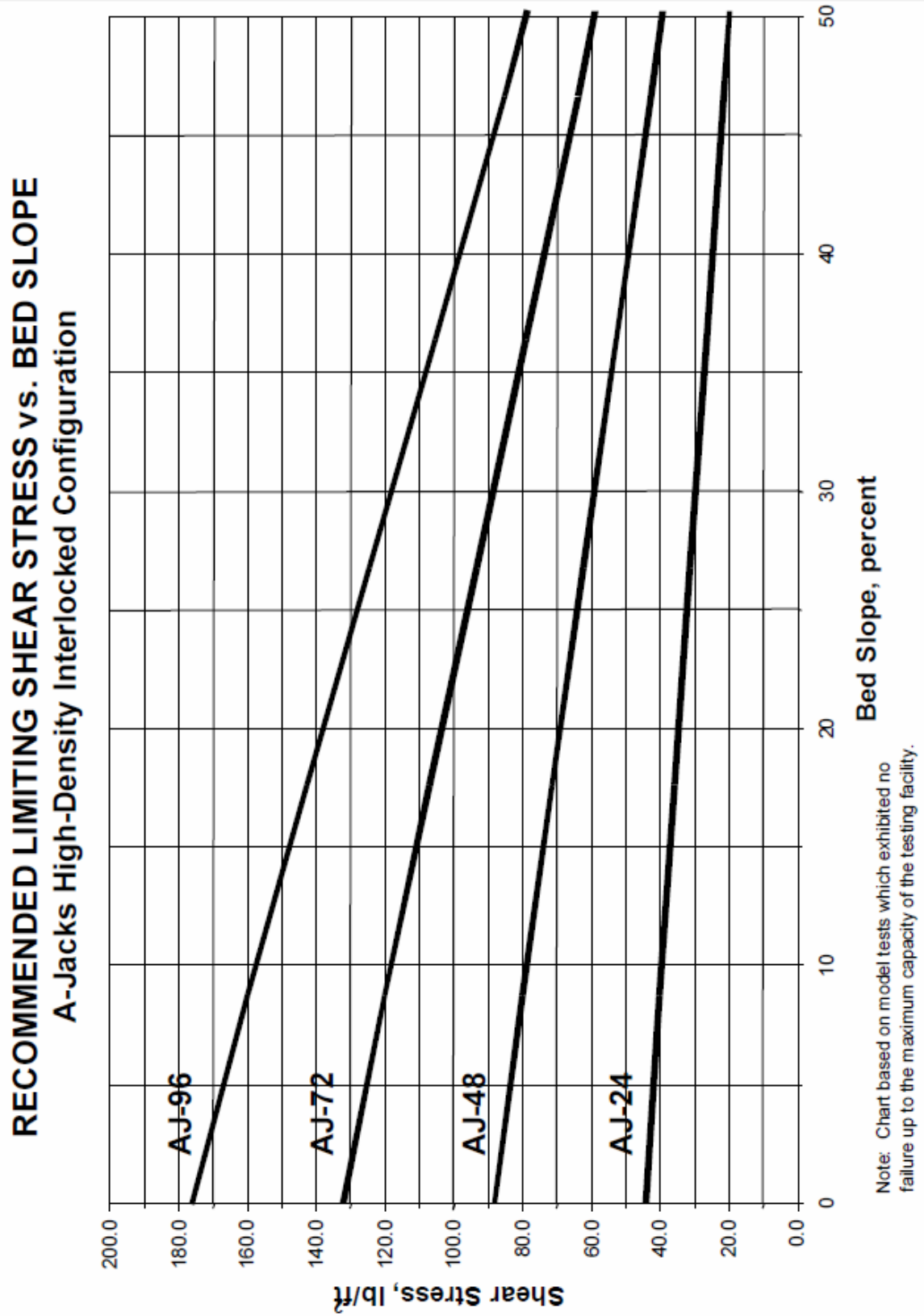


Figure 2.10

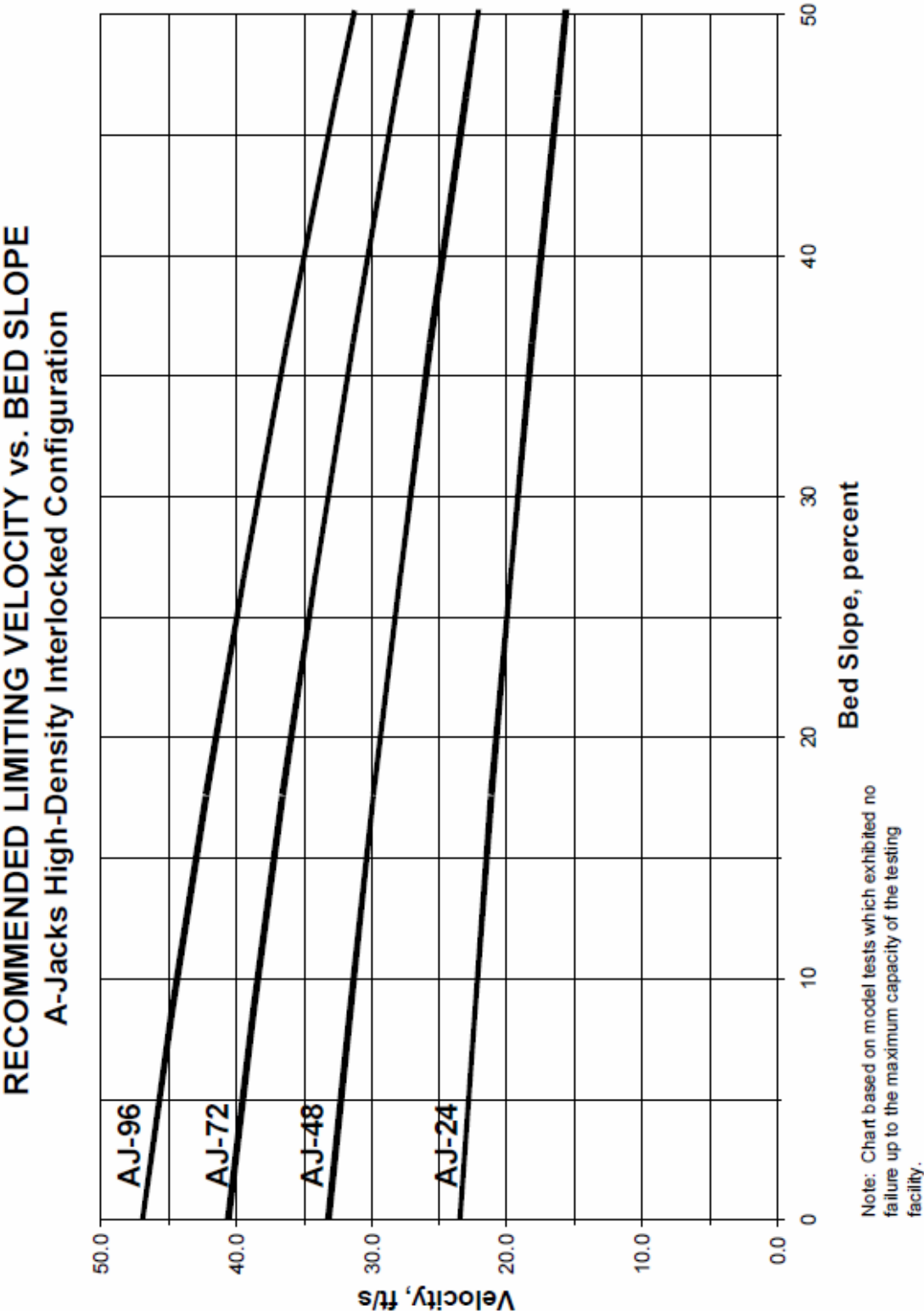
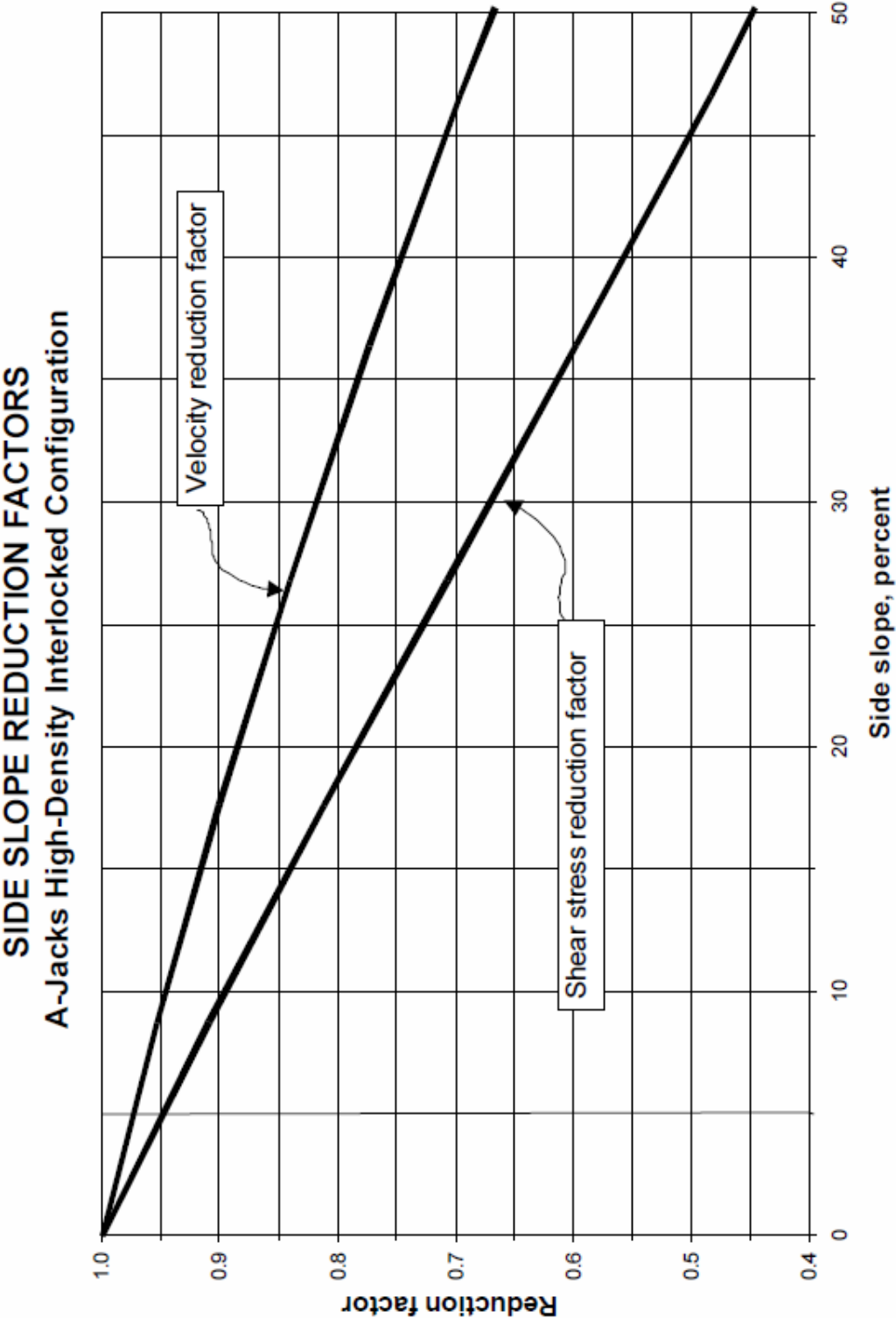


Figure 2.11



Articulating Concrete Block:

River Details:

$$100 \text{ year design discharge: } Q = 4,235 \text{ ft}^3/\text{s}$$

$$\text{Max Depth: } y = 8.55 \text{ ft.}$$

$$\text{Slope of Energy Grade Line: } S_f = 0.012 \text{ ft/ft}$$

$$\text{Maximum Velocity: } V_{des} = 6.68 \text{ ft/s}$$

$$\text{Bend Coefficient: } K_b = 1$$

Target Factor of Safety for Channel Bed or Bank

$$SF = 1.4$$

Design Shear Stress

$$\begin{aligned}\tau_{des} &= K_b(\gamma)(y)(S_f) \\ &= (1)(62.4)(8.55)(0.012) \\ &= 6.45 \text{ lb/ft}^2\end{aligned}$$

Calculate the Factor of Safety Parameters

The following table displays the given block cell information by SHORETEC Articulated Concrete Revetment Mat Systems. The block cell information will be utilized through various parameters for calculating the factor of safety for that block.

Open Cell Unit	Block Thickness (in.)	Block Width (in.)	Block Length (in.)	Weight (lbs.)	Moment Arms				τ_c (lb/ft ²)
					l_1	l_2	l_3	l_4	
SD-400 OC	4.00	15.50	17.40	57	2	11.65	3.2	11.65	32

Additional Lift & Drag on a Protruding Block

$$\begin{aligned}F'_L = F'_D &= 0.5\rho b(\Delta z)(V_{des})^2 \\ &= 0.5(1.94 \text{ slugs/ft}^2)\left(\frac{2(11.65 \text{ in})}{12\frac{\text{in}}{\text{ft}}}\right)\left(\frac{0.5}{12\frac{\text{in}}{\text{ft}}}\right)\left(6.68 \text{ ft/s}\right)^2 \\ &= 3.502 \text{ lb}\end{aligned}$$

Stability Number for a Block on a Horizontal Surface

$$\begin{aligned}\eta_0 &= \frac{\tau_{des}}{\tau_c} \\ &= \frac{6.45}{32} \\ &= 0.202\end{aligned}$$

Angle between Side Slope Projection of Submerged block Weight and the Vertical

$$\begin{aligned}\theta &= \arctan\left(\frac{\tan \theta_0}{\tan \theta_1}\right) \\ &= \arctan\left(\frac{\tan 0.57^\circ}{\tan 26.6^\circ}\right) \\ &= 1.14^\circ\end{aligned}$$

Projection of Submerged Block Weight into Plane of Subgrade

$$\begin{aligned}a_\theta &= \sqrt{(\cos \theta_1)^2 - (\sin \theta_0)^2} \\ &= \sqrt{\cos^2(26.6) - \sin^2(0.57)} \\ &= 0.894\end{aligned}$$

Angle between Block Motion and the Vertical

$$\begin{aligned}\beta &= \arctan\left(\frac{\cos(\theta_0 + \theta)}{\left(\frac{l_4}{l_5} + 1\right) \frac{\sqrt{1 - (0.894)^2}}{0.202 \left(\frac{11.65}{2}\right)} + \sin(\theta_0 + \theta)}\right) \\ &= \arctan\left(\frac{\cos(0.57 + 1.14)}{\left(\frac{11.65}{3.2} + 1\right) \frac{\sqrt{1 - (0.894)^2}}{0.202 \left(\frac{11.65}{2}\right)} + \sin(0.57 + 1.14)}\right) \\ &= 29.13^\circ\end{aligned}$$

Angle between Drag Force and Block Motion

$$\begin{aligned}\delta &= 90^\circ - \beta - \theta \\ &= 90^\circ - 29.13^\circ - 1.1\end{aligned}$$

$$= 59.73^\circ$$

Stability Number on a Sloped Surface

$$\begin{aligned}\eta_1 &= \left(\frac{l_4/l_3 + \sin(\theta_0 + \theta + \beta)}{l_4/l_3 + 1} \right) \eta_0 \\ &= \left(\frac{11.65/3.2 + \sin(0.57^\circ + 1.14^\circ + 59.73^\circ)}{11.65/3.2 + 1} \right) 0.202 \\ &= 0.197\end{aligned}$$

Submerged Block Weight

$$\begin{aligned}W_s &= W \left(\frac{\gamma_c - \gamma_w}{\gamma_c} \right) \\ &= 57 \left(\frac{140 - 62.4}{140} \right) \\ &= 31.594 \text{ lbs}\end{aligned}$$

Factor of Safety

$$\begin{aligned}SF &= \frac{\left(\frac{l_2}{l_1} \right) a_\theta}{\cos \beta \sqrt{1 - a_\theta^2} + \eta_1 \left(\frac{l_2}{l_1} \right) + \frac{l_3 F'_D \cos \delta + l_4 F'_L}{l_1 W_s}} \\ &= \frac{\left(\frac{11.65}{2} \right) 0.894}{\cos(29.13^\circ) \sqrt{1 - (0.894)^2} + 0.197 \left(\frac{11.65}{2} \right) + \frac{(3.2)(3.502) \cos(64.53^\circ) + 11.65(3.502)}{2.375(37.137)}} \\ &= 2.29\end{aligned}$$

$$1.4 < 2.29$$

The factor of safety for the SD-400 OC block meets the target factor of safety.

Bridge Erosion Alternatives Design Calculations

Rip-Rap Design Calculations:

$K_1 = \text{Side slope correction factor}$

$$K_1 = \sqrt{1 - \left(\frac{\sin(\theta - 14^\circ)}{\sin(32^\circ)} \right)^{1.6}}$$

$\theta = 26.6^\circ$ (The bank angle in degrees)

$$K_1 = \sqrt{1 - \left(\frac{\sin(26.6^\circ - 14^\circ)}{\sin(32^\circ)} \right)^{1.6}} = 0.871$$

$d_{30} = \text{Particle size for which 30\% is finer by weight, ft}$

$$d_{30} = y(S_f C_s C_v C_T) \left[\frac{V_{des}}{\sqrt{K_1(S_g - 1)gy}} \right]^{2.5}$$

$y = 8.55 \text{ ft}$ (Local depth of flow, ft)

$S_f = 1.5$ (Safety Factor)

$C_s = 0.3$ for angular rock (Stability coefficient)

$C_v = 1$ for straight channels (Velocity distribution coefficient)

$C_T = 1$ (Blanket thickness coefficient)

$V_{des} = 8 \frac{\text{ft}}{\text{sec}}$ (Design velocity)

$S_g = 2.65$ (Specific gravity of riprap)

$g = 32.2 \frac{\text{ft}}{\text{sec}^2}$ (Acceleration due to gravity)

$$d_{30} = 8.55(1.5 \times 0.3 \times 1 \times 1) \left[\frac{8.0}{\sqrt{0.871(2.65 - 1)32.2 \times 8.55}} \right]^{2.5} = 0.395 \text{ ft}$$

$d_{50} = \text{Median Size of RipRap}$

$d_{50} = 1.2 (d_{30})$

$d_{50} = 1.2 (0.395) = 0.474 \text{ ft} = 5.68 \text{ in}$

Side Slope Correction Factor	0.871
Bank Angle, Degrees	26.6
Local Depth of Flow, ft	8.55
Safety Factor	1.5
Stability Coefficient	0.3
Velocity Distribution Coefficient	1
Blanket Thickness Coefficient	1
Design Velocity, ft/sec	8
Specific Gravity of RipRap	2.65
Acceleration Due to Gravity	32.2
d30, ft	0.395
d50, ft	0.474
d50, in	5.68

Articulating Concrete Block Calculations:

The articulating concrete block mat calculations for the bridge erosion control are the same as the articulating concrete block mat calculations for the channel protection. This is because both are based on the flow of the river, not the channels.

Geo-mat Design Calculations:

Use EGA30 with 6 inch cells from design guide to allow for aggregate and soil backfill.

Provided information for EGA30:

- 0.15m (0.5') Cell Height
- 0.32m (1.05') Cell Width
- 0.29m (0.95') Cell Length
- 8.35m (27.4') Panel Length
- 2.56m (8.4') Panel Width
- 8 Cells per Width

Variable Key:

- NSF = Net Sliding Force
- H = Height of Cell
- L = Length of Slope
- γ = Unit Weight of Fill
- S = Snow Load
- W = Slope Inclination (Horizontal to Vertical)
- ϕ = Lowest Angle of Internal Friction of Soil
- FS = Factor of Safety

Side Calculations / Needed Values:

$$L = 31 \text{ ft} = 9.4488 \text{ m}$$

$$\varphi = 38^\circ \text{ for \#57 stone}$$

$$W = 1 \text{ to } 1 = 45^\circ$$

$$\gamma = 102.9 \text{ lbs/ft}^3 \times \frac{1 \text{ kN/m}^3}{6.366 \text{ lbs/ft}^3} = 16.164 \text{ kN/m}^3$$

$$S = 20 \text{ lbs/ft}^2 \times \frac{1 \text{ kN/m}^3}{20.885 \text{ lbs/ft}^3} = 0.9576 \text{ kN/m}^3$$

Net Sliding Force:

$$NSF = [(H \times L \times \gamma) + (L \times S)] \times [\sin W - (\cos W \times \tan \varphi)]$$

$$NSF = [(0.15 \times 9.4488 \times 16.164) + (9.4488 \times 0.9576)] \times [\sin 45 - (\cos 45 \times \tan 38)]$$

$$NSF = 4.94 \text{ kN/m}^3$$

Anchor Trench Dimensions:

$$L \times H = \frac{NSF \times FS}{\gamma \times \tan \varphi} = \frac{4.94 \text{ kN/m}^3 \times 2}{16.164 \text{ kN/m}^3 \times \tan 38} = 0.782 \text{ m}^2 = 8.42 \text{ ft}^2$$

$$L \times H = 3' \text{ back} \times 2'10'' \text{ deep}$$

Mat Staking:

Optional for NSF of 4.94 kN/m³

Recommend 1 stake per yd²

Tendons:

$$\frac{NSF \times \text{Panel Width} \times FS}{\text{Tendon Design Strength}} = \frac{4.94 \text{ kN/m}^3 \times 2.56 \text{ m} \times 3}{13(\text{given})} = 2.92 \approx$$

3 tendons per 2.56m (8.4') panel

Staples:

4 Staple per adjoining cell for 6" cell height

Outlook Loading Design Calculations

Outlook at Outfall #1:

Conceptual Design of a Composite Wood Deck with simply supported piers.

Deck Specifications:

18 feet wide by 12 feet deep (of the bank edge towards the river) and will land roughly 16 feet over the edge of the river.

Calculations:

Using and assumed 20psf for snow load in NW Ohio (California Residential Code, 2010), and an assumed 10psf (Bergman 2013) for the Dead Weight of the materials in constructing the structure:

Area:

$$12' \times 18' = 216 \text{ sf}$$

Estimated Live Load:

$$\frac{\frac{216 \text{ sf}}{2 \text{ sf/person}} \times 200 \text{ lb/person}}{216 \text{ sf}} = 100 \text{ psf}$$

Factored Load Calculation:

$$(1.2 \times \text{Dead Load}) + (1.6 \times \text{Live Load}) = \text{Design Load}$$

$$1.2(25 \text{ psf}) + 1.6(100 \text{ psf} + 20 \text{ psf}(\text{snow load})) = 204 \text{ psf}$$

Design Outlook Loading: 222psf

Outlook near Outfall #2:

Conceptual Design of a Cantilever Concrete Deck

Deck Specifications:

20 feet wide by 12 feet deep (of the bank edge towards the river) and will land roughly 16 feet over the edge of the river.

Calculations:

Using and assumed 20psf for snow load in NW Ohio (California Residential Code, 2010), an assumed 150psf for the Dead Weight of Concrete, and a slab thickness of 1 foot:

Area:

$$12' \times 20' = 240 \text{ sf}$$

Estimated Live Load:

$$\frac{\frac{240 \text{ sf}}{2 \text{ sf/person}} \times 200 \text{ lb/person}}{240 \text{ sf}} = 100 \text{ psf}$$

Estimated Dead Load:

$$\frac{150 \text{ lb}}{\text{ft}^3} \times 1 \text{ foot thickness} = 150 \text{ psf}$$

Factored Load Calculation:

$$(1.2 \times \text{Dead Load}) + (1.6 \times \text{Live Load}) = \text{Design Load}$$

$$1.2(150 \text{ psf}) + 1.6(100 \text{ psf} + 20 \text{ psf}(\text{snow load})) = 372 \text{ psf}$$

Design Outlook Loading: 372psf

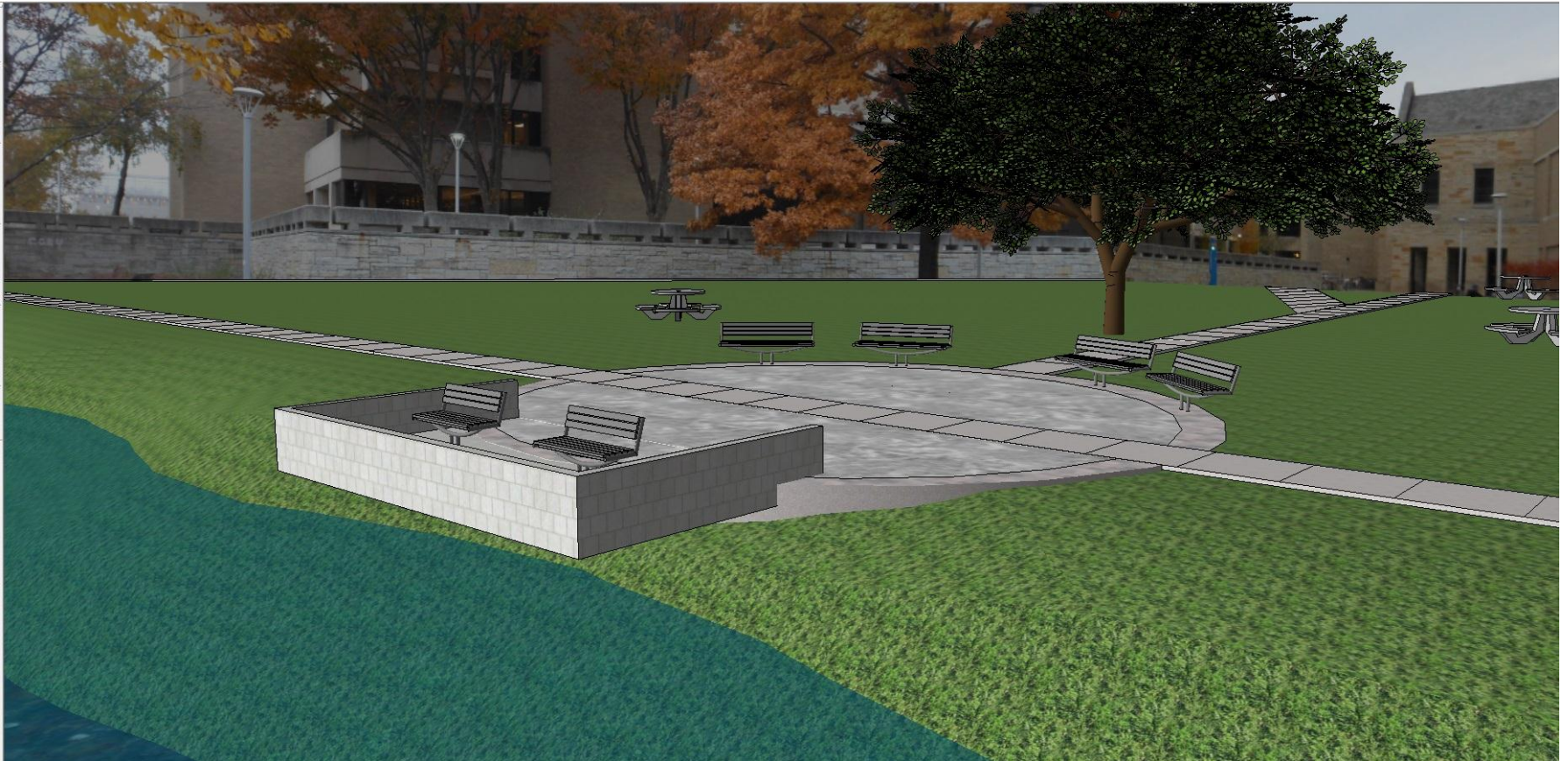
Appendix B – Conceptual and CAD Drawings

Appendix B - Conceptual and CAD Drawings

Picture 1 - Composite Deck Overlook at Outfall #1



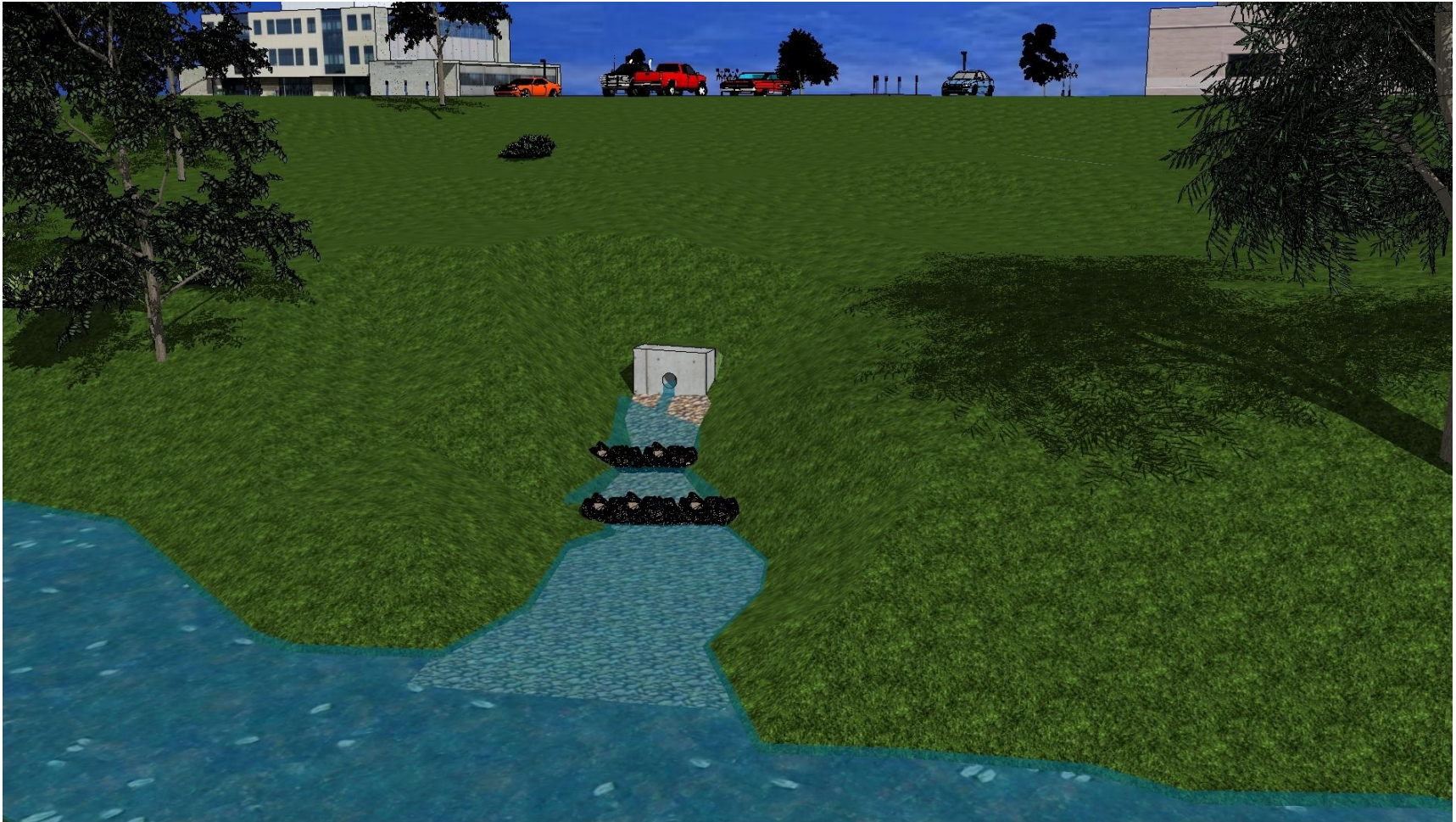
Picture 2 - Concrete Overlook at Outfall #2 View of Student Plaza



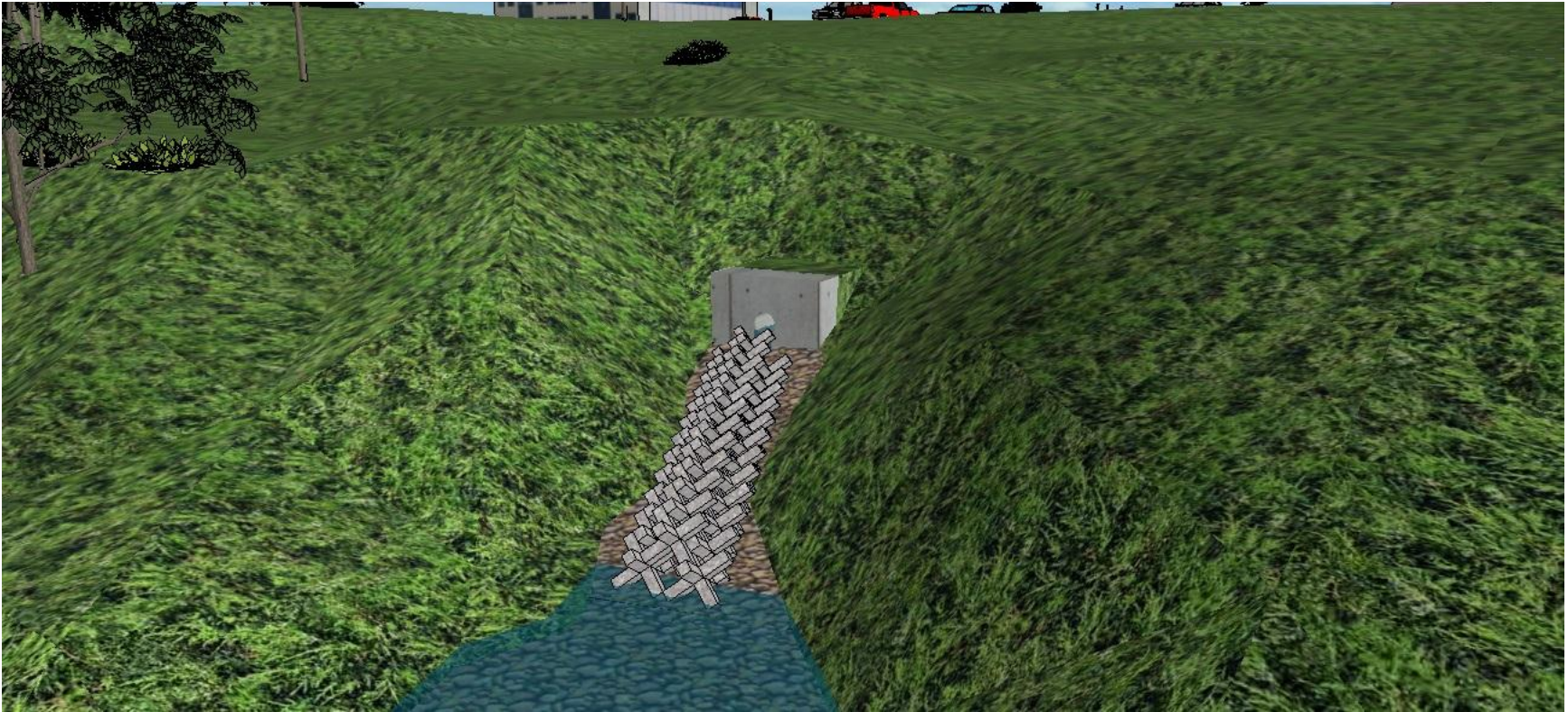
Picture 3 - Concrete Overlook at Outfall #2 View of River



Picture 4 - Rock Check Dam Channel Protection



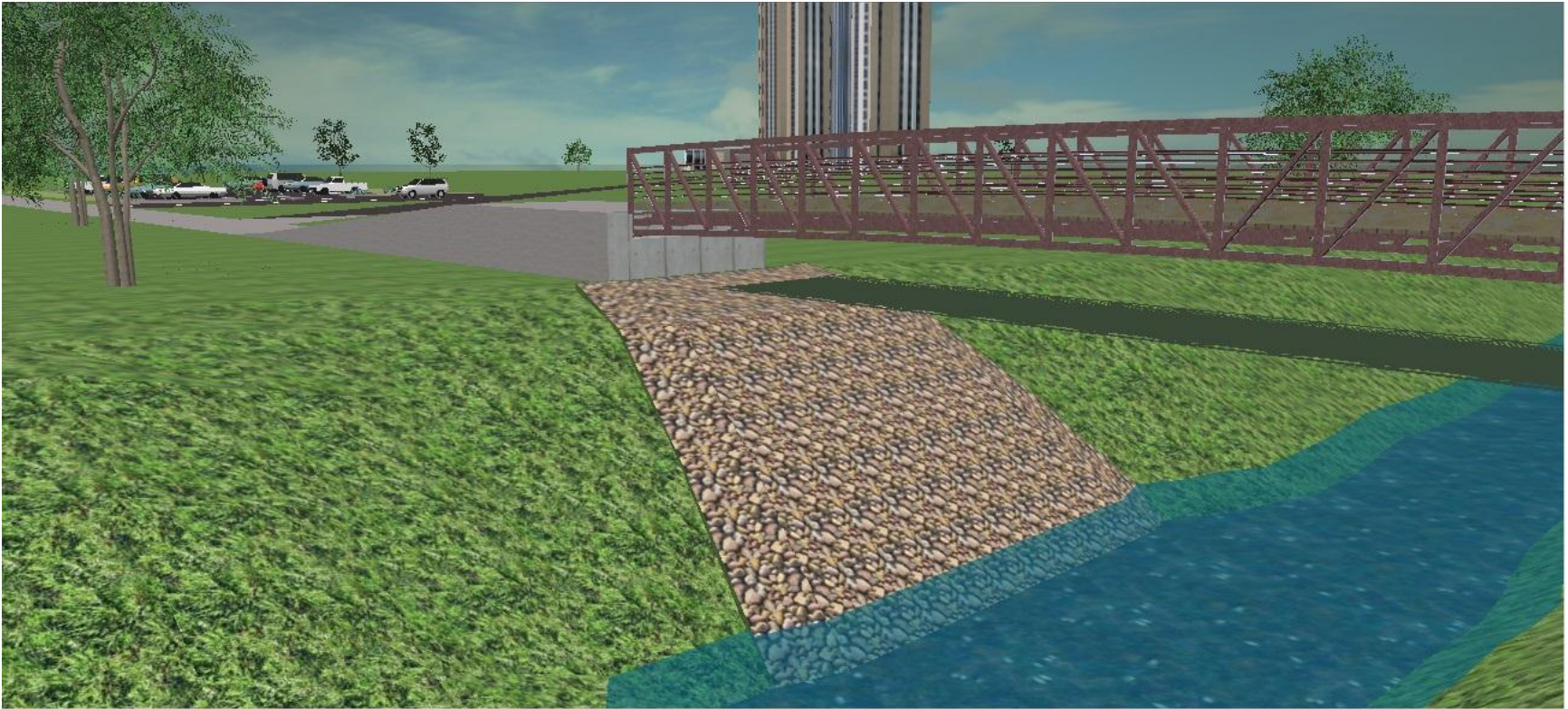
Picture 5 - A-Jack Channel Protection



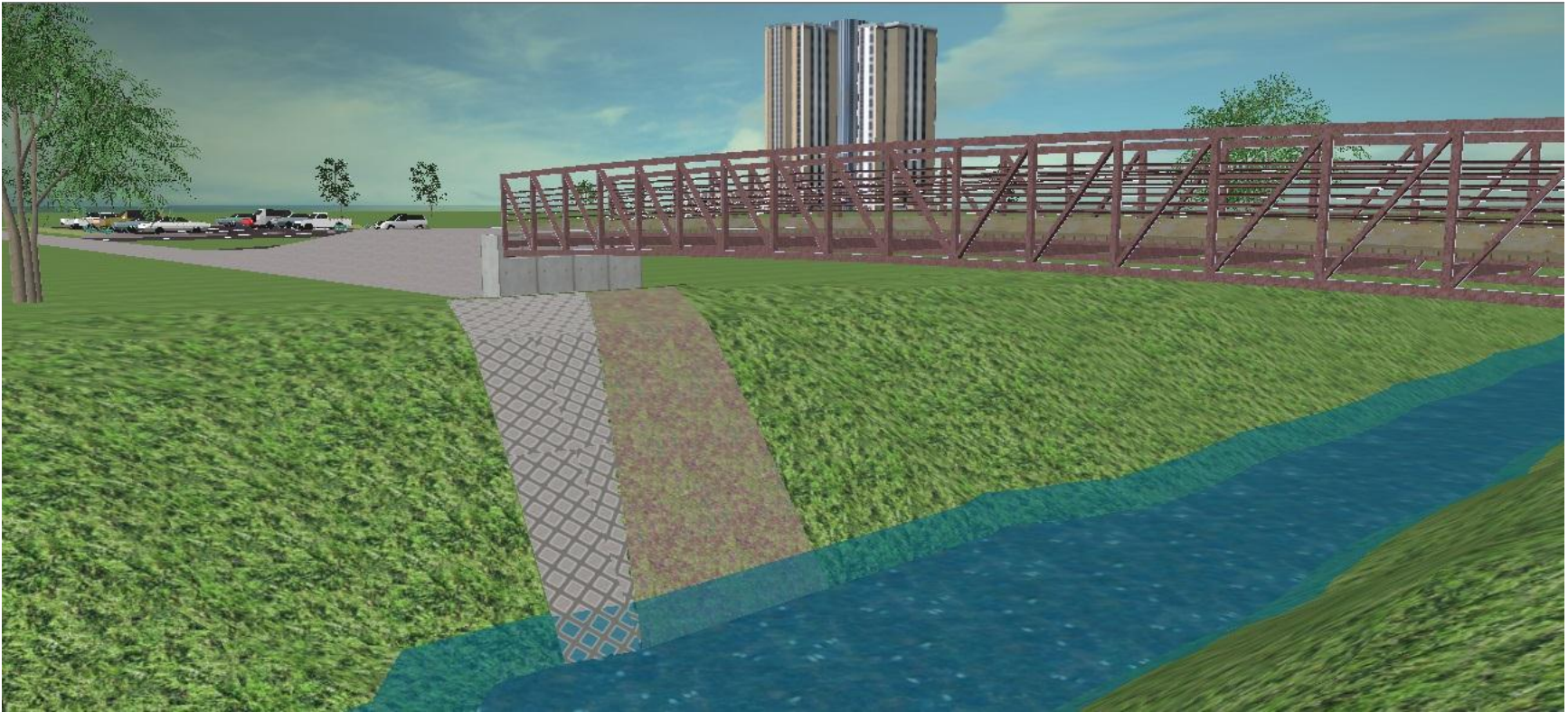
Picture 6 - Articulating Concrete Block Channel Protection



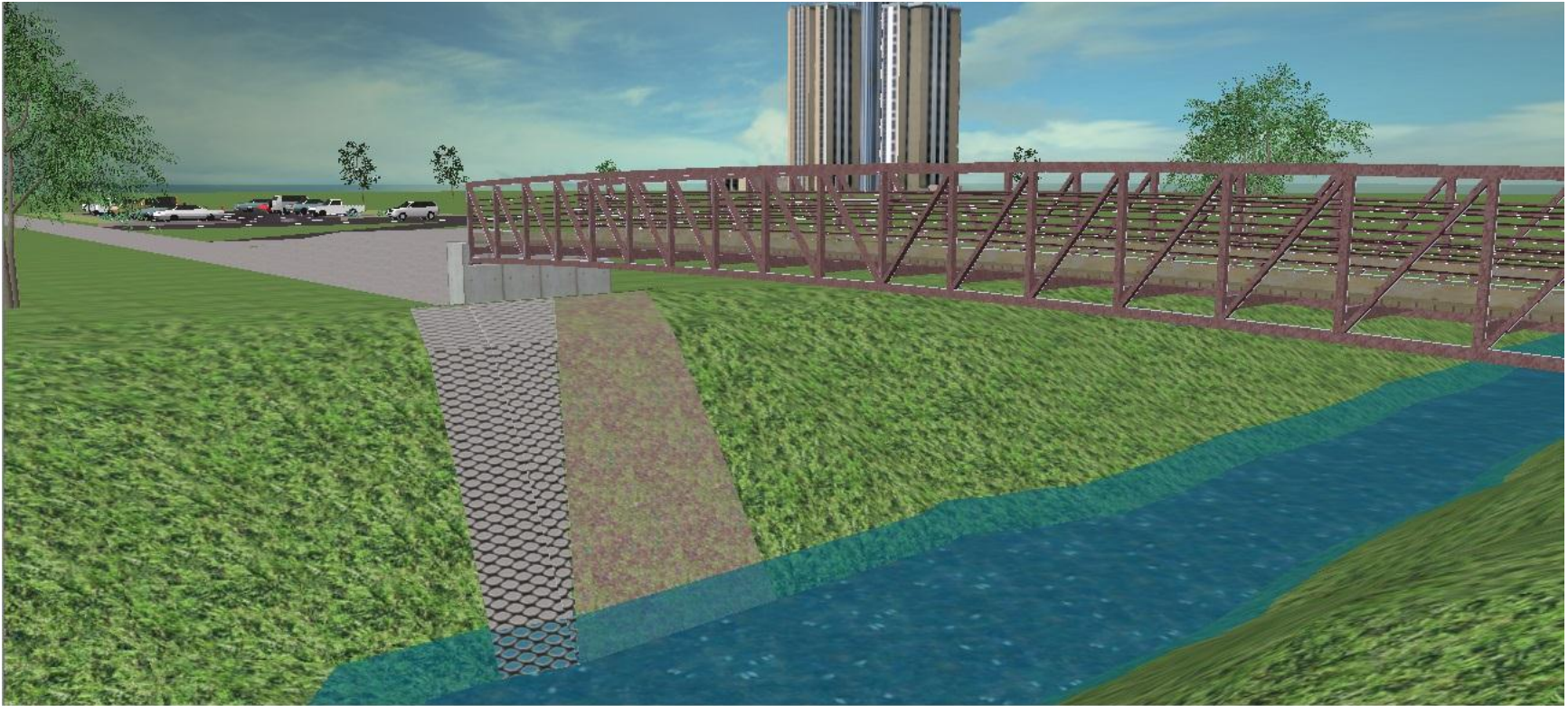
Picture 7 - Rip Rap Bridge Erosion Alternative



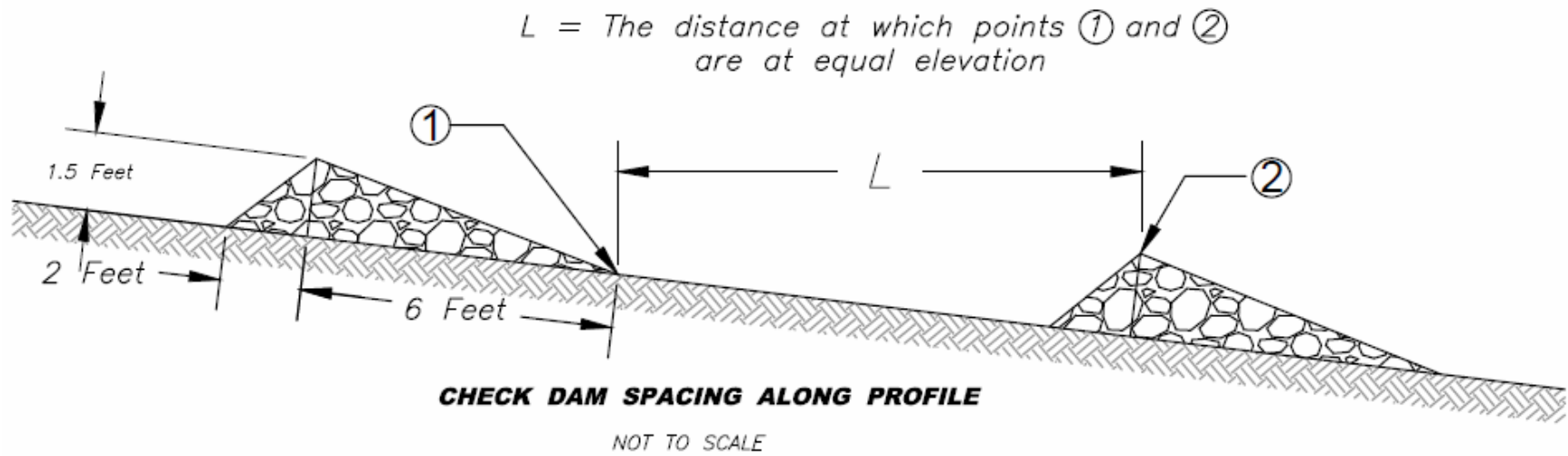
Picture 8 - Articulating Concrete Block Bridge Erosion Alternative



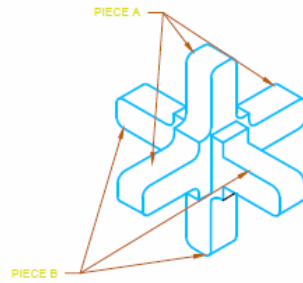
Picture 9 - Geomat Bridge Erosion Alternative



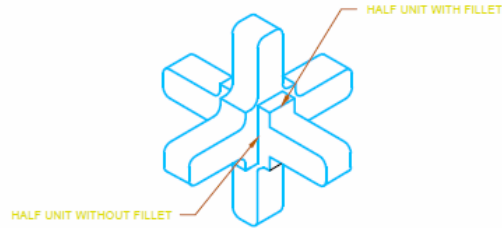
Drawing 1 - Rock Check Dam Layout



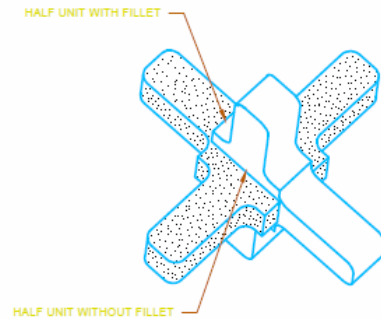
Drawing 2 - A-Jack Specifications



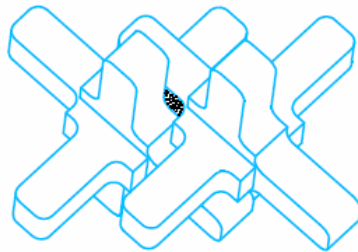
1. IDENTIFY A-JACKS COMPONENTS. PLEASE NOTE THAT EACH UNIT HALF IS IDENTICAL WITH ALTERNATING FILLET FEATURES TO AID IN ORIENTATION WHEN PLACED.



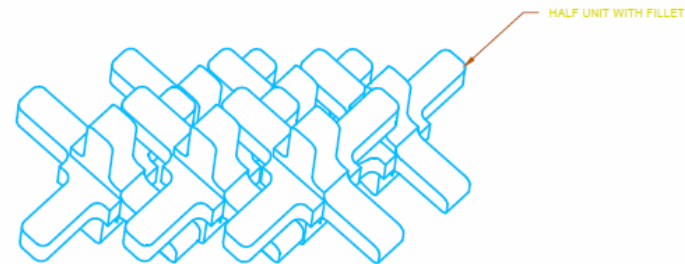
2. IDENTIFY CORNERS WITH AND WITHOUT FILLETS.



3. PROPER ROTATION OF A-JACKS (SEE INSTALLATION GUIDE IN SUBMITTAL DOCUMENTS FOR ADDITIONAL INFORMATION).

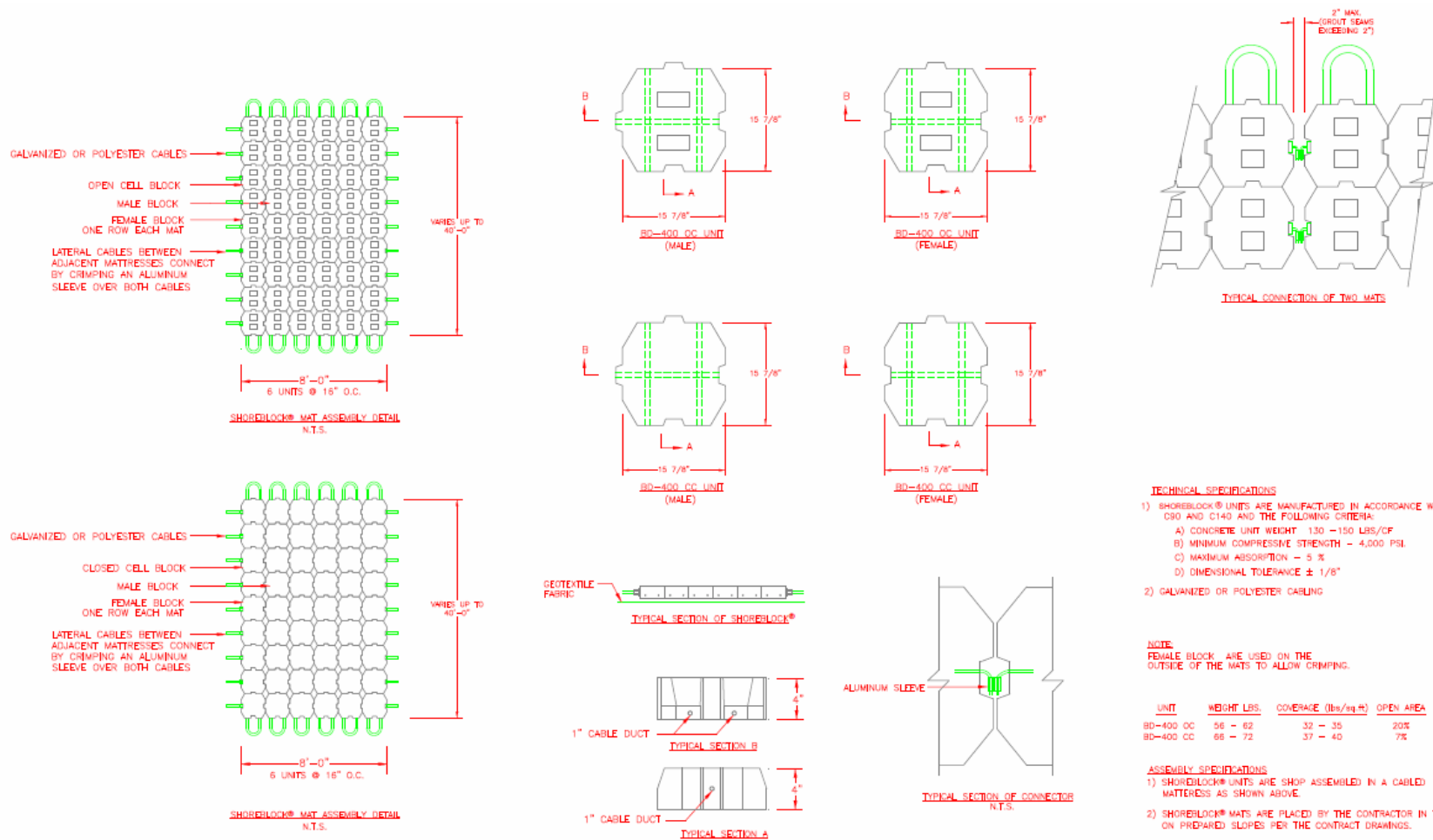


4. ALIGN ALL A-JACKS IN SAME DIRECTION, CORNERS WITHOUT FILLET MUST LINE UP (SEE INSTALLATION GUIDE IN SUBMITTAL DOCUMENTS FOR ADDITIONAL INFORMATION).



5. INSTALL 2ND ROW OF A-JACKS USING SAME ALIGNMENT IN ORDER TO CONSTRUCT MODULES. SUCCESSIVE ROWS ARE PLACED TO ACHIEVE DESIRED MODULE DIMENSION (AS SPECIFIED BY OWNER, INSTALLING CONTRACTOR OR AUTHORIZED PROJECT REPRESENTATIVE.).

Drawing 3 - Articulating Concrete Block Specifications



TECHNICAL SPECIFICATIONS

- 1) SHORELOCK® UNITS ARE MANUFACTURED IN ACCORDANCE WITH ASTM C80 AND C140 AND THE FOLLOWING CRITERIA:
 - A) CONCRETE UNIT WEIGHT - 130 - 150 LBS/CF
 - B) MINIMUM COMPRESSIVE STRENGTH - 4,000 PSI
 - C) MAXIMUM ABSORPTION - 5 %
 - D) DIMENSIONAL TOLERANCE $\pm 1/8"$
- 2) GALVANIZED OR POLYESTER CABLEING

NOTE

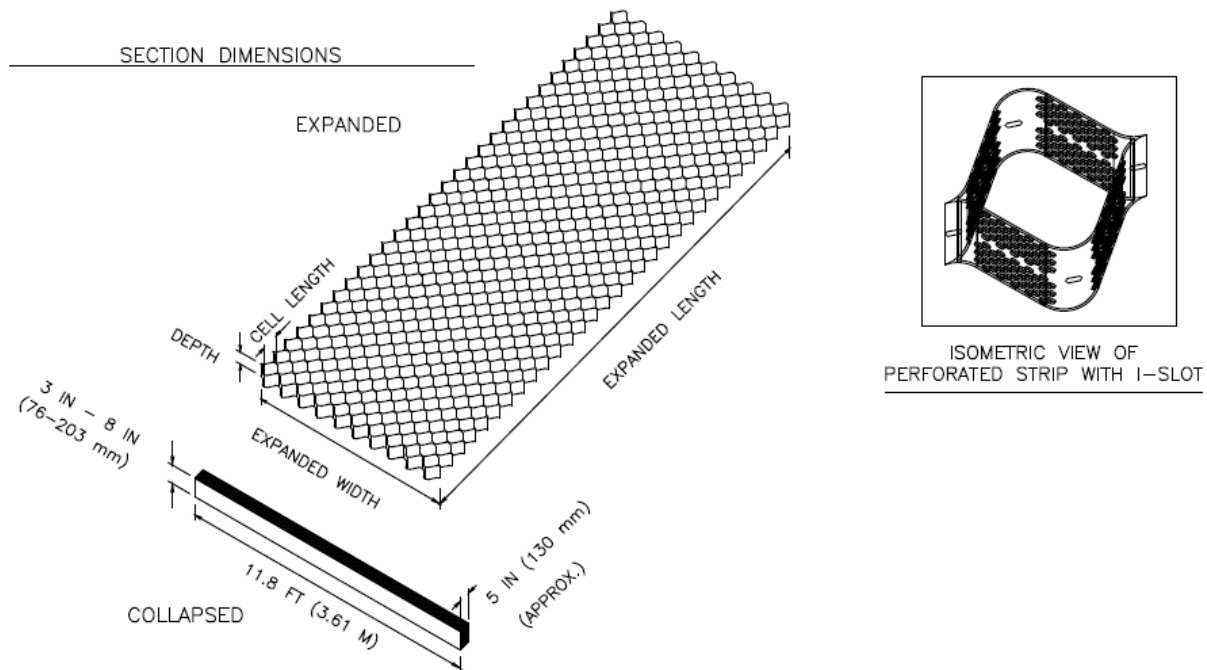
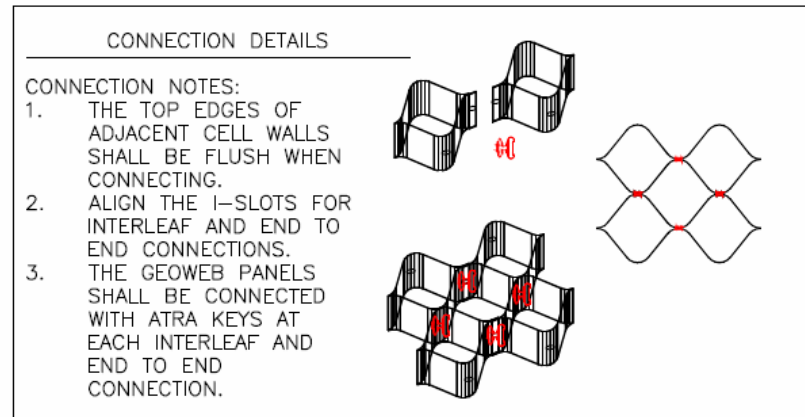
FEMALE BLOCKS ARE USED ON THE OUTSIDE OF THE MATS TO ALLOW CRIMPING.

UNIT	WEIGHT LBS.	COVERAGE (lbs/sq ft)	OPEN AREA
RD-400 OC	56 - 62	32 - 35	20%
RD-400 CC	66 - 72	37 - 40	7%

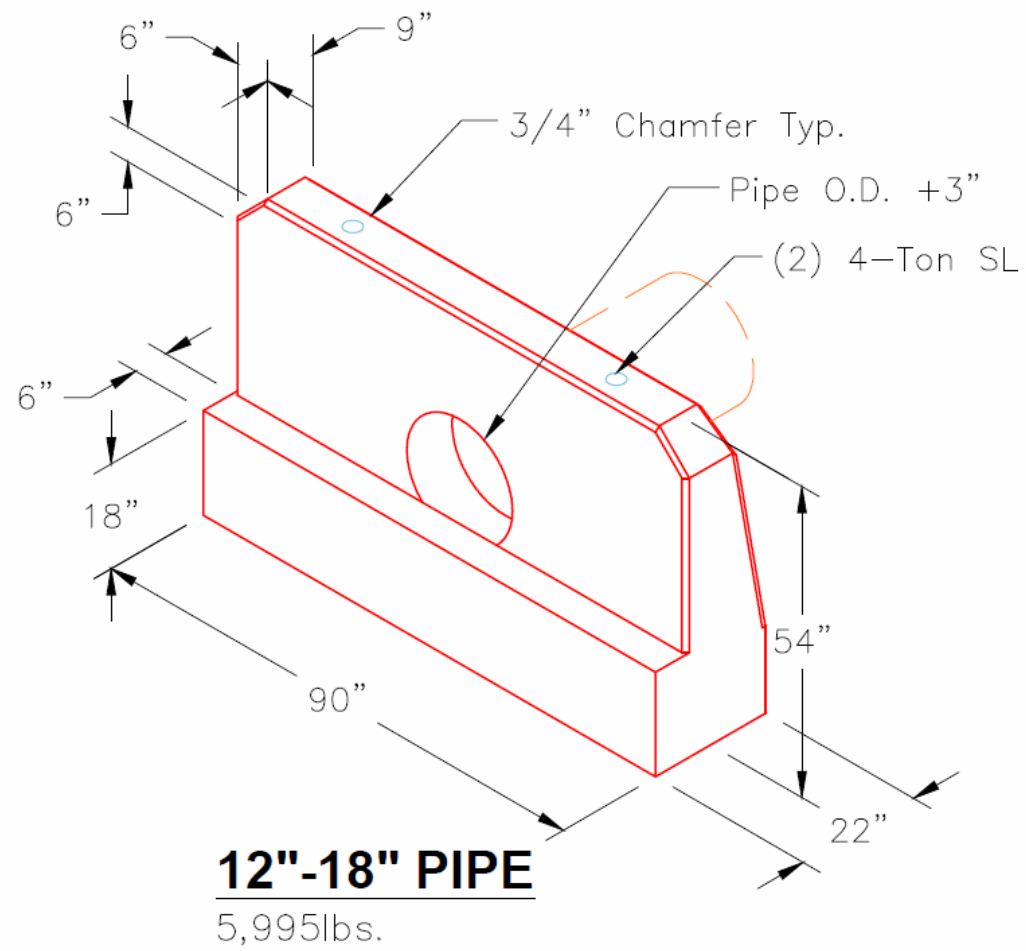
ASSEMBLY SPECIFICATIONS

- 1) SHORELOCK® UNITS ARE SHOP ASSEMBLED IN A CABLED MATTERESS AS SHOWN ABOVE.
- 2) SHORELOCK® MATS ARE PLACED BY THE CONTRACTOR IN THE FIELD ON PREPARED SLOPES PER THE CONTRACT DRAWINGS.

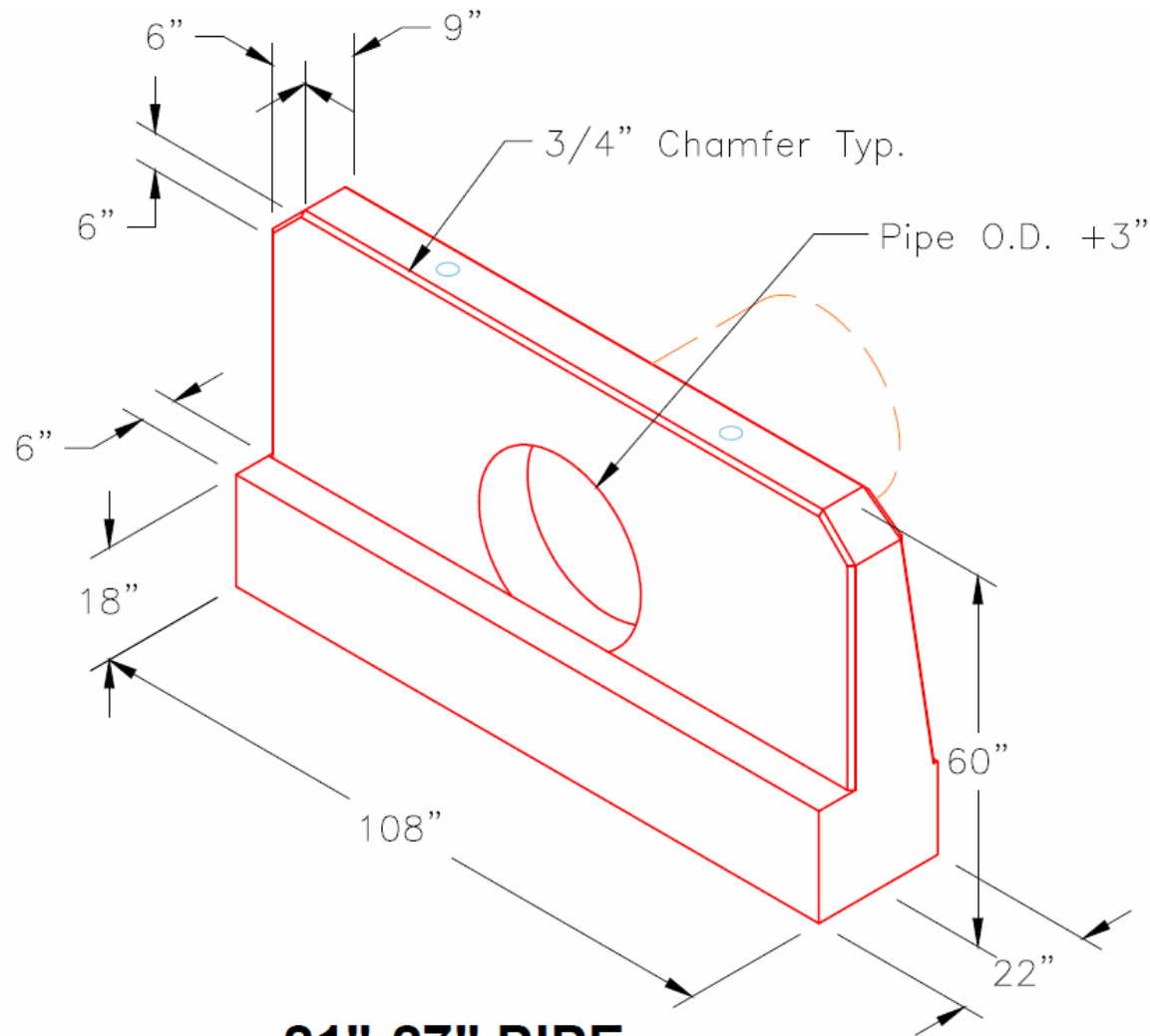
Drawing 4 - Geomat Layout Specifications



Drawing 5 - Headwall Specification for 12"-18" Pipe Diameter



Drawing 6 - Headwall Specification for 21"-27" Pipe Diameter



21"-27" PIPE

8000lbs.