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Prepared by
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Patricia B. Johnson[3], Dennis W. Powers[4], Dale O. Bowman[2]

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## Abstract

Advancements in directional drilling and well completion technologies have resulted in an exponential growth in the use of hydraulic fracturing for oil and gas extraction. Within the New Mexico Permian Basin, water demand to complete each hydraulically fractured well is estimated to average 7.3 acre-feet (2.4 million gallons), resulting in an increase to the regional water demand of over 5000 acre-feet per year. This rising demand is creating concern for the regions ability to meet the demand in a manner that fulfills BLM's role of protecting human health and the environment while sustainably meeting the needs of various of water users in the region. This report documents a study that establishes a water-level and chemistry baseline and develops a modeling tool to aid the BLM in understanding the regional water supply dynamics under different management, policy, and growth scenarios and to pre-emptively identify risks to water sustainability.

## ACKNOWLEDGMENTS

We would like to thank the Bureau of Land Management for funding this project and the many unnamed people at the BLM Carlsbad Field Office and Santa Fe State Office whose comments, suggestions, and in-kind contributions added greatly to this study.

## TABLE OF CONTENTS

## FIGURES

## TABLES

## NOMENCLATURE

| Abbreviation | Definition |
|---|---|
| **AF** | Acre-feet |
| **AMSL** | Above mean sea-level |
| **bgs** | Below ground surface |
| **BLM** | Bureau of Land Management |
| **CAGW** | Carlsbad Area Groundwater Water Availability Model |
| **CDF** | Cumulative distribution function |
| **CRE** | Capitan Reef East |
| **CRW** | Capitan Reef West |
| **DTW** | Depth to water |
| **EOR** | Enhanced oil recovery |
| **GIS** | Geographic Information System |
| **GRN** | Gamma-ray neutron |
| **HEAL** | Hall Environmental Analysis Lab |
| **HPA** | High potential area |
| **ICP** | Intercontinental Potash, Inc. |
| **MCL** | Maximum contaminant load |
| **NMOCD** | New Mexico Oil Conservation District |
| **NMOSE** | New Mexico Office of State Engineer |
| **NMSBA** | New Mexico Small Business Assistance program |
| **NMWQCC** | New Mexico Water Quality Control Commission |
| **PVACD** | Pecos Valley Area Conservation District |
| **RFD** | Reasonable foreseeable development |
| **SD** | System dynamics |
| **SNL** | Sandia National Laboratories |
| **SR/DL** | Santa Rosa / Dewey Lake |
| **TDS** | Total dissolved solids |
| **USGS** | United States Geological Survey |
| **WIPP** | Waste Isolation Pilot Plant |

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# 1. INTRODUCTION

This project examines changes in water sustainability due to hydraulic fracturing for oil and gas extraction on Federal and Indian lands in the New Mexico portion of the Permian Basin and produces a model to help decision makers understand the implications of their choices. It utilizes a multi-disciplinary approach that synthesizes data collection, field verification, and system dynamics modeling to increase our understanding of the regional water supply and demand to identify risks to water sustainability and develop alternatives to help avoid those risks.

A study of the 'Reasonable Foreseeable Development' (RFD) within Chavez, Lea, Eddy, and Roosevelt counties estimates that the yearly number of oil wells drilled will steadily increase over the next 20 years, with an ever increasing percentage of those wells relying on horizontal drilling and hydraulic fracturing (Engler et al. 2012). Along with the increase in hydraulic fracturing comes an increase in water demand, with each fractured well estimated to use between 5 and 12 AF (1.6 – 3.9 million gallons) of water (Broadhead et al. 2004; Engler et al. 2012). Water demand for enhanced oil recovery (EOR) activities is also forecast to increase as the numerous pools and plays advance to more mature phases of their reservoir life. Produced water from EOR and other drilling activities has been increasing at a rate of about 1250 AF/yr for the last 13 years, most of which is reinjected (Engler et al. 2012). As a result, the infrastructure for the disposal and injection of produced water will also need to be continuously expanded and maintained.

There is increasing concern as to the regions ability to meet the long-term increases in water demand in a manner that protects human health and the environment while sustainably meeting the needs of the variety of water users in the region. To address this concern, this project uses a

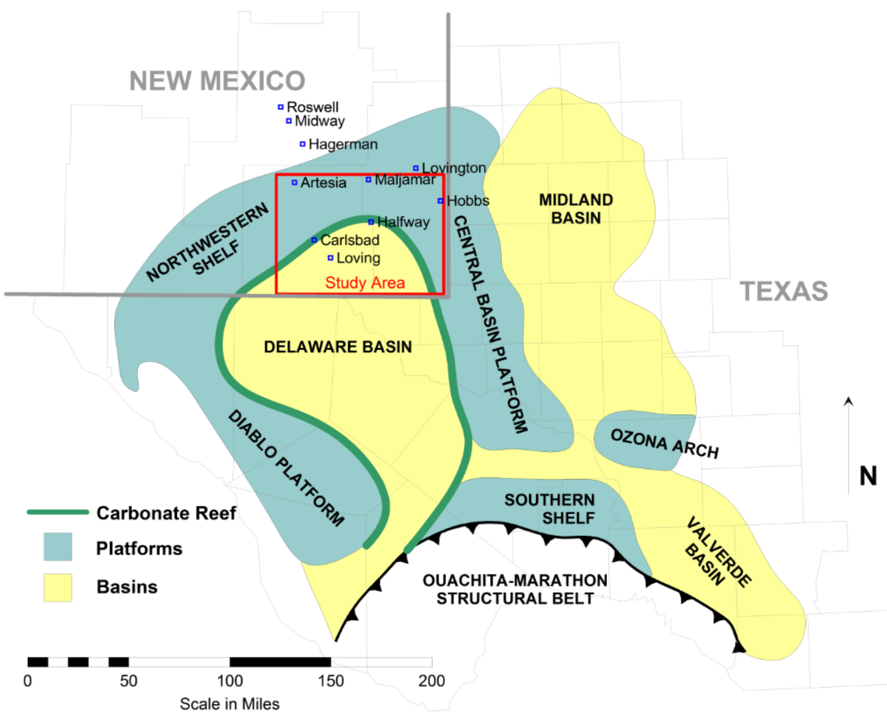



*Figure 1 - Map of Permian Basin and its components. The approximate outline of the study area is shown in red.*

combination of field work and modeling to establish a baseline of the regions groundwater resources and to develop a simulation tool to assess the impacts of future growth.

The approach combines activities in data collection, field data verification, field testing, GIS analysis, and systems dynamics (SD) modeling with the goal of producing insight and understanding that is beyond what can be produced if the activities were executed individually. Each of these activities is described as follows:

1. **Data Collection** – This activity creates an inventory of the water users (demand) and water sources (supply) in the region. Since no surface water rights are available for future exploitation, of particular interest is cataloguing the location, water production capacity and/or use, source formation, depth to groundwater, etc. of each groundwater source. Information from past pump tests (e.g. for the WIPP site), gas and oil well logs, and results from other relevant studies were also collected and compiled as were water sources from outside the basin (e.g., the Ogallala, the Capitan Reef formation, other back-reef formations, etc.).
2. **Field Data Verification** – Field data verification is used to ground-truth the data from the data collection effort beginning with a subset of the largest water users and working downwards from there. We contacted and worked with each water user to access their well(s) to take spot measurements of depth to groundwater, water quality, and to verify the borehole construction (e.g., completion depth, borehole size, etc.). In return for their cooperation, water users received a formatted report of the data and description of their well(s).
3. **Field Testing** – In addition to sampling and verification, the project tested and monitored a select number of wells to determine the hydrogeologic characteristics of the source formation.
4. **GIS Analysis** – This activity collected and catalogued the verified field data into a single GIS geodatabase that can be updated by the BLM in the future as information becomes available.
5. **System Dynamics Modeling** – A SD tool was developed that simulates water availability over a range of different future scenarios. The model is informed by the data and insights of the first four activities and simulates increases in drilling activity and water demand relative to each water source to identify the areas that are most vulnerable and to estimate the risk to water sustainability.

The projects intent is to create a data and simulation foundation that can be utilized and expanded as more information and understanding becomes available in the future.

The balance of this report is broken into six chapters. Chapter 2 provides a brief overview of the geologic and hydrogeologic setting for the study area. Chapter 3 expands on Chapter 2 by describing and presenting a series of geologic cross-sections made from borehole logs within the study area. Chapter 4 describes the process and details involved with the data collection, verification, and field testing efforts. Chapter 5 describes the SD model from its conceptual and mathematical points of view. Chapter 6 provides a high-level summary of the work and suggestions for follow-on studies.

## 2. PHYSICAL SETTING

### 2.1. The Permian Basin

The focus of this study is on water use for extracting oil and gas within the New Mexico portion of the Permian Basin. The motivation for this work is predicated on the current near-record level of drilling activity that does not appear to be waning anytime soon. Drilling in the Permian began in the 1920's and since then, there have been many peaks and troughs with respect to production levels. Over the past decade and half, new technologies in horizontal well drilling and fracking have led to the current increase in drilling activity in the Permian. The Texas Railroad Commission (who regulates oil and gas drilling in Texas) estimates that since its inception, the Permian Basin has produced over 29 billion barrels of oil and 75 trillion cubic feet of natural gas. They also estimate that with the new fracking technology, the current amount of recoverable oil and gas *exceeds* what has been produced over the last 90 years. Within New Mexico, the New Mexico Oil Conservation Division (NMOCD) website (NMOCD 2017) lists more than 27000 active oil wells in the basin alone and a near all-time high production rate of 462,000 barrels of oil extracted in August, 2017, twice what was being pumped six years earlier (Ortega 2017).

The RFD describes the future of oil and gas extraction in the region and assigns potential ratings of ‘low’, ‘moderate’, and ‘high’ to the various oil and gas plays in the region (Figure 2). This project focuses on the high potential areas (HPA’s) associated with the Alto Platform, Bone Spring, and Delaware Mountain Group plays, limiting the extent of each to development on federal lands managed by the BLM (Figure 3).

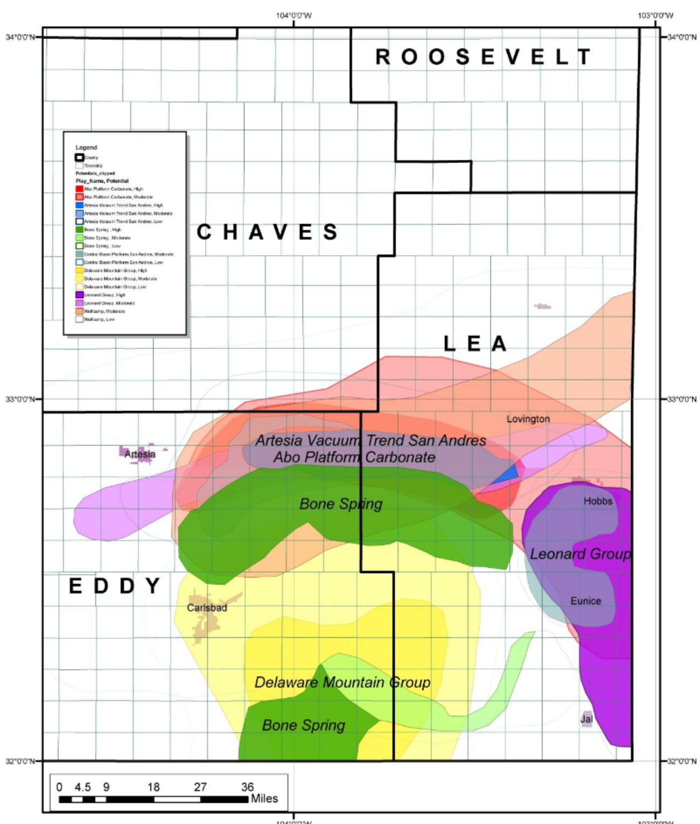



*Figure 2 - Potential map for all plays in Southeastern New Mexico. From Engler et al. (2012).*


*Figure 3 – The project study area showing the HPA's.*

## 2.2. Hydrogeologic Description

The study area consists of five main aquifers; the Pecos Valley alluvium, the Dewey Lake and Santa Rosa, the Culebra, the Magenta, and the Capitan aquifers. For this project, the Culebra and Magenta are considered as a single aquifer and are designated as the Rustler aquifer (the Rustler Formation being the host formation for the Culebra and Magenta). It should be noted that the Rustler Formation as a whole is not considered to be an aquifer and that its designation here should always be interpreted to be the collective capacity of the Culebra and Magenta units.

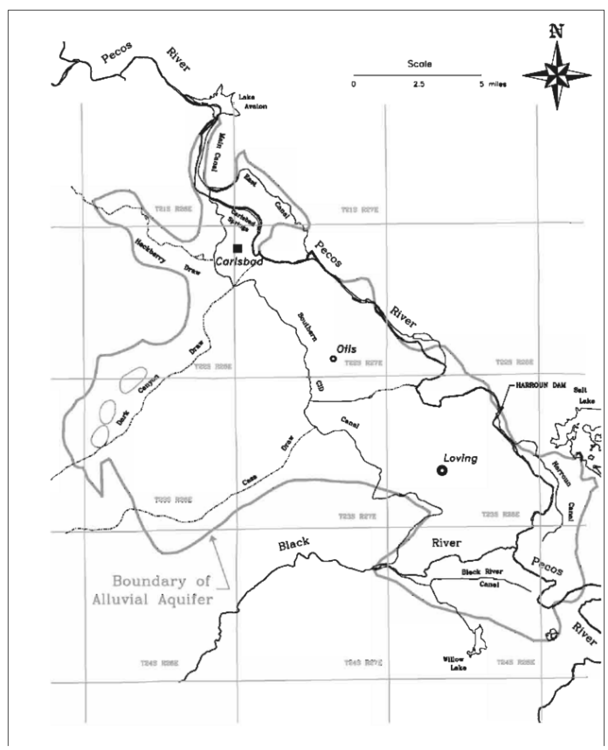
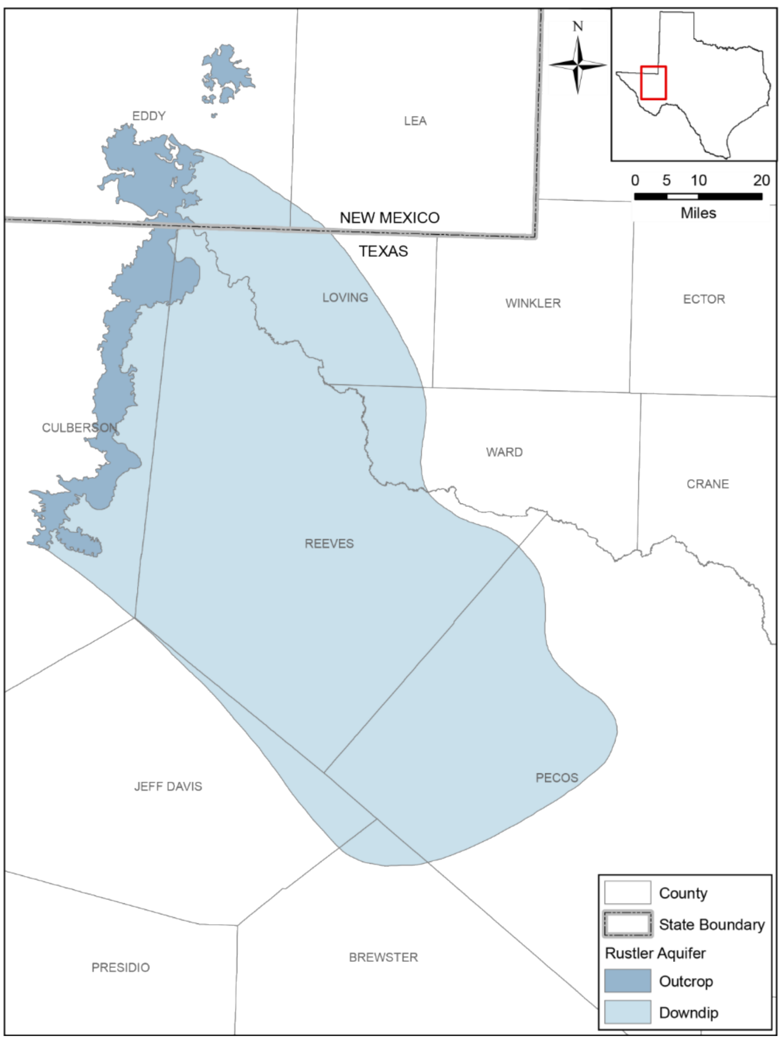



*Figure 4 - Extent of the Pecos Valley alluvium aquifer (grey line). From the Carlsbad Area Groundwater Model report (Barroll et al. 2004).*

Within the study area, the Pecos Valley alluvium aquifer (called the alluvial aquifer in this project) consists of Quaternary surficial deposits, existing in a narrow strip along the Pecos River between just below Lake Avalon to the confluence of the Pecos and Black Rivers (Figure 4) (Barroll et al. 2004). In New Mexico, the saturated thickness of the alluvium reaches 150 feet in the north decreasing to 50 ft in the south (NMISC 2016). The alluvial aquifer is recharged from areal precipitation, streamflow events from several ephemeral streams, and recharge from irrigation canals and Lake Avalon, with water generally flowing west to east from the recharge points to the river. The interaction with the river is important in that over-pumping of the aquifer can lead to reduced flows in the Pecos River, which may have implications with respect to the State of New Mexico meeting the requirement of the Pecos River Compact (Carron 2003). Average pumping from the aquifer is close to 30,000 AF/yr (based on data from 1980-2000) and is split between agricultural (48%), municipal (32%), and industrial (20%) uses (Barroll et al. 2004). While the aquifer is off limits to future development, there are no restrictions on existing users selling their water for other purposes, including sales to oil and gas companies for fracking.

The Santa Rosa and Dewey Lake (SR/DL) are two distinct geologic formations that have been combined for this study. They refer to the collective redbed sandstones that generally overlay the Rustler Formation and underlay the Tecovas Formation within the Permian Basin (Schiel 1994). These formations primarily exist in southeastern New Mexico and west Texas. The formations extend east into Texas to the communities of Midland and Odessa and west towards the Pecos river. It is understood that the SR/DL Formations have potential water producing capabilities; however significant quantities of water do not occur consistently within these formations (Lowry et al. 2015). The isolated water zones within these formations are likely caused by heavy cementation of the geology in areas that has hindered vertical flow into the Rustler formation (Powers 2003).




The Rustler Formation is directly below the Dewey Lake and above the Salado Formation (Engler et al. 2012). Figure 5 shows the extent of the Rustler Formation. The Rustler Formation is home to two water-bearing units, the Culebra and the Magenta. The Culebra Dolomite is typically located along the bottom of the Rustler formation and just above the Los Medanos Formation, which transitions into the Salado Formation. The Culebra has a fairly uniform thickness of approximately 12 meters and is the primary water producing unit of the Rustler. As can be seen in Figure 5, the majority of the Rustler Aquifer is within the Trans-Pecos area of Texas generally aligning with the Pecos River. The Rustler is thought to be



*Figure 5 - The spatial extent of the Rustler Formation across New Mexico and Texas. From Ewing et al. (2012).*

hydrologically connected to the Pecos River from around the town of Malaga, southwards to the Texas border. In New Mexico, the western edge of the formation outcrops near Carlsbad and generally dips towards the east (Land 2016). The dip of the formation appears to influence the permeability of the Rustler formation with higher hydraulic conductivities to the west and lower conductivities to the east. The groundwater produced from the Rustler is used primarily for livestock watering and in support of oil and gas production. The water quality tends to be fresher in the west and more brackish towards the east. Fresh water recharge of the Rustler occurs along the outcropping in the west, but is limited and not fully understood.

The Capitan Reef is exposed along the southeast escarpment of the Guadalupe Mountains in southeastern New Mexico and west Texas. Moving west to east, the reef plunges into the

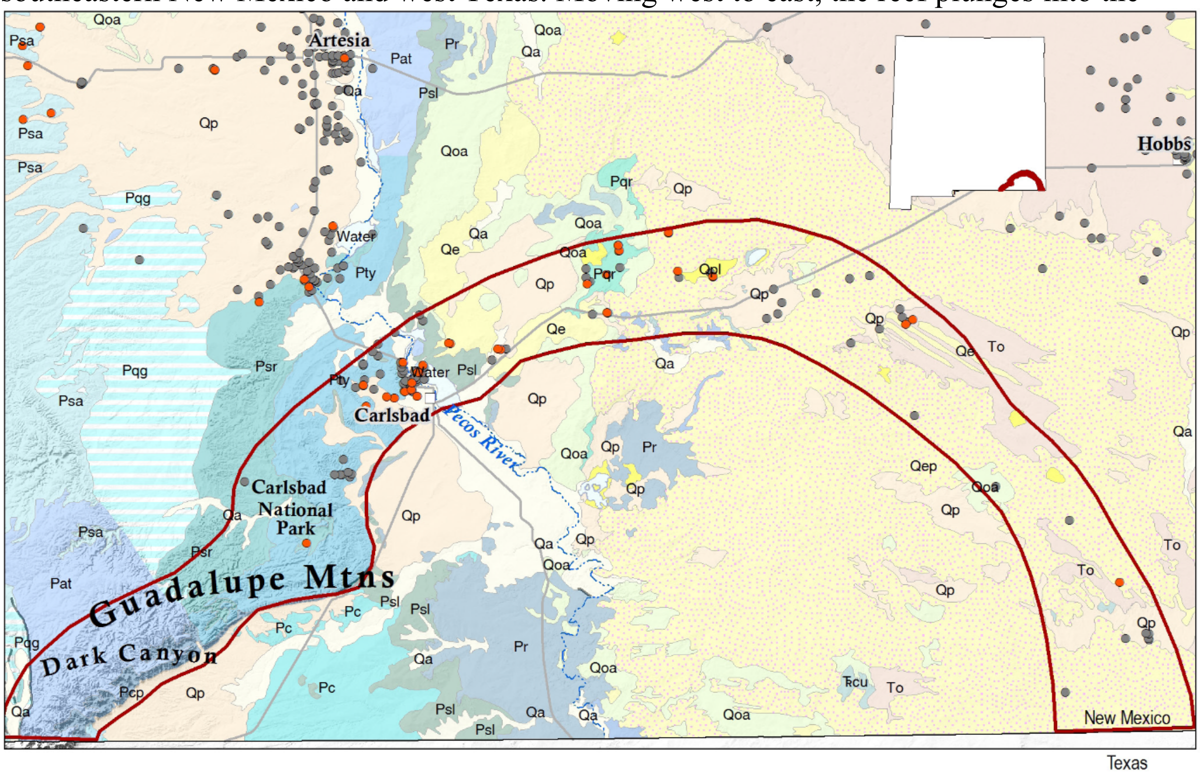



*Figure 6 - The extent of the Capitan Reef aquifer. From Land (2016).*

subsurface and passes beneath the city of Carlsbad, where it is a karstic aquifer that is the principal source of fresh water for the community (Figure 6). From there, it passes beneath the Pecos River and continues east and south into Lea County, then south into west Texas for several hundred kilometers where it outcrops again in the Glass Mountains near Alpine, Texas. The Capitan Reef is also the main source of the natural springs that feeds the Pecos River just north of Carlsbad. The water quality varies across the aquifer in that it is relatively fresh in the immediate vicinity of its recharge area in the Guadalupe Mountains, becoming brackish as it moves eastward and south into Texas (NMOSE 2016). Because of its proximity to the recharge area, Carlsbad is the only community in the region using water from the Capitan. Table 1 summarizes the aquifers included in this study.

*Table 1 - Listing and summary of the water bearing units included in this study.*

| Aquifer Name | Description |
|---|---|

| | |
|---|---|
| Pecos Valley Alluvium | Surficial deposits along the Pecos River. Hydraulically connected with the river. |
| Dewey Lake and Santa Rosa | Redbed sandstones. Inconsistent water source. |
| Rustler Formation (Culebra and Magenta) | Dolomite, fractured and dissolution zones. Good spatial distribution. Hydraulically connected with the Pecos River in the southern portion of the study area. |
| Capitan Reef | Limestone, Karstic formation. Good water quality west of the Pecos, low quality towards the east. |
| Ogallala | Sand and gravel. Water from the Ogallala is imported into the study area. |

A stratigraphic cross-section through the northern portion of the site is recreated from (Summers 1972) in Figures 7 and 8. The Mescalero Ridge delineates the western edge of the Ogallala Formation (Figure 8).

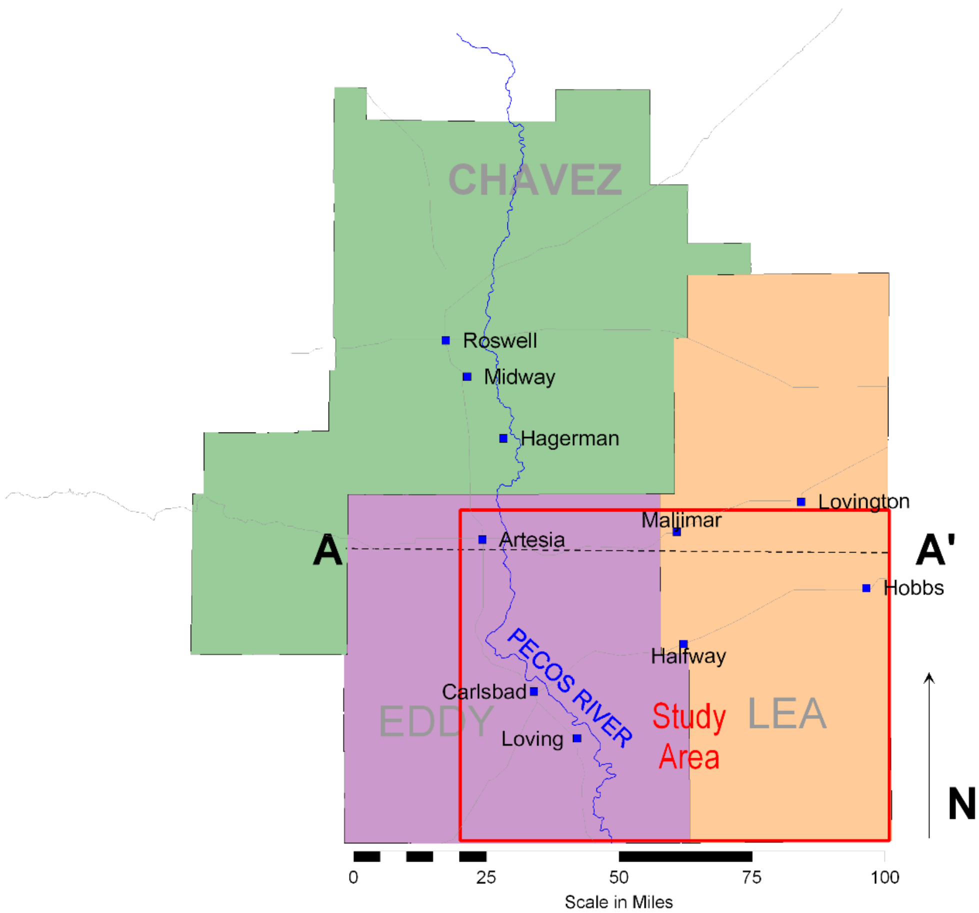



*Figure 7 - Map view of study area and location of cross-section, A-A', depicted in Figure 8.*

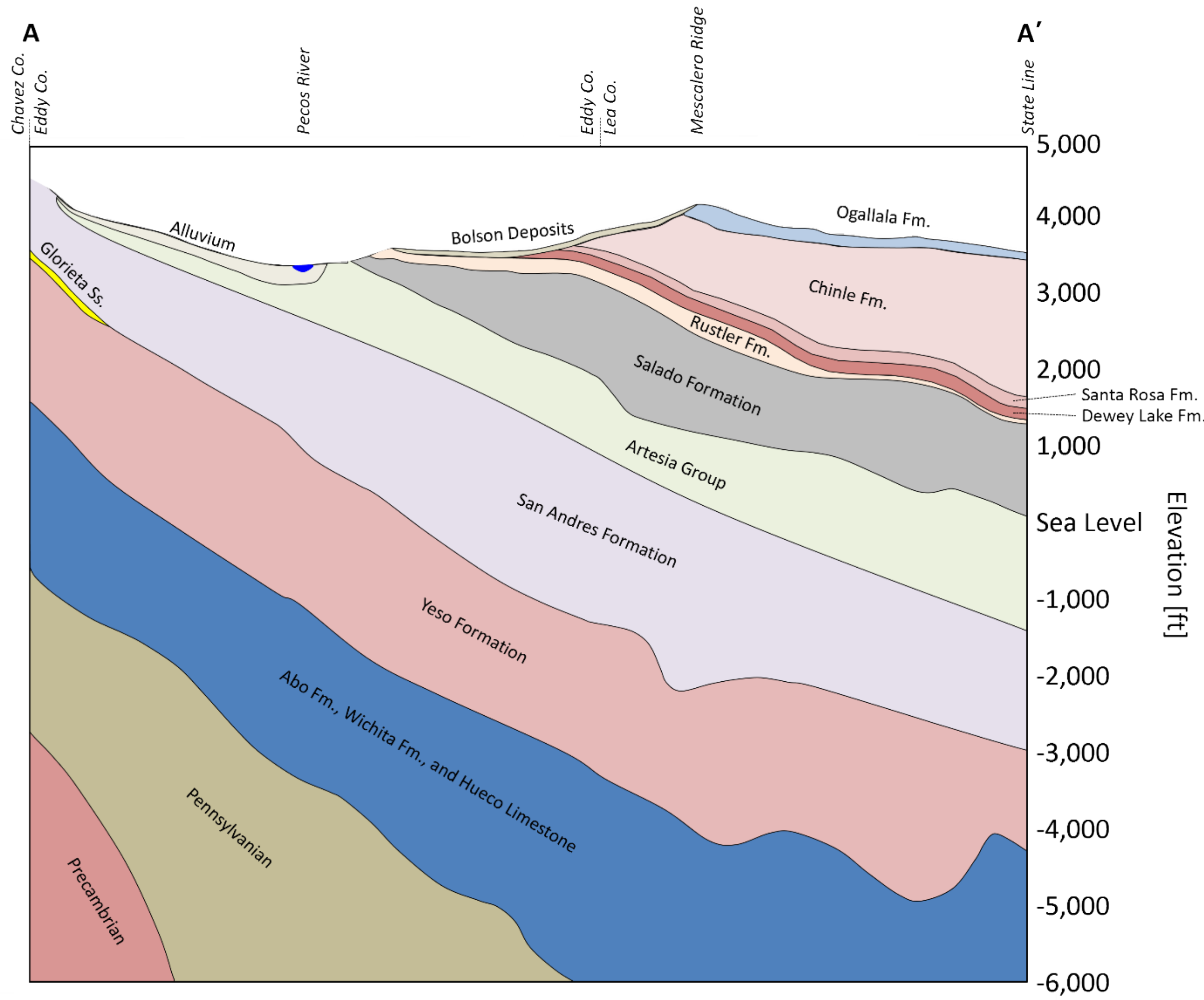



*Figure 8 - Cross-section of major geologic formations across the northern part of the study area. Recreated from Summers, 1972.*

## 3. CROSS SECTIONS

Four cross-sections were constructed using geophysical logs through the HPA’s. Most of the geophysical logs cover geology from the lower Rustler or uppermost Salado to near the surface. The spatial placement of these cross sections in relation to the HPA’s is shown in Figure 9.

Throughout southeastern New Mexico, the most common geophysical log through these shallow formations is the gamma ray-neutron (GRN) combination. Where available and relevant, resistivity, acoustic, and density logs were examined and included. Logs were selected for coverage of the shallow formations in the appropriate area and for their quality.

To the extent possible, the geophysical log images are presented at the same scale. Original large-format cross-sections have been reduced to fit 11 inch x 17 inch formats for easier printing. Each geophysical log cross-section has a reference elevation and has been placed relative to that elevation. Water wells are represented in relationship to the nearest geophysical logs, at the same vertical scale, and relative to the reference elevation for all logs.

Except for the log of 30-015-05767 (Mid-North West-East), all logs were downloaded from the NMOCD, Minerals and Natural Resources Department (NMOCD 2017). The exception was purchased at no cost to SNL from TGS (www.tgs.com) and may be used or reproduced for distribution or sale.

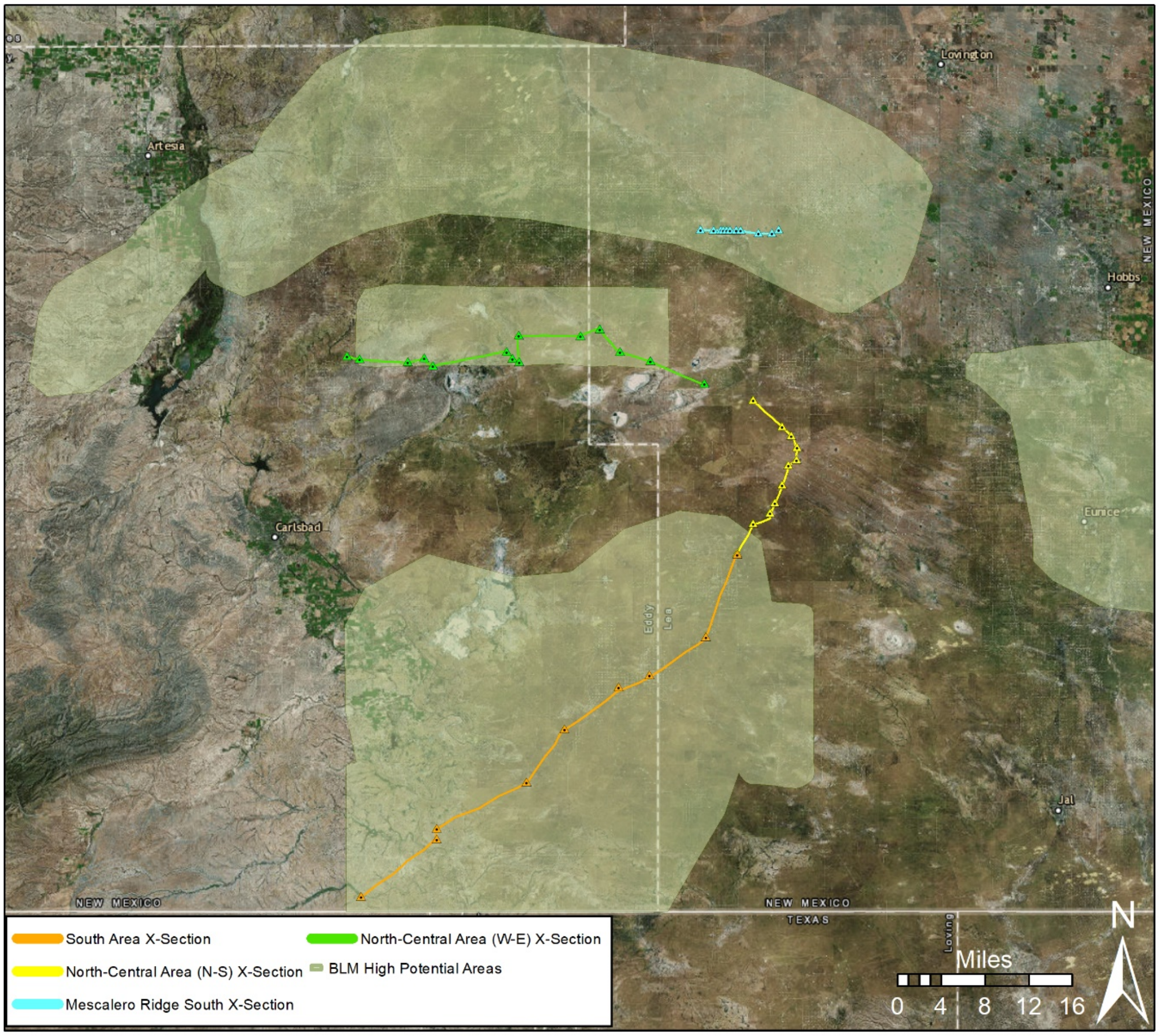


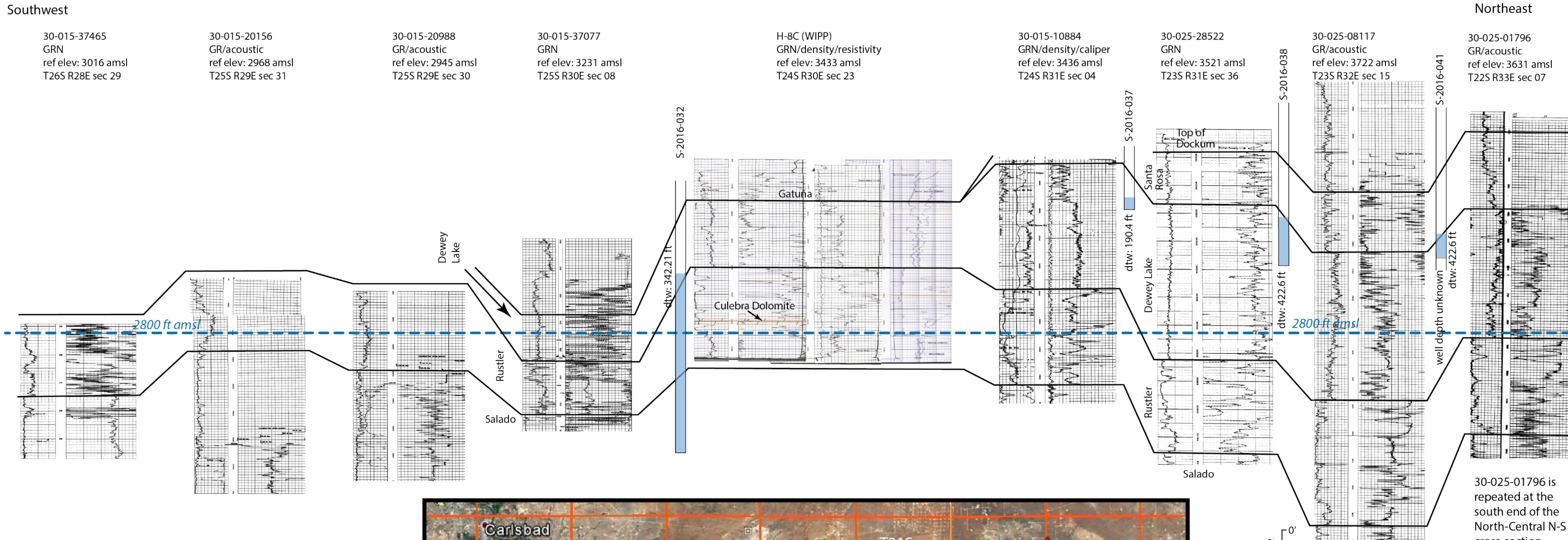

*Figure 9 - Cross-section locations and spatial relation to the HPA study areas.*

The "South" cross-section trends SW-NE across southern Eddy County and into Lea County. The South cross-section crosses a very geologically complicated area, ranging from a relatively thin overall section of Rustler outcrops west of the Pecos River to much thicker sections in the northern part of the Delaware Basin. From the NE end to SW end, erosion has removed successively deeper formations. In addition, Rustler to upper Salado dissolution has affected hydrologic integrity for the remaining formation. Ewing et al. (2012) delineated structure domains for the Rustler in the area of this cross-section, reflecting the structure of the Rustler and interpreted processes. The lack of good well depth and water level data from water wells in the area around the cross-section made it unreasonable to them in the plot. At the southwest end, the Rustler Formation's depth begins at approximately 850 ft, the Dewey Lake Formation's depth begins at approximately 350 ft., and the Santa Rosa Formation’s depth begins at approximately 250 ft.

The “North-Central” cross-section generally trends W-E. This cross-section is north of the Delaware Basin, located mainly on the Northwest Shelf area. It reveals the regional eastward dip in the eastern half of the section as well as the progressive down-stratigraphic erosion to the west. This cross-section was constructed to include logs near wells where depth and water levels were available. The Rustler Formation’s depth varies from approximately 70 ft in the west to 1700 ft in the east. The Dewey Lake Formation varies from surface exposure in the middle of the cross section to a depth of 1000 ft in the east. The Santa Rosa also appears at the surface in the middle of the study area and increases in depth to 850 ft in the east.

The “Southeast Mid-North” cross-section trends generally N-S. This cross-section passes from the Northwest Shelf/Capitan Reef area at the north end into the Delaware Basin at the southern end. The cross-section shows small dips from north and south toward the low area at the approximate boundary between the Capitan Reef and the Delaware Basin. This cross-section was constructed to include logs near several water wells in this area. The northernmost log is approximately 4 miles from the log at the east end of the Mid-North West-East cross-section and can be correlated. The southernmost geophysical log of the Mid-North Southeast cross-section is the same log at the NE end of the South cross-section. The thickness of each geologic unit is relatively constant. The Rustler formation begins at an approximate depth of 1500 ft, the Dewey Lake formation begins at an approximate depth of 1000 ft, and the Santa Rosa begins at an approximate depth of 800 ft.

The “Mescalero Ridge South” cross-section trends E-W. This cross-section was constructed to examine stratigraphic relationships across the Mescalero Ridge as there are a number of water wells on the west side of the ridge. The stratigraphic control is therefore tighter (more-closely spaced) compared to the Mid-North and South cross-sections. By agreement, this cross-section is not across the area of most water wells in order to provide better stratigraphic control. Slight eastward dip is present, and most stratigraphic units appear to thicken slightly towards the east.



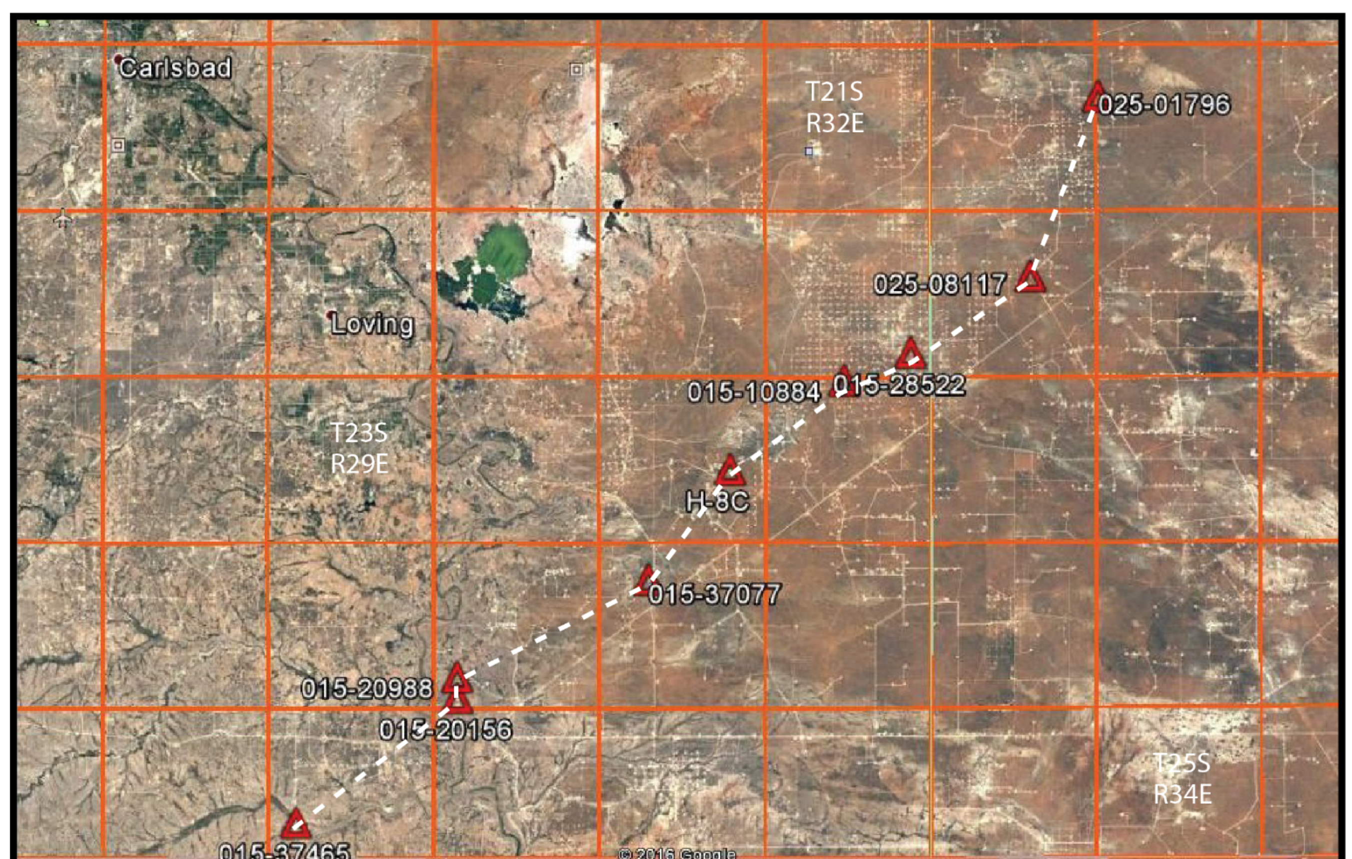

# South Area

## Southwest-Northeast Geophysical Log Cross-section

*All logs are placed relative to mean sea level (reference line is 2800 ft amsl)*

*Water wells are not included due to lack of depth and water level data along trend*

*Logs are not placed horizontally to scale*




## Explanation

GR - gamma ray

GRN - gamma ray/neutron log

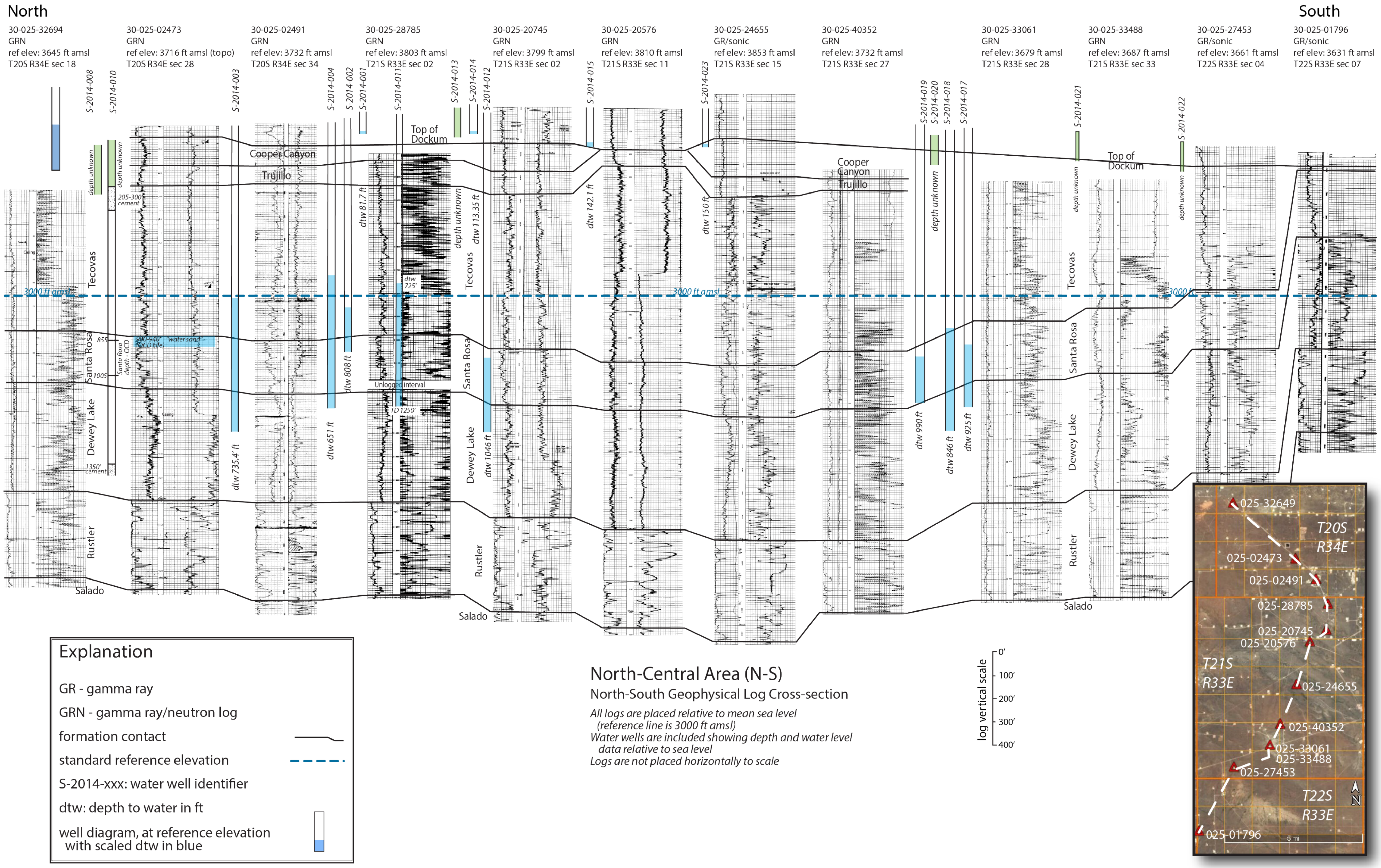
formation contact

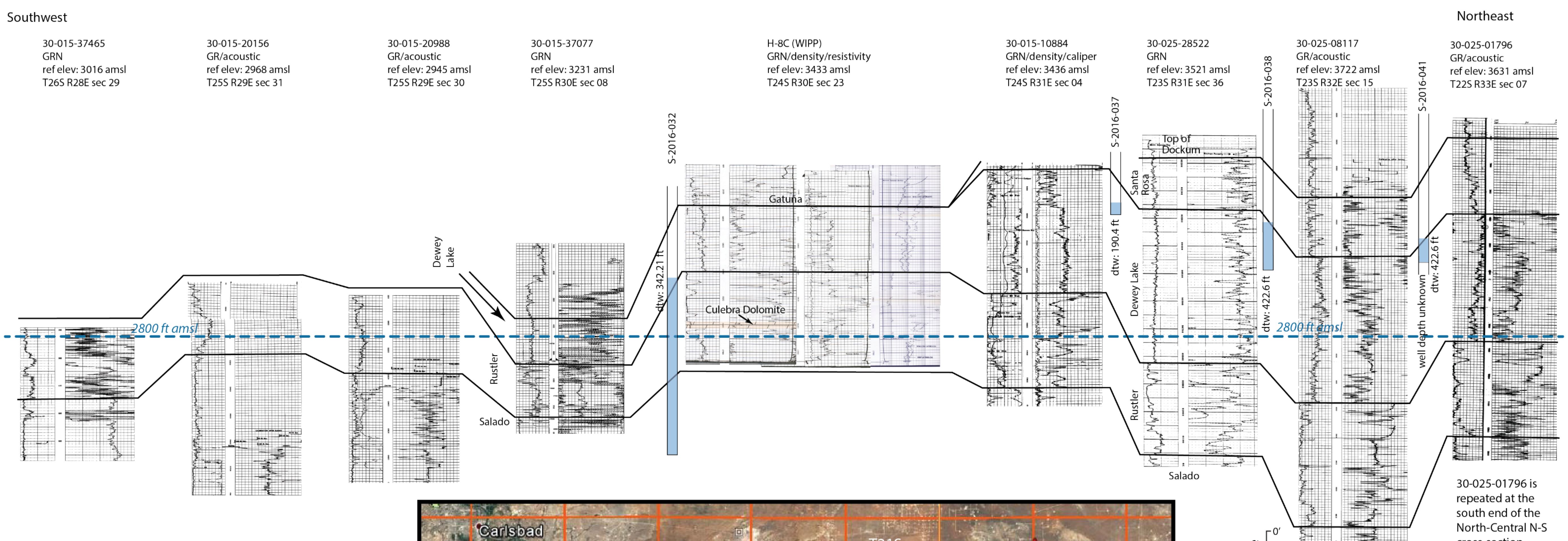
standard reference elevation

S-2016-xxx: water well identifier

dtw: depth to water in ft

well diagram, at reference elevation with scaled dtw in blue


North
South
30-025-32694
GRN
ref elev: 3645 ft amsl
T20S R34E sec 18
30-025-02473
GRN
ref elev: 3716 ft amsl (topo)
T20S R34E sec 28
30-025-02491
GRN
ref elev: 3732 ft amsl
T20S R34E sec 34
30-025-28785
GRN
ref elev: 3803 ft amsl
T21S R33E sec 02
30-025-20745
GRN
ref elev: 3799 ft amsl
T21S R33E sec 02
30-025-20576
GRN
ref elev: 3810 ft amsl
T21S R33E sec 11
30-025-24655
GR/sonic
ref elev: 3853 ft amsl
T21S R33E sec 15
30-025-40352
GRN
ref elev: 3732 ft amsl
T21S R33E sec 27
30-025-33061
GRN
ref elev: 3679 ft amsl
T21S R33E sec 28
30-025-33488
GRN
ref elev: 3687 ft amsl
T21S R33E sec 33
30-025-27453
GR/sonic
ref elev: 3661 ft amsl
T22S R33E sec 04
30-025-01796
GR/sonic
ref elev: 3631 ft amsl
T22S R33E sec 07
Top of Dockum
Cooper Canyon
Trujillo
Tecovas
Santa Rosa
Dewey Lake
Rustler
Salado
3000 ft amsl
dtw 735.4' ft
dtw 651 ft
dtw 808 ft
dtw 81.7 ft
dtw 725'
dtw 113.35 ft
dtw 1046 ft
dtw 142.1 ft
dtw 150 ft
dtw 990 ft
dtw 846 ft
dtw 925 ft
depth unknown
Unlogged interval
TD 1250'
Explanation
GR - gamma ray
GRN - gamma ray/neutron log
formation contact
standard reference elevation
S-2014-xxx: water well identifier
dtw: depth to water in ft
well diagram, at reference elevation with scaled dtw in blue
North-Central Area (N-S)
North-South Geophysical Log Cross-section
All logs are placed relative to mean sea level (reference line is 3000 ft amsl)
Water wells are included showing depth and water level data relative to sea level
Logs are not placed horizontally to scale
log vertical scale
0'
100'
200'
300'
400'
T20S R34E
T21S R33E
T22S R33E



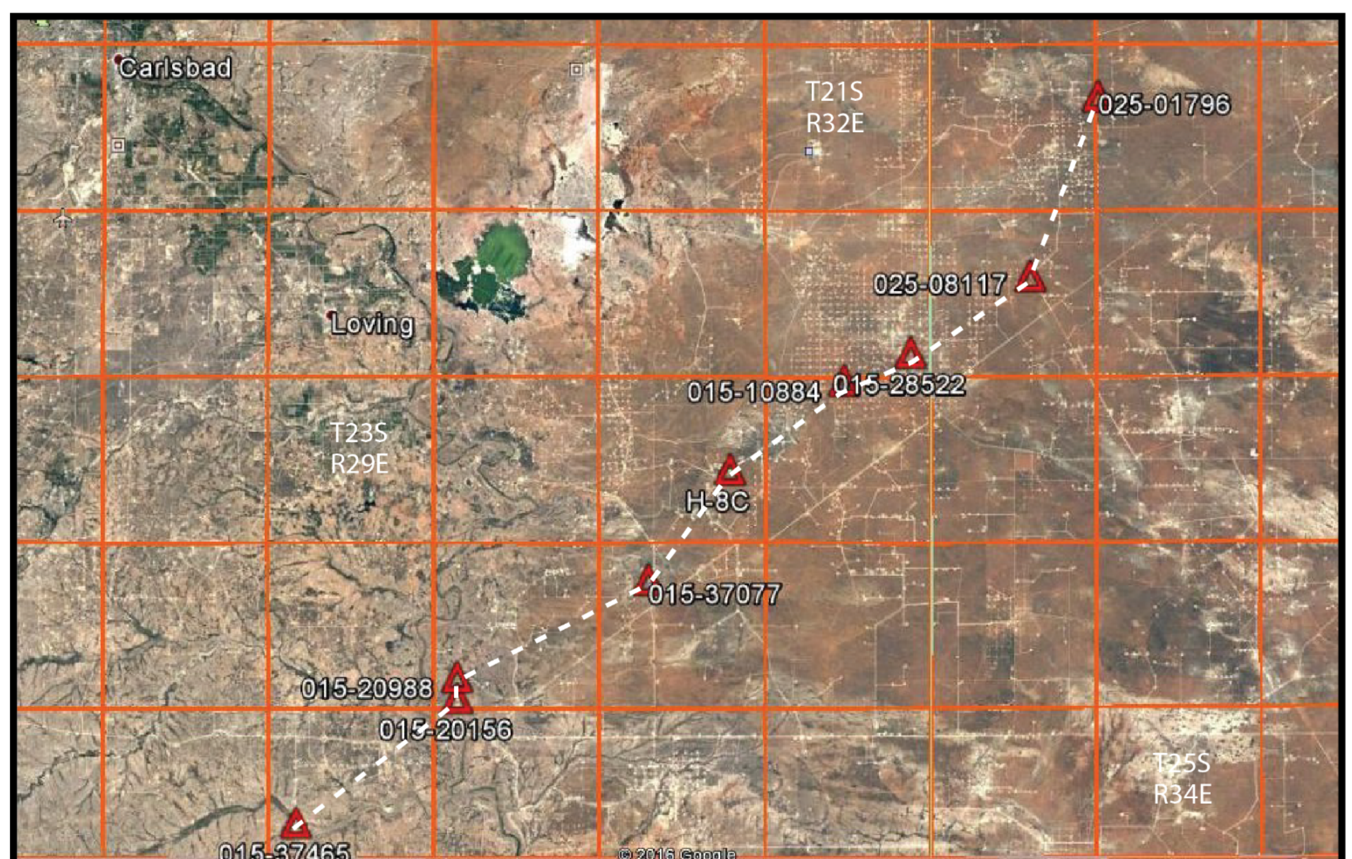

## South Area

### Southwest-Northeast Geophysical Log Cross-section

*All logs are placed relative to mean sea level (reference line is 2800 ft amsl)*

*Water wells are not included due to lack of depth and water level data along trend*

*Logs are not placed horizontally to scale*




**Explanation**

GR - gamma ray

GRN - gamma ray/neutron log

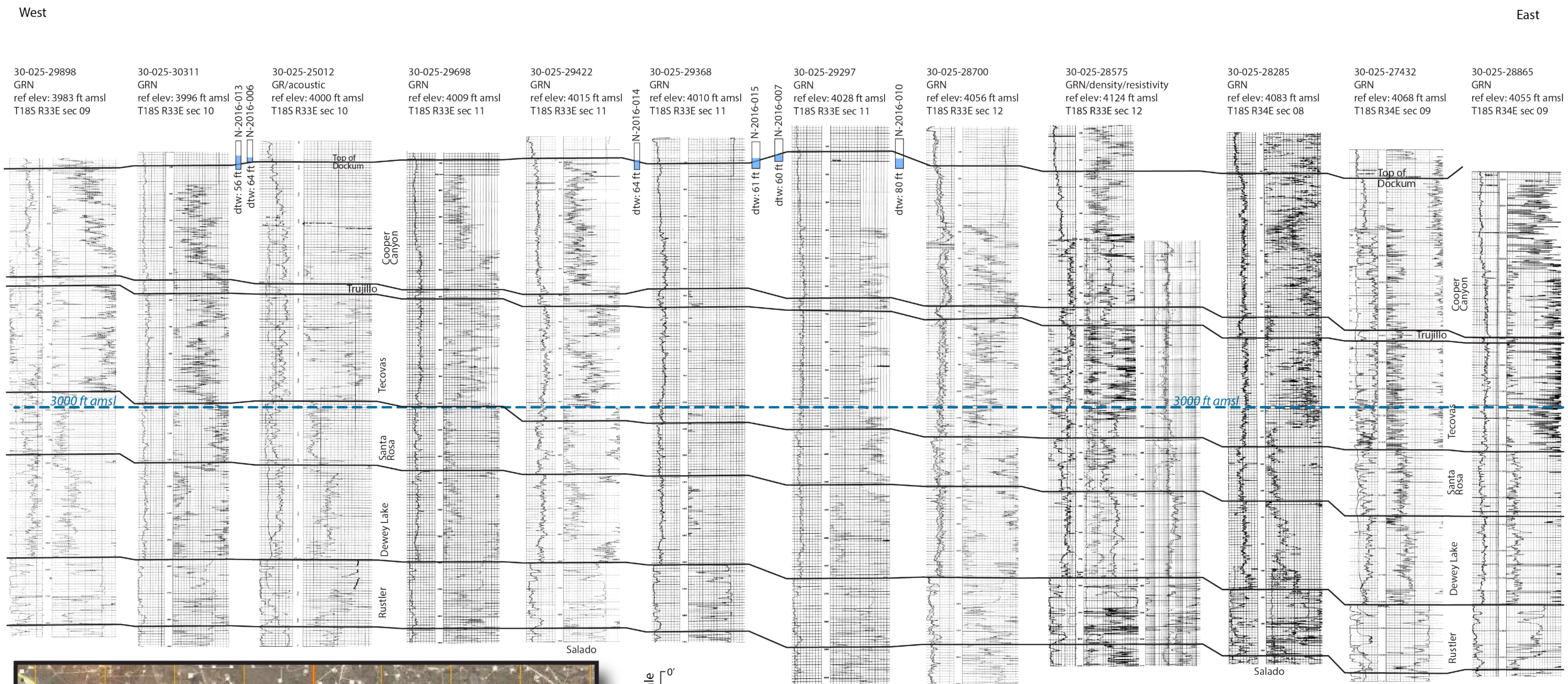
formation contact

standard reference elevation

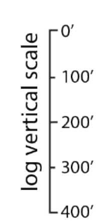
S-2016-xxx: water well identifier

dtw: depth to water in ft

well diagram, at reference elevation with scaled dtw in blue








## Mescalero Ridge South

West-East Geophysical Log Cross-section

*All logs are placed relative to mean sea level (reference line is 3000 ft amsl)*
*Nearby water wells are projected into the log cross-section where depth and water level data are available*
*Logs are not placed horizontally to scale*

### Explanation

GR - gamma ray

GRN - gamma ray/neutron log

formation contact

standard reference elevation

N-2016-xxx: water well identifier

dtw: depth to water in ft

well diagram, at reference elevation with scaled dtw in blue

# 4. FIELD WORK

## 4.1. Introduction

The primary focus of the field work was to evaluate the existing and potential water resources that were available within the HPA's.

Based on the size of the areas and the complexity of the various potential water resources, a decision was made by Sandia and the BLM to limit the field studies to only three of the four HPA's. The east HPA (see Figure 3), which primarily represents the Ogallala aquifer, was excluded from the study because over 1000 wells were identified in the NMOSE database and only a small percentage of the land is managed by the BLM. The Ogallala Aquifer is heavily pumped for agricultural purposes throughout several states, and determining the potential impacts from oil and gas production without a broader study of the overall aquifer was beyond the scope of this project.

## 4.2. Well Selection

The field work began by assembling water well locations from the NMOSE to verify and/or determine; 1) their exact location; 2) total well depth (used to help determine the geologic formation producing the water); 3) depth to water; 4) well construction (used to determine suitability for long-term monitoring); 5) water quality; and 6) how the water was being utilized.

The NMOSE database listed a large number (~1000) of well locations in the study area. This number was culled to 354 based on their location within or near a HPA and on their potential to be measured and/or serve as monitoring wells. Many of the shallower windmill locations had simply dried up and were no longer producing water. Some wells were very low-producing and only suitable for livestock watering. Other wells, although identified by the NMOSE, no longer existed, were misidentified as to location, were never actually constructed, or were closely located to other monitored wells.

A further limiting factor in well selection was access. Many of the wells investigated were under BLM or State surface ownership and thus did not require prior permission to access the property. In instances where permission was needed to obtain access to private wells, a written permission form was signed or verbal permission was given by the landowner or well owner. The signed permission letters of participation were turned over to the BLM Carlsbad Field Office. If a landowner permitted water quality sampling of their well(s), a report that outlined the background of the project, the field reconnaissance approach, and disclosed the results of the water quality analysis for wells that were sampled was given to the landowner. Table 2 through Table 8 lists the wells sampled in each of the HPA's. In order to protect the privacy of the well owners, the landowner names and NMOSE well numbers are redacted and replaced with a unique identifiers.

The well locations were mapped and then used by Sandia personnel to direct field reconnaissance to verify the well location and collect information on them. Successful reconnaissance allowed us to collect 1) photos of the wells, 2) well status (i.e. livestock or commercial), 3) GPS coordinates, 4) diameter and casing measurements, 5) depth to water and 6) total depth. It is important to note that additional locations were occasionally added to the study when field personnel found wells that were not listed by OSE database, such as the Dayton Road Well.

Continued investigations within the model boundary wells from a previous study on the DL/SR (Lowry et al. 2015) identified additional NMOSE wells in the western portion of Lea County that were not part of the original set, which were added to this study. While not within the HPA boundaries, they are being pumped for commercial water sales that are potentially being piped into the Center North and South HPA's.

Where possible, water samples were collected either through existing equipment or utilizing a passive sample method referred to as Snap-Sampling. The samples were typically analyzed for cation, anion, pH, and conductance. A smaller subset of wells were also analyzed for basic metals, deuterium, Carbon-14, and tritium. The deuterium, Carbon-14 and tritium analysis were part of an age dating effort of the Capitan Reef waters by Lewis Land of the National Cave and Karst foundation. His work is documented in a separate report (Land 2017). One of the primary drivers for water quality (WQ) sampling is to establish a baseline of water chemistry. Overall 30 wells in the South HPA, 11 wells in the Center North HPA, and 19 wells in the North HPA were selected for WQ analysis. (Figures 10 and 11). In addition, increased aquifer activity increases the potential exposure of the aquifer to contamination. Baseline water quality data can be used to flag these conditions. With the wide spatial area of the HPA's and the complex geology across the area, well depth alone did not always clearly identify which formation was producing the water so water chemistry was also used to help confirm the source formation.

The final aspect of the field activities was the collection of water level data, establishing a network of wells that could be used by the BLM to monitor the long-term water levels throughout the study areas. Viable wells were evaluated as either a manual water level location or a continuous water level monitoring location. Ultimately, 37 wells were identified for manual water level measurements, and 24 wells were identified and instrumented for continuous water level monitoring during the project, with 13 of those being continuously monitored past this project. In addition, 67 of the 354 wells were sampled for water quality. Most of the wells (255 or 72%) were either not found or not measurable.

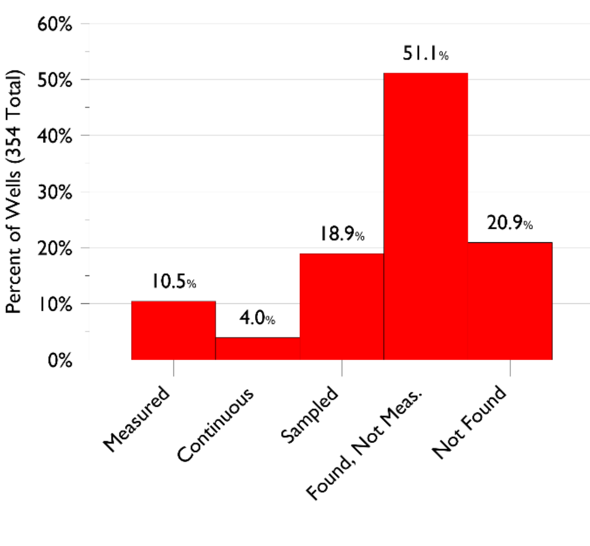



*Figure 10 - Results of field verification activities.*

The initial scope of work for this project included conducting pump tests to determine the transmissivities of the various formations throughout the HPA's. It was determined early on that a pump test in the Capitan Reef would be too expensive due to the depth of the resource and the water disposal costs. For the other formations, it was decided that pump tests would only provide localized information due to the heterogeneity of the source aquifers, adding little to the regional understanding of the water resource (Sandia, as part of the WIPP project, has measured transmissivities for the Rustler Formation that vary by several orders of magnitude in less than 10 miles).

Results of the field investigations by HPA are described in the following sections.

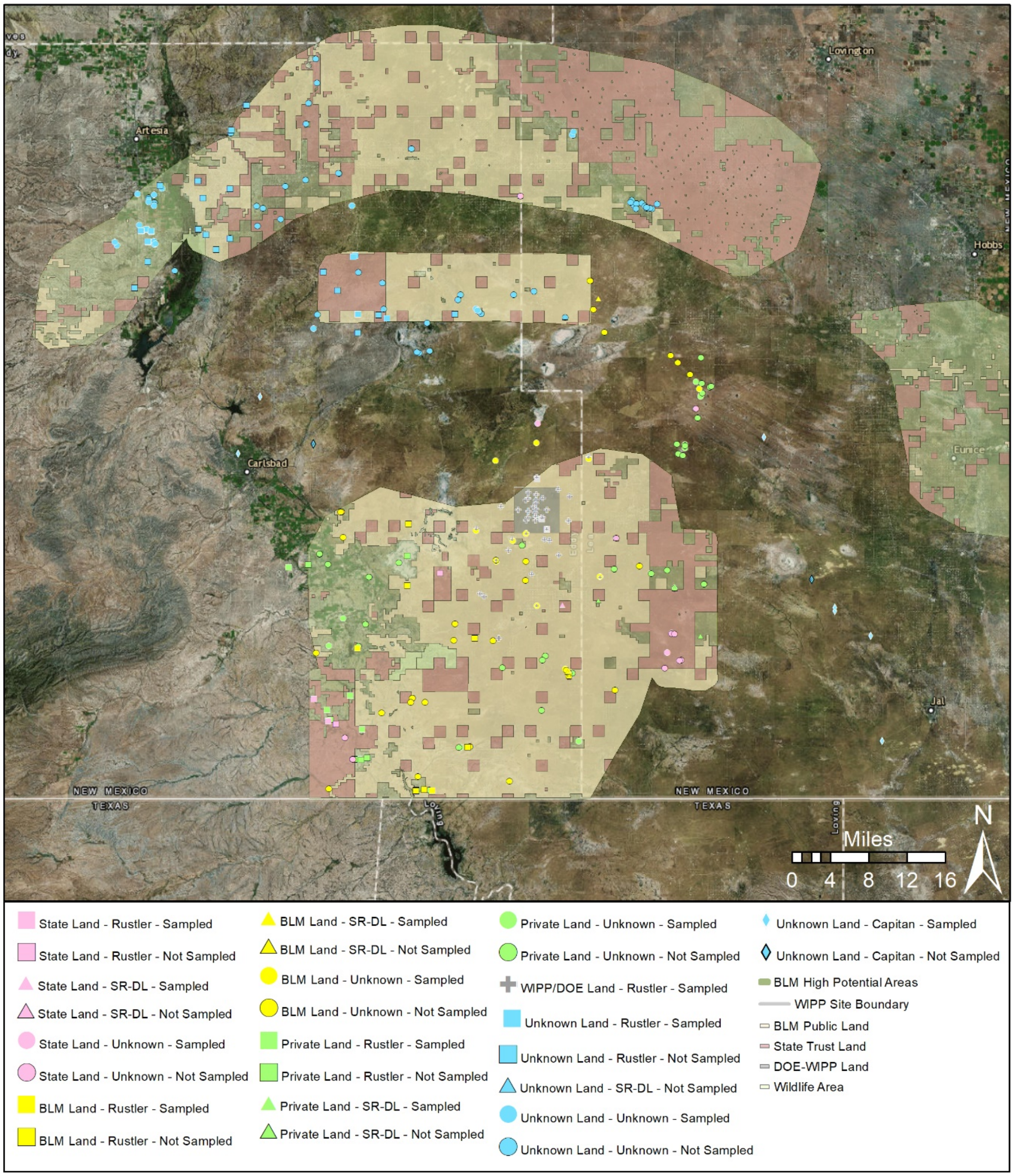



*Figure 11 - Map of wells identified for sampling showing their sampling status and land use within each HPA.*

### 4.2.1. North HPA

Although the North HPA was thoroughly canvased, very few water wells within the center portion (near Loco Hills) of this HPA were found. Several commercial water stations were identified that obtained their water from source lines nearby. The lines could not be traced back to any water wells within the study area. Some of the discussions with the BLM and a commercial water provider, indicated these water stations are likely sourcing aquifers further east in the Ogallala formation, although this information could not be verified.

Well density along the Pecos River on the west side of the North HPA was considerably higher than in other areas due to the availability of shallow water and increased residential population. Based on field investigations, the primary use of this water was for agriculture, ranging from pecan orchards to cotton and alfalfa production. To cut down on the number of wells to investigate, a GIS-based radial search was used to exclude wells within a 1 mile radius of wells that are listed in the NMOSE database as being pumped at rates larger than an average residence. The large majority of these wells were on private land and consequently, required permission for entry. A door-to-door approach was taken, but many residents were not home or did not permit access, resulting in a low number of wells inventoried. Some commercial oil and gas source wells could be observed from a distance, but were on private land and permission could not be obtained to investigate further.

Members of the Pecos Valley Area Conservancy District (PVACD) were alerted to this project and requested a meeting with the BLM and SNL to share their concerns with the inventory efforts in the western portion of the North HPA. The PVACD did not want to see redundant efforts as they had performed a similar study in the Pecos River Basin alluvium and continue to monitor the use and recharge of the aquifer. The BLM and Sandia discussed information sharing with the PVACD and wish to acknowledge the helpfulness of the PVACD in providing information pertinent to this study.

Although the Ogallala aquifer was not part of this study, field discoveries yielded a considerable number of water source wells just below the Caprock Escarpment rim. These wells were selected for field investigations before it was known that they are likely sourcing the Ogallala aquifer. Water depths collected indicated a shallower zone than would be expected if they were sourced in the SR/DL or Rustler aquifers. Based on flowmeter totals, the volumes are indicative of the Ogallala aquifer.

*Table 2 - Wells sampled for water quality in North HPA. Values in red are from the NMOSE website and are unconfirmed. DTW = depth to water. TD = total depth.*

| Location ID | Geo-Name (HPA) | Monitoring Unit | Land Ownership | Type | UTM Zone | Easting | Northing | Elev. (ft) | DTW (ft) | TD (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| N-2016-067 | North | Other | Private | Commercial | 13S | 618216 | 3635126 | 4107 | 77 | 275 |
| N-2016-068 | North | --- | Private | Commercial | 13S | 618394 | 3635563 | 4141 | --- | --- |
| N-2016-074 | North | --- | Private | Residential | 13S | 559072 | 3619557 | 3360 | --- | --- |
| N-2016-075 | North | --- | Private | Residential | 13S | 559101 | 3619118 | 3365 | --- | --- |
| N-2016-076 | North | --- | Private | Residential | 13S | 559260 | 3619252 | 3359 | --- | --- |
| N-2016-077 | North | Rustler | Private | Residential | 13S | 558182 | 3619515 | 3388 | 116.4 | 158.5 |
| N-2016-078 | North | --- | Private | Residential | 13S | 553775 | 3618986 | 3459 | --- | --- |
| N-2016-079 | North | --- | Private | Residential | 13S | 553491 | 3619444 | 3456 | --- | --- |
| N-2016-080 | North | Rustler | Private | Residential | 13S | 557930 | 3621236 | 3381 | --- | 128 |
| N-2016-081 | North | Rustler | Private | Monitoring | 13 S | 557225 | 3621074 | 3414 | 136.79 | 184 |
| N-2016-082 | North | --- | Private | Residential | 13 S | 556960 | 3621815 | 3416 | --- | --- |
| N-2016-086 | North | --- | Private | Agricultural | 13 S | 559051 | 3624562 | 3344 | --- | --- |
| N-2016-088 | North | --- | Private | Agricultural | 13 S | 559041 | 3626163 | 3341 | --- | --- |
| N-2016-090 | North | --- | Private | Agricultural | 13 S | 559855 | 3627506 | 3326 | --- | --- |
| N-2016-092 | North | --- | Private | Agricultural | 13 S | 559856 | 3627382 | 3339 | --- | --- |
| N-2016-093 | North | --- | Private | Agricultural | 13 S | 560141 | 3627010 | 3325 | --- | --- |
| N-2016-096 | North | --- | Private | Agricultural | 13 S | 558277 | 3625130 | 3350 | --- | --- |
| N-2016-097 | North | --- | Private | Residential | 13 S | 556681 | 3626237 | 3377 | --- | --- |
| N-2016-098 | North | Rustler | Private | Residential | 13S | 558663 | 3621040 | 3342 | 80 | 149 |

*Table 3 - Wells continuously and/or manually monitored for water level in the North HPA. Values in red are from the NMOSE website and are unconfirmed. DTW = depth to water. TD = total depth.*

| Location ID | Geo-Name (HPA) | Monitoring Unit | Land Ownership | Type | UTM Zone | Easting | Northing | Elev. (ft) | DTW (ft) | TD (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| N-2016-067 | North | Other | Private | Commercial | 13S | 618216 | 3635126 | 4107 | 77 | 275 |
| N-2016-068 | North | --- | Private | Commercial | 13S | 618394 | 3635563 | 4141 | --- | --- |
| N-2016-069 | North | Other | Private | Inactive | 13S | 618351 | 3635047 | 4120 | 76.75 | 117.5 |
| N-2016-078 | North | --- | Private | Residential | 13S | 553775 | 3618986 | 3459 | --- | --- |
| N-2016-081 | North | Rustler | Private | Monitoring | 13 S | 557225 | 3621074 | 3414 | 136.79 | 184 |
| N-2017-001 | North | --- | BLM | Commercial | 13S | 610443 | 3625733 | 3774 | --- | --- |

### 4.2.2. Center North HPA

This area encompasses a region known as Burton Flats. Meetings with the BLM indicated this is a desirable area to drill for water, and it is anticipated that drilling in this area will increase. In addition, two Potash mines (Intrepid Potash and Mosaic Potash) have interest holdings within this HPA with both currently or historically producing potash ore from the underlying formations. Potash mines have water wells that are used for mining activities. With the increased activity in oil and gas development, Potash mines have sold water commercially to oil and gas operators for drilling and fracking. The potash companies did not disclose how much water was being used and sold to oil and gas, or where the water is sourced. Intrepid Potash did disclose water use information in their HB In-Situ Project Environmental Impact Statement (BLM 2012), as it relates to the HB Solution Mine operations and also provided water chemistry analysis results from their monitoring wells.

The Center-North's study area is the only HPA that lies over the Capitan Aquifer (see Figure 3). However, none of the water wells discovered within the boundary of the Center-North appeared to source it. The nearest Capitan water well to the Center-North HPA is the North Cedar Hills

Hiss (CR-2015-002) well and would likely provide the best information for this aquifer's behavior.

*Table 4 - Wells sampled for water quality in the Center North HPA. Values in red are from the NMOSE website and are unconfirmed. DTW = depth to water. TD = total depth.*

| Location ID | Geo-Name (HPA) | Monitoring Unit | Land Ownership | Type | UTM Zone | Easting | Northing | Elev. (ft) | DTW (ft) | TD (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| CN-2015-010 | Center North | Rustler | BLM | Commercial | 13S | 592208 | 3608929 | 3333 | 115 | 213 |
| CN-2015-013 | Center North | Rustler | BLM | Inactive | 13S | 588089 | 3609458 | 3312 | 63.5 | 217 |
| CN-2015-015 | Center North | --- | BLM | Commercial | 13S | 581791 | 3607407 | 3284 | --- | --- |
| CN-2016-007 | Center North | Rustler | State | Commercial | 13S | 587665 | 3617776 | 3420 | 205.6 | --- |
| CN-2016-011 | Center North | --- | Private | Residential | 13S | 604860 | 3610418 | 3482 | --- | 231 |
| CN-2016-014 | Center North | --- | Private | Commercial | 13S | 605067 | 3610265 | 3513 | --- | --- |
| CN-2016-016 | Center North | --- | Private | Inactive | 13S | 605049 | 3610206 | 3442 | 135.7 | 285.4 |
| CN-2016-017 | Center North | Rustler | State | Commercial | 13S | 587359 | 3617602 | 3424 | 194.27 | --- |
| CN-2016-018 | Center North | --- | BLM | Monitoring | 13S | 587101 | 3624767 | 3471 | 146.23 | --- |
| CN-2016-019 | Center North | --- | BLM | Monitoring | 13S | 587080 | 3624771 | 3476 | 146.25 | --- |

*Table 5 - Wells continuously and/or manually monitored for water level in the Center North HPA. Values in red are from the NMOSE website and are unconfirmed. DTW = depth to water. TD = total depth.*

| Location ID | Geo-Name (HPA) | Monitoring Unit | Land Ownership | Type | UTM Zone | Easting | Northing | Elev. (ft) | DTW (ft) | TD (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| CN-2014-009 | Center North | Other | BLM | Inactive | 13S | 621018 | 3614521 | 3639 | 248.82 | --- |
| CN-2014-010 | Center North | Other | BLM | Livestock/Commercial | 13S | 620970 | 3614519 | 3629 | 354.54 | --- |
| CN-2015-012 | Center North | Rustler | BLM | Inactive | 13S | 591012 | 3609386 | 3330 | 115 | 225 |
| CN-2015-013 | Center North | Rustler | BLM | Inactive | 13S | 588089 | 3609458 | 3312 | 63.5 | 217 |
| CN-2016-001 | Center North | SR/Dewey Lake | BLM | Commercial | 13S | 617506 | 3609297 | 3558 | --- | 575 |
| CN-2016-002 | Center North | Other | BLM | commercial | 13S | 617501 | 3609310 | 3554 | 246.11 | --- |
| CN-2016-003 | Center North | SR/Dewey Lake | BLM | Commercial | 13S | 617490 | 3609360 | 3577 | --- | 575 |
| CN-2016-005 | Center North | Rustler | State | Inactive | 13S | 585161 | 3612791 | 3303 | 68.21 | 133.5 |
| CN-2016-007 | Center North | Rustler | State | Commercial | 13S | 587665 | 3617776 | 3420 | 205.6 | --- |
| CN-2016-017 | Center North | Rustler | State | Commercial | 13S | 587359 | 3617602 | 3424 | 194.27 | --- |

### 4.2.3. South HPA

The South HPA was the last to be investigated and is the largest in terms of area as well as the busiest in terms of oil and gas exploration and development. Many of the agricultural wells near Malaga and Loving have been converted to supply water for oil and gas operations. An example is in the area near the intersection of US 285 and El Paso Gas Plant turn-off where a cluster of wells historically used for farming have been converted to supply wells for frack tanks and fresh water stations. Areas within the South HPA were eliminated so that investigations could focus on newer water wells. SNL monitors a water well network surrounding the Waste Isolation Pilot Plant (WIPP) for the Department of Energy (DOE) that focuses on the Culebra and Magenta Dolomites of the Rustler Formation. The network has been studied significantly and provides the best information available as it relates to changes to the aquifer from commercial activities. SNL has pressure transmitter instruments installed in all the wells, providing water levels at 15 minute intervals. Because of this, SNL eliminated a large portion of acreage around the WIPP site for investigative work.

Similar to the North HPA, SNL employed the process of elimination due to the high density of wells along the Pecos River. In an effort to economize the time spent searching for wells in this vicinity, the same GIS-based exclusions were employed for high density well locations, focusing on the highest production volume wells. Large, contiguous tracts of private lands made it necessary to conduct a door-to-door approach to obtain permission to access water wells. Another factor for reducing the number of wells investigated in this area was that well information collected in several earlier projects, funded through the New Mexico Small Business Assistance (NMSBA) program, provide a useful and robust set of data that are included in this study.

*Table 6 - Wells sampled for water quality in the South HPA. Values in red are from the NMOSE website and are unconfirmed. DTW = depth to water. TD = total depth.*

| Location ID | Geo-Name (HPA) | Monitoring Unit | Land Ownership | Type | UTM Zone | Easting | Northing | Elev. (ft) | DTW (ft) | TD (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| S-2014-001 | South | Other | BLM | Inactive | 13S | 636687 | 3599451 | 3778 | 81.7 | 93.8 |
| S-2014-003 | South | --- | Private | Commercial | 13S | 636206 | 3600472 | 3720 | --- | --- |
| S-2014-012 | South | --- | Private | Commercial | 13S | 636887 | 3598448 | 3807 | --- | --- |
| S-2014-013 | South | --- | Private | Residential | 13S | 637000 | 3598675 | 3795 | --- | --- |
| S-2014-014 | South | Other | Private | Inactive | 13S | 636896 | 3598376 | 3811 | 113.35 | 127 |
| S-2014-017 | South | --- | Private | Commercial | 13S | 634772 | 3591053 | 3710 | --- | --- |
| S-2014-019 | South | --- | Private | Commercial | 13S | 634784 | 3591565 | 3724 | --- | --- |
| S-2016-001 | South | SR/Dewey Lake | Private | Residential | 13S | 633583 | 3571446 | 3681 | --- | --- |
| S-2016-002 | South | --- | Private | Livestock/Commercial | 13S | 633561 | 3571193 | 3662 | --- | --- |
| S-2016-007 | South | --- | Private | Livestock/Commercial | 13S | 630163 | 3573231 | 3693 | --- | --- |
| S-2016-013 | South | --- | State | Residential | 13S | 634391 | 3560899 | 3453 | --- | --- |
| S-2016-015 | South | --- | State | Commercial | 13S | 633217 | 3564786 | 3564 | --- | --- |
| S-2016-019 | South | SR/Dewey Lake | BLM | Inactive | 13S | 618606 | 3559310 | 3452 | 410.84 | 727 |
| S-2016-028 | South | --- | BLM | Commercial | 13S | 618088 | 3559497 | 3462 | --- | --- |
| S-2016-046 | South | --- | Private | Commercial | 13S | 603234 | 3548161 | 3114 | --- | --- |
| S-2016-048 | South | Rustler | Private | Inactive | 13S | 578513 | 3573542 | 3145 | 122.1 | 208.33 |
| S-2016-049 | South | --- | Private | Residential | 13S | 578492 | 3573530 | 3140 | --- | --- |
| S-2016-055 | South | Rustler | BLM | Inactive | 13S | 599292 | 3542004 | 2894 | 76.31' | 117.75 |
| S-2016-063 | South | Rustler | State | Livestock | 13S | 584334 | 3551770 | 2973 | 12.95 | --- |
| S-2016-065 | South | Rustler | Private | Inactive | 13S | 588791 | 3546346 | 2983 | 161.43 | --- |
| S-2016-084 | South | Rustler | BLM | Commercial | 13S | 588416 | 3562115 | 2962 | 68.25 | --- |
| S-2016-090 | South | --- | State | Commercial | 13S | 632645 | 3562037 | 3519 | --- | --- |
| S-2016-094 | South | --- | Private | Residential | 13S | 584332 | 3562443 | 3036 | --- | --- |
| S-2016-095 | South | Rustler | Private | Livestock | 13S | 587454 | 3555435 | 2945 | 47.48 | --- |
| S-2016-096 | South | Rustler | Private | Residential | 13S | 589193 | 3550650 | 3257 | 51.05 | --- |
| S-2016-097 | South | Rustler | State | Livestock | 13S | 582268 | 3554859 | 3926 | 65.31 | 91 |
| S-2016-098 | South | Rustler | Private | Commercial | 13S | 584145 | 3553363 | 2992 | 152.75 | --- |
| S-2016-100 | South | --- | Private | Commercial | 13S | 586340 | 3566367 | 3018 | --- | --- |
| S-2017-001 | South | --- | Private | Commercial | 13S | 620163 | 3549272 | 3279 | --- | --- |
| S-2017-005 | South | --- | State | Monitoring | 13S | 613781.4 | 3594299 | 3510 | 439.08 | 644 |
| S-2017-006 | South | --- | BLM | Monitoring | 13S | 610394.3 | 3577600 | 3291 | 311.53 | 480 |
| S-2017-007 | South | --- | BLM | Monitoring | 13S | 605191.8 | 3579000 | 3134 | 124.81 | 299.3 |
| S-2017-008 | South | --- | BLM | Monitoring | 13S | 613605.4 | 3591529 | 3372 | 305.77 | 566 |
| S-2017-009 | South | --- | BLM | Monitoring | 13S | 607813.5 | 3588947 | 3219 | 155.82 | 381 |
| S-2017-010 | South | --- | BLM | Monitoring | 13S | 621131.4 | 3589375 | 3656 | 614.94 | 884 |
| S-2017-011 | South | --- | WIPP/DOE | Monitoring | 13S | 613788.2 | 3586474 | 3425 | 367.77 | 972 |
| S-2017-012 | South | --- | BLM | Monitoring | 13S | 612264.3 | 3578687 | 3332 | 364.58 | 518 |
| S-2017-013 | South | --- | BLM | Monitoring | 13S | 608122.8 | 3574646 | 3162 | 169.41 | 286 |
| S-2017-014 | South | --- | BLM | Monitoring | 13S | 613954.6 | 3568419 | 3405 | 436.91 | --- |
| S-2017-015 | South | --- | BLM | Monitoring | 13S | 622876 | 3572661 | 3695 | 730.72 | --- |
| S-2017-016 | South | --- | WIPP/DOE | Monitoring | 13S | 614515 | 3580716 | 3417 | 452.88 | 778.7 |
| S-2017-017 | South | --- | WIPP/DOE | Monitoring | 13S | 615253.3 | 3579309 | 3415 | 450.89 | 755 |

*Table 7 - Wells continuously and/or manually monitored for water level in the South HPA. Values in red are from the NMOSE website and are unconfirmed. DTW = depth to water. TD = total depth.*

| Location ID | Geo-Name (HPA) | Monitoring Unit | Land Ownership | Type | UTM Zone | Easting | Northing | Elev. (ft) | DTW (ft) | TD (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| S-2016-019 | South | SR/Dewey Lake | BLM | Inactive | 13S | 618606 | 3559310 | 3452 | 410.84 | 727 |
| S-2016-020 | South | SR/Dewey Lake | BLM | Inactive | 13S | 618459 | 3559113 | 3468 | 539.05 | 639 |
| S-2016-037 | South | SR/Dewey Lake | State | Inactive | 13S | 617645 | 3568581 | 3483 | 190.4 | 235.33 |
| S-2016-038 | South | SR/Dewey Lake | Private | Inactive | 13S | 622747 | 3569234 | 3644 | 422.6 | 600 |
| S-2016-041 | South | SR/Dewey Lake | State | Inactive | 13S | 625123 | 3578148 | 3624 | 446.03 | --- |
| S-2016-043 | South | --- | BLM | Inactive | 13S | 610320 | 3543443 | 3106 | 185.14 | 419.16 |
| S-2016-044 | South | Rustler | BLM | Inactive | 13S | 604295 | 3548251 | 3091 | 208.8 | 687.25 |
| S-2016-045 | South | Rustler | BLM | Commercial | 13S | 604282 | 3548261 | 3098 | 223.03 | 800 |
| S-2016-048 | South | Rustler | Private | Inactive | 13S | 578513 | 3573542 | 3145 | 122.1 | 208.33 |
| S-2016-050 | South | Rustler | Private | Inactive | 13S | 581311 | 3573959 | 3097 | 72.1 | --- |
| S-2016-055 | South | Rustler | BLM | Inactive | 13S | 599292 | 3542004 | 2894 | 76.31' | 117.75 |
| S-2016-063 | South | Rustler | State | Livestock | 13S | 584334 | 3551770 | 2973 | 12.95 | --- |
| S-2016-082 | South | Rustler | BLM | Monitoring | 13S | 595420 | 3571095 | 2989 | 19.75 | 75.42 |
| S-2016-084 | South | Rustler | BLM | Commercial | 13S | 588416 | 3562115 | 2962 | 68.25 | --- |
| S-2016-097 | South | Rustler | State | Livestock | 13S | 582268 | 3554859 | 3926 | 65.31 | 91 |
| S-2016-098 | South | Rustler | Private | Commercial | 13S | 584145 | 3553363 | 2992 | 152.75 | --- |
| S-2017-005 | South | --- | State | Monitoring | 13S | 613781.4 | 3594299 | 3510 | 439.08 | 644 |
| S-2017-006 | South | --- | BLM | Monitoring | 13S | 610394.3 | 3577600 | 3291 | 311.53 | 480 |
| S-2017-007 | South | --- | BLM | Monitoring | 13S | 605191.8 | 3579000 | 3134 | 124.81 | 299.3 |
| S-2017-008 | South | --- | BLM | Monitoring | 13S | 613605.4 | 3591529 | 3372 | 305.77 | 566 |
| S-2017-009 | South | --- | BLM | Monitoring | 13S | 607813.5 | 3588947 | 3219 | 155.82 | 381 |
| S-2017-010 | South | --- | BLM | Monitoring | 13S | 621131.4 | 3589375 | 3656 | 614.94 | 884 |
| S-2017-011 | South | --- | WIPP/DOE | Monitoring | 13S | 613788.2 | 3586474 | 3425 | 367.77 | 972 |
| S-2017-012 | South | --- | BLM | Monitoring | 13S | 612264.3 | 3578687 | 3332 | 364.58 | 518 |
| S-2017-013 | South | --- | BLM | Monitoring | 13S | 608122.8 | 3574646 | 3162 | 169.41 | 286 |
| S-2017-014 | South | --- | BLM | Monitoring | 13S | 613954.6 | 3568419 | 3405 | 436.91 | --- |
| S-2017-015 | South | --- | BLM | Monitoring | 13S | 622876 | 3572661 | 3695 | 730.72 | --- |
| S-2017-016 | South | --- | WIPP/DOE | Monitoring | 13S | 614515 | 3580716 | 3417 | 452.88 | 778.7 |
| S-2017-017 | South | --- | WIPP/DOE | Monitoring | 13S | 615253.3 | 3579309 | 3415 | 450.89 | 755 |

### *4.2.4. Capitan Wells*

Permission from Intercontinental Potash Incorporated (ICP) was granted to inventory two of their wells drilled into the Capitan Aquifer, however, the permission was limited to inventorying only and no water quality data were obtained. These wells are mentioned in this study and should permission be granted by ICP for more work in the future, these wells could further enhance the understanding of the Capitan aquifer.

Seven of the Capitan wells are part of a previous study by William Hiss in the 1960's to ascertain the impacts to the Capitan aquifer from extractive use activities in Lea County, NM, and Winkler and Ward Counties in Texas and the potential impacts from those uses to the Pecos River in Carlsbad, NM (Hiss 1973). In 2012 the BLM, in conjunction with the United States Geologic Survey (USGS), resurrected a monitoring program for these wells and set up manual water level measurements on a quarterly schedule. Five of the 7 wells were chosen to be instrumented, they are: City of Carlsbad #13 (CR-2015-001), North Cedar Hills #1 (CR-2015-002), Miller-Nicks-Yates (CR-2015-003), South Wilson Deep #1 (CR-2015-004) and the North Custer Mtn. (CR-2015-005).

*Table 8 - List of Capitan Reef wells. DTW = depth to water. TD = total depth.*

| Location ID | Geo-Name (HPA) | Monitoring Unit | Land Ownership | Type | UTM Zone | Easting | Northing | Elev (ft) | DTW (ft) | TD (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| CR-2015-001 | Outside | Capitan | Private | Monitoring | 13S | 571208 | 3589656 | 3006 | 22.39 | 500, Plugged back to 327 |
| CR-2015-002 | Outside | Capitan | BLM | Monitoring | 13S | 574229 | 3597710 | 3277 | 192.56 | 11,629, Plugged back to 2,500 |
| CR-2015-004 | Outside | Capitan | State | Monitoring | 13S | 645952 | 3592786 | 3729 | 779.26 | 14,368, Plugged back to 8,000 |
| CR-2015-006 | Outside | Capitan | Private | Monitoring | 13S | 661637 | 3564828 | 3369 | 1050.26 | 17,961, Plugged back to 5,713 |
| CR-2015-007 | Outside | Capitan | Private | Monitoring | 13S | 663480 | 3549937 | 2981 | 383.68 | 13,505, Plugged back to 5,300 |

The sampling of these wells via the Snap-Sampler passive sampling system found that two of the wells were obstructed as the sampler mechanism could not reach the desired depth. The Miller-Nix-Yates and the North Cedar Hills wells were later video-logged to try and identify the encountered obstructions. The obstruction in the North Cedar Hills well was an old float mechanism that was part of the USGS water level monitoring tool. A USGS employee was able to remove this obstruction so that monitoring could continue at this well. The Miller-Nix-Yates well however, was obstructed by an unidentifiable blockage that totally encumbered the well casing. The video was not conclusive enough to identify the obstruction and the camera was not able to penetrate through the blockage. The transducer installed in this well was removed, as the data are likely influenced by this obstruction.

## 4.3. Water Level Data

A long-term monitoring program is essential for aquifer protection and management. Select wells in each HPA were monitored using both continuous and manual water level measurements throughout the duration of this study. While continuous monitoring is preferred, manual water level data collection can be less expensive. Continuous water level measurements require more equipment (transducer, transducer cable, reader) while manual water level measurements only require a downhole water sounder. As is such, an appropriate implementation of both methods can create a comprehensive monitoring program.

As demonstrated by most of the wells in which continuous and manual water level measurements are taken, the resolution of the manual measurements does not capture the high-frequency dynamics of the pressure profile where there is active pumping. It is recommended that manual water level measurements be implemented in regions where little aquifer activity (pumping, injection, etc.) is expected. Continuous monitoring is then reserved for either high-activity regions or regions in which there is a specific interest or concern about water level changes.

Continuous water level monitoring was accomplished using pressure transducers in 25 wells which were programmed to record pressure data on constant time intervals, with a focus on the SR/DL and the Rustler Formations. Spatially, transducers were placed in the North, Center North, and South HPA study areas. Some additional transducers were installed in Capitan Reef wells outside of the HPAs.

### *4.3.1. North HPA*

The North HPA used wells N-2016-069 and N-2016-081 for continuous monitoring (Figures 12 and 13). Well N-2016-069 recorded pressure data on a 4-hour interval, while well N-2016-081 captured data 15 minute intervals. Water levels in the wells fluctuated only slightly (>1 psi) and carried no obvious trend, indicating a high likelihood that the water level variations are naturally occurring through seasonal and barometric pressure fluctuations. Well N-2016-069 lies on a sub-shelf below the Mescalero Ridge and based on water levels, may be in the Ogallala aquifer. The well is situated within a cluster of 4-5 wells that are commercially sourced for oil and gas development in the nearby area. It was expected that this well would be heavily influenced by the pumping of the nearby wells, however, this trend was not picked up (Figure 12). The well was a newer well, drilled for commercial water supply, but was not used by the commercial water supplier due to poor pumping volumes.

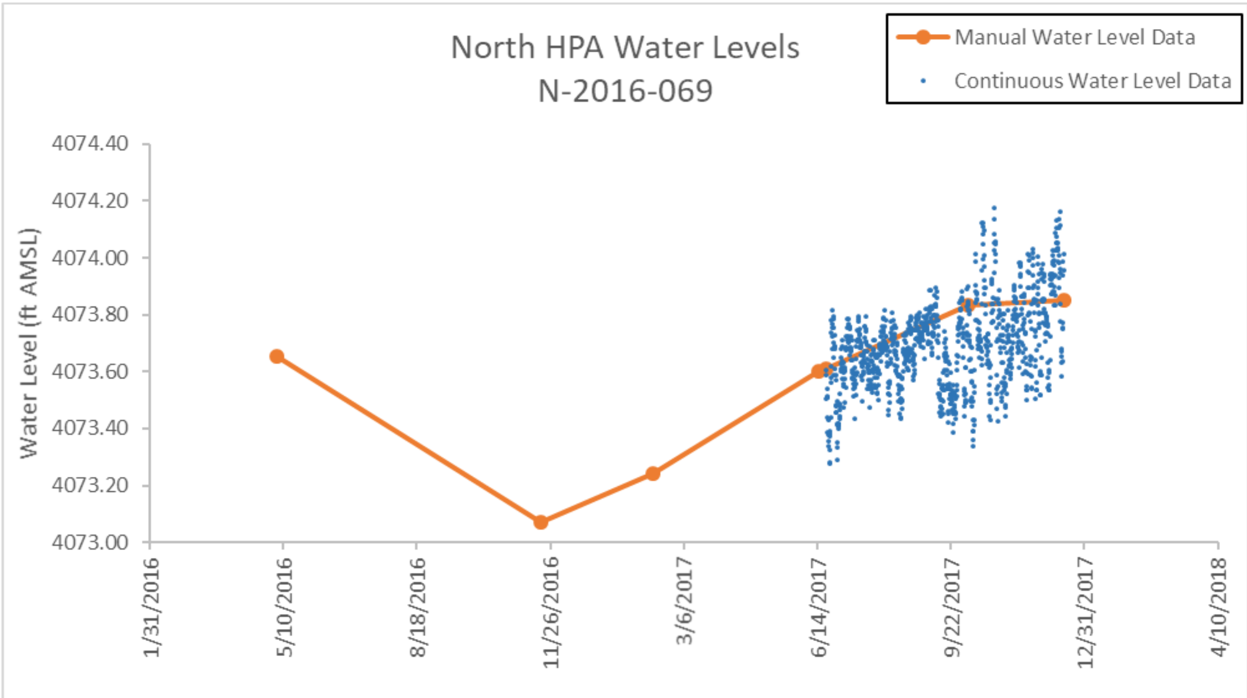



*Figure 12 - Manual and continuous water level data measurements for well N-2016-069. This well is situated within a cluster of 4-5 wells that are commercially sourced for oil and gas development and is likely completed in the Ogallala Aquifer.*

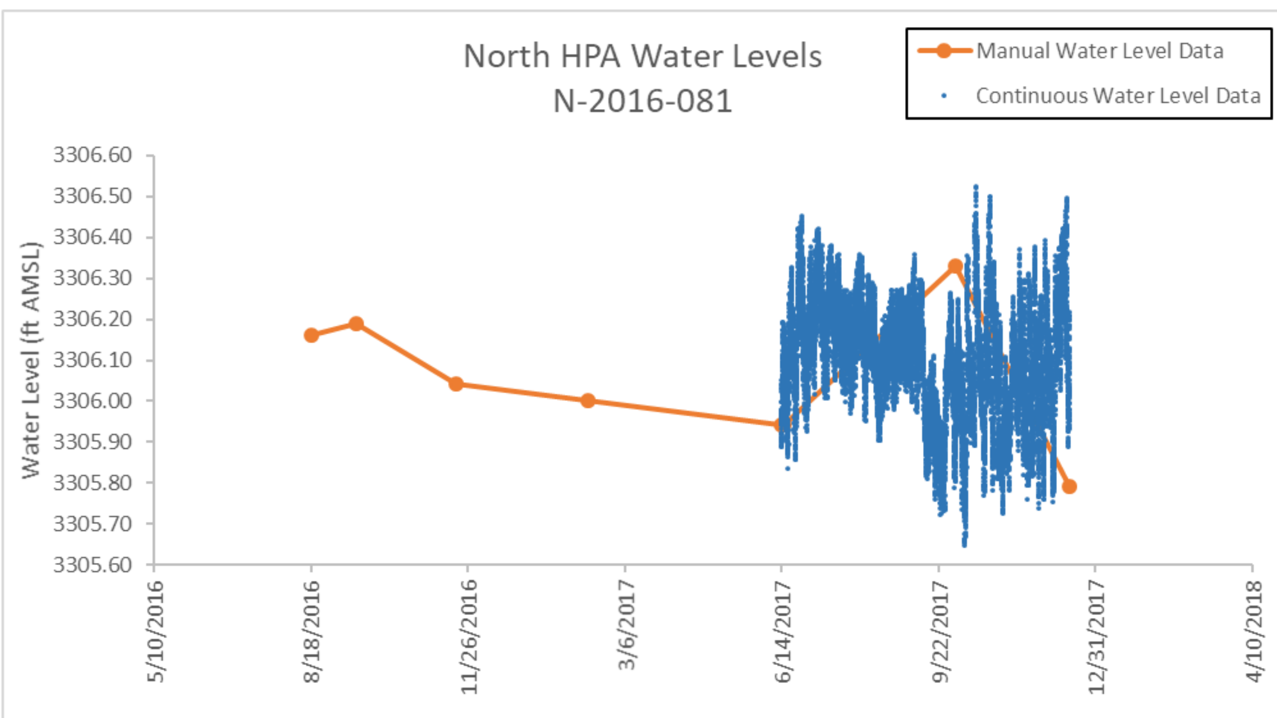



*Figure 13 - Manual and continuous water level data measurements for well N-2016-081.*

### 4.3.2. Center North HPA

Rustler wells CN-2015-013 and CN-2016-005 were chosen for continuous monitoring in the Center North HPA (Figures 14 and 15). Wells CN-2015-013 and CN-2016-005 both captured pressure data on 4-hour intervals. Like the wells in the North HPA, well CN-2015-013 only show water level changes suggestive of barometric effects and seasonal change (Figure 14). Well CN-2016-005, however, displays a sharp water level increase in its most recent data (Figure 15). The cause of this change is difficult to identify, but it is likely that it is from active drilling, pumping, or injecting near the well. The two instrumented wells in this area are not considered commercial. According to NMOSE records, the driller reported losing circulation on well CN-2015-013 at ~60' and drilled blind to 230'.

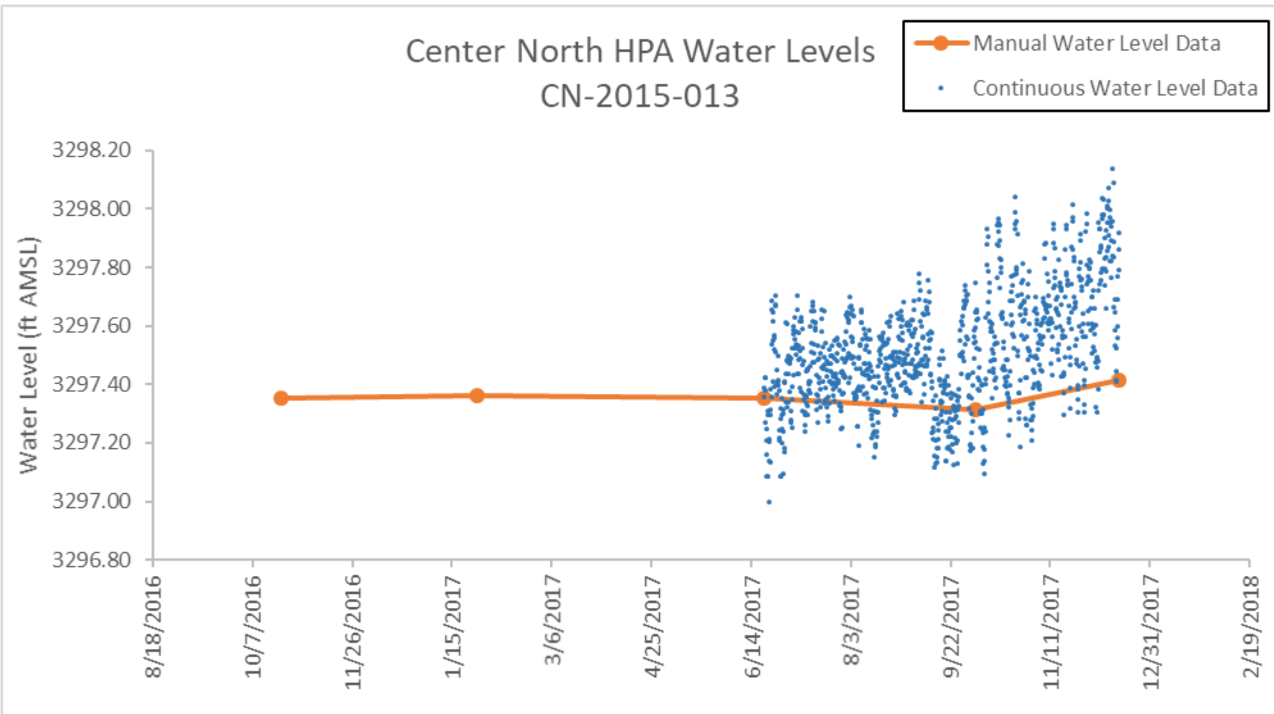



*Figure 14 - Manual and continuous water level data measurements for well CN-2015-013. Variations are indicative of barometric and seasonal effects only.*

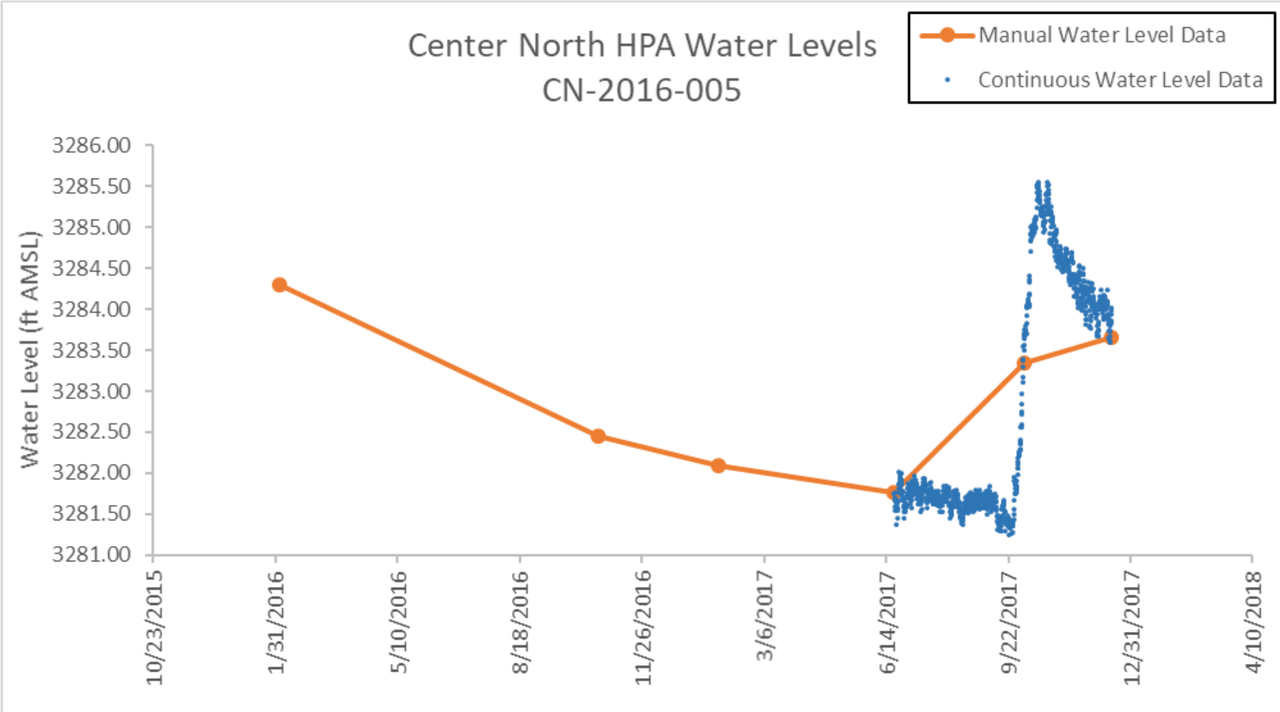



*Figure 15 - Manual and continuous water level data measurements for well CN-2016-005. The sharp increase at the end of September, 2017 is likely due active drilling, pumping, or injection near the well.*

### ***4.3.3. Capitan Reef Wells***

The Capitan Reef monitoring used wells CR-2015-001, CR-2015-002, CR-2015-003, CR-2015-004, and CR-2015-005 for continuous monitoring (Figures 16 through 20). These wells recorded water level data on 1-hour intervals. Wells CR-2015-001, CR-2015-002, and CR-2015-003 show a correlated pressure decrease (Figures 16, 17, and 18). The source of the pressure change is undetermined, however it is likely these wells are influenced by precipitation given their shallow depth and the karstic nature of the formation, as well as from localized municipal pumping by the City of Carlsbad. When you look at CR-2015-001 (Figure 16), it displays sharp daily increases and decreases in water levels that would typically be associated with nearby municipal pumping activities.

Wells CR-2015-004 and CR-2015-005 show a different response with water levels increasing at a relatively constant rate (Figures 19 and 20). In the Hiss study (Hiss 1973), these wells were declining and it was suspected at the time, that it was due to withdrawal of water for industrial purposes. The recent trend shows the opposite and suggest that the aquifer in the eastern part of the Capitan is experiencing recharge. However, the incremental rise in these wells could also be enhanced by injection wells into the Capitan Aquifer coupled with a slow recovery trend.

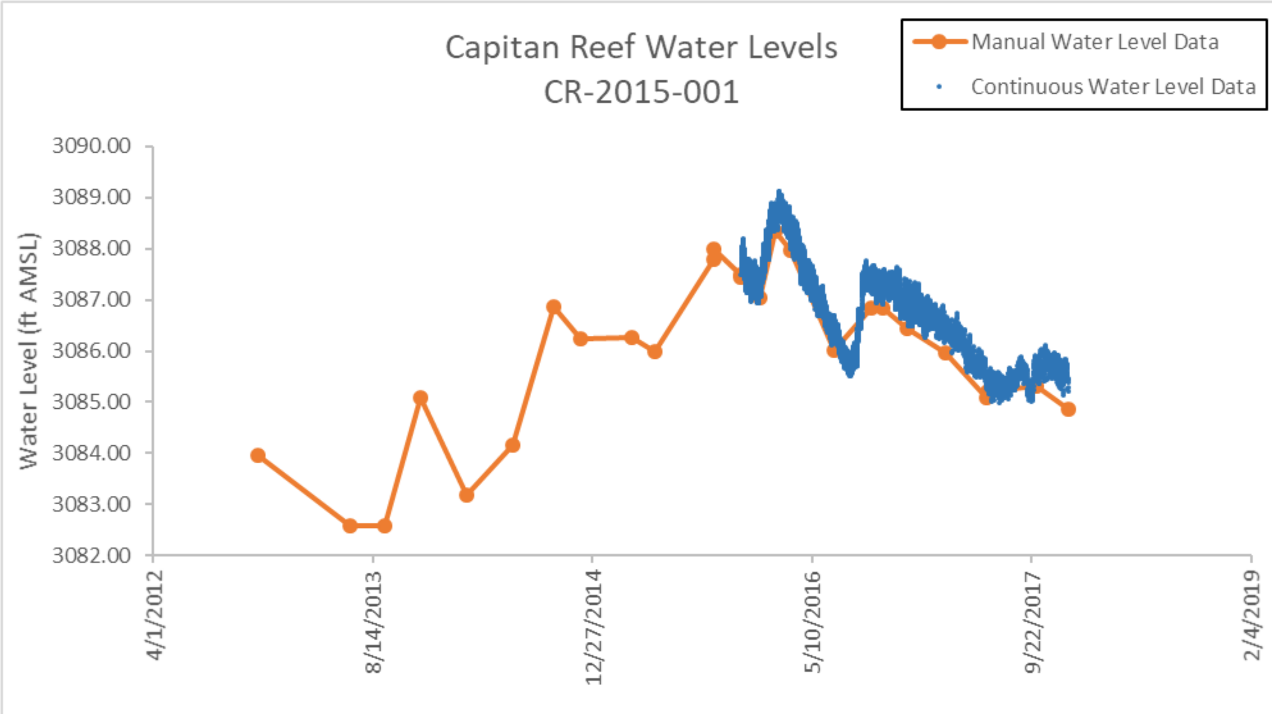



*Figure 16 - Manual and continuous water level data measurements for well CR-2015-001. The source of the pressure variations are undetermined, however it is likely due to precipitation events and the shallow, karstic nature of the formation, as well as from localized municipal pumping by the City of Carlsbad.*

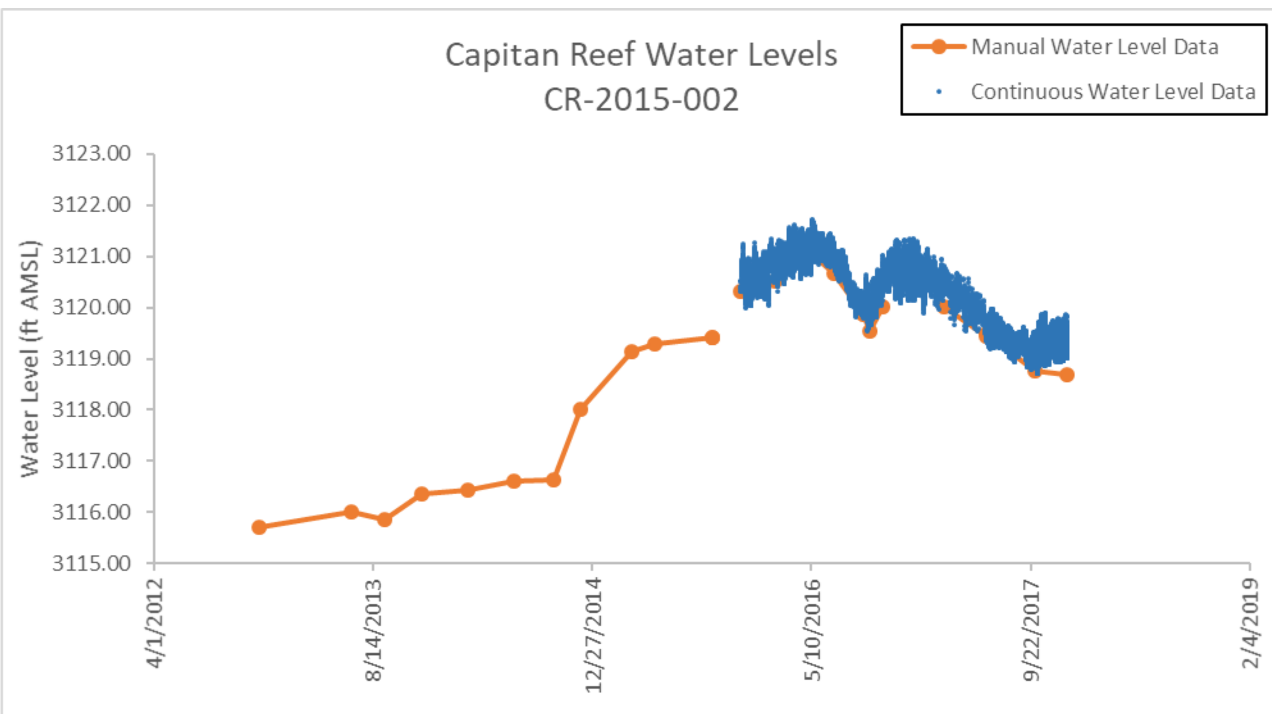



*Figure 17 - Manual and continuous water level data measurements for well CR-20215-002. The source of the pressure variations are undetermined, however it is likely due to precipitation events and the shallow, karstic nature of the formation, as well as from localized municipal pumping by the City of Carlsbad.*

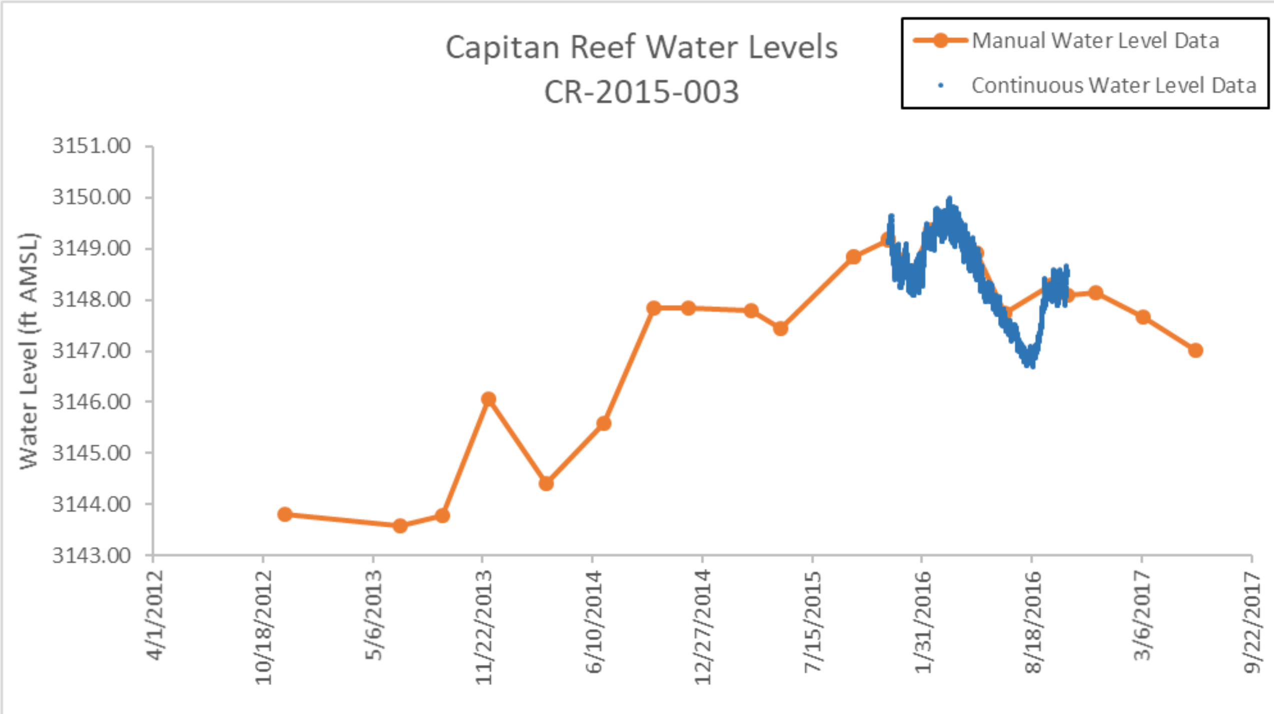



*Figure 18 - Manual and continuous water level data measurements for well CN-2015-003. The source of the pressure variations are undetermined, however it is likely due to precipitation events and the shallow, karstic nature of the formation, as well as from localized municipal pumping by the City of Carlsbad.*

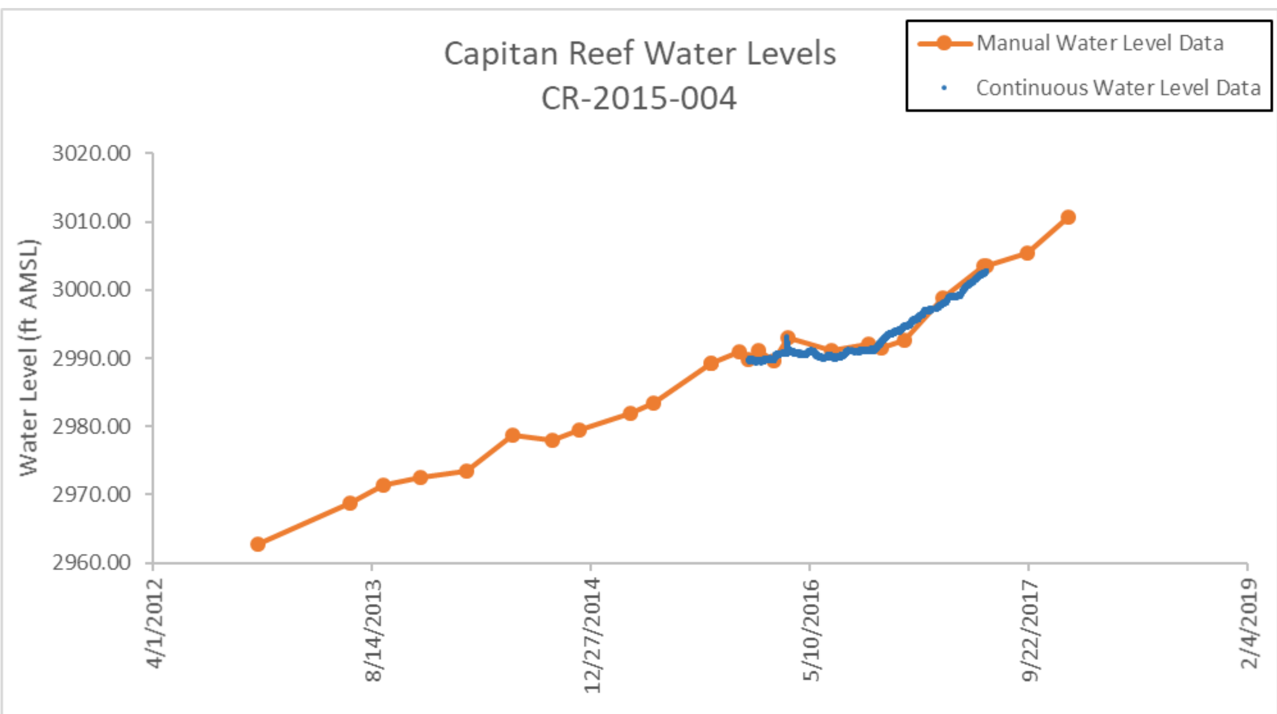



*Figure 19 - Manual and continuous water level data measurements for well CR-2015-004. The recent upward trend is opposite of that found by Hiss (1973) and suggests that the aquifer in the eastern part of the Capitan is experiencing recharge, possibly enhanced by injection wells into the Capitan Aquifer.*

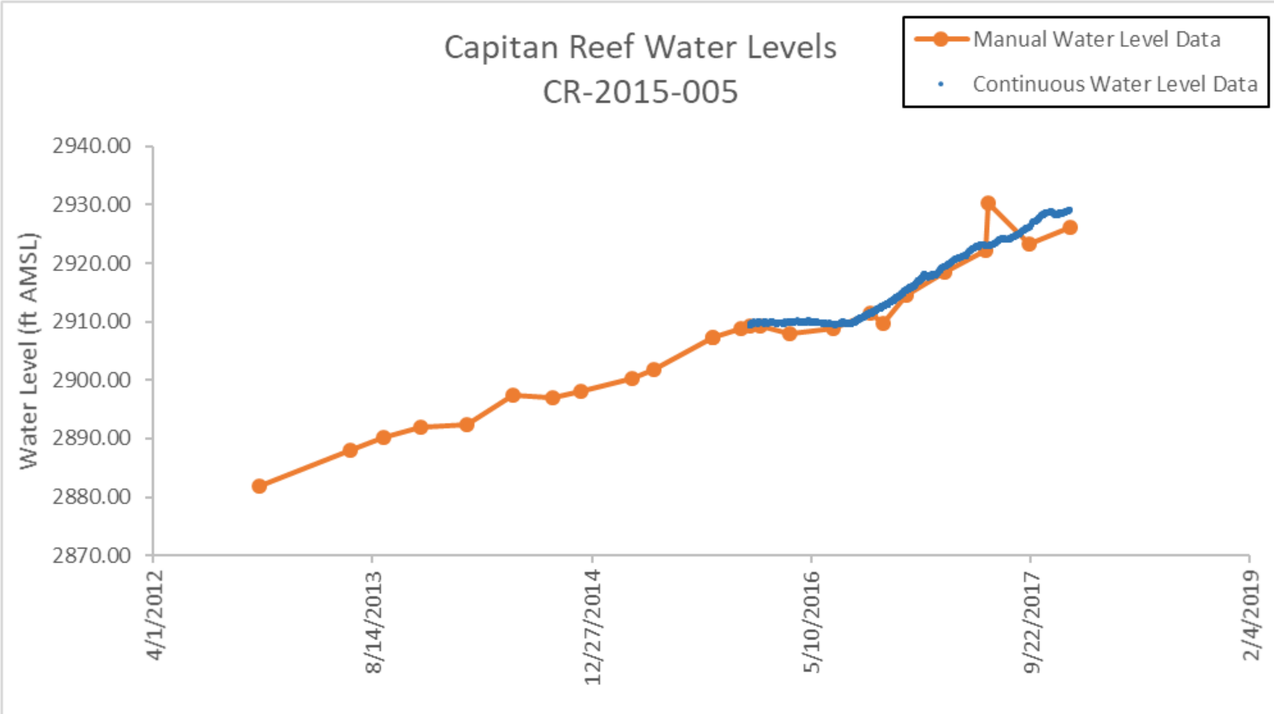



*Figure 20 - Manual and continuous water level data measurements for well CR-2015-005. The recent upward trend is opposite of that found by Hiss (1973) and suggests that the aquifer in the eastern part of the Capitan is experiencing recharge, possibly enhanced by injection wells into the Capitan Aquifer.*

### *4.3.4. South HPA*

The SR/DL wells, S-2017-004, S-2016-019, S-2016-037, and S-2016-048 (Figures 21 through 24), were chosen to monitor in the South HPA along with Rustler wells S-2017-005, S-2017-006, S-2017-007, S-2017-008, S-2017-009, S-2017-010, S-2017-011, S-2017-012, S-2017-013, S-2017-014, S-2017-016, and S-2017-017 (Figures 25 through 36).

The SR/DL wells, S-2016-019 (Figure 22) and S-2016-037 (Figure 23), recorded pressure data on a 4-hour interval and show minimal water level change with a slight increasing trend over time. These wells do not indicate the aquifer is presently being locally impacted by pumping or aquifer development. Wells S-2017-004 (Figure 21) and S-2016-048 (Figure 24), which recorded pressure on a 4-hour and 8-hour time interval, respectively, show pressure variations that are typical to near-by pumping. Well S-2016-004 is located near a known oil supply well which is the likely driver to the drawdown and recovery response being recorded in this well. Well S-2016-048 is located near a municipal water supply well and its erratic response is indicative of pumping cycles associated with a small community water supply.

The Rustler wells in the South HPA vary in their water level response. Each of these wells recorded water level data on 15-miunte intervals. Wells S-2017-005 (Figure 25), S-2017-006 (Figure 26), S-2017-008 (Figure 28), S-2017-011 (Figure 31), and S-2017-016 (Figure 35) display water level changes that are typical for aquifers affected by seasonal variations in pressure and barometric effects.

Wells S-2017-007, S-2017-009, and S-2017-014 (Figures 27, 34, and 29) show minor water level changes likely due to activity in adjacent wells. The origin of the aquifer activity affecting each well are unknown, but likely due to oil-field drilling activities.

Well S-2017-010 (Figure 30) had drastic changes in water level as a result of nearby pumping tests conducted by Sandia as part of their WIPP work. Each water level change event was documented by SNL, and there are no unknowns associated with these changes.

Wells S-2017-012, S-2017-013, and S-2017-017 (Figures 32, 33, and 36) display water level changes due to large-scale pumping in the area south of the WIPP withdrawal boundary. These changes came as somewhat of a surprise as a production well was not known to be in the area. Figure 32 shows the distinct change in water level behavior as pumping began to impact the aquifer on August 8, 2013. This series of what appeared to be pumping events were investigated by SNL and were found to be the result of high production pumping by a local ranch. The details of the pumping, its effects on the WIPP monitoring wells, and the impacts on the WIPP monitoring program are detailed by (Thomas et al. 2017).

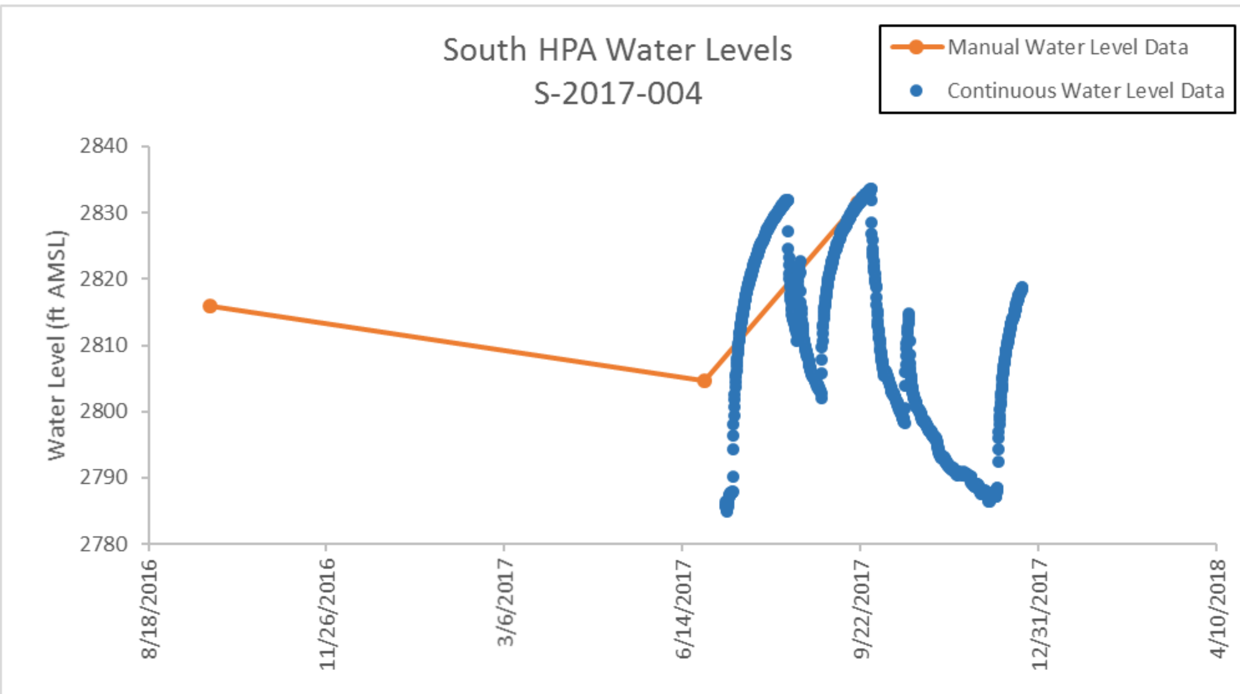



*Figure 21 - Manual and continuous water level data measurements for well S-2017-004. Pressure variations are typical of wells adjacent to near-by pumping.*

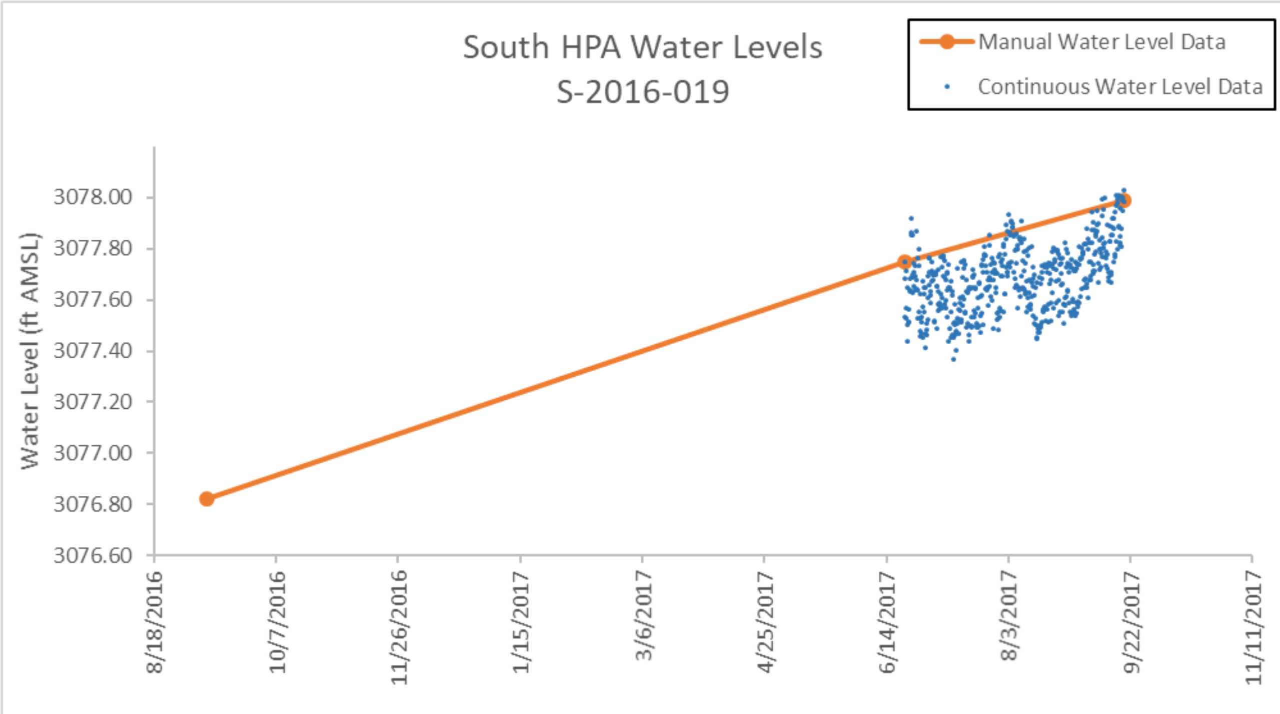



*Figure 22 - Manual and continuous water level data measurements for well S-2017-019. Note the tight scale of the y-axis that shows that the water in this well is fairly steady indicating little impact by pumping or aquifer development.*

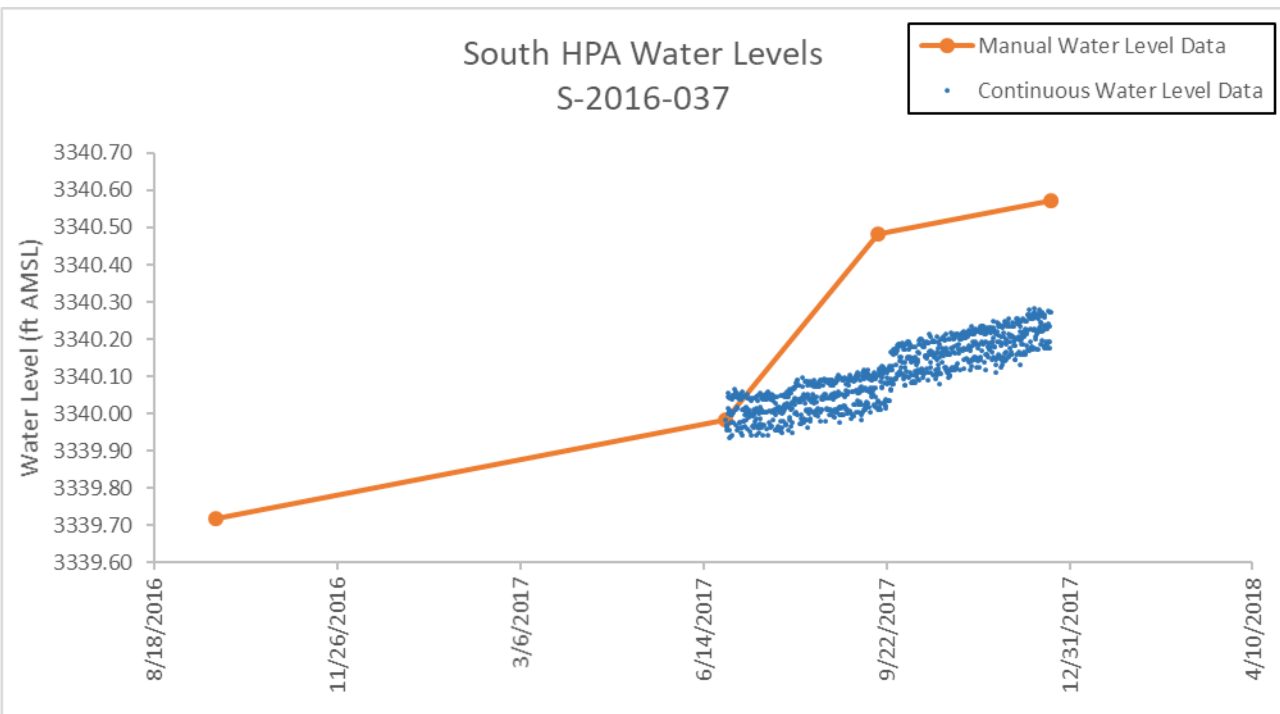



*Figure 23 - Manual and continuous water level data measurements for well S-2017-037. Note the tight scale of the y-axis that shows that the water in this well is fairly steady indicating little impact by pumping or aquifer development.*

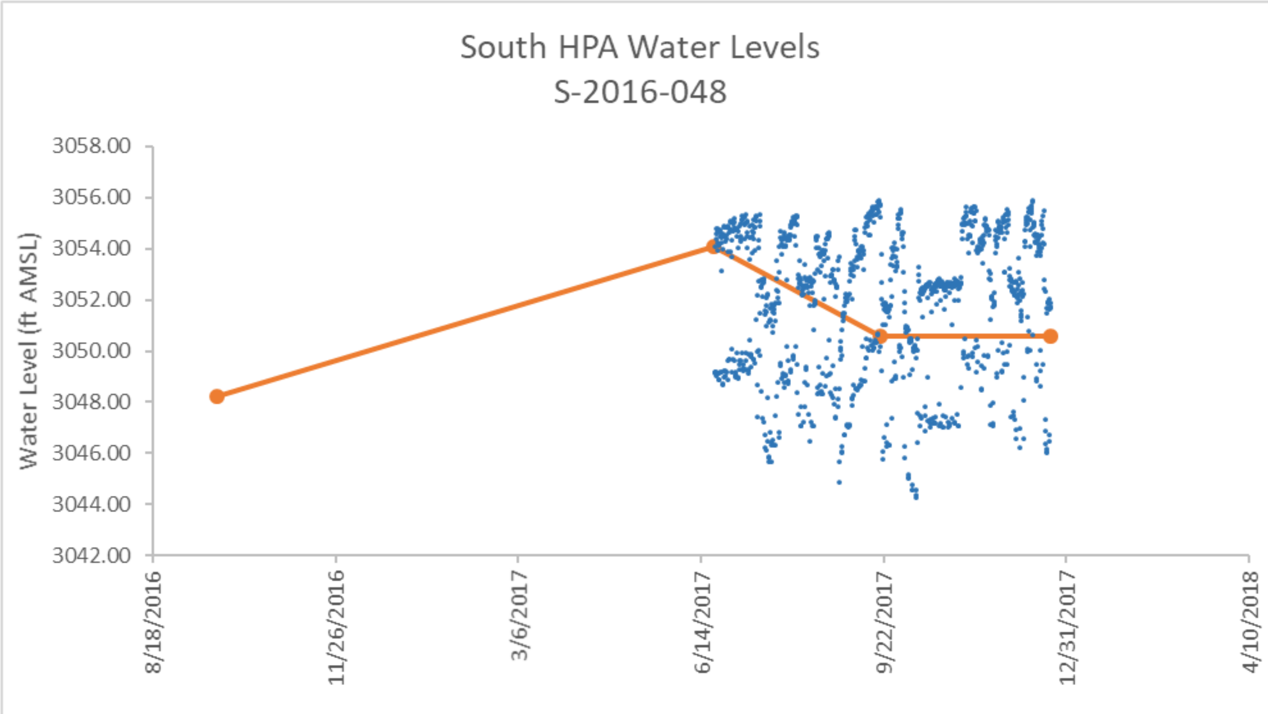



*Figure 24 - Manual and continuous water level data measurements for well S-2017-048. This well is located near a municipal water supply well and its erratic response is indicative of pumping cycles associated with a small community water supply.*

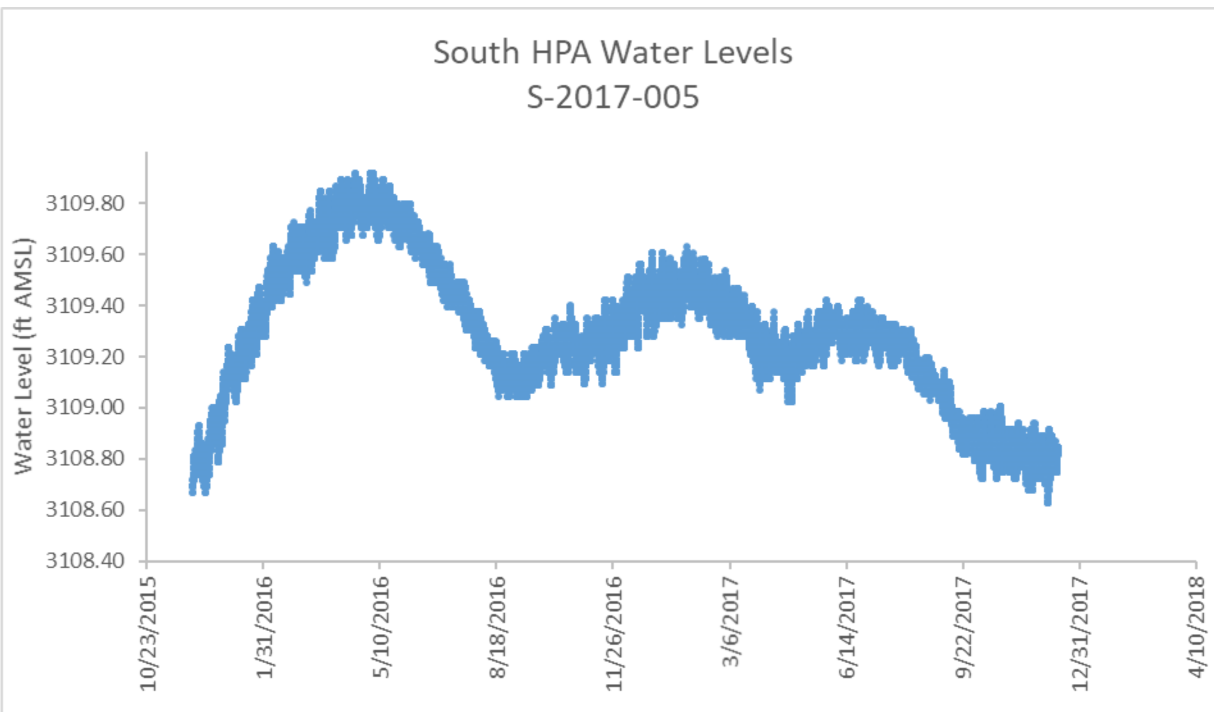



*Figure 25 - Continuous water level data measurements for well S-2017-005. Variations are typical for aquifers affected by seasonal variations in pressure and barometric effects.*

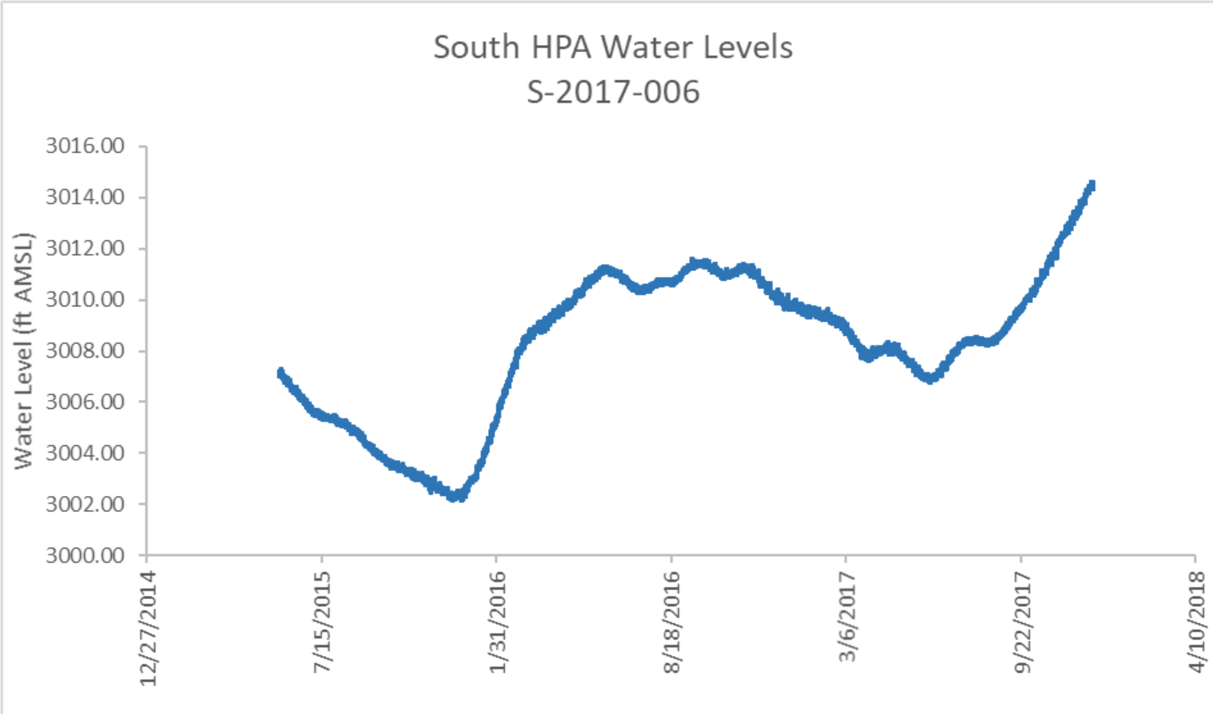



*Figure 26 - Continuous water level data measurements for well S-2017-006. Variations are typical for aquifers affected by seasonal variations in pressure and barometric effects.*

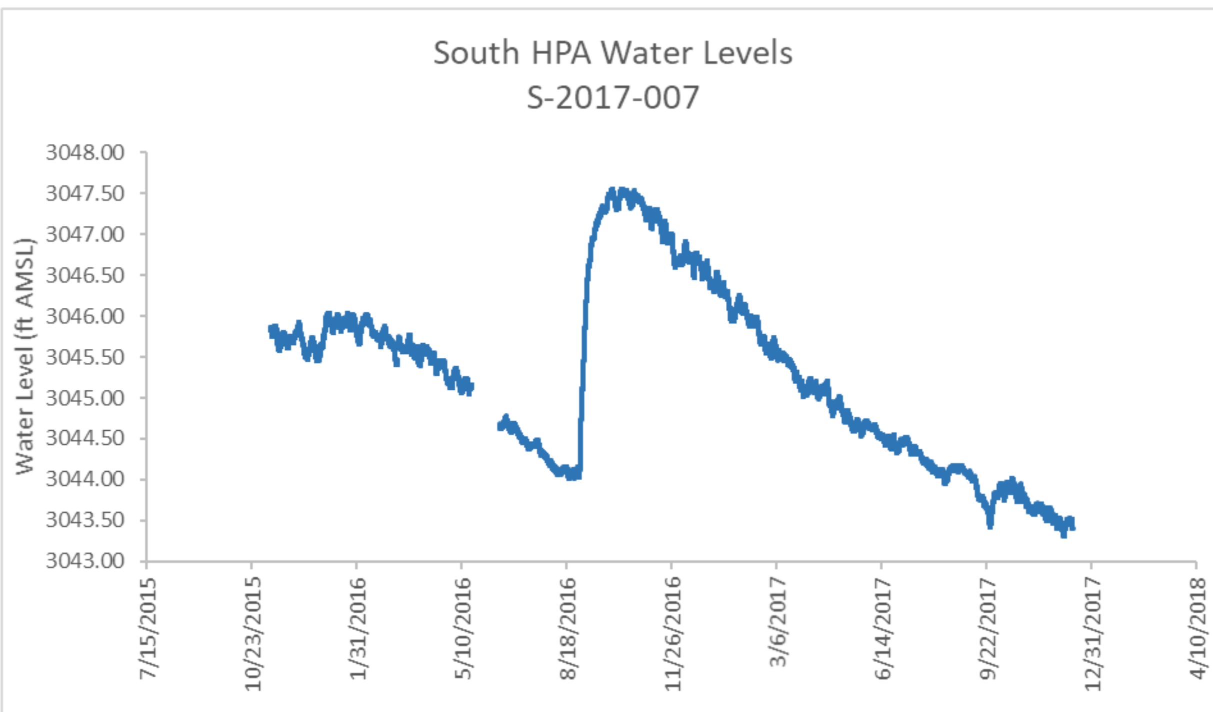



*Figure 27 - Continuous water level data measurements for well S-2017-007. Variations are likely due to activity in adjacent wells.*

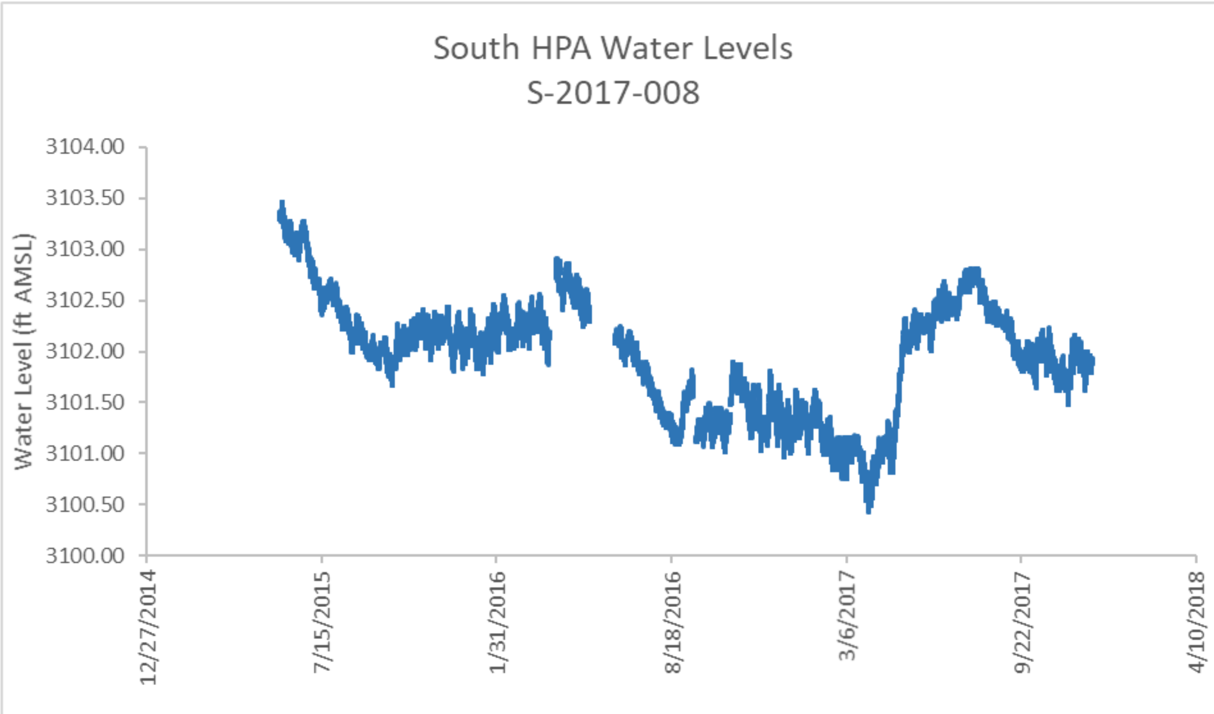



*Figure 28 - Continuous water level data measurements for well S-2017-008. Variations are typical for aquifers affected by seasonal variations in pressure and barometric effects.*

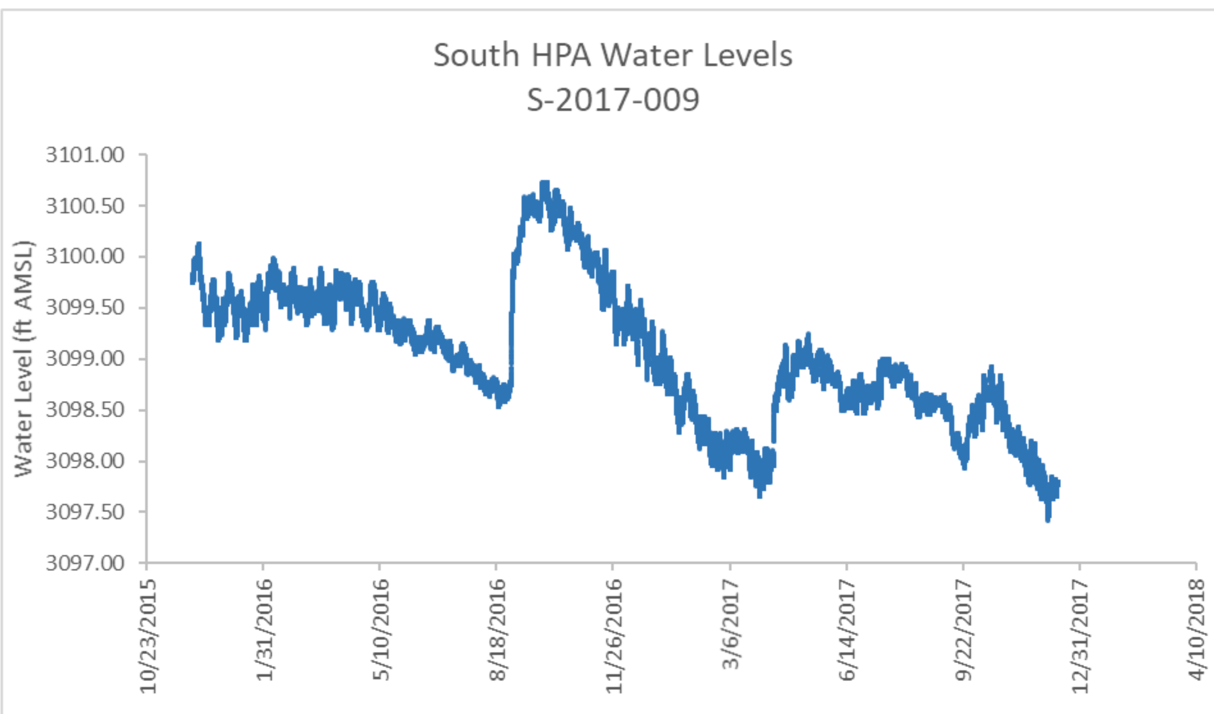



*Figure 29 - Continuous water level data measurements for well S-2017-009. Variations are likely due to activity in adjacent wells.*

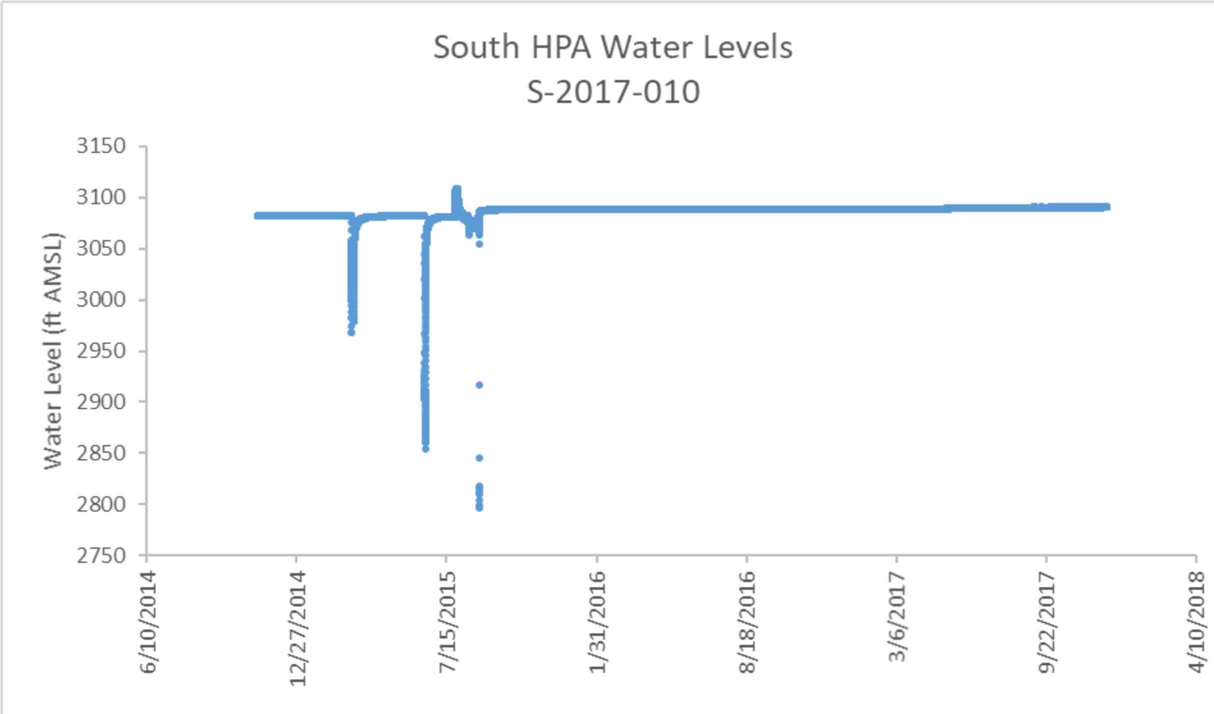



*Figure 30 - Continuous water level data measurements for well S-2017-010. The large periodic changes in water level result from nearby pumping tests conducted by Sandia as part of their WIPP work*

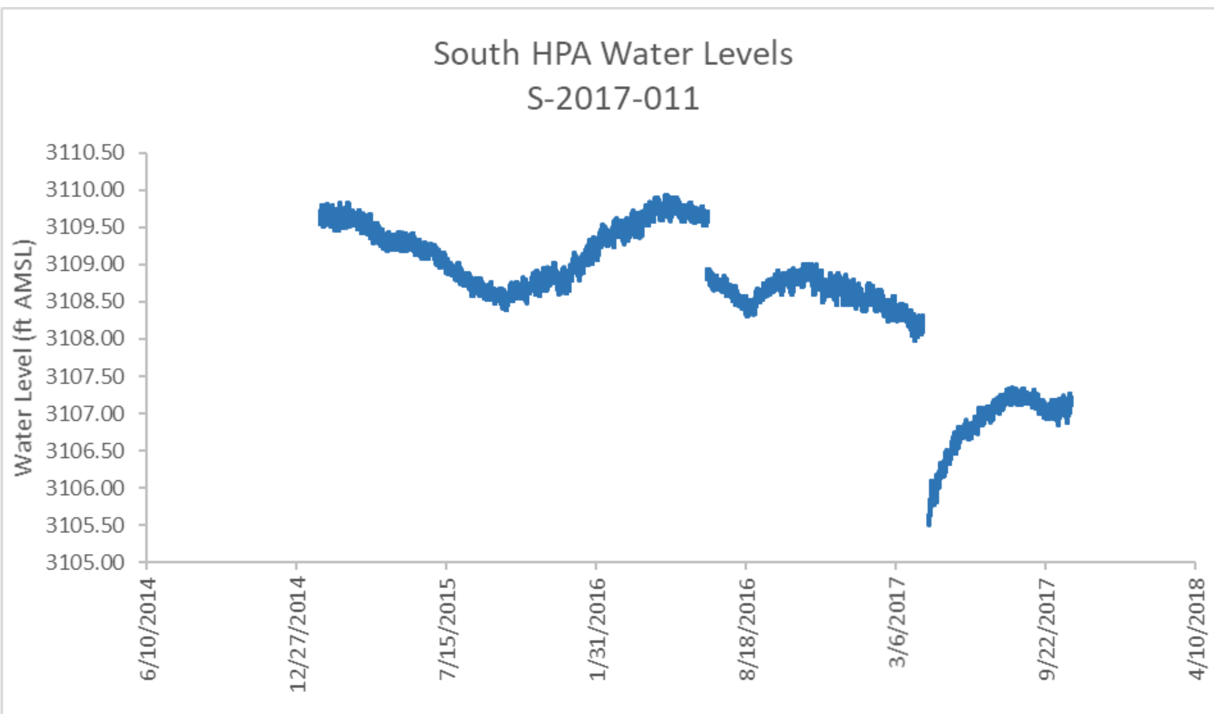



*Figure 31 - Continuous water level data measurements for well S-2017-011. Variations are typical for aquifers affected by seasonal variations in pressure and barometric effects.*

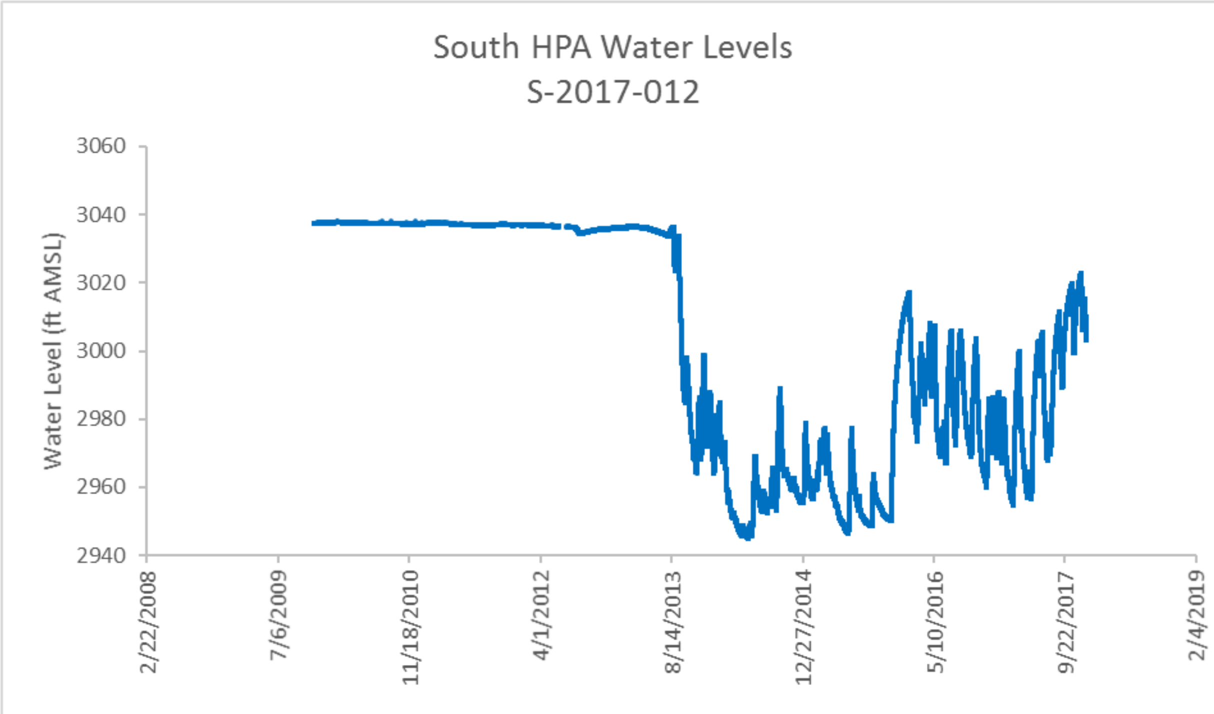



*Figure 32 - Continuous water level data measurements for well S-2017-012. Variations are indicative of large-scale pumping in the area south of the WIPP withdrawal boundary. The source of the pumping is from a nearby high-production ranch well.*

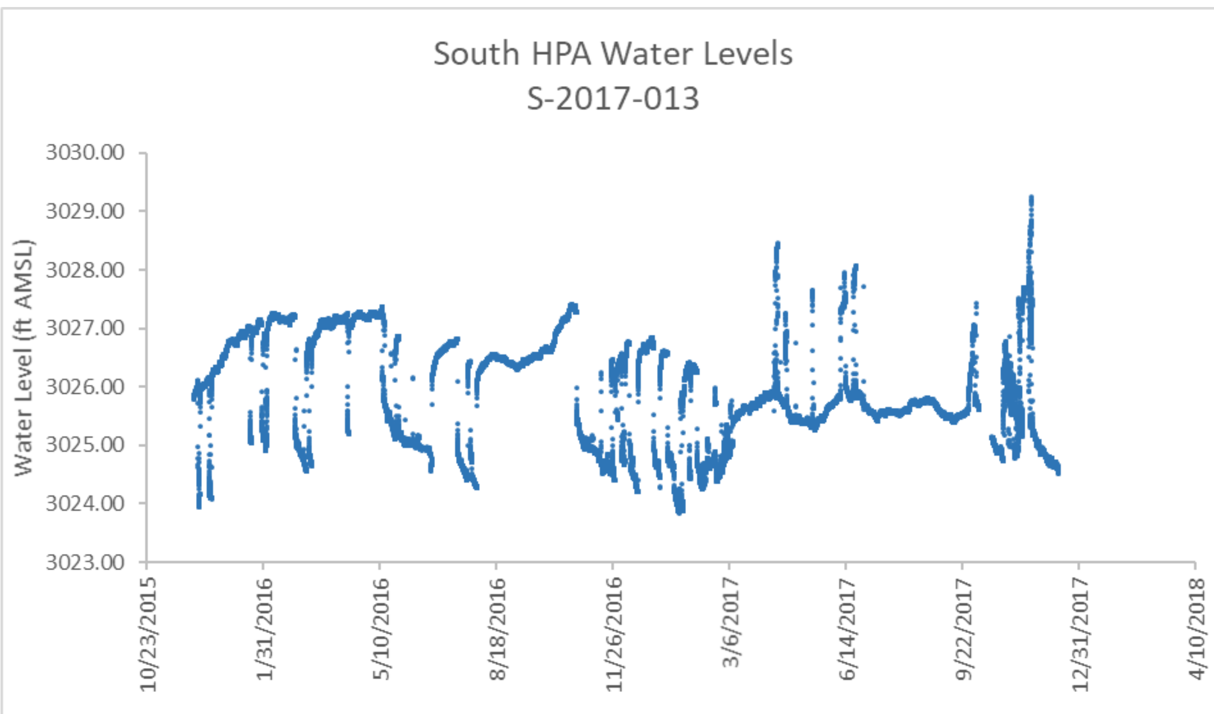



*Figure 33 - Continuous water level data measurements for well S-2017-013. Variations are indicative of large-scale pumping in the area south of the WIPP withdrawal boundary. The source of the pumping is unknown.*

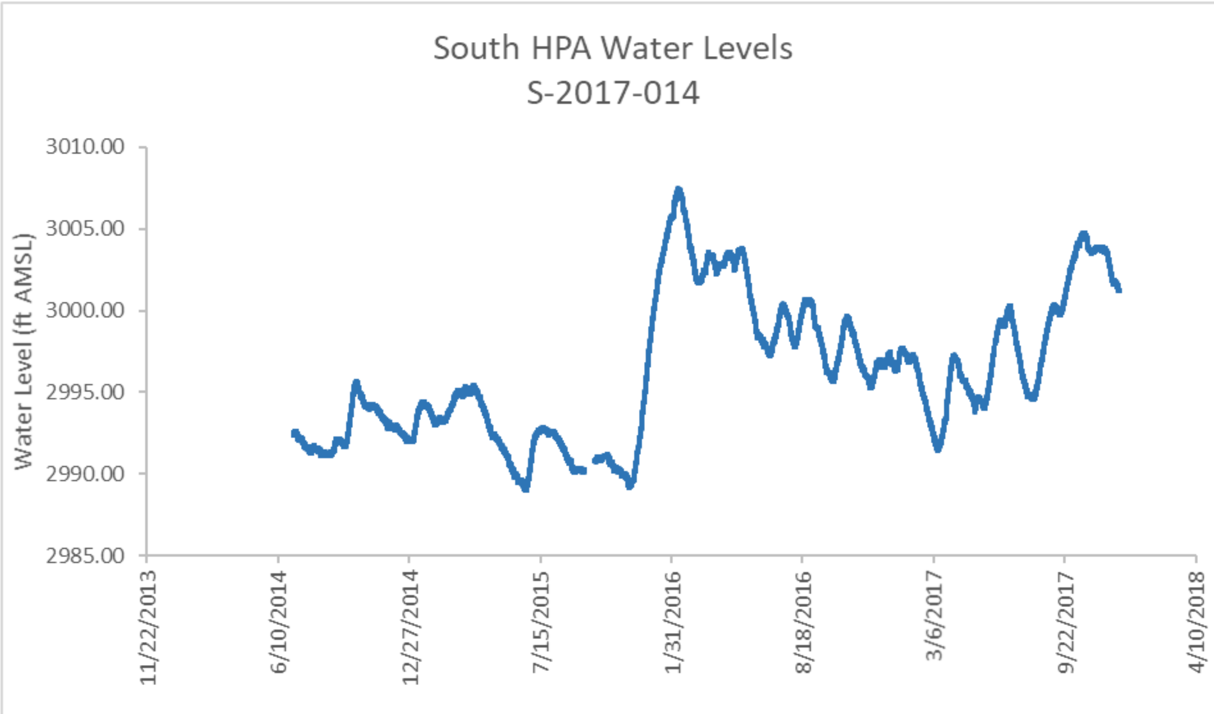



*Figure 34 - Continuous water level data measurements for well S-2017-014. Variations are likely due to activity in adjacent wells.*

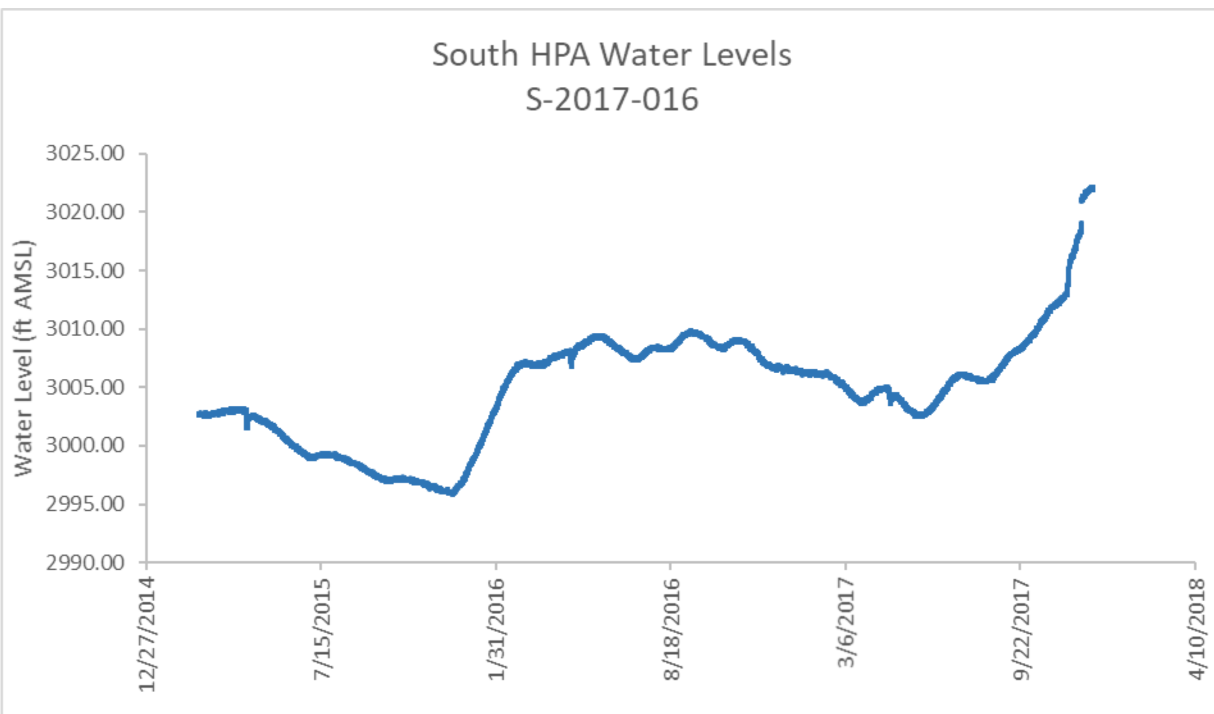



*Figure 35 - Continuous water level data measurements for well S-2017-016. Variations are typical for aquifers affected by seasonal variations in pressure and barometric effects.*

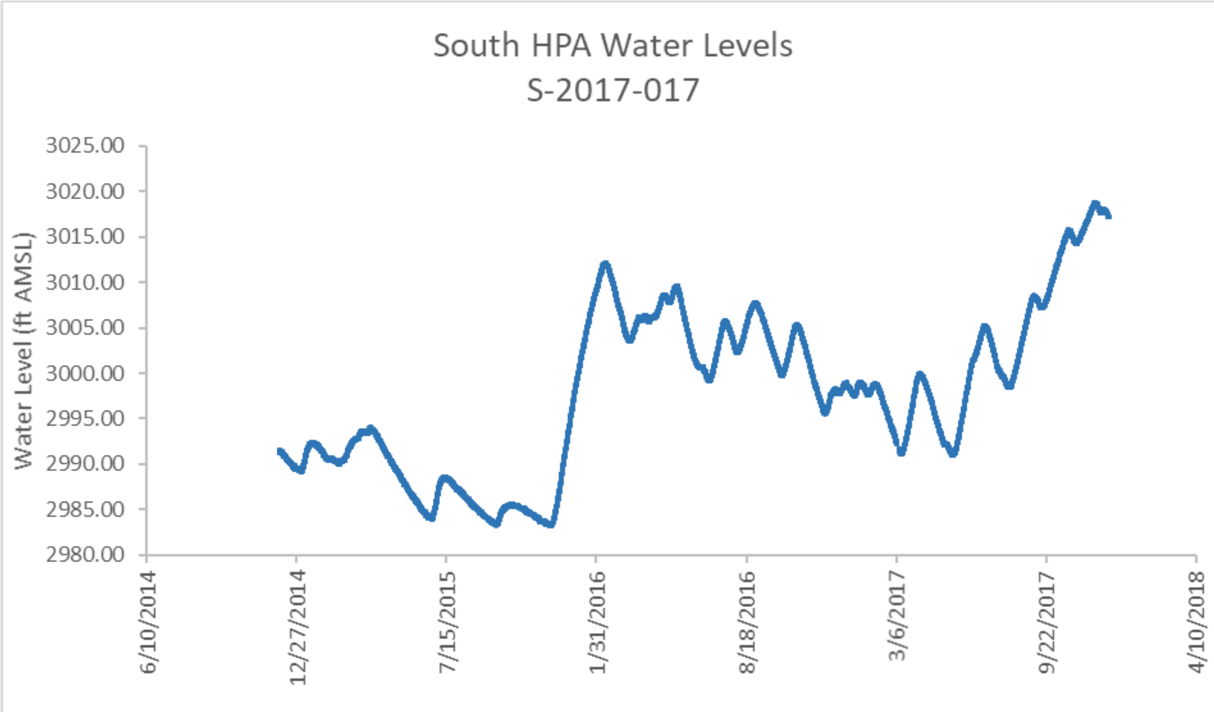



*Figure 36 - Continuous water level data measurements for well S-2017-017. Variations are indicative of large-scale pumping in the area south of the WIPP withdrawal boundary. The source of the pumping is unknown.*

### 4.3.5. Manual Water Level Data

Manual water level data was collected for multiple wells in each study area and was gathered on a quarterly basis using a down-hole water sounder. Additional water level measurements were also taken for continuously monitored wells when a transducer was installed or replaced. The measurements were referenced to a fixed point at each well (typically associated with the well casing) and then adjusted to reflect the elevation above mean sea level (AMSL).

The following tables list the manual water levels recorded for each well in the study area along with their corresponding AMSL water level. In instances where a water level could not be recorded (dry well, well head welded shut, etc.), N/A was listed as water depth.

*Table 9 - Manual water level measurement data for the North HPA. DTW = Depth to Water. BGS = Below Ground Surface.*

| Name | Date | Time | DTW [ft BGS] | W-Elev. [ft AMSL] |
|---|---|---|---|---|
| N-2016-004 | 07/21/19 | 00:00 | 50.60 | 3926.40 |
| N-2016-005 | 12/16/14 | 11:43 | 458.20 | 3347.80 |
| | 11/18/16 | 08:20 | 454.05 | 3351.95 |
| N-2016-006 | 03/01/16 | 11:58 | 64.11 | 3941.89 |
| N-2016-007 | 11/26/14 | 12:41 | 247.17 | 3532.83 |
| N-2016-013 | 03/01/16 | 12:06 | 55.84 | 3947.16 |
| N-2016-050 | 03/18/16 | 14:50 | 53.20 | 3379.80 |
| N-2016-060 | 03/24/16 | 10:00 | 38.60 | 3546.40 |
| N-2016-065 | 05/05/16 | 09:58 | 86.91 | 4023.09 |
| | 11/18/16 | 09:30 | 81.92 | 4028.08 |
| | 06/14/17 | 12:49 | 76.80 | 4034.20 |
| | 06/20/17 | 09:50 | 76.79 | 4034.21 |
| | 10/04/17 | 10:50 | 76.57 | 4034.43 |
| | 12/15/17 | 11:12 | 76.55 | 4034.45 |
| N-2016-066 | 05/05/16 | 10:05 | 103.70 | 4019.30 |
| N-2016-067 | 11/18/16 | 09:35 | 77.61 | 4063.39 |
| | 06/14/17 | 12:53 | 74.18 | 4066.82 |
| | 10/04/17 | 10:41 | 71.95 | 4069.05 |
| | 12/15/17 | 11:03 | 71.81 | 4069.19 |
| N-2016-068 | 05/05/16 | 10:48 | 77.00 | 4030.00 |
| | 02/10/17 | 10:40 | 116.80 | 3990.20 |
| | 06/14/17 | 12:45 | 102.55 | 4004.45 |
| | 10/04/17 | 10:31 | 104.47 | 4002.53 |
| | 12/15/17 | 11:03 | 104.53 | 4002.47 |
| N-2016-069 | 05/05/16 | 11:29 | 76.75 | 4034.25 |
| | 11/18/16 | 10:28 | 77.33 | 4033.67 |
| | 02/10/17 | 10:30 | 77.16 | 4033.84 |
| N-2016-073 | 07/19/16 | 11:30 | 151.40 | 3210.60 |
| N-2016-078 | 07/19/16 | 09:05 | 129.83 | 3455.17 |
| | 11/18/16 | 12:44 | 130.71 | 3454.29 |
| | 02/10/17 | 11:55 | 132.62 | 3452.38 |
| | 06/15/17 | 11:25 | 131.26 | 3453.74 |
| | 10/02/17 | 12:38 | 134.80 | 3450.20 |
| | 12/14/17 | 12:30 | 130.22 | 3454.78 |
| N-2016-081 | 08/18/16 | 09:00 | 133.34 | 3518.66 |

*Table 10 - Manual water level measurement data for the Center North HPA. DTW = Depth to Water. BGS = Below Ground Surface.*

| Name | Date | Time | DTW [ft BGS] | W-Elev. [ft AMSL] |
|---|---|---|---|---|
| CN-2014-005 | 10/29/14 | 11:55 | N/A | N/A |
| CN-2014-008 | 10/29/14 | 11:15 | 289.50 | 3307.50 |
| CN-2014-009 | 09/26/13 | 13:34 | 246.25 | 3392.75 |
| | 06/13/14 | 12:00 | 248.11 | 3390.89 |
| | 11/06/14 | 15:53 | 248.82 | 3390.18 |
| | 06/14/17 | 10:35 | 248.70 | 3390.30 |
| | 10/04/17 | 09:48 | 249.60 | 3389.40 |
| | 12/15/17 | 10:25 | 250.89 | 3388.11 |
| CN-2014-010 | 06/13/14 | 13:40 | 354.28 | 3274.72 |
| | 11/06/14 | 15:42 | 354.54 | 3274.46 |
| | 10/04/17 | 09:45 | 354.10 | 3274.90 |
| | 12/15/17 | 10:17 | 355.28 | 3273.72 |
| CN-2015-10 | 06/20/17 | 11:58 | 133.61 | 3178.39 |
| CN-2015-012 | 09/15/16 | 08:00 | 133.31 | 3518.69 |
| | 11/18/16 | 12:30 | 133.46 | 3518.54 |
| | 02/10/17 | 11:43 | 133.50 | 3518.50 |
| | 06/15/17 | 11:42 | 133.56 | 3518.44 |
| | 10/02/17 | 11:29 | 133.17 | 3518.83 |
| | 12/14/17 | 12:07 | 133.71 | 3518.29 |
| CN-2015-013 | 10/21/16 | 12:58 | 63.76 | 3248.24 |
| | 01/27/17 | 13:02 | 63.75 | 3248.25 |
| | 06/20/17 | 12:07 | 63.76 | 3248.24 |
| | 10/04/17 | 13:28 | 63.80 | 3248.20 |
| | 12/15/17 | 14:00 | 63.70 | 3248.30 |
| CN-2016-001 | 01/27/17 | 11:20 | 248.55 | 3309.45 |
| | 06/14/17 | 09:55 | 248.37 | 3309.63 |
| | 10/04/17 | 08:58 | 248.39 | 3309.61 |
| | 12/15/17 | 09:39 | 248.39 | 3309.61 |
| CN-2016-002 | 02/03/16 | 13:36 | 246.11 | 3307.89 |
| | 01/27/17 | 11:10 | 240.60 | 3313.40 |
| | 06/14/17 | 09:57 | 237.68 | 3316.32 |
| | 10/04/17 | 09:01 | 238.48 | 3315.52 |
| | 12/15/17 | 09:42 | 237.71 | 3316.29 |
| CN-2016-003 | 01/27/17 | 11:10 | 248.78 | 3328.22 |
| | 06/14/17 | 10:00 | 248.75 | 3328.25 |
| | 10/04/17 | 09:04 | 248.80 | 3328.20 |
| | 12/15/17 | 09:44 | 248.85 | 3328.15 |
| CN-2016-005 | 02/03/16 | 13:36 | 68.21 | 3301.79 |
| | 10/21/16 | 12:20 | 70.06 | 3299.94 |
| | 01/27/17 | 12:38 | 70.42 | 3299.58 |
| | 06/20/17 | 13:20 | 70.75 | 3299.25 |

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|---|---|---|---|---|
| | 10/04/17 | 13:59 | 69.16 | 3300.84 |
| | 12/15/17 | 13:20 | 68.85 | 3301.15 |
| CN-2016-007 | 10/21/16 | 11:30 | 195.34 | 3228.66 |
| | 01/27/17 | 12:15 | 211.73 | 3212.27 |
| | 06/14/17 | 14:08 | 210.80 | 3213.20 |
| | 06/20/17 | 14:20 | 201.80 | 3222.20 |
| | 10/04/17 | 14:13 | 196.72 | 3227.28 |
| | 12/15/17 | 12:38 | 196.00 | 3228.00 |
| CN-2016-008 | 02/02/16 | 11:39 | 205.60 | 3214.40 |
| CN-2016-016 | 02/04/16 | 11:36 | 135.70 | 3306.30 |
| CN-2016-017 | 06/22/16 | 09:38 | 194.57 | 3229.43 |
| | 10/21/16 | 11:49 | 199.42 | 3224.58 |
| | 01/27/17 | 12:19 | 199.91 | 3224.09 |
| | 06/20/17 | 14:00 | 201.00 | 3223.00 |
| | 10/04/17 | 14:20 | 201.98 | 3222.02 |
| | 12/15/17 | 12:59 | 196.17 | 3227.83 |

*Table 11 - Manual water level measurement data for the South HPA. DTW = Depth to Water. BGS = Below Ground Surface.*

| Name | Date | Time | DTW [ft BGS] | W-Elev. [ft AMSL] |
|---|---|---|---|---|
| S-2014-001 | 10/29/2014 | 07:50 | 81.70 | 3696.30 |
| S-2014-002 | 10/29/2014 | 09:23 | 808.22 | 2943.78 |
| | 10/04/2017 | 13:59 | 69.16 | 3300.84 |
| | 12/15/2017 | 13:20 | 68.85 | 3301.15 |
| S-2014-003 | 10/29/2014 | 11:00 | N/A | 0.00 |
| S-2014-004 | 10/29/2014 | 11:15 | 763.44 | 2968.56 |
| S-2014-005 | 10/29/2014 | 11:00 | N/A | 0.00 |
| S-2014-006 | 10/29/2014 | 11:00 | N/A | 0.00 |
| S-2014-011 | 10/29/2014 | 11:15 | N/A | 0.00 |
| S-2014-012 | 10/29/2014 | 11:15 | N/A | 0.00 |
| S-2014-014 | 11/11/2014 | 14:00 | 113.35 | 3697.65 |
| S-2014-015 | 11/11/2014 | 14:57 | 142.10 | 3654.90 |
| S-2014-016 | 10/29/2014 | 11:15 | N/A | 0.00 |
| S-2014-017 | 11/14/2014 | 11:00 | N/A | 0.00 |
| S-2014-018 | 11/14/2014 | 11:00 | N/A | 0.00 |
| S-2014-021 | 11/14/2014 | 11:15 | N/A | 0.00 |
| S-2016-003 | 09/06/2016 | 09:10 | 465.60 | 3199.40 |
| S-2016-019 | 09/08/2016 | 14:05 | 410.84 | 3041.16 |
| | 06/21/2017 | 10:53 | 409.91 | 3042.09 |
| | 09/19/2017 | 11:05 | 409.67 | 3042.33 |
| S-2016-020 | 09/08/2016 | 14:30 | 539.05 | 2928.95 |
| | 09/19/2017 | 11:18 | 505.65 | 2962.35 |
| | 12/20/2017 | 12:04 | 544.92 | 2923.08 |
| S-2016-023 | 09/08/2016 | 11:15 | 422.30 | 3027.70 |

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|---|---|---|---|---|
| | 11/12/2016 | 11:50 | 410.10 | 3039.90 |
| | 06/21/2017 | 11:34 | 416.38 | 3033.62 |
| | 09/19/2017 | 11:27 | 411.54 | 3038.46 |
| | 12/20/2017 | 12:28 | 414.08 | 3035.92 |
| S-2016-026 | 06/21/2017 | 11:27 | 404.45 | 3069.55 |
| | 09/19/2017 | 11:10 | 404.52 | 3069.48 |
| | 12/21/2017 | 12:20 | 405.23 | 3068.77 |
| S-2016-032 | 09/09/2016 | 12:45 | 342.21 | 3011.79 |
| S-2016-037 | 09/20/2016 | 10:15 | 189.82 | 3293.18 |
| | 06/26/2017 | 09:05 | 189.55 | 3293.45 |
| | 09/17/2017 | 13:07 | 189.05 | 3293.95 |
| | 12/20/2017 | 14:26 | 188.96 | 3294.04 |
| S-2016-038 | 09/20/2016 | 11:00 | 422.60 | 3221.40 |
| | 09/19/2017 | 12:06 | 419.55 | 3224.45 |
| | 12/20/2017 | 13:08 | 417.42 | 3226.58 |
| S-2016-041 | 09/20/2016 | 12:30 | 446.03 | 3177.97 |
| | 09/19/2017 | 12:35 | 444.55 | 3179.45 |
| | 12/20/2017 | 13:56 | 446.63 | 3177.37 |
| S-2016-043 | 09/21/2016 | 11:25 | 185.14 | 2920.86 |
| | 06/26/2017 | 12:12 | 185.15 | 2920.85 |
| | 09/20/2017 | 10:18 | 185.03 | 2920.97 |
| S-2016-044 | 09/21/2016 | 12:25 | 208.80 | 2882.20 |
| | 06/26/2017 | 11:15 | 220.10 | 2870.90 |
| | 09/20/2017 | 10:53 | 193.17 | 2897.83 |
| S-2016-045 | 09/21/2016 | 12:25 | 223.03 | 2874.97 |
| | 06/26/2017 | 11:28 | 190.00 | 2908.00 |
| S-2016-047 | 09/20/2017 | 11:12 | 147.34 | 2932.66 |
| S-2016-048 | 09/22/2016 | 08:30 | 122.10 | 3022.90 |
| | 06/21/2017 | 08:29 | 116.22 | 3028.78 |
| | 09/20/2017 | 07:49 | 119.74 | 3025.26 |
| | 12/22/2017 | 10:15 | 119.74 | 3025.26 |
| S-2016-050 | 09/22/2016 | 09:30 | 72.10 | 3024.90 |
| | 06/21/2017 | 09:15 | 75.96 | 3021.04 |
| | 09/20/2017 | 07:35 | 70.87 | 3026.13 |
| | 12/22/2017 | 10:27 | 75.69 | 3021.31 |
| S-2016-055 | 09/27/2016 | 10:45 | 76.31 | 2817.69 |
| | 06/26/2017 | 13:13 | 75.56 | 2818.44 |
| | 09/20/2017 | 09:47 | 75.87 | 2818.13 |
| | 12/21/2017 | 10:37 | 76.05 | 2817.95 |
| S-2016-063 | 09/29/2016 | 11:10 | 12.95 | 2960.05 |
| | 09/20/2017 | 08:32 | 21.90 | 2951.10 |
| S-2016-064 | 09/29/2016 | 11:40 | 172.75 | 2815.25 |
| S-2016-065 | 09/29/2016 | 12:00 | 161.43 | 2821.57 |
| S-2016-068 | 09/29/2016 | 12:30 | 148.95 | 2842.05 |

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|---|---|---|---|---|
| S-2016-070 | 09/29/2016 | 13:25 | 130.03 | 2838.97 |
| S-2016-080 | 10/25/2016 | 10:45 | 48.83 | 2972.17 |
| S-2016-081 | 10/25/2017 | 10:00 | 63.38 | 2963.62 |
| S-2016-082 | 10/25/2016 | 11:30 | 19.75 | 2969.25 |
| | 10/06/2017 | 08:58 | 19.28 | 2969.72 |
| S-2016-084 | 10/25/2016 | 10:00 | 68.25 | 2893.75 |
| | 09/20/2017 | 12:15 | 79.55 | 2882.45 |
| S-2016-095 | 12/06/2016 | 10:55 | 47.48 | 2897.52 |
| S-2016-096 | 12/06/2016 | 11:15 | 51.05 | 3205.95 |
| | 12/21/2017 | 09:55 | 58.62 | 3198.38 |
| S-2016-097 | 12/14/2016 | 12:35 | 65.31 | 3578.69 |
| | 10/06/2017 | 09:49 | 65.53 | 3578.47 |
| | 12/21/2017 | 08:52 | 65.56 | 3578.44 |
| S-2016-098 | 12/14/2016 | 13:00 | 152.75 | 2839.25 |
| | 10/06/2017 | 10:04 | 147.34 | 2844.66 |
| | 12/21/2017 | 09:06 | 128.24 | 2863.76 |
| S-2017-004 | 06/26/2017 | 11:15 | 348.30 | 2742.70 |
| | 09/20/2017 | 11:01 | 241.40 | 2849.60 |
| | 12/21/2017 | 11:00 | 265.00 | 2826.00 |

*Table 12 - Manual water level measurement data for the Capitan Reef. DTW = Depth to Water. BGS = Below Ground Surface.*

| Name | Date | Time | DTW [ft BGS] | W-Elev. [ft AMSL] |
|---|---|---|---|---|
| CR-2015-001 | 11/27/2012 | 09:00 | 22.15 | 3043.85 |
| | 06/24/2013 | 09:00 | 23.52 | 3042.48 |
| | 09/09/2013 | 09:00 | 23.52 | 3042.48 |
| | 12/02/2013 | 09:00 | 21.03 | 3044.97 |
| | 03/17/2014 | 09:00 | 22.94 | 3043.06 |
| | 06/30/2014 | 09:00 | 21.96 | 3044.04 |
| | 09/29/2014 | 09:00 | 19.24 | 3046.76 |
| | 12/01/2014 | 09:00 | 19.88 | 3046.12 |
| | 03/26/2015 | 09:00 | 19.84 | 3046.16 |
| | 05/18/2015 | 09:00 | 20.13 | 3045.87 |
| | 09/28/2015 | 09:00 | 18.31 | 3047.69 |
| | 09/28/2015 | 08:30 | 18.13 | 3047.87 |
| | 12/01/2015 | 09:00 | 18.62 | 3047.38 |
| | 12/01/2015 | 09:13 | 18.66 | 3047.34 |
| | 01/13/2016 | 14:07 | 19.08 | 3046.92 |
| | 02/16/2016 | 08:56 | 17.76 | 3048.24 |
| | 03/21/2016 | 09:00 | 18.15 | 3047.85 |
| | 06/29/2016 | 09:00 | 20.10 | 3045.90 |
| | 09/21/2016 | 09:00 | 19.26 | 3046.74 |

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|---|---|---|---|---|
| | 10/18/2016 | 11:50 | 19.27 | 3046.73 |
| | 12/12/2016 | 09:00 | 19.67 | 3046.33 |
| | 03/09/2017 | 08:40 | 20.14 | 3045.86 |
| | 06/12/2017 | 07:30 | 21.03 | 3044.97 |
| | 06/13/2017 | 09:25 | 20.89 | 3045.11 |
| | 10/02/2017 | 10:09 | 20.81 | 3045.19 |
| | 12/14/2017 | 10:42 | 21.24 | 3044.76 |
| CR-2015-002 | 11/27/2012 | 10:00 | 194.75 | 3082.25 |
| | 06/24/2013 | 10:00 | 194.45 | 3082.55 |
| | 09/09/2013 | 10:00 | 194.60 | 3082.40 |
| | 12/02/2013 | 10:00 | 194.10 | 3082.90 |
| | 03/17/2014 | 10:00 | 194.04 | 3082.96 |
| | 06/30/2014 | 10:00 | 193.85 | 3083.15 |
| | 09/29/2014 | 10:00 | 193.84 | 3083.16 |
| | 12/01/2014 | 10:00 | 192.46 | 3084.54 |
| | 03/26/2015 | 10:00 | 191.32 | 3085.68 |
| | 05/18/2015 | 10:00 | 191.17 | 3085.83 |
| | 09/28/2015 | 10:00 | 191.06 | 3085.94 |
| | 09/28/2015 | 09:17 | 191.06 | 3085.94 |
| | 12/01/2015 | 10:30 | 190.15 | 3086.85 |
| | 01/13/2016 | 13:38 | 189.90 | 3087.10 |
| | 02/16/2016 | 11:23 | 189.95 | 3087.05 |
| | 03/21/2016 | 10:00 | 189.45 | 3087.55 |
| | 05/10/2016 | 11:46 | 189.42 | 3087.58 |
| | 06/29/2016 | 10:00 | 189.80 | 3087.20 |
| | 09/05/2016 | 10:40 | 190.60 | 3086.40 |
| | 09/21/2016 | 10:00 | 190.92 | 3086.08 |
| | 10/18/2016 | 13:14 | 190.46 | 3086.54 |
| | 12/12/2016 | 10:00 | 166.85 | 3110.15 |
| | 03/09/2017 | 09:15 | 190.45 | 3086.55 |
| | 06/13/2017 | 09:25 | 191.04 | 3085.96 |
| | 06/13/2017 | 09:49 | 190.99 | 3086.01 |
| | 10/02/2017 | 10:40 | 191.70 | 3085.30 |
| | 12/14/2017 | 11:12 | 191.79 | 3085.21 |
| CR-2015-003 | 11/26/2012 | 11:00 | 91.57 | 3114.43 |
| | 06/24/2013 | 11:00 | 91.80 | 3114.20 |
| | 09/09/2013 | 11:00 | 91.59 | 3114.41 |
| | 12/02/2013 | 11:00 | 89.31 | 3116.69 |
| | 03/17/2014 | 11:00 | 90.97 | 3115.03 |

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|---|---|---|---|---|
| | 06/30/2014 | 11:00 | 89.80 | 3116.20 |
| | 09/29/2014 | 11:00 | 87.54 | 3118.46 |
| | 12/01/2014 | 11:00 | 87.54 | 3118.46 |
| | 03/26/2015 | 11:00 | 87.59 | 3118.41 |
| | 05/18/2015 | 11:00 | 87.94 | 3118.06 |
| | 09/28/2015 | 11:00 | 86.53 | 3119.47 |
| | 09/28/2015 | 10:10 | 86.54 | 3119.46 |
| | 12/01/2015 | 11:00 | 86.22 | 3119.78 |
| | 12/01/2015 | 12:51 | 86.19 | 3119.81 |
| | 01/13/2016 | 12:47 | 86.81 | 3119.19 |
| | 02/16/2016 | 12:56 | 86.02 | 3119.98 |
| | 03/21/2016 | 11:00 | 85.70 | 3120.30 |
| | 05/10/2016 | 09:18 | 86.46 | 3119.54 |
| | 06/29/2016 | 11:00 | 87.63 | 3118.37 |
| | 09/21/2016 | 11:00 | 87.10 | 3118.90 |
| | 10/21/2016 | 09:19 | 87.30 | 3118.70 |
| | 12/12/2016 | 11:00 | 87.25 | 3118.75 |
| | 03/09/2017 | 10:00 | 87.71 | 3118.29 |
| | 06/12/2017 | 09:25 | 88.36 | 3117.64 |
| CR-2015-004 | 11/27/2012 | 12:00 | 804.26 | 2924.74 |
| | 06/24/2013 | 12:00 | 798.30 | 2930.70 |
| | 09/09/2013 | 12:00 | 795.63 | 2933.37 |
| | 12/02/2013 | 12:00 | 794.47 | 2934.53 |
| | 03/17/2014 | 12:00 | 793.54 | 2935.46 |
| | 06/30/2014 | 12:00 | 788.44 | 2940.56 |
| | 09/29/2014 | 12:00 | 789.06 | 2939.94 |
| | 12/01/2014 | 12:00 | 787.57 | 2941.43 |
| | 03/26/2015 | 12:00 | 785.16 | 2943.84 |
| | 05/18/2015 | 12:00 | 783.57 | 2945.43 |
| | 09/28/2015 | 12:00 | 777.91 | 2951.09 |
| | 09/28/2015 | 11:24 | 777.91 | 2951.09 |
| | 12/01/2015 | 12:00 | 776.12 | 2952.88 |
| | 12/22/2015 | 13:30 | 777.26 | 2951.74 |
| | 01/13/2016 | 11:24 | 776.04 | 2952.96 |
| | 02/17/2016 | 10:10 | 777.52 | 2951.48 |
| | 03/21/2016 | 12:00 | 774.03 | 2954.97 |
| | 06/29/2016 | 12:00 | 775.92 | 2953.08 |
| | 09/21/2016 | 12:00 | 774.99 | 2954.01 |
| | 10/21/2016 | 10:40 | 775.60 | 2953.40 |

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|---|---|---|---|---|
| | 12/12/2016 | 12:00 | 774.41 | 2954.59 |
| | 03/09/2017 | 10:30 | 768.18 | 2960.82 |
| | 06/12/2017 | 10:35 | 763.54 | 2965.46 |
| | 06/16/2017 | 11:00 | 763.57 | 2965.43 |
| | 09/19/2017 | 08:47 | 761.62 | 2967.38 |
| | 12/20/2017 | 09:43 | 756.46 | 2972.54 |
| CR-2015-005 | 11/29/2012 | 12:00 | 536.09 | 2848.91 |
| | 06/24/2013 | 12:00 | 529.82 | 2855.18 |
| | 09/09/2013 | 12:00 | 527.73 | 2857.27 |
| | 12/02/2013 | 12:00 | 526.05 | 2858.95 |
| | 03/17/2014 | 12:00 | 525.52 | 2859.48 |
| | 06/30/2014 | 12:00 | 520.42 | 2864.58 |
| | 09/29/2014 | 12:00 | 520.81 | 2864.19 |
| | 12/01/2014 | 12:00 | 519.81 | 2865.19 |
| | 03/27/2015 | 12:00 | 517.51 | 2867.49 |
| | 05/18/2015 | 12:00 | 515.97 | 2869.03 |
| | 09/28/2015 | 12:00 | 510.56 | 2874.44 |
| | 09/28/2015 | 11:24 | 510.56 | 2874.44 |
| | 12/02/2015 | 12:00 | 509.01 | 2875.99 |
| | 12/22/2015 | 09:21 | 508.53 | 2876.47 |
| | 01/13/2016 | 10:16 | 508.68 | 2876.32 |
| | 03/21/2016 | 12:00 | 509.91 | 2875.09 |
| | 06/29/2016 | 12:00 | 508.99 | 2876.01 |
| | 09/21/2016 | 12:00 | 506.50 | 2878.50 |
| | 10/21/2016 | 11:50 | 508.14 | 2876.86 |
| | 12/12/2016 | 12:00 | 503.34 | 2881.66 |
| | 03/09/2017 | 12:45 | 499.45 | 2885.55 |
| | 06/12/2017 | 11:55 | 495.72 | 2889.28 |
| | 06/16/2017 | 09:45 | 487.52 | 2897.48 |
| | 09/19/2017 | 09:51 | 494.50 | 2890.50 |
| | 12/20/2017 | 10:41 | 491.71 | 2893.29 |
| CR-2015-006 | 11/29/2012 | 12:00 | 1093.86 | 2675.14 |
| | 06/25/2013 | 12:00 | 1043.25 | 2725.75 |
| | 09/10/2013 | 12:00 | 1051.89 | 2717.11 |
| | 12/03/2013 | 12:00 | 1051.38 | 2717.62 |
| | 03/18/2014 | 12:00 | 1050.88 | 2718.12 |
| | 07/01/2014 | 12:00 | 1048.38 | 2720.62 |
| | 09/30/2014 | 12:00 | 1049.36 | 2719.64 |
| | 12/02/2014 | 12:00 | 1048.92 | 2720.08 |

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|---|---|---|---|---|
| | 03/27/2015 | 12:00 | 1048.31 | 2720.69 |
| | 05/19/2015 | 12:00 | 1048.02 | 2720.98 |
| | 09/29/2015 | 12:00 | 1047.56 | 2721.44 |
| | 09/29/2015 | 10:14 | 1047.56 | 2721.44 |
| | 12/02/2015 | 12:00 | 1047.07 | 2721.93 |
| | 02/16/2016 | 10:15 | 1046.77 | 2722.23 |
| | 03/22/2016 | 12:00 | 1046.59 | 2722.41 |
| | 06/30/2016 | 12:00 | 1046.02 | 2722.98 |
| | 09/22/2016 | 12:00 | 1045.66 | 2723.34 |
| | 12/13/2016 | 12:00 | 1045.30 | 2723.70 |
| | 03/10/2017 | 11:35 | 1044.75 | 2724.25 |
| | 06/13/2017 | 11:45 | 1044.15 | 2724.85 |
| CR-2015-007 | 11/29/2012 | 12:00 | 400.38 | 2580.62 |
| | 06/25/2013 | 12:00 | 396.16 | 2584.84 |
| | 09/10/2013 | 12:00 | 395.55 | 2585.45 |
| | 12/03/2013 | 12:00 | 394.58 | 2586.42 |
| | 03/18/2014 | 12:00 | 395.48 | 2585.52 |
| | 07/01/2014 | 12:00 | 392.84 | 2588.16 |
| | 09/30/2014 | 12:00 | 390.22 | 2590.78 |
| | 12/02/2014 | 12:00 | 389.30 | 2591.70 |
| | 03/27/2015 | 12:00 | 386.86 | 2594.14 |
| | 05/19/2015 | 12:00 | 384.66 | 2596.34 |
| | 09/29/2015 | 12:00 | 380.93 | 2600.07 |
| | 09/29/2015 | 11:41 | 380.93 | 2600.07 |
| | 12/02/2015 | 12:00 | 380.37 | 2600.63 |
| | 02/17/2016 | 14:35 | 381.69 | 2599.31 |
| | 03/22/2016 | 12:00 | 381.84 | 2599.16 |
| | 06/30/2016 | 12:00 | 367.69 | 2613.31 |
| | 09/22/2016 | 12:00 | 379.10 | 2601.90 |
| | 12/13/2016 | 12:00 | 377.00 | 2604.00 |
| | 06/13/2017 | 13:50 | 368.99 | 2612.01 |
| CR-2016-001 | 03/22/2016 | 10:10 | 590.44 | 2891.56 |
| | 03/22/2016 | 12:00 | 589.93 | 2892.07 |
| | 06/30/2016 | 12:00 | 591.17 | 2890.83 |
| | 09/22/2016 | 12:00 | 589.71 | 2892.29 |
| | 12/13/2016 | 12:00 | 585.85 | 2896.15 |
| | 03/10/2017 | 10:35 | 582.30 | 2899.70 |
| | 06/13/2017 | 10:45 | 579.42 | 2902.58 |
| CR-2016-002 | 03/22/2016 | 10:52 | 585.82 | 2883.18 |

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|---|---|---|---|---|
| | 03/22/2016 | 12:00 | 585.57 | 2883.43 |
| | 06/30/2016 | 12:00 | 586.14 | 2882.86 |
| | 09/22/2016 | 12:00 | 583.94 | 2885.06 |
| | 12/13/2016 | 12:00 | 579.73 | 2889.27 |
| | 03/10/2017 | 10:50 | 575.72 | 2893.28 |
| | 06/13/2017 | 11:05 | 572.26 | 2896.74 |

## 4.4. Water Chemistry

One of the primary drivers for water quality sampling was to establish a baseline of water chemistry in the HPA's. The analyses were completed to better understand the variability of water quality, which ranges from fresh to very saline. In addition, baseline water quality data can be used to flag potential future contamination that is more likely with increased drilling activities that involve drilling through the aquifers.

For characterization purposes, water samples were collected from wells accessed either through existing downhole pumps and equipment or by utilizing a passive discrete-depth bailer method referred to as a "Snap-Sampler". The samples were typically analyzed for cations, anions, pH, and electrical conductance, and a smaller subset of wells were also analyzed for basic metals. Since most of the wells accessed and sampled were constructed as water wells and are open to multiple water-bearing or hydrostratigraphic units, the water quality data cannot definitively determine the completion units. However, the contributing formations can be surmised based on depth of well and water quality. Due to the very large spatial extents of the HPA's and the varied and complex geology across the areas, the geologic units being intercepted by the wells were not always determined.

### *4.4.1. General Water Quality in the Area*

Groundwater quality in Eddy and Lea Counties and in the Lower Pecos Valley varies considerably depending on the aquifer and location. In general, groundwater on the west side of the Pecos River is fresher than east of the Pecos River (NMOSE 2016). East of the Pecos River, salinity is higher and can reach concentrations of 35,000 milligrams per Liter (mg/L). Shallow groundwater quality can be very good in the alluvial aquifers, but of poor quality in deeper geologic formations due to the presence of salt, gypsum, and other evaporite deposits. Groundwater tends to be mineralized or 'hard' in the eastern portion of the HPA's, west of the Ogallala aquifer, which is an area that was not included in this study. Typical ranges of total dissolved solids (TDS) along with the general aquifer materials are shown in Table 13.

### *4.4.2. WIPP Water Quality*

Characterization of the WIPP site began in 1972 and consisted of drilling boreholes and to investigate and understand the hydrogeology over- and under-lying the proposed waste repository. Approximately 120 boreholes have been drilled at the WIPP site since the selection process was initiated and for continued compliance and characterization monitoring. Per the Strategic Plan for Groundwater Monitoring at the WIPP, the ground surface elevation in the vicinity of WIPP ranges from approximately 950 to 1,125 meters AMSL (DOE 2003). The ground surface is higher to the east and north of the WIPP boundary and lower to the west and south towards Nash Draw. The boreholes drilled at the WIPP site have ranged in total depth from approximately 55 feet below ground surface (bgs) to over 4500 feet bgs (DOE 2003). The units of interest at the WIPP have primarily consisted of the Dewey Lake Formation, the Rustler Formation, the upper Salado Formation, and the deeper Bell Canyon and Castile Formations. The water quality in wells at the WIPP site is generally fresher to the west near Nash Draw and more saline to the east. In the compliance wells at the WIPP site, which consist of WQSP-1 through WQSP-6, the water type is considered sodium-chloride (Na-Cl) and consists of higher chlorides and sodium and potassium, and lower sulfate and calcium.

*Table 13 - Typical TDS ranges found in the region's main aquifers.*

| Aquifers in HPAs | Aquifer Material | Typical TDS Range (mg/L) |
|---|---|---|
| Pecos | Alluvium | <200 to 10,000[2] |
| Rustler (includes Culebra and Magenta) | Carbonates and Evaporites | <1,000 to 4,600[1] |
| Dockum (includes Dewey Lake and Santa Rosa) | Sandstone and Conglomerates | <5,000 to >10,000 [3] |
| Capitan Reef | Dolomite and Limestone | 300 to >5,000 [4] |

[1] http://www.twdb.texas.gov/groundwater/aquifer/minors/rustler.asp

[2] http://www.twdb.texas.gov/publications/reports/numbered_reports/doc/R382_PecosValley.pdf

[3] http://www.twdb.texas.gov/publications/reports/numbered_reports/doc/R359/Report%20359%20Dockum%20Final.pdf

[4] http://www.twdb.texas.gov/groundwater/aquifer/minors/capitan-reef-complex.asp

### 4.4.3. Sampling method and Analyses Performed

In general, wells were chosen for monitoring and sampling based on location and accessibility. Water quality samples were collected either through existing pump or well equipment or using a Snap Sampler device. The Snap Sampler is a discrete depth bailer that is deployed downhole with open sample bottles, and then is triggered from the surface to close the bottles when the device is at the desired depth. Approximately 13% of the water samples were collected using the Snap Sampler or other bailer device and approximately 87% were collected utilizing existing well equipment.

Samples were analyzed by either Hall Environmental Analysis Laboratories (HEAL), SNL, or both. Water quality samples were analyzed for cation-anion balance and the other constituents listed in Table 14.

The metals analyses were performed by SNL and while SNL is not a drinking water 'qualified' laboratory, their standard operating procedures and quality control procedures are accepted under strict guidelines set by the Department of Energy. HEAL is certified in drinking water chemical and drinking water microbiological analyses by the State of New Mexico Environment

Department. There was excellent agreement between samples that were analyzed by both HEAL and SNL.

*Table 14 - List of constituents analyzed in the water quality samples.*

| Constituents Measured in All Samples | | Metals Measured in Some Samples | |
|---|---|---|---|
| pH | Chloride ($Cl^-$) | Aluminum (Al) | Lithium (Li) |
| Specific Conductance | Bicarbonate ($HCO_3^-$) | Arsenic (As) | Manganese (Mn) |
| Total Dissolved Solids | Carbonate ($CO_3^-$) | Barium (Ba) | Nickel (Ni) |
| Calcium ($Ca2^+$) | Sulfate ($SO_4^{2-}$) | Bromide ($Br^-$) | Silver (Ag) |
| Magnesium ($Mg2^+$) | Fluoride ($F^-$) | Cadmium (Cd) | Silicon (Si) |
| Sodium ($Na^+$) | Nitrate ($NO_3^-$) | Chromium (Cr) | Strontium (Sr) |
| Potassium ($K^+$) | Nitrite ($NO_2^-$) | Copper (Cu) | Uranium (U) |
| | | Iron (Fe) | Vanadium (V) |
| | | Lead (Pb) | |

### 4.4.4. Water Quality in the HPAs

A summary of the wells accessed and sampled is provided in Table 15 below for the North, Center North, and South HPAs, and for wells completed in the Capitan Reef.

*Table 15 – Number and percentage of wells sampled in each HPA. The number of sampled wells in the south includes the WIPP wells.*

| | North Wells | Center North Wells | South Wells | Capitan Reef |
|---|---|---|---|---|
| **Total Number of Wells** | 127 | 60 | 158 | 9 |
| **# of Wells Sampled** | 19 | 11 | 42 | 5 |
| **% of Wells Sampled** | 15% | 18% | 27% | 56% |

Of the sampled wells, the known and unknown hydrostratigraphic units are summarized below.

*Table 16 – Number of wells sampled in each formation by HPA. Does not include the WIPP wells.*

| | Rustler | Santa Rosa/ Dewey Lake | Capitan | Other/ Unknown |
|---|---|---|---|---|
| **North** | 4 | 0 | 0 | 15 |
| **Center North** | 4 | 1 | 0 | 6 |
| **South** | 9 | 3 | 0 | 30 |
| **Capitan Reef** | 0 | 0 | 5 | 0 |

Analysis of the field data, water chemistry, and cross-sections suggest that the primary hydrostratigraphic unit(s) intercepted by wells in the North HPA is the Dockum (mainly SR/DL), in the Center-North HPA are the SR/DL and Rustler Formations, and in the South HPA are the SR/DL Formation.

AquaChem (AquaChem 2018) was utilized to analyze the water types of the sampled groundwater. Based on the cation-anion balance results in the samples collected, the predominant water types for each of the HPA's and the Capitan Reef are listed below and shown in Figures 37 and 38.

- North – calcium and magnesium dominant
- Center-North – sodium and calcium dominant
- South – sodium and calcium dominant
- WIPP – sodium and chloride dominant
- Capitan Reef – sodium dominant

Although there are outliers, the Box and Whisker, Schoeller, and Piper diagrams (Figures 39 to 45) below depict the general water types listed above for each HPA. Figures 39 to 41 depict the data by known formation while Figures 42 to 45 categorize the data by HPA. The water chemistry data in table form are shown in Appendix A.

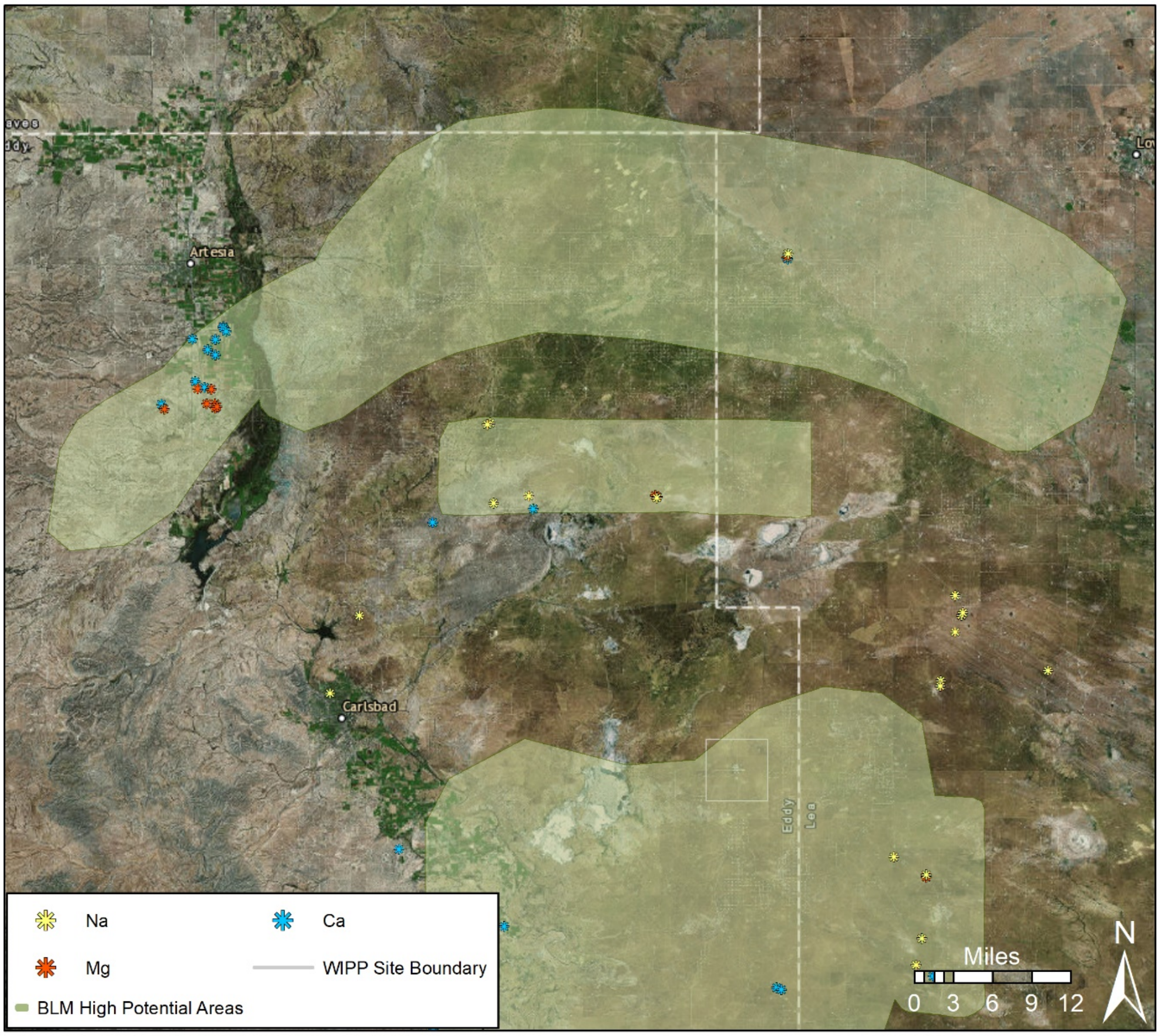


*Figure 37 - Plot of sampled wells showing predominant water types for the North and North Central HPA's.*

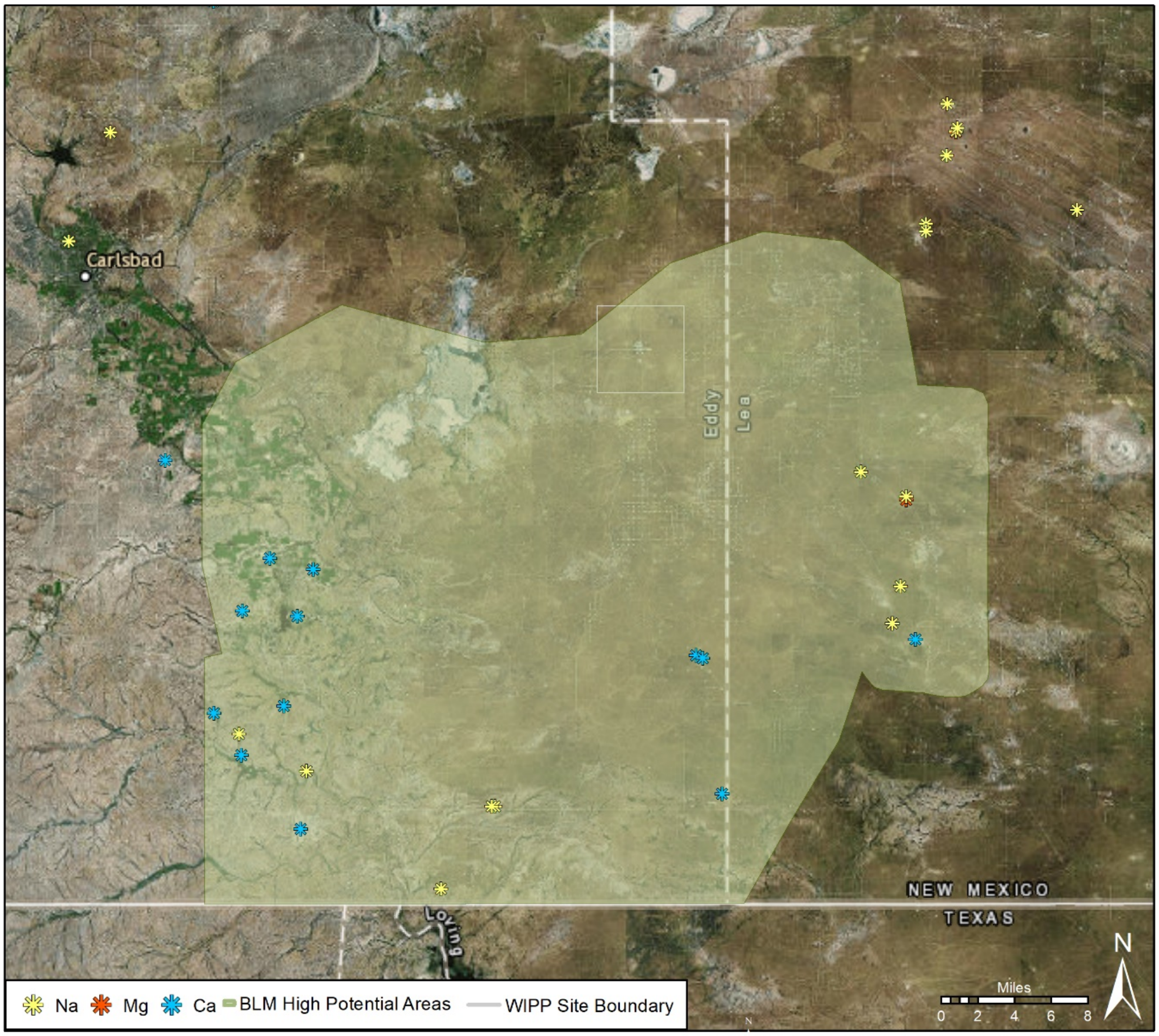


*Figure 38 - Plot of sampled wells showing predominant water type in the South HPA.*

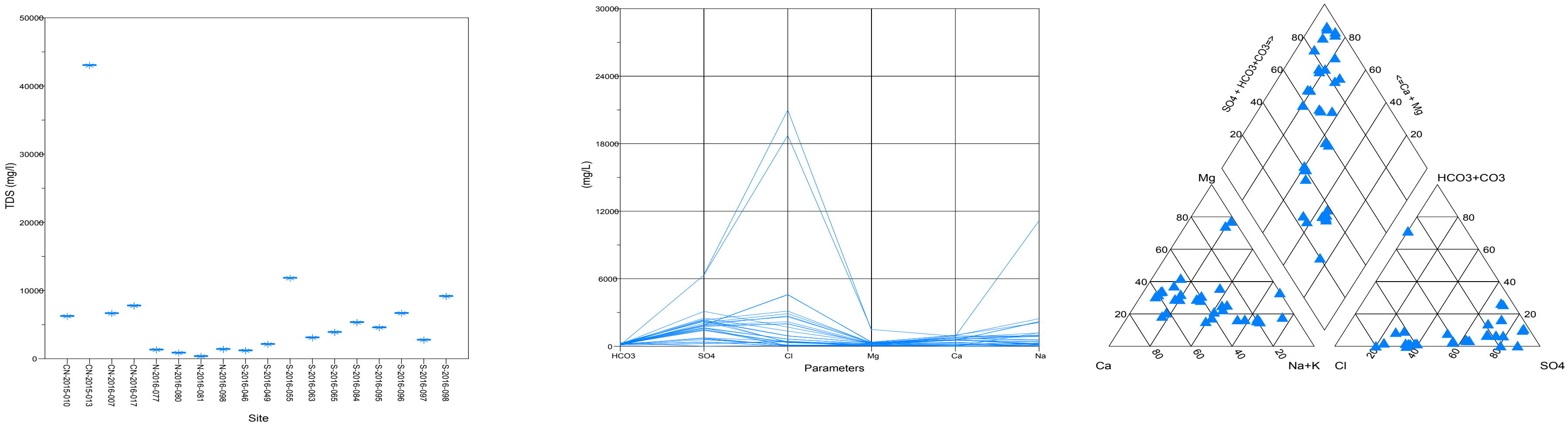


*Figure 39 - Box and Whisker, Schoeller, and Piper diagrams for wells sampled in the Rustler Formation.*

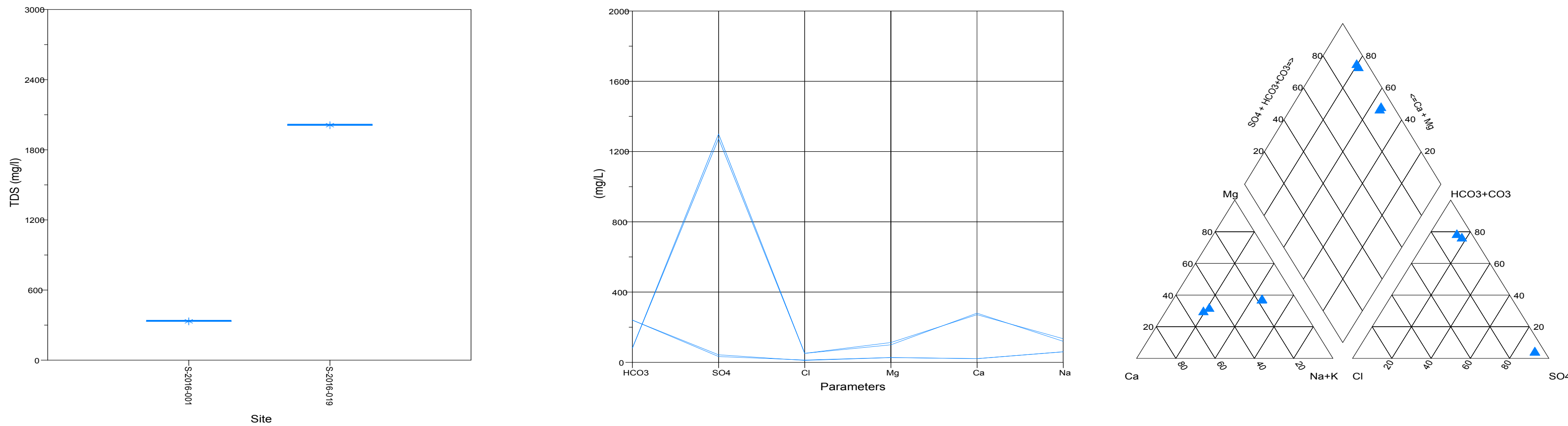


*Figure 40 - Box and Whisker, Schoeller, and Piper diagrams for wells sampled in the Santa Rosa and Dewey Lake Formations.*

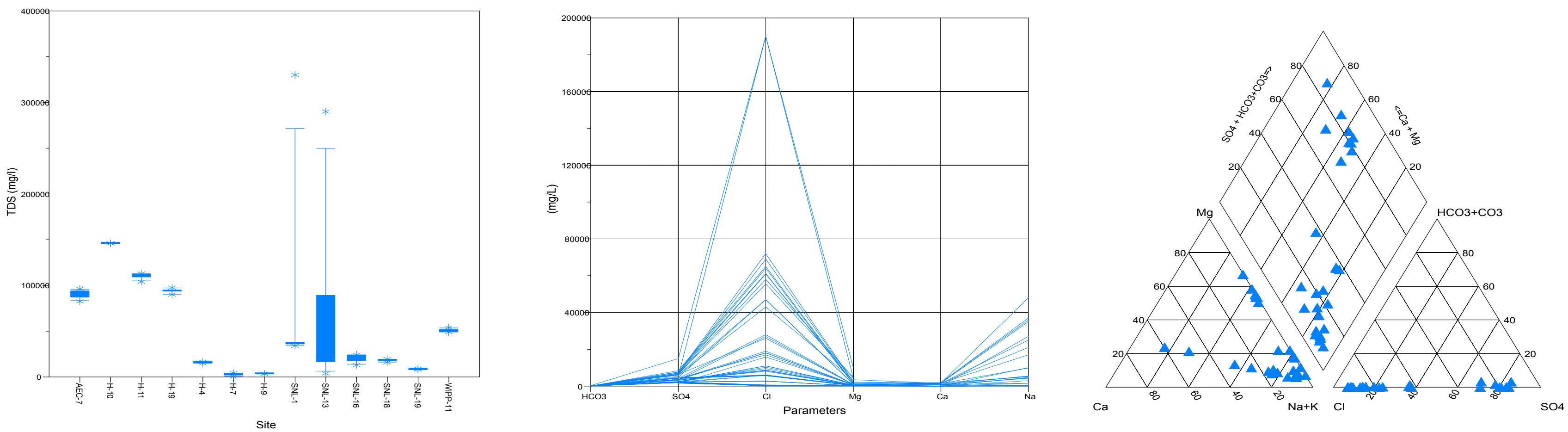


*Figure 41 - Box and Whisker, Schoeller, and Piper diagrams for the WIPP wells in the Culebra Formation.*

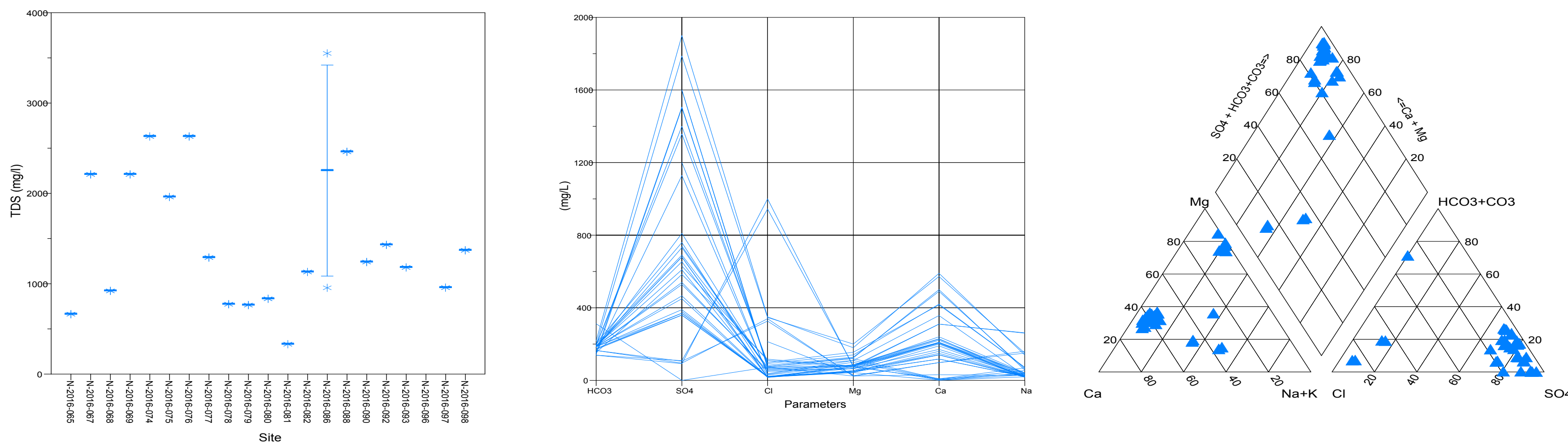


*Figure 42 - Box and Whisker, Schoeller, and Piper diagrams for wells sampled in the North HPA.*

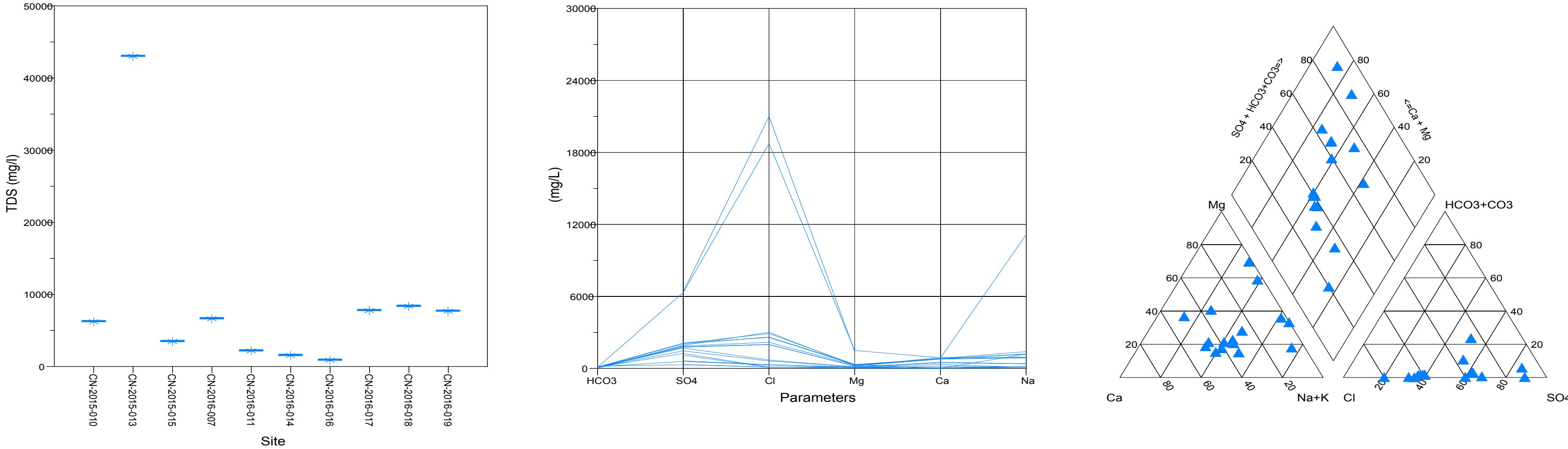


*Figure 43 - Box and Whisker, Schoeller, and Piper diagrams for wells sampled in the Center North HPA.*

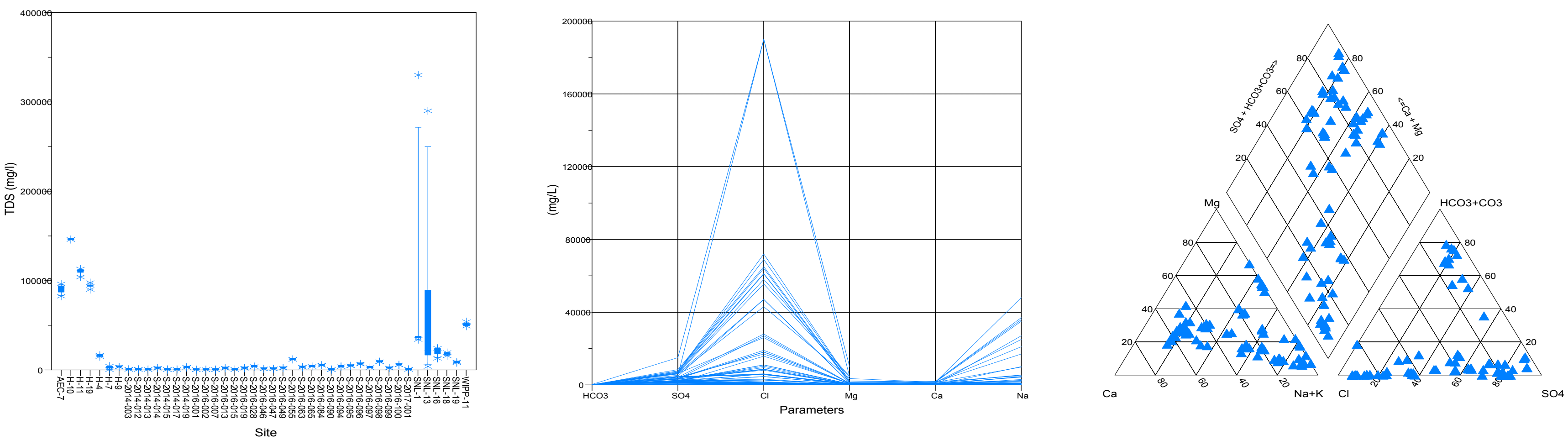


*Figure 44 - Box and Whisker, Schoeller, and Piper diagrams for wells sampled in the South HPA.*

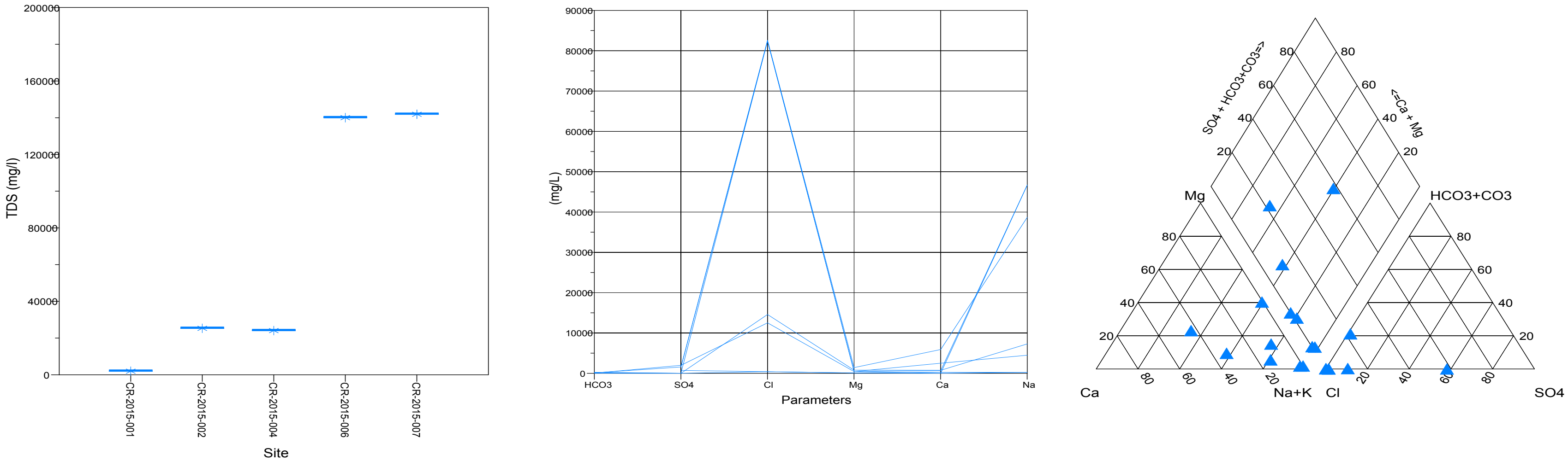


*Figure 45 - Box and Whisker, Schoeller, and Piper diagrams for wells sampled in the Capitan Reef.*

### 4.4.5. Water Quality Compared to Standards

To better understand the relative quality of the samples, they were compared to the New Mexico Water Quality Control Commission (NMWQCC) human health, domestic water supply, and irrigation use standards for groundwater with a TDS concentration of 10,000 mg/L or less (20.6.2.3103 NMAC). Observations related to the comparison of results to the standards are:

- Seventeen of the water quality parameters analyzed have applicable NMWQCC standards, including pH, TDS, $Cl^-$, $SO_4^{2-}$, $F^-$, $NO^{3-}$+ $NO^{2-}$, Ag, Al, As, Ba, Cd, Cr, Cu, Fe, Mn, Ni, Pb
- No exceedances were observed for eight of the parameters with NMWQCC standards, including pH, Ag, Al, Ba, Cd, Cr, Cu, and Ni

Table 16 compares the NMWGCC drinking water standards to the measured values.

*Table 17 – Listing of the sampled water quality parameters by HPA against the New Mexico Water Quality Control Commission standard for drinking water. Units are milligrams per liter (mg/L) unless otherwise noted.*

| | NMWQCC Standard | Range of Results | | | |
|---|---|---|---|---|---|
| | | North HPA | Central North HPA | South HPA (with WIPP) | Capitan Reef |
| pH (pH units) | 6 to 9 | 7.07 - 7.97 | 7.53 - 7.97 | 6.18 - 8.59 | 8.08 - 8.86 |
| Specific Conductance (µmhos/cm) | -- | 1000 - 3905 | 1300 - 83000 | 600 - 270000 | 2770 - 174500 |
| Total Dissolved Solids (TDS) | 1000 | 331 - 3550 | 869 - 43000 | 322 - 330000 | 1951 - 141875 |
| Calcium ($Ca^{2+}$) | -- | 0.73 - 590 | 2.6 - 920 | 0.7 - 1900 | 1.4 - 5902 |
| Magnesium ($Mg^{2+}$) | -- | 23 - 200 | 44 - 1492 | 2.10 - 10000 | 82.26 - 1420 |
| Sodium ($Na^+$) | -- | 18 - 262 | 92.58 - 12000 | 26 - 95000 | 225 - 46700 |
| Potassium ($K^+$) | -- | 0 - 30 | 4 - 1136 | 0 - 21000 | 6.58 - 3352 |
| Chloride ($Cl^-$) | 250 | 16 - 1000 | 97 - 21000 | 11 - 190000 | 388.80 - 82602.1 |
| Alkalinity (CaCO3) | -- | 139 - 312 | 19.9 - 181.2 | 23 - 297.10 | 18.53 - 250.10 |
| Bicarbonate ($HCO3^-$) | -- | 139 - 312 | 19.8 - 181.2 | 39.72 - 297.10 | 18.74 - 249.27 |
| Carbonate ($CO3^-$) | -- | 0 - <2 | 0 - <2 | 0 - 16.08 | 0 - 0.83 |
| Sulfate ($SO_4^{2-}$) | 600 | 0 - 1900 | 306.71 - 6400 | 0 - 15000 | 0 - 1975.67 |
| Fluoride ($F^-$) | 1.6 | 0 - 1.3 | 0.82 - 2.60 | 0.00 - 3.63 | 0.09 - 0.52 |
| Nitrite (NO2) | 10 | 0 - 6.27 | 0 - 8.8 | 0.00 - 20.08 | 0.05 - 7.60 |
| Nitrate (NO3) | | 0 - 10 | 2.6 - 8.8 | 0 - 19 | 0.04 - 7.60 |
| Silver (Ag) | 0.05 | -- | -- | -- | 0 - 0.04 |

| | NMWQCC Standard | Range of Results | | | |
|---|---|---|---|---|---|
| | | North HPA | Central North HPA | South HPA (with WIPP) | Capitan Reef |
| Aluminum (Al) | 5 | -- | 0.18 | 0 – 4.06 | -- |
| Arsenic (As) | 0.1 | 0.02 – 0.06 | 0.03 - 0.32 | 0 – 0.29 | 0.10 |
| Barium (Ba) | 1 | 0.01 – 0.13 | 0.01 - 0.03 | 0- 0.1 | 0.02 - 0.25 |
| Bromide (Br) | -- | 0 - 7.8 | 0.28 - 12.00 | 0 - 1400 | 0.3 - 12.73 |
| Cadmium (Cd) | 0.01 | -- | -- | -- | -- |
| Copper (Cu) | 1 | 0.02 | 0.03 | 0.06 - 0.37 | -- |
| Iron (Fe) | 1 | 3.34 | 0.04 | 0.01 - 1.62 | 3.41 |
| Lithium (Li) | -- | 0.14 - 1.70 | 0.140 - 1.695 | 0.05 - 0.85 | 0.04 - 4.49 |
| Manganese (Mn) | 0.2 | 0 - 0.06 | 0 - 0.20 | 0 - 0.06 | 0 - 7.61 |
| Nickel (Ni) | 0.2 | -- | 0 - 0.02 | 0 - 0.01 | 0.01 |
| Lead (Pb) | 0.05 | 0.04 | -- | 0.02 - 0.06 | -- |
| Silicon (Si) | -- | 2.67 - 18.38 | 1.9 - 23.4 | 4.91 - 47.0 | 0 - 7.10 |
| Strontium ($Sr^{2+}$) | -- | 0.63 - 8.47 | 2.73 - 13.75 | 0.05 - 32.0 | 2.52 - 104.8 |
| Vanadium (V) | -- | -- | 0.01 - 0.03 | 0 - 0.1 | -- |

Notes:

"—" = not applicable or not detected

Values rounded to two decimal places

# 5. MODELING

## 5.1. Introduction

The Permian Basin Water Availability Model (PB-Water) was constructed as part of this project to look at the regional water balance and to predict potential pinch-points where water sustainability and availability may become a problem. It is built on a system dynamics (SD) platform, which is a modeling approach that emphasizes temporal dynamics over spatial detail. Originally developed for business applications to model complex supply chain inventory problems (Forrester 1971), SD models have been applied to a large range of techno-economic problems, including problems focused on water supply (Tidwell et al. 2004; Lowry et al. 2008; Tidwell et al. 2009; Lowry et al. 2010) and power generation (Lowry et al. 2012). Because they lack spatial detail, SD models are quick to execute, which allows for conducting tradeoff analyses, optimization, and risk assessment.

## 5.2. Conceptual Model

PB-Water allows the user to look at the balances between water demand and water availability to predict and track potential risks to the water supply (Figure 46). It includes the four 'deep' aquifers (Capitan Reef West, Capitan Reef East, Rustler, and Santa Rosa / Dewey Lake) and the alluvial aquifer along the Pecos River from Lake Avalon to its confluence with the Delaware River. As a SD model, PB-Water treats each aquifer as a single unit where the parameters are considered effective parameters that are calibrated to match as closely as possible the dynamic behavior of the historical data (water elevations, stream flows, etc.). The calibration process is discussed in more detail below.

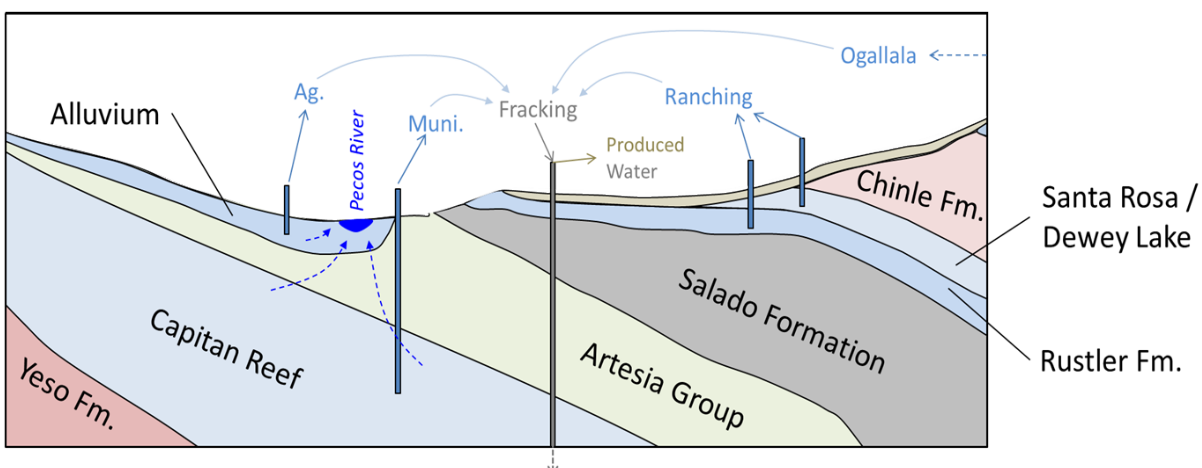


*Figure 46 – Water balances simulated in the PBWater model. Modified from Summers (1972).*

The alluvial aquifer and the Pecos River are broken into three reaches; north, central, and south (Figure 47). The North Reach runs 8.1 miles from the USGS 08404000 gage immediately below Avalon Dam to the USGS 08405200 gage just below Lower Tansill Lake (also known as Carlsbad Municipal Lake). It also includes inflows from Dark Canyon (USGS gage #08405150). The Central Reach stretches from the end of the North Reach, 27.0 miles down to the USGS

08406500 gage (Pecos River at Malaga) and includes inflows from the Black River (USGS gage #08406000). The South Reach is also 27.0 miles and runs from the bottom of the Central Reach to the confluence with the Pecos and Delaware rivers.

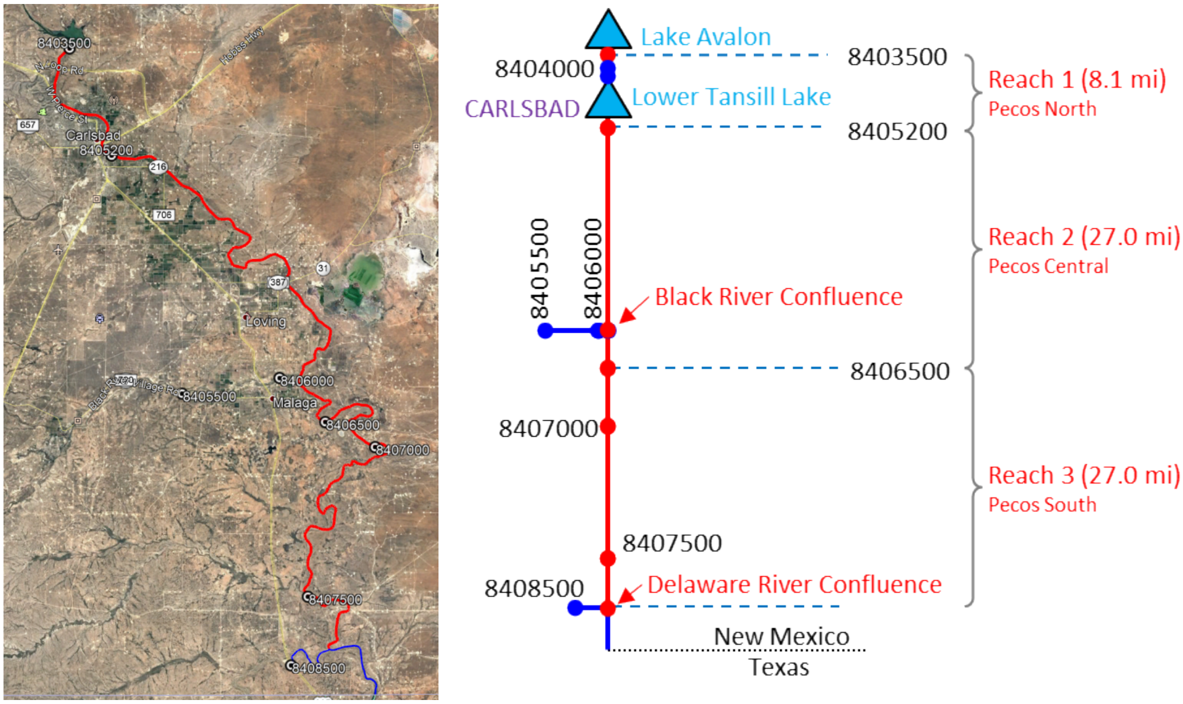


*Figure 47 - Map view and conceptualization of the model domain. The model simulates 62.1 miles along the Pecos River from just below Lake Avalon (gage #8403500) to the confluence with the Delaware River.*

Each reach consists of the appropriate length of river and the adjoining alluvial aquifer. The aquifer delineations, pumping, and recharge rates are obtained from the Carlsbad Groundwater Availability Model (CAGW) report (Barroll et al. 2004, Table 4-3). The river elevation is assumed to be stationary within each reach and is set to the average elevation along the reach.

Water is allowed to move between each river reach and its corresponding alluvial aquifer as a function of the aquifer water elevation and a calibrated conductance term

The Capitan Reef aquifer is split into an east and west portion (CRW and CRE), with the west running from its outcrop area in the Guadalupe Mountains west of Carlsbad to just east of the Pecos River. The CRE is not dynamically modeled and is included in the model as a fixed head boundary condition connected to the CRW. The CRW receives natural recharge along the outcrop area in the Guadalupe Mountains as well as from leakage from Lake Avalon. The historical recharge, leakage, and extraction rates (pumping) are taken from Figure 2-20 in the CAGW report (Barroll et al. 2004, page 36). Discharge from the CRW is through the Carlsbad Springs as a function of the head in the CRW and a calibrated conductance value. While the CRE is assumed static, there are placeholders in the model for recharge and pumping rates to and from the CRE to allow for future development of the model to include variable head in the CRE.

The Rustler aquifer in the model represents both the Culebra and Magenta members as a single, transmissive unit. Its extent is the same as represented in the WIPP regional groundwater flow model (Corbet et al. 1996). Following the conceptualization in the regional model, the Rustler aquifer is assumed to recharge along Nash Draw and discharge to the Pecos River along the length of the South Reach. Discharge to the Pecos is controlled by the head level in the Rustler and a conductance term that is calibrated to produce an average discharge over time of 1.94 cfs. The recharge rate to the Rustler is the area averaged value used in the WIPP regional model.

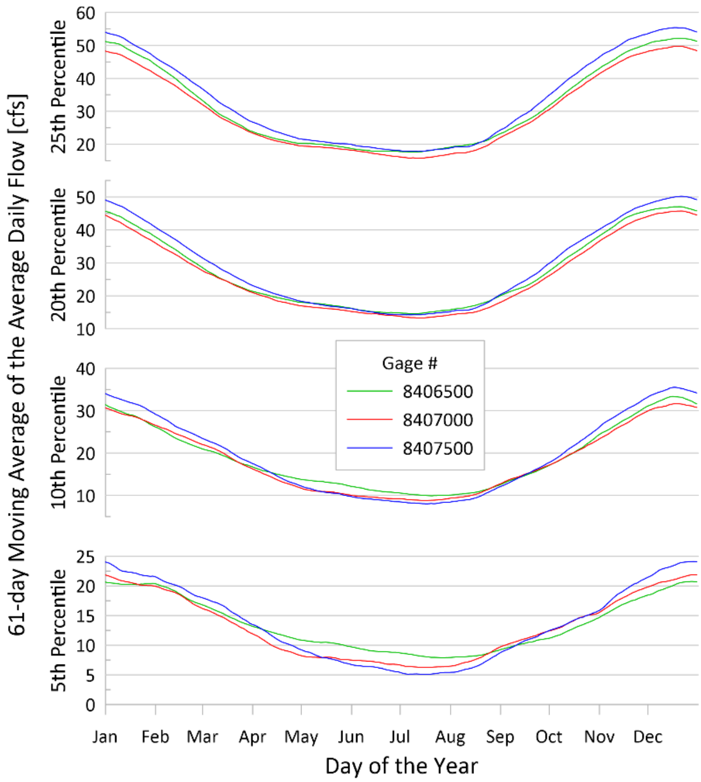


*Figure 48 - Plots of the 61 day moving average for each percentile at each gage.*

The 1.94 cfs average discharge rate for flow from the Rustler into the South Reach is calculated by comparing the historical flow rates between USGS gages #08406500 (Pecos River near Malaga - 6500), #08407000 (Pecos River at Pierce Canyon Crossing - 7000), and #08407500 (Pecos River at Red Bluff – 7500). Gage 6500 is at the top of the South Reach, gage 7000 is 6.5 river miles below that, and gage 7500 is another 14.8 river miles below that. The calculation begins by taking the 61 day moving average of the USGS calculated 5$^{th}$, 10$^{th}$, 20$^{th}$, and 25$^{th}$ percentiles of the average daily flow for each gage (Figure 48). The daily differences between gages 6500 and 7000, 7000 and 7500, and 6500 and 7500 are taken and then averaged for the year. For all percentiles, the span between the 6500 and 7000 gages is losing water to the aquifer, the span between the 7000 and 7500 gage is gaining water, and the net flow between gages 6500 to 7500 is also gaining. To weight the aquifer inflow along the entire length of the reach, we normalize the flow differences using the length of each span and then assume that the normalized differences vary linearly with distance and thus represent the arithmetic average of the inflows at the corresponding gage locations (Figure 49). Assuming also that the inflow rate has an upper limit, the normalized inflow along the 5.7 mile span below gage 7500 is assumed to be the same as that at the 7500 gage. The normalized flow rates are multiplied by the length of each span to get the total inflow along the reach. The average across each percentile returns the 1.94 cfs value used in the calibration.

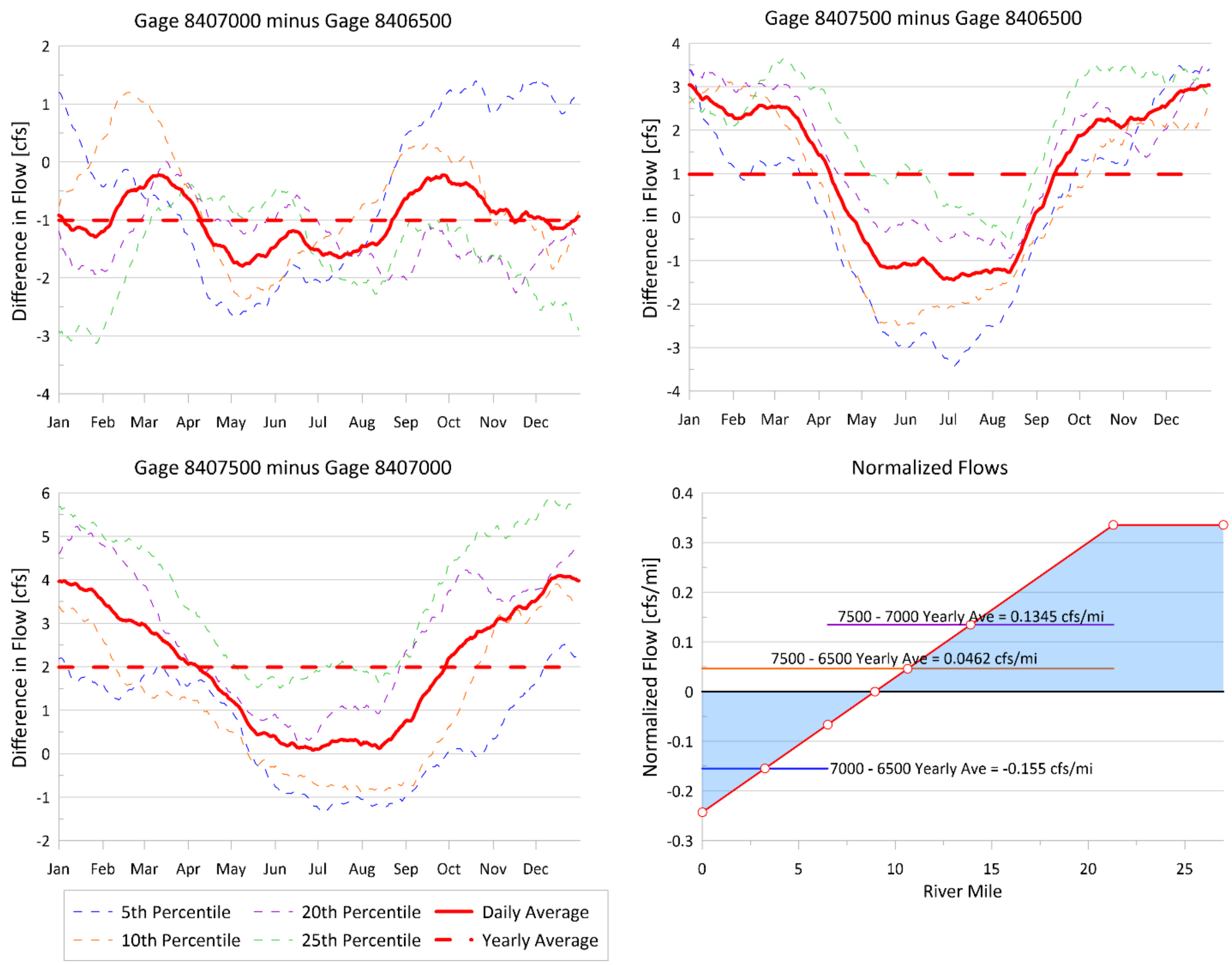


*Figure 49 – Upper plots and lower left: Differences in the 61-day moving average flows between the three gages. Lower right: Interpolation of normalized flow along Reach 3 of the PBWater model. The blue areas in the lower right plot represent the integration of the normalized flows into and out of the Pecos, which sums to 1.94 cfs.*

The Santa Rosa / Dewey Lake (SR/DL) aquifer is treated as an isolated aquifer in that it has no interaction with surface water (other than recharge) or with any of the other aquifers. The aquifer dimensions, transmissivity, recharge rates, and other relevant parameters are taken from an updated, but unpublished version of the regional groundwater flow model developed by (Corbet et al. 1996) as well as from the SR/DL groundwater model developed in Lowry et al. (2015). Initial pumping rates are set equal to the recharge rate to maintain a long-term steady-state water level in the system.

## 5.3. Numerical Model

SD models are constructed by linking a series of first-order, linear differential equations that describe time-dependent changes in a given commodity over time. Interactions within the model are represented by stocks and flows, where stocks describe the storage and accumulation of the commodity over time and the flows represent stresses on the system that cause the commodity to flow into or out of the stock. For PBWater, the commodity is water, with each aquifer acting as its own stock. Flows consist of the recharge rates into the system, pumping rates out of the system, flows to and from surface water (for the North, Central, and South alluvial aquifers and the Pecos River, the CRW and Carlsbad Springs, and the South Central Pecos and the Rustler), and flows between aquifers (the CRW and CRE). The governing equation for this is represented by:

$$\frac{\partial S}{\partial t} = Q_r - Q_p + Q_{sw} + Q_{gw} \tag{1}$$

where $\frac{\partial S}{\partial t}$ represents the changes in storage over time, $Q_r$ is recharge inflow, $Q_p$ is outflow from pumping, $Q_{sw}$ is flow to or from surface water, and $Q_{gw}$ is flow to or from other groundwater sources (aquifers). Note that $Q_{sw}$ and $Q_{gw}$ can be positive or negative (positive indicating flow into the aquifer). All units are $L^3/t$.

With the exception of the Central Pecos, recharge is from rainfall percolation to the aquifer and is specified in the model as a user defined time series. The Central Pecos also includes recharge from irrigation canals and farm runoff. Likewise, pumping rates are represented as user defined time series.

Interactions between surface and groundwater are represented using a Darcy flow equation as:

$$Q_{sw} = (H - SWE)C_{sw} \tag{2}$$

where $H$ [L] is the head in the aquifer, $SWE$ [L] is the surface water elevation (constant), and $C_{sw}$ [$L^2/t$] is a conductance term that is a function of the contact area between the aquifer and the surface water body as well as the hydraulic conductivity of the sediments in the river. Flow is limited to a maximum value for cases where the head in the aquifer drops below the bottom of the river sediments (i.e., when there is an unsaturated zone between the river and the aquifer). In all cases, the surface water elevation is held constant and is assumed to be three feet deep on average. The sediment thickness is set at 10 feet, the same as used in the CAGW model (Barroll et al. 2004).

Flow between the CRW and the CRE uses the same form as equation (2) but with the conductance term split into its components:

$$Q_{gw} = \frac{(H_{crw} - H_{cre})KbW}{L} \tag{3}$$

where $H_{crw}$ [L] is the calculated head in the CRW, $H_{cre}$ [L] is the head in the CRE (constant at 3080 ft), $K$ [L/t] is the effective conductivity between the two aquifers, $b$ [L] is the saturated thickness of the CRW, $W$ [L] is the width of the CRW, and $L$ [L] is a characteristic length that represents the distance between the CRW and the CRE. Splitting the conductance term into its separate components allows the conductance to change with time as a function of the changing saturated thickness of the CRW.

The aquifers in the model are represented by stocks that reflect the volume of water in each aquifer. The head in each aquifer is calculated as a function of the aquifer volume and storage coefficient (or the specific yield for the alluvial aquifers). As mentioned above, the storage values are estimated from the literature and within the model, control the rate at which the head rises and falls over time (Figure 50). Mathematically, the head calculation is:

$$H = \frac{V}{AS} + E_b \tag{4}$$

where $V$ [L$^3$] is the volume of water in the aquifer, A [L$^2$] is the aquifer area, $S$ [unitless] is the storage term, and $E_b$ [L] is the bottom elevation of the aquifer. Because equations (2) and (3) only require the aquifer head and not the saturated thickness, the bottom elevation, $E_b$, is set to an arbitrarily low value that prevents the aquifer from going dry in extreme cases.

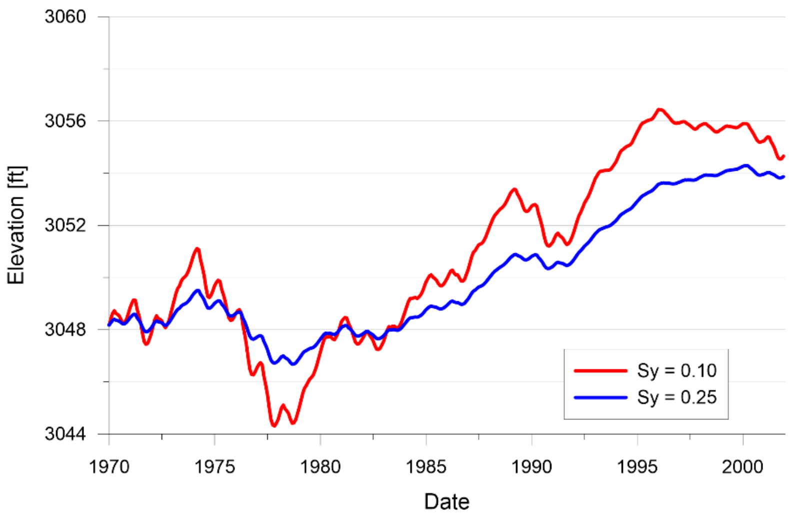


*Figure 50 - Example of the storage value influence on the rate of change and amplitude of head in the Central Pecos alluvial aquifer. In this case, the storage value is represented by the specific yield ($S_y$).*

### 5.3.1. Localized Impacts

Localized impacts are modeled using the well drawdown function for confined aquifers (Fetter 1994, page 201). Also known as the Theis equation, the confined drawdown function is:

$$h_o - h = \frac{Q}{4\pi T}\int_u^\infty \frac{e^{-u}}{u} du \tag{5}$$

where $h_o$ [L] is the hydraulic head before pumping started, $h$ [L] is hydraulic head, $Q$ [L$^3$/t] is the pumping rate, and $T$ [L$^2$/t] is the aquifer transmissivity. The value $h_o - h$ on the left hand side of the equation is the drawdown. The integral on the right hand side of equation (5) is known as the well function and is equivalent to the following infinite series:

$$\int_u^\infty \frac{e^{-u}}{u} du = -0.5772 - ln(u) + u - \frac{u^2}{2 \cdot 2!} + \frac{u^3}{3 \cdot 3!} - \frac{u^4}{4 \cdot 4!} + \cdots \tag{6}$$

where $u$ is defined as:

$$u = \frac{r^2 S}{4Tt} \tag{7}$$

and $r$ [L] is the distance from the well, $S$ [unitless] is the aquifer storativity, and $t$ [t] is the time since pumping began. The model estimates the well function using the first 8 terms of equation (6), which provides accuracy to within a fraction of 1%.

Equation (6) is calculated for the drawdown during pumping and for the recovery when and if pumping has stopped. The radius, $r$, is set to 500 m, which after much testing has proven to be large enough to 'smooth out' un-modeled heterogeneities yet still small enough to indicate areas that may be experiencing over extraction.

The user supplies the geographic coordinates, the pumping rate, and the start date and end date of pumping for each well and the model calculates the local drawdown at that location. Cumulative impacts are modeled by mapping the geographic coordinates of each well to a grid with 1/200$^{th}$ degree (~500 m) spacing. Using the concept of superposition, the total pumping from a cell is the sum of the pumping rates for all wells that fall within its boundaries. The total pumping rate within a cell can change over time as wells go on and off line. A hypothetical example of a drawdown and recovery curve for three wells in a single cell coming on and offline at different times is shown in Figure 51. It should be noted that drawdown is always zero at the start of a simulation such that drawdowns are given as positive numbers (negative drawdowns indicate rising water levels) and are relative to the head at the time when pumping starts.

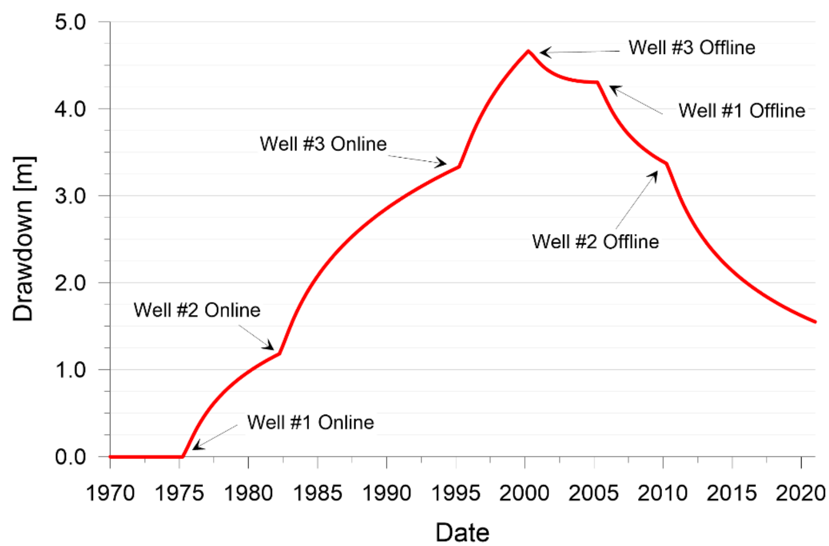


*Figure 51 – Hypothetical example of a drawdown and recovery curve for a cell with three wells that come online and offline at different times. Well #1 pumps from 1/1975 to 1/2005, Well #2 pumps from 1/1982 to 1/2010, and Well #3 pumps from 1/1995 to 1/2000. This reflects parameters of $T$ = 1.296 $m^3$/da, $S$ = 0.0051, $r$ = 500 m, and $Q$ = 3 AF/yr for all wells.*

The model has a user defined option to write the drawdowns for each well, as well as in each cell to an excel file called 'Well Data Output.xlsx' to worksheets 'Well Drawdown' and 'Grid Drawdown', respectively. The output is unformatted with no headers or row descriptions. Each column begins with the longitude and latitude followed by the time series of the drawdown and recovery for a single well (or cell). The main purpose of the output is for post-processing, since each well and grid can be visualized in the interface. The default value is NOT to write the output to Excel since doing slows down the simulation considerably.

### 5.3.2. *Simulated Future*

The model is constructed and calibrated around historical data however, as a forecasting model, provisions for providing realistic inputs for future streamflow and pumping must be included. The user has two options to simulate future input variables; historical mean or statistical forecast. The historical mean option uses the monthly historical mean and produces a forecast that repeats each year into the future. The statistical forecast is based on the cumulative distribution function (CDF) of the historical data for each month and a random number generator. The flow (or pumping or recharge) for each month is sampled from the appropriate monthly CDF based on a new random number that is generated at the start of each season of the water year. Seasons are broken into fall, winter, spring, and summer using three month blocks of October-December, January-March, April-June, and July-September, respectively. The seasonal random number is assumed uniformly distributed between 0 and 1. A yearly deviation is added to the random number using a normal distribution with a mean of 0.5 and a variance of 0.17. The yearly deviation is calculated as the difference between the generated random number and the mean (0.5). The deviation is 'smoothed' over time using the Powersim information delay function, 'delayinf', with a delay time of 6 months and an order of 3. The sum of the deviation and the seasonal random number, limited to be between 0.5 and 0.95, is used with the monthly CDF to determine the value used in the simulation. A plot of the historical data, along with a 12 year future prediction of flows for Gage #0846500 using the historical mean and the statistical forecast is shown in Figure 52.

The time when the simulated forecast begins is different for each variable, depending on the extent and quality of the historical data. The historical recharge and pumping data from Table 4-3 in the CAGW report (Barroll et al. 2004) spans from 1940 through 2000 with yearly timesteps. To generate the CDF for each variable, a subset of those dates were used

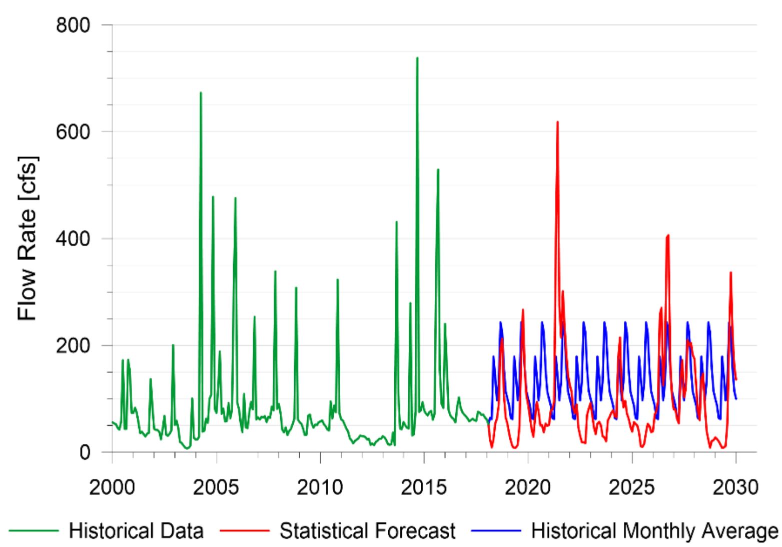


*Figure 52 – Example using flow data from the 0846500 gage (Pecos near Malaga) of the historical monthly average versus the statistical forecast options for simulating future conditions.*

Within the model, the user has the choice of a constant or random seed to initialize the random variables. The constant seed produces the same series of random numbers each time the model is simulated and is good for testing the sensitivity of the model to input variables that are independent of the forecast variables. Using a random seed produces a different forecast each time the simulation is run and is good for performing Monte Carlo analysis and risk assessment. By generating the random number each year as opposed to each timestep, the model is able to capture wet years and dry years as whole occurrences.

# 6. SUMMARY AND RECOMMENDATIONS

The key outputs from this project is an extensive dataset that establishes a baseline for the regional hydrogeology and water chemistry and a model that allows BLM to screen future water extraction that may be unsustainable. The dataset consists of water level measurements across the region in 5 different aquifers, the Pecos Alluvium, the Santa Rosa / Dewey Lake, the Rustler (Culebra and Magenta), and the Capitan Reef. The project uses a combination of field work, water quality analysis, and modeling to create an up-to-date picture of the hydrogeological state of the region.

The objective of the field work was to perform a reconnaissance on water well data from the New Mexico Office of the State Engineer to verify the wells location, construction, and status. Of the 324 wells selected for investigation, 72% were either unable to be located or were unmeasurable for various reasons. The field work was able to measure depth to water in 37 of the wells and took samples from 67 of the wells. During the span of the project, 24 wells were continuously monitored with 13 of the those extended beyond the length of this project using separate money.

The water quality analysis attempted to verify source waters in the wells that were sampled by establishing unique chemistry signatures of the water. Unfortunately, most of the wells appeared to have a mix of source waters and establishing definitive signatures for each aquifer was not possible. However, evidence shows that the main water source for wells in the North HPA are from the SR/DL aquifer or another perched source in the host Dockum Formation. For the Center North HPA, the main sources are from the SR/DL and the Rustler Formation and for the South HPA, it is mainly the SR/DL.

The model allows the user to look at the balances between water demand and water availability by predicting and tracking potential risks to the water supply. It includes the four ‘deep’ aquifers (Capitan Reef West, Capitan Reef East, Rustler, and SR/DL) and the alluvial aquifer along the Pecos River from Lake Avalon to its confluence with the Delaware River. As a system dynamics model, it treats each aquifer as a single unit where the parameters are considered effective parameters that are calibrated to match as closely as possible the dynamic behavior of the historical data (water elevations, stream flows, etc.). In addition, the model has a separate module for examining localized impacts on a grid with 1/200$^{th}$ degree spacing (~500 m) that can also serve as a database of permitted wells.

While the development of the water level and chemistry baseline data and the development of the model are important factors for understanding the water resources in area, important gaps have been discovered that should be addressed in future work. First off is that the field verification work should continue with more emphasis put on filling in spatial gaps outside the HPA’s where water may be sourced and exported for use. Along with this effort should be a mechanism for identifying and accounting for imported water (e.g. from the Ogallala) and for tracking water from source well to the user.

Geologically, we need a better understanding of the SR/DL and Rustler Formation aquifers in the southern part of the state, especially with the amount of drilling that is occurring in the South HPA. While there are a few studies that cover this region, most of the characterization of these aquifers in that area are extrapolations from the better understood areas to the north, particularly around the WIPP site. In addition, better understanding the recharge mechanisms and aquifer river interactions in the South HPA is also important in that the Pecos River is highly connected with the groundwater system through this area.

Finally, we recommend that a high-resolution regional-scale groundwater model that includes the Capitan, SR/DL, Rustler, and Pecos alluvium aquifers and the exchange between surface and groundwater resources be developed. Ideally the region should cover the entire southeast corner of New Mexico from Artesia in the north and the Guadalupe Mountains to the west. The value of this type of model will increase our understanding of the complex groundwater system in the area and allow for estimating an inventory of the available water resources, which in turn will allow the BLM to better manage the resource over the long-term.

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# APPENDIX A: WATER QUALITY DATA

*Table 18 – Listing of water quality sampling data for each of the HPA's and for the WIPP wells located in the South HPA. Values in red are those that exceed the NMWQCC limit.*

| | Station ID | Sample ID | Sample Date | Project | Water Type | Reference | Lab Code | pH (lab) | El. Cond. (uS/cm) | TDS (mg/L) | Ca (mg/L) | Mg (mg/L) | Na (mg/L) | K (mg/L) | Cl (mg/L) | Measured Alkalinity (mg/L) | HCO3 (mg/L) | CO3 (mg/L) | SO4 (mg/L) | F (mg/L) | NO2 (mg/L) | NO3 (mg/L) | Ag (mg/L) | Al (mg/L) | As (mg/L) | Ba (mg/L) | Br (mg/L) | Cd (mg/L) | Cu (mg/L) | Fe (mg/L) | Li (mg/L) | Mn (mg/L) | Ni (mg/L) | Pb (mg/L) | Si (mg/L) | Sr (mg/L) | U (mg/L) | V (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North HPA | N-2016-065 | N-2016-065_18 Nov 16_2 | 11/18/2016 | BLM | Mg-Na-Cl | North | | | 1020.00 | 663.00 | | 31.62 | 41.42 | 6.68 | 213.14 | | | | | 0.67 | 3.53 | | | | | 0.11 | 0.68 | | | | 0.04 | 0.00 | | | 16.91 | 1.38 | | |
| | N-2016-067 | N-2016-067_18 Nov 16 | 11/18/2016 | BLM | Ca-Na-Cl | North | 1611B81-001 | 7.86 | 3400.00 | 2210.00 | 310.00 | 75.00 | 260.00 | 7.30 | 1000.00 | 138.80 | 138.60 | <2 | 92.00 | 1.30 | 1.60 | 0.00 | | | | | 7.80 | | | | | | | | | | | |
| | N-2016-068 | N-2016-068_18 Nov 16_2 | 11/18/2016 | BLM | Na-Ca-Cl | North | | | 1500.00 | 921.00 | 98.00 | 26.24 | 160.40 | 7.55 | 326.73 | 164.80 | 164.80 | | 105.42 | 0.51 | 2.45 | | | | | 0.04 | 0.92 | | | | 0.10 | | | | 17.34 | 1.25 | | |
| | N-2016-068 | N-2016-068_18 Nov 16 | 11/18/2016 | BLM | Na-Ca-Cl | North | 1611B81-002 | 7.93 | 1500.00 | 921.00 | 98.00 | 23.00 | 150.00 | 4.80 | 340.00 | 164.80 | 164.80 | <2 | 95.00 | 0.28 | 2.00 | 0.00 | | | | | 2.90 | | | | | | | | | | | |
| | N-2016-069 | N-2016-069_18 Nov 16_2 | 11/18/2016 | BLM | Ca-Na-Mg-Cl | North | | | 3400.00 | 2210.00 | 310.00 | 79.94 | 261.97 | 11.06 | 944.68 | 138.80 | 138.80 | | 108.75 | 0.71 | 6.27 | | | | | 0.13 | 2.45 | | | | 0.08 | | | 0.04 | 18.38 | 3.63 | | |
| | N-2016-074 | N-2016-074_19 Jul 16_2 | 7/19/2016 | BLM | Ca-Mg-SO4 | North | | | 2763.00 | 2630.00 | 499.80 | 123.84 | 56.70 | 5.82 | 76.68 | 155.40 | 155.40 | | 1506.21 | 0.96 | | | | | 0.05 | 0.01 | 0.50 | | | | 0.08 | | | | 11.84 | 7.01 | | |
| | N-2016-074 | N-2016-074_19 Jul 16 | 7/19/2016 | BLM | Mg-SO4 | North | 1607962-001 | 7.67 | 2800.00 | 2630.00 | 5.50 | 110.00 | 54.00 | 1.90 | 69.00 | 155.40 | | <2 | 1600.00 | 0.84 | <0.1 | 5.50 | | | | | 0.44 | | | | | | | | | | | |
| | N-2016-075 | N-2016-075_19 Jul 16_2 | 7/19/2016 | BLM | Ca-Mg-SO4 | North | | | 2137.00 | 1960.00 | 357.30 | 109.40 | 27.16 | 5.27 | 37.03 | 150.80 | 150.80 | | 1128.85 | 0.69 | 2.60 | | | | 0.06 | 0.01 | 0.27 | | | | 0.05 | | | | 10.78 | 4.72 | | |
| | N-2016-075 | N-2016-075_19 Jul 16 | 7/19/2016 | BLM | Mg-SO4 | North | 160794-001 | 7.76 | 2100.00 | 1960.00 | 2.60 | 100.00 | 30.00 | 1.50 | 33.00 | 150.80 | | <2 | 1200.00 | 0.87 | <0.1 | 2.60 | | | | | 0.21 | | | | | | | | | | | |
| | N-2016-076 | N-2016-076_19 Jul 16_2 | 7/19/2016 | BLM | Ca-Mg-SO4 | North | | | 2808.00 | 2630.00 | 490.30 | 127.90 | 64.74 | 6.15 | 83.45 | 143.10 | 143.10 | | 1501.26 | 0.79 | | | | | 0.05 | 0.01 | 0.65 | | | | 0.08 | 0.00 | | | 13.12 | 7.02 | | |
| | N-2016-076 | N-2016-076_19 Jul 16 | 7/19/2016 | BLM | Mg-SO4 | North | 1607966-001 | 7.75 | 2800.00 | 2630.00 | 8.00 | 120.00 | 69.00 | 2.20 | 76.00 | 143.10 | | <2 | 1600.00 | 0.65 | <0.1 | 8.00 | | | | | 0.60 | | | | | | | | | | | |
| | N-2016-077 | N-2016-077_19 Jul 16_2 | 7/19/2016 | BLM | Ca-Mg-SO4 | North | | | 1673.00 | 1290.00 | 220.90 | 78.32 | 33.62 | 5.16 | 116.76 | 152.60 | 152.60 | | 583.71 | 0.56 | | | | | 0.03 | 0.01 | 0.86 | | | | 0.03 | | | | 10.54 | 2.91 | | |
| | N-2016-077 | N-2016-077_19 Jul 16 | 7/19/2016 | BLM | Mg-SO4-Cl-HCO3 | North | 1607961-001 | 7.73 | 1700.00 | 1290.00 | 10.00 | 74.00 | 36.00 | 1.50 | 110.00 | 152.60 | | <2 | 630.00 | 0.59 | <0.1 | 10.00 | | | | | 0.82 | | | | | | | | | | | |
| | N-2016-078 | N-2016-078_19 Jul 16_2 | 7/19/2016 | BLM | Ca-Mg-SO4-HCO3 | North | | | 1029.00 | 773.00 | 117.50 | 47.64 | 21.30 | 4.81 | 19.45 | 170.40 | 170.40 | | 359.34 | 0.71 | | | | | | 0.01 | 0.14 | | | | 0.03 | 0.01 | | | 11.25 | 1.79 | | |
| | N-2016-078 | N-2016-078_19 Jul 16 | 7/19/2016 | BLM | Mg-SO4-HCO3 | North | 1607957-001 | 7.88 | 1000.00 | 773.00 | 0.73 | 43.00 | 20.00 | 1.10 | 18.00 | 170.40 | | <2 | 380.00 | 0.59 | <0.1 | 0.73 | | | | | <0.1 | | | | | | | | | | | |
| | N-2016-079 | N-2016-079_19 Jul 16_2 | 7/19/2016 | BLM | Ca-Mg-SO4-HCO3 | North | | | 1041.00 | 764.00 | 117.80 | 48.66 | 19.93 | 4.85 | 20.72 | 175.00 | 175.00 | | 360.39 | 0.81 | | | | | 0.02 | 0.01 | 0.14 | | | | 0.03 | | | | 11.75 | 1.86 | | |
| | N-2016-079 | N-2016-079_19 Jul 16 | 7/19/2016 | BLM | Ca-Mg-SO4-HCO3 | North | 1607960-001 | 7.97 | 1000.00 | 764.00 | 140.00 | 44.00 | 18.00 | 1.20 | 19.00 | 175.00 | 175.00 | 0.00 | 370.00 | 0.68 | 0.00 | 0.73 | | | | | 0.00 | | | | | | | | | | | |
| | N-2016-080 | N-2016-080_18 Aug 16_2 | 8/18/2016 | BLM | Ca-Mg-SO4-HCO3 | North | | | 1116.00 | 833.00 | 149.10 | 48.18 | 20.16 | 4.91 | 22.82 | 185.30 | 185.30 | | 370.35 | 0.75 | | | | | 0.06 | 0.01 | 0.13 | | | | 0.02 | | | | 8.60 | 1.85 | | |
| | N-2016-080 | N-2016-080_18 Aug 16 | 8/18/2016 | BLM | Ca-Mg-SO4-HCO3 | North | 1608C21-001 | 7.55 | 1200.00 | 833.00 | 160.00 | 48.00 | 21.00 | 1.20 | 21.00 | 185.30 | 185.30 | 0.00 | 390.00 | 0.74 | 0.00 | 0.00 | | | | | 0.00 | | | | | | | | | | | |
| | N-2016-081 | N-2016-081_16 Sep 16_2 | 9/16/2016 | BLM | Mg-Ca-HCO3-Cl | North | | | | 331.00 | 30.81 | 24.03 | 27.89 | 30.13 | 72.89 | 312.00 | 312.00 | | 0.00 | 0.27 | 4.80 | 0.04 | | | 0.03 | 0.01 | 0.36 | | | 3.34 | 0.02 | 0.06 | | | 2.67 | 0.63 | | |
| | N-2016-082 | N-2016-082_18 Aug 16_2 | 8/18/2016 | BLM | Ca-Mg-SO4 | North | | | 1480.00 | 1130.00 | 170.80 | 63.94 | 28.14 | 4.91 | 56.24 | 188.50 | 188.50 | | 528.63 | 0.83 | | | | | 0.04 | 0.01 | 0.16 | | | | 0.02 | | | | 8.02 | 2.43 | | |
| | N-2016-082 | N-2016-082_18 Aug 16 | 8/18/2016 | BLM | Ca-Mg-SO4 | North | 1608C22-001 | 7.47 | 1500.00 | 1130.00 | 210.00 | 64.00 | 29.00 | 1.10 | 49.00 | 188.50 | 188.50 | 0.00 | 540.00 | 0.63 | 0.00 | 0.00 | | | | | 0.00 | | | | | | | | | | | |
| | N-2016-086 | N-2016-086_09 Aug 16_2 | 8/9/2016 | BLM | Ca-Mg-SO4 | North | | | 1680.00 | 955.00 | 229.50 | 86.60 | 24.12 | 4.99 | 29.03 | 205.40 | 205.40 | | 759.57 | 0.88 | | | | | 0.05 | 0.02 | 0.18 | | | | 0.03 | | | | 8.95 | 3.05 | | |
| | N-2016-086 | N-2016-086_09 Aug 16 | 8/9/2016 | BLM | Ca-Mg-SO4 | North | 1608596-001 | 7.11 | 3900.00 | 3550.00 | 590.00 | 180.00 | 140.00 | 1.70 | 350.00 | 218.00 | 218.00 | 0.00 | 1900.00 | 0.00 | 0.00 | 5.40 | | | | | 0.90 | | | | | | | | | | | |
| | N-2016-088 | N-2016-088_09 Aug 16_2 | 8/9/2016 | BLM | Ca-Mg-SO4 | North | | | 2718.00 | 2460.00 | 416.00 | 155.14 | 72.00 | 5.77 | 99.65 | 192.80 | 192.80 | | 1357.45 | 0.54 | | | | | 0.06 | 0.01 | 0.45 | | 0.02 | | 0.05 | | | | 10.68 | 4.66 | | |
| | N-2016-088 | N-2016-088_09 Aug 16 | 8/9/2016 | BLM | Ca-Mg-SO4 | North | 1608594-001 | 7.07 | 2700.00 | 2460.00 | 420.00 | 140.00 | 72.00 | 2.00 | 93.00 | 192.80 | 192.80 | 0.00 | 1400.00 | 1.30 | 0.00 | 7.10 | | | | | 0.40 | | | | | | | | | | | |
| | N-2016-090 | N-2016-090_09 Aug 16_2 | 8/9/2016 | BLM | Ca-Mg-SO4 | North | | | 1502.00 | 1240.00 | 206.30 | 78.66 | 21.24 | 4.93 | 20.70 | 188.70 | 188.70 | | 653.95 | 0.88 | | | | | 0.05 | 0.02 | 0.16 | | | | 0.03 | | | | 9.36 | 2.68 | | |
| | N-2016-090 | N-2016-090_09 Aug 16 | 8/9/2016 | BLM | Ca-Mg-SO4 | North | 1608597-001 | 7.32 | 1500.00 | 1240.00 | 210.00 | 74.00 | 22.00 | 1.30 | 20.00 | 188.70 | 188.70 | 0.00 | 680.00 | 0.75 | 0.00 | 0.90 | | | | | 0.00 | | | | | | | | | | | |
| | N-2016-092 | N-2016-092_09 Aug 16_2 | 8/9/2016 | BLM | Ca-Mg-SO4 | North | | | 1735.00 | 1430.00 | 209.50 | 83.98 | 41.10 | 5.25 | 60.66 | 185.00 | 185.00 | | 731.75 | 0.90 | | | | | 0.05 | 0.02 | 0.16 | | | | 0.04 | 0.00 | | | 9.70 | 3.24 | | |
| | N-2016-092 | N-2016-092_09 Aug 16 | 8/9/2016 | BLM | Ca-Mg-SO4 | North | 1608598-001 | 7.33 | 1800.00 | 1430.00 | 240.00 | 79.00 | 42.00 | 1.40 | 55.00 | 185.00 | 185.00 | 0.00 | 810.00 | 0.66 | 0.00 | 0.00 | | | | | 0.00 | | | | | | | | | | | |
| | N-2016-093 | N-2016-093_09 Aug 16_2 | 8/9/2016 | BLM | Ca-Mg-SO4 | North | | | 1447.00 | 1180.00 | 204.30 | 73.46 | 19.60 | 5.00 | 19.10 | 190.70 | 190.70 | | 609.66 | 0.87 | | | | | 0.04 | 0.02 | 0.16 | | | | 0.02 | 0.00 | | | 8.84 | 2.55 | | |
| | N-2016-093 | N-2016-093_10 Aug 16 | 8/10/2016 | BLM | Ca-Mg-SO4 | North | 1608599-001 | 7.38 | 1500.00 | 1180.00 | 200.00 | 67.00 | 19.00 | 1.40 | 18.00 | 190.70 | 190.70 | 0.00 | 680.00 | 0.76 | 0.00 | 0.00 | | | | | 0.00 | | | | | | | | | | | |
| | N-2016-096 | N-2016-096_09 Aug 16_2 | 8/9/2016 | BLM | Ca-Mg-SO4 | North | | | 3905.00 | | 572.20 | 200.40 | 150.18 | 5.99 | 346.33 | 195.50 | 195.50 | | 1787.28 | 0.78 | | | | | 0.05 | 0.01 | 0.57 | | | | 0.06 | 0.00 | | | 10.64 | 8.47 | | |
| | N-2016-097 | N-2016-097_18 Aug 16_2 | 8/18/2016 | BLM | Ca-Mg-SO4-HCO3 | North | | | 1248.00 | 957.00 | 141.43 | 53.09 | 18.67 | 2.68 | 19.03 | 186.40 | 186.40 | | 465.71 | 0.92 | | | | | 0.03 | 0.01 | 0.11 | | | | 0.02 | | | | 7.56 | 2.27 | | |
| | N-2016-097 | N-2016-097_18 Aug 16 | 8/18/2016 | BLM | Ca-Mg-SO4-HCO3 | North | 1608C24-001 | 7.61 | 1300.00 | 957.00 | 190.00 | 54.00 | 18.00 | 0.00 | 16.00 | 186.40 | 186.40 | 0.00 | 450.00 | 0.80 | 0.00 | 0.00 | | | | | 0.00 | | | | | | | | | | | |
| | N-2016-098 | N-2016-098_19 Jul 16_2 | 7/19/2016 | BLM | Ca-Mg-SO4 | North | | | 1714.00 | 1370.00 | 226.80 | 82.52 | 37.34 | 5.02 | 73.54 | 199.60 | 199.60 | | 690.57 | 0.70 | | | | | 0.04 | 0.01 | 0.20 | | | | 0.03 | 0.00 | | | 10.27 | 3.06 | | |
| | N-2016-098 | N-2016-098_19 Jul 16 | 7/19/2016 | BLM | Mg-SO4-HCO3 | North | 1607968-001 | 7.68 | 1700.00 | 1370.00 | 3.00 | 80.00 | 40.00 | 1.20 | 66.00 | 199.60 | | <2 | 740.00 | 0.67 | <0.1 | 3.00 | | | | | <0.1 | | | | | | | | | | | |
| Center North | CN-2015-010 | CN-2015-010_22 Jun 16_2 | 6/22/2016 | BLM | Ca-Na-Cl-SO4 | Center North | | | 8380.00 | 6220.00 | 777.70 | 202.00 | 874.20 | 44.64 | 1984.03 | 94.16 | 94.16 | | 1769.92 | 2.06 | 4.60 | | | | 0.12 | 0.01 | 2.50 | | | | 0.40 | 0.05 | | | 14.89 | 11.13 | | 0.02 |
| | CN-2015-010 | CN-2015-010_08 Jul 16 | 7/8/2016 | BLM | Ca-Na-Cl-SO4 | Center North | 1606C87-001 | 7.70 | | 6200.00 | 920.00 | 190.00 | 910.00 | 22.00 | 2000.00 | 94.16 | 94.16 | 0.00 | 1800.00 | 2.10 | | | | | | | 2.70 | | | | | | | | | | | |
| | CN-2015-013 | CN-2015-013_28 Jun 16_2 | 6/28/2016 | BLM | Na-Cl | Center North | | | 53500.00 | 43000.00 | 886.10 | 1492.00 | 11160.00 | 1136.00 | 18741.30 | 99.36 | 99.36 | | 6327.36 | | | | | | 0.32 | 0.03 | | | | | 1.70 | 0.20 | 0.02 | | 5.53 | 13.75 | | |
| | CN-2015-013 | CN-2015-013_28 Jun 16 | 6/28/2016 | BLM | Na-Cl | Center North | 1606G00-001 | 7.57 | 83000.00 | 43000.00 | | 1400.00 | 12000.00 | 540.00 | 21000.00 | 99.36 | | <2 | 6400.00 | <2 | | | | | | | 12.00 | | | | | | | | | | | |
| | CN-2015-015 | CN-2015-015_22 Jun 16_2 | 6/22/2016 | BLM | Ca-Na-Mg-SO4-Cl | Center North | | | 4344.00 | 3460.00 | 472.00 | 133.20 | 379.70 | 17.97 | 614.59 | 96.84 | 96.84 | | 1458.46 | 2.02 | 6.10 | | | | 0.06 | 0.01 | 0.31 | | 0.03 | | 0.24 | 0.00 | | | 14.54 | 6.20 | | 0.03 |
| | CN-2015-015 | CN-2015-015_22 Jun 16 | 6/22/2016 | BLM | Ca-Na-SO4-Cl | Center North | 1606C86-001 | 7.83 | 4100.00 | 3460.00 | 510.00 | 120.00 | 390.00 | 9.30 | 700.00 | 96.84 | 96.84 | 0.00 | 1700.00 | 2.60 | 0.00 | 6.10 | | | | | 0.28 | | | | | | | | | | | |
| | CN-2016-007 | CN-2016-007_22 Jun 16_2 | 6/22/2016 | BLM | Na-Ca-Mg-Cl-SO4 | Center North | | | 10550.00 | 6620.00 | 791.80 | 328.80 | 1178.00 | 53.86 | 2613.95 | 106.60 | 106.60 | | 2040.12 | 1.39 | 3.30 | | | | 0.08 | 0.01 | 1.41 | | | | 0.36 | | | | 12.70 | 12.58 | | 0.01 |
| | CN-2016-011 | CN-2016-011_28 Jun 16_2 | 6/28/2016 | BLM | Ca-Mg-SO4 | Center North | | | 2453.00 | 2170.00 | 321.20 | 143.70 | 92.58 | 8.51 | 100.16 | 110.30 | 110.30 | | 1244.82 | 0.99 | 5.10 | | | | 0.04 | 0.01 | 0.48 | | | | 0.14 | | | | 14.12 | 6.64 | | 0.02 |
| | CN-2016-011 | CN-2016-011_28 Jun 16 | 6/28/2016 | BLM | Mg-SO4 | Center North | 1606G01-001 | 7.78 | 2500.00 | 2170.00 | 5.10 | 130.00 | 99.00 | 4.00 | 97.00 | 110.30 | | <2 | 1100.00 | 0.82 | <0.1 | 5.10 | | | | | 0.49 | | | | | | | | | | | |
| | CN-2016-014 | CN-2016-014_28 Jun 16_2 | 6/28/2016 | BLM | Mg-Ca-Na-SO4-Cl | Center North | | | 2198.00 | 1530.00 | 165.90 | 117.64 | 125.50 | 14.59 | 284.80 | 147.80 | 147.80 | | 579.28 | 1.06 | 8.80 | | | | 0.04 | 0.01 | 1.23 | | | | 0.25 | | | | 23.40 | 3.55 | | 0.03 |
| | CN-2016-014 | CN-2016-014_28 Jun 16 | 6/28/2016 | BLM | Mg-Na-SO4-Cl | Center North | 1606G02-001 | 7.90 | 2100.00 | 1530.00 | 8.80 | 110.00 | 130.00 | 8.70 | 310.00 | 147.80 | | <2 | 630.00 | 1.10 | <0.1 | 8.80 | | | | | 1.30 | | | | | | | | | | | |
| | CN-2016-016 | CN-2016-016_28 Jun 16_2 | 6/28/2016 | BLM | Na-Mg-Ca-SO4-Cl-HCO3 | Center North | | | 1338.00 | 869.00 | 73.46 | 48.36 | 144.60 | 8.88 | 112.89 | 181.20 | 181.20 | | 306.71 | 1.47 | 5.40 | | | | 0.03 | 0.02 | 0.66 | | | | 0.18 | | | | 9.88 | 2.73 | | 0.03 |
| | CN-2016-016 | CN-2016-016_28 Jun 16 | 6/28/2016 | BLM | Na-Mg-SO4-HCO3-Cl | Center North | 1606F99-001 | 7.97 | 1300.00 | 869.00 | 5.40 | 44.00 | 140.00 | 4.00 | 110.00 | 181.20 | | <2 | 320.00 | 1.40 | <0.1 | 5.40 | | | | | 0.79 | | | | | | | | | | | |
| | CN-2016-017 | CN-2016-017_22 Jun 16_2 | 6/22/2016 | BLM | Na-Ca-Mg-Cl-SO4 | Center North | | | 9150.00 | 7750.00 | 794.90 | 268.40 | 949.90 | 35.08 | 2176.46 | 105.60 | 105.60 | | 1870.20 | 1.86 | 2.60 | | | | 0.06 | 0.01 | 1.32 | | | | 0.31 | 0.00 | | | 13.08 | 12.48 | | 0.01 |
| | CN-2016-017 | CN-2016-017_22 Jun 16 | 6/22/2016 | BLM | Na-Mg-Cl-SO4 | Center North | 1606C84-001 | 7.53 | 9600.00 | 7750.00 | 2.60 | 320.00 | 1200.00 | 27.00 | 2900.00 | 105.60 | | <2 | 2100.00 | <2 | <2 | 2.60 | | | | | 1.40 | | | | | | | | | | | |
| | CN-2016-018 | CN-2016-018_17 Jun 16_2 | 6/17/2016 | BLM | Na-Ca-Cl-SO4 | Center North | | | | 8340.00 | 836.90 | 225.80 | 1399.00 | 69.08 | 3009.81 | 19.90 | 19.80 | 0.10 | 1924.89 | 1.10 | 2.29 | | | | 0.13 | 0.01 | 2.93 | | | | 0.36 | | 0.00 | | 1.90 | 13.24 | | |
| | CN-2016-019 | CN-2016-019_17 Jun 16_2 | 6/17/2016 | BLM | Na-Ca-Mg-Cl-SO4 | Center North | | | | 7661.00 | 801.80 | 297.20 | 1210.00 | 55.62 | 2581.67 | 109.10 | 109.10 | 0.00 | 2112.56 | 2.35 | 3.31 | | | 0.18 | 0.07 | 0.01 | 2.67 | | | 0.04 | 0.37 | 0.01 | 0.01 | | 13.01 | 12.88 | | 0.01 |

| | Station ID | Sample ID | Sample Date | Project | Water Type | Reference | Lab Code | pH (lab) | El. Cond. (uS/cm) | TDS (mg/L) | Ca (mg/L) | Mg (mg/L) | Na (mg/L) | K (mg/L) | Cl (mg/L) | Measured Alkalinity (mg/L) | HCO3 (mg/L) | CO3 (mg/L) | SO4 (mg/L) | F (mg/L) | NO2 (mg/L) | NO3 (mg/L) | Ag (mg/L) | Al (mg/L) | As (mg/L) | Ba (mg/L) | Br (mg/L) | Cd (mg/L) | Cu (mg/L) | Fe (mg/L) | Li (mg/L) | Mn (mg/L) | Ni (mg/L) | Pb (mg/L) | Si (mg/L) | Sr (mg/L) | U (mg/L) | V (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| South HPA | S-2014-003 | S-2014-003_02 Dec 14 | 12/2/2014 | BLM | Na-HCO3-SO4 | South | 1412226-001 | 8.43 | 1000.00 | 636.00 | | 4.90 | 210.00 | 1.60 | 32.00 | 240.00 | | 4.90 | 190.00 | 1.40 | | | | | | | 0.18 | | | | | | | | | | | |
| | S-2014-012 | S-2014-012_02 Dec 14 | 12/2/2014 | BLM | Na-HCO3-SO4 | South | 1412226-003 | 8.54 | 940.00 | 590.00 | | 4.30 | 190.00 | 1.60 | 25.00 | 240.00 | | 8.10 | 170.00 | 1.40 | | | | | | | 0.14 | | | | | | | | | | | |
| | S-2014-013 | S-2014-013_02 Dec 14 | 12/2/2014 | BLM | Na-HCO3-SO4 | South | 1412226-002 | 8.52 | 800.00 | 495.00 | | 2.10 | 170.00 | 1.20 | 23.00 | 260.00 | | 7.40 | 77.00 | 1.60 | | | | | | | 0.10 | | | | | | | | | | | |
| | S-2014-014 | S-2014-014_07 Jan 15 | 1/7/2015 | BLM | Mg-Cl | South | 1501370-001 | 6.18 | 2300.00 | 2020.00 | | 73.00 | 67.00 | 8.40 | 890.00 | 23.00 | | <2 | 150.00 | 0.20 | | | | | | | 1.90 | | | | | | | | | | | |
| | S-2014-015 | S-2014-015_07 Jan 15 | 1/7/2015 | BLM | Na-Mg-Cl-HCO3 | South | 1501370-002 | 7.93 | 690.00 | 481.00 | | 18.00 | 52.00 | 5.90 | 130.00 | 130.00 | | <2 | 29.00 | 1.20 | | | | | | | 0.70 | | | | | | | | | | | |
| | S-2014-017 | S-2014-017_02 Dec 14 | 12/2/2014 | BLM | Na-HCO3-SO4-Cl | South | 1412228-002 | 8.10 | 840.00 | 513.00 | | 16.00 | 130.00 | 2.50 | 60.00 | 190.00 | | <2 | 130.00 | 1.70 | | | | | | | 0.34 | | | | | | | | | | | |
| | S-2014-019 | S-2014-019_02 Dec 14 | 12/2/2014 | BLM | Na-Cl | South | 1412228-001 | 7.83 | 4300.00 | 2870.00 | | 86.00 | 630.00 | 12.00 | 1300.00 | 160.00 | | <2 | 390.00 | 1.00 | | | | | | | 1.90 | | | | | | | | | | | |
| | S-2016-001 | S-2016-001_02 Nov 16_2 | 11/2/2016 | BLM | Na-Mg-HCO3 | South | | | 600.00 | 332.00 | 21.00 | 27.77 | 60.34 | 4.58 | 13.26 | 240.60 | 240.60 | | 33.05 | 1.07 | 1.53 | | | | | 0.06 | 0.17 | | | | 0.07 | | | | 5.37 | 0.80 | | |
| | S-2016-001 | S-2016-001_02 Nov 16 | 11/2/2016 | BLM | Na-Mg-HCO3 | South | 1611191-001 | 7.98 | 600.00 | 332.00 | 21.00 | 27.00 | 60.00 | 2.80 | 11.00 | 240.60 | 240.60 | 0.00 | 43.00 | 1.10 | 0.00 | 1.50 | | | | | 0.00 | | | | | | | | | | | |
| | S-2016-002 | S-2016-002_02 Nov 16_2 | 11/2/2016 | BLM | Mg-Na-Ca-HCO3 | South | | | 660.00 | 377.00 | 26.00 | 33.65 | 62.55 | 4.82 | 28.07 | 237.10 | 237.10 | | 50.00 | 1.08 | 2.02 | | | | | 0.06 | 0.22 | | | | 0.07 | | | | 5.30 | 0.96 | | |
| | S-2016-002 | S-2016-002_02 Nov 16 | 11/2/2016 | BLM | Mg-Na-Ca-HCO3 | South | 1611191-002 | 7.97 | 660.00 | 377.00 | 26.00 | 33.00 | 62.00 | 3.10 | 26.00 | 237.10 | 237.10 | 0.00 | 49.00 | 1.10 | 0.00 | 2.10 | | | | | 0.25 | | | | | | | | | | | |
| | S-2016-007 | S-2016-007_02 Nov 16_2 | 11/2/2016 | BLM | Na-Mg-HCO3 | South | | | 660.00 | 378.00 | 25.00 | 30.43 | 66.27 | 4.65 | 24.58 | 233.30 | 233.30 | | 57.25 | 1.25 | 2.07 | | | | | 0.05 | 0.17 | | | | 0.06 | | | | 6.30 | 0.91 | | |
| | S-2016-007 | S-2016-007_02 Nov 16 | 11/2/2016 | BLM | Na-Mg-Ca-HCO3 | South | 1611191-003 | 8.02 | 660.00 | 378.00 | 25.00 | 30.00 | 67.00 | 2.80 | 20.00 | 233.30 | 233.30 | 0.00 | 50.00 | 1.30 | 0.00 | 2.00 | | | | | 0.17 | | | | | | | | | | | |
| | S-2016-013 | S-2016-013_02 Nov 16_2 | 11/2/2016 | BLM | Ca-Mg-Na-SO4-Cl | South | | | 2700.00 | 1960.00 | 230.00 | 112.59 | 210.51 | 13.41 | 333.32 | 185.60 | 185.60 | | 705.68 | 3.63 | 18.58 | | | | | 0.04 | 2.32 | | | 0.01 | 0.32 | | | 0.03 | 39.19 | 5.50 | 0.02 | 0.07 |
| | S-2016-013 | S-2016-013_02 Nov 16 | 11/2/2016 | BLM | Ca-Na-Mg-SO4-Cl | South | 1611192-001 | 7.87 | 2700.00 | 1960.00 | 230.00 | 100.00 | 200.00 | 9.00 | 300.00 | 185.60 | 185.60 | 0.00 | 610.00 | 3.60 | 0.00 | 16.00 | | | | | 0.00 | | | | | | | | | | | |
| | S-2016-015 | S-2016-015_02 Nov 16_2 | 11/2/2016 | BLM | Na-Mg-HCO3-SO4 | South | | | 870.00 | 509.00 | 25.00 | 30.15 | 118.59 | 5.80 | 27.61 | 256.00 | 256.00 | | 143.61 | 1.27 | 1.33 | | | | | 0.04 | 0.23 | | | | 0.10 | | | | 6.07 | 7.85 | | |
| | S-2016-015 | S-2016-015_02 Nov 16 | 11/2/2016 | BLM | Na-Mg-HCO3-SO4 | South | 1611192-002 | 8.09 | 870.00 | 509.00 | 25.00 | 27.00 | 120.00 | 3.70 | 25.00 | 256.00 | 256.00 | 0.00 | 110.00 | 1.20 | 0.00 | 0.68 | | | | | 0.27 | | | | | | | | | | | |
| | S-2016-019 | S-2016-019_12 Jan 17_2 | 1/12/2017 | BLM | Ca-Mg-Na-SO4 | South | | | 2300.00 | 2010.00 | 271.60 | 112.96 | 134.66 | 7.21 | 51.31 | 81.44 | 81.44 | | 1273.65 | 1.47 | 4.20 | | | | | 0.00 | 0.19 | | | | 0.15 | 0.00 | | 0.02 | 7.59 | 4.71 | 0.02 | |
| | S-2016-019 | S-2016-019_12 Jan 17 | 1/12/2017 | BLM | Ca-Mg-SO4 | South | 1701606-002 | 7.65 | 2300.00 | 2010.00 | 280.00 | 100.00 | 120.00 | 0.00 | 51.00 | 81.44 | 81.44 | 0.00 | 1300.00 | 1.90 | 0.00 | 0.00 | | | | | 0.00 | | | | | | | | | | | |
| | S-2016-028 | S-2016-028_02 Feb 17_2 | 2/2/2017 | BLM | Ca-Mg-Na-SO4 | South | | | 4100.00 | 3770.00 | 543.07 | 164.10 | 285.74 | 13.99 | 338.84 | 69.44 | 69.44 | | 2030.97 | 1.81 | | | | | | 0.01 | 0.31 | | | | 0.28 | 0.00 | | 0.04 | 11.98 | 7.85 | 0.05 | |
| | S-2016-028 | S-2016-028_02 Feb 17 | 2/2/2017 | BLM | Ca-Mg-Na-SO4-Cl | South | -605205.00 | 7.62 | 4100.00 | 3770.00 | 560.00 | 160.00 | 270.00 | 9.10 | 380.00 | 69.44 | 69.44 | 0.00 | 2000.00 | 1.80 | 0.00 | 0.68 | | | | | 0.25 | | | | | | | | | | | |
| | S-2016-046 | S-2016-046_22 Dec 16_2 | 12/22/2016 | BLM | Na-Cl-SO4 | South | | | 2100.00 | 1170.00 | 77.00 | 42.37 | 290.70 | 9.02 | 447.99 | 102.30 | 102.30 | | 233.03 | 1.38 | 0.99 | | | | | 0.02 | 0.14 | | | | 0.09 | 0.06 | | | 5.97 | 1.85 | | |
| | S-2016-046 | S-2016-046_22 Dec 16 | 12/22/2016 | BLM | Na-Ca-Cl-SO4 | South | 1612D00-002 | 7.68 | 2100.00 | 1170.00 | 77.00 | 37.00 | 280.00 | 5.70 | 390.00 | 102.30 | 102.30 | 0.00 | 250.00 | 1.20 | 0.00 | 0.00 | | | | | 0.00 | | | | | | | | | | | |
| | S-2016-047 | S-2016-047_22 Dec 16_2 | 12/22/2016 | BLM | Na-Ca-Cl-SO4 | South | | | 2100.00 | 1250.00 | 99.00 | 42.78 | 235.71 | 8.87 | 353.30 | 136.80 | 136.80 | | 295.77 | 1.60 | 0.99 | | | | | 0.02 | 0.15 | | | | 0.10 | 0.04 | | | 8.35 | 2.01 | | |
| | S-2016-047 | S-2016-047_22 Dec 16 | 12/22/2016 | BLM | Na-Ca-Cl | South | 1612D00-003 | 8.00 | 2100.00 | 1250.00 | 99.00 | 37.00 | 240.00 | 5.70 | 350.00 | 138.80 | 136.80 | 0.00 | 0.00 | 1.30 | 0.00 | 0.00 | | | | | 0.00 | | | | | | | | | | | |
| | S-2016-049 | S-2016-049_22 Sep 16_2 | 9/22/2016 | BLM | Ca-Mg-SO4-Cl | South | | | 3000.00 | 2100.00 | 317.77 | 109.67 | 138.59 | 6.36 | 447.99 | 151.70 | 151.70 | | 752.59 | 0.58 | | | | | 0.04 | 0.01 | 0.32 | | | | 0.14 | | | | 10.37 | 4.18 | | |
| | S-2016-055 | S-2016-055_12 Jan 17_2 | 1/12/2017 | BLM | Na-Ca-Cl-SO4 | South | | | 19000.00 | 11800.00 | 955.11 | 376.49 | 2447.67 | 58.56 | 4572.72 | 223.80 | 223.80 | | 1887.06 | 1.10 | | | | | | 0.01 | 4.61 | | | | 0.57 | | | 0.04 | 17.78 | 0.05 | 0.07 | |
| | S-2016-055 | S-2016-055_12 Jan 17 | 1/12/2017 | BLM | Na-Ca-Cl-SO4 | South | 1701606-001 | 6.99 | 19000.00 | 11800.00 | 990.00 | 340.00 | 2100.00 | 29.00 | 4600.00 | 223.80 | 223.80 | 0.00 | 1900.00 | 1.30 | 0.00 | 0.00 | | | | | 20.00 | | | | | | | | | | | |
| | S-2016-063 | S-2016-063_11 Jan 17_2 | 1/11/2017 | BLM | Ca-Mg-SO4-Cl | South | | | 3500.00 | 3060.00 | 560.00 | 114.09 | 177.17 | 9.93 | 344.52 | 180.50 | 180.50 | | 1458.25 | 1.35 | 5.20 | | | | | 0.01 | 0.32 | | | | 0.13 | | | 0.02 | 11.58 | 4.26 | 0.04 | |
| | S-2016-063 | S-2016-063_11 Jan 17 | 1/11/2017 | BLM | Ca-SO4-Cl | South | 1701494-004 | 7.32 | 3500.00 | 3060.00 | 560.00 | 98.00 | 160.00 | 6.10 | 320.00 | 180.50 | 180.50 | 0.00 | 1400.00 | 1.90 | 0.00 | 0.00 | | | | | 0.24 | | | | | | | | | | | |
| | S-2016-065 | S-2016-065_12 Jan 17_2 | 1/12/2017 | BLM | Ca-Mg-SO4-Cl | South | | | 4400.00 | 3860.00 | 570.00 | 226.91 | 241.89 | 18.21 | 626.98 | 118.40 | 118.40 | | 1653.14 | 1.27 | 6.65 | | | | | 0.01 | 0.96 | | | | 0.35 | | | 0.05 | 10.65 | 10.60 | 0.08 | |
| | S-2016-065 | S-2016-065_12 Jan 17 | 1/12/2017 | BLM | Ca-Mg-SO4-Cl | South | 1701606-003 | 7.35 | 4400.00 | 3860.00 | 570.00 | 190.00 | 210.00 | 10.00 | 640.00 | 118.40 | 118.40 | 0.00 | 1600.00 | 1.50 | 0.00 | 3.60 | | | | | 2.30 | | | | | | | | | | | |
| | S-2016-084 | S-2016-084_22 Dec 16_2 | 12/22/2016 | BLM | Ca-Mg-Na-SO4-Cl | South | | | 6100.00 | 5300.00 | 690.00 | 295.88 | 545.97 | 17.90 | 914.00 | 182.70 | 182.70 | | 2230.02 | 2.08 | | | | | | 0.01 | 0.78 | | | | 0.32 | | | 0.05 | 15.20 | 10.29 | 0.06 | |
| | S-2016-084 | S-2016-084_22 Dec 16 | 12/22/2016 | BLM | Ca-Na-Mg-SO4-Cl | South | 1612D01-001 | 7.62 | 6100.00 | 5300.00 | 690.00 | 290.00 | 580.00 | 11.00 | 930.00 | 182.70 | 182.70 | <2 | 2300.00 | 1.50 | 1.30 | 0.00 | | | | | 0.72 | | | | | | | | | | | |
| | S-2016-090 | S-2016-090_02 Nov 16_2 | 11/2/2016 | BLM | Na-Mg-HCO3-SO4 | South | | | 740.00 | 431.00 | 21.00 | 26.67 | 101.45 | 6.10 | 12.68 | 297.10 | 297.10 | | 71.36 | 1.43 | 5.85 | | | | | 0.04 | 0.17 | | | | 0.09 | 0.00 | | | 4.91 | 0.67 | 0.02 | |
| | S-2016-090 | S-2016-090_02 Nov 16 | 11/2/2016 | BLM | Na-Mg-HCO3 | South | 1611192-003 | 8.05 | 740.00 | 431.00 | 21.00 | 25.00 | 100.00 | 4.00 | 12.00 | 297.10 | 297.10 | 0.00 | 59.00 | 1.40 | 0.00 | 0.00 | | | | | 0.00 | | | | | | | | | | | |
| | S-2016-094 | S-2016-094_11 Jan 17_2 | 1/11/2017 | BLM | Ca-Mg-SO4-Cl | South | | | 4300.00 | 3760.00 | 670.00 | 160.90 | 235.14 | 7.31 | 627.61 | 143.60 | 143.60 | | 1646.30 | 1.38 | 6.24 | | | | | 0.01 | 2.19 | | | | 0.16 | 0.00 | | 0.04 | 12.34 | 8.52 | 0.01 | |
| | S-2016-094 | S-2016-094_11 Jan 17 | 1/11/2017 | BLM | Ca-SO4-Cl | South | 1701494-005 | 7.50 | 4300.00 | 3760.00 | 670.00 | 140.00 | 210.00 | 4.00 | 730.00 | 143.60 | 143.60 | 0.00 | 1900.00 | 0.75 | 0.00 | 0.00 | | | | | 2.50 | | | | | | | | | | | |
| | S-2016-095 | S-2016-095_11 Jan 17_2 | 1/11/2017 | BLM | Ca-Mg-Na-SO4 | South | | | 4700.00 | 4550.00 | 530.00 | 253.61 | 438.19 | 28.25 | 328.70 | 253.80 | 253.80 | | 2385.71 | 0.83 | 9.22 | | | | | 0.01 | 0.79 | | | | 0.32 | | | 0.06 | 13.46 | 6.91 | 0.03 | |
| | S-2016-095 | S-2016-095_11 Jan 17 | 1/11/2017 | BLM | Ca-Mg-Na-SO4 | South | 1701494-002 | 7.24 | 4700.00 | 4550.00 | 530.00 | 220.00 | 390.00 | 19.00 | 390.00 | 253.80 | 253.80 | 0.00 | 2200.00 | 0.00 | 0.00 | 0.00 | | | | | 0.76 | | | | | | | | | | | |
| | S-2016-096 | S-2016-096_11 Jan 17_2 | 1/11/2017 | BLM | Na-Ca-Mg-SO4-Cl | South | | | 7800.00 | 6650.00 | 590.00 | 307.50 | 1003.42 | 27.19 | 1346.02 | 177.90 | 177.90 | | 2505.45 | 1.15 | | | | | | 0.01 | 1.74 | | | | 0.53 | | | 0.06 | 10.53 | 7.96 | 0.04 | |
| | S-2016-096 | S-2016-096_11 Jan 17 | 1/11/2017 | BLM | Na-Ca-Mg-SO4-Cl | South | 1701494-003 | 7.43 | 7800.00 | 6650.00 | 590.00 | 280.00 | 880.00 | 17.00 | 1700.00 | 177.90 | 177.90 | 0.00 | 3100.00 | 0.30 | 0.00 | 0.00 | | | | | 6.90 | | | | | | | | | | | |
| | S-2016-097 | S-2016-097_11 Jan 17_2 | 1/11/2017 | BLM | Ca-Mg-SO4 | South | | | 2800.00 | 2720.00 | 350.00 | 202.96 | 119.28 | 13.63 | 49.68 | 240.00 | 240.00 | | 1624.28 | 2.10 | 5.27 | 0.07 | | | | 0.01 | 0.20 | | 0.37 | | 0.32 | | | 0.02 | 11.64 | 7.06 | 0.04 | |
| | S-2016-097 | S-2016-097_11 Jan 17 | 1/11/2017 | BLM | Ca-Mg-SO4 | South | 1701494-001 | 7.44 | 2800.00 | 2720.00 | 350.00 | 160.00 | 100.00 | 9.40 | 33.00 | 240.00 | 240.00 | 0.00 | 1500.00 | 2.60 | 0.00 | 2.00 | | | | | 0.00 | | | | | | | | | | | |
| | S-2016-098 | S-2016-098_22 Dec 16_2 | 12/22/2016 | BLM | Na-Cl-SO4 | South | | | 13000.00 | 9130.00 | 550.00 | 280.42 | 2173.97 | 34.98 | 3125.33 | 130.20 | 130.20 | | 2339.74 | 2.44 | | | | | | 0.04 | 0.72 | | | | 0.10 | | | | 6.91 | 8.94 | | |
| | S-2016-098 | S-2016-098_22 Dec 16 | 12/22/2016 | BLM | Na-Ca-Cl-SO4 | South | 1612D00-001 | 7.56 | 13000.00 | 9130.00 | 550.00 | 270.00 | 2200.00 | 19.00 | 2700.00 | 130.20 | 130.20 | 0.00 | 1900.00 | 1.40 | 0.00 | 0.00 | | | | | 0.59 | | | | | | | | | | | |
| | S-2016-099 | S-2016-099_22 Sep 16 | 9/22/2016 | BLM | Ca-Mg-SO4-Cl | South | 1609D24-001 | 7.74 | 3000.00 | 2100.00 | 380.00 | 110.00 | 130.00 | 3.70 | 440.00 | 151.70 | 151.70 | <2 | 830.00 | 0.91 | <0.1 | 3.90 | | | | | 0.29 | | | | | | | | | | | |
| | S-2016-100 | S-2016-100_22 Dec 16_2 | 12/22/2016 | BLM | Ca-Na-Cl-SO4 | South | | | 7100.00 | 5700.00 | 890.00 | 202.84 | 693.68 | 6.70 | 1426.34 | 162.70 | 162.70 | | 1780.80 | 1.26 | 1.06 | | | | | 0.01 | 0.92 | | | | 0.19 | | | 0.05 | 12.80 | 11.55 | 0.01 | |
| | S-2016-100 | S-2016-100_22 Dec 16 | 12/22/2016 | BLM | Ca-Na-Cl-SO4 | South | 1612D01-002 | 7.65 | 7100.00 | 5700.00 | 890.00 | 210.00 | 820.00 | 3.80 | 1500.00 | 162.70 | 162.70 | <2 | 1800.00 | 0.62 | 9.90 | 0.00 | | | | | 0.85 | | | | | | | | | | | |
| | S-2017-001 | S-2017-001_02 Feb 17_2 | 2/2/2017 | BLM | Ca-Mg-Na-HCO3-SO4 | South | | | 820.00 | 578.00 | 64.09 | 19.49 | 27.35 | 4.32 | 23.81 | 134.50 | 134.50 | | 55.60 | 1.78 | 20.08 | | | | | 0.10 | 0.16 | | | | 0.05 | 0.04 | | | 12.37 | 1.08 | | |
| | S-2017-001 | S-2017-001_02 Feb 17 | 2/2/2017 | BLM | Ca-Mg-SO4-HCO3 | South | -605174.00 | 7.89 | 820.00 | 578.00 | 65.00 | 19.00 | 26.00 | 2.60 | 23.00 | 134.50 | 134.50 | 0.00 | 160.00 | 0.10 | 0.00 | 19.00 | | | | | 0.00 | | | | | | | | | | | |
| Capitan Reef | CR-2015-001 | CR-2015-001_16 Feb 16 | 2/16/2016 | BLM | Na-Mg-SO4-Cl | Capitan Reef | | 8.08 | 2770.00 | 1951.00 | 1.40 | 82.30 | 225.00 | 6.60 | 388.80 | 182.50 | | 0.00 | 728.70 | 0.50 | 0.05 | 1.40 | <0.005 | | | 0.02 | 0.30 | <0.005 | <0.005 | | 0.04 | <0.001 | | | 7.10 | 2.52 | | |
| | CR-2015-001 | CR-2015-001_16 Feb 16_2 | 2/16/2016 | BLM | Ca-Na-Mg-Cl | Capitan Reef | | | 2770.00 | 1951.00 | 253.10 | 82.26 | 225.00 | 6.58 | 388.85 | 182.50 | 182.50 | 0.00 | 8.08 | 0.52 | 1.38 | 0.05 | | | | 0.02 | 0.32 | | | | 0.04 | | | | 7.10 | 2.52 | | |
| | CR-2015-002 | CR-2015-002_15 Sep 16_2 | 9/15/2016 | BLM | Na-Cl | Capitan Reef | | | | 25284.00 | 746.60 | 780.11 | 7297.10 | 358.36 | 14585.80 | 18.53 | 18.74 | 0.21 | 0.00 | 0.09 | | | | | 0.10 | 0.25 | 12.73 | | | 3.41 | 0.26 | 3.07 | 0.01 | | | 8.38 | | |
| | CR-2015-004 | CR-2015-004_19 Feb 16_2 | 2/19/2016 | BLM | Na-Ca-Cl | Capitan Reef | | | 36330.00 | 24039.00 | 2502.00 | 434.90 | 4490.00 | 949.20 | 12524.35 | 55.60 | 54.99 | 0.61 | 1975.67 | 0.10 | 4.26 | 0.05 | 0.02 | | | 0.12 | | | | | 0.72 | 0.15 | | | | 19.96 | | |
| | CR-2015-006 | CR-2015-006_17 Feb 16 | 2/17/2016 | BLM | Na-Cl | Capitan Reef | | 8.86 | 174500.00 | 140028.00 | 7.60 | 463.40 | 46700.00 | 3352.00 | 82396.50 | 249.27 | | 0.83 | 1528.30 | <0.1 | 0.05 | 7.60 | <0.005 | | | 0.02 | <0.1 | <0.005 | <0.005 | | 1.75 | 1.80 | | | <1 | 13.78 | | |
| | CR-2015-006 | CR-2015-006_17 Feb 16_2 | 2/17/2016 | BLM | Na-Cl | Capitan Reef | | | 174500.00 | 140028.00 | 648.90 | 463.40 | 46700.00 | 3352.00 | 82396.50 | 250.10 | 249.27 | 0.83 | 8.86 | | 7.60 | 0.05 | | | | 0.02 | | | | | 1.75 | 1.80 | | | | 13.78 | | |
| | CR-2015-007 | CR-2015-007_17 Feb 16_2 | 2/17/2016 | BLM | Na-Cl | Capitan Reef | | | 170000.00 | 141875.00 | 5902.00 | 1420.00 | 38700.00 | 1835.00 | 82602.10 | 109.40 | 108.98 | 0.42 | 1561.47 | | 6.80 | 0.04 | 0.04 | | | 0.15 | | | | | 4.49 | 7.61 | | | | 104.80 | | |

| | Station ID | Sample ID | Sample Date | Project | Water Type | Reference | Lab Code | pH (lab) | El. Cond. (uS/cm) | TDS (mg/L) | Ca (mg/L) | Mg (mg/L) | Na (mg/L) | K (mg/L) | Cl (mg/L) | Measured Alkalinity (mg/L) | HCO3 (mg/L) | CO3 (mg/L) | SO4 (mg/L) | F (mg/L) | NO2 (mg/L) | NO3 (mg/L) | Ag (mg/L) | Al (mg/L) | As (mg/L) | Ba (mg/L) | Br (mg/L) | Cd (mg/L) | Cu (mg/L) | Fe (mg/L) | Li (mg/L) | Mn (mg/L) | Ni (mg/L) | Pb (mg/L) | Si (mg/L) | Sr (mg/L) | U (mg/L) | V (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WIPP Wells (South HPA) | AEC-7 | AEC-7R_10 May 17 | 5/10/2017 | WIPP Test | Na-Mg-Cl | South | -79255.00 | 7.06 | 180000.00 | 91800.00 | 1500.00 | 3500.00 | 21000.00 | 1400.00 | 43000.00 | 54.77 | 57.44 | <2 | 6000.00 | <5 | <20 | <5 | | | | | 130.00 | | | | | | | | | | | |
| | AEC-7 | AEC-7R_15 Jul 14_ | 7/15/2014 | WIPP Test | Na-Mg-Cl | South | 1407862-001 | 7.38 | 130000.00 | 96300.00 | | 4330.00 | 23000.00 | 1800.00 | 55500.00 | 46.00 | 46.00 | <2 | 6450.00 | <2 | | | | | | | 170.00 | | | | | | | | | 32.00 | | |
| | AEC-7 | AEC-7R_11 Mar 15_ | 3/11/2015 | WIPP Test | Na-Mg-Cl | South | 1503573-001 | 7.41 | 180000.00 | 82500.00 | | 4700.00 | 22000.00 | 1900.00 | 58000.00 | 49.00 | 49.00 | <2 | 6600.00 | <5 | | | | | | | 160.00 | | | | | | | | | 29.00 | | |
| | H-4 | H-4bR_13 Aug 09_2 | 8/13/2009 | WIPP Test | Na-Cl-SO4 | South | 908237.00 | | | | | 260.00 | 4000.00 | 130.00 | 5900.00 | | | | 4600.00 | 1.60 | | | | | | | 39.00 | | | | | | | | | | | |
| | H-4 | H-4bR_13 Aug 09_ | 10/15/1987 | WIPP Test | Na-Cl-SO4 | South | 908237.00 | 7.76 | 24000.00 | 14900.00 | | 280.00 | 3800.00 | 130.00 | 6100.00 | 54.00 | 54.00 | <2 | 4500.00 | 2.90 | | | | | | | 24.00 | | | | | | | | | 12.00 | | |
| | H-4 | H-4bR_09 Mar 17_ | 3/9/2017 | WIPP Test | Na-Cl-SO4 | South | -98978.00 | 7.82 | 30000.00 | 16500.00 | 710.00 | 320.00 | 4400.00 | 130.00 | 5700.00 | 72.48 | 72.48 | <2 | 4400.00 | <1 | | | | | | | 41.00 | | | | | | | | | | | |
| | H-4 | H-4bR_09 Mar 17_2 | 3/9/2017 | WIPP Test | Na-Cl-SO4 | South | H700629-01 | 7.67 | 28100.00 | 16000.00 | 710.00 | 309.00 | 4270.00 | 130.00 | 5650.00 | 76.00 | 93.00 | <1 | 4390.00 | <3 | | | | | | | 26.20 | | | | | | | | | | | |
| | H-7 | H-7b1_27 Mar 86_1 | 3/27/1986 | WIPP Test | Mg-Na-SO4-Cl | South | DOE/WIPP 86-006 | 7.50 | 3390.00 | | 0.70 | 130.00 | 210.00 | 7.00 | 700.00 | 130.00 | | 0.00 | 2300.00 | 1.20 | | 0.70 | | <0.1 | 0.01 | 0.01 | 1.00 | | <0.010 | | | 0.05 | <0.03 | <0.05 | 43.00 | 5.80 | | |
| | H-7 | H-7b1_25 Apr 88_1 | 4/25/1988 | WIPP Test | Mg-Na-SO4-Cl | South | DOE/WIPP 89-001 | 6.95 | 3970.00 | | 0.70 | 130.00 | 200.00 | 8.20 | 290.00 | 120.00 | | 0.00 | 2000.00 | 1.50 | | 0.70 | <0.1 | <1.0 | 0.01 | <0.05 | <2 | <0.050 | <0.1 | | 0.12 | 0.06 | <0.3 | <0.5 | 20.00 | 8.40 | | <0.1 |
| | H-7 | H-7b1_25 Feb 87_1 | 2/25/1987 | WIPP Test | Mg-Na-SO4-Cl | South | DOE/WIPP 88-006 | 7.38 | 4120.00 | | 0.80 | 140.00 | 210.00 | 8.00 | 310.00 | 130.00 | | 0.00 | 1700.00 | 1.50 | | 0.80 | <0.1 | <1.0 | <0.050 | <0.05 | <2 | <0.050 | <0.1 | | 0.12 | 0.07 | <0.3 | <0.5 | 46.00 | 8.70 | | 0.10 |
| | H-7 | H-7b1_19 May 89_1 | 5/19/1989 | WIPP Test | Mg-Na-SO4-Cl | South | DOE/WIPP 91-025 | 7.00 | 4510.00 | | 0.74 | 130.00 | 170.00 | 7.20 | 250.00 | 110.00 | | 0.00 | 1700.00 | 1.50 | | 0.74 | <0.1 | <1.0 | 0.00 | <0.05 | 3.00 | <0.050 | <0.1 | | 0.11 | <0.05 | <0.3 | <0.5 | 20.00 | 8.20 | | 0.10 |
| | H-7 | H-7b1_09 Nov 90_ | 11/9/1990 | WIPP Test | Mg-SO4-Cl | South | ITLAB WKSHT | 7.14 | 3760.00 | | 0.90 | 140.00 | 100.00 | <50 | 280.00 | 92.00 | | 0.00 | 2100.00 | 1.50 | | 0.90 | <0.1 | <2.0 | <0.010 | <2 | <2 | <0.050 | <0.25 | | <0.1 | <0.15 | <0.4 | <0.5 | 23.00 | 8.50 | | <0.5 |
| | H-7 | H-7b1_26 Mar 86_ | 3/26/1986 | WIPP Test | Mg-Na-SO4-Cl | South | SAND86-0917 Tbl- 64 | 7.30 | 3700.00 | 322.00 | 2.80 | 130.00 | 207.00 | 7.00 | 320.00 | 120.00 | | 0.00 | 1850.00 | 1.50 | | 2.80 | | | <0.005 | | 0.57 | | | 0.08 | 0.10 | 0.05 | | | 47.00 | 8.50 | | |
| | H-7 | H-7b1_20 Apr 88_ | 4/20/1988 | WIPP Test | Cl | South | DOE/WIPP 89-001 | 7.20 | 3670.00 | | | | | | 297.00 | | | | | | | | | | | | | | | 0.03 | | | | | | | | |
| | H-7 | H-7b1_25 Apr 88_2 | 4/25/1988 | WIPP Test | Cl | South | DOE/WIPP 89-001 | 7.20 | 3680.00 | | 2.50 | | | | 294.00 | | | | | | | 2.50 | | | 0.00 | | | | | 0.04 | | | | | | | | |
| | H-7 | H-7b1_23 Apr 88_ | 4/23/1988 | WIPP Test | Cl | South | DOE/WIPP 89-001 | 7.20 | | | | | | | 291.00 | | | | | | | | | | | | | | | 0.04 | | | | | | | | |
| | H-7 | H-7b1_22 Apr 88_ | 4/22/1988 | WIPP Test | Cl | South | DOE/WIPP 89-001 | 7.20 | | | | | | | 293.00 | | | | | | | | | | | | | | | 0.04 | | | | | | | | |
| | H-7 | H-7b1_24 Apr 88_ | 4/24/1988 | WIPP Test | Cl | South | DOE/WIPP 89-001 | | | | | | | | 293.00 | | | | | | | | | | | | | | | 0.04 | | | | | | | | |
| | H-7 | H-7b1_27 Mar 86_2 | 3/27/1986 | WIPP Test | Cl | South | DOE/WIPP 86-006 | 7.20 | 3700.00 | | | | | | 308.50 | | | | | | | | | | | | | | | 0.05 | | | | | | | | |
| | H-7 | H-7b1_21 Apr 88_ | 4/21/1988 | WIPP Test | Cl | South | DOE/WIPP 89-001 | 7.20 | | | | | | | 292.00 | | | | | | | | | | | | | | | 0.06 | | | | | | | | |
| | H-7 | H-7b1_18 May 89_ | 5/18/1989 | WIPP Test | Cl | South | DOE/WIPP 91-025 | 7.29 | | | | | | | 292.00 | | | | | | | | | | | | | | | 0.06 | | | | | | | | |
| | H-7 | H-7b1_17 May 89_ | 5/17/1989 | WIPP Test | Cl | South | DOE/WIPP 91-025 | 7.26 | | | | | | | 291.00 | | | | | | | | | | | | | | | 0.07 | | | | | | | | |
| | H-7 | H-7b1_25 Mar 86_ | 3/25/1986 | WIPP Test | Cl | South | DOE/WIPP 86-006 | 7.20 | | | | | | | 312.00 | | | | | | | | | | | | | | | 0.08 | | | | | | | | |
| | H-7 | H-7b1_22 Mar 86_ | 3/22/1986 | WIPP Test | Cl | South | DOE/WIPP 86-006 | | | | | | | | 284.80 | | | | | | | | | | | | | | | 0.09 | | | | | | | | |
| | H-7 | H-7b1_19 May 89_2 | 5/19/1989 | WIPP Test | Cl | South | DOE/WIPP 91-025 | 7.28 | 3640.00 | | | | | | 289.00 | | | | | | | | | | | | | | | 0.09 | | | | | | | | |
| | H-7 | H-7b1_24 Mar 86_ | 3/24/1986 | WIPP Test | Cl | South | DOE/WIPP 86-006 | 7.30 | | | | | | | 312.00 | | | | | | | | | | | | | | | 0.09 | | | | | | | | |
| | H-7 | H-7b1_21 Mar 86_ | 3/21/1986 | WIPP Test | Cl | South | DOE/WIPP 86-006 | 7.20 | | | | | | | 284.80 | | | | | | | | | | | | | | | 0.10 | | | | | | | | |
| | H-7 | H-7b1_16 May 89_ | 5/16/1989 | WIPP Test | Cl | South | DOE/WIPP 91-025 | 7.27 | 3610.00 | | | | | | 289.00 | | | | | | | | | | | | | | | 0.11 | | | | | | | | |
| | H-7 | H-7b1_23 Mar 86_ | 3/23/1986 | WIPP Test | Cl | South | DOE/WIPP 86-006 | 7.30 | | | | | | | 309.50 | | | | | | | | | | | | | | | 0.11 | | | | | | | | |
| | H-7 | H-7b1_06 Nov 90_ | 11/6/1990 | WIPP Test | Cl | South | DOE/WIPP 91-008 | 7.36 | | | | | | | 276.00 | | | | | | | | | | | | | | | 0.12 | | | | | | | | |
| | H-7 | H-7b1_07 Nov 90_ | 11/7/1990 | WIPP Test | Cl | South | DOE/WIPP 91-008 | 7.32 | | | | | | | 277.00 | | | | | | | | | | | | | | | 0.14 | | | | | | | | |
| | H-7 | H-7b1_05 Nov 90_ | 11/5/1990 | WIPP Test | Cl | South | DOE/WIPP 91-008 | 7.35 | | | | | | | 276.00 | | | | | | | | | | | | | | | 0.15 | | | | | | | | |
| | H-7 | H-7b1_08 Nov 90_ | 11/8/1990 | WIPP Test | Cl | South | DOE/WIPP 91-008 | 7.34 | 3620.00 | | | | | | 275.00 | | | | | | | | | | | | | | | 0.17 | | | | | | | | |
| | H-7 | H-7b1_02 Nov 90_ | 11/2/1990 | WIPP Test | Cl | South | DOE/WIPP 91-008 | 7.35 | 3520.00 | | | | | | 277.00 | | | | | | | | | | | | | | | 0.22 | | | | | | | | |
| | H-7 | H-7b1_04 Nov 90_ | 11/4/1990 | WIPP Test | Cl | South | DOE/WIPP 91-008 | 7.38 | | | | | | | 277.00 | | | | | | | | | | | | | | | 0.55 | | | | | | | | |
| | H-7 | H-7b1_25 Feb 87_2 | 2/25/1987 | WIPP Test | SO4-Cl | South | DOE/WIPP 88-006 | 7.40 | 3300.00 | | | | | | 299.00 | | | | 1600.00 | | | | | | 0.00 | | | | | <0.02 | | | | | | | | |
| | H-7 | H-7b1_23 Feb 87_ | 2/23/1987 | WIPP Test | SO4-Cl | South | DOE/WIPP 88-006 | 7.20 | | | | | | | 297.00 | | | | 1600.00 | | | | | | | | | | | <0.02 | | | | | | | | |
| | H-7 | H-7b1_19 Feb 87_ | 2/19/1987 | WIPP Test | SO4-Cl | South | DOE/WIPP 88-006 | 7.20 | 3700.00 | | | | | | 284.00 | | | | 1800.00 | | | | | | | | | | | <0.02 | | | | | | | | |
| | H-7 | H-7b1_20 Feb 87_ | 2/20/1987 | WIPP Test | SO4-Cl | South | DOE/WIPP 88-006 | 7.30 | | | | | | | 287.00 | | | | 1800.00 | | | | | | | | | | | <0.02 | | | | | | | | |
| | H-7 | H-7b1_21 Feb 87_ | 2/21/1987 | WIPP Test | SO4-Cl | South | DOE/WIPP 88-006 | | | | | | | | 291.00 | | | | 1800.00 | | | | | | | | | | | <0.02 | | | | | | | | |
| | H-7 | H-7b1_22 Feb 87_ | 2/22/1987 | WIPP Test | SO4-Cl | South | DOE/WIPP 88-006 | 7.10 | | | | | | | 295.00 | | | | 1900.00 | | | | | | | | | | | <0.02 | | | | | | | | |
| | H-7 | H-7b1_24 Feb 87_ | 2/24/1987 | WIPP Test | SO4-Cl | South | DOE/WIPP 88-006 | 7.30 | | | | | | | 297.00 | | | | 2000.00 | | | | | | | | | | | <0.02 | | | | | | | | |
| | H-7 | H-7b1_20 Mar 80_ | 3/20/1980 | WIPP Test | Mg-Na-SO4-Cl | South | USGS WRIR 83-4016_39 | 7.00 | | 3610.00 | | 130.00 | 210.00 | 1.40 | 350.00 | | 100.00 | | 1900.00 | 1.40 | | | | | | | | | | | | | | | 39.00 | | | |
| | H-7 | H-7b1_12 Jul 17_ | 7/12/2017 | WIPP Test | Ca-Na-Mg-SO4-Cl | South | 657439.00 | 7.45 | 4900.00 | 4240.00 | 610.00 | 160.00 | 410.00 | 16.00 | 630.00 | 127.40 | 127.40 | <2 | 2200.00 | 1.60 | | | | | | | <1 | | | | | | | | | | | |
| | H-7 | H-7b1_20 Mar 86_ | 3/20/1986 | WIPP Test | Cl | South | DOE/WIPP 86-006 | 7.30 | 3600.00 | | | | | | 261.10 | | | | | | | | | | | | | | | | | | | | | | | |
| | H-9 | H-9bR_07 Aug 12_ | 8/7/2012 | WIPP Test | Mg-SO4 | South | 1208471-001 | 7.60 | 3400.00 | 3350.00 | | 140.00 | 130.00 | 8.30 | 160.00 | 94.00 | 94.00 | <2 | 1900.00 | 3.00 | | | | | | | <1 | | | | | | | | | 7.70 | | |
| | H-9 | H-9bR_07 Jun 17_ | 6/7/2017 | WIPP Test | Ca-Mg-SO4 | South | 216592.00 | 7.87 | 3700.00 | 3360.00 | 580.00 | 140.00 | 180.00 | 7.30 | 210.00 | 89.56 | 89.56 | <2 | 1900.00 | 3.00 | | | | | | | <0.5 | | | | | | | | | | | |
| | H-9 | H-9bR_28 Jun 11_ | 6/28/2011 | WIPP Test | Mg-SO4 | South | 1106C12-01 | 7.98 | 3400.00 | 3330.00 | | 150.00 | 140.00 | 6.90 | 170.00 | 100.00 | 100.00 | <2 | 2000.00 | 3.20 | | | | | | | 0.26 | | | | | | | | | 7.20 | | |
| | H-9 | H-9bR_20 Aug 12_ | 8/20/2012 | WIPP Test | Mg-SO4 | South | 1208942-001 | 7.68 | 3400.00 | 3380.00 | | 140.00 | 150.00 | 7.40 | 180.00 | 94.00 | 94.00 | <2 | 2000.00 | 3.40 | | | | | | | <1 | | | | | | | | | 8.00 | | |
| | H-10 | H-10cR_27 Jul 17_ | 7/27/2017 | WIPP Test | Na-Cl | South | 1707E52-001 | 7.48 | 270000.00 | 146000.00 | 1500.00 | 2100.00 | 48000.00 | 930.00 | 69000.00 | 63.64 | 63.64 | <2 | 7000.00 | <10 | <100 | <10 | | | | | 60.00 | | | | | | | | | | | |
| | H-10 | H-10cR_26 Jul 17_ | 7/26/2017 | WIPP Test | Na-Cl | South | 1707E53-001 | 7.50 | 270000.00 | 146000.00 | 1600.00 | 2200.00 | 35000.00 | 960.00 | 72000.00 | 65.44 | 65.44 | <2 | 7100.00 | <10 | | | | | | | 58.00 | | | | | | | | | | | |
| | H-11 | H-11b4R_09 Mar 17_ | 3/9/2017 | WIPP Test | Na-Cl | South | -99344.00 | 7.33 | 200000.00 | 113000.00 | 1800.00 | 1300.00 | 37000.00 | 710.00 | 64000.00 | 91.28 | 91.28 | <2 | 7700.00 | <5 | <20 | <5 | | | | | 170.00 | | | | | | | | | | | |
| | H-11 | H-11b4R_11 Jun 12_ | 6/11/2012 | WIPP Test | Na-Cl | South | 1206571-001 | 7.24 | 180000.00 | 111000.00 | | 1400.00 | 41000.00 | 840.00 | 61000.00 | 45.00 | 45.00 | <2 | 6900.00 | <10 | | | | | | | 48.00 | | | | | | | | | 29.00 | | |
| | H-11 | H-11b4R_09 Mar 17_2 | 3/9/2017 | WIPP Test | Na-Cl | South | H700630-01 | 7.26 | 182000.00 | 104000.00 | 1900.00 | 1340.00 | 35900.00 | 747.00 | 61200.00 | 116.00 | 142.00 | <1 | 7560.00 | <20 | | | | | | | 43.60 | | | | | | | | | | | |
| | H-11 | H-11b4R_14 Jun 12_ | 6/14/2012 | WIPP Test | Na-Cl | South | 1206666-001 | 7.24 | 180000.00 | 112000.00 | | 1500.00 | 42000.00 | 940.00 | 65000.00 | 42.00 | 42.00 | <2 | 8400.00 | <20 | | | | | | | 41.00 | | | | | | | | | 29.00 | | |
| | H-19 | H-19b0_10 May 17_ | 5/10/2017 | WIPP Test | Na-Cl | South | -78890.00 | 8.18 | 190000.00 | 97700.00 | 1400.00 | 950.00 | 25000.00 | 560.00 | 47000.00 | 74.08 | 74.08 | <2 | 6100.00 | <5 | <20 | <5 | | | | | 37.00 | | | | | | | | | | | |
| | H-19 | H-19b0_31 Aug 06_ | 8/31/2006 | WIPP Test | Na-Cl | South | 609003.00 | 7.42 | 170000.00 | 90000.00 | <5 | 1100.00 | 27000.00 | 680.00 | 47000.00 | 46.00 | 46.00 | <2 | 4800.00 | <5 | <50 | <5 | | | | | 50.00 | | | | | | | | | 23.00 | | |
| | SNL-1 | SNL-1_15 Jun 16_ | 6/15/2016 | WIPP Test | Na-Cl | South | | 7.31 | 67000.00 | 37644.00 | 2.10 | 734.10 | 10050.00 | 351.00 | 18112.34 | 143.50 | | <2 | 3599.49 | 1.97 | <0.1 | 2.10 | <0.001 | <0.010 | 0.29 | 0.02 | 11.68 | | 0.06 | 0.03 | 0.85 | 0.29 | 0.01 | <0.005 | 8.88 | 18.69 | <0.005 | <0.001 |
| | SNL-1 | SNL-1_10 Mar 05_ | 3/10/2005 | WIPP Test | Na-Cl | South | 503129.00 | 6.68 | 130000.00 | 34000.00 | | 670.00 | 11000.00 | 250.00 | 18000.00 | 230.00 | 230.00 | <4 | 3500.00 | 1.70 | | | | | | | 32.00 | | | | | | | | | | | |
| | SNL-1 | SNL-1_08 Aug 17_ | 8/8/2017 | WIPP Test | Na-Cl | South | 1028524.00 | 7.10 | 70000.00 | 36600.00 | 1400.00 | 590.00 | 9800.00 | 260.00 | 17000.00 | 137.00 | 137.00 | <2 | 4200.00 | <10 | | | | | | | 12.00 | | | | | | | | | | | |
| | SNL-1 | SNL-1_29 May 04_ | 5/29/2004 | WIPP Test | Na-Cl | South | 536320.00 | 7.22 | 150000.00 | 36000.00 | | 730.00 | 10000.00 | 340.00 | 19000.00 | 76.00 | 76.00 | <2 | 3700.00 | <2.5 | | | | | | | 17.00 | | | | | | | | | | | |
| | SNL-1 | SNL-1_25 Mar 04_ | 3/25/2004 | WIPP Test | Na-Cl | South | 536432.00 | 6.82 | 199900.00 | 330000.00 | | 4500.00 | 91000.00 | 21000.00 | 190000.00 | 290.00 | 290.00 | <2 | 15000.00 | <50 | | | | | | | 440.00 | | | | | | | | | | | |
| | SNL-1 | SNL-1_06 Dec 03_ | 12/6/2003 | WIPP Test | Na-Cl | South | | | | | | 828.00 | 5770.00 | 378.00 | 15799.00 | 97.00 | | | 1465.00 | | | | | | | | | | | | | | | | | | | |
| | SNL-13 | SNL-13_12 Apr 05_ | 4/12/2005 | WIPP Test | Mg-Na-SO4-Cl | South | 504146.00 | 8.02 | 4300.00 | 3800.00 | 5.20 | 150.00 | 270.00 | 5.70 | 440.00 | 58.00 | 58.00 | <2 | 2200.00 | 1.60 | <0.1 | 5.20 | | | | | 1.30 | | | | | | | | | | | |
| | SNL-13 | SNL-13_17 Jul 06_ | 7/17/2006 | WIPP Test | Na-Cl-SO4 | South | 607213.00 | 8.49 | 40000.00 | 21000.00 | | 330.00 | 5200.00 | 190.00 | 8500.00 | 50.00 | 50.00 | <2 | 3300.00 | 3.20 | | | | | | | 31.00 | | | | | | | | | 16.90 | | |
| | SNL-13 | SNL-13_26 Apr 05_ | 4/26/2005 | WIPP Test | Na-Cl | South | 504272.00 | 6.55 | 190000.00 | 290000.00 | | 10000.00 | 95000.00 | 2300.00 | 190000.00 | 76.00 | 76.00 | <4 | 5300.00 | <20 | | | | | | | 1400.00 | | | | | | | | | | | |
| | SNL-13 | SNL-13_08 Mar 17_ | 3/8/2017 | WIPP Test | Na-Cl-SO4 | South | -98248.00 | 8.31 | 35000.00 | 22300.00 | 990.00 | 310.00 | 5400.00 | 180.00 | 8100.00 | 41.72 | 39.72 | 2.00 | 3400.00 | <5 | | | | | | | 39.00 | | | | | | | | | | | |
| | SNL-16 | SNL-16_15 Jun 16_ | 6/15/2016 | WIPP Test | Na-Cl | South | | 7.33 | 39000.00 | 23353.00 | 2.53 | 590.40 | 4703.00 | 473.00 | 10263.20 | 93.50 | | <2 | 2306.38 | 1.83 | <0.1 | 2.53 | <0.001 | <0.010 | 0.29 | 0.02 | 4.54 | | <0.005 | 0.07 | 0.74 | 0.13 | 0.01 | <0.005 | 13.50 | 23.64 | <0.005 | <0.001 |
| | SNL-16 | SNL-16_09 Jun 06_ | 6/9/2006 | WIPP Test | Na-Cl | South | 606131.00 | 7.19 | 35000.00 | 18000.00 | | 430.00 | 4400.00 | 290.00 | 8600.00 | 97.00 | 97.00 | <2 | 2500.00 | 2.50 | | | | | | | <5 | | | | | | | | | 18.20 | | |
| | SNL-16 | SNL-16_18 Apr 06_ | 4/18/2006 | WIPP Test | Na-Mg-Cl-SO4 | South | 604195.00 | 7.25 | 23000.00 | 13000.00 | | 600.00 | 2000.00 | 61.00 | 6000.00 | 110.00 | 110.00 | <2 | 1900.00 | 2.80 | | | | | | | <5 | | | | | | | | | | | |
| | SNL-16 | SNL-16_08 Aug 17_ | 8/8/2017 | WIPP Test | Na-Ca-Cl | South | 1027794.00 | 7.20 | 39000.00 | 24000.00 | 1700.00 | 500.00 | 5100.00 | 280.00 | 11000.00 | 94.24 | 94.24 | <2 | 2400.00 | <10 | | | | | | | 4.10 | | | | | | | | | | | |
| | SNL-16 | SNL-16_09 Nov 15_ | 11/9/2015 | WIPP Test | Na-Cl | South | 817780.00 | 7.27 | 40000.00 | 24200.00 | | 530.00 | 5300.00 | 300.00 | 11000.00 | 96.40 | 96.40 | <2 | 2400.00 | <2 | | | | | | | 2.90 | | | | | | | | | 24.00 | | |
| | SNL-18 | SNL-18_14 Jun 16_ | 6/14/2016 | WIPP Test | Na-Cl-SO4 | South | | 7.78 | 17000.00 | 15841.00 | 2.52 | 345.10 | 2996.00 | 142.00 | 6053.85 | 51.90 | | <2 | 2311.21 | 1.74 | <0.1 | 2.52 | <0.001 | 4.06 | 0.24 | 0.03 | 4.50 | | <0.005 | 1.62 | 0.40 | 0.60 | 0.01 | <0.005 | 20.04 | 13.00 | <0.005 | <0.001 |
| | SNL-18 | SNL-18_18 Aug 06_ | 8/18/2006 | WIPP Test | Na-Cl-SO4 | South | 608258.00 | 7.51 | 38000.00 | 19000.00 | | 360.00 | 5200.00 | 120.00 | 8700.00 | 75.00 | 75.00 | <2 | 3700.00 | 1.70 | | | | | | | 5.60 | | | | | | | | | 15.90 | | |
| | SNL-18 | SNL-18_12 Jul 17_ | 7/12/2017 | WIPP Test | Na-Cl | South | 658169.00 | 7.69 | 34000.00 | 19500.00 | 1100.00 | 380.00 | 5500.00 | 120.00 | 9500.00 | 60.92 | 60.92 | <2 | 3100.00 | <1 | | | | | | | 7.70 | | | | | | | | | | | |
| | SNL-19 | SNL-19_14 Jun 16_ | 6/14/2016 | WIPP Test | Na-Cl-SO4 | South | | 7.64 | 12000.00 | 8933.00 | 2.35 | 244.60 | 1591.00 | 77.00 | 2679.78 | 93.50 | | <2 | 2193.62 | 2.01 | <0.1 | 2.35 | <0.001 | <0.010 | 0.14 | 0.01 | 2.63 | | <0.005 | 0.13 | 0.34 | 0.03 | <0.0005 | <0.005 | 15.54 | 12.00 | <0.005 | <0.001 |
| | SNL-19 | SNL-19_28 Jul 06_ | 7/28/2006 | WIPP Test | Na-Cl-SO4 | South | 608005.00 | 7.74 | 12000.00 | 8100.00 | | 220.00 | 1600.00 | 43.00 | 2700.00 | 90.00 | 90.00 | <2 | 2300.00 | 1.50 | | | | | | | 1.60 | | | | | | | | | 11.40 | | |
| | SNL-19 | SNL-19_11 Jul 17_ | 7/11/2017 | WIPP Test | Na-Ca-Cl-SO4 | South | 657074.00 | 7.48 | 13000.00 | 8180.00 | 790.00 | 210.00 | 1600.00 | 40.00 | 2800.00 | 98.08 | 98.08 | <2 | 2200.00 | <1 | | | | | | | <1 | | | | | | | | | | | |
| | WIPP-11 | WIPP-11_15 Dec 04_ | 12/15/2004 | WIPP Test | Na-Cl | South | 538587.00 | 7.47 | 91000.00 | 50000.00 | | 890.00 | 16000.00 | 370.00 | 28000.00 | 56.00 | 56.00 | <4 | 4200.00 | 1.10 | | | <0.5 | | | | 23.00 | | | | | | | | | | | |
| | WIPP-11 | WIPP-11_12 Apr 17_ | 4/12/2017 | WIPP Test | Na-Cl | South | -464587.00 | 8.59 | 100000.00 | 54000.00 | 1600.00 | 660.00 | 17000.00 | 380.00 | 27000.00 | 30.80 | <20 | 16.08 | 3300.00 | <1 | <10 | <1 | | | | | 22.00 | | | | | | | | | | | |
| | WIPP-11 | WIPP-11_20 Feb 05_ | 2/20/2005 | WIPP Test | Na-Cl | South | 502260.00 | 7.03 | 160000.00 | 49000.00 | | 810.00 | 15000.00 | 360.00 | 26000.00 | 78.00 | 78.00 | <4 | 6300.00 | <2 | | | | | | | 37.00 | | | | | | | | | | | |

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