Water Committee Meeting
Wednesday, September 27, 2023 6:00 PM
Lower Platte North NRD Office
P.O. Box 126
Wahoo, NE 68066

1. UNFINISHED BUSINESS

2. REGULATORY

2.A. GROUND WATER MANAGEMENT AREA

2.A.1. Variance Request in the Hydrologically Connected Area (Limited Development Area)
The District reviewed 49 applications totaling 569.74 acre feet of new depletion, and 3520 acres. Attached is the ranking sheet for these applications.

The Board can approve up to 200 acre feet of new depletion per year.

2.A.2. Variance Requests in the Restricted Development Areas

2.A.3. Well Permit Program

2.A.4. Well Permit Kevin Indra
Kevin Indra applied for a Well Permit classified as Other (Wildlife/Wetlands) for the NW SW S13-17N-5E, Saunders County. He plans on utilizing the well normally in October for waterfowl and only when necessary.
Attached are the well permit and maps of the location.

2.A.5. Well Permit Classification
Jeff Temme applied for a replacement well permit for G-064047 on the NW NE S23-22N-6W, Boone County on May 18, 2023. NRD staff approved the permit and the well was drilled. Part of the process is that Jeff is required to abandon the old well to classify it as a replacement well. Jeff would like to keep the old well as a livestock well and put in a submersible pump that would pump about 20 GPM. The NRD would change his permit from a replacement well to a new well with no increase in irrigated acres. The new well would receive a new DNR well number if the well permit is classified as a new well.

2.A.6. Special Quantity Subareas
Staff met with Jesse Korus- UNL CSD and Lower Elkhorn (LE) staff to discuss the data available for SQS #2 and the area north of the line. Jesse commented on the study he had been working on showing the unconfining and confining layers, that the pumping wells to the north would not have much influence on what is happening within the LPN District. LE completed a similar study with LRE on geological assessment that LPN has just completed. It was discussed that LPN and LE GIS personnel would complete some maps showing both sides

of the NRD lines utilizing the current data. Discussion on allocations and confining layers and does it help during the pumping season, as groundwater pressure in some areas comes back to previous levels yearly.
Attached is some information from graduate students and Jesse Korus. The first attachment is a map and description of some of the areas in the SQS 2 areas, with the other attachment attachment the complete study conducted by these individuals. Also shown is a presentation given by Jesse at the Committee meeting in March of 2022.

2.A.7. Cost Share Programs

2.A.7.a. Irrigation Well Sample Kits

337 kits to producers so far in 2023. 318 of these have been returned.

2.A.7.b. Flow Meter Maintenance Program

The flow meter maintenance contract will expire in the spring of 2024. Attached is a letter that will be sent out to individuals and firms that might have an interest in doing flow meter maintenance within LPNNRD. Staff will be sending the letter out in the first part of October with Committee reviewing at the next Committee Meeting with Board Approval in November. The firm selected will not start until fall/winter 2024-25. The District does maintenance on about 300 - 350 meters a year at this time.
The Committee had no changes to the letter and staff will proceed with sending it out in October.

2.A.8. Bellwood Phase 2 Area

2023 is the twenty-first year for this Phase 2 Area.

	Nitrate-nitrogen Range	**Percent Nitrate-nitrogen 0 to 8.0 ppm**	**Percent Nitrate-nitrogen 8.01 to 10.00 ppm**	**Percent Nitrate-nitrogen 10.01 to 15 ppm**	**Percent Nitrate-nitrogen greater than 15 ppm**
	0 to 25 ppm	46.3% (44 of 95)	8.4% (8 of 95)	45.3% (43 of 95)	
	0 to 25 ppm	47% (44 of 94)	15% (14 of 94)	38% (36 of 94)	
	0 to 24 ppm	41% (29 of 71)	14% (10 of 71)	45% (32 of 71)	
	0 to 31 ppm	48% (48 of 100)	9% (9 of 100)	43% (43 of 100)	
	0 to 28 ppm	53.75% (43 of 80)	7.5% (6 of 80)	38.75% (31 of 80)	

	0 to 22 ppm	45.5% (41 of 90)	15.5% (14 of 90)	39% (35 of 90)	
	0 to 35.7 ppm	48.65% (54 of 111)	11.71% (13 of 111)	39.64% (44 of 111)	
	0 to 26.6 ppm	51% (56 of 110)	6% (7 of 110)	43% (47 of 110)	
	0 to 28.9 ppm	57% (61 of 107)	9% (10 of 107)	34% (36 of 107)	
	0 to 25.8 ppm	50% (53 of 107)	9% (10 of 107)	14% (44 of 107)	26%
	0 to 22.3 ppm	51% (55 of 108)	13% (14 of 108)	18% (39 of 108)	20%
	0 to 32.3 ppm	43% (31 of 72)	8% (6 of 72)	14% (35 of 72)	33%
	0 to 35.1 ppm	34% (25 of 74)	11% (8 of 74)	26% (41 of 74)	26%
	0 to 23.5 ppm	36% (27 of 74)	15% (11 of 74)	19% (36 of 74)	22%
	0 to 30.9 ppm	40% (25 of 63)	11% (7 of 63)	22% (31 of 63)	28%
	0 to 24.5 ppm	46% (22 of 48)	10% (5 of 48)	28% (21 of 48)	22%
	0 to 20.5 ppm	33.33% (20 of 60)	13.33% (8 of 60)	35% (21 of 60)	18.33% (11 of 60)
	0.12 to 27.7 ppm	40.6% (26 of 64)	15.6% (10 of 64)	25% (16 of 64)	18.8% (12 of 64)

	0.13 to 23.0 ppm	43.75% (28 of 64)	12.50% (8 pf 64)	26.56% (17 of 64)	17.19% (11 of 64)
	0 to 19.8	50.8% (32 of 63	15.9% (10 of 63)	20.6% (13 of 63)	12.7% (8 of 63)

2.A.9. Richland - Schuyler Phase 3 Area

2023 is the eighth year of this Phase 3 Area. This Phase 3 area went into effect September 1, 2015. The 55 sections of this area first went into a Phase 2 Area in 2004. The ten sections that were in Phase 2 are now in Phase 3. As such, the 2020, 2021 and 2022 numbers (at bottom of table) are for 65 sections.

Year	Nitrate-nitrogen Range	Percent Nitrate-nitrogen 0 to 8.0 ppm	Percent Nitrate-nitrogen 8.01 to 10.00 ppm
2004	0 to 47 ppm	30% (42 of 139)	10% (14 of 139)
2005	0 to 120 ppm	31.3% (74 of 236)	10.2% (24 of 236)
2006	0 to 53 ppm	28% (50 of 181)	14% (26 of 181)
2007	0 to 99 ppm	32% (75 of 231)	10% (22 of 231)
2008	0 to 46 ppm	28% (53 of 190)	12% (23 of 190)
2009	0 to 57 ppm	33% (72 of 216)	6% (13 of 216)
2010	0 to 57.5 ppm	31% (70 of 229)	7% (15 of 229)
2011	0 to 65.8 ppm	28% (67 of 241)	9% (21 of 241)
2012	0 to 52.6 ppm	29% (70 of 241)	9% (21 of 241)
2013	0 to 94.0 ppm	25% (63 of 252)	9% (23 of 252)
2014	0 to 101.0 ppm	27% (68 of 251)	9% (22 of 251)
2015	0 to 53.3 ppm	23% (55 of 238)	12% (29 of 238)
2016	0 to 50.5 ppm	25% (58 of 228)	10% (22 of 228)
2017	0 to 53.4 ppm	25% (60 of 238)	6% (14 of 238)
2018	0 to 56.9 ppm	26.5% (50 of 189)	6.3% (12 of 189)
2019	0 to 39.4 ppm	25% (53 of 209)	11% (22 of 209)
2020	0 to 50.8 ppm	26% (69 of 261)	6% (15 of 261)

2021	0 to 43.0 ppm	25.5% (67 of 263)	8.4% (22 of 263)
2022	0 to 58.5 ppm	23.0% (57 of 248)	6.45% (16 of 248)
2023	0 to 46.5 ppm	27% (68 of 255)	6% (16 of 255)

Five more samples from this area have been returned - these are at HHS lab.

2.A.10. LPNNRD Operator Certification

Attached is the list of producers that have been identified as active producers but have let their LPNNRD certification expire. NRD staff has offered a couple of options during the summer, which a couple of producers in attendance to get into compliance. This list is only for individuals that attended a certification class in the past but does not include individuals that have never attended. Discussion points.

- Should the NRD certification class be offered Districtwide or only in management areas (quantity and quality)?
  - The committee would prefer keeping the rule Districtwide.
- Enforcement ideas after non-compliance determination.
  - 1 - year timeout from well permits and variances after becoming in compliance.
  - At this time, a person can become in compliance immediately upon an application.
  - The well permit could have some legality.
- Well permits could be an issue, but most well drillers won't drill without a permit.
  - The committee questioned how this might be handled with landowners and tenants . More discussion at future Committee meetings.
- Chemigation is another option, but you don't want someone doing something illegally.
- No NRD cost-share for a certain amount of time.

The committee asked staff about what should happen next. Staff will make phone calls to all of the producers on the list for one last attempt to bring them into compliance.

2.B. CHEMIGATION

no updates for chemications, same 5 left to do after harvest

2.C. GROUND WATER ENERGY LEVELS

Attached is information on summer water levels in WANN Basin.

3. GROUND WATER PROGRAMS

3.A. DECOMMISSIONED WELL PROGRAM

3.A.1. Well Estimates

1 new wells has been reviewed and approved for decommissioning since the last Committee meeting.

Well Owner	Type of Well	Cost Share Estimate	County
Luke Glaser and Christina Glaser	Domestic	1044.30	Saunders

3.A.2. Plugged Wells

wells have been plugged, reviewed, and ready for cost share payment approval this month.

Well Owner	Type of Well	Cost Share Estimate	County

3.B. LOWER PLATTE NORTH NRD GROUND WATER STUDIES

3.B.1. Phase Area Update

An invoice is attached from LRE for $4,872.13 for Hydrological Assessment per contract.
The staff would like some clarification on Phase 4 water quality rules:
Rule 1 - Levels of nitrate exceed 15.01 ppm for nitrates or other non-point source containments.
Rule 2 - Continuation of Phase One, Two and Three Rules. Consideration of the reporting deadline so soil samples are taken into consideration in the same crop year. A 2 part reporting process or one deadline of March 15.
-- Discussion at the committee meeting on why it is important to receive information prior to the upcoming crop year.
Rule 3 - Split application of commercial nitrogen is required with 80 pounds maximum applied before May 1.
Rule 4 - Nitrogen application must not exceed District Recommendations.
-- Discussion at the Committee meeting on how this was calculated on LPN reports.
Rule 5 - Flow meters are required on all high capacity wells
Rule 6 - A rolling acre-inch allocation, in 3-year increments, will be put into place by the District and will be based on the aquifer subarea, crop planted, irrigation

distribution system, percent decline of the aquifer, water use of the aquifer, climatic conditions, net corn crop requirements, and discretionary factors.
Rule 7 - NRD staff will work directly with individuals on Best Management Practices.

3.B.2. Phoenix Database

An invoice from Phoenix Web Group for $8,635 is attached for the second part of the payment per contract approved in June 2023. This was an update to the NRD database.
The staff made a presentation at the Committee on the new updates and how it will streamline some of the entries when the producer is entering the data online.

3.B.3. Lower Platte River Consortium

The next meeting will be held October 17 at MUD Platte River West. This meeting will discuss options to consider new or removal of existing projects..

3.C. MONITORING WELLS EQUIPMENT

Staff has been installing In-Situ equipment for a few of the wells within the District. An invoice from In-Situ is attached for $83,225.95, which the Board approved a quote at the July Board meeting for $91,901.45. There might be other costs in the future as NRD staff keeps repairing the cables.
Discussion at the committee meeting showed the issue with the splices in the cable and the need to fix them correctly before other issues arise. A representative from In-Situ was present to answer questions and staff showed the website where the data is displayed.

4. Groundwater Retreat

A groundwater retreat is being planned for the water committee and any other board member for Wednesday, November 29 from 2:30 to 5:30 pm, Water Committee meeting will start at 6 pm.

Tentative Agenda Item:

- First 30 minutes, there will be an update and review of general groundwater information.
- Discussion on SQS #2 and management
- Nitrogen Management
- Crop Insurance and changing practices.
- Other Issues?

5. SURFACE WATER PROGRAMS

5.A. STATE LAKES, FOR THE WEEK OF

This week's beach Bacteria and Harmful Algal Bloom results are now posted on the NDEE web page (Current Health Alerts and Sampling Results For This Week).
There will be **1** beach on Health Alert this week. Willow Creek Reservoir in Pierce County remains on Health Alert. While Glenn Cunningham Lake in Douglas County will be removed from Health Alert. When a lake exceeds 8 ppb of microcystin it will be placed on Health Alert.

Current Lakes on "Health Alert"

Lake	County	Microcystin (ppb)	Sample Date
Willow Creek Reservoir	**Pierce**	**>35**	**9/18/2023**

A lake that is placed on Health Alert will remain under Health Alert status until it has tested below 8 ppb. If a lake is under a Health Alert, signs will be posted recommending people avoid full body contact activities such as swimming, wading, skiing, jet skiing, etc.

We have **0** beaches with *E.coli* testing above 235 colonies/100 ml.

Lakes with High *E.coli* Bacteria			
Lake	**County**	***E.coli* (mpn)**	**Sample Date**
NONE!			

When *E. coli* bacteria levels test above 235 colonies/100 ml a Health Alert is not issued. However, conditions are at a higher risk to human health when swimming. Considering the more rapid changes in bacteria conditions, signs are not posted with these higher levels. Although, we want people to be aware of beach conditions and use their own judgment as to whether they use a listed water body.

Have a great weekend!

Justin Haas
State Lakes Coordinator
Nebraska Department of Environment and Energy
P.O. Box 98922
245 Fallbrook Blvd., Suite 100
Lincoln, Nebraska 68509-8922
Direct: 402-471-4224 | Main office: 402-471-2186
http://dee.ne.gov | Twitter | Facebook

6. OTHER

GMDA winter conference is January 23-25, 2024 in Nashville.

6.A. COMMENTS FROM THE PUBLIC

Application ID	Applicant	Application Type	County	Sub Area	Ranking Score	Acres	New Depletion	Comments2	Section	Township	Range	Dir
LPN-V-023-0610	William G Pageler	expansion	Saunders	Todd Valley	539.7	50.00	6.16		7	16	7	E
LPN-V-023-0593	Meduna Family Land LLC	expansion	Saunders	Todd Valley	519.7	42.16	6.34		34	16	7	E
LPN-V-023-0600	Alex E Kavan	expansion	Saunders	Todd Valley	494.4	18.00	2.28		2	16	7	E
LPN-V-023-0594	Wilfred Janecek	expansion	Saunders	Todd Valley	489.7	56.00	8.42		27	16	7	E
LPN-V-023-0626	Rodney L & Maxine J Barnhill, Tree	new	Saunders	Todd Valley	485.3	98.00	15.64		36	17	6	E
LPN-V-023-0627	Nick Schmit	new	Butler	David City	478.3	68.00	10.07		6	15	1	E
LPN-V-023-0629	Rainier Resources Holdings 1 LLC	new	Saunders	Todd Valley	475	60.00	7.76		2	14	8	E
LPN-V-023-0615	Jason Thiesen	expansion	Saunders	Todd Valley	473.8	33.88	3.97		9	16	7	E
LPN-V-023-0602	Susan Scott	expansion	Dodge	North Bend	470.1	15.00	2.09		22	18	5	E
LPN-V-023-0628	Rainier Resources Holdings 1 LLC	expansion	Saunders	Todd Valley	469.2	55.00	6.88		14	14	8	E
LPN-V-023-0609	Roger L and Luann Andersen	new	Saunders	Todd Valley	464.6	66.00	11.29		35	16	7	E
LPN-V-023-0599	Randy C Kavan	expansion	Saunders	Todd Valley	460.7	10.00	1.66		14	15	7	E
LPN-V-023-0620	Joe Chmelka	expansion	Saunders	Todd Valley	459	40.00	6.88		28	16	7	E
LPN-V-023-0631	Connor Fujan	new	Saunders	Todd Valley	458.8	80.00	14.21		28	17	7	E
LPN-V-023-0617	Jason Glock	new	Saunders	Todd Valley	456.8	70.00	12.39		29	16	8	E
LPN-V-023-0598	Rod Scott	new	Dodge	North Bend	456.7	50.00	6.97		22	18	5	E
LPN-V-023-0633	WODE Farms LLC	expansion	Saunders	Todd Valley	438.6	130.00	16.25		14	14	8	E
LPN-V-023-0616	Jason Thiesen	expansion	Saunders	Todd Valley	438.5	20.00	4.32		14	16	6	E
LPN-V-023-0605	Gary Torczon	expansion	Platte	Platte Center	418	67.10	8.36		36	19	2	W
LPN-V-023-0625	Janice M Kessler-Fischer	expansion	Platte	Middle Shell Creek	414	5.00	0.80		11	19	3	W
LPN-V-023-0597	McPhillips Bros.	expansion	Platte	Middle Shell Creek	410.8	10.00	2.00		26	19	3	W
LPN-V-023-0601	Casey Bender	expansion	Platte	Middle Shell Creek	404	10.00	1.76		9	19	3	W
LPN-V-023-0622	John J Vybiral	new	Saunders	Todd Valley	399.4	70.00	14.06		8	14	8	E
LPN-V-023-0623	Bradley Williams	new	Saunders	Todd Valley	393.5	98.00	20.17		4	16	6	E
						Acres: 1222.14	**Acre Feet: 190.73**					
LPN-V-023-0624	John Larson	new	Boone	Upper Newman Grove	391.5	135.00	12.61		13	22	6	W
LPN-V-023-0630	Rainier Resources Holdings 1 LLC	new	Saunders	Todd Valley	389.6	60.00	11.57		15	13	9	E
LPN-V-023-0612	Galen J. Pokorny	expansion	Butler	David City	387	40.00	6.14	69% Class 6+ HEL	32	16	2	E
LPN-V-023-0603	Andrew Wallin	new	Boone	Upper Shell Creek	376.5	138.00	13.24		27	22	5	W
LPN-V-023-0604	Sylvia Walters	expansion	Boone	Upper Newman Grove	371.8	75.00	9.95		15	21	5	W
LPN-V-023-0613	Barta Family Limited Liability Partnership	new	Butler	Octavia	363.7	17.00	3.00	Well drilled and pivot installed	32	17	4	E
LPN-V-023-0596	McPhillips Bros.	new	Platte	Middle Shell Creek	358	135.00	24.22		26	19	3	W
LPN-V-023-0632	TMV Investments LLC	new	Butler	Prague	354.4	63.86	7.93		18	16	4	E
LPN-V-022-0585	Rick L Beranek	new	Saunders	Swedeburg	354	79.00	25.21		13	13	8	E
LPN-V-022-0582	Jeanie Trofholz	new	Colfax	North Bend	351.4	130.00	24.58		2	17	4	E
LPN-V-021-0547	Jeremy Janssen	expansion	Platte	Platte Center	349.7	34.00	7.16		10	18	2	W
LPN-V-021-0546	Scott Loseke	expansion	Platte	Platte Center	346.2	130.00	23.29		33	19	2	W
LPN-V-021-0541	Larry D Karloff Tree	new	Saunders	Yutan South	342.5	68.00	13.79		34	15	9	E
LPN-V-023-0635	Mike Heldt	new	Saunders	Yutan South	342	160.00	31.00	Sub-Irrigated	9	14	9	E
LPN-V-023-0611	Michael Chapman	expansion	Saunders	Prague	333.4	35.00	7.02		22	16	6	E
LPN-V-023-0608	Morseth Trust	new	Madison	Newman Grove	331.9	70.00	10.81		22	21	4	W
LPN-V-023-0606	Justin Lee	new	Madison	Upper Newman Grove	326.3	122.00	18.59		17	21	4	W
LPN-V-021-0532	Kent Lee	new	Madison	Upper Newman Grove	325.66	133.00	20.27		17	21	4	W
LPN-V-023-0619	Harlan Jacobson	new	Madison	Newman Grove	321	140.00	20.01		15	21	4	W
LPN-V-023-0595	Kristin Nelson	new	Madison	Newman Grove	320.1	130.00	18.59		15	21	4	W
LPN-V-022-0570	Carolyn A Petersen	expansion	Platte	Platte Center	319.2	70.00	13.55	William Wemhoff Tenant and Applicant	8	18	2	W
LPN-V-023-0618	Spencer Beller	new	Platte	Newman Grove	311.5	145.00	20.67		4	20	3	W
LPN-V-023-0614	Ralph M Papa	expansion	Butler	Octavia	307.7	17.00	3.67	Gravity to Pivot	9	16	3	E
LPN-V-021-0545	Roland D Kavan	new	Saunders	Morse Bluff	302.5	74.00	10.99		1	16	5	E
LPN-V-023-0621	Eugene Kremlacek	new	Saunders	Prague	302.2	132.00	25.83		31	15	7	E
LPN-V-023-0607	Gregory Kobza	new	Butler	Octavia	302	75.00	15.52		11	16	2	E
						2407.86	399.21					
						3630.00	589.94					
LPN-V-023-0636	Mike Heldt	new	Saunders	Wann	299.5	145.00	29.78	Sub-Irrigated	24	14	9	E
LPN-V-023-0634	Lazy Bear Woods LLC	new	Saunders	Swedeburg	274.3	130	26.82		29	13	9	E

USDA Certified Wetland Determination

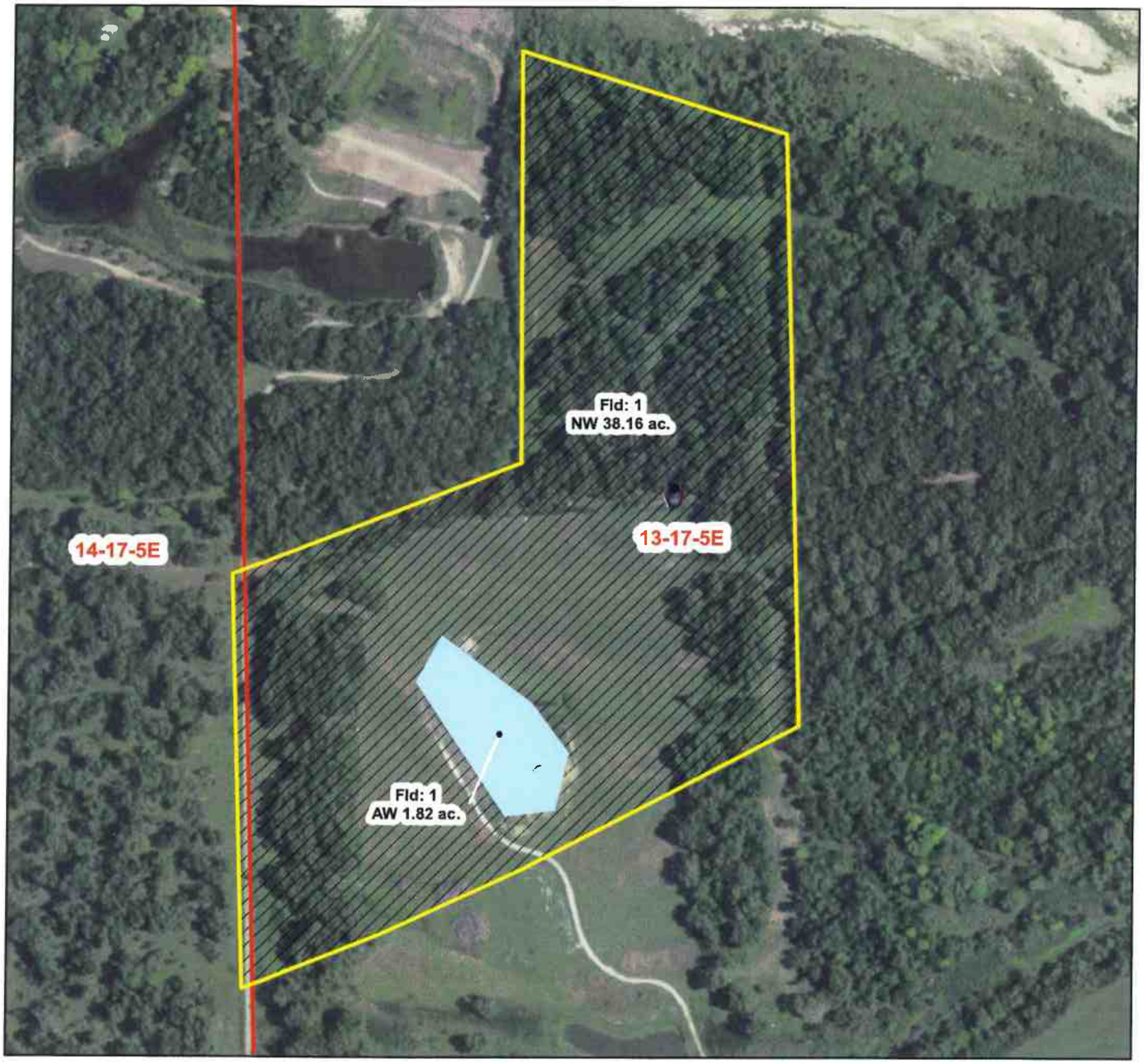
Customer Name: Kevin Indra

NRCS Admin. Office: Wahoo

Farm: 13721 **Tract:** 16198 **Fields:** 1

Finalized By: Richard Smith

Legal Description: 13-17-5E Saunders



0 170 340 680 Feet

Map Created: 8/15/2023

N

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

Legend

Fields
Section
AW
NW

Some fields or portions of fields may not have certified wetland determinations completed.

4 parcel id's = owned
Land is all grass/trees

APPLICATION FOR A PERMIT TO CONSTRUCT A WATER WELL
IN THE *LOWER PLATTE NORTH NATURAL RESOURCES DISTRICT*

DNR & NRD USE ONLY

Permit No. ________________ Date Approved/Denied ____________ NRD Representative ____________
Permit Type: New, Replacement or Late Date Received ____________________ Paid: Cash or Check
Date Post-inspected ____________ Registration No. ______________ Updated Form: May 2008

1176
50.00

ALL APPLICANTS SEEKING A WATER WELL PERMIT MUST COMPLETE PAGES 1 AND 2, AND THE APPROPRIATE SECTION BASED ON THE PURPOSE OF THE WELL. (CLASS 1 – 4 WELL PERMIT)
WATER WELL PERMITS FOR IRRIGATED ACRES GREATER THAN 160 ACRES IN SIZE OR TOTAL ANNUAL WATER USE BETWEEN 150 AND 300 ACRE FEET PER YEAR MUST COMPLETE PAGES 1, 2, AND 3, AND THE APPROPRIATE SECTION BASED ON THE PURPOSE OF THE WELL. (CLASS 3 WELL PERMIT)
WATER WELL PERMITS FOR TOTAL ANNUAL WATER USE EQUAL TO OR GREATER THAN 300 ACRE FEET PER YEAR, REGARDLESS OF NUMBER OF IRRIGATION ACRES, MUST COMPLETE PAGES 1, 2, AND 4, AND THE APPROPRIATE SECTION BASED ON THE PURPOSE OF THE WELL. (CLASS 4 WELL PERMIT)

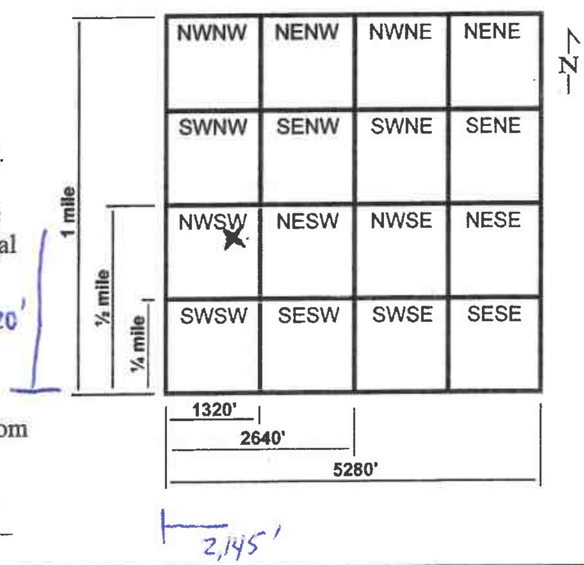
1. NAME AND ADDRESS OF **LAND OWNER**:
Kevin Indra
1064 County Road W
Fremont, NE 68025
Phone: 402-720-3875

NAME AND ADDRESS OF **CONTACT**:
____
____
____
Phone: ______________________

2. **PURPOSE OF NEW WATER WELL (indicate one):**
__ Irrigation (Complete section A)
__ Livestock (Complete section C)
__ Industrial (Complete section E)
__ Recovery or Remediation (Complete section G)
X Other (specify) Wildlife/Wetlands (Complete section H)
__ Dewatering (Over 30 days, Complete section B)
__ Domestic (Irr. on one acre or larger, Complete section D)
__ Public Water Supply (Complete section F)

3. **IDENTIFY LOCATION OF PROPOSED WELL:**
A. Saunders County, NW ¼ of the SW ¼ of Section 13, Township 17 North, Range 5E East/West. (circle one)

B. The box at the right represents one square mile, (section). Indicate with an "X", the proposed location of the well. Outline the proposed water use area. If the water is to be used outside the above written legal description, give legal description of water use area,
____ ¼ of the ____ ¼ of Section ____, Township ____North, Range ____ East/West.



C. The well will be located 2,320' feet from the North/South section line, and will be 2,145' feet from the East/West section line. Or enter Lat. / Long.
Latitude Degree ______ Minute ______ Second ______
Longitude Degree ______ Minute ______ Second ______

4. **REPLACEMENT AND ABANDONED WELL INFORMATION:**
A. Is this a replacement well? __ Yes, X No If yes, fill out the rest of this section.
B. Registration number of well to be replaced: ______________
C. Well to be replaced was last operated (month/year): ______________
D. Replacement well is ____________ feet from original well.
E. Decommissioning of Original well on (month/day/year): ______________
F. If water use is for irrigation, list the number of acres watered by the original well: ______________
G. If water use is for irrigation, will replacement well, water the same tract of land as the decommissioned well?
__ Yes, __ No: If No, list the number of additional acres ____________ and legal description ____ ¼ of the ____ ¼ of Section ____, Township ____ North, Range ____ East/West. (circle one)

- A replacement water well must deliver water to the same tract of land as the original water well, pump from a comparable aquifer, and yield approximately the same gallons per minute and total annual water use as the original water well.

5. **SPECIFICATIONS OF INTENDED WELL AND PUMP:**
   A. Approximate date when construction will begin (month/day/year): ASAP
   B. Expected total well depth: 60' feet.
   C. Well Casing Diameter: 16" inches.
   D. Pump Column Diameter: 6" inches.
   E. Estimated pumping capacity: 300-350 GPM.
   F. Expected total annual water use in Acre Inches / Year ______ or Total Gallons / Year 100,000
   G. The system is to be powered by X Electric __ Fuel
   H. Will the well be used in a system with other wells? __ Yes, X No. If Yes, How many ______
   List well registration number and legal description of each well in Section 6 below.
   I. Name of Well Driller: Grosch Irrigation Co (Please attach test hole log, if available.)
   Lucas 308-773-2261

6. List additional information requested in this Section or attached additional sheet.
   Well will be used during water fowl season to keep pond full.

7. Addition information and requirements for Lower Platte North NRD review.

- Attach current tax assessor records including map, parcel number, and current land use such as irrigated acres.
- Attach aerial photo showing location of water source(s) and area water or reuse water is to be used.
- All new and replacement water wells must install a District approved flow meter and report water pumped annually to the LPNNRD by January 31st of the following year.
- Water well permit conditions maybe required for approval by the Lower Platte North NRD for each individual well.

8. I certify that I am familiar with the information contained in this application, and it's restrictions, rules and regulations and that to the best of my knowledge and belief such information is true, complete and accurate.

   Date 9-20-22 Signature of Applicant [signature]
   Signature of Well System Operator, if different than Applicant ______
   NRD Certification Number of Landowner or Operator ______ (Required for irrigation, livestock, domestic (with irrigation on one acre or more of land), industrial, and public water supply wells.)

9. **Lower Platte North NRD Use Only. Comments by District Representative.**

File: WellPermit2008_050908.doc

APPLICATION FOR A PERMIT TO CONSTRUCT A WATER WELL
IN THE *LOWER PLATTE NORTH NATURAL RESOURCES DISTRICT*

WATER WELL PERMIT FOR IRRGATED ACRES GREATER THAN 160 ACRES IN SIZE OR TOTAL ANNUAL WATER USE BETWEEN 150 AND 300 ACRE FEET PER YEAR, PROVIDE INFORMATION REQUESTED ON PAGES 1, 2, AND 3. (CLASS 3 WELL PERMIT)

---

10. WATER SOURCE INFORMATION:

In a TWO-mile radius around the water source location, provide the following information to the LPNNRD in both paper copy and electronically in Excel Spreadsheet (Microsoft) or Access Database (Microsoft) format.

A. List of all registered wells in this area giving registration number, well identification number, legal description, latitude / longitude or UTM coordinates in NAD 83, elevation in feet above mean sea level, and well log for each well.

B. List of all test holes in the area that have been published by Conservation and Survey Division of the University of Nebraska.

C. List of all surface water rights in this area giving appropriation number, priority date, legal description, use, status, current total acres (if applicable), and grant amount.

---

11. WATER USE LOCATION INFORMATION:

In the location where the water will be used, provide the following information to the LPNNRD in both paper copy and electronically in Word (Microsoft) format.

A. Description of expanded water use including: latitude / longitude or UTM coordinates in NAD 83 of water use location and timeframe or schedule when water will be used.

B. Amount of water that will be reused or recycled at this new location.

C. Description of how water will be used at this new location, i.e. process water vs. cooling water, etc. and estimated total annual water use for each purpose.

INDUSTRIAL AND COMMERCIAL WELLS **(SECTION E)**

A. Name of facility ____________________

B. Products produced by facility ____________________

C. In Section 6 or on a separate sheet of paper, list well registration number and legal description of current wells supplying water to this facility.

D. In Section 6 or on a separate sheet of paper, provide a short description how water is used within the facility and the expected annual amount of water for each use. For example: "The manufacturing plant will use 45% of total annual water use, or 1.45 million gallons per year, for electroplating of galvanized pipe and the remaining 55% of total annual water use, or 1.77 million gallons per year, will be used for non-contact cooling water throughout the plant".

E. Will any of the used water or waste water from this facility be re-used for another purpose? __ Yes, __ No.
If Yes, list purpose, location and expected total amount of water use in acre-inches / year or total gallons / year.
____
____

PUBLIC WATER SUPPLY WELLS **(SECTION F)**

A. On a separate sheet of paper, list the well registration numbers and legal description of current wells supplying water to this community.

B. Attach a list of the five largest industrial water users that your community supplies water to, and the total annual amount of water supplied to each of these industries for the last five years.

C. For these same industries list the total annual amount of water returned to the community as waste water for each of the last five years.

D. Will waste water be used for another purpose, such as livestock, irrigation, etc.? __ Yes, __ No
If Yes, list purpose, location and expected total amount of water use in acre-inches / year or total gallons / year.
____
____

E. Attach a list of the golf courses that the community supplies water to and list the location and number of acres for each one.

RECOVERY OR REMEDIATION WELLS **(SECTION G)**

A. Reason for recovery or remediation well, i.e. leaking underground storage tank. ____________________
____

B. Contaminates of concern ____________________

C. Treatment method of contaminates ____________________

D. Approximate dates (month/day/year) in operation: Start ____________ End ____________

E. Legal description of water discharge location: ____ ¼ of the ____ ¼ of Section ____, Township ____North, Range ____ East/West and name of river, stream or water body ____________________

F. Will cleanup water be used for another purpose, such as livestock, irrigation, etc.? __ Yes, __ No
If Yes, list purpose, location and expected total amount of water use in acre-inches / year or total gallons / year.
____
____

OTHER WELLS **(SECTION H)**

A. Purpose of water use wildlife/wetlands

B. Will the well be used for one calendar year or less? __ Yes, X No

a. If Yes, list approximate dates (month/day/year) the well will be in operation: Start ____________ End ____________

b. If No, list the approximate dates (months) or seasons of the calendar year that well is expected to be in peak or highest use. October annually or as needed in dry year

C. Legal description of water discharge location: SW ¼ of the SW ¼ of Section 13, Township 17 North, Range 5 (East)/West and name of river, stream or water body Platte River

File: WellPermit2008_050908.doc

This form must be completed in full and accompanied by a non-refundable $50.00 filing fee (payable to the Lower Platte North Natural Resources District). In addition, for Class 3 well permits an added fee of $250.00 is required for District review. For Class 4 well permits an added fee of $500.00 is required for District review. Forward this application and filing fees to:

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P.O. Box 126
Wahoo, NE 68066
Phone: (402) 443-4675

Please take the time and fill out the information correctly. The District will return an incomplete or defective application, with 60 days being allowed for resubmission. The District shall issue all permits with conditions attached, or denied not later than 30 days after receipt of a complete and properly prepared application.

WATER WELL PERMIT RESTRICTIONS

1. A well permit is required prior to the construction of a water well. If construction of a water well is commenced prior to obtaining a permit, a late permit must be completed and accompanied by a $250.00 application fee. Construction or operation of a new water well without an approved water well permit shall result in the District issuing a 'cease and desist order' against further construction or use of that water well.
2. An irrigation well shall not be constructed within 1000 feet of any registered industrial or public water supply well or within 600 feet of a registered irrigation well; A public water supply well shall not be constructed within 1000 feet of any registered irrigation, industrial or other public water supplier's well; An industrial well shall not be constructed within 1000 feet of any registered irrigation, industrial or public water supply well pursuant to §46-609 and §46-651. These spacing restrictions shall not apply to water wells owned by the same person. Any person may apply to the Nebraska Department of Natural Resources for a special permit to drill a water well without regard to the spacing requirements pursuant to §46-653. The District may adopt stricter well spacing requirements based on different aquifer subareas. Check with the District office if you have any questions.
3. This permit does not register the well with the Department of Natural Resources. All wells are required to be registered by the well driller with the Nebraska Department of Natural Resources within 60 days after the well is completed.
4. A replacement water well is one, which replaces an abandoned water well that has been operated within the last three years, and is constructed to water the same tract of land as the abandoned water well that is being replaced. A replacement water well must be pumping from a comparable aquifer and yield approximately the same gallons per minute and total annual water uses as the original water well it is replacing. As of January 1, 1997, both new and replacement wells need a permit from the Lower Platte North Natural Resources District.
5. Consumptive water use in acre-inches is determined from the Department of Natural Resources (DNR) Net Corn Crop Irrigation Requirement map or a similar map produced by the University of Nebraska.
6. If the well is being replaced it must be properly abandoned according to state guidelines. A copy of these guidelines is available from the Lower Platte North NRD.
7. If the water well is not constructed within a one-year period from the date of approval, a new permit is needed.
8. Water wells may not be drilled within 50 feet of a stream bank without first obtaining a surface water right for that water withdrawal from the Department of Natural Resources pursuant to §46-637.
9. Any person who, on or after January 1, 1997, commences or causes construction of such a well for which the required permit has not been obtained, or who knowingly furnishes false information regarding such a permit, shall be guilty of a Class IV misdemeanor pursuant to §46-602.01 and §46-613.02.
10. Permits are not required for test holes or temporary dewatering wells (30 days or less). Permits are needed for water wells designed to pump 50 gallons per minute or less in Level 3 and Stay management areas.
11. Tax assessor records submitted with water well permit must include map, parcel number and an accurate account of current land use, such as irrigated acres.
12. With the well permit application, submit an aerial photograph with markings to show the location of the water source(s) and the location of where the water is to be used.
13. Any person, who knowingly furnishes false information regarding a water well permit, shall be subject to the imposition of penalties imposed through the controls adopted by the District pursuant to §46-746.
14. All new or replacement water wells must install a District approved flow meter and report water pumped annually in acre-inches per year or total gallons per year on LPNNRD approved forms by January 31st of each following year.

APPLICATION FOR A PERMIT TO CONSTRUCT A WATER WELL
IN THE *LOWER PLATTE NORTH NATURAL RESOURCES DISTRICT*

5/18/23
Gresch
Albion
ck 3506
$50-

DNR & NRD USE ONLY

Permit No. LPN-023-1848 Date (Approved)/Denied TB NRD Representative TB
Permit Type: New, Replacement or Late Date Received 5-18-23 Paid: Cash or (Check)
Date Post-inspected ______ Registration No. G-064047 Updated Form: June 2022

ALL APPLICANTS SEEKING A WATER WELL PERMIT MUST COMPLETE PAGES 1 AND 2, AND THE APPROPRIATE SECTION BASED ON THE PURPOSE OF THE WELL. (CLASS 1 – 4 WELL PERMIT)
WATER WELL PERMITS FOR IRRIGATED ACRES GREATER THAN 160 ACRES IN SIZE OR TOTAL ANNUAL WATER USE BETWEEN 150 AND 300 ACRE FEET PER YEAR MUST COMPLETE PAGES 1, 2, AND 3, AND THE APPROPRIATE SECTION BASED ON THE PURPOSE OF THE WELL. (CLASS 3 WELL PERMIT)
WATER WELL PERMITS FOR TOTAL ANNUAL WATER USE EQUAL TO OR GREATER THAN 300 ACRE FEET PER YEAR, REGARDLESS OF NUMBER OF IRRIGATION ACRES, MUST COMPLETE PAGES 1, 2, AND 4, AND THE APPROPRIATE SECTION BASED ON THE PURPOSE OF THE WELL. (CLASS 4 WELL PERMIT)

1. NAME AND ADDRESS OF **LAND OWNER:**
Jeffery J Temme
2656 State Highway 32
Petersburg NE 68652
Phone: ______

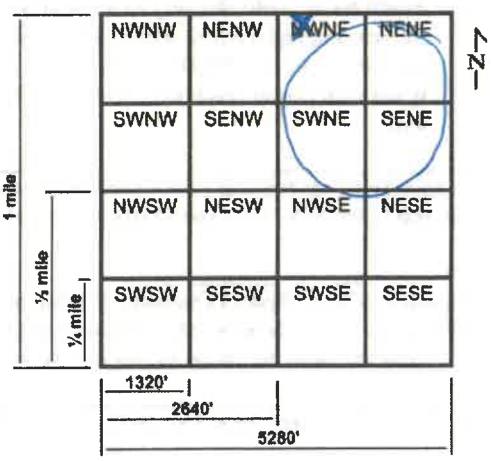
NAME AND ADDRESS OF **CONTACT:**
______
Phone: ______

2. **PURPOSE OF NEW WATER WELL (indicate one):**
X Irrigation (Complete section A)
__ Livestock (Complete section C)
__ Industrial (Complete section E)
__ Recovery or Remediation (Complete section G)
__ Other (specify) ______ (Complete section H)
__ Dewatering (Over 30 days, Complete section B)
__ Domestic (Irr. on one acre or larger, Complete section D)
__ Public Water Supply (Complete section F)

3. **IDENTIFY LOCATION OF PROPOSED WELL:**
A. Boone County, NW ¼ of the NE ¼ of Section 23, Township 22 North, Range 6 East/(West). (circle one)

B. The box at the right represents one square mile, (section). Indicate with an "X", the proposed location of the well. Outline the proposed water use area. If the water is to be used outside the above written legal description, give legal description of water use area,
____ ¼ of the ____ ¼ of Section ____,
Township ____ North, Range ____ East/West.

C. The well will be located ______ feet from the North/South section line, and will be ______ feet from the East/West section line. Or enter Lat. / Long.
Latitude Degree 41 Minute 52 Second 19.61
Longitude Degree -97 Minute 58 Second 40.42



4. **REPLACEMENT AND ABANDONED WELL INFORMATION:**
A. Is this a replacement well? X Yes, __ No If yes, fill out the rest of this section.
B. Registration number of well to be replaced: G-064047
C. Well to be replaced was last operated (month/year): 9-15-22
D. Replacement well is 50 feet from original well.
E. Decommissioning of Original well on (month/day/year): ______
F. If water use is for irrigation, list the number of acres watered by the original well: 159
G. If water use is for irrigation, will replacement well, water the same tract of land as the decommissioned well?
X Yes, __ No: If No, list the number of additional acres ______ and legal description ____ ¼ of the ____ ¼ of Section ____, Township ____ North, Range ____ East/West. (circle one)

- A replacement water well must deliver water to the same tract of land as the original water well, pump from a comparable aquifer, and yield approximately the same gallons per minute and total annual water use as the original water well.

5. SPECIFICATIONS OF INTENDED WELL AND PUMP:

A. Approximate date when construction will begin (month/day/year): May 2023

B. Expected total well depth: 360 feet.

C. Well Casing Diameter: 16 inches.

D. Pump Column Diameter: 8 inches.

E. Estimated pumping capacity: 900 GPM.

F. Expected total annual water use in Acre Inches / Year ________ or Total Gallons / Year ________

G. The system is to be powered by X Electric __ Fuel

H. Will the well be used in a system with other wells? __ Yes, X No. If Yes, How many ________
List well registration number and legal description of each well in Section 6 below.

I. Name of Well Driller: Grosch Irrigation Albion (Please attach test hole log, if available.)

6. List additional information requested in this Section or attached additional sheet.

7. Addition information and requirements for Lower Platte North NRD review.

- Attach current tax assessor records including map, parcel number, and current land use such as irrigated acres.
- Attach aerial photo showing location of water source(s) and area water or reuse water is to be used.
- All new and replacement water wells must install a District approved flow meter and report water pumped annually to the LPNNRD by January 31st of the following year. See approved list in this packet.
- Water well permit conditions maybe required for approval by the Lower Platte North NRD for each individual well.

8. I certify that I am familiar with the information contained in this application, and it's restrictions, rules and regulations and that to the best of my knowledge and belief such information is true, complete and accurate.

Date ________ Signature of Applicant X Jeffrey J Temme

Signature of Well System Operator, if different than Applicant ________

NRD Certification Number of Landowner or Operator ________ (Required for irrigation, livestock, domestic (with irrigation on one acre or more of land), industrial, and public water supply wells.)

9. Lower Platte North NRD Use Only. Comments by District Representative.

File: WellPermit2008_050908.doc

APPLICATION FOR A PERMIT TO CONSTRUCT A WATER WELL
IN THE *LOWER PLATTE NORTH NATURAL RESOURCES DISTRICT*

WATER WELL PERMIT FOR IRRGATED ACRES GREATER THAN 160 ACRES IN SIZE OR TOTAL ANNUAL WATER USE BETWEEN 150 AND 300 ACRE FEET PER YEAR, PROVIDE INFORMATION REQUESTED ON PAGES 1, 2, AND 3. (CLASS 3 WELL PERMIT)

---

10. WATER SOURCE INFORMATION:

In a TWO-mile radius around the water source location, provide the following information to the LPNNRD in both paper copy and electronically in Excel Spreadsheet (Microsoft) or Access Database (Microsoft) format.

A. List of all registered wells in this area giving registration number, well identification number, legal description, latitude / longitude or UTM coordinates in NAD 83, elevation in feet above mean sea level, and well log for each well.

B. List of all test holes in the area that have been published by Conservation and Survey Division of the University of Nebraska.

C. List of all surface water rights in this area giving appropriation number, priority date, legal description, use, status, current total acres (if applicable), and grant amount.

---

11. WATER USE LOCATION INFORMATION:

In the location where the water will be used, provide the following information to the LPNNRD in both paper copy and electronically in Word (Microsoft) format.

A. Description of expanded water use including: latitude / longitude or UTM coordinates in NAD 83 of water use location and timeframe or schedule when water will be used.

B. Amount of water that will be reused or recycled at this new location.

C. Description of how water will be used at this new location, i.e. process water vs. cooling water, etc. and estimated total annual water use for each purpose.

APPLICATION FOR A PERMIT TO CONSTRUCT A WATER WELL IN THE *LOWER PLATTE NORTH NATURAL RESOURCES DISTRICT*

WATER WELL PERMIT FOR TOTAL ANNUAL WATER USE EQUAL TO OR GREATER THAN 300 ACRE FEET PER YEAR, REGARDLESS OF NUMBER OF IRRIGATED ACRES, PROVIDE INFORMATION REQUESTED ON PAGES 1, 2, AND 4. (CLASS 4 WELL PERMIT)

---

12. WATER SOURCE INFORMATION:

In a FIVE-mile radius around the water source location, provide the following information to the LPNNRD in both paper copy and electronically in Excel Spreadsheet (Microsoft) or Access Database (Microsoft) format.

A. List of all registered wells in this area giving registration number, well identification number, legal description, elevation in feet above mean sea level, latitude / longitude or UTM coordinates in NAD 83, and well log for each well.

B. List of all test holes in the area that have been published by Conservation and Survey Division of the University of Nebraska.

C. List of all surface water rights in this area giving appropriation number, priority date, legal description, use, status, current total acres (if applicable), and grant amount.

---

13. WATER USE LOCATION INFORMATION:

In the location where the water will be used, provide the following information to the LPNNRD in both paper copy and electronically in Word (Microsoft) format.

A. Description of expanded water use including: latitude / longitude or UTM coordinates in NAD 83 of water use location and timeframe or schedule when water will be used.

B. Amount of water that will be reused or recycled at this new location.

C. Description of how water will be used at this new location, i.e. process water vs. cooling water, etc. and estimated total annual water use for each purpose.

---

14. AQUIFER PUMP TEST:

In the location of the proposed water source a District approved aquifer pump test is to be performed to obtain geologic data that will be used in the ensuing ground water modeling effort. Data from the pump test is to be reported to the LPNNRD in both paper copy and electronically in Excel Spreadsheet (Microsoft) or Access Database (Microsoft) format.

A. Description of pumping well should include legal description of well, latitude / longitude or UTM coordinates in NAD 83, elevation of well in feet above mean sea level, total amount of water pumped, gallons per minute during pump test, duration of pump test, well construction, well log, water discharge location and method.

B. Description of each monitoring well should include legal description of well, latitude / longitude or UTM coordinates in NAD 83, spacing in feet and direction from pumping well, elevation of well in feet above mean sea level, well log, and well construction.

C. Depth to bedrock, bedrock material, and name of geologic formation.

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15. GROUNDWATER MODEL:

In a FIVE-mile radius of the location of the proposed water source a ground water model using MODFLOW software, or similar software approved by LPNNRD, is to be done. Data from the ground water model is to be reported to the LPNNRD in both paper copy and electronically using the appropriate software.

A. Model should list boundary conditions used, grid size, include all high capacity wells in modeled area, streams and rivers in the modeled area, expected recharge rates, location and flow amounts, hydrologic conductivity and transmissivity values used.

B. At least one iteration, reviewed and approved by LPNNRD, should model steady state conditions over a five-year period with a no flow boundary, and little or no recharge to simulate drought conditions.

APPLICATION FOR A PERMIT TO CONSTRUCT A WATER WELL
IN THE *LOWER PLATTE NORTH NATURAL RESOURCES DISTRICT*

PURPOSE OF WELL

IRRIGATION WELLS **(SECTION A)**

A. How many acres will be irrigated? 159 acres
B. Crops to be planted: corn, beans Crop rotation schedule every other year
C. Type of irrigation system. X Center Pivot, __ Gravity, __ Other (specify) ______
D. The irrigation system is to be powered by X Electric __ Fuel
E. Expected total annual consumptive water use in Acre Inches / Year ______ or
Total Gallons / Year ______
F. Will Fertilizer, Chemicals or Animal waste be applied through the system? __ Yes, __ No

DEWATERING WELLS OVER 30 DAYS **(SECTION B)**

A. Purpose of dewatering well, such as installation of building foundation, etc. ______
B. Expected total number of days the dewatering well will be in use ______
C. Approximate dates (month/day/year) in operation: Start ______ End ______
D. Legal description of water discharge location: ____ ¼ of the ____ ¼ of Section ____, Township ____North, Range ____ East/West and name of river, stream or water body ______
E. Will discharge water be used for another purpose, such as livestock, irrigation, etc.? __ Yes, __ No
If Yes, list purpose, location and expected total amount of water use in acre-inches / year or total gallons / year.

LIVESTOCK WELLS **(SECTION C)**

A. Name of facility ______
B. Type of Livestock: ___ Feeder Cattle, ___ Dairy Cattle, ___ Swine over 55 lbs., ___ Swine under 55 lbs., ___ Sheep, ___ Poultry, ___ Horses
C. Average number of livestock per year ______ and average weight per animal ______ lbs.
D. Peak number of livestock ______ and time of year ______
E. Is facility approved by Nebraska Department of Environmental Quality? __ Yes, __ No. If Yes, list NDEQ certification IIS number ______ If No, complete the rest of this section.
F. Type of facility: ___ Open lot, ___ Covered Building
G. If facility is Open lot, list soil type ______
H. Estimated depth to ground water under feedlot ______ ft.
I. Describe manure collection system of feedlot ______
J. Name and distance of nearest surface watercourse from feedlot ______
K. For each manure land application site, list legal description and size in acres, method of application, and distance from feedlot operation. ______

DOMESTIC WELLS WITH IRRIGATION ON ONE ACRE OR MORE **(SECTION D)**

A. Check all that apply:
   a. Water use: ___ Lawn and number of acres to be irrigated ______ acres.
   b. Water use: ___ Commercial garden and number of acres to be irrigated ______ acres.
   c. Water use: ___ Tree Farm and number of acres to be irrigated ______ acres.
   d. Water use: ___ Type of livestock ______ and number ______
B. Type of irrigation system. __ Sprinkler, __ Drip Tape, __ Other (specify) ______
C. If applicable, give Street address and town ______

* One acre equals 43,560 square feet.

INDUSTRIAL AND COMMERCIAL WELLS **(SECTION E)**

A. Name of facility ______________________________

B. Products produced by facility ______________________________

C. In Section 6 or on a separate sheet of paper, list well registration number and legal description of current wells supplying water to this facility.

D. In Section 6 or on a separate sheet of paper, provide a short description how water is used within the facility and the expected annual amount of water for each use. For example: "The manufacturing plant will use 45% of total annual water use, or 1.45 million gallons per year, for electroplating of galvanized pipe and the remaining 55% of total annual water use, or 1.77 million gallons per year, will be used for non-contact cooling water throughout the plant".

E. Will any of the used water or waste water from this facility be re-used for another purpose? __ Yes, __ No.
If Yes, list purpose, location and expected total amount of water use in acre-inches / year or total gallons / year.

____

____

PUBLIC WATER SUPPLY WELLS **(SECTION F)**

A. On a separate sheet of paper, list the well registration numbers and legal description of current wells supplying water to this community.

B. Attach a list of the five largest industrial water users that your community supplies water to, and the total annual amount of water supplied to each of these industries for the last five years.

C. For these same industries list the total annual amount of water returned to the community as waste water for each of the last five years.

D. Will waste water be used for another purpose, such as livestock, irrigation, etc.? __ Yes, __ No
If Yes, list purpose, location and expected total amount of water use in acre-inches / year or total gallons / year.

____

____

E. Attach a list of the golf courses that the community supplies water to and list the location and number of acres for each one.

RECOVERY OR REMEDIATION WELLS **(SECTION G)**

A. Reason for recovery or remediation well, i.e. leaking underground storage tank. ______________________________

____

B. Contaminates of concern ______________________________

C. Treatment method of contaminates ______________________________

D. Approximate dates (month/day/year) in operation: Start ______________ End ______________

E. Legal description of water discharge location: ____ ¼ of the ____ ¼ of Section ____, Township ____North, Range ____ East/West and name of river, stream or water body ______________________________

F. Will cleanup water be used for another purpose, such as livestock, irrigation, etc.? __ Yes, __ No
If Yes, list purpose, location and expected total amount of water use in acre-inches / year or total gallons / year.

____

____

OTHER WELLS **(SECTION H)**

A. Purpose of water use ______________________________

B. Will the well be used for one calendar year or less? __ Yes, __ No

   a. If Yes, list approximate dates (month/day/year) the well will be in operation: Start ______________
   End ______________

   b. If No, list the approximate dates (months) or seasons of the calendar year that well is expected to be in peak or highest use. ______________________________

C. Legal description of water discharge location: ____ ¼ of the ____ ¼ of Section ____, Township ____North, Range ____ East/West and name of river, stream or water body ______________________________

File: WellPermit2008_050908.doc

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9. Any person who, on or after January 1, 1997, commences or causes construction of such a well for which the required permit has not been obtained, or who knowingly furnishes false information regarding such a permit, shall be guilty of a Class IV misdemeanor pursuant to §46-602.01 and §46-613.02.
10. Permits are not required for test holes or temporary dewatering wells (30 days or less). Permits are needed for water wells designed to pump 50 gallons per minute or less in Level 3 and Stay management areas.
11. Tax assessor records submitted with water well permit must include map, parcel number and an accurate account of current land use, such as irrigated acres.
12. With the well permit application, submit an aerial photograph with markings to show the location of the water source(s) and the location of where the water is to be used.
13. Any person, who knowingly furnishes false information regarding a water well permit, shall be subject to the imposition of penalties imposed through the controls adopted by the District pursuant to §46-746.
14. All new or replacement water wells must install a District approved flow meter and report water pumped annually in acre-inches per year or total gallons per year on LPNNRD approved forms by January 31st of each following year.
15. If multiple water sources are used, landowner must supply flow records from each water source in acre-inches per year or total gallons per year on LPNNRD approved forms by January 31st of each following year.
16. Water well permit applications require that the applicant or operator of irrigation, livestock, domestic (with irrigation on one acre or more of land), industrial, and public water supply wells by NRD certified.

<u> Landowners must list new irrigated acres with the County Assessor, update the DNR well registration, and comply with any additional conditions within 90 days of LPNNRD approval of this water well permit. LPNNRD staff may perform a site visit to verify information provided in the well permit application. **</u>**

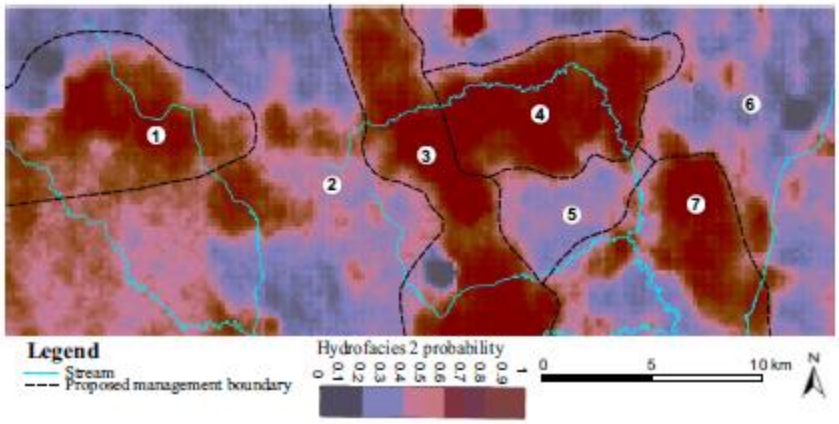

Fig. 15 Proposed management boundaries with respect to hydrofacies 2 probability, represented as a horizontal slice through the model at 444 m elevation

Table 1 Management zones, recovery, hydrogeologic characteristics and management issue(s)

Zone	Primary management issue(s)	Hydrogeologic characteristic(s)	Recovery time (days)	Drawdown (m)
1	Unknown	Unconfined	>30	8
2	Local well interference	Heterogeneous, abrupt variations between confined and unconfined, Low transmissivity	5–25	5–12
3	Excessive drawdown near boundaries	Unconfined, laterally constrained	20–30	5–8
4	Well interference	Confined	50	8–15
5	Well interference, rapid loss of well yield	Extreme heterogeneity, confined, low transmissivity	50	12–15
6	Aquifer depletion	Extreme heterogeneity, abrupt variations between confined and unconfined, limited recharge	>285 (incomplete between pumping periods)	6–8
7	Stream depletion	Hydrologically connected to stream, local recharge pathways	1–20	<1

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PAPER

Multiple-point statistical modeling of three-dimensional glacial aquifer heterogeneity for improved groundwater management

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Abstract

Quaternary glacial aquifers are important water sources for irrigation in many agricultural regions, including eastern Nebraska, USA. Quaternary glacial aquifers are heterogeneous, with juxtaposed low-permeability and high-permeability hydrofacies. Managing groundwater in such aquifers requires a realistic groundwater-flow model parameterization, and characterization of the aquifer geometry, spatial distribution of aquifer properties, and local aquifer interconnectedness. Despite its importance in considering uncertainty during decision-making, hydrofacies probabilities generated from multiple-point statistics (MPS) are not widely applied for groundwater model parameterization and groundwater management zone delineation. This study used a combination of soft data, a cognitive training image, and hard data to generate 100 three-dimensional (3D) conditional aquifer heterogeneity realizations. The most probable model (probability of hydrofacies) was then computed at node spacing of $200 \times 200 \times 3$ m and validated using groundwater-level hydrographs. The resulting hydrofacies probability grids revealed variations in aquifer geometry, locally disconnected aquifer systems, recharge pathways, and hydrologic barriers. The profiles from hydrofacies probability at various locations show spatial variability of the streambed and aquifer connectivity. Groundwater-level hydrographs show evidence of these aquifer characteristics, verifying the general structure of the model. Using the MPS-generated 3D hydrofacies probability and hydrologic data, a novel workflow was developed in order to better define high-resolution groundwater management zones and strategies. In general, the conditional probability of hydrofacies helps improve the understanding of glacial aquifer heterogeneity, the characterization of aquifer-to-aquifer and streambed-aquifer connections, and the delineation of groundwater management zones. This MPS workflow can be adapted to other areas for modeling 3D aquifer heterogeneity using multisource data.

Keywords Airborne electromagnetics · Glacial aquifers · Heterogeneity · Hydrofacies · Geostatistics

Introduction

Glacial aquifer systems supply water for various uses worldwide, particularly in the northern latitudes that experienced widespread glaciation during the Quaternary (Miller 1999; Russell et al. 2004; Ehlers and Gibbard 2007; Margat and van der Gun 2013). In the United States, glacial aquifers underlie parts of 26 states and supply water to about 42 million people, or 5% of the US population (Yager et al. 2018). Aquifer heterogeneity is defined as the spatial variation of aquifer hydraulic properties (Hiscock and Bense 2021). Glacial aquifer systems are heterogeneous and comprise sediment assemblages with a wide range of hydraulic properties (Brodzikowski and van Loon 1987; Anderson 1989; Whittaker and Teutsch 1999; Benn and Evans 2014). Aquifer heterogeneity results in complex patterns of groundwater flow, which impact head distribution and travel time (He et al. 2013), groundwater and surface interactions (Fleckenstein et al. 2006; Zhao and Illman 2017), limit infiltration rate and groundwater discharge (Åberg et al. 2021) and managed aquifer recharge (Maples et al. 2020). Aquifer heterogeneity produces tortuous groundwater flow paths (Comte et al. 2019) and challenges groundwater management (Kelly et al.

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2013). Characterizing the spatial scales of heterogeneity in the subsurface volume of interest is essential to appropriately simulate flow and manage groundwater resources (Giudici 2010). The relevant data to characterize aquifer heterogeneity at a scale of interest are rarely available, and as a result, aquifer heterogeneity is simplified for groundwater simulation. Simplifying heterogeneity may lead to unrealistic aquifer characteristics (Lukjan and Chalermyanont 2017) and incorrect aquifer connections, resulting in overgeneralized groundwater flow paths.

Sustainable groundwater management requires an improved understanding of aquifer-to-aquifer connections, stream–aquifer connections, and vertical and horizontal water flow components and processes between or within an aquifer. Groundwater management activities such as regulating well pumping and well interferences, siting new pumping wells, protecting streamflow depletion, safeguarding recharge zones and enhancing aquifer recharge, necessitate a realistic aquifer framework and properties. Groundwater management decisions often rely on the results of groundwater models and monitoring systems. Well hydrographs are often used to map aquifer heterogeneity and properties during calibrations; however, even with good calibration results, uncertainty may persist. A unique set of parameters cannot be obtained during calibration–multiple hydraulic conductivity values may provide a good fit, and solutions are nonunique (Konikow and Bredehoeft 1992). Inadequate conceptual geological model and aquifer parameter estimations are sources of uncertainty in groundwater flow models (Rojas et al. 2010; Refsgaard et al. 2012; Enemark et al. 2019; Yin et al. 2021). Errors in aquifer heterogeneity and structure can result in biases related to parameterization, calibration and prediction (Christensen et al. 2017b). Comparing the estimated aquifer parameters by the inverse calibration model to prior knowledge of aquifer structures or a 3D aquifer realization model can help validate the inverse model-based estimated aquifer properties and model accuracy, reducing the potential impact of ill-posed calibrations on model-aided decision-making. Three-dimensional (3D) modeling of hydrofacies is fundamental to constructing a groundwater flow model for groundwater management. Hydrofacies probability is also a useful tool for understanding and assessing uncertainty in an aquifer structure and aquifer properties. However, it is not widely used in groundwater model parameterization and groundwater management zone delineation due to a lack of data and difficulties in implementing the concept in practical applications.

Aquifer permeability is influenced by lithofacies distribution (Bersezio et al. 1999; Zappa et al. 2006; Suriamin and Pranter 2018). Lithofacies from borehole data are frequently used to model hydrofacies. Different lithofacies can be grouped into single hydrofacies (Klingbeil et al. 1999; De Caro et al. 2020). Estimation of hydraulic conductivity is typically done by analyzing lithofacies data and limited pumping test wells to model groundwater flow. The groundwater flow model necessitates realistic parameterization of spatial variations in aquifer properties. Accurately estimating spatial variations of complex glacial aquifer hydraulic conductivities requires a large amount of data. The estimation of realistic aquifer heterogeneity and properties can be aided by modeling spatial variations in hydrofacies. The hydrofacies model can be used to estimate the hydraulic conductivity of an aquifer (Theel et al. 2020; Xue et al. 2022). Geophysical data are often used to enhance the horizontal resolution of hydrofacies modeling, but translating geophysical data to hydrofacies can be challenging due to the nonuniqueness of the information derived from geophysical data. Airborne electromagnetics (AEM) is a geophysical technique that provides spatially dense data between boreholes and can yield critical information on the aquifer extent and confining units (Hanson et al. 2012; Korus et al. 2013, 2017, 2021; Korus 2018). To interpret AEM data, the AEM data must first be inverted and interpolated to generate a 3D resistivity grid. Then the resistivity-borehole lithological relationship is used to convert 3D AEM resistivity data into hydrofacies. Combining AEM-derived resistivity-depth models with borehole logs can improve geological heterogeneity simulation and reliability (Jørgensen et al. 2013; Foged et al. 2014; Korus et al. 2017). The integration of AEM with a borehole can be utilized to map the aquifer system (Knight et al. 2018), estimate the upper top of the saturated zone (Dewar and Knight 2020) and locate incised valley fill for recharging the aquifer (Knight et al. 2022). Combining AEM data with well hydrograph data is useful for mapping impermeable aquifer boundaries (Korus 2018). The information derived from AEM data is also valuable in bolstering the accuracy of groundwater models. Marker et al. (2015) employed AEM data in combination with borehole data to produce clay fraction estimates, categorized them into hydrostratigraphic zones, estimated hydraulic conductivity for each zone, used these values in groundwater calibration, and observed an enhancement in hydrological performance. Christensen et al. (2017a) used AEM data to create 3D distributions of hydraulic conductivity and reported that the accuracy of the groundwater predictive model improved, specifically, predictions of recharge area, head change and stream discharge.

Three-dimensional modeling of glacial aquifer heterogeneity is challenging because it requires spatially dense data and sophisticated methods. The cognitive approach produces only a single aquifer heterogeneity and involves significant effort and expertise to create multiple 3D realizations of aquifer heterogeneity in a glacial region. Geostatistical simulations such as two-point and multiple-point statistics (MPS) are also commonly used to model aquifer heterogeneity. The MPS approach has many advantages over cognitive and two-point geostatistical methods (Liu et al. 2005; Hu and Chugunova 2008). Unlike two-point geostatistics, which use a variogram approach to generate geological heterogeneity, MPS uses statistics from a training image (TI) and better simulates complex geological patterns than two-point techniques (Strebelle 2002). MPS generates multiple plausible realizations by combining TI, hard data (certain borehole data) and soft data (geophysical data); however, locational measurement and driller's borehole lithological logs descriptions are always subject to uncertainty and borehole data are not 100% certain. Despite such errors, hard data are treated as certain and used to constrain the MPS realization. MPS realizations are compelled to perfectly match the hard data during simulations, but MPS realizations are not forced to match soft data (Hansen et al. 2018; Vilhelmsen et al. 2019; Madsen et al. 2021).

In areas where there are no hard data, MPS fills simulation grids by borrowing geological features from a TI and soft data. Statistical information is derived from TI using a search tree template and stored in a tree (Liu 2006). The selection of an appropriate search template is vital to capture geological heterogeneity and information presented in the TI. A small search mask may exclude vital geological features in the TI, and too large a search mask prolongs MPS simulation time and leads to nonrepresentative statistics (Hu and Chugunova 2008). The TI pattern that appears in the search mask is recorded in the search tree (Ba et al. 2019).

Near the eastern margin of the High Plains Aquifer (HPA) in Nebraska, the geological system consists of complex glacial deposits and productive paleovalley (buried valley) aquifers (Divine et al. 2009; Korus et al. 2017). The boundary of the HPA in eastern Nebraska is concealed by glacial deposits and loess, and there are multiple generations of paleovalleys in the subsurface (Korus et al. 2017). These paleovalley aquifers are complex and heterogeneous, resulting in significant spatial variability in aquifer properties. The variability of aquifer properties, as well as the presence of low permeability hydrofacies, can limit water flow between and within the aquifers as well as recharge to the aquifer. Effective groundwater management in this area requires an understanding of paleovalley aquifer continuity, confining units, and features controlling groundwater flow. This study aims to answer the following questions by simulating detailed glacial aquifer heterogeneity: (1) Are the palaeovalley aquifers connected? (2) Is the streambed-aquifer system connected? (3) Can a 3D MPS-generated probability be used to define management boundaries?

Probabilistic simulations of glacial aquifer heterogeneity using MPS are not often utilized to analyze the connection between buried valleys aquifers, aquifers and streambeds and to define groundwater management zones. Simulations of various conditional realizations aid in determining plausible glacial aquifer heterogeneity and aquifer-to-aquifer connectivity, which is an important step in considering the uncertainty of aquifer characterization in groundwater modeling and management. Visual inspections and borehole logs are commonly utilized to validate hydrostratigraphic units produced by MPS (Barfod et al. 2018a). Although well hydrographs can provide information about the properties of aquifers and hydrostratigraphic units, they are rarely used to validate MPS-generated hydrofacies and aquifer heterogeneity. Unlike other examples, this study uses a novel application of groundwater head monitoring for qualitative validation of aquifer heterogeneity and computed 3D hydrofacies probability to account for uncertainty. To the authors' knowledge, hydrographs have not been applied to validate glacial aquifer heterogeneity. This study demonstrated that MPS can be a useful tool for modeling glacial-aquifer heterogeneity. Furthermore, a workflow for delineating management boundaries that take into account the spatially variable nature of these aquifers was provided, which is critical for tailored management solutions.

Physical setting

The study area is located in eastern Nebraska, USA (Fig. 1). It includes the watersheds of Elm Creek, Taylor Creek, and Loseke Creek, which flow into Shell Creek, a tributary of the Platte River. The elevation of the study area ranges between 424 and 533 m. Groundwater is managed by the Lower Platte North Natural Resources District, which has established management rules for this area because of periodic groundwater shortages related to well interference and large-magnitude groundwater-level declines during irrigation pumping. The management area is approximately 643 km^2 and is about 40 km in the E–W direction and 17 km in the N–S direction.

Shell Creek watershed lies near the maximum western extent of Pleistocene glaciation in North America. The Laurentide Ice Sheet advanced over preglacial and proglacial deposits in this area, producing a complex arrangement of buried valleys, tills, and spatially variable sand and gravel bodies. Glacial sediments are mantled by multiple loess units. Bedrock consists of impermeable Cretaceous rocks, principally shale, chalky shale, and limestone, which serve as the lower boundary for groundwater flow. Unconsolidated sand and gravel units above bedrock serve as the primary aquifers for municipal and irrigation purposes. The glacial aquifers system consists of sand and gravel deposits in buried valleys atop bedrock (paleovalleys), and discontinuous sand and gravel bodies within unconsolidated glacial sediments (Divine et al. 2009).

Materials and methods

Borehole data processing

Boreholes logs were obtained from the Nebraska Department of Natural Resources (NDNR) and test holes were drilled by the Nebraska Conservation and Survey Division (CSD) (Fig. 2). The borehole lithological logs were used to evaluate geophysical inversion, conduct MPS

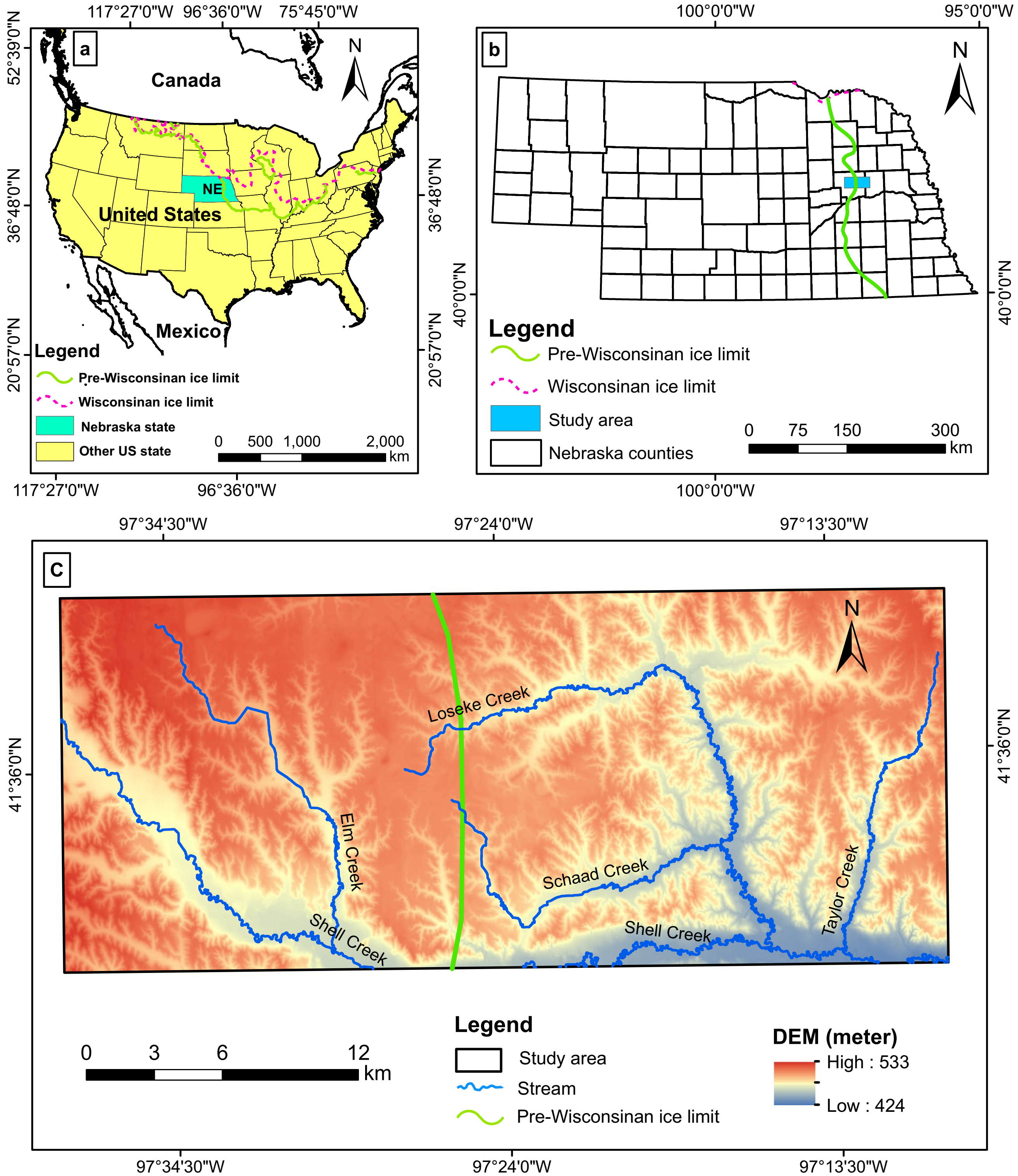

Fig. 1 Locations of **a** the State of Nebraska (NE) and the glaciation ice limits in the USA, and **b** the study area in Nebraska. **c** Geographic features of the study area, including a digital surface elevation model (DEM, m above sea level)

simulation, and support results and interpretation. Borehole uncertainty impacts the translation of AEM resistivity to sediment probability and is weighted to account for uncertainty. Borehole data can be weighted based on location accuracy, sampling frequency, drilling method, and borehole geophysical data criteria to account for

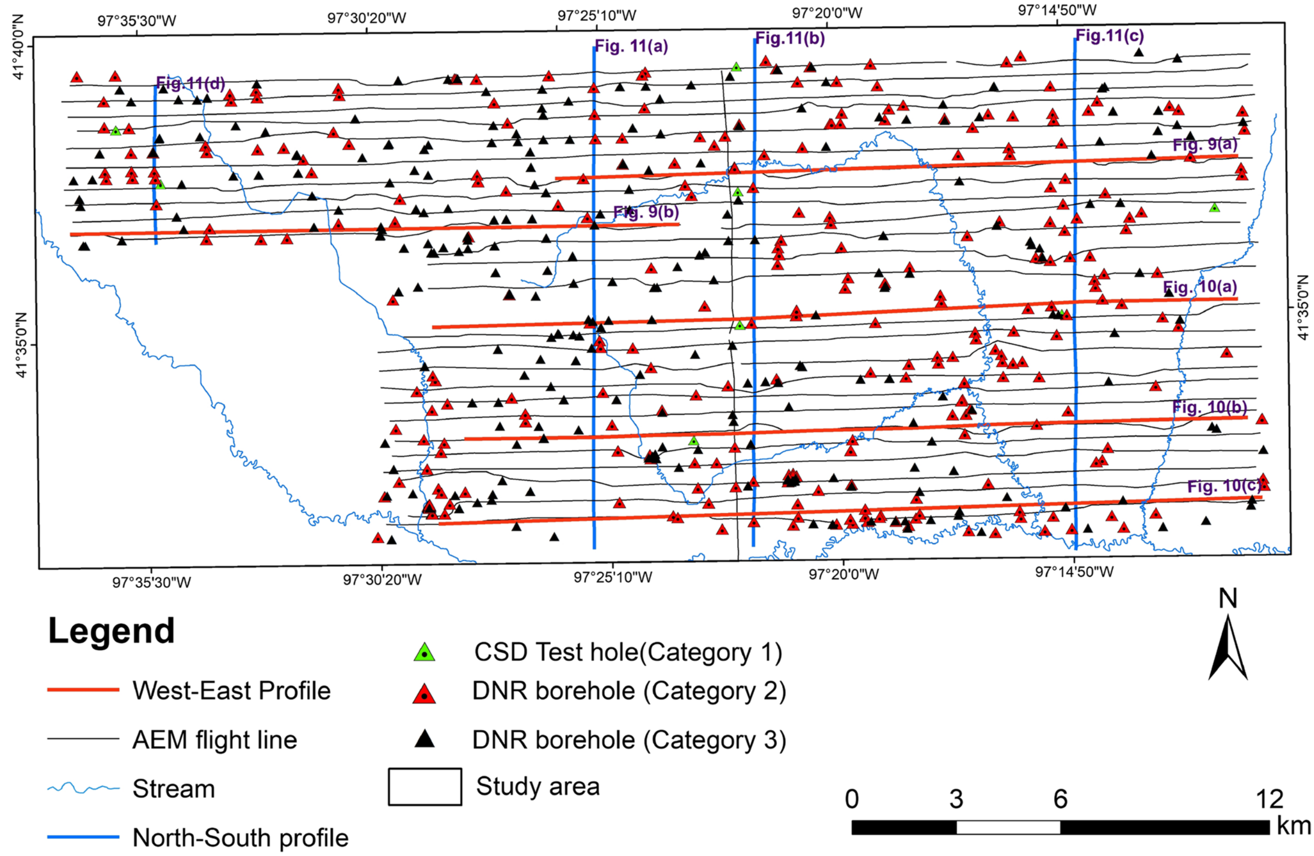

Fig. 2 Airborne electromagnetics (AEM) flight lines, Nebraska Conservation and Survey Division (CSD) test holes, Nebraska Department of Natural Resources (DNR) boreholes, and W–E and N–S section profiles shown herein. Borehole categories refer to quality criteria explained in the text

borehole uncertainty (Barfod et al. 2016; He et al. 2014b; Høyer et al. 2015, 2017). Høyer et al. (2017) used a uniform uncertainty of 20% for all boreholes. In this study, data quality is rated using a subdivision into four groups based on location accuracy and borehole log resolution following the decision tree borehole quality assessment method (Korus and Hensen 2020). Location quality rating depends on the source of geographic coordinates. If a borehole location is determined using a global positioning system (GPS) or by measuring N–S and E–W distance from a nearby line (resulting in low location error, typically <10 m), it is considered to have good location quality. Otherwise, it is classified as having poor quality. For the quality of the lithological description, the borehole depth is divided by the borehole logs intervals and if the average is less than 6.1, the description is considered as detailed. If the average is 6.1 or higher, the description is considered not detailed. Using these criteria, the 1,007 boreholes in the study area were classified into four distinct categories. Category 1 boreholes have good location quality and detailed lithological descriptions. Category 1 boreholes were used as hard data because their locations and lithological logs were meticulously recorded by skilled geologists. Category 2 boreholes (a total of 394 boreholes) have detailed borehole lithological logs and good location quality (coordinates measured using GPS or measured footage N–S and E–W nearest sections line). Category 3 boreholes (a total of 387 boreholes) lack detailed borehole lithological logs but have good location quality. Both category 2 and 3 boreholes were not logged by a trained geologist or were unknown, and thus considered soft data (uncertain data). For category 2 and 3 boreholes, a 75 and 65% probability of certainty was assigned to category 2 and 3 boreholes, respectively. The lithohydrofacies from category 2 and 3 boreholes were merged and normalized and integrated with hydrogeophysical facies probabilities obtained from AEM resistivity data, which were used as soft data. A total of 218 boreholes were excluded in category 4 due to their inaccurate and ambiguous location quality to prevent errors from being introduced into the soft data when merging these boreholes with AEM data and utilizing them in MPS simulation.

AEM data processing and inversions

An AEM survey was conducted in 2016 using the SkyTEM304M system (Sørense and Auken 2004) to generate data for hydrostratigraphic units. SkyTEM is a helicopter-borne transient electromagnetic (TEM) method that consists of a transmitter coil and a receiver loop. The TEM method is based on the time-varying magnetic field caused by the rapid turnoff of current sent by the transmitter coil, and it provides subsurface electrical properties via Faraday's law of induction (Christiansen et al. 2006). The induction generates a secondary magnetic field measured at the receiver and contains information about the subsurface resistivity. The data are recorded in time windows called gates and consist of a single sounding at one location. The flight speed and the measurement interval determine the distance between soundings. SkyTEM has two moments: a low moment (3,000 A•m^2) enables measurement of early time data and provides details about shallow subsurface structures, and a high moment (160,000 A•m^2) enables measurement of late time data, penetrates deeper and offers details about deep subsurface structures (Sørense and Auken 2004). There are 26 flight lines in the study area (Fig. 2), and the distance between flights is about 500 m. The AEM survey lines run east to west, and one line runs north to south. The AEM survey instrumentation and data acquisition for the study area were presented in AGF (2017).

AEM data were processed using Aarhus Workbench 6.2 software which has geophysical and GIS platforms. Manual and automatic methods were applied to adjust altitude and voltage data, as described by Auken et al. (2009). A spatially constrained inversion (SCI) (Viezzoli et al. 2008) was used that forms a quasi-3D model by constraining laterally along and across the flight lines to generate resistivity depth for 30 layers. A 30-layer model was used, with thicknesses increasing logarithmically with depth. The thickness of the first and 29th layers is 3 and 25.9 m, respectively. The depth to the base of the 29th layer is 312 m below the land surface. The Kriging technique with a node spacing of 200 m × 200 m × 3 m was used to interpolate one-dimensional (1D) inverted resistivity to a 3D resistivity grid. The vertical resolution (3 m) was selected to capture vertical heterogeneity in resistivity.

Hydrologic data

Groundwater levels are monitored in a network of two observation wells and 20 irrigation wells in the study area. Monitoring of water levels in irrigation wells is achieved through the use of pipes installed in the filter pack of the well between the well casing and the borehole wall. Automatic groundwater level monitoring systems were installed in July of 2020 to collect daily real-time groundwater-level data. The groundwater level monitoring was aimed to assess drawdown and potential impacts of well interferences during irrigation pumping. Well hydrographs were used to evaluate and verify the interconnections between the aquifer systems and streams. Water-table measurements from spring 2017 were interpolated using the Ordinary kriging method to determine the position of the water table in the aquifer system. There were numerous water level data available from a measurement campaign conducted in the spring of 2017. Water levels data in the spring of 2017 were used to map static water levels because spring is the best time to measure static water levels (no irrigation pumping).

MPS modeling

The MPS work is carried out in this study using the 3D geological modeling software GeoScene3D. The software allows for visualization and integration of different geo-data types and consists of all the necessary tools for a full MPS workflow, from generating the 3D training image through simulation to computing the statistics/hydrofacies probabilities. In this study, the borehole lithological logs were categorized into hydrofacies. Hydrofacies 1 consists of poorly permeable sediments (silt, clay, soil, clay and silt, silt and clay, clay and sand, clay and gravel, shale, till and siltstone) and hydrofacies 2 consists of medium to highly permeable sediments (sand, gravel, silt and sand, sand and gravel, fine sand, coarse sand, gravel and silt). Hydrofacies 2 forms the glacial aquifer, while hydrofacies 1 forms the confining units (aquitard) and bedrock units. Figure 3 depicts the methodology used to simulate aquifer heterogeneity. The simulations are performed using the preferential simulation path technique (Hansen et al. 2018) and the SNESIM algorithm of the open-source software MPSLIB (Hansen et al. 2016) which is embedded in GeoScene3D.

Soft data conditioning

The soft data were prepared in three steps. First, the AEM data were processed, inverted, and interpolated to a 3D grid. Second, borehole data were grouped, ranked, and assigned to the 3D grid. The borehole lithological logs were then classified as lithohydrofacies. Lithohydrofacies 1 consists of fine-grained sediments and lithohydrofacies 2 consists of coarse-grained sediments. This study used lithohydrofacies generated from boreholes with detailed lithological logs and good location quality to determine the corresponding resistivity values for each lithohydrofacies. The lithohydrofacies were assigned to a 200 m × 200 m × 3 m grid and the distribution of resistivity values for each lithohydrofacies was evaluated by examining the correlation between corresponding lithohydrofacies and resistivity values. The correlation between resistivity and lithohydrofacies can be affected by factors such as subsurface

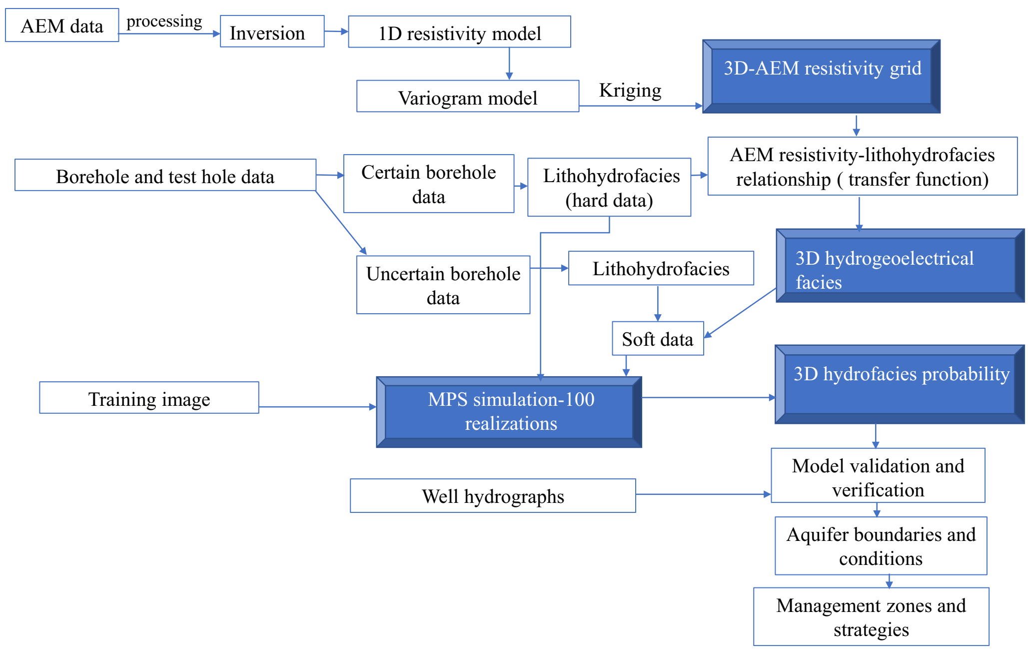

Fig. 3 Multiple-point statistic (MPS) simulation workflow used in this study

water quality, clay minerals, and porosity. In the study area, the effect of porewater conductivity on the relationship is negligible and clay minerals exert a dominant control on resistivity (Korus et al. 2017). The built-in automatic transfer function in GeoScene3D was used to establish the correlation between resistivity values and lithohydrofacies. The transfer function highlights resistivity values of 22 Ω•m as cutoffs for hydrogeoelectrical facies (Fig. 4). A hydrogeoelectrical facies was then generated from AEM resistivity data using this cutoff value. A hydrogeoelectrical facies is a group of sediments that have similar lithological, hydraulic, and electrical properties (Cattaneo 2014). For the successive phases of the workflow, it would be very useful to distinguish hydrogeoelectrical facies based on their resistivity value. Figure 4 shows the probability of the two hydrogeoelectrical facies for the whole range of electrical resistivities in the study area. As resistivity values increase, the percentage of hydrogeoelectrical facies 1 decreases while the percentage of hydrogeoelectrical facies 2 increases. The hydrogeoelectrical facies probabilities were merged with lithohydrofacies from uncertain borehole data and used as soft data. Using information derived from AEM data as soft data leads to a more detailed and representative subsurface realization than relying solely on borehole data (Barfod et al. 2018b). The soft data were used together with TI to determine the probability of hydrofacies at a simulated grid. Using the tau model (Journel 2002), the SNESIM algorithm adjusts the influence of soft data (He et al. 2014a, b; Ma and Jafarpour 2019). A higher value of tau means that the soft data will have a stronger influence, while a lower value of tau means that the soft data will have a weaker influence (Ma and Jafarpour 2019). The value of tau can be estimated from the data. The probability of finding hydrofacies at a specific simulation grid node is calculated based on conditional probability by combining the training image and soft data. One hundred realizations are carried out to ensure that reliable hydrofacies events occur at the simulated grid and to calculate the probability at the simulated location.

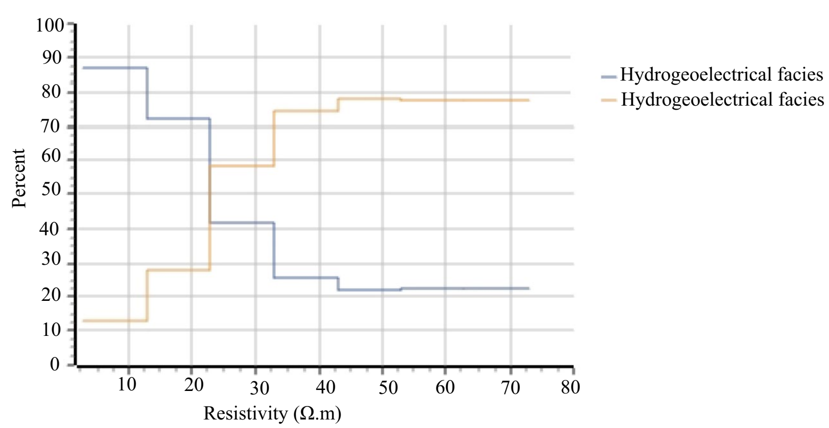

Fig. 4 The transfer function illustrating the probability of hydrogeoelectrical facies

The number of realizations should be large enough to ensure the stability of the results while also considering the intended processing time of the realizations (Remy et al. 2009).

Hard data conditioning

Hard data conditioning forces MPS realizations to match hard data exactly. In this study, lithohydrofacies generated from eight boreholes that overlap AEM flight lines (Fig. 2) were used as hard data to condition the MPS realizations and reduce uncertainty by forcing the models to match the hard data.

Training image (TI)

In hard-data-scarce areas, MPS realizations rely more on the statistics derived from a TI, which is a cognitive model (Høyer et al. 2017), and from soft data. The ability of the MPS approach to generate realistic representations of geological heterogeneity is heavily dependent on the user-generated TI. TI can be generated from a wide range of data sources; geophysical data such as airborne electromagnetic data (AEM) (He et al. 2013, 2014a; Jørgensen et al. 2015), field data in combination with borehole data (Dall'Alba et al. 2020), and geological background knowledge of the study area. A 3D TI was generated for this study using the same cell size as the 3D AEM resistivity grid but with a smaller footprint (Fig. 5). The aquifer heterogeneity incorporation into the TI was based on a conceptual understanding of the geology of the study area, its aquifer system, glacial processes, interpretations of hydrostratigraphic borehole units, surface geological information, and the AEM model (Korus et al. 2021). Then, expected aquifer heterogeneity in the vertical and horizontal directions was incorporated into the TI. The TI image consists of 106,796 nodes for hydrofacies units. The TI consists of a buried bedrock paleovalley trending W–E, a buried channel trending N–S, and glaciotectonic thrust wedges. The structure and geometry of the glacial deposits in the study area were incorporated into the TI to guide MPS simulation.

MPS parameters and hydrofacies probability calculation

Choosing appropriate MPS parameters, such as search templates and multiple grids, is critical for simulating heterogeneous and discontinuous glacial aquifer systems. The MPS algorithm and the parameters used significantly impact spatial structures derived from the TI (Liu 2006; Høyer et al. 2017). Larger search templates of multiple grids are used to detect large-scale structures and patterns in the TI, while finer templates are used to detect smaller structures within the TI (Mariethoz and Caers 2014). Different MPS model parameters were evaluated to simulate aquifer realizations using the preferential simulation path implemented in GeoScene3D. An advantage of the preferential simulation path is that more informed model parameters are visited preferentially to less informed ones (Hansen et al. 2018). The model was simulated with a cell size of 200 m × 200 m × 3 m. A minimum search template of 3 × 3 × 3 and a maximum search template of 10 × 10 × 10 were used to scan and derive information from the TI. Different numbers of multiple grids were tested and of the multiple grids, six provided good results. The impact of multigrids on MPS realization has been well documented by Liu (2006).

The hydrofacies assigned to the simulation grid are determined using the TI, hard, and soft data. During simulation, hard data provides the first conditioning nodes and patterns to be matched (Madsen et al. 2021). If a grid cell lacks hard data, grid cell-based conditional hydrofacies are calculated by scanning information stored in a search tree and soft data.

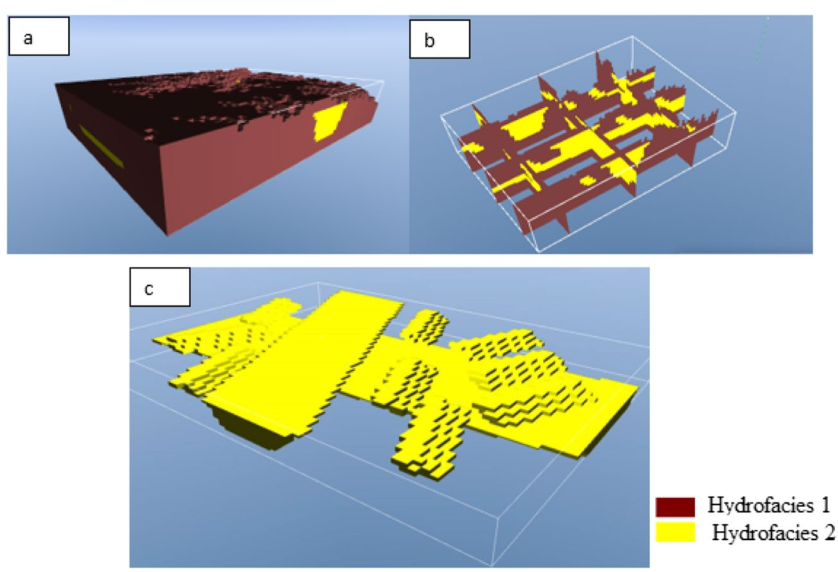

Fig. 5 Training images: **a** three-dimensional **b** W–E and N–S slices **c** only hydrofacies 2 presented

One hundred 3D aquifer realizations were simulated and the probability of each hydrofacies was calculated at each grid of 200 m × 200 m × 3 m.

Model evaluation

Qualitative evaluations of 3D hydrofacies probability were performed using high-quality borehole logs and heterogeneity features presented in the TI. In addition, well hydrographs were used to determine the connection between aquifers and possible well interferences. The connections between aquifers were assessed following the approach of Butler et al. (2013) and Butler et al. (2021) using several characteristics of the hydrographs, including (1) duration of drawdown during pumping, (2) length of the recovery period after cessation of pumping, (3) year-to-year changes in peak groundwater levels, and (4) slope of hydrograph during nonirrigation months (after drawdown recovery and before the onset of pumping).

Results

Model evaluation

Pseudo wells were placed in the model space at various locations (Fig. 6) to extract attributes from the hydrofacies probability grid and soft data (AEM and boreholes) grids for comparison (Fig. 7). Pseudo wells (Fig. 7) show that the probability of hydrofacies 2 is low at shallow depth (elevation 490–520 m), which corresponds to loess and till (confining unit). The probability of hydrofacies 2 is also low below the bedrock surface (elevation 420 m), which corresponds to shale. The highest hydrofacies 2 probability exists between the elevation of 420–495 m. In general, probabilities of soft data match well with hydrofacies probabilities from MPS simulations at the locations of pseudo wells. High probability (> 0.7) from soft data corresponds to high hydrofacies 2 probability (> 0.6) from MPS simulation in all pseudo wells.

Glacial aquifer system and heterogeneity

Spatial patterns hydrofacies 2 probability varies with depth (Fig. 8). The horizontal slices reveal different zones of hydrofacies 2 probability: low (<0.2), low-medium (from 0.2 to 0.4), medium (from 0.4 to 0.6) and medium to high probability (>0.6). Low hydrofacies 2 probability at elevation 486 m indicates a shallow, clay-rich confining unit (clay, silt, and till units; Fig. 8a). The deepest slice at 386 m shows shale-dominant bedrock units (Fig. 8f). Low-medium hydrofacies 2 probability values indicate heterogeneous units, whereas high hydrofacies 2 probability values indicate coarse sediments deposited in a buried valley and other glacial sand bodies. High hydrofacies 2 probabilities are oriented N–S at elevations of 473, 444 and 432 m (Fig. 8b–d). The interconnectedness of high hydrofacies 2 probability varies spatially: it is localized and discontinuous in the eastern and western parts of the study area. High hydrofacies 2 probability is a productive aquifer composed of sand and gravel deposits in channel deposits and buried valleys.

The horizontal slices (Fig. 8), W–E profiles (Fig. 9), and N–S profiles (Fig. 10) show three types of aquifer connectivity: (1) connected N–S and W–E trending paleovalley

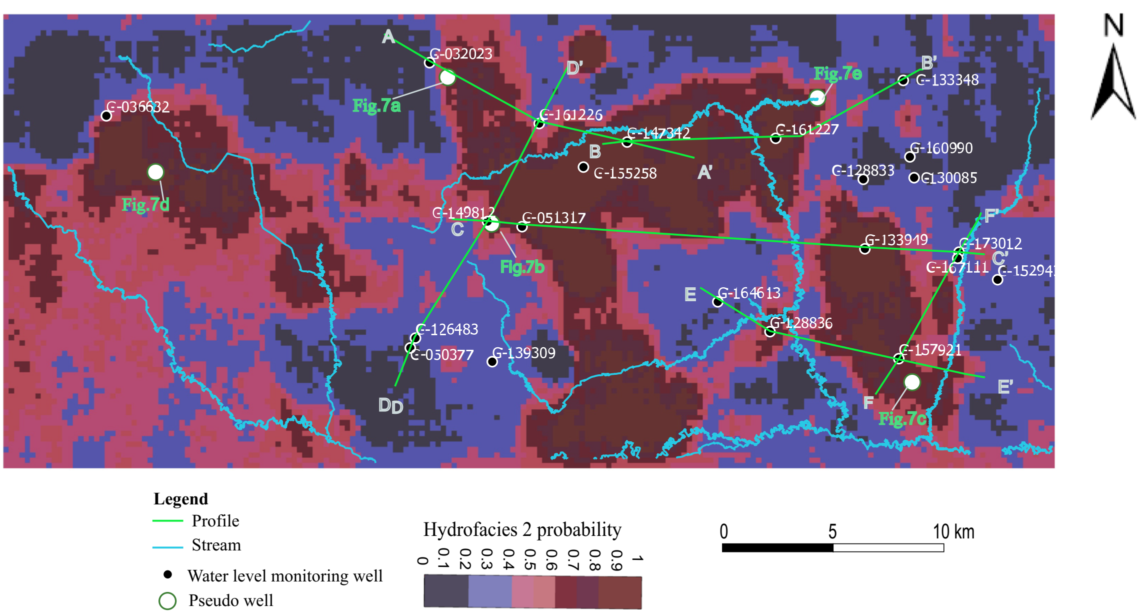

Fig. 6 Locations of pseudo wells, sources of well hydrographs, and profiles between monitoring wells

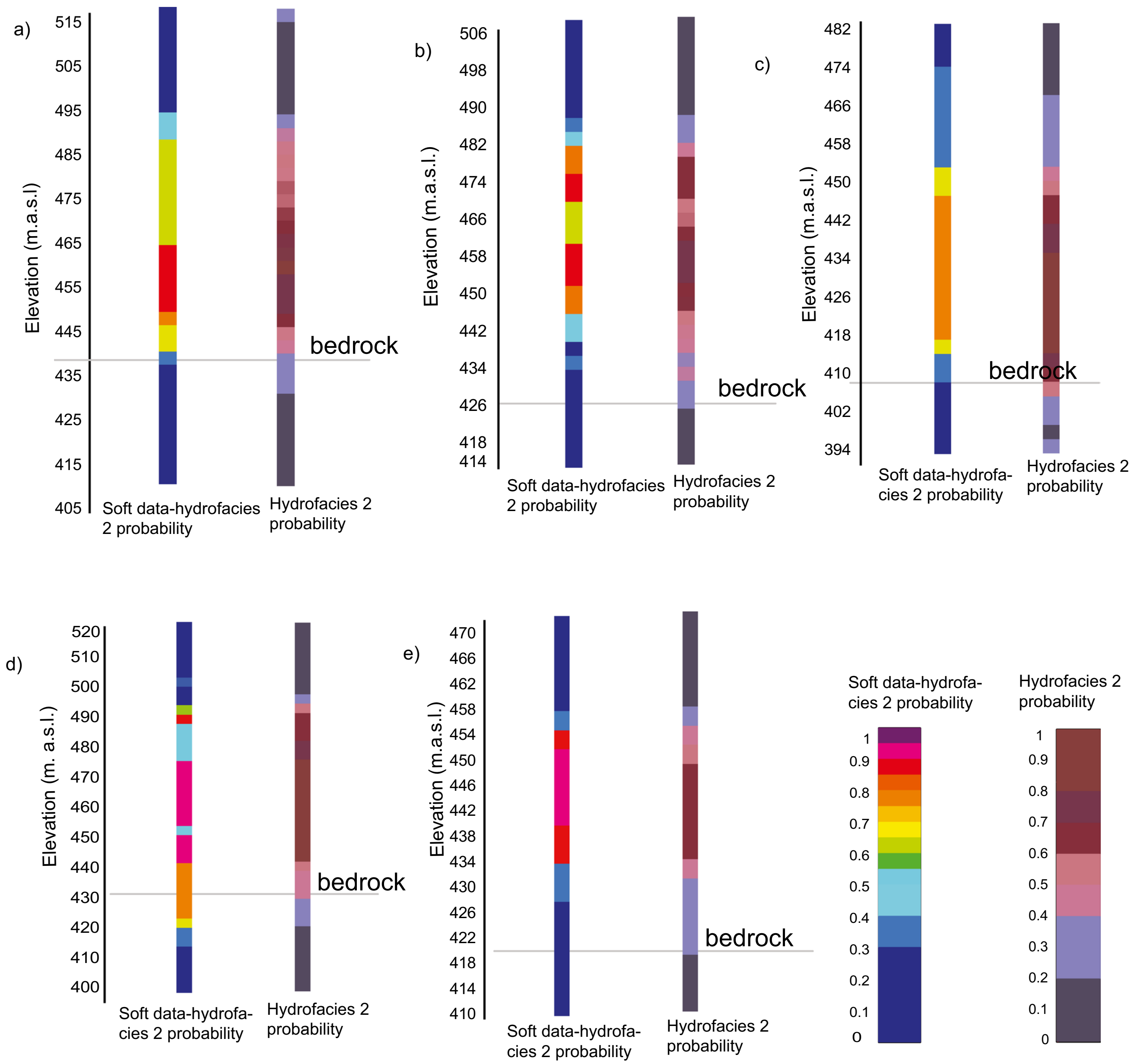

Fig. 7 Comparison of hydrofacies 2 probability from MPS and soft data probability; the borehole locations are shown in Fig. 6 as "Fig. 7a–e"

aquifers (Fig. 8c), (2) medium to poorly connected valley aquifer type where heterogeneous units (medium hydrofacies 2 probability) are found between high hydrofacies 2 probability (Fig. 8c–e) and (3) isolated valley aquifer type where the aquifer is bounded by aquitard units (Fig. 8a, b). The depths of confining units (low hydrofacies 2 probability at shallow depth), aquifer zones (high hydrofacies 2 probability), and bedrock (low hydrofacies 2 probability) in the profile correspond well to the lithological borehole logs. The top layer is the main confining unit in the study area, which is underlain by the aquifer materials, as seen in the W–E and N–S profiles (see Figs. 9, 10 and 11). The paleovalley aquifers have a high probability of hydrofacies 2 (composed of permeable coarse-grained sediments). The aquifer materials are not continuous, and there are heterogeneous zones (hydrofacies 2 probability from 0.4 to 0.6). The thickness of the aquifer varies spatially. The heterogeneous zones consist of clay, silt, and coarse-grained sediments such as sand and gravel. The units below the aquifer materials are till and shale units with a low hydrofacies 2 probability (<0.2).

In general, the profiles (Figs. 9, 10 and 11) show the presence of heterogeneous, clay-rich sediments and complex hydrostratigraphic units. The aquifer zone has a variable thickness, limited spatial extent, and is discontinuous. The

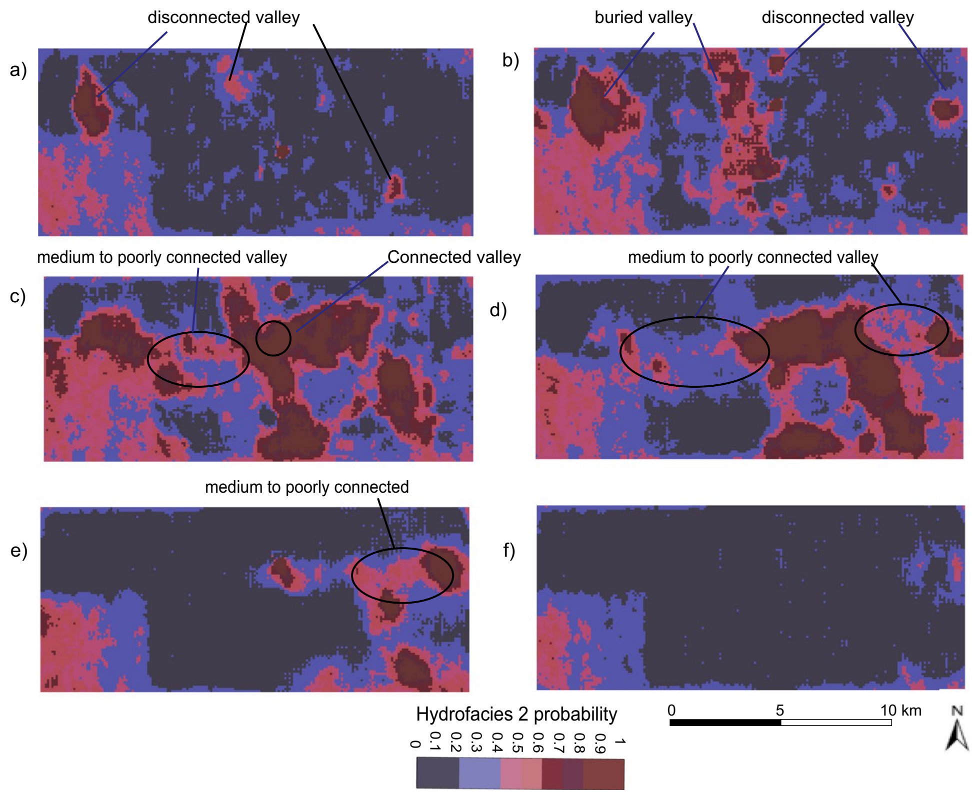

Fig. 8 Horizontal slice view of hydrofacies 2 probability from MPS **a** 486 m **b** 473 m, **c** 444 m, **d** 432 m, **e** 410, **f** 386 m

thickness of the confining unit is also variable, resulting in complex confining conditions. Figures 10 and 11 show that aquifers are locally exposed to the land surface and thus act as a direct local recharge zone.

Hydraulic conditions and connections between aquifers

All monitoring wells in the study area show groundwater-level fluctuations in response to irrigation pumping. During summer months, irrigation pumping occurs intermittently for a period lasting less than 80 days. The magnitude and rate of drawdown during this period, as well as the subsequent recovery of groundwater levels, relate to variable aquifer conditions (confined and unconfined), lateral extents, aquifer-to-aquifer connectivity, and other aquifer characteristics (Butler and Liu 1991; Butler et al. 2013, 2021; Korus 2018). Differences in the patterns, magnitudes, and rates of drawdown and recovery highlight important spatial variations in the aquifer framework. As such, evidence from well hydrographs is used to qualitatively assess the hydrofacies probability model (Fig. 12).

The hydrograph for well G-032023 is typical of wells completed in the N–S paleovalley aquifer (Fig. 13). Water-level drawdown of 5–8 m occurs over several months. This steady drawdown is punctuated by 3–5-day periods of rapid (about 1 h) drawdown of more than 10 m, followed by similarly rapid recovery. The long-term declines in water level could be a result of the combined drawdown from multiple nearby irrigation wells.

The shorter, rapid periods of drawdown record the development of a seepage face in the filter pack, which is a common occurrence in wells that are screened in unconfined aquifers (Rushton 2006; Chenaf and Chapuis 2007; Behrooz-Koohenjani et al. 2011; Houben 2015a, b). Following the irrigation season, the length of the groundwater-level recovery is only a small fraction of the pumping period (Fig. 13). This rapid recovery is evidence of a laterally constrained aquifer (Butler et al. 2021). Indeed, this well is bounded by low-permeability units in a W–E direction and is located very near the western boundary (Figs. 6, and 12a).

Well G-161226 is located on the eastern margin of the same N–S paleovalley aquifer, where it intersects the W–E paleovalley aquifer (Fig. 6). The hydrograph for this well is similar to that of G-032023, except it lacks evidence of filter-pack dewatering and its recovery period is slightly longer. G-161226 is bounded by medium (from 0.4 to 0.6) hydrofacies 2 probability, so the longer recovery period could reflect lower transmissivity or lack of boundary influence. The lack of dewatering suggests that the aquifer is confined, which agrees with the hydrofacies model (Fig. 12a).

The well hydrographs from G-147342 and G-161227 (Fig. 13) are typical of wells screened in the W–E paleovalley aquifer. The hydrographs show drawdown varying between 8 and 15 m and recovery times of about 50 days.

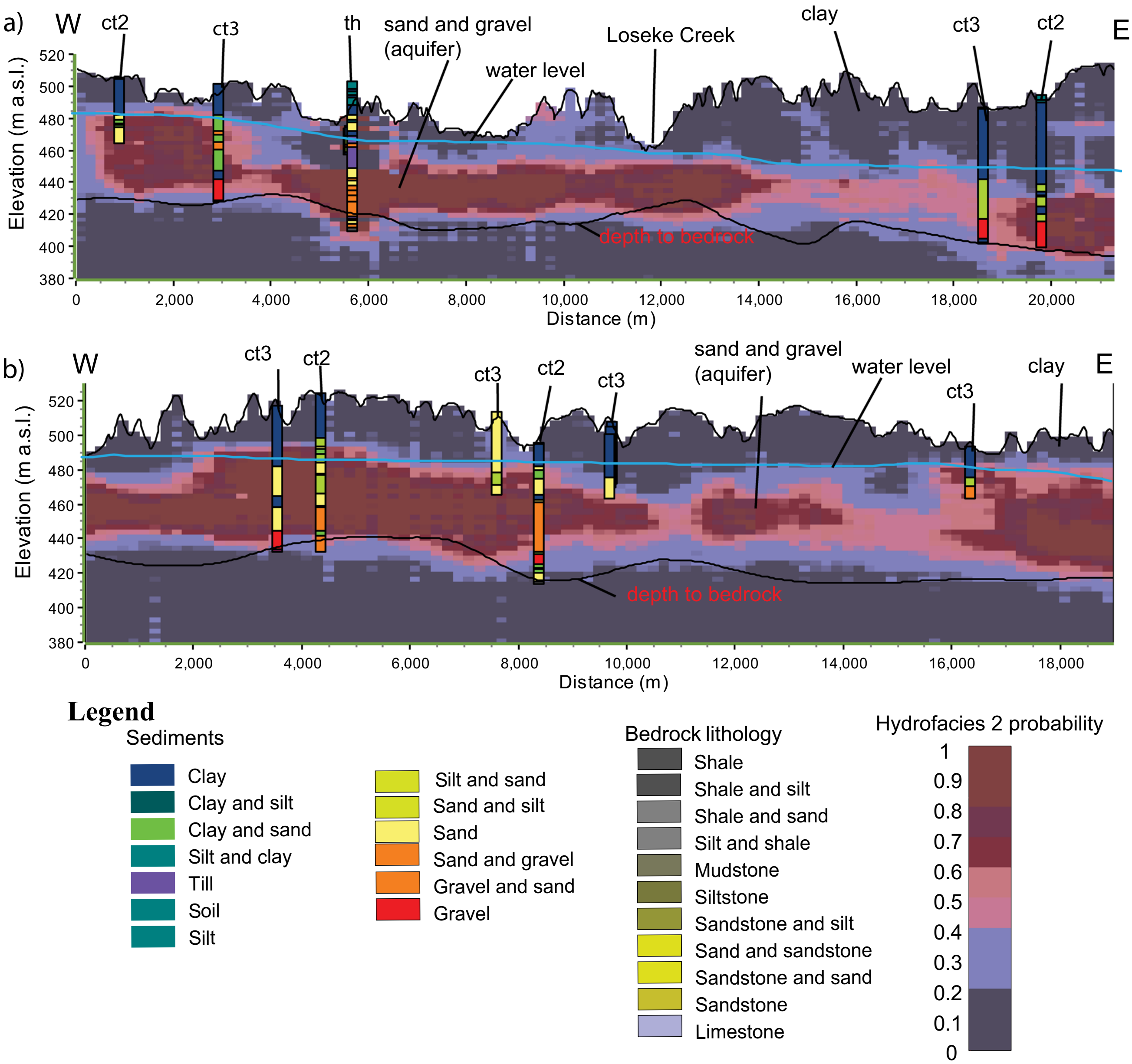

Fig. 9 W-E profiles of hydrofacies 2 probability in the northern part of the study area at different locations. Test holes (th) are hard data; Borehole category 2 (ct2) and borehole category 3 (ct3) are soft data. The water level refers to spring 2017. Location of the profile is shown in Fig. 2. as "Fig. 9(a–b)"

The hydrofacies probability shows a high hydrofacies 2 probability (>0.7) between these two wells and throughout the 6-km-wide aquifers, which matches with coarse sediments shown in borehole lithological logs (Fig. 12b). It also shows a confining layer above the aquifer. The groundwater-level fluctuations are consistent with the interpretation of confined conditions, interconnections between wells in the paleovalley, and minimal influence of aquifer boundaries.

Well G-133348 lies in a zone of significant heterogeneity east of the W–E paleovalley aquifer (Fig. 12b). Groundwater level declines and recovery times differ significantly from those described previously. Recovery is incomplete following each irrigation season. Annual peak water levels in the well have declined by about 6 m over the past 6 years. Hydrofacies 2 probability is low (0.2–0.4) and the aquifers in this area are poorly connected to the W–E paleovalley aquifer (Figs. 8 and 12b). Borehole logs also show heterogeneous and thin coarse sediments in the vicinity of G-133348.

Monitoring wells G-149812 and G-051317 are located in the middle part of the N–S paleovalley aquifer (Fig. 6). The

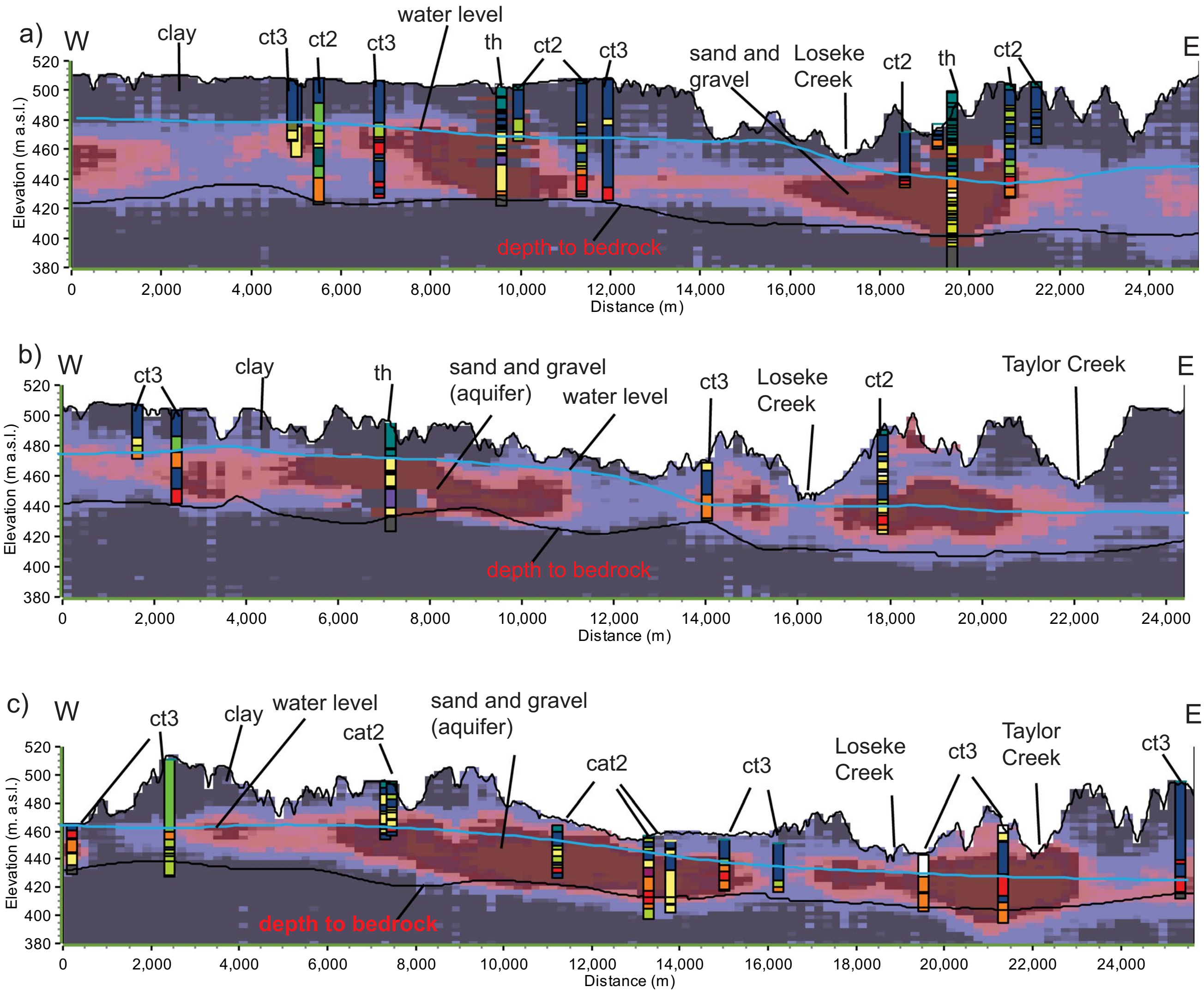

Fig. 10 W-E profiles of hydrofacies 2 probability in the middle and southern (downstream reaches) of the study area at diffrent locations; Legend presented in Fig. 9. Test holes (th) are hard data; Borehole category 2 (ct2) and borehole category 3 (ct3) are soft data. The water level refers to spring 2017. Location of the profile is shown in Fig. 2. as "Fig. 10(a–c)"

hydrographs show evidence for filter-pack dewatering, indicating they tapped an unconfined aquifer. The hydrographs (Fig. 14) show that the aquifer has fully recovered before the next irrigation season. Eastward, near Loseke Creek (Fig. 12c), the water-level surface drops abruptly, indicating a hydraulic boundary. The location of this boundary corresponds to a heterogeneous zone separating the E–W paleovalley from deposits farther east. On the easternmost side of this profile, well G-173012 shows incomplete recovery between irrigation seasons, similar to other wells in this heterogeneous zone.

The well hydrograph from G-126483 is typical of wells in the heterogeneous zone west of the N–S paleovalley (Fig. 14). It shows a high drawdown (~12 m) and rapid recovery (~5 days; Fig. 14). It also shows rapid dewatering of the filter pack. This well hydrograph is characteristic of a thin unconfined aquifer with low transmissivity and enclosed by hydraulic boundaries. The hydrofacies model (Fig. 12d) shows a thin high hydrofacies 2 probability (>0.6) bounded by heterogeneous hydrofacies 2 probability (probability ranges between 0.2 and 1.0). It also shows a poor connection with the N–S paleovalley aquifer (Fig. 12d).

Connections between streambed and aquifers

Hydrofacies 2 probability indicates spatial variability of streambed and aquifer connectivity (Figs. 9, 10, 11 and 12). Upstream reaches of the streams show low hydrofacies 2 probability between the stream bank, streambed, and aquifer, indicating a poor connection to the aquifer (Fig. 12a–c). In downstream reaches near the stream outlets, however, there is medium to high (>0.6) hydrofacies 2 probability between

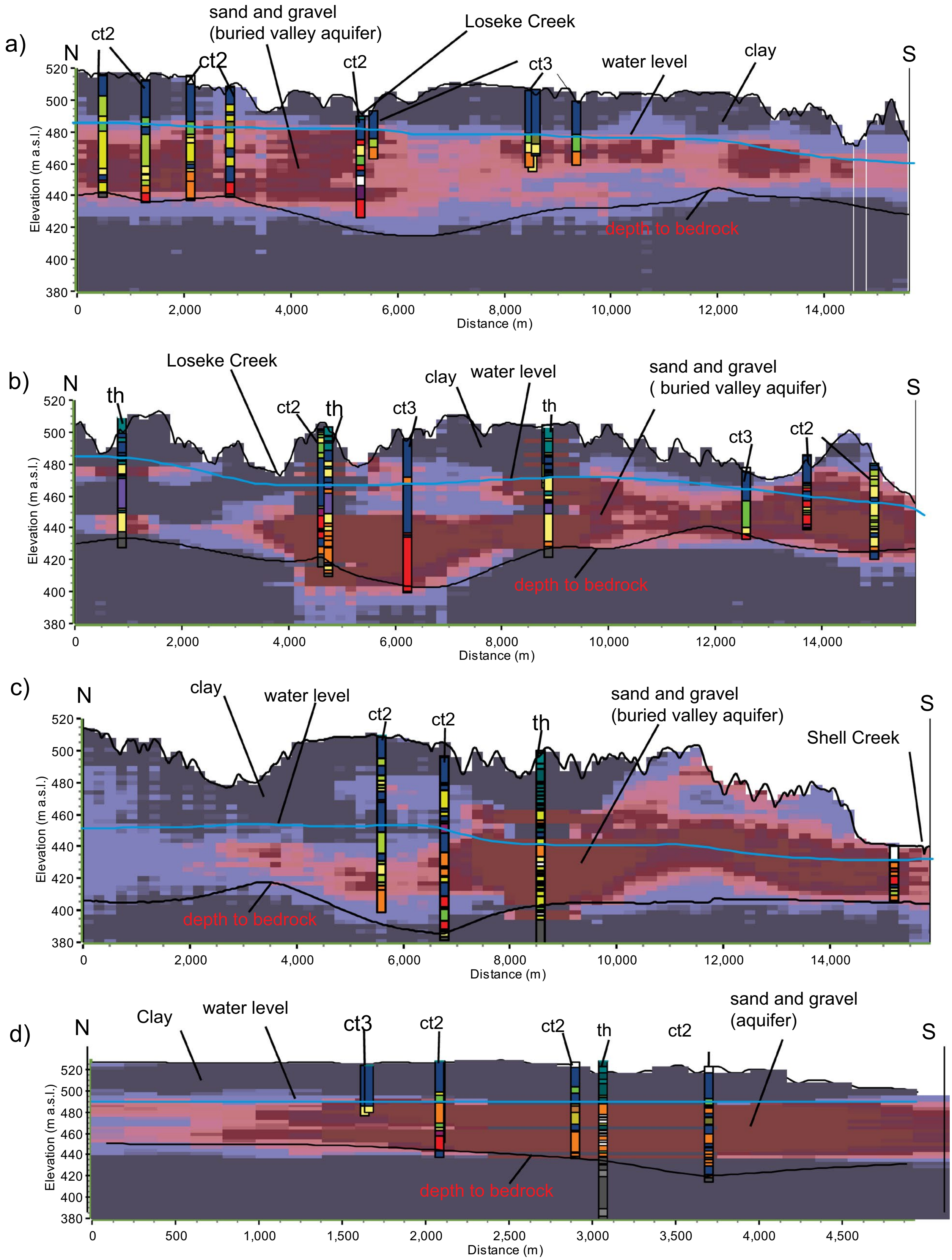

Fig. 11 N-S profiles of hydrofacies 2 probability at different locations. Legend is presented in Fig. 9. Test holes (th) are hard data. Borehole category 2 (ct2) and borehole category 3(ct3) are soft data. The water level refers to spring 2017. Location of the profile is shown in Fig. 2. as "Fig. 11(a–d)"

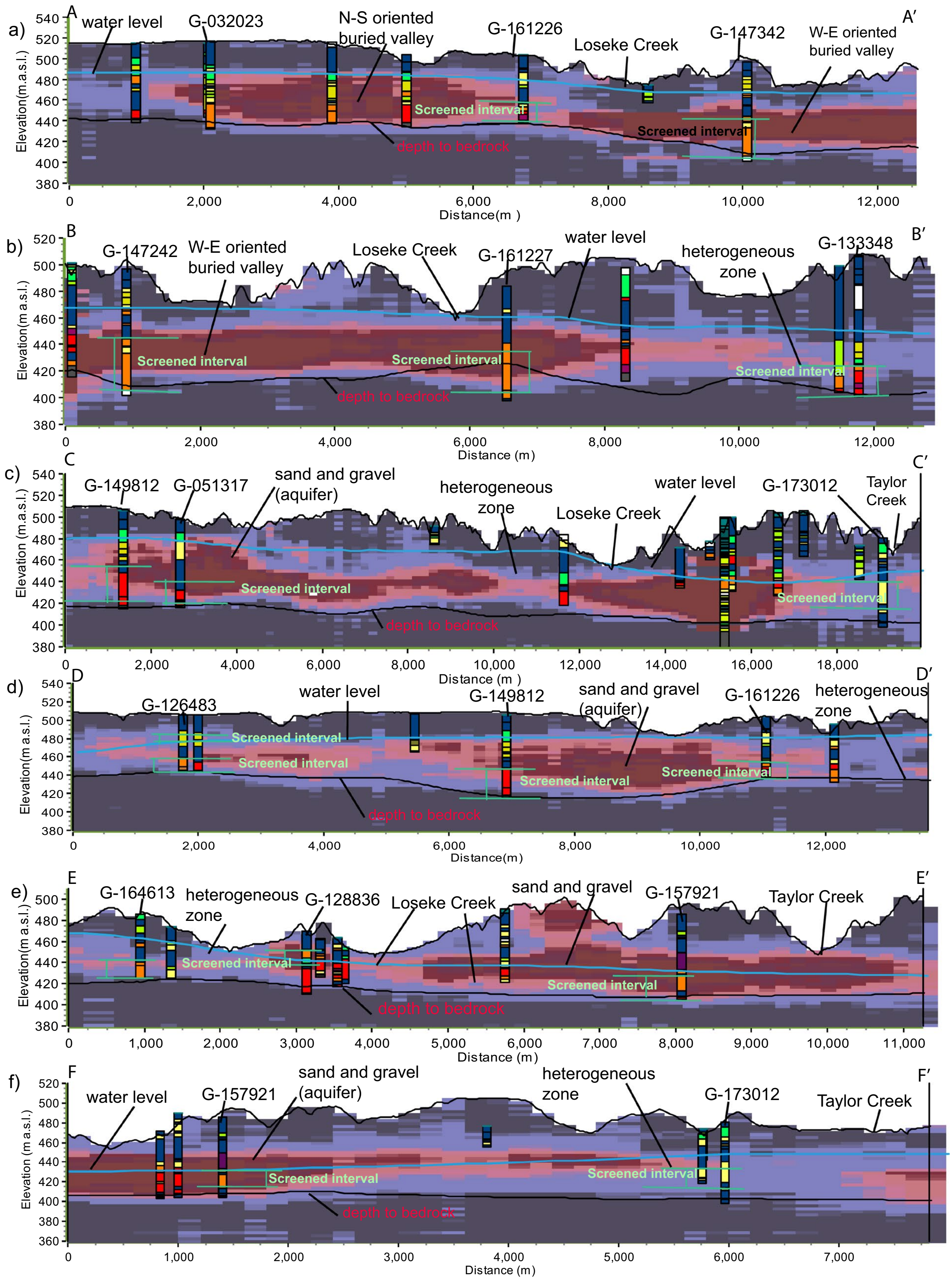

Fig. 12 Profiles of probability of hydrofacies from MPS between groundwater monitoring wells, **a**) A-A' **b**) B-B' **c**) CC' **d**) D-D' **e**) E-E' **f**) F-F'. Location of the profile is shown in Fig. 6. Legend presented in Fig. 9. The water level refers to spring 2017

the aquifer and the bed of Taylor Creek (Fig. 12e). Loseke Creek's stream bed also shows medium (from 0.4 to 0.6) hydrofacies 2 probability. Furthermore, there are local connections of streambed and aquifer in upland areas between streams (Fig. 12e).

The hydrographs for wells G-126483 and G-157921, which are located near the stream outlets (Fig. 12e, f), are unlike any hydrographs in the upstream reaches (Figs. 13 and 14). Both wells show evidence of pumping-induced drawdown, but water levels recover rapidly and completely. There is little to no long-term drawdown of the water table in the vicinity of these wells during the irrigation season, despite evidence of large-magnitude drawdown in wells G-164613 and 173012, which are located just a few kilometers away. These observations strongly suggest that the aquifers in the downstream area are compartmentalized and are affected by recharge boundaries. It also suggests that there may be localized pathways for rapid recharge in upland areas between streams.

Delineation of groundwater management zones

Seven groundwater management zones were developed based on hydrofacies probability and hydrograph characteristics (Fig. 15). Table 1 shows the detailed characteristics of each zone as well as the management issue. Zone 1 is an unconfined aquifer, while zone 2 is heterogeneous and has abrupt variations between confined and unconfined aquifers. The main management issue in zone 2 is local well interference. The horizontal slice (Fig. 15, zones 3–4) demonstrates the connection between N–S and E–W-oriented palaeovalley aquifers. The decline in groundwater level in connected valley aquifers is most likely the result of multiple well interferences caused by nearby irrigation well pumping (Fig. 15, zone 4). Well interferences increase groundwater-level drawdown and affect well yield for crop production. Zone 3 indicates a narrow, bounded, unconfined aquifer with high hydrofacies 2 probability. Excessive drawdown can be seen in the hydrographs of the wells in zone 3 located near the boundaries. Zones 3 and 4 can be managed as a single aquifer. Future well permits and siting should consider the effects of well interferences and sustainable yield in these zones. Variability in groundwater level declines and recovery in nearby wells indicate a weak connection between aquifers (Fig. 15, zones 5–6). These zones are characterized by extreme heterogeneity that affects direct aquifer recharge. Well permitting in zones 5 and 6 should consider the impact of high drawdown during

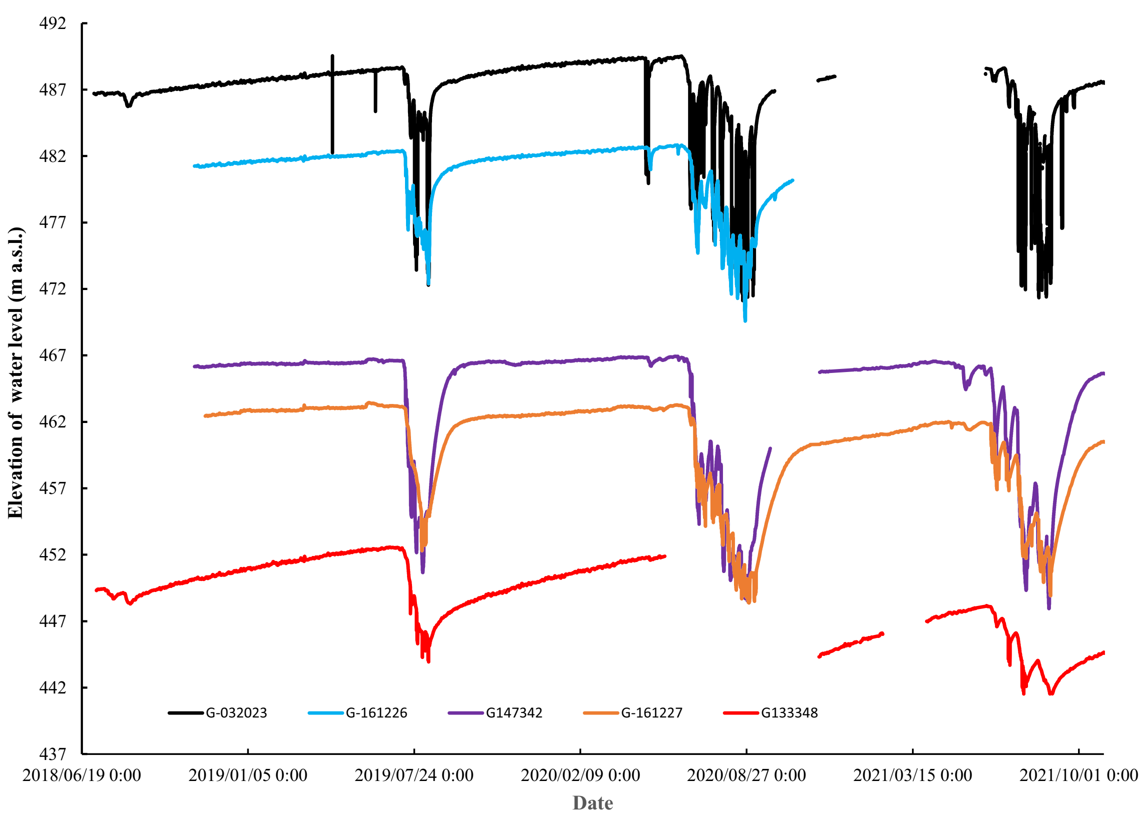

Fig. 13 Hydrographs from observation wells showing drawdown and recovery 2018–2022 in the upstream reaches of the study area. See Fig. 12a, b for locations of wells

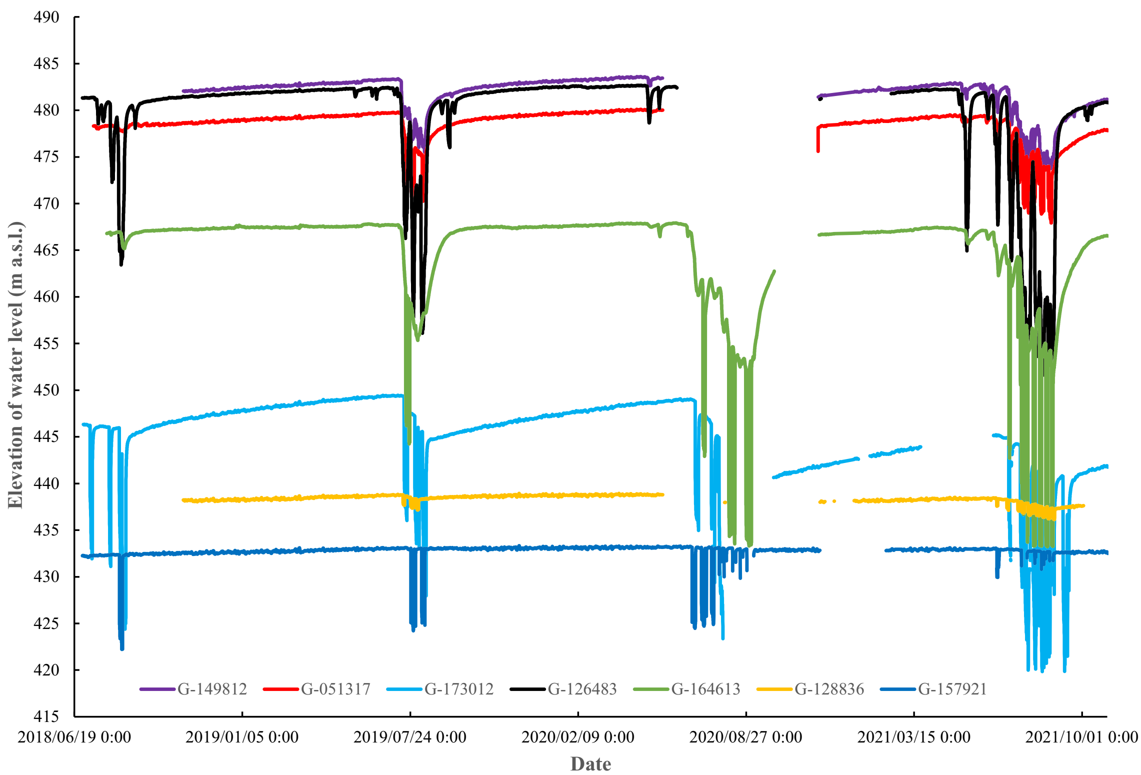

Fig. 14 Hydrographs from observation wells showing drawdown and recovery during 2018–2021 in the middle and downstream reaches of the study area. See Fig. 12c–f for locations of wells

irrigation periods (aquifer depletion) and the disconnected valley's groundwater potential to support irrigation pumping.

Discussion

This paper presents the first MPS-derived hydrofacies model of glacial aquifers in Nebraska. It provides an important test of the applicability of this method to aquifers in this region and to glacial aquifers in general. The hydrofacies probability model helps answer questions related to aquifer heterogeneity, whereas the groundwater-level hydrographs verify characteristics observed in the hydrofacies model such as aquifer boundaries (no-flow and recharge) and aquifer state (confined vs. unconfined). Paleovalley aquifers, which have a high probability of hydrofacies 2, are the most productive aquifers in the study area. Overall, hydrofacies 2 is heterogeneous and discontinuous. These aquifers

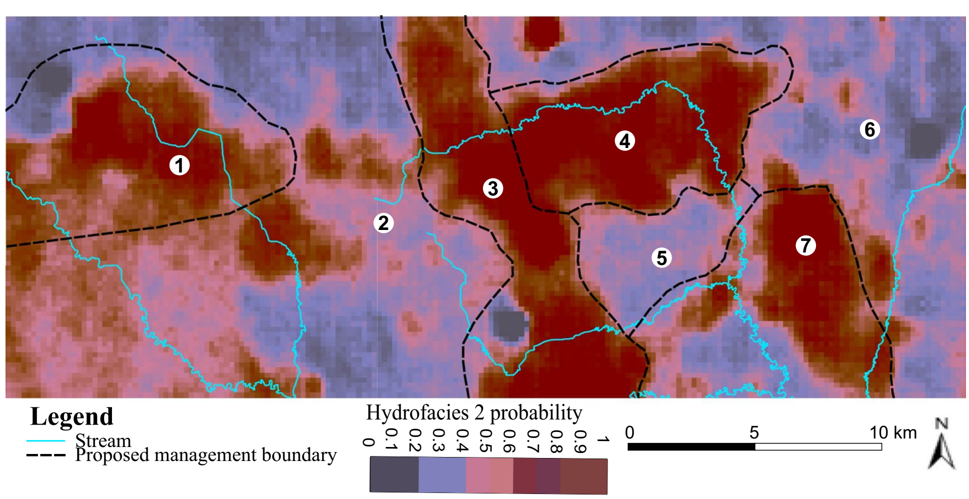

Fig. 15 Proposed management boundaries with respect to hydrofacies 2 probability, represented as a horizontal slice through the model at 444 m elevation

Table 1 Management zones, recovery, hydrogeologic characteristics and management issue(s)

Zone	Primary management issue(s)	Hydrogeologic characteristic(s)	Recovery time (days)	Drawdown (m)
1	Unknown	Unconfined	>30	8
2	Local well interference	Heterogeneous, abrupt variations between confined and unconfined, Low transmissivity	5–25	5–12
3	Excessive drawdown near boundaries	Unconfined, laterally constrained	20–30	5–8
4	Well interference	Confined	50	8–15
5	Well interference, rapid loss of well yield	Extreme heterogeneity, confined, low transmissivity	50	12–15
6	Aquifer depletion	Extreme heterogeneity, abrupt variations between confined and unconfined, limited recharge	>285 (incomplete between pumping periods)	6–8
7	Stream depletion	Hydrologically connected to stream, local recharge pathways	1–20	<1

are hydrologically connected only in one small area. This heterogeneity presents a major challenge for groundwater management because major changes in hydrologic behavior occur over short distances. MPS provides a framework for delineating proposed management boundaries (Fig. 15) and hydrographs reveal the hydrologic behaviors specific to each zone (Fig. 14). Thus, the workflow presented here can be used to create tailored management solutions for highly heterogeneous aquifers. Fluctuations and recovery in groundwater levels are influenced by groundwater pumping, well interference and the nature of the aquifer. The heterogeneity of the aquifer obstructs groundwater flow to wells and if the cone of depression intersects with impermeable layers, significant drops in water levels occur. Some well hydrographs in zone 5, which are typical of wells that extract water from aquifers surrounded by impermeable formations, exhibit abrupt decreases in groundwater levels during irrigation pumping (Korus 2018). The hydrofacies probability profiles (Figs. 11 and 12e) show the existence of a localized aquifer. This localized aquifer is exposed to the land surface that may serve as a favorable location for the implementation of managed aquifer recharge techniques, such as an artificial recharge basin (Knight et al. 2022; Pepin et al. 2022; Uhlemann et al. 2022).

The use of appropriate aquifer and streambed heterogeneity could help to reduce uncertainty in groundwater–stream interaction modeling. The discontinuity and existence of low hydraulic conductivity affect groundwater flow (Åberg et al. 2021). In a heterogeneous aquifer system, the use of a classical model that involves layering a confining-layer system may result in errors in the groundwater model. The results from hydrofacies probability improve hydrostratigraphic conceptualizations and aid in parameterizing groundwater flow models for model calibrations. The hydrofacies 2 probability can be clustered and the relationship between the clustered hydrofacies 2 probability and hydraulic conductivity can be assessed to parameterize the groundwater model. The K-means clustering method can be used to group hydrofacies probabilities, which can then be used to estimate the hydraulic conductivity for each group. Furthermore, K-means clustering can be used to generate hydrofacies probability zones, and inverse groundwater modeling can be used to estimate hydraulic conductivity for each clustered zone. Marker et al. (2015) used K-means clustering to categorize voxel models of electrical resistivity and clay fraction into hydrostratigraphic zones and estimated hydraulic conductivity for each zone using hydrological calibration.

The heterogeneity of streambed sediment controls the water exchange between streams and groundwater. The hydraulic conductivity of the streambed is more variable in meandering rivers than in straight channels (Abimbola et al. 2020). Fleckenstein et al. (2006) compared stream and groundwater interactions in homogeneous and heterogeneous aquifers and reported that facies distribution affects flux and groundwater levels. Kalbus et al. (2009) investigated the influence of aquifer and streambed heterogeneity on groundwater discharge distribution and reported that aquifer heterogeneity has a larger effect on stream–groundwater interactions than streambed heterogeneity. MPS hydrofacies simulation can help to assess streambed hydraulic conductivity and thickness which are vital for assessing groundwater–stream interaction modeling. The correlation between MPS-generated hydrofacies probability along streams and hydraulic conductivity can be used to assess the spatial variations of hydraulic conductivity of the streambed and streambank. This can help to reduce uncertainty in the results of stream–aquifer interactions modeling. In addition, MPS hydrofacies probability can be used in conjunction with stream coring data to estimate the spatial variation of streambed thickness for the stream–groundwater interactions model. In the upstream parts of the study area, thick confining units are found between the streambed and aquifer. The hydrofacies 2 probability indicates thin clay-rich units between the streambed and the aquifer, indicating no direct connection between the streams and the aquifer in the middle parts of Loseke and Taylor creeks. This complicates water infiltration through streambeds and causes a delay in stream and groundwater exchange during groundwater pumping, prolonging stream depletion. Near all stream outlets (see Figs. 12e and 15, zone 7), there is a high hydrofacies 2 probability that is exposed to the land surface. This permeable unit can lead to stream depletion as the groundwater level in the aquifer decreases during pumping, or it can provide groundwater contribution to streams. The effects of irrigation pumping on streamflow and ecosystems should be considered in areas where the streambed and aquifer are connected. In general, the streambed hydrofacies probability can be extracted and the relationship between streambed hydraulic conductivity and hydrofacies probability can be established to estimate spatial variability in streambed conductivity.

Conclusions

In this research, glacial aquifer heterogeneity was simulated to support the groundwater management system in the Shell Creek watershed of eastern Nebraska, USA. Borehole data, training images (TI), and airborne electromagnetics (AEM) were used to simulate aquifer heterogeneity realizations and compute hydrofacies probability at each simulated node of 200 m × 200 m × 3 m. Monitored groundwater heads were used to validate aquifer heterogeneity modeling. The following conclusions were drawn based on the expected value of hydrofacies 2 probability at the simulated node.

- The principal aquifers in the area are two buried valley aquifers that intersect at a right angle. These aquifers are marked by high hydrofacies 2 probability and comparatively high spatial continuity.
- The heterogeneous aquifers consist of hydrofacies 2 probability between 0.4–0.6 and have a variable thickness.
- The paleovalley aquifers are disconnected in some places and bounded by low hydrofacies 2 probability, which can cause significant drawdown when a cone of depression intersects this low hydrofacies 2 probability area.
- Thin layers are resolved well in the vicinity of hard data, resulting in an abrupt change of aquifer framework near these grid nodes.
- Hydrofacies 2 probability shows a poor connection between streambank, streambed and aquifer at upstream reaches of the streams. In downstream reaches near the stream outlets, however, there is medium to high (> 0.6) hydrofacies 2 probability between the aquifer and streambed.
- The well hydrographs show that groundwater responds differently to pumping in upstream and downstream reaches, particularly water levels recover faster near stream outlets in some wells than the monitoring wells located upstream.
- The 3D hydrofacies 2 probability at the simulated nodes and well hydrographs are essential for delineating groundwater management zones, prioritizing future well-monitoring locations and identifying a potential site for managed aquifer recharge.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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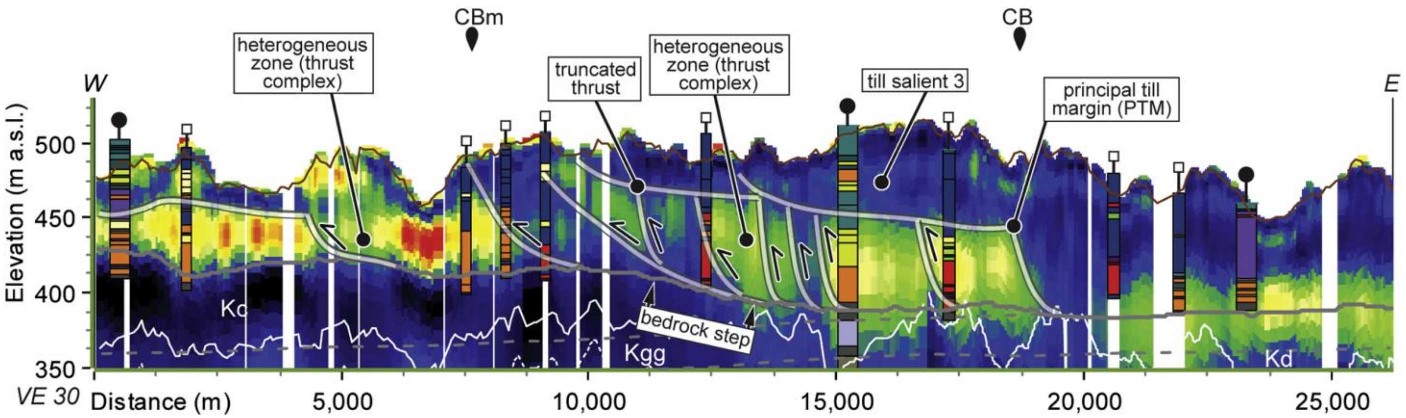
Geological complexity of the SQS2 area

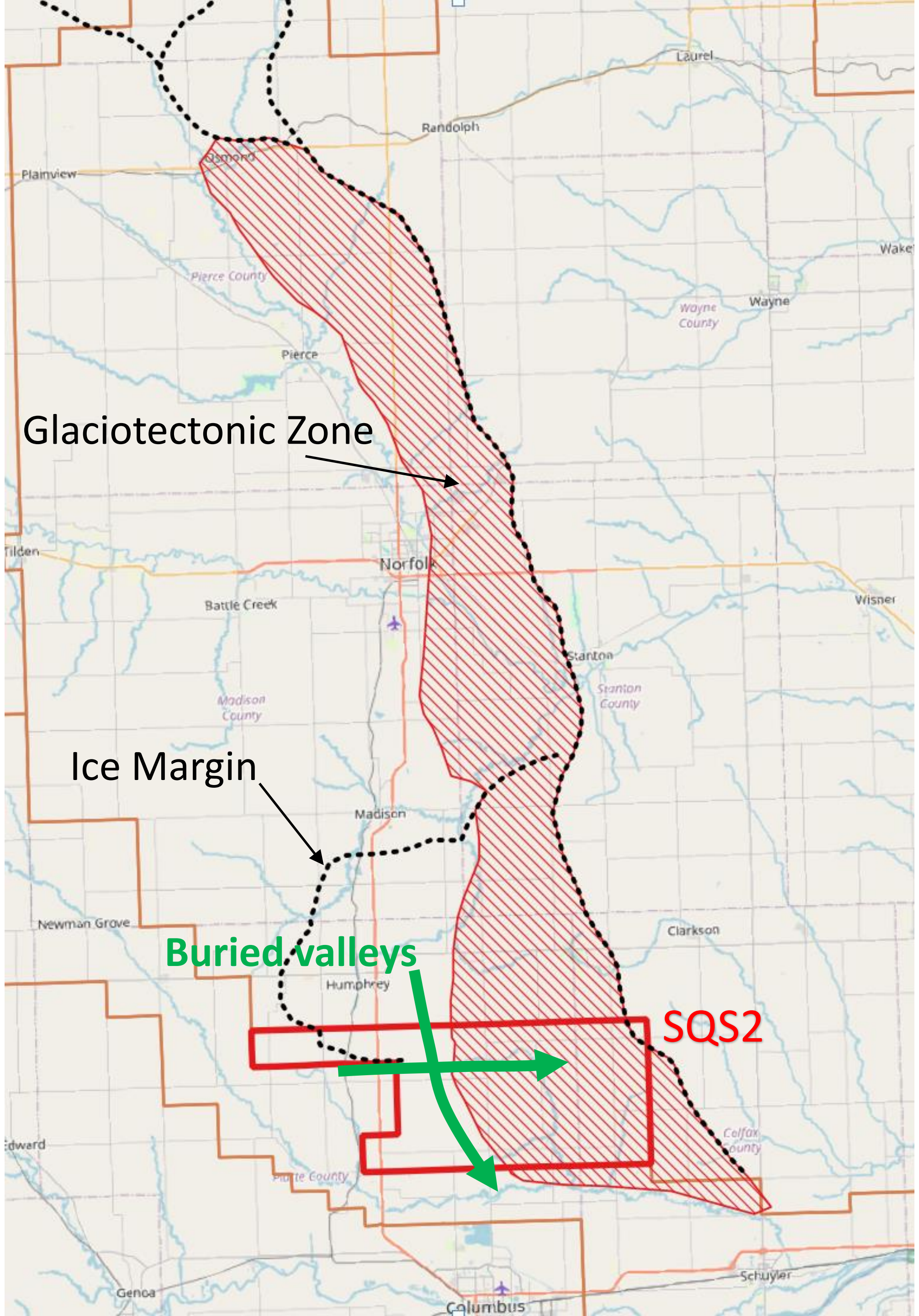
Multiple till sheets & salients

Glaciotectonic deformation (folding, faulting)

Intersecting buried valleys

Juxtaposed aquifers (High Plains & glacial aquifers)





Hydrostratigraphic Modeling Method

Prepare input data

HARD DATA

CSD test holes

SOFT DATA

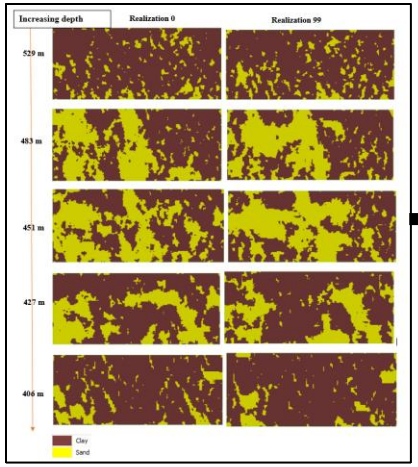
Registered water wells
****AEM****

TRAINING IMAGE

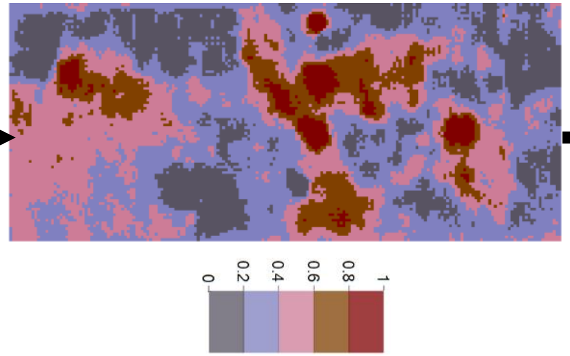
Geological knowledge

Adjust parameters

Run models



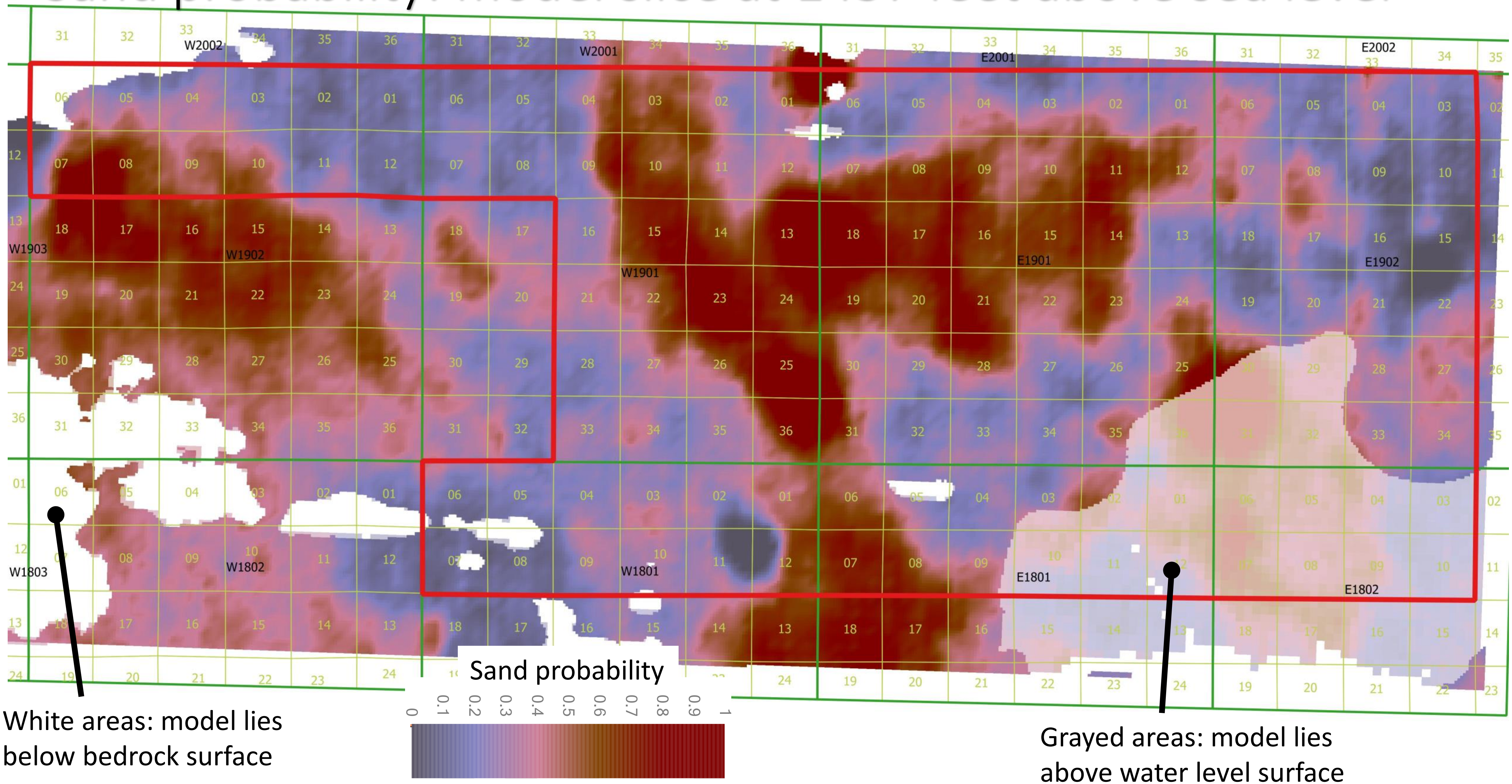
Calculate probability *(geological "forecast")*



Validate

Repeat as necessary

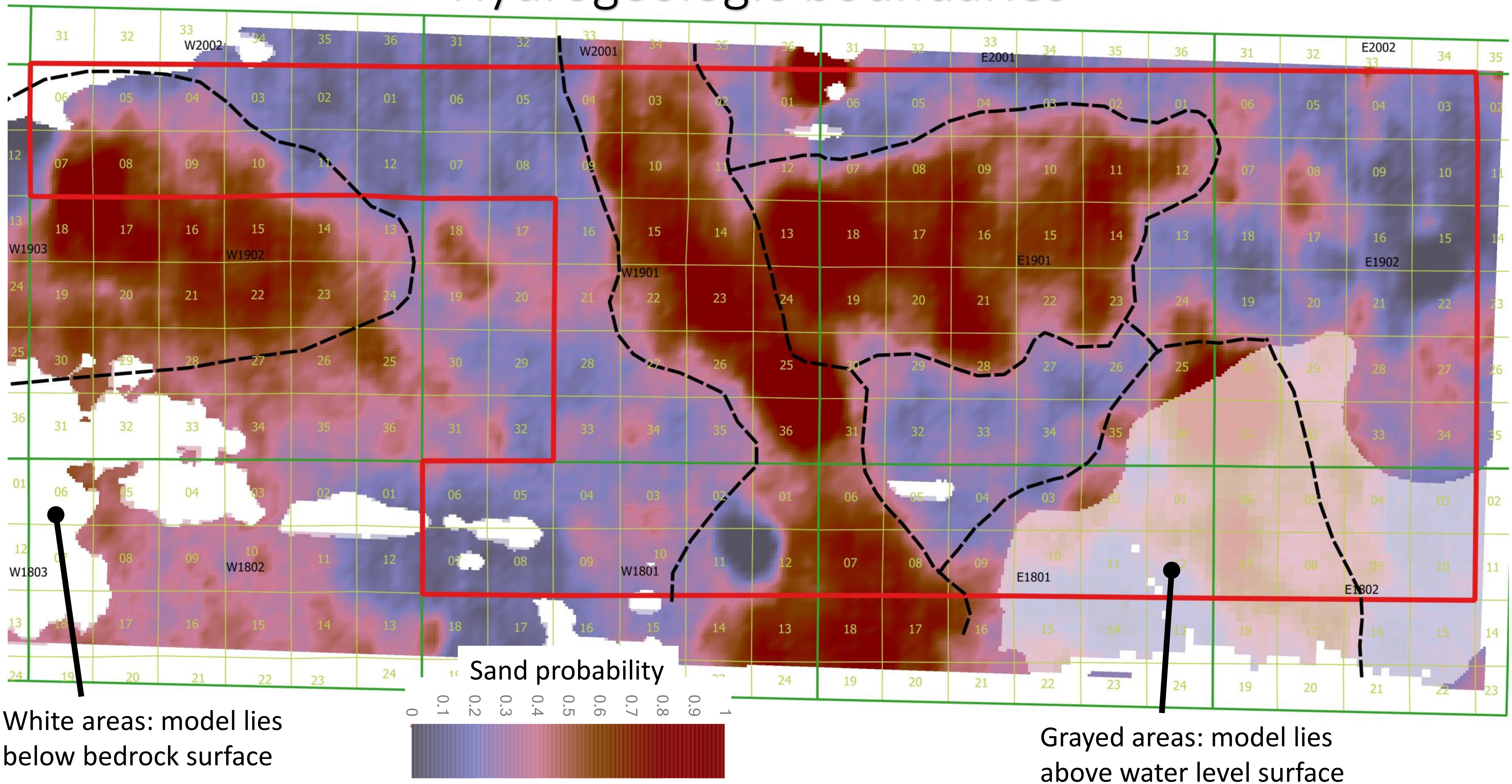
Sand probability: model slice at 1457 feet above sea level



White areas: model lies below bedrock surface

Grayed areas: model lies above water level surface

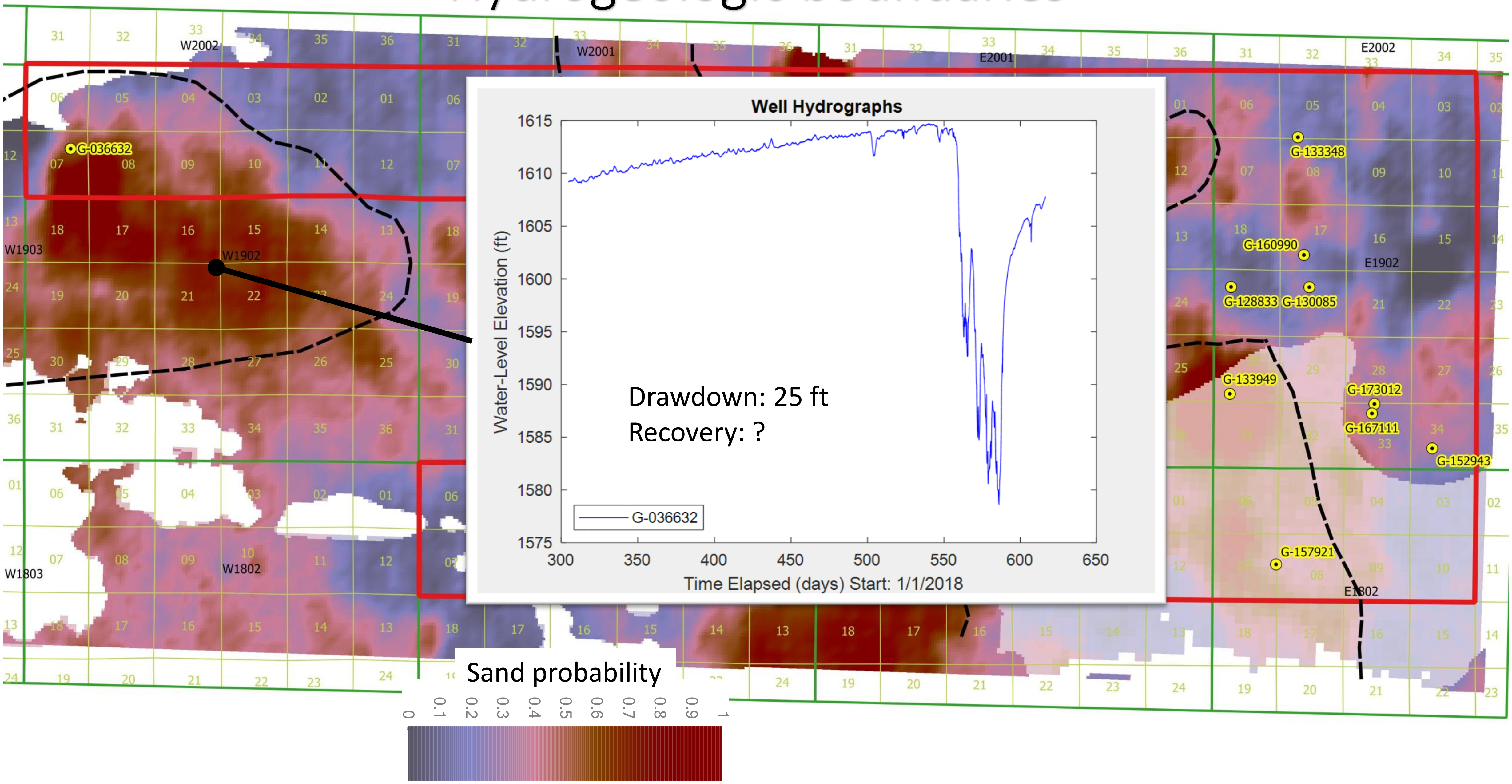
Hydrogeologic boundaries



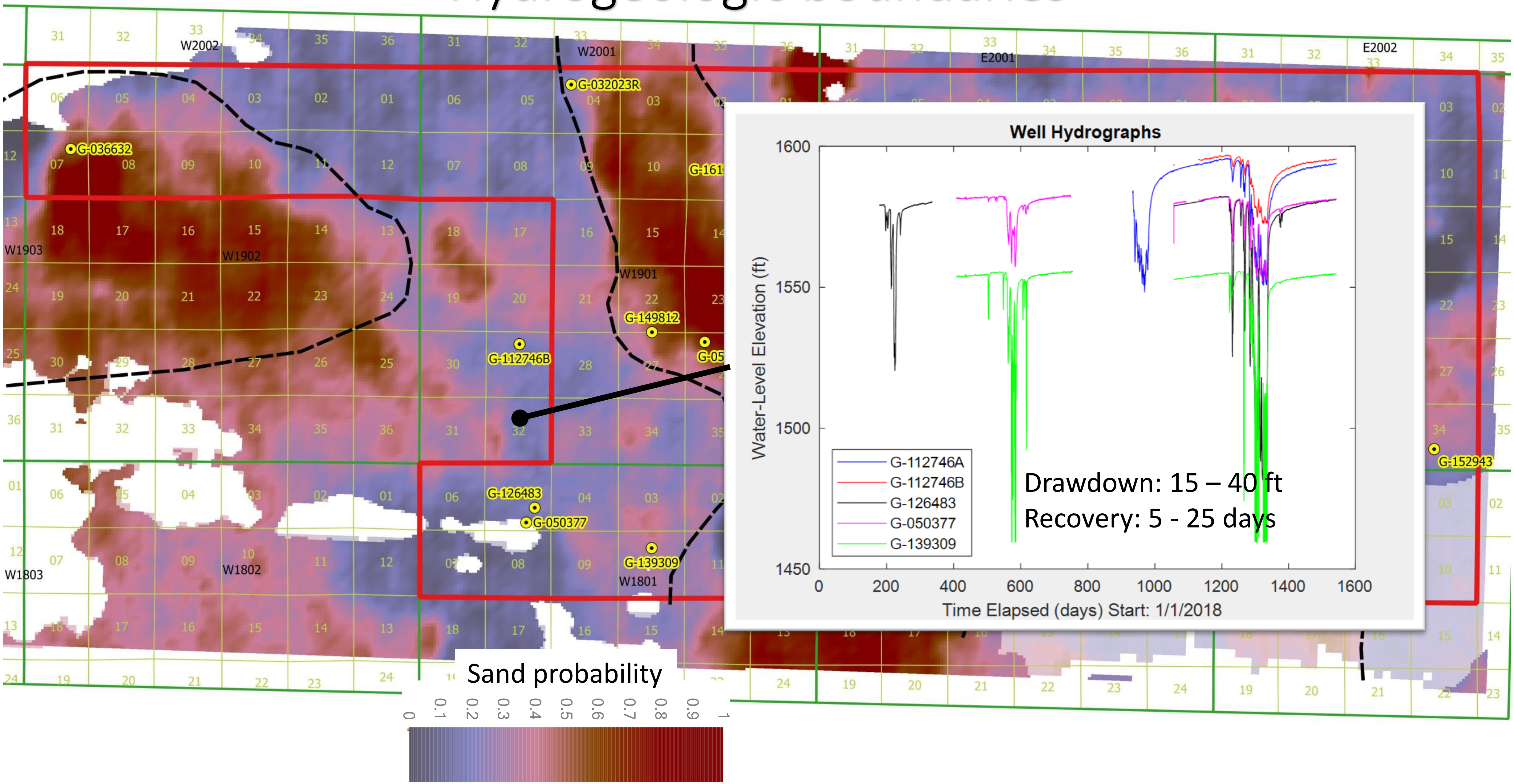
White areas: model lies below bedrock surface

Grayed areas: model lies above water level surface

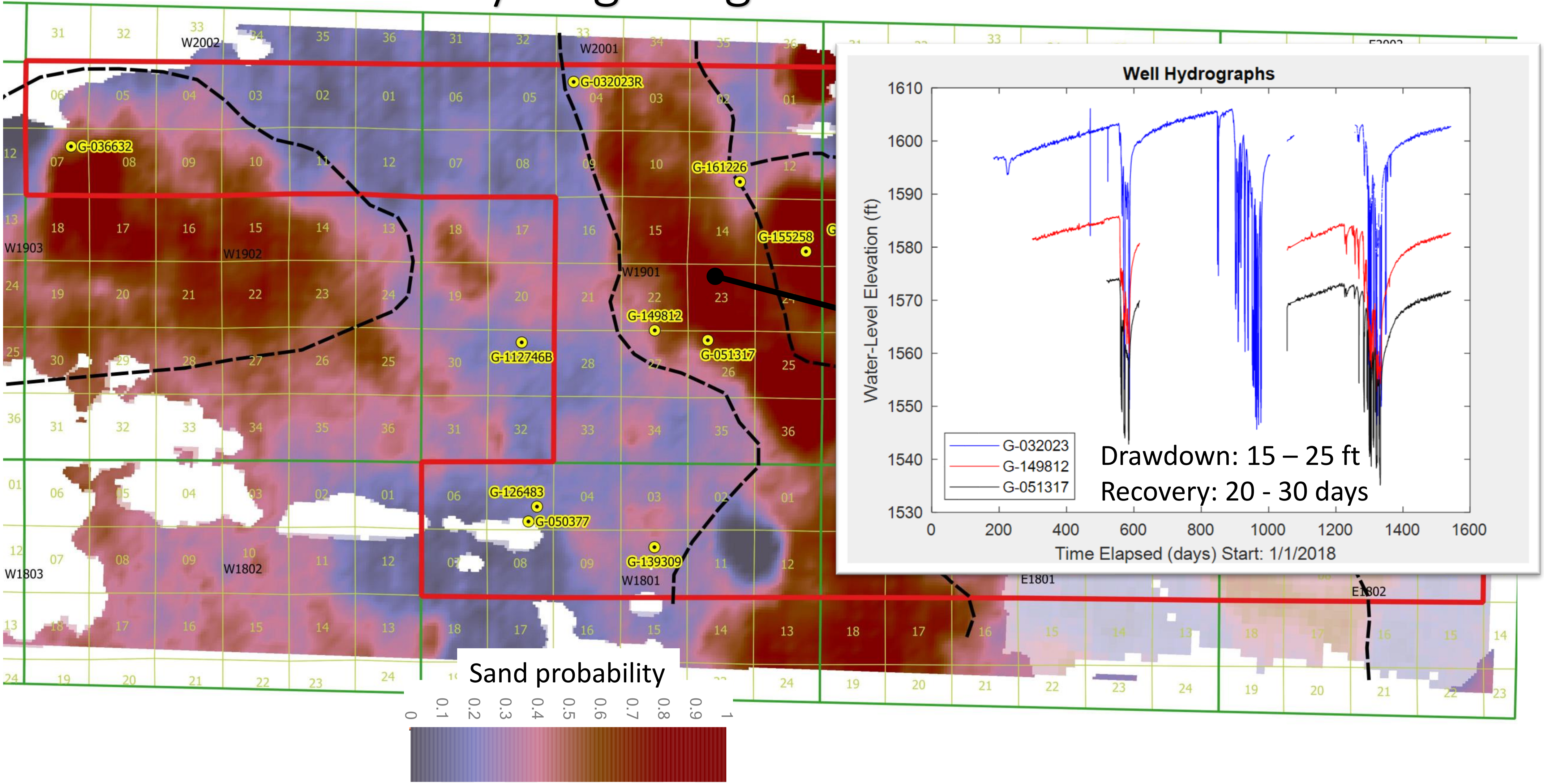
Hydrogeologic boundaries



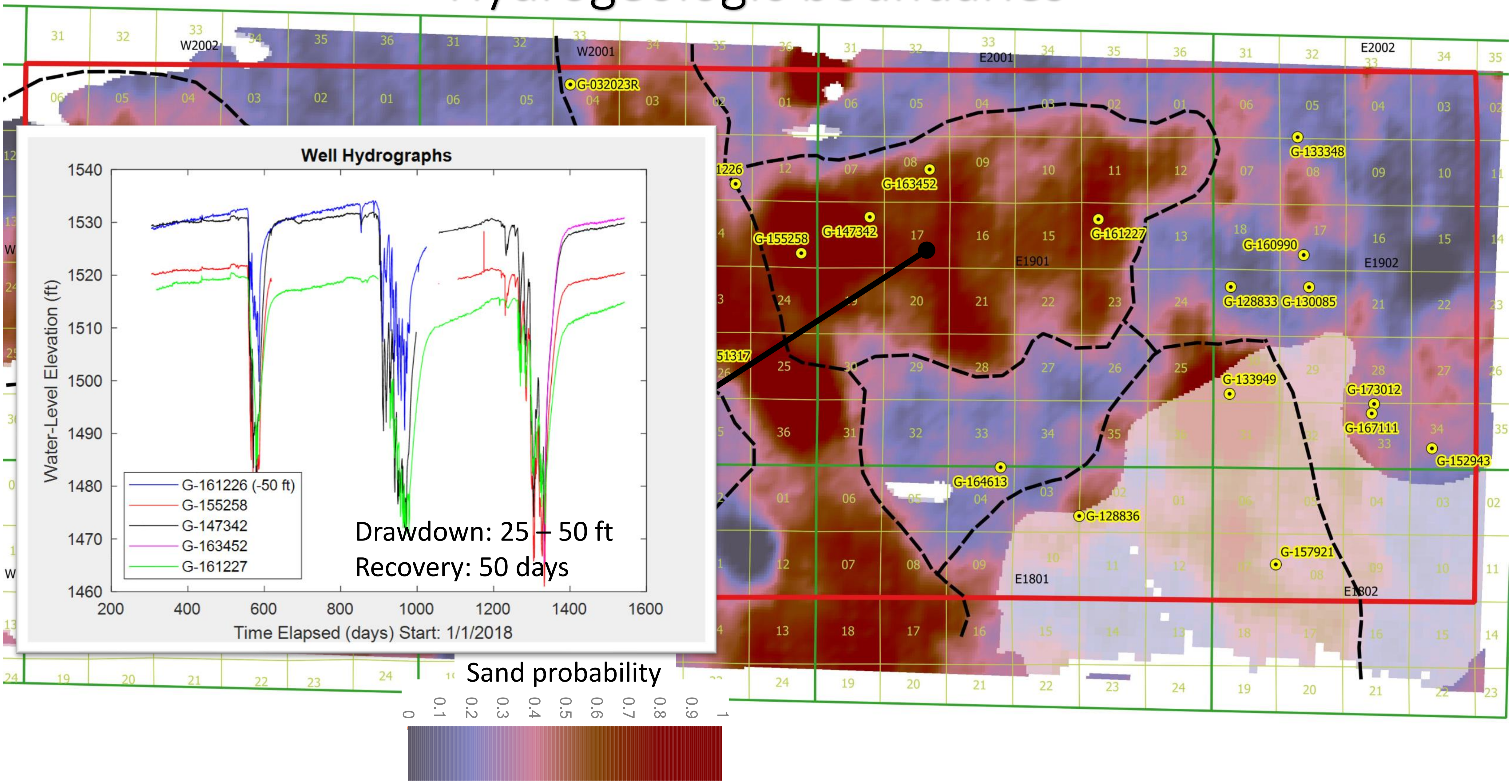
Hydrogeologic boundaries



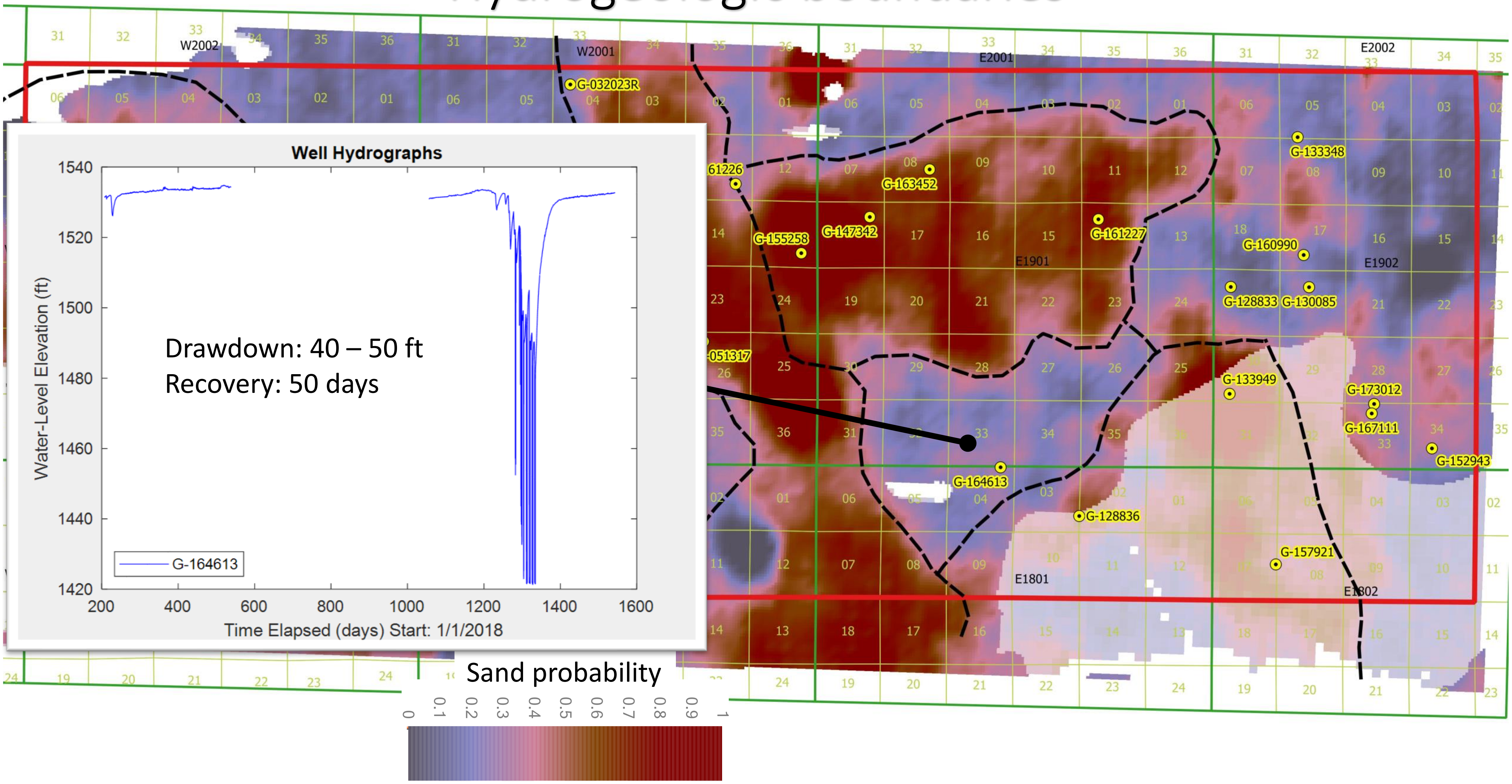
Hydrogeologic boundaries



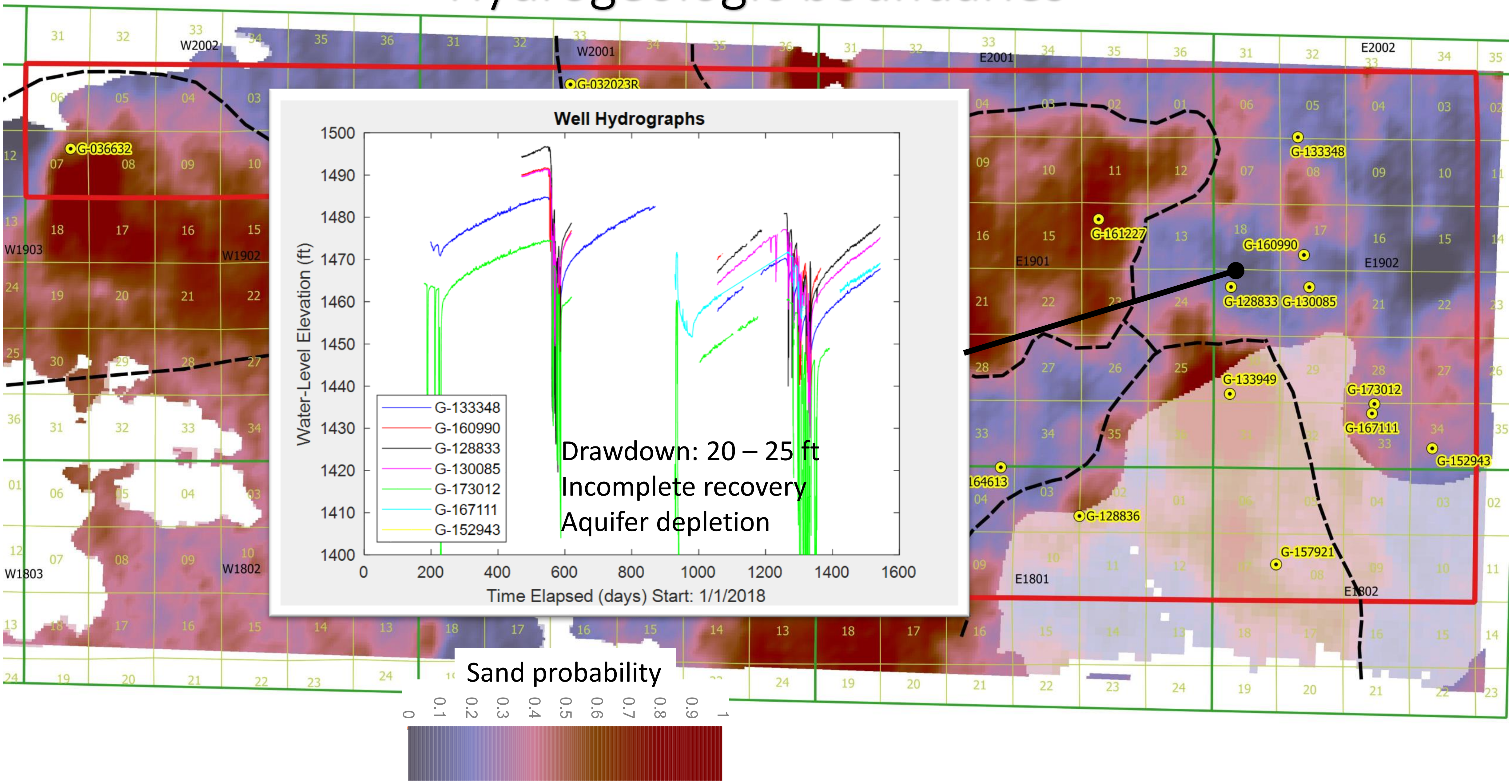
Hydrogeologic boundaries



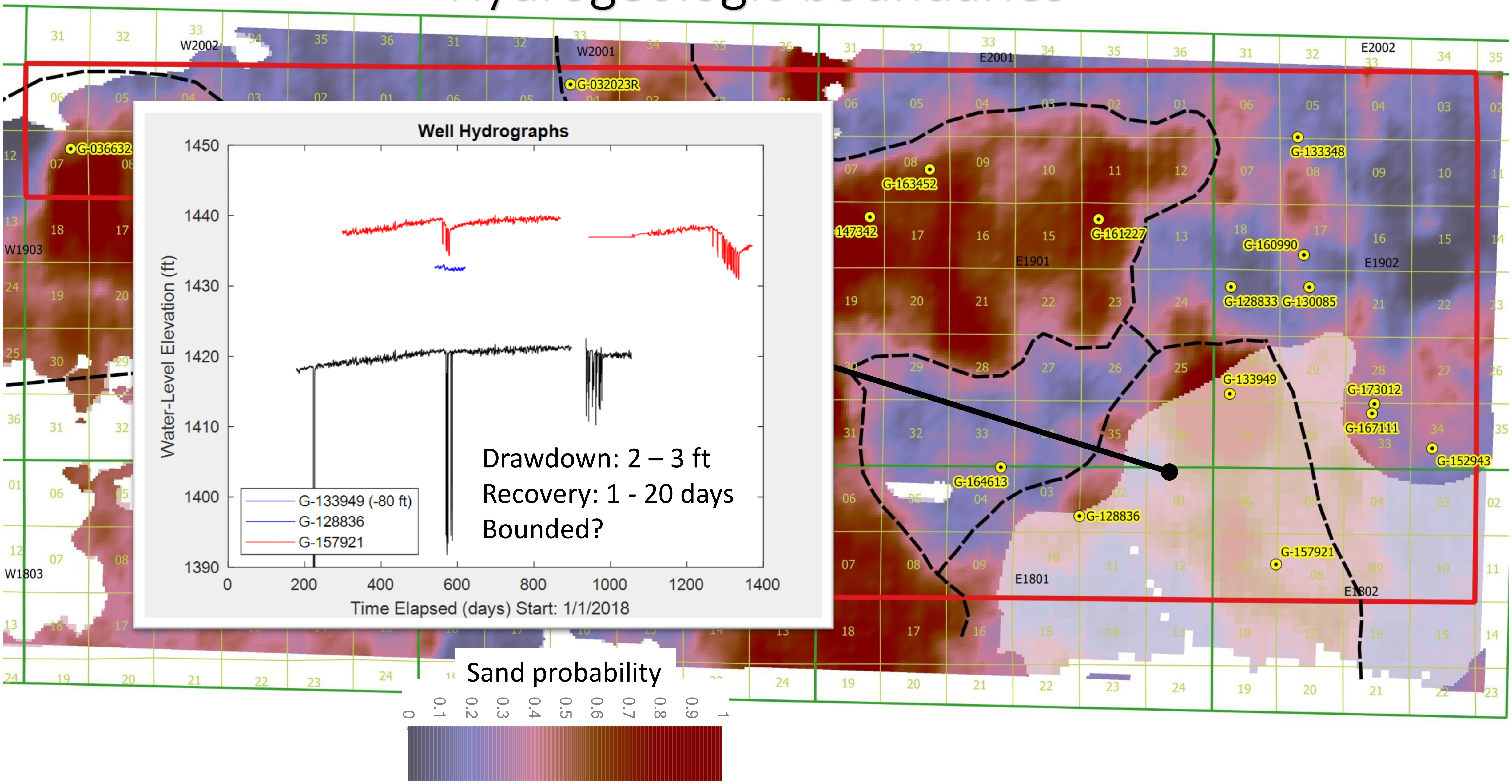
Hydrogeologic boundaries



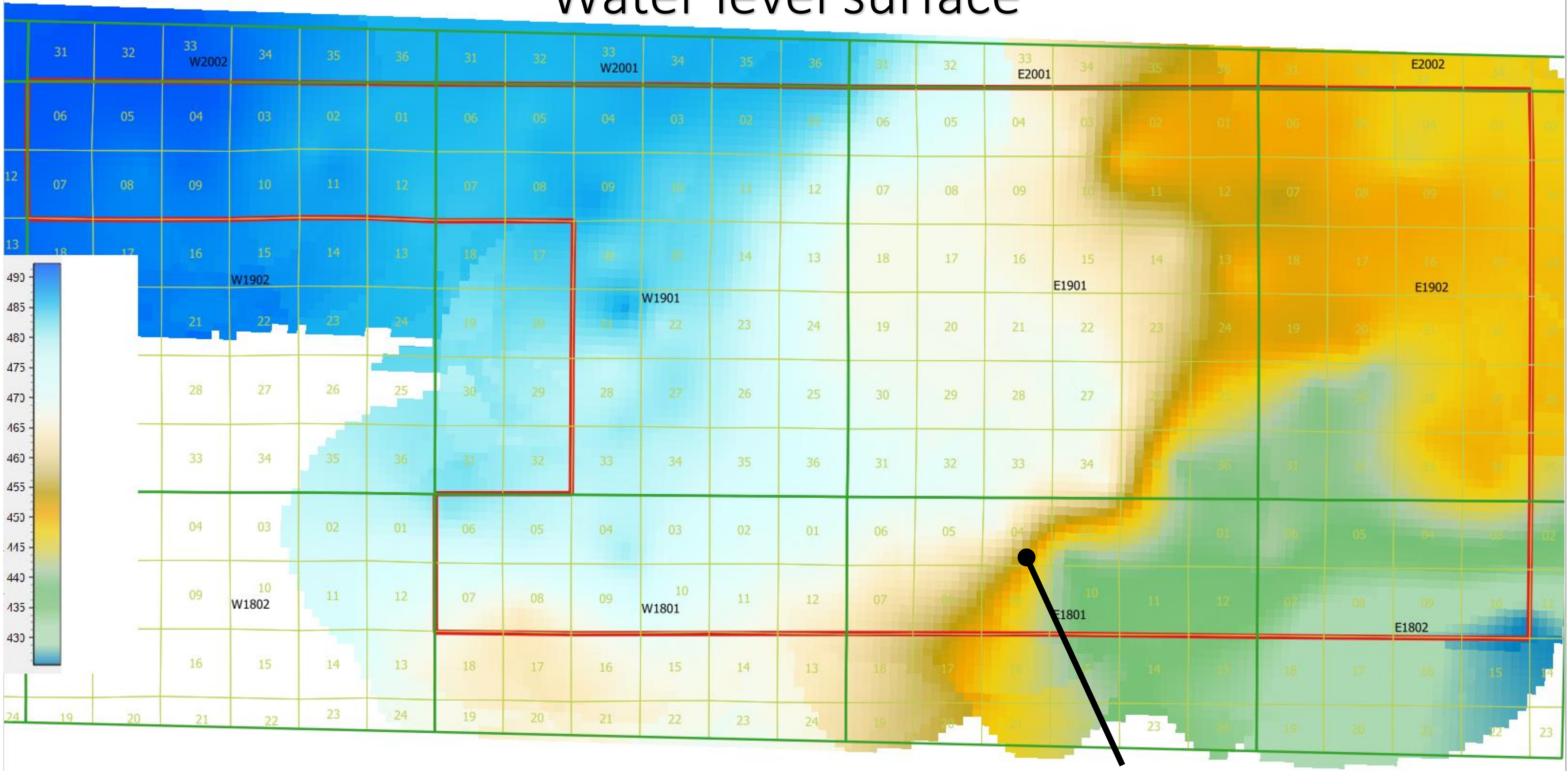
Hydrogeologic boundaries



Hydrogeologic boundaries

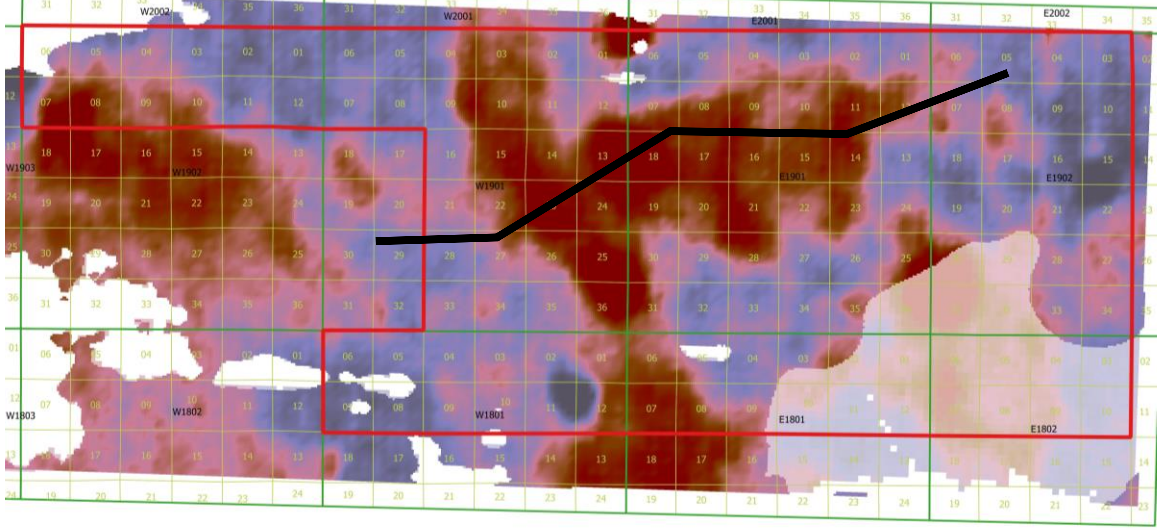


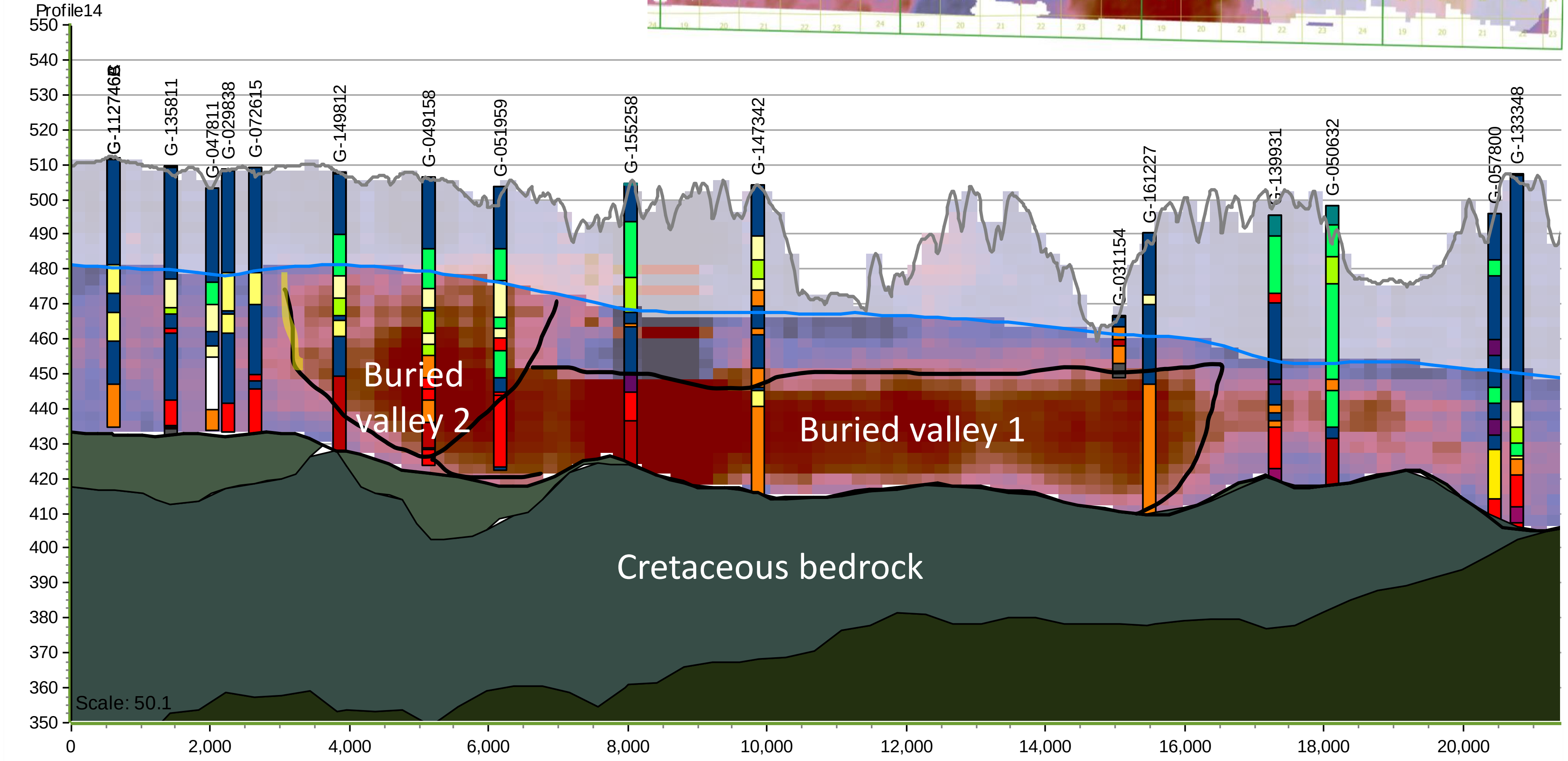
Water level surface

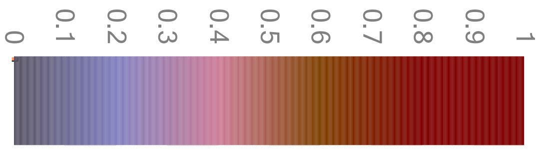


Discontinuity = hydrogeologic boundary

Cross section showing sand probability and borehole lithology

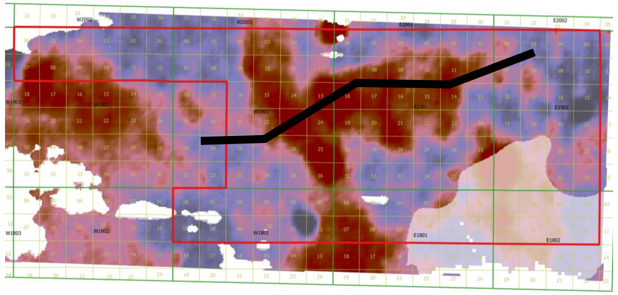




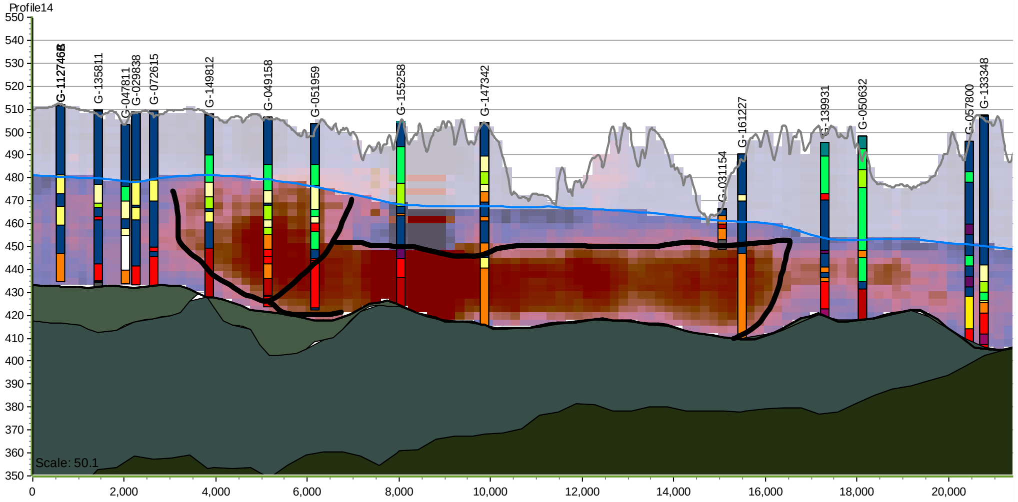


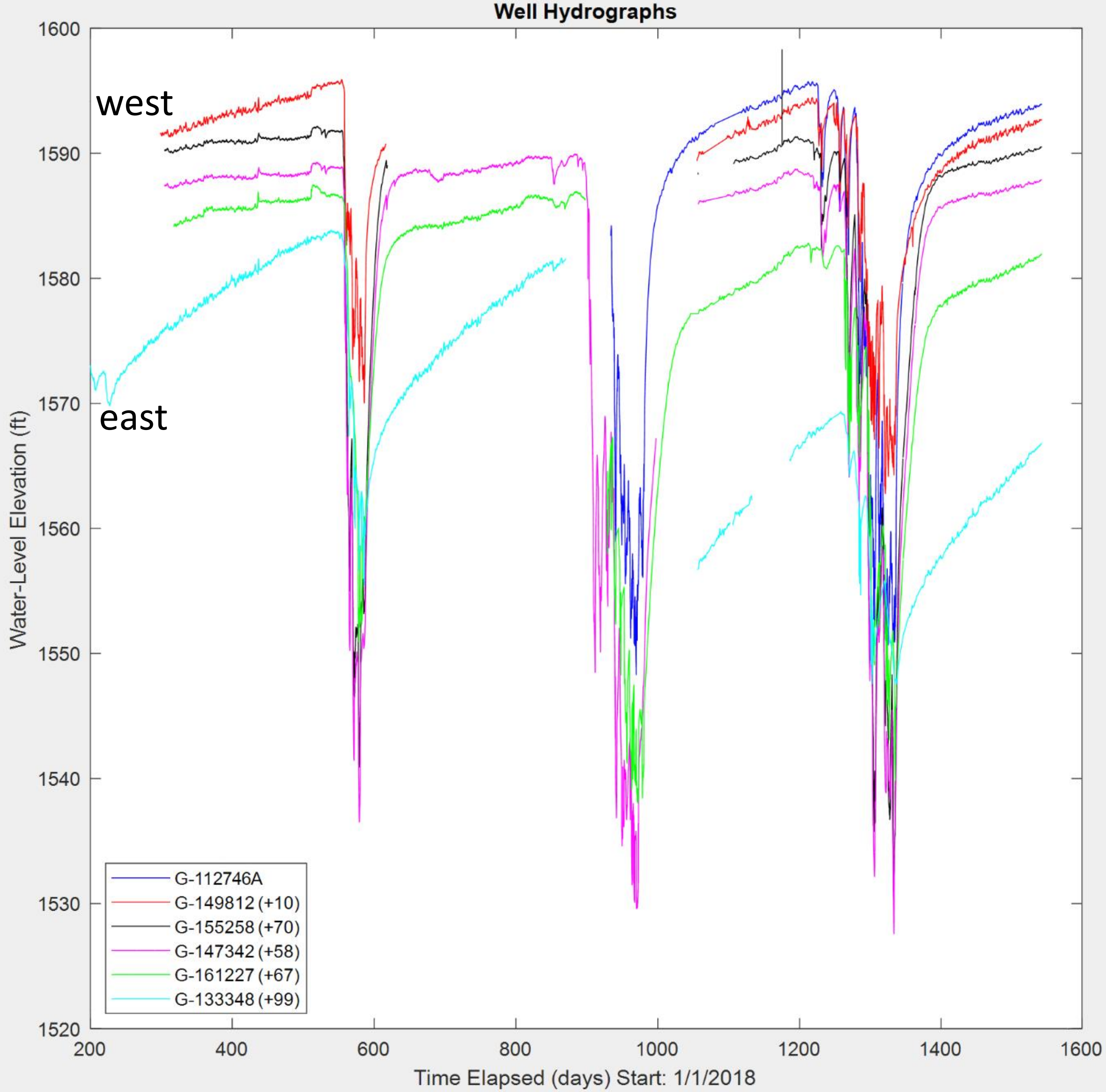
Groundwater-level hydrographs along west-east profile

west

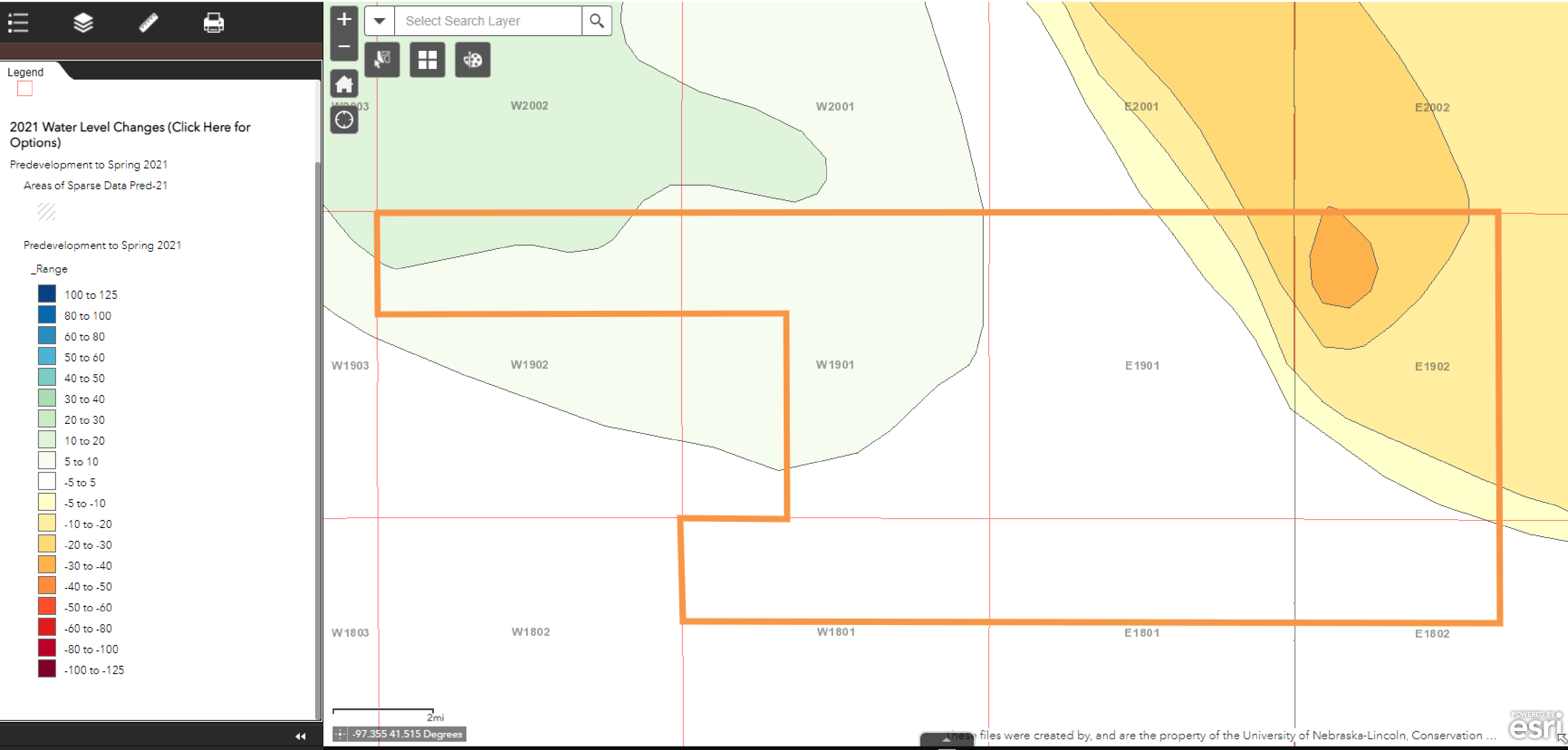


east

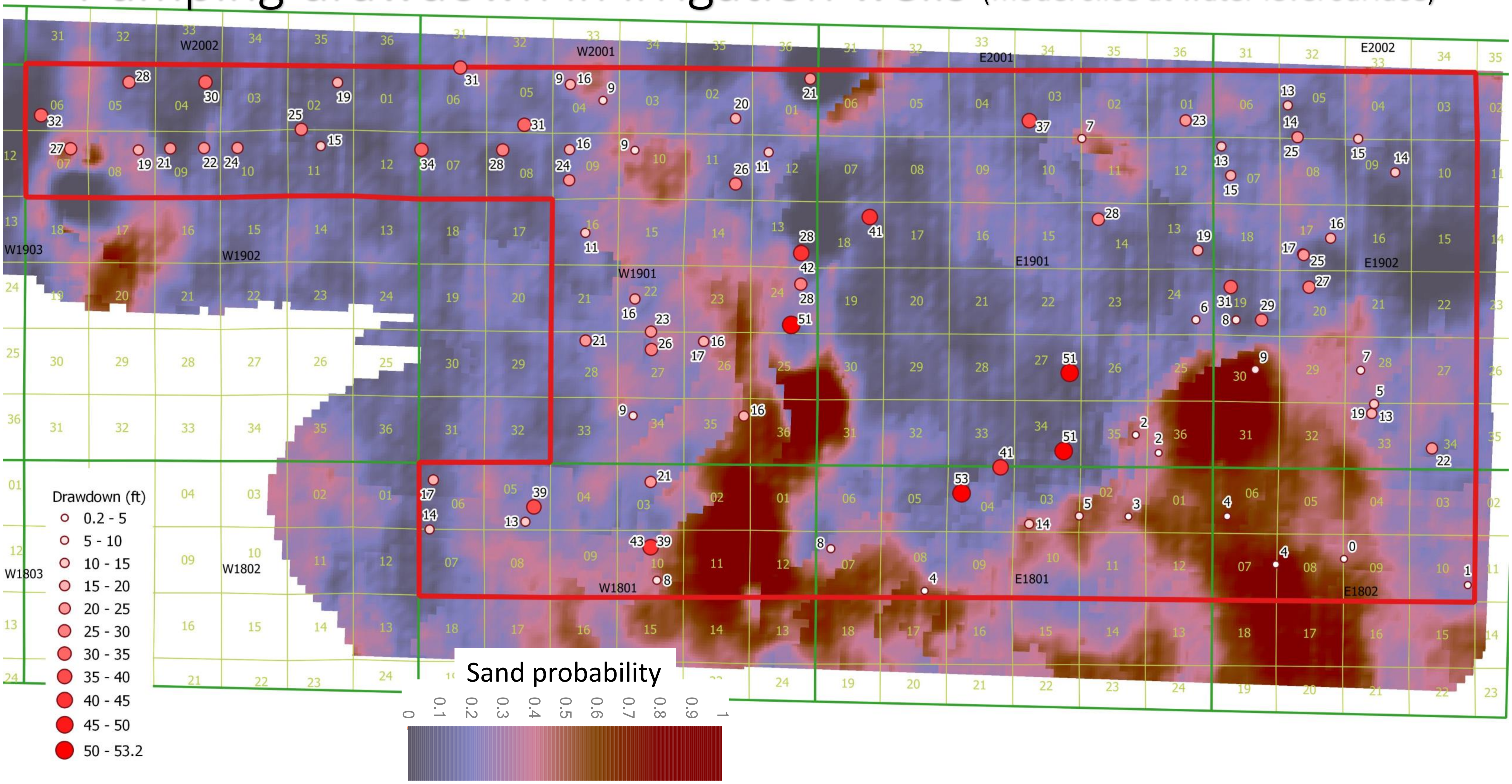




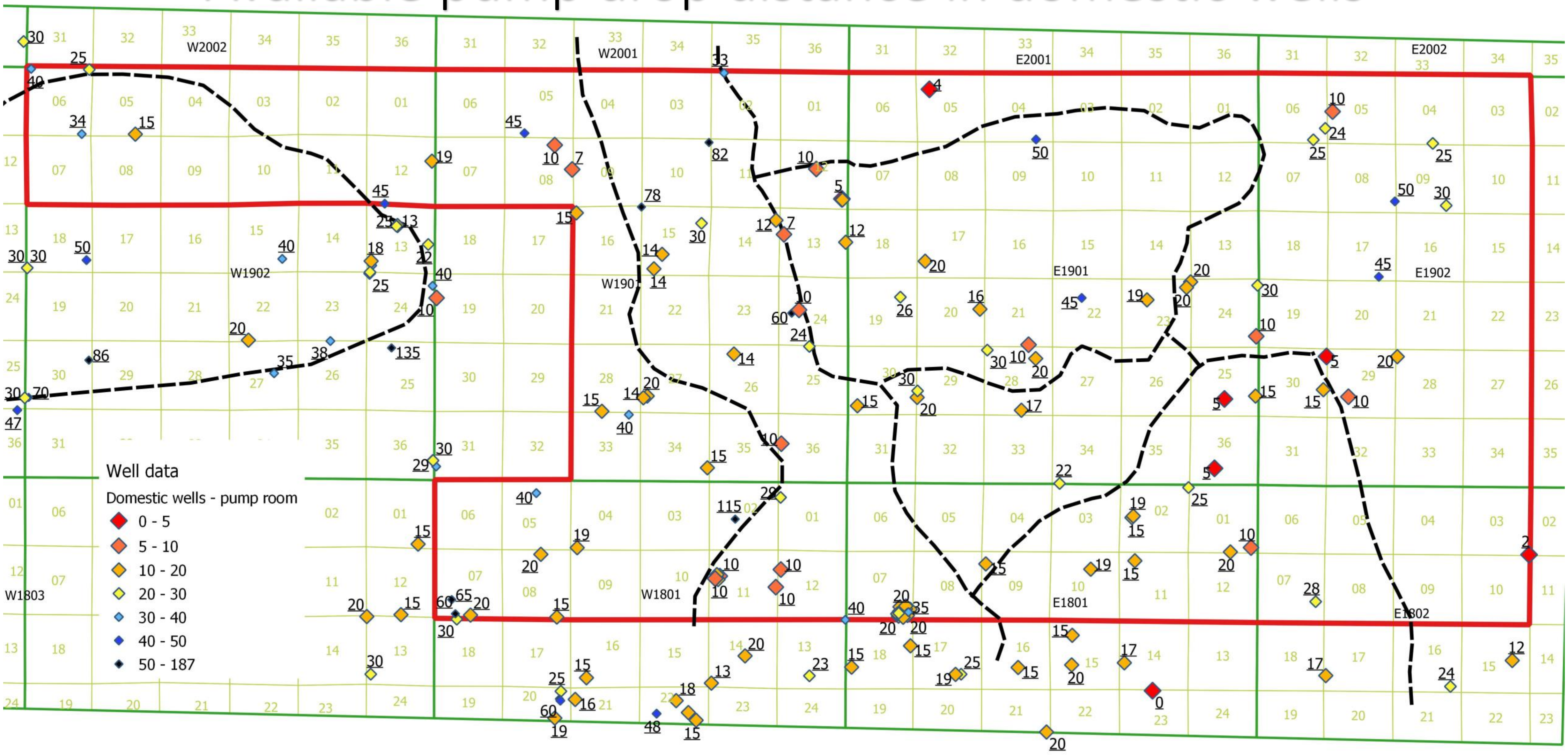
Groundwater-level changes predevelopment to 2021



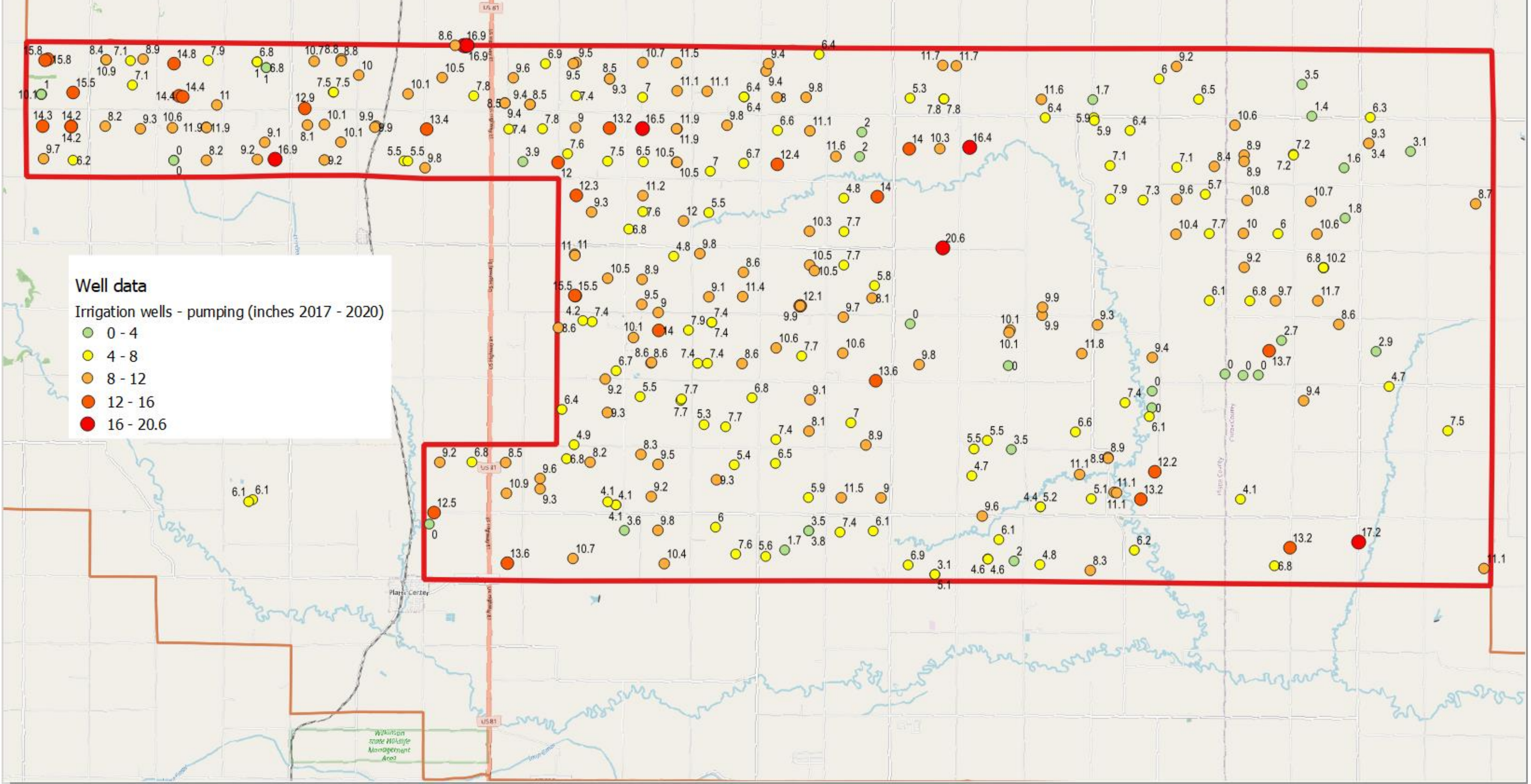
Pumping drawdown in irrigation wells (model slice at water level surface)



Available pump drop distance in domestic wells



Groundwater pumping (total inches applied 2017 – 2020)



LOWER PLATTE NORTH
Natural Resources District
PO Box 126 511 Commercial Park Road Wahoo, NE 68066
Phone 402.443.4675 www.lpnnrd.org lpnnrd@lpnnrd.org

Flow Meter Maintenance Service Agreement

The Lower Platte North NRD (LPNNRD) is requesting proposals from the area flow meter companies, irrigation system dealers, well drillers, and pump installers to complete flow meter maintenance throughout the whole LPNNRD District including the two allocated Special Quantity Subareas (SQS #1 & SQS #2). There are approximately 1,000 registered wells within the district that have a district approved flow meter installed with more being added yearly. The plan is to inspect each of the installed flow meters once every four years and perform any required maintenance to make sure the meters are in proper working order. The scope of work for each maintenance year shall be completed between the dates of November 1st – March 1st (weather dependent). The scope of work to be completed is listed below:

- The hired contractor will have a flat fee for each site visited. This will include travel and labor cost of the contractor to visit the sites.
- The contractor must also give a detailed report on maintenance and the inspection performed at each flow meter site.
- If any meter maintenance is required, the contractor shall perform that work and bill the LPNNRD for the labor associated with the work. The landowner is to be billed for any parts that are required for each site. The bill shall breakdown the cost for each site where any equipment is repaired or replaced.
- LPNNRD prefers the following added features for all propeller flow meters:
    - Over-run bearing (or extra bearing) for smother operation and to extend life of the meter.
    - Canopy cover to protect meter.
- The hired contractor will replace batteries on all magnetic and digital read flow meters at least once every four years. The landowner, who will be billed by the contractor, will be responsible for 100% of the battery replacement.
- Included in this letter is a list of the LPNNRD District approved Mechanical flow meters that are installed throughout the LPNNRD. New electronic read meters will be installed only on an extreme case-to-case basis. Currently there are approximately 85 battery powered meters.
- If interested in placing a bid or would like further details on the Flow Meter Maintenance Program, please contact the Lower Platte North NRD by Date at 402-443-4675.
- This will be a 4-year contract and expire in 2028 with the selected firm needing liability insurance for any damages.

If no further information is needed, please submit bid proposals to the Lower Platte North NRD by Date. These will be reviewed by the Water Committee on Date and the contract will be awarded at the Date Board meeting. The LPNNRD has the right to reject all bids. Thank you.

Daryl Andersen
Water Resources Manager

Noah Franzen
Water Resources Specialist

Lower Platte North NRD Mechanical Meter Approval List

Manufacturer	Model	Notes
McCrometer	McPropeller	All Propeller Models
Sparling	Propeller saddle meter	Model 312 propeller meter
ARAD Group	Saddle Water meter	Meter for irrigation applications
Geyser	Saddle meter	All propeller models for Farmland Irrigation

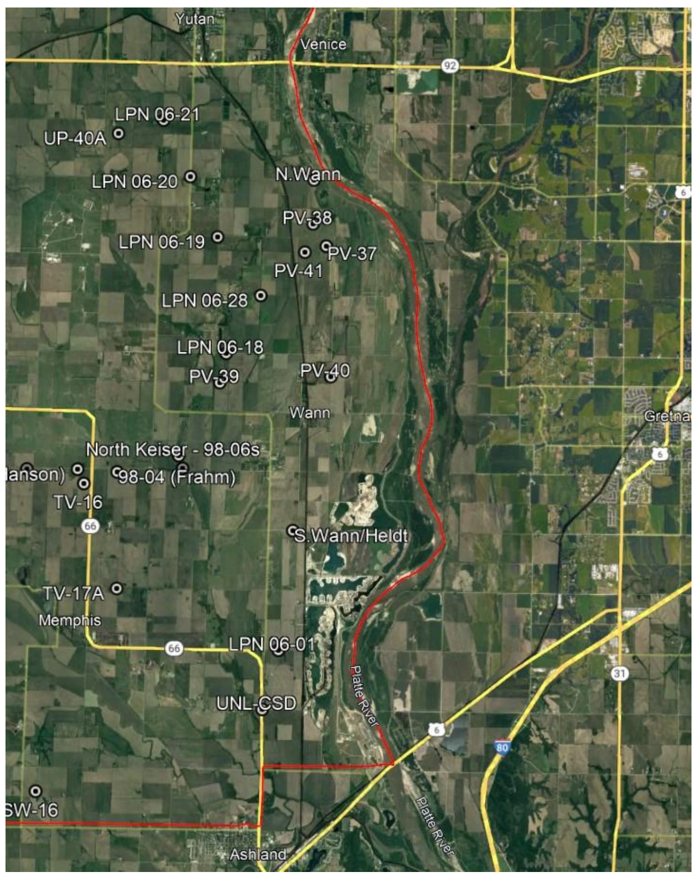
Expiration Yea	Name	one Nu	ell Num	ls/ well	.andow	Tenan	Address	City	Sta
2020	Brian Moser	402 447-9!	402-430-2920				962 S. 5th Street	Albion	NE
2023	Lynn Wondercheck	402-741-2	402-741-2072				2083 300 Avenue	Albion	NE
2022	Christopher D Nicolas	402 538-4:	402-367-9203				253 42nd Road	Bellwood	NE
2021	Brian Vech	402 628-6{	402 480-3039				2063 County Road W	Cedar Blu	NE
2021	Sean Callahan	402-663-5	402 202-6984				2432 County Road 22	Cedar Blu	NE
2023	Rodney Wiegand	402 628-6285					2644 County Road 17	Cedar Blu	NE
2023	Christopher M Dvorak	402-487-2	402-860-2029				369 Road N	Clarkson	NE
2021	Daryl Finecy	402-564-0:	402 910-1030				7866 E 29th Avenue	Columbus	NE
2021	Edward Bakenhus	402-563-3	402-910-1397				21223 310th Street	Columbus	NE
2021	James Hotovy	402-563-2	402 276-1598				2506 whitetail dr	Columbus	NE
2023	James Klug	402-564-3	402-563-4458				4795 Seminole Ave	Columbus	NE
2023	Jeffrey T. Lusche	402-910-4	402 910-4656				11843 291st Street	Columbus	NE
2023	Jeremy Killham	402-563-8	402 910-2844				5284 East 8th Street	Columbus	NE
2023	Rory Went	402 495-3{	402 270-2834				6555 Shadow Ridge Place	Columbus	NE
2023	Steven J Gehring	402-285-0266					21080 415 Street	Creston	NE
2023	Jack W. Nagel	402-785-7	402-430-6717				19584 N 40th St	Davey	NE
2021	Gregory Romshek	402 538-2(	402 276-0905				3891 JK Road	David City	NE
2021	Barry Benson	402 721-5(	402 719-0760				5281 Ventura Dr	Fremont	NE
2021	Robert Vering	402-721-8	402-720-1441				602 Thornbird Drive	Fremont	NE
2022	Ted Nelson	402-727-0	402-459-3810				1860 County Road 20 Avenu	Fremont	NE
2023	Jon Dinslage		402-206-4772				2568 County Road 12	Fremont	NE
2023	Todd J Aspy	402-727-1	402-720-8116				1743 County Road 18	Fremont	NE
2023	Rodney Johnson		402-770-0209				3609 Palomine Place	Grand Isla	NE
2020	Steve Frauendorfer	402-640-0.	402 640-0271				51285 355 Avenue	Humphre	NE
2021	James Krings	402 923-1	402 276-7800				29785 - 430th Street	Humphre	NE
2023	Bill Fischer	402-923-0	402-270-3731				42933 - 355th Avenue	Humphre	NE
2023	Glen Weidner	402 923-0	402-920-2897				34609 490 St	Humphre	NE
2022	Bryce Grotelueschen	402-487-2	402-260-9116				259 Road P	Leigh	NE
2023	Mark T and Don Hoessel	402 487-2	402-276-1084				11695 415 Street	Leigh	NE
2019	Chris Bierman	402-428-4732					44966 - 445 Avenue	Lindsay	NE
2019	Ken Kurtenbach	402-428-4	402-920-0661				119 East 1st Street	Lindsay	NE
2023	Daryl Herchenbach	402 428-4	402 920-0267				40786 490th St	Lindsay	NE
2023	Dean J Gronenthal	402 428-5	402 920-3439				45079 445th Ave	Lindsay	NE
2023	Donald L. Gasper, Sr.	402 428-4	402 920-0302				51672 430 AVE	Lindsay	NE
2023	Ronald Pfeifer	402-428-3375					412 E 4 Street	Lindsay	NE

Expiration Year	Name	one Numb	ell Numbe	ls/ well ov	andowner	Tenant	Address	City	Stat
2021	Clifton J Goff	402-666-5(	402-679-2227				2311 46 1/2 Road	Linwood	NE
2023	David L Macholan	402-666-5!	402-641-7496				4581 UV Road	Linwood	NE
2022	Morris Erickson		402-624-6765				1170 County Road J	Mead	NE
2023	Gary D. & Diane Harms	402 246-3(	402 276-0694				33335 355 AVE	MONROE	NE
2023	Dan Bauer	402-666-5!	402-720-1284				2643 County Road 25	Morse Blu	NE
2023	Randal F Kremlacek	402-666-5.	402 720-5388				230 Maud Street	Morse Blu	NE
2023	John T. Kaufman	402 447-2	402-741-1203				82480 HWY 45	Newman (	NE
2020	Jack Mulliken	402 -721-3	402-720-0592				1677 County Road 24	Nickerson	NE
2019	Kurt Dunker	402-652-3!	402-720-6573				940 Foothill Road	North Ber	NE
2021	Robert Saalfeld	402 652-81	402 317-2971				1112 County Road R	North Ber	NE
2023	Christopher W Armstrong	402-652-3!	402-860-3867				622 County Road M	North Ber	NE
2023	Jeffrey K Voss	402 -652-3	402-720-3458				1211 County Road R	North Ber	NE
2023	Seth Feala	402-652-8.	402-720-5234				1727 County Road 7	North Ber	NE
2021	harvey sloup	402-393-7439					3229 Sth 91st St.	Omaha	NE
2021	Terry Lutjens	402 246-2(	402 649-6744				35802 235th Ave	Platte Cer	NE
2023	Chad E Sander	402 246-3!	402-270-6481				35056 235th Ave	Platte Cer	NE
2023	Lee Hueschen	402-246-3.	402-276-1166				345277 – 355th Avenue	Platte Cer	NE
2023	Richard D and Lila M Brock	402 246-4(	402 270-4603				24634 355 St	Platte Cer	NE
2020	Dennis C Fujan	402-663-5.	402-480-4950				3060 County Road O	Prague	NE
2020	Mark Rickert		402 276-0339				490 County Road 1	Richland	NE
2023	Robert C Kluck, Jr	402 352-5	402 615-0578				396 County Road F	Richland	NE
2023	Randy Kassmeier	402 352-2(	402 615-0103				750 Road 7	Schuyler	NE
2023	Bruce Staub	402-368-5	402-640-0721				83465 Hwy 45	Tilden	NE
2023	John R Krueger	402 368-5	402 841-0980				1169 State Hwy 45	Tilden	NE
2021	Todd Swanson	402-443-5!	402 443-6592				1851 County Road L	Wahoo	NE
2022	Roger Harders	402-443-3:	402 443-3198				1775 County Road M	Wahoo	NE
2023	Dave Rood	402-443-8	402 443-8471				1665 County Road I	Wahoo	NE
2023	Ronald Sladky	402-443-5.	402 443-8351				1435 County Road L	Wahoo	NE
2021	Michael Thomas	402 625-2	402 443-6213				1352 Yutan Road	Yutan	NE

Lower Platte North Update on Water Levels:

- WANN Basin Day on August 29, 2023
    - 60 wells were measured for summer water levels in 2023.
    - The average difference comparing 2022 to 2023 was 0.42 feet lower in 2023 (median was 0.06 ft). 57 wells were compared.
    - The average difference comparing 2012 to 2023 was 0.06 feet lower in 2023 (median was 0.18)
    - Agencies involved in measurements for this area are LWS, USGS, LPNNRD and ECC (company that manages Mead Ordinance plant).
    - LPNNRD assists in measuring for MUD and LPSNRD.

Map of area for reference



- Staff at Lower Platte North received a call for a domestic well running dry the first part of September.
- Some early reported numbers from pivots are 6 - 13 acre/inches of water use.

Daryl Andersen
Lower Platte North NRD
511 Commercial Park Road
Wahoo, NE 68066-0126

September 13, 2023
Project No: 5036LPN02
Invoice No: 24101

Project 5036LPN02 LPNNRD Hydrogeologic Assessment

Professional Services through August 25, 2023.

Task 03 Deliverables

Professional Personnel

	Hours	Rate	Amount	
Mohr, Jonathan	9.75	183.00	1,784.25	
Sopiwnik, Roscoe	16.25	187.00	3,038.75	
Totals	26.00		4,823.00	
Total Labor				**4,823.00**

Reimbursable Expenses

Mohr, Jonathan	49.13	
Total Reimbursables	**49.13**	**49.13**

Total this Task **$4,872.13**

Total this Invoice **$4,872.13**

Outstanding Invoices

Invoice Number	Date	Balance
23745	8/14/2023	3,301.25
		3,301.25

Total Now Due **$8,173.38**

TERMS: Net 30 days. A finance charge of 1.5% per month is applied to past due amounts.

Phoenix Web Group, Inc
10824 N. 142nd Street, P.O. BOX 307
Waverly, NE 68462
402-786-5111

Invoice 130811

BILL TO
Eric Gottschalk
Lower Platte North NRD
P.O. Box 126
Wahoo, NE 68066

DATE	PLEASE PAY	DUE DATE
08/14/2023	**$8,635.00**	08/14/2023

DATE	ACTIVITY	QTY	RATE	AMOUNT
08/14/2023	**Project** 2023 Additions and Modifications (Adjusted) 2nd of 2 payments	1	8,635.00	8,635.00

Thank you for your business.

*The cusotmer is responsible for paying applicable taxes in addition to the price shown above.

SUBTOTAL	8,635.00
TAX	0.00
TOTAL	8,635.00
TOTAL DUE	$8,635.00

THANK YOU.

In-Situ, Inc.
221 E Lincoln Ave
Fort Collins, CO 80524-2533

Fed ID: 83-0245889
GSA: 47QSWA23D001X

water simplified.

Invoice

PSINV100462
08/10/2023

Billing Address
LOWER PLATTE NORTH NRD
MR. LARRY ANGLE
511 COMMERCIAL PARK ROAD
P.O. BOX 126
WAHOO, NE 68066
United States

Ship-to Address
LOWER PLATTE NORTH NRD
RUSSELL OAKLUND
511 COMMERICAL PARK ROAD
WAHOO, NE 68066
United States

Customer PO No.	Order Date	Order No.	Due Date
	07/28/2023	SO101586	September 9, 2023
Shipping Agent Code	Shipment Method	Payment Terms	Salesperson
FEDEX	FOB Origin	Net 30 days	Stephane Mary
Package Tracking No.	Final Installation	Email	Customer Account No.
	NE		C004961

No.	Description	Quantity	Unit	Unit Price	Line Amount
0094840	VuLink CI (Global Cellular, does not include antenna)	64	Each	716.00	45,824.00
Serial No. 1054165, 1054689, 1055281, 1055266, 1054688, 1055264, 1055144, 1052671, 1052468, 1055309, 1055016, 1052320, 1052464, 1052666, 1054158, 1052500, 1051689, 1055049, 1055262, 1052662, 1052139, 1052719, 1052454, 1052435, 1052452, 1052451, 1052450, 1045738, 1052461, 1052440, 1052332, 1052443, 1052352, 1052442, 1052434, 1046187, 1045728, 1046480, 1046421, 1046456, 1045720, 1045598, 1046495, 1046643, 1045709, 1046455, 1051378, 1050734, 1051380, 1050321, 1051377, 1050288, 1051384, 1051447, 1051681, 1050080, 1050063, 1050075, 1051513, 1050725, 1051405, 1051412, 1051438, 1051379					
0043630	VuLink 4G/LTE/2G Cellular Antenna with 1.5m cable (IP67, recommended for VuLink CI)	64	Each	29.75	1,904.00
0103050	VuLink Lithium Batteries (Set of 3)	64	Each	68.00	4,352.00
850-367	MACE FloSeries3 - HydroMace XCi	6	Each	1,610.75	9,664.50
Serial No. 96590, 96595, 96591, 96589, 96080, 96596					
850-368	MACE FloSeries3 - SDI-12 Master Card	10	Each	505.75	5,057.50
Serial No. 95178, 95180, 95179, 94215, 94217, 94218, 90371, 90379, 90372, 95177					

850-422	MACE FloSeries3 - WebComm Card w/ Antenna- 4G	6	Each	505.75	3,034.50
Serial No. 95818, 95843, 95822, 95815, 95852, 95856					
0084530	HydroVu Sim Card-HydroVu Sim Card	6	Each	31.45	188.70
Serial No. 005817428, 005175999, 005817467, 005817601, 005817600, 005817598					
814-015	MACE FloSeries3 - Solar Panel (12V/10W)	6	Each	284.75	1,708.50
850-302	MACE FloSeries3 - Mounting Kit - Device & Solar Panel (5W/10W)	6	Each	97.75	586.50
850-363	MACE FloSeries3 - USB External Comms Lead	1	Each	165.75	165.75
0099240	Level TROLL 400, Level Sensor Range - 11m, 35 ft (30 PSIA)	15	Each	716.00	10,740.00
Serial No. 1052744, 1052747, 1052753, 1052767, 1052739, 1052733, 1052107, 1052749, 1052772, 1052099, 1052731, 1052734, 1052101, 1052750, 1052775					
0102510	HydroVu Professional Cellular Prepaid Code	7	Each	0.00	0.00
0102510	HydroVu Professional Cellular Prepaid Code	7	Each	0.00	0.00
0102510	HydroVu Professional Cellular Prepaid Code	7	Each	0.00	0.00
0102510	HydroVu Professional Cellular Prepaid Code	7	Each	0.00	0.00
0102510	HydroVu Professional Cellular Prepaid Code	7	Each	0.00	0.00
0102510	HydroVu Professional Cellular Prepaid Code	7	Each	0.00	0.00
0102510	HydroVu Professional Cellular Prepaid Code	7	Each	0.00	0.00
0102510	HydroVu Professional Cellular Prepaid Code	7	Each	0.00	0.00
0102510	HydroVu Professional Cellular Prepaid Code	7	Each	0.00	0.00
0102510	HydroVu Professional Cellular Prepaid Code	7	Each	0.00	0.00
			Subtotal		83,225.95
			Total Tax		0.00
			Total Amount in USD		**83,225.95**

Amount Subject to Sales Tax	0.00	Bank Name	Vectra Bank Colorado
Amount Exempt from Sales Tax	83,225.95	Bank Account No.	5801330001
		Payment Routing No.	102003154

Click to Pay

Click Here to Pay