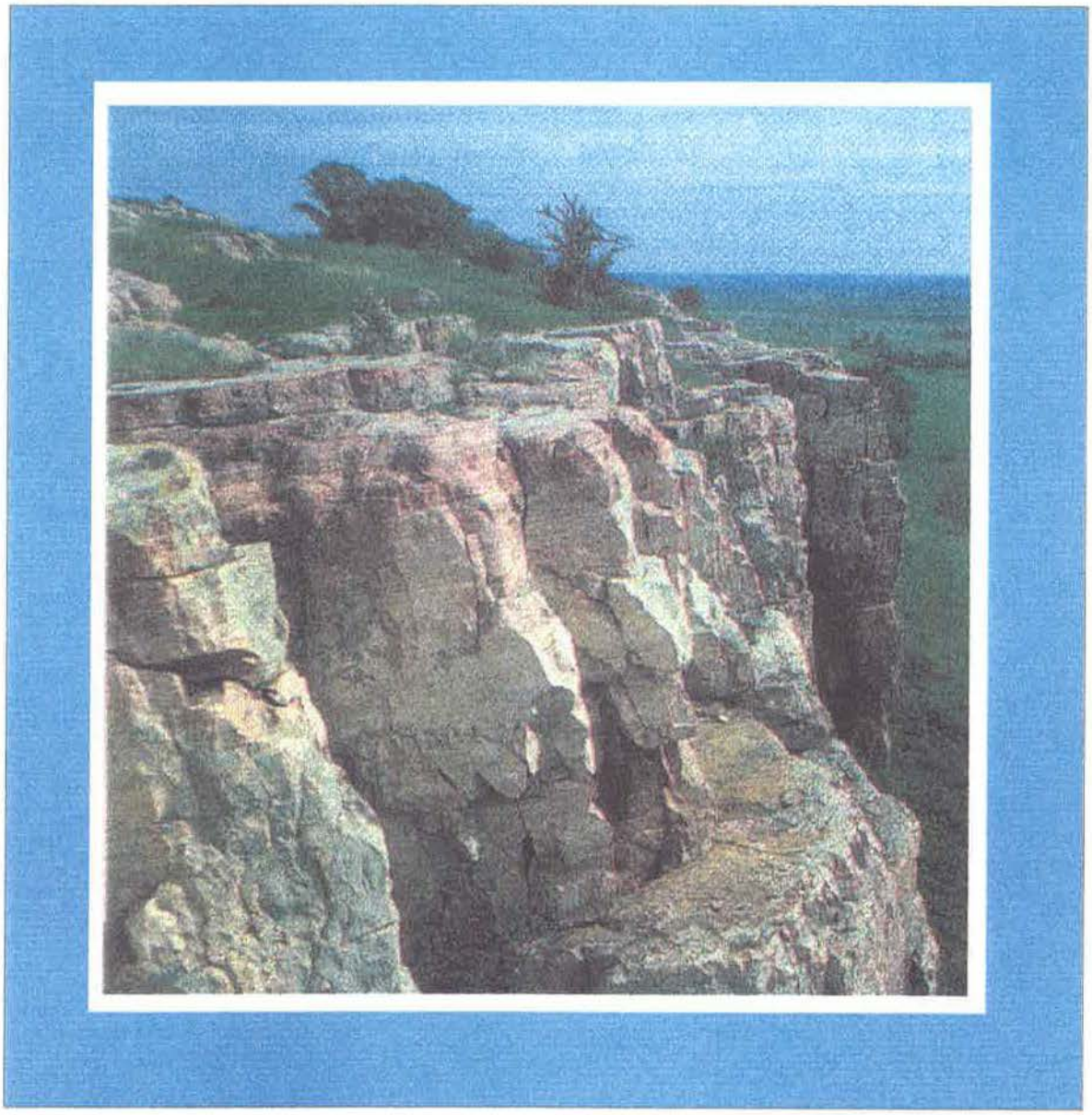
AGGREGATE RESOURCE EVALUATION

A Sand and Gravel Evaluation for a Site near Blue Mounds State Park



Minnesota Department of Natural Resources
Division of Lands and Minerals
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A Sand and Gravel Evaluation for a Site near Blue Mounds State Park

BY HEATHER ANDERSON

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William C. Brice, Director

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SUMMARY

The purpose of this study is to evaluate the volume, quality, and mining accessibility of a parcel of land near Blue Mounds State Park. The parcel is approximately 229 acres and is currently owned by Mr. Dennis DeJongh. Blue Mounds State Park is interested in purchasing the land from Mr. DeJongh. Previous investigations determined that a large deposit of sand and gravel exists on the parcel. To address the aggregate potential of the parcel, the Minnesota Department of Natural Resources (DNR) Lands and Minerals Division was commissioned by DNR-Parks to conduct an aggregate survey in April of 1999.

To ascertain the volume, quality, and accessibility of the deposit, the following methods were used: aerial photograph and map interpretations, drilling, sampling, laboratory and computer analysis. A summary of the results is listed below:

- The study area is located in section 25, T103, R45W.
- Currently the study area is zoned A1 for agricultural use.
- The sand and gravel was deposited by a glacial meltwater channel.
- A total of 89 drill holes were completed and a sample was taken from each drill hole.
- Except for the western ledge of the study area, the parcel consists almost entirely of sand and gravel, with a thickness ranging from 8 to 53.5 feet.
- The average thickness of the deposit is 13 feet.
- The deposit is moderately to well-sorted and consists primarily of pea sized gravel in a fine to medium-grained sand matrix. The gravel particles are rounded with the dominant lithology being limestone. Most of the deposit is relatively clean with little silt and no clay balls. However, there are seams of silt-rich gravel that were encountered. Larger quantities of silt-rich sand and gravel are found to the north.
- The estimated volume of the sand and gravel within the calculated boundary is 2,884,500 ± 20% cubic yards. The estimated boundary does not include material that is:
  - -In approximately 17 acres of the study area that was inaccessible to drill. This area is considered a data gap.
  - -60 feet from the centerline of Rock County Road 8.
  - -30 feet from the Blue Mounds State Park property line.
- Gradations of the composites meet MNDOT specifications for Class 5 material with some amounts of very coarse aggregate (rocks with the diameter greater than 1 inch). Coarse material can be screened.
- The deposit passes the MNDOT specifications for shale, thin and elongate rocks, and all sizes of spall. The southwestern section of the study area is borderline passing for the MNDOT specification for soft rock.
- The deposit passes both tests to determine durability during handling and freeze thaw cycles (LAR and Magnesium Sulfate).
- The amount of limestone does not pass MNDOT specifications for superstructure concrete.
- The deposit does not pass the MNDOT specification for water absorption.
- The quality of the deposit is fair to good. The deposit passes specifications all deleterious rocks and gradations for Class 5 material. However, the amount of limestone particles in the depsoit is very high and the amount of water absorbed does not pass MNDOT specifications.
- The mining accessibility is also fair to good. There is negligible overburden (thickness of the topsoil) and access to roads; however the water table varies from 2-10 feet. This would increase the cost of production which decreases profitability. And there are residential structures near the thickest portions of the deposit.
- This study was completed with a >80% certainty (margin of error ± 20%). Although drilling gives a fairly accurate representation of the deposit, unencountered variations within the deposit may exist. Also, to drill deeper sections of the deposit required the addition of more augers to the flight of the MNDOT drill rig. The handling of augers reduces sample retention and stratigraphic integrity which introduces error.

INTRODUCTION

The purpose of this report is to provide a sand and gravel resource estimate on a parcel of land that the state is interested in purchasing. The parcel is approximately 229 acres and is located in Section 25, T103N, R45W, Rock County, Minnesota (Figure 1). Currently owned by Mr. Dennis DeJongh, the parcel is within the Blue Mounds State Park statutory boundary.

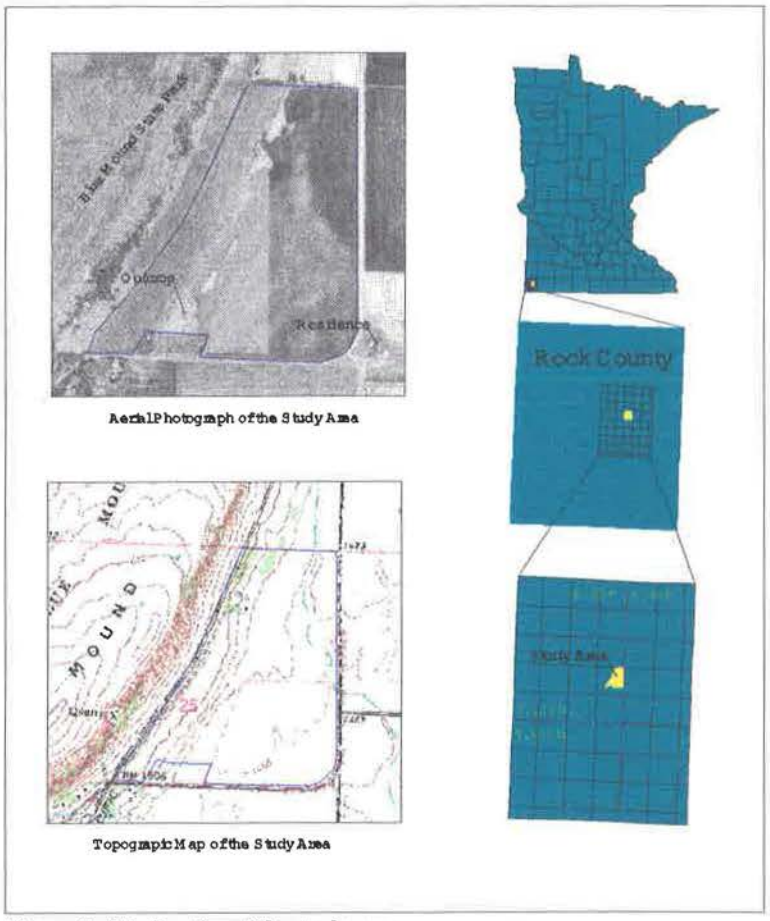


Figure 1. The location of the study area.

Previous exploration of sand and gravel determined that a large deposit exists on the parcel. A private gravel operator, Northern ConAgg Construction Materials performed the cursory evaluation.

Because the parcel is within the statutory boundary of the park and the location of the parcel is below the Blue Mound vista, Blue Mounds State Park is interested in acquiring the land from Mr. DeJongh. Addressing the interest of sand and gravel, an aggregate inventory was commissioned to describe the aggregate resources for the assessment of the parcel's real estate value. Therefore an aggregate survey was conducted in April of 1999 in conjunction with the Department of Natural Resources (DNR) Lands and Minerals Division, DNR- Parks Division, and Minnesota Department of Transportation (MNDOT).

The main function of the aggregate survey is to assess the volume, quality, and mining accessibility of the deposit. These goals are achieved through research, drilling, laboratory analysis, and computer modeling. The results of this survey will determine the parcel's aggregate resource value.

GEOLOGIC SETTING

Blue Mounds State Park is situated on a bedrock nob overlooking the Rock River valley. The bedrock nob in the state park is a very resistant type of rock called Sioux Quartzite. The Sioux Quartzite is a lithified sandstone that was deposited 1.47 to 1.5 billion years ago (Austin, 1972). The Sioux Quartzite has undergone several geologic events which carved deep valleys into the

bedrock. Therefore, the topography of the bedrock is dramatic with level highs, steep bluffs, and abrupt drop-offs. In fact, the bluff exposed in Blue Mounds State Park is characteristic of the regional bedrock topography (Patterson, 1997).

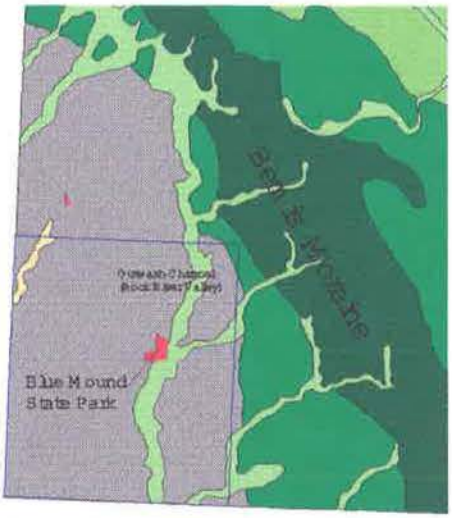


Figure 2. Surficial geology map modified from Hobbs and Goebel, 1982. The darker greens represent material deposited by a glacier (the Des Moines Lobe). The lighter green represents meltwater deposits and the gray represents older glacial material. The Rock county boarder is represented in purple.

Looking at the landscape today, most of the Sioux Quartzite is covered by younger sediments. The younger sediments that buried the Sioux Quartzite are from two major geologic events. The most recent of the two events is the glaciation of Minnesota. Glaciers advanced several times during the Pleistocene, a period of geologic time from two million years ago to about 8,000 years ago. Approximately 14,000 years before present, the ice margin of a glacier (called the Des Moines Lobe) was at a position north and east of the study area (the Bemis Moraine). As the glacial ice melted, large quantities of water eroded meltwater channels. The Rock River valley is an old meltwater channel of the Des Moines Lobe. The geologic history of the Rock River valley includes two geomorphic phases: erosion and deposition. First the channel eroded older glacial sediments and bedrock during a high outflow of glacial meltwater. As the water outflow decreased, the meltwater stream dropped the sediment load and deposited the sand and gravel. Therefore, the study area is located below the bluffs of the Sioux Quartzite in a glacial meltwater channel.

METHODOLOGY

An aggregate survey was conducted to determine the sand and gravel volume, quality, and mining accessability. Mining accessability was determined by evaluating overburden thickness, access to roads and depth to ground water. Therefore, the aggregate survey consisted of aerial photograph and topographic map interpretation, drilling, sampling, geologic logging, laboratory analysis and computer modeling.

MAP INTERPRETATION

Geologic interpretations were partially based on the analysis of topographic maps and aerial photographs. Topographic maps were analyzed to identify landforms, delineate trends and to locate other gravel pits. The following 7.5 minute U.S. Geological Survey topographical quadrangles were used: Luverne, Edgerton South, and Magnolia. Additional geologic information was gathered from color infrared aerial photographs (NAPP, 1992), which were used to delineate boundary lines, identify land marks, and determine the orientation of gravel deposits.

DRILLING

The Minerals drill plan included two types of drilling, exploratory and sampling drilling, which were conducted simultaneously in April of 1999.

Exploratory Drilling

The goal of exploratory drilling was to find the areas of no gravel. The purpose was to decrease the overall costs. Exploratory drilling was conducted by using a Giddings Probe. A Giddings Probe is a truck mounted soil auguring machine (Figure 4, F&H). The auger used was approximately 4 inch diameter. The size of the auger is too small to take samples, but the design of the machine allows for quick and numerous holes to be drilled.

The exploratory drill plan was to confirm the lack of gravel along the western ledge of the study area and also determine the western boundary of the gravel. Since the gravel seemed thicker to the south, another point of concern was a thinner deposit to the north. Therefore, Giddings Probe holes were also drilled in the northern portion of the study area.

Sampling Drilling

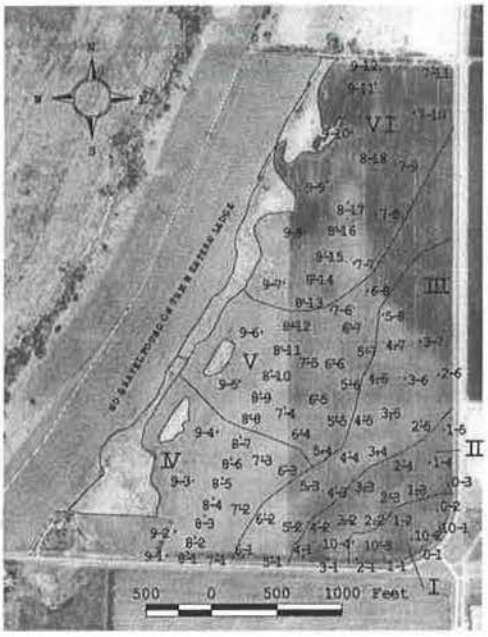


Figure 3. Location of sampling holes; there are ten rows (0-9) trending N-S and one row (row 10) trending E-W. The outlined areas numbered I-VI show which bore holes are composited together for MNDOT testing.

The time frame to complete the sampling drilling was bounded by the start of the growing season, the scheduling of the drill rig, and the weather. The latter of the three proved to be the biggest factor. Drilling was planned to start sometime after March and to be completed before the start of Mr. DeJongh's farming season in late April. Due to a couple of mid-March blizzards, field work did not begin until the middle of April.

The drill rig has a twenty foot continuous auger with a diameter of ten inches (Figure 4, A-E). Length was added to the drill flight with the addition of 5 and 10 foot augers. The bore hole pattern was based on information gathered with the Giddings Probe and the assumptions made about the data gathered in 1980. Drilling was done in parallel rows starting from the south end of the site going north (Figure 3). One more row, consisting of 4 holes, was orientated from east to west. A total of 89 bore holes were drilled. Holes were drilled until the bottom of the deposit was reached. All holes were filled immediately after completion.

SAMPLING

One sample was gathered from each bore hole (Figure 3). The sampling procedure consisted of hand-scraping material from the auger flight and placing it on a rubber mat (Figure 4). Approximately thirty pounds of sample was obtained. Thirty pounds represents the minimum sample size that properly represents material taken from the ground. If the material scraped from the auger greatly exceeded 30 pounds, then a modified AASHTO (American Association of State Highway and Transportation Officials) method of "quarter and split" sample reduction was used. All samples, including the larger volume samples, were mixed with the shovel to ensure

A. MNDOT drill rig with 20 foot continuous auger.
B. The auger has a 10 inch diameter.
C. Sampling from the auger and placing material on rubber mat.
D. Mixing sample with shovel.
E. Adding auger flights to drill.
F. The Giddings Probe: a truck mounted soil auguring machine. Used for exploration drilling to define the limits of the gravel deposit.
G. A field test to determine the amount of sand and gravel. Describing the piles of material from left to right: (1) sand, (2) fine gravel, and (3) coarse gravel.
H. Geologist and drill operator using the Giddings Probe.

randomization. The quarter and split method of sample reduction required splitting a cone pile into four smaller and equal sized piles. Then, two quarters from non-adjacent piles were combined into a sample. The bore hole samples were placed in a canvass bag with identification tags on both the inside and outside of the bag; then transported to the MNDOT Research Laboratory in Maplewood, MN.

GEOLOGIC OBSERVATIONS

Geologic observations provided crucial information to all aspects of the aggregate evaluation. By observing the different types of sediments in context to the geology, the sediments of the study area can be put into a larger geologic frame work. Noting the geology of a site can provide insight when interpreting subtle patterns, changes, and anomalies within a deposit. The geology also acts as a "control" when analyzing both the statistical and analytical models of the deposit and ensuring models accurately represent the natural deposit. Geologic observations included overburden thickness, geologic contacts, descriptions of the different sediment types, depth of the deposit, the amount of sand, the amount of gravel, depth to water table, composition of the sand and gravel, deleterious material and depositional patterns of the sediment (Appendix A&B).

Within the geologic log of the Blue Mounds drilling project, gravel is defined as a sediment size that is retained on a 2 millimeters (mm) sieve. Two millimeters is roughly the size of a match head and is a standard grain size minimum threshold throughout the gravel industry. To obtain rough estimates of gravel on some of the bore holes, a 2mm sieve was used (Figure 4G). Field observations of grain size were based on the Wentworth grain size scale (Appendix C).

SURVEYING

Two surveying projects were completed: one using GPS and another with a survey crew. The DNR Lands and Minerals surveyed the bore hole locations using a Trimble ProXR® Global Positioning System (GPS). GPS used satellite radio transmittance to provide a location in three dimensions (X, Y, and Z). Since the Z coordinate (the elevation) was not accurate enough for the study, a survey crew from the DNR- Bureau of Engineering was commissioned. The Bureau of Engineering surveyed 239 points within the study area. Surveyed data was used to contour the elevation of the study area with a 5 foot interval. Smaller contour intervals aided the computer modeling of the gravel body in TechBase. The Bureau of Engineering used two control points: a 7252 Department Survey Marker at the northeastern corner of Section 25 and a located point from a previous survey. An accuracy elevation check using the Bench Mark 6707 AL located along the County Road 8 was measured within 5 hundredth of a foot.

LABORATORY ANALYSIS

The samples were taken to the MNDOT Research Facilities for analysis. Several different laboratory tests were performed on the samples to determine the quality of the sand and gravel. Each sample from each bore hole was sieved for both fine and coarse gradations (Appendix D). Samples were then composited to get a representative result of the various gravel areas and to reduce the cost of analysis. The samples were then divided into six groups and tests were performed on the six composited samples (Table 1).

Composited samples were tested for certain rock lithologies and the presence of shale. These tests identified the amount of deleterious rock, or substandard rock, for the use of concrete and bituminous mixtures. Other tests included a magnesium sulfate test and the Los Angeles Rattler (LAR) which measures the susceptibility of breakdown due to freeze-thaw cycles and durability during handling respectively.

COMPUTER ANALYSIS

The data from geologic logs and laboratory analyses were entered into a database. The data was then processed in TechBase which calculated the volume in cubic yardage of each area. The method used by TechBase extrapolated data and projected an estimated depth of gravel into a "cell." The cell represented an area of 100 ft by 100 ft. The projection was based on information gathered from two or more of the closest bore holes which estimates a value into the cell.

The volume is a integrated function of the area times the depth. Depth information was gathered by MNDOT drilling. The calculated area of the sand and gravel deposit was modeled by the availability of data and Rock County ordinances as of April of 1999 (Appendix E). Due to standing water in the farm field, a portion of the study area was inaccessible to drill. The non-drilled area represents a data gap in which the volume can not be accurately modeled. Therefore, the volume calculations do not include the potential gravel within this area. The second parameter was determining the edge, or perimeter, to be modeled and was based on county ordinances. A summary of Rock county gravel mining ordinances state:

-Mining can occur 10 feet away from right away (Subdivision 4-6-h).
-Mining can occur 30 feet away from the state park property (Subdivision 4-6-h).
-Mining must be 500 feet away from a residential structure unless there is written permission by the owner (Subdivision 4-5-g).

The ordinances above are the only mining restrictions that could affect the volume estimate at the DeJongh parcel. However, the model included two of the three mentioned ordinances. Since the 500 foot radius from a residential structure took out the some of deepest portions of the deposit, we modeled the volume under the assumption that written permission could be obtained (Figure 5). The right away for the left side of County Road 8 along the study area is 50 feet from the center line. This information was obtained by personal communication with Mark Sher from the County Engineer's Office. The final calculation of volume used a straight line boundary that was drawn 30 feet from the state owned property and 60 feet from the center line of County Road 8.

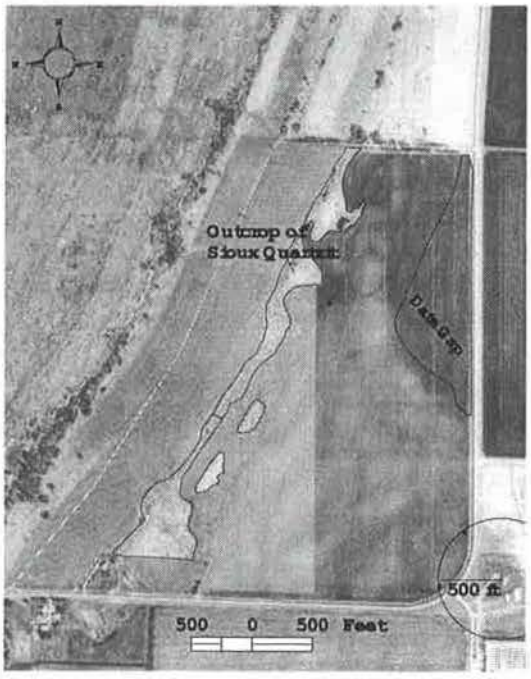


Figure 5. Map showing the area of the data gap, the 500 ft radius from a residential structure, and bore holes.

RESULTS

GEOLOGIC OBSERVATIONS

Drilling confirmed that the deepest section of the deposit is in the southeast corner where the maximum depth is approximately 50 feet. In this area, the average size of the gravel is pea to small pebbles in a medium sand matrix. There are some thick lenses of well-sorted, fine to medium-grained sand lenses. However, the lenses were difficult to document due to low sample retention off the auger. The average thickness of the deposit across the study area is approximately 13 feet. The trend of the deposit shallows to the north and to the west and becomes siltier to the north. Despite the high silt content, there is also a high amount of coarse gravel to the north.

MINING ACCESSABILITY

Determining the mining accessability of a deposit is a function of several factors including: road access, overburden thickness, and the water table. Being directly adjacent to County Road 8, the parcels road access is very good. The overburden thickness is essentially the thickness of the topsoil, there fore the stripping ratio is also very good. As mentioned earlier, the water table has a tendency to rise in the northeast section. In fact, the northeast section is subject to flooding; which is probably due to the water being perched above a silt layer directly below the topsoil. Inferring from the water table levels observed from drilling and nearby gravel pits, the water table would potentially become a factor after the first 5-10 feet of mining. A high water table can depreciate the value of the gravel, due to the expense of underwater mining operations.

MNDOT GRADATIONS

The results of the MNDOT gradations are listed in Table 1. Gradations measure the different amounts of certain sized sediments. The gradations are separated into composites. The composite gradations are calculated by weighted average by depth. Comparing the composited gradations to MNDOT standards for Class 5 material, the gravel deposits passes specifications except for coarse material (Figure 6). The deposit contains an excess of very coarse material (sediment with a diameter greater than 1 inch). Class 5 can be met by screening or crushing.

VOLUME ESTIMATES

The volume calculation is 2,884,500 ± 20% cubic yards. As previously stated, the volume estimate does not include sand and gravel in the data gap area, 60 feet from the center line of County Road 8, and 30 feet from state owned land (Blue Mounds State Park boundary). It does include sand and gravel within the 500 foot radius of the residential structure located near the southwest corner of the study area.

We produced three different maps to indicate the nature of the volume. The first map shows the bore hole locations, the boundary of the study area, the straight line boundary, and volume calculations (Plate I). The second map shows three cross-sections of the deposit (Plate II). The first cross-section parallels the trend of the Sioux quartzite and the direction of the paleo-current. This will show the nature of the deposit along it length. The remaining two are perpendicular to the direction of flow indicating the nature of the deposits along the width. The lines showing the lower and upper limit

Table 1
MNDOT Gradations of Composites

COMPOSITE 1

id	1 25.0mm	3/4 19.0mm	3/8 9.5mm	#4 4.75mm	#10 2.00mm	#40 425um	#200 75um	Gravel Thickness
MNDOT Max	100	100	90	80	65	35	10	
MNDOT Min	100	90	50	35	20	10	3	
BH 0-1	99	97	89	76	57	23	5.0	49.5
BH 0-2	99	98	91	78	60	25	3.4	53.5
BH 1-1	NA	94	85	75	58	23	3.5	45
BH 1-2	96	92	83	71	55	25	4.9	40
BH 2-1	97	96	90	79	63	23	4.7	41
BH 10-1	99	96	86	73	55	24	4.6	41
BH 10-2	98	95	86	74	57	22	4.7	41
BH 10-3	98	97	91	79	63	27	6.5	39
BH 10-4	97	95	87	76	59	28	4.6	42.5
AVERAGE	98	96	88	76	59	24	5	

COMPOSITE 2

id	1 25.0mm	3/4 19.0mm	3/8 9.5mm	#4 4.75mm	#10 2.00mm	#40 425um	#200 75um	Gravel Thickness
MNDOT Max	100	100	90	80	65	35	10	
MNDOT Min	100	90	50	35	20	10	3	
BH 0-3	97	96	86	73	56	24	4.7	28.5
BH 1-3	99	97	85	70	52	21	5.2	29
BH 1-4	97	95	84	72	56	21	3.9	29
BH 1-5	97	95	86	72	55	21	4.1	28
BH 2-2	NA	95	88	77	60	27	4.5	32
BH 2-3	98	96	86	72	55	20	4.1	29
BH 2-4	97	94	84	70	51	21	6.6	21
BH 3-1	94	92	82	71	55	20	3.6	25
BH 3-2	93	90	81	70	54	20	2.7	30
BH 3-3	93	89	79	67	51	20	3.4	30
BH 4-1	93	91	84	73	59	24	4.1	27
BH 4-2	96	94	85	73	57	20	3.7	23
AVERAGE	96	94	84	72	55	22	4	

COMPOSITE 3

id	1 25.0mm	3/4 19.0mm	3/8 9.5mm	#4 4.75mm	#10 2.00mm	#40 425um	#200 75um	Gravel Thickness
MNDOT Max	100	100	90	80	65	35	10	
MNDOT Min	100	90	50	35	20	10	3	
BH 2-5	94	90	80	66	47	16	6.1	8
BH 2-6	97	94	82	64	46	15	4.4	12
BH 3-4	93	90	80	65	47	15	4.3	15
BH 3-5	85	81	70	58	40	15	7.0	12
BH 3-6	94	89	75	62	47	24	9.4	12
BH 3-7	95	90	77	52	46	20	6.9	15
BH 4-3	95	92	82	67	51	16	4.5	15
BH 4-4	95	92	82	69	53	22	3.9	11.5
BH 4-5	87	84	71	58	41	15	6.0	14
BH 4-6	92	86	72	59	45	18	7.1	10
BH 4-7	92	88	76	63	48	18	4.7	9
BH 5-1	97	95	86	74	56	24	3.4	21
BH 5-2	94	90	79	65	47	17	5.1	17
BH 5-3	92	88	78	67	54	15	3.4	14
BH 5-7	93	91	83	72	53	15	3.5	17
BH 5-8	94	90	78	65	49	17	2.6	17
BH 6-1	83	78	67	56	44	17	5.1	14
BH 6-2	93	89	77	64	47	15	3.3	25.0
AVERAGE	92.7	89.0	77.9	64.1	48.2	17.4	4.8	

COMPOSITE 4

id	1 25.0mm	3/4 19.0mm	3/8 9.5mm	#4 4.75mm	#10 2.00mm	#40 425um	#200 75um	Gravel Thickness
MNDOT Max	100	100	90	80	65	35	10	
MNDOT Min	100	90	50	35	20	10	3	
BH 6-3	91	85	72	60	47	20	4.4	13
BH 7-1	90	87	77	65	50	21	5.6	14
BH 7-2	97	96	86	74	58	17	4.2	14
BH 7-3	90	87	76	66	53	23	4.0	9
BH 8-1	96	95	86	74	58	21	4.8	13
BH 8-2	97	94	84	72	31	30	6.3	16
BH 8-3	98	95	84	72	59	23	7.9	13
BH 8-4	71	65	53	42	33	15	5.6	15
BH 8-5	93	88	74	61	47	21	7.7	13.5
BH 8-6	94	91	81	69	55	26	8.1	16
BH 8-7	87	82	70	57	44	16	4.9	13
BH 9-1	89	87	76	65	51	16	3.7	16
BH 9-2	85	79	68	60	51	22	4.7	19
BH 9-3	97	94	86	76	63	30	6.6	13
BH 9-4	89	82	69	58	44	15	4.7	13
AVERAGE	91	87	76	65	49	21	6	

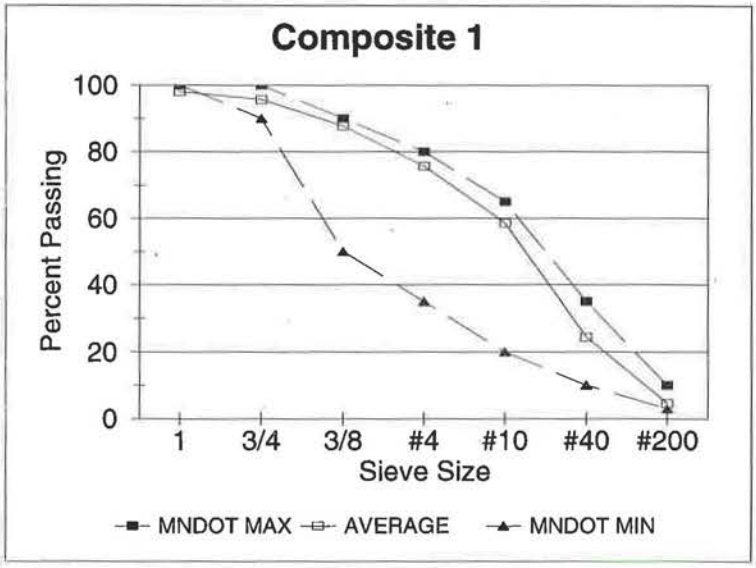
COMPOSITE 5

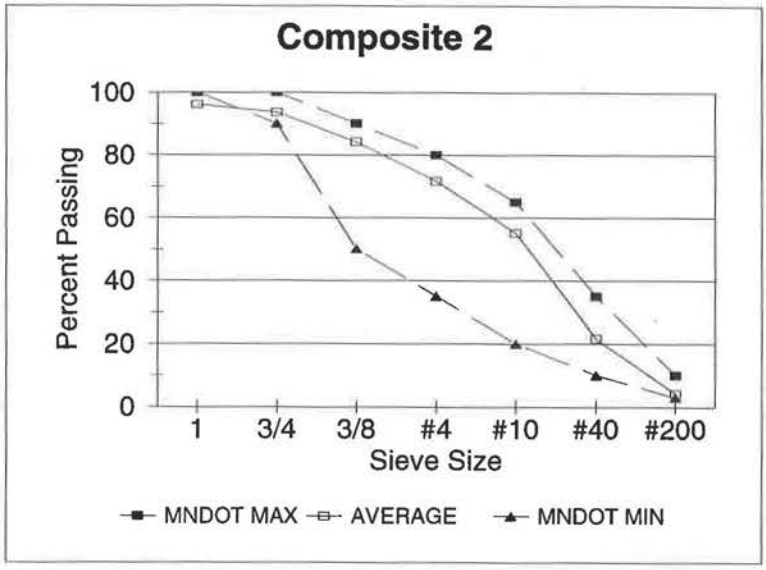
id	1 25.0mm	3/4 19.0mm	3/8 9.5mm	#4 4.75mm	#10 2.00mm	#40 425um	#200 75um	Gravel Thickness
MNDOT Max	100	100	90	80	65	35	10	
MNDOT Min	100	90	50	35	20	10	3	
BH 5-4	96	93	81	68	53	23	5.0	10
BH 5-5	85	78	63	50	36	18	9.6	9
BH 6-4	85	79	65	53	41	18	6.9	11
BH 6-5	92	87	75	61	49	20	4.0	7
BH 6-6	97	94	83	69	52	15	3.6	8.5
BH 6-7	94	91	79	63	47	17	3.9	14
BH 6-8	95	91	81	68	53	24	5.1	12.5
BH 7-4	91	85	73	61	51	37	4.3	8
BH 7-5	92	88	76	63	49	19	4	14.5
BH 7-6	99	97	89	77	58	20	2.9	18
BH 8-7	87	82	70	57	44	16	4.9	13
BH 8-8	97	92	79	65	47	16	4.5	11.5
BH 8-9	95	92	81	68	49	16	4.3	13.5
BH 8-10	96	92	81	66	51	18	4.7	14.5
BH 8-11	88	82	69	56	39	13	3.5	12.5
BH 8-12	90	84	71	58	42	12	3.7	10
BH 9-5	98	96	89	82	70	28	10.7	12
BH 9-6	97	94	86	78	60	20	4.2	10
AVERAGE	93.3	89.2	77.9	65.2	49.8	19.2	4.9	

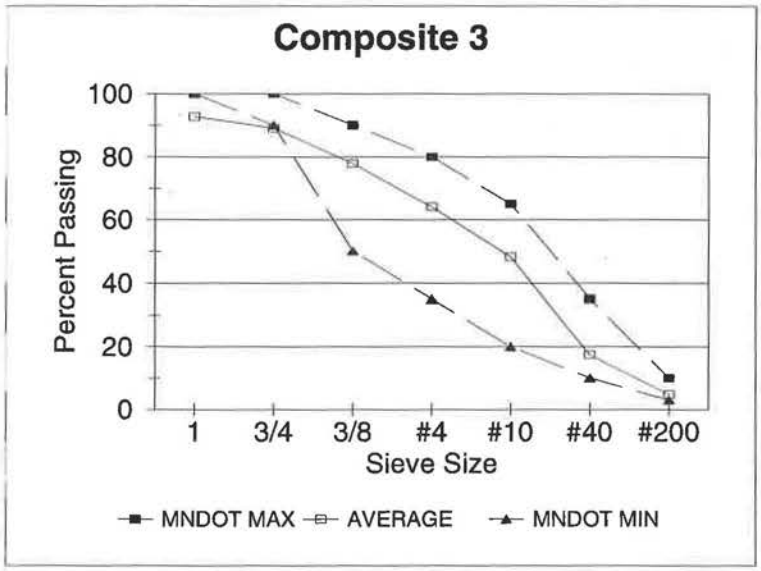
COMPOSITE 6

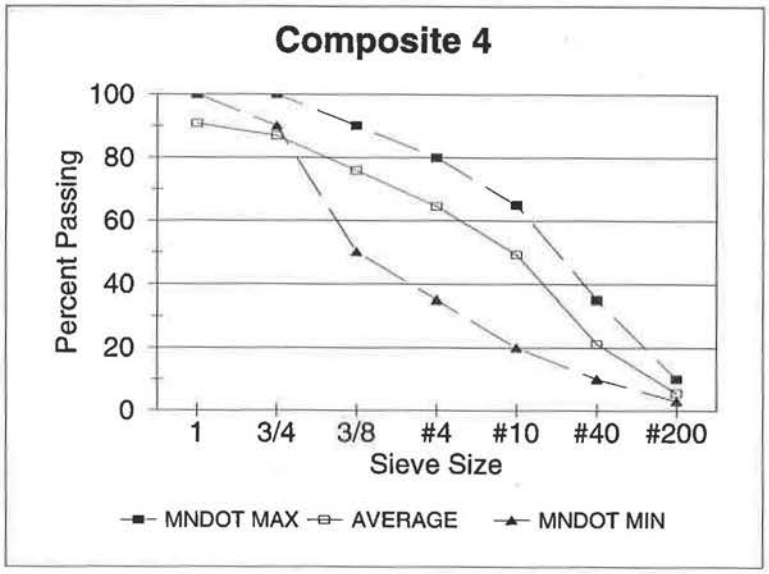
id	1 25.0mm	3/4 19.0mm	3/8 9.5mm	#4 4.75mm	#10 2.00mm	#40 425um	#200 75um	Gravel Thickness
MNDOT Max	100	100	90	80	65	35	10	
MNDOT Min	100	90	50	35	20	10	3	
BH 7-7	99	97	88	76	62	17	3	17.5
BH 7-8	87	81	66	51	38	17	9.8	17.5
BH 7-9	96	91	76	64	46	16	1	14.5
BH 7-10	73	66	50	38	28	12	5.1	15
BH 7-11	79	71	55	43	30	15	8.3	15
BH 8-13	84	81	68	56	44	17	6.1	13
BH 8-14	95	91	79	64	48	15	4.7	11
BH 8-15	97	93	81	69	55	21	5.3	10
BH 8-16	91	88	76	62	44	14	3.5	12
BH 8-17	87	82	72	60	47	15	4.1	12
BH 8-18	87	83	71	58	44	19	7.8	19
BH 9-7	97	94	84	72	54	18	6.1	16
BH 9-8	90	87	78	65	61	21	5.5	19
BH 9-9	89	86	74	61	47	21	9.3	13
BH 9-10	92	87	74	62	49	20	6.5	13
BH 9-11	92	89	80	70	59	25	8.9	8
BH 9-12	83	77	64	53	45	24	12.1	10
AVERAGE	89.2	84.8	72.6	60.0	47.0	17.8	6.2	

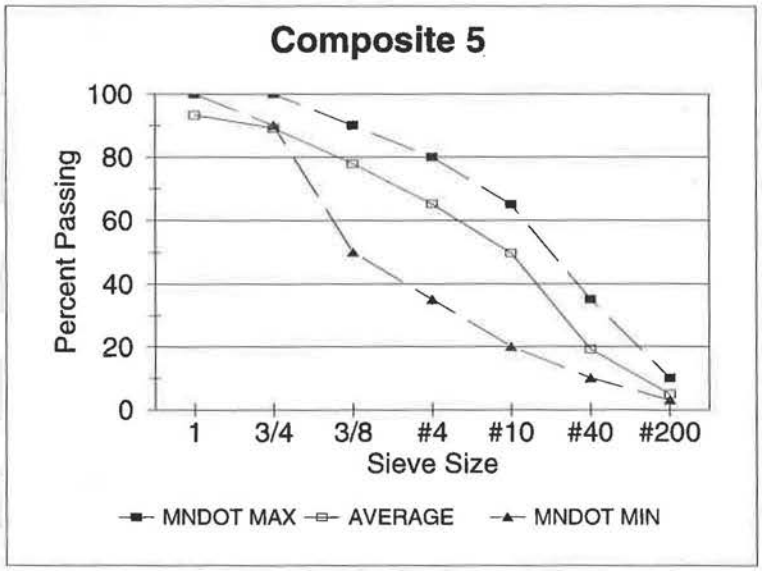
Figure 6. MNDOT Class 5 Aggregate
Composited Averages vs MNDOT Standards

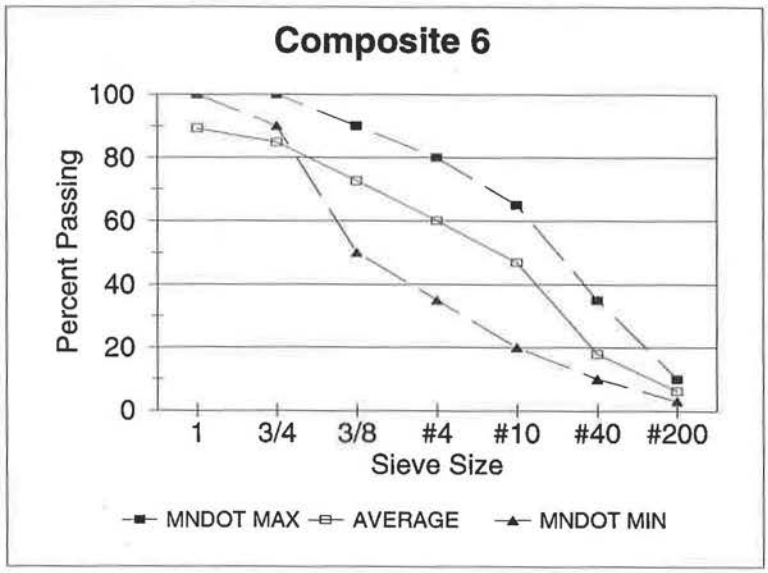












of the sand and gravel deposit may not directly correspond to some of the bore holes within the cross section. The reason for the discrepancy is because some bore holes do not lie directly on the cross section line. These bore holes are close enough to be included but have to be "warped" into the cross section. The warped bore holes may have a different contact elevation than the elevation along the cross section. The third map is a color map showing the depth of the deposit (Plate III). Shallow parts of the deposit are represented by shades of blue while the thicker sections are shaded in reds.

Quality Analysis

Tests performed at the MNDOT Research Laboratory included coarse and fine gradations, coarse and fine spall content, lithological exam, shale float test, LAR and Magnesium Sulfate. The sand and gravel is tested to determine the quality of the material. Since the coarse and fine gradations have already been discussed, this section will address the results of the remaining tests.

Test results and MNDOT specifications for concrete are summarized in Table 2. The deposit passes MNDOT specifications for the following tests: shale, thin and elongate particles, and all sizes of spall. Spall rocks are considered deleterious in concrete and bituminous mixtures. Composites 3 and 4 are borderline passing for soft rock. However, the test on the remaining composites show no soft rock particles. Mixing and blending would remedy these hot spots. One concern of the deposit is the amount of limestone. Since the percentages of limestone are above 30, this deposit could not be used in concrete mixtures for superstructures (like bridges, railing, posts, and medians). However, there is no specification for limestone content related to non-superstructure concrete mixtures.

TESTS (% by mass)	1	2	3	4	5	6	SPECS*
% Shale 1/2"+	0.00	0.00	0.10	0.00	0.10	0.00	<0.40
% Shale in Sand	N.C.	0.91	N.C	N.C	N.C	0.34	
% Shale Total (+4)	0.00	0.00	0.00	0.00	0.00	0.30	<0.70
% Soft Rock	0.0	0.00	0.30	0.20	0.00	0.00	<0.30
% Carbonate	51	33.00	49.00	24.00	40.00	41.00	30
% Other Rock	47.3	66.50	50.70	75.60	59.70	58.90	
% Thin/Elong	0.00	0.00	0.00	0.00	0.00	0.00	<.15
% Spall 1"	0.00	0.00	0.00	0.00	0.00	0.30	
% Spall 1/2"	0.40	0.20	0.40	0.30	0.20	0.00	<1.0
% Spall #4	0.8	1.00	0.50	0.50	1.00	0.50	<1.5
% Total Spall +4	0.00	0.00	0.00	0.00	0.00	0.30	<1.0
% Spall and Soft Rock	0.00	0.00	0.30	0.20	0.00	0.30	<2.5
Blk SpG +4	2.602	2.603	2.609	2.623	2.621	2.597	
App. SpG +4	2.736	2.746	2.732	2.751	2.747	2.744	
% Absorbt +4	1.88	2.000	1.720	1.770	1.760	2.060	1.7
% Absorbt -4	1.33	1.500	1.460	1.300	1.430	1.000	1.7
Bulk SpG -4	2.583	2.597	2.542	2.571	2.555	2.572	
App. SpG -4	2.675	2.677	2.640	2.660	2.652	2.640	
Total Bulk SpG			2.609	2.623	2.621		
LAR B-Pct Loss						34.43	<40
Mag% Loss 1 1/2-1						6.480	<15
Mag% Loss 1-3/4						9.430	<15

Table 2: MNDOT specifications for concrete. Measurements are in percent by mass. Numbers 1-6 are the six composites.

Other tests performed on the sand and gravel are specific gravity, absorption, LAR, and Magnesium Sulfate. The specific gravity (SpG) is used for the design of bituminous and concrete mixes. It is one factor in many that helps develop various mix designs. Specific gravity is defined as the ratio of the weight of a unit volume of material to the equal weight of an equal volume of water. Absorption (Absorbt) measures the amount of water absorbed in the

small cracks and capillaries of a pebble. The more water a pebble can absorb, the more likely it could crack by freeze thaw cycles and break down during handling. Water absorption in the coarse fraction of the deposit is measured between 1.72 to 2.06. This exceeds the MNDOT absorption specification of 1.7. The high absorption is due to the high amounts of limestone particles in the deposit. Limestone is a porous rock that can dissolve in water. However, the deposit passes both test (Los Angeles Rattler) and Magnesium Sulfate test which are designed to test the durability when handling and freeze thaw cycles, respectively.

CONCLUSION

The three primary functions of this geology survey are to determine the quantity of gravel, the quality of the gravel, and the mining accessability of the deposit. Mining accessability includes determining the overburden thickness, access to roads, and the depth of the water table. The aggregate survey includes examining air photos and published maps, geologic logging, sampling, computer analysis and laboratory analysis. Reviewed below are the results and conclusions of this study:

- The study area is located in section 25, T103, R45W.
- Currently the study area is zoned A1 for agricultural use.
- The sand and gravel was deposited by a glacial meltwater channel.
- A total of 89 drill holes were completed and a sample was taken from each drill hole.
- Except for the western ledge of the study area, the parcel consists almost entirely of sand and gravel, with a thickness ranging from 8 to 53.5 feet.
- The average thickness of the deposit is 13 feet.
- The deposit is moderately to well-sorted and consists primarily of pea sized gravel in a fine to medium-grained sand matrix. The gravel particles are rounded with the dominant lithology being limestone. Most of the deposit is relatively clean with little silt and no clay balls. However, there are seams of silt-rich gravel that were encountered. Larger quantities of silt-rich sand and gravel are found to the north.
- The estimated volume of the sand and gravel within the calculated boundary is 2,884,500 ± 20% cubic yards. The estimated boundary does not include material that is:
  - -In approximately 17 acres of the study area that was inaccessible to drill. This area is considered a data gap.
  - -60 feet from the centerline of Rock County Road 8.
  - -30 feet from the Blue Mounds State Park property line.
- Gradations of the composites meet MNDOT specifications for Class 5 material with some amounts of very coarse aggregate (rocks with the diameter greater than 1 inch). Coarse material can be screened.
- The deposit passes the MNDOT specifications for shale, thin and elongate rocks, and all sizes of spall. The southwestern section of the study area is borderline passing for the MNDOT specification for soft rock.
- The deposit passes both tests to determine durability during handling and freeze thaw cycles (LAR and Magnesium Sulfate).
- The amount of limestone does not pass MNDOT specifications for superstructure concrete.
- The deposit does not pass the MNDOT specification for water absorption.

- The quality of the deposit is fair to good. The deposit passes specifications all deleterious rocks and gradations for Class 5 material. However, the amount of limestone particles in the deposit is very high and the amount of water absorbed does not pass MNDOT specifications.
- The mining accessibility is also fair to good. There is negligible overburden (thickness of the topsoil) and access to roads; however the water table varies from 2-10 feet. This would increase the cost of production which decreases profitability. And there are residential structures near the thickest portions of the deposit.
- This study was completed with a >80% certainty (margin of error ± 20%). Although drilling gives a fairly accurate representation of the deposit, unencountered variations within the deposit may exist. Also, to drill deeper sections of the deposit required the addition of more augers to the flight of the MNDOT drill rig. The handling of augers reduces sample retention and stratigraphic integrity which introduces error.

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APPENDICES

Appendix A
Geologic Descriptions of Bore Holes

Drill Hole Row-Hole	To (ft)	From (ft)	Sediment Size	Color	%G	Sort	Rdnss	Litho	Comment
BH 0-1	0	3	Topsoil	blk					Grades from topsoil to silt, wt at 6.5 ft
	3	6.5	Silt	blk					Massive, no grvl
	6.5	7.5	Silty S&G						Poorly sorted
	7.5	15	Sand & Pea Gravel	tan	(30-60)	MW			Mostly pea grvl in med sand
	15	17.5	Fine Sand	brn		W			
	17.5	20.5	S&G						Mostly cobble w/ some pea
	20.5	34	Sand & Pea Gravel						
	34	36	Silt	brn					Some sand
	36	38	Fine Sand			MW			Fine to medium grained
	38	45	Sand & Pea Gravel		(40-60)			Lmst, sh	Slighlty silty to clean, mostly pea gravel
	45	49	Silt	gry		W			Massive
	49	56	Sand & Pea Gravel			WM			Clean, falling off auger, mostly pea gravel
	56	58	Diamict	blu-gry		P			Stiff
BH 0-2	0	2.5	Topsoil	blk					Loamy, moist, grades into silt
	2.5	6	S&G			M			Dry, mostly pebble, slightly silty to clean
	6	16	Sand & Pea Gravel			M			Wet, wt @ 6, clean grvl, mostly pea, occt cobble
	16	21	Fine Sand	brn		W			Massive, no grvl
	21	46	S&G			M		Lmst, sh	Pea to pebble with occt cobble
	46	50	Diamict	blu-gry		P			Stiff, lmst rich
BH 0-3	0	3.5	Topsoil	blk					Grades from topsoil to silt,
	3.5	5	S&G			M			Dry, slightly silty to clean,
	5	9	Silty S&G	brn		P			Pea to cobble, very silty
	9	13	Sand & Pea Gravel						Clean, some pebbles, few cobbles, med-fine matrix
	13	21	Fine Sand	tan		W			Under-represented in sample, falling off auger
	21	32	Sand & Pea Gravel						Fine to medium sand with pea and pebble gravel
	32	36	Diamict	blu-gry		P			End of drilling
BH 1-1	0	2	Topsoil	blk-brn					Grades from topsoil to silt
	2	11	S&G	gry	(50-60)	M			Medium sand, some silt, pea-cobble gravel, wt@7ft
	11	13	Silty S&G	tan		P			Very silt rich
	14	16	Fine Sand	gry		MW			Occt. pebbles
	16	18	S&G			M			Cobble rich in med-coarse sand matrix
	18	20	Fine Sand			M			Some pea gravel
	21	47	S&G			M			Pea to pebble, poor recovery, silt zones
	48	50	Diamict	blu-gry		P			End of drilling
BH 1-2	0	3	Topsoil	blk					Grades from topsoil to silt
	3	11	Silty S&G			P			Mostly cobble w/ some pea, wt @ 6
	11	14	S&G	tan					Mostly pea and pebble grvl
	14	15	Fine Sand	tan		W			
	15	21	S&G		(40-70)	M		Lmst, cht	Pea-pebble, fine to medium sand matrix
	21	26	Fine Sand	brn		W			Occt. pebbles
	26	43	Sand & Pea Gravel						Occt cobbles, some sand layers, poor recovery
	43	45	Diamict	blu-gry		P			End of drilling
BH 1-3	0	3	Topsoil	blk					Grades from topsoil to silt
	3	6	Silty S&G		40	M			Mostly pea and pebble grvl w/ small cobbles

			&G						Pea-pebble, fine to medium sand matrix, wt @ 6 ft
	15	32	Sand & Pea Gravel						Limestone rich
	32	36	Diamict						End of drilling
BH 1-4	0	3	Topsoil	blk					Grades from topsoil to silt
	3	6	S&G						Very sandy
	6	13	Silty S&G	brn		P			Cobble rich, rust stains, wt @ 9 ft
	13	32	S&G	gry					Mostly pea and pebble grvl w/ small cobbles
	32	36	Diamict	blu-gry					End of drilling
BH 1-5	0	3	Topsoil						Grades from topsoil to silt
	3	8	Silty S&G		(45-55)	MP			Pea-sm. cobbles, wt @ 6 ft
	8	12	S&G	gry					Rust stains, mostly pea-pebble
	12	15	Medium Sand	gry		W			Unoxidized
	15	27	S&G			M		Lmst	Pea-sm. cobbles, little silt,
	27	29	Fine Sand	wht		W			
	29	31	S&G						Very poor recovery
	31	36	Diamict	blu-gry		P			End of drilling
BH 2-1	0	4	Topsoil	blk					Grades from topsoil to silt w/ some pebbles
	4	9	Silty S&G			P			Cleaner w\ depth, mostly pebble w\ occt cobble
	9	12	S&G			M			Pea-sm. cobbles, little silt, some cobbles
	12	15	Fine Sand	lt gry		W			Some pea gravel
	15	23	S&G			MW			Mostly coarse sand w/ fine gravel
	23	26	Fine Sand	brn		W			
	26	31	S&G			MW			Mostly coarse sand w/ fine gravel
	31	34	Fine Sand			W			
	34	39	S&G						Mostly coarse sand w/ fine gravel
	39	41	NA						No recovery
	41	42	Silt	brn		W			
	42	45	NA						No recovery
	45	46	Diamict	blu-gry					End of drilling
BH 2-2	0	2	Topsoil	blk					Grades from topsoil to silt
	2	5	Silty S&G			P			Fine to medium sand with pea and pebble gravel
	5	11	S&G			MW	R		Pea grvl in coarse sand
	11	14	Fine Sand	gry		MW			Occational pea to pebble
	14	18	Sand & Pea Gravel			MW	R	Lmst	Some pea gravel and cobbles
	18	20	Fine Sand			W			
	20	28	S&G			M			Pea grvl in coarse sand, some cobbles
	28	32	Fine Sand	brn-gry		W			
	32	34	Sand & Pea Gravel			W			Mostly pea grvl
	34	36	Diamict	blu-gry					End of drilling
BH 2-3	0	2	Topsoil						
	2	5	S&G			PM			Medium sand with pea-sm. boulders size grvl
	5	31	Sand & Pea Gravel	lt gry		M	WR		Mostly pea grvl, some cobbles, some silt lenses, WT @ 8 ft
	31	32	Diamict	blu-gry					End of drilling
BH 2-4	0	3	Topsoil	blk					Grades from topsoil to silt
	3	5	Silt	brn		W			Mottled silt layer
	5	8	Silty S&G			P			Silt/fine matrix sand w/ pea to cobble grvl, WT @ 7 ft
	8	14	Sand & Pea Gravel		(40-60)	W		Lmst	Fine to medium sand with pea and pebble gravel

			Fine S	n			rust stained, some pebbles
	18	24	Sand & Pea Gravel		M		Organic layer at 18 ft,
	24	26	Diamict	blu-gry	P		End of drilling
BH 2-5	0	4	Topsoil	blk			Grades from topsoil to silt
	4	12	S&G	tan	M		Some silt, rust layer at 10ft, mostly pea, WT @ 7
	12	15	Diamict	blu-gry	P		End of drilling
BH 2-6	0	3	Topsoil	blk			Grades from topsoil to silt
	3	9	Silty S&G		P		Pea to cobble, very silty, cleaner with depth, WT @ 6
	9	13	S&G		W	Mafics	Coarse sand with fine grvl
	13	15	Fine Sand	brn			Some rust, thin lense of silty grvl
	15	18	Diamict	blu-gry	P		End of drilling
BH 3-1	0	3	Topsoil	blk			Grades from topsoil to silt
	3	12	S&G	tan			Coarse sand w/ pea-cobble, grades to mostly pea, WT @ 6.5 ft
	12	15	Fine Sand		W		Massive, no grvl
	15	27	Sand & Pea Gravel	gry	MW		Some sand layers, organics, fine to coarse matrix
	27	28	NA				No recovery
	27	30	Diamict	blu-gry	P		End of drilling
BH 3-2	0	3	Topsoil	blk			Grades from topsoil to silt
	3	10	S&G	tan	M		Slightly silty near surface, pea to cobble, WT @ 5
	10	11	Silty S&G		P		High silt content
	11	14	Fine Sand		MW		Some pebbles
	14	27	Sand & Pea Gravel	gry	M		Many sand layers, mostly pea gravel, some silt
	27	33	Medium Sand	gry	M		Occational pebbles
	33	36	Diamict	blu-gry	P		End of drilling
BH 3-3	0	2	Topsoil	blk			Grades from topsoil to silt
	2	23	Sand & Pea Gravel	tan-gry	M		Mostly pea grvl, some cobbles, some silt lenses, WT @ 7 ft
	23	25	Fine Sand	gry	W		Massive, no grvl
	25	32	Sand & Pea Gravel	gry	MW		Some rust, thin lense of sand, occational cobbles
	32	34	Diamict	blu-gry	P		End of drilling
BH 3-4	0	3	Topsoil	blk			Grades from topsoil to silt
	3	10	S&G	tan-gry	M		Pea to cobble, silty, cleaner with depth, WT @ 8
	10	13	Medium Sand	gry	W		
	13	18	Sand & Pea Gravel	gry	M	Mafics	Mostly pea grvl in coarse sand
	18	21	Diamict	blu-gry	P		End of drilling
BH 3-5	0	4	Topsoil	blk			Grades from topsoil to silt
	4	10	Silty S&G	tan			Grades into less silt w/ depth, pea to sm boulder, WT @ 7 ft
	10	13	S&G	gry	M		Mostly pea grvl w/ cobbles in med sand
	13	16	Silty S&G	brn	P		Cobble rich, rust stains,
	16	20	Diamict	blu-gry	P		End of drilling
BH 3-6	0	3	Topsoil	blk			Grades from topsoil to silt to loamy sand
	3	7	Silty S&G	tan	P		Cobble rich, rust stains, fine sand matrix
	7	8	Sand & Pea Gravel	gry	M	Lmst	Less silt
	8	15	Silty S&G	tan	P		Difficult drilling, large silt content,
	15	17	Diamict	blu-gry	P		End of drilling
BH 3-7	0	3	Topsoil	blk			Grades from topsoil to silt
	3	5	Silty S&G	tan	P		Silt/fine matrix pea to occational cobbles, WT @ 3
	5	17	S&G	gry	M	Lmst	Pea to pebble, some cobbles, some silt

		1	t	br		V.			Loamy texture, old soil?
	18	19	Diamict	blu-gry		P			End of drilling
BH 4-1	0	2	Topsoil	blk					Grades from topsoil to silt
	2	10	S&G	tan	50	M	WR	Lmst	Fine to medium sand with pea and pebble gravel
	10	13	Silty S&G		30	P			Pea to sm boulder,
	13	16	Fine Sand			W			No pebbles
	16	20	Sand & Pea Gravel			M			Fingers of fine and coarse sand matrix
	20	29	S&G	gry		M			Scattered cobbles, sand layers,
	29	31	Diamict	blu-gry		P			End of drilling
BH 4-2	0	2	Topsoil	blk					Grades from topsoil to silt
	2	6	Silty S&G	tan		P			Cobble rich in silty sand matrix, WT @ 6
	6	22	Sand & Pea Gravel	gry		M			Sand layers, mostly pea grvl, washed
	22	25	Fine Sand			W			Some silt layers
	25	26	Silt	blu-gry					End of drilling
BH 4-3	0	3	Topsoil	blk					Grades from topsoil to silt
	3	5	Silty S&G	brn		P			Silty sand matrix w/ pea-cobble grvl
	5	11	S&G	tan	(40-60)	M			Pea to cobble, cleanier w/ depth, WT @ 7
	11	18	Sand & Pea Gravel	gry		MW			Scattered cobbles, sand layers
	18	20	Silt	blu-gry					Grades into a silty diamict, end of drilling
BH 4-4	0	1.5	Topsoil	blk					Grades from topsoil to silt
	1.5	10	S&G	tan		MW			Pea to cobble, matrix coarser with depth, WT @ 7
	10	12	Sand & Pea Gravel	gry		MW			Clean, some pebbles, cobble layers, med-fine matrix
	12	13	Silt	tan					Grades into a silty diamict
	13	17	Diamict	blu-gry		P			End of drilling
BH 4-5	0	2	Topsoil	blk					Grades from topsoil to a brown silt
	2	6	Silty S&G	tan		P			Cobble rich in silty sand matrix
	6	9	S&G			M			Scattered cobbles, less silt, abundant coarse grvl
	9	13	Sand & Pea Gravel			M			Lenses of pea grvl, WT @ 9
	13	16	Silty S&G	tan		P			Pea to cobble in silt matrix
	16	18	Diamict	blu-gry		P			End of drilling
BH 4-6	0	3	Topsoil	blk					Grades from topsoil to a brown silt
	3	7	Silty S&G	tan		P			Pea to cobble in silt matrix, WT @ 5
	7	10	S&G	tan		W			Clean, some pebbles, cobble layers, med-fine matrix
	10	13	Sand & Pea Gravel		50	M			Gets siltier near diamict contact
	13	15	Diamict	blu-gry		P			End of drilling
BH 4-7	0	3	Topsoil	blk					Grades from topsoil to a brown silt
	3	6	Silty S&G	tan		P			Silty sand matrix w/ pea-cobble grvl, WT @ 6
	6	12	Sand & Pea Gravel	tan-gry	40	MW			Clean, some pebbles, med-fine matrix
	12	15	Diamict	blu-gry		P			End of drilling
BH 5-1	0	1	Topsoil	blk					
	1	10	S&G	tan					Grading from cobble rich to pea grvl, WT @ 8
	10	22	Sand & Pea Gravel	tan-gry		M			Some silt and fine sand layers, occt cobble
	22	23	Silt	gry					End of drilling
BH 5-2	0	3	Topsoil	blk					Grades from topsoil to a brown silt
	3	5	Silty S&G	tan		P			Cobble rich in silty sand matrix, silt balls
	5	10	S&G			P	R		Pea grvl w/ abundant cobbles in med sand, WT@ 7
	10	12	Sand & Pea Gravel			W		Lmst	Fine gravel in coarse sand

		1	kG						
	16	17	Fine Sand			W			
	17	20	S&G		(30-50)				Cobble rich with some pea grvl, clean
BH 5-3	0	2	Topsoil						
	2	5	S&G		(40-60)	M			Cobble rich with some pea grvl, clean
	5	7	Fine Sand			W			Massive, no grvl
	7	15	Sand & Pea Gravel			M	R		Washed, thin silt and cobble layers, coarse snad matrix
	15	16	Silt	gry		W			Massive, no grvl- reworked till?
	16	21	Diamict	blu-gry		P			End of drilling
BH 5-4	0	3	Topsoil	blk					Grades from topsoil to a brown silt
	3	5	Silty S&G			P			Silty sand matrix w/ pea-cobble grvl,
	5	7	Fine Sand			W			Massive
	7	11	S&G		(40-60)			Sh, lmst	Pea to cobble in sand matrix, WT @ 5
	11	13	Silty S&G						Very silt rich, gravel clumps
	13	16	Diamict	brn-gry		P			Oxidized, end of drilling
BH 5-5	0	3	Topsoil	blk					Grades from topsoil to a brown silt
	3	5	Silty S&G			P			Silty sand matrix w/ pea-cobble grvl
	5	10	S&G			PM			Cobble rich with some pea grvl, some silt
	10	12	Silty S&G	brn		P			Gravel in silt matrix, large cobbles
	12	14	Silt	gry					Hard, grades into diamict
BH 5-6	0	2	Topsoil	blk					Grades from topsoil to a brown silt
	2	3	Silty S&G	brn		P			Fine gravel
	4	9	S&G		(40-50)	M			Mostly pea grvl w/ cobbles in med sand
	9	10	Silty S&G			P			High silt content
	10	14	Fine Sand	brn		W			Massive, v. few pebbles
	14	16	Diamict	blu-gry		P			End of drilling
BH 5-7	0	2	Topsoil	blk					Grades from topsoil to a brown silt
	2	3	Silty S&G	brn		P			Cobble rich in silty sand matrix
	3	6	Sand & Pea Gravel			M			Washed, occt pebbles, WT @ 4
	6	10	Silty S&G			MP			Cobble and pea grvl in silty sand matrix
	10	15	Sand & Pea Gravel			M			Mostly pea to pebble, some cobbles, some silt
	15	19	S&G			M	R		Coarse sand matrix w/ scattered lrg cobbles
	19	21	Silt	blu-gry					End of drilling
BH 5-8	0	2	Topsoil	blk					Grades from topsoil to a brown silt
	2	3	Silty S&G			P			Cobble rich in silty sand matrix
	3	5	Sand & Pea Gravel						Mostly pea to pebble, some cobbles, some silt, WT @ 3ft
	5	10	S&G			50 M			Sand layers, mostly pea grvl, washed
	10	19	Sand & Pea Gravel	gry		W			Losing sample, mostly pea, scattered boulders, clean
	19	20	Diamict	blu-gry		P			Boulder lag at contact, end of drilling
BH 6-1	0	4	Topsoil	blk					Grades from topsoil to a brown silt
	4	10	S&G			40 M	R		Very coarse sand and gravel, cobble rich, WT @ 7
	10	18	Sand & Pea Gravel			40 M			Coarse sand w/ pea grvl, sand layers, few boulders
	18	20	Silt	blk					Old soil horizon, end of drilling
BH 6-2	0	2	Topsoil	blk					
	2	5	S&G			MP			Cobble rich w/ pea grvl, some silt, some clay balls
	6	9	Sand & Pea Gravel	brn-gry		M			More pebbles, less cobbles, lenses of pea grv, WT @ 9
	9	27	S&G	gry		M		Lmst	Sand and silty gravel lenses, finer gravel w/ depth

			Diamict	blu-gry			End of drilling
BH 6-3	0	1	Topsoil	blk			
	1	3.5	Silty S&G	brn	P		Cobble rich w/ clay balls, high silt content
	3.5	14	S&G	gry	M		Scattered cobbles, less silt, grading to finer grvl, WT @ 9.5
	14	17	Diamict	blu-gry			Grades from oxidized brn to blu-gry, end of drilling
BH 6-4	0	3	Topsoil	blk			Grades from topsoil to a brown silt
	3	5	Silty S&G	brn	P		Cobble rich w/ clay balls, high silt content
	5	11	Sand & Pea Gravel	brn-gry	M		Less cobbles and silt with depth,
	11	14	Silty S&G				Mostly pea to pebble, high silt content,
	14	17	Diamict	blu-gry	P		Grades from oxidized brn to blu-gry, end of drilling
BH 6-5	0	3	Topsoil	blk			Grades from topsoil to a brown silt
	3	5	S&G			R	Coarse sand w/ cobbles, some silt
	5	8	Fine Sand		W		Some lenses of coarse and med sand, no grvl
	8	10	S&G				Cobble rich, clean, in fine-med sand
	10	13	Diamict	blu-gry	P		Grades from loam to diamict
BH 6-6	0	3.5	Topsoil	blk			Grades from topsoil to a brown silt
	3.5	10	S&G		M		Pea to cobble in sand matrix, grvl fines w/ dpth, WT @ 6
	10	12	Sand & Pea Gravel	gry	MW		Mostly pea to pebble in coarse sand, few cobbles
	12	15	Diamict	blu-gry			End of drilling
BH 6-7	0	3	Topsoil	blk			Grades from topsoil to a brown silt
	3	6	Silty S&G				Cobble rich, high silt content, WT @ 5.5
	6	17	Sand & Pea Gravel		M		Mostly pea to pebble some scattered cobbles
	17	19	Diamict	blu-gry	P		Grades from silt to diamict, end of drilling
BH 6-8	0	3.5	Topsoil	blk			Grades from topsoil to a brown silt
	3.5	5	Silty S&G	brn			Pea to cobble in sand/silt matrix,WT @ 3.5
	5	13	Sand & Pea Gravel		M		Less silt, mosity pea, occt cobble
	13	16	Silty S&G		P		Gets siltier w/ depth, mostly pea size grvl
	16	18	Diamict	blu-gry	P		End of drilling
BH 7-1	0	1	Topsoil	blk			
	2	3	Fine Sand	brn	W		
	3	16	S&G		M		Some rust, mostly pea to pebble, WT @ 6
	16	18	Silt	blk			Organic, old soil, end of drilling
BH 7-2	0	3	Topsoil	blk			Grades from topsoil to a brown silt
	3	9	S&G	brn	W	R	Cobble rich, silt layer, WT @ 9
	9	11	Sand & Pea Gravel		W		Mostly pea to pebble some scattered cobbles
	11	12	Silty S&G		P		High silt content, cobble layer at lower contact
	12	14	Sand & Pea Gravel				Mostly pea to pebble some scattered cobbles
	14	17	NA				No recovery
	17	20	Diamict	blu-gry	P		End of drilling
BH 7-3	0	3	Topsoil	blk			Grades from topsoil to a brown, mottled silt
	3	10	Sand & Pea Gravel	tan			Cobble layer at upper contact, sand lenses, little silt,
	10	12	Fine Sand	brn	W		Occational pebbles
	12	15	Silt	blu-gry			Upper layers oxidixed
BH 7-4	0	2	Topsoil	blk			
	2	5	Silt	brn	W		
	5	8	S&G				Cobble rich, clean, dry
	8	10	Silty S&G	brn			Grvl in silt matrix, did not sample

			llam		t	y			nd of
BH 7-5	0	2.5	Topsoil	blk					Grades from topsoil to a brown silt
	2.5	17	S&G			M			Cobble rich, mostly pea-pebble, clean, WT @ 11
	17	18	Diamict	blu-gry		P			End of drilling
BH 7-6	0	2	Topsoil	blk					Grades from topsoil to a brown silt
	2	20	Sand & Pea Gravel			M-MW		Lmst	Mostly pea to pebble some scattered cobbles, WT @ 7
	20	21	Diamict	blu-gry		P			End of drilling
BH 7-7	0	1.5	Topsoil	blk					
	1.5	17	Sand & Pea Gravel	tan-gry		M			Mostly pea to pebble some scattered cobbles, WT @ 7, silt layers
	17	19	Medium Sand	gry		W			Some rust, some pebbles
	19	21	Diamict	blu-gry		P			End of drilling
BH 7-8	0	1.5	Topsoil	blk					
	1.5	5	Silt	gry-tan		W			Massive, mottled silt, WT @ 4
	5	10	Silty S&G	yel-gry		P			Pea to pebble, some cobbles, high silt content, no sample
	10	16	S&G			M			Cobble rich, mostly pea-pebble, possible contamination from above
	16	19	Sand & Pea Gravel			MW			Little sand matrix, a couple of fine sand lenses, mostly pea gravel
	19	21	Diamict	blu-gry		P			End of drilling
BH 7-9	0	3.5	Topsoil	blk					Grades from topsoil to a brown silt, WT @ 3.5
	3.5	18	S&G						Cobble rich, mostly pea-pebble, grades for some silt to little silt
	18	20	Diamict	blu-gry		P			End of drilling
BH 7-10	0	2	Topsoil	blk					
	2	5	Silt	brn					Massive, mottled silt, WT @ 3.5
	5	17	S&G	brn		M			Cobble rich, mostly pea-pebble, intermittant cobble and silt layers
	17	20	Diamict	blu-gry		P			End of drilling
BH 7-11	0	2	Topsoil	blk					Grades from topsoil to a brown silt, WT @ 2
	2	5	Silt	blk					Organics
	5	17	S&G	brn			R		Cobble rich, some pea-pebble, intermittant cobble and silt layers
	17	20	Diamict	blu-gry		P			End of drilling
BH 8-1	0	3	Topsoil	blk					Grades from topsoil to a brown silt,
	3	8	S&G			M			Pea to pebble, medium grained matrix, WT @ 8
	8	9	Sand & Pea Gravel			W			Mostly pea in coarse sand matrix
	9	16	S&G			M			Pea to pebble, medium grained matrix, some cobbles
	16	20	Diamict	blu-gry		P			End of drilling
BH 8-2	0	1	Topsoil	blk					
	1	5	Fine Sand	brn-tan		W			Cobble layer at 2 ft
	5	14	S&G		60	M	WR		Cobble rich, some pea-pebble, WT @ 9.5
	14	17	Sand & Pea Gravel	gry	50	MW			Fine gravel in fine-coarse sand, some silt
	17	20	Diamict	blu-gry		P			Organics, woody fragments, grades to blue diamict
BH 8-3	0	3	Topsoil	blk					Grades from topsoil to a brown silt
	3	10	S&G	brn-gry	(40-60)	M			Cobble rich, some pea-pebble, WT @ 9
	10	16	Sand & Pea Gravel	gry					Pea to pebble, medium grained matrix, some silt layers
	16	17	Diamict	blu-gry		P			End of drilling
BH 8-4	0	2	Topsoil	blk					
	2	5	S&G						Cobble rich apprx 20%, some pea-pebble
	5	17	Sand & Pea Gravel	gry					Some cobbles, silt layers, mn coating, sightly silty, WT @ 10.5
	17	20	Diamict	blu-gry					End of drilling
BH 8-5	0	2.5	Topsoil	blk					

	[illegible]	[illegible]	S&G		[illegible]			obble [illegible]ome [illegible] bble, [illegible]y silty
	7	16	Silty S&G	tan	P			Silt rich, cobble layer, pea-cobble size grvl,coarse sand, WT @ 10
	16	19	Diamict	blu-gry	P			End of drilling
BH 8-6	0	1	Topsoil	blk				
	1	5	Fine Sand	gry	M			Fine silty sand, few pebbles, cobble layer @ 5
	5	13	S&G	tan				Medium sand, pebble rich, slightly silty
	13	17	Silty S&G	gry	P			Silt rich, mostly pea-pebble
	17	19	Diamict	blu-gry	P			End of drilling
BH 8-7	0	1	Topsoil	blk				
	1	5	S&G					Cobble rich sand and gravel
	5	14	Silty S&G		P			Silt rich, mostly pea-pebble w/ occt cobble, grades siltier w/ depth
	14	16	Diamict	blu-gry	P			End of drilling
BH 8-8	0	1.5	Topsoil					
	1.5	4	S&G					Cobble rich sand and gravel
	5	7	Sand & Pea Gravel		M			Pea to pebble, coarse sand matrix
	7	10	Silty S&G	gry	P			Silt rich, some organics, some elongated clasts, WT @ 13
	10	13	S&G		M			Some silty layers
BH 8-9	0	1.5	Topsoil	blk				
	1.5	5	S&G		50			Cobble rich sand and gravel, layered with med sand
	5	15	Sand & Pea Gravel	gry	60			Pea to pebble, little silt, some ox. nodes, WT@ 7
	15	17	Diamict	blu-gry	P			End of drilling
BH 8-10	0	1.5	Topsoil	blk				
	1.5	11	S&G	tan-gry	M			Mostly pea to pebble some scattered cobbles, WT @ 9,
	11	16	Sand & Pea Gravel	gry	M			Some silty layers, mostly pea grvl in fine-med sand
	16	17	Diamict	blu-gry	P			End of drilling
BH 8-11	0	1.5	Topsoil	blk				
	1.5	4	S&G		40	M		Cobble rich, layered fine sand, slightly silty
	4	14	Sand & Pea Gravel	gry		MW		Mostly pea to pebble, med-coarse sand, little silt, WT @ 9
	14	16	Diamict	blu-gry	P			End of drilling
BH 8-12	0	2	Topsoil	blk				
	2	5	S&G		60			Cobble rich, layered med-coarse sand, slightly silty
	5	12	Sand & Pea Gravel	gry	M			Mostly pea to pebble, med-coarse sand, little silt, WT @ 7.5
	12	14	Diamict	blu-gry	P			Grades from silt to diamict, end of drilling
BH 8-13	0	3	Topsoil	blk				Grades from topsoil to a brown silt
	3	5	S&G			R		Cobble rich, layered med-coarse sand
	5	16	Sand & Pea Gravel	gry				Mostly pea to pebble, some cobbles, little silt, WT @ 8.5
	16	17	Diamict	blu-gry	P	A		End of drilling
BH 8-14	0	3	Topsoil	blk				Grades from topsoil to a brown silt
	3	5	S&G					Mostly pea to pebble, some cobbles to sm. boulders
	5	7	Silty S&G	tan	30	P	Lmst	Pea to pebble, silt, less grvl
	7	12.5	Sand & Pea Gravel			M		Mostly pea to pebble, some cobbles, less silt
	12.5	14	Silty S&G	yel-gry				Very silt rich, gravel clumps
	14	15	Diamict	blu-gry	P			End of drilling
BH 8-15	0	3	Topsoil	blk				Grades from topsoil to a brown silt
	3	13	S&G		M			Fine gravel in fine-coarse sand, some silt, WT @ 8
	13	15	Diamict	blu-gry	P			End of drilling
BH 8-16	0	3	Topsoil	blk				Grades from topsoil to a brown silt

			tG			M	Cobble rich, layered med-coarse sand
	7	16	Sand & Pea Gravel			MW	Mostly pea to pebble, some cobbles, WT @ 8
	16	17	Diamict	blu-gry			End of drilling
BH 8-17	0	3	Topsoil	blk			Grades from topsoil to a brown silt
	3	5	S&G			M	Cobble rich, layered med-coarse sand
	5	15	Sand & Pea Gravel				Mostly pea to pebble, some cobbles, WT @ 6
	15	17	Diamict	blu-gry		P	End of drilling
BH 8-18	0	3	Topsoil	blk			Grades from topsoil to a yellow silty loam
	3	10	Silty S&G	tan		P	Pea to pebble, very silty,
	10	22	S&G	gry			Pea to cobble, some silt layers, grades finer, WT@ 10.5
	22	23	Silt	blu-gry		W	
BH 9-1	0	2	Topsoil	blk			Grades from topsoil to a brown silt
	2	18	S&G			M	R Mostly pea to pebble, grades finer, some cobbles, WT @ 9
	18	21	Diamict	blu-gry		P	End of drilling
BH 9-2	0	2	Topsoil	blk			Grades from topsoil to a brown silt
	2	5	S&G			M	Cobble rich, layered med-coarse sand
	5	16	Sand & Pea Gravel			M	Fine gravel in fine-coarse sand, some silt layers, WT @ 10
	16	20	Diamict	blu-gry		P	End of drilling
BH 9-3	0	3	Topsoil	blk			Grades from topsoil to a brown silt
	3	5	S&G			M	Cobble rich
	5	16	Sand & Pea Gravel	gry		M-W	Sand and silt layers, mostly pea to pebble grvl, WT @ 10.5
	16	18	Silt	gry			Organics, old soil, sandy loam
BH 9-4	0	4	Topsoil	blk			Grades from topsoil to a brown silt
	2	11	S&G		35		Cobble rich zones, mostly pea to pebble, WT @ 11
	11	17	Sand & Pea Gravel			M	Sand and silt layers, mostly pea to pebble, finer grvl
	17	19	Diamict	blu-gry		P	End of drilling
BH 9-5	0	4	Topsoil/Silt	blk			Grades from topsoil to a brown silt
	4	16	Silty S&G	tan		P	Very silt rich, poor sorting, mostly silt matrix, gets cleaner with depth
	16	20	Diamict	blu-gry		P	End of drilling
BH 9-6	0	6	Topsoil/Silt	blk			Grades from topsoil to a brown silt
	6	16	Sand & Pea Gravel			M	Sand and silt layers, mostly pea to pebble, finer grvl, WT @ 9.5
	16	18	Diamict	blu-gry		P	Grades from silt to diamict, end of drilling
BH 9-7	0	5	Topsoil/Silt	blk			Grades from topsoil to a brown silt, rust mottles
	5	8	Silty S&G			P	High silt content, pea-sm boulder, did not sample
	8	15	Sand & Pea Gravel			M	Mostly pea to pebble, grades finer, some cobbles, WT @ 8
	15	17	S&G		30	M	Pea to cobble, little silt content
	17	19	Silt	gry			Old soil horizon, end of drilling
BH 9-8	0	2	Topsoil	blk			
	2	6	S&G				Cobble rich, layered med-coarse sand
	6	15	Sand & Pea Gravel			M	Mostly pea to pebble, cand layers, some cobbles, WT @ 7
	15	18	Silt	gry		P	Old soil horizon, end of drilling
BH 9-9	0	4	Topsoil/Silt	blk			Grades from topsoil to a brown silt, gry mottles
	4	6	S&G			M	Cobble rich, layered med-coarse sand
	6	8	Silty S&G			P	High silt content, did not sample, WT @ 6
	8	16	Sand & Pea Gravel			MW	Mostly pea to pebble, sand layers, some cobbles,
	16	18	Diamict	blu-gry		P	End of drilling
BH 9-10	0	4	Topsoil/Silt	blk			Grades from topsoil to a brown silt

		6	Silty S&G		P	High silt content, cobble rich
	6	17	Sand & Pea Gravel		MW	Mostly pea to pebble, sand layers, some cobbles, WT @ 7
	17	18	Diamict	blu-gry	P	End of drilling
BH 9-11	0	6	Topsoil/Silt	blk		Grades from topsoil to a brown silt
	6	8	Silty S&G		P	High silt content, cobble rich, WT @ 6.5
	8	16	Sand & Pea Gravel		M	Some silty layers, mostly pea grvl in fine-med sand, poor recovery
	16	18	Diamict	blu-gry	P	End of drilling
BH 9-12	0	6	Topsoil/Silt	blk	W	Grades from topsoil to a brown silt, no pebbles in silt, WT @ 3
	6	14	S&G		M	Cobble rich, some silty zones, graded finer, poor recovery
	14	16	NA			No recovery
	16	18	Diamict	blu-gry	P	End of drilling
BH 10-1	0	3	Topsoil	blk		
	3	6	S&G		M	Cobble rich, slightly silty, fine-med sand matrix, WT @ 6
	6	8	Sand & Pea Gravel			Mostly pea to pebble
	8	10	Fine Sand		W	
	10	13	Silty S&G		P	Pea to cobble, high silt content
	13	15	Fine Sand		W	
	15	44	Sand & Pea Gravel		M-W	Mostly pea to pebble, some silt zones and sand layers, occt cobble
	44	46	Diamict	blu-gry	M	
BH 10-2	0	3	Topsoil			Grades from topsoil to a fine sand
	3	9	Sand & Pea Gravel		W	Mostly pea to pebble, coarse sand, WT @ 6
	9	10	Silty S&G		P	Pea to cobble, high silt content
	10	18	Sand & Pea Gravel		W	Mostly pea to pebble, medium to coarse sand, few cobbles
	18	20	Fine Sand		W	
	20	36	Sand & Pea Gravel			Mostly pea to pebble, medium to coarse sand, few cobbles
	36	43	S&G		M-W	Sandy silt w/ some grvl grading to a pea gravl
	43	46	Diamict	blu-gry	P	End of drilling
BH 10-3	0	3	Topsoil	blk		Grades from topsoil to silt
	3	18	Sand & Pea Gravel		M	Mostly pea to pebble, medium to coarse sand, few cobbles, WT @ 5
	18	22	Fine Sand	tan	W	
	22	30	Sand & Pea Gravel		M	Mostly pea to pebble, medium to coarse sand, few cobbles
	30	34	Silty S&G		M-P	High silt content w/ some sand, pea grvl abundant
	34	42	Sand & Pea Gravel			Mostly pea to pebble, medium to coarse sand, few cobbles
	42	44	Diamict		P	End of drilling
BH 10-4	0	1.5	Topsoil	blk		
	1.5	7	S&G		M	Cobble rich, slightly silty, fine-med sand matrix
	7	9	Sand & Pea Gravel		W	Mostly pea to pebble, medium to coarse sand, few cobbles
	9	22	S&G		M	Coarse sand matrix, mostly pea w/ scattered cobbles,
	22	44	Sand & Pea Gravel		M	Mostly pea to pebble, medium to fine sand, few cobbles
	44	46	Diamict	blu-gry	P	End of drilling

Appendix B
Geologic Descriptions of Giddings Probe Holes

Drill Hole Number	To (ft)	From (ft)	Sediment Size	Color	%G	%S	Sort	Hardness	Lithology	Comment
GP-1	0	0.75	Topsoil, sandy loam	blk						Cobbles at surface
	0.75	6	Sand w/ grvl	yel-brn			P	SR-R		Cobbles to 2in,
GP-2	0	2	Topsoil	blk						
	2	4	Sandy silt	yel-gry			P			Iron (Fe) stained, Mottles, hard
	4	9	Silty sand w/ grvl	light brn	30	40	P	SR-R		Very silty, cobble to 2", poor recovery w/ depth
GP-3	0	0.5	Topsoil	blk						
	0.5	1.7	Sandy silt	lt gry						
	1.7	4	Gravelly silt	yel-brn	10	20	P	SR-R	Mix	Stiff
	4	9	Silty sand w/ grvl	yel-brn	(10-30)		P		Mix	Some silt and pea grvl zones, grvl mostly<1/2"
GP-4	0	0.5	Topsoil	blk						
	0.5	7.5	Sandy silt	lt gry						Fe stains at 1.5-7.5, 1/2" pebbles
	7.5	9	Silty clay	blu-gry						
GP-5	0	1	Topsoil	blk						
	1	2	Silt	lt gry	0					
	2	3.5	Sandy silt	yel-tan	0					
	3.5	6	Sand to silt	yel-brn	5		P	SA-SR		Muddy silt and sand zones w/ occ 1/4" grvl
	6	9	Sand w/ grvl	brn	(30-50)		P	SR-R	grn, ls	Muddy, 3/8" max size, some sandy lenses
GP-6	0	0.75	Topsoil	blk						
	0.75	2	Silt	lt gry						
	2	5	Silt to sandy silt	yel-gry						Sandier at base
	5	6	Silty sand w/ grvl	brn	40		MP		grn, ls	Grvl is to 1.5" cobble
	6	9	Sand and silt	brn			P		grn, ls	Cant tell if grvl is mixed with silt- 1/2" cobbles
GP-7	0	1	Topsoil	blk						
	1	4	Silt	gry						
	4	6	Silty sand w/ grvl	brn	20			SR-R		Muddy, silt matrix to 1"pebbles
	6	9	Silty sand w/ grvl	brn	40			SR-R		
GP-8	0	0.5	Topsoil	blk						
	0.5	4	Sandy silt	yel-brn						
	4	6.5	Gravely silt	yel-brn					chrt, ls	Poor recovery 4-6'
	6.5	9	Silty sand w/ grvl	yel-brn	30					Some grvl is clean
GP-9	0	0.75	Topsoil	blk						
	0.75	1.5	Silt	gry						
	1.5	4	Sandy silt	yel-brn						
	4	9	Sandy silt w/ grvl	yel-brn						Pebbles to 1", some clean grvl lenses, v. muddy 6-9
GP-10	0	0.75	Topsoil	blk						
	0.75	2	Silt	gry						
	2	5.5	Silt	yel-brn			P			Sticky, orange mottles
	5.5	6	Silty sand	brn			P			
	6	9	V. silty sand w/grvl	brn			P			To 1" pebbles, very muddy
GP-11	0	3	Topsoil- silty loam	blk						
	3	9	Silty sand	yel-brn						Fe mottles and streaks
GP-12	0	2.5	Topsoil	blk						
	2.5	3.5	Silt (till?)	dk gry						White snails, few small pebbles 1/4"
	3.5	5.5	Silt	yel-brn						Sandier at base, Fe streaks and mottles
	5.5	12	Muddy sand and grvl	yel-brn				SA-SR		Muddy grvl, thin silt at 6' and 8', cobbles to 1"
GP-13	0	2	Topsoil	blk						
	2	4	Silt	gry						
	4	9	Muddy gravel	yel-brn						Up to 1.5" cobbles
GP-14	0	2.5	Topsoil	blk						
	2.5	3.5	Sandy silt	yel-gry						
	3.5	9	Silty sand w/ grvl	yel-brn	35			R-SR		Poor recovery 6-9', pebbles to 1.5"
GP-15	0	1.5	Topsoil	blk						
	1.5	2	Silt	gry						
	2	4	Silt w/ grvl	gry-brn						Mostly pebbles 1/4", Fe stains
	4	9	Muddy sand and grvl	brn						Less coarse, mostly 1/4", v. poor recovery, 6-9'
GP-16	0	2	Topsoil	blk						
	2	4.5	Silt	gry-brn						
	4.5	9	Sand w/ grvl	yel-brn	20					Many silt layers, pebbles 1/4" to 1.5"
GP-17	0	2	Topsoil	blk						
	2	4	Silt	yel-brn						Sandy w/ occ pebble 1/4" at 5-6'

GP-18	0	1.5	Topsoil	blk						
	1.5	6.5	Silt	yel-gry						Minor Fe staining
	6.5	15	Sandy gravel	brn					buff ls	Pebbles to 1.5", some silt 9 to 12', drk silt lenses
GP-19	0	1.5	Topsoil	blk						
	1.5	3	Silt	yel-brn						Rare pebbles
	3	6	Sand w/ gravel	brn	30					Clean, possible silt at 6'
	6	9	Stony silt	blk						Numerous 1" pebbles
GP-20	0	1.5	Topsoil	blk						
	1.5	4.5	Silt	yel-brn						Some organics, no pebbles
	4.5	6	Coarse sand	brn	15	80				Clean sand
	6	7.5	Silt w/ thin sand lens	brn						
	7.5	12.5	Sand w/ gravel	yel-brn				R-SR	ls	3/8" to 1/2" max, occ cobble, no rec from 9-12'
GP-21	0	2.5	Topsoil	blk						
	2.5	9	Silt	yel-gry						Some sand, layered
	9	14	Silty gravel	brn	40				ls, gm	3/4" grvl, possible clay balls, some c. sand lenses
GP-22	0	2	Organic rich Topsoil	blk						
	2	8	Clayey Silt	gry-brn						
	8	10	Silty Clay	lt brn						Laminated, color change at 8'
	10	14.5	Silty sand w/ grvl	lt brn						Drill resistant at 12', probably pebble rich grvl
GP-23	0	2	Topsoil	blk						
	2	7.5	Silt	gry-brn						Homogeneous, no mottles/laminations, few pebbles
	7.5	8.5	Coarse sand w/ grvl	drk brn	40					Some silt
GP-24	0	2	Topsoil	blk						Organic-rich
	2	3	Silt	gry-brn						
	3	5	Pebbly silt	lt brn						
	5	6	Silty sand w/ grvl							Drill resistant at 7', probably pebble rich grvl
	6	9	Gravelly sand							Oxidized, could not pull drill out, poor sample
GP-25	0	2	Topsoil							Organic-rich
	2	6	Silt	gry-brn						
	6	10.5	Clayey silt	gry						Lt green cast, laminae is very thin
	10.5	12.5	Gravelly sand							
GP-26	0	3	Topsoil	blk						Organic-rich
	3	10.5	Clayey silt	brn						Drill resistant at 7', laminae thin
	10.5	12	Gravelly coarse sand							Uncertain of contact, poor recovery
GP-27	0	1.5	Topsoil	blk						
	1.5	3	Silt	yel-brn						
	3	7.5	Sandy gravel	lt brn						2" cobble
GP-28	0	2	Topsoil	blk						
	2	4.5	Clayey silt	yel-tan						
	4.5	7	Silty sand w/ grvl	yel-brn						
	7	9	Sandy silt	yel-brn						
GP-29	0	3	Topsoil	blk						Cobbles at surface
	3	5	Clayey silt	yel-gry						Boulder at 4.5
	5	5.5	Sandy silt w/ grvl	yel-brn						
GP-30	0	1.5	Topsoil	blk						
	1.5	4	Sandy silt	yel-brn						Topsoil sandier with depth
	4	4.5	Silty sand w/ grvl	yel-brn						V. tough drilling at 4.5, lots of 1.5" cobbles
	4.5	6	Sand and gravel	yel-brn						Numerous 2-3" cobbles
GP-31	0	1.5	Topsoil	blk						
	1.5	4	Clayey silt	yel-gry						Topsoil lighter with depth, contains several pebbles
	4	9	Sand and gravel	lt brn	50		WM	R-SR		Slightly silty
GP-32	0	2.5	Topsoil	blk						
	2.5	4	Silt	yel-brn						Rocks at 4', tough drilling
	4	5	Sand and gravel							
GP-33	0	2.5	Topsoil							
	2.5	5.5	Silt	yel-brn						Clay rich at top and grades to sand with depth
	5.5	6.5	Sand with gravel	lt brn						Bedrock at 6.5'
GP-34	0	2.5	Topsoil	blk						
	2.5	4	Silt	yel-tan						
	4	7	Silty sand w/ grvl	yel-brn						Gravel is rare
	7	9	Coarse sand w/ grvl	lt brn						Gravel is <1/4"

	0	1.5	Topsoil	blk					Occasional cobbles at surface
	1.5	2.5	Silt	yel-brn					
	2.5	3	Sandy silt	brn					
	3	6.5	Coarse sand w/ grvl	brn			W		V. tough drilling at 6
	6.5	8.25	Silty sand w/ grvl	lt gry			P		Quite silty, hit bedrock
GP-36	0	2	Topsoil	blk					
	2	4.5	Silt	yel-brn					
	4.5	5.5	Sandy silt	yel-brn					Iron (Fe) stained
	5.5	6.5	Silty medium sand	brn					No gravel, hit bedrock at 6.5'
GP-37	0	4	Topsoil	blk					
	4	6	Sandy silt w/ grvl	gry-blk					Pebble sized gravel
	6	8.5	Coarse sand w/ grvl	brn			P		Possibly layered silt and sand
	8.5	9	Silty sand w/ grvl	brn					
	9	14	Silty sand	brn	10	90			Sparse gravel
	14	18	Med-coarse sand	brn			M		Slightly silty, fairly clean, no gravel
GP-38	0	2.5	Topsoil	blk					
	2.5	10	Clayey silt	gry-yel					Some pebbles then laminated at 5'
	10	13	Sandy silt	lt brn					Very silty, w/ coarse sand and 1/8" gravel
	13	15	Sand with gravel	brn					All rocks < 1/4"
GP-39	0	2.5	Topsoil	blk					Pebbles at surface
	2.5	4	Silt	lt gry					
	4	5	Sandy silt	yel-brn					
	5	8	Silty sand	brn					Some silt, some cobbles
	8	9	Medium sand w/ grvl	lt brn			W		Clean sand w/ gravel
GP-40	0	2.5	Topsoil	blk					Silty loam, pebbles at surface, lt gray 2-2.5'
	2.5	3.5	Silt	yel-brn					
	3.5	8	Medium sand w/ grvl		35		WM		Silty at 3.5-4, then clean, 1/2" pebbles, rocks at 6-8
	8	9	Silty sand w/ grvl						
GP-41	0	2.5	Topsoil	blk					Some pebbles at surface
	2.5	8.25	Clayey silt	lt tan					Laminated at 4-6 feet
	8.25	9.5	Silty sand w/ grvl	brn			WM	SA	Sand is coarse, minor silt content
	9.5	12	Clayey silt	lt gry					Till? w/ occasional pebbles
GP-42	0	2	Topsoil	blk					
	2	5.5	Silt	lt gry					
	5.5	9	Sand with gravel	brn	30		WM		Rocks at 6', minor silt
GP-43	0	2	Topsoil	blk					
	2	8	Silt	gry-yel					Some pebbles till 4' then laminated w/ Fe oxidation
	8	8.5	Coarse sand w/ grvl	brn					
	8.5	9.25	Sandy silt	gry-blk					Contains pebbles and sand, hit bedrock
GP-44	0	2.5	Topsoil	blk					Pebbles at surface
	2.5	3.5	Clayey silt	yel-brn					
	3.5	9	Sand with gravel	yel-brn	30		M	R	Silty at top
GP-45	0	2.5	Topsoil	blk					
	2.5	7.5	Clayey silt	yel-brn					Contains some pebbles and sand at 4'
	7.5	8	Sandy silt	yel-brn					Gradational upper and lower contact
	8	10	Medium sand w/ grvl	yel-brn	10				Rare gravel, rocks are large a 8-9'
	10	10.5	Sandy silt	gry-tan					Bedrock at 10.5'
GP-46	0	1.5	Topsoil	blk					
	1.5	3.5	Sandy silt	yel-brn					Bedrock at 3.5'
GP-47	0	2.5	Topsoil	blk					
	2.5	5.5	Clayey silt	yel-brn					
	5.5	6	Silty sand	gry-brn					Fe stains, hit bedrock at 6'
GP-48	0	2	Topsoil	blk					Few cobbles at surface
	2	4.5	Clayey silt	yel-brn					Laminated in lower foot
	4.5	9	Sand with gravel	brn	40				
GP-49	0	2.5	Topsoil	blk					
	2.5	3.5	Silt	gry-blk					
	3.5	5	Sandy silt	lt gry					
	5	12	Silty sand	yel-gry					Fe stains at 5.5-6', silt zones
GP-50	0	1.5	Topsoil	blk					
	1.5	4	Silt	drk gry					Green tint
	4	7.5	Sandy silt	yel-tan					Some zones are silty sand, some gravel

	11	13.5	Sand with gravel	drk brn	30			Some silt content, "dirty"
	13.5	14.5	Silty sand	yel-tan	0			Sand is fine grained
	14.5	15	Till	blu-gry				
GP-51	0	1.5	Topsoil	blk				Numerous pebbles at surface
	1.5	2.5	Silt	yel-brn				
	2.5	4	Gravelly silt	gry-brn				
	4	9	Sand with gravel	lt gry	35	WM	SR-R	Fairly clean, gravelly silt at 6-7'
GP-52	0	3.5	Topsoil	blk				Occasional pebbles at surface
	3.5	6	Clayey silt	yel-gry				Laminated
	6	7.75	Gravelly silt	drk brn				Very silty
	7.75	13.5	Sand with gravel	drk brn	40			Some silt zones, bedrock at 13.5'
GP-53	0	2.5	Topsoil	blk				
	2.5	4.5	Silt	yel-brn				
	4.5	5.5	Gravelly silt	gry-brn				Some pebbles
	5.5	12	Silty sand w/ grvl	yel-brn	(40-50)			Moderately silty
GP-54	0	2.25	Topsoil	blk				
	2.25	7	Clayey silt	yel-brn				Firm
	7	12	Fine sand	lt yel		W		Clean, very tough drilling, more silt in last 1/2'
GP-55	0	2	Topsoil	blk				
	2	9	Clayey silt	yel-brn				Firm, laminated at 4-4.5', oxidation (Fe) at 5'
GP-56	0	2.5	Topsoil	blk				
	2.5	10	Silt	yel-brn				Upper contact gradational, firm, lower 2' is sandy
	10	14	Fine sand	tan				Occational silt layer in lower 2', bedrock at 14'
GP-57	0	2	Topsoil	blk				Quartzite fragments at surface
	2	8	Silt	brn-yel				Laminated at 4-5'
	8	13	Fine sand	yel-brn				Some silt zones, bedrock at 9'
GP-58	0	1.5	Topsoil	blk				
	1.5	6	Silt	yel-brn				Laminated at 4', upper contact is gradational
	6	7	Medium sand	lt brn				Bedrock at 7'
GP-59	0	1.5	Topsoil	blk				Micrite
	1.5	8.5	Silt	yel-brn				
	8.5	12	Fine sand	tan				Grades to medium grained sand at 11'
	12	16	Silty sand w/ grvl	drk brn	10			Some gravel, very silty, bedrock at 16'
GP-60	0	1.5	Topsoil	blk				
	1.5	4.5	Silt	yel-brn				
	4.5	6.5	Medium sand	tan	3	WM		Fairly clean, minor gravel
	6.5	10	Silty sand w/ grvl	brn	20			Very silty, bedrock at 10'
GP-61	0	2	Topsoil	blk				
	2	8	Silt	yel-brn				
	8	11.5	Silty sand w/ grvl	red-brn	40			Fairly silty, bedrock at 11.5'
GP-62	0	4	Topsoil	blk				
	4	7	Silt	gry-brn				Sticky texture
	7	11.5	Silty sand w/ grvl	yel-brn	40			Silty from 7-8', then is cleaner with depth
	11.5	12.5	Medium sand	yel-brn		WM		Rare gravel, bedrock at 12.5'
GP-63	0	1.5	Topsoil	blk				Numerous lm and grnt pebbles at surface
	1.5	3	Silt	brn				
	3	8	Clayey silt	lt brn				
	8	11	Sandy silt	tan				Oxidized layer, roots, soft
	11	12	Fine sand	tan				Rare gravel, bedrock at 12'
GP-64	0	1.25	Topsoil	blk				Numerous quartzite and some ls pebbles at surface
	1.25	5.75	Silt	brn				Grades to a lighter colored silt
	5.75	6.5	Medium sand	tan				Quartzite fragments and powder, bedrock at 6.5'
GP-65	0	1.5	Topsoil	blk				Some gravel sized quartzite at surface
	1.5	3.5	Silt	brn				Gradational upper and lower contact
	3.5	8.5	Clayey silt	yel-brn				Laminated to 5', some Fe stains
	8.5	15.3	Fine sand	yel-tan				Some silt zones, tough drilling past 10'
GP-66	0	2	Topsoil	blk				
	2	4	Silt	drk gry				
	4	6	Clayey silt	yel-brn				Laminated and some Fe stains
	6	8	Silty sand w/ grvl	yel-brn				Very silty
	8	9.5	Coarse sand w/ grvl	red-brn				Fairly clean w/ some silt in lower 6"

GP-67	0	2.5	Topsoil	blk		
	2.5	4.5	Silt	gry-brn		
	4.5	7.5	Clayey silt	yel-brn		Laminated
	7.5	8.5	Silty sand w/ grvl	gry-brn		Very silty
	8.5	14	Coarse sand w/ grvl	brn	50	Fairly clean w/ silty layer 10-11', 3/4" pebbles
	14	16	Sandy silt	lt gry	0	
	16	18	Coarse sand w/ grvl	brn	40	
GP-68	0	1.5	Topsoil	blk		Loamy, moist
	1.5	9	Silt	brn		Well sorted, massive, lt gray mottles at 7ft
GP-69	0	1	Topsoil	blk		Loamy, moist
	1	4	Silt	brn		Well sorted, massive, moist
	4	6	Medium sand	brn		Well sorted
GP-70	0	2	Topsoil	blk		Loamy, moist
	2	9	Sandy silt	lt brn		Some pebbles, silt zones, and sand layers, wet
GP-71	0	1	Topsoil	blk		Loamy, moist
	1	6	Silt	lt brn		Silt is dry and crumbly, sand lense at 5ft
	6	9	Medium sand			Well sorted, no pebbles
GP-72	0	2	Topsoil	blk		Moist
	2	7.5	Silt	brn		Well sorted, no pebbles, grades into silty fine sand
GP-73	0	2	Topsoil	blk		Moist
	2	5.5	Silt	lt brn		Some sand/grit in silt, moist
GP-74	0	2.5	Topsoil	blk		Crumbly
	2.5	6.5	Silt	brn		Massive, moist
GP-75	0	1	Topsoil	blk		Loamy
	1	6.5	Silt	brn		Some sand/grit in silt, moist
GP-76	0	1	Topsoil	blk		Loamy
	1	4	Silt	brn		Well sorted

Appendix C
Wentworth Grain Size Scale

WENTWORTH GRAIN SIZE SCALE

Limiting particle diameter						
mm	ø units				Size class	
2048	− 11			Very large	Boulders	GRAVEL
1024	− 10			Large		
512	− 9			Medium		
256	− 8			Small		
128	− 7			Large	Cobbles	
64	− 6			Small		
32	− 5			Very coarse	Pebbles	
16	− 4			Coarse		
8	− 3			Medium		
4	− 2			Fine		
2	− 1			Very fine	Granules	
1	0			Very coarse	Sand	
			μm			
½	+ 1		500	Coarse		
¼	+ 2		250	Medium		
⅛	+ 3		125	Fine		
1/16	+ 4		62	Very fine		
1/32	+ 5		31	Very coarse	Silt	MUD
1/64	+ 6		16	Coarse		
1/128	+ 7		8	Medium		
1/256	+ 8		4	Fine		
1/512	+ 9		2	Very fine		
					Clay	

Appendix D
Bore Hole Gradations

Appendix D
MNDOT Gradations
1 of 2

Sieve	Size	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH
Inches	Metric	0-1	0-2	0-3	1-1	1-2	1-3	1-4	1-5	2-1	2-2	2-3	2-4	2-5	2-6	3-1	3-2	3-3	3-4	3-5	3-6	3-7
3	75mm																	100				
2 1/2	63mm																100	98	100	100		
2	50mm			100	100				100		100	100	100			100	98	NA	98	97		
1 1/2	37.5mm		100	99	96	100	100	100	99	100	99	99	99	100	100	98	96	97	98	92	100	100
1 1/4	31.5mm	100	100	98	96	98	100	99	98	99	97	98	98	97	99	96	94	95	96	90	98	97
1	25mm	99	99	97	NA	96	99	97	97	97	NA	98	97	94	97	94	93	93	93	85	94	95
3/4	19mm	97	98	96	94	92	97	95	95	96	95	96	94	90	94	92	90	89	90	81	89	90
5/8	16mm	95	97	94	92	89	94	92	92	95	93	93	91	88	91	90	88	87	88	79	85	86
1/2	12.5mm	93	95	91	89	87	90	89	89	93	91	90	88	84	87	86	85	83	84	75	80	82
3/8	9.5mm	89	91	86	85	83	85	84	86	90	88	86	84	80	82	82	81	79	80	70	75	77
#4	4.75mm	76	78	73	75	71	70	72	72	79	77	72	70	66	64	71	70	67	65	58	62	52
#8	2.36mm	60	63	59	62	59	55	59	58	66	63	58	54	51	50	58	57	55	51	43	50	48
#10	2mm	57	60	56	58	55	52	56	55	63	60	55	51	47	46	55	54	51	47	40	47	46
#16	1.18mm	46	50	47	48	48	42	45	46	52	49	45	40	36	36	44	44	42	37	32	40	38
#30	600um	32	34	33	32	34	28	30	31	34	35	29	28	22	22	26	29	28	23	21	30	26
#40	425um	23	25	24	23	25	21	21	21	23	27	20	21	16	15	20	20	20	15	15	24	20
#50	300um	15	15	15	15	15	13	12	13	15	17	12	15	12	10	13	12	12	9	11	18	14
#100	150um	7	5	6	6	7	7	5	6	7	6	5	9	8	6	5	4	5	5	8	12	9
#200	75um	5.0	3.4	4.7	3.5	4.9	5.2	3.9	4.1	4.7	4.5	4.1	6.6	6.1	4.4	3.6	2.7	3.4	4.3	7.0	9.4	6.9

Sieve	Size	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH
Inches	Metric	4-1	4-2	4-3	4-4	4-5	4-6	4-7	5-1	5-2	5-3	5-4	5-5	5-6	5-7	6-1	6-2	6-3	6-4	6-5	6-6	6-7
3	75mm					100																
2 1/2	63mm	100		100		97				100	100		100		100	100			100			
2	50mm	95	100	99	100	93	100	100		98	99		98	100	95	97	100	100	98	100		100
1 1/2	37.5mm	NA	98	98	99	92	98	98	100	NA	96	100	95	97	94	91	98	97	95	98	100	97
1 1/4	31.5mm	94	97	96	97	91	95	95	98	96	94	98	90	93	NA	86	96	95	90	96	100	95
1	25mm	93	96	95	95	87	92	92	97	94	92	96	85	89	93	83	93	91	85	92	97	94
3/4	19mm	91	94	92	92	84	86	88	95	90	88	93	78	84	91	78	89	85	79	87	94	91
5/8	16mm	90	91	89	90	81	82	85	93	87	86	89	74	80	89	75	86	81	76	83	91	88
1/2	12.5mm	87	888	85	87	76	77	81	90	83	82	85	69	76	86	71	82	77	71	79	87	84
3/8	9.5mm	84	85	82	82	71	72	76	86	79	78	81	63	72	83	67	77	72	65	75	83	79
#4	4.75mm	73	73	67	69	58	59	63	74	65	67	68	50	60	72	56	64	60	53	61	69	63
#8	2.36mm	62	60	54	56	43	47	51	59	50	56	55	38	50	57	46	51	50	44	51	55	50
#10	2mm	59	57	51	53	41	45	48	56	47	54	53	36	47	53	44	47	47	41	49	52	47
#16	1.18mm	49	46	42	44	32	37	39	48	37	44	44	31	41	41	36	37	40	35	40	41	38
#30	600um	34	29	25	31	20	24	26	34	24	25	31	22	31	24	24	23	29	25	28	23	24
#40	425um	24	20	16	22	15	18	18	24	17	15	23	18	24	15	17	15	20	18	20	15	17
#50	300um	14	12	10	13	11	12	12	14	11	8	17	14	16	9	11	9	12	13	11	10	10
#100	150um	6	5	5	5	7	8	6	5	6	4	6	11	8	5	7	4	6	8	5	6	5
#200	75um	4.1	3.7	4.5	3.9	6.0	7.1	4.7	3.4	5.1	3.4	5.0	9.6	5.7	3.5	5.1	3.3	4.4	6.9	4.0	3.6	3.9

Sieve	Size	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH
Inches	Metric	6-8	7-1	7-2	7-3	7-4	7-5	7-6	7-7	7-8	7-9	7-10	7-11	8-1	8-2	8-4	8-5	8-6	8-7	8-8	8-9	8-10	8-11
3	75mm												100										
2 1/2	63mm						100			100			97			100							
2	50mm	100	100	100	100	100	98			98	100	100	94	100		94	100	100	100	100	100		100
1 1/2	37.5mm	98	97	98	97	96	96		100	96	99	89	88	99	100	83	97	98	95	99	98	100	96
1 1/4	31.5mm	97	93	98	95	94	95	100	99	92	98	80	85	98	100	75	95	96	91	99	97	99	92
1	25mm	95	90	97	90	91	92	99	99	87	96	73	79	96	97	71	93	94	87	97	95	96	88
3/4	19mm	91	87	96	87	85	88	97	97	81	91	66	71	95	94	65	88	91	82	92	92	92	82
5/8	16mm	89	85	93	84	81	85	96	95	77	87	60	66	93	91	62	85	89	79	89	89	89	78
1/2	12.5mm	85	81	91	80	77	81	93	92	71	83	55	61	90	87	57	79	85	75	85	86	85	74
3/8	9.5mm	81	77	86	76	73	76	89	88	66	76	50	55	86	84	53	74	81	70	79	81	81	69
#4	4.75mm	68	65	74	66	61	63	77	76	51	64	38	43	74	72	42	61	69	57	65	68	66	56
#8	2.36mm	55	53	61	55	52	51	61	65	41	49	30	32	61	63	34	50	57	46	50	52	54	41
#10	2mm	53	50	58	53	51	49	58	62	38	46	28	30	58	31	33	47	55	44	47	49	51	39
#16	1.18mm	45	42	45	45	47	41	47	52	32	37	23	25	48	52	28	40	47	36	36	38	40	31
#30	600um	33	29	25	31	40	27	30	30	23	24	16	18	31	38	20	28	34	23	23	23	25	19
#40	425um	24	21	17	23	37	19	20	17	17	16	12	15	21	30	15	21	26	16	16	16	18	13
#50	300um	14	14	10	15	8	12	10	9	12	8	9	12	13	22	11	15	18	11	11	10	11	9
#100	150um	6	7	6	7	5	5	4	4	10	3	6	9	7	10	7	10	11	6	6	5	6	5
#200	75um	5.1	5.6	4.2	4.0	4.3	4	2.9	3	9.8	1	5.1	8.3	4.8	6.3	5.6	7.7	8.1	4.9	4.5	4.3	4.7	3.5

Sieve	Size	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH	BH
Inches	Metric	8-12	8-13	8-14	8-15	8-16	8-17	8-18	9-1	9-2	9-3	9-4	9-5	9-6	9-7	9-9	9-10	9-11	9-12	10-1	10-2	10-3	10-4
3	75mm						100	100								100							
2 1/2	63mm	100	100			100	98	97	100			100		100		97	100		100				
2	50mm	98	97	100		98	96	95	98	100	100	96	100	98	100	93	98	100	97		100		
1 1/2	37.5mm	98	94	98	100	96	95	93	95	95	98	94	99	NA	99	93	95	94	90	100	99	100	100
1 1/4	31.5mm	94	90	97	99	93	91	89	94	90	97	92	98	98	99	91	95	94	85	99	99	99	100
1	25mm	90	84	95	97	91	87	87	89	85	97	89	98	97	97	89	92	92	83	99	98	98	97
3/4	19mm	84	81	91	93	88	82	83	87	79	94	82	96	94	94	86	87	89	77	96	95	97	95
5/8	16mm	81	77	88	90	86	79	81	84	75	92	78	94	92	91	83	82	87	73	94	93	96	93
1/2	12.5mm	76	73	84	86	82	75	76	80	72	89	74	91	90	88	79	78	83	68	91	90	94	91
3/8	9.5mm	71	68	79	81	76	72	71	76	68	86	69	89	86	84	74	74	80	64	86	86	91	87
#4	4.75mm	58	56	64	69	62	60	58	65	60	76	58	82	78	72	61	62	70	53	73	74	79	76
#8	2.36mm	45	46	51	58	48	49	47	53	53	66	46	72	63	57	49	52	61	47	59	60	66	62
#10	2mm	42	44	48	55	44	47	44	51	51	63	44	70	60	54	47	49	59	45	55	57	63	59
#16	1.18mm	33	36	38	46	33	40	37	42	46	55	37	61	52	43	39	42	51	40	46	46	52	50
#30	600um	19	23	23	31	20	23	26	25	32	40	23	43	33	27	28	28	35	31	32	31	38	37
#40	425um	12	17	15	21	14	15	19	16	22	30	15	28	20	18	21	20	25	24	24	22	27	28
#50	300um	8	12	10	13	9	9	13	9	13	21	10	19	11	11	15	13	18	18	15	14	17	17
#100	150um	5	7	6	7	5	5	9	5	6	9	6	14	5	7	11	8	11	14	6	6	8	7
#200	75um	3.7	6.1	4.7	5.3	3.5	4.1	7.8	3.7	4.7	6.6	4.7	10.7	4.2	6.1	9.3	6.5	8.9	12.1	4.6	4.7	6.5	4.6

Appendix E
Rock County Mining Ordinances

Board of County Commissioners and the Minnesota State Department of Health before construction.

(c) Individual sewer systems shall be constructed according to standards and specifications adopted by the Board of County Commissioners and the State of Minnesota.

(d) Individual sewer systems shall be located at least fifty (50) feet from any well.

2. Water Systems:

(a) Public water facilities, including pipe fittings, hydrants, etc., shall be installed as required by standards and specifications as established by the Board of County Commissioners and the State of Minnesota.

(b) Where public water facilities are not available, the Board of County Commissioners may by ordinance grant a franchise for such water facilities, to serve all properties within the area where a complete and adequate community water distribution system is designed, and complete plans for the system are submitted to and approved by the Board of County Commissioners and the Minnesota State Board of Health.

(c) Individual wells shall be constructed according to standards and specifications adopted by the Board of County Commissioners and the State of Minnesota.

(d) Individual wells shall be located at least fifty (50) feet from any sewer system.

Subdivision 4. Extraction of Materials and Minerals, Open Pits and Impounding of Waters.

All excavations, extraction of materials and minerals, open pits and impounding of waters hereafter established or enlarged shall conform with the provisions of this Subdivision and any other ordinance or regulations of Rock County.

1. Definition:

Excavations, as used in this Subdivision, shall mean any artificial excavation of the earth within the county: dug, excavated or made by the removal from the natural surface of the earth of sod, soil , sand, gravel, stone or other matter or made by tunneling or breaking or undermining the surface of the earth. Excavations ancillary to other construction of any installation erected or to be erected, built or placed thereon at the same time with or immediate-

ly following such excavation and covering or to cover such excavation when completed are excepted, if a permit has been issued for such construction or installation. Excavations not exceeding one thousand five hundred (1,500) square feet of surface area and six (6) feet in depth and agricultural excavations are excepted.

2. Administration:

Permit Review - A Conditional Use Permit shall be required for all commercial extraction operations. Said permit shall be valid for a one (1) year period; after which a permit renewal shall be required.

Bond May Be Required:

The Board of County Commissioners may require either the applicant or the owner or user of the property on which the open pit or excavation or impounded waters are located to post a bond, in such form and sum as the Board shall determine, with sufficient surety running to the County, conditioned to pay the County the extraordinary cost and expense of repairing, from time to time, any highways, streets or other public ways where such repair work is made necessary by the special burden resulting from hauling and travel, in removing materials from any pit, excavation or impounded waters, the amount of such cost and expense to be determined by the County Engineer; and conditioned further to comply with all the requirements of this Subdivision and to pay any expense the County may incur by reason of doing anything required to be done by any applicant to whom a permit is issued.

3. Application:

Application for a permit for the extraction of minerals, open pits and impounding of waters shall be made in such form, and the applicant shall furnish such information, as shall be required by the Board of County Commissioners, and among other things shall include:

(a) His true name and address.

(b) A full description of the location and acreage of the area where the pit or excavation is or is to be or where the impounded waters are or are to be maintained and also a full description of the location on such land of the pit, excavation or impounded waters.

(c) The following maps of the entire site and to include all areas within five hundred (500) feet of the site. All maps shall be drawn at a scale of one (1) inch to one hundred (100) feet unless otherwise stated below or as otherwise approved by the county.

Map A - Existing conditions to include:
Contour lines at ten (10) foot intervals.
Existing vegetation.
Existing drainage and permanent water areas.
Existing structures.
Existing wells.

Map B - Proposed operations to include:
Structures to be erected.
Location of sites to be extracted showing depth of proposed excavation.
Location of tailings deposits showing maximum height of deposits.
Location of machinery to be used in the extraction operation.
Location of storage of extracted materials, showing height of storage deposits.
Location of vehicle parking.
Location of storage of explosives.
Erosion and sediment control structures.

Map C - End use plan to include:
Location and species of vegetation to be replanted.
Location and nature of any structures to be erected in relation to the end use plan.

(d) A soil erosion and sediment control plan.

(e) A plan for dust and noise control.

(f) When required by the State of Minnesota, an approval by the State to impound such waters or to make such excavation as described in the application.

(g) The purpose of the pit or excavation or the quantity of water impounded.

(h) The highways, roads or other public ways in the County upon and along which any material for removal is to be hauled or carried.

(i) A full and adequate description of all phases of the proposed operation to include an estimate of duration of the extracting operation.

(j) Any other information requested by the Planning Commission or governing body.

4. Renewal of Extraction Permits

All property owners and residents within one thousand (1,000)

feet of the extracting operation shall be notified of an extraction permit renewal request.

5. Use Restrictions

The crushing, washing, refining or processing other than the initial removal of material shall be considered a Conditional Use.

6. Performance Standards

The governing body may impose additional performance standards as part of the Conditional Use Permit.

(a) properly fence any pit or excavation; including the following standards when any extracting operation is adjacent to a residential zone or within three hundred (300) feet of two (2) or more residential structures:

(1) Where collections of water occur that are one and one-half (1½) feet or more in depth existing for any period of at least one (1) month, and occupy an area of seven hundred (700) square feet or more, all access to such collections of water shall be barred by a fence or some similarly effective barrier such as a snow fence of at least four (4) feet in height.

(2) In locations where slopes occur that are steeper than one (1) foot vertical to three (3) feet horizontal existing for a period of one (1) month or more, access to such slopes shall be barred by a fence or some similarly effective barrier such as a snow fence at least four (4) feet in height.

(b) slope the banks and otherwise properly guard and keep any pit or excavation in such condition as not to be dangerous from caving or sliding banks;

(c) properly drain, fill or level any pit or excavation, after created, so as to make the same safe and healthful as the Board shall determine;

(d) keep any pit, excavation or impounded waters within the limits for which the particular permit is granted; including the following standards:

(1) The extracting operation shall not be allowed to interfere with surface water drainage beyond the boundaries of the extracting operation.

(2) The extracting operation shall not adversely affect the quality of surface or subsurface water resources.

(3) Surface water originating outside and passing through the operation site shall, at its point of departure from the site, be of equal quality to the water at the point where it enters the site. The extracting operator shall perform any water treatment necessary to comply with this provision.

(e) provide, for the purpose of retaining impounded waters, a container of sufficient strength and durability and maintain such container in safe and proper condition.

(f) remove excavated material from any pit or excavation away from the premises, upon and along such highways, streets or other public ways as the Board shall order and direct; including the following standard:

(1) The location of the intersection of extracting operation access roads with any public roads shall be selected such that traffic on the access roads will have a sufficient distance of the public roads in view so that any turns onto the public roads can be completed with a margin of safety.

(g) to minimize problems of dust and noise and to shield operations from public view, a screening barrier may be maintained between the extracting site and adjacent residential and commercial properties. A screening barrier shall also be maintained between the extracting site and any public road within five hundred (500) feet of any extracting or processing operations. The screening barrier shall be planted with a species of fast growing trees such as green ash.

Existing trees and ground cover along public road frontage shall be preserved, maintained (and supplemented), for the depth of the roadside setback except where traffic safety requires cutting and trimming.

(h) Extracting activities shall not be conducted closer than one hundred (100) feet to the property line nor closer than five hundred (500) feet to any residential or commercial structures located prior to commencement of extracting operations without the written consent of all owners and residents of said structures.

Extracting operations shall not be conducted closer than thirty (30) feet to the boundary of any zone where such operations are not permitted, nor shall such production or processing be conducted closer than thirty (30) feet to the boundary of an adjoining property line, unless the

written consent of the owner in fee of such adjoining property is first secured in writing.

Extracting operations shall not be conducted closer than ten (10) feet to the right-of-way line of an existing or platted street, road or highway with no less than a six (6) foot-to-one (1) foot (6 - 1) slope.

(i) all buildings, structures and plants used for the production or processing of sand and gravel shall be maintained in such a manner as is practicable and according to acceptable industrial practice as to assure that such buildings, structures and plants will not become dangerously dilapidated.

(j) all extracting operations shall be conducted between the hours of 7:00 a.m. and 7:00 p.m. Any operations not conducted between the hours of 7:00 a.m. and 7:00 p.m. shall require a Conditional Use Permit. Such permits shall be granted for public or private emergency or whenever any reasonable or necessary repairs to equipment are required to be made.

(k) General Provisions - Weeds and any other unsightly or noxious vegetation shall be cut or trimmed as may be necessary to preserve a reasonably neat appearance and to prevent seeding on adjoining property.

No sand and gravel operation shall be conducted on parcels of less than twenty (20) acres in size. This limitation shall not apply when the tract of land is contiguous to an active operation, provided that both tracts are being operated by the same sand and gravel producer.

All equipment used for extracting operations shall be constructed, maintained and operated in such a manner as to minimize, as far as is practicable, noises and vibrations which are injurious or substantially annoying to persons living in the vicinity.

All equipment used for extracting operations shall be constructed, maintained and operated in such a manner as to minimize, as far as is practicable, dust conditions which are injurious or substantially annoying to persons living within six hundred (600) feet of the extracting operation lot lines.

All access roads from extracting operations to public highways, roads or streets or to adjoining property shall be paved or surfaced with gravel to minimize dust conditions.

These limitations above shall not apply to any extracting operation in any industrial zone, unless such operations are closer than one hundred fifty (150) yards to another zone other than an industrial zone.

7. Waiver of Setback Requirement:

The governing body may provide, in the permit, for the waiver of the requirements for setbacks from the center line of highways and other public rights-of-way in appropriate circumstances where such waiver shall not constitute a safety or health hazard; provided, that such modified setback shall not conflict with applicable state or federal laws and regulations.

8. [redacted]

All extracting sites shall be rehabilitated immediately after extracting operations cease. Rehabilitation shall be complete within one (1) year. The following standards shall apply:

(a) [redacted] (6) months, or within three (3) months after expiration of an extraction permit, all buildings, structures and plants incidental to such operation shall be dismantled and removed by, and at the expense of, the extracting operator last operating such buildings, structures and plants. A temporary variance may be granted for those buildings, structures, machinery and plants required to process previously extracted materials stored on the site. Such variance may apply for only one (1) year, after which said buildings, structures, machinery and plants shall be removed.

(b) The peaks and depressions of the area shall be graded and backfilled to a surface which will result in a gently rolling topography in substantial conformity to the land area immediately surrounding, and which will minimize erosion due to rainfall. [redacted]e.

(c) Reclaimed areas shall be sodded or surfaced with soil of a quality at least equal to the topsoil of land areas [redacted] (3) inches.

Such required topsoil shall be planted with legumes and grasses. Trees and shrubs may also be planted but not as a substitute for legumes and grasses. Such planting shall adequately retard soil erosion.