Union County Hydrogeology Project

Annual Progress Report

2014-2015

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Introduction

This report is Zeigler Geologic Consulting, LLC's (ZGC) annual progress report for the Union County Hydrogeology Project, sponsored by the Northeastern Soil and Water Conservation District. This report builds on data and observations previously presented in Zeigler (2011, 2012), Rawling (2013) and Zeigler et al. (2013, 2014). During the 2014-2015 fiscal year, ZGC measured static water level in 52 wells in January, continued revisions of the four 1:50,000 scale quadrangles for the Dry Cimarron valley, obtained a tritium dating water sample, examined geophysical logs from four additional petroleum wells in the county and downloaded data from six data recorders, as well as installing two new data recorders. We also measured baseline water levels for an additional 22 wells in the Dry Cimarron valley in June and July that will be added to the monitoring network in January 2016. Here we describe the progress in each of these tasks. A final report with detailed interpretations and integration of all data sets will be produced at the culmination of this project in 2018. We gratefully acknowledge the generous hospitality of families along the Dry Cimarron valley, as well as the assistance of Mr. Nathaniel Boyd. Additional logistical support has been provided by the staff of the NRCS and FSA offices in Clayton. Previous funding for this project was generously provided by the Northeastern SWCD, Soil and Water Conservation Commission (NM Department of Agriculture), El Llano Estacado RC&D, Union County, the City of Clayton and by capital outlay funding.

Static Water Level Measurements

Beginning in August of 2007, depth to water has been measured in fifty-plus wells spread across the county in January (minimum pumping) and August (maximum pumping). A 300 ft steel tape is used for most of the wells and a 500 ft steel tape for wells deeper than 300 ft. For open casing wells, we use a well level sounder (maximum length of 300 ft). The measuring point, or height of the entrance to the well above land surface, is subtracted from the total depth measurement such that the final static water level for all wells is calculated relative to the land surface. Measurements are repeated until two values that are within 0.1 ft or less of one another are obtained. Four wells have been removed from the study for various reasons (going dry, casing disintegrating, etc.): 23N 35E 29.122 (Anderson Rd.), 23N 34E 16.422 (Thomas Hwy South), 30N 37E 20.321 (Kenton Hwy North), 28N 36E 28.131 (Kenton Hwy) and 27N 37E 18.222 (Seneca Valley). Twenty-four wells have been added to the study: Bennefield #3, Burchard #2, Brown 1-3, Spool 1-12, and Durrett 1-7. Each of these only has a single or two measurements, but these wells will be tracked for the next few years.

Of the wells that have been tracked, 24 show an overall increase in water level and 30 show a decline (numbers include wells dropped from the study in 2012 through 2015). Individual hydrographs for each well still being monitored are found in Appendix I. Water level trends were determined using only the January measurements in order to avoid potential issues with measurements on wells that had perhaps not fully recovered after having pumps turned off. Average increase is 1.0 ft and the average decline is 1.5 ft, each over eight years. Geographically, wells that show a decline are located primarily around the Sedan and Seneca Valley areas, with a smaller area of decline east of Gladstone (Figure 1, Table 1, Appendix II).

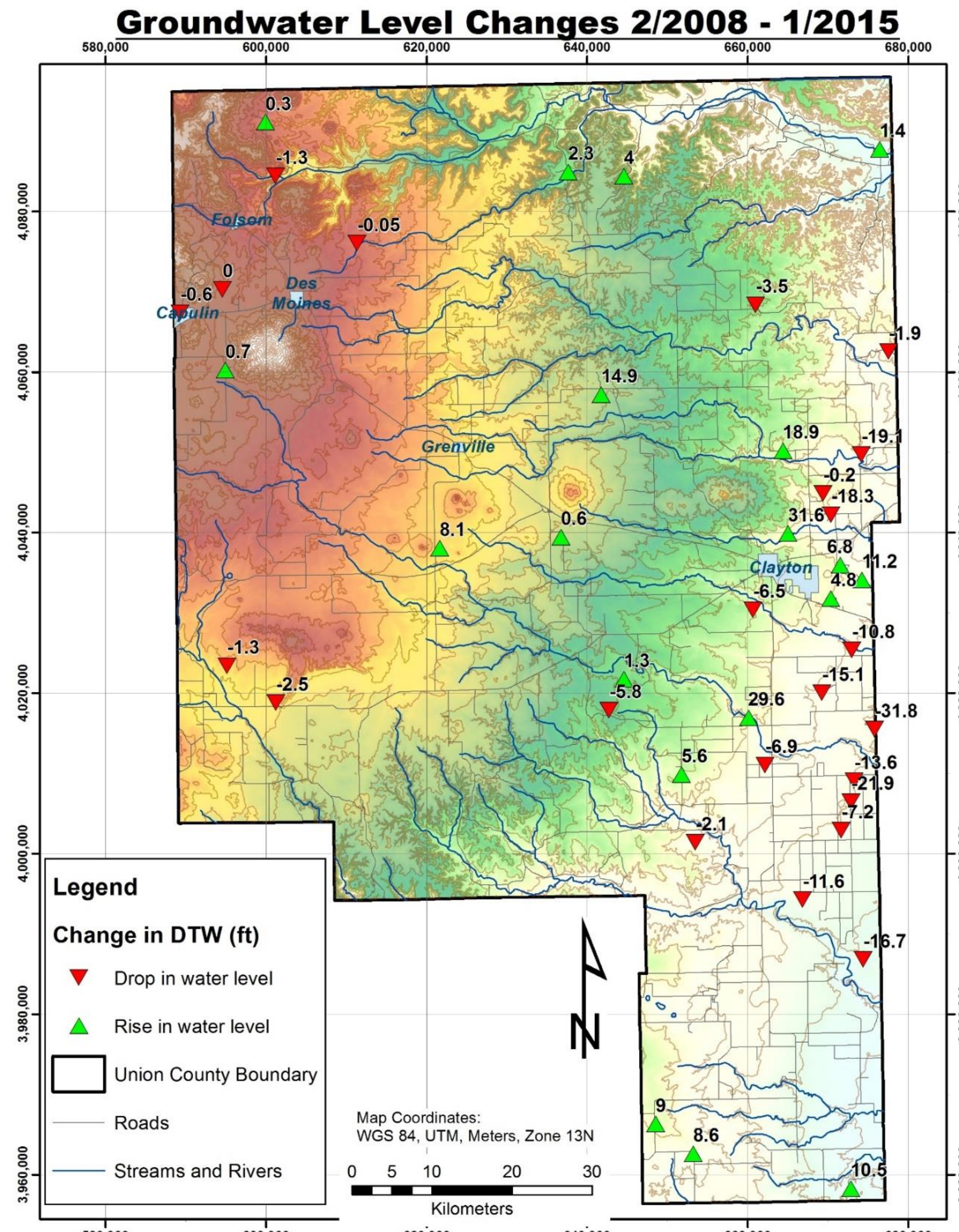


Figure 1. Changes in static water level from January 2008 to January 2015.

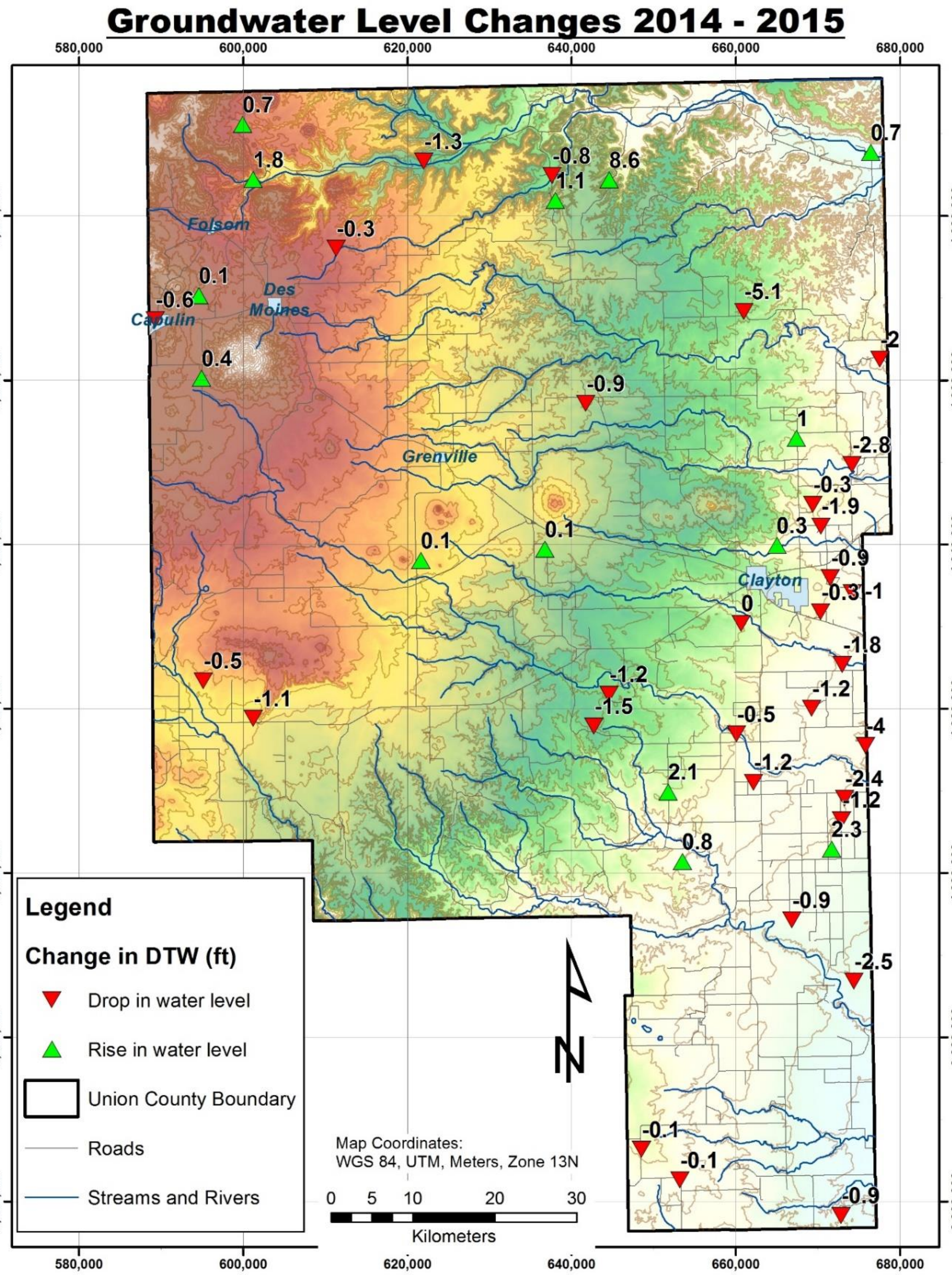


Figure 2. Changes in static water level from January 2014 to January 2015.

Tritium Dates

We collected two liters of water (one primary sample, one duplicate sample) from one well on the west flank of Sierra Grande that has one of the youngest radiocarbon dates in the county (Figure 3). The sample was analyzed by the Tritium Laboratory at the University of Miami. Tritium is a radioactive isotope that has a very short half-life of just 12.3 years. It is most commonly used to determine relative age of waters that are less than fifty years old (Clark and Fritz, 1997). Tritium is produced both as a natural byproduct of interaction of cosmic radiation with the stratosphere and comes into the water cycle by precipitation, but also was produced anthropogenically in large volumes during testing of thermonuclear bombs in the 1950s. The majority of the bomb-produced tritium has decreased significantly such that most modern dating is reflecting the natural tritium signal (Clark and Fritz, 1997). In the 2013-2014 sampling effort, four wells were sampled for tritium, three of which had previously been sampled for radiocarbon dating. In 2014-2015, a single sample was collected. Bannon Oak Canyon, Kennedy, Major Creek and Jordan Road wells have both radiocarbon and tritium results. Bennefield #1 has only tritium results.

In the table below, the results of the tritium analyses are displayed, as well as in the attendant figure. Generally, a tritium value (in tritium units or TU) less than 0.8 TU indicates pre-1952 or no modern recharge. Tritium values between 0.8 TU and 4.0 TU indicate a mixture of modern recharge and pre-1952 recharge and values between 5 and 15 TU indicate waters that are modern (5-10 years old). The Oak Canyon and Bennefield #1 wells are located in tributary canyons to the Dry Cimarron valley and it is reasonable to expect young recharge, given that the radiocarbon dates in wells along the Dry Cimarron are all relatively young when compared to the rest of the county. Jordan Road well is southwest of Clayton and has the oldest radiocarbon date of these wells. Other wells in this part of the county have significantly older radiocarbon dates associated with them. Major Creek well has the youngest radiocarbon date for the southeast part of the county, and is located in a tributary to Tramperos Creek. Kennedy Road well is on the western flank of Sierra Grande and has one of the youngest radiocarbon ages for wells not within the Dry Cimarron or its tributaries.

Well ID	Tritium (in TU)	Age Interpretation	^{14}C Date
Bannon Oak Canyon	6.11	Modern	590
Bennefield #1	5.38	Modern	Not sampled
Jordan Road	0	Pre-1952/no recharge	1500
Major Creek	1.57	Mixed modern and pre-1952 recharge	920
Kennedy Road	0.74	Pre-1952/no recharge	190

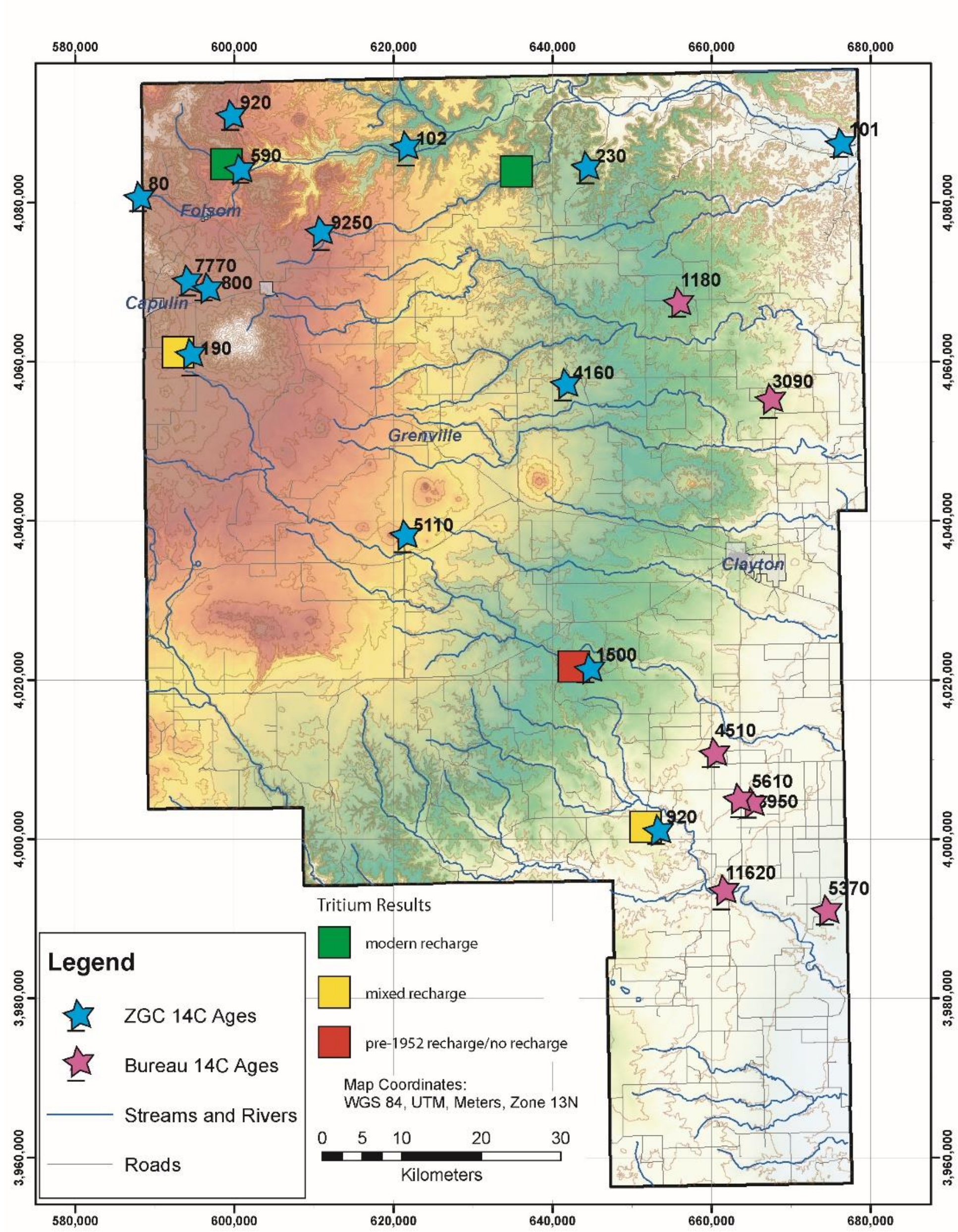


Figure 3. ^{14}C and tritium age determinations representing average residence time of groundwater in aquifer units.

Geologic Mapping

We are continuing to revise geologic maps of the 1:50,000 quadrangles that encompass the Dry Cimarron valley (previously published as Baldwin and Muehlberger, 1959). Maps that have had in-field revisions completed are currently being digitized. The Raton-Capulin volcanic field and related features dominate the headwaters of the Dry Cimarron valley with multiple stacked basalt flows that overlap one another as well as older Mesozoic rocks. Within the Dry Cimarron valley itself, outcrop exposures include (in ascending age order): Triassic Dockum Group, Jurassic Exeter Sandstone, Wanakah (=Bell Ranch) Formation and Morrison Formation, Cretaceous Lytle Sandstone, Glencairn Formation and Dakota Group. The Dockum Group is dominantly red to purple siltstones and fine sandstones with some mudstones and conglomerates. Four formations are exposed locally (in ascending order): Baldy Hill, Travesser, Sloan Canyon and Sheep Pen Formations. The Dockum Group is folded into broad, open anticlines and synclines with hingelines oriented approximately north-south. The lowest unit in the Dockum Group, the Baldy Hill Formation, is exposed only around Baldy Hill itself, in the center of the Dry Cimarron valley.

The Exeter Sandstone is a pinkish red to bright yellow to white eolian sandstone with large scale trough crossbeds that has a variable thickness created by infilling of the folded Dockum surface. On some anticline hinges, no Exeter Sandstone is present and on others, up to a meter or two may be present. Syncline hinges preserve upwards of 26 to 30 m of Exeter outcrop. The Wanakah Formation is a brownish red siltstone to fine sandstone with stringers, nodules and lenses of alabaster. The thickness of this unit varies from less than a meter to upwards of 10 meters. The overlying Morrison Formation includes green, blue and purple mudstones with ledges of lake-deposited limestone and an occasional channel sandstone. The limestone units are very pale gray lithographic micrite that are very well cemented. The channel sandstones vary in thickness and width, are medium to coarse grained, often pebbly and with common interstitial clay. The Lytle Sandstone outcrops as a prominent white to yellow band about two-thirds of the way up the slope. It is coarse grained with pebbles scattered throughout its thickness as well as crossbeds. It grades upwards into the claystone-dominated Glencairn Formation. The transition between the two units is often marked by a bed rich in gryphaeid oyster shells.

The Dakota Group consists of a lower thick sandstone unit, a middle shale unit, and an upper sandstone unit. The lower sandstone is the Mesa Rica Sandstone and represents deposition in a braided river/fan system. The shale unit, termed the Pajarito Formation, contains oyster shell fragments and most likely was deposited under shallow marine conditions and the upper sandstone is called the Romeroville Sandstone and is a complex sequence of beach sands, bar deposits and thin shales representing slightly deeper water conditions. Above the Romeroville

Sandstone is the Graneros Shale, which consists of dark gray shales and mudstone with thin limestone beds in the middle part of the unit. Often these thin limestone beds are full of oyster shells from inoceramids, shark teeth and can retain impressions of ammonoid shells.

In addition to mapping the bedrock geology, we have collected data on fracture orientations along the Dry Cimarron. Dominant directions of fractures can be used to estimate potential groundwater flow paths. In the Dry Cimarron, fractures are oriented primarily east-west. In the western Dry Cimarron and at Travesser Park in the central part of the valley, fractures and the large grabens are oriented east-northeast to west-southwest. Just east of Travesser Park, in the area of Peacock Canyon, the fractures are due east-west. To the east, around Sloan Canyon, the fractures are east-southeast to west-northwest oriented.

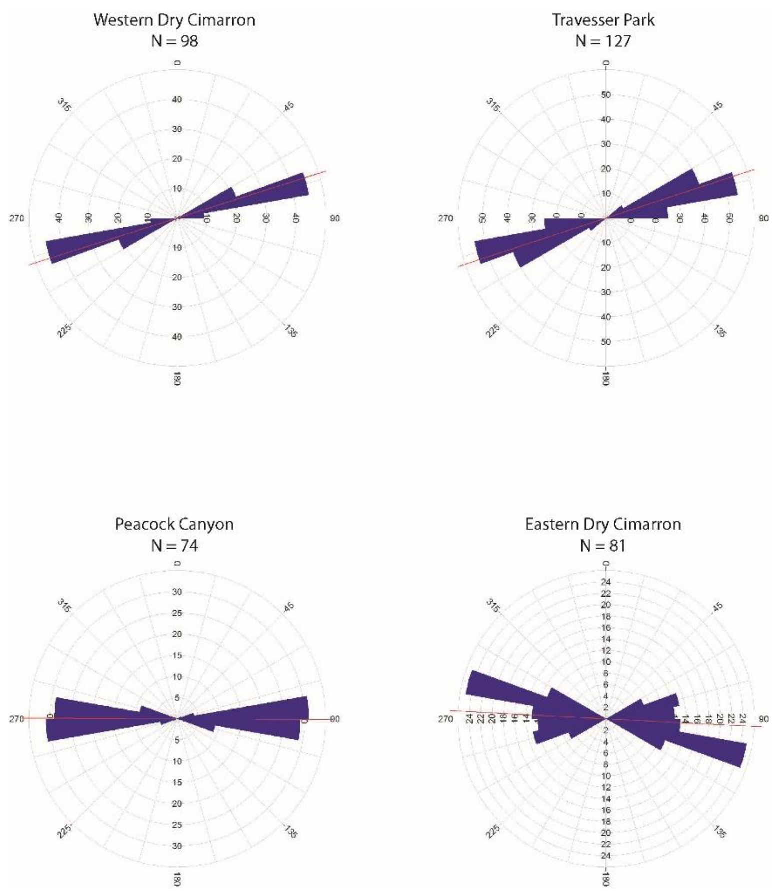
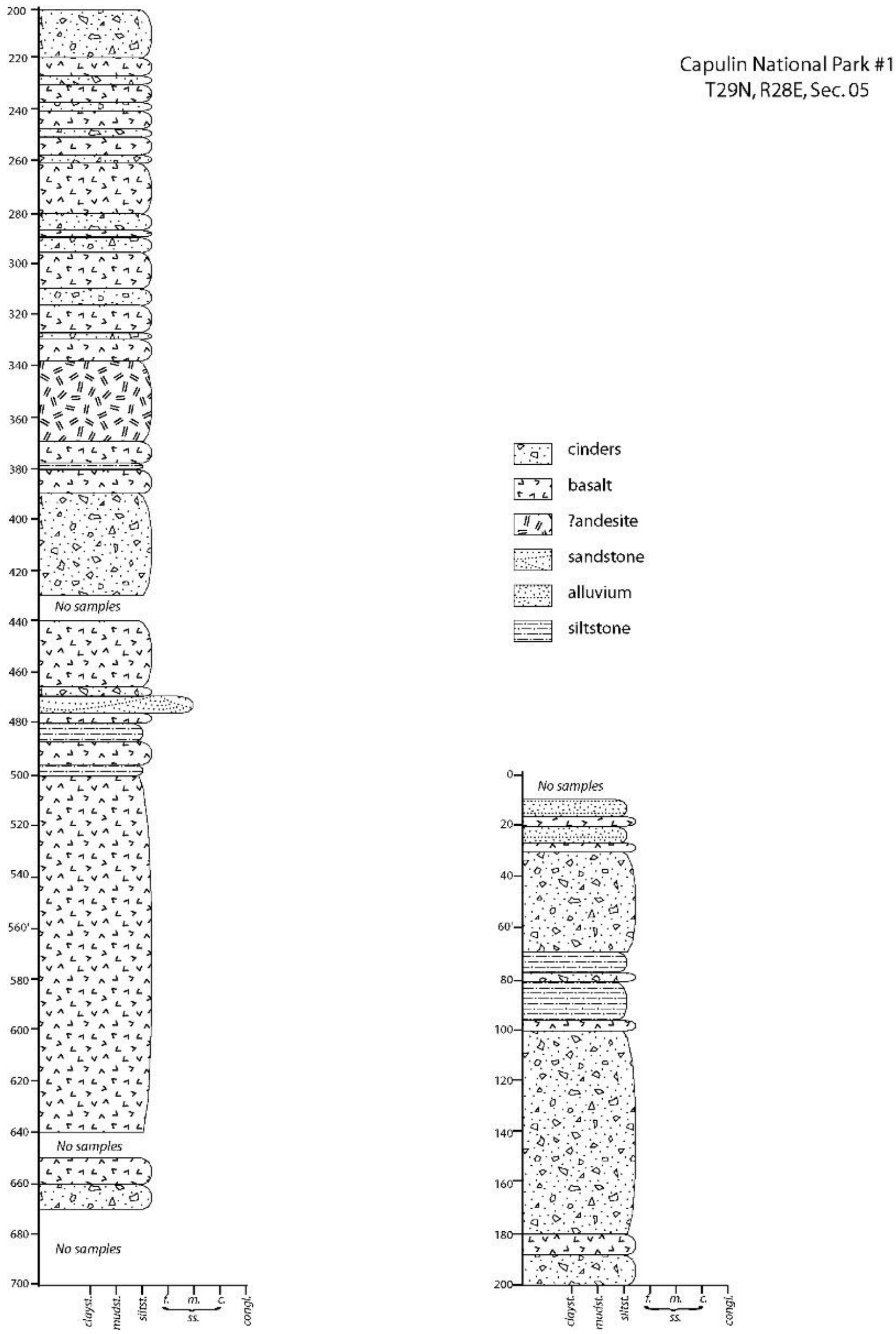
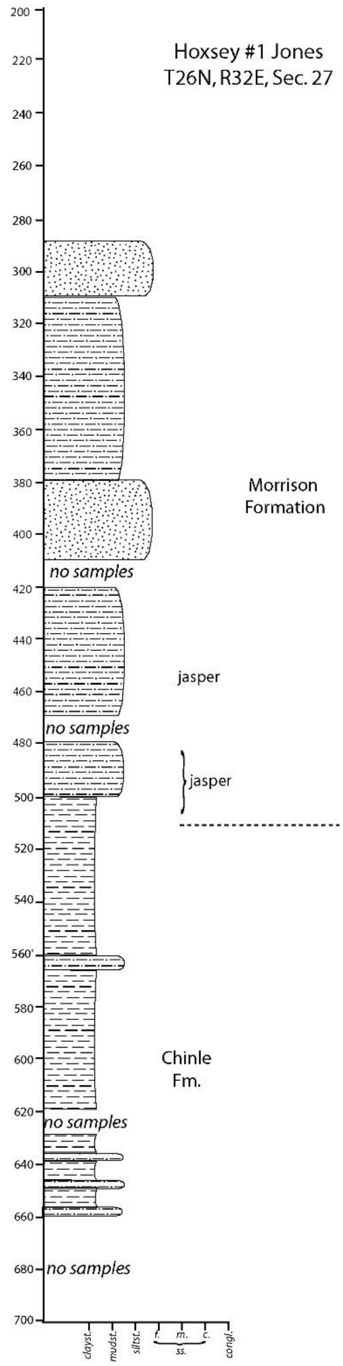


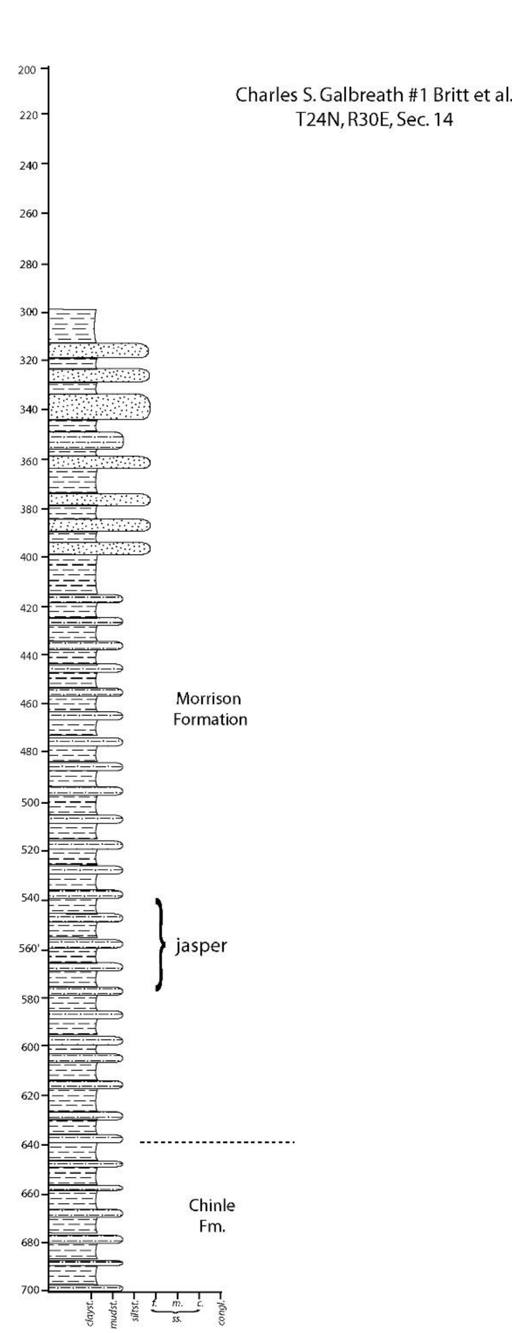
Figure 4. Fracture orientations from bedrock exposures in the Dry Cimarron.

Petroleum Well Cuttings and Subsurface Analysis

Cuttings and logs were examined from four wells in western and central Union County (Figures 5 and 6). Wells that provide information for a partial southwest to northeast cross-section include the Galbreath #1 W.E. Britt et al., Hoxsey #1 Jones and Freeman #1 Smith. The fourth well examined is at Capulin National Monument. These wells show the variability of the contact between the Triassic redbeds and overlying Jurassic strata. There does not appear to be significant Exeter Sandstone in the three central wells. The Capulin National Monument well is comprised almost entirely of volcanic debris. All of these observations provide insight into the dimensions and relative positions of potential aquifer units in the subsurface, but we caution against attempting to use these data to predict the depth and size of an aquifer unit.


Capulin National Park #1
T29N, R28E, Sec. 05
cinders
basalt
?andesite
sandstone
alluvium
siltstone
No samples
No samples
No samples
No samples
clayst.
mudst.
siltst.
f.
m.
c.
ss.
congl.


Hoxsey #1 Jones
T26N, R32E, Sec. 27
Morrison Formation
no samples
jasper
no samples
jasper
Chinle Fm.
no samples
no samples
clayst.
mudst.
siltst.
f.
m.
c.
ss.
congl.


Charles S. Galbreath #1 Britt et al.
T24N, R30E, Sec. 14
Morrison Formation
jasper
Chinle Fm.
clayst.
mudst.
siltst.
f.
m.
c.
ss.
congl.

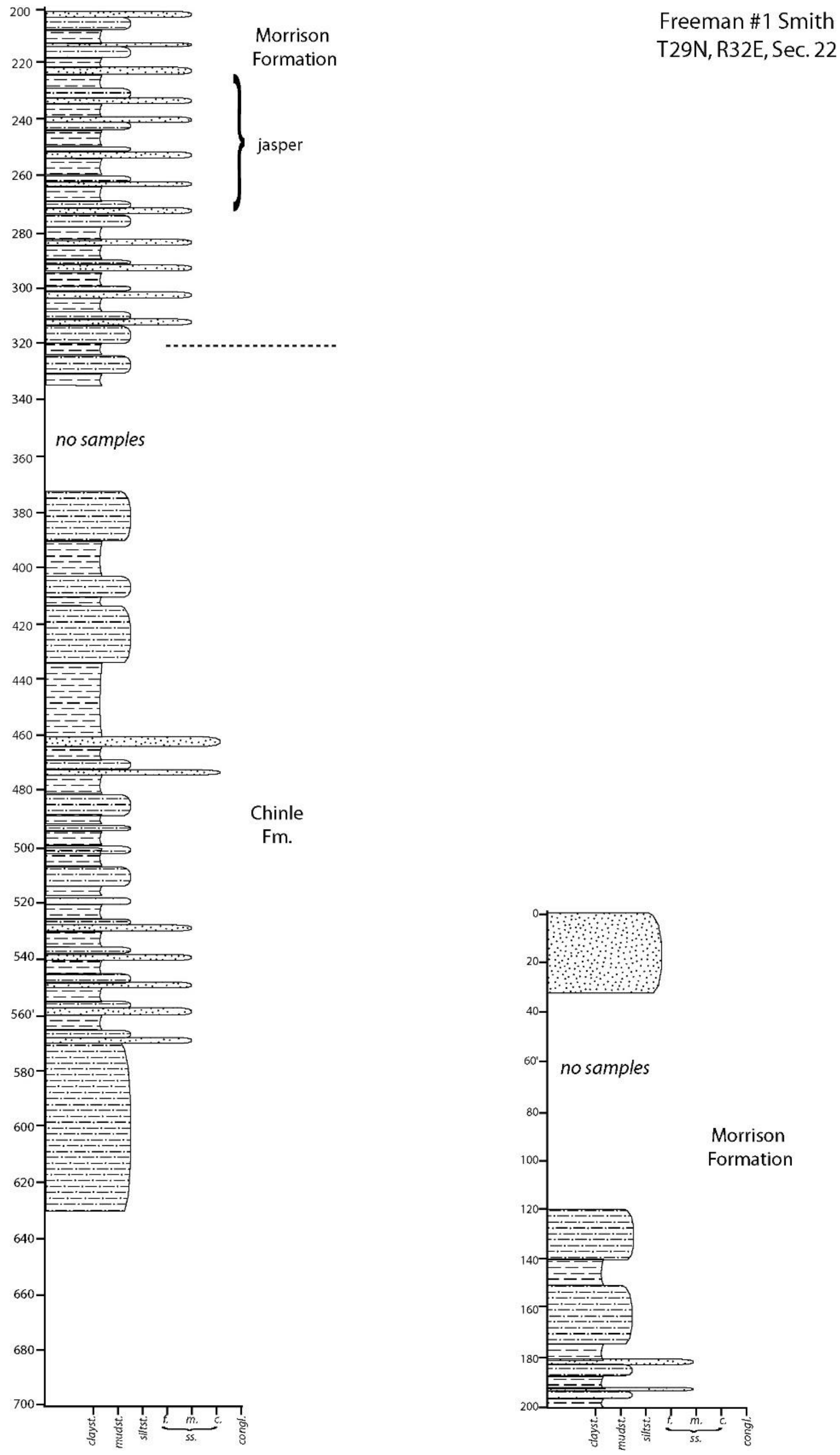


Figure 5. Interpretive stratigraphic columns for petroleum exploration wells from west central Union County to Clayton.

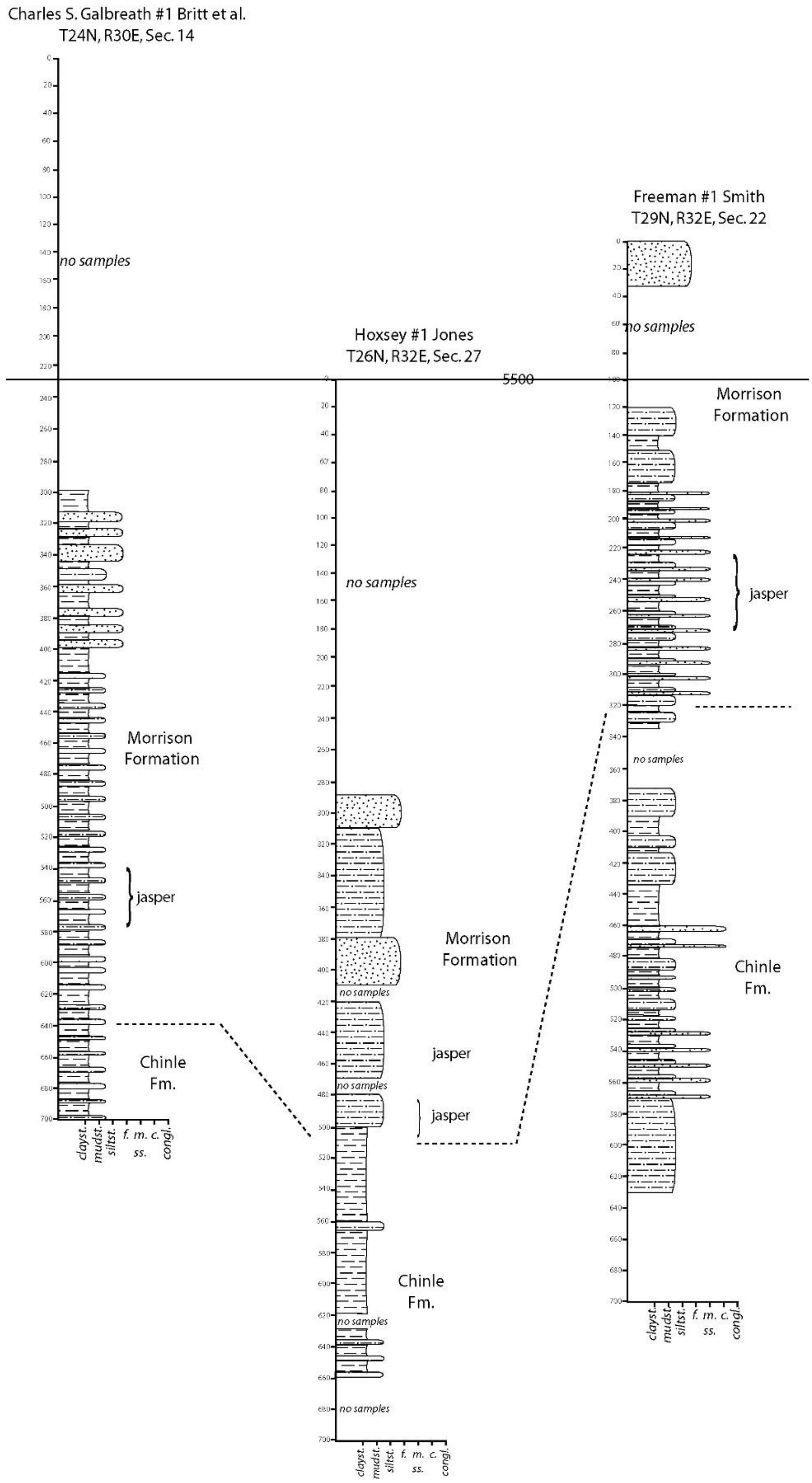
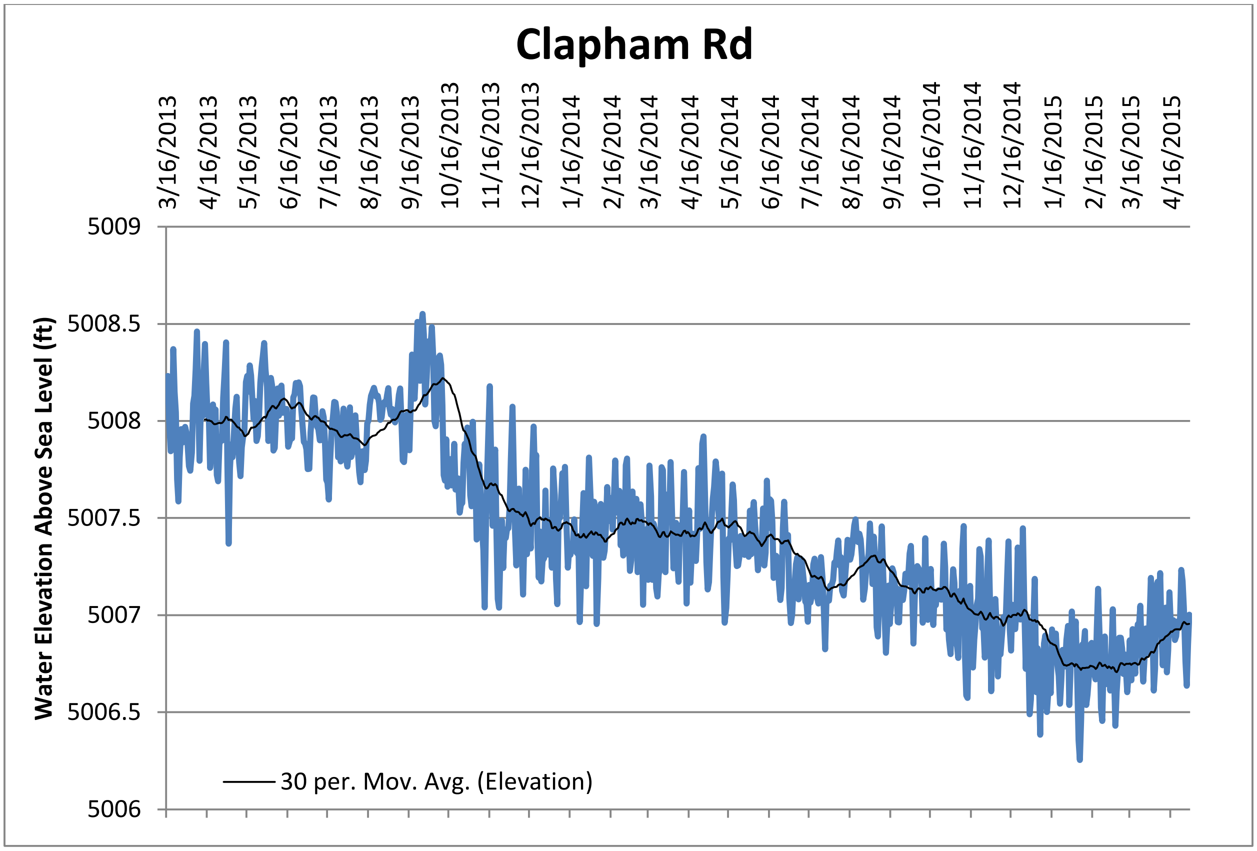


Figure 6. Interpretive stratigraphic columns with possible correlations hung from 5500' elevation.

Data Recorders

In the spring of 2013, eight data recorders were installed in wells that had been abandoned. The wells were chosen along a northwest-southeast transect that begins at the Texas state line and ends just southwest of Clayton. The data recorders are programmed to record the static water level in each well twice a day (at 6 am and 6 pm). The data recorders are removed from the wells every three months so that the data can be downloaded and then are returned to the wells. Two data recorders were lost in the first six months of operation. These two were replaced in the summer of 2014 (Harris East and Poling). The original six are still being monitored and have now been in place for 25 months. Hydrographs for each well appear nearly identical and show primarily a barometric pressure response, with small daily fluctuations (Figure 7 and 8). Generally, the data loggers record an overall decline in water levels in the area, which matches the static water level measurements. Pettegrew Farm, Romero Road and Seaman East Pasture all show a small increase in the last few months. This may reflect a displacement of water elsewhere in the aquifer unit versus recharge of those units. However, this displacement may well reflect recharge entering the water table from farther west. The abrupt changes in the Romero Road and Tramperos Creek hydrographs reflect periods when the data recorder did not reinstall properly.


Clapham Rd
Water Elevation Above Sea Level (ft)
5009
5008.5
5008
5007.5
5007
5006.5
5006
3/16/2013
4/16/2013
5/16/2013
6/16/2013
7/16/2013
8/16/2013
9/16/2013
10/16/2013
11/16/2013
12/16/2013
1/16/2014
2/16/2014
3/16/2014
4/16/2014
5/16/2014
6/16/2014
7/16/2014
8/16/2014
9/16/2014
10/16/2014
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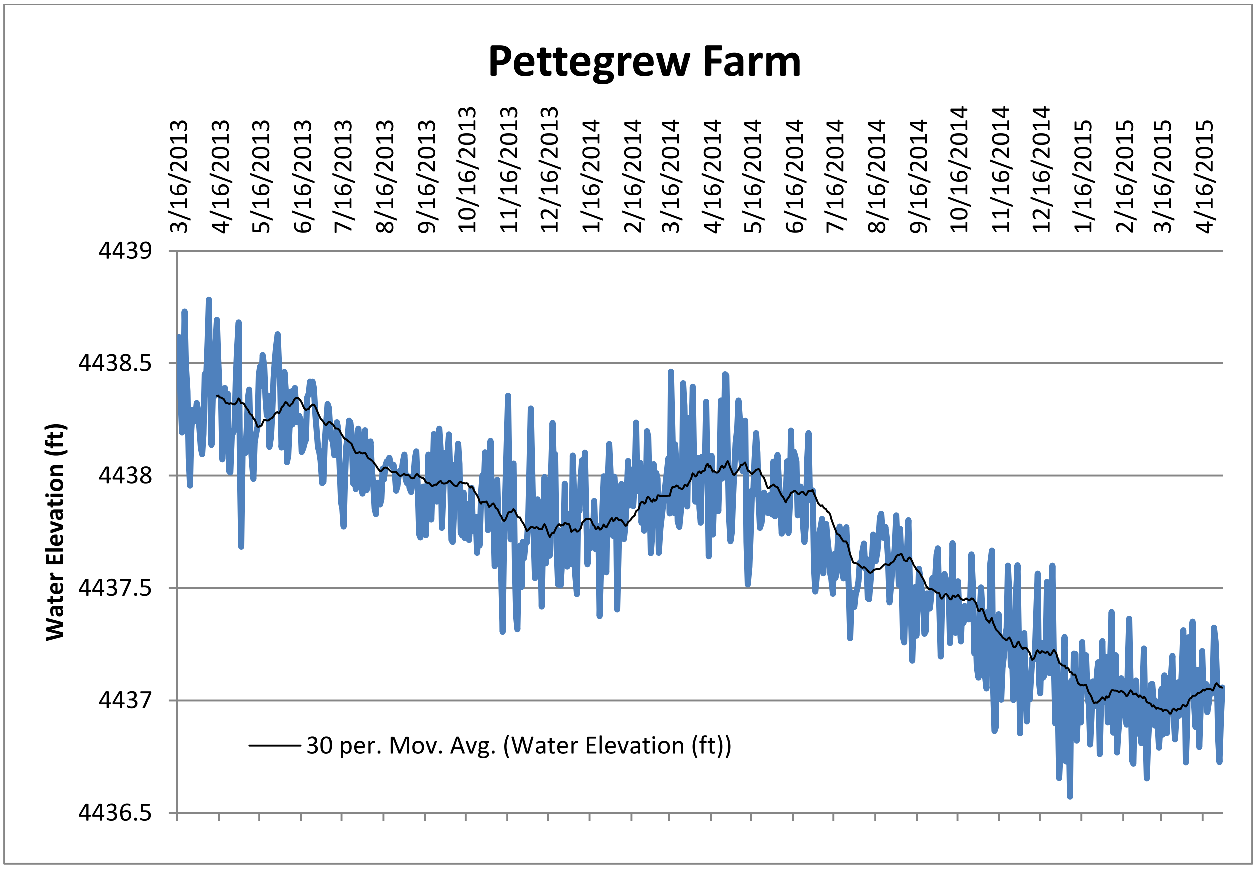
3/16/2015
4/16/2015
30 per. Mov. Avg. (Elevation)


Pettegrew Farm
Water Elevation (ft)
4439
4438.5
4438
4437.5
4437
4436.5
3/16/2013
4/16/2013
5/16/2013
6/16/2013
7/16/2013
8/16/2013
9/16/2013
10/16/2013
11/16/2013
12/16/2013
1/16/2014
2/16/2014
3/16/2014
4/16/2014
5/16/2014
6/16/2014
7/16/2014
8/16/2014
9/16/2014
10/16/2014
11/16/2014
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1/16/2015
2/16/2015
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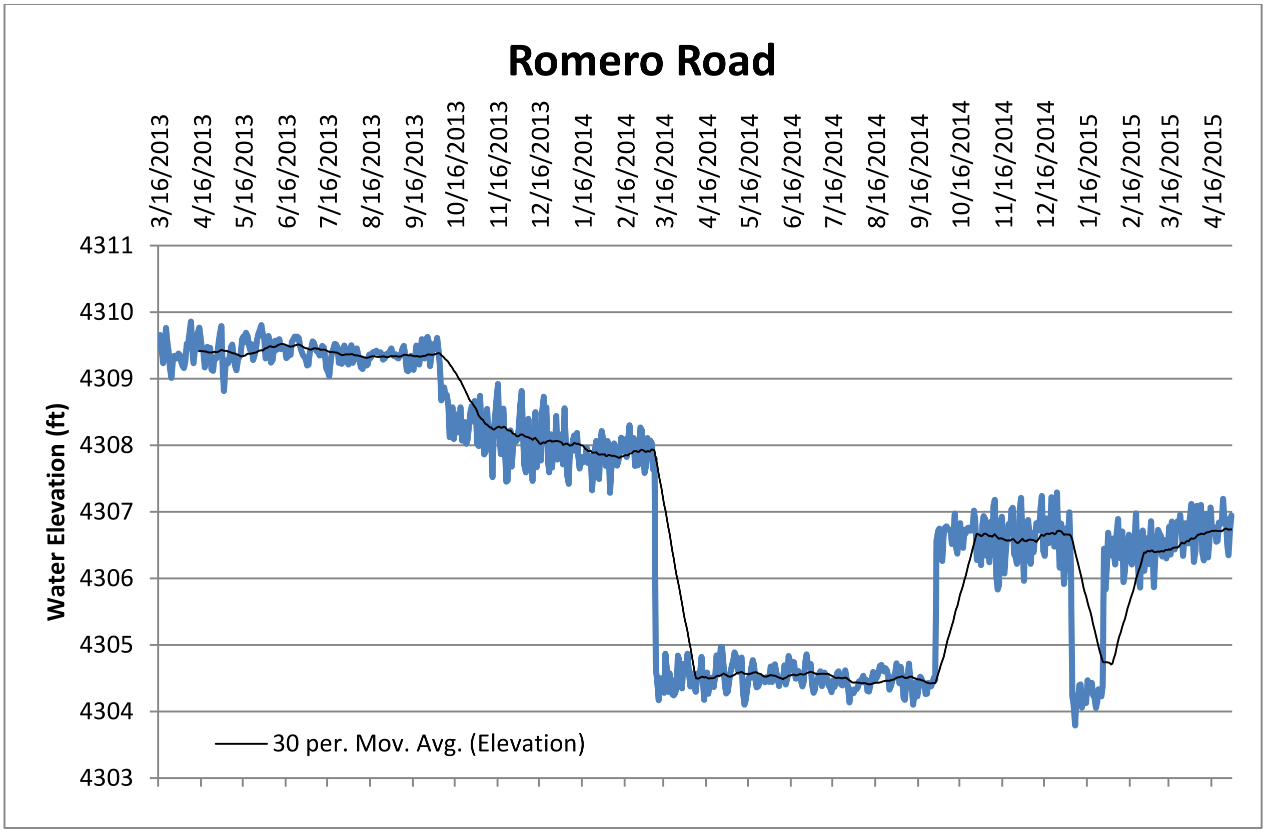
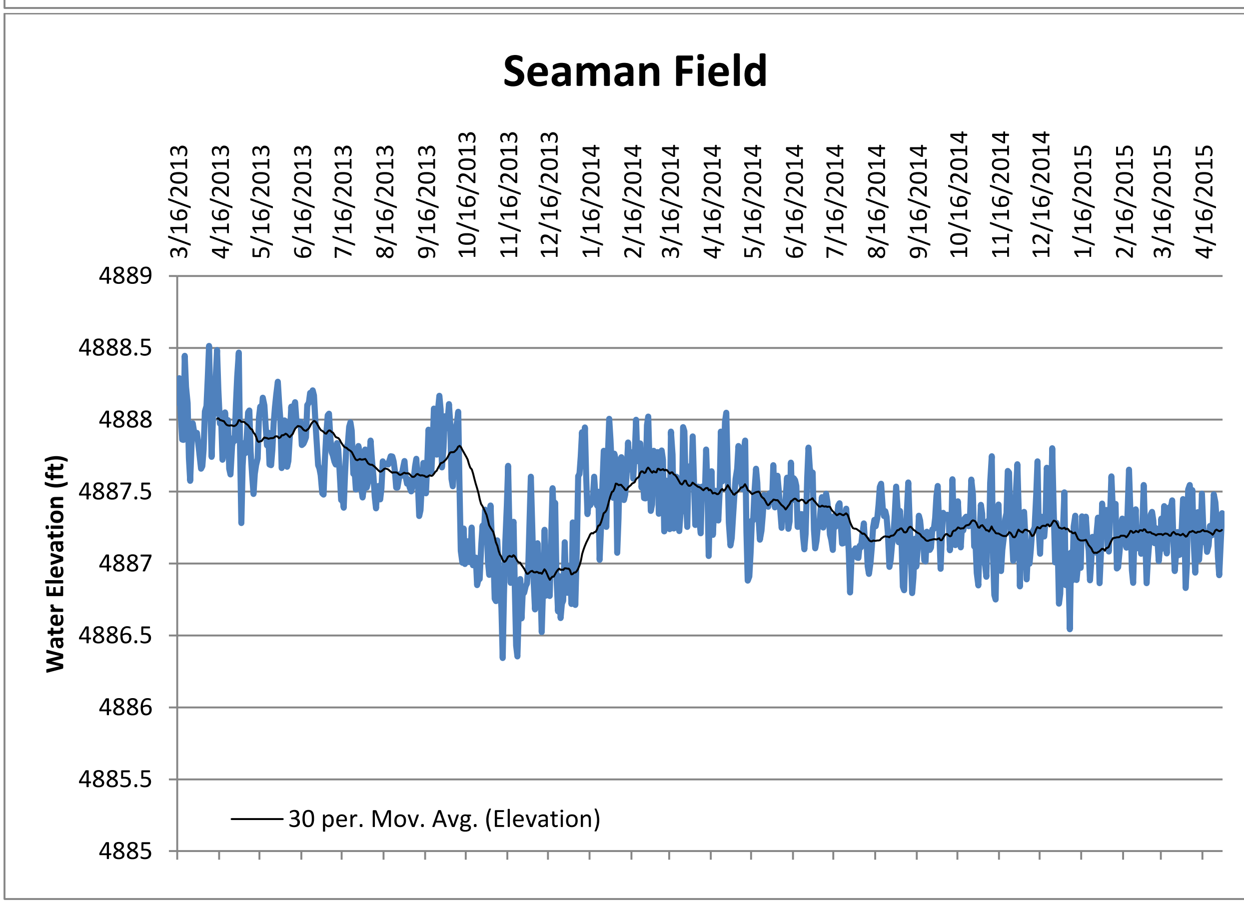
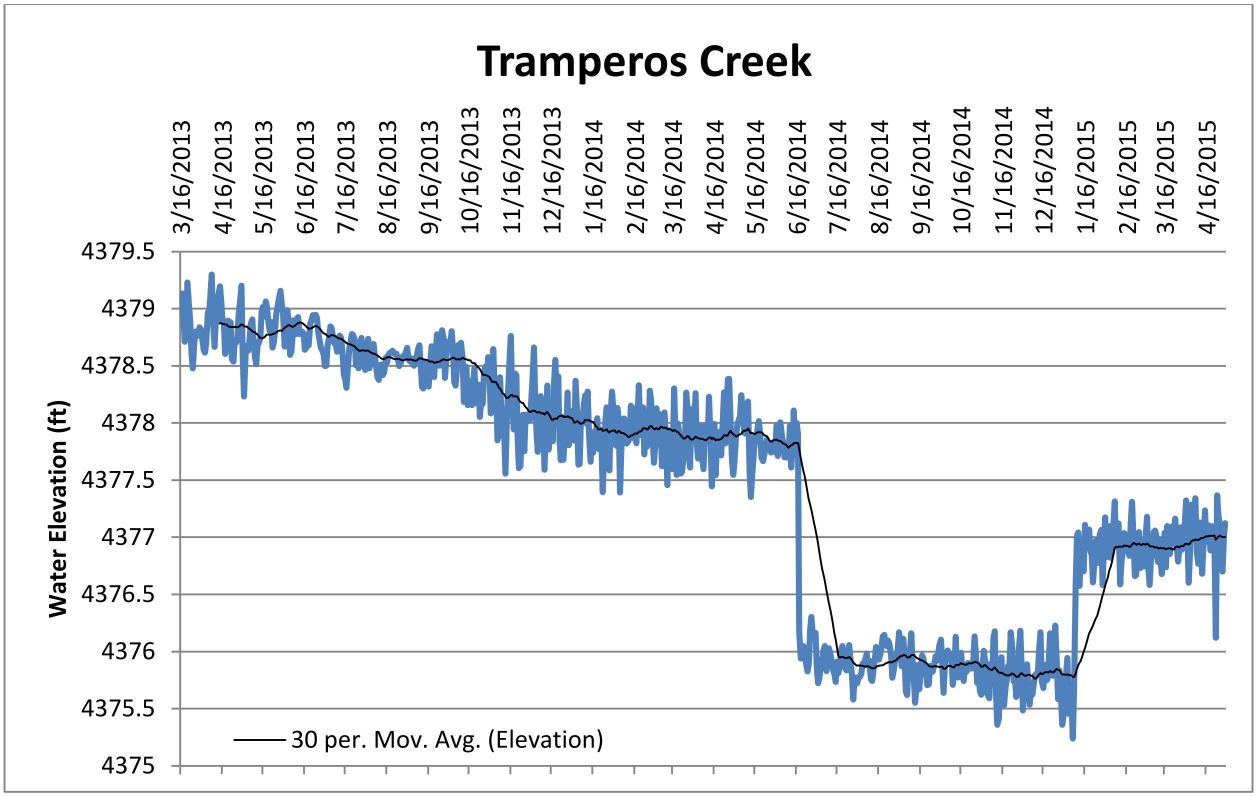
4/16/2015
30 per. Mov. Avg. (Water Elevation (ft))


Romero Road
3/16/2013
4/16/2013
5/16/2013
6/16/2013
7/16/2013
8/16/2013
9/16/2013
10/16/2013
11/16/2013
12/16/2013
1/16/2014
2/16/2014
3/16/2014
4/16/2014
5/16/2014
6/16/2014
7/16/2014
8/16/2014
9/16/2014
10/16/2014
11/16/2014
12/16/2014
1/16/2015
2/16/2015
3/16/2015
4/16/2015
Water Elevation (ft)
4311
4310
4309
4308
4307
4306
4305
4304
4303
30 per. Mov. Avg. (Elevation)


Seaman Field
3/16/2013
4/16/2013
5/16/2013
6/16/2013
7/16/2013
8/16/2013
9/16/2013
10/16/2013
11/16/2013
12/16/2013
1/16/2014
2/16/2014
3/16/2014
4/16/2014
5/16/2014
6/16/2014
7/16/2014
8/16/2014
9/16/2014
10/16/2014
11/16/2014
12/16/2014
1/16/2015
2/16/2015
3/16/2015
4/16/2015
Water Elevation (ft)
4889
4888.5
4888
4887.5
4887
4886.5
4886
4885.5
4885
30 per. Mov. Avg. (Elevation)



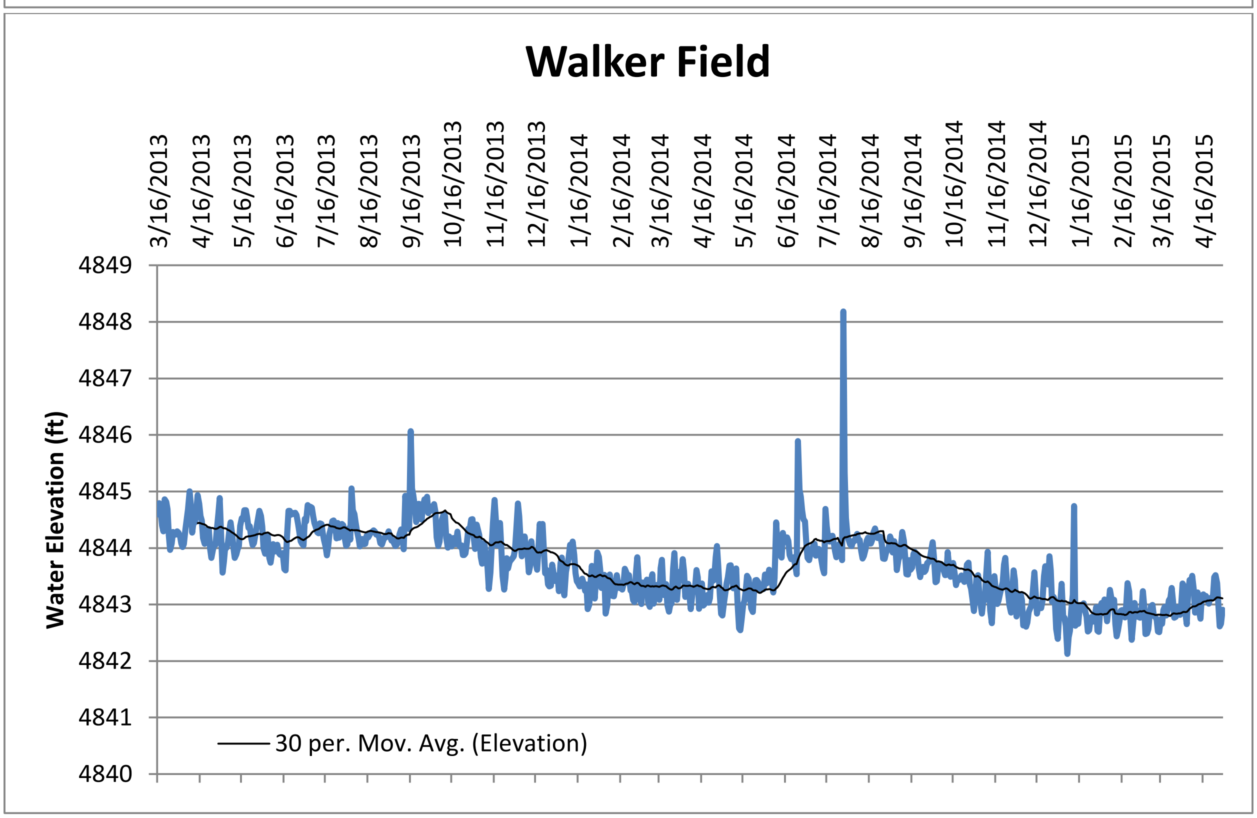
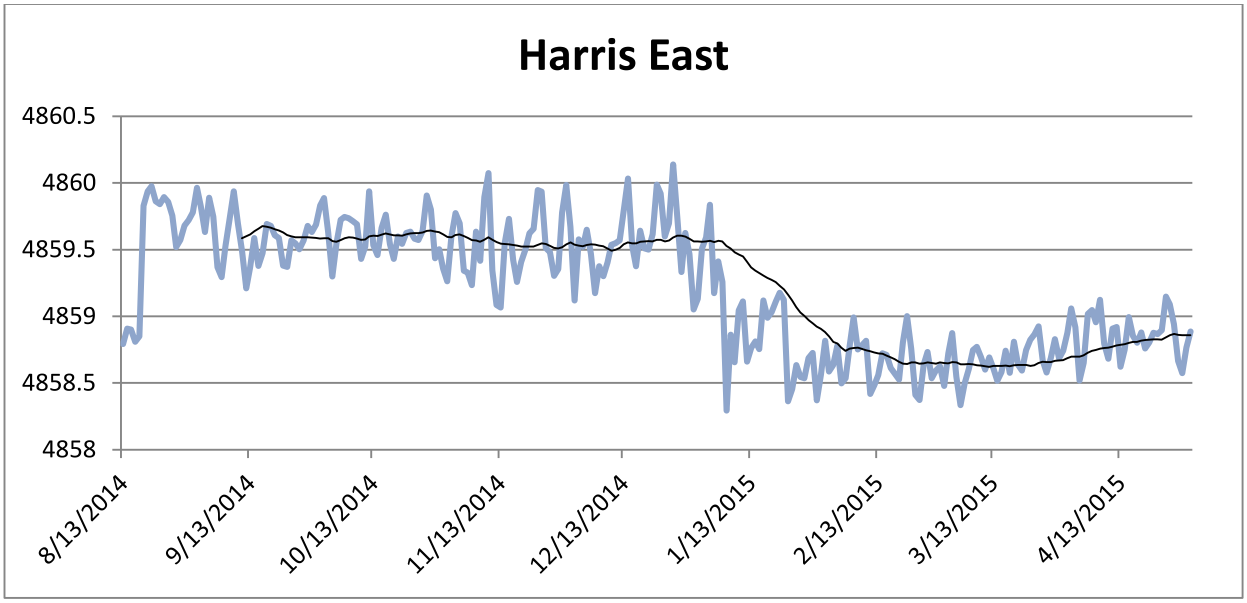


Figure 7. Hydrographs for data loggers installed in eastern Union County from March 2013 to April 2015.



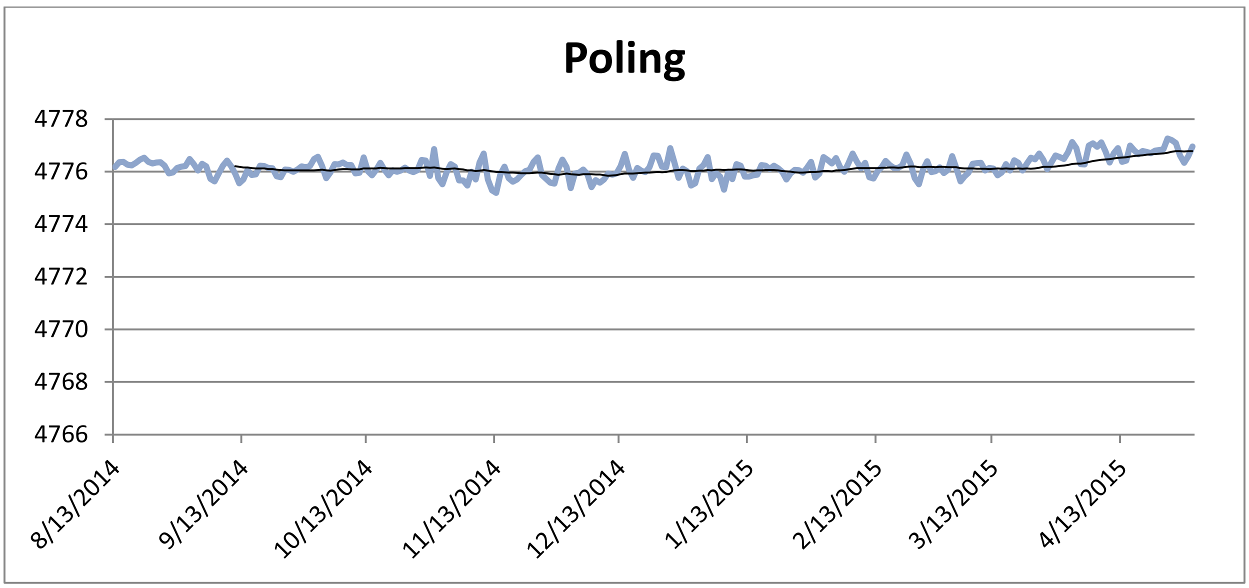


Figure 8. Hydrographs for replacement data loggers installed in eastern Union County from August 2014 to April 2015.

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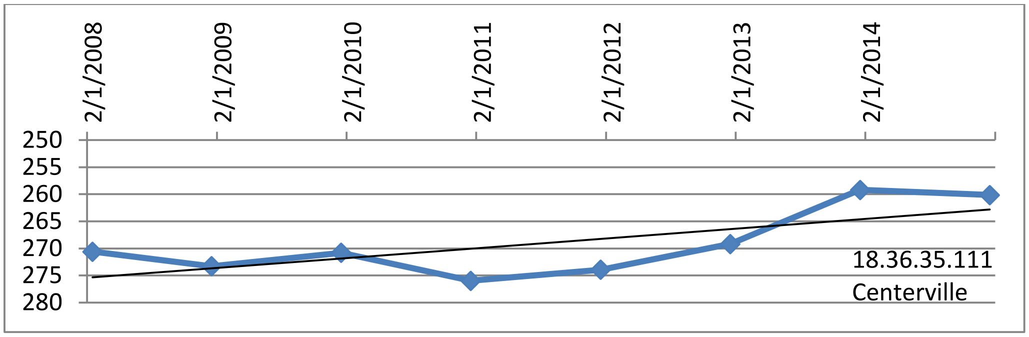
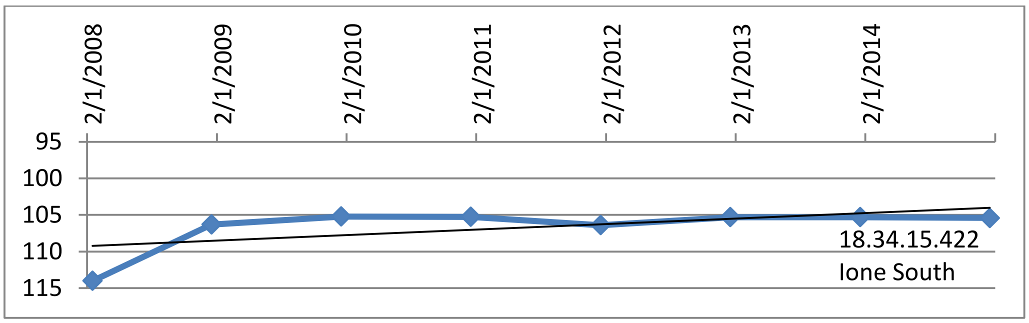
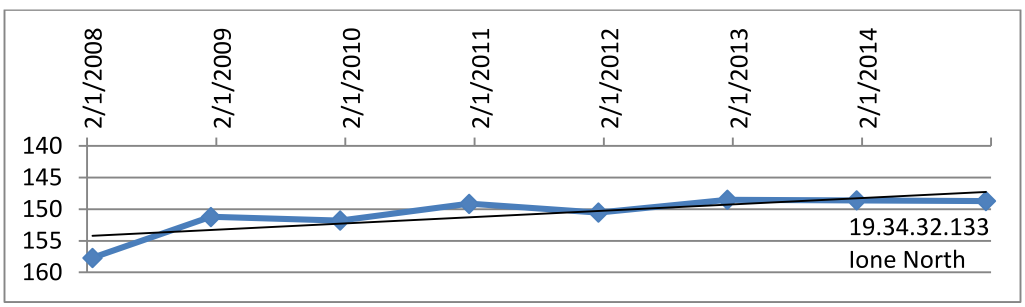
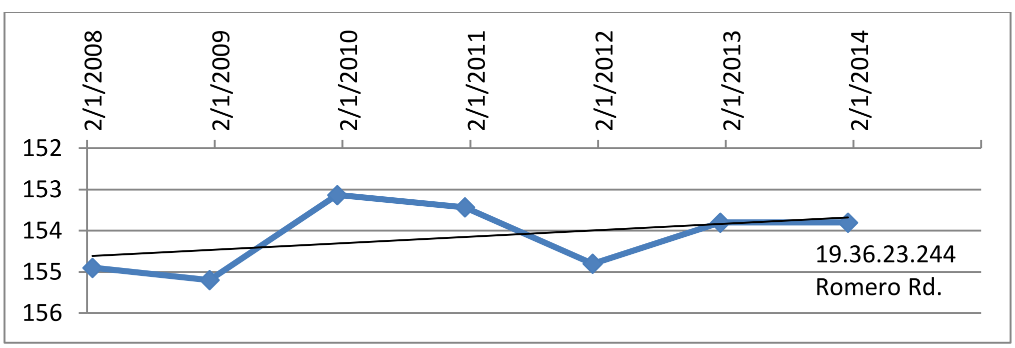
Appendices

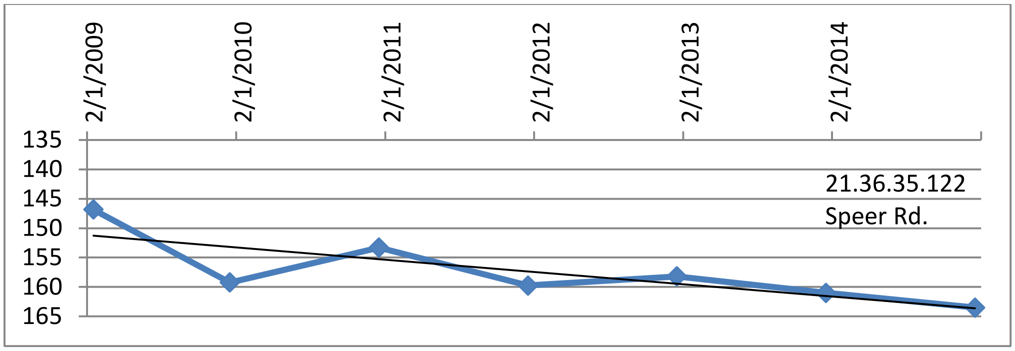
Appendix I: January Static Water Level Hydrographs 2008-2015 (does not include wells removed from study in 2012, 2014 or 2015).

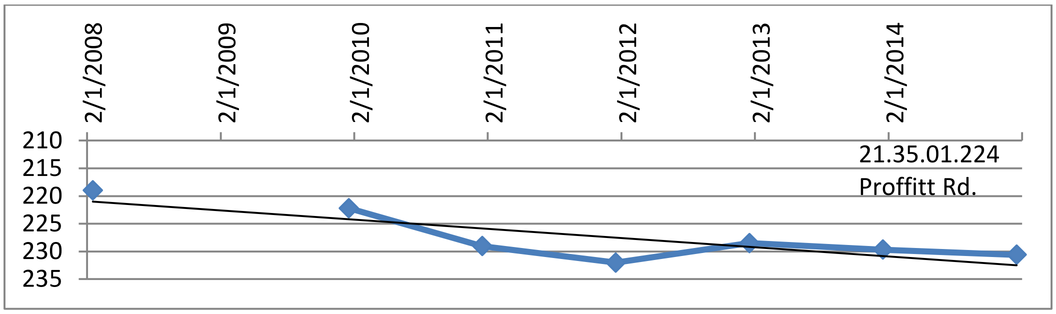









2/1/2009
2/1/2010
2/1/2011
2/1/2012
2/1/2013
2/1/2014
135
140
145
150
155
160
165
21.36.35.122
Speer Rd.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2/1/2009
2/1/2010
2/1/2011
2/1/2012
2/1/2013
2/1/2014
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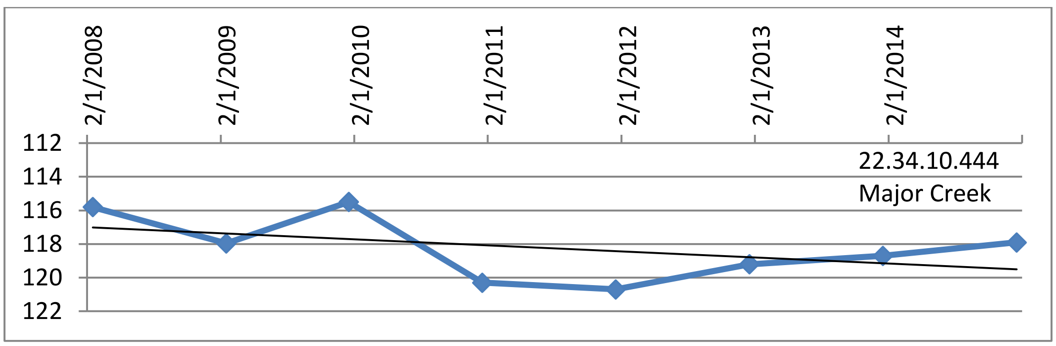
220
225
230
235
21.35.01.224
Proffitt Rd.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2/1/2014
112
114
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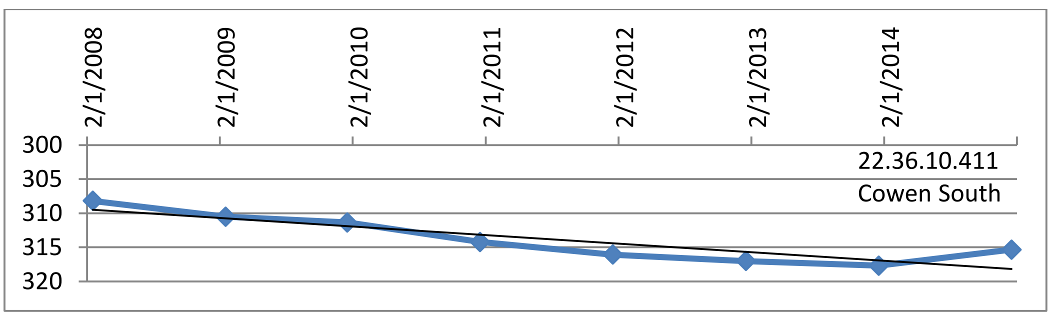
122
22.34.10.444
Major Creek


2/1/2008
2/1/2009
2/1/2010
2/1/2011
2/1/2012
2/1/2013
2/1/2014
300
305
310
315
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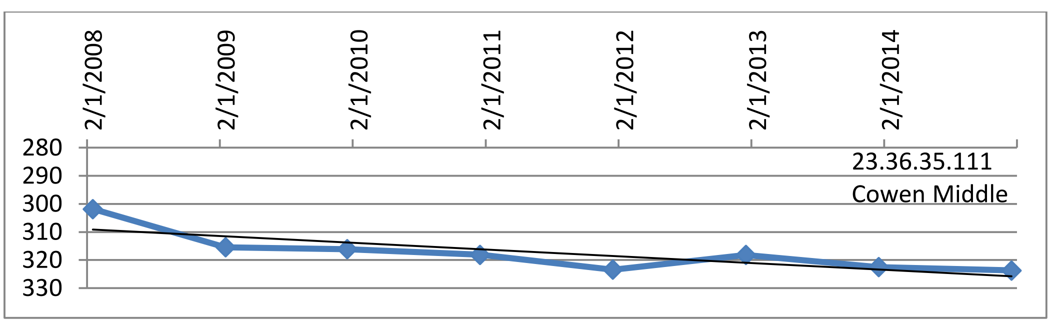
22.36.10.411
Cowen South


2/1/2008
2/1/2009
2/1/2010
2/1/2011
2/1/2012
2/1/2013
2/1/2014
280
290
300
310
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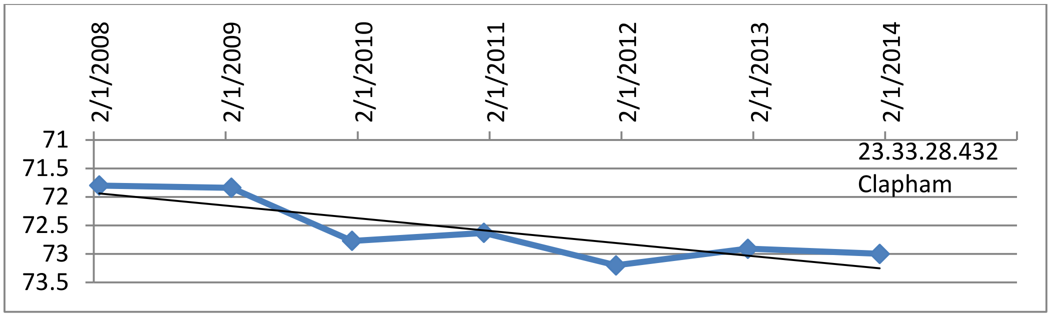
23.36.35.111
Cowen Middle


2/1/2008
2/1/2009
2/1/2010
2/1/2011
2/1/2012
2/1/2013
2/1/2014
71
71.5
72
72.5
73
73.5
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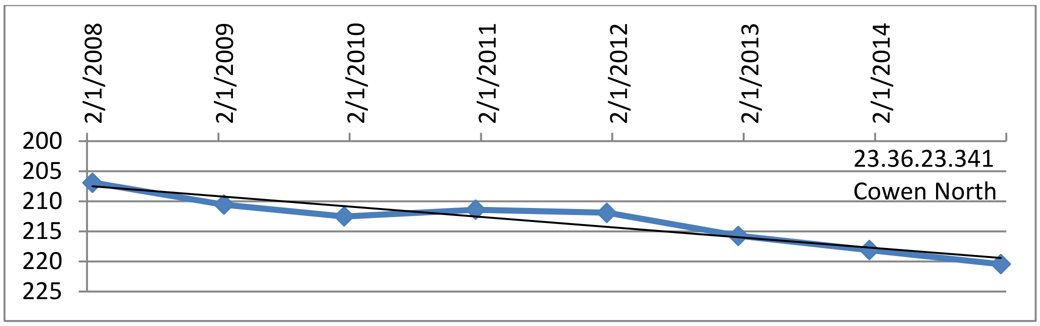
Clapham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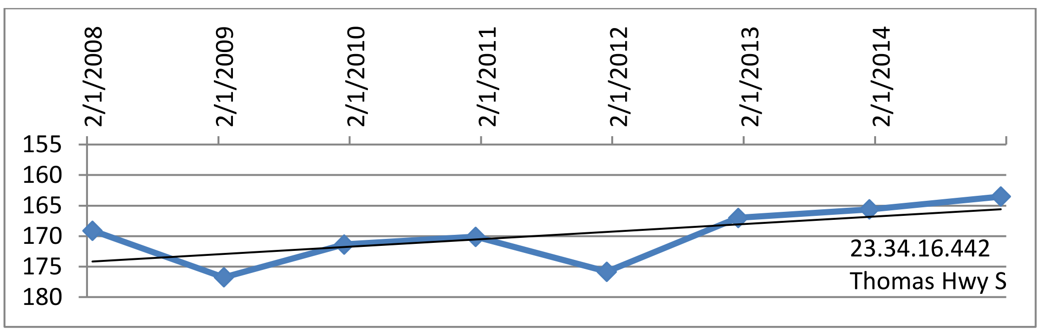
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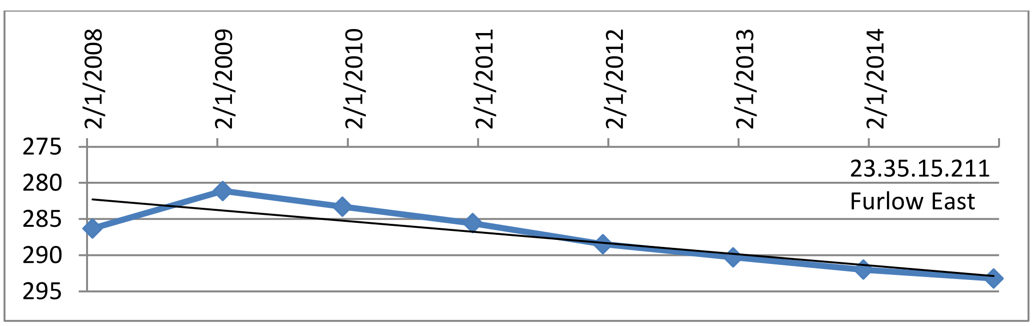
Thomas Hwy S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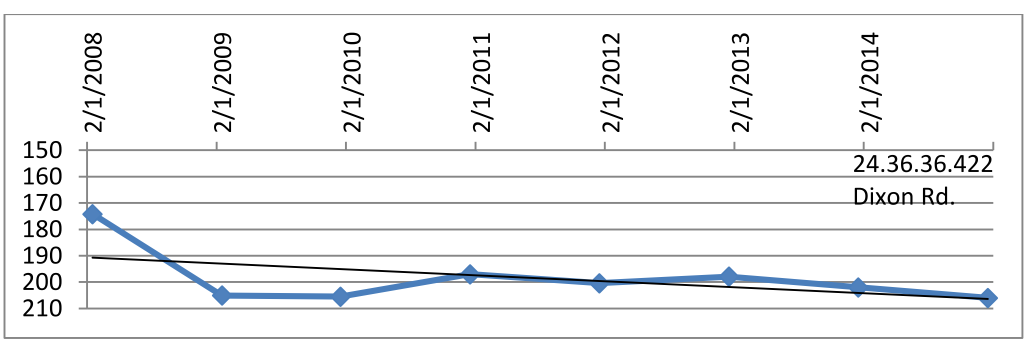
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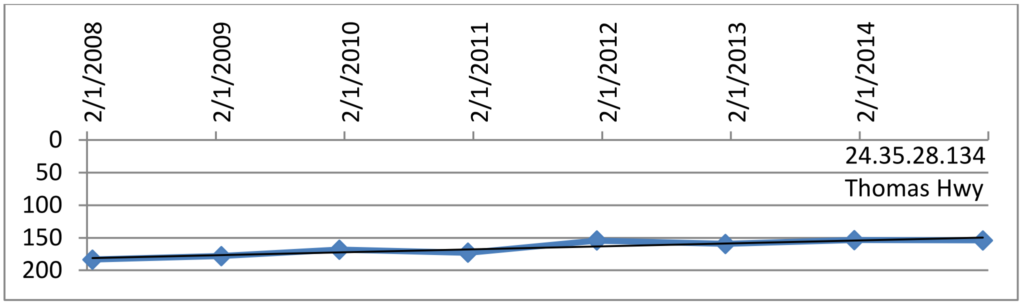
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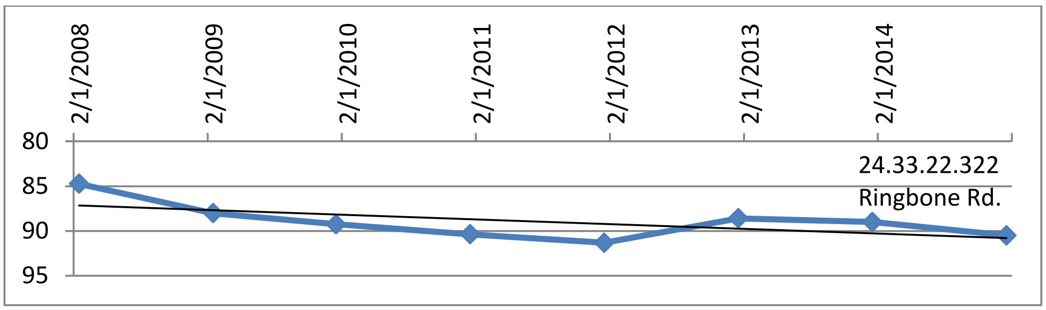
Thomas Hwy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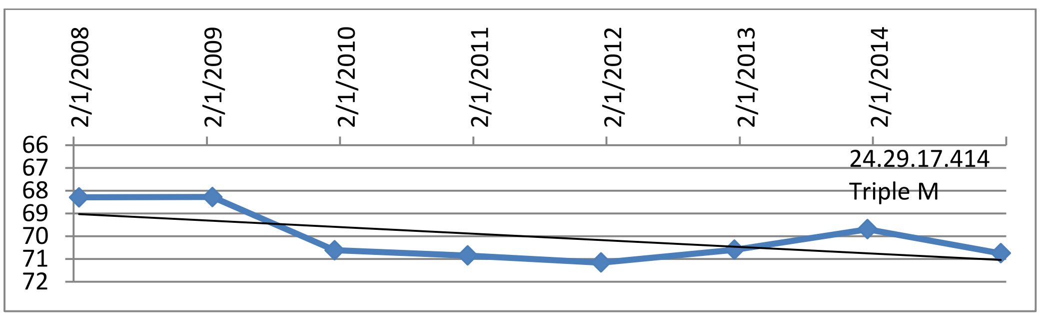
Ringbone Rd.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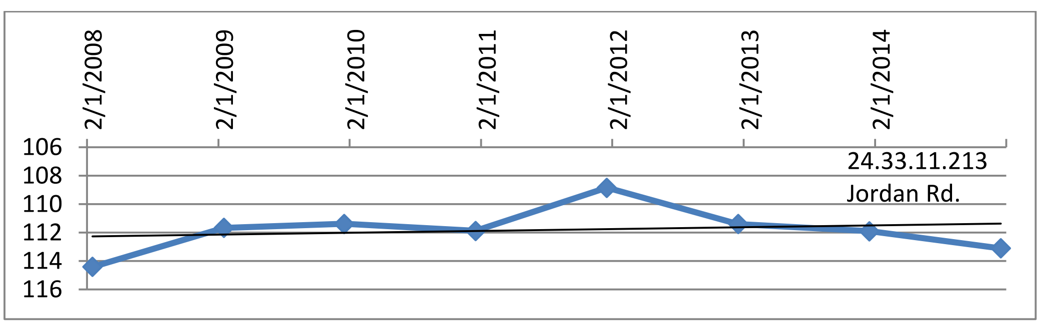
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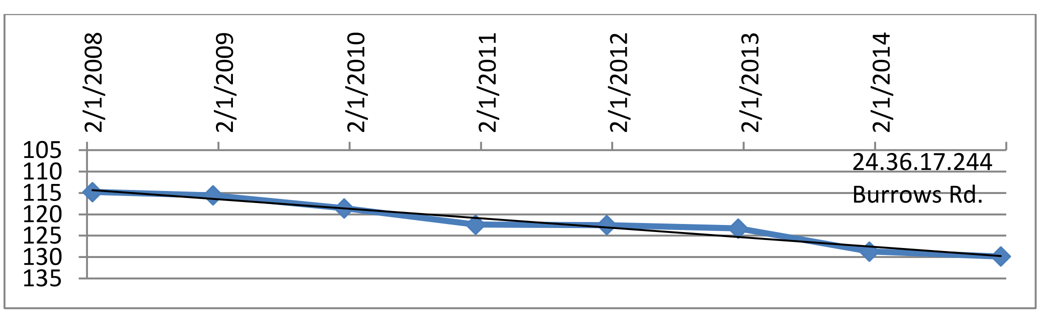
Jordan Rd.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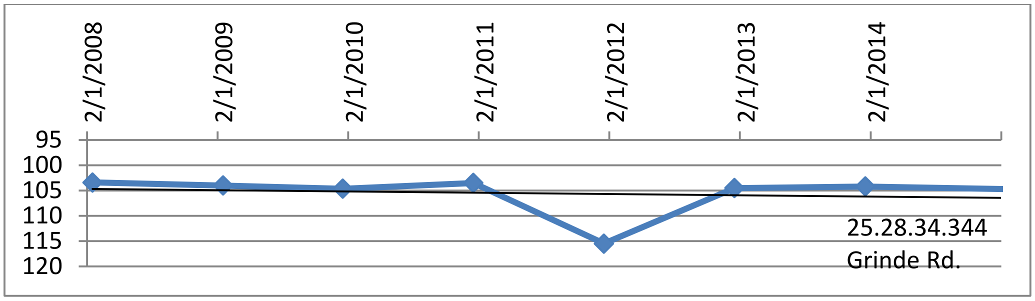
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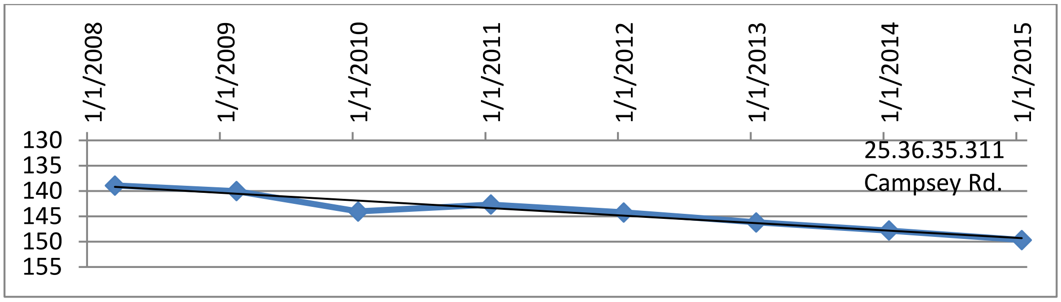
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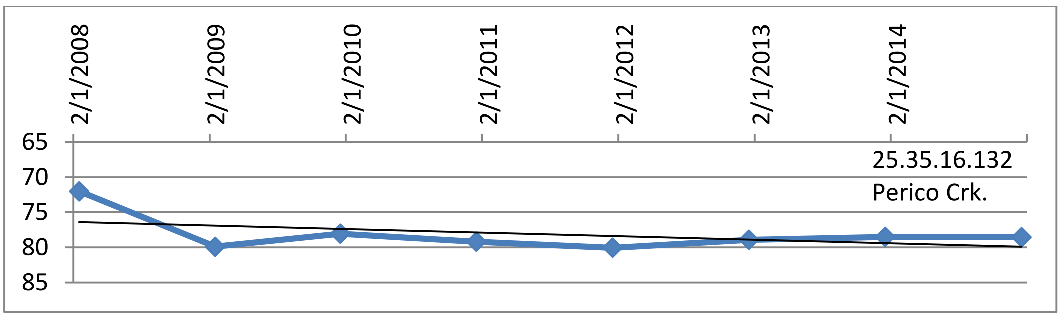
Campsey Rd.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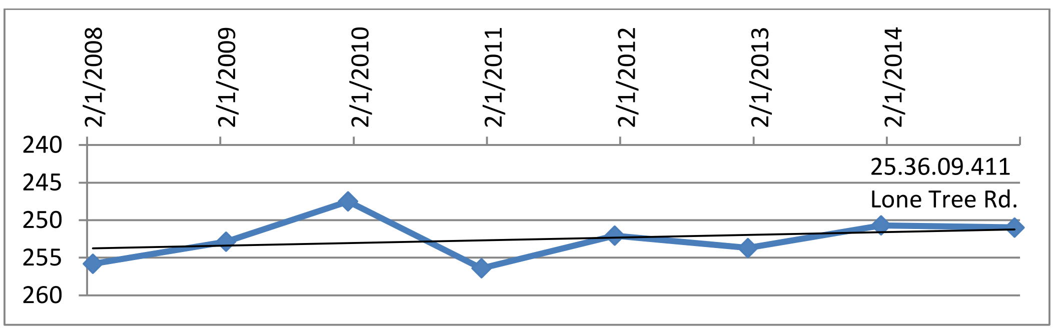
Perico Crk.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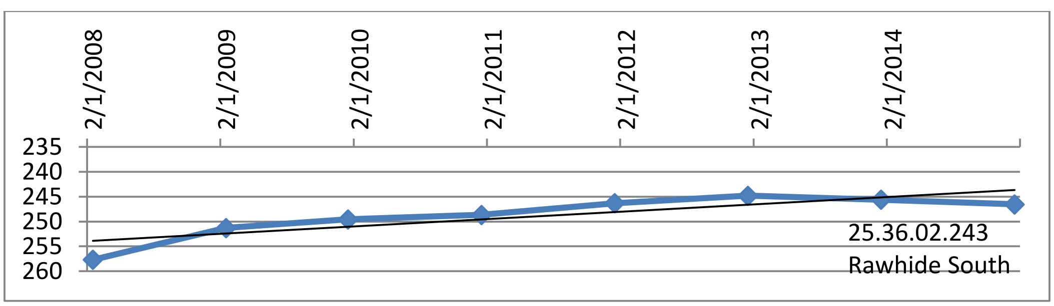
Lone Tree Rd.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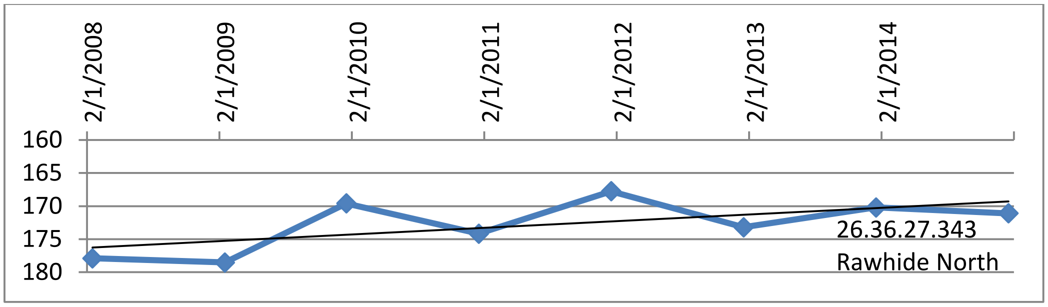
Rawhide South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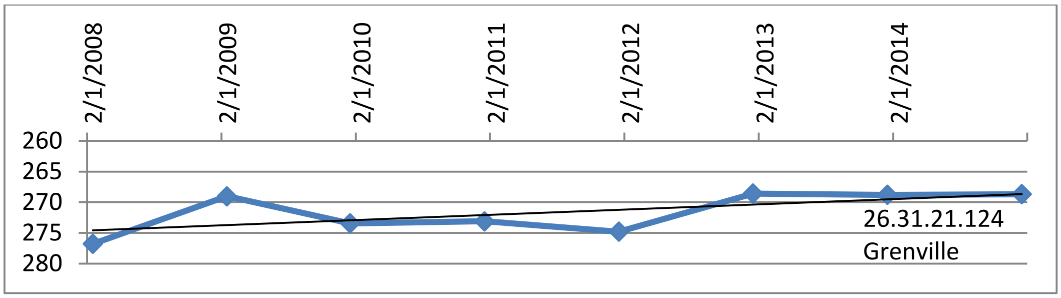
Rawhide North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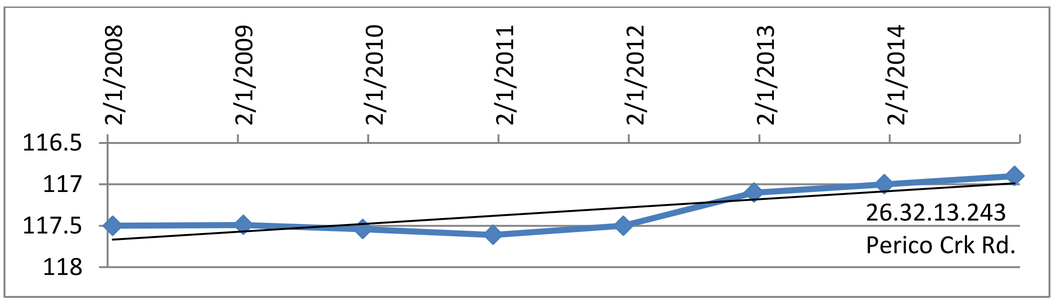
Grenville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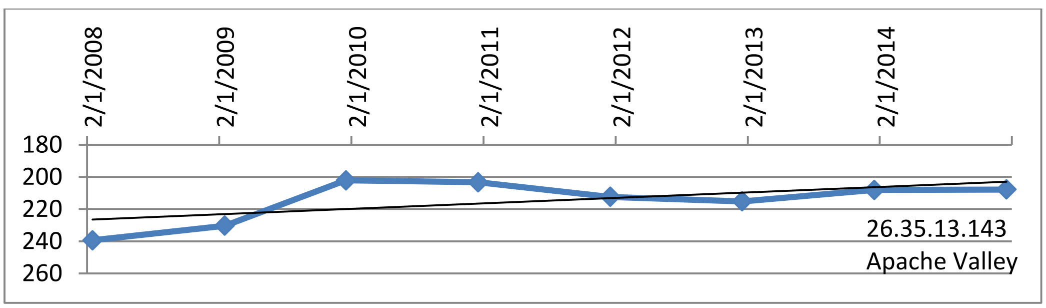
Perico Crk Rd.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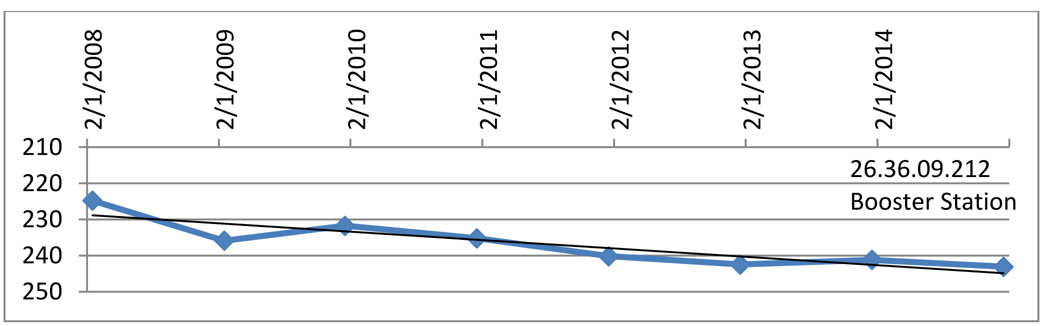
Apache Valley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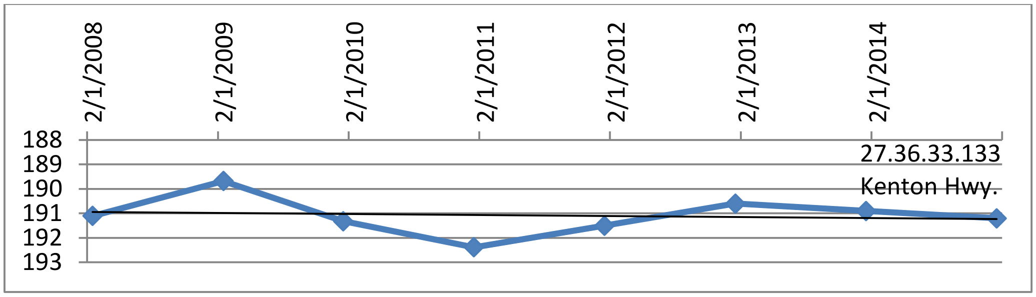
Booster Station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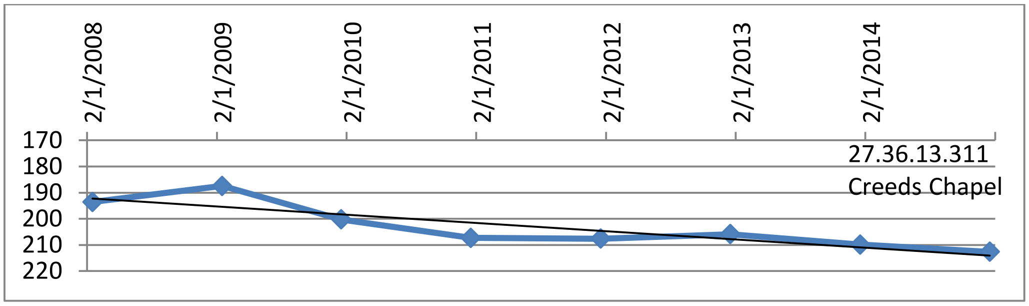
Kenton Hwy.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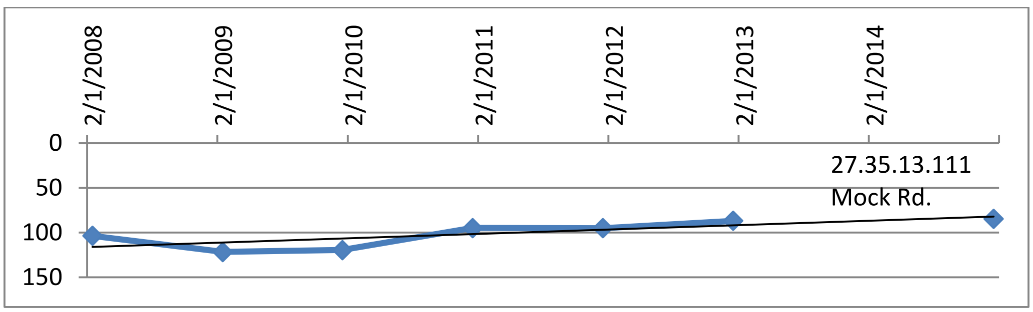
Creeds Chapel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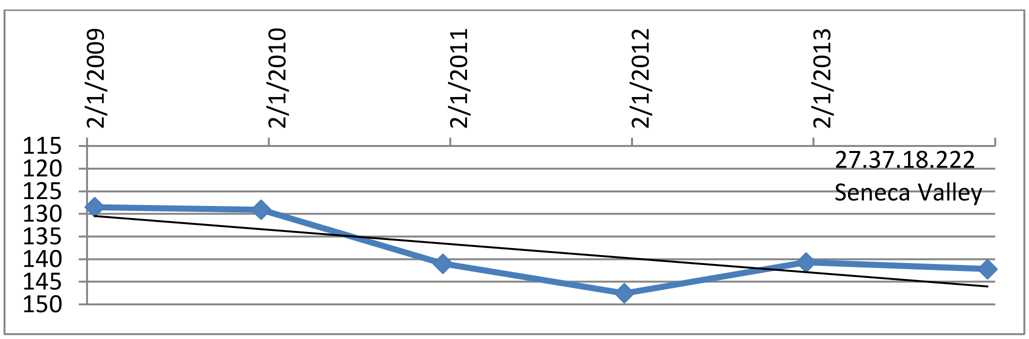
Mock Rd.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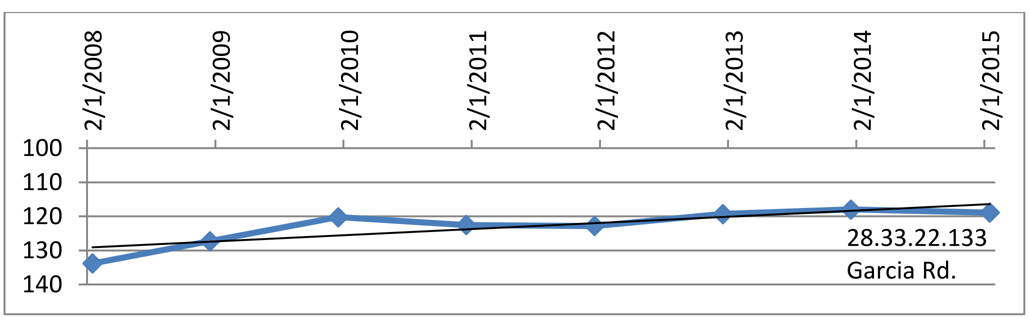
Seneca Valley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120
130
140
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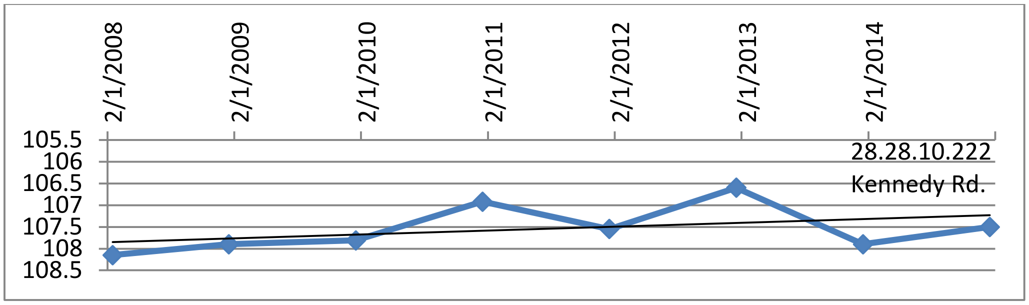
Garcia Rd.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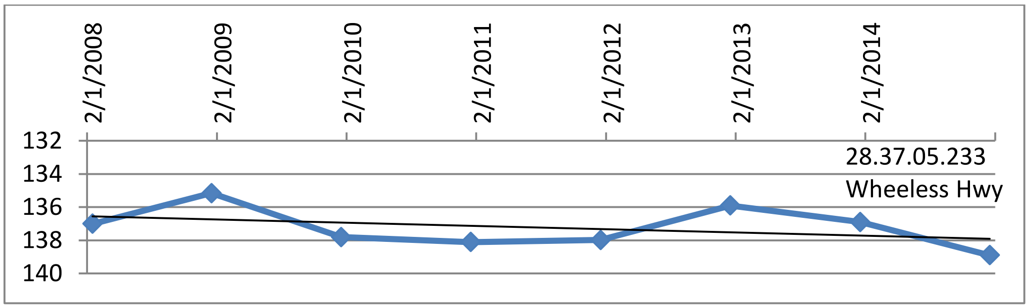
28.28.10.222
Kennedy Rd.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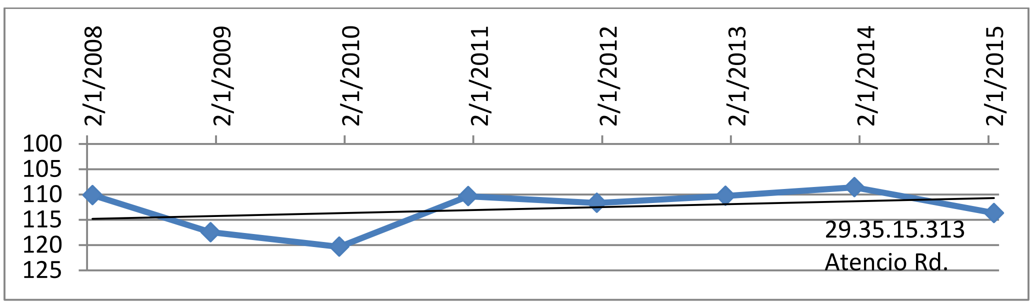
Wheeless Hwy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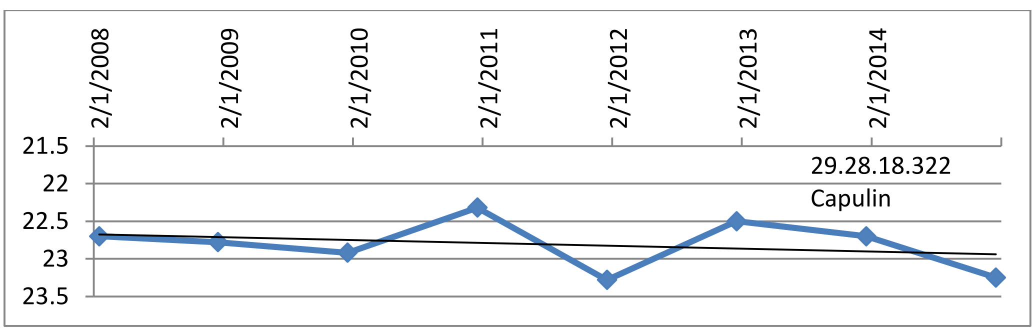
Atencio Rd.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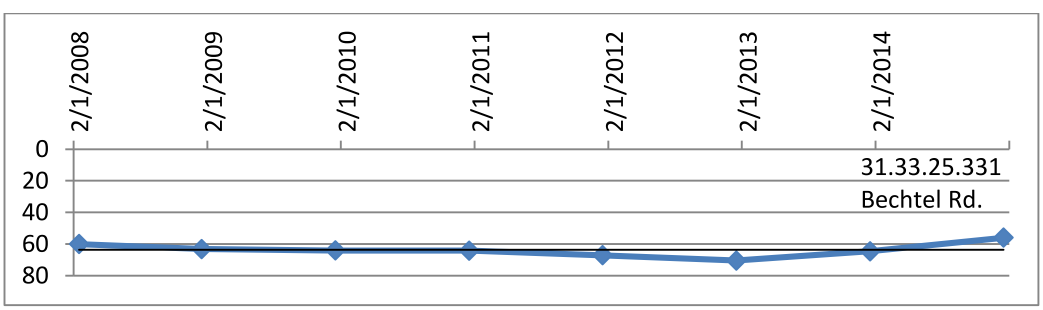
Capulin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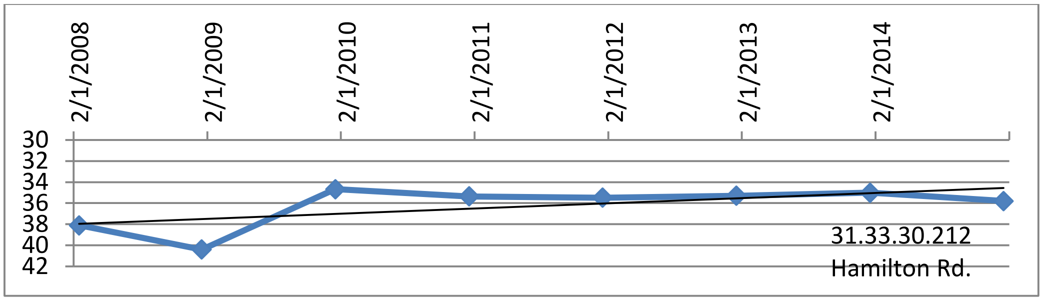
Bechtel Rd.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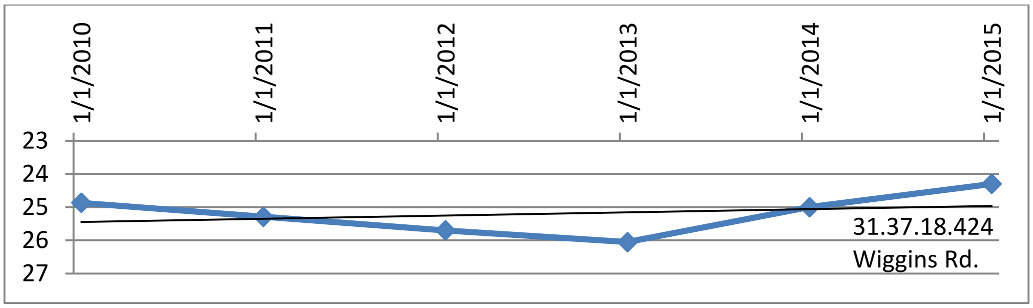
Hamilton Rd.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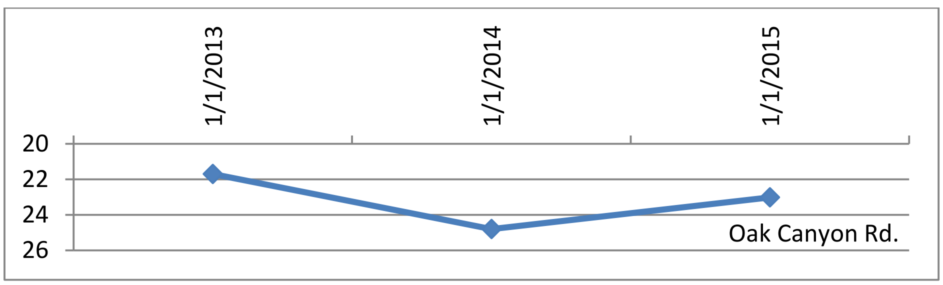
Wiggins Rd.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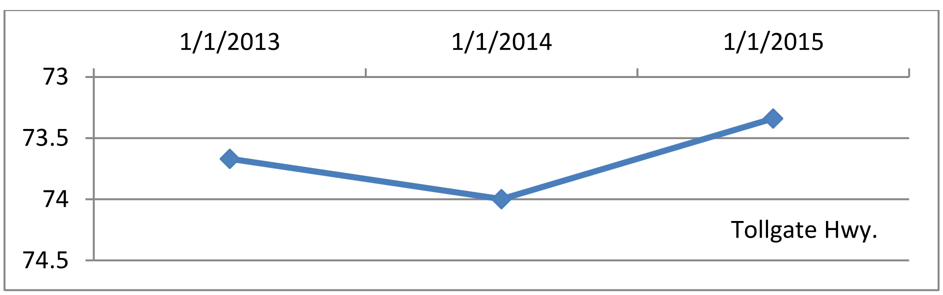
Oak Canyon Rd.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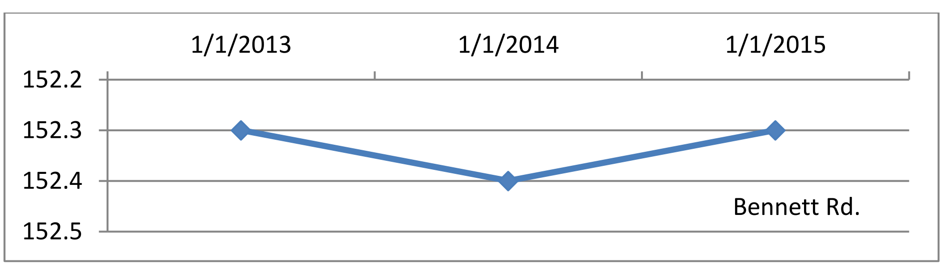
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152.4
152.5
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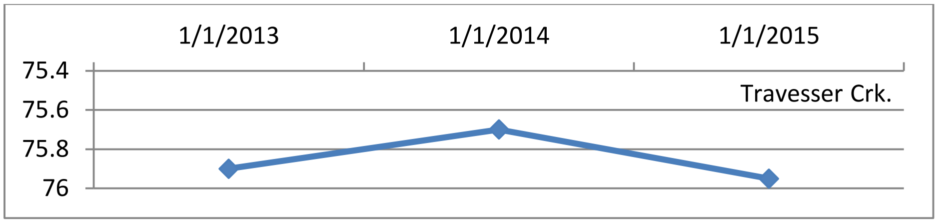
1/1/2013
1/1/2014
1/1/2015
75.4
75.6
75.8
76
Travesser Crk.

Appendix II: January Static Water Level Measurements

Individual well static water level measurements from January 2008 through January 2015.

ID & Elevation	Date	Depth to Water (from land surface)	Delta Depth	Years	Rate
18N36E35.111	2/18/2008	270.6	10.45	8	1.31
4465'	1/30/2009	273.3			
Centerville	1/5/2010	270.8			
	1/1/2011	275.99			
	1/3/2012	273.95			
	1/6/2013	269.2			
	1/3/2014	259.2			
	1/8/2015	260.15			
18N34E15.422	2/18/2008	114	8.6	8	1.08
4764'	1/30/2009	106.3			
Ione South	1/6/2010	105.2			
	1/7/2011	105.25			
	1/3/2012	106.38			
	1/6/2013	105.3			
	1/3/2014	105.3			
	1/8/2015	105.4			
19N34E32.133	2/18/2008	157.7	9	8	1.13
4883'	1/30/2009	151.2			
Ione North	1/1/2010	151.8			
	1/1/2011	149.14			
	1/3/2012	150.54			
	1/6/2013	148.5			
	1/3/2014	148.6			
	1/8/2015	148.7			
19N36E23.244	2/6/2008	154.9	1.1	7	0.16
4360'	1/30/2009	155.2			
Romero	1/1/2010	153.13			
*data recorder	1/1/2011	153.43			
	1/3/2012	154.8			
	1/6/2013	153.8			

	1/3/2014	153.8			
20N35E11.333	2/18/2008	85.9	-23.4	6	-3.90
4558'	2/24/2009	81			
Nara Visa Hwy	1/10/2010	80.35			
	1/1/2011	103.91			
	1/7/2012	83.17			
	1/6/2013	109.3			
	1/4/2014	Removed from study			
20N35E01.211	2/18/2008	92.4	1.61	5	0.32
Tompkins Rd	1/30/2009	90.3			
	1/20/2010	91.1			
	1/13/2011	94.55			
	1/3/2012	90.79			
	8/1/2012	Removed from study			
21N36E35.122	2/24/2009	146.82	-16.68	7	-2.38
4450'	1/12/2010	159.24			
Speer Rd	1/14/2011	153.29			
	1/7/2012	159.74			
	1/6/2013	158.2			
	1/4/2014	161			
	1/4/2015	163.5			
21N35E01.224	2/18/2008	219	-11.61	8	-1.45
4570'	2/16/2009				
Proffitt Rd	1/11/2010	222.22			
	1/14/2011	229.05			
	1/2/2012	232.04			
	1/6/2013	228.5			
	1/4/2014	229.7			
	1/3/2015	230.61			
22N34E10.444	2/26/2008	115.8	-2.1	8	-0.26
4765'	2/16/2009	117.96			
Major Creek Rd	1/11/2010	115.5			
	1/11/2011	120.3			
	1/3/2012	120.7			
	1/6/2013	119.2			
	1/5/2014	118.7			

	1/8/2015	117.9			
22N36E04.121	3/4/2008	192	-16.68	5	-3.34
4611'	2/9/2009	205.5			
Vandiver Rd	1/13/2010	189.04			
	1/13/2011	203.16			
	1/2/2012	208.68			
22N36E10.411	2/19/2008	308.2	-7.15	8	-0.89
4558'	2/9/2009	310.51			
Cowen South	1/13/2010	311.35			
	1/13/2011	314.23			
	1/2/2012	316.08			
	1/6/2013	317			
	1/4/2014	317.7			
	1/3/2015	315.35			
23N36E35.111	2/19/2008	301.8	-21.9	8	-2.74
4611'	2/9/2009	315.44			
Cowen Middle	1/11/2010	316.1			
	1/12/2011	318.1			
	1/2/2012	323.42			
	1/6/2013	318.2			
	1/4/2014	322.5			
	1/11/2015	323.7			
23N33E28.432	2/26/2008	71.8	-1.2	7	-0.17
5020'	2/16/2009	71.84			
Clapham	1/12/2010	72.77			
*data recorder	1/15/2011	72.63			
	1/3/2012	73.2			
	1/6/2013	72.91			
	1/5/2014	73			
23N35E29.122	2/26/2008	184.5	-7.2	7	-1.03
4794'	2/24/2009	192.24			
Anderson Rd	1/13/2010	189.32			
	1/15/2011	189.79			
	1/3/2012	188.1			
	1/6/2013	183.8			
	1/4/2014	191.7			

	1/8/2015	Removed from study			
23N36E23.341	2/19/2008	206.9	-13.56	8	-1.70
4761'	2/9/2009	210.56			
Cowen North	1/15/2010	212.52			
	1/20/2011	211.4			
	1/2/2012	211.91			
	1/6/2013	215.74			
	1/4/2014	218.1			
	1/3/2015	220.46			
23N34E16.442	2/26/2008	169.1	5.6	8	0.70
4925'	2/16/2009	176.74			
Thomas South	1/14/2010	171.35			
	1/20/2011	170.1			
	1/3/2012	175.82			
	1/6/2013	167			
	1/5/2014	165.6			
	1/8/2015	163.5			
23N35E15.211	2/26/2008	286.3	-6.91	8	-0.86
4797'	2/24/2009	281.13			
Furlow East	1/25/2010	283.29			
	1/15/2011	285.58			
	1/3/2012	288.47			
	1/6/2013	290.3			
	1/4/2014	292			
	1/8/2015	293.21			
23N35E16.121	2/26/2008	295.7	-1.9	-6	0.32
4812'	2/3/2009	314.9			
Furlow West	1/12/2010	295.62			
	1/14/2011	289.52			
	1/3/2012	292.83			
	1/6/2013	297.6			
	1/4/2014	Removed from study			
24N36E36.422	2/19/2008	174.2	-31.8	8	-3.98
4720'	2/13/2009	205.1			
Dixon Rd	1/15/2010	205.48			
	1/13/2011	196.99			

	1/6/2012	200.42			
	1/6/2013	197.9			
	1/4/2014	202			
	1/9/2015	206			
24N35E28.134	2/27/2008	183.5	29.6	8	3.70
4643'	2/16/2009	178.17			
Thomas Hwy	1/15/2010	168.25			
	1/16/2011	172.79			
	1/3/2012	154.19			
	1/6/2013	159.5			
	1/5/2014	153.4			
	1/8/2015	153.9			
24N33E22.322	2/27/2008	84.75	-5.75	8	-0.72
5410'	2/11/2009	88.03			
Ringbone Rd	1/15/2010	89.25			
	1/15/2011	90.39			
	1/4/2012	91.33			
	1/6/2013	88.6			
	1/7/2014	89			
	1/8/2015	90.5			
24N29E17.414	2/28/2008	68.3	-2.45	8	-0.31
5760'	2/4/2009	68.28			
Triple M	1/16/2010	70.62			
	1/12/2011	70.85			
	1/4/2012	71.16			
	1/6/2013	70.6			
	1/7/2014	69.7			
	1/2/2015	70.75			
24N33E11.213	2/27/2008	114.4	1.3	8	0.16
5675'	2/4/2009	111.66			
Jordan Rd	1/16/2010	111.38			
	1/15/2011	111.88			
	1/6/2012	108.84			
	1/6/2013	111.4			
	1/7/2014	111.9			
	1/2/2015	113.1			

24N36E.12.111	8/16/2007	137.64			
4668'	2/5/2008	146.07			
	8/12/2008	Removed from study			
24N36E17.244	2/16/2008	114.76	-15.09	8	-1.89
4707'	1/17/2009	115.57			
Burrows Rd	1/15/2010	118.6			
	1/23/2011	122.41			
	1/6/2012	122.5			
	1/6/2013	123.3			
	1/5/2014	128.7			
	1/9/2015	129.85			
25N28E34.344	2/28/2008	103.4	-1.29	8	-0.16
5960'	2/4/2009	104			
Grinde Rd	1/14/2010	104.65			
	1/13/2011	103.5			
	1/6/2012	115.5			
	1/6/2013	104.5			
	1/7/2014	104.2			
	2/11/2015	104.69			
25N36E.35.311	3/5/2008	138.9	-10.75	8	-1.34
4682'	2/13/2009	140.01			
Campsey Rd	1/14/2010	144.04			
	1/15/2011	142.68			
	1/6/2012	144.21			
	1/6/2013	146.2			
	1/5/2014	147.8			
	1/9/2015	149.65			
25N35E30.222	2/27/2008	93.7	0.6	5	0.12
5007'	2/13/2009	93.04			
Leavitt Rd	1/13/2010	91.98			
	1/23/2011	93			
	1/6/2012	93.1			
	1/4/2014	Removed from study			
25N31E20.222	2/4/2009	205.65	5.36	4	1.34
	1/13/2010	198.52			
Snyder Rd	1/13/2011	196.72			

	1/4/2012	200.29			
	8/1/2012	Removed from study			
25N35E16.132	2/27/2008	72	-6.53	8	-0.82
5045'	2/26/2009	79.9			
John Gard's	1/14/2010	78.04			
	1/12/2011	79.19			
	1/6/2012	80.05			
	1/6/2013	78.9			
	1/5/2014	78.5			
	1/11/2015	78.53			
25N36E09.411	2/27/2008	255.8	4.82	8	0.60
4850'	2/11/2009	252.86			
Texline Hwy	1/14/2010	247.5			
	1/13/2011	256.4			
	1/6/2012	252.05			
	1/6/2013	253.7			
	1/8/2014	250.7			
	1/11/2015	250.98			
25N36E.02.243	2/27/2008	257.7	11.15	8	1.39
4810'	2/11/2009	251.29			
Rawhide South	1/15/2010	249.58			
	1/14/2011	248.68			
	1/6/2012	246.31			
	1/6/2013	244.8			
	1/8/2014	245.6			
	1/11/2015	246.55			
26N36E.27.343	2/27/2008	177.9	6.8	8	0.85
4810'	2/11/2009	178.51			
Rawhide North	1/15/2010	169.6			
	1/13/2011	174.17			
	1/6/2012	167.75			
	1/6/2013	173.2			
	1/8/2014	170.2			
	1/11/2015	171.1			
26N31E.21.124	2/28/2008	276.8	8.1	8	1.01
6010'	2/4/2009	269.04			

Grenville	1/21/2010	273.45			
	1/14/2011	273.1			
	1/4/2012	274.8			
	1/6/2013	268.6			
	1/7/2014	268.8			
	1/10/2015	268.7			
26N32E.13.243	2/28/2008	117.5	0.6	8	0.07
5600'	2/4/2009	117.49			
Perico Creek Rd	1/23/2010	117.54			
	1/12/2011	117.61			
	1/4/2012	117.5			
	1/6/2013	117.1			
	1/7/2014	117			
	1/10/2015	116.9			
26N35E.13.143	2/2/2008	239.4	31.58	8	3.95
4850'	2/4/2009	230.38			
Apache Valley	1/21/2010	202.1			
	1/12/2011	203.34			
	1/6/2012	212.38			
	1/6/2013	215.2			
	1/10/2014	208.1			
	1/10/2015	207.82			
26N36E.09.212	2/2/2008	224.8	-18.32	8	-2.29
4792'	2/11/2009	235.9			
Booster Station	1/12/2010	231.76			
	1/12/2011	235.2			
	1/6/2012	240.16			
	1/6/2013	242.5			
	1/8/2014	241.2			
	1/6/2015	243.12			
27N36E.33.133	2/28/2008	191.1	-0.1	8	-0.01
4892'	2/11/2009	189.68			
Kenton Hwy	1/12/2010	191.32			
	1/11/2011	192.38			
	1/6/2012	191.5			
	1/6/2013	190.6			
	1/8/2014	190.9			

	1/6/2015	191.2			
27N36E13.311	2/29/2008	193.6	-19.06	8	-2.38
4776'	2/11/2009	187.47			
Creeds Chapel	1/8/2010	200.29			
	1/2/2011	207.3			
	1/6/2012	207.66			
	1/6/2013	205.9			
	1/8/2014	209.9			
	1/6/2015	212.66			
27N35E.13.111	2/2/2008	103.6	18.9	8	2.36
4963'	2/28/2009	121.66			
Mock Rd	1/5/2010	119.54			
	1/14/2011	94.8			
	1/5/2012	95.02			
	1/6/2013	86.9			
	1/8/2014				
	1/6/2015	84.7			
27N37E.18.222	2/9/2009	128.5	-13.7	5	-2.74
4718'	1/9/2010	129.08			
Seneca Valley	1/15/2011	141			
	1/6/2012	147.52			
	1/6/2013	140.7			
	1/8/2014	142.2			
	1/6/2014	Removed from study			
28N36E28.131	2/2/2008	213.1	-5.5	6	-0.92
4905'	1/31/2009	222.83			
Kenton Hwy	1/12/2010	217.49			
R. Baker	1/3/2011	223.2			
	1/5/2012	224.23			
	1/6/2013	218.6			
	1/6/2015	Removed from study			
28N33E.22.133	2/10/2008	133.8	14.93	8	1.87
5546'	1/21/2009	127.3			
Garcia Rd	1/6/2010	120.22			
	1/7/2011	122.55			
	1/4/2012	122.83			

	1/6/2013	119.3			
	1/9/2014	118			
	2/11/2015	118.87			
28N28E.10.222	2/28/2008	108.15	0.65	8	0.08
6814'	1/31/2009	107.9			
Kennedy Rd	1/6/2010	107.81			
	1/20/2011	106.92			
	1/4/2012	107.55			
	1/6/2013	106.6			
	1/6/2014	107.9			
	1/10/2015	107.5			
28N37E.05.233	2/2/2008	137	-1.9	8	-0.24
4811'	1/30/2009	135.16			
Billy Mock	1/7/2010	137.8			
	1/8/2011	138.1			
	1/5/2012	137.98			
	1/6/2013	135.9			
	1/6/2014	136.9			
	1/6/2015	138.9			
29N35E.15.313	2/10/2008	110.15	-3.52	8	-0.44
5180'	1/31/2009	117.48			
Atencio Rd	1/7/2010	120.36			
	1/8/2011	110.36			
	1/4/2012	111.69			
	1/6/2013	110.3			
	1/9/2014	108.6			
	2/11/2015	113.67			
29N28E.18.322	2/28/2008	22.7	-0.55	8	-0.07
6890'	1/31/2009	22.78			
Capulin	1/9/2010	22.92			
	1/6/2011	22.32			
	1/4/2012	23.28			
	1/6/2013	22.5			
	1/6/2014	22.7			
	1/10/2015	23.25			
30N37E20.321	2/2/2008	59.42	-14.08	7	-2.01

4720'	2/3/2009	65.82			
Stone house	1/7/2010	67.2			
	1/8/2011	73.53			
	1/5/2012	73.17			
	1/6/2013	73.5			
	1/6/2014	73.5			
	1/4/2014	Removed from study			
31N33E25.331	2/10/2008	60.05	4.04	8	0.51
5372'	1/31/2009	63.18			
Bechtel	1/8/2010	64.05			
	1/9/2011	64.18			
	1/5/2012	67.12			
	1/6/2013	70.5			
	1/6/2014	64.6			
	1/5/2015	56.01			
31N33E.30.212	2/10/2008	38.1	2.3	8	0.29
5120'	1/31/2009	40.4			
Lake Hwy	1/8/2010	34.68			
	1/8/2011	35.36			
	1/5/2012	35.48			
	1/6/2013	35.3			
	1/6/2014	35			
	1/5/2015	35.8			
31N37E.18.424	1/6/2010	24.87	0.57	6	0.10
4356'	1/5/2011	25.29			
Wiggins Rd	1/5/2012	25.7			
	1/6/2013	26.05			
	1/6/2014	25			
	1/5/2015	24.3			
Bannon Oak Canyon	1/6/2013	21.7	-1.32	3	-0.44
	1/6/2014	24.8			
	1/5/2015	23.02			
Bannon Tollgate	1/6/2013	73.67	0.33	3	0.11
	1/6/2014	74			
	1/5/2015	73.34			

Bennett #1	1/8/2013	152.3	0	3	0.00
open casing	1/9/2014	152.4			
	1/10/2015	152.3			
Bennett #3	1/8/2013	75.9	-0.05	3	-0.02
Travesser Crk	1/9/2014	75.7			
	2/11/2015	75.95			
Harris West	1/8/2014	104.4			
Seneca	1/6/2015	103.4			
Harris East	1/8/2014	198.6			
Seneca	8/12/2014	202.5			
*data recorder	1/6/2014	DR			
Burchard #1	3/12/2014	19.78			
west pasture	6/23/2014	20.2			
	1/5/2015	21.09			
Burchard #2	1/5/2015	16.85			
east pasture					
Bennefield #3	6/27/2014	20.05			
	1/5/2015	18.91			
Poling DR	8/12/2014	107.5			
*data recorder	1/10/2015	106.75			

Appendix III: Union County Well Cuttings 2015

Charles S. Galbreath #1 W.E. Britt et al. (14-24N-30E, TD: 2603')

300-310'	Medium gray mudstone, -HCl. Pale yellow quartz arenite, fine grained, subround to subangular, well sorted, 98% Q, 2% opaques, <15% clay matrix, -HCl. [85% mudstone, 15% sandstone]
310-320'	" [60% mudstone, 40% sandstone]
320-330'	", much of sandstone as loose sand. [55% mudstone, 45% sandstone]
330-340'	" " "
340-350'	Medium gray mudstone, -HCl. White to pale yellow quartz arenite, fine to medium grained, subround to subangular, moderately sorted, 98% Q, 2% opaques, ≤15% clay matrix, -HCl. Pale red and pale green mudston, -HCl. [50% sandstone, 45% red and green mudstone, 5% gray mudstone]
350-360'	Pale gray siltstone, mostly as loose silt, +HCl. Pale red and pale green mudstone, -HCl. [90% siltstone, 10% mudstone]
360-370'	Medium gray mudstone, -HCl. White to pale yellow quartz arenite, fine to medium grained, subround to subangular, moderately sorted, 98% Q, 2% opaques, ≤15% clay matrix, -HCl. Pale red and pale green mudston, -HCl. [50% sandstone, 45% red and green mudstone, 5% gray mudstone]
370-380'	" [70% red and green mudstone, 25% sandstone, 5% gray mudstone]
380-390'	"
390-400'	"
400-410'	Pale greenish gray mudstone, -HCl. Rare small spheres of pyrite.
410-420'	Pale red and green mudstone, +HCl. Very pale gray siltstone, -HCl. [70% mudstone, 30% siltstone]
420-430'	Pale red and green mudstone, +HCl. Very pale gray siltstone, -HCl. Medium gray mudstone, -HCl. [70% red and green mudstone, 25% siltstone, 5% gray mudstone]
430-440'	" [50% red and green mudstone, 30% siltstone, 20% gray mudstone]
440-450'	" "
450-460'	" [45% red and green mudstone, 40% siltstone, 15% gray mudstone]
460-470'	" [55% red and green mudstone, 40% siltstone, 5% gray mudstone]
470-480'	" [45% red and green mudstone, 40% siltstone, 15% gray mudstone]
480-490'	" "
490-500'	" "
500-510'	Pale red and green mudstone, +HCl. Very pale gray siltstone, -HCl. [70% mudstone, 30% siltstone]
510-520'	" "
520-530'	" " [85% mudstone, 15% siltstone]
530-540'	" " "
540-550'	" " ", jasper **
550-560'	" " ", jasper **
560-570'	" " ", jasper **
570-580'	" " ", jasper ** (rare)

580-590’	Pale red and green mudstone, +HCl. Very pale gray siltstone, -HCl. [70% mudstone, 30% siltstone]
590-600’	“
600-610’	“ and medium gray mudstone, -HCl. [55% red and green mudstone, 40% siltstone, 5% gray mudstone]
610-620’	“ “ “ “ “
620-630’	Pale red and green mudstone, +HCl. Very pale gray siltstone, -HCl. [70% mudstone, 30% siltstone]
630-640’	“ [60% mudstone, 40% siltstone] jasper **
640-650’	Pale red and green mudstone, +HCl. Very pale gray siltstone, -HCl. Brownish red mudstone, +HCl. [55% red mudstone, 40% red and green mudstone, 10% siltstone] → Chinle top
650-660’	“ [80% red mudstone, 15% red and green mudstone, 5% siltstone]
660-670’	“ [80% red mudstone, 10% red and green mudstone, 10% siltstone]
670-680’	“ [80% red mudstone, 15% red and green mudstone, 5% siltstone]
680-690’	“ “ “ “
690-700’	“ [60% red mudstone, 30% red and green mudstone, 10% siltstone]

Capulin National Park #1 (5-29N-28E, TD: 670’, water well)

10-20’	Medium gray alluvium as loose muddy silt. Basalt, avesicular, some olivine. [80% alluvium, 20% basalt]
20-30’	“ [70% alluvium, 30% basalt]
30-40’	Red and dark gray cinders/basalt.
40-50’	Reddish brown cinders
50-60’	“
60-70’	“
70-80’	Reddish brown cinders. Reddish brown loose silt? [60% silt, 40% cinders]
80-90’	Reddish brown siltstone, -HCl. (baked Ogallala? Interflow alluvium?)
90-100’	Reddish brown siltstone, -HCl. Vesicular basalt fragments. [85% siltstone, 15% basalt]
100-110’	Reddish brown cinders.
110-120’	Purplish gray cinders.
120-130’	Reddish brown cinders.
130-140’	“
140-150’	“
150-160’	“
160-170’	Purplish gray cinders.
170-180’	“
180-190’	Reddish brown cinders. Dark gray basalt with red olivine. [95% basalt, 5% cinders]
190-200’	“ “ [60% cinders, 40% basalt]
200-210’	Red and dark gray cinders/basalt.
210-220’	“ (separate 210’ bag: dark gray metallic material, very fine grained, pockets of hematite? And transparent feldspar)
220-230’	Reddish brown cinders. Dark gray basalt with red olivine. [60% basalt, 40% cinders]
230-240’	“ “ [80% basalt, 20% cinders]

240-250’ Reddish brown cinders. Dark gray basalt. ?Granitic material. [70% basalt, 25% cinders, 5% granitic]

250-260’ Reddish brown cinders. Dark gray basalt. [85% basalt, 15% cinders] – sporadic euhedral transparent quartz crystals from 180’ down.

360-270’ Medium gray basalt.

270-280’ “

280-290’ Reddish brown cinders. Dark gray basalt. [60% cinders, 40% basalt]

290-300’ “ “ “

300-310’ Medium gray basalt.

310-320’ Reddish brown cinders. Medium gray basalt. [85% cinders, 15% basalt]

320-330’ “ “ [60% basalt., 40% cinders]

330-340’ “ “ [70% basalt, 30% cinders]

340-350’ Pale gray ?andesite with olivine.

350-360’ “

360-370’ “

370-380’ Red and dark gray cinders/basalt. Medium gray basalt with red olivine. [80% basalt, 20% cinders]

380-390’ Red and dark gray cinders/basalt.

390-400’ “

400-410’ Reddish brown cinders.

410-420’ “

420-430’ “

430-440’ No samples.

440-450’ Medium gray basalt with red olivine.

450-460’ “

460-470’ Reddish brown cinders. Medium gray basalt. [60% basalt, 40% cinders]

470-480’ Medium gray basalt. Orange silt to sand, loose, grains are basalt, quartz or cinders. [60% loose sand, 40% basalt]

480-490’ Pale orange siltstone, baked, +HCl. Medium gray basalt [85% siltstone, 15% basalt]

490-500’ “ “ [60% basalt, 40% siltstone]

500-510’ Medium gray basalt.

510-520’ “

520-530’ “

530-540’ “

540-550’ “

550-560’ “

560-570’ “

570-580’ Medium gray basalt with red olivine.

580-590’ “

590-600’ “

600-610’ “

610-620’ “

620-630’ “

630-640’ “

640-650’ No samples.
650-660’ Medium gray basalt with red olivine.
660-670’ Reddish brown cinders.

Freeman #1 Smith (22-29N-32E, TD: 2959’)

0-30’ Buff loose sand, fine grained, subround to subangular, well sorted, 100% Q, some fragments of sandstone present have abundant hematite.
30-60’ No samples in bag. (cuttings strip indicates same as 0-30’)
60-90’ “ “
90-120’ No samples.
120-150’ Reddish brown siltstone, -HCl. Very pale green mudstone, -HCl. [70% siltstone, 30% mudstone]
150-180’ Reddish brown siltstone, -HCl. Very pale green mudstone, -HCl. Pale orange quartz arenite, fine grained, subangular, well sorted, 100% Q, -HCl. [70% siltstone, 28% mudstone, 2% sandstone]
180-190’ “ [45% siltstone, 45% mudstone, 10% sandstone]
190-200’ “ [40% siltstone, 40% mudstone, 20% sandstone]
200-210’ “ [50% siltstone, 48% mudstone, 2% sandstone]
210-220’ “ [40% siltstone, 40% mudstone, 20% sandstone]
220-230’ “, jasper ** [70% mudstone, 28% siltstone, 2% sandstone]
230-240’ “ [60% mudstone, 25% sandstone, 15% siltstone]
240-250’ “, jasper ** [75% mudstone, 20% siltstone, 5% sandstone]
250-260’ “ [75% mudstone, 20% siltstone, 5% sandstone]
260-270’ “, jasper ** [60% mudstone, 30% siltstone, 10% sandstone]
270-280’ “ [50% siltstone, 48% mudstone, 2% sandstone]
280-290’ “ [80% mudstone, 15% siltstone, 5% sandstone]
290-300’ “ “
300-310’ “ [60% mudstone, 30% siltstone, 10% sandstone]
310-320’ Reddish brown siltstone, +HCl. Pale green mudstone, +HCl. [80% siltstone, 20% mudstone] → top of Chinle?
320-330’ “
330-370’ No samples.
370-380’ Reddish brown siltstone, ~HCl.
380-390’ Reddish brown and very pale red mottled siltstone, +HCl. Reddish brown and very pale green mottled mudstone, -HCl.
390-400’ Reddish brown and pale green mottled siltstone, +HCl.
400-410’ Very pale yellow siltstone, +HCl. Pale reddish brown and pale green mudstone, -HCl. Quartz arenite, fine to very fine grained, subrounded, well sorted, ≤15% clay matrix, +HCl. [no percentages – only 6 items in bag]
410-420’ Very pale yellow siltstone, +HCl. Pale reddish brown siltstone, -HCl. Quartz arenite, fine to very fine grained, subrounded, well sorted, ≤15% clay matrix, +HCl. [no percentages – only 5 items in bag]

420-430’ Very pale yellow siltstone, +HCl. Pale reddish brown and pale green siltstone, -HCl. Pale green and reddish brown mudstone, -HCl. [45% red and green siltstone, 43% mudstone, 2% pale orange siltstone]

430-440’ Reddish brown and very pale green mudstone, -HCl. Quartz arenite, fine to very fine grained, subrounded, well sorted, ≤15% clay matrix, +HCl. [65% mudstone, 35% sandstone]

440-450’ Reddish brown, very pale green and very pale red mottled mudstone, -HCl.

450-460’ Reddish brown, very pale green and very pale red mottled mudstone, -HCl. Pale reddish brown rip-clast sandstone, coarse grained, subrounded, well sorted, 100% reddish brown and pale green mud rip-up clasts, +HCl. [95% mudstone, 5% sandstone]

460-470’ Reddish brown, very pale green and very pale red mottled mudstone, -HCl. Very pale orange to very pale gray siltstone, +HCl. Pale reddish brown rip-clast sandstone, coarse grained, subrounded, well sorted, 100% reddish brown and pale green mud rip-up clasts, +HCl. [80% mudstone, 18% siltstone, 2% sandstone]

470-480’ Reddish brown, very pale green and very pale red mottled mudstone, -HCl. Very pale orange to very pale gray siltstone, +HCl. [85% mudstone, 15% siltstone]

480-490’ Very pale yellow siltstone, +HCl. Pale reddish brown and pale green siltstone, -HCl. Pale green and reddish brown mudstone, micaceous, -HCl. [45% red and green siltstone, 45% mudstone, 10% pale orange siltstone]

490-500’ Pale reddish brown and pale green siltstone, -HCl. Pale green and reddish brown mudstone, micaceous, -HCl. [60% mudstone, 40% siltstone]

500-510’ Very pale yellow siltstone, +HCl. Pale reddish brown and pale green siltstone, -HCl. Pale green and reddish brown mudstone, micaceous, -HCl. [60% mudstone, 35% red and green siltstone, 5% pale orange siltstone]

510-520’ “ [55% red and green siltstone, 40% mudstone, 5% pale orange siltstone]

520-530’ Reddish brown and very pale green and mudstone, -HCl. Very pale orange to very pale gray siltstone, +HCl. Pale reddish brown rip-clast sandstone, coarse grained, subrounded, well sorted, 100% reddish brown and pale green mud rip-up clasts, +HCl. [70% mudstone, 20% siltstone, 10% sandstone]

530-540’ “ “

540-550’ “ [80% mudstone, 15% siltstone, 5% sandstone]

550-560’ “

560-570’ “ [85% mudstone, 13% siltstone, 2% sandstone]

570-580’ Pale green and reddish brown siltstone, ~HCl.

580-590’ “

590-600’ “

600-610’ Pale green, reddish brown and very pale gray siltstone, ~HCl.

610-620’ “

620-630’ “

Hoxsey #1 Jones (27-26N-32E, TD: 3898’)

290-300’ Medium gray loose sand, fine grained, subrounded, well sorted, 100% Q.

300-310’ “

310-320’ Very pale gray silt, mostly loose.

320-330’ “

330-340’	“
340-350’	“
350-360’	“
360-370’	“
370-380’	“
380-390’	Medium gray loose sand, fine grained, subrounded, well sorted, 100% Q.
390-400’	“ with some pale green rip-up clasts.
400-410’	“ “, common pyrite.
410-420’	No samples.
420-430’	Very pale greenish gray silt, mostly loose.
430-440’	Pale gray silt, mostly loose.
440-450’	“
450-460’	“, abundant jasper**
460-470’	“ “
470-480’	No samples.
480-490’	Very pale red and pale green siltstone, mostly loose, abundant jasper**.
490-500’	“, jasper, rare pyrite.
500-510’	Pale reddish brown and pale green mudstone, some jasper.
510-520’	Reddish brown and pale green mudstone, +HCl. → Chinle top?
520-530’	“
530-540’	“
540-550’	“
550-560’	“
560-570’	“ Pale orange silt, loose. [60% silt, 40% mudstone]
570-580’	Reddish brown and pale green mudstone, +HCl. (some jasper – mixed in from above?)
580-590’	“
590-600’	“ (some jasper)
600-610’	“
610-620’	“
620-630’	No samples.
630-640’	“ Very pale gray siltstone, +HCl. [80% mudstone, 20% siltstone]
640-650’	“ “ “
650-660’	“ “ “
660-700’	No samples.