WELL IMPACT ANALYSIS FOR THE MIDDLE TRINITY AQUIFER

Prepared for:

Barton Springs-Edwards Aquifer Conservation District

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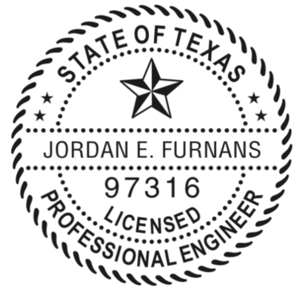

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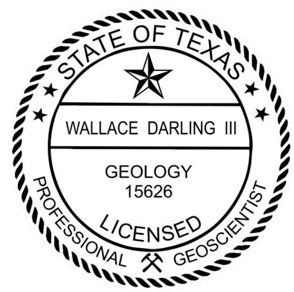

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EXECUTIVE SUMMARY

LRE Water ("LRE") provides herein a summary of work completed under the Barton Springs-Edwards Aquifer Conservation District ("BSEACD" or "District") Well Impact Analysis for the Trinity Aquifer (RFQ No. 1023-01). The purpose of the well impact analysis is to identify areas within the BSEACD and surrounding counties that are more vulnerable to water level declines to support the development of a regional sustainable groundwater policy. This study identified where declining groundwater conditions in the Middle Trinity Aquifer may impact existing and future wells.

The focus of this well impact analysis is on the Middle Trinity Aquifer, which is the primary groundwater resource for the central and western portions of Hays County and the south-central portion of Travis County. LRE and BSEACD developed a Modified Well Database consisting of 2,714 wells completed solely or dually in the Middle Trinity Aquifer and located in Hays and Travis counties. A subset of 452 wells out of a total of about 1,200 wells were located within the BSEACD boundaries. This subset of wells had well construction data available, which was crucial for performing the impact analyses. Based on discussions with the BSEACD, LRE believes the 452 wells to be representative of the spatial distribution and general well construction of Middle Trinity wells located within the BSEACD boundaries. Impacts to wells were evaluated on the basis of water levels theoretically falling below the top of the Middle Trinity Aquifer, the top of the screen, the total depth of the well, and coming within 20 feet of the pump. The well impact analysis indicated that generally, wells completed in the shallow updip portions of the Middle Trinity Aquifer (specifically in the western part of Hays County) are more susceptible to future water level declines. These areas are more likely to become unconfined as water levels decline. The database evaluation and development showed that pump information was available for a small proportion of wells within the entire dataset. A proxy was developed to assign hypothetical pump depths to wells for which actual pump depth information is unknown. This highlights the need for more pump depth data to better-inform future analyses and decision making.

Additional considerations in this analysis included limited well data and construction information, casing size limitations, and wells that are already considered to be impacted or more vulnerable to water level declines. These more vulnerable or already impacted wells currently have water levels below the top of the Middle Trinity Aquifer. Updates to the BSEACD well database will ensure that all well information is as accurate as possible, and that water level decline impacts can be properly mitigated.

Understanding of how broad regional declines in aquifer levels will impact existing wells is valuable for evaluating potential impacts to beneficial groundwater users and the environment. Continuous water level monitoring in the Middle Trinity Aquifer, specifically in areas where wells are vulnerable to water level declines, can lead to proactive groundwater management strategies and sustainable resource utilization.

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BFZ – Balcones Fault Zone
BSEACD – Barton Springs-Edwards Aquifer Conservation District
GMZ – groundwater management zone
HTGCD – Hays Trinity Groundwater Conservation District
LRE – LRE Water
SDR Database – Submitted Drillers Report Database
STCGCD – Southwestern Travis County Groundwater Conservation District
TWDB GWDB – Texas Water Development Board Groundwater Database

ft – feet
fbg – feet below ground
TD – total depth
TOS – top of screen
WL – water level

SECTION 1: INTRODUCTION

1.1 SCOPE OF WORK

The Trinity Aquifer is a primary groundwater resource in Hays County that provides drinking water to many residents as well as recharge to artesian springs and the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer. Having a better understanding of how broad regional declines in aquifer levels will impact existing wells is valuable for evaluating potential impacts to groundwater users and the environment.

The well impact analysis summarized herein was completed to support the BSEACD's development of a regional sustainable groundwater policy by identifying when and where declining groundwater conditions will impact existing wells. Available well data and well construction information were compared to varying groundwater levels to determine the number and location of wells impacted at a given water level.

The work undertaken by LRE was divided into three tasks. Task 1 of the Well Impact Analysis ("Well Database Review") included reviewing and assessing the BSEACD's existing well database for completeness for use in the well impact analysis. Task 2 ("Trinity Aquifer Designation") included assigning aquifers for wells in the BSEACD Modified Well Database created during Task 1. Task 3 of this effort ("Well Impact Analysis") included evaluating which wells would be impacted by theoretical water level decline scenarios.

1.2 STUDY AREA

The Barton Springs-Edwards Aquifer Conservation District (BSEACD) covers 430 square miles in parts of Travis, Hays, and Caldwell counties. The study area for this well impact analysis includes portions of the BSEACD, the Southwestern Travis County Groundwater Conservation District (STCGCD), and the Hays Trinity Groundwater Conservation District (HTGCD) in Travis and Hays counties. A map of the study area and GCD boundaries is provided in Figure 1.1.

The well impact analysis was conducted at three overlapping study areas, as shown in Figure 1.1: Study Area 1 includes the entire BSEACD jurisdiction. Study area 2 included only the southwest corner of BSEACD, and study area 3 included portions of the jurisdictions of the BSEACD, STCGCD, and HTGCD. The southwest corner of BSEACD (Study Area 2) was chosen as a focus area for the analysis as it is an area that may be particularly sensitive to water level declines. Study Area 2 is denoted on graphics as having a rectangular shape, yet our analysis of well impacts in this area is limited only to the portion of the rectangle also within the BSEACD.

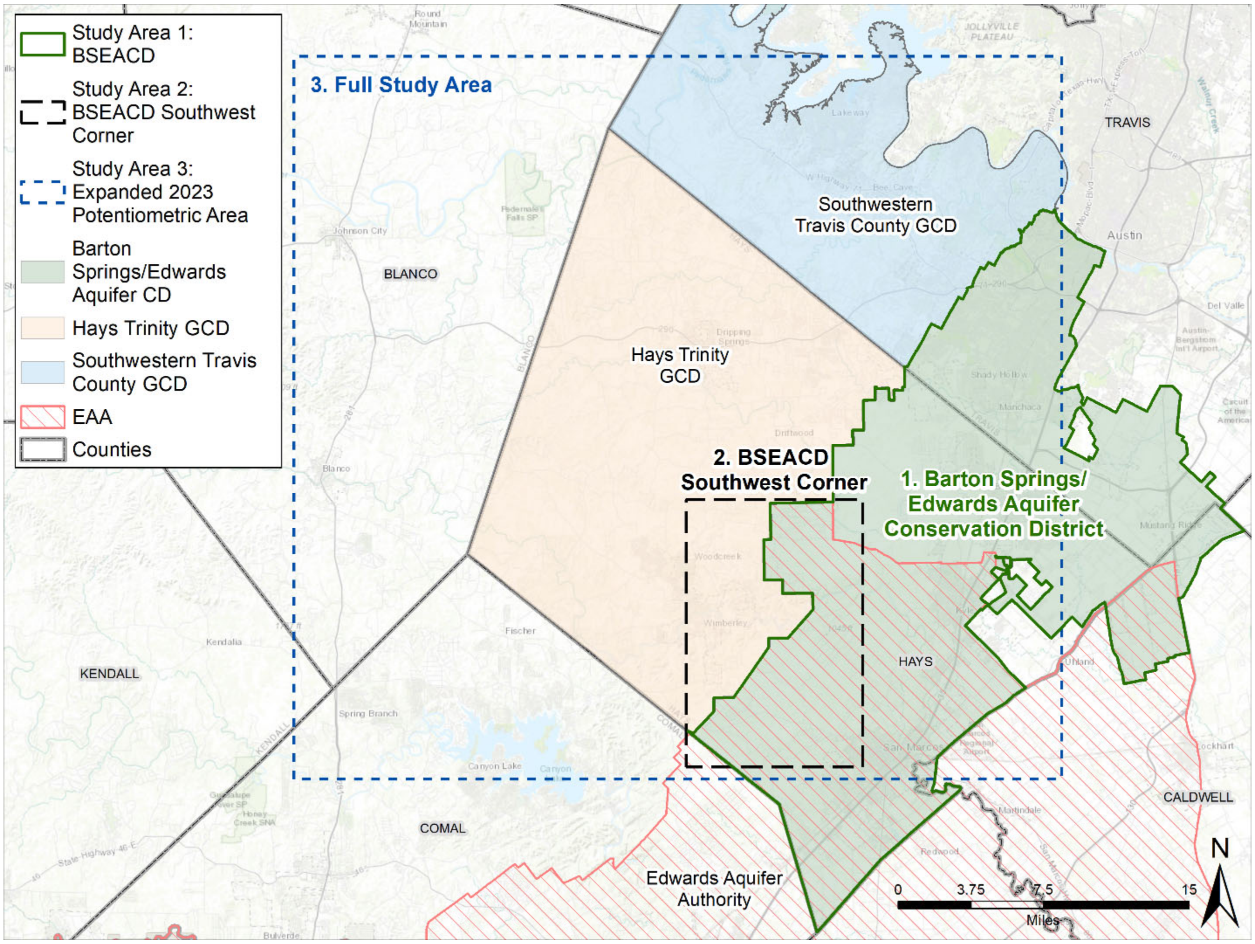


Figure 1.1: Map of study area showing the three spatial extents used in the well impact analysis.

1.3 TRINITY AQUIFER

The Trinity Aquifer is a primary groundwater resource in Travis and Hays counties, providing water of suitable quality for several uses including public supply, domestic use, irrigation, commercial use, and livestock. The Trinity Aquifer also provides recharge to artesian springs and the Barton Springs segment of the Edwards (Balcones Fault Zone) Aquifer. The aquifer outcrops in the western portion of Travis and Hays counties and is present in the subsurface in the eastern portion of the two counties.

The Trinity Aquifer is routinely subdivided into three units (from youngest to oldest): the Upper Trinity, the Middle Trinity, and the Lower Trinity. Stratigraphically, from highest to lowest, the Upper Trinity is comprised of the Upper Glen Rose Formation, the Middle Trinity is comprised of the Lower Glen Rose, Hensel, and Cow Creek formations, and the Lower Trinity is composed of the Sligo and Hosston Formations. This well impact analysis used data from previous studies conducted by the District (BSEACD, 2019; BSEACD, 2024), which focused primarily on the Middle Trinity Aquifer.

SECTION 2: TASK 1 – WELL DATABASE REVIEW

Under Task 1, LRE reviewed and assessed the BSEACD's existing well database for completeness for use in the well impact analysis. Specifically, the subtasks completed under this phase of work were to review the database for completeness with respect to the following well properties needed to perform a well impact analysis:

- Well coordinates (latitude/longitude);
- Well name and ID (District ID, State Well Number, and/or Well Tracking Number);
- Land surface elevation;
- Borehole and/or well depth;
- Well status (inactive, active/production, monitor, plugged, etc.);
- Well use (domestic, public supply, irrigation, industrial, etc.);
- Well type (withdrawal of water, spring, oil and gas well, etc.);
- Well construction (screen and casing depth intervals, well diameter, changes in well diameter); and
- Pump setting depth.

2.1 METHODOLOGY

LRE received the following project files from the BSEACD on February 13, 2024:

- *"all_records_unmerged.xlxs"*
- *"BSSEA_WELL_INVENTORY_14_09_2023.xlxs"*
- *"WELL_INVENTORY_METHODS.docx"*

In addition, LRE received the following project files on February 14, 2024 to assist with the database review:

- *"WellRegistration_SurveyMonkey_2023.kbe.xlsx"*
- *"CHC_WellDB_ForIntera.mdb"*
- *"DatabaseWellsLayer_230214_monitoring.xlsm"*
- *"WELLS_PROD4_062023.mdb"*

LRE reviewed the "*WELL_INVENTORY_METHODS.docx"* document to understand the methods BSEACD used to create their "master" well dataset. These methods were deemed satisfactory for the creation of a usable well dataset for the well impact analysis. The "*BSSEA_WELL_INVENTORY_14_09_2023.xlxs"* document (considered the "master well dataset" and referred to herein as "BSEACD Dataset") was reviewed and is the file from which the final dataset was based. The remaining files reviewed by LRE were not altered and did not contain information relevant for completion of this task.

The BSEACD Dataset contained 8,887 entries (rows) with a total of 68 fields (columns). Most of these columns indicate the data value with the original data source provided in parentheses, including: the Well Registration Database and CHC Database (“Reg”), Monitoring Well Spreadsheets (“Mon”), BSEACD Well Database (“District DB”), Texas Water Development Board Groundwater Database (“GWDB”), and the Submitted Driller’s Report Database (“SDR”). All the database fields (column names) in the BSEACD Dataset are provided below:

> Inventory ID, Potential Duplicates, State Well Number, Well Report Tracking Number, Original Well Report (SDR), Adjusted SWN (Reg), Adjusted SWN (District DB), Adjusted SWN (Mon), Well ID (GWDB), In District Database, Monitoring Status (Mon), Within District Boundaries, Well ID (Mon), Well ID (Reg), Well ID (District DB), Latitude (Reg), Longtidue (Reg), Latitude (Mon), Longitude (Mon), Latitude (District DB), Longitude (District DB), Latitude (GWDB), Longitude (GWDB), Latitude (SDR), Longitude (SDR), County (GWDB), County (SDR), Address (Reg), Address (District DB), Owner (Mon), Owner (Reg), Owner (District DB), Owner (GWDB), Owner (SDR), Drill Date (Reg), Drill Date (GWDB), Drill Date (District DB), Drill Date (SDR), Drill Date (Mon), Surface Elevation (Reg), Surface Elevation (GWDB), Surface Elevation (District DB), Surface Elevation (Mon), Borehole Depth (Reg), Borehole Depth (GWDB), Borehole Depth (District DB), Borehole Depth (SDR), Borehole Depth (Mon), Screen Depths (GWDB), Screen Depths (SDR), Casing Depth (Reg), Pump Depth (Reg), Pump Depth (SDR), Pump Depth (GWDB), Borehole Diameter Inches (Reg), Casing Diameter Inches (Reg), Casing Diameter (District DB), Aquifer Code (District DB), Well Type (District DB), Well Type (Reg), Datasource (Reg), Method of Construction (District DB), Type of Lift (District DB), Type of Power (District DB), Horespower (District DB), Screen Material (District DB), Notes (Reg), Comments (GWDB).

Two spelling errors were identified and corrected: “Longtidue (Reg)” to “Longitude (Reg),” and “Horespower (District DB)” to “Horsepower (District DB).”

LRE created a new dataset (“*LRE_MOD_ 3_12_24.xlxs*” herein referred to as “LRE Modified Dataset”) to track the changes and modifications made to the BSEACD Dataset. An initial review of the BSEACD Dataset was conducted to identify missing or incorrect data required for the well impact analysis. Table 2.1 outlines the “flagging” criteria established by LRE to identify well records in the BSEACD Dataset for which information was missing or incomplete. Customized queries were created for each flagging criterion to automate the flagging process. A new column named “Inventory_Flag_Data” was added to the LRE Modified Dataset, which lists the corresponding flag value(s) using LRE’s criteria outlined in Table 2.1.

Table 2.1: Flagging criteria for the BSEACD Dataset

Parameter	Flag	Description of Flag	Column(s)
Location	1	All well coordinate columns checked. Flagged for missing or incomplete data. Checked for location accuracy and update coordinates if incorrect.	Latitude (Reg), Longitude (Reg), Latitude (Mon), Longitude (Mon), Latitude (District DB), Longitude (District DB), Latitude (GWDB), Longitude (GWDB), Latitude (SDR), Longitude (SDR)
Well Name /ID	2	All well ID columns checked. Flagged if well name or ID is missing or incomplete.	State Well Number, Well Report Tracking Number, Well ID (GWDB), Well ID (Mon), Well ID (Reg), Well ID (District DB)
Surface Elevation	3	All surface elevation columns checked. Flagged for missing or incomplete data.	Surface Elevation (Reg), Surface Elevation (GWDB), Surface Elevation (District DB), Surface Elevation (Mon)
Depth	4	All depth columns checked. Borehole depths were compared to reported depths in the *"WellLithology.txt"* and *"WellStrata.txt"* files for wells in the SDR Database. Flagged for missing, incorrect or incomplete data.	Borehole Depth (Reg), Borehole Depth (GWDB), Borehole Depth (District DB), Borehole Depth (SDR), Borehole Depth (Mon), Casing Depth (Reg)
Well Status	5	Monitoring well status column checked. Flagged for missing or incomplete data	Monitoring Status (Mon)
Well Use Type	6	All well type columns checked. Flagged for missing or incomplete data.	Well Type (District DB), Well Type (Reg)
Screen Depths	7	All screen depth columns checked. Flagged for missing or incomplete data.	Screen Depths (GWDB), Screen Depths (SDR)
Casing/ Borehole Diameter	8	All casing diameter and borehole columns checked. Flagged for missing or incomplete data.	Casing Diameter, Inches (Reg), Casing Diameter (District DB)
Pump Depth	9	All pump depth columns checked. Flagged for missing or incomplete data.	Pump Depth (Reg), Pump Depth (SDR), Pump Depth (GWDB)

Upon the initial review and flagging of the BSEACD Dataset, LRE proceeded with the following six (6) sequential steps for the Database Review:

Step 1. Downloaded all records from the Texas Water Development Board Groundwater Database (GWDB) and Submitted Drillers Report (SDR) Database on February 14, 2024, which included *"WellMain.txt"*, *"WellCasing.txt", "WellTest.txt",* and *"WellBorehole.txt"* text files from the TWDB GWDB, and *"WellData.txt"*, *"WellBorehole.txt", "WellCasing.txt", and "WellTest.txt"* text files from the SDR Database. LRE created customized python scripts to generate a master file for each downloaded text file.

Step 2. Merged the downloaded files from the GWDB and SDR Database. In both the GWDB and SDR Database, text fields such as "MigratedCasingInfo", "Comments", and "Remarks" contain valuable information regarding the well construction, pump test data, and other pertinent well information. LRE developed python scripts to extract and sort the data from these text files into their respective columns in the LRE Modified Dataset. LRE reviewed the extracted data by conducting a manual QA/QC review to ensure accuracy.

Step 3. Compiled merged data downloaded from the GWDB and SDR Database with the BSEACD Dataset in the LRE Modified Dataset. LRE added a new column labeled 'Key_ID' to the LRE Modified Dataset to issue a unique identifier to each row, as previous methods used to merge the BSEACD Dataset and SDR/GWDB databases created multiple entries in the 'Inventory_ID' column and therefore did not allow for a "proper" unique identifier. LRE developed python scripts to filter and combine the appropriate fields into a usable and readable format. To further ensure that each well in the dataset was unique, LRE used spatial analysis techniques in ArcPro to identify wells that were within 10 feet of each other. These wells were noted in a new column in the LRE Modified Dataset called 'Spatial_Duplicates_ID' which contained values of the duplicate well 'Key_ID'.

Step 4. LRE assigned surface elevations to all well records based on the 2017 Central Texas LiDAR Digital Elevation Model (DEM) and entered those values in a new column labeled 'LiDAR_Elevation' in the LRE Modified Dataset. The 2017 Central Texas DEM is the most recent elevation dataset for the area (StratMap, 2017).

Step 5. As a separate project, LRE is currently involved with developing a dashboard and analytical tool for the BSEACD. The dashboard contains well data with aquifer designations for well completion, specifically for the "Upper Trinity, Middle Trinity, and Lower Trinity" aquifers. LRE downloaded all the well data from the dashboard and created a query to merge this dataset with the LRE Modified Dataset. The only information from the dashboard that was included in the LRE Modified Dataset is the aquifer designation.

Once data from the other sources had been added to the LRE Modified Dataset, LRE created a new column in the LRE Modified Dataset called 'LRE_Added_Flag' to indicate where data had been added by LRE for the records in the BSEACD Dataset that were flagged using the criteria outlined in Table 2.1. LRE developed queries (in Python) to identify flag data that had been added by LRE, and the corresponding flag value(s) are listed under the 'LRE_Added_Flag' column. LRE added a new column named 'Remaining_Flagged' to the LRE Modified Dataset, which flags records that were still missing information after LRE's database processing efforts. Table 2.2 provides a description of all the columns within the LRE Modified Dataset.

The quality assurance and quality control (QA/QC) process included manually reviewing the 'Remaining_Flagged' column in the LRE Modified Dataset and filling in missing or incorrect information. In addition, LRE reviewed any conversion or location errors within the LRE Modified Dataset and noted any additional corrections made to the dataset that were not detected in the automated flagging process.

A finalized technical memorandum detailing the methodology and results from Task 1 is provided in Appendix A.

Table 2.2: LRE Modified Dataset Column Descriptions

Column Name	Description
Key_ID	LRE-assigned unique identifier
Inventory_ID	Well identifier from the BSEACD Dataset (INTERA-assigned). Can contain multiple values separated by ","
District_ID	District-assigned well identifier. Based on the grid location of the well and the owners initials
StateWellNumber	Texas Water Development Board (TWDB) Database State Well Identification number
WellReportTracking Number	Submitted Drillers Report (SDR) Database Well Identification number
Address	Physical address of the well. Provided by District
Aquifer_TWDB	TWDB-assigned aquifer code and name
Aquifer_District	Aquifer assigned to well from BSEACD dashboard
Latitude	NAD 83 latitude for the well location, in decimal degrees
Longitude	NAD 83 longitude for the well location, in decimal degrees
Well_Use	TWDB-assigned, primary use of the water (ex. Domestic, irrigation, industrial, livestock)
Well_Type	TWDB-assigned, primary use of the well (ex. Withdrawal of water, spring, oil or gas)
Well_Status	Well permit/production status, District-assigned (ex. Exempt, non-exempt)
Surface_Elevation	Surface elevation of the well based on reported values from all datasets (BSEACD, GWDB, SDR), in feet above mean sea level
LiDAR_Elevation	Surface elevation, in feet mean sea level. If elevation was not available from the BSEACD Dataset, then this field includes surface elevation from LiDAR data (2017 Central Texas LiDAR DEM), in feet above mean sea level
Borehole_Depth	Depth of the borehole, in feet below land surface
Well_Depth	Depth of the well, bottom of casing or screen, in feet
Casing_Depth	Depth of the bottom of the casing, in feet. Value may be where the screen starts
Casing_Diameter	Outer casing diameter, in inches
Borehole_Diameter	Diameter of borehole, in inches
Borehole_Changes	Depth interval for each change in borehole diameter, in feet below land surface
Casing_Changes	Depth intervals for each change in diameter, in feet below land surface
Screen_Intervals	Screen Interval, in feet below ground level. [(top of screen 1, bottom of screen 1), (top of screen 2, bottom of screen 2)]

Table 2.2 continued

Column Name	Description
Pump_Depth	Depth of pump in the well, in feet
Water_Level	Most recent water level measurement, in feet below land surface
Yield	Yield of water from pump test, in gallons per minute
Drawdown	Amount of total drawdown in the well from pump test, in feet
Hours	Hours of pumping from pump test
MigratedCasingInfo	Text field from TWDB GWDB/SDR Database, contains well construction information
Inventory_Flag_Data	List of values that represent flags for missing data in the BSEACD Dataset
LRE_Added_Data	List of values that represent flags for data that was added by LRE
Remaining_Flag	List of values that represent flags for missing data after adding data from other sources
Spatial_Duplicate_ID	Duplicates of wells identified from a spatial query. Value is the Key ID of the duplicate well
Distance_ft	Distance from the main well and the spatial duplicate, in feet

SECTION 3: TASK 2 – TRINITY AQUIFER DESIGNATION

Under Task 2, LRE used well completion information, including surface elevation, well depth, screen interval, and well location from the LRE Modified Well Database to designate aquifers for wells in the database (e.g., Edwards, Upper Trinity, Middle Trinity, Lower Trinity). LRE employed spatial analyst tools in ArcGIS (ArcMap version 10.8.1 and Pro version 3.3.0) to develop and extract formation depths from aquifer elevation surfaces. Aquifer units were assigned to each Trinity Aquifer well record in the database where well construction information was reported ("Upper Trinity", "Middle Trinity", or "Lower Trinity").

3.1 METHODOLOGY

LRE used the LRE Modified Well Database from Task 1 in this analysis and proceeded with the following steps. The final database from this task, which added additional fields (columns) to the LRE Modified Well Database, is herein referred to as the BSEACD Modified Well Database.

Step 1. Extracted stratigraphic picks from the "*BSEACD_GeologyContacts.gdb*" file provided by BSEACD;

Step 2. Developed aquifer structure elevation surfaces using geoprocessing tools in ArcGIS ("Topo to Raster"). Aquifer surfaces were created from stratigraphic picks in the BSEACD Geology database in units of feet above mean sea level and feet below land surface;

Step 3. Appended formation depths from each aquifer surface to wells in the database using spatial analyst tools in ArcGIS;

Step 4. Assigned aquifer(s) based on the relationship between the formation depths and well construction setting depth information; and

Step 5. Manually reviewed well records where wells were identified as dual completed, open hole, located near structural features (i.e. faults), or where well construction information was limited.

3.1.1 Assumptions

The following assumptions were used while designating aquifer completions for wells in the BSEACD Modified Well Database:

1. Where screen intervals were reported and set entirely within an aquifer extent, LRE assigned the well completion to the aquifer that confined the screen interval;
2. Wells with multiple screen intervals or where screen was set within multiple aquifer extents were assumed to be "dual completed" and were flagged for further assessment;
3. Wells with reported "open hole" screen intervals were flagged for further assessment;
4. Where 20 feet or more of an aquifer was screened, that aquifer was assigned to the well;
5. Dual-completed wells were assumed when screen intervals were set at least 20 feet or more into multiple formations;
6. If screen intervals were not reported, LRE used the well depth and/or borehole depth to assign aquifer completions. It was assumed that screen was set within the bottom 50 feet of a well;
7. Wells with reported "open hole" completions that were drilled into the Hammett Shale were assumed to produce from the overlying formation(s). Any wells that penetrate the Hammett Shale will not remain "open" after completion, as the formation swells and naturally fills open annular space, thereby acting as a "bottom plug" to seal the borehole;
8. Where no well construction information was available (including screen interval, well depth, and/or borehole depth) aquifer designations were classified as "Unknown"; and
9. Wells located east of the US Highway I-35 within the Balcones Fault Zone (BFZ) were reviewed in more detail due to the complex geology caused by local faulting. In some instances, shallow formation offsets were used to estimate offsets for the deeper Trinity Aquifer units.

Well records that were marked as dual-completed, open hole, or located in faulted areas were flagged for further assessment. During the QA/QC process, all wells were spatially georeferenced, and aquifer designations were compared to designations of surrounding wells. In addition, LRE reviewed the stratigraphic picks and assessed aquifer depths from surrounding wells, characteristic geophysical log signatures, and lithologic reports to assist with designating aquifer completions.

3.2 RESULTS

Table 3.1 summarizes the number of wells in the BSEACD Modified Well Database that were designated with an aquifer completion. Table 3.2 summarizes the number of wells with aquifer designations using the BSEACD aquifer classifications (Edwards BFZ, Upper Trinity, Middle Trinity, and Lower Trinity). This assessment resulted in designating 1,410 wells in the BSEACD Modified Well Database with aquifer assignments and 203 wells where the aquifer was identified as "Unknown" due to the lack of available well construction information.

Table 3.1: Summary of Aquifer Designations.

Aquifer Designation	Formation Designation	Number of Wells
Single Aquifer and Formation Completion Designation		
Edwards BFZ	Edwards Group	53
Upper Trinity	Upper Glen Rose Limestone	223
Middle Trinity	Lower Glen Rose Limestone	283
	Hensel	40
	Cow Creek Limestone	354
Aquitard	Hammett Shale	0
Lower Trinity	Sligo Formation	26
	Hosston Formation	289
	Unknown	203
	Single Aquifer Completion Totals	**1,471**
Multiple Formation Designations		
Edwards BFZ / Upper Trinity	Edwards Group / Upper Glen Rose	1
Upper / Middle Trinity	Upper Glen Rose / Lower Glen Rose	20
Middle Trinity	Lower Glen Rose / Hensel	31
Middle Trinity	Lower Glen Rose / Hensel / Cow Creek	22
Middle Trinity	Hensel / Cow Creek	40
Middle / Lower Trinity	Cow Creek, Sligo, Hosston	1
Middle / Lower Trinity	Hensel, Cow Creek, Sligo, Hosston	1
Upper / Middle Trinity	Glen Rose, Hensell, Cow Creek	6
Upper / Middle / Lower Trinity	Glen Rose, Hensel, Cow Creek, Sligo, Hosston	1
Middle / Lower Trinity	Lower Glen Rose, Hensel, Cow Creek, Sligo, Hosston	1
Lower Trinity	Sligo / Hosston	18
	Multiple Formation Completion Totals	**142**

Table 3.2: Summary of BSEACD Aquifer Designations.

BSEACD Aquifer Completion Designation	Number of Wells
Edwards BFZ	53
Edwards / Upper Trinity	11
Upper Trinity	213
Upper / Middle Trinity	26
Middle Trinity	773
Middle / Lower Trinity	4
Lower Trinity	330
Unknown	203
Total	**1,613**

Any wells that were completed above the Trinity Aquifer were assigned to the "Edwards Balcones Fault Zone (BFZ)" aquifer, which includes the Austin Chalk, the Edwards, and associated limestones. It should be noted that aquifer completions identified by LRE may be subjective and differ from the actual aquifer in which the well is completed. Some degree of error and uncertainty is inherent when generating raster surfaces due to the raster cell size, which may affect the reported formation depths. In addition, the location of structural features may not be accurately depicted from the stratigraphic picks, especially where data is not available. Moreover, some aquifer designations may be incorrect where well construction data are limited or not accurately reported.

A finalized technical memorandum detailing the methodology, assumptions, and results of Task 2 is provided in Appendix B.

SECTION 4: TASK 3 – WELL IMPACT ANALYSIS

Under Task 3, wells in the BSEACD Modified Well Database that were designated as solely or dually-completed in the Middle Trinity Aquifer were evaluated for impacts from theoretical water level declines.

4.1 METHODOLOGY

Using the District's 2023 potentiometric surface for the Middle Trinity Aquifer (BSEACD, 2024) and the BSEACD Modified Well Database from Task 2, LRE performed an impact analysis for wells completed in the Middle Trinity Aquifer using the following steps:

Step 1. Filtered Dataset Creation. The BSEACD Modified Well Database was filtered for wells completed in the Middle Trinity Aquifer. Wells that are completed solely in the Middle Trinity Aquifer and those dual-completed in the Middle Trinity Aquifer and another aquifer were included in the filtered dataset. Well uses were also reviewed, and wells were excluded from the dataset if they were found to be used for geothermal or injection well applications. Aquifer designations were added to "Unknown" wells in the BSEACD Modified Well Database using information from the TWDB GWDB and SDR Database. Incorporating these wells added an additional 1,431 Middle Trinity wells to the filtered dataset, for a total of 2,714 wells. The filtered dataset, *WIA_FINAL_12_23_24.xlsx*, is herein referred to as the BSEACD Middle Trinity Well Database.

Step 2. Review Pump Depth Data. Pump depth data were reviewed and used to calculate the average position of the pump in relation to both the well/borehole depth and the screen interval.

Step 3. Define Pump Depth by Region. Through consultation with BSEACD, the District boundaries were used to characterize recorded pump depths.

a. For wells within BSEACD boundaries:
   i. Average pump depth: 95 feet above the top of the screen
   ii. 212 feet above the bottom of the well/borehole
b. For wells outside BSEACD boundaries:
   i. Average pump depth: 20 feet below the top of the screen
   ii. 83 feet above the bottom of the well/borehole

Step 4. Assign Hypothetical Pump Depths. For wells without recorded pump depths, a hypothetical pump depth was assigned per the definitions in Step 3. Conditions for applying the definitions are summarized in Table 4.1 below.

Table 4.1: Methods and conditions for estimating hypothetical pump depths, applied to wells missing pump depth records.

Hypothetical Pump Depth Estimation Method	Conditions
1a. 95 ft above the top of the screen	• Well is located within BSEACD • Well has screen interval information
1b. 212 ft above the bottom of the well/borehole	• Well is located within BSEACD • Screen interval information is missing
2a. 20 ft below the top of the screen	• Well is located outside BSEACD • Well has screen interval information
2b. 83 ft above the bottom of the well/borehole	• Well is located outside BSEACD • Screen interval information is missing

Step 5. Review of Special Case Wells. Hypothetical pump depths as defined in Step 3 could not be assigned to shallow or open hole wells. These wells were designated as “Special Case” wells and were reviewed manually.

A well was considered “shallow” if the conditions defined in Step 3 could not be met reasonably. For example, a well where the top of the screen was at 100 fbg would have been assigned a hypothetical pump depth of 5 feet, which was considered unrealistic. Similarly, a well that was 200 feet total depth and missing screen information would have been assigned a hypothetical pump depth of 12 feet above ground, which was also unrealistic. If a well was shallow and,

a. Had no screen information: Hypothetical pumps were set at half of the total depth of the well/borehole. For example, a well that was 100 feet deep would be assigned a hypothetical pump depth of 50 feet below ground.
b. Had screen information:
    i. Wells with single screen interval: Pump set at the top of the screen.
    ii. Wells with two screen intervals: Pump set at the bottom of the top screen interval.
    iii. Wells with more than two screen intervals: Pump set within the screen, equal to the top of the screen plus half the difference of the screen interval. For example, a well with screen intervals of 100-120, 140-150, 200-220 feet below ground would be assigned a hypothetical pump depth of 160 feet below ground.

Completion information was reviewed to confirm if wells were open hole completions. Wells with an open hole designation and recorded screen interval(s), and/or wells where the casing depth is equal to the total depth were specified as Lined Open Hole completions in the dataset ("Lined OH"). If no screen information was recorded in an open hole well, a hypothetical pump depth was applied by following the method of placing the pump above the recorded total depth of the borehole (i.e., 212 feet above the bottom of the borehole if well was within the BSEACD, and 83 feet above the bottom of the borehole if well was outside of the BSEACD).

Step 6. Potentiometric Surface Creation. The "2023_potmap_contours" shapefile was provided by BSEACD and used to generate a potentiometric surface which served as the baseline for analyzing well impacts. The "Topo to Raster" spatial analyst tool in ArcGIS (ArcMap version 10.8.1 and Pro version 3.3.0) was used to interpolate the potentiometric surface from the contour shapefile. With the District's approval, the potentiometric surface contours were extrapolated so that additional wells in the southwestern portion of the BSEACD could be included in the analysis for Study Areas 1 and 2 (Figure 4.1). Some degree of error and uncertainty is inherent when generating raster surfaces especially in proximity to structural features. Therefore, the extrapolated 2023 potentiometric surface generated by LRE should only be used for the purpose of this well impact analysis.

Step 7. Water Level Scenarios. Various scenarios of water level declines throughout the Middle Trinity Aquifer were simulated. Using the expanded 2023 potentiometric surface as the baseline, water level declines were applied equally across all well points. Scenarios were created for declines of 50 feet, 100 feet, 150 feet, 200 feet, 250 feet, and 300 feet.

Step 8. Well Impact Analysis. The various water level scenarios were compared to the top of the Middle Trinity Aquifer, top of the screen, total depth, and pump depth for each well to determine individual well impacts. Impacted wells were marked with "TRUE" or "FALSE" in the BSEACD Middle Trinity Well Database, and impacts were defined as described in Table 4.2.

With respect to the pump settings, impacted wells were identified as having water levels less than 20 ft above the pump. This 20 feet buffer was applied as a safety threshold because inadequate submergence can lead to pump cavitation, overheating, and eventual failure.

Available drawdowns were calculated from 2023 groundwater levels to the top of the aquifer, screen, total well depth, and 20 feet above the pump for each well. These drawdown determinations were used to identify the water level declines that would impact a given percentage of wells within the BSEACD (0-100% of wells).

Table 4.2: Definitions of well impacts.

Impact:	Impact = "TRUE" if:
Middle Trinity Aquifer	Water level elevation < Top of the aquifer elevation
Top of the Screen	Water level depth > Depth of the top of the screen interval
Total Depth	Water level depth > Borehole total depth
Pump Setting	Water level depth ≥ 20 feet of the Pump setting depth
Casing Size Limitation	Water level depth > Depth of casing size reduction

Step 9. Shapefile Creation and Impact Flagging. LRE created a shapefile containing the results from all water level simulations from the BSEACD Middle Trinity Well Database (*"WIA_FINAL_12_23_24.shp"*). The Database allows for the calculation of water level declines at individual wells. The database contained 2,714 entries (rows) with a total of 88 fields (columns). A data dictionary explaining each field is presented in Appendix C.

4.1.1. Assumptions

The following assumptions were applied in the well impact analysis:

1. The top of the Middle Trinity Aquifer was defined as 50 feet below the top of the Lower Glen Rose Formation. This is consistent with previous hydrogeological investigations that determined that the topmost water-bearing zone of the aquifer

is generally about 50 feet below the top of the Lower Glen Rose Formation (BSEACD, 2024).

2. Where well depth was not available, the well depth was assumed to be equal to the borehole depth. The borehole depth was used in lieu of well depth for the well impact analysis because very few well depths are available in the database. Of the 46 wells with well depth data, recorded well depths were equal to the borehole depths, suggesting that using the borehole depth as a proxy for well depth is reasonable.

4.2. RESULTS

Impacts to wells were evaluated based on available drawdown above the Middle Trinity Aquifer, top of the screen interval, total depth, and pump setting. Importantly, the baseline scenario used for these analyses (i.e., 0 feet of water level decline) reflects 2023 drought conditions rather than average hydrologic conditions. Results are presented for the three study areas of interest: the BSEACD boundary (Section 4.2.3), the southwest corner of the BSEACD (Section 4.2.3.5), and the full study area which includes Hays Trinity GCD, Southwestern Travis County GCD, and parts of the Edwards Aquifer Authority (Section 4.2.4).

4.2.1. Final Dataset

The final dataset for the full study area (Study Area #3) contained a total of 2,745 wells solely or dual-completed in the Middle Trinity Aquifer. Thirty-one wells completed in the Middle Trinity Aquifer that were used for geothermal or injection applications were removed from the dataset. The final dataset used in the well impact analysis contained 2,714 wells; 2,629 were designated as Middle Trinity Aquifer wells, and 85 wells were determined to be dual-completed in the Middle Trinity and another aquifer (Figure 4.1). Of the 452 wells within the boundary of the BSEACD (Study Area 1), 398 wells were designated as solely Middle Trinity Aquifer wells, and 54 wells were determined to be dual-completed. Of the 452 wells within the BSEACD boundary, 163 well records included screen data, and 131 well records included a pump setting. The southwest corner of the BSEACD (Study Area 2) included 384 wells; 127 well records included screen data and 113 included a pump setting.

Table 4.3: Summary of Middle Trinity Aquifer Well Dataset.

Description	Number of Wells
STUDY AREA 3	
Final dataset	2,714
Completed in Middle Trinity	2,629
Dual-completed in Middle Trinity	85
Wells with screen information	1,220
Wells with recorded pump depth	590
STUDY AREA 1	
Wells in the BSEACD	452
Completed in Middle Trinity	398
Dual-completed in Middle Trinity	54
Wells with screen information	163
Wells with recorded pump depth	131
STUDY AREA 2	
Wells in the southwest corner of BSEACD	384
Wells with screen information	126
Wells with recorded pump depth	113

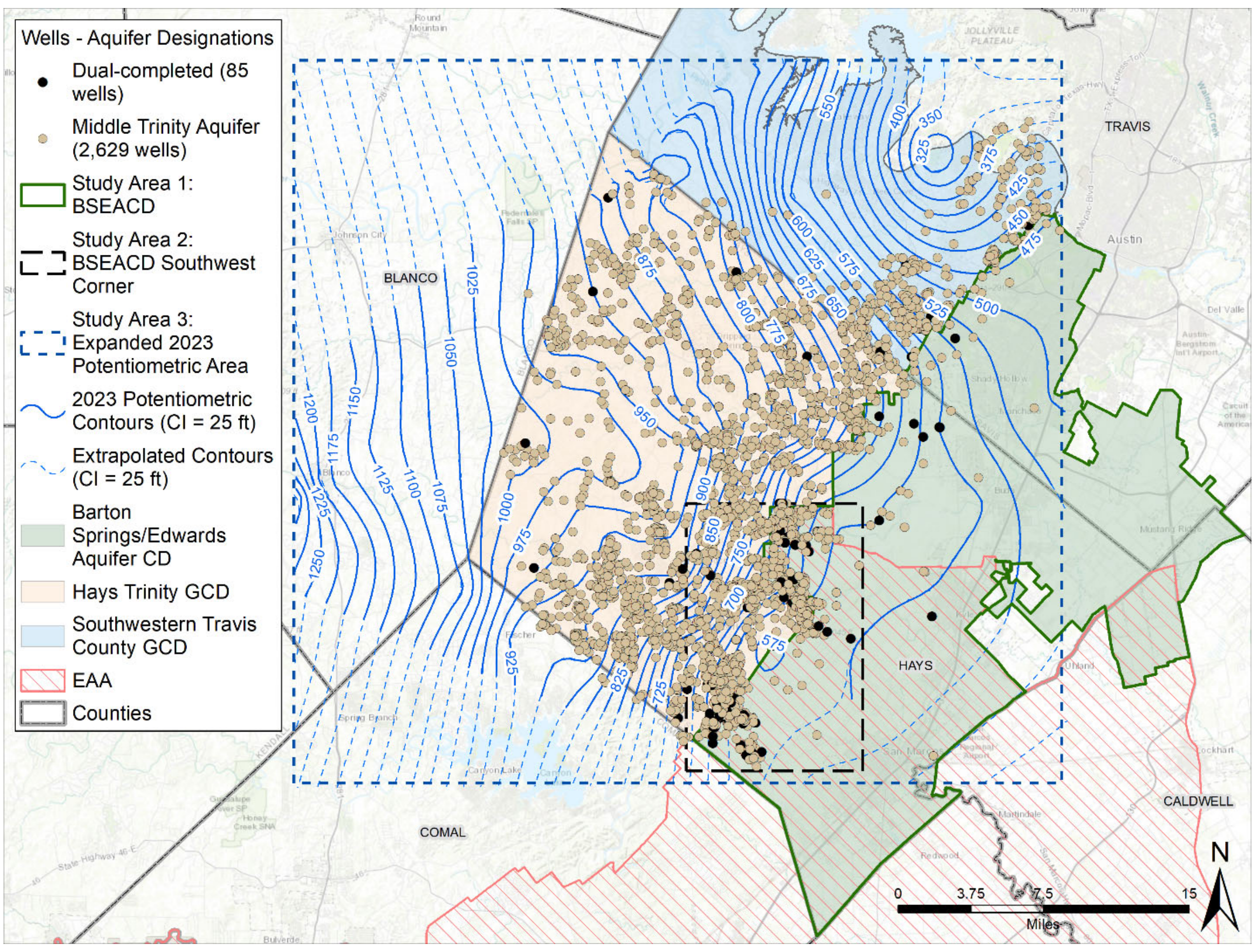


Figure 4.1: Study areas and final wells database used in the well impact analysis.

4.2.2. Well Impact Analysis for BSEACD Wells

4.2.2.1. Available Drawdown Above the Aquifer in Study Area 1

Once groundwater levels fall below the top of an aquifer at a well location, the aquifer transitions from confined conditions to unconfined conditions which decreases the transmissivity around the well, resulting in less flow and more energy required to pump water to the surface (Yelderman and others, 2020). The percentages of impacted wells based on available drawdown above the Middle Trinity Aquifer are presented in Figure 4.3. In 2023 (baseline), all wells in the Middle Trinity Aquifer within BSEACD were under confined conditions and were not considered impacted. A water level decline of 135 feet would result in 10% of BSEACD wells becoming unconfined (impacted), and half of the wells in the BSEACD would become unconfined (impacted) with a water level decline of 238 feet. The spatial trend of increasing numbers of impacted wells as water level declines progresses from northwest to the southeast across Study Area 3. This trend follows the south-eastward dip of the aquifer and results in wells in the northwestern (updip) part of the BSEACD being impacted before wells in the southeast (downdip) part of the BSEACD.

4.2.2.2. Impacted Screens in Study Area 1

The percentages of impacted wells based on available drawdown above the top of the screen are presented in Figure 4.4. The analysis was based on a subset of 163 wells that had recorded screen interval information. In 2023, the water level in the Middle Trinity Aquifer was below the top of the screen for 3% (5 out of 161) wells within the BSEACD. This impact even at baseline water levels reflects the wells that were dual-completed across the Upper and Middle Trinity aquifers. A water level decline of 158 feet would impact 10% (16 out of 161) of BSEACD wells, and a water level decline of 372 feet would impact half of the wells (81 out of 161) in the District. There is a general progression of impacted wells following the dip of the Middle Trinity Aquifer. Wells northwest of the BSEACD are most likely to be impacted by groundwater levels falling below the top of their recorded screen interval.

4.2.2.3. Dry Wells in Study Area 1

Groundwater levels dropping below the total depth of a well would effectively result in a dry well, requiring re-drilling the well or resulting in the abandonment of the well. The percentages of impacted wells based on available drawdown above the total depth of the well are presented in Figure 4.5. In 2023, no wells within the BSEACD were impacted (i.e. had already become dry wells). A water level decline of 219 feet would impact 10% (45 out of 452) of BSEACD wells, and half of the wells in the District (226 out of 452) would become dry with a water level decline of 440 feet. All wells in the BSEACD would be impacted by a water level decline of 2,025 feet.

4.2.2.4. Impacted Pumps in Study Area 1

If groundwater levels are expected to fall below the pump, the pump will need to be lowered to continue operation and water production. Additionally, as water levels approach the pump, the lack of adequate submergence can cause pump cavitation, overheating, and eventual failure. Therefore, LRE used a safety threshold of 20 feet above the pump to indicate an impacted well. However, is it possible that there may not be signs of negative influence on pump operations at this 20-ft water level, depending on the size and efficiency of the pump.

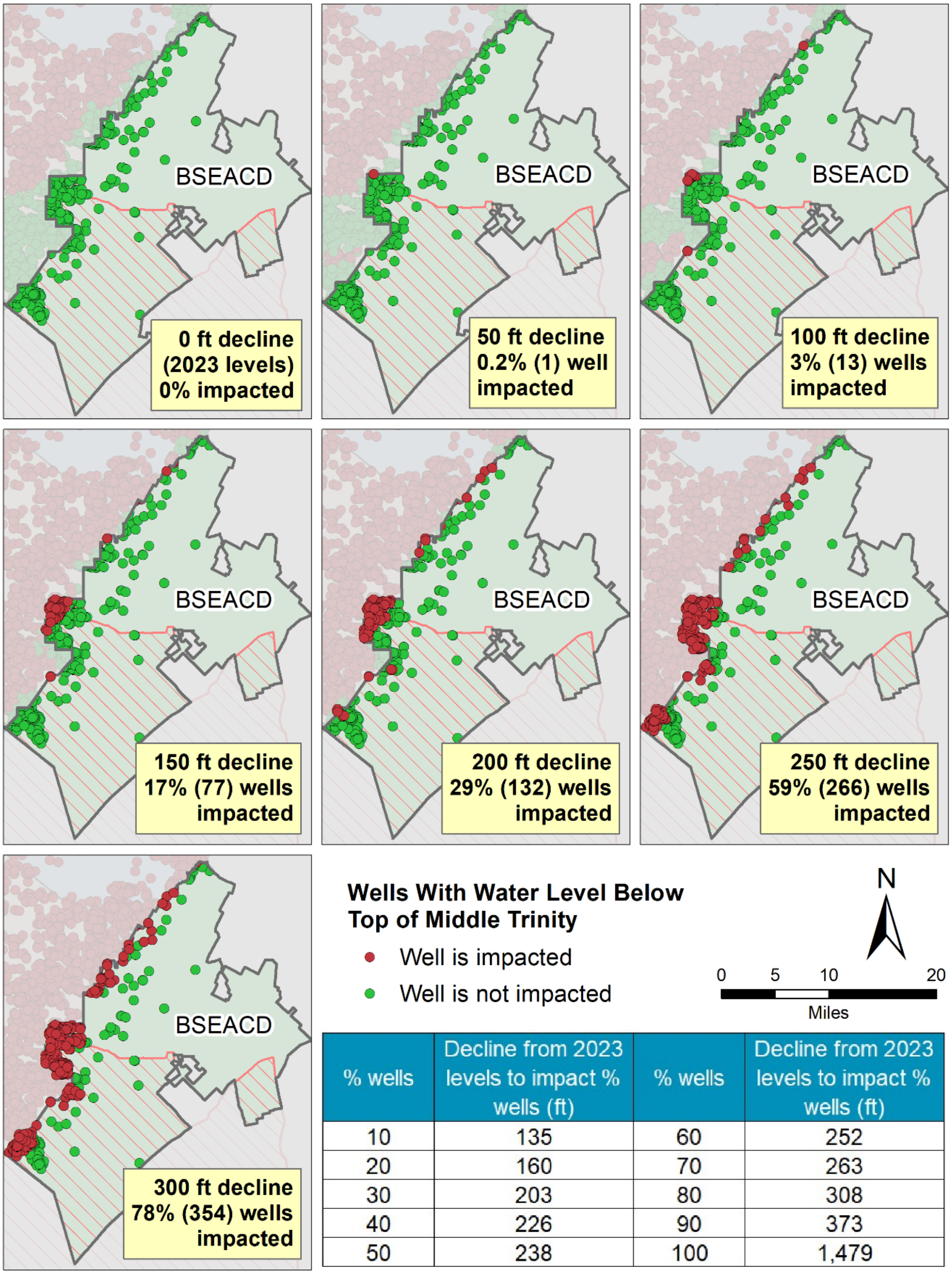
The percentages of impacted wells based on available drawdown above the pump setting are presented in Figure 4.6. Of the 452 wells within the BSEACD, 131 wells had a recorded pump depth, and 321 wells were assigned hypothetical pump depths. In 2023, the groundwater level was within 20 ft of the pump for 5% of wells with recorded pump settings (7 of 131 wells) and 14% of wells assigned a hypothetical pump (46 of 321 wells) within the BSEACD. A water level decline of about 199 feet would impact pumps for half of the wells with recorded pump settings, and 215 feet of decline would impact 50% of wells with hypothetical pump settings.

4.2.2.5. Wells in Southwest Corner of BSEACD (Study Area 2)

Through discussions with BSEACD, the southwest corner of the BSEACD was identified as a potentially sensitive area for well impacts, and for potential consideration in the future as a groundwater management zone (“GMZ”). As such, LRE replicated the well impact analysis focusing on a subset of wells in the southwest part of the BSEACD (Study Area 2). Impacts to the 384 wells within this area are presented in Figures 4.7 through 4.10 and Table 4.5. Geospatial trends for well impacts in this area are similar to impacts in the BSEACD (Study Area 1).

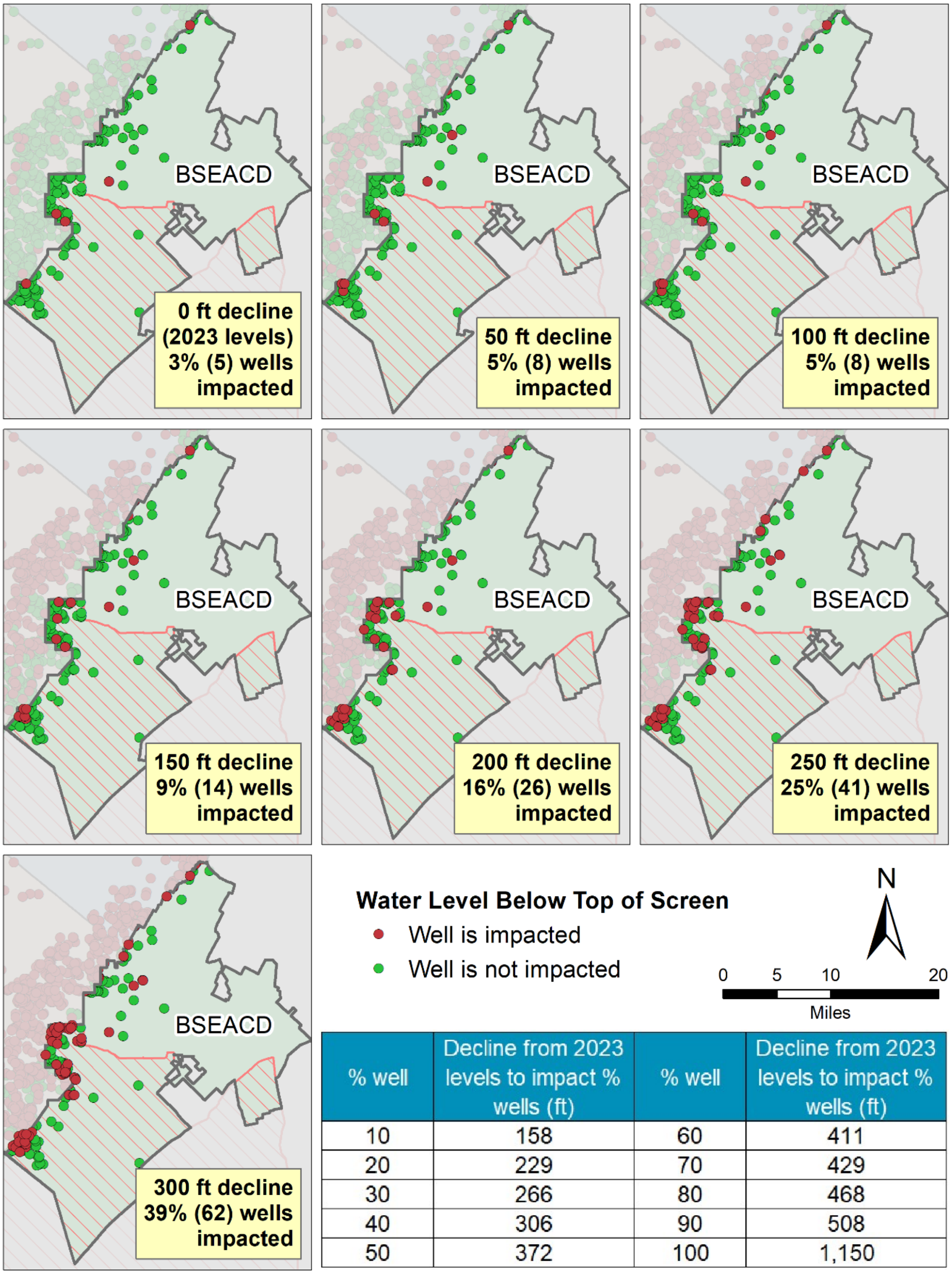
4.2.3. Well Impact Analysis for the Full Study Area (Study Area 3)

Impacts to wells within the full study area are presented in Table 4.6. The majority of impacted wells are located in the Hays Trinity GCD, which are primarily in the updip portion of the Middle Trinity Aquifer. Wells located in Hays Trinity GCD are more susceptible to water level decline impacts, given the south-eastward dip of the Middle Trinity Aquifer.



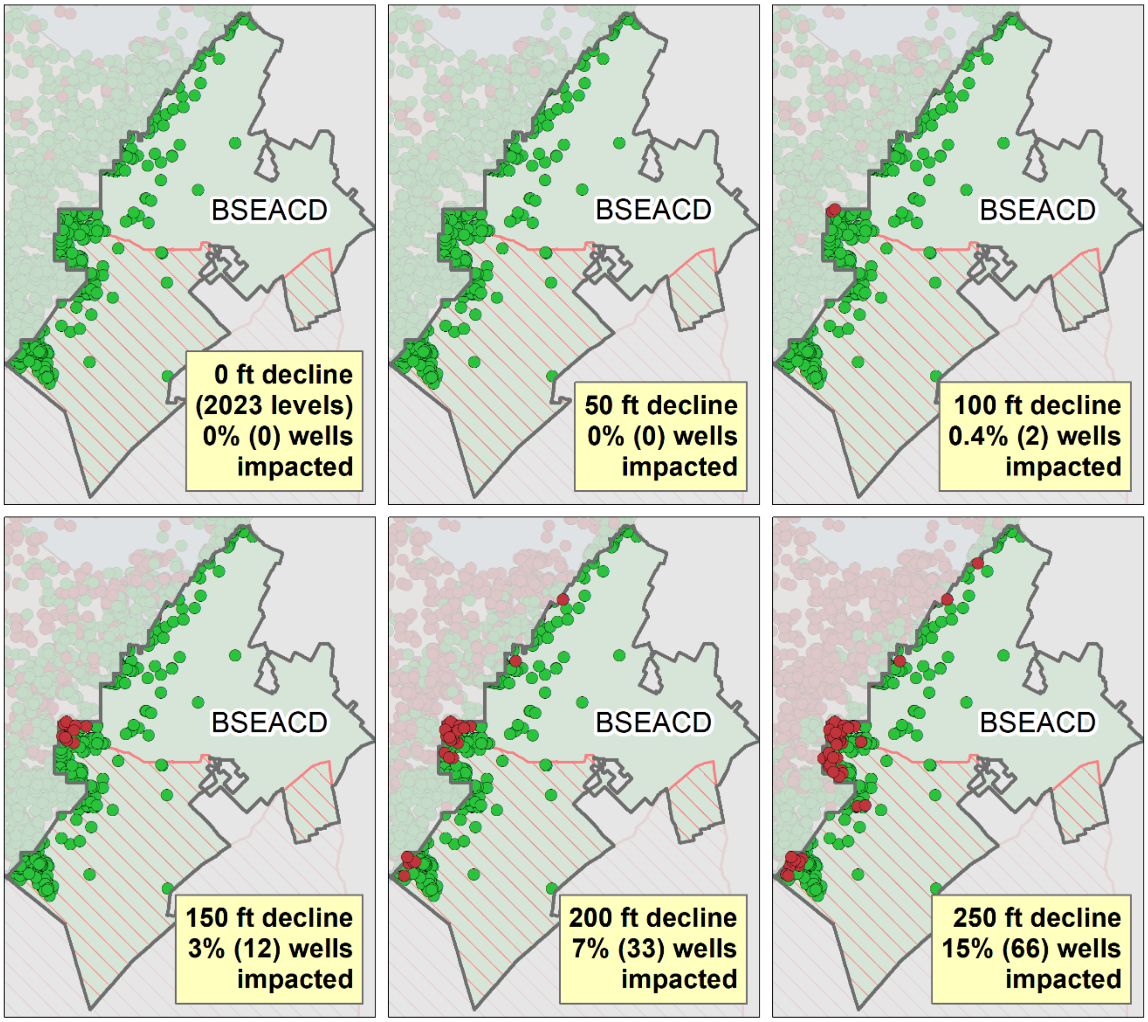
% wells	Decline from 2023 levels to impact % wells (ft)	% wells	Decline from 2023 levels to impact % wells (ft)
10	135	60	252
20	160	70	263
30	203	80	308
40	226	90	373
50	238	100	1,479

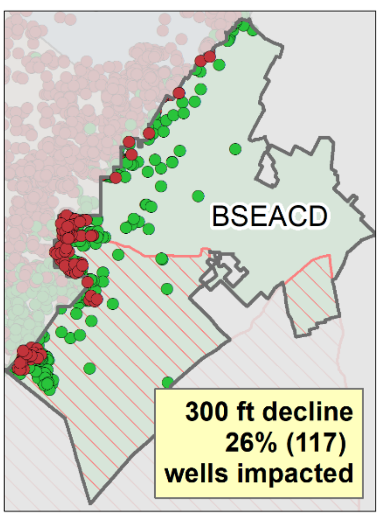
Figure 4.2: Wells in BSEACD (Study Area 1) impacted by water levels dropping below the top of the Middle Trinity Aquifer.

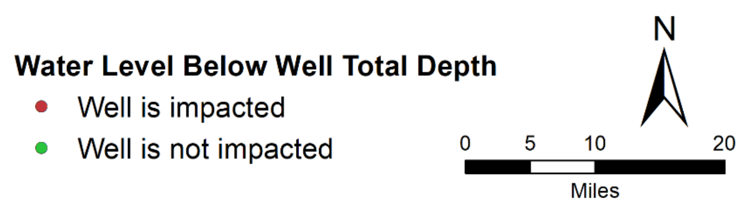


% well	Decline from 2023 levels to impact % wells (ft)	% well	Decline from 2023 levels to impact % wells (ft)
10	158	60	411
20	229	70	429
30	266	80	468
40	306	90	508
50	372	100	1,150

Figure 4.3: Wells in BSEACD (Study Area 1) impacted by water levels dropping below the top of the screen. Analysis is based on a subset of 161 wells that have screen information.







% wells	Decline from 2023 levels to impact % wells (ft)	% wells	Decline from 2023 levels to impact % wells (ft)
10	219	60	483
20	273	70	519
30	314	80	551
40	371	90	629
50	440	100	2,025

Figure 4.4: Wells in BSEACD (Study Area 1) impacted by water levels dropping below the total depth of the well.

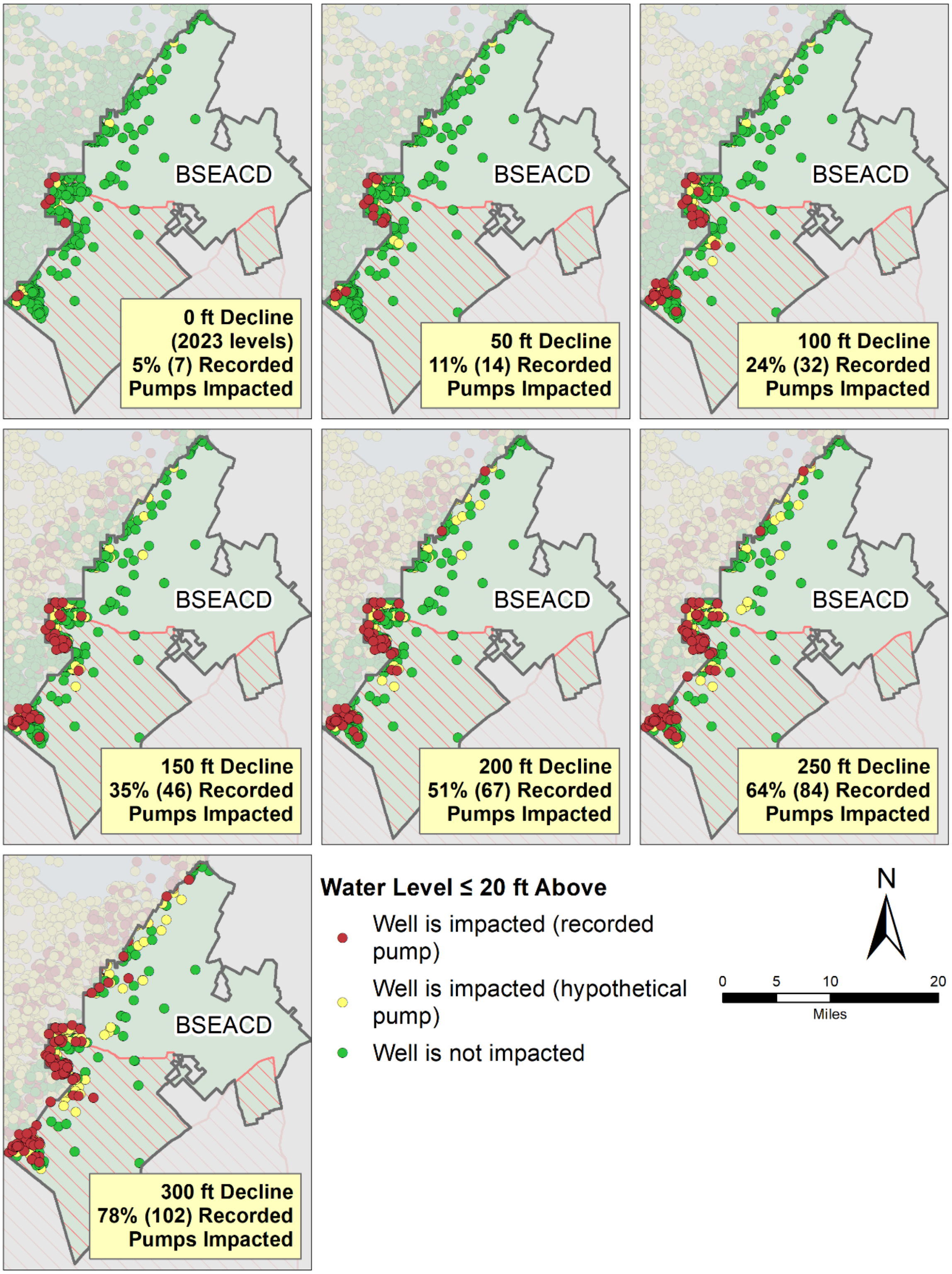
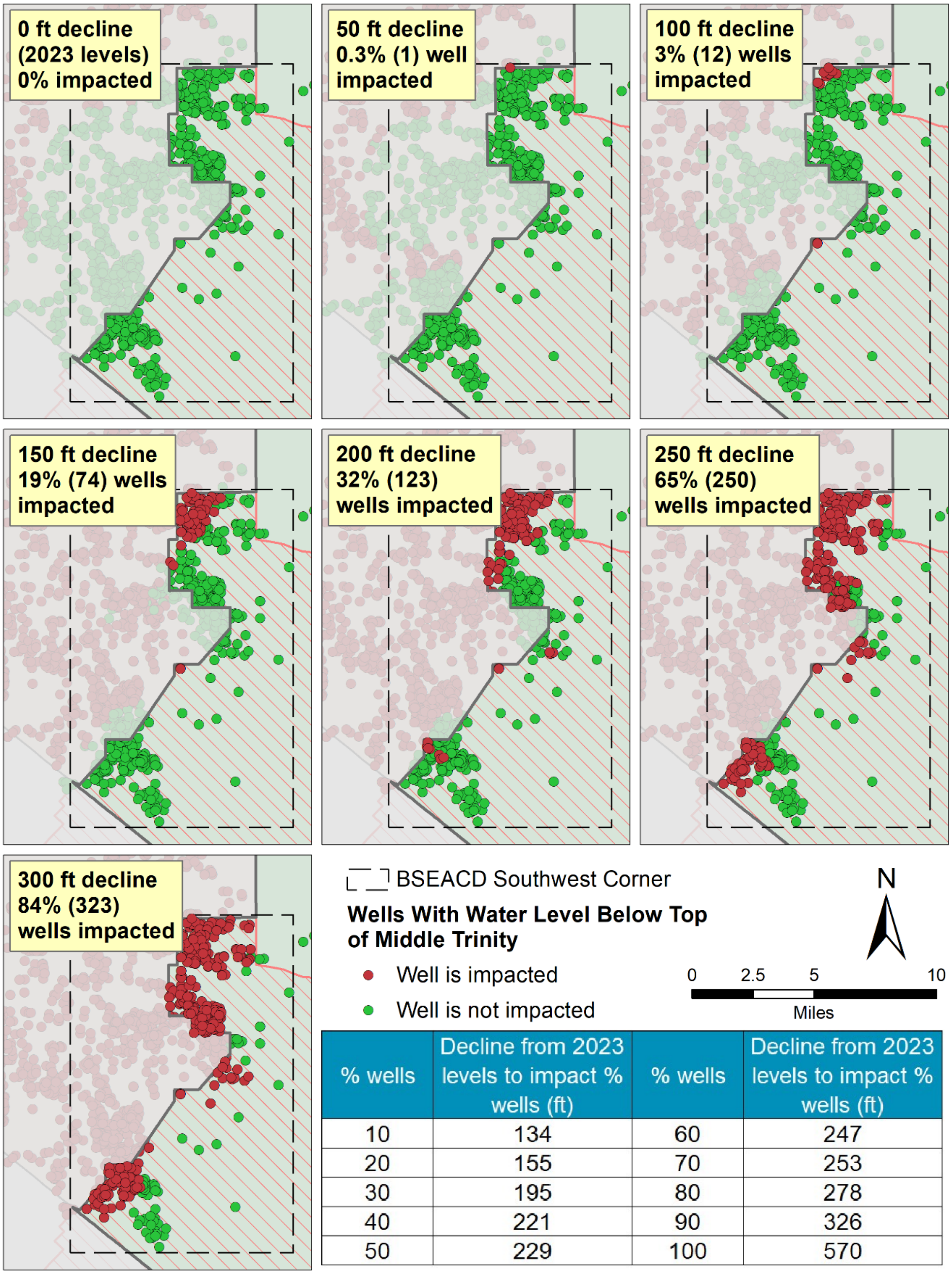


Figure 4.5: Wells in BSEACD (Study Area 1) impacted by water levels dropping within 20 feet of the pump setting.

Table 4.4: Drawdown thresholds to impact wells within the BSEACD based on water levels coming within 20 feet of the pump.

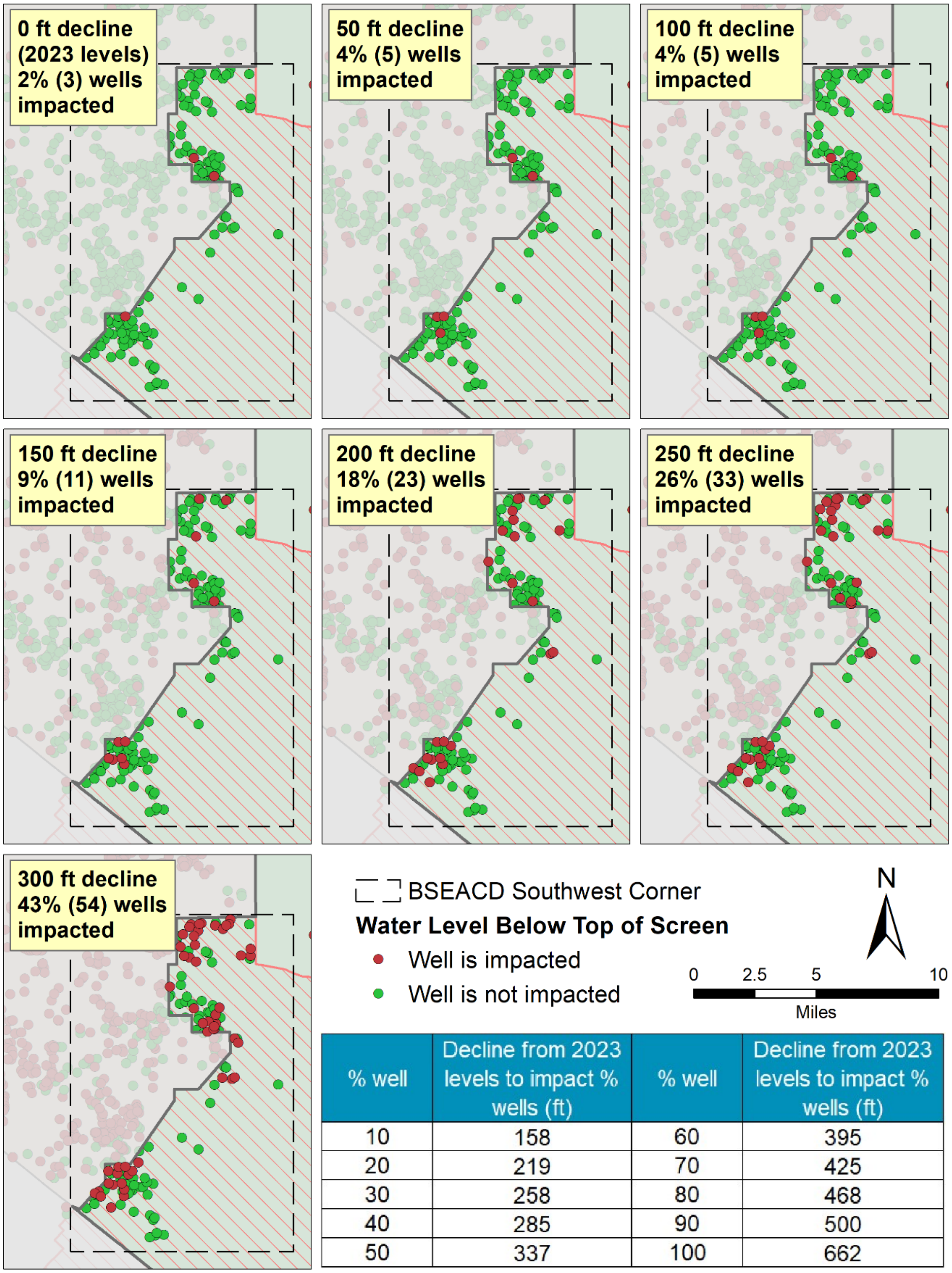
% wells	Drawdown from 2023 levels (ft) to Within 20 ft Above the Pump	
	Recorded Pumps Only (131 wells)	Hypothetical Pumps (321 wells)
10%	38	--*
20%	84	30
30%	126	76
40%	165	139
50%	199	215
60%	226	264
70%	265	298
80%	311	345
90%	378	435
100%	698	1,154

** Considering wells with hypothetical pump depths only, 14% of wells had groundwater levels within 20 ft of the pump in 2023.*



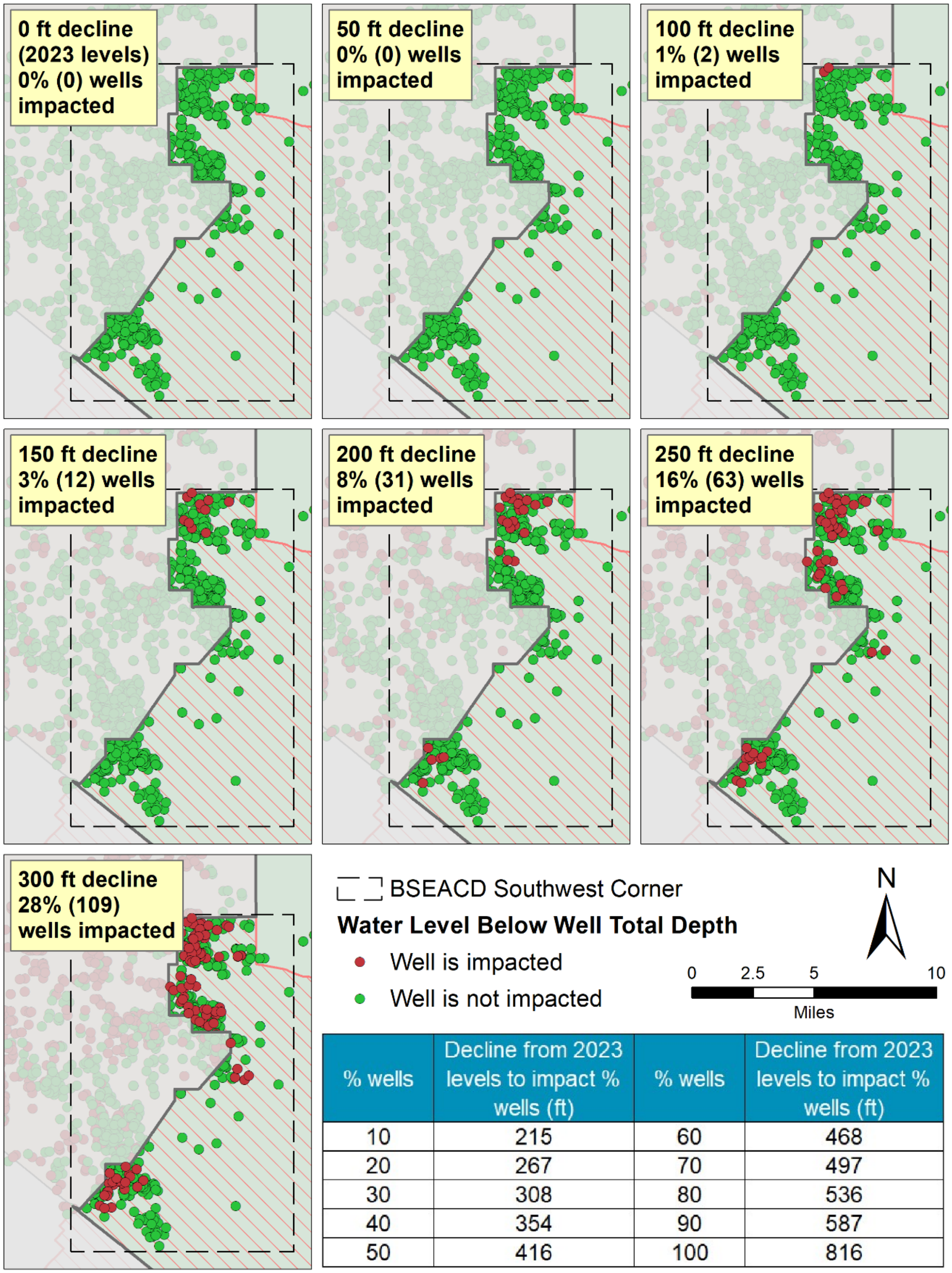
% wells	Decline from 2023 levels to impact % wells (ft)	% wells	Decline from 2023 levels to impact % wells (ft)
10	134	60	247
20	155	70	253
30	195	80	278
40	221	90	326
50	229	100	570

Figure 4.6: Wells in the southwest corner of BSEACD (Study Area 2) impacted by water levels dropping below the top of the Middle Trinity Aquifer.



% well	Decline from 2023 levels to impact % wells (ft)	% well	Decline from 2023 levels to impact % wells (ft)
10	158	60	395
20	219	70	425
30	258	80	468
40	285	90	500
50	337	100	662

Figure 4.7: Wells in the southwest corner of BSEACD (Study Area 2) impacted by water levels dropping below the top of the screen. The analysis was based on 126 wells with screen information.



% wells	Decline from 2023 levels to impact % wells (ft)	% wells	Decline from 2023 levels to impact % wells (ft)
10	215	60	468
20	267	70	497
30	308	80	536
40	354	90	587
50	416	100	816

Figure 4.8: Wells in the southwest corner of BSEACD (Study Area 2) impacted by water level dropping below the total depth of the well.

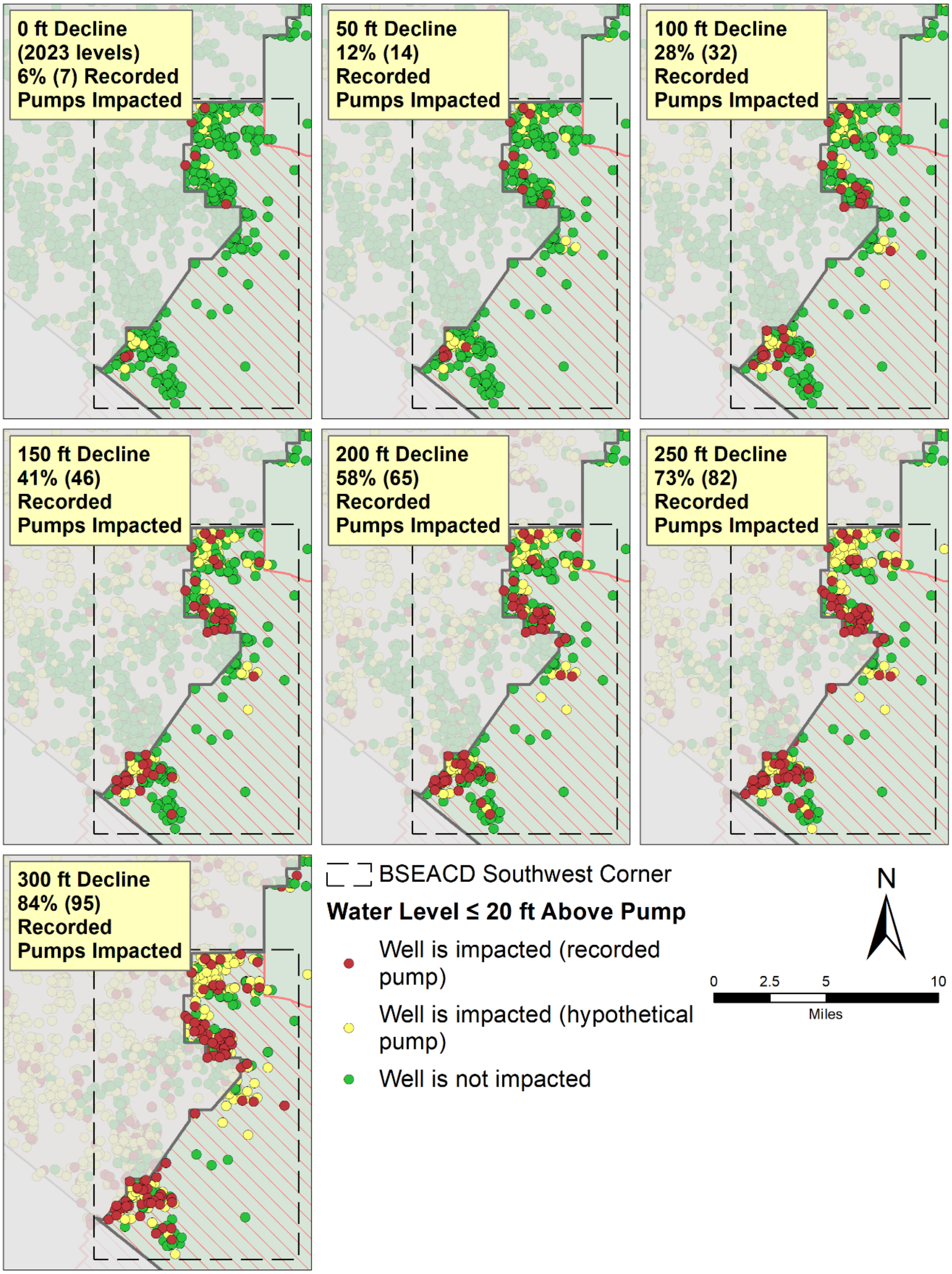


Figure 4.9: Wells in the southwest corner of BSEACD (Study Area 2) impacted by water levels dropping within 20 feet of the pump.

Table 4.5: Drawdown thresholds to impact wells in the Southwest Corner of BSEACD (Study Area 2) based on water levels coming within 20 feet of the pump.

% wells	Drawdown from 2023 levels (ft) to Within 20 ft Above the Pump	
	Recorded Pumps (113 wells)	Hypothetical Pumps (271 wells)
10%	29	--*
20%	79	22
30%	110	63
40%	149	118
50%	179	190
60%	205	250
70%	239	287
80%	265	319
90%	326	393
100%	488	584

** Considering wells with hypothetical pump depths only, 16% of wells had groundwater levels within 20 ft of the pump in 2023.*

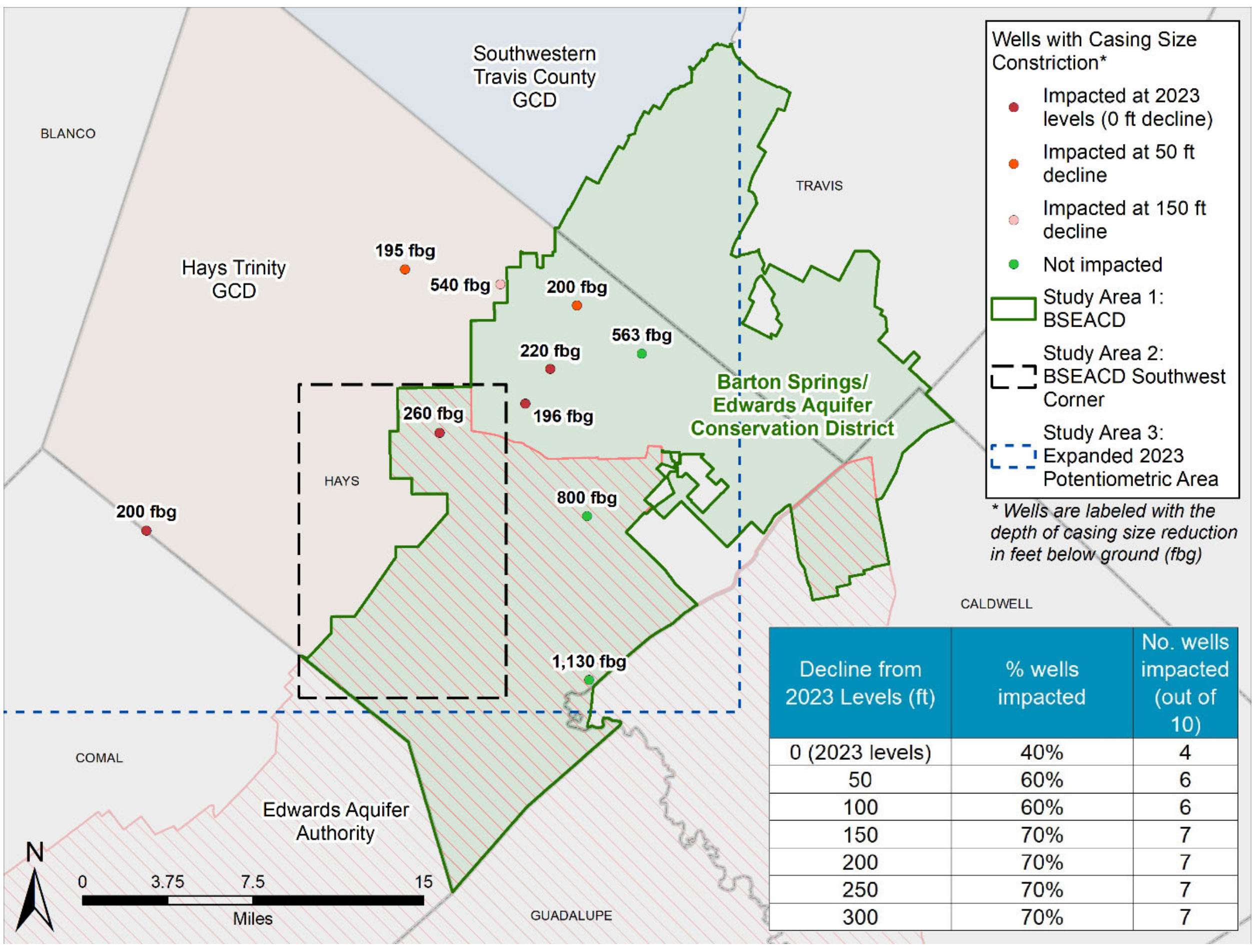
Table 4.6: Summary of impacts to wells in Study Area 3.

Drawdown from 2023 Drought Levels (ft)	% Wells with WL Below Top of Aquifer	% Wells with WL Below Top of Screen *	% Wells with WL Below Total Depth (i.e., dry)	% Wells with WL Equal/Less Than 20 ft Above the Pump
0 (2023 levels)	51%	6%	4%	18%
50	58%	17%	7%	32%
100	67%	36%	15%	49%
150	79%	54%	30%	64%
200	83%	66%	48%	74%
250	91%	76%	60%	83%
300	96%	84%	70%	90%

** Based on a subset of wells that have screen interval data (1,220 out of 2,714 wells)*

4.2.4. Wells with Casing Size Limitations (Telescoping Wells)

Wells with casing size constraints (i.e., telescoping wells) are a concern as groundwater levels decline in the Middle Trinity Aquifer, because it may not be possible to lower a pump past the top of the smaller diameter casing. Evaluation of casing size information in the BSEACD Middle Trinity Well Database indicated that ten wells were completed with casing size constrictions in the full study area (Study Area 3), seven of which are within the BSEACD (Study Area 1) and one of which is within the Southwest Corner (Study Area 2). (Figure 4.2). The depth of casing size reductions ranged from about 200 feet below ground (fbg) in the western part of Study Area 3 to greater than 1,100 fbg in the eastern part of the Study Area 3. At 2023 aquifer levels, four out of ten wells had water levels below their depths of constriction. An additional 150 feet of water level decline would result in seven of the ten wells with water levels below their depths of constriction.



Decline from 2023 Levels (ft)	% wells impacted	No. wells impacted (out of 10)
0 (2023 levels)	40%	4
50	60%	6
100	60%	6
150	70%	7
200	70%	7
250	70%	7
300	70%	7

Figure 4.10: Locations of wells with casing size constrictions within the study area.

4.2.5. Evaluation of the Hypothetical Pump Methods

Summary statistics and linear regression were used to evaluate the representativeness of the methods for estimating hypothetical pump depths. For this evaluation, the estimation methods were applied to wells with recorded pump settings, and hypothetical pump depths were compared to recorded pump depths. The percent difference between the two pump depth determinations were calculated for each well, and a summary of the results are provided in Table 4.7. A percent difference greater than zero indicates that the hypothetical pump is shallower than the recorded pump, while a value less than zero indicates that the hypothetical pump is deeper than the recorded pump. It is important to emphasize that the median and mean percentage differences are near 0%. The majority of percent differences being near 0% indicates that the estimation methods do a good job of assigning hypothetical pump depths. The large ranges suggest that pump depth estimations in very shallow and very deep settings are less certain. Further confidence in the estimation methods is indicated in Figure 4.11 which plots recorded pump depths against their associated hypothetical pump depths. An estimation method that perfectly predicts pump depth would result in R^2 and slope values of 1. The R^2 values for the estimation methods range from 0.9201 to 0.9699. The slope values indicate that the methods applied to wells within the BSEACD slightly underestimates pump depths, while methods applied to wells outside the BSEACD slightly overestimates pump depths.

Table 4.7: Summary statistics comparing the percent difference between recorded and hypothetical pump depths.

Statistic	% Diff. Within BSEACD		% Diff. Outside BSEACD	
	Wells With Screen Information (Method 1a: 95 ft Above TOS)	Wells Without Screen Information (Method 1b: 212 ft Above TD)	Wells With Screen Information (Method 2a: 20 ft Below TOS)	Wells Without Screen Information (Method 2b: 83 ft Above TD)
COUNT	69	62	389	70
MIN	-69.35	-72.36	-400.00	-62.67
MAX	108.36	42.40	85.82	30.53
RANGE	177.72	114.76	485.82	93.19
MEDIAN	5.71	2.20	0.00	2.40
MEAN	-1.92	-1.62	-1.58	-9.44

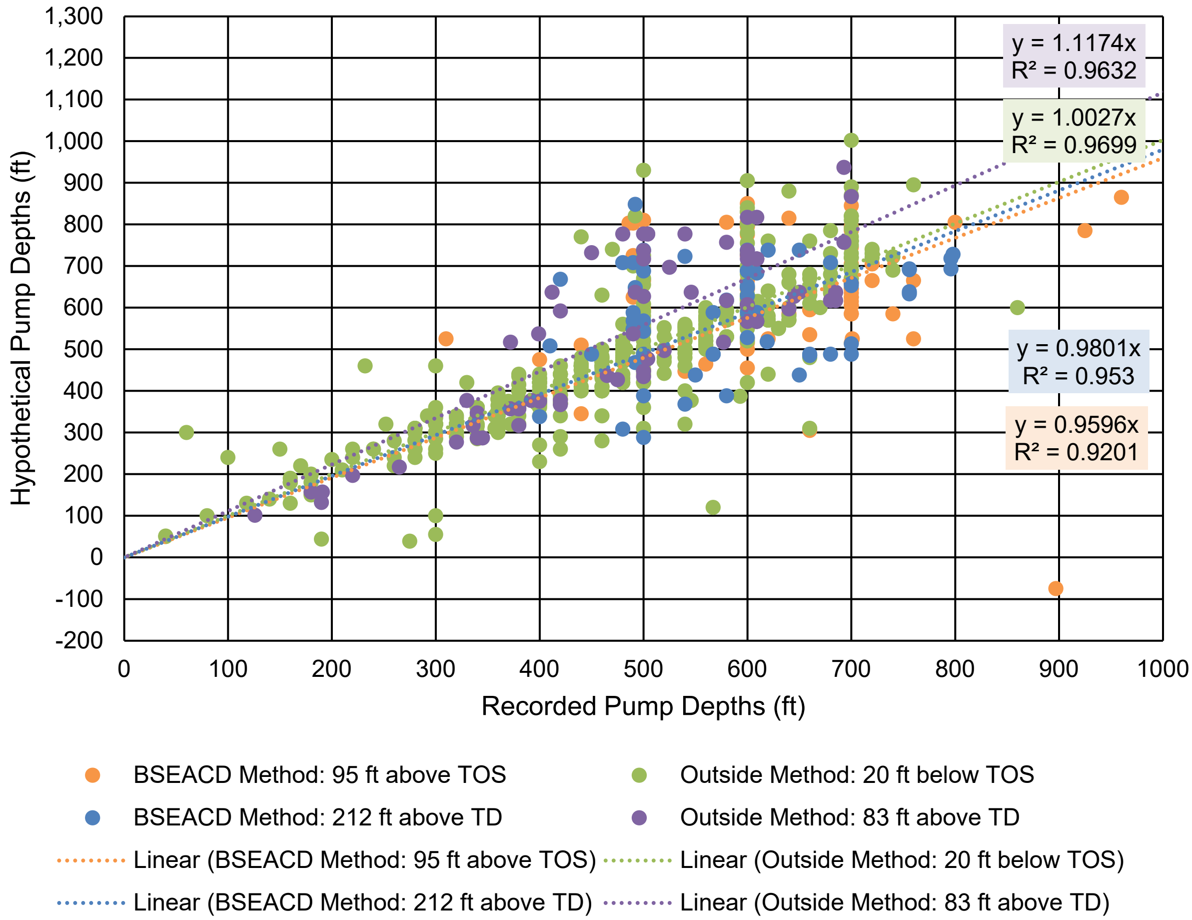


Figure 4.11: Linear regression plot of recorded pump depths versus hypothetical pump depths.

SECTION 5: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This well impact analysis shows that wells completed in the outcrop or shallow updip portion of the Middle Trinity Aquifer are more susceptible to future water level declines. More specifically, these areas are more likely to become unconfined under theoretical drawdown scenarios. Several changes can occur when a confined aquifer transitions to unconfined conditions, including reduced well yields, decreased well efficiency, changes in water chemistry, and a decrease in transmissivity as a result of dewatering. Therefore, careful monitoring of water levels and regulation of pumping in these areas can help mitigate the effects of water level declines and reduce the risk of confined aquifers transitioning to unconfined conditions. The following considerations were highlighted in this analysis:

- **Final Dataset:** The final dataset used in the well impact analysis contained 2,714 wells within the full study area which encompasses BSEACD, Hays Trinity GCD, and Southwestern Travis County GCD. Within the boundary of the BSEACD there are about 1,200 wells, of which 452 wells had construction data: 163 well records included screen data, and 131 well records included a pump setting. While this subset of wells is not comprehensive of all wells within the District, they are likely representative of the spatial distribution and general well construction of Middle Trinity Wells within the BSEACD. Of the 452 wells, 398 wells were designated as Middle Trinity Aquifer wells, and 54 wells were determined to be dual-completed. The southwest corner of within the BSEACD boundary includes 384 wells; 127 well records included screen data and 113 included a pump setting.
- **Casing Size Limitations:** Impacts to wells with casing size constrictions (telescoping wells) are of concern, as a reduction in casing diameter can limit the depth that pumps can be lowered to adapt to future groundwater level declines. Despite initial concerns that telescoping wells might be a common well construction within the study areas, review of the database showed that a relatively small number of wells are constructed with casing size constrictions (7 wells within the BSEACD and 3 wells within Hays Trinity GCD).
- **Initial Impact at Baseline (2023) Water Levels:** Even during the 2023 drought levels, no wells within the BSEACD were impacted by water levels falling below the top of the Middle Trinity Aquifer. For the subset of wells with screen information, 4% of wells (7 out of 163) within the BSEACD are impacted by water levels falling below the top of the screen. The impacted wells are dual-completed across the Upper and Middle Trinity Aquifers, and water levels falling below the top of the screen are related to aquifer units above the Middle Trinity.
- **Pump Submergence Issues:** For the subset of wells with recorded pump depths, 5% (7) of wells within the BSEACD are impacted by 2023 water levels being within

20 feet of the pump. Considering recorded and hypothetical pump depths, 18% of wells in the full study area contain water levels that are equal to or less than 20 feet above the assumed pump setting at 2023 water levels. The method used to assign hypothetical pump depths seems to be most representative for pump depths around 200 feet and is less representative for very shallow or very deep wells. Nevertheless, water levels falling near pump depths are concerning as this can lead to pump cavitation, overheating, and eventual failure due to inadequate submergence if pumps are not lowered. Lowering pumps can result in additional labor and electricity costs, which may be cost-prohibitive to exempt well users within the BSEACD. In some cases, higher horsepower pumps may be needed for deeper settings in the well, and such pumps are typically more expensive.

- **Aquifer Dip Implications:** Given that the Middle Trinity Aquifer dips eastward, wells located in the shallower portion of the aquifer (western part of the BSEACD and within the Hays Trinity GCD) are more susceptible to drawdown impacts. In contrast, wells completed in the deeper, confined portion of the Middle Trinity Aquifer (particularly in the eastern portion of the study area) are less susceptible to future water level declines. This is primarily due to the additional available drawdown in these portions of the aquifer.
- **Potential GMZ in Southwestern BSEACD:** The southwestern corner of the BSEACD is likely more vulnerable to water level declines compared to the rest of the BSEACD. This is because the aquifer is generally shallower in this area, and there is a large concentration of wells within this region. As such, designation of this area as a potential groundwater management zone (GMZ), perhaps with special rules or permitting requirements, may yield sustainability benefits for well owners/operators within the region. LRE believes this to be a defensible long-term groundwater management strategy for BSEACD to consider.

The results of this analysis may be useful for well owners as they plan mitigation efforts, and for future well owners (and District permittees) who must strategically plan, design, and construct groundwater wells for optimal production given expected aquifer conditions. Continuous water level monitoring in the Middle Trinity Aquifer, specifically in areas that are vulnerable to water level declines, can lead to proactive groundwater management strategies, which will ensure sustainable resource utilization.

LRE Water recommends the BSEACD consider notifying well owners of the results of this study, especially those owners whose wells may be impacted with 50-foot or 100-foot future water level declines. We also recommend the district request well design information, including pump setting, pump brand/model, and electrical costs on permit applications or renewals. Improving District well databases will lead to more accurately assessed impacts of water level declines on well pumping. Results from this study could be included on District-owned online dashboards, allowing individual well owners to efficiently assess likely water level decline impacts on their particular interests.

LRE Water also recommends the BSEACD consider surveying local pump installers, to assess likely example costs related with lowering pumps in wells where deeper pump depths are feasible. By utilizing standard hydraulic engineering theory, it is possible to quantify increased electrical/operational costs that will result from lowering regional aquifer water levels. Such increased costs could become part of a mitigation strategy the District may consider implementing when evaluating future permitting efforts. We recommend a Phase II well impact analysis study to focus on the District-wide well operation cost increases that will result from hypothetical water level declines.

REFERENCES

Barton Springs-Edwards Aquifer Conservation District (BSEACD), 2019, March 2018 Potentiometric Map of the Middle Trinity Aquifer, Central Texas. *BSEACD Report of Investigations 2019-0109, January 2019*. 33 p.

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APPENDIX A

Final Technical Memorandum for Task 1
Well Database Review

CONNECTING WATER TO LIFE

Technical Memorandum

To:	Dr. Tim Loftus, General Manager
From:	Vince Clause, PG, GISP Theresa Budd, PG Wally Darling, GIT
Reviewed By:	Jordan Furnans, PhD, PE, PG
Date:	April 2, 2024
Project:	Well Impact Analysis for the Trinity Aquifer
Subject:	Task 1 Update – Database Review

LRE Water ("LRE") provides herein an update regarding the progress made under Task 1 (Database Review) for the Barton Springs Edwards Aquifer Conservation District ("BSEACD") Well Impact Analysis for the Trinity Aquifer (RFQ No. 1023-01). Services provided herein are in accordance with the terms outlined in the Master Service Agreement established on October 13, 2022 between LRE and the BSEACD under Task Order No. 2 (Well Impact Analysis) dated November 22, 2023, and as amended on February 2, 2024. Task 1 of the Well Impact Analysis ("Well Database Review") included reviewing and assessing the BSEACD's existing well database for completeness to use in the well impact analysis. Specifically, the tasks completed under this phase of work were to review the database for completeness with respect to the following well properties needed to perform a well impact analysis:

- Well coordinates (latitude/longitude);
- Well name and ID (District ID, State Well Number, and/or Well Tracking Number);
- Land surface elevation;
- Borehole and well depth;
- Well status (inactive, active/production, monitor, plugged, etc.);
- Well use (domestic, public supply, irrigation, industrial, etc.);
- Well type (withdrawal of water, spring, oil and gas well, etc.);
- Well construction (screen and casing depth intervals, well diameter, changes in well diameter); and
- Pump setting depth.

LRE received the following project files from the BSEACD on February 13, 2024:

- *"all_records_unmerged.xlxs"*
- *"BSSEA_WELL_INVENTORY_14_09_2023.xlxs"*
- *"WELL_INVENTORY_METHODS.docx"*

In addition, LRE requested the following project files on February 14, 2024 to assist with the database review:

- *"WellRegistration_SurveyMonkey_2023.kbe.xlsx"*
- *"CHC_WellDB_ForIntera.mdb"*
- *"DatabaseWellsLayer_230214_monitoring.xlsm"*
- *"WELLS_PROD4_062023.mdb"*

LRE reviewed the "*WELL_INVENTORY_METHODS.docx"* document to understand the methods BSEACD used to create their "master" well dataset. These methods were deemed satisfactory for the creation of a usable well dataset. The "*BSSEA_WELL_INVENTORY_14_09_2023.xlxs"* document (considered the "master well dataset" and referred to herein as "BSEACD Dataset") was reviewed and is the file from which the final dataset is based. The remaining files requested by LRE were reviewed but were not altered and did not contain information relevant for completion of this task.

The BSEACD Dataset contained 8,887 entries (rows) with a total of 68 fields (columns). Most of these columns indicate the data value with the original data source provided in parentheses, including: the Well Registration Database and CHC Database ("Reg"), Monitoring Well Spreadsheets ("Mon"), BSEACD Well Database ("District DB"), Texas Water Development Board Groundwater Database ("GWDB"), and the Submitted Driller's Report Database ("SDR"). Table 1 provides all the database fields (column names) in the BSEACD Dataset. Two spelling errors were identified and corrected: "Longtidue (Reg)" to "Longitude (Reg)," and "Horespower (District DB)" to "Horsepower (District DB)."

Table 1 – BSEACD Dataset Fields (Column Names)

'Inventory ID'	'Potential Duplicates'	'State Well Number'	'Well Report Tracking Number'	'Original Well Report (SDR)'	'Adjusted SWN (Reg)'	'Adjusted SWN (District DB)'
'Adjusted SWN (Mon)'	'Well ID (GWDB)'	'In District Database'	'Monitoring Status (Mon)'	'Within District Boundaries'	'Well ID (Mon)'	'Well ID (Reg)'
'Well ID (District DB)'	'Latitude (Reg)'	**'Longtidue (Reg)'**	'Latitude (Mon)'	'Longitude (Mon)'	'Latitude (District DB)'	'Longitude (District DB)'
'Latitude (GWDB)'	'Longitude (GWDB)'	'Latitude (SDR)'	'Longitude (SDR)'	'County (GWDB)'	'County (SDR)'	'Address (Reg)'
'Address (District DB)'	'Owner (Mon)'	'Owner (Reg)'	'Owner (District DB)'	'Owner (GWDB)'	'Owner (SDR)'	'Drill Date (Reg)'
'Drill Date (GWDB)'	'Drill Date (District DB)'	'Drill Date (SDR)'	'Drill Date (Mon)'	'Surface Elevation (Reg)'	'Surface Elevation (GWDB)'	'Surface Elevation (District DB)'
'Surface Elevation (Mon)'	'Borehole Depth (Reg)'	'Borehole Depth (GWDB)'	'Borehole Depth (District DB)'	'Borehole Depth (SDR)'	'Borehole Depth (Mon)'	'Screen Depths (GWDB)'
'Screen Depths (SDR)'	'Casing Depth (Reg)'	'Pump Depth (Reg)'	'Pump Depth (SDR)'	'Pump Depth (GWDB)'	'Borehole Diameter Inches (Reg)'	'Casing Diameter Inches (Reg)'
'Casing Diameter (District DB)'	'Aquifer Code (District DB)'	'Well Type (District DB)'	'Well Type (Reg)'	'Datasource (Reg)'	'Method of Construction (District DB)'	'Type of Lift (District DB)'
'Type of Power (District DB)'	**'Horespower (District DB)'**	'Screen Material (District DB)'	'Notes (Reg)'	'Comments (GWDB)']		

Methodology

LRE created a new dataset ("*LRE_MOD_ 3_12_24.xlxs*" herein referred to as "LRE Modified Dataset") to track the changes and modifications made to the BSEACD Dataset. An initial review of the BSEACD Dataset was conducted to identify missing or incorrect data required for the Well Impact Analysis. Table 2 outlines the "flagging" criteria established by LRE to identify well records in the BSEACD Dataset where information was missing or incomplete. Customized Python queries were created for each flagging criterion to automate the flagging process. A new column named "Inventory_Flag_Data" was added to the LRE Modified Dataset, which lists the corresponding flag value(s) using LRE's criteria outlined in Table 2.

Table 2 – LRE "flagging" Criteria for the BSEACD Dataset

Parameter	Flag	Description of Flag	Column
Location	1	All well coordinate columns checked. Flagged for missing or incomplete data. Checked for location accuracy and update coordinates if incorrect.	'Latitude (Reg)' 'Longitude (Reg)' 'Latitude (Mon)' 'Longitude (Mon)' 'Latitude (District DB)' 'Longitude (District DB)' 'Latitude (GWDB)' 'Longitude (GWDB)' 'Latitude (SDR)' 'Longitude (SDR)'
Well Name /ID	2	All well ID columns checked. Flagged if well name or ID is missing or incomplete.	'State Well Number' 'Well Report Tracking Number' 'Well ID (GWDB)' 'Well ID (Mon)' 'Well ID (Reg)' 'Well ID (District DB)'
Surface Elevation	3	All surface elevation columns checked. Flagged for missing or incomplete data.	'Surface Elevation (Reg)' 'Surface Elevation (GWDB)' 'Surface Elevation (District DB)' 'Surface Elevation (Mon)'
Depth	4	All depth columns checked. Borehole depths were compared to reported depths in the *"WellLithology.txt"* and *"WellStrata.txt"* files for wells in the SDR Database. Flagged for missing, incorrect or incomplete data.	'Borehole Depth (Reg)' 'Borehole Depth (GWDB)' 'Borehole Depth (District DB)' 'Borehole Depth (SDR)' 'Borehole Depth (Mon)' 'Casing Depth (Reg)'
Well Status	5	Monitoring well status column checked. Flagged for missing or incomplete data	'Monitoring Status (Mon)'
Well Use Type	6	All well type columns checked. Flagged for missing or incomplete data.	'Well Type (District DB)' 'Well Type (Reg)'
Screen Depths	7	All screen depth columns checked. Flagged for missing or incomplete data.	'Screen Depths (GWDB)' 'Screen Depths (SDR)'
Casing/ Borehole Diameter	8	All casing diameter and borehole columns checked. Flagged for missing or incomplete data.	'Casing Diameter, Inches (Reg)' 'Casing Diameter (District DB)'
Pump Depth	9	All pump depth columns checked. Flagged for missing or incomplete data.	'Pump Depth (Reg)' 'Pump Depth (SDR)' 'Pump Depth (GWDB)'

Upon the initial review and flagging of the BSEACD Dataset, LRE proceeded with the following six (6) sequential steps for the Database Review:

1) Downloaded all records from the Texas Water Development Board Groundwater Database (GWDB) and Submitted Drillers Report (SDR) Database on February 14, 2024, which included *"WellMain.txt"*, *"WellCasing.txt", "WellTest.txt",* and *"WellBorehole.txt"* text files from the TWDB GWDB, and *"WellData.txt"*, *"WellBorehole.txt", "WellCasing.txt", and "WellTest.txt"* text files from the SDR Database. LRE created customized python scripts to generate a master file for each downloaded text file.
2) Merged the downloaded files from the GWDB and SDR Database. In both the GWDB and SDR Database, text fields such as "MigratedCasingInfo", "Comments", and "Remarks" contain valuable information regarding the well construction, pump test data, and other pertinent well information. LRE developed python scripts to extract and sort the data from these text files into their respective columns in the LRE Modified Dataset. LRE reviewed the extracted data by conducting a manual QA/QC review to ensure accuracy.
3) Compiled merged data downloaded from the GWDB and SDR Database with the BSEACD Dataset in the LRE Modified Dataset. LRE added a new column labeled 'Key_ID' to the LRE Modified Dataset to issue a unique identifier to each row, as previous methods used to merge the BSEACD Dataset and SDR/GWDB databases created multiple entries in the 'Inventory_ID' column and therefore did not allow for a "proper" unique identifier. LRE developed python scripts to filter and combine the appropriate fields to a usable and readable format. To further ensure that each well in the dataset is unique, LRE used spatial analysis techniques in ArcPro to identify wells that were within 10 feet of each other. These wells are noted in a new column in the LRE Modified Dataset called 'Spatial_Duplicates_ID' that corresponds to the duplicate well 'Key_ID'.
4) LRE assigned surface elevations to all well records based on the 2017 Central Texas LiDAR Digital Elevation Model (DEM) and entered those values in a new column labeled 'LiDAR_Elevation' in the LRE Modified Dataset. The 2017 Central Texas DEM is the most recent dataset for the area.
5) LRE is currently involved with developing a dashboard and analytical tool for the BSEACD. The dashboard contains well data with aquifer designations for well completion, specifically for the "upper Trinity, middle Trinity, and lower Trinity" aquifers. LRE downloaded all the well data from the dashboard and created a query to merge this dataset with the LRE Modified Dataset. The only information

from the dashboard that was included in the LRE Modified Dataset is the aquifer designation.

6) Once data from the other sources had been added to the LRE Modified Dataset, LRE created a new column in the LRE Modified Dataset called 'LRE_Added_Flag' to indicate where data ad been added by LRE for the records in the BSEACD Dataset that were flagged using the criteria outlined in Table 2. LRE developed queries in Python to identify flag data had been added by LRE, and the corresponding flag value(s) are listed under the 'LRE_Added_Flag' column. LRE added a new column named 'Remaining_Flagged' to the LRE Modified Dataset, which flags records that are still missing information.

For example, if a well record in the BSEACD Dataset was missing information in any of the 'Surface Elevation' and 'Borehole Depth' columns, the 'Inventory_Flag_Data' column in the LRE Modified Dataset would contain the values "[3, 4]". If LRE added a "Surface Elevation" value for this well record using the LiDAR data, then there would be a surface elevation value for that well record in the 'LiDAR_Elevation' column of the LRE Modified Dataset. Since there is available data in the 'Surface Elevation' column of the LRE Modified Dataset, the corresponding value in the 'LRE_Added_Flag' column of the LRE Modified Dataset would be "[3]". If there was still missing information on the borehole depth for that well record in the BSEACD Dataset and the LRE Modified Dataset, then the value in the 'Remaining_Flagged' column would appear as "[4]". Therefore, for any values or columns where LRE added information from the GWDB, SDR Database, or the dashboard, there will be a corresponding flag value under the 'LRE_Added_Flag' column in the LRE Modified Dataset. The flag value(s) listed under the 'Remaining_Flagged' columns indicate that is still missing or incorrect information for those well records. The well records with remaining flags will be manually checked during the QA/QC period.

Table 3 provides a description of all the columns within the LRE Modified Dataset.

Table 3 – LRE Modified Dataset – Column Descriptions

Column Name	Description
Key_ID	LRE-assigned unique identifier
Inventory_ID	Well identifier from the BSEACD Dataset (INTERA-assigned). Can contain multiple values separated by ","
District_ID	District-assigned well identifier. Based on the grid location of the well and the owners initials
StateWellNumber	Texas Water Development Board (TWDB) Database State Well Identification number
WellReportTracking Number	Submitted Drillers Report (SDR) Database Well Identification number
Address	Physical address of the well. Provided by District
Aquifer_TWDB	TWDB-assigned aquifer code and name
Aquifer_District	Aquifer assigned to well from BSEACD dashboard
Latitude	NAD 83 latitude for the well location, in decimal degrees
Longitude	NAD 83 longitude for the well location, in decimal degrees
Well_Use	TWDB-assigned, primary use of the water (ex. domestic, irrigation, industrial, livestock)
Well_Type	TWDB-assigned, primary use of the well (ex. withdrawal of water, spring, oil or gas)
Well_Status	Well permit/production status, District-assigned (ex. exempt, non-exempt)
Surface_Elevation	Surface elevation of the well based on reported values from all datasets (BSEACD, GWDB, SDR), in feet above mean sea level
LiDAR_Elevation	Surface elevation, in feet mean sea level. If elevation was not available from the BSEACD Dataset, then this field includes surface elevation from LiDAR data (2017 Central Texas LiDAR DEM), in feet above mean sea level
Borehole_Depth	Depth of the borehole, in feet below land surface
Well_Depth	Depth of the well, bottom of casing or screen, in feet
Casing_Depth	Depth of the bottom of the casing, in feet. Value may be where the screen starts
Casing_Diameter	Outer casing diameter, in inches
Borehole_Diameter	Diameter of borehole, in inches
Borehole_Changes	Depth interval for each change in borehole diameter, in feet below land surface
Casing_Changes	Depth intervals for each change in diameter, in feet below land surface
Screen_Intervals	Screen Interval, in feet below ground level. [(top of screen 1, bottom of screen 1), (top of screen 2, bottom of screen 2)]
Pump_Depth	Depth of pump in the well, in feet
Water_Level	Most recent water level measurement, in feet below land surface
Yield	Yield of water from pump test, in gallons per minute
Drawdown	Amount of total drawdown in the well from pump test, in feet
Hours	Hours of pumping from pump test
MigratedCasingInfo	Text field from TWDB GWDB/SDR Database, contains well construction information
Inventory_Flag_Data	List of values that represent flags for missing data in the BSEACD Dataset
LRE_Added_Data	List of values that represent flags for data that was added by LRE
Remaining_Flag	List of values that represent flags for missing data after adding data from other sources
Spatial_Duplicate_ID	Duplicates of wells identified from a spatial query. Value is the Key ID of the duplicate well
Distance_ft	Distance from the main well and the spatial duplicate, in feet

The quality assurance and quality control (QA/QC) process will include manually reviewing the 'Remaining_Flagged' column in the LRE Modified Dataset and filling in missing or incorrect information. In addition, LRE will review any conversion or location errors within the LRE Modified Dataset and note of any additional corrections made to the dataset that were not detected in the automated flagging process.

As of March 21, 2024, $9,911.50 of the $15,000.00 budget for Task 1 has been used for the Database Review. The remaining funds will be used towards QA/QC for the remaining flagged records to ensure the dataset is complete. If additional funds are required for this task, LRE may re-allocate funds from subsequent tasks to ensure that the information in the database is updated and complete (if authorized by BSEACD). Table 4 summarizes the schedule and cost of the projects tasks in accordance with the MSA.

Table 4 –Schedule and Project Costs

Task	Task Description	Estimated Cost	Date of Completion
1	Well Database Review	$15,100	April 8, 2024
2	Trinity Aquifer Designation	$19,492	June 8, 2024
3	Well Impact Analysis	$23,236	July 8, 2024
4	Reporting	$17,712	August 31, 2024
	Project Management	$6,424	August 31, 2024
Total		$81,964	

Work performed under this task can be competed by April 8, 2024 in accordance with the schedule provided in the Master Service Agreement. Once the services performed under this task have been fulfilled, LRE will provide the BSEACD with a copy of the final flagged database to be used in the Well Impact Analysis. LRE will commence with work under Task 2 (Trinity Aquifer Designation) only upon receipt of authorization from BSEACD.

Please let us know if you have any questions.

Sincerely,

Vince Clause, PG, GISP
Texas Groundwater Lead

Theresa Budd, PG
Senior Project Hydrogeologist

APPENDIX B

Final Technical Memorandum for Task 2
Aquifer Designations

DRAFT Technical Memorandum

To: Dr. Tim Loftus, General Manager

From: Vince Clause, PG, GISP
Theresa Budd, PG
Wally Darling, GIT

Date: June 24, 2024

Project: Well Impact Analysis for the Trinity Aquifer

Subject: Task 2 Update – Aquifer Designations

LRE Water ("LRE") provides herein an update regarding Task 2 (Aquifer Designations) for the Barton Springs Edwards Aquifer Conservation District ("BSEACD") Well Impact Analysis for the Trinity Aquifer (RFQ No. 1023-01). Services provided herein are in accordance with the terms outlined in the Master Service Agreement established on October 13, 2022 between LRE and the BSEACD under Task Order No. 2 (Well Impact Analysis) dated November 22, 2023, and as amended on February 2, 2024. Task 2 of the Well Impact Analysis included designating aquifers (e.g., Edwards, Upper Trinity, Middle Trinity, Lower Trinity) for wells in the BSEACD Modified Well Database ("*LRE_MOD_3_12_24.xlxs*") from Task 1. LRE used well completion information, including surface elevation, well depth, screen interval, and well location from the BSEACD Modified Well Database in this analysis. LRE employed spatial analyst tools in ArcGIS to develop and extract formation depths from aquifer elevation surfaces. Under this task, aquifers were assigned to each Trinity Aquifer well record in the BSEACD Modified Well Database where well construction information was reported.

Methodology

LRE used the BSEACD Modified Well Database from Task 1 in this analysis and proceeded with the following steps:

1) Extracted stratigraphic picks from the "*BSEACD_GeologyContacts.gdb*" file provided by BSEACD;
2) Developed aquifer structure elevation surfaces using geoprocessing tools in ArcGIS ("Topo to Raster"). Aquifer surfaces were created from stratigraphic picks in the BSEACD Geology database in units of feet above mean sea level and feet below land surface;
3) Appended formation depths from each aquifer surface to wells in the BSEACD Modified Well Database using spatial analyst tools in ArcGIS;

4) Assigned aquifer(s) based on the relationship between the formation depths, and well construction setting depth information; and
5) Manually reviewed well records where wells were identified as dual completed, open hole, located near structural features, or where well construction information was limited.

Assumptions

The following assumptions were used while designating aquifer completions for wells in the BSEACD Modified Well Database:

1. Where screen intervals were reported and set entirely within an aquifer production zone, LRE assigned the well completion to the aquifer that confined the screen interval;
2. Wells with multiple screen intervals or where screen was set within multiple aquifer production zones were assumed to be "dual completed" and were flagged for further assessment;
3. Wells with reported "open hole" screen intervals were flagged for further assessment;
4. Where 20 feet or more of an aquifer was screened, that aquifer was assigned to the well;
5. Dual completed wells were assumed when screen intervals were set at least 20 feet or more into multiple formations;
6. If screen intervals were not reported, LRE used the well depth and/or borehole depth to assign aquifer completions. It was assumed that screen was set within the bottom 50 feet of a well;
7. Wells with reported "open hole" completions that were drilled into the Hammett Shale were assumed to produce from the overlying formation(s). Any wells that penetrate the Hammett Shale will not remain "open" after completion, as the formation swells and naturally fills open annular space and acts as a "bottom plug";
8. Where no well construction information was available (including screen interval, well depth, and/or borehole depth) aquifer designations were classified as "Unknown"; and
9. Wells located east of the I-35 corridor within the Balcones Fault Zone (BFZ) were reviewed in more detail due to the complex geology caused by faulting. In some instances, shallow formation offsets were used to estimate offsets for the deeper Trinity Aquifer units.

Well records that were marked as dual-completed, open hole, or located in faulted areas were flagged for further assessment. During the QA/QC process, the wells were spatially georeferenced and aquifer designations were compared to surrounding wells. In addition, LRE reviewed the stratigraphic picks and assessed aquifer depths from surrounding wells, characteristic geophysical log signatures, and lithologic reports to assist with designating aquifer completions. Figure 1 provides a schematic well diagram of the assumptions associated with various well completions and aquifer designations determined under this task.

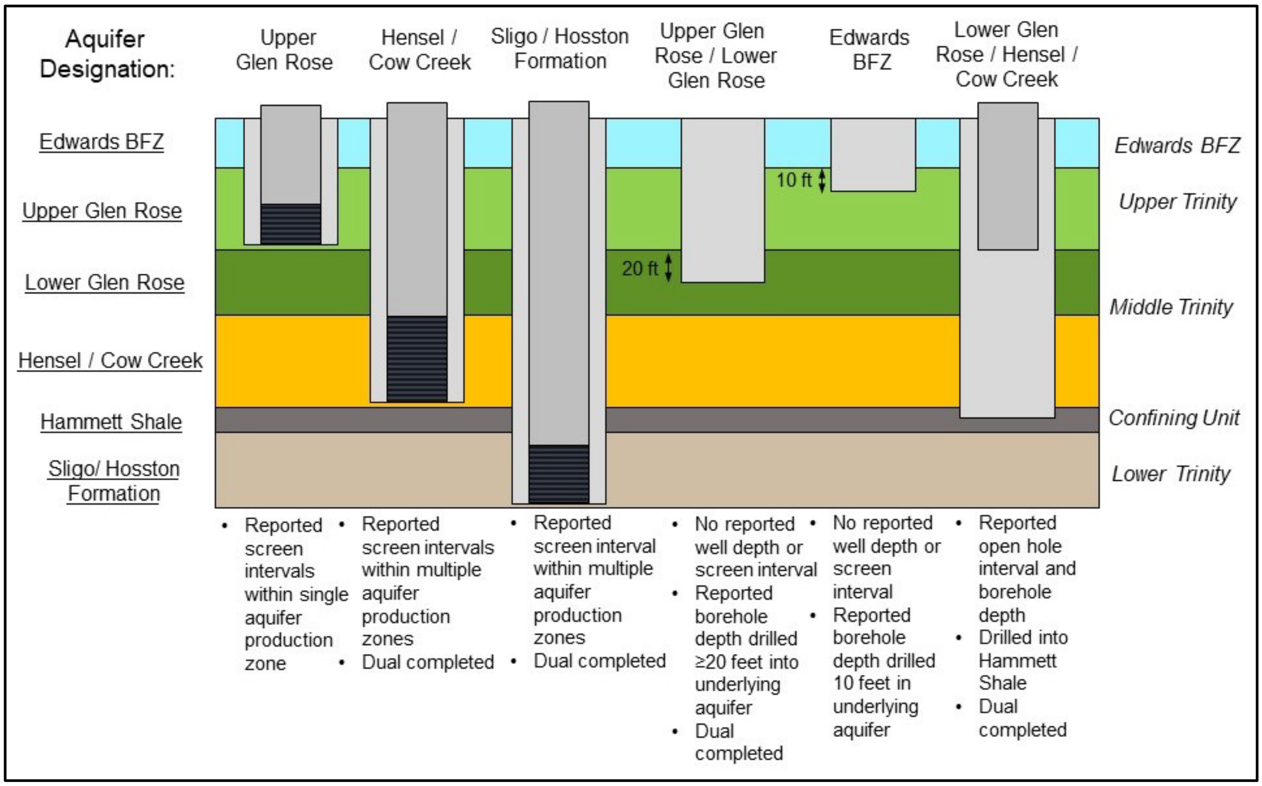

Figure 1. Schematic Diagram of Assumptions for Aquifer Designations

Results

Table 1 summarizes the number of wells in the BSEACD Modified Well Database that were designated an aquifer completion. Table 2 summarizes the number of wells with aquifer designations using the BSEACD aquifer classifications (Edwards BFZ, Upper Trinity, Middle Trinity, and Lower Trinity). This assessment resulted in designating 1,410 wells in the BSEACD Modified Well Database with aquifer assignments and 203 wells where the aquifer was identified as "Unknown" due to the lack of available well construction information.

Table 1 – Summary of Aquifer Designations

Aquifer Designation	Number of Wells
Single Aquifer Completion Designation	
Edwards (Balcones Fault Zone)	53
Upper Glen Rose Limestone	223
Lower Glen Rose Limestone	283
Hensel	40
Cow Creek Limestone	354
Hammett Shale	0
Sligo Formation	26
Hosston Formation	289
Unknown	203
Single Aquifer Completion Totals	1,471
Dual Aquifer Completion Designation	
Edwards BFZ / Upper Glen Rose	1
Upper Glen Rose / Lower Glen Rose	20
Lower Glen Rose / Hensel	31
Lower Glen Rose / Hensel / Cow Creek	22
Hensel / Cow Creek	40
Cow Creek, Sligo, Hosston	1
Hensel, Cow Creek, Sligo, Hosston	1
Glen Rose, Hensell, Cow Creek	6
Glen Rose, Hensel, Cow Creek, Sligo, Hosston	1
Lower Glen Rose, Hensel, Cow Creek, Sligo, Hosston	1
Sligo / Hosston	18
Dual Aquifer Completion Totals	142

Table 2 – Summary of BSEACD Aquifer Designations

BSEACD Aquifer Completion Designation	
Edwards BFZ	53
Edwards / Upper Trinity	1
Upper Trinity	223
Upper / Middle Trinity	26
Middle Trinity	770
Middle / Lower Trinity	4
Lower Trinity	333
Unknown	203

Figure 2 shows the spatial distribution of wells in the BSEACD Modified Well Database with aquifer classifications.

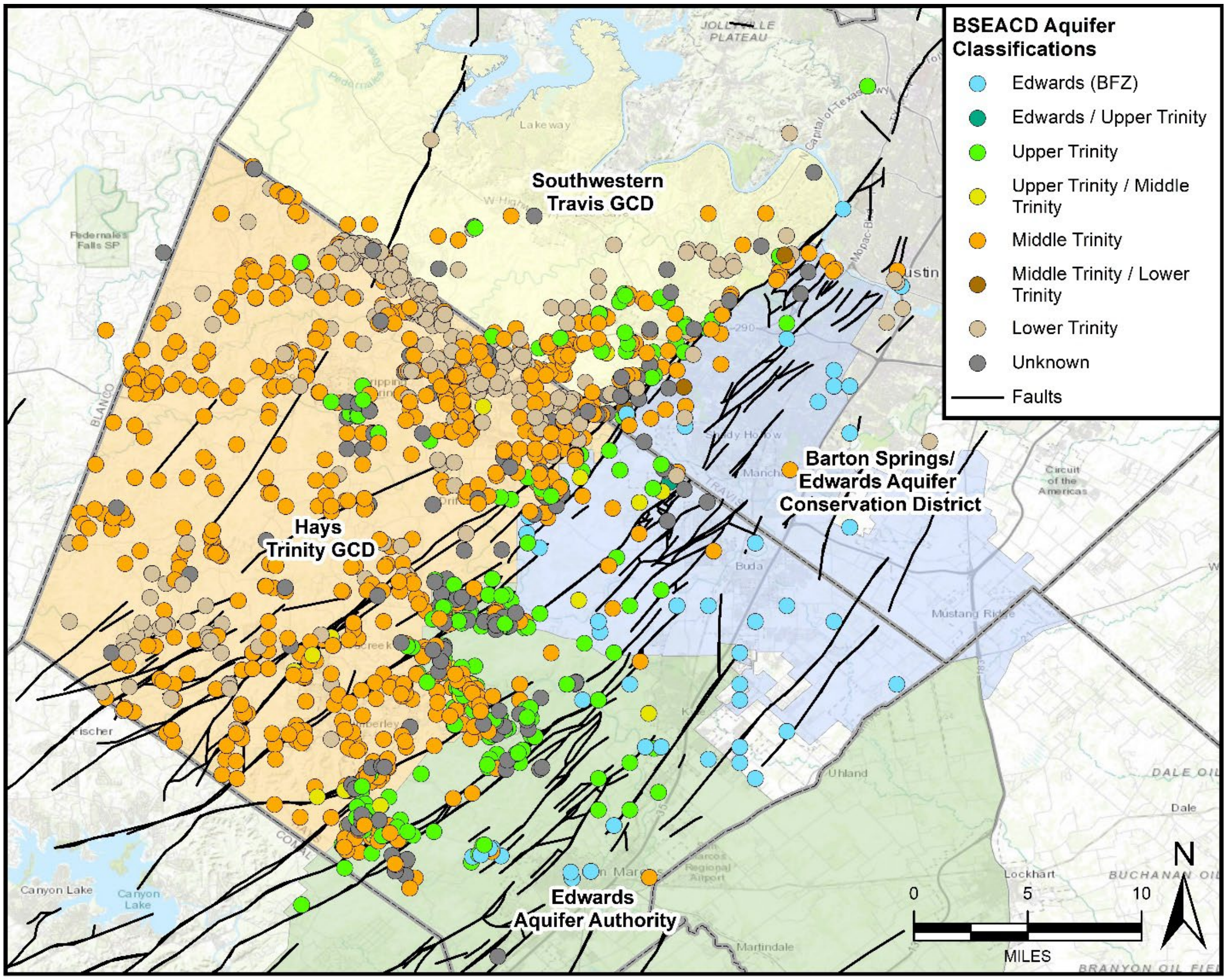

Figure 2. Aquifer Classifications for Wells in BSEACD Database

Any wells that were completed above the Trinity Aquifer were assigned to the "Edwards Balcones Fault Zone (BFZ)" aquifer, which includes the Austin Chalk, the Edwards, and associated limestones. It should be noted that aquifer completions identified by LRE may be subjective and differ from the actual aquifer in which the well is completed. Some degree of error and uncertainty is inherent when generating raster surfaces due to the raster cell size, which may affect the reported formation depths. In addition, the location of structural features may not be accurately depicted from the stratigraphic picks, especially where data is not available. Moreover, some aquifer designations may be incorrect where well construction is limited or not accurately reported. Therefore, the aquifer designations identified by LRE for the wells in the BSEACD Modified Well Database should only be used for the purpose of this study. LRE will use the BSEACD Modified Database with LRE's designated aquifers in Task 3 of the Well Impact Analysis.

Project Cost Updates

As of June 21, 2024, $3,460 of the $19,492 budget remains for Task 2 (Trinity Aquifer Designation). If the remaining funds from Task 2 are not used, they may be used for subsequent tasks (if needed). Table 2 summarizes the remaining funds for the projects tasks in accordance with the MSA.

Table 3 – Project Cost Updates

Task	Task Description	Estimated Cost	Remaining Funds
1	Well Database Review	$15,100.00	$ 44.50
2	Trinity Aquifer Designation	$19,492.00	$ 3,460.00
3	Well Impact Analysis	$23,236.00	$ 23,236.00
4	Reporting	$17,712.00	$ 15,068.00
	Project Management	$6,424.00	$ 5,622.00
Total		$81,964.00	$ 47,430.50

Work performed under Task 2 was completed on June 21, 2024. LRE will provide the BSEACD with a copy of the BSEACD Modified Well Database with LRE's Aquifer Designations as a final deliverable for this task. LRE will commence with work under Task 3 upon receipt of authorization to proceed from the BSEACD.

Please let us know if you have any questions.

Sincerely,

Vince Clause, PG, GISP
Texas Groundwater Lead

Theresa Budd, PG
Senior Project Hydrogeologist

APPENDIX C

BSEACD Middle Trinity Well Database
Data Dictionary

Field Name	Field Type	Units	Description
Key_ID	Numeric	NA	
Inventory_	Numeric	NA	
StateWellN	Numeric	NA	State well number, as recorded in the TWDB Groundwater Database
TrackingNu	Numeric	NA	State driller's report tracking number
District_I	Text	NA	
Well_Name	Text	NA	Well name
well_id	Numeric	NA	
Address	Text	NA	Address of well location
Latitude	Numeric	decimal degrees	Well's Y coordinate
Longitude	Numeric	decimal degrees	Well's X coordinate
LiDAR_Elev	Numeric	feet mean sea level	Lidar elevation at well location
DB_Origin	Text	NA	Database of origin
WIA_used	Y/N	NA	Whether well was used in well impact analysis
IN_DISTRICT	Boolean	NA	Whether well is located within BSEACD or not
IN_SWC	Boolean	NA	Whether well is located within the southwest corner (SWC) of the BSEACD
Borehole_D	Numeric	feet	Borehole depth
Comment	Text	NA	Comments
Screen_Int	Numeric	feet below ground	Screen interval(s)
Screen_Top	Numeric	feet below ground	Top of (uppermost) screen
Pump_Orig	Numeric	feet below ground	Original recorded pump depth
Hypo_Pump Depth	Numeric	feet below ground	Field consolidating recorded and hypothetical pump depths
Pump_Flag	Text	NA	Indicates whether well has a recorded pump depth ("ORIGINAL") or a hypothetical pump depth ("HYPO")
Method_Used	Text	NA	Indicates which method was used to estimate pump depth: "No Method" (i.e., well has a recorded pump depth), "Inside Method", "Outside Method", or "Special Case"
Borehole_C	Numeric	inches, feet below ground	Record of borehole diameter(s) and associated depth interval(s)
Casing_Cha	Numeric	inches, feet below ground	Record of casing diameter(s) and associated depth interval(s)
Cas_Bot	Numeric	feet below ground	Bottom of casing
BoreholeCompletion	Text	NA	Type of borehole completion, as recorded in State Drillers Reports
CasingType	Text	NA	Casing type, as recorded in State Drillers Reports
Open_Hole_Flag	Text	NA	Indicates whether a well is an open hole ("TRUE"), and lined open hole ("LINED OH"), or not an open hole completion ("FALSE")
Telescp_Flag	Boolean	NA	Indicates whether a well has a casing size reduction, i.e., telescoping well
Tel_Dpth	Numeric	feet below ground	The depth of casing size change
AQ_Class	Text	NA	The geological units a well is screened in. "CC" - Cow Creek, "GRL" - Lower Glen Rose, "GRU" - Upper Glen Rose, "HE" - Hensel, "HO" - Hosston, "SL" - Sligo

Field Name	Field Type	Units	Description
AQ_Complet	Text	NA	The well's aquifer designation. "Middle Trinity" - well is solely screened in the Middle Trinity Aquifer; "Multiple" indicates well is screened in the Middle Trinity Aquifer as well as another aquifer.
Kgrl_top	Numeric	feet mean sea level	Top of the Lower Glen Rose Formation
MT_top	Numeric	feet mean sea level	Top of the Middle Trinity Aquifer, defined as 50 feet below the top of the Lower Glen Rose Formation.
WL23el	Numeric	feet mean sea level	Water level elevation in 2023
WL23d	Numeric	feet below ground	Water level depth in 2023
IA23MT	Boolean	NA	Indicates whether 2023 water level is below the top of the Middle Trinity Aquifer.
IA23P	Boolean	NA	Indicates whether 2023 water level is within 20 feet of the pump depth.
IA23TOS	Text	NA	Indicates whether 2023 water level is below the top of the (uppermost) well screen. "NA" indicates a well with no screen information
IA23T	Text	NA	Indicates whether 2023 water level is below the point of casing size reduction. "NA" indicates well is not telescoping.
IA23TD	Boolean	NA	Indicates whether 2023 water level is below the total depth of the well.
WL23050el	Numeric	feet mean sea level	Water level elevation, 50 feet lower than 2023 level
WL23050d	Numeric	feet below ground	Water level depth, 50 feet lower than 2023 level
IA23050MT	Boolean	NA	Indicates whether water level 50 feet lower than 2023 level is below the top of the Middle Trinity Aquifer.
IA23050P	Boolean	NA	Indicates whether water level 50 feet lower than 2023 level is within 20 feet of the pump depth.
IA23050TOS	Text	NA	Indicates whether water level 50 feet lower than 2023 level is below the top of the (uppermost) well screen. "NA" indicates a well with no screen information
IA23050T	Text	NA	Indicates whether water level 50 feet lower than 2023 level is below the point of casing size reduction. "NA" indicates well is not telescoping.
IA23050TD	Boolean	NA	Indicates whether water level 50 feet lower than 2023 level is below the total depth of the well.
WL23100el	Numeric	feet mean sea level	Water level elevation, 100 feet lower than 2023 level
WL23100d	Numeric	feet below ground	Water level depth, 100 feet lower than 2023 level
IA23100MT	Boolean	NA	Indicates whether water level 100 feet lower than 2023 level is below the top of the Middle Trinity Aquifer.
IA23100P	Boolean	NA	Indicates whether water level 100 feet lower than 2023 level is within 20 feet of the pump depth.
IA23100TOS	Text	NA	Indicates whether water level 100 feet lower than 2023 level is below the top of the (uppermost) well screen. "NA" indicates a well with no screen information
IA23100T	Text	NA	Indicates whether water level 100 feet lower than 2023 level is below the point of casing size reduction. "NA" indicates well is not telescoping.
IA23100TD	Boolean	NA	Indicates whether water level 100 feet lower than 2023 level is below the total depth of the well.
WL23150el	Numeric	feet mean sea level	Water level elevation, 150 feet lower than 2023 level
WL23150d	Numeric	feet below ground	Water level depth, 150 feet lower than 2023 level

Field Name	Field Type	Units	Description
IA23150MT	Boolean	NA	Indicates whether water level 150 feet lower than 2023 level is below the top of the Middle Trinity Aquifer.
IA23150P	Boolean	NA	Indicates whether water level 150 feet lower than 2023 level is within 20 feet of the pump depth.
IA23150TOS	Text	NA	Indicates whether water level 150 feet lower than 2023 level is below the top of the (uppermost) well screen. "NA" indicates a well with no screen information
IA23150T	Text	NA	Indicates whether water level 150 feet lower than 2023 level is below the point of casing size reduction. "NA" indicates well is not telescoping.
IA23150TD	Boolean	NA	Indicates whether water level 150 feet lower than 2023 level is below the total depth of the well.
WL23200el	Numeric	feet mean sea level	Water level elevation, 200 feet lower than 2023 level
WL23200d	Numeric	feet below ground	Water level depth, 200 feet lower than 2023 level
IA23200MT	Boolean	NA	Indicates whether water level 200 feet lower than 2023 level is below the top of the Middle Trinity Aquifer.
IA23200P	Boolean	NA	Indicates whether water level 200 feet lower than 2023 level is within 20 feet of the pump depth.
IA23200TOS	Text	NA	Indicates whether water level 200 feet lower than 2023 level is below the top of the (uppermost) well screen. "NA" indicates a well with no screen information
IA23200T	Text	NA	Indicates whether water level 200 feet lower than 2023 level is below the point of casing size reduction. "NA" indicates well is not telescoping.
IA23200TD	Boolean	NA	Indicates whether water level 200 feet lower than 2023 level is below the total depth of the well.
WL23250el	Numeric	feet mean sea level	Water level elevation, 250 feet lower than 2023 level
WL23250d	Numeric	feet below ground	Water level depth, 250 feet lower than 2023 level
IA23250MT	Boolean	NA	Indicates whether water level 250 feet lower than 2023 level is below the top of the Middle Trinity Aquifer.
IA23250P	Boolean	NA	Indicates whether water level 250 feet lower than 2023 level is within 20 feet of the pump depth.
IA23250TOS	Text	NA	Indicates whether water level 250 feet lower than 2023 level is below the top of the (uppermost) well screen. "NA" indicates a well with no screen information
IA23250T	Text	NA	Indicates whether water level 250 feet lower than 2023 level is below the point of casing size reduction. "NA" indicates well is not telescoping.
IA23250TD	Boolean	NA	Indicates whether water level 250 feet lower than 2023 level is below the total depth of the well.
WL23300el	Numeric	feet mean sea level	Water level elevation, 300 feet lower than 2023 level
WL23300d	Numeric	feet below ground	Water level depth, 300 feet lower than 2023 level
IA23300MT	Boolean	NA	Indicates whether water level 300 feet lower than 2023 level is below the top of the Middle Trinity Aquifer.
IA23300P	Boolean	NA	Indicates whether water level 300 feet lower than 2023 level is within 20 feet of the pump depth.
IA23300TOS	Text	NA	Indicates whether water level 300 feet lower than 2023 level is below the top of the (uppermost) well screen. "NA" indicates a well with no screen information
IA23300T	Text	NA	Indicates whether water level 300 feet lower than 2023 level is below the point of casing size reduction. "NA" indicates well is not telescoping.

Field Name	Field Type	Units	Description
IA23300TD	Boolean	NA	Indicates whether water level 300 feet lower than 2023 level is below the total depth of the well.
AvDD_MT	Numeric	feet	Available drawdown between 2023 water level and the top of the Middle Trinity Aquifer
AvDD_Pump	Numeric	feet	Available drawdown between 2023 water level and the top of the pump
AvDD_TOS	Numeric	feet	Available drawdown between 2023 water level and the top of the screen
AvDD_TD	Numeric	feet	Available drawdown between 2023 water level and the top of the total depth of the well