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Aggregate Resource Evaluation of the Rako, Birchdale, and Birchdale East Pits Near Baudette, Minnesota

Minnesota DEPARTMENT OF NATURAL RESOURCES

Minnesota Department of Natural Resources
Division of Lands and Minerals
William C. Brice, Director

Project 334-8
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ACKNOWLEDGMENTS

This report is the culmination of cooperative efforts by numerous individuals and organizations. This project was initiated through the efforts of DNR personnel Cindy Buttleman, Lands and Minerals (LAM) and Dave Thomas (Forestry). They wanted to know whether aggregate remained at particular pits, and whether some portions were exhausted so they could be reclaimed. Mike Kamnikar, Minnesota Department of Transportation (MnDOT), Dick Rossman (DNR Forestry), and Dennis Martin (LAM) provided input and support.

Ron Madsen, the driller from MnDOT, operated the MnDOT rigs very well. Mike Kamnikar coordinated to have samples analyzed at their Bemidji laboratory at no charge. Dick Rossman logged the Little Digger auger holes. Bill Lockner (DNR Forestry) logged most of the Giddings holes at the Rako and Birchdale Pits and did a fine job.

Others from Lands and Minerals that helped out in the field by operating the Giddings Probe at various times and other field support included Mike Ellett, Al Dzuck, and Ricco Riihiluoma.

Executive Summary

This report summarizes the results of aggregate evaluations at three locations in the Baudette area. This project was undertaken as a partnership between DNR Region 1 Forestry, the Minnesota Department of Transportation (MnDOT) district office in Bemidji, and DNR Lands and Minerals (LAM). DNR Forestry managed pits that were reportedly nearly exhausted, MnDOT was interested in documenting aggregate resources in certain areas for future road projects, and LAM wanted to demonstrate their aggregate resource evaluation service to DNR Forestry.

The first site, called the Rako Pit, is midway between Baudette, MN and Waskish, MN in Section 8, T. 157N., R. 31W. of southeastern Lake of the Woods County. The Birchdale Pit is about 5 miles south of Birchdale, MN in Section 18, T. 159N., R. 27W. of northwestern Koochiching County. The Birchdale East Pit is about one mile east of the Birchdale Pit in Sections 17 and 20, T. 159N., R. 27W.

Field work occurred between May 10th and May 20th with one day of follow-up drilling on September 8th, 1999. Three drilling machines were used to evaluate the sites. Two machines, the Giddings Probe and the Little Digger were used to determine the extent of the gravel. The third machine, the MnDOT rig, was used for deeper drilling and sample collection. Samples were collected to measure size gradations and quality of the gravel. Results are summarized below.

Rako Pit

- ❑ The area that contains aggregate is outlined in Plate 1 and covers about 30 acres.
- ❑ This deposit contains numerous pits and virtually the entire area is disturbed.
- ❑ Some pits or portions of pits still contain aggregate. Many areas between the pits also contain aggregate.
- ❑ The gravel quality ranges from granular borrow in the north to Class 5 in the south.
- ❑ The deposit is divided into six tracts, labeled A through F, based on gravel quality and the existence of gradation data.
- ❑ The deposit contains about 60,000 cubic yards of granular borrow (Tracts A and B), about 150,000 cubic yards of borderline Class 5 aggregate (Tracts D, E, and F), and about 45,000 cubic yards of aggregate intermediate between the two (Tract C).
- ❑ The shale content is too high for bituminous or concrete uses.
- ❑ Topsoil thickness is 0.5 feet or less in undisturbed areas.
- ❑ Overburden thickness is zero in most places, but can be as thick as 5 feet.
- ❑ Depth to water table ranges from 0 to 5 feet below the land surface. It may be possible to create several acres of wetland at this site.

Birchdale Pit

- ❑ The aggregate deposit outlined in Plate 2 covers about 0.8 acres (excludes existing 0.3 acre pit).

- The portion north of the existing pit covers 0.4 acres and contains about 3,000 cubic yards of low-grade gravel (meets MnDOT's current class 1 gradations).
- The portion south of the existing pit covers 0.4 acres and contains about 2,000 cubic yards of granular borrow.
- The aggregate can be upgraded by supplementing crushed rock from the adjacent bedrock outcrop.
- The existing pit is depleted.
- The aggregate ranges in thickness from 3 to 6 feet.
- Less than 0.5 feet of overburden (topsoil immediately overlies aggregate).
- The aggregate overlies till.
- The water table ranges from near the surface to more than 4.5 feet below the land surface. Water occurs deeper or not at all north of the existing pit as compared to south of the pit where water occurs within 1.5 feet of the land surface. It may be possible to create about a half acre of wetland at this site.

Birchdale East Pit

- The aggregate deposit outlined in Plate 2 covers about 2.9 acres (excludes existing 0.25 acre pit) and contains about 17,000 cubic yards of high quality aggregate likely acceptable for Class 5, bituminous and concrete uses.
- The existing pit is depleted.
- The aggregate ranges in thickness from 3 to 5.5 feet.
- Overburden consists of about 0.3 feet of topsoil.
- The aggregate overlies till.
- The depth and occurrence of apparently perched water on till varied greatly throughout the deposit. Water occurred at depths ranging from 0.5 to 5 feet or not at all.

Bedrock

- Bedrock knobs occur adjacent to both of the Birchdale Pits.
- The bedrock at the Birchdale Pit is a metavolcanic trap rock and covers about 6.4 acres. The bedrock knob protrudes roughly 40 feet above the landscape. Over the entire 6.4 acres, there are about 100,000 cubic yards of in-place rock, or about 150,000 cubic yards after crushing, for every 10 feet of depth. Stated another way, at a thickness of 40 feet, each acre of bedrock contains about 65,000 cubic yards of in-place rock or about 95,000 cubic yards after crushing.
- The bedrock at the Birchdale East site is primarily granitic and covers about 11.3 acres. The bedrock knob protrudes roughly 25 feet above the landscape. Over the entire 11.3 acres, there are about 180,000 cubic yards of in-place rock, or about 270,000 cubic yards after crushing, for every 10 feet of depth. Stated another way, at a thickness of 25 feet, each acre of bedrock contains about 40,000 cubic yards of in-place rock or about 60,000 cubic yards after crushing.

Recommendations

Rako Pit: The access road mostly traverses the western edge of the north-to-south trending deposit, and mostly low ground exists east of the deposit. As a rule, then, future mining should commence, within each tract, at the edge of the deposit most distant from the access road to minimize waste of the resource and allow for progressive permanent reclamation as portions are depleted. The recommended mining technique is a large backhoe or excavator with the mining steadily retreating towards the access road.

Tract D contains significant quantities of aggregate and requires special planning because the deposit has a variable gravel content, laterally and vertically, that is border line for Class 5 in places. Some portions of this tract are border line for Class 5 because the aggregate is deficient to borderline in the percent of particles larger than 3/8 inch in diameter. It is expected that the actual gradations will be slightly better than those reported here (closer to or exceed Class 5 gradations) because the small auger we used does not adequately sample the larger pebbles. Regardless, the goal is to mine the entire tract and not to high grade the few remaining "better" pockets. If, for example, it is important for an operator to meet MnDOT's Class 5 gradations, then they will need to blend aggregate from different parts of the working face, or they may have to screen the sand and finer particles from some of the aggregate to create a concentrate which is then blended to get the desired product. Mining constraints in the other tracts, other than starting locations, are not necessary.

Even though this aggregate is compared to MnDOT's Class 5 requirements, local road authorities, such as counties or townships may have different requirements for their roads. The land manager is encouraged to provide the data in this report to prospective lessee's and consider innovative ideas they might offer pertaining to mining this site. Assistance is available from LAM if a contractor has questions about mining or if additional gradations are needed.

Royalties are commensurate with the quality of the aggregate, so Tract A commands the lowest royalty and Tracts D, E, and probably F command the highest royalties. Operators should be directed to appropriate tracts depending on their needs.

Birchdale Pit: Consideration should be given to not mining the aggregate south of the existing pit because the quantity is small and the road crosses much of it. Then the eastern edge of the existing pit and the portion along the north side of the road could be reclaimed.

If the aggregate north of the pit is reserved until bedrock crushing is operational (not guaranteed), then crushed bedrock aggregate can be blended with the natural aggregate to improve its grade.

Birchdale East Pit: A pit face that extends the entire width of the deposit, from north to south, should be established at the eastern end of the deposit. Then mining would progress westward with blending of all parts of the working face to assure a quality product, minimize waste, and permit progressive permanent reclamation of depleted areas east of the working face.

Introduction

This project was undertaken as a partnership between DNR Region 1 Forestry, Minnesota Department of Transportation (MnDOT) district office in Bemidji, and DNR Lands and Minerals (LAM). DNR Forestry managed pits that were apparently nearly exhausted, MnDOT was interested in documenting aggregate resources in certain areas for future road projects, and LAM wanted to demonstrate their aggregate resource evaluation service to DNR Forestry.

Three separate gravel pits managed by the Baudette Area Office of DNR Forestry were evaluated by drilling to estimate remaining volumes and quality of the aggregate. The three pits evaluated were the Rako Pit, Birchdale Pit, and Birchdale East Pit. For clarity, this report consists of two parts where Part 1 covers the Rako Pit and Part 2 covers the two Birchdale Pits.

Part 1: Rako Pit

NW 1/4, Section 8, T. 157N., R. 31W.
Lake of the Woods County, MN

The area evaluated covers about 70 to 80 acres of state land in southeastern Lake of the Woods County (Figure 1). This included the Rako pit and the immediate area surrounding it. The foot print of the Rako Pit covers about 30 acres. This site is within one mile of the Beltrami Island State Forest. The site is adjacent to the start of the Rapid River State Forest Road (unpaved minimum maintenance), four miles from the Pitt Grade Trail (unpaved minimum maintenance), one mile from County Road 77 (gravel), and 7 miles from State Highway 72 (paved).

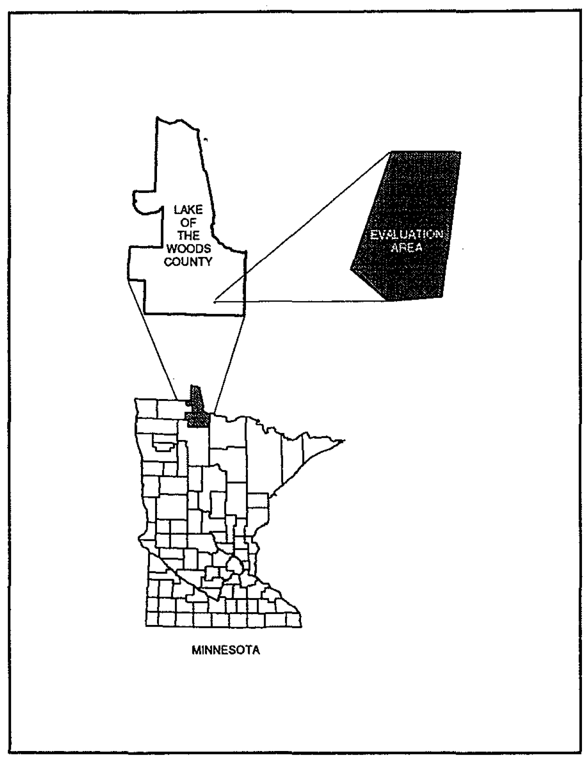


Figure 1. Index map showing the location of the Rako Pit evaluation area.

Purpose – The Rako pit was evaluated to determine whether gravel remained in the vicinity of the existing pit. The intended use of this gravel is for future MnDOT road projects on State Highway 72 or Class 5 aggregate for gravel roads (county or forest roads).

Dates of field work – May 10-13, 1999. Follow up GPS work and drilling with the Giddings probe was done on September 8, 1999.

Geologic Setting

This gravel body probably was deposited by glacial ice from a north-northwestern source

(Koochiching lobe) around 12,000 years ago. The gravel deposit likely formed when glacial meltwaters flowed into crevasses in the ice where sand and gravel accumulated. An elongated kame (hill of gravel) remained after the glacier melted completely. As the glacier retreated northward into Canada, the evaluation area was inundated by Glacial Lake Agassiz. Drilling information indicates that waves washed the top of the kame leaving a lag of small pebbles. At the same time or later, sand or silt deposited by lake currents or wind buried most of the kame.

Methods

Map interpretation – Air photos (NAPP 3066-40 to 42 flown 4/25/91), U. S. Geological Survey (USGS) Quadrangle maps (Chase Brook, MN), and digital orthophotos (DOQ's) were analyzed for geological interpretations and the identification of features and landforms on the property.

Auger drilling – Auger drilling, using three different machines, was used to determine the extent (perimeter), geology of the gravel deposit, and for sample collection to determine quality. Sixty-two holes were drilled using the pickup-mounted Giddings Soil probe with a 2" auger. Of these 62 holes, 11 were drilled west of the study area (Figure 2). These holes were exploratory in hopes of finding new gravel deposits. No gravel was found in these holes. Another eleven of these holes were drilled with the Giddings on September 8, 1999 to fill gaps in the drilling grid. Most of the Giddings holes tested to a depth of 9 feet. Sixteen holes were drilled using the Little Digger. The Little Digger is a gasoline powered auger (6-inch) pulled behind an ATV. The Little Digger holes tested to a depth of 8 feet. Twenty-four holes were drilled with a Parmanco Model F86B drill truck provided by the MnDOT office in Bemidji. A four-inch auger (with flights about 1.25 inches in width) was used on this rig to collect samples for gradation and quality testing. Extremely wet soil conditions prevented access with the DOT rig to some areas along the east side of the deposit. As a result, samples for gradation testing were not obtained for some areas. All three rigs operated concurrently with Dick Rossman (DNR Forestry) logging the holes drilled with the Little Digger, Bill Lockner (DNR Forestry) logging most of the holes drilled with the Giddings Probe, and Glenn Melchert logging the holes drilled with the DOT rig and some of the holes drilled with the Giddings Probe.

Gradations and quality analysis – Twenty-seven aggregate samples from 18 holes were sieved for gradations by MnDOT at their laboratory in Bemidji. Afterwards, MnDOT composited all the samples into one sample and tested it for deleterious materials, including shale and iron oxide content. Gradation results were compared to MnDOT's Class 5 guidelines. Deleterious materials were compared against the requirements for concrete and bituminous.

GIS – All of the holes were located by GPS (real-time differentially corrected). Access roads were digitized from DOQ's using ArcView. Pit perimeters were digitized from rectified color infrared aerial photos from DNR Forestry dated October 4, 1996.

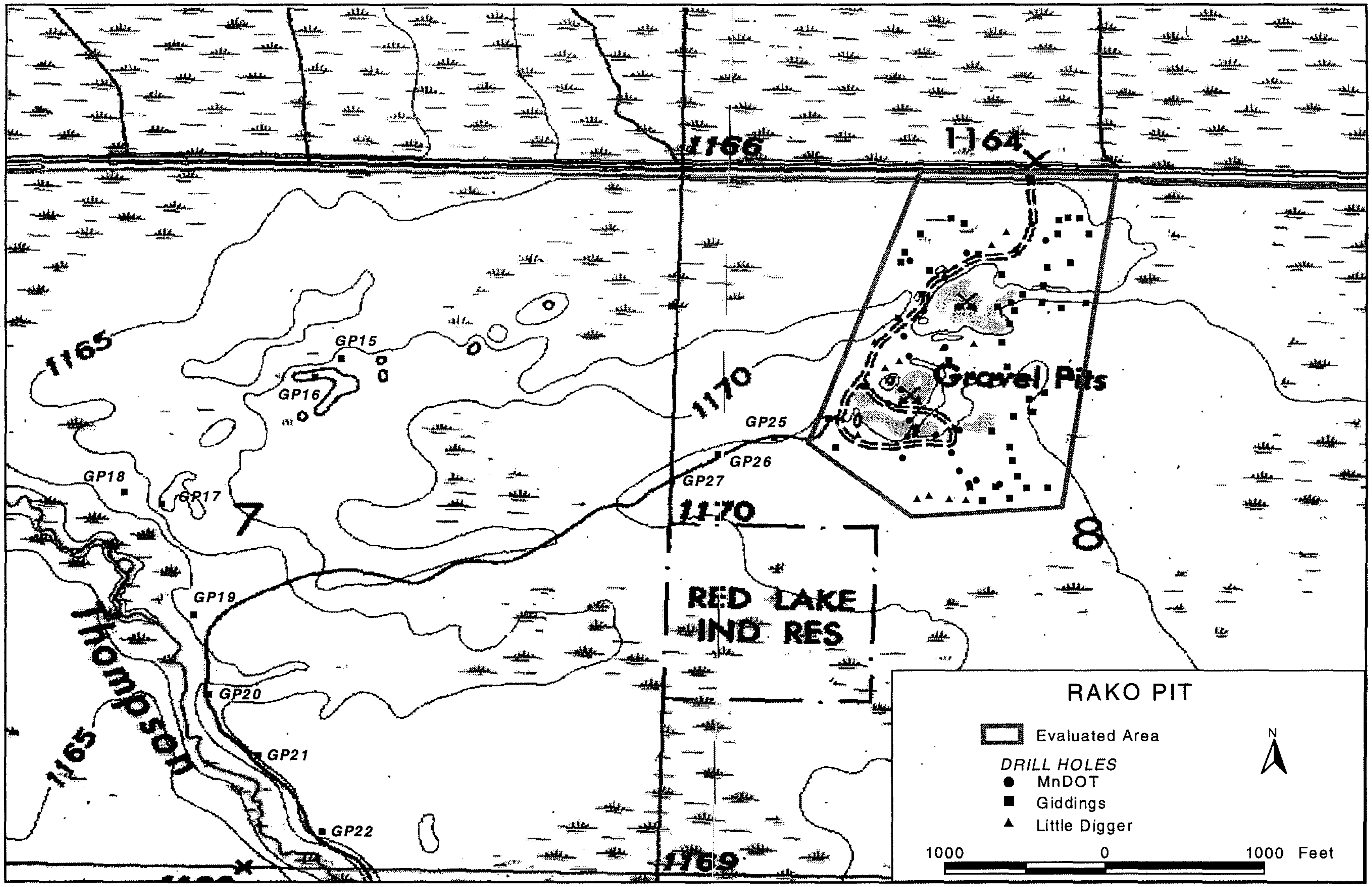


Figure 2. USGS 7.5 minute Chase Brook, MN Quadrangle showing the locations of all drill holes. Shown also are the exploration holes drilled to the west of the evaluation area.

Results

Drilling – The extent of the gravel deposit is indicated on Plate 1. Figure 3 depicts the gravel deposit divided into several tracts. These tracts are based on variations in the gravel quality across the deposit, availability of gradation data, and logical geographic divisions. The edge of the gravel deposit is defined as where the gravel thins to about three feet if it occurs within about a foot of the land surface. With deeper gravel, the edge is defined as where the stripping ratio (feet of overburden relative to feet of gravel) increases to about 50%. In a couple of instances, the requirement for a stripping ratio of 50% or less was relaxed. This occurred when the drill hole did not drill through the bottom of the gravel and it was reasonable to expect the hole would have met the 50% requirement had it drilled deep enough. Except for along the northern and western perimeter of Tract A, the edge of the gravel deposit ends abruptly by changing to sand.

In undisturbed areas, the topsoil is about 0.5 feet thick or less. Overburden occurs beneath the topsoil and consists of fine sand or silt. Within the outline of the gravel deposit, gravel is buried beneath overburden that ranges in thickness from 0 to about 5 feet (Figure 4 in Plate 1). In some places, spoil piles, consisting mostly of topsoil, are piled over gravel. The gravel was counted in these areas because the piles do not cover much area and the piles will be used for reclamation.

The maximum gravel thickness is 25 feet. The gravel is underlain by blue gray till in some places, but in most places it is underlain by gray fine sand. In most holes, gravel occurs directly below the topsoil, but in some areas, mostly along the perimeter, several feet of brown sand or silt may occur above the gravel.

In general, the gravel gets finer and the amount (percent of particles larger than the #10 sieve, or about 2 mm in diameter) of gravel decreases with depth. In Tracts C and D, where the gravel is thicker than 10 to15 feet or so, the amount of gravel often decreases by about 10% in the lower half, but in some holes in the same area, the gravel content remains constant or even increases by about 10%.

Sand layers occur within the gravel deposit in portions of Tract D (see Figure 4 of Plate 1). Holes 13 and 17, in Tract D, encountered a high quality gravel until 7.5 to 8 feet below the surface, then a gravelly sand layer about 4 and 7 feet thick, respectively. About 10 feet of gravel occurs below this sand in both holes. Gradation data from hole 17 indicate the deeper gravel layer does not meet Class 5 gradations by itself, but does if blended with the sand layer and upper layer of gravel. The sand layer in hole 13 was not analyzed, so the grade of gravel resulting after blending all layers is not known.

The depth to water table varies from 0 to 5 feet. The area covering the deposit that is undisturbed is forested with aspen, balsam poplar, and alder. The large stand of jack pine just west of the pit grows on sand. The ground elevation there is a few feet higher than adjacent areas.

Quantity – The estimated quantity of in-place gravel contained within each tract is presented in

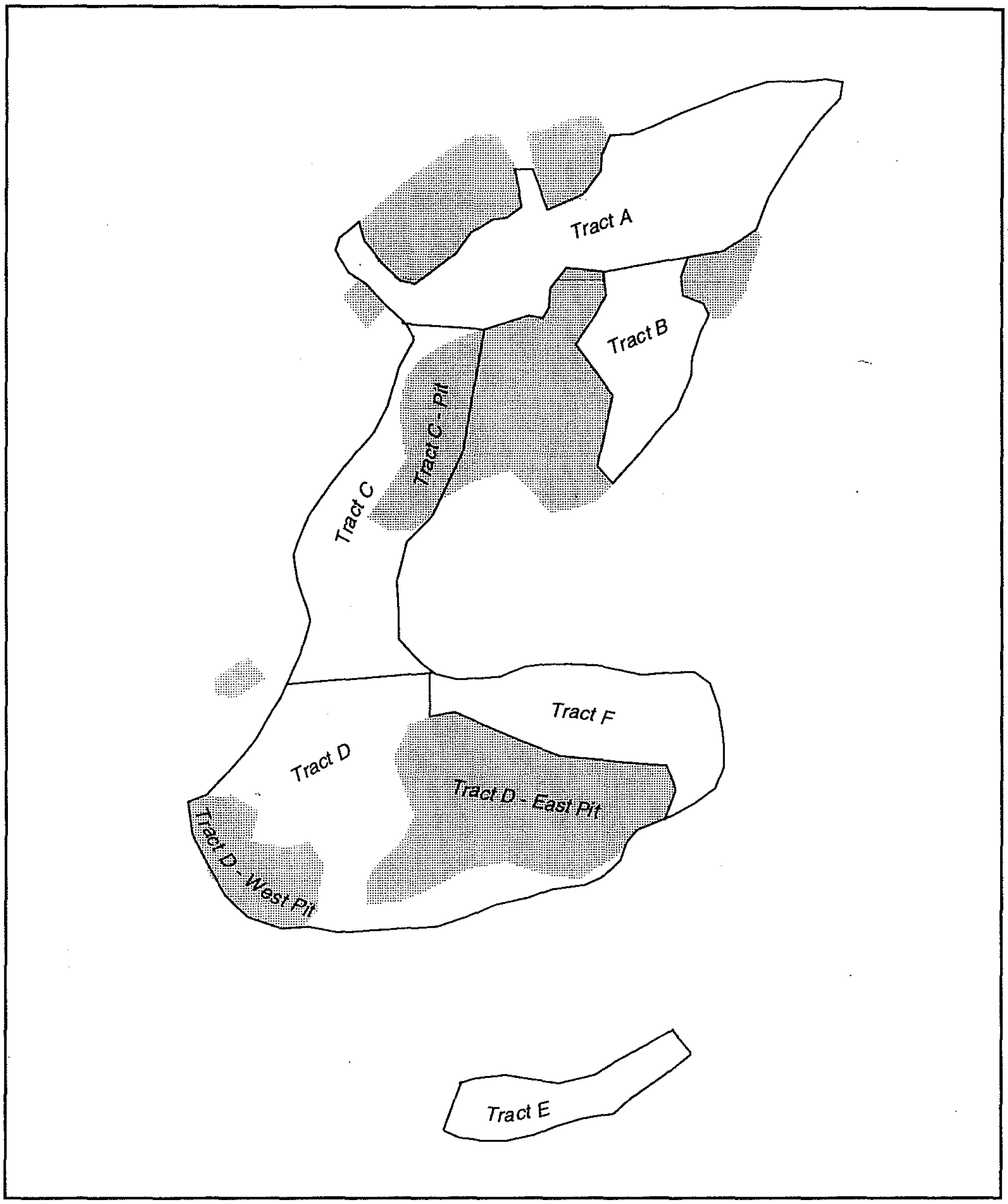


Figure 3. This illustration, derived from plate 1, shows the gravel deposit divided into several tracts based on the character of the gravel. The stippled pattern represents water-filled pits at the time of the evaluation, and no test holes exist in these areas. Portions of pits not included within a tract are considered depleted. Details about size and volumes of gravel associated with each tract are presented in Table 1.

Table 1. The estimates are simple calculations of the average thickness of gravel multiplied by area. The area of each tract was determined in ArcView, and thickness is the arithmetic average of the thickness of gravel found in each test hole within that tract. The uncertainty associated with these calculations is indicated by the error value in the table. The eastern and western limits of the gravel in tract E were not defined due to time constraints.

Table 1. Simple volumetric calculations of in-place gravel contained in the tracts depicted in Figure 3 and Plate 1. The error is an estimate based on the uncertainty of the data used for the calculations to derive the volumes for each unit. Volume is a 3-dimensional shape. A significant source of volume error is the gravel thickness may vary substantially between drill holes. Granular or select granular borrow is about the lowest grade of aggregate. If the grade is unknown, it means there were no samples analyzed from those areas to verify the grade.

Tract	Area (ft^2)	Acres	Gravel thickness (feet)	Volume (cubic yards)		Grade of gravel
				Resource	Error (+/-)	
A	196,600	4.5	6.6	48,000	20	granular/ select borrow
B	68,900	1.6	5.5	14,000	35	unknown
C	97,200	2.2	9	32,000	25	not Class 5
C (pit)	48,300	1.1	8	14,000	25/100[a]	unknown
D	154,900	3.6	16	92,000	25	borderline Class 5
D(west pit)	44,000	1.0	5	8,000	25/100[a]	unknown
D(east pit)	142,500	3.3	6	31,000	25/100[a]	unknown
E	48,200	1.1	7.5	13,000	25	Class 5
F	97,400	2.2	6	21,000	35	unknown

[a]The existing water-filled pits were not drilled, so there is a chance that they are depleted of gravel, hence the 100% negative error.

The gravel remaining in the water-filled pits is estimated from nearby test holes (depth to water table and thickness of gravel) and notes on the depth of water in each pit.

Gradations and quality analysis – The gradation data show that the gravel content is highest in the southern tracts (Tracts D and E) and lowest in the north (Tract A), and Tract C is intermediate (Figure 4, Table 2). Gravel content is defined as the percent of particles larger than the 10 mesh (2 millimeters) sieve. On average, Tracts D and E meet MnDOT's Class 5 gradations. Portions of Tract D, however, do not meet them because of a shortage of particles larger than 3/8 inch. Tract A does not meet Class 5 gradations, but may qualify as granular or select borrow. Tract C is intermediate between the north and south tracts in terms of gravel content. It misses meeting the Class 5 gradation for the 3/8" sieve size by 3%. In most parts of the deposit the gravel becomes finer and less abundant with depth. Complete gradation data are in Appendix C.

This deposit has a high shale content (Table 3) which precludes its use for concrete or bituminous aggregate on MnDOT projects. The shale tests were done on a composite representing the overall deposit, so it is not known whether certain tracts would meet specifications. In the field, shale was noted in all areas of the deposit and appeared to be more abundant with depth.

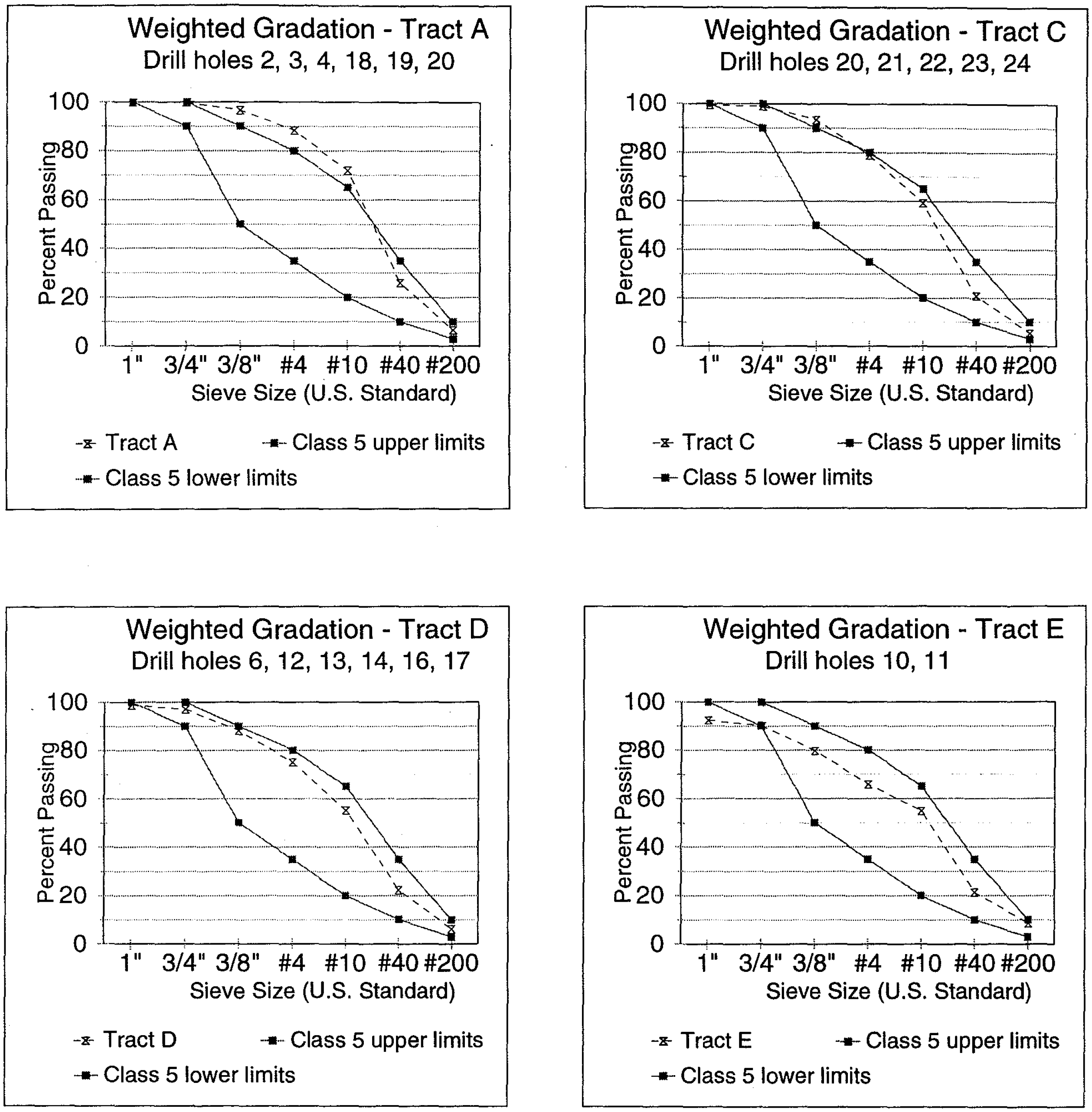


Figure 4. These graphs compare the weighted average size gradations of the samples from each tract to MnDOT's gradation requirements for Class 5 aggregate. These graphs are intended to provide a point of reference to a familiar gravel product (Class 5). Specific projects may require material meeting a different gradation or even more than one. Percent passing refers to the proportion of the sample by weight that passes through a particular sieve size. Particles larger than 3/4 inch would be crushed.

Table 2. Weighted average gradations for the tracts at the Rako Pit. The sieve sizes get smaller moving to the right in the table. The values below each sieve size are the percent, by weight, of the total sample that falls through (passes) that sieve. The cutoff we use for the gravel fraction is material larger than the #10 sieve (2 millimeters). For example, for Tract A, 72% of the sample, by weight, was smaller (passed through) the #10 sieve. Stated another way, this tract has an average of 28% gravel (100-72=28). The two columns on the right show the percent of material retained (bigger) than the respective sieves. Values in parentheses represent the range for all the samples.

Rako Pit	Percent of Material ***Passing*** Respective Sieve							Weight Percent ***Retained*** on Respective Sieve	
	1"	3/4"	3/8"	#4	#10	#40	#200	crushable +3/4"	gravel +#10
Tract A	100	100	97	88	72	26	6.6	0 (0-1)	28 (15-37)
Tract C	99	99	93	79	59	21	5.4	1 (0-3)	41 (34-55)
Tract D	99	97	88	75	55	22	6.2	3 (0-6)	45 (27-64)
Tract E	92	90	80	66	55	21	8.6	10 (1-15)	45 (37-50)
Class 5 upper limits	100	100	90	80	65	35	10	0	35
Class 5 lower limits	100	90	50	35	20	10	3	10	80

Table 3. Laboratory test results for deleterious materials in the gravel. These values are for a composite sample of all the samples collected (see Appendix C). Rows in the first column identified with a +1/2", + 4, or -4 refer to only the portion of the sample retained on (larger than) a ½" sieve, a #4 sieve, and passing through (smaller than) a #4 sieve, respectively. Total spall values exceed the limits for bituminous and concrete uses.

	Rako Pit average (%)	Class 5 specs	Bituminous specs (maximum %)			Concrete specs (max. %)
			Type 31	Type 41, 47	Type 61	
+1/2" shale	2.28					0.4
+4 shale	4.41					0.7
-4 shale	1.65			5.0		
+4 iron oxide	0.23					0.3
total shale	6.06	7/10[a]				
total spall	6.29		5.0		1.0	
total +4 spall	4.64			2.5		1.5
LAR loss(%)	24.42	40	40	40	40	40

[a] Maximum is 10% shale except when the part passing the 200 sieve exceeds 7%, the shale shall not exceed 7%.

Mining Plan

Development of a mining plan requires consideration for production of a desired product or products, economics, scale and scope of operations, and reclamation. Every gravel deposit has its own unique geometry, variation in quality, and setting within the landscape, and each land manager has their own vision of how the final reclaimed landscape should look. Therefore, mining plans are unique for each pit. There are, however, five steps that are necessary for any mining activity. They are permitting, clearing, stripping, mining, and reclamation.

Overview – This mining plan encourages and anticipates that all of the aggregate resource, including that below water, will be mined eventually, although final discretion is left to the land manager. It is likely that mining will occur in phases because of the large quantity of aggregate available relative to demand and the different materials in each tract. This plan presents a basic design for mining of the gravel and of the final reclaimed area.

Custom designs, specific pit management, and reclamation plans for the site are left to the discretion of the land manager. Once mining is complete, the final reclaimed landscape within the pit will be a series of shallow to deep wetlands. Scattered existing topsoil spoil piles would be spread on disturbed uplands and shorelines.

This gravel deposit consists of a buried irregular ridge of gravel and sand. There is no obvious topographic expression reflecting the extent of the deposit. Drilling has determined that the edges of the deposit are fairly distinct for the southern half of the deposit where it rather abruptly changes from gravel to sand or occasionally silty till.

Some areas already disturbed or mined still contain substantial quantities of gravel. It appears that portions of the pit were high-graded in the past, perhaps in part due to a high water table and perhaps in part because of the variable nature of this deposit. This is apparent in the portions of Tracts C, D, and F where the upper several feet of the deposit (probably with a high gravel content) were mined, often leaving behind deeper gravel. The deeper gravel still meets MnDOT's Class 5 gradations in some places.

The aggregate in Tracts D and E, as an overall average, meets Class 5 gradations. Some portions of Tract D, however, do not quite meet Class 5 gradations. This is addressed further in the mining section below. Tract C does not meet Class 5 gradations because of a 3% shortage of rock between 3/4" and 3/8" size. This material may be suitable for forest roads and road shoulders. Alternatively, this material could be upgraded to Class 5 if crushed rock was added or the sand was screened from a portion of the deposit to concentrate and increase the gravel content. Tract A contains a low percentage of gravel and is suitable for granular or select granular borrow. Large amounts of this type of aggregate are often needed when road reconstruction occurs in swampy areas.

Permitting – Generally the state is exempt from local permitting. However, if local zoning ordinances or other rules exist for borrow pits or extraction of aggregate, such as setbacks from roads or property lines, the land manager should be aware of and consider them when developing the pit. Permits likely are required, however, if water is drained or pumped from the pit or if wetlands, possibly even those inside the pit, are impacted (Appendix D). It is not anticipated that wetlands outside the presently disturbed areas will be impacted. An Environmental Assessment Worksheet (EAW) is not mandatory since the ultimate pit size is less than 40 acres.

Clearing – Timber of economic value should be harvested prior to pit expansions. Brush and unsaleable timber should be reserved in piles for upland or under-water habitats, for visual screening, or disposed of away from the proposed and future mining areas at the discretion of the land manager.

Stripping – Topsoil and overburden are already stripped over most of the aggregate deposit. In places where overburden does occur, such as the southern edge of Tract D, all of Tract E, and parts of Tracts A and B, it should be removed and stockpiled (not merely pushed into a small windrow) prior to each phase of mining. These piles should be located outside of the area to be mined now or in the future, or spread on areas ready for permanent reclamation. The idea is to move the overburden as few times as possible and also to place it as close as practical to where it will be ultimately spread during reclamation. Ideally, the material stripped should be placed in an adjacent area that is ready for reclamation–an area where the gravel is depleted or a decision was made to no longer mine that particular area.

The dark topsoil portion of the overburden should be stripped and piled separately from the underlying subsoils to improve upon final reclamation and revegetation of the site. Then, at sites ready for permanent reclamation, the materials could be spread in reverse order to give the best practical growing medium for vegetation. Topsoil and overburden piles that are not spread (for reclamation) in a timely fashion can be seeded with a cover (nurse) crop of oats (spring and summer seasons), winter wheat (fall season), or other species at the discretion of the land manager to minimize erosion and weed growth.

Stripping must extend far enough past the expected tops of pit walls so that final or temporary sloping can be done during or at the close of active mining without incorporating topsoil or other deleterious materials into the slope. After each mining phase is complete, the working face shall not be steeper than 1:1 for safety.

Mining – A mining strategy is partly dependent on the scale of the mining operation. A company planning to mine 100,000 yards or more at a time has greater opportunity and flexibility in utilizing the entire resource, especially when the deposit is variable, than when mining small quantities at a time. Regardless of the size, however, to maximize the amount of gravel ultimately mined from this pit prior to final reclamation, a good approach would be to start at one end of each tract, depending on the material needed, and mine the entire deposit, from top to bottom, before advancing laterally. Where mining starts and the direction it advances should follow a logical sequence so that access to remaining aggregate always exists and that some permanent reclamation, if practical, may occur after each mining phase.

A large excavator should be the preferred mining equipment used at this pit. Then the entire gravel interval could be mined as a single lift and dewatering by pumping is not necessary. Using this technique, mining must start at the furthest points from the access roads (generally the eastern edges of the deposit). As mining progresses, the equipment and working face retreat toward the roads until the entire deposit is mined. This method minimizes the chance of cutting off access to parts of the deposit.

Since much of the deposit is disturbed, but not depleted, initial mining could be directed to 'clean up' areas within each tract where a relatively small quantity is left to be mined per unit area. The intent is to enable permanent reclamation on relatively large portions of the pit at the earliest opportunity. Some of these areas are noted in the reclamation section below.

This gravel deposit varies laterally and with depth, and has a somewhat undulating bottom. The lateral variations were mostly addressed by dividing the resource into several tracts. Variations with depth are best dealt with by mining the gravel deposit as a single lift from top to bottom. This allows for the varied layers of gravel and sand to be blended during the excavation phase. This creates the most uniform product, eliminates high grading, and is the quickest way to deplete sections of the pit for reclamation.

Special attention to gradations is warranted for Tract D. Even though the average weighted gradations for the entire tract meet Class 5 gradations, sandy pockets of variable thickness and extent occur around mid-depth in parts of this tract or in some places the bottom half of the gravel is too fine on its own for Class 5. The shortfall is too little material larger than 3/8 inch. Only in the vicinity of holes #6 and #14 is there a reasonable assurance that the entire gravel interval of 17 to 20 feet would produce Class 5 material. There are not enough data points (test holes with gradation data) to fully define the gravel variation within this tract. On a positive note, during mining the actual gravel content may end up slightly higher than these data predict because of sampling bias introduced by using a relatively small auger to retrieve the samples. Small augers routinely under represent the coarse particles. Although large pebbles and cobbles are not abundant in this deposit, many with diameters of 2 to 3 inches were observed in the leftover aggregate piles.

Figure 5 shows two of the worst test holes from Tract D where the gravel content falls outside MnDOT's guidelines for Class 5 (see also Table 4). In hole #12, the worst hole in this tract, the upper and lower gravel intervals fall outside the Class 5 gradations. Unfortunately this hole is near the center of the tract. In hole #17, the upper and lower intervals meet Class 5 gradations, but the middle section does not. The average of all three intervals misses the gradation by 1% on the 3/8 inch sieve. Also note that the fines (200 mesh) in this hole are fairly high compared to all the other samples, most of which fall on the low side of the guidelines (Appendix C). This is an

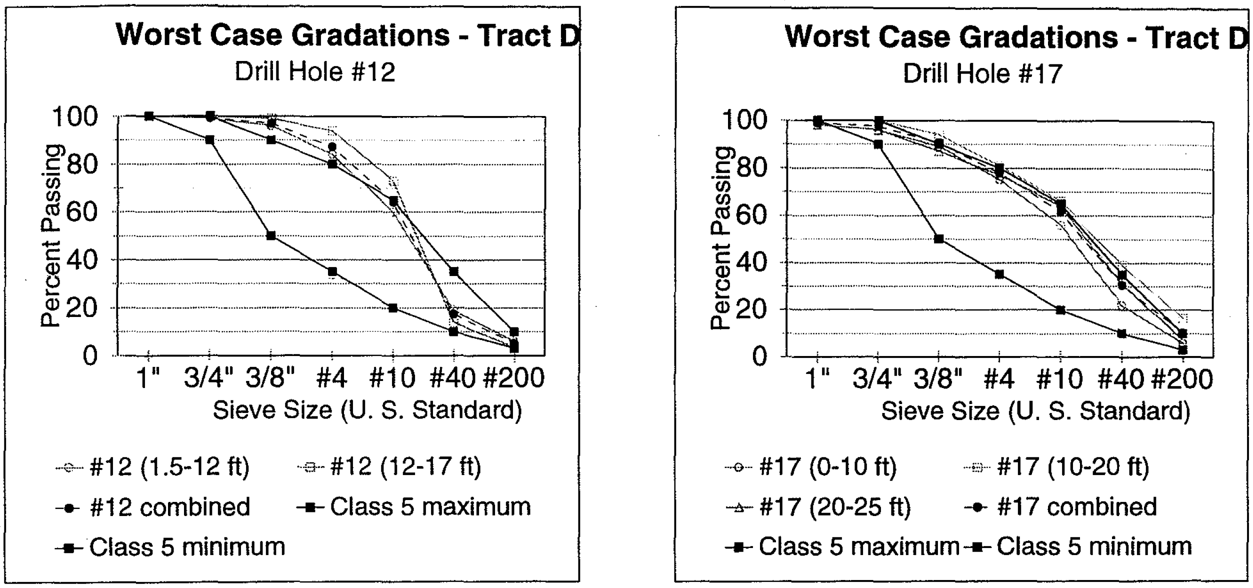


Figure 5. These graphs compare the two test holes with the lowest gravel content to MnDOT's gradations for Class 5 aggregate. No part of hole 12 meets the gradation limits. In hole 17, the intervals from 0 to 10 feet and from 20 to 25 feet fall within the gradation limits, but the layer between falls just outside. The gradation of all three layers combined into a weighted average falls very near the upper limit for Class 5. Aggregate with lots of gravel and coarse particles (rock) will plot lower on this graph than aggregate comprised mostly of sand. Percent passing refers to the proportion of the sample, by weight, that passes through a particular sieve size.

example where if the upper gravel was mined first, the two lower units have a harder time meeting the Class 5 gradations, whereas if the entire interval was mined as a single lift, there is a good chance the material would make Class 5. The only other hole that has borderline gradations is #13. In this hole, the upper 7.5 feet meet the gradations, but the lower gravel and intervening sand layer do not.

Table 4. Gradation results for two of the poorest quality holes in Tract D.

Test Hole	Percent of Material Passing Each Respective Sieve						
	1"	3/4"	3/8"	#4	#10	#40	#200
#12 (1.5-12 ft)	100	99	96	84	60	19	5.9
#12 (12-17 ft)	100	100	99	94	73	14	3.5
#12 combined	100	99	97	87	64	17	5.1
#17 (0-10 ft)	98	96	89	75	56	22	5.8
#17 (10-20 ft)	100	100	94	81	66	39	16.5
#17 (20-25 ft)	98	96	87	77	64	31	7.5
#17 combined	99	98	91	78	62	31	10.4
Class 5 upper limits	100	100	90	80	65	35	10
Class 5 lower limits	100	90	50	35	20	10	3

The exact mining and blending methodologies used in Tract D depend on the material needed. If aggregate slightly less than Class 5 is acceptable, then this tract is not so difficult to manage. But if Class 5, according to MnDOT's guidelines, is needed, then blending from different locations in the tract is required at times. If blending is not practical at certain times, the operator will have to screen the sand out of part of the deposit and blend the retained coarser portion with the part being mined to improve on the quality.

It is clear that the best way to deal with the variability in Tract D is to mine the entire tract, as a single lift, at one time. Whether this is practical or not depends on demand. The nature of Tract D also is not amenable to mining small quantities at a time, especially if Class 5 is needed. This is because opportunities for blending are minimal and the operator might be pressed to mine the higher quality sections which are mostly in the upper 10 feet. An option for maximizing the use of this resource would be for an operator to set up a long-term operation on site, which would cover Tracts D and C. They would process stockpiles of various grades of aggregate for their needs and also make them available to third parties.

Only a couple of boulders were observed. They were approximately 1.5 feet in diameter. Boulders that are mined and not crushed should be piled separately and used as barriers, rip rap, or as wildlife habitat on site, or sold. Boulders are valued higher than aggregate.

The land manager is encouraged to provide these data to prospective lessee's and consider innovative ideas they might offer pertaining to mining this site.

Reclamation – During mining or at the conclusion of each mining phase, areas where future mining will occur should undergo interim reclamation and permanent reclamation should occur where mining will not occur again.

General provisions.

Interim reclamation. Interim reclamation shall consist of sloping all pit faces or walls to provide a safe condition (suggested slope angles are no steeper than 1:1, horizontal to vertical). This includes the banks adjacent to the ponds. The topsoil and overburden must be stripped far enough past the expected pit edge to allow for proper sloping without incorporating overburden or other deleterious material into the slopes.

Permanent reclamation. All topsoil shall be retained for reclamation. All slopes should be sloped no steeper than 3:1. This includes shaping the banks so that a 3:1 slope extends several feet into the water. This is important for safety, slope stability, and to create a larger littoral zone (shallow water). Waste materials such as overburden or fine sand may be placed in parts of the water-filled pits to create islands and additional littoral area. Slopes should be covered with available overburden subsoils and then covered with 4 inches or more of topsoil, if available. Remaining topsoil should be spread on remaining surfaces most prone to erosion.

Placement of 4 inches or more of the topsoil in the shallow portions (6 feet or less of water) of created ponds will help vegetation establish along shorelines and the littoral zone. Advice on creating wetlands and banking the acres of wetland created are available from personnel at the Minnesota Board of Water and Soil Resources (BWSR) and DNR Division of Ecological Services.

Areas such as haul roads and staging areas undergoing permanent reclamation may require preparation (loosening) of subsoils prior to the addition of topsoil. All reclaimed areas should be seeded to minimize the spread of weedy species, minimize erosion, and accelerate the reclamation process.

Specific considerations. Reclamation may be done immediately in those areas outside the "extent of aggregate" as depicted in Figures 1 and 2 of Plate 1. Some mixed topsoil and overburden is stockpiled on the mine site, but there probably isn't enough to cover all the disturbed areas. The overburden could be used to permanently reclaim those areas nearby that are depleted of gravel with preference to shorelines and highly erodible areas. Many of the larger overburden piles are indicated in Figure 6.

Future mining should be directed to first 'clean up' areas within each tract where a relatively small quantity remains to be mined before permanent reclamation can occur. With this approach, relatively large portions of the pit can be reclaimed first. Suggested areas are indicated in Figure 6. If the access road in Tract A is moved northwest to the southern edge of the water-filled pits, then virtually everything west of the road in this tract could be reclaimed.

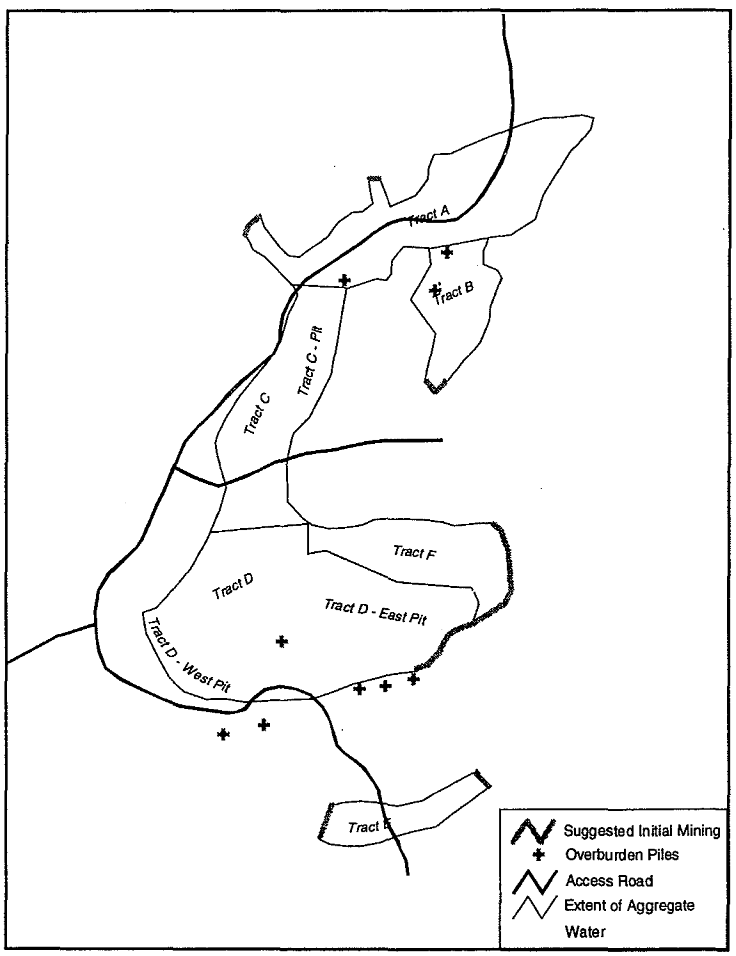


Figure 6. Locations of most of the larger overburden stockpiles and suggested locations to start mining.

Four fact sheets on aggregate mining are attached in Appendix F. Additional information is presented in the publication by Cynthia G. Buttleman, 1992, "A Handbook for Reclaiming Sand and Gravel Pits in Minnesota", Minnesota Department of Natural Resources.

Leasing, reclamation, and mining advice are available from DNR Division of Lands and Minerals.

Part 2: Birchdale Pits

Birchdale Pit
NW 1/4, SW 1/4 Section 18, T. 159N., R. 27W.
Koochiching County, MN

Birchdale East Pit
S 1/2, SW 1/4 Section 17 and N 1/2, NW 1/4 Section 20, T. 159N., R. 27W.
Koochiching County, MN

The two Birchdale Pits are located in northwestern Koochiching County (Figure 7). The area evaluated at the Birchdale and Birchdale East pits covers about 7 and 15 acres, respectively. The Birchdale pit is adjacent to county road 87 (gravel) and about 5 miles from state highway 11 (paved) and the town of Birchdale, MN. The Birchdale East pit is about 1.25 miles east of the Birchdale pit via a low maintenance forest road (Figure 8).

Purpose – The Birchdale pits were evaluated to determine whether marketable gravel remained in the vicinity of the existing pits. The intended use of this gravel is for future MnDOT road projects on State Highway 11 or Class 5 aggregate for gravel roads (county or forest roads).

Dates of field work – May 17-20, 1999. Follow up GPS work was done on August 5, 1999.

Geologic Setting

These gravel bodies apparently were deposited in a similar fashion by glacial ice from the north-northwest (Koochiching lobe) around 12,000 years ago. Both deposits are situated adjacent to prominent bedrock knobs and appear to be sand and gravel bars deposited by waves and currents from Glacial Lake Agassiz. The bedrock knobs probably were near to or protruded slightly above the lake surface. Wave energy eroded the glacial sediments, washing away the fine particles and leaving behind sand and gravel which formed the aggregate deposits depicted on Plate 2.

It is also possible the gravel deposits are small ice-contact features where small glacial meltwater streams flowed into small crevasses

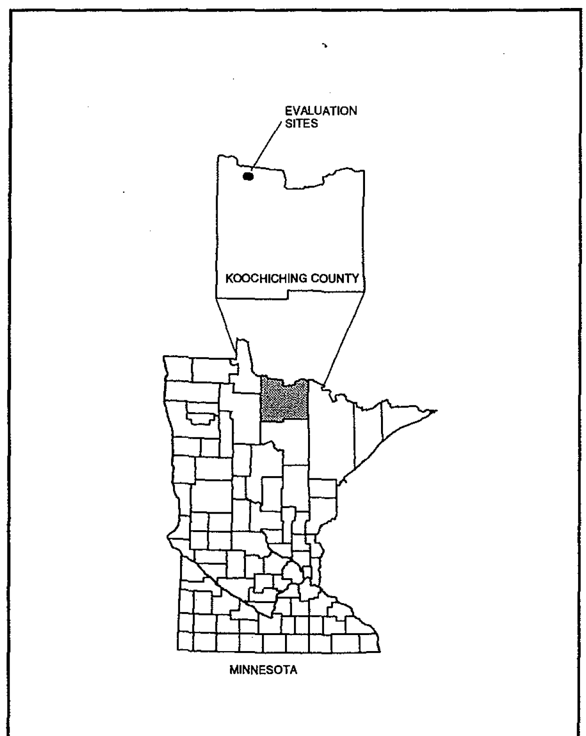


Figure 7. Index map showing the locations of the two Birchdale Pits.

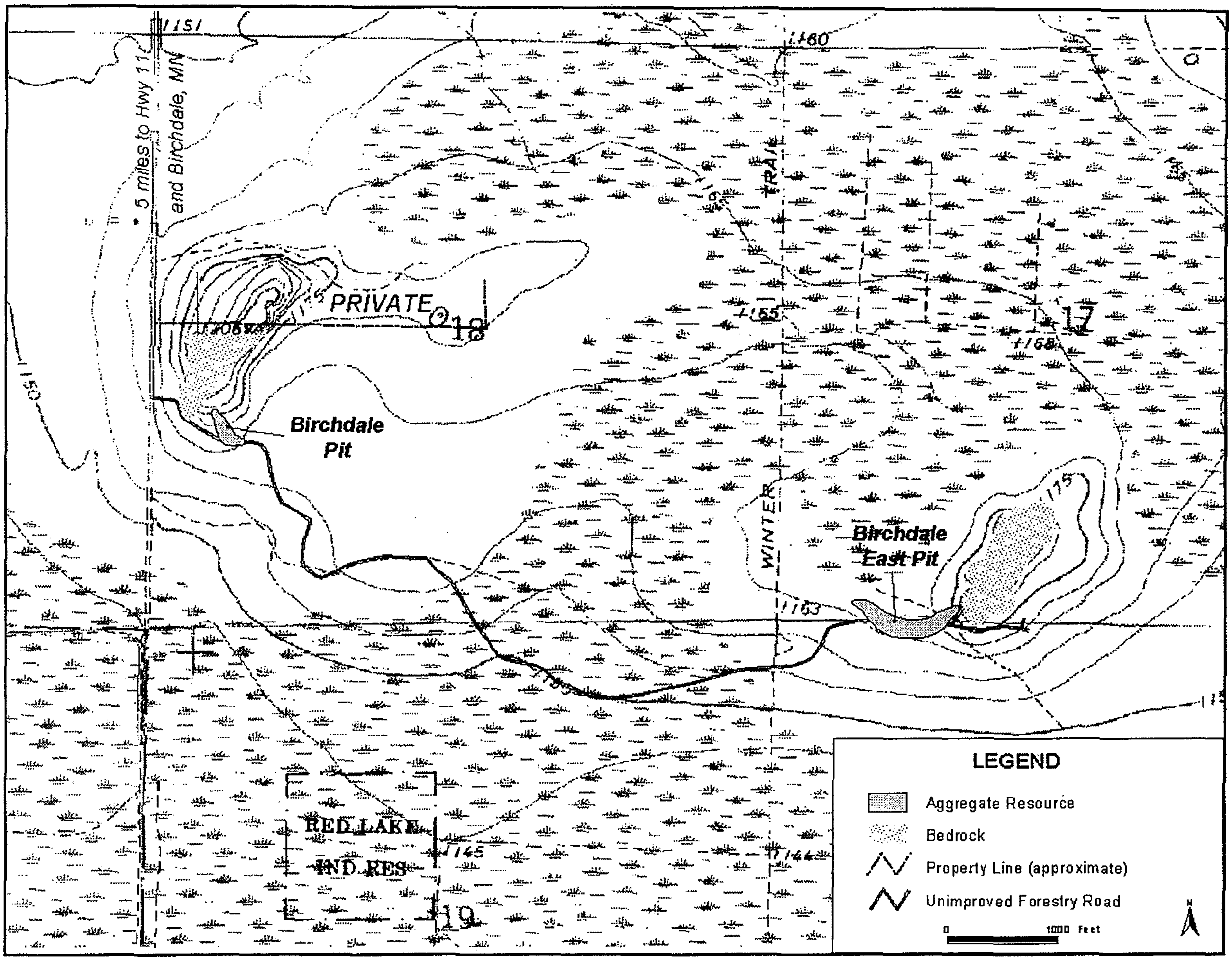


Figure 8. This map shows the extent of the two aggregate deposits, access, their position in the landscape and proximity to bedrock exposures. Note the deposit outlines appear channel-like. The base map is a portion of the USGS 7.5 minute Birchdale SW, MN Quadrangle.

where sand and gravel accumulated. As the glacier retreated northward, the area was inundated by Glacial Lake Agassiz. Waves and currents modified the gravel deposits into their present character. Both deposits occur at an elevation of between 1165 and 1175 feet.

Methods

Map Interpretation – Air photos (NAPP 3048-8 flown 5/19/91), U. S. Geological Survey (USGS) Quadrangle maps (Birchdale SW, MN), and digital orthophotos (DOQ's) were analyzed for geological interpretations and the identification of features and landforms on the property.

Auger drilling – Auger drilling was the method used to determine the extent (perimeter) of the gravel deposit.

with a 2" auger. The depth of the Giddings holes ranged from 1 to 9 feet with most being 6 feet or less. Twenty holes were drilled with a small rubber-tracked drill rig provided by the MnDOT office in Bemidji. An auger 3 ½ inches in diameter was used on this rig to collect samples for gradation and quality testing. The auger flights (fins) were 7/8 of an inch wide. Both rigs operated concurrently with Bill Lockner (DNR Forestry) logging most of the holes drilled with the Giddings Probe.

All the holes at the Birchdale East pit were drilled with the MnDOT rig. Thirty-five holes were drilled to a maximum depth of 7.5 feet.

Gradations and quality analysis – Gravel samples from 8 holes and 19 holes at the Birchdale and Birchdale East Pit, respectively, were sieved for gradation analysis at the MnDOT laboratory in Bemidji. The 27 samples (one sample from each hole) were then composited into one sample and tested for deleterious materials, which included shale and iron oxide content. Gradation results were compared to Class 5 guidelines. Deleterious materials were compared to specifications for concrete and bituminous.

GIS – All of the holes and pit boundaries were located by GPS (differentially corrected) using a Garmin 12XL unit. Access roads were digitized from DOQ's and GPS points.

Results

Drilling – Drilling and observations of the existing pits revealed both aggregate deposits are relatively thin, somewhat lense-shaped, and limited in extent (Plate 2). The maximum thickness of gravel in the Birchdale and Birchdale East deposits are 6 and 5.5 feet, respectively. Both deposits gradually thin to less than a foot of aggregate at their edges. Both deposits are covered with 3 to 6 inches of dark sandy topsoil and underlain by light grayish brown till. Cobbles and boulders were rare at both deposits. The largest pebbles commonly observed at the Birchdale and Birchdale East sites were 1.5 and 2.5 inches in diameter, respectively.

Ground water was encountered in some holes at both sites. It appears that precipitation infiltrates into the sandy or gravelly soils and becomes perched upon the underlying till. The evaluation was done shortly after some relatively big rainfalls. It is anticipated that the perched water nearly dries up during dry spells.

Quantity – The two deposits outlined in Plate 2, excluding existing pits, cover about 0.8 and 2.9 acres for the Birchdale and Birchdale East sites, respectively. A minimum of 3 feet of aggregate was chosen for extent and volume calculations. About 5,000 cubic yards remain at the Birchdale site and about 18,000 cubic yards remain at the Birchdale East site (Table 5). The estimates are simple calculations of the average thickness of gravel multiplied by area. The area of each deposit or portion was determined in ArcView, and the thickness is the arithmetic average of the

Table 5. Simple volumetric calculations of gravel (in place) remaining in the Birchdale Pits as of fall 1999. The error is an estimate of potential error based on the uncertainty associated with the average thickness and mineable extent for each tract. Granular borrow is about the lowest grade of aggregate.

Tract	Area (ft^2)	Acres	Feet of gravel	Volume (cubic yards)		Grade of Gravel
				Resource	Error (+/-)	
Birchdale Pit						
North of pit	17,000	0.4	4.9	3,000	25	not Class 5
South of pit	16,400	0.4	3.7	2,000	20	Granular borrow
Existing pit	13,400	0.3	0	0	NAp	NAp
Birchdale East Pit						
West of pit	124,100	2.8	3.8	17,000	20	Class 5
East of pit	5,400	0.1	3.5	700	40	not Class 5[a]
Existing pit	13,400	0.3	0	0	NAp	NAp

[a] This small quantity should be blended with the rest of the deposit to make Class 5.
Nap = not applicable

thickness of gravel found in each drill hole within that tract. Uncertainty associated with these calculations is indicated by the estimate of error in the table. No gravel remains within any of the existing pits as depicted on Plate 2.

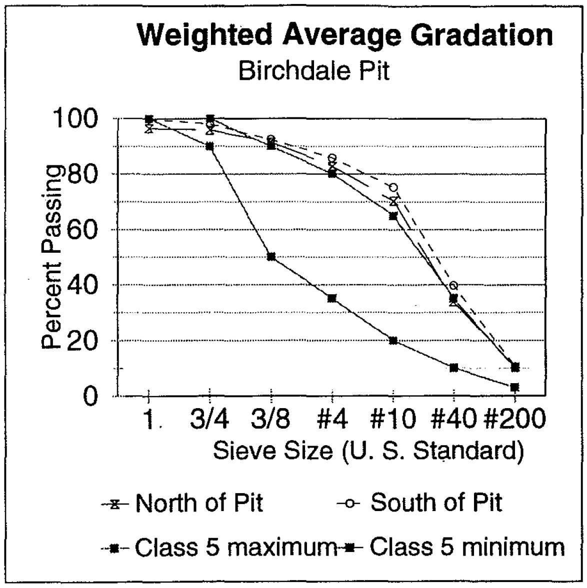
Gradations and quality analysis – Gradation results for each site are illustrated graphically in Figure 9. For illustrative purposes, the data are plotted against MnDOT's typical requirements for Class 5 material. Note that these are only general guidelines useful for planning. Specific testing, if necessary, should be done for each pile of aggregate processed. Crushing affects the values slightly because the material larger than 3/4 inch is incorporated into the smaller sizes.

For the Birchdale Pit (left graph), separate curves are plotted for the aggregate from either side of the existing pit. Both curves fall outside the Class 5 limits, although the northern portion is much closer than the southern portion.

The right graph shows that the Birchdale East deposit, as depicted in Plate 2, on average, falls within the Class 5 limits.

Table 6 lists the data used to construct the graphs. Raw data from individual test holes are presented in Appendices C.2 and C.3.

Shale and other spall content were tested as one composite of both sites together. Results indicate this aggregate may be acceptable for some bituminous or concrete uses (Table 7). No shale was observed in the field, but occasionally iron oxides (another kind of spall) were.



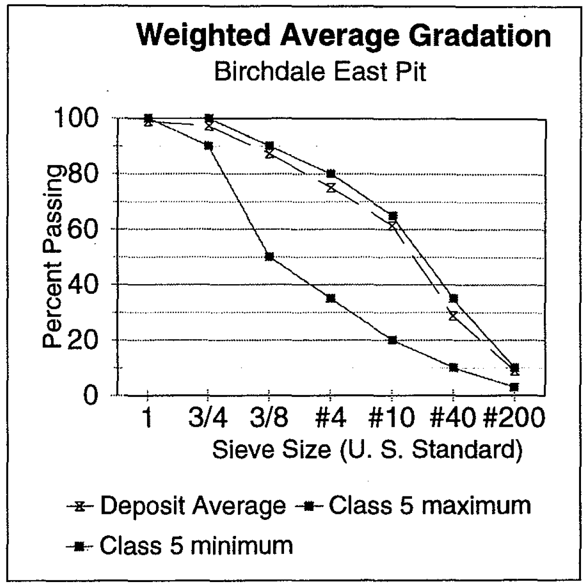


Figure 9. Graphic comparisons of the average gradations for the Birchdale (left graph) and Birchdale East (right graph) deposits to MnDOT's gradation limits for Class 5 aggregate. The Birchdale deposit falls outside the Class 5 limits. The Birchdale East deposit meets the Class 5 criteria. These graphics provide a point of reference to the familiar aggregate product called Class 5. Percent passing refers to the proportion of the sample, by weight, that passes through a particular sieve size. Sieve sizes get smaller from left to right, ranging starting at 1 inch and decreasing to #200 mesh (0.075 millimeters).

Table 6. Weighted average gradations for the two Birchdale Pits. The sieve sizes get progressively smaller moving to the right in the table. The values below each sieve size are the percent, by weight, of the total sample that falls through (passes) that sieve. The cutoff we use for the gravel fraction is material larger than the #10 sieve. For example, for the Birchdale Pit, 73% of the sample, by weight, passed through the #10 sieve. Stated another way, this deposit has an average of 27% gravel (100 - 73 = 27). The two columns on the right show the percent of material retained (bigger) than the respective sieves. Values in parentheses represent the range for all samples.

	Percent of Material ***Passing*** Respective Sieve							Weight Percent ***Retained*** on Respective Sieve	
	1	3/4	3/8	#4	#10	#40	#200	crushable +3/4"	gravel +#10
Birchdale Pit (north of pit)	96	96	91	83	70	34	10.4	4 (3-5)	30 (28-32)
Birchdale Pit (south of pit)	100	98	92	86	75	40	10.5	2 (0-6)	25 (16-38)
Birchdale Pit Average	98	97	92	84	73	37	10.4	3 (0-6)	27 (16-38)
Birchdale East Pit	99	97	87	75	61	29	8.9	3 (0-7)	39 (27-47)
Class 5 upper limits	100	100	90	80	65	35	10	0	35
Class 5 lower limits	100	90	50	35	20	10	3	10	80

Table 7. Test results for deleterious materials in the gravel. These values are for a composite sample of all samples collected from both sites (see Appendix C). Rows in the first column identified with a +1/2", + 4, or -4 refer to only the portion of the sample retained on the ½" sieve, retained on the #4 sieve, and passing through the #4 sieve, respectively.

	Pit average (%)	Class 5 specs	Bituminous specs (maximum %)			Concrete specs (max. %)
			Type 31	Type 41, 47	Type 61	
+1/2" shale	0.0					0.4
+4 shale	0.7					0.7
-4 shale	3.8			5.0		
+1/2" spall	0.0					0.3
total shale	4.5	7/10[a]				
total spall	5.0		5.0		1.0	
total +4 spall	1.2			2.5		1.5
LAR loss (%)	24.74	40	40	40	40	40

[a] Maximum is 10% shale except when the part passing the 200 sieve exceeds 7%, the shale shall not exceed 7%.

Bedrock – A prominent bedrock knob occurs at each site. The approximate foot prints of exposed bedrock are indicated on Plate 2. Allowing for a 100-foot setback from the property to the north, the footprint at the Birchdale Pit covers about 6.4 acres. Over the entire 6.4 acres, there are about 100,000 cubic yards of solid in-place rock, or about 150,000 cubic yards after crushing, for every 10 feet of depth. Stated another way, for a thickness of 40 feet, each acre of bedrock contains about 65,000 cubic yards of in-place rock or about 95,000 cubic yards after crushing. This knob projects roughly 40 feet above the landscape.

The footprint at the Birchdale East Pit covers about 11.3 acres. Over the entire 11.3 acres, there are about 180,000 cubic yards of solid in-place rock, or about 270,000 cubic yards after crushing, for every 10 feet of depth. Stated another way, for a thickness of 25 feet, each acre of bedrock contains about 40,000 cubic yards of in-place rock or about 60,000 cubic yards after crushing. This knob projects 25-30 feet above the landscape.

Different types of rock comprise each bedrock knob. Both offer potential as a crushed quarry aggregate for road projects. Two samples taken from the south end of the bedrock knob at the Birchdale Pit were analyzed by MnDOT's geology unit at their Materials Lab in Maplewood, MN (Appendix E). The rock is a metamorphosed, dark, fine-grained volcanic rock (trap rock). It is not known whether this rock type is consistent through the entire bedrock knob.

At the Birchdale East site, the southern portion of the bedrock knob is granitic, with some inclusions of dark rock similar to that at the Birchdale Pit. This bedrock was not analyzed by MnDOT.

Mining Plan

Development of a mining plan requires consideration for production of a desired product or products, economics, scale and scope of operations, and reclamation. Every gravel deposit has its own unique geometry, variation in quality, and setting within the landscape, and each land manager has their own vision of how the final reclaimed landscape should look. Therefore, mining plans are unique for each pit. There are, however, five steps that are necessary for any mining activity. They are permitting, clearing, stripping, mining, and reclamation.

Overview – This mining plan encourages and anticipates that all of the natural aggregate resource will be mined. This plan presents a basic design for mining of the gravel and of the final reclaimed area. Custom designs, mine management (determining what is mined), and reclamation plans for the site are left to the discretion of the land manager. Once mining is complete, the final reclaimed landscape within the pit at both sites will be a shallow depression. Created wetlands are likely in these depressions at the Birchdale site and possible in small portions of the Birchdale East site. No topsoil spoil piles from prior mining were evident at either site.

Both gravel deposits occur as elongate lenses. The Birchdale East deposit shows a slight topographic ridge reflecting its presence. The edges of both deposits are indistinct because they thin for some distance. No gravel remains inside the existing pits.

The aggregate at the Birchdale Pit overall contains a low percentage of gravel and may be suitable as granular or select granular borrow. Whether this material could be used for low maintenance forest roads or other roads is not known. Alternatively, this material could be upgraded to Class 5 if crushed rock was blended with it. The portion north of the existing pit has a higher gravel content than that south of the existing pit.

The aggregate at the Birchdale East site, as an overall average, meets Class 5 gradations. Some portions of this deposit fall just short of meeting the Class 5 gradations, however. This is addressed further in the mining section below.

No discussion on mining the bedrock knobs is offered at this time. Personnel at the Division of Lands and Minerals are willing to provide assistance when appropriate.

Permitting – Generally the state is exempt from local permitting, however, if local zoning ordinances or other rules exist for extraction of aggregate, the land manager should be aware of and consider them when developing the pit. Permits likely are required, however, if water is drained or pumped from the pit or if wetlands, possibly even those inside the pit, are impacted (Appendix E). An Environmental Assessment Worksheet (EAW) is not mandatory since the ultimate pit size is less than 40 acres.

Clearing – Timber of economic value should be logged prior to pit expansions. Brush and unsaleable timber should be reserved in piles for upland or under-water habitats, for visual screening, or disposed of away from the proposed and future mining areas at the discretion of the land manager.

Stripping – Topsoil is the only overburden at either pit that should be stripped prior to mining. If the topsoil will be used for permanent reclamation immediately after mining ceases (the same summer that mining occurs), the overburden can be pushed into berms just past the northern and southern edges of the deposit to expose the portion of aggregate to be mined in a given phase.

Stripping shall extend far enough past the expected toe of the pit so that final or temporary sloping can be done during or at the close of active mining without incorporating topsoil or other deleterious materials into the slope. After each mining phase is complete, the temporary working face cannot be steeper than 1:1 for safety.

Topsoil stockpiles that are not spread in a timely fashion can be seeded with a cover (nurse) crop of oats (the spring and summer seasons), winter wheat (the fall season), or other species at the discretion of the land manager to minimize erosion and weed growth.

Mining – One mining strategy for the Birchdale site is to mine the portion north of the pit in one operation. Consideration should be given to not mining the portion south of the existing pit because the forest road crosses much of it, and the quantity is small.

One approach for the Birchdale East deposit is to mine the entire width and thickness of the deposit so that the active pit face moves westward. The active pit face will have a north-south alignment. Then all of the area east of the pit face can be permanently reclaimed after each mining phase. In some places, the existing forest road would need to be re-routed along the southern edge of the deposit or through the bottom of the pit.

Even though the deposit average meets Class 5 gradations, three individual holes do not. Hole 11 is the worst (Figure 10). The other two, Holes #1 and #15 are very close to meeting the gradations. These holes occur along the south half of the deposit and only are a concern if very small quantities are mined at a time and Class 5 is needed. If the deposit is mined in rather large quantities at a time with a working pit face that trends north-south, there is little concern with meeting Class 5 gradations. In addition, during mining the final gradations may end up slightly

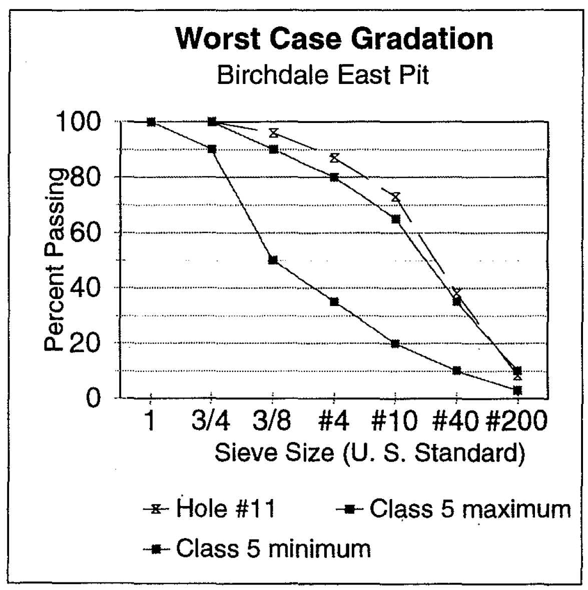


Figure 10. This graph shows that the worst test hole from the Birchdale East pit does not meet MnDOT's gradation requirements for Class 5 gravel. Hole 11 is too sandy.

better than these data predict because of sampling bias introduced by using a relatively small auger to retrieve the samples. Small augers routinely under represent the coarse particles.

A strategy to mitigate for variations within the deposit may be to mine and process the entire deposit in a single operation, and place the aggregate into one or two large piles.

Comparisons from the Birchdale pit are not shown since none of it meets Class 5 gradations.

The land manager is encouraged to provide these data to prospective lessees and consider innovative ideas they might offer pertaining to mining operations.

Reclamation – At the close of each mining phase, interim reclamation should occur where future mining will occur and final reclamation should occur in those areas where mining will not occur again.

General provisions.

Interim reclamation. Interim reclamation shall consist of sloping all pit faces or walls to provide a safe condition (suggested slope angles are no steeper than 1:1, horizontal to vertical). This includes the banks adjacent to ponds. Topsoil must be stripped far enough past the expected pit edge to allow for proper sloping without incorporating topsoil or other deleterious material into the slope.

Permanent reclamation. The final pit perimeters should be sloped no steeper than 3:1. These slopes should be covered with available overburden subsoils and then covered with 4 inches or more of topsoil, if available. Remaining topsoil should be spread on flat areas.

Placing four inches of topsoil or more in the beds of created wetlands will help vegetation establish. Advice on creating wetlands and banking the acres of wetland created are available from personnel at the Minnesota Board of Water and Soil Resources (BWSR) and DNR Division of Ecological Services.

All reclaimed areas should be seeded to minimize the spread of weedy species and accelerate the reclamation process.

Specific Considerations.

Birchdale Pit. The entire perimeter of the existing pit except the north side may be sloped and reclaimed if it is decided to leave the remaining aggregate south of the pit. The existing 0.3-acre pit contains water at least part of the year, so the final reclamation plan for this site should include a created wetland. If it is likely the created wetland would interfere with mining of the adjacent bedrock knob, it might be prudent to not formally create the wetland for wetland banking credit. This is because there is time, effort, and paper work involved to create a relatively small wetland which would have to be repeated to replace this wetland if it gets destroyed when the bedrock is mined. In addition, a deed restriction is required. If the DNR later wanted to destroy the wetland, approval, which may not be granted, is necessary from the DNR and possibly the Army Corps of Engineers. Wetland regulations are complicated and are modified frequently, so advice on this issue from the Division of Ecological Services is recommended.

Birchdale East Pit. Once the small quantity of gravel just northeast of the existing pit is mined, everything north and east of the working face can be permanently reclaimed. Subsequent reclamation would occur after each mining phase where the working face would undergo temporary reclamation and all disturbances east of the working face would receive permanent reclamation.

Four fact sheets on aggregate mining are attached in Appendix F. Additional information is presented in the publication by Cynthia G. Buttleman, 1992, "A Handbook for Reclaiming Sand and Gravel Pits in Minnesota", Minnesota Department of Natural Resources.

Additional leasing and mining information are available from DNR Division of Lands and Minerals personnel.

Glossary

boulder– a stone (usually rounded) larger than 256 mm (9 inches) in diameter.

cobble– a stone larger than 64 mm (2.5 inches) and smaller than a boulder.

crevasse– a fissure or open break within glacial ice.

deleterious material– any material that detracts from the quality of a sand or gravel product, and if deleterious materials are present in sufficient quantities the gravel product may be unsuitable for particular uses. Common deleterious materials are shale, iron oxides, unsound chert, clay balls, and other soft particles.

drumlin– a streamlined hill or ridge of glacial deposits with its long axis paralleling the direction of flow of the former glacier

esker– serpentine ridges of sand and gravel. They are formed by streams flowing on or in glacial ice and when the ice eventually melts, the sediments from the stream bed form a ridge.

feature– a physical phenomenon that exists on the earth's surface, such as a lake, valley, or hill.

GIS– stands for geographic information system. It is a computer system for the input, editing, storage, maintenance, analysis, and output of spatial information. Each type or category of data is commonly thought of as a separate layer of information.

GPS– stands for global positioning system. It is a satellite-based system which, in conjunction with a receiver, determines locations on the earth's surface.

granule– particles of rock between 2 mm (0.08 inch) and 4 mm (0.16 inch) in diameter.

gravel– an accumulation of granular material, usually deposited by running water, that contains sufficient pebbles and larger stones to be marketable as gravel. When listed as a percentage of gravel, it is a measurement or estimate of the amount of the material, by weight, that is larger than 2 mm (commonly described as plus #10 mesh or retained on the #10 mesh).

ice-contact feature– layered deposits or accumulations of material deposited in contact with melting glacier ice. Examples are kames and eskers.

kriging algorithm– A regular grid of cells is overlain the scattered drill data. Values for each cell are estimated by fitting a mathematical surface to the scattered data.

landform– any naturally occurring recognizable physical form or feature on the earth's surface, such as hill, valley, esker, plain, plateau, mountain.

overburden– material of any nature that overlies a deposit of useful material.

pebble– stones ranging in size from 4mm (0.16 inch) to 64 mm (2.5 inch) in diameter.

Appendices A - F

Appendix A: Test holes with location coordinates, feet of aggregate, and water table information.

- **A.1:** Rako Pit
- **A.2:** Birchdale Pit
- **A.3:** Birchdale East Pit

Appendix B: Detailed geologic descriptions for each test hole.

- **B.1:** Rako Pit
- **B.2:** Birchdale Pit
- **B.3:** Birchdale East Pit

Appendix C: Complete gradation data for each sample.

- **C.1:** Rako Pit
- **C.2:** Birchdale Pit
- **C.3:** Birchdale East Pit

Appendix D: Aggregate quality data for the Rako and Birchdale sites.

Appendix E: Birchdale Bedrock Analysis–MnDOT.

Appendix F: Four DNR fact sheets on aggregate mining.

Appendix A.1. Test holes at the Rako Pit with location coordinates, simplified geology, and water table information. Coordinates are in UTM NAD 83. Feet of gravel refers to sand and gravel layers with an estimated gravel content of 15% or more. In the 'Test hole' column, the prefixes 'GP' and 'LD' refer to the Giddings Probe and Little Digger machine, respectively. Those without a prefix refer to the MnDOT drilling machine.

Test hole	UTM easting	UTM northing	Top of gravel (ft)	Base of gravel (ft)	Feet of gravel	Total Depth Drilled (ft)	Depth to water table(ft)
1	377296	5366468	0.00	0.00	0.00	10.00	3.00
2	377295	5366367	0.50	8.00	7.50	10.00	1.75
3	377065	5366283	4.00	14.00	10.00	25.00	4.00
4	377266	5366308	1.00	10.50	9.50	25.00	4.00
5	377050	5365833	0.00	0.00	0.00	10.00	NM
6	377159	5365896	1.00	18.50	17.50	19.00	4.00
7	377144	5365844	0.00	0.00	0.00	10.00	4.00
8	377159	5365802	7.00	12.50	5.50	12.50	NM
9	377190	5365781	8.00	10.00	2.00	10.00	3.00
10	377176	5365773	1.00	7.00	6.00	15.00	NM
11	377235	5365771	1.70	12.00	10.30	15.00	3.00
12	377063	5365917	1.50	17.00	15.50	20.00	3.50
13	377062	5365881	0.00	20.00	20.00	22.00	3.00
14	377115	5365883	0.00	20.50	20.50	25.00	3.00
15	376976	5365996	0.00	2.00	2.00	10.00	3.00
16	377023	5365956	0.50	11.00	10.50	15.00	1.00
17	377049	5365988	0.00	25.00	25.00	30.00	0.00
18	377322	5366328	0.00	7.00	7.00	10.00	4.00
19	377173	5366300	0.50	8.00	7.50	15.00	5.00
20	377131	5366243	5.50	15.00	9.50	20.00	4.00
21	377094	5366171	2.00	16.00	14.00	20.00	3.00
22	377132	5366085	1.00	4.50	3.50	10.00	1.00
23	377063	5366066	1.50	9.00	7.50	15.00	2.00
24	377054	5366111	0.75	11.00	10.25	15.00	1.50
GP1	377195	5366298	0.00	6.00	6.00	9.00	2.50
GP2	377347	5366375	2.00	9.00	7.00	9.00	3.00
GP3	377048	5366280	0.00	0.00	0.00	9.50	3.00
GP4	377057	5366303	0.00	0.00	0.00	8.00	NM
GP5	377085	5366343	0.00	0.00	0.00	8.00	3.00
GP6	377145	5366381	0.00	0.00	0.00	8.00	3.00
GP7	377169	5366368	0.00	0.00	0.00	8.00	3.00
GP8	377088	5366207	0.00	0.00	0.00	9.00	4.00
GP9	377045	5366153	0.00	0.00	0.00	8.00	NM
GP10	377179	5365766	0.50	8.00	7.50	8.00	NM
GP11	377227	5365766	0.00	8.00	8.00	8.00	NM
GP12	377285	5365763	4.50	7.00	2.50	8.00	NM
GP13	377326	5365764	5.50	8.00	2.50	8.00	NM
GP14	377203	5365735	0.00	0.00	0.00	8.00	NM
GP15	375982	5366060	0.00	0.00	0.00	7.00	NM
GP16	375932	5366019	0.00	0.00	0.00	7.50	NM
GP17	375637	5365727	0.00	0.00	0.00	7.00	NM
GP18	375568	5365755	0.00	0.00	0.00	7.00	NM
GP19	375699	5365470	0.00	0.00	0.00	7.00	NM
GP20	375730	5365286	0.00	0.00	0.00	7.50	NM
GP21	375821	5365147	0.00	0.00	0.00	6.00	NM

Test hole	UTM easting	UTM northing	Top of gravel (ft)	Base of gravel (ft)	Feet of gravel	Total Depth Drilled (ft)	Depth to water table(ft)
GP22	375943	5364973	0.00	0.00	0.00	3.00	NM
GP23	376908	5365923	0.00	0.00	0.00	6.00	NM
GP24	376925	5365856	0.00	0.00	0.00	8.50	NM
GP25	376806	5365878	0.00	0.00	0.00	6.00	NM
GP26	376699	5365839	0.00	0.00	0.00	9.00	NM
GP27	376611	5365778	0.00	0.00	0.00	6.00	NM
GP29	377261	5365927	0.00	0.00	0.00	9.00	NM
GP30	377321	5365981	0.00	0.00	0.00	8.50	NM
GP31	377371	5366016	0.00	0.00	0.00	6.00	NM
GP32	377298	5365938	0.00	0.00	0.00	6.00	NM
GP33	377278	5366012	1.00	9.00	8.00	9.00	NM
GP34	377250	5366040	0.00	0.00	0.00	8.50	4.00
GP35	377228	5366016	0.00	8.00	8.00	8.00	NM
GP36	377185	5366019	0.00	6.50	6.50	8.50	NM
GP37	377140	5366055	0.00	0.00	0.00	9.00	NM
GP38	377240	5366097	0.00	0.00	0.00	6.00	NM
GP39	377254	5366137	0.00	0.00	0.00	9.00	NM
GP40	377263	5366171	3.00	6.00	3.00	8.00	NM
GP41	377279	5366207	2.50	8.00	5.50	8.00	NM
GP42	377399	5366188	0.00	0.00	0.00	6.00	NM
GP43	377354	5366174	0.00	0.00	0.00	8.00	NM
GP44	377315	5366187	7.00	9.00	2.00	9.00	NM
GP45	377232	5366177	0.00	3.00	3.00	9.00	NM
GP46	377317	5366227	8.00	9.00	1.00	9.00	NM
GP47	377326	5366269	8.00	9.00	1.00	9.00	NM
GP48	377371	5366278	0.00	0.00	0.00	8.50	NM
GP49	377345	5366345	2.00	6.00	4.00	9.00	NM
GP50	377387	5366380	0.00	0.00	0.00	8.00	NM
GP51	377405	5366344	0.00	0.00	0.00	8.50	NM
GP52	377269	5365791	3.00	12.50	9.50	13.00	4.70
GP53	377255	5365857	0.00	0.00	0.00	9.00	3.50
GP54	377260	5365828	0.00	0.00	0.00	16.50	5.50
GP55	377254	5365740	6.00	7.50	1.50	9.00	5.00
GP56	377221	5365894	4.50	9.00	4.50	12.00	5.00
GP57	377155	5366019	0.00	3.00	3.00	9.00	NM
GP58	377256	5366187	0.00	10.00	10.00	12.00	4.00
GP59	377364	5366381	1.25	6.50	5.25	9.00	4.00
GP60	377103	5366260	2.25	6.00	3.75	12.00	2.50
GP61	377292	5365965	0.00	9.50	9.50	12.00	2.50
GP62	377241	5366250	3.00	9.00	6.00	11.00	4.00
LD2	377001	5366099	0.00	0.00	0.00	8.00	NM
LD4	377174	5365738	2.00	8.00	6.00	8.00	NM
LD5	377141	5365740	0.00	5.00	5.00	8.00	NM
LD6	377103	5365747	4.00	8.00	4.00	8.00	NM
LD7	377081	5365738	4.50	8.00	3.50	8.00	NM
LD8	376969	5365887	0.00	0.00	0.00	8.00	NM
LD9	377020	5366039	5.00	6.50	1.50	8.00	NM
LD10	376985	5365997	0.00	0.00	0.00	8.00	NM
LD11	377188	5366095	0.00	0.00	0.00	8.00	NM
LD12	377129	5366085	0.00	0.00	0.00	6.00	NM
LD13	377047	5366056	4.00	8.00	4.00	8.00	NM

Test hole	UTM easting	UTM northing	Top of gravel (ft)	Base of gravel (ft)	Feet of gravel	Total Depth Drilled (ft)	Depth to water table(ft)
LD15	377250	5366348	3.00	8.00	5.00	8.00	NM
LD16	377222	5366318	2.00	6.00	4.00	8.00	NM

NM = not mesured.

Appendix A.2. Test holes at the Birchdale Pits with location coordinates, feet of gravel, and water table information. Coordinates are in UTM NAD 83. Feet of gravel refers to sand and gravel layers with an estimated gravel content of 15% or more. In the 'Test hole' column, the prefix 'GP' refers to the Giddings Probe. Those without a prefix refer to the MnDOT drilling machine.

Test hole	UTM Easting	UTM Northing	Feet of gravel	Total Depth Drilled (ft)	Depth to water table (ft)
2-1	414055	5382378	4.25	6	1
2-2	414023	5382362	3.00	4.5	1
2-3	414020	5382334	1.80	3	1
2-4	414004	5382378	2.00	4	NM
2-5	413982	5382381	0.50	4	4+
2-6	413989	5382401	2.50	4	NM
2-7	414067	5382313	2.00	4	1
2-8	414073	5382350	3.00	6.5	1.5
2-9	414147	5382324	0.80	4.5	4.5+
2-10	414156	5382352	0.00	4	4+
2-11	413991	5382453	1.75	4	1.5
2-12	413965	5382434	1.50	6.5	1.5
2-13	414007	5382448	6.00	8	NM
2-14	414036	5382409	4.25	6.5	3.5
2-15	414058	5382411	1.00	6.5	4
2-16	414083	5382402	1.50	4	NM
2-17	414078	5382361	4.00	6	0.4
2-18	414119	5382361	1.50	3.5	0
2-19	414041	5382315	2.00	4	1
2-20	414022	5382305	1.00	4	1
GP1	414060	5382374	4.50	9	0.5
GP2	413999	5382366	2.50	6	1.5
GP3	414020	5382349	2.00	5.5	0.5
GP4	413897	5382493	0.00	6	NM
GP5	413903	5382521	0.00	3	NM
GP6	413901	5382466	0.00	1	NM
GP7	414161	5382323	0.00	3	NM
GP8	414176	5382217	0.00	3	NM
GP9	413951	5382412	1.50	2.5	NM
GP10	413960	5382426	3.00	5.5	NM
GP11	413974	5382463	1.00	1	NM
GP12	414010	5382458	0.50	6	NM
GP13	414051	5382418	0.00	6	NM
GP14	414083	5382422	1.50	3	NM
GP15	414025	5382423	5.50	6	NM
GP16	413988	5382427	0.00	6	NM
GP17	414007	5382446	4.00	6	NM
GP18	413902	5382394	0.00	3	NM
GP19	413914	5382419	0.00	3	NM
GP20	413953	5382374	0.00	3	NM
GP21	413941	5382391	0.00	3	NM

NM = not mesured.

Appendix A.3. Test holes at the Birchdale East Pit with location coordinates, feet of gravel, and water table information. Coordinates are in UTM NAD 83. Feet of gravel refers to sand and gravel layers with an estimated gravel content of 15% or more.

Test hole	UTM Easting	UTM Northing	Feet of gravel	Total Depth Drilled (ft)	Depth to water table (ft)	Comments
3-1	416061	5381904	3.5	4	4+	
3-2	415998	5381874	2.8	6	2	
3-3	415951	5381862	3.3	4	0.6	
3-4	416046	5381842	2.3	4	2	
3-5	415918	5381861	3.8	6	1	
3-6	415849	5381865	5.5	7.5	5	
3-7	415790	5381861	0.8	4	4+	
3-8	415728	5381850	0.0	4	4+	
3-9	416033	5381797	0.0	4	NM	
3-10	416041	5381819	0.0	4	4+	
3-11	415977	5381838	3.3	4	0.7	
3-12	415976	5381801	1.0	4	0.5	
3-13	415984	5381895	0.5	4	NM	
3-14	415907	5381893	1.0	4	4+	
3-15	415910	5381835	3.8	6.5	NM	
3-16	415907	5381815	2.5	4	0.75	
3-17	415903	5381780	2.0	4	NM	
3-18	415835	5381834	2.5	4	0.75	
3-19	415834	5381778	0.8	4	1	
3-20	415845	5381908	2.8	4	4+	
3-21	415848	5381923	1.3	4.25	4.25+	
3-22	415784	5381890	2.3	4	1.3	
3-23	415793	5381921	3.3	4	1.25	
3-24	415794	5381939	2.5	4	1	
3-25	415751	5381940	2.3	4	1	
3-26	415715	5381948	1.8	4	0.75	
3-27	415681	5381966	1.0	4	0.5	
3-28	415747	5381908	2.5	4	0.75	
3-29	415748	5381884	1.0	4	NM	
3-30	415707	5381933	2.5	4	NM	
3-31	415759	5381971	0.5	4	4+	
3-32	416079	5381885	0.8	4	NM	
3-33	416062	5381948	0.7	4	2	
3-34	416098	5381837	0.0	4	4+	
3-35	416173	5381838	0.0	4	4+	
	415717	5381928				Tree Line
	415848	5381931				Tree Line
	415914	5381900				Tree Line
	415981	5381919				Tree Line
	416052	5381888				NE Corner of Pit
	416000	5381902				NW Corner of Pit
	415995	5381873				SW Corner of Pit
	416032	5381867				SE Corner of Pit

NM = not mesured.

Appendix B.1. Detailed geologic descriptions for each test hole at the Rako Pit. Abbreviations: lt = light, dk = dark, gry = gray, blk = black, brn = brown, yel = yellow, org = orange, ob = overburden, grvl = gravel, sd = sand, slt = silt, vf = very fine grained, f = fine grained, m = medium grained, c = coarse grained, ft = feet, est = estimate.

Test hole	From (ft)	To (ft)	Layer	Color	gravel % (est)	Comments
1	0	0.5	soil	brown black		sandy
1	0.5	6	sand	lt brown	1	rare gravel, gray f sand at 2.25-3.25ft
1	6	10	till	gray	10	sandy, gravel is pea size and smaller
2	0	0.5	soil	dark		
2	0.5	8	f grvl	lt brown/gray	40	gray below 5ft, occ. large cobbles, max gravel is 3/4", with c sand
2	8	10	f sand	gray	0	
3	0	4	sand	brown		
3	4	8	grvly sd	lt brown	25	with c sand, gravel to 1"
3	8	14	f grvl	gray	35	with c sand, mostly pea size, darker than above due to shale, occ. cobbles
3	14	22	f sand	gray	0	sand gets finer with depth
3	22	25	grvly sd	gray	20	mostly pea size
4	1	7	grvly sd	brown	20	mostly pea, rare 3/4"
4	7	8	f grvl	brown	30	with c sand, rock at 6.5ft
4	8	10.5	grvly sd	brown		medium sand
4	10.5	18	f sand	gray		some pea gravel, rocks at 11, 12, 12.5, and 13 ft
4	18	25	sand	gray		occ. f gravel, 6" thick c sand with gravel at 23ft
5	0	3	silt	brown	0	sandy silt, upper 2ft may be fill
5	3	10	sand	brown	0	clean fine to med sand
6	0	1	sand			
6	1	13	grvl	brown	38	minor silt, pebbles to 2", grinding rocks from 2-9ft, good gradation
6	13	18.5	f grvl			mostly pea gravel with c sand, rocks at 16-18.5ft
6	18.5	18.5	till?			refusal on boulder, probably top of till
7	0	0.5	soil	dark	0	
7	0.5	3	silt	lt brown	0	
7	3	8.5	f sand	lt brown	0	silty, coarsens downward
7	8.5	10	sand	gray	0	
8	0	0.5	soil	dark		
8	0.5	5	slty sd	brown		quite silty, some ½" pebbles
8	5	7	sand	brown		relatively clean "milkshake" sand
8	7	12.5	f grvl	gray/brown	30	with m-c sand, orange-brown at 7-8ft, grinding rocks at 7-10ft, too much sand contamination to sample
9	0	0.5	soil			
9	0.5	8	f sand	lt brown		sticky, silty
9	8	10	grvl		30	pea to ½" size, no grinding
10	0	1	soil	brown black		
10	1	7	grvl	brown	30	good binder content, pea to 3/4" size, cleaner below 5ft
10	7	13	c sand	brown & gray	2	minor pea gravel, becomes finer at base
10	13	15	sand	brown		
11	0	0.3	soil	black		
11	0.3	1.7	slty sd	brown	5	rocks below 1 ft
11	1.7	12	grvl	brown	40	3" cobbles, grinding rocks at 2-4, 6, 7, 7.5, 8, 11, 12 ft, some silt
11	12	15	till	blue gray		rocks at 13 and 14 ft
12	0	1.5	soil	dk brown		gravelly, sandy loam
12	1.5	12	grvl	brown	40	50% limestone gravel, gravel to 1.5", lots of pea size,
12	12	17	f grvl	gray	15	mostly pea with rare ½" size, high shale content
12	17	20	sand	gray	3	
13	0	7.5	grvl	brown	50	cobbles to 3" recovered, 100% gravel at 1.5-3 ft
13	7.5	11	sand	gray	10	gravel could be contamination
13	11	20	f grvl	gray brown	30	mostly pea to 3/4" size, rocks at 11, 12, 12.5, 13, 14,

Test hole	From (ft)	To (ft)	Layer	Color	gravel % (est)	Comments
						15.5 ft, bottom 1 ft may be gray f sand.
13	20	22	till	blue gray		
14	0	10	grvl	brown	40	some silt, grinding rocks throughout
14	10	20.5	f grvl	brown gray	30	grinding rocks at 16-20 ft, darker below 15 ft due to 1/4" shale, lower 1.5 ft is gray sand with gravel
14	20.5	25	till	blue gray		
15	0	2	grvl	brown	35	½" of topsoil
15	2	7.5	sand	brown	5	rare gravel, pea and smaller
15	7.5	10	grvly sd	brown	15	c sand, gravel to 3/4"
16	0	0.5	sand	brown		
16	0.5	11	grvl	brown	40	reddish color at 3-5 ft, grinding rocks throughout, recovered 2.5" cobble
16	11	15	f sand	gray		marl-like material at top of interval
17	0	8	grvl	brown	30	greenish gray at 2-3 ft, slightly muddy, good gravel at 3-5 ft, grinding on rocks throughout
17	8	15	grvly sd	brown	10	fairly muddy, occasional grinding on rocks
17	15	25	grvl	brown/gray	30	darker tint due to 1/8 - 1/4" shale, red granites distinct, abundant shale at 24-25 ft
17	25	30	sand	gray		poor recovery, possible pea gravel
18	0	7	grvl	brown	20	top 1 ft is loamy, rocky at 3-5 ft
18	7	10	f sand	brown		
19	0	0.5	soil	dark		
19	0.5	8	grvl	brown	28	sand varies from med to coarse, grinding rocks at 1-8 ft
19	8	15	f sand	gray		sand has a greenish tint
20	0	3	sand	brown		clean, rare pebble, larger rock at 2 ft
20	3	5.5	c sand	brown	0	clean
20	5.5	15	f grvl	brown	35	gets coarser with depth, mostly pea to 8 ft, hit rocks at 11-14 ft
20	15	18	sand	gray	4	top 2 ft is well sorted sand
20	18	20	f grvl	gray	30	pea gravel with c sand
21	0	2	soil	dark	5	sandy gravelly loam
21	2	11	grvl	brown	30	grinding rocks at 4, 5-11 ft, some silt, clean c sand matrix at 7-10 ft
21	11	16	slty grvl	gray	35	well graded to 1" size, very silty, grinding rocks at 12, 14, 16 ft
21	16	20	till	gray	10	difficult drilling, contains numerous pea to ½" limestone pebbles
22	0	1	sand	brown	0	
22	1	4.5	slty grvl	brown	30	muddy, pebbles to 1.5"
22	4.5	10	sand	greenish gray		
23	0	1.5	sand	reddish brn	0	4" rock at 1 ft
23	1.5	9	f grvl	brown	35	mostly pea but some pebbles to 2", rocks at 6 and 8 ft
23	9	11	slty sd	brown	10	very silty with minor fine gravel
23	11	15	sand	gray brown	0	
24	0	0.75	sand	brown		
24	0.75	5	grvl	brown	40	mostly 3/4" and smaller
24	5	11	f grvl	brown	60	fairly clean, mostly pea rock, rocks at 6, 7, 8, 11 ft
24	11	15	f sand	gray	0	very clean (no silt)
LD1	0	6	sand	brown	0	
LD1	6	8	silt	gray	0	silty clay loam
LD2	0	8	sand	brown	0	well-drained medium sand
LD4	0	2	silt	brown	0	
LD4	2	8	grvl	brown	20	good gravel to 3/4", some silt
LD5	0	5	grvl	brown	20	coarse sand, good gravel
LD5	5	8	c sand	lt brown	5	clean with fine gravel
LD6	0	4	f sand	brown	0	
LD6	4	8	grvl	brown	30	coarse sand, good gravel, some silt
LD7	0	4.5	silt	brown	0	wet, fine sandy clay loam

Test hole	From (ft)	To (ft)	Layer	Color	gravel % (est)	Comments
LD7	4.5	8	grvl	lt brown	25	coarse sand with gravel, some silt
LD8	0	8	sand		0	
LD9	0	5	c sand	brown	5	some fine gravel with silt
LD9	5	6.5	grvl	brown	20	good binder (silt)
LD9	6.5	8	silt	gray	1	dense sandy clay loam
LD10	0	8	c sand	brown	2	clean sand with minor fine gravel
LD11	0	6	c sand		3	wet, some fine gravel
LD11	6	8	f sand	dk gray	0	wet
LD12	0	2	sand	brown	1	
LD12	2	4	silt	gray	1	sandy clay loam
LD12	4	6	sand		3	
LD13	0	2	sand		1	
LD13	2	4	c sand		4	some fine gravel
LD13	4	6	grvl		20	with c sand
LD13	6	8	f grvl		70	clean pea gravel
LD14	0	2	sand		0	
LD14	2	8	grvly sd		10	with c sand, some pebbles to 1"
LD15	0	3	sand		4	c sand and minor gravel in lower 2ft
LD15	3	8	grvl		35	with c sand
LD16	0	2	f sand		2	
LD16	2	4	slty grvl		20	
LD16	4	6	f grvl		30	with c sand
LD16	6	8	sand		5	
GP1	0	4	grvl		30	c. sand, siltier in upper, 1-1.5" pebbles
GP1	4	4.75	sand			some gravel present
GP1	4.75	6	grvly sd		15	c. sand
GP1	6	9	c sand		10	
GP2	0	9	c sand		5	minor pea gravel
GP3	0	6	sand			
GP3	6	9.5	c sand	gray		
GP4	0	4.5	sand			2" of silt at 1ft depth
GP4	4.5	8	c sand			gray at 5.5 ft
GP5	0	4.5	sand			
GP5	4.5	8	c sand			some fine gravel, gray at 6 ft
GP6	0	5	sand			
GP6	5	8	f sand			
GP7	0	6	f sand			
GP7	6	7	c sand			minor gravel
GP7	7	8	sand			
GP8	0	4	sand			
GP8	4	9	c sand			minor fine gravel
GP9	0	8	sand			
GP10	0	0.5	soil		15	
GP10	0.5	8	slty grvl		20	coarser gravel in lower
GP11	0	1	soil			
GP11	1	8	slty grvl		20	hit rock with auger
GP12	0	4.5	sand			
GP12	4.5	7	grvl			with coarse sand
GP12	7	8	f sand			
GP13	0	5.5	sand			
GP13	5.5	8	grvl			with c. sand, hit cobbles at 5.5ft
GP14	0	7	silt			
GP14	7	8	c sand			
GP15	0	7	sand		0	uniform
GP16	0	7.5	sand		0	
GP17	0	7	f sand		0	uniform
GP18	0	2	f sand		0	uniform
GP18	2	7	silt		0	

Test hole	From (ft)	To (ft)	Layer	Color	gravel % (est)	Comments
GP19	0	3	f sand		0	
GP19	3	7	silt		0	
GP20	0	2	f sand			
GP20	2	7.5	silt			
GP21	0	0.5	sand		0	
GP21	0.5	6	silt		0	
GP22	0	2	f sand			silty
GP22	2	3	silt			
GP23	0	6	sand		0	coarser in lower
GP24	0	4	f sand		0	
GP24	4	7	sand		0	
GP24	7	8.5	c sand		0	silt at 7-7.5 ft
GP25	0	4	f sand		0	
GP25	4	6	sand		0	
GP26	0	4	f sand		0	thin silt at 2 ft
GP26	4	9	sand		0	
GP27	0	6	f sand		0	
GP28	0	9	grvl		40	some silt and pebbles
GP29	0	2	sand			silt at 2 ft
GP29	2	3	c sand		2	
GP29	3	4	f sand			
GP29	4	9	grvly sd		2	
GP30	0	1	f sand		0	
GP30	1	8	sand			rare gravel
GP30	8	8.5	c sand			
GP31	0	6	sand		0	
GP32	0	3	slty sd			
GP32	3	6	f sand			
GP33	0	1	c sand			
GP33	1	9	f grvl		20	match and pea size
GP34	0	1	soil			
GP34	1	2.5	sand			
GP34	2.5	4	c sand			
GP34	4	7	silt			very wet, whitish clay mix
GP34	7	8.5	sand			
GP35	0	5	grvl		20	silt in upper foot only
GP35	5	8	grvly sd		10	
GP36	0	4	grvl		20	
GP36	4	6.5	grvly sd		10	
GP36	6.5	8.5	f sand		2	
GP37	0	1	sand			
GP37	1	4	silt		3	occ. pea gravel
GP37	4	8	sand			occ. gravel at 6-8ft
GP37	8	9	f sand			
GP38	0	4	sand		0	
GP38	4	6	f sand		0	
GP39	0	4	sand			
GP39	4	7	c sand			
GP39	7	8	slty sd			
GP39	8	9	c sand		2	some fine gravel
GP40	0	3	c sand			some silt
GP40	3	6	f grvl		25	match and pea size, some silt
GP40	6	7	silt		2	
GP40	7	8	slty grvl		10	very silty
GP41	0	2.5	c sand			
GP41	2.5	8	grvly sd		10	fine gravel with c. sand
GP42	0	6	f sand		0	
GP43	0	3	f sand		0	

Test hole	From (ft)	To (ft)	Layer	Color	gravel % (est)	Comments
GP43	3	8	sand		0	
GP44	0	7	sand			rare fine gravel in lower
GP44	7	9	grvly sd			
GP45	0	3	grvly sd		4	
GP45	3	5	silt		2	
GP45	5	6	grvl		10	
GP45	6	9	silt		8	
GP46	0	3	sand			
GP46	3	6	c sand		2	gravelly
GP46	6	8	slty sd			
GP46	8	9	grvl		15	
GP47	0	2.5	sand			silty
GP47	2.5	6	c sand			
GP47	6	8	slty sd			
GP47	8	9	grvly sd		2	
GP48	0	7.5	sand			
GP48	7.5	8.5	c sand			
GP49	0	1	f grvl		5	silty, mostly pea
GP49	1	2	c sand			minor gravel
GP49	2	6	grvl		10	
GP49	6	9	slty grvl		5	clayey
GP50	0	4.5	f sand		0	
GP50	4.5	8	c sand			minor gravel
GP51	0	5	f sand		0	
GP51	5	6	sand			rare small pebbles
GP51	6	7	f sand			
GP51	7	8.5	sand			
GP52	0	0.33	soil	black		
GP52	0.33	1.7	f sand	brown	1	
GP52	1.7	3	silt	gray brown	5	saprolitic whitish gray silty clay at 2.7-3ft
GP52	3	12.5	slty grvl	brown	50	gravel is mostly minus 3/4", moved rig twice due to boulders at 4ft.
GP52	12.5	13	till?			no recovery, very hard drilling
GP53	0	4	sand	brown	0	
GP53	4	6	f sand	gray & brown		gets finer with depth
GP53	6	9	sand	lt brown		clean, rare match in lower
GP54	0	0.33	soil	black		
GP54	0.33	2	sand	brown	1	rare pea
GP54	2	2.5	silt	gray brown		
GP54	2.5	3.25	sand	brown		
GP54	3.25	10.5	slty grvl	brown	50	very silty (firm), may be too silty, auger grinding rocks at 4-6ft.
GP54	10.5	12	grvl	brown	25	less silt than above, pea to ½" size
GP54	12	14	slty grvl	brown	25	very silty (firm), may be too silty, to ½" size, firm
GP54	14	16	till?			no recovery, very hard drilling
GP55	0	0.33	soil	black		
GP55	0.33	6	sand	brown		pale gray and orange mottles at 5-6ft
GP55	6	7.5	slty grvl	brown	25	pea to ½" size
GP55	7.5	9	sand	brown	10	silty to firm in lower
GP56	0	4.5	sand	brown	0	well sorted
GP56	4.5	8	grvl	gray brown	55	good gradation to 3/4"
GP56	8	9	f grvl	gray brown	35	mostly match to pea
GP56	9	12	slty grvl	gray brown	30	very silty (firm), may be too silty, to ½" size, firm
GP57	0	3	grvl	brown	45	good gradation to 1.5"
GP57	3	7	slty grvl	brown	30	very silty (firm), may be too silty, mostly 3/8" and smaller, firm
GP57	7	9	f sand	gray brown	0	
GP58	0	3	grvl	lt brown	30	mostly ½" and smaller

Test hole	From (ft)	To (ft)	Layer	Color	gravel % (est)	Comments
GP58	3	10	slty grvl	brown	35	mostly 3/4" and smaller, alternating layers of muddy grvl and very silty (firm) gravel
GP58	10	12	f sand	gray brown	2	uniform
GP59	0	0.25	soil	black		
GP59	0.25	1.25	sand	brown		
GP59	1.25	2	slty grvl	whitish tan	25	3/8" and smaller gravel, very silty (firm)
GP59	2	3.5	grvl	lt brown	35	½" and smaller gravel
GP59	3.5	6.5	sand	brown	10	few match to 3/8"
GP59	6.5	9	f sand	blue gray	0	
GP60	0	2.25	sand	lt brown	0	
GP60	2.25	3	slty grvl	yellow brn	25	
GP60	3	6	c sand	gray brown	10	clean, mostly match size
GP60	6	7	slty sd	brown	5	very silty (firm)
GP60	7	9.5	sand	brown	8	slightly muddy
GP60	9.5	11	slty sd	lt brown	5	very silty (firm)
GP60	11	12	grvly sd	brown	15	
GP61	0	3	grvl	lt brown	45	mostly pea and 3/8" gravel
GP61	3	4	slty grvl	lt brown	35	
GP61	4	6	grvl	lt brown	30	
GP61	6	8	slty grvl	lt brown	30	very silty (firm), mostly pea to 3/8"
GP61	8	9.5	grvl	lt brown	40	
GP61	9.5	10.25	slty grvl	brown	25	very silty (firm), mostly pea to ½"
GP61	10.25	12	sand	brown		
GP62	0	3	sand	dk brown		
GP62	3	4	slty grvl	lt brown	25	3/8" and smaller
GP62	4	6.25	f grvl	yellow brn	30	3/8" and smaller, muddy
GP62	6.25	7	grvly sd	brown	20	
GP62	7	9	f grvl	brown	35	3/8" and smaller, muddy
GP62	9	11	f sand	yellow brn	0	firm, sli silty

Appendix B.2. Detailed descriptions for each test hole at the Birchdale Pit. Abbreviations: lt = light, dk = dark, gry = gray, blk = black, brn = brown, yel = yellow, org = orange, ob = overburden, grvl = gravel, sd = sand, slt = silt, vf = very fine grained, f = fine grained, m = medium grained, c = coarse grained, ft = feet, est = estimate. Descriptions for holes GP4 through GP21 were logged by a third party.

Hole	From (ft)	To (ft)	color	sediment	Layer	gravel % (est)	dominant grvl size (inches)	max grvl (inches)	comments
2-1	0	4.25	brn	slty c sd w/grvl	grvly sd	25	0.25		crunching at 2 ft, water table at 1 ft
2-1	4.25	6	lt brn	clayey silt	till				stiff drilling
2-2	0	0.5	black	sandy loam	topsoil				
2-2	0.5	3.5	brn	slty c sd & grvl	grvl	50		2	not muddy, water at 1 ft
2-2	3.5	4.5	lt brn	clayey silt	till	5			firm
2-3	0	0.75	black		topsoil				
2-3	0.75	2.5	brn	c sd & grvl	grvl	40	1.5		well graded, water at 1 ft
2-3	2.5	3	lt brn	grvly clayey slt	till				mottled
2-4	0	0.5	brn	slty sd & grvl	grvly sd	20		5	pebbles are dominantly limestone
2-4	0.5	2	brn	grvl	grvl	50	0.25		some pebbles
2-4	2	3	brn	sand	sand	5	0.25	0.25	
2-4	3	4	lt brn gry	grvly clayey slt	till			0.25	orange mottles
2-5	0	0.33	black	sdy loam	topsoil				
2-5	0.33	1.5	dk brn	c sd	sand			0.5	occ pebbles
2-5	1.5	2	brn	sd & grvl	grvl	40		0.75	no water detected
2-5	2	4	lt brn gry	clayey silt	till			0.5	orange mottles, crunching at 3 ft
2-6	0	2.5	brn	sd & grvl	grvl	25		3	varied layers, grvl ranges 10-40%
2-6	2.5	4	lt brn gry	clayey silt	till	5			
2-7	0	0.5	black	sdy loam	topsoil				
2-7	0.5	1	lt brn	slty sd	sand				water at 1 ft
2-7	1	1.75	lt brn	slty sd w/grvl	grvly sd	15			
2-7	1.75	3	lt brn	sd & grvl	grvl	30		1.5	well graded
2-7	3	4	lt brn	clayey silt	till				
2-8	0	0.75	black	sdy loam	topsoil				
2-8	0.75	1.75	lt brn	slty sd w/grvl	grvly sd	15			water at 1.5 ft
2-8	1.75	3.75	lt brn	slty grvl	grvl	40			
2-8	3.75	6.5	lt brn gry	clayey silt	till				gets more gray with depth
2-9	0	0.75	brn	slty sd w/grvl	grvl	25		1.5	
2-9	0.75	4.5	lt brn	clayey silt	till			0.75	white pebbles, no water table detected
2-10	0	1	dk brn	sand	sand				
2-10	1	4	lt yel brn	clayey silt	till	5			stiff
2-11	0	1.5	dk brn	slty sd	sand	2			large rock at 1 ft, 7.5 ft from exposed bedrock
2-11	1.5	3.25	brn	c sd w/grvl	grvly sd	15	0.25	0.75	water at 1.5 ft
2-11	3.25	4	lt gry	clayey silt	till				upper part looks gradational
2-12	0	1.5	dk brn	grvl	grvl	35		3	some silt, some cobbles at surface
2-12	1.5	3.5	brn	slty sd	sand	5		0.5	water at 1.5 ft
2-12	3.5	6.5	lt gry	clayey silt	till				
2-13	0	1	dk brn	slty grvl	grvl	30			graded, about 2" of topsoil

Hole	From (ft)	To (ft)	color	sediment	Layer	gravel % (est)	dominant grvl size (inches)	max grvl (inches)	comments
									here
2-13	1	6	brn	grvl	grvl	30	0.25	1.5	graded, grvl decreases with depth
2-13	6	8	lt gry	clayey silt	till	2			whitish color at top
2-14	0	0.1	black	grvly loam	topsoil				
2-14	0.1	4.25	brn	grvl	grvl	35	0.75		sandy layer at 2-2.5 ft, c sd and pea grvl in lower part, water at 3.5 ft
2-14	4.25	6.5	lt gry	clayey silt	till				
2-15	0	2.5	blk to brn	sand	sand	3			possible this is an old spoil pile
2-15	2.5	3.5	brn	grvl	grvl	30		1	graded
2-15	3.5	6.5		clayey silt	till				crunching at 4-5 ft, water at 4 ft
2-16	0	0.75	blk	loam	topsoil				
2-16	0.75	2.25	lt brn	slty c sd	grvly sd	10	0.13	0.5	mostly c sd
2-16	2.25	3	lt brn	sand	sand				grades into till below
2-16	3	4	lt brn	clayey silt	till				top 3" is whitish brn
2-17	0	0.5	blk	sdy loam	topsoil				water at 0.4 ft
2-17	0.5	1	brn	slty sd w/grvl	grvly sd	15			
2-17	1	4.5	brn	grvl	grvl	30		1	crunching
2-17	4.5	6		clayey silt	till				
2-18	0	0.5	blk		topsoil				water at surface
2-18	0.5	2	brn	sand	sand			0.75	clean, occ granules and pebbles
2-18	2	3.5	slty grvl	grvl	grvl	30			more grvl in lower part
2-18	3.5	4	lt brn	clayey silt	till				
2-19	0	0.5	blk	loam	topsoil				
2-19	0.5	1.5	dk brn	slty c sd	sand	5		0.75	minor grvl, water at 1 ft
2-19	1.5	2.5	yel brn	slty grvl	grvl	30		1	slightly muddy, crunching at 1.5-2 ft
2-19	2.5	4		clayey silt	till	2			
2-20	0	0.5	blk		topsoil	1			
2-20	0.5	1	dk brn/grn	sand	sand	5			water at 1 ft
2-20	1	2	lt yel brn	slty grvl	grvl	40	0.5		
2-20	2	4	yel gry	clayey silt	till				
GP1	0	4.5	brn	slty grvl	grvl	40			less grvl at 3-4.5 ft, water at 0.5 ft
GP1	4.5	7	lt yel gry	clayey silt	till	5			some c sd and granules in matrix
GP1	7	9	dk gry	clayey silt	till	1			stiff
GP2	0	0.5	blk		topsoil				
GP2	0.5	3	brn	grvl	grvl	40		1.5	water at 1.5 ft
GP2	3	6	lt gry brn	clayey silt	till				orange mottles at 3-5 ft, darkens with depth, stiff
GP3	0	0.5	blk	grvly loam	topsoil				water at 0.5 ft
GP3	0.5	2.5	brn	v slty grvl	grvl	30		1.5	
GP3	2.5	5.5	lt brn gry	clayey silt	till	5		0.25	orange mottles
GP4	0	6		clayey silt	till	0			
GP4	6	6		bedrock	bedrock	0			
GP5	0	0.5		sdy clay	clay	0			
GP5	0.5	1		c sd	sand	0			
GP5	1	3			till	0			

Hole	From (ft)	Tocolor (ft)	sediment	Layer	gravel % (est)	dominant grvl size (inches)	max grvl (inches)	comments
GP6	0	1	loamy grvl	grvl	0	0.25		
GP6	1	1	bedrock	bedrock	0			3 attempts
GP7	0	3	clayey silt	till	0			
GP8	0	3	clayey silt	till	0			
GP9	0	1	slty sd	sand	2			
GP9	1	2.5	sd w/grvl	grvly sd	5			
GP10	0	3	grvl	grvl	25			
GP10	3	5.5	c sd	sand	2			occ grvl
GP11	0	1	grvly loam	topsoil	10			
GP11	1	1	bedrock	bedrock				
GP12	0	4	slty sd	sand				occ pea grvl
GP12	4	4.5	grvl	grvl	10			
GP12	4.5	6	clayey silt	till				occ grvl
GP13	0	2.5	humus	topsoil				
GP13	2.5	3	slty sd	sand				
GP13	3	4	sd w/grvl	grvly sd	2			
GP13	4	5	sand	sand				
GP13	5	6	clayey silt	till				
GP14	0	1	sd w/grvl	grvly sd	5			has pebbles
GP14	1	1.5	grvl	grvl	10			
GP14	1.5	2.5	sand	sand				
GP14	2.5	3	clayey silt	till				
GP15	0	1.25	slty grvl	grvl	20			has pebbles
GP15	1.25	3	sd w/grvl	sdy grvl	10	0.25		
GP15	3	5.5	grvl	grvl	20			
GP15	5.5	6	clayey silt	till				
GP16	0	1	sd w/grvl	grvly sd	4			
GP16	1	4.5	c sd	sand				
GP16	4.5	6	clayey silt	till				
GP17	0	1.5	slty grvl	grvl	20			
GP17	1.5	4	sd w/grvl	sdy grvl	8			
GP17	4	4.5	f sd	sand				
GP17	4.5	6	clayey silt	till				
GP18	0	2	m sd	sand				
GP18	2	3	clayey silt	till				
GP19	0	3	m sd	sand				
GP19	3		clayey silt	till				
GP20	0	2	m sd	sand				some granules
GP20	2	3	clayey silt	till				
GP21	0	3	m sd	sand	0			
GP21	3		clayey silt	till				

Appendix B.3. Detailed descriptions for each test hole at the Birchdale East Pit. Abbreviations: lt = light, dk = dark, gry = gray, blk = black, brn = brown, yel = yellow, org = orange, ob = overburden, grvl = gravel, sd = sand, slt = silt, vf = very fine grained, f = fine grained, m = medium grained, c = coarse grained, ft = feet, est = estimate.

Test Hole	From (ft)	To (ft)	Color	Layer	Gravel % (est)	Comments
3-1	0	3.5	brown	gravel	45	good gradation to 2.5" size, minor silt, soil is scraped off here
3-1	3.5	4	grayish tan	till		
3-2	0	0.25	black	soil		
3-2	0.25	3	brown	gravel	40	lots of 1-2" pebbles, less gravel and finer in lower foot, water at 2 ft
3-2	3	6	grayish tan	till	5	stiff, gravelly
3-3	0	3.25	brown	slty gravel	45	muddy, lots of 3/4 - 2" pebbles, water at 0.6 ft
3-3	3.25	4	lt grayish tan	till	10	gravelly
3-4	0	0.25	black	soil		some 3-6" cobbles on surface
3-4	0.25	2.5	brown	gravel	25	lots of large cobbles were not included in sample, water at 2 ft
3-4	2.5	4	lt brown	till		very rocky
3-5	0	0.25	black	soil		
3-5	0.25	3	yellow brn	gravel	50	good gradation, lots of ½ to 1.5", water at 1ft
3-5	3	4	lt brown	gravel	20	some pebbles present
3-5	4	6	lt grayish tan	till	10	lots of cobbles
3-6	0	3	brown	gravel	50	soil removed
3-6	3	5.5	brown	gravel	25	more rocks at base, water at 5 ft
3-6	5.5	7.5	lt grayish tan	till		rocky clay silt
3-7	0	0.25	black	soil		no water detected
3-7	0.25	1	brown	gravel	30	
3-7	1	4	yellow brn/gray	till		
3-8	0	0.33	black	soil	2	no water detected
3-8	0.33	1	lt brown	silt	2	rare cobbles
3-8	1	4	lt brown	till		rare pea and pebbles
3-9	0	0.3	black	soil		
3-9	0.3	1	brown	sand	2	rare pea and pebbles
3-9	1	4	whitish gray/tan	till		clay silt
3-10	0	0.3	black	soil	0	no water detected
3-10	0.3	1.75	dk brown	slty sand	5	rare pea and pebbles
3-10	1.75	4	grayish tan	till		occasional pebbles
3-11	0	0.25	black	soil		
3-11	0.25	3.5	brown	gravel	40	good gradation to 2" size, silty sand in upper ½ ft, water at 0.7 ft
3-11	3.5	4	lt brown	till		
3-12	0	0.5	black	soil		
3-12	0.5	1	dk brown	slty sand		rare gravel, water at 0.5 ft
3-12	1	2	lt brown	gravel	30	lots of pea size
3-12	2	4	lt brown	till		clay silt, 4 ft gneiss boulder nearby
3-13	0	0.3	black	soil		
3-13	0.3	0.75	dk brown	sand		

Test Hole	From (ft)	To (ft)	Color	Layer	Gravel % (est)	Comments
3-13	0.75	1.25	brown	gravel	40	good gradation
3-13	1.25	4		till		
3-14	0	0.25	black	soil		no water detected
3-14	0.25	1.25	brown	slty gravel		top 6" is siltier
3-14	1.25	4		till		gravelly, lots of pea size
3-15	0	3.75	brown	gravel	45	upper 6" is siltier, 2" cobbles, 3" of soil is scraped off here, many pebbles at 1-2.5 ft
3-15	3.75	6.5		till		
3-16	0	2.5	brown	slty gravel	35	muddy, rocks at 1.5-2.5 ft, 3" soil scraped off, water at 0.75 ft
3-16	2.5	4		till		
3-17	0	0.25	black	soil		
3-17	0.25	2.25	brown	gravelly sand		muddy in upper, clean in lower portion
3-17	2.25	4		till		
3-18	0	0.25	black	soil		
3-18	0.25	2.75	yellow brown	gravel	45	good gradation, pebble to 2" size, water at 0.75 ft
3-18	2.75	4	yellow brown	till		
3-19	0	1	brown	slty sand	2	rare pea, water at 1 ft
3-19	1	1.75	yellow brown	gravelly sand	15	fairly clean
3-19	1.75	4		till		
3-20	0	2.75	brown	gravel	30	silty in top foot, good gradation to 1" size, 3" soil is scraped off, no water detected
3-20	2.75	4		till	10	
3-21	0	1.25	brown	gravelly sand	10	½" and finer, 3" soil is scraped off, no water detected
3-21	1.25	4.25		till		pebbly
3-22	0	2.25	brown	gravel	35	darker in top 0.75 ft, numerous cobbles, water at 1.3 ft
3-22	2.25	4	lt brown	till		very gravelly
3-23	0	3.25	lt brown	gravel	45	top ½ ft is darker and siltier, ½ to 2 ft is v. gravelly, 3" soil removed, water at 1.25 ft
3-23	3.25	4		till		gravelly
3-24	0	1.5	dk brown	gravelly sand	20	water at 1 ft
3-24	1.5	2	lt brown/gray	gravelly f sand	15	soft
3-24	2	2.5	brown	gravelly sand	25	good gradation to 1.5"
3-24	2.5	4	lt brown/gray	till		firm
3-25	0	0.75	dk brown	gravelly sand	10	pea size and smaller
3-25	0.75	2.25	lt brown	gravel	45	good gradation, finer sand at base, water at 1 ft
3-25	2.25	4	grayish tan	till	15	lots of ½" gravel
3-26	0	0.75	dk brown	sand		4" organic soil scraped off, water at 0.75 ft
3-26	0.75	2.5	lt brown	f gravel	40	mostly pea size
3-26	2.5	4		till		
3-27	0	0.75	dk brown	sand	5	rare pea, 8" soil scraped, water at 0.5 ft
3-27	0.75	1.75	lt brown	gravelly sand	20	mostly pea size
3-27	1.75	4	lt brown/gray	till		upper is soft and sandy, some pea size pebbles
3-28	0	0.75	dk brown	gravel	25	pea and ½" size, 4" soil scraped, water at

Test Hole	From (ft)	To (ft)	Color	Layer	Gravel % (est)	Comments
						0.75 ft
3-28	0.75	2.5	lt brown	gravel		to 1.5" size
3-28	2.5	4		till		
3-29	0	0.5	brown	f sand		
3-29	0.5	1.5	lt brown	gravel	45	lots of pea and pebbles to 3/4"
3-29	1.5	4	grayish tan	till	15	pea to 3/4" size pebbles
3-30	0	0.25	black	soil		
3-30	0.25	1	brown	gravelly sand	20	pebbles to 1.5"
3-30	1	2.75	lt brown	gravel	35	lots of pea and pebbles to 3/4"
3-30	2.75	4	grayish tan	till	10	less gravel than hole 28 and 29
3-31	0	0.25	black	soil		
3-31	0.25	1.25	brown	silty sand	5	big rocks at 1-1.5 ft
3-31	1.25	1.75	brown	silty gravel	30	no water detected
3-31	1.75	4	grayish tan	till	3	firm, pea size and smaller gravel
3-32	0	0.75	dk brown	gravelly sand	10	
3-32	0.75	2	lt brown	clay silt	2	rare pea to 3/4" size
3-32	2	3	grayish white	clay silt		rare pea to 3/4" size
3-32	3	4	lt brown	till		
3-33	0	0.3	black	soil		
3-33	0.3	1.3	brown	f sand	5	clean, rare pea
3-33	1.3	2	brown	gravel		good gradation to 1", water at 2 ft
3-33	2	4	grayish tan	till	5	pea and pebble
3-34	0	0.25	black	soil		
3-34	0.25	1	brown	sandy silt		no water detected
3-34	1	4	grayish tan	till	5	mostly pea size
3-35	0	0.25	black	soil		
3-35	0.25	0.75	dk brown	slty sand	5	
3-35	0.75	4	grayish tan	till	5	gravelly

Appendix C.1. Complete gradation sieve data for each sample from the Rako Pit. The values in this table represent the percentage of the sample, by weight, that passed through a given sieve size. These data, except as noted, were used to calculate a thickness-weighted average gradation for each tract for comparison to MnDOT's class 5 gradations. There were no pebbles larger than 2 ½ inches.

Tract	Test Hole	From (ft)	To (ft)	Feet of material	Sieve size (U. S. Standard)															
					2 ½" 63mm	2" 50mm	1 ½" 37.5mm	1 1/4" 31.5mm	1" 25mm	3/4" 19mm	5/8" 16mm	½" 12.5mm	3/8" 9.5mm	#4 4.75mm	#10 2.0mm	#20 0.85mm	#40 0.425mm	#80 0.175mm	#100 0.15mm	#200 0.075mm
A	2	0.50	8.00	7.5	100	100	100	100	100	100	100	99	97	88	71	43	24	15	14	11.1
A	3	4.00	10.00	6	100	100	100	100	100	100	100	99	98	94	85	65	41	16	13	7.3
A	3	10.00	14.00	4	100	100	100	100	99	99	99	98	96	88	65	42	24	10	7	3.5
A	4	1.00	10.50	9.5	100	100	100	100	100	100	100	99	99	91	76	50	26	10	9	7.3
A	18	0.00	7.00	7	100	100	100	100	100	100	99	98	96	NA	72	47	23	9	8	6.7
A	19	0.50	8.00	7.5	100	100	100	100	100	100	100	99	97	89	72	51	30	11	10	7.8
A	20	5.50	15.00	9.5	100	100	100	100	100	99	99	97	94	84	63	40	18	6	5	3.8
Tract A weighted average					100	100	100	100	100	100	100	98	97	88	72	48	26	11	9	6.6
C	20	5.50	15.00	9.5	100	100	100	100	100	99	99	97	94	84	63	40	18	6	5	3.8
C	21	2.00	11.00	9	100	100	100	99	99	98	97	95	91	78	56	29	13	5	4	2.5
C	21	11.00	16.00	5	100	100	100	100	100	100	99	97	93	80	65	44	34	28	27	13.7
C	22	1.00	4.50	3.5	100	100	100	98	98	97	95	93	91	80	66	53	43	23	20	10.8
C	23	1.50	9.00	7.5	100	100	100	100	99	99	98	97	95	63	45	29	18	9	8	5.6
C	24	5.00	11.00	6	100	100	100	100	100	100	99	98	97	90	62	30	17	5	5	3.0
C	24	0.75	5.00	4.25	100	100	100	100	100	99	98	96	91	79	66	45	20	7	6	4.1
Tract C weighted average					100	100	100	100	99	99	98	96	93	79	59	37	21	10	9	5.4
D	6	1.00	18.50	17.5	100	100	100	99	97	94	90	86	79	66	53	39	27	11	9	5.5
D	12	1.50	12.00	10.5	100	100	100	100	100	99	99	98	96	84	60	34	19	9	8	5.9
D	12	12.00	17.00	5	100	100	100	100	100	100	100	99	99	94	73	37	14	6	5	3.5
D	13	0.00	7.50	7.5	100	100	100	100	99	96	93	88	82	61	36	21	14	5	4	3.0
D	13	11.00	20.00	9	100	100	100	100	100	100	100	99	98	89	51	27	15	5	5	2.8
D	14	0.00	10.00	10	100	100	100	100	98	94	91	84	78	63	49	34	23	9	8	5.3
D	14	10.00	20.50	10.5	100	100	100	100	99	98	94	92	90	77	57	33	19	9	8	5.4
D	16	0.50	11.00	10.5	100	100	100	99	99	97	96	92	88	72	51	31	17	9	8	5.8
D	17	0.00	10.00	10	100	100	100	99	98	96	95	93	89	75	56	36	22	10	9	5.8
D	17	10.00	20.00	10	100	100	100	100	100	100	99	97	94	81	66	51	39	28	26	16.5
D	17	20.00	25.00	5	100	100	100	100	98	96	94	91	87	77	64	49	31	15	14	7.5

Tract D weighted average					100	100	100	100	99	97	95	92	88	75	55	36	22	11	10	6.2
E	10	1.00	7.00	6	100	100	100	100	100	99	99	97	93	76	63	40	20	12	11	7.8
E	11	1.70	12.00	10.3	100	96	96	89	88	85	82	78	72	60	50	33	22	15	13	9.0
E*	10*	7.00	13.00	6.00	100	100	100	100	100	100	100	100	100	97	91	66	25	12	10	7.8
Tract E weighted average					100	97	97	93	92	90	88	85	80	66	55	36	21	14	12	8.6
Class 5 upper limits									100	100			90	80	65		35			10
Class 5 lower limits									100	90			50	35	20		10			3

* not included in the resource volume calculations and therefore not used for calculating the weighted average.
NA = not analyzed due to excessive lumps.

Appendix C.2. Complete gradation sieve data for each sample from the Birchdale Pit. The values in this table represent the percentage of the sample, by weight, that passed through a given sieve size. These data, except where noted, were used to calculate a thickness-weighted average gradation for each tract for comparison to MnDOT's class 5 gradations. There were no pebbles larger than 2 ½ inches.

Test Hole	From (ft)	To (ft)	Feet of material	Sieve Size (U. S. Standard)															
				2 ½" 63mm	2" 50mm	1 ½" 37.5mm	1 1/4" 31.5mm	1" 25mm	3/4" 19mm	5/8" 16mm	½" 12.5mm	3/8" 9.5mm	#4 4.75mm	#10 2.0mm	#20 0.85mm	#40 0.425mm	#80 0.175mm	#100 0.15mm	#200 0.075mm
2-1	0	4.25	4.25	100	100	100	100	100	99	99	98	98	95	84	60	34	12	11	8
2-2	0.5	3.5	3	100	100	100	100	99	94	90	86	81	72	62	48	33	16	15	11.4
*2-3	0.75	2.5	1.75	100	100	100	100	98	97	96	93	89	80	66	46	30	16	15	11.1
*2-4	0.5	2	1.5	100	100	100	100	100	100	98	97	95	82	61	51	44	18	16	10.9
*2-6	0	2.5	2.5	100	100	100	99	98	98	97	94	91	82	75	64	50	13	11	8.4
*2-7	1	3	2	100	100	100	100	100	99	98	96	92	79	63	48	37	20	19	14.2
2-8	0.75	3.75	3	100	100	100	100	100	99	99	97	94	86	76	64	43	19	17	11.9
*2-11	1.5	3.25	1.75	100	100	100	100	100	97	97	97	96	93	85	63	38	19	18	13.2
*2-12	0	1.5	1.5	100	100	100	100	100	98	97	96	93	86	76	64	46	19	17	10.4
2-13	0	5.5	5.5	100	100	100	96	96	95	94	92	91	84	72	54	36	16	15	10.3
2-14	0	4.25	4.25	100	97	97	97	97	97	96	95	92	81	68	48	31	15	14	10.6
*2-16	0.75	2.25	1.5	100	100	100	100	100	100	100	100	99	99	96	88	79	60	58	52.5
2-17	0.5	4	3.5	100	100	100	100	100	100	99	96	94	86	75	63	49	17	15	11.4
*2-19	0.5	2.5	2	100	100	100	100	100	100	99	95	93	82	68	50	35	16	15	10.6
Weighted average				100	99	99	99	98	97	96	94	92	84	73	56	37	16	14	10.4
Class 5 upper limits								100	100			90	80	65		35			10
Class 5 lower limits								100	90			50	35	20		10			3

* Not included in the resource volume calculations and therefore not used for calculating the weighted average.

Appendix C.3. Complete gradation sieve data for each sample from the Birchdale East Pit. The values in this table represent the percentage of the sample, by weight, that passed through a given sieve size. These data, except where noted, were used to calculate a thickness-weighted average gradation for each tract for comparison to MnDOT's class 5 gradations. There were no pebbles larger than 2 ½ inches.

Test Hole	From (ft)	To (ft)	Feet of material	Sieve Size (U. S. Standard)																	
				8" 200mm	3" 75mm	2 ½" 63mm	2" 50mm	1 ½" 37.5mm	1 1/4" 31.5mm	1" 25mm	3/4" 19mm	5/8" 16mm	½" 12.5mm	3/8" 9.5mm	#4 4.75mm	#10 2.0mm	#20 0.85mm	#40 0.425mm	#80 0.175mm	#100 0.15mm	#200 0.075mm
3-1	0	3.5	3.5	100	100	100	100	100	99	99	98	98	96	94	81	63	42	24	13	12	9.1
3-2	0.25	3	2.75	100	100	100	100	100	100	100	98	91	86	82	72	63	47	25	14	13	9.0
3-3	0	3.25	3.25	100	100	100	100	100	100	99	98	95	92	87	75	62	46	30	17	16	12.1
*3-4	0.25	2.5	2.25	100	100	100	100	100	100	100	99	98	95	91	84	75	60	41	22	20	14.3
3-5	0.25	4	3.75	100	100	100	100	100	99	99	95	94	90	85	73	60	46	31	16	14	9.5
3-6	0	5.5	5.5	100	100	100	99	98	97	96	93	90	86	80	66	53	38	23	11	10	7.2
3-11	0.25	3.5	3.25	100	100	100	100	100	100	100	100	99	98	96	87	73	56	38	14	12	8.4
3-15	0	3.75	3.75	100	100	100	100	100	100	99	98	97	95	91	81	68	53	32	12	11	7.6
*3-16	0	2.5	2.5	100	100	100	100	100	100	100	100	100	98	95	86	78	64	42	21	20	15.9
*3-17	0.25	2.25	2	100	100	100	100	100	100	100	100	100	100	99	93	81	68	55	23	19	11.2
*3-18	0.25	2.75	2.5	100	100	100	100	100	100	100	100	99	99	96	96	74	58	38	20	18	13.8
3-20	0	2.75	2.75	100	100	100	100	100	100	100	100	99	96	90	77	63	46	30	17	15	11.4
*3-22	0	2.25	2.25	100	100	100	100	100	100	97	93	91	88	82	68	54	40	25	15	14	10
3-23	0	3.25	3.25	100	100	100	100	100	100	100	98	96	91	84	68	53	41	30	11	10	7.5
*3-24	0	2.5	2.5	100	100	100	100	100	100	100	100	99	98	96	87	80	67	52	25	23	14.8
*3-25	0	2.25	2.25	100	100	100	100	100	100	100	100	98	94	88	78	68	54	38	21	20	15.4
*3-26	0	2.5	2.5	100	100	100	100	100	100	100	99	99	95	93	81	68	54	36	17	16	12.3
*3-28	0	2.5	2.5	100	100	100	100	100	100	98	97	95	92	87	78	62	44	26	15	14	9.9
*3-30	0.25	2.75	2.5	100	100	100	100	100	100	100	99	99	98	95	85	74	59	38	16	15	11.4
Weighted average				100	100	100	100	100	99	99	97	95	92	87	75	61	46	29	14	12	8.9
Class 5 upper limits										100	100			90	80	65		35			10
Class 5 lower limits										100	90			50	35	20		10			3

* Not included in the resource volume calculations and therefore not used for calculating the weighted average.

Appendix D: Aggregate quality data for the Rako and Birchdale sites

Minnesota Department of Transportation

NORTHWEST DISTRICT
3919 Highway 2 West
PO Box 490
Bemidji, MN 56619

Office Tel: 218-755-3800
Fax: 218-755-2028

July 1, 1999

Cindy Buttleman, Regional Minerals Specialist
MnDNR, Division of Minerals
2115 Birchmont Beach Road NE
Bemidji, MN 56601

Subject: Lab Test Results - Rako and Birchdale Pits

Enclosed please find test result summary sheets for the two gravel sources that were drilled as part of our partnership project between MnDOT Bemidji District, DNR Region 1 Forestry Division and DNR Minerals Division. The information includes gradations and quality (lithological) on those samples submitted for testing.

The test sheets indicate test hole number, sample depth, and sample number for each sample tested. Listed below this heading information is the % passing each sieve size. MnDOT specifications to make base, bituminous, and concrete aggregate have been given to Dennis Martin, DNR Minerals, St. Paul.

Lithological information is presented for each gravel source on the last page of the test result summary sheets. Shale and spall values are given for the gravel source as a whole. It was not possible to provide a more detailed analysis on quality information such as combining certain borehole samples.

Please contact me when you have had a chance to look over the information. We can then set up a time and place to meet to discuss the test results in more detail.

We believe that the partnership is advantageous and beneficial to each of our agencies and wish to continue the project. I look forward to meeting with you soon.

Sincerely,

Mike Kamnikar, MnDOT Soils Engineer

cc: Graig Gilbertson
Bob Busch
Steve Baker
Dennis Martin, DNR ✓
Glenn Melchert, DNR

State of Minnesota Department of Transportation
Aggregates Test Report

AUG 2 6 1999

Sample ID CO-GS99-0191

Field ID: Rako | Project No: OTH Gravel Prospecting
Date Sampled: 5/12/99 | Proj Eng: Mike Kaminkar
Date Received: 8/12/99 | County
Usage: Gravel Prospecting | Bridge #:
Submitter: G. Melchent - DNR | Sampled From: Test Holes
Grad Spec: | Pit #: RAKO PIT
Spec. Class: | Pit Name:
Quality Spec: | Comment:

Sample ID

Field ID: | Project No:
Date Sampled | Proj Eng:
Date Received | County
Usage: | Bridge #:
Submitter: | Sampled From:
Grad Spec: | Pit #:
Spec. Class: | Pit Name:
Quality Spec: | Comment:

% Passing Sieve:	Lab Test	Field Test	Spec. Limits Low	Spec. Limits High	Lab Test	Field Test	Spec. Limits Low	Spec. Limits High
LAR B-Pct Loss	24.42							

cc: GRADE AND BASE OFFICE ✓
M. KAMINKAR ✓
D-2 LAB

Approved By: [signature]

Charge: 1 - 1018

* Value does not meet Spec
** Value out of Field-Lab Tolerance
% Shale in Sand N.C. = Trace

☐ Meets Requirements
☐ Does Not Meet Requirement
☑ For Info Only

AUG 2 6 1999

State of Minnesota Department of Transportation
Aggregates Test Report

Sample ID CO-GS99-0190		**Sample ID**	
Field ID: Birchdale	Project No: OTH Gravel Prospecting	Field ID:	Project No:
Date Sampled: 5/7/99	Proj Eng: Mike Kaminkar	Date Sampled	Proj Eng:
Date Received: 8/12/99	County	Date Received	County
Usage: Gravel Prospecting	Bridge #:	Usage:	Bridge #:
Submitter: G. Melchent - DNR	Sampled From: Test Holes	Submitter:	Sampled From:
Grad Spec:	Pit #: BIRCHDALE PIT	Grad Spec:	Pit #:
Spec. Class:	Pit Name:	Spec. Class:	Pit Name:
Quality Spec:	Comment:	Quality Spec:	Comment:

% Passing Sieve:	Lab Test	Field Test	Spec. Limits Low	Spec. Limits High	Lab Test	Field Test	Spec. Limits Low	Spec. Limits High
LAR B-Pct Loss	24.74							

cc: GRADE AND BASE
M. KAMINKAR ✓
D2 LAB

Approved By: [signature]

Charge: 1 - 1018

* Value does not meet Spec
** Value out of Field-Lab Tolerance
% Shale in Sand N.C. = Trace

- [ ] Meets Requirements
- [ ] Does Not Meet Requirement
- [x] For Info Only

District 2

Minnesota Department of Transportation
Prospect Sample

6/2/99 9:27 AM

Submitted By: G.MELCHERT
Date Submitted: 5/12/99
PROJECT # 334-8

Pit Name/#: **RAKO PIT**
Legal Desc: NW1/4 157-31-8

Lab ID 2-PS	99001	99002	99003	99004	99005	
Test Hole #	1-2	1-3	1-3	1-4	1-6	
Sample #	1	1	2	1	1	
Depth	0.5-8'	4-10'	10-14'	1-10.5'	1-18.5'	
SIEVES	Gradation1 % Passing	Gradation2 % Passing	Gradation3 % Passing	Gradation4 % Passing	Gradation5 % Passing	Gradation6 % Passing
8	100	100	100	100	100	#DIV/0!
3	100	100	100	100	100	#DIV/0!
2 1/2	100	100	100	100	100	#DIV/0!
2	100	100	100	100	100	#DIV/0!
1 1/2	100	100	100	100	100	#DIV/0!
1 1/4	100	100	100	100	99	#DIV/0!
1	100	100	99	100	97	#DIV/0!
3/4	100	100	99	100	94	#DIV/0!
5/8	100	100	99	100	90	#DIV/0!
1/2	99	99	98	99	86	#DIV/0!
3/8	97	98	96	99	79	#DIV/0!
#4	88	94	88	91	66	#DIV/0!
#10	71	85	65	76	53	#DIV/0!
#20	43	65	42	50	39	#DIV/0!
#40	24	41	24	26	27	#DIV/0!
#80	15	16	10	10	11	#DIV/0!
#100	14	13	7	9	9	#DIV/0!
#200	11.1	7.3	3.5	7.3	5.5	#DIV/0!

Remarks: -4 Shale = 1.65
+1/2 shale = 2.28
+4 shale = 4.41
+4 Iron Oxide = .23
} Pit Averages

☐
☐
☑ For Your Info

Approved By: ____________

CC: Materials Engineer
Soils Engineer
Aggregate Engineer
RON MADSEN
G.MELCHERT - DNR

District 2 | Minnesota Department of Transportation | 6/16/99 11:22 AM

Prospect Sample

Submitted By: G.MELCHERT

Date Submitted: 18-May

Pit Name/#: BIRCHDALE EAST

Legal Desc: T.59R.27SEC.17/18 1/4SW

Lab ID 2-PS	28	29	30	31	32	33
Test Hole #	3-1	3-2	3-3	3-4	3-5	3-6
Sample #	1	1	1	1	1	1
Depth	0-3.5	.25-3	0-3.25	.25-2.5	.25-4	0-5.5
SIEVES	Gradation1 % Passing	Gradation2 % Passing	Gradation3 % Passing	Gradation4 % Passing	Gradation5 % Passing	Gradation6 % Passing
8	100	100	100	100	100	100
3	100	100	100	100	100	100
2 1/2	100	100	100	100	100	100
2	100	100	100	100	100	99
1 1/2	100	100	100	100	100	98
1 1/4	99	100	100	100	99	97
1	99	100	99	100	99	96
3/4	98	98	98	99	95	93
5/8	98	91	95	98	94	90
1/2	96	86	92	95	90	86
3/8	94	82	87	91	85	80
#4	81	72	75	84	73	66
#10	63	63	62	75	60	53
#20	42	47	46	60	46	~~53~~ 38
#40	24	25	30	41	31	23
#80	13	14	17	22	16	11
#100	12	13	16	20	14	10
#200	9.1	9.0	12.1	14.3	9.5	7.2

Remarks:
-4 shale = 3.8%
+1/2 shale = 0.0%
+1/2 spall = 0.0%
+4 shale = 0.7%
+4 spall = 1.2%

☐ Meets Requirements

☐ Does Not Meet Requirments

☒ For Your Info

Approved By: Krist Olson

CC: Materials Engineer
Soils Engineer
Aggregate Engineer
K. Madsen

Appendix E: Birchdale Bedrock Analysis–MnDOT

Minnesota Department of Transportation

District 2
3919 Hwy 2 West, P.O. Box 490
Bemidji, Minnesota 56619

Office Tel: 218/755-3800
Fax: 218/755-2028

April 20, 2000

Glenn Melchert
Industrial Minerals Geologist
Minnesota Department of Natural Resources
Division of Lands & Minerals
1525 3rd Ave. E.
Hibbing, MN 55746

SUBJECT: Birchdale Bedrock Analysis

Dear Glenn:

Enclosed please find a copy of the analysis performed on the bedrock samples collected from the Birchdale site last year. The petrographic analysis was accomplished by the Mn/DOT Geology Unit located at our Materials Lab in Maplewood.

I did not locate any copies of slides taken during the petrographic analysis nor does the memo refer to any such slides.

Mn/DOT is very interested in this site as a source for aggregate during the reconstruction to occur on Trunk Highway 11 from Baudette to International Falls over the next 5 - 10 years.

Mn/DOT will be in touch with the MnDNR - Minerals Division to determine a method beneficial to both parties in developing this site as an aggregate source in an environmentally sound manner.

Please contact me if you require any further information. We look forward to continuing our work with you on this site.

Sincerely,

Mike Kamnikar
Pre-Design Engineer

cc: Robert Busch
Graig Gilbertson
Cindy Buttleman - DNR Bemidji
Dennis Martin - DNR - St. Paul
Terry Beaudry
Charles Howe
Gerry Rohrbach
Steve Baker
Joe McKinnon
Dave Rettner

Minnesota Department of Transportation

Memo

Office of Materials and Road Research
Geotechnical Engineering Section
Mail Stop 645
1400 Gervais Ave
Maplewood MN 55109

Office: (651) 779-5607
Fax: (651) 779-5616

July 7, 1999

To: Mike Kamnikar, PG/PE
Soils Engineer, District 2

From: Jason Richter, Geologist JLR
Charles Howe, PG CKH
Chief Engineering Geologist

Subject: Analysis of Rock Types from Birchdale Area

At your request, we performed a petrographic analysis to determine the rock type which you sampled from the referenced area. The petrographic analysis was performed by Jason Richter and is as follows:

> Both outcrop and float samples can be classified as Amphibolites or, in this case, can also be referred to as metamorphosed mafic volcanic rocks. The dominant mineral in both is actinolite and accounts for approximately greater than 90 to 95% of the rock's composition. The remainder of both rock assemblages is comprised mostly of plagioclase found primarily as vein material and interstitial material between actinolite grains. A substantial amount of kaolinite/sericite is also evident in the float rock as a result of visible plagioclase alteration (plagioclase is much finer grained in the outcrop sample). Accessory magnetite is also present but only in the outcrop sample and is associated with ilmenite found in the form of exsolution lamellae. Alteration of ilmenite to leucoxene can be seen in both but is found predominantly in the float sample. Both rocks contain minor quartz and calcite found predominantly in veins. The float rock example also consists of minor epidote and iron-rich chlorite which are also found mostly as vein material.
>
> Texturally, both rocks are very fine grained (float sample is coarser than outcrop sample, however). Actinolite in the outcrop sample is bladed shaped as opposed to fibrous in the float sample. Plagioclase is also coarser in the float sample.
>
> As a result of the intense structural history recorded on northern Minnesota Archaen volcanics, prominent deformation fabrics have also been imprinted on these rocks. For the sake of brevity, however, they will not be discussed.

Both Birchdale samples, which are loosely referred to as greenstones, essentially have compositions and specific gravities (3.008) which are similar to the Kelliher Quarry rocks (also greenstones) sent down to us last August. Though genetically and temporally equivalent to Kelliher rocks, geologists have grouped the Birchdale samples into the Wabigoon Volcanic Superbelt as opposed to the Wawa

Superbelt which includes the Kelliher rocks. Both outcrop and float samples appear to be of sufficient quality to use in highway construction. We would, however, recommend that a C1293 "Canadian Prism" test be performed prior to use as concrete aggregate.

If you have any questions please feel free to call.

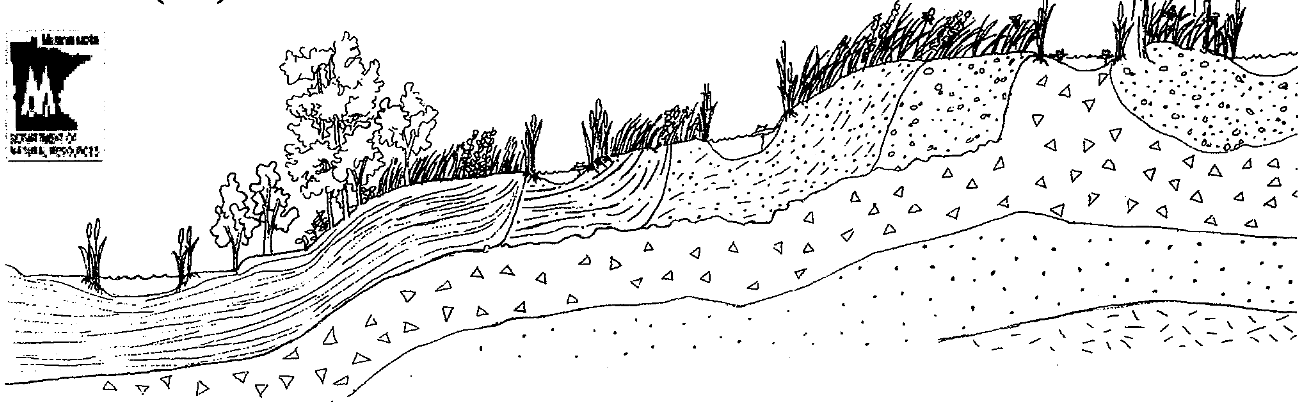
cc: Dave Rettner

Appendix F: Four DNR fact sheets on aggregate mining

Environmental Regulations for Aggregate Mining

Fact Sheet 1
January 2001

Prepared by the Minnesota Department of Natural Resources
Division of Lands and Minerals
500 Lafayette Road
St. Paul, MN 55155-4045
http://www.dnr.state.mn.us/lands_and_minerals/
Contact: (651) 296-4807



SIZE AND SCOPE OF AGGREGATE MINING OPERATIONS VARY

There is a wide variability in the size and scope of aggregate mining operations in Minnesota. Some are active only for one season to serve road construction projects. Others are long-term sites that operate continuously over several years. The materials being mined and the mining methods also vary greatly. Some operations mine unconsolidated sand and gravel materials left by glaciers; others produce crushed rock blasted from bedrock. Some operations mine within the groundwater table and others remain above the water table. There are various types of auxiliary facilities used at an aggregate operation, such as crushers, wash plants and asphalt plants. Permits required for aggregate mining depend on the size, scope and location of the operation.

LOCAL PERMITS

Counties, townships or municipalities have the primary authority for regulating extractive uses like aggregate mining. In many counties, aggregate mining requires a Conditional Land Use Permit (CLUP) from the county planning and zoning office. A township or municipality may also require a permit in addition to (or instead of) a county permit. Local permits are generally required for new operations that exceed a certain threshold of activity, or for expansion of an existing operation. The threshold for triggering a permit varies from one county to the next and may be related to area, production volumes, or length of time. Operations that were active before the effective date of a required permit may be exempt.

Local permits may address issues such as: hours of operation, noise, traffic, dust, and reclamation. Performance bonds or some other form of financial assurance may be required. The term of local permits can vary from one year to the life of the mine. Increasingly, local authorities are requiring a mining and reclamation plan along with the permit. For more information on the local permits required for aggregate mining, contact the local county zoning or planning office.

STATE PERMITS

In general, state agencies have no regulatory role in administering or reviewing local permits. Depending on the size and scope of the mining operation, however, some state and federal permits may apply to certain aggregate mining operations.

Minnesota Department of Natural Resources (DNR)

Water Appropriation Permit A permit from the Department of Natural Resources - Division of Waters may be required if there is a need to appropriate water as part of the mining operation. Appropriation permits are required for activities such as pit dewatering or aggregate washing plants that consume water at a rate of 10,000 gallons per day or 1,000,000 gallons per year. Contact: Jim Japs (651) 297-2835

Work in the Bed of Protected Waters Permit. If the mining activity will impact a protected body of water, a *Work in the Bed of Protected Waters* permit may also be needed. For more information about these permits, contact the area hydrologist at the local area DNR office (see the website at http://www.dnr.state.mn.us/waters/resources/index.html for the closest office, or call the general number for the division (651) 296-4800) or contact Ron Anderson at the DNR central office, Division of Waters, St. Paul, at (651) 296-0520.

Burning Permit. A burning permit may also be required if the applicant needs to burn brush from clearing and stripping operations. Burning permits are available at many locations throughout the state. For more information, contact your local DNR office: http://www.dnr.state.mn.us/regions/

Shorelands, Floodplains, Wild and Scenic Rivers. DNR is responsible for three other programs established by law which might affect certain aggregate operations. The Shoreland Management Act, the Floodplain Management Act, and the Minnesota Wild and Scenic Rivers Act, are "land use" or "zoning" type laws that require the DNR to institute minimum statewide development standards for shoreland, floodplains and on certain rivers designated as Wild and Scenic Rivers. These standards must then be adopted through local zoning or land use ordinance. The shoreland regulations, for example, require that aggregate mining be a permissible land use within a given shoreland zoning use district. If it is a permissible use, a plan must be prepared that addresses dust, noise, hours of operation, possible pollutant discharges, erosion control, mitigation of environmental impacts, and reclamation. The law allows local units of government to be more restrictive than the minimum standards. For information on how these regulations might affect a specific operation within a shoreland, floodplain or wild and scenic river, contact your local county planning and zoning office.

Minnesota Board of Water and Soil Resources (BWSR)

Wetland Permit. The Wetland Conservation Act requires a permit for certain activities that impact wetlands. The Act requires that the project proposer follow a sequence of development steps that includes avoiding impacts to wetlands, minimizing unavoidable impacts, and mitigating for the loss of wetlands due to a specific regulated activity. The overall authority for the Wetlands Conservation Act is through the Minnesota Board of Water and Soil Resources (BWSR) with implementation through a local governmental unit. For more information, contact BWSR (central office) at (651) 296-3767 or contact your local Soil and Water Conservation District Office: http://www.bwsr.state.mn.us/

Minnesota Pollution Control Agency (MPCA)

Fuel and Hazardous Materials Management. The containment, storage, recycling and disposal of used oil, lubricants, antifreeze, paint, solvents, vehicle clean wastes, recovered Freon, asbestos, PCBs, shop wastes and other hazardous materials must be in compliance with MPCA requirements. For more information, contact MPCA (general number) at (800) 657-3864 or (651) 296-6300.

Liquid Storage Tanks. Management of liquid storage tanks, whether above ground or underground must be in compliance with MPCA requirements. For more information, contact MPCA.

Air Quality Aggregate mining facilities must meet minimum standards for dust and noise. Crushing operations may have to meet federal standards for emissions of particulates from processing equipment. Depending on production capacity, an air emission permit may be required. For more information, contact MPCA at (651) 282-6143 or (800) 657-3938.

Water Quality. The following activities at aggregate operations require a water quality permit from MPCA:

- Discharge from washing plants that leave the mine, whether by gravity flow or pumping.
- Pumping or siphoning out a mine to create a dewatering discharge.
- Storm water runoff from mine stockpiles and pit walls, as well as from equipment like rock crushers, hot mix asphalt, and concrete production plants.
- Generation of wastewater by air emission control systems.

For more information, contact MPCA at (651) 296-7238.

FEDERAL PERMITS

U.S. Army Corps of Engineers (COE)

Section 404 Permit. The Army Corps of Engineers is a federal agency that regulates the discharge of dredged or fill material within waters or wetlands. At aggregate mining operations, activities in wetlands that might trigger a 404 permit include mining activities, the construction of access roads, building sites, storage areas, or water retention ponds. Each county has its own project manager. General information is available from the District Office of the Army Corps of Engineers at (651) 290-5375.

ENVIRONMENTAL REVIEW

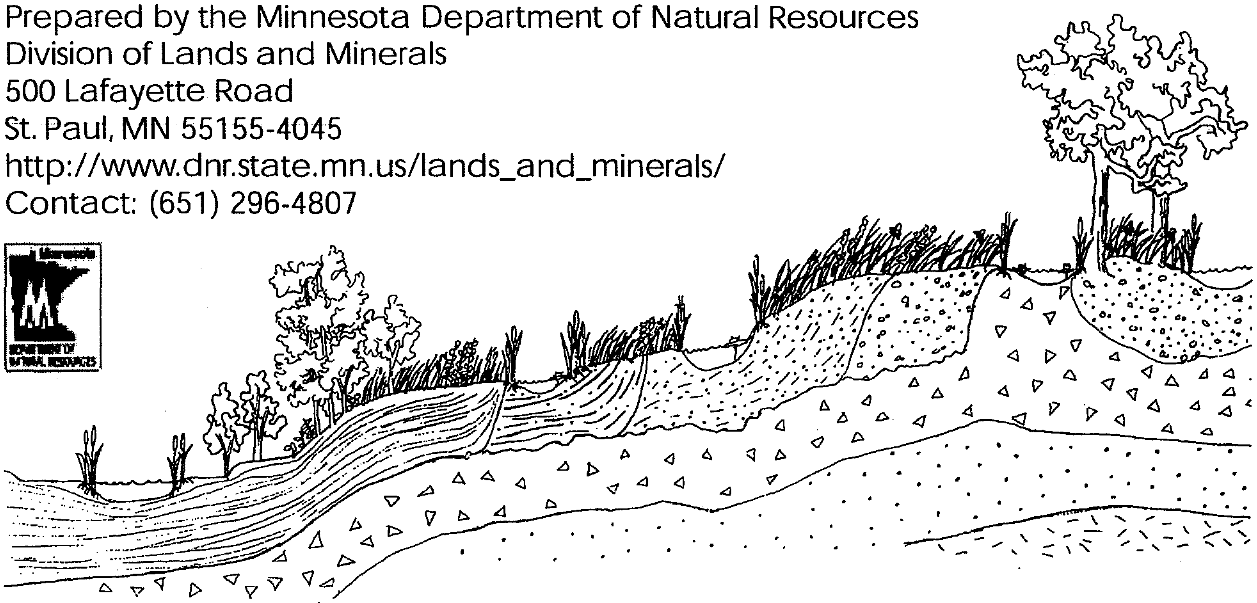
Environmental Quality Board (EQB)

Environmental Review. Rules developed by the state Environmental Quality Board determine when environmental review is needed for development projects. Environmental review in the form of an Environmental Assessment Worksheet (EAW) is required when an aggregate mining operation is expected to exceed 40 acres in size to a mean depth of 10 feet. Environmental Impact Statements (EIS) are mandatory for operations exceeding 160 acres. EAWs can be conducted on a discretionary basis if a proposed project is below the mandatory threshold under certain conditions. The EQB rules specify the governmental unit that is responsible for completing environmental review. For aggregate mining proposals, completing environmental review is the responsibility of local government, most often the county planning or zoning office in which the proposed project is located. For more information about environmental review, contact EQB at (800) 657-3794 or (651) 296-8253 or the local county zoning and planning office.

Mining Plans for Aggregate Operations

Fact Sheet 2
January 2001

Prepared by the Minnesota Department of Natural Resources
Division of Lands and Minerals
500 Lafayette Road
St. Paul, MN 55155-4045
http://www.dnr.state.mn.us/lands_and_minerals/
Contact: (651) 296-4807



WHAT IS A MINING PLAN?

A mining plan is a combination of maps and written information that describes every aspect of the proposed operation from inventory of the gravel resource to post-mining management of the site. The mining plan describes activities to be conducted at the mine site over the life of the operation. A mining plan is prepared before mining begins, often as a requirement for a permit.

The purpose of a mining plan is to ensure environmentally sound mining, including leaving the area in a safe, nonpolluting condition, and preserving as much land value as possible. A mining plan may consider view, noise, dust, hours of operation, traffic, final reclamation, and many other concerns. The requirements and provisions of plans vary with the local authority.

Because there is market fluctuation in the aggregate industry, the mining plan must be sufficiently flexible to accommodate such changes. The plan should be updated to reflect operating plan changes. Many operating permits also require updates. A mining plan ensures that activities progress according to a general concept that includes site reclamation.

A mining plan aids the cost efficiency and minimizes the environmental impact of the site. It allows for early identification of environmental concerns, efficient removal of the aggregate, and cost-effective reclamation. Through planning, materials can be placed in the appropriate location during stripping operations. Areas requiring fill material can be identified. Final landforms can be constructed during active mining.

ARE MINING PLANS REQUIRED FOR AGGREGATE OPERATIONS?

Currently, there is no state or federal mining permit in Minnesota that requires aggregate operators to submit a mining plan or to reclaim the site after mining. Aggregate mining operations are reviewed at the local unit of government–county, township or municipality, not at the state or federal level. Zoning ordinances and land use planning are employed to control mining operations. The local permits frequently address view, noise, dust, hours of operation, traffic, and final reclamation. Increasingly, local aggregate operation permits require a mining plan.

WHAT INFORMATION IS INCLUDED IN A MINING PLAN?

A mining plan is geared to the size and scope of the project. Small projects generally will require a simpler plan; larger operations will need a more elaborate one. Aggregate mining operations share certain characteristics, but each one is unique and needs a mining plan tailored to its site. The information needed for a mining plan generally includes the following:
Inventory of the aggregate resource including the shape, extent and depth of the aggregate deposit and its relationship to the groundwater.

General knowledge of the aggregate deposit is important. The best available information about the deposit must be collected from water well logs, existing surveys or maps, and previous testing work in the area. The most complete inventory data is obtained from drilling or test pitting on the site, but such data is not always available or necessary. Additional site specific work may be needed.

Characteristics of the deposit will determine in part the layout of the mine, the sequence for mine development, and the plan for how to blend the various aggregate materials to meet specifications. Economic considerations likely to influence the rate of mining should also be discussed in the plan, such as the thickness of the overburden, the quality of the aggregate, and haul distance.

Assessment of pre-mining conditions, including current land uses, ownership, infrastructure, previous excavations, existing vegetation and water features among others
An "assessment of pre-mining conditions" describes the setting before mining begins. This may include, among other things: the direction of flow in surface waters; the depth to and direction of groundwater flow; location of buildings and other infrastructure (roads, wells), existing land uses, presence of endangered species and cultural resources. An assessment can identify and mitigate environmental problems and public concerns associated with the project.

Description of mining methods including processing methods
A description of mining methods addresses how the resource will be mined and processed, and describes any proposed mitigation measures. This could include proposed operation hours, how complaints will be addressed, specific erosion control measures to be used, or how screening will be utilized.

Discussion on the staging and sequencing of operations
This discussion is closely linked with the above and is directed at how the mining operation will develop over time. Some mining operations remove the resource in several discreet stages over a short period of time, and others mine it in one stage for a longer period of time. The staging of operations has implications for reclamation. Can reclamation be accomplished progressively throughout the operation or is it best accomplished at the end of active mining?

Proposed reclamation, schedule, and post-mining management

Proposed reclamation describes the intended end uses of the site. Reclamation can consist of simply stabilizing slopes or it can include steps to restore wildlife habitats or preparation of the land for residential construction. When an operator has an end use goal in mind, mining activities like clearing, stripping, stockpiling, and landform construction can be directed toward the planned reclamation throughout the mining phase.

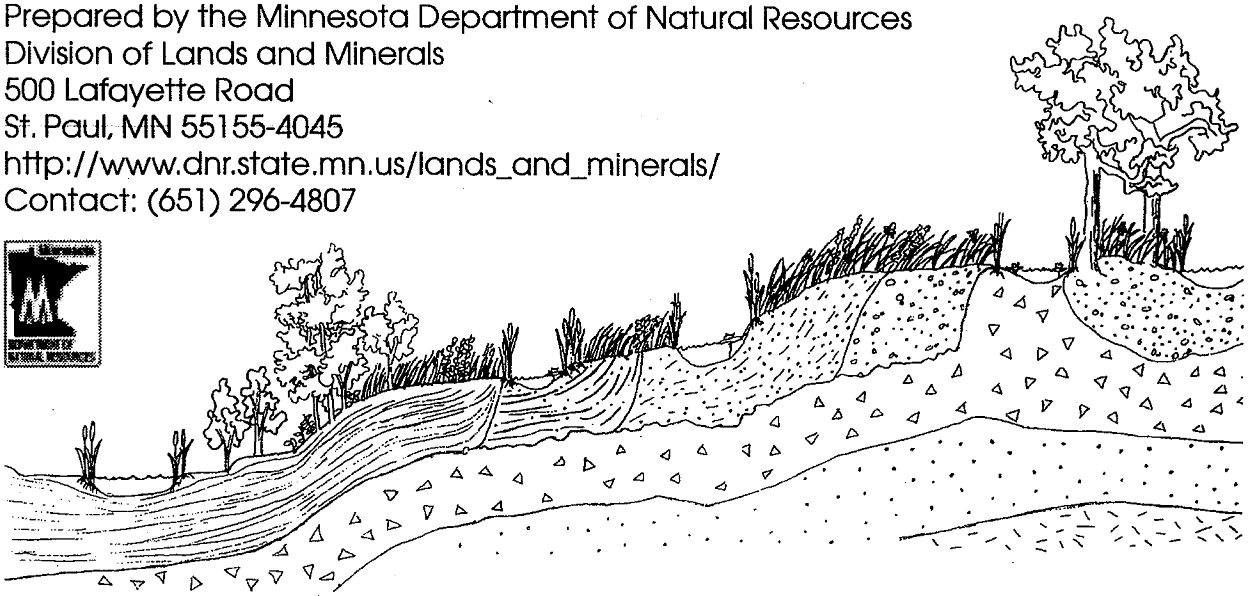
WHAT DOES A MINING PLAN LOOK LIKE?

Mining plans typically employ maps, an effective way to convey the needed information. The vicinity of a proposed operation is often shown on a topographic quadrangle map at a scale of 1:24,000. Specifics of the plan for mining the site are most often depicted on a more detailed plan view map. Proposed features of the mining operations (such as stripping areas, cuts, excavations, processing facilities, roads, stockpiles, ditches, berms, water control structures, etc.) and reclamation features (screened areas, areas to be revegetated, final slopes and grades, etc.) can be depicted on the detailed map. Vertical details are shown with contour lines and cross sections. A series of sequential maps can illustrate how operations will proceed over time. A base map with overlays can effectively show the proposed stages of the operation

Reclamation at Aggregate Mining Sites

Fact Sheet 3
January 2001

Prepared by the Minnesota Department of Natural Resources
Division of Lands and Minerals
500 Lafayette Road
St. Paul, MN 55155-4045
http://www.dnr.state.mn.us/lands_and_minerals/
Contact: (651) 296-4807



WHAT IS RECLAMATION?

Reclamation, at its most basic level, is a process that results in a safe and non-polluting mining site that will retain some land value. For example, gravel operations may be graded after closure to remove hazardous steep slopes. Revegetation, erosion control, and site cleanup are included in basic reclamation operations.

Sometimes reclamation is employed to prepare a site for a subsequent use ("end use") after mining operations are completed. For example, if the planned end use of a site is for green space, landscaping may be used to restore the site to a state that is aesthetically pleasing, or if the site will be used for residential development, areas may be left unfilled to prepare for installation of water and sewer connections.

A mining plan, when required, would normally include a description of post-mining management necessary to support the end use. It would also identify the party responsible for conducting it.

IS RECLAMATION OF AGGREGATE MINING SITES REQUIRED?

Currently, there is no state or federal mining permit in Minnesota that requires aggregate mining operations to be reclaimed. Reclamation at active aggregate mining sites is most often addressed in a local permit or through leasing agreements between landowners and mining companies. The most extensive review of aggregate mining operations takes place at the local unit of government –county, township or municipality. In Minnesota, there are 87 counties, 1,802 townships and 855 cities. Each of these entities has the authority to regulate aggregate mining through zoning ordinances and land use planning. Operating concerns such as view, noise, dust, hours of operation, traffic, and final reclamation are frequently addressed in local permits. There are differences in the ways in which local governments regulate aggregate mining and final reclamation. The standards for reclamation vary by county, township, and city.

RECLAMATION IS A PUBLIC CONCERN

Aggregate mining is the most common form of mining in Minnesota. Because aggregate is relatively inexpensive to mine but expensive to transport, most operations are located close to where the resource will be used. As a result, aggregate sites are found in every county and are highly visible along roadways. There are an estimated 4,000 gravel pits and 1,500 rock quarries in Minnesota.

Whether in populated areas or in rural settings across the state, aggregate mining is often regarded as an unwelcome neighbor. Conflicts between aggregate mining and other land uses are escalating. At the same time, the need for aggregate materials for construction projects and infrastructure is increasing commensurate with the strong economy and burgeoning population in Minnesota. Reclamation is a key concern voiced by the public.

RECLAMATION AT ACTIVE MINING OPERATIONS

Methods used to reclaim active operations can differ greatly from those used to reclaim abandoned sites. Although the precise numbers change yearly, an estimated 1,500 of the 4,000 gravel pits and about 150 of the 1,500 quarries are active operations where public concerns are usually addressed through a local permit. For active operations, final reclamation is most often considered in a local permit or through leasing agreements between landowners and mining companies.

RECLAMATION AT ABANDONED OR INACTIVE MINING OPERATIONS

Prior to the 1980s, reclamation of aggregate mining sites was not a routine practice. Today, there are an estimated 2,500 gravel pits and 1,350 rock quarries in Minnesota that are either permanently abandoned or intermittently active and often fall outside the regulatory authority of the counties. Problems associated with these sites may include: 1) safety concerns such as steep pit walls and deep water, 2) colonization by noxious weeds and other unwanted vegetation, and 3) unauthorized activities such as illegal dumping, target shooting, off-road vehicle use, and parties. There are increased problems at unreclaimed sites.

Abandoned sites are difficult to reclaim. When reclaimed, the results can be disappointing compared to reclamation done at the time of mine closure as part of a mining plan. There may be no responsible party and/or no money to do reclamation on abandoned sites. Costs to reclaim these sites may be higher because unwanted vegetation must be cleared and landforms reconstructed. Topsoil is needed for revegetation, and often the topsoil has been removed from unreclaimed sites.

AGGREGATE MATERIAL TAX

In Minnesota, a possible funding source for reclaiming abandoned pits on public land is the Aggregate Material Tax (Minn. Stat 298.75) which is a production tax on the removal of aggregate material. At present, 23 of the 87 counties in Minnesota have authority to collect the tax. In

1998, three townships in St. Louis County were authorized to collect the tax. In 1999, a total of $2,885,716 was collected by those counties and townships. The tax imposed on operators is ten cents per cubic yard. According to the statute, 90 percent of the tax is distributed to county or township road funds and the remaining 10 percent is allocated to individual county reserve funds for restoring abandoned pits or quarries on public land in those counties that collect the tax.

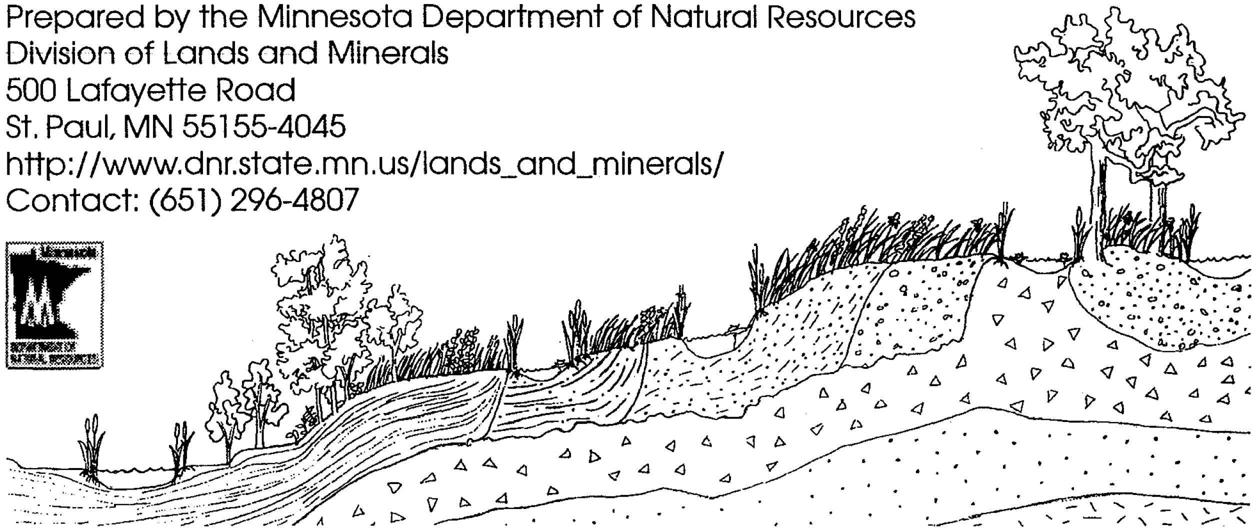
The reserve funds have not been frequently used for reclamation in part because few proposals have been identified. There is relatively little experience in the public or private sector in reclaiming aggregate sites that have been abandoned for a long period of time.

To add to the existing expertise and experience in the state, the DNR Division of Lands and Minerals initiated and managed several reclamation projects involving abandoned aggregate sites on public lands in northwestern Minnesota using partnerships and revenue generated by the aggregate material tax. This work is an effort to develop cost effective methods for reclaiming active and abandoned aggregate sites using conventional and native plant materials.

Using Native Prairie Species for Reclaiming Aggregate Mining Sites

Fact Sheet 4
January 2001

Prepared by the Minnesota Department of Natural Resources
Division of Lands and Minerals
500 Lafayette Road
St. Paul, MN 55155-4045
http://www.dnr.state.mn.us/lands_and_minerals/
Contact: (651) 296-4807



WHAT IS PRAIRIE?

"Prairie," in the simplest of terms, is a community of plants. Prairie plants are specially adapted to the climate and conditions found in western and southern Minnesota including extremes of temperature and weather, and high winds. Before European settlement 150 years ago, prairie covered much of southwestern and western and northwestern Minnesota. The extreme conditions and constant grazing by bison kept competing plants to a minimum. Prairie plants have long roots that hold the soil in place and allow the plants to survive drought. They are perennial, surviving the winter.

There are several different types of prairie in the Midwest. The tallgrass (or mesic) prairie, common in areas of moderate soil moisture levels, was typically found in western Minnesota where prairie grasses sometimes grew six feet high. Prior to European settlement, almost the entire Red River Valley consisted of tallgrass prairie.

USING PRAIRIE SPECIES FOR RECLAMATION

At depleted aggregate mining sites in areas where tallgrass prairie occurs, it is reasonable to consider revegetating with native prairie plants. Certain key characteristics of prairie plants make them a good choice for former mining sites. Because they are perennial, native prairie grasses, once established, can provide a long-term cover that is self-sustaining and requires little maintenance. Mowing may be needed, and prescribed burning is recommended on a rotation starting three or four years after planting.

Although a former aggregate site restored with native species offers many benefits, it does not restore native prairie. Restoring more than a fraction of the species found in a native prairie is beyond present capabilities because seed sources are not readily available in commercial quantities for all prairie species.

In places where tallgrass prairie does not occur, and in certain other locations, native prairie plants may be inappropriate for reclamation projects. Most warm-season prairie grass seed germinate late, most need prolonged moisture and warm soil. Areas seeded with native prairie plants may not germinate until the spring after initial seeding. Warm-season prairie grasses establish an extensive root system during the first year. The top growth is limited to small leaves that can be difficult to identify. Full scale plants develop during the second year. To compensate for slow establishment of prairie plants, a cover crop of wheat or oats can be planted along with the native seeds. Cover crops grow quickly, providing protection for the slower establishing native species. In addition, cover crops tend to die off rapidly, within one or two years, and therefore do not compete with more permanent native cover.

The slow initial growth of native plantings makes them less effective in erosion-prone locations. They are, therefore, not recommended on steep slopes composed of erodible soils. In addition to possible problems with slow development, prairie seed can be relatively expensive and can be difficult to find. Sometimes, a specially-adapted seed drill is needed for large areas. Adequate site preparation and regular weed control are essential for establishment. Due to the increasing popularity of native prairie plantings, however, these difficulties are quickly being overcome. Although the initial costs may be higher, the long term benefits of native plantings are great. Provided below are basic guidelines for planting native species.

GENERAL GUIDELINES

Site preparation:
Native plantings need a firm weed-free seed bed. Several herbicide applications followed by disking or mowing may be necessary on sites where vegetation is already established.

Seed source:
Seed harvested from as close to the project site as possible will preserve genetic characteristics and establish the vegetation types best adapted to the site.

Seed mixture and seeding rate:
The seed mixture and the seeding rate used for a reclamation project should be selected based on the site characteristics. In general, a diverse mix of grasses and forbs will provide the best results at a seeding rate in the range of 15 lbs/acre to 30 lbs/acre. If seed is harvested from a nearby site and used for reclamation, an analysis of the seed harvest should be conducted and additional seeding may be needed to complement the planting. Seed purchased from vendors can be blended to contain a diversity of species. The Minnesota Department of Transportation (Mn/DOT) has developed several general seed mixes for use on roadsides and ditches. The mixes are a baseline that can be modified as appropriate for local conditions. For more information on native species seed mixes, consult Mn/DOT's Year 2000 Specifications for Construction or contact Mn/DOT at (651) 284-3750.

Seeding method:
Native seed can be planted using a specially adapted drill that accommodates the light fluffy native seed. The final planting depth should be 1/2 to1 inch and maximum row spacing of about 8 inches, at right angles to surface drainage. An alternative to drilling is to till the site and broadcast the seed. Planting depth should be from 1/4 to 1/2 inch. After seeding, the site should be dragged with a rake or harrow and packed. Hand seeding is a good method for small areas.

Hydroseeding is an acceptable seeding method on steep slopes or other areas inaccessible to a seed drill. Hydroseeding is not recommended if the weather is hot and dry.

Cover crop:
A cover crop can be seeded with native seed mixtures. The type of cover crop depends on the season. Some possible cover crops are oats at a rate of 20 lbs/acre in the spring plantings, winter wheat at 20 lbs/acre for fall plantings, and annual rye grass at 10 lbs/acre for dormant seedings.

Timing:
Native grasses should be planted from May 1 to June 30. Seeding may be done in the fall, but the seeding rates should be increased slightly to account for seed mortality over the winter. Many species of wildflowers require a cold period to break dormancy and are best seeded late in the fall. If seeded in the spring, they may not be seen until the second year after planting. Seedling plants can be used to add diversity to the plantings. Some desirable species are difficult to propagate from seed and are only available as seedlings.

Maintenance:
During the first growing season, if the cover crop or annual weeds reach 18 inches or more in height, the site should be mowed to a height not less than 6 inches with a rotary mower. Prescribed burns can be implemented on a three to five year rotation starting the third or fourth year after planting. Fall haying is an alternative in areas where burning is not possible.

For more information:
Contact your local DNR area office, local Natural Resource Conservation Service office, or the U.S. Fish and Wildlife Service.