# Wisconsin clay deposits. December 1979

[s.l.]: Exxon Minerals Company, December 1979

https://digital.library.wisc.edu/1711.dl/OTU2RZDQ5EY2M8F

EXXON MINERALS COMPANY, U.S.A.

Wisconsin Clay Deposits
December 1979

## TABLE OF CONTENTS

# APPENDICES

# INTRODUCTION

Purpose of the Report: The purpose of this report is to document occurrences of clay-rich soils in Wisconsin which could be considered for mining and use at Crandon as a disposal basin lining material. The availability of commercially produced clay from outside of the state has been considered in the second section of this two part report for the purpose of a cost comparison with local clay sources.

Conclusions and Recommendations: It is concluded that clay deposits within Wisconsin are generally poorly sorted, of limited size, and consist of calcium montmorillonite or illite. This places the in-state deposits at a distinct disadvantage when compared to cleaner, much larger, Western sodium montmorillonite deposits. The sodium based clays are preferred because of their superior swelling characteristics.

High land usage within Wisconsin greatly adds to exploration, development and acquisition costs. Many of the better clay deposits within this state cannot be considered for mining because they occur beneath or adjacent to environmentally sensitive areas such as wetlands and wildlife preserves. Land conflicts, where high yield farmlands overlie or surround some Wisconsin deposits could result in sensitive socioeconomic issues being raised. Therefore, the obtaining of a permit to mine clay could become another uncertainty that cannot be clearly quantified as to time nor cost.

It is recommended that commercially produced Western clays be considered as a primary source of tailings basin lining material.

Proposed Waste Disposal Rules and Regulations: State and federal rules and regulations have not been promulgated for the disposal of mine waste products nor lining of impoundment areas within Wisconsin. A part of the legislative delay is the government's uncertainty whether to classify pyrite-rich mine wastes as hazardous or non-hazardous products.

The Environmental Protection Agency (EPA) proposed rules on hazardous waste guidelines and regulations, and the Resource Conversation and Reclamation Act indicate that various thicknesses of in-place or introduced impermeable soils are required to line waste disposal areas. The impermeable soil thickness is dependent upon the waste classification and upon the facility design. Such design considerations as membrane liners or leachate collection systems may reduce the amount, but not the quality of the soil liner.

Soils Specifications: The EPA has proposed that earth materials used in a soils liner or natural in-place soil barrier shall meet the following minimum criteria:

- Be classified under the Unified Soil Classification System CL, CH, SC, and OH (ASTM Standard D2487-69),
- Allow greater than 30 percent passage through a no. 200 sieve (ASTM Test D1140),
- Have a liquid limit equal to or greater than 30 units (ASTM Test D423),
- Have plasticity greater than or equal to 15 units (ASTM Test D424),
- Have a pH or 7.0 or higher, and
- Have a permeability not adversely affected by anticipated waste.

Soils Liner Requirements Needed at Crandon: The latest proposed waste storage facility design encompasses an area of about 400 hectares (1000 acres). However, segregation of potential leachate producing waste from chemically inert waste could reduce the area to be lined to about 240 hectares (600 acres).

It is estimated that a minimum of 3.7 million cubic meters (4.84 million cubic yards) of clay soils will be required to line 240 hectares to a depth of 1.5 meters (5 feet). A maximum of 385,000 cubic meters (13.6 million cubic yards) is anticipated to cover the same area to a depth of 3 meters (10 feet).

Data Source: Data sources used during the compilation of this report may be found under references and in Appendix I.

## PART I THE OCCURRENCE OF CLAY-RICH SOILS IN WISCONSIN

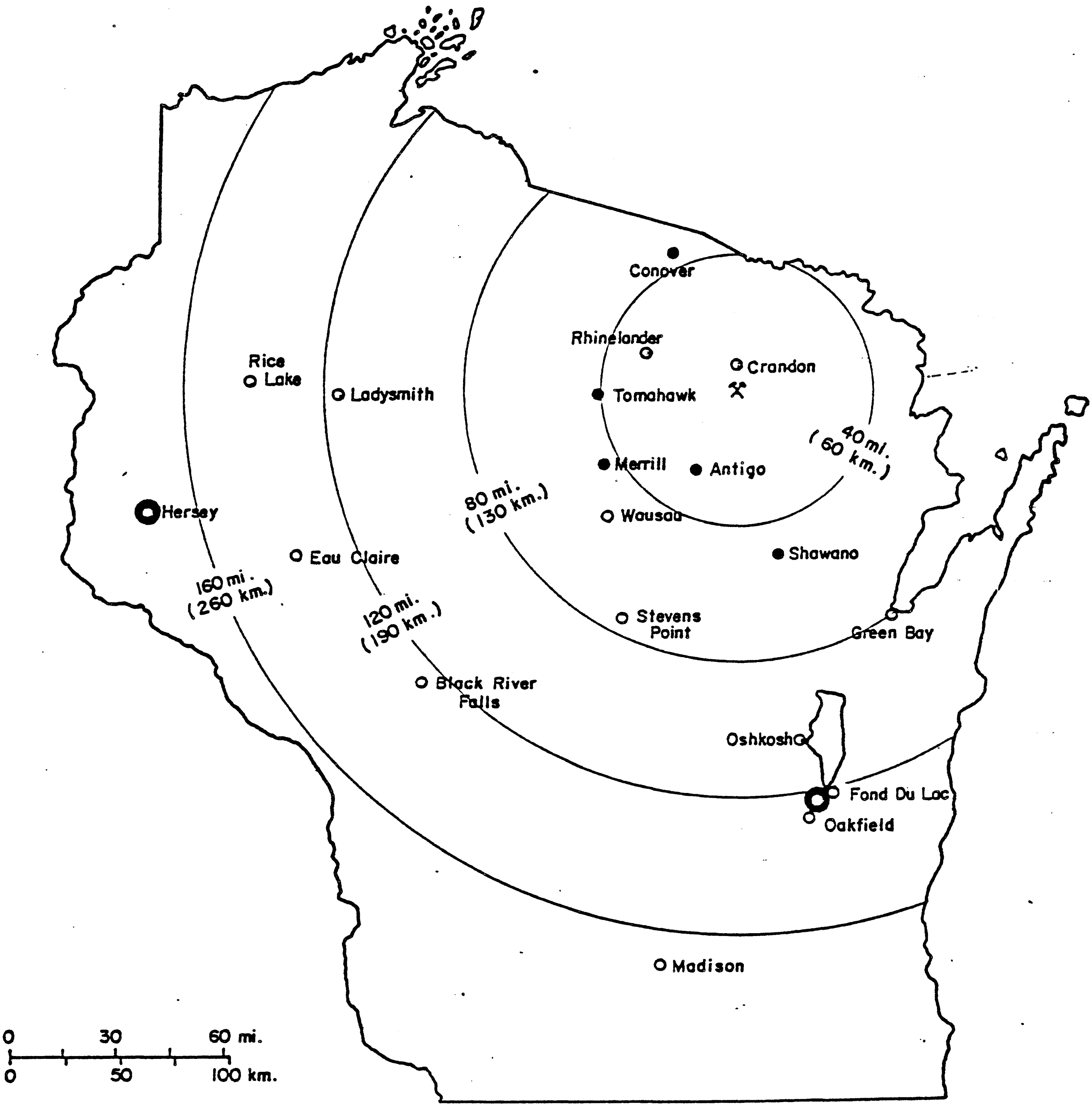
History of Clay Production: Near the turn of the century, Wisconsin had a large clay industry that produced building bricks, tile, and terra cotta products. In 1897, 225,000,000 bricks were produced from clay pits scattered across the state. Wisconsin also contained one of the nations' largest kaolinite clay pits located near Hersey, in Dunn County (Figure 1). A decline in the use of brick, lack of plant modernization, high energy costs, and the opening of larger, better quality clay deposits in other states led to the rapid decline of this once thriving industry.

Today, Wisconsin has only one producing clay mine. This pit, located near Oakfield (Figure 1), produces about 1800 tonnes (2000 tons) of illite clay per year.

Wisconsin Soil Classes: Wisconsin clay rich soils can be divided into two classes, residual and transported. Residual soils are formed by in-place bedrock

FIGURE I

# CLAY PRODUCING OR POTENTIAL CLAY PRODUCING AREAS WISCONSIN




● ABANDONED CLAY PITS CLOSEST TO CRANDON

⭘ PRODUCING OR POTENTIAL CLAY PRODUCING AREAS disintegration. Transported soils are those soils which have been moved from the original bedrock and redeposited at another location (Krynine, 1957). Transporting agents were ice (glacial), water (fluvial and lacustrine), and wind (aeolian). The general distribution of residual and transported soils is illustrated on Figure 2.

Distribution of Residual Soils: Residual soils are located in the southwest and west central areas of Wisconsin. A narrow band of clay altered shale extends from the west side of the Door Peninsula south parallel to Lake Michigan and into Illinois. At least two areas of residual soils have been noted in northwest Wisconsin near the communities of Rice Lake and Ladysmith.

Residual Clay Deposits: Four distinct kinds of residual clay soils have been found within Wisconsin:

Precambrian Saprolite

Ordovician Maquoketa Shale

Cretaceous Hersey Soil

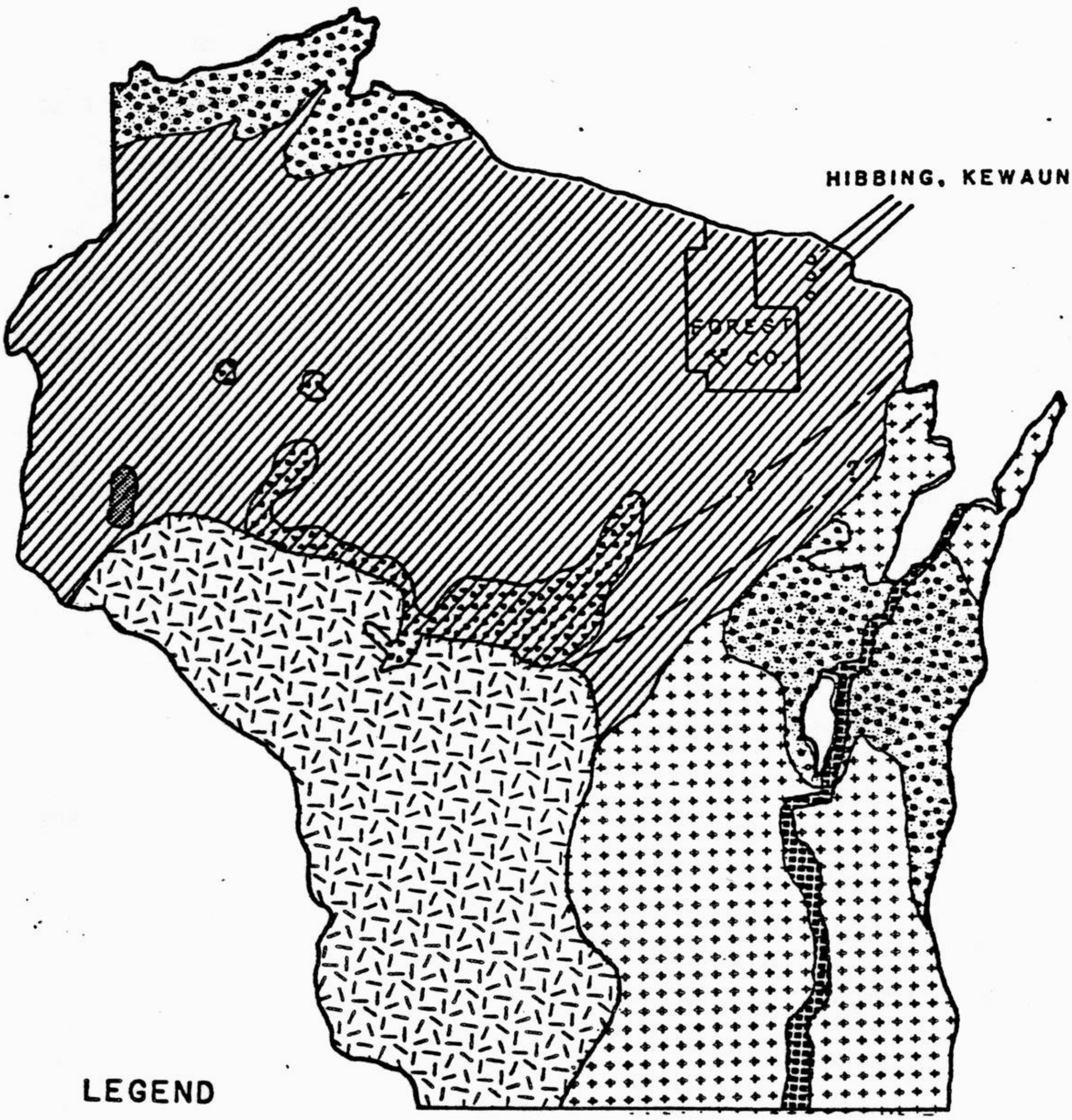
Driftless Area Soils

(a) Precambrian Saprolite. Saprolite does not appear to be a viable source of clay. Environmental concerns, variable permeabilities, and high development costs negate further consideration of the saprolite for use at Crandon.

Saprolite is a general term to denote a thoroughly decomposed, earthy, and untransported material. In Wisconsin, saprolite is a Precambrian soil that has been protected from erosion by deposits of Paleozoic rocks.

FIGURE 2

# SIMPLIFIED RESIDUAL – TRANSPORTED SOILS MAP OF WISCONSIN




LEGEND

- IRON RIVER, GOGEBIC, WITHEE, OMEGA
- ONAWAY, DODGE
- HIBBING, KEWAUNEE
- THE DRIFTLESS AREA
- CRETACEOUS (?) HERSEY
- ORDOVICIAN MAQUOKETA
- PRECAMBRIAN SAPROLITE

KILOMETERS 0 80 160

MILES 0 50 100

Saprolite deposits are found scattered along or close to the contact between the steeply dipping Precambrian and more gently dipping Paleozoic rocks. This contact arcs convexly across Central Wisconsin from Rice Lake east to Wausau. Erosion has dissected the contact in several places to expose saprolite along river channels and at the base of valley wall bluffs. Saprolite soils have been recorded where the Chippewa, Black, and Wisconsin Rivers and some of their tributaries cross the Precambrian-Paleozoic rock contact.

Saprolite has not been recorded east of Wausau even though the Precambrian-Paleozoic contact continues to arc convexly to the northeast. Perhaps the absence of a major river system necessary to deeply erode the contact or thick moraine deposits, or a combination of these and other factors could explain why saprolite has not been recorded in this area.

The saprolite mineralogy and permeability can vary erratically since these physical properties are dependent upon the chemical composition of the underlying parent rock. Areas of saprolite underlain by volcanic rock having an intermediate composition are likely to contain micron-sized chlorite, quartz and mica. A granite parent rock would probably produce kaolinite. Materials other than clay are often present such as quartz fragments or blocks of partially decomposed bedrock. These materials often increase the saprolite permeability.

Saprolite was mined in the late 1890s' 95 km (60 Miles) southeast of the Crandon project site near Stevens Point. However, this and other more distal saprolite pits were small producers. Most pit operators mined about a 3 meter thick layer of saprolite. One of the largest pits was located at Black River Falls, where a 4 meter (12 foot) thick layer was mined for a distance of 400 meters (1300 feet) along the Black River.

It is concluded that Precambrian saprolite is not a viable source of clay. Saprolite is generally found along major river channels which have dissected the Precambrian-Paleozoic rock contact. A pit developed this close to a navigable stream would present environmental difficulties. Most saprolite occurrences are capped by Paleozoic rock which increase the stripping ratio and removal cost.

(b) Ordovician Maquoketa Shale. The Oakfield-Fond du Lac area may warrant consideration for mining of a clay-rich shale. In many locations dolomite needs to be stripped to expose the Maquoketa formation. This dolomite could be a potential source of acid neutralizing rock.

The Maquoketa Shale formation is of late Ordovician age and is underlain by middle Ordovician Galena dolomite. The age of the overlying rock is in question, since the upper contact probably represents an erosional surface. In places, the Neda Iron Formation, which could be either late Ordovician or early Silurian, overlies the Maquoketa; elsewhere, the Silurian Mayville Dolomite forms the cap rock. All these rocks are a part of the Paleozoic sequence that forms the western edge of the Michigan sedimentary basin. These formations strike in a north-south direction, and dip very gently, about 5 degrees to the east. In areas of minor folding or flexturing, the beds may be horizontal or the dip reversed. The Maquoketa shale (Figure 2) has a true thickness of approximately 30 meters (100 feet).

Abandoned clay pits are scattered along the Maquoketa shale south of Green Bay. The Oakfield pit, a one man operation, is the only Wisconsin producing clay mine. Production records have been held confidential since 1976, but prior records indicate an annual production of 1800 tonnes from a 20 meter (60 foot) face. Personal communications with the State Geologist suggest that the Maquoketa shale has been altered to illite with minor chlorite. In some places, the decomposed shale can contain as much as 10 to 20 percent montmorillonite.

Mining the Maquoketa shale appears to be unfeasible north of Fond du Lac because of its close proximity to water (Lake Winnebago, Fox River and Green Bay), and because of overlying intensely productive farmland. Farmland, forest and Horicon Wildlife Refuge cover the shale south of Oakfield. Therefore, land acquisition costs will be high and social acceptance probably low to unacceptable in these areas.

The Oakfield-Fond du Lac area may warrant further consideration as a source of clay and dolomite that could be used to neutralize acid leachates. This area contains several abandoned dolomite quarries that overlie the Maquoketa shale. During quarrying, the Mayville dolomite was mined close to the shale, leaving a few meters of dolomite in the pit floor. The Oakfield area is accustomed to mining, so that its renewal would probably be tolerated. Some lower parts of the Maquoketa shale could contain deposits of sufficient size to supply a large plant (U. S. Geological Survey, 1976).

No engineering test data for Maquoketa shale samples has been found during preparation of this report. There is question in the authors' minds as to whether the physical properties of the Maquoketa shale can meet the minimum EPA soil criteria. Adverse economics are anticipated due to high land acquisition, transportation, and environmental costs.

(c) Cretaceous (?) Hersey Soil. The Hersey area contains relatively thick, continuous, near surface, expandable clay soils. Mining of clay on a limited scale is considered viable at Hersey, but there is serious question whether there is sufficient quantity to meet the projected Crandon requirement.

Montmorillonite deposits of possible Cretaceous age occur scattered throughout the eastern part of St. Croix and the west part of Dunn Counties, (Figure 1). Several studies (Akers, 1961, Clum et al, 1976, and Dasgupta et al, in print) have been conducted to determine the suitability of this clay as a binder in pelletizing magnetite concentrates. It was concluded that these clays were suitable provided certain additives were used.

Seventy years ago, this area produced kaolinite which, at the peak of mining activity, ranked Wisconsin as one of the nation's largest producers. The kaolinite deposits are reported to be exhausted, but large volumes of calcium-rich montmorillonite remain close to the surface. An estimated 3.2 million tonnes (3.5 million tons) of montmorillonite was identified by Wisconsin Survey Geologists during an evaluation of the state's clay resources (Dasgupta et al, in print). Exxon Geologists estimate that there are 1.9 million tonnes (2.1 million tons) using a 3 meter minimum mining thickness.

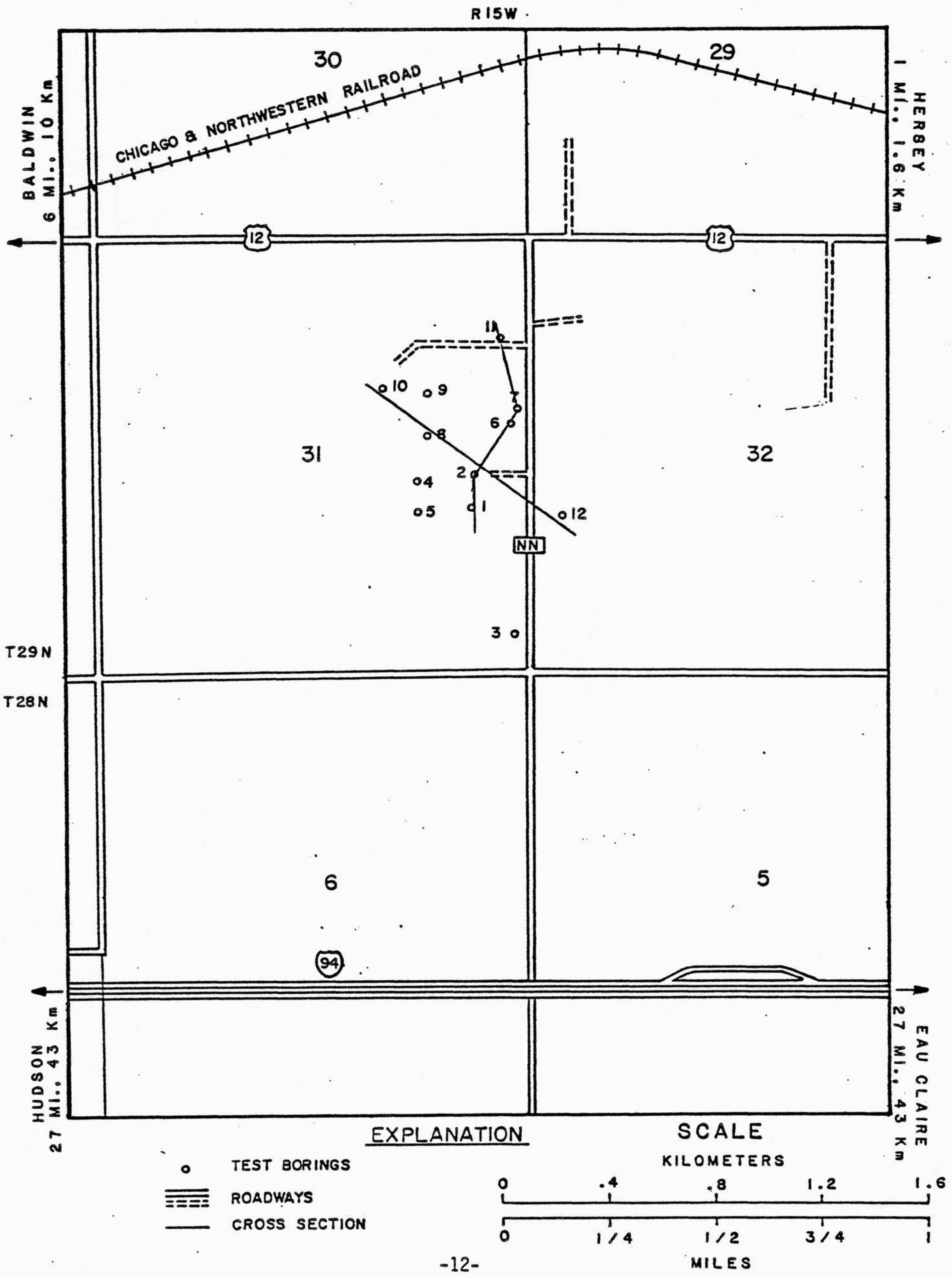
A twelve auger hole test program was undertaken by the Wisconsin Geological Survey in Section 31, Township 29 North, and Range 15 West, St. Croix County (Figure 3). Differential thermal and X-ray diffraction analyses of the augered samples determined that the clay consists of montmorillonite with quartz and trace amounts of vermiculite and illite (Wiederhdeft, et al, 1972). The -200 mesh sieve fraction contains 65 percent calcium montmorillonite. The chemical composition and size distribution data are summarized in Appendix II. No engineering test results have been found to determine whether this calcium montmorillonite clay meets EPA soil criteria. It is the authors' opinion that this clay would meet the EPA standards, but obviously samples need to be collected, tested, and the results analyzed in order to verify this conclusion.

A couple of fence diagrams were prepared from the twelve test boring logs. Fence I (Figure 4) was drawn in a north-south direction looking east; Fence II (Figure 5) was drawn at 45 degrees to Fence I and looking to the northeast. It is concluded that:

- the thickness of the clay soil increases to the east and northeast onto lands that were not test drilled,
- clay thicknesses range from a few centimeters to over 8 meters (26 feet). Drill logs are found in Appendix III.
- interbedded with the clay are narrow lenses of sand, silty sand and silty clay,
- an estimated 0.8 million cubic meters (1.040 million cubic yards) of clay is indicated.

FIGURE

Locations of clay test borings about 3 Km southwest of village of Hersey in the E 1/2 of Section 31, T 29 N, R 15 W, St. Croix County.



FENCE I

SOIL SECTION
HERSEY, WISCONSIN

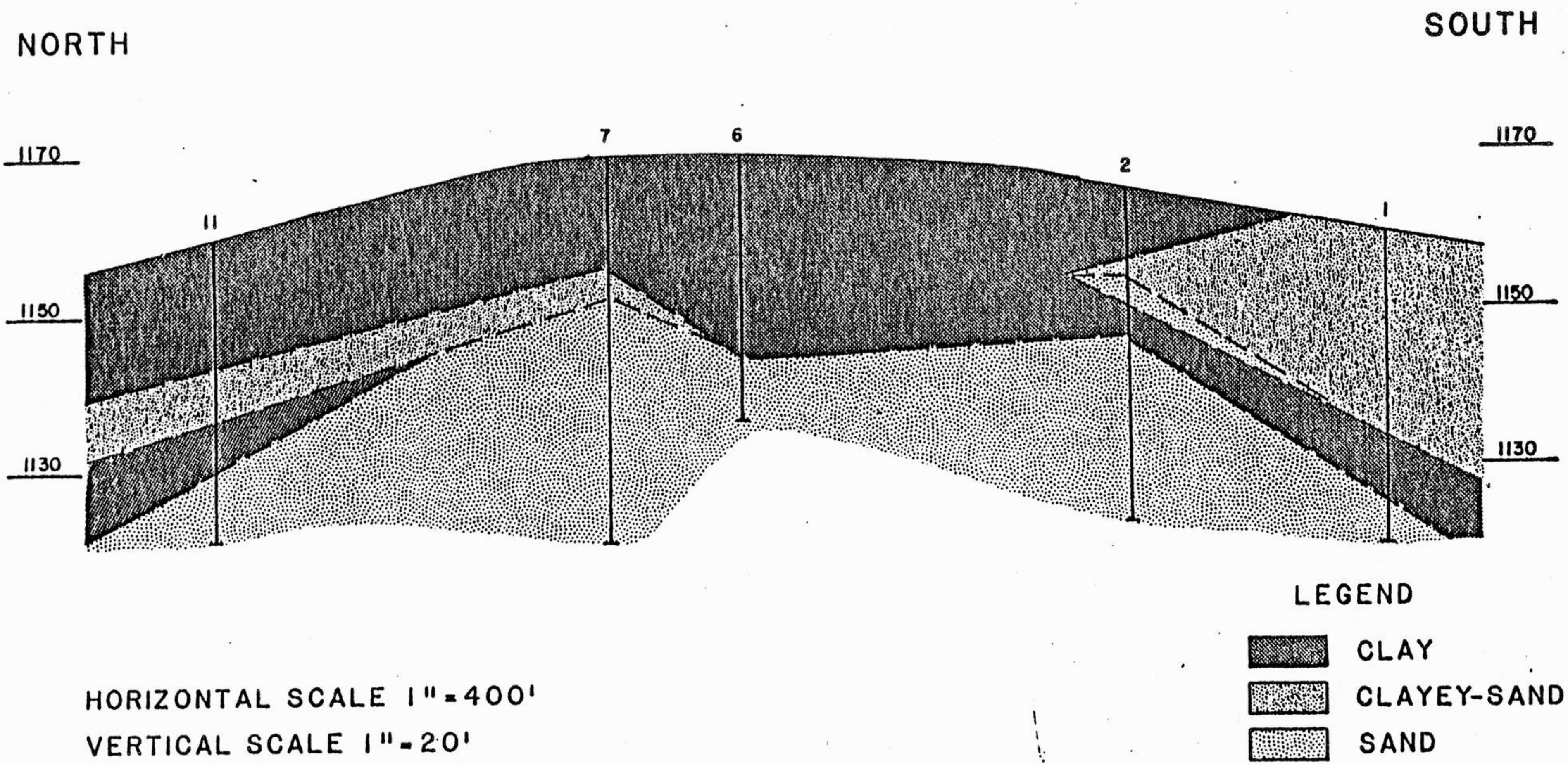


FIGURE 5

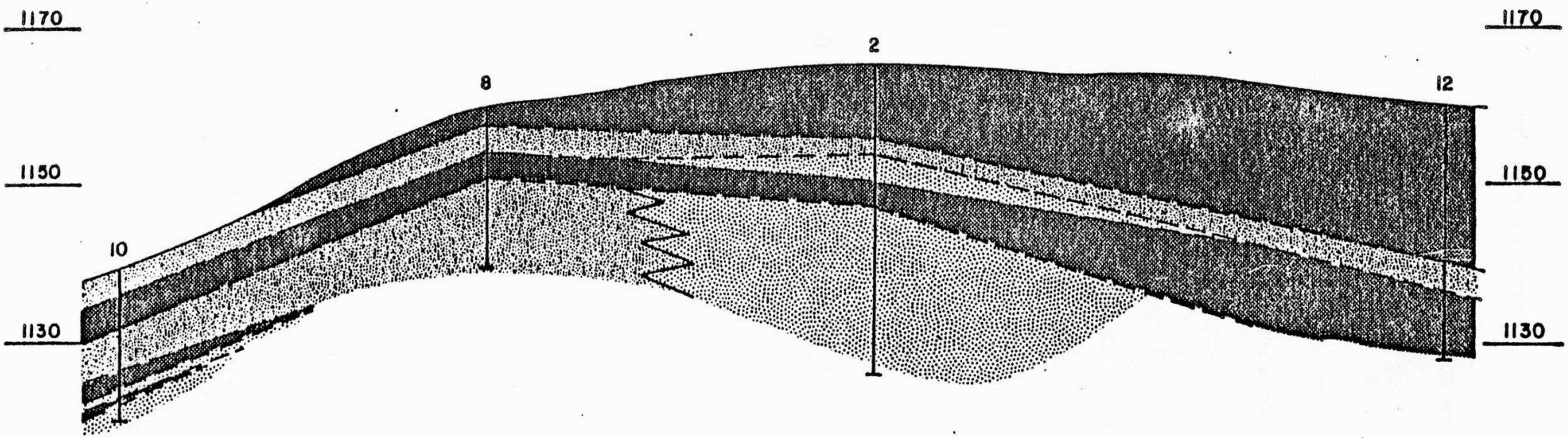


FENCE 11

SOIL SECTION
HERSEY, WISCONSIN

NORTHWEST

SOUTHEAST




LEGEND

CLAY

CLAYEY-SAND

SAND

HORIZONTAL SCALE 1" 400'

VERTICAL SCALE 1" 20'

This clay inventory could be significantly increased if drilling east of the road is successful.

The Hersey area offers one of the best sites for possible mining of relatively thick, continuous, calcium montmorillonite clay beds. Transportation facilities are excellent since the deposit lies within a mile of a railroad and interstate highway. However, transportation costs will be high to bring the clay 380 km (240 miles) to the Crandon site. Considerable amount of test work will need to be done in the field and laboratory to determine the quantity, and quality of the clay. Evaluation of these results would assist in concluding whether it is feasible to mine clay at Hersey versus the purchase of Western clays.

(d) Driftless Area Soils. The mining of the Driftless Area clay deposits can not be considered a viable alternative. These deposits are small, irregular in distribution, and are confined to the floors of steep sided valleys. Many of the deposits are poorly sorted, since they have been reworked and contaminated by glacially derived and more coarse grained material. It is recommended that this area receive no further consideration.

Underlying the Driftless Area are Upper Cambrian aged rocks that consist of the Elk Mound, Tunnel City and Trempealeau groups. These Cambrian sandstone, siltstone and dolomite rocks outcrop along and north of the Wisconsin River. Cambrian outcrops north of the Wisconsin River Valley are found at the headwaters of numerous short streams which flow west into the Mississippi. Ordovician dolomite with sandstone horizons is found on the highlands between the valleys in the west one half of the Driftless Area.

Residual clays have been formed by the alteration of the Cambrian and Ordovician calcareous rocks. Montmorillonite is the chief mineral with lessor amounts of kaolinite, illite and vermiculite. It has been suggested (Akers, 1961), that these residual clays have been contaminated by glacial and aeolian materials which were transported into the valleys. Therefore, most of these valley clay deposits are a mixture of poorly sort residual and transported materials.

The Driftless area soils are not considered a good source of clay suitable to line tailing ponds.

Distribution of Transported Soils: All of Wisconsin excluding the Driftless Area is mantled by a variety of transported soils. Forest County soils are transported by glacial, fluvial and lacustrine processes. For the purpose of this report, the transported soils have been divided into:

Pleistocene Glacial Drift, and

Pleistocene Lacustrine

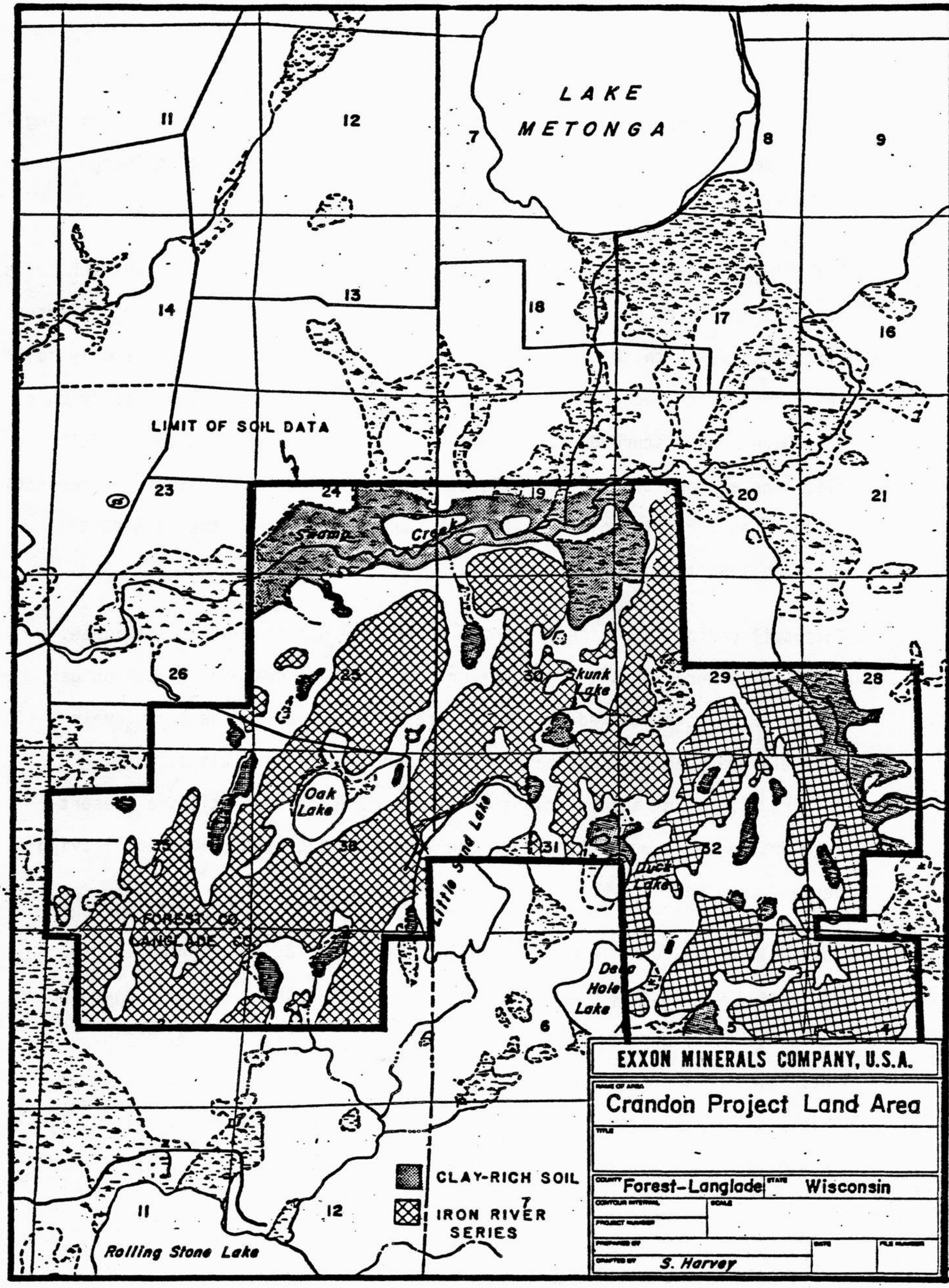
(a) Pleistocene Glacial Drift. The mining of sufficient clay to meet Crandon needs does not appear to be viable in the Pleistocene Glacial Drift soil region. Clay soils that meet minimum EPA standards occur as thin beds. Considerable land disturbance would occur to mine clay in volumes sufficient to line the Crandon tailings ponds. Environmental restrictions preclude exploration of the most promising areas because of the close association between the clay-rich soils and wetlands.

The drift consists of very poorly sorted and highly interstratified morains which were deposited during several glacial periods. Adding to the complexity of the drift soil profile was the deposition of fluvial outwash during glacial retreats. As the glacier withdrew, large blocks of ice were left partially or completely buried by outwash material. These blocks melted leaving depressions (kettles) scattered across the outwash plain. Into these flooded depressions were deposited silt and clay that accumulated to form thin impermeable lacustrine deposits. Most lacustrine deposits have overlying perched water tables which, where exposed to the surface, form lakes or wetlands. Therefore, there is a close relationship between many lacustrine clay deposits and wetlands.

The Soils Conservation Service office has mapped soils that overlie the Crandon project site (Figure 6). An overlay to Figure 6 illustrates the association between the clay-rich soils of the Gogebic-Iron River series and wetlands.

Three major soil regions overlie Northern Wisconsin. These are the Gogebic, Withee and the Omega. Engineering test data of these soils is found in Appendix IV. The Gogebic and Omega soils fail to meet minimum criteria established by the EPA. Representative samples of the Withee soils were tested and found to meet all EPA minimum standards. Withee soils occur in the northern and eastern one halves of Forest County as well as much of Central Wisconsin.

Many clay pits have been developed within the Pleistocene Glacial Drift area, but none remain in production today. Most of these pits lie 65 km (40 miles) from the project site, (Figure 1). One of the largest pits, the Shawano pit, contained 5 meters (15 feet) of clay beneath 1 meter (3 feet) of sand and




DATA SOURCE: USDA SOIL CONSERVATION SERVICE topsoil (Buckley, 1901). Other area pits reported clay thicknesses ranging from 1 meter to 4 meters. The clay seams are poorly sorted containing intercalated sands with occasional pebble sized particles.

(b) Pleistocene Lacustrine. Mining of Pleistocene Lacustrine clay-rich soils does not appear to be a viable consideration for the Crandon project. Personal communications with the State Geologist indicate that many of these clay soils are difficult to mechanically compact to an acceptable EPA permeability once they have been disturbed. Some Kewaunee soils have been used successfully to clay line an industrial pond at Escanaba (personal communications, W. Perpich). However, the trucking distance to haul the Kewaunee soils to the Escanaba site was less than 32 km (20 miles).

This soil region is divided into two soils, the Hibbing and the Kewaunee. These soils were deposited when river channels that drained Lakes Michigan and Superior were blocked by glacial ice. Consequently, the lake levels were elevated, and flooded parts of Northern and Eastern Wisconsin (Figure 2). Thick accumulations of clay were deposited until the present lake drainageways were reopened. The lake elevations were lowered, leaving perched clay beds.

The soil region covers about 1.0 million hectares (2.6 million acres) and contains a distinctive reddish-brown silty clay which is known as the Hibbing soils near Lake Superior and as the Kewaunee soils near Lake Michigan. These glacio-lacustrine deposits contain little or no gravel, although pebbly-sandy lenses do occur. The Hibbing soils contain more clay, but are less calcareous than the Kewaunee (Table I).

Table I
A Comparison of the Hibbing Kewaunee Particle Size

| | Hibbing | Kewaunee | Hibbing | Kewaunee |
|---|---|---|---|---|
| Clay | 55* | 30-40* | 50** | 53** |
| Silt | 35 | 30-40 | 45 | 30 |
| Carbonate | 10 | 25-35 | | |
| Sand | | | 5 | 17 |

* Buckley, 1901
** Hole, 1976

The Kewaunee soils were studied by B. G. Lee (Lee, 1972) who reported montmorillonite as the most abundant clay mineral with lessor amounts of chlorite, vermiculite and kaolinite. Specific surface measurements of the Kewaunee medium sized clay fraction showed that about 36 percent total expanding silicates of which 23 percent is montmorillonite and 13 percent vermiculite. These clays are not as expandable as the Western NA-rich clays. Three areas of lacustrine clay soil, interpreted as part of the Hibbing-Kewaunee region have been mapped in Florence County (Figure 2). No engineering test data results has been located for these Florence County clay soils.

A matrix, Table II, in back pocket, compares engineering, environmental, and transportation concerns for the above described residual and transported soils.

## PART II A COMPARISON OF COSTS TO PRODUCE CLAY FROM HERSEY, WISCONSIN VERSUS COMMERCIAL PURCHASE FROM A WESTERN SOURCE

Part II makes a very rough cost comparison between developing a clay deposit near Hersey, Wisconsin versus purchase of commercially produced Western clays. Several assumptions had to be made in order to make this cost comparison and these are discussed in a subsequent section.

The greatest uncertainties in making this evaluation are, (1) the tailings pond design is not finalized, (2) government rules that dictate the amount of clay liner to be used are not promulgated, (3) the Hersey clay deposit has not been delineated, and (4) there is a dearth of engineering test data by which to compare the Hersey clays with the Western States bentonite product.

The cost per ton delivered for the two clay products is close (Table III). However, there are intangible costs at Hersey, which are difficult to quantify with the available data. These intangible costs are directly linked to the needs to satisfy environmental concerns in order that permits be granted for clay mining.

It is recommended that we pursue the purchase of commercially produced Western clay, since there is little indicated cost advantage or assurance of sufficient local product. Furthermore, it is suggested that our engineers determine the volume of high quality betonite that needs to be added to in-place soils beneath the proposed tailings ponds. The selection of in-place materials having the best soils properties, including low permeability, is important. The identification

## TABLE III

A Cost Comparison between developing the Hersey Clay versus purchase of clay from a commercial source.

(Cubic Meters - C.M. X 1,000,000)

| Possible Clay Source | Cost/Ton | CASE I | CASE II | |
|---|---|---|---|---|
| | | Acreage 240 hectares<br>Thickness 1.5 meters<br>Crandon needs 3.7 c.m.<br>Hersey reserves 0.8 c.m. | Acreage 400 hectares<br>Thickness 1.5 meters<br>Crandon needs 5.2 c.m.<br>Hersey reserves 1.9 c.m. | Acreage 400 hectares<br>Thickness 3 meters<br>Crandon needs 10.4 c.m.<br>Hersey reserves 1.9 c.m. |
| Hersey Bulk - truck | 58.30 | $ 30 million | $ 63 million | Sufficient reserves not indicated |
| NS Bentonite Wyoming Bulk - rail | 63.55 | $ 21 million | $ 35 million | $ 42 million |

The above costs do not include rail siding facilities, transportation of clay on site, nor application and compaction of clay to form the liner.

of the best soil horizon into which bentonite clay could be introduced, mixed, and compacted according to specifications could reduce the amount of clay needed to be purchased.

Assumptions used to make a very preliminary cost comparison:

CASE I

- at least 240 hectares of tailings ponds will be lined using clay.
- a minimum of 1.5 meters of clay liner having an impermeability of 1.0 x $10^{-7}$ cm/sec.
- there are 979 kilograms of clay per cubic meter.
- Hersey clay reserves are 0.8 million cubic meters using 3 meters as a minimum mining thickness.

CASE II

- a maximum of 400 hectares needs to be clay lined.
- a minimum of 1.5 meters of clay liner will be government required.
- Hersey clay reserves are 1.9 million cubic meters base on the Wisconsin geological survey estimate (Dasgupta, 1977).
- 240 hectares will need to be clay lined.
- 12 kilograms of bentonite will be required per square meter in order to achieve minimum EPA standards of $10^{-7}$ transmissivity.

CASE I

| | |
|---|---|
| Land Acquisition: (200 hectares plus Surface improvements) | $ 1,250,000 |
| Evaluation Project: | |
| Drilling (80 holes to 8 m) + Mobilization, Costs, Etc. | 250,000 |
| Engineering Studies | 130,000 |
| Relocate County "NN" | 170,000 |
| Bulk Mining of Surface Clay | 1,300,000 |
| Capital - Drying and Screening Plant, Conveyors, etc. | 4,750,000 |
| Crush, Dry and Screen to -200 mesh | 1,100,000 |
| Transport - Stockpile to Crandon (380 km) | 12,250,000 |
| Reclamation | 2,100,000 |
| | $23,300,000 |
| Contingency :25% | 5,825,000 |
| | $29,125,000 |

| | |
|---|---|
| Total Hersey production | 0.8 million cubic meters |
| Crandon minimum clay requirements | 3.7 million cubic meters |
| Deficit | 2.9 million cubic meters |

This means that about $30 million dollars would generate less than 25 percent of the Crandon clay requirement.

CASE II

| | | |
|---|---|---|
| Land Acquisition (490 hectares for Surface improvements) | | $ 3,300,000 |
| Evaluation/Engineering | | 1,700,000 |
| Road Relocation | | 170,000 |
| Bulk Surface Mining | | 3,125,000 |
| Stripping | | 1,100,000 |
| Capital | | 5,000,000 |
| Crush, Dry, and Screen | | 2,775,000 |
| Transport | | 29,500,000 |
| Reclamation | | 3,600,000 |
| | | $50,270,000 |
| | Contingency :25% | 12,500,000 |
| | | $62,770,000 |

| | |
|---|---|
| Total Hersey Production | 1.9 million cubic meters |
| Crandon maximum requirements | 5.2 million cubic meters |
| Deficit | 3.3 million cubic meters |

An approximate $63 million dollar outlay would provide about 37 percent of the Crandon clay requirement. The most stringent interpretation of federal landfill regulations suggests the installation of 3 meters of clay soil liner. Therefore, to line 400 hectares of tailings pond to the maximum proposed clay soil thickness, would require 12 million cubic meters (16 million cubic yards) of material. The Hersey deposit can only supply 16 percent of this clay requirement.

Engineers from commercial producers indicate that National Standard Bentonite (200 mesh) applied at a rate of 12 kilograms per square meter (2.5 pounds/sq. ft.)

prehydrated with water and mixed with the upper 5 centimeters (2 inches) of sandy loam prior to compaction, will yield a permeability of $10^{-6}$ cm. Current prices for National Standard Bentonite (NSB) at 200 mesh is as follows:

F.O.B. Bagged Wyoming 200 mesh NSB - English Tons

Truck: $34.10/ton - bagged
Rail: $33.10/ton - bagged
- add $7.50/ton if palletized

Current freight rates for bagged bentonite

Truck: $1.69/100# + 9½% fuel surcharge
Rail: $2.01/100# + 2¼% fuel surcharge

Current price of bulk bentonite, F.O.B., Wyoming

Rail: $24.70/ton (may depend on car availability)
Freight: $1.90/100# + 2¼% fuel surcharge

It is doubtful whether there is 5.2 million cubic meters of available clay at Hersey. To find out will require time, land position, large drilling expenditure, and a costly soils engineering test program. It is recommended that we further pursue a commercial clay source.

Commercial suppliers recommend application of 12 kilograms of NSB in 15 cm (6 inch) lifts. The cost of a 15 cm lift is:

- Truck - Bagged:

| | |
|---|---|
| Bentonite: | $1,114,047.00 |
| Freight: | 1,209,149.00 |
| | $2,323,196.00 |
| Pallets: | 245,025.00 |
| Total: | $2,568,221.00 |

- Rail - Bagged:

| | |
|---|---|
| Bentonite: | $1,081,377.00 |
| Freight: | 1,342,884.00 |
| | $2,424,261.00 |
| Pallets: | 245,025.00 |
| Total: | $2,669,286.00 |

- Rail - Bulk:

| | |
|---|---|
| Bentonite: | $ 806,949.00 |
| Freight: | 1,269,393.00 |
| Total: | $2,076,342.00 |

Therefore, to purchase clay for a 1.5 meter thick clay soil liner via a bulk rail system will cost:

$2.08 million x 10 = $20.80 million.

Clay purchase cost for a 3 meter clay-soil liner would be $41.60 million for 240 hectares.

## REFERENCES

Akers, Ronald H., 1961, Clay Minerals of Glacial Deposits of West-Central Wisconsin: Master of Science Thesis, University of Wisconsin.

Clum, J.A., Heins, R.W. and Tiemann, T.D., 1976, Substitutes for Western Bentonite in Magnetic Taconite Pellets: AIME Prepoint No. 76-B-11.

Buckley, E.R., 1901, The Clays and Clay Industries of Wisconsin: Wisconsin Geological and National History Survey, Bull No. VII, Part I, Economic Series No. 4.

Dasgupta, R., Heins, R.W., Ostrum, M.E. and Tiemann, T.D., 1977, Potential of a Wisconsin Clay for Bonding Taconite Pellets: in print.

Hole, F.D., 1976, Soils of Wisconsin: The University of Wisconsin Press, Madison.

Hole, F.D., Beatty, M.T., Lee, G.B. and Kingelhoets, A.J., 1974, Soils of Wisconsin: University of Wisconsin-Extension, Geological and Natural History Survey, 1315 University Avenue, Madison.

Krynine, D.P. and Judd, W.R., 1957, Principles of Engineering Geology and Geotechnics: McGraw-Hill Book Company, Inc., New York.

Lee, G.B., Janke, W.E. and Horn, M.E., 1972, Characteristics and Genetic Relationships of Soils and Soil Parent Materials in the Valderan Drift Region of Eastern Wisconsin: Proc. 15th Conf. Great Lakes Res.

Ries, A., 1906, The Clays of Wisconsin and Their Uses: Wisconsin Geological and National History Survey, Bull No. XV, Economic Series No. 10.

Sargent, D. H., Johnson , W. O., Boyer, J. and Frahme, R. B., 1979 Marketing and Transportation of Western Bentonite; Mining Engineering Vol. 31, No. 9.

U.S. Department of Agriculture, 1972, Engineering Test Data of Wisconsin Soils.

U.S. Department of Agriculture, 1978, Soil Survey of St. Croix County, Wisconsin: Soil Conservation Services Publication.

U.S. Geological Survey, 1976, Mineral and Water Resources of Wisconsin: U.S. Government Printing Office, Washington, D.C.

Appendix I. Persons consulted during the compilation of this report.

Dr. M. L. Jackson, Professor, Department of Soils Science, Madison,

Dr. G. La Berge, Assistant Professor, Department of Geology, Oshkosh,

Dr. G. B. Lee, Professor, Department of Soils Science, Madison,

William Ludwig, Engineer, Soils Conservation Services, Rhinelander,

Dr. Michael Mudrey, Geologist, Wisconsin Geological Survey, Madison,

Dr. M. E. Ostrum, Director, Wisconsin Geological Survey, Madison,

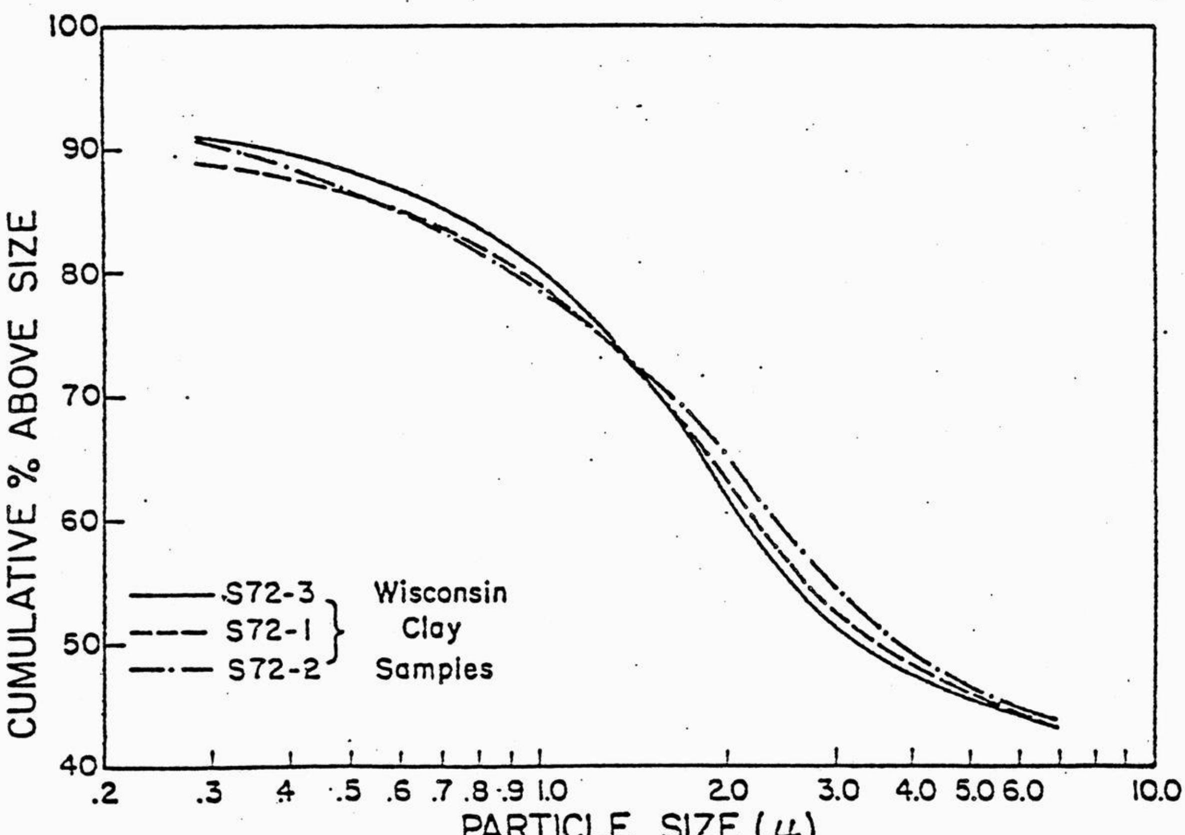
William Perpich, President, Soils Testing Services, Green Bay,

Dr. E. J. Tyler, Assistant Professor, Department of Soils Science, Madison.

# APPENDIX II

Chemical Composition and Size Distribution
of
Hersey Clay Samples

| | |
|---|---|
| $SiO_2$ | 52.41 |
| $Al_2O_3$ | 34.10 |
| $Fe_2O_3$ | 0.15 |
| $CaO$ | 0.05 |
| $MgO$ | 0.12 |
| $Na_2O$ | 0.18 |
| $K_2O$ | 0.46 |
| $TiO_2$ | 0.80 |
| $H_2O$ | 11.89 |
| Total | 100.16 |

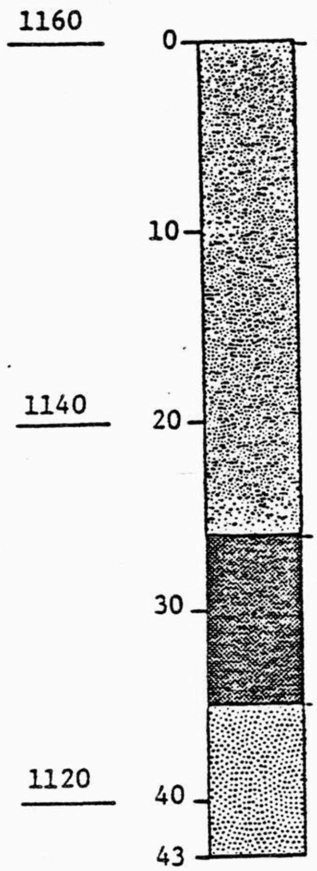



SIZE DISTRIBUTION

# APPENDIX III

Auger Drill Logs
Hersey, Wisconsin

# HOLE # 1



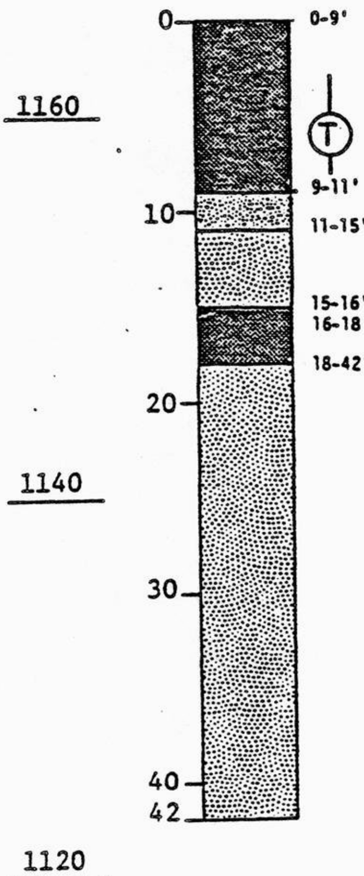

0-26' <u>Clayey Sand</u> Sand with minor clay, very light yellow gray, quartz.

Sand, quartz, with minor clay, light yellow brown, medium- and fine-grained. Clay primarily kaolinite with minor montmorillonite.

26-35' <u>Clay</u> Clay, dark brown gray to light yellow brown; less than 5 percent quartz sand. Clay primarily montmorillonite with minor to no kaolinite.

35-43' <u>Sand</u> Sand, quartz, with trace of clay, yellow brown, medium- and fine-grained. Clay about equal proportions of kaolinite and montmorillonite.

# HOLE #2




0-9' **Clay** Clay, brown mottled and streaked yellow brown, very plastic; 5-10 percent quartz sand; few rock fragments and little white chert; plant fragments 3 to 4 feet. Clay is montmorillonite with very minor kaolinite.

9-11' **Clayey Sand** Clay, brown gray and yellow brown; 30 percent quartz sand. Clay is montmorillonite with minor kaolinite.

11-15' Sand, quartz, light yellow brown; 10 percent clay; scattered fragments of white chert to ½ inch. Clay is montmorillonite with very minor kaolinite.

15-16' **Clay** Clay, gray mottled yellow brown, plastic, waxy. Clay is montmorillonite with minor kaolinite.

16-18' **Sand** Clay, gray brown; sandy with chert fragments to ½ inch. One fragment oolitic indicative of Ordovician Prairie du Chien Group dolomites. Clay is kaolinite with very minor to no montmorillonite.

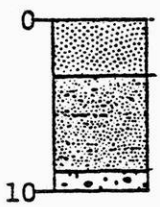
18-42' Sand, light brown gray, medium- and fine-grained; minor white clay; few fragments of oolitic white chert 38-42'. Proportion of kaolinite to montmorillonite estimated to be 7:3.

T Tested for binding taconite pellets.

# HOLE #3

1160

1140



0-3' Sand Soil and sand. Sand has variable mineral composition and is medium- and coarse-grained; 6 inch brown clay at base. Likely glacial deposit.

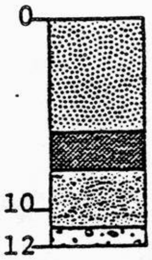
3-8' Clayey Sand Sand, brown, fine- and medium-grained; mostly quartz, clayey, few pebbles. Clay about equal proportions of kaolinite and montmorillonite.

8-9' Gravel or altered bedrock, dolomitic.

1120

# HOLE #4

1160




0-1' <u>Sand</u> Soil

1-6' <u>Clay</u> Sand, yellow brown, quartz, fine- to medium-grained. Little clay and few limonite pebbles from 3 feet to 6 feet. Clay about equal proportions of kaolinite and montmorillonite; little illite 4 to 6 feet.

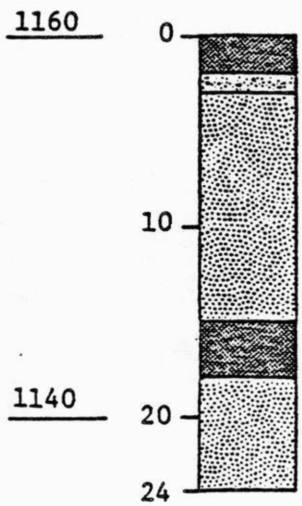
6-8' Clay, yellow brown and light green to white. Yellow brown is slightly streaked with light green and contains si and little very fine sand. Pale green only slightly silty with no sand. Both contain pebbles of limonite and sandy limonite. Clay is montmorillonite and illite in about equal proportions with minor kaolinite.

8-11' <u>Clayey Sand</u> Sand, brown and red brown, medium- and fine-grained, quartx, slightly clayey. Clay is kaolinite and montmorillonite in approximate proportion of 7:3.

11-12' Gravel and sand, slightly clayey, and sand as above. Pebbles of sandstone up to 1 inch. Clay kaolinite and mortmorillonite in about equal amounts.

1140

# HOLE #5




0-2' Clay Clay, white, silty. Clay is kaolinite with only slight trace of illite.

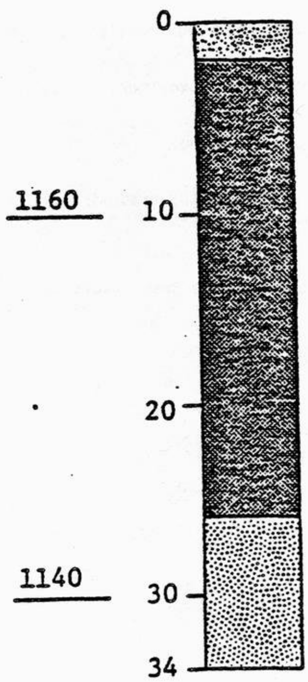
2-3' Clayey Sand Clay and sand, dark gray brown. Clay consists of approximately equal proportions of kaolinite, montmorillonite, and illite.

3-15' Sand Sand, light gray, quartz, fine- and medium-grained; little clay. Clay is kaolinite and montmorillonite in approximate proportion of 6:4.

15-18' Clay Clay, red brown with partings of pale green clay, silty; little quartz sand; few pebbles of limonite in low foot. Trace white clay. Clay about equal proportions of kaolinite and montmorillonite (poor record).

18-24' Sand Sand, red brown, abundant sandstone pebbles in lower 2 feet; very clayey in lower 1 foot. Clay primarily montmorillonite (poor record).

# HOLE #6



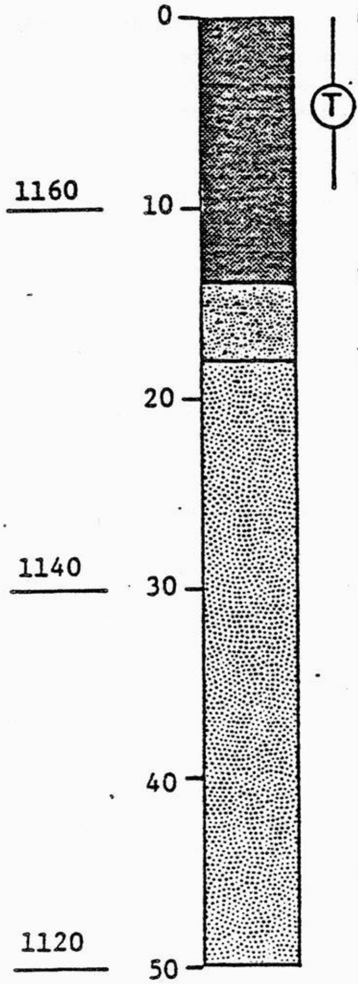

0-2' <u>Sandy Clay</u> Clay and sand, yellow brown, plastic. Clay predominantly montmorillonite with little kaolinite.

2-5' <u>Clay</u> Clay, yellow brown, plastic; little sand. Clay predominantly montmorillonite with little kaolinite.

5-26' Clay, yellow brown and gray, plastic; trace to little sand; plant fragments 17 feet to 18 feet. Clay more than 90 percent montmorillonite.

26-34' <u>Sand</u> Sand, yellowish gray, medium- and fine-grained; little clay. Clay more than 90 percent montmorillonite.

# HOLE #7




0-3' Clay Clay, dark brown gray, slightly sandy with pebbles. Clay predominantly montmorillonite with little kaolinite.

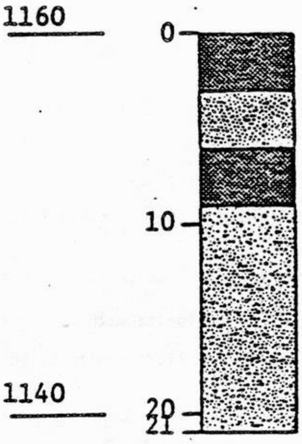
3-9' Clay, light yellow brown and gray, plastic; trace of sand. Clay predominantly montmorillonite with little kaolinite.

9-14' Clayey Sand Clay, dark gray to light yellow brown, plastic; trace of sand. Clay predominantly montmorillonite with little kaolinite.

14-18' Sand, light yellow brown; little clay. Clay predominantly montmorillonite with trace kaolinite.

18-50' Sand Sand, light yellow brown, fine- to medium-grained, quartz. Not sampled.

# HOLE #8




0-2' __Clay__ Clay, dark gray brown and yellow brown, plastic; trace of sand. Clay montmorillonite with trace of kaolinite.

2-3' Clay, brown gray, plastic. Clay montmorillonite with trace of kaolinite.

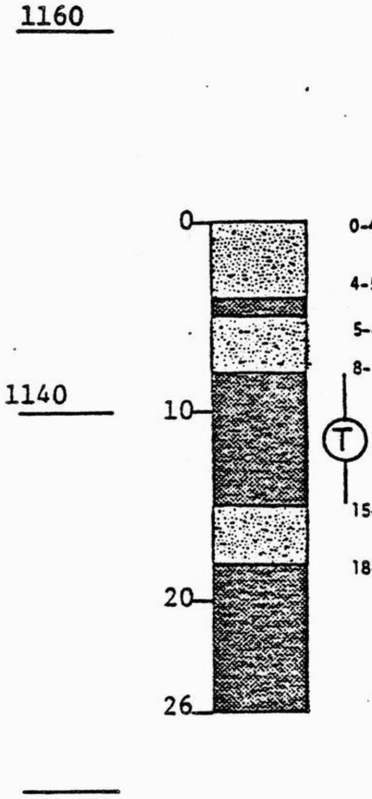
3-6' __Clayey Sand__ Sand and clay, light brown gray, sand is quartz; trace white chert lower foot. Clay montmorillonite with trace of kaolinite.

6-9' __Clay__ Clay, light yellow gray, plastic, slightly sandy. Upper foot montmorillonite; lower 2 feet montmorillonite and kaolinite in about equal proportions.

9-14' __Clayey Sand__ Sand and clay, light yellowish gray, sand is quartz. Montmorillonite and kaolinite in about equal proportions; kaolinite locally more abundant.

14-21' Sand and clay; clay white and gray, plastic. Clay kaolinite and montmorillonite in approximate proportion of 5:1.

# HOLE #9




0-4' Clayey Sand Sand and clay, brown; few chert pebbles. Clay montmorillonite with little kaolinite.

4-5' Clay Clay, brown, plastic; trace of quartz sand. Clay predominantly montmorillonite with little kaolinite.

5-8' Clayey Sand Sand and clay, brown; sand quartz. Clay predominantly montmorillonite with little kaolinite.

8-15' Clay Clay, gray and brown gray, plastic; trace of quartz sand. Clay montmorillonite with slight trace of kaolinite.

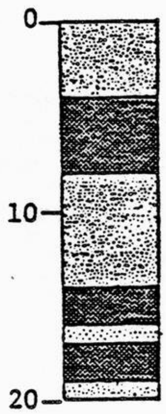
15-18' Clayey Sand Sand, yellow brown and brown gray; trace of clay. Clay is predominantly montmorillonite with trace of kaolinite.

18-26' Clay Clay, gray brown, plastic; little quartz sand; few chert pebbles in upper foot. Clay montmorillonite with trace to little kaolinite.

# HOLE #10

1160

1140




0-4' __Clayey Sand__ Sand and clay, brown. Clay montmorillonite with trace of kaolinite.

4-8' __Clay__ Clay, brown mottled light gray, plastic; trace of quartz sand in upper 2 feet. Clay montmorillonite with trace kaolinite.

8-14' __Clayey Sand__ Sand and clay, light yellow gray and brown. Kaolinite and montmorillonite in approximately equal proportions.

14-16' __Clay__ Clay, gray, plastic. Clay montmorillonite with trace of kaolinite.

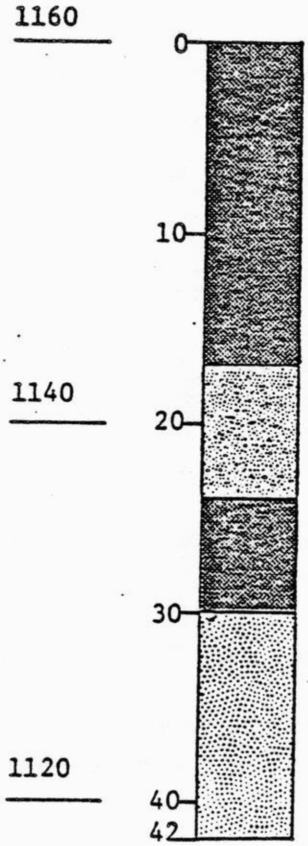
16-17' __Sand__ Sand with trace of clay, light yellow brown. Clay montmorillonite with little kaolinite.

17-19' __Clay__ Clay, light yellow brown; little sand. Clay montmorillonite with little illite and trace of kaolinite.

1120

19-20' __Clayey Sand__ Clay and sand, brown and reddish brown; few igneous rock pebbles. Clay mortmorillonite with little illite and kaolinite.

# HOLE #11




0-15' Clay Clay, yellow brown with gray streaks, plastic; slightly sandy; few pebbles. Clay montmorillonite with less than 10 percent kaolinite.

15-17' Clay, gray with some yellow brown, sandy to very sandy in lower 2 feet. Clay montmorillonite with trace of kaolinite.

17-24' Clayey Sand Sand, light yellow brown to yellow gray, medium- to fine-grained, slightly to moderately clayey. Clay montmorillonite with trace of kaolinite.

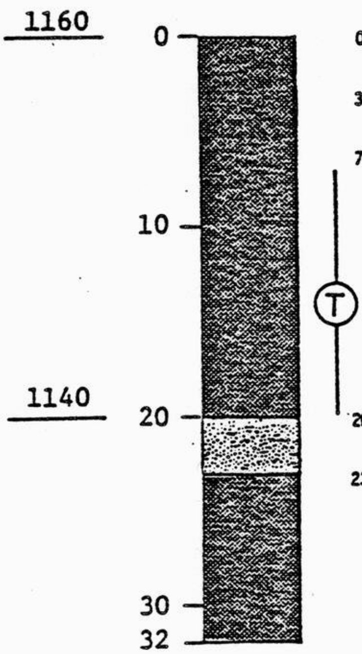
24-30' Clay Clay, gray, plastic, slightly sandy. Clay montmorillonite with trace of kaolinite.

30-42' Sand Sand, light yellow gray, medium- and fine-grained, quartz; trace of clay. Clay fraction consists of montmorillonite with only slight trace of kaolinite. Lower 6 inches very clayey and contains igneous rock pebbles. Clay in lower 6 inches montmorillonite with little kaolinite.

# APPENDIX IV

Soil Engineering Test Data

# HOLE #12




0-3' Clay Clay, yellow brown, plastic, silty at top to sandy at base. Clay montmorillonite with trace of kaolinite.

3-7' Clay with abundant gravel consisting of egneous rock pebbles. Clay predominantly montmorillonite with trace of kaolinite.

7-20' Clay, gray streaked with light yellow brown, plastic, slightly sandy in upper foot. Clay montmorillonite with trace to little kaolinite in lower 2 feet.

20-23' Clayey Sand Sand with clay, yellow brown, quartz. Clay montmorillonite with trace of kaolinite.

23-32' Clay Clay, gray and yellow brown with trace red brown; slightly sandy 26 feet to 30 feet; egneous rock pebbles in lower foot. Clay montmorillonite with only slight trace of kaolinite.

| Soil name and sample location | Depth in inches | Horizon | Moisture density: Maximum dry density (lbs. per cu. ft.) | Moisture density: Optimum moisture (percent) | Mechanical Analysis: Percentage passing sieve: 2" | 1" | 3/4" | 3/8" | #4 4.7 mm. | #10 2.0 mm. | #40 .42 mm. | #200 .074 mm. | Percent smaller than: 0.05 mm. | 0.02 mm. | .005 mm. | .002 mm. | Liquid limit | Plasticity index | Classification: AASHO (group index ratings in parenthesis) | Unified |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Guenther loamy fine sand | 30-38 | B2* | - | - | - | - | - | - | - | 100 | 81 | 28 | 26 | 18 | 10 | 7 | - | NP | A-2-4(0) | SM |
| Wood Co., Wis. | 45-60 | C* | 113 | 18 | - | - | - | - | - | 100 | 90 | 57 | 52 | 35 | 17 | 13 | 28 | 5 | A-4(4) | ML |
| Hebron loam | - | B2 | - | - | - | - | - | - | 100 | 87 | 58 | 37 | - | - | 26 | - | 46 | 25 | A-7-6(3) | SC |
| Racine Co., Wis. | | | | | | | | | | | | | | | | | | | | |
| Hebron sandy loam | 15-36 | B2 | - | - | - | - | - | - | - | 100 | 95 | 58 | 54 | 46 | 35 | 30 | 31 | 15 | A-6(7) | CL |
| Ozaukee Co., Wis. | 36-48 | C | - | - | - | - | - | - | - | 100 | 97 | 65 | 55 | 40 | 26 | 18 | 23 | 8 | A-4(0) | CL |
| Hebron sandy loam | 12-28 | B2* | 121 | 12 | - | - | - | - | 100 | 95 | 79 | 28 | 28 | 26 | 20 | 18 | 22 | | | |
| Racine Co., Wis. | 32-42 | C* | 113 | 17 | - | - | - | - | - | 100 | 99 | 96 | 96 | 95 | 64 | 44 | 36 | 18 | A-6(11) | CL |
| Hiawatha loamy sand | 4-19 | B2ir | - | - | - | - | - | - | - | 100 | 81 | 21 | 20 | 14 | 7 | 5 | - | NP | A-2-4(0) | SM |
| Bayfield Co., Wis. | 26-60 | C | 107 | 14 | - | - | - | - | - | 100 | 93 | 5 | 3 | 2 | 1 | 1 | - | NP | A-3(0) | SP-SM |
| Hibbing silt loam | 16-27 | B2* | 114 | 16 | - | - | - | - | - | 100 | 97 | 73 | 69 | 62 | 46 | 37 | 37 | 22 | A-6(13) | CL |
| Bayfield Co., Wis. | 27-34 | C* | 119 | 13 | - | - | - | - | - | 100 | 96 | 69 | 64 | 55 | 41 | 31 | 33 | 20 | A-6(11) | CL |
| | 13-32 | B2 | - | - | - | - | - | - | - | 100 | 96 | 81 | 79 | 72 | 54 | 37 | 40 | 23 | A-6(13) | CL |
| | 32-38 | C | - | - | - | - | - | - | - | 100 | 82 | 48 | 46 | 43 | 34 | 23 | 29 | 16 | A-6(5) | SC |
| | 16-34 | B2 | - | - | - | - | - | - | - | 100 | 95 | 75 | 73 | 67 | 52 | 39 | 43 | 26 | A-7-6(16) | CL |
| | 34-40 | C | - | - | - | - | - | - | - | 100 | 94 | 73 | 71 | 66 | 49 | 35 | 36 | 20 | A-6(12) | CL |
| Hixton loam | 14-25 | B2 | - | - | - | - | - | - | - | 100 | 88 | 60 | 57 | 41 | 17 | 12 | 19 | 4 | A-4(5) | CL-ML |
| Trempealeau Co., Wis. | 29-34 | C | - | - | - | - | - | - | - | 100 | 48 | 6 | 5 | 4 | 3 | 3 | - | NP | A-1-b(0) | SP-SM |
| | 13-20 | B2* | 128 | 10 | - | - | - | - | - | 100 | 73 | 49 | 48 | 37 | 16 | 11 | 21 | 5 | A-4(3) | SC-SM |
| | 26-42 | C* | 122 | 9 | 98 | 91 | 89 | 89 | 89 | 89 | 63 | 5 | 5 | 4 | 3 | 3 | - | NP | A-3(0) | SP-SM |
| | 21-29 | B2 | - | - | - | - | - | - | - | 100 | 90 | 55 | 52 | 38 | 19 | 15 | 21 | 7 | A-4(4) | CL-ML |
| | 33-53 | C | - | - | - | - | - | - | - | 100 | 79 | 7 | 5 | 4 | 3 | 2 | - | NP | A-3(0) | SP-SM |
| Hochheim loam | 8-12 | B2 | - | - | - | - | - | - | - | 100 | 95 | 74 | 69 | 60 | 43 | 37 | 53 | 31 | A-7-6(19) | CH |
| Calumet Co., Wis. | 18-30 | C | - | - | 100 | 90 | 88 | 81 | 76 | 68 | 60 | 39 | 32 | 21 | 11 | 7 | - | NP | A-4(1) | SM |
| Hochheim silt loam | 11-15 | B2* | 110 | 16 | - | 99 | 99 | 97 | 96 | 95 | 91 | 68 | 63 | 53 | 38 | 33 | 44 | 25 | A-7-6(13) | CL |
| Fond du Lac Co., Wis. | 25-40 | C* | 140 | 7 | 96 | 91 | 90 | 86 | 82 | 79 | 71 | 49 | 41 | 28 | 14 | 9 | 15 | 3 | A-4(3) | SM |
| | 12-15 | B2 | - | - | - | - | - | - | - | 100 | 99 | 91 | 88 | 71 | 47 | 40 | 56 | 32 | A-7-6(19) | CH |
| | 30-40 | C | - | - | - | 90 | 84 | 69 | 57 | 40 | 19 | 10 | 8 | 5 | 3 | 2 | - | NP | A-1-a(0) | SP-SM |
| | 8-19 | B2 | 104 | 19 | 100 | 97 | 97 | 96 | 96 | 95 | 93 | 77 | 74 | 62 | 47 | 39 | 48 | 27 | A-7-6(17) | CL |
| | 22-42 | C | 119 | 13 | - | - | - | - | 100 | 98 | 94 | 77 | 74 | 58 | 37 | 25 | 26 | 11 | A-6(8) | CL |
| Hochheim silt loam | 18-25 | B22t | 112 | 15 | - | - | - | - | - | 100 | 94 | 68 | 65 | 50 | 32 | 26 | 33 | 16 | A-6(9) | CL |
| Manitowoc Co., Wis. | 42-51 | C1 | 131 | 9 | 99 | 94 | 92 | 89 | 85 | 82 | 75 | 46 | 39 | 24 | 12 | 8 | 19 | 4 | A-4(2) | SC-SM |

| Soil name and sample location | Depth in inches | Horizon | Moisture-density: Maximum dry density (lbs. per cu. ft.) | Moisture-density: Optimum moisture (percent) | Mechanical Analysis — Percentage passing sieve: 2" | 1" | 3/4" | 3/8" | #4 4.7 mm. | #10 2.0 mm. | #40 .42 mm. | #200 .074 mm. | Percent smaller than: 0.05 mm. | 0.02 mm. | .005 mm. | .002 mm. | Liquid limit | Plasticity index | Classification: AASHO (group index ratings in parenthesis) | Unified |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hochheim silt loam | 9-18 | B2 | - | - | - | - | - | - | - | 100 | 99 | 81 | 77 | 62 | 45 | 38 | 47 | 26 | A-7-6(15) | CL |
| Ozaukee Co., Wis. | 21-42 | C | - | - | - | 98 | 98 | 96 | 95 | 94 | 92 | 71 | 64 | 40 | 23 | 16 | 20 | 6 | A-4(7) | CL-ML |
| | 7-15 | B2 | - | - | - | 98 | 97 | 93 | 90 | 86 | 76 | 46 | 43 | 35 | 27 | 25 | 36 | 19 | A-6(5) | SC |
| | 20-42 | C | - | - | 100 | 85 | 82 | 74 | 64 | 58 | 46 | 21 | 17 | 9 | 5 | 4 | - | NP | A-1-b(0) | SM |
| Hochheim silt loam | 10-18 | IIB2t | - | - | - | - | - | - | - | 100 | 96 | 83 | 80 | 65 | 42 | 35 | 44 | 25 | A-7-6(15) | CL |
| Sheboygan Co., Wis. | 22-60 | IIC | 126 | 9 | 97 | 88 | 86 | 85 | 84 | 75 | 67 | 34 | 28 | 14 | 6 | 5 | - | NP | A-2-4(0) | SM |
| Hochheim silt loam | 8-17 | B2 | 106 | 19 | - | - | 100 | 98 | 96 | 93 | 82 | 57 | 55 | 49 | 38 | 33 | 42 | 21 | A-7-6(9) | CL |
| Waukesha Co., Wis. | 21-60 | C | 140 | 6 | 100 | 93 | 88 | 80 | 74 | 67 | 56 | 35 | 32 | 22 | 11 | 7 | 14 | 2 | A-2-4(0) | SM |
| Hortonville loam | 21-27 | B2 | 110 | 15 | - | - | - | - | - | 100 | 96 | 71 | 70 | 59 | 44 | 35 | 37 | 21 | A-6(11) | CL |
| Brown Co., Wis. | 33-40 | C | 116 | 13 | - | 100 | 99 | 97 | 95 | 95 | 89 | 67 | 65 | 54 | 37 | 25 | 28 | 13 | A-6(8) | CL |
| Hortonville silt loam | 19-25 | B2* | 103 | 21 | - | - | - | - | - | 100 | 98 | 87 | 85 | 77 | 49 | 35 | 42 | 22 | A-7-6(13) | CL |
| Brown Co., Wis. | 28-48 | C* | 119 | 13 | - | 98 | 96 | 94 | 93 | 91 | 87 | 78 | 76 | 64 | 31 | 17 | 25 | 8 | A-4(8) | CL |
| Hortonville silt loam | 11-25 | B21t | - | - | - | - | - | - | - | 100 | 98 | 78 | 75 | 63 | 47 | 36 | 42 | 22 | A-7-6(13) | CL |
| Outagamie Co., Wis. | 25-60 | C | 123 | 11 | 100 | 95 | 92 | 87 | 83 | 79 | 72 | 54 | 50 | 39 | 23 | 14 | 24 | 9 | A-4(4) | CL |
| Hortonville silt loam | 7-17 | B2 | - | - | - | - | - | - | - | 100 | 96 | 76 | 72 | 61 | 47 | 39 | 45 | 25 | A-7-6(15) | CL |
| Ozaukee Co., Wis. | 20-42 | C | - | - | - | 99 | 96 | 94 | 92 | 89 | 84 | 65 | 62 | 49 | 31 | 22 | 29 | 14 | A-6(8) | CL |
| | 8-19 | B2 | 104 | 19 | 100 | 97 | 97 | 96 | 96 | 95 | 93 | 77 | 74 | 62 | 47 | 39 | 48 | 27 | A-7-6(17) | CL |
| | 22-42 | C | 119 | 13 | - | - | - | - | 100 | 98 | 94 | 77 | 74 | 58 | 37 | 25 | 27 | 11 | A-6(8) | CL |
| Hortonville silt loam | 22-30 | B2 | 109 | 17 | - | - | - | - | - | 100 | 97 | 73 | 71 | 63 | 46 | 33 | 42 | 23 | A-7-6(13) | CL |
| Waupaca Co., Wis. | 36-60 | C | 117 | 13 | - | 100 | 99 | 97 | 96 | 95 | 91 | 67 | 65 | 54 | 32 | 22 | 29 | 13 | A-6(8) | CL |
| Iron River fine sandy loam | 10-18 | B21r | - | - | - | - | - | - | - | 100 | 91 | 54 | 50 | 27 | 10 | 6 | - | NP | A-4(4) | ML |
| Ashland Co., Wis. | 18-24 | A'2x | - | - | - | - | - | - | - | 100 | 88 | 37 | 32 | 18 | 8 | 5 | - | NP | A-4(0) | SM |
| | 32-38 | B'2tx | - | - | - | 99 | 98 | 96 | 95 | 93 | 79 | 36 | 32 | 20 | 10 | 8 | 17 | 2 | A-4(0) | SM |
| | 38-60 | IIC | 132 | 7 | 100 | 95 | 93 | 87 | 82 | 76 | 57 | 16 | 13 | 7 | 3 | 2 | - | NP | A-2-4(0) | SM |
| Iron River silt loam | 17-28 | B* | 134 | 8 | 97 | 91 | 90 | 89 | 89 | 84 | 73 | 42 | 37 | 22 | 8 | 5 | - | NP | A-4(1) | SM |
| Forest Co., Wis. | 28-60 | C* | 135 | 8 | 100 | 90 | 88 | 85 | 85 | 85 | 76 | 39 | 35 | 20 | 9 | 6 | - | NP | A-4(1) | SM |
| Iron River silt loam | 33-47 | IIB22t | - | - | 100 | 94 | 92 | 86 | 82 | 78 | 62 | 27 | 24 | 15 | 9 | 6 | - | NP | A-2-4(0) | SM |
| Sawyer Co., Wis. | 64-70 | IIC | - | - | - | 99 | 97 | 92 | 89 | 85 | 70 | 29 | 25 | 15 | 6 | 4 | - | NP | A-2-4(0) | SM |
| Jackson silt loam Pepin Co., Wis. | - | C | - | - | - | - | - | - | - | 100 | 100 | 98 | - | - | 23 | - | 29 | 10 | A-4(8) | CL |
| Jump River fine sandy loam | 16-28 | B2 | - | - | - | - | - | - | - | - | 100 | 85 | 80 | 44 | 20 | 15 | 28 | 4 | A-4(8) | ML |
| Rusk Co., Wis. | 32-50 | C | - | - | - | - | - | - | - | 100 | 99 | 19 | 18 | 8 | 6 | 4 | - | NP | A-2-4(0) | SM |

| Soil name and sample location | Depth in inches | Horizon | Moisture-density: Maximum dry density (lbs. per cu. ft.) | Moisture-density: Optimum moisture (percent) | Mechanical Analysis: Percentage passing sieve: 2" | 1" | 3/4" | 3/8" | #4 4.7 mm. | #10 2.0 mm. | #40 .42 mm. | #200 .074 mm. | Percent smaller than: 0.05 mm. | 0.02 mm. | .005 mm. | .002 mm. | Liquid limit | Plasticity index | Classification: AASHO (group index ratings in parenthesis) | Unified |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kewaunee silt loam | 8-22 | B21t | - | - | - | - | - | - | - | 100 | 97 | 83 | 82 | 76 | 56 | 44 | 49 | 30 | A-7-6(18) | CL |
| Sheboygan Co., Wis. | 36-60 | C | - | - | - | - | - | - | - | 100 | 97 | 85 | 82 | 69 | 46 | 31 | 30 | 15 | A-6(10) | CL |
| Keweenaw loamy sand | 4-8 | B21ir | - | - | - | - | - | - | - | 100 | 87 | 22 | 17 | 8 | 3 | 2 | - | NP | A-2-4(0) | SM |
| Ashland Co., Wis. | 37-60+ | C | 115 | 11 | - | - | - | 100 | 98 | 96 | 84 | 19 | 12 | 4 | 2 | 1 | - | NP | A-2-4(0) | SM |
| Kibbie fine sandy loam | 28-34 | B2* | 115 | 15 | - | - | - | - | - | - | 100 | 91 | 84 | 59 | 31 | 25 | 33 | 11 | A-6(8) | CL |
| Dodge Co., Wis. | 44-68 | C* | 113 | 16 | - | - | - | - | - | 100 | 99 | 96 | 92 | 61 | 28 | 20 | 31 | 10 | A-4(8) | CL |
| Kibbie silt loam | 15-22 | B2 | - | - | - | - | - | - | - | 100 | 94 | 49 | 44 | 32 | 20 | 16 | 21 | 5 | A-4(3) | SC-SM |
| Kenosha Co., Wis. | 31-60 | C | - | - | - | - | - | - | - | 100 | 98 | 75 | 67 | 37 | 16 | 12 | 19 | 2 | A-4(8) | ML |
| Kibbie silt loam | 14-20 | B2 | - | - | - | - | - | - | - | - | 100 | 89 | 87 | 77 | 36 | 25 | 35 | 16 | A-6(10) | CL |
| Outagamie Co., Wis. | 22-60 | C | - | - | - | - | - | - | - | - | - | 96 | 82 | 25 | 8 | 6 | - | NP | A-4(8) | ML |
| | 9-23 | B22t | - | - | - | - | - | - | - | - | 100 | 87 | 78 | 42 | 18 | 13 | 25 | 4 | A-4(8) | ML |
| | 48-60 | C2 | 113 | 13 | - | - | - | - | - | - | - | 90 | 82 | 30 | 8 | 4 | 20 | NP | A-4(8) | ML |
| Kibbie silt loam | 17-20 | B2* | 111 | 16 | - | - | - | - | - | 100 | 99 | 53 | 47 | 36 | 27 | 22 | 29 | 11 | A-6(4) | CL |
| Racine Co., Wis. | 44-52 | C* | 120 | 12 | - | - | - | - | - | - | - | 79 | 68 | 34 | 11 | 7 | - | NP | A-4(8) | ML |
| | 21-28 | B2 | - | - | - | - | - | - | - | - | 100 | 27 | 21 | 17 | 16 | 15 | - | NP | A-2-4(0) | SM |
| | 30-54 | C | - | - | - | - | - | - | - | - | 100 | 27 | 13 | 3 | 1 | 1 | - | NP | A-2-4(0) | SM |
| Kibbie silt loam | 9-17 | B2 | - | - | - | - | 100 | 99 | 98 | 96 | 93 | 64 | 58 | 35 | 18 | 14 | 27 | 7 | A-4(6) | CL-ML |
| Waukesha Co., Wis. | 20-60 | C | - | - | - | - | - | - | - | - | - | 84 | 70 | 21 | 6 | 5 | - | NP | A-4(18) | ML |
| Kidder sandy loam | 11-26 | B21t | - | - | - | - | - | - | - | 100 | 94 | 39 | 38 | 31 | 23 | 19 | 23 | 9 | A-4(1) | SC |
| Green Lake Co., Wis. | 34-60 | C | 135 | 8 | 96 | 95 | 94 | 91 | 89 | 88 | 79 | 35 | 32 | 20 | 11 | 8 | - | NP | A-2-4(0) | SM |
| Kiva gravelly loam | 5-13 | B21ir* | - | - | - | 98 | 97 | 94 | 92 | 92 | 84 | 27 | 26 | 18 | 9 | 5 | - | NP | A-2-4(0) | SM |
| Door Co., Wis. | 32-36 | IIC2* | - | - | 96 | 62 | 55 | 43 | 36 | 27 | 14 | 6 | 5 | 3 | 1 | 1 | - | NP | A-1-a(0) | GM-GW |
| Knowles silt loam Green Lake Co., Wis. | 28-33 | IIB24t | - | - | - | - | - | - | - | 100 | 96 | 84 | 82 | 67 | 47 | 40 | 53 | 30 | A-7-6(18) | CH |
| Knowles silt loam Washington Co., Wis. | 17-27 | B2 | - | - | - | - | - | - | - | 100 | 96 | 72 | 71 | 60 | 45 | 40 | 44 | 24 | A-7-6(13) | CL |
| | 24-32 | B2* | 98 | 25 | - | - | - | - | - | 100 | 93 | 71 | 68 | 59 | 45 | 40 | 46 | 25 | A-7-6(14) | CL |
| | 18-26 | B2 | - | - | - | - | - | - | - | 100 | 85 | 58 | 54 | 45 | 32 | 27 | 35 | 16 | A-6(7) | CL |
| Kolberg silt loam | 22-28 | B22t | - | - | - | - | - | - | - | 100 | 98 | 87 | 83 | 71 | 50 | 37 | 38 | 20 | A-6(12) | CL |
| Door Co., Wis. | 33-38 | IIC | - | - | - | 99 | 96 | 92 | 89 | 84 | 79 | 71 | 64 | 42 | 24 | 17 | 21 | 6 | A-4(7) | CL-ML |
| Lafont silt loam | - | B2 | - | - | - | - | - | - | 100 | 94 | 81 | 46 | - | - | 11 | - | 17 | 2 | A-4(2) | SM |
| Oneida Co., Wis. | - | C | - | - | - | - | - | - | 100 | 83 | 69 | 29 | - | - | 8 | - | 12 | 1 | A-2-4(0) | SM |

| Soil name and sample location | Depth in inches | Horizon | Moisture-density: Maximum dry density (lbs. per cu. ft.) | Moisture-density: Optimum moisture (percent) | Mechanical Analysis: Percentage passing sieve: 2" | 1" | 3/4" | 3/8" | #4 4.7 mm. | #10 2.0 mm. | #40 .42 mm. | #200 .074 mm. | Percent smaller than: 0.05 mm. | 0.02 mm. | .005 mm. | .002 mm. | Liquid limit | Plasticity index | Classification: AASHO (group index ratings in parenthesis) | Unified |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Karlin sandy loam | 5-21 | B2ir | - | - | - | - | - | - | 100 | 96 | 75 | 23 | 22 | 13 | 6 | 4 | - | NP | A-2-4(0) | SM |
| Bayfield Co., Wis. | 30-42 | C1 | 109 | 12 | - | - | 100 | 99 | 96 | 91 | 69 | 2 | 2 | 2 | 1 | 1 | - | NP | A-3(0) | SP |
| | 42-53 | C2 | 104 | 16 | - | - | - | - | - | 100 | 96 | 2 | 2 | 2 | 1 | 1 | - | NP | A-3(0) | SP |
| Kennan loam | - | B2 | - | - | - | - | - | - | 100 | 91 | 71 | 30 | - | - | 12 | - | 18 | 3 | A-2-4(1) | SM |
| Marathon Co., Wis. | - | C | - | - | - | - | - | - | 100 | 86 | 64 | 20 | - | - | 8 | - | - | NP | A-2-4(0) | SM |
| Kennan loam | 13-27 | IIB2t | - | - | - | 98 | 98 | 94 | 91 | 85 | 67 | 24 | 23 | 19 | 15 | 13 | 23 | 8 | A-2-4(0) | SC |
| Portage Co., Wis. | 32-60 | IIC | - | - | - | 99 | 96 | 93 | 89 | 83 | 62 | 14 | 12 | 8 | 6 | 4 | - | NP | A-2-4(0) | SM |
| Kennan silt loam | 19-38 | B* | 132 | 8 | - | 99 | 99 | 96 | 92 | 87 | 68 | 20 | 18 | 14 | 8 | 6 | - | NP | A-2-4(0) | SM |
| Portage Co., Wis. | 52-60 | C* | 131 | 8 | - | 99 | 97 | 95 | 92 | 88 | 67 | 19 | 16 | 13 | 7 | 6 | - | NP | A-2-4(0) | SM |
| | 19-31 | B | - | - | - | - | - | - | - | 100 | 85 | 41 | 37 | 25 | 15 | 12 | 21 | 6 | A-4(1) | SC-SM |
| | 45-60 | C | - | - | - | 100 | 97 | 92 | 87 | 81 | 56 | 15 | 13 | 11 | 7 | 6 | - | NP | A-2-4(0) | SM |
| Kennan silt loam | 31-40 | B | - | - | - | 100 | 98 | 94 | 89 | 81 | 60 | 20 | 18 | 14 | 8 | 6 | - | NP | A-2-4(0) | SM |
| Shawano Co., Wis. | 44-50 | C | - | - | - | 98 | 96 | 91 | 85 | 85 | 62 | 18 | 15 | 11 | 7 | 5 | - | NP | A-2-4(0) | SM |
| Kert silt loam | 14-22 | IIA&B | - | - | - | - | - | - | - | 100 | 98 | 29 | 27 | 20 | 12 | 9 | - | NP | A-2-4(0) | SM |
| Wood Co., Wis. | 40-52 | VC2 | 107 | 20 | - | - | - | - | - | 100 | 98 | 92 | 91 | 84 | 64 | 50 | 55 | 30 | A-7-6(19) | CH |
| Kewaunee silt loam | 11-20 | B2t | - | - | - | - | - | - | - | 100 | 97 | 68 | 66 | 60 | 46 | 35 | 41 | 25 | A-7-6(13) | CL |
| Brown Co., Wis. | 48-54 | C | - | - | - | - | - | - | - | 100 | 96 | 73 | 71 | 60 | 44 | 30 | 31 | 17 | A-6(11) | CL |
| Kewaunee silt loam | 11-20 | B2 | - | - | - | - | - | - | - | 100 | 99 | 95 | 95 | 93 | 79 | 65 | 72 | 39 | A-7-5(20) | CH |
| Calumet Co., Wis. | 39-48 | C | - | - | - | 100 | 99 | 98 | 97 | 97 | 96 | 92 | 92 | 91 | 77 | 62 | 52 | 31 | A-7-6(18) | CH |
| | 12-23 | B2 | - | - | - | - | - | - | - | 100 | 99 | 90 | 88 | 83 | 68 | 58 | 54 | 30 | A-7-6(19) | CH |
| | 34-55 | C | - | - | - | 97 | 96 | 95 | 93 | 91 | 88 | 79 | 77 | 68 | 51 | 37 | 35 | 18 | A-6(11) | CL |
| Kewaunee silt loam | 10-21 | B2* | 98 | 20 | - | - | - | 100 | 99 | 99 | 97 | 88 | 87 | 86 | 74 | 62 | 54 | 28 | A-7-6(18) | CH |
| Fond du Lac Co., Wis. | 28-47 | C* | 115 | 16 | - | 99 | 98 | 95 | 92 | 89 | 84 | 74 | 71 | 64 | 52 | 41 | 44 | 24 | A-7-6(14) | CL |
| Kewaunee silt loam | 21-30 | C1 | - | - | - | - | - | - | - | 100 | 96 | 77 | 73 | 65 | 48 | 40 | 44 | 28 | A-7-6(16) | CL |
| Manitowoc Co., Wis. | 30-45 | C2 | - | - | - | - | - | - | - | 100 | 94 | 78 | 74 | 64 | 48 | 36 | 34 | 20 | A-6(12) | CL |
| | 10-18 | B2 | - | - | - | - | - | - | - | 100 | 98 | 76 | 74 | 67 | 53 | 45 | 47 | 29 | A-7-6(17) | CL |
| | 18-26 | C | - | - | - | - | - | - | - | 100 | 96 | 80 | 76 | 66 | 49 | 36 | 37 | 22 | A-6(13) | CL |
| Kewaunee silt loam | 10-22 | B2 | 99 | 23 | - | - | - | - | - | 100 | 99 | 90 | 89 | 85 | 67 | 57 | 58 | 33 | A-7-6(20) | CH |
| Milwaukee, Wis. | 22-48 | C | 115 | 15 | - | 100 | 99 | 98 | 97 | 95 | 90 | 76 | 73 | 63 | 43 | 31 | 22 | 15 | A-6(10) | CL |
| Kewaunee silt loam | 7-20 | B2 | - | - | - | - | - | - | - | 100 | 98 | 87 | 85 | 75 | 57 | 48 | 52 | 30 | A-7-6(18) | CH |
| Ozaukee Co., Wis. | 23-42 | C | - | - | - | 100 | 99 | 98 | 97 | 95 | 92 | 81 | 79 | 67 | 48 | 36 | 38 | 25 | A-6(12) | CL |

| Soil name and sample location | Depth in inches | Horizon | Moisture-density: Maximum dry density (lbs. per cu. ft.) | Moisture-density: Optimum moisture (percent) | Mechanical Analysis: Percentage passing sieve 2" | 1" | 3/4" | 3/8" | #4 4.7 mm. | #10 2.0 mm. | #40 .42 mm. | #200 .074 mm. | Percent smaller than 0.05 mm. | 0.02 mm. | .005 mm. | .002 mm. | Liquid limit | Plasticity index | Classification: AASHO (group index ratings in parenthesis) | Unified |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Morley silt loam | 15-23 | B2 | - | - | - | - | - | - | - | 100 | 94 | 77 | 74 | 67 | 50 | 41 | 52 | 33 | A-7-6(14) | CH |
| Kenosha Co., Wis. | 30-54 | C | - | - | - | 100 | 98 | 95 | 93 | 92 | 86 | 71 | 64 | 44 | 26 | 17 | 21 | 8 | A-4(7) | CL |
| | 9-17 | B2 | - | - | - | - | - | - | - | 100 | 97 | 83 | 81 | 74 | 54 | 43 | 52 | 31 | A-7-6(18) | CH |
| | 37-48 | C | - | - | - | - | 100 | 96 | 93 | 89 | 80 | 59 | 53 | 38 | 19 | 10 | 21 | 7 | A-4(5) | CL-ML |
| | 11-20 | B2 | - | - | - | - | - | - | - | 100 | 99 | 92 | 92 | 91 | 70 | 60 | 60 | 35 | A-7-6(11) | CH |
| | 36-50 | C | - | - | - | - | - | - | - | 100 | 98 | 89 | 89 | 84 | 52 | 36 | 32 | 14 | A-6(10) | CL |
| | 10-24 | B2 | - | - | - | - | - | - | - | 100 | 97 | 86 | 85 | 79 | 56 | 44 | 48 | 25 | A-7-6(16) | CL |
| | 36-48 | C | - | - | - | - | - | - | - | 100 | 97 | 81 | 75 | 49 | 21 | 15 | 20 | 3 | A-4(8) | ML |
| Norden silt loam | 18-23 | B21 | 110 | 15 | - | - | - | - | - | 100 | 99 | 91 | 82 | 50 | 28 | 21 | 27 | 8 | A-4(8) | CL |
| Dunn Co., Wis. | 23-28 | B22 | 114 | 16 | - | - | - | - | - | 100 | 99 | 59 | 52 | 40 | 32 | 27 | 34 | 17 | A-6*8) | CL |
| | 14-28 | B21* | 107 | 17 | - | - | - | - | - | - | - | 99 | 95 | 60 | 30 | 26 | 35 | 14 | A-6(10) | CL |
| | 34-40 | B22* | 115 | 15 | - | - | - | - | - | 100 | 99 | 80 | 72 | 46 | 27 | 22 | 30 | 12 | A-6(9) | CL |
| Norden silt loam | 16-20 | B2 | 105 | 18 | - | - | - | - | - | - | - | 96 | 92 | 60 | 32 | 28 | 42 | 20 | A-7-6(12) | CL |
| Pepin Co., Wis. | 38-50 | C | 115 | 12 | 94 | 87 | 83 | 79 | 76 | 73 | 73 | 15 | 12 | 11 | 7 | 7 | - | NP | A-2-4(0) | SM |
| Octagon silt loam | 13-16 | B22t | 105 | 19 | - | - | - | - | - | 100 | 98 | 84 | 84 | 69 | 42 | 35 | 51 | 34 | A-7-6(18) | CH |
| Dane Co., Wis. | 33-60 | C1 | 13[illegible] | 8 | - | 96 | 94 | 90 | 87 | 84 | 75 | 28 | 25 | 14 | 7 | 6 | - | NP | A-2-4(0) | SM |
| Okee loamy fine sand | 10-25 | B1* | - | - | | 99 | 99 | 96 | 93 | 91 | 82 | 12 | 10 | 7 | 5 | 3 | - | NP | A-2-4(0) | SP-SM |
| Green Lake Co., Wis. | 31-45 | IIB22t* | - | - | - | - | - | - | - | 100 | 92 | 29 | 27 | 21 | 16 | 14 | - | NP | A-2-4(0) | SM |
| | 45-60 | IIC* | 134 | 7 | | 98 | 97 | 94 | 91 | 89 | 81 | 29 | 23 | 16 | 10 | 7 | - | NP | A-2-4(0) | SM |
| | 28-35 | IIB21t | - | - | - | - | - | - | - | 100 | 99 | 51 | 42 | 28 | 16 | 12 | 20 | 4 | A-4(3) | CL-ML |
| Okee loamy fine sand, fine loamy variant Green Lake Co., Wis. | 55-60 | IIC | 139 | 6 | 100 | 93 | 91 | 86 | 83 | 80 | 72 | 31 | 25 | 15 | 6 | 4 | - | NP | A-2-4(0) | SM |
| Omega sand Washburn Co., Wis. | 20-40 | C | - | - | - | - | - | - | - | 100 | 99 | 12 | - | - | - | - | - | NP | A-2-4(0) | SP-SM |
| Onamia sandy loam | 16-22 | B2 | - | - | 93 | 85 | 83 | 82 | 81 | 81 | 70 | 46 | 45 | 34 | 20 | 16 | 30 | 13 | A-6(3) | SC |
| Chippewa Co., Wis. | 29-42 | C | - | - | 94 | 77 | 70 | 55 | 45 | 32 | 13 | 4 | 3 | 2 | 1 | 1 | - | NP | A-1-a(0) | GP |
| Onaway loam | 15-20 | B2* | 115 | 14 | - | 97 | 96 | 94 | 93 | 91 | 86 | 58 | 54 | 45 | 33 | 27 | 34 | 18 | A-6(8) | CL |
| Door Co., Wis. | 30-54 | C* | 104 | 8 | - | 97 | 96 | 91 | 87 | 82 | 74 | 43 | 34 | 20 | 7 | 5 | - | NP | A-4(2) | SM |
| | 20-26 | B'2t | - | - | - | - | - | - | - | 100 | 94 | 50 | 45 | 37 | 28 | 24 | 24 | 9 | A-4(3) | CL |
| | 30-60 | C | 132 | 8 | - | - | 100 | 96 | 94 | 89 | 81 | 39 | 33 | 22 | 13 | 10 | 15 | NP | A-4(1) | SM |
| Onaway loam | 14-21 | B2 | - | - | - | 98 | 97 | 96 | 96 | 94 | 89 | 46 | 42 | 32 | 23 | 18 | 26 | 12 | A-6(3) | SC |
| Marinette Co., Wis. | 35-45 | C | - | - | - | 98 | 96 | 92 | 89 | 84 | 74 | 30 | 24 | 14 | 8 | 5 | - | NP | A-2-4(0) | SM |

| Soil name and sample location | Depth in inches | Hori-zon | Moisture-density: Maximum dry density (lbs. per cu. ft.) | Moisture-density: Optimum moisture (percent) | Mechanical Analysis: Percentage passing sieve: 2" | 1" | 3/4" | 3/8" | #4 4.7 mm. | #10 2.0 mm. | #40 .42 mm. | #200 .074 mm. | Percent smaller than: 0.05 mm. | 0.02 mm. | .005 mm. | .002 mm. | Liquid limit | Plas-ticity index | Classification: AASHO (group index ratings in parenthesis) | Unified |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Washburn sandy loam Ashland Co., Wis. | 3-7 | B2hir | - | - | - | 94 | 94 | 92 | 91 | 89 | 76 | 33 | 29 | 17 | 7 | 4 | - | NP | A-2-4(0) | SM |
| | 19-29 | A&Bx | - | - | - | 98 | 98 | 96 | 92 | 88 | 69 | 27 | 24 | 13 | 5 | 3 | - | NP | A-2-4(0) | SM |
| | 29-42 | IIBtx | - | - | - | 99 | 97 | 94 | 91 | 86 | 69 | 22 | 18 | 10 | 4 | 2 | - | NP | A-2-4(0) | SM |
| | 61-72 | IIIC2 | 126 | 9 | 100 | 98 | 97 | 94 | 91 | 88 | 69 | 21 | 17 | 9 | 4 | 2 | - | NP | A-2-4(0) | SM |
| Washburn sandy loam Vilas Co., Wis. | 21-41 | B | - | - | 98 | 93 | 90 | 88 | 88 | 88 | 73 | 18 | 14 | 11 | 6 | 4 | - | NP | A-2-4(0) | SM |
| | 41-60 | C | - | - | 100 | 94 | 92 | 87 | 83 | 77 | 63 | 14 | 12 | 8 | 4 | 2 | - | NP | A-2-4(0) | SM |
| | 19-39 | B | - | - | 100 | 93 | 91 | 86 | 85 | 85 | 67 | 14 | 12 | 8 | 5 | 4 | - | NP | A-2-4(0) | SM |
| | 39-60 | C | - | - | - | - | - | - | - | 100 | 81 | 18 | 14 | 11 | 6 | 7 | - | NP | A-2-4(0) | SM |
| Washburn sandy loam Washburn Co., Wis. | 35-44 | B2t | 131 | 9 | - | 100 | 99 | 96 | 94 | 92 | 75 | 23 | 21 | 14 | 10 | 8 | - | NP | A-2-4(0) | SM |
| | 44-56 | C | 131 | 8 | - | 100 | 99 | 98 | 95 | 93 | 74 | 24 | 22 | 12 | 8 | 6 | - | NP | A-2-4(0) | SM |
| Waukegan silt loam St. Croix Co., Wis. | - | B2 | - | - | - | - | - | - | - | 100 | 90 | 77 | - | - | 25 | - | 32 | 10 | A-4(8) | CL |
| Waymor silt loam Sheboygan Co., Wis. | 9-19 | B2t | - | - | - | - | - | - | - | 100 | 98 | 75 | 73 | 66 | 51 | 42 | 43 | 24 | A-7-6(19) | CL |
| | 29-60 | C | 125 | 11 | - | - | 100 | 98 | 96 | 93 | 89 | 71 | 66 | 50 | 29 | 21 | 25 | 10 | A-6(7) | CL |
| | 9-21 | B2t | - | - | - | - | - | - | - | 100 | 99 | 88 | 86 | 79 | 59 | 47 | 46 | 25 | A-7-6(15) | CL |
| | 31-60 | C | 124 | 11 | - | 100 | 99 | 97 | 96 | 93 | 89 | 69 | 64 | 49 | 29 | 20 | 24 | 10 | A-4(7) | CL |
| Westville loam Green Co., Wis. | 30-44 | B2 | - | - | - | 99 | 99 | 98 | 97 | 96 | 88 | 47 | 45 | 36 | 23 | 19 | 29 | 15 | A-6(4) | SC |
| | 56-60 | C | - | - | - | 97 | 95 | 90 | 86 | 82 | 74 | 36 | 34 | 22 | 11 | 7 | - | NP | A-4(0) | SM |
| | 22-58 | B2 | - | - | - | 96 | 92 | 85 | 79 | 73 | 60 | 34 | 32 | 27 | 19 | 16 | 43 | 19 | A-2-7(2) | SC |
| | 58-70 | B3 | - | - | 100 | 97 | 96 | 90 | 84 | 77 | 58 | 19 | 17 | 13 | 9 | 7 | - | NP | A-2-4(0) | SM |
| | 24-40 | B2* | 111 | 17 | - | - | - | - | - | 100 | 94 | 64 | 62 | 52 | 37 | 31 | 35 | 17 | A-6(9) | CL |
| | 52-60 | C* | 132 | 8 | - | 92 | 90 | 85 | 80 | 77 | 68 | 38 | 36 | 22 | 9 | 7 | - | NP | A-4(1) | SM |
| Whalan silt loam Green Co., Wis. | 32-38 | B2 | - | - | - | - | - | - | - | 100 | 95 | 41 | 40 | 34 | 27 | 23 | 28 | 16 | A-6(9) | SC |
| | 17-35 | B2* | 124 | 12 | - | - | - | - | - | 100 | 94 | 58 | 56 | 46 | 28 | 23 | 25 | 11 | A-6(8) | CL |
| | 15-29 | B2 | - | - | - | - | - | - | - | 100 | 98 | 68 | 65 | 53 | 31 | 26 | 34 | 18 | A-6(10) | CL |
| Whalan silt loam St. Croix Co., Wis. | 20-30 | IIB23t | - | - | 100 | 86 | 82 | 80 | 79 | 79 | 72 | 46 | 41 | 28 | 18 | 16 | 30 | 14 | A-6(3) | SC |
| | 30-34 | IIIB3t | - | - | - | - | - | - | - | 100 | 89 | 62 | 61 | 56 | 38 | 28 | 39 | 21 | A-6(10) | CL |
| Withee silt loam Marathon Co., Wis. | 18-30 | B2 | - | - | - | - | - | - | - | 100 | 94 | 78 | 76 | 60 | 36 | 30 | 41 | 24 | A-7-6(14) | CL |
| | 37-50 | C | - | - | - | - | - | - | - | 100 | 91 | 68 | 66 | 54 | 38 | 32 | 40 | 25 | A-6(13) | CL |
| Withee silt loam Wood Co., Wis. | 25-31 | B2* | 117 | 15 | - | - | - | - | - | 100 | 94 | 74 | 69 | 54 | 37 | 30 | 39 | 24 | A-6(14) | CL |
| | 37-50 | C* | 119 | 14 | - | - | - | - | - | 100 | 96 | 66 | 62 | 50 | 38 | 30 | 36 | 23 | A-6(11) | CL |
| | 23-30 | B2 | - | - | - | - | - | - | - | 100 | 93 | 67 | 63 | 46 | 27 | 23 | 32 | 16 | A-6(8) | CL |
| | 37-60 | C | - | - | - | - | - | - | - | 100 | 91 | 63 | 60 | 50 | 36 | 32 | 39 | 25 | A-6(12) | CL |