2017 Fen Well Monitoring Report

Prepared for the Lower Minnesota River Watershed District
by Dakota County Soil and Water Conservation District

Contents

Introduction

The Minnesota River corridor, just upstream of the confluence with the Mississippi River, is a unique habitat consisting of calcareous fens, intersected with small trout streams (see map in Appendix 1). Flora and fauna of the fens and streams rely on groundwater input to maintain water levels and provide cool water. The abundance of dissolved minerals, particularly calcium carbonate, causes the water to be more alkaline (higher pH), a typical signature of streams and wetlands with a significant groundwater influence.

As a result of development in the area, little natural fen remains and there is concern over the quality of the fen habitat and the ability to support the wildlife that is well adapted to its unique characteristics. Groundwater pumping, infrastructure, and stormwater input have had a noticeable effect on water quality and quantity. Several assessments of this natural resource and the need for continued monitoring were done, and in 2007 the Lower Minnesota River Watershed District began working with the Dakota County Soil and Water Conservation District to conduct annual fen well monitoring.

Weather Summary

Monthly precipitation data was retrieved from the Minnesota Department of Natural Resources (MD DNR) website for the Minneapolis/St. Paul airport weather station. Since 2006, there have been a mix of years with precipitation above (2007, 2010, 2013, 2014, 2015, 2016, 2017) and below (2006, 2008, 2009, 2011, 2012) the 30 year average, as shown in Figure 1.

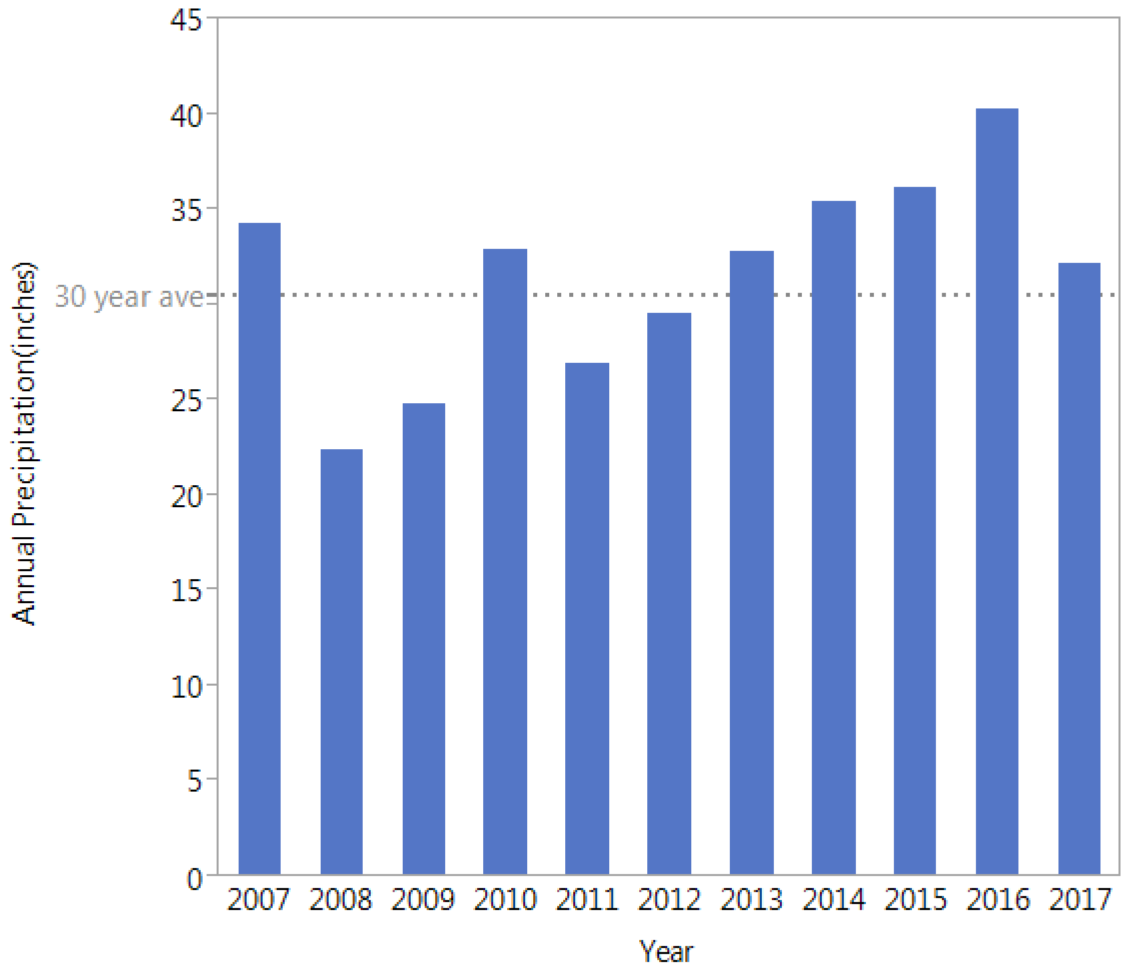


Figure 1. Total rainfall (inches) from 2007-2017 at Minneapolis/St. Paul weather station, data courtesy of the MN DNR. Gray dotted line indicates the 30 year (1987-2017) total annual average precipitation of 30.5 inches.

In the Quarry Island and Fort Snelling fens, the well water level did not seem to change much as a result of precipitation in previous or current years. On the other hand, the Nichols wells seemed to be heavily influenced by annual precipitation. According to the “Environmental Monitoring of Nichols Fen” study conducted in 2008 by WSB & Associates, Inc., the Nichols fen has an 18-24 month response time to precipitation. Based on the data summarized here, it appears that a year with higher well level measurements is preceded by a year in which total precipitation is above average. Alternatively, years with lower well level measurements are preceded by years in which total precipitation is below average. For example, 2010 was an above average year for total rainfall, and several wells in the Nichols fen show higher levels in 2011.

Methods

Fen wells were monitored on a monthly basis from March through December from 2007 through 2017 (no monitoring was undertaken in 2014). The monitoring network consists of two wells in the Quarry Island fen, 13 wells in the Fort Snelling fen, and 13 wells in the Nichols fen for a total of 28 wells.

A Solinst Water Level Meter (Model 101) was used to measure the distance from the benchmark at the top of the well casing down to the water surface. Data was later transcribed into mean sea level and reported as elevation, in feet. In cases where the water level was "flowing" or too shallow to measure, the elevation of the pipe casing was used. In cases where the water in the pipe was frozen, no level data was recorded. See figures captions and fen grouping summaries for more description.

Data are reported to the Minnesota Department of Natural Resources and can be retrieved by following this link (http://www.dnr.state.mn.us/waters/cgm/index.html).

Interpreting Statistical Values

Kendall's tau (T) test is commonly used to evaluate monontonic trends in water quality data as a function of time. Most generally, it is a test for whether well elevations tend to increase or decrease with time. The test determines which wells are significantly trending, but does not seek to explain the cause of the trend.

The P-value is used to quantify the statistical significance of the data. It shows the likelihood that the null hypothesis is true; i.e., there is no change in well level over time. A P-value of 0.001 means there is a 0.1% probability that there is no change in well level over time. Since this probability is so small, it indicates that the pattern in the data would be highly unlikely if there was no trend (change in level over time). Thus we can reject the null hypothesis and be fairly confident that there is a change in well level over time. Generally, a P-value below 0.05 is acceptable.

The Pearson correlation coefficient (R) is used to describe the noisiness and direction of a linear relationship. If the well level is decreasing over time there will be a negative R value close to -1, if the well level is increasing over time there will be a positive R value close to 1. If there is no clear linear trend and points are scattered around the line, the R value will be close to 0.

The coefficient of determination (R^2) is a measure of how well the predicted regression line approximates the observed data points. Data that are closely associated with the line have an R^2 close to 1, while data that are very scattered around the line have an R^2 close to 0. R^2 does not indicate whether the independent variables are a cause of the changes in the dependent variable; and thus, R^2 alone cannot be used to determine if a variable is significantly trending (up or down) or not.

Fen Well Monitoring Results and Discussion

Several statistical parameters were calculated to determine if well levels were significantly increasing or decreasing with time (Table 1). Linear regressions for each dataset are shown in Appendix 3. MN DNR visited the fen wells in September 2016 and recorded new elevations for 21 of the 28 wells. Elevations at seven wells in the Fort Snelling fen did not change as they are installed on more stable ground that does not experience seasonal and annual shifts.

Table 1. Water level trends over time for each fen well. Statistics are included only for those wells in which P-values were statistically significant. [1]No clear trend although the P-value is acceptable, the R and R^2 values do not indicate a strong trend and more data is needed. [2] Trends seem to be heavily influenced by precipitation.

	Well	Trend	Kendall's T, P-value	R	R^2
Quarry Island	P1-S	No clear trend			
	P1-D	No clear trend			
Fort Snelling	N3	Increasing	.3465, < .0001	0.514	0.27
	N4	Increasing	.3613, < .0001	0.5283	0.26
	N5	Increasing	.3287, <.0001	0.4016	0.16
	W1	No clear trend[1]	0.2246, 0.0015	0.2285	0.05
	W2	No clear trend[1]	0.2457, 0.0006	0.2699	0.07
	W3	No clear trend[1]	0.1838, 0.0130	0.2363	0.05
	W4	No clear trend[1]	0.2663 , 0.0002	0.299	0.09
	S1-USGS	No clear trend			
	S1	No clear trend			
	S2-USGS	No clear trend			
	S2	Increasing	0.7707 , 0.0010	0.9319	0.87
	S3-USGS	No clear trend			
	S3	No clear trend			
Nichols	1LN	No clear trend			
	1LS	No clear trend			
	F3	No clear trend			
	F4	No clear trend			
	WN1-USGS	No clear trend[1]	-0.6364 , 0.0064	-0.071	0.45
	WN5-USGS	No clear trend[1]	0.4394 , < .0001	0.6242	0.04
	WT-1	Decreasing	-0.3107 , < .0001	-0.341	0.18
	WT-2	No clear trend[1]	0.4047 , < .0001	0.5946	0.02
	WT-3	No clear trend[1]	0.3518, < .0001	0.5409	0.08
	WT-4	No clear trend[1]	0.3605, < .0001	0.5769	0.02
	WT-5	No clear trend			
	F1	No clear trend[1]	0.4461 , < .0001	0.6445	0.02
	F2	Decreasing[2]	-0.3092 , < .0001	-0.337	0.12

Quarry Island

The Quarry Island Fen had originally been part of the larger Snelling Fen complex and was cut off during the construction of Highway 494 and watershed development. There may be little potential for restoration in the fen as the watershed is largely developed already.

The shallower well (P1-S) monitors water level in the peat layer while the deeper well (P1-D) monitors the layer immediately below the peat. The water levels in the Quarry Island Fen appeared to be significantly decreasing over time (though individual monitoring events showed some variability) and show some annual seasonality with measurements collected in the early fall having the lowest level measurements (Figure 2). MN DNR visited the fen wells in September 2016 and recorded a new elevation for both wells. Beginning in October 2016, water levels have been adjusted to reflect the new elevations (demarcated by red line). Because of the new well elevations, continued monitoring is necessary to determine if the downward trend is statistically supported by the data.

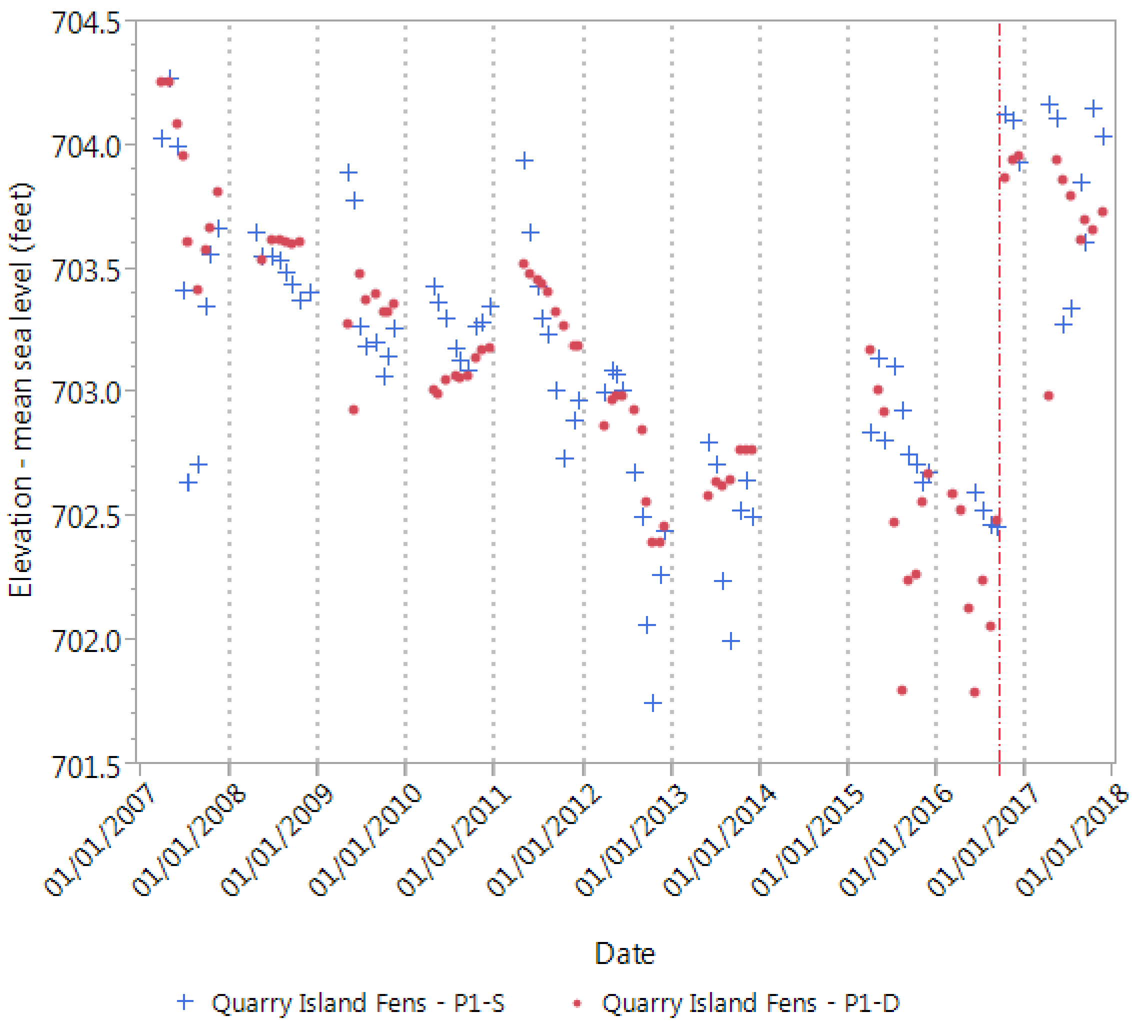


Figure 2. Water level elevation for Quarry Island Fen wells.

Fort Snelling

The Fort Snelling fen is of good quality and seems to be quite stable (Figure 3). MN DNR visited the fen wells in September 2016 and recorded a new elevation for each well. Beginning in October 2016, water levels have been adjusted to reflect the new elevations (demarcated by red line). S1-USGS has historically shown a downward trend in water level, but statistical analysis following the elevation change no longer supports that conclusion. Continued monitoring of the Fort Snelling fen will strengthen trend analyses and allow for any degradation to be more quickly recognized and addressed.

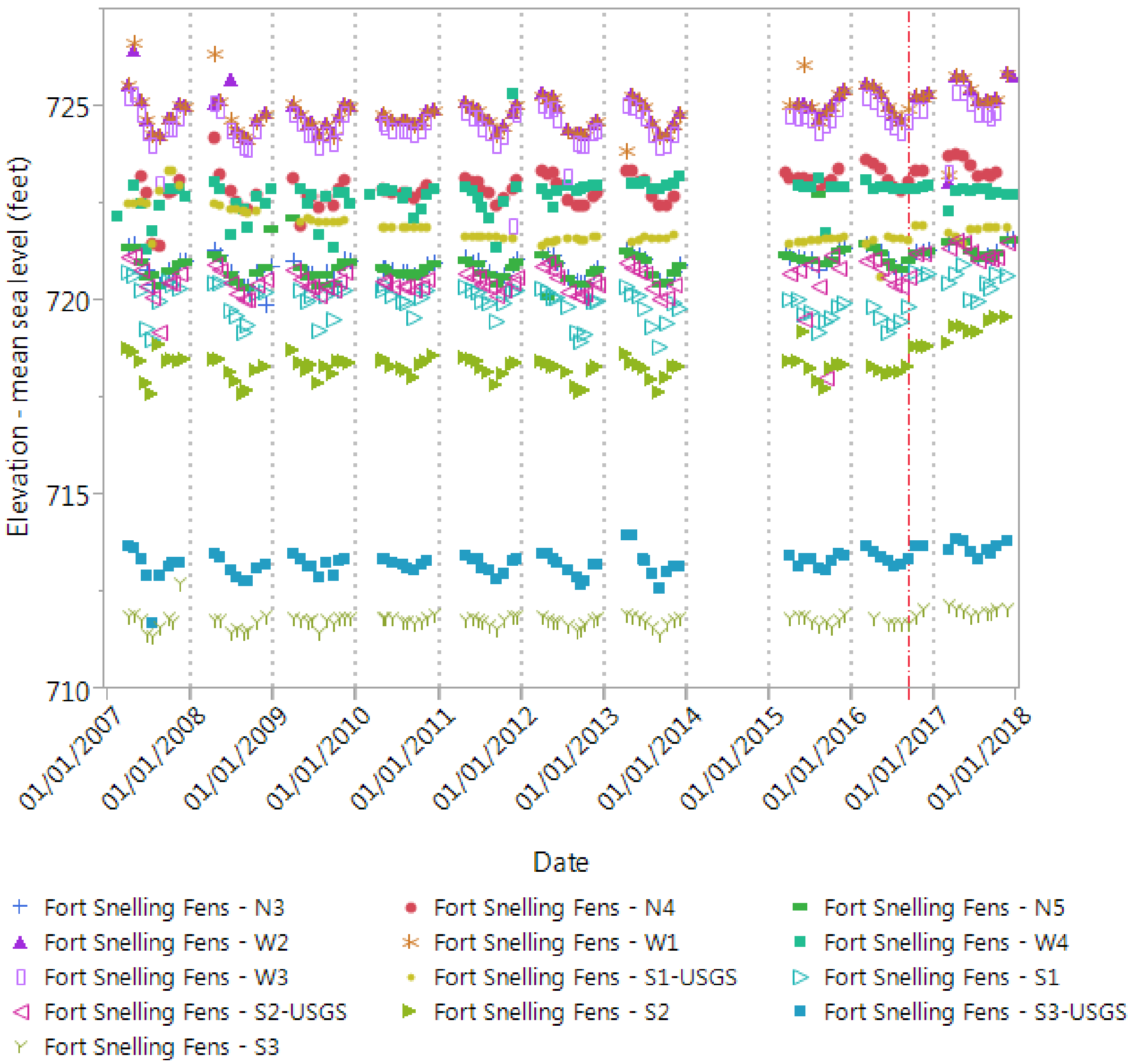


Figure 3. Water level elevation for the Fort Snelling fen wells. At well S3-USGS, when the water was overflowing, the elevation of the top of the pipe (Historical - 713.97 and 2016 – 714.18) was recorded. See individual well graphs in Appendix 3.

Nichols

Figures 4-6 summarize the results of the fen well level measurements from 2007 through 2017 (no data were collected in 2014). Data are presented across several figures for clarity and grouping is based on proximity, not hydrologic characteristics.

Several wells show increasing trends; however, it should be noted that these trends seem to be closely tied to precipitation. Years with higher well level measurements were preceded by years which had higher than average total rainfall, and years with lower well level measurements were preceded by years which had lower than average total rainfall. This suggests a 1-2 year relationship between precipitation and groundwater elevations within the fen, similar to the conclusion made by the 2008 Nichols fen report by WSB & Associates, Inc.

MN DNR visited the fen wells in September 2016 and recorded a new elevation for both well. Beginning in October 2016, water levels have been adjusted to reflect the new elevations (demarcated by red line). Prior to the survey effort, wells F3, F4, WN1-USGS, and WN5-USGS showed significant increasing trends in the data well measurements due to elevated water levels in 2011 and 2013 that were higher than in other years. The two years prior, 2010 and 2012, had higher than average total precipitation. Water levels in 2016 were elevated, much like in 2011 and 2013, which is consistent with the theory that heavy rainfall the previous year contributed to elevate measurements during the field season as rainfall was above average in 2015. Water levels at F2 had been trending upwards starting in 2013 after low values measured in 2012 (following a below average total rainfall year in 2011). Longer datasets for these wells will help to determine if there are long-term increasing or decreasing trends, and will be less heavily influenced by one to two, wet or dry years.

Each of the wells seems to show some annual seasonality with late summer having the lowest level measurements and early spring and summer having higher levels.

With the change in known well elevations in this fen, continued monitoring is necessary to improve confidence in the historical trends and determine if there is long-term drawdown of the water table as a result of watershed impacts or if the groundwater levels in the Nichols fen are recovering and stabilizing.

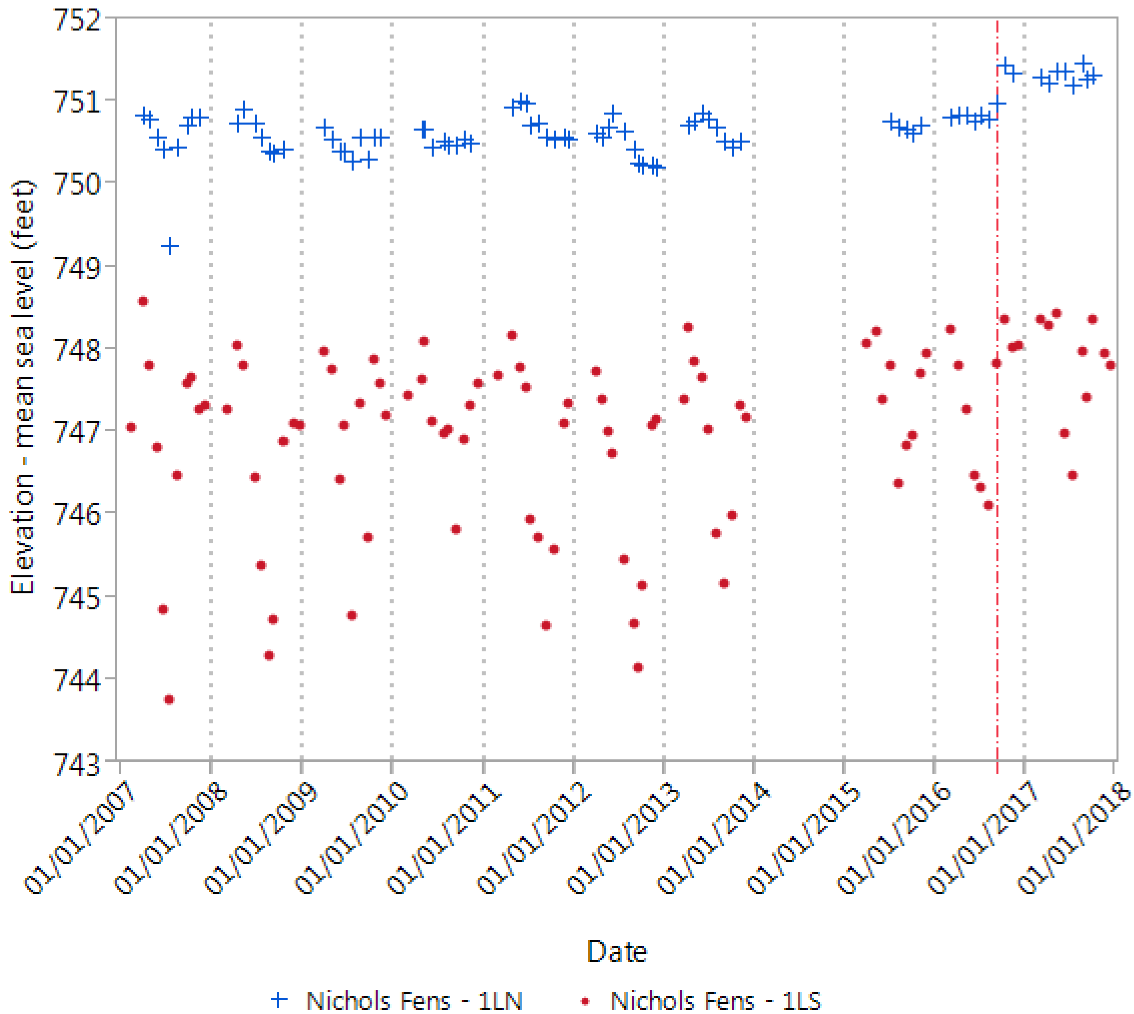


Figure 4. Water level elevation for the Nichols Fen wells (set 1 of 3).

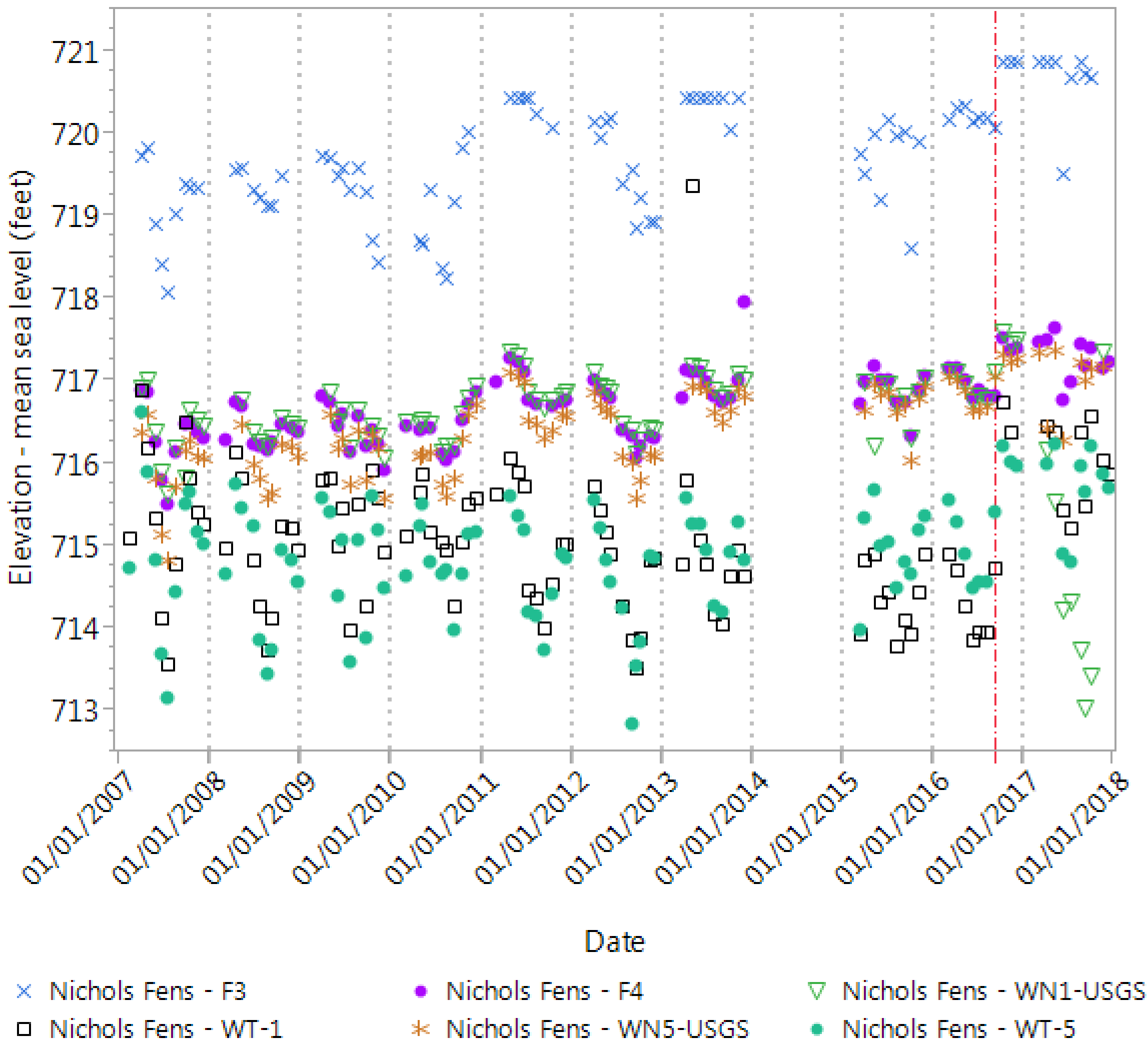


Figure 5. Water level elevation for the Nichols Fen wells (set 2 of 3). At well F3 and WT-1, the water was often overflowing and the elevation of the top of the pipe (F3: Historical - 720.43 and 2016 – 720.88; WT-1: Historical - 719.37 and 721.25) was recorded. See individual well graphs in Appendix 3.

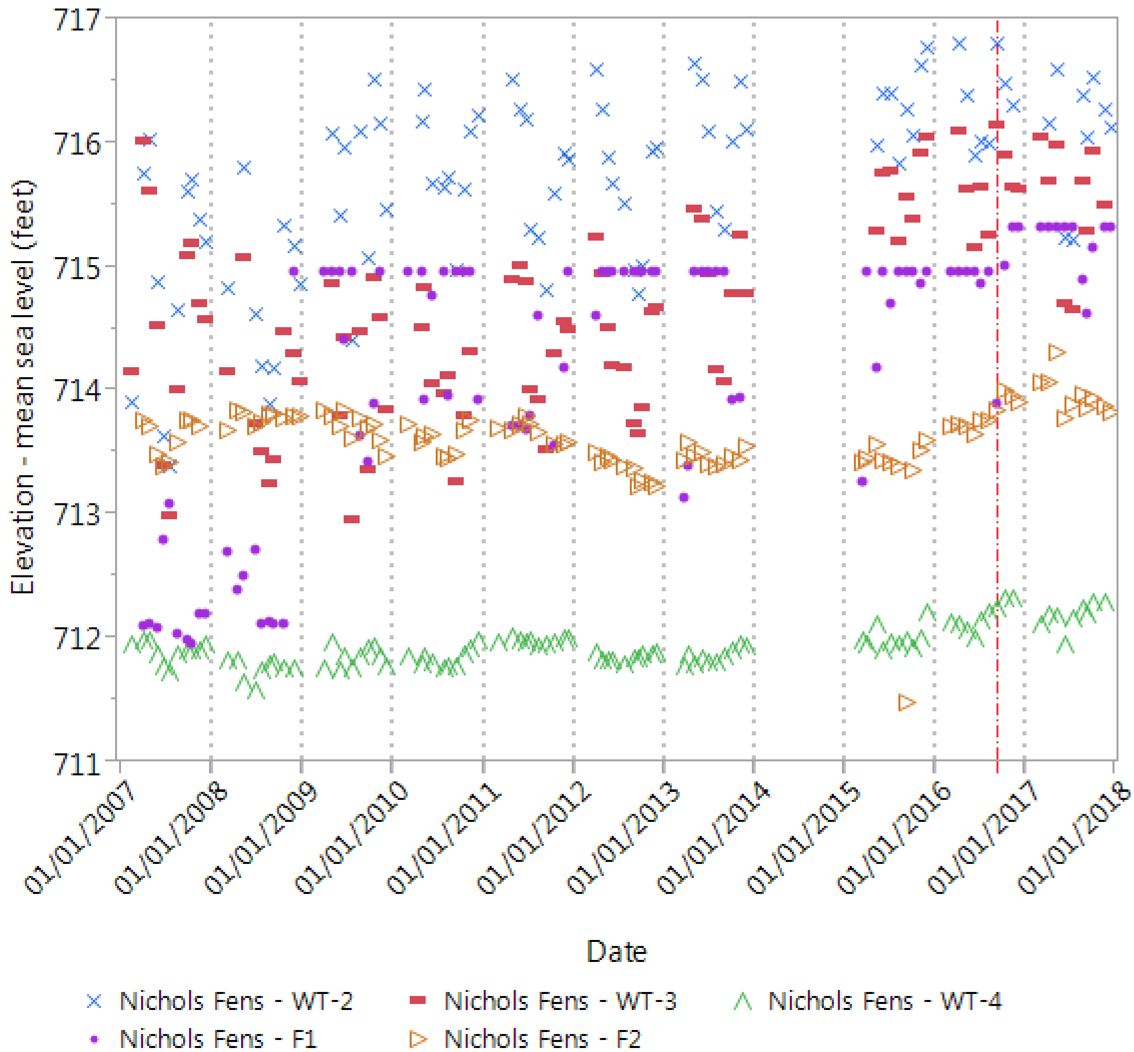


Figure 6. Water level elevation for the Nichols Fen wells (set 3 of 3). At well F1, the water was often overflowing and the elevation of the top of the pipe (Historical - 714.97 and 2016 – 715.32) was recorded. See individual well graphs in Appendix 3.

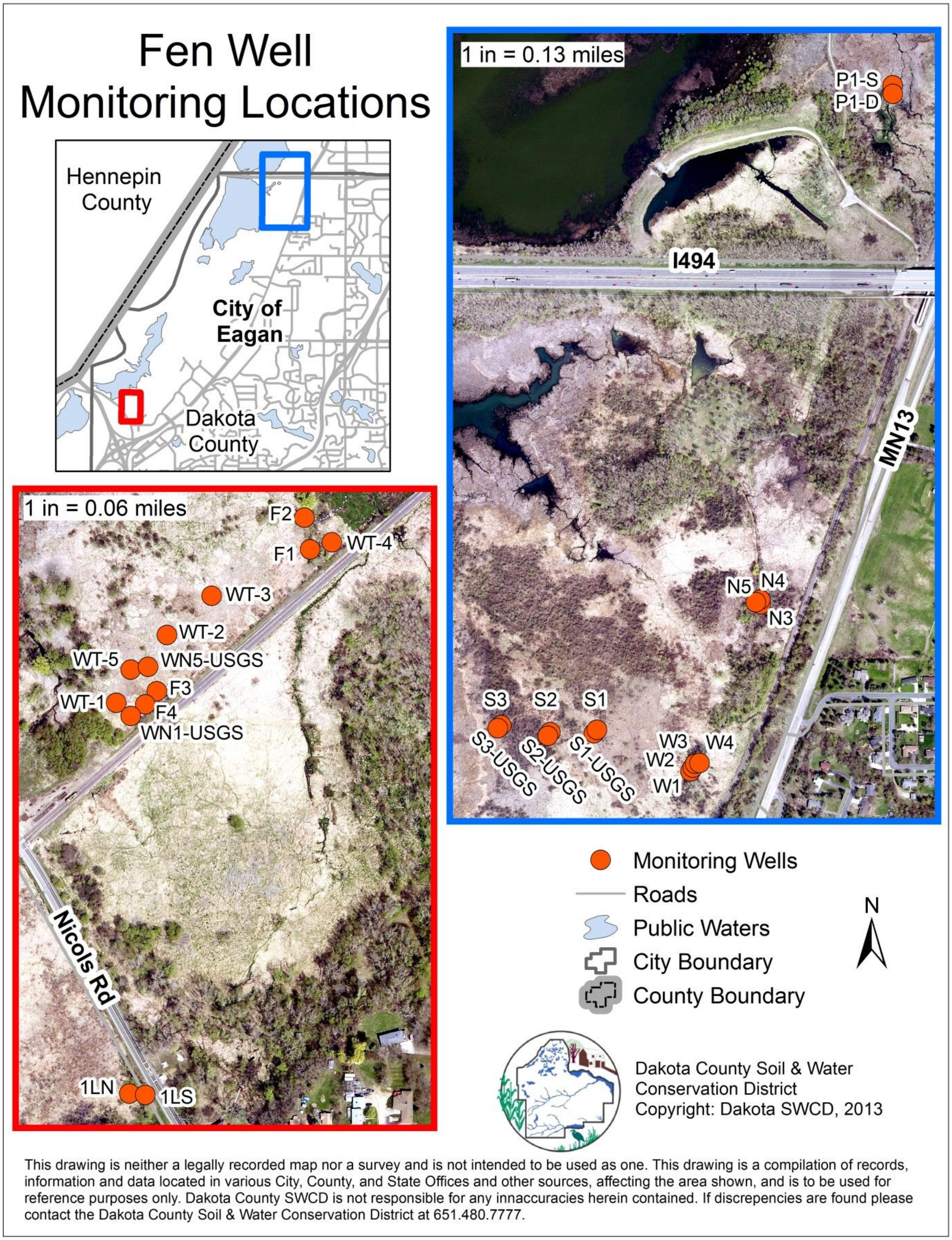
Conclusion

Due to the resurveying of well elevations in the fall of 2016, it is difficult to determine trends in groundwater levels as the data record is now only one year for many of the wells in the different three fens. The data record at the seven wells that were not resurveyed in 2016 was maintained through the 2017 monitoring season. Three of those wells (N3, N4, N5) show an increasing trend in groundwater level, though continued monitoring is recommended as the data set is limited.

When evaluating groundwater levels in a fen, it is important to consider that seasonal changes in temperature, precipitation, flow, etc., can influence fen well water levels, especially over short periods of time. For some of the fen wells, water levels fluctuate seasonally, as well as annually, based on current and past weather patterns. Above average precipitation years seem to be followed by higher well level measurements during subsequent years. The opposite is also true when total annual precipitation is below average.

Longer datasets are needed to confirm degradation or stability of fens (such as for the Quarry Island fen and Fort Snelling fen, respectively), and also to determine if the Nichols Fen is recovering or if the historical increasing trend at many of the wells is just an artifact of the recent wetter than average years.

Appendix 1: Map of Fen Well Monitoring Locations



Appendix 2: Well Metadata

Approximate depth, coordinates, and mean sea-level elevation for each well (data courtesy of Minnesota Department of Natural Resources).

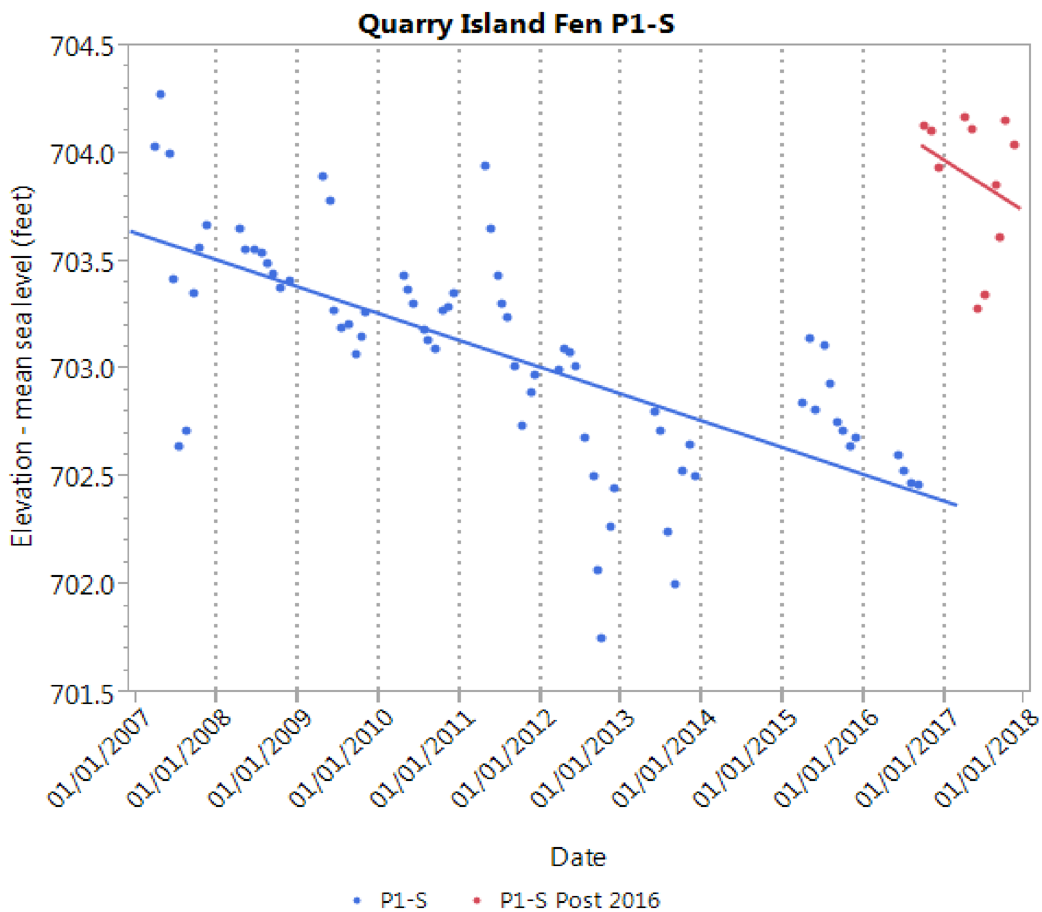
Well	Approximate depth (feet)	Northing (UTM)	Easting (UTM)	Elevation (feet)	2016 Elevation (feet)
P1-S	4	243025.4	535925.6	707.29	708.56
P1-D	8	243024.2	535925	706.98	708.67
N3	45.21	240030.6	535345.7	723.87	
N4	75.34	240030.5	535349.3	724.27	
N5	21.69	240035.5	535347.4	724.06	
W1	77.00	239330.3	535121.9	728.45	
W2	50.12	239325.1	535119.2	728.47	
W3	21.83	239330.7	535130.5	726.87	
W4	12.00	239333.3	535130.2	727.6	
S1-USGS	20.67	239503.2	534796.5	723.44	723.83
S1	5.35	239502.7	534796.6	723.83	722.98
S2-USGS	27.00	239519.2	534506.9	722.35	722.77
S2	5.25	239518.1	534507	721.13	721.59
S3-USGS	21.68	239547.5	534222.3	713.97	714.18
S3	21.68	239548.3	534222.9	715.06	715.32
1LN	29	226915.8	525306.8	751.59	751.93
1LS	8	226913.4	525308.8	751.43	751.78
F3	75	228058.8	525367.6	720.43	720.88
F4	21	228055.9	525364.7	720.36	720.65
WN1-USGS	19.82	228054.3	525357.3	719.51	719.92
WN5-USGS	16.08	228125.3	525293.5	717.92	718.13
WT-1	9	228054.7	525356	719.37	721.25
WT-2	9	228222.7	525372.2	719.88	719.55
WT-3	8	228330.4	525514.2	721.27	718.26
WT-4	6	228457.4	525783.2	713.58	713.63
WT-5	7	228126	525293	720.69	721.51
F1	N/A	228466.4	525785	714.96	715.32
F2	15	228454.9	525794.3	714.68	714.77

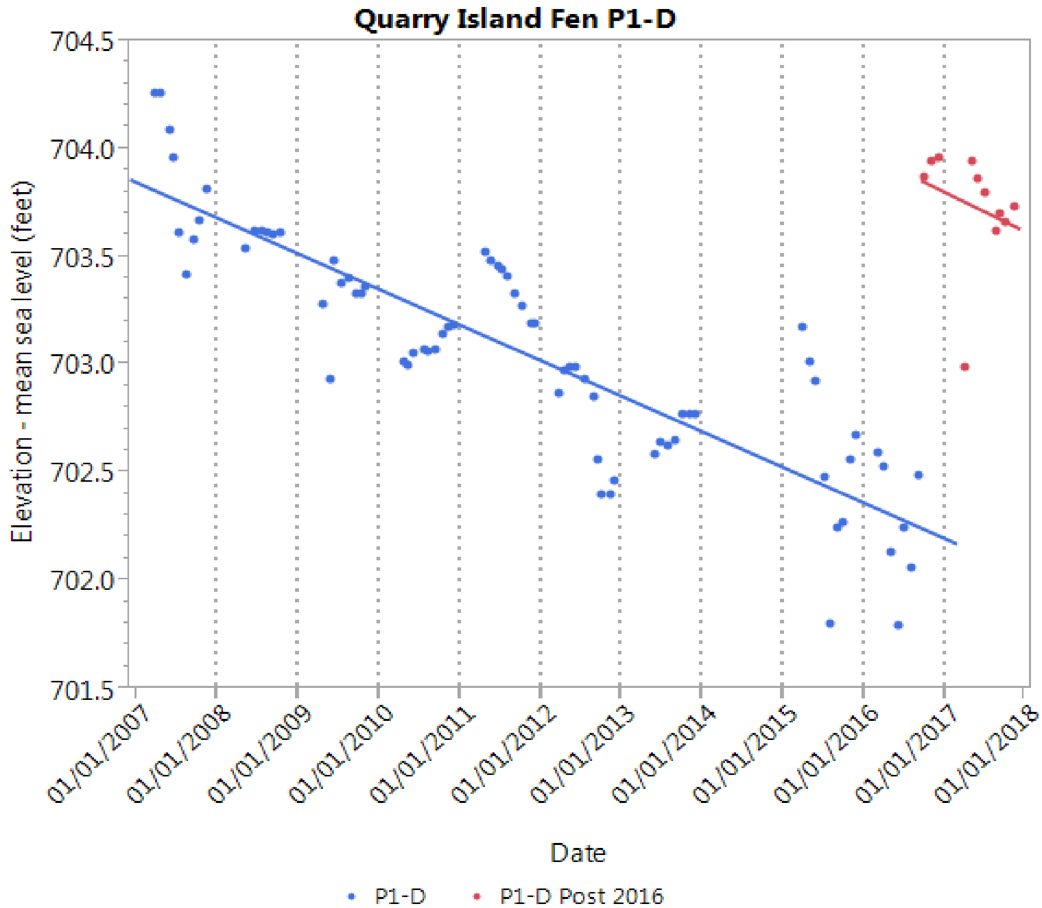
Appendix 3: Linear Regressions for Each Well Dataset

Linear regressions are included for each of the wells. As well elevations were resurveyed in the fall of 2016 for all but seven of the wells, updated linear regressions lines are shown for 2017. More data is needed to further determine trends in these wells.

Two of the well nests in Fort Snelling Fen have more stable footing and were not resurveyed as part of the 2016 effort. Elevations at W1, W2, W3, W4, N3, N4, and N5 did not change in 2016, so there is a single linear regression on the graphs.

In cases where wells were overflowing, the top of the pipe elevation was recorded and is shown with a black dashed line. When the water in the well was frozen, no water level measurement was recorded.




Quarry Island Fen P1-D
Elevation - mean sea level (feet)
704.5
704.0
703.5
703.0
702.5
702.0
701.5
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01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
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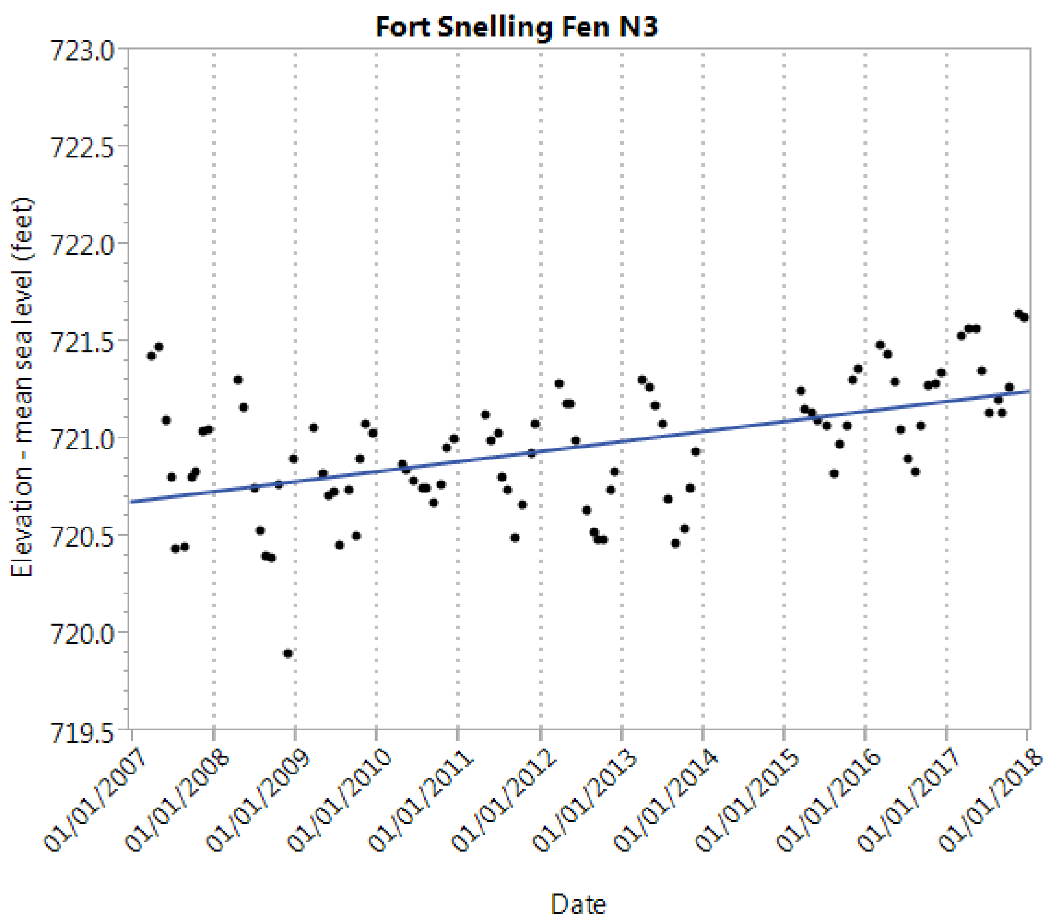
Date
P1-D
P1-D Post 2016


Fort Snelling Fen N3
Elevation - mean sea level (feet)
723.0
722.5
722.0
721.5
721.0
720.5
720.0
719.5
01/01/2007
01/01/2008
01/01/2009
01/01/2010
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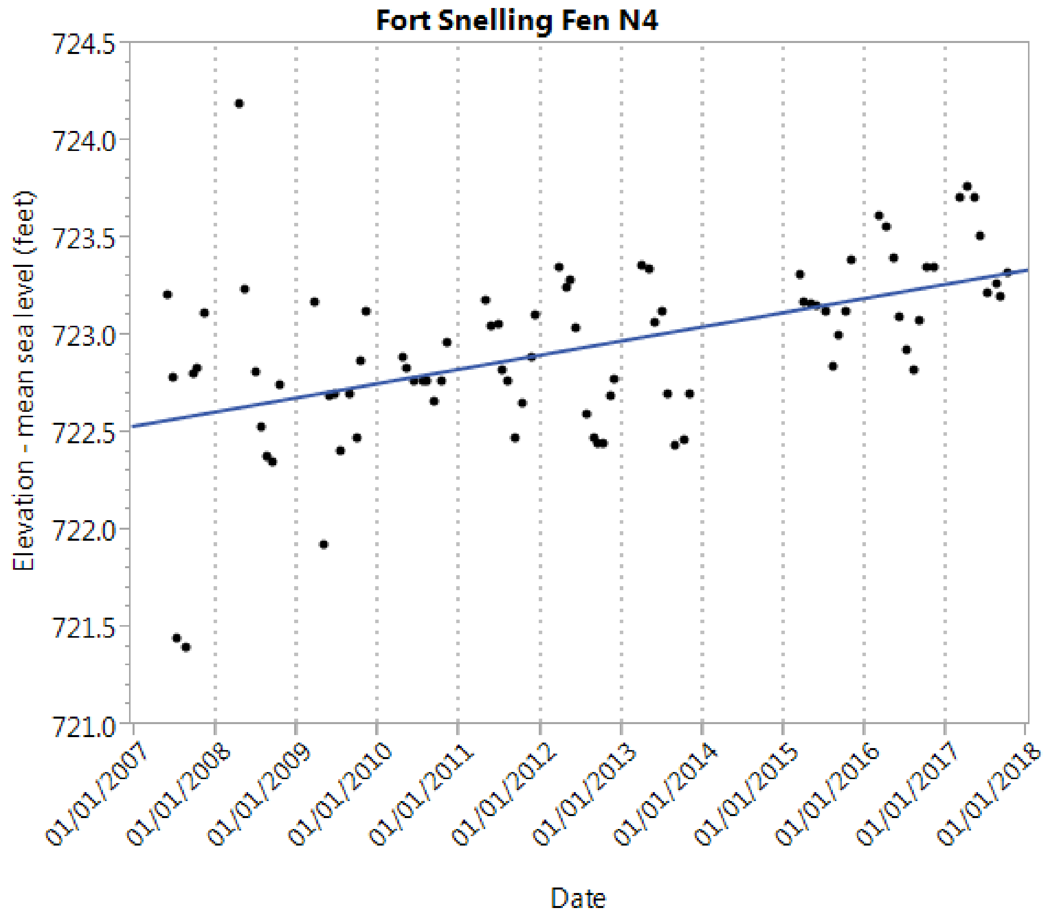
01/01/2017
01/01/2018
Date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Elevation - mean sea level (feet)
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723.5
723.0
722.5
722.0
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01/01/2007
01/01/2008
01/01/2009
01/01/2010
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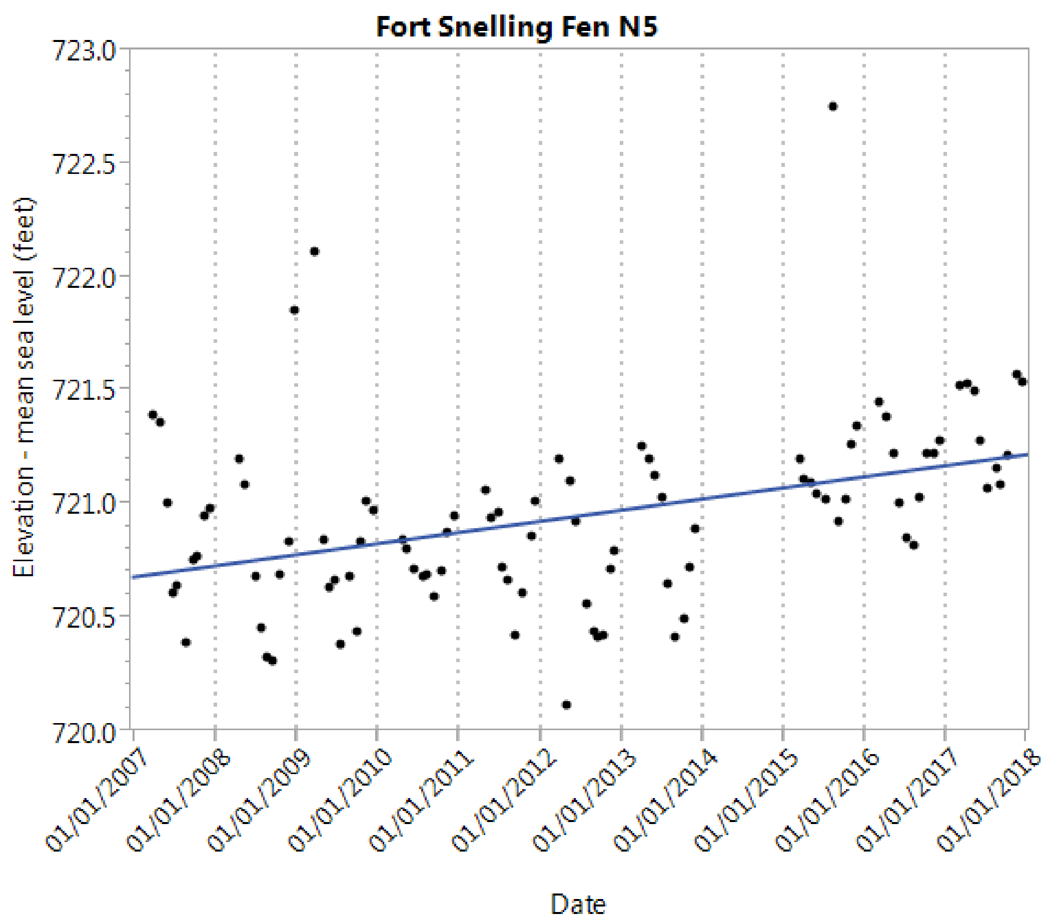
Date


Fort Snelling Fen N5
Elevation - mean sea level (feet)
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722.5
722.0
721.5
721.0
720.5
720.0
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01/01/2008
01/01/2009
01/01/2010
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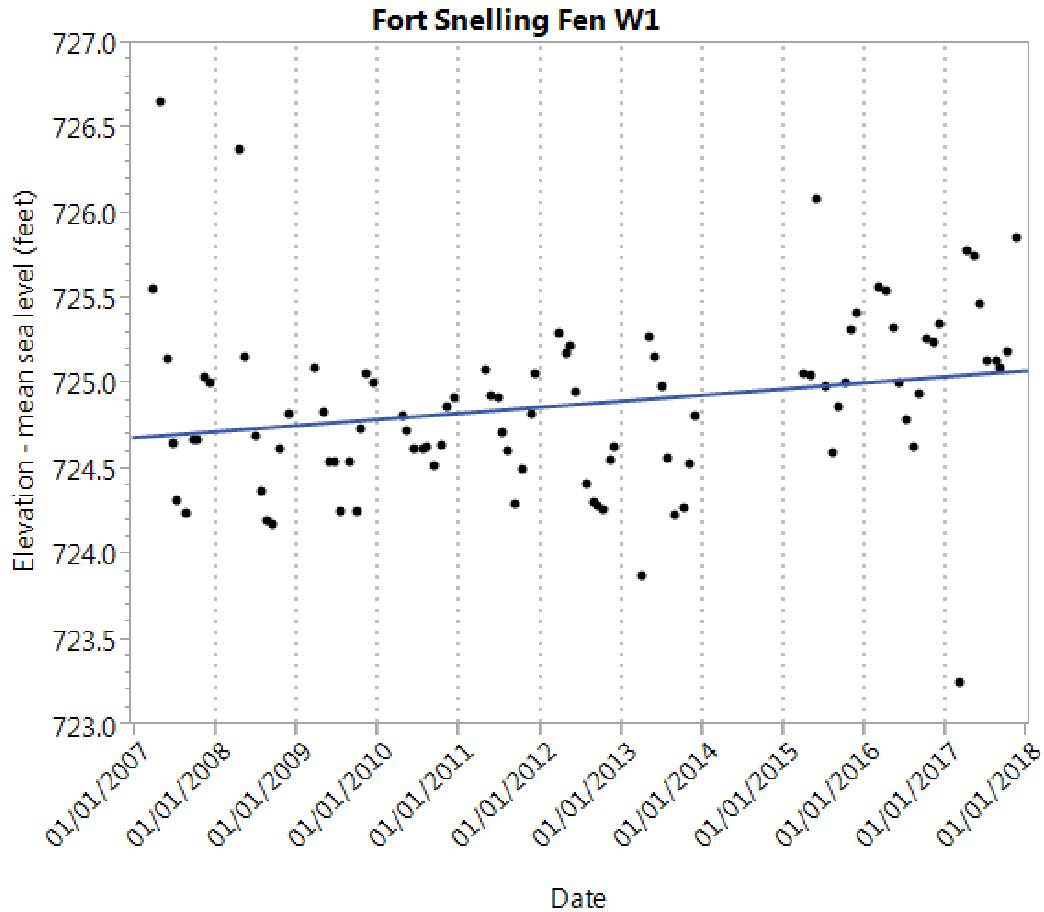
Fort Snelling Fen W1
Elevation - mean sea level (feet)
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726.5
726.0
725.5
725.0
724.5
724.0
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01/01/2007
01/01/2008
01/01/2009
01/01/2010
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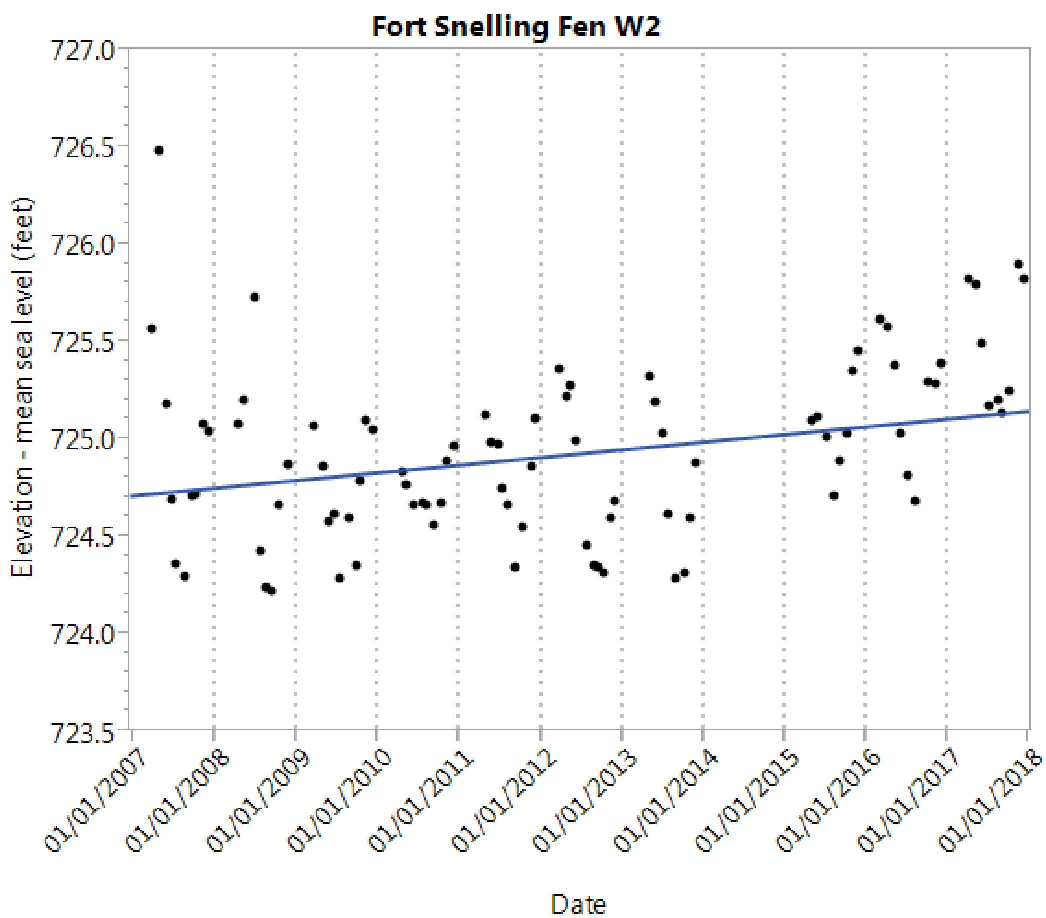
Date


Fort Snelling Fen W2
Elevation - mean sea level (feet)
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726.5
726.0
725.5
725.0
724.5
724.0
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01/01/2008
01/01/2009
01/01/2010
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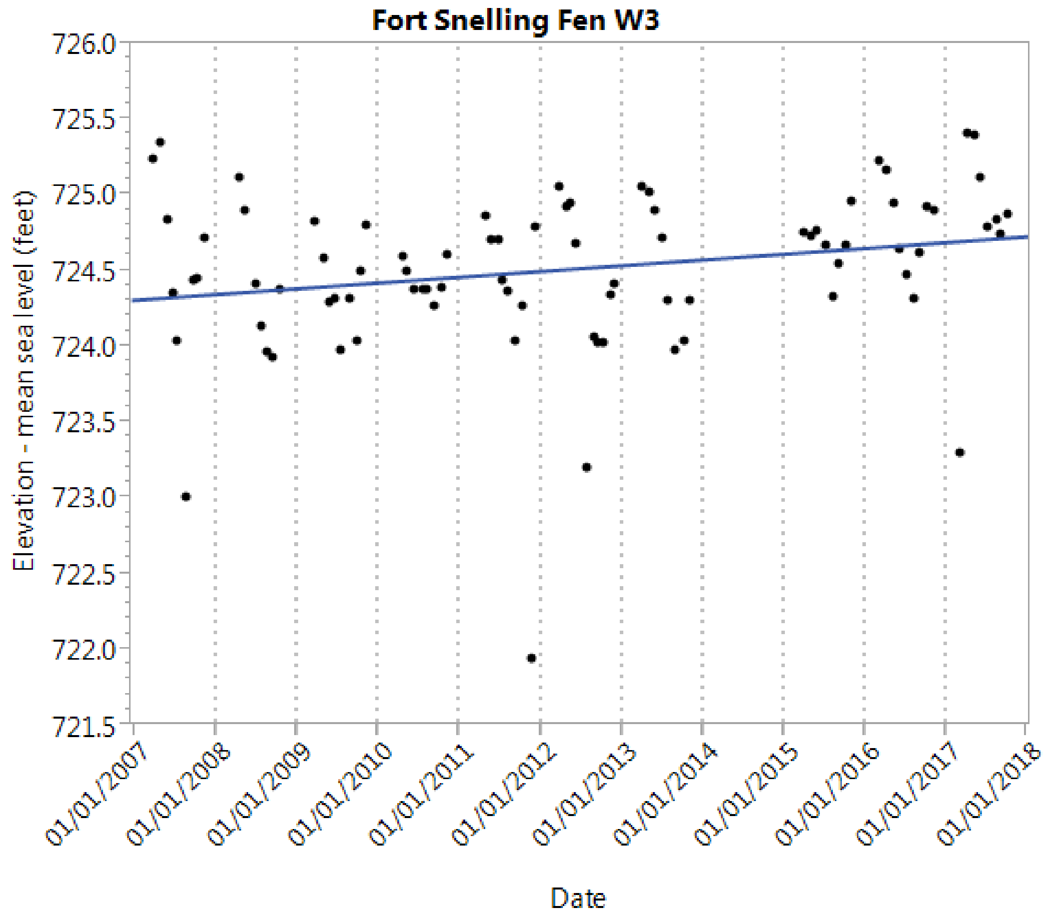
01/01/2018
Date


Fort Snelling Fen W3
726.0
725.5
725.0
724.5
724.0
723.5
723.0
722.5
722.0
721.5
Elevation - mean sea level (feet)
01/01/2007
01/01/2008
01/01/2009
01/01/2010
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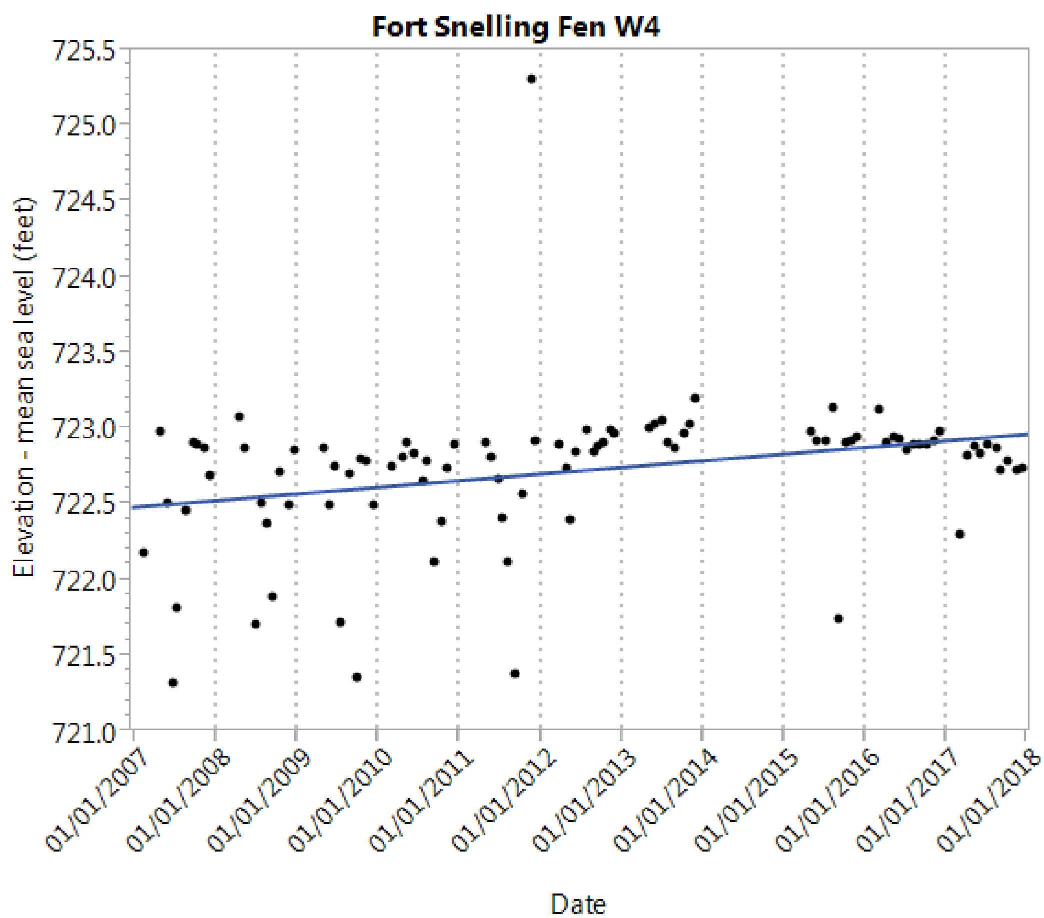
01/01/2017
01/01/2018
Date


Fort Snelling Fen W4
725.5
725.0
724.5
724.0
723.5
723.0
722.5
722.0
721.5
721.0
Elevation - mean sea level (feet)
01/01/2007
01/01/2008
01/01/2009
01/01/2010
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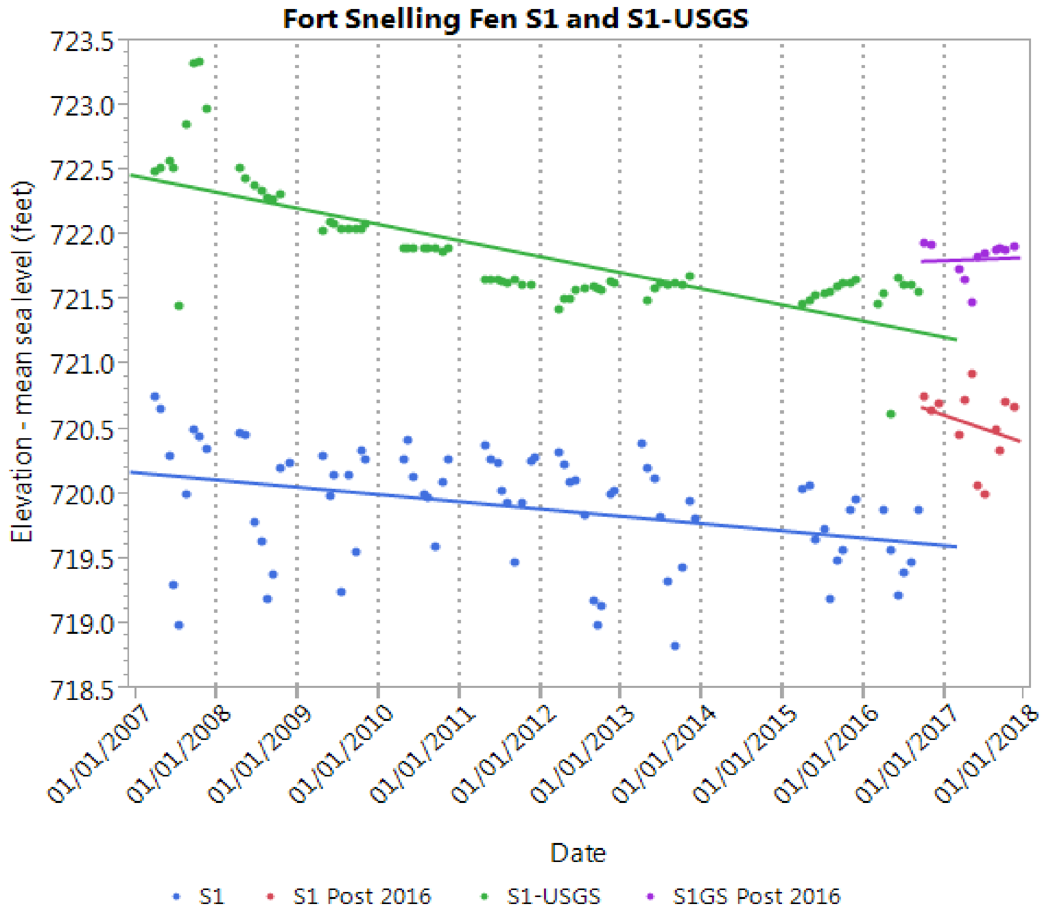
01/01/2018
Date



Fort Snelling Fen S1 and S1-USGS
Elevation - mean sea level (feet)
723.5
723.0
722.5
722.0
721.5
721.0
720.5
720.0
719.5
719.0
718.5
01/01/2007
01/01/2008
01/01/2009
01/01/2010
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S1
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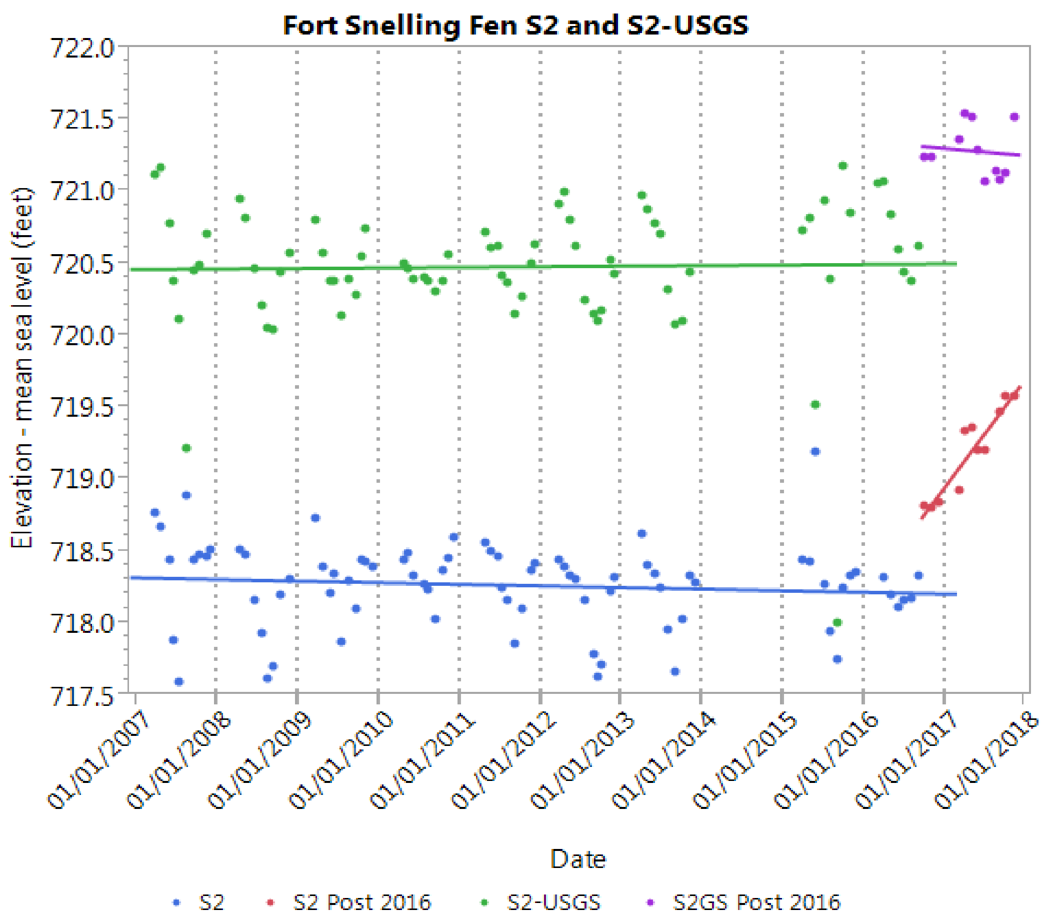
S1-USGS
S1GS Post 2016



Fort Snelling Fen S2 and S2-USGS
Elevation - mean sea level (feet)
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721.5
721.0
720.5
720.0
719.5
719.0
718.5
718.0
717.5
01/01/2007
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01/01/2009
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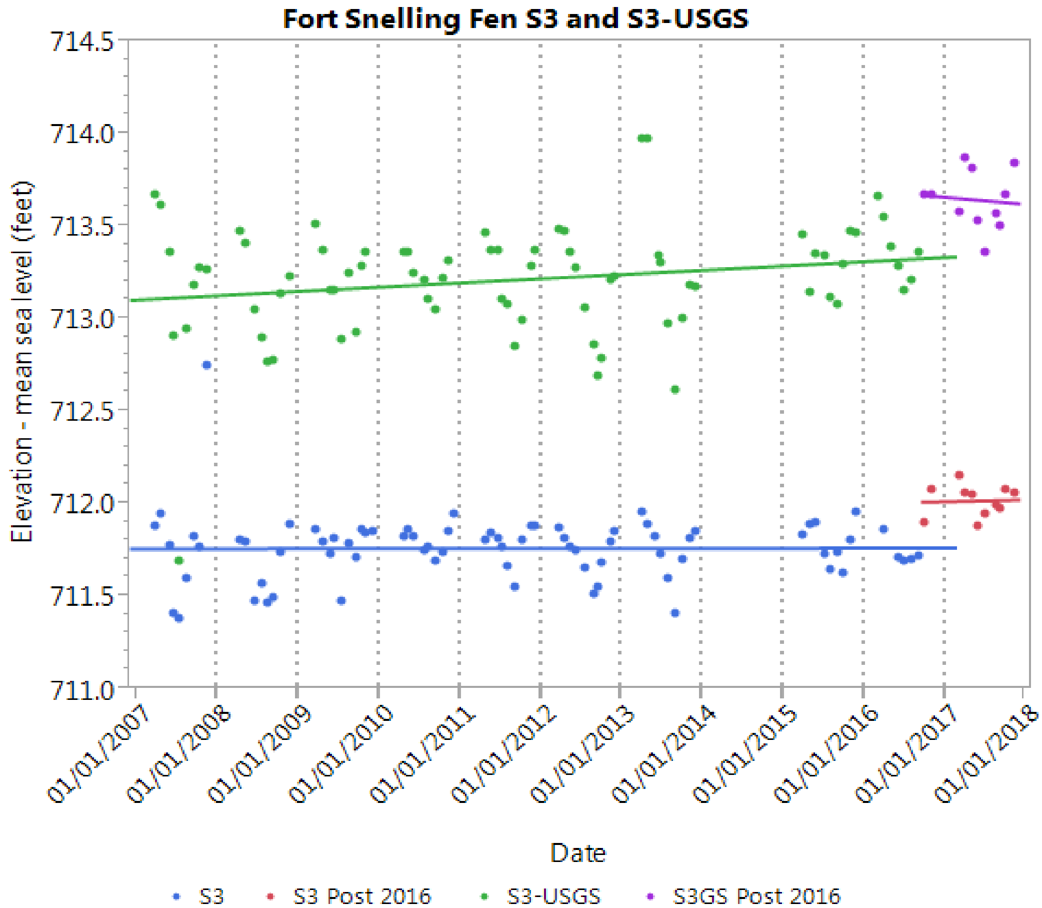
S2-USGS
S2GS Post 2016


Fort Snelling Fen S3 and S3-USGS
Elevation - mean sea level (feet)
714.5
714.0
713.5
713.0
712.5
712.0
711.5
711.0
01/01/2007
01/01/2008
01/01/2009
01/01/2010
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Date
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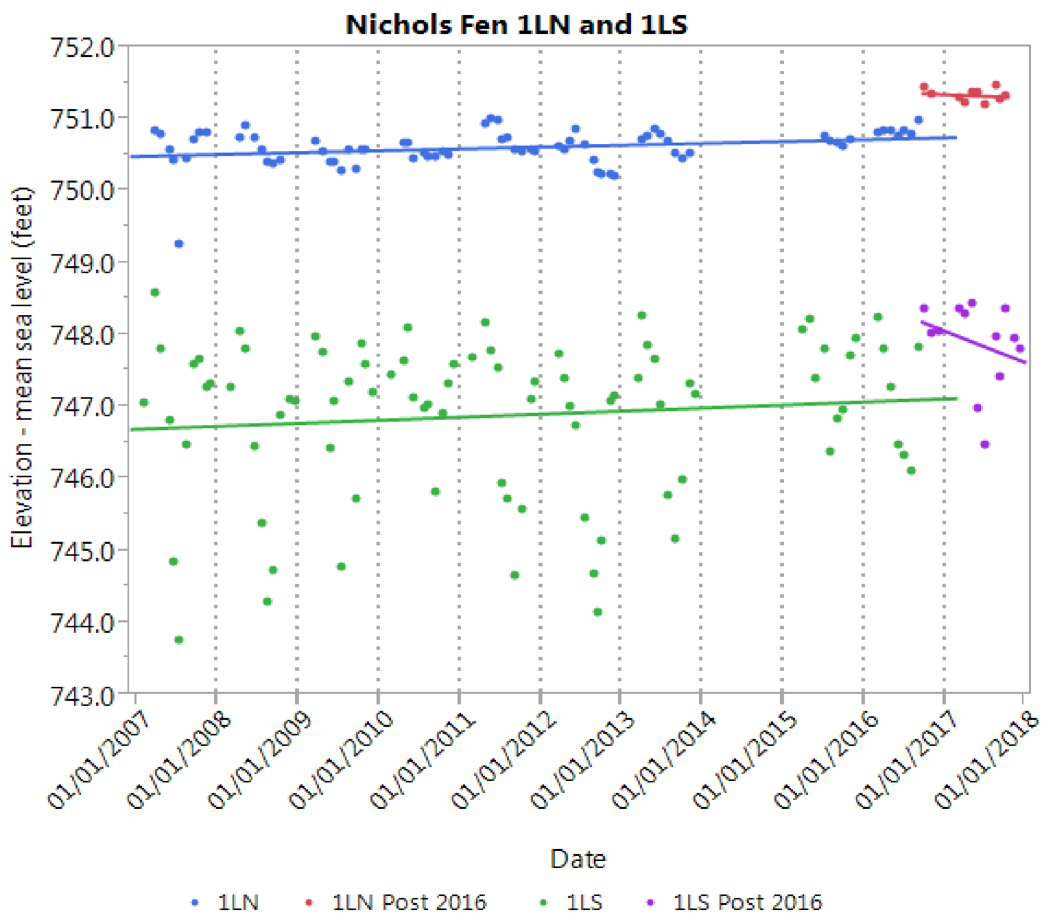
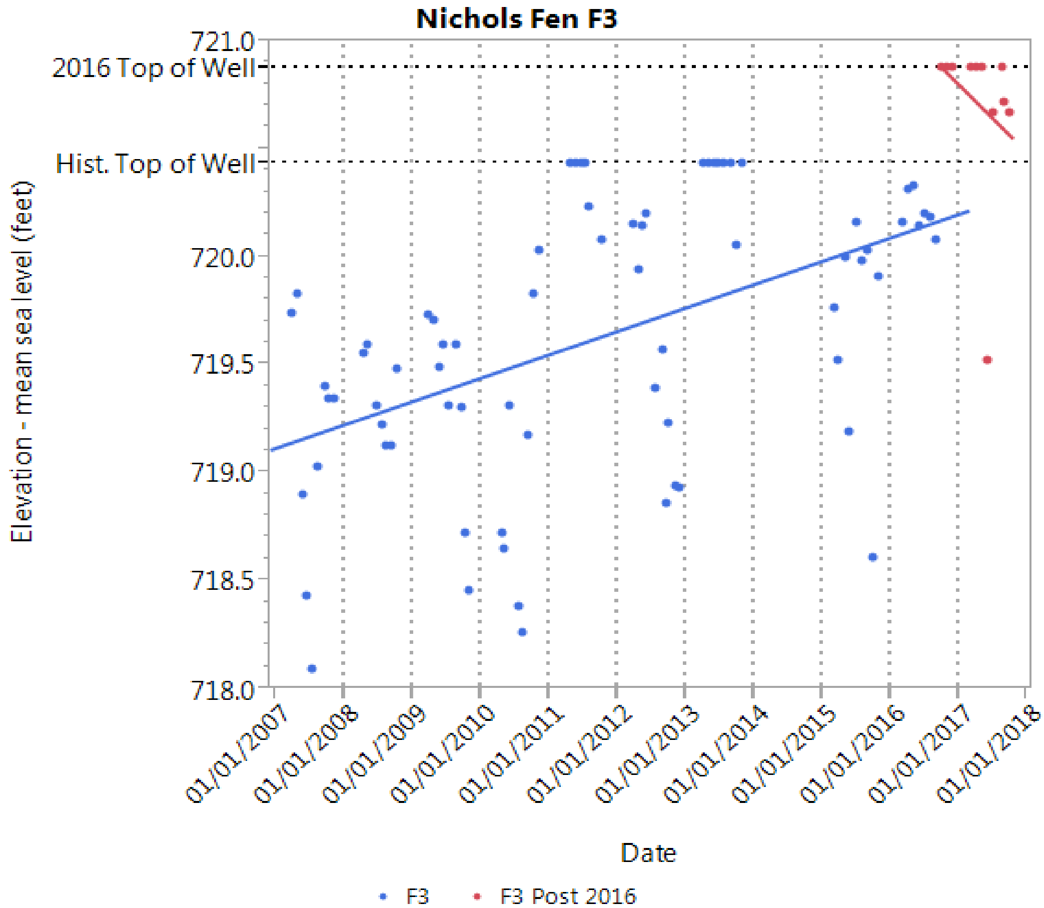
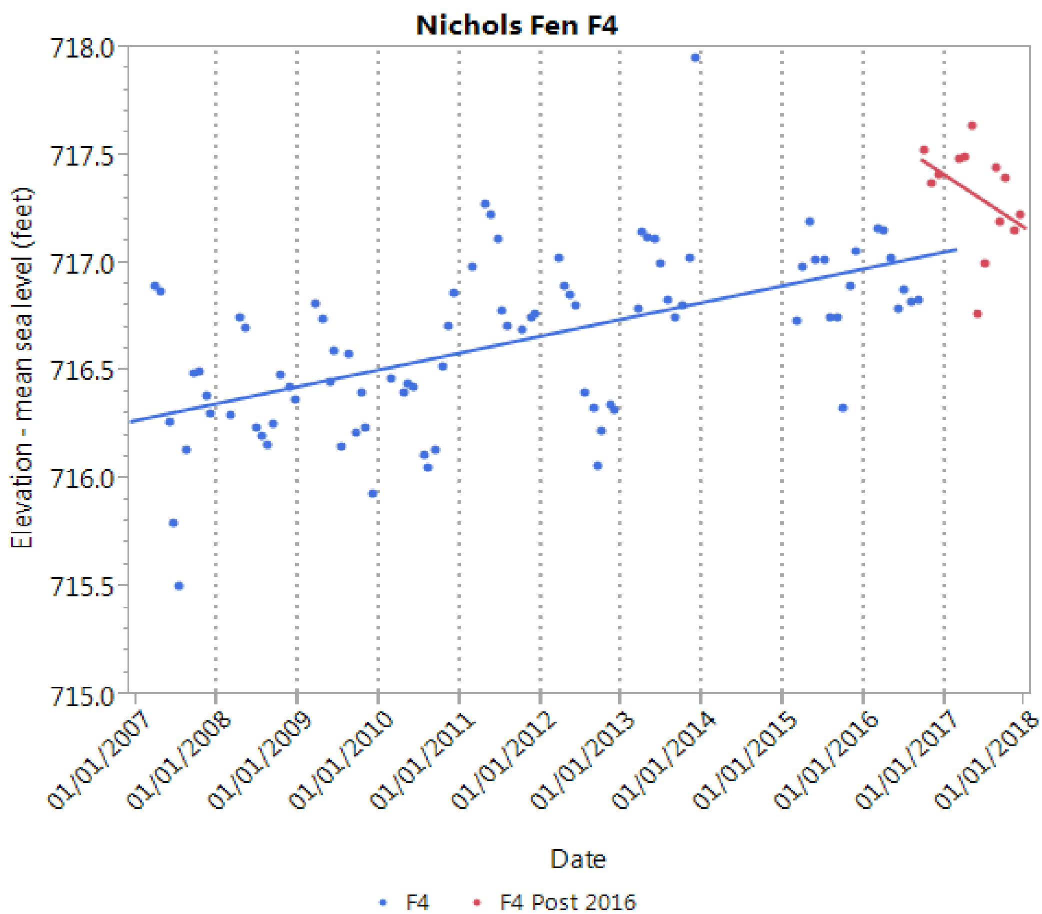
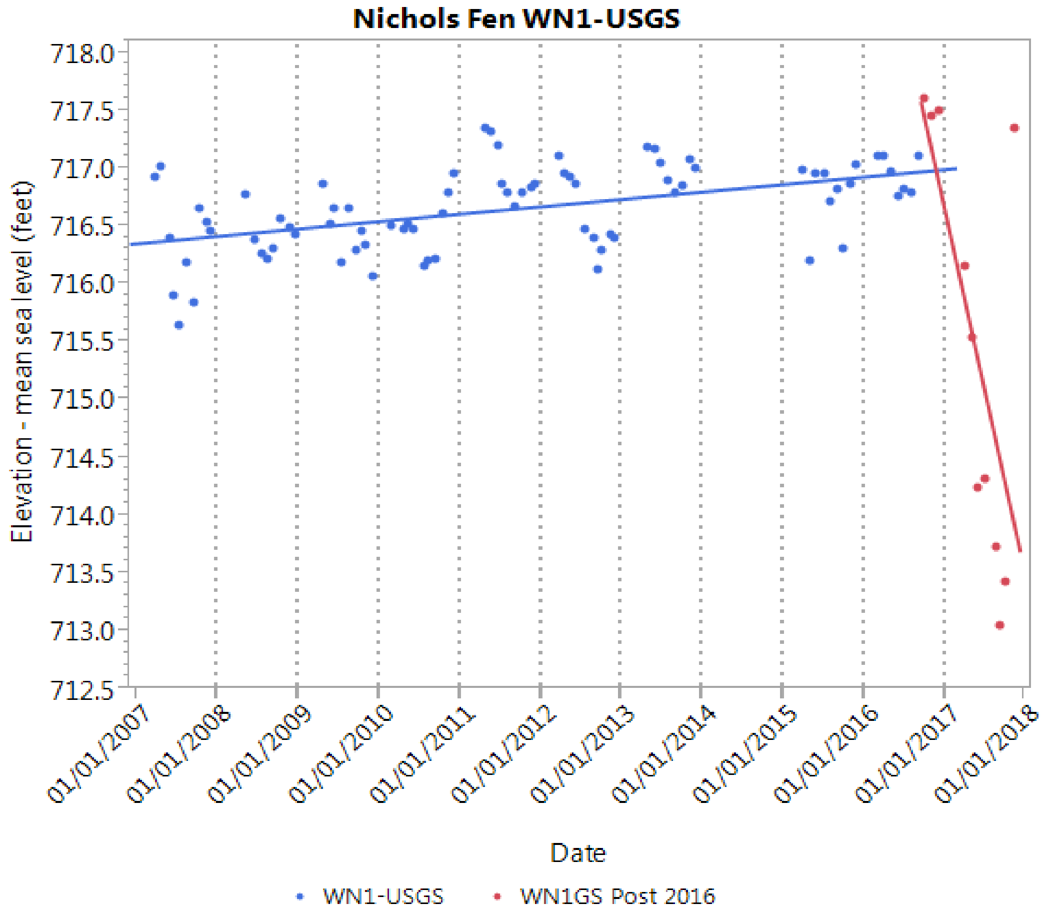
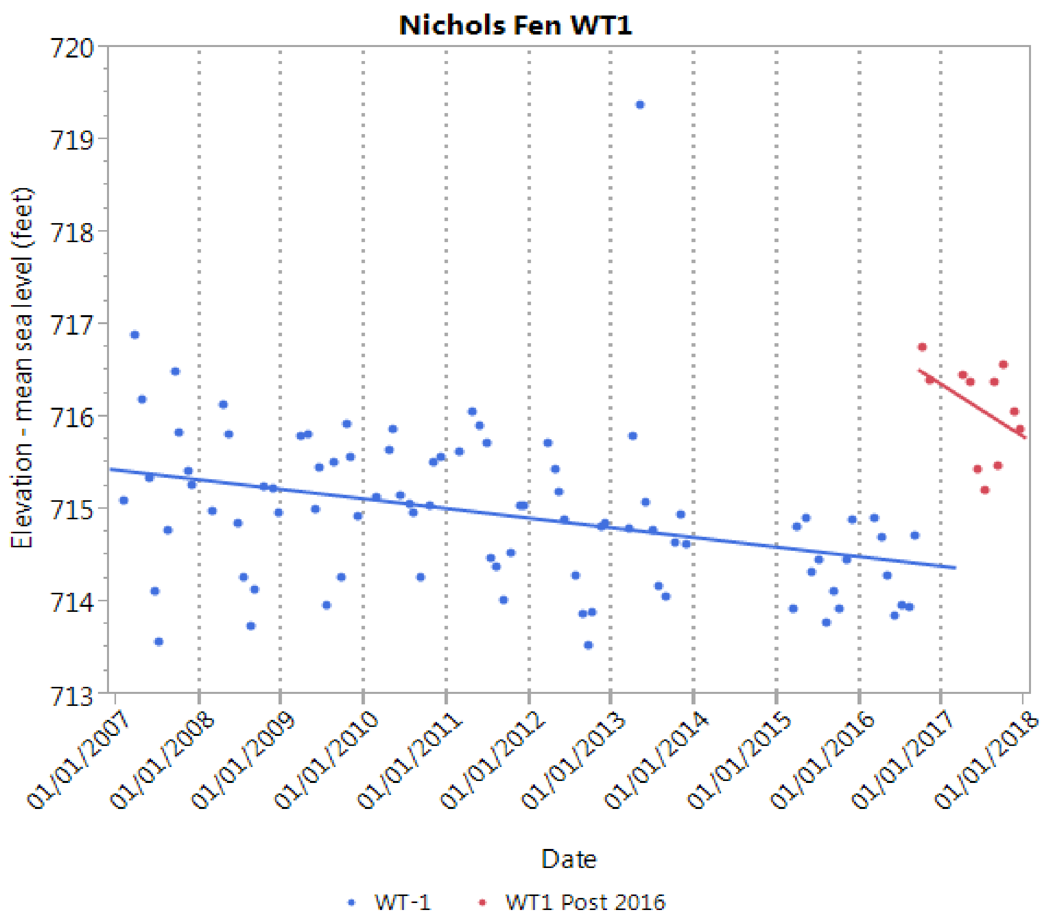
S3-USGS
S3GS Post 2016

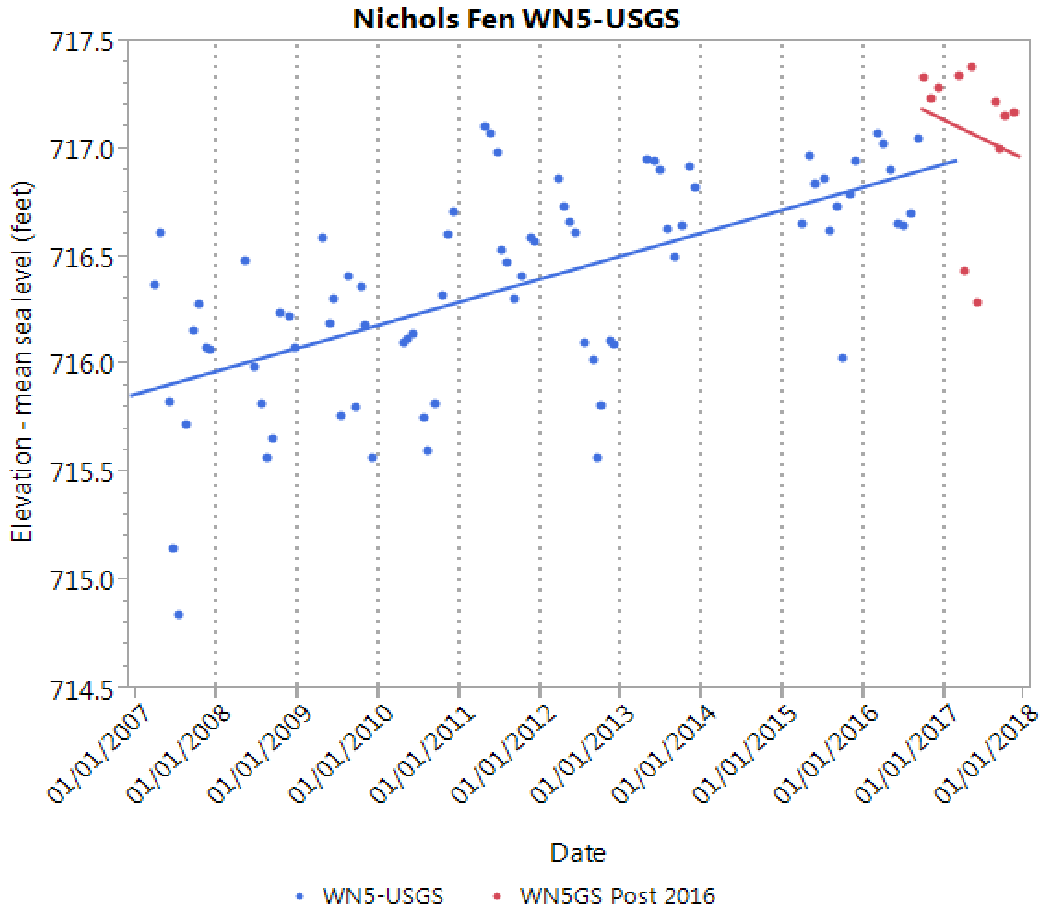

Nichols Fen 1LN and 1LS
Elevation - mean sea level (feet)
752.0
751.0
750.0
749.0
748.0
747.0
746.0
745.0
744.0
743.0
01/01/2007
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
Date
1LN
1LN Post 2016
1LS
1LS Post 2016

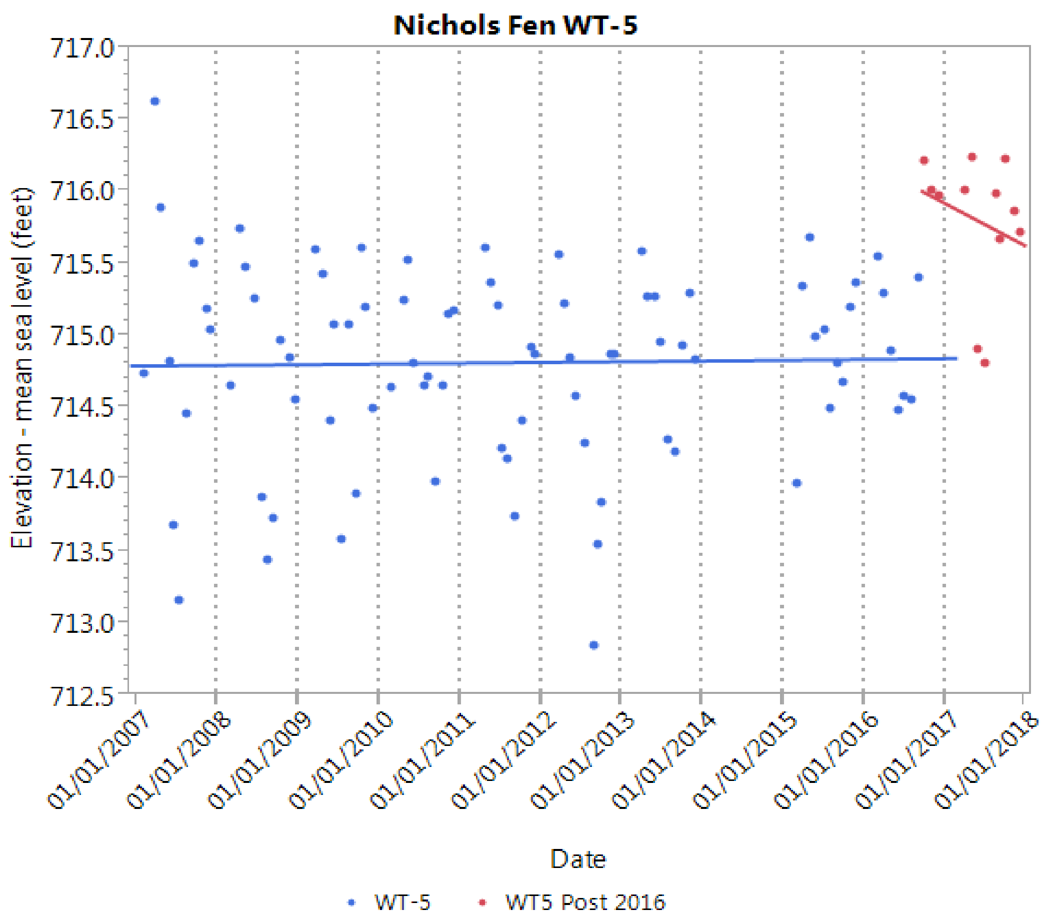

Nichols Fen F3
Elevation - mean sea level (feet)
721.0
2016 Top of Well
Hist. Top of Well
720.0
719.5
719.0
718.5
718.0
01/01/2007
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
Date
F3
F3 Post 2016

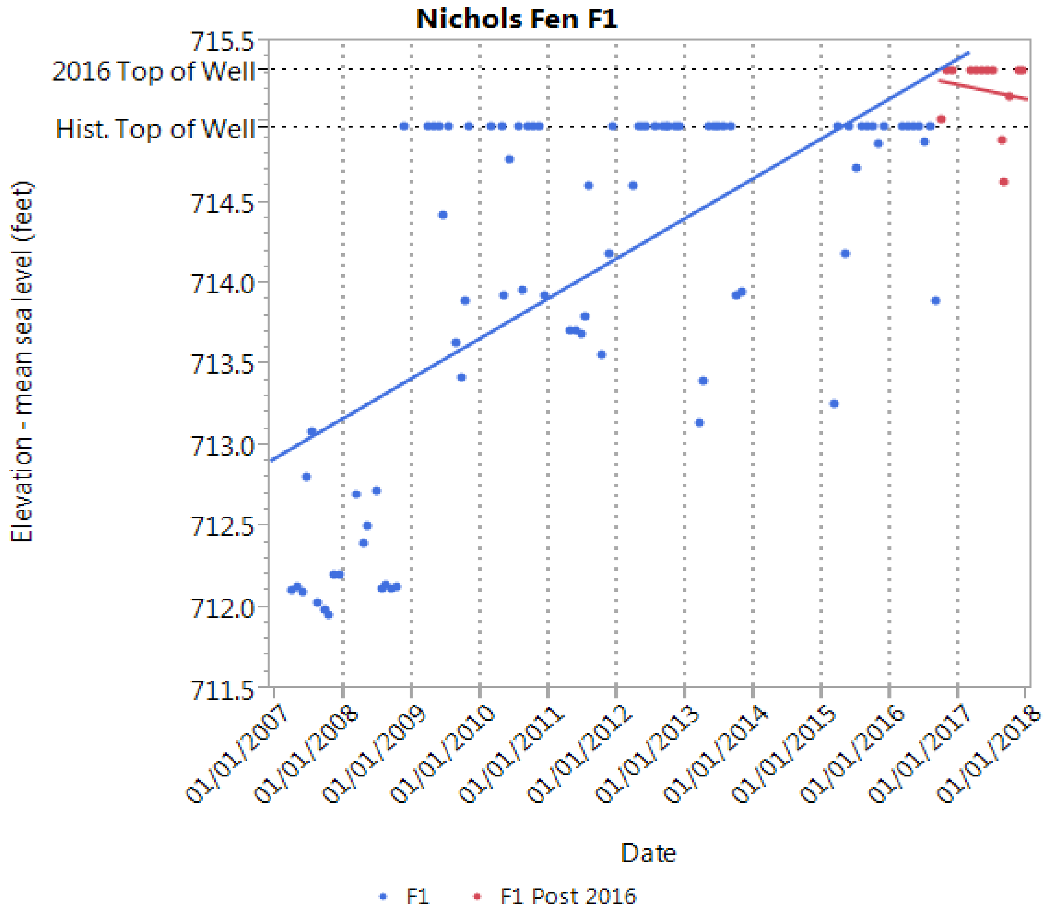

Nichols Fen F4
Elevation - mean sea level (feet)
718.0
717.5
717.0
716.5
716.0
715.5
715.0
01/01/2007
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
Date
F4
F4 Post 2016

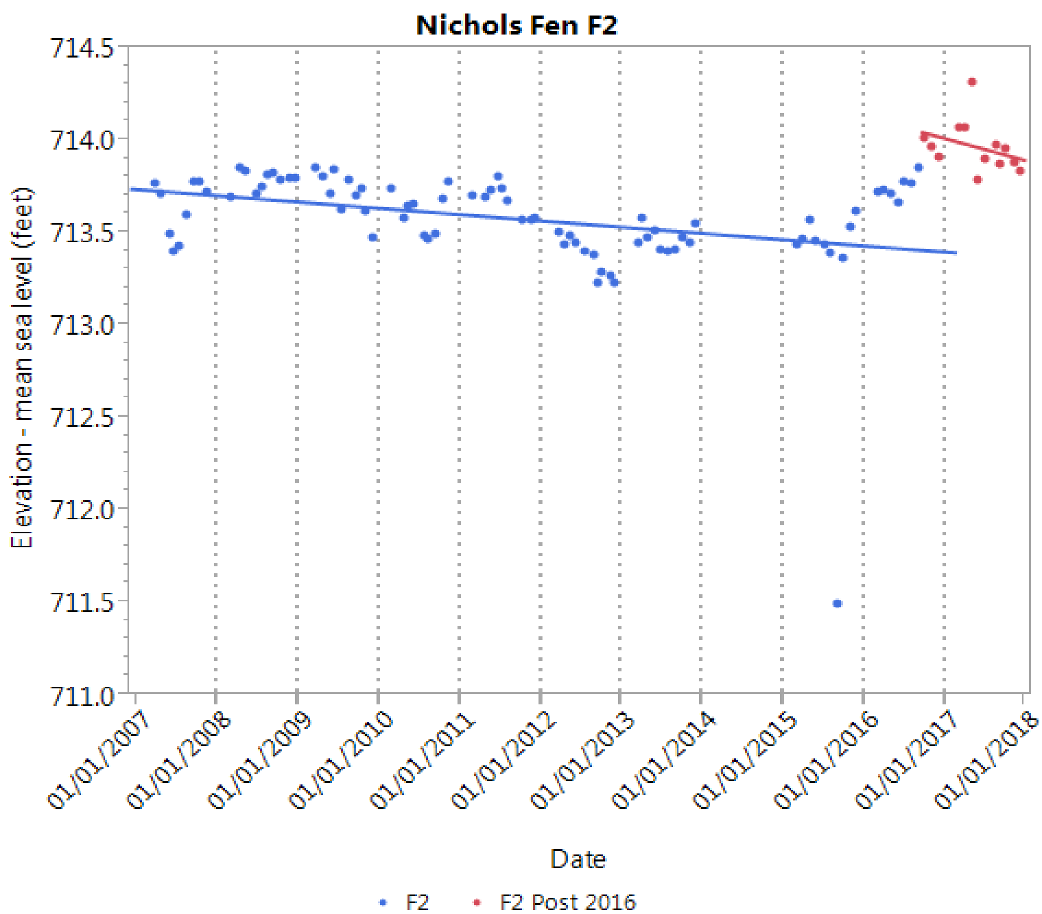

Nichols Fen WN1-USGS
Elevation - mean sea level (feet)
718.0
717.5
717.0
716.5
716.0
715.5
715.0
714.5
714.0
713.5
713.0
712.5
01/01/2007
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
Date
WN1-USGS
WN1GS Post 2016

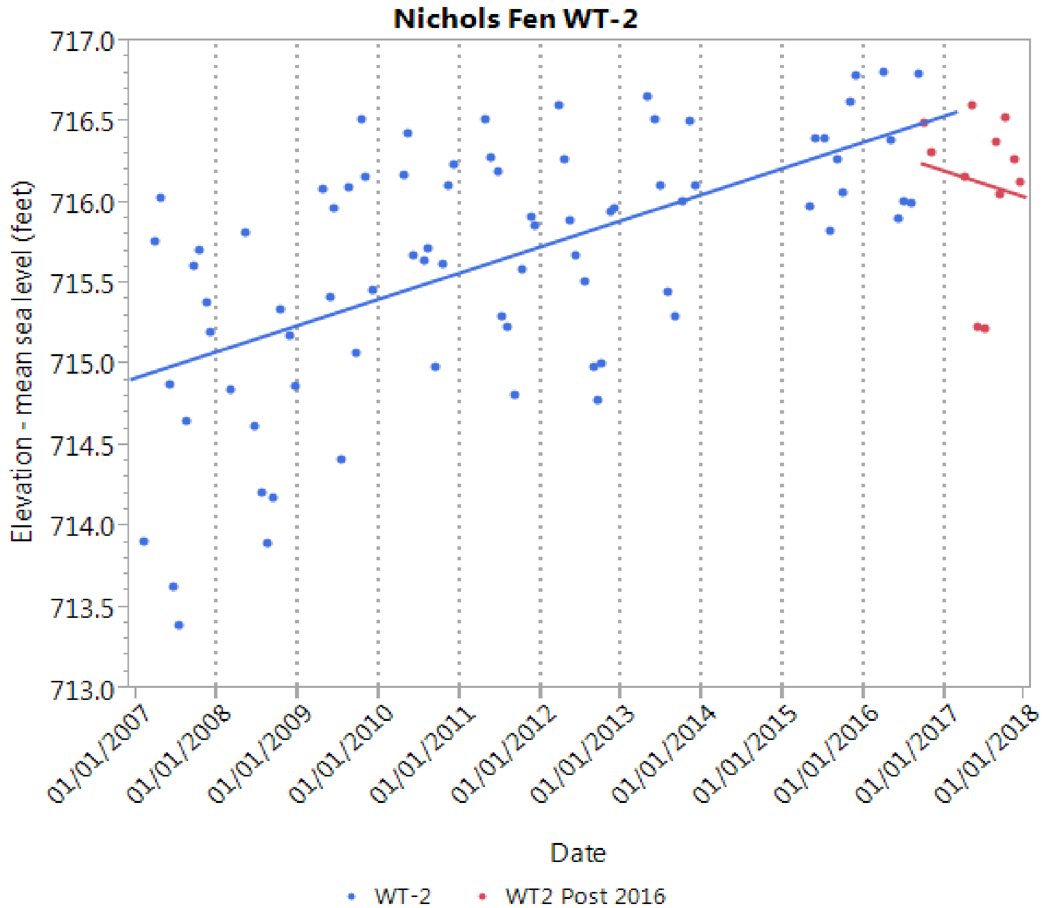

Nichols Fen WT1
Elevation - mean sea level (feet)
720
719
718
717
716
715
714
713
01/01/2007
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
Date
WT-1
WT1 Post 2016

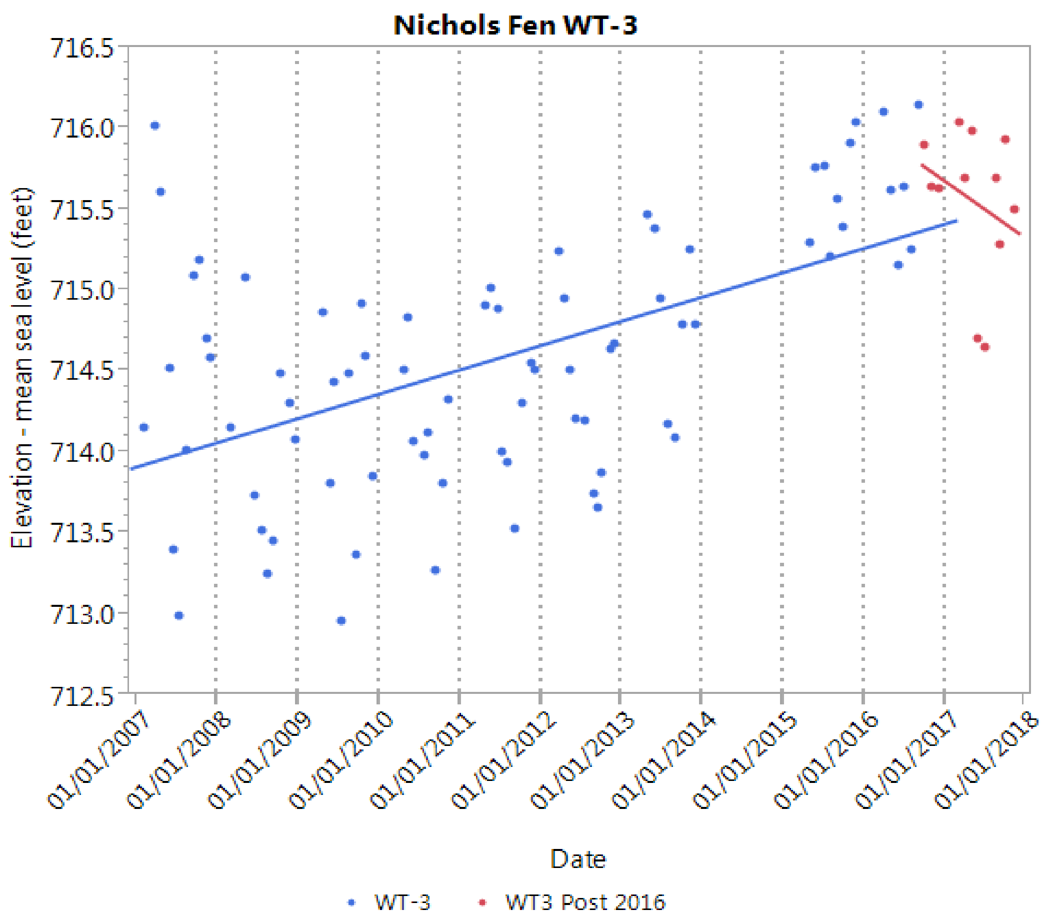

Nichols Fen WN5-USGS
Elevation - mean sea level (feet)
717.5
717.0
716.5
716.0
715.5
715.0
714.5
01/01/2007
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
Date
WN5-USGS
WN5GS Post 2016

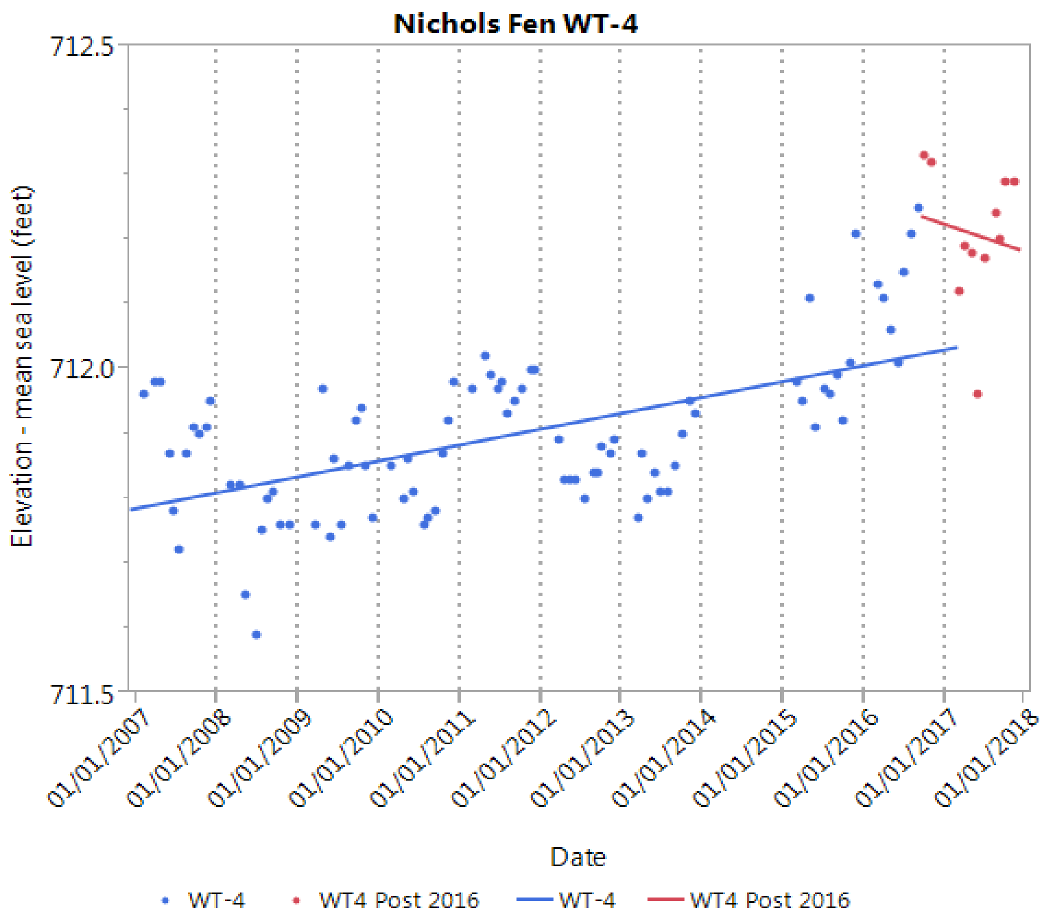

Nichols Fen WT-5
Elevation - mean sea level (feet)
717.0
716.5
716.0
715.5
715.0
714.5
714.0
713.5
713.0
712.5
01/01/2007
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
Date
WT-5
WT5 Post 2016


Nichols Fen F1
715.5
2016 Top of Well
Hist. Top of Well
714.5
714.0
713.5
713.0
712.5
712.0
711.5
Elevation - mean sea level (feet)
01/01/2007
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
Date
F1
F1 Post 2016


Nichols Fen F2
714.5
714.0
713.5
713.0
712.5
712.0
711.5
711.0
Elevation - mean sea level (feet)
01/01/2007
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
Date
F2
F2 Post 2016


Nichols Fen WT-2
Elevation - mean sea level (feet)
717.0
716.5
716.0
715.5
715.0
714.5
714.0
713.5
713.0
01/01/2007
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
Date
WT-2
WT2 Post 2016


Nichols Fen WT-3
Elevation - mean sea level (feet)
716.5
716.0
715.5
715.0
714.5
714.0
713.5
713.0
712.5
01/01/2007
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
Date
WT-3
WT3 Post 2016


Nichols Fen WT-4
712.5
712.0
711.5
Elevation - mean sea level (feet)
01/01/2007
01/01/2008
01/01/2009
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
01/01/2017
01/01/2018
Date
WT-4
WT4 Post 2016
WT-4
WT4 Post 2016