Mesabi Iron Range Water and
Mineral Resource Planning

Stockpile Ownership, Composition, and Use

for two study areas located near Virginia and Calumet, Minnesota

By
The Minnesota Department of Natural Resources
Division of Lands and Minerals

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EXECUTIVE SUMMARY

This report summarizes the results of a data collection project focused on stockpile ownership, material composition, and material use for two study areas located near Virginia and Calumet, Minnesota. The information collected may be used to determine the suitability of stockpile materials for future use. Funding for the project was from the Legislative Commission on Minnesota Resources. The project was conducted by the Minnesota Department of Natural Resources, Division of Lands and Minerals.

Surface and mineral ownership research was completed for 2,839.32 acres in the Virginia study area. A total of 4,067.02 acres were researched in the Calumet study area, with an additional 2,498.99 acres, which were previously researched, checked for ownership changes. Stockpile ownership was determined for a majority of the stockpiles located within the study areas, however, many stockpiles still have undetermined ownership.

A total of 232 stockpiles were inventoried in the two study areas. The stockpile inventory involved gathering information regarding material composition, material classification, sample analysis, and volume estimation. Material was classified into ten material types based upon geology and iron content. The footprint of each stockpile was digitized to capture the location of the stockpile.

Eighty-two samples were collected from stockpiles. The samples were tested for aggregate and iron ore. Aggregate tests included: specific gravity, absorption, soundness, and gradations. The test results were compared to the Minnesota Department of Transportation specifications for general aggregate use. Iron ore testing was comprised of chemical assays of the eight most common oxides.

A relational database was designed to store the information gathered for this project. This is the first known attempt to model and develop a database which would accommodate the complexities of stockpiles and ownership on the Mesabi Iron Range. The database consists of over 30 related tables and forms for browsing the information.

Vegetation covers on the stockpiles were determined through aerial photography interpretation and field checked during the fall of 2000. The current transportation infrastructure, which includes major roads and railroads, and private mining roads and old railroads, was mapped during the summer of 2000.

The stockpiles were examined for use in the aggregate industry and the iron mining industry. Generalizations can be made about each material type based upon qualitative and quantitative data. The material type with the highest potential for aggregate use was glacial overburden. Cretaceous ore and natural ore fine tailings have a high potential for iron.

I. INTRODUCTION

Over 100 years of mining on the Mesabi Iron Range has resulted in large scale land disruptions. Large, deep water bodies, mounds of stockpiled materials, and vast plains of tailings make up the landscape of the Mesabi Iron Range. The Mesabi Iron Range Water and Mineral Resources Planning project initiates the effort to provide the people of the Range with technical data that will assist them in planning and developing this landscape.

This portion of the Legislative Commission on Minnesota Resources (LCMR) project focuses on Stockpile Ownership, Composition, and Use. The project's purpose is to collect data on stockpile ownership and material composition within two study areas. The data may be used to determine the suitability of stockpile materials for future uses. The large volume of stockpiled material on the Mesabi Iron Range has great potential for re-use. Certain materials have the potential to be used as aggregate, while some materials have the potential to be mined for iron units with the development of new processing techniques. Helping to sustain the mining industry and local communities by utilizing stockpiles requires the development of information on stockpile ownership and composition.

This is a first attempt to join and reconcile the complexity of ownership data on mining properties with data defining and categorizing stockpile material types. Because each data set has distinct geographic boundaries, the difficulty in combining them is compounded. Disparate data sets needed to be gathered, organized, linked, and then stored.
To accomplish these tasks the project was broken down into five parts:

- Ownership Research
- Stockpile Inventory
- Database Design
- Stockpile Access
- Potential Material Use

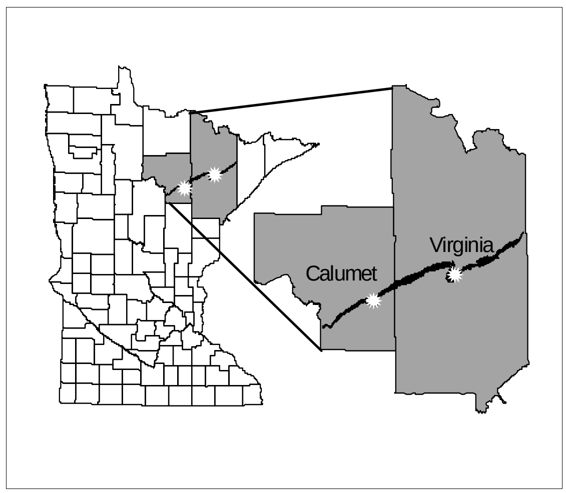


Figure 1. Location map of the two study areas near the towns of Virginia and Calumet, Minnesota.

Ownership involved title research to determine the mineral, surface, and stockpile ownership. The stockpile inventory was based upon pre-existing information gathered from various mining companies and field work. For the purposes of this project, a "stockpile" is defined as any earthen material piled during the process of mining. This includes tailing basins, overburden piles, and rock dumps. If the material had another intended use, such as material used for a dike, overpass, or road base, that material is not considered to be a stockpile for purposes of this project. The various aspects of ownership research and the stockpile inventory were organized and linked in a database designed in Microsoft Access. To further facilitate the use of stockpiled material, accessibility was examined by mapping vegetation and mining roads. The potential use of stockpiles was summarized by past leasing experience and through sampling analysis of different types of stockpiled material.

The project was conducted over two study areas on the Mesabi Iron Range (Figure 1). One site is located on the east end of the Mesabi Iron Range, east of the city of Virginia, in St. Louis

County, comprising approximately 3,000 acres (hereafter referred to as the “Virginia” site). The Virginia site encompasses portions of Township 58 North, Range 17 West. The second site is located on the west end of the Mesabi Iron Range, in the vicinity of the cities of Calumet and Marble, in Itasca County, comprising approximately 6,000 acres (hereafter referred to as the “Calumet” site). The Calumet site encompasses portions of Township 56 North, Range 23 West and Township 56 North, Range 24 West (Figure 2).

The study areas were selected based upon the following site criteria: 1) numerous stockpiles within the area with a variety of potential materials; 2) area with known state surface ownership; 3) inactive iron ore/taconite mining area; and 4) proximity to transportation. An east Range site and a west Range site were selected to show differences that may be encountered in different mining areas along the Range. In the interest of project manageability, the two combined study areas were not to contain more than a total of 10,000 acres. The boundaries of the study areas were determined using plat maps, preliminary site visits, and personal knowledge of the stockpile areas by the Minnesota Department of Natural Resources (DNR), Division of Lands and Minerals staff. The boundaries were drawn following public land survey lines along forty-acre parcels or government lots. Some stockpiles within the study areas may extend beyond these boundary lines.

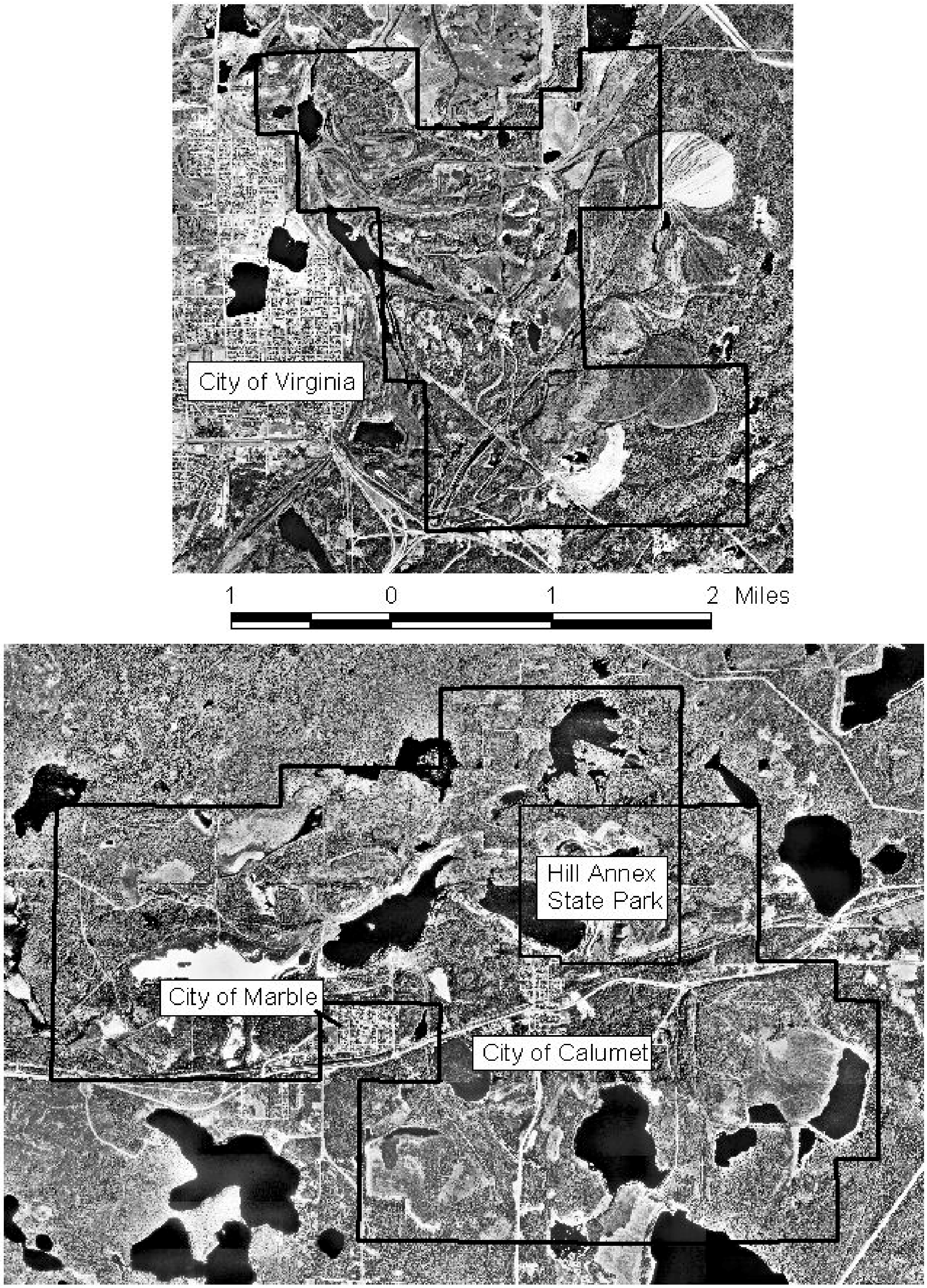
II. SCOPE

Throughout this project, DNR, Division of Lands and Minerals staff have made a best effort to collect accurate data using available sources. Because this project is geared towards aggregate and iron ore potential, the method by which this information was organized and mapped was customized for that purpose. The methodology used could be expanded Range-wide, however, modifications would be needed in the database and in stockpile classification. The database structure designed for this project may or may not work for other stockpile inventories and ownership research. It is also important to note that the designed database is the first attempt to gather and store many pieces of stockpile information in one place.

Information gathered from private companies is based upon the best information available at the time the information was collected. Every company has its own method of collecting data and field checks were not always conducted. Therefore, the accuracy of the data cannot be relied upon without conducting a closer examination of stockpiled materials.

The information gathered from the two study areas occurred between 1999 and 2001. The project only provides a “snapshot in time” for the areas. This is especially true regarding the surface, mineral and stockpile ownership. Due to ownership changes which occur whenever a conveyance of property is made, ownership is only accurate as of the day the ownership was reviewed. Currently, there is no plan to update the stockpile information database to reflect changes which may occur in the two study areas after June 30, 2001.

Figure 2. Virginia and Calumet Study Areas



III. METHODOLOGY
A. OWNERSHIP

Surface and Mineral Ownership

The surface and mineral ownership were determined based upon a review of the documents comprising the chain of title for each forty-acre parcel or government lot within the study areas. Only those documents recorded in the Itasca County Recorder's Office and the St. Louis County Recorder's Office, which were indexed against the specific parcels in each study area, were reviewed.

Ownership research for the Virginia study area was conducted in St. Louis County from August 1999 through January 2000. Due to the absence of a complete tract index (an index of recorded documents by legal description) in the St. Louis County Recorder's Office, assistance was provided by Consolidated Abstract and Title Company in Duluth, Minnesota in locating documents recorded in the county's records. Ownership research for the Calumet study area was conducted in Itasca County from June 2000 through January 2001.

Ownership is broken down to the forty-acre parcel or government lot (Figure 3). (Government lots numbers were generally assigned to those parcels which have more or less than the standard forty acres, or parcels adjoining meandered waters). Some parcels contain partial descriptions for differing ownership within the parcel. Multiple owners with undivided, fractional interests in a parcel are common for parcels throughout the two study areas. Parcels that have been platted as lots and blocks were not researched, due to their small acreage and often complicated ownership. Since property ownership changes over time with conveyances of the property, the ownership results are only valid as of the date the research was conducted in the county.

In areas where there has been mining activity, it is common for parcels to have separate surface and mineral ownership. The surface estate and mineral estate are considered one entity until a transaction separates them, creating a "severance" of the mineral estate. Where the minerals have been severed, the surface owner and the mineral owner will differ. The owner of severed minerals must file a statement of such ownership with the county recorder in the county where the minerals are located. The owner is then assessed taxes on this mineral ownership. Failure to file the statement or pay the taxes results in the forfeiture of the mineral rights.

A short explanation is needed regarding State ownership of the surface and minerals. The State may own real estate acquired through different methods. State trust fund lands are lands owned by the State through a direct conveyance from the United States government. The State may also acquire land from a private owner by purchase or gift, or through an exchange of State land for private land. The State may have acquired property through a reversionary deed. A reversionary deed grants ownership only until a specific date or event occurs. Upon reaching the specified date or when the event occurs, the property goes back (or reverts) to the owner who conveyed the property. The State may also own land through real estate tax forfeiture. These lands are administered for the State by the county. State mineral ownership includes two additional categories: severed mineral tax forfeiture and non-registered severed mineral forfeiture. Severed

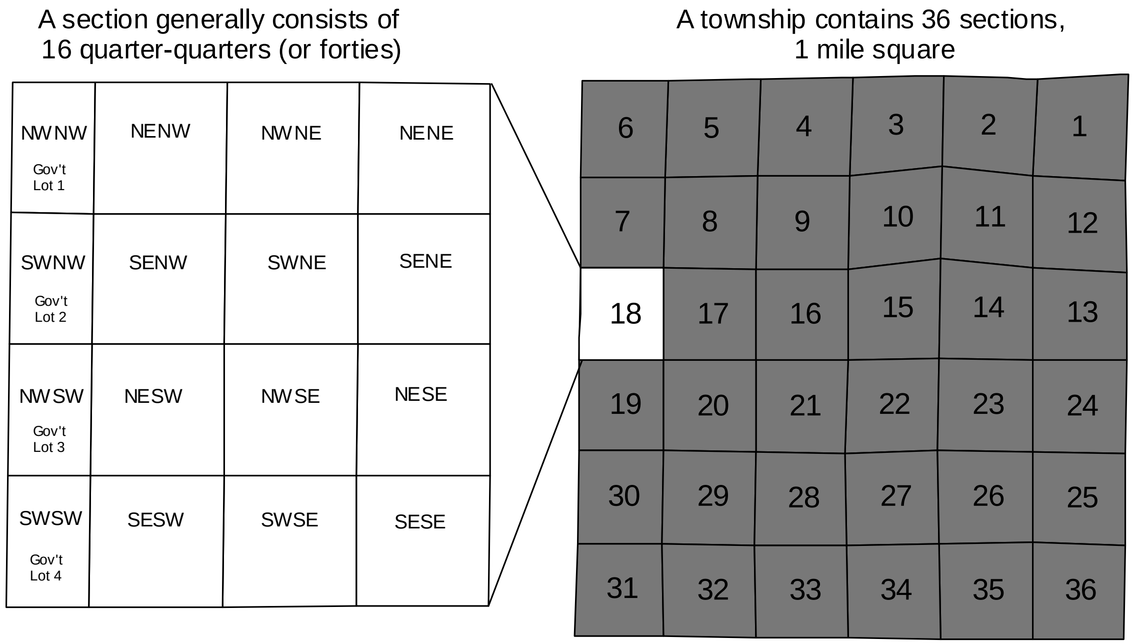


Figure 3. Description of a section, government lot, and township.

mineral tax forfeiture is a forfeiture for nonpayment of the severed mineral interest tax. Non-registered severed mineral forfeiture is a forfeiture for failure to file the required statement of severed mineral interest within the required time specified by statute. The State is deemed to be the owner of non-registered severed minerals upon the failure to file the statement. However, the State's ownership is not absolute until a final forfeiture judgment is made by the courts.

Stockpile Ownership

The ownership of stockpiled material is difficult to determine since ownership depends upon the intent of the parties involved at the time the stockpile was created. The intent of the parties may be revealed through examining documents such as leases, operating agreements, stockpiling agreements, and commingling agreements.

When minerals are severed from their natural bed with an intention that the minerals be disposed of as other than real property, a conversion occurs, and the minerals become personal property. ("Real property" refers to the land itself and whatever is affixed to the land. "Personal property" generally refers to all property other than real estate.) This personal property conversion can occur with stockpiled materials which were stored for possible future use. One problem that can arise is when materials are stockpiled on land not owned by the owner of the stockpiled materials. This occurrence can produce separate ownership of the underlying real estate and the stockpiled materials, which now constitute the visible surface of the land. Similarly, if the real property on which the stockpile is located is conveyed without specifically including all personal property located on the parcel, the stockpiled materials may not be conveyed to the new owner of the real property. There are instances, and probable instances, where stockpiles within the study areas have different owners than that of the underlying surface real estate.

Most of the documents necessary to determine stockpile ownership are not available for public review. Many private mining leases and agreements, which may provide information on stockpiles, are not recorded in the official county land records. The ownership information gathered for this project was based upon the best available information accessible to the DNR, Division of Lands and Minerals. Information was located in documents filed in county land records, State mining records, and information provided by private mining companies with land holdings in the two study areas.

Numerous stockpiles are still actively managed by mining companies and other private owners. Information was obtained from these companies/owners regarding the stockpiles they own and manage. Stockpiles of surface material, or overburden, is generally thought to have the same ownership as that of the surface estate on which it is now located. This material was removed through mining to gain access to the mineral wealth below, thus there was no intent to create a separate personal property interest. Many stockpiles still have undetermined ownership. The ownership of these stockpiles may be determined by locating an agreement between private parties or by tracing the mineral owner of the material back to the property from which it was mined. This project made an effort to locate such documentation and to trace the mineral owner of the stockpiled material back to the mined property without success.

B. Stockpile Material Inventory

Several steps were taken throughout the stockpile inventory portion of the project. First, information was gathered to determine the composition of stockpiled material. Then a classification system was designed to incorporate all the types of material encountered in the two study areas. To define the location of the stockpiles, an outline, or "footprint", of each stockpile was digitized and labeled. The samples taken from the assorted stockpile material types were analyzed. Volumes for some of the stockpiles were estimated.

Stockpile Composition

The determination of stockpile composition, or material type, was based on many sources of information. These sources were given a hierarchical rank of importance, which was then used to determine the material type of a particular stockpile. Reviewed below are the sources of information and methodology used to determine the material type, listed in order of importance.

Company Information

Pre-existing information about stockpiles was a key factor in determining the material type. Information, such as iron units and volume, were calculated and values assigned as a stockpile was being built. This information was found to be more reliable than any comparable stockpile sampling technique. Stockpiles can be large in size, contain different ore grades, and the material can be cumbersome to sample. So the importance of pre-existing records is the result of how difficult it is to "represent" a stockpile by sampling. For these reasons, specific information pertaining to a single pile was obtained solely from company records.

This information was gathered with the cooperation of several stockpile owners by providing them with a list of stockpiles that referenced common names or locations of stockpiles. This list applied primarily to iron ore stockpiles. Detailed information such as iron, silica, and aluminum content, and volume was provided. The accuracy of these records could vary between sources; however, they are the best available information.

Field Work

Most stockpiles (over 95%) were visited in the field. The primary purpose of the field work was to confirm the material type, sample the material when possible, and photograph various piles. Stockpiles were described using the guidelines:

- Material type (glacial overburden, natural ore, fine tailings)
- Mineralogy (identifying iron ore minerals, such as hematite, magnetite, goethite, etc.)
- Range of rock size within the pile
- Approximate average rock size
- Rock angularity
- Sorting of stockpile
- Estimated amount of sand and gravel the pile may contain
- Other observations and comments

Where no company information was available for a stockpile, field descriptions were the next best source of information. The limitation to observing stockpiles in the field is that only portions of the surface of the pile can be observed. This was especially true for glacial overburden stockpiles where vegetation was dense and soil development was thick. Another limitation to observing the stockpile surface is that the visual portion represents only a small percent of the total stockpile volume. Therefore, it is important to note different material types may be present within the stockpile.

Various stockpiles were sampled throughout the two study areas. The purpose of sampling was primarily to obtain a range of results for various stockpile material types. Aggregate tests were conducted on most samples, and chemical assays were conducted only on the iron ore bearing materials. This approach was taken because of the difficulty associated with representative sampling of stockpiles. Of all accepted sampling techniques, stockpile sampling is the least accurate (Minnesota Department of Transportation Aggregate Production I, 1998). Therefore, the sampling methodology of this project is geared towards showing the range of values that may be encountered while working with a specific material type. The object of the test results is to help determine what type of material would suit a particular use. Once a material type is chosen, additional testing of a particular stockpile may be required by the user to determine if that stockpile meets the desired needs and specifications.

The samples were collected as random grab samples. For stockpiles, a 20 pound sample was taken at the surface or at an edge of a pile using a small shovel. For tailing basins, a hand auger was used with a 4-inch diameter bucket and samples were obtained by auguring approximately 3 feet down from the surface. This produced roughly a 20 pound sample. The sample sites were chosen by ease of access to the piles and material type. Stockpiles that were not accessible by truck were not sampled. In basins, the “finer” (silt and clay sized particles) portions are very densely vegetated while the sandier portions are open. For this reason, the coarser areas of tailing basins were sampled more frequently. There were two reasons a stockpile material type was not sampled. The material was either too large to fit into a sample bag (+2 feet) or the material was known to be a poor aggregate. For example, slate and paint rock are considered to be spall or substandard rock; thus, neither were sampled.

Photographs were taken of several stockpiles. The purpose was to give a visual aspect to the stockpiles. All samples and photograph locations were gathered using a Global Positioning System (GPS) unit. The accuracy of each location is within 15 meters. Other observation points were also collected. These were located by either GPS or aerial photography techniques.

Aerial Photographic Interpretation

To further confirm observations made in the field, several sets of aerial photographs were interpreted. Material types could be differentiated in the air photo by identifying certain material characteristics. For example, overburden piles were light in color and rock piles were dark; tailing basins appeared to have a network of water channels that resembled "veins" when they were active; and large rock piles had a "bumpy" texture. However, some distinctions could not be determined (i.e., the differences between two types of ore). For the Virginia site the following aerial photographs were used:

- MNDNR Color Infrared 1997 (1:15,840)
- NAPP Color Infrared 1991 (1:40,000)
- Black and White 1961 (1:40,000)
- Black and White 1947 (1:40,000)

For the Calumet site the following aerial photographs were used:

- MNDNR Color Infrared 1995 (1:15,840)
- NAPP Color Infrared 1991 (1:40,000)
- Black and White 1969 (1:80,000)
- Black and White 1966 (1:40,000)

Mining Maps

There are three sets of mining maps that were consulted when identifying stockpiles: the 1982 USX Plates and the 1955 and 1959 editions of the Great Northern Iron Ore Properties' Map of the Mesabi Range. These maps helped identify commonly known stockpile names, confirm some material types, and show footprints of some stockpiles. The maps and aerial photographs also helped identify the relative age of the stockpiles.

Stockpile Material Classification

In the process of gathering pre-existing information from mining companies and assembling information gathered in the field, it was apparent there were several different material type classifications used by various mining companies. One material type could have several different "material type" labels. Some examples are:

Lean Ore versus Lean Material
Taconite versus Taconite Rejects versus Taconite Dumps versus Lean Taconite
Heavy Media versus Cone Tailings versus Jig Tailings

Within each example above, the materials are very similar. Although various classifications may have specific meaning to a particular mine, or process, or an indication of iron content, they may not be applicable in both study areas. On a broader scale, these classifications cannot be used Range-wide with certainty. Therefore, a classification system was developed specifically for this project. It represents an attempt to look at stockpiled material in a broader view so that material types can be generalized yet accurately represented. If a similar stockpile inventory were to be conducted for the entire Mesabi Iron Range, it would be most useful if a universal material classification system was developed. The classification system used in this project combines geology and iron content (mining practices) to differentiate stockpile material types.

There are approximately 10 material types (Figure 4). The types are initially broken down by geologic type: bedrock versus unconsolidated sediment. Unconsolidated sediment is generally considered overburden in the mining industry. Two types of overburden were observed: glacial and Cretaceous. There are some bedrock units that can be considered overburden. An example is the Virginia Slate that overlies the iron formation. However, there are several slaty units within the iron formation. In the classification system, slate stockpiles were not labeled overburden because they may contain slate mined from within the iron formation.

Bedrock and sediment is then subdivided by the "intent of mining" (i.e., not mined for iron units versus mined for iron units). Although the material types of "paint rock" and "slate" may contain some iron units, for the purposes of this project, they were not considered to be an iron ore. The

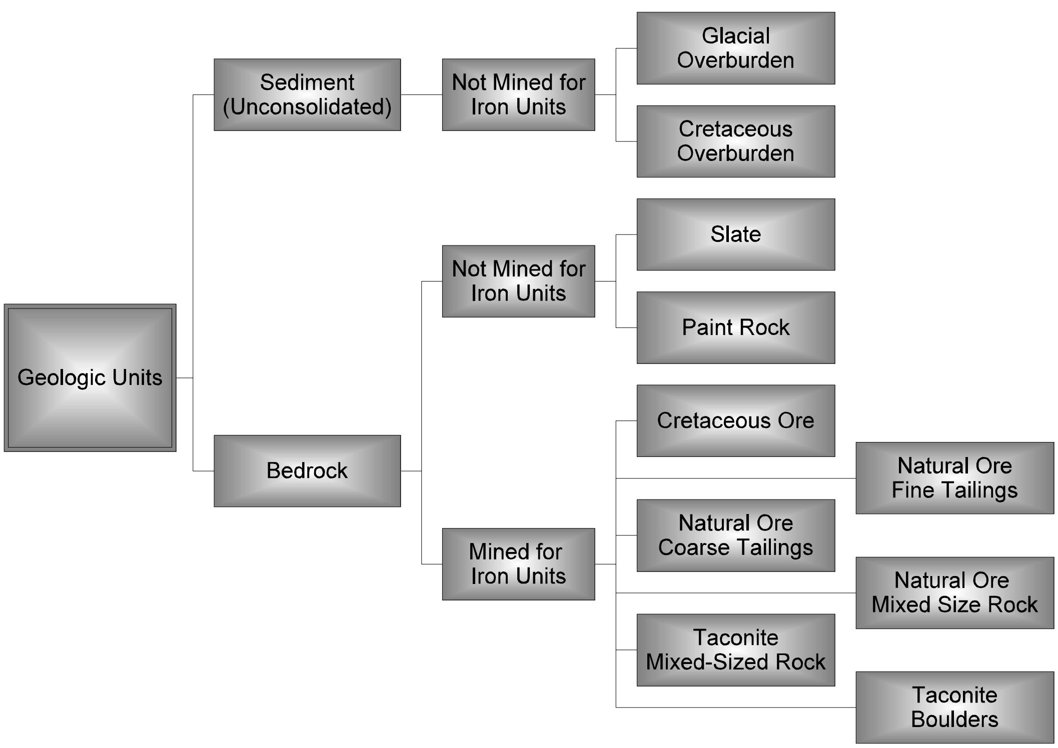


Figure 4. Schematic diagram of stockpile classification system. The material types are somewhat arranged by the stratigraphy as seen in the field.

material types that fall under “mined for iron units” are: Cretaceous ore, natural ore fine tailings, natural ore coarse tailings, natural ore mixed-sized rock, taconite mixed-sized rock, and taconite boulders. These material types were designed to include the following range of materials:

Coarse tailings - includes cone tailings, jig tailings, and heavy media rejects
Taconite boulders - includes taconite, taconite rejects, taconite dumps, lean taconite
Natural ore mixed-sized rock - includes lean ore, natural and wash ore, and lean ore material (magnetic).

Aggregate Testing

A total of 82 samples were taken of various stockpile materials. For aggregate testing, most of the samples were sieved to determine the gradations of particle size. This test was conducted at the DNR Hibbing Laboratory using methodologies specified by the Minnesota Department of Transportation (MNDOT). Some samples were too fine to sieve; these samples included numbers 45 and 46. To test the material thoroughly with as many aggregate quality tests as possible, samples were composited. This process combines several samples into one. For example, samples 53, 54, 55, 56, and 57 were combined to form composite A1. Then composites A1, A2, A3, and A4 were combined to form composite ZZ1(Table 1). For the most part, composited samples are within the same stockpile. In other cases, samples from many stockpiles, that were the same material type, were combined. The aggregate testing was conducted at Braun Intertec Corporation, Minneapolis, Minnesota. The aggregate tests are listed by material type in Table 2. (An explanation of the individual aggregate tests and location map of the samples are found in Appendix A).

Iron Ore Testing

For iron ore testing, chemical assays were completed on a total of 51 iron ore samples. The testing was conducted at Midland Research Center, Nashwauk, Minnesota. The chemical assays performed on each sample determined the amount of major oxides, which helped to characterize the material type.

Table 1: Sample list by material type.

Material Type	Pile #	Samples	Composite 1	Composite 2
A. Coarse Tailings	418	53, 54, 55, 56, 57	A1	ZZ1 Includes A1-A4
	419	49, 50, 51, 52	A2	
	424	43, 44	A3	
	429	39, 40, 41, 42	A4	
	313	27	A5	ZZ2 Includes A5-A8
	362	18, 19, 20, 21	A6	
	369, 374	68, 69	A7	
	430	79, 80	A8	
B. Cretaceous Ore	373, 361, 336	17, 22, 23	B9	ZZ3
C. Fine Tailings	340	58, 59, 60, 82	C10	ZZ4 Includes C10-C12
	327	61, 62, 63	C11	
	325	64, 65	C12	
	417	45, 46	C13	NOT TESTED
	432	35, 36, 37, 38	C14	ZZ5 Includes C14-C16
	417	47, 48	C15	
	335	29, 30, 31	C16	
	302	24, 25, 26	C17	ZZ6 Includes C17-C19
	423	76, 77, 78	C18	
	396	81	C19	
D. Glacial Overburden	409	70, 71, 72, 73	D20	ZZ7 Includes D20-D22
	360	66	D21	
	305	28	D22	
	402	75	D23	ZZ8 Includes D23-D26
	353	33, 34	D24	
	372	67	D25	
	154	1*	D26	
	130	2, 3, 4, 5	D27	ZZ9 Includes D27-D29
	168	6, 7, 8, 9	D28	
	Not a pile	11, 12, 13	D29	
E. Mixed-Sized Rock (Taconite & Natural Ore)	174	14, 15	E30	ZZ10 Includes E30-E32
	411	74	E31	
	339	32	E32	

Table 2. Tests performed on each sampled material type.

	TEST	NUMBER OF TESTS	COMPOSITE 1	COMPOSITE 2
A. Coarse Tailings				
Specific Gravity (Coarse and Fine)	C127 and C128	8	A1 through A8	
Absorption (Coarse and Fine)	C127 and C128	8	A1 through A8	
Flatness and Elongated	D4791	8	A1 through A8	
Clay Lumps	C142	8	A1 through A8	
Abrasion	C88	2		ZZ1 and ZZ2
Soundness	C131/C535	2		ZZ1 and ZZ2
B. Cretaceous Ore				
Specific Gravity (Coarse and Fine)	C127 and C128	1	B9	
Absorption (Coarse and Fine)	C127 and C128	1	B9	
Clay Lumps	C142	1	B9	
Abrasion	C88	0		Not enough sample
Soundness	C131/C535	1		ZZ3
C. Fine Tailings				
Specific Gravity (Fine)	C128	9	C10 through C19	
Absorption (Fine)	C128	9	C10 through C19	
Fine Aggregate Particle	T304	3		ZZ4, ZZ5, and ZZ6
D. Glacial Overburden				
Specific Gravity (Coarse and Fine)	C127 and C128	10	D20 through D29	
Absorption (Coarse and Fine)	C127 and C128	10	D20 through D29	
Flatness and Elongated	D4791	10	D20 through D29	
Clay Lumps	C142	10	D20 through D29	
Spall	(MNDOT)	10	D20 through D29	
Lightweight Particles	C123	10	D20 through D29	
Abrasion	C88	3		ZZ7, ZZ8, ZZ9
Soundness	C131/C535	3		ZZ7, ZZ8, ZZ9
E. Mixed-Sized Rock				
Specific Gravity (Coarse and Fine)	C127 and C128	3	E30 though E33	
Absorption (Coarse and Fine)	C127 and C128	3	E30 though E33	
Flatness and Elongated	D4791	3	E30 though E33	
Clay Lumps	C142	3	E30 though E33	
Soundness	C131/C535	1		ZZ10

Stockpile Digitizing

The footprints of the stockpiles were digitized to capture the geographic location and areal extent of each stockpile. This was necessary to map the material types as well as to determine stockpile ownership. The footprints of the stockpiles were derived from two sources. The majority of the lines were digitized within this project using the terms and definitions specific to this project. Where applicable, lines from a mining features layer that is currently in-progress at the DNR, Division of Lands and Minerals were used.

For this project, digitizing was based on an existing dataset called the Mesabi Iron Range Elevation Project. This data set includes 1998 digital orthophoto quads (digital air photographs), elevation contours at a 5 foot interval, and lines that highlight breaks of slope. The digitizing was conducted at a scale of 1:4,000 and was completed in February, 2001. The stockpiles were assigned numbers within each study area. Virginia stockpiles are numbered 101 to 198; Calumet stockpiles are numbered 301 to 434.

Volume Estimation

Stockpile volumes were estimated for some stockpiles in loose cubic yards. The estimates were calculated by a surficial mapping software program (Surfer), using data from the 1998 Mesabi Iron Range Elevation Project. Only some piles were chosen for the volume estimations. This was due to the difficulty of modeling the bottom surface of many stockpiles. Since the underlying topography below a stockpile is generally unknown, and directly affects a volume estimate, a primary assumption was made for modeling purposes:

All stockpile volume estimations are based upon a flat, planar, bottom surface.

Therefore, a flat, planar, bottom surface was captured by using the surrounding elevation adjacent to the stockpile edge. By capturing the elevation where the stockpile met the natural topography, the bottom plane can be thought to retain the natural slopes or dips in the natural topography. If a pile was built into a hill or adjacent to another pile, the bottom slope could not be obtained; therefore, the pile was not estimated.

The upper surface of a pile was modeled using elevation points from the Mesabi Range Elevation Project. The elevation data was derived from pre-existing survey points donated by the mining companies and 1998 aerial photography. From the elevation information, 5 meter grid points that contain the x, y, and z coordinates were utilized. Using this grid, the upper and lower surface of the pile was modeled. Listed below are the modeling parameters implemented to obtain the upper and lower surface of a stockpile:

- Gridding Method: Kriging
- Spacing: 5 meters
- Variogram Model: Linear
- Search Radius: No search radius, all surrounding data was used.

Both surfaces were "blanked" or trimmed to the footprint of the stockpile. The volume was then calculated by determining the cubic yards between the upper and lower surface.

C. DATABASE DESIGN

The database was designed with three goals in mind: (1) capture the results of the research (material type, ownership, sampling, etc.), (2) capture the results so the information could be queried and browsed from many different viewpoints, and (3) mirror "real world" relationships within a relational database structure. To our knowledge, this is the first attempt at modeling and developing a database design that would accommodate the complexities of stockpiles and ownership on the Mesabi Iron Range. To develop a database design that would accommodate the complexities of stockpiles on the Range required the use of a structured data modeling methodology. There are many benefits to using a relational structure for the database design. From the modeling and analysis sessions, a common vocabulary develops that facilitates communication within the project group. Breaking down the information into the smallest possible parts allows knowledgeable database users to combine, compare, and analyze the largest possible combination of factors. Data stored in this manner also allows the structure to be quite stable, which gives the application developers greater flexibility for design. To accomplish these goals, a structured data modeling methodology was required. The chosen methodology was a modified version of project development created by Advanced Strategies, Incorporated of Atlanta, Georgia (Technical Data Modeling, 2000).

From the onset of data modeling, it was clear the database would be a prototype. The development stage required several modeling sessions to develop the Business Object Model, Conceptual/Logical Data Model, and Physical Data Model (Appendix B). The process of designing this database required a clearly outlined project definition (Appendix C). This definition partially addresses the following questions:

- What type of information was to be put in the database (i.e., sample locations, surface ownership by forty, the volume of a stockpile)?
- What type of information was to be extracted from the database (i.e., How many glacial overburden stockpiles does the state own? Are there any samples of this stockpile? If so, what are the aggregate results)?
- Who will be asking the questions (i.e., a landowner, an aggregate contractor, other state and local governments)?

After these sessions, it was clear that the database needed to be designed solely for data input and storage. Any further development, like a "point and click" interface (as seen on the Internet) would be like putting a prototype straight onto a production line. This also allowed the focus of the project to accurately capture all of these "real world" data sets that were encountered within the two study areas, and to hammer out their convoluted relationships. In addition, the geographical information (i.e., outlines and labels of digitized stockpiles) had to relate to information stored in the database. The resulting database was implemented using Microsoft Access 97. The corresponding geographical information was captured using ArcView 3.2.

It is important to note that the data are meant to capture a snapshot in time, and there are no plans to maintain or update the database. This decision impacted the database design in a couple of ways. First, historical information, such as the chain of title for each property is not included. Secondly, the data structure is simplified when collected information does not need to be tracked and stored over time. Also, if this project expands into a Range-wide study, the database would need certain modifications. One reason for modification may include new relationships that were not encountered within the two study areas.

D. STOCKPILE ACCESS

The intent of this section is to provide users an estimate of the type of access to stockpiles, considering vegetation cover and existing roads. This allows stockpiles near major transportation routes and/or covered by thick vegetation to be identified. Access is not necessarily a limiting factor because it can be improved. Reviewed below is the methodology used to create a stockpile vegetation layer and a transportation layer.

Vegetation

Vegetation cover of stockpiles can affect the use of stockpiles. For example, extensive reclamation projects have been conducted on some stockpiles. Reclaimed stockpiles can be identified by the type of vegetation covering the stockpile. Also, some of the stockpiles are very old, which has resulted in a dense vegetation cover. Where this occurs, timber harvesting could be one method of exposing the area that would utilize all resources associated with a stockpile.

Vegetation layers for both study areas were digitized using ArcView and a combination of aerial photo interpretation and field checks during the fall of 2000. Vegetation was delineated for stockpile areas using color infrared aerial photographs (dated September 1995 for the Calumet site, and September 1997 for the Virginia site) with a 1:15,840 scale. Major forest vegetation cover types were determined to be aspen-birch (in order of prevalence: aspen, paper birch, and balsam poplar) and conifers (in order of prevalence: red pine, jack pine, balsam fir, white spruce, and white cedar). Generally, the aspen-birch cover type was naturally occurring; whereas, the major conifer cover types were plantation-planted red pine and jack pine. Size class determinations were based upon merchantability of the stand within a cover type. If the majority of trees in a stand had over a 50% canopy cover and an average diameter at breast height (dbh) greater than 5 inches, it was viewed as merchantable. Stands containing a majority of trees in the canopy with a dbh less than 5 inches were viewed as non-merchantable. Open areas were also delineated. These areas included barren ground, open water, grasslands, shrubs, or tree reproduction areas (less than 1 inch dbh), and any forest canopy with less then 50% cover.

Transportation

Because aggregate is a high bulk, low value commodity, a travel distance of 20 to 30 miles can double the transportation costs (Aggregate Task Force, 1998). Therefore, the current transportation infrastructure was mapped during the summer of 2000. Private mining roads were digitized and classified. The classification is based upon current conditions and if the road is a railroad grade. The two road types are roads in “good to moderate” and “poor to moderate” condition. Good to moderate condition implies the road may be used as is or with some modifications. Poor to moderate condition implies the road needs many to some modifications. The modifications may include widening and/or grading the road to rebuilding it due to washouts. Railroad grades and old railroad grades are mapped to show the potential use of rail to transport stockpiled material. Many old railroad grades have had ties removed and are currently being used as roads. In some instances, railroad ties are still in place. The transportation layer was mapped similarly to the stockpile footprints. The scale of mapping was done at 1: 4,000.

IV. Results
A. Ownership

Surface and Mineral Ownership
Surface and mineral ownership were determined for all parcels within the two study areas. A total of 2,839.32 acres was researched in the Virginia study area. A total of 4,067.02 acres was researched in the Calumet study area. Surface and mineral ownership were updated for an additional 2,498.99 acres in the Calumet site that had been previously researched by the DNR, Division of Lands and Minerals. Parcels platted into lots and blocks were not researched.

The project database provides detailed information regarding the surface and mineral ownership for each parcel within the two study areas. Ownership within the database is organized by Township-Range-Section and is detailed to the forty-acre parcel or government lot. All parcels within the Virginia site are within Township 58, Range 17. Parcels within the Calumet site are within either Township 56, Range 23 or Township 56, Range 24. Parcels divided between multiple owners have owners listed with the description of the portion of the parcel they own. Many parcels have multiple owners, each owning an undivided, fractional interest in the parcel. For these parcels, each owner is listed along with the fractional interest owned. Surface and mineral ownership are only as accurate as of the date the title work was conducted for the parcel. Ownership changes may have taken place since the parcel was researched.

Surface and mineral owners have been identified in the project database. Private individual owners have not been named. These owners have the designation “private” when one individual is involved, or “many private” when more than one individual is involved. Platted areas, such as within the cities of Calumet and Marble, were not researched and have surface and mineral ownership listed as “undetermined.” For parcels that have an ownership interest by the State of Minnesota, the means by which the State became the owner is also provided. State ownership can be through the following means: trust fund, acquired, exchange, tax forfeiture, reversionary deed, and non-registered severed minerals. For non-registered severed minerals, the owner was listed as “undetermined” rather than the State. This is because the State’s ownership in such minerals has yet to be judged as absolute by the courts. (See Ownership Methodology for additional information regarding means of State ownership).

Plates I and II show a generalization of the surface and mineral ownership in the Calumet and Virginia study areas. Some owners have been grouped together for simplicity in mapping. These maps are not to be relied upon for exact ownership. Exact ownership for each parcel can be found in the database. Ownership is mapped to the forty-acre parcel or government lot. Railroad right-of-way ownership has not been mapped. Any ownership, from one acre to the entire parcel, by the State of Minnesota, through any means, takes precedence in deciding the mapping unit. An explanation for the mapping units used to depict surface and mineral ownership follows.

State - State of Minnesota owns the parcel through any means, except through a real estate tax forfeiture.

County Real Estate Tax Forfeit - State of Minnesota owns the parcel through real estate tax forfeiture; county administers the land for the State.

Other government - the parcel is owned by a government entity other than the State. The government owner may be county, city, tribal, or regional in nature.

[Mining company name] - the parcel is owned by the named mining-related company. The companies specifically named are Cliffs Biwabik Ore Corporation, Great Northern Iron Ore Properties, Inland Steel Mining Company, LTV Steel, M.A. Hanna Company, Rendrag, Inc., and USX.

Private - the parcel is owned by one individual or one non-mining company. Non-mining company refers to any company that is not one of the seven mining-related companies named above.

Many private - the parcel is owned by two or more individuals or non-mining companies.

Part State and other - State of Minnesota owns a portion (1-99%) of the parcel, through any means other than a real estate tax forfeiture, and one or more others own the remainder of the parcel. The other owner can be any combination of the above mapping units.

Part County Real Estate Tax Forfeit and other - State owns a portion (1-99%) of the parcel through real estate tax forfeiture along with one or more, other, non-State owners.

Part Mining Company and other - one of the seven named mining-related companies (see list above) owns a portion of the parcel along with one or more, other, non-State owners.

Undetermined - platted property; surface and mineral ownership not researched.

Non-registered severed minerals - Absolute ownership by the State of Minnesota to all minerals upon completion of forfeiture action, due to the mineral owner not filing their statement of severed mineral interest.

<u>Stockpile Ownership</u>

Stockpile ownership can be difficult to determine. Ownership of stockpiles is dependent upon the intent of the parties at the time the stockpile was created. (See Ownership Methodology for information regarding how stockpile ownership is determined). A best effort was made throughout this project to determine the owners of all stockpiles within the two study areas using available sources. Ownership was determined for a majority of the stockpiles located within the study areas. However, many stockpiles still have undetermined ownership. The ownership remains undetermined since the intent of the parties could not be discovered. No documentation pointing to ownership was found. Absent documentation, the stockpile ownership may be determined by tracing the mineral owner of the stockpiled material back to the property from which it was mined. This also proved to be a difficult task, since this information was often unavailable.

Stockpile ownership in the database is organized by forty-acre parcel or government lot. However, unlike surface and mineral ownership, stockpiles are not confined to the boundaries of forty-acre parcels or government lots. To resolve this conflict, the database identifies each stockpile with an identification number. A unique number (referred to in the database as the "PLS intersected stockpile ID) is assigned to each portion of a stockpile that lies within a particular forty-acre parcel or government lot. Ownership of a stockpile may be the same for the entire stockpile, thus all polygons connected to this stockpile will have the same owner. A checkbox in the database indicates whether an ownership entry applies to the entire stockpile. Overburden stockpiles have their ownership tied to the underlying parcel's current surface estate owner. Therefore, each area of these overburden stockpiles may have different owners, resulting in a fragmented ownership across forty-acre or government lot boundaries. A checkbox in the database indicates whether an ownership entry is connected to the surface ownership.

The owner for each portion of a stockpile is listed in the database according to the PLS intersected stockpile ID number. As with the surface and mineral ownership, private individual owners have not been named in the database. These owners are designated as either “private” when one individual is involved, or “many private” when there are two or more individuals. Stockpiles listed in the database as having “undetermined” ownership are those in which documentation regarding stockpile ownership could not be found or the mineral owner of the material could not be traced back to the mine from which it was removed. State-owned stockpiles also list the means by which the State became the owner.

Plates I and II show a generalization of ownership for all stockpiles located within the Calumet and Virginia study areas. Ownership has been condensed into ownership groups for simplicity. The maps are not to be relied upon for exact determinations of stockpile ownership. The database should be consulted for precise information about each stockpile’s ownership. For those stockpiles in which ownership is connected to the underlying surface ownership, the stockpile ownership may appear fragmented across forty-acre or government lot boundaries due to changes in ownership.

Stockpile ownership is mapped using the same mapping units as those used for mapping surface and mineral ownership. As with surface and mineral ownership, any ownership by the State of Minnesota, through any means, takes precedence in deciding the mapping unit. Definitions of the mapping units used for the stockpile ownership are as follows:

State - State of Minnesota owns the stockpile through any means, except through a real estate tax forfeiture.

County Real Estate Tax Forfeit - State of Minnesota owns the stockpile through real estate tax forfeiture; county administers the land for the State.

Other government - the stockpile is owned by a government entity other than the State. The government owner may be county, city, tribal, or regional in nature.

[Mining company name] - the stockpile is owned by the named mining-related company. The companies specifically named are Cliffs Biwabik Ore Corporation, Great Northern Iron Ore Properties, Inland Steel Mining Company, LTV Steel, M.A. Hanna Company, Rendrag, Inc., and USX.

Private - the stockpile is owned by one individual or non-mining company. Non-mining company refers to any company that is not one of the seven mining-related companies named above.

Many private - the stockpile is owned by two or more individuals or non-mining companies.

Part State and other - State of Minnesota owns a portion (1-99%) of the stockpile, through any means other than a real estate tax forfeiture, and one or more others own the remainder of the parcel. The other owner can be any combination of the above mapping units.

Part County Real Estate Tax Forfeit and other - State owns a portion (1-99%) of the stockpile through real estate tax forfeiture along with one or more, other, non-State owners.

Part Mining Company and other - one of the seven named mining-related companies (see list above) owns a portion of the stockpile along with one or more, other, non-State owners.

Undetermined - stockpile ownership is undetermined. The owner of the stockpile may be determined by locating a stockpile agreement (if one exists); or if the mine of origin is known, by determining the mineral owner of the stockpiled material.

B. Stockpile Material Inventory

The results of the stockpile inventory of material type are summarized in Plates III and IV. The plates show the stockpile outlines in relationship to the material type, stockpile identification number, sample locations, photograph locations, and observation points. A total of 232 stockpiles were inventoried: 98 in Virginia and 134 in Calumet. A breakdown of the number of stockpiles by material type is as follows:

70	Taconite Rock (Boulders)
65	Glacial Overburden
32	Natural Ore Mixed-Size Rock
24	Natural Ore Fine Tailings
14	Natural Ore Coarse Tailings
13	Taconite Mixed-Size Rock
6	Paint Rock
5	Cretaceous Ore
2	Cretaceous Overburden
1	Slate

Company records for iron units were obtained for 73 stockpiles. Therefore, approximately 43% of the iron-bearing stockpiles (excluding glacial overburden and slate) have some detailed company information. Volume estimates were completed for 22 stockpiles.

<u>Stockpile Material Descriptions</u>

For the stockpile material type classification system, a brief description was created for each material type. This description is an attempt to describe and classify material observed in the field.

Glacial Overburden: This includes unconsolidated sediment deposited by glaciers that was removed to gain access to the iron ore. Material consists of sediments deposited during the Quaternary Period (10,000 to 2 million years ago). The sediments range from till (material deposited directly by glacial ice) to sand and gravel (material deposited from glacial meltwater). Till is an unsorted sediment with grain sizes ranging from clay to +5 foot boulders. Multiple glacial advances deposited several till units in the region. Between some of these till units are

Figure 5. Picture of glacial till. Note the grain size ranges from silts to boulders. Twelve inch ruler is for scale.

discrete lenses of sand and gravel. In several overburden stockpiles, many of these various units are mixed together. The stockpiles tend to be boulder-rich with a sandy, silt matrix (Figure 5). The color ranges from buff to reddish-brown. Rock particles are sub-angular to sub-rounded. A few stockpiles contain primarily outwash sand and gravel. The sand and gravel is moderately sorted, oxidized to a light brown color, contains little silt, and is cobble-rich. The rock particles are sub-rounded.

Cretaceous Overburden: This includes unconsolidated sediment in the form of saprolitic clay and rock particles that forms from chemically weathered iron formation. Weathering events occurred during the Cretaceous period (65 to 146 million years ago). This material dominantly contains clay with some rock particles. Within a given stockpile, Cretaceous overburden may contain glacial till and other "overburden" type sediments.

Cretaceous Ore: Semi-lithified conglomerate deposited during the Cretaceous period. The conglomerate contains sub-angular to rounded hematite cobbles and sands within an iron-rich, glauconitic, carbonate matrix. Cretaceous ore piles have moderately poor sorting and range in grain size from clay to 3 foot boulders. The boulders are highly cemented blocks of smaller rock particles.

Slate: A local term used to described a fine-grained rock composed mostly of siliceous minerals. Slate is found above and within the iron formation and is approximately 1.9 billion years old. Although the slate is mostly fine grained, some clastic bedding is evident. Fracturing, or splitting, occurs along bedding planes (Figure 6). Within the pile, slate appears to have a dark grey appearance. Rock sizes range from 1/8 of an inch to +3 feet.

Natural Ore Mixed-Sized Rock: This includes soft iron ore that has been altered and re-mineralized along faults and fractures. This material was originally taconite, which was then oxidized to create trough, fissure, or flat-lying natural iron ore bodies. The mineralogy consists of mostly hematite, goethite, and limonite, with minor amounts of magnetite and manganese oxides. There are a range of textures from compact to rubbly or friable. Bedding and other primary features are often evident. Within a stockpile, this material is unsorted. Rock sizes range from clay to +6 foot boulders with an estimated average rock size being 3/8 of an inch to 5 inches. The amount of clay in natural ore piles is difficult to quantify; however, the clay seems to be a natural cement that stabilizes the stockpile. Natural ore rocks fracture, or part, parallel to bedding planes. Taconite boulders are frequently observed along the slopes of natural ore stockpiles and may have been placed there for slope and erosion control.

Figure 6. Picture of material called slate. Fractures occur along bedding planes. Pen is for scale.

Natural Ore Coarse Tailings: This includes a by-product of the natural iron ore mining processes. This by-product contains mostly siliceous rocks with some hematite banding. The stockpiles are moderately-well sorted, ranging in size from 3/8 to 4 inches in diameter, and has an angular particle shape (Figure 7). In the processing of coarse tailings, the material was washed; therefore, there is little to no silt within the pile.

Figure 7. Picture of coarse tailings. Note the range of material size. Shovel is 2 feet long.

Natural Ore Fine Tailings: This includes a by-product of the natural iron ore mining processes. Fine tailings have been crushed and usually deposited into a "tailings" basin. This material is very well sorted with a rock size ranging from clay to 3/8 of an inch. Rock fragments are sub-angular.

Paint Rock: A highly decomposed, slate-like rock with a tacky, powdery texture on exposed surfaces. The decomposition of these rocks is attributed to weathering of altered slate and natural ore along fault or joint planes. The descriptor "paint" refers to the red to rust colored, colloidal particles that partially constitute the rock. Within the stockpiles, paint rock can range from fine sand to +3 foot rocks. Similar to natural ore, paint rock fractures parallel to bedding planes.

Taconite Rock Boulders: This includes magnetic and some non-magnetic iron-bearing boulders. Characterized by alternating bands of iron oxides (magnetite and/or hematite) with bands of silicates and carbonates. Bedding and other primary structures are evident. Most taconite stockpiles consist of boulder-sized rocks ranging from 2 feet to +9 feet in diameter with an estimated average of three feet. The boulders tend to have a blocky shape. Some glacial boulders may be incorporated into the pile.

Taconite Mixed-Size Rock: Magnetic and non-magnetic iron ore, some of which may have been processed. The rock characterization is described in Taconite Rock Boulders above. This stockpile type is difficult to discern from "Natural ore mixed-sized rock" in the field and may contain other material within the stockpile; classification is based upon company records pertaining to individual stockpiles. These piles are poorly sorted with a rock size from 2mm to +6 feet. Taconite boulders frequently occur along the slope and edges of these piles.

Aggregate Testing Results

The aggregate testing results are separated into two parts: material overview and material comparison by tests. The material overview presents all aggregate testing results categorized by material types. Under each of the material types, there are two tables. The first table shows the results of Composite 1 (composited samples, as listed in Table 1). For some of the aggregate tests, the MNDOT specifications for general aggregate use are listed under the "Spec" column (MNDOT Standard Specifications for Construction, 1995). The second table shows the results of Composite 2 (composite of composites, as listed in Table 1).

The sampled material types are then compared to each other using the results from four individual tests. These four tests include specific gravity, absorption, soundness (magnesium sulfate), and gradations.

Glacial Overburden-

- Gradations: In general, glacial overburden piles contain abundant fine sands and silts. Some piles consisting of mostly glacial outwash (rather than glacial till), may fall within Class 5 specifications.
- Absorption: Absorbs little to moderate amounts of water (Table 3).
- Specific Gravity: Results fall within a tight range of one another. This result was a bit surprising because samples were taken from both study areas.
- Clay Lumps: Meets specifications.
- Shale: Within specifications for both fine and coarse aggregate.
- Total Sum of Spall: Within specifications.
- Soft Iron Oxides: Results vary; some samples are within specifications.
- Soundness (Magnesium Sulfate): Within specifications. Sample ZZ8 has a higher value due to the inclusion of iron ore in composite (Table 4).
- Abrasion: Within specifications.
- Field Observations: There are abundant stockpiles of this material type. The stockpiles are generally boulder-rich.

Table 3. Composite 1 results for testing glacial overburden material type.

Composite 1	D20	D21	D22	D23	D24	D25	D26	D27	D28	D29	Specs
Tests		**ZZ7**			ZZ8		I.O.*		ZZ9		
Shale ASTM +1/2"	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
+ #4 total	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.7
Soft Iron Oxide	0.2	0.5	1.6	0.1	0.8	0.6	1.1	0.2	0.4	0.1	0.3
Chert	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	3.0
Total Spall +1/2"	0.0	0.2	0.4	0.0	0.3	0.9	0.2	0.2	0.1	0.0	
+ #4 Total	0.3	1.8	2.3	0.7	1.3	2.4	2.3	0.4	0.4	0.1	
Soft Particles	0.8	0.4	0.0	NA	0.6	0.1	0.7	0.4	0.0	0.0	
Clay Balls & Lumps	0.3	0.3	0.3	0.5	0.5	0.5	0.4	0.5	0.5	0.6	2.0
Sum of Spall, Soft Particles, Clay balls	1.4	2.5	2.6	1.3	2.4	3.0	3.4	1.3	0.9	0.7	3.5
Flat and Elongated	0.0	0.3	4.2	1.8	0.0	2.5	3.3	1.0	1.2	6.1	
Lightweight Particles	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.5
Specific Gravity											
Bulk Oven Dry	2.636	2.614	2.629	2.609	2.653	2.605	3.369	2.630	2.641	2.564	
Bulk Saturated Surface Dry	2.658	2.650	2.665	2.642	2.688	2.642	3.542	2.646	2.660	2.621	
Apparent Oven Dry	2.695	2.711	2.729	2.696	2.750	2.705	4.063	2.676	2.691	2.719	
Absorption	0.83	1.36	1.41	1.24	1.34	1.42	5.06	.067	0.70	2.23	1.7

*I.O. Was tested as glacial overburden. Sample is actually mixed-sized rock.

Table 4. Composite 2 results for testing glacial overburden material type.

Composites 2	ZZ7	ZZ8	ZZ9	Specs
Los Angeles Abrasion	24.5	22.7	19.9	40
Magnesium Sulfate	6.1	12.0	3.5	12

Cretaceous Ore-

- Gradations: Some gradations fall within Class 5.
- Absorption: There is only one composite from which to make observations. However, this result indicates the material is very absorptive (Table 5).
- Specific Gravity: Is relatively higher than for glacial overburden. This is due to the presence of iron.
- Clay Lumps: Contains a significant amount of clay balls and lumps.
- Soundness (Magnesium Sulfate): Does not pass specifications since the composite broke down 71.5% of its weight by volume (Table 6).
- Field Observations: There are very few stockpiles of this material and they are located within the Calumet study area.

Table 5. Composite 1 results for testing Cretaceous ore material type.

Composite 1	B9	Spec
Clay Balls & Lumps	10.2	0.3
Specific Gravity		
Bulk Oven Dry	2.799	
Bulk Saturated Surface Dry	3.023	
Apparent Oven Dry	3.565	
Absorption	7.67	1.7

Table 6. Composite 2 results for testing Cretaceous ore material type.

Composites 2	ZZ3	Spec
Los Angeles Abrasion	NA	40
Magnesium Sulfate	71.5	12

Natural Ore Coarse Tailings-

- Gradations: The gradations may make Class 5, but can contain excess coarse rock. The coarse fraction of the stockpile may have other valuable aggregate applications other than Class 5.
- Absorption: Material is very absorptive, which may affect the performance of this material type as an aggregate (Table 7).
- Specific Gravity: Is slightly higher due to the higher density of iron.
- Clay Lumps: Meets specifications.
- Soundness (Magnesium Sulfate): The material does not meet specifications (Table 8).
- Abrasion: The material does not meet specifications for abrasion.
- Field Observation: The piles contain sorted, pre-crushed rocks and are near major highways.

Table 7. Composite 1 results for testing natural ore coarse tailings material type.

Composite 1	A1	A2	A3	A4	A5	A6	A7	A8	Spec
Tests	ZZ1				ZZ2				
Clay Balls & Lumps	0.62	0.62	0.39	0.39	0.43	0.43	1.08	1.0	2.0
Flat and Elongated	0.0	1.9	0.0	0.0	0.7	1.8	0.0	1.4	
Specific Gravity									
Bulk Oven Dry	2.794	2.648	2.748	2.887	2.817	2.690	2.971	2.564	
Bulk Saturated Surface Dry	2.940	2.812	2.904	2.977	3.023	2.825	3.134	2.719	
Apparent Oven Dry	3.263	3.169	3.257	3.172	3.552	3.113	3.507	3.005	
Absorption	5.13	6.19	5.70	3.12	7.35	5.06	5.14	6.02	1.7

Table 8. Composite 2 results for testing natural ore coarse tailings material type.

Composites 2	ZZ1	ZZ2	Spec
Los Angeles Abrasion	45.3	46.5	40
Magnesium Sulfate	33.8	29.3	12

Natural Ore Fine Tailings-

- Gradations: The gradations are too fine to meet Class 5 specifications, however it may fall within the specifications of other construction Classes.
- Absorption: Material is very absorptive of water, which may affect the performance of this material type as an aggregate (Table 9).
- Specific Gravity: Is slightly higher due to the higher iron content and is variable. This is likely due to the presence of both cherty and iron-bearing rock particles.
- Fine Aggregate Angularity: Between 50 and 60 percent of the rock particles are considered to have angular "edges" (Table 10).
- Field Observations: This material is very well sorted because it was transported and deposited into basins filled with water. The fine tailings are graded by size within a basin.

Table 9. Composite 1 results for testing natural ore fine tailings material type.

Composite 1	C10	C11	C12	C14	C15	C16	C17	C18	C19	Spec
Tests	ZZ4			ZZ5			ZZ6			
Clay Balls & Lumps	0.31	0.31	0.40	0.40	0.32	0.00	0.80	0.00	0.00	2.0
Specific Gravity (Fine)										
Bulk Oven Dry	3.695	3.623	3.660	3.268	3.137	3.170	3.312	3.195	2.894	
Bulk Saturated Surface Dry	3.773	3.680	3.715	3.326	3.197	3.234	3.409	3.292	2.957	
Apparent Oven Dry	4.007	3.844	3.873	3.469	3.339	3.385	3.667	3.539	3.090	
Absorption-	2.10	1.59	1.50	1.77	1.93	2.00	2.92	3.05	2.18	1.7

Table 10. Composite 2 results for testing natural ore fine tailings material type.

Composites 2	ZZ4	ZZ5	ZZ6
Fine Aggregate Angularity	59.3	56.1	55.3

Mixed-Sized Rock (Taconite and Natural Ore)-

- Gradations: The gradations will vary considerably with this material because the stockpiles are unsorted. The results over-represent the particles that are smaller than a cobble, due to the sampling methodology. Some parts of the pile may need to be crushed.
- Absorption: Material is very absorptive of water, which may affect the performance of this material type as an aggregate (Table 11). The sample D26 was tested with the glacial overburden samples, but originates from a mixed-sized rock stockpile. It was included in these results to give further qualitative data about mixed-sized rock material type.
- Specific Gravity: Is slightly higher due to the higher density of iron and is variable. This may be due to the presence of both cherty and iron-bearing rock particles.
- Soundness (Magnesium Sulfate): The material does not meet specifications for soundness (Table 12).
- Field Observations: The difference between the "natural ore" and "taconite" are difficult to discern in the field. There are different rock types observed within these piles (i.e., paint rock and glacial boulders).

Table 11. Composite 1 results for mixed-sized rock (natural ore and taconite) material type.

Composite 1	E30	E31	E32	D26	Spec
Tests	ZZ10				
Clay Balls & Lumps	0.80	0.80	0.81	0.40	2.0
Flat and Elongated	4.3	4.2	8.6	3.3	
Specific Gravity					
Bulk Oven Dry	2.827	3.321	3.475	3.369	
Bulk Saturated Surface Dry	3.009	3.431	3.593	3.542	
Apparent Oven Dry	3.454	3.726	3.946	4.063	
Absorption-	6.42	3.28	3.44	5.06	1.7

Table 12. Composite 2 results for mixed-sized rock (natural ore and taconite) material type.

Composites 2	ZZ10	Spec
Magnesium Sulfate	26.2	12.0

Specific Gravity (bulk oven dry)

The graph shown in Figure 8 shows the range of values for the "bulk oven dry" specific gravity results. The results are graphed in a "box and whisker" plot. Out of all the material types, glacial overburden yielded the most consistent results showing a small range of values. Coarse tailings also are relatively consistent. Fine tailings and mixed-rock (includes natural ore and taconite) have a large range of values for specific gravity. The implication of these results suggest that these materials have varying rock mineralogy. For fine tailings, the specific gravity results may show the varying amount of hematite and chert.

Both the fine portion and coarse portion of the samples were tested for specific gravity for all samples with the exception of fine tailings. (Because of the fine particle size, only the fine specific gravity test was requested). The results are the composite of the fine and coarse test results.

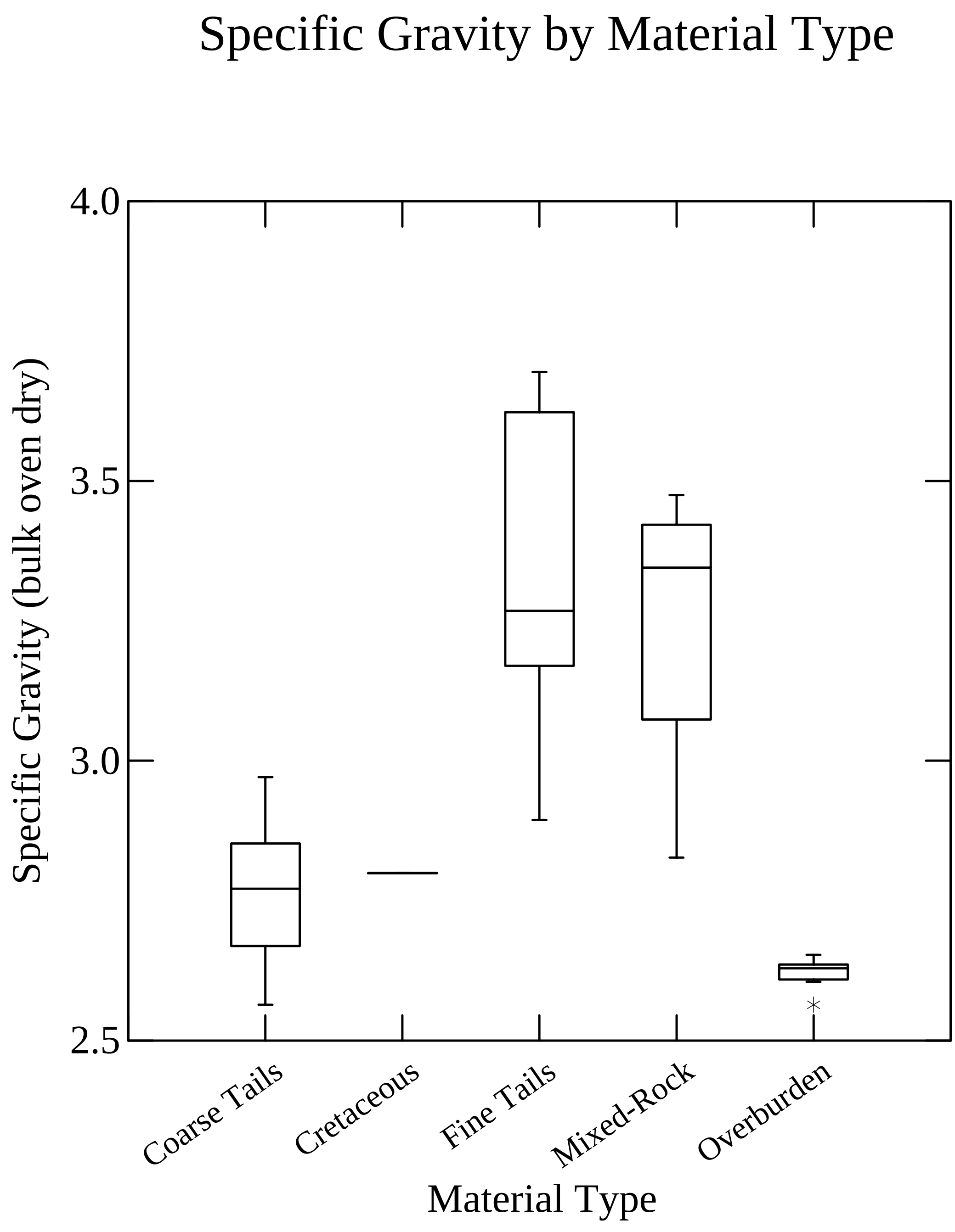


Figure 8. A "box and whisker" plot of specific gravity. The line in the box represent the median value. The box indicates the 1st standard deviation. The vertical lines represent the range of values. The star represents an outlier.

Absorption

Absorption measures the amount of water soaked into the small pores and fractures on a rock surface. Out of all the materials, overburden is the least absorptive (Figure 9). Fine tailings is also a relatively non-absorbent material and has the narrowest range of results. Cretaceous ore and coarse tailings have the highest values for absorption. These results are consistent with field observations. Cretaceous ore consists of moderately cemented rocks that contain smaller rocks. The cement of this conglomerate has a porous texture. The cherty rocks that comprise coarse tailing piles are also very porous.

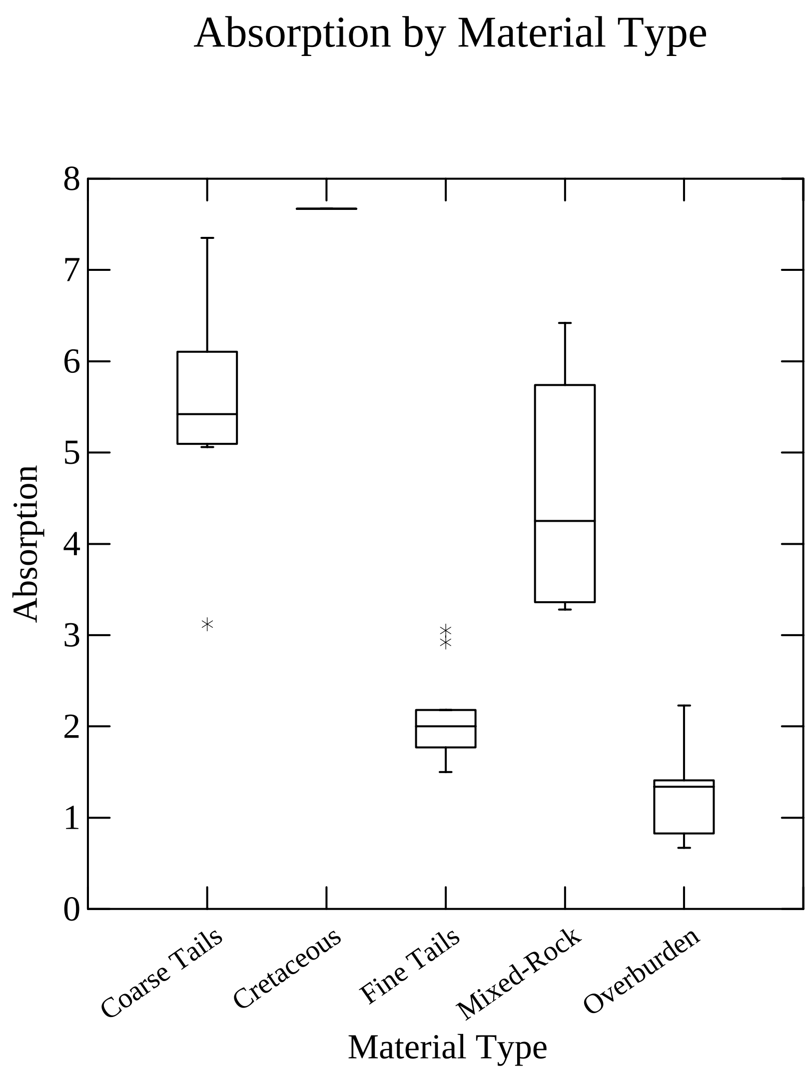


Figure 9. A "box and whisker" plot of absorption. The line in the box shows the median value. The box indicates the 1st standard deviation. The vertical lines represent the range of values. The stars represent outliers.

Soundness

The soundness test uses magnesium sulfate to re-create freeze/thaw processes. The more a material breaks down due to freezing and thawing, the higher the potential that the material will perform poorly as a construction material. This test was performed on the second level of composites (the composites of composites). Therefore, one soundness result comes from the combination of 15 or less samples.

Four material types were tested: coarse tailings, cretaceous ore, glacial overburden, and mixed-sized rock. The maximum value set by MNDOT for construction aggregate for concrete and bituminous material is 12.0. Only glacial overburden passes this specification (Figure 10). One of the three glacial overburden values reaches the maximum limit of the specification. This result is upwardly skewed because of the inclusion of mixed-sized rock with that particular composite. Both natural ore and mixed-sized rock exceed the specification. Cretaceous ore greatly exceeds the specification with the value of 71.5% loss.

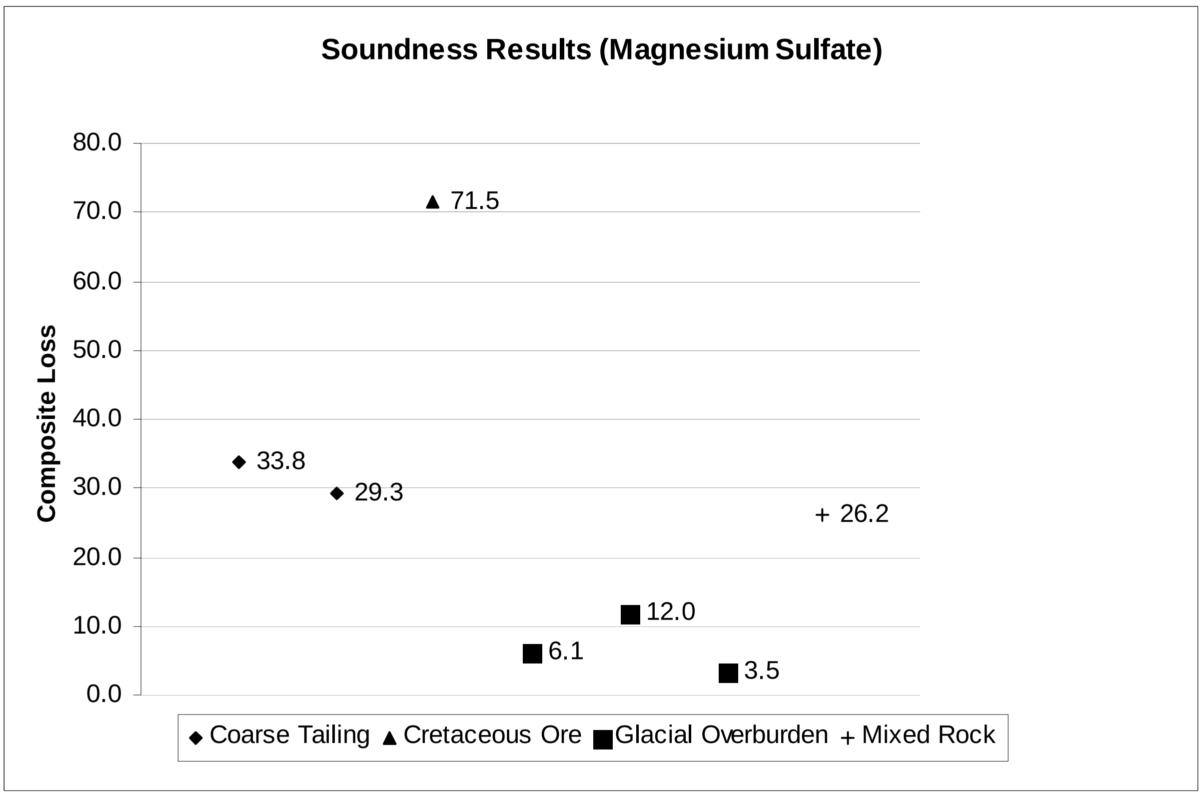


Figure 10. Soundness by material type.

Gradations

Five charts with examples of the various material types vs. Class 5 specifications are presented (Figure 11). All but 2 of the 82 samples were sieved and the results are listed in Appendix D. In the examples below, the results are shown in comparison with Class 5 specifications. This comparison is used because Class 5 has many construction applications. The results indicate glacial overburden piles contain an abundant amount of fines and may need to be mixed with coarser material to make Class 5. Coarse tailings tend to contain larger rock sizes. Fine tailings contain too many fines to be used in Class 5; however, they may fit in the gradations specified for another material class. For mixed-size rock, the gradations indicate that it could pass Class 5 specifications; however, the sample under-represents the large particle size within the stockpile. Cretaceous ore may fall within Class 5 gradations; however other aggregate tests show this to be a substandard construction material.

<u>Iron Ore Results</u>

The results for the iron ore testing are listed in a tabular format in Appendix E. The results can also be viewed in the database. Iron ore testing included chemical assays of the eight most common oxides. The percent hematite was calculated using this conversion:

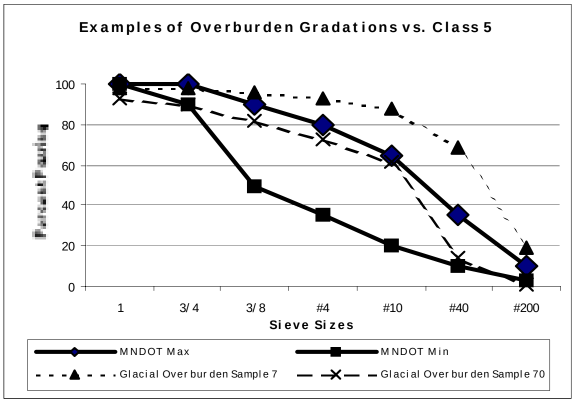
$$(Fe - Fe^{++}) \times 1.4297 = \text{Hematite}$$

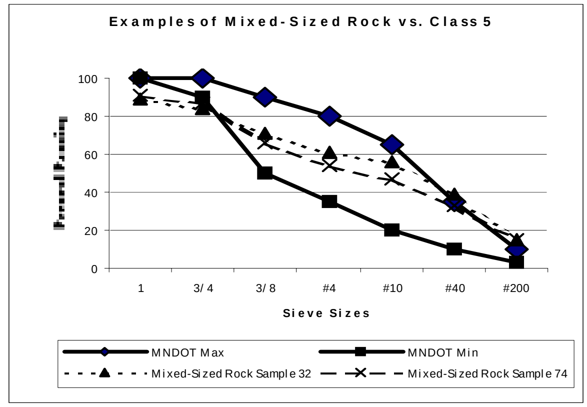
The iron oxide results were calculated using this conversion:

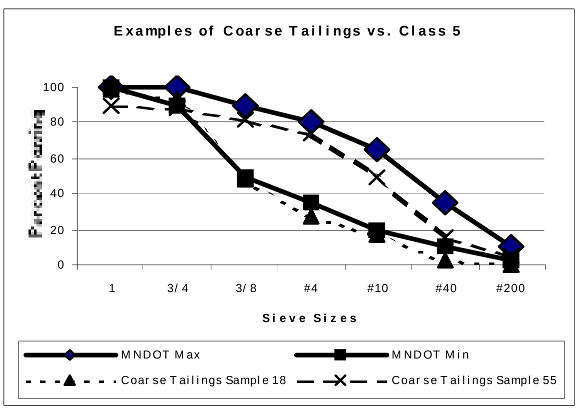
$$Fe^{++} \times 1.2870 = FeO$$

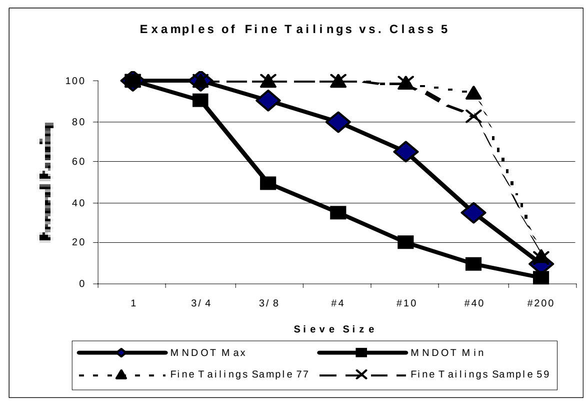
If so desired, the other mineralogy can be determined from these assays. The samples are random grab samples and do not represent the average iron percent for the total stockpile.

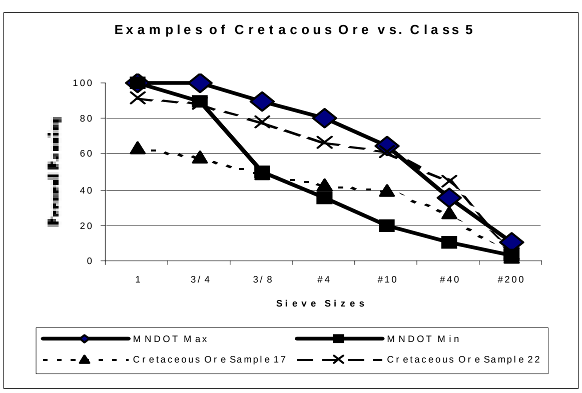
Figure 11. Examples of gradation results











C. Database Results

From the initial database modeling, about 95% of the data and relationships were designed and captured. The database consists of many related tables and forms for browsing the information. Other tables and queries were created for the purposes of mapping and error checking. Though information about stockpile composition, sample results, and other data can be browsed using existing forms and queries, a familiarity with database design and programming concepts is necessary to develop other products.

The links or relationships between the main tables in the database may be viewed within Microsoft Access using the Tools, Relationships function. A view of the relationships may be seen in Appendix B (Physical Data Model). While most of the data relationships can be seen in the database, other relationships, such as stockpile ownership versus surface and mineral ownership, must use Geographic Information Systems (GIS) software for viewing.

For the stockpiles, the database needs to be used in conjunction with Plates III and IV. The stockpile identification (ID) numbers correspond between the plates and the database. The stockpiles found in Virginia have ID numbers ranging from 101 to 198. The stockpiles within the Calumet site have ID numbers ranging from 301 to 434. The entire database is included on the CD-ROM that is part of this report. The CD-ROM also contains ArcView shapefiles of the stockpile footprint, vegetation cover types, and the mining roads. Copies of associated metadata for both the shapefiles and database tables are included in both PDF and HTML formats. The report is in both WordPerfect 9 and PDF formats. The plates are available in EPS and PDF formats.

D. Stockpile Access

Plates III and IV summarize stockpile access within the Calumet and Virginia study areas. The two access issues mapped for this project were vegetation cover type on each stockpile and transportation to stockpiles.

Vegetation

The vegetation coverage was limited to areas delineated as stockpiles. The major forest vegetation types found in the two study areas were aspen-birch and conifers. The mapping units summarizing the vegetation are based upon these forest types and their merchantability. Five mapping units were created for vegetation:

Aspen-Birch, 1-5 inch dbh: aspen-birch is the major species of the forest canopy, with over 50% canopy cover. A majority of the trees have a diameter at breast height (dbh) over 1 inch, but less than 5 inches. Trees this size are generally considered non-merchantable.

Aspen-Birch, >5 inch dbh: aspen-birch is the major species of the forest canopy, with over 50% canopy cover. A majority of the trees have a diameter at breast height (dbh) over 5 inches. Trees this size may be merchantable.

Conifer, 1-5 inch dbh: conifers are the major species of the forest canopy, with over 50% canopy cover. A majority of the trees have a diameter at breast height (dbh) over 1 inch, but less than 5 inches. Trees this size are generally considered non-merchantable.

Conifer, >5 inch dbh: conifers are the major species of the forest canopy, with over 50% canopy cover. A majority of the trees have a diameter at breast height (dbh) over 5 inches. Trees this size may be merchantable.

Open: areas that are barren, contain open water, grassland, shrubs, or are tree reproduction areas. Tree reproduction areas are those areas containing trees with a diameter at breast height of less than 1 inch. This category also includes any forest canopy with less than 50% cover.

Transportation

Transportation infrastructure within the two study areas included major roads and railroad grades, and private mining roads and old railroad grades. Coverages of major roads and railroad grades were obtained from the Minnesota Department of Transportation. Private mining roads and old railroad grades were digitized and classified according to information gathered by field checks. Berms or washouts were not mapped. Mapping units were created to summarize the condition of private mining roads found in the study areas and if the road is a former railroad grade. A private mining road in "good to moderate condition" is easily accessible and needs little modification. Private mining roads in "poor to moderate condition" may need to be re-graded, widened, or have other modifications.

The classification of the roads is based upon information gathered during the summer of 2000. Road conditions change over time and field checks may be necessary to verify a particular road's condition. Private mining roads are not open to public transportation. The surface owner is to be contacted for permission to use any private road.

V. STOCKPILE USES

Part of the purpose for gathering data about stockpiles was to determine their potential uses. Specifically, the stockpiles were to be examined for use in the aggregate industry and iron mining industry. This was accomplished by:

- examining current use of mine waste material
- examining past use of stockpile material
- gathering historical information about iron content from mining companies
- classifying stockpile material types
- quantifying aggregate material types through sampling
- characterizing material as it was seen in the field.

There is a current demand and usage of mine waste material. As of the fall of 1998, four mining companies have approval from MNDOT to use their taconite tailings in bituminous mixtures (personal communication, John Garrity, MNDOT). Unique specifications for taconite in mixtures include a maximum limit on specific gravity and geographical restriction. In addition to taconite tailings, glacial overburden is processed as it is stripped off the iron formation. Processing from old stripping stockpiles also occurs. The State also has leases with aggregate and logging companies for mining natural ore coarse tailings stockpiles. These coarse tailings are currently being used for road base, logging roads, fill, and pipelines.

The process of re-using iron stockpiles is not new to the Range. In the past, old natural ore piles and tailing basins have been reprocessed for iron ore with the introduction of new processing technologies. This has occurred within the Calumet study area. The coarser particles from basin 431 were excavated and processed for iron in the late 1950's.

The first step to determine usage of iron stockpiles is to examine methodologies conducted in the past to locate the iron-rich piles. First, the location of these piles were identified through stockpile records or anecdotal knowledge by the people who built these piles. Then, the mining companies performed site-specific evaluations to determine the economic return for setting up a processing plant. The first part of this methodology, identification of potential stockpiles through historical research, has been accomplished by gathering and organizing stockpile information within the two study areas. Out of all the iron ore stockpiles, approximately 43% of the them contain some iron information.

The classification of stockpile material type has the greatest implication for usage. Generalizations based upon quantitative and qualitative data can be made about each material type. The quantitative data are derived from the sample analysis; the qualitative data are derived from field observations. Listed below are some potential uses for stockpile material types. This list is a guide to help determine which material type is most likely to suit some commonly known demands (i.e., fill, Class 5, railroad ballast, etc.). This list is not intended to exclude a material type from being used for other applications.

Glacial Overburden

High Aggregate Potential*

- Good source of glacial boulders
  - -To be used as landscaping rocks
  - -To be crushed for aggregate material
  - -To be used as rip-rap
- Good source for fill
- Can be screened to make class 5
- Screened fines can be used as a binder
- Market already exists for this material type
- Has consistent specific gravity and absorption test results for both study areas
- Meets most specifications for concrete and bituminous mixtures

Low Iron Potential

- Little to no iron is present in this material type

*Glacial overburden stockpiles do not degrade as it is being piled. This is the most abundant material type and one of the best sources of aggregate. In addition, steeply sloped, open-pit mine walls can be easily reclaimed by allowing aggregate contractors to mine the material exposed along the upper half of the mine wall.

Natural Ore Coarse Tailings

High to Moderate Aggregate Potential

- Material is has been pre-crushed and pre-sorted
- Could be screened to meet Class 5 specifications
- Could be used for fill and potentially in bituminous mixtures
- Markets already exist for this material type
- Material did not perform well in laboratory tests

Low to Moderate Iron Ore Potential

- Piles generally contain between 20 and 30 percent iron. This information is derived from known iron ore contents

Natural and Taconite
Mixed-Sized Rock

Moderate Aggregate Potential

- Material could meet Class 5 specification with screening and washing
- Could be used for fill and road base
- Out of all the stockpile types, the material has the largest variation between stockpiles
- Material did not perform well in laboratory tests
- Leaves a red residue and can stain

Unknown Iron Potential

- Cannot generalize iron potential for this material type due to the large variation

Taconite Rock Boulders

Moderate Aggregate Potential

- Material is a good source for rip rap
- This material was not tested in the laboratory. Could not sample in the field due to the large size of boulders
- Boulder size makes the material more difficult to handle
- Could potentially be a source for crushed rock; but the hardness of this rock type may wear on crushing machines

Moderate Iron Potential

- Older piles may contain a high taconite content

Natural Ore Fine Tailings

Moderate Aggregate Potential

- A source of finely crushed rock that is very well sorted
- Sand may be used as iron source for bituminous mixtures
- Clay particles are source of pigments for bricks and other specialty needs
- Performed moderately in laboratory tests

Moderate Iron Potential

- Has been mined in the past for iron within the study area

Cretaceous Ore

Limited Aggregate Potential

- Performed very poorly in laboratory tests

High to Moderate Iron Potential

- Stockpiles is comprised of 40 to 50% iron ore

Cretaceous Overburden

Limited Aggregate Potential

- Piles contain may contain a variety of material types including paint rock and glacial overburden
- Only one gradation sample was taken

Moderate Iron Potential

- Iron percentages are in the mid-forties

Slate

Limited Aggregate Potential

- Is considered substandard rock for use in construction material
- However, may be used as decorative rock (i.e., flagstone)

Limited Iron Potential

- Contains mostly silica minerals

Paint Rock

Limited Iron Potential

- Is considered substandard rock for use in construction material
- The powdery texture may be a source for pigment

Limited Iron Potential

- Iron has been partially leached out of rock as it was altered; however, the rock as a higher Aluminum Oxide content

Ownership References

Itasca County Recorder/Registrar of Titles Office.

St. Louis County Recorder/Registrar of Titles Office.

Consolidated Title and Abstract Company (Duluth, MN).

Great Northern Iron Ore Properties, December 1995, Lean Ore and Tailings Booklet.

U.S. Steel Group - Northern Lands and Minerals, Rouchleau Area stockpile information and 1982 USX plates.

Minnesota Department of Natural Resources, 1999, Division of Lands and Minerals, Annual Operations Report and State Stockpile Map Supplement.

Minnesota Department of Natural Resources, May 1998, Division of Minerals, Stockpile Report to St. Louis and Itasca Counties.

Minnesota Department of Natural Resources, January 1986, Division of Minerals, Minnesota Mesabi Range Maps.

Aggregate References

Aggregate Resources Task Force: Final Report to the Minnesota Legislature, 2000.

Lean Ore and Tailings Booklet, 1995, Great Northern Iron Ore Properties, Map 3 and Map 17.

Maps of the Mesabi Range, 1982, United Steel Corporation, Plates 5, 6, 24, and 25.

Mesabi Range Maps, 1959, Great Northern Iron Ore Properties.

Mesabi Range Maps, 1955, Great Northern Iron Ore Properties.

Minnesota Department of Natural Resources, 1999, Division of Lands and Minerals, Annual Operations Report and State Stockpile Map Supplement.

MNDOT, 1995, Standard Specifications for Construction, Minnesota Department of Transportation, pp. 695-721.

MNDOT, 1998, Aggregate Production I Handbook, Minnesota Department of Transportation, pp. 5.1 - 5.74.

APPENDIX A

Explanation of Aggregate Tests
Map of Sample Locations

Explanation of Aggregate Tests

Specific Gravity and Absorption (Fine and Coarse Aggregate):
Specific gravity is the measure of weight divided by volume. These numbers help engineers and contractors design concrete and bituminous mixes. It is done on fine particles (less than 4.75 mm) and coarse particles (equal to or greater than 4.75 mm). Absorption measures the porosity which is the amount of water a material absorbs. This basic test was performed on all material types and composites (A1 though E32).

Flatness and Elongated:
This is the measure of rock particles to determine what percent of the material has a flat and elongated shape. This test determines the amount of deleterious particles, like shale and slate, that are in a construction material. The following material types were tested: Coarse Tailings, Glacial Overburden, and Mixed-Sized Rock (A1-A8, D20-D29, and E30-E32).

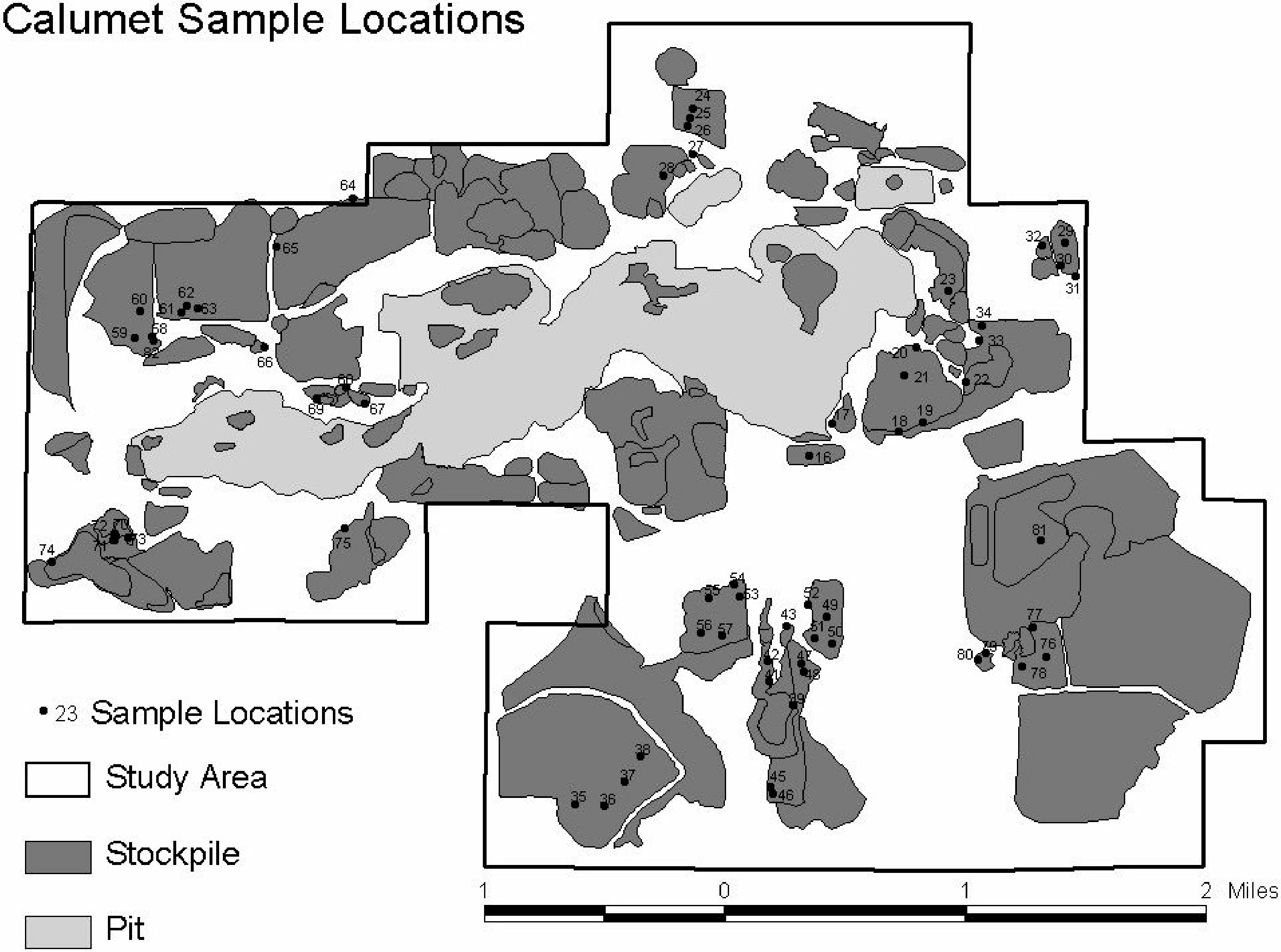
Clay Lumps:
Clay lumps sometime occur in material that has abundant silt and clay size particles. Clay lumps are easily broken down and are considered deleterious in concrete and bituminous mixtures. This test was performed on all material types (A1-E32).

Fine Aggregate Particles:
This test measures the angularity of fine rock particles. This test was only performed on Fine Tailings composites (C10-C19).

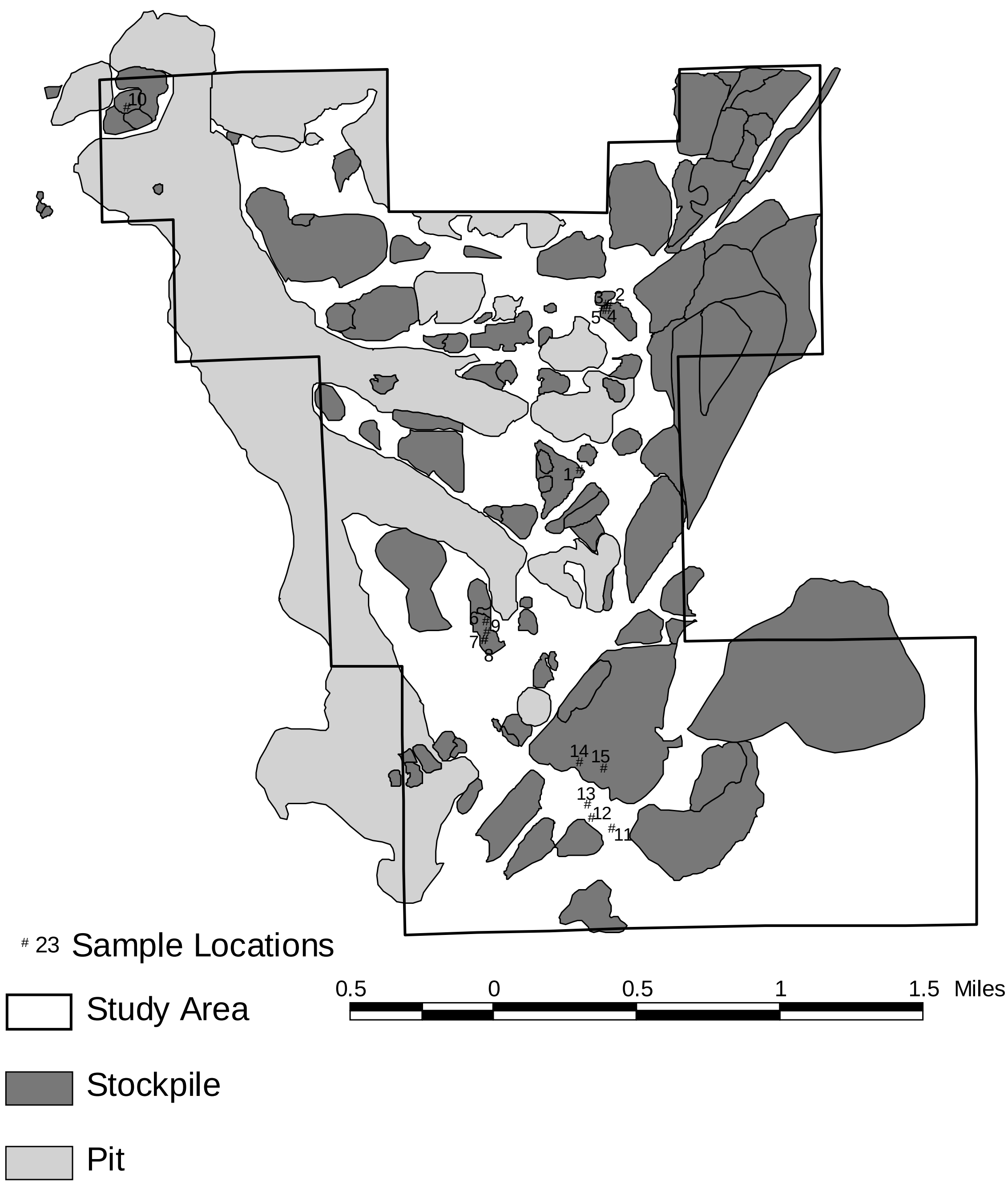
Lightweight Particles and Spall:
A lightweight particle test is used to determine the amount of argillite and shale in a given material. These are considered to be harmful rocks in mixtures because of their ability to absorb water. The crystal/mineral alignments cause planes of weakness as the particles break down due to freeze and thaw. Spall is a general term applied to all rock particles that are considered deleterious to mix designs. These two tests were performed only on Glacial Overburden composites (D20-D29).

Abrasion and Soundness:
Abrasion is a predictive test to determine how well a material can withstand “handling.” Because materials break down into smaller particles as they are being scooped, dumped, and transported, this test attempts to measure the potential breakage. Soundness is a chemical test to determine how well a material can withstand freezing and thawing. These tests were performed on composites (ZZ1-ZZ3, and ZZ7-ZZ10).

Calumet Sample Locations



Virginia Sample Locations

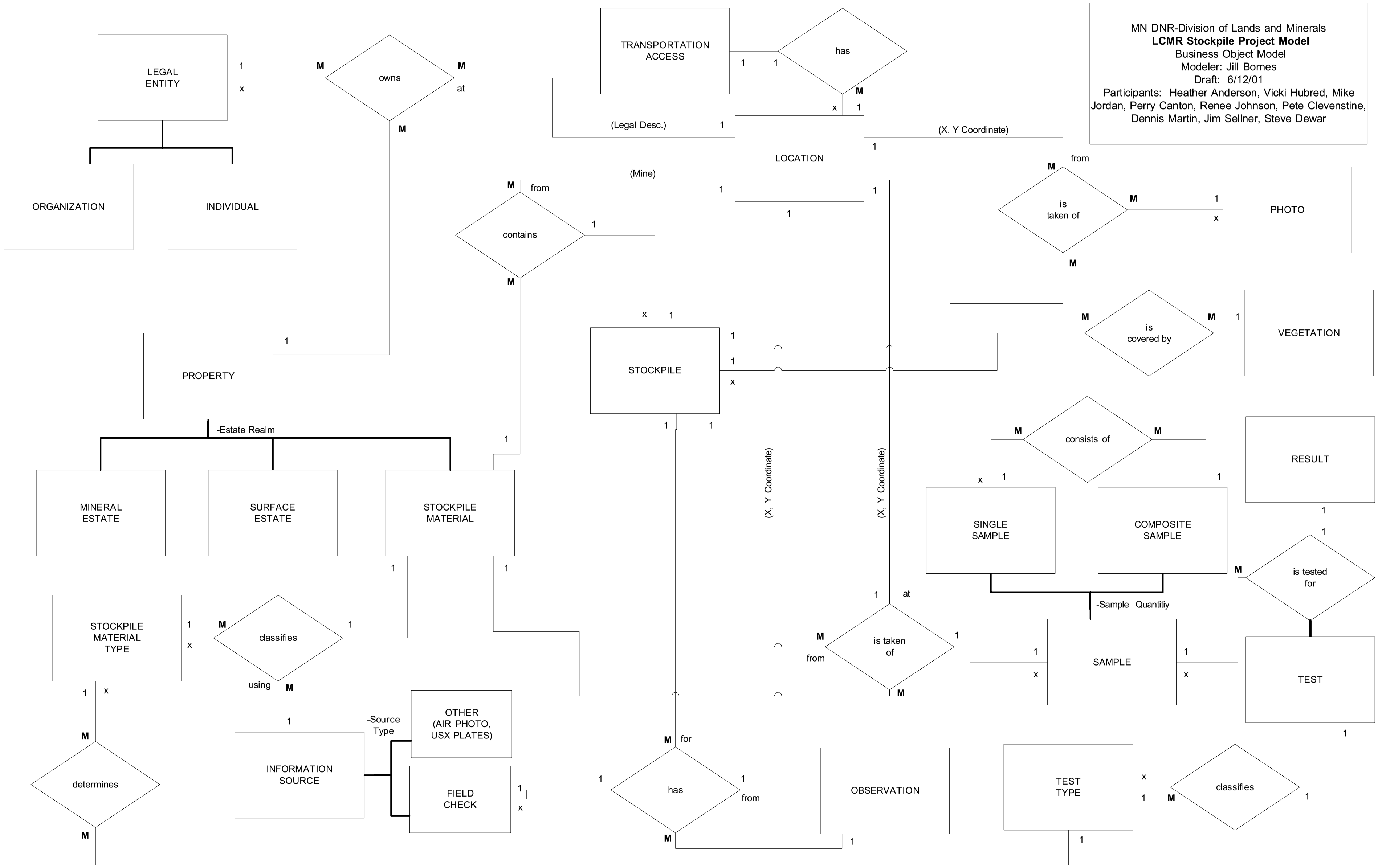


APPENDIX B

Business Object Model
Conceptual/Logical Data Model
Physical Data Model

Business Object Model

MN DNR-Division of Lands and Minerals
LCMR Stockpile Project Model
Business Object Model
Modeler: Jill Bornes
Draft: 6/12/01
Participants: Heather Anderson, Vicki Hubred, Mike Jordan, Perry Canton, Renee Johnson, Pete Clevenstine, Dennis Martin, Jim Sellner, Steve Dewar



Conceptual/Logical Data Model

MN DNR-Division of Lands and Minerals
LCMR Stockpile Project Model
Conceptual/Logical Data Model
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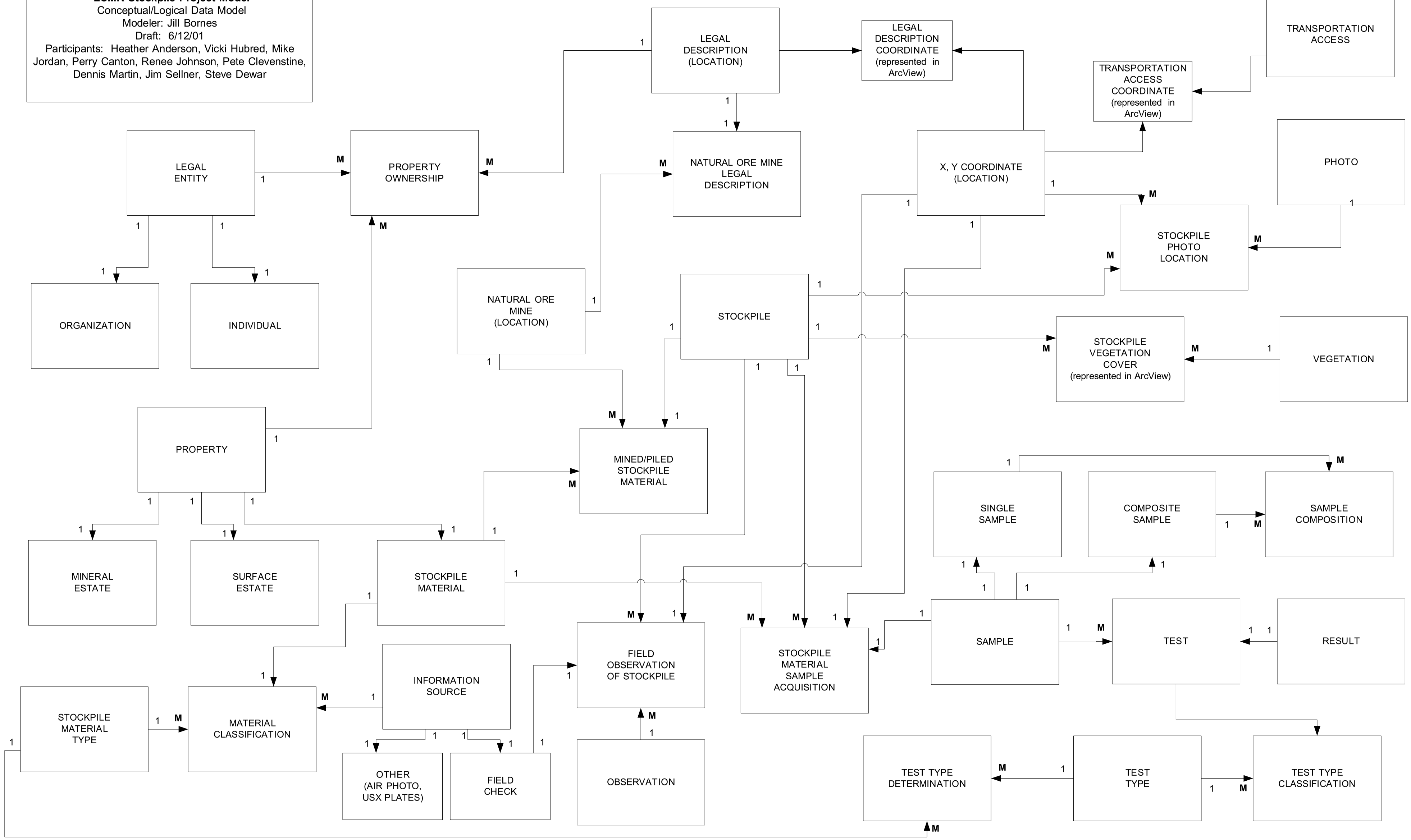
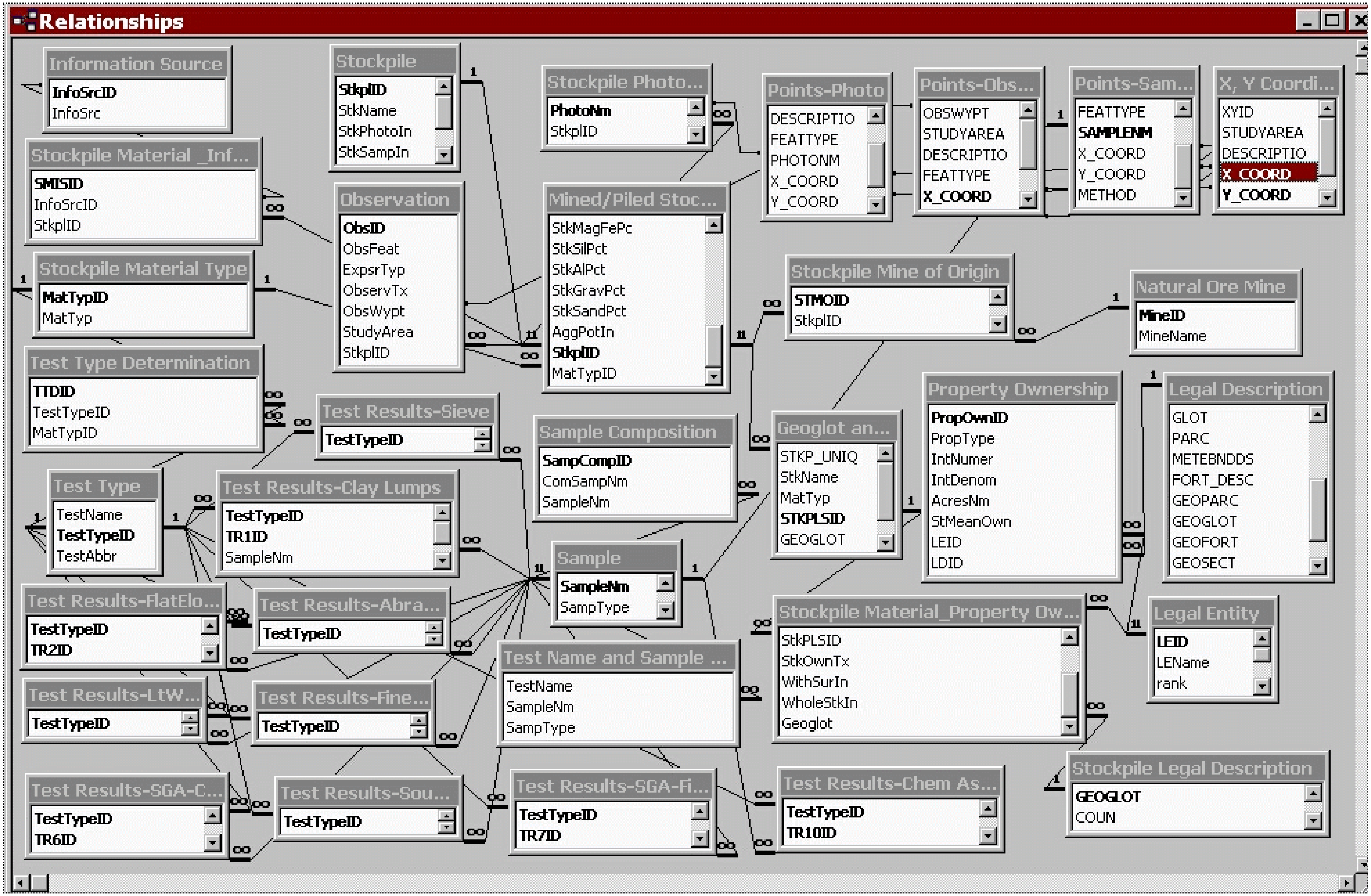


Physical Data Model

(view from Microsoft Access 97)



APPENDIX C

Project Definition

Project Definition:
Focus Statement and Information Needs
for LCMR Stockpiles project

Attendees:

Heather Anderson (HA)
Steve Dewar (SD)
Vicki Hubred (VH)
Dennis Martin (DM)

Facilitator/Modeler:

Jill Bornes

Coach/Recording Analyst:

Renee Johnson

Focus Statement for Project:

1) Breadth: Create an information gathering tool that deals with stockpile information for the two defined study areas (known as Calumet and Virginia) on the Mesabi Iron Range. More specifically, this data is being compiled and related to help discover alternative uses for stockpile material. "Clearinghouse of information"–I.e., We (the state and other fee owners) will be looked at to provide this information to clients, that is, to provide a service of interpreting the information that is being collected as part of this project.

From...When the material was taken out of the ground (for geology, mineral and mining purposes) or a snapshot of what is happening now, in the year 2000 (for ownership and vegetation purposes).

To...When project is completed in June 2001. The database will not be maintained/updated after the project end date.

Including: Surface, mineral and material ownership, location of stockpile, also location relative to a road, vegetation on the stockpile, description of material type at surface of stockpile, samples taken at stockpiles (includes overburden, rock and tailing basins), references to historical information (this includes reports and other sources containing information about material types, iron content, silica content, tonnages, etc.), and basic broad information from fee owners.

Excluding: DNR environmental review process (archaeology, grape fern, merchantable timber (forestry)), chain of title for material, surface or minerals, granting access rights (easements, trespass restrictions), location of berms, fences or gates, iron ore reserves and in situ bedrock and blasted material.

2) Emphasized Perspective: DNR Lands & Minerals Division, disciplines include: attorneys, geologists, engineers, etc., other fee owners (e.g., US Steel), Counties (St. Louis and Itasca). Not Joe Public.

3) Depth: Full detail model

4) Universality: How flexible? How specific or generic?

We want to be able to account for other issues, such as ownership and sampling that may appear outside of our study areas (since we are a pilot project). For example, if a tailings basin is drilled, we need flexibility to account for other sampling information and perhaps other historical information.

Geopolitical: Mesabi Iron Range in Minnesota

Time: Hard to guess? Depends on future requests from division director and others. The database will not be maintained/updated after the project end date.

5) Scope of Integration:

DNR's Division of Forestry--Forest inventory, other DNR reviews/uses like Wildlife, Eco Services, etc. Permit to Mine review (only for material being used for iron units), future mine plans in adjacent areas, forecasting (e.g., MIS-Minnesota Iron & Steel), M Permit and M Lease database in Lands & Minerals.

Information Needs

	Questions to be answered with the results of this project (In focus-should be part of project, Out focus-beyond the project scope)	person	in/out Focus
1)	Where is the nearest overburden stockpile in relation to construction site?	HA	IN
2)	Where is stockpile with base coarse aggregate, Class 5 aggregate, and/or concrete aggregate, in relation to construction site? *(Aggregate classes are too specific compared to the information that is being collected, we will be able to provide a more general answer to this question.)*	DM	IN
3)	For 'X' stockpile at 'Y' location, who do I have to talk to in order to use this pile? (question may be asked by DNR or Agg. Operator)	VH	IN
4)	Any materials to use as road fill within "reasonable" haul distance of highway 169 at Pengilly?	SD	IN
5)	How may yards available(volume) for construction project?	SD	IN
6)	Has stockpile been previously sampled [in the past], if so, what are the specs? (Results?)	HA	IN
7)	For "Bovey beautification project", which property contains 1000 glacial boulders for landscaping? Want to buy them, money is no object. *(Will probably be able to provide general info. by material type, like 'boulders', and we can hint where good sources may be, but not specific info like 1000 glacial boulders.)*	DM	IN
8)	For 'X' property (by common name or legal desc.), who owns the property and what is stockpiled there?	VH	IN
9)	What is access like to the stockpile? Does road exist? What type? Improvements needed? (*We nixed the idea that we could capture or care about if improvements were needed--per the focus statement*.)	HA	IN
10)	M.I.S. needs 5 m. tons of low grade iron ore (<40% total iron), how close to the proposed M.I.S. plant? (*Some of this information will be included when available*)	DM	IN
11)	Which stockpiles contain material suitable for aggregate?	VH	IN
12)	For coloring bricks, need red pigment (red ore tailings), Where? Who owns it? Who do I talk to?	SD	IN
13)	Is stockpile covered with trees? Do we need to clear cut?	HA	IN

14)	Animal farm needs an area with no vegetation, can I lease this area from you? (Key is non-material use of the property)	DM	IN
15)	Company wants to use aggregate. What does the company need to do? Will the company need to do reclamation?	RJ	OUT
16)	Railroad needs rock of certain hardness and maybe certain size to crunch up and make into ballast. (*Maybe rock type can indicate this*)	SD	IN
17)	Is stockpile in a park or other possible restricted area, how many hoops to jump thru? (*'in the park' is IN, but 'hoops to jump thru' is OUT*.)	HA	IN
18)	Why isn't there more information about an area or stockpile? (Assuming a gap exists in the information for certain attributes in the system) (*An explanation for this inconsistency will be included in the metadata*.)	HA	IN
19)	Are there other owners to talk to about trespass issues?	HA	IN
20)	Do you have pictures of the stockpiles 'A', 'B', or 'C'?	DM	IN
21)	How many different owners are involved in this stockpile (commingling)?	HA	IN
22)	I'm a student, I want all of your information. (Public information)	RJ	IN
23)	Calumet Ski Hill–want to make stockpile into a ski hill. How much will it cost to purchase? (Appraisal)	DM	OUT
24)	Has this stockpile been previously used for aggregate? From where on the stockpile has material been removed? (*MNDNR M lease/M permits may contain information about which stockpile is used, but not which part of the stockpile material is removed from. M permits and leases are part of the scope of integration.*)	HA SD	OUT
25)	If material (from item #24) has been used, by whom?	"	OUT
26)	Where was this material (from item #24) used?	"	OUT
27)	Where are **all** stockpiles on the Range that have been used for aggregate? (*It was decided that our answer to this inquiry could be 'No, we cannot easily provide that information range wide', or maybe this would be an integration with the M lease/M permit database to provide a partial answer. This project only covers two study areas, perhaps the new mining features coverage could be used to find ALL stockpiles?*)	SD	OUT

APPENDIX D

Sieve Results

Gradation Test Results

Sample Number	Stockpile ID	4	3	2.5	2	1.5	1.25	1	3/4	5/8	1/2	3/8	4	8	10	16	30	40	50	100
1	154	100	100	100	100	99	98	97	94	92	88	78	51	48	47	41	33	28	22	11
2	130	100	100	100	100	99	96	94	93	91	90	88	84	80	79	74	64	58	49	29
3	130	100	100	100	100	99	99	98	97	96	94	92	87	83	82	76	63	53	45	27
4	130	100	100	100	100	100	98	97	95	94	93	91	84	81	80	74	63	56	48	30
5	130	100	100	100	100	95	93	92	91	88	86	84	78	74	72	69	60	53	45	28
6	168	100	100	100	92	92	91	90	88	87	85	84	76	74	73	69	55	46	37	22
7	168	100	100	100	100	100	99	98	98	98	97	96	93	89	88	85	76	69	60	36
8	168	100	100	100	96	95	94	93	92	90	87	86	82	78	78	73	61	54	46	30
9	168	100	100	100	100	100	99	98	96	95	93	91	89	88	87	82	68	61	54	38
10	107	100	100	100	100	98	93	92	90	88	85	83	72	67	65	53	43	39	37	33
11	0	100	100	100	100	86	78	69	60	55	51	47	39	36	35	30	24	20	17	10
12	0	100	100	97	96	86	79	76	71	68	66	63	59	57	55	50	42	36	31	19
13	0	100	100	100	100	99	99	99	98	98	98	97	97	86	81	65	46	36	25	11
14	174	100	100	100	83	69	66	59	48	45	38	33	19	14	13	10	8	7	6	4
15	174	100	100	100	92	70	65	60	56	52	47	41	27	19	17	11	8	7	6	4
16	338	100	100	100	98	95	93	89	83	80	76	69	56	51	48	41	32	27	22	14
17	373	91	91	91	78	72	68	63	58	55	52	49	43	40	39	34	30	28	13	3
18	353	100	100	100	100	100	100	98	94	88	63	48	28	20	18	11	5	2	1	0
19	362	100	100	100	98	95	91	84	70	63	48	36	19	12	11	8	6	4	3	2
20	362	100	100	100	99	97	96	94	89	85	68	57	24	22	21	16	6	2	1	0
21	362	100	100	100	97	88	83	77	71	67	64	60	52	50	49	46	36	27	20	8
22	361	100	100	100	97	95	93	92	89	86	82	78	66	63	61	56	49	45	40	19
23	336	100	100	100	100	99	95	91	88	86	82	78	68	66	64	60	55	52	50	31
24	302	100	100	100	100	100	100	100	100	100	100	100	100	99	98	94	82	71	56	26

Sample Number	Stockpile ID	4	3	2.5	2	1.5	1.25	1	3/4	5/8	1/2	3/8	4	8	10	16	30	40	50	100
25	302	100	100	100	100	100	100	100	100	100	100	100	99	92	89	84	70	55	41	20
26	302	100	100	100	100	100	100	100	100	100	100	100	100	99	99	96	87	73	54	24
27	313	100	100	100	100	99	99	95	84	78	72	65	41	25	21	12	6	3	3	2
28	305	100	100	93	93	91	89	88	85	84	82	79	72	69	68	61	43	31	21	8
29	335	100	100	100	100	100	100	100	100	100	100	100	100	98	97	94	92	91	91	89
30	335	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99	99	97	72
31	335	100	100	100	100	100	100	100	100	100	100	100	100	100	99	97	96	96	95	89
32	339	100	100	100	97	93	91	89	84	81	77	71	61	57	56	52	45	39	34	25
33	353	100	100	100	98	98	94	91	87	85	82	78	67	55	52	39	22	14	9	4
34	353	100	100	100	100	97	95	93	92	90	87	84	75	72	71	62	45	34	25	12
35	432	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99	97	92	67
36	432	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98	90	75	56	27
37	432	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	97	88	67	26
38	432	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99	90	71	48	18
39	429	90	90	85	80	68	61	51	34	26	15	8	2	1	1	1	1	0	0	0
40	429	100	100	98	93	83	80	75	73	71	69	64	48	40	38	33	25	19	16	11
41	429	100	100	98	96	90	90	88	86	83	80	72	41	34	32	26	17	12	9	5
42	429	100	92	90	76	57	49	42	37	35	33	30	23	20	19	16	13	11	10	8
43	424	100	100	100	100	100	100	100	100	100	98	63	27	20	17	13	9	7	6	4
44	424	100	100	100	100	100	100	100	100	100	100	96	58	48	45	37	25	19	15	11
47	434	100	100	100	100	100	100	100	100	100	100	100	100	99	99	96	72	56	44	30
48	434	100	100	100	100	100	100	100	100	100	100	100	100	100	92	67	55	46	33	17
49	419	100	100	100	100	98	98	94	87	83	76	63	52	31	26	18	15	14	13	11
50	419	100	100	100	100	100	97	94	90	86	80	69	35	26	24	18	14	13	12	10
51	419	100	100	100	100	99	98	95	92	88	82	71	28	20	19	16	14	13	12	10
52	419	100	100	100	100	94	82	67	58	53	50	44	10	1	1	1	1	0	0	0

Sample Number	Stockpile ID	4	3	2.5	2	1.5	1.25	1	3/4	5/8	1/2	3/8	4	8	10	16	30	40	50	100
53	418	100	100	100	98	96	93	90	85	81	78	68	37	32	30	24	16	13	10	7
54	418	100	100	87	76	69	64	56	52	49	45	40	26	20	19	16	11	7	5	3
55	418	100	100	97	94	92	90	89	89	88	85	82	74	54	50	38	22	15	11	7
56	418	100	100	100	97	96	96	95	93	92	90	87	69	60	58	49	34	25	19	13
57	418	100	100	100	100	98	96	95	91	89	85	75	46	36	35	29	21	17	15	11
58	340	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99	95	84	66	24
59	340	100	100	100	100	100	100	100	100	100	100	100	100	99	99	97	91	83	70	35
60	340	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	94	84	70	33
61	327	100	100	100	100	100	100	100	100	100	100	100	100	98	97	97	93	88	77	41
62	327	100	100	100	100	100	100	100	100	100	100	100	100	99	99	98	94	88	80	48
63	327	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99	95	89	79	42
64	325	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99	95	88	77	38
65	325	100	100	100	100	100	100	100	100	100	100	100	100	99	98	97	94	88	76	34
66	360	100	100	100	97	96	95	93	92	91	90	87	67	61	58	40	16	8	4	1
67	372	100	100	100	97	97	96	94	93	92	91	89	83	76	74	60	35	24	15	4
68	369	100	100	100	100	100	99	98	94	92	85	78	67	65	64	61	43	31	19	9
69	374	100	100	100	100	98	97	93	84	81	75	65	41	38	37	35	29	24	19	11
70	409	100	100	100	97	97	95	93	90	88	85	82	73	64	62	47	24	15	8	2
71	409	100	100	100	99	97	96	92	90	88	86	82	74	69	67	52	24	12	5	1
72	409	100	100	100	98	96	95	94	93	92	90	89	85	78	76	61	32	19	10	3
73	409	100	93	93	93	93	93	93	92	92	92	91	90	88	88	79	57	41	28	8
74	411	100	100	100	97	94	93	91	87	83	74	66	54	49	47	42	37	33	31	25
75	402	100	100	100	97	96	95	93	92	91	90	89	85	82	82	74	52	39	27	12
76	423	100	100	100	100	100	100	100	100	100	100	100	100	100	99	99	96	90	72	27
77	423	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99	98	94	80	31
78	423	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	96	90	76	33

Sample Number	Stockpile ID	4	3	2.5	2	1.5	1.25	1	3/4	5/8	1/2	3/8	4	8	10	16	30	40	50	100
79	430	100	100	100	98	97	95	86	62	50	35	23	12	10	10	9	8	7	6	5
80	430	100	100	100	100	92	87	80	71	65	57	47	17	11	10	9	8	8	7	6
81	396	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99	99	98	94	56
82	340	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99	94	83	67	27

APPENDIX E

Iron Ore Testing Results

Iron Ore Chemical Assay Results

Sample Number	Fe	Hematite	Fe++	FeO	SiO2	AL2O3	CaO	MgO	Na2O	K2O	MnO	FreeSiO2	CO2
14	41.91	59.38	0.38	0.49	30.58	2.200	0.079	0.057	0.023	0.053	0.869	26.69	0.06
15	37.85	52.69	0.98	1.26	40.14	1.088	0.036	0.056	0.010	0.029	0.355	37.10	0.07
16	29.94	41.43	0.98	1.26	48.30	6.426	0.760	0.397	0.528	0.576	0.115	38.56	0.15
17	45.21	63.35	0.90	1.16	25.40	3.764	0.283	0.211	0.007	0.079	0.057	20.01	0.08
18	20.95	29.52	0.30	0.39	68.50	0.465	0.063	0.033	0.021	0.020	0.097	66.14	0.10
19	18.62	26.08	0.38	0.49	71.10	0.313	0.092	0.028	0.063	0.007	0.054	70.07	0.06
20	31.84	44.88	0.45	0.58	49.84	1.036	0.202	0.145	0.143	0.176	0.144	47.32	0.06
21	37.10	52.28	0.53	0.68	44.22	0.724	0.086	0.053	0.102	0.084	0.096	41.29	0.08
22	45.06	63.02	0.98	1.26	26.76	2.688	0.212	0.231	0.013	0.092	0.093	22.78	0.07
23	45.87	64.29	0.90	1.16	22.16	2.685	1.010	0.345	0.013	0.181	0.218	17.26	0.44
24	36.73	51.66	0.60	0.77	45.46	0.581	0.078	0.034	0.038	0.037	0.087	44.58	0.04
25	40.61	57.63	0.30	0.39	40.80	0.671	0.103	0.031	0.022	0.027	0.103	30.94	0.06
26	42.87	60.86	0.30	0.39	36.38	0.563	0.060	0.028	0.026	0.025	0.087	34.36	0.01
27	41.31	58.63	0.30	0.39	38.12	0.847	0.136	0.068	0.050	0.062	0.067	36.47	0.02
29	19.10	26.66	0.45	0.58	68.36	2.048	0.123	0.139	0.014	0.020	0.099	65.28	0.05
30	44.37	63.01	0.30	0.39	32.96	0.746	0.035	0.072	0.020	0.019	0.131	31.72	0.12
31	25.63	36.21	0.30	0.39	61.50	0.621	0.034	0.058	0.007	0.007	0.062	60.30	0.05
32	45.94	65.15	0.37	0.48	31.16	0.708	0.026	0.075	0.016	0.022	0.117	30.02	0.01
35	24.43	34.28	0.45	0.58	63.00	0.616	0.043	0.034	0.010	0.014	0.067	61.36	0.04
36	41.06	58.27	0.30	0.39	37.96	0.718	0.051	0.054	0.020	0.028	0.118	35.74	0.13
37	42.26	60.09	0.23	0.30	36.48	0.650	0.044	0.035	0.014	0.025	0.233	34.34	0.02
38	44.37	63.12	0.22	0.28	32.94	0.768	0.074	0.046	0.031	0.036	0.077	31.30	0.02

Sample Number	Fe	Hematite	Fe++	FeO	SiO2	AL2O3	CaO	MgO	Na2O	K2O	MnO	FreeSiO2	CO2
39	10.06	13.74	0.45	0.58	84.82	0.303	0.033	0.021	0.003	0.005	0.020	82.78	0.01
40	28.93	40.83	0.37	0.48	55.04	0.476	0.075	0.066	0.020	0.021	0.068	54.24	0.03
41	26.74	37.47	0.53	0.68	59.14	0.467	0.070	0.038	0.036	0.038	0.067	56.24	0.01
42	24.93	35.00	0.45	0.58	62.12	0.227	0.044	0.020	0.007	0.009	0.035	61.52	0.03
43	30.88	43.72	0.30	0.39	51.82	0.483	0.040	0.048	0.010	0.017	0.066	51.68	0.06
44	30.73	43.29	0.45	0.58	52.48	0.511	0.020	0.049	0.007	0.012	0.076	51.44	0.02
45	51.86	73.72	0.30	0.39	19.40	2.027	0.134	0.141	0.017	0.050	0.186	15.28	0.01
46	53.21	75.65	0.30	0.39	17.22	2.026	0.134	0.136	0.017	0.044	0.183	13.70	0.03
47	30.53	43.32	0.23	0.30	52.92	0.539	0.044	0.043	0.030	0.036	0.077	50.70	0.02
48	34.44	48.81	0.30	0.39	47.20	0.497	0.061	0.046	0.038	0.049	0.082	46.96	0.03
49	27.49	38.66	0.45	0.58	57.22	0.341	0.033	0.038	0.006	0.009	0.080	54.63	0.03
50	28.69	40.47	0.38	0.49	56.46	0.548	0.089	0.052	0.031	0.034	0.088	54.64	0.05
51	39.05	55.40	0.30	0.39	39.72	0.286	0.023	0.033	0.004	0.006	0.052	37.93	0.04
52	24.73	34.93	0.30	0.39	62.12	0.582	0.084	0.055	0.033	0.047	0.065	60.52	0.08
53	26.53	37.50	0.30	0.39	58.94	0.421	0.023	0.048	0.021	0.027	0.137	56.98	0.05
54	26.44	37.26	0.38	0.49	60.02	0.393	0.038	0.040	0.007	0.011	0.052	58.66	0.03
55	36.35	51.43	0.38	0.49	43.10	0.491	0.043	0.057	0.010	0.016	0.096	43.09	0.05
56	38.43	54.41	0.37	0.48	42.88	0.572	0.057	0.079	0.032	0.047	0.106	40.66	0.03
58	48.94	68.90	0.75	0.97	26.12	0.330	0.045	0.054	0.004	0.006	0.201	24.88	0.42
57	28.33	39.86	0.45	0.58	55.92	0.398	0.030	0.021	0.006	0.011	0.041	55.18	0.01
59	41.13	58.47	0.23	0.30	36.90	0.439	0.055	0.072	0.013	0.015	0.195	36.56	0.15
60	51.66	73.43	0.30	0.39	22.06	0.379	0.032	0.056	0.004	0.008	0.194	21.20	0.14
76	34.97	49.45	0.38	0.49	46.30	0.425	0.061	0.071	0.013	0.016	0.169	45.86	0.14
77	31.48	44.36	0.45	0.58	51.40	0.385	0.071	0.080	0.015	0.017	0.137	49.20	0.06
78	37.62	53.36	0.30	0.39	42.48	0.496	0.063	0.059	0.019	0.020	0.136	39.90	0.08

Sample Number	Fe	Hematite	Fe++	FeO	SiO2	AL2O3	CaO	MgO	Na2O	K2O	MnO	FreeSiO2	CO2
79	25.38	35.74	0.38	0.49	61.96	0.443	0.035	0.041	0.006	0.009	0.051	61.18	0.01
80	20.39	28.62	0.37	0.48	67.76	0.346	0.048	0.034	0.005	0.007	0.084	67.22	0.07
81	19.55	27.52	0.30	0.39	69.84	0.367	0.065	0.039	0.019	0.020	0.068	69.06	0.06
82	58.36	82.25	0.83	1.07	12.32	0.361	0.073	0.088	0.003	0.006	0.242	11.12	0.74