WATERSHED RECLAMATION AT BUTLER TACONITE, UNDER MINNESOTA DEPARTMENT OF NATURAL RESOURCES "RULES RELATED TO MINELAND RECLAMATION" CHAPTER 6130--6130.01-6130.63[1]

by
Dan R. Chilton[2]

Abstract. Butler Taconite became the first major mining company in Minnesota to permanently close, after the "Rules" became law in 1980. The company was operating in an area that had been mined for natural iron ore (hematite) since the early 1900's. Thus the reclamation project inherited problems that had been accumulating over a long period of time. Three of the four creeks that required reclamation empty into Swan Lake, a very sensitive sport fishing and recreational body of water, whose shoreline is almost completely occupied by either summer cottages or year around residences. Some of the historic stream beds were now occupied by the mine pits, while others were involved in tailings basins. The closure plans were all closely scrutinized by the MDNR, the MPCA and the "Concerned Citizens for Swan Lake". The closure same on very short notice, caused by the bankruptcy of one of the company partners. State regulations call for notification of closure to be given and a closure plan to be submitted two years in advance. Therefore, the plans were in violation of state regulations, even before they were written.
ADDITIONAL KEY WORDS: Water quality, Water quantity, Embankment stabilization, Flow gradient, Stream erosion and Mine water acre· feet.

Location and History

Butler Taconite was a magnetic taconite mining and processing operation on the Mesabi Iron Range of northeastern Minnesota. It was located about midway between the cities of Hibbing and Grand Rapids with the closest small city being Nashwauk in Itasca County. Toward the west end of the Mesabi Range, the magnetic taconite is interrupted by frequent zones of oxidized material, resulting in smaller

[1]Paper presented at 1992 American Society for Surface Mining and Reclamation Meeting, Duluth, MN June 14-18, 1992.

[2]Dan R. Chilton was the Senior Mining Engineer for the Hanna Mining Company. He retired in 1985 and at present he is a Mining Consultant for the Butler Taconite Closure.

Proceedings America Society of Mining and Reclamation, 1992 pp 705-724
DOI: 10.21000/JASMR92010705

https://doi.org/10.21000/JASMR92010705

mines than those of the Eastern Range. Butler had opened up three such deposits, namely Pits 1, 2 and 5. For the most part the mining area had been previously mined for natural iron (oxidized hematite), beginning in the early 1900's and continuing until taconite mining began. Here again, there had been a series of relatively small mines, some connected and some not. The surface of overburden excavation was continuous, however, from the west edge of the city of Nashwauk to the southwest for about two miles. Since this activity was carried on above the magnetic taconite horizon, it made that commodity more available.

Butler Taconite was a venture made up of three partners, namely, Inland Steel Company, Wheeling-Pittsburg Steel Company, and the Hanna Mining Company, Hanna being the operating company. It had been in operation since January 1967, and had produced 40.5 million tons of quality iron ore pellets. Permanent closure came June 29, 1985, because Wheeling-Pittsburg Steel filed for Chapter 11 bankruptcy and was unable to purchase its share of the pellets. In such an event, the venture agreement called for total liquidation of the operation.

According to the rules related to Mineland Reclamation Chapter 6130.01-6130.63, a closure plan was to be submitted two years prior to closure. However, but since there had been only 30 days' notice, it was only possible to notify the DNR and the PCA and start working on a plan. This plan contained four main sections: (1) Watershed; (2) Mine Stockpiles; (3) Revegetation; and (4) the Plant, Shop and Office area. In this paper, only the watersheds and the revegetation related to them will be considered.

The Butler Taconite mining area falls within the upper Mississippi watershed, with the most important sub-watershed being the Swan Lake-Swan River drainage. A minor acreage is included in the Sucker Creek to Prairie River drainage. The soils were laid down during the Wisconsin Glacial Period and consist of: (1) a lower till deposited by the Brainerd SubLobe of the Rainy Lake Lobe or possibly the Superior Lobe, (2) a middle outwash deposited near "Ice Edge" areas during ice melt advance and retreat, and (3) an upper till deposited from the Alborn Phase of the St. Louis SubLobe.

Five creeks drain the area: Oxhide, Pickerel, and O'Brien flowing into Swan Lake; Moose flowing into Hay Creek; and Swan Lake and Sucker flowing through the Sucker Lake Chain and into the Prairie River. The Laurentian Divide, separating flowage to the Gulf of Mexico from the flowage to Hudson's Bay, is only a few miles north of Nashwauk. As a consequence, none of the streams are large. Figure 1 shows the location of these watersheds.

Swan Lake, where three of the streams involved empty, is a fishing and recreational body of water about four miles long and 1 1/2 miles wide at its widest point. There are three other streams feeding the lake, namely Hay Creek, Hart Creek, and Snowball Creek. The maximum depth is about 60 ft. in the trough that runs down the center. Flowing out of the West Bay is the Swan River, which winds its way to the Mississippi. The shoreline is very developed with almost an even split between summer homes and year around residences.

In 1964, the Hanna Mining Company was developing plans to open up two taconite operations, Butler Taconite near Nashwauk, and National Steel Pellet Company near Keewatin. Since all of the water appropriated by either plant would come from the watersheds feeding Swan Lake or from Swan Lake itself, Hanna applied for and received a Joint Water Permit. This permit stipulated that the level of Swan Lake could not be allowed to fall below the elevation of 1334 ft.

Both plants were built with expansion in mind. The original combined capacity was about 4.5 million tons per year, but the overly optimistic forecast of the 1960's looked forward to a combined capacity of 16 million tons per year. In 1966, as a part of plant construction, a two-level sheet piling weir was placed across Swan River about 1/2 mile downstream from the outlet. The effect of this weir was to raise the lake about 6" and retard low level discharge.

After the plants started up in 1967, there was a period of above average rainfall, resulting in complaints about high water. In the early 1980's it became apparent that the plants were not going to expand and that the projected water use per ton of product had been high. Butler Taconite had pulled their pumps from Swan Lake and installed them at their tailings basin. As far as hanna was concerned the weir was no longer required.

The company sent a questionnaire to the lakeshore owners, asking what they wanted done to the lake level. The results showed that the majority like the lake as it was, but enough people wanted it lowered that the DNR Commissioner felt a public hearing was in order. Those who wanted a change attended the hearing; those who were satisfied stayed home. The hearing officer recommended a change and it was the decision of the DNR Commissioner that the weirs should be lowered 6". This decision was forwarded in early 1985, prior to the announced closing of Butler Taconite, but the job could only be done in the fall during a period of low flow; thus it became the first project of the closure.

The channel about the weirs was cleaned out and the spoil material spread and planted. Then the sheet piling weirs were sandbagged upstream and cut with a torch. Everything went smoothly and to the satisfaction of the DNR and those who wanted the lake lowered. The next summer, when the lake level dropped during an extended dry period, many people, who had not bothered to go to the hearing complained of low water. The was our first lesson. Only those who want a change go to a hearing, and the results are not always what the majority want but only what the majority of those who attend want.

At the same time that the weirs were being cut, plans were being formulated for the reclamation of the upstream watersheds. These plans had to satisfy the DNR, the PCA and the "Concerned Citizens of Swan Lake", hereafter referred to as the CCSL. This local organization was formed to protect the quality of the waters of the lake which had been deteriorating for several years. The CCSL were not united in their desires. Some wanted the mine water pumping resumed or replaced at once, while others were sure that all the problems of the lake were caused by the mining company.

In formulating the watershed reclamation plan it soon became apparent that work should start as soon as possible in the fall of 1985 and continue through the winter so that spring runoff would be routed where it was needed. These reasons will be discussed later in the paper.

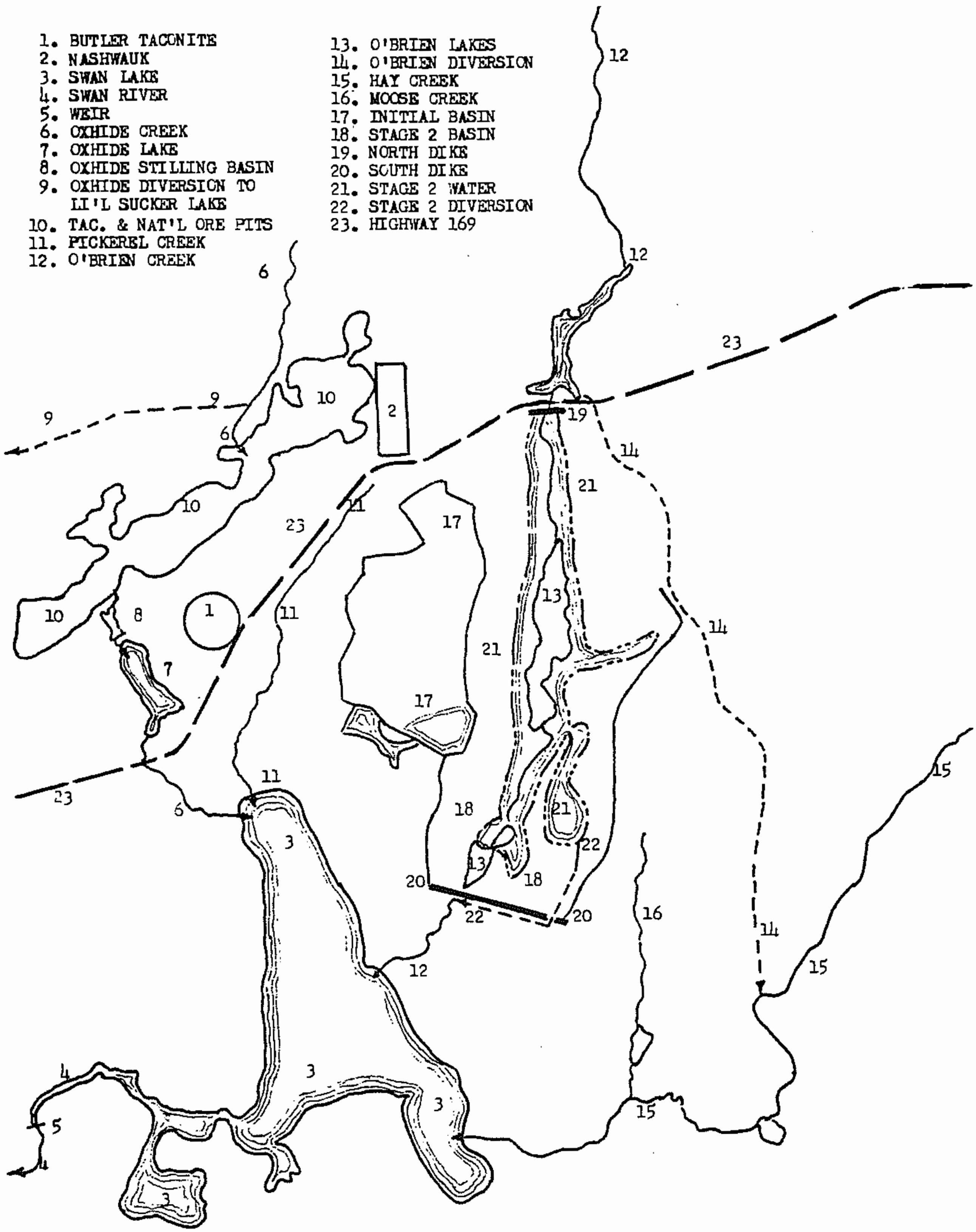
As soon as the watershed plans were complete we presented them to the DNR and explained out need for haste. The agreed with our analysis but the "Rules" call for publication and a period for response. To short cut this lengthy time period we proposed a public meeting where we could present our plans, explain their function and ask for approval. The DNR agreed that if we could satisfy the CCSL and the general public at our meeting, we could proceed at our own risk with the construction phase of the reclamation.

The meeting was held, and with the aid of large scale maps, we presented all the watershed changes we intended to make and explained how these changes would affect the lake. We also put to rest the fears of many people who had thought that Butler Taconite was going to close its doors and leave everything as it was. The excellent job we had just completed at the weirs gave us a track record. We were able to field most of the concerns of the lake residents. At the conclusion of the meeting we received a vote of confidence to proceed with the reclamation as planned.

For discussion purposes, this paper will consider each watershed individually, beginning with the history and condition of the stream, the closure, and concluding with the solution, construction, and final reclamation.

An inherent problem for each watershed was the beaver population. In the 70's and 89's there has been a beaver population explosion in northeastern Minnesota. In the Butler Taconite mining area there were beaver everyplace there was running water, even where the runoff was only seasonal. Some of the plans were made because of beaver; sometimes the beaver aided the plans by stilling the water downstream of construction and sometimes they tried to wreck the plans.

Figure 1. Location of plant site, streams, creeks, and lakes.



Oxhide Creek and Sucker Creek Watersheds

The Oxhide Creek watershed, upstream from Oxhide Lake, was originally 8.9 sq. mi. The creek rose northwest of Nashwauk and flowed south and west into Oxhide Lake. From there it continued southeasterly into the north end of Swan Lake. When iron ore was discovered west of Nashwauk, Oxhide Creek was found to be flowing over the minable portion of the iron formation. As a consequence, starting in 1925, the stream was rerouted each time a new mine was opened. Finally in 1953, when the Langdon Mine was opened, it became impossible to design a channel that would still flow into Oxhide Lake. A permit was obtained to reroute the upper portion of Oxhide Creek about 1.8 sq. mi. into Little Sucker Lake and the Sucker Creek watershed. By this action, Little Sucker Lake watershed was increased from 2.4 sq. mi. to 4.2 sq. mi. while Oxhide Lake watershed was reduced to 2.3 sq. mi. Between the Langdon Mine and Oxhide Lake, a stilling basin was constructed across the Oxhide Creek valley. Until 1985, mine water was pumped into this basin and then discharged into Oxhide Lake. There was and still is a NPDES permit to cover this discharge to public waters. In July of 1985, all mine pumping ceased.

The solution for this watershed was to allow the pits to fill with water and overflow down Oxhide Creek. To make the overflow level as low as possible, a channel was dug from Pit 5 into the Oxhide Basin, at an elevation of 1355'. For the time being, the stilling basin dike was left intact. It would be breached later when water started flowing through the channel. At 1355' a small stilling pond would remain in the basin.

A review of the pits showed that at 1355' there would be one body of water from Nashwauk southwest to and including Pit 1. Between Pit 1 and Pit 5 was a hump of iron formation that had never been mined. The highest elevation here was 1380'. Two rows of holes were drilled across this hump down to an elevation of 1350'. The blast produced a French Drain that will allow water to flow into Pit 5. This drain should also tend to make that flow more even.

Upper Oxhide Creek was rerouted to flow into the pits and not into Little Sucker Lake. The watersheds are now: Little Sucker Lake, 2.6 sq.mi.; Oxhide Lake, when the Pits overflow, 8.7 sq.mi.

So how soon would the Pits overflow? We tabulated all the known data as shown in Table 1.

So far the calculations were fairly straightforward, but at this point some assumptions had to be made. The positive effect of the return of upper Oxhide Creek flowage to the pits was combined with the negative effect of the water table returning to 1355' in the iron formation surrounding the pits. Therefore, 150% of the water volume capacity for each pit was used and 1,000 acre-feet/year of evaporation was

Table 1. Pit Water Elevation and Average Yearly Pumping Volumes.

Pit	Water Elv 8/1/85	Vol to 1355 Acre Ft	Pumping Acre Ft	Years To Fill
Hawkins	1349'	682		
Harrison	1331'	464		
2	1269'	7,270		
1	1150'	18,418		
Sub-Total		26,834		
5	1240	4,647	5,887	4.6
Total		41,096	2,323	6.1
			8,210	5.0

deducted from the inflow. The result of this pseudo-engineering calculation was 8.5 years, or sometime in early 1994. Of course, no matter how you calculate it, the rainfall and runoff are going to determine the end results. A recalculation made in the summer of 1991 showed we are still on target.

The DNR required a minimum flow of 200 GPM into Oxhide Lake during the months of June, July and August. To fulfill this obligation, a 450 GPM submersible pump was installed in Pit 5. Then a small dike was constructed across our new channel between Pit 5 and the Oxhide Stilling Basin. The floating decant, which was still in the basin, was repaired. This system allows us to pump at 450 GPM int the basin and discharge at about 250 GPM into Oxhide Lake. The system works well except that beavers try to plug the decant with weeds and mud.

The only other concern was low oxygen fish kill in Oxhide Lake during the winter. The stilling basin dike leaks a fair amount and by filling the basin during November and December, we get a low inflow into the lake during January, February and March. So far this has kept oxygen levels high enough to prevent any winter kill.

To prevent additional problems caused by beavers, all the culverts in the upper Oxhide Creek waterway were removed, as these prime targets for plugging by the beaver. There are also a series of small beaver dams on the creek and they do pond some of the water we could use to run into the pits, but there is no successful way to control this problem.

West of Pit 5 were a series of fresh water ponds used for a natural ore operation. These dikes were breached and the water directed toward Pit 5. All excavations were vegetated.

Pickerel Creek Watershed

Pickerel Creek has its beginning just south of Nashwauk and flows southwest parallel to Highway 169 and the Burlington Northern Railroad. Then it flows almost due south into the north end of Swan Lake. The flow appears to start from a spring and there are springs feeding it for most of its length. In pre-mining days, Pickerel Creek supported trout, and it was designated as a Trout Stream by the DNR, although there were no trout in it at this time. Mine water had been released to the creek for many years so that it had carried higher than its normal volume. Northwest of Highway 169, a stilling basin had been constructed to receive this water. The discharge flowed under the highway and the railroad before emptying into the stream. In 1966, two more ponds were created on the creek. The downstream dam was called Dike 13. About 1/2 mile upstream from Dike 13, Dike 14 was constructed. In the pond above Dike 14 was a floating decant to regulate the flow. Upstream from Dike 14 and opposite the plant, the tailings line crossed Pickerel Creek on a fill about 40 ft. high and at this point, the creek ran through a 48" culvert. Just west of Dike 14 is the Butler Taconite Sewage Lagoon. The plant and office/shop buildings each had a septic tank and the overflow from these tanks was discharged to the lagoon. The discharge from the lagoon emptied into Pickerel Creek above Dike 14 and, it must be noted, that at no time had the lagoon discharge ever violated the discharge permit.

Pickerel Creek flowed near Highway 169 allowing easy public access to the area and any work we did had high visibility to the public. Several members of the CCSL had the opinion that the pond created by Dike 14 -was the sewage lagoon and no amount of sampling or explanation could change their opinions. As a result, they wrote letters of protest to the DNR and the PCA about the work we were doing in this area.

It should also be noted the Butler Taconite policy in regard to visits by any organization, either state or private: "All such visits must be accompanied by someone from Butler. Any sample could be taken at any location provided it was spilt with Butler, or Butler could take its own sample at the same location. Any analysis could be run on the sample taken provided Butler was informed what that analysis was going to be and could run a like analysis". This policy was not always followed by all the visitors to our property. This led to some misunderstandings at later meetings.

The DNR/Fisheries staff wanted all ponds on Pickerel Creek eliminated so that warm pond water would not raise the stream temperature. With this criterion in mind we started the reclamation of the Pickerel Creek Watershed.

The first project was a cut through the 40 ft. tailings line fill and the removal of the 48" culvert. Beaver were already working just upstream and they hadn't heard about the "No Pond" idea and if they plugged the culvert the resulting pond would threaten the adjacent railroad. A cut with a 10 ft. bottom and 2.5 to 1 back-slopes was made through this fill. Flow in the creek was low so that the stream could be blocked off when then final cut was made, greatly reducing the down stream suspended solids. The cut was completed late in 1986, so we were forced to do dormant seeding in late October and to mulch using asphalt tacifier. By July, 1987, there was a very good vegetative cover on the slopes.

The next project was Dike 14. Here again we would construct a cut with a 10 ft. bottom and 2.5 to 1 back-slopes. The bottom and sides for five feet had to be rocked as the stream had a rather steep gradient at this point. We used 6" crushed taconite of which there was a good supply back at the plant. We lowered the water in stages by burying a pipe almost through the fill and then digging a slot from the pipe to the pond. To do this the pipe should have outside baffles welded to it and the backfill must be firmly compacted. The project went well, but when we released the last water we noticed quite a few fish went with it.

The final work on Pickerel Creek was the removal of Dike 13. Because there were no more ponds downstream to act as stilling basins and to regulate the flow, the PCA required that the pond be pumped down. The cut here would have a 20 ft. bottom and 2.5 to 1 backslopes. Most of the work was done with dozers pushing soil to a spoil pile to the west of the dike. By pumping all the water out we were not able to release any of the fish. The work was done in the hot summer weather of 1987, and as the water dropped down into the old stream bed it became quite warm. The DNR were notified but were not interested, the fish being mostly long skinny Northern Pike, known locally as "Hammer Handles". Suddenly there appeared on the scene three men in bathing suits and tennis shoes. They were equipped with landing nets and cardboard boxes. They plowed around through the mud and retrieved most of the larger fish and carried them away. We never learned where they came from, how they knew about the situation, who they were or what they did with the fish. The remaining fish died as the last of the water was pumped out. There was quite a stench until the crows and ravens found the place. Someone reported a "Massive Fish Kill" and the CCSL wrote a letter to the DNR complaining that everything we had been doing was wrong. The DNR did not agree with this accusation.

We were able to seed the cut and spoil areas while the soil was still damp, and the response was very rapid. In the pond bottom, the vegetation which had been under water for 20 years came to life and there were grasses, willows and even aspen springing up all over. In the pond area above Dike 13, we did some hand planting where it was possible, but the areas we couldn't reach revegetated almost as fast, and the cover was just as good. The off-stream stilling basin northwest of the highway was also breached at this time. This completed the work on Pickerel Creek.

<u>O'Brien Creek Watershed</u>

O'Brien Creek is the largest stream in the reclamation area.

It rises very near to the Laurentian Divide and used to flow through a partly filled, preglacial valley. It trended south and then southwest, entering Swan Lake about at the midpoint of the east side. On the way it had passed through O'Brien Lake and Little O'Brien Lake. At O'Brien Lake it was joined by Welcome Creek, coming in from the northeast (see Figure 1).

The O'Brien valley was a prime location for a tailings basin. In the past, natural ore tailings had been deposited into a portion of O'Brien Lake. Permits were obtained to use about 4 1/2 miles of the valley for taconite tailings. To facilitate this, two dikes were built across the valley, called, The "North O'Brien Dike" and the "South O'Brien Dike". The North Dike created Reservoir No. 4, whose purpose was to raise the level of the water about 30 ft. and discharge upper O'Brien Creek into the O'Brien Diversion Channel. This channel, constructed east of the O'Brien valley, also intercepted Welcome Creek and finally emptied into Hay Creek. Hay Creek in turn emptied into Swan Lake on the east of the South Bay. The North Dike has a very wide top and carries the 4 lanes of Highway 169, the Burlington Northern Railroad and a mine service road.

The O'Brien South Dike was the retaining dam of the Butler Taconite Stage 2 Tailings Basin. It was designed to be built in stages and at the time of closure had been completed to an elevation of 1385'. The basin enclosed by these two dikes created a lake of about 900 acres and had a watershed of about 5,400 acres. This was large enough to produce its own source of water. Part of this flow came from the under-dam seepage of the North Dike, but most of it came from snow melt and rainfall runoff. After the dike was closed off and before the area was used for tailings, the excess water had to be syphoned over the dike and into Lower O'Brien Creek.

West of the 2nd Stage Basin and east of Highway 169 and the Butler Plant was the Initial Basin, an area of about 950 acres. This basin had been in use since 1967 and by 1983 very little capacity remained. The capacity that remained was reserved for the standby tailings line. The primary or normal line started pumping the longer distance into the 2nd stage. Connected to the Initial Basin was a clearwater pond where the pumps taken from Swan Lake had been installed. They pumped through a buried line to the head tank at the plant. A float pump was installed in the 2nd Stage Basin to pump to the clearwater pond.

In the 2nd Stage Basin, tailings had been spigoted on the upstream face of the South Dike. Then the line had been moved 600 ft. north at a higher elevation and was in the process of spigoting the next ridge parallel to the dike. When the plant shut down in 1985 and pumping ceased, the water started to rise. The greatest problem might be the next spring, when the combination of heavy snows, a late spring, and then rain, result in a large spring runoff. It wouldn't overtop the dike but at about 1378' elv. it would flow over into the Moose Creek watershed, down Moose Creek to Hay Creek and into Swan Lake. At that time we had no discharge permit nor would we get one until the water quality satisfied the PCA and the CCSL.

Swan Lake was having problems as it was high in phosphates and nitrates. They had to be coming from someplace and who better to blame than a mining company; no matter that no tailings water had ever been discharged to the lake. An extensive water testing program was started but in the meantime the PCA said they would take a very dim view if water flowed into Moose Creek.

The pumps had to be reinstalled and water was pumped to the head tank where it overflowed and ran into the Oxhide Stilling Basin and then backwards through our new channel into Pit 5. This occurred before we had diked off this channel as noted in the Oxhide Watershed reclamation.

The next project was to design and install a permanent outlet for the Stage 2 Tailings Basin. The solution had to meet the following criteria:

1.Return this O'Brien water to lower O'Brien Creek so it would flow to the central portion of Swan Lake.

2.Provide a permanent, maintenance-free channel that would flow with a minimum of erosion (see Table 2).

3.Provide a system that could safely handle storm occurrences (see Table 3).

4.Provide a control at the outlet that would allow the safe release of the accumulated excess water without causing undue channel erosion or downstream flooding.

Here is a description of the channel that fit the above criteria. Following that will be the explanation and calculations that proved the solution. It is only fair to acknowledge that I relied heavily on the design of the O'Brien Diversion Channel. Rather than go with trial and

Table 2. Channel Water Depth, Velocity and Discharge.

Water Depth (ft)	Cross Section Area (Sq. ft)	Velocity (Ft/Sec)	Discharge (Cu.ft/Sec)	Discharge (Acre ft/hr)
0.5	4.6	1.0	4.6	0.4
1.0	10.5	1.6	16.8	1.4
1.5	17.6	2.1	37.0	3.0
2.0	26.0	2.5	65.0	5.4
2.5	35.6	2.8	99.7	8.2
3.0	46.5	3.2	148.8	12.3
3.5	58.6	3.5	205.1	17.0
4.0	72.0	3.9	280.8	23.2

Table 3. Water Balance and Storm Event Data.

Butler Taconite Tailings Basin - Water Balance

Drainage Area	5,443.1	Acres
Pond Area	900.4	Acres
Total Area	6,343.5	Acres

Precipitation/Year/Inches	25	30	35	40
	Acre - Feet			
Water into Basin	13,216	18,859	18,502	21,145
Water Out of Basin				
Evaporation Pond 25"	1,876	1,876	1,876	1,876
Evaporation Land 11"	4,990	4,990	4,990	4,990
Transpiration 7"	3,715	3,715	3,715	3,715
Total Remaining	10,041	10,041	10,041	10,041
Excess Water	3,175	5,818	8,461	11,104
Ave. Discharge cu.ft/sec.	4.4	8.0	11.7	15.3
Ave. flow depth	0.5	0.7	0.8	1.0

Effects of storms on the Stage 2 Basin

Dike Elevations 1385' Normal Pond Elev. 1370'

Pond Elev	Pond Size-Acres	Storm Capacity Acre-Feet
1370.5'	900.4	0
1375'	1,088.4	4,474.8
1378'	1,363.6	8,152.8
1380'	1,547.1	11,063.6

(a) PROBABLE MAXIMUM PRECIPITATION

Storm Dura- ation Hrs.	Precip- itation Inches	Assumed Runoff Inches	Feet	Water Acre-Feet	Elev.
24	23.8	15.1	1.26	7,992.7	1377.9
12	22.0	16.9	1.41	8,944.2	1378.6
6	19.0	15.7	1.31	8,309.8	1378.1

Assumptions: Initial runoff loss 1.5 inches, Infiltration rate 0.3 inches/hr. Conclusion: 1. Dike at 1385' would not be overtopped. 2. Some water may flow out to Moose Creek. 3. At 1376' the channel would be discharging 55.9 acre-feet/hr.

(b) 100 year storm - 10 day precipitation = 10 inches. Assumed runoff 7.8 inches or 0.65 feet. Accumulated water 4,123.2 Acre-feet.

Conclusion: Water would rise about four feet and be no problem.

(c) In 1988, after an extended dry period, there was a nine inch rain in 24 hours. There was some erosion but no real problem in the channel.

error I started with a cross-section that had been tried in the same type of soil. That was an 8 ft. bottom with 2.5:1 backslopes. The cast material would be sloped at 2.5:1 continuous with the channel slope. There would be an 8 ft. top to the pile with a slight pitch away from the channel and then a 3.5:1 slope to natural ground (see Figure 2).

To the east of the main body of water was a shallow bay where the channel could start at an elevation of 1370'; no tailings had reached this point. The channel would discharge in the old O'Brien Creekbed, downstream from the toe of the South Dike, at an elevation of 1343'. The channel, called the South Dike and then turn and run parallel to the dike until it reached O'Brien Creek, a distance of 7200 ft. and a drop of 27 ft. The problem was that the resultant stream gradient would be 3.75 ft. per 1000 ft. yielding a stream velocity much too high for the clayey till soil. To solve this problem we designed five energy-dissipating, rock-lined drops or small falls. There would be 1-2 ft. drop and 4-4 ft. drops with a 35 ft. level bench between them. They would be built into the natural bank at O'Brien Creek as shown in Figure 3. This used up 250 ft. but raised the channel 18 ft. The resulting stream gradient was now 1.3 ft. per 1,000 ft. The velocity would be 1 ft./sec. with 0.5 ft. of flow and 1.6 ft./sec with a one ft. flow (see Table 2).

At the rock-drop areas the channel was dug 14 ft. wide and five ft. below grade. This allowed for 1 ft. of bedding, 2 ft. of -6" crushed taconite and 2 ft. + 6" to 18" blasted rock on the bottom and sides (see Table 4). The final channel would be 10 ft. wide.

The channel entered O'Brien Creek at right angles to the stream bed. Here we built a sweeping curve all out of rock with a rock bottom. There were one major bend and one minor bend in the channel. At these locations the bottom was dug 12 ft. wide and 3 ft. of crushed taconite riprap placed on the outside of the curve.

The Outlet Control was constructed 240 ft. downstream from the pond outlet. A 3 ft. deep slot 20 ft. wide was dug across the channel in the bottom and up the backslopes. This was filled with crushed taconite. On top of this was placed a dike made of the same material. It had a 20 ft. wide top at elevation 1376'. Upstream a 20 ft. wide plug of un-dug material was left. Then the channel was dug upstream into the pond as far as the equipment could reach.

As soon as a discharge permit was received the plug would be removed and the rock weir dug out to 6 in. below pond level. As the pond lowered, the rock would be lowered until all that remained was the erosion control ring.

After the excess water was released, the dike on the Initial Basin was breached with a 20 ft. wide cut and 2.5:1 backslopes: an erosion ring was placed in this cut also. A small pond was left for duck habitat and stilling. The 950 acres of this basin became part of the 2nd Stage Watershed.

Channel Design Calculations

In the Taggert-Handbook of Mineral Dressing (1945), we found and used the "Diagram for Kutter Formula after Kennison" it gave us the flow data shown in Table 2.

As we released water we metered the stream and found that up to 2 ft., which was as far as we went, Kutter and Kennison knew what they were diagraming.

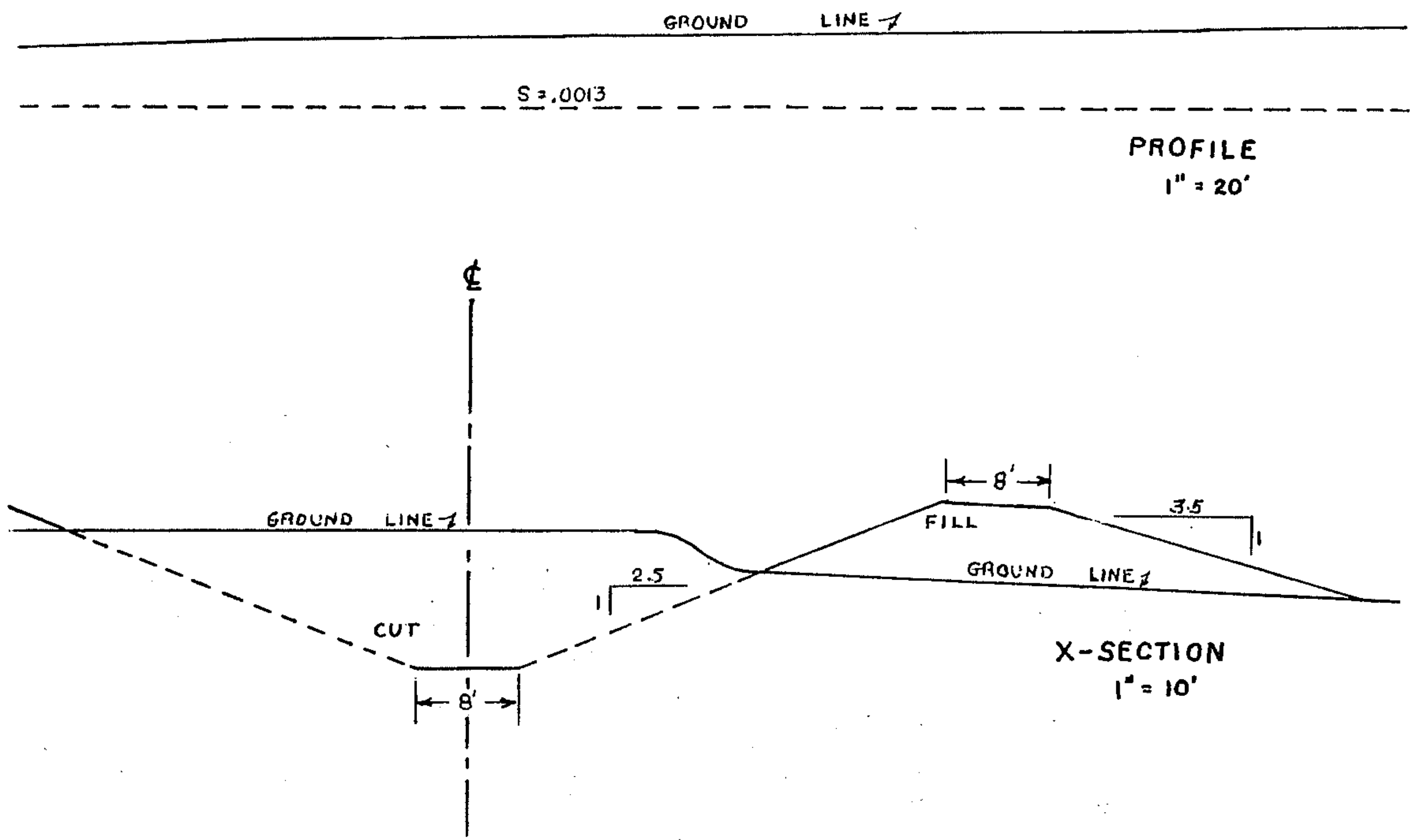


Figure 2. Cross section of the outlet channel for the Stage 2 Basin.

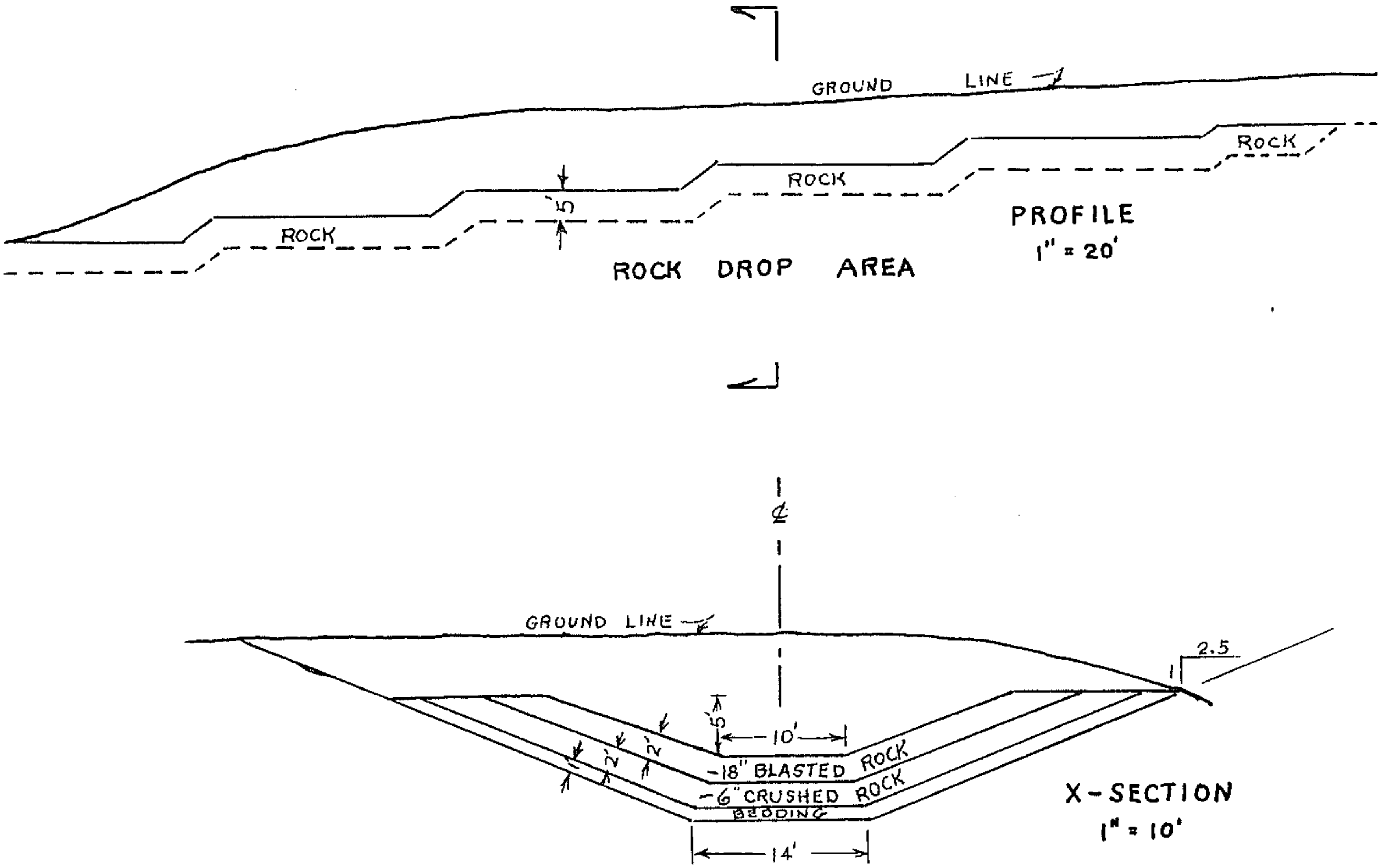


Figure 3. Cross section of the Rock lined drops used in the Stage 2 outlet channel.

Table 4. Construction Material Screen Analysis

NATURAL PIT RUN SANDY GRAVEL

Inches	Mesh	% wt on	Cum % wt	% wt Passing
1.0		11.4	11.4	88.6
.75		3.3	14.7	85.3
.50		3.0	17.7	82.3
.375		3.1	20.8	79.2
	4	4.4	25.2	74.8
	8	4.5	29.7	70.3
	14	7.1	36.8	63.2
	28	12.1	48.9	51.1
	48	20.5	69.4	30.6
	100	16.7	86.1	13.9
	-100	13.9	100.0	

CRUSHED TACONITE ORE

Inches	Mesh	% wt on	Cum % wt	% wt Passing
6		15	15	95
2		45	60	30
1		20	80	20
½		10	90	10
	4	5	95	5
	-4	5	100	

COARSE BLASTED ROCK

Inches	% wt on	Cum % wt	% wt Passing
12	60	60	40
6	25	85	15
-6	15	100	

WATER QUALITY

Without going into details of the testing, the 2nd Stage water proved to be of much better quality than the water in Swan Lake. Where did the phosphates and nitrates come from? To quote "Pogo" by Walt Kelly, "We have met the enemy and they is us". The discharge permit was tied to a Stipulation Agreement. The suspended solids and turbidity in O'Brien at Swan Lake could be no higher than the suspended solids and turbidity in Hay Creek at Swan Lake. There was a break-in grace period, which was lucky, because we had a near disaster.

When we started the flow, the water got under the rock at the 5 little falls and started to erode the soil. We knew at once what the problem was. We didn't have a good layer of rock bedding. It came about by a series of mishaps.

The bedding we had planned to use was a waste product of natural ore benefication called Coarse Heavy Media Tails. It is red in color but we had used it countless times without problems. Once in place and covered it produced no "red water" and it was an excellent bedding material.

The contractor had only hauled a few loads across the highway and to the site when he came to us and told us he had received vague threats if he continued to move this material. Minds were made up and there was no use trying to explain or talk about our prior use and good results.

A look at the screen analysis of the -6" crushed taconite led us to believe there were enough fines to do the bedding. There may have been, but the rock was being loaded and hauled in the winter and the fines were frozen and never were hauled to the site.

We shut the flow off and studied our options. We could take out all the rock and start over with a different bedding or a soil cloth, or we could try to correct the problem in place. We hated to tear out our falls. The crushed taconite and coarse rock had been placed with care and the outside face was just the way we wanted it. So we tried the in-place solution.

Near the site was a deposit of dirty gravel. By that, I mean it had a complete range of sizes. (See Table 4) We hauled it to the site and spread it over the rock in thin layers. Then we washed it down into the rock with hoses until no more would go down. This took about a week and we made lots of muddy water but none of it was red. When we started up the water again the problem had been solved. Clean water came to the falls and clean water left the falls. We gradually increased the flow until we had over 2 feet of water coming down the channel. There were no further problems.

We are ready to try and match Hay Creek. To do this we cut the flow to about 1 ft and started taking our samples. We were helped in this test by some beaver. Downstream on O'Brien Creek were 4 large beaver dams which ponded the water, reduced the velocity and, I'm sure, aided in the reduction of suspended solids and turbidity. It was a tough test, a new raw ditch against an old stream, but we passed it.

Before any water was released, the whole channel area was planted, the slopes were hydro-seeded and then hay mulch with asphalt tacifier was blown over them. It was a hard job as the cast piles had been shaped in the winter while the channel was being dug and some ice and snow had gone into them. They were far from being consolidated, but our planter kept at it and got the job done. The results were excellent. The mulch with tacifier kept the banks from eroding until the vegetation could take over. (See Table 5)

O'Brien South Dike

The top, downstream slope and downstream benches were protected by the placement of 1 foot of rip-rap bedding and 1 foot of -6" crushed taconite rip-rap. It should be noted here that this is excellent rip-rap. It is blocky, not

Table 5. Seed and Fertilizer Mixtures Used For Reclamation Of Embankments and Other Areas

HYDROSEEDING EMBANKMENTS

Species	lbs/Acre
Yellow Sweet Clover	7 inoculated
Alfalfa (Rhizoma)	7 inoculated
Birdsfoot Trefoil	5 inoculated
Smooth Brome	7
Red Fescue	10
Timothy	6
Perennial Ryegrass	8
	50

Fertilizer	16-16-16	200 lbs/Acre
Mulch	Hay	2.5 Tons/Acre
Anchored with Asphalt tacifier		200 gal/Acre

CAST PILES & WASTE AREAS

Conventional Fertilizing & Seeding

Species	lbs/Acre
White Dutch Cover	6 inoculated
Birds-foot Trefoil	10 inoculated
Sweet Clover	5 inoculated
Smooth Brome	10
Red Fescue	12
Perennial Ryegrass	7
	50

Fertilizer	16-16-16	150 lbs/Acre
Mulch	Hay-Crimped	0.5 Tons/Acre

rounded and it is heavier than glacial rock rip-rap. Once place it tends to lock together.

This completed many projects required to reclaim the Butler Taconite Watersheds.

I wish to acknowledge the aid of the following people in the design, field engineering and implementation of this watershed reclamation: Clyde Leinon, George Elich, and Elmer Rhode.

Literature Cited

Barr Engineering Co. Preliminary Design Considerations. The O'Brien Creek Diversion Channel 1970, Revised 1976.

Cotter, R.D., Young, H.L, Wanter, T.C., Preliminary Surficial Geologic Map of the Mesabi - Vermilion Iron Range Area, Northeastern Minnesota, U.S. Geologic Survey

Hewitt, Victor P.E., Butler Taconite Tailings Disposal System, Comprehensive Design & Management Plan 1980.

Taggart - Handbook of Mineral Dressing, Ores and Industrial Mineral, Wiley Handbook Series, Copy 1945.