APPENDIX F. GRINDSTONE RIVER DAM REMOVAL DRAFT ENVIRONMENTAL IMPACT STATEMENT

Geology and Geophysical Survey of the Grindstone Dam Reservoir Area

Geology and Geophysical Survey of the Grindstone Dam Reservoir Area

Hydrogeology and Groundwater Unit

Ecological and Water Resources Division

Minnesota Department of Natural Resources

October 2021

Introduction and methods

The Lower Grindstone Reservoir and the City of Hinckley are located in a potentially karst-prone area for the underlying Hinckley Sandstone. Approximately 15 miles northeast of Hinckley, hundreds of sinkholes have been mapped in the Hinckley Sandstone as present near Sandstone and Askov, Minnesota (Shade and others, 2001). In Askov, lagoons for the wastewater treatment facility were unknowingly constructed over active karst terrain, which caused lagoon failure, and drainage concerns due to the presence of conduits and sinkholes in the Hinckley Sandstone. Karst-related features have not been documented in the area of the dam, however, similar geological conditions in the Grindstone Dam Removal Project area (less than 50 feet of glacial sediment overlying sandstone), raised questions regarding the possibility of land slumping or sinking due to dewatering and collapse of karst related conduits or sinkholes in bedrock beneath the area.

In order to better understand potential impacts from the proposed project due to the geology of the area, the Final Scoping Decision Document for the Grindstone Dam removal project recommended collecting site-specific information regarding the electrical resistivity of subsurface geological materials near the Dam and in nearby cleared terrestrial areas within a 250-meter zone, (see section 6.5 Geology Study of the Final Scoping Decision Document). Under favorable conditions, the resistivity method can show karst fractures, especially if the resistivity survey lines are oriented approximately perpendicular to fracture and karst trends. Prior to siting the resistivity lines, staff decided to conduct an investigation of surface anomalies observed on LIDAR imagery that might be karst-related features such as sinkholes, seeps, or springs.

Field survey of LIDAR imagery surface anomalies April 30, 2021

Prior to the 2021 field season, Professor Emeritus Dr. E. Calvin Alexander, Jr. was contacted regarding geological interpretations of the area and volunteered to participate in the field survey. As a coauthor of the Sinkhole Distribution Plate of the Geologic Atlas of Pine County and author of numerous karst publications, Dr. Alexander is knowledgeable about this topic. DNR provided Dr. Alexander with the best available LIDAR hillshade imagery of the area, and he identified 22 small circular depressions on the imagery that could indicate sinkholes. On April 30, 2021, Jim Berg, DNR hydrogeologist, and Dr. Alexander visited 12 of the anomalies to determine if they were closed depressions that could be sinkholes. The locations are shown on **Figure 1** and the results are summarized in **Table 1**.

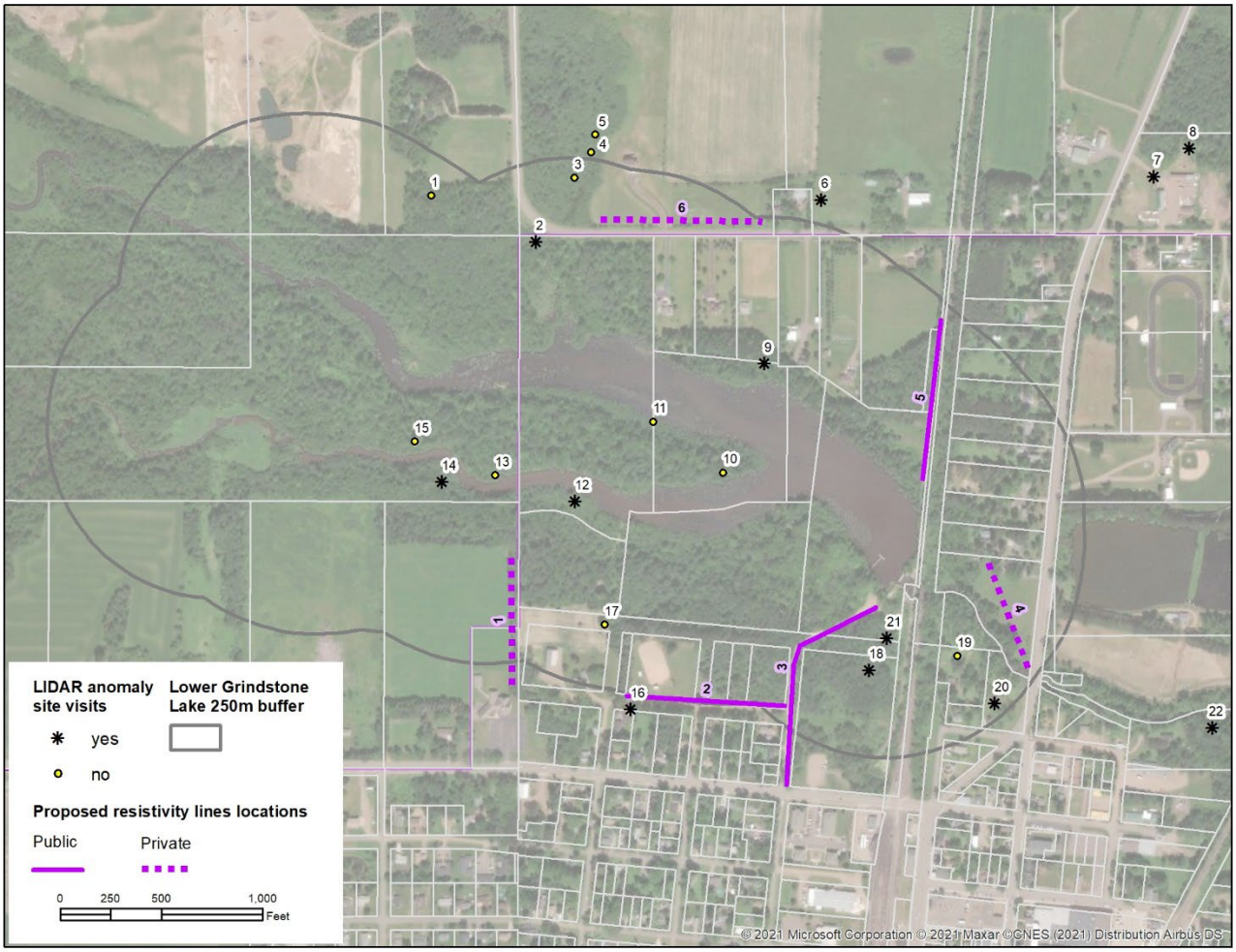


Figure 1 **Locations of LIDAR surface anomalies and proposed resistivity lines**

Table 1 Summary of LIDAR anomaly field observations

Feature ID	Staff	Public land	Observations	Interpretation	Comments
1	JAB	no	none	none	Called landowner for permission, no answer or call back
2	JAB, ECA	yes	**Groundwater seep**	Karst association unknown	Marsh marigolds observed
3, 4, and 5	JAB, ECA	no	none	none	Features not seen, property access denied
6	JAB, ECA	no	Brush filled hole in mowed field, approx. 10 x 20 feet diameter	**Possible sinkhole feature similar to that seen in SE MN**	Feature viewed from off the property, direct access denied, **photo included**
7	JAB, ECA	no	Near septic tank	No visible karst related features	LIDAR anomaly may have been a hole at one time but are now filled.
8	JAB, ECA	no	Subtle depression at edge of woods, Recently covered with fill	No visible karst related features	LIDAR anomaly may have been a hole at one time but are now filled.
9	JAB, ECA	yes	Depression seen but feature was not closed	No visible karst related features	none
10 and 11	none	yes	none	none	Features not visited due to peninsula location

Feature ID	Staff	Public land	Observations	Interpretation	Comments
12	JAB, ECA	yes	No depression found site is very overgrown	No visible karst related features	none
13	none	yes	none	none	Feature not visited due to peninsula location
14	JAB, ECA	yes	**Low flow spring** found near this location	Karst association unknown	none
15	none	yes	none	none	Feature not visited due to peninsula location
16	JAB	no	No closed depression, drainage ditch area	No visible karst related features	Area visible from the street
17	JAB	no	none	none	Could not contact landowner
18-1 and 18-2	JAB, ECA	yes	Two -- 5-to-8-foot diameter water filled holes approx. 2 feet deep	**Possible sinkholes**	**Photos included**
19	JAB	no	none	none	Could not contact landowner
20	JAB	no	Low wet area near well.	Karst association unknown	The landowner indicated that this area was a **filled in seep**
21	JAB, ECA	yes	Large (30 feet diameter) water filled depression	Possible borrow pit	Seemed too big to be karst related.

Feature ID	Staff	Public land	Observations	Interpretation	Comments
22	JAB, ECA	yes	Subtle depression in woods at city park	Karst association unknown	none

JAB – James A, Berg, ECA – E. Calvin Alexander

LIDAR surface anomaly site visit results

In the County Geologic Atlas of Pine County Part A (Plate 6, Shade and others, 2001) the authors write;" Although the sinkholes in Pine County occur in a variety of shapes and sizes, a common morphology is a sinkhole a few meters in diameter and less than two meters deep that is a concave downward funnel. The debris filled hole at location 6 (**Figure 2.** left photo) seemed like a probable sinkhole to Dr. Alexander based on the similarity of this feature to sinkholes that he has seen in southeastern Minnesota and other parts of Pine County. The two water-filled holes at location 18 **(Figure 2**, right two photos) could have been sinkholes since they are closed depressions (possible sinkholes, photos included). Three seep or spring features were found (locations 2, 14, and 20) which may or may not be related to karst features. One of the limitations of trying to find karst features from LIDAR anomalies is the age of the LIDAR coverage (2006, https://gisdata.mn.gov/dataset/elev-lidar-pine2006). It is possible that some of the locations that might have been holes in 2006 have since been filled in this urban area.

Figure 2. LIDAR surface anomaly locations 6, 18-1, and 18-2 interpreted as probable and possible sinkholes.

Ideally the surface and subsurface phases of the project (LIDAR anomaly evaluation and electrical resistivity survey) would have been integrated and complementary by locating the resistivity lines near the possible or probable sinkholes. Unfortunately, LIDAR surface anomaly location 6 was located on land where the MNDNR staff were denied access permission. LIDAR surface anomalies 18-1 and 18-2 were in a forested area that could not be directly accessed with resistivity survey equipment and the nearby areas (proposed resistivity lines 3 and 4) were not suitable for the resistivity survey method due to buried metal pipes and crushed rock.

Electrical resistivity survey - Introduction

Resistivity imaging may help resolve karst features in fracture-controlled karst. The method was successfully employed in the Galena karst at Mystery Cave State Park (Petersen, 2001). The Hinckley karst in Pine County is sandstone karst and resistivity imaging may not illuminate this type of karst as well as it does the limestone karst at Mystery Cave.

The Grindstone Dam Removal Final Scoping Decision Document, Section 6.5, suggested conducting up to 10 resistivity lines in a fashion similar to that completed at Mystery Cave. The resistivity lines at Mystery Cave were 165 meters long and oriented approximately perpendicular to the main cave passage orientation (which follows the major joint orientation).

Most known sinkholes in the Hinckley Sandstone are near Banning State Park and Askov. The major orientation of sinkholes and caves in that area is approximately southwest-northeast. Robinson's Ice Cave (a cave in the Hinckley Sandstone along the Kettle River just north of the City of Sandstone) has the same southwest-northeast orientation. Thus, an ideal resistivity line orientation might be approximately northwest-southeast in the Grindstone Dam area.

Since much of the land is privately held and the State of Minnesota owned land is heavily forested, site access near Grindstone Dam is very limited. This lack of access limited the ability to collect data in a pattern similar to the survey at Mystery Cave.

Proposed resistivity survey sites

Initially six locations were considered for resistivity surveys **(Figure 1).** Ultimately only two of the locations were surveyed due to a lack of access permission from private landowners at proposed locations 4 and 6, underground utilities at proposed location 3, and buried rock fill at location 5.

One of the proposed sites was the Munger Trail (location 5). A resistivity line at that location was not feasible because the trail is an old rail line built on rock ballast and it is not possible to inject electric current through that material. Furthermore, upon site inspection, DNR staff learned that there was not enough cleared area beyond the toe of the crushed rock base to allow the set up and retrieval of the field equipment. Proposed line 4 (**Figure 1**) is on private property east of the dam. DNR staff talked to the landowner when they were in the field but were refused admission to the property.

Resistivity data were collected along proposed lines 1 and 2, renamed Pine 15 and Pine 14, respectively. The lines were called Pine 14 and Pine 15 because they are the 14th and 15th resistivity lines collected in Pine County (lines 1-13 were collected for other projects). Pine 15 was collected on private property north of St. Paul Lutheran Church along proposed site 1. Pine 14 was located on the north edge of 3rd Street NW along proposed site 2 **(Figure 3).** DNR staff had permission to access the site from both the church and the neighboring property owner.

After reviewing data from the line at Pine 14, the DNR team determined that water and sewer pipes from the City of Hinckley underlay the entire area near Pine 14 and proposed line 3 so the team did not collect data along proposed line 3 (**Figure 1**).

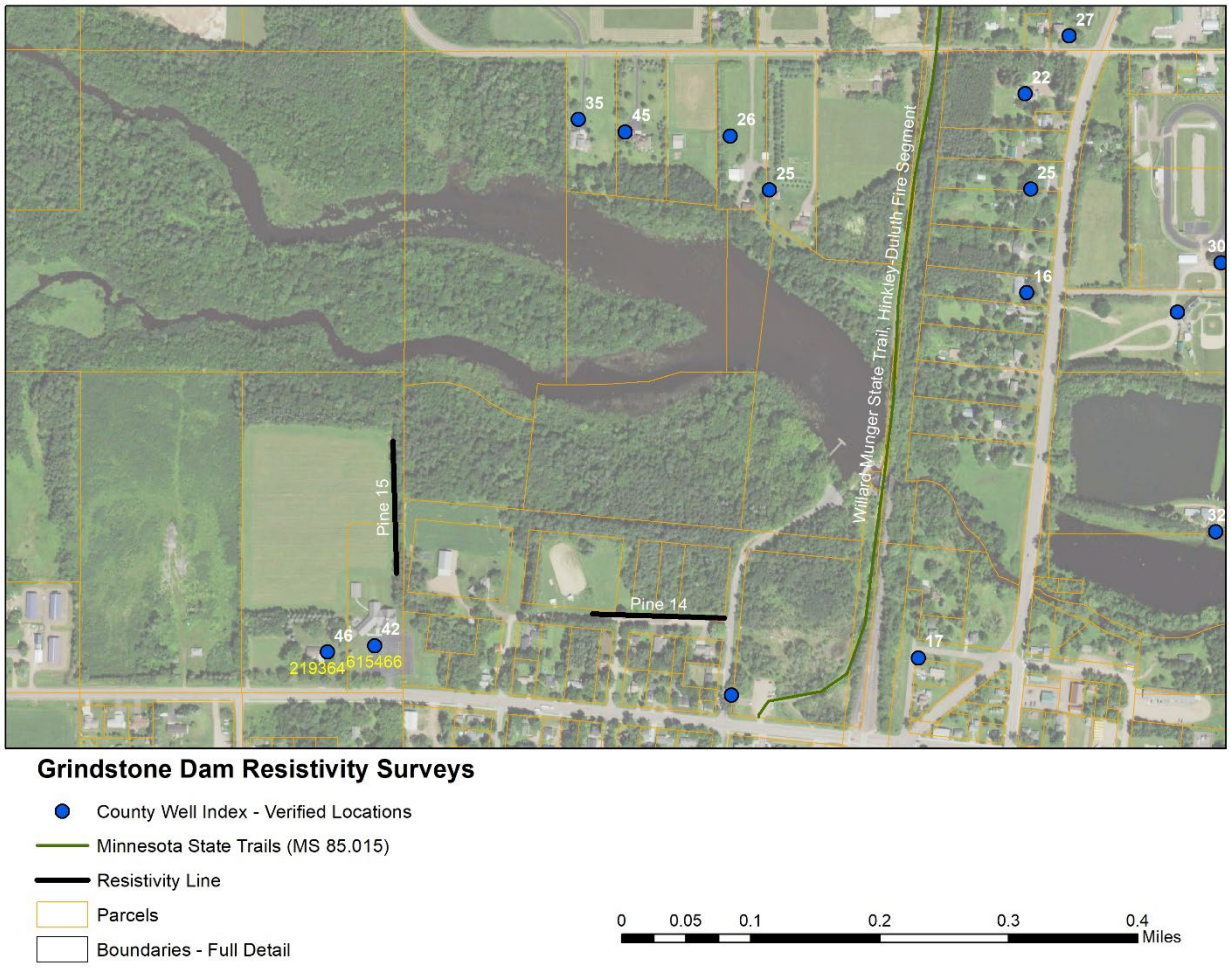


Figure 3. Map showing location of two resistivity lines collected near Grindstone Dam in August 2021. White numbers by wells indicate depth to bedrock in feet. Yellow numbers by wells indicate Minnesota Well Unique Number. Line names Pine 14 and Pine 15 were used, because they are the 14th and 15th resistivity lines collected in Pine County.

Resistivity imaging method and data processing

The resistivity imaging method uses standard arrays developed as sounding techniques and modifies them to create two-dimensional resistivity profiles. A line of electrodes is placed at equal 3-meter intervals along the desired profile. Four electrodes are used at one time. Two inject current into the ground and two read the electrical potential between them. The resistivity meter and switch box automatically read many combinations of current and potential electrodes from short offsets to long offsets starting at one side of the electrode spread and moving toward the opposite end. The short offsets analyze the shallow earth, and the longer offsets penetrate more deeply.

At Grindstone Dam, the resistivity data were collected with a Sting R1 Resistivity Meter in conjunction with the Swift automatic multi-electrode system. Fifty-six electrodes spaced 3 meters apart (for a total length of 165 meters) were used to collect each line. Data were collected using the dipole-dipole array.

The resistivity field data comprise resistance measurements between various electrodes and related geometry information. An apparent resistivity value is calculated, which depends only on the resistance measurements and the array geometry. These data are plotted as a pseudosection, which is a plot of the apparent resistivity values based on the geometry of the electrodes. Each apparent resistivity value is plotted midway between the set of electrodes used in making the measurement. The pseudo depth of each point is plotted at the median depth of investigation for the particular array. Pseudosections are difficult to work with and are not very meaningful to non-geophysicists. For these reasons, a data inversion is done to help with the interpretation. The inversion produces a plot that shows a resistivity value for each horizontal and vertical node. This resistivity inversion section is then used to interpret subsurface lithology.

These data were inverted with EarthImager, a commercially available program. Programming steps include editing out bad data points, setting up appropriate horizontal and vertical filters, selecting the inversion method, and then interpreting the data.

Results of electrical resistivity survey

Pine 15

Resistivity Line Pine 15 shows glacial material overlying Hinckley Sandstone. Line Pine 15 runs south to north (**Figures 3 and 4**) and is located on the east edge of a soybean field. The area interpreted as likely Hinckley Sandstone has higher resistivity than the overlying glacial sediment (**Figure 4**). The resistivity data show glacial material overlying Hinckley Sandstone to a depth of approximately 15 meters. This is generally consistent with the depth to Hinckley Sandstone of 42 feet reported at the church well (unique well 615466) and 46 feet reported at the neighbor's well (unique number 219364). The Hinckley Sandstone south of electrode 36 has slightly lower apparent resistivity than the rest of the line. This anomaly may indicate weathered sandstone, but that cannot be confirmed without drilling.

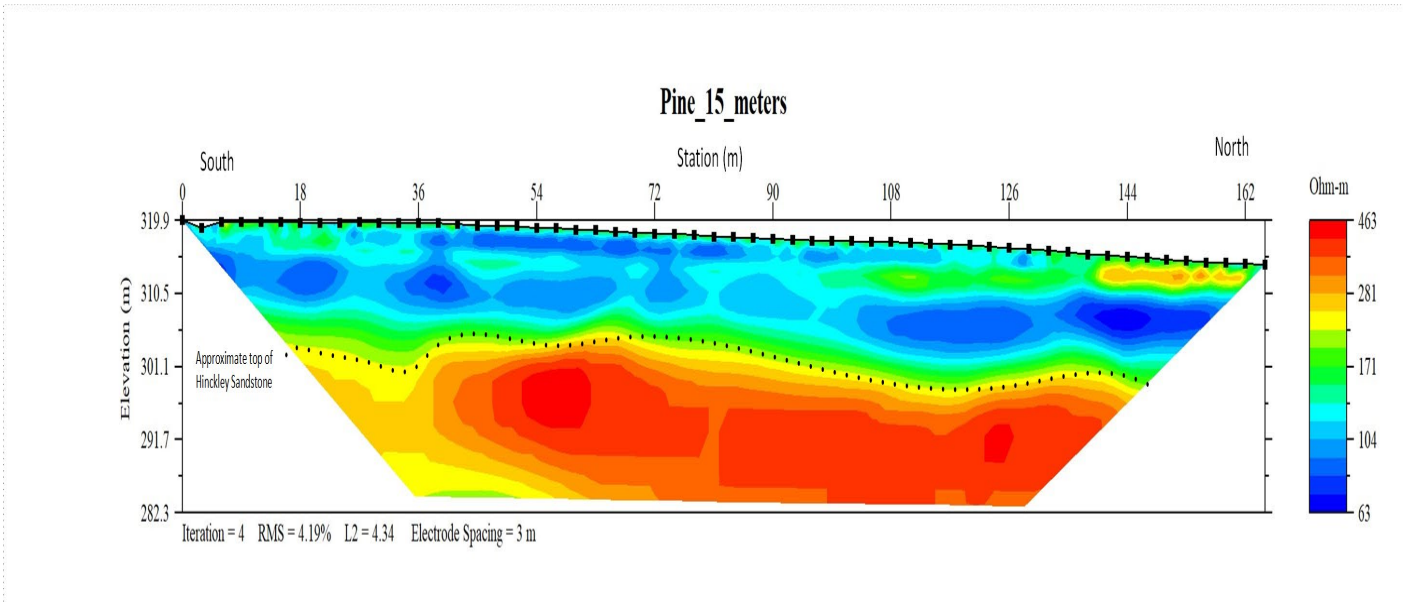


Figure 4. Resistivity imaging line Pine 15 showing interpretation of Hinckley Sandstone. Horizontal coordinates are in meters.

The study design described in the Final Scoping Decision Document had recommended "If bedrock anomalies are identified by the resistivity study, shallow (approximately 5 to 25 feet) augured borings would be drilled at these locations to determine if these anomalies represent sinkholes or conduits associated with karst." This anomaly may indicate the presence of weathered sandstone, but that cannot be confirmed without drilling. The anomaly detected at Pine 15 is probably 40 to 60 feet deep. This depth range is deeper than the shallow interval of 5 to 25 feet outlined in the Final Scoping Decision Document for the Grindstone Dam removal project. Shallow karst features were assumed to present a higher risk for land subsidence than deeper features that would be farther below the lowered water table after the reservoir was drained. Therefore, this deeper feature imaged on Pine 15 did not justify a higher level of scrutiny that drilling and coring might have provided.

Minnesota Unique Well Number

219364

County Pine
Quad Hinckley
Quad ID 188C

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING REPORT
Minnesota Statutes Chapter 1031

Entry Date 04/17/1988
Update Date 02/14/2014
Received Date

Well Name	Township	Range	Dir	Section	Subsection
LYON, JOHN	41	21	W	23	ADDCAD

Elevation 1052 **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address
C/W HINCKLEY MN 55037

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
RED CLAY	0	42		
SAND & ROCKS	42	46		
ROTTEN SANDROCK	46	59		
SANDROCK	59	100		

Remarks

Well Depth 100 ft. **Depth Completed** 100 ft. **Date Well Completed** 04/13/1968
Drill Method **Drill Fluid**
Use domestic **Status** Active
Well Hydrofractured? Yes ☐ No ☐ **From** **To**
Casing Type Single casing **Joint**
Drive Shoe? Yes ☐ No ☐ **Above/Below** 0 ft.
Casing Diameter 5 in. To 62 ft. **Weight** lbs./ft.
Open Hole From 62 ft. To 100 ft.
Screen? ☐ **Type** **Make**
Static Water Level 37 ft. land surface Measure 04/13/1968
Pumping Level (below land surface) 80 ft. hrs. Pumping at 13 g.p.m.
Wellhead Completion
Pitless adapter manufacturer Model
☐ Casing Protection ☐ 12 in. above grade
☐ At-grade (Environmental Wells and Borings ONLY)
Grouting Information Well Grouted? ☐ Yes ☐ No ☒ Not Specified
Nearest Known Source of Contamination
feet Direction Type
Well disinfected upon completion? ☐ Yes ☐ No
Pump ☐ Not Installed Date Installed
Manufacturer's name
Model Number HP 0 Volt
Length of drop pipe ft Capacity g.p. Typ
Abandoned
Does property have any not in use and not sealed well(s)? ☐ Yes ☐ No
Variance
Was a variance granted from the MDH for this well? ☐ Yes ☐ No
Miscellaneous
First Bedrock Hinckley Sandstone Aquifer Hinckley
Last Strat Hinckley Sandstone Depth to Bedrock 46 ft
Located by Minnesota Geological Survey
Locate Method Digitized - scale 1:24,000 or larger (Digitizing Table)
System UTM - NAD83, Zone 15, Meters X 503731 Y 5096141
Unique Number Verification Information from Input Date 01/01/1990
Angled Drill Hole
Well Contractor
Rosga Well Co. 58069 ROSGA, A.
Licensee Business Lic. or Reg. No. Name of Driller

Minnesota Well Index Report | 219364 | Printed on 08/17/2021 HE-01205-15

Figure 5. Well log for Minnesota Unique Well 219364

Minnesota Unique Well Number

615466

County Pine
Quad Hinckley
Quad ID 188C

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING REPORT
Minnesota Statutes Chapter 1031

Entry Date 02/11/1999
Update Date 02/14/2014
Received Date

Well Name	Township	Range	Dir	Section	Subsection
SCHMIDT, G.A.	41	21	W	23	ADDDAC

Elevation 1053 **Elev. Method** 7.5 minute topographic map (+/- 5 feet)

Address

Well 405 2ND ST NW HINCKLEY MN 55037

Stratigraphy Information

Geological Material	From	To (ft.)	Color	Hardness
TOP SOIL	0	2		
CLAY	2	30		
BOULDERS	30	42		
SANDSTONE	42	85		

Remarks

Well Depth 85 ft. **Depth Completed** 85 ft. **Date Well Completed** 11/17/1998

Drill Method Non-specified Rotary **Drill Fluid** Bentonite

Use domestic **Status** Active

Well Hydrofractured? Yes ☐ No ☒ **From** **To**

Casing Type Single casing **Joint** Welded

Drive Shoe? Yes ☒ No ☐ **Above/Below**

Casing Diameter	Weight	Hole Diameter
6 in. To 46 ft.	18.9 lbs./ft.	10 in. To 46 ft.
		6 in. To 85 ft.

Open Hole From 46 ft. To 85 ft.

Screen? ☐ **Type** **Make**

Static Water Level
30 ft. land surface Measure 11/17/1998

Pumping Level (below land surface)
85 ft. 1 hrs. Pumping at 25 g.p.m.

Wellhead Completion
Pitless adapter manufacturer Model
☐ Casing Protection ☒ 12 in. above grade
☐ At-grade (Environmental Wells and Borings ONLY)

Grouting Information Well Grouted? ☒ Yes ☐ No ☐ Not Specified

Material	Amount	From	To
	13 Sacks	0 ft.	46 ft.

Nearest Known Source of Contamination
101 feet South Direction Septic tank/drain field Type
Well disinfected upon completion? ☒ Yes ☐ No

Pump ☒ Not Installed Date Installed
Manufacturer's name
Model Number HP Volt
Length of drop pipe ft Capacity g.p. Typ

Abandoned
Does property have any not in use and not sealed well(s)? ☐ Yes ☒ No

Variance
Was a variance granted from the MDH for this well? ☐ Yes ☒ No

Miscellaneous
First Bedrock Hinckley Sandstone Aquifer Hinckley
Last Strat Hinckley Sandstone Depth to Bedrock 42 ft
Located by Minnesota Geological Survey
Locate Method Digitized - scale 1:24,000 or larger (Digitizing Table)
System UTM - NAD83, Zone 15, Meters X 503790 Y 5096149
Unique Number Verification Tag on well Input Date 07/16/1999

Angled Drill Hole

Well Contractor
Mccullough & Sons 82054 COX, B.
Licensee Business Lic. or Reg. No. Name of Driller

Minnesota Well Index Report | 615466 | Printed on 08/17/2021 HE-01205-15

Figure 6. Well log for Minnesota Unique Well 615466.

Pine 14

Line Pine 14 runs west to east (**Figure 3**). The four red vertical hatch marks show the location of water valves that were just north of line Pine 14 (**Figure 7**). The underground water pipes that feed these valves likely run north-south underneath resistivity line Pine 14. Unfortunately, the geology was totally obscured by the presence of water and sewer lines which provide short-circuit paths and electrical noise that interfere with measurements. Thus, a geologic interpretation cannot be made along this line.

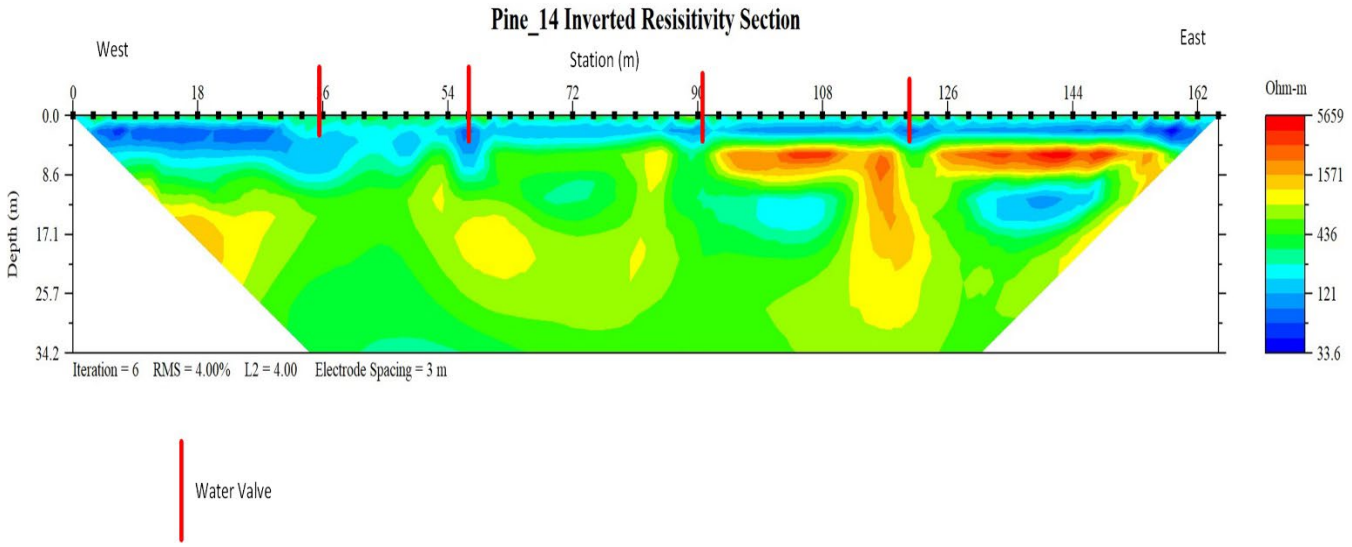


Figure 7. Resistivity Line Pine 14. The resistivity features on this line are all related to water and sewer pipes that underlie the line. The "water valves" show the location of pipes that lie underneath and perpendicular to the resistivity line. The inversion software that created this figure cannot properly account for the current flow through pipes, so the deeper data are not meaningful.

Table 2 Proposed resistivity lines compared with collected lines, with explanatory comments. Six lines were proposed, two were collected.

Proposed Resistivity Line	Collected Resistivity Line	Comments
1	Pine 15	Interpretable resistivity line showing glacial sediment over Hinckley Sandstone. Small resistivity anomaly in Hinckley Sandstone on south end of line.
2	Pine 14	Water and sewer pipes underlie the resistivity line. Resistivity data show location of pipes. Cannot make geologic interpretation below pipes.
3	--	Did not collect resistivity data. Water and sewer pipes underlie proposed site.
4	--	Did not collect resistivity data. Landowner denied access.
5 (on Munger Trail)	--	Did not collect resistivity data. Munger Trail is underlain by rock ballast. Cannot conduct resistivity survey on rock ballast.
6	--	Did not collect resistivity data. Landowner denied access.

Summary and conclusions

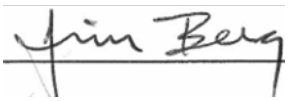
Review of the best available LIDAR hillshade imagery highlighted 22 possible karst features on the land surface near the Grindstone Dam site. A field survey including 12 of the potential 22 sites provided some evidence of karst features. The density and depth of the features are significantly less than that documented in the Askov area.

The resistivity method was chosen as a non-invasive geophysical technique that could possibly show karst fractures. The resistivity method can show karst fractures, especially if the resistivity survey lines are oriented approximately perpendicular to fracture and karst trends. Due to limited access and cultural noise (buried water and sewer lines) within the City of Hinckley, only two sites were successfully surveyed. Line Pine 14 was collected over buried water and sewer lines and provided no useful geologic information. Line Pine 15 showed the approximate top of the Hinckley Sandstone at a depth of about 15 meters (approximately 45 feet) and a slight resistivity anomaly on the south end of the line. This resistivity anomaly might be associated with more weathered Hinckley Sandstone. The study design described in the Final Scoping Decision Document had recommended "If bedrock anomalies are identified by the resistivity study, shallow (approximately 5 to 25 feet) augured borings would be drilled at these locations to determine if these anomalies represent sinkholes or conduits associated with karst." Shallow karst features were assumed to present a higher risk for land subsidence than deeper features that would be farther below the lowered water table after the reservoir was drained. Therefore, this deeper feature imaged on Pine 15 did not justify a higher level of scrutiny that drilling and coring might have provided.

Prior to these investigations the general consensus of the DNR geoscientists involved was that the risk was low to negligible for land subsidence in the area from reservoir drainage and associated water table affects. After these limited surface and geophysical surveys, the risk is still considered low to negligible.

PROFESSIONAL GEOLOGIST

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Geologist under the Laws of the State of Minnesota.

License No: 30501 *Signature:* 

Jim Berg

License No: 30173 *Signature:* 

Todd Petersen

References

Shade, Beverley, L. and others, 2001, Geologic atlas of Pine County, Minnesota: Minnesota Geological Survey, County Atlas Series C-13, Part A, Plate 6.

Petersen, Todd A. and James A. Berg, 2001, Karst mapping with geophysics at Mystery Cave State Park, Minnesota. https://files.dnr.state.mn.us/waters/groundwater_section/geophysics/reports/mystery_karst.pdf