Minnesota Department of Natural Resources
Division of Lands and Minerals
Director Joseph Henderson

AGGREGATE RESOURCES
SAND & GRAVEL POTENTIAL
Kandiyohi County, MN

Produced by the Aggregate Resource Mapping Program
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DEPARTMENT OF NATURAL RESOURCES

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Purpose: The purpose of this project is to identify and classify potential construction aggregate resources (sand and gravel) in Kandiyohi County, Minnesota. This mapping was completed in accordance with the Minnesota Statute Section 84.94 directing the Department of Natural Resources (MN DNR), in cooperation with the Minnesota Geological Survey (MGS) and Minnesota Department of Transportation (MnDOT), to provide information to local governments in order to plan and protect future supplies of aggregate resources. This map and accompanying databases are intended to inform 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 resources. Having locally available, low-cost construction aggregates is fundamental to building and maintaining public infrastructure and private sector development.

Aggregate materials are high-bulk, low-value commodities, which means transportation costs account for a considerable amount of the delivered price. Lower construction costs for public and private projects can be achieved by accessing local aggregate supplies. In addition to transportation costs, land use conflicts can impact the availability, usability, and supply of aggregate. Land use conflicts, such as cities expanding into adjacent rural areas, aggregate resource deposits being covered by new developments, new developments occurring adjacent to aggregate resources, and/or land use designations that exclude aggregate mining, are becoming more common. Specifications for the construction of roads and bridges require higher quality aggregate, which may be available only in limited and specific areas. The need and increased use of aggregate material in and around regional economic centers are depleting permitted supplies. As a result, aggregate resources are becoming less available and the transportation distances are increasing, which is passed on in costs to the consumer.

This is a regional reconnaissance-scale map. 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.

Prior Work: The Geologic Atlas of Kandiyohi County (Hamilton et al, 2019), compiled by the MGS, specifically the Surficial Geology (Plate 3), the Quaternary Stratigraphy (Plate 4) and Sand-Distribution Model (Plate 5), were helpful in the completion of this map. Previously completed aggregate potential maps of surrounding Renville (Anderson, 2003), Meeker (Arends, 2005), and Stearns (Arends and Ellingson, 2012) counties, regional geologic maps (Patterson, 1994; Patterson, 1999; Setterholm, 1995), and other in depth mapping efforts (Whitehall, 2002) helped to give regional geologic context to Kandiyohi County.

METHODOLOGY: The map was compiled using Geographic Information Systems (GIS).

Data Gathering: Literature reviews and data searches are conducted to obtain a basic understanding of the regional geology. Some of the data gathered includes aerial photographs, topographic maps, digital elevation models, shaded relief maps, subsurface data, gravel pit and quarry data, 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, the Aggregate Source Information System (ASIS), and Quaternary Data Index (QDI) are important datasets used to interpret subsurface geology and for creating sand and gravel resource maps. CWI is an online database (https://mnwellindex.web.health.state.mn.us/) 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 Kandiyohi County, there are 6,431 wells with defined locations (Figure 2), and an additional 121 unlocated wells that have been approximately placed within the county boundary. The majority of CWI logs contain geologic descriptions. ASIS is a dataset compiled and maintained by MnDOT that consists of aggregate quality data, sand and gravel grain size analysis, and pit sheets displaying the descriptions of shallow test-hole logs with diagrams of test-hole locations. This information refers to specific sites that MnDOT evaluated from approximately 1930 to 2000. The QDI is an internal working database maintained by MGS that consists of field collected data and analysis, from soil borings to gravity and aeromagnetic data. There are currently 781 QDI sites in Kandiyohi County.

Field Work: Several weeks were spent driving accessible roads in the county looking for outcrops and exposures of geologic materials to further define aggregate deposits. Sediments exposed in artificial (e.g. road cuts, trails, foundation excavations, construction projects) and natural (e.g. stream cuts and animal burrows) exposures offer sites where surface materials and glacial stratigraphy can be observed. A total of 67 field observations were logged in Kandiyohi County. Fieldwork also included documenting sediment in existing gravel pits, which provided additional quality data and views of stratigraphic cross-sections. These larger views into the structure of the subsurface layers allowed the geologist to interpret the depositional setting and thereby better predict the extent of the deposit.

Sand and Gravel Data Compilation and Interpretation: Aggregate bearing landforms are typically created by glacial meltwater and non-glacial streams and lakes. Sand-and-gravel-bearing features such as outwash channels, bars, terraces, and other more complex landforms that were created in contact with, or beneath the ice, are distinguished on this map using a land systems approach. This involves the identification of the processes by which glacial landscapes were created, and can provide predictions about the occurrence of a particular sediment type within a given feature. Other sediment characteristics such as color, texture, and grain shape, also help determine how the sediment was deposited. These substrates also have distinctive tones or patterns when viewed from aerial photographs. Furthermore, a particular vegetation type might prefer well-drained soils, such as sand and gravel. Aggregate resources were delineated by layering multiple datasets. Topographic maps (USGS 1:24,000), high resolution elevation data (LiDAR), shaded relief maps, aerial photographs, subsurface data, field observations, the location and distribution of existing pits, and soil surveys, CWI, ASIS, and QDI were used to identify features containing sand and gravel resources. Aggregate resource information was mapped at a scale of 1:24,000 and compiled at a scale of 1:50,000.

RESULTS: Kandiyohi County has a complex glacial history. The majority of the surface deposits are associated with different phases of the Des Moines lobe, a source of ice that transported and deposited sediments from the northwest during the most recent glaciation (>10,000 years ago). This lobe flowed along the Minnesota River Valley, depositing sediments throughout Kandiyohi County. A smaller stream of ice flowing off the main section of the Des Moines lobe, referred to as the Bonanza sub-lobe, flowed into Kandiyohi County from the north. The section between the main lobe and this sub-lobe is referred to as an interlobate region. This region extends from the northwest corner of the county, down to an area surrounding New London, and up to an area just west of Hawick. There is also a small section of exposed surface deposits in the northeast corner of Kandiyohi County that was deposited by an earlier pulse of ice that flowed from the north through central Minnesota, referred to as the Wadena lobe. However, these deposits are not a significant source of sand and gravel within this county.

There are abundant sand and gravel resources within Kandiyohi County. The majority of these resources are concentrated in the northern portion of the county. Several large and extensive sand and gravel deposits are mapped within the northern half of the county. The largest and most notable of these deposits are multiple outwash and interlobate features located in the north-central to northeast corner of the county, a tunnel valley-outwash complex extending from just north of Willmar to the area around New London, and a set of smaller outwash features south of Atwater. By understanding the glacial source of the deposit, quality issues can be predicted and assessed. Based on the source area, quality issues typically associated with Des Moines lobe sand and gravel include higher amounts of shale and limestone that can make certain deposits unsuitable for concrete applications. In general, the amounts of shale observed within Kandiyohi County appear to decrease from the southwest to the northeast.

CLASSIFYING SAND AND GRAVEL POTENTIAL
Characterizing aggregate resources in Kandiyohi County's geologic landforms

Sand and gravel resources were divided into four categories based on the type of geologic feature, probability (certainty), sand and gravel thickness, overburden thickness, deposit size (areal extent), textural characteristics (grain size distribution), quality (soundness and durability), and the sediment description as observed in the field (see definitions of terms in Footnotes). For example, a classified landform, such as an ice contact feature, typically contains sand and gravel. The resource has a high probability of containing aggregate when the landform has gravel pits located within its boundaries, sand and gravel is observed at or near the surface, and sand and gravel is encountered in surrounding water wells. Historical laboratory test results of aggregate quality are compiled, interpreted, and extrapolated from MnDOT pit sheets. In addition to MnDOT quality data, observations of quality characteristics are assessed during field work. Thickness of overburden and sand and gravel were determined from observations and water well information. For example, if a deposit has areal extent greater than 15 acres, has thickness greater than 10 feet, has overburden thickness of 10 feet or less, has moderately high quality, moderately good texture, and an existing gravel pit, then the resource is classified as having high potential (Table 1).

The areas classified as nonsignificant sand and gravel resource potential meet the low or limited potential criteria listed in Table 1. Deposits that are too small in areal extent; are too thin; have too thick of overburden; contain significantly more sand than gravel; lack identified resources; or do not meet quality specifications are in these categories.

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

Sand and Gravel Features
- Gravel Pits
- ASIS Gravel Pits
  Very Small <1 Ac. · Small 1-5 Ac. · Medium 5-15 Ac. · Large >15 Ac.
- Sand Pits
- Borrow Pits
- Prospects

Field Observations
- Sand and Gravel
- Sand
- Till
- Silt

Aggregate Potential
- Hp — High
- Mp — Moderate
- Lp — Low
- Ltd — Limited

Transportation Features
- MN Highway
- 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

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

Table 1: Classification of 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, durability (Los Angeles Rattler test), and percent of deleterious rock types such as iron oxide, disintegrating rock, or unsound chert. Field observations supplement histone data.

SAND AND GRAVEL POTENTIAL: Sand and gravel potential is an assessment of the relative probability that a sand and gravel deposit exists within a given mapping 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 "Sand and Gravel Potential," but rather, that within such a map unit, geologic processes were active that could have created aggregate deposits within certain map units. Geologic measurements of sand and gravel deposits such as thickness or overburden 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 have data exhibiting geologic characteristics associated with sand and gravel-bearing landforms. Existing gravel pit and MnDOT aggregate sources within these units are considered to be identified, or known resources, that increase the level of confidence for that mapping unit.

Hp **High Sand and Gravel Potential:** Includes landforms such as outwash features, ice contact features, interlobate features and tunnel valleys. Predominant sediment typically consists of sand and gravel. The probability[2] that a potential sand and gravel resource exists within any map unit is moderately high to very high. Deposit thickness ranges from 10-50+ feet with less than 10 feet of overburden[3]. The sand and gravel resources occurring in this unit are moderately large to very large in areal extent[4] and the textural characteristics[5] are moderately good to good. The quality[6] is moderate to moderately high relative to other sand and gravel resources within Kandiyohi County.

Mp **Moderate Sand and Gravel Potential:** Includes landforms such as alluvial valleys, outwash features, ice contact features, end/lateral moraines, interlobate features and tunnel valleys. Predominant sediment ranges from sand with gravel to sand and gravel. The probability that a potential sand and gravel resource exists within any map unit is moderately low to moderately high. Deposit thickness is typically greater than 10 feet, but in some landforms can range from 0-30+ feet with 0-15+ feet of overburden. The sand and gravel resources occurring in this unit are moderately small to moderately large in areal extent and the textural characteristics are moderate to moderately good. The quality is typically moderate to moderately high relative to other sand and gravel resources within Kandiyohi County.

NONSIGNIFICANT[1] SAND AND GRAVEL POTENTIAL: Units that generally have little or no potential for significant aggregate resources or lack sufficient data to support a classification of significant aggregate resources. These units typically contain clay, silt, fine sand, unsorted sediments (till), or very thin layers of sand and gravel. Units may include aggregate resources that are too small to map or with significant overburden.

Lp **Low Sand and Gravel Potential:** Includes landforms such as alluvial valleys, outwash features, ice contact features, moraines, interlobate features and tunnel valleys. Predominant sediment varies and can include till, silt, and sand with minor gravel. The probability that a potential sand and gravel resource exists within any map unit is low to moderate. Deposit thickness typically is less than 20 feet, but can range from 0-20+ feet with overburden thickness ranging from 0-50+ feet. The sand and gravel resources occurring in this unit are small to moderately large in areal extent and the textural characteristics are poor to moderate. The quality ranges from low to moderate relative to other sand and gravel resources within Kandiyohi County.

Ltd **Limited Sand and Gravel Potential:** Includes landforms such as collapse features, arcuate depressions, moraines, interlobate features, and tunnel valleys. The deposits of this unit contain all or one of the following: clay with boulders (till), clay, silt, sand, and/or gravel. The probability that a significant sand and gravel resource exists within this unit is low to moderately low. The thickness of the deposits is typically less than 10 feet but can range from 0-20+ feet with overburden thickness ranging from 0-50+ feet. The sand and gravel resources occurring in this unit are very small to moderately small in areal extent and textural characteristics are very poor to moderately poor. The quality ranges from very low to moderately low relative to other sand and gravel resources within Kandiyohi County. A limited potential rating includes the circumstance where characteristics are unknown; there was insufficient data to give a higher ranking; limited access to an area for further investigation; and/or no obvious landform-sediment association.

IDENTIFIED SAND AND GRAVEL RESOURCES: Several sources of information were used to identify gravel pit locations including topographic maps, aerial photographs, soil surveys, MnDOT files, fieldwork, gravel operators, and other sources. Gravel mines range in size from less than 1 acre to greater than 50 acres and may be active, inactive, reclaimed or partially reclaimed. The sand and gravel quality vary. Pits were placed in a category based on the relative areal extent of the total mining footprint as of 2020. The size of some fully reclaimed pits was estimated using historic aerial photographs.

n = 120 · n = 49 · n = 21 · n = 12 — **Gravel Pits:** Includes sites that have been or are currently being mined.

n = 3 · n = 17 · n = 22 · n = 21 — **Gravel Pits - MnDOT ASIS:** Sites were identified by MnDOT 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 = 1 — **Sand Pit – MnDOT ASIS:** Site contains significant amount of sand with little to no gravel and was identified by MnDOT as part of ASIS. Although identified as a potential resource location, site has not necessarily been mined or geologically evaluated

n = 37 — **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 = 31 — **Prospects:** Indicates a site that has been prospected and/or leased by MnDOT. A prospected classification does not necessarily imply that the source is actually producing aggregate. In fact, it may only indicate an aggregate deposit that was at one time leased by MnDOT and whose aggregate quality has been tested, but from which no material has ever been excavated.

GEOLOGIC DATA SOURCES FOR MAP UNIT INTERPRETATION: Field observations, County Well Index (CWI) database, Quaternary Data Index (QDI), and MnDOT Aggregate Prospecting System (APS) material data were information sources used in the interpretation of sand and gravel potential.

- Sand and Gravel
- Sand
- Till
- Silt

Field Observations: A total of 67 field observations were logged throughout the course of the project. Pits were also inventoried and include a total of 265 gravel pits, 1 sand pit, and 37 borrow pits. Surficial geologic sediment and glacial stratigraphy were observed in road cuts; stream exposures; excavations, such as judicial ditches, construction projects, and (cable, pipe, tiling); and animal holes. Field observations of gravel pits and sand pits are shown on the map as Gravel Pits and Sand Pits (See Identified Sand and Gravel Resources). Field observations are symbolized by primary material type observed.

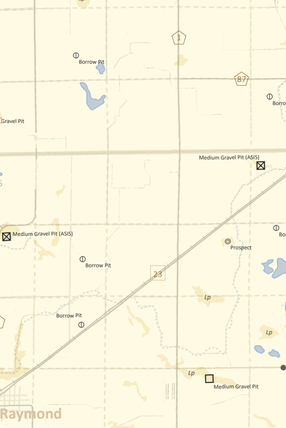

Figure 2: CWI Locations
The CWI is an online database maintained by the Minnesota Geological Survey and the Minnesota Department of Health. Figure 2 displays the 6,431wells (as of 02/21) located within Kandiyohi County that were referenced to create this map. There are an additional 121 unlocated wells also referenced for this map though not shown here. Unlocated wells have not been field verified by the MGS for location accuracy

BASE MAP DATA SOURCES:

Lakes, rivers, streams, and drainage ditches from MN DNR PWI (Public Waters Inventory), 2020; PLS (Public Land Survey) townships and sections layers extracted from PLS Project, 2013, MN DNR, Division of Lands and Minerals; Cities were by the Minnesota Geospatial Information Office (MnGeo). A selected subset of these was used for this map, MnGeo 2017; 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, 2013; Roads from MnDOT Base map, 2012; Railroad Tracks from MnDOT Base map, 2015; Topographic relief or hillshade created from a 1-meter LiDAR from MN DNR and MnGeo, 2012.

ADDITIONAL RESOURCES:

This map was compiled from resources published in digital formats to the Minnesota Geospatial Commons and MN DNR website. Updates and web map tools may be found at these websites:
https://gisdata.mn.gov/dataset/geos-aggregate-mapping
https://www.dnr.state.mn.us/lands_minerals/aggregate_maps/index.html

GIS Support and Cartography by James Olson, MN DNR, Division of Lands and Minerals.

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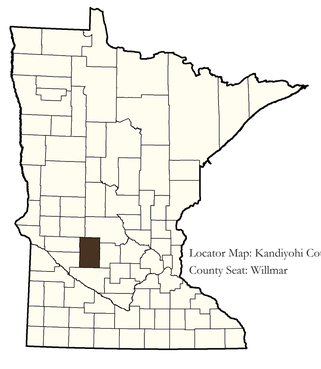
0 0.5 1 2 3 4 5 Miles
0 0.5 1 2 3 4 5 6 7 Kilometers

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



Locator Map: Kandiyohi County
County Seat: Willmar

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Products of this project include print maps, GIS data, web services, and metadata
Plate A, Report 383, Kandiyohi County Aggregate Resources, Sand and Gravel Potential