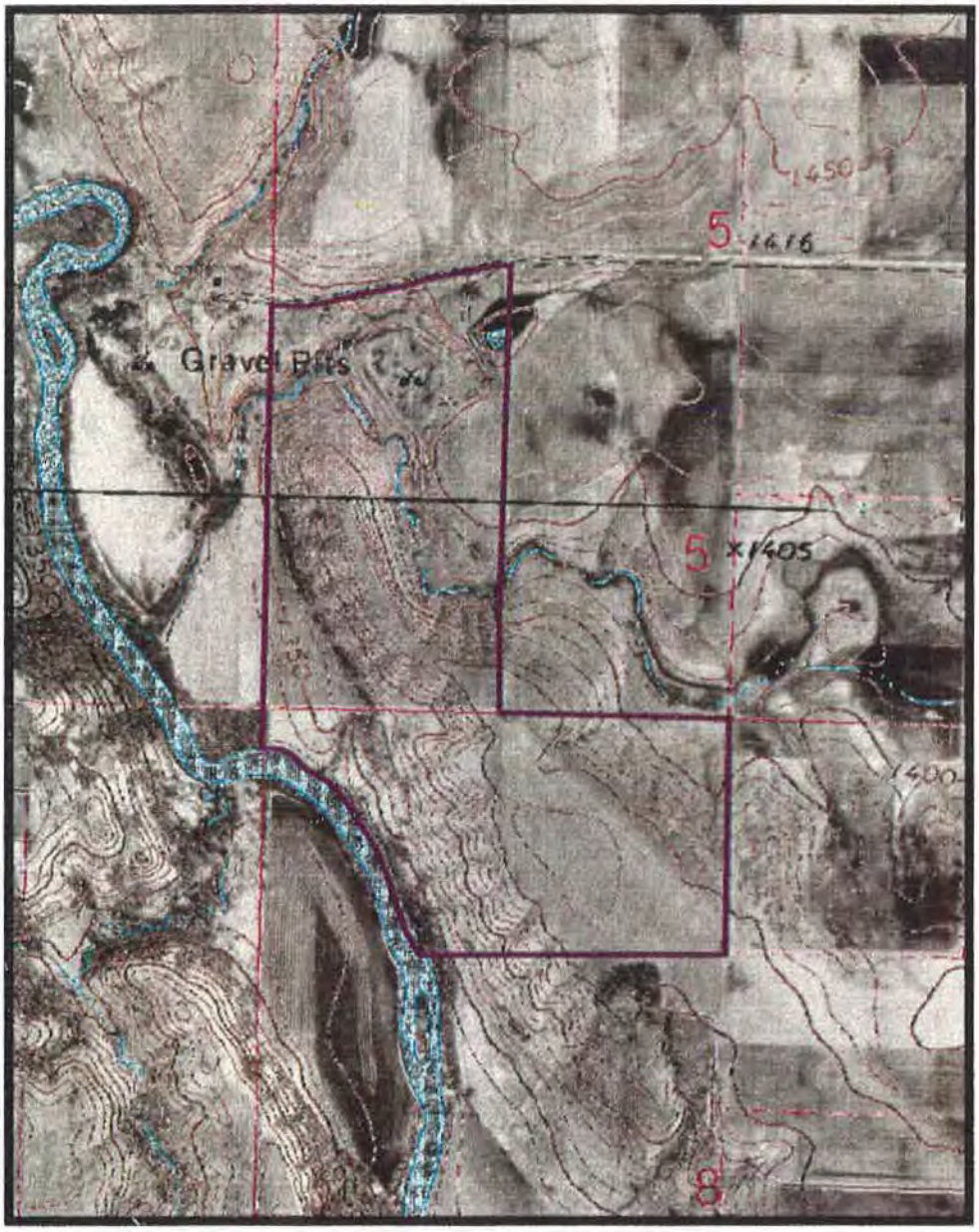
# Aggregate Resource Evaluation for a Potential SNA Site in Jackson County, Minnesota.




by the Minnesota Department of Natural Resource
Division of Minerals
Report 334-2
July 1998

# Aggregate Resource Evaluation for a Potential SNA Site in Jackson County, Minnesota

by Heather Anderson

1998

Report 334-2

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

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# List of Figures, Plates, and Tables

# I. OVERVIEW

Purpose

The purpose of this report is to provide a resource estimate of sand and gravel on a 144-acre parcel of land located in Jackson County, Minnesota (Plate 1). This resource estimate is an analysis of data gathered during a geologic survey to produce an aggregate inventory. The survey was conducted in May and June of 1998 by the Department of Natural Resource (DNR)-Minerals Division in conjunction with the DNR-Bureau of Real Estate Management (BREM), the DNR section of Wildlife and the Minnesota Department of Transportation (MNDOT). The parcel of land is currently owned by Donald Holthe and may be acquired by the DNR as a Science and Natural Area. An aggregate inventory was commissioned to describe the aggregate resource for the assessment of the parcel's real estate value. Because of SNA, there were restrictions placed upon the fieldwork, and a more accurate evaluation of measured reserves was not required. The design was a compromise between the least possible impact and necessary samples.

The geologic survey consisted of airphoto and topographic map interpretation, drilling, logging, sampling, field descriptions, quality tests, geographic positioning systems information (GPS). Analysis of the data produces a resource estimate that identifies sand and gravel resources, delineates volume, identifies mining accessibility (including overburden thickness, water table and proximity to water bodies) defines gradations and quality from collected samples. The summary of the findings are stated below:

Summary of Findings

-The aggregate resource was deposited in an outwash environment.
-The estimated area of gravel ≈ 49 acres, the average thickness ≈ 20 feet, the volume ≈ 1,580,000 cubic yards. It is our opinion this could vary by ± 30%.
-The gravel is found between the elevations of 1380 feet and 1400 feet above sea level.
-The average thickness of overburden stripping is 50 feet.
-Stripping ratio = 2.5: 1
-The potential volume for boulders is 3,000 cubic yards ± 50% cubic yards.
-Average depth to water table: 70 feet on ridge and 7 feet in northeast corner.
-Aggregate Quality: gravel percent ranges between 30-50%; coarse aggregate percentages qualify for the use of class 5 base and surfacing material; gravel does not meet MNDOT concrete specifications for shale, spall, and clay balls. The boulders can either be crushed or used for rip rap.

Regional Setting

The Holthe site is located on the southeastern base of the Coteau des Prairies, a large flatiron-shaped plateau which forms a water divide contributing to the Des Moines River water shed. The Coteau is a glacially eroded landform carved by Late Wisconsin glacial advances of the Des Moines and the James Lobes (Patterson, 1997). As the Coteau was being carved, it also acted as a confining wall to the ice margin (Matsch, 1972). Located along the southeastern base of the Coteau several indistinct moraines represent stagnant ice positions of the Des Moines Lobe.

The bedrock of Jackson County consists of Precambrian rock and loosely consolidated Cretaceous sediments. Precambrian bedrock lithologies include purple Sioux Quartzite and coarse grained gneiss and granite. Cretaceous lithologies are highly variable but generally consists of mudstone, siltstone (shale) and sands which were deposited in a shallow marine environment. The type of bedrock contributes significantly to the characteristics of glacial deposits and aggregate.

Glacial sediments overlay the bedrock in thicknesses between 200 and 400 feet. The average depth to bedrock at the Holthe site is 250 feet. This thickness represents several glacial advances; however present landforms are usually attributed to glacial advances of the Des Moines Lobe. The Holthe site is located on a belt of hummocky stagnation topography deposited by the margin of the Des Moines Lobe. Irregular hills, outwash sediments, and collapse features are typical landforms deposited in ice marginal environments. The Des Moines ice flow and ice margin in southwestern Minnesota trend from the northwest to the southeast. Meltwater streams in ice marginal environments tend to parallel the direction of the ice margin. This is seen in some outwash channels of the Des Moines lobe which trend from the northwest to the southeast.

Ice margin depositional environments are highly variable. It is an environment where many different depositional processes are within close proximity to each other. Such environments include sediments deposited by water, ice, and gravity (slumpage off the glacier or unstable slopes). Once the sediments have been deposited, they can also be transported and redeposited by the same or different transport systems.

The Des Moines Lobe advanced and retreated several times between 11,700 and 14,000 years before present. Consequently, these advancements deposited several layers of till. As the lobe retreated, outwash sediments were deposited. Therefore, gravel layers can be observed between two deposits of the same origin (or the same glacial lobe). This is one explanation for the stratigraphy seen at the Holthe Site.

## II. METHODOLOGY

Several means of gathering data were implemented to produce a resource estimate for the Holthe site: map interpretation, field work, and laboratory analysis.

### Map Interpretation

Geologic interpretations were partially based on analysis of topographic maps and aerial photos. The topographic maps were analyzed to identify landforms, delineate trends and locate other gravel pits. Four 7.5 minute topographic maps from the U.S. Geological Survey were used: Windom, Lakefield NE, Bergen and Jackson. Inferred aerial photographs (NAPP 1992) provided information on boundary lines, land marks, and drainage pattens in the area.

**Figure 1**: The drill rig

Field Work

Field work consisted of drilling, logging, sampling, GPS, and geologic observations. A drill rig was used to determine overburden thickness, areal extent, deposit thickness, depth to ground water, make geologic observations, and obtain representative samples. The drilling was performed under cooperative agreement between MNDOT and the DNR. MNDOT provided the drill rig, drill equipment, and operator to work with a DNR-Minerals Division geologist. The MNDOT drill rig holds a 10 inch auger with the initial flight being continuous for 25 feet (see figure 1). When drilling past the depth of 21 feet additional flights were attached in 5 foot segments. Drilling proceeded for four days in which 23 test holes were completed with depths ranging from 10 to 51 feet. Upon drilling each test hole, the drill rig augured into the first 3 to 4 feet to note topsoil thicknesses. Drilling was continued in 4 to 20 foot increments then pulled to log and sample sediments. The drilling increments increase upon drilling depth. The reason for large increments at depth was due to adding and removing the 5 foot auger flights.

Sample increments depended on two factors: thickness of the gravel unit and amount of sample retained on the auger. The goal was to obtain approximately 30 pounds for every 6 to 10 feet of gravel. At times the sample increment was increased to retrieve enough sample. This was primarily due low adherence of sand and gravel to the auger as it was being withdrawn. Once withdrawn, the sample was hand scraped from the auger, placed on a rubber mat, mixed with a shovel, and scooped into a labeled white canvass bag with an identification tag inside.

Additional samples were taken in areas that were difficult to access with the drill rig. Three samples were obtained by manually digging holes using posthole diggers, hand augers, and spades. Each sample consisted of three holes; therefore a total of 9 holes were dug. The depth of the individual holes ranged between 2 to 4 feet. For the most accurate representation of the entire gravel unit, holes were spaced as follows: one near the upper gravel contact, one in the middle of the gravel unit, and one near the lower gravel contact. Approximately 2.5 pounds of gravel were collected for every 6 inches augured to obtain a total of 30 pounds.

Locations of the test holes, upper contact of the gravel layer, and lower contact of the gravel layer were surveyed using a Trimble ProXR® Global Positioning System (GPS). GPS uses satellite radio transmissions to provide a location in three dimensions (X, Y, and Z). Since the Z coordinate can be inaccurate, only the X and Y coordinates were measured, and then plotted on a

Digital Raster Graphic-a digitized topographic map (Plate 2). The gravel layer is located between two tills. Data gathered by GPS provides insight to the nature of the gravel unit. For example, does the gravel layer undulate? At what elevations are the contacts? To answer these questions, several methods were used to survey the upper and lower gravel contacts coupled with field checks using a hand auger. The upper contact was traced using a subtle change of the slope in the hill side. A slope change indicates a change in material or sediments. Some sediments can resist erosional processes more than other sediments, thus creating differences in slope. When a sediment is resistant it forms cliffs, whereas a non-resistant sediment forms slopes. In relative terms, glacial sediments rich in clay are "cliff formers" and sand and gravel are "slope formers" (see figure 2a). The lower contact was more difficult to trace. There were two indicators of sediment change that were used for surveying: change in vegetation and soil thickness. At the lower contact short grasses widely spaced seem to be growing in the gravel layer. Longer, greener, and densely spaced grasses seem to be associated with the lower till unit (see figure 2b). In addition, the soils tend to be thinner in the gravel and thicker in the till.

Laboratory Analysis

Samples were taken to the MNDOT Research Facilities in Maplewood and analyzed. Several laboratory tests were performed on the samples. All the samples were tested for both fine and coarse gradations. Samples were then lumped into composites by geographical location. Composites were combined to get a representative result of the entire gravel unit and to lower processing costs . Some samples were not grouped into composites due to geologic differences. Samples 8 and 9 were stratigraphically below the samples collected from the bluff. Sample 5 was probably an overbank deposit of the Des Moines River. Below is a list of the composites and their constituents:

| | Testhole # | Sample # | Depth (ft) |
|---|---|---|---|
| COMPOSITE A* | 1 | 1 | 35-44 |
| | 1 | 2 | 44-51 |
| COMPOSITE B* | 3 | 3 | 3-10 |
| | 3 | 4 | 10-17 |
| | 22 | 10 | 24-32 |
| | 22 | 11 | 32-46 |
| | 23 | 12 | 1-7 |
| COMPOSITE C | 15 | 6 | 2.5-10 |
| | 15 | 7 | 10-18 |
| COMPOSITE D* | Hand Auger 1 | 13 | |
| | Hand Auger 2 | 14 | |
| COMPOSITE E* | Hand Auger 3 | 15 | |
| NO COMPOSITE | 4 | 5 | 7-10 |
| | 8 | 18 | 30-40 |
| | 9 | 19 | 4-10 |

(*) Indicates samples collected from the largest and most significant gravel unit.

# FIGURE 2

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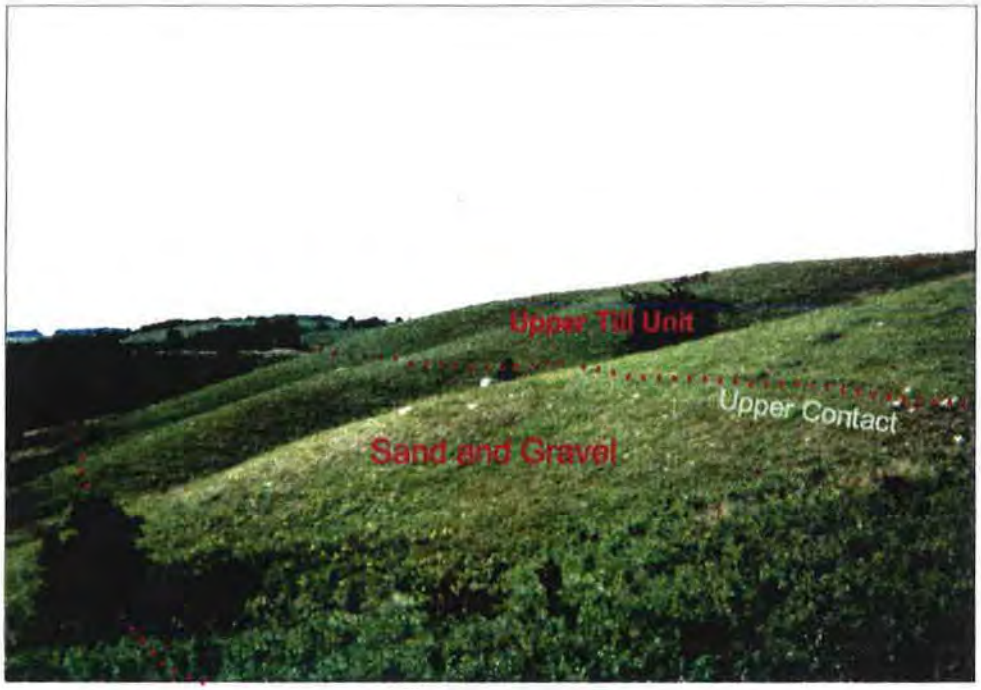
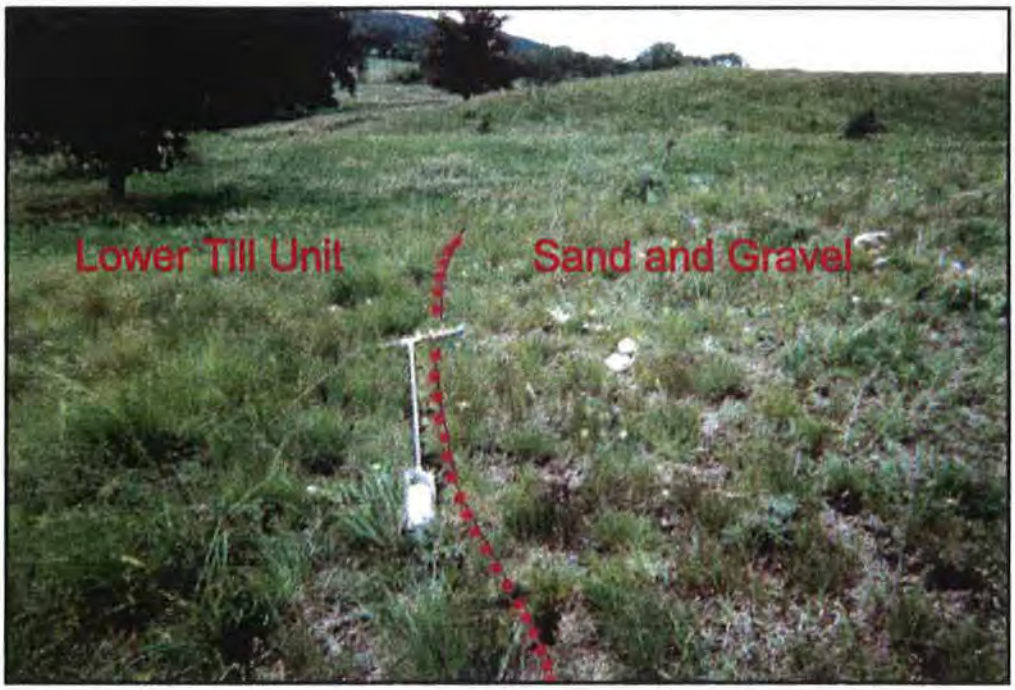



A. Note the change in slope. The hillside levels near the upper contact of the sand and gravel.




B. Note the change of vegetation. To the right of the line, the grass is short, sparse, and "dry". To the left of the line, the grass is long, dense, and "plush".

# Figure 3

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**A. One of four rock piles that could be potentially used for rip rap. The piles are located in the reclaimed pits in the northern section of the site area.**

B. This is a close up of the deposit from which the boulders were mined Boulders range in size and are supported by a loamy matrix. This deposit may be meltout or supraglacial till (till that was transported ontop of the glacier). The purplish boulders are Sioux Quartzite, the lighter colored boulders are limestone, and the darker colored are mafics and gniess.

Tests performed on the composites include lithologic exams, shale float tests, spall, gradations, and absorption tests. Spall is a term for sub standard rock in terms of durability for concrete. Absorption measures how much water a rock can retain or absorb which can be detrimental to concrete during freeze and thaw weather cycles.. A magnesium sulfate test was performed on only one sample. Magnesium sulfate measures the susceptibility of rocks for breakdown from freeze-thaw weather cycles. Levels of magnesium sulfate do not vary significantly within a single gravel unit.

## III. RESULTS

The results are summarized on a set of maps showing testhole locations (Plate 2), surveyed contacts and observation points (Plate 3), area of gravel (Plate 4), observed gravel thicknesses (Plate 5), cross sections (Appendix B), drill log descriptions (Table 1), particle size distribution (Table 2), quality test (Tables 3-5), and MNDOT grain size specification (Table 6).

Gravel is defined as particle size greater than 2 millimeters (mm). Within the site area there are four different sources of aggregate: the large gravel layer found in the slopes of the bluff, Des Moines River overbank deposits located in the far southwest corner of section 5 and northwest corner of section 8, the boulder rich till of the reclaimed pits, and a buried stream deposit from drill hole 18 (located near the reclaimed pits). Both stream deposits have a negligible amount of gravel found in local pockets. Although the elevation of hole 15 is near 1400 feet, the gravel does not seem to be associated to the gravel in the bluffs. One, there is a lack of till. Two, test results from samples 6, 7, and composite C vary significantly in composition and gradations than samples collected from the bluffs. Three, there is a large livestock watering hole directly to the east and the sediments may be the construction material.

The largest and most significant gravel layer, here labeled Unit 1, is located between two till units. GPS results indicate that the gravel layer contacts are generally found at consistent elevations (Plate 3). The elevation of the upper contact is approximately near 1400 foot contour line. The lower contact elevation is approximately near the 1380 foot contour elevation. The GPS data imply that the gravel bedding does not undulate on a large scale and is consistently observed as a 20 foot band along the hillside. The band does span continuously across the ridge in section 5 and along the bluff in section 8. From the GPS data, the area of the gravel layer was drawn (Plate 4). Area can be calculated with some certainty from the bluff; but the degree of certainty decreases as going east into the farm field. Since the drill could not penetrate the thick sequence of overburden (see table 1 for drill log descriptions), the areal extent of the layer is unknown, but we know the unit does not increase "upward" inside the hill.. An observation point was dug in the eastern most cow pasture (Plate 5). A gravel thickness of eighteen inches was found near the 1400 contour line. Therefore when calculating area, a dotted line was drawn at the mid-section property line trending in the same direction of the bluff. The total calculated area is 49 acres. The volume is calculated at 1,580,000 $\pm$ 30% cubic yards.

Drill logs and cross sections show a thick sequence of glacial till. The stripping ratio calculates out to 1 foot of sand and gravel for every 2.5 feet of overburden. Overburden thickness is relatively thin for the first 10 to 15 feet of mining into the ridge. However, overburden rapidly

increases to an average thickness of 50 on the ridge. Water levels were not encountered in the ridge. However the water table in the NE section of the property at the time of drilling was under a large hydraulic head. Water levels rose to the surface during the drilling of hole 17. In the reclaimed pit, water levels intersect the surface to form a small wetland.

The amount of gravel present in Unit 1 ranges from 30% to 50% with an average value of 38% Table 2). Concentrations of gravel size are within the 3/8" to the 1/8" range which is considered a fine grained gravel. Coarse gradations meet MNDOT specifications for Class 3, 4, and 5 material for base and surfacing percentages. This gravel unit does not meet MNDOT specifications for concrete aggregate due to the presence of deleterious shale, spall and clay balls. Shale, spall, and clay balls (Tables 3-5). Samples collected from the bluff pass one of two shale specifications. Shale can not exceed 0.7 weight% of the total material of +4.75mm gravel. For samples collected on the bluff, the retained weight percentages ranges from 0.2 to 0.81% with an average of 0.61%. Another shale specification is the percent retained in the 1/2 inch sieve; only 0.40% retained material can be shale. Samples range 0.4 to 1.10% retained. The specification for spall is 1.5% in +4.75mm and gravel samples contain between 0.8 and 13.8%. Clay balls are limited to 0.30% and composite B contains 12.2%.

In the reclaimed pit there are four large piles of boulders. These boulders are sourced from a boulder rich till blanketing the area east of the ridge. The sand and gravel from this area have been previously mined. This particular deposit is very "dirty" (containing a large amount of silt) and was probably used for the construction of the watering hole. However, the remaining boulders are potentially valuable. Large rock is used for rip rap which is placed along embankments to reduce erosion or it can be crushed. A rough estimate for volume of boulders is about 3,000 cubic yards $\pm$ 50%.

## IV. DISCUSSION

The calculated volume in this resource estimate has only a moderate degree of certainty and that was acceptable to our clients during planning. Since the overburden thickness from the top of the ridge exceeded the usual working depth of 55 feet for this drill rig, all desired samples were not obtained. For example, there are no test holes drilled through both the upper and lower contact. Also, the areal extent is not delineated by drilling. The gravel layer could potentially swell in thickness or pinch out and 30% variations have been observed in other outwash deposits. With limited sampling, assessing gradational variances is difficult. Hole 3 and 22 seem to grade coarser with depth while hole 1 grades finer. In addition, it has been observed at other sites that coarser gradations occur near the spring, but intentionally no samples were taken near the spring at this site. Therefore, a large margin of error was figured into all calculations. Given the data set, this report is an indicated resource estimate, not a measured reserve.

The mining accessability of Unit 1 was evaluated by the overburden thickness and proximity to the Des Moines River. An assumption was made that thick overburden stripping would be feasible at this site, due to the shape of the ridge and the long slope down in which to push overburden. Gravel operations are restricted from mining within 300 feet of a stream or river

unless granted special permits. Unit 1 is located beyond the 300 foot buffer.

The gravel at Holthe does not meet MNDOT specifications for concrete. However the boulder pile contains lithologies that may work well in bituminous and concrete. Potential applications for the sand and gravel are class five materials. The value and application of the gravel is effected by the abundance of shale, spall, and clay balls.

## V. REFERENCES

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# APPENDICES

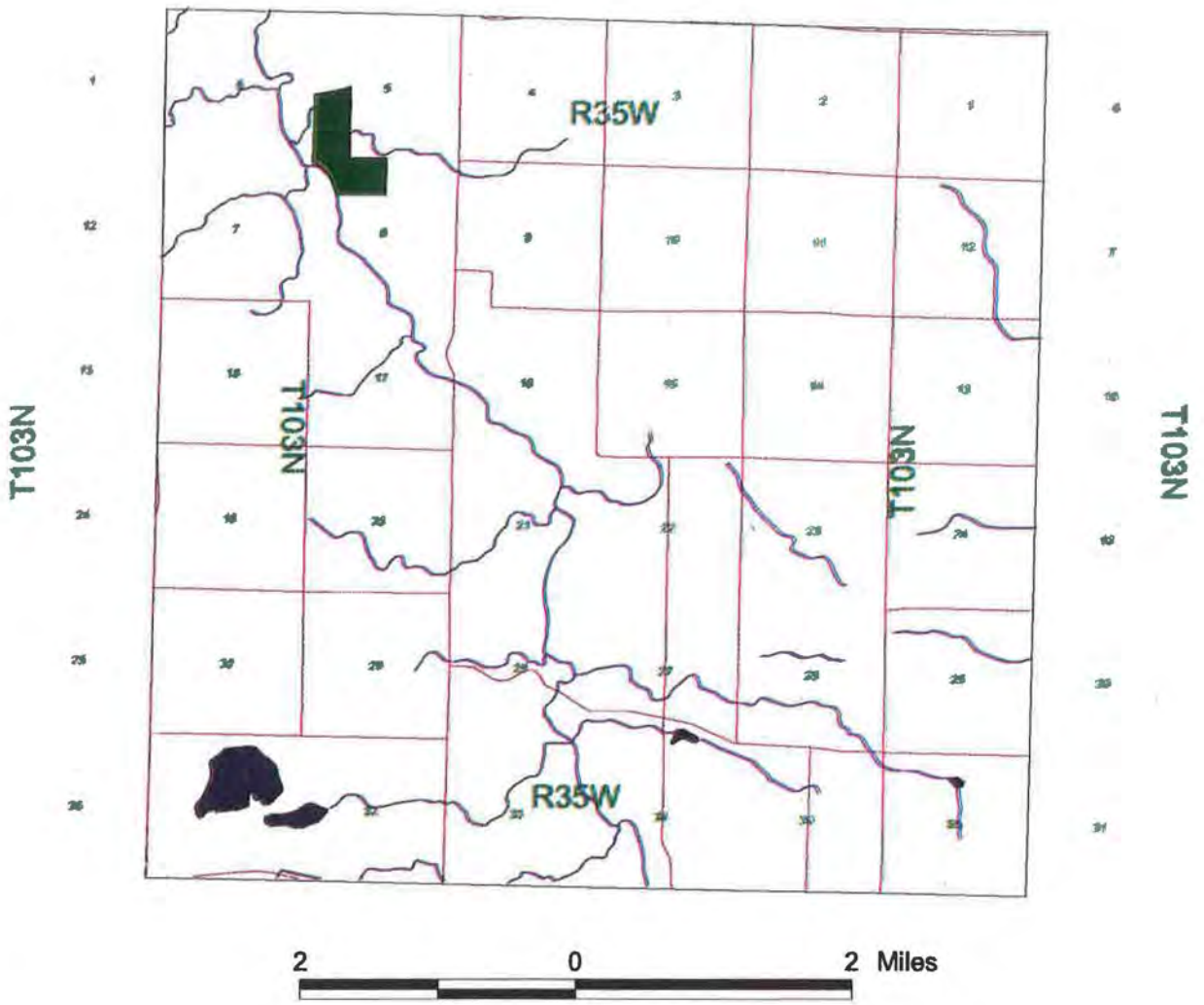
# APPENDIX A

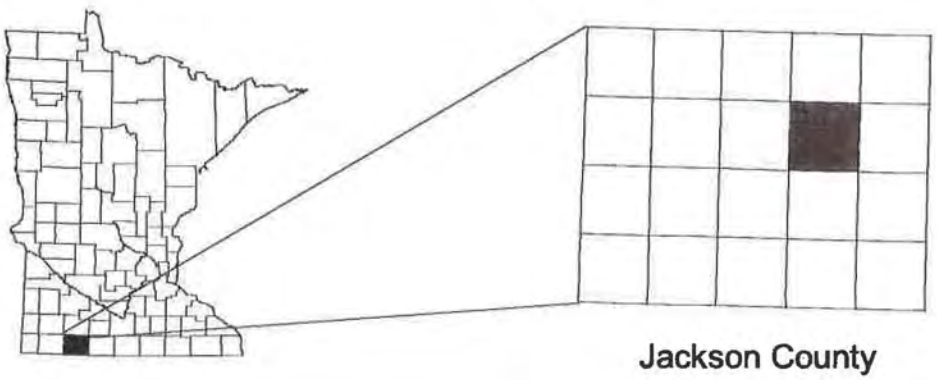
Plates 1 through 5

# PLATE 1

# Site Map of Holthe Property

## Belmont Township





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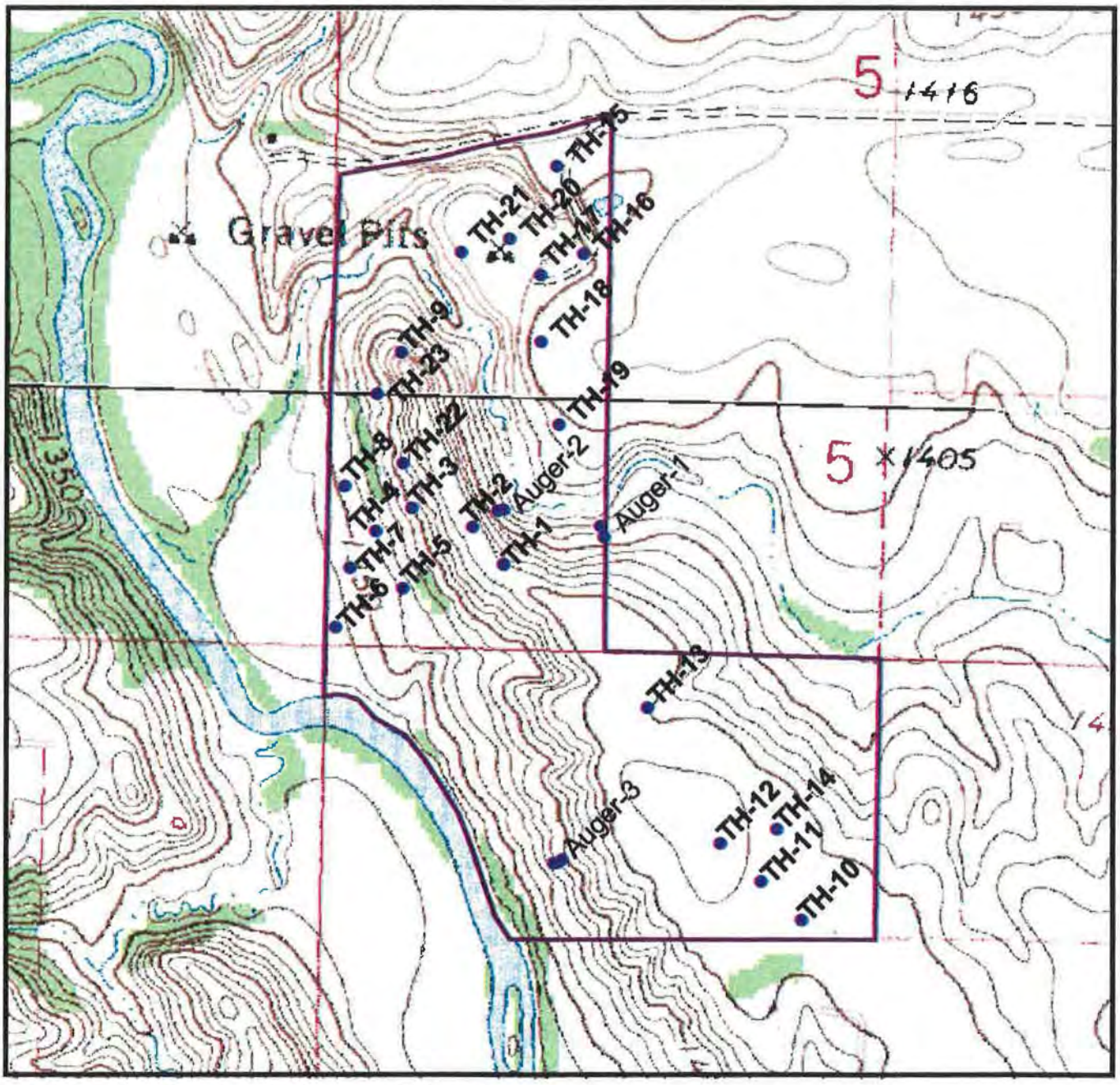
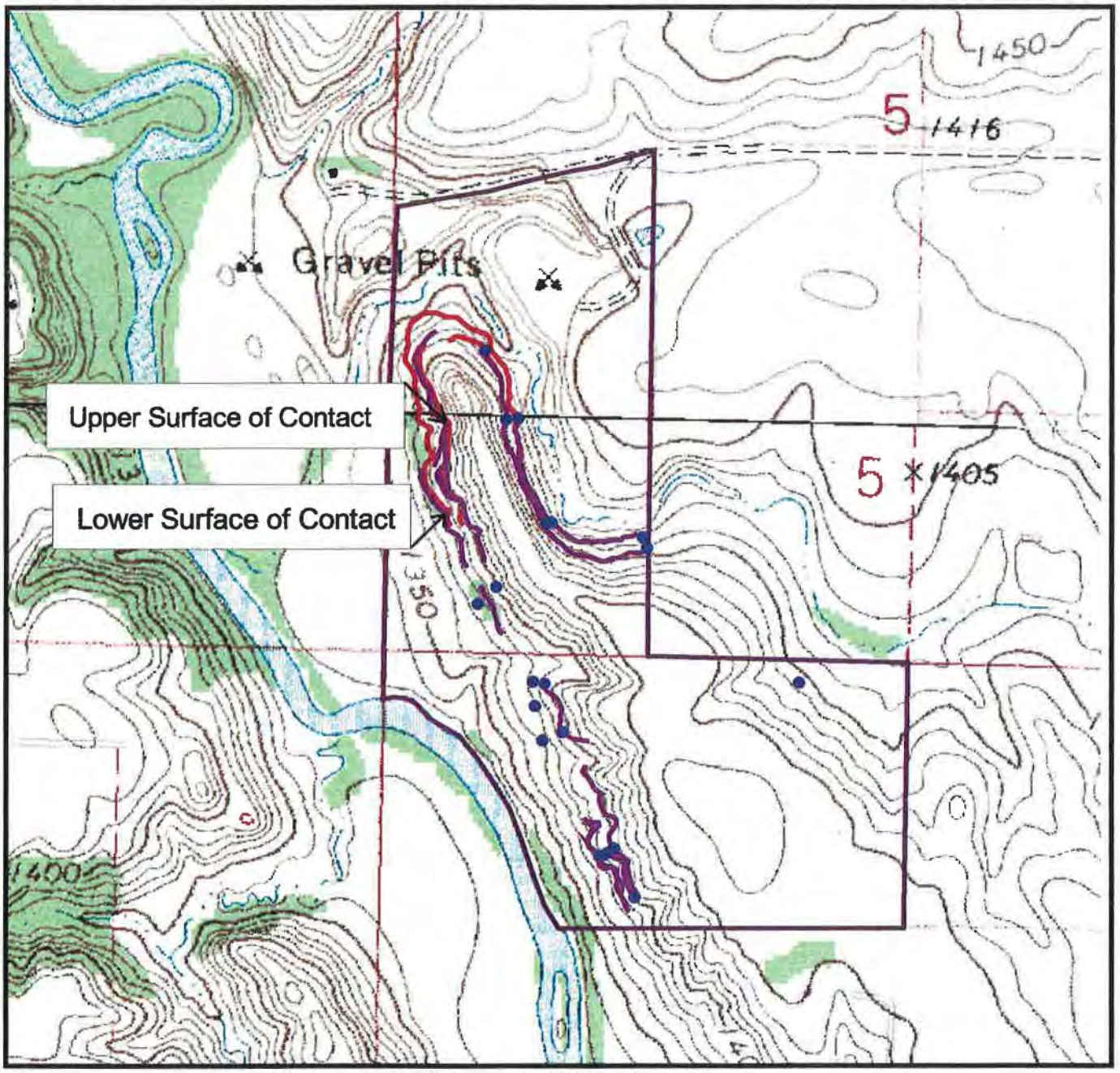
# PLATE 2

# Testhole Locations



# PLATE 3

## Contact Measurements and Observation Points




700 0 700 1400 2100 Feet

- Observation Points
- Site Area
- Upper and Lower Surface of Gravel 6/15/98
- Upper and Lower Surface of Gravel 5/29/98

N
W E
S

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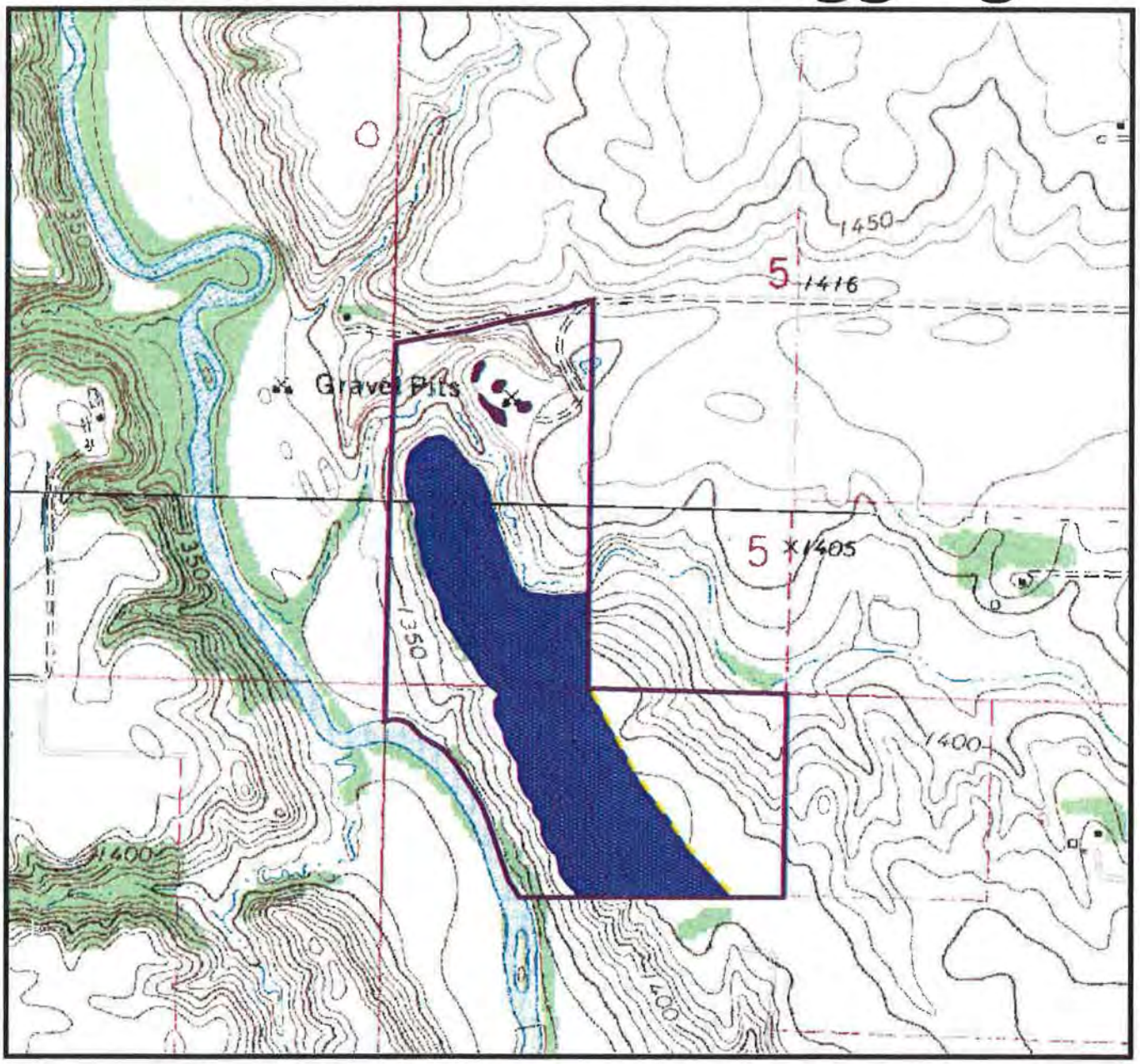
# PLATE 4

# Estimated Area of Aggregate




800 0 800 1600 Feet

Site Area
Estimated Gravel Contact
49 Acres of Gravel
Boulder Pile Locations

N
W E
S

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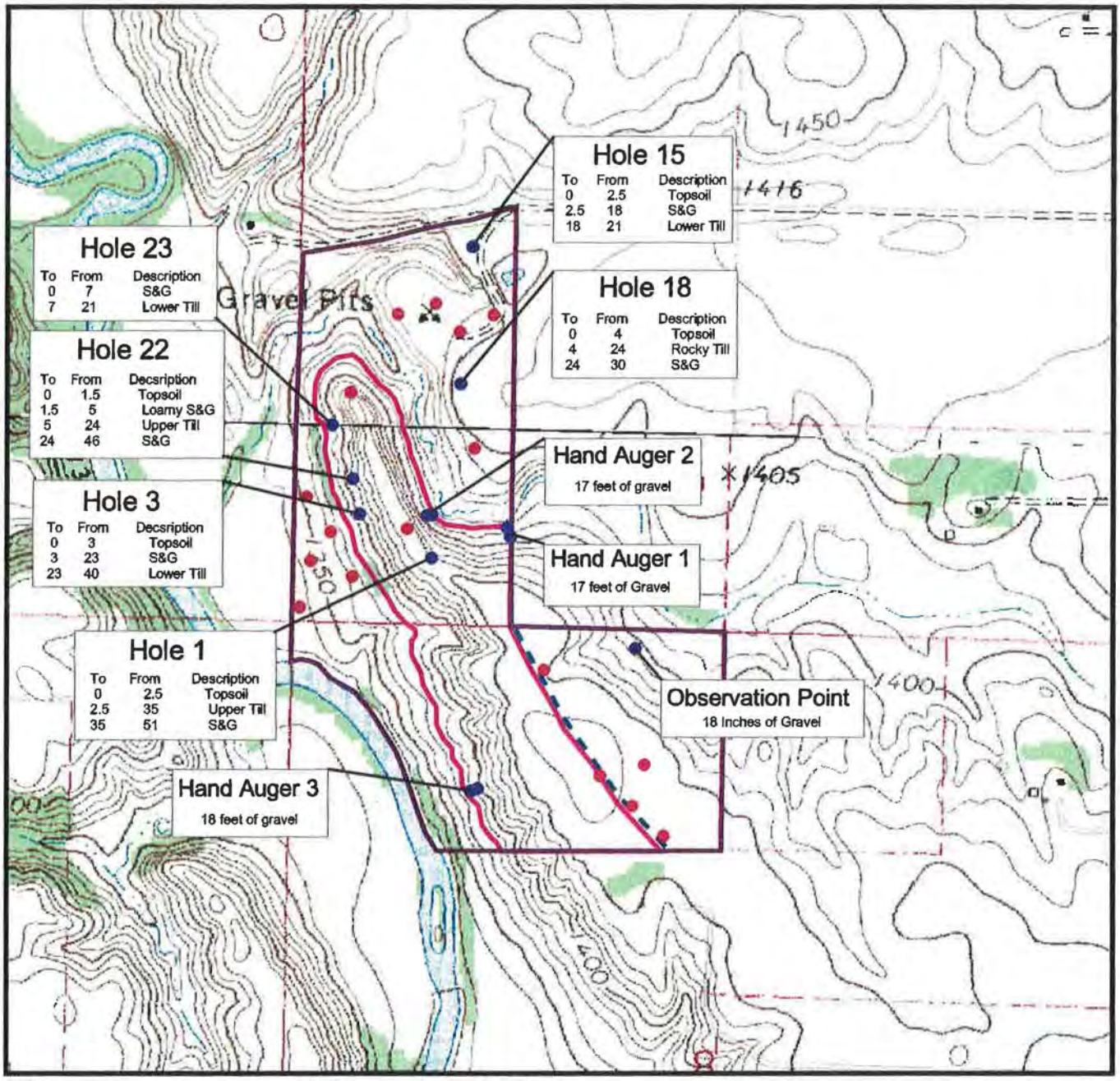
# PLATE 5

## Observed Gravel Thicknesses




700 0 700 1400 Feet

- Gravel at Testhole
- No Gravel at Testhole
- Site Area
- Estimated Gravel Contact
- 49 Acres of Gravel

N W E S

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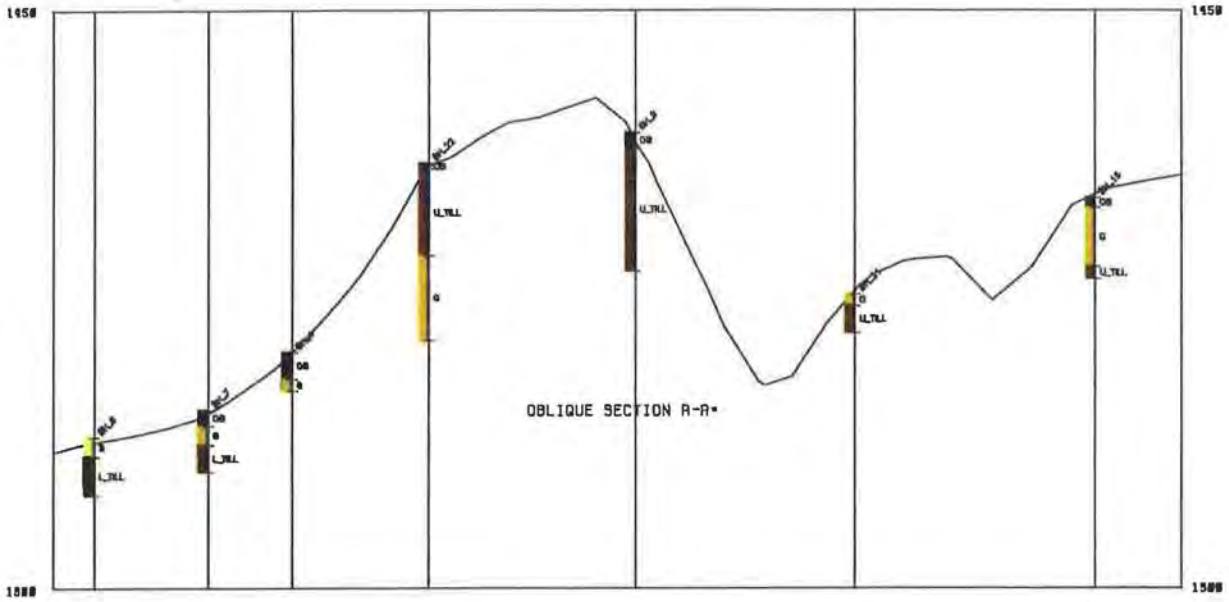
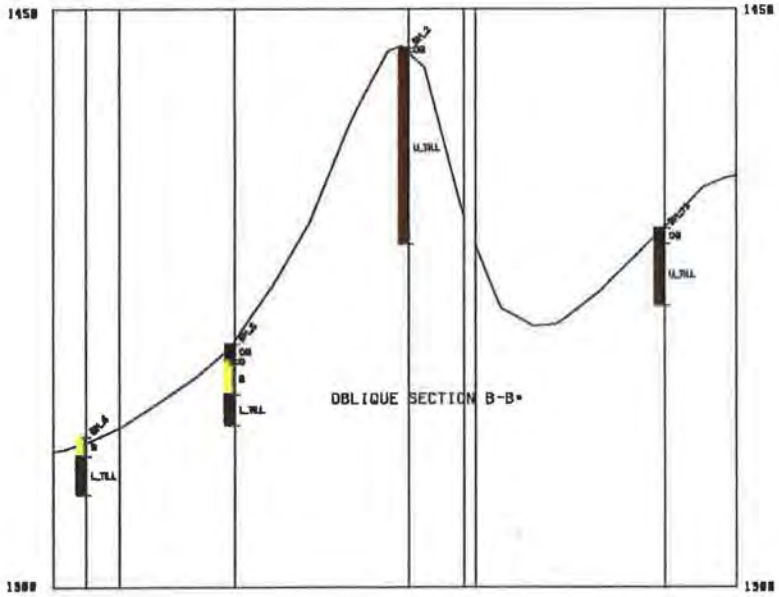
# APPENDIX B

Cross Section and Map



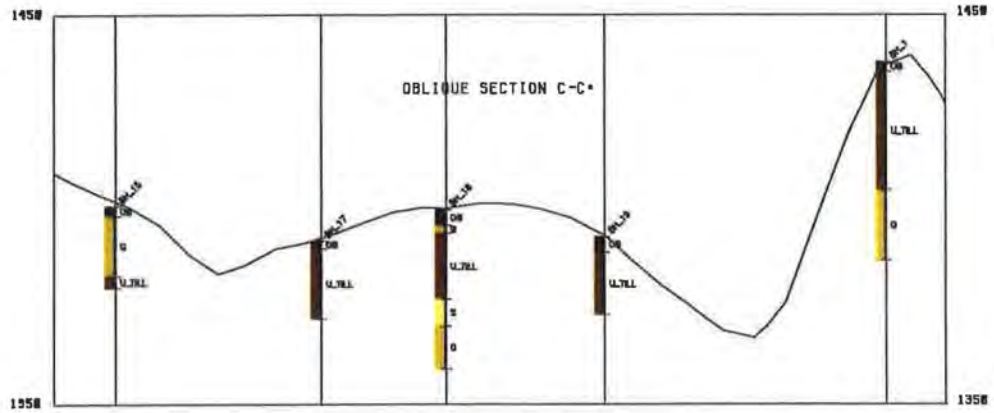

**JACKSON COUNTY**

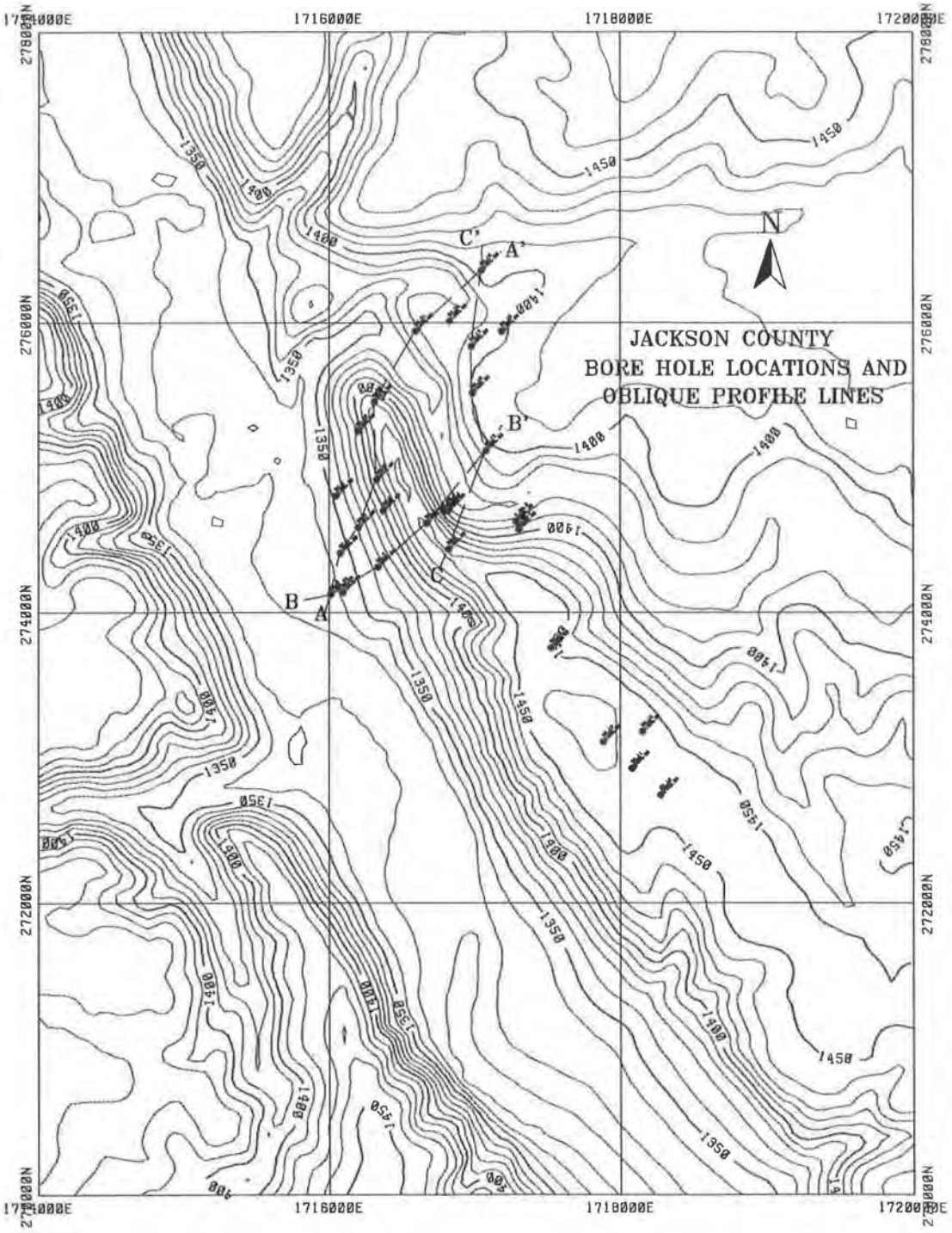
**GRAVEL EXPLORATION X-SECTIONS**

**OBLIQUE SECTIONS A-A' B-B' C-C'**

**SCALE : 1in. = 500ft. Horiz.**

**1in. = 50ft. Vert.**




1714000E
1716000E
1718000E
1720000E
278000N
276000N
274000N
272000N
270000N
N
JACKSON COUNTY
BORE HOLE LOCATIONS AND
OBLIQUE PROFILE LINES
A
A'
B
B'
C
C'

# APPENDIX C

Field Descriptions of Drill Holes and Hand Auger

**Table 1**
**Drill Hole Descriptions**

## Jackson-Hole #1

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 2.5 | Stripping-Overburden: black topsoil. |
| 2.5 | 13 | Stripping-Overburden: Till: light brown to yellowish brown clay, little sandy, occasion pebble, very dry, falls apart easily, increase in sand, granules, and pebbles downward, grading into a very sandy till with coarse sand and fine gravel. |
| 13 | 19 | Stripping-Overburden: Till: silty, sandy clay, light brown, tan, and yellowish brown in color, occasional pebbles and coarse sand, easy drilling. |
| 19 | 25 | Stripping-Overburden: Till: sandy, gravelly clay, to a dirty gravel. |
| 25 | 33 | Stripping-Overburden: Till: very sandy clay, occasional pebble, unsorted. |
| 33 | 35 | Stripping-Overburden: Interbedded till and dirty gravel, a little rockier, thin cobble layers encountered, easy drilling. |
| 35 | 44 | Gravel and Coarse Sand: approximately 45% fine gravel, consisting mostly of granules and small pebbles, no shale found, low limestone content. |
| 44 | 51 | Gravel and Coarse Sand: washed coarse sand dominant, granules and pebbles very abundant, approximately 40% gravel, little shale and limestone found. |

**Samples Collected:** Sample #1 (35ft-44ft), Sample #2 (44ft-51ft), & Composite A (35ft-51ft).

## Jackson-Hole #2

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 1 | Stripping-Overburden: black topsoil. |
| 1 | 8 | Stripping-Overburden: Till: silty clay, powdery dry, occasional pebble and cobble. |
| 8 | 31 | Stripping-Overburden: Till: silty, sandy, gravely clay, well consolidated, pebbles are rare but occur. |
| 31 | 41 | Stripping-Overburden: Till: gray unoxidized till, same as above just not oxidized. |
| 41 | 51 | Stripping-Overburden: Gravelly Till: silty, sandy, gravelly clay with layers of very dirty gravel (less than 6 inches). |

## Jackson-Hole #3

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 3 | Stripping-Overburden: Sandy topsoil. |
| 3 | 10 | Granules and Coarse Sand: granules (pea sized) most common, with pebbles throughout, occasional small cobble, and medium and coarse sand. |
| 10 | 13 | Gravel and Coarse Sand: sandier than above with more cobbles, the cobbles are usually less than 3.5 inches but are very abundant. |
| 13 | 17 | Gravel: very nice spread out gravel, granules and pebbles are most abundant with a coarse-grained sand matrix, medium-grained sand and cobbles are also found throughout. |
| 17 | 23 | Gravel: same gravel as above, however it contains armored clay balls which increase in frequency downward, granules and pebbles are very abundant, with a coarse sand matrix, cobbles and medium-grained sand are found throughout. |
| 23 | 40 | Till: bluish-gray basal till, dominated by a silty, sandy clay. |

**Samples Collected:** Sample #3 (3ft-10ft), Sample #4 (10ft-17ft), & Composite C (3ft-23ft).

## Jackson-Hole #4

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 5 | Stripping-Overburden: black clayey topsoil |
| 5 | 7 | Fine- to Medium-Grained Sand: mostly fine sand and silty clay, probably overbank deposit. |
| 7 | 10 | Fine- to Medium-Grained Sand: light brown, fine- to medium-grained sand, cobbles and pebbles throughout, silty and clayey layers scattered throughout, thin cobble layer from 9-10 feet, it took 5 attempts (locations) to drill this hole through a boulder pavement at the surface. |

**Samples Collected:** Sample #5 (7ft-10ft) & No Composite (5ft-10ft).

## Jackson-Hole #5

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 4 | Stripping-Overburden: Clay |
| 4 | 5 | Cobble Layer: 3-5 inch cobbles. |
| 5 | 10 | Fine- to Medium-Grained Sand: clay and silt layers found throughout, probably an overbank deposit. |
| 10 | 13 | Fine- to Medium-Grained Sand: well sorted fine-grained sand with a few shale pebbles, light-brown color. |
| 13 | 21 | Till: old bluish-gray basal till, dominated by a pebbly, silty, sandy clay. |

## Jackson-Hole #6

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 5 | Silty Sand: silty, clayey, fine-grained sand, river bank deposit. |
| 5 | 15 | Till: bluish-gray basal till, dominated by a silty, sandy clay. |

## Jackson-Hole #7

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 4 | Stripping-Overburden: topsoil grading into silty sand. |
| 4 | 5 | Coarse Sand and Granules: thin gravel layer containing mostly coarse sand, granules and a few pebbles. |
| 5 | 7 | Fine- to Medium-Grained Sand: overbank deposit, containing silt and clay layers. |
| 7 | 9 | Gravel: heavily oxidized, sandy, silty, clayey gravel, iron stained, very dirty. |
| 9 | 16 | Till: old bluish-gray basal till, dominated by a pebbly, silty, sandy clay. |

## Jackson-Hole #8

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 4 | Stripping-Overburden: topsoil grading to clay, few sandy, silty, clayey layers. |
| 4 | 15 | Fine-Grained Sand: light brown to tan colored, well-sorted, with silty, clayey, and thin gravel layers throughout, occasion pebble. |
| 15 | 31 | Till: old bluish-gray basal till, dominated by a pebbly, silty, sandy clay. |

## Jackson-Hole #9

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 4 | Stripping-Overburden: silty topsoil, loess. |
| 4 | 36 | Stripping-Overburden: Till: light brown clayey till, consolidated, gray layers and lenses < 1 cm, silty and sandy layers and lenses, pebbles and cobbles occur throughout (usually less than 5 inches, lignite pieces are rare but present, iron staining is common, a large boulder stopped the drilling at 36 feet. |

## Jackson-Hole #10

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 4 | Stripping-Overburden: black topsoil. |
| 4 | 6 | Stripping-Overburden: Till: light brown to yellowish brown clay, little sandy, occasion pebble, very dry, falls apart easily, gray mottling, contains some pebbles but rare, small fragments of shale present, calcareous and oxidized. |
| 6 | 12 | Stripping-Overburden: Silt: light gray with brown orange mottling, very well sorted, massive, non-calcareous, no pebbles, very little sand present, moist, easy drilling, more pebbles with depth. |
| 12 | 17 | Stripping-Overburden: Till: brown clayey loam with more gray mottling, oxidized, moist, grades to sandier content, more pebbles >2mm around 14 feet, pebble lithology seems to be predominantly limestone and granites. |
| 17 | 22 | Stripping-Overburden: Till: gray/blue, unoxidized, moist, occasional pebbles |
| 22 | 24 | Stripping-Overburden: Till: gray/blue, unoxidized, moist, a little rockier, more clay fraction. |
| 24 | 34 | Stripping-Overburden: Till: gray/blue, unoxidized, moist, pebble fraction seems to be decreasing. |
| 34 | 41 | Stripping-Overburden: Till: gray/blue, unoxidized, moist, pebble fraction seems to be decreasing. |

## Jackson-Hole #11

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 4 | Stripping-Overburden: black topsoil, dry. |
| 4 | 8 | Stripping-Overburden: Till: light brown to yellowish brown silty loam, little sandy, occasion pebble, pebble lithology predominately limestone, crumbly, gray mottling, small fragments of shale present, calcareous and oxidized. |
| 8 | 11 | Stripping-Overburden: Till: light brown to yellowish brown silty loam, rusty mottling, little sandy, occasion pebble, moist, contains some pebbles but rare, small fragments of shale present, calcareous and oxidized. |
| 11 | 13 | Stripping-Overburden: Silt: light brown, very well sorted, massive, non-calcareous, no pebbles near top, very little sand present, moist, easy drilling, more pebbles with depth. |
| 13 | 20 | Stripping-Overburden: Till: light brown silty loam, rusty mottling, little sandy, moist, small fragments of shale present, calcareous and oxidized. |

## Jackson-Hole #12

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 4 | Stripping-Overburden: black topsoil, dry. |
| 4 | 14 | Stripping-Overburden: Till: light brown to yellowish brown silty loam, unsorted, some sandier concentrations near top, occasion pebble, crumbly, gray mottling turns more orange with depth, small fragments of shale present, calcareous and oxidized. |
| 14 | 15.5 | Stripping-Overburden: Silt: light brown to tan, calcareous, massive, very well sorted, no pebbles present. |
| 15.5 | 20 | Stripping-Overburden: Till: brown silty loam, unsorted, more iron mottling, unoxidized, occasional pebbles, calcareous. |

## Jackson-Hole #13

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 3 | Stripping-Overburden: black topsoil, dry. |
| 4 | 14 | Stripping-Overburden: Till: light brown to yellowish brown silty loam, unsorted, some sandier concentrations near top, occasion pebble, crumbly, gray mottling turns more orange with depth, small fragments of shale present, calcareous and oxidized. |
| 14 | 15 | Stripping-Overburden: Silty Sand: poorly sorted brown silty sand layer, wet, sand is fine to medium grained. |
| 15 | 21 | Stripping-Overburden: Till: brown silty loam, unsorted, more iron mottling, oxidized, occasional pebbles, calcareous. |
| 21 | 31 | Stripping-Overburden: Till: blue gray silty loam, unsorted, unsorted, unoxidized, occasional pebbles, calcareous, moist. |
| 31 | 41 | Stripping-Overburden: Till: blue gray silty loam, unsorted, unoxidized, occasional pebbles, calcareous, moist. |
| 41 | 50 | Stripping-Overburden: Till: blue gray silty loam, unsorted, unoxidized, occasional pebbles, calcareous, moist. |

## Jackson-Hole #14

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 2 | Stripping-Overburden: black topsoil, dry. |
| 2 | 6 | Stripping-Overburden: Till: light brown to yellowish brown silty/sandy loam, unsorted, sandier, crumbly, dry, gray mottling, calcareous and oxidized. |
| 6 | 9 | Stripping-Overburden: Till: light brown to gray, silty loam, unsorted, sandier, crumbly, dry, brownish mottling, calcareous and oxidized. |
| 9 | 15 | Stripping-Overburden: Till: brown silty loam, unsorted, gray mottling, oxidized, occasional pebbles, calcareous. |
| 15 | 16 | Stripping-Overburden: Till: brown sandy, sand layer, wet, sand is moderately sorted, medium grained, oxidized. |
| 16 | 20 | Stripping-Overburden: Till: brown till with clumps of silt rich gray till, crumbles, sandier, some gray mottles, calcareous, unsorted. |

## Jackson-Hole #15

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 2.5 | Stripping-Overburden: black topsoil. |
| 2.5 | 4 | Gravel and Course Sand: approximately 40% fine to medium pebbles, 60% loamy medium grained sand, poorly sorted, pebbles and granules are well rounded, pebble lithology predominately consists of limestone, quartzite, mafics, and very weathered granites, some shale, moist. |
| 4 | 10 | Gravel and Course Sand: sandier; approximately 20% fine to medium pebbles, 80% loamy medium grained sand, poorly sorted, pebbles and granules are rounded, pebble lithology predominantly consists of limestone, quartzite, mafics, and very weathered granites, some shale. |
| 10 | 18 | Gravel and Course Sand: approximately 30% fine to medium pebbles, 70% medium to coarse sand, sand is dirty, hit water table at 13 feet, poorly sorted, rounded pebbles, pebble lithology is same as above, shale is still present. |
| 18 | 21 | Till: dark gray, clay-rich till, pebble poor, unoxidized, unsorted. |

**Samples Collected:** Sample #6 (2.5ft-10ft), Sample #7 (10ft-18ft), & Composite B (2.5ft-18ft).

## Jackson-Hole #16

| Depth (ft) From | To | Description |
|---|---|---|
| | | No Top Soil |
| 0 | 8 | Loamy Sand and Gravel: brown diamict, too loamy to sieve, some parts have till -like, owner Don Holthe said this area was refilled, poorly sorted, pebbles are fine to coarse, large silt and clay fraction |
| 8 | 15 | Till: dark gray till, clay rich, pebble poor, limestone pebbles predominate lithology, unsorted, unoxidized, moist. |
| 15 | 21 | Till: dark gray till, clay rich, pebble poor, limestone pebbles predominate lithology, unsorted, unoxidized, moist. |
| 21 | 25 | Till: dark gray, clay-rich till, pebble poor, unoxidized, unsorted. Hit a confined water table at 21 feet below surface. Hydraulic head was higher than surface causing water to rise. Stopped drilling. |

## Jackson-Hole #17

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 2 | Stripping-Overburden: sandy topsoil. |
| 2 | 10 | Till: brown, very sandy till with large clumps of silt rich till, large rust mottles in silt clumps, dry and crumbly, unsorted, large clast, hit rock at 10 feet, very oxidized, |
| 10 | 15 | Till: same as above, large clasts, moister, clast lithologies are quartzite, granites, shale and mafics. |
| 15 | 21 | Till: dark gray, clay rich, finer matrix than above, pebble and clast poor, unsorted, unoxidized. |

## Jackson-Hole #18

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 4 | Topsoil- sandy, dry, rocky. (Hit rock, had to move three feet over) |
| 4 | 6 | Stripping-Overburden: Till: brown, sandy loam, occasional pebbles, very rocky, more than till on ridge. |
| 6 | 9 | Stripping-Overburden: Till: brown, silty loam, gray mottling, rocky |
| 9 | 15 | Stripping-Overburden: Till: brown with more gray mottling, very pebbly. Pebbles are sub-angular, lithologies include limestone, shale, granites, and mafics. |
| 15 | 23 | Stripping-Overburden: Till: dark gray, no mottling, silty loam. |
| 24 | 30 | Fine Sand: lt brown, very well sorted, very wet, hit water table at 25. Losing material, not enough for a sample. |
| 30 | 41 | Silty-sandy Gravel: very coarse fraction, very wet and soupy, gravel is mostly large granules, sub-rounded to sub angular, about 50% gravel, 50% sand. Difficult to tell what is going on. Took a sample. |

**Samples Collected:** Sample #8 (30ft-40ft) No Composite

## Jackson-Hole #19

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 4 | Topsoil |
| 4 | 10 | Till: brown, sandy gravelly loam, very large cobbles to boulders, predominate lithology is Sioux Quartzite, mottled balls of hard and crumbly silt. This is what they were mining in old pit. Some gravel, 20% gravel, 40% sand, 40% silt. Very dirty, gravel is sub-rounded to sub-angular. |
| 10 | 15 | Till: brown starting to become contain significantly less gravel and becoming more loamier, dry, and crumbly. |
| 15 | 20 | Till: brown, loamy, no change. |

**Samples Collected:** Sample #9 (4ft-10ft) No Composite

## Jackson-Hole #20

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 2 | Sandy Gravel: red brown, looks very oxidized, poorly sorted, dirty (silty) gravel, rounded. This may be fill of the gravel pit |
| 2 | 4 | Fine Gravel: red brown, 35% gravel, 65% sand, rounded, poorly sorted. |
| 4 | 10 | Till: dark gray, silt/clay rich, pebble poor |

## Jackson-Hole #21

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 3 | Sandy Gravel: red brown, looks very oxidized, poorly sorted, crumbles. This may be fill of the gravel pit |
| 3 | 10 | Till: dark gray, silt/clay rich |

## Jackson-Hole #22

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 1.5 | Stripping-Overburden: black topsoil, dry. |
| 1.5 | 5 | Loamy Sand and Gravel: brown, till-like, large silt component, 30% gravel, 30% sand, 40% silt/clay. Gravel is sub-rounded |
| 10 | 15 | Stripping-Overburden: Till: brown till, silt/clay rich, pebble poor. |
| 15 | 20 | Stripping-Overburden: Till: brown till, silt/clay rich, pebble poor. |
| 20 | 24 | Stripping-Overburden: Till: brown till, silt/clay rich, pebble poor. |
| 24 | 32 | Sand and Gravel: 60% gravel with cobbles, 40% poorly sorted med-coarse sand, gravel is predominately small pebbles to granules, rounded, coarse content is limestone rich. |
| 32 | 36 | Sand and Gravel: similar to gravel above, cobbles present, sand seems to be a little finer. |
| 36 | 37 | Till Stringer: a layer of till in gravel, brown, silt/clay rich. |
| 37 | 40 | Sandy Gravel: 65% sand, 35% gravel. Sand is med-fine grain, well sorted. Gravel is small medium pebbles to granules, few cobbles. |
| 40 | 46 | Sand and Gravel: similar to the above, seems sandier 70% sand, 30% gravel, Sand is fine grained, well sorted. Gravel is medium pebbles to granular, limestone rich. |

**Samples Collected**: Sample #10 (24ft-32ft), Sample #11 (32ft-46ft), & A part of composite #C (24ft-46ft).

## Jackson-Hole #23

| Depth (ft) From | To | Description |
|---|---|---|
| 0 | 7 | Sand and Gravel; no topsoil, 40% gravel, 60% sand. Sand is moderately sorted, medium grained, gravel is pebble to granular, rounded, very few cobbles, loose and dry. |
| 7 | 10 | Till: loamy, brown, oxidized, silt/clay rich, pebble poor. |
| 10 | 15 | Till: loamy, brown, oxidized, silt/clay rich, pebble poor. |
| 15 | 21 | Till: loamy, brown, oxidized, silt/clay rich, pebble poor. |

**Samples Collected**: Sample #12 (1ft-7ft), A part of composite C.

## Jackson-Trench #1

**Depth (ft)**

**Top (approximately 6 feet below upper contact)**

| From | To | Description |
|---|---|---|
| 0 | .5 | Topsoil |
| .5 | 1.5 | Sand and Gravel: 40% gravel, 60% sand. Sand is moderately sorted, medium grained, gravel is medium grained, granular to pebbly, rounded, very few cobbles, loose and dry, shale present. |
| 3.5 | 4.5 | Sand and Gravel: sandier than above, 70% sand, 30% gravel, sand is medium to fine grained, moderately to well sorted, no apparent bedding structures, gravel is rounded, shale is present |

**Middle (approximately 12 feet below upper contact)**

| From | To | Description |
|---|---|---|
| 0 | .5 | Topsoil |
| .5 | 3 | Sand and Gravel: 60% sand, 40% gravel, sand is medium grained, contains iron oxide streaks, no apparent bedding, some well rounded cobbles, gravel is granular to pebble size, rounded and contains abundant limestone and shale. |

**Bottom (approximately 3 feet above lower contact)**

| From | To | Description |
|---|---|---|
| 0 | .5 | Topsoil |
| .5 | 2.5 | Sand and Gravel: 50% sand, 50% gravel, sand is fine to medium grained, well to moderately sorted, contained iron oxide concentrations in layers, gravel is abundant is shale, limestone and Sioux quartzite. |
| 2.5 | 3 | Till |

**Samples Collected**: Sample #13, A part of composite #D.

## Jackson-Trench #2

**Depth (ft)**

**Top (approximately 2 feet below upper contact)**

| From | To | Description |
|---|---|---|
| 0 | 4 | Sand and Gravel: 40% gravel, 60% sand. Sand is moderately sorted, medium grained, gravel is fine grained, granular, rounded, 5% cobbles, loose and dry, shale present. Gravel is coarser. |

**Middle (approximately 6 feet below upper contact)**

| From | To | Description |
|---|---|---|
| 0 | 4 | Sand and Gravel: 60% sand, 40% gravel, sand is medium grained, contains iron oxide streaks, no apparent bedding, some well rounded cobbles, gravel is granular to pebble size, rounded and contains abundant limestone and shale. |

**Bottom (approximately 4 feet above lower contact)**

| From | To | Description |
|---|---|---|
| 0 | 4 | Sand and Gravel: 60% sand, 40% gravel, sand is fine grained, well to moderately sorted, a silt ball the diameter of 6 inches, gravel is finer, granular, rounded, shale, limestone and Sioux quartzite is abundant. |

**Samples Collected**: Sample #14, A part of composite #D.

## Jackson-Trench #3

**Depth (ft)**

**Top (approximately 4 feet below upper contact)**

| From | To | Description |
|---|---|---|
| 0 | .5 | Topsoil |
| 0.5 | 2 | Sand and Gravel: 35% gravel, 65% sand. Sand is moderately sorted, medium grained, gravel is granular with 10% cobbles, rounded, sand grades finer, limestone and shale is abundant, |
| 2 | 2.5 | Sand and Gravel: 30% gravel, 70% sand. Sand is finer, well sorted, no apparent bedding, gravel is matrix supported, rounded, sand is cleaner, gravel is rounded, well sorted, and limestone, shale, Sioux quartzite and weathered coarse granites. |

**Middle (approximately 12 feet below upper contact)**

| From | To | Description |
|---|---|---|
| 0 | 0.5 | Topsoil |
| 0.5 | 1.5 | Sand and Gravel: 50% sand, 50% gravel, sand is medium grained, contains iron oxide streaks, no apparent bedding, some well rounded cobbles (10%) usually found in cobble layers, gravel is granular to pebble size, rounded and contains abundant limestone and shale. |

**Bottom (approximately 3 feet above lower contact)**

| From | To | Description |
|---|---|---|
| 0 | 0.5 | Topsoil |
| 0.5 | 2.5 | Sand and Gravel: 60% sand, 40% gravel, sand is medium to fine grained, moderately sorted, gravel is finer granular with occasional cobbles (5%), sub-rounded, shale, limestone and Sioux quartzite is abundant. |
| 2.5 | 3 | Till: clay rich, crumbly, brown with gray mottles |

**Samples Collected**: Sample #15, Composite E.

# APPENDIX D

Tables 2 through 6

# Table 2
## Coarse and Fine Grain Size Distribution for all Samples
## Project 334-2

| | Sieve Size | | Composite A Sample No - Hole No | | Composite | | Composite | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inches | mm | 1-1* | 2-1* | 6-15 | 7-15 | 3-3* | 4-3* | 10-22* | 11-22* | 12-23* |
| | 2 1/2" | 63 | | | | | 100 | 100 | 100 | 100 | |
| | 2" | 50 | | | | | 98 | 100 | 100 | 99 | 98 |
| | 1 1/2" | 37.5 | | 95 | 100 | 100 | 98 | 100 | 100 | 95 | 98 |
| G | 1 1/4" | 31.5 | 99 | 95 | 99 | 100 | 98 | 97 | 100 | 95 | 97 |
| R | 1" | 25 | 98 | 94 | 98 | 100 | 96 | 96 | 98 | 94 | 94 |
| A | 3/4" | 19 | 97 | 93 | 96 | 100 | 95 | 94 | 95 | 92 | 92 |
| V | 5/8" | 16 | 95 | 90 | 95 | 100 | 93 | 93 | 92 | 90 | 90 |
| E | 1/2" | 12.5 | 93 | 87 | 93 | 99 | 89 | 92 | 87 | 87 | 87 |
| L | 3/8" | 9.5 | 90 | 84 | 91 | 99 | 86 | 89 | 81 | 84 | 85 |
| | 4 | 4.75 | 78 | 71 | 85 | 97 | 71 | 80 | 62 | 75 | 76 |
| | 8 | 2.36 | 71 | 58 | 79 | 95 | 59 | 72 | 53 | 71 | 66 |
| | 10 | 2.00 | 68 | 54 | 77 | 94 | 56 | 69 | 50 | 70 | 63 |
| | 16 | 1.18 | 57 | 42 | 67 | 88 | 45 | 60 | 41 | 65 | 50 |
| S | 30 | 600um | 36 | 23 | 53 | 71 | 29 | 37 | 30 | 55 | 32 |
| A | 40 | 425um | 26 | 16 | 44 | 54 | 20 | 24 | 25 | 48 | 22 |
| N | 50 | 300um | 16 | 10 | 33 | 34 | 12 | 15 | 21 | 42 | 13 |
| D | 100 | 150um | 9 | 6 | 19 | 15 | 6 | 8 | 15 | 28 | 5 |
| | 200 | 75um | 6.4 | 4.5 | 13.7 | 10.2 | 4.2 | 5.0 | 10.2 | 18.8 | 3.5 |
| | % Gravel | 63-2mm | 32.00 | 46.00 | 23.00 | 6.00 | 44.00 | 31.00 | 50.00 | 30.00 | 37.00 |
| | % Sand | 1.18mm-75u | 61.60 | 49.50 | 63.30 | 83.80 | 51.80 | 64.00 | 39.80 | 51.20 | 59.50 |
| | % Silt/Clay | <75um | 6.40 | 4.50 | 13.70 | 10.20 | 4.20 | 5.00 | 10.20 | 18.80 | 3.50 |

| | Sieve Size | | Composite D Auger 1&2* | | Composite Auger 3* | No Composite Sample- Hole No | | | MNDOT Ave % * |
|---|---|---|---|---|---|---|---|---|---|
| | Inches | mm | 13 | 14 | 15 | 5-4 | 8-18 | 9-19 | |
| | 2 1/2" | 63 | | | | | | | |
| | 2" | 50 | 100 | 100 | | 100 | | 100 | |
| | 1 1/2" | 37.5 | 99 | 98 | | 90 | 100 | 97 | |
| G | 1 1/4" | 31.5 | 99 | 98 | 100 | 90 | 99 | 97 | |
| R | 1" | 25 | 97 | 96 | 98 | 86 | 97 | 95 | |
| A | 3/4" | 19 | 95 | 95 | 97 | 83 | 94 | 92 | |
| V | 5/8" | 16 | 93 | 93 | 95 | 82 | 93 | 90 | |
| E | 1/2" | 12.5 | 91 | 91 | 91 | 78 | 89 | 87 | |
| L | 3/8" | 9.5 | 87 | 89 | 87 | 76 | 85 | 82 | |
| | 4 | 4.75 | 74 | 81 | 71 | 68 | 72 | 67 | |
| | 8 | 2.36 | 68 | 70 | 60 | 65 | 65 | 66 | |
| | 10 | 2.00 | 66 | 67 | 56 | 64 | 63 | 66 | |
| | 16 | 1.18 | 57 | 54 | 38 | 60 | 58 | 64 | |
| S | 30 | 600um | 42 | 34 | 19 | 53 | 53 | 61 | |
| A | 40 | 425um | 34 | 24 | 12 | 49 | 50 | 59 | |
| N | 50 | 300um | 26 | 16 | 7 | 44 | 46 | 52 | |
| D | 100 | 150um | 12 | 7 | 4 | 26 | 35 | 34 | |
| | 200 | 75um | 5.5 | 4.9 | 2.4 | 14.0 | 26.2 | 22.8 | |
| | % Gravel | 63-2mm | 34.00 | 33.00 | 44.00 | 36.00 | 37.00 | 36.00 | |
| | % Sand | 1.18mm-75u | 60.50 | 62.10 | 53.60 | 50.00 | 39.80 | 41.20 | |
| | % Silt/Clay | <75um | 5.50 | 4.90 | 2.00 | 14.00 | 26.20 | 22.80 | |

* Indicates samples taken from the described gravel layer. Only the data marked with an asterick will be included in Table 6.

Table 3
MNDoT Laboratory Analysis: Composites A and B
Project 334-2

## Coarse and Fine Grain Size Distribution:

Composite

| | Sieve Size | | Sample-Hole | |
|---|---|---|---|---|
| | Inches | mm | 1-1 | 2-1 |
| GRAVEL | 2 1/2" | 63 | | |
| | 2" | 50 | | |
| | 1 1/2" | 37.5 | | 95 |
| | 1 1/4" | 31.5 | 99 | 95 |
| | 1" | 25 | 98 | 94 |
| | 3/4" | 19 | 97 | 93 |
| | 5/8" | 16 | 95 | 90 |
| | 1/2" | 12.5 | 93 | 87 |
| | 3/8" | 9.5 | 90 | 84 |
| | 4 | 4.75 | 78 | 71 |
| | 8 | 2.36 | 71 | 58 |
| | 10 | 2.00 | 68 | 54 |
| SAND | 16 | 1.18 | 57 | 42 |
| | 30 | 600um | 36 | 23 |
| | 40 | 425um | 26 | 16 |
| | 50 | 300um | 16 | 10 |
| | 100 | 150um | 9 | 6 |
| | 200 | 75um | 6.4 | 4.5 |

| | | | |
|---|---|---|---|
| % Gravel | 63-2mm | 32.00 | 46.00 |
| % Sand | 1.18mm-75um | 61.60 | 49.50 |
| % Silt/Clay | <75um | 6.40 | 4.50 |

### Laboratory Analysis:

| % PASSING SIEVE: | Composite | MNDoT Specs |
|---|---|---|
| % Shale in Sand | 0.81 | 0.70 |
| % Spall #4 | 1.30 | 1.50 |
| % Absorption (-4) | 1.32 | |
| Bulk SpG (-4) | 2.580 | |
| App. SpG (-4) | 2.671 | |
| Mag%Lost 3/8-4 | 9.62 | 15.00 |
| % Absorption (+4) | 1.82 | |
| Bulk SpG (+4) | 2.605 | |
| App. SpG (+4) | 2.738 | |

## Coarse and Fine Grain Size Distribution:

Composite B

| | Sieve Size | | Sample-Hole | |
|---|---|---|---|---|
| | Inches | mm | 6-15 | 7-15 |
| GRAVEL | 2 1/2" | 63 | | |
| | 2" | 50 | | |
| | 1 1/2" | 37.5 | 100 | 100 |
| | 1 1/4" | 31.5 | 99 | 100 |
| | 1" | 25 | 98 | 100 |
| | 3/4" | 19 | 96 | 100 |
| | 5/8" | 16 | 95 | 100 |
| | 1/2" | 12.5 | 93 | 99 |
| | 3/8" | 9.5 | 91 | 99 |
| | 4 | 4.75 | 85 | 97 |
| | 8 | 2.36 | 79 | 95 |
| | 10 | 2.00 | 77 | 94 |
| SAND | 16 | 1.18 | 67 | 88 |
| | 30 | 600um | 53 | 71 |
| | 40 | 425um | 44 | 54 |
| | 50 | 300um | 33 | 34 |
| | 100 | 150um | 19 | 15 |
| | 200 | 75um | 13.7 | 10.2 |

| | | | |
|---|---|---|---|
| % Gravel | 63-2mm | 23.00 | 6.00 |
| % Sand | 1.18mm-75um | 63.30 | 83.80 |
| % Silt/Clay | <75um | 13.70 | 10.20 |

### Laboratory Analysis:

| % PASSING SIEVE: | Composite | MNDoT Specs |
|---|---|---|
| % Shale in Sand | 6.48 | 0.70 |
| % Spall #4 | 13.80 | 1.50 |
| % Absorption (-4) | 4.31 | |
| Bulk SpG (-4) | 2.387 | |
| App. SpG (-4) | 2.661 | |
| Mag%Lost 3/8-4 | 22.76 | 15.00 |
| % Absorption (+4) | 5.88 | |
| Bulk SpG (+4) | 2.343 | |
| App. SpG (+4) | 2.745 | |

Table 4
MNDoT Laboratory Analysis: Composites C and D
Project 334-2

## Coarse and Fine Grain Size Distribution:

Composite C

| | Sieve Size | | Sample-Hole | | | | |
|---|---|---|---|---|---|---|---|
| | Inches | mm | 3-3 | 4-3 | 10-22 | 11-22 | 12-23 |
| | 2 1/2" | 63 | 100 | 100 | 100 | 100 | 100 |
| | 2" | 50 | 98 | 100 | 100 | 99 | 98 |
| | 1 1/2" | 37.5 | 98 | 100 | 100 | 95 | 98 |
| G | 1 1/4" | 31.5 | 98 | 97 | 100 | 95 | 97 |
| R | 1" | 25 | 96 | 96 | 98 | 94 | 94 |
| A | 3/4" | 19 | 95 | 94 | 95 | 92 | 92 |
| V | 5/8" | 16 | 93 | 93 | 92 | 90 | 90 |
| E | 1/2" | 12.5 | 89 | 92 | 87 | 87 | 87 |
| L | 3/8" | 9.5 | 86 | 89 | 81 | 84 | 85 |
| | 4 | 4.75 | 71 | 80 | 62 | 75 | 76 |
| | 8 | 2.36 | 59 | 72 | 53 | 71 | 66 |
| | 10 | 2.00 | 56 | 69 | 50 | 70 | 63 |
| | 16 | 1.18 | 45 | 60 | 41 | 65 | 50 |
| S | 30 | 600um | 29 | 37 | 30 | 55 | 32 |
| A | 40 | 425um | 20 | 24 | 25 | 48 | 22 |
| N | 50 | 300um | 12 | 15 | 21 | 42 | 13 |
| D | 100 | 150um | 6 | 8 | 15 | 28 | 5 |
| | 200 | 75um | 4.2 | 5.0 | 10.2 | 18.8 | 3.5 |
| | % Gravel | 63-2mm | 44.00 | 31.00 | 50.00 | 30.00 | 37.00 |
| | % Sand | 1.18mm-75um | 51.80 | 64.00 | 39.80 | 51.20 | 59.50 |
| | % Silt/Clay | <75um | 4.20 | 5.00 | 10.20 | 18.80 | 3.50 |

### Laboratory Analysis:

| % PASSING SIEVE: | Comp C | MNDoT Specs |
|---|---|---|
| % Shale , 1/2"+ | 1.10 | 0.40 |
| % Shale in Sand | 0.74 | 0.70 |
| % Clay Balls | 12.20 | 0.30 |
| % Other Rock | 87.80 | |
| % Spall 1/2" | 2.50 | 1.00 |
| % Spall #4 | 0.80 | 1.50 |
| | | |
| % Absorption (-4) | 1.60 | |
| Bulk SpG (-4) | 2.572 | |
| App. SpG (-4) | 2.682 | |
| Mag%Lost (3/8-4) | 13.07 | 15.00 |
| % Absorpt (3/4-3/8) | 1.72 | |
| Bulk SpG (3/4-3/8) | 2.616 | |
| App. SpG (3/4-3/8) | 2.741 | |
| % Absorpt (3/8-4) | 2.06 | |
| Bulk SpG (3/8-4) | 2.598 | |
| App. SpG (3/8-4) | 2.748 | |

## Coarse and Fine Grain Size Distribution:

Composite D

| | Sieve Size | | Auger 1&2 | |
|---|---|---|---|---|
| | Inches | mm | 13 | 14 |
| | 2 1/2" | 63 | | |
| | 2" | 50 | 100 | 100 |
| | 1 1/2" | 37.5 | 99 | 98 |
| G | 1 1/4" | 31.5 | 99 | 98 |
| R | 1" | 25 | 97 | 96 |
| A | 3/4" | 19 | 95 | 95 |
| V | 5/8" | 16 | 93 | 93 |
| E | 1/2" | 12.5 | 91 | 91 |
| L | 3/8" | 9.5 | 87 | 89 |
| | 4 | 4.75 | 74 | 81 |
| | 8 | 2.36 | 68 | 70 |
| | 10 | 2.00 | 66 | 67 |
| | 16 | 1.18 | 57 | 54 |
| S | 30 | 600um | 42 | 34 |
| A | 40 | 425um | 34 | 24 |
| N | 50 | 300um | 26 | 16 |
| D | 100 | 150um | 12 | 7 |
| | 200 | 75um | 5.5 | 4.9 |
| | % Gravel | 63-2mm | 34.00 | 33.00 |
| | % Sand | 1.18mm-75um | 60.50 | 62.10 |
| | % Silt/Clay | <75um | 5.50 | 4.90 |

### Laboratory Analysis:

| % PASSING SIEVE: | Comp D | MNDoT Specs |
|---|---|---|
| % Shale , 1/2"+ | 0.40 | 0.40 |
| % Shale in Sand | 0.69 | 0.70 |
| % Shale (Total) +4 | 0.40 | |
| % Iron Oxide | 0.200 | 0.30 |
| % Soft Rock | 0.400 | 2.50 |
| % Other Rock | 99.00 | |
| % Spall 1/2" | 0.70 | 1.00 |
| % Spall #4 | 2.50 | 1.50 |
| % Totl Spall +4 | 0.70 | |
| % Spall&Soft Rock | 0.70 | |
| | | |
| % Absorption (-4) | 1.79 | |
| Bulk SpG (-4) | 2.520 | |
| App. SpG (-4) | 2.640 | |
| % Absorption (+4) | 2.35 | |
| Bulk SpG (+4) | 2.574 | |

Table 5
MNDoT Laboratory Analysis: Composite E and "No Composite"
Project 334-2

## Coarse and Fine Grain Size Distribution:

Composite E

| | Sieve Size | | Auger 3 |
|---|---|---|---|
| | Inches | mm | 15 |
| GRAVEL | 2" | 50 | |
| | 1 1/2" | 37.5 | |
| | 1 1/4" | 31.5 | 100 |
| | 1" | 25 | 98 |
| | 3/4" | 19 | 97 |
| | 5/8" | 16 | 95 |
| | 1/2" | 12.5 | 91 |
| | 3/8" | 9.5 | 87 |
| | 4 | 4.75 | 71 |
| | 8 | 2.36 | 60 |
| | 10 | 2.00 | 56 |
| SAND | 16 | 1.18 | 38 |
| | 30 | 600um | 19 |
| | 40 | 425um | 12 |
| | 50 | 300um | 7 |
| | 100 | 150um | 4 |
| | 200 | 75um | 2.4 |

| | | |
|---|---|---|
| % Gravel | 63-2mm | 44.00 |
| % Sand | 1.18mm-75um | 53.60 |
| % Silt/Clay | <75um | 2.40 |

## Laboratory Analysis:

| % PASSING SIEVE: | Comp E | MNDoT Specs |
|---|---|---|
| % Shale in Sand | N.C. | 0.70 |
| % Shale (Total) +4 | 0.20 | |
| % Iron Oxide | 0.10 | 0.30 |
| % Other Rock | 69.60 | |
| % Spall #4 | 0.40 | 1.50 |
| % Totl Spall +4 | 0.30 | |
| % Spall&Soft Rock | 0.30 | |
| % Absorption (-4) | 1.29 | |
| Bulk SpG (-4) | 2.598 | |
| App. SpG (-4) | 2.688 | |
| % Absorpt (3/8-4) | 2.25 | |
| Bulk SpG (3/8-4) | 2.583 | |

## Coarse and Fine Grain Size Distribution:

No Composite

| | Sieve Size | | Sample-Hole | | |
|---|---|---|---|---|---|
| | Inches | mm | 5-4 | 8-18 | 9-19 |
| GRAVEL | 2" | 50 | 100 | | 100 |
| | 1 1/2" | 37.5 | 90 | 100 | 97 |
| | 1 1/4" | 31.5 | 90 | 99 | 97 |
| | 1" | 25 | 86 | 97 | 95 |
| | 3/4" | 19 | 83 | 94 | 92 |
| | 5/8" | 16 | 82 | 93 | 90 |
| | 1/2" | 12.5 | 78 | 89 | 87 |
| | 3/8" | 9.5 | 76 | 85 | 67 |
| | 4 | 4.75 | 68 | 72 | 66 |
| | 8 | 2.36 | 65 | 65 | 66 |
| | 10 | 2.00 | 64 | 63 | 64 |
| SAND | 16 | 1.18 | 60 | 58 | 61 |
| | 30 | 600um | 53 | 53 | 59 |
| | 40 | 425um | 49 | 50 | 52 |
| | 50 | 300um | 44 | 46 | 52 |
| | 100 | 150um | 26 | 35 | 34 |
| | 200 | 75um | 14.0 | 26.2 | 22.8 |

| | | | | |
|---|---|---|---|---|
| % Gravel | 63-2mm | 36.00 | 37.00 | 36.00 |
| % Sand | 1.18mm-75um | 50.00 | 39.80 | 41.20 |
| % Silt/Clay | <75um | 14.00 | 26.20 | 22.80 |

Table 5
MNDoT Laboratory Analysis: Composite E and "No Composite"
Project 334-2

## Coarse and Fine Grain Size Distribution:

Composite E

| | Sieve Size | | Auger 3 |
|---|---|---|---|
| | Inches | mm | 15 |
| GRAVEL | 2" | 50 | |
| | 1 1/2" | 37.5 | |
| | 1 1/4" | 31.5 | 100 |
| | 1" | 25 | 98 |
| | 3/4" | 19 | 97 |
| | 5/8" | 16 | 95 |
| | 1/2" | 12.5 | 91 |
| | 3/8" | 9.5 | 87 |
| | 4 | 4.75 | 71 |
| | 8 | 2.36 | 60 |
| | 10 | 2.00 | 56 |
| SAND | 16 | 1.18 | 38 |
| | 30 | 600um | 19 |
| | 40 | 425um | 12 |
| | 50 | 300um | 7 |
| | 100 | 150um | 4 |
| | 200 | 75um | 2.4 |

| | | |
|---|---|---|
| % Gravel | 63-2mm | 44.00 |
| % Sand | 1.18mm-75um | 53.60 |
| % Silt/Clay | <75um | 2.40 |

## Laboratory Analysis:

| % PASSING SIEVE: | Comp E | MNDoT Specs |
|---|---|---|
| % Shale in Sand | N.C. | 0.70 |
| % Shale (Total) +4 | 0.20 | |
| % Iron Oxide | 0.10 | 0.30 |
| % Other Rock | 69.60 | |
| % Spall #4 | 0.40 | 1.50 |
| % Totl Spall +4 | 0.30 | |
| % Spall&Soft Rock | 0.30 | |
| | | |
| % Absorption (-4) | 1.29 | |
| Bulk SpG (-4) | 2.598 | |
| App. SpG (-4) | 2.688 | |
| | | |
| % Absorpt (3/8-4) | 2.25 | |
| Bulk SpG (3/8-4) | 2.583 | |

## Coarse and Fine Grain Size Distribution:

No Composite

| | Sieve Size | | Sample-Hole | | |
|---|---|---|---|---|---|
| | Inches | mm | 5-4 | 8-18 | 9-19 |
| GRAVEL | 2" | 50 | 100 | | 100 |
| | 1 1/2" | 37.5 | 90 | 100 | 97 |
| | 1 1/4" | 31.5 | 90 | 99 | 97 |
| | 1" | 25 | 86 | 97 | 95 |
| | 3/4" | 19 | 83 | 94 | 92 |
| | 5/8" | 16 | 82 | 93 | 90 |
| | 1/2" | 12.5 | 78 | 89 | 87 |
| | 3/8" | 9.5 | 76 | 85 | 67 |
| | 4 | 4.75 | 68 | 72 | 66 |
| | 8 | 2.36 | 65 | 65 | 66 |
| | 10 | 2.00 | 64 | 63 | 64 |
| SAND | 16 | 1.18 | 60 | 58 | 61 |
| | 30 | 600um | 53 | 53 | 59 |
| | 40 | 425um | 49 | 50 | 52 |
| | 50 | 300um | 44 | 46 | 52 |
| | 100 | 150um | 26 | 35 | 34 |
| | 200 | 75um | 14.0 | 26.2 | 22.8 |

| | | | | |
|---|---|---|---|---|
| % Gravel | 63-2mm | 36.00 | 37.00 | 36.00 |
| % Sand | 1.18mm-75um | 50.00 | 39.80 | 41.20 |
| % Silt/Clay | <75um | 14.00 | 26.20 | 22.80 |

# Table 6
# MNDOT Gradation Comparisons with Gravel Samples taken from the Bluff
# Project 334-2

MNDOT Base and Surfacing Percentages

| | Sieve | | Class 3 | Class 4 | Class 5 | | Vol of size fraction |
|---|---|---|---|---|---|---|---|
| | Inches | mm | % | % | % | Ave % passing | in cubic yards |
| GRAVEL | 2 1/2" | 63 | | | | | |
| | 2" | 50 | 100 | 100 | | 0 | |
| | 1 1/2" | 37.5 | | | | | |
| | 1 1/4" | 31.5 | | | | | |
| | 1" | 25 | | | 100 | 96 | 63200 |
| | 3/4" | 19 | | | 90-100 | 95 | 15800 |
| | 5/8" | 16 | | | | 92 | 47400 |
| | 1/2" | 12.5 | | | | 90 | 31600 |
| | 3/8" | 9.5 | | | 50-90 | 86 | 63200 |
| | 4 | 4.75 | 35-100 | 35-100 | 35-80 | 74 | 189600 |
| | 8 | 2.36 | | | | 65 | 142200 |
| | 10 | 2.00 | 20-100 | 20-100 | 20-65 | 62 | 47400 |
| SAND | 16 | 1.18 | | | | 51 | 173800 |
| | 30 | 600um | | | | 34 | 268600 |
| | 40 | 425um | 5-50 | 10-50 | 10-35 | 25 | 142200 |
| | 50 | 300um | | | | 18 | 110600 |
| | 100 | 150um | | | | 10 | 126400 |
| | 200 | 75um | 5-10 | 4-10 | 3-10 | 6.5 | 55300 |

Total 1580000 cubic yards

The averaged samples are denoted with an aterisk (*) in tables 2-5.

# APPENDIX E

Parcel B Memo

DEPARTMENT: Natural Resources
Division of Minerals

STATE OF MINNESOTA
# Office Memorandum

DATE: July 27, 1998
TO: Lee Markell
Parks Planner
FROM: Heather Anderson
Geologist
PHONE: 218-262-7331
FAX: 218-262-7328

SUBJECT: Supplement Volume Estimate

Lee,
Upon your request, I estimated the volume of gravel for land extending south of the current evaluation site. As per our conversation last Wednesday, this estimate is for land 400 feet south from the north quarter section line in T103N, R35W, Section 8 and 1600 feet east from the Des Moines River.

Due to some confusion of the site's southern most boundary, a sample was accidentally taken and analyzed from this area. Since Mr. Holthe pointed out that this was out of the proposed area, it was omitted from the report.

As stated in Report 334-2, the findings are a resource estimate and determined with a large margin of error. I determined the area of gravel by extending the current gravel boundaries from Report 334-2; the 1380 foot contour line and the "dotted" line to the east. Although, I have not observed the true thickness of deposit in this area, I am assuming that the gravel layer maintains the thickness of 20 feet.

-Approximate Area of Gravel ≅ 9 acres
-Approximate Volume of Gravel ≅ 290,400 ± 30% cubic yards.
-Lab Results were for coarse and fine gradations and were similar to the samples to the north:

| Sieve Size: Inches | mm | Percent Passing |
|---|---|---|
| 3" | 75 | 100 |
| 2.5" | 63 | 98 |
| 1.25" | 31.5 | 95 |
| 1 | 25.0 | 93 |
| 3/4" | 19.0 | 90 |
| 5/8" | 16.0 | 89 |
| 1/2" | 12.5 | 86 |
| 3/8" | 9.5 | 83 |
| #4 | 4.75 | 71 |
| #8 | 2.36 | 62 |
| #10 | 2.00 | 59 |
| #16 | 1.18 | 44 |
| #30 | 600um | 24 |
| #40 | 425um | 15 |
| #50 | 300um | 7 |
| #100 | 150um | 1 |
| #200 | 75um | 0.5 |

This information will be included in the final version of Report 334-2. If you have any questions please feel free to call me.

-Heather Anderson