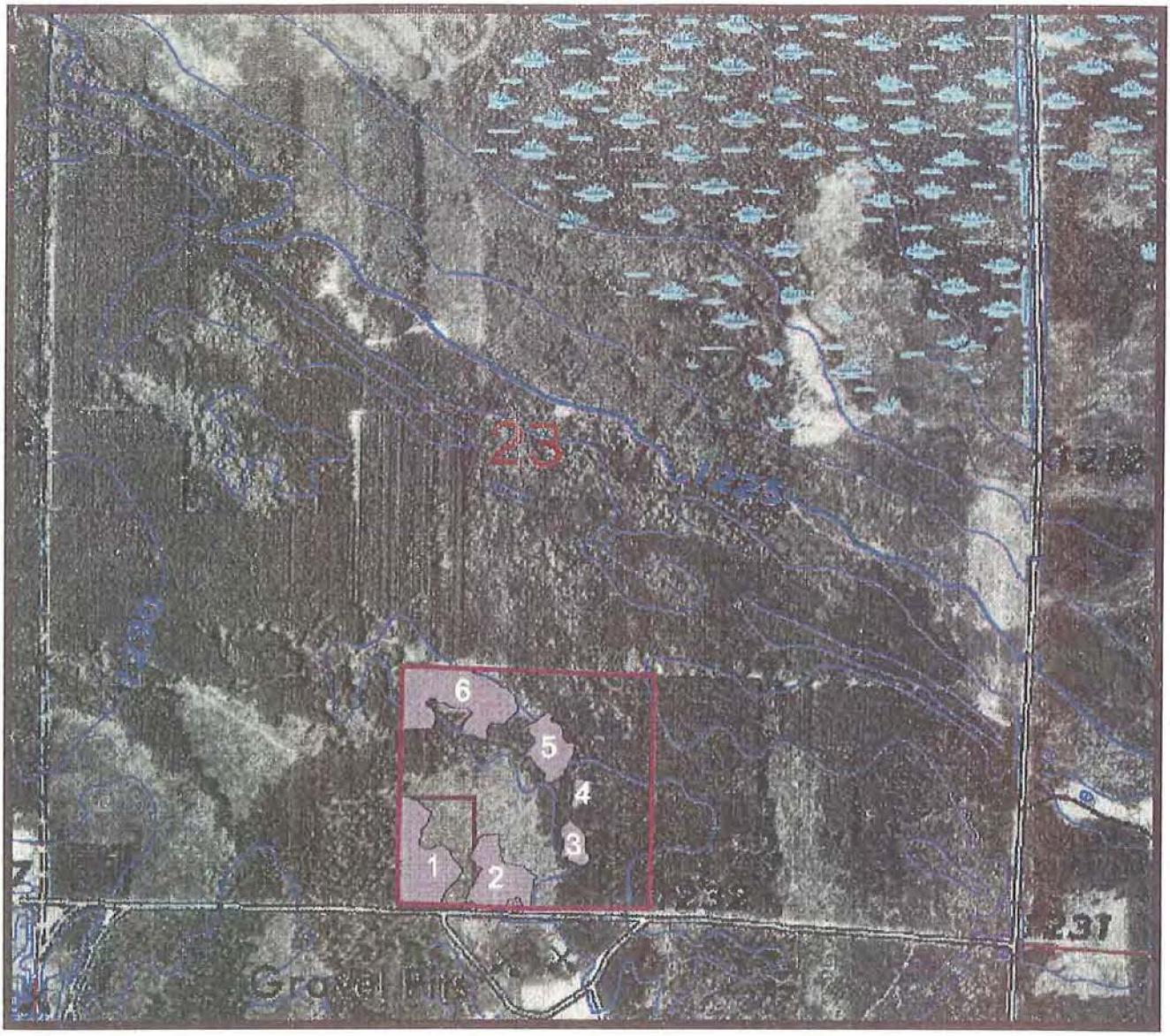
AGGREGATE RESOURCE EVALUATION

A Sand and Gravel Evaluation for a Site near Big Falls, Minnesota



Minnesota Department of Natural Resources
Division of Minerals Report 334-6, 1999

INTRODUCTION

The purpose of this study is to evaluate the volume and quality of a potential sand and gravel deposit located on a parcel of land near Big Falls, Minnesota (Figure 1). The study area is approximately 38.4 acres and located in the west ½ of SW-SE and east ½ of SE-SW of section 23, T.155N., R.25W. A portion of the study area was previously mined for sand and gravel. The gravel pit is located in the southwest corner of the study area and encompasses approximately 5 acres of the study area. A stockpile of Class 5 aggregate with an estimated volume of 9,000 cubic yards exists due to this mining. Currently, the Minnesota Department of Natural Resources (DNR)- Forestry Division manages the parcel. To plan for the future management of the parcel, the DNR- Forestry commissioned DNR-Minerals to conduct a geologic survey. The three primary functions of the survey were to determine how much gravel is left in the existing pit, how much gravel is located on the remaining 35 acres of the parcel, and determine the quality of the gravel. In conjunction with the DNR- Forestry, DNR- Minerals, and the Minnesota Department of Transportation, the geologic survey was conducted in October of 1998.

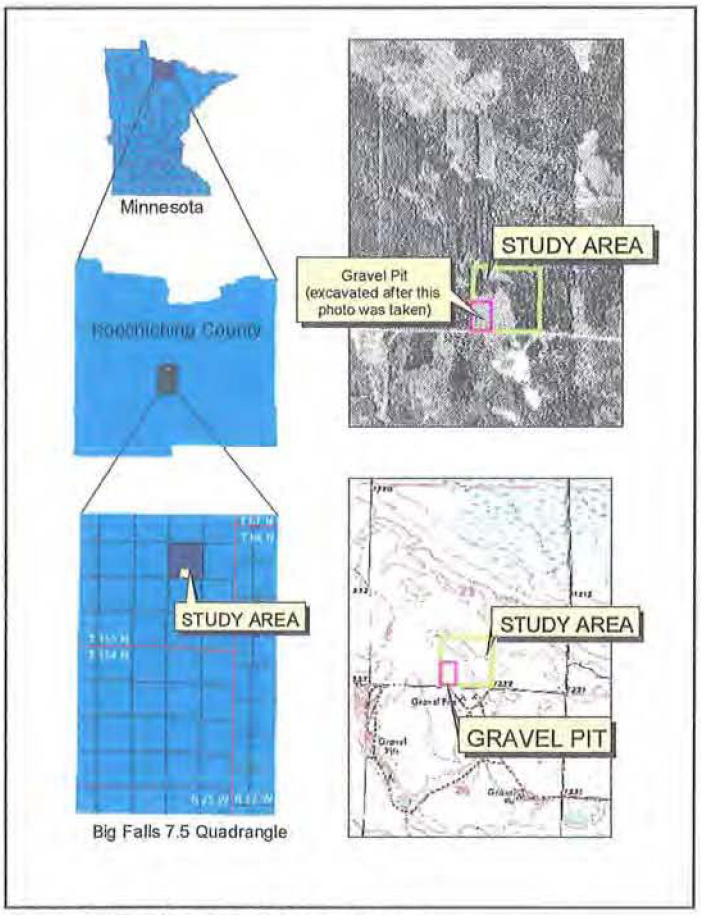


Figure 1. The location of the study area.

GEOLOGIC SETTING

Large continental glaciers advanced and receded several times during the Pleistocene Epoch. When the last glacier receded about 10,000 years before present, a large basin filled with water and inundated northern Minnesota and south central Canada. The lake was called Glacial Lake Agassiz and it is the largest lake that existed in the northern hemisphere (Woodworth-Lynas and Guigne, 1990). The lake reworked and modified pre-existing glacial sediments. The parcel is located on a much larger landform interpreted as a beach ridge of this glacial lake. This beach ridge may have covered a pre-existing landform, called a moraine, deposited earlier by the glaciers. Then, as the lake drained, sand and gravel was deposited. This is the same deposit that is currently being mined today.

METHODOLOGY

The results of a geologic survey determine the sand and gravel volume, quality, and mining accessability by determining overburden thicknesses and depth to ground water. Therefore, the geologic survey consisted of aerial photograph and topographic map

interpretation, drilling, sampling, logging, field work, geophysical studies, 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: Big Falls, Lindford SE, and Lindford SW. Geologic information was additionally gathered from infrared aerial photographs (NAPP, 1992) which were used to delineate boundary lines, identify land marks, and determine the orientation of gravel deposits.

Drilling

Two phases of drilling were conducted at the site. The first phase included exploratory drilling with a Giddings Probe. A Giddings Probe is a truck-mounted soil auguring machine. The purposes of exploratory drilling were to determine the potential thickness of the deposit, overburden thicknesses, and the areal extent of the deposit. A total of 24 holes were drilled ranging from 5 to 13 feet in depth. There were both preselected drill sites and random "check-point" drill holes sites.

Figure 2. MNDOT drill rig with 20 foot continuous auger.

The information gathered from the Giddings Probe aided in determining the drill hole pattern for the second phase of drilling. The second phase of drilling involved the use of a MNDOT drill rig with a twenty-foot, continuous auger that has a diameter of 10 inches (Figure 2). The MNDOT drill hole pattern was planned on the basis of three observations: the deposit was shallow, concentrated to the west, but was patchy over a large area. Therefore the drill hole pattern consisted of 8 rows, totaling 57 bore holes, that formed a grid with a greater amount of bore holes to the west. Although preliminary drilling did not find a substantial deposit to the east, more drilling was required to confirm the absence of gravel. Once the grid was completed, the additional bore holes, 58 through 66, were drilled to further delineate the known gravel boundaries. Of these additional holes, bore holes 65 and 66 were drilled outside the study area boundaries. The holes were drilled to help define the outer gravel boundaries for computer modeling.

The shallow depth of the gravel deposit required an average drilling depth to be 6 feet. However, five bore holes were drilled to the depth of 20 feet. The deeper holes were necessary to confirm that additional gravel layers did not exist at deeper intervals. The location of these drill holes included one in each of the four corners of the study area with the fifth being in the center. Due to the shallow nature of the deposit, only one sample could be obtained per drill hole.

Sampling

For a sample of sand and gravel to be processed at the MNDOT laboratory, thirty pounds of sample must be obtained. Thirty pounds was the minimum sample size that properly represents the sample from the ground. Therefore, this was the primary sampling criteria for each drill hole. Sampling consisted of hand-scraping material from the auger flight and placing it on a rubber mat (Figure 3). Once the entire sample was gathered, the sample was mixed with a shovel before it was bagged. Mixing ensured the randomization of the sample to represent the composition of the entire hole and prevented segregation of grain size. Finally the sample was scooped into a canvass bag with identification tags inside and outside of the bag. All samples were then transported to the MNDOT Laboratory in Maplewood, MN for gravel quality tests.

Figure 3. Sampling off 10 inch diameter auger onto rubber mat. Upper Right: 2mm sieve used to separate sand from gravel.

Geologic Logging

Geologic logging provided crucial information to all aspects of the gravel evaluation. By logging the different types of sediments in context to the geology, the sediments of the study area can be put into a larger geologic framework. Determining the geology of the site helps to recognize 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 human generated models accurately represents the natural deposit. Geologic observations included noting overburden thickness, geologic contacts, detailed descriptions of the different types of sediments, the depth of the deposit, the amount of sand, the amount of gravel, the depth to the water table, composition of the sand and gravel, and depositional patterns of the sediments (Appendix A).

Within the geologic log of the Big Falls site, gravel is defined as a sediment size that is greater than or equal to 2mm. Two millimeters is roughly the size of a match head. To obtain a rough estimate of gravel on some of the drill holes a 2mm sieve was used.

Geophysical Study

Further data was gathered by an Electromagnetic (EM) Conductivity study. The EM study was performed to partially fulfill one of the project's objectives: to determine the remaining gravel resource in and adjacent to the existing gravel pit (Figure 4). Therefore the EM study was focused on land directly east and north of the gravel pit. The data collected from the EM survey helped to define trends between the drill holes, to provide inferred information for the areas not drilled, and to correlate the textural characteristics of known areas with those in question. The equipment used for this study was a portable, two-person operated device called the EM34-4.

The EM34-4 used two coils to transmit an electric magnetic signal (Figure 5A-4C). How

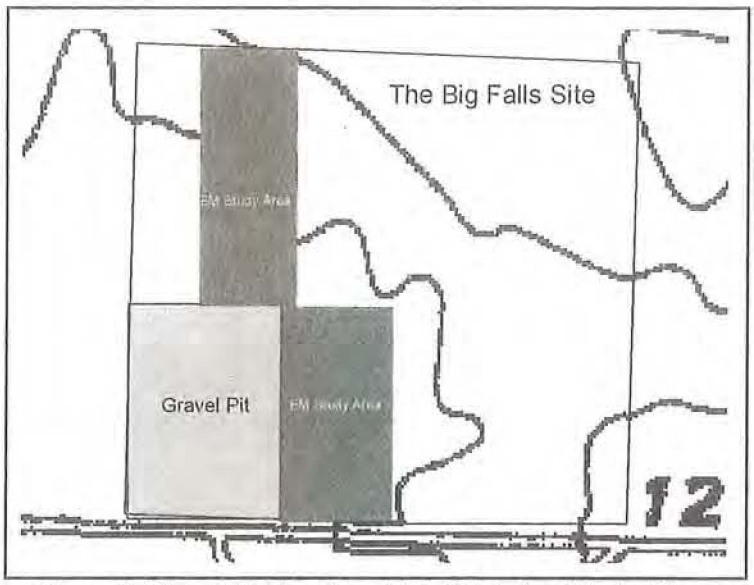


Figure 4. The relative location of the EM study within the Big Falls study area.

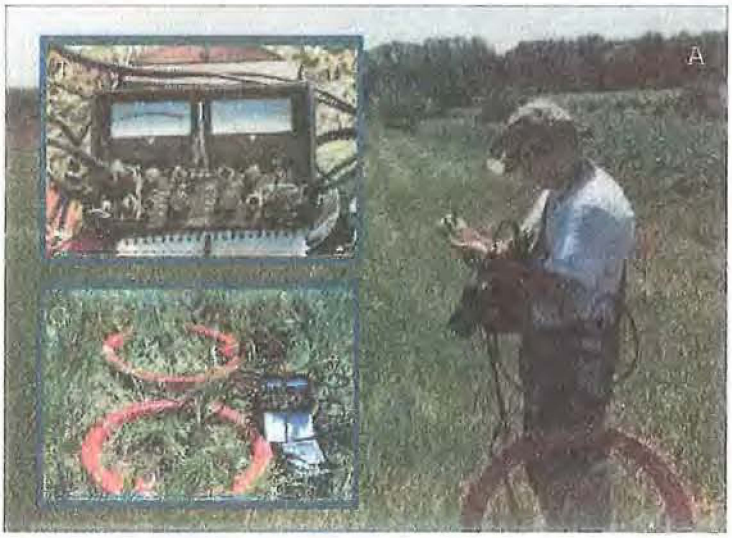


Figure 5A) EM operator recording signal on the receiving end of coil. 5B) The EM receiving equipment. 5C) Both EM transmitting and receiving coil with polyrecorder.

well the signal conducted through different sediment types was due to differences in grain size, pore spaces, and levels of saturation. For example, silts were more conductive than gravel.

The potential depth of the deposit determined the coil spacing. There were three different coil spacings to choose from: 10, 20, or 40 meters. The larger the coil spacing the deeper the magnetic pulse penetrated into the ground. Since the gravel deposit is located in the upper six feet, a 10 meter coil space was used.

Before conducting the survey a 10 meter grid pattern was laid out on the parcel. One person operated the transmitter and a second person operated the receiver while standing exactly 10 meters apart. The readings represented the half way point between the two people. Two readings were taken per station; a horizontal reading and a vertical reading. The horizontal mode recorded the conductivity in 7.5 meters (24.5 feet) of sediment. The vertical mode recorded the conductivity of the lower 15 meters (49 feet) of sediment (McNeil, 1980). The results of this survey is processed using the computer software Surfer. Surfer shows the change of sediment laterally and at depth with different shades of gray (Appendix B).

Field Work

Additional field work included visiting the surrounding gravel pits and surveying the location of drill holes. Observations were made of exposed active and inactive gravel pits in the surrounding area. Surrounding gravel pits exposed cross sections of the deposit that was being evaluated. Additional field work included a survey crew that located the x, y, and z coordinates of the drill holes.

Laboratory Analysis

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

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.

Sample	Test	Depth	Composite
1	7	1-6	
2	8	1-9	Composite 1
3	9	0-8	(Area 1)
4	18	0-10	
5	33	2-5	
6	34	2-7	Composite 2
7	42	1-4	(Area 2&3)
8	52	2-4	
9	44	1-6	
10	45	2-5	Composite 3
11	61	2-5	(Area 4&5)
12	1	1-4	
13	2	1-4	
14	3	0.5-4	
15	10	1-7	
16	11	2-7	Composite 4
17	20	2-6	(Area 6)
18	21	2-4	
19	28	1.5-6	
20	59	1-4	
21	63	2- 4.5	

Table 1. Sample combinations that form composites.

Computer Analysis

The data from geologic logs and laboratory analyses were entered into a database. The data was then processed in TechBase which outlined various areas of gravel and calculated the cubic yardage of each area (in Table 3, areas are listed with corresponding composites). The method used by TechBase processes data and projects an estimated depth of gravel into a "cell." The cell represented an area of 10 ft by 10 ft. The projection was based on information gathered from two or more of the closest bore holes which kriged a value into the cell. Since there were quite a few drill holes with 3 feet or less of sand and gravel, a buffer was used to ignore those holes. Therefore, the outlined areas of sand and gravel were 3 feet or greater in depth.

RESULTS

Geologic Characteristics

The Big Falls site consists of pockets or isolated areas of sand and gravel. The gravel is on the surface with negligible overburden (Plate I). The area of sand and gravel are separated silts, fine sands and thin gravel. The depths of the deposits range from .5 to 10 feet. There are six areas that contain gravel of thicknesses greater than 3 feet. Four of the six areas, 1, 2, 5, and 6, are approximately 10,000 cubic yards are greater. The smaller deposits, areas 3 and 4, are

relatively shallow with the first foot being mostly oxidized sand. From the drilling log, the larger deposits, areas 1, 2, 5, and 6, are adjacent and to the north of the current gravel pit.

Underlying the sand and gravel is either a massive, homogeneous layer of well sorted, fine, white sand, or a tan/gray silt, or a blue gray silt containing various sized rocks. The fine white sand is interpreted as beach sands. The tan/gray silts are lake deposits and the blue/gray silt with rocks is interpreted as being washed or modified till (sediments deposited by glaciers). The dominant lithology of the gravel particles is limestone.

Areas Suitable for Mining	Bore Holes in Area	Volume (Cubic Yards)
1	7-9, 18	20,435
2	33, 34, 42, 52	16,013
5	44, 45, 61	9,503
6	1-3, 10, 11, 20, 21, 28, 59, 6 3	23,930
Total		**69,881**

Table 2. Volume calculations for areas suitable for mining

Volume Estimates

The volume estimates for potential mining areas are summarized in Table 2. The location of these areas can be seen in Plate I. The estimated volume for areas determined suitable for mining is approximately 70,000 cubic yards $\pm$ 15%. This calculation does not include the estimated volumes for area 3 and area 4 (3,026 and 1,490 cubic yards respectively). These deposits are relatively shallow with the upper layers being heavily oxidized and were interpreted unsuitable for mining.

Areas of gravel were ascertained using data gathered from the drill logs and survey crew. To determine the volume for each area, the geographical location of the drill holes and the surface elevations were entered into TechBase. This roughly corresponds to the x, y, z, coordinates of the drill holes. Then the depth of gravel is calculated in relationship to drill location to produce an estimate of volume. It is important to note that the volume estimate is a statistical model that represents the geologic boundaries. These boundaries are approximate with an error of $\pm$ 15%. For example, Area 1 does not include all of the gravel under the stockpile and under the berms that surround the gravel pit. These potential gravel bodies are not included in the TechBase calculation due to the inaccessibility to the data. Since the drill rig could not drill through the stockpile and berms to reach the underlying deposit; therefore no data was gathered in those areas. With the lack of data, TechBase can not accurately project and determine volume of gravel in those areas; therefore the calculations under represent the true volume of the deposit.

Electromagnetic Study

The geophysical study further helps to define textural variations. The study focuses on approximately 10 acres of land to the east and directly north of the gravel pit. There are two data sets that can be derived from the geophysics: data collected in the horizontal mode and data collected in the vertical mode. As previously stated, the horizontal mode reflects changes in 24 feet of sediment and the vertical mode reflect changes in 24-49 feet of sediment. The results of the horizontal mode show two areas of low conductivity separated by a ridge of material with a higher conductivity (Appendix B). The lower conductive material is interpreted as sand and

Figure 6

Areas Suitable for Mining Based on Geological Interpretations

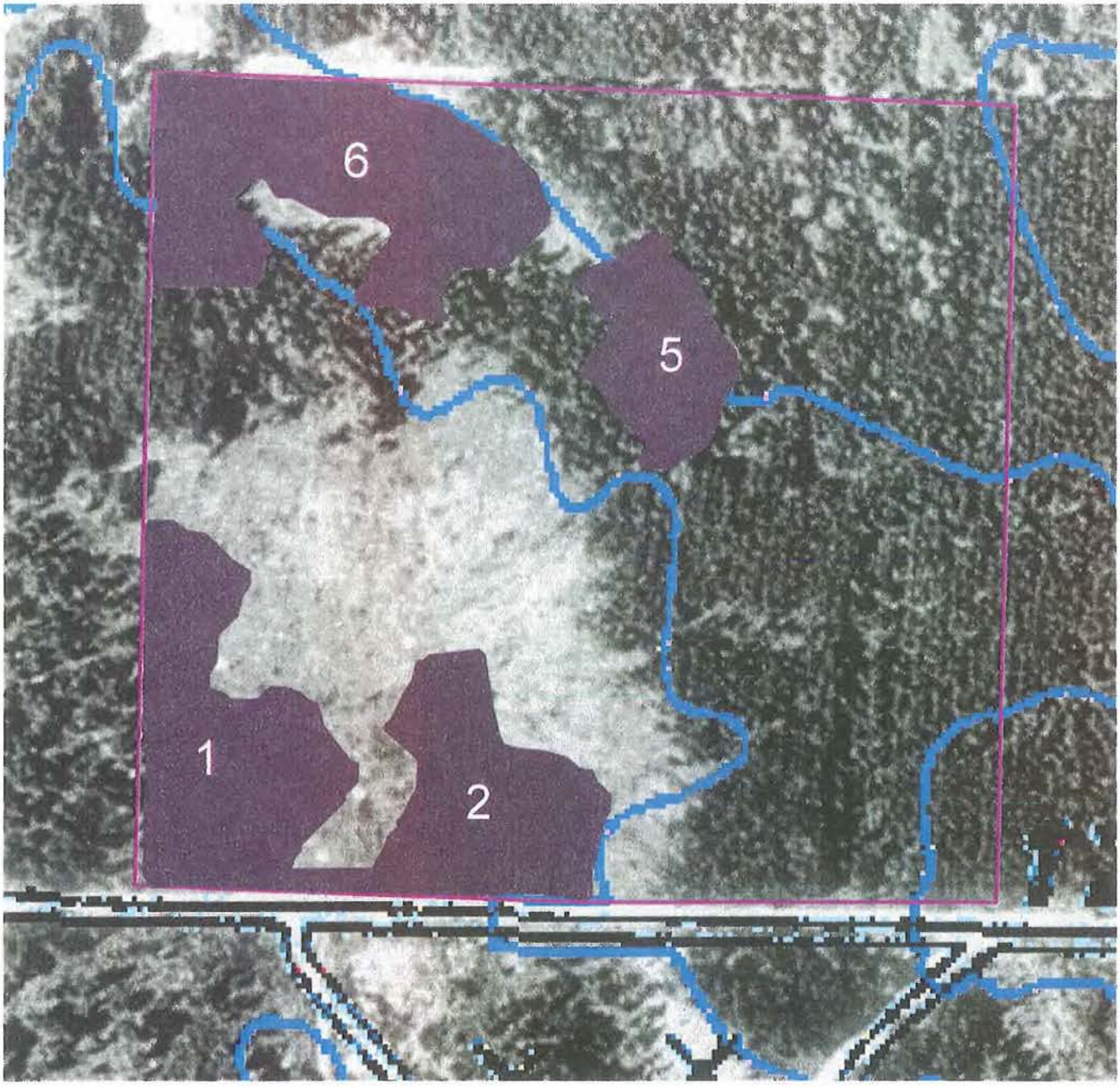


TABLE 3
MNDOT LABORATORY RESULTS

GRADATIONS:

Sieve Inches	Size Metric	BH 1	BH 2	BH 3	BH 7	BH 8	BH 9	BH 10	BH 11	BH 18	BH 20	BH 21	BH 28	BH 33	BH 34	BH 42	BH 44	BH 45	BH 52	BH 59	BH 61	BH 63
3	75mm							100														
2 1/2	63mm	100			100			96				100				100	100	100		100		
2	50mm	98	100		98	100	100	84	100	100		97	100	100		98	91	97	100	98	100	100
1 1/2	37.5mm	98	99		94	99	99	84	98	99	100	95	95	99	100	94	87	96	99	96	97	98
1 1/4	31.5mm	97	97	100	93	97	99	80	98	98	99	92	93	99	97	93	85	96	98	89	95	97
1	25mm	96	96	99	90	95	99	77	97	95	97	90	89	98	95	91	84	94	93	85	95	97
3/4	19mm	94	94	98	89	93	99	74	97	91	95	88	83	97	92	91	83	91	90	78	94	96
5/3	16mm	94	93	98	87	91	99	72	96	89	92	86	80	96	89	91	82	90	88	74	93	95
1/2	12.5mm	93	92	97	84	88	99	69	94	84	88	83	76	95	85	90	81	88	83	68	90	92
3/8	9.5mm	92	90	96	80	85	98	67	92	79	83	80	72	93	81	88	79	85	79	62	89	89
#4	4.75mm	88	86	93	70	74	93	61	85	66	75	72	62	78	71	80	75	76	69	51	84	80
#8	2.36mm	82	77	88	55	60	78	52	77	54	67	62	53	56	62	65	71	68	59	42	79	72
#10	2mm	80	75	86	52	57	74	49	75	51	65	59	51	51	59	61	69	65	57	39	78	69
#16	1.18mm	72	65	79	42	47	59	40	68	40	59	52	45	38	48	49	61	58	50	33	72	64
#30	600um	61	50	68	27	30	43	27	56	17	51	43	37	25	25	38	48	47	43	25	58	56
#40	425um	55	41	60	21	24	38	20	46	13	46	36	31	22	15	34	38	37	36	23	47	49
#50	180um	35	28	42	17	18	28	16	28	11	26	26	20	19	9	27	20	22	23	19	26	30
#100	150um	5	8	8	7	5	4	6	6	4	4	8	5	7	3	11	5	8	6	5	6	6
#200	75um	2.7	4.6	4.2	3.6	2.5	1.8	3.7	3.5	1.8	1.8	4.4	2.9	4.1	1.4	6.4	3.2	5.9	3.4	2.5	3.7	3.9

OTHER MNDOT TESTS:

TESTS (% by mass)	COMPOSITES 1	2	3	4	SPECS*
% Shale 1/2" +	0.04	0.00		0.10	<0.40
% Shale in Sand	N.C	N.C		N.C	
% Shale Total	0.00	0.00		0.10	<0.70
% Iron Oxide 1/2+	0.21	0.40		0.40	<0.30
% Iron Oxide #4	0.30	0.40		0.20	<0.30
% Ochre 1/2+	0.21	0.00			
% Ochre #4	0.10	0.00			
% Unsound Chert #4	0.05	0.00		0.50	
% Spall 1"	0.00	0.00		0.00	
% Spall 1/2"	0.30	0.40		0.40	
% Spall #4	0.40	0.40		0.70	

TESTS (% by mass)	COMPOSITES 1	2	3	4	SPECS*
Blk SpG +4	2.616	2.605	2.643	2.611	
App. SpG +4	2.760	2.757	2.772	2.744	
% Absorbt +4	2.000	2.110	1.760	1.840	
% Absorbt -4	0.920	0.940	1.110	0.940	
Bulk SpG -4	2.647	2.603	2.560	2.581	
App. SpG -4	2.713	2.668	2.634	2.646	
Total Bulk SpG				2.611	
LAR B-Pct Loss				26.25	<40
Mag% Loss 1 1/2-1				1.900	<15
Mag% Loss 1-3/4				1.380	<15

COMPOSITED BORE HOLES

COMPOSITE 1: BH 7-9, BH 18 (Area 1)

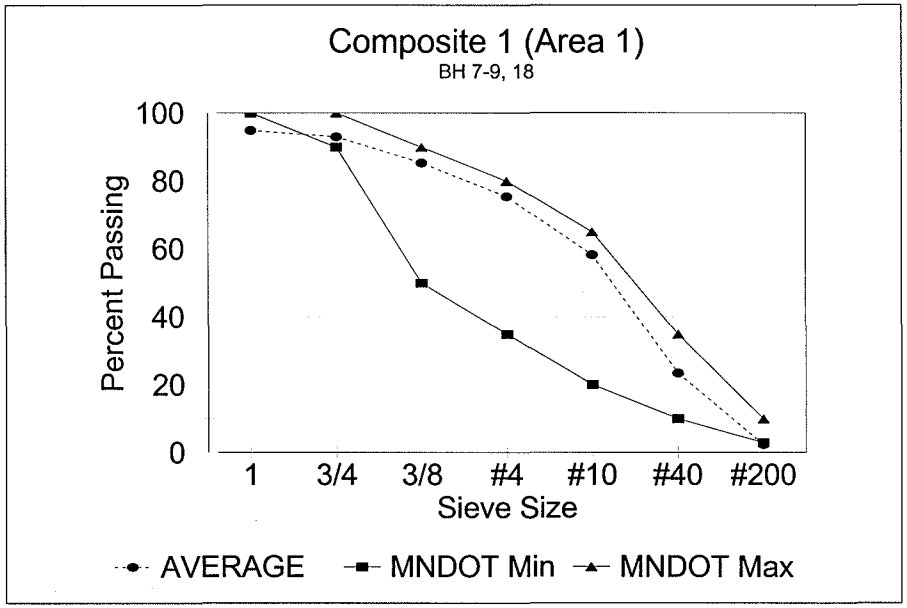
COMPOSITE 2: BH 33, BH 34, BH 42, BH 52 (Area 2&3)

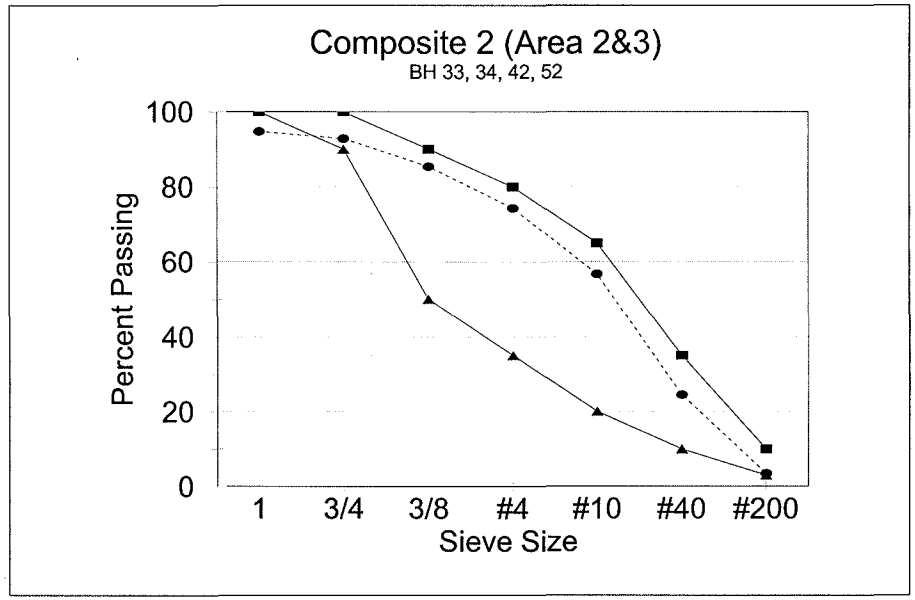
COMPOSITE 3: BH 44, BH 45, BH 61 (AREA 4&5)

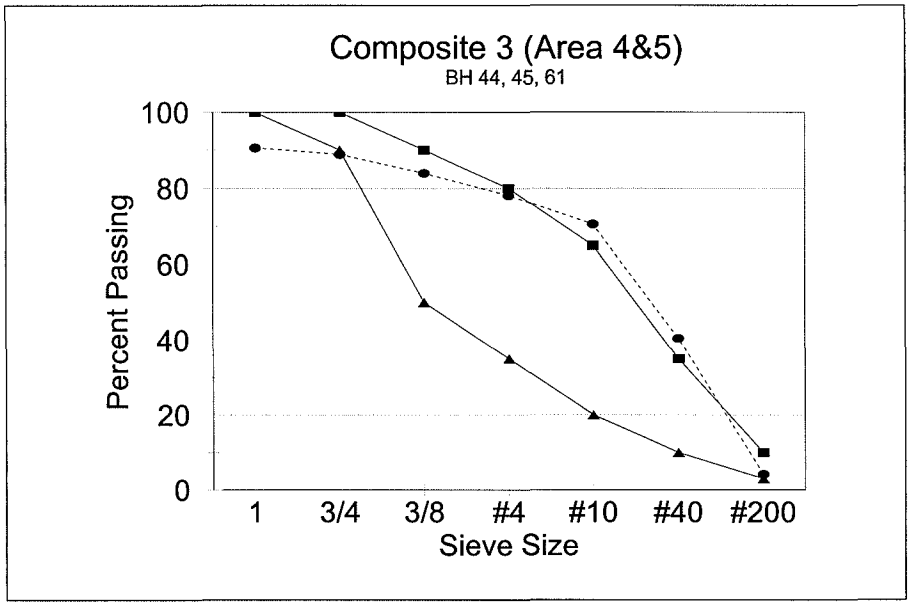
COMPOSITE 4: BH 1-3, BH 10, BH 11, BH 20, BH 21, BH 28, BH 59, BH 63 (Area 6)

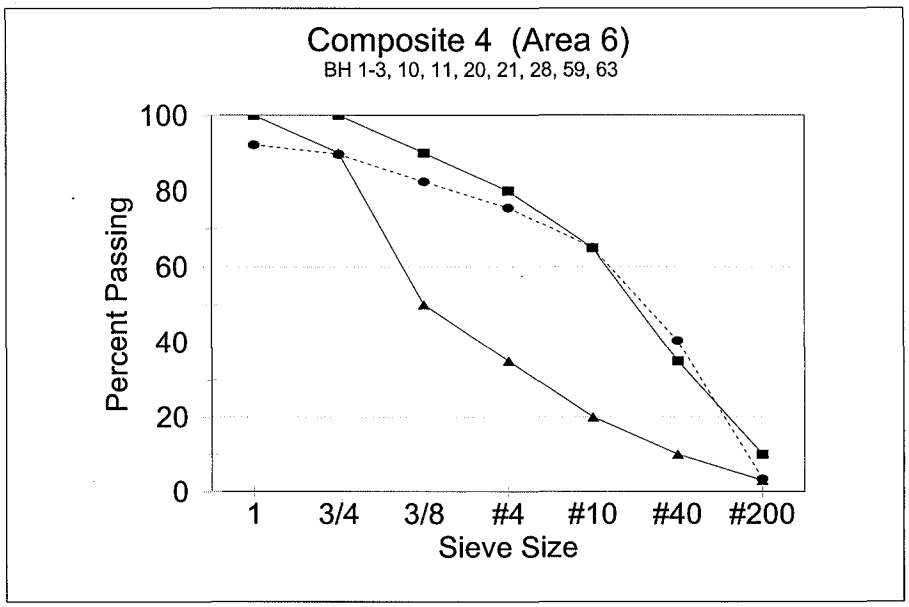
* SPECS: MNDOT specifications for concrete.
Test results are recorded in percentage by mass.

Figure 7. MNDOT Class 5 Aggregate Composited Averages vs MNDOT Standards









gravel and the higher conductive material is interpreted as silt. The orientation of the ridge of silt is parallel to the orientation of the glacial lake beach line. Results from the horizontal mode correspond well with the bore hole data: gravel areas outlined by TechBase overlap the shaded areas of low conductivity and confirm the general location of the gravel in areas 2 and 6.

The vertical mode shows similar trends: areas of lower conductivity separated by a ridge of higher conductivity. Although the vertical mode recorded low conductive material at depth, it is important to note that no gravel was found at depth. Indicated by the geologic log, the low conductive material recorded in the vertical mode is the fine, homogeneous, beach sand. The conductivity between the moist fine sand and the gravel does not notably vary.

Quality Analysis

The quality of the sand and gravel helps to determine the various usages of the deposit. Tests performed at MNDOT include: coarse and fine gradations, coarse and fine spall content, lithologic exam, shale float test, LAR and magnesium sulfate.

The results of the coarse and fine lithologic exam are listed in Table 3. The gradation table lists sampled bore holes, sieve sizes and the percent of material passing through each sieve. The data indicates that samples taken from bore holes around the current gravel pit have higher percentages of gravel (Appendix C). The average percentage of gravel for these areas (Area 1 and 2) are approximately 42% gravel. Area 6, the largest deposit, contains approximately 35% gravel. Comparing the gradations of the sand and gravel to the MNDOT specifications for Class 5 usage, the gravel deposits exceed some of the maximum grain size specifications (Figure 6). Therefore, mixing the deposit with finer material (sand and silts) is recommended.

The results of the remaining tests indicate the gravel deposit is a high quality deposit and meets most of the MNDOT specifications for concrete and bituminous mixtures. There are two points of concern. One, there are high amounts of iron oxide. Two, the amount of shale conflicts with geologic observations. The shale float test only records minor traces of shale in the deposit. In the field, several large rocks of shale were observed and seemed abundant within the deposit. The difference between observation and laboratory tests may be due to the size of the shale. The observed rocks were large and may not have broken down into smaller particles. However, shale is very friable and can break easily when handled. If used for concrete or bituminous mixtures, the aggregate mixture would need further testing for both iron oxide and shale.

CONCLUSIONS AND INTERPRETATIONS:

The three primary functions of this geologic survey were to determine how much gravel is left in the existing pit, how much gravel is located on the remaining 35 acres of the parcel, and test the quality of the gravel. Other objectives include determining depth to the water table and overburden thicknesses. The geologic survey includes examining air photos and published maps, drilling, geologic logging, sampling, geophysics, computer analysis and laboratory analysis.

Reviewed below are the results and conclusions of this study:

- The study area is approximately 38.4 acres located west ½ of SW-SE and east ½ of SE-SW of section 23, T155N., R25W.
- The deposit is located on a beach ridge of a large glacial lake. Wave action of the lake reworked previously existing glacial sediments to deposit the sand and gravel.
- The gravel is located in six isolated pockets or areas. The surrounding sediments are fine sands or silts.
- The depth of the deposit is no greater than 8 feet deep.
- Overburden thickness is minimal, approximately 0.5 feet, which is the thickness of the topsoil.
- The volume of the six areas are:
  - Area 1: 20,435 cubic yards
  - Area 2: 16,013 cubic yards
  - Area 3: 3,026 cubic yards
  - Area 4: 1,490 cubic yards
  - Area 5: 9,503 cubic yards
  - Area 6: 23,930 cubic yards
- Areas determined suitable for mining are: 1, 2, 5, and 6.
- The calculated volume for these four areas is 70,000 cubic yards (± 15%).
- This volume estimate does not include gravel in the stockpile and gravel found below the stockpile; therefore the volume calculations under estimates the gravel in Area 1.
- Areas 3 and 4 are not suitable for mining because they are relatively shallow with the first foot being mostly oxidized sand.
- The existing gravel pit contains no gravel at depth; however mining could be continued laterally to the west and east of the pit.
- Depth to the water table is found approximately 20 feet below surface which is well below the maximum depth of the gravel.
- The amount of gravel in the four areas range between 35-42% gravel.
- The dominant lithology of the gravel particles is limestone.
- The gradations of the gravel could meet Class 5 specifications with some minor mixing.
- The gravel meets MNDOT specifications for concrete and bituminous mixtures except for high amounts of iron oxides.
- MNDOT shale float test indicate little shale content, this conflicts with field observations. Field observations noted an abundance of shale with a diameter of 2 inch and greater.
- A geophysic study was focused on the areas east and directly north of the gravel pit.
- Geophysic study (EM work) suggests that gravel is located in the northwest corner of the study area (Area 6) and along the west boundary of the gravel pit (Area 2).
- From the EM results and geologic logging, Area 6 is separated from Area 1 and 2 by a band of silt. This silt deposit is orientated in the same direction as the contours of the beach line.

In conclusion, the gravel resource is of high quality and has a number of end uses. The accessibility of the gravel is very good. There is little overburden, the water table is low, and there are both county and forest roads to service the potential pits. Although the gravel deposit needs some mixing to qualify for MNDOT specifications, the sources for mixing can be found on the site. Both the fine sand and the silt could be used.

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APPENDICES

Appendix A
Drill Hole Descriptions

Report 336-6
Appendix A
Drill Hole Descriptions

Drill Hole	To	From	Description
BH 1	0.00	0.25	Overburden: Very thin, sandy topsoil, dry
	0.25	5.00	S&G: Buff color, well sorted, little silt content,
	5.00	5.25	Rock Layer: Marks contact between S&G and fine sand
	5.25	18.00	Fine Sand: White/buff color, very well sorted, some silt layers, but massive
	18.00	20.00	Silt: Gray well sorted, massive, slightly calcareous
BH 2	0.00	0.25	Overburden: Very thin, sandy topsoil, dry
	0.25	5.00	S&G: Upper foot is oxidized med sand, unit is 30% gravel, lmst- rich, some shale
	5.00	10.00	Silt: Gray in color, well sorted, massive, slightly moist
BH 3	0.00	0.25	Overburden
	0.25	5.00	S&G: Upper foot is oxidized sand, gravel cobble to pea size, rounded, mod sorted
	5.00	7.00	Silt: Gray massive tan mottles, moist, very well sorted.
BH 4	0.00	0.25	Overburden
	0.25	1.50	S&G: Mostly oxidized sand with some gravel, gravel unit is pinching out
	1.50	10.00	Silt: Gray in color, tan mottles, well sorted, massive, slightly moist, calcareous
BH 5	0.00	0.25	Overburden: Very thin, sandy topsoil, dry
	0.25	1.00	S&G: Mostly oxidized sand with some gravel, sharp contact
	1.00	6.00	Silt: Gray in color, tan mottles, well sorted , massive, slightly moist, calcareous
BH 6	0.00	0.25	Overburden
	0.25	3.00	S&G: Very course sand and gravel, %50 gravel, oxidized
	3.00	8.00	Silt: Gray in color, massive, dry, some sand grit
	8.00	10.00	Fine Sand: White in color, well sorted, massive
BH 7	0.00	0.25	Overburden
	0.25	7.00	S&G: First foot ox. sand, unit is 30% gravel, pea to cobble, little silt content
	7.00	8.00	Fine Sand: White in color, well sorted, massive
BH 8	0.00	8.00	S&G: First foot ox. sand, unit is 30-40% gravel, pea to cobble, little silt content
	8.00	10.00	Fine Sand: White in color, well sorted, massive
BH 9	0.00	8.00	S&G: Unit is 30-40% gravel, pea to cobble size, grades coarser, hit rock layer
	8.00	9.00	Fine Sand: White in color, well sorted, massive
BH 10	0.00	0.25	Overburden
	0.25	7.00	S&G: Upper foot is oxidized sand, gravel cobble to pea size, rounded, mod sorted
	7.00	7.25	Rock Layer
	7.25	8.00	Fine Sand: White in color, well sorted, massive
BH 11	0.00	0.25	Overburden
	0.25	8.00	S&G: Upper foot is oxidized sand, 30% cobble to pea size, rounded, mod sorted
	8.00	9.00	Silt: Gray in color, massive, dry, some sand grit, calcareous
BH 12	0.00	0.25	Overburden
	0.25	2.00	S&G:Mostly oxidized sand with some pebbles
	2.00	2.25	Rock Layer
	2.25	5.00	Silt: Hard silt with some rocks, rx are mafic, mottled
BH 13	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly oxidized sand with some pebbles
	2.00	5.00	Silt: Gray, calcareous, mottled
BH 14	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly oxidized sand with some gravel
	2.00	5.00	Silt: Gray, calcareous, mottled, massive
BH 15	0.00	0.25	Overburden
	0.25	3.00	S&G: Very coarser, 50% gravel, capped by oxidated sand layer
	3.00	3.25	Rock Layer
	3.25	5.00	Fine Sand: White in color, well sorted, massive
BH 16	0.00	0.25	Overburden
	0.25	3.00	S&G: Very coarser, large cobbles present
	3.00	3.25	Rock Layer
	3.25	5.00	Fine Sand: White in color, well sorted, massive

Drill Hole	To	From	Description
BH 17	0.00	0.25	Overburden
	0.25	5.00	Fine Sand: White in color, well sorted, massive
	5.00	6.00	Silt: Thin layer
	6.00	10.00	Fine Sand: White in color, well sorted, massive
BH 18	0.00	10.00	S&G: Well sorted, coarse sand matrix, 40% gravel, grades finer
	10.00	12.00	Fine Sand: white in color, well sorted, massive
BH 19	0.00	0.25	Overburden
	0.25	2.00	Sand and Gravel: Brown oxidized sand, med to coarse grained, 5% gravel
	2.00	5.00	Fine Sand: White in color, well sorted, massive, occasional silt layers
BH 20	0.00	0.25	Overburden
	0.25	6.00	S&G: Tan in color, 35% gravel, grades finer with depth, sand matrix is med grained
	6.00	7.00	Fine Sand: White in color, well sorted, massive
BH 21	0.00	0.25	Overburden
	0.25	4.00	S&G: Tan in color, 30% gravel, gravel is pea to cobble
	4.00	5.00	Silt: Moist, gray, no rocks, massive well sorted
BH 22	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown oxidized sand with some pea sized pebbles
	2.00	5.00	Silt: Moist, gray, no rocks, massive, mottled, well sorted
BH 23	0.00	0.25	Overburden
	0.25	1.50	S&G: Mostly brown oxidized sand with some pea sized pebbles
	1.50	5.00	Silt: Moist, gray, no rocks, massive, mottled, well sorted
BH 24	0.00	0.25	Overburden
	0.25	1.50	S&G: Mostly brown oxidized sand with some pea sized pebbles
	1.50	5.00	Fine Sand: White in color, well sorted, massive
BH 25	0.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous
BH 26	0.00	19.00	Fine Sand: White in color, well sorted, massive, very homogenous
	19.00	20.00	Silt: Wet, hit water table, well sorted, dark gray
BH 27	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown oxidized sand with some pea sized pebbles
	2.00	6.00	Silt: Well sorted, massive, gray, moist
	6.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous
BH 28	0.00	0.25	Overburden
	0.25	6.00	S&G: First foot ox. sand, unit is 30% gravel, pea to cobble, little silt content
	6.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous
BH 29	0.00	0.25	Overburden
	0.25	3.00	S&G: Mostly brown oxidized sand with some pea sized pebbles
	3.00	8.00	Silt: Well sorted, massive, gray, moist
	8.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous
BH 30	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown oxidized sand with some pea sized pebbles
	2.00	6.00	Silt: well sorted, massive, gray, moist
BH 31	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown oxidized sand with some pea sized pebbles
	2.00	8.00	Silt: Well sorted, massive, gray, moist
BH 32	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown oxidized coarse sand with some pea sized pebbles
	2.00	5.00	Fine Sand: white in color, well sorted, massive, very homogenous
BH 33	0.00	0.25	Overburden
	0.25	5.50	S&G: First foot ox med. sand, 40% gravel, dry, clean, mod sorted
	5.50	6.00	Silt: Well sorted, massive, gray, moist
BH 34	0.00	0.25	Overburden
	0.25	7.00	S&G: First foot ox med. sand, 40% gravel, pea to cobble, dry, clean, mod sorted
	7.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous
BH 35	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown oxidized coarse sand with some pea sized pebbles
	2.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous
BH 36	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown oxidized coarse sand with some pea sized pebbles
	2.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous

Drill Hole	To	From	Description
BH 37	0.00	0.25	Overburden
	0.25	1.00	S&G: Mostly brown oxidized coarse sand with some pea sized pebbles
	1.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous
BH 38	0.00	0.25	Overburden
	0.25	6.00	Silt: Well sorted, massive, gray, moist
	6.00	20.00	Fine Sand: White in color, well sorted, massive, very homogenous, moist
BH 39	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown oxidized coarse sand with some pea sized pebbles
	2.00	6.00	Fine Sand: White in color, well sorted, massive, very homogenous, moist
	6.00	10.00	Silt: Well sorted, massive, gray, moist
BH 40	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown, oxidized, coarse sand with some pea sized pebbles
	2.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous, moist
BH 41	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown, oxidized, coarse sand with some pea sized pebbles
	2.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous, moist
BH 42	0.00	0.25	Overburden
	0.25	4.00	S&G: First foot is ox. sand, 40% gravel, pea to cobble size, dry, little silt
	4.00	6.00	Silt: Well sorted, massive, gray, moist
	6.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous, moist
BH 43	0.00	0.25	Overburden
	0.25	1.00	S&G: Mostly brown, oxidized, coarse sand with some pea sized pebbles
	1.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous, moist
BH 44	0.00	0.25	Overburden
	0.25	6.00	S&G: First foot ox med. sand, 10% gravel, pea to cobble, dry, some mixing with white sand
	6.00	8.00	Silt: Well sorted, massive, tan, moist
	8.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous, moist
BH 45	0.00	0.25	Overburden
	0.25	5.00	S&G: First foot ox med. sand, gravel seems to be mixed with fine sand
	5.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous, moist
BH 46	0.00	0.25	Overburden
	0.25	3.00	S&G: First foot ox med. sand, wet, coarse,
	3.00	9.00	Silt: Well sorted, massive, tan, moist, crumbly at depth
	9.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous, moist
BH 47	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown, oxidized, coarse sand with some pea sized pebbles
	2.00	6.00	Silt: Well sorted, massive, gray, moist, crumbly at depth
	6.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous, dry
BH 48	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown, oxidized, coarse sand with some pea sized pebbles
	2.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous,
BH 49	0.00	0.25	Overburden
	0.25	10.00	Fine Sand: Upper 5 feet seem to be ox., some silt balls present, well sorted
BH 50	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown, oxidized, coarse sand with some pea sized pebbles
	2.00	4.00	Fine Sand: White in color, well sorted, massive, very homogenous, grades into a gravel
	4.00	5.00	S&G: Thin gravel layer, dry, 30% gravel, rounded, similar to previously described
	5.00	8.50	Silt: Well sorted, massive, gray, moist, calcareous
	8.50	10.00	Fine Sand: White in color, well sorted, massive, very homogenous
BH 51	0.00	0.25	Overburden
	0.25	4.00	S&G: Thin gravel layer, mixed with med. sand tan in color
	4.00	4.25	Rock Layer
	4.25	10.00	Diamict: Blue/tan silt with rocks, v. calcareous, moist, grades into well sorted silt
BH 52	0.00	0.25	Overburden
	0.25	4.00	S&G: First foot ox med. sand, wet, coarse, 40% gravel, pea to pebble matrix
	4.00	10.00	Diamict: Blue/tan silt with rocks, v. calcareous, moist, grades into well sorted silt
BH 53	0.00	0.25	Overburden
	0.25	3.00	S&G: Brown ox. sand over a lense of gravel, 40% gravel, mostly pea size
	3.00	10.00	Silt: Well sorted, massive, gray, moist, calcareous

Drill Hole	To	From	Description
BH-54	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown ox. sand with some pea sized gravel
	2.00	4.00	Silt: Well sorted, massive, gray, powdery with rust mottles
	4.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous
BH-55	0.00	0.25	Overburden
	0.25	3.00	S&G: Mostly brown ox. sand with some pea sized gravel
	3.00	10.00	Diamict: Blue/tan silt with rocks, v. calcareous, moist, grades into well sorted silt
BH-56	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown ox. sand with some pea sized gravel
	2.00	20.00	Blue Diamict: silt matrix with rocks and sand, moist, difficult to drill
BH-57	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown ox. sand with some pea sized gravel
	2.00	2.25	Rock Layer
	2.25	8.00	Diamict: Blue/tan silt with rocks, v. calcareous, moist, grades into well sorted silt
BH-58	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown ox. sand with some pea sized gravel
	2.00	8.00	Silt: Well sorted, massive, tan, powdery with rust mottles, some interfingering with sands
	8.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous
BH-59	0.00	0.25	Overburden
	0.25	4.00	S&G: First foot ox med. sand, coarse, 30% gravel, fine gravel- mostly pea
	4.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous
BH-60	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly oxidized sand with few pebbles
	2.00	6.00	Silt: Well sorted, massive, tan,
	6.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous
BH-61	0.00	0.25	Overburden
	0.25	5.00	S&G: First foot ox med. sand, coarse, 20% gravel
	5.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous
BH-62	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown ox. sand with some pea sized gravel
	2.00	2.25	Rock Layer
	2.25	5.00	Silt: Well sorted, massive, tan
	5.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous
BH-63	0.00	0.25	Overburden
	0.25	4.50	S&G: First foot ox med. sand, coarse, grades into silt
	4.50	10.00	Silt: Well sorted, tan with white mottles, moist
BH-64	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly oxidized sand with few pebbles
	2.00	10.00	Diamict: Blue/tan silt with rocks, v. calcareous, moist, grades into well sorted silt
BH-65	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly oxidized sand with few pebbles
	2.00	5.00	Fine Sand: White in color, well sorted, massive, very homogenous
BH-66	0.00	0.25	Overburden
	0.25	8.00	S&G: First foot ox med. sand, dry, v. coarse, out of study area
	8.00	10.00	Fine Sand: White in color, well sorted, massive, very homogenous
GP-1	0.00	2.00	S&G: Mostly brown ox. sand with some pea sized gravel,
	2.00	12.00	Fine Sand: White in color, well sorted, massive, very homogenous
GP-2	0.00	0.50	S&G: Thin layer left to armor fine sand.
	0.50	13.00	Fine Sand: White in color, well sorted, massive, very homogenous
GP-3	0.00	6.00	S&G: First foot ox med. sand, dry, v. coarse, 30-40% gravel
	6.00	6.25	Rock Layer
GP-4	0.00	0.25	Overburden
	0.25	5.00	S&G: First foot ox med. sand, 30-40% gravel, seem to be in lenses
	5.00	5.25	Rock Layer
	5.25	9.00	Fine Sand: White in color, well sorted, massive, very homogenous
GP-5	0.00	0.25	Overburden
	0.25	5.00	S&G: First foot ox med. sand, 30-40% gravel, rocks go from cobble to pea
	5.00	7.00	Fine Sand: White in color, well sorted, massive, very homogenous

Drill Hole	To	From	Description
GP-6	0.00	0.25	Overburden
	0.25	4.00	Fine Sand: White in color, well sorted, massive, very homogenous
	4.00	9.00	Silt: Well sorted, tan with white mottles, moist
GP-7	0.00	0.25	Overburden
	0.25	6.00	S&G: First foot ox med. sand, 20-30% gravel in med. sand matrix, difficult to drill
	6.00	7.00	Fine Sand: White in color, well sorted, massive, very homogenous
GP-8	0.00	0.25	Overburden
	0.25	6.00	S&G: First foot ox med. sand, 30-40% gravel in med. sand matrix, difficult to drill
	6.00	8.00	Fine Sand: White in color, well sorted, massive, very homogenous
GP-9	0.00	0.25	Overburden
	0.25	7.00	Fine Sand: White in color, well sorted, massive, very homogenous
	7.00	9.00	Silt: Well sorted, tan with white mottles, moist
GP-10	0.00	0.25	Overburden
	0.25	3.00	S&G: First foot ox med. sand, 30-40% gravel in silty/sand matrix
	3.00	5.00	Silt: Well sorted, tan with white mottles, moist
GP-11	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown ox. sand with some pea sized gravel
	2.00	5.00	Silt: Well sorted, tan with white mottles, moist
GP-12	0.00	0.25	Overburden
	0.25	2.00	S&G: Mostly brown ox. sand with some pea sized gravel
	2.00	6.00	Silt: Well sorted, tan with white mottles, moist
GP-13	0.00	0.25	Overburden
	0.25	3.00	S&G: Mostly brown ox. sand with some pea sized gravel, last foot 20% gravel
	3.00	6.50	Diamict: Blue/tan silt with rocks, v. calcareous, moist, grades into well sorted silt
GP-14	0.00	1.00	Overburden
	1.00	3.00	S&G: Mostly brown ox. sand with some pea sized gravel, last foot 5% gravel
	3.00	8.00	Silt: Blue/gray clayey silt, massive, tan mottles, well sorted, similar to diamict
	8.00	9.00	Fine Sand: White in color, well sorted, massive, very homogenous
GP-15	0.00	0.25	Overburden
	0.25	3.00	Fine Sand: White in color, well sorted, massive, very homogenous
	3.00	7.00	Silt: Well sorted, tan, massive
GP-16	0.00	0.25	Overburden
	0.25	6.50	S&G: First foot ox med. sand, 30-40% gravel in med. sand matrix, lmst rich
	6.50	7.00	Fine Sand: White in color, well sorted, massive, very homogenous
GP-17	0.00	0.25	Overburden
	0.25	4.50	S&G: First 2 ft ox med. sand, 30-40% gravel in med. sand matrix, lmst rich
	4.50	6.00	Silt: Well sorted, tan, massive
GP-18	0.00	0.25	Overburden
	0.25	9.00	Fine Sand: White in color, well sorted, massive, very homogenous
GP-19	0.00	1.00	Overburden
	1.00	3.00	S&G: First foot ox med. sand, 15% gravel in sand matrix, pea size, lmst rich
	3.00	6.00	Silt: Well sorted, blue/tan, massive, clayey, moist
GP-20	0.00	0.25	Overburden
	0.25	5.00	S&G: First foot ox med. sand, 20% gravel in sand matrix, pea size, lmst rich
	5.00	5.25	Rock Layer
GP-21	0.00	0.25	Overburden
	0.25	5.00	S&G: First foot ox med. sand, 20% gravel in sand matrix, pea size, lmst rich
	5.00	7.00	Diamict: Blue/tan silt with rocks, v. calcareous, moist, grades into well sorted silt
GP-22	0.00	0.25	Overburden
	0.25	4.00	S&G: First 3 feet ox med. sand, 20% gravel in sand matrix, pea size, lmst rich
	4.00	5.50	Silt: Well sorted, tan, massive, moist
GP-23	0.00	1.00	Overburden
	1.00	5.00	S&G: First 3 feet ox med. sand, 15% gravel in sand matrix, pea size, lmst rich
	5.00	6.00	Silt: Well sorted, tan, massive, moist
GP-24	0.00	0.25	Overburden
	0.25	5.00	S&G: First foot ox med. sand, 30% gravel in sand matrix, cobble-pea size, lmst rich
	5.00	6.00	Fine Sand: White in color, well sorted, massive, very homogenous

Appendix B
Geophysical Data

LINES: Go west to east (left to right) from line11 to line 20.

STATIONS: Go south to north (down to up). Lines 11-15 start at station 20 and end at station 40. Line 16 start at station 1 and end at station 30. Lines 17-20 start at station 1 and end at station 20.

Geophysical Readings
Recorded October 1999

Line	Station	Line (m)	Station (m)	Vert (mS/m)	Horz (mS/m)
19	1	190	10	5.78	3.23
19	2	190	20	5.32	1.81
19	3	190	30	5.32	2.56
19	4	190	40	4.86	3
19	5	190	50	3.97	4.28
19	6	190	60	4.54	4.04
19	7	190	70	5.08	4.05
19	8	190	80	5.03	4.14
19	9	190	90	4.98	4.14
19	10	190	100	5.3	3.85
19	11	190	110	4.67	3.79
19	12	190	120	4.95	4.01
19	13	190	130	4.43	3.78
19	14	190	140	4.8	3.63
19	15	190	150	4.47	3.39
19	16	190	160	4.69	3.72
19	17	190	170	5.1	4.03
19	18	190	180	4.86	5.46
19	19	190	190	6.71	6.94
19	20	190	200	6.23	6.93
20	1	200	10	7.19	4.59
20	2	200	20	4.59	3.25
20	3	200	30	5.23	3.4
20	4	200	40	4.76	3.52
20	5	200	50	5.16	4.11
20	6	200	60	5.39	4.2
20	7	200	70	4.97	3.95
20	8	200	80	3.6	3.63
20	9	200	90	4.85	3.92
20	10	200	100	4.94	3.69
20	11	200	110	4.27	3.57
20	12	200	120	4.84	3.89
20	13	200	130	4.63	3.95
20	14	200	140	5.18	3.95
20	15	200	150	5.53	3.87
20	16	200	160	4.28	4.02
20	17	200	170	6.08	5.4
20	18	200	180	5.64	6.24
20	19	200	190	7.39	7.45
20	20	200	200	7.88	8.63
18	1	180	10	6.02	4.6
18	2	180	20	5.94	4.09
18	3	180	30	6	3.86
18	4	180	40	5.27	3.67
18	5	180	50	4.88	4.39
18	6	180	60	5.35	4.67
18	7	180	70	5.6	4.16
18	8	180	80	4.92	3.71
18	9	180	90	5.19	3.69
18	10	180	100	5.1	3.8
18	11	180	110	5.4	4.37

Geophysical Readings
Recorded October 1999

18	12	180	120	5.3	4.11
18	13	180	130	5.56	4.16
18	14	180	140	5.1	3.44
18	15	180	150	4.42	3.69
18	16	180	160	4.66	3.93
18	17	180	170	5.13	3.48
18	18	180	180	5.34	4.22
18	19	180	190	5.62	6.02
18	20	180	200	6.25	6.22
17	1	170	10	6.42	4.23
17	2	170	20	6.37	4.07
17	3	170	30	6.43	4.02
17	4	170	40	6.03	3.8
17	5	170	50	5.25	4.12
17	6	170	60	5.82	4.37
17	7	170	70	5.74	4.31
17	8	170	80	5.56	3.96
17	9	170	90	5.25	3.71
17	10	170	100	5.95	4
17	11	170	110	5.2	3.79
17	12	170	120	5.81	4.1
17	13	170	130	5.73	4.17
17	14	170	140	4.96	3.86
17	15	170	150	4.98	3.93
17	16	170	160	4.95	3.9
17	17	170	170	5.09	3.74
17	18	170	180	5.2	3.46
17	19	170	190	5.28	3.97
17	20	170	200	5.42	5.48
16	1	160	10	6.74	4.54
16	2	160	20	6.64	3.95
16	3	160	30	6	3.78
16	4	160	40	5.96	3.56
16	5	160	50	5.67	3.94
16	6	160	60	4.74	4.3
16	7	160	70	5.28	4.18
16	8	160	80	5.41	3.89
16	9	160	90	5.54	3.96
16	10	160	100	12.21	3.98
16	11	160	110	8.7	4.1
16	12	160	120	5.78	3.99
16	13	160	130	6.03	4.22
16	14	160	140	5.45	4.17
16	15	160	150	4.89	4.06
16	16	160	160	5.27	3.76
16	17	160	170	5.29	3.64
16	18	160	180	4.63	4.17
16	19	160	190	5.3	5.09
16	20	160	200	7.54	5.71
16	21	160	210	6.55	7.34
16	22	160	220	11.95	8.58
16	23	160	230	8.52	10.46

Geophysical Readings
Recorded October 1999

14	20	140	200	5.95	4.45
14	21	140	210	6.19	5.92
14	22	140	220	4.36	9.29
16	24	160	240	5.61	11.07
16	25	160	250	3.6	11.16
16	26	160	260	10.14	9.63
16	27	160	270	5.43	9.96
16	28	160	280	5.85	8.73
16	29	160	290	5.94	6.12
16	30	160	300	4.98	5.16
14	23	140	230	7.95	9.48
14	24	140	240	8.19	10.41
14	25	140	250	9.78	12.03
14	26	140	260	10.5	12.87
14	27	140	270	11.1	12.09
14	28	140	280	11.85	10.83
14	29	140	290	6.51	10.02
14	30	140	300	9.12	8.85
14	31	140	310	6.81	7.17
14	32	140	320	5.67	5.94
14	33	140	330	4.68	4.98
14	34	140	340	4.41	3.99
14	35	140	350	4.8	3.06
14	36	140	360	3.93	2.79
14	37	140	370	4.05	2.4
14	38	140	380	3.69	2.61
14	39	140	390	3.72	2.76
14	40	140	400	4.29	2.61
15	20	150	200	4.95	4.59
15	21	150	210	4.68	6.72
15	22	150	220	2.46	9.03
15	23	150	230	6.6	8.94
15	24	150	240	8.1	10.86
15	25	150	250	12.27	12.09
15	26	150	260	9.75	12.09
15	27	150	270	9.06	12.12
15	28	150	280	9.27	10.44
15	29	150	290	6.78	8.46
15	30	150	300	5.16	6.69
15	31	150	310	3.6	5.19
15	32	150	320	5.79	4.68
15	33	150	330	3.54	3.9
15	34	150	340	4.5	3.21
15	35	150	350	4.2	2.97
15	36	150	360	3.87	3.03
15	37	150	370	3.3	2.82
15	38	150	380	3.93	2.34
15	39	150	390	3.18	2.88
15	40	150	400	4.11	2.22
13	20	130	200	4.8	3.27
13	21	130	210	6.84	3.9
13	22	130	220	3	6.18

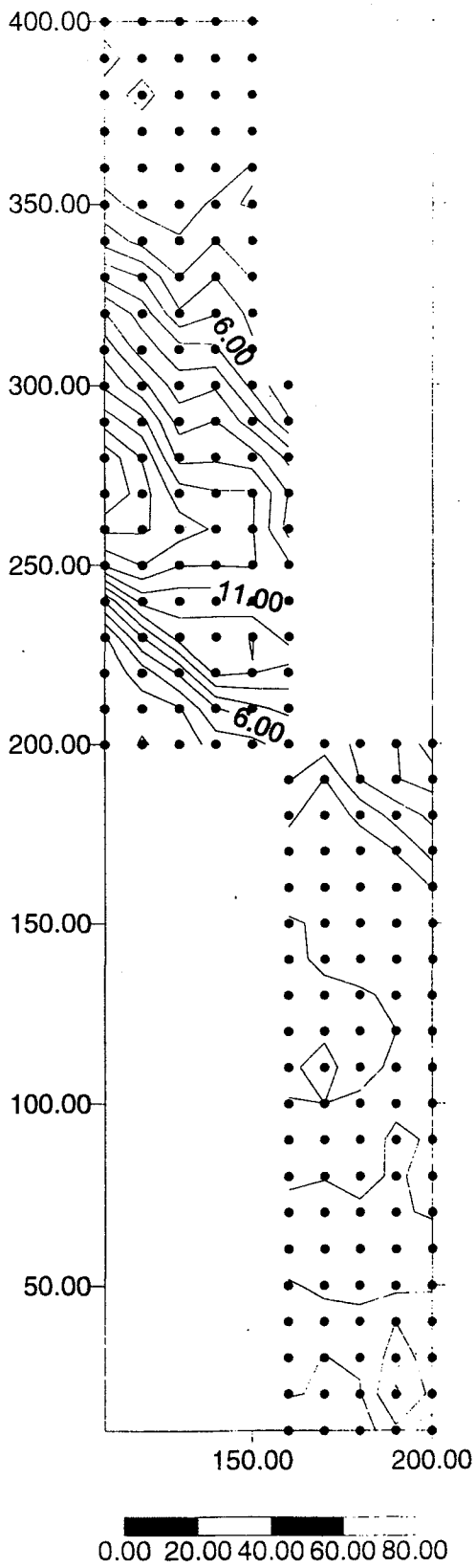
Geophysical Readings
Recorded October 1999

13	23	130	230	7.77	9.54
13	24	130	240	11.34	10.41
13	25	130	250	9	12.03
13	26	130	260	9.66	13.5
13	27	130	270	9.18	12.48
13	28	130	280	8.88	10.71
13	29	130	290	11.49	9.6
13	30	130	300	7.05	8.43
13	31	130	310	6.18	7.38
13	32	130	320	5.37	5.13
13	33	130	330	5.34	3.99
13	34	130	340	3.6	3.03
13	35	130	350	4.26	2.85
13	36	130	360	3.3	2.37
13	37	130	370	3.99	2.22
13	38	130	380	3.75	2.07
13	39	130	390	3.36	2.16
13	40	130	400	3.33	2.28
12	20	120	200	3.93	4.14
12	21	120	210	5.25	3.57
12	22	120	220	7.89	4.41
12	23	120	230	3.87	7.02
12	24	120	240	5.43	10.38
12	25	120	250	8.37	13.02
12	26	120	260	12.6	14.13
12	27	120	270	9.87	14.46
12	28	120	280	7.5	13.95
12	29	120	290	11.46	12.36
12	30	120	300	8.82	10.35
12	31	120	310	9.36	8.55
12	32	120	320	6.51	7.59
12	33	120	330	4.98	5.94
12	34	120	340	4.95	3.63
12	35	120	350	4.08	2.67
12	36	120	360	4.05	2.73
12	37	120	370	3.57	2.31
12	38	120	380	3.51	3.48
12	39	120	390	3.63	2.34
12	40	120	400	3.69	2.1
11	20	110	200	4.29	3.09
11	21	110	210	4.83	3.18
11	22	110	220	5.43	3.39
11	23	110	230	6.78	3.84
11	24	110	240	2.97	7.05
11	25	110	250	9.96	12.09
11	26	110	260	9.54	14.19
11	27	110	270	11.07	16.11
11	28	110	280	13.92	15.75
11	29	110	290	14.22	13.59
11	30	110	300	10.71	11.85
11	31	110	310	8.07	10.68
11	32	110	320	7.14	9.03

Geophysical Readings
Recorded October 1999

11	33	110	330	6.21	6.78
11	34	110	340	4.56	4.65
11	35	110	350	3.93	3.33
11	36	110	360	3.54	2.58
11	37	110	370	3.48	2.55
11	38	110	380	3.87	2.25
11	39	110	390	2.85	1.77
11	40	110	400	3.36	2.22

Big Falls
Horizontal Conductivity (mS/m)



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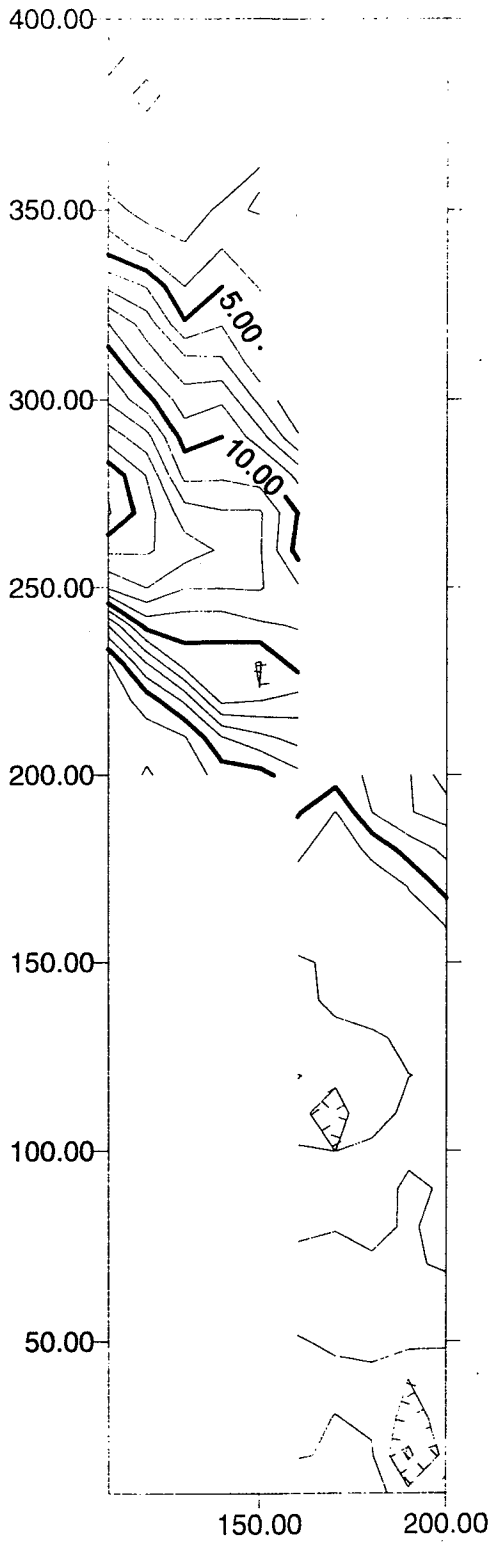
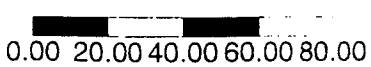
Big Falls
Horizontal Conductivity (mS/m)





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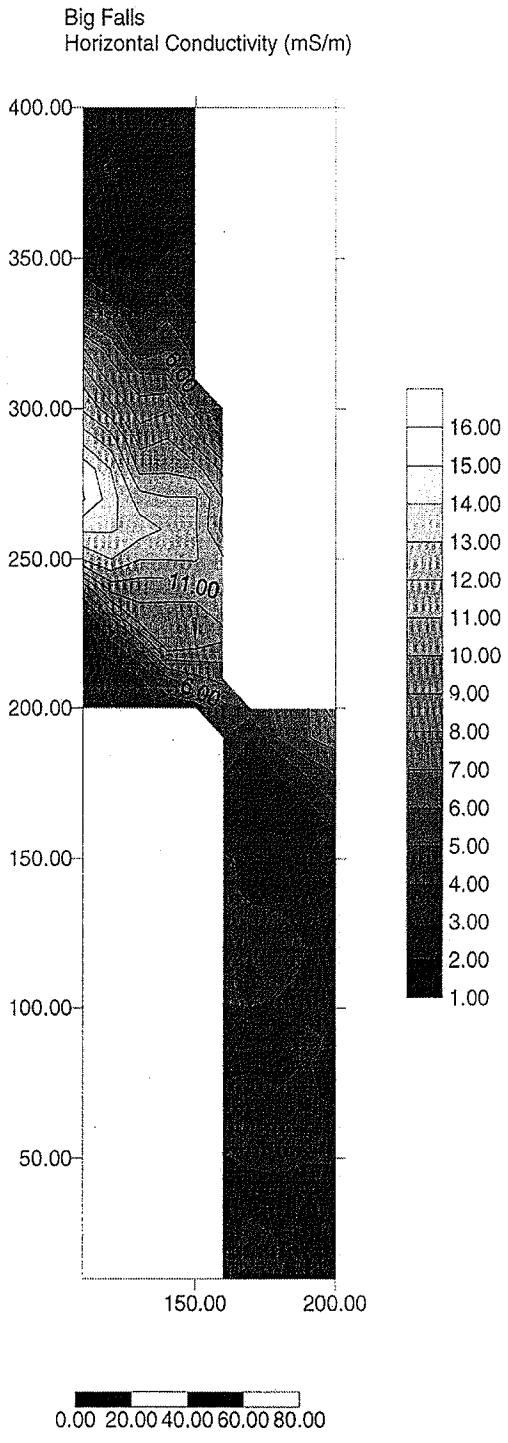
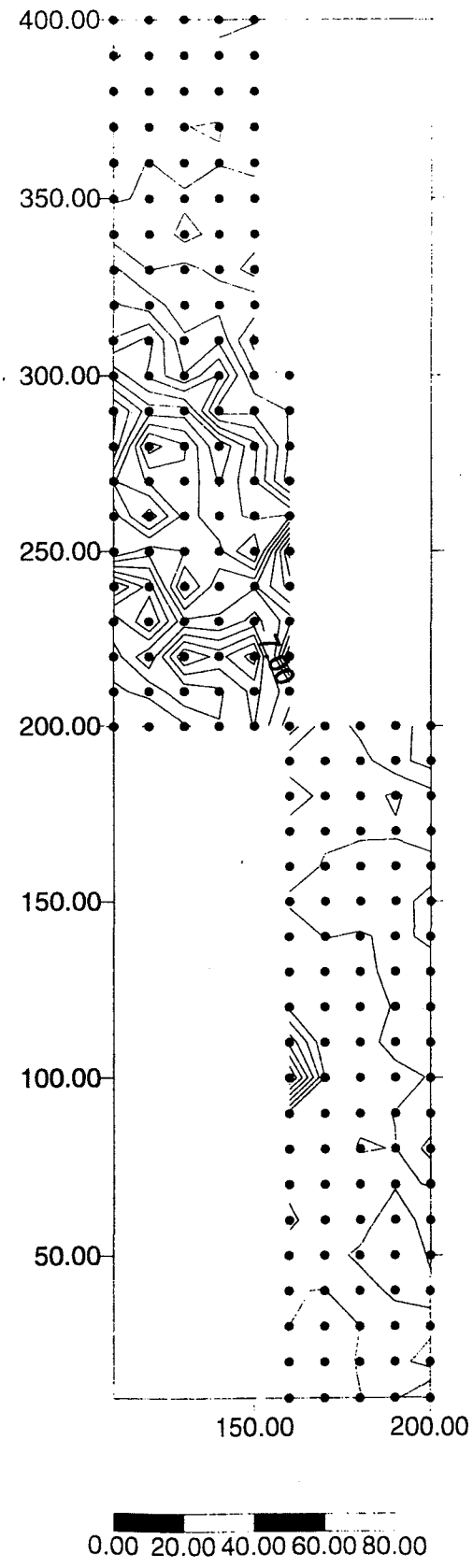
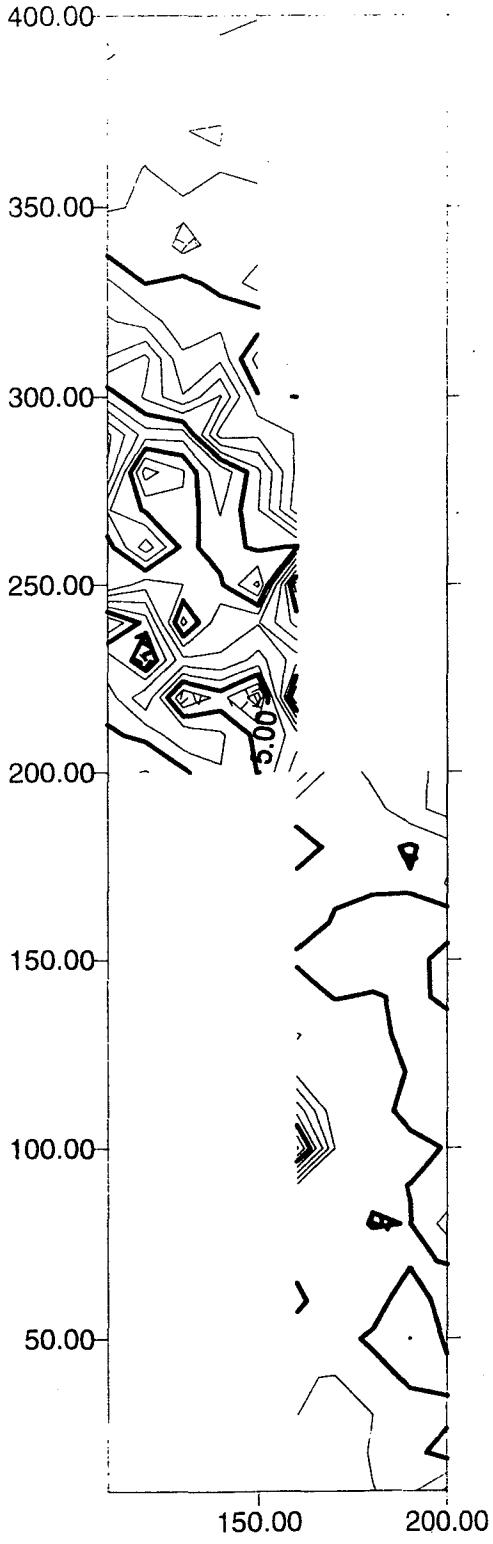

Big Falls
Horizontal Conductivity (mS/m)
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
11.00
9.00
150.00
200.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00 20.00 40.00 60.00 80.00
Scale 1:2000

Big Falls
Vertical Conductivity (mS/m)



Scale 1:2000

Big Falls
Vertical Conductivity (mS/m)



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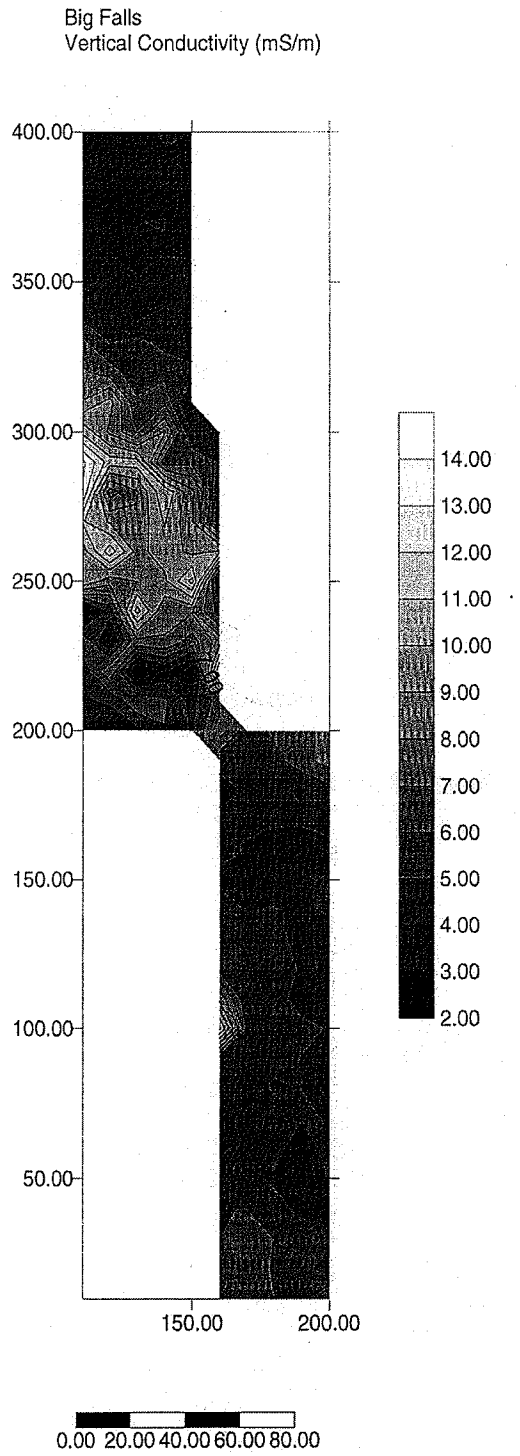
Big Falls
Vertical Conductivity (mS/m)
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
150.00
200.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
0.00 20.00 40.00 60.00 80.00
Scale 1:2000

Appendix C
Composited Data

Appendix C
Fine and Coarse Gradations
Seperated into the Composites

COMPOSITE 1								
(Area 1)	1	3/4	3/8	#4	#10	#40	#200	
id	25.0mm	19.0mm	9.5mm	4.75mm	2.00mm	425um	75um	Gravel Thickness
MNDOT Max	100	100	90	80	65	35	10	(Class 5)
MNDOT Min	100	90	50	35	20	10	3	
BH 7	90	89	80	70	52	21	3.6	6.75
BH 8	95	93	85	74	57	24	2.5	8
BH 9	99	99	98	93	74	38	1.8	8
BH 18	95	91	79	66	51	13	1.8	10
AVERAGE	94.9	93.0	85.3	75.4	58.3	23.4	2.3	
Total Cubic Yd	20435							

COMPOSITE 2								
(Area 2&3)	1	3/4	3/8	#4	#10	#40	#200	
id	25.0mm	19.0mm	9.5mm	4.75mm	2.00mm	425um	75um	Gravel Thickness
MNDOT Max	100	100	90	80	65	35	10	(Class 5)
MNDOT Min	100	90	50	35	20	10	3	
BH 33	98	97	93	78	51	22	4.1	5.75
BH 34	95	92	81	71	59	15	1.4	6.75
BH 42	91	91	88	80	61	34	6.4	3.75
BH 52	93	90	79	69	57	36	3.4	3.75
AVERAGE	94.7	92.9	85.4	74.3	56.7	24.5	3.5	
Total Cubic Yd	19039							

COMPOSITE 3								
(Area 4&5)	1	3/4	3/8	#4	#10	#40	#200	
id	25.0mm	19.0mm	9.5mm	4.75mm	2.00mm	425um	75um	Gravel Thickness
MNDOT Max	100	100	90	80	65	35	10	(Class 5)
MNDOT Min	100	90	50	35	20	10	3	
BH 44	84	83	79	75	69	38	3.2	5.75
BH 45	94	91	85	76	65	37	5.9	4.75
BH 61	95	94	89.0	84.0	78.0	47.0	3.7	4.8
AVERAGE	90.5	88.9	84.0	78.1	70.6	40.5	4.2	
Total Cubic Yd	10993							

COMPOSITE 4								
(Area 6)	1	3/4	3/8	#4	#10	#40	#200	
id	25.0mm	19.0mm	9.5mm	4.75mm	2.00mm	425um	75um	Gravel Thickness
MNDOT Max	100	100	90	80	65	35	10	(Class 5)
MNDOT Min	100	90	50	35	20	10	3	
BH 1	96	94	92	88	80	55	2.7	4.75
BH 2	96	94	90	86	75	41	4.6	4.75
BH 3	99	98	96	93	86	60	4.2	4.75
BH 10	77	74	67	61	49	20	3.7	6.75
BH 11	97	97	92	85	75	46	3.5	7.75
BH 20	97	95	83	75	65	46	1.8	5.75
BH 21	90	88	80	72	59	36	4.4	3.75
BH 28	89	83	72	62	51	31	2.9	5.75
BH 59	85	78	62	51	39	23	2.5	3.75
BH 63	97	96	89	80	69	49	3.9	4.25
AVERAGE	92.1	89.7	82.5	75.5	65.1	40.5	3.4	
Total Cubic Yd	23930							