Minnesota Department of Natural Resources
Division of Lands and Minerals
Director Larry Kramka

AGGREGATE RESOURCES
SAND & GRAVEL POTENTIAL
Kanabec County, MN

Produced by the Aggregate Resource Mapping Program
Division of Lands and Minerals
& Funded by the Minnesota Department of Transportation

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INTRODUCTION: The purpose of this project is to identify and classify potential construction aggregate resources (sand and gravel) in Kanabec County, Minnesota for use by local governments to plan for future supplies. This information is intended to assist local planners and others in making comprehensive land-use and zoning decisions regarding aggregate resources, introduce aggregate resource protection, spread the burden of development, and promote orderly and environmentally sound development of the resource. Having locally available, low-cost construction aggregates is fundamental to building and maintaining public infrastructure and private sector development. To accomplish these goals, a sand and gravel potential plate and a comprehensive data set on a CD-ROM were created.

There are several factors related to aggregate resources that affect their availability, usability, and supply. These factors include the cost of transportation of aggregate materials, the quality of the material, and land-use conflicts. Aggregate materials are high-bulk, low-value commodities, which means transportation costs can account for a considerable amount of the delivered price. Lower construction costs for public and private projects can be achieved by using local aggregate supplies. Aggregate products, such as concrete and asphalt, have specific quality requirements depending on the end use so aggregate resources must be evaluated in relation to quality standards. At the same time, land-use conflicts are becoming more common. This may be caused by cities expanding into adjacent rural areas, aggregate resource deposits being covered by new developments, new development occurring adjacent to aggregate resources, and/or permanent conservation easements that exclude aggregate mining. As a result, the distance from the aggregate source to its consumers is increasing. Due to the increased use of aggregate material in and around populated areas, aggregate resources are being depleted.

With these and other issues in mind, the 1984 Minnesota Legislature passed a law (Minn. Statute, sec. 84.94, Aggregate Planning and Protection) that directs the Minnesota Department of Natural Resources, in cooperation with the Minnesota Geological Survey (MGS) and the Minnesota Department of Transportation (Mn/DOT), to identify and classify potential aggregate resources. When the mapping is completed, the information is provided to local governments and the public. Since this is a reconnaissance-level survey of aggregate resources, site-specific evaluations are still necessary prior to any development of the resource, especially in regards to aggregate quality or environmental review. Factors such as ownership, zoning, protected waters and wetlands, environmental permitting, and other individual site characteristics are not part of the geological resource data summarized here.

METHODOLOGY: The method used for aggregate mapping integrates traditional geologic mapping techniques such as field observations and drilling that are compiled using computer software programs (Geographic Information Systems, GIS). Sand and gravel mapping is accomplished through three phases of work: 1) preliminary information gathering consisting of compiling, interpreting, and summarizing data, 2) field work and ground verification data, and 3) aggregate resource classification.

Data Gathering: The first step in the mapping process is conducting literature and data searches to obtain a basic understanding of the regional geology. Some of the data used are aerial photographs, topographic maps, digital elevation models, shaded relief maps, subsurface data, gravel pit and quarry data, soil surveys, existing maps of surficial and bedrock geology, published papers and reports, land-use, as well as several datasets of background information, including roads, railroads, PLS township, range, and section boundaries, and other data.

The County Well Index (CWI) database and the Aggregate Source Information System (ASIS) are subsurface geologic datasets used for constructing sand and gravel resource maps. The CWI is an online database (www.health.state.mn.us/divs/eh/cwi) developed and maintained by MGS and the Minnesota Department of Health. These resources contain basic information for over 300,000 wells drilled throughout Minnesota. In Kanabec County, there are approximately 650 wells with well defined locations. An additional 2805 unlocated wells are approximately placed within their corresponding sections and may also include some located wells. The majority of CWI well logs contain geologic descriptions. ASIS is a dataset compiled and maintained by Mn/DOT consisting of aggregate quality data, sand and gravel grain size analysis, and pit sheets displaying the descriptions of shallow test-hole logs and diagrams of test-hole locations. This information refers to specific sites that Mn/DOT evaluated from approximately 1930 to 2000. Subsurface information is important to identify buried sand and gravel deposits, determine the depth of bedrock, and identify the type of bedrock encountered.

Field Work: Several weeks in the fall of 2010 and spring of 2011 were spent driving accessible roads in the county looking for outcrops and exposures of geologic materials, as well as drilling test holes to further define aggregate deposits. Sediments exposed in road cuts, stream exposures, trails, foundation excavations, construction projects, and animal burrows, offered sites where surface materials and glacial stratigraphy could be examined. A total of 291 field observations were logged in Kanabec County. Field work also included documenting sediment in existing gravel pits, which provided additional quality data and views of stratigraphic cross-sections that helped the geologist interpret how the sediment was deposited. A drilling program was completed with the collaboration of Mn/DOT Foundation Unit and Material Laboratory. A total of 86 test holes were drilled, to depths ranging from 3 to 19 feet, which helped define the areal extent and depth of a deposit. Samples were taken from selected test holes for quality testing. The drilling program was a reconnaissance-level evaluation and the quality results do not statistically represent an entire deposit.

Sand and Gravel Data Compilation and Interpretation: Aggregate resources are identified and classified using a glacial mapping technique known as the landsystems approach. This technique relies on the principle that depositional glacial landforms contain a predictable range of sediments, from sorted sand and gravel, to silts, clays, and/or unsorted materials. In addition to the landsystems approach, other sediment characteristics, such as color, texture, shape, size, size trends, and patterns help determine how the material was deposited. For example, a particular vegetation type might prefer well drained soils, such as sand and gravel. These substrates also have a distinctive texture, tone or pattern when viewed in aerial photographs. Aggregate-bearing features such as outwash plains, eskers, and other meltwater features can be observed and distinguished using this technique.

Using GIS software, aggregate resources are delineated by layering multiple datasets. Topographic maps (USGS 1:24,000), digital elevation data, shaded relief maps, aerial photographs, subsurface data, field observations, the location and distribution of existing pits, and soil surveys, are used to identify features containing sand and gravel resources. Aggregate resources are mapped at a scale of 1:50,000.

RESULTS: In Kanabec County, three large-scale landforms contain sand and gravel: outwash features, ice marginal landforms and ice contact features (Figure 1). Areally extensive sand and gravel outwash features deposited as outwash plains are located in southern Kanabec County. These deposits contain many larger-sized high quality aggregate mines that meet Mn/DOT concrete specifications. The second type of deposit is ice marginal landforms, also known as recessional moraines. The largest ice marginal landform is located immediately west of Mora and contains a major aggregate producing deposit within the county. Smaller ice marginal landforms occur throughout the county. Ice contact features are generally found in the north central and east central Kanabec County, however, small ice contact features are dispersed throughout the county. The largest ice contact deposits are sinuous ridges, eskers, within large meltwater-eroded valleys. In Kanabec County, these deposits tend to be under-utilized for aggregate production. These deposits can be formed by a series of geologic processes, and thus, the sand and gravel texture, or grain-size distribution varies considerably.

Figure 1: Three General Landforms in Kanabec County that Contain Sand and Gravel Resources

The large outwash plain in southern Kanabec County consists of sorted material ranging from sand to gravel and cobbles. Silt content varies throughout the outwash plain and cobbles and boulders are typically rare. Sediment from the ice marginal landforms contains variable grain sizes, from silt/clay to boulders, but overall contains high amounts of silt. Ice contact deposits have pockets of well-sorted sediment with some cobbles and boulders and also have variable silt/clay content.

The sand and gravel within Kanabec County is generally high quality (Table 2). The quality of material is due to the source of the glacier that transported and deposited the sediment. Except for a thin cover of lacustrine silt and clay in the southern portion of the county, the sediment in Kanabec County was deposited by a glacier traversing the Lake Superior basin, the Superior lobe. As a result, sand and gravel within the county contains characteristic North Shore Volcanic Group rocks, which are competent rocks in terms of aggregate durability. Consequently, Superior lobe sand and gravel tends to be higher in quality and have a higher potential of meeting Mn/DOT specifications for bituminous and concrete.

Sand and gravel deposits were delineated and classified by potential for sand and gravel resources according to the eight characteristics listed in Table 1. The amount of supporting data directly affects the potential classification of a sand and gravel deposit. Where supporting data exists, such as gravel pits and field observations, sand and gravel deposits were ranked with higher probability, and thus, higher potential. Where data was lacking regarding the extent, depth or quality of a sand and gravel deposit, the resulting probability, or certainty, was lowered. Lower probability decreased the overall potential of a deposit. Some areas were inaccessible and consequently, the map unit designation for these landforms was primarily based on interpretations of aerial photographs, topographic signatures, and regional soil surveys. For example, large ridges were observed remotely and are typically considered excellent sources of sand and gravel, but because there was limited data to confirm the presence of a sand and gravel deposit, the map unit delineating the landform was assigned a lower probability, resulting in a lower sand and gravel potential value.

AGGREGATE POTENTIAL: Aggregate potential is defined as an assessment of the relative probability that an aggregate deposit exists within a given map unit. Almost all emphasis is placed upon geologic evidence, physical parameters such as areal extent, and interpretation at the reconnaissance level, rather than upon economic feasibility, site-specific level of evaluation, or other related parameters. This assessment does not imply that economic aggregate deposits exist everywhere within a given map unit designated as significant resources, but rather, that within such a map unit, geologic processes were active that could have created aggregate deposits at specific sites. Geologic measurements of aggregate deposits such as thickness or quality test data remain constant, but economic criteria and environmental permitting vary across time and at different locations. Important site-specific factors such as ownership, zoning, protected waters and wetlands, sensitive or protected environments, permitting, distance to markets, royalties, and individual site characteristics, such as access, all contribute to the feasibility of mining specific parcels; however, these factors are not considered in this reconnaissance-level study.

SIGNIFICANT POTENTIAL FOR SAND AND GRAVEL RESOURCES: Geologic units that are inferred to contain sand and gravel resource potential. These units exhibit geologic characteristics that typically produce sand and gravel resources. Existing gravel pits and Mn/DOT aggregate sources within these units are considered to be identified, or known resources, that increase the level of confidence for a map unit.

Mp **High Potential for Sand and Gravel Resources:** Outwash terraces, outwash features, recessional moraines and ice contact features. Within these features sand and gravel is the predominant sediment. The probability that a potential sand and gravel resource exists within any map unit is moderately high to very high. Thickness of the deposits range from 10-50+ feet with less than 10 feet of overburden. These features are moderately large to very large in areal extent and the textural characteristics are good to very good. The quality is moderately high to very high.

Mp **Moderate Potential for Sand and Gravel Resources:** Outwash channels, outwash features, outwash terraces, recessional moraines, tunnel valleys, and ice contact features. Predominant sediment ranges from sand and gravel to sand with gravel. Isolated pockets of sorted sand and gravel exist within recessional moraines. The probability that a potential sand and gravel resource exists within this unit is moderate to high. Deposit thickness ranges from 5-30+ feet with less than 15 feet of overburden. These features are moderate to moderately large in areal extent and the textural characteristics are moderate to good. The quality is moderate to high.

NONSIGNIFICANT POTENTIAL FOR SAND AND GRAVEL RESOURCES: Geologic units that generally have little or no potential for significant sand and gravel resources or lack sufficient data to support a classification of significant sand and gravel resources. These units typically contain clay, silt, fine sand, unsorted sediments (till), very thin layers of sand and gravel, or buried sand and gravel. Such units may include sand and gravel resources that are too small to map (<10 acres).

Lp **Low Potential for Sand and Gravel Resources:** Outwash features, tunnel valleys, alluvial valleys, lake plains, recessional and ground moraines, and ice contact features. Predominant sediment varies and can include sand, sand with gravel, or silty sand and gravel. The probability that a potential resource exists within this unit is low to moderately low. Thickness of the deposits range from 0-20+ feet with overburden thickness ranging from 0-50 feet. These features are small to moderately small in areal extent and the textural characteristics are poor to moderately poor. The quality ranges from low to moderately low.

Ltd **Limited Potential for Sand and Gravel Resources:** Outwash channels, outwash features, alluvial valleys, tunnel valleys, lake plains, recessional and ground moraines. Deposits of this unit contain one or more of the following, clay with gravel, sand, silt and/or organics. The probability that a significant sand and gravel resource exists within this unit is very low to low. The thickness of these deposits is typically less than 10 feet but can range from 0 to 20 feet with overburden thickness ranging from 0 to 100 feet. The sand and gravel resources occurring in this unit are very small to small in areal extent. The textural characteristics are very poor to moderately poor with the quality ranging from very low to moderately low. A limited potential rating includes the circumstance where characteristics are unknown and there was insufficient data, such as no access and no obvious landform-sediment association.

IDENTIFIED SAND AND GRAVEL RESOURCES: Locations where sand and gravel have been or are currently being mined. Several sources of information identify gravel mine locations: topographic maps, aerial photographs, soil surveys, MGS field mapping sites, Mn/DOT files, fieldwork, gravel operators, and other sources. Gravel mines range in size from less than 1 acre to greater than 100 acres and may be active, inactive, or reclaimed. The sand and gravel quality varies (Table 2 & ASIS).

Small	Medium	Large
< 5 Ac.	5-15 Ac.	> 15 Ac.
n = 152	*n = 20*	*n = 9*
n = 42	*n = 28*	*n = 15*

Gravel Pits: Includes sites that have been or are currently being mined.

Gravel Pits - Mn/DOT ASIS: Sites were identified by Mn/DOT as part of the Aggregate Source Information System (ASIS). Although identified as a potential resource location, sites have not necessarily been mined or geologically evaluated. Some locations were modified to better correlate to present gravel pit boundaries.

n = 5 **Sand Pits:** Contains significant amounts of sand with little to no gravel. Includes sites that have been or are currently being mined.

n = 2 **Sand Pits – Mn/DOT ASIS:** Sites were identified by Mn/DOT as part of ASIS. Although identified as a potential resource location, sites have not necessarily been mined or geologically evaluated. Some locations were modified to better correlate to present gravel pit boundaries.

OTHER FEATURES:

n = 8 **Borrow Pits:** Contains other unconsolidated sediment like clay, silt, and clay with boulders and do not contain significant amounts of sand and/or gravel. Include sites that have been or are currently being mined.

n = 16 **Prospects:** Indicates a site that has been prospected and/or leased by Mn/DOT. A prospected classification does not necessarily imply that the source is actually producing aggregate at the present time. In fact, it may only indicate an aggregate deposit that was at one time leased by Mn/DOT and whose aggregate quality has been tested, but from which no material has ever been excavated.

n = 4 **Dimension Stone Granite Quarries:** Indicates a site that was mined for dimension stone and is less than 5 acres in size.

GEOLOGIC DATA SOURCES FOR MAP UNIT INTERPRETATION: Field observations, County Well Index (CWI) database, and test-holes were data sources used in the interpretation of sand and gravel potential.

Primary Material Observed

- ■ Sand and Gravel
- ▲ Sand
- ● Till
- × Silt/Clay

Field Observations: A total of 291 field observations, were logged during the fall of 2010 and the spring of 2011, including pits and test holes. Pits were also inventoried. They include 266 gravel pits, 7 sand pits, 8 borrow pits, 16 prospects, and 4 dimension stone quarries. Surficial geologic sediment and glacial stratigraphy were observed in pits, road cuts and embankments, construction projects, ditches, trails, river banks, and animal burrows. Field observations of gravel pits and sand pits are identified on the map as Gravel Pits and Sand Pits (See Identified Sand and Gravel Resources).

Figure 2: County Well Index Database Locations
(well locations are not shown on the larger resource map)

The **CWI** is an online database maintained by the Minnesota Geological Survey and the Minnesota Department of Health. Figure 2 displays the 650 wells (as of 06/10) located within Kanabec County that were referenced to create this map. There are an additional 2805 unlocated wells also referenced for this map though not shown here. Unlocated wells have not been field verified by the MGS for location accuracy.

Test-Holes: Test holes were completed during a cooperative drilling program between MN DNR and Mn/DOT. A total of 86 test holes were drilled to verify the presence or absence of sand and gravel. Each test hole is labeled with the significant material(s) extracted from the test hole. Selected samples from test holes were analyzed for aggregate quality at a Mn/DOT material laboratory. Sampled test holes are shown on the map as TH-### and the corresponding results can be found below in Table 2.

Test Hole Sampling by Mn/DOT for Construction Aggregate Quality: Sample quality has been characterized at the reconnaissance level by 16 samples and more than a hundred visual field observations. The Mn/DOT Lithological Exam identifies certain deleterious rock types present within a sample. The number is calculated as a weight percent.

Test results indicate 15 samples meet all of the lithological standards for concrete. However, one sample (TH-374) contains a higher percentage of deleterious sandstone which lowers the overall quality of the deposit. This is likely caused by incorporation of local sandstone bedrock. All tested samples met the <5% standard for %Total Sample Spall (Table 2). The lowest quality sample, TH-374 collected from a moderately-sized outwash feature had 10.7% sandstone and 2.0% Total Sample Spall, the highest recorded value for all tested samples. Within the tested samples, gravel and silt/clay percentages ranged from 21-52 and 3.8-19.2, respectively. Samples from ice contact features (Figure 1) had both the lowest and highest silt/clay content (3.8% and 19.2%) while samples taken from outwash features had both the lowest and highest gravel content (21% and 52%). No samples were taken from ice marginal landforms.

In general, the lithological characteristics of the sampled sand and gravel within Kanabec County are very good. Sand and gravel deposits within the county are low in shale, low in carbonate, and usually have lower amounts of spall compared to elsewhere within the state. The bituminous specification (Mn/DOT 3139.2), for allowable total sample spall by weight is 5%. All tested samples meet Mn/DOT bituminous specification for %total sample spall (Mn/DOT Standard Specifications for Construction, 2005). However, to characterize any one deposit, many samples of that deposit would need to be tested.

Table 2: Test-Hole Samples Tested by Mn/DOT for Construction Aggregate Quality

Test Hole ID	Map Location	% Gravel	% Silt/Clay	% Shale in Sand	% Spall Argillite	% Carbonate	% Sandstone	% Iron Oxide	% Unsound Chert	% Total Sample Spall	% BA Spall +4
TH-293	T.38 N, R.25, S.26	30	5.0	0.1	0.9	0.0	1.2	0.2	0.1	0.4	1.1
TH-313	T.39 N, R.23, S.33	22	7.3	0.1	0.4		1.1	0.3	0.1	0.3	1.0
TH-314	T.39 N, R.23, S.15	25	6.9	0.0	1.5		1.0	0.7		0.6	2.2
TH-338	T.39 N, R.25, S.4	39	8.4	0.1	1.1	0.2	1.9	0.4	0.1	0.7	1.7
TH-343	T.38 N, R.23, S.23	24	4.8	0.1	0.7			0.3	0.03	0.3	1.0
TH-348	T.38 N, R.24, S.30	40	5.6	0.1	0.2		1.0	0.2	0.1	0.4	0.8
TH-349	T.38 N, R.24, S.31	46	11.2	0.1	1.0	0.1		0.1	0.1	0.6	1.1
TH-356	T.38 N, R.25, S.31	33	3.8	0.1	1.4	0.0	0.3	0.0	0.1	0.6	1.5
TH-357	T.40 N, R.24, S.15	52	11.6	0.1	0.9	0.1	1.1	0.1	0.1	0.6	1.1
TH-363	T.39 N, R.25, S.23	37	12.0	0.1	0.7	0.0	2.6	0.2	0.2	0.5	1.1
TH-370	T.39 N, R.25, S.4	42	9.0	0.1	0.5	0.1	2.7	0.4	0.04	0.5	0.9
TH-374	T.39 N, R.23, S.5	47	4.7	0.0	2.2		10.7	0.5	0.1	2.0	4.2
TH-376	T.39 N, R.23, S.15	21	8.7	0.1	1.0	0.0	1.2	0.3		0.3	1.4
TH-377	T.42 N, R.23, S.12	25	19.2	0.1	0.8	0.1		0.2		1.1	4.2
TH-379	T.42 N, R.23, S.12	42	17.9	0.1	0.4	0.1	0.4	0.4	0.2	0.6	1.1
TH-381	T.42 N, R.23, S.35	37	9.0	0.1	1.1	0.0		0.7	0.04	0.8	1.9

Table 2: Results for 16 samples tested for Mn/DOT Concrete Aggregate Lithological Exam quality characteristics including: weight percent shale in sand, weight percent spall argillite, weight percent carbonate, weight percent sandstone, weight percent iron oxide, weight percent unsound chert, weight percent total sample spall, and weight percent bulk aggregate (BA) spall for greater than 4.75mm. Sample locations are labeled by Test Hole ID and the primary materials extracted. Blank values represent samples that were not tested for that specific quality attribute. This was a reconnaissance-level sampling methodology and sample test results do not represent the quality characteristics of an entire sand and gravel deposit.

BASEMAP SYMBOLS:
Symbols may appear in different shades because of the overlaying sand and gravel resource map units

Transportation Features
- 18 MN Highway
- 2 County Highways and Roads
- Township and Other Roads
- Municipal Roads
- Railroad Tracks

Bounding Features
- County
- PLS Townships
- PLS Sections

County Seat & Cities
- County Seat
- Cities

Physical Features
- Lakes
- Rivers and Streams
- Ditches

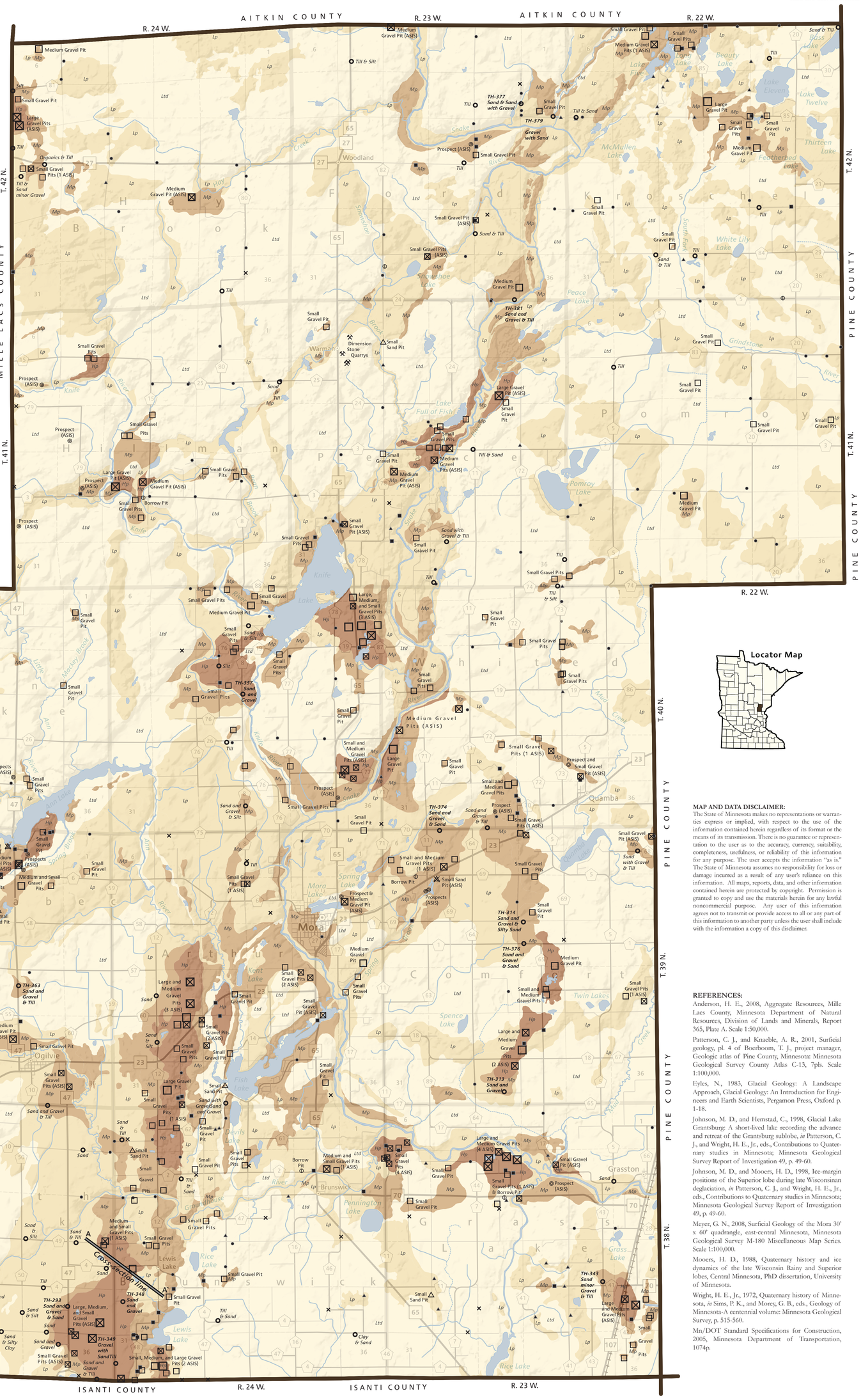
Topographic Relief
- Hillshade (Azimuth = 315 Altitude = 345)

BASE MAP DATA SOURCES:
Lakes, rivers, streams, and drainage ditches from NWI (National Wetland Inventory), Mn/DOT (Minnesota Department of Transportation) Base map, MN DNR 24K Streams, compiled at 1:24,000 from aerial photography (1979-1988) and USGS quadrangle maps (1980-1990); PLS (Public Land Survey) townships and sections layers extracted from PLS Project, 2001, MN DNR, Division of Lands and Minerals; Cities were derived from the GNIS (Geographic Name Information System) by pulling out the features that were coded as populated places. A selected subset of these was used for this map, 2003; County boundaries from MN DNR, derived from combination of 1:24,000 scale PLS lines, 1:100,000 scale TIGER, 1:100,000 scale DLG, and 1:24,000 hydrography lines, 1993; Hydrography labels derived from selected Mn/DOT County Highway Maps water feature annotations, 2002; Roads from Mn/DOT Base map, Fall of 2006; Railroad Tracks from Mn/DOT Base map, 2001; Topographic relief or hillshade created from a 10-meter digital elevation model (DEM) from the USGS National Elevation Dataset.

GIS Support and Cartography by Kevin J. Hanson, MN DNR, Division of Lands and Minerals.

Printed Map Scale 1:63,360
1" = 1 Mile
Based on a 1:50,000 scale MN DNR resource assessment

0 1 2 3 Miles
0 1 2 3 4 Kilometers



Locator Map

MAP AND DATA DISCLAIMER:
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Mn/DOT Standard Specifications for Construction, 2005, Minnesota Department of Transportation, 1074p.

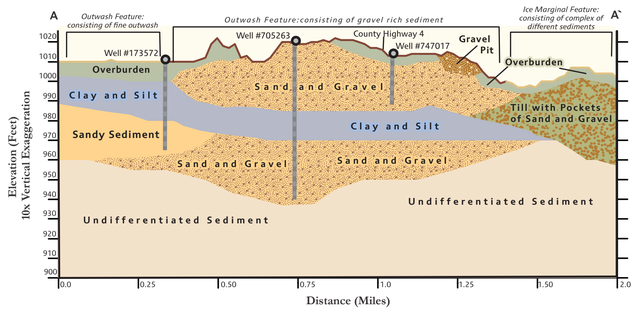
Table 1: Classification of Sand and Gravel Potential

Characteristics	SIGNIFICANT RESOURCES		NONSIGNIFICANT[1] RESOURCES	
	High Potential	Moderate Potential	Low Potential	Limited Potential
Surficial Geology Features	Outwash terrace; outwash feature; ice contact feature; recessional moraine	Outwash channel/ feature/ terrace; ice contact feature; tunnel valley; recessional moraine	Outwash features; ice contact feature; tunnel /alluvial valley; lake plain; recessional/ ground moraine	Outwash channel/ feature; alluvial valley; lake plain; tunnel valley; recessional/ ground moraine
Predominant Sediment Description	Sand and gravel	Sand and gravel to sand with gravel	Till, clay, silt, sand, organics	
Probability[2]	Moderately high to very high	Moderate to high	Low to moderate	Very low to low
Sand and Gravel Thickness (in feet)	10-50+	5-30+	0-20+	0-20
Overburden[3] Thickness (in feet)	0-10	0-15	0-50	0-100
Sand and Gravel Deposit Size (areal extent[4])	Moderately large to very large (10-30+ acres)	Moderate to moderately large (5-15+ acres)	Small to moderately small (3-10+ acres)	Very small to small (<1-5+ acres)
Sand and Gravel Textural Characteristics[5]	Good to very good	Moderate to good	Poor to moderate	Very poor to poor
Sand and Gravel Quality[6]	High to very high	Moderate to high	Low to moderate	Very low to low

Footnotes Associated with Sand and Gravel Potential

[1]**Nonsignificant:** Aggregate resources that do not meet the criteria for high or moderate aggregate potential according to the characteristics listed in Table 1. This is a relative classification that changes from one mapping region to another.
[2]**Probability:** The degree of certainty that aggregate exists within a map unit largely defined by the amount of available information. Many gravel pits verify the certainty for many map units classified as high potential.
[3]**Overburden:** The material that lies above the sand and gravel that must be removed to access a deposit.
[4]**Areal Extent:** The size, horizontal extent, or distribution of a unit (e.g., area in acres). This attribute does not necessarily reflect the size of an individual polygon but the size of a deposit found within that polygon.
[5]**Textural Characteristics:** Particle size distribution, defined as the percentage of gravel or sand vs. silt or clay (e.g., sieve analysis).
[6]**Quality:** The physical characteristics of the material, such as soundness (e.g., magnesium sulfate test), durability (Los Angeles Rattler test), and percent of deleterious rock types such as iron oxide, disintegrating rock, or unsound chert. Field observations supplement historic data.

Figure 3: Geologic Cross-Section and Sand and Gravel Potential



Cross-Section Description: The cross-section highlights landforms and their respective sediment associations. Aggregate-bearing landforms in the cross-section include outwash features and ice-marginal landforms that are thinly mantled by overburden. Additional landform and sediment associations are described in Results (Figure 1). To the east, overburden consists of lacustrine silt, and to the west it consists of till or clay with gravel. The color of the line representing surface elevation correlates to sand and gravel potential. Surface and subsurface geology is interpreted from county well information and gravel pit locations (Figure 2). Only wells with a higher degree of geological and spatial accuracy were used to interpret the subsurface stratigraphy. The elevation of the cross-section has a ten times vertical exaggeration.

A A' **Cross-Section Line on Map:** Cross-section line trending from northwest to southeast.

Products of this project include a CD/ROM with digital maps, GIS data, and metadata
Plate A, Report 384, Kanabec County Aggregate Resources, Sand and Gravel Potential