

Grey Cloud Island Water Quality Project



Quality Management Defenders

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Executive summary

This document was prepared to define an effective design solution to mitigate the water quality problem of Grey Cloud Island channel. A collapsed culvert has blocked the inlet to the channel, and the channel is without flow. The Quality Management Defenders (QMD) determined the best solution is to remove the existing collapsed and blocked steel culvert, and install a concrete box culvert that provides increased flow to the channel, sediment movement to decrease total phosphorus concentrations within the channel. The concrete box culvert should reduce the potential for algal blooms, Eurasian Water Milfoil, and other excessive plant growth that has increased over the last several years. These algal blooms have resulted in a severe loss in fish populations, and native plant and animal wildlife in the channel. This watershed around the channel is mostly rural but being surrounded by suburbs of the Twin Cities, MN, the area is likely to be developed in the near future. When this happens, many more water quality issues may arise. The channel should see remarkable water quality improvements as a result of the repaired culvert and additional expected application of stormwater Best Management Practices (BMPs).

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Introduction

The Quality Management Defenders (QMD) is a team of four Biosystems and Agricultural Engineering undergraduate students enrolled at the University of Minnesota – Twin Cities. The students will graduate with a degree emphasis on the environment. QMD chose the Grey Cloud Island water quality project as their Capstone Design Project. The Grey Cloud Island water quality project is in collaboration with HDR, Inc; a scientific-based engineering and consulting firm located in Golden Valley, MN. The Quality Management Defenders have designated Suresh Hettiarachchi, P.E. as the representative advisor from HDR, Inc. The project will include looking at the history of the Grey Cloud Channel conveyance; determination of flow history; a decision matrix; design specification and standards; engineering calculations and drawings; safety, hazard, and economic analyses; and final recommendations.

Problem Statement

The problem presented to the Quality Management Defenders (QMD) is a water quality issue with Mississippi backwater at Grey Cloud Island. This channel separates the Grey Cloud Island, from the mainland. The northern bridge that formed the connection to the mainland was washed away during a flood, in the late 1960's, and was replaced by a road with culverts. The culverts filled with sediment and have lost flow capacity over time, which has caused less flow through the channel. The low flow conditions are suspected of causing poor water quality in the channel. There is visual evidence of Eurasian Water Milfoil, algal blooms, and diminished fish population that results from the poor water quality issues. This project will investigate and confirm the cause of water quality degradation in the channel and develop solutions to improve water quality.

Phosphorus loading¹

Phosphorus is usually the limiting nutrient that affects plant and weed growth in the freshwater lakes and streams of Minnesota. Phosphorus loading occurs when precipitation runs off nearby land containing residual phosphorus. The large contributors are municipal wastewater, fertilizers, and livestock feed and manure holding operations. When phosphorus enters the Grey Cloud Island channel it becomes attached to sediments and usually settles to the bottom. With out

¹Overview of the Primary Contaminants of Association with Manure (<http://www.pca.state.mn.us/hot/feedlot-sonar.pdf>)

significant flow, nutrients can be recycled for decades or centuries, which continually creates eutrophication and dissolved oxygen problems. Relatively small amounts of manure can have detrimental effects on surface water quality. Although, phosphorus leaching is not usually in large quantities, nearby farms may leach phosphorus to ground water, which eventually leads to the channel.

Blue-green algae

Algae (specifically blue-green algae) are prevalent in almost every lake of Minnesota. The warm weather in combination with alkaline, nutrient rich waters during the summer months drives the potential for algae to become overly concentrated and form a thick mat. This thick mat of algae is considered an "algae bloom." These blooms can be toxic². As with the Grey Cloud Island channel, most problems occur when algae is concentrated around a shoreline, where pets, wild animals, and birds drink the water and subsequent algae. Farmers may suffer severe losses in livestock due to blue-green algae poisoning. In the case of humans, the blooms become more of an aesthetic hindrance than a toxic hazard. However, humans and animals should avoid skin contact especially while toxins are produced. In the case of humans, the blooms become more of an aesthetic and recreational hindrance than a toxic hazard. They have been blamed for getting caught in boat propellers as well as building up in shallower water levels. The harmful algae blooms also pose a threat to fish populations; fishing is a local favorite recreational activity the metropolitan area.

Eurasian Water Milfoil

Eurasian Water Milfoil (*Myriophyllum spicatum* L.) is an aquatic plant not native to Minnesota water bodies³. This aquatic (water-living) plant thrives in shallow waters, such as the Grey Cloud Island channel. The plant is similar to Minnesota native Northern Milfoil. Eurasian Water Milfoil differs in that the species contains 12 to 21 leaflet pairs and is soft and pliable, whereas the native has 5 to 10 leaflet pairs and is stiff and bristly. The plant reproduces quickly by breaking off at the stem and roots in the ground. Eurasian Water Milfoil can tolerate cold temperatures,

² Wisconsin Department of Natural Resources.(2004).*WDNR-Blue-green Algae in Recreational Waters*. Retrieved October 18,2005.from Wisconsin Department of Natural Resources site:
<http://dnr.wi.gov/org/land/parks/safety/bluegreenalgae.html>

³ Newman, R.M.(2003).*Eurasian Milfoil*. Retrieved October 18, 2005.from Biocontrol of Eurasian milfoil:
<http://www.fw.umn.edu/research/milfoil/milfoilbc/milfoil.html>

giving it the capability to grow in early in the spring. The early start and high growth rate causes the plant to overcome native species and reduce the amount of light that enters the channel. Losing native beneficial plant species creates a void in the food-web and subsequent losses in wildlife diversity. This situation is especially detrimental to invertebrates and local fish populations whose life depends on open waters to eat and survive. If the deep water vegetation can not get access to light they die, leaving native fish life with no source of food. This problem will lead aquatic populations to other locations outside the channel.

Location

Grey Cloud Island is located in the southwest corner of Washington County, Minnesota. *Figure 1* shows the location of Grey Cloud Island (indicated by red star) with respect to the State of Minnesota.

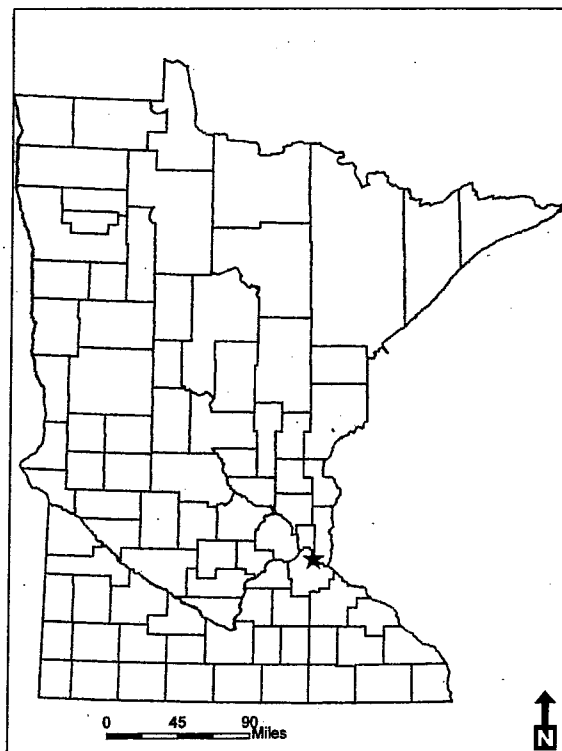


Figure 1: Location of Grey Cloud Island⁴

⁴ Created with ArcGIS by ESRI, Data Layers from Minnesota Department of Natural Resources, <http://deli.dnr.state.mn.us>

Grey Cloud Island Township is bordered by Cottage Grove on the east and south, St. Paul Park on the north, and by the Mississippi River on the west (Figure 2).

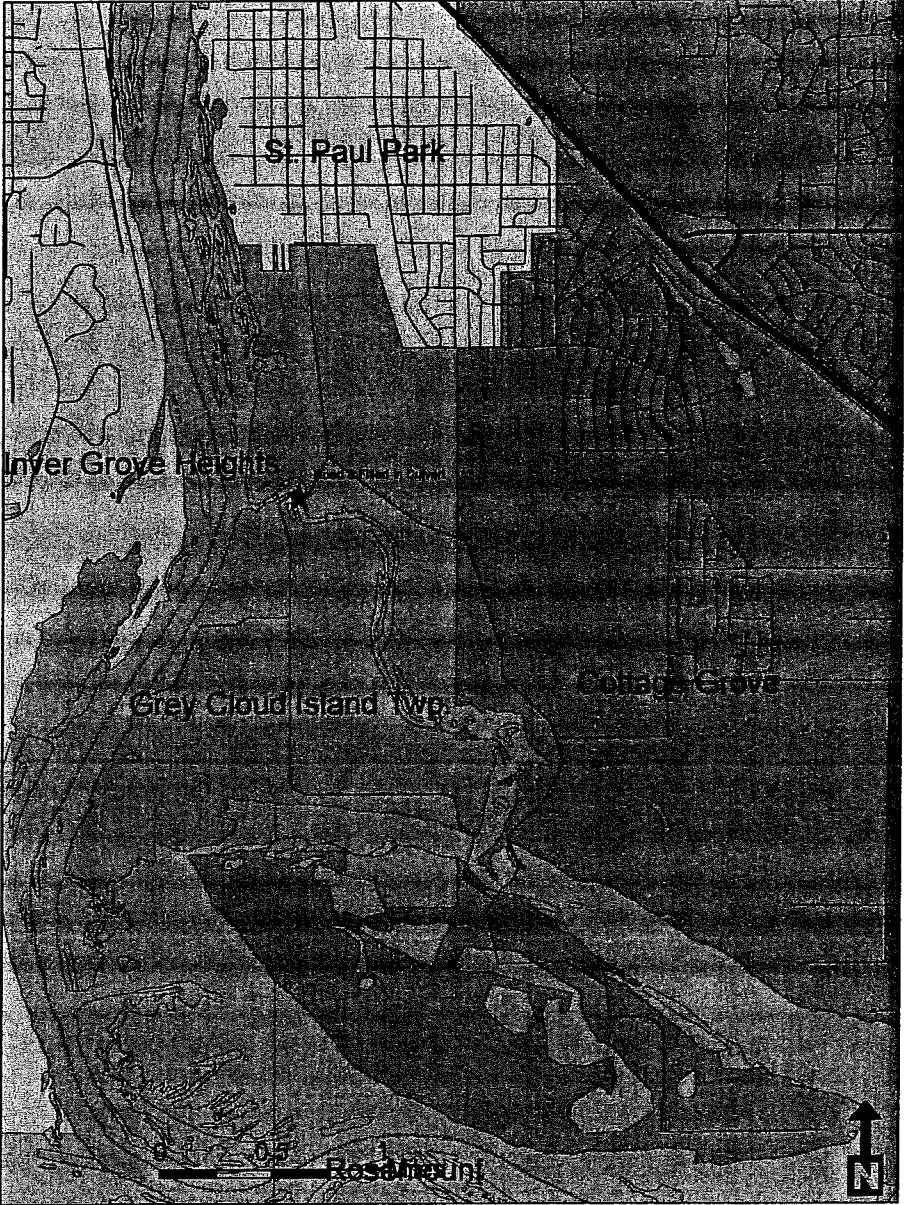


Figure 2: Surrounding area⁵

⁵ Created with ArcGIS by ESRI, Data Layers from Minnesota Department of Natural Resources, <http://deli.dnr.state.mn.us> and MetroGIS, <http://www.datafinder.org/>

Grey Cloud Island Channel, highlighted in orange, separates Grey Cloud Island from the mainland (Figure 3). The water quality problem that the project addresses is present in this channel. The northernmost road, marked with the yellow star, indicates where the culverts have collapsed.

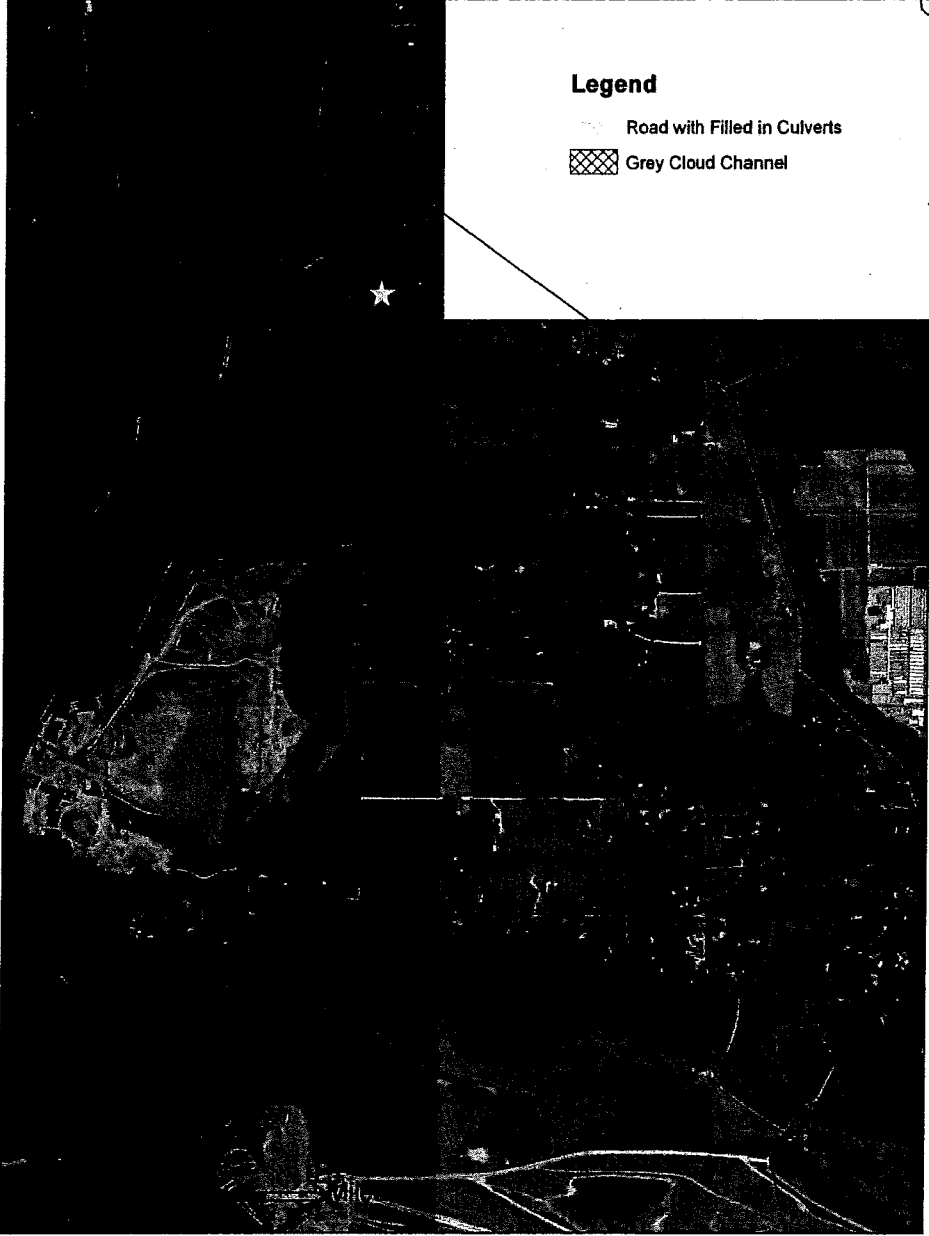


Figure 3: Aerial photo⁶

⁶ Created with ArcGIS by ESRI, Data Layers from Minnesota Department of Natural Resources, <http://deli.dnr.state.mn.us>

General Information on Grey Cloud Island

Grey Cloud Island was founded in 1856. When Washington County was created in 1858, Grey Cloud Island became part of the Newport Township along St. Paul Park and Newport. In the 1960s, after St. Paul Park and Newport began separate cities, the rest of the Newport Township was consolidated into Grey Cloud Island Township. In the early 1980s, the southwest part of Grey Cloud Island was annexed to Cottage Grove⁷.

Including water, Grey Cloud Island Township is currently 2,092 acres with a shoreline of 18 miles, while in terms of only land it is 1,595 acres. Back in the early 1900s the island alone contained about 3,800 acres. The population at the time was 125, but by 1990 is topped to 400. Most recent count in 2000 puts the population down to 307. The island is primarily rural residential, but it has and does house some industry. The most prominent industry is the limestone quarry, which still remains active to this day.

The island has two accesses to the main land. The southern access has gone through three to four bridge incarnations. The northern access route has changed over the last century from a bridge to a roadway with a culvert. The bridge was wiped out in a flood event in the late 1960s. It was then replaced with the current roadway as well as a culvert. Within the last 10 years the culvert failed to handle the flow and sediment load, leading to its collapse and burial under the side slopes. Since then the channel has not had a working inlet. This blockage has created a mostly stagnant channel with only a backflow, spring, and runoff inputs. This stagnant situation has allowed the channel to build up sediment concentrations, phosphorus concentrations, and the dominance of the evasive species, such a Eurasian milfoil⁸. This build up has lead to the decrease of channel water quality.

River's Edge project

On October 3, 2005, the St. Paul Park City Council approved an amendment to annex land from Grey Cloud Island Township to the River's Edge project. The approved project is predicted to

⁷ Washington County Historical Society. (2005). *WCSH: Grey Cloud Island*. Retrieved December 2, 2005, from Washington County Historical Society Web site:

http://www.wchsmn.org/research/communities/grey_cloud_island/

⁸ D. Hanna (person communication, October 7, 2005)

bring as many as 1,900 housing units and approximately 40,000 square feet of commercial space to 600 acres in St. Paul Park and Grey Cloud Island Township along the Mississippi River.⁹ The density of the project is now under careful consideration as it was to originally have about 2,400 housing units and 83,000 square feet of commercial space. The water quality of Grey Cloud Island channel will be more difficult to protect as population and commercial density increases. This will be an important factor when selecting a design and providing an accurate cost analysis.

Overall Methodology

QMD began researching background information on the channel as well as information on the factors that were known to have impacts on the water quality of the channel. QMD visited the site a couple of times early on and discussed the problem with local residents that elaborated on the change in water quality over time. Photographs were taken to document the water conditions present earlier this fall. During the beginning stages of the design project, QMD began investigating economic and social issues, water quality standards, any laws and regulations that might affect the project.

Once the project parameters and goals were set, QMD researched hydraulic systems, water biology, and water chemistry of the channel and the Mississippi River. Understanding the hydraulic factors affecting the water movement into and through the channel is important in understanding the cause of the poor water quality and possible methods to resolve the poor water quality. In conversation with a local resident, Denni Hanna, the situation was discovered that Eurasian Water Milfoil has expanded in the channel choking off other aquatic plants, and the game fish populations had decreased dramatically in since the late 1990's. To better understand these dangers, QMD researched the organisms, such as Eurasian Water Milfoil, harming the local marine life and driving down these local organisms populations down.

Once the facts and parameters of the channel were better understood, QMD started to form possible solutions to resolve the water quality issue. These solutions were then organized into a decision matrix and described. The decision matrix was sent out to several professional engineers and specialists, who are familiar with water quality issues. After they evaluated the

⁹ (2005, August 17).St. Paul Pioneer Press

different design options, the results were analyzed and used in conjunction with the knowledge already acquired to determine that reinstalling the culvert was the best option.

QMD created a Water Quality Model that would model the total phosphorus concentrations within the channel. From the model, the culvert size was determined based on the optimal flows needed to keep the phosphorus concentration as low as possible.

QMD then designed the culvert and road using the applicable standards. After the specifications were determined for the road, culvert, and sluice gate, an economic analysis was run to determine the cost of construction of the project. The cost analysis was done along with the safety analysis and political/social analysis.

The safety analysis applied the study of the examination of safety before and after the culvert implementation. This dual examination analyzed the hazards that currently exist as well as those that would be solved and/or created due to the culvert. Along with the examination of safety, a hazard analysis and Hadden chart were done to specifically look at the dangers involving the culvert and summarize the before, during, and after prevention of the culvert construction. The social/political analysis pulled from the social and political issues occurring currently in and surrounding Grey Cloud Island Township. These affect how well the community will accept the design and if the project design is having a difficulty in meeting local county and state laws and regulations. Lastly, the design was summarized into final recommendations.

Timeline

The following timeline provided a structured order for the progress of the Grey Cloud Island Water Quality Project. As a group, we selected individuals tasks based on background experience and willingness to undertake the specific task.

ID	Task Name	Start	Finish	Duration	Actual Finish	Completed By	Sep 2005				Oct 2005				Nov 2005				Dec 2005		
							9/4	9/11	9/18	9/25	10/2	10/9	10/16	10/23	10/30	11/6	11/13	11/20	11/27	12/4	12/11
1	Project Selection	9/7/2005	9/20/2005	14d	9/20/2005	All	█														
2	Timeline Creation	9/26/2005	10/3/2005	8d	10/3/2005	All		█													
3	Design Proposal	9/30/2005	10/5/2005	6d	10/5/2005	All			█												
4	Design Proposal Due	10/3/2005	10/3/2005	0d	10/3/2005	All				◆											
5	Investigation of Site and Parameters	10/3/2005	10/14/2005	12d	10/31/2005	All				█											
6	Research	10/10/2005	11/11/2005	33d	11/11/2005	All					█										
7	Decision Matrix	10/31/2005	11/11/2005	12d	11/16/2005	All						█									
8	Analysis	10/17/2005	11/28/2005	43d	11/28/2005								█								
9	Hydraulic Analysis	10/31/2005	11/23/2005	24d	11/23/2005	Anne							█								
10	Water Quality Model	10/17/2005	11/28/2005	43d	12/2/2005	Tom								█							
11	Safety Analysis	11/5/2005	12/2/2005	28d	11/28/2005	Anne, Neal									█						
12	Design Update Presentation	11/14/2005	11/14/2005	0d	11/14/2005	All										◆					
13	Project Design	11/21/2005	11/30/2005	10d	11/30/2005												█				
14	Culvert Design	11/21/2005	11/25/2005	5d	12/5/2005	Mike, Tom												█			
15	Road Design	11/28/2005	11/30/2005	3d	12/7/2005	Anne, Mike													█		
16	Economic Analysis	12/2/2005	12/9/2005	8d	12/12/2005	Neal														█	
17	Write Final Design Report	11/14/2005	12/7/2005	24d	12/11/2005	All														█	
18	Final Design Report Due	12/14/2005	12/14/2005	0d	12/14/2005	All															◆
19	Work on Presentation	12/7/2005	12/12/2005	6d	12/12/2005	All															█
20	Final Presentation Due	12/14/2005	12/14/2005	0d	12/14/2005	All															◆
21	Final Poster Due	12/14/2005	12/14/2005	0d	12/14/2005	All															◆

Figure 4: Timeline

Summary

As part of a weekly routine, each member of QMD was responsible for compiling a memorandum to inform Professor Goodrich of individual progress. The memorandum included what the individual had completed over the past week, and cited references as to where the information could be found in his or her design notebook. The overall adherence to the timeline was sufficient to complete the Grey Cloud Island water quality project by the expected due date. This was made possible in part with weekly meetings with advisor Suresh Hettiarachchi and other engineers and biologists at HDR, Inc.

Decision matrix

QMD created a decision matrix which is a chart that allowed the team to systematically identify, analyze, and rate the strength of a design solution given a specific set of design criteria. The matrix is especially useful for looking at large numbers of criteria and assessing its relative importance among the solutions.

Method

Quality Management Defenders (QMD) first identified potential solutions. These solutions are listed across the top of the matrix. The next step was to brainstorm and identify key criteria on which the design solutions are to be considered. These criteria are listed on the left side of the matrix (Table 1). As part of the final design solution consideration, QMD composed a letter and sent the letter out to 10 professionals, including public and private sector, and University of Minnesota professors. The evaluators were asked to rank each project with respect to the different criteria. Before the results were analyzed, QMD assigned weights to each criterion. The weights are assigned because some decision criteria are deemed more important than others (Table 1). As an example, because QMD's main objective for redesigning the Grey Cloud Island channel is a result of decreased water quality, "Water Quality Improvement" received the highest weighing factor. The final step was to total the scores. Totaling the scores is completed by first multiplying each score by its corresponding weigh factor, followed by summing the total.

Table 1: Decision Matrix Criteria and Weighting

Criteria	Weight
Cost	15%
Maintenance	5%
Environmental Impact	15%
Feasibility	15%
Construction Time	5%
Safety to Humans	10%
Water Quality Improvement	25%
Adaptability	5%
Aesthetics	5%

Decision Matrix Results

Based on the results of the decision matrix (and previous QMD knowledge of the existing situation), QMD has determined to reinstall the culvert. Reinstalling the culvert is followed in rank by pumping clean water from the nearby quarry and constructing an overland bridge.

Table 2: Decision Matrix Results

Design Solution	Points (out of 1.6)	Rank
Reinstall culvert	1.37	1
Pump clean water from nearby quarry	1.30	2
Overland bridge	1.29	3
Alum Treatment	1.07	4
Leave as is (datum)	0.92	5
Underground Tunnel	0.89	6

Design standards

As part of the design, the procedure must adhere to local-set standards. The Minnesota Pollution Control Agency (MPCA), Minnesota Department of Transportation, and Minnesota State Statutes regulate the standards. These standards are required for the protection of humans and the environment.

Eutrophication Standards for Lakes¹⁰

The Grey Cloud Island channel shows effects of excess nutrient loading from point and non-point sources. With increased daylight and warmer temperatures in the summer, the channel turns green with excess algae growth. As mentioned earlier, a reduction in water clarity resulting in large floating mats of algae, and other undesirable effects are possibilities associated with algae blooms. An algae bloom makes the water body less inviting for swimming and fishing, and in severe cases can be toxic to pets, wildlife, and humans¹¹. Excess phosphorous is a primary culprit of these undesirable changes. "Eutrophication" is the term applied to this increase in biological productivity due to increased nutrient loading. "Cultural eutrophication" is the term used when the excess nutrients are a result of human activities.

Expanded Application of 1 mg/l Phosphorus Effluent Limit¹⁰

As of January 1, 2007, the MPCA is proposing new or expanding dischargers must meet a 1 mg/l total phosphorus (TP) effluent limit. The current rule (Minn. R. 7050.0211, subp. 1a.) applies a 1

¹⁰ MPCA (<http://www.pca.state.mn.us/water/standards/rulechange.html>)

¹¹ Wisconsin Department of Natural Resources.(2004). *WDNR-Blue-green Algae in Recreational Waters*. Retrieved October 18,2005.from Wisconsin Department of Natural Resources site:
<http://dnr.wi.gov/org/land/parks/safety/bluegreenalgae.html>

mg/l TP limit to dischargers if the discharge is directly to or affects a downstream lake or reservoir. This part of the existing rule will not change, but under this proposal, new or expanding facilities that discharge more than 1800 pounds of phosphorus per year, will get a 1 mg/l limit without the need to demonstrate "affects." The Grey Cloud Island channel should experience significant improvements after this proposal has been approved. The stringent rule should help to regulate industrial facilities, such as the Pig's Eye brewing facility located upstream of Grey Cloud Island. Although the channel may see benefits from reduced TP loading, other potential hazards to water quality are present such as acetochlor and metochlor, two common agricultural pesticides used in Minnesota.

Standards for Acetochlor and Metolachlor¹⁰

The MPCA has been asked by the Minnesota Department of Agriculture (MDA) to develop standards for several agricultural pesticides commonly used in Minnesota. The MPCA has agreed to develop standards for acetochlor and metolachlor. The MPCA must develop these standards without resources from the EPA, who has made no efforts to publish an aquatic life criterion for either chemical.

Both acetochlor and metolachlor are herbicides used to control annual grasses and some broadleaf weeds. In 2000, over three million pounds of acetochlor and one million pounds of metolachlor were sold to propagate corn and soybeans.

These two herbicides are very important to the Grey Cloud Island channel in that algae occurs also appears to be the most sensitive aquatic organisms to the effects. Both herbicides appear to be mobile in most soils and moderately persistent in the environment, but they apparently do not bio-accumulate in fish and wildlife. Full research has not been completed by the MPCA that is required to arrive at final proposed standards at this time.

The MDA pesticide monitoring programs have found both herbicides in ground water and surface waters. MDA is recommending the implementation of voluntary best management practices to protect groundwater from acetochlor and metolachlor and to protect surface waters from acetochlor.

Because the MPCA has not yet implemented these standards, QMD has not made efforts to use acetochlor and metolachlor in water quality and quantity modeling. Once these standards have been approved, the issue may need to be investigated in regards to newly developed land and residential housing in and around Grey Cloud Island Township, MN.

Engineering calculations

Hydrologic Analysis

To calculate the water surface elevation (WSE) the data from the US Army Corps of Engineers¹² site. The data used was from the closest dam, which was Lock and Dam #2 (Dam 2). This location had records on the water surface height at Dam 2 and pool elevations at South St. Paul (SSP), and St. Paul (STP). The records dated back to 1932. The distances between the Dam 2 pool and STP, SSP, and the inlet and outlet location of Grey Cloud Island channel were measured using a USGS maps. The measured distances between are as follows: Dam 2 pool to STP location (25.2 miles), Dam 2 pool to SSP location (17.3 miles), Dam 2 pool to channel outlet (7.8 miles), and Dam 2 pool to channel inlet (12 miles). After the data need had been gathered, the change of elevation (ΔH) between Dam 2 pool and both STP locations tails were found for all the values from 1932-2005.

$$\Delta H_{dam-SSP} = H_{dam} - H_{SSP}$$

$$\Delta H_{dam-STP} = H_{dam} - H_{STP}$$

Using these ΔH values and the distances between the sites, the slope change can be found using the equations below. The slope will then help us find the WSE for the inlet and outlet of Grey Cloud channel over the daily time range.

$$Slope = \frac{\Delta H_{dam-SSP}}{17.3 * 5280}$$

¹² US Army Corps of Engineers.(2004).*CORE:Lock & Dam 2*. Retrieved:October 17, 2005.from US Army Corps of Engineers Website: <http://www.mvp.usace.army.mil/navigation/default.asp?pageid=145&subpageid=161>

$$Slope = \frac{\Delta H_{dam-STP}}{25.2 * 5280}$$

$$WSE_{inlet} = H_{dam} + Slope * 12 * 5280$$

The inlet WSE can now be used to find out what frequency of days have a certain WSE. The vital cut off point for the project is at 90%. Therefore, the elevation at 90% and any elevations that exceed that elevation are of particular interest to figuring out the placement height of the culvert. To do find the elevation that occur 90% on a daily schedule, the WSE values calculated must be placed in descending order. After ordering them, rank them according to their new order. This rank (R) will then be used in finding the elevations frequency occurrence. The R_T is the total number of ranked values. Below is the equation for finding the plotting position (P_p).

$$P_p = \frac{R}{(R_T + 1)}$$

The P_p is the frequency value in decimal form. Taking the P_p value and multiplying by 100 will give you the frequency in terms of the percent. Figure 5 shows the decrease in elevation frequency as the elevation of the surface water increases. This makes sense since the higher WSE will occur during floods events that are often infrequent.

**Water Surface Elevation Probability of Exceedance
Daily (Yearlong)**

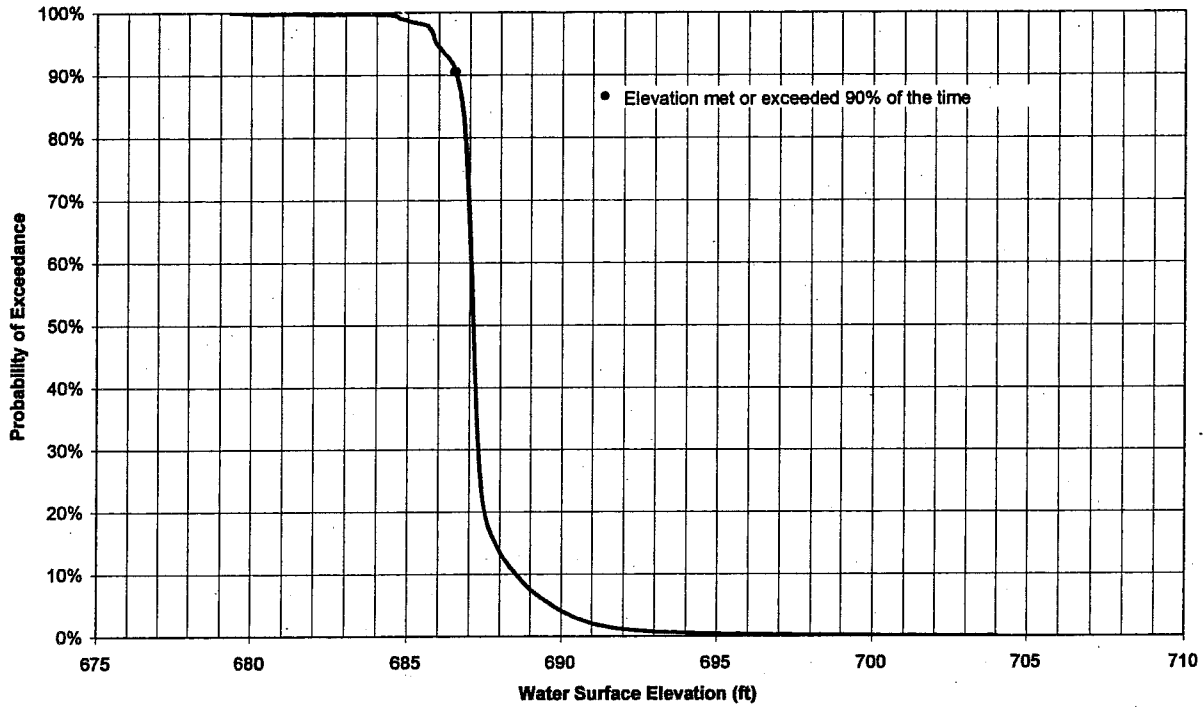


Figure 5: Water Surface Elevation Probability of Exceedance

Water Quality Model

In order to assess the response of the channel system with any proposed improvements, a water quality model (model) was created. Since the channel is phosphorus limit, as many freshwater bodies are, the nutrient the water quality parameter modeled was total phosphorus (TP). The model used two different equations to determine the desired flow to achieve the desired TP channel concentration and the time to reach the equilibrium TP channel concentration based on the previously calculated flow. The Canfield-Bachmann Natural Lake Model was used to calculate the TP channel concentration at various flows. A phosphorus mass balance and a water balance were used to calculate the time to reach the equilibrium TP channel concentration.

Concepts of Model

The modeling of total phosphorus can become very complicated and the model assumed a few things to make it simple enough that it would be able to be created within a few weeks but also complex enough that it was able to predict the things that were desired. The assumptions that were made are:

- Triangular channel with a maximum depth of 15 feet or 4.6 meters
- Completely mixed
- Steady state
- Fluxes from underwater springs and infiltration balance each out
- Fluxes from precipitation and runoff are negligible

According to the State Climatology Office¹³, Grey Cloud Island receives on average 31-32 inches of precipitation per year. Assuming a drainage area of 10 square miles (which is far greater than actual area) and that all precipitation runs off directly into the channel, the average flow is around 27 cfs. Since the average concentration discharging out of a local municipality's storm sewer is around 0.310 mg/L¹⁴, the flux of runoff can be incorporated into inflow flux.

In order to determine many parameters of the model, the channel dimensions were estimated from USGS Topographical maps¹⁵. The estimates are contained in Table 3.

Table 3: Channel Dimensions

	Dimensions	
Depth	15 ft	4.57 m
Mean Depth	7.5 ft	2.29 m
Width	325 ft	99.06 m
Length	11000 ft	3353 m
CSArea	2438 ft ²	226 m ²
Volume	26812500 ft ³	759245 m ³
Surf Area	3575000 ft ²	332128 m ²

The next step was to determine the fluxes into the channel. The nine fluxes that affect the channel are diagramed in Figure 6. Of the nine fluxes, evaporation, precipitation, and runoff are

¹³ Climatology Working Group.(2005).Retrieved October 14, 2005.from The Minnesota Climatology Working Group Homepage: <http://www.climate.umn.edu/>

¹⁴ Wilson, Bruce. (2005). [Preliminary results fromUSFWS Storm Water Project]. Unpublished raw data.

¹⁵ USGS. (1993) Saint Paul Park, MN & Inver Grove Heights, MN

negligible. The model assumes the flux from the springs and due to infiltration cancel each other out since neither one is easy to measure in the time span of the design project. Sedimentation is represented by K_s in the mass balance equation, and the sediment dissolving flux or the sediment release rate was determined from literature to be either $10 \frac{mg}{m^2-d}$ for eutrophic systems or $20 \frac{mg}{m^2-d}$ for hypereutrophic systems¹⁶.

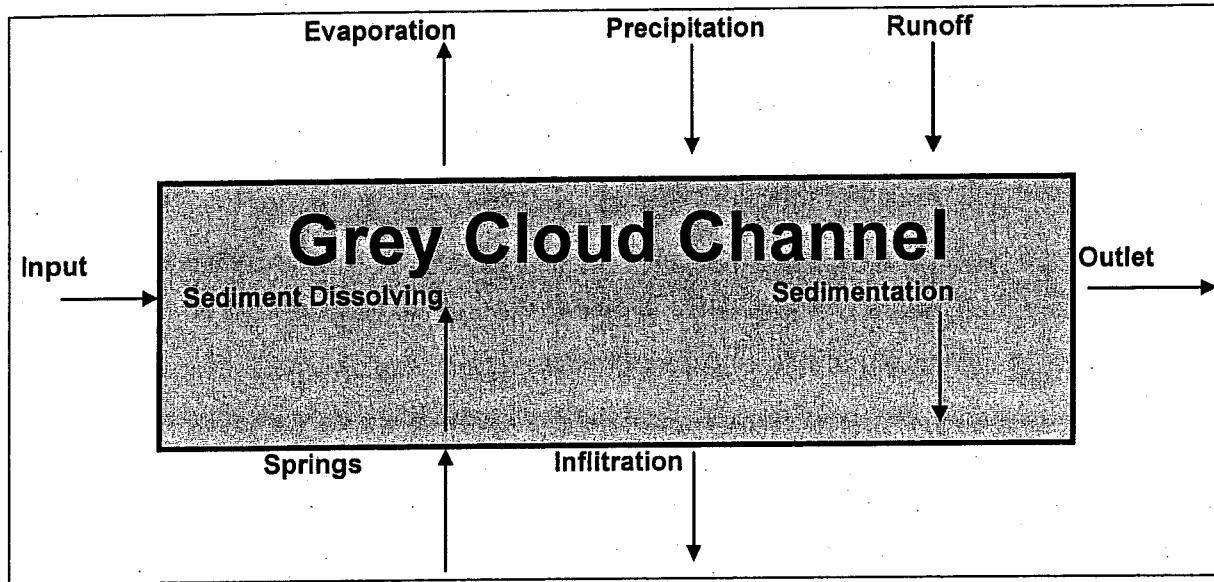


Figure 6: Water Quality Flux Model

Canfield-Bachmann Natural Lake Model

The Canfield-Bachmann Natural Lake Model¹⁷ was used to predict the equilibrium TP concentration.

$$P = \frac{L}{z \left[0.162 \left(\frac{L}{z} \right)^{0.458} + \rho \right]}$$

where:

¹⁶ From Paul Nelson of HDR, Inc

¹⁷ Iowa Department of Natural Resources. (2004) *Total Maximum Daily Load for Algae and Turbidity, Ingham Lake, Emmet County, Iowa.* (pp. 11).

$$P = \text{Predicted in-lake TP concentration } \left[\frac{\mu\text{g}}{\text{L}} \right]$$

$$L = \text{Areal TP load } \left[\frac{\text{mg}}{\text{m}^2\text{-yr}} \right]$$

$$z = \text{Mean lake depth } [m]$$

$$\rho = \text{Lake flushing rate } [yr^{-1}]$$

The aerial TP load was calculated based on the inflow discharge and TP concentration along with the TP release rate of the sediments in the channel.

$$L = \rho P_{\text{inf}} + TP_{\text{sed}}$$

where:

$$TP_{\text{sed}} = \text{Sediment Release Rate } \left[\frac{\text{mg}}{\text{m}^2\text{-yr}} \right]$$

The inflow concentration, P_{inf} , was determined from MPCA grab samples taken on the Mississippi River near Grey Cloud Island¹⁸. An inflow TP concentration used in the model was $P_{\text{inf}} = 0.275 \text{ mg/L}$.

The lake flushing rate was calculated as follows

$$\rho = \frac{Q}{V}$$

The inflow discharge was varied from 0-1765 cfs (0 – 50 $\frac{\text{m}^3}{\text{s}}$). The model was able to predict the equilibrium TP channel concentration according to the Canfield-Bachmann Natural Lake Model. The full model is included in *Appendix D: Water Quality Model Spreadsheets (Canfield-Bachmann Natural Lake Model)*.

Analysis of Water Quality Model

After the model used the Canfield-Bachmann Natural Lake Model to predict the equilibrium TP channel concentration, the results were compiled into an analysis matrix to determine the optimal flow to achieve the lowest equilibrium TP channel concentration. Full results are contained in *Appendix C: Analysis Matrix, TP Release Rates*. Figure 7 shows that the equilibrium concentration starts around 450 $\frac{\mu\text{g}}{\text{L}}$ with no flow and then drops dramatically depending on the TP sediment release rate but then slightly rises until it reaches the influent concentration at very high flows (>10,000 cfs).

¹⁸ From MPCA water quality monitoring Data

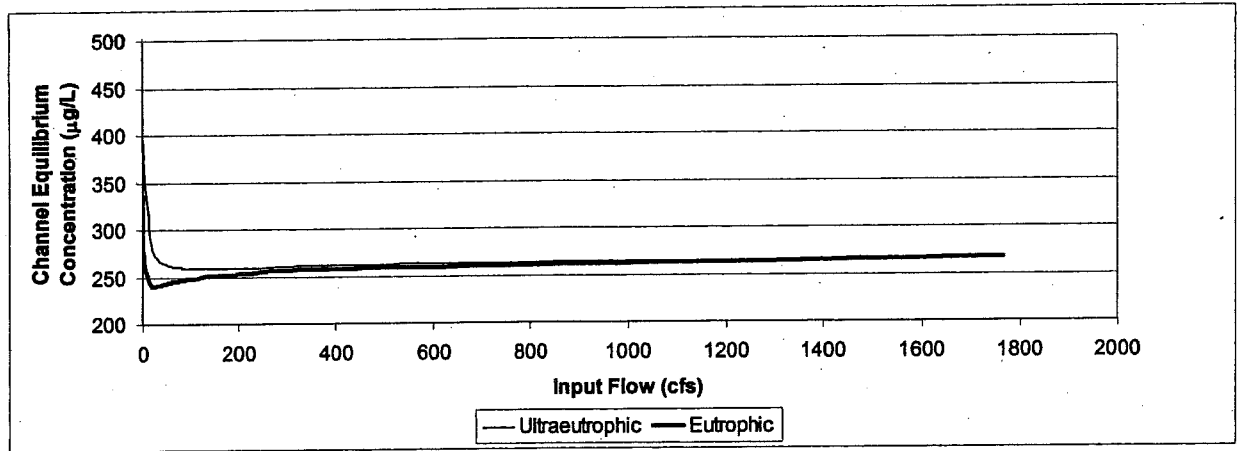


Figure 7: Channel Equilibrium Conc. vs. Input Flow and Various TP Sediment Release Rates

In order for the channel to have as low as possible equilibrium concentration the inflow rate should be greater than 60 cfs. If the flow is greater than 60 cfs but less than 1,766 cfs the reduction of TP from the initial conditions of no flow varies little. Thus the optimal flow through the culvert will be 70 cfs. Channel flows greater than 70 cfs will likely cause bank erosion and channel instability. *Figure 8* shows this optimal operating range.

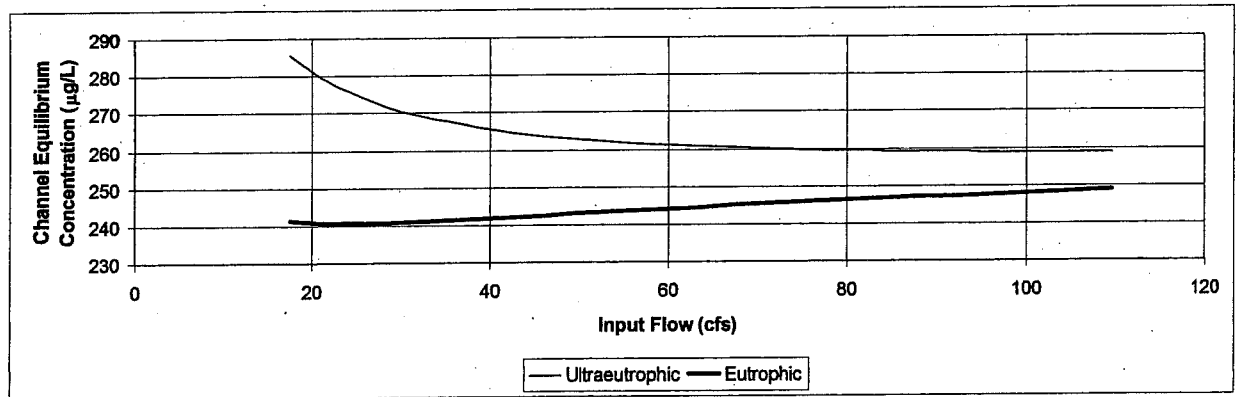


Figure 8: Channel Equilibrium Conc. vs. Input Flow and Various TP Sediment Release Rates (Optimal Operating Range)

The TP channel equilibrium concentrations under ultra-eutrophic and eutrophic conditions with no inflow are $490 \frac{\mu\text{g}}{\text{L}}$ and $336 \frac{\mu\text{g}}{\text{L}}$, respectively. At 70 cfs there is approximately a 47% reduction in TP concentration for ultra-eutrophic conditions, and a 25% reduction in TP concentrations for

eutrophic conditions (Table 4). The table also demonstrates that there is actually a decrease in reduction of TP when the flow around 1766 cfs.

Table 4: Total Phosphorus Channel Concentration at Various Flows

Condition	No flow	70 cfs		1766 cfs	
	TP μg/L	TP μg/L	Reduction in TP	TP μg/L	Reduction in TP
Ultraeutrophic Conditions	490	260	47%	267	45%
Eutrophic Conditions	336	253	25%	267	21%

Mass and Water Balance

The mass and water balance equations were used in the model to determine the time it would take for the channel to reach the equilibrium concentration that the Canfield-Bachmann Natural Lake Model predicted. The assumption made in this part of the model was that the flows would remain constant.

The water balance equation is as follows:

$$\sum Q_{in} = \sum Q_{out}$$

The mass balance equation¹⁹ used is:

$$V \frac{dp}{dt} = W - K_s p V - Q p$$

where:

V = Volume of Channel [m^3]

p = TP in Lake [$\frac{mg}{L}$]

Q = Outflow [$\frac{m^3}{yr}$]

W = External sources of phosphorus [$\frac{mg}{yr}$]

K_s = Overall loss rate of phosphorus [$\frac{1}{yr}$]

t_d = Detention Time [yr]

Both equations were put into a spreadsheet with a time step of one day. In order to put the mass balance equation into a time step spreadsheet the equation was modified to:

$$dp = \left(\frac{W}{V} + \left(K_s - \frac{1}{t_d} \right) p_0 \right) \Delta t$$

¹⁹ Thomann, R. V. & Mueller J. A. (1987) Principles of Surface Water Quality Modeling and Control. New York, NY. Harper Collins Publishers. (pp. 404).

$$p_0 + dp = p_i$$

where:

p_0 = TP conc. during previous time step

p_i = Current TP conc. in pool

K_s was back calculated using the mass and water balance spreadsheet using the equilibrium concentrations determined from the Canfield-Bachmann Natural Lake Model. During this calculation the model was able to predict the number of days the channel would take to reach the equilibrium concentration if the flow rate remained constant at the specified value. According to Table 5, the channel should reach the equilibrium concentration within 23 days of the culvert flowing within in its optimal operating range. Various flows are graphically represented with their corresponding response time in Figure 9. The full model is in *Appendix E: Water Quality Model Spreadsheets (Mass and Water Balance)*. This means if the flow is restored to values greater than 70 cfs in early spring, the TP concentrations in the channel should be near the level of the influent water from the main channel of the Mississippi River. This should cut back on the nutrients available to the algae and Eurasian milfoil currently infesting the channel.

Table 5: Days for Channel to Reach Equilibrium Concentration

Q cfs	Equil. TP Conc. mg/L	K_s 1/yr	v_s cm/hr	Days to Reach Equilibrium
35	0.268	-1.15	0.015	45
53	0.262	-3.05	0.040	34
70	0.260	-4.78	0.063	23
88	0.259	-6.35	0.083	18
106	0.259	-7.81	0.102	13
124	0.259	-9.16	0.120	11
141	0.259	-10.42	0.136	9
159	0.259	-11.61	0.152	8

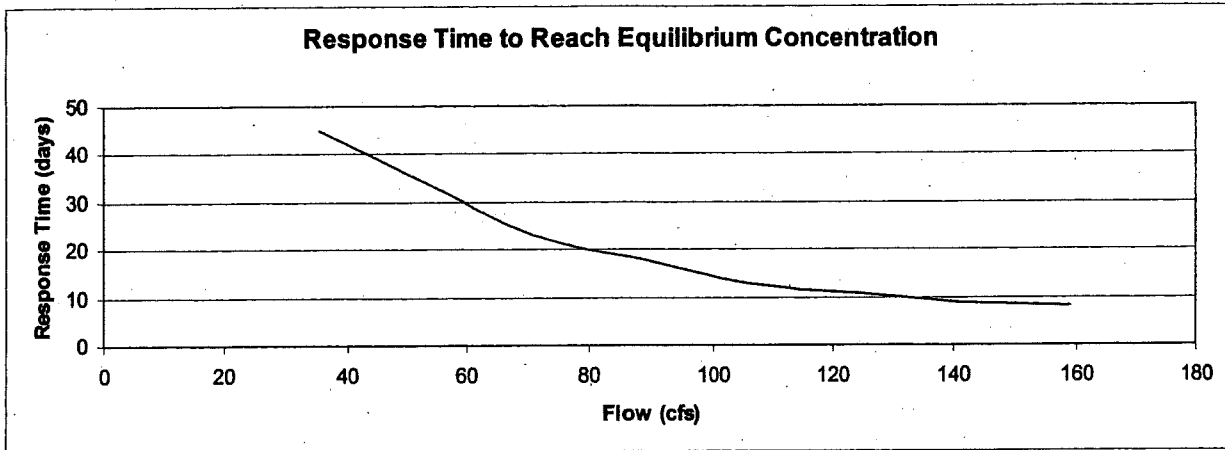


Figure 9: Days for Channel to Reach Equilibrium Concentration at Various Flows

Culvert Design

Manning's Equation

After using the flow model to determine the necessary flow through the culvert to achieve the desired TP concentration within the channel, a spreadsheet was created to find the height and velocity of the water through a given culvert. Different culvert sizes were explored until one was found that would allow for a flow rate of 70 cfs while still keeping the velocity of the water within the culvert at an acceptable level (<9 ft/s). Originally, Manning's equation was used to determine the velocity of the water through the culvert as a function of the height of the water.

$$v = \frac{1.49}{n} R^{2/3} S^{1/2}$$

where:

$$v = \text{Flow} \left[\frac{ft}{s} \right]$$

n = Mannings roughness coefficient

R = Hydraulic radius [ft]

S = Longitudinal slope of the channel $\left[\frac{ft}{ft} \right]$

A box culvert is better suited for this design solution because of the ease of cleaning debris from the flow area.

For a box culvert the following equations were used:

$$R = \frac{A}{P} \quad A = Wy \quad P = 2y + W$$

where:

P = Wetted Perimeter [ft]

A = Flow cross-sectional area [ft²]

W = Width of box culvert [ft]

y = Water depth [ft]

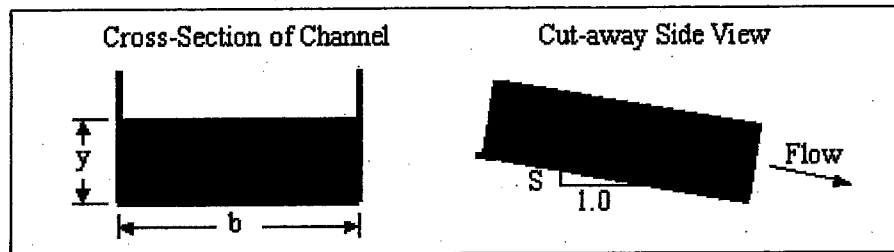


Figure 10: Diagram of Manning's Equation Parameters²⁰

The discharge was then calculated using

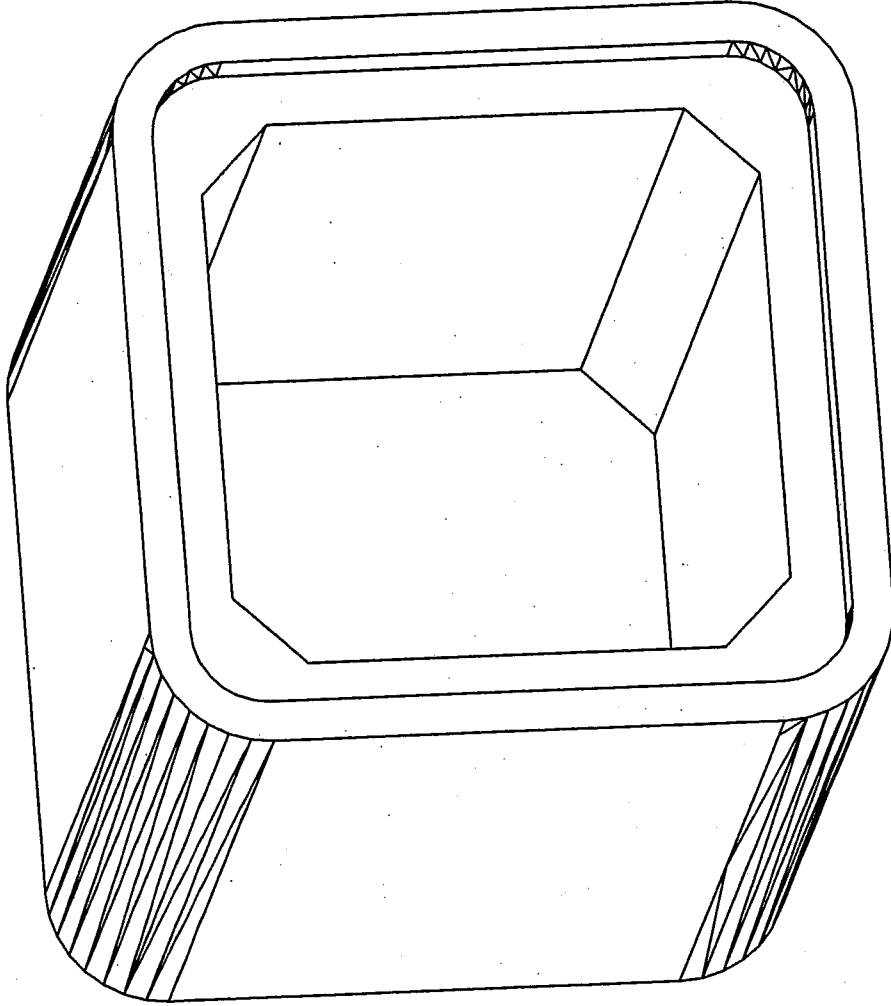
$$Q = vA$$

After using the parameters of

$$S = 0.005 \frac{ft}{ft} \quad n = 0.012 \quad 25 \leq Q \leq 70 cfs$$

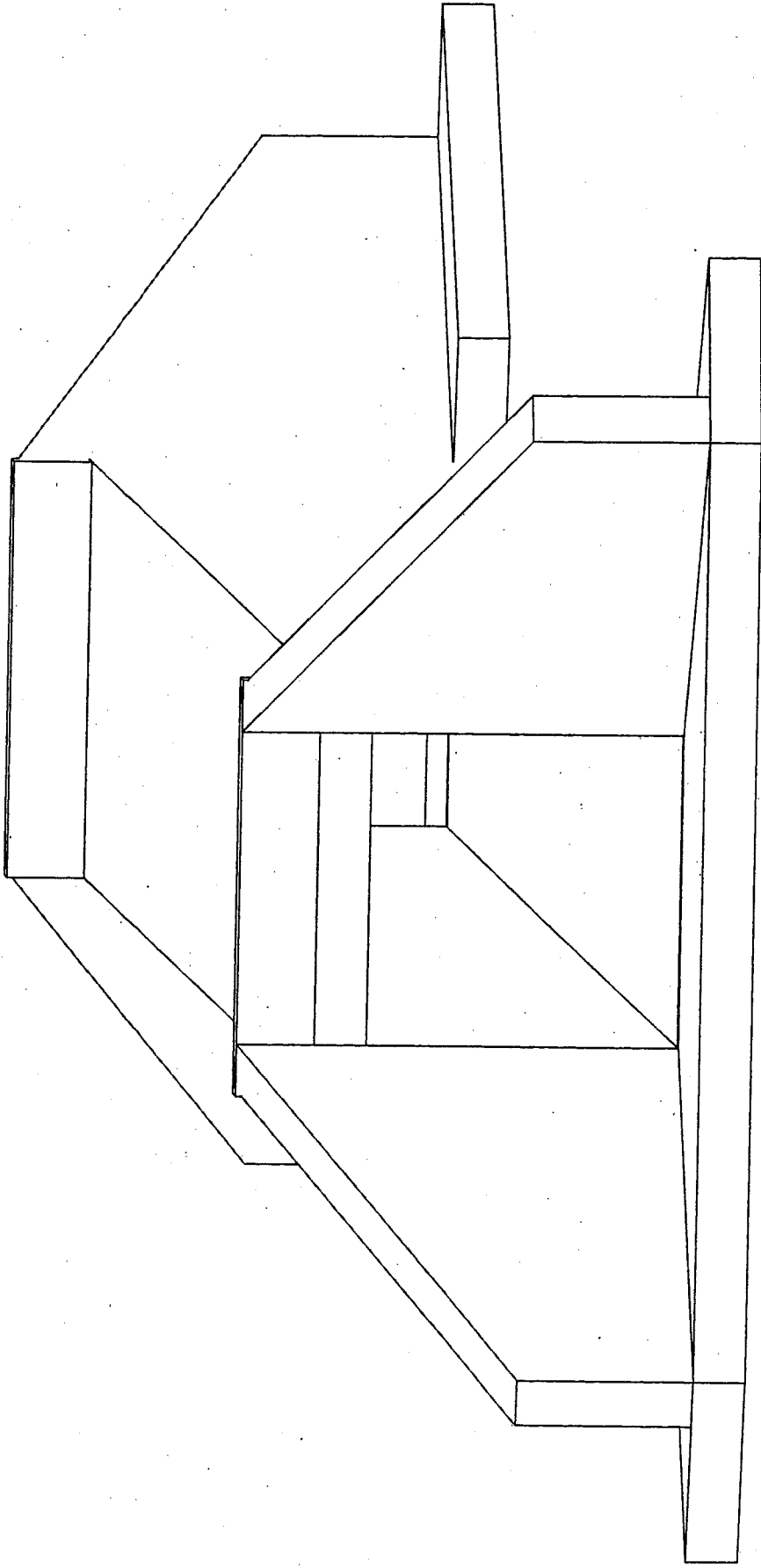
the optimal size culvert was determined to be a 4 ft by 4 ft box culvert. (See DWG. NO. 1 & 10)

²⁰ LMNO Engineering. (2000). *Rectangular Open Channel Design Calculations*. Retrieved November 25, 2005, from LMNO Engineering Homepage: <http://www.lmnoeng.com/water.htm>



Grey Cloud Island Water Quality Project			
Designed by	Date	Checked by	Date
Tom Zeorley	12/12/05	MS	12/24/05
Single-Cell Box Culvert (3D View)			
DWG NO.	1	SHEET	1 of 5
Scale			REV





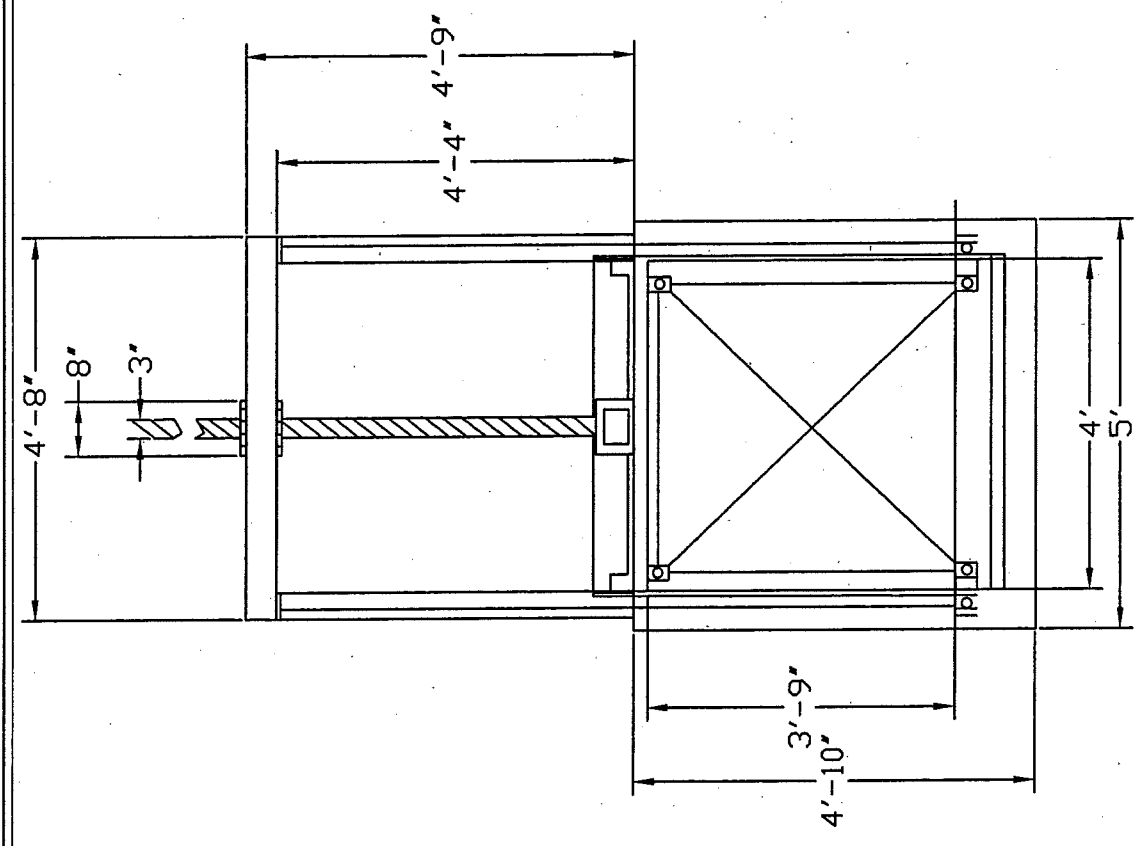
Grey Cloud Island Water Quality Project			
Designed by	Date	Checked by	Date
Michael Jobs	12/07/05	TJ	12/14/05
Full Culvert with Flares (3D View)			
DWG NO.	10	SHEET	1 of 1
Scale		REV	

Sluice Gate

Since the banks of the channel downstream of the road would most likely erode if the flow was too great through the channel. A maximum discharge of 70 cfs through the culvert is desired and must be maintained during high flow events. A sluice gate will be placed at the inlet opening of the culvert to allow the flow to be controlled when the inlet water elevation becomes greater than 2 feet high in the culvert which corresponds to a discharge of 70 cfs. The sluice gate will be a manual crank operated gate that will lower and rise at the inlet of the culvert. Since the culvert will be located on a side channel of the Mississippi River within a pool of a lock and dam, the water levels will not change fast. (See DWG. NO. 11)

Culvert Placement

The culvert will be placed in the middle of the width of the channel. It will also run perpendicular to the road. The elevation of the bottom of the opening of the culvert will be placed at 686.58 ft. The elevation was determined, by using the hydraulic analysis for which a water surface elevation that will be met or exceeded 90% of the time producing a flow of 27 cfs through the culvert. In order to produce a flow of 27 cfs in the culvert, the culvert must be 1 foot full of water. The water surface elevation that is met or exceeded 90% of the time is 686.58 ft. According to the hydraulic analysis, the culvert will not need the use of the sluice gate 81.5% of the time.



Grey Cloud Island Water Quality Project

Designed by Anne Salazar	Date 12/07/05	Checked by 13	Date 12/14/05
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Sluice Gate (Closed)

DWG NO. 11	SHEET 1 of 1	REV
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Scale

Road Design

Since the design solution requires that the existing road be dug up to replace the collapsed culvert, the road must be rebuilt after the new box culvert is installed. According to MnDOT road design standards, each traffic lane must be at least 12 ft. wide and a shoulder of 8 ft. is also required²¹. The thickness of the road was determined to be 2 ft. with 1 ft. being dedicated to asphalt and the other 1 ft. occupied by sand to provide a foundation for the road. There must also be a minimum of 3 ft. between the top of the culvert and the road above it. In our design solution, there will be 9.42 ft of fill between the top of the culvert and the road. The embankment of the road was constructed using a side-slope ratio of 2:1.

Bank and Channel Stabilization

To stabilize the channel, class 5 rock will be used. The class 5 rock will be used along the entire length of the channel embankment which has a side slope ratio of 2:1. The inlet and outlet side of the channel will also be stabilized with the same class 5 rock.

Design Specifications

The following section contains the design specifications for the box culvert and road:

²¹ MnDOT.(2005).*Road Design Manual*. Retrieved December 7, 2005.from MnDOT Website:
<http://www.dot.state.mn.us/tecsup/rdm/>

Culvert Specifications

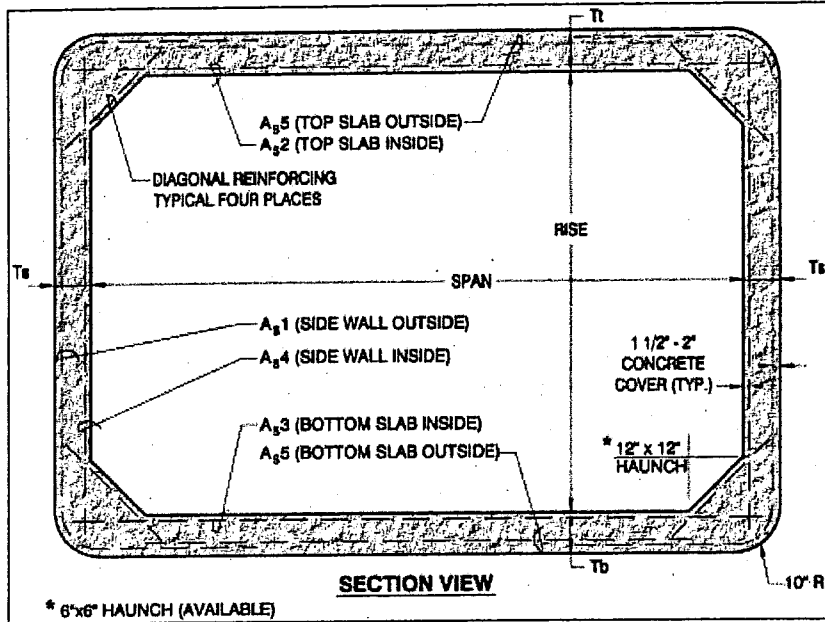


Figure 11: Standard MnDOT Precast Concrete Box Culvert²²

Table 6: MnDOT Precast Concrete Box Culvert Specifications²²

Standard MnDOT Precast Concrete Box Culvert						
Class	f _c (psi)	Fill Height Range (Feet)	T _t (Inches)	T _b (Inches)	T _s (Inches)	Weight (lbs./ft.)
2	5000	15-Feb	8	8	8	2480

Standard MnDOT Precast Concrete Box Culvert									
Reinforcement Requirements									
Class	As1			As2		As3		As4	
	As	Length	M	As	Length	As	Length	As	Length
2	0.4	8'-1"	2'-2"	0.53	6'-6"	0.57	6'-6"	0.2	4'-6"

Loading, Design methods and materials comply with Figure 11

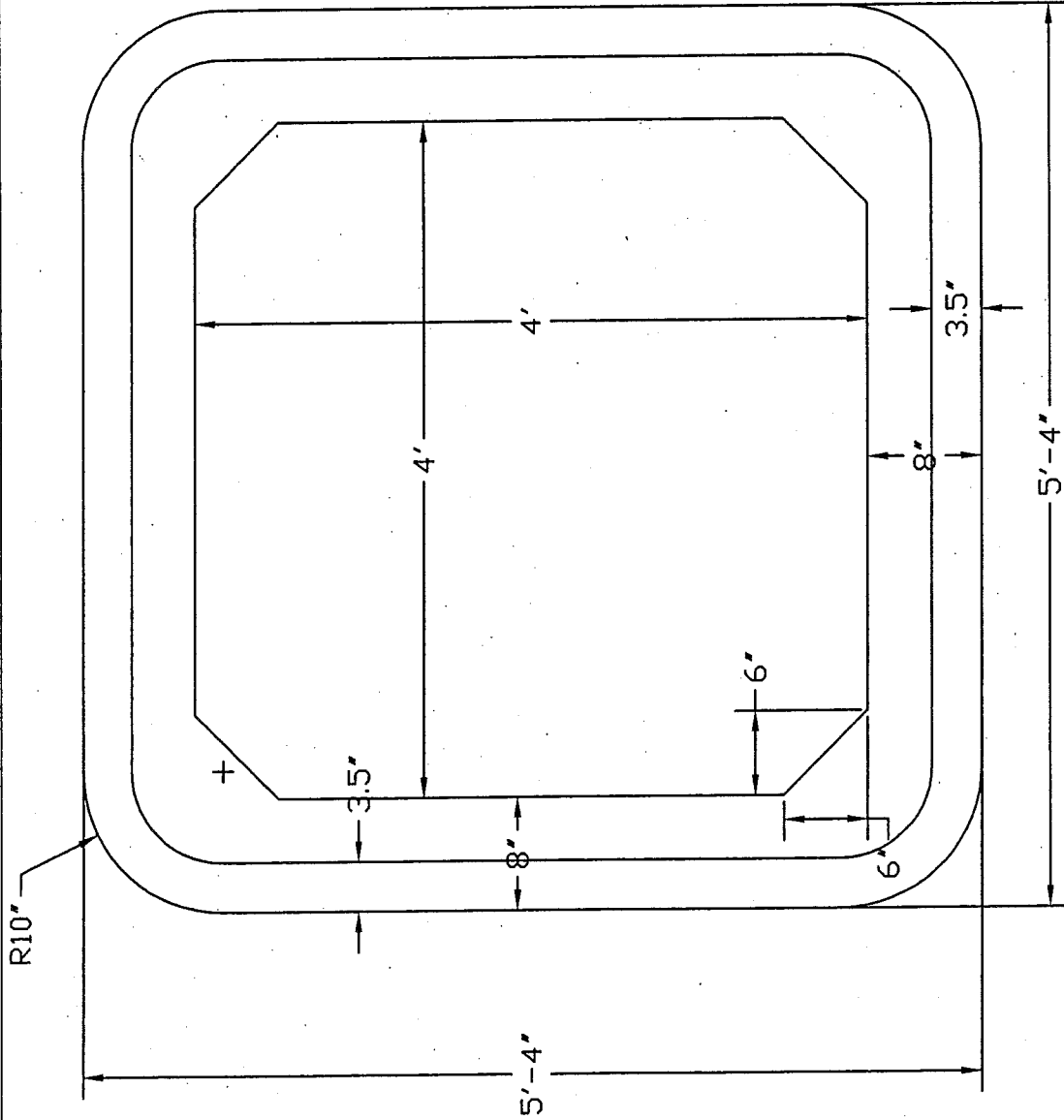
Standard laying length = 6'-0"

WWF ASTM A182, f_s (shear)=65 KSI (1 KSI = 1000 pounds/in²)

Concrete Strength, f_c(compression)=5 KSI

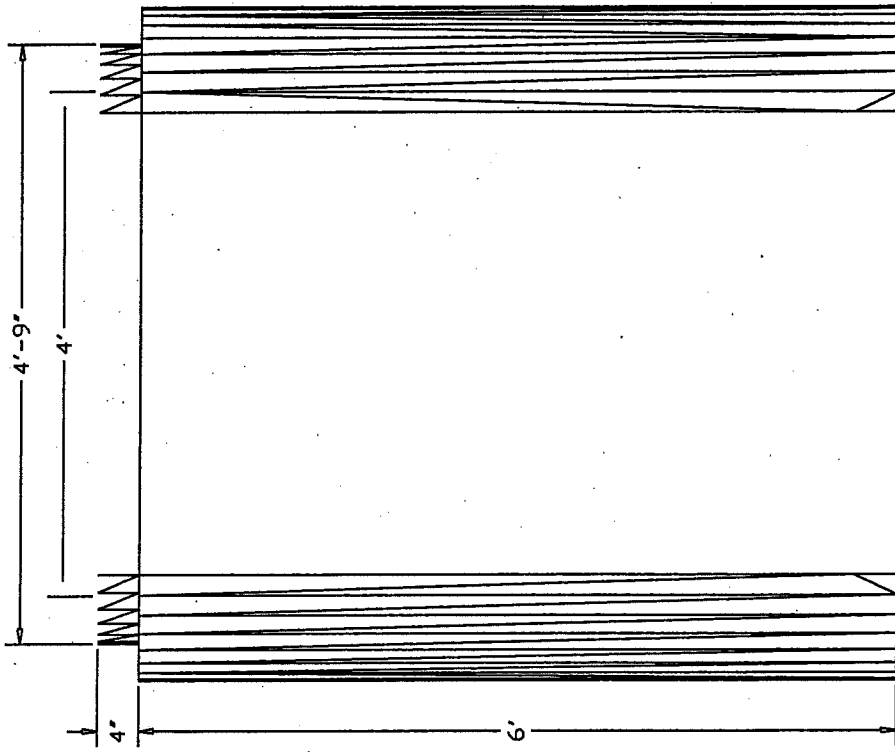
(See DWG. NO. 2 – 5)

²² Cretex Concrete Products North, Inc: <http://www.ercp.com/Catalog/ERCP/ercpcatalog.htm>



Grey Cloud Island Water Quality Project			
Designed by Tom Zearley	Date 12/12/05	Checked by MS	Date 12/14/05
Single-Cell Box Culvert (Side View)			
DWG NO. 2	SHEET	2 of 5	REV
Scale			





Grey Cloud Island Water Quality Project

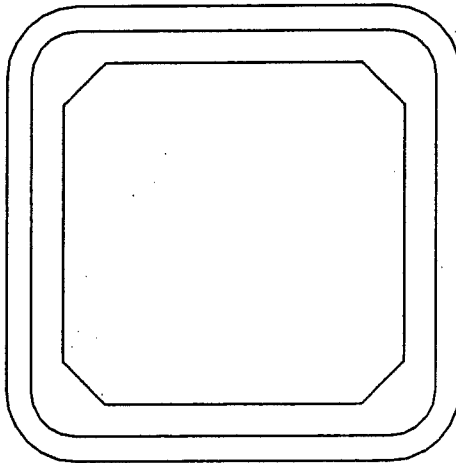
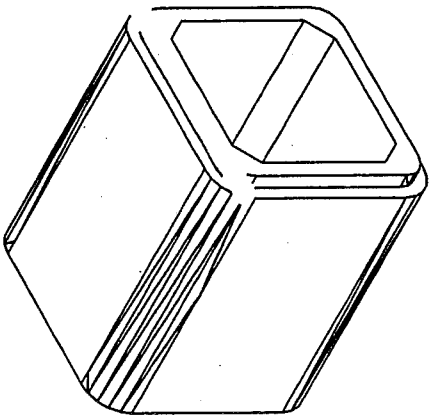
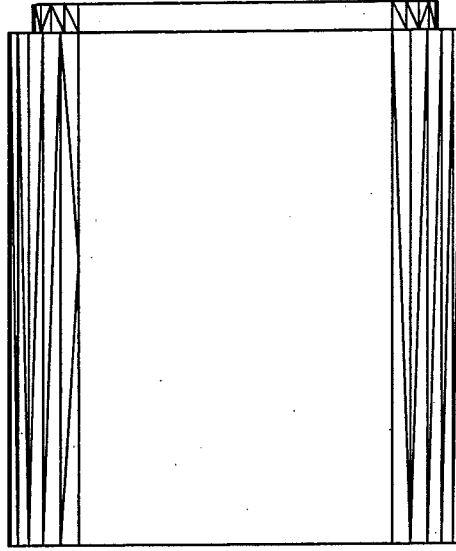
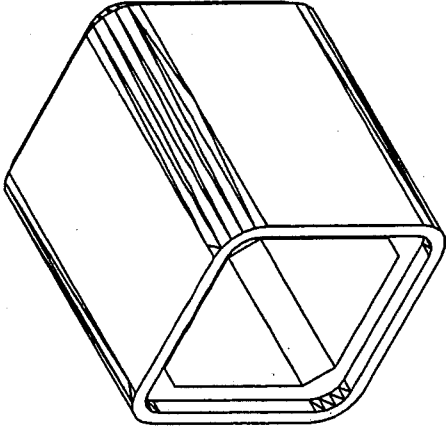
Designed by	Date	Checked by	Date
Ton Zeorley	12/12/05	MJS	12/14/05

Single-Cell Box
Culvert (Top View)

DWG NO.	SHEET	REV
3	3 of 5	



Scale



Grey Cloud Island Water Quality Project

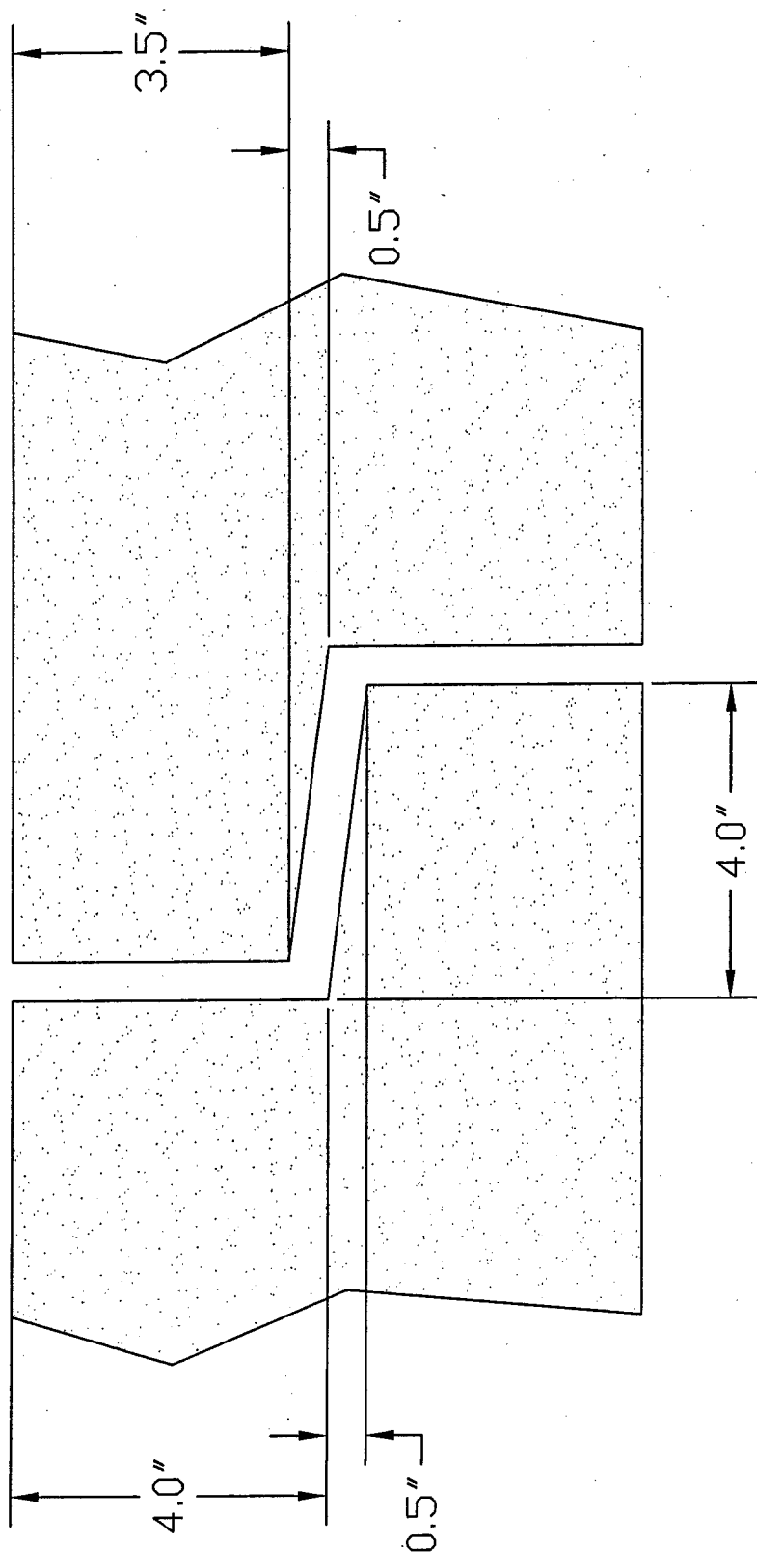
Designed by	Date	Checked by	Date
Tom Zearley	12/12/05	MS	12/14/05


Single-Cell Box
Culvert (Multiview)

DWG NO.	SHEET	REV
4	4	5



Scale



				Grey Cloud Island Water Quality Project	
Designed by Tom Zearley	Date 12/12/05	Checked by MS	Date 12/14/05	Single-Cell Box Culvert Joint	
Scale			DWG NO. 5	SHEET 5 of 5	REV

Flare Ends

The culvert will have flared ends on both openings. The flares will provide bank stability especially during high flow events and the freeze-thaw cycle.

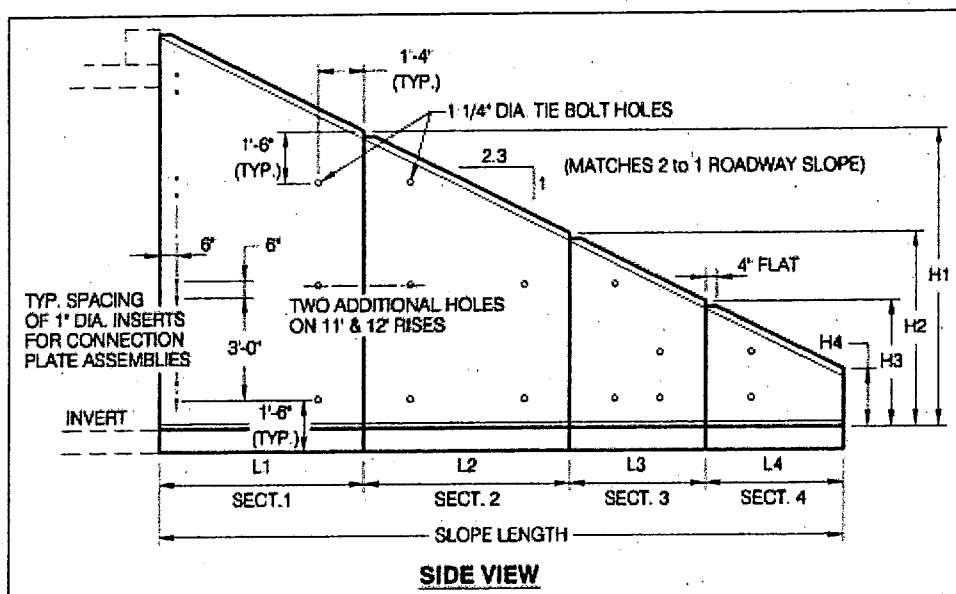


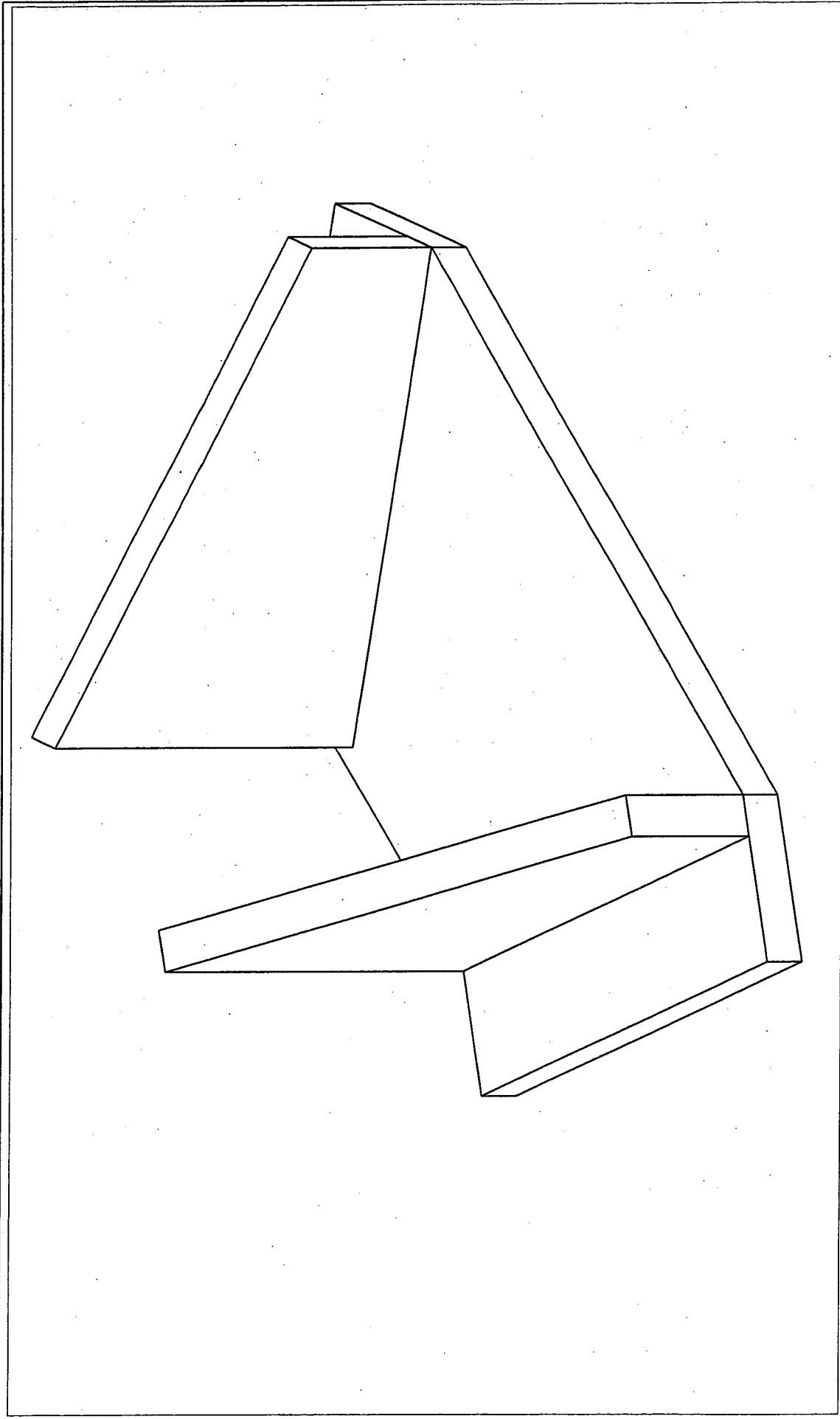
Figure 12: Box Culvert Flared End Section²²


Table 7: Box Culvert Flared End Section Specifications²²

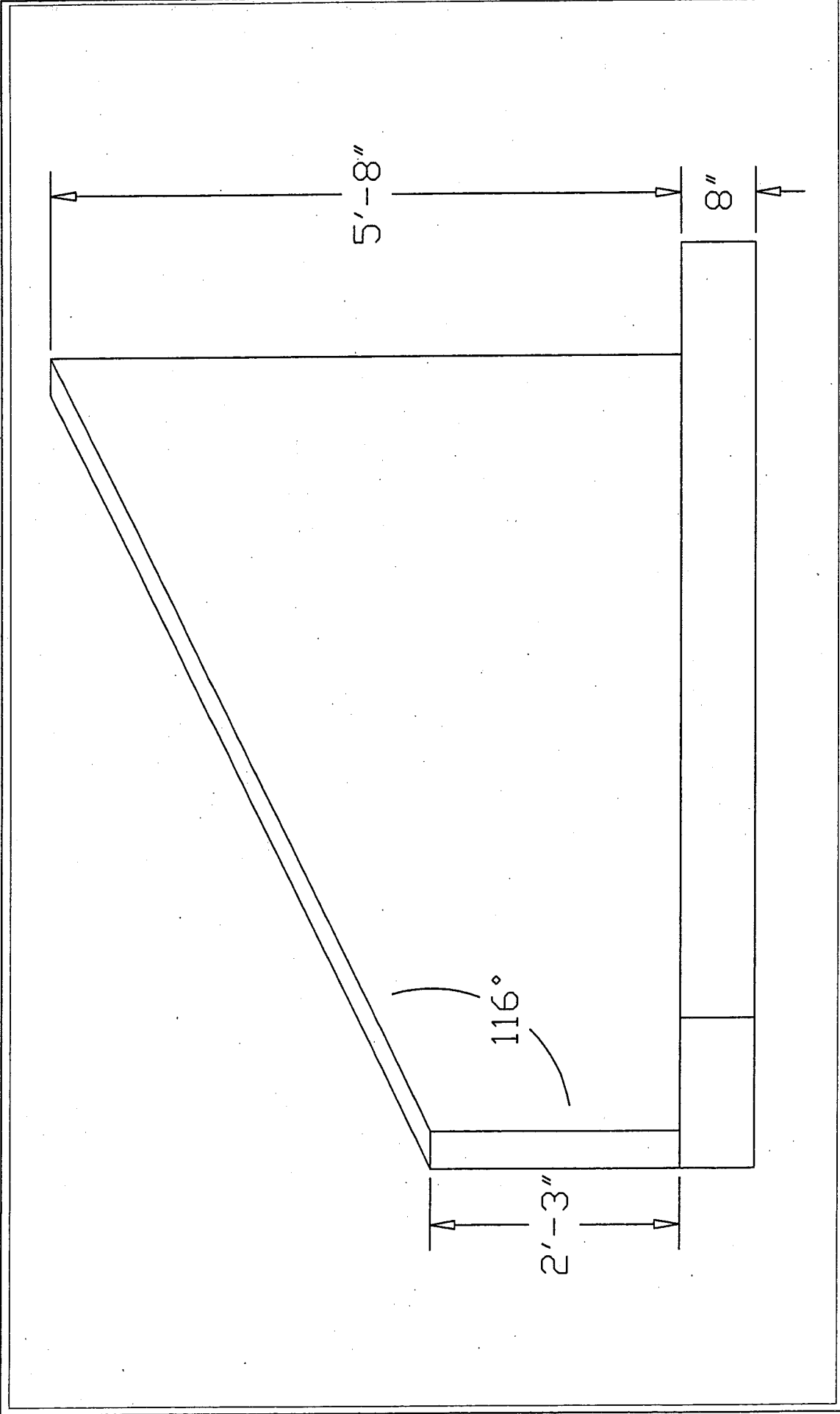
Rise	Slope length	L1	L2	L3	L4	H1	H2	H3	H4	* Weight (lbs.)
										Sect. 1
4'	8'	8'	-	-	-	2'-3"	-	-	-	6,900


*Dimensions and weights are calculated with top of footing set at box culvert invert. When the footing is set below the invert add (100 lbs per square foot x D x L) to tabulated weight. Example 8' rise sect. #1 at 2' lower = 10,100 + (100x2x8) = 11,700 lbs.

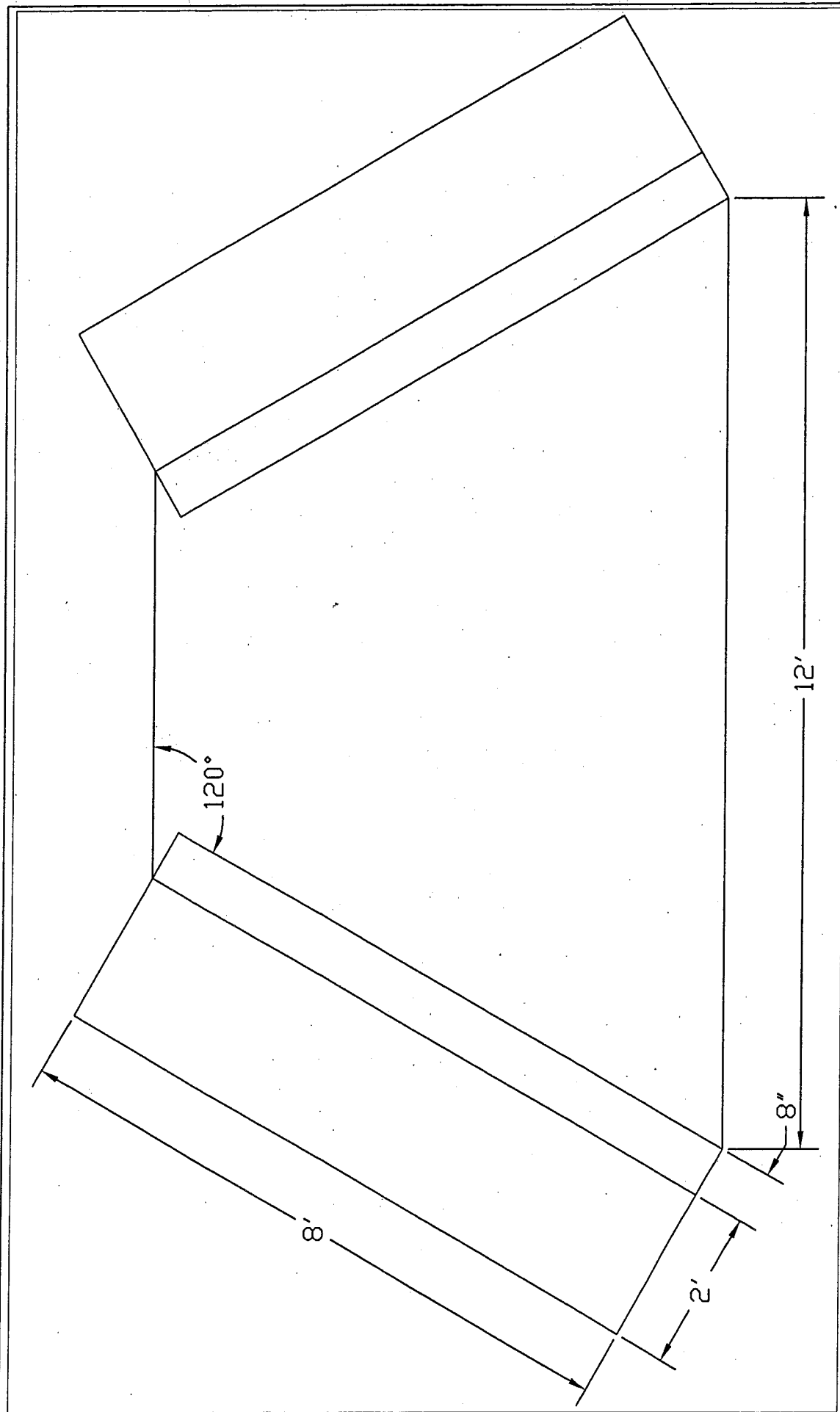
(See DWG. NO. 6 - 9)



Grey Cloud Island Water Quality Project			
Designed by Tom Zeorley	Date 12/12/05	Checked by NDT	Date 12/14/05
Scale		Flare (3D View)	
DWG NO. 6	SHEET	1 of 4	
REV			
			



		Grey Cloud Island Water Quality Project	
Designed by Tom Zearley	Date 12/12/05	Checked by NSB	Date 12/14/05
Scale		Flare (Side View)	
DWG NO. 7		SHEET	2 of 4
REV		REV	



Grey Cloud Island Water Quality Project			
Designed by Tom Zearley	Date 12/12/05	Checked by NJB	Date 12/14/05
Flare (Top View)			REV
Scale		DWG NO. 8	SHEET 3 of 4

Grey Cloud Island Water Quality Project

Designed by	Date	Checked by	Date
Tom Zearley	12/12/05	NSR	12/14/05

Flare (Multiview)



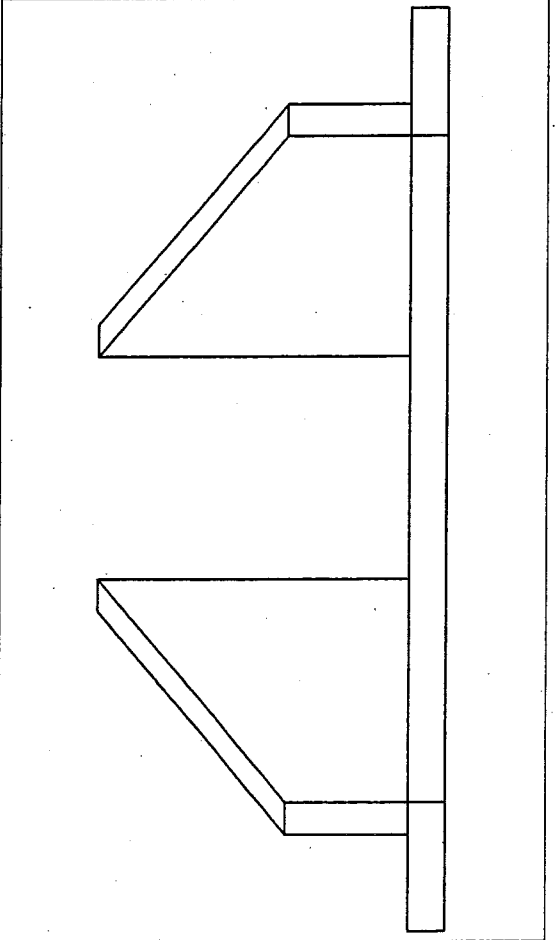
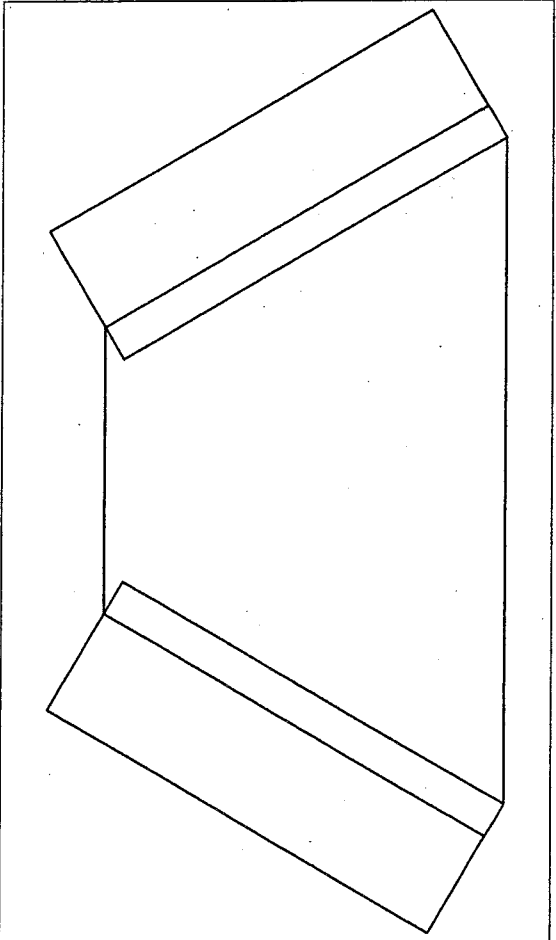
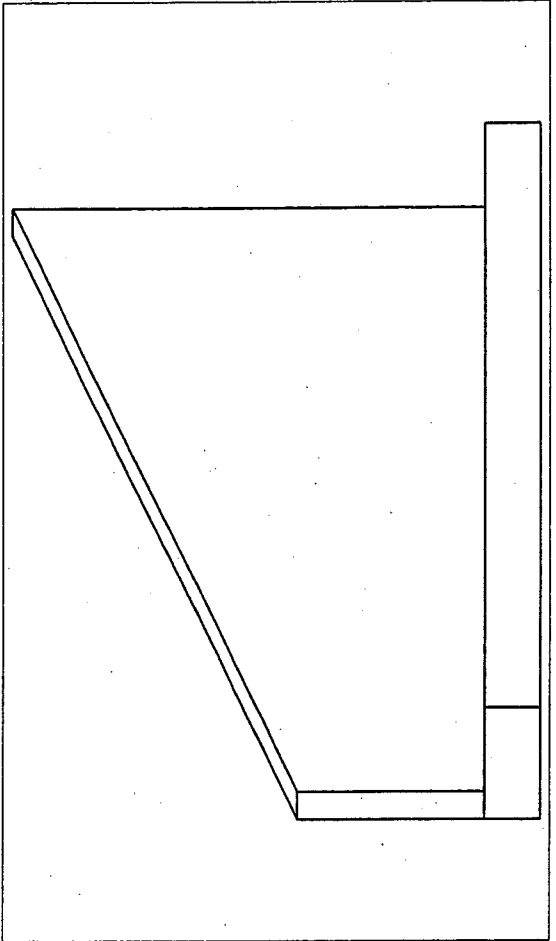
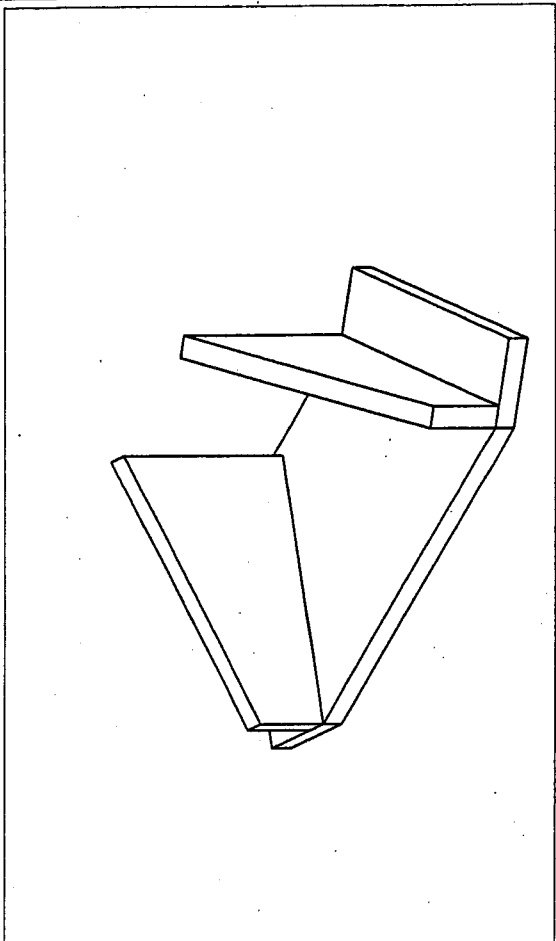
Scale

DWG NO. 9

SHEET

4 of 4

REV



Road Specifications

Table 8: Stopping and Reaction Distances

At 30 miles per hour

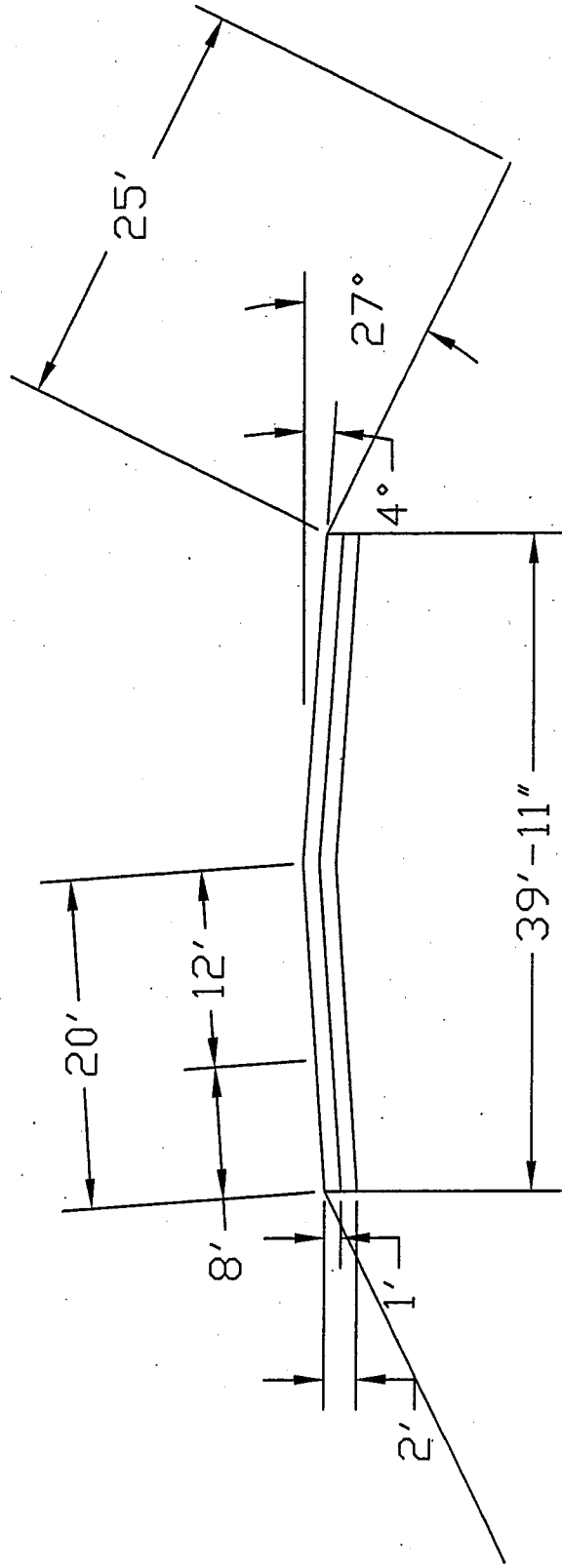
Stopping sight distance	200 ft
Breaking reaction distance	110.3 ft
Braking distance	86.4 ft


Table 9: Road Specifications

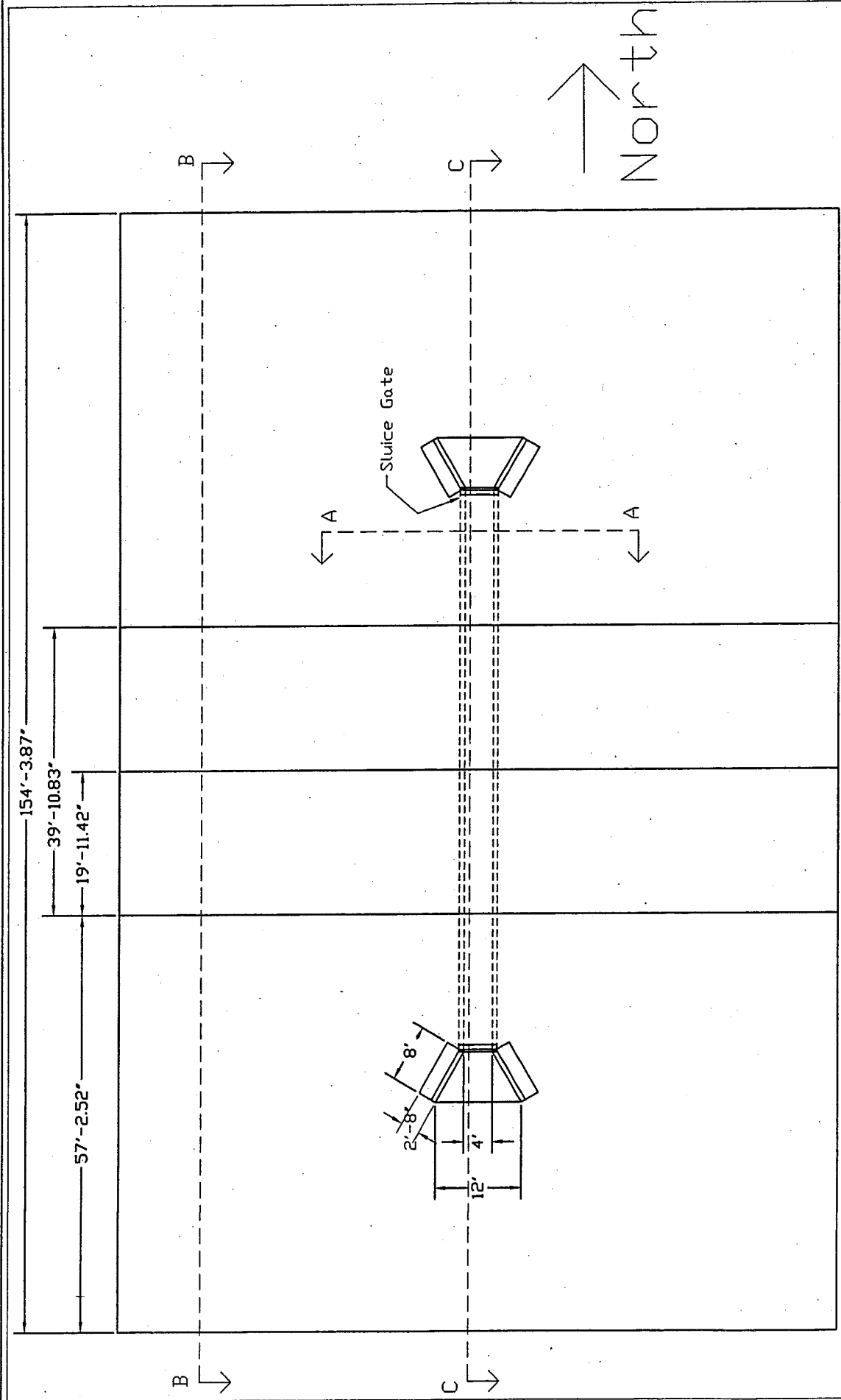
Lane width	12 ft
Shoulder width	8 ft


(See DWG. NO. 14)

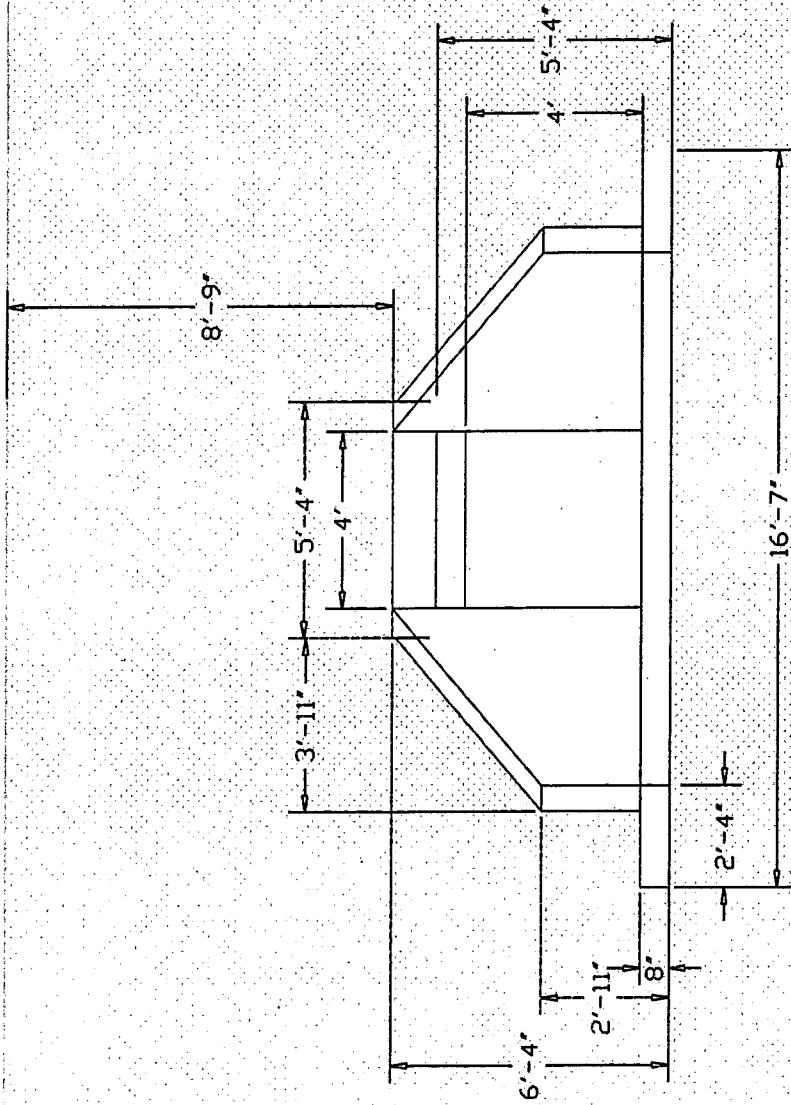
Engineering Drawings



		Grey Cloud Island Water Quality Project	
Designed by Michael Jobs	Date 12/07/05	Checked by T.J.	Date 12/14/05
Road Profile (B-B)			
Scale	DWG NO. 14	SHEET 1 of 1	REV



				Grey Cloud Island Water Quality Project			
Designed by	Date	Checked by	Date	Designed by	Date	Checked by	Date
Anne Salazar	12/04/05	[Signature]	12/14/05	Anne Salazar	12/04/05	[Signature]	12/14/05
Scale				Aerial View			
DWG NO. 12				SHEET 1 of 1			
REV				REV			

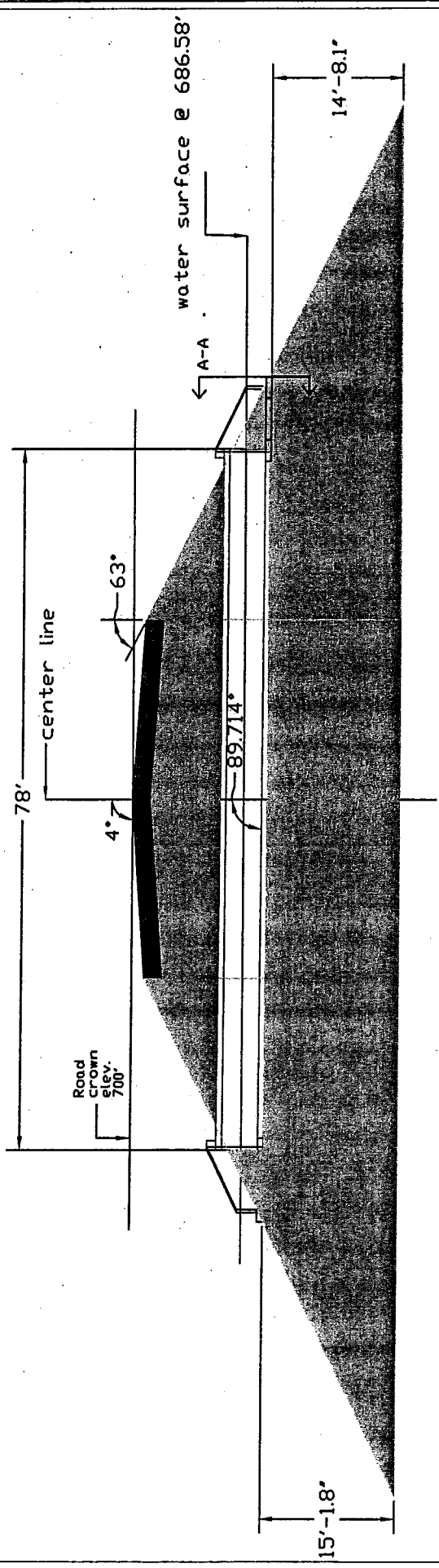



Grey Cloud Island Water Quality Project

Designed by Neal Bauer	Date 12/12/05	Checked by <i>[Signature]</i>	Date 12/14/05
Upstream culvert and flare details (A-A)			
DWG NO. 13	SHEET 1 of 1	REV	



Scale



			
Grey Cloud Island Water Quality Project			
Designed by Neal Bowler	Date 12/12/05	Checked by <i>at</i>	Date 12/14/05
Road & culvert CROSS SECTION (C-C)			
DWG NO. 15	SHEET 1 of 1	REV	
Scale			

Safety and Hazard Analysis

Safety issues for this project have been examined both in present situation and after the implementation of QMD's design solution. The following section will review the chemical, biological, and physical hazards that exist and will occur after the culvert has been reinstalled.

Current Safety Issues

The ecologic community of Grey Cloud Island Channel consists of a variety of plant and animal species that reside on the banks of the channel. The ecosystem has chemical, biological, and physical factors that impact these living organisms. These factors may influence human life and/or create environmental impacts. The current ecosystem is experiencing chemical hazards through issuance of farm and factory waste runoff upstream. The chemical impacts on the channel's water quality are dangerous, particularly when the water becomes stagnant. The water is currently less hospitable for local landowners to use for recreation, and is less desirable to new home buyers.

The stagnant water condition creates biologic hazards in the form of unwanted invasive plant and animal species. The most prominent is the Eurasian milfoil and algal blooms, also known as "blue-green" algae. Both species are harmful to the local vegetation and fish populations. Since Eurasian milfoil has a high growth rate, due to its ability to reproduce from fragments and form mats of bloom, it has an advantage over native species. These mats retard sunlight, rendering deepwater vegetation incapable of harvesting sunlight to thrive. Heightened algal blooms cause similar conditions and become problematic to the rest of the ecological community creating conditions unsuitable for living. Thus populations will decrease as the local species die out and/or migrate to more hospitable environments²³. The algae can also be poisonous to humans if exposed, causing skin irritation and possibly death²⁴. The combination of stagnant water and the higher concentration of dissolved phosphorus in the channel are due to no channel inlet and fertilizer runoff.

²³ Newman, R.M.(2003).*Eurasian Milfoil*. Retrieved October 18, 2005. from Biocontrol of Eurasian milfoil: <http://www.fw.umn.edu/research/milfoil/milfoilbc/milfoil.html>

²⁴ Wisconsin Department of Natural Resources.(2004).*WDNR-Blue-green Algae in Recreational Waters*. Retrieved October 18,2005. from Wisconsin Department of Natural Resources site: <http://dnr.wi.gov/org/land/parks/safety/bluegreenalgae.html>

Post-Construction Safety Issues

Choosing to reinstall the culvert along the channel will help to reduce these safety issues. However, as with any design implementation, there are risks of introducing new hazards and dangers to the local environment. Therefore, we have done a safety hazard analysis for the below channel design solution. The table can be found in *Table 11*.

Reinstalling a culvert will increase flow to the channel, and ultimately remove the stagnant water condition. At higher flows, the milfoil and blue-green algae will incur a significant decrease in population size. The turn over period would increase pushing any chemical hazards through the channel. The faster turn over and flow may or may not reduce the concentration; it depends more on the concentration flowing downstream and subsequent entering of the channel. The QMD believes this factor is uncontrollable. The QMD can only make suggestions as to how the size of discharge through the channel. The culvert design will help increase the flow, as well as, provide control. Since the collapse of the last culvert, due to its inability to handle the flow size, this culvert will be engineered to handle the average flow and the flood events.

New hazards are introduced as a result of implementing the design. The design structure will require safety measures that can be engineered, enforced through law, and/or educated by public recreation boards and other organizations. The hazards include in and around the culvert, and the habitat of wayfarers, such as beavers, deer, and other amphibious animals. The culvert will maintain a large flow, resulting in a risk for both animals and people. Safe guards will need to be implemented, along with warning signs and education on the dangers involving the culvert. Among these safe guards would be safety railings to keep kids and animals away from the culvert. Since the box culvert will be considerably large, only the constant maintenance of the culvert should be needed to prevent large material from blocking up the culvert. Using a cement box culvert should control seepage and engineering the culvert with flares and protective seepage guards should keep the water from overall or quickly leaking into the soil. The use of cement will eliminate the release of any poisons that could have come from another material used on the culvert.

Haddon's Safety Matrix

Table 10: Haddon's Matrix for Grey Cloud Island Water Quality (Culvert Installation)

		Factors			
		Person	Vehicle/vector (causal factors)	Physical environment	Social Environment
Phases	Pre-event	Water quality education	Education pamphlets, outreach activities, signs	Safeguards (ie. fencing), milfoil removal via boat	Law enforcement
	Event	Pump water from nearby quarry, reduce fertilizer use	Install culvert, issue alum	Increase native plant growth	Law enforcement, maintenance/upkeep
	Post-event	Reintroduce fingerlings (fish), native plants	Routine culvert flushing	Establish stream bank, adjust culvert size	Adequate funding, maintenance, grassroots/non-profit observations

The Haddon safety matrix analyzes solutions in terms of project phases and suggests remedies for the problem. In the above table, the water quality problem is assessed before, during, and after the culvert is installed. Within a given period, an analysis of the causal factors, causal factors, the physical and social environments, and the actions people can take are examined and suggestions are made.

Hazard analysis

The hazard analysis matrix is a useful tool for assessing local areas of the Grey Cloud Island channel to determine where the hazards are and how to best remedy. Hazard is a function of risk and severity. To quantify the situation, if either risk or severity can be reduced to zero, the hazard is rendered ineffective. The Quality Management Defenders has compiled a hazard analysis matrix (Table 11).

Table 11: Hazard Analysis for Grey Cloud Culvert Project

Design Element or Subsystem	Hazard Description	Potential Causal Factors	Potential Effects	Hazard Risk Index	Hazard Control Recommendations	Effect of Recommendation on Hazard Risk Index	Hazard Control References
Grey Cloud Island channel culvert							
1A	Sedimentation	sediment transport load	Channel maintenance, culvert fill-in, loss in flow		Install culvert, design for velocity > 25ft/s	3D	US Army Corps of Engineers (CORE)
1B	Bank Erosion	high flow, high precipitation	Loss of topsoil, land quality, loss of biodiversity, channel bank degradation, culvert collapsing		Sluice Gate, Erosion Sediment Control, Best Management Practices, channel stabilization		Minnesota Erosion Control Association (MECA)
2A	Flooding	Mississippi River and/or excessive rainfall	Human injury, economic/social impact, loss of road		Emergency Response Plans, Best Management Practices, raise road		Minnesota Pollution Control Agency (MPCA)
2B	Drowning	Excessive flow and/or depth	injury, death, liability		Education/Awareness, warning signs, railings		Minnesota Department of Transportation (MNDOT)
3A	Blocked culvert	Excessive sediment, debris	Flooding, liability, erosion		Safety guards, best management practices		USGS, CORE

Table 12: Hazard Risk Index Definitions

Hazard Category	Catastrophic	Critical	Marginal	Negligible
A - Frequent				4A
B - Probable				4B
C - Occasional				3C
D - Remote				3D
E - Improbable	1E	2E	3E	

Hazard Risk Index	Risk Decision Criteria
1E, 2E, 3D, 3E, 4A, 4B	Unacceptable; stop operations and rectify immediately
2E, 3D, 3E, 4A, 4B	Undesirable; upper-management decisions to accept or reject risk
3D, 3E, 4A, 4B	Acceptable with management review
4A, 4B	Acceptable without review

Map of Surrounding Area

TOPOI map printed on 11/11/05 from "Untitled.tpo"

93°26.000' W 93°15.000' W 93°04.000' W WGS84 92°44.000' N

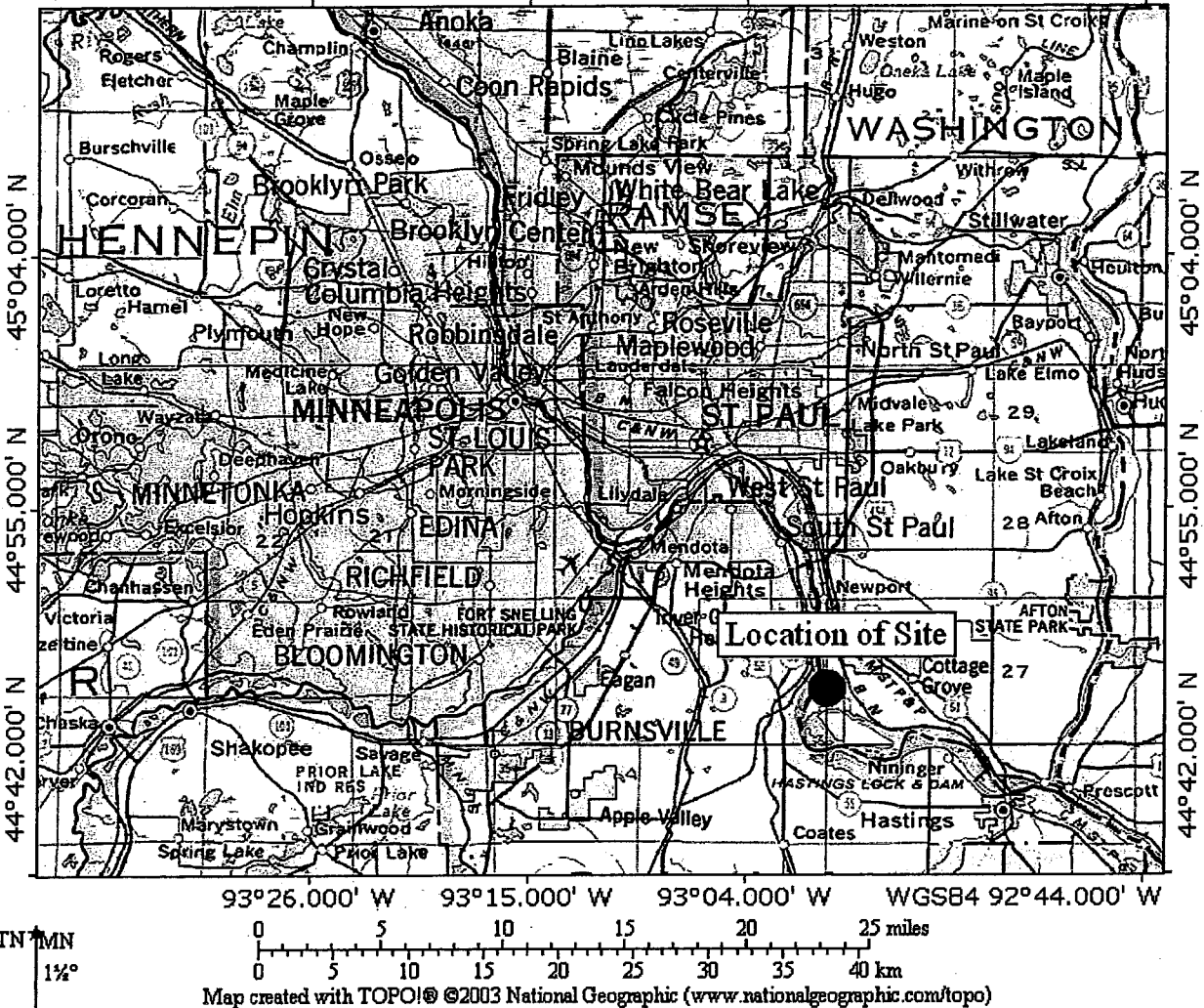


Figure 1: Surrounding Area

Map of Grey Cloud Island Channel

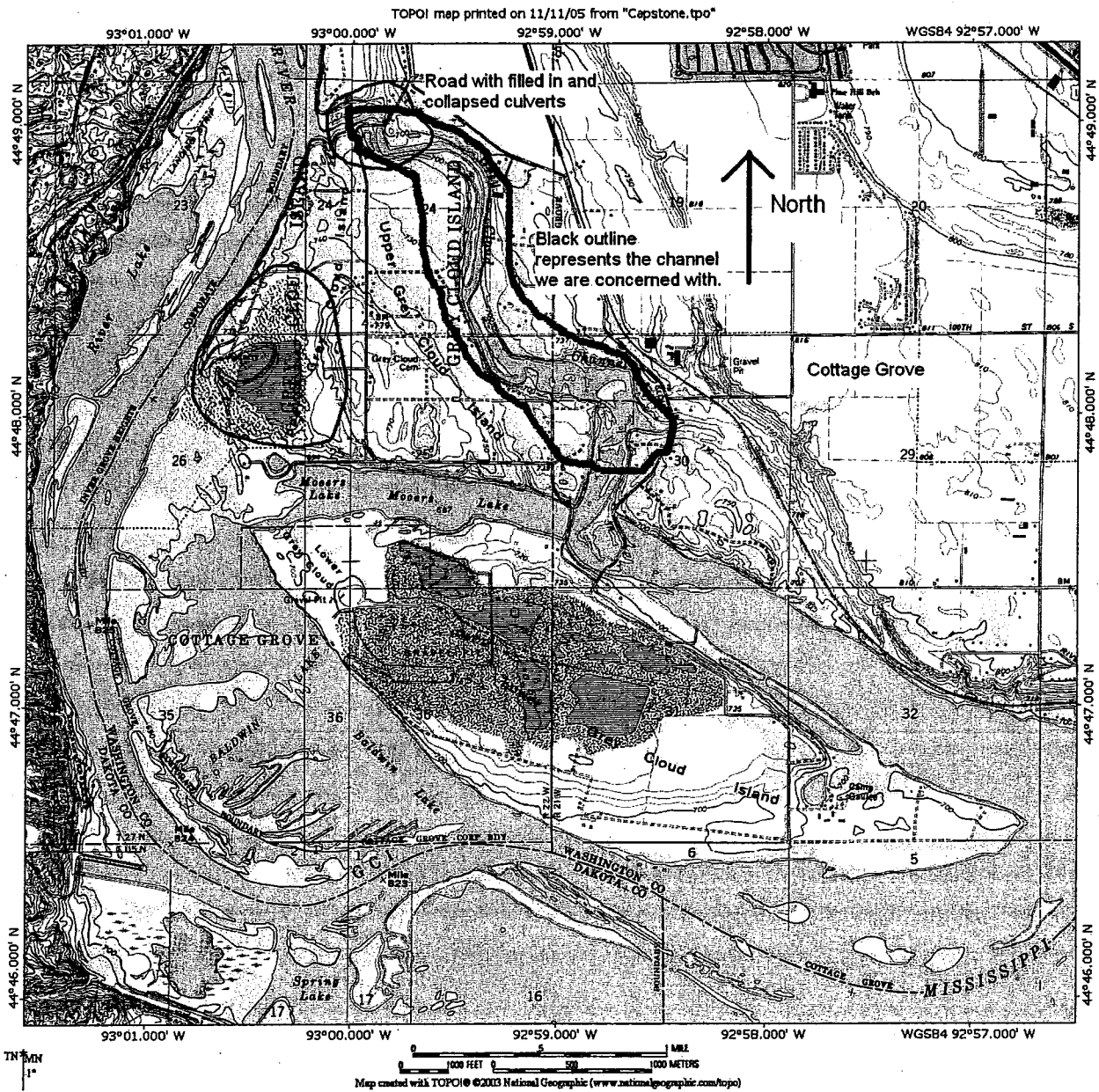


Figure 2: Grey Cloud Island Channel outlined in black.

Design Matrix

Please rank each design option, 1-6, with respect to each criteria listed in the left hand column. Explanations of the criteria (Page 7) and design solutions (Page 5-6) are on the succeeding pages.

1 = Least desirable, least favorable, least beneficial 6 = Most desirable, most favorable, most beneficial

Criteria	Design Solutions					
	Leave as is (datum)	Reinstall culvert	Overland bridge	Pump clean water from nearby quarry	Alum Treatment	Underground Tunnel
Cost						
Maintenance						
Environmental Impact						
Feasibility						
Construction Time						
Safety to Humans						
Water Quality Improvement						
Adaptability						
Aesthetics						

Comments:

Design Solutions Descriptions

Leave as is (datum)

The first option is to leave the channel as it currently is and apply no design method to improving the water quality. By doing nothing the current condition of the channel would remain and be maintained by natural ecological processes. This approach would require no design changes, no new procedures to implement; no money will need to be put forth for construction or maintenance of a design.

Reinstall Culvert

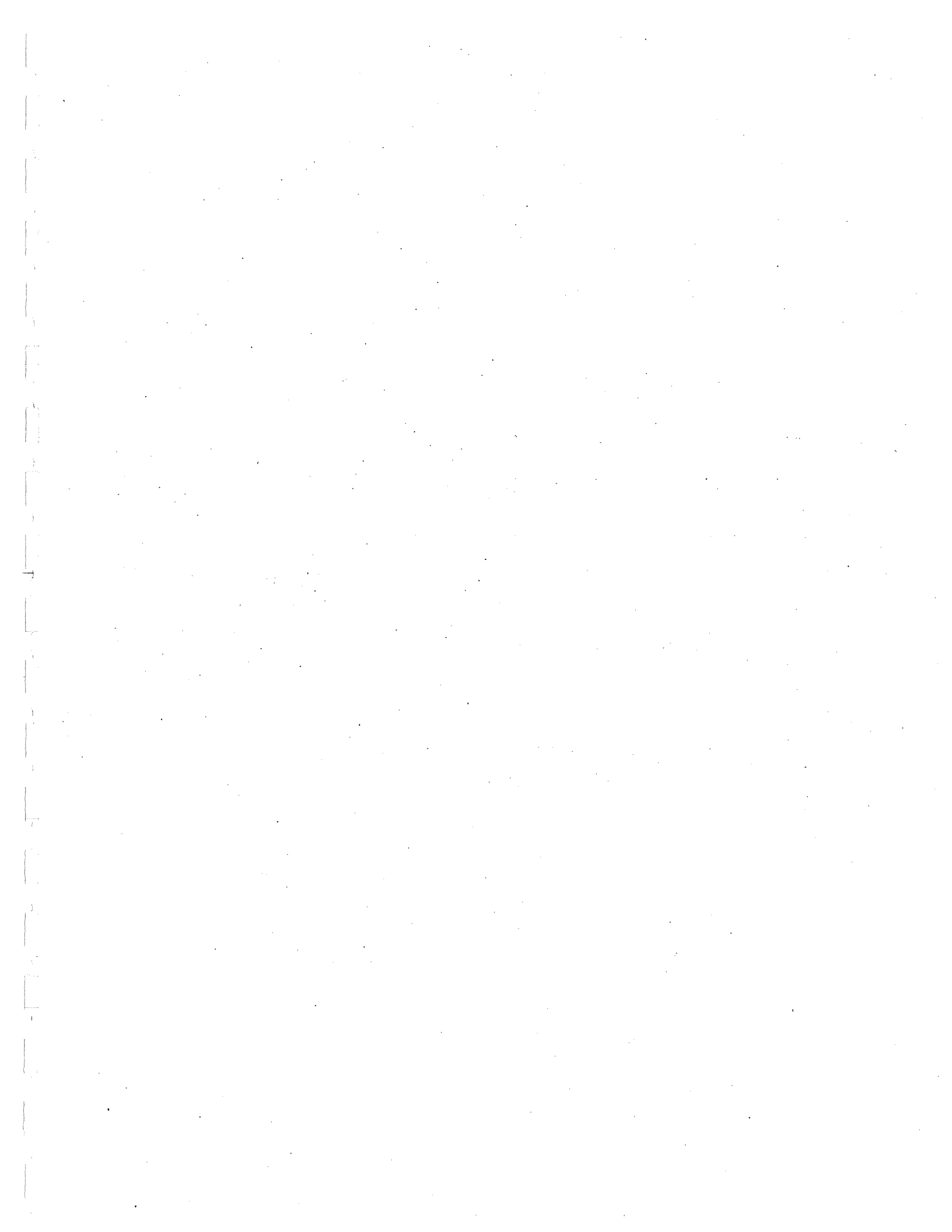
A possible solution is to reinstall the culverts underneath the road. The continuous flow would change the channel from backwater into a flowing channel. This would increase the turnover rate of the channel, and prevent the milfoil from taking root in the streambed. The culvert will have two entrances: a primary opening for the average daily flow, and a culvert above the primary one for handling flood events. The primary culvert will be sized according to the average inflow to the channel during non-flood periods. The secondary culvert will be designed to handle a flow great enough to prevent water from flowing over the road during a large flood event. Both culverts will be fit with safe guards or metal netting to keep out people, animals, and large debris.

Previously, culverts replaced the washed out bridge. Due to stress from the above road as well as sediment build up, the culvert collapsed and became filled in. A concern with the culvert is its ability to handle current traffic on County Road-75 (CR-75) as well as potential increases in traffic as more people move into the local area of Grey Cloud Island. This will need to be overcome with the design and components chosen for the culvert.

Overland bridge

Another design option to improve the water quality is to increase the water flow through the channel by replacing the current road with a two lane bridge. The bridge would still allow for access to and from the island. It would also allow for a constant flow without worrying about debris or sediment build up. The bridge could also be designed to compliment the local ecosystem by adding vegetation to support the existing environment.

A concern with the bridge will be to avoid the bridge from washing out again. Thus to prevent such a damaging event a consideration of the bridge raised height, construction material, size, stabilization method, and the frequency and size of stress will be examined. The traffic loads and frequency will decide the physical parameters of material and size of the culverts. The traffic amount consists primarily of the small population of the residents with considerable traffic from construction sites and the limestone quarry located on the island. Maintenance will need to be done regularly to make sure there is no danger of collapse as well as increasing the longevity of the design.



Design Solutions Descriptions (con't)

Dewater Quarry

A nearby limestone quarry dewater its mining pit continuously. The quarry currently discharges the clear water directly into the Mississippi River. The quarry is willing to move its discharge pipe to just downstream of the road with the collapsed and filled-in culverts. The pumping would be of little cost since the quarry company needs to dewater anyway.

Alum Treatment

This process would involve adding alum (aluminum sulfate) to the channel. The aluminum sulfate will react with the phosphate that is present in the water and will precipitate out and eventually settle. This will help alleviate the algal blooms because the phosphate will no longer be available for the algae to use. The Department of Wildlife, Fisheries, and Parks recommends about 5-15 pounds of alum per surface acre of water. The main problem with using alum to filter out the phosphate is that it will greatly lower the pH of the water. This problem can be counteracted by adding hydrated lime to the water which will increase the pH.

Underground tunnel

Replace the current road and filled in culverts with an underground tunnel to restore the flow through the channel. Some benefits may include little resistance to stream flow, and a lesser impact on terra and aquatic life. Some non-beneficial aspects may include high initial costs (excavation) and time to complete project. There is also risk to damage of the ecological environment due to excavation and vegetation loss.

Descriptions of Design Matrix Criteria:

Cost –

How much will the design solution cost to implement? (Ex. Labor, supplies, permits)

Maintenance –

How much and how often must maintenance be done to maintain the design structure?

Environmental Impact –

How will the design solution affect the environmental quality of the area? (Ex. Fish populations, algal blooms, water quality)

Feasibility –

Is the design solution possible? Is the technology available to complete the plan?

Construction Time –

Can the design solution be completed in a reasonable amount of time (i.e. within three years)?

Safety to Humans –

How safe is the design with regard to human life?

Water Quality Improvement –

Does the design solution accomplish the goal of improving the water quality of the channel?

Adaptability –

Can the design solution be easily upgraded over time as new technology becomes available? Can the design solution handle frequent flow changes, changes in development, barge trafficking, dam breach?

Aesthetics –

How does the design solution look? Would it be an eye sore?

Appendix B: Decision Matrix

Design Matrix

Please rank each design option, 1-6, with respect to each criteria listed in the left hand column. Explanations of the criteria (Page 7) and design solutions (Page 5-6) are on the succeeding pages.

1 = Least desirable, least favorable, least beneficial 6 = Most desirable, most favorable, most beneficial

Criteria	Design Solutions					
	Leave as is (datum)	Reinstall culvert	Overland bridge	Pump clean water from nearby quarry	Alum Treatment	Underground Tunnel
Cost						
Maintenance						
Environmental Impact						
Feasibility						
Construction Time						
Safety to Humans						
Water Quality Improvement						
Adaptability						
Aesthetics						

Comments:

Appendix C: Analysis Matrix, TP Release Rates

**Analysis Matrix TP Release Rate 10 mg/m²*d
Eutrophic Conditions**

Q _{influent}	Q _{influent}	TP	Xinfluent	TP Release	V _{ave}	θ			
cfs	m ³ /s	μg/L	μg/L	mg/m ² *d	m/s	s	hr	d	yr
0.0	0	336	275	10	0.00	NA	NA	NA	NA
0.04	0.001	335	275	10	0.00				24
0.4	0.01	322	275	10	0.00				2.4
3.5	0.1	268	275	10	0.00			87.9	0.24
35.3	1	241	275	10	0.00	759245	211	8.79	2.4E-02
53.0	1.5	243	275	10	0.01	506164	141	5.86	1.6E-02
70.6	2	245	275	10	0.01	379623	105	4.39	1.2E-02
88.3	2.5	247	275	10	0.01	303698	84	3.52	9.6E-03
106	3	248	275	10	0.01	253082	70	2.93	8.0E-03
124	3.5	250	275	10	0.02	216927	60	2.51	6.9E-03
141	4	251	275	10	0.02	189811	53	2.20	6.0E-03
159	4.5	252	275	10	0.02	168721	47	1.95	5.4E-03
177	5	253	275	10	0.02	151849	42	1.76	4.8E-03
194	5.5	253	275	10	0.02	138045	38	1.60	4.4E-03
212	6	254	275	10	0.03	126541	35	1.46	4.0E-03
230	6.5	255	275	10	0.03	116807	32	1.35	3.7E-03
247	7	255	275	10	0.03	108464	30	1.26	3.4E-03
265	7.5	256	275	10	0.03	101233	28	1.17	3.2E-03
283	8	256	275	10	0.04	94906	26	1.10	3.0E-03
300	8.5	257	275	10	0.04	89323	25	1.03	2.8E-03
318	9	257	275	10	0.04	84361	23	0.98	2.7E-03
335	9.5	258	275	10	0.04	79921	22	0.93	2.5E-03
353	10	258	275	10	0.04	75925	21	0.88	2.4E-03
530	15	261	275	10	0.07	50616	14	0.59	1.6E-03
706	20	262	275	10	0.09	37962	11	0.44	1.2E-03
883	25	264	275	10	0.11	30370	8	0.35	9.6E-04
1059	30	264	275	10	0.13	25308	7	0.29	8.0E-04
1236	35	265	275	10	0.15	21693	6	0.25	6.9E-04
1413	40	266	275	10	0.18	18981	5	0.22	6.0E-04
1589	45	266	275	10	0.20	16872	5	0.20	5.4E-04
1766	50	267	275	10	0.22	15185	4	0.18	4.8E-04

Analysis Matrix TP Release Rate 20 mg/m²*d
Ultraeutrophic Conditions

Q _{influent}	Q _{influent}	TP	X _{influent}	TP Release	V _{ave}	θ			
						s	hr	d	yr
0.0	0	490	275	20	0.00	NA	NA	NA	NA
0.04	0.001	487	275	20	0.00				24
0.4	0.01	470	275	20	0.00				2.4
3.5	0.1	372	275	20	0.00			87.9	0.24
35.3	1	268	275	20	0.00	759245	211	8.79	2.4E-02
53.0	1.5	262	275	20	0.01	506164	141	5.86	1.6E-02
70.6	2	260	275	20	0.01	379623	105	4.39	1.2E-02
88.3	2.5	259	275	20	0.01	303698	84	3.52	9.6E-03
106	3	259	275	20	0.01	253082	70	2.93	8.0E-03
124	3.5	259	275	20	0.02	216927	60	2.51	6.9E-03
141	4	259	275	20	0.02	189811	53	2.20	6.0E-03
159	4.5	259	275	20	0.02	168721	47	1.95	5.4E-03
177	5	259	275	20	0.02	151849	42	1.76	4.8E-03
194	5.5	259	275	20	0.02	138045	38	1.60	4.4E-03
212	6	260	275	20	0.03	126541	35	1.46	4.0E-03
230	6.5	260	275	20	0.03	116807	32	1.35	3.7E-03
247	7	260	275	20	0.03	108464	30	1.26	3.4E-03
265	7.5	260	275	20	0.03	101233	28	1.17	3.2E-03
283	8	260	275	20	0.04	94906	26	1.10	3.0E-03
300	8.5	261	275	20	0.04	89323	25	1.03	2.8E-03
318	9	261	275	20	0.04	84361	23	0.98	2.7E-03
335	9.5	261	275	20	0.04	79921	22	0.93	2.5E-03
353	10	261	275	20	0.04	75925	21	0.88	2.4E-03
530	15	263	275	20	0.07	50616	14	0.59	1.6E-03
706	20	264	275	20	0.09	37962	11	0.44	1.2E-03
883	25	265	275	20	0.11	30370	8	0.35	9.6E-04
1059	30	266	275	20	0.13	25308	7	0.29	8.0E-04
1236	35	266	275	20	0.15	21693	6	0.25	6.9E-04
1413	40	267	275	20	0.18	18981	5	0.22	6.0E-04
1589	45	267	275	20	0.20	16872	5	0.20	5.4E-04
1766	50	267	275	20	0.22	15185	4	0.18	4.8E-04

***Appendix D: Water Quality Model Spreadsheets (Canfield-Bachmann
Natural Lake Model)***

	Dimensions
Depth	15 ft
Mean Dept	4.57 m
Width	7.5 ft
Length	325 ft
CSArea	11000 ft
Volume	2438 ft ²
Surf Area	26812500 ft ³
Slope	3575000 ft ²
	0.092
	759245 m ³
	332128 m ²
	0.092

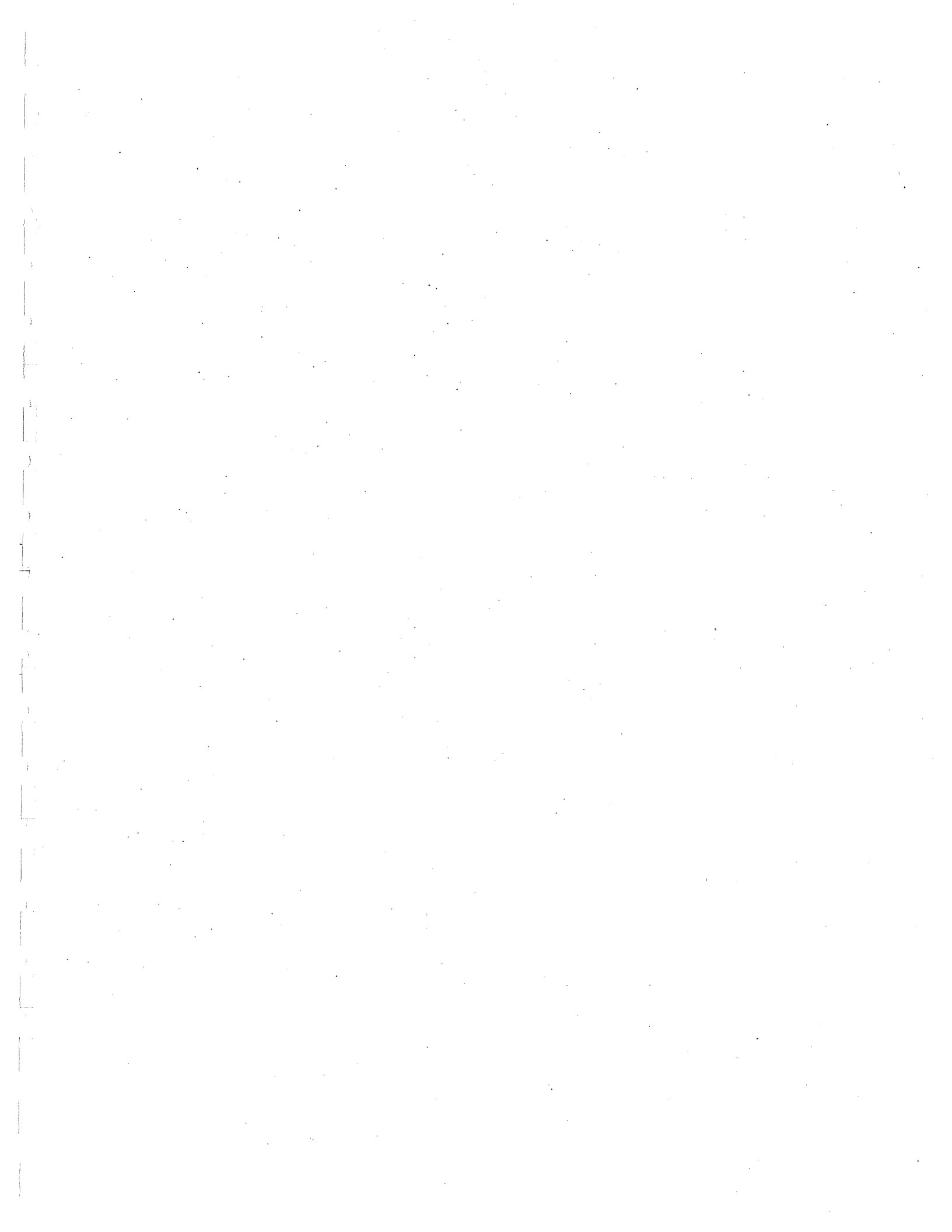
	Using Rate & Retention Time
P	0.00E+00 1/s
θ	0.00E+00 1/yr
	#DIV/0! s
	#DIV/0! d
	#DIV/0! yr

Time				Pool			+		In
Q	Day	Hr	Δt	Conc	Mass	Volume	Q		
cfs			sec	μg/L	kg	m ³	m ³ /s		
0	0	0	0	489.538	3.72E+05	0.00E+00	0		
0.353147	1	24	86400	469.533	3.56E+05	8.64E+02	0.01		
3.531467	2	48	86400	371.916	2.82E+05	8.64E+03	0.1		
17.65734	3	72	86400	285.387	2.17E+05	4.32E+04	0.5		
17.65734	4	96	86400	285.387	2.17E+05	4.32E+04	0.5		
21.1888	5	120	86400	279.479	2.12E+05	5.18E+04	0.6		
24.72027	6	144	86400	275.190	2.09E+05	6.05E+04	0.7		
28.25174	7	168	86400	271.972	2.06E+05	6.91E+04	0.8		
31.7832	8	192	86400	269.495	2.05E+05	7.78E+04	0.9		
35.31467	9	216	86400	267.551	2.03E+05	8.64E+04	1		
38.84614	10	240	86400	266.000	2.02E+05	9.50E+04	1.1		
42.3776	11	264	86400	264.746	2.01E+05	1.04E+05	1.2		
45.90907	12	288	86400	263.723	2.00E+05	1.12E+05	1.3		
49.44054	13	312	86400	262.879	2.00E+05	1.21E+05	1.4		
52.97201	14	336	86400	262.179	1.99E+05	1.30E+05	1.5		
56.50347	15	360	86400	261.594	1.99E+05	1.38E+05	1.6		
60.03494	16	384	86400	261.104	1.98E+05	1.47E+05	1.7		
63.56641	17	408	86400	260.692	1.98E+05	1.56E+05	1.8		
67.09787	18	432	86400	260.344	1.98E+05	1.64E+05	1.9		
70.62934	19	456	86400	260.050	1.97E+05	1.73E+05	2		
74.16081	20	480	86400	259.802	1.97E+05	1.81E+05	2.1		
77.69227	21	504	86400	259.592	1.97E+05	1.90E+05	2.2		
81.22374	22	528	86400	259.415	1.97E+05	1.99E+05	2.3		
84.75521	23	552	86400	259.267	1.97E+05	2.07E+05	2.4		
88.28668	24	576	86400	259.142	1.97E+05	2.16E+05	2.5		
91.81814	25	600	86400	259.039	1.97E+05	2.25E+05	2.6		
95.34961	26	624	86400	258.954	1.97E+05	2.33E+05	2.7		
98.88108	27	648	86400	258.884	1.97E+05	2.42E+05	2.8		
102.4125	28	672	86400	258.829	1.97E+05	2.51E+05	2.9		
105.944	29	696	86400	258.786	1.96E+05	2.59E+05	3		
	30	720	86400						

put	Runoff			Precipitation			Outlet			Cannfield- Assume Lake		
	Conc mg/L	Mass kg	0.275	Volume m ³	Q m ³ /s	Conc mg/L	Mass kg	0	Volume m ³	Q m ³ /s	Conc mg/L	Mass kg
0.275	0.00	0	0.310	0	0	0	0.00	0.00E+00	0	0.4895	371.7	489.538
0.275	0.24	0	0.31	0	0	0.00	0.00	-8.64E+02	-0.01	0.4695	356.5	469.533
0.275	2.38	0	0.31	0	0	0.00	0.00	-8.64E+03	-0.1	0.3719	282.4	371.916
0.275	11.88	0	0.31	0	0	0.00	0.00	-4.32E+04	-0.5	0.2854	216.7	285.387
0.275	11.88	0	0.31	0	0	0.00	0.00	-4.32E+04	-0.5	0.2854	216.7	285.387
0.275	14.26	0	0.31	0	0	0.00	0.00	-5.18E+04	-0.6	0.2795	212.2	279.479
0.275	16.63	0	0.31	0	0	0.00	0.00	-6.05E+04	-0.7	0.2752	208.9	275.190
0.275	19.01	0	0.31	0	0	0.00	0.00	-6.91E+04	-0.8	0.2720	206.5	271.972
0.275	21.38	0	0.31	0	0	0.00	0.00	-7.78E+04	-0.9	0.2695	204.6	269.495
0.275	23.76	0	0.31	0	0	0.00	0.00	-8.64E+04	-1	0.2676	203.1	267.551
0.275	26.14	0	0.31	0	0	0.00	0.00	-9.50E+04	-1.1	0.2660	202.0	266.000
0.275	28.51	0	0.31	0	0	0.00	0.00	-1.04E+05	-1.2	0.2647	201.0	264.746
0.275	30.89	0	0.31	0	0	0.00	0.00	-1.12E+05	-1.3	0.2637	200.2	263.723
0.275	33.26	0	0.31	0	0	0.00	0.00	-1.21E+05	-1.4	0.2629	199.6	262.879
0.275	35.64	0	0.31	0	0	0.00	0.00	-1.30E+05	-1.5	0.2622	199.1	262.179
0.275	38.02	0	0.31	0	0	0.00	0.00	-1.38E+05	-1.6	0.2616	198.6	261.594
0.275	40.39	0	0.31	0	0	0.00	0.00	-1.47E+05	-1.7	0.2611	198.2	261.104
0.275	42.77	0	0.31	0	0	0.00	0.00	-1.56E+05	-1.8	0.2607	197.9	260.692
0.275	45.14	0	0.31	0	0	0.00	0.00	-1.64E+05	-1.9	0.2603	197.7	260.344
0.275	47.52	0	0.31	0	0	0.00	0.00	-1.73E+05	-2	0.2600	197.4	260.050
0.275	49.90	0	0.31	0	0	0.00	0.00	-1.81E+05	-2.1	0.2598	197.3	259.802
0.275	52.27	0	0.31	0	0	0.00	0.00	-1.90E+05	-2.2	0.2596	197.1	259.592
0.275	54.65	0	0.31	0	0	0.00	0.00	-1.99E+05	-2.3	0.2594	197.0	259.415
0.275	57.02	0	0.31	0	0	0.00	0.00	-2.07E+05	-2.4	0.2593	196.8	259.267
0.275	59.40	0	0.31	0	0	0.00	0.00	-2.16E+05	-2.5	0.2591	196.8	259.142
0.275	61.78	0	0.31	0	0	0.00	0.00	-2.25E+05	-2.6	0.2590	196.7	259.039
0.275	64.15	0	0.31	0	0	0.00	0.00	-2.33E+05	-2.7	0.2590	196.6	258.954
0.275	66.53	0	0.31	0	0	0.00	0.00	-2.42E+05	-2.8	0.2589	196.6	258.884
0.275	68.90	0	0.31	0	0	0.00	0.00	-2.51E+05	-2.9	0.2588	196.5	258.829
0.275	71.28	0	0.31	0	0	0.00	0.00	-2.59E+05	-3	0.2588	196.5	258.786

Bachman	Ultraeutrophic				TP Rel. Rate=20				TP Release					
	L	z	P	TP Release	RR	P	L	TP Release	P	L	TP Release	P	L	TP Release
mg/m ² *yr	m	1/yr	kg	mg/m ² *d	mg/m ² *d	µg/L	mg/m ² *yr	kg	µg/L	mg/m ² *yr	kg	µg/L	mg/m ² *yr	kg
7300	2.3	0	7	20.00	20.00	418.86	5475	5	15.00	336.22	3	3650	3	
7561	2.3	0	7	20.00	20.00	401.05	5736	5	15.00	321.79	3	3911	3	
9911	2.3	4	7	20.00	20.00	321.87	8086	5	15.00	267.63	3	6261	3	
20356	2.3	21	7	20.00	20.00	263.51	18531	5	15.00	241.19	3	16706	3	
20356	2.3	21	7	20.00	20.00	263.51	18531	5	15.00	241.19	3	16706	3	
22967	2.3	25	7	20.00	20.00	260.24	21142	5	15.00	240.69	3	19317	3	
25578	2.3	29	7	20.00	20.00	258.01	23753	5	15.00	240.59	3	21928	3	
28189	2.3	33	7	20.00	20.00	256.43	26364	5	15.00	240.71	3	24539	3	
30800	2.3	37	7	20.00	20.00	255.30	28975	5	15.00	240.97	3	27150	3	
33412	2.3	42	7	20.00	20.00	254.49	31587	5	15.00	241.31	3	29762	3	
36023	2.3	46	7	20.00	20.00	253.89	34198	5	15.00	241.69	3	32373	3	
38634	2.3	50	7	20.00	20.00	253.46	36809	5	15.00	242.09	3	34984	3	
41245	2.3	54	7	20.00	20.00	253.15	39420	5	15.00	242.51	3	37595	3	
43856	2.3	58	7	20.00	20.00	252.93	42031	5	15.00	242.93	3	40206	3	
46467	2.3	62	7	20.00	20.00	252.78	44642	5	15.00	243.34	3	42817	3	
49079	2.3	66	7	20.00	20.00	252.69	47254	5	15.00	243.75	3	45429	3	
51690	2.3	71	7	20.00	20.00	252.65	49865	5	15.00	244.15	3	48040	3	
54301	2.3	75	7	20.00	20.00	252.63	52476	5	15.00	244.55	3	50651	3	
56912	2.3	79	7	20.00	20.00	252.65	55087	5	15.00	244.93	3	53262	3	
59523	2.3	83	7	20.00	20.00	252.69	57698	5	15.00	245.30	3	55873	3	
62134	2.3	87	7	20.00	20.00	252.74	60309	5	15.00	245.66	3	58484	3	
64745	2.3	91	7	20.00	20.00	252.81	62920	5	15.00	246.01	3	61095	3	
67357	2.3	96	7	20.00	20.00	252.89	65532	5	15.00	246.34	3	63707	3	
69968	2.3	100	7	20.00	20.00	252.98	68143	5	15.00	246.67	3	66318	3	
72579	2.3	104	7	20.00	20.00	253.07	70754	5	15.00	246.99	3	68929	3	
75190	2.3	108	7	20.00	20.00	253.18	73365	5	15.00	247.30	3	71540	3	
77801	2.3	112	7	20.00	20.00	253.28	75976	5	15.00	247.60	3	74151	3	
80412	2.3	116	7	20.00	20.00	253.39	78587	5	15.00	247.89	3	76762	3	
83024	2.3	120	7	20.00	20.00	253.50	81199	5	15.00	248.17	3	79374	3	
85635	2.3	125	7	20.00	20.00	253.62	83810	5	15.00	248.44	3	81985	3	

Appendix E: Water Quality Model Spreadsheets (Mass and Water Balance)



Dimensions	
Depth	15 ft 4.57 m
Mean Depth	7.5 ft 2.29 m
Width	325 ft 99.06 m
Length	11000 ft 3353 m
CSArea	2438 ft ² 226 m ²
Volume	26812500 ft ³ 759245 m ³
Surf Area	3575000 ft ² 332128 m ²
Slope	0.092

Using Rate & Retention Time	
p	5.93E-06 1/s
	1.87E+02 1/yr
θ	1.69E+05 s
	5.35E-03 yr

Conversions			
	A	B	A/B
t	1 sec	1.16E-05 day	86400
L	1 ft	0.3048 m	3.280839895
Vol	1 gal	3.786235 l	0.264114583

Time			Pool			In	
Day	Hr	Δt sec	Conc mg/L	Mass kg	Volume m ³	Q m ³ /s	+
0	0	0				4.5	
1	24	86400	0.3639	2.76E+02	3.89E+05	4.5	
2	48	86400	0.3068	2.33E+02	3.89E+05	4.5	
3	72	86400	0.2808	2.13E+02	3.89E+05	4.5	
4	96	86400	0.2689	2.04E+02	3.89E+05	4.5	
5	120	86400	0.2635	2.00E+02	3.89E+05	4.5	
6	144	86400	0.2610	1.98E+02	3.89E+05	4.5	
7	168	86400	0.2599	1.97E+02	3.89E+05	4.5	
8	192	86400	0.2594	1.97E+02	3.89E+05	4.5	
9	216	86400	0.2591	1.97E+02	3.89E+05	4.5	
10	240	86400	0.2590	1.97E+02	3.89E+05	4.5	
11	264	86400	0.2590	1.97E+02	3.89E+05	4.5	
12	288	86400	0.2589	1.97E+02	3.89E+05	4.5	
13	312	86400	0.2589	1.97E+02	3.89E+05	4.5	
14	336	86400	0.2589	1.97E+02	3.89E+05	4.5	
15	360	86400	0.2589	1.97E+02	3.89E+05	4.5	
16	384	86400	0.2589	1.97E+02	3.89E+05	4.5	
17	408	86400	0.2589	1.97E+02	3.89E+05	4.5	
18	432	86400	0.2589	1.97E+02	3.89E+05	4.5	
19	456	86400	0.2589	1.97E+02	3.89E+05	4.5	
20	480	86400	0.2589	1.97E+02	3.89E+05	4.5	
21	504	86400	0.2589	1.97E+02	3.89E+05	4.5	
22	528	86400	0.2589	1.97E+02	3.89E+05	4.5	
23	552	86400	0.2589	1.97E+02	3.89E+05	4.5	
24	576	86400	0.2589	1.97E+02	3.89E+05	4.5	
25	600	86400	0.2589	1.97E+02	3.89E+05	4.5	
26	624	86400	0.2589	1.97E+02	3.89E+05	4.5	
27	648	86400	0.2589	1.97E+02	3.89E+05	4.5	
28	672	86400	0.2589	1.97E+02	3.89E+05	4.5	

put

Assume Lake

Conc mg/L	Mass kg	Mass kg	µg/L	P mg/L	0.230	0	dp mg/L	t _d yr	t _d days	K _s 1/yr
0.275	106.92	276.3	489	0.489	0.125	0	-0.125	0.005	1.953	-11.61
0.275	106.92	276.3	364	0.364	0.125	0.125136478				
0.275	106.92	232.9	307	0.307	0.182	0.182212914	-0.057	0.005		-12
0.275	106.92	213.2	281	0.281	0.208	0.208246246	-0.026	0.005		-12
0.275	106.92	204.1	269	0.269	0.22	0.220120401	-0.012	0.005		-12
0.275	106.92	200.0	263	0.263	0.226	0.225536362	-0.005	0.005		-12
0.275	106.92	198.2	261	0.261	0.228	0.228006656	-0.002	0.005		-12
0.275	106.92	197.3	260	0.260	0.229	0.22913339	-0.001	0.005		-12
0.275	106.92	196.9	259	0.259	0.23	0.229647308	-0.001	0.005		-12
0.275	106.92	196.7	259	0.259	0.23	0.229881714	0.000	0.005		-12
0.275	106.92	196.7	259	0.259	0.23	0.229988629	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.230037395	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.230059637	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.230069782	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.23007441	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.23007652	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.230077483	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.23007922	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.230078122	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.230078214	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.230078255	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.230078274	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.230078283	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.230078287	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.230078289	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.23007829	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.23007829	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.23007829	0.000	0.005		-12
0.275	106.92	196.6	259	0.259	0.23	0.23007829	0.000	0.005		-12

Economic analysis

The price estimates for the design solution are contained in Table 13. These costs include: labor, material, rebuilding the road, and maintenance. All together the project comes to a final, total price that is estimated at \$45,500. The quote for the excavating of the old culvert and rebuilding the road came from MnDOT. Each of the components of the culvert control came from companies in the industry. The price for the box culvert and the flares came from Cretex Concrete Products North, Inc, a national private concrete product company²². For the sluice gate, the price was accepted from Rodney Hunt Company, a national company involved in water power and control²⁵.

Table 13: Cost breakdown

Subject	Individual Cost	Product/Work Segments	Total Cost
4' X4' box concrete culvert per foot	\$300.00	78	\$23,400
Concrete flare ends	\$3,600.00	2	\$7,200
Cast iron manual rising sluice gate	\$7,500.00	1	\$7,500
Maintenance per culvert	\$400.00	1	\$400
Cost of excavating and rebuilding the road	\$7,000.00	-	\$7,000
Final Cost	-	-	\$45,500

Final Recommendation (Conclusion)

The water quality of Grey Cloud Island channel is heavily dependent on education, engineering, and regulation enforcement. In this project report, the Quality Management Defenders have suggested the design of a single solution. By reinstalling the culvert with flares, QMD is using fundamental engineering principles to help increase water quality and sustainability of the channel. To aid the culvert in controlling the water flow, a sluice gate will be added that can keep the flow of water below 70 cfs.

²⁵ Rodney Hunt Company: <http://www.rodneyhunt.com/> 48

For future considerations, the road elevation should be raised by approximately 6 feet. During the hydraulic analysis, it was discovered that the water surface elevation will exceed the elevation of the road for events greater than 10 year water level. Also potential new development in the watershed of the channel may have a large impact on the water quality of the channel in the future. The QMD recommends for other areas to follow phosphorus load reduction strategies developed by the MPCA

Appendix A: Decision Matrix Letter

11/16/05

Phil Goodrich
Biosystems and Agricultural Engineering
1390 Eckles Ave
St Paul, MN 55108

Dear Phil Goodrich,

The Quality Management Defenders is a group of Biosystems and Agricultural Engineering students working on a senior capstone project. For our senior design project, we have developed different design solutions and would like to request your input in analyzing these solutions.

The purpose of our capstone project is to address the poor water quality of the Grey Cloud Island Channel. In the last 3-5 years the channel water quality has dramatically declined and local residents would like the water quality improved. The Grey Cloud Island Channel is located along the Mississippi River between Grey Cloud Island and Cottage Grove (please see Figures 1 and 2). The water quality problem involves the Mississippi River backwater at Grey Cloud Island. This channel separates the island from the mainland. The bridge connected to the mainland on the north end of the island was washed out during a flood in the late 1960's. A road with culverts to accommodate the flow of the channel was installed to replace the washed out bridge. The culverts have since collapsed and filled in with sediment resulting in considerably less flow through the channel. The retardation of flow is suspected of causing the water quality issues. As a result, poor water quality has increased weed growth (Eurasian milfoil), algae blooms, and diminished fish population.

Residents in the area would like the channel's aesthetics, water quality, and the overall health to be restored back to their conditions present in the 1990's. We would like you to evaluate the different design solutions we have created as possible solutions to the water quality problem. Please evaluate each design solution individually. We have provided maps of the areas, the design matrix, descriptions of our design solutions, and descriptions of our design matrix criteria to help you evaluate the different design solutions. Please include any comments or suggestions that you may have regarding the different design solutions.

If you have any questions, please feel free to call or e-mail Tom Zearley at zear0002@umn.edu or 612.220.4095. We would appreciate it if you would return the filled out design matrix to zear0002@umn.edu, by November 23rd. Thank you for your time in assisting us with our design. Your input is greatly appreciated and will help further our education.

Sincerely,

Quality Management Defenders

References