County Geologic Atlas Program
Part A: Geologic Setting

Bob Tipping
Minnesota Geological Survey

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

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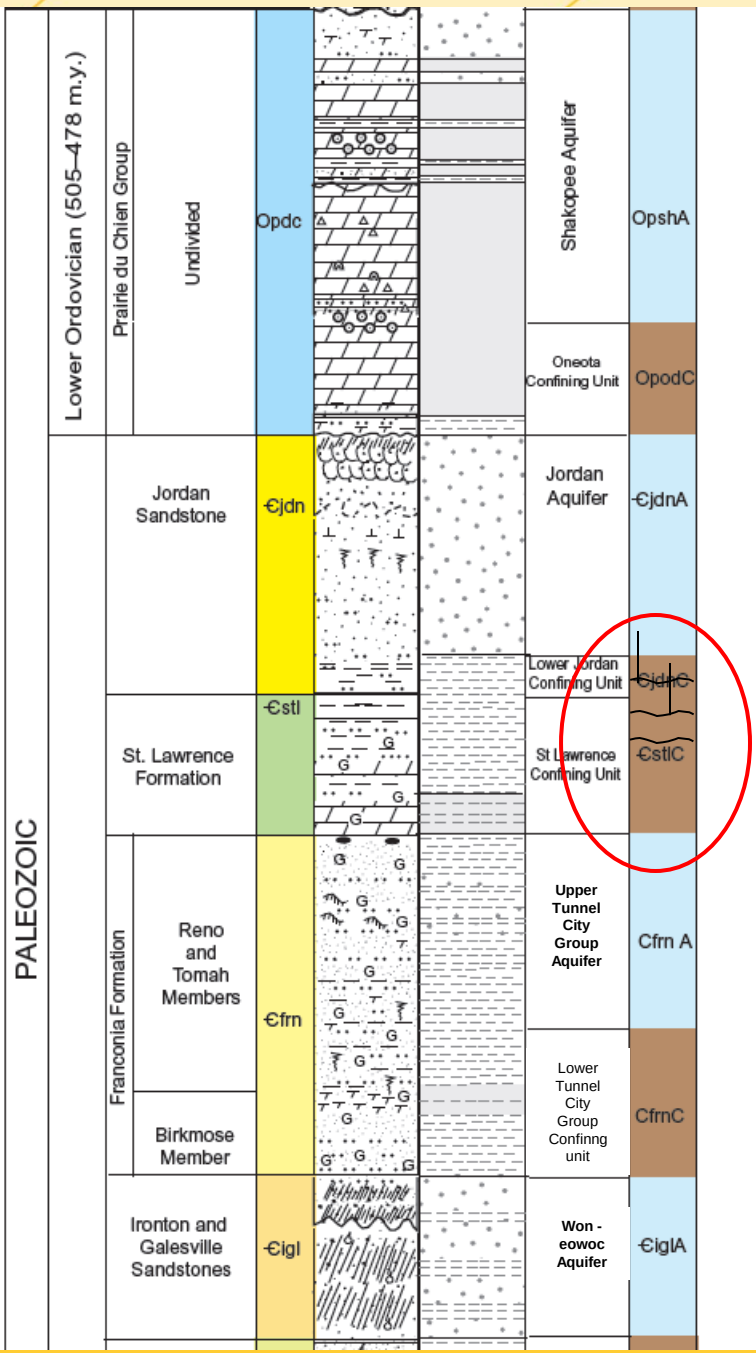
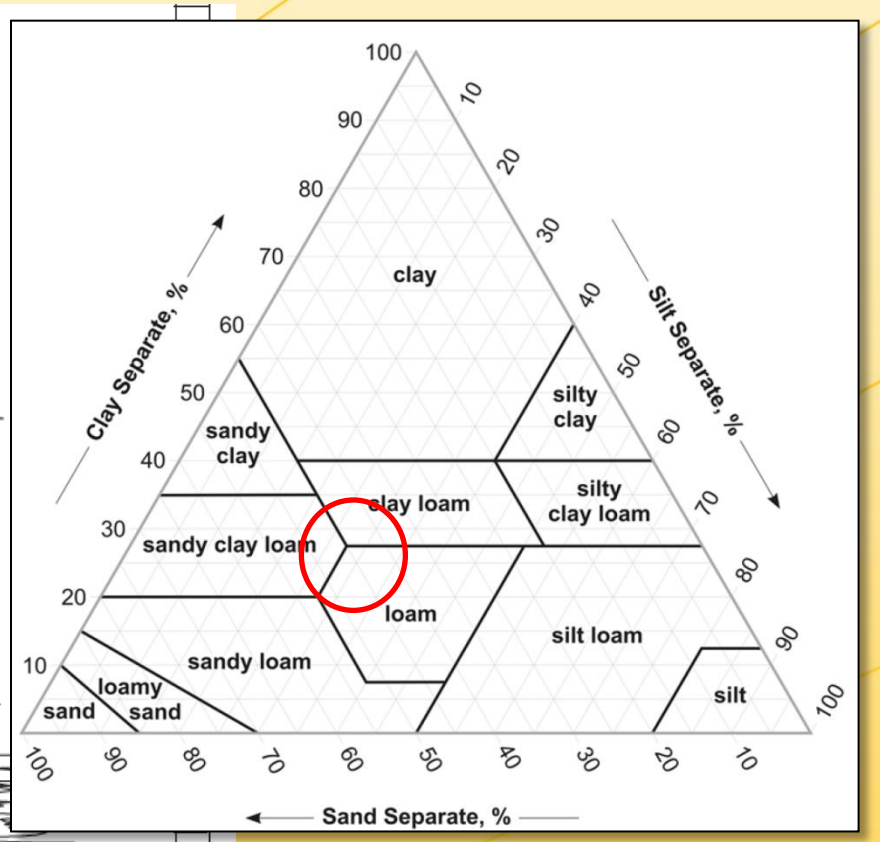
CLEAN WATER LAND & LEGACY AMENDMENT

Talk Outline

- Physical setting – formatting data suitable for modelers and water planners
- Components of a Part A data base plate
  - examples from Washington County
- What's next
  - Mapping heterogeneities in bedrock and unconsolidated deposits
  - Linking Part A products to other datasets
- Current Part A mapping status

- ***Physical setting – formatting data suitable for modelers and water planners [from USGS Circular 1186 'Sustainability of Ground-water Resources']***
  - *Mapping the extent, boundaries and upper and lower surfaces of aquifers and confining layers*
  - *Distribution of porosity and permeability **within** bedrock and unconsolidated deposits – mapping spaces within rocks and sediment*
    - *Aquifers*
    - *Confining layers*





UNIVERSITY OF MINNESOTA

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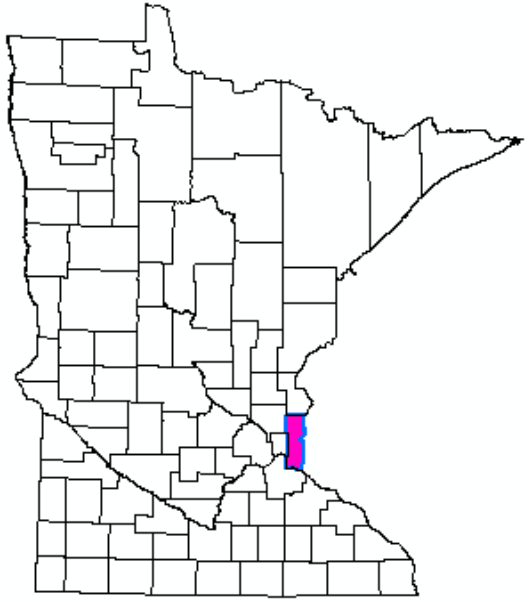
GEOLOGIC ATLAS OF WASHINGTON COUNTY, MINNESOTA
C-39, PART A

Emily J. Bauer, Project Manager

MINNESOTA GEOLOGICAL SURVEY
2016

⚡ = Hyperlink tool (menu bar) to activate links in the blue box

⚡ **Geologic Atlas User's Guide**



UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
Harvey Thorleifson, Director

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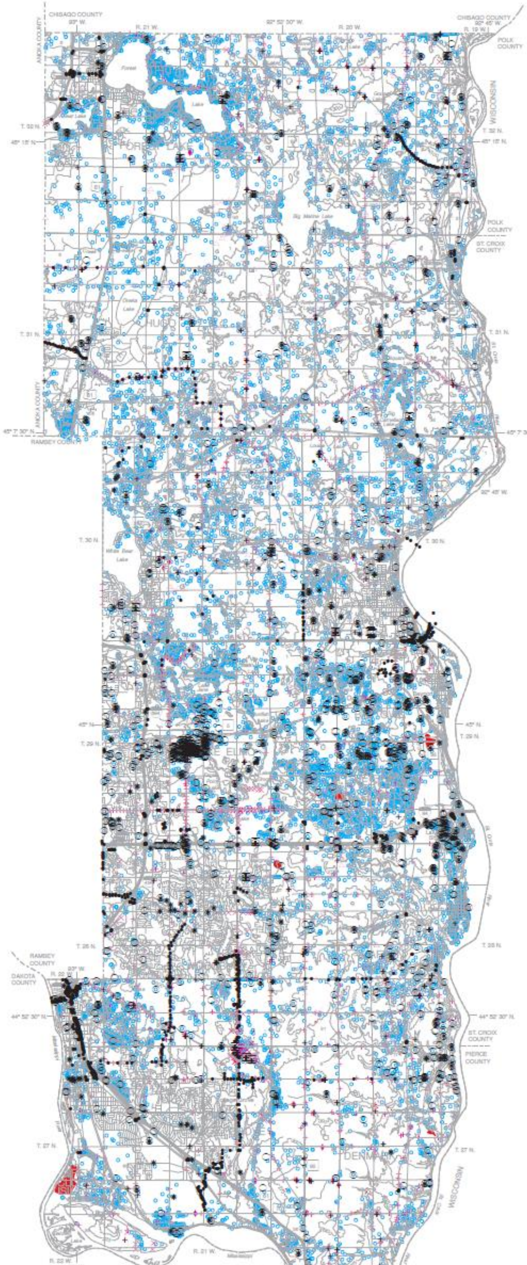
COUNTY ATLAS SERIES
ATLAS C-39, PART A
Washington County
Plate 1—Data-Base Map



Digital base modified from the Minnesota Department of Transportation BaseMap data; digital base annotation by the Minnesota Geological Survey.

Elevation contours were derived from the U.S. Geological Survey 30-meter Digital Elevation Model (DEM) by the Minnesota Geological Survey.

LOCATION DIAGRAM

DATA-BASE MAP

By

Emily J. Bauer and V.W. Chandler

2016

MAP SYMBOLS

- Record of water-well construction (well driller's log)
- Rotary-sonic core sample
- Cutting sample
- Borehole geophysical log
- Soil boring
- Giddings probe hole
- Field site
- Soil auger hole
- Textural analysis
- Passive seismic sounding
- Seismic refraction sounding
- Bedrock outcrop

Note: More than one symbol can occur at the same location

INTRODUCTION

The public health and economic development of Washington County are directly dependent on the wise use and management of its land and water resources. Geologic and hydrologic information are essential before decisions are made that affect natural resources. Although the amount of geologic information required for making specific decisions can vary, the information will not be used if it is unavailable when needed, or if it is available only in a highly technical form, or scattered in many different maps and reports. The data bases described here address this need.

County atlases, prepared jointly by the Minnesota Geological Survey and the Minnesota Department of Natural Resources, Division of Ecological and Water Resources, present detailed geologic and hydrologic information in an interpretive as well as descriptive form. Maps and texts summarize the current basic geologic and hydrologic conditions at a county scale, and interpret these conditions in terms of the impacts of possible land- and water-use decisions at the time they were created. The maps and texts in this current set of county geologic atlas plates are a reworking of the original maps that were created for the 1990 Washington County geologic atlas. The amount of data available for Washington County has more than tripled in the intervening 25 years since the original maps were published and our understanding of some of the geologic processes governing geologic features seen in the county has grown; thus it was necessary to update the maps to reflect these new data. Site-specific information is available in some areas at a greater level of technical detail than shown on the maps of this atlas. The data are too voluminous to present at the scale of this atlas, but have been incorporated into readily accessible files housed at the Minnesota Geological Survey.

Several sources commonly provide information about an area or an individual property, but they may use different classification schemes to describe the same geologic materials. As a result, discrepancies in interpreting the data may arise or the different sources may appear to contradict each other. For example, water-well drillers may describe glacial till as "clay," but engineering records will describe it as "clayey sand." Both descriptions are acceptable for their original purpose of describing the physical attributes of the material. "Clay," the term used by well drillers, defines the general inability of the till to yield groundwater to a well. "Clayey sand," the term from the engineering record, defines the physical composition of the till relative to particle size and engineering properties. The geologist must take the analysis one step further and define the material in terms of how it formed rather than how it is to be used. In this example, till consists of an unsorted mixture of rock fragments ranging in size from clay to cobbles and boulders, and it is interpreted by the geologist to have been deposited directly by glacial ice. Understanding the process by which the material formed allows geologists to make predictions about what lies between and beyond data points.

All of the types of data described on this plate were interpreted by geologists or hydrogeologists to make them meaningful for mapping purposes. The 1:100,000 scale of the maps in this atlas was chosen because it shows the geologic and topical studies of the county while keeping the physical size of each plate to a manageable level. As a result, some detailed information that was gained by data interpretation and mapping cannot be shown on these maps or discussed in the texts. Some of this information is available in digital files that accompany the atlas.

Whether to use the atlas alone, or in combination with the data bases, depends on the amount of detail needed. Generally, data-base information must be used to evaluate site-specific conditions.

DATA-BASE MANAGEMENT

All of the data shown on the maps were plotted on 7.5-minute topographic quadrangle maps or highway alignment maps and assigned inventory numbers. Automated data bases and a few manual files were developed to provide easy access and rapid retrieval of these site-specific data. The data may be obtained from the Minnesota Geological Survey.

Computer storage and retrieval systems are better than manual files for manipulating large amounts of data because automated geologic data bases can be designed to interact with other computer files, such as land-use data. Such interaction permits more efficient assessment of cause-and-effect relationships concerning natural resources than is commonly possible with manual files.

WASHINGTON COUNTY DATA BASES

Computerized files were developed for point-source data such as wells and borings in Washington County. They use Public Land Survey descriptions, Universal Transverse Mercator (UTM), and latitude-longitude coordinates as location criteria; thus, they are compatible with the natural-resource data bases housed at the Minnesota Land Management Information Center (LMIC). The computerized data base developed for Washington County by the Minnesota Geological Survey is the County Well Index (CWI).

County Well Index (CWI)—Information from water-well records and exploration holes is entered into this statewide data base. Each well log is assigned a six-digit unique number and each exploration drill hole is assigned either a five- or six-digit unique number. These reference numbers are also used by state agencies and the Water Resources Division of the U.S. Geological Survey. Elevations are expressed in feet above sea level and were determined either from topographic maps (see the index to 7.5-minute quadrangles) or Minnesota's lidar high-resolution elevation data set. Elevations from the topographic maps are generally accurate to plus or minus 5 feet (1.5 meters) and the lidar elevations are generally accurate to within 3 feet (1 meter). The street address of each well is also included wherever possible to provide data users with a well-location system that is compatible with local regulatory programs. Software at the Minnesota Geological Survey is used to display and tabulate many of the data elements contained on the original well log.

The County Well Index is currently stored in a data base that consists of ten related tables. These tables contain information such as well depths, well construction, addresses, aquifers, dates drilled, static water levels, and pumping test data. They also contain alternate well identifiers such as permit numbers or emergency-service numbers, the well stratigraphy (the geologic materials encountered during drilling), and the azimuth and inclination of angled exploration holes.

CWI application software developed by the Minnesota Department of Health provides two types of reports:

WELL LOG contains all the information about the well as it was reported by the contractor (Fig. 1). There may also be additional location information, land-surface elevation, aquifer designation, and remarks about the drill hole.

WELL STRATIGRAPHY contains the geologic log with a geologist's stratigraphic interpretations, which are based on her or his knowledge and understanding of the geology of Washington County and augmented in some cases by additional data sources, such as cuttings, borehole geophysical logs, or core (Fig. 2). Only those drill holes with verified locations have stratigraphy assigned to them.

File data of the Minnesota Geological Survey—Details about other types of data shown on this plate are available from digital (including the Quaternary Data Index, an internal working data base) and paper files at the Minnesota Geological Survey. These include descriptions of cutting samples, soil borings, Giddings probe holes, field sites, soil auger holes, textural analyses, gravity and aeromagnetic data, passive seismic sites, and aggregate resources sites.

FUTURE DATA COLLECTION

Additional geologic information is generated continuously as new water wells are drilled, construction activities expose more bedrock, or additional wells are tested for water quality. To address this, the library of information prepared for Washington County is flexible so that old data can be reevaluated in light of new information, and new forms of data can be added if required. The need to manage groundwater and other natural resources wisely will never become outdated. Future demands on these resources will require current data to assess the impacts.

ACKNOWLEDGEMENTS

The staff from the Washington County Public Health and Environment Office contributed greatly to the development of the County Well Index (CWI) data base for this update of the county geologic atlas. We thank local water-well contractors and landowners for their valuable assistance.

THE DATA-BASE MAP

The types, locations, and density of information used to prepare the Washington County atlas are shown on this map. The data are described below to aid the user in assessing what types may be useful for a particular information need. The Data-Base Map serves as a guide to the precision of the other maps in the atlas. It shows where data are sparse or lacking and interpretation and extrapolation were required to prepare the maps. All data were collected by Minnesota Geological Survey staff unless otherwise specified.

DRILL-HOLE INFORMATION

A **record of water-well construction (well driller's log)** is a water-well contractor's description of the geologic materials penetrated during drilling and the construction materials used to complete the well. Not all wells extend to bedrock. In areas of thick, unconsolidated Quaternary deposits, drillers commonly do not need to drill through the entire thickness of overburden to find sufficient groundwater. Hydrologic data, such as the static water level and test-pumping results, are commonly included. Before any driller's log can be used, the location of the well must be verified, and a geologist must interpret the log. Driller's logs are the primary source of subsurface geologic and hydrologic data for Washington County; about 14,200 logs were used for this atlas; they can be found in the County Well Index (CWI).

Core samples were collected at various sites throughout Washington County as a means to establish the nature of the subsurface material. Rotary-sonic cores were collected by the Minnesota Geological Survey from 12 sites in the county (labelled WR-1 through WR-3 and WS-1 through WS-9) to aid both the interpretation of the Quaternary deposits and in determining bedrock depth and nature (where encountered). The coring technique enables recovery of a continuous core, 3.5 inches (8.9 centimeters) in diameter, from glacial deposits and bedrock (where intersected). It provides excellent subsurface samples for detailed study and comparison with cuttings, geophysical logs, and driller's logs from surrounding sites. Detailed geologist's logs for some of the cores are shown on Plate 4, *Quaternary Stratigraphy*. These logs are entered into the County Well Index (CWI) and any sampling results are available in Minnesota Geological Survey file data. There were an additional two rotary-sonic cores collected on the 3M site in Cottage Grove where two monitor wells were installed. The cores are available for inspection at the Minnesota Department of Natural Resources, Division of Lands and Minerals offices in Hibbing.

Cutting samples collected during drilling provide physical evidence of subsurface geologic materials. Cuttings are the samples generated as the drill bit cuts through the subsurface material and are used to interpret and verify driller's logs. They are logged and stored at the Minnesota Geological Survey.

Borehole geophysical logs are created by lowering instruments down a well or drill hole and measuring the physical and chemical properties of the geologic materials through which the hole passes. Different logging techniques measure naturally occurring gamma radiation, spontaneous potential, and resistivity. Gamma logs characterize in graphic form the geologic formations penetrated. Spontaneous potential and resistivity are mainly used to locate water levels in wells and the depth of the well casing. An interpretive log is prepared by a geologist from the geophysical log and correlated with drilling samples from the same hole, information obtained from nearby exposures, or a geophysical log from a nearby drill hole. Geophysical logs can provide high-quality subsurface geologic and hydrologic information for wells that have little or no other information available. The information obtained from a geophysical log is added to the County Well Index (CWI) and the paper log is on file at the Minnesota Geological Survey.

Soil borings are test holes drilled to obtain information about the physical properties of subsurface materials for engineering, mapping, or exploration purposes. They are logged by an engineer or a geologist using a variety of classification schemes based on particle sizes, penetration rate, moisture content, and color. Soil-boring data were collected by the Minnesota Department of Transportation and Washington County Public Works. They are somewhat limited in distribution in that they are concentrated along major roads such as U.S. Highway 10 and County Highway 19. These data are most useful in determining the composition of unconsolidated deposits. Descriptions of the geologic materials penetrated can be accessed in digital and paper files at the Minnesota Geological Survey; all other information collected is contained in paper files. The data are available from the Minnesota Department of Transportation, Foundations Unit webpage (http://www.mrr.dot.state.mn.us/geotechnical/foundations/Gis/gis_splash.html) and Washington County Public Works.

Giddings probe holes are borings of glacial materials, 2 inches (5.1 centimeters) in diameter, collected by a truck mounted hydraulic auger. A description was generated at every site and at most locations a sample or samples were taken for textural analyses. Samples were generally taken about every 5 feet (1.5 meters), at unit contacts, or where the geologist believed it was important.

OTHER INFORMATION

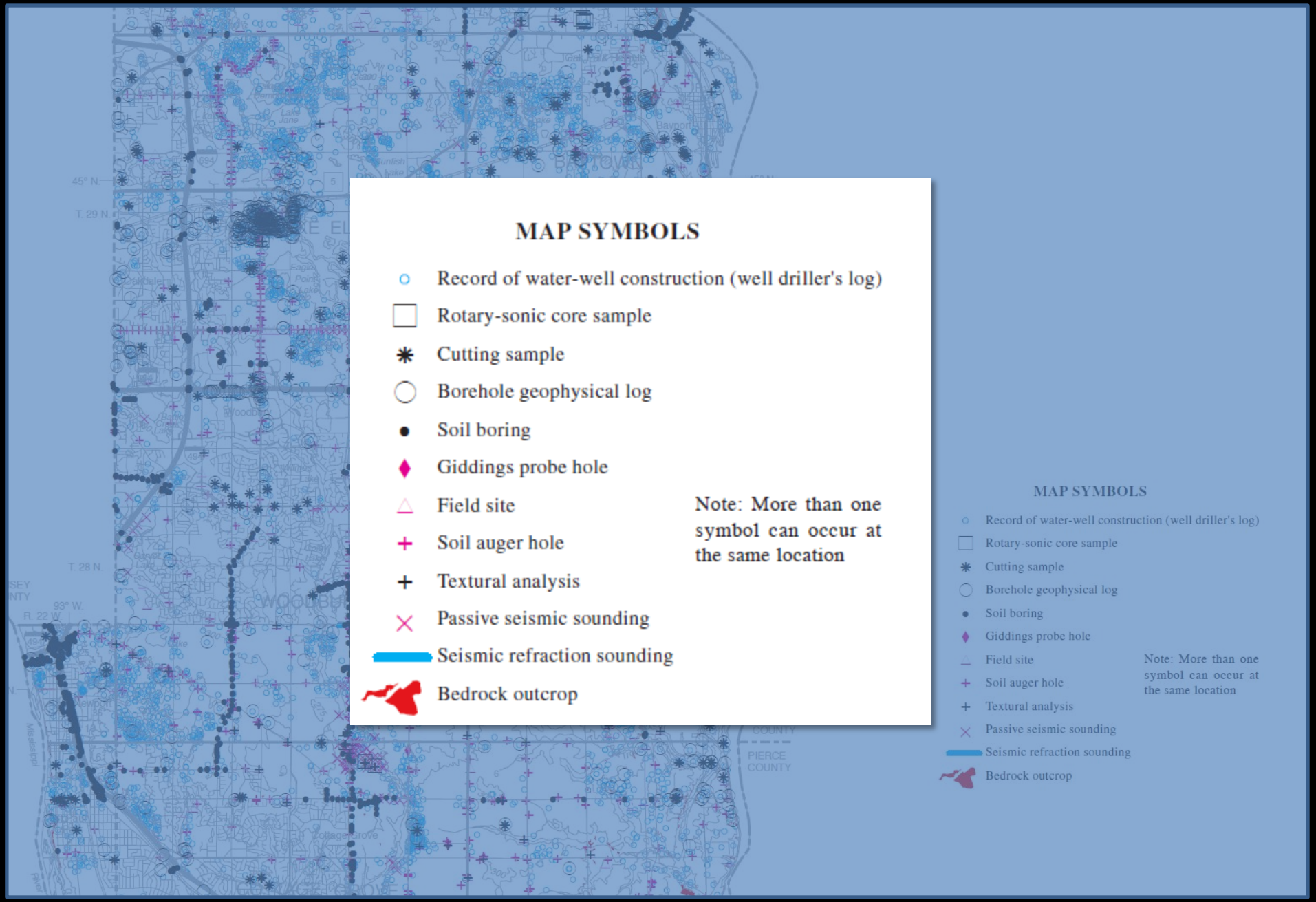
Field sites are natural and artificial exposures of unconsolidated Quaternary deposits that were described in detail; samples from many sites were texturally analyzed. Field sites include stream and river cuts, gravel pits, excavations, and road cuts. Data from the field sites can be found in Minnesota Geological Survey files. Additional gravel pit data may be found at the Minnesota Department of Transportation, Aggregate Source Information System webpage (http://www.dot.state.mn.us/materials/asismap.html).

Soil auger holes are shallow borings created to generate a description of the subsurface material. They are generally less than 5 feet (1.5 meters) in depth. The Minnesota Geological Survey used a hand auger and Washington County Public Works used a truck mounted auger to create the borings. Data from the soil auger holes can be found in Minnesota Geological Survey files.

Textural analyses express the proportion of sand-, silt-, and clay-size particles that make up a sample. The samples analyzed were taken from natural and artificial exposures, Giddings holes, soil auger holes, cutting samples, and the rotary-sonic cores. They are helpful in determining origin, correlation, and hydrologic properties of unconsolidated sediment. The data are available in Minnesota Geological Survey files.

Passive seismic depth to bedrock soundings provide information based on measurement and analysis of ambient shear and surface-wave energy in the ground that allow a calculation of the depth to bedrock (thickness of Quaternary deposits) beneath that point. The measurements employ a recording seismograph system that is implanted into the ground surface and records ambient ground vibrations in three orthogonal directions (2 horizontal and 1 vertical) during a 16-minute interval. The method is called passive because no energy is directly input into the ground at the time of measurement, such as is the case for conventional seismic sounding. Instead, the unit measures background vibrations from a variety of natural and artificial sources that include machinery, traffic, and wind. The averaged horizontal spectra of the seismic noise is divided by the corresponding vertical spectrum, and the resulting horizontal to vertical spectral ratio (HVSR) should display a prominent peak that closely approximates the resonant frequency (shear-wave) of the unconsolidated sequence overlying the bedrock surface. The resonant frequency of unconsolidated overburden is a useful parameter for seismic risk investigations, but here it is used to estimate the thickness of the overburden itself, which in our case is the Quaternary sequence. In this application, the HVSR method is calibrated by taking measurements at locations (control points) where the thicknesses of Quaternary deposits are known from either well data or from conventional seismic sounding. The control points are selected to approximately span the expected range of bedrock depths for the region, and the calibration curve that is fitted to these data can be used to estimate bedrock depth in areas lacking either drill hole or seismic control. Most bedrock depths from the HVSR method are estimated to be accurate to within an error of 15 to 25 percent, which is somewhat more than the 5 to 15 percent error that is generally expected with conventional seismic methods (refraction and reflection). Nonetheless, HVSR depth estimates are adequate for many county geologic atlas applications, and the HVSR method is considerably faster and cheaper, assuring that many soundings over a large area can be inexpensively acquired by one or two operators.

Seismic refraction soundings measure the time required for sound or pressure waves to travel from a source through the subsurface and be refracted back to a receiver. Travel time can be correlated with the density and rigidity of the geologic material. Precambrian rocks usually exhibit acoustic- or pressure-wave velocities 1.5 to 2.5 times those of unconsolidated Quaternary sediments below the water tables. The spacing of the receivers (geophones) and the arrival times (measured in milliseconds) are used to calculate the depth to Precambrian bedrock. Seismic refraction soundings are more labor intensive than passive seismic sounding, but can provide velocity information and higher-quality depth estimates. Seismic refraction soundings were not acquired for this update of the Washington County geologic atlas, but such soundings were used in the original atlas to help determine the depth to Paleozoic bedrock buried beneath the Quaternary deposits prevalent in the county. These data were acquired by the Minnesota Department of Natural Resources.


MAP SYMBOLS
Record of water-well construction (well driller's log)
Rotary-sonic core sample
Cutting sample
Borehole geophysical log
Soil boring
Giddings probe hole
Field site
Soil auger hole
Textural analysis
Passive seismic sounding
Seismic refraction sounding
Bedrock outcrop
Note: More than one symbol can occur at the same location
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Soil boring
Giddings probe hole
Field site
Soil auger hole
Textural analysis
Passive seismic sounding
Seismic refraction sounding
Bedrock outcrop
Note: More than one symbol can occur at the same location
45° N.
T. 29 N.
T. 28 N.
93° W.
R. 22 W.
PIERCE COUNTY

Unique Well Number 761628

County Washington
Quad Prescott
Quad Id 102D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

MINNESOTA STATUTES CHAPTER 1031

Entry Date 2008/07/11
Update Date 2014/08/18
Received Date 2008/08/26

Well Name AFTON ALPS I.W.

Township	Range	Dir	Section	Subsection	Field Located Elevation	MGS
27	20	W	2	BCBCCB	702.00	ft.

Well and Contact Address AFTON ALPS
6600 PELLER AV S
HASTINGS MN 55033 Changed

Well Depth	Depth Completed	Date Well Completed
285.00 ft	285.00 ft	2008/08/15

Drillhole Angle

Drilling Method Non-specified Rotary

Drilling Fluid Other

Well Hydrofractured? ☐ YES ☑ NO
From ft. to

Use Irrigation

Casing Type Steel (black or low Drive Shoe? ☑ YES ☐ NO
Diameter 16 Depth 90
16.00 in. from 0.00 to 90.00 ft. 16.58 lbs/ft

Hole Diameter (in.)
22.00 To 90.0
15.00 To 285.0

Description	Color	Hardness	From	To (ft.)
SAND/GRAVEL	BROWN	SOFT	0	75
SANDROCK	GREEN	M.HARD	75	78
SANDROCK	GREEN	MEDIUM	78	230
SANDROCK	GREEN	MEDIUM	230	240
SANDROCK	GRAY	MEDIUM	240	285

Screen No
Make
Diamter Slot Length Set
Type

Open Hole(ft.) From 90.0 to 285.0

Unique Well Number	County	Washington	MINNESOTA DEPARTMENT OF HEALTH	Entry Date	2008/07/11
761628	Quad	Prescott	WELL AND BORING RECORD	Update Date	2014/08/18
	Quad Id	102D	*MINNESOTA STATUTES CHAPTER 1031*	Received Date	2008/08/26

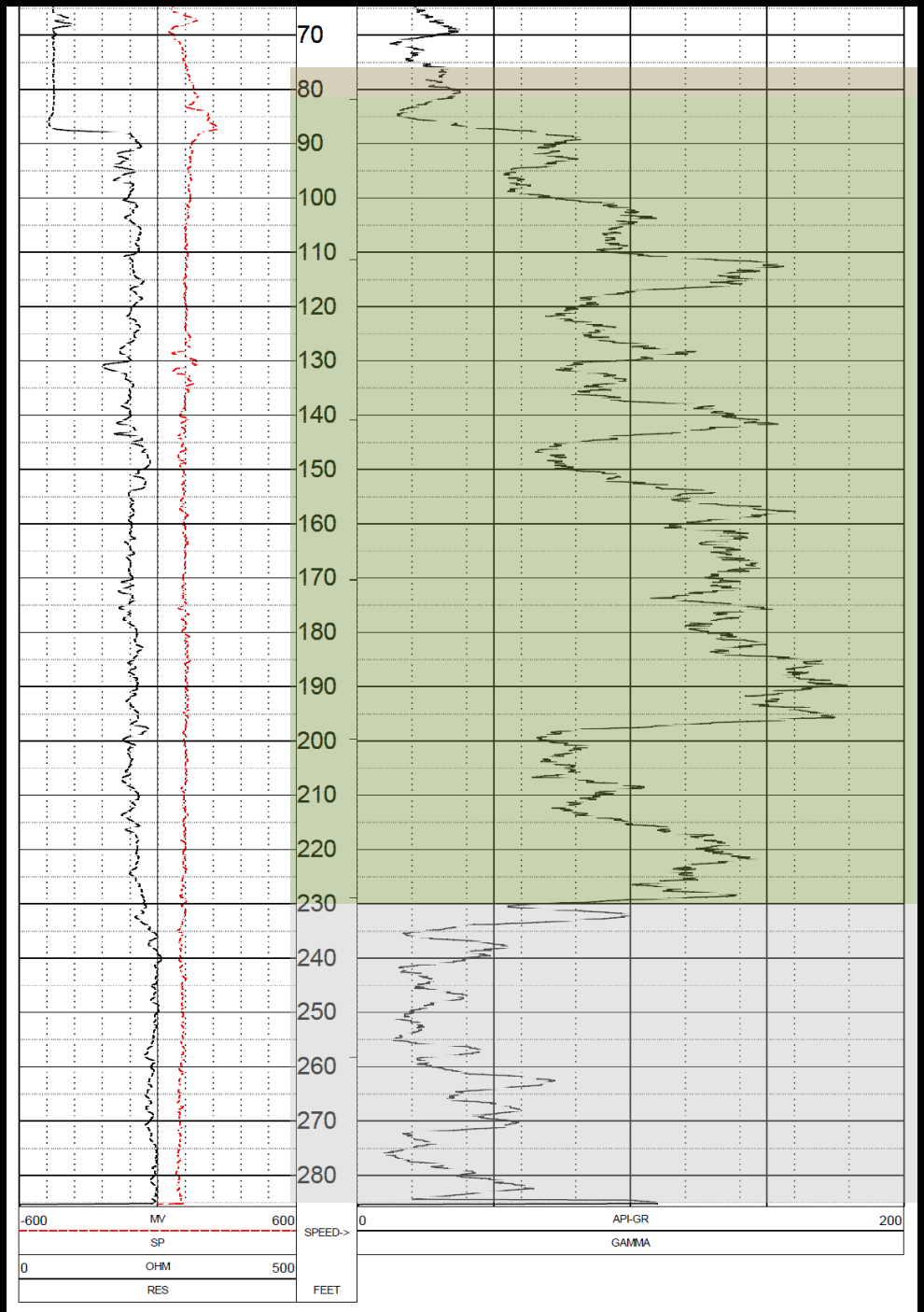
Elevation 702.00 **ft.** **Method** 7.5 minute topographic **Aquifer** Tunnel City-Wonewoc **Depth to Bedrock** 78 **ft.** **Ope**

Field Located Minnesota Geological Survey
Program
Uni No.Verified Information from owner
Geologic Interpretation John Mossler

Location Method Digitization (Screen) - Map (1:2 Unive
Input Source Minnesota Geological Survey
Input Date 2008/07/11
Agency MGS

Geological Material	Color	Hardness	DEPTH From	DEPTH To	Thick	ELEVATION From	ELEVATION To	Stratigraphy
SAND/GRAVEL	BROWN	SOFT	0	75	75	702	627	sand +larger-brown
SANDROCK	GREEN	M.HARD	75	78	3	627	624	Quaternary deposit
SANDROCK	GREEN	MEDIUM	78	230	152	624	472	Tunnel City Group
SANDROCK	GREEN	MEDIUM	230	240	10	472	462	Wonewoc Sandstone
SANDROCK	GRAY	MEDIUM	240	285	45	462	417	Wonewoc Sandstone

Interpretation Method Cuttings + geophysical log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OHM
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SPEED->
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API-GR
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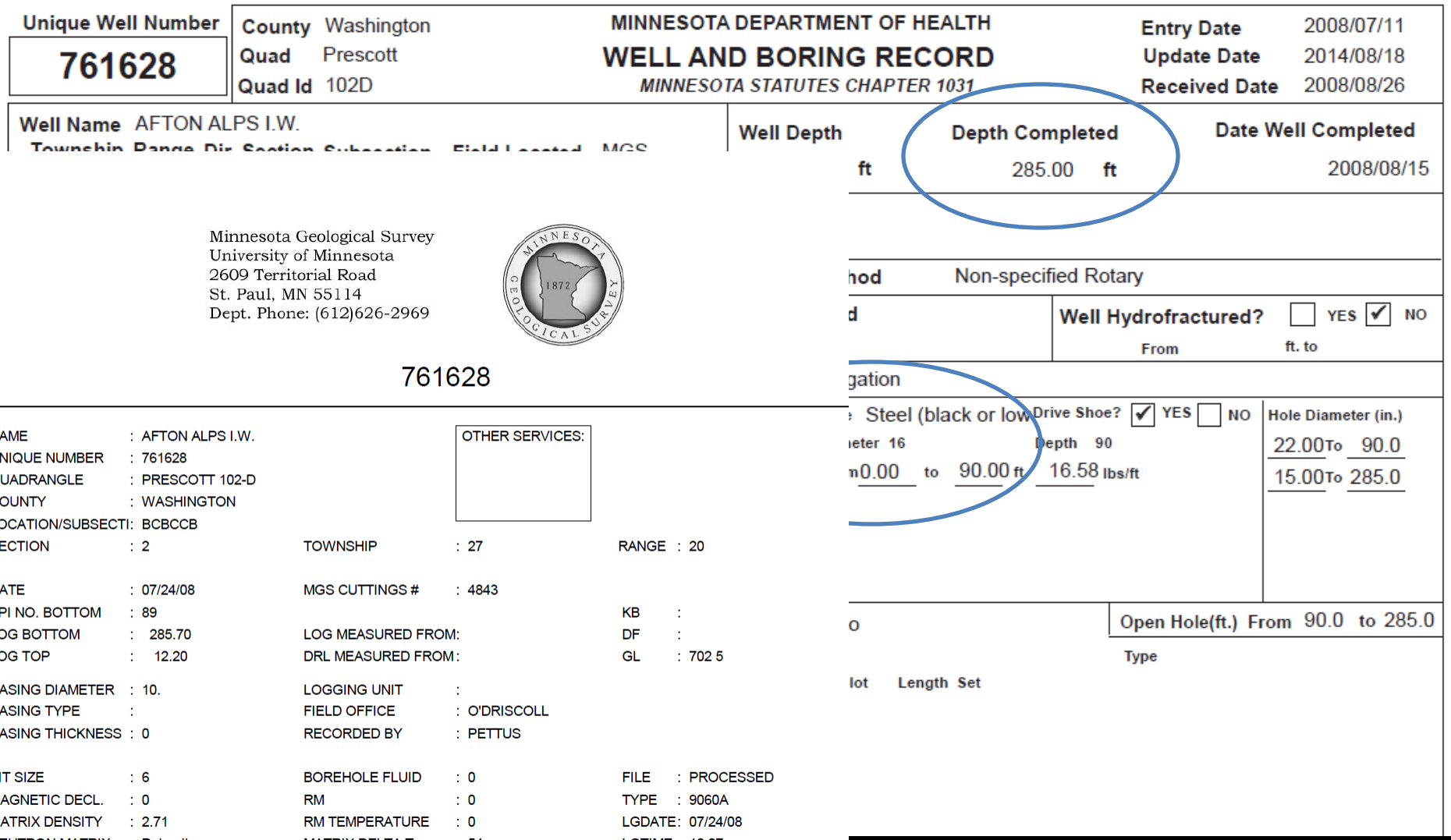

Unique Well Number
761628

County Washington
Quad Prescott
Quad Id 102D

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
MINNESOTA STATUTES CHAPTER 1031

Entry Date 2008/07/11
Update Date 2014/08/18
Received Date 2008/08/26

Well Name AFTON ALPS I.W.
Township Range Dir Section Subsection Field Located MGS

Well Depth
ft

Depth Completed
285.00 ft

Date Well Completed
2008/08/15

hod Non-specified Rotary

d

Well Hydrofractured? YES NO
From ft. to

gation

Steel (black or low
Drive Shoe? YES NO
eter 16
Depth 90
n 0.00 to 90.00 ft 16.58 lbs/ft

Hole Diameter (in.)
22.00 To 90.0
15.00 To 285.0

o

Open Hole(ft.) From 90.0 to 285.0

Type

lot Length Set

Minnesota Geological Survey
University of Minnesota
2609 Territorial Road
St. Paul, MN 55114
Dept. Phone: (612)626-2969

761628

NAME : AFTON ALPS I.W.
UNIQUE NUMBER : 761628
QUADRANGLE : PRESCOTT 102-D
COUNTY : WASHINGTON
LOCATION/SUBSECTI: BCBCCB
SECTION : 2 TOWNSHIP : 27 RANGE : 20

OTHER SERVICES:

DATE : 07/24/08 MGS CUTTINGS # : 4843
API NO. BOTTOM : 89 KB :
LOG BOTTOM : 285.70 LOG MEASURED FROM: DF :
LOG TOP : 12.20 DRL MEASURED FROM: GL : 702 5

CASING DIAMETER : 10. LOGGING UNIT :
CASING TYPE : FIELD OFFICE : O'DRISCOLL
CASING THICKNESS : 0 RECORDED BY : PETTUS

BIT SIZE : 6 BOREHOLE FLUID : 0 FILE : PROCESSED
MAGNETIC DECL. : 0 RM : 0 TYPE : 9060A
MATRIX DENSITY : 2.71 RM TEMPERATURE : 0 LGDATE: 07/24/08
NEUTRON MATRIX : Dolomite MATRIX DELTA T : 54 LGTIME : 12:07:
THRESH: 2500

SWL : -2
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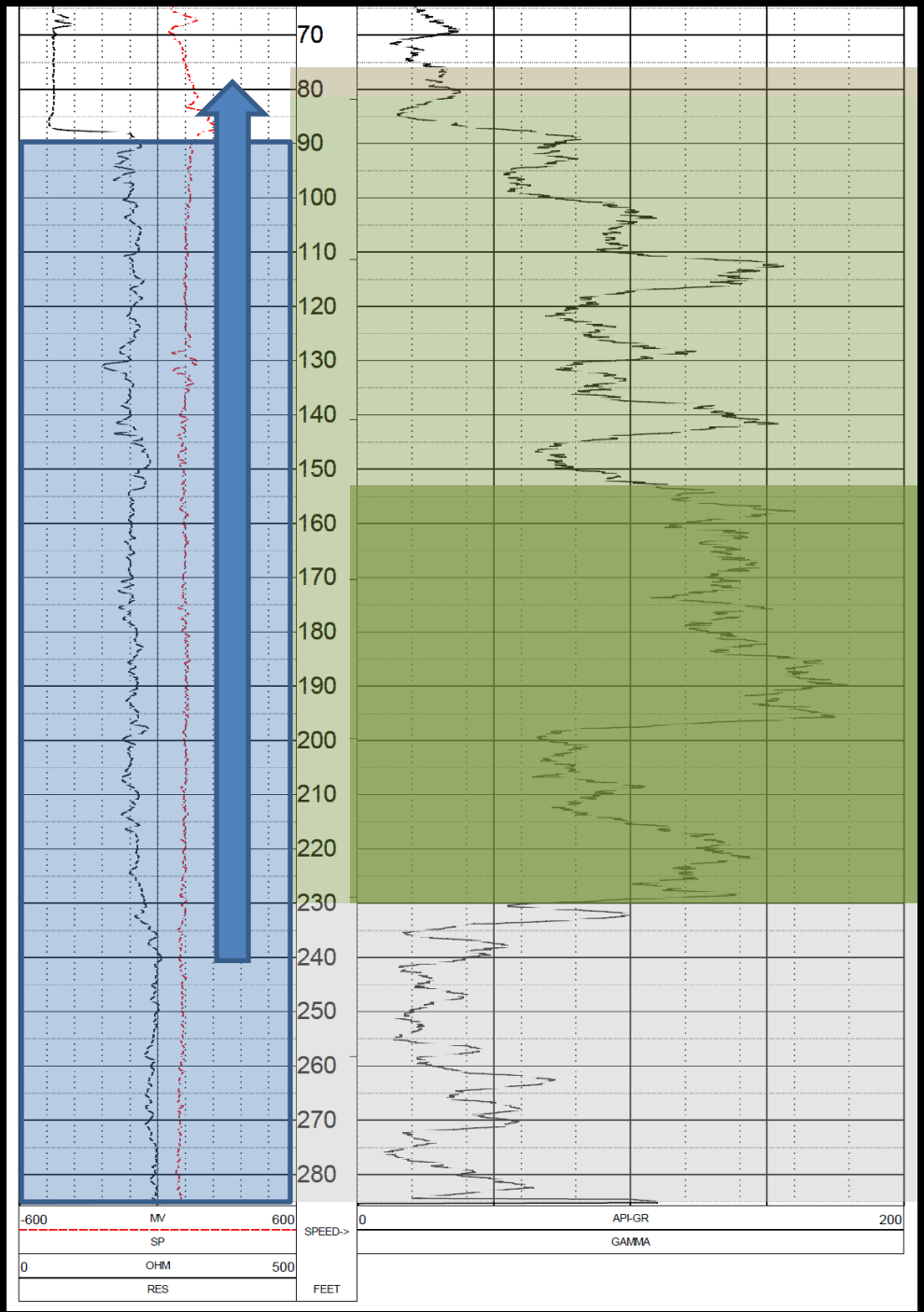
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220
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260
270
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OHM
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FEET
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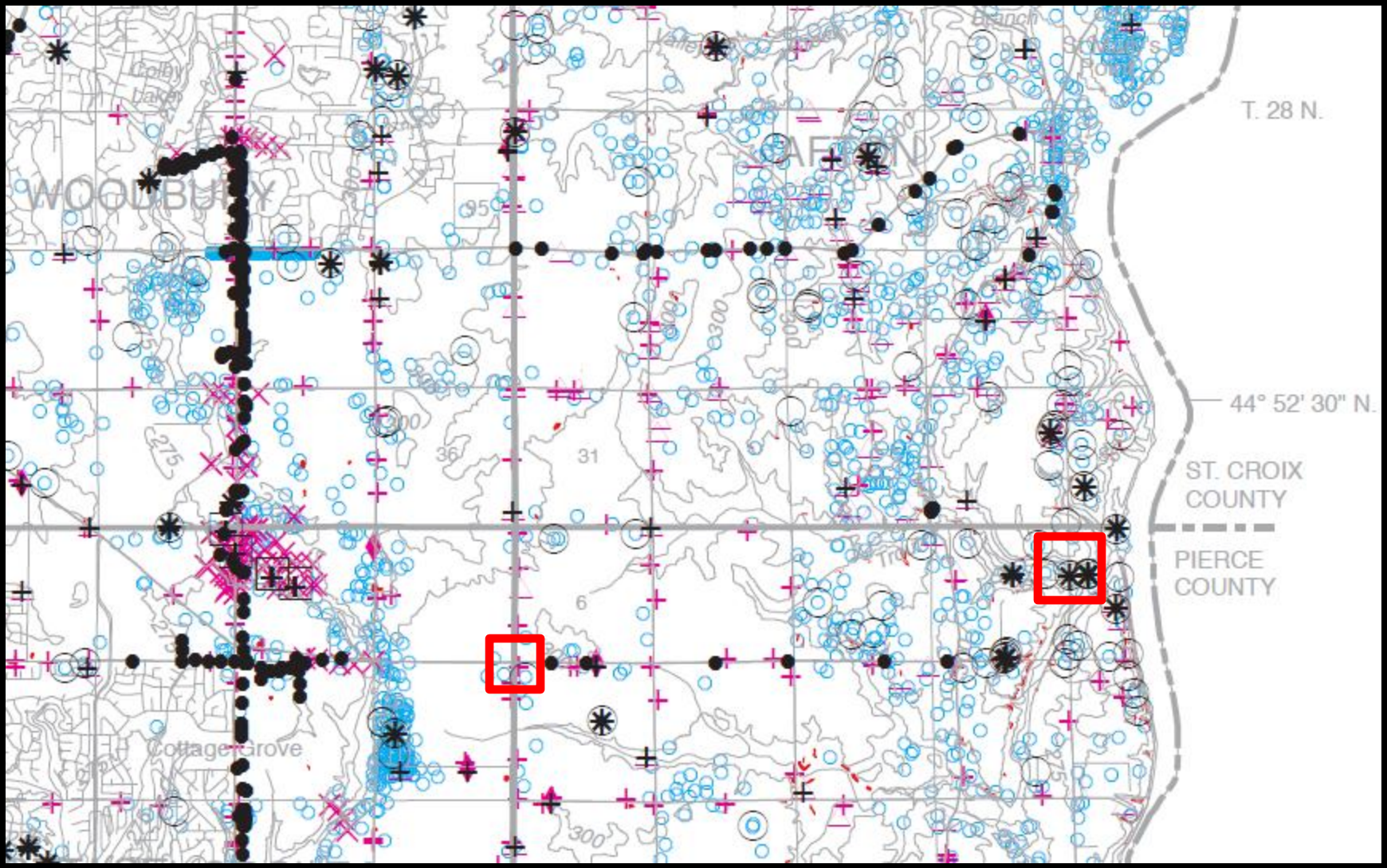
GAMMA


T. 28 N.
44° 52' 30" N.
ST. CROIX
COUNTY
PIERCE
COUNTY
WOODBURY
Cottage Grove
95
36
31
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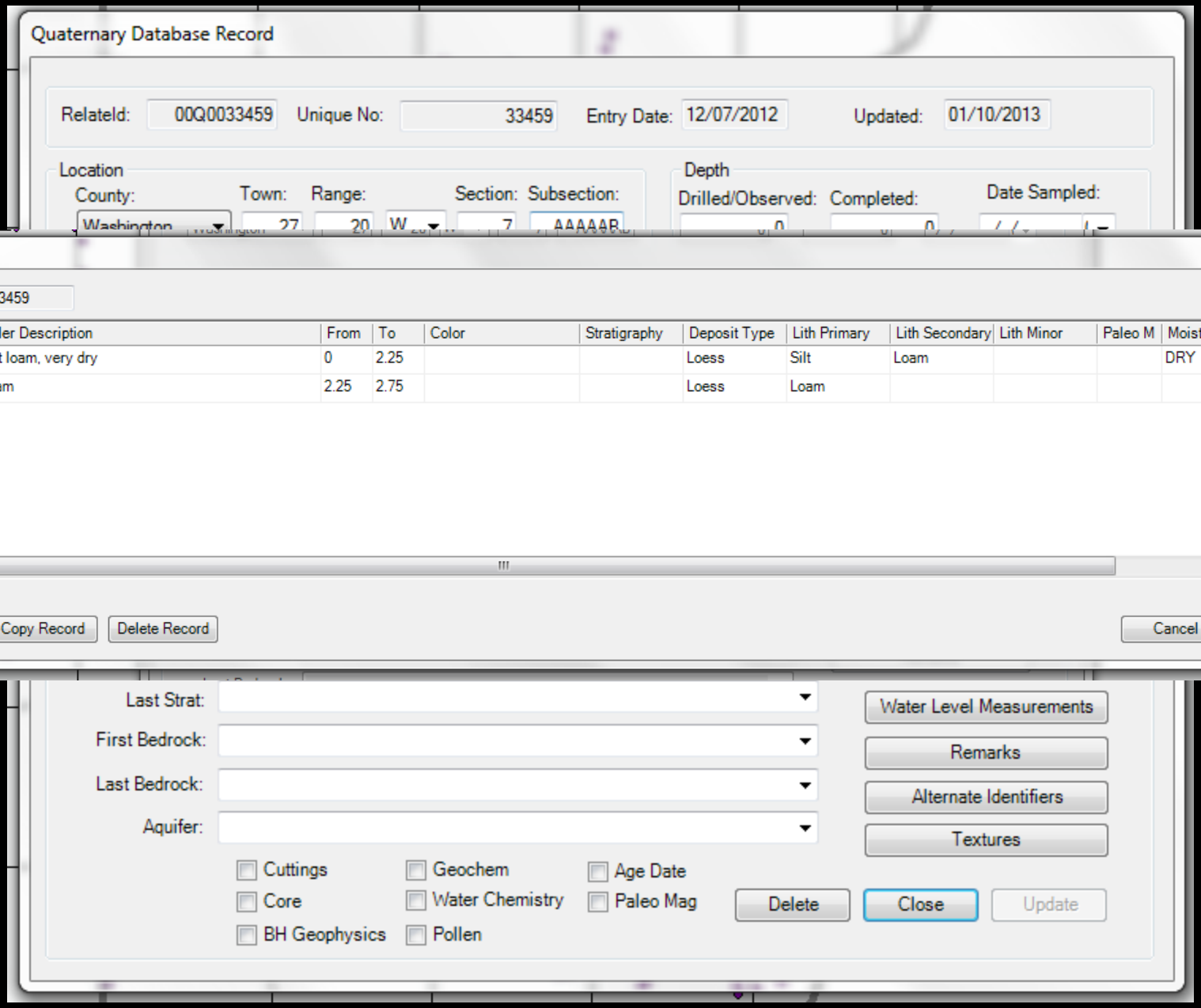
1
300
275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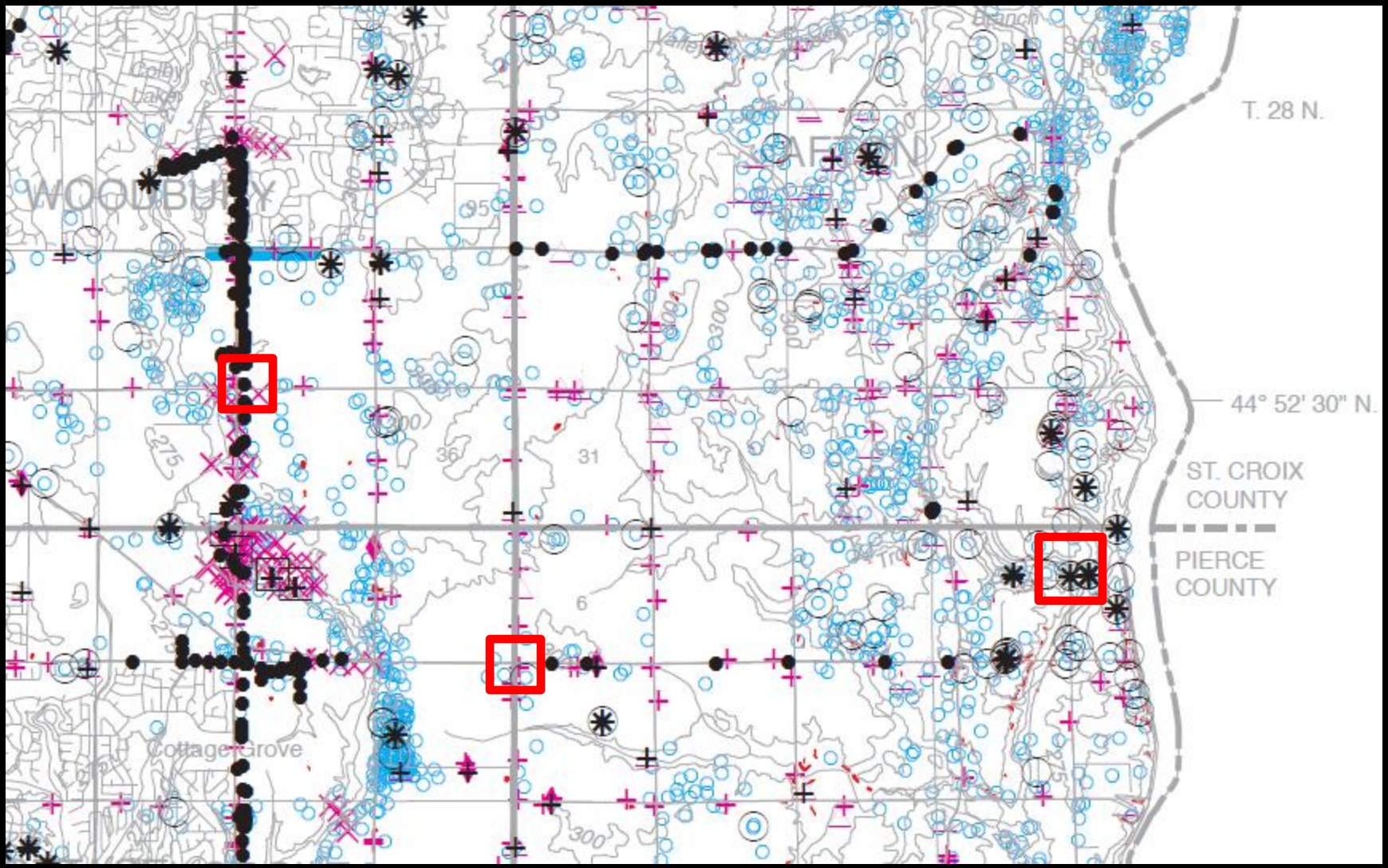
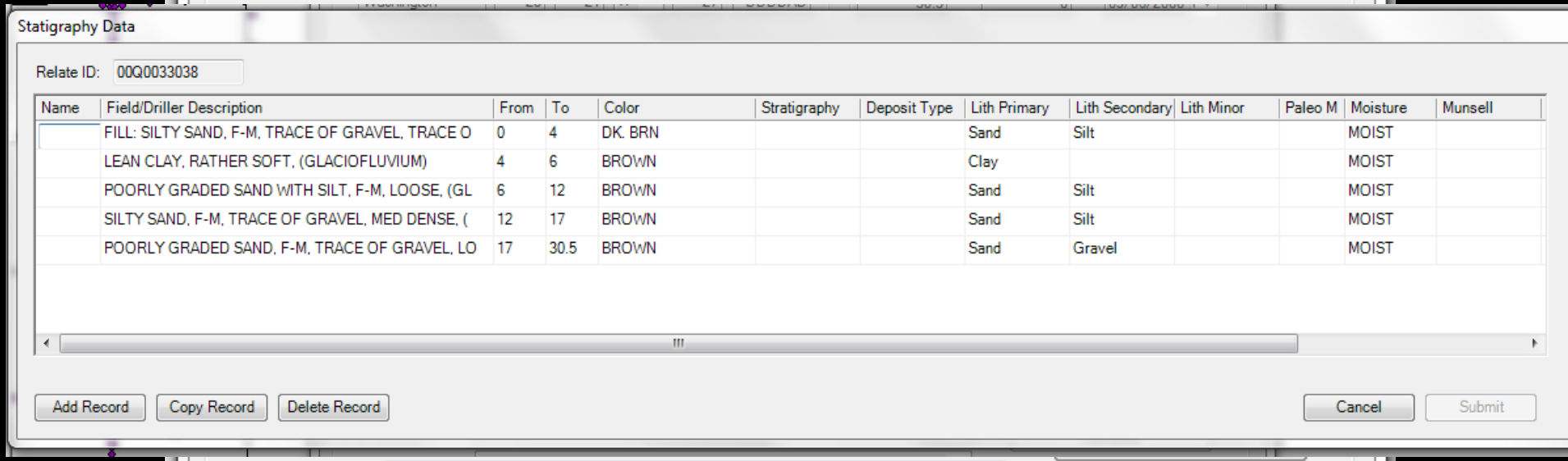
Unique No: 33459
Entry Date: 12/07/2012
Updated: 01/10/2013
Location
County:
Town:
Range:
Section:
Subsection:
Depth
Drilled/Observed:
Completed:
Date Sampled:
Statigraphy Data
Relate ID: 00Q0033459
Name
Field/Driller Description
From
To
Color
Stratigraphy
Deposit Type
Lith Primary
Lith Secondary
Lith Minor
Paleo M
Moisture
Munsell
Loess, silt loam, very dry
0
2.25
Loess
Silt
Loam
DRY
10YR 5/6
Loess, loam
2.25
2.75
Loess
Loam
10YR 5/6
Add Record
Copy Record
Delete Record
Cancel
Submit
Last Strat:
First Bedrock:
Last Bedrock:
Aquifer:
Water Level Measurements
Remarks
Alternate Identifiers
Textures
Cuttings
Core
BH Geophysics
Geochem
Water Chemistry
Pollen
Age Date
Paleo Mag
Delete
Close
Update


T. 28 N.
44° 52' 30" N.
ST. CROIX
COUNTY
PIERCE
COUNTY
WOODBURY
Cottage Grove
95
36
31
6
1
300
275



Quaternary Database Record

RelateId: 00Q0033038 Unique No: 33038 Entry Date: 10/17/2012 Updated: 11/01/2012

Location
County: Washington Town: 28 Range: 21 W Section: 27 Subsection: DDDDAD

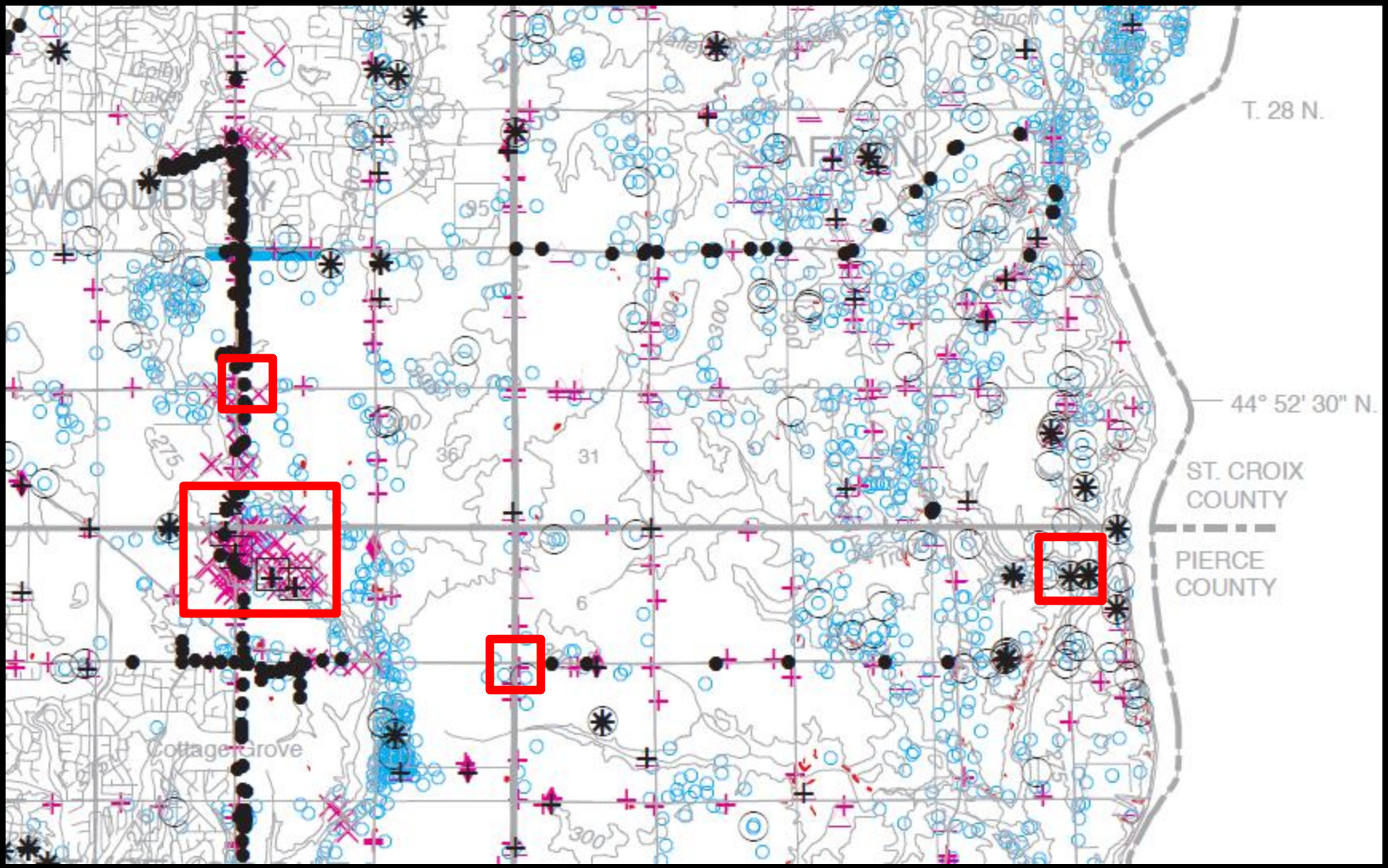
Depth
Drilled/Observed: 30.5 Completed: 0 Date Sampled: 09/06/2000

First Bedrock:
Last Bedrock:
Aquifer:

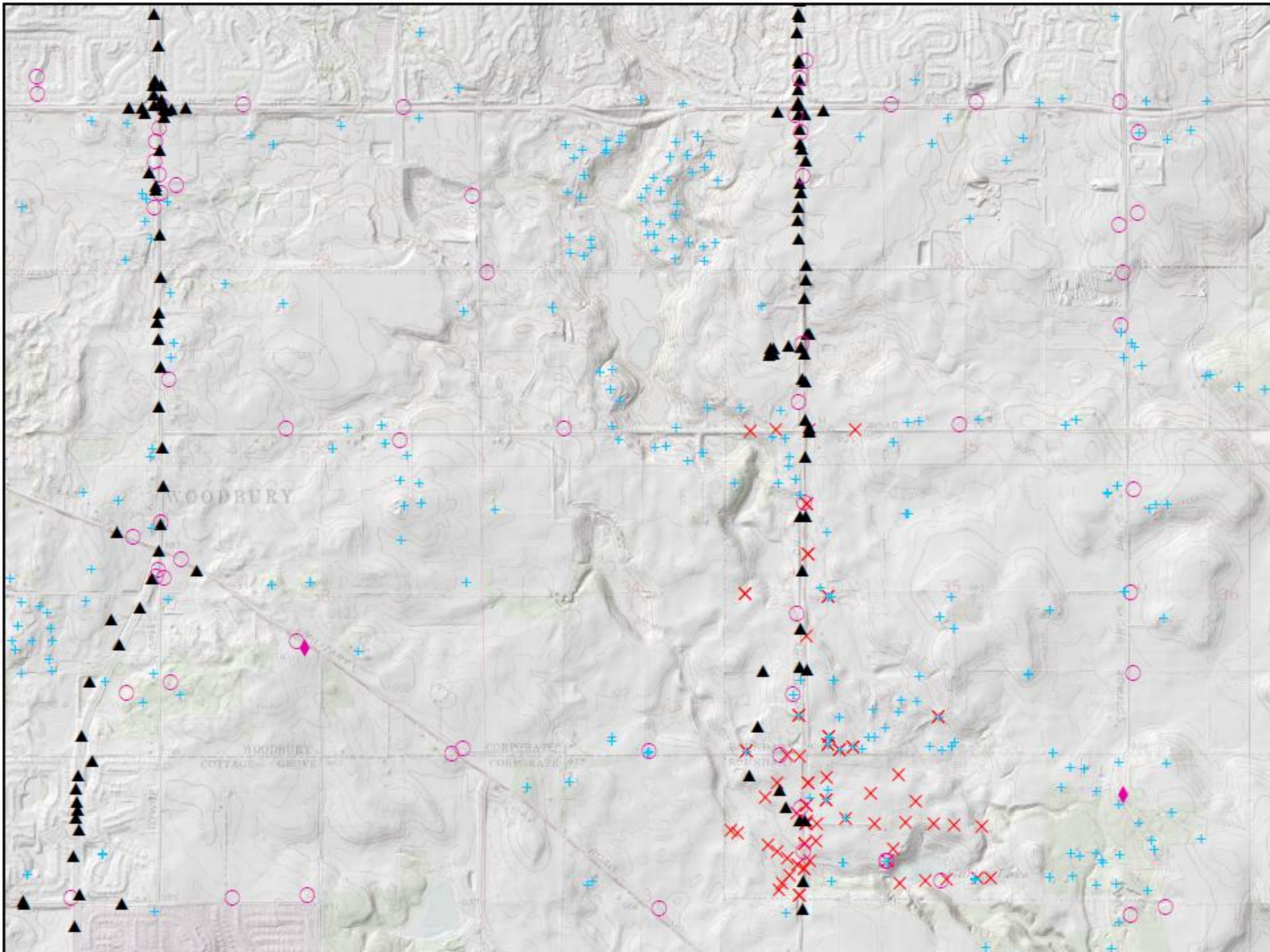
Remarks
Alternate Identifiers
Textures

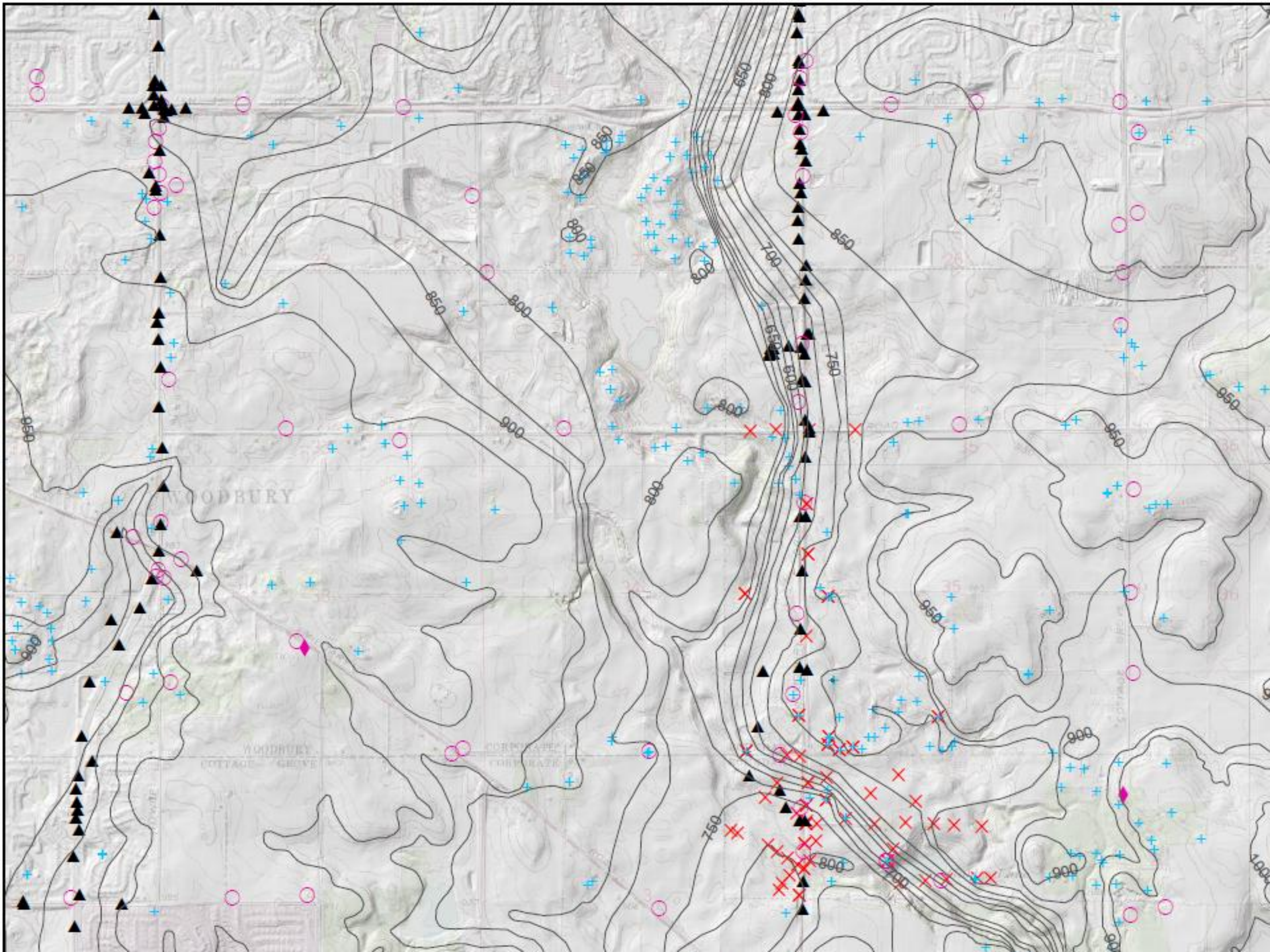
Cuttings
Core
BH Geophysics
Geochem
Water Chemistry
Pollen
Age Date
Paleo Mag

Delete
Close
Update

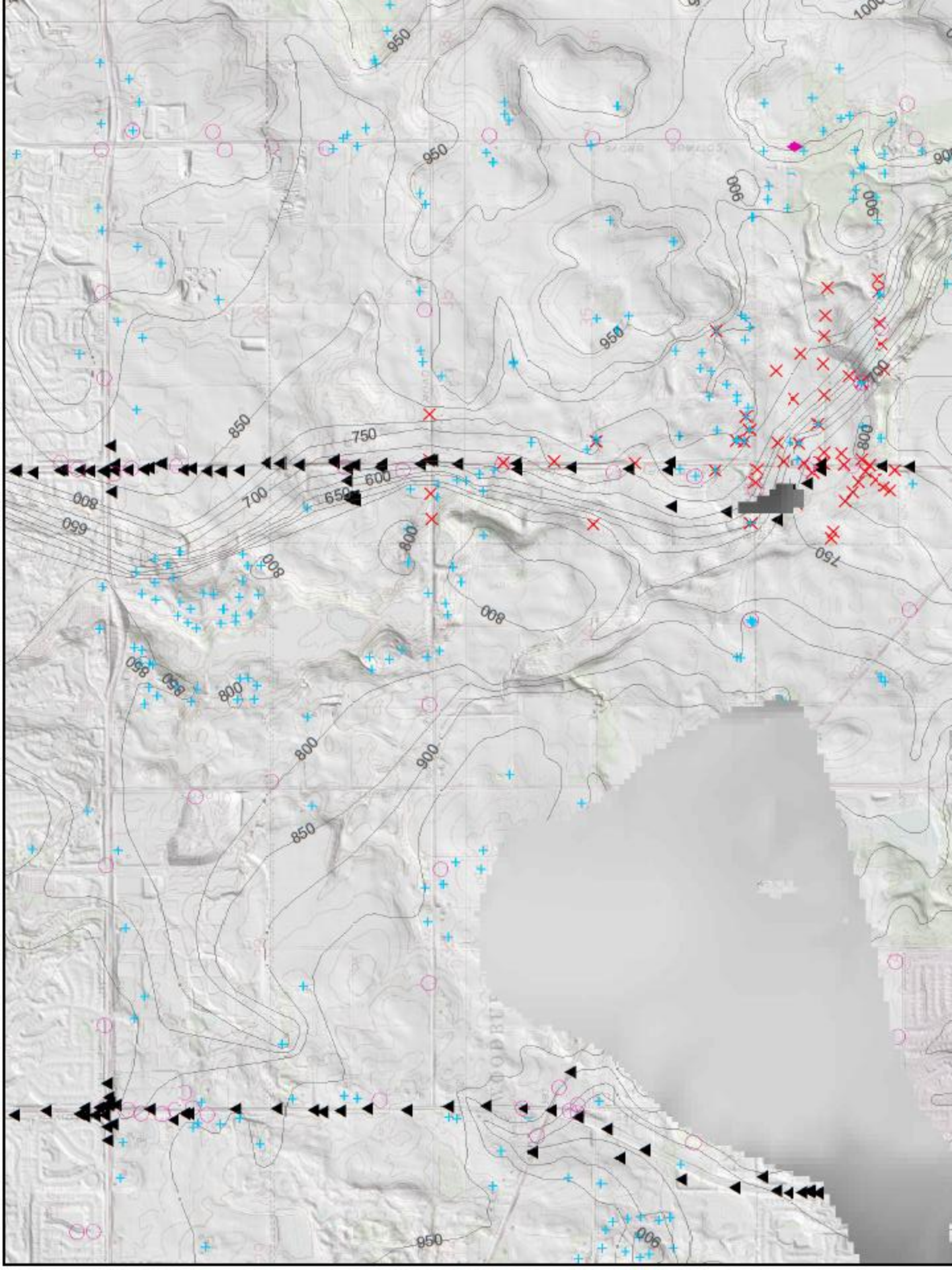

T. 28 N.
44° 52' 30" N.
ST. CROIX
COUNTY
PIERCE
COUNTY
WOODBURY
Cottage Grove

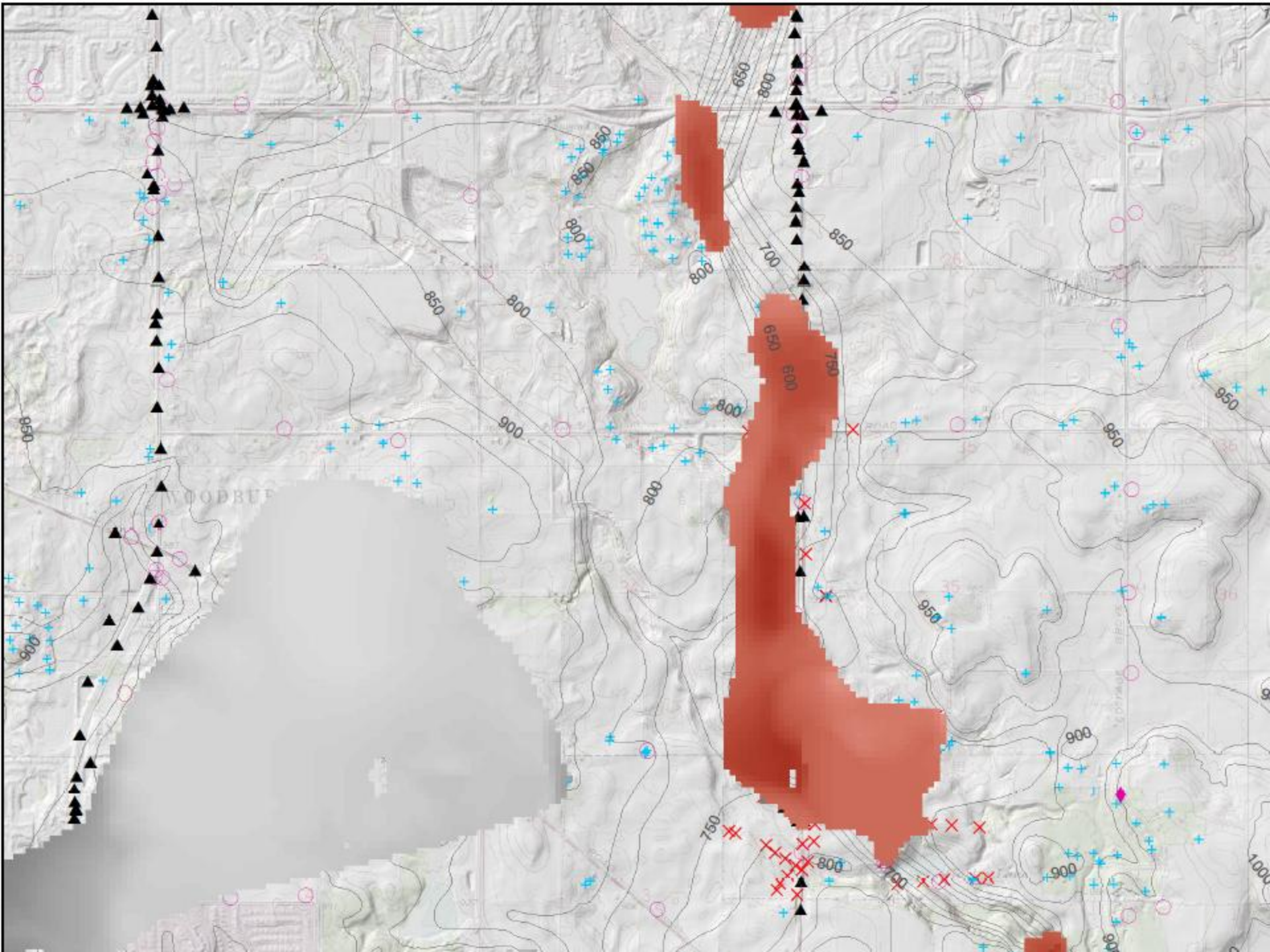
HVSR Station Deployment at Fort Ridgely State Park, Nicollet County, Minnesota


WOODBURY
WOODBURY
COTTAGE GROVE



650
800
850
850
800
850
700
800
850
800
650
750
600
800
950
900
WOODBURY
800
950
950
950
900
WOODBURY
COTTAGE GROVE
CORPORATE
CORPORATE
750
800
700
900
900


950
950
900
900
950
700
850
750
600
650
800
700
650
800
800
800
850
850
800
800
900
850
950
900


650
800
850
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800
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600
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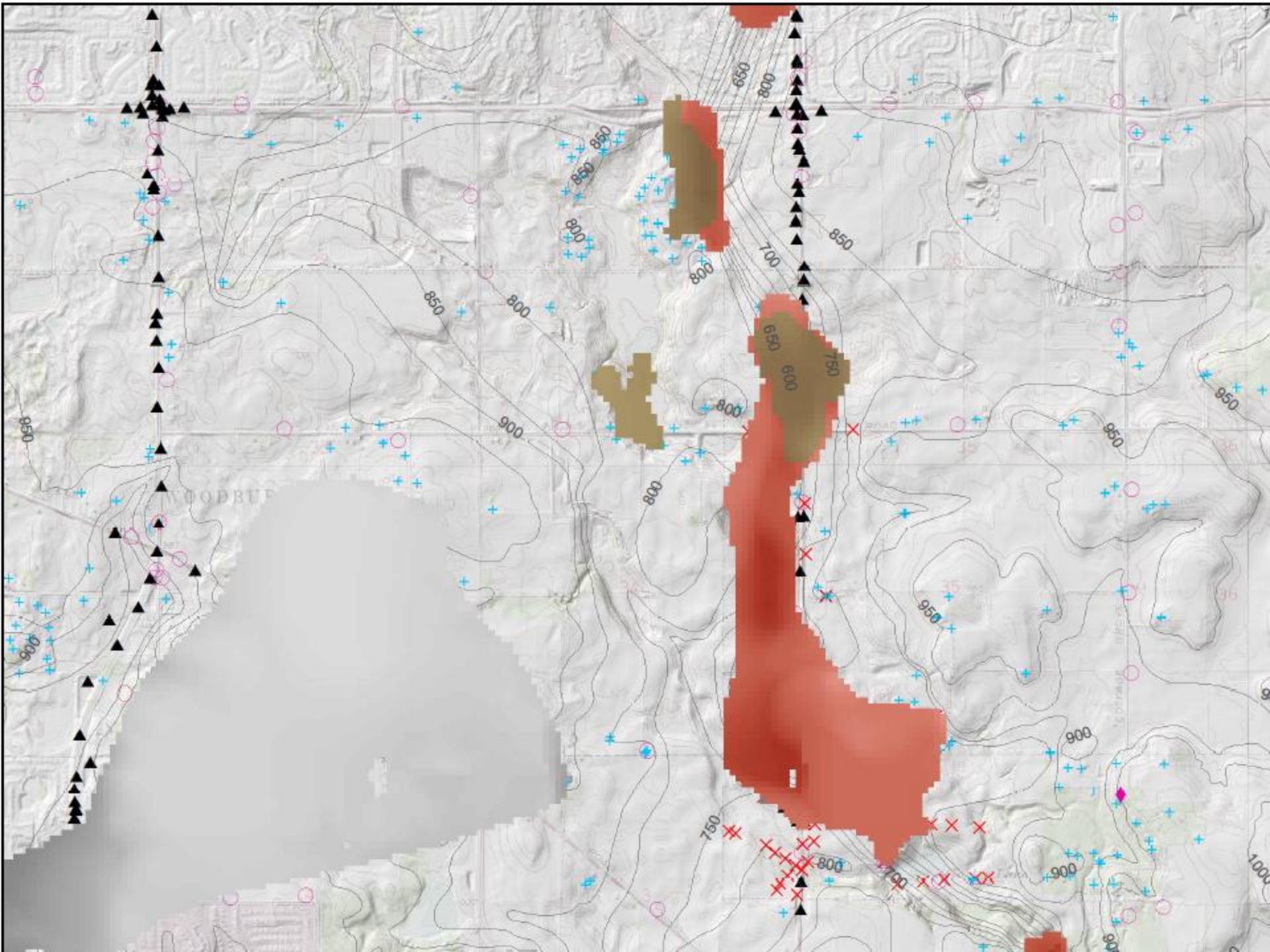
750
800
700
900
1000


650
800
850
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750
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700
900
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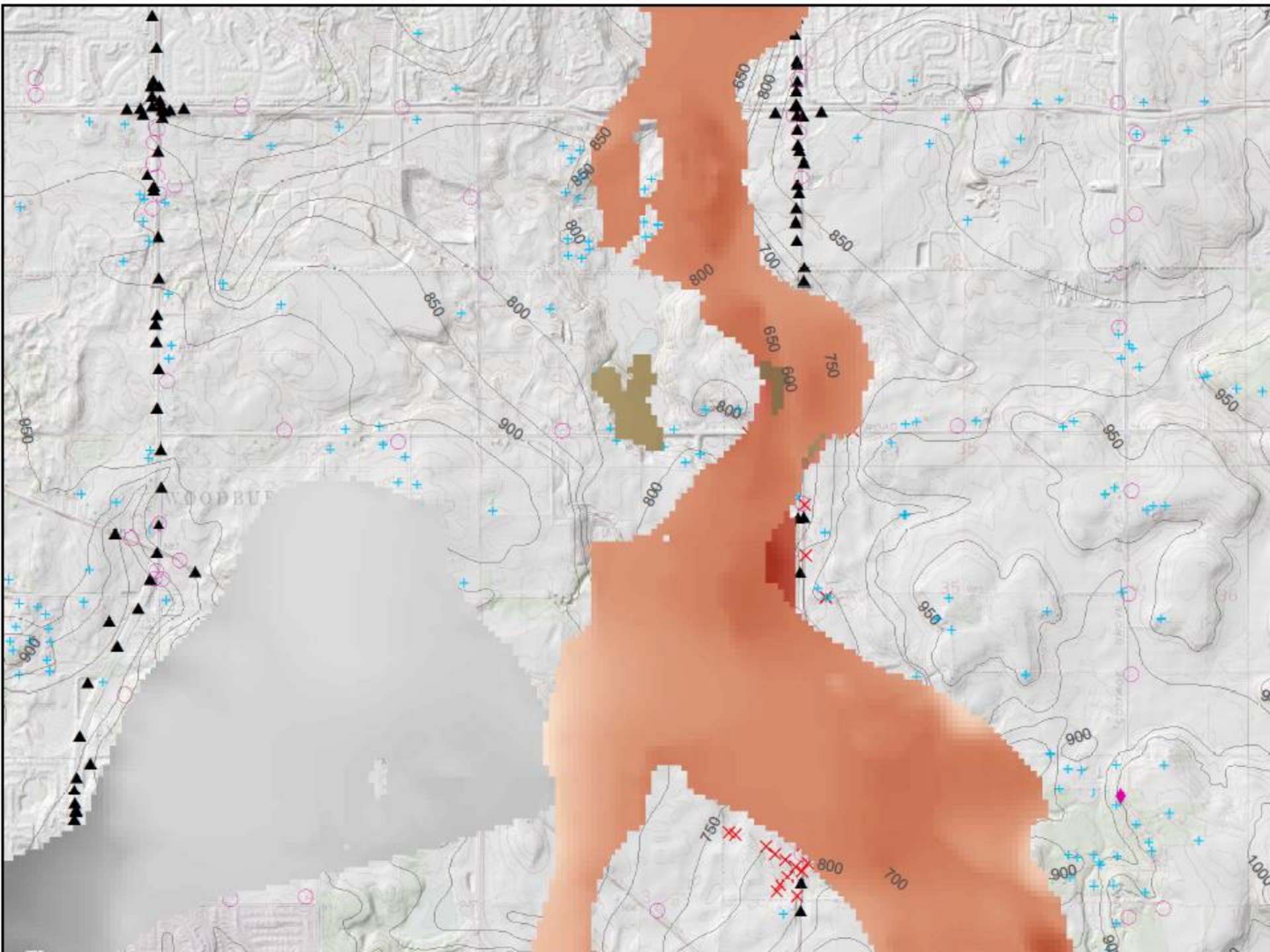
650
800
850
850
800
850
800
700
800
650
600
750
850
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900
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950
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900
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750
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700
900
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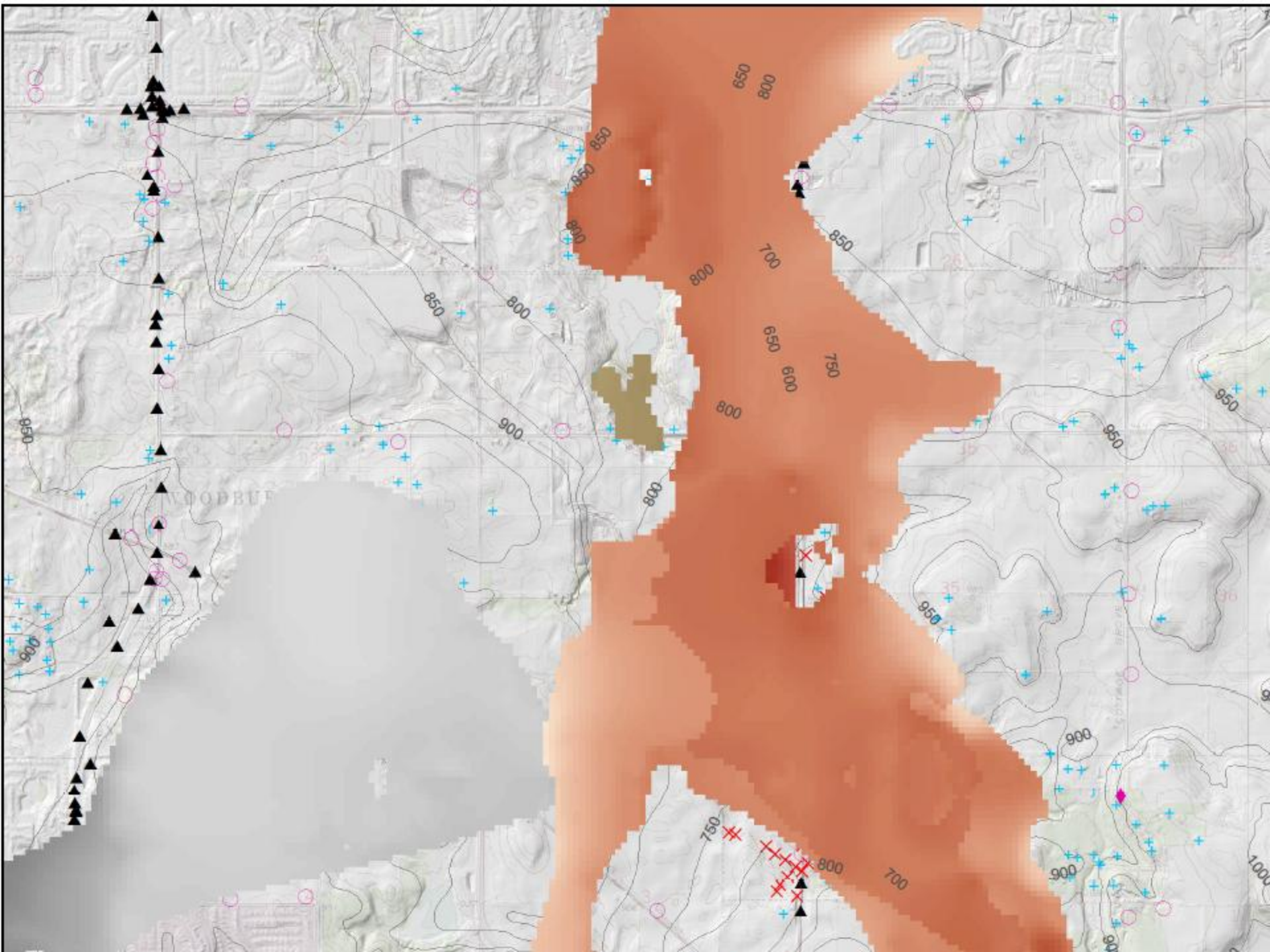
650
800
850
850
800
850
800
700
800
650
600
750
800
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900
950
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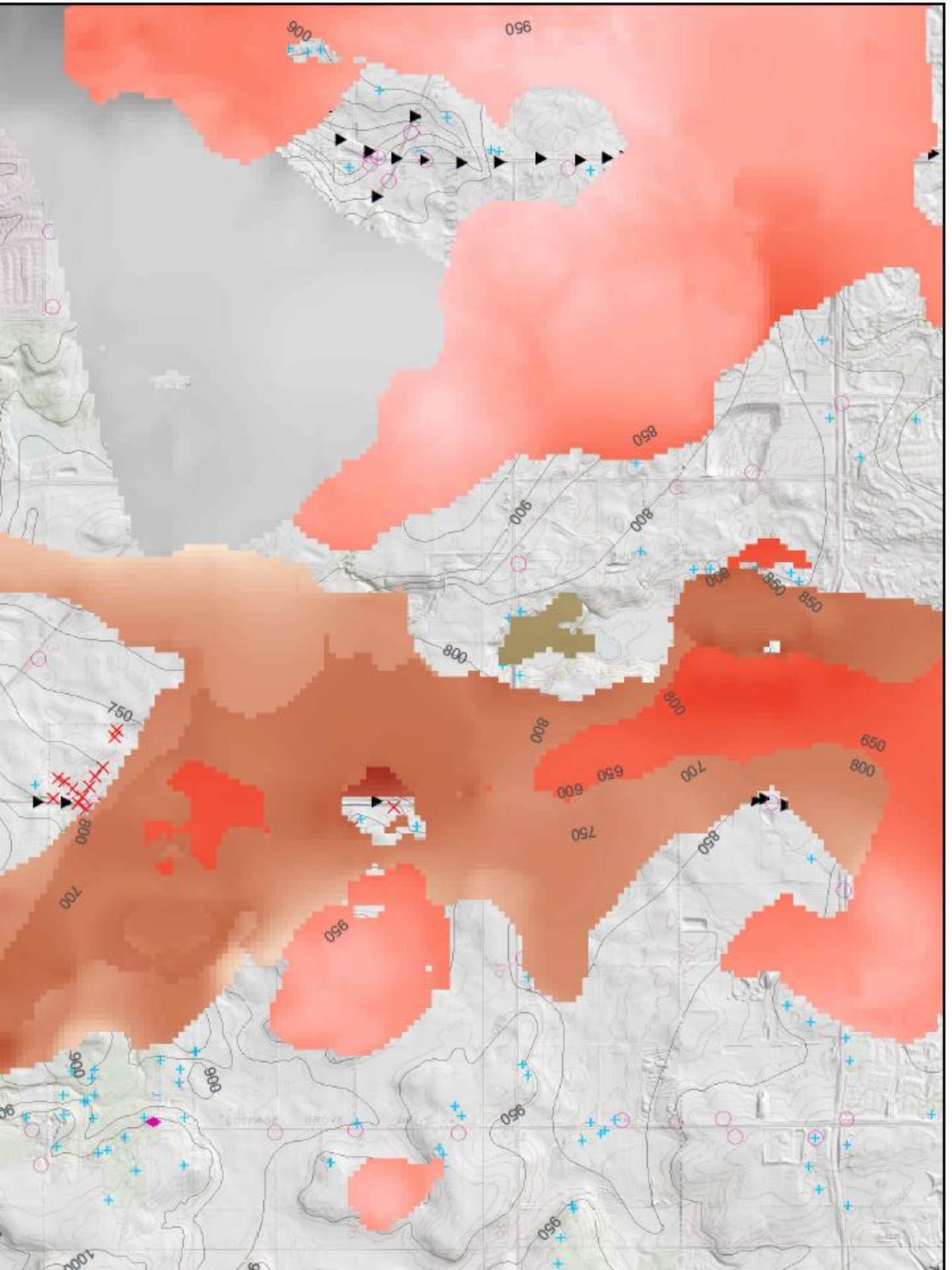
950
900
900
750
800
700
900
1000


950
850
900
800
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750
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650
700
600
650
800
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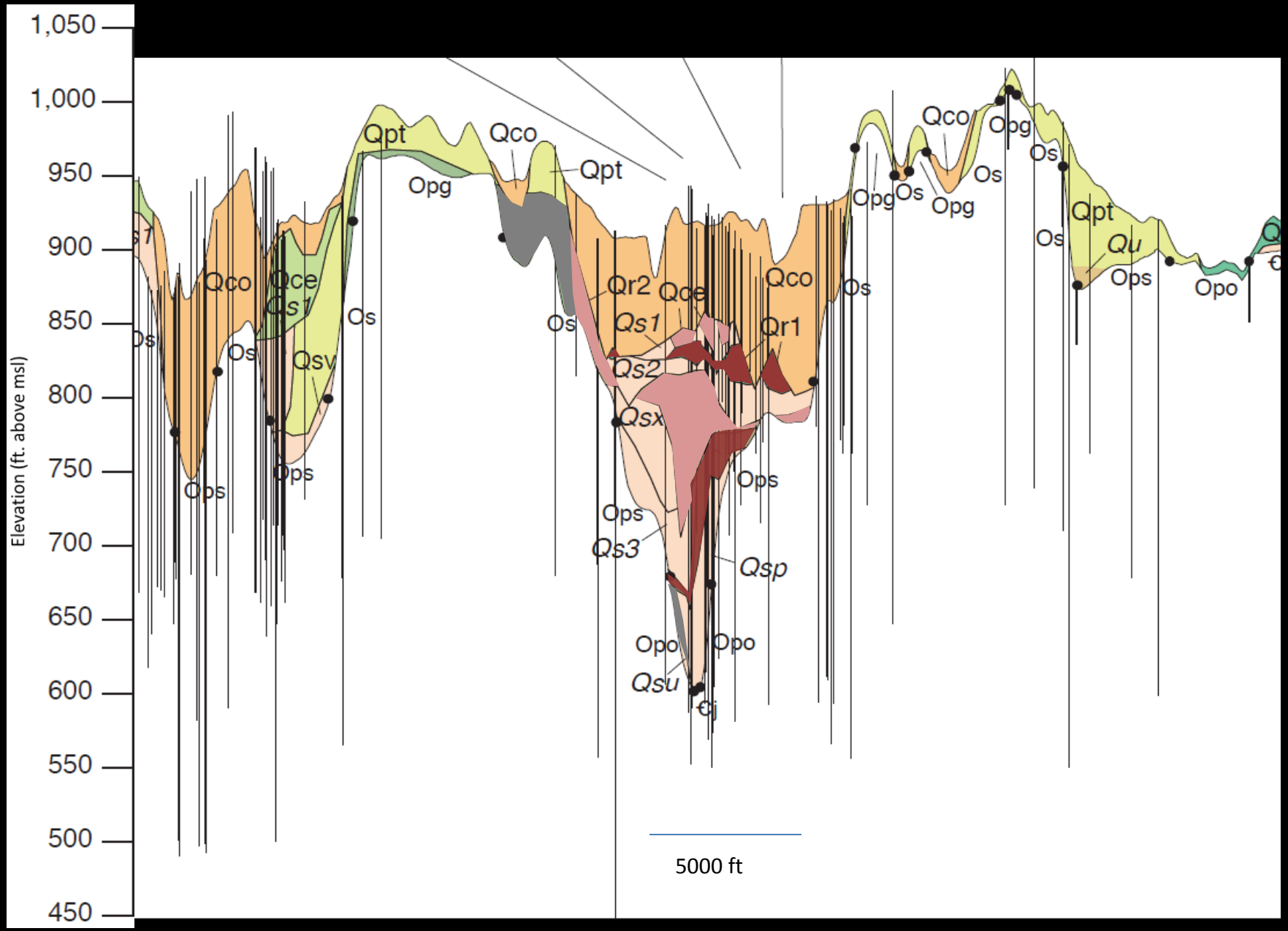
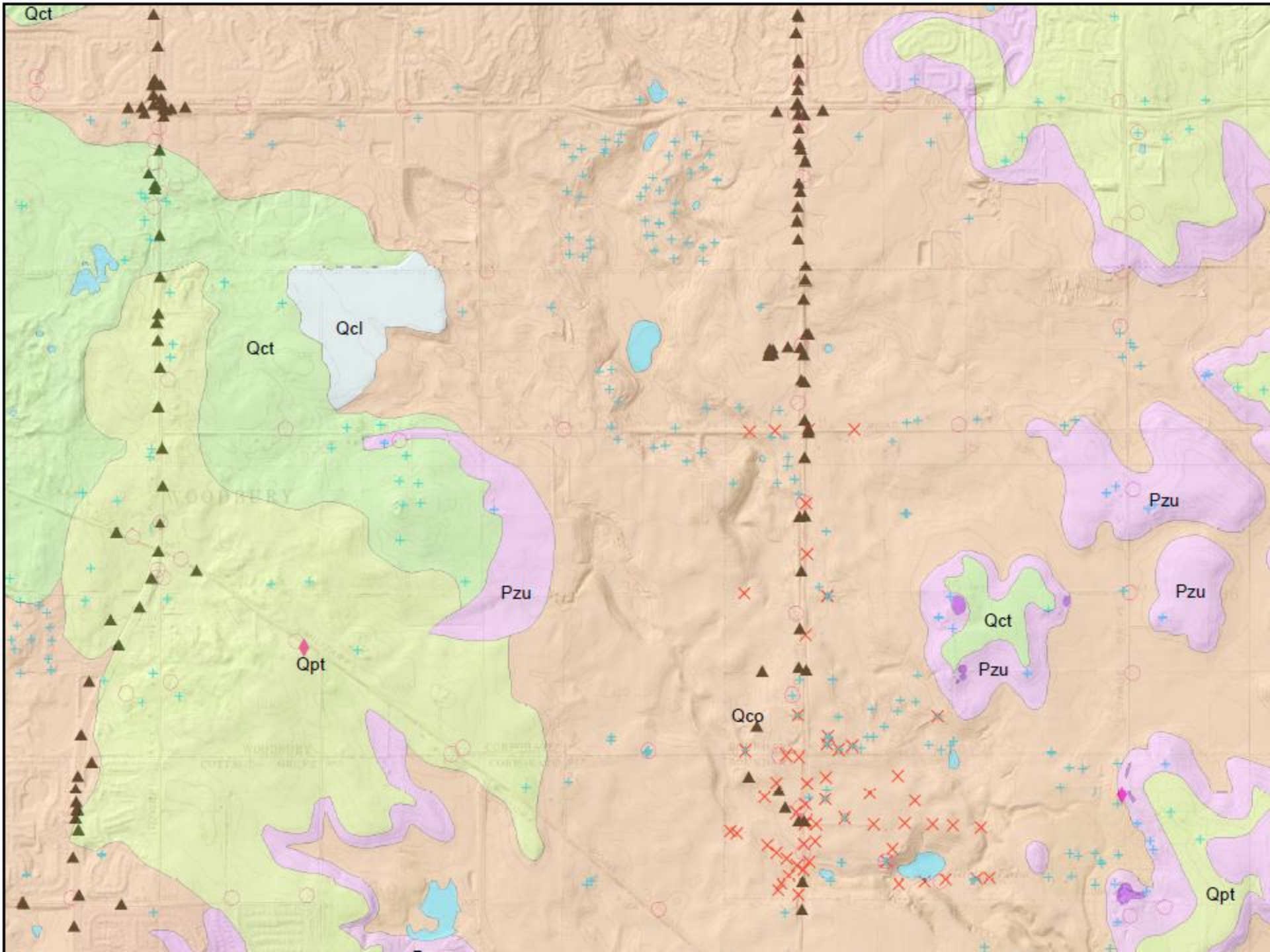
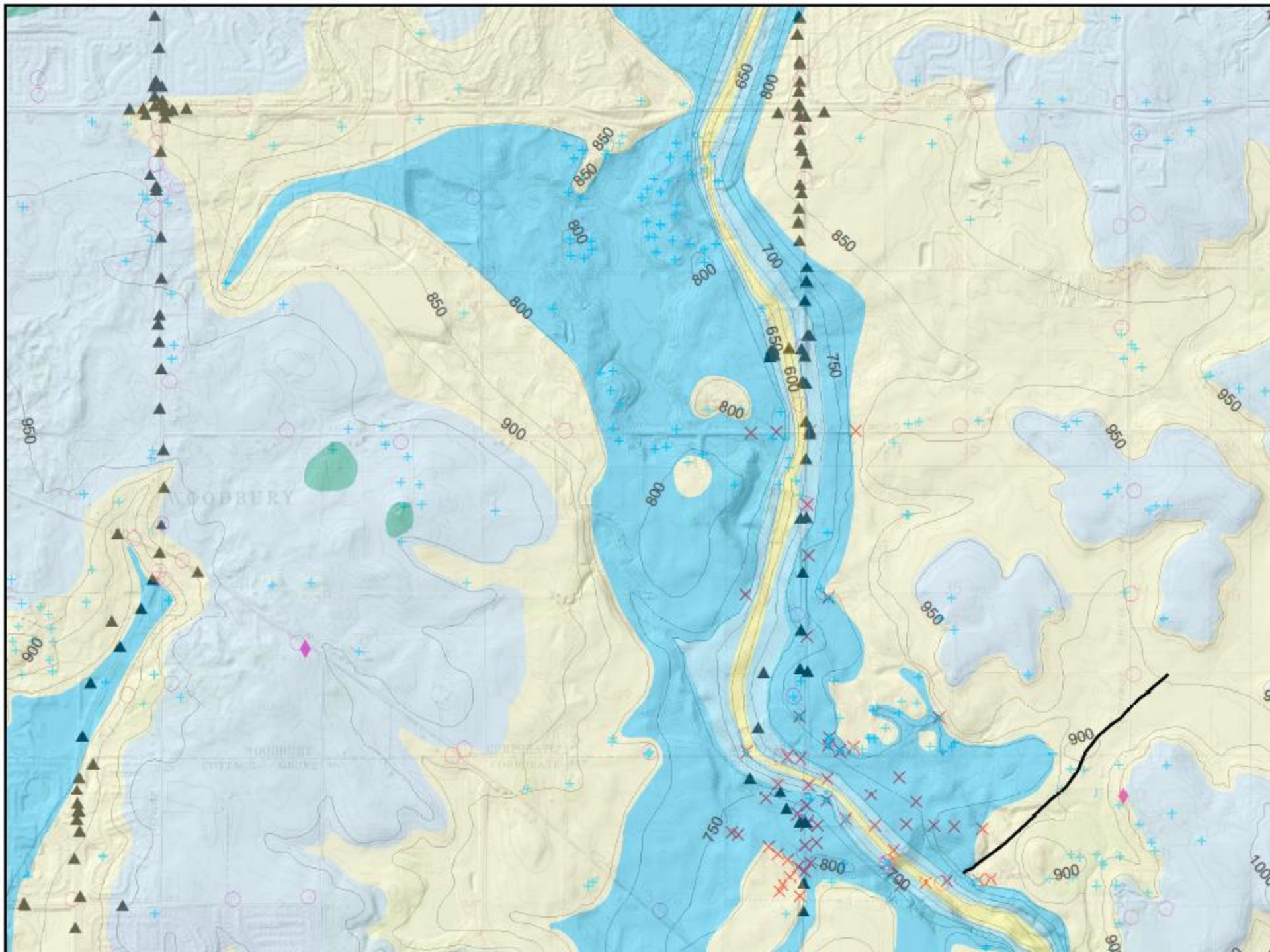
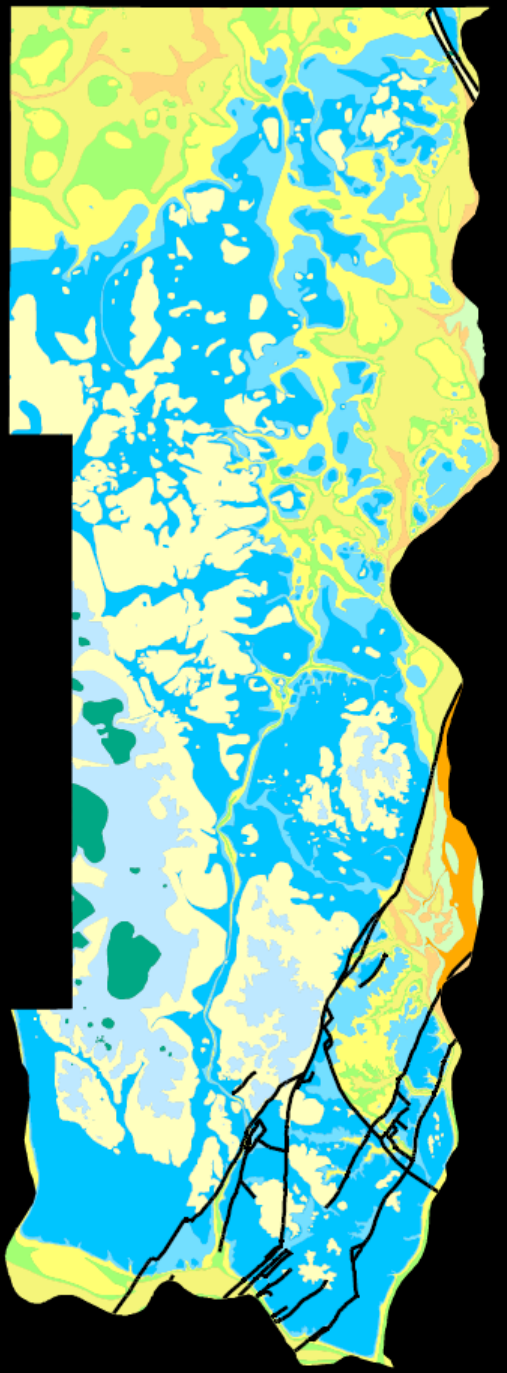
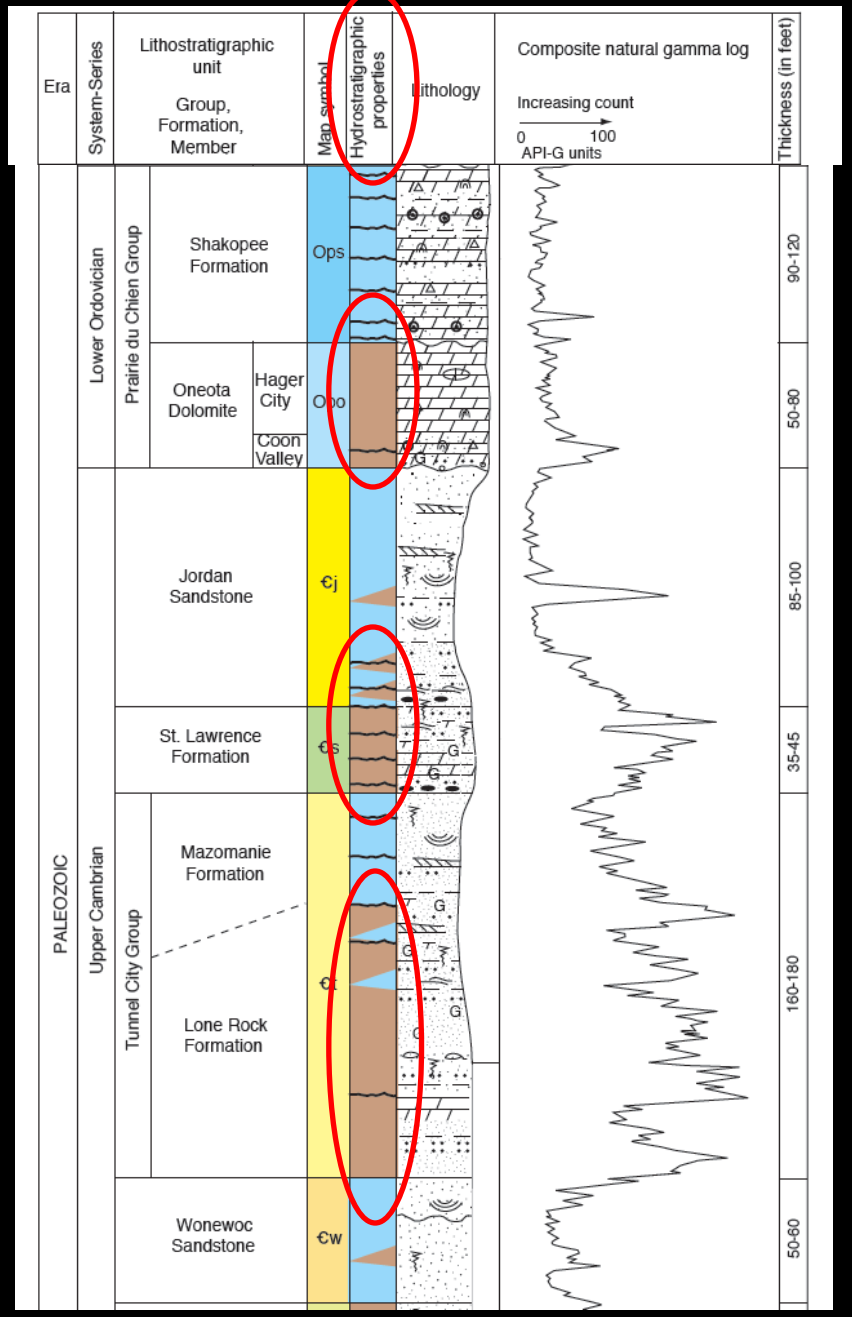
950
900
900
950
950

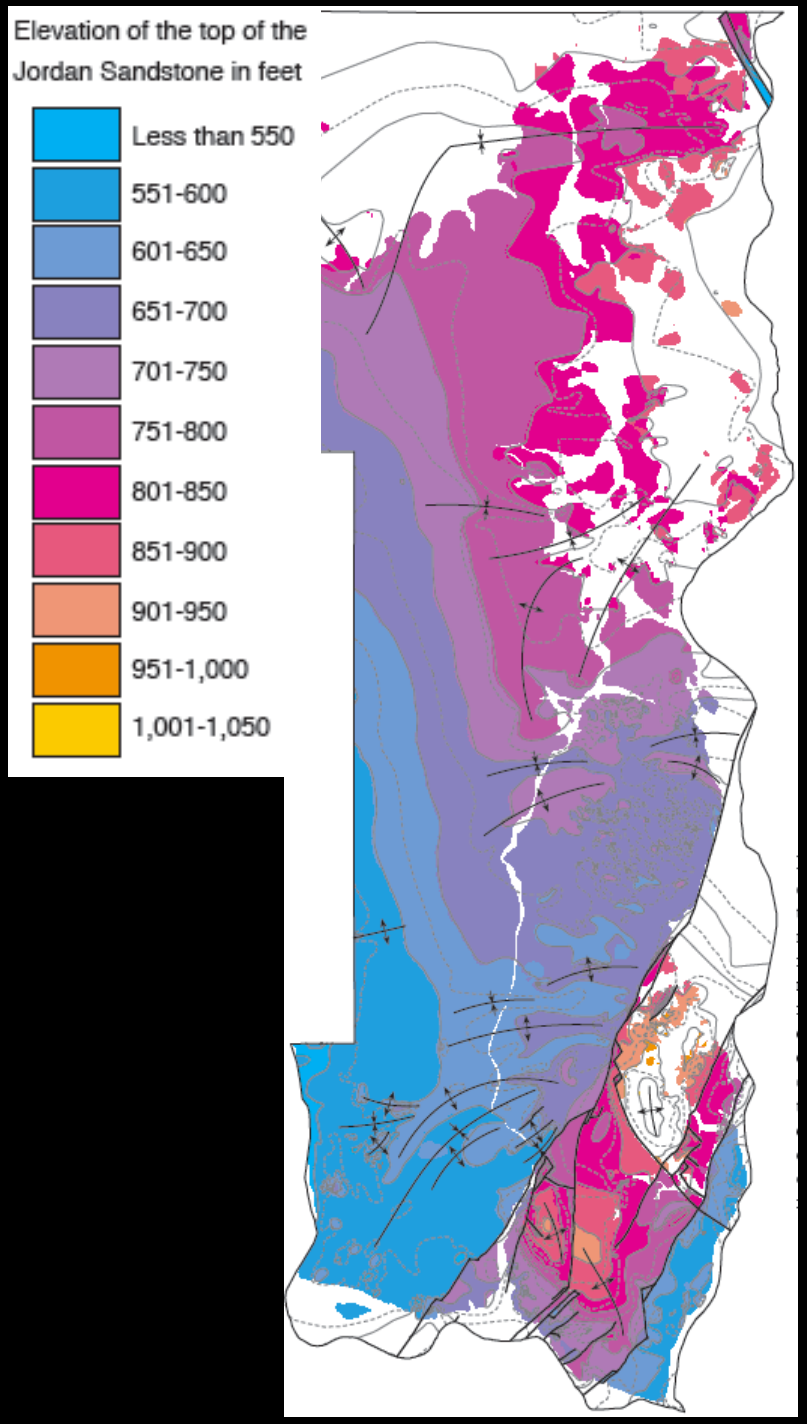

Elevation (ft. above msl)
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
Qpt
Qco
Opg
Qce
Qs1
Qsv
Os
Ops
Qr2
Qr1
Qs2
Qsx
Qs3
Qsp
Opo
Qsu
€j
Qu
5000 ft

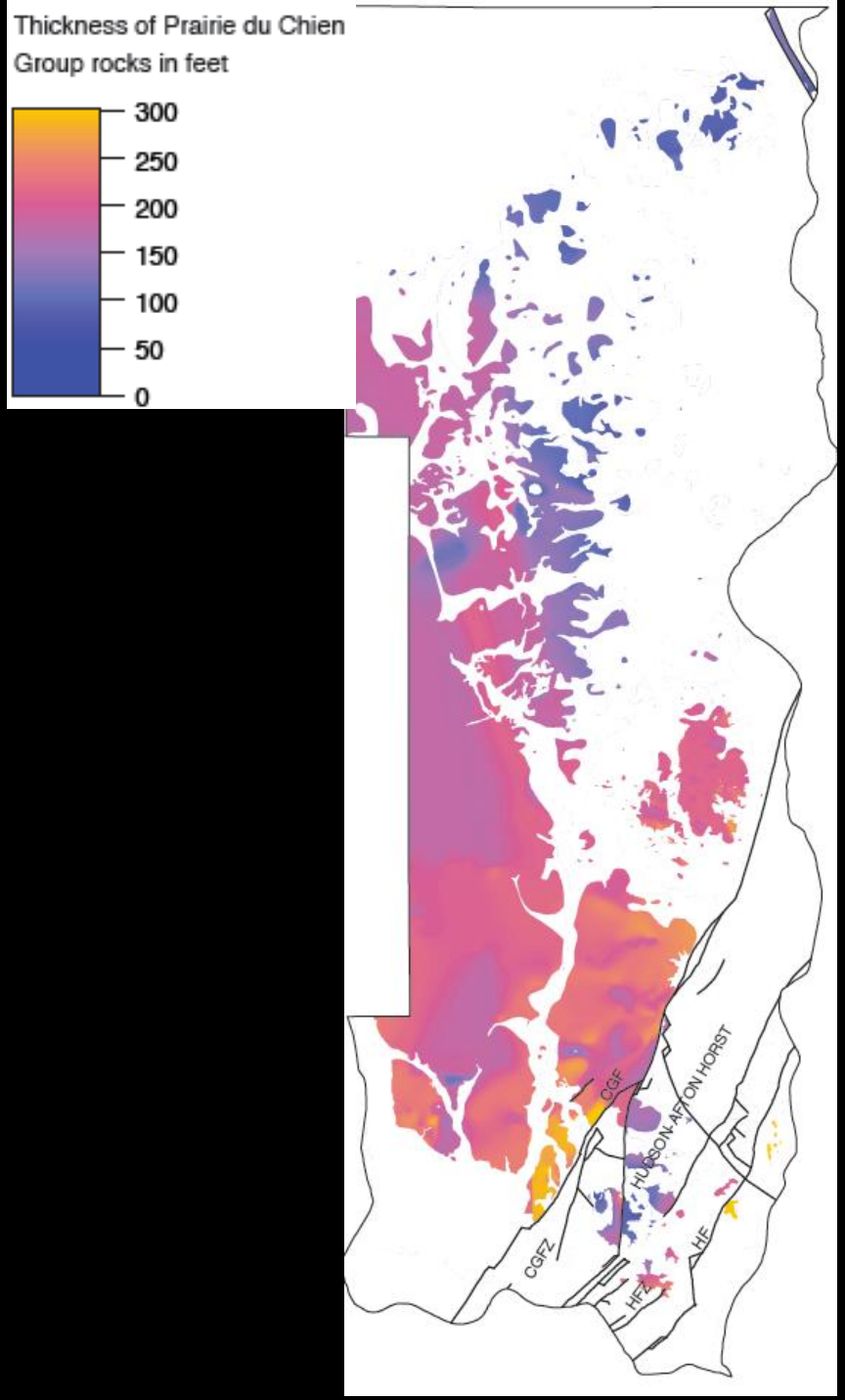

Qct
Qcl
Qct
Pzu
Qpt
Pzu
Qct
Pzu
Pzu
Qcp
Qpt

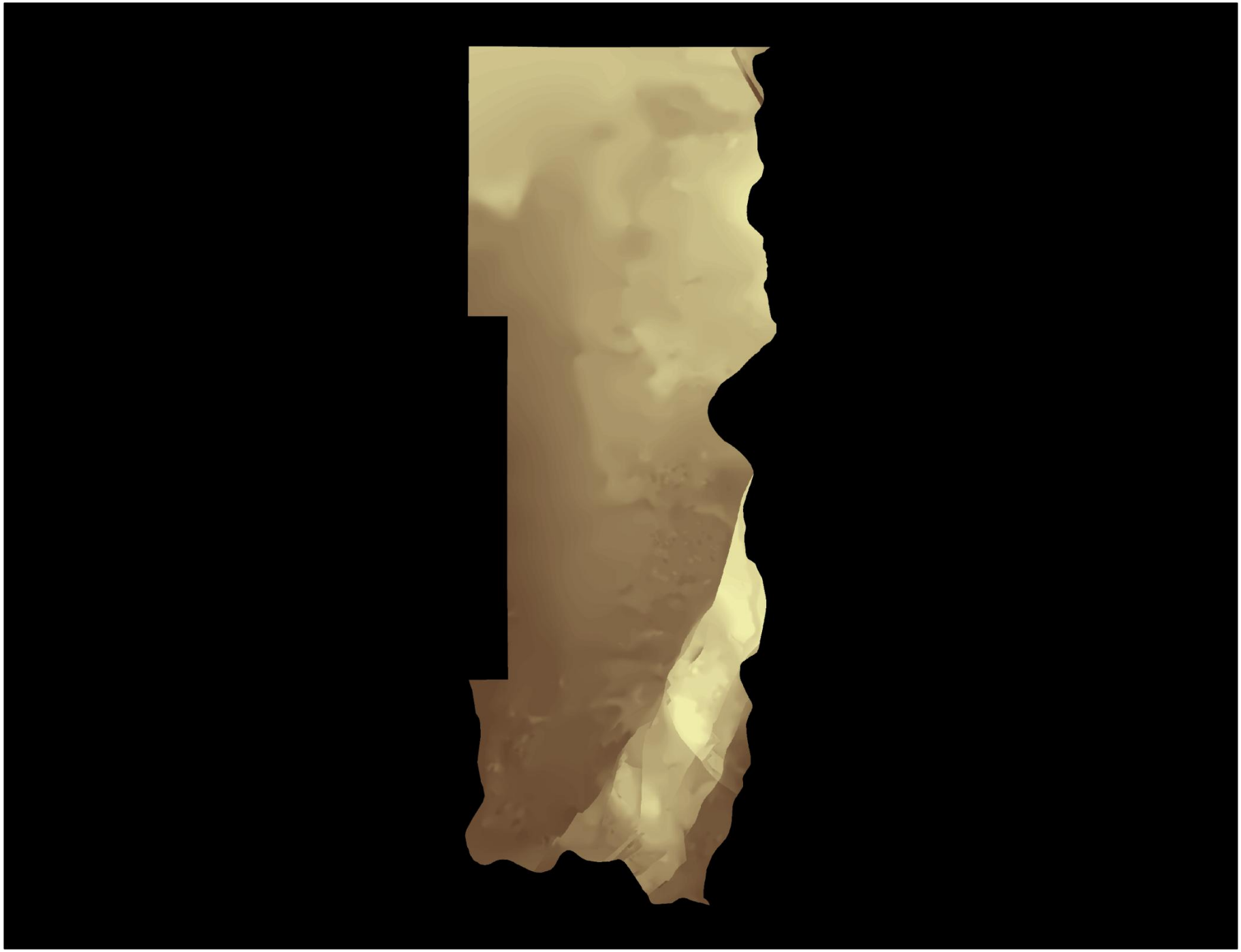

650
800
850
850
800
850
700
800
800
650
600
750
800
950
950
900
800
950
900
900
750
800
700
900
900
1000

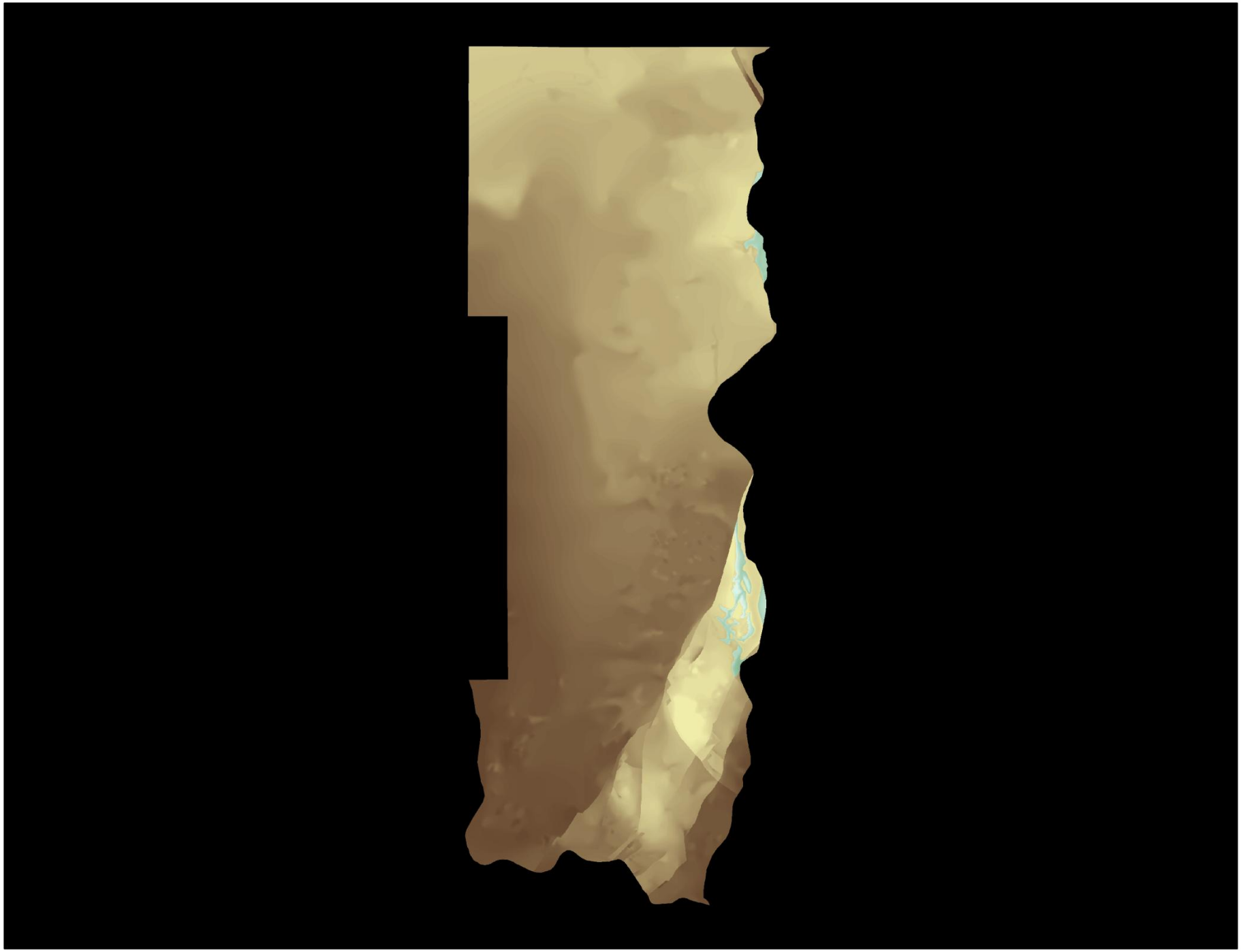


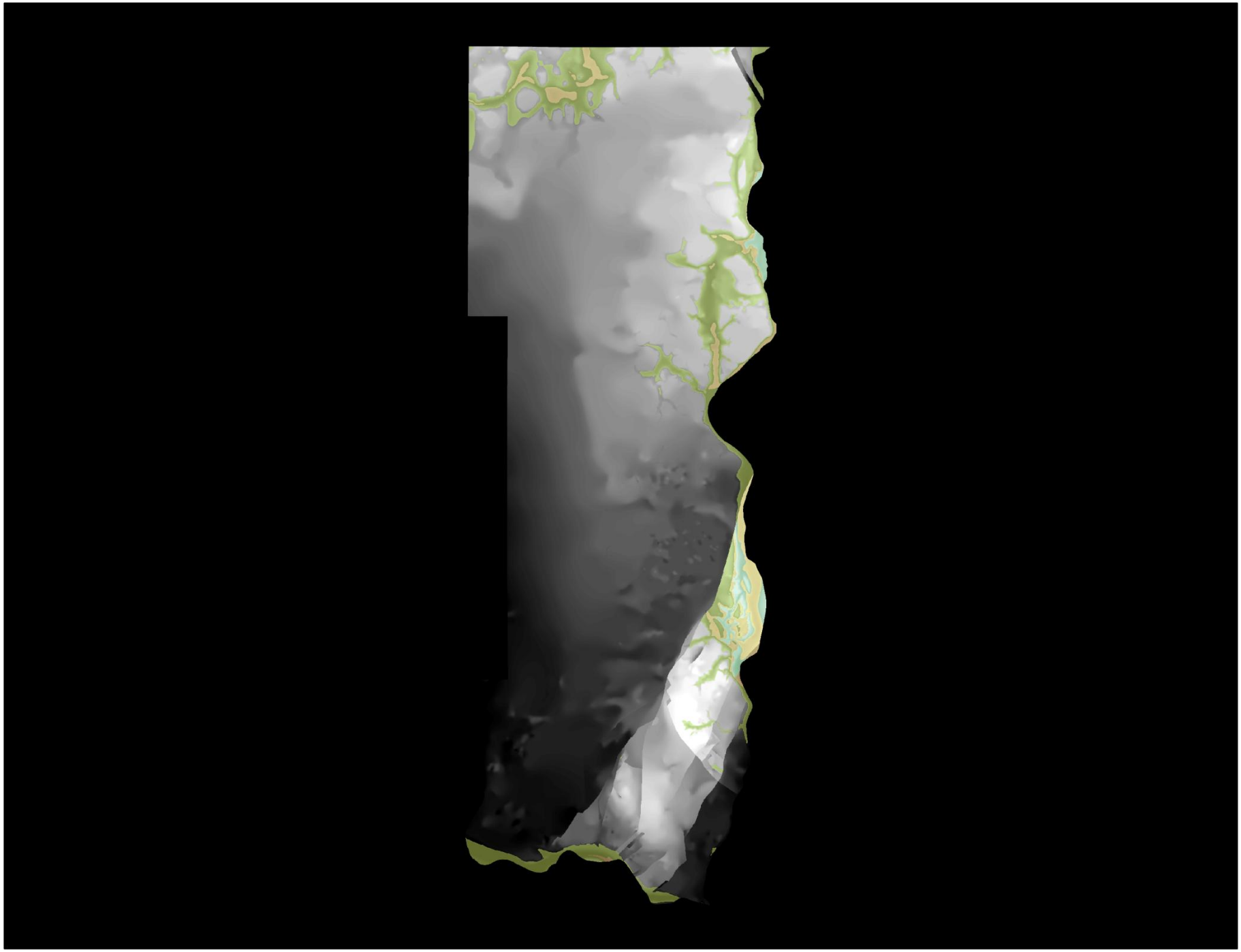

Era
System-Series
Lithostratigraphic unit
Group, Formation, Member
Map symbol
Hydrostratigraphic properties
Lithology
Composite natural gamma log
Increasing count
0
100
API-G units
Thickness (in feet)
PALEOZOIC
Lower Ordovician
Upper Cambrian
Prairie du Chien Group
Shakopee Formation
Oneota Dolomite
Hager City
Coon Valley
Ops
Ooo
Jordan Sandstone
€j
St. Lawrence Formation
€s
Tunnel City Group
Mazomanie Formation
Lone Rock Formation
€t
Wonewoc Sandstone
€w
90-120
50-80
85-100
35-45
160-180
50-60

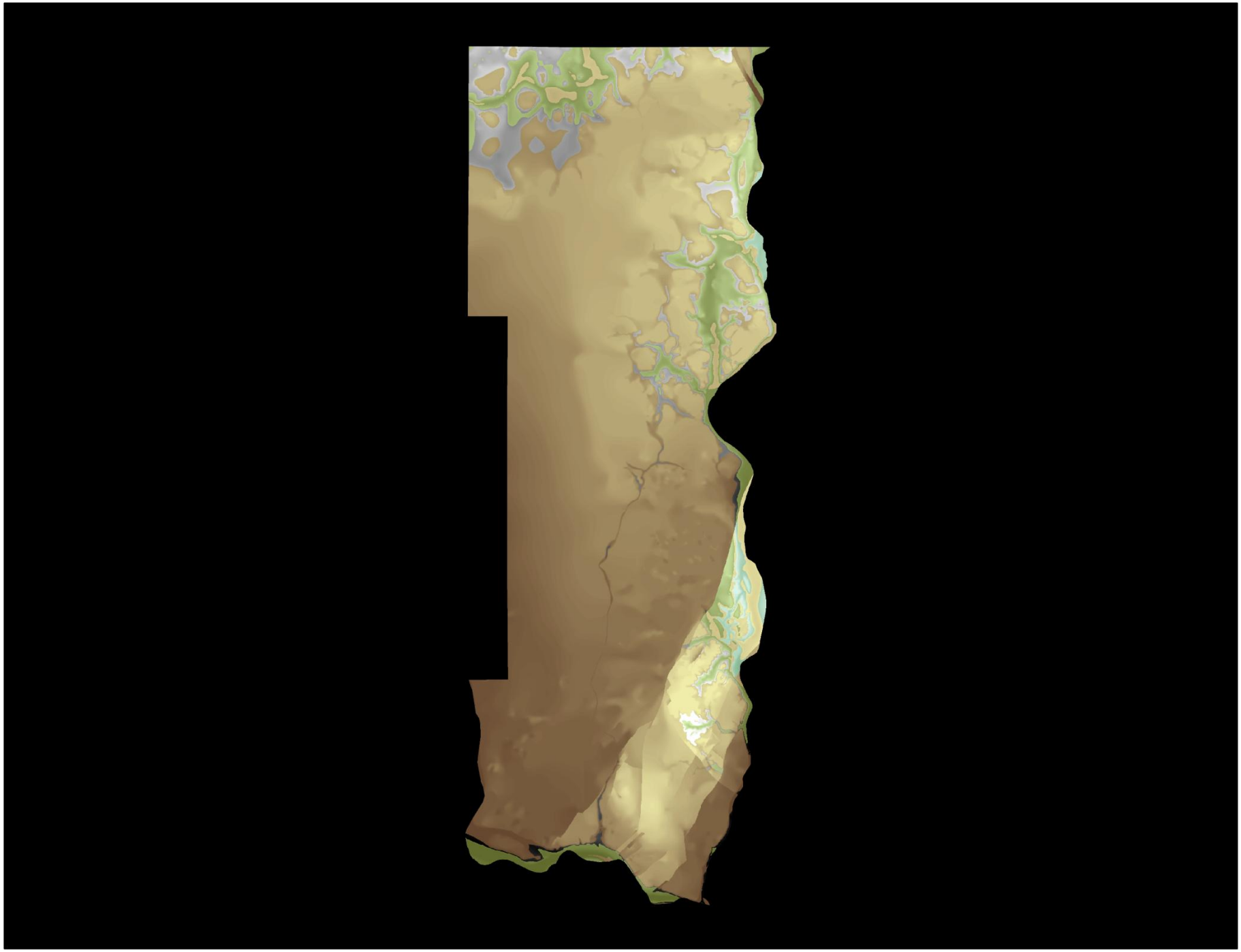

Elevation of the top of the Jordan Sandstone in feet
Less than 550
551-600
601-650
651-700
701-750
751-800
801-850
851-900
901-950
951-1,000
1,001-1,050

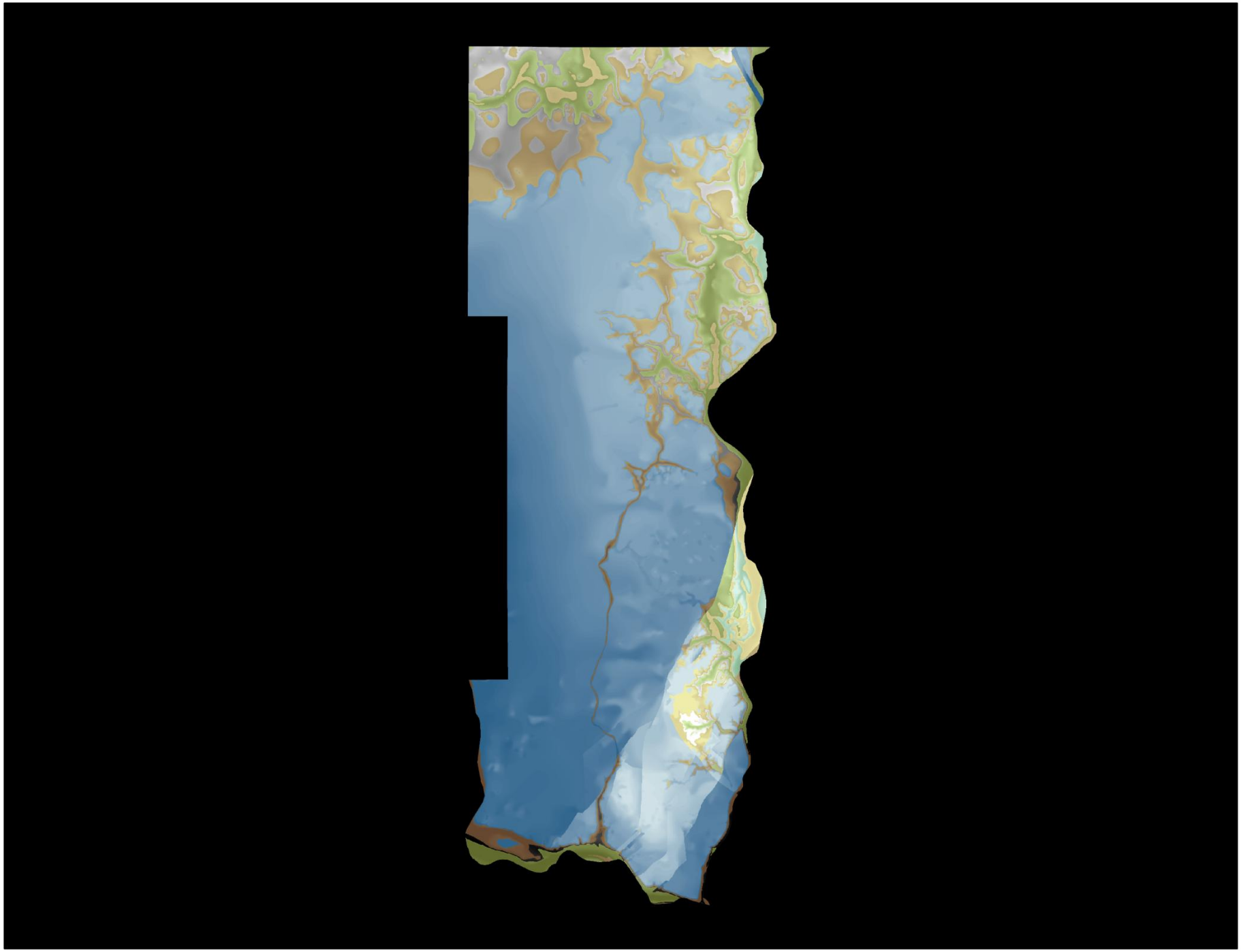

Thickness of Prairie du Chien Group rocks in feet
300
250
200
150
100
50
0
CGF
HUDSON-ALTON HORST
CGFZ
HF
HFZ

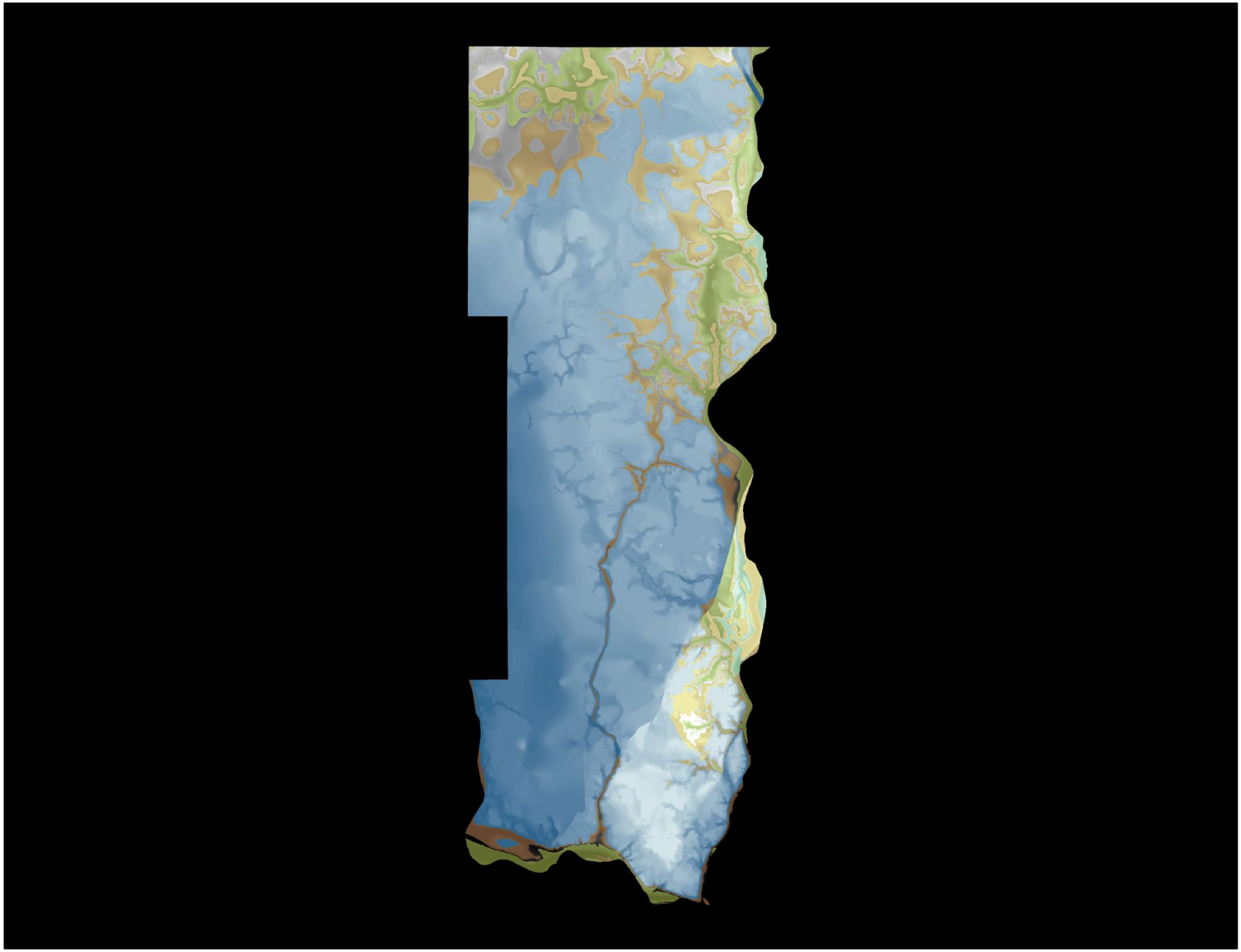


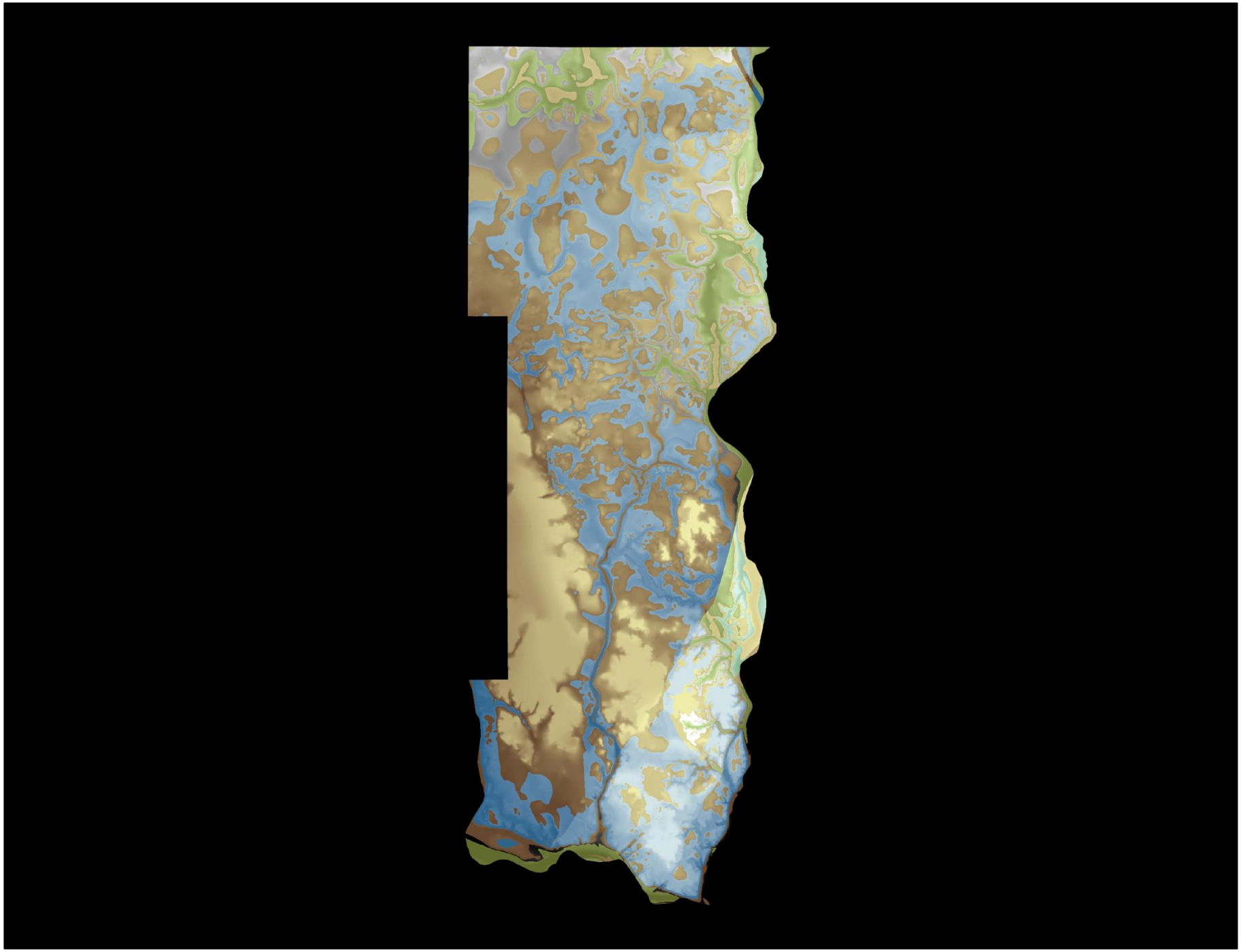


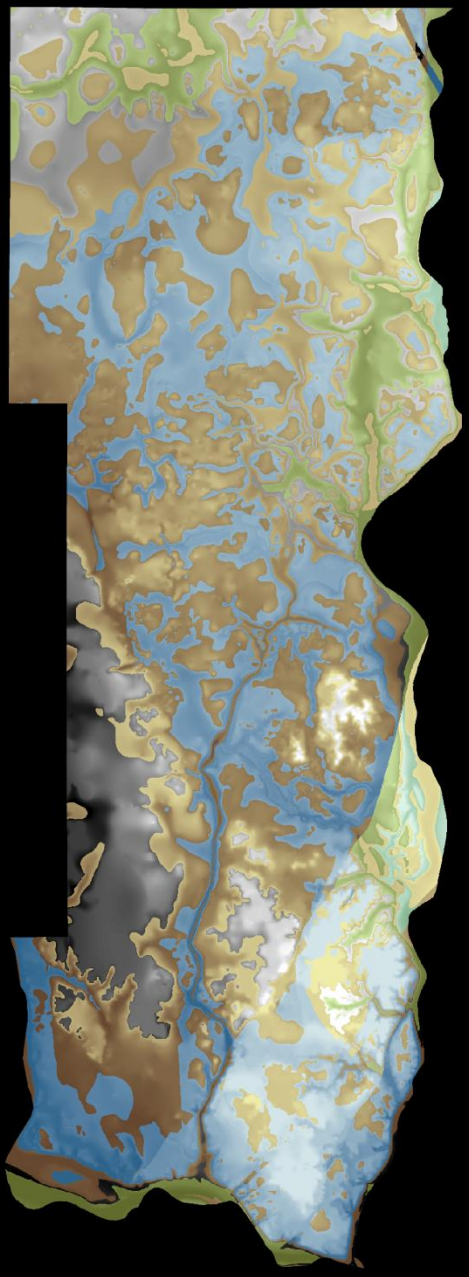


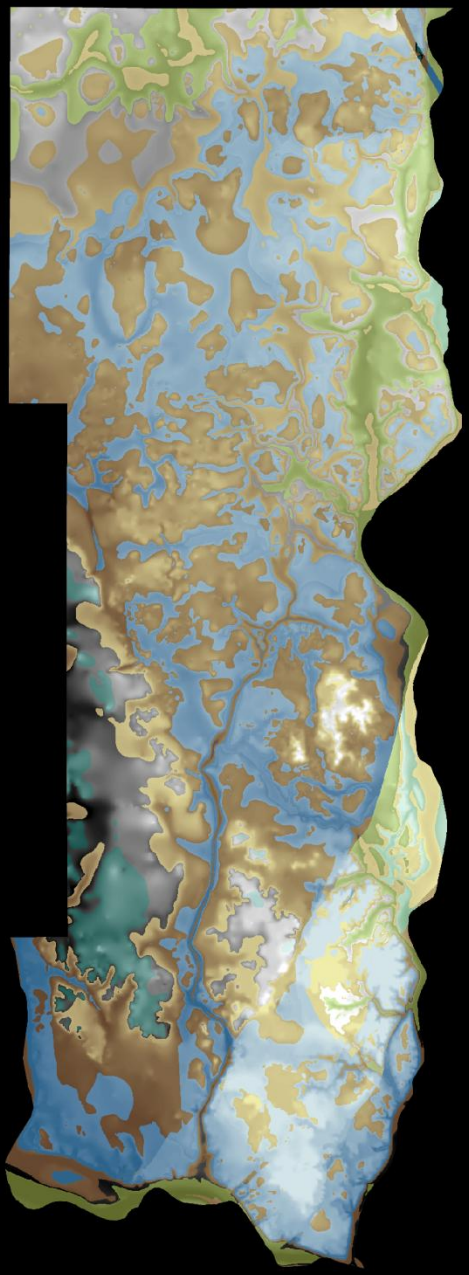


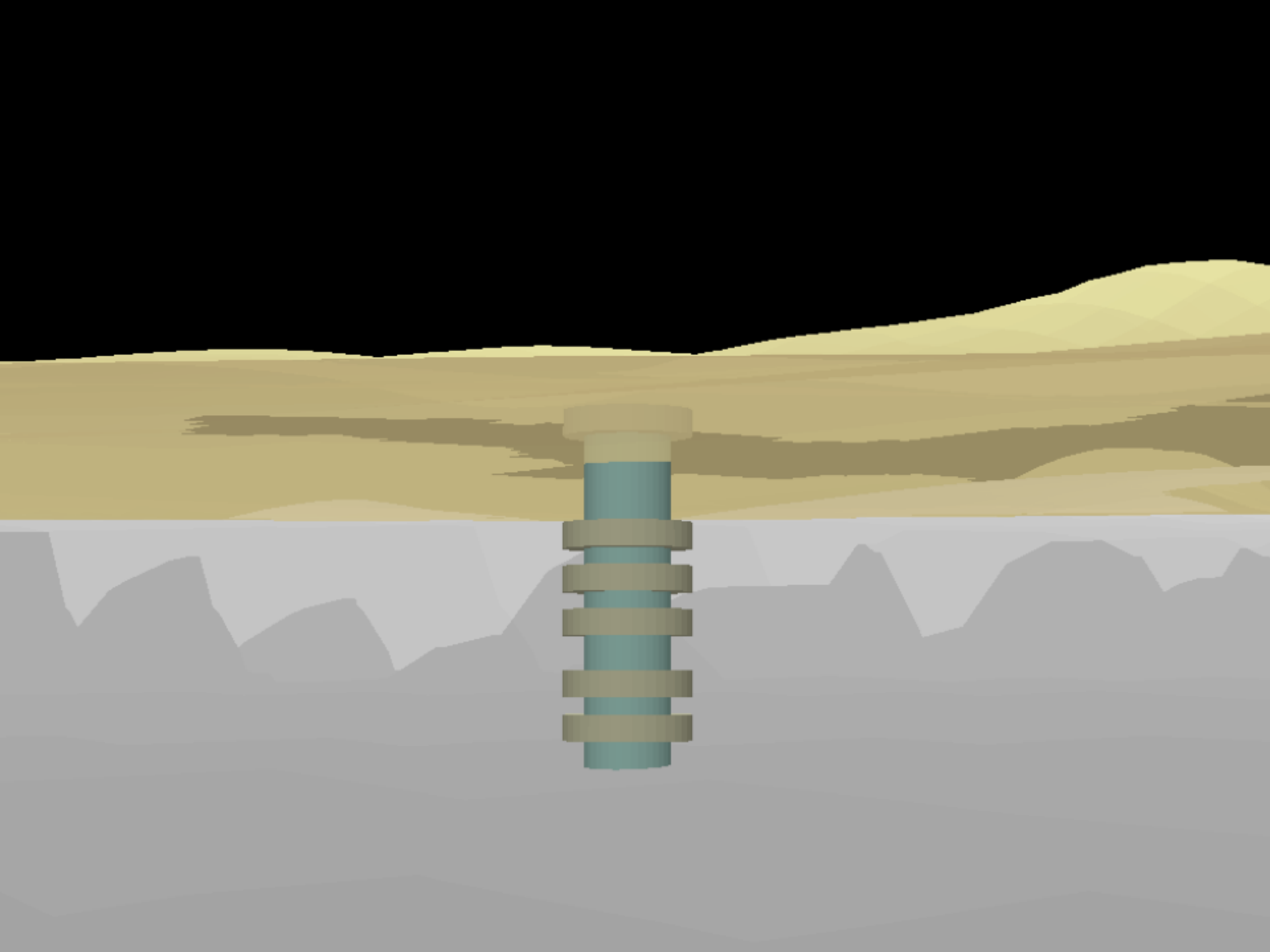


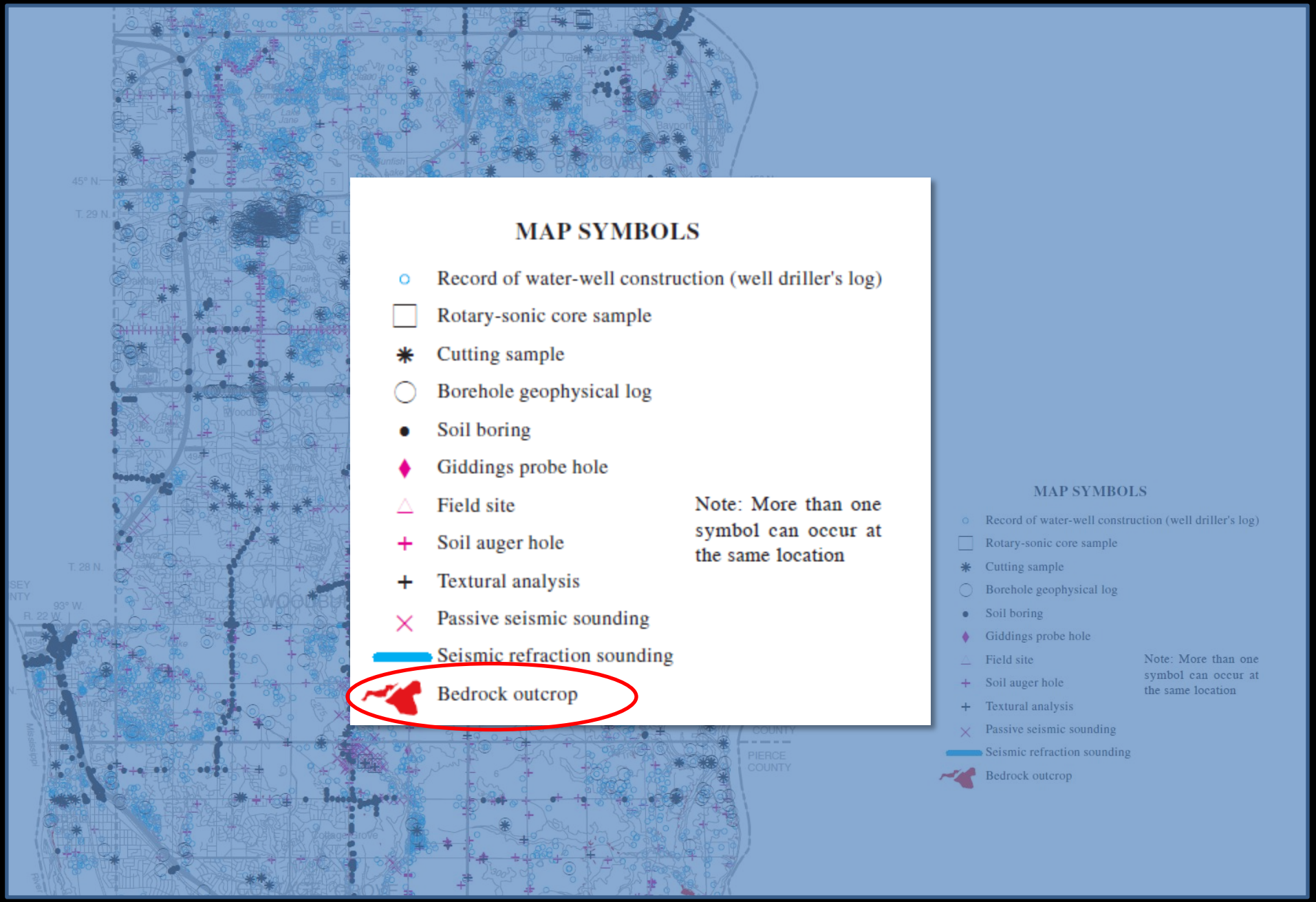


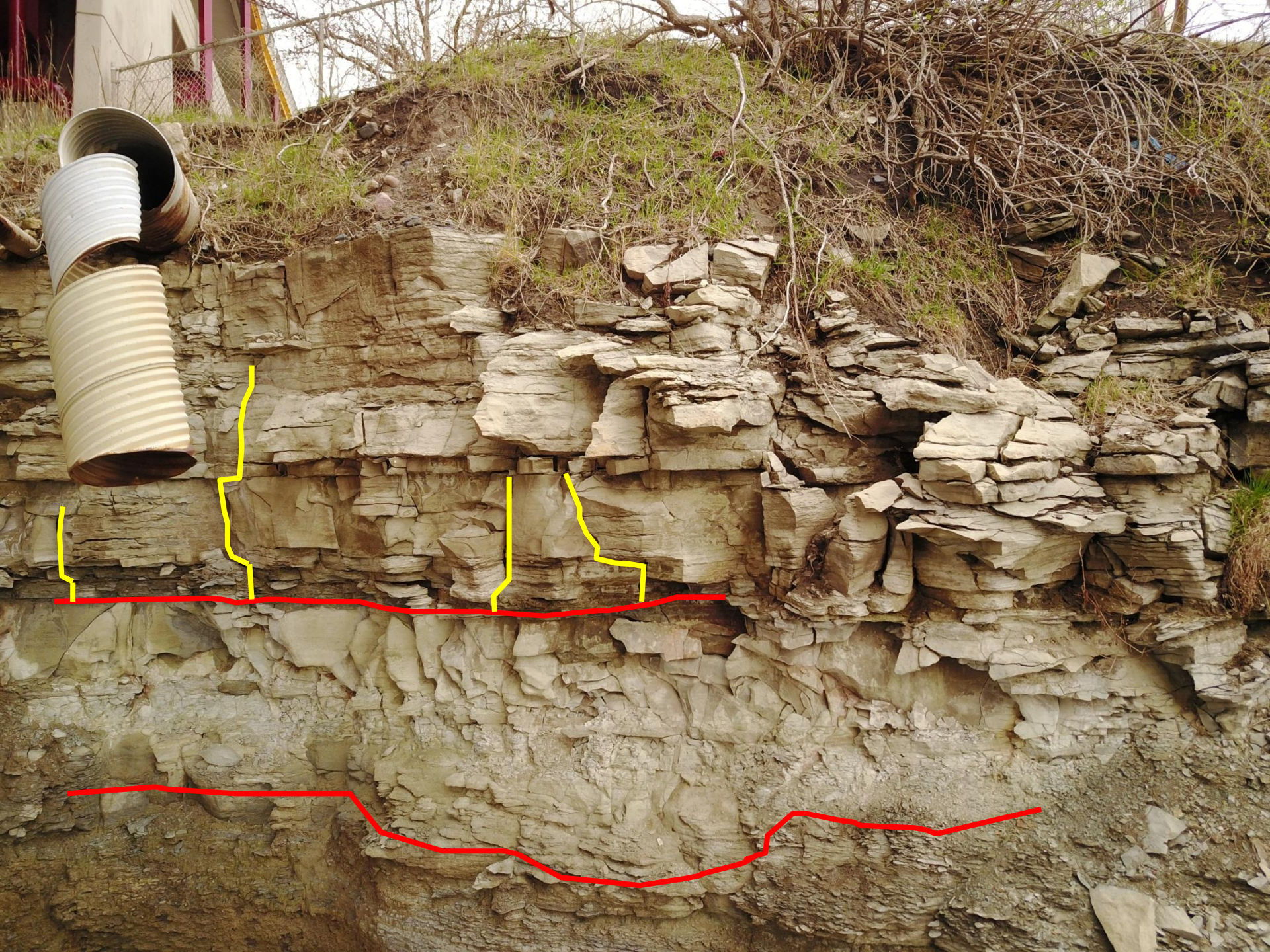








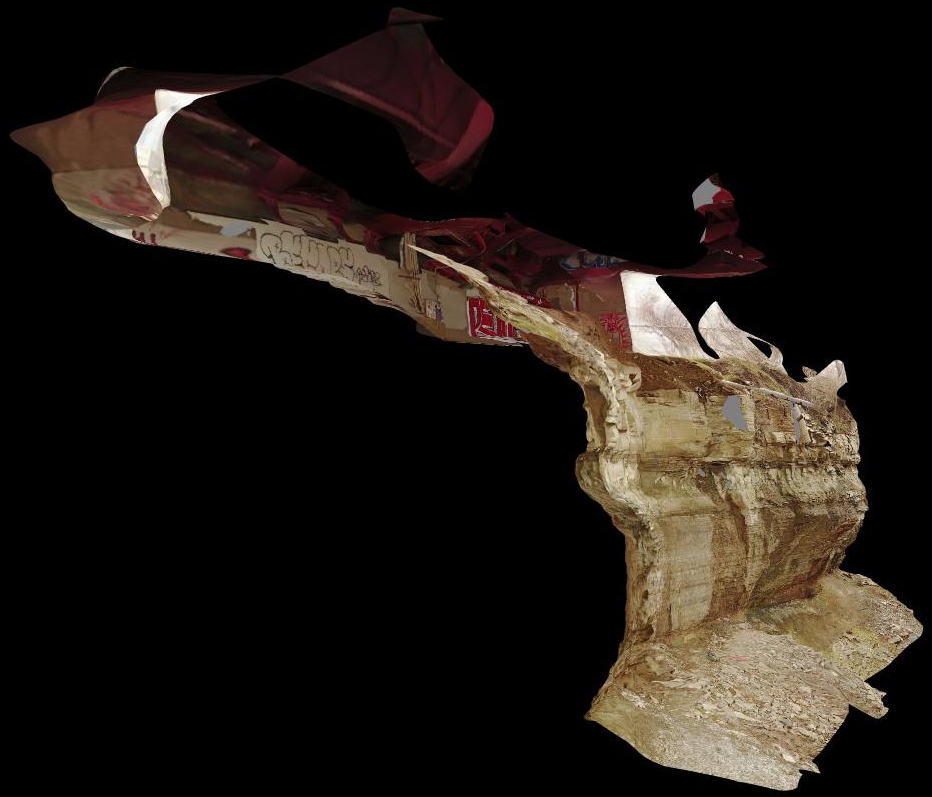

MAP SYMBOLS
Record of water-well construction (well driller's log)
Rotary-sonic core sample
Cutting sample
Borehole geophysical log
Soil boring
Giddings probe hole
Field site
Soil auger hole
Textural analysis
Passive seismic sounding
Seismic refraction sounding
Bedrock outcrop
Note: More than one symbol can occur at the same location
MAP SYMBOLS
Record of water-well construction (well driller's log)
Rotary-sonic core sample
Cutting sample
Borehole geophysical log
Soil boring
Giddings probe hole
Field site
Soil auger hole
Textural analysis
Passive seismic sounding
Seismic refraction sounding
Bedrock outcrop
Note: More than one symbol can occur at the same location

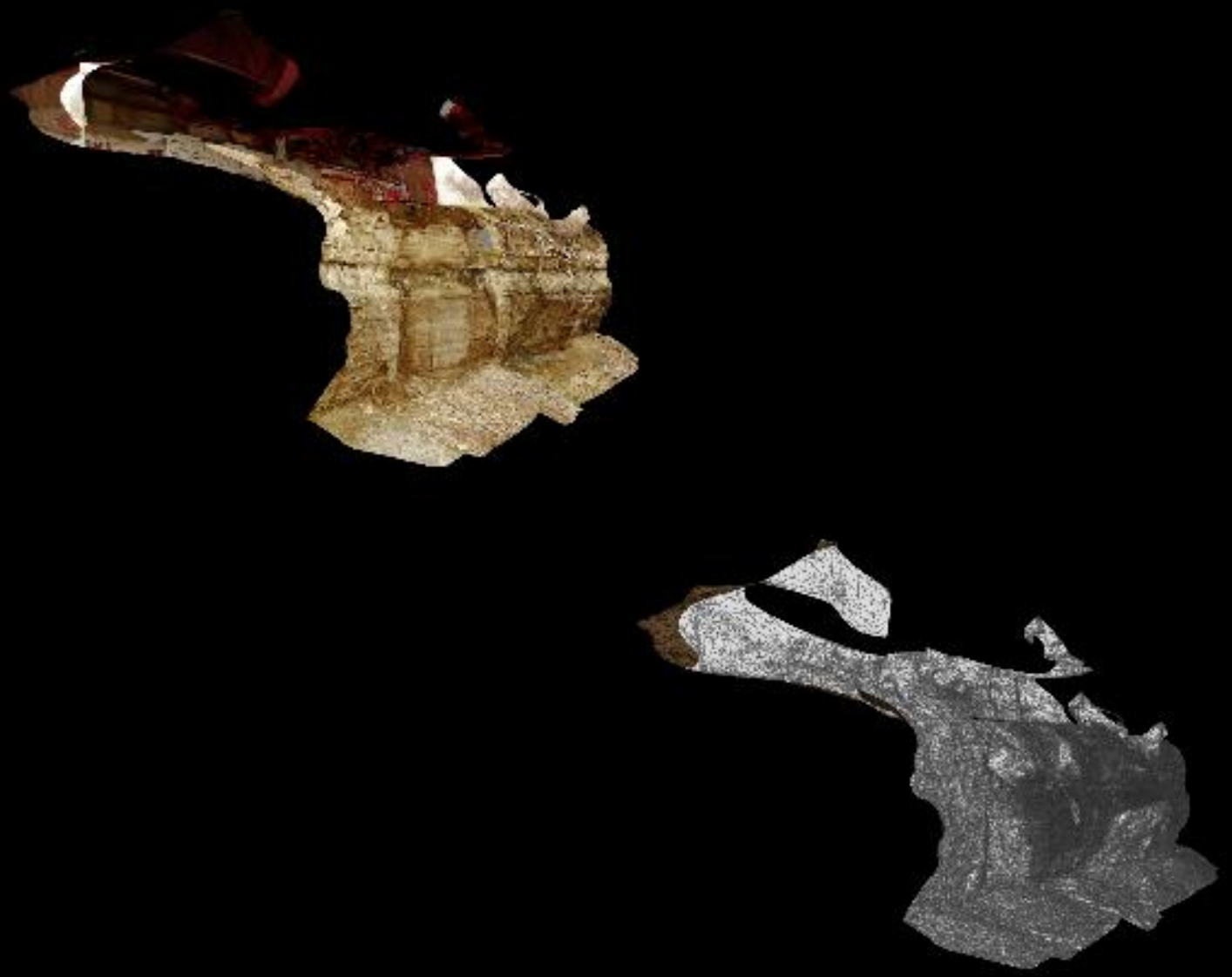


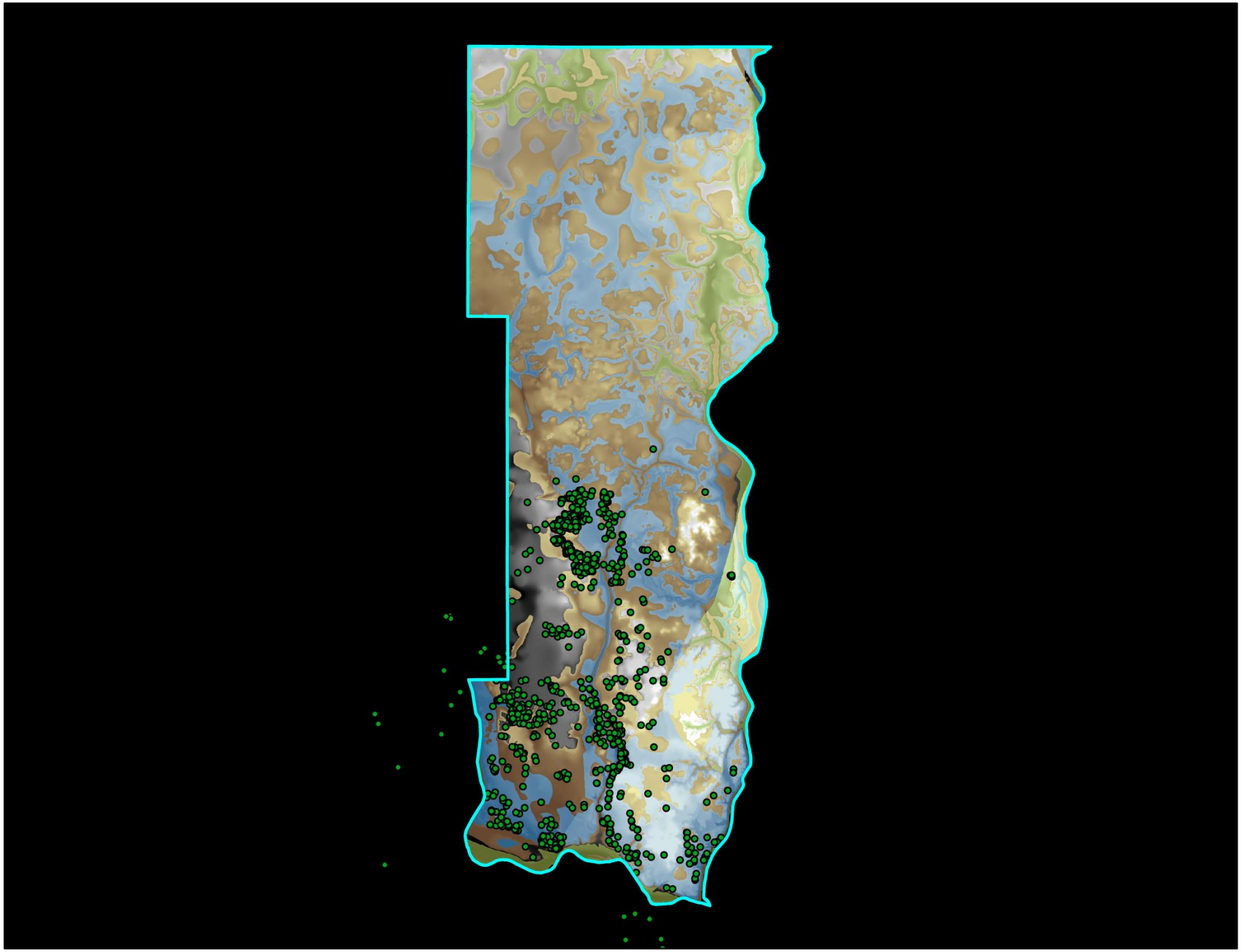

DEON

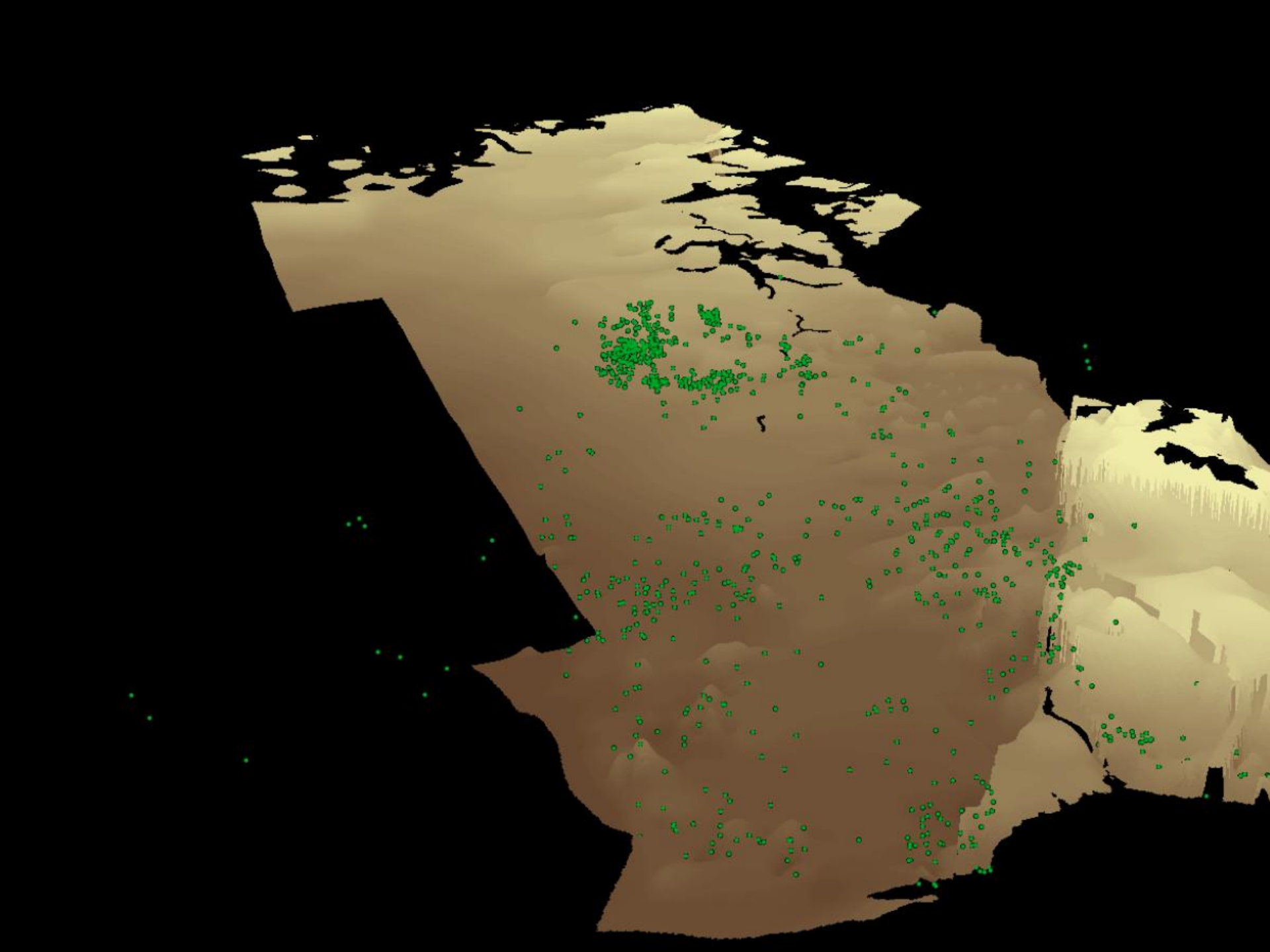

REON

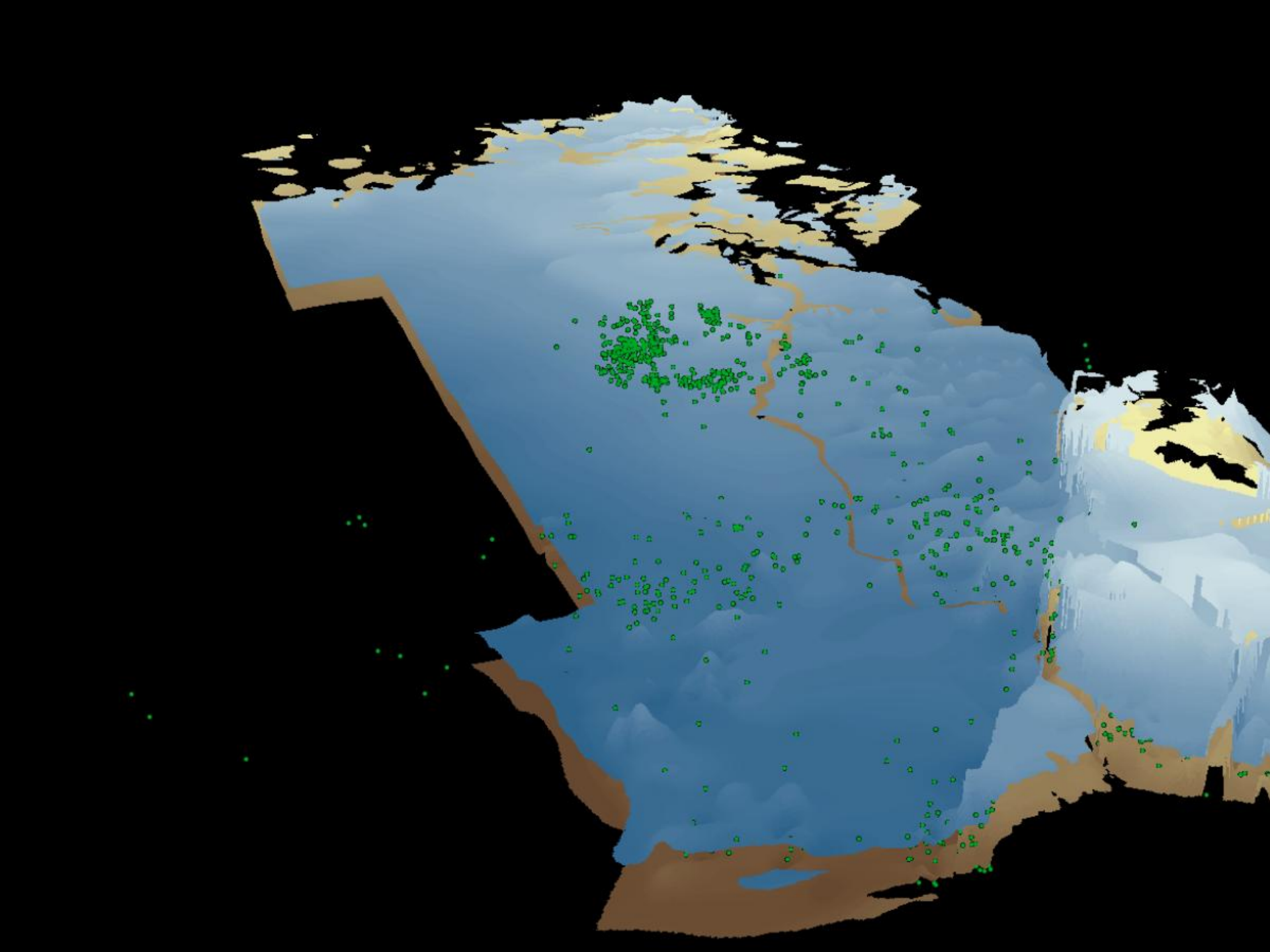

PEON

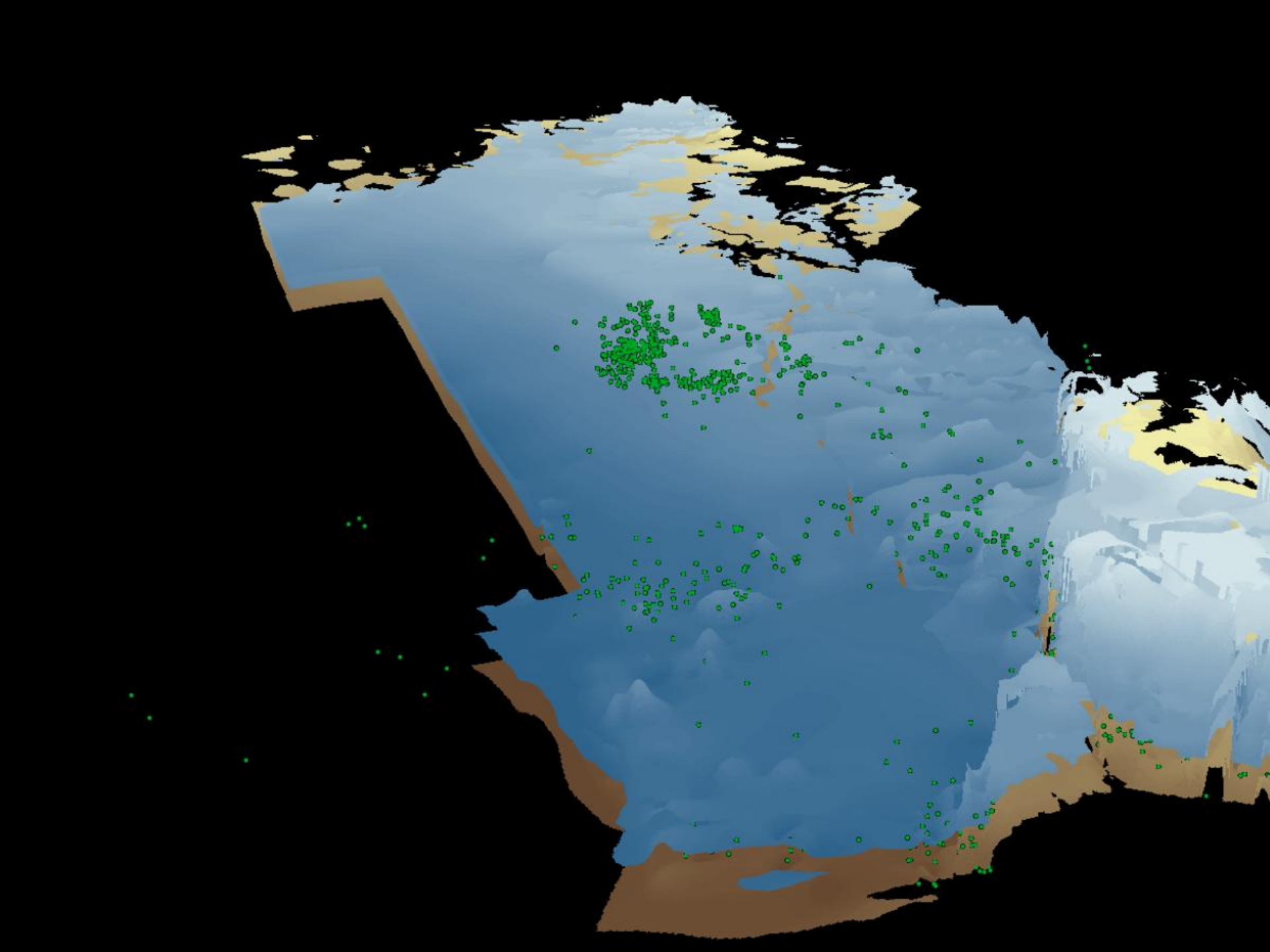


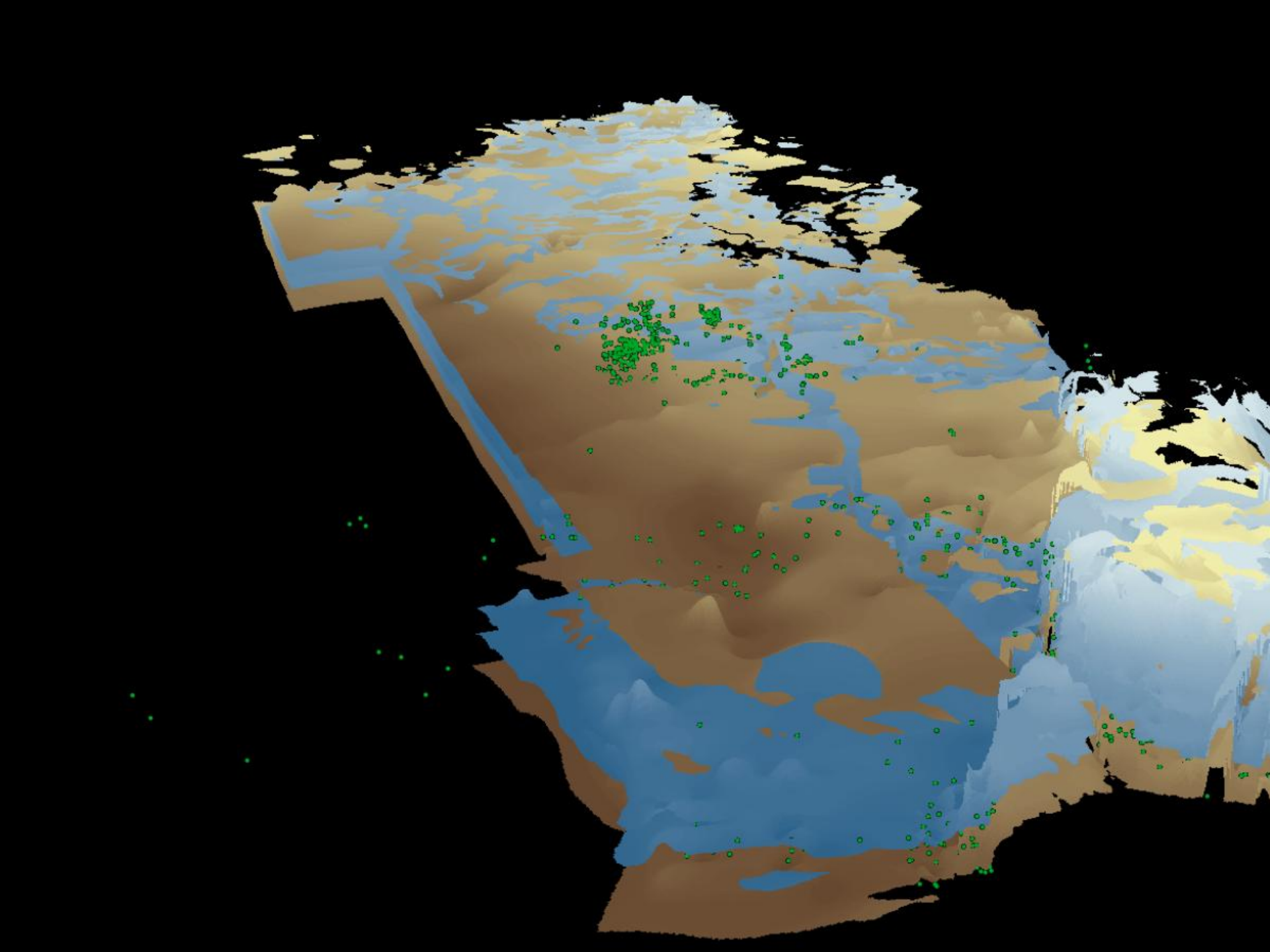


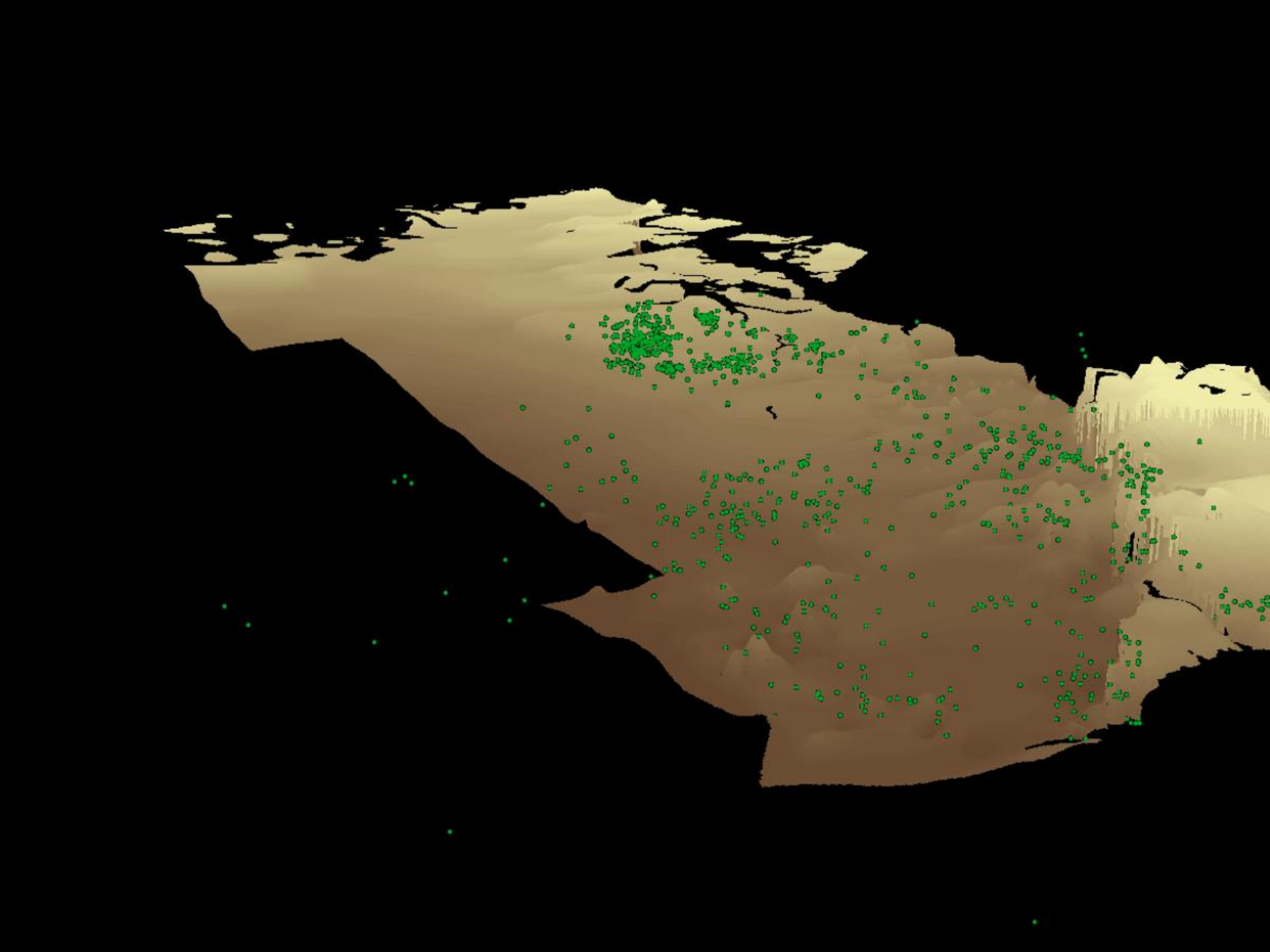


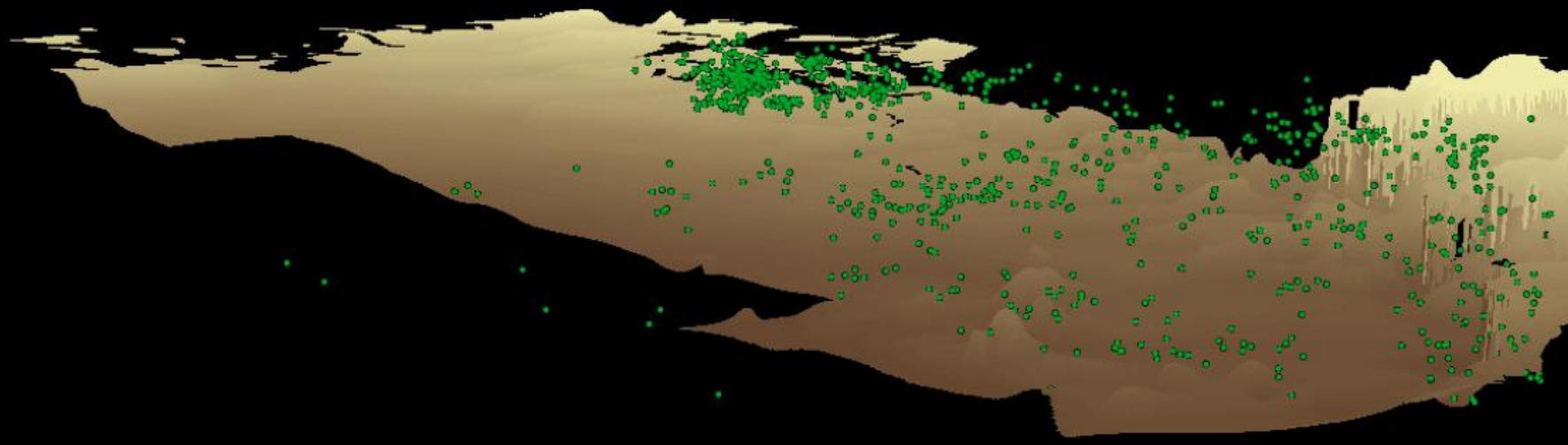


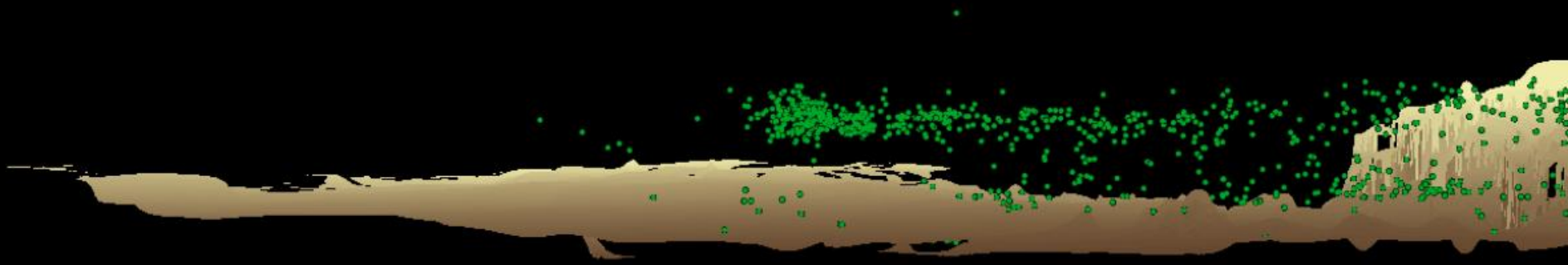


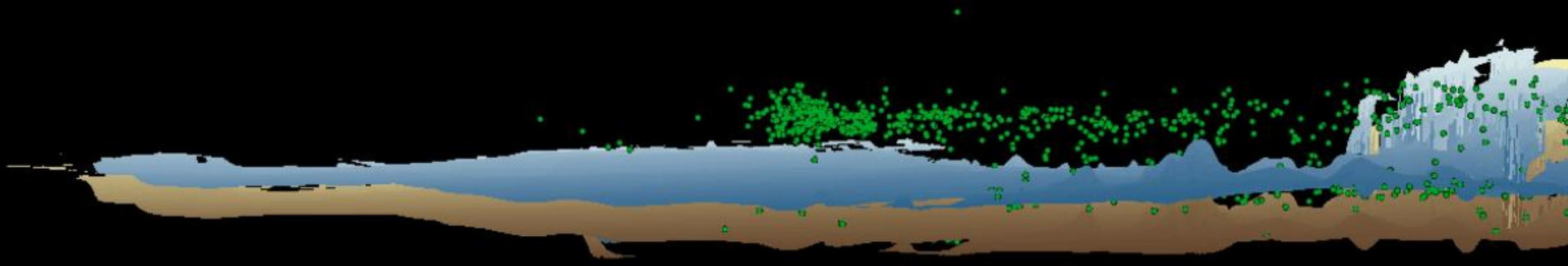


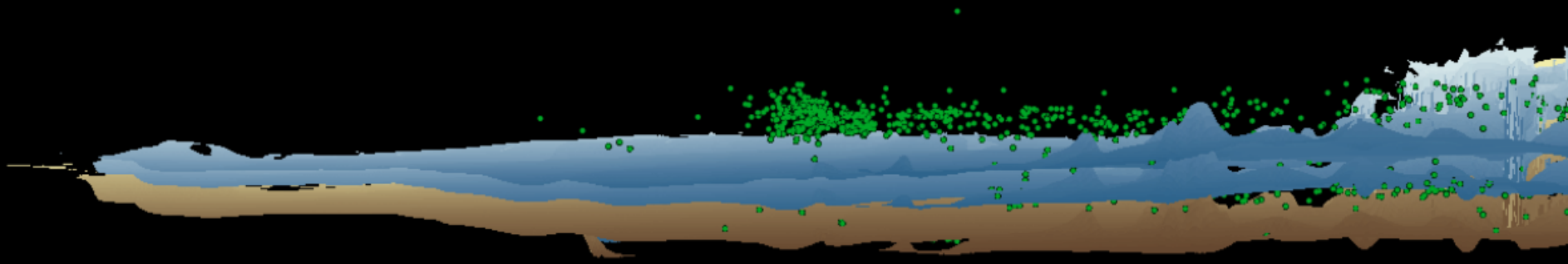


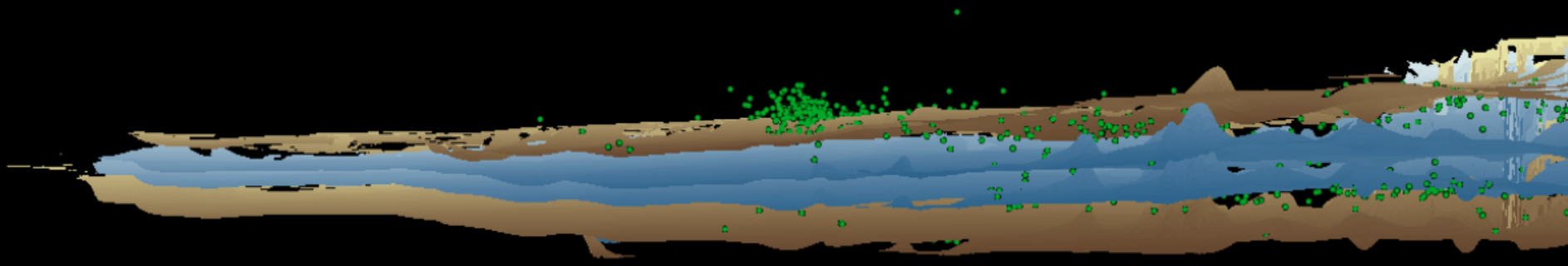


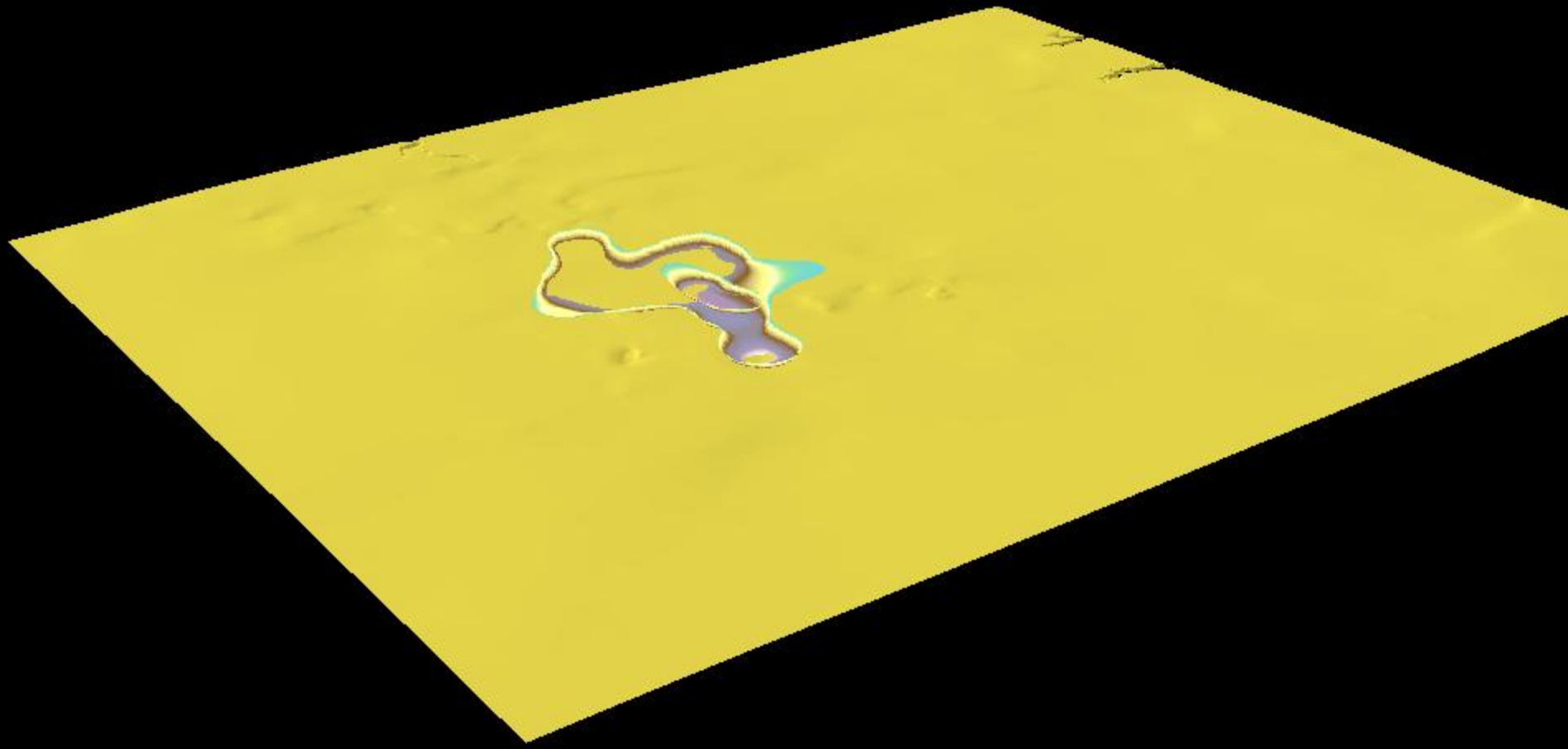


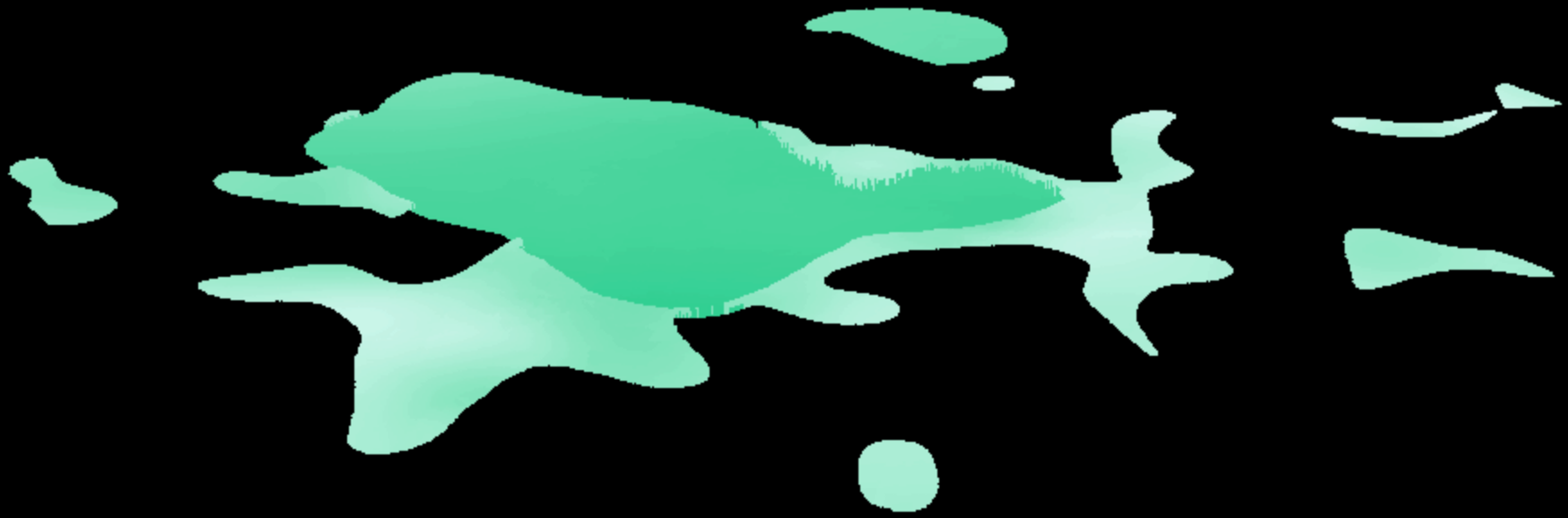


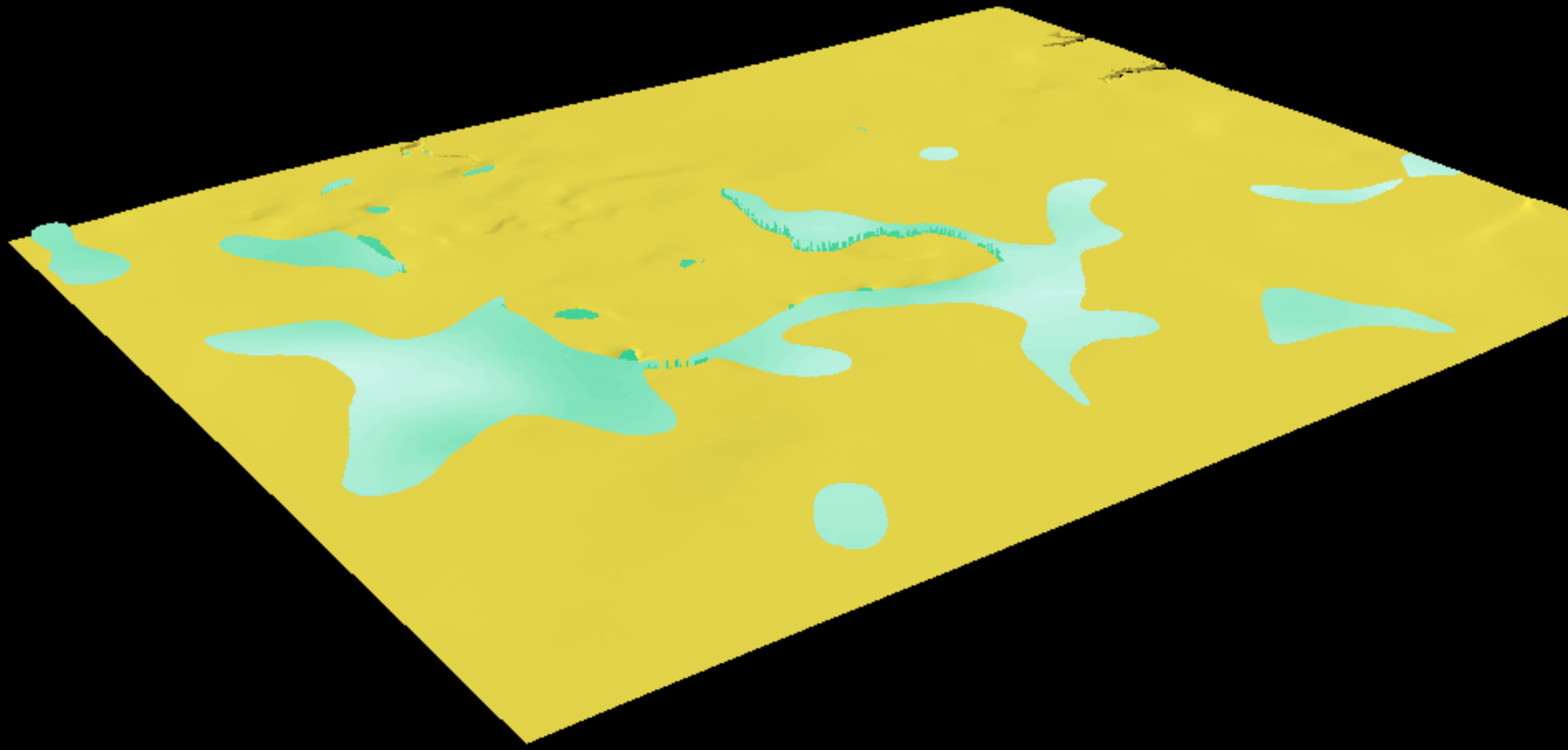


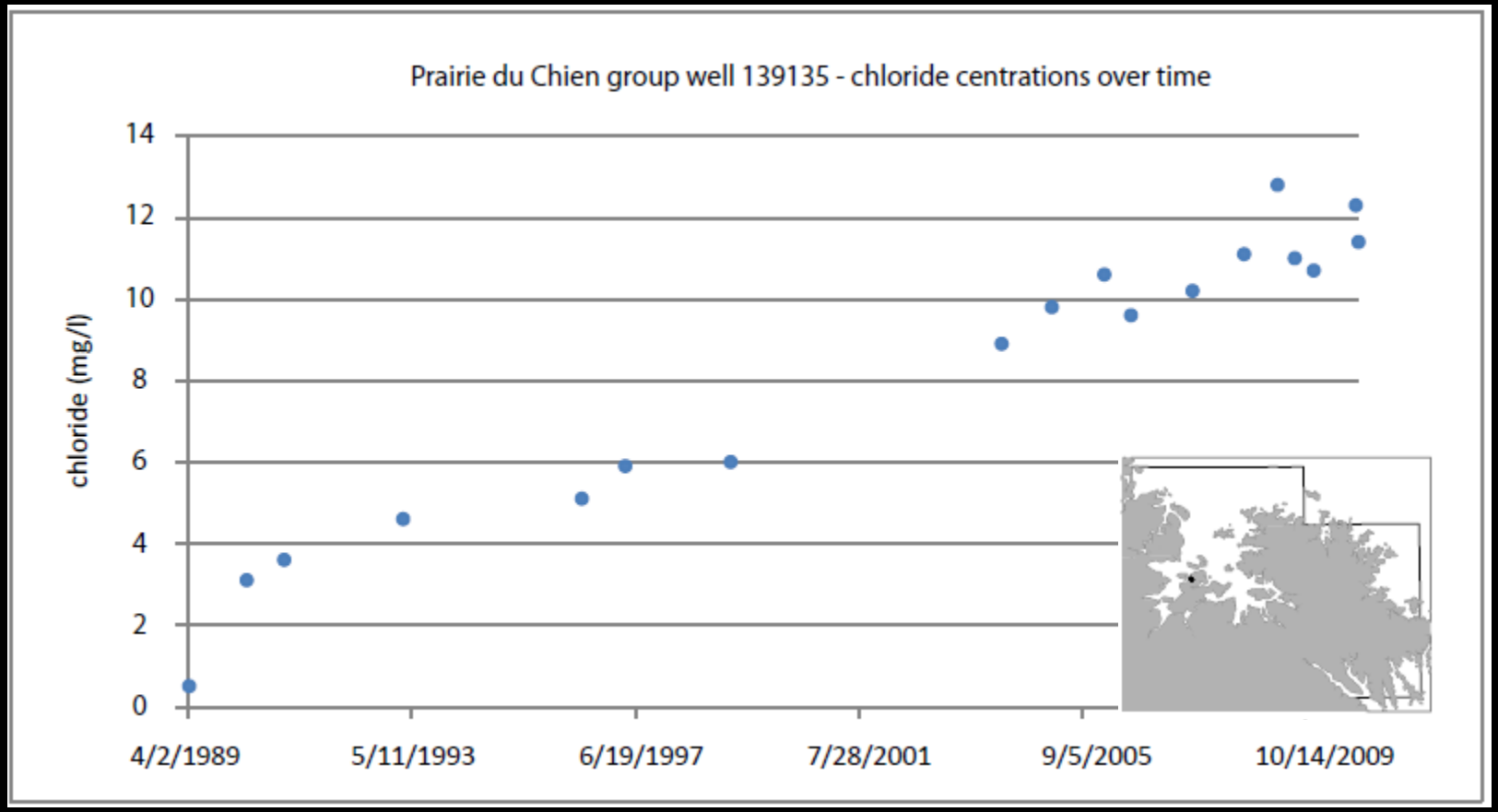


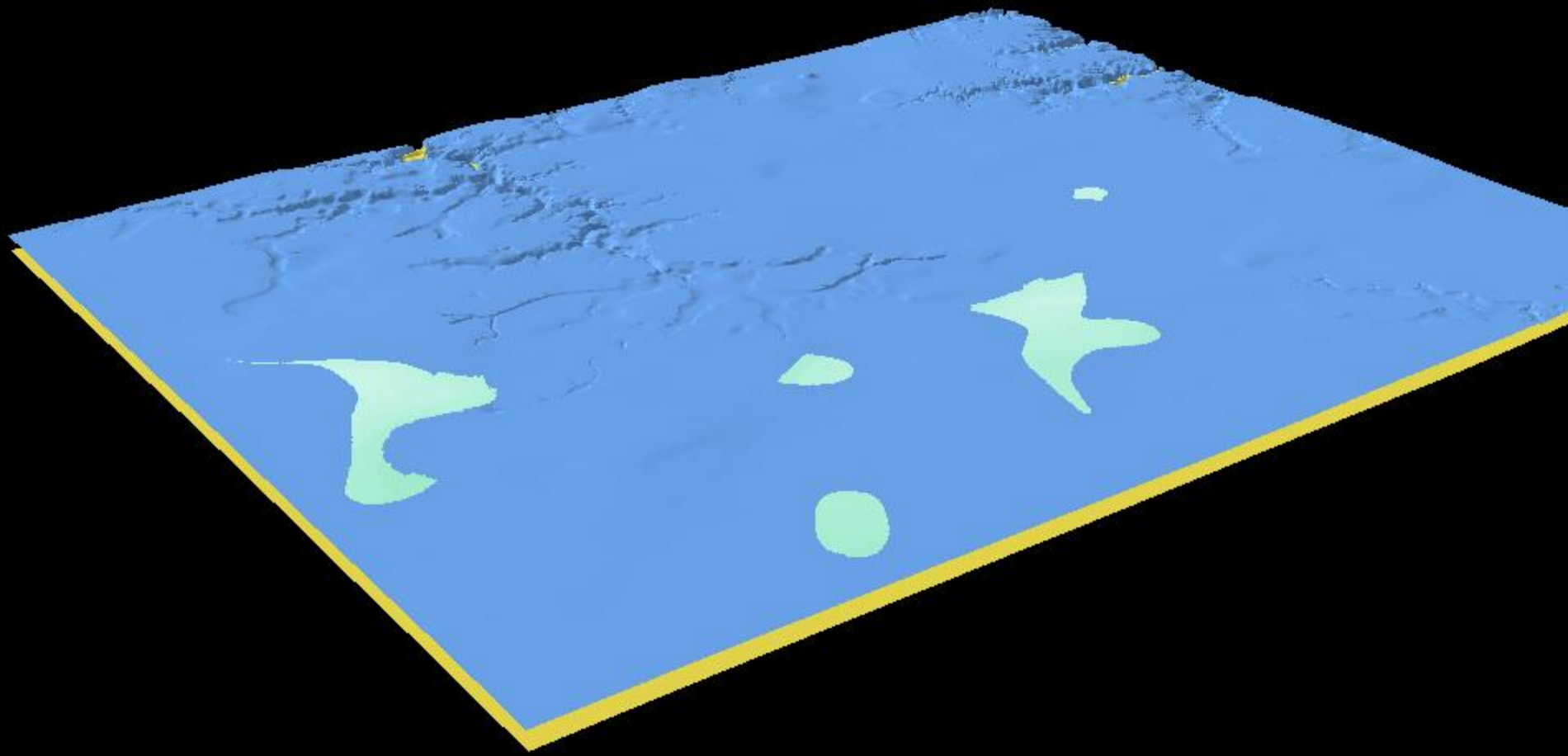


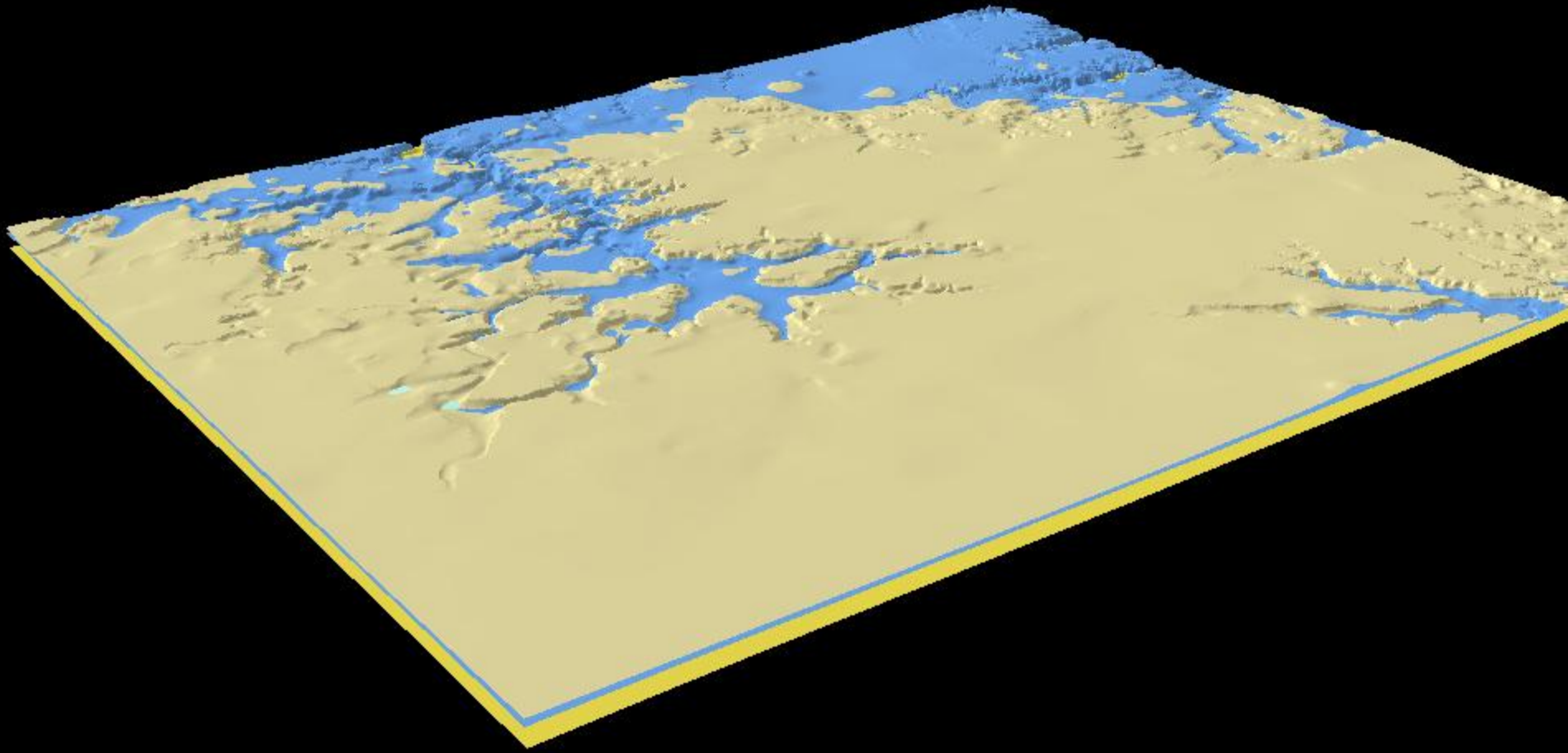


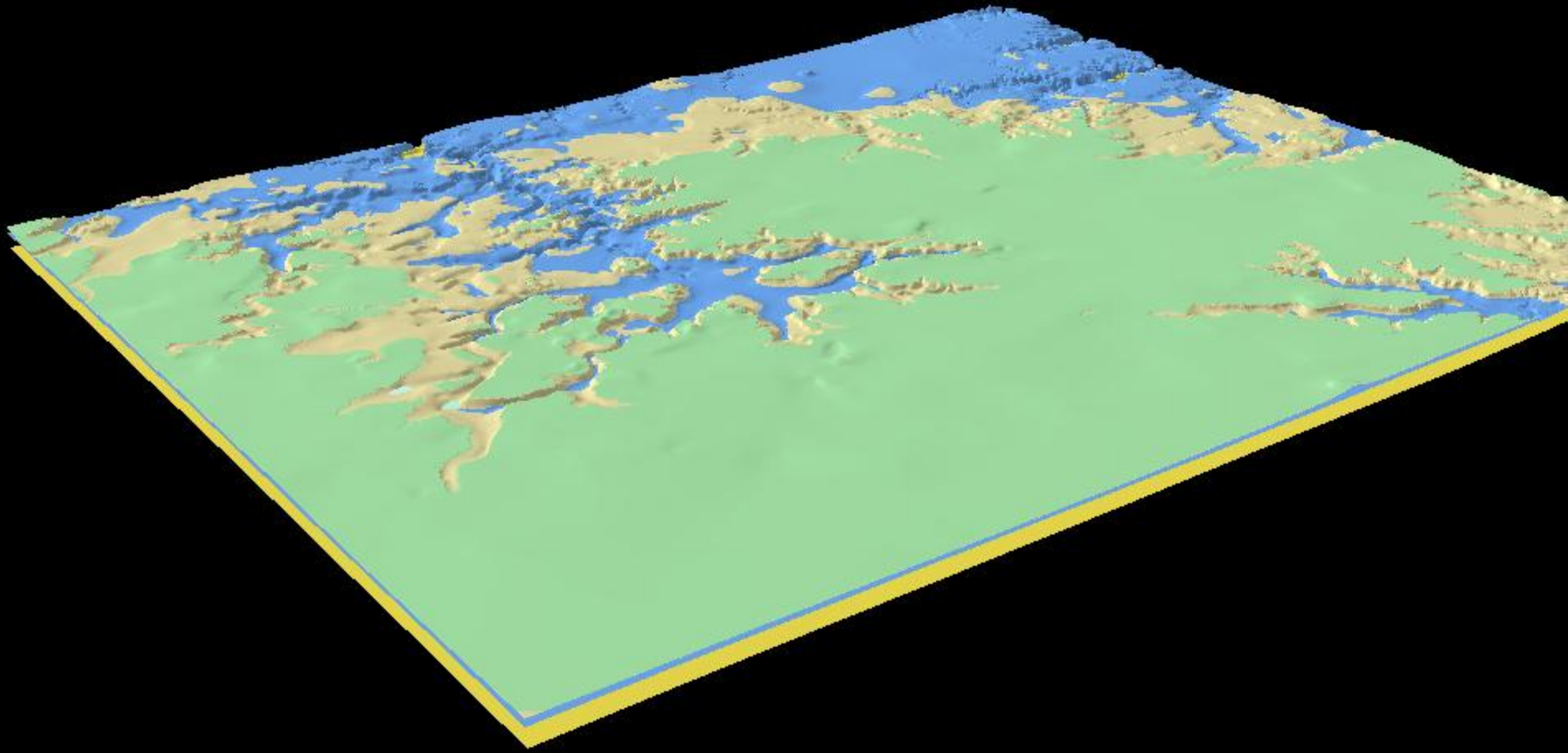


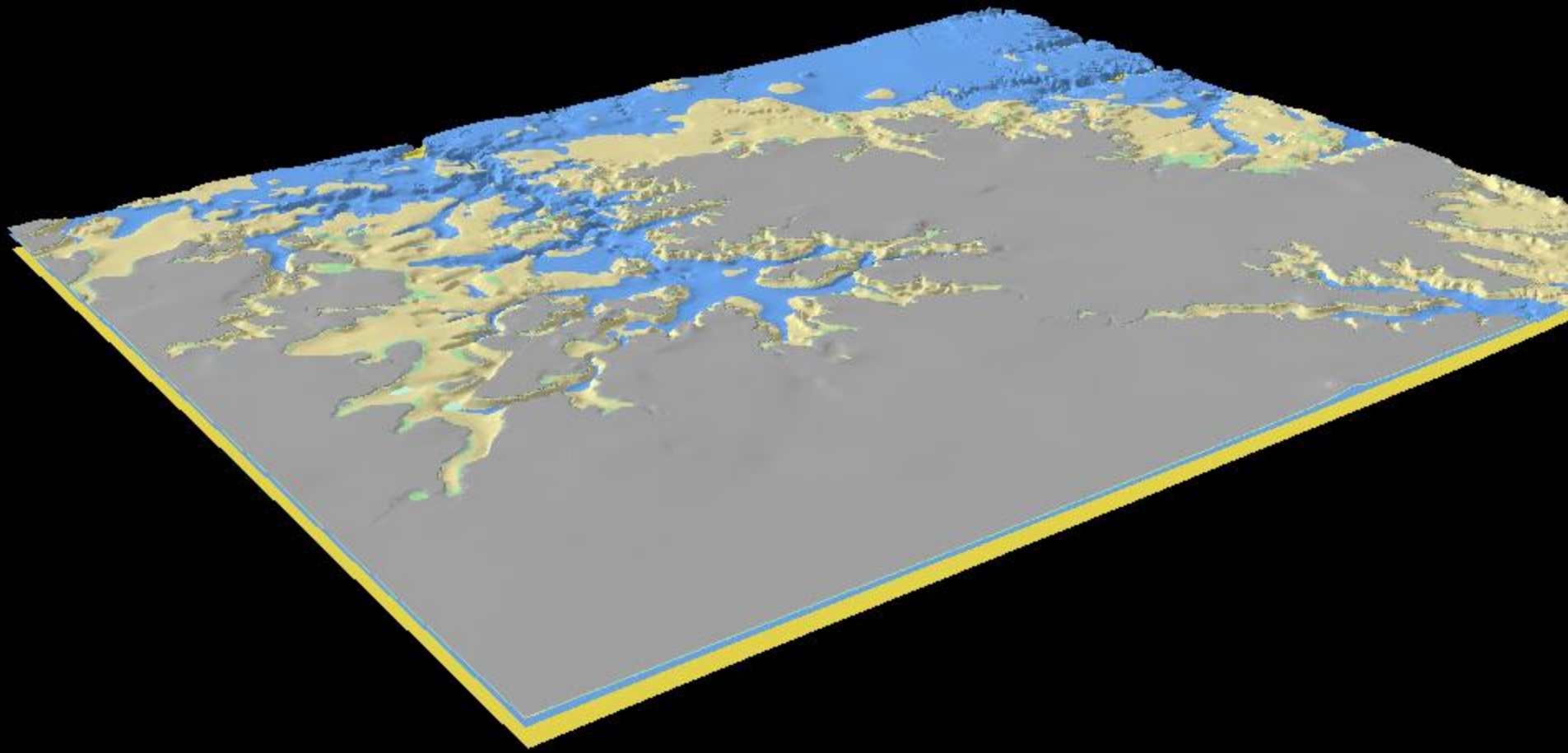


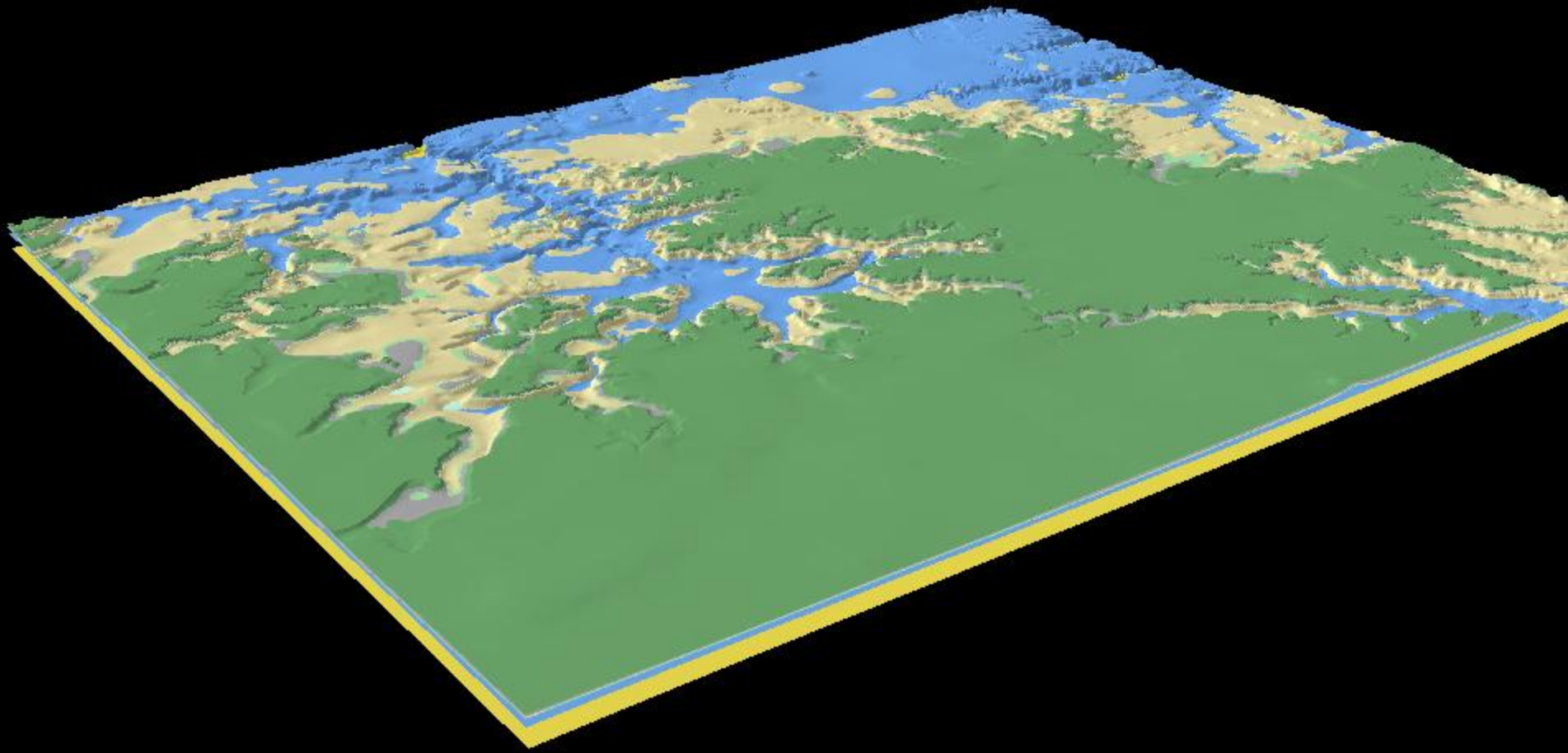

Prairie du Chien group well 139135 - chloride centrations over time
chloride (mg/l)
14
12
10
8
6
4
2
0
4/2/1989
5/11/1993
6/19/1997
7/28/2001
9/5/2005
10/14/2009

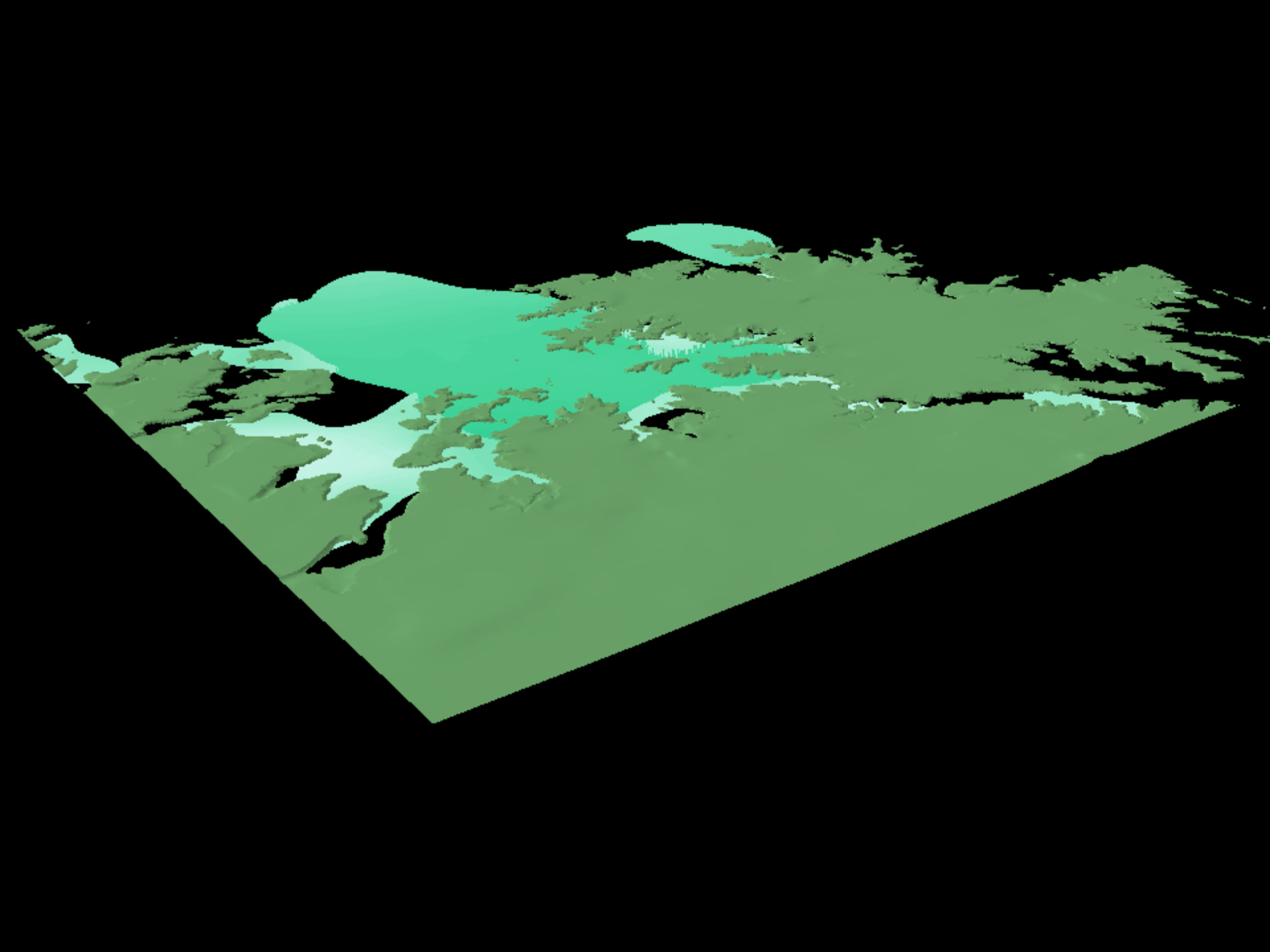


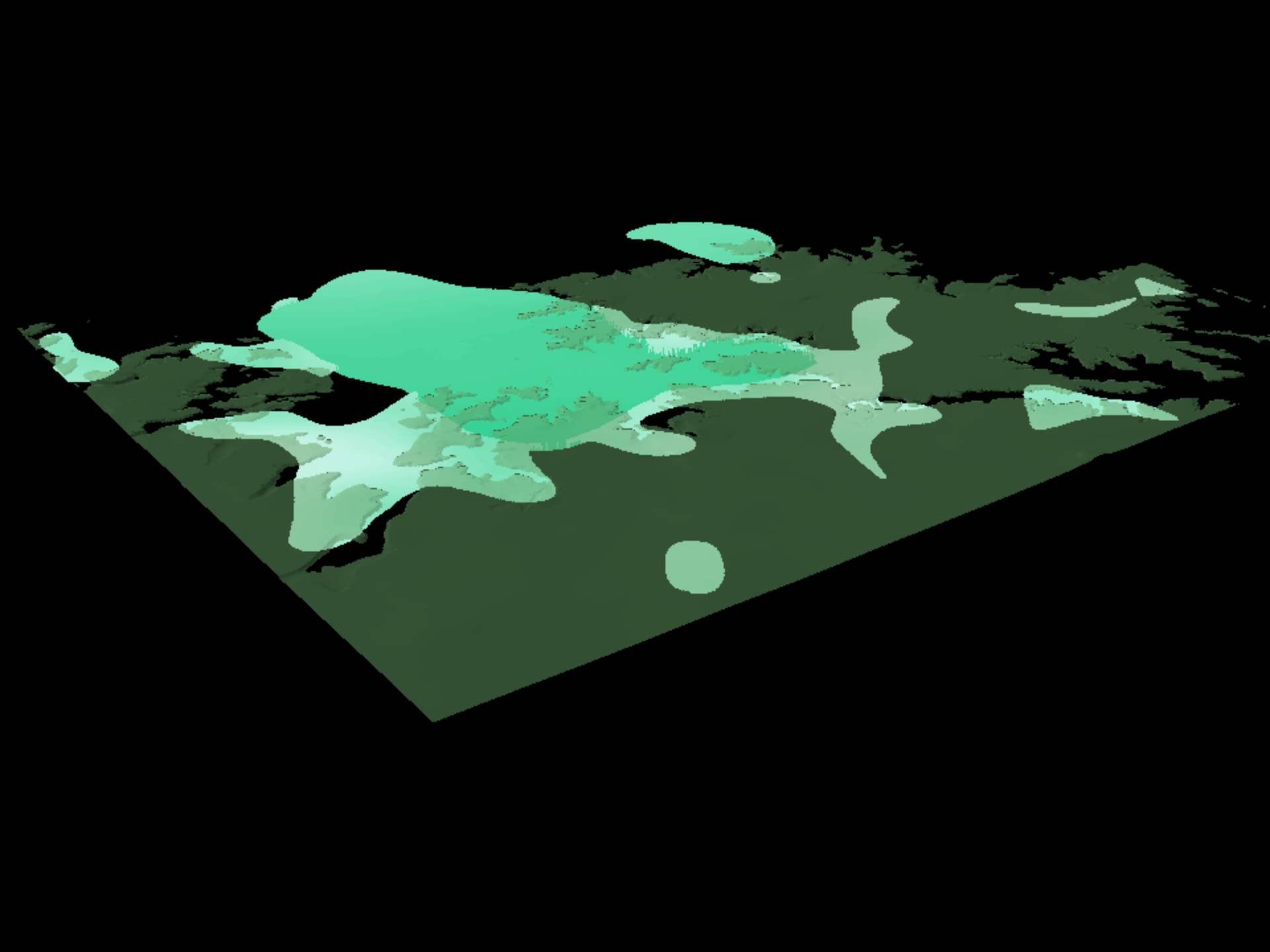


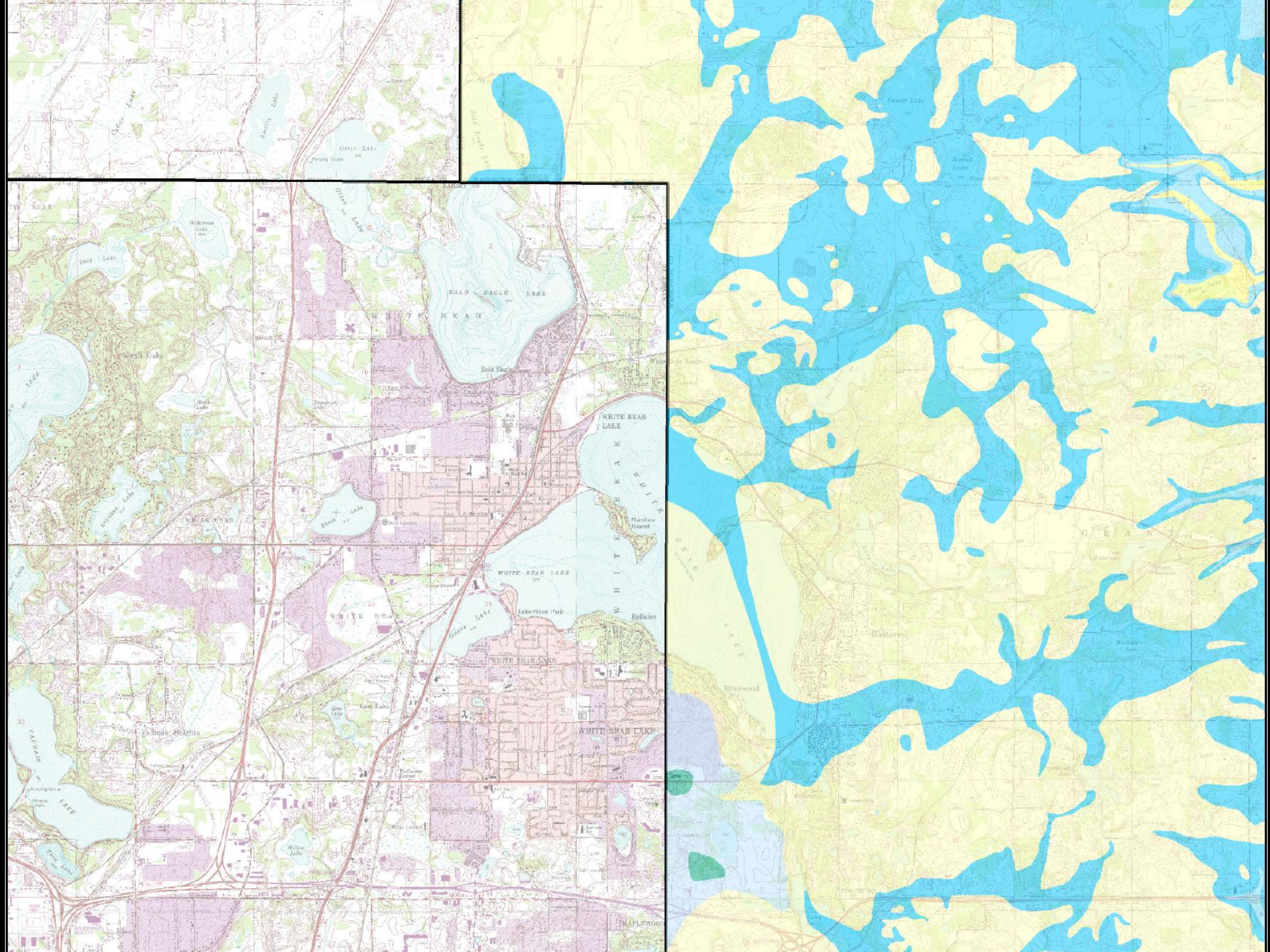








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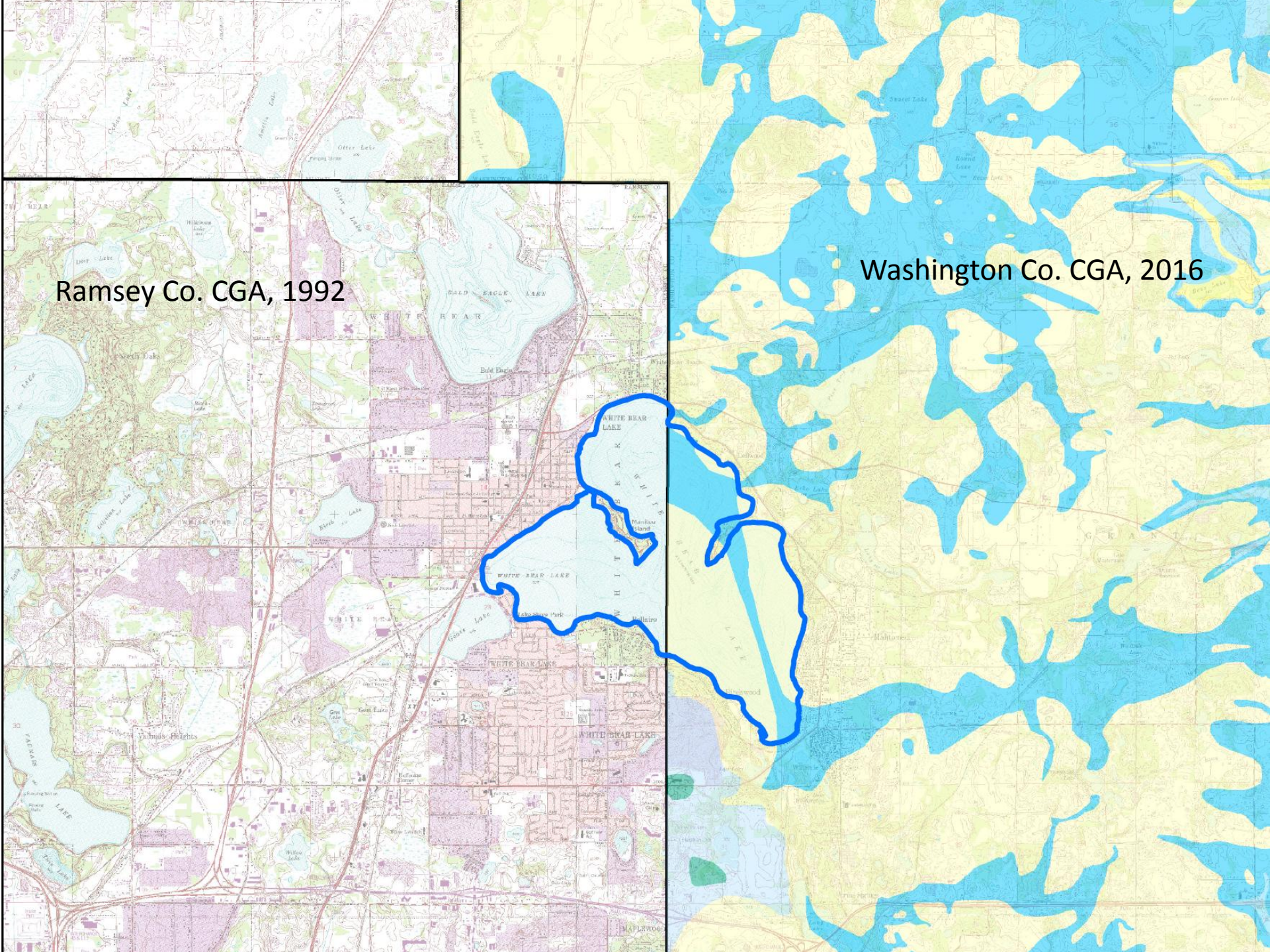
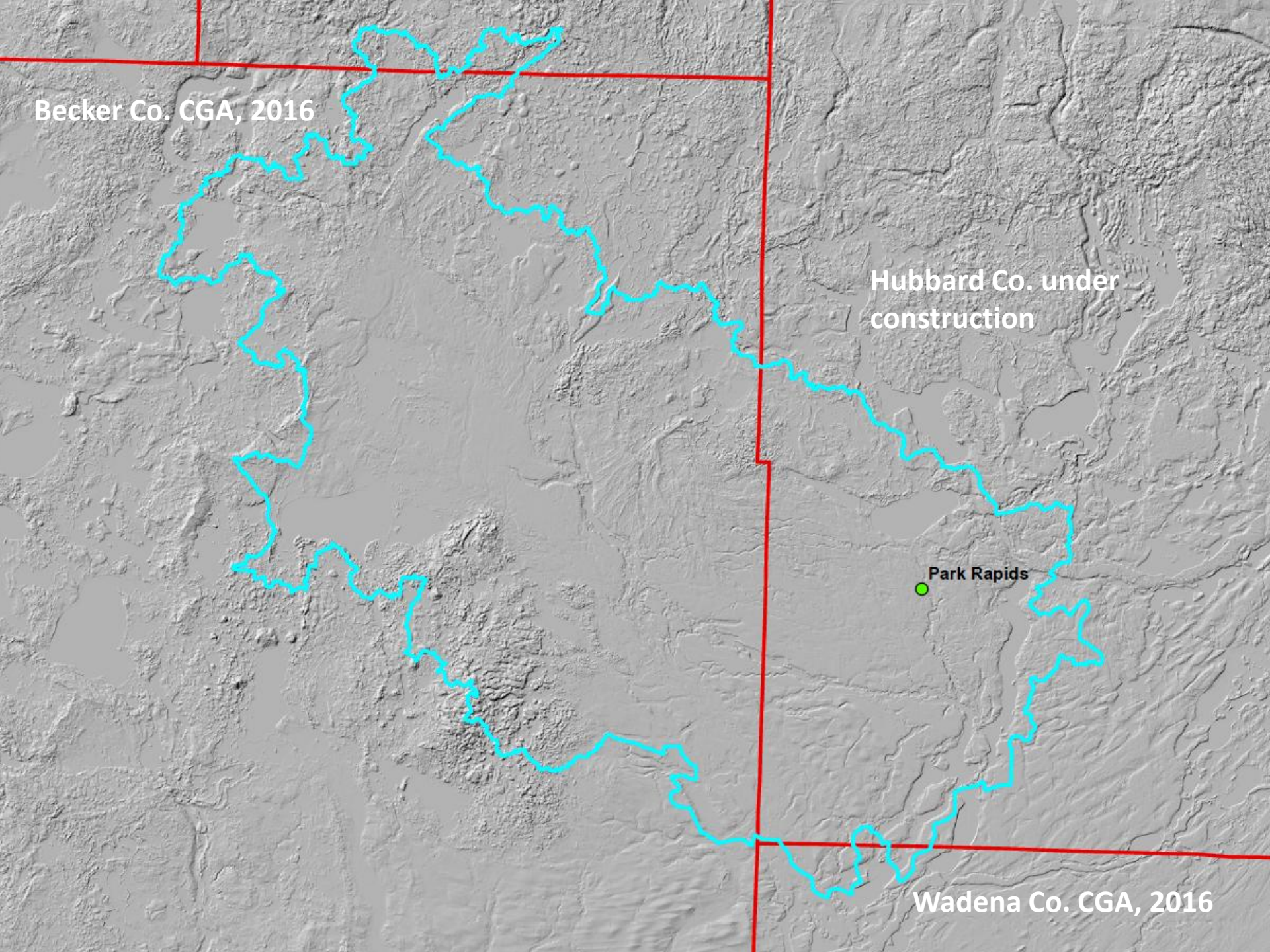
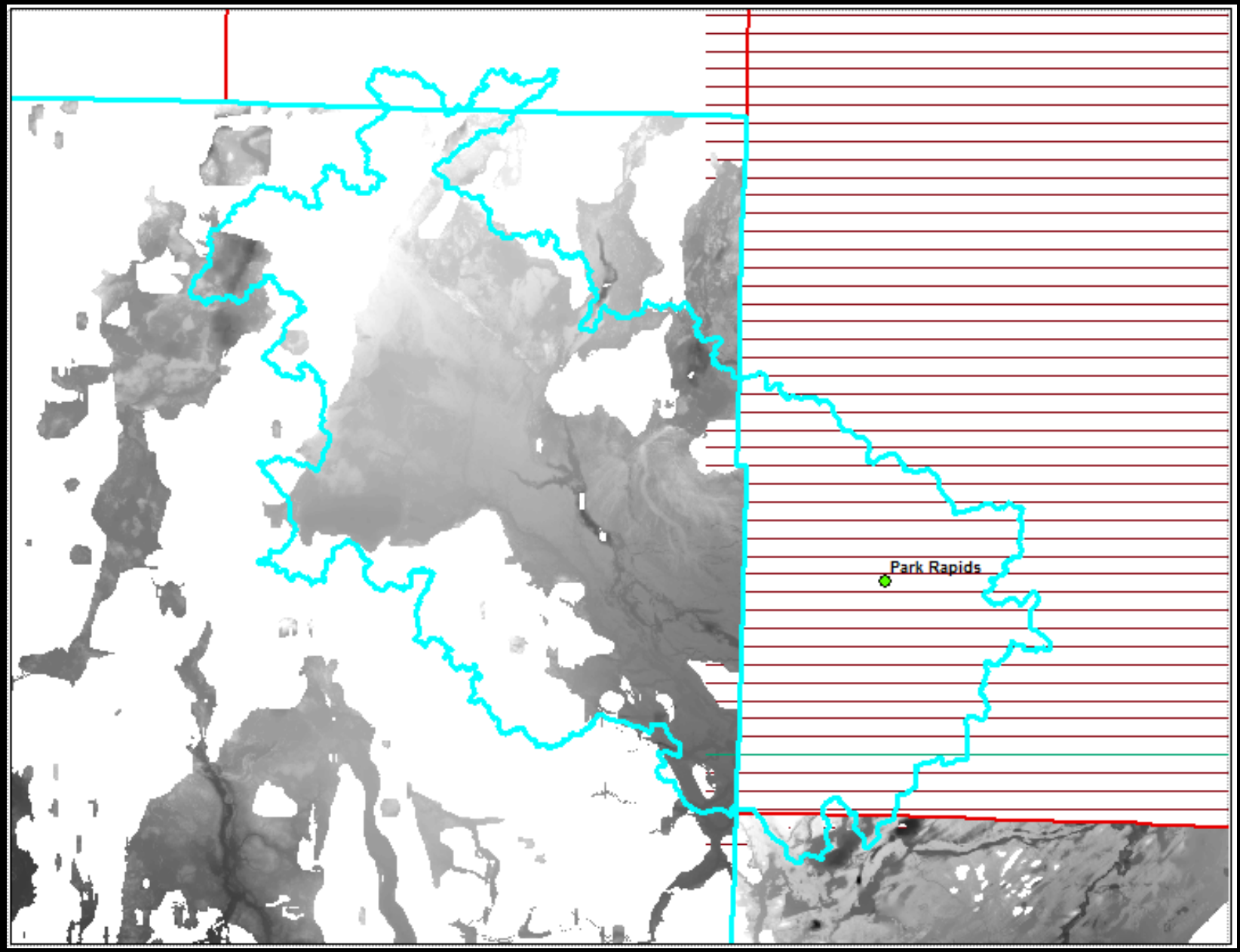
WHITE BEAR
Bald Eagle
North Oaks
WHITE BEAR LAKE
Manitou Island
Birch Lake
Goose Lake
Lake Shore Park
Bellaire
Gem Lake
Vadnais Heights
VADNAIS LAKE
Otter Lake
MAPLEWOOD
Mahtomedi
Birchwood


Ramsey Co. CGA, 1992
Washington Co. CGA, 2016


Becker Co. CGA, 2016
Hubbard Co. under construction
Park Rapids
Wadena Co. CGA, 2016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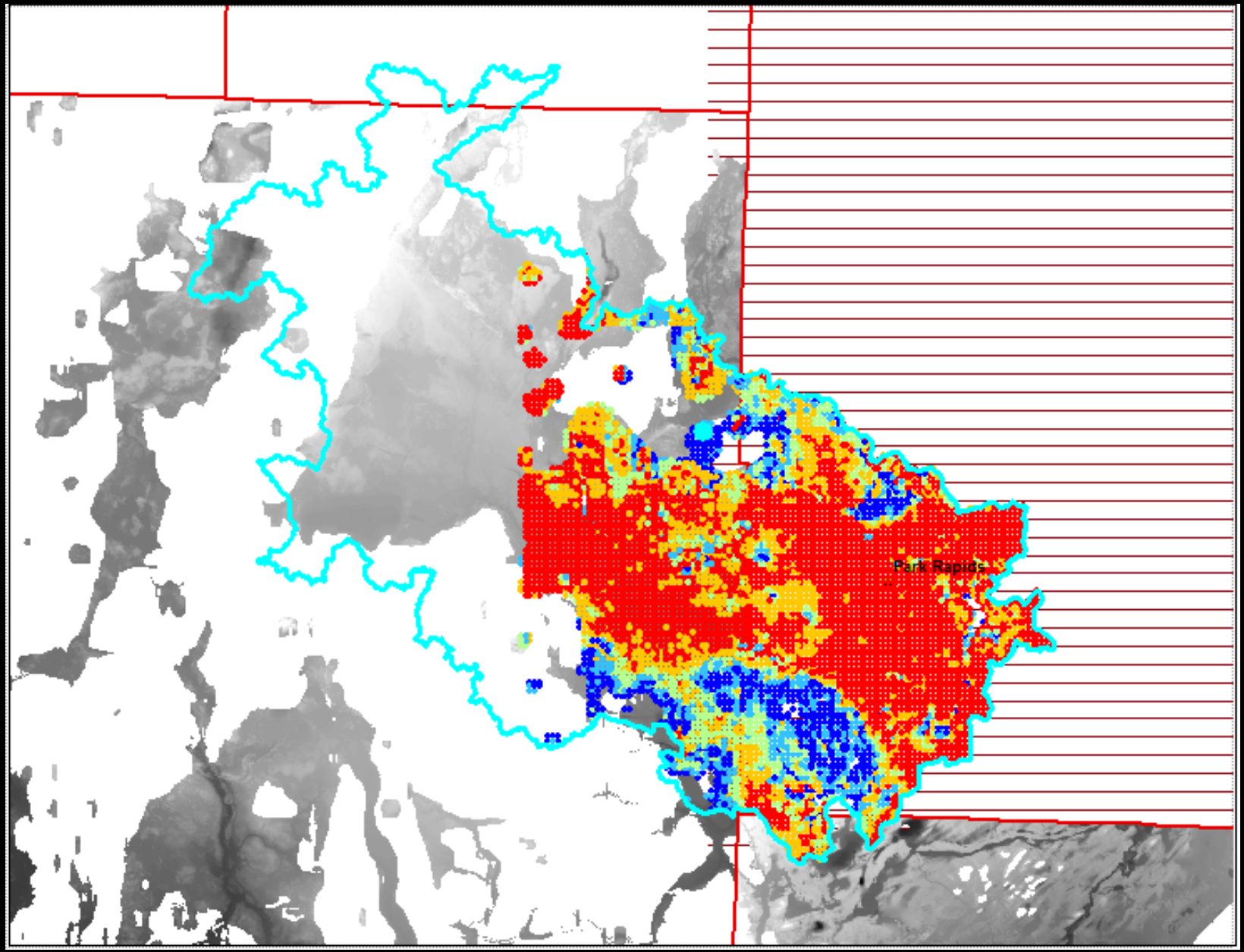
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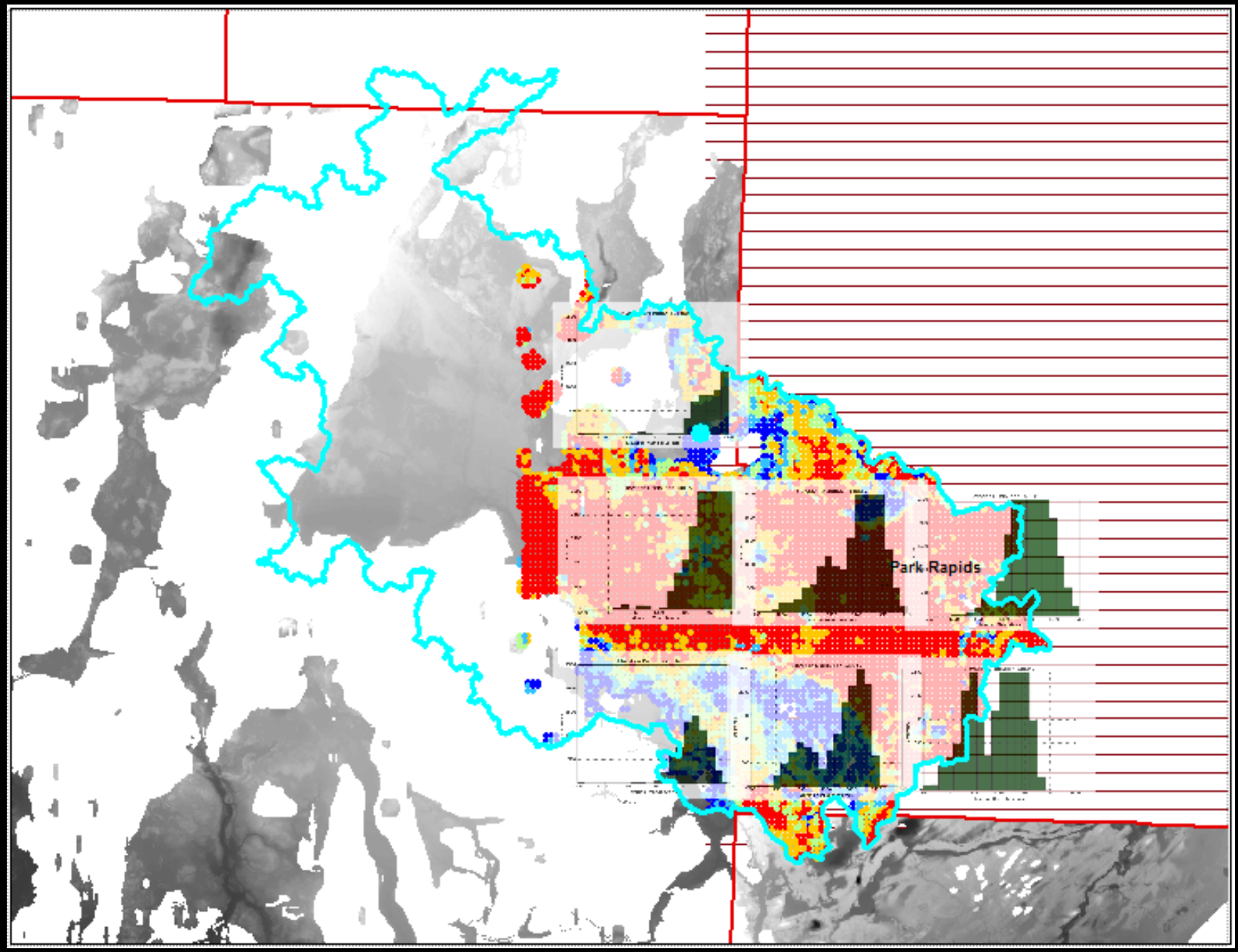
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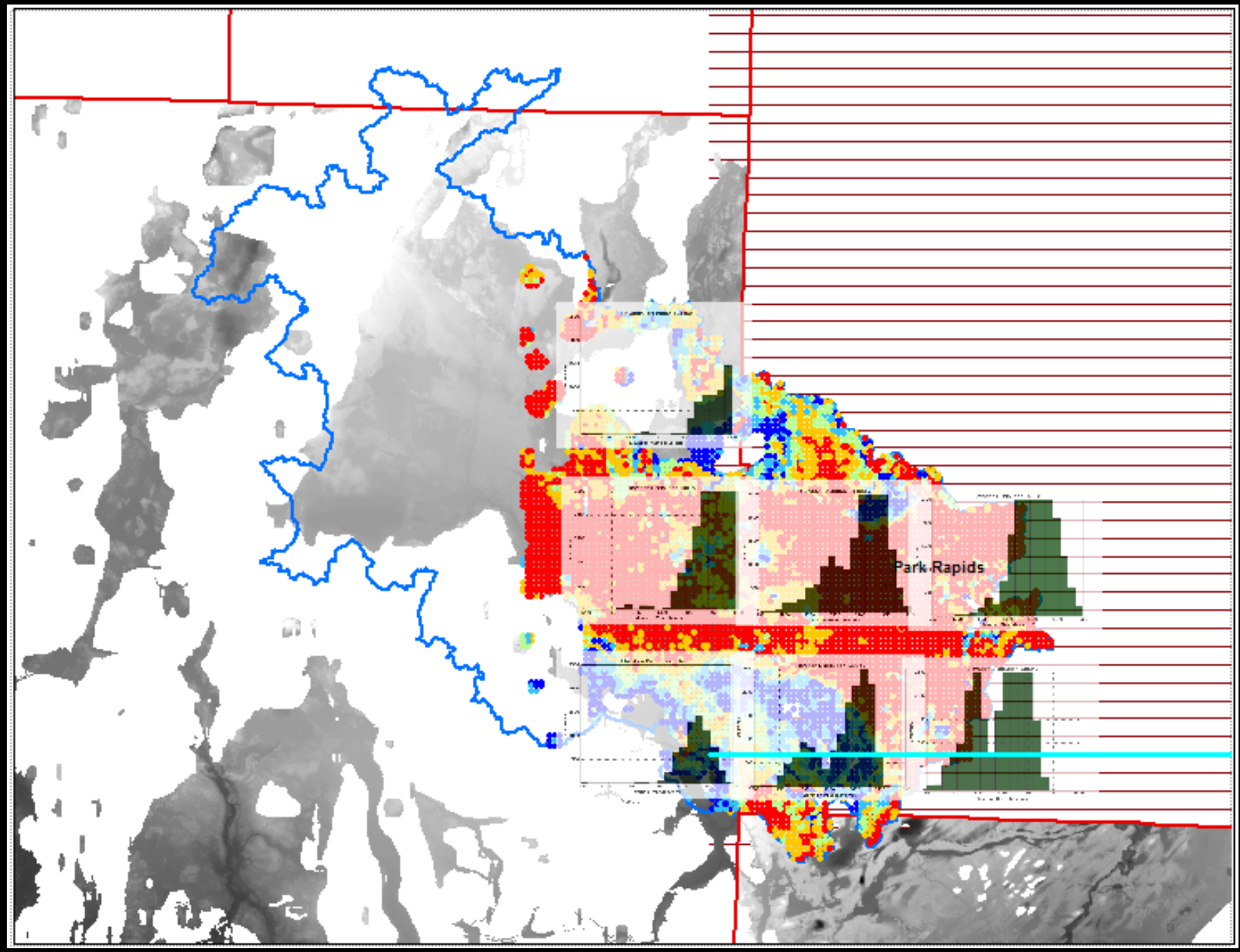
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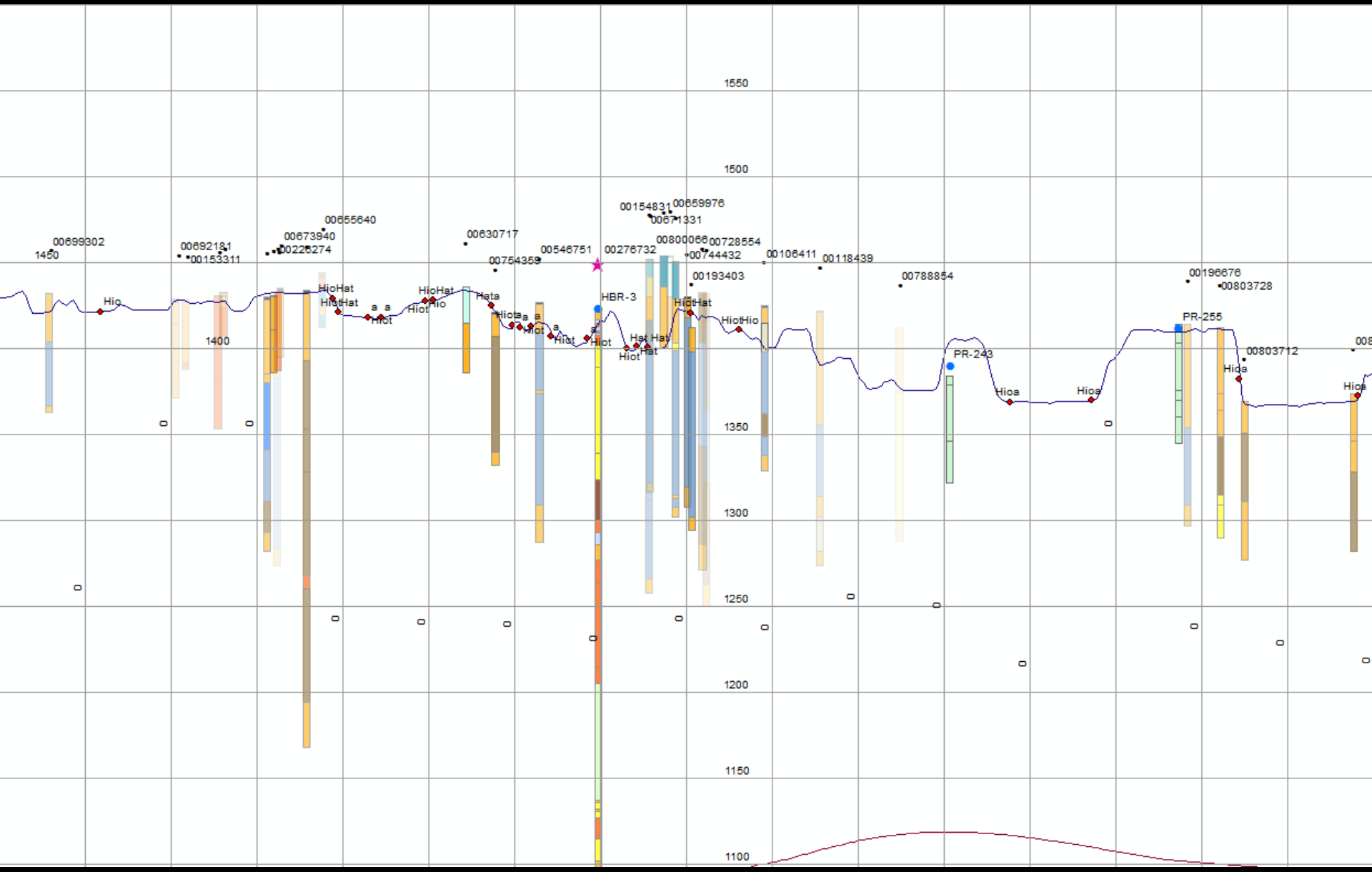
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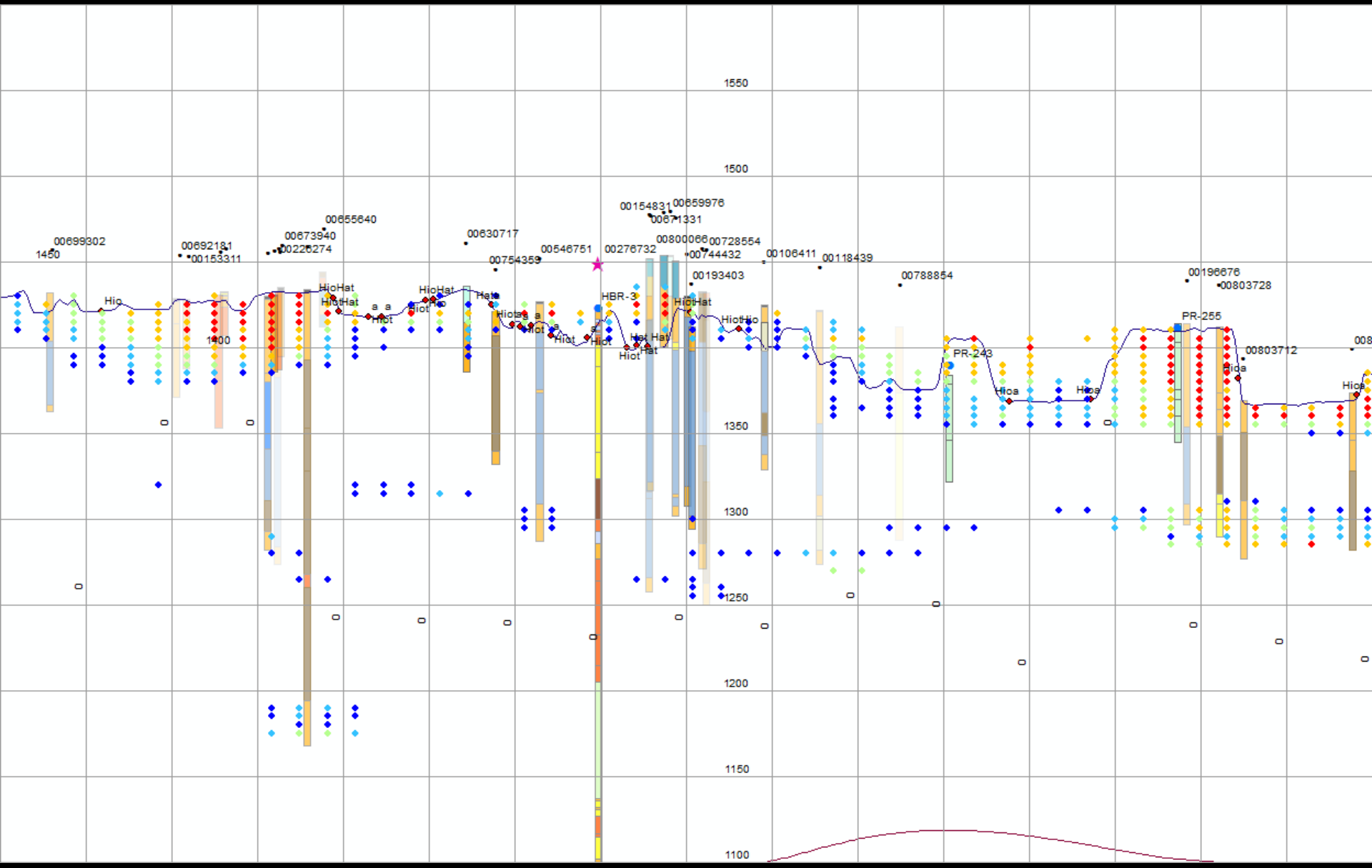
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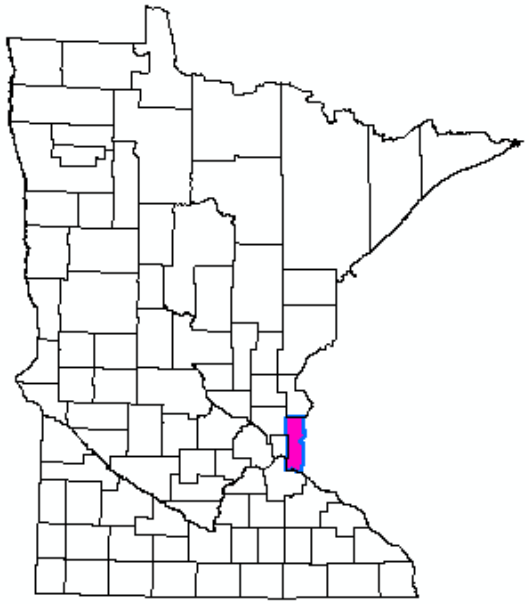
GEOLOGIC ATLAS OF WASHINGTON COUNTY, MINNESOTA
C-39, PART A

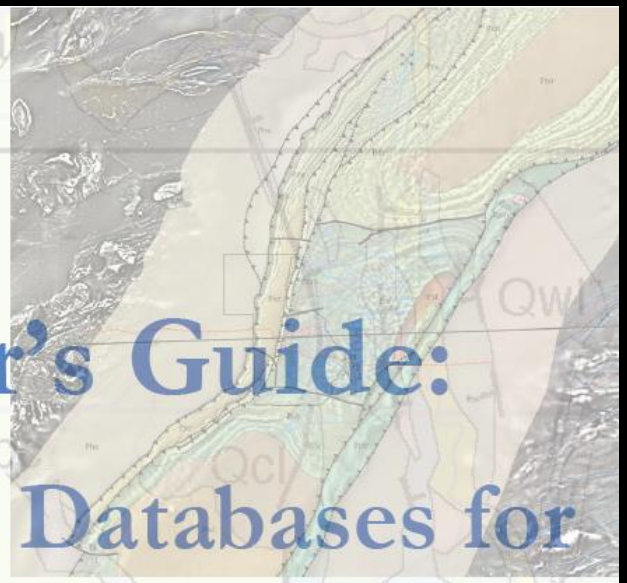
Emily J. Bauer, Project Manager

MINNESOTA GEOLOGICAL SURVEY
2016

= Hyperlink tool (menu bar) to activate links in the blue box

Geologic Atlas User's Guide





Geologic Atlas User's Guide:

Using Geologic Maps and Databases for Resource Management and Planning

Minnesota Geological Survey
Open-File Report OFR-12-1

2014

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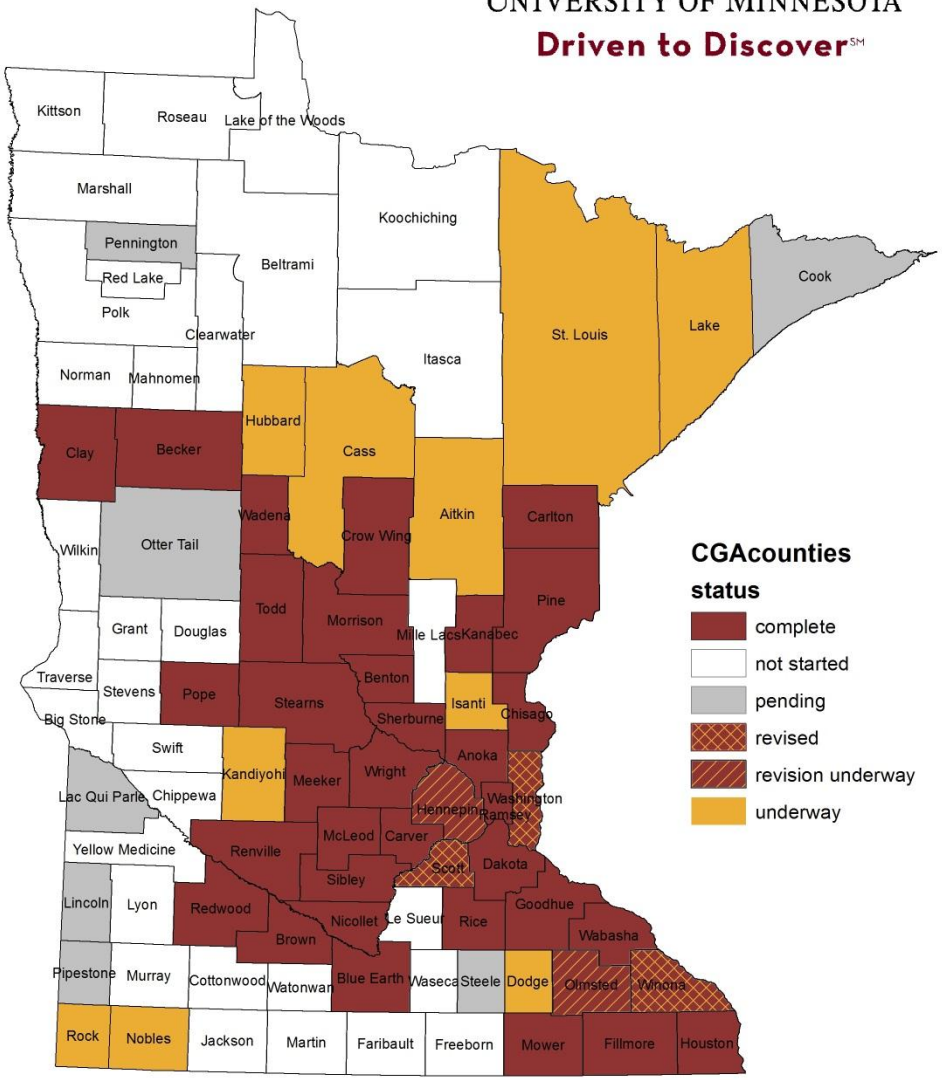

Conclusions

- Physical setting – getting data in a format suitable for modelers and water planners
- Total cost of an atlas part A is ~ $400,000 with funding provided by:
  - The Environmental and Natural Resources Trust Fund,
  - The Clean Water Land and Legacy Amendment
- County contribution is the in-kind cost of well locating

Questions?

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