Colfax County

Hydrogeology Project

Annual Progress Report

2018-2019

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Zeigler Geologic Consulting, LLC
13170 Central Ave. SE, Suite B #137
Albuquerque, NM 87123
zeiglergeo@gmail.com; zeiglergeo.com
(505) 263.5448 (575) 207.7826

Kate Zeigler, Ph.D., CPG

Ethan Williams, B.S.

Brooklyn Armijo

WESTERN GEOINFORMATICS
415 Camino de la Tierra
Corrales, NM 87048
(406) 544.2133

Andrew Yuhas, M.S.

Contents

Introduction

This report is Zeigler Geologic Consulting, LLC's (ZGC) progress report for the Colfax County Hydrogeology Project, sponsored by Colfax County and the Colfax Soil and Water Conservation District (SWCD). During the 2018 calendar year, ZGC measured static water level in 25 wells in December and in January 2019, continued geologic mapping around Maxwell, obtained seven general chemistry and trace metals, as well as xxx 14-carbon and seven tritium isotope samples. Here we describe the progress in each of these tasks. We would like to thank Colfax County and the Colfax SWCD for funding this project. The Soil & Water Conservation Commission provided additional funding to support data collection, as well as a series of workshops in local schools and communities.

Static Water Level Measurements

In both summer and winter, depth to water was measured in 38 wells in the eastern and central part of the county to document maximum draw on the water table (July) and minimum draw (December-January) (Figure 1). A 300-foot steel tape is used for most of the wells and a 500-foot steel tape for wells deeper than 300 ft. For open casing wells, we use an e-tape with a 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 0.01 ft of one another are obtained. If we cannot obtain two measurements within 0.01 ft of one another, the closest values are averaged and the data is flagged in the database as of lower precision. We observe three groups of water levels: shallow water levels (10-40' below ground surface - bgs), intermediate water levels (80-120' bgs) and deeper water levels (200-220' bgs). Shallow water levels occur primarily in wells located immediately adjacent to drainages.

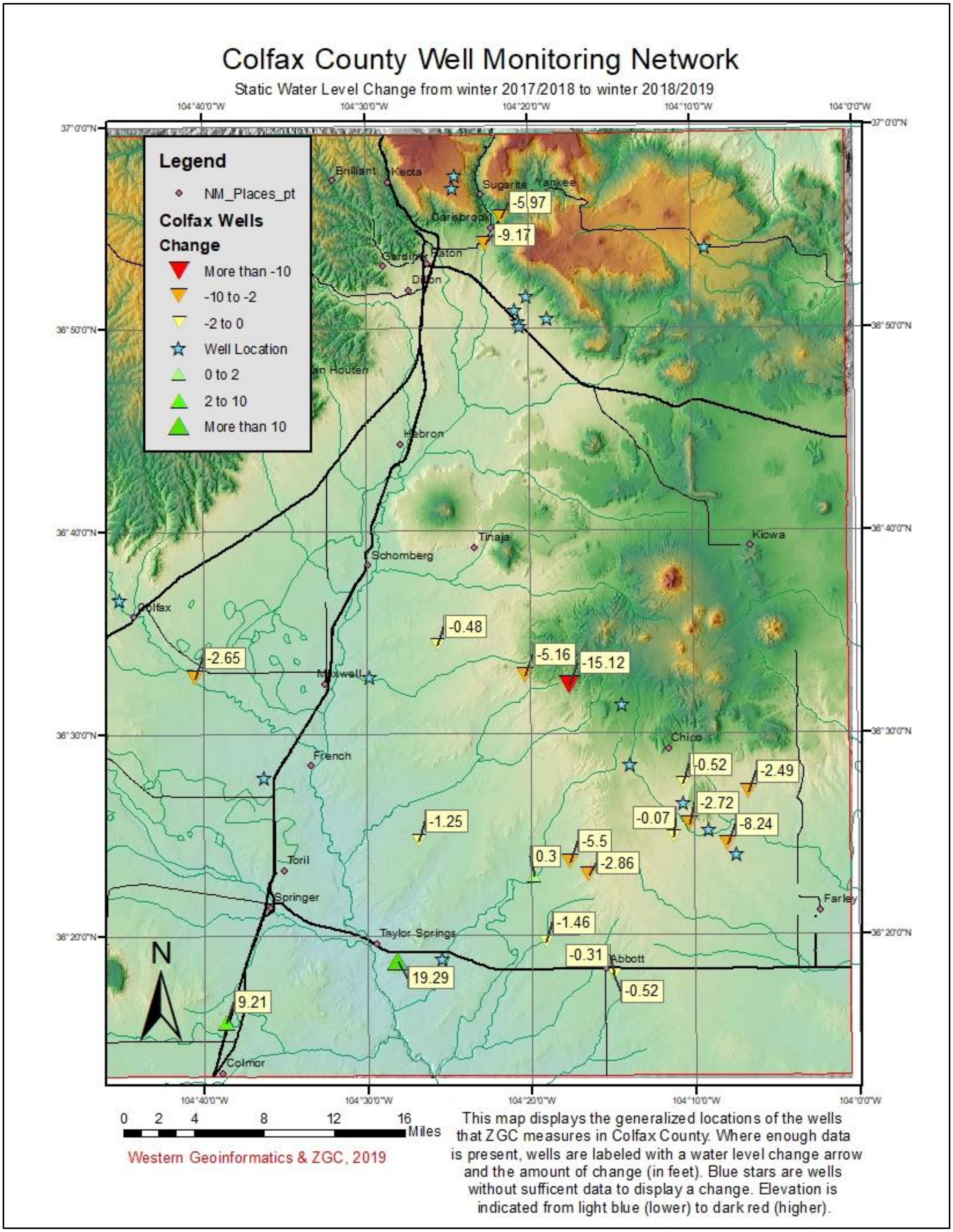

Figure 1. Location of wells and comparison of water levels from winter of 17/18 to winter of 18/19 where possible for wells in the Colfax groundwater network.

From winter of 2017 to winter of 2018, nine of the wells showed increasing water levels, 25 showed decreasing water levels, two were inconclusive and two were inaccessible in January 2019. Wells with intermediate and deeper water levels often show declining water levels. Over the last year, many of the shallow wells also showed declining water levels. Wells with inconclusive results included wells that appeared to not fully recover from the time the well was turned off to when a measurement was taken and wells where the water line on the steel tape was not clear and water levels were thus an average value of uncertain measurements.

Water Chemistry

Beginning in March 2017, approximately half a liter of water was collected from each of 14 wells distributed across the county for basic water chemistry analyses of major cations and anions as well as trace metals. The analytical work was conducted by the New Mexico Bureau of Geology and Mineral Resources in Socorro. Major ion chemistry analyses include the cations calcium (Ca), sodium (Na), magnesium (Mg), and potassium (K), and the anions carbonate (CO_3), bicarbonate (HCO_3), sulfate (SO_4), and chloride (Cl). Trace metal analyses showed moderately elevated levels of arsenic, barium, boron, lithium, uranium and vanadium in many wells, although no wells had concentrations of any of the 26 different trace metals tested for above drinking water standards (EPA method 200.8). We recommend Hem's (1985) *Study and Interpretation of the Chemical Characteristics of Natural Waters* for an in-depth review of groundwater chemistry. A Piper diagram (Figure 2) shows the concentrations of major cations and anions for all of the wells sampled to date.

Analyses of these 14 samples resulted in Ca, Mg, and Na as dominant cations and HCO_3, and SO_4 as dominant anions. Of these samples, seven are of the Ca-HCO3 water type, five are Na-HCO3, five are Ca-(Na-)-SO4 type and the remaining two are mixed cation-anion. The Ca-Mg-HCO_3 types correspond to wells completed through the Dakota Group, Ogallala Formation, Quaternary alluvium and springs exiting from Quaternary basalt flows. Ca-Mg-HCO_3 waters have been used as an indicator of shorter residence time of groundwater in aquifer systems, due to the lack of other cations and anions indicating too short a time for significant dissolution. Na-HCO_3 water types are assumed to indicate a longer residence time during which cation exchange with clays can take place and these water types correspond to waters from the Greenhorn

Limestone and the Niobrara Group, which consists of black and gray shales, thin limestone beds and limey sandstone units. Ca-(Na-)-SO4 water types primarily reflect water from Greenhorn Limestone, Carlile Shale and minor Niobrara Group strata and correspond to the presence of local zones with higher concentrations of gypsum, a calcium sulfate.

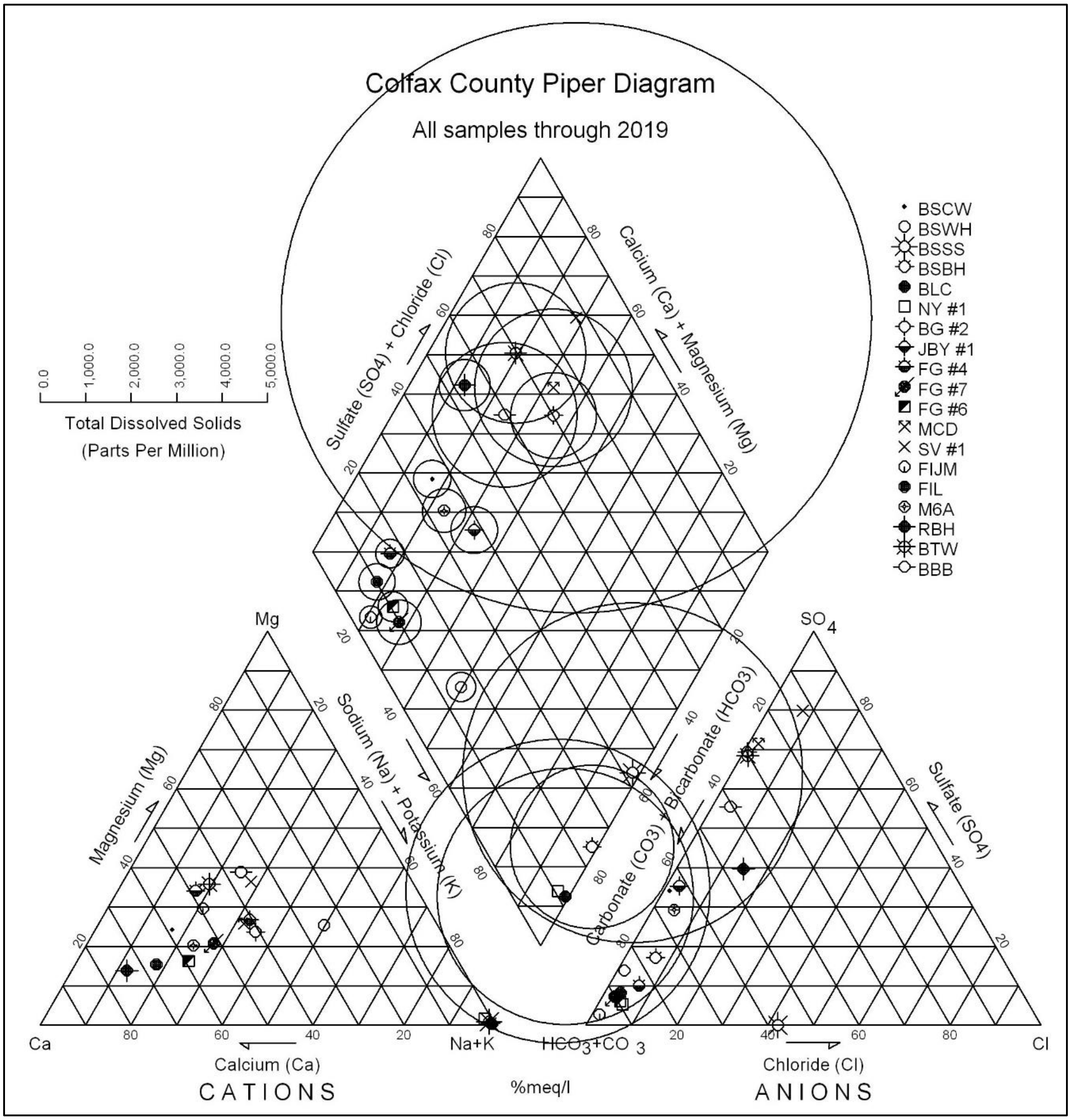

Figure 2. Piper diagram for water chemistry samples collected from 2017 through January 2019 from Colfax County. Circles indicate total dissolved solids for each well – larger circles indicate higher TDS.

Carbon-14 and Tritium Dates

One liter of water was collected from 17 wells for carbon-14 isotope analysis (Figure 4) and the samples were analyzed by Beta Analytic, Inc. in Miami, Florida. Groundwater age is related to the rate at which water migrates through the subsurface. It is important to remember that water molecules may enter and leave the system via cross-formational flow and that any given mass of groundwater will exchange water molecules with masses of water on all sides of it (Bethke and Johnson, 2008). Hence, a mass of water that entered the groundwater and had a single age associated with it will end up with many of those particles dispersed, rather than traveling entirely as a discrete package. A groundwater sample, therefore, is an average of the ages of all of the molecules of water contained in that sample (Bethke and Johnson, 2008). The distribution of these ages for each sample may include much older molecules and much younger molecules, and may be heavily skewed in one direction or the other. One complication for the ^{14}C method is that the oxidation of ancient organic matter or the dissolution of carbonates (e.g., limestone) will add ^{14}C-depleted carbon (also called “dead” carbon) into the groundwater (Bethke and Johnson, 2008). This process will create an erroneously old age and so ages of water extracted from systems that are suspected of including carbonate interactions should be corrected for this depleted carbon addition.

For this study, geochemical interactions with the host rocks in the Dakota Group or the shallow alluvial aquifers are unlikely to contribute significant amounts of “dead” carbon due to a lack of significant quantities of carbonate rocks. However, wells drawing water from the shale and limestone-dominated units above the Dakota Group, including the Graneros Shale, Greenhorn Limestone, and Niobrara Group, will probably have skewed age results due to the presence of limestone beds within these units.

Eighteen samples were 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). 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 TU and 15 TU indicate waters that are modern (5-10 years old).

Table 1: Tritium and 14-Carbon Results.

Sample ID	**Tritium (in TU*)**	**^{14}C Date (YBP*)**	**Age Interpretation**
JBY #1	5.65	300	Modern
SV #1	5.14	0	Modern
FG #4	0.89	3,300	Pre-1952
BLC	-0.07	33,570**	Pre-1952
NY#1	0.03	37,370**	Pre-1952
FG #7	-0.02	16,240**	Pre-1952
MCD	5.4	280	Modern
SBr	1.26	14,690**	Mixed
SWH	-0.01	13,050**	Pre-1952
SSS	-0.03	43,500**	Pre-1952
SCw	0.25	7,810	Pre-1952
M6A	3.8	460	Mixed to Modern
FG #6	1.78	1,800	Mixed
WF #1	0.51	4,210	Pre-1952
WF #2	3.89	120	Modern
RBH	2.47	1,110	Mixed
GI #2	4.92	2,940	Mixed to Modern
CD #5	3.73	Results not returned	Mixed to Modern

*TU = tritium units. YBP = Years before present.
**14-carbon results may be skewed by presence of "dead" carbon in limestone units.

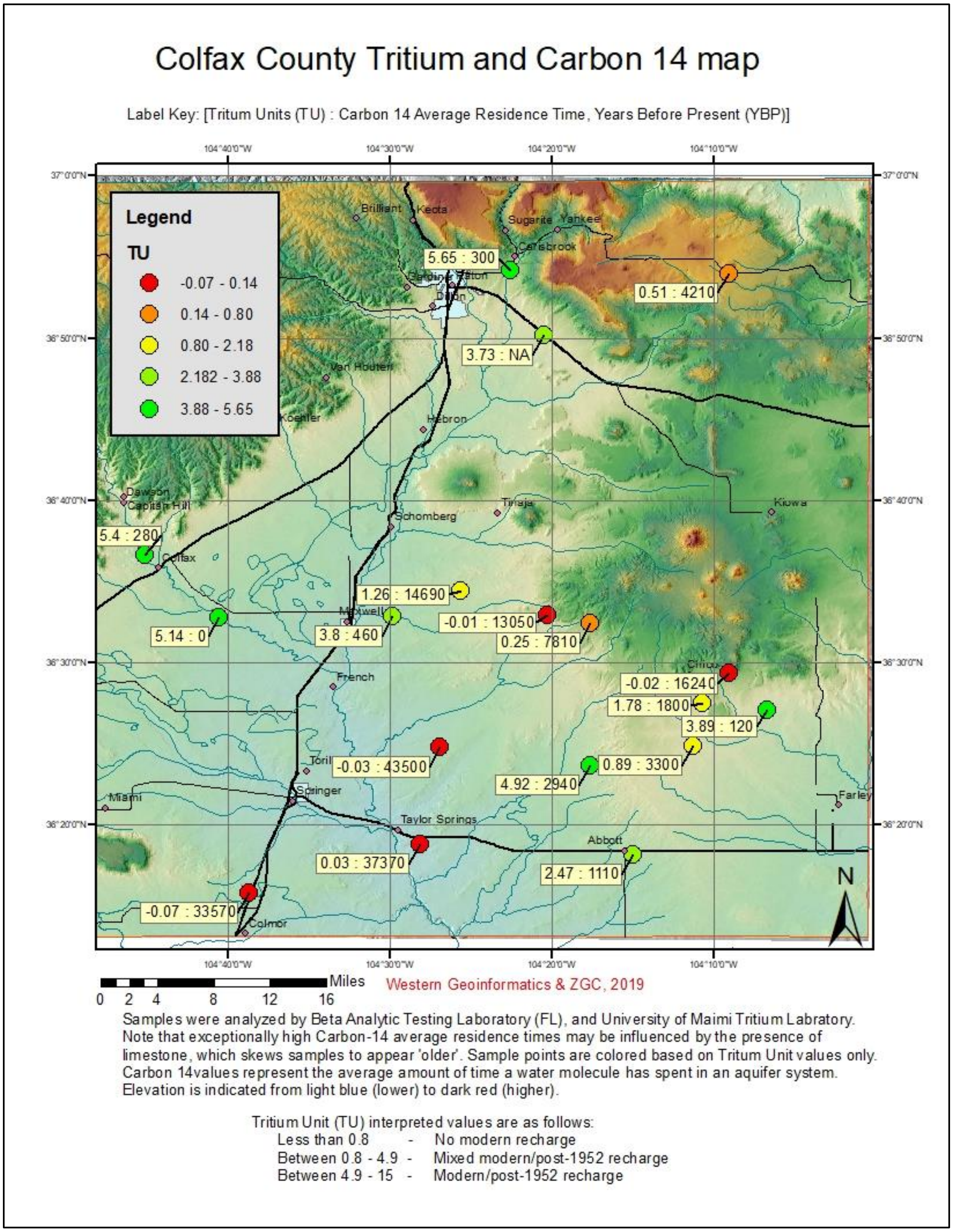

Figure 3. 14-carbon and tritium isotopic results for the Colfax area.

Wells showing significant tritium levels and younger average residence times are all located close to drainages and have shallow water levels. Wells with little to no measurable tritium and older average residence times generally have deeper water levels and do not seem to be receiving significant modern recharge. Several of the 14-carbon results are presumably skewed by the presence of limestone in the rock units these wells are drawing water from.

Geologic Mapping

Three 1:24,000 scale quadrangles east of the village of Maxwell are in the digitizing phase: Maxwell, Loco Arroyo and Circle Dot quadrangles, and one map is currently in the field-mapping phase: Yankee quadrangle. Locally, the geology includes significant surficial deposits of Quaternary alluvium along drainages and young sheetwash and eolian sheet sand deposits in the intervening space between drainages. Bedrock exposures include Tertiary igneous rocks and Cretaceous sedimentary rocks. In addition, there may be thin relict deposits of the Ogallala Formation, but these deposits need further review. See the 2017 progress report for detailed descriptions of the geology observed on the Loco Arroyo and Circle Dot quadrangles.

Summary

Preliminary results suggest three zones of water levels: shallow water tables in wells located adjacent to drainages and intermediate to deeper water levels in wells completed in bedrock aquifers. A greater density of wells is needed to determine if this pattern holds a greater area of the county. Wells in the Sangre de Cristos Mountains will reflect an entirely different geologic regime and future work will include incorporating wells in the mountain front. Initial water chemistry shows a strong relationship between bedrock a well is completed in, as well as influence from nearby surface water for shallow wells. Tritium and 14-carbon data indicate that shallow wells near drainages appear to receive fairly significant modern recharge, but deeper wells completed in bedrock aquifers generally do not appear to receive significant recharge. In addition, the presence of abundant limestone locally has resulted in artificially older 14-carbon residence times.

Future work includes continued monitoring of static water level measurements to continue tracking rates of changes between minimum and maximum use seasons as well as changes over an annual basis. Further sampling for tritium and 14-carbon isotopes will help us continue to refine our understanding of where modern recharge is occurring on the landscape. Water chemistry analyses are useful not only for documenting current water quality in these wells, but assist with tying together the geologic maps and the subsurface geology. Continued geologic mapping and petroleum well log analyses will also help with developing a better picture of the complexities of the subsurface.

References

Bethke, C.M. and Johnson, T.M., 2008, Groundwater age and groundwater age dating: Annual Review of Earth and Planetary Sciences, v. 36, p. 121-152.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural waters: U.S. Geological Society Water-Supply Paper 2254, 264 p.

Staatz, M.H., 1987, Geologic map of the Tres Hermanos Peak quadrangle: U.S. Geological Survey GQ-1605, 1:24,000 scale.

Appendices

Appendix I: Static Water Level Measurements

Individual well static water level measurements, corrected to land surface. NM = not measured.

ID	Date Measured	Depth to Water Below Land Surface (feet)
MK #1	3/7/17	96.10
	7/27/17	162.38
	2/1/18	95.46
	7/19/18	190.50
	12/20/18	NM
MK #2	3/7/17	79.31
	7/27/17	77.94
	2/1/18	77.45
	7/19/18	78.01
	12/20/18	NM
SV #1	3/7/17	15.10
	7/27/17	13.26
	2/21/18	11.59
	8/15/18	14.61
	12/18/18	14.24
FG #1	3/7/17	122.27
	7/31/17	122.69
	1/30/18	112.58
	12/19/18	120.82
FG #2	3/7/17	121.31
	7/31/17	122.35
	1/30/18	NM
	8/13/18	NM
	REMOVED 2019	
FG #3	3/7/17	64.07
	7/31/17	68.80

	1/30/18	63.62
	8/13/18	63.16
	12/19/18	71.37
FG #3b	1/30/18	200.09
	8/13/18	205.31
	12/19/18	202.81
FG #4	3/7/17	134.97
	7/31/17	138.69
	1/30/18	134.07
	8/13/18	138.11
	12/19/18	134.14
FG #5	3/7/17	64.40
	7/31/17	63.30
	1/30/18	60.32
	8/13/18	60.80
	12/19/18	NM
FG #6	3/7/17	35.68
	7/31/17	37.99
	1/30/18	35.97
	8/13/18	41.55
	12/19/18	36.49
FG #7	3/7/17	78.46
	7/31/17	73.66
	8/13/18	80.87
	12/19/18	79.23
BLC	3/16/17	32.85
	7/26/17	32.75
	2/21/18	40.90
	8/13/18	33.16
	12/11/18	31.69
BLFT	3/16/17	43.20
	7/26/17	11.45
	2/21/18	NM
	8/13/18	9.84

	1/31/19	14.10
BLCC	3/16/17	94.32
	7/26/17	115.96
	8/13/18	115.41
	12/20/18	115.68
NY#1	3/16/17	92.67
	7/27/17	92.03
	2/21/18	95.22
	8/15/18	74.82
	12/18/18	75.93
BG #1	3/17/17	10.37
	7/25/17	13.52
	1/30/18	9.21
	8/14/18	9.43
	2/11/19	8.91
BG #2	3/17/17	26.71
	7/25/17	18.88
	1/30/18	22.47
	8/14/18	NM
	2/11/19	27.97
BG #3	3/17/17	12.56
	7/25/17	20.90
	1/30/18	11.25
	8/14/18	13.19
	12/19/18	14.11
BG #4	3/17/17	10.90
	7/25/17	13.54
	1/30/18	5.94
	8/14/18	6.52
	12/18/18	7.40
	8/14/18	12.13
	2/11/19	11.90
JBY #1	3/17/17	31.86

	7/28/17	23.92
	2/1/18	23.78
	8/15/18	27.80
	12/20/18	32.95
JBY #2	3/17/17	22.55
	7/28/17	20.24
	2/1/18	17.52
	8/15/18	22.34
	12/20/18	23.49
MCD	7/19/18	19.10
	12/18/18	20.94
MV6A	7/28/17	21.32
	2/21/18	18.51
BSSS	2/22/17	216.72
	7/26/17	231.30
	2/2/18	216.86
	7/18/18	232.13
	12/18/18	218.11
BSCW	2/22/17	118.36
	7/26/17	114.17
	2/2/18	53.56
	7/18/18	63.87
	12/21/18	68.68
BSWH	2/22/17	104.30
	7/26/17	104.19
	2/2/18	13.24
	7/18/18	19.13
	12/18/18	18.40
BSBH	2/22/17	65.11
	7/26/17	9.25
	2/2/18	6.90
	7/18/18	9.69
	12/21/18	7.38

WF #1	8/15/18	213.88
	12/20/18	NM
WF #3	1/31/18	29.15
	8/14/18	31.70
	12/21/18	31.64
RB #2	1/31/18	73.04
	8/14/18	73.16
	12/19/18	73.56
RB #3	1/31/18	72.70
	8/14/18	72.91
	12/19/18	73.01
RSP	8/14/18	28.65
	12/19/18	29.03
RUW	8/14/18	58.54
	12/19/18	58.66
CD #1	8/15/18	35.11
	12/19/18	30.17
CD #2	8/15/18	54.87
	12/19/18	52.47
CD #3	8/15/18	19.02
	12/19/18	19.38
CD #4	8/15/18	8.70
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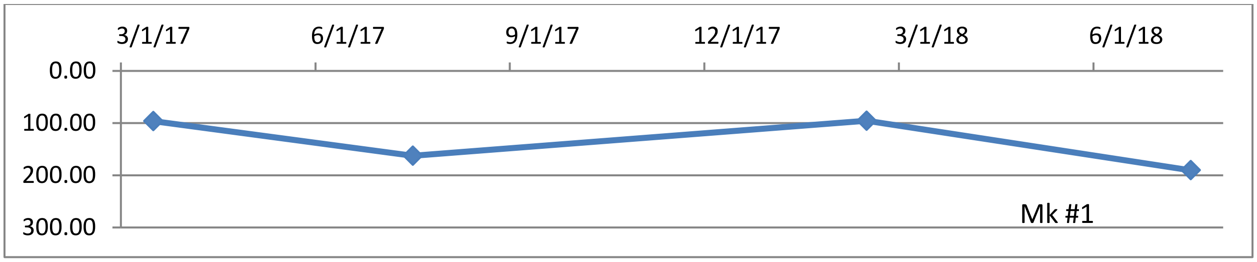
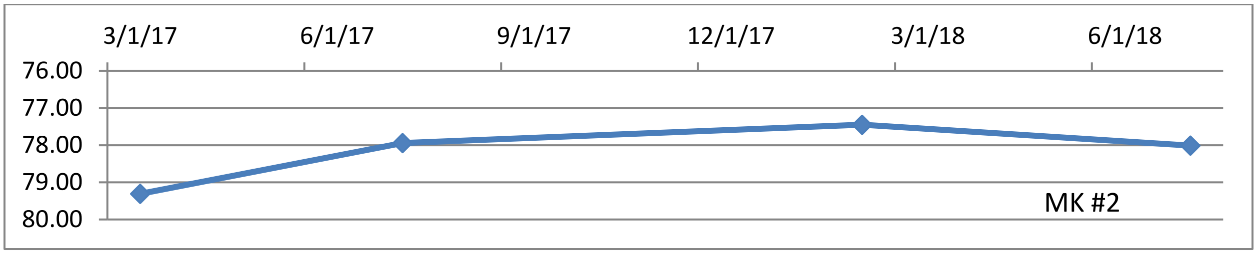
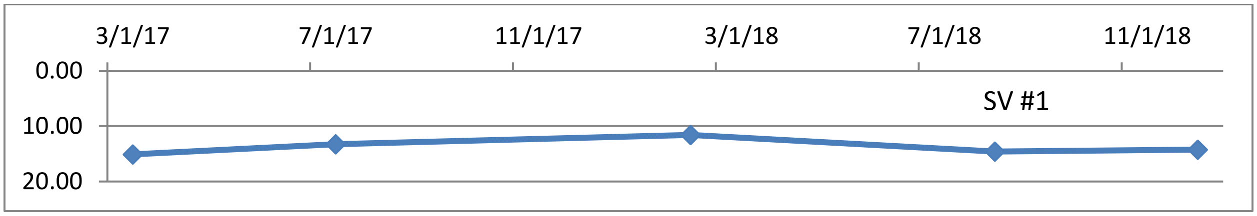
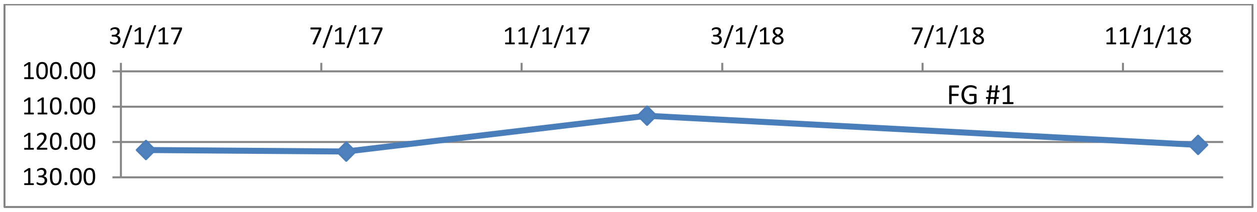
CD #5	8/15/18	5.75
	12/19/18	4.65
CD #6	12/19/18	NM

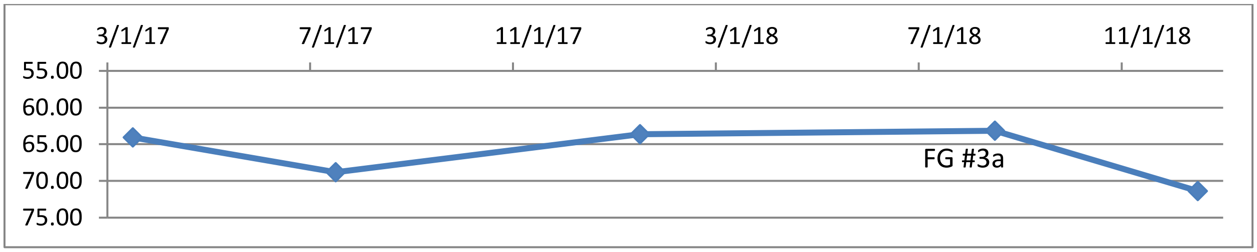
Appendix II: Well Hydrographs

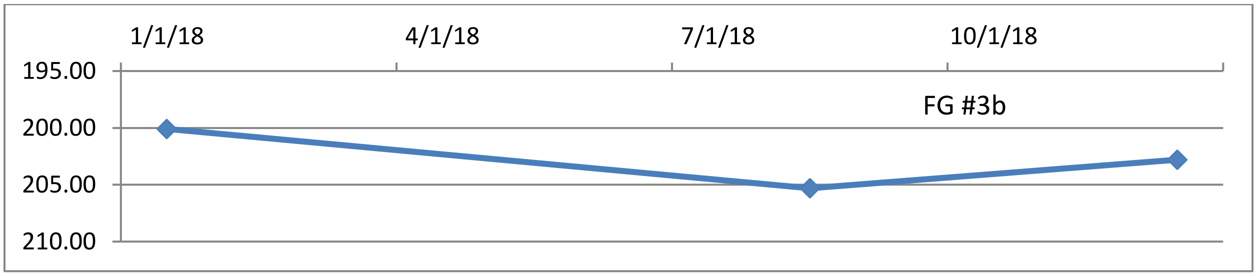


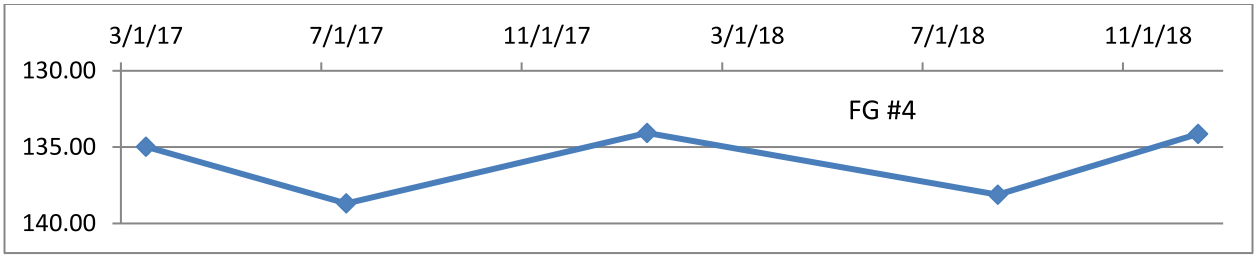








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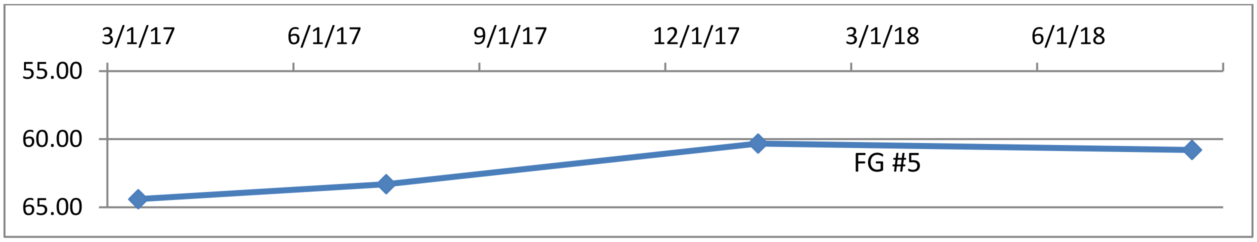
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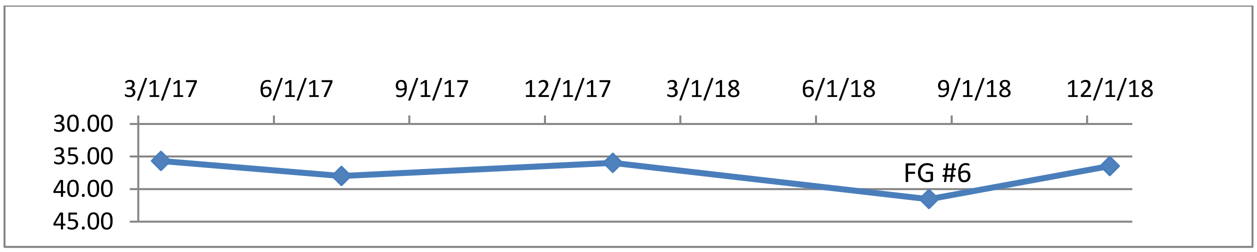
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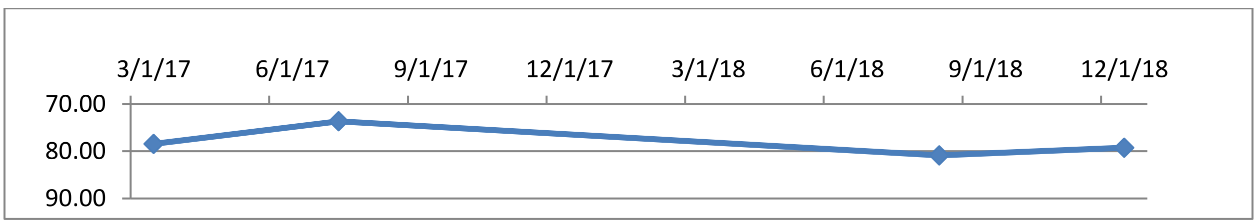
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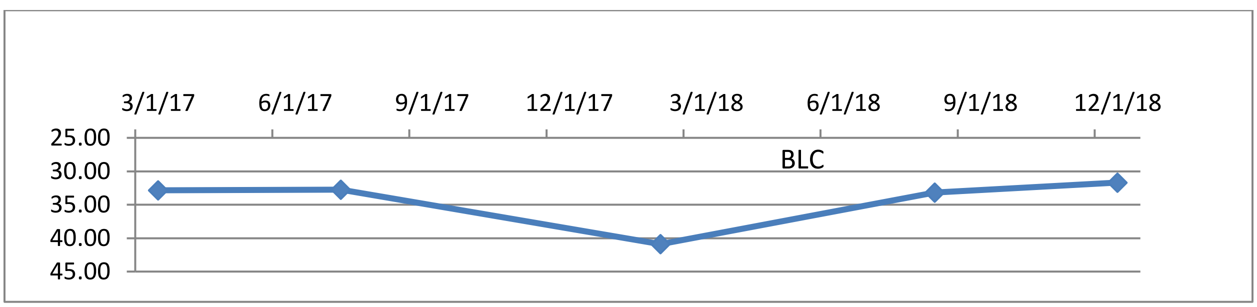
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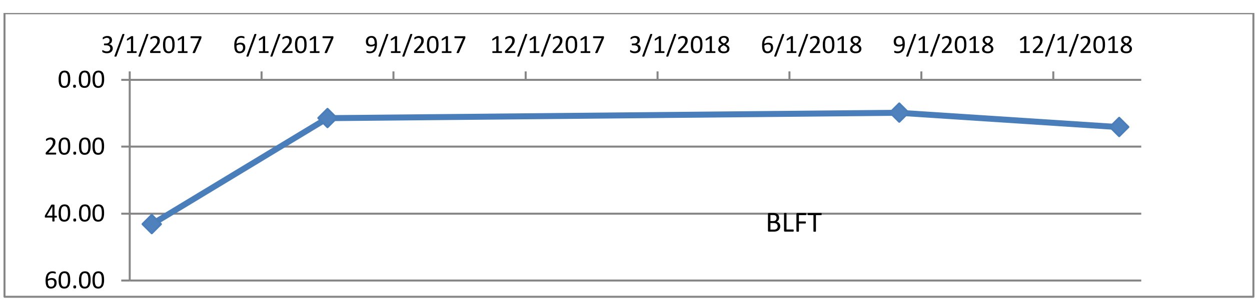
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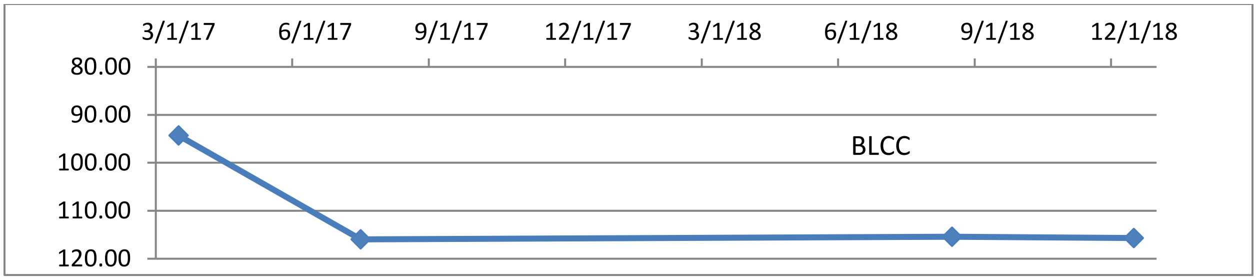
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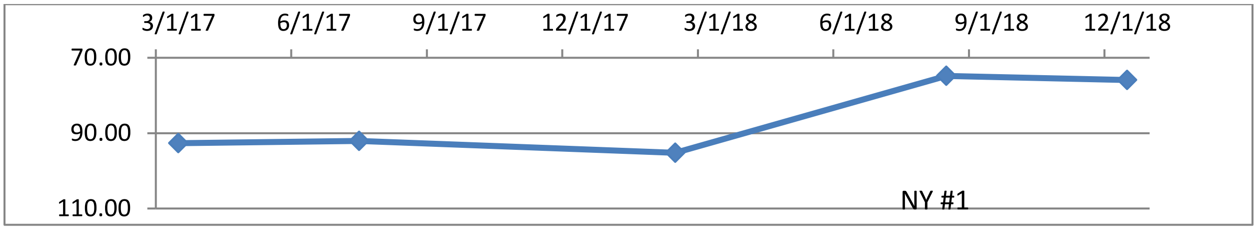
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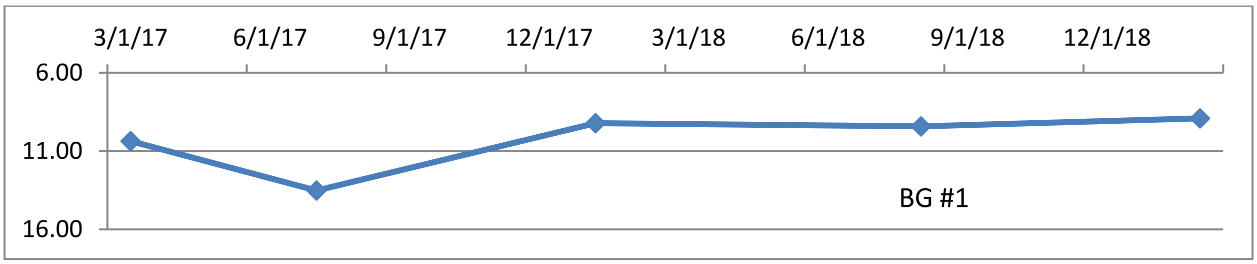
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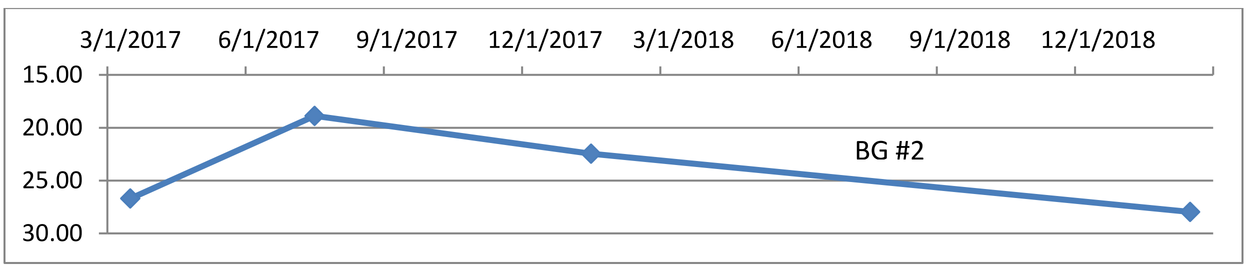
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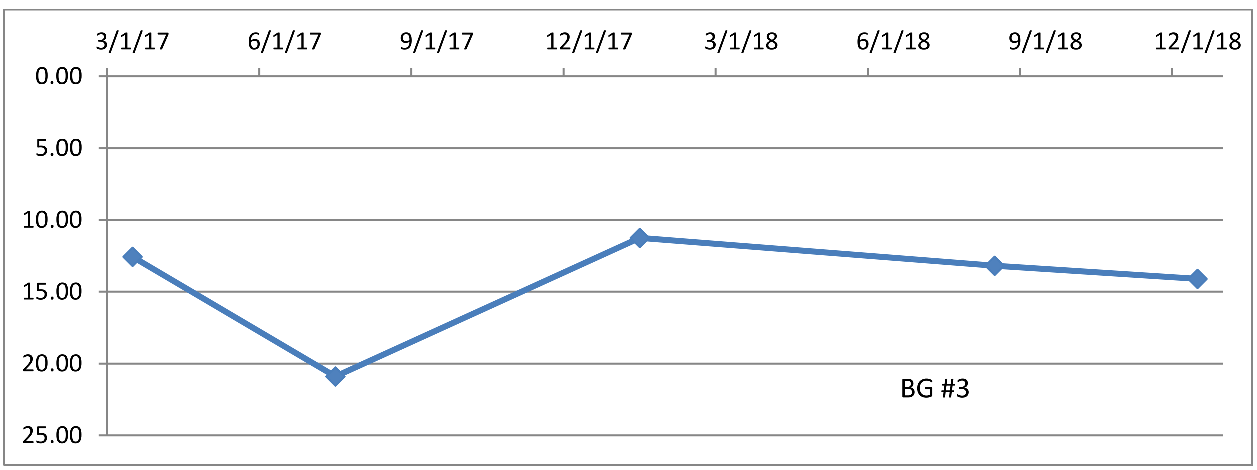
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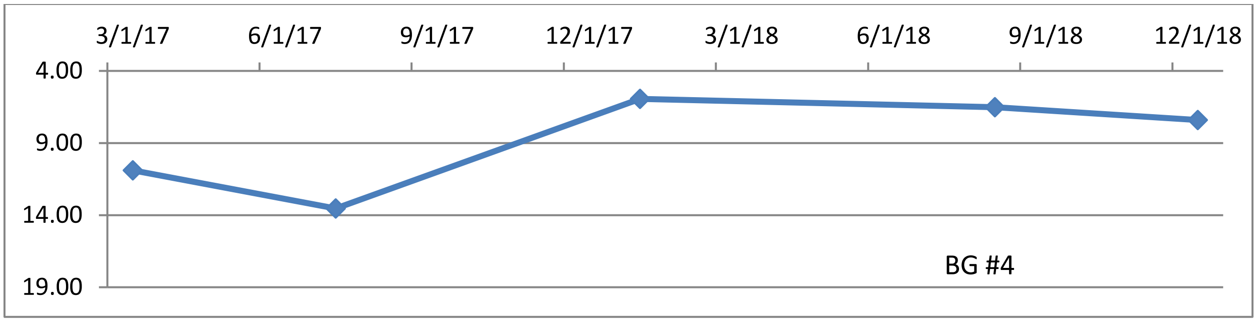
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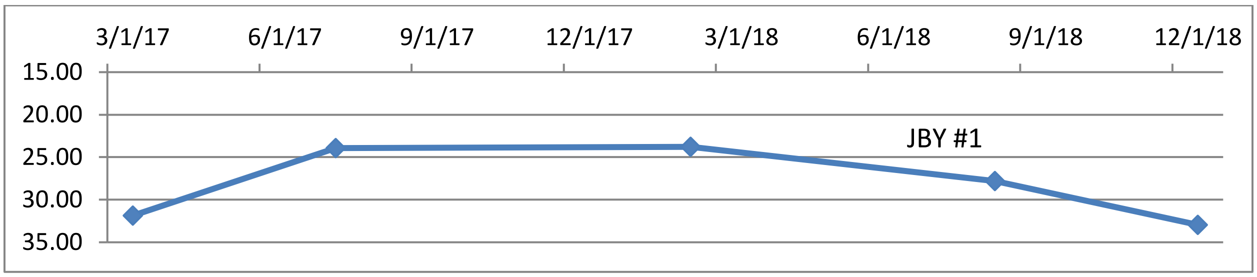
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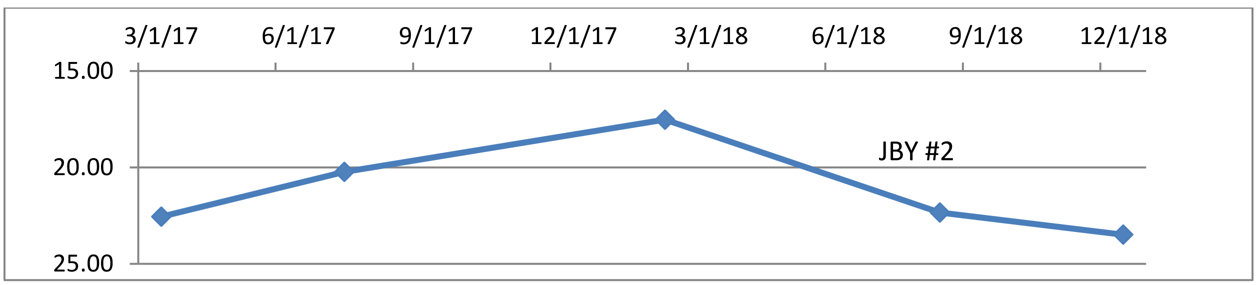
20.00
25.00
30.00
35.00
JBY #1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25.00
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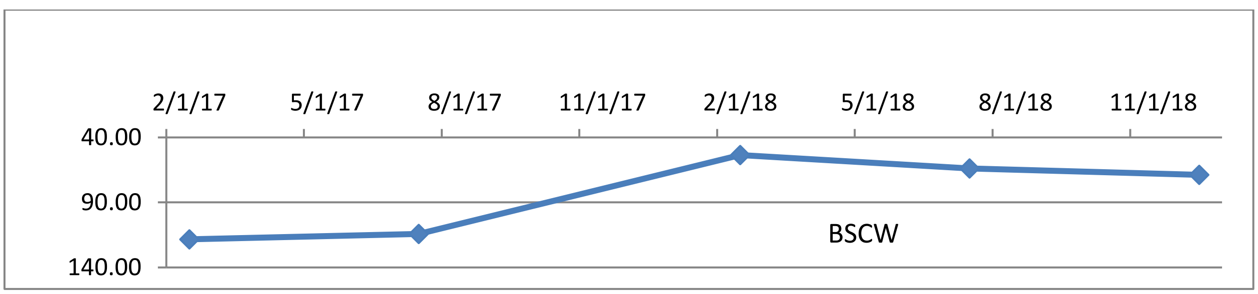
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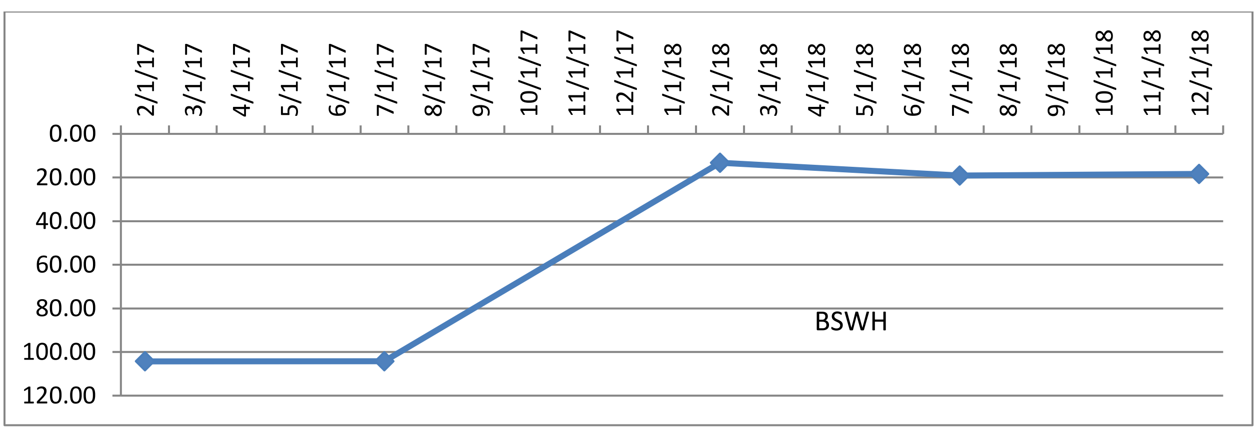
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9/1/18
10/1/18
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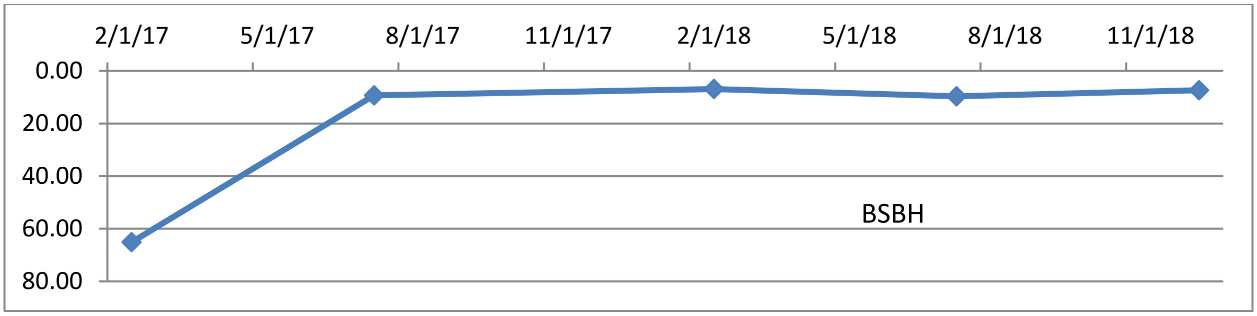
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40.00
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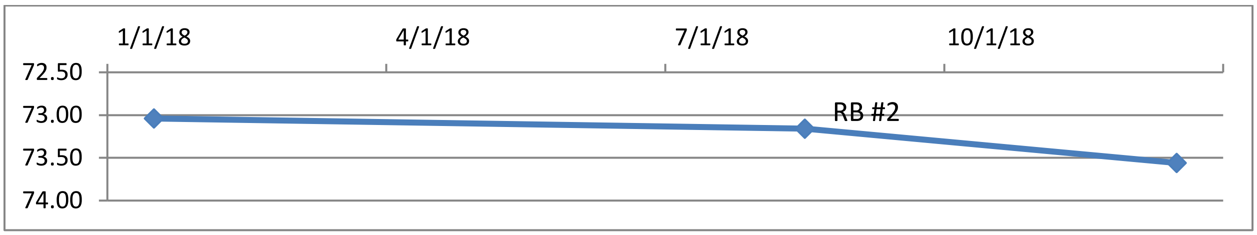
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10/1/18
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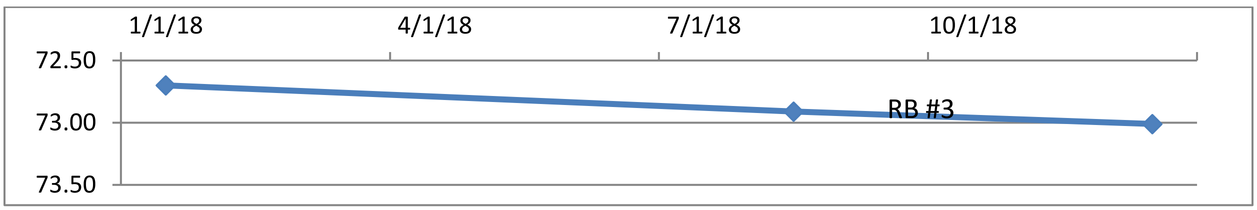
RB #2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