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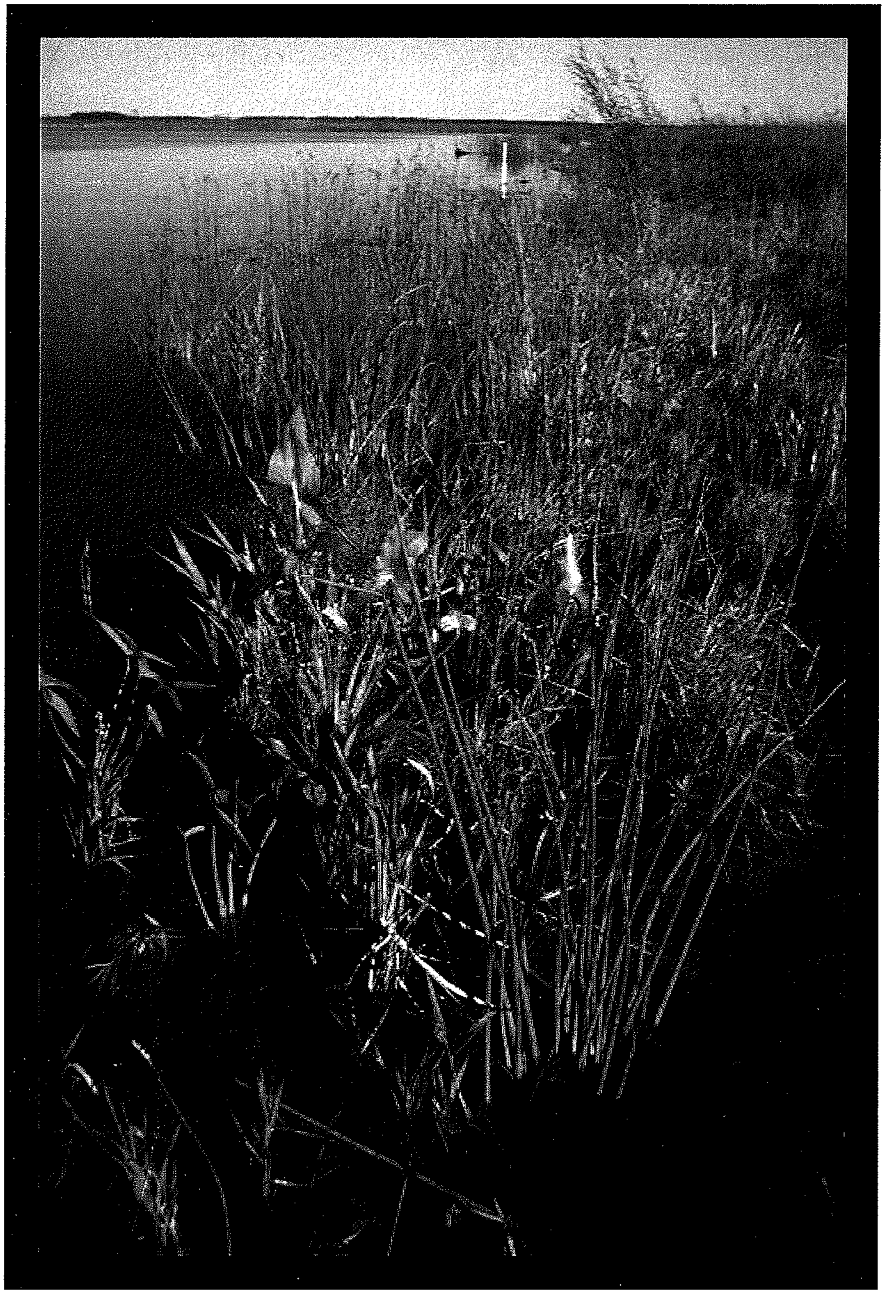

Final Report, January 2000

Minnesota Department of Natural Resources
Division of Lands and Minerals

THE USE OF DREDGE MATERIAL AS AN ORGANIC SUBSTRATE TO CREATE WETLANDS IN TACONITE TAILINGS BASINS

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Acknowledgments

Many people have been responsible for the success of this project. Terry Long, with the U.S. Army Corps of Engineers, Detroit District, initially promoted the idea of using dredge material for mineland reclamation and provided funding to initiate the project. Additional funding was received from the Minerals Environmental Cooperation Research Program. Bob Westlund and Ted Anderson at National Steel Pellet Company were instrumental in making this project a success. The company offered sites for the project and also provided in-kind services for construction of the plots. We appreciated how fast the company repaired one of the plots after the extreme rain event in July 1999 washed out the dike. Anne Jangunich (MN DNR Lands and Minerals) assisted with field sampling, and Michele Crozier, now at the University of Wyoming, was responsible for the first year field work and data analysis. Analytical services were provided by Zena Kassa and Pat Kirby at the Minnesota Department of Agriculture. Marilynn DeVoe managed to transform endless pages of scribbling into legible text, and lists of numbers into neat tables, and Jon Wagner produced the figures for the report.

Executive Summary

Dredge material from Lake Superior offers a suitable substrate for use in mineland reclamation projects. The dredge used in this study resembled a heavy loam soil, had an organic matter content similar to topsoil, and was not contaminated by trace metals or organic compounds.

Two demonstration areas were constructed at National Steel Pellet Company's taconite tailings basin in Keewatin, MN, to examine the suitability of dredge material as a substrate for the creation of wetlands. At the North site, dredge material was compared to standard reclamation practices and the effect of different seed mixes was investigated. At the South site, two thicknesses of dredge material were compared to locally available materials, including topsoil, overburden, and black dirt (a commercially prepared mixture of peat and sand). Different seed mixes were selected for the shoreline, wetland fringe and upland areas.

<u>Dredge vs Standard Reclamation, North Site</u>

Vegetative success on the dredge material was markedly greater than on the unamended bare tailings control. In 1998, percent cover on all the dredge plots exceeded 94%, almost four times the 27% cover for the unamended tailings. In 1999, percent cover decreased slightly on the dredge plots, but was still about two times greater than the 48% for the tailings. In 1999, average biomass on all portions of the dredge plots was about three times greater than the control. In the first year, vegetation was dominated by cover crop and opportunistic (non-planted) species. In the second year, the dominant species was redtop (*Agrostis alba*) a facultative wetland species, which was included in the upland seed mix and was present on the site before the plots were constructed. Invasive species, including cattails (*Typha sp*), giant reed grass (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*) contributed up to 25% of the cover near the shoreline. These species were not planted but had existed in the area prior to establishing the plots. It is too early to determine if a diverse wetland community will develop at the North site.

<u>Dredge vs. Other Amendments, South Site</u>

Percent cover and biomass differed little among the amendments for the upland and wetland fringe portions of the plots, but all the amended plots had percent cover values 2 to 3 times the unamended tailings plots, and produced 2 to 10 times as much biomass.

High water levels in the pond, the result of above normal precipitation, eroded portions of the shoreline. Based on a qualitative evaluation of percent cover and the number of wetland species present, vegetation varied in the order: topsoil ≈ 6 inches of dredge > 4 inches of dredge ≈ black dirt > overburden > control.

Effect of Dredge Material on Water Quality

Dredge material did not adversely impact water quality. There was little to no release of any trace elements and all samples, both surface and groundwater, met water quality standards.

Costs

Using amendments to provide a substrate for wetland vegetation is expensive. The cost to obtain, transport, and apply the amendments in this study ranged from $4,800 per acre for 6 inches of local glacial overburden to $16,000 for 6 inches of dredge material. Rail transport of the dredge material can reduce the cost by about 33%, and based on the results of this study the depth of dredge material can be reduced from 6 inches to 4 inches. Four inches of rail hauled dredge material would cost $7,500 per acre and would be less expensive than purchased black dirt and about 10% more expensive than local topsoil. If the cost of using dredge material can be reduced by about $5 per yard, dredge material would cost the same as glacial overburden. Some possible approaches for reducing the total cost include:

1. Trade sand contained within the pier to a contractor in lieu of payment for the transport of the dredge material to the railhead. Sand has previously been removed from the pier for construction projects.
2. Unload the dredge material closer to the railhead. DMIR has a disposal area where dredge material has been deposited in the past.
3. Load suitable dredge material directly from the barge into trucks.
4. Provide a subsidy for movement of the material.

Since the amendment is only applied along the shoreline, and not in the pond portion, the total cost per acre of viable wetland would be lower than the cost per acre of shoreline, and less than the cost of paying $4,350 per acre to purchase wetland credits.

Conclusion

Dredge material can be used successfully to establish vegetation in mining areas without producing water quality impacts. The use of dredge material for reclamation can provide a beneficial use for material currently considered waste.

Introduction

Every year, the US Army Corps of Engineers (COE) dredges about 135,000 cubic yards of sand, silt, and clay from the Duluth Harbor in Lake Superior. Since 1980, this material has been placed into a bermed basin known as the Erie Pier Confined Disposal Facility (Erie Pier), in Duluth, MN (Figure 1). This basin covers about 82 acres, is about 20 feet deep, currently contains an estimated 2.5 million cubic yards of material, and is almost filled to capacity. Data collected by the COE has shown that much of the material in the basin is relatively low in contaminants and some is high in nutrients and organic carbon. In fact, the contaminant level in most of the material meets regulatory guidelines for placement at an upland site, and some of the material may be suitable as a substrate for creating replacement wetlands (Eger et al., in preparation).

The Wetland Conservation Act, passed in 1991, required that all wetlands impacted by mining operations be replaced. Since northern Minnesota still contains over 90% of its pre-settlement wetlands and taconite mining impacts thousands of acres of land, wetland disturbance can not be avoided, and therefore, wetland replacement will be required at almost all of Minnesota's mining operations.

Wetlands have developed in acres disturbed by mining, but in general, these wetlands were dominated by cattails (*Typha* sp.) and had low species diversity (Melchert et al., 1996). One factor that contributed to the lack of diversity in the wetlands was the infertile nature of the mine waste. Applying dredge material to these areas would not only improve fertility but also provide a beneficial use for the dredge material. Tailings basins, which are constructed containment facilities for ground waste from the taconite process, appear to have suitable hydrology for creating wetlands. Tailings are pumped as a slurry into these basins which can exceed 100 feet in height and cover several thousand acres. These areas must be reclaimed at the end of operation and since they hold water, could be converted to a wetland. However, tailings are infertile, contain little organic material, and do not provide a favorable substrate for wetland vegetation. Small test plots constructed at the reclaimed Butler Tailings Basin in Nashwauk, MN, demonstrated that the addition of wetland soil and glacial till produced higher vegetative cover and produced more biomass than the tailings plots (Melchert et al., 1996; Eger et al., in preparation). Therefore, the addition of the silty, organic-rich dredge material should improve vegetative success on replacement wetlands.

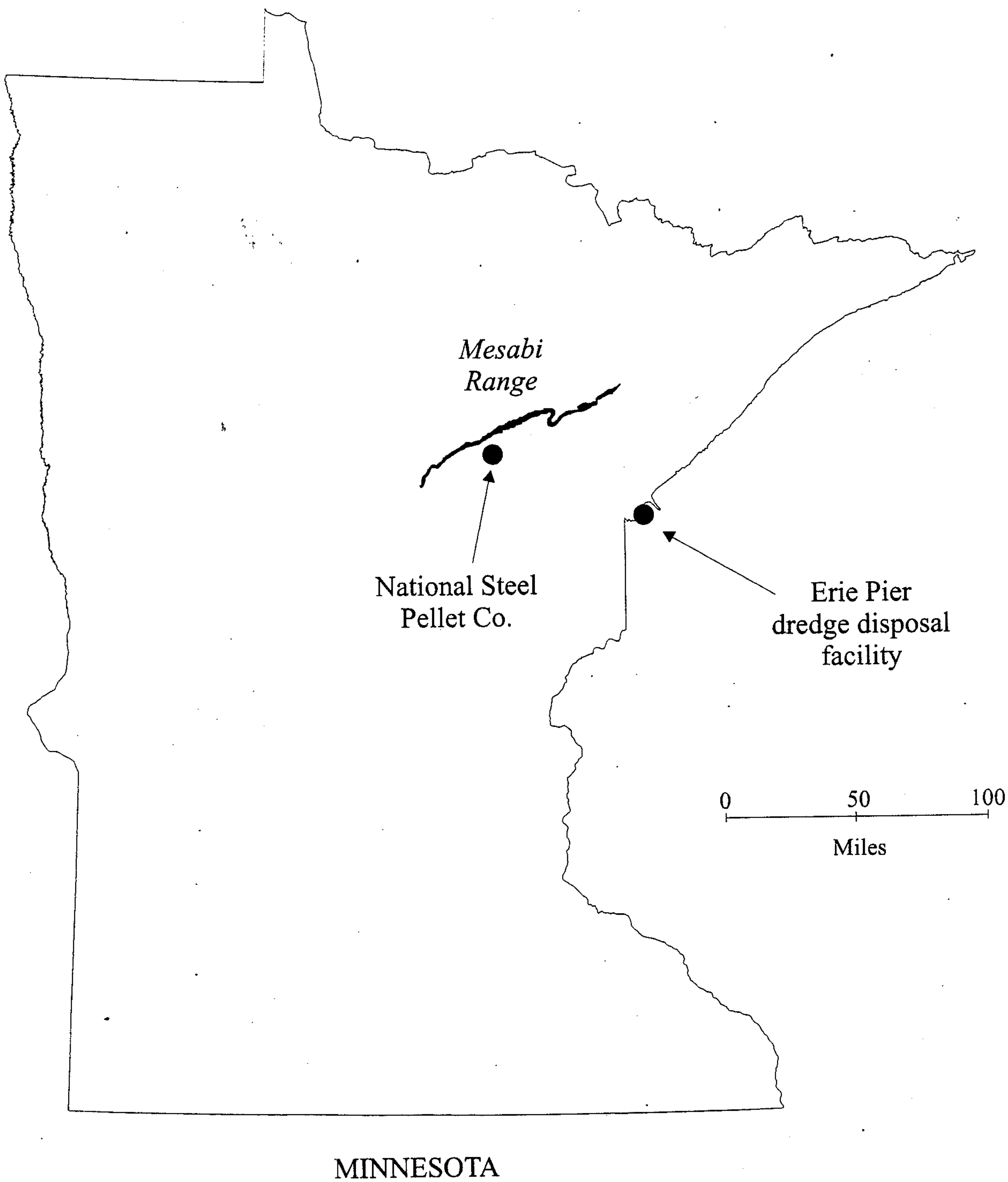
Objectives

1. Determine the effectiveness of dredge material as a substrate to support wetland vegetation.
2. Determine the impact of dredge material on water quality in the wetland.
3. Compare the vegetation on dredge material to the vegetation on other locally available substrates.

Approach

National Steel Pellet Company (NSPC) in Keewatin, MN (Figure 1) has impacted approximately 85 acres of wetlands and was required to develop a plan to replace wetlands by section 404 of the Clean

Figure 1. Location of the project site (at National Steel Pellet Co.) and the Erie Pier dredge disposal facility.



Water Act and the Minnesota Wetland Conservation Act. In this plan, several sites in their tailings basin were identified as candidates for wetland creation based upon existing hydrology. This plan was approved by the Army Corps of Engineers and the Minnesota Department of Natural Resources (MN DNR), but NSPC had to demonstrate that viable wetlands could be created in the basin.

The minimum requirements that a created wetland must meet are the following (COE, 1987):

1. The site must have sufficient water (wetland hydrology). The soil must be inundated or saturated to the surface over a continuous time period of at least 12.5% of the growing season. For northern Minnesota, this is equivalent to 17 days during the period May 16 to September 26.
2. The site must have wetland vegetation. At least 50% of the dominant plant species must be obligate wetland species, facultative wetland, or facultative species (Appendix 1).

Two sites were selected for this study (Figure 2). The North site was 300' long by 40' wide and was located along an old coarse tailings dike which formed one side of a small pond area (Figures 3 and 4). This site was used to study the impact of dredge material on water quality and on the establishment of wetland vegetation.

Three plots were established and included the following treatments:

1. Unamended tailings (control) seeded with a standard mineland reclamation (SMR) seed mix
2. 6 inches of dredge spoils seeded with SMR seed mix
3. 6 inches of dredge spoils seeded with two wetland species seed mixes (MNDOT seed mix 25A, custom wetland seed mix)

At the South site, dredge material was compared to locally available soil amendments. Soil treatments applied on these plots included the following treatments (Figures 5 and 6):

1. Unamended tailings; control
2. 6 inches glacial overburden
3. 6 inches local topsoil
4. 6 inches local black dirt (combination of sand and wetland soil)
5. 6 inches dredge material
6. 4 inches dredge material

Three different seed mixes were selected based on the expected moisture conditions within the plot. Seed mixtures were selected for the shoreline, fringe and upland areas of each plot.

Figure 2. Location of demonstration sites at National Steel's tailings basin (schematic).

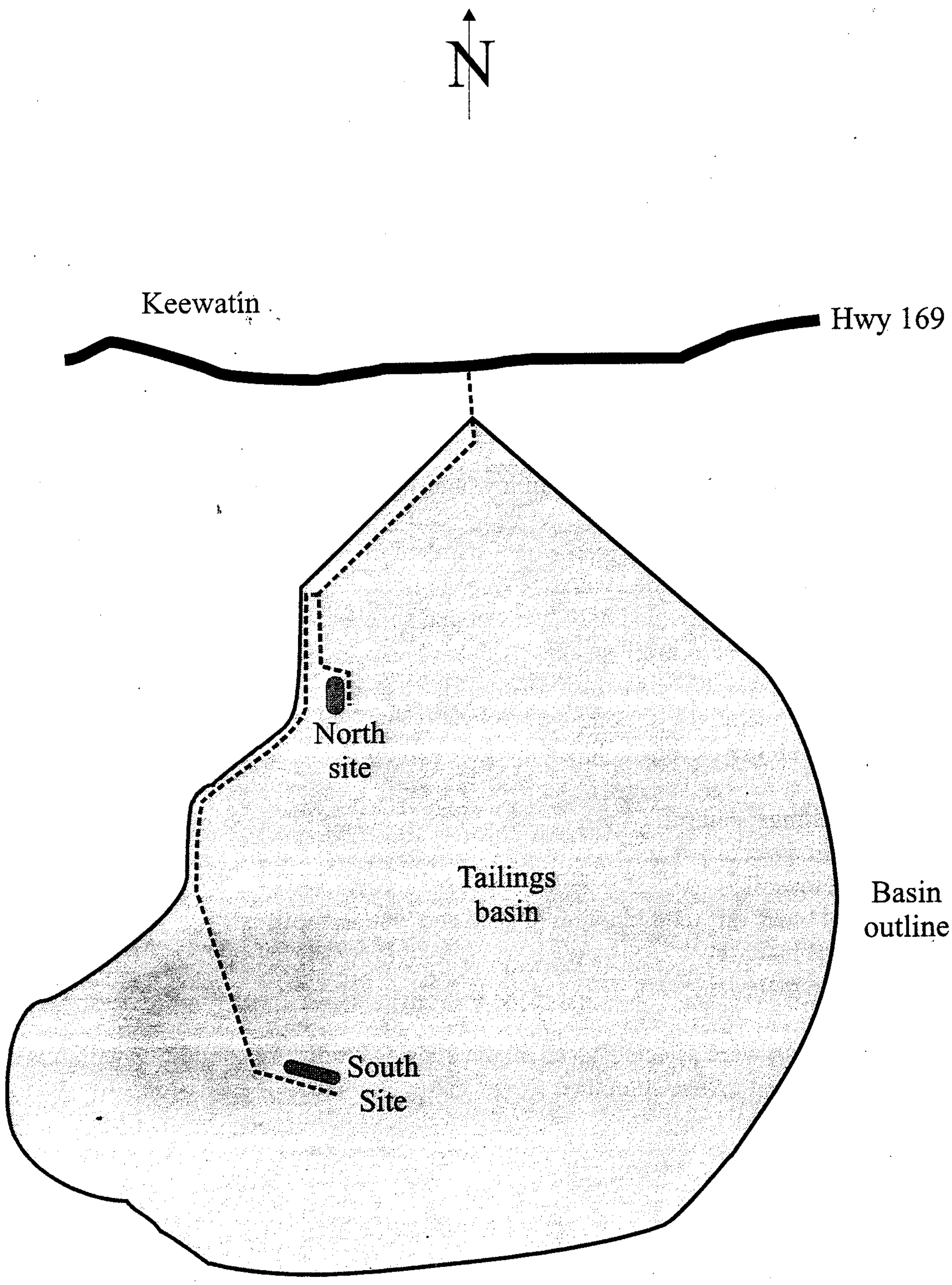


Figure 3. Wetland creation demonstration area schematic; North site, National Steel.

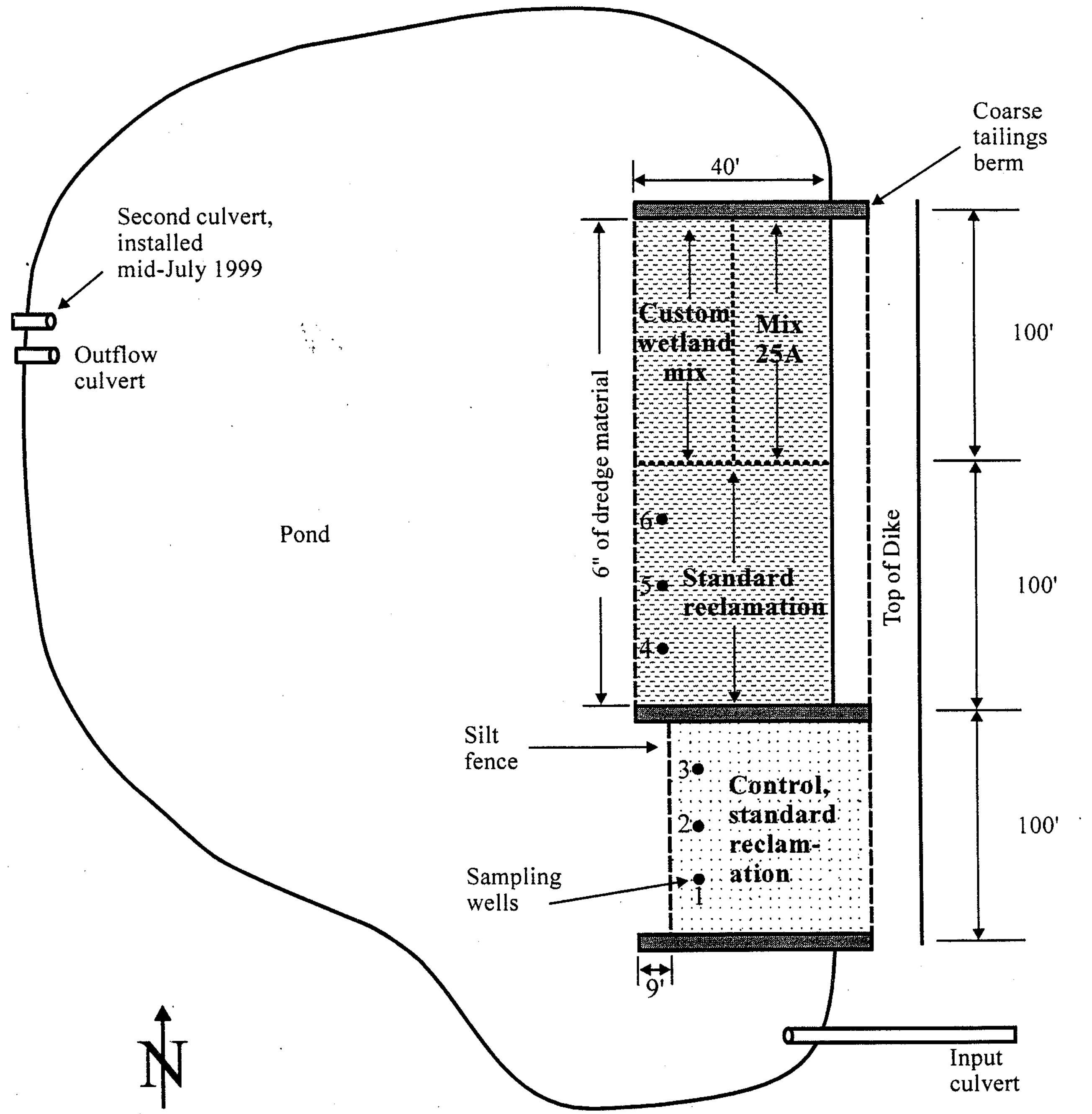
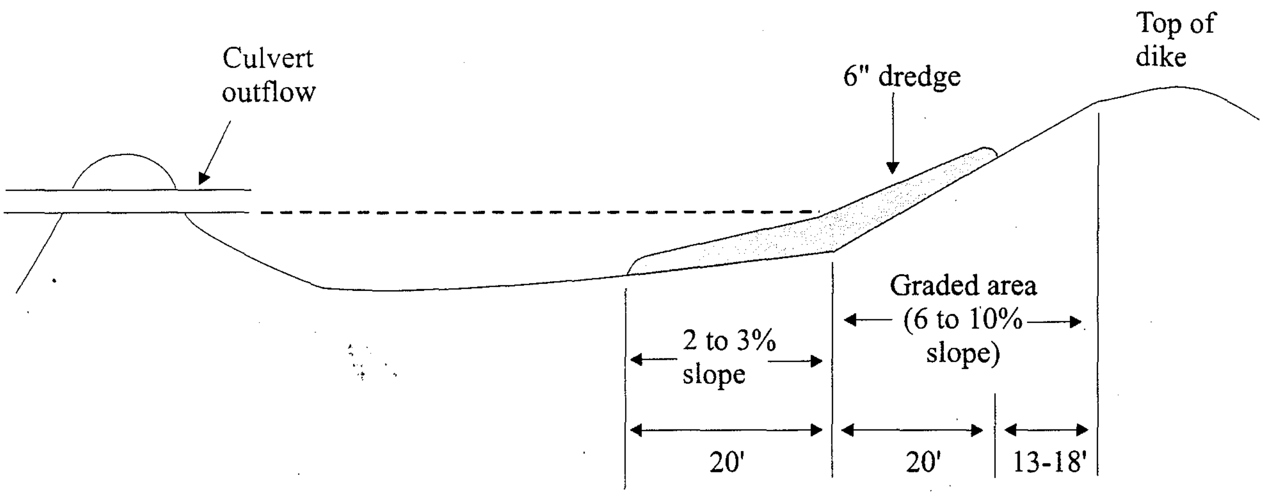


Figure 4. Cross-section of the middle wetland plot at the North Site (National Steel); schematic.



Methods

Materials

Dredge Material

Dredge material was collected from an area adjacent to the south dike of the Erie Pier (Figure 7). Based on preliminary sample data, this site contained material with a high silt and organic content and a low contaminant load. Since the site was adjacent to the dike, removal and loading of the dredge material could be accomplished with standard construction equipment.

Unfortunately, the original target area was covered by 3 feet of sand during the disposal of dredge material in the summer of 1997. Several alternate sites were evaluated, but the best approach appeared to be to remove the sand layer and use the material in the original target area. Due to extremely wet soil conditions, only material immediately adjacent to the dike could be reached and excavated with the backhoe (Figure 7).

Additional information on the characteristics of the dredge material throughout the Erie Pier will be provided in a future report (Eger et al., in preparation).

Glacial Overburden

Glacial overburden or glacial till is the general name given to subsoil in northern Minnesota. This material is removed prior to mining and generally stockpiled close to the mine. The subsoil at the National mine was obtained from a nearby stockpile and was classified as a sandy loam material.

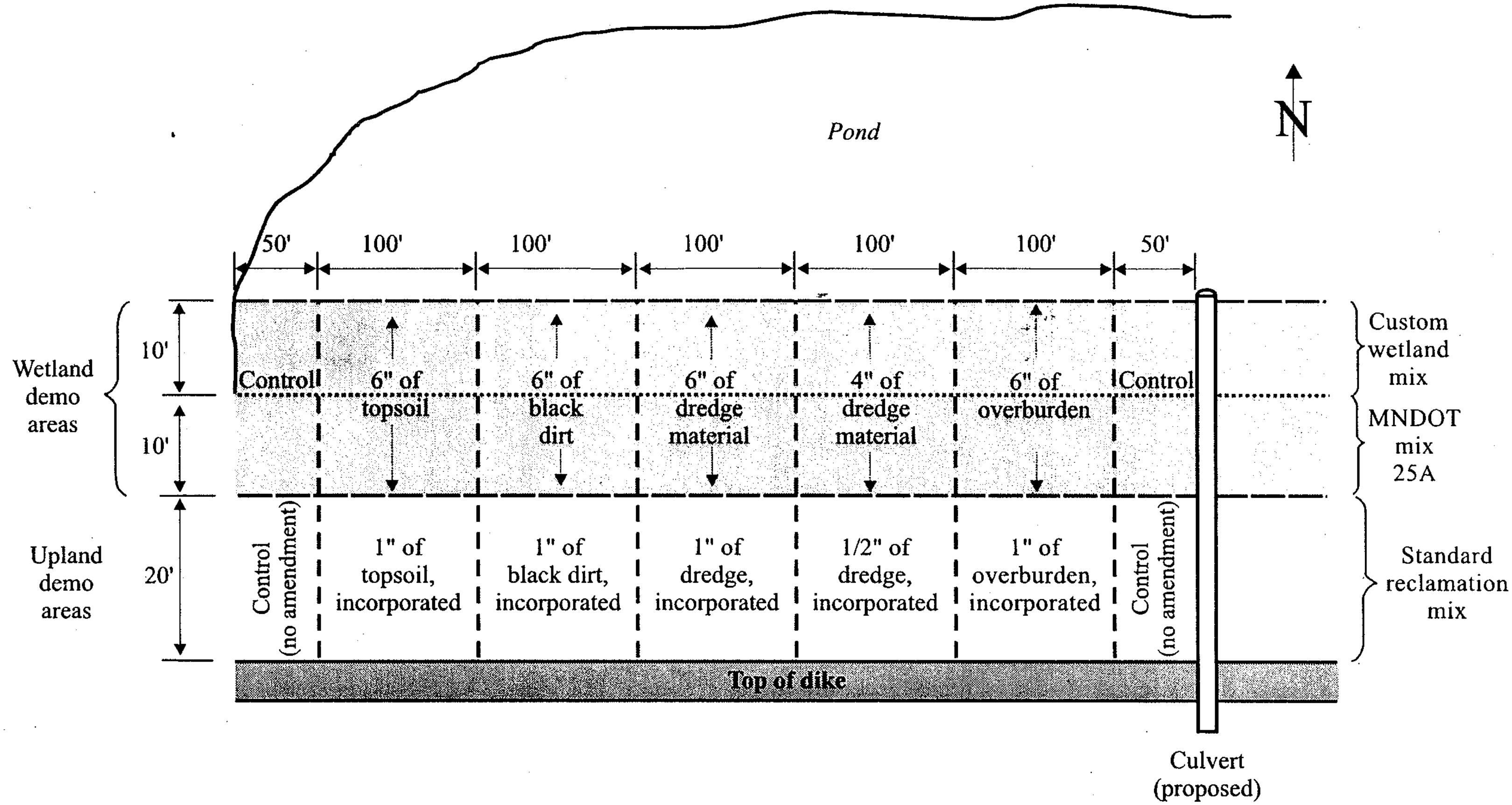
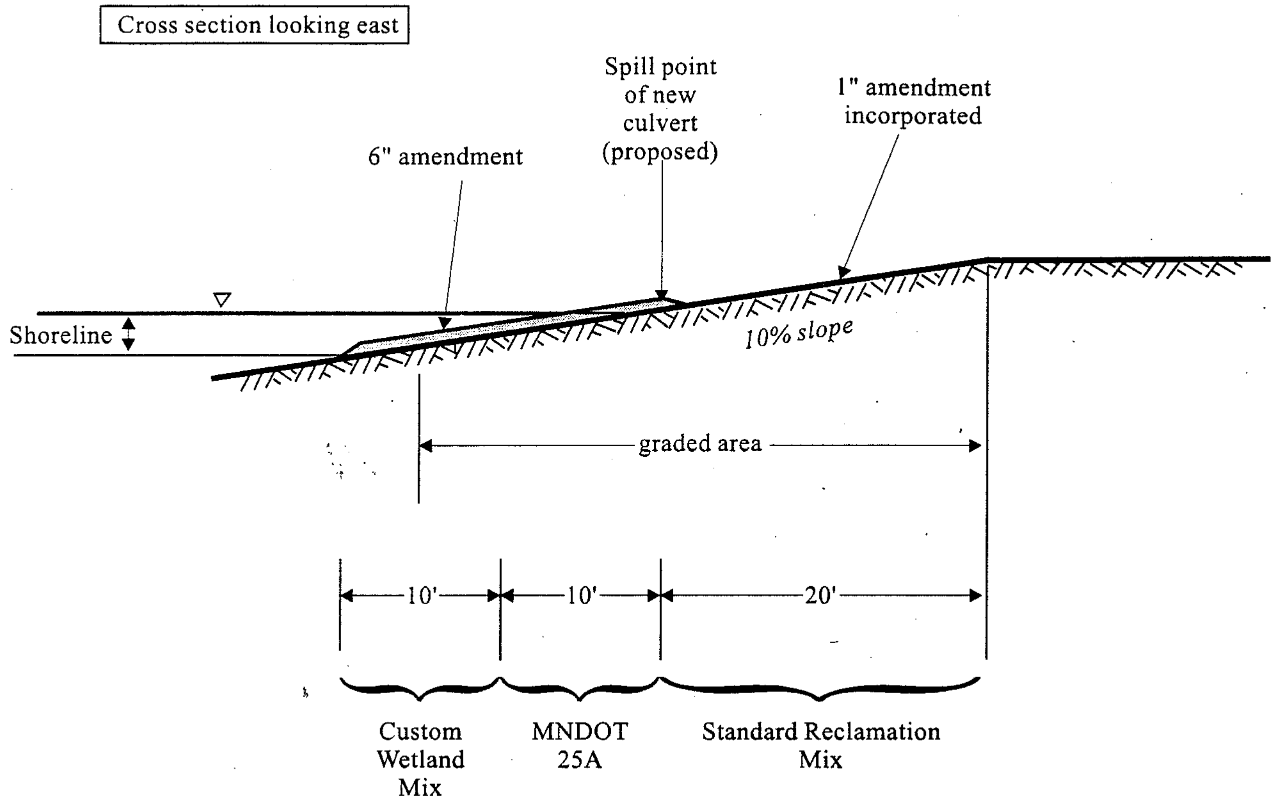


Figure 5. Wetland creation demonstration area schematic; National Steel, South Site.

Figure 6. Cross section of a wetland demonstration plot; South site, National Steel, schematic.



Topsoil

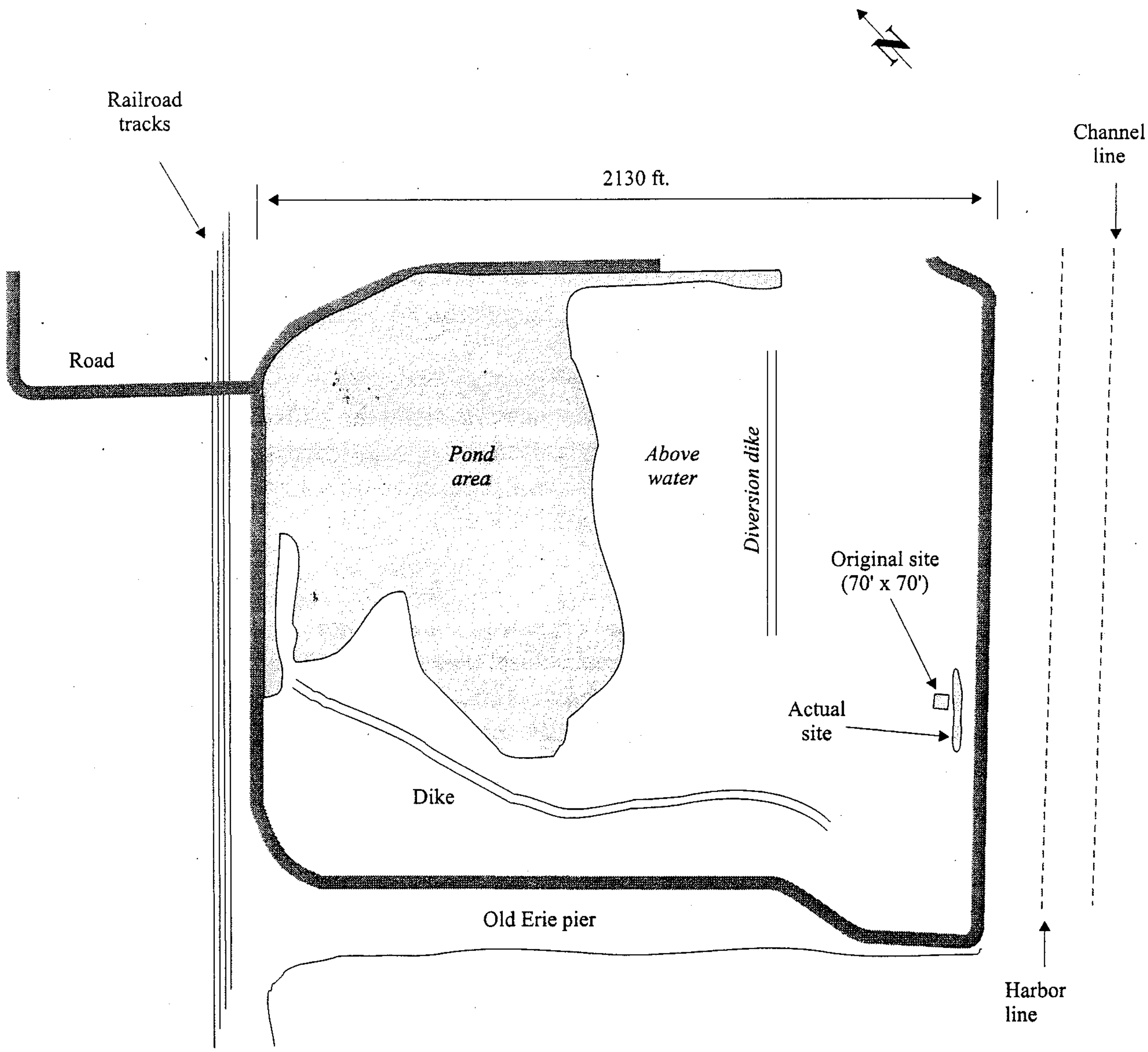
Upland soils in Itasca County are mainly light-colored and were formed in glacial material. The upper organic-rich layer is typically only several inches thick (USDA, 1987). The topsoil used in this study was obtained from a nearby farm, and is classified as a loamy sand.

Black Dirt

Wetland soil is generally recommended as the best substrate for wetland creation projects. This soil type develops under saturated conditions and often contains a viable seed bank of wetland species. At the Flambeau mine in Ladysmith, Wisconsin, wetland soil was removed and stored for final reclamation and wetland mitigation.

No local nearby wetland soil was available for this project so a commercial black dirt product produced by mixing wetland soil with sand was obtained from a producer in Hibbing, about 6 miles east of the site.

Figure 7. Location of dredge material at the Erie Pier dredge disposal facility.



Material Placement

In September 1997, the dike slopes at both the North and South sites were graded from a 2 or 3 to 1 slope to about a 10 to 1 slope. The dike at the North site had been reclaimed approximately 10 years earlier, so the vegetation was scraped and pushed into berms at the ends of the plots prior to grading (Figure 3). Due to moist conditions, it was not possible to remove all of the vegetation at the toe of the dike, especially the roots. Pre-existing vegetation included cattails (*Typha* sp.), redtop (*Agrostis alba*), reed canary grass (*Phalaris arunidinacea*), and giant reed grass (*Phragmites australis*). The following spring before seeding, but after the dredge material had been spread, the area within the plot boundaries was sprayed with a broad spectrum herbicide (Roundup, with glyphosate as the active ingredient). There was no prior reclamation activity at the South site so pre-existing vegetation was not a concern.

In October 1997, approximately 305 yards of the dredge material was truck-hauled to the tailings basin. The goal was to have a final depth of 6 inches of dredge on the plots after spreading and settling. In general, loose soil occupies 30% more volume than settled soil, so a swell factor of 1.3 was applied to determine the amount of dredge material needed. The North site received about 216 yards and the 6 inch and 4 inch plots at the South site received 54 and 36 yards, respectively. NSPC did not apply a swell factor to the other amendments, so about 48 yards of each amendment (topsoil, black dirt, and overburden) were placed on their respective plots. This calculates volumetrically to a thickness of approximately 4.5 inches after settling (Eger et al., 1999). The upper portion of the plots received about 1 inch of material.

Each truck load of amendment was dumped in a separate pile along the plots. At the North site the piles were dumped near the toe of the slope, while at the South site the piles were dumped about mid-slope. The piles were to be spread by NSPC that fall; however, early freezing conditions prevented the company from spreading the material until spring.

Amendment piles were spread between April 23 and 24, 1998 by a D8 caterpillar bulldozer. At the North site the operator was to spread the material uniformly over the plot. At the South site, the plots were divided into an upland and wetland zone. The upland area received ½ to1 inch of material, while the wetland area received 4 to 6 inches. Generally, the bulldozer was able to spread the amendments fairly uniformly by simply pushing the material down the slope.

The water level at the South site was fairly high during spreading, but the bulldozer was able to push the material 5 to 6 feet into the water. It was very difficult to drag material up-slope. Once the amendment was spread, as a rule, the amount of amendment at the upslope ends of the plots was less than that near the toe. This was also true for the portions of the plots that received 1 inch of material.

After the bulldozer operator was done spreading the material, a road grader was used to smooth the materials by grading parallel to the slope. This technique worked well along the upper one-half to two-thirds of the dike, but not for the lower 10 to 15 feet. Near the bottom of the slope, the tailings were too soft and the grader tires created ruts up to 1.5 feet deep. Most of the ruts ended up getting filled with amendment or a mixture of tailings and amendment, resulting in an uneven distribution of the amendments.

As much as three feet of the material in the centers of the dredge and black dirt piles was still frozen when the material was spread. The bulldozer operator broke the chunks into approximately 1 foot pieces by running over them or by pushing down on them with the blade. In some cases this resulted in portions of the frozen material being incorporated into the tailings, resulting in a pocket with extra thick amendment.

At the North site, dredge material was also spread further into the pond than originally planned and extended about 10 to 15 feet beyond the original plot boundaries. The vegetation had not been scraped in this area and as a result was covered by the dredge.

Silt Fences

Three foot high silt fences were installed at both sites to provide some physical separation between plots. At the North site, silt fences were installed between the plots and across the bottom of the plots to prevent movement of the dredge material and to minimize mixing of surface water among the plots (Figure 3).

At the South site, the fences were installed at the shoreline between the plots to minimize movement of the amendments between plots (Figure 5).

Soil Analyses

General fertility analyses were done by Minnesota Valley Testing Laboratories (MVTL) in New Ulm, MN, using agronomic methods. Trace metals, PCB's, and organic constituents were analyzed by Braun Intertec Corporation in Minneapolis, MN, using EPA methods.

Water Quality

Due to the dry season and the delay in installing a culvert, there was insufficient water to establish a pond at the North site in 1998. As a result, no water quality samples were collected during the first growing season. Four sets of samples were collected in 1999; April 1, July 6, 19, and September 20. Both surface and shallow groundwater samples were collected in the plots, and samples of the inflow and outflow were also collected.

Surface water quality samples were collected within three feet of each of the groundwater sampling wells. Two 500 mL grab samples were collected at each well, at the input culvert, and before the outlet culvert on the North site wetland.

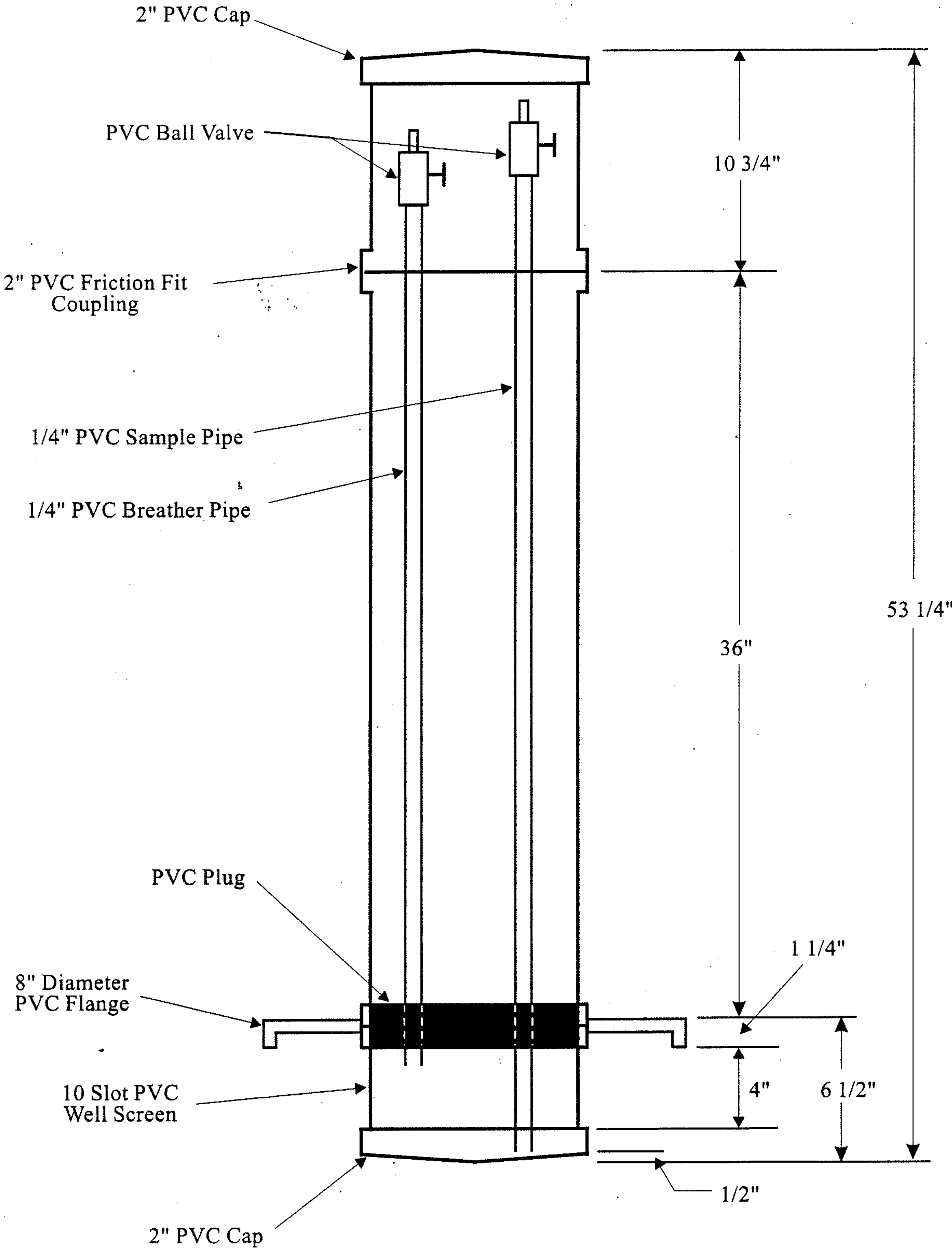
Groundwater was sampled at the North site from six sampling wells (Figure 8), three wells in the control plot with no dredge (wells 1, 2, and 3) and three in the dredge plot that contained the 25A and Custom seed mixes (wells 4, 5, and 6). The sampling wells were constructed of PVC as illustrated in Figure 8. The sampling wells were installed by augering a hole about 6 ½ inches deep with a 3 1/4 inches bucket auger. The auger created a hole about 1 inch larger than the pipe, so this area (annular space) was filled to the extent practical with silica sand. The silica sand was placed in the annulus by pouring it through a flexible hose that was routed under the flange. Then the flange was seated into the material and about a half inch of soil was placed over the flange to minimize the chance of short circuiting. The riser portion of the well was clamped to the cross member of an "H" brace for stability. This brace also supported planking used for access to the wells under high water conditions.

The dredge was thicker than 6 ½ inches at wells 4 and 5, but only around 6 inches at well 6. Since the well was designed to be surrounded only by dredge material, about 1 inch of dredge was packed into the bottom of the hole before the well at site 1 was placed. The flange stood slightly above the ground, so additional dredge material was mounded around the well to seal the flange. No additional material was needed for the other wells. A portable Masterflex (model 7570-10) sampling pump equipped with 6 mm ID Tygon tubing was used to collect water from the wells. A 300 mL volume was purged from each of the wells prior to sample collection. Two 500 mL samples were collected, one for nutrients and one for all other parameters.

Once collected, water samples were brought to the DNR laboratory, refrigerated and analyzed within one day of collection. The pH of each sample was measured directly in the collection bottle with an Orion SA 720 pH meter equipped with a Ross combination electrode (model 8165). Specific conductance was measured with a Myron L (model EP) conductivity meter. Alkalinity was measured using standard titration techniques (method 2320) in APHA et.al., (1992). The remaining sample was filtered through 0.45 micron Gelman filters for Hg, and sulfate, and for metals (September 20th sample only). Metal samples taken on April 1, July 6 and July 19 were analyzed as total metals. Metal and Hg samples were acidified with 0.2 ml of Baker Instra-Analyzed nitric acid per 50 mL. Nutrient samples were acidified with 0.5 ml of Baker Instra-Analyzed sulfuric acid per 500 mL.

Metal, sulfate and nutrient samples were sent to the Minnesota Department of Agriculture's (MDA) laboratory in St. Paul, MN. Sulfate and chloride were analyzed using the Ion Chromatographic Method (Wastewater Method 4500-SO_4 B) with a Latchet QuickChem 8000. A Varian 400 SPECTRAA atomic absorption spectrophotometer in the flame mode was used to analyze the following metals; Fe, Ca, Mg, Na and K. All other metals (Ag, As, Ba, Cd, Co, Cu, Cr, Ni, Pb, Se, Zn) were analyzed by an ICP/MS with a linear operating range that overlaps graphite furnace and flame AA. The ICP/MS is a Hewlett Packard HP4500 Series, model# G1820A, serial# 3622J00524, and the technology utilizes argon inductively coupled plasma with quadrapoule separation. Mercury samples were analyzed by Cold Vapor Atomic Absorption (standard method 3112A) using a Varian Model SPECTRAA 220/FS atomic absorption with Varian Model VGA-77 vapor generator. Nutrient analysis was conducted using the Automated Cadmium Reduction Method (Wastewater Method 4500-NO_3 F) on a Technician AA11 for Nitrate + Nitrite Nitrogen, the Ammonia-Selective Electrode Method (Wastewater Method 4500-NH_3 F) on an Accumet 950 pH/ion meter for Ammonia Nitrogen, the Ascorbic Acid Method (Wastewater Method 4500-P E) on a Perkin Elmer 552 Spectrophotometer for Total Phosphorus, and the Semi-Automated Colorimetric Method (EPA 351.2) with a Bran & Luebbe Traacs 800 for Total Kjeldahl Nitrogen (this analysis was sub-contracted to Metropolitan Council in St. Paul, MN).

Figure 8. Monitoring well design (North Site).



Vegetation

Seed Mixes

Three seed mixes were used in this project. The standard reclamation mix (Table 1) was used in upland areas at the South site, and at the North site to compare to wetland seed mixes. However, with the exception of redtop, the plants in this mix will not generally grow in wet areas, and are usually replaced by species more tolerant of wet conditions. Based on a previous survey of incidental wetlands, areas originally seeded with the standard reclamation mix develop into cattail monocultures (Melchert et al., 1995). In an attempt to create a more diversified wetland community, two other seed mixes were planted.

MN DOT Mix 25A (excluding fringed brome, which was not available) was used on the drier edges of the wetland where the soil is expected to be above water except during very wet periods. Mix 25A is a native meadow mix developed by the Minnesota Department of Transportation for wet ditches and wetland restoration (Tables 2 & 3). It contains a wide mixture of plant species. The mix was applied by hand on May 19, 1998 at the rate of 16.1 lb/acre native seed plus 4.9 lb/acre annual rye grass and 23.6 lb/acre of winter wheat for a total of 44.6 lb/acre.

The third seed mix, a custom mix of wetland species, was created by the MN DNR with the intent of planting many obligate wetland species to see which native wetland species will grow within a wetland established on tailings. This mix was used below the expected average water line. Thirty-seven native species were included in the custom mix, selected primarily for their availability from the closest nurseries. This mix was applied by hand at a rate of 10 lb/acre with 20 lb/acre of winter wheat and 8 lb/acre of annual rye grass as nurse crops for a total of 38 lb/acre. These seeds were not stratified, but they were kept refrigerated until seeding. A species list is provided in Table 4. Additional information on the seed mix, including detailed costs, is included in Appendix 7.

Seed bed preparation, fertilizing, mulching and seeding (with the standard reclamation seed mix) was done by D&T Landscaping of Bemidji, MN. Fertilizer was applied to all plots by a tractor equipped with a broadcast spreader at the rate of 550 lbs/acre of diammonium phosphate (DAP). A second tractor pulled a double disc (angled) with a seeder mounted near the back of the disc. The seeder had 7 to 8 one-inch hoses that mounted behind the disc about 1 foot off the ground and spaced about 2 feet apart. Below the hose outlet was a small deflector plate where the seed is blown against and deflected onto the soil. A drag was towed behind the disc to smooth the plot and cover the seeds. On the plots with 1 inch of amendment, the disc penetrated deep enough to mix the amendment quite well into the tailing. The disc did not penetrate deeply enough, for the most part, on the plots with six inches of amendment to incorporate any of the amendment into the underlying tailings. Due to soft soil conditions near the bottom of the slopes at both sites, the bottom 5 feet of the slopes were not disced. The MN DOT 25A and wetland custom mix were seeded by hand on all plots.

Table 1. Standard reclamation seed mix (SMR) used on upland areas at National Steel.

Species	Common name	Wetland Indicator Status	Lbs/Acre	% by Weight
Lolium perenne	Perennial Rye	FACU	8	13.3
Bromus inermis	Smooth Broome Grass	UPL	12	20.0
Secale cereale	Rye Grain	UPL	8	13.3
Agrostis alba	Redtop	FACW	8	13.3
Trifolium hybridum	Alsike Clover*	FAC-	5	8.4
Medicago sativa	Ranger Alfalfa*	UPL	11	18.4
Melilotus officinalis	Yellow Sweet Clover*	FACU	8	13.3
Total:			60	100.0

Fertilizer: 550 lbs/acre of diammonium phosphate (18-46-0), N-P-K.
Mulch: 2 tons of hay per acre - crimped to a depth of 3 inches.

* Innoculated with nitrogen-fixing bacteria.

At the South site, no seeds were spread on the bottom 2 to 3 feet of the amendment that was under water. After seeding, a bale buster using large round bales, scattered mulch at the rate of 2 tons per acre and the mulch was crimped into the soil with another disc (not angled). The mulch was not crimped into the bottom half of the custom plot.

Vegetation Survey

Percent cover, a measure of the density of the vegetation, was used as a comparison of vegetation success among the various amendments. Percent cover is defined as the percent of the surface that would be covered by vegetation if the area of the vegetation was projected vertically down onto the soil surface. Percent cover can include both living vegetation and litter. In 1998 only live vegetation was counted since the first year litter was almost entirely mulch, which was added to the plot and was not the result of vegetative growth within the plot. In 1999, not much litter had been produced, so only live vegetation was counted.

Percent cover was estimated at each of the plots in late August using a combination of visual estimation and systematic point-quadrat sampling (Raelson and McKee, 1982). For each of the plots at the North site, the percent vegetative cover was visually estimated to the nearest cover class in twenty-four 0.5 square meters quadrats along three transects parallel to the dike. The transects for the SMR seed mix on tailings and the SMR seed mix on dredge were systematically spaced ten

Table 2. MN DOT 25A seed mix used on shoreline along the anticipated water level.

Species	Common Name	Indicator Status	Pure Seed %	Germination %	Dormant Seed %	Genetic Origin	Pure Live Seed %	Bulk Seed %	Location Where Grown
Calamagrostis canadensis	Bluejoint grass	OBL	0.54	0	0.00	Sherburne Co., MN		2.04	Minnesota
Andropogon gerardi	Big bluestem	FAC-	9.77	89	0.75	Sherburne Co., MN	9.18		Minnesota
Spartina pectinata	Cord grass	FACW+	1.57	55.5	0.12	Sherburne Co., MN		2.04	Minnesota
Sorghastrum nutans	Indian grass	FACU+	9.77	89	4.74	Anoka Co., MN	9.18		Minnesota
Triticum aestivum	Winter wheat	Cover crop	50.16	98	0.00	North Dakota		53.06	Minnesota
Lolium multiflorum	Annual rye grass	FACU+ cover crop	10.30	90	0.00	Minnesota		11.22	North Dakota
Panicum virgatum	Switch grass	FAC+	5.64	86	0.00	Sherburne Co., MN	5.1		Minnesota
Agropyron trachycaulum	Slender wheat grass	FAC	2.85	85	0.00	Canada		3.06	Canada
Elymus canadensis	Canada wild rye	FAC-	3.31	87.5	0.00	Sherburne Co., MN	3.06		Minnesota
Native wildflower mixture			2.00	See following table					
Weed seed %			0.14	NAp					
Other crop seed %			0.24						
Inert matter %			6.74						

Net weight: 1.06 lbs, Pure Live Seed (PLS) lbs: 1.0, Test date - 3/15/97, NAp: not applicable.

Table 3. Wildflower component of MN DOT 25A seed mix.

Species name (Genus species)	Species name (Common name)	Indicator status	Pure Seed %	Germination %	Hard Seed %	Bulk Seed %
Acorus calamus	Sweet flag	OBL	3.73	NAp	NAp	4.0
Agastache foeniculum	Giant hyssop	**	0.84	NAp	NAp	1.0
Alisma plantago	Water plantain	OBL	3.87	NAp	NAp	4.0
Asclepias incarnata	Swamp milkweed	OBL	3.93	NAp	NAp	4.0
Aster simplex(lanceolatus)	Panicled aster	FACW	0.81	86	NAp	4.0
Aster novae-angliae	New England aster	FACW	3.50	47	NAp	8.0
Aster puniceus	Red stalked aster	OBL	0.70	NAp	NAp	1.0
Desmodium canadense	Canada tick trefoil	FAC-	2.99	NAp	NAp	3.0
Eupatorium maculatum	Joe-pye weed	OBL	6.19	NAp	NAp	8.0
Eupatorium perfoliatum	Boneset	FACW+	3.29	NAp	NAp	6.0
Solidago graminifolia	Grass-leaved goldenrod	FACW-	0.64	NAp	NAp	2.0
Helenium autumnale	Sneezeweed	FACW	0.74	NAp	NAp	1.0
Helianthus rigida	Giant sunflower	**	1.58	NAp	NAp	2.0
Heliopsis helianthoides	Common ox-eye	**	3.83	89	9	4.0
Hypericum pyramiditum.	Greater St. John's wart	FAC+	1.80	NAp	NAp	2.0
Iris versicolor	Wild Iris	OBL	0.92	NAp	NAp	1.0
Liatris pycnostachya	Tall blazing star	FAC-	8.13	NAp	NAp	10.0
Monarda fistulosa	Wild bergamot	FACU	1.35	NAp	NAp	2.0
Petalostemon candidum	White prairie clover	**	0.93	NAp	NAp	1.0
Petalostemon grandiflorum	Purple prairie clover	**	1.74	NAp	NAp	2.0
Pycnathemum virginianum	Mountain mint	FACW+	3.55	NAp	NAp	4.0
Rudbeckia hirta	Black-eyed Susan	FACU	3.29	NAp	NAp	4.0
Solidago rigida	Stiff goldenrod	FACU-	2.26	NAp	NAp	3.0
Thalictrum pubescens	Tall meadow rue	FAC	1.83	NAp	NAp	2.0
Verbena hastata	Blue vervain	FACW+	5.08	30	18	6:0
Vernonia fasciculata	Ironweed	FACW	2.60	NAp	NAp	5.0
Veronicastrum virginicum	Culver's root	FAC	0.26	NAp	NAp	4.0

Table 3. Wildflower component of MN DOT 25A seed mix (continued).

Species name (Genus species)	Species name (Common name)	Indicator status	Pure Seed %	Germination %	Hard Seed %	Bulk Seed %
Zizea aurea	Golden alexanders	FAC+	1.98	NAp	NAp	2.0
Weed seed %			0.12	NAp		
Other crop seed %			0.01			
Inert matter %			27.63			

** Information not available. Assumed to be upland species. See Appendix 1 for wetland species definitions.

Genetic origin: within Isanti, Sherburne, and Benton Counties, .NAp = not applicable because seed is above standard or no standard exists. Net weight: 0.32 oz., Lot number: TW-1-97, noxious weed seed: none, Test date - 3/24/97, all seeds grown in Minnesota and purchased from: Prairie Restorations, 33922 128th Street, Princeton, MN 55371: Phone (612) 389-4342

feet apart, beginning 10 feet from the bottom of the plot to avoid edge effects. Quadrats were systematically spaced about 11 feet apart, starting 10 feet from the end of each plot. The dredge plot containing two seed mixes was sampled similarly, except the transects were only five feet apart beginning five feet from the bottom of the plots. In 1999, 80 percent of the custom seed plot was covered by water, and the invasive species spread to cover about 25% of the plot. As a result, vegetative success was measured by an overall visual estimation.

Sampling transects also ran parallel to the dike at the South site, but were spaced differently than the North site because the plots were narrower. Two transects were positioned on the upland sections (SMR seed mix), and aligned five feet from the bottom and top of plot boundaries. Twenty-four 0.5 square meters quadrats were spaced about 7.5 feet apart beginning 9 feet from the edge of the plot. Due to their smaller size, the MN DOT 25A and Custom seed mixes had only one transect down the center of each plot. Seventeen quadrats were spaced 5 feet apart along the transect starting 10 feet from the end. In 1999, no quadrat sampling of the custom seed mix plots was used to measure percent cover, since much of the plot was under water and up to 50% of the amendment had been eroded away by wind and wave action. Instead, a simple ranking of vegetative success for the remaining portions of the plots was determined by visual estimation.

Quadrats were defined using a steel frame with dimensions 1.0 meter by 0.5 meter. To prevent bias in frame placement, a nail was blindly tossed in the area to be surveyed and the corner of the frame was placed at the point of the nail. Overall percent cover was taken as the average of the cover class medians for each quadrat.

Vegetative biomass was measured on the same day that percent cover data was collected. Subsets of the 1.0 meter by 0.5 meter percent cover quadrats were randomly selected to measure biomass. Samples were collected from the quadrats using a 0.1 square meter steel frame as a template. The frames were located at a pre-designated corner of the percent cover quadrats. In 1998, six 0.1 square meter areas were clipped for all of the plots at the North site and only the upland plots at the

Table 4. Custom wetland seed mix.

Genus	Species	Common Name	Indicator Status	% of mix by weight[1]
Acorus	calamus	Sweet flag	OBL	2.58
Alisma	plantago-aquatica	Water plantain	OBL	2.58
Alisma	subcordatom	Mud plantain	OBL	2.58
Angelica	atropurpurea	Angelica	OBL	2.58
Asclepias	incarnata	Swamp milkweed	OBL	2.58*
Aster	puniceus	Swamp aster	OBL	2.58
Aster	simplex(lanceolatus)	Panicled aster	FACW	2.58
Calamagrostis	canadensis	Blue Joint grass	OBL	5.16
Carex	bebbii	Bebbs sedge	OBL	2.58
Carex	comosa	Bottle-brush sedge	OBL	2.58
Carex	retrorsa	Retrose sedge	OBL	2.58
Carex	scoparia	Pointed broom sedge	FACW	2.58
Carex	vulpinoidea	Fox sedge	OBL	2.58
Elymus	virginicus	Virginia Wild rye	FACW-	5.83**
Eupatorium	maculatum	Joe pye weed	OBL	2.58*
Eupatorium	perfoliatum	Common Boneset	FACW+	2.58*
Glyceria	canadensis	Canada manna grass	OBL	2.58
Glyceria	grandis/maxima	Giant Manna grass	OBL	2.58
Glyceria	striata	Fowl manna grass	OBL	2.58
Helenium	autumnale	Common Sneeze weed	FACW+	2.58
Impatiens	biflora(capensis)	Jewel weed-touch me not	FACW	2.58
Iris	versicolor	Wild iris	OBL	2.58
Juncus	effusus	Common rush	OBL	2.58
Lobelia	siphilitica	Great Blue lobelia	FACW+	2.58
Mimulus	ringens	Monkey flower	OBL	2.58
Onoclea	sensibilis	Sensitive fern	FACW	2.58
Sagittaria	latifolia	Broad-leaf arrowhead	OBL	2.58
Scirpus	acutus	Hardstem bulrush	OBL	2.58
Scirpus	atrovirens	Green bulrush	OBL	2.58
Scirpus	cyperinus	Wool grass	OBL	2.58
Scirpus	validus	Soft stem bulrush	OBL	2.58
Solidago	riddellii	Riddell's goldenrod	OBL	2.58*
Solidago(Euthamia)	graminifolia	Grass-leaf goldenrod	FACW-	1.36*
Sparganium	eurycarpum	Giant burr reed	OBL	2.58
Spartina	pectinata	Cord grass	FACW+	2.58
Verbena	hastata	Blue Vervain	FACW+	2.58
Vernonia	fasciculata	Common ironweed	FACW	2.58

* Defluffed seed ** *Elymus virginicus* is 89.10% PLS.

[1] Bulk seed.

See Appendix 1 for wetland species definitions.

South site. The MN DOT 25A and custom wetland seed mix plots at the South site had only four 0.1 square meters areas sampled for biomass estimation. In 1999, no biomass samples were collected from the custom seed mix plots at the South site due to water cover and erosion. In 1999 at the North site, four biomass samples were collected at the MN DOT 25A dredge plot and only two biomass samples were collected at the custom mix/dredge plot due to water cover and the invasion of *Phragmites* and *Typha* in the plot.

All of the vegetation inside the 0.1 square meter frame was cut at the surface of the soil and placed in paper bags. Biomass samples were consolidated into one bag for each plot in 1998, but were analyzed separately in 1999. The samples were dried in an oven at approximately 70 degrees centigrade for 48 hours. After drying, the samples were weighed on an electronic scale to determine dry biomass. Total biomass for each plot was used for vegetation comparison. Species composition and relative abundance data, determined by a visual survey of each entire plot, were also collected and are summarized in Appendix 1.

Results

Amendment Chemistry

Soil fertility data for all the amendments are summarized in Table 5. The commercially prepared black dirt contained the highest percentage of organic matter (21.6%) and had the highest cation exchange capacity (CEC) and nitrate-nitrogen content. The dredge material contained 3.7 to 4.7% organic matter (more than both the topsoil and glacial overburden) and had the highest percentage of silt and clay (~70%) of all the amendments.

Dredge material was analyzed for trace metals, semi-volatile organic compounds (base and neutral compounds only) and polychlorinated biphenyls (PCB's). Tailings at the North site were analyzed for metals only. The results of these analyses are summarized in Table 6.

In general, contaminant levels in the dredge material were quite low and were similar to natural background levels. The dredge material shipped to National Steel had similar contaminant levels to the initial samples collected at the Erie Pier, with the exception of arsenic. Arsenic in the samples collected at Erie Pier were less than 2.2 mg/kg while the material at National Steel averaged 8.8 mg/kg. This value was still less than the 13 mg/kg observed in the tailings.

No contaminants exceeded Minnesota standards for application of Class 1 compost, and most were within the low effect guidelines for open water disposal set by Ontario, Canada. Contaminants above the Ontario guidelines were Ni, Hg, As, and Cu. PCB's were not detected but the detection limit was slightly higher than the guideline. Although the detection limits for the PCB arochlors were not as low as desired, the concentration of PCB 1260 at National Steel was less than half of the concentration of the samples from Erie Pier (<0.099 vs 0.17 mg/kg). No other PCB arochlors were detected in either sample.

Dredge Thickness

Detailed measurements of dredge thickness were collected at the North site and on the upland areas of the South site. Average thickness for the lower sections of the South site plots was calculated based on the initial volume of material and the volume spread on the upland portions (Appendix 8).

Table 5. Soil fertility data, National Steel wetland creation project.[1]

Parameters[2]	Dredge North Site	Dredge South Site	Tailings North Site	Tailings South Site	Black Dirt[3]	Topsoil	Glacial Overburden
pH	6.9	7.1	8.0	8.0	6.3	5.8	7.4
% Organic Matter	4.7	3.7	0.6	0.5	21.6	2.5	1.9
Nitrate-Nitrogen[6] (lbs/acre)	2	4	2	2	45	18	2
Phosphorus[7]							
Bray 1	10	8	8	2	9	57	6
Olsen	30	29	12	9	10	38	10
Potassium	30	30	260	220	70	40	40
Calcium	1000	700	400	300	1800	700	800
Magnesium	170	150	120	100	200	30	90
Sodium	25	18	33	42	25	19	11
Iron	60.3	66.3	41	37.3	73.5	51.4	18.1
Manganese	51.7	49.1	16.9	10.2	4.2	6.5	10.3
Copper	1.5	1.6	0.3	0.5	1.2	0.8	1.8
Zinc	5.1	5.2	2.0	.9	4.6	1.5	0.7
Boron	0.7	0.8	0.5	0.6	0.9	0.7	0.7
Sulfate-Sulfur	8.0	9.0	2.0	4.0	42.0	7.0	33.0
CEC[4]	6.6	4.9	3.8	3.1	10.9	5.9	4.9
Soil Texture[5]							
Sand	27.5	35.0	85	80	80	85	62.5
Silt	42.5	42.5	12.5	12.5	5	5	17.5
Clay	30	22.5	2.5	7.5	15	10	20

[1] Analyses by MVTL; data represents plant-available concentrations; Ca, Mg, K and Na were extracted with ammonium acetate, trace metals were extracted with DTPA.

[2] All parameters in mg/kg unless noted.

[3] Commercially prepared mixture of sand and well-decomposed peat, produced in Hibbing, MN.

[4] By summation.

[5] Determined by hydrometer test. For mineral soils, values are typically good to 2.5% (T. Koeble, personal communication, 1997). "Black Dirt" is comprised primarily of well-decomposed peat and some sand. Tailings have higher density than typical mineral soils. Settling test may not be as accurate for these materials.

[6] Calculated nitrate in a 6 inch thick section of material.

[7] Bray, P. - Extractable P, better measure of available P, when pH $\leq$ 7.3. Olsen, P. - Extractable P, better measure of available P when pH $\geq$ 7.3.

Table 6 (page 1 of 4). Trace metal and organic concentrations in dredge material compared to background levels and land application guidelines. Note: All concentrations represent total values in mg/kg (dry weight basis).

Parameters	Dredge Material		Tailings[3]	Natural Background			Ontario Guidelines, Open Water Disposal 8/93[7]		Land Application Standards		
									Minnesota		Wisconsin
	Erie Pier[1]	National[2]		Wetland[4]	Mineral[5]	Great Lakes Sediment[6]	Low Effect[8]	Severe Effect[9]	Class 1[10]	EQ Sludge[11]	NR538 (draft)[12]
Metals:											
As	<2.2	8.8	13	2.4	7.2	4.2	6	33	41	41	0.042[19]
Cd	0.91	0.60	<2.5	0.6	<2	1.1	0.6	10	39	39	7.8
Cr	23	24	<5.0	7.4	90.3	31	26	110	NL	NL	14.5[13]
Cu	18	20	11	5.2	16.8	25	16	110	1500	1500	625
Pb	21	23	<9.5	22.1	16.5	23	31	250	300	300	50
Hg	0.13	0.11	<0.02	0.12	NA	0.10	0.02	2	5	174	4.7
Ni	16	18	<5.0	4.7	31.3	31	16	75	420	420	310
Se	<3	3.5	7.1	0.3	NA	NL	NL	NL	100	100	78
Zn	102	110	28	49.5	65.4	65	120	820	2800	2800	4700
Organics:[14]											
Acenaphthene	<0.065	NA	NA	NA	NA	NA	NL	NL	NL	NL	900
Acenaphtylene	<0.065	NA	NA	NA	NA	NA	NL	NL	NL	NL	8.8
Anthracene	<0.065	NA	NA	NA	NA	NA	0.22	370	NL	NL	5,000

Table 6 (page 2 of 4). Trace metal and organic concentrations in dredge material compared to background levels and land application guidelines. Note: All concentrations represent total values in mg/kg (dry weight basis).

Parameters	Dredge Material		Tailings[3]	Natural Background			Ontario Guidelines, Open Water Disposal 8/93[7]		Land Application Standards		
									Minnesota		Wisconsin
	Erie Pier[1]	National[2]		Wetland[4]	Mineral[5]	Great Lakes Sediment[6]	Low Effect[8]	Severe Effect[9]	Class 1[10]	EQ Sludge[11]	NR538 (draft)[12]
Benz[a] anthracene	0.08	NA	NA	NA	NA	NA	0.32	1,480	NL	NL	0.088
Benzo[b] fluoranthene	0.11	NA	NA	NA	NA	NA	NL	NL	NL	NL	0.088
Benzo(k) fluoranthene	<0.065	NA	NA	NA	NA	NA	0.24	1340	NL	NL	0.88
Benzo(g,h,i) perylene	<0.065	NA	NA	NA	NA	NA	0.17	320	NL	NL	0.88
Benzo[a]pyrene	0.09	NA	NA	NA	NA	NA	0.37	1440	NL	NL	0.0088
Chrysene	0.09	NA	NA	NA	NA	NA	0.34	460	NL	NL	8.8
Dibenzo(a,h) anthracene	<0.065	NA	NA	NA	NA	NA	0.06	130	NL	NL	0.0088
bis (2-Ethylhexyl phthalate)	0.36	NA	NA	NA	NA	NA	NL	NL	NL	NL	NL
Fluoranthene	0.14	NA	NA	NA	NA	NA	0.75	1020	NL	NL	600
Fluorene	<0.065	NA	NA	NA	NA	NA	0.19	160	NL	NL	600

Table 6 (page 3 of 4). Trace metal and organic concentrations in dredge material compared to background levels and land application guidelines. Note: All concentrations represent total values in mg/kg (dry weight basis).

Parameters	Dredge Material		Tailings[3]	Natural Background			Ontario Guidelines, Open Water Disposal 8/93[7]		Land Application Standards		
									Minnesota		Wisconsin
	Erie Pier[1]	National[2]		Wetland[4]	Mineral[5]	Great Lakes Sediment[6]	Low Effect[8]	Severe Effect[9]	Class 1[10]	EQ Sludge[11]	NR538 (draft)[12]
Indeno(1,2,3-cd) pyrene	<0.065	NA	NA	NA	NA	NA	0.20	320	NL	NL	0.088
1-methyl naphthalene	NA	NA	NA	NA	NA	Na	NL	NL	NL	NL	8.8
2-methyl naphthalene	<0.065	NA	NA	NA	NA	NA	NL	NL	NL	NL	8.8
Naphthalene	0.09	NA	NA	NA	NA	NA	NL	NL	NL	NL	600
Phenanthrene	0.06	NA	NA	NA	NA	NA	0.56	950	NL	NL	0.88
Pyrene	0.11	NA	NA	NA	NA	NA	0.49	850	NL	NL	500
PAH (Total)[15]	1.30	NA	NA	NA	NA	NA	4	10,000	NL	NL	NL
PCB's:											
PCB 1016[16]	<0.01	<0.099	NA	NA	NA	NA	0.07	53	NL	NL	NL
PCB 1248[16]	<0.01	<0.099	NA	NA	NA	NA	0.03	150	NL	NL	NL
PCB 1254[16]	<0.01	<.099	NA	NA	NA	NA	0.06	34	NL	NL	NL
PCB 1260[16]	0.17	<.075	NA	NA	NA	NA	0.005	24	NL	NL	NL
PCB Total	0.17[17]	<0.099[18]	NA	NA	NA	NA	.07	530	6	NL	NL

NL = not listed NA = not analyzed

Table 6 (page 4 of 4). Trace metal and organic concentrations in dredge material compared to background levels and land application guidelines.

[1]Average of three composite samples collected from target site at Erie Pier, June 1997 (Eger et al., 1998).
[2]Composite of dredge material to be used for wetland creation at the National Steel North site (Eger et al., 1998).
[3]Composite of tailings at the National Steel North site (Eger et al., 1998).
[4]Average concentrations from surface samples of Minnesota Peat (Eger et al., 1998).
[5]Average concentrations from B horizon soils, Lake Vermillion Area (Eger et al., 1998).
[6]Values from Ontario guidelines, based on pre-colonial sediments.
[7]Guidelines based on open water disposal, levels are lower than for typical on-land application of organic amendments.
[8]Low Effect Level = "Clean to Marginally Polluted" - No effect on majority of sediment dwelling organisms. If concentrations exceed this level further testing and a management plan may be required.
[9] Severe Effect Level = "Heavily Polluted" - Likely to affect health of sediment dwelling organisms.
[10]Standards for Class 1 compost, Minnesota Rules.
[11]Metals standards for exceptional quality sludge, Minnesota Rules.
[12]Wisconsin Solid Waste Rules, Beneficial Use of Industrial By-Products, February 1996 draft, standards for Category 1 material.
[13]Hexavalent chromium.
[14]A complete base-neutral scan was conducted on the dredge samples from Erie Pier. Only those parameters for which there are guidelines or where there were detectable values are listed.
[15]PAH compounds not detected were assumed to have a concentration equal to their detection limit (0.063) for this calculation.
[16]Guidelines for PCB arochlors are tentative.
[17]Only arochlor that was detected was 1260, all other arochlors were less than 0.01; PCB total is assumed to be equal to arochlor 1260.
[18]All arochlors were less than detection limit, 0.075-0.099, PCB total is assumed to be equal to the maximum reported value for a single arochlor.
[19]Based on increased cancer risk of 1×10^{-8}.

Table 7: Dredge depth at the North site plots, 1998.

	Wetland dredge				Standard Reclamation Dredge		
		25[1]	50[1]	75[1]	25[1]	50[1]	75[1]
Pond	36[2]	0	0.54	0.03	0.31	0.53	0
Middle	28[2] 20[2]	0.34 0.54	0.42 0.59	0.8 1	1.02 0.71	0.74 1.02	0 0.83
Uphill	12[2] 4[2]	0.31 0.2	0.23 0.07	0.71 0.02	0.56 0.05	0.75 0.2	0.53 0.02
	Overall Average Depth = 0.386				Average SMR Depth = 0.484		

Predicted depth was 0.5 ft throughout plot. Actual dredge depth is reported in tenths of feet. The dredge is thickest in the center of the plots. Standard reclamation dredge was thicker than the plot seeded with the custom wetland seed mix.

[1]Distance in feet from the left edge of the plot.

[2]Distance in feet from the upland edge of the plot.

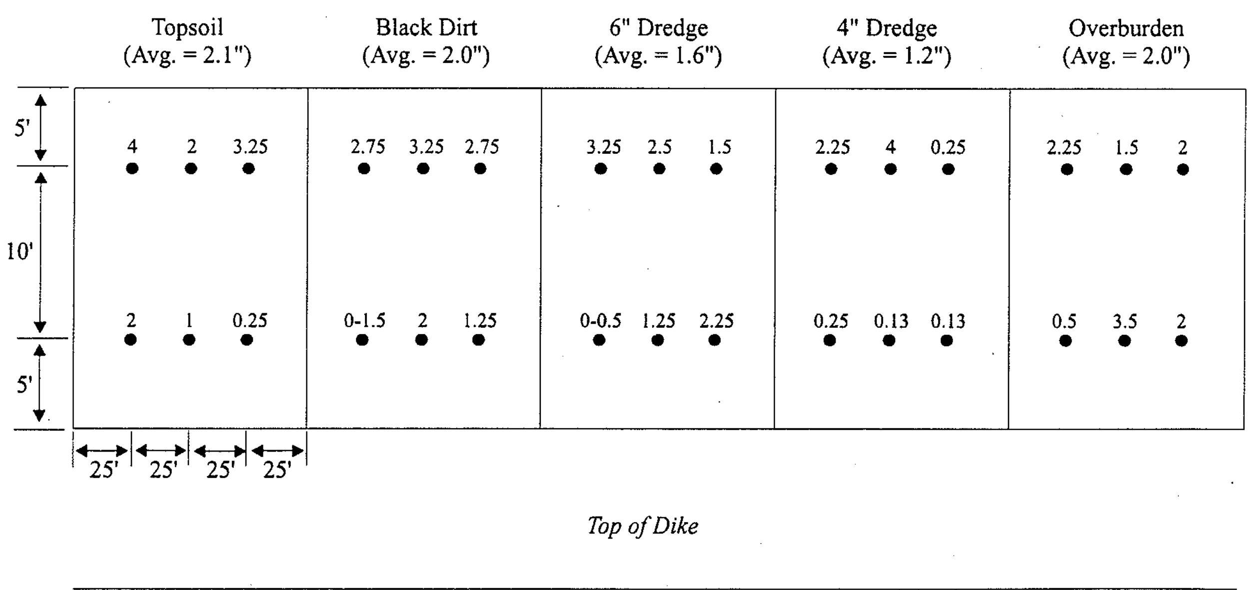


Figure 9. Uncompacted amendment thickness in the upper portions of the wetland plots (National Steel, South Site).

At the North site, the amendment thickness was greatest between one-fourth and three-fourths the way down the plots (Table 7). Because of the change in slope near the pond, it was difficult for the bulldozer operator to maintain an equal thickness of dredge along the slope. Dredge thickness ranged from 0 to 1 foot along the slope, with an overall average of 0.44 feet (5.3 inches).

At the South site, areas that were to receive ½ to 1 inch of material ended up with 1 to 2 inches of material overall, as it was not possible to spread it very evenly (Figure 9). These measurements were taken after the grader had spread the material and the amendment was mixed with tailings for about half of the measurements. It was not possible to determine the thickness of amendment without the incorporated tailings, so these measurements may overestimate the thickness of amendment. Based on the measurements of the upland slopes and the total volume of amendment applied, calculated thickness for the bottom portions of the plots ranged from 3.9 to 5.5 inches (Table 8).

Climate

Temperature and precipitation data for 1998 and 1999 from nearby sources indicate that temperatures were substantially above average every month except June 1998 and October 1999, which were close to normal. In 1998, precipitation was below average most of the summer (Table 9). June and October were the only months with precipitation substantially above normal. Precipitation in July and August, the two hottest months of the year, was 33% below normal. In 1999, precipitation was well above normal, especially the months of May, July, and September. The month of July itself had 15 inches of rain, 8 inches of which fell in a single storm on July 4th.

Water Levels

Water levels in the pond at the South site reflected precipitation patterns. In 1998, the water level at the staff gage reached a maximum reading of 0.5 meters after June rain storms and decreased to

Table 8. Amendment thickness at the South site plots (National Steel).

Amendment	Amendment thickness, inches	
	Upland plots[1]	MNDOT 25A and custom plots[2]
Topsoil	1.6	3.9
Black dirt	1.5	4.0
Dredge (6 inch)	1.2	5.5
Dredge (4 inch)	0.9	3.6
Glacial overburden	1.5	4.0

[1] Measured

[2] Calculated based on total volume of amendment and the measured thickness on the upland slopes.

Table 9. Climatic data for the 1998 and 1999 field seasons.

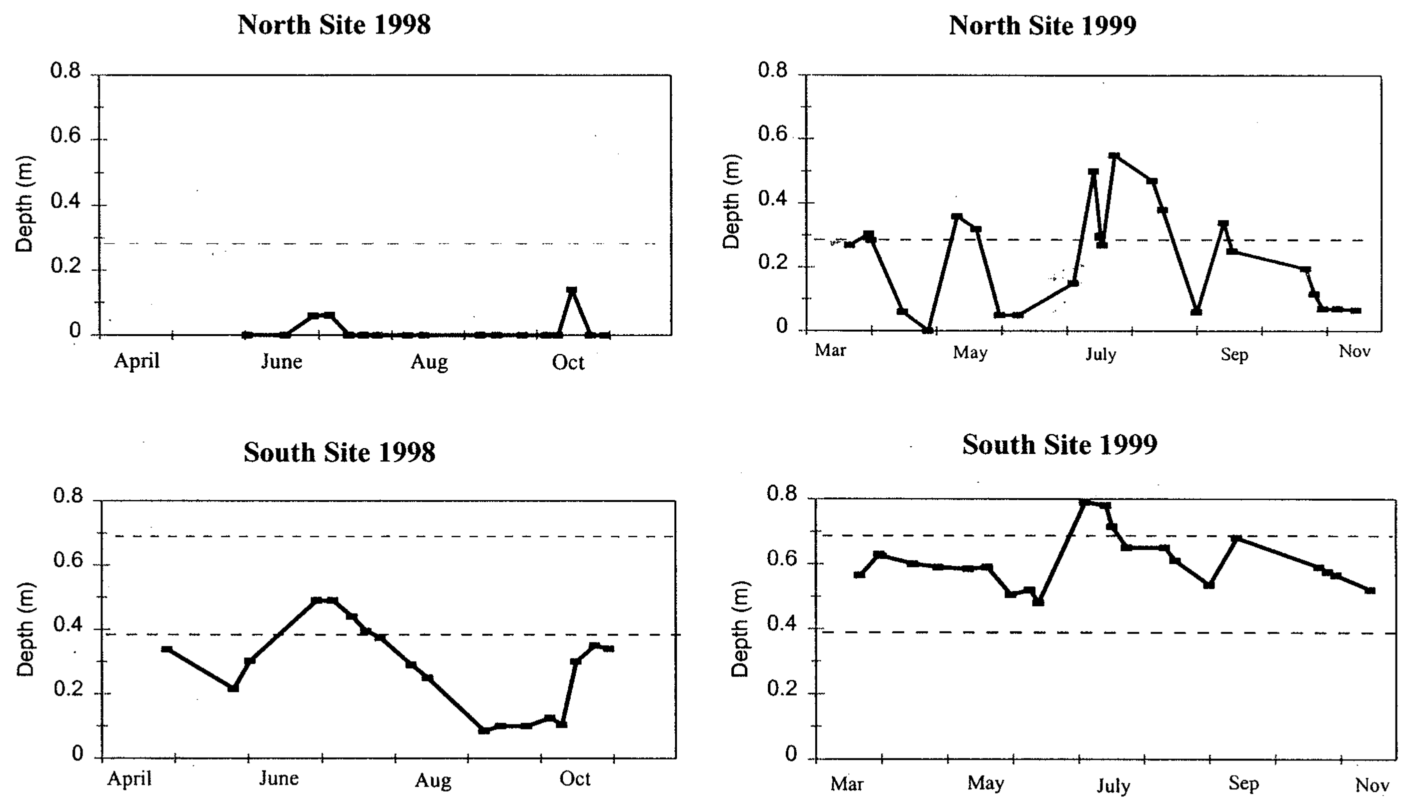
	Temperature (°F)					Precipitation (inches)				
	Average[1]		Normal	Departure[2]		Total		Normal	Departure[2]	
	1998	1999		1998	1999	1998[3]	1999[4]		1998	1999
January	15	7.4	4.1	10.9	3.3	0.57	0.76	0.71	-0.14	0.05
February	28.5	20.6	10.3	18.2	10.3	1.13	0.8	0.49	0.64	0.31
March	27	28.7	23.8	3.2	4.9	1.15	1.21	1.02	0.13	0.19
April	44	42.7	38.9	5.1	3.8	0.6	2.06	1.68	-1.08	0.38
May	57.6	54.2	51.5	6.1	2.7	2.68	5.71	2.62	0.06	3.09
June	60	62.4	60.3	-0.3	2.1	5.37	3.56	3.85	1.52	-0.29
July	66	69.2	65.6	0.4	3.6	2.31	15.62	3.81	-1.5	11.81
August	66.2	63.8	62.7	3.5	1.1	1.66	4.17	3.59	-1.93	0.58
September	58.6	54.4	52.8	5.8	1.6	2.94	6.8	3.12	-0.18	3.68
October	45.4	41.6	42.2	3.2	-0.6	4.84	1.67	2.24	2.6	-0.57
November	29.6	34.4	26	3.6	8.4	1.5	0.13	1.12	0.38	0.99
December	15.3	18.2	10.1	5.2	8.1	1.21	0.21	0.72	0.49	-0.51
Average/ Total						25.96	42.49	24.97	0.99	17.73

[1] Temperature values were recorded at the Hibbing Airport, located approximately 11 miles east of the plots.
[2] Departure is the monthly average (temperature) or total (precipitation) minus the 30-year average (1961-1990) for Hibbing, Minnesota.
[3] 1998 precipitation values were measured the DNR Forestry office in Hibbing , which is located about 7 miles northeast of the plots.
[4] 1999 precipitation values were measured near Riley, Minnesota , which is located approximately 6 miles east of the plots (December values were measured at the Hibbing Airport).

about 0.1 meters after the hot and dry summer months. In 1999, water levels increased in the spring to 0.6 meters and reached a maximum of 0.8 meters after the 4th of July storm . The water level remained elevated at about 0.6 meters due to the continued rainfall input and the lack of a direct outlet for the pond (Figure 10, Appendix 4).

Water levels in the North pond also fluctuated in response to precipitation but the variation was much more dramatic than at the South site. Water levels at the North site were controlled by an outlet culvert which was not installed until mid-July 1998. Due to the late installation of the culvert and the extremely dry summer, there was no water in the pond for most of 1998. Water levels

Figure 10. Surface water levels at the North and South site ponds, 1998 and 1999.



* Due to the fast fluctuation of water levels and the number of readings during a given time, some water elevation peaks and valleys may not be represented in the graphs.

** The dashed line on the North site graphs represents the outlet elevation (0.28 meters). Dashed lines on the South site graphs represent elevation estimates (elevations within plots vary; see Appendix 5) of the bottom (0.37 meters) and the top (0.67 meters) of the custom mix plots.

increased in the spring of 1999 after spring melt but much of the water was lost by the end of April. Water levels fluctuated with precipitation until the July 4th storm, which washed out the dike north of the culvert and drained most of the water from the pond. The dike was repaired by July 16, and water levels began to follow precipitation patterns. Water levels were much more variable than at the South site and ranged from 0.5 meters at the end of July to 0.06 at the beginning of September.

Water Quality

Water quality samples were collected at the North site on four dates in 1999; April 1, July 6, July 19, and September 20. The objective was to collect samples throughout the year when there was both surface and ground water present in the plots.

The first set of samples was collected on April 1 shortly after snow melt. At the time of sampling, water depth at the well sites ranged from 3/4 inch to 4 1/4 inches above the flange of the well. The water level decreased in the wetland and on April 16, the wells were checked and all of them had heaved due to frost and/or ice action. The wells moved despite the efforts taken to minimize heaving. The wells were bolted to a wooden support structure that was set about 2 feet into the tailings. Since the wells were PVC, the plastic slid up under the clamp. The amount of movement ranged from about 1/4 to 1 inch, but all the wells appeared to have at least some slotted area directly exposed to surface water. Since the objective was to sample the water in direct contact with the substrate, the data from the April samples were not used in the analysis of the ground water. The wells were reset on May 21, and all functioned properly except well 2 (control site). The slotted area must have become plugged since the recharge rate was very low. This well was not included in the analysis. Therefore, groundwater analysis was restricted to control wells (1 and 3) and dredge wells (4, 5 and 6) on July 6, July 19 and September 20.

Since adequate water was not present at all the surface sites on July 6, the samples from April 1, July 19 and September 20 were used in the surface water analysis. Figure 11 explains how to read the box plot analysis of the ground and surface water results.

Many of the metals (Ag, Cd, Cr, Co, Hg, Ni, Pb, and Se) were not detected in either the surface or ground water wells and will not be discussed. A complete set of water quality data is presented in Appendix 2, and the quality assurance program is summarized in Appendix 6.

Surface Water

The pH of the water entering and leaving the wetland was around 8.6, and most of the surface samples also had pH values above 8 (Figure 12). Specific conductance, calcium, magnesium, and sulfate decreased as water moved through the wetland and there was essentially no difference between the surface water in the control and dredge plots (Figure12). Total Kjeldahl nitrogen and total phosphorus concentrations were higher in the plots than in the inlet, and the concentrations in the outlet, although low, were slightly higher than the inlet (Figure 12; Table 10).

Figure 11. Box plot explanation.

The median of a data set is marked by the center horizontal line. The upper and lower quartiles (i.e. the *hinges*) are represented by the other two horizontal edges of the box. The *Hspread* is comparable to the interquartile range or midrange. It is the absolute value of the difference between the values of the two hinges.

The *inner fences* are defined as follows:

Lower fence = lower hinge - (1.5 Hspread)
Upper fence = upper hinge + (1.5 Hspread)

The *outer fences* are defined as follows:

Lower fence = lower hinge - (3 Hspread)
Upper fence = upper hinge + (3 Hspread)

Values outside the inner fences are plotted with asterisks. Values outside the outer fences are plotted with empty circles.

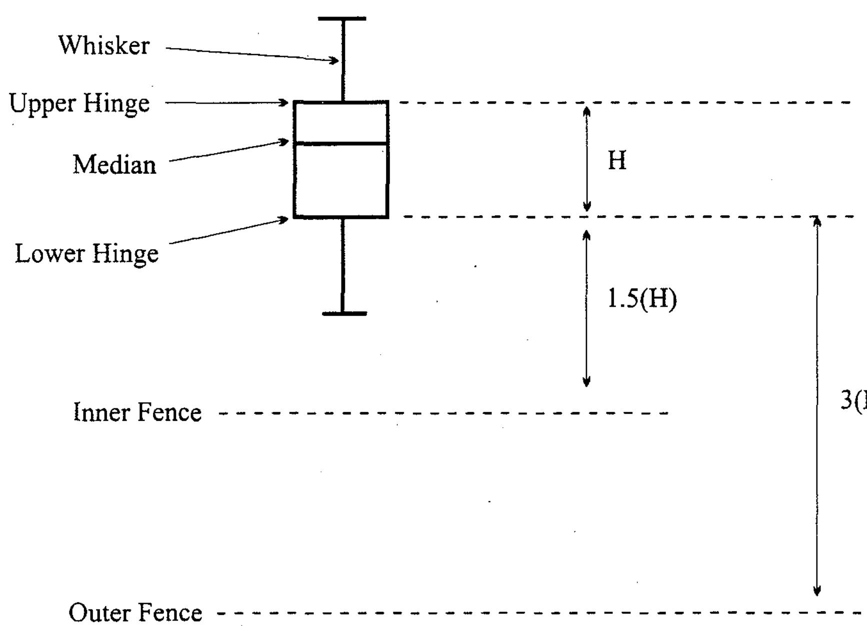
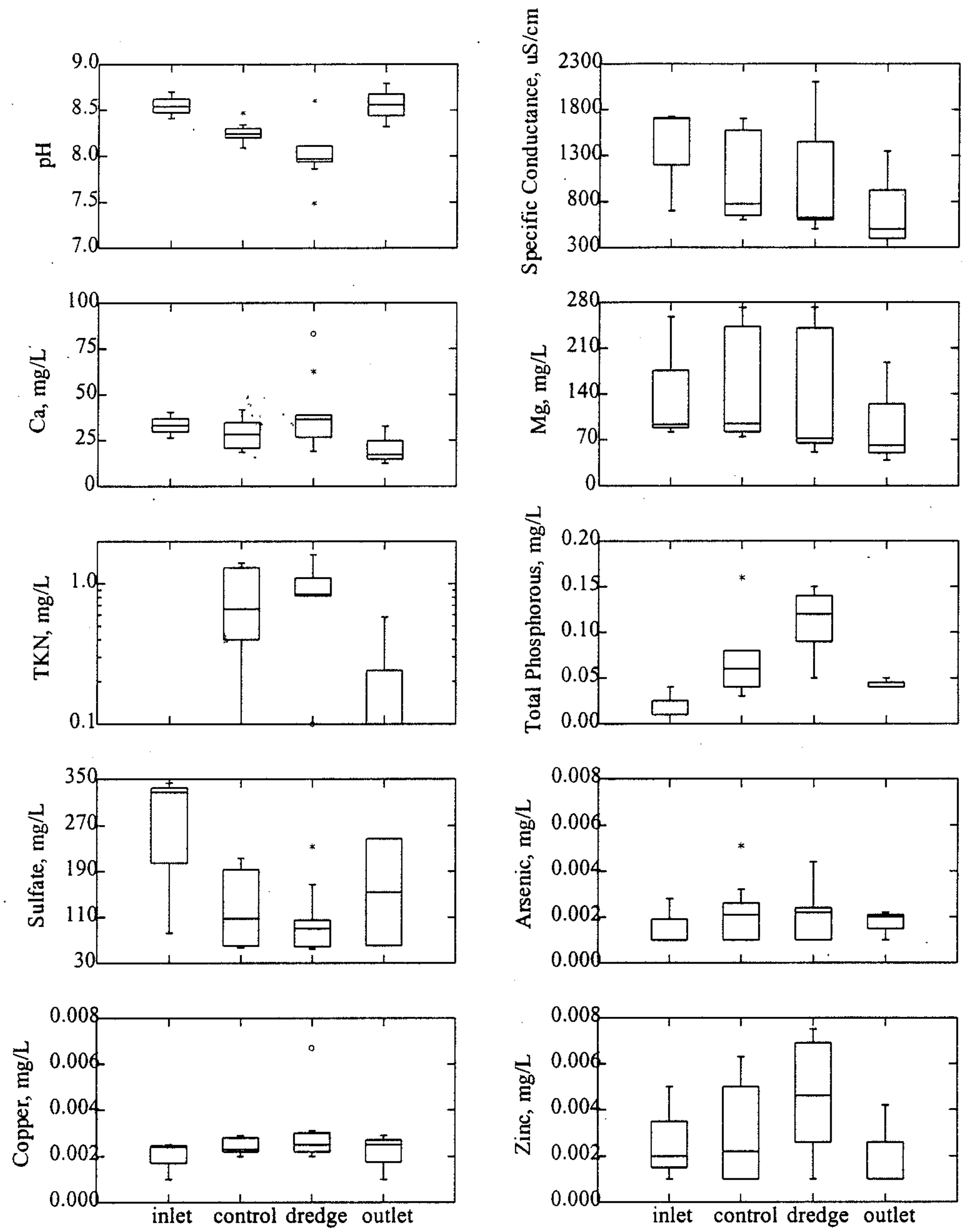


Figure 12. Chemical data from the surface water, inlet and outlet at the North site, 1999.



Notes: The boxes for the inlet and outlet each represent three samples. The boxes for the control and dredge combine all values from all sites and contain nine samples. In the TKN (Total Kjeldahl Nitrogen) plots, the values are plotted on a log scale to provide a better visual representation of the data. Some values are ≤ 0.1 mg/L and do not appear in the box plots.

The only trace elements with concentrations consistently above the detection limit (0.002 mg/L) were arsenic, copper and zinc. All concentrations were less than or equal to 0.008 mg/L, well below the water quality standards for 2B waters (aquatic life criteria for warm water fisheries, Minnesota Rules 7050.0220, 1997; Figure 12).

Groundwater

Samples were collected from the top 6 inches of the substrate and should represent the "worst case" effect of the dredge on water quality. The pH was similar in all the wells and ranged between 7.5 and 8.0, and was substantially less than the inlet and outlet value of 8.6 (Figure 13). Specific conductance generally exceeded 2000 umhos/cm in all the wells and was higher than both the inlet and the outlet with values of about 1400 umhos/cm and 700 umhos/cm, respectively.

Calcium and magnesium concentrations were also appreciably higher in the wells than surface water concentrations. Calcium was considerably higher in the dredge than the control but magnesium was much lower. Sulfate concentrations were similar in both ground and surface water, but alkalinity was 2 to 5 times higher in the well samples than the corresponding surface samples (Table 10). Arsenic, copper, and zinc were slightly higher in the wells than in the surface water, but all concentrations were still low. Maximum concentrations were 0.008 mg/L arsenic, 0.020 mg/L copper, and 0.025 mg/L zinc (Figure 13). The maximum arsenic value was measured in the control wells.

Vegetation

Vegetative success of standard reclamation projects on upland sites is judged by overall percent cover and biomass. However, for a wetland creation project, indicators of success include the type and number of species present. Wetland hydrology and wetland vegetation must be present in order for the project to be judged a success.

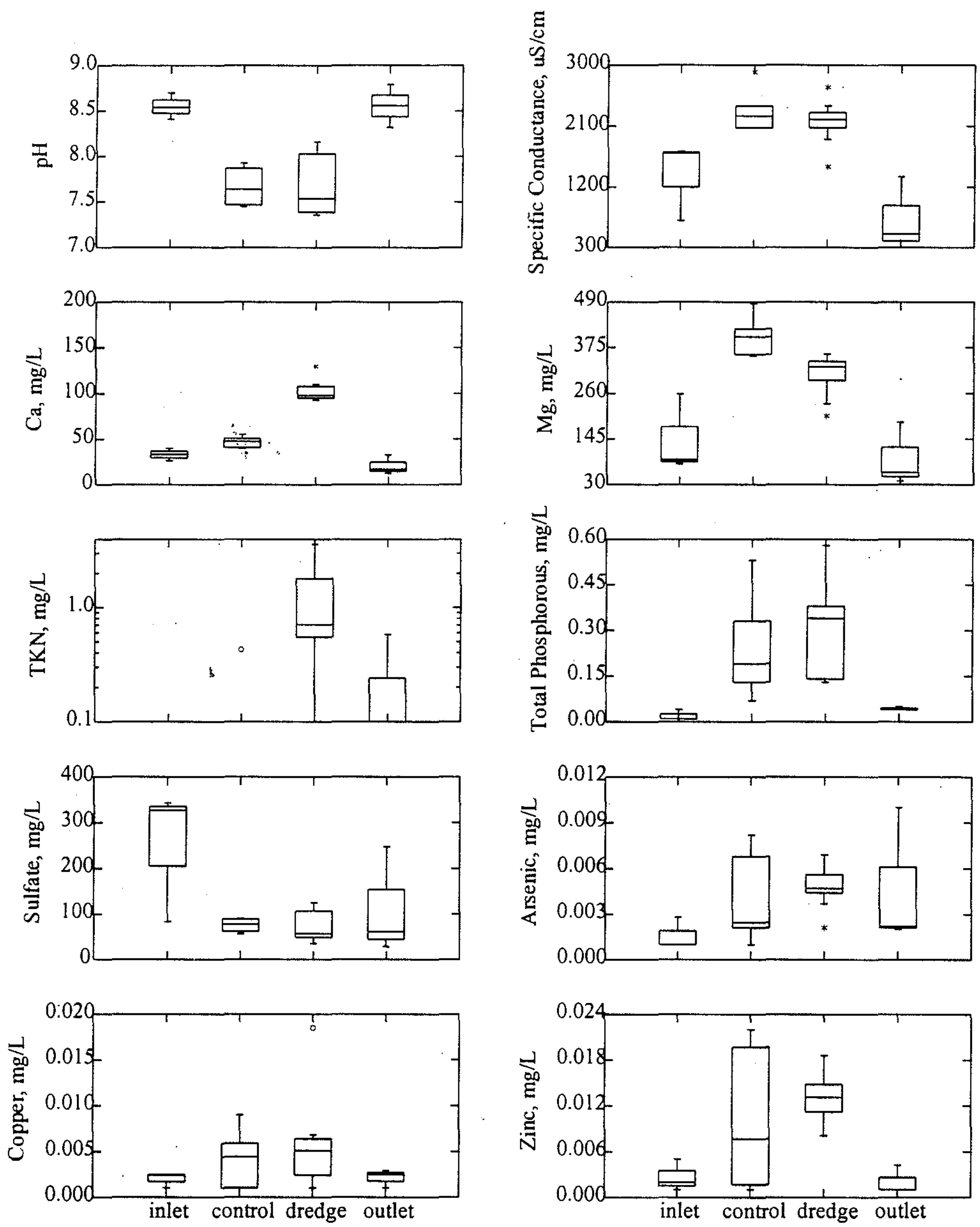
The primary objective of this project was to determine if dredge material would be a suitable substrate for wetland creation in tailings basins. A secondary objective was to compare vegetation success of the dredge material to other locally available amendments. Three seed mixes were used to examine their usefulness in wetland development. These seed mixes were chosen based upon the hydrology of the sites, with the custom wetland seed mix applied at the wettest portion of the plot, Mn DOT 25A seed mix applied to the periodically wet portion and the SMR mix applied to the dry, upland portion of the plots.

Tailings vs. Dredge Material (North Site)

Effect of Amendment

In both sampling years (1998 and 1999), the dredge plot seeded with the standard reclamation mix had a higher percent cover and biomass than the control (unamended tailings). Percent cover on the dredge plot exceeded 90% for both 1998 and 1999, while percent cover was 27 and 48% for the control. Maximum biomass was measured on the dredge plots in 1998, and was almost 20 times

Figure 13. Chemical data from the wells, inlet and outlet at the North site, 1999.



Notes: The boxes for the inlet and outlet each represent three values. The boxes for the control and dredge combine all values from the treatment and contain six to nine values. In the TKN (Total Kjeldahl Nitrogen) plots, the values are plotted on a log scale to provide a better visual representation of the data. Some values are $\leq$ 0.1 mg/L and do not appear in the box plots.

Table 10. Water quality results (average concentrations per treatment) from the North site, 1999.

		Well[1]		Surface[2]			Surface Water[3] Standards (mg/l)
	Inlet	**Control**	**Dredge**	**Control**	**Dredge**	**Outlet**	
pH	8.55	7.67	7.68	8.26	8.01	8.56	6.5 - 9.0
Alkalinity	690	1700	1520	540	540	380	
Specific Conductance	1380	2320	2150	1000	990	720	
Major Cations/Anions:							
Calcium	33	47	103	29	39	21	
Magnesium	145	404	304	145	159	96	
Sodium	29	23	23	25	27	20	
Potassium	4.3	4.9	5.4	4.0	5.9	3.2	
Chloride	4.2	2.4	2.3	2.3	2.2	2.2	230
Sulfate	251.0	75.3	76.3	125.7	105.9	112.1	
Nutrients:							
Total Kjeldahl Nitrogen	0.10	0.16	1.43	0.76	0.85	0.26	
Ammonia-Nitrogen	0.02	0.02	0.09	0.04	0.04	0.02	0.04[5]
Nitrate-Nitrogen [4]	2.1	<0.4	<0.4	<0.4	<0.4	<0.4	
Total Phosphorous	0.02	0.24	0.31	0.07	0.11	0.04	
Trace Metals:							
Arsenic	0.002	0.004	0.005	0.002	0.002	0.002	0.053
Barium	0.009	0.029	0.100	0.003	0.017	0.003	
Cadmium*							0.0015 - 0.0034
Chromium*			0.002				0.011[6]
Cobalt*		0.002	0.002				0.005
Copper	0.002	0.004	0.006	0.002	0.003	0.002	0.015 - 0.023
Lead*							0.008 - 0.019
Mercury*							0.000007
Nickel			0.002		0.002		0.283 - 0.509

Table 10. Water quality results (average concentrations per treatment) from the North site, 1999 (continued).

		Well[1]		Surface[2]			Surface Water[3] Standards (mg/l)
	Inlet	**Control**	**Dredge**	**Control**	**Dredge**	**Outlet**	
Selenium*	0.007						0.005
Silver*							0.001
Zinc	0.003	0.010	0.013	0.003	0.004	0.002	0.191 - 0.343

[1]Water quality values for the wells were derived from the following three sampling dates: July 6, 1999; July 19, 1999; and September 20, 1999.

[2]Water quality values for the surface water were derived from the following three sampling dates: April 1, 1999; July 19, 1999; and September 20, 1999.

[3] Surface water quality criteria (chronic standard) for 2B waters (aquatic life and recreation, non-drinking water). Standards for the trace metals are a function of water hardness. A range of 200 mg/L to 400 mg/L was used to compute chronic toxicity values for Cd, Cu, Pb, Ni, Ag and Zn. Metals that do not currently have a standard were left blank. Reference: Minnesota Rules, 1997, Chapter 7050.0222, Waters of the State (http://www.revisor.leg.state.mn.us/arule/7050/0222.htm).

[4] Values for nitrate-nitrogen were from the September 20 sampling date only. Values for other dates were anomalus and could be due to laboratory error (Appendix 2).

[5]Ammonia standard is for un-ionized ammonia. The fraction of the total ammonia that is un-ionized is a fraction of water temperature and pH and is calculated from the following equations:

$$f = \frac{1}{10^{(pKa-pH)} + 1} \times 100$$

where f = the percent of total ammonia in the un-ionized state
and pKa = 0.09 + (2730/T) is the dissociation constant for ammonia

f increases as pKa decreases (temperature increases) and pH increases, pKa ranges from 10.09 at 0°C to 9.25 at 25° C, when pH = pKa, f = 0.5. The maximum value of f for all samples in this study was 0.18.

[6] The chromium standard was based on Cr^{+6}, standard values for Cr^{+3} ranged from 0.365 to 0.644mg/L (water hardness of 200 to 400 mg/L).

*Values for Ag, Cd, Co, Cr, Ni, Pb were less than the detection limit of 0.002 mg/l (unless otherwise noted), and all Hg values were less than the detection limit of 0.001 mg/l.

greater than the control. In 1999 biomass increased on the control and decreased on the dredge plot, but biomass on the dredge plot was still almost four times greater than the control (Table 11, Figure 14).

Effect of seed mix

Although percent cover and biomass were highest with the standard reclamation seed mix, both percent cover and biomass in all sections of the dredge plot with the MNDOT 25A and custom seed mix were substantially greater than the control (Table 11). Percent cover and biomass decreased in the MNDOT 25A plot in 1999 and it was not possible to get a representative value for the custom portion of the plot since it was almost entirely under water at the time of the survey.

Redtop (*Agrostis alba*) was one of the major species on all the plots in 1999, and contributed from 25 to 50% of the overall cover on the control (unamended tailings) and custom portion of the dredge plot to greater than 75% on the dredge plot with the SMR seed mix. The only other species to contribute more than 25% cover occurred in the dredge plots with the MNDOT 25A and custom seed mix. In the 25A mix, these species were yellow sweet clover (*Melalotus officinalis*) and timothy (*Phleum pratense*), both upland species. Dominant species in the plots with the custom mix included the pre-existing invasive wetland species, cattails (*Typha sp*), giant reed grass (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*).

Species richness, the number of species present, is an indicator of plant diversity. A higher number of species indicates a more diverse and often healthier community. Species richness declined in 1999 in all portions of the plots with the exception of the dredge plot with the MNDOT 25A seed mix. The total number of species in 1999 ranged from 11 for the custom mix to 14 for both the MNDOT 25A and the SMR mix in the control. The number of wetland species also declined in all sections and ranged from 4 species in the 25A mix to 8 in the custom mix (Table 11).

The majority of the wetland species identified in the plots were those that existed in the area prior to plot construction and were dominated by two invasive species, cattails (*Typha* sp), and giant reed grass (*Phragmites australis)*. Only three of the wetland species that were identified had been seeded. The cattails and giant reed grass had invaded the bottom portion of each plot, and covered about 25% of the custom seed mix plot.

Smart weed which had contributed over 25% of the cover in the dredge plots in 1998 virtually disappeared. The cover crop, annual rye, also disappeared in 1999.

Dredge vs. Other Amendments (South site)

Effects of Amendments

Biomass and percent cover were used to compare vegetative success among amendments, while species richness was used to compare diversity of plant communities. Three seed mixes were applied to each amendment plot according to moisture conditions at the site (SMR, MN DOT 25A, Custom). The results for each seed mix are presented separately since no one amendment produced the best results with all mixes. All vegetation data for the South site is contained in Appendix 1.

SMR (upland)

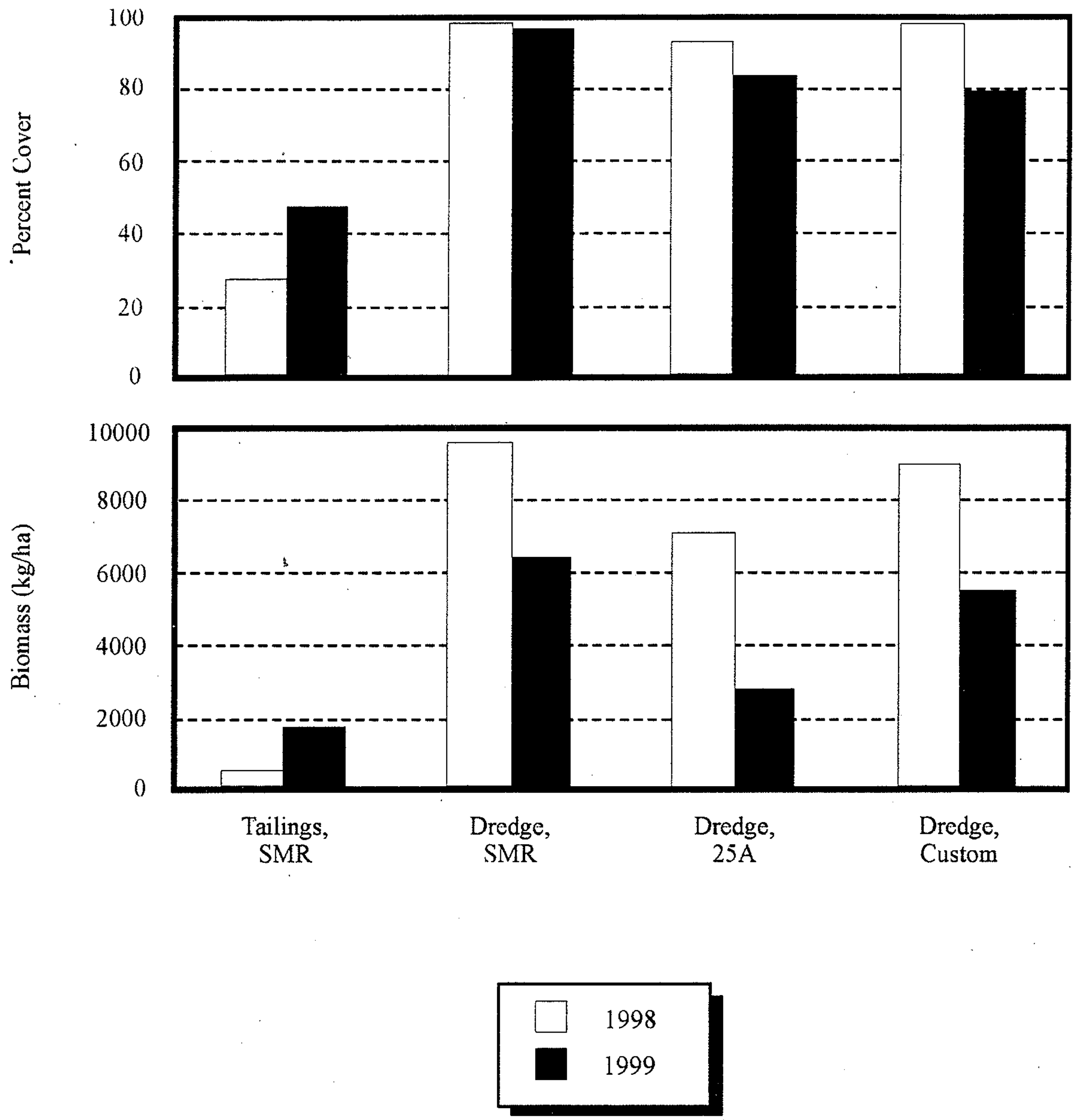
Percent cover and biomass increased in all plots in 1999 and vegetation on all of the amended plots was much more successful than on the control. Percent cover ranged from 61% for the ½ inch dredge plot to 84% for the 1 inch of topsoil, both well above the 28% for the unamended control. Biomass was greatest on the ½ inch dredge plot, and all the amended plots produced at least twice as much biomass as the control (Figure 15, Table 12).

Table 11. Vegetation results from the North site plots.

Treatment	Seed Mix	Percent Cover		Biomass (kg/ha)		Total Species Planted	Species Richness		Wetland Species Present		Comments
		1998	1999	1998	1999		1998	1999	1998 [3]	1999 [3]	
Control (no amendment)	SMR	27	48	481	1706	7	19	14	8 (5)	6 (1)	4 species pre-existing in plot
6" Dredge Material	SMR	99	98	9461	6527	7	21	12	13 (6)	6 (2)	2 species pre-existing in plot
	MN DOT 25A	94	85	7043	2795 [2]	37	11	14	7 (1)	4 (2)	
	DNR Custom Wetland	98	80 [1]	8888	5513 [2]	37	22	11	14 (3)	8 (1)	5 species pre-existing in plot

[1] The percent cover value was determined by a visual estimate (not the point quadrat method) due to high water and the invasive plant species.
[2] Four biomass samples were collected for the MN DOT 25A mix, and two for the Custom Wetland seed mix.
[3] Numbers in parentheses indicate the number of wetland species (facultative or obligate) present that were planted initially, a higher number of wetland species present than planted indicate species that were either pre-existing or invasive species.

Figure 14. Percent cover and biomass of vegetation at the North site.



[1] The percent cover value for the Dredge, Custom-mix plot was determined by an overall visual estimate (not point-quadrat method) of the entire plot.

[2] Biomass for the Dredge, MN DOT 25A mix-plot was based on four subsets.

[3] Biomass for the Dredge, Custom mix-plot was based on two subsets since a portion of the plot was under water and the presence of invasive species.

MN DOT 25A (fringe area)

This plot is located upslope of the water line and below the upland plots. The area was expected to be periodically wet, and the seed mix was a standard MN DOT mix designed for wet meadow and ditch areas.

In 1999 percent cover and biomass increased in all plots, with percent cover approaching 100% in all plots except the control, which had only 55% cover. Biomass ranged from 3250 kg/ha to 5600 kg/ha for the amended plots, four to nine times greater than the control. Total species increased markedly in most plots, but the number of wetland species remained relatively low (Table 13, Figure 15).

In the first year the dominant species on all plots was the cover crop annual rye, which comprised 50 to75% of the total cover. Smart weed (*Polygonum pensylvanicum* L.) was prevalent on the two dredge plots and accounted for 25 to 50% of the total cover.

By the second year, the annual rye (*Lolium multiflorum* L.) and smart weed had essentially disappeared and the major species identified were red clover (*Trifolium pratense*) and timothy (*Phleum pratense*). These two species accounted for 50 to 100% of the cover in the plots (Appendix 1).

Custom (shoreline)

This section was immediately adjacent to and in the water. The portion of the plot not under water at seeding time was planted with primarily obligate wetland species.

Water levels were substantially higher in 1999 than in 1998 and as much as one-half of the amendments were eroded by wave action. The largest loss of shoreline occurred in the glacial overburden plot. Since most of the remaining plots were under water at the time of the percent cover and biomass measurements, it was not possible to obtain quantitative results using the same methods used in 1998. An overall visual estimate of the plot was used to rank the amendments. Percent cover was greatest on the topsoil and 6 inch dredge plot and lowest in the control. Percent cover rankings for the other plots were:

Top soil ≈ 6 inches dredge > 4 inches dredge ≈ black dirt > overburden > control

Although there was no consistent change in the total number of species present, the number of wetland species increased in all the plots except the overburden. The increase in the number of wetland species ranged from 2 in the black dirt plot to 8 in the topsoil plot (Table 14, Figure 15).

Both dredge plots, the topsoil and black dirt plots had 9 to 11 wetland species. Despite the increase, there were only a few plants of each species in the plots with most of the plots being covered by barnyard grass (*Echinochloa crusgalli*), an early colonizing species, redtop (*Agrostis alba*), included in the SMR seed mix, timothy (*Phleum pratense*), and reed canary grass (*Phalaris arundinacea*), an aggressive species common in wet areas. Smart weed and the cover crop perennial rye, which were the dominant species in 1998, were reduced to a few isolated plants by 1999.

Table 12. Vegetation results of the SMR mix plots at the South site.

SMR MIX (upland)								
Treatment	% Cover		Biomass (kg/ha)		Species Richness [1]		Wetland Species Present [2]	
	1998	1999	1998	1999	1998	1999	1998[3]	1999[3]
Control	17	28	91	565	9	13	1 (0)	2 (1)
1" Overburden	34	72	480	1217	9	5	1 (0)	0 (0)
1" Topsoil	47	84	492	2156	12	8	3 (0)	1 (1)
1" Black dirt	41	65	839	1155	11	8	2 (0)	1 (1)
1" Dredge	39	64	705	1542	13	8	3 (0)	2 (1)
½" Dredge	33	61	800	2470	10	9	2 (0)	2 (1)

[1] The SMR mix contained 7 plant species.
[2] Two of the seven species in the mix were facultative species, and are found in wet areas.
[3] Numbers in parentheses indicate the number of wetland species present that were planted initially, a higher number of wetland species present than planted indicate species that were either pre-existing or invasive species.

Table 13. Vegetation results of the MN DOT 25A mix plots at the South site.

MN DOT 25A MIX (Fringe)								
Treatment	% Cover		Biomass (kg/ha)		Species Richness [1]		Wetland Species Present [2]	
	1998	1999	1998	1999	1998	1999	1998[3]	1999[3]
Control	16	55	85	684	7	15	2 (0)	4 (1)
6" Overburden	68	98.5	2066	5147	10	9	3 (1)	3 (1)
6" Topsoil	52	99.5	4710	3251	8	7	2 (0)	2 (0)
6" Black dirt	85	99	3153	4084	8	16	4 (1)	4 (1)
6" Dredge	94	96	3947	5400	7	13	4 (1)	3 (1)
4" Dredge	91	98.5	4582	5592	6	10	3 (0)	6 (1)

[1] The MN DOT 25A mix contained 37species.
[2] Twenty-six of the 37 species in the mix were wetland species.
[3] Numbers in parentheses indicate the number of wetland species present that were planted initially, a higher number of wetland species present than planted indicate species that were either pre-existing or invasive species.

Table 14. Vegetation results of the DNR Custom wetland mix plots at the South site.

DNR CUSTOM WETLAND MIX (shoreline)								
Treatment	% Cover		Biomass (kg/ha)		Species Richness [2]		Wetland Species Present	
	1998	1999[1]	1998	1999[1]	1998	1999	1998[3]	1999[3]
Control	18		355		6	7	2 (0)	5 (1)
6" Overburden	58		2486		10	5	4 (1)	3 (1)
6" Topsoil	80		6486		7	11	2 (0)	10 (2)
6" Black dirt	74		2949		12	11	7 (0)	9 (2)
6" Dredge	75		5443		11	15	6 (2)	11 (3)
4" Dredge	91		3112		11	11	7 (1)	10 (3)

[1]It was not possible to make quantitative measurement of percent cover and biomass in 1999 due to shoreline erosion and because part of the plot was under water.
[2]The Custom Wetland mix contained 37 wetland species.
[3] Numbers in parentheses indicate the number of wetland species present that were planted initially, a higher number of wetland species present than planted indicate species that were either pre-existing or invasive species.

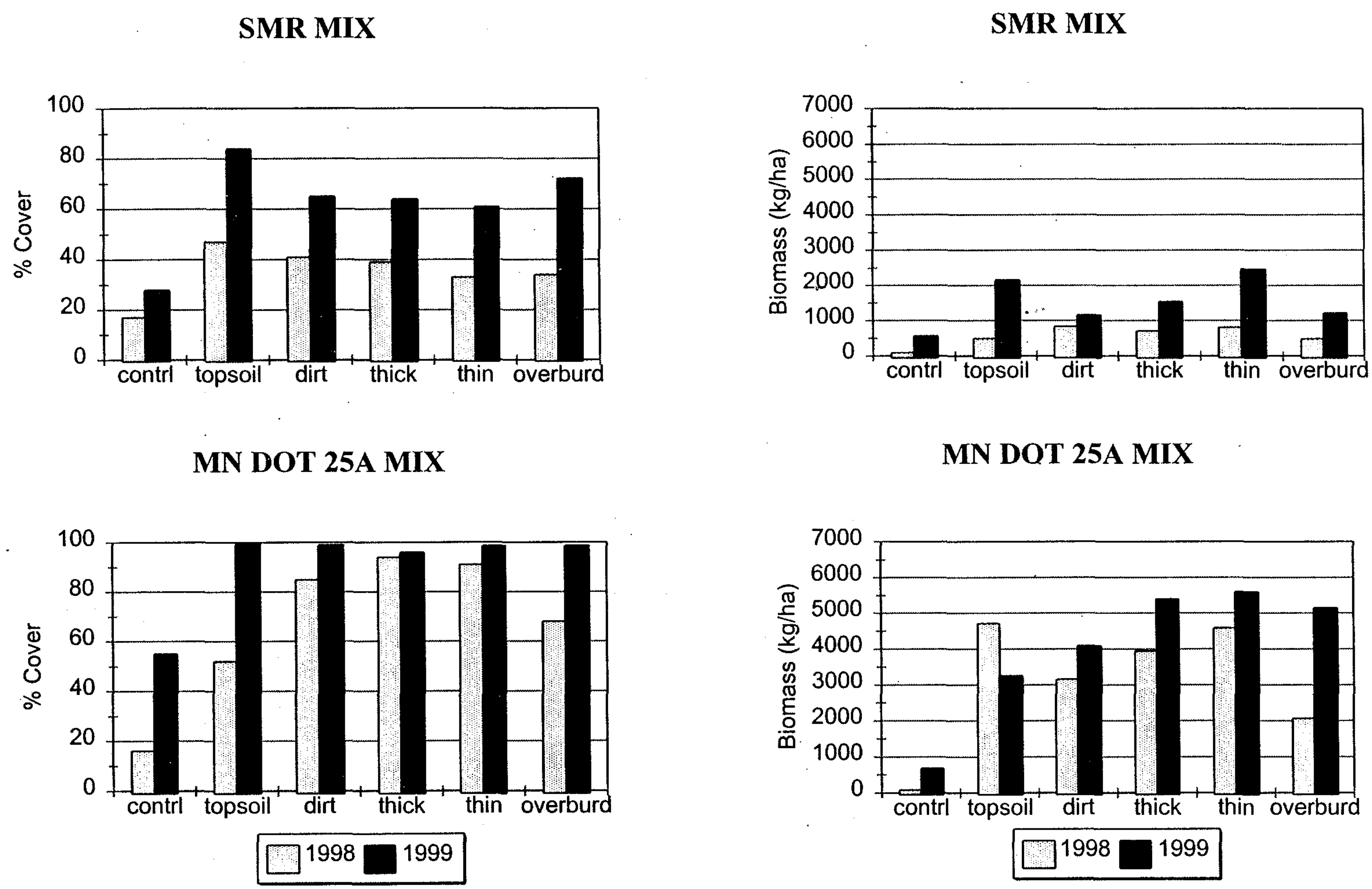
Discussion

Amendment Chemistry

A variety of criteria were used to judge the acceptability of the dredge material for use in wetland creation in tailings basins. In general, regulatory standards are not as restrictive for application to upland areas, where the material will not be in contact with water. Trace metal and organic concentrations in the dredge were well below requirements for class 1 compost and exceptional quality sludge. In general, when compost or sludge meet these requirements they can be applied to upland sites without restriction. Currently there are no Minnesota standards for the use of material as a substrate for wetland creation. The Minnesota Pollution Control Agency has been using guidelines for open water disposal developed by Ontario. These criteria do not actually specify safe or acceptable values; rather they establish concentrations from which they expect effects ranging from low to sever.

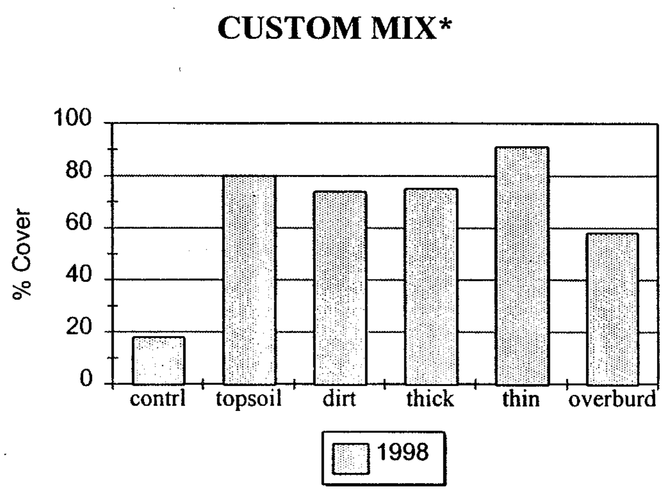
The low effect concentrations are extremely low, such that natural background concentrations prior to non-indigenous settlement for cadmium, chromium, nickel and copper exceed the low effect levels (Table 6). In the case of the dredge, nickel, mercury, arsenic and copper exceeded the recommendations, but were near the acceptable level. The concentrations in the dredge material were in the range of natural background levels for soils in the area, and for some parameters were lower than the tailings themselves.

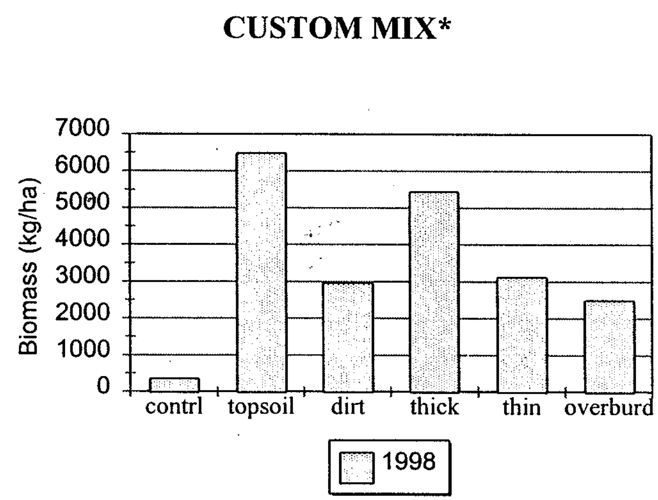
Figure 15. Page 1 of 2. Percent cover and biomass of vegetation at the South site.



Note: The labels called "thick" indicates 6" of dredge, while the labels called "thin" refer to 4" of dredge. The label called "dirt" refers to black dirt (a mixture of peat and sand).

Figure 15. Page 2 of 2. Percent cover and biomass of vegetation at the South site.





Note: The labels called "thick" indicates 6" of dredge, while the labels called "thin" refer to 4" of dredge. The label called "dirt" refers to black dirt (a mixture of peat and sand).

* Percent cover and biomass were not measured on the Custom mix plots in 1999 due to shoreline erosion and a portion of the plot was covered with water.

The low concentrations of contaminants in the dredge material reflect the overall improvement in dredge quality over time as more and better pollution control measures have been initiated for the discharges to Lake Superior. Sediment currently removed from the lake almost always meets the low effect level in the Ontario guidelines. As a result, the US Army Corps of Engineers has requested permission to place new dredging material into deep holes in Lake Superior (D. Bowman, personal communication, 1999).

The concentrations in this dredge material are somewhat lower than typical concentrations for material from the Erie Pier Disposal Site. Additional samples were collected and historic data was compiled as part of a large scale wetland creation project to be conducted at EVTAC Mining in Eveleth, MN. Concentrations in most of the pier are higher than the material used in this study, but a large fraction would still meet the criteria for wetland creation (Eger et al., in preparation).

Representatives of the Corps of Engineer believe that some of the material used in this study originated from a channel widening project, which involved removing some native sediments that had never been previously disturbed, and could explain the slightly lower concentrations. (A. Klein, personal communication, 1999).

<u>Material Placement</u>

At both sites, the amendment near the bottom of the slope could only be worked once or twice because of the unstable tailing. The greatest concern was not that the equipment would get stuck, but that it created ruts. The more the site was worked, the deeper the ruts the equipment created. These ruts caused an uneven distribution of amendment.

It turned out to be fairly difficult to back drag the proper amount of material and the result was varying thicknesses of material across the plots. Generally, most material ended up near where the piles originally stood and less material was along the up slope edge and plot corners. At the North site, a better distribution could have been achieved if the dredge material had been placed at the top of the slope rather than at the bottom, since it was easier to push the material than back drag. It may have been possible to distribute the material a little more evenly on the upper half of the slopes where the underlying tailings were firm, but it was not clear that the additional effort would have improved the distribution significantly. Spreading results in a large project will probably be similar to those in this project.

<u>Dredge Thickness</u>

Originally, one of the plots at the South site was to receive freshly dredge material. If dredge spoils could be loaded directly for shipment to the site, the material would not be handled twice and overall costs would be reduced. In the past, dredge material typically had been removed from the barge mechanically and then moved with water to separate the coarse and fine fractions. In 1997, however, the material was moved hydraulically directly from the barge into the disposal facility. Therefore, it was impossible to obtain a representative sample of freshly dredge material. Rather than eliminate a plot, it was decided to apply less dredge (4 inch) to the second dredge plot.

This depth was selected based on previous studies conducted by the DNR at the former Butler tailings basin. Vegetative growth was evaluated on plots with 2 and 6 inches of peat and overburden amendments on fine tailings (Melchert et al., 1996). Percent cover and biomass on 2 inches of amendment was markedly greater than on the unamended tailings but less than on the 6 inch plots (Eger, et al., in preparation). Based on these results an intermediate depth of 4 inches was chosen for this plot.

After two years there was little difference between percent cover, biomass and species composition between the 4 inch and 6 inch plots. The plots will be evaluated at 3 and 5 years to determine if there is any difference in the wetland community that develops.

Climate

The hot dry summer of 1998 may have reduced vegetative success during the first growing season, but percent cover increased on most of plots during the extremely wet 1999 growing season. Percent cover on most of the unamended tailings plots was within the range observed in previous studies (Melchert et al, 1993; Eger et al., 1999). The only exception was on the upland portion of the control, at the South site, where vegetation was unable to recover from the poor growing conditions in 1998.

Water Levels

At the North site, the water level and the amount of wetland shoreline was controlled by the outlet elevation and the rate of inflow into the wetland. During the wet summer of 1999, water depths up to about 8 inches were observed in the culvert. When the water elevation was at the outlet level of the culvert about 20 feet of the plots were covered by water (Figure 10, Appendix 4). Since the slope of the plots is about 10 percent, for every inch of water in the culvert an additional 10 inches of shoreline would be inundated. At the maximum observed water level in the pond, an additional 7 feet of the plot would have been periodically covered by water.

At the South site water left the pond through seepage so water level continued to rise during the wet summer of 1999. The slope at the South plot was about 10%, so for every one foot of water rise an additional ten feet of shoreline was covered.

Water covered the bottom portion of the custom plots at the South site for most of 1998 and all of 1999. In 1999 water covered the entire custom plot for the month of July and early part of August and covered about one-half the MNDOT 25A plot after the record July 4th rainfall.

Water Quality

With the exception of calcium and magnesium, there was no major difference in water quality between the dredge and control plots. Average values for all parameters in the dredge and control plots, for both surface and groundwater data, are all below water quality standards as cited in Minnesota Rules 7050 (Table 10).

There was some variation among the samples from within each treatment as can be seen from the spread in the box plots (Figures 12 and 13). Data from each site was limited to three values and box plots for each individual site are included in Appendix 2.

One of the major concerns with land applying waste materials, particularly in saturated environments, is the potential release of trace elements. As a result, land application requirements for placement in saturated environments range from about 7 to over 100 times lower than for application to unsaturated upland sites (Table 6). Trace metals in the dredge material applied at National were all below or near the low effect level in the Ontario guidelines, and so no release of metals was expected. Most of the trace elements were not detected in the water samples and even the more common micro-nutrients, copper and zinc, were below 0.025 mg/L.

The only parameters that were slightly elevated were phosphorous and total Kjeldahl nitrogen (TKN). The phosphorus concentrations could be related to the 550 lb/acre of 18-46-0 fertilizer that was added to the plots during planting in 1998. TKN is the sum of organic nitrogen and ammonia nitrogen, and since the variation in the ammonium nitrogen was small, the difference is related to a variation in the amount of organic nitrogen in the samples. The concentrations in the dredge plot were within the range observed in the surface water of groundwater fens in Minnesota (Clausen et al., 1980). Typical values ranged from 0.29 to 0.87 mg/L for TKN, and from 0.05 to 0.13 mg/L for total phosphorous.

Vegetation

One of the goals of this study was to determine if dredge material would provide a suitable substrate for wetland development. Vegetation did well on all the dredge plots at both the North and South sites. After two growing seasons, there was little overall difference between the dredge plots, the topsoil and the black dirt. Good growth was observed on the glacial overburden plot with the standard reclamation mix and the MNDOT 25A mix, but only three wetland species were observed on the custom portion of the plot. Dredge material was clearly superior to the unamended tailings control, as demonstrated by the two-fold difference in percent cover and biomass measurements at the North site.

Despite planting a wide variety of species, only 5 of the 37 wetland species in the custom mix were identified. The original plan was to seed the plots in the fall, since fall or late summer is a common time to create wetlands. During the fall, conditions are relatively dry, outlet controls can be installed, and wetlands fill with water the following spring when the seeds are ready to germinate. Many native seeds have built in dormancy mechanisms that keep them from germinating too late in the growing season and in times of drought. A fall seeding provides the early spring conditions needed by many species to break dormancy and assure that seed germination occurs under suitable conditions, thereby providing a good chance of survival. If conditions are not favorable, the seeds will remain dormant, possibly for tens of years. Various delays precluded a fall seeding. Since the seeds had already been mixed, it was not possible to change the mix which included winter wheat as the major cover crop. No winter wheat was observed in any of the plots. This may have been due to predation by geese or poor germination.

In the wetland portions of the plots, at the end of the first growing season, only one or two of the species that were seeded were actually identified, which was expected. Most sedges, rushes, and forbs require cold-moist stratification before they will germinate and most grasses require cold, dry storage over the winter prior to germination (Appendix 5 in Melchert, et al., 1996). The seeds used in this project were kept in dry, cold storage for about six months prior to seeding in the spring. This means that most of the sedges, rushes, and forbs will not germinate and grow until the next spring after undergoing natural stratification through the winter. Most of the grasses should have germinated the first year, if proper moisture conditions existed. Most native perennial grasses do not grow very large their first year but instead expend their energy developing a root system. As a result, these plants are usually not recognizable until their second year of growth when seed heads often develop.

Proper hydrology is also a very important factor in determining the germination success of native seeds. If soil moisture and light conditions are not correct, many seeds will not germinate and instead go into dormancy until proper conditions occur (Appendix 5 in Melchert, et al., 1996). It is possible that many of the species did not germinate the first year or they germinated and died because of the summer drought. In 1998, the pond at the North site was dry for most of the growing season (Figure 10). There was moisture along the shoreline at the South site, but unfortunately, seeding took place under high water conditions which meant that the moist soil that was exposed as the shoreline receded did not have any seeds.

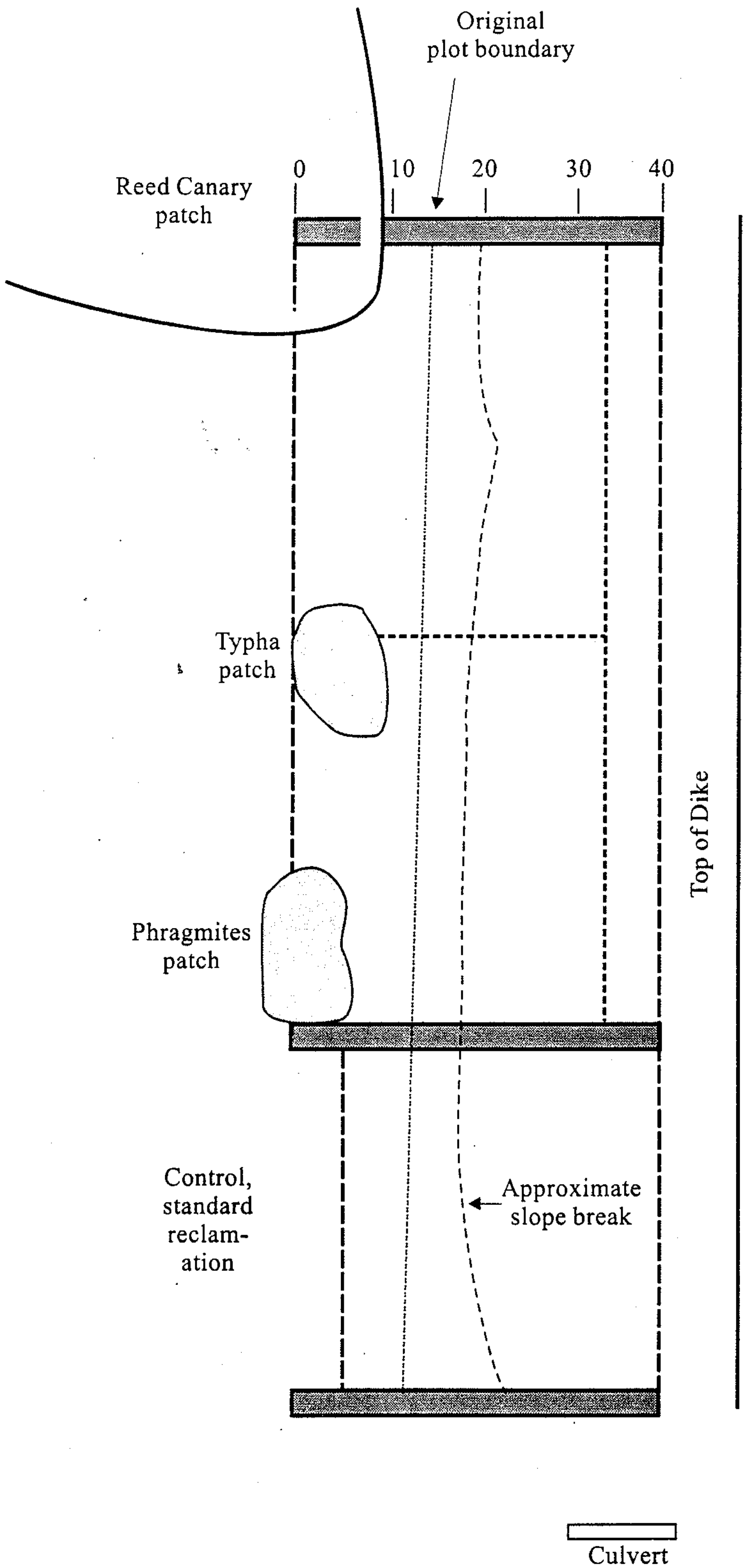
Water levels rose substantially at both sites in 1999 and periodically inundated 20 to 30 feet of the North plot and 10 to 20 feet of the South plot. Several additional wetland species were observed, including three that had been planted (Table 16, Appendix 1).

Additional species could have been present in the plots but were not observed, due either to a small number of plants or no identifiable (visual) seed structure. Most of the seeded species that have been identified are the forbs which tend to be more easily identified due to their leaf structure and flowers. It is possible that some of the grass and sedge species have germinated but were not observed during the flowering stage, and as a result, were not identified. Additional observations will be made next year throughout the growing season to identify additional species. Since a complete evaluation of wetland creation projects is not typically completed until after five growing seasons, the vegetation results must be considered preliminary.

Some of the early colonizing species (e.g. smartweed) and the cover crop (annual rye) which were dominant in 1998 disappeared in 1999, and more of the seeded species have been observed (plantain, arrowhead). Red clover which was the dominant cover on the MNDOT 25A plots at the South site was not part of the original seed mix and its source is unknown.

A large number of species were included in the custom mix in order to determine which species could grow in wetlands created on tailings. It is too early to determine which species will be ultimately successful, except that wetland seed was not effective when invasive vegetation was present. At the North site cattail (*Typha* sp.) and giant reed grass (*Phragmites* sp.) invaded to cover about 25 % of the custom seed portion, and small portions of the two SMR plots. Since the dredge material was spread beyond the area scraped of vegetation these species were already present in the bottom 10 to15 feet of the plots (Figure 16). Despite cutting, and despite direct application of

Figure 16. Location of invasive vegetation at start of the study.



herbicides in both 1998 and 1999, it was not possible to stop the spread of these species. Since the plants of these species can exceed 6 feet in height and form a very dense cover, they can easily out-compete the seeded species.

Purple loosestrife, a plant classified as a noxious weed, exists within the Erie Pier (Eger et al., in preparation). The dredge material used in this study was collected outside the main area of loosestrife infestation at the Pier, but several isolated plants had been observed near the excavated site. At NSPC, two plants were pulled in 1998, and no additional plants were found in any of the plots in 1999.

Costs

To create a viable wetland, it will likely cost more than the $500/acre mining companies currently spend to reclaim tailings. Currently, companies may be able to purchase wetland credits from a wetland bank instead of replacing the wetlands they disturb. Wetland credits typically cost $0.10 per square foot of wetland, or $4350 per acre. If wetlands can not be created at a cost lower than this figure, companies may consider purchasing credits rather than mitigating on site. However, companies may be willing to pay more to create a diversified wetland community along the shore and fringe area of a pond, particularly if their replacement ratios can be reduced. The replacement ratio is defined as the number of acres of created or restored wetlands divided by the number of acres disturbed. Since the Wetland Conservation Act was passed in 1992, a replacement ratio of 1:1 has been applied for wetlands disturbed by mining. This ratio was derived based on the mining companies' restoration of off-site drained areas, or creation of wetlands on non tailings areas. NSPC is the first company to propose creating wetlands in tailings basins as compensation for their wetland impacts. Since tailings are so infertile, wetland vegetation growing on unamended tailings has not been found to be as vigorous or diverse as the vegetation in natural wetlands. Therefore, it has not yet been decided if NSPC will receive credit for the wetlands created on tailings on a 1:1 basis or if the ratio will be higher. If the tailings, at least along the shoreline, are amended with a fertile top dressing, a healthier wetland should develop and the resulting replacement ratio should be very close to 1:1. Since the flooded area counts as wetland, a higher per foot cost for the shoreline may be justified if the overall quality of the wetland is improved.

Our costs, due to the limited scale, were probably higher than would be expected on a large scale project. Amendment costs range from $4,800 per acre for 6 inches of local overburden to $16,000 per acre for 6 inches of dredge material (Table 15). Dredge material was the most expensive since the one way haul distance was on the order of 75 miles. For a large scale project to be cost effective, a cheaper form of transportation would be needed.

For a large scale wetland creation demonstration project at EVTAC mining, transportation of dredge material from the DMIR railhead in Duluth, MN to EVTAC (Eveleth, MN) will be $6/yard. The cost of removing the material from the Erie Pier Disposal Facility and transporting it the one-half mile to the railhead has been estimated to be about $3 per yard. To move the dredge material from the railhead to the reclamation site would cost an additional $2 to $4/yard depending on the haul distance. Using $3 per yard, the overall cost would be $12 per yard or two-thirds of the cost for the truck transport to National. If the dredge material was hauled by rail, 4 inches of dredge would cost $7,500, less than the 6 inch plot of black dirt, and about 10% more than 6 inches of

Table 15: Wetland Creation Costs.

Substrate Cost	Normal Thickness	Yards Required Per Acre[1]	Costs Per Yard		Spreading	Total	Total Cost Per Acre
			Material	Transport			
Dredge	4" 6"	540 800	0 0	18[3] (12)[4] 18 (12)[4]	2 2	20 20	10,800 (7,500)[5] 16,000 (11,200)[5]
Topsoil	6"	800	2.5	4[2]	2	8.5	6,800
Black Dirt	6"	800	9	5[2]	2	16	10,800
Overburden	6"	800	0	4[2]	2	6.0	4,800

Seeding Cost:	Seed Mix	Cost/Acre
	Standard mineland reclamation:	$ 350[6]
	MNDOT 25A:	885[7]
	Custom seed mix:	2,030[7]

[1]"Loose" material, as hauled, settled thickness will be less than the nominal values.
[2] Estimated cost to load and haul to project site.
[3]Truck transport from Erie Pier CDF in Duluth.
[4]Estimated cost to remove material from Erie Pier and have rail hauled to the mine site, and truck hauled from the railhead to the reclamation site.
[5]Cost using rail haul.
[6] Contract price paid by NPSC, typical range for other operations is $450-500/acre.
[7]The total cost was estimated by adding the cost of the seed mix to the cost of standard mineland reclamation.

topsoil. Six inches of dredge would cost $11,200, less than 5% more than the purchased black dirt (Table 15).

Seed costs ranged from $350 per acre for standard reclamation to $2,030 for the custom wetland seed mix. The custom seed mix contained 37 species which ranged in price from around $2/oz to $60/oz, with most species costing between $2-$10/oz. Since one of the objectives of the study was to determine what wetland species would grow, the custom seed mix was developed to include the largest number of available species, irrespective of cost (Appendix 7). After two years, five of the seeded species had been identified. However, most of these species were forbs, which are typically not the dominant species in a wetland (Table 13). Additional vegetation work will be done next year to determine which grass and sedge species are present, and a new seed mix will be developed based on these results. The total cost per acre for these amended plots with the custom seed mix ranged from $6,800 for glacial overburden to $18,000 for 6 inches of dredge mixture.

Although it appears that the cost per acre for these plots are exorbitantly high, the plots represent only the shoreline of the wetland. If the entire shoreline around the pond at the South site was reclaimed using 4 inches of truck hauled dredge material and a custom seed mix, the cost per acre would be about $12,800. There are about three acres of shoreline around the pond that would need to be reclaimed, but the total created wetland would include the 15 acre pond, for a total of 18 acres (Appendix 7). The net cost per acre of wetland would be on the order of $2,100, or less than one-half the typical cost of purchasing wetland credits from a wetland bank. If rail haul was available the cost would decrease to $1,600.

If topsoil or wetland soil needs to be removed as part of the mining operation, using them as a substrate for wetland creation projects would be a sound approach. From an overall sustainable development approach, it would not be a wise use of resources to mine soil from an undisturbed area to use in the reclamation of a disturbed area. Using dredge material, which originates as soil from the St. Louis River watershed, is a better use of resources than mining topsoil or wetland soil since it returns soil to the watershed and provides a beneficial use for a material currently seen as waste.

Conclusions

After two years, vegetative growth on all of the amendments was substantially better than the unamended tailings. Dredge material was one of the better amendments, but topsoil and black dirt produced comparable results. There was little difference in vegetative success between the 4 and 6 inch dredge plots, indicating that 4 inches of dredge would provide an acceptable substrate.

The dredge material produced no adverse impacts on water quality. No trace elements were released and all water quality data met water quality standards.

It is still too early to determine how many wetland species will ultimately grow. Only a few of the wetland species that have been identified were seeded (Table 16), but it will take several more

Table 16. Observed wetland species from the DNR Custom seed mix, 1999.

Species	Common Name	Indicator Status	Comments
Alisma plantago-aquatica	Water plantain	OBL	Present in all amended plots at South site
Carex sp[1]	Sedge	OBL	Present in all amended plots at South site (except overburden and control)
Sagittaria	Broadleaf arrowhead	OBL	Present in topsoil and dredge plots
Scripus validus[2]	Soft stem bulrush	OBL	Present in all plots (South and North)
Aster simplex willd.	Panicled aster	FACW	Present in 1998 at North site and in overburden and 6 inch dredge plot, not observed in 1999

[1] Specific species have not been identified, were included in the custom mix.

[2] Existed in the wetland (although not in the South plot area).

years to fully evaluate the species composition of each plot. Additional seeded species, including water plantain and arrowhead, were new species observed in 1999. Sedges and grasses are more difficult to identify until seeds are produced, which can take several years.

It is extremely difficult to establish a wide variety of wetland species if invasive species exist in the area. Despite repeated attempts to control them, cattails and giant reed grass continue to expand into the plots at the North site. It is more expensive to use dredge material than locally available glacial overburden or topsoil, but if rail haul is available the cost of using 4 inches of dredge is only about 10% more expensive than local topsoil. If the cost to ship the dredge material could be reduced by $5 per yard, 4 inches of dredge material would be no more expensive than glacial overburden. The use of dredge material not only creates a suitable growing environment, but also provide a beneficial use for a product that is currently considered waste.

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APPENDIX 1

VEGETATION

Attachment A1.1 Classification of wetland vegetation species - definitions.

Indicator status of the plant species covered in the text according to the National Wetland Inventory – Wetland Plant List.

Obligate (OBM): Plants that are always found in wetlands under natural conditions (frequency greater than 99 percent). However, they may persist in non-wetlands if planted there by man or in wetlands that have been drained, filled, or otherwise transformed into non-wetlands.

Facultative Wetland (FACW): Plants that are usually found in wetlands (67 to 99 percent frequency), and may occasionally be found in non-wetlands.

Facultative (FAC): Plants that are sometimes found in wetlands (34 to 66 percent frequency), but also occur in non-wetlands.

Facultative Upland (FACU): Plants that are occasionally found in wetlands (1 to 33 percent frequency) and usually occur in non-wetlands.

Non-wetland (UPL): Plants that occur in wetlands of another region, but are not found (less than 1 percent frequency) in wetlands in the region specified. If a species does not occur in wetlands in any region, it is not included on the list.

Drawdown (DRA): Plants that are typically associated with the drier stages of wetlands, such as mudflats.

A positive (+) sign following the indicator means that particular plant species has a tendency towards the higher end of the indicator category (more frequently found in wetlands), and a negative (-) sign means a tendency towards the lower end of the indicator category (less frequently found in wetlands).

The term "wetland species" is used in this report for all species, from facultative to obligate.

Attachment A1.2. Definitions of vegetation cover classes:

Definitions of cover classes (percent cover) for the point-quadrat method:

A modification of the method described in Raelson and McKee (1982) was used to determine vegetation cover. Vegetative cover was condensed into 8 classes and the mid-point of the cover class range was used as the percent cover values. This modification gave a more true value of overall percent cover of the plots.

Percent Cover	Class	Mid-point
0-1	1	0.5
1-5	2	3
5-25	3	15
25-50	4	37.5
50-75	5	62.5
75-95	6	85
95-99	7	97
99-100	8	99.5

Cover class definitions of species abundance in Tables A1.1 through A1.4.

Cover Class	Overall abundance in plot
5	<75 %
4	50 to 75 %
3	25 to 50 %
2	5 to 25 %
1	1 to 5 %
+	0.5 % (few)
-	0.25 % (solitary)
P	present, abundance not measured

Portions of the amendments in the custom mix plots at the South site eroded prior to the vegetation survey in 1999. Therefore, no quantitative measurements were taken and all the species observed were marked as P (present) in Table A1.4.

Table A1.1. Page 1 of 2. Species list of vegetation from the North site, August 31, 1998.

Cover class (abundance): 5 >75%; 4 = 50 -75%; 3 = 25-50%; 2 = 5-25%; 1 = 1-5%; + = 0.5% (few); - = 0.25% (solitary).

Genus	Species	Common Name	Indicator Status	25A Dredge	Seeded	Custom Dredge	Seeded	SMR Dredge	SMR Control	Seeded
Agropyron	repens	Quackgrass	FACU	1		1		2	1	
Agrostis	alba	Redtop	FACW			1	**	2	2	yes
Amaranthus	retroflexus	Green Amaranth	FACU+			-		-		
Ambrosia	artemisiifolia L.	Common Rag weed	FACU			-				
Aster	simplex Willd.	Panicled aster	FACW	-		+	yes			
Chenopodium	album	Lambs Quarters	FAC-	1		+		1		
Chenopodium	glaucum	Oak-leaved Goosefoot	FACW			+			1	
Chenopodium	hybridum?	Maple-leaved Goosefoot	*						+	
Cirsium	arvense	Canada Thistle	FACU			-				
Echinochloa	crusgalli	Barnyard Grass	FACW	1				-	-	
Echinochloa	crusgalli var. frumentacea	Japanese millet	FACW					+		
Elymus	canadensis	Canada wild rye	FAC-	+	yes					
Epilobium	ciliatum Raf.	Willow herb	FACU			+				
Fagopyrum	esculentum	Buckwheat	*UPL						1	
Hordeum	jubatum	Foxtail Barley	FAC+	-		-		1	1	
Kochia	scoparia	Summer cypress	FACU-	-					-	
Lolium	multiflorum L.	Annual Rye	*	4	yes	4	yes			
Lolium	perenne	Perennial Rye Grass	FACU					2	3	yes
Matricaria	maritima L.	Scentless chamomile	FAC	+		1		-		
Medicago	sativa	Alfalfa	*UPL					1	2	yes
Melilotus	officinalis	Sweet Clover (yellow)	FACU					2	2	yes
Phalaris	arundinacea	Reed Canary Grass	FACW+			1	**	1		**
Phleum	pratense	Timothy	FACU			+		2	1	
Phragmites	australis	Common Reed	FACW+			2	**	1		**
Polygonum	pensylvanicum L.	Smartweed	FACW+	3		3		3	1	
Rumex	acetosella L.	Sheep sorrel	FAC			+				
Rumex	orbiculatus Gray	Water, Smooth Dock	OBL			+				

Table A1.1. Page 2 of 2. Species list of vegetation from the North site, August 31, 1998 (cont.).

Cover class (abundance): 5 >75%; 4 = 50 -75%; 3 = 25-50%; 2 = 5-25%; 1 = 1-5%; + = 0.5% (few); - = 0.25% (solitary).

Genus	Species	Common Name	Indicator Status	25A Dredge	Seeded	Custom Dredge	Seeded	SMR Dredge	SMR Control	Seeded
Salix	sp.	Willow	OBL?					-		
Salsola	kali	Russian Thistle	FACU						-	
Saponaria	officinalis	Bouncing Bet	FACU						1	
Scirpus	validus	Softstem bullrush	OBL			1	**yes		+	**
Secale	cereale L.	Rye grain	UPL*					+	1	yes
Sonchus	arvensis	Sow Thistle	FAC-	-		+		+	1	
Tanacetum	vulgare	Tansy	*	1		1		-		
Trifolium	hybridum L.	Alsike Clover	FAC-					2		yes
Typha	sp.	Cattail	OBL			1	**		+	**
Xanthium	strumarium L.	Cocklebur	FAC-					1		

*Species not found in the National List of Plant Species that occur in Wetlands, 1988.

**These species were pre-existing at some locations in the plots.

Blank cells indicate no species were present.

The question mark (?) in the indicator status for Salix was used since the specific species of willow was not identified.

Table A1.2. Page 1 of 2. Species list of vegetation from the North site, August, 1999.

Cover class (abundance): 5 >75%; 4 = 50 -75%; 3 = 25-50%; 2 = 5-25%; 1 = 1-5%; + = 0.5% (few); - = 0.25% (solitary).

Genus	Species	Common Name	Indicator Status	25A Dredge	Seeded	Custom Dredge	Seeded	SMR Dredge	SMR Control	Seeded
Achillea	millefolium	yarrow	FACU	-						
Agropyron	repens	Quackgrass	FACU	1		1		1	2	
Agrostis	alba	Redtop	FACW	4		3	**	5	3	yes
Amaranthus	retroflexus	Green Amaranth	FACU+							
Ambrosia	artemisiifolia L.	Common Rag weed	FACU	1						
Aster	sp.	aster	FACW		yes		yes			
Bromus	inermis	Smooth brome grass	UPL					1		yes
Chenopodium	album	Lambs Quarters	FAC-							
Chenopodium	glaucum	Oak-leaved Goosefoot	FACW							
Chenopodium	hybridum?	Maple-leaved Goosefoot	*							
Cirsium	arvense	Canada Thistle	FACU	-						
Echinochloa	crusgalli	Barnyard Grass	FACW							
Echinochloa	crusgalli var. frumentacea	Japanese millet	FACW							
Elymus	canadensis	Canada wild rye	FAC-	2	yes					
Epilobium	ciliatum Raf.	Willow herb	FACU							
Fagopyrum	esculentum	Buckwheat	*UPL							
Hordeum	jubatum	Foxtail Barley	FAC+						1	
Kochia	scoparia	Summer cypress	FACU-							
Lolium	multiflorum L.	Annual Rye	FACU+		yes				+	
Lolium	perenne	Perennial Rye Grass	FACU						2	yes
Matricaria	maritima L.	Scentless chamomile	FAC							
Medicago	sativa	Ranger Alfalfa	*UPL	1				1	2	yes
Melilotus	officinalis	Yellow Sweet Clover	FACU	3				2	2	yes
Phalaris	arundinacea	Reed Canary Grass	FACW+			3	**	1	2	**
Phleum	pratense	Timothy	FACU	3				1	1	
Phragmites	australis	Common Reed	FACW+			3	**	1		**
Polygonum	pensylvanicum L.	Smartweed	FACW+			1				

Table A1.2. Page 2 of 2. Species list of vegetation from the North site, August, 1999.

Cover class (abundance): 5 >75%; 4 = 50 -75%; 3 = 25-50%; 2 = 5-25%; 1 = 1-5%; + = 0.5% (few); - = 0.25% (solitary).

Genus	Species	Common Name	Indicator Status	25A Dredge	Seeded	Custom Dredge	Seeded	SMR Dredge	SMR Control	Seeded
Rudbeckia	hirta	Black-eyed Susans	FACU	1	yes					
Rumex	acetosella L.	Sheep sorrel	FAC							
Rumex	orbiculatus Gray	Water, Smooth Dock	OBL			+				
Salix	sp.	Willow	OBL?							
Salsola	kali	Russian Thistle	FACU							
Saponaria	officinalis	Bouncing Bet	FACU							
Scirpus	sp.	bulrush	OBL			2	**yes	1	1	**
Secale	cereale L.	Rye grain	UPL*							yes
Silene	cucubalus	Bladder campion						+	2	
Solidago	sp.	Goldenrod				1	yes			
Sonchus	arvensis	Sow Thistle	FAC-	+					1	
Tanacetum	vulgare	Tansy	*	+		+				
Trifolium	hybridum L.	Alsike Clover	FAC-	2		1		1		yes
Trifolium	pratense	Red clover	FACU+	1					+	
Typha	sp.	Cattail	OBL			3	**	+	1	**
Xanthium	strumarium L.	Cocklebur	FAC-							

*Species not found in the National List of Plant Species that occur in Wetlands, 1988.
**These species were pre-existing at some locations in the plots.
Blank cells indicate no species were present.
The question mark (?) in the indicator status for Salix was used since the specific species of willow was not identified.

Table A1.3. Page 1 of 2. Species list of vegetation from the South site, August 31, 1998.

Cover class (abundance): 5 >75%; 4 = 50 -75%; 3 = 25-50%; 2 = 5-25%; 1 = 1-5%; + = 0.5% (few); - = 0.25% (solitary).

			Indicator	SMR							25A							custom						
Genus	Species	Common Name	Status	a	b	c	d	e	f	seeded	a	b	c	d	e	f	seeded	a	b	c	d	e	f	seeded
Agropyron	repens	Quackgrass	FACU		+		1	+	+															
Amaranthus	retroflexus	Green Amaranth	FACU+															-						
Ambrosia	artemisiifolia L.	Common Rag weed	FACU			-						-	+								-			
Aster	simplex Willd.	Panicled aster	FACW																		-		-	yes
Bidens	cernua	Bur-marigold	OBL																	-				
Bromus	inermis	Smooth brome	*UPL	1	+	1	1	1	1	yes						1								
Chenopodium	album	Lambs Quarters	FAC-	+	1	1	1	1			+	1	1	1	2							+	-	
Chenopodium	glaucum	Oak-leaved Goosefoot	FACW								+							1				+		
Chenopodium	hybridum?	Maple-leaved Goosefoot	*								+							1						
Cirsium	arvense	Canada Thistle	FACU																				-	
Echinochloa	crusgalli	Barnyard Grass	FACW										+						1	+				
Elymus	canadensis	Canadian wild rye	FAC-										-	-		+	yes							
Epilobium	ciliatum Raf.	Willow herb	FACU																		+			
Fagopyrum	esculentum	Buckwheat	*UPL	+		+	+		+							1								
Hordeum	jubatum	Foxtail Barley	FAC+				-													-	-	-		
Lolium	multiflorum L.	Annual Rye	*								4	4	4	3	4	4	yes	4	3	4	3	3	5	
Lolium	perenne	Perennial Rye Grass	FACU	4	3	3	2	2	2	yes														
Lychnis	alba	White campion	*		-						-													
Matricaria	maritima L.	Scentless chamomile	FAC											-							1	1		
Medicago	sativa	Alfalfa	*UPL	2	3	3	3	3	3	yes		+		+		1								
Melilotus	officinalis	Sweet Clover (yellow)	FACU	2	3	3	3	3	3	yes	+									+	+	-		
Oenothera	biennis	Evening Primrose	FACU									-							+					
Phleum	pratense	Timothy	FACU	2	1	1	1	1	1							2								
Plantago	major	Common Plantain	FAC+																	+				
Polygonum	erectum	Erect knotweed	FACU																-	-	-		-	
Polygonum	pensylvanicum	Smartweed	FACW+		+	-	+	+	+			1	1	3	3	1			3	2	4	3	-	
Polygonum	sagittatum	Arrow-leaved tearthumb	OBL																	+				
Polygonum	scandens	Climbing false buckwheat	FAC																	-				
Salix	exigua	Sandbar Willow	OBL												-						+	-		
Saponaria	officinalis	Bouncing Bet	FACU	+							-							-						
Secale	cereale L.	Rye grain	UPL*	1	+	+	+	+		yes														
Scirpus	validus	Soft stem bulrush	OBL																		+	+		yes

Table A1.3. Page 2 of 2. Species list of vegetation from the South site, August 31, 1998.

Cover class (abundance): 5 >75%; 4 = 50 -75%; 3 = 25-50%; 2 = 5-25%; 1 = 1-5%; + = 0.5% (few); - = 0.25% (solitary).

			Indicator	SMR							25A							custom						
Genus	Species	Common Name	Status	a	b	c	d	e	f	seeded	a	b	c	d	e	f	seeded	a	b	c	d	e	f	seeded
Sisymbrium	altissimum?	Tumble mustard	FACU				-												-					
Sonchus	arvensis	Sow Thistle	FAC-													-		+					+	
Tanacetum	vulgare	Tansy	*																				-	
Trifolium	pratense	Red Clover	FACU+		-							1	2	1	2	1				+		1	1	
Trifolium	repens L.	White Dutch Clover	FACU+									1	1		1	1			+	+		1	2	
		bottle brush foxtail			+	+	+	+	+															

*Species not found in the National List of Plant species that occur in Wetlands, 1998.

Blank cells indicate no species were present.

Site codes:
- a - unamended tailing (control)
- b - local topsoil
- c -c black dirt (peat and sand)
- d - thick dredge
- e - thin dredge
- f - overburden

Table A1.4. Page 1 of 2. Species list of vegetation from the South site, August, 1999.

Cover class (abundance): 5 >75%; 4 = 50 -75%; 3 = 25-50%; 2 = 5-25%; 1 = 1-5%; + = 0.5% (few); - = 0.25% (solitary).

Genus	Species	Common Name	Indicator	Upland							25A							Custom						
			Status	a	b	c	d	e	f	seeded	a	b	c	d	e	f	seeded	a	b	c	d	e	f	seeded
Agropyron	repens	Quackgrass	FACU											1										
Agrotis	alba	Redtop	FACW	2	2	2	2	2		yes	1	2	3	1	2	1		P	P	P	P	P		
Alisma	plantago-aquatica	Water plantain	OBL														yes		P	P	P	P		yes
Amaranthus	retroflexus	Green Amaranth	FACU+																					
Ambrosia	artemisiifolia L.	Common Rag weed	FACU																					
Aster	sp.	aster	FACW														yes							yes
Bidens	cernua	Bur-marigold	OBL																P	P	P	P		
Bromus	inermis	Smooth brome grass	*UPL	2	1	1	1	1		yes	2		2	1										
Carex	sp.	sedge	OBL																P	P	P	P		yes
Chenopodium	album	Lambs Quarters	FAC-																					
Chenopodium	glaucum	Oak-leaved Goosefoot	FACW																					
Chenopodium	hybridum?	Maple-leaved Goosefoot	*																					
Cirsium	arvense	Canada Thistle	FACU										+											
Cirsium	sp.	Thistle sp.		1							1		+	1		+								
Echinochloa	crusgalli	Barnyard Grass	FACW																P	P		P		
Elymus	canadensis	Canadian wild rye	FAC-								1		+	1	1	1	yes	P						
Epilobium	ciliatum Raf.	Willow herb	FACU																					
Erigeron	sp.	Daisy fleabane																			P	P	P	
Fagopyrum	esculentum	Buckwheat	*UPL																					
Hordeum	sp.	Foxtail	FAC+																		P			
Kochia	scoparia	Summer cypress	FACU-															P						
Lolium	multiflorum L.	Annual Rye grass	*FACU+								1						yes							
Lolium	perenne	Perennial Rye Grass	FACU	1			1	1	1	yes	1	1	1	1				P			P		P	
Lychnis	alba	White campion	*	+	+	-																		
Matricaria	maritima L.	Scentless chamomile	FAC																					
Medicago	sativa	Ranger alfalfa	*UPL	1	3	3	3	3	4	yes	1		1			1								
Melilotus	officinalis	Yellow sweet clover	FACU	2	3	3	3	3	3	yes	1		2	+										
Oenothera	biennis	Evening Primrose	FACU		-							1												
Phalaris	arundinacea	Reed canary grass	FACW+												1	1		P	P	P	P		P	
Phleum	pratense	Timothy	FACU	+	1	2	2	2			2	3	3	3	2	1				P	P			
Plantago	major	Common Plantain	FAC+																					
Poa	sp.	Blue grass					1	1			2													
Polygonum	erectum	Erect knotweed	FACU																					
Polygonum	pensylvanicum L.	Smartweed	FACW+									-		+					P	P	P	P	P	
Polygonum	sagittatum	Arrow-leaved tearthumb	OBL																					

Table A1.4. Page 2 of 2. Species list of vegetation from the South site, August, 1999.

Cover class (abundance): 5 >75%; 4 = 50 -75%; 3 = 25-50%; 2 = 5-25%; 1 = 1-5%; + = 0.5% (few); - = 0.25% (solitary); P = present.

Genus	Species	Common Name	Indicator Status	SMR a	SMR b	SMR c	SMR d	SMR e	SMR f	SMR seeded	25A a	25A b	25A c	25A d	25A e	25A f	25A seeded	Custom a	Custom b	Custom c	Custom d	Custom e	Custom f	Custom seeded
Polygonum	scandens	Climbing false buckwheat	FAC																					
Potentilla	sp.	Cinquefoil														-								
Rudbeckia	hirta	Black-eyed Susan	FACU								2	2	+	1	1		yes							
Rumex	sp.	Dock	OBL												+				P					
Sagittaria	larifolia	broad leaf arrowhead	OBL																P		P	P		yes
Salix	exigua	Sandbar Willow	OBL																					
Salix	sp.	Willow	OBL?	-							-		-		+			P			P	P		
Saponaria	officinalis	Bouncing Bet	FACU	2																				
Scirpus	sp.	bulrush	OBL															P	P	P	P	P	P	yes
Secale	cereale L.	Rye grain	UPL*	1						yes														
Silene	cucubalus	Bladder campion		1		+		+	-				-											
Sisymbrium	altissimum	Tall tumble mustard	FACU																					
Slidago	sp.	goldenrod															yes		P					yes
Sonchus	arvensis	Sow Thistle	FAC-								2		-		1									
Tanacetum	vulgare	Tansy	*										+	+										
Trifolium	hybridum	Alsike Clover	FACU-	+						yes	2		1	1	1	1				P	P			
Trifolium	pratense	Red Clover	FACU+		3	2	2	2	2		2	4	3	3	3	4								
Typha	sp.	Cattail	OBL																	P	P	P		

*Species not found in the National List of Plant species that occur in Wetlands, 1998.

Blank cells indicate no species were present.

Site codes:
- a - unamended tailing (control)
- b - local topsoil
- c -c black dirt (peat and sand)
- d - thick dredge
- e - thin dredge
- f - overburden

In 1999, portions of the custom mix plots had eroded at the time of the survey, and much of the plot was under water. Therefore, no quantitative measurements were made, and species present are referred to as P (present).

Table A1.5. Percent cover and biomass data from the North and South sites, 1998.

South Plots

Plot Amendment	Seed mix	Thickness	Biomass (kg/ha)	Percent Cover
Tailings (none)	25A	n/a	85	16
Overburden	25A	6"	2066	68
Black dirt	25A	6"	3153	85
Topsoil	25A	6"	4710	52
6" Dredge	25A	6"	3947	94
4" Dredge	25A	4"	4582	91
Tailings (none)	custom	n/a	355	18
Overburden	custom	6"	2486	58
Black dirt	custom	6"	2949	74
Topsoil	custom	6"	6486	80
6" Dredge	custom	6"	5443	75
4" Dredge	custom	4"	3112	91
Tailings (none)	upland	n/a	91	17
Overburden	upland	1"	480	34
Black dirt	upland	1"	839	41
Topsoil	upland	1"	492	47
6" Dredge	upland	1"	705	39
4" Dredge	upland	0.5"	800	33

North Plots

Plot Amendment, seed mix	Biomass (kg/ha)	Percent Cover
Dredge, Mix 25A	7043	94
Dredge, Custom mix	8888	98
Dredge, SMR Mix	9461	99
Tailings, SMR Mix	481	27

Table A1.6. Percent cover and biomass data from the North site, 1999.

Percent Cover

Quadrant #	Tailings SMR	Dredge SMR	Dredge 25A
1	62.5	99.5	85.0
2	62.5	99.5	97.0
3	37.5	99.5	62.5
4	62.5	97.0	37.5
5	62.5	99.5	37.5
6	37.5	97.0	85.0
7	15.0	99.5	62.5
8	37.5	99.5	85.0
9	85.0	99.5	97.0
10	15.0	97.0	85.0
11	15.0	99.5	97.0
12	97.0	97.0	97.0
13	62.5	97.0	99.5
14	37.5	97.0	85.0
15	15.0	99.5	85.0
16	37.5	99.5	85.0
17	37.5	97.0	85.0
18	15.0	97.0	97.0
19	85.0	85.0	85.0
20	37.5	97.0	97.0
21	15.0	99.5	97.0
22	85.0	97.0	99.5
23	62.5	99.5	97.0
24	62.5	97.0	99.5
Average	**47.58**	**97.75**	**84.98**

Biomass

Amendment	Mix	Quad #	Total wt. (g/0.1m2)	Bag wt. (g/0.1m2)	Final wt. (g/0.1m2)	Total wt. (g/0.1m2)	Biomass (kg/ha)
Tailings (control)	SMR	5	44.04	27.57	16.47		
Tailings (control)	SMR	6	55.31	32.57	22.74		
Tailings (control)	SMR	10	40.25	32.80	7.45		
Tailings (control)	SMR	16	55.31	32.63	22.68		
Tailings (control)	SMR	19	51.07	28.38	22.69		
Tailings (control)	SMR	23	38.82	28.49	10.32	102.35	1706.24
Dredge	SMR	2	113.70	32.66	81.04		
Dredge	SMR	3	95.95	32.85	63.10		
Dredge	SMR	7	73.47	32.39	41.08		
Dredge	SMR	16	120.90	33.01	87.89		
Dredge	SMR	17	89.37	32.69	56.68		
Dredge	SMR	23	93.67	31.93	61.74	391.53	6526.81
Dredge	25A	5	63.24	32.23	31.01		
Dredge	25A	9	61.41	32.72	28.69		
Dredge	25A	18	64.56	32.14	32.42		
Dredge	25A	22	52.79	33.13	19.66	513.63	12840.85
Dredge	Custom	1	105.29	32.37	72.92		
Dredge	Custom	4	64.75	27.42	37.33	110.25	5512.50

Table A1.7. Percent cover data from the SMR and MN DOT 25A plots at the South site, 1999.

Quadrant	Upland (SMR)						MN DOT 25A					
#	Control	Topsoil	Black dirt	1" Dredge	1/2" Dredge	Overburden	Control	Topsoil	Black dirt	6" Dredge	4 " Dredge	Overburden
1	37.5	37.5	15.0	15.0	15.0	62.5	37.5	97.0	97.0	99.5	97.0	99.5
2	37.5	85.0	37.5	37.5	62.5	85.0	62.5	97.0	99.5	99.5	97.0	99.5
3	37.5	85.0	62.5	15.0	15.0	62.5	62.5	99.5	97.0	99.5	99.5	99.5
4	62.5	85.0	62.5	37.5	62.5	62.5	85.0	99.5	97.0	99.5	85.0	99.5
5	3.0	85.0	62.5	37.5	15.0	85.0	62.5	99.5	99.5	97.0	99.5	99.5
6	15.0	62.5	85.0	62.5	37.5	62.5	62.5	99.5	99.5	99.5	99.5	99.5
7	0.5	85.0	37.5	15.0	3.0	85.0	62.5	99.5	99.5	99.5	99.5	99.5
8	15.0	85.0	62.5	85.0	62.5	62.5	85.0	99.5	99.5	99.5	97.0	85.0
9	15.0	97.0	62.5	37.5	15.0	37.5	15.0	99.5	99.5	99.5	97.0	99.5
10	3.0	62.5	62.5	62.5	37.5	37.5	62.5	99.5	99.5	99.5	99.5	97.0
11	15.0	85.0	15.0	15.0	62.5	62.5	37.5	99.5	99.5	99.5	97.0	99.5
12	3.0	85.0	37.5	99.5	85.0	37.5	62.5	99.5	99.5	99.5	99.5	99.5
13	15.0	85.0	85.0	85.0	62.5	97.0	85.0	99.5	99.5	97.0	97.0	99.5
14	62.5	97.0	85.0	97.0	85.0	85.0	85.0	99.5	99.5	97.0	99.5	99.5
15	37.5	85.0	97.0	85.0	62.5	97.0	37.5	99.5	99.5	62.5	99.5	99.5
16	62.5	97.0	85.0	97.0	99.5	85.0	37.5	99.5	99.5	99.5	99.5	99.5
17	37.5	97.0	85.0	97.0	85.0	62.5	37.5	99.5	99.5	85.0	97.0	99.5
18	62.5	85.0	99.5	85.0	85.0	85.0						
19	15.0	85.0	85.0	37.5	62.5	62.5						
20	37.5	97.0	62.5	97.0	85.0	85.0						
21	37.5	97.0	62.5	62.5	85.0	62.5						
22	15.0	85.0	62.5	85.0	97.0	85.0						
23	37.5	85.0	62.5	85.0	99.5	85.0						
24	15.0	85.0	85.0	97.0	85.0	85.0						
Ave	**28.3**	**84.1**	**65.0**	**63.7**	**61.1**	**71.6**	**57.6**	**99.2**	**99.1**	**96.0**	**97.6**	**98.5**

Table A1.8. Biomass data from the SMR and MN DOT 25A plots at the South site, 1999.

Seed Mix	Amend	Quad #	Final wt. (g/0.1m²)	Amend Total wt. (g/0.1m²)	Total Biomass (kg/ha)
SMR	Control	1	7.81		
SMR	Control	4	5.60		
SMR	Control	8	6.26		
SMR	Control	15	2.34		
SMR	Control	18	2.66		
SMR	Control	20	9.23	33.90	565.08
SMR	Topsoil	1	7.04		
SMR	Topsoil	7	23.87		
SMR	Topsoil	10	24.09		
SMR	Topsoil	13	27.80		
SMR	Topsoil	15	26.64		
SMR	Topsoil	23	19.87	129.31	2155.60
SMR	Black dirt	5	16.44		
SMR	Black dirt	6	19.89		
SMR	Black dirt	10	3.10		
SMR	Black dirt	16	18.33		
SMR	Black dirt	19	4.76		
SMR	Black dirt	23	6.76	69.28	1154.90
SMR	1" dredge	2	7.63		
SMR	1" dredge	10	14.57		
SMR	1" dredge	11	1.76		
SMR	1" dredge	13	22.10		
SMR	1" dredge	15	20.66		
SMR	1" dredge	22	25.77	92.49	1541.81
SMR	1/2" dredge	10	4.10		
SMR	1/2" dredge	12	14.61		
SMR	1/2" dredge	15	20.42		
SMR	1/2" dredge	16	55.41		
SMR	1/2" dredge	18	17.25		
SMR	1/2" dredge	22	36.36	148.15	2469.66
SMR	Overburden	2	16.85		
SMR	Overburden	3	8.80		
SMR	Overburden	7	14.84		
SMR	Overburden	8	8.03		
SMR	Overburden	10	9.22		
SMR	Overburden	16	15.26	73.00	1216.91

Seed Mix	Amend	Quad #	Final wt. (g/0.1m²)	Amend Total wt. (g/0.1m²)	Total Biomass (kg/ha)
25A	Control	13	7.37		
25A	Control	14	5.10		
25A	Control	15	5.64		
25A	Control	16	9.25	27.36	684.00
25A	Topsoil	2	31.38		
25A	Topsoil	8	28.05		
25A	Topsoil	12	35.44		
25A	Topsoil	13	35.17	130.04	3251.00
25A	Black dirt	1	28.06		
25A	Black dirt	5	59.15		
25A	Black dirt	9	15.62		
25A	Black dirt	10	60.53	163.36	4084.00
25A	6" dredge	4	75.46		
25A	6" dredge	9	53.23		
25A	6" dredge	11	44.39		
25A	6" dredge	12	42.91	215.99	5399.75
25A	4" dredge	5	45.82		
25A	4" dredge	13	78.71		
25A	4" dredge	14	59.73		
25A	4" dredge	17	39.43	223.69	5592.25
25A	Overburden	1	56.59		
25A	Overburden	7	55.36		
25A	Overburden	9	10.30		
25A	Overburden	14	83.61	205.86	5146.50

APPENDIX 2

WATER QUALITY

Attachment A2.1.	Water quality analysis notes
Table A2.1.	Drainage quality results for well and surface water samples at the North site, 1999.
Table A2.2.	Drainage quality results for the inlet and outlet of the North site wetland, 1999.
Table A2.3.	Drainage quality results (average concentrations) from the North site, 1999.
Figure A2.1.	Box plots of drainage quality for surface water, inflow and outflow at the North site, 1999.
Figure A2.2.	Box plots of drainage quality for the wells, inflow and outflow at the North site, 1999.

Attachment A2.1. Water quality analysis notes.

The culvert at the North site was not installed until July 16th, 1998, as a result of the late installation and low rainfall, a pond was not established in 1998 and no water quality samples were taken.

The bold numbers in Tables A2.1 and A2.2 appear to be anomalous values. The only values clearly anomalous were the extremely high nitrate values. Nutrient samples are routinely acidified with sulfuric acid, however, one possibility that may explain these high values could be that they were inadvertently acidified with nitric acid. Typical values for nitrate in tailings basins range from 1 - 6 mg/L (Jakel, 1999, personal communication).

Table A2.3. contains drainage summary data for the wells, surface water, inlet and outlet at the North site. It was observed that the wells heaved from ice just after the first water quality sampling date. Therefore, the April 1, 1999 sampling date for the wells was dropped from the analysis because it was unclear if this data was truly representative of the water in contact with the soil or was actually surface water. Also, well # 2 (control) was dropped from the analysis. After resetting the well, the slots of the drain tile were apparently plugged as no sample could be pumped from the well.

Figures A2.1 and A2.2. box plots of drainage data are deceiving because they contain only three values. The software constructs the box automatically and as a result there appears to be more data than shown. The lower whisker of the box represents the lowest value, the upper whisker represent the highest value and the center line of the box represents the median value for that sampling site.

In Figures A2.1 and A2.2 the total Kjeldahl nitrogen (TKN) values are plotted on a log scale to provide a better visual representation of the data. Some values are ≤ 0.1 mg/L and do not appear in the box plots.

Table A2.1. Page 1 of 2. Drainage quality results for well and surface water samples at the North site, 1999 (pH recorded in standard units, SC in umhos and metals in mg/L).

ID	Amend	Date	pH	SC	Alk	CL	SO4	TKN	NH3N	NO32	TP	AS	BA	CA	MG	NA	K
well 1	Control	4/1/99	8.18	600	300	2.5	88.7	1.40	0.06	**438.0**	0.47	0.0023	0.0021	24.1	87.7	13.9	2.1
		7/6/99	7.87	2900	2040	3.5	76.1	<0.2	0.02	**412.0**	0.23	0.0023	<0.002	46.2	486.0	20.7	4.6
		7/19/99	7.75	2300	1780	2.5	56.2	<0.2	<0.02	**870.0**	0.53	0.0082	0.0060	40.1	422.0	19.0	3.9
		9/20/99	7.47	2200	1600	1.0	88.8	0.43	0.04	<0.4	0.331	0.0068	0.0038	40.9	408.0	23.6	3.8
well 2	Control	4/1/99	8.2	700	345	7.4	104.0	0.34	0.05	**450.0**	0.05	<0.002	0.0024	26.5	98.2	19.6	3.2
		7/20/99	7.63	2050	NA	3.9	60.0	NA	NA	NA	NA	0.0069	0.0147	35.2	351.0	26.6	6.0
well 3	Control	4/1/99	8.19	850	425	4.4	144.0	1.00	0.06	**463.0**	0.17	<0.002	0.0023	32.4	124.1	25.4	3.5
		7/6/99	7.93	2400	1680	3.5	78.5	<0.2	<0.02	**398.0**	0.15	<0.002	<0.002	48.7	397.0	24.6	5.5
		7/19/99	7.45	2075	1580	3.0	62.1	<0.2	<0.02	**765.0**	0.13	0.0026	0.1560	50.8	354.0	24.8	6.2
		9/20/99	7.53	2075	1490	0.7	89.8	<0.2	0.02	<0.4	0.067	0.0021	0.0052	55.3	358.0	25.0	5.5
well 4	Dredge	4/1/99	7.47	700	380	4.4	104.0	2.30	0.09	**428.0**	0.27	<0.002	0.0648	89.3	75.3	8.5	3.2
		7/6/99	8.03	2300	1620	2.5	100.0	0.71	0.04	**386.0**	0.13	0.0021	<0.002	130.0	327.0	23.2	5.7
		7/19/99	7.38	2075	1530	1.5	53.1	0.57	0.10	**831.0**	0.14	0.0048	0.0111	110.0	311.0	23.7	6.4
		9/20/99	7.4	1900	1300	0.9	48.2	0.54	0.09	<0.4	0.138	0.0037	0.1330	92.8	293.0	22.4	5.8
well 5	Dredge	4/1/99	7.46	800	415	5.4	116.0	3.60	0.07	**469.0**	0.45	<0.002	0.0610	73.1	96.7	13.7	4.6
		7/6/99	8.16	2400	1680	2.5	107.0	1.50	0.02	**403.0**	0.28	0.0044	0.1080	93.7	359.0	28.6	4.8
		7/19/99	7.44	2125	1540	2.2	35.3	<0.2	<0.02	**838.0**	0.46	0.0056	0.1810	108.0	328.0	25.8	5.3
		9/20/99	7.36	2200	1510	0.7	42.1	0.55	0.17	<0.4	0.352	0.0047	0.1550	97.1	342.0	27.8	5.2
well 6	Dredge	4/1/99	7.27	950	470	7.4	233.0	1.40	0.10	**444.0**	0.59	0.0025	0.0984	138.8	106.5	12.4	5.7
		7/6/99	NA	1500	NA	7.4	125.0	3.50	0.07	**397.0**	0.34	0.0047	0.0754	101.0	203.0	12.3	4.4
		7/19/99	7.64	2675	1550	1.5	57.2	3.60	<0.02	**808.0**	0.58	0.0069	0.1340	95.5	234.0	16.5	5.5
		9/20/99	8.03	2200	1460	1.1	119.0	1.80	0.32	<0.4	0.382	0.0065	0.1010	98.3	341.0	26.0	5.2
surface 1	Control	4/1/99	8.24	600	280	3.4	104.0	1.40	0.05	**470.0**	0.06	<0.002	0.0026	28.3	79.5	20.6	3.5
		7/19/99	8.27	800	410	2.0	60.4	1.30	0.03	**902.0**	0.08	0.0032	0.0023	20.7	102.0	15.9	3.6
		9/20/99	8.34	1600	1035	2.2	212.0	0.94	0.04	<0.4	0.155	0.0051	0.0022	34.8	271.0	33.5	4.1
surface 2	Control	4/1/99	8.2	600	255	2.5	108.0	1.30	0.05	**425.0**	0.04	<0.002	0.0025	27.4	81.9	22.3	3.5
		7/19/99	8.19	775	400	1.5	57.3	<0.2	0.03	**868.0**	0.06	0.0024	0.0031	20.1	94.4	16.0	3.7
		9/20/99	8.47	1575	880	2.1	213.0	0.66	0.04	<0.4	0.045	0.0026	0.0035	36.7	243.0	38.7	5.2
surface 3	Control	4/1/99	8.23	700	310	3.4	127.0	<0.20	0.04	**469.0**	0.03	<0.002	0.0023	28.7	90.5	23.3	3.7
		7/19/99	8.09	650	310	1.5	57.0	0.40	0.04	**949.0**	0.08	0.0021	0.0037	18.6	74.6	14.9	3.5
		9/20/99	8.3	1700	970	1.7	193.0	0.60	0.02	<0.4	0.038	0.0021	0.0036	41.8	272.0	36.4	4.8
surface 4	Dredge	4/1/99	7.94	600	250	2.5	98.7	0.84	0.05	**394.0**	0.12	<0.002	0.0111	28.8	76.3	18.9	4.8
		7/19/99	8.11	625	290	2.5	58.2	1.10	<0.02	**820.0**	0.09	0.0022	0.0077	20.6	66.0	14.6	3.5
		9/20/99	8.6	1450	720	2.3	233.0	0.82	0.05	<0.4	0.13	0.0027	0.0059	38.7	215.0	40.9	5.1
surface 5	Dredge	4/1/99	7.86	550	230	2.5	90.5	1.60	0.04	**447.0**	0.12	<0.002	0.0137	26.8	68.0	16.9	5.0
		7/19/99	8.09	600	270	2.5	59.0	<0.2	<0.02	**866.0**	0.15	0.0022	0.0070	19.0	64.0	14.5	3.4
		9/20/99	7.96	1700	1060	1.3	167.0	0.82	0.03	<0.4	0.075	0.0024	0.0315	62.6	266.0	33.4	5.4
surface 6	Dredge	4/1/99	7.49	500	225	3.4	86.4	1.30	0.08	**439.0**	0.14	<0.002	0.0340	36.5	50.9	11.4	13.0
		7/19/99	7.97	775	400	2.0	55.6	<0.2	0.02	**815.0**	0.05	<0.002	<0.002	37.2	272.0	63.0	8.1
		9/20/99	8.11	2100	1435	1.0	105.0	1.00	0.04	<0.4	0.153	0.0044	0.0383	83.1	351.0	27.8	4.5

*Anomalous nitrate-nitrogen values were verified with the Department of Agriculture. Shelf life of the samples was 2 to 3 weeks so re-analysis was not possible.

Table A2.1. Page 2 of 2. Drainage quality results for well and surface water samples at the North site, 1999 (pH recorded in standard units, SC in umhos and metals in mg/L).

ID	Amend	Date	AG	CD	CO	CR	CU	NI	HG	PB	SE	ZN
well 1	Control	4/1/99	<0.002	<0.002	<0.002	<0.002	0.0029	<0.002	<.0001	<0.002	<0.002	0.0044
		7/6/99	<0.002	<0.002	<0.002	0.002	0.0059	<0.002	<0.001	NA	NA	0.0017
		7/19/99	<0.002	<0.002	0.0034	<0.002	0.009	<0.002	<0.001	<0.002	<0.002	0.0220
		9/20/99	<0.002	<0.002	0.0023	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	0.0077
well 2	Control	4/1/99	<0.002	<0.002	<0.002	<0.002	0.0023	<0.002	<.0001	<0.002	<0.002	0.0075
		7/20/99	<0.002	<0.002	0.0025	0.003	0.0118	0.0025	<0.001	<0.002	<0.002	0.0243
well 3	Control	4/1/99	<0.002	<0.002	<0.002	<0.002	0.0032	<0.002	<0.001	<0.002	<0.002	0.0049
		7/6/99	<0.002	<0.002	<0.002	<0.002	0.0034	<0.002	<0.001	NA	NA	0.0010
		7/19/99	<0.002	<0.002	<0.002	0.002	0.0054	0.0027	<0.001	<0.002	0.002	0.0197
		9/20/99	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	<0.002	<0.002	0.0076
well 4	Dredge	4/1/99	<0.002	<0.002	<0.002	<0.002	0.0062	<0.002	<0.001	0.0027	<0.002	0.0140
		7/6/99	<0.002	<0.002	<0.002	<0.002	0.0068	<0.002	<0.001	NA	NA	0.0186
		7/19/99	<0.002	<0.002	0.0038	<0.002	0.0057	<0.002	<0.001	<0.002	<0.002	0.0177
		9/20/99	<0.002	<0.002	0.002	0.002	<0.002	0.002	<0.001	<0.002	<0.002	0.0112
well 5	Dredge	4/1/99	<0.002	<0.002	<0.002	<0.002	0.0064	<0.002	<0.001	0.0022	<0.002	0.0130
		7/6/99	<0.002	<0.002	<0.002	0.002	0.0064	<0.002	<0.001	NA	NA	0.0131
		7/19/99	<0.002	<0.002	0.002	0.002	0.0043	0.0027	<0.001	<0.002	0.002	0.0148
		9/20/99	<0.002	<0.002	0.0021	0.002	<0.002	0.002	<0.001	<0.002	<0.002	0.0081
well 6	Dredge	4/1/99	<0.002	<0.002	<0.002	<0.002	0.0082	0.0036	<0.001	0.0055	<0.002	0.0254
		7/6/99	<0.002	<0.002	<0.002	<0.002	0.0185	0.0021	<0.001	NA	NA	0.0133
		7/19/99	<0.002	<0.002	<0.002	0.002	0.0051	0.0026	<0.001	<0.002	<0.002	0.0131
		9/20/99	<0.002	<0.002	<0.002	0.0021	0.0024	0.002	<0.001	<0.002	<0.002	0.0085
surface 1	Control	4/1/99	<0.002	<0.002	<0.002	<0.002	0.0026	<0.002	<0.001	<0.002	<0.002	0.0026
		7/19/99	<0.002	<0.002	<0.002	<0.002	0.0028	<0.002	<0.001	<0.002	<0.002	<0.002
		9/20/99	<0.002	<0.002	<0.002	<0.002	0.002	<0.002	<0.001	<0.002	<0.002	0.0055
surface 2	Control	4/1/99	<0.002	<0.002	<0.002	<0.002	0.0022	<0.002	<0.001	<0.002	<0.002	0.0022
		7/19/99	<0.002	<0.002	<0.002	<0.002	0.0029	<0.002	<0.001	<0.002	<0.002	<0.002
		9/20/99	<0.002	<0.002	<0.002	<0.002	0.0023	<0.002	<0.001	<0.002	<0.002	0.0050
surface 3	Control	4/1/99	<0.002	<0.002	<0.002	<0.002	0.0022	<0.002	<0.001	<0.002	<0.002	0.0022
		7/19/99	<0.002	<0.002	<0.002	<0.002	0.0028	<0.002	<0.001	<0.002	<0.002	<0.002
		9/20/99	<0.002	<0.002	<0.002	<0.002	0.0021	<0.002	<0.001	<0.002	<0.002	0.0063
surface 4	Dredge	4/1/99	<0.002	<0.002	<0.002	<0.002	0.0023	<0.002	<0.001	<0.002	<0.002	0.0026
		7/19/99	<0.002	<0.002	<0.002	<0.002	0.003	<0.002	<0.001	<0.002	<0.002	<0.002
		9/20/99	<0.002	<0.002	<0.002	<0.002	0.0025	<0.002	<0.001	<0.002	<0.002	0.0047
surface 5	Dredge	4/1/99	<0.002	<0.002	<0.002	<0.002	0.0022	<0.002	<0.001	<0.002	<0.002	0.0026
		7/19/99	<0.002	<0.002	<0.002	<0.002	0.0028	<0.002	<0.001	<0.002	<0.002	<0.002
		9/20/99	<0.002	<0.002	<0.002	<0.002	0.0021	<0.002	<0.001	<0.002	<0.002	0.0072
surface 6	Dredge	4/1/99	<0.002	<0.002	<0.002	<0.002	0.0031	<0.002	<0.001	<0.002	<0.002	0.0045
		7/19/99	<0.002	<0.002	<0.002	<0.002	0.0067	0.0067	<0.001	<0.002	<0.002	0.0075
		9/20/99	<0.002	<0.002	<0.002	<0.002	0.0020	<0.002	<0.001	<0.002	<0.002	0.0066

Table A2.2. Drainage quality results for the inlet and outlet of the North site wetland, 1999 (pH recorded in standard units, SC in umhos and metals in mg/L).

ID	Date	pH	SC	Alk	CL	SO4	TKN	NH3N	NO32	TP	AS	BA	CA	MG	NA	K
inlet	4/1/99	8.27	1000	405	7.4	218.0	1.10	0.03	**449**	0.02	<0.002	<0.002	40.8	147.5	39.8	4.6
	7/6/99	8.7	700	340	3.0	82.9	<0.2	0.03	**374**	0.04	<0.002	<0.002	26.4	82.3	16.8	2.5
	7/19/99	8.41	1725	950	6.4	327.0	<0.2	<0.02	**845**	<0.02	0.0028	0.0250	33.3	93.7	15.0	3.9
	9/20/99	8.54	1700	780	3.1	343.0	<0.2	<0.02	2.1	<0.02	<0.002	<0.002	40.4	258.0	55.2	6.4
outlet	4/1/99	8.34	NA	200	1.5	78.5	<0.20	0.03	**467**	0.04	<0.002	<0.002	19.3	61.9	17.2	2.8
	7/6/99	8.56	300	160	2.0	28.4	<0.2	0.03	**379**	0.04	<0.002	<0.002	12.5	39.0	6.7	1.4
	7/19/99	8.32	500	290	2.0	60.8	<0.2	<0.02	**853**	0.05	0.0022	0.0032	17.1	61.3	14.4	3.2
	9/20/99	8.79	1350	680	2.5	247.0	0.58	0.03	<0.4	0.036	0.0020	0.0036	32.7	188.0	39.8	4.9

ID	Date	AG	CD	CO	CR	CU	NI	HG	PB	SE	ZN
inlet	4/1/99	<0.002	<0.002	<0.002	<0.002	0.0033	<0.002	<.0003	<0.002	<0.002	0.0040
	7/6/99	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	NA	NA	0.0020
	7/19/99	<0.002	<0.002	<0.002	<0.002	0.0025	<0.002	<0.001	<0.002	<0.002	<0.002
	9/20/99	<0.002	<0.002	<0.002	<0.002	0.0024	<0.002	<0.001	<0.002	<0.025	0.0050
outlet	4/1/99	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<.0003	<0.002	<0.002	<0.002
	7/6/99	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001	NA	NA	<0.002
	7/19/99	<0.002	<0.002	<0.002	<0.002	0.0029	<0.002	<0.001	<0.002	<0.002	<0.002
	9/20/99	<0.002	<0.002	<0.002	<0.002	0.0025	0.0023	<0.001	<0.002	<0.002	0.0042

*Anomalous nitrate-nitrogen values were verified with the Department of Agriculture. Shelf life of the samples was 2 to 3 weeks so re-analysis was not possible.

Table A2.3. Page 1 of 2. Drainage quality results (average concentrations) from the North site, 1999.

		Well[1]					Surface[2]							Surface Water[3] Standards
		Control		Dredge			Control			Dredge				
Date	Inlet	W 1	W 3	W 4	W 5	W 6	S 1	S 2	S 3	S 4	S 5	S 6	Outlet	
pH	8.55	7.70	7.64	7.60	7.65	7.84	8.28	8.29	8.21	8.22	7.97	7.86	8.56	6.5 - 9.0
Alkalinity	690	1810	1580	1480	1580	1510	580	510	530	420	520	688	380	
Specific Conductance	1400	2500	2200	2100	2200	2100	1000	1000	1000	900	1000	1100	700	
Major Cations/Anions:														
Calcium	33.4	42.4	51.6	110.9	99.6	98.3	27.9	28.1	29.7	29.4	36.1	52.3	20.8	
Magnesium	144.7	438.7	369.7	310.3	343.0	259.3	150.8	139.8	145.7	119.1	132.7	224.6	96.1	
Sodium	29.0	21.1	24.8	23.1	27.4	18.3	23.3	25.7	24.9	24.8	21.6	34.1	20.3	
Potassium	4.3	4.1	5.7	6.0	5.1	5.0	3.7	4.1	4.0	4.5	4.6	8.5	3.2	
Chloride	4.2	2.3	2.4	1.6	1.8	3.3	2.5	2.0	2.2	2.4	2.1	2.1	2.2	230
Sulfate	251.0	73.7	76.8	67.1	61.5	100.4	125.5	126.1	125.7	130.0	105.5	82.3	112.1	
Nutrients:														
Total Kjeldahl Nitrogen	0.01	0.21	0.10	0.61	0.72	2.97	1.21	0.69	0.37	0.92	0.84	0.80	0.26	
Ammonia-Nitrogen	0.02	0.02	0.01	0.08	0.07	0.13	0.04	0.04	0.03	0.04	0.03	0.05	0.02	0.04
Nitrate-[4] Nitrogen	2.1	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	
Total Phosphorous	0.02	0.36	0.12	0.14	0.36	0.43	0.10	0.05	0.05	0.11	0.12	0.11	0.04	

Table A2.3. Page 2 of 2. Drainage quality results (average concentrations) from the North site, 1999.

		Well[1]					Surface[2]							Surface Water[3] Standards
		Control		Dredge			Control			Dredge				
Date	**Inlet**	**W 1**	**W 3**	**W 4**	**W 5**	**W 6**	**S 1**	**S 2**	**S 3**	**S 4**	**S 5**	**S 6**	**Outlet**	
Trace Metals:														
Arsenic	0.002	0.006	0.002	0.004	0.005	0.006	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.053
Barium	0.009	0.004	0.054	0.048	0.148	0.103	0.002	0.003	0.003	0.008	0.017	0.024	0.003	
Cadmium*														0.015 - 0.0034
Chromium*					0.002	0.002								0.011[5]
Cobalt*		0.002		0.002	0.002									0.005
Copper	0.002	0.005	0.003	0.005	0.004	0.009	0.002	0.002	0.002	0.003	0.002	0.004	0.002	0.015 - 0.023
Lead*														0.008 - 0.019
Mercury*														0.000007
Nickel*			0.002		0.002	0.002						0.003		0.283 - 0.509
Selenium*	0.007		0.002		0.002									0.005
Silver*														0.001
Zinc	0.003	0.010	0.009	0.016	0.012	0.012	0.003	0.003	0.003	0.003	0.004	0.006	0.002	0.191 - 0.343

[1] Water quality values for the wells were derived from the three following sampling dates: July 6, 1999; July 19, 1999; and September 20, 1999.

[2] Water quality values for the surface water were derived from the three following sampling dates: April 1, 1999; July 19, 1999; and September 20, 1999.

[3] Surface water quality criteria (chronic standard) for 2B waters (aquatic life and recreation, non-drinking water). Standards for the trace metals are a function of water hardness. A range of 200 to 400 mg/L was used to compute chronic toxicity values for Cd, Cu, Pb, Ni, Ag and Zn. The standard for ammonia-nitrogen represents ammonia un-ionized as nitrogen, percent un-ionized can be calculated for any pH and temperature. Metals that do not currently have a standard were left blank. Reference: Minnesota Rules, 1997, Chapter 7050.0222, Waters of the State (http://www.revisor.leg.state.mn.us/arule/7050/0222.htm).

[4] Values for nitrate-nitrogen were from the September 20, 1999 sampling date only. Values for other dates appear to be anomalus and could be due to lab error.

[5] The Chromium standard was based on Cr +6, standard values for Cr +3 ranged from 0.365 to 0.644 mg/L (water hardness 200 to 400 mg/L).

*Values for Ag, Cd, Co, Cr, Ni, Pb were less than the detection limit of 0.002 mg/L (unless otherwise noted), and all Hg values were less than 0.001 mg/L.

Figure A2.1. Box plots of drainage quality for surface water, inflow and outflow at the North site, 1999.

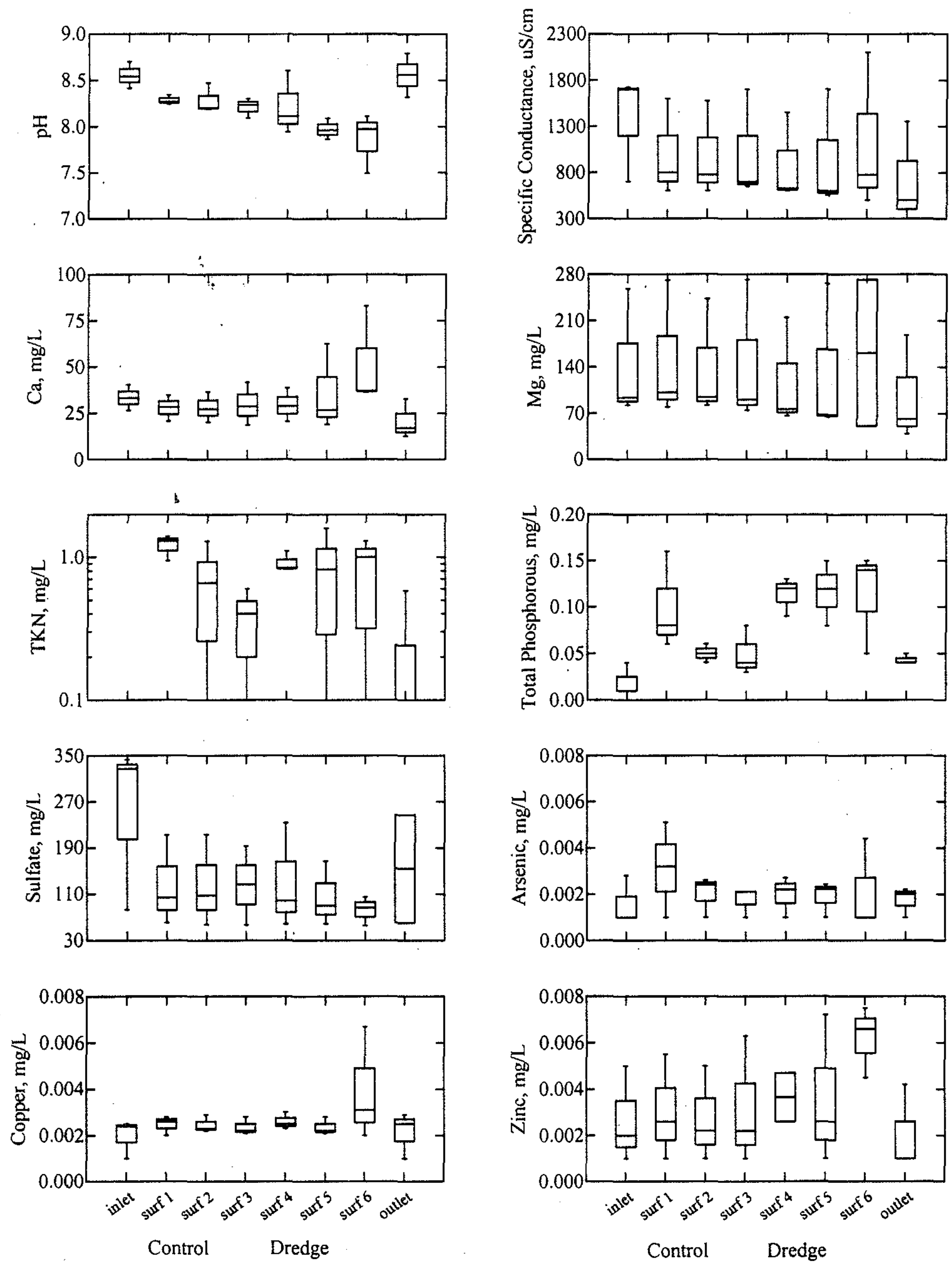
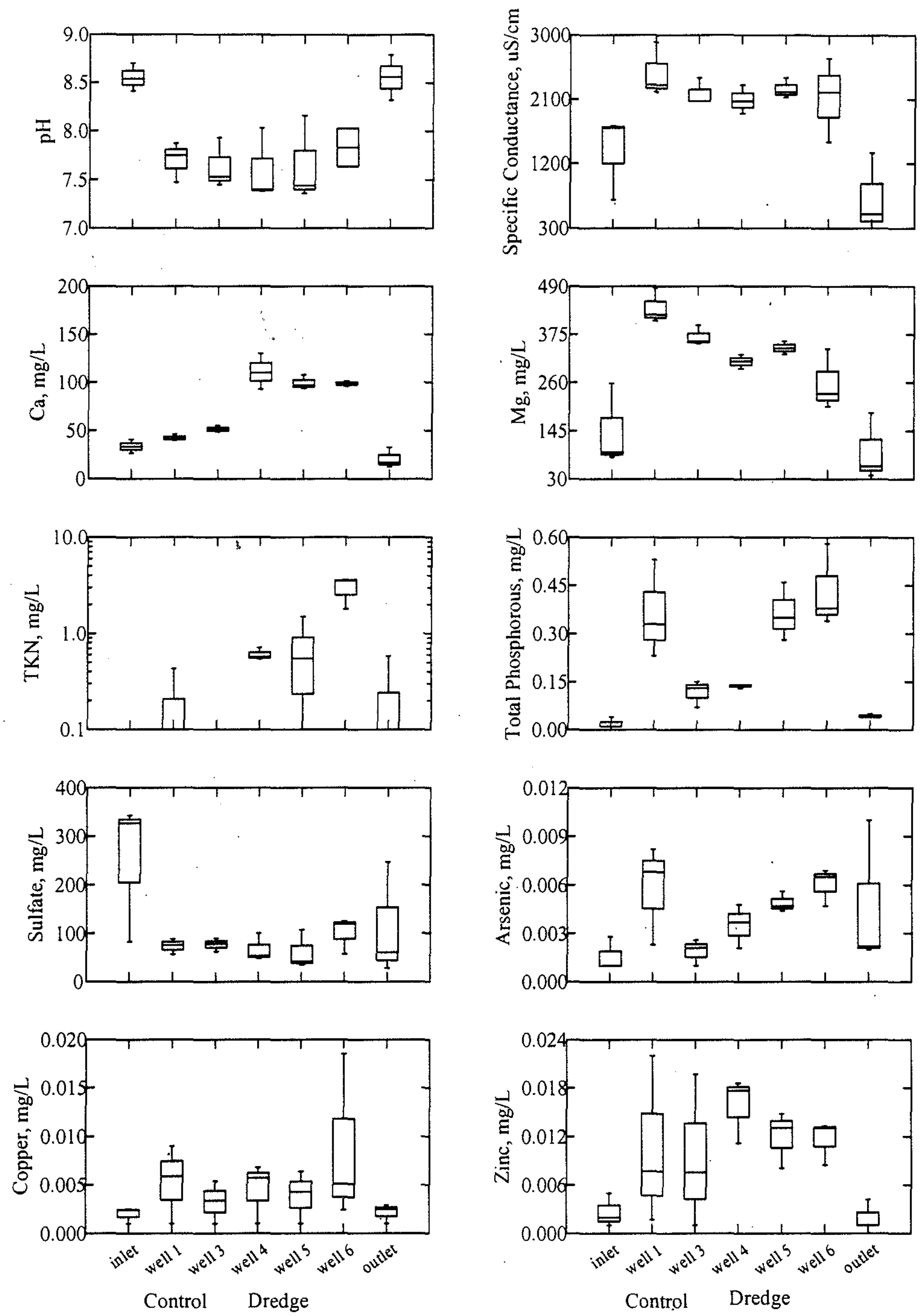


Figure A2.2. Box plots of drainage quality for the wells, inflow and outflow at the North site, 1999.



APPENDIX 3

ACTIVITY TIMELINE

Attachment A3.1. Activity timeline 1996 to 1999.

Attachment A3.1. Activity timeline 1996 to 1999.

1996

10/96 Asked to attend Duluth-Superior Metropolitan Interstate Committee to discuss the use of dredge materials for mineland reclamation.

11/96 Made preliminary inspection of the Erie Pier dredge disposal site. Preliminary sampling showed some potential for use in reclamation.

12/96 Contacted by Terry Long, COE Detroit. He asked that we submit a study proposal utilizing dredge material.

1997

2/97 Preliminary proposal sent to COE for a 2 year study at National Steel Mining Company.

4/97 Preliminary approval of proposal by COE. Subsequently a work plan was submitted to COE.

5/97 Potential sites at the Erie Pier dredge disposal area were inspected and sampled. MPCA approval of the study proposal to apply dredge material at National for reclaiming tailing basins.

6/97 Area for source of dredge identified and flagged at Erie Pier. Revised work plan submitted to COE.

8/97 Bid on excavating and hauling of dredge from Erie Pier to National tailing basin awarded to Udeen Trucking.

9/97 Discovery of sandy dredge disposal during the summer over targeted preferred silt/clay dredge. Contract with Udeen delayed.

10/97 Contract with Udeen amended to remove approximately three feet of sandy dredge. Contract amendment approved. Udeen excavated and hauled 305 yards of dredge to National basin.

11/97 National unable to spread dredge due to freezing conditions. National will spread dredge material after dredge has thawed (April 1998).

1998

4/23 Piles of dredge and soil spread on South site by D8 bulldozer and grader. The centers of many of the dredge and black dirt piles were frozen (up to 3 feet diameter).

4/24 *North*: Observed spread piles, picked up dredge that was moved to control plot by tires. The bulldozer and grader spread the piles earlier in the day. Some upwellings of tailings worked through the dredge to surface. No flow into the cell.
South: added silt fence 24' between plots to prevent spreading of amendments in water.

4/29 *North (Wetland 1)*: Surveyed area. Grader had returned to pull some material back up slope. No flow into cell.
South (Wetland 4): Surveyed slope area. No new activity.

5/5 Met Ted Anderson & D&T contractors to explain sites. Discussed fertilizing and discing sites. Observed reed grass and cattails growing on North site, *Scirpus validus* on South. Added 20' flags in accordance with shoreline on South site.

5/13 Applied 2 gallons of water + 300 mL Roundup to North site to remove reed canary grass *(Phragmites)* and cattails *(Typha)*.

5/18 A major rain storm occurred the evening of 5/15. The North site has minor flow (1 gpm est.) into the cell, but it disappears about 100' into the cell. Noted some rill development in the tails but not the dredge. South site: ranking by increasing erosion: 1) dredge; 2) overburden; 3) topsoil; 4) black dirt; 5) tails. Ranking by increasing vegetation: 1 & 2) black dirt and tails (none); 3) overburden (a few grasses); 4) dredge (a few grasses and forbs); 5) topsoil (a few grasses and lots of forbs, mainly lambs quarters).

5/19 D&T fertilized and disced both sites late in the day. They also seeded the standard reclamation portions. The dics did not reach the lower 5' or so at the south site. D&T applied hay mulch with a bale buster. DNR seeded by hand the Mix 25A and custom mix at both sites.

5/26 Installed 6 sampling ports on North site. (1-3 are in areas of thick dredge, 4-6 on tailings.) 200 cc of silica sand were poured into the annulus of each well to improve even filtration. Wooden supports installed on Well 1.

5/27 Completed installation of wooden supports on North site. Staked and surveyed the proposed culvert invert, ground elevation of wells, and measured plank lengths. South site: staked and surveyed the proposed culvert invert, placed flags at 20' mark (divides Mix 25A from Standard Reclamation seed).

6/3 Installed planks to wells and OSS gage at North wetland. No standing water. OSS gage installed at South site.

6/12 Installed supports below wooden planks. Began installation of silt fence at North plot.

6/19 Silt fence installation continues. Cattails and *Phragmites* removed manually.

7/1 Checked status of plots, made observations on growth of vegetation.

7/8 Surveyed erosion and patchy cover on plots.

7/16 Culvert has been installed at North site. Streambed that once ran through area has been removed by large machinery. No water flowing into plot at this time.

7/22 Completed silt fence installation. Routine check of North and South sites. Searched for water source for North site, but did not find one.

7/28 Added stakes to lengthen silt fences, and marked division between Mix 25A and Custom wetland mix vegetation. On North site, dredge depth measured.

8/10 Routine check of North and South sites.

8/17 Routine check of sites.

8/27 Vegetation sampling (percent cover and biomass) at South site- Glenn, Michelle, and Anne.

8/28 Vegetation sampling at the South-site plots (biomass and percent cover)

8/31 Vegetation sampling at the North-site plots (Biomass and percent cover).

9/10 Routine check of sites.

9/17 Routine check of sites. Area on nearby slopes of south site and area that will be the wetland pond on the North site have been mulched and seeded. Some cattails and *Phragmites* have been manually removed from North site. Cattails left on other side of fence, outside of plot. *Phragmites* seed heads removed from site.

9/28 Routine check. Cut entire cattail inside North-site plots, removed all seed heads from cattails outside of plot. Most of the vegetation is browning.

10/8 Vegetation is brown, save some clover blooming on South site. Remaining *Phragmites* harvested from North site.

10/13 Routine check of sites.

10/27 Site visit from Paul, Glenn, Michelle, Pat Churak from EVTAC, Al Klein and others from Corps of Engineers.

11/2 Final annual visit of sites. Routine check.

1999

3/22 Spring site visit. North-site pond ice up to wells, no vegetation, and patchy snow. South-site pond ice to mid-silt fence, patchy snow on plots.

3/31 North-site pond no ice, South-site pond still contains ice.

4/1 Sample wells and surface water at the North-site pond. Purged 300 mLs of water prior to sampling of each well. Also took surface samples near each well and samples from inlet and outlet. Vegetation on dredge plots greater than tailings.

4/16 Repaired silt fences and noticed that wells at the North site had heaved from ice. Small pools of water around base of wells otherwise no water in plots.

4/28 North site pond; totally dry. All wells had heaved, so first sample may have had some surface water.Ranked wells by amount of upheaval from ice. Twisted well #4 back into place. Took photos of plots, especially where wells had heaved.

5/12 Water at North-site pond again (water to middle support of boardwalks). Grass growing in all plots (esp. dredge) also alfalfa in plots. Grass, clover and alfalfa growing in South-site plots. Algae along shoreline.

5/21 Reset wells at North site.

6/1 Low water level at North-site pond, no water touches plots, small trickle of water into pond. Upland vegetation looks great. Upland vegetation at South-site plot looks great, vegetation height varies among plots. Shoreline of South-site pond varies.

6/10 Rain evening of 6/9. Water flowing into North-site pond from inlet (estimated 40-50 gal/min). Low water at North-site pond, no water touches plots. South site variety of plants in dredge plots.

6/14 Low water at North-site pond, no water flowing at inlet, no water touches plots. Sweet clover 2-2 ½ " and flowering on upland of North-site plots. Dredge/SMR excellent cover.

7/6 7" rain in Hibbing on the 4th of July. Inlet to North-site pond eroded by rushing water of storm. Vegetation still sparse in lowlands of the plots. Hole in dike near the outlet and resulted in lower water level than would be expected from the heavy rains. Sampled wells but not surface water. High water at South-site pond.

7/16 Dike at the North site was repaired and a second culvert added, plots and inlet full of water. Good flow of water out of the outlet. South-site pond, Custom mix plot underwater and part of 25A plot under water.

7/19 Sampled wells and surface water at North-site plots. Well #2 only enough water to purge volume of well. Water leaving original culvert only. Bittern frequenting North-site plots.

7/20 Collected about 250 ml of water from well #2. No water leaving pond through outlet culvert.

7/26 More rain, extensive gulling near inlet at North site. Water in plots ½ way up boardwalks. Water level 1/4 height of outlet culvert.

8/3 Site visit with NSPC, COE and DNR . Sweet clover beginning to cure out.

8/13 More rain (3"). Water in North-site plots past middle of boardwalk and 1/4 way up outlet culvert. South-site 80% of Custom mix plots have eroded away most likely due to a combination of high water and wave action.

8/18 Conducted vegetation surveys (species abundance) at North-site plots.

8/19 Conducted vegetation surveys (% cover, biomass) North-site plots, and species abundance at South-site plots.

8/20 Vegetation surveys (% cover) South-site plots.

8/23 Vegetation surveys (biomass) South-site plots.

9/3 Inlet to North-site pond continues to widen with each rain. Very little water in plots except for a few puddles. Pond boundary is 5 ft away from fence. No water leaving pond. South site has plants still coming in. Bur marigold blooming, identified submergent plants in pond as sago pondweed. New smartweed (*Polygonum pensylvanicum*) blooming in both plots since vegetation surveys and more water plantain in South-site plots.

9/16 Video footage and pictures of plants at both sites. Grasses dying out.

9/20 Fall sampling of wells and surface water at the North site. Once again no sample for well #2 (tailings).

10/25 Routine site visit. Noticed shoreline enhancement by NSPC at the South-site plots (topsoil plot and overburden plot).

10/29 No standing water in the North-site plots, soil saturated to middle of boardwalk planks.

11/2 Survey of high water level on North-site plots.

11/18 North-site pond nearly dry. Soil in mid-section of plots damp and saturated in lower section of plots.

APPENDIX 4

WATER LEVEL DATA

Table A4.1. Water level data (meters) from the North and South site ponds for 1998 and 1999.

Table A4.1. Water level data (meters) from the North and South site ponds for 1998 and 1999.

Date	South site	North site
04/29/98	0.338	NA
05/27/98	0.216	NA
06/03/98	0.302	0.000
06/19/98	NA	0.000
07/01/98	0.490	0.060
07/08/98	0.490	0.062
07/16/98	0.440	0.000
07/22/98	0.395	0.000
07/28/98	0.374	0.000
08/10/98	0.290	0.000
08/17/98	0.250	0.000
09/10/98	0.085	0.000
09/17/98	0.100	0.000
09/28/98	0.100	0.000
10/08/98	0.125	0.000
10/13/98	0.105	0.000
10/19/98	0.300	0.140
10/27/98	0.350	0.000
11/02/98	0.340	0.000
03/22/99	0.565	0.270
03/31/99	0.630	0.305
04/01/99	0.625	0.285
04/16/99	0.600	0.060
04/28/99	0.590	0.000
05/12/99	0.585	0.360
05/21/99	0.590	0.320
06/01/99	0.505	0.050
06/10/99	0.520	0.050
06/14/99	0.480	NA
07/06/99	0.790	0.150
07/16/99	0.780	0.500
07/19/99	0.715	0.300
07/20/99	NA	0.270
07/26/99	0.650	0.550
08/13/99	0.650	0.470
08/18/99	0.610	0.380
09/03/99	0.535	0.060
09/16/99	0.680	0.340
09/20/99	NA	0.250
10/25/99	0.590	0.195
10/29/99	0.575	0.115
11/02/99	0.565	0.07
11/09/99	NA	0.07
11/18/99	0.52	0.065

APPENDIX 5

ELEVATION DATA

Attachment A5.1. Water level elevations.

North Site

A benchmark (steel fence post driven 5 feet into the ground [below frost depth]) was established in the control plot in July of 1998. The staff gauge was set so that the 0.0 meter reading on the gauge was essentially 0 water in the pond.

In July of 1999 a second outlet culvert was added to the pond after the dike was washed out by the record rainfall on July 4th. This culvert was installed slightly higher than the original culvert, so the original culvert controls the water level (both culverts are 22 inches in diameter).

No surveys were conducted during the summer of 1999, but based on water level observations, the spill point was 0.28 meters (Table A5.1). A survey conducted in January 2000 recorded the elevation of the invert of the culvert at 0.25 meters. Since the survey was taken after freeze up, the staff or culvert could have shifted. The staff gauge is attached to a piece of PVC pipe which was set about 2 feet in the ground. The site will be re-surveyed after ice-out.

South Site

The old culvert was used as a benchmark and a steel post was installed between the 4 inch dredge plot and the overburden plot. (The steel fence post was driven about 5 feet into the ground.) Elevation for the culvert is 0.88 and the benchmark is 4.58 feet (July 1998). Surveys were conducted in July 1998 and January 2000. There was a 3 inch discrepancy in the elevation of the staff gauge between the two surveys, and the 2000 survey was judged to be more accurate, since the summer measurement required the rod holder to lean out over the water and hold the rod on the gauge. It is assumed that the elevation of the staff gauge did not shift between 1998 and 1999. The elevation of 0.0 meter on the staff gauge was 0.62 feet and when the plots were established in April of 1988 the elevation of the toe of the western control plots was 2 feet, which corresponded to an elevation of 0.37 meters on the staff gauge.

The elevation where the upland mix started in the plots ranged from 3.46 to 4.64 (Figure A5.1). The division between the custom mix and the MNDOT 25A was not surveyed but based on an estimated elevation of the 2.0 for the bottom of the plots and a constant plot slope, the elevation would be about 3.0. This would correspond to a staff reading of 0.67 meters which corresponds fairly well with the field observations (Table A5.1).

Since up to 50% of the amendment in the custom plot was removed by shoreline erosion, the plots will need to be re-staked and re-surveyed during the summer of 2000. For this report, the boundary of the custom mix and the MNDOT 25A will be estimated to be 0.67 meters and the standard reclamation mix the staff gauge reading of about 0.97 meters. However, the elevation within the plots varies substantially (Figure A5.1) and the actual elevation between the MNDOT 25A and the standard mix varies from 3.48 to 4.64. These elevations correspond to a range in staff readings of 0.82 to 1.16 meters.

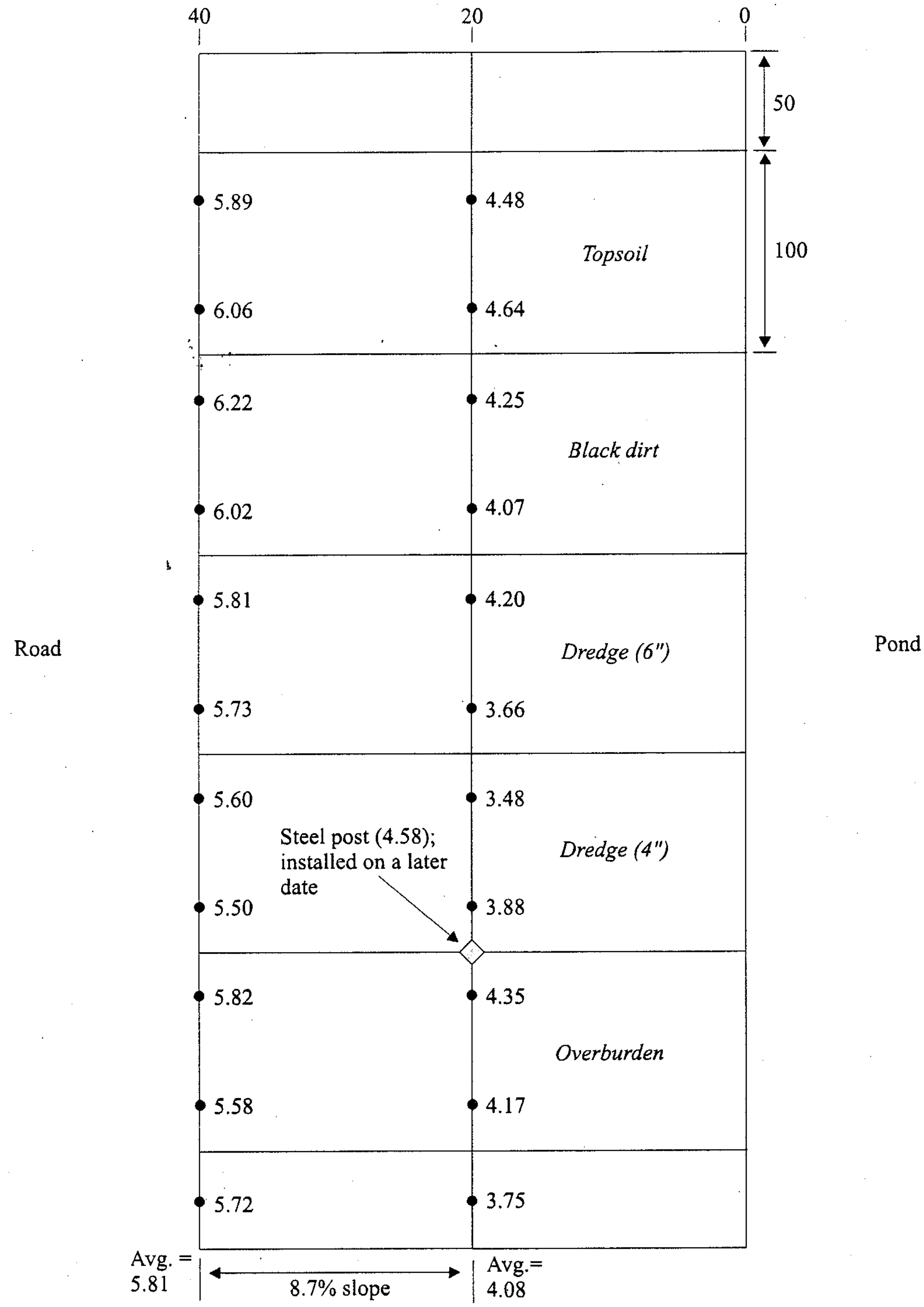
Table A5.1. Water level notes.

Site	Date	Staff gauge reading (m)	Observations
North	4/1/99	0.285	Water just lapping at edge of the culvert, a few drips out other end.
	7/19/99	0.30	Water out original culvert only (¼" water through the culvert).
	7/20/99	0.27	No water leaving pond through culvert.
	7/26/99	0.55	Water at original culvert one-quarter of the way up the side (approximately 5-6", not measured).
	8/13/99	0.47	Water about one-quarter of the way up the outlet culvert.
	9/20/99	0.25	Water almost to the edge of the culvert.
South	7/6/99	0.79	Water past yellow flag.
	7/16/99	0.78	Custom mix and part of MNDOT 25A underwater; water level in dredge plots up to SMR.
	8/13/99	0.65	Water covers 80-100% of the custom mix in plots.

Table A5.2. South site elevation summary.

Location	Staff gauge reading (m)	Elevation (ft) relative to steel post bench mark	Comments
Reference	0.0	0.62	Based on 2000 survey.
Edge of plots	0.370	2.0 ft.	Based on one pont in west control
Division between custom and MNDOT 25A	0.67	3.0 ft.	Estimate of average elevation; assumes all plot edge at 2; average of elevation between upland and MNDOT 25A ~ 4 ft.
Division between MNDOT 25A and SMR	0.82 to 1.16	3.48 to 4.64	Based on survey in 7-98.

Figure A5.1. Elevations of the wetland plots at National on 7/28/98 (South Site; schematic). All values are in feet.



• 6.15 (low spot on dike)

APPENDIX 6

QUALITY ASSURANCE

Attachment A6.1	Minnesota Department of Agriculture Quality Assurance Program.
Attachment A6.2	Department of Natural Resources Laboratory Quality Assurance Program.

Attachment A6.1.

Minnesota Department of Agriculture
Quality Assurance Program

Quality Assurance Objectives

Precision, accuracy, completeness, data comparability and sample representativeness are necessary attributes to ensure that analytical data are reliable, scientifically sound, and defensible. Each analytical result or set of results generated for this project should be fully defensible in any legal action, whether administrative, civil or criminal.

1. Definitions
   1.1 Precision
   Whenever possible, a minimum of one duplicate sample should be run in order to determine precision. It is understood that in some cases there may be insufficient sample to run duplicates and therefore a determination of precision would not be possible.
   1.2 Accuracy
   Whenever possible, a minimum of one matrix spike should be run in order to determine accuracy. It is understood that in some cases there may be insufficient sample to run matrix spikes and therefore a determination of accuracy would not be possible.
   1.3 Completeness
   Should be 100% ideally. Realistically a minimum level of 90% is expected.
   1.4 Comparability
   Should be ensured by adherence to method protocols.
   1.5 Representativeness
   Should be ensured by adherence to standard laboratory sub-sampling protocols. The nature of the material being sampled must be taken into account when subsampling.

The precision and accuracy of each method is dependent on the sample matrix and analyte concentration. Therefore, for these types of analyses, the matrix and concentration determine the values of precision and accuracy (bias) which are acceptable.

2. Parameter List, Matrix Type, Required Action Limits, Method Detection Limits

   Parameters
   Metals, sulfates and nutrients.

   Matrices
   Aqueous and Solids

Required Action Limit
Required action limits will be determined by the MDNR personnel prior to the analysis of samples by MDA. Action limits will be communicated to the Laboratory by the Minerals Reclamation Laboratory QA Officer.

Method Detection Limit
Method detection limits are determined by the laboratory following guidelines defined in EPA CFR 40 Part 136, Appendix B. Reporting limits are based on the lab MDLs and requirements for the program.

3. Laboratory Methods
   The laboratory will follow methods based on EPA methodologies and Standard Methods for the Examination of Water and Wastewater.

4. Samples
   4.1 Required Turn-Around Time for Analysis
   "Regular" parameters: 30 days after MDA receipt.
   "Permit" parameters within the stated time listed in the MPCA permit.

5. Quality Control Samples
   5.1 Field Blanks: One blank for every 50 samples of each experiment.
   5.2 Laboratory QC requirements and minimum volume of sample needed:
   - Metals- 60 mL
   - Sulfates- 60 mL

   5.3 Blind Set Points: One submitted with every box of samples.

Field Sampling Requirements

1. Type of Samples to be Collected.
   Aqueous samples will be colleted.

2. Field Sampling Requirements: NA

3. NPDES samples will require chain of custody and proper preservation as required for permit samples. This is required in the QA plan approved by Minnesota Department of Health.

4. Preservation
   All metals samples will be preserved with ultra pure nitric acid. Samples requiring refrigeration (storage at 4°C ± 2°) will be shipped on ice or cool packs to the MDA laboratory.

Sample Custody Requirements

1. Transportation of Samples from Field to Laboratory
   Regulator samples will either be shipped by State contract courier or hand delivered by Minerals personnel to MDA within 2 working days.
   Permit samples will wither be shipped by State contract courier or hand delivered by Minerals personnel to MDA within 2 working days of shipment. The samples will be sent on ice.

2. Notification Procedure
   MDA will be notified by the MDNR Program Coordinator or MDNR QA Officer when *Permit* samples are being shipped. MDNR will also alert MDA when "non regular" samples are being shipped.

3. Sample Log-in Procedure
   Upon receipt of the sample(s), the sample custodian inspects the shipping container(s), the sample(s), the official seal(s), and documentation related to the sample(s) and other records. If accepted for analysis, the sample(s) are entered by the sample custodian into the sample logbook, database and assigned a unique laboratory number.

Samples are to be properly documented, preserved, packaged, maintained under custody and transferred to the laboratory in a defensible manner. The Laboratory Information Section Supervisor should notify the MDNR Program Coordinator, appropriate MDNR Field Project Leader or Reclamation Laboratory QA Officer when problems are encountered with the quality of incoming samples or when laboratory problems arise that could affect the reliability and/or defensibility of analytical results.

4. Analysis
   A supervisor assigns the sample(s) to an analyst. After assignment, the sample custodian retrieves the sample(s) and transfers it to the analyst who completes the appropriate lines on the custody form. If the sample(s) is assigned to a different analyst, the appropriate lines in the second column of the custody form are completed by the new analyst. Similarly, the third column or even additional sheets can be used to document additional sample transfers within the laboratory. The original seal(s) should be kept with the sample(s) and maintained in a legible condition. Upon completion of the analysis, any remaining sample is placed in the appropriate storage location.

Calibration Procedures and References

1. Field Equipment Calibration
   None

2. Laboratory Calibration
   Each instrument used routinely in the laboratory should be monitored, calibrated, and maintained. Specifications for instrument maintenance, calibration and monitoring are described in manufacturer's manuals, in analytical methods, and/or appropriate standard operating procedures. If an instrument malfunctions, or if improper sensitivity, resolution and/or reproducibility is detected, corrective action is necessary before analyses are attempted. Any corrective action taken will be documented in the appropriate instrument manual.

   Analytical standards used to prepare calibration or standard solutions are obtained from the National Institute for Standards and Technology (NIST), EPA, USDA, FDA or other reliable sources. Stock standard solution(s) are prepared as specified in the SOP. All inform on their preparation is recorded in the designated logbook(s).

   Depending on the method, a three to five point calibration curve will be used.

Analytical Procedures

1. Analytical Procedures
   All analyses for permit samples will be done according to methods approved by the Minnesota Department of Health as written in the MDA methods manual. These methods are based on approval EPA methodologies and Standard Methods for the Examination of Water and Wastewater.

   Other analyses will be done using laboratory methods based on EPA, ASTM, AOAC, etc. methodologies.

Data Analysis, Validation and Reporting

This section describes the basic procedures for data analysis, validation and reporting for this project.

1. Data Analysis
   Data analysis is performed on a batch run basis for samples analyzed using FAA and GFAA. Out of range samples are diluted manually for FAA and automatically for GFAA. Colorimetric autoanalysis usually relies on batch data analysis where confirmatory samples are then redirected to another automated method (IC) or a manual method. Manual methodology requires a sample by sample data analysis procedure, with confirmation by an alternate method if indicated. Details of data analysis are contained individual methods.

2. Validation of Results
   Validation of data is described in detail in the laboratory standard operating procedures. In most cases, data validation consists of a review of the analytical method. calculations and quality control results. Initial review is done by the analyst, and final review by the Chemistry Supervisor or a designated Senior Analyst. Certain samples or cases may be validated by the Laboratory Quality Assurance Officer if required or desirable. When a review indicates a need, the analysis is repeated using either the same method or an alternate method. Questionable data may result from the condition of the sample, inadequacy of the method, lack of validation, time constraints or other factors.

   Any questionable data will be clearly identified and qualified. The Laboratory Quality Assurance Officer conducts periodic in-depth audits to assure compliance with the validation requirements.

3. Reporting
   Analytical data is reported according to the format(s) provided in the standard operating procedures. In addition to the analytical results, the reference for the method and quality control results are reported. Quality control results may include spike recovery, results of duplicate analyses, analysis of reagent blanks, but are not limited to these. When the compound(s) of interest is not detected in the sample(s), it is reported as such with the method detection limit. Any pertinent observations about the samples or the analytical process are also reported.

   All written reports will be sent to the MDNR Program Coordinator.

Internal Quality Control Checks

The internal quality control (QC) checks are a systematic in-house approach to ensure the production of high quality data. The objectives of these control checks are:

- To provide reliable and defensible analytical results,
- To provide a measure of the precisions and accuracy of the analytical methods,
- To monitor the accuracy and precision of the analyst,
- To identify problematic methods which can be flagged for further research,
- To detect training needs within the laboratory,
- To provide a permanent record of instrument performance which is used for validating data and projecting instrument repair or replacement needs,
- To monitor the effectiveness of the quality assurance program and laboratory performance and provide a basis for modifications of the quality assurance program.

The quality control procedures for analytical methods used for misuse cases may include:

- Demonstration of analytical capability,
- Analysis of a quality control check sample, when available,
- Daily instrument check,
- Recoveries of or matrix spikes,
- Analysis of reagent blank,
- Duplicate analysis,
- Analysis of laboratory control standards,
- Blind performance evaluation samples,
- Analysis of instrument quality control standards,
- Confirmation of analyte.

Performance and System Audits

The Minnesota Department of Agriculture is committed to participate in the evaluation of the laboratory quality assurance program and to lend itself to any coordinated on-site systems audits by qualified representatives of MDNR. The department is also committed to using the results of such performance and systems audits to improve the reliability, defensibility, capability and efficiency of the laboratory and filed operations. A quality assurance/quality control manual will also be available to the MDNR-mineral for review.

LSD will maintain accreditation with the Minnesota Department of Health with respect to clean water requirements including participation in EPA WP and WS proficiency samples.

Systems and laboratory audits along with analytical data and record review, may be performed by qualified representatives of MDNR which reserves such audit rights. The audit is conducted upon joint consent of both agencies. The report of all findings and recommendations are made promptly to the MDA. The systems audit includes areas in the laboratory immediately impacting overall quality assurance.

The Laboratory Quality Assurance Officer performs in-house systems audits to identify strengths, weaknesses, potential problems and solutions to problems. The audits provide an evaluation of the adequacy of the overall measurement systems to provide data of sufficient quantity and quality to meet the comprehensive laboratory pesticide program's objectives. The in-house systems audits are the basis for quality assurance reports to management.

The in-house systems audit consist of observing the various aspects of the laboratory activities related to this project. Check lists which delineate the critical aspects of each procedure are used during the audit and serve to document all observations. At a minimum, the following topics will be evaluated during the internal audit:

1. GENERAL PROCEDURES
   A. Procedures for Sampling and Sample Documentation
   B. Documentation of Procedures
   C. Sample Receipt and Storage
   D. Sample Preparation
   E. Sample Tracking

2. ANALYTICAL PROCEDURES
   A. General Instrumentation Procedures
   B. Calibration Procedures
   C. Internal Quality Control
   D. Data Handling Procedures

Preventative Maintenance Procedure and Schedule

1. Field Maintenance
   None

2. Laboratory Instrument Maintenance
   The primary objective of a comprehensive maintenance program is to ensure the timely and effective completion of a measurement effort. Preventive maintenance is described in the laboratory or field standard operating procedures (SOPs) and appropriated instrument manual. It is designed to minimize the down time of crucial sampling and/or analytical equipment due to component failure. The focus of the program is in four primary areas:
   - Establishment of maintenance responsibility.
   - Establishment of maintenance schedules for major and/or critical instrumentation and apparatus.
   - Establishment of an adequate inventory of critical spare parts and equipment.
   - Documentation and filing of all service and maintenance records.

   The Agronomy Laboratory supervisor is responsible for maintenance of laboratory instruments and equipment. The appropriate program managers are responsible for the maintenance of field equipment. With assistance from the Laboratory and Reclamation Laboratory Services Quality Assurance Officers, the Agronomy Laboratory establishes maintenance procedures and schedules for each piece of major equipment. Responsibility for individual items is delegated to technical personnel. The manufacture's recommendations and/or the protocols for instrument maintenance and calibration are followed. Each piece of major equipment is designated a repair and maintenance logbook where all maintenance activities are dated and documented by laboratory or filed personnel.

   In the interest of maintaining instruments in top operating condition, it is management's policy to secure annual service contracts with instrument manufacturers whenever financially possible. The service contracts are especially desirable for laboratory instruments. Under the service contracts, certified service engineers perform preventive maintenance, calibration and repair for instruments. Laboratory personnel perform routine maintenance and repair between manufacturers' service to ensure correct performance of an instrument.

Analytical balances are serviced by certified service engineers at least once a year. In addition to performing repair and maintenance, the engineer calibrates and certifies each analytical balance. Laboratory personnel check the calibration of the balance with a class S weight at least four times a year. Digital pH meters are checked before each use with standards and calibrated according to the manufacturer's directions. Freezers and refrigerators are monitored to assure that proper temperatures are maintained and that failure has not occurred.

An adequate inventory of spare parts is maintained to minimize equipment down time. This inventory emphasizes those parts which:

- Are subject to frequent failure,
- Have limited useful lifetime,
- Cannot be obtained in a timely manner should failure occur.

Assessment of Data

An objective of the laboratory is to demonstrate that performance on all analyses is in statistical control. Routine procedures used to assess reliability and quality of data are specified in the laboratory standard operating procedures (SOPs).

For residue analysis, duplicates are used to establish precision, spike sample recoveries are used to establish accuracy and blanks are analyzed to assure non-interference from solvents, reagents and laboratory environment.

Precision refers to the reproducibility of replicate results about a mean which is not necessarily the true value. Duplicate analysis is the primary means of evaluating measurement data variability or precision. Two commonly used measures of variability which adjust for the magnitude of analyte concentration are coefficient of variation and relative percent difference.

The coefficient of variation is used most often when the size of the standard deviation changes with the magnitude of the mean. Coefficient of variation (CV), also called relative standard deviation (RSD), is defined:

$$CV \; or \; RSD = \left(\frac{s}{y} \right) * 100$$

where: y = mean of replicate analyses
s = sample standard deviation, defined as:

$$S = \sqrt{\sum_{i=1}^{N} \frac{(y_i - y)^2}{n - 1}}$$

where: y_i = measured valued of the ith replicate
y = mean of replicate analyses
n = number of replicates

Sample standard deviation (s) and coefficient of variation (CV) are used when there are at least three replicate measurements.

The second measure of variability which adjusts for the magnitude of the analyte is relative percent difference (RPD) or relative range (RR). This measure is used when duplicate measurements are made and is defined:

$$RR \ or \ RPD = \frac{|A - B|}{\left(\frac{A + B}{2}\right)} * 100$$

where: A = First observed values
B = Second observed values

Precision is monitored by plotting control charts for repetitive analysis. A warning limit of ±2s is established with a control limit of ±3s (see Section 3).

Accuracy is the nearness of a result to the true value and is often described as error, bias or percent recovery. Accuracy estimates are frequently based on the recovery of surrogate spikes and/or the recovery of know analytes. The percent recovery is calculated as:

$$\%R = \left(\frac{SSA - S}{SA}\right) * 100$$

where: SSA = measured concentration in spiked aliquot
S = measured concentration in unspiked aliquot
SA = actual concentration of spike added

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount expected to be obtained under correct, normal conditions. For all measurements, completeness is defined:

$$\%C = \left(\frac{V}{n} \right) * 100$$

where: %C = percent completeness
V = number of measurements judged valid
n = number of measurements necessary to achieve a specified statistical level of confidence in decision making

To determine "n" a judgment must be made regarding the amount of data required to provide adequate evidence that a system is in control. Completeness is calculated for monitoring programs where similar analyses are performed on a regular basis. Loss of data due to such occurrences as breakage of containers, spilling of the sample, contamination, instrument failure or exceeding holding time before analysis must account for no more than 10 percent of all requested analysis. If excessive loss of data occurs, the reasons must be identified and evaluated and, if necessary, action must be taken to solve the problem(s).

Corrective Action

Corrective action is taken whenever data is determined as unacceptable.

Corrective action is taken in the order listed below.

Review of sample collection procedures.
Review of analytical raw data and calculations.
Review of laboratory procedures - Was the analytical method followed?
Review of analytical method - Is it applicable?
Review of instrument operation, calibration and maintenance.
Review of the calibration standard(s) used.
Review of quality control measurement (spike, duplicate, surrogate, etc.).

As a result of the above review, further corrective action may be identified and pursued as necessary:

Repeat the sampling and corresponding documentation.
Issuing an amended analytical report.
Repeat analysis (confirmation methods).
Repair, recalibration or replacement of instrumentation.
Additional training of staff.

Persistent problems require a thorough review of all field and analytical data (including quality control measurements and procedures), increased check sample and reference material analyses and additional field and/or analytical system evaluations by outside agencies or individuals.

QA Reports to Management

A quality assurance report is generated by the Minnesota Department of Agriculture and Laboratory Services Division and sent to MDA and MDNR management at least once a year.

The report may contain the following:

- Changes in Quality Assurance Project Plan,
- Summary of quality assurance/quality control programs, training and accomplishments,
- Results of technical systems and performance evaluation audits,
- Significant quality assurance/quality control problems, recommended solutions and results of corrective actions,
- Summary of data quality assessment for precision, accuracy, representativeness, completeness, comparability and method detection limit,
- Discussion of whether the quality assurance objectives were met and the resulting impact on technical and enforcement areas,
- Limitations on use of the measurement data and discussion of the effects of such limitations on the defensibility of the data.

The MDNR Reclamation Laboratory QA Officer and MDA QA Officer will review this plan once a year.

Guide to analytical Values for Flame and Zeeman GFAA

Matrix Water
Date December 1995
The following detection limits were determined by analyzing the corresponding analyses on Flame and Zeeman GFAA.
Seven standard solutions of the same concentration, alternating with seven blanks were used to get the corresponding absorbance.
From the absorbance reading each detection limit was calculated using the Method Detection Limits according to US EPA recommendation.

Analyze	Method	Method Description	Detection Limit ug/L	Method	Method Description	Detection Limit ug/L
Al	3111D	Flame/Nitrous oxide	500			
As				3113B	Furnace Zeeman	0.8
Ca	3111B	Flame/Acetylene	100			
Ca	3111D	Flame/Nitrous oxide	80			
Cd	3111B	Flame/Acetylene	100	3113B	Furnace Zeeman	0.4
Co	3111B	Flame/Acetylene	100	3113B	Furnace Zeeman	0.4
Cu	3111B	Flame/Acetylene	100	3113B	Furnace Zeeman	0.4
Fe	3111D	Flame/Acetylene	100			
Hg				2452	Auto Cold Vapor	0.5
K	3111B	Flame/Acetylene	50	3113B		
Mg	3111B	Flame/Acetylene	80	3113B		
Mn	3111B	Flame/Acetylene	100	3113B		
Na	3111B	Flame/Acetylene	50	3113B		
Ni	3111B	Flame/Acetylene	100	3113B	Furnace Zeeman	0.8
Pb	3111B			3113B	Furnace Zeeman	0.8
Sb				3113B	Furnace Zeeman	0.4
Zn	3111B	Flame/Acetylene	50	3113B		

Key:

3111B = Flame analyses using Air/acetylene gas
3111D = Flame analyses using Acetylene/Nitrous oxide gas
3113D = Zeeman Graphite Furnace analyses using argon gas

Source:

1) Standard Methods for the examination of water and wastewater 18th Ed. 1993.
Greenberg, E. Arnold: Clesceri, S. Lenore and Easton, D. Andrew.
2) Analytical Methods for Graphite Tube Atomizers, Varian. 1988.
Rothery, R. Varian Australia Pty. Ltd.
3) Analytical Methods Flame Atomic Absorption Spectrometry. 1989.
Rothery, E. Varian Australia Pty. Ltd.
4) Methods for the determination of metals in environmental samples. 1992.
U. S. Environmental Protection Agency.
Smoley, C. K.

$$MDL = (t) * (s)$$

Where t = Student's t value for a 99% confidence level and a standard deviation estimate with n-1 degrees of freedom. (t - 3.14 for several replicates).
s = standard deviation of the replicate analyses.

Attachment A6.2.

Department of Natural Resources
Laboratory Quality Assurance Program

Laboratory Calibration

- pH and specific conductance (SC) analysis of laboratory distilled water.
- Reference checks of Eh meter and probe.
- Daily calibration of pH meters with standard buffer solutions.
- Calibration of conductivity meters with standard reference solutions.
- Precision comparison between pH meters.
- Calibration at any time meter or probe is suspect.
- Accuracy check with inter-laboratory set point standards for pH, SC and alkalinity.
- Dissolved oxygen meters are calibrated before each sampling.

Laboratory Instrument Maintenance

- pH probes are cleaned according to probe manual instructions (EDTA) plus additional cleaning when used for measuring pH of extraordinarily dirty or organic samples (HCL).
- SC meters are cleaned using a mild cleaning solution when needed.

Analytical set points and distilled water blanks

- One masked set point per 50 metals or sulfate samples sent to the Minnesota Dept. of Agriculture.
- One masked distilled water blank per 50 samples sent to the Minnesota Dept. of Agriculture to monitor for contamination from sample collection or laboratory washing procedures.

APPENDIX 7

SEED MIX - SELECTION AND COSTS

Attachment A7.1	Seed mix selection
Table A7.1	Master list of species for use in seeding wetlands on tailings basins.
Figure A7.1	Design schematic of the South site at National Steel.

Attachment A7.1. Seed mix selection

Seed mixes – nursery recommendations for native seeds

Prairie Restorations:

- Broadcast seed 16-18 lb/acre of grasses plus 1-5 lb/acre of forbs. If the seeds are drilled, the grass portion can be 8-10 lb/acre.
- Light raking after seeding.
- Mulch with clean oat straw at a rate where the soil is visible through the mulch, approximately 1.5-2 tons/acre.

Prairie Moon:

- 6-10 lb/acre grasses plus 2-4 lb/acre forbs.
- 20 lb/acre oats and 5 lb/acre annual rye grass as nurse crops combined.
- Lightly drag to a depth of 2 inches after seeding.
- Mulch.
- Note: for broadcast seeding, they recommend a filler of moistened sawdust or vermiculite.

Prairie Nursery:

- 10 lb/acre native seeds consisting of about 50% grasses.
- One of the following nurse crops: oats @ 64 lb/acre (2 bushels), annual rye grass @ 5 lb/acre (7-8 lb/acre on slopes), annual flax @ 10 lb/acre.
- Note: they recommend a filler of moistened sawdust, vermiculite, or sand.
- Note: they do not recommend using rye grain as a nurse crop.

MnDOT: (for Mix 25A)

- native seed mix is prescribed in the Seeding Manual.
- Broadcast rate: About 1 lb/acre of forbs plus 15.5 lb/acre of grasses.
- Drill rate: This rate is 60 % of the broadcast rate.
- About 23 lb/acre of oats or winter wheat plus about 5 lb/acre of annual rye grass as nurse crops.
- Fertilize with 6-24-24 (N-P-K) at the rate of 200 lb/acre.
- Mulch with prairie hay or meadow hay at 1.5 tons/acre or straw (less desirable) at 2 tons/acre.
- Note: Winter wheat is substituted for oats after September 15.
- Seeding times: Spring: May 1- July 10
Fall: none
Dormant: September 15 - November 15

Seeding times (based on nursery recommendations): The best time to seed is from late May through June. Fall seeding is best from late September until freeze up.

Attachment A7.1. Seed mix selection (cont.)

Rationale for selection of custom seed mix

Almost all of the species listed in the table below were ordered if they were available. Generally, cost was not the biggest concern in selecting the species. Most important was to order as many species as was reasonable in order to create a wetland with as great a diversity as possible. Secondly, a high number of species were chosen simply to see which species would grow. We used 37 species in our custom mix. All except for a couple were sown at equal rates by weight. This was for convenience in assessing relative success of the various species.

An application rate of 10 lb/acre native seed is about the minimum rate that is recommended by nurseries. Rates used in past studies by the DNR were 5 and 2 lb/acre. These rates were used to keep the seed costs down and yet introduce at least some native species to the areas seeded. Unfortunately, hydrologic conditions were drier than anticipated in these studies and many species did not grow. It is not clear if this was due to the hydrology or because there were so few seeds sown. Since the highest priority in the current study was to see which species would grow and survive in a tailing basin environment rather than to keep costs down, the 10 lb/acre rate was used.

After two or three years, a mix could be developed that excludes species that do not grow. Also, the proportions of each species in the seed mix could be adjusted based on past results.

The nurse crops we used and their application rates generally followed the guidelines of the nurseries and MnDOT. A relatively high rate of annual rye was used to minimize erosion because the plots were on a slope.

Seed Costs – Details

Custom Wetland Mix

10 lb/acre native grasses and forbs	@ $167.08/lb	=	$1,670.80
20 lb/acre winter wheat (variety: Roughrider)	@ $0.167/lb	=	3.34
8 lb/acre annual rye grass	@ $1.05/lb	=	8.40
Total = 38 lb/acre			$1,682.54
Final price per pound = $44.28			

MnDOT Mix 25A

44.6 lb/acre	@ 11.97/lb	=	$ 533.86

Attachment A7.1. Seed mix selection (cont.)

The above price is for the complete mix, which consists of:

Winter wheat (or oats)	23.6 lb/acre
Annual rye grass	4.9 lb/acre
Native grasses	15.2 lb/acre
Native forbs	0.9 lb/acre

Discussion on reducing costs

The cost of the custom mix can be reduced significantly by ordering in quantity. As a rule, per pound prices are about 6.25% less than the per ounce price (you get 16 ounces for the price of 15). Even the price of the Mix 25A could be reduced if it was purchased in quantities. For example, when we ordered about 8 lbs of Mix 25A, the cost was $11.97 / lb. Later, we needed another pound which cost $15/lb. The large order was about 20% cheaper than the small order.

Costs can also be reduced by using less of the expensive species and more of the cheaper species. This rationale is usually valid because often the more expensive species have smaller seeds, and therefore less are needed in proportion to the other species. Usually the forbs are more expensive than the grasses. There were 16 grasses and 21 forbs in the custom mix used in this project. The forbs comprised about half of the native mix. The average price per ounce of grass and forb species were $8.42 and $14.58, respectively. If the proportion of the species used in the mix was varied so that the forbs comprised only 15 to 25% of the native mix, then seed costs could be reduced in the range of 13 to 19%.

Transplants

We have not used transplants. They are becoming more abundant and may be a way to improve the wetland community by interspersing transplants in a seeded area. The quantity of native seed used could be reduced to compensate for the cost of the transplants. This approach seems best suited in substrates with poor fertility and no seed bank. The best way to assure a particular species grows in an area is by using transplants. Typical transplant spacing is 1-2 meters.

Currently Marshland Transplant and Prairie Moon Nursery offer a selection of seedlings that range in price from $0.17 to over $1.00 per plant. Note that an order should be placed well in advance to assure a supply and to reduce costs. The seedlings typically would be planted among an area that already was seeded and starting to grow. Planting of the transplants is most successful during the wettest periods of the summer.

Attachment A7.1. Seed mix selection (cont.)

Wetland seed master list

This list (see table below) was compiled by reviewing the catalogs of the three nurseries closest to northeastern Minnesota. The nurseries are:

Prairie Restorations, Inc. (about 125 miles south)
31922 - 128th Street
PO Box 327
Princeton, MN 55371
(612) 389-4342

Marshland Transplant Aquatic Nursery (about 300 miles southeast)
PO. Box 1
Berlin, WI 54923
(414) 361-4200

Prairie Moon Nursery (about 225 miles south)
Route 3 Box 163
Winona, MN 55987
(507) 452-1362

All of the FACW and OBL species listed in the three catalogs (except for alien species) are listed in the table.

Species availability varies from year to year which in part affects cost. Costs vary substantially between nurseries for some of the species listed. There are two primary reasons for this. The first reason is supply related. If a nursery has a source where a large quantity of seeds can be harvested, then their price may be relatively low compared to a nursery that has a short supply of that species. The second reason has to do with quality of the product. Most of these seeds are sold in bulk and the amount of chaff and debris included with the seed can vary immensely by species and nursery. Some of the nurseries clean their seed better than others, so the buyer purchases more seeds per unit weight from that nursery. Due to the extra labor involved in cleaning the seeds, a higher price is often charged. So in many cases, you get what you pay for.

Absent from the table are FAC species. Many facultative species are available. Rather than specify individual species, it was more efficient to rely on MnDOT's Mix 25A and the associated forb list for northeast Minnesota as the species recommended for areas in transition between wetland and upland. The MnDOT mix is now sold in bulk and so the price is relatively cheap.

Table A7.1. Page 1 of 2. Master list of species for use in seeding wetlands on tailings basins (costs were quoted in September, 1997).

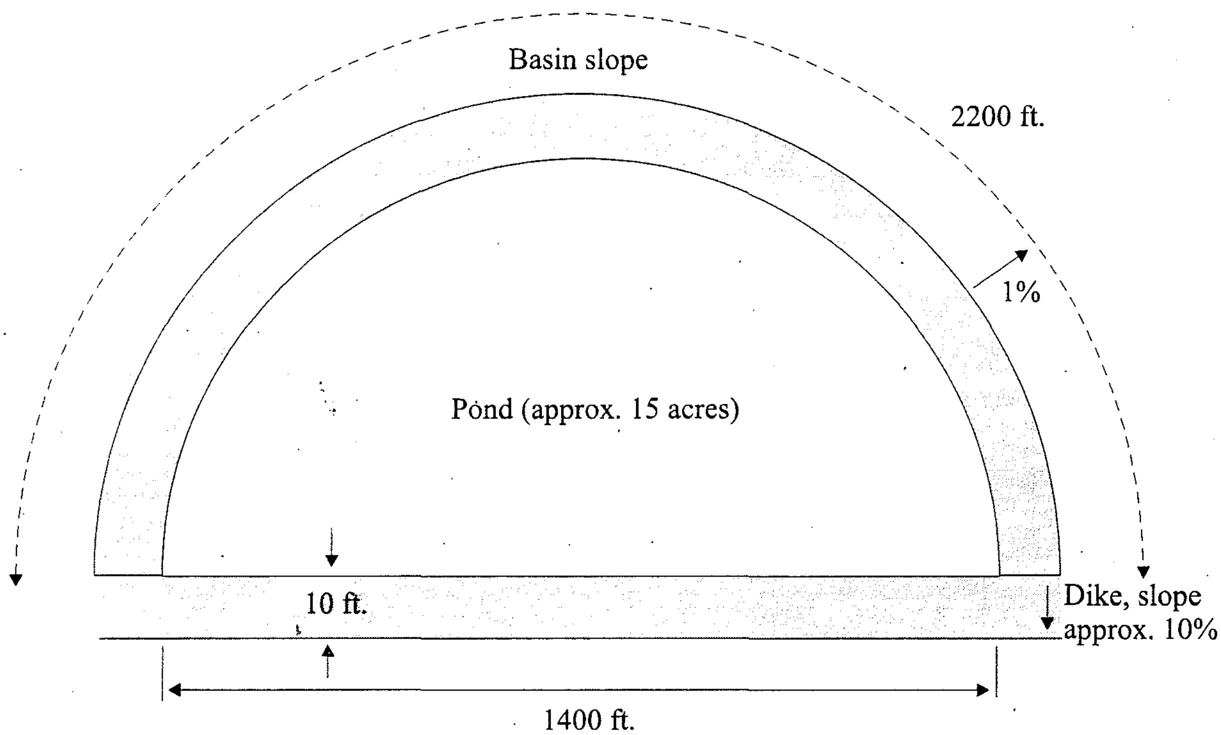
					Per Ounce Cost		
			IND		Nursery		
GENUS	SPECIES	COMMON NAME	STATUS	ordered	A	B	C
Acorus	calamus	Sweet flag	OBL	x	16	5	5
Alisma	plantago-aquatica	Water plantain	OBL	x	8	6	
Alisma	subcordatom	Mud plantain	OBL	x			3
Angelica	atropurpurea	Angelica	OBL	x		10	2
Asclepias	incarnata	Swamp milkweed	OBL	x	20	15	12*
Aster	puniceus	Swamp aster	OBL	x	20	30	40*
Aster	simplex(lanceolatus)	Panicled aster	FACW	x	20	30	
Aster	umbellatus	Flat-topped aster	FACW			30	30*
Bidens	cernua	beggar tick, nodding	OBL			10	10
Bidens	coronata	Tickseed-sunflower	OBL			12	10
Calamagrostis	canadensis	Blue Joint grass	OBL	x	7.5	12	60**
Carex	bebbii	Bebbs sedge	OBL	x		12	
Carex	comosa	Bottle-brush sedge	OBL	x	20	12	8
Carex	retrorsa	Retrose sedge	OBL	x		12	12
Carex	scoparia	Pointed broom sedge	FACW	x		12	8
Carex	vulpinoidea	Fox sedge	OBL	x	20	5	4
Cicuta	maculata	Water hemlock	OBL			10	10
Eleocharis	acicularis	Least Spike rush	OBL			50	
Eleocharis	obtusa	Blunt Spike rush	OBL			50	
Elymus	virginicus	Virginia Wild rye	FACW-	x	7.5	2	2**
Epilobium	coloratum	Willow herb, purple leaf	OBL			25	
Eupatorium	maculatum	Joe pye weed	OBL	x	8	15	12*
Eupatorium	perfoliatum	Common Boneset	FACW+	x	8	10	15*
Gentiana	andrewsiii	Bottle Gention	FACW			35	30
Glyceria	canadensis	Canada manna grass	OBL	x		8	10
Glyceria	grandis/maxima	Giant Manna grass	OBL	x	15	8	5
Glyceria	striata	Fowl manna grass	OBL	x		8	10
Helenium	autumnale	Common Sneeze weed	FACW+	x		5	6
Impatiens	biflora(capensis)	Jewel weed-touch me not	FACW	x			20
Iris	versicolor	Wild iris	OBL	x		10	10
Juncus	effusus	Common rush	OBL	x		20	20
Lobelia	siphilitica	Great Blue lobelia	FACW+	x		15	10
Mimulus	ringens	Monkey flower	OBL	x		35	20
Onoclea	sensibilis	Sensitive fern	FACW	x			10
Pedicularis	lanceolata	Marsh betony	FACW+			25	15
Penthorum	sedoides	Ditch stonecrop	OBL			5	10

Table A7.1. Page 2 of 2. Master list of species for use in seeding wetlands on tailings basins (costs were quoted in September, 1997).

Polygonum	lapathifolium	Knot weed	FACW+				
Polygonum	pensylvanicum	Pink weed	FACW+				
Ranunculus	pensylvanians	Buttercup	OBL				
Sagittaria	latifolia	Broad-leaf arrowhead	OBL	x		12	8
Scirpus	acutus	Hardstem bulrush	OBL	x	25	10	12
Scirpus	atrovirens	Green bulrush	OBL	x	7.5	7	8
Scirpus	cyperinus	Wool grass	OBL	x	2.75	7	8
Scirpus	validus	Soft stem bulrush	OBL	x	20	10	10
Solidago	riddellii	Riddell's goldenrod	OBL	x		25	20*
Solidago(Euthamia)	graminifolia	Grass-leaf goldenrod	FACW-	x	20	20	60*
Sparganium	eurycarpum	Giant burr reed	OBL	x	5.25	10	3
Spartina	pectinata	Cord grass	FACW+	x	10	15	10**
Verbena	hastata	Blue Vervain	FACW+	x	6	6	3
Vernonia	fasciculata	Common ironweed	FACW	x	8	10	20*
* Indicates seeds are defluffed.							
** Indicates seeds are pure live seed (PLS).							

Nursery A = Prairie Restorations
Nursery B = Marshland Transplant
Nursery C = Prairie Moon

Figure A7.1 Design schematic of the South site at National Steel.



Reclamation

Dike: Since the slope is much steeper, only a thin strip (approx. 10 ft. wide) would be reclaimed with substrate and the custom seed mix. (Approximate area: 0.3 acres.)

Basin: The slope within the basin is much more gradual than the dike. The estimated slope is about 1%. Therefore, for a 1 foot fluctuation of water level in the pond, the shoreline will move 100 ft. in the basin, but only 10 ft. on the dike. The reclaimed strip shouold be wider than the basin area, or at least 50 ft. wide. (Approximate area: 2.5 acres.)

Total Cost

4 inches of amendment:	\$10,800/acre x 0.3 acre = \$32,400
Custom seed mix:	\$2000/acre x 0.3 acre = \$6000
	Total: \$38,400

Net cost per acre of wetland = \$38,400/18 = \$2100