CEDAR KNOX RURAL WATER PROJECT

MEMORANDUM

FOR

WATER SUPPLY & WATER TREATMENT PLANT SITE SELECTION

PREPARED FOR:

LEWIS & CLARK NRD NATURAL RESOURCES DISTRICT

PREPARED BY:

Bartlett & West

Driving Community and Industry Forward, Together.

&

LRE WATER

CONNECTING WATER TO LIFE

P.N. 19242.300

DECEMBER 2021

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LIST OF FIGURES

1.0 WTP Site Review

The review of several potential water treatment plant sites was performed at locations provided by Cedar Knox staff. These various sites were reviewed based on several different criteria listed below:

1. Site terrain.
2. Location relative to paved roads providing good access.
3. Pipe routing required to tie into existing system.
4. Estimated cost for routing of waterline to each proposed WTP and well site.
5. Acres available.
6. Does the proposed site have access to potential drainage for RO concentrate.
7. Approximate site elevation.
8. Access to 3-Phase Power

1.1 Proposed WTP Site No. 1

Proposed WTP Site No. 1 is located in the Dolphin Area approximately 1 mile west of the Village of Crofton in Section 22, Township 32, Range 2W. (See Figure 1.1 below).

Pro's:

- This site has direct access to State Highway 12.
- Located in a rural area not directly bordering a community.
- Access to a minimum of 20acres.
- Terrain reasonably flat sloping to the northwest.
- Site Elevation approx. 1,460 ft MSL

Con's:

- No direct drainage option for RO concentrate.
- Estimated Project Costs for Transmission Piping, raw water piping, and related distribution facilities.
    - Approx. $5,230,000

BAR IS ONE INCH ON OFFICIAL DRAWINGS 0 1" IF NOT ONE INCH, ADJUST SCALE ACCORDINLY

EXISTING GROUND STORAGE TANKS

POTENTIAL 12 - INCH TRANSMISSION MAIN

POTENTIAL WATER STORAGE FACILITY

POTENTIAL WTP SITE #1

BPS

POTENTIAL RAW WATERLINE

MACKEPRANG SITE TEST HOLE 01-LC-20

TEST HOLE 04-LC-15

TEST HOLE 03-LC-20

TEST WELL (3IT)

State Highway 12

State Highway 121

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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CHECKED BY: JAR
PROJECT ENGR: JAR

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CEDAR KNOX RURAL WATER SYSTEM
LEWIS & CLARK NATURAL RESOURCE DISTRICT

Figure 1 - 1
SITE #1 ROUTING
DOLPHIN AREA
WATER SUPPLY

Legend

Note

- 12" Transmission Line
- Raw Waterline

SHEET GRID INDEX 5 / 1 - 4

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DRAWING NO: 1
SHEET NO: 1 of 5

1.2 Proposed WTP Site No. 2

WTP Site No. 2 is located in the Dolphin Area approximately 2 miles southwest of the Village of Crofton in Section 35, Township 32, Range 2W. (See Figure 1.2 below)

Pro's:

- This site has direct access to State Highway 121
- Located in a rural area not directly bordering a community.
- Acres available - Minimum of 20 acres.
- Terrain reasonably flat and contains high spot relative to local area.
- Site Elevation approx. 1,620 ft MSL

Con's:

- No direct drainage option for RO concentrate.
- Not on direct route from potential wells to existing system.
- Estimated Project Costs for Transmission Piping, raw water piping, and related distribution facilities.
    - Approx. $5,300,000

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EXISTING GROUND STORAGE TANKS

POTENTIAL 12 - INCH TRANSMISSION MAIN

POTENTIAL WATER STORAGE FACILITY

POTENTIAL WTP SITE #2

POTENTIAL RAW WATERLINE

MACKEPRANG SITE TEST HOLE 01-LC-20

TEST HOLE 04-LC-15

TEST HOLE 03-LC-20

TEST WELL (3IT)

BPS

State Highway 12

State Highway 121

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Figure 1 - 2
SITE #2 ROUTING
DOLPHIN AREA
WATER SUPPLY

Legend

Note

12" Transmission Line

Raw Waterline

SHEET GRID INDEX 5 | 1 - 4

PROJ NO: 19242.300
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DATE: DECEMBER 2021

DRAWING NO: 2
SHEET NO: 2 of 5

1.3 Proposed WTP Site No. 3

WTP Site No. 3 is located in the Dolphin Area just on the north edge of the Village of Crofton in Section 24, Township 32, Range 2W. (See Figure 1.3 below)

Pro's:

- This site has direct access to State Highway 121
- Acres available - Minimum of 20 acres.
- Terrain reasonably flat sloping to the northwest.
- Site Elevation approx. 1,410 ft MSL

Con's:

- No direct drainage option for RO concentrate.
- Relative location to Crofton and residential areas may create additional permitting issues.
- Estimated Project Costs for Transmission Piping, raw water piping, and related distribution facilities.
    - Approx. $5,650,000

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EXISTING GROUND STORAGE TANKS

POTENTIAL 12 - INCH TRANSMISSION MAIN

POTENTIAL WATER STORAGE FACILITY

POTENTIAL WTP SITE #3

POTENTIAL RAW WATERLINE

MACKEPRANG SITE TEST HOLE 01-LC-20

TEST HOLE 04-LC-15

TEST HOLE 03-LC-20

TEST WELL (3IT)

BPS

State Highway 12

State Highway 121

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Figure 1 - 3
SITE #3 ROUTING
DOLPHIN AREA WATER SUPPLY

Legend

Note

- 12" Transmission Line
- Raw Waterline

SHEET GRID INDEX 5 — 1 - 4

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DRAWING NO: 3

SHEET NO: 3 of 5

1.4 Proposed WTP Site No. 4

WTP Site No. 4 is located in the Dolphin Area southeast of the intersection of 886th Rd & 546th Ave in Section 18, Township 31, Range 2W. (See Figure 1.4 below)

Pro's:

- Located in line with proposed wells relative to existing system connection.
- Located in a rural area not directly bordering a community.
- Acres available - Minimum of 20 acres.
- Terrain slopes sloping to the southwest.
- Site Elevation approx. 1,750 ft MSL
- Estimated Project Costs for Transmission Piping, raw water piping, and related distribution facilities.
    - Approx. $4,500,000

Con's:

- No direct drainage option for RO concentrate.
- Closest paved road approximately 4 miles from site.

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EXISTING GROUND STORAGE TANKS

POTENTIAL 12 - INCH TRANSMISSION MAIN

POTENTIAL WATER STORAGE FACILITY

MACKEPRANG SITE TEST HOLE 01-LC-20

POTENTIAL WTP SITE #4

TEST HOLE 04-LC-15

POTENTIAL RAW WATERLINE

TEST HOLE 03-LC-20

TEST WELL (3IT)

BPS

State Highway 12

State Highway 121

Sharon

Liberty

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Figure 1 - 4
SITE #4 ROUTING
DOLPHIN AREA WATER SUPPLY

Legend

Note

- 12" Transmission Line
- Raw Waterline

SHEET GRID INDEX: 5 / 1 - 4

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DATE:	DECEMBER 2021
DRAWING NO:	4
SHEET NO:	4 of 5

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

1.5 Proposed WTP Site No. 5

WTP Site No. 5 is located in the Aten Area in the northwest ¼ of Section 16, Township 33, Range 1W. (See Figure 1.5 below)

Pro's:

- Located relatively close to proposed well sites.
- Located in a rural area not directly bordering a community.
- Acres available - Minimum of 20 acres.
- Terrain slopes gently to the northeast.
- Potential direct drainage option for RO concentrate.
- Estimated Project Costs for Transmission Piping, raw water piping, and related distribution facilities.
    - Approx. $4,300,000

Con's:

- Site Elevation approx. 1,180 ft MSL.
- Lower elevation of plant will require increased pumping costs to deliver finished water to the existing system.

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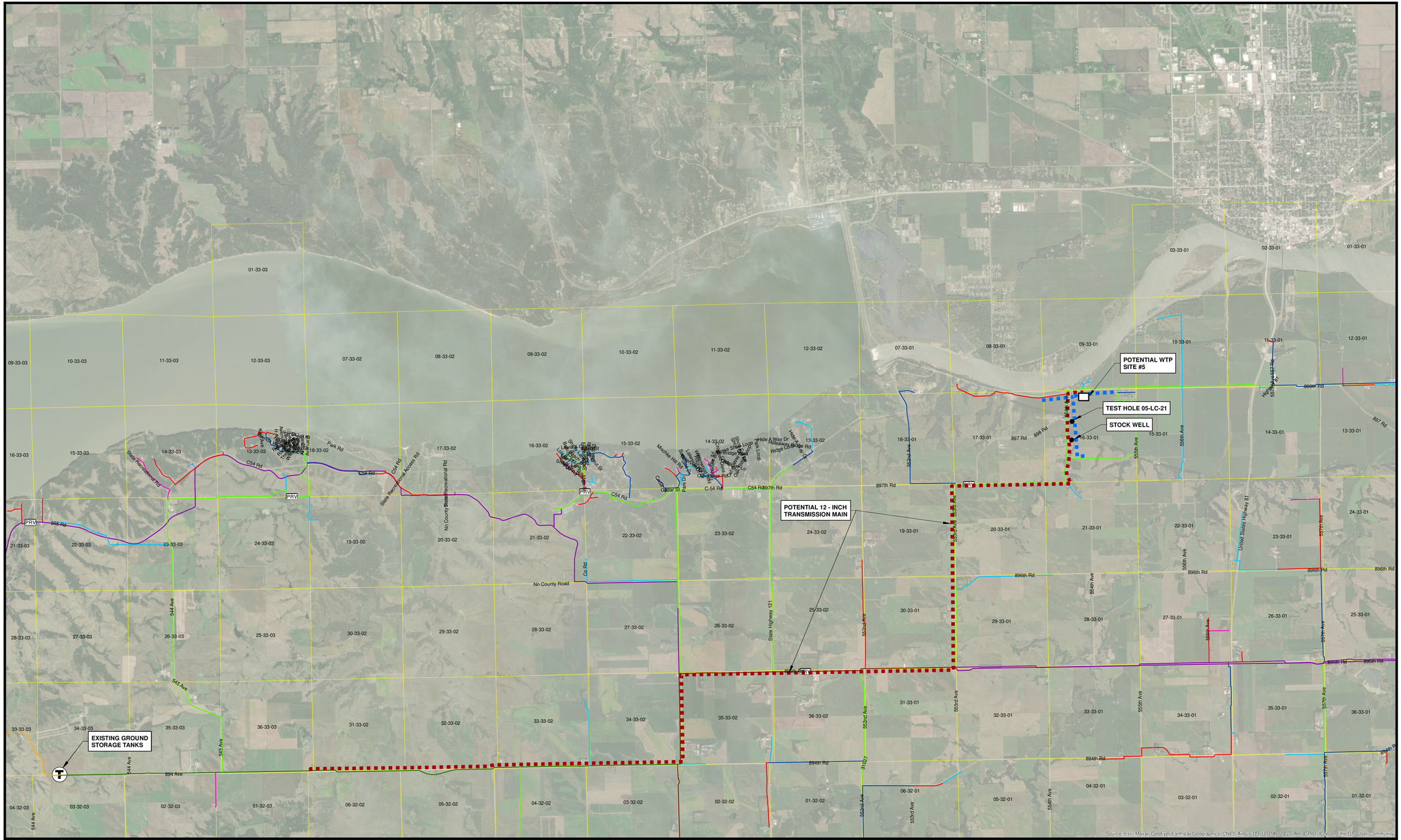

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CEDAR KNOX RURAL WATER SYSTEM
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Figure 1 - 5

ATEN AREA WATER SUPPLY

Legend

Note

- 12" Transmission Line
- Raw Waterline

SHEET GRID INDEX: 5 / 1 - 4

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DRAWING NO: 5

SHEET NO: 5 of 5

2.0 Why the Aten Area and the Dolphin Area Supply Options Aren't Pursued Simultaneously?

- Significant expense of test drilling, well development, pumping, and water quality analysis of each area.

- Currently the Nebraska Department of Environment & Energy is requesting that the CKRWP select a specific location by December 2021 for the project to move forward.

3.0 Why is a Collector Well not being pursued?

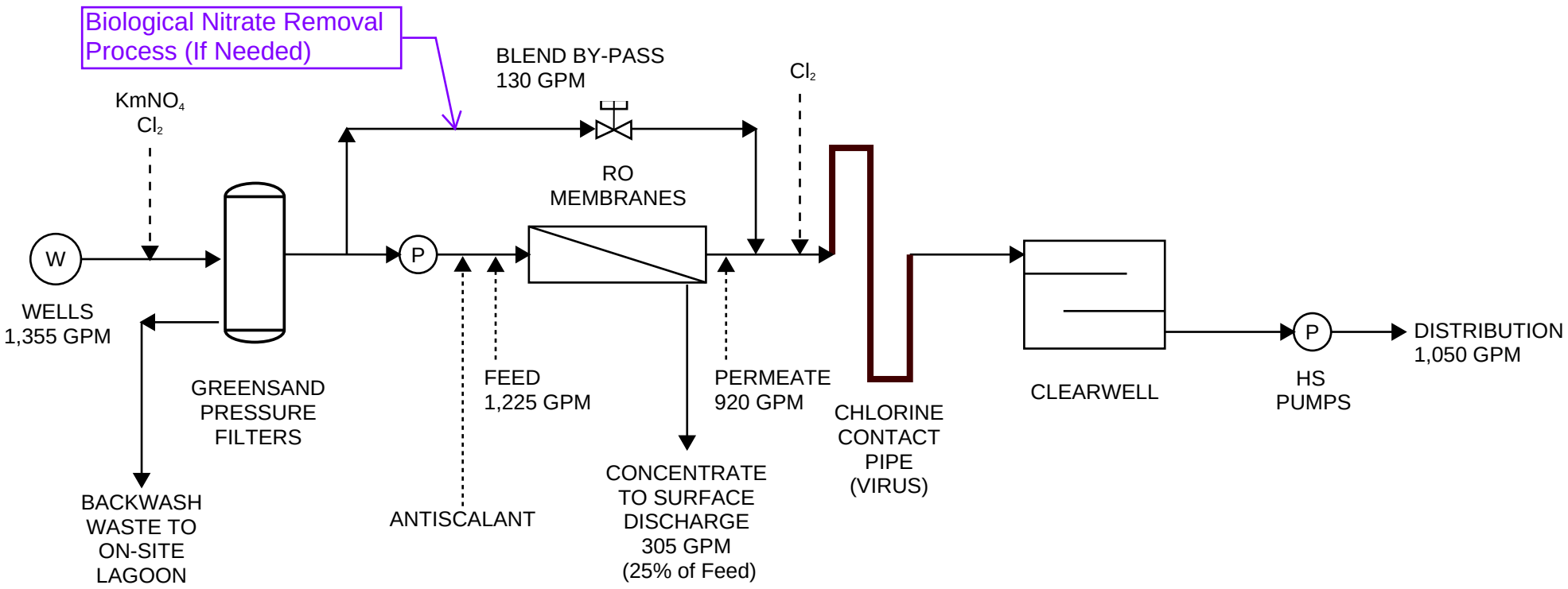
- There is a significant added cost for constructing a collector well.

- Collector wells are generally used for higher production needs to defray capital costs over higher production levels.

- 1.5 MGD can potentially be produced in the areas being reviewed with 3 to 4 vertical wells for a much lower cost.

- Collector well in the Aten area would most likely be under the influence of surface water requiring more extensive treatment of the water.

SCHEMATIC NO. 1
ATEN SITE GROUNDWATER FOR 1.5 MGD FINISHED WATER SUPPLY



1. Iron and Manganese Removal
2. RO Membrane Softening
3. RO Membrane Nitrate Removal
4. Modular Allows for Ease of Expansion

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4.0 Estimated WTP Costs for the Aten and Dolphin Areas

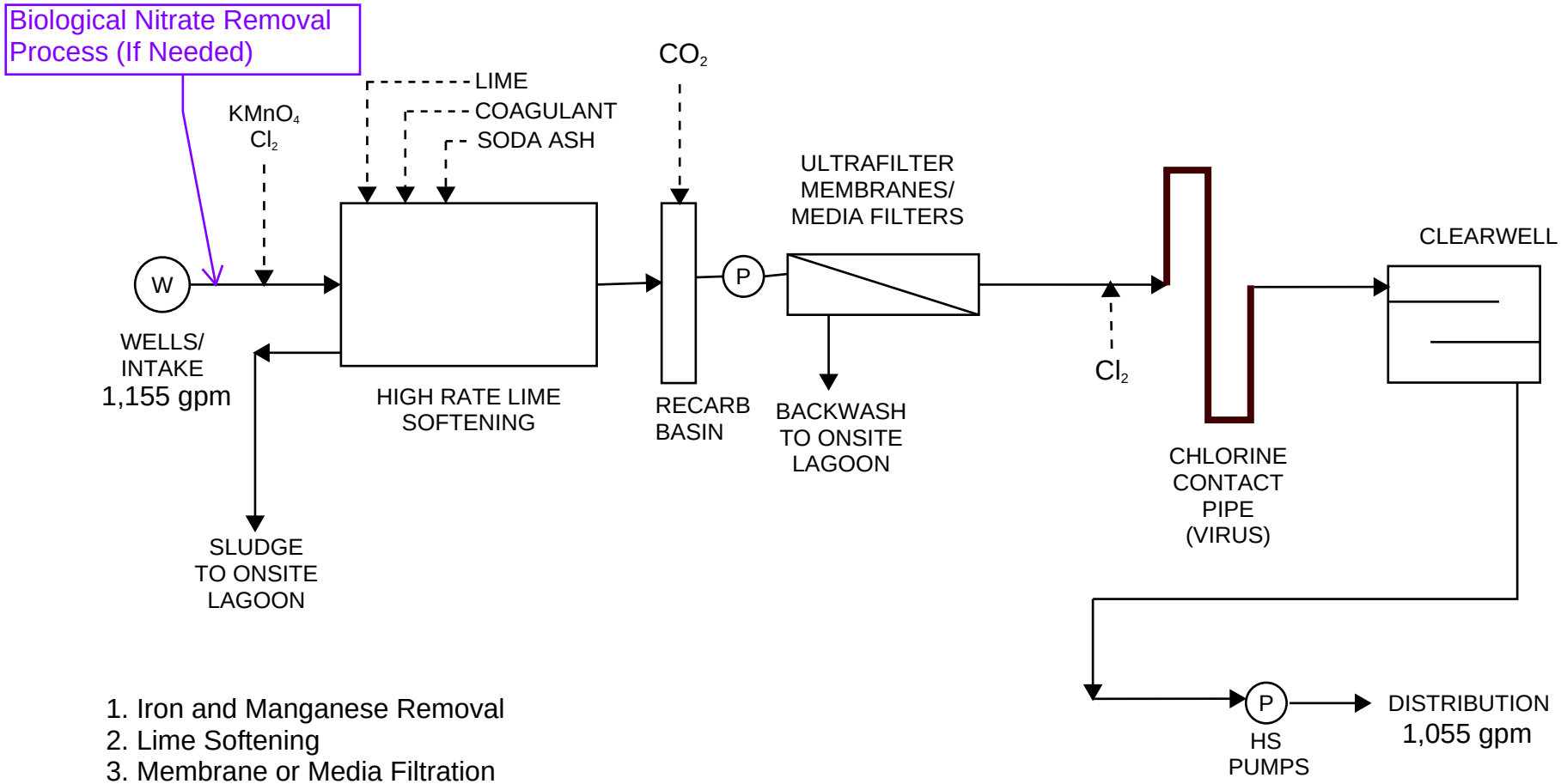
4.1 Aten Water Treatment Plant Estimated of Construction Cost w/RO

Figure 4.1 – Aten WTP Estimate of Construction Cost w/RO

Aten Site Groundwater and WTP w/ RO

DIVISION 01 - GENERAL REQUIREMENTS	$	460,000.00
DIVISION 03 - CONCRETE	$	880,000.00
DIVISION 05 - METALS	$	440,000.00
DIVISION 06 - WOOD, PLASTICS & COMPOSITES	$	20,000.00
DIVISION 07 - THERMAL AND MOISTURE PROTECTION	$	50,000.00
DIVISION 08 - OPENINGS	$	66,000.00
DIVISION 09 - FINISHES & DIVISION 10 - SPECIALTIES	$	210,000.00
DIVISION 10 - SPECIALTIES	$	210,000.00
DIVISION 12 - FURNISHINGS	$	25,000.00
DIVISION 22 - PLUMBING	$	200,000.00
DIVISION 23 - HEATING, VENTILATING AND AIR-CONDITIONING	$	420,000.00
DIVISION 26 - ELECTRICAL	$	1,100,000.00
DIVISION 31 - EARTHWORK	$	200,000.00
DIVISION 32 - EXTERIOR IMPROVEMENTS	$	150,000.00
DIVISION 33 - UTILITIES	$	350,000.00
DIVISION 40 - PROCESS INTEGRATION	$	1,100,000.00
DIVISION 43 - PROCESS GAS & LIQUID HANDLING, PURIFICATION, & STORAGE EQUIPMENT	$	350,000.00
DIVISION 46 - WATER EQUIPMENT	$	2,300,000.00
Well Field	$	600,000.00
HSPS/Clearwell	$	950,000.00
Construction Total	$	10,000,000.00

SCHEMATIC NO. 2
DOLPHIN SITE GROUNDWATER FOR 1.5 MGD WATER SUPPLY



1. Iron and Manganese Removal
2. Lime Softening
3. Membrane or Media Filtration
4. Pre-Manufactured Tanks and Modular Filters

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4.2 Dolphin WTP Estimate of Construction Cost

Figure 4.2 - Dolphin WTP Estimate of Construction Cost

Dolphin Site Groundwater and WTP		
GENERAL REQUIREMENTS	$	460,000.00
CONCRETE	$	980,000.00
METALS	$	440,000.00
WOOD, PLASTICS & COMPOSITES	$	20,000.00
THERMAL AND MOISTURE PROTECTION	$	50,000.00
OPENINGS	$	66,000.00
FINISHES & DIVISION 10 - SPECIALTIES	$	210,000.00
SPECIALTIES	$	1,000.00
FURNISHINGS	$	25,000.00
PLUMBING	$	200,000.00
HEATING, VENTILATING AND AIR-CONDITIONING	$	420,000.00
ELECTRICAL	$	1,100,000.00
EARTHWORK	$	300,000.00
EXTERIOR IMPROVEMENTS	$	150,000.00
UTILITIES	$	350,000.00
PROCESS INTEGRATION	$	1,100,000.00
PROCESS GAS & LIQUID HANDLING, PURIFICATION, & STORAGE EQUIPMENT	$	1,300,000.00
WATER EQUIPMENT	$	1,700,000.00
Well Field	$	600,000.00
HSPS/Clearwell	$	950,000.00
Construction Total	$	10,400,000.00

If nitrates would begin to rise in the Dolphin area, the potential treatment to remove nitrates exceeding the MCL would either be Ion Exchange or Biological Treatment. RO is not an option in the Dolphin Area because there is no place to discharge the RO concentrate stream. The additional cost to add nitrate removal to the Dolphin WTP is estimated to be $1,000,000 in additional capital costs. This will be defined in more detail with the WTP Design Report.

5.0 LRE Ground Water Review and Recommendation

Memorandum

To:	Brian Hoellein and John Ruckman - Bartlett & West (B&W)
From:	Dave Hume, PG - LRE Water (LRE)
Copy to:	Sue Lackey - Conservation and Survey Division (CSD) of the University of Nebraska, Lincoln; Mitch Kannenberg - LRE; Jon Libra - LRE
Reviewed by:	Roscoe Sopiwnik - LRE
Date:	December 8, 2021
Project:	Cedar Knox Rural Water Project (CKRWP)
Subject:	Desktop Preliminary Well Siting Assessment

1.0 PURPOSE AND OBJECTIVES

The purpose of this memorandum is to provide a summary of the findings from LRE's desktop preliminary well siting assessment (Assessment), and recommendations for future work related to the CKRWP Project (Project). LRE understands the Project includes identifying, investigating, and developing a new groundwater source, and designing and building a new water treatment plant.

The objective of the Assessment was to further evaluate the potential for groundwater source development at two sites, referred to as the **Dolphin Site** and the **Aten Site**, and to provide preliminary recommendations for further investigation and the estimated costs to develop each site. The location of the Dolphin Site and Aten Site are on **Figure 1**.

The Assessment was completed by obtaining, reviewing, and evaluating site-specific existing information, most of which was provided by Sue Lackey with the CSD.

The Dolphin and Aten sites were selected for the Assessment over the Lindy, Menominee and Obert sites based on CSD's investigation work completed over several years and presented to the NRD and CKRWP boards in March 2021. The focus on the Dolphin and Aten sites was verified during our kickoff meeting on November 22, 2021, and during our subsequent meeting with Sue Lackey, and Annette Sudbeck and Scott Fielder (both with LCNRD) on November 30, 2021. These sites have questionable quantity, greater potential for well interference, limited aquifer extents, unknown water quality, and greater distances to CKRWP's existing large water mains compared to the Dolphin and Aten sites.

The minimum yield goal for a potential new CKRWP well field is 1,050 gallons per minute day or 1.5 million gallons per day (MGD). For the purposes of this Assessment, it is

assumed that it would be acceptable to meet the 1.5 MGD yield goal by constructing multiple wells at either site. A collector well option for the Aten Site is also provided for cost comparison purposes.

2.0 HYDROGEOLOGIC SETTING

The Dolphin Site is located in west-central Knox County in the northern drift groundwater region. The two primary aquifer systems include the Tertiary-age Ogallala aquifer (Ogallala) and the younger Quaternary-age buried sand and gravel aquifers (Quaternary aquifer). Together these aquifers make up the Principal Aquifer. In some places, the two aquifers are in contact and hydraulically connected, and in other places they are separated by a low-permeable confining unit.

The Aten Site is located in the Missouri River Lowland where the target aquifer consists of Quaternary-age shallow alluvial sand and gravel (alluvial aquifer) associated with the Missouri River Valley.

Groundwater in the Principal Aquifer and alluvial aquifer generally flows from the upland areas where groundwater is recharged by precipitation and flows toward topographic lows and eventually discharging to perennial (i.e., groundwater-fed) streams and rivers.

The general groundwater flow directions across the sites are shown on **Figure 2**.

3.0 RESULTS – DOLPHIN SITE

3.1 Summary of Recent CSD Work

- The Dolphin Site has been investigated recently by CSD as possible water source.
- The registered wells, test holes, observation wells, and test well locations from CSD's previous work are shown on **Figure 3**.
- The investigation included the following activities:

    - Drilled test holes in 2015 and 2020 and logged the geology;
    - Installed three nested (i.e., adjacent shallow and medium depth) pairs of observation wells for groundwater sampling and water level measurements;
    - Collected groundwater samples and evaluated the water quality;
    - Identified a possible well field location in the eastern part of the site, installed a Test Well, and completed an aquifer pumping test;
    - Prepared draft saturated thickness maps of the Ogallala and Quaternary aquifers based on test holes and geologic logs from the Nebraska Registered Wells, well hydrographs, and nitrate concentration plots; and,

- Presented the initial results to the CKRWP and LCNRD boards in March 2021

3.2 Principal Aquifer Characteristics

LRE evaluated the saturated thickness, nitrate results, and aquifer parameters from the March 2021 aquifer pumping test on the Test Well to refine the assessment of the Dolphin Site as a possible groundwater source.

Saturated Thickness and Extent

LRE prepared saturated thickness contour maps of the Ogallala and Quaternary aquifers. The maps are shown on **Figures 4 and 5**. Two hydrogeologic cross sections were also created along transects A-A' and B-B' shown on **Figure 6**. The cross sections are on **Figures 7 and 8.**

- Contoured thickness values were provided by CSD and reviewed by LRE.
- The geology on the cross sections was interpreted from geologic logs from the registered wells and test holes shown on the transects. These along with the contour maps were discussed with CSD.
- The following conclusion can be made regarding the thickness and extent of the Principal Aquifer at the Dolphin Site:

    - The Ogallala ranges from over 80 feet thick in the north-northwest and thins to the south and southeast where it eventually pinches out;
    - The Quaternary aquifer appears to thicken from 20 feet or less to the north and west to more than 80 feet to south and east. The thickest area is near observation well pair 31S/M, and the Test Well in the southeastern portion of the site where it is approximately100 feet thick;
    - Cross section A-A' shows the Ogallala and the Quaternary aquifers are separated by a low-permeable confining unit in the north, west, and central portions of the site. The confining unit appears to be absent in places to the south and east corresponding to the areas where the Ogallala, if present, can be in direct contact with the Quaternary aquifer;
    - The Quaternary aquifer is at or very near the ground surface in and adjacent to the West Bow Creek Valley making the aquifer vulnerable to surface contaminants in this area;
    - The aquifer in the southeast portion of the Site where the Test Well is located is less vulnerable because of thicker overlying low-permeable silts and clays; and,

- Based on the greater thickness and extent of the Quaternary aquifer in the southeastern portion of the Dolphin Site, in addition to lower nitrate concentrations, this area has the most promise for future development.

Nitrate Concentrations in Principal Aquifer

The most recent nitrate concentrations in groundwater for the Principal Aquifer are shown on **Figure 9**. The historical nitrate concentrations plots are in **Attachment A**. The following conclusions can be made regarding the nitrates in the Principal Aquifer:

- Concentrations are typically higher in the Quaternary aquifer and exceed the maximum contaminant level (MCL) of 10 parts per million (ppm) in most wells sampled in the central and western portion of the study area; however, some wells are also screened across the Ogallala. As a results, monitoring wells 22S/M, 31S/M, and 32S/M, and the Test Well may provide the most reliable results because of their isolated screened intervals and well construction integrity;
- Nitrate concentrations appear to be higher in the central portion of the site hydraulically downgradient or east-northeast of West Bow Creek where the aquifer is more vulnerable;
- Concentrations in the Quaternary aquifer are less than 10 ppm in the southeastern portion of the study area based on results from the 31S/M, a few private wells, and the Test Well; and,
- Thicker low-permeable silts and clays overlying the aquifer in the southeast portion of the Site where the Test Well is located may help reduce nitrate concentrations in the Quaternary aquifer in the area. The underlying Ogallala may also contribute low-nitrate concentrated water where the confining unit separating the two aquifers is absent and the two system are combined.

Transmissivity of Quaternary Aquifer Near Test Well

The aquifer pumping test completed on the Test Well in October 2021 was analyzed by LRE to estimate the aquifer transmissivity (T). The T is a parameter that describes the ability of the aquifer to transmit groundwater throughout its entire saturated thickness. It is applied to estimate the drawdown or groundwater level decline in an aquifer caused by a pumping well. The results of the analysis are presented in **Attachment B,** and are summarized below:

- The Test Well was pumped at 300 gpm for 8 hours. Approximately 7.5 feet of drawdown was measured in the Test Well resulting in a specific capacity 40 gpm/ft of drawdown;
- A T value of approximately 3.3 x 10^4 feet squared per day (ft^2/day) was calculated, resulting in a hydraulic conductivity of approximately 530 feet per day (ft/day), assuming an aquifer thickness of about 62 feet. This is indicative of a medium to coarse sand and gravel, and a prolific aquifer; and,
- Negative (i.e., no- or low-flow) aquifer boundaries were not observed during the test and influence was not observed in the stock well (108645) located approximately 1,180 feet northeast of the Test Well.

Preliminary Well and Field Design

A preliminary production well design and a well field design were completed using the specific capacity and T values from the pumping test described above. The results of the analysis and assumptions are as follows:

- 16-inch production well adjacent to the Test Well screened from 180 to 210 feet below grade (sieve analysis to be determined or use Test Well results);
  - Assuming a static water level of 150 feet leaves 20 feet of available head with 10 feet of water column above the top of the screen;
  - Assuming a specific capacity of 50 gpm/ft in a 16-inch well, the estimated yield is 1,000 gpm per well; and,
- Three wells spaced approximately 1,000 to 2,000 feet apart to minimize interference, each pumping 600 gpm, and the third as a backup could potentially meet the 1.5 MGD demand.

4.0 RECOMMENDATIONS AND PRELIMINARY COST ESTIMATES

DOLPHIN SITE

Recommendations for the Dolphin Site are as follows:

- Evaluate the existing water quality results for potential water treatment issues;
- Survey the top of casing of selected wells in the area of the Site and Test Well and measure static water levels to determine the site-specific groundwater flow direction;
- Continue to monitor selected wells for nitrates;

- Identify areas that have cooperative landowners for drilling test holes and possible well options;
- Drill a total of four test holes in areas west, south, and east of the Test Well to better characterize the extent of the aquifer and identify future production well sites;
- Install a 16-inch diameter production well 100 feet from the test Well and use the Test Well as an observation well;
- Conduct a 7-day aquifer pumping test at a rate of 800 to 1,000 gpm in the production well and collect water quality samples throughout the test; and,
- Analyze the data and design the final well field configuration.

The estimated costs to complete the following including the installation of three production wells to meet the 1.5 MGD demand is in **Table 1**.

Table 1. Estimated Costs for Exploration and Well Field Development – Dolphin Site

Item	Estimated Cost Ranges			
	Drilling Contractor		Hydrogeology Consultant (LRE Water)	
Specifications and Bidding	NA	NA	$10,000	$15,000
Work Plan	NA	NA	$10,000	$15,000
Drilling Mobilization	$10,000	$15,000	NA	NA
Test Hole Drilling	$10,000	$15,000	$15,000	$20,000
Observation Well Installation	$10,000	$10,000	$10,000	$15,000
One (1) 16-inch Production Well	$100,000	$110,000	$5,000	$5,000
Well Development	$10,000	$20,000	$5,000	$5,000
7-Day Pumping Test	$25,000	$30,000	$20,000	$25,000
Analysis and Reporting	NA	NA	$15,000	$20,000
Well Field Design	NA	ND	$5,000	$5,000
Install two (2) Additional 16"-inch Production Wells for final Well Field	$235,000	$250,000	$25,000	$25,000
Total	**$400,000**	**$450,000**	**$120,000**	**$150,000**

Note: Costs do not include electrical, pumps, motors, etc. for the final production wells.

5.0 RESULTS AND RECOMMENDATIONS – ATEN SITE

5.1 Summary of Recent CSD Work

- The Aten Site has been investigated recently by CSD as a possible water source.
- The registered wells and test holes locations from previous work are shown on **Figure 10**.

- The investigation included the following activities:

    - Drilled test holes in 2019 and conducted Geoprobe logging (electrical conductivity profiling) and coring 2021 to log the geology;
    - Installed one observation well (33S) for groundwater sampling and water level measurements;
    - Collected groundwater samples and evaluated the water quality;
    - Identified a possible location of a production well; and,
    - Presented initial results to the CKRWP and LCNRD boards in March 2020.

5.2 Alluvial Aquifer Characteristics

LRE evaluated the saturated thickness, nitrate results, and estimated the T value to refine the assessment of the Aten Site as a groundwater source.

Saturated Thickness and Extent

LRE reviewed the test hole logs, Geoprobe core and EC logs, and registered well logs to estimate the range of saturated thickness values of the alluvial aquifer. The map with the thickness values is shown on **Figure 11**.

- The following conclusions can be made about the thickness and extent of the alluvial aquifer at the Aten Site:

    - The thickness is quite variable over short distances, ranging from about 20 feet thick in the southwest, 30 to 60 feet thick in the northwest near the Missouri River, and greater than 67 feet in the center of the site;
    - The aquifer consists of medium to coarse sand and gravel interbedded with thin silt and clay layers typical of an alluvial environment;
    - A large boulder or cobble zone appears to be present at the base of the sand and gravel aquifer in many locations making drilling below the top of this zone very difficult with standard drilling methods (i.e., mud rotary and auger);
    - The aquifer is highly vulnerable to surface contaminants because of the thin overlying low-permeable silts and clays;
    - The aquifer is hydraulically connected to the Missouri River and if stressed under pumping conditions or under high stage conditions has the potential to be under the direct influence of surface waters; and,

- Based on the greater thickness in the center of the site, this area has the most promise for future development of a production well; however, it appears thicknesses can be quite variable.

Nitrate Concentrations in the Alluvial Aquifer

The most recent nitrate concentrations in groundwater for the alluvial aquifer were collected in 2020 and presented by CSD in March 2021. The following conclusions can be made regarding the nitrates in the alluvial aquifer:

- Nitrates in portions of the western end of the site had concentrations greater than 25 ppm; and,
- Concentrations in the field to the east and northern half of the field to the west were less than 5 ppm.

Transmissivity of Alluvial Aquifer

No pumping test data are available for the alluvial aquifer at the site to estimate T; however, two specific capacity results from two irrigation wells (22456 and 223879) in the east field were calculated at 31 and 85 gpm/ft, at pumping rates of 250 and 800 gpm, respectively. These indicate high-capacity wells could be developed to meet 1.5 MGD.

Preliminary Well and Field Design

A preliminary production well design and a well field design were completed using the lower specific capacity value of 31 gpm/ft above to be conservative. The results of the analysis and assumptions are as follows:

- 16-inch production installed at location 05-LC-21 and screened from 45 to 60 feet below grade (sieve analysis to be determined);
  - Assuming a static water level of 20 feet, leaves 15 feet of available head with 10 feet of water column above the top of the screen;
  - Assuming specific capacity of approximately 30 gpm/ft in a 16-inch well, the estimated yield is 300 gpm; and,
- Under this scenario, five wells would be required to meet the 1.5 MGD demand, with one well out of service as a backup.

5.3 RECOMMENDATIONS AND PRELIMINARY COST ESTIMATES

ATEN SITE

Recommendations for the Aten Site are as follows:

- Evaluate the existing water quality results for potential water treatment issues, including ground water under the influence;
- Continue to monitor selected wells for nitrates;
- Identify areas that have cooperative landowners for further investigation, drilling test holes, and possible well options;
- Based on landowner approval and potential well sites, conduct an electrical resistivity survey using surface geophysics to locate areas in the aquifer with greater thickness and higher hydraulic conductivities indicative of higher water producing zones;
- Drill a total of six test holes at target locations based on the geophysical results, to better characterize the extent of the aquifer and identify future production well sites;
- If the results are promising, install a 16-inch diameter production well at 05-LC-21 screened from 45 to 60 feet below grade (sieve analysis to be determined), and a number of observation wells to evaluate aquifer boundary conditions and water quality, and river stage;
- Develop a detailed aquifer pumping test work plan;
- Conduct a 7-day aquifer pumping test at the production well to determine a maximum yield and collect water quality samples throughout the test; and,
- Analyze the data and design the final well field configuration based on the pumping test and geophysical and test hole results.

The estimated costs to complete the following including the installation of five production wells or a collector well to meet the 1.5 MDG demand are outlined in **Table 3**:

Table 2. Estimated Costs for Exploration and Well Field Development – Aten Site

Option 1 - Vertical Wells	Estimated Cost Ranges			
	Drilling Contractor		Hydrogeology Consultant (LRE Water)	
Specifications and Bidding	NA	NA	$10,000	$15,000
Surface Geophysics	NA	NA	$30,000	$40,000
Work Plan	NA	NA	$10,000	$10,000
Drilling Mobilization	$10,000	$15,000	NA	NA
Test Hole Drilling	$15,000	$20,000	$15,000	$20,000
Four (4) Obs Well Installation	$30,000	$35,000	$10,000	$15,000
One (1) 16-inch Production Well	$40,000	$50,000	$5,000	$5,000
Well Development	$10,000	$15,000	$5,000	$5,000
7-Day Pumping Test	$25,000	$30,000	$20,000	$30,000
Analysis and Reporting	NA	NA	$20,000	$25,000
Well Field Design	NA	NA	$10,000	$20,000
Four (4) Additional 16-inch Production Wells for final Well Field (1)	$200,000	$235,000	$15,000	$15,000
Total	**$330,000**	**$400,000**	**$150,000**	**$200,000**

Option 2 - Collector Well	Drilling Contractor		Hydrogeology Consultant (LRE Water)	
Specifications and Bidding	NA	NA	$10,000	$15,000
Surface Geophysics	NA	NA	$30,000	$40,000
Work Plan	NA	NA	$10,000	$15,000
Investigation (2)	NA	NA	$80,000	$100,000
Contractor Drilling and Well Construction	$4,000,000	$5,000,000	$20,000	$30,000
Total	**$4,000,000**	**$5,000,000**	**$150,000**	**$200,000**

Notes: Costs do not include electrical, pumps, motors, etc. for the final production wells. (1) Includes, specifications, mobilization of test holes, installation, and development, and oversight.
(2) Includes test hole logging, aquifer testing, analysis, reporting and screen installation oversight.

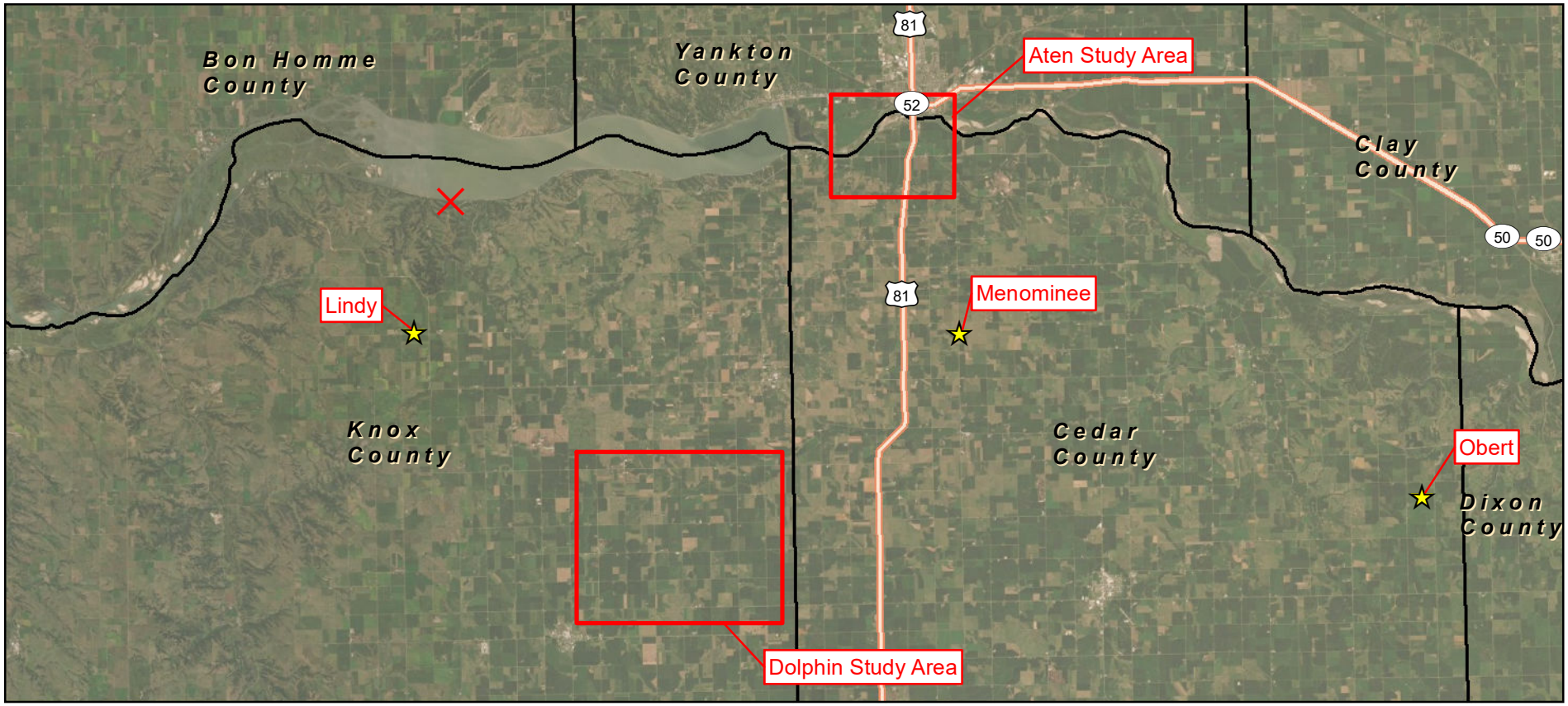
6.0 CONCLUSIONS

Based on the results of the Assessment, reviewing previous work, and discussion with CSD and B&W, both sites have their advantages and disadvantages, which are summarized in **Table 3**.

Based on this information that is currently available, the recommended site for further exploration is the Dolphin Site

Table 1. Pros and Cons of the Dolphin Site and Aten Site

Site	Pros	Cons
Dolphin (East Side)	Good saturated aquifer thickness and extent defined over most of the area	Additional test hole drilling and deeper aquifer to target other production wells
	Initial testing shows very good quantity	More testing needed to define aquifer characteristics at higher rates
	Low nitrates in vicinity of Test Well	Potential for nitrates to increase over time
	Low hardness compared to Aten	Elevated manganese levels
	Aquifer is less vulnerable to surface contamination with overlying till	Vulnerable area to the west near West Bow Creek Potential for well interference
	Appears higher nitrates to the west may be moving north-northeast	Need to verify groundwater flow direction
	Demand can be met with three wells	
Aten	Shallow aquifer less costly to construct	Highly vulnerable to surface contamination
	Recharge source from Missouri River	Potential for GUDISW
	Potential for high yields similar to Dolphin	No existing aquifer test data
	Vertical well option is less expensive to develop compared to Dolphin	High nitrates, manganese, sulfates, and hardens
		More investigation required to target well sites and design well field
		Appears four to five vertical wells may be needed to meet demand pending aquifer thicknesses and well field design



CNRWP Intake

Other Targeted Areas Considered

Study Areas Included in LRE Water 12/2021 Assessment

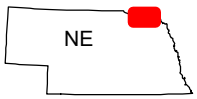
N

0 30,000 Feet

Notes:

Sources:

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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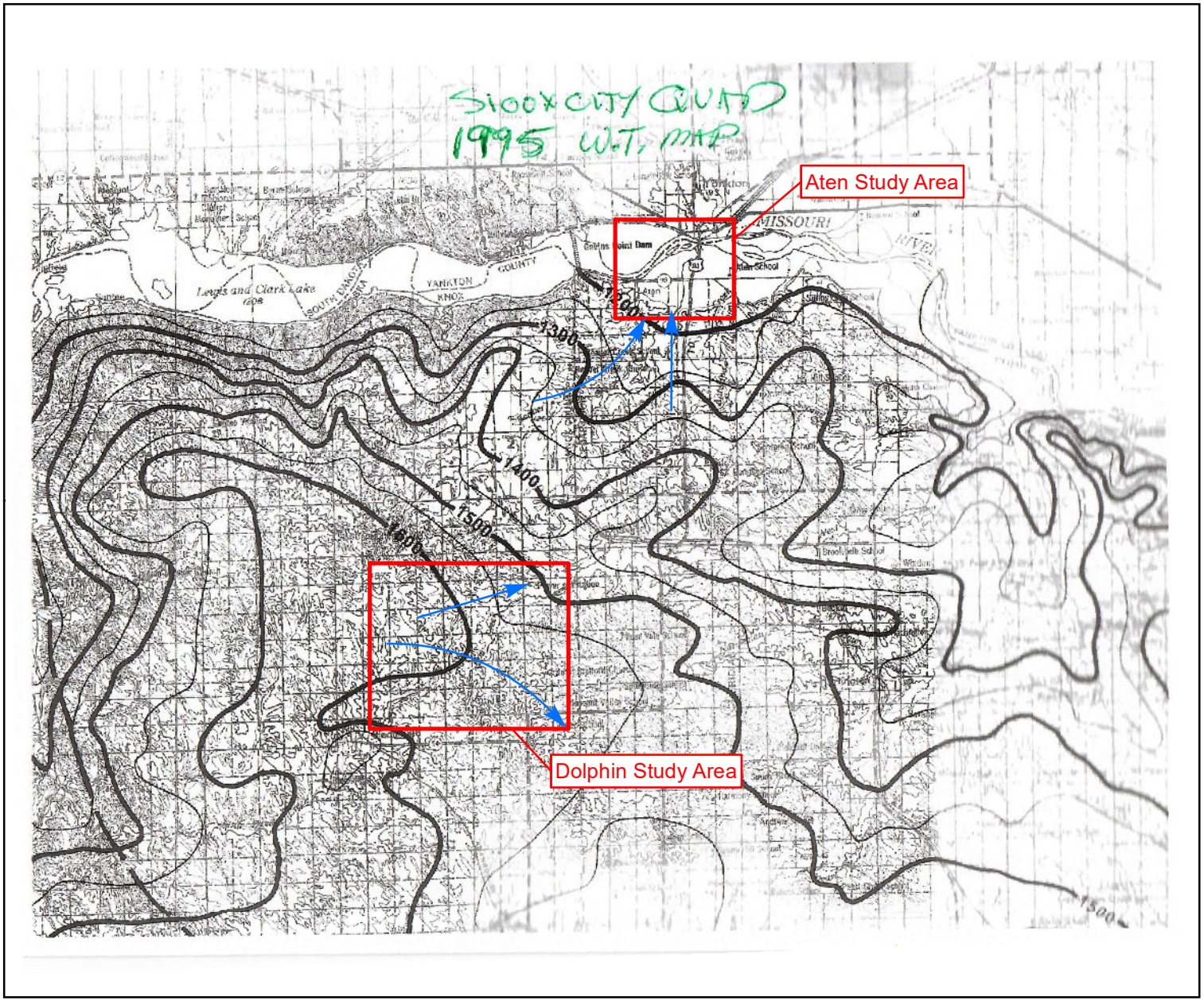
BARTLETT & WEST
CEDAR KNOX RURAL WATER PROJECT
KNOX COUNTY

LOCATIONS OF POTENTIAL GROUNDWATER SOURCE AREAS

FILE: BWCKRWP01d.MXD | DATE: 12/7/2021 | FIGURE: 1

C:\GIS\GIS\BW_Cedar_Knox_RWS\maps\BWCKRWP01d.mxd, 12/7/2021, 7:41:10 PM, NAD 1983 UTM Zone 14N

Groundwater Flow Direction



N

0 30,000 Feet

Notes:

If two values are listed for a well, typically the higher value was used for contouring.
In places, the thickness may include portions of the overlying Quaternary sand and gravel unit where the two units have similiar characteristics, making it difficult to differentiate.

Sources:

Service Layer Credits:

Map Provided by S. Lakey, CSD

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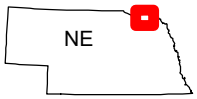

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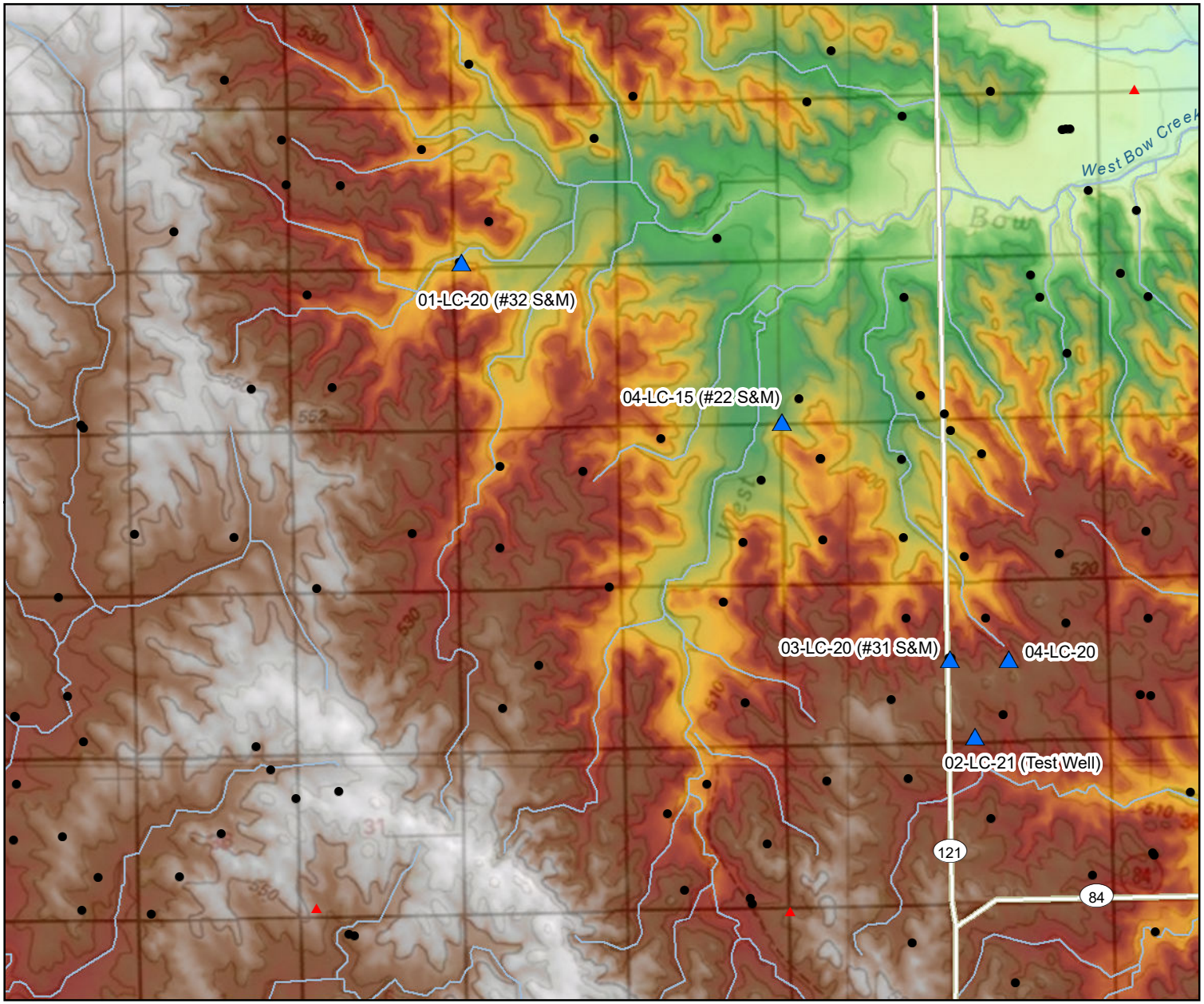
WATER LEVEL CONTOURS WITH DOLPHIN AND ATEN SITE LOCATIONS

FILE: BWCKRWP01I.MXD	DATE: 12/7/2021	FIGURE: 2



Notes:

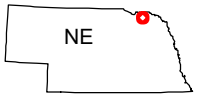
DEM clipped from Esri's online terrain dataset.

Sources:

Service Layer Credits: Copyright:© 2013 National Geographic Society, i-cubed

Cedar Knox Rural Water District Test Hole Locations: Provided by University of Nebraska-Lincoln staff.

Well Locations: Nebraska Wells Database.



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DOLPHIN SITE WELLS AND TEST HOLES

FILE: BWCKRWP01c.MXD | DATE: 12/8/2021 | FIGURE: 3

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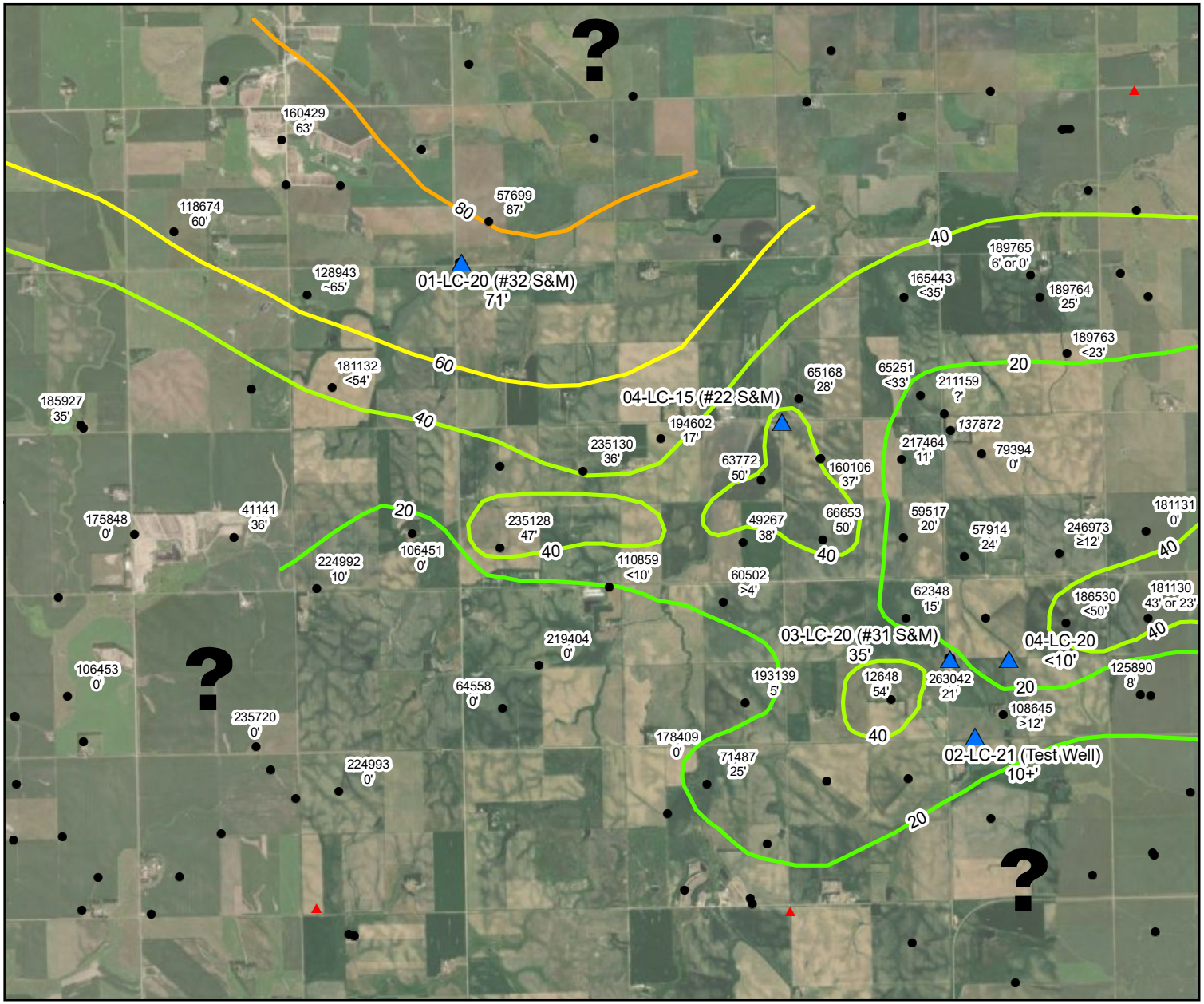

Notes:

If two values are listed for a well, typically the higher value was used for contouring.
In places, the thickness may include portions of the overlying Quaternary sand and gravel unit where the two units have similiar characteristics, making it difficult to differentiate.

Sources:

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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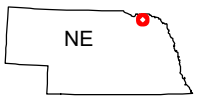

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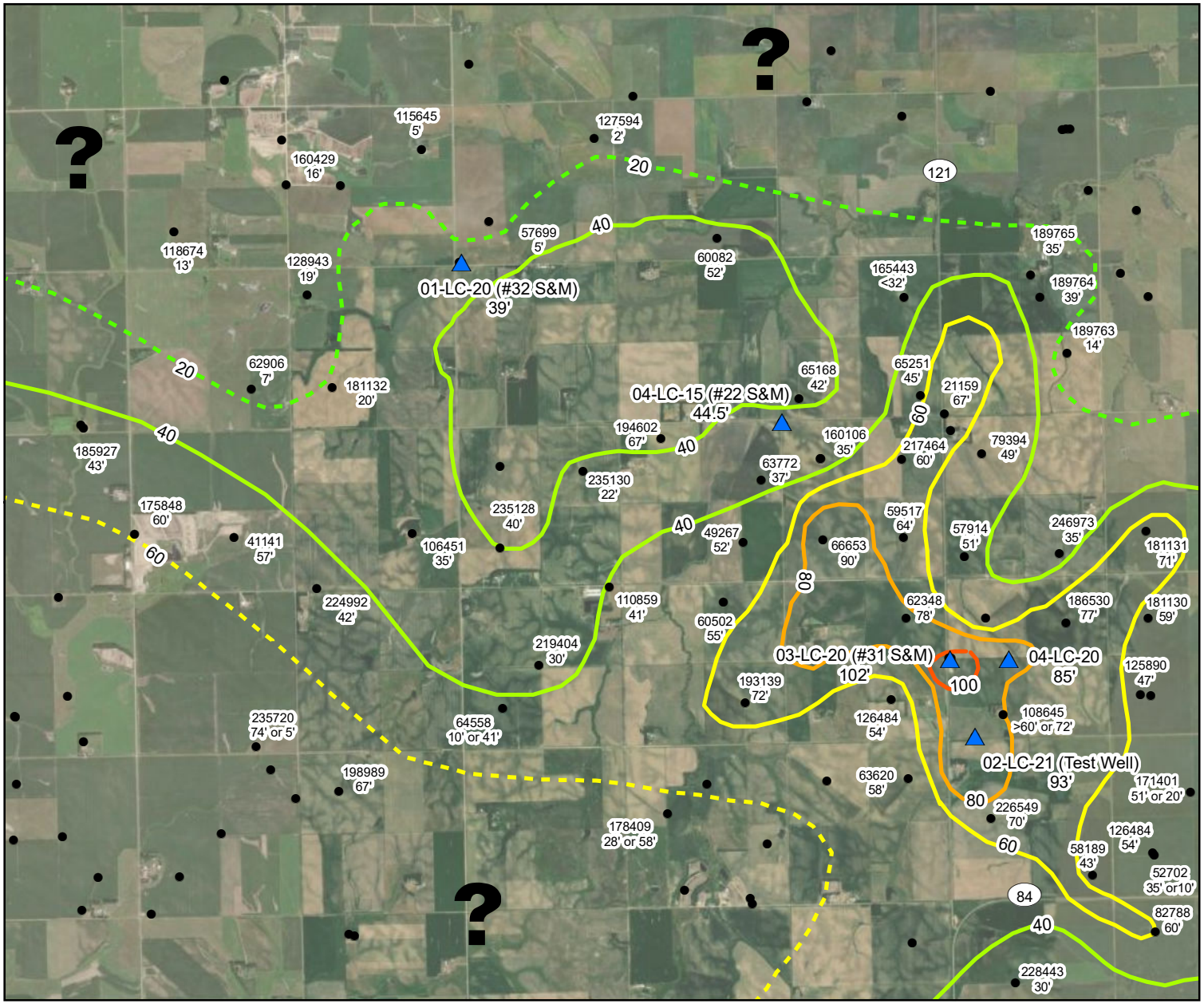
SATURATED THICKNESS (ISOPACH) OF TERTIARY OGALLALA AQUIFER - DOLPHIN SITE

FILE: BWCKRWP01e1.MXD	DATE: 12/8/2021	FIGURE: 4



Dolphin Area Test Hole Logged by CSD
Refers to Shallow (S) and Middle (M) Depth Observation Wells and Aquifer Thickness (in feet) Below

Nebraska Registered Well With Registration Number (57699) and Aquifer Thickness (in feet) Below

Nebraska CSD Test Hole

Saturated Thickness Contour Lines, Dashed where Inferred (ft)

20
40
60
80
100

? Saturated Thickness Not Mapped

N

0 5,000 Feet

Notes:

If two values are listed for a well, typically the higher value was used for contouring.
In places, the thickness may include portions of the overlying Quaternary sand and gravel unit where the two units have similiar characteristics, making it difficult to differentiate.

Sources:

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Cedar Knox Rural Water District Test Hole Locations: Provided by University of Nebraska-Lincoln staff.

Well Locations: Nebraska Wells Database.

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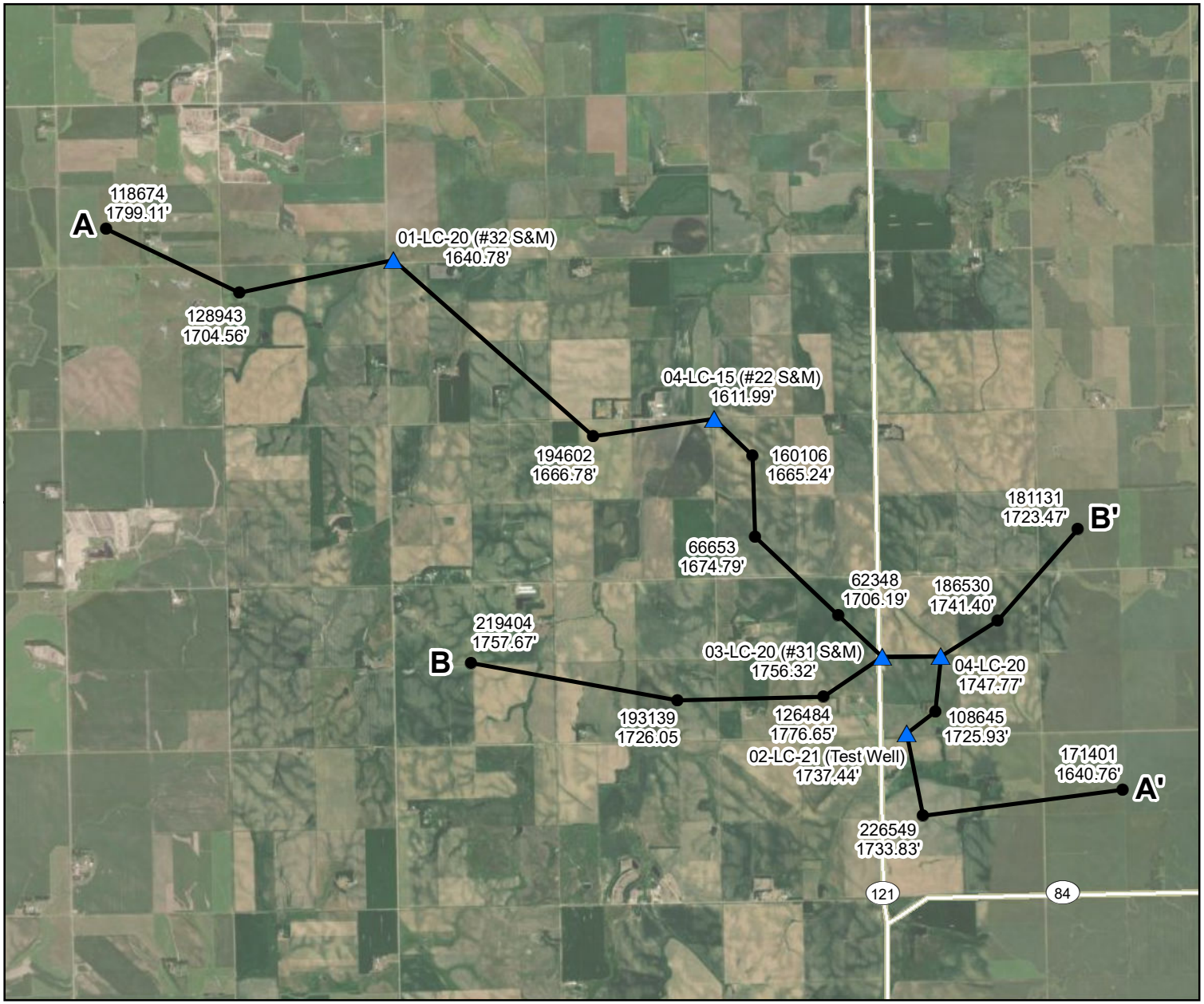
SATURATED THICKNESS (ISOPACH) OF QUATERNARY SAND AND GRAVEL AQUIFER
DOLPHIN SITE

FILE: BWCKRWP01g.MXD | DATE: 12/8/2021 | FIGURE: 5



Dolphin Area Test Hole Logged by CSD

Nebraska Registered Well

118674 —— Unique NE Well ID / TH ID
1799.11' —— Grade Elevation (feet)

N

0 5,000 Feet

Notes:

Sources:

Cedar Knox Rural Water District Test Hole Locations: Provided by University of Nebraska-Lincoln staff.

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Well Locations: Nebraska Wells Database.

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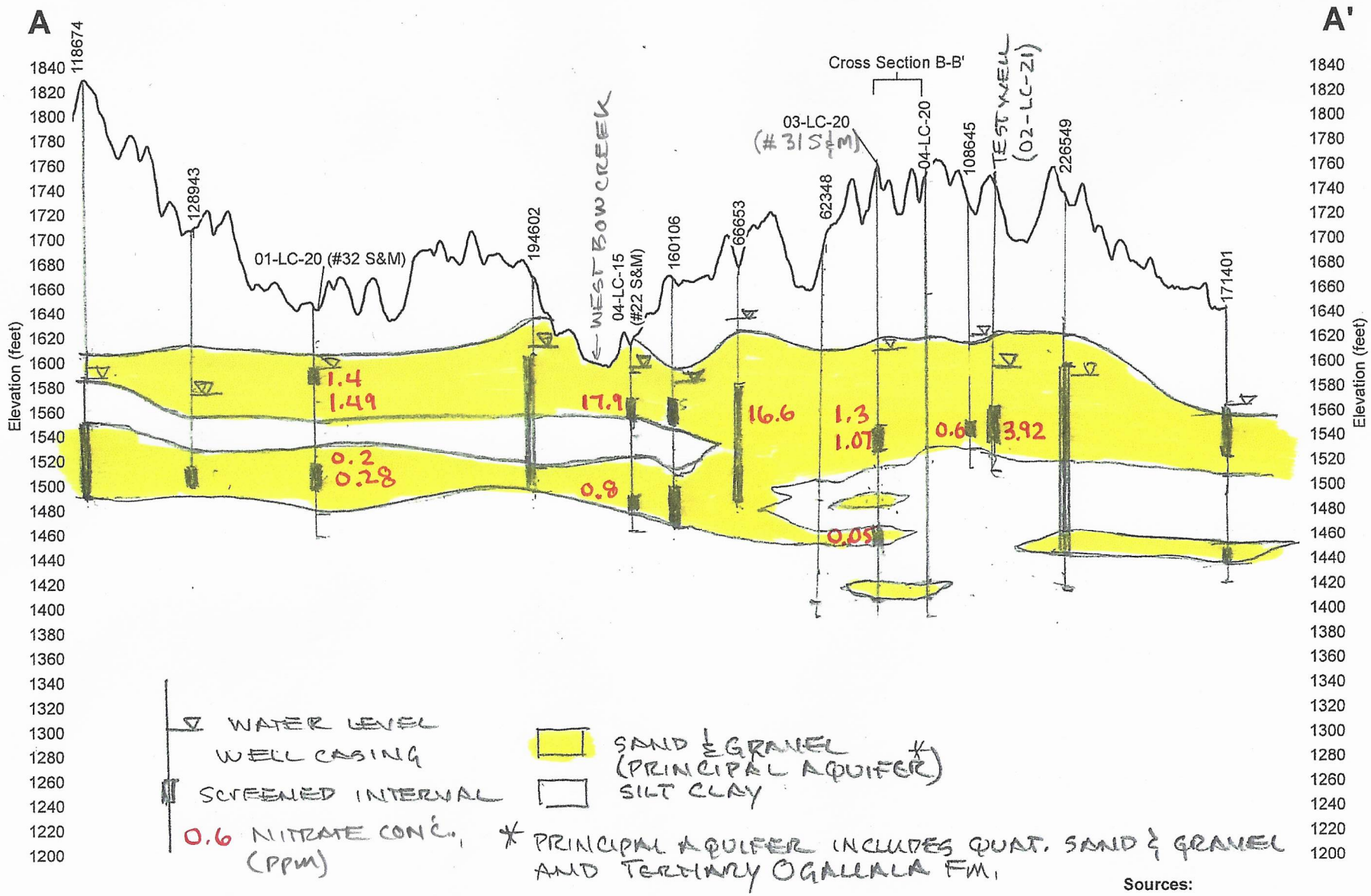
HYDROGEOLOGIC CROSS SECTION TRANSECTS - A-A' AND B-B'

FILE: BWCKRWP01h.MXD	DATE: 12/7/2021	FIGURE: 6



C:\GIS\GIS\BW Cedar Knox RWS\maps\BWCKRWP01i - xsectA-A.mxd, 12/6/2021, 12:27:02 PM, NAD 1983 StatePlane Nebraska FIPS 2600 Feet

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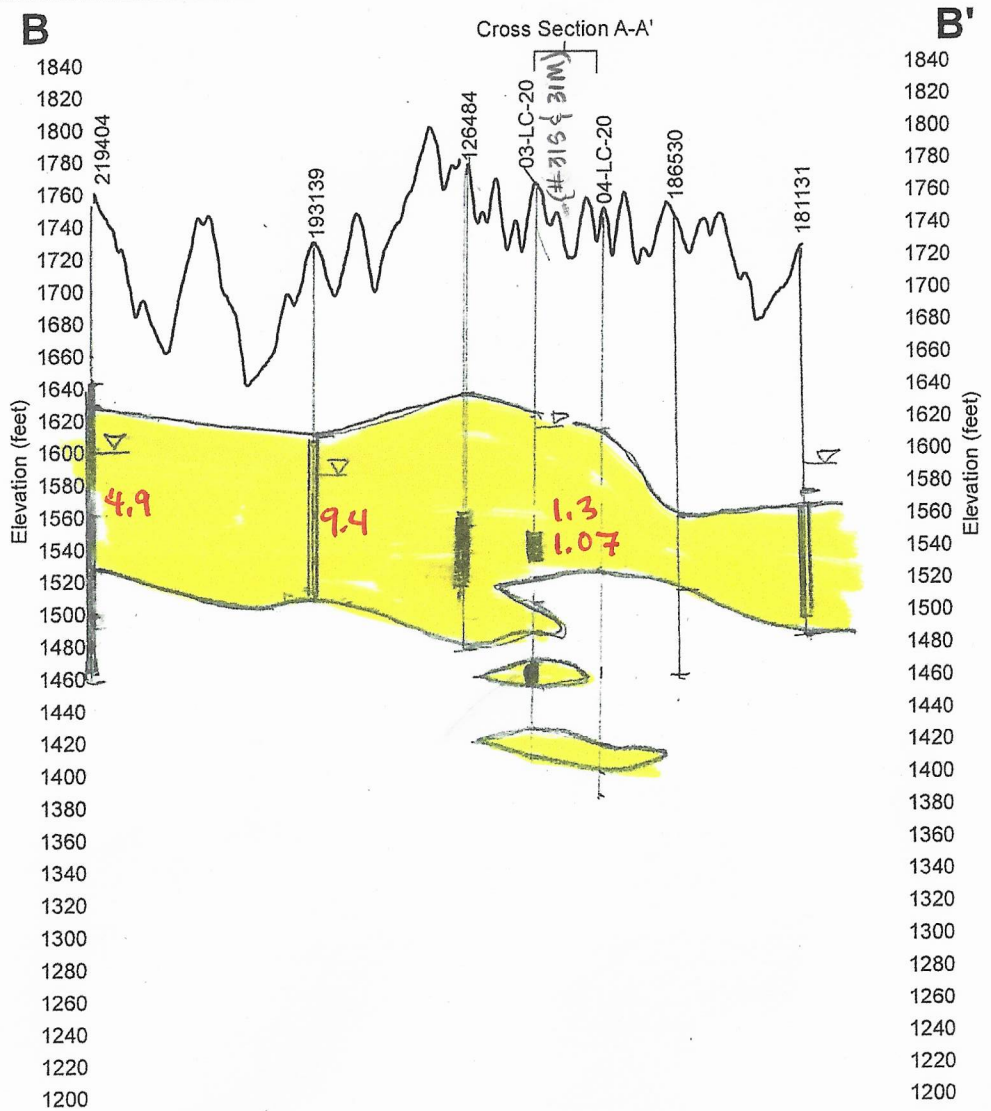
HYDROGEOLOGIC CROSS SECTION A-A'

FILE: BWCKRWP01i - xsectA-A.MXD | DATE: 12/6/2021 | FIGURE: 7

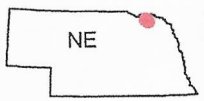


0 6,000 Feet

One inch vertical equals 120 feet
One inch horizontal equals 6,000 feet
Use 60 Scale on Engineers Ruler

Sources:

Geologic logs from Nebraska wells database and Cedar Knox Rural Water.



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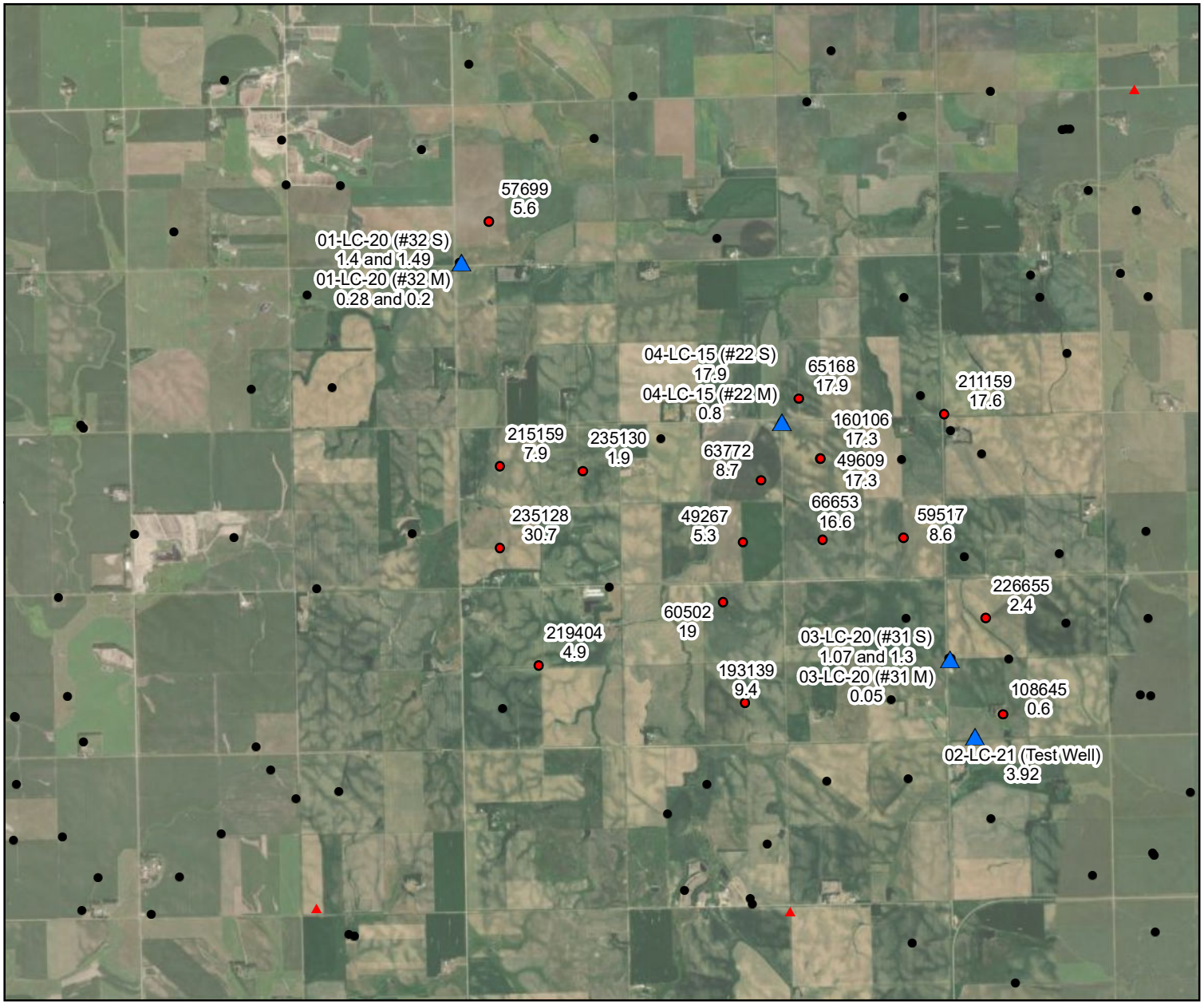
HYDROGEOLOGIC CROSS SECTION B-B'

FILE: BWCKRWP01i - xsectB-B.MXD | DATE: 12/6/2021 | FIGURE: 8

C:\GIS\GIS\BW Cedar Knox RWS\maps\BWCKRWP01i - xsectB-B.mxd, 12/6/2021, 12:26:24 PM, NAD 1983 StatePlane Nebraska FIPS 2600 Feet



Dolphin Area Test Hole Logged by CSD and Completed as a Shallow (S) or Middle (M) Depth Observation Well with Nitrate Concentration (ppm)

Nebraska Registered Well With Registration number in (57699)

Nebraska Registered Well With Nitrate Concentration (ppm)

Nebraska CSD Test Hole

N

0 5,000 Feet

Notes:

Nitrate data is last recorded value

Sources:

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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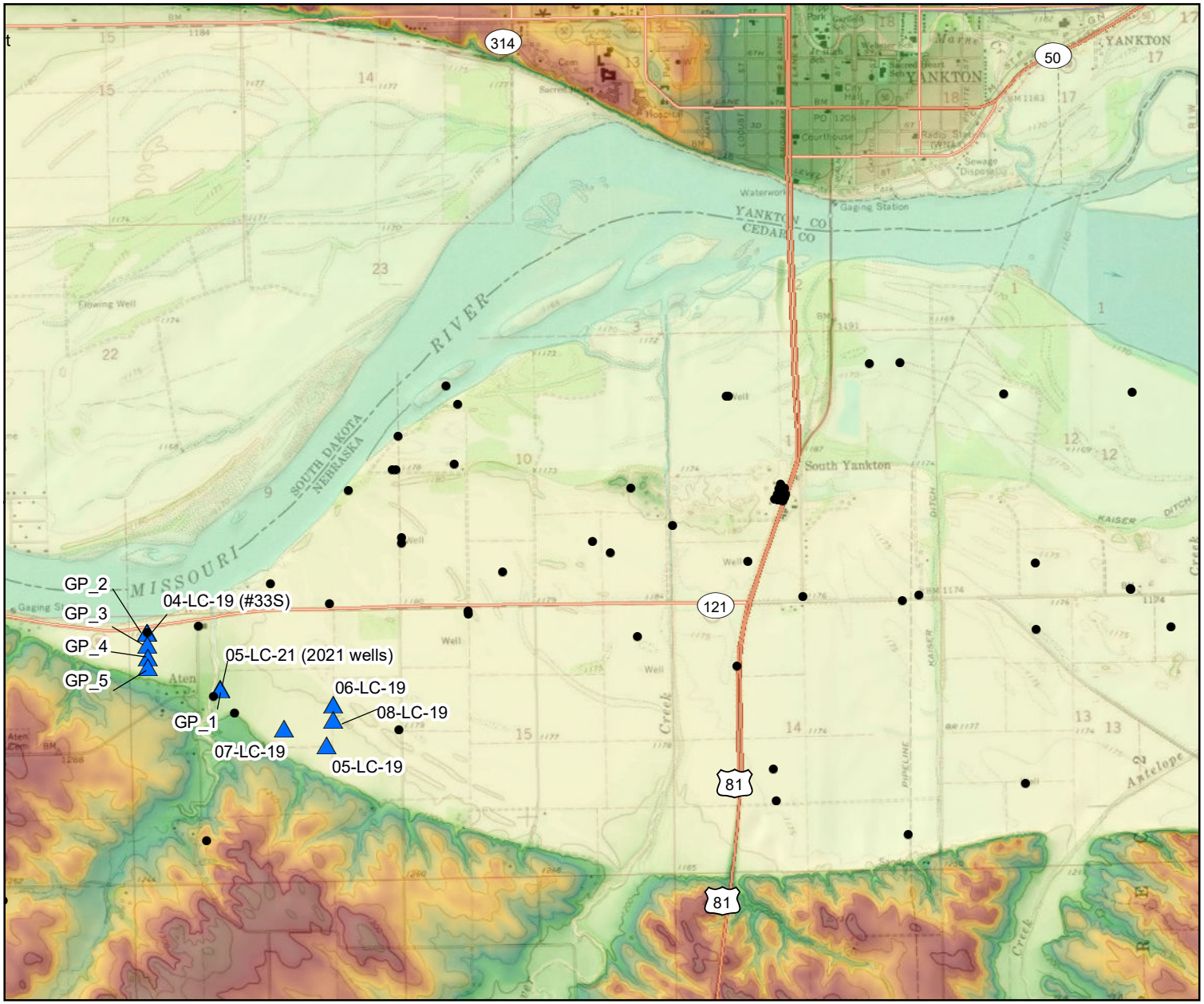
LAST REPORTED NITRATE CONCENTRATION (PPM) IN GROUNDWATER

FILE: BWCKRWP01j.MXD | DATE: 12/7/2021 | FIGURE: 9



Notes:

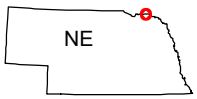
DEM clipped from Esri's online terrain dataset.

Sources:

Service Layer Credits: Copyright:© 2013 National Geographic Society, i-cubed

Cedar Knox Rural Water District Test Hole Locations: Provided by University of Nebraska-Lincoln staff.

Well Locations: Nebraska Wells Database.



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ATEN SITE WELLS AND TEST HOLES

FILE: BWCKRWP01f.MXD | DATE: 12/8/2021 | FIGURE: 10

C:\GIS\GIS\BW_Cedar_Knox_RWS\maps\BWCKRWP01f.mxd, 12/8/2021, 10:00:43 AM, NAD 1983 UTM Zone 14N

Aten Area Test Hole Logged by CSD

Nebraska Registered Well With Registration number (57699)

Refers to Shallow (S) and Middle (M) Depth Observation Wells

GP_1 (>65') Well Name (Saturated Sand Thickness)

N

0 1,000 Feet

Notes:

Sources:

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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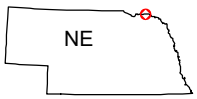

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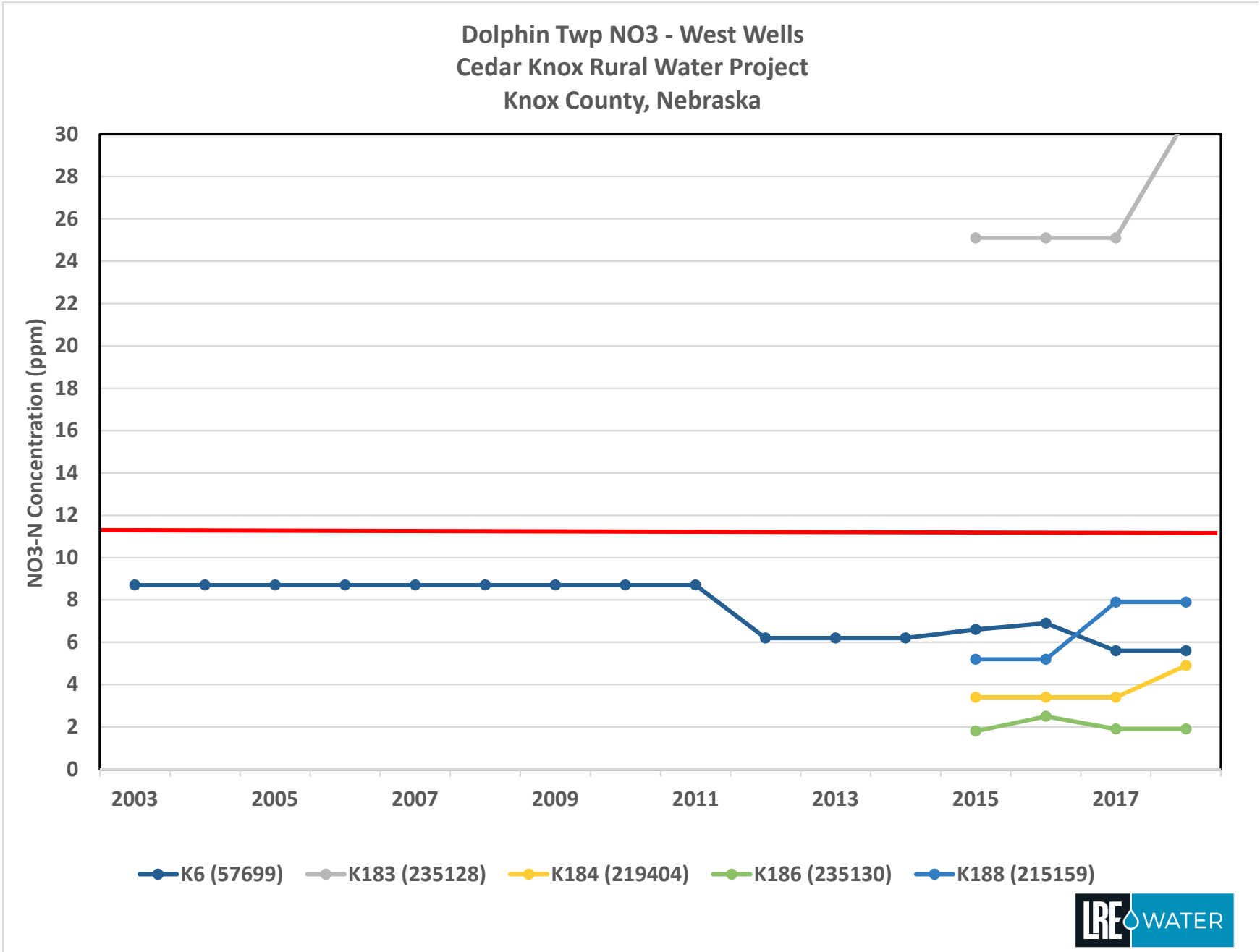
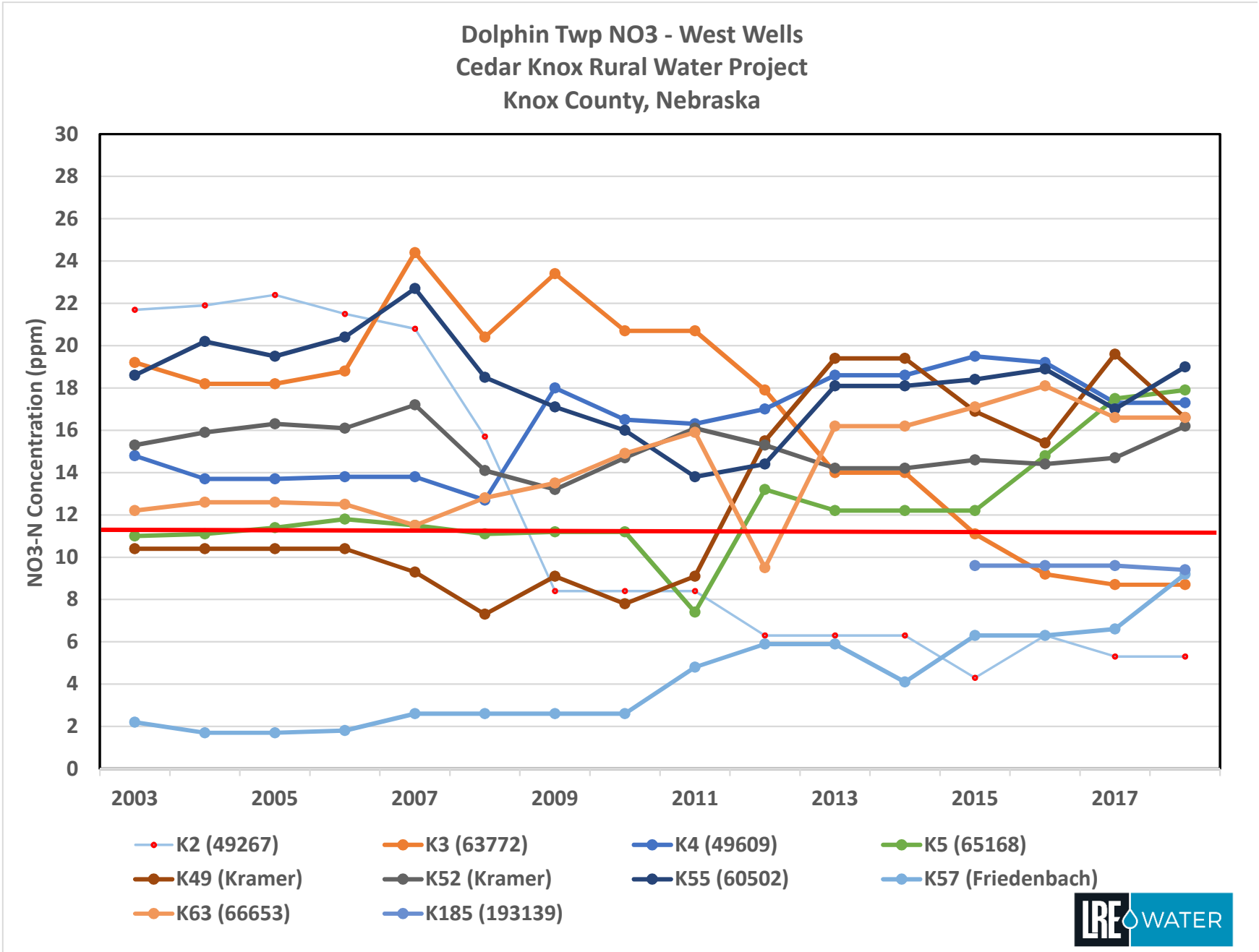
ATEN SITE SATURATED SAND THICKNESS

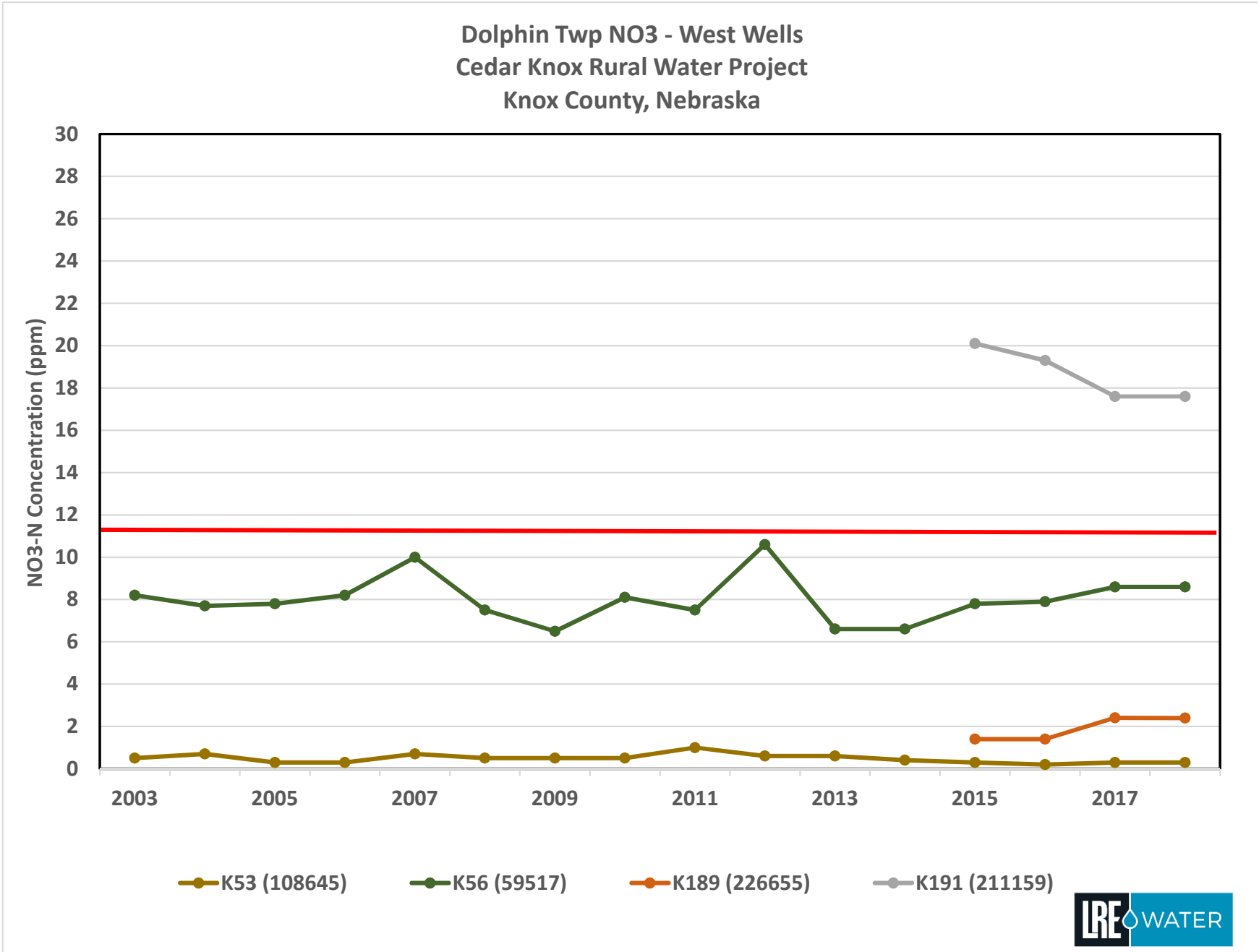
FILE: BWCKRWP01k.MXD | DATE: 12/7/2021 | FIGURE: 11

ATTACHMENT A

NITRATE CONCENTRATION PLOTS


Dolphin Twp NO3 - West Wells
Cedar Knox Rural Water Project
Knox County, Nebraska
NO3-N Concentration (ppm)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
2003
2005
2007
2009
2011
2013
2015
2017
K6 (57699)
K183 (235128)
K184 (219404)
K186 (235130)
K188 (215159)
LRE WATER


Dolphin Twp NO3 - West Wells
Cedar Knox Rural Water Project
Knox County, Nebraska
NO3-N Concentration (ppm)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
2003
2005
2007
2009
2011
2013
2015
2017
K2 (49267)
K3 (63772)
K4 (49609)
K5 (65168)
K49 (Kramer)
K52 (Kramer)
K55 (60502)
K57 (Friedenbach)
K63 (66653)
K185 (193139)
LRE WATER


Dolphin Twp NO3 - West Wells
Cedar Knox Rural Water Project
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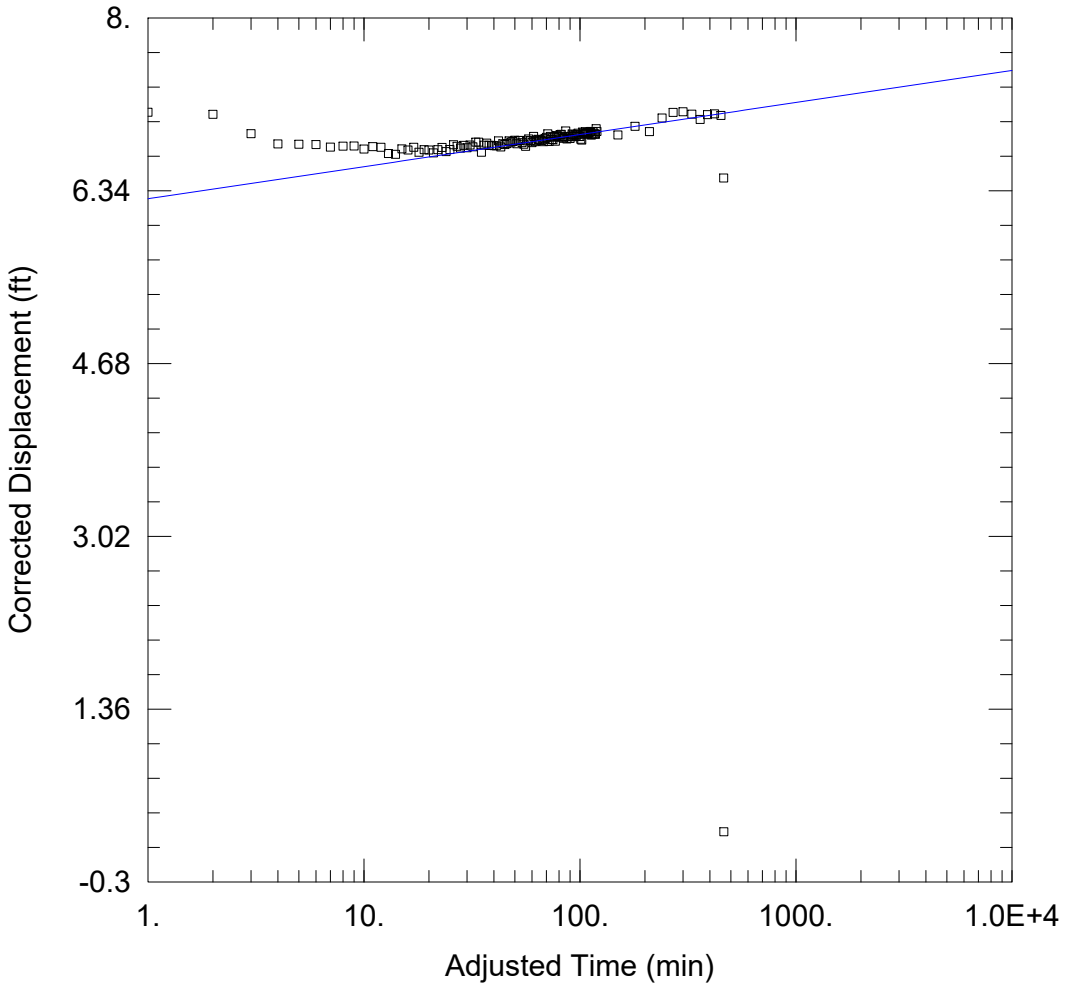
20
18
16
14
12
10
8
6
4
2
0
2003
2005
2007
2009
2011
2013
2015
2017
K53 (108645)
K56 (59517)
K189 (226655)
K191 (211159)
LRE WATER

ATTACHMENT B

8-HOUR PUMPING TEST RESULTS



WELL TEST ANALYSIS

Data Set: U:\...\Dolphin Test Well - CJ Unconfined.aqt
Date: 12/08/21 Time: 06:33:31

PROJECT INFORMATION

Company: LRE Water
Client: B&W
Project: 5002BAR06
Location: Nebraska
Test Well: Test Well
Test Date: 10-7-2021

AQUIFER DATA

Saturated Thickness: 61.8 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Dolphin Test Well	0	0

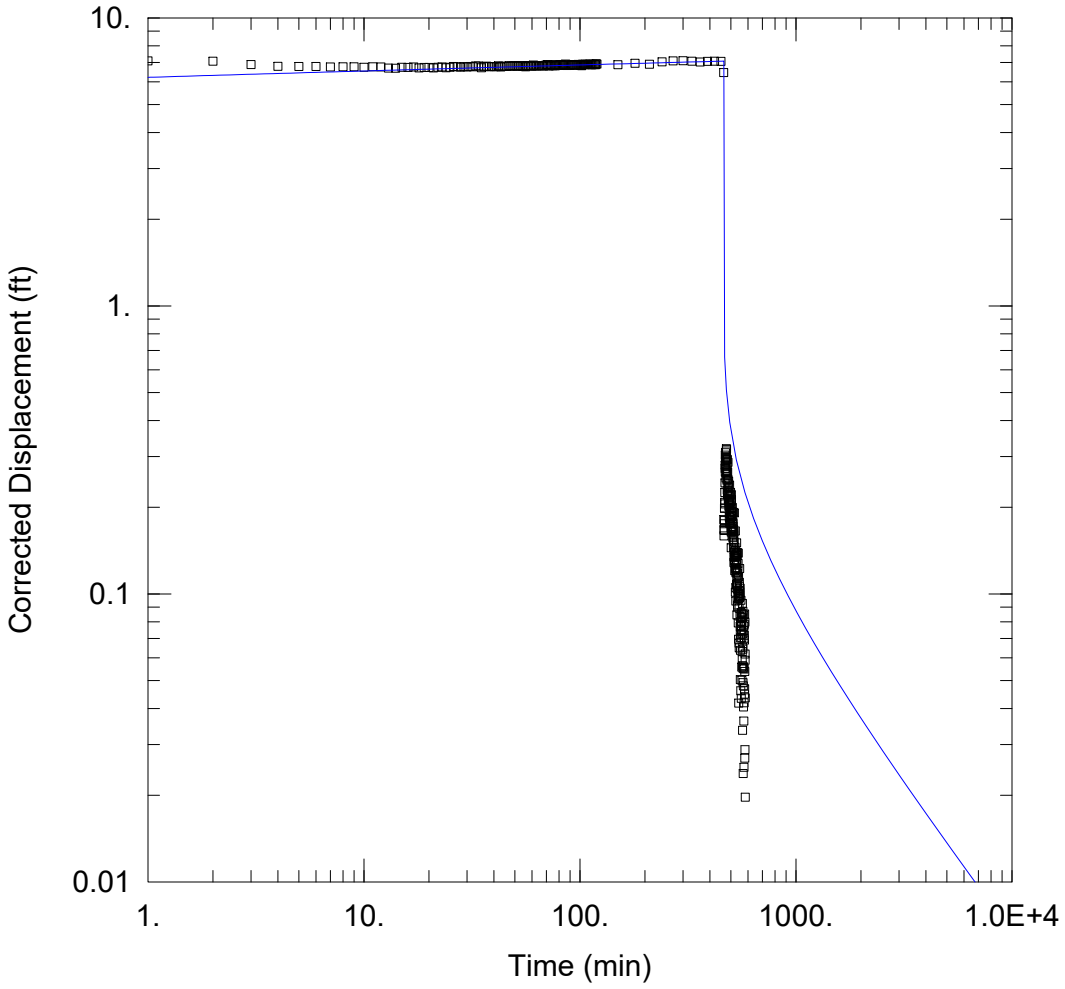
Observation Wells

Well Name	X (ft)	Y (ft)
Dolphin Test Well	0	0

SOLUTION

Aquifer Model: Unconfined Solution Method: Cooper-Jacob

T = 3.434E+4 ft^2/day S = 1.009E-18



WELL TEST ANALYSIS

Data Set: U:\...\Dolphin Test Well - Theis Unconfined.aqt
Date: 12/08/21 Time: 06:34:00

PROJECT INFORMATION

Company: LRE Water
Client: B&W
Project: 5002BAR06
Location: Nebraska
Test Well: Test Well
Test Date: 10-7-2021

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Dolphin Test Well	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ Dolphin Test Well	0	0

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 3.272E+4 ft^2/day
S = 1.862E-14
Kz/Kr = 1.
b = 61.8 ft

6.0 Next Steps

- **Once area for potential water supply is selected develop a specific testing plan for the location selected. (Covered in Section No. 5)**

- **Perform field testing, data collection, and prepare a report including:**
    - **Water quality data**
    - **Review of transmissivity.**
    - **Results of long-term flow testing at location of test wells.**

- **Pilot testing of anticipated treatment processes based on locations water quality.**

- **WTP Design Report including:**
    - **Detailed description of treatment process to be used.**
    - **Detailed layout of WTP**
    - **Detailed cost estimates based on specific treatment required.**
    - **O & M estimates developed for specific plant.**

- **Design Report Presented to the Cedar Knox Board and submitted to the State for review and approval.**

- **Prepare Design Documents for WTP, water supply wells, and transmission facilities.**

- **Submission of final design plans & specifications the NDEE for review and approval.**

- **Bidding of projects.**

- **Award of Bids and construction.**