www.wwbwc.org

Walla Walla Basin Watershed Council

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# Shallow Aquifer Monitoring in the Walla Walla Basin

## *2018-2019 Water Year*

## ***Final Report***

*In Cooperation with:*

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# *Shallow Aquifer Monitoring in the Walla Walla Basin*

## Introduction

### Overview

Since 2001 the Walla Walla Basin Watershed Council (WWBWC) has collected data from a network of monitoring wells in the Walla Walla River Valley as part of its long-term efforts to understand the shallow (unconfined) alluvial aquifer. The primary objectives of this network are to provide data necessary for informed water management in the bi-state basin and help water and fisheries managers in the basin better understand surface-groundwater interactions as they relate to salmon recovery and groundwater sustainability. The monitoring network is also used to track the effectiveness of artificial managed aquifer recharge projects currently in operation and provide data for hydrologic modeling projects.

The WWBWC worked with the Oregon Water Resource Department (OWRD) and Washington Department of Ecology (WDOE) to develop protocols for monitoring well locations, measurement, and maintenance. Many of the original monitoring wells in the network were established or drilled by OWRD and WDOE. Other partners in the basin such as Hudson Bay District Improvement Company, Gardena Farms Irrigation District #13, Walla Walla River Irrigation District, Fruitvale Water Users Association, The Native Creek Society, the City of Walla Walla and dozens of private property owners have contributed to utility of the monitoring network by providing well access, supplying historical information and making contact with prospective participants. Some of the dedicated monitoring wells were established as part of WWBWC's managed aquifer recharge program.

This past water year we decommissioned three wells because of no access to the well. Also, funding was not available to monitor wells in Washington. We will continue to engage potential funders in an effort to provide current water level data for the shallow aquifer on the Washington side of the Walla Walla Basin. See Table 1 for a summary of the established monitoring wells we are currently monitoring in Oregon.

Table 1. Overview of the Shallow Aquifer Monitoring Network.

| Monitoring Group | State | Number of Wells |
|---|---|---|
| OWRD | Oregon | 6 |
| WWBWC | Oregon | 62 |

Well monitoring consists of measuring the groundwater level (the depth to water), water temperature and specific conductance. The well monitoring network is comprised of two types of monitoring wells: continuous monitoring wells that are instrumented with pressure transducers that log water level at a programmed interval (typically every 15 or 60 minutes), and non-continuous wells, which are measured manually approximately every three months. Conductivity measurements are taken quarterly at both types of monitoring wells if access permits.

The WWBWC has continued to update and maintain a Monitoring Well Database with historical records and information about wells in the network. The database includes landowner contact information, water rights, well logs, USGS, WDOE and OWRD historical water level measurements, well GPS coordinates, elevation, maps, and photos of the wells. Wells in the monitoring network have been surveyed with survey-grade GPS units to determine accurate longitude, latitude and elevation data. The Monitoring Well Database serves as institutional memory of the monitoring network and gives insight into historical uses and conditions of the wells and aquifer. It also allows WWBWC to easily share well information with the community and other agencies.

## Shallow Aquifer Monitoring Area

The Walla Walla River basin is a bi-state region located in northeastern Oregon and southeastern Washington (Figure 1). The river basin covers approximately 1,760 square miles, with an underlying shallow alluvial aquifer of about 200 square miles (Figure 2). Shallow depth-to-water in certain locations in the valley and year-round supply make the shallow aquifer a highly important source of water for irrigated agricultural lands as well as domestic and livestock uses.

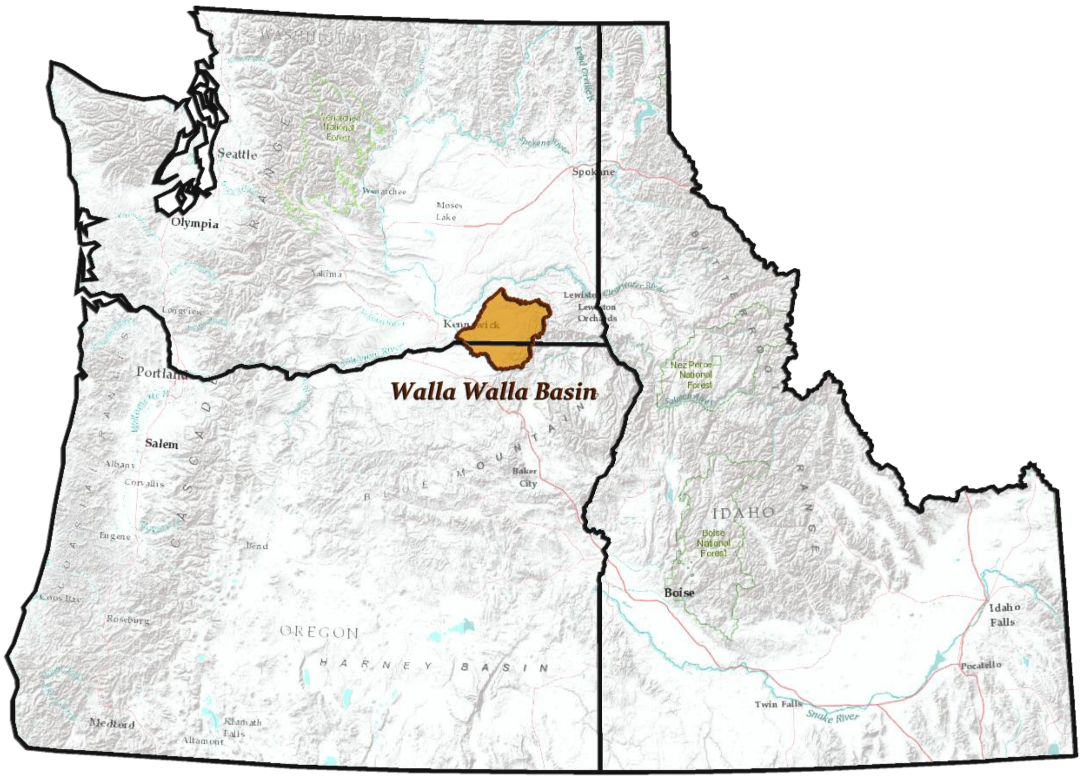


Figure 1. The bi-state Walla Walla River basin in northeastern Oregon and southeastern Washington. Due to lack of funding, we are currently not monitoring Washington wells.

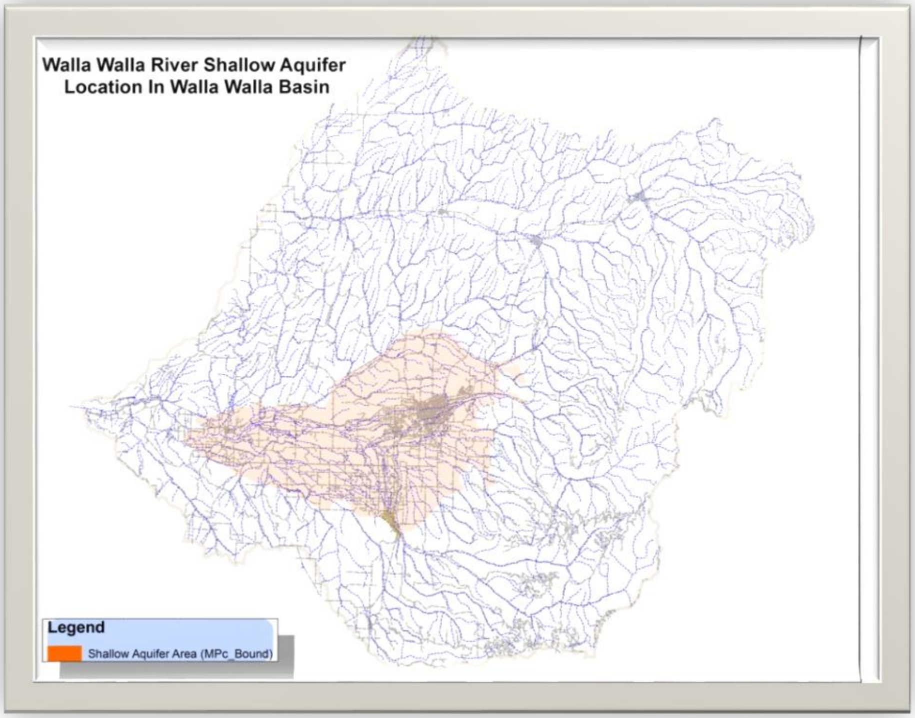


Figure 2. The Walla Walla River basin with the underlying shallow alluvial aquifer.

In addition to supplying water for the wells, the shallow alluvial aquifer also feeds the numerous springs, streams, and rivers of the Walla Walla basin. The high connectivity between the shallow aquifer and surface water bodies is important for enhancing base flows and cooling summer water temperatures for ESA-listed bull trout, mid-Columbia River summer steelhead, and reintroduced spring Chinook salmon in the basin.[1]

Since 2001, the WWBWC and its partners have utilized a community-based groundwater monitoring network. This network was developed to enhance knowledge about long-term water level trends and provide hydrogeological information. In 2001, only a dozen shallow aquifer wells were monitored in Oregon and Washington. These wells were inadequate to effectively monitor and manage the vast aquifer which supplies hundreds of domestic and agricultural wells, provides water for the dozens of creeks and springs throughout the valley, and discharges cool water into the Walla Walla River during base flows. WWBWC and its state and local partners currently monitor 68 wells (Figure 3).

Wells in the monitoring network currently include both urban and rural wells in and around Milton-Freewater and Umapine, OR, and historically in and around Walla Walla, College Place, Lowden, and Touchet, WA. The wells are owned by a variety of water users, including government agencies (state, county, and city), businesses, universities, and private landowners within the basin. Prior to drilling dedicated monitoring wells, most of the monitoring wells were irrigation (both active and abandoned) or old domestic wells owned by private land owners. All of the well owners participate voluntarily, aiding in the effort to understand and mitigate the decline of the aquifer, a critically important economic and ecological resource to the communities located within the Walla Walla basin.

[1] Winter, T.C., *et al*. 1998. *Ground Water and Surface Water: A Single Resource.* U.S. Geological Survey Circular 1139.

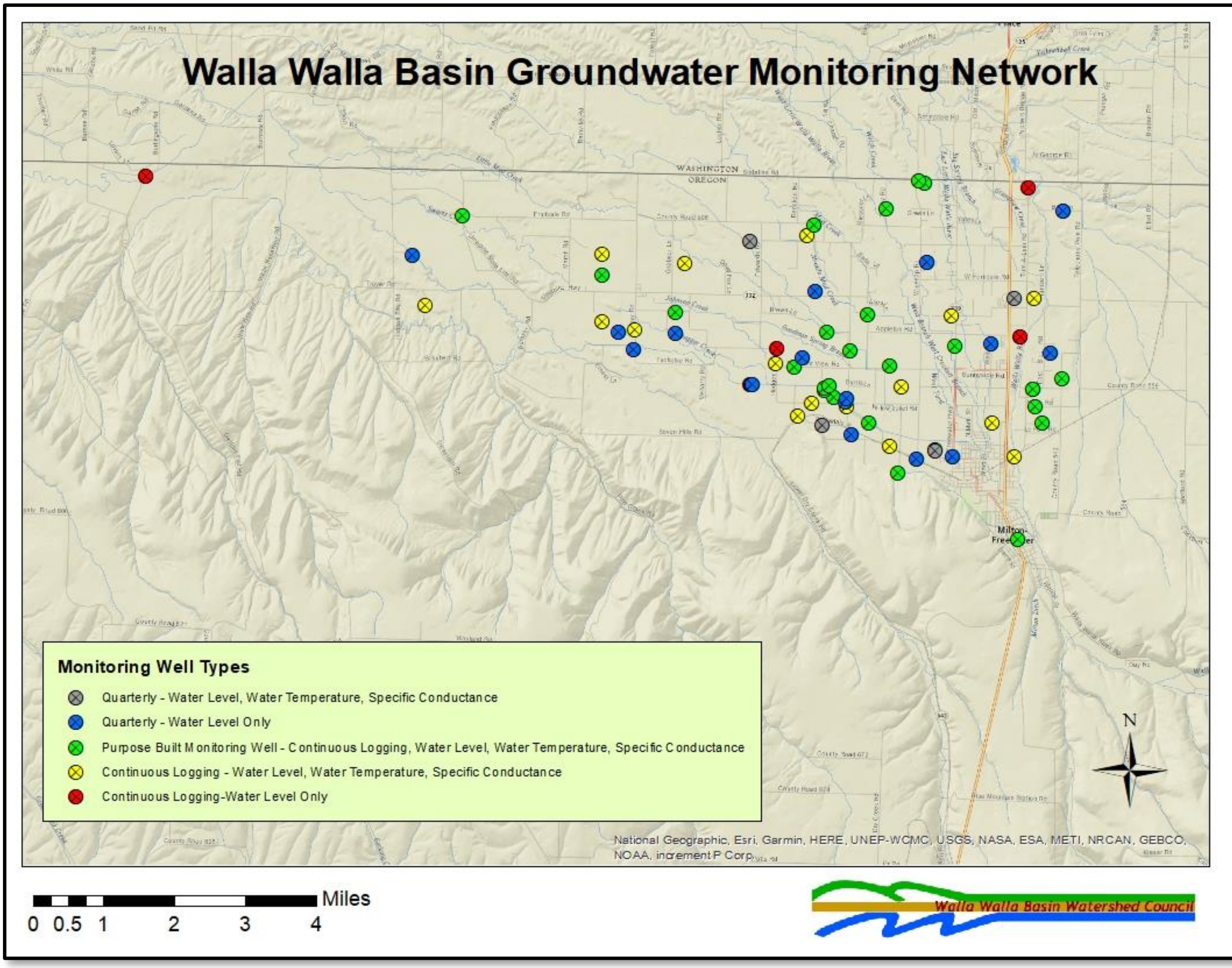


Figure 3. Map overview of wells in the Shallow Aquifer Monitoring Network as of September 2019. Due to lack of funding, we are currently not monitoring Washington wells.

## Methodology

All monitoring was conducted according to our standard operating procedures[2] based on USGS, Washington and Oregon state methods for groundwater monitoring. [Click here for the WWBWC's Standard Operating Procedures](#)

### Continuous and Non-continuous Wells

The WWBWC shallow groundwater alluvial aquifer well network includes both continuous and non-continuously monitored wells. As of September 2017, five of our groundwater monitoring locations have been equipped with a radio, solar panel, battery and datalogger capable of sending near-real time data through our telemetry network. The data are updated daily and available at the Groundwater Monitoring page on the WWBWC website. These data

[2] Walla Walla Basin Watershed Council 2018. *WWBWC Standard Operating Procedures – Version 1.3.* www.wwbwc.org.

are available year around but are particularly useful for tracking aquifer recharge water when the Johnson (GW_46), Lefore (GW_152), Chuckhole (GW_169), Mud Creek (GW_170) and Fruitvale (GW_171) recharge sites are operating during the winter months.

During the 2018 water year, about one third of the monitoring wells were continuously monitored using one of four different pressure transducers (Figure 4) that were suspended below the water level but not resting on the bottom of the well. Pressure transducers were suspended using 1/16$^{th}$ inch aviation cable, 14 gauge speaker wire, fishing line or a communication cable provided by the manufacturer. The pressure transducers electronically determine and record the water pressure (pounds per square inch or feet of water) and water temperature (either °F or °C) on a programmed log interval (typically every 15 or 60 minutes). Transducer data were downloaded on a quarterly schedule. Manual water level measurements were made during the quarterly download to standardize the pressure transducer data. Water level measurements were collected manually using an e-tape (Solinst Water Level Meter, Model 102, www.solinst.com). All water level values were measured from an established measurement point, adjusted for top of grade ("stickup height") and recorded as "feet below ground surface."

Although it would be ideal to have all of the wells instrumented for continuous data collection, many abandoned and irrigation wells have small access ports or the pump is in the way, prohibiting deployment of a pressure transducer. Static (non-continuous) wells provide an inexpensive way to collect "snap shot" information of the aquifer and track trends throughout the valley. Wells not instrumented with a pressure transducer were monitored quarterly. Manual measurements were taken using the e-tape from an established measurement point, adjusted for top of grade ("stickup height") and recorded as "feet below ground surface." At irrigation wells, pump condition (on or off) was recorded during each visit. A summary of continuous and non-continuous monitoring wells is shown in Table 2.


Figure 4. Pressure transducers used in the Shallow Aquifer Monitoring Network. Continuously monitored wells were equipped with one of the above types of pressure transducers.

| Data Type | State | Number of Wells |
|---|---|---|
| Continuous water level and quarterly conductivity | Oregon | 42 |
| Continuous water level only | Oregon | 5 |
| Quarterly static water level and conductivity | Oregon | 4 |
| Quarterly static water level only | Oregon | 17 |

Table 2. Summary of data types collected in the Shallow Aquifer Monitoring Network.

## Conductivity Sampling

Where well access permitted, conductivity was measured on a quarterly basis. Water samples were taken when the pressure transducer was downloaded or a water level measurement was taken. Water samples were collected using a bailer and transferred into a graduated cylinder[3]. Conductivity values were measured using a handheld conductivity meter (YSI 30, www.ysi.com). At irrigation wells, pump condition (on or off) was also recorded during each visit. Further details regarding transducer downloading, deployment, maintenance, and quarterly data collection can be found in the WWBWC 2018 Standard Operating Procedures - Version 1.3[2].

Conductivity data allows the WWBWC to better understand the hydrogeological connections between groundwater and surface water. By knowing the conductivity we are able to map where groundwater is contributing to surface flows and where surface water is recharging the aquifer.

## Data Processing and Analysis

Most loggers used by WWBWC for groundwater monitoring were absolute (non-vented) pressure transducers, creating a need to compensate the water level data for atmospheric pressure. Using AQUARIUS Time Series software (www.aquaticinformatics.com), water level data were processed by subtracting barometric pressure collected by transducers located at several barometric monitoring stations throughout the valley (Figure 5). Also using AQUARIUS, water level logger data were converted from PSI to feet of water when necessary and graphed with manual water level measurements for a visual check of the data. Corrections were applied to account for pressure transducer drift.

Data were graded to document logger hang-ups on pumps or other obstructions, well pumping during manual water measurement, and other irregularities affecting data quality.

The well datasets mentioned below were evaluated using a Mann-Kendall (M-K) Nonparametric trend analysis. This type of analysis helps find positive, negative, or neutral trends in the well water level data.

[3] Oregon Department of Environmental Quality 1998. *DEQ Lab's Field Sampling Reference Guide.*

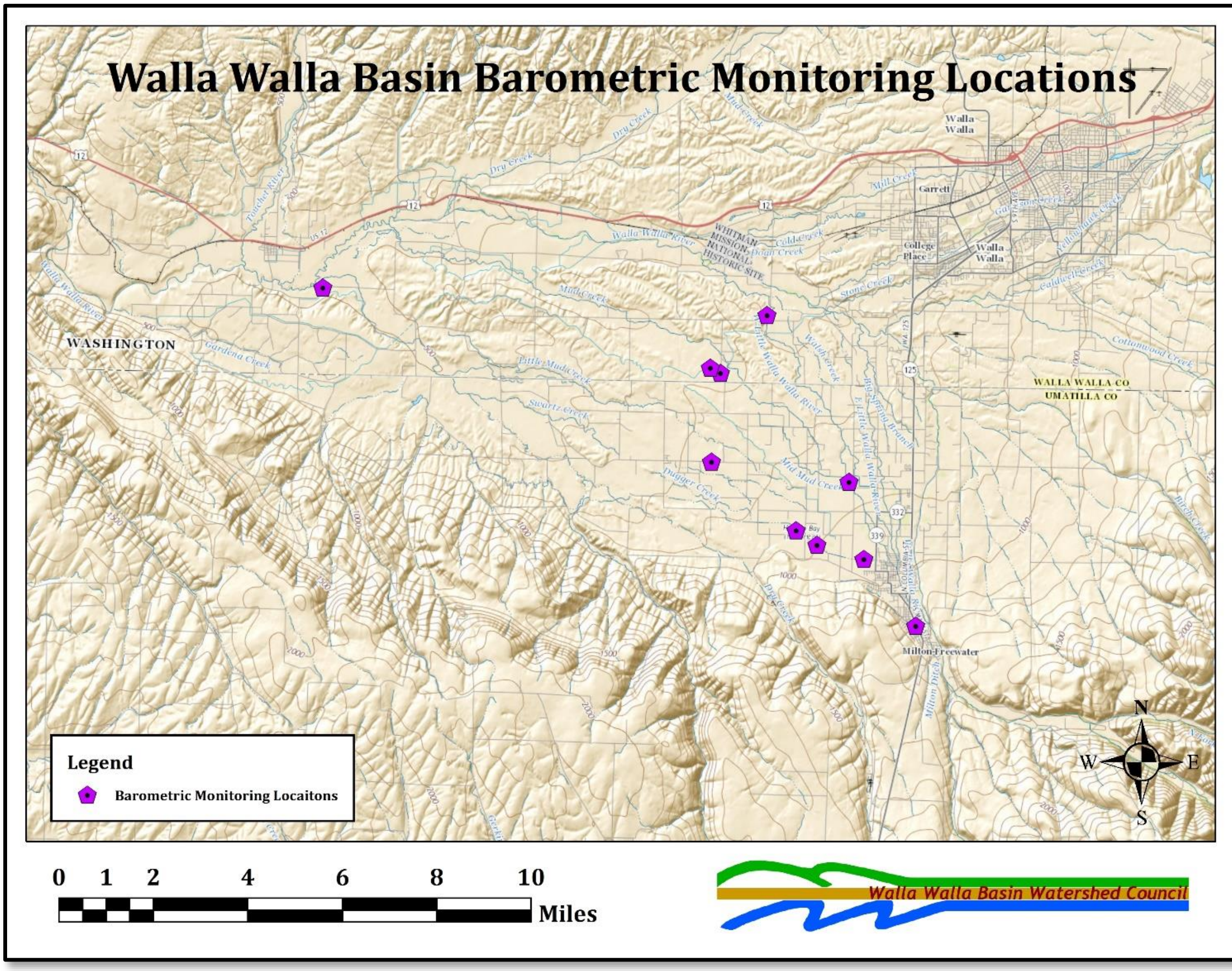


Figure 5. Barometric pressure transducer locations within the Shallow Aquifer Monitoring Network.

## Results and Discussion

For all well data please visit the WWBWC's Groundwater Monitoring Page. There you can view hydrographs and download data for the wells.

### Historic Wells

Six of the wells currently being monitored in the shallow aquifer are historic wells with data going back as far as 1933 (Figure 6). These wells are used to see long term trends in the Walla Walla basin's shallow alluvial aquifer. All of the historic wells we are currently monitoring had been showing declines up until the year 2001. Groundwater declines could be related to the increasing number of wells and increasing water usage for domestic and agricultural activities requiring more water withdrawal than is naturally recharged. Additionally, a significant water management change in 2001 could be having an effect on the basin's aquifer. In that year, the Civil Penalty Settlement Agreement between U.S. Fish and Wildlife Service and the three irrigation districts in the Walla Walla basin (Walla Walla River Irrigation District, Hudson Bay District Improvement Co, Gardena Farms Irrigation District #13) required that 18 cubic feet per second (cfs) remain in the Walla Walla River during summer months and be incrementally raised to 25 cfs during fall and spring. For the previous ~100 years, the Walla Walla River ran dry during the summer because all water was diverted for irrigation uses. This water flowed through the vast array of irrigation ditches in the basin, providing groundwater recharge as seepage occurred within the ditch systems. Since the Settlement Agreement in 2001, less water has been flowing through the Walla Walla/Gardena/Hudson Bay systems during the summer months leading to a reduced amount of groundwater recharge through the ditch system. However, since the decline in the aquifer seems to have started prior to the 2001 Settlement Agreement, the reduced recharged from surface flows in the irrigation system does not fully explain the downward trend. Increased efficiency for irrigation (ditch piping projects and modern irrigation methods) has further reduced the amount of groundwater recharge from irrigation ditches and canals. Historic irrigation practices included flood irrigation, which allowed for groundwater recharge, while newer drip and sprinkler systems only deliver as much water as is needed. Also, many irrigators have begun using supplemental wells more than in the past and new irrigation wells have been drilled.

One of the six wells, GW_20, was historically declining but, since water management changes in 2001 and the start of the WWBWC aquifer recharge program in the spring of 2004, have stabilized and possibly started to recover (Figure 12). While only one well shows stability, the other five wells still show declines (GW_15, 18, 19 and 23, Figures 13-16). Some of the historic wells are shallow hand-dug wells and have gone dry in the recent past. GW_27 has been dry since 1989 (Figure 17).

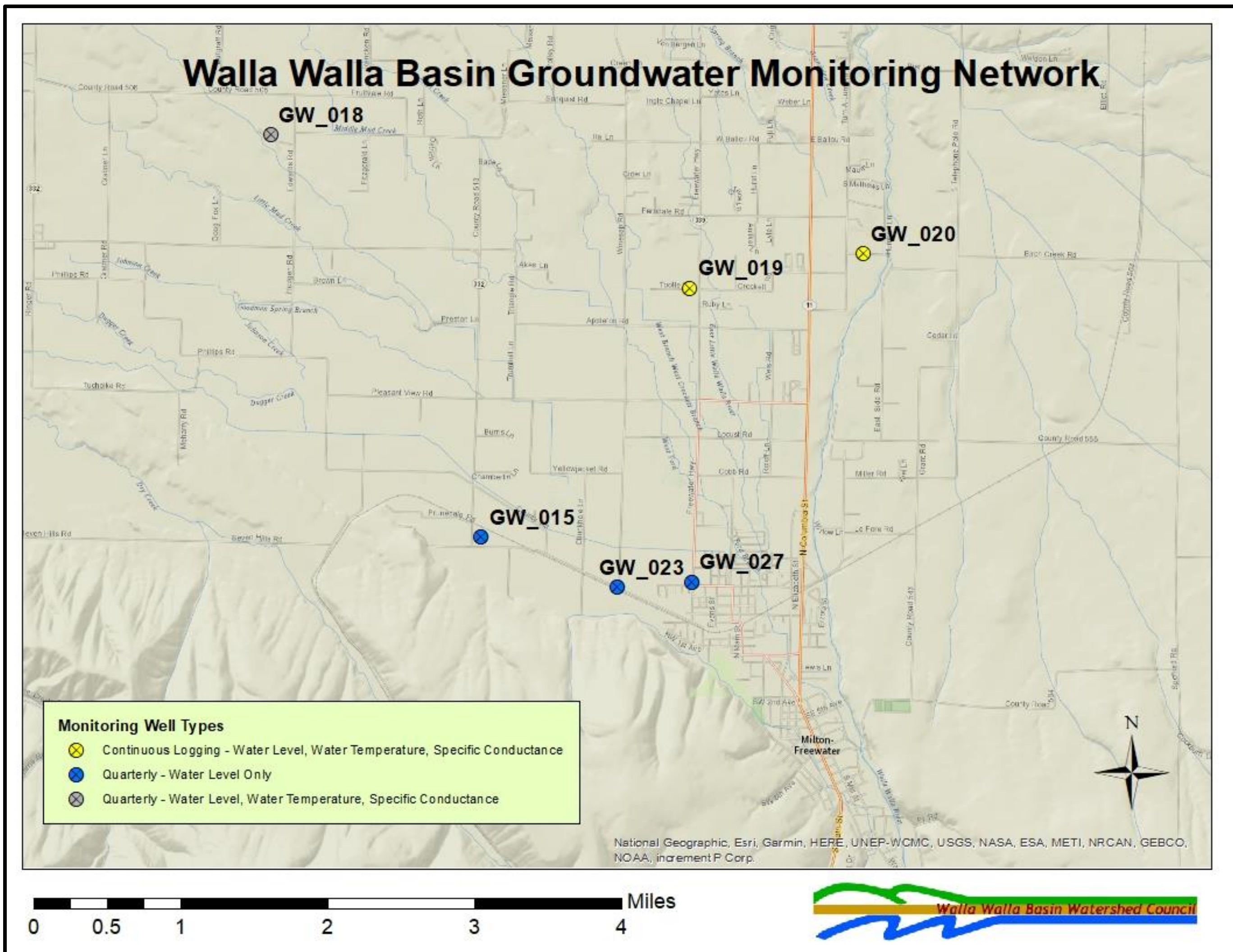


Figure 6. Historic wells included in the Shallow Aquifer Monitoring Network.

## Declining Groundwater Levels

Since 2011-2012, data indicate significant declines in groundwater levels in the Touchet-Gardena area (Figure 7). The historic data (funded by Bonneville Power Administration and Washington Department of Ecology) from monitoring wells south of the City of Touchet (GW_86, 106, 123, and 125, Figures 18-21) and the Gardena area (GW_82, 93, 124, 137, and 138, Figures 22-26) in Washington showed groundwater declines. Two monitoring wells in the Touchet-Gardena area on the Oregon side (GW_68 and 92, Figures 27-28) continue to show groundwater declines. Although the cause is not certain, the downward trend correlates with the timing of water management changes in the region including two major ditch piping projects on the Gardena Farms Irrigation District delivery system completed in 2010 and 2012. Seepage data indicate that groundwater contributions make up a meaningful portion of Walla Walla River flows downstream of Touchet during the summer months[4]. As Touchet-Gardena area groundwater levels drop, one might expect a decrease in groundwater contributions to the river. The potential impact of groundwater declines for water users and on Walla Walla River flows may warrant a focused study on the surface water and groundwater interactions in this region. Unfortunately, funding wasn't available to monitor the wells in the Touchet-Gardena area on the Washington side during the 2019 water year. Since current data are available only for GW_68 and GW_92, the severity of groundwater declines in the region is difficult to fully characterize.

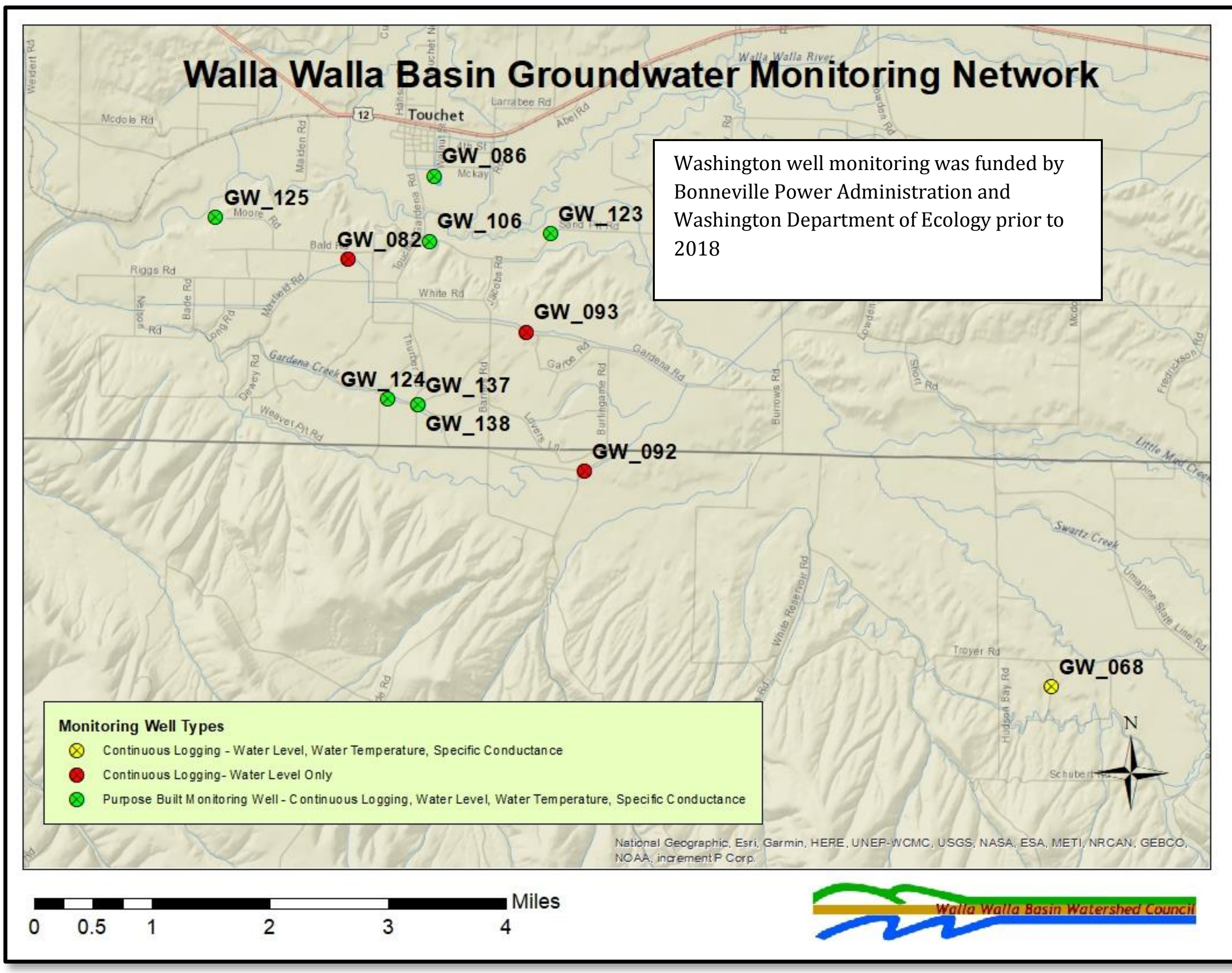


Figure 7. Monitoring wells in the Touchet-Gardena Area.

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[4] Baker T.W. 2017. *Walla Walla Basin Seasonal Seepage Assessments Report: Walla Walla River, Mill Creek, and Touchet River.* Walla Walla Basin Watershed Council. www.wwbwc.org.

Data also indicate groundwater declines north of Milton-Freewater (Figure 8). Four monitoring wells (GW_10, 14, 28 and 116, Figures 29-32) show groundwater declines along with GW_19, which is referenced above in the Historic Wells section. This trend could be due to less water flowing through the Little Walla Walla River system. As mentioned in the Historic Wells section, significant management changes occurred in 2001 which led to less water flowing through the irrigation ditches.

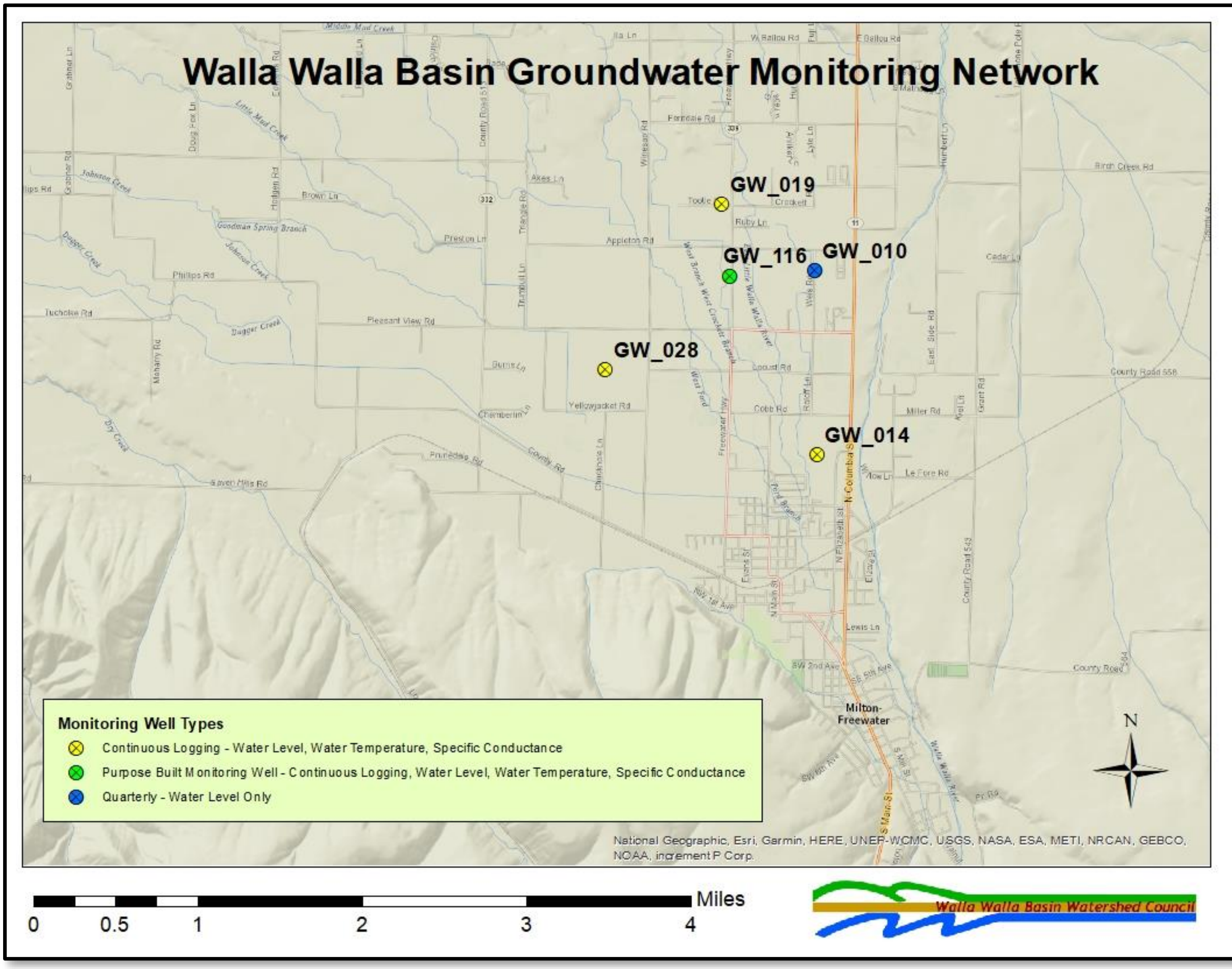


Figure 8. Monitoring wells north of Milton-Freewater.

## Near Real-time Groundwater Monitoring

Over the last three years, the WWBWC has significantly expanded its telemetry system. Included in this expansion is the near real-time monitoring of groundwater levels at several locations around the valley. Currently, the WWBWC has five near real-time groundwater monitoring locations (Figure 9). These sites allow landowners, water managers and other interested parties to get a more up-to-date understanding on current groundwater levels. These near real-time monitoring locations also allow for better operation and tracking of managed aquifer recharge sites. Figure 10 is an example of how the near real-time groundwater data are displayed on the WWBWC website.

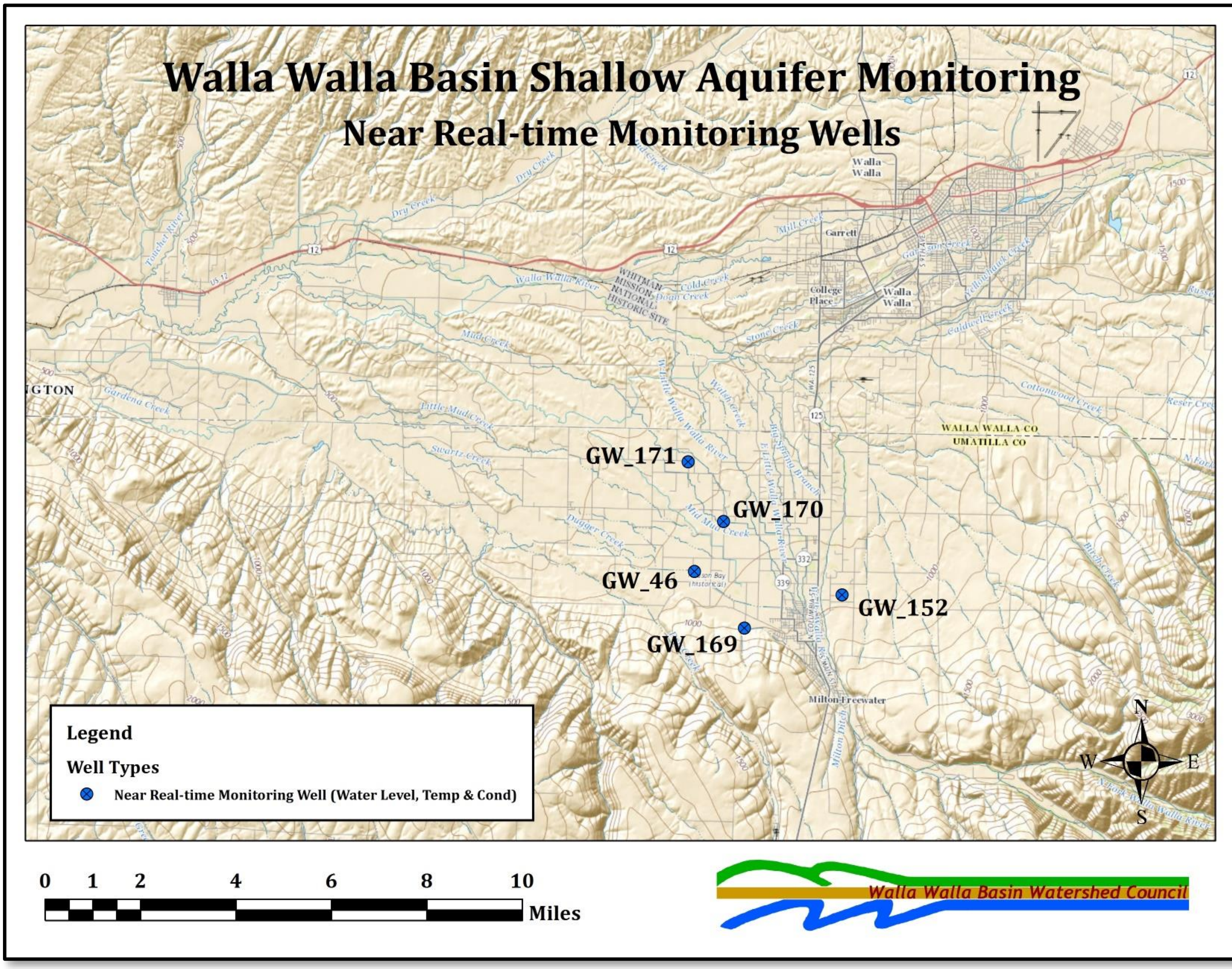


Figure 9. Near Real-time monitoring wells in the Walla Walla Valley.

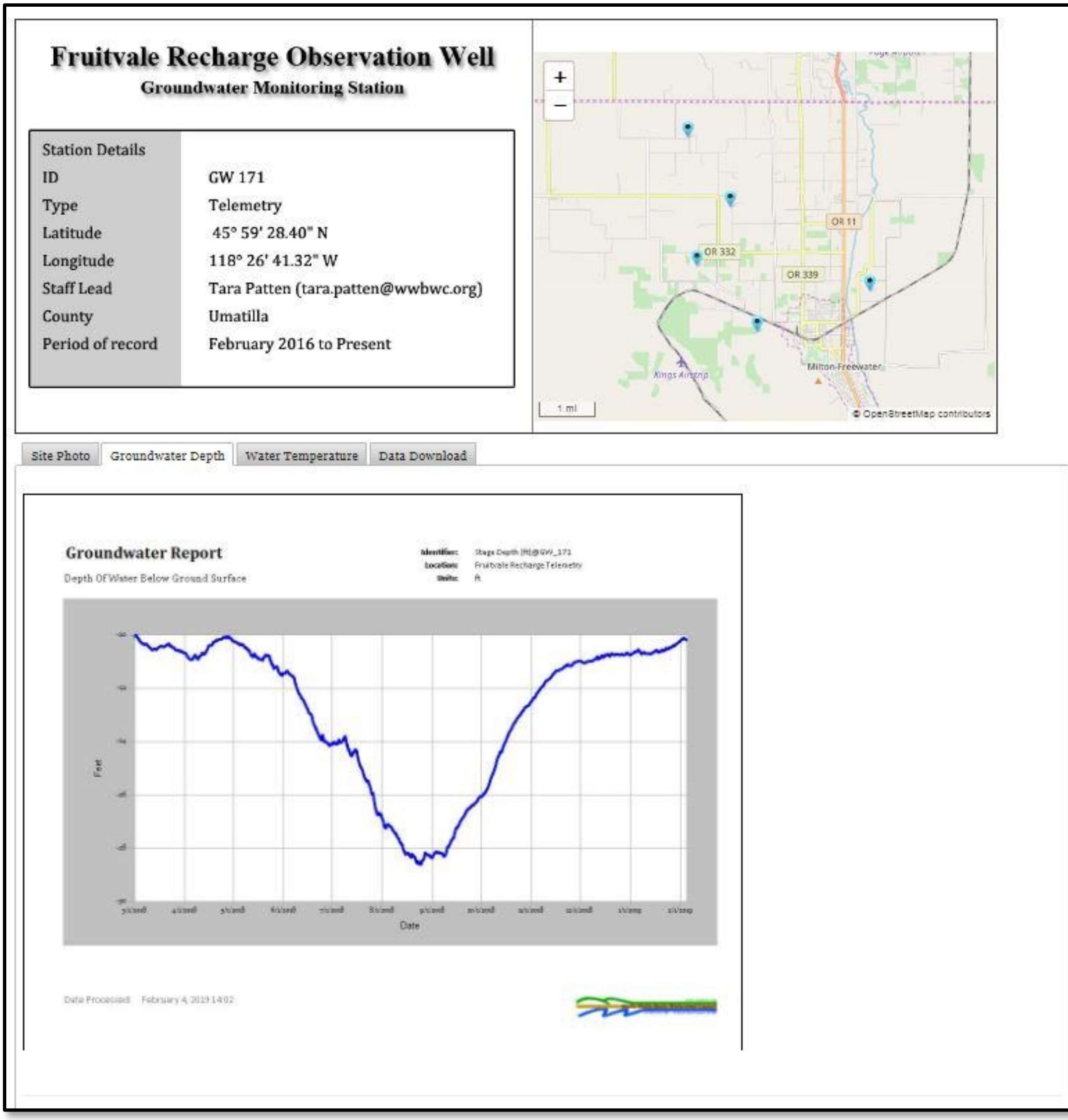


Figure 10. Example webpage for near real-time groundwater monitoring in the WWBWC's Shallow Aquifer Monitoring Network.

## Areas of Groundwater Stability and Potential Positive Trends

Not all wells in the valley are showing groundwater declines. Groundwater levels in Milton-Freewater and Umapine areas (Figure 11) appear to be relatively stable (GW_31, 66 and 115, Figures 33-35). Monitoring wells at three managed aquifer recharge sites located between Milton-Freewater and Umapine, Northwest Umapine, Johnson, and Anspach, show potential positive trends. GW_62 and 141 (Figures 36-37) near the Anspach recharge site show an increase in groundwater levels. Similar results can be seen with monitoring wells at the Johnson (GW_40, 45, 46, 47, 48, and 118, Figures 38-43) and Northwest Umapine recharge sites (GW_34 and 144, Figures 44 and 45).

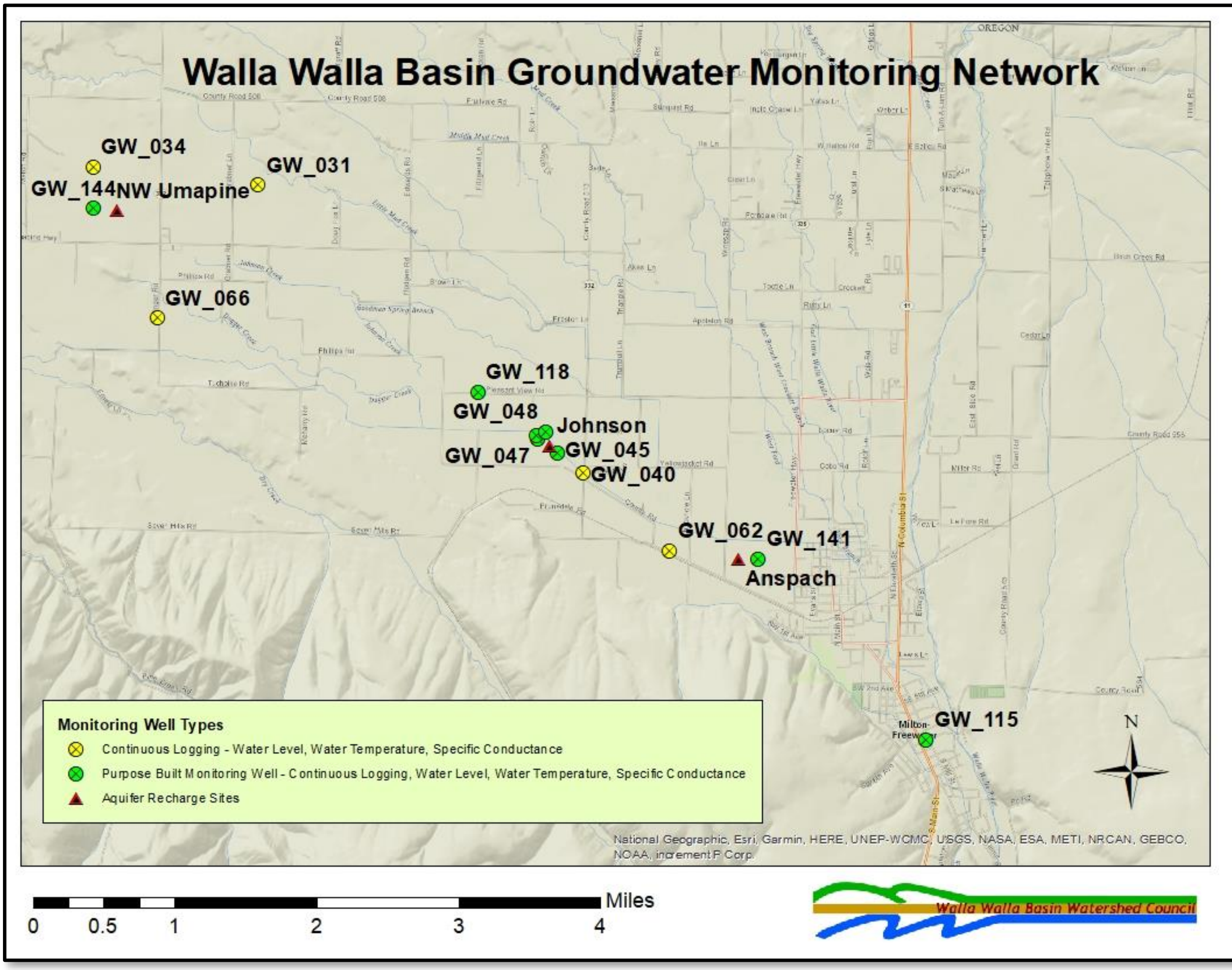


Figure 11. Monitoring wells showing stable and/or increasing groundwater levels in the Walla Walla Valley

## Summary

WWBWC's alluvial monitoring program, grown from only a dozen wells in 2001, provides basin partners with a valuable understanding of groundwater conditions and trends during the last 18 years. Although we were unable to monitor wells on the Washington side of the basin during the 2019 water year, WWBWC continued to extend the data record for 68 alluvial aquifer wells in Oregon. WWBWC funders and basin partners continue to support and affirm the value of the shallow aquifer monitoring project as a vital component of current and future understanding of groundwater resources, aquifer decline and recharge, surface-groundwater interactions, and groundwater returns to the Walla Walla River. The well monitoring network data are being used to inform decisions about current and future aquifer recharge projects and are also supporting the on-going Walla Walla Basin Integrated Flow Enhancement Study. The data being collected will continue to provide insight for water management professionals and local communities to make water related decisions into the future.

The Shallow Aquifer Monitoring Project is successful not only in compiling aquifer data but also as a mechanism for community outreach because it depends heavily on voluntary land owner participation and local support. Many citizens have contributed vital information to the project and also have become more aware of the declining aquifer and other water issues in the Walla Walla Basin.

## Acknowledgments

We gratefully acknowledge the contributions of our generous funders including Bonneville Power Administration, Oregon Water Resources Department, and the Oregon Watershed Enhancement Board. Thanks also to local collaborators including private landowners, irrigation districts, and the City of Milton-Freewater for allowing property access for groundwater monitoring. Without their support this work would not be possible.

# Appendix A

## Hydrographs of wells mentioned in the report

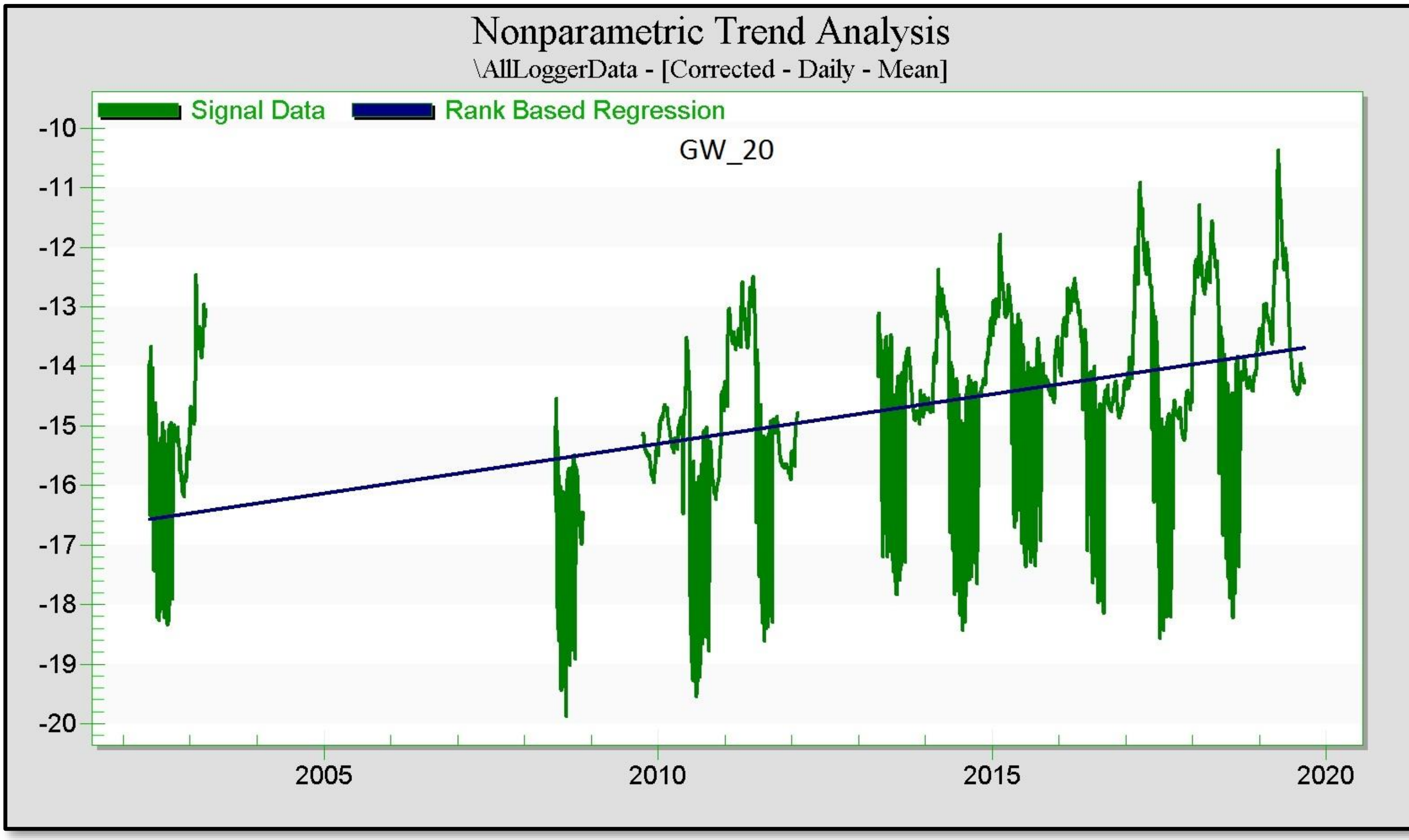


Figure 12. Pressure transducer data (green line) in feet below ground surface for the historic well GW_20 located in the WWBWC's Shallow Aquifer Monitoring Network. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

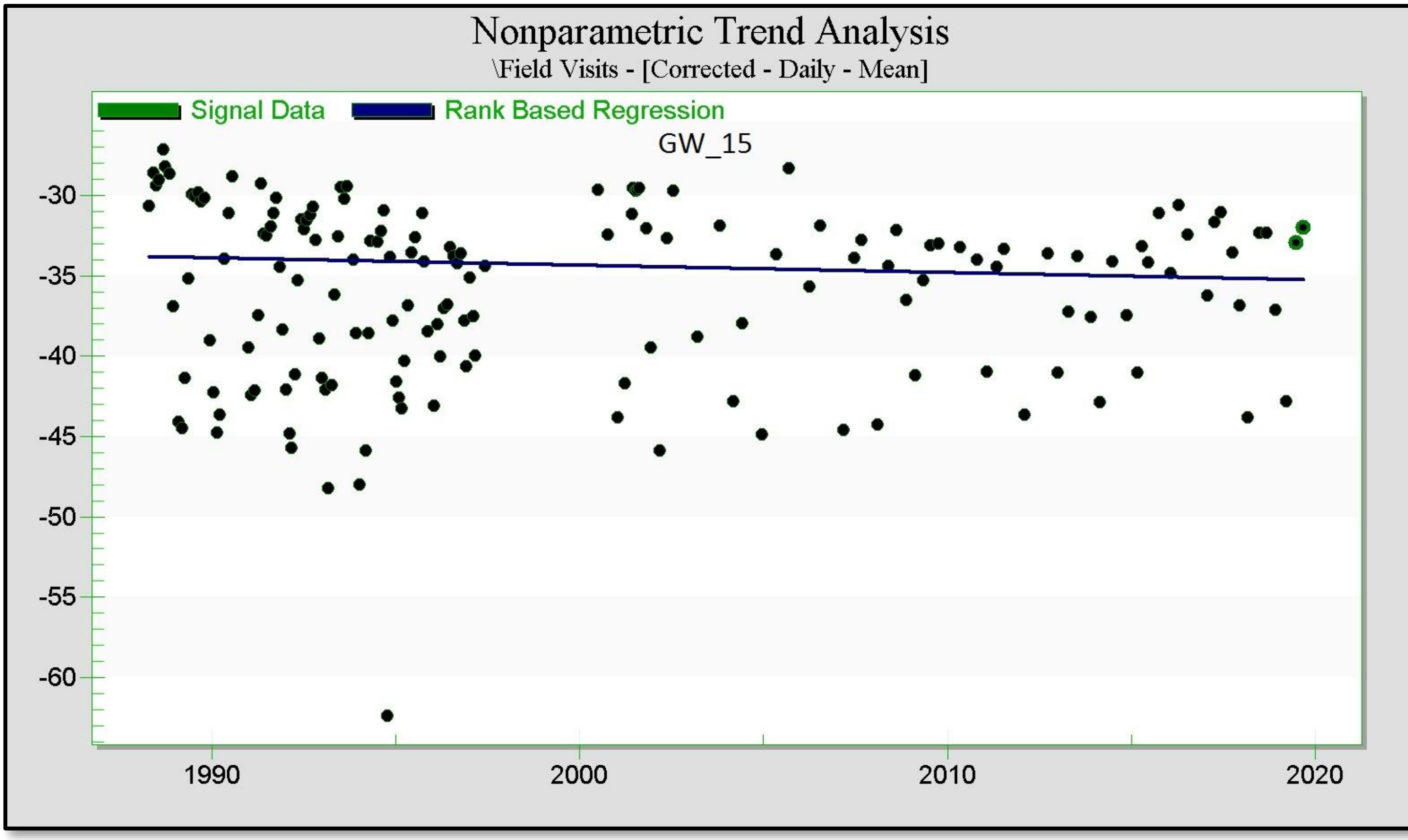


Figure 13. Manual water level measurements (green dots) in feet below ground surface for the historic well GW_15 located in the WWBWC's Shallow Aquifer Monitoring Network. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

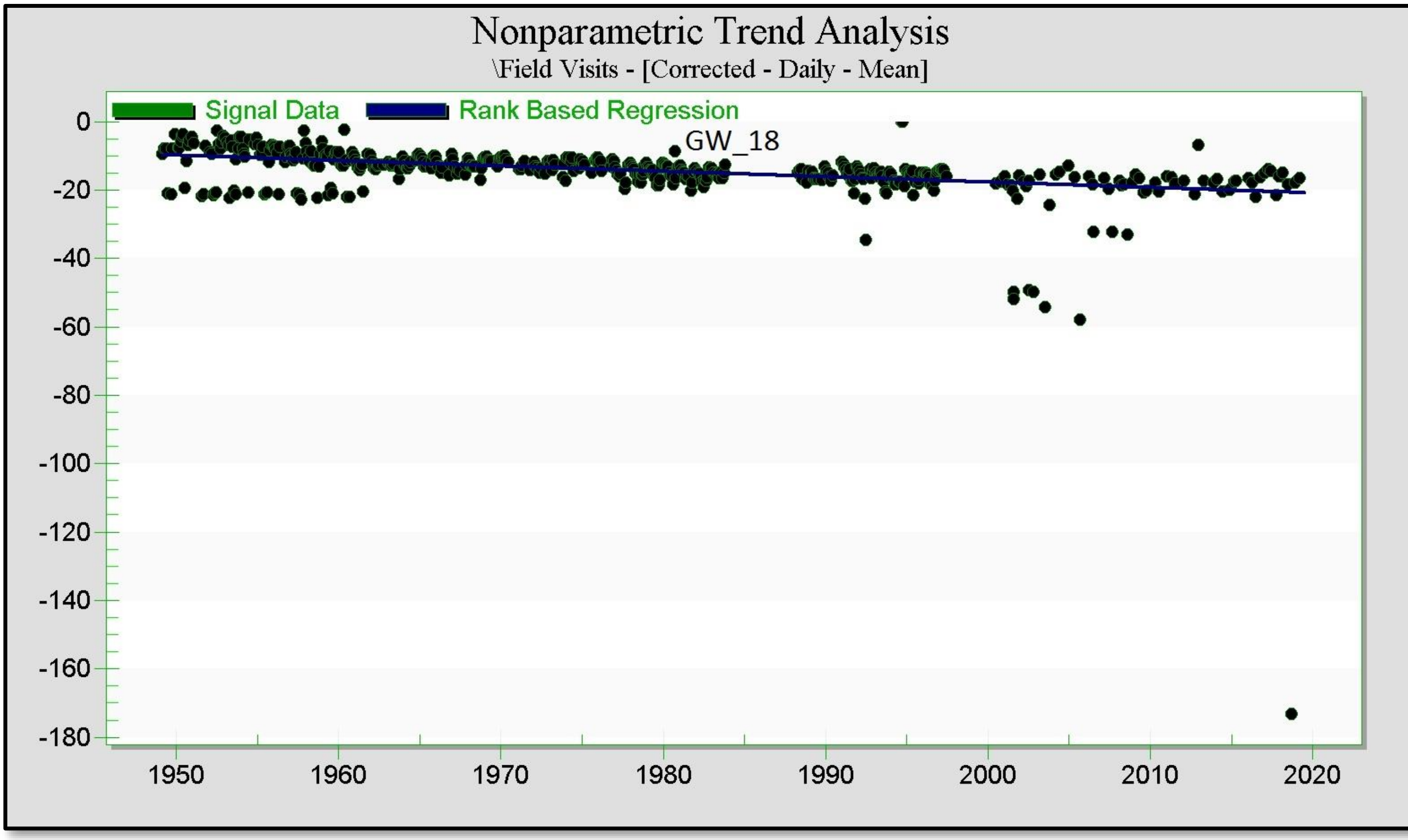


Figure 14. Manual water level measurements (green dots) in feet below ground surface for the historic well GW_18 located in the WWBWC's Shallow Aquifer Monitoring Network. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

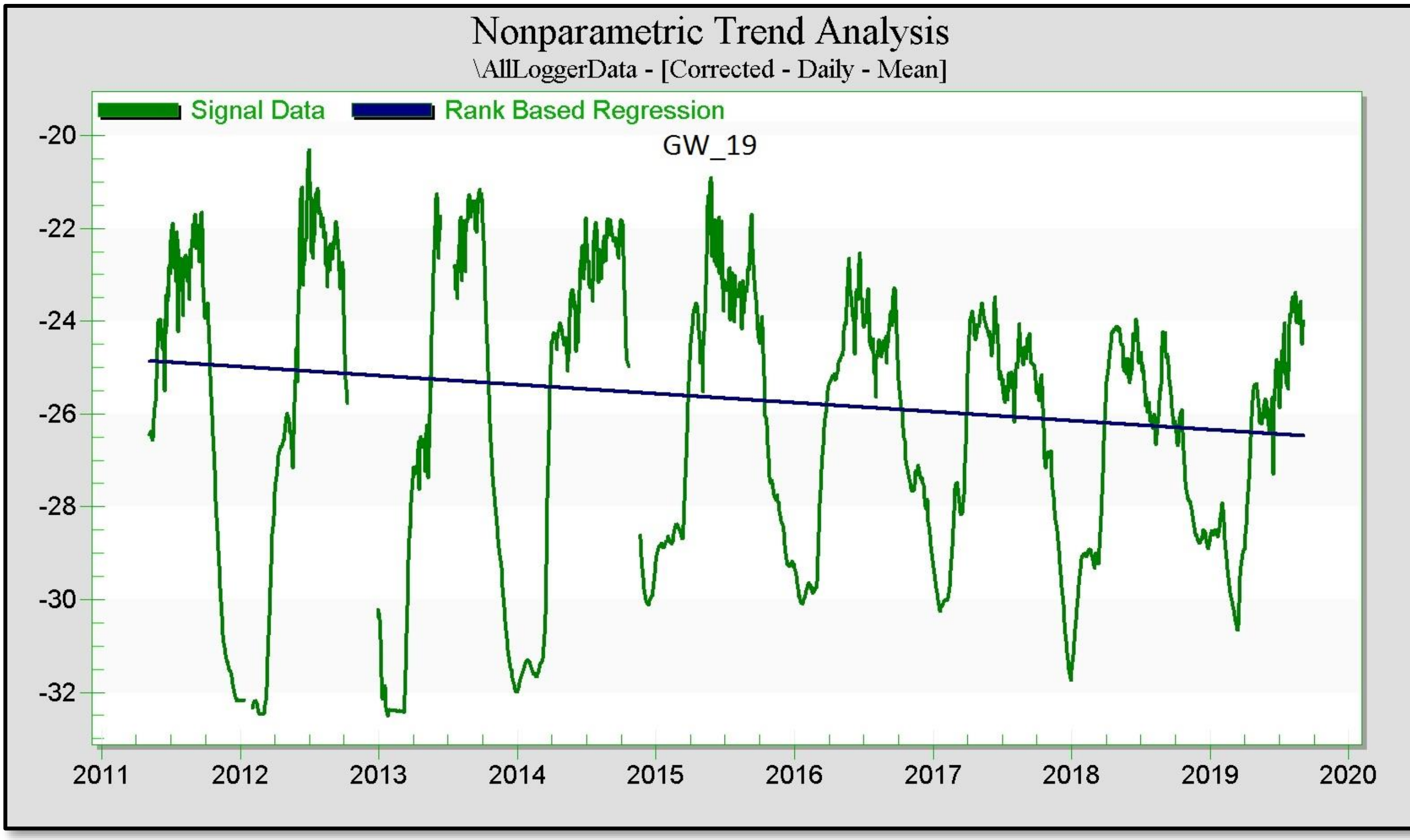


Figure 15. Pressure transducer data (green line) in feet below ground surface for the historic well GW_19 located in the WWBWC's Shallow Aquifer Monitoring Network. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

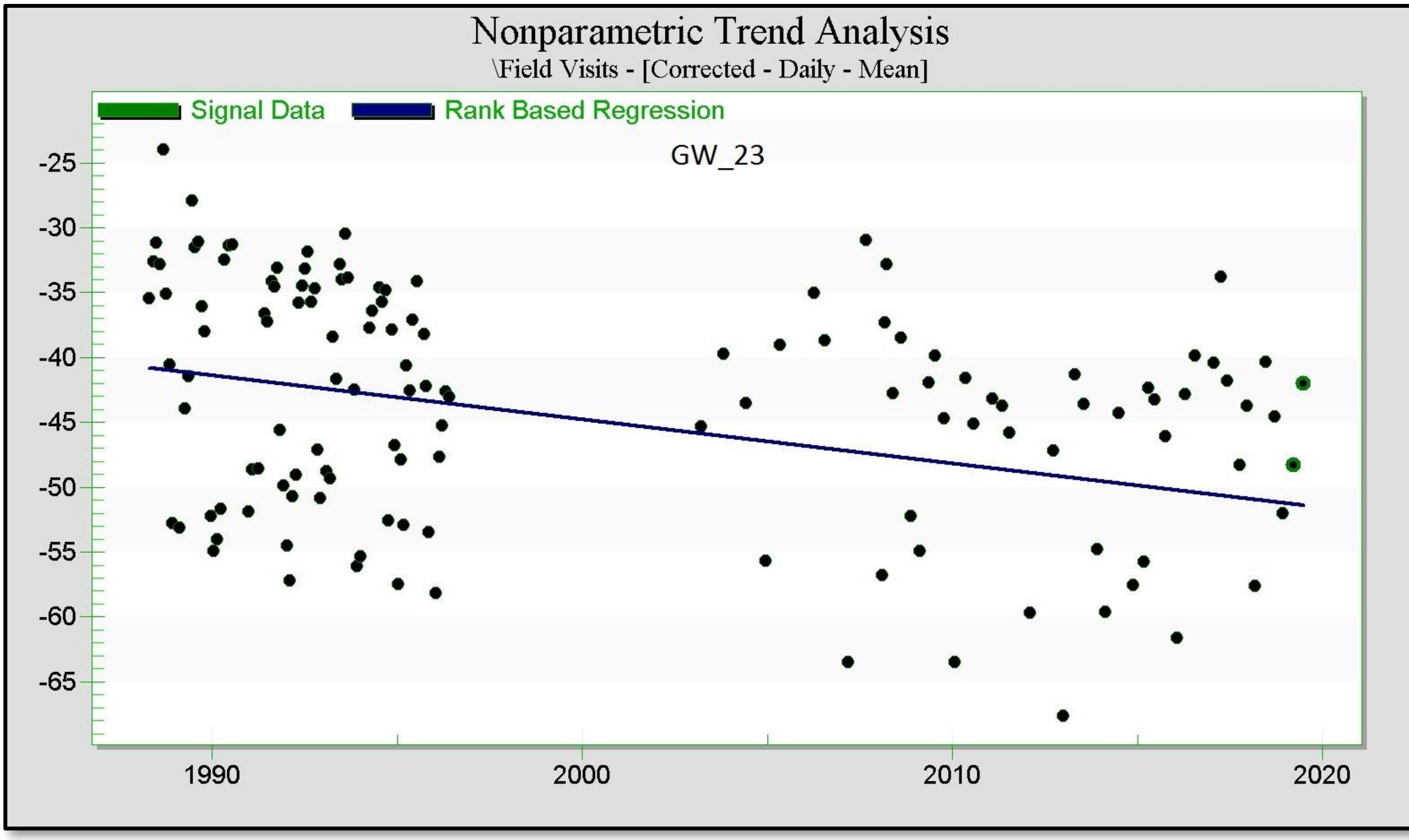


Figure 16. Manual water level measurements (green dots) in feet below ground surface for the historic well GW_23 located in the WWBWC's Shallow Aquifer Monitoring Network. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

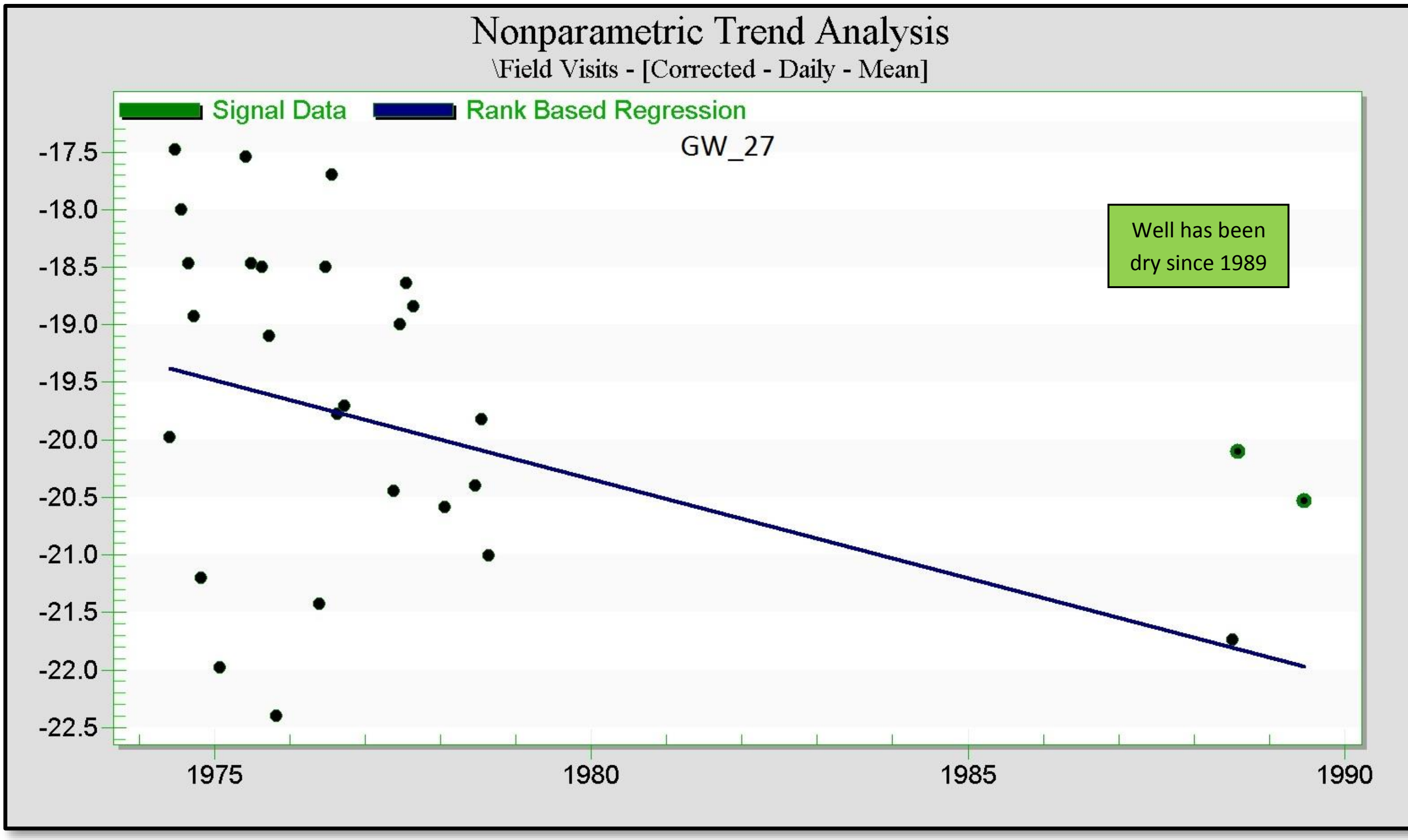


Figure 17. Manual water level measurements (green dots) in feet below ground surface for the historic well GW_27 located in the WWBWC's Shallow Aquifer Monitoring Network. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

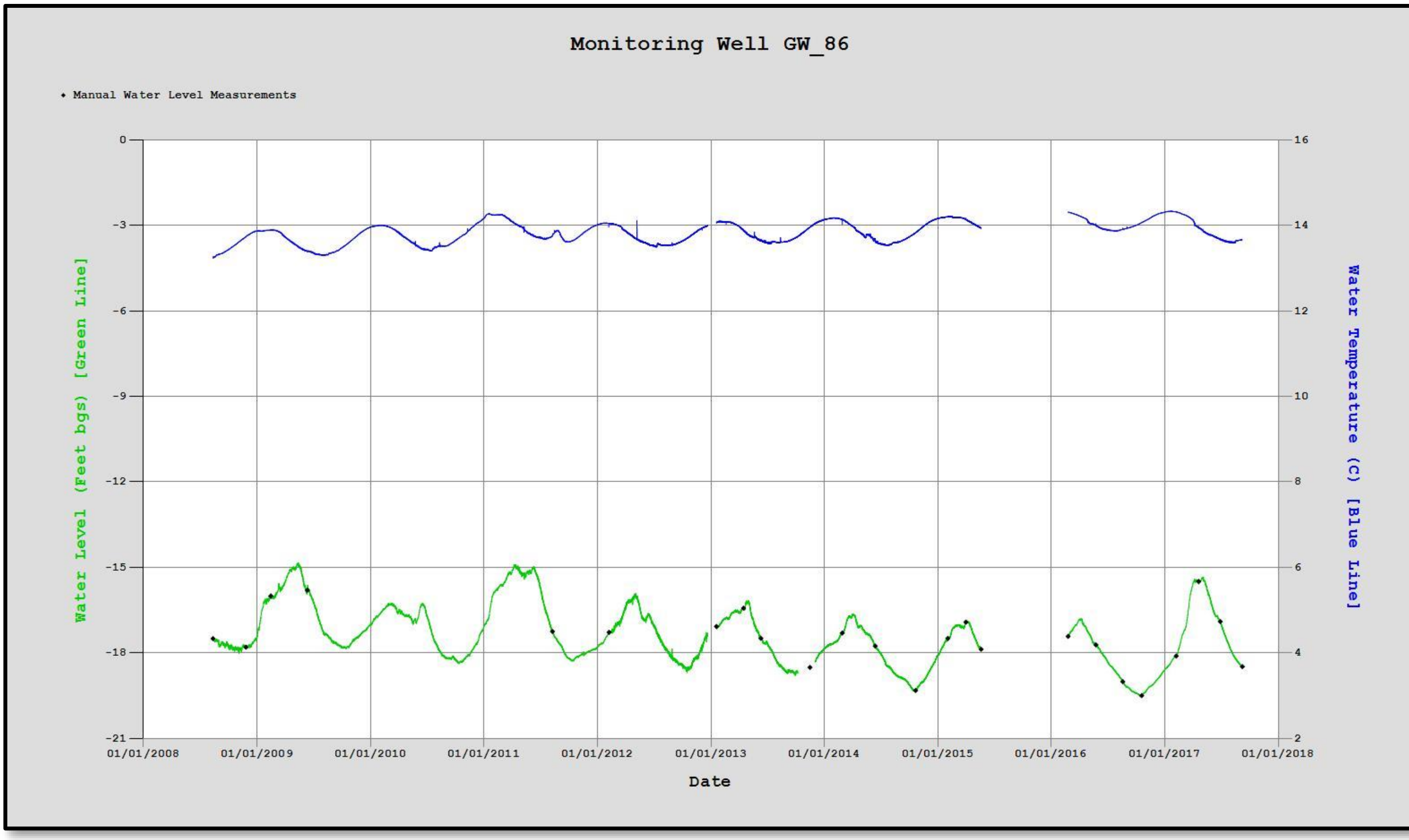


Figure 18. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_86 from 2008-2018. This monitoring was funded by Bonneville Power Administration and Washington Department of Ecology.

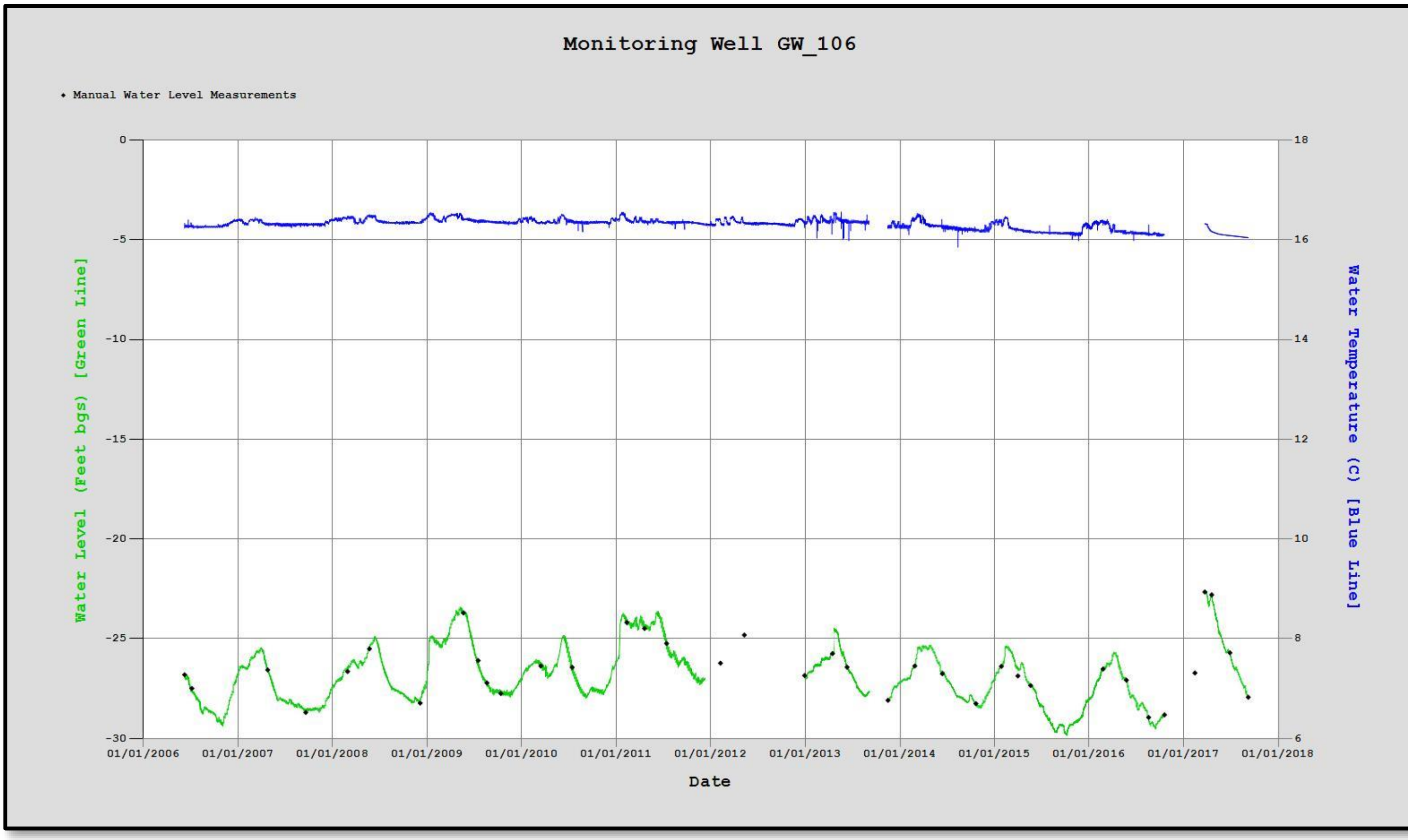


Figure 19. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_106 from 2006-2018. This monitoring was funded by Bonneville Power Administration and Washington Department of Ecology.

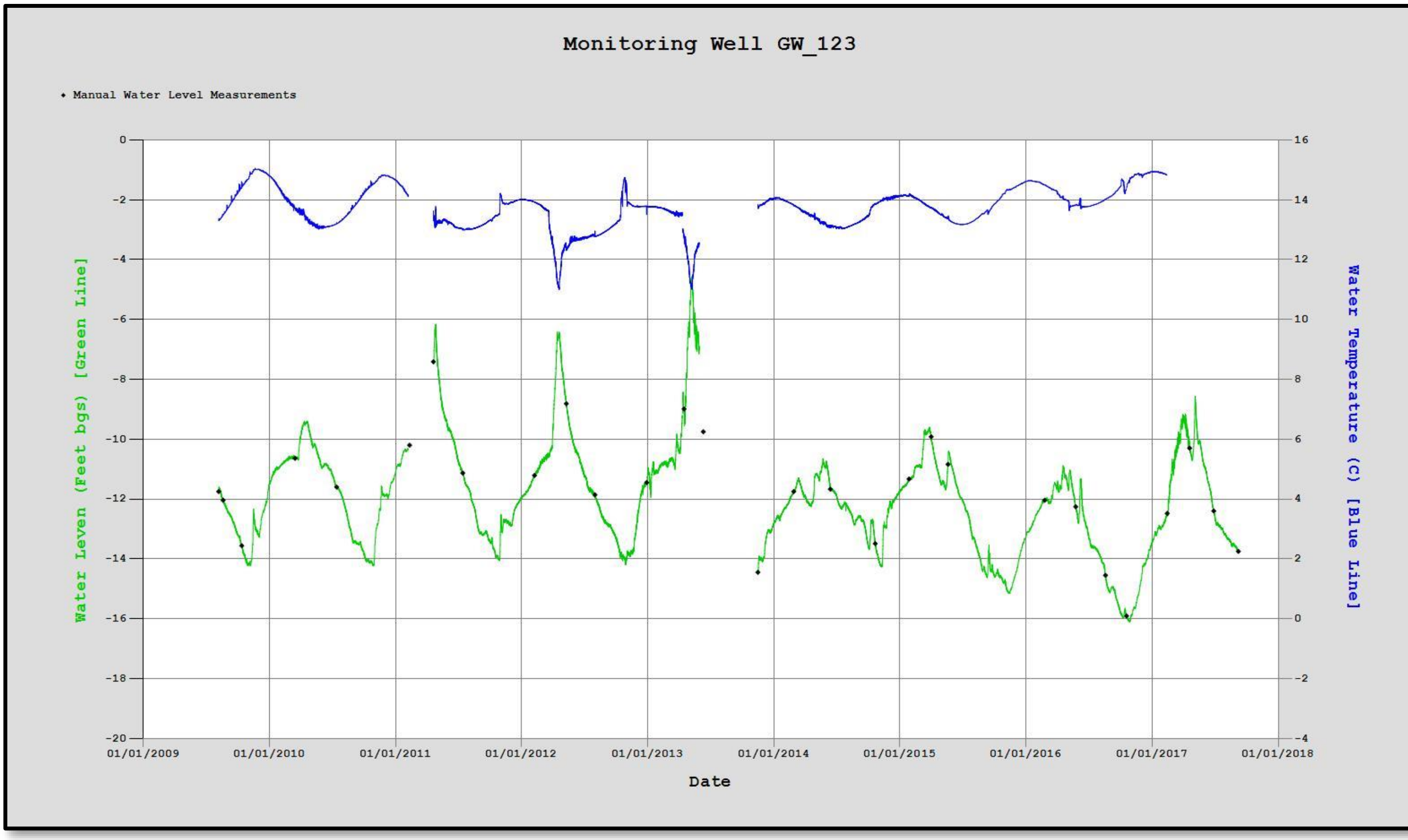


Figure 20. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_123 from 2009-2018. This monitoring was funded by Bonneville Power Administration and Washington Department of Ecology.

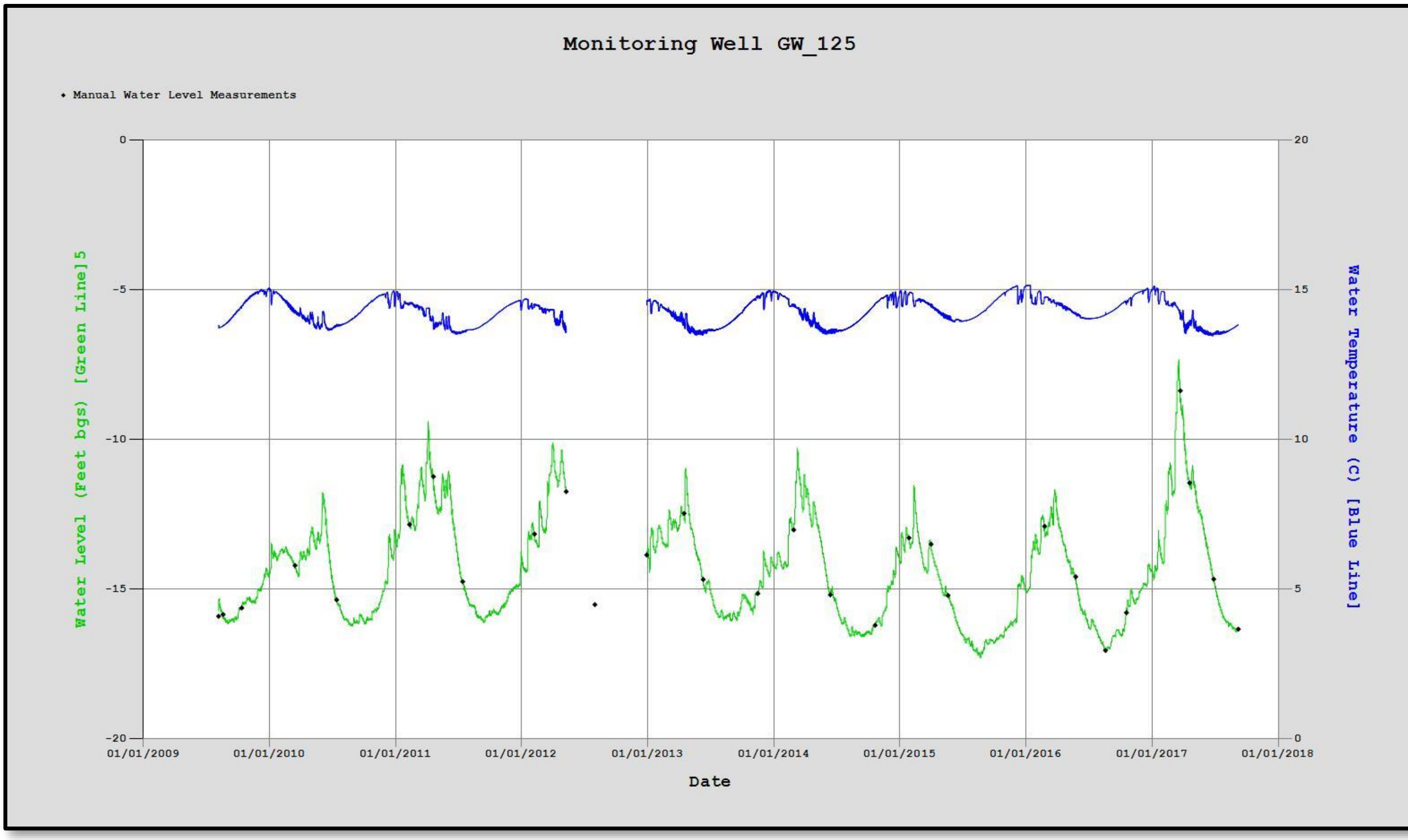


Figure 21. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_125 from 2009-2018. This monitoring was funded by Bonneville Power Administration and Washington Department of Ecology.

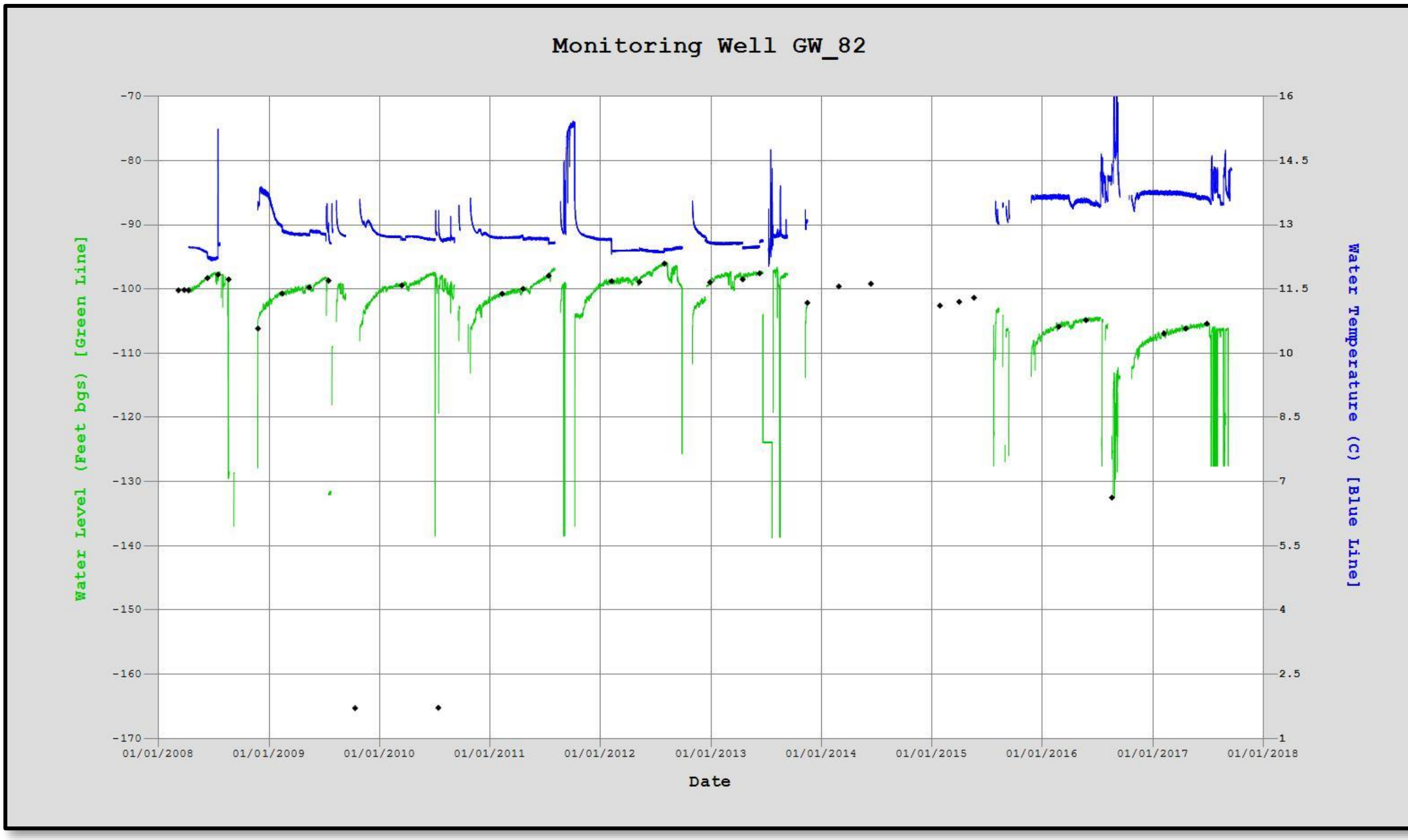


Figure 22. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_82 from 2008-2018. This monitoring was funded by Bonneville Power Administration and Washington Department of Ecology.

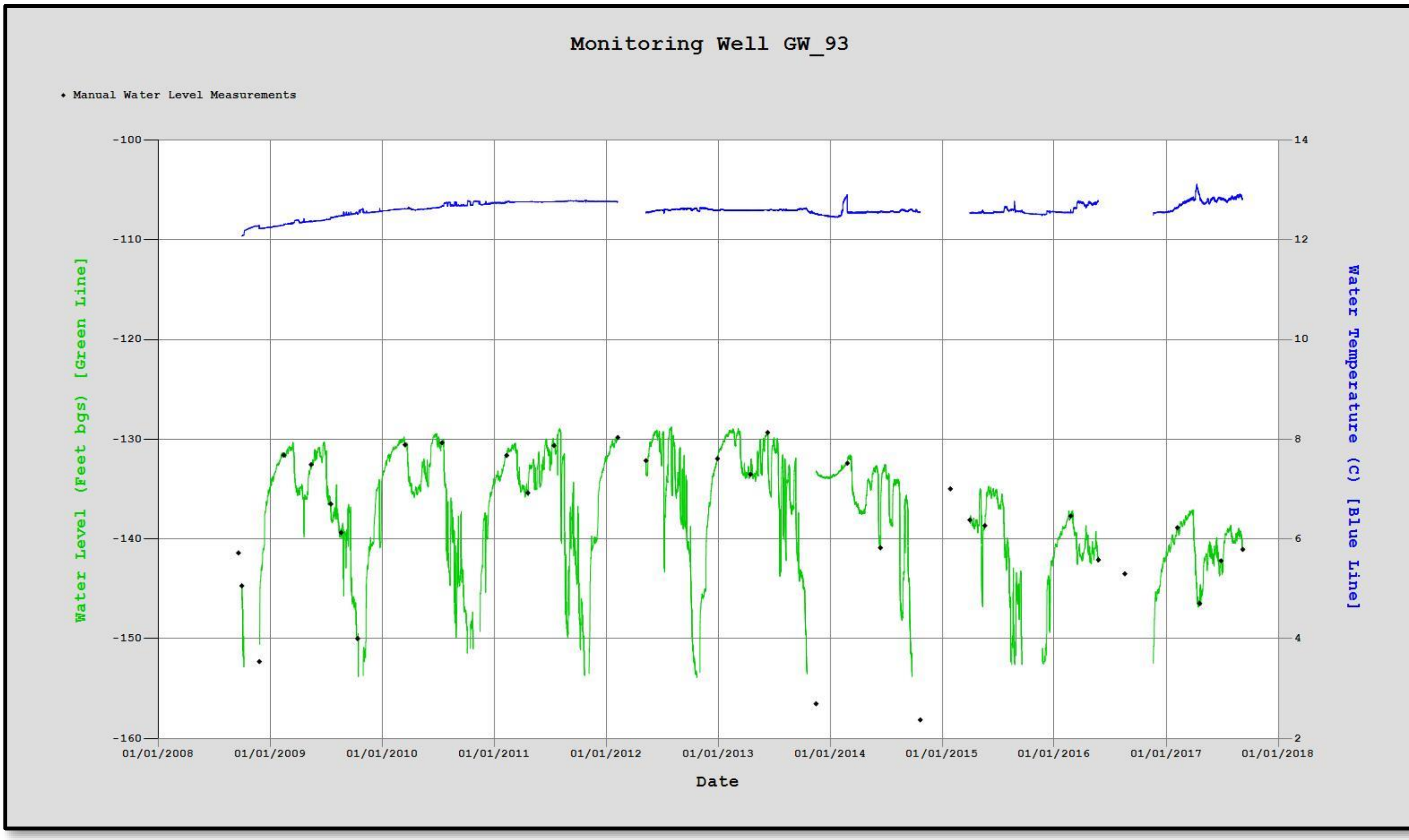


Figure 23. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_93 from 2008-2018. This monitoring was funded by Bonneville Power Administration and Washington Department of Ecology.

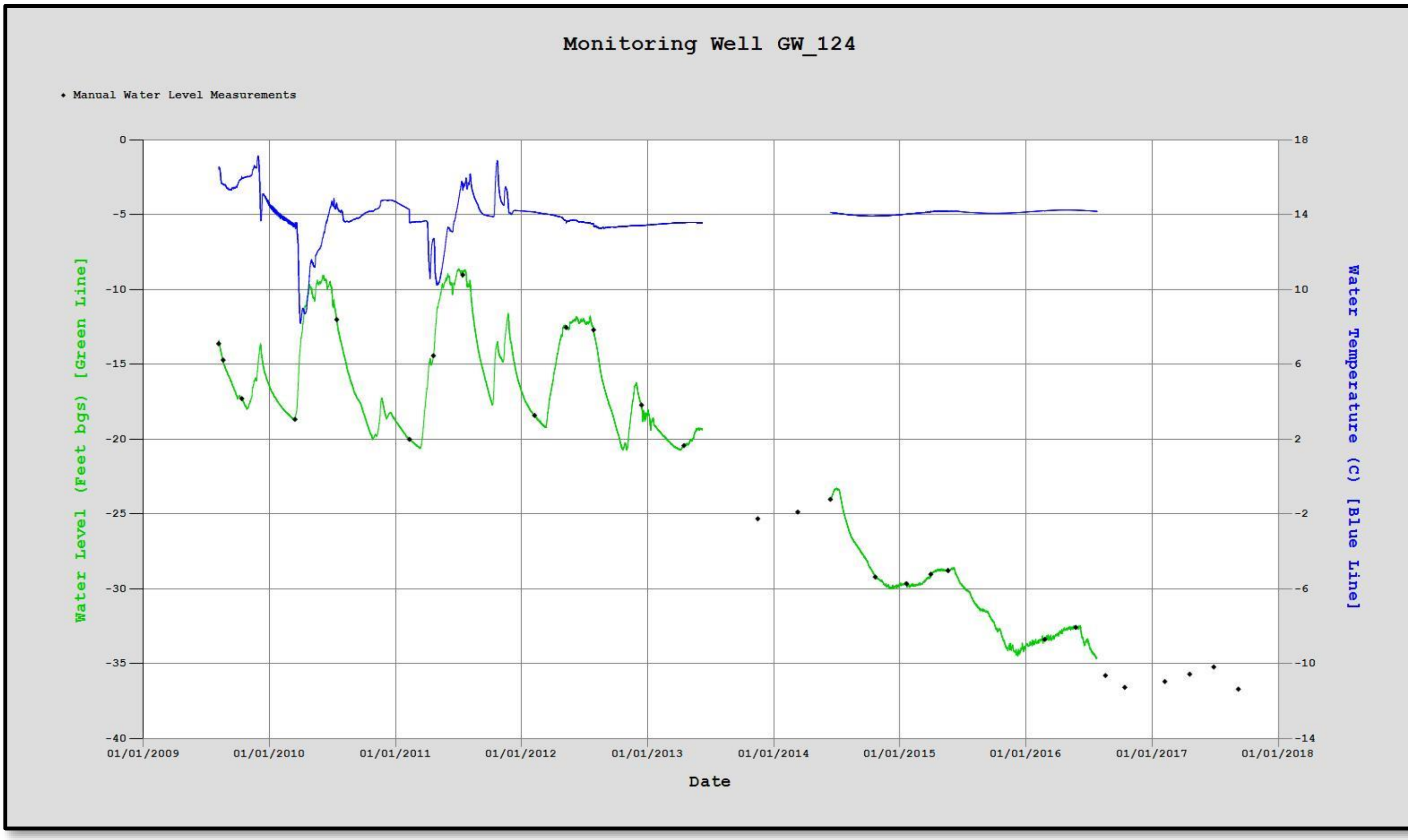


Figure 24. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_124 from 2009-2018. This monitoring was funded by Bonneville Power Administration and Washington Department of Ecology.

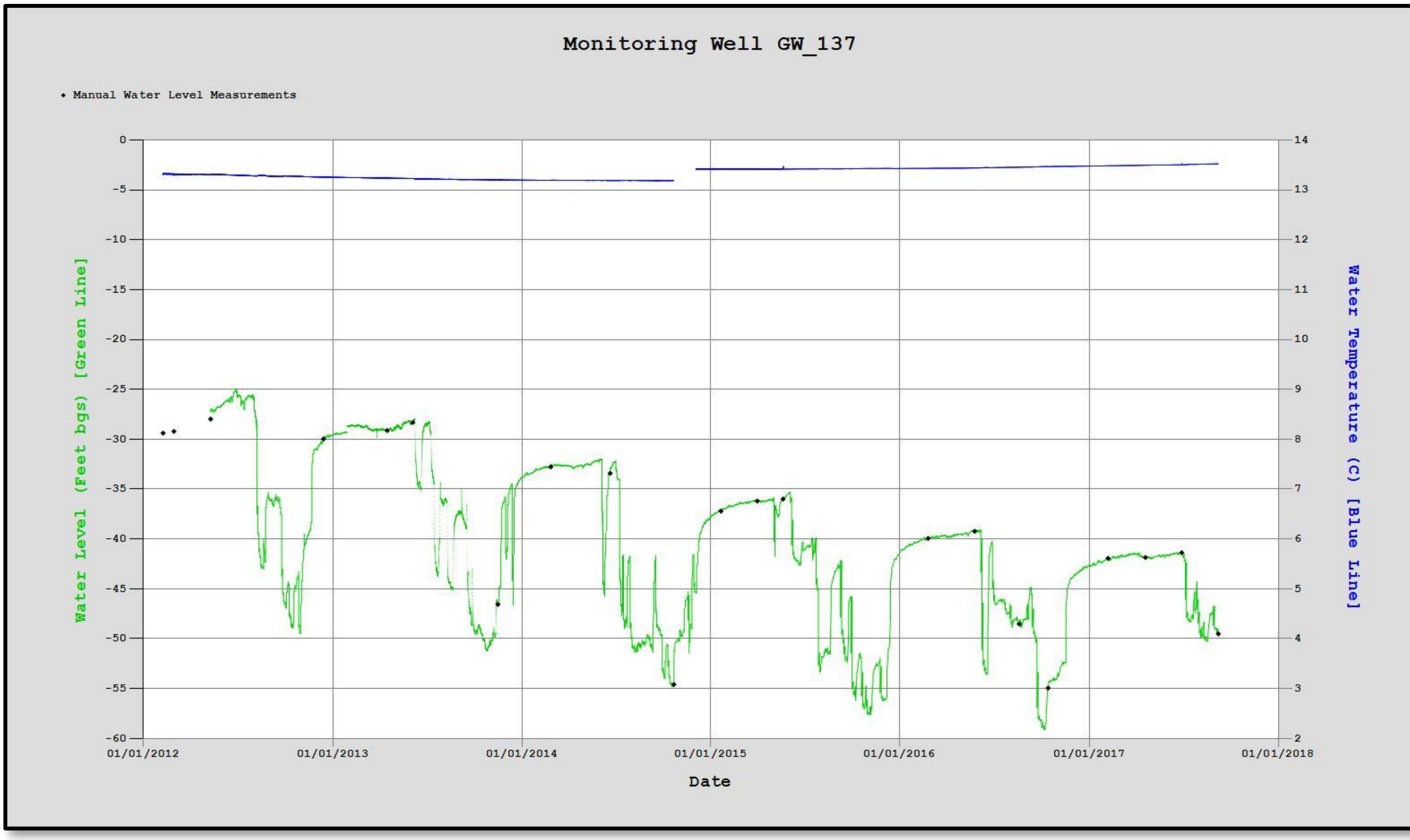


Figure 25. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_137 from 2012-2018. This monitoring was funded by Bonneville Power Administration and Washington Department of Ecology.

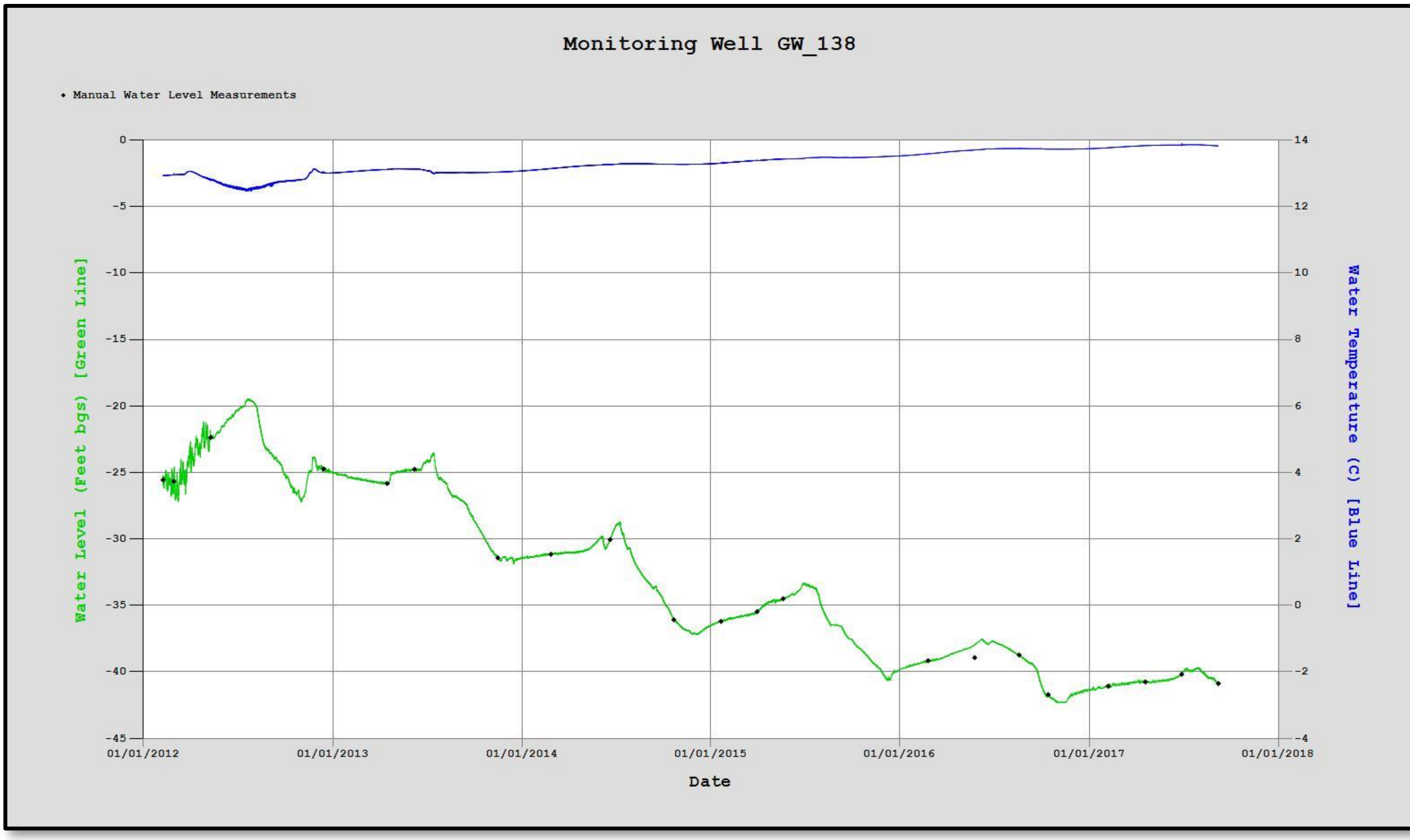


Figure 26. Manual water level measurements (black diamonds) and pressure transducer data (green line) in feet below ground surface for the well GW_138 from 2012-2018. This monitoring was funded by Bonneville Power Administration and Washington Department of Ecology.

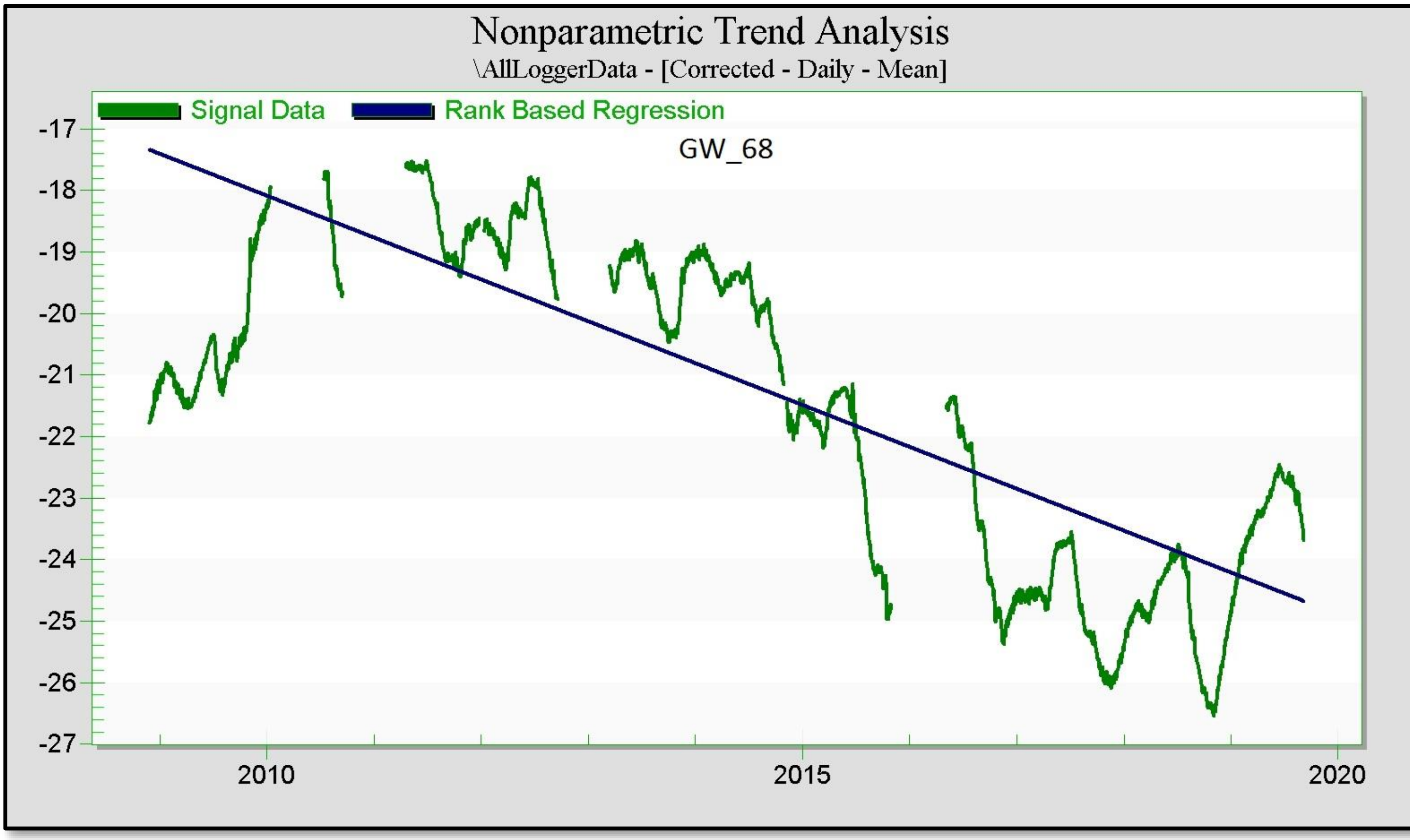


Figure 27. Pressure transducer data (green line) in feet below ground surface for the well GW_68 located in the WWBWC's Shallow Aquifer Monitoring Network. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

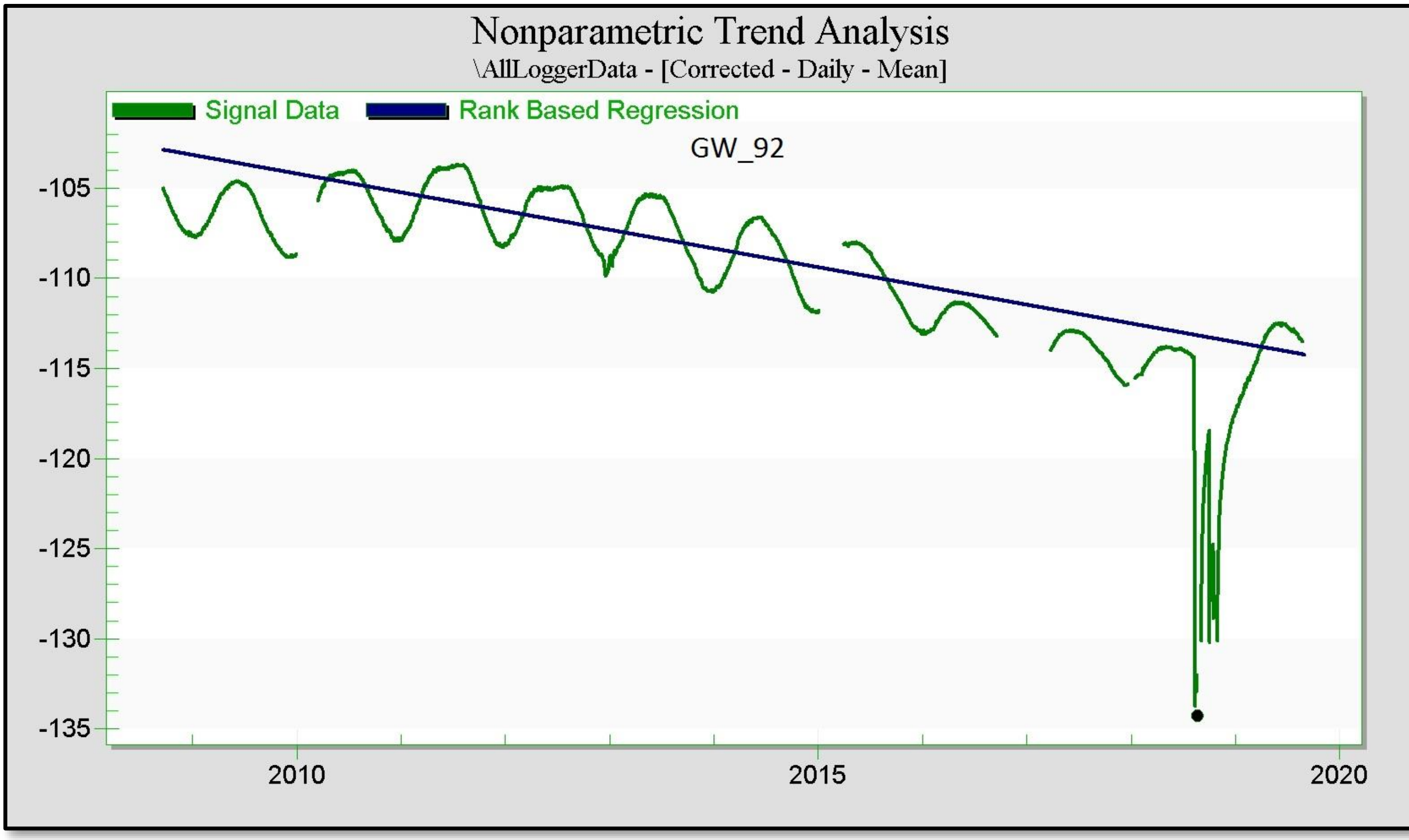


Figure 28. Pressure transducer data (green line) in feet below ground surface for the well GW_92 located in the WWBWC's Shallow Aquifer Monitoring Network. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

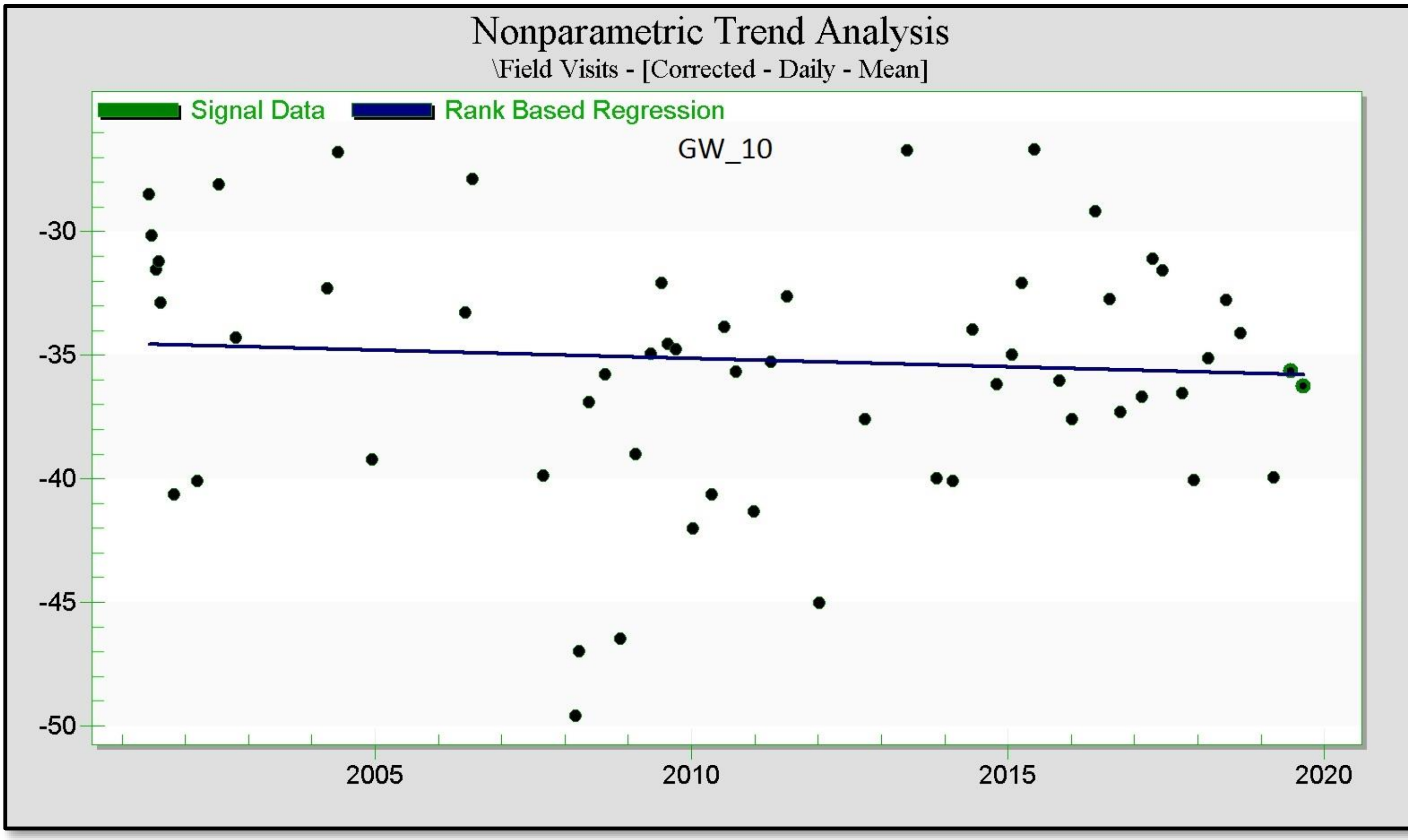


Figure 29. Manual water level measurements (green dots) in feet below ground surface for the historic well GW_10 located in the WWBWC's Shallow Aquifer Monitoring Network. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

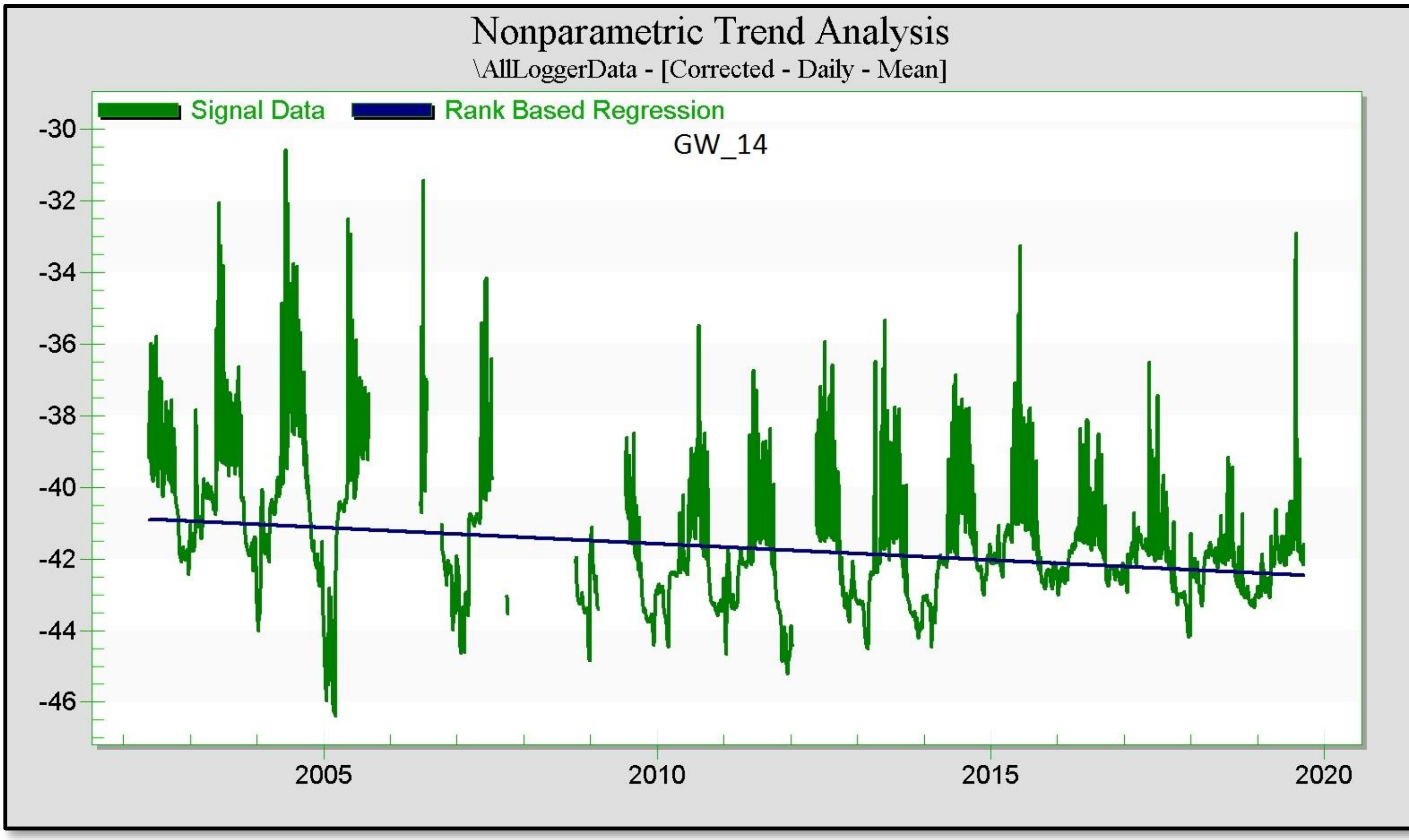


Figure 30. Pressure transducer data (green line) in feet below ground surface for the well GW_14 located in the WWBWC's Shallow Aquifer Monitoring Network. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

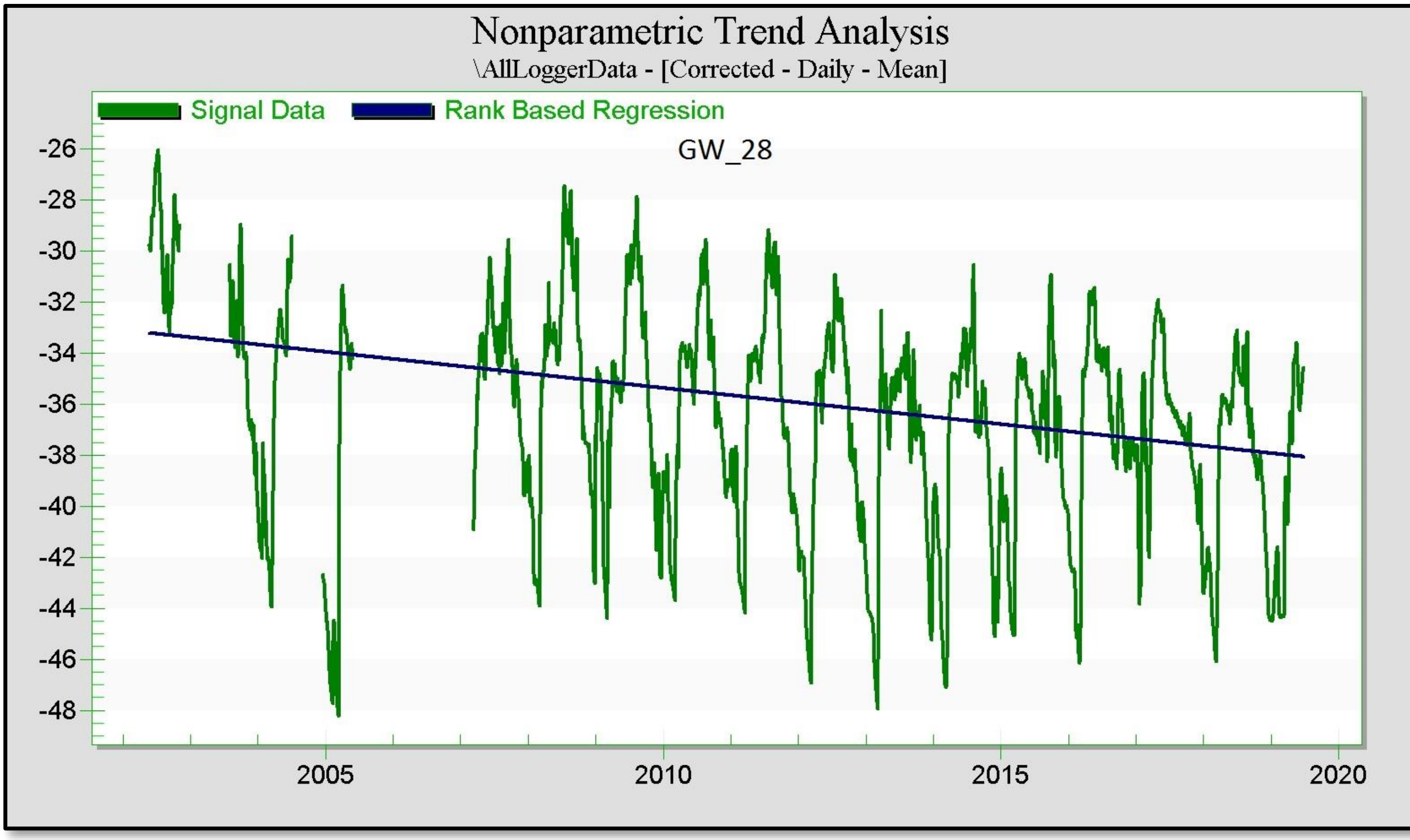


Figure 31. Pressure transducer data (green line) in feet below ground surface for the well GW_28 located in the WWBWC's Shallow Aquifer Monitoring Network. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

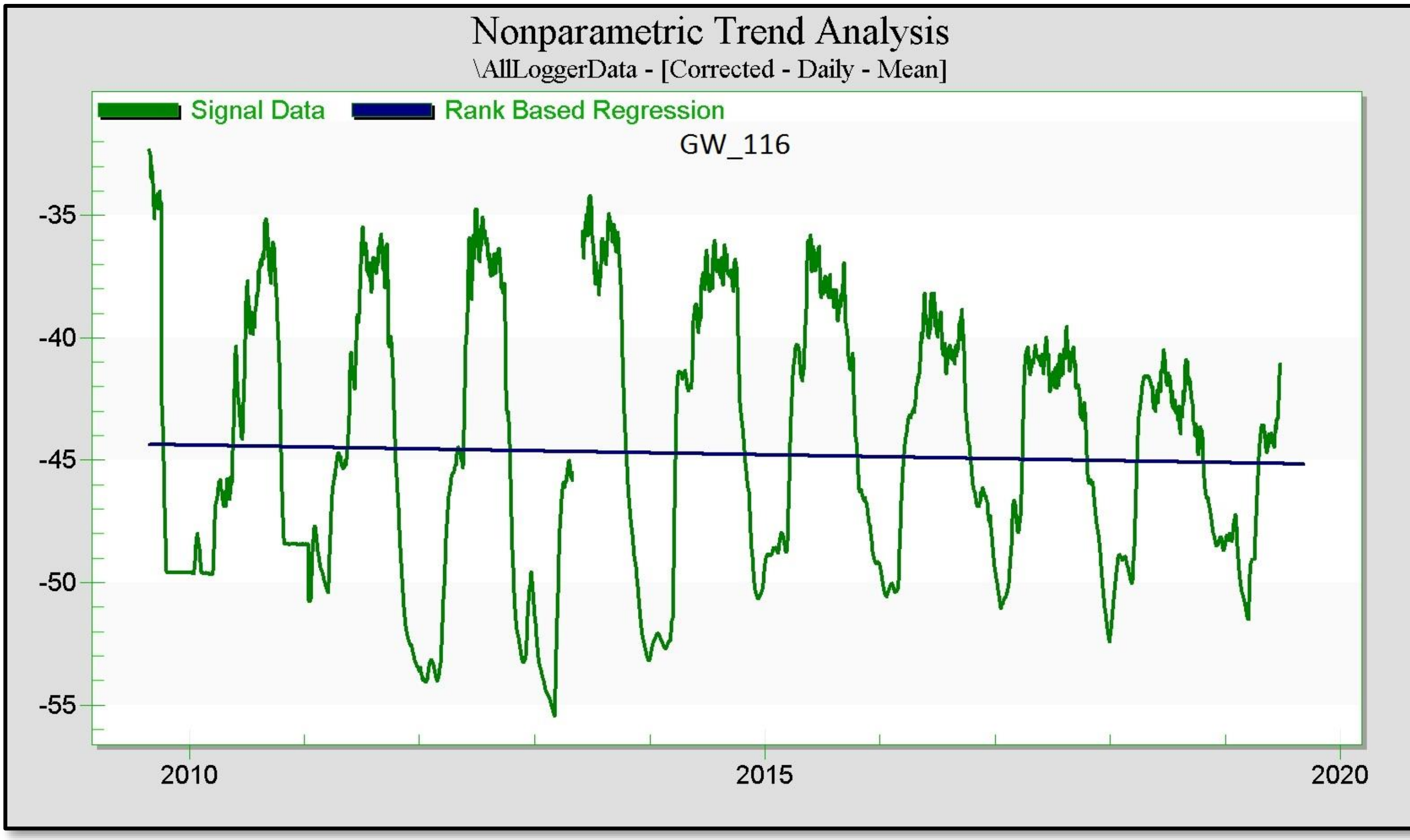


Figure 32. Pressure transducer data (green line) in feet below ground surface for the well GW_116 located in the WWBWC's Shallow Aquifer Monitoring Network. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

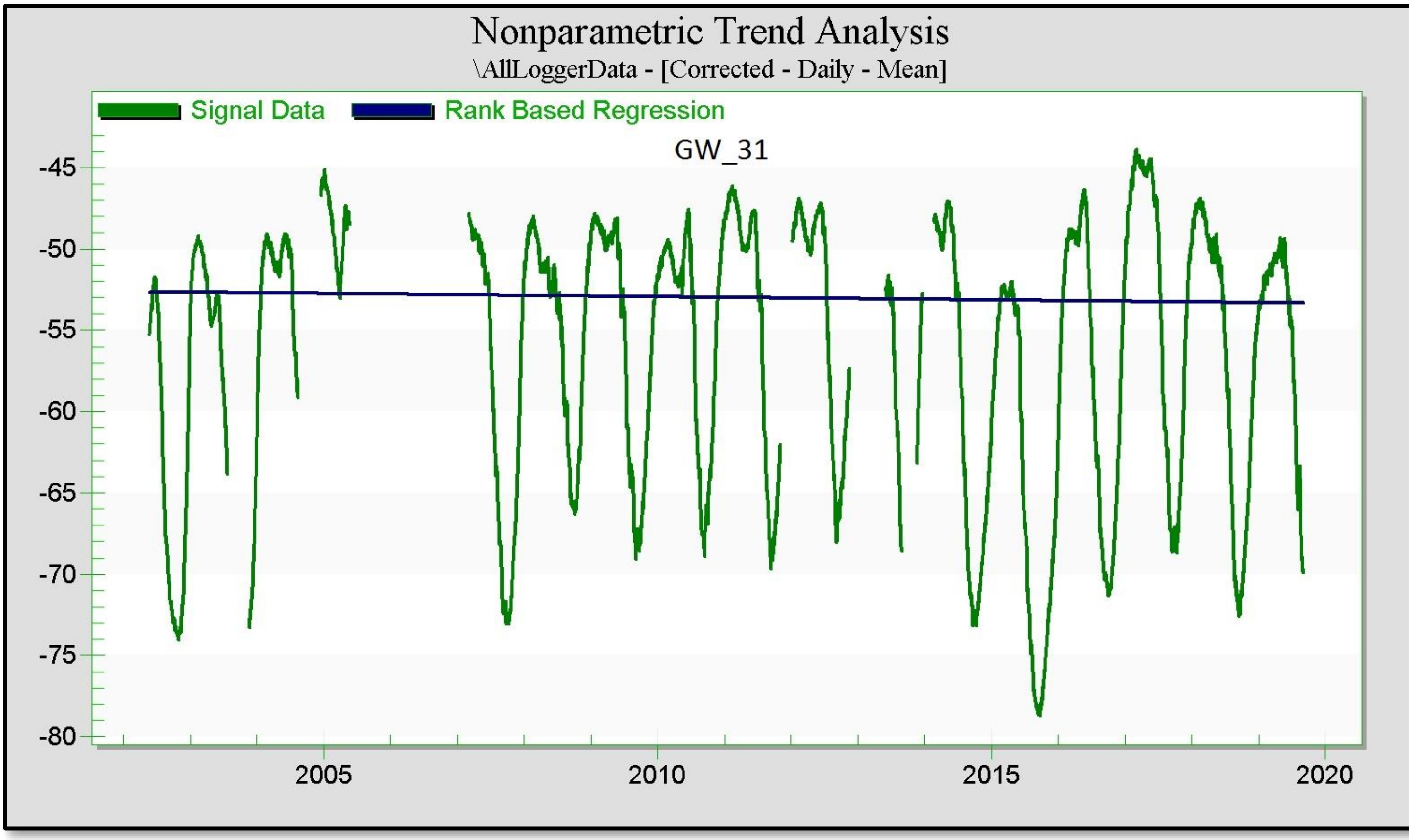


Figure 33. Pressure transducer data (green line) in feet below ground surface for the well GW_31 located in the WWBWC's Shallow Aquifer Monitoring Network. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

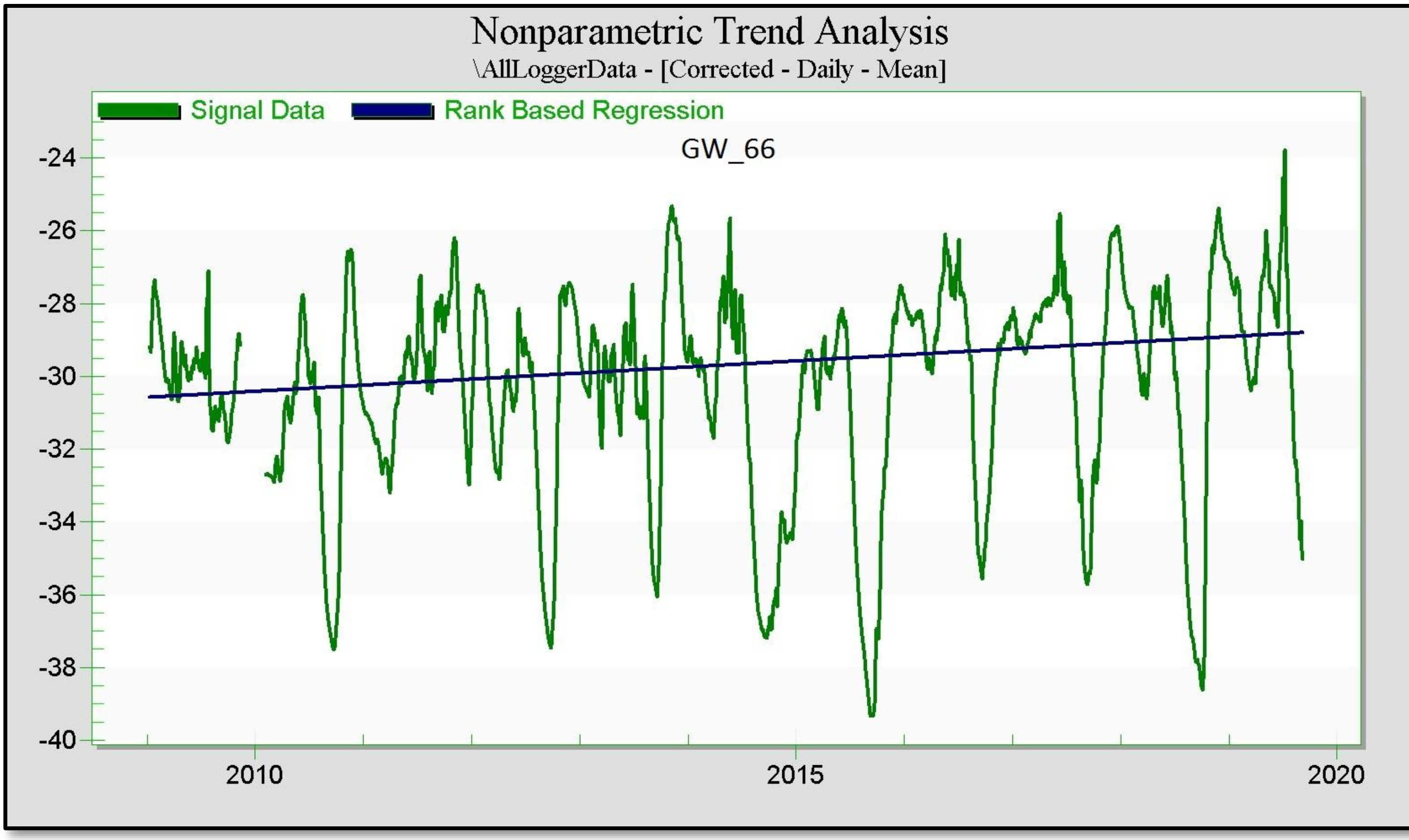


Figure 34. Pressure transducer data (green line) in feet below ground surface for the well GW_66 located in the WWBWC's Shallow Aquifer Monitoring Network. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

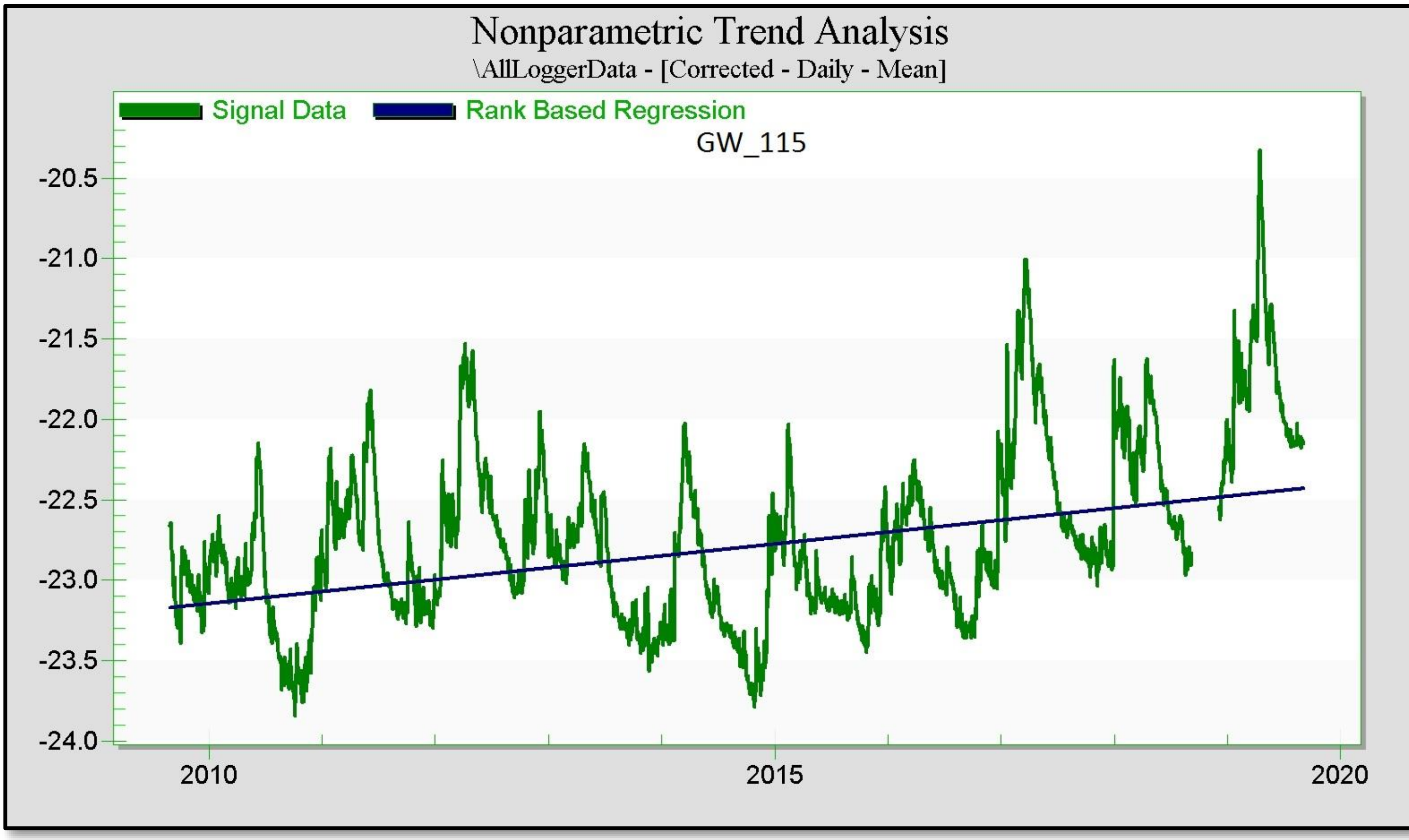


Figure 35. Pressure transducer data (green line) in feet below ground surface for the well GW_115 located in the WWBWC's Shallow Aquifer Monitoring Network. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

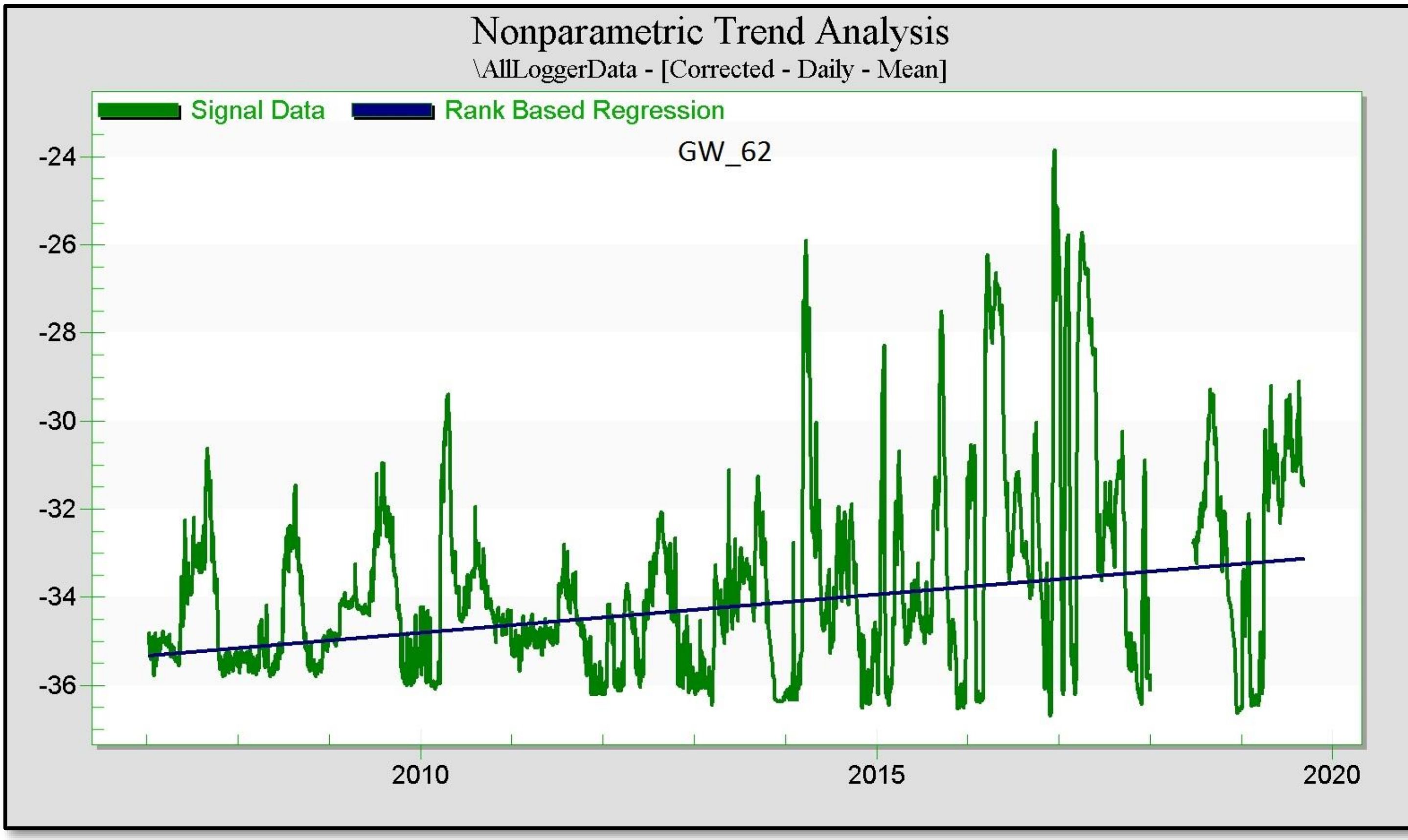


Figure 36. Pressure transducer data (green line) in feet below ground surface for the well GW_62 located near the Anspach aquifer recharge site. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

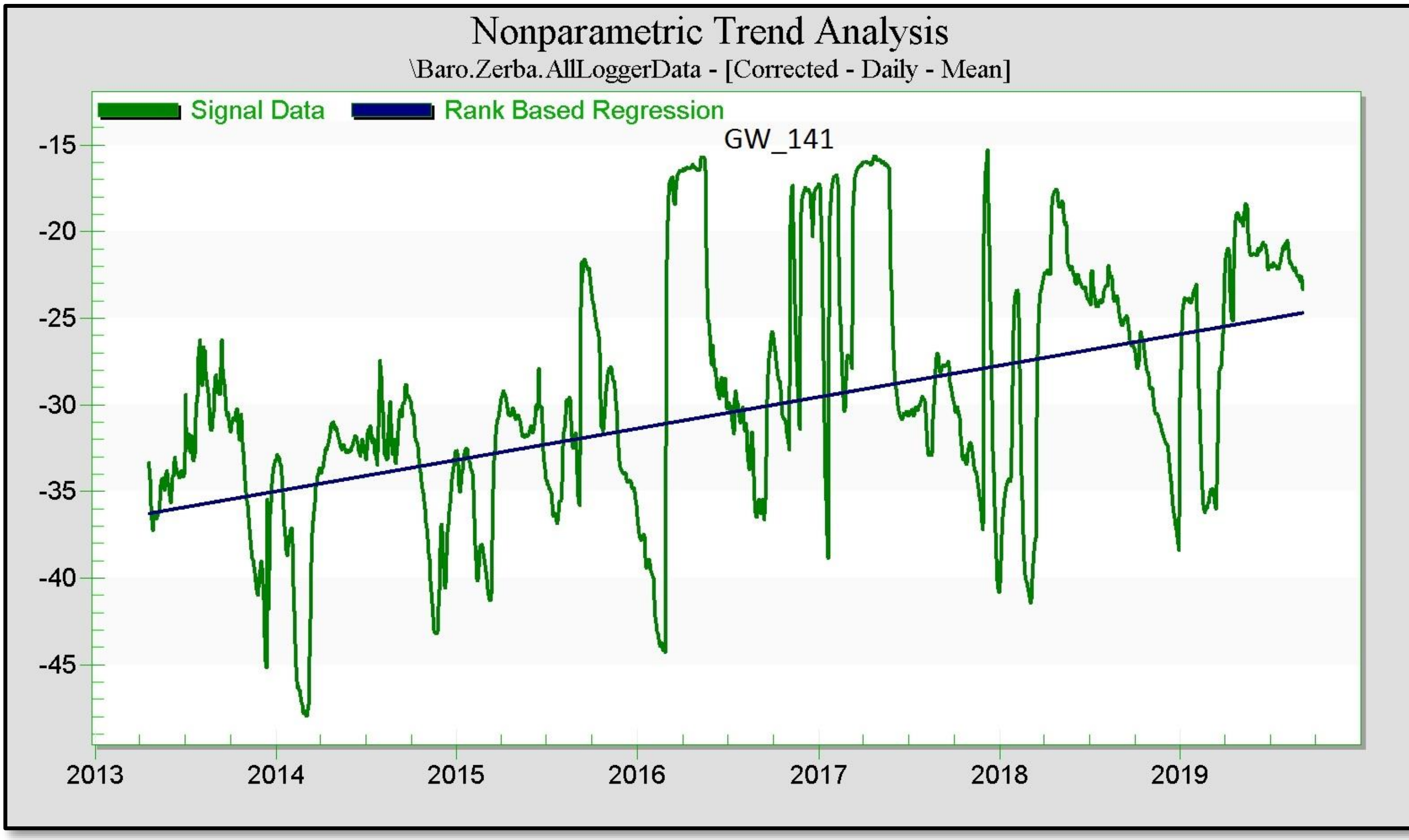


Figure 37. Pressure transducer data (green line) in feet below ground surface for the well GW_141 located near the Anspach aquifer recharge site. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

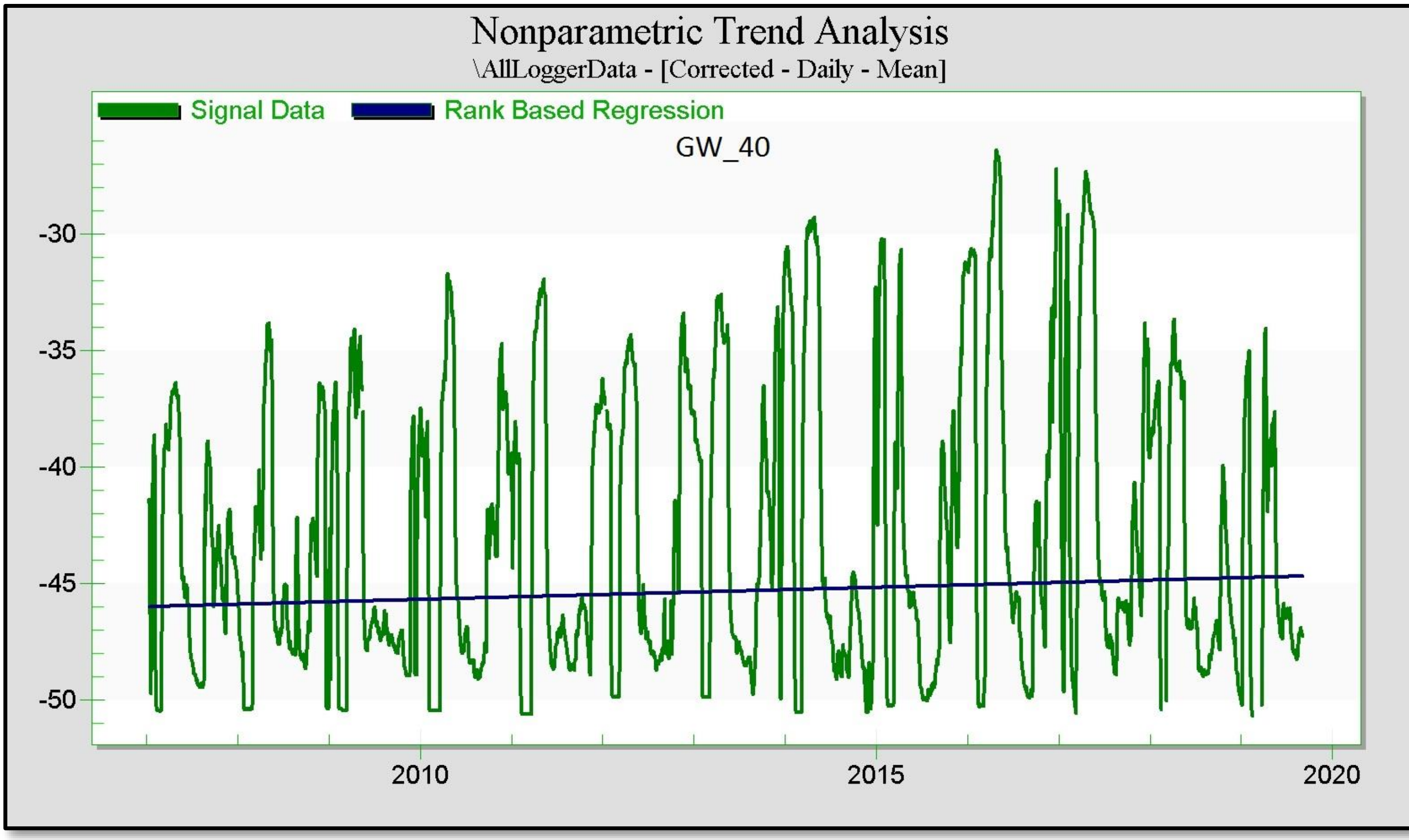


Figure 38. Pressure transducer data (green line) in feet below ground surface for the well GW_40 located near the Johnson aquifer recharge site. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

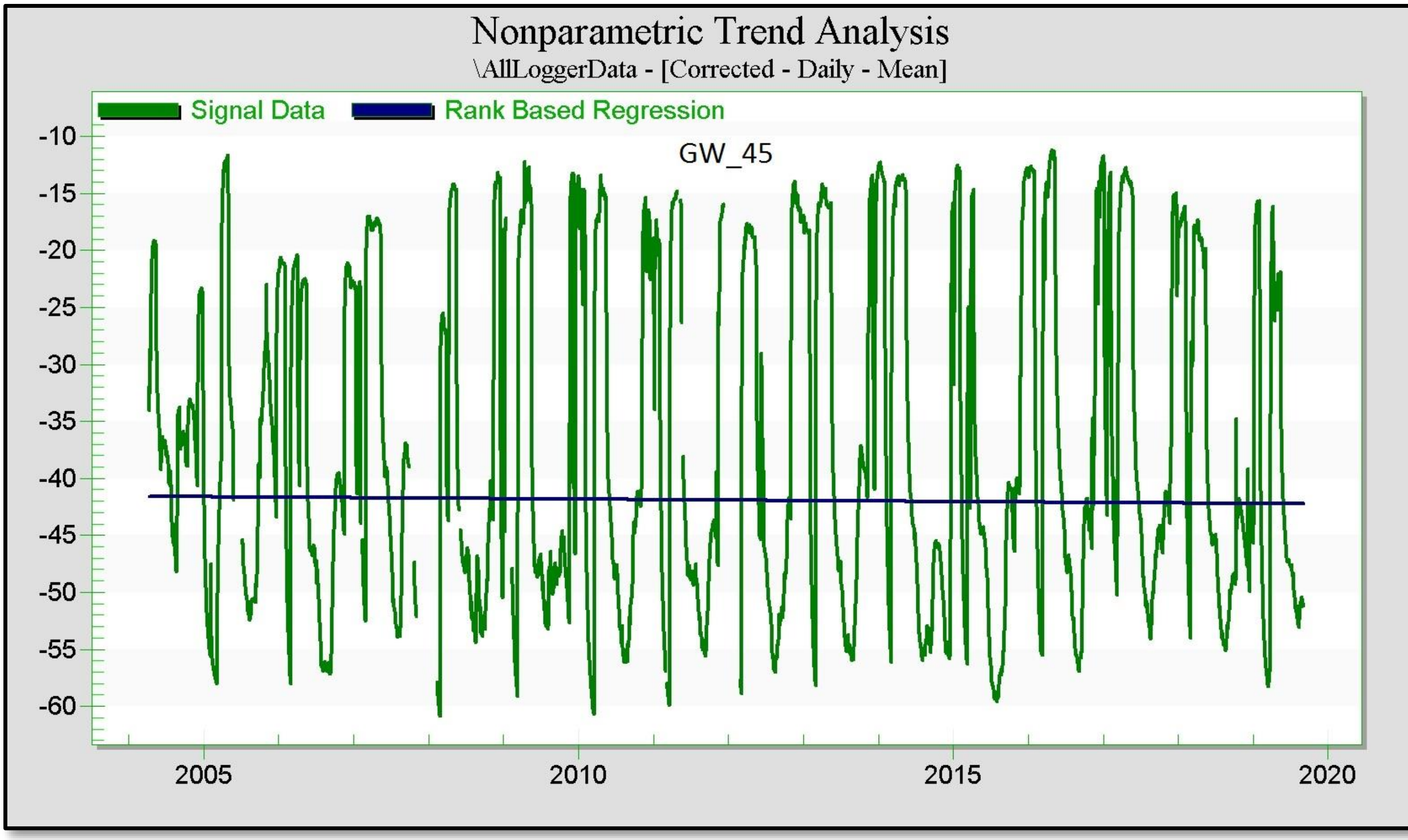


Figure 39. Pressure transducer data (green line) in feet below ground surface for the well GW_45 located at the Johnson aquifer recharge site. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

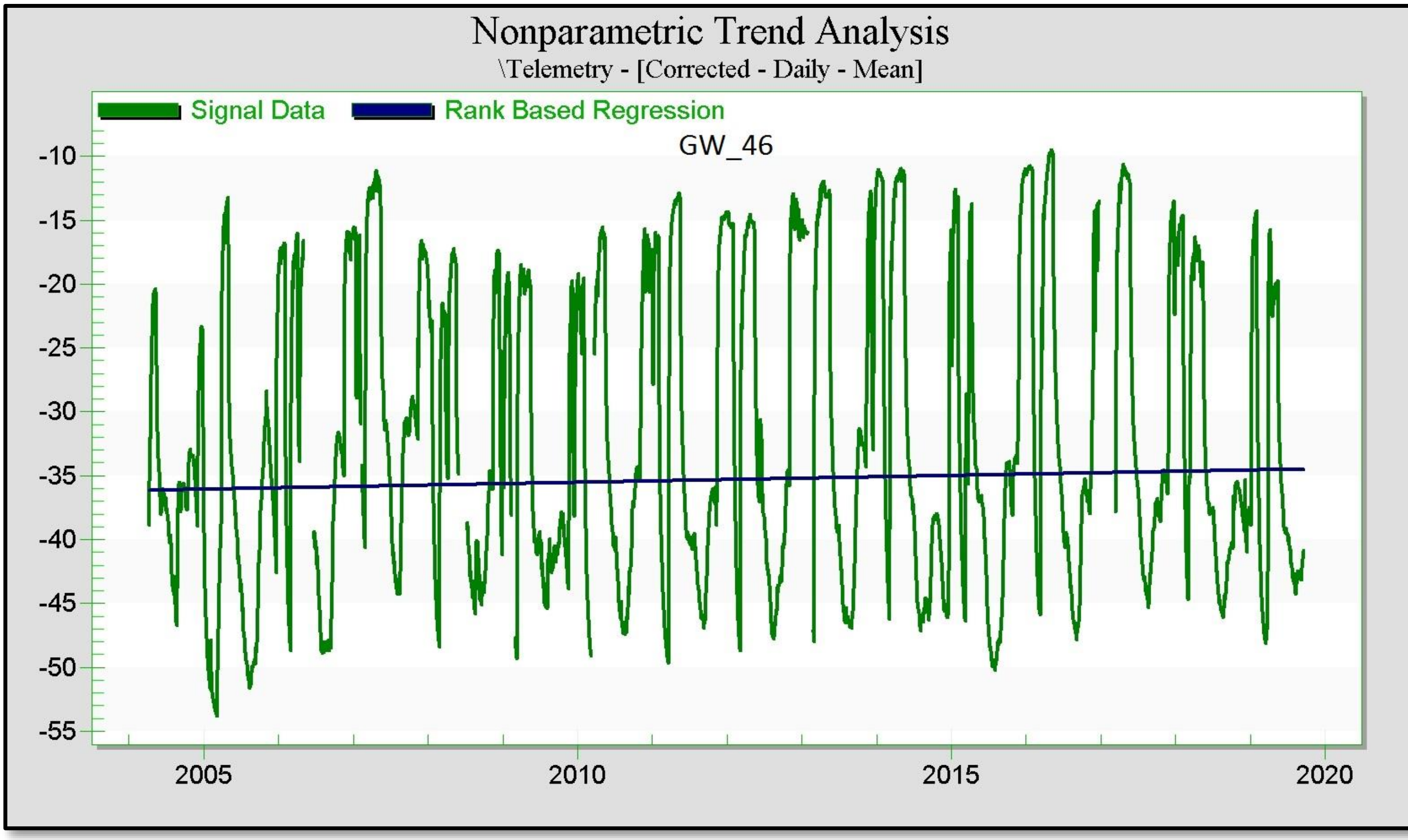


Figure 40. Pressure transducer data (green line) in feet below ground surface for the well GW_46 located at the Johnson aquifer recharge site. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

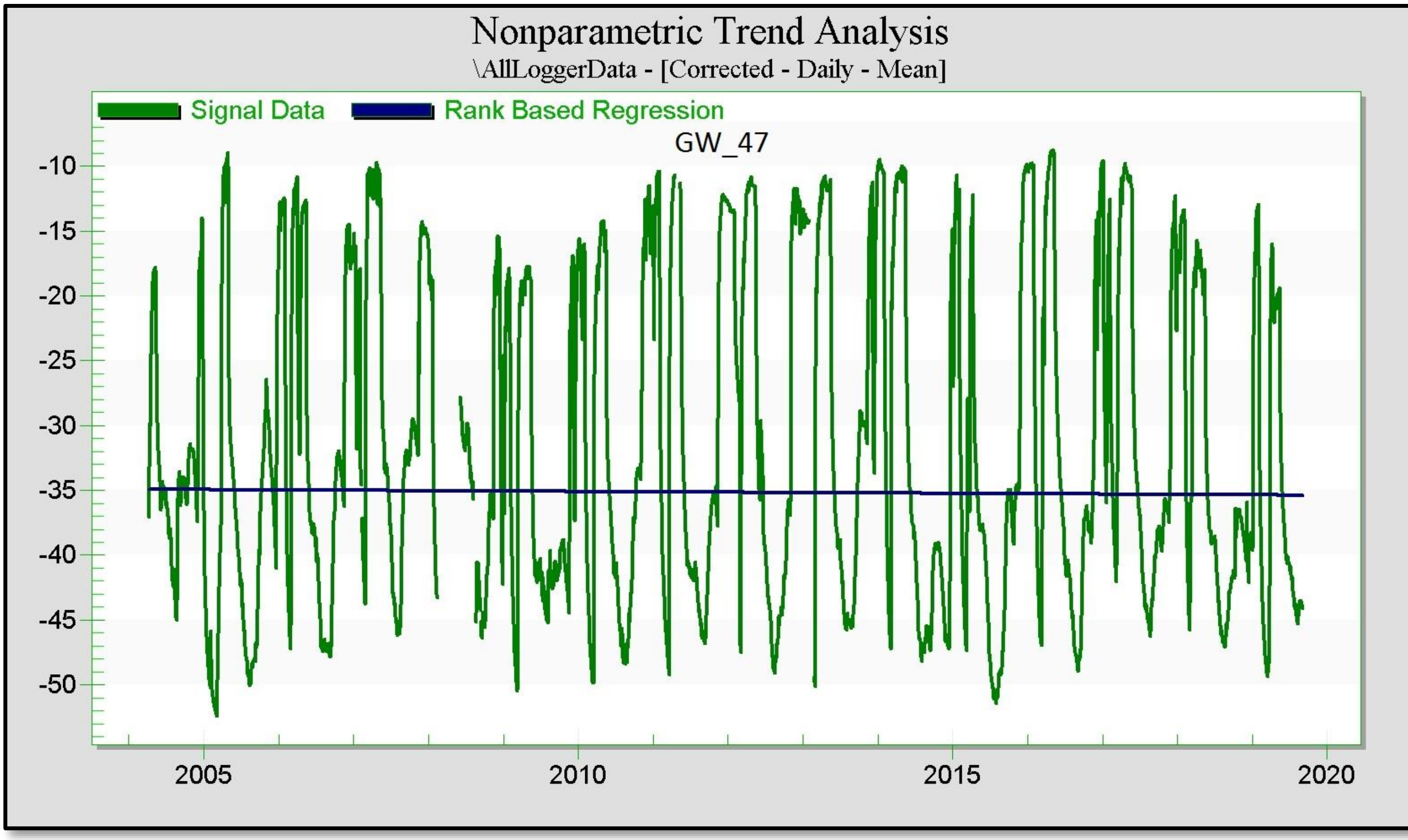


Figure 41. Pressure transducer data (green line) in feet below ground surface for the well GW_47 located near the Johnson aquifer recharge site. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

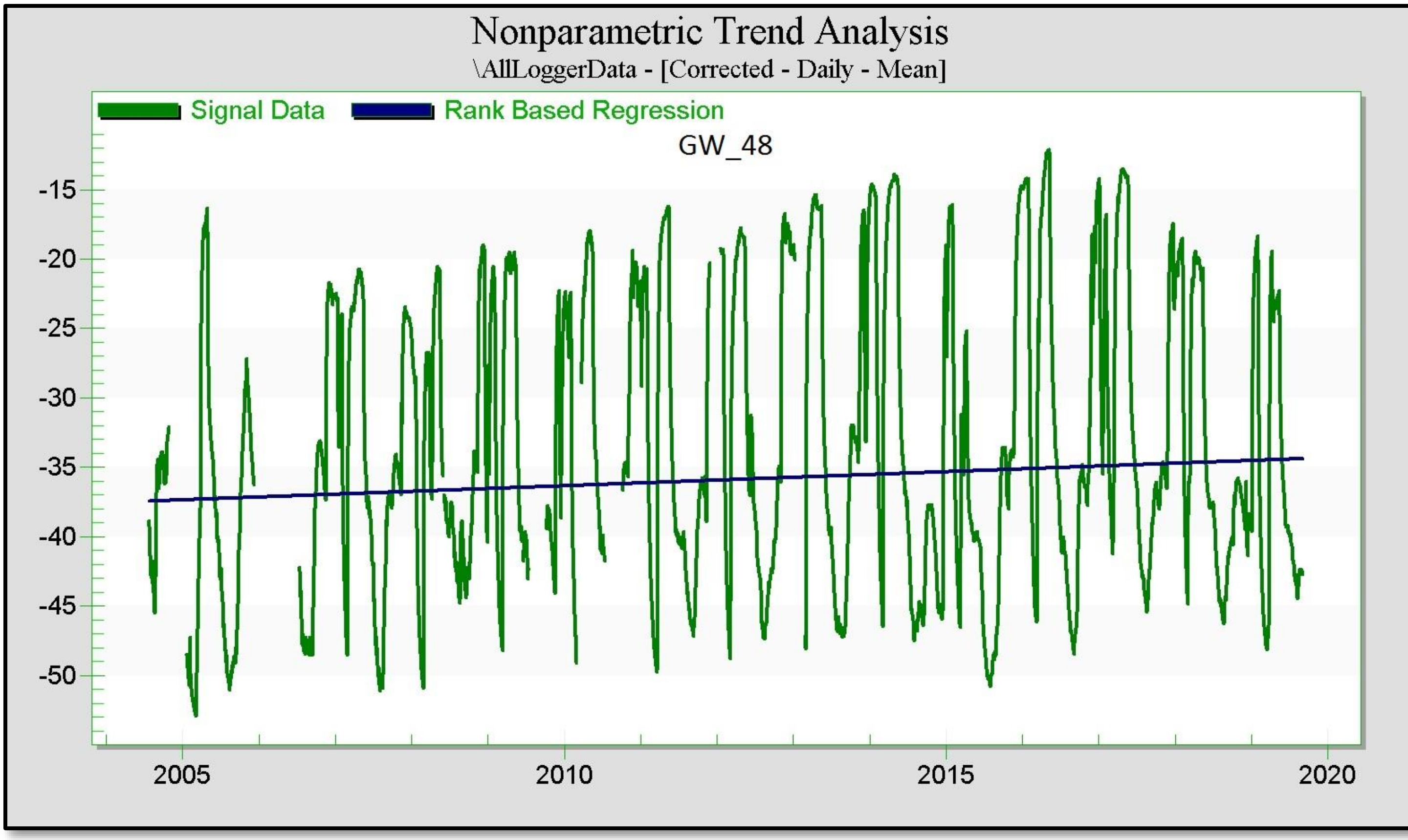


Figure 42. Pressure transducer data (green line) in feet below ground surface for the well GW_48 located near the Johnson aquifer recharge site. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

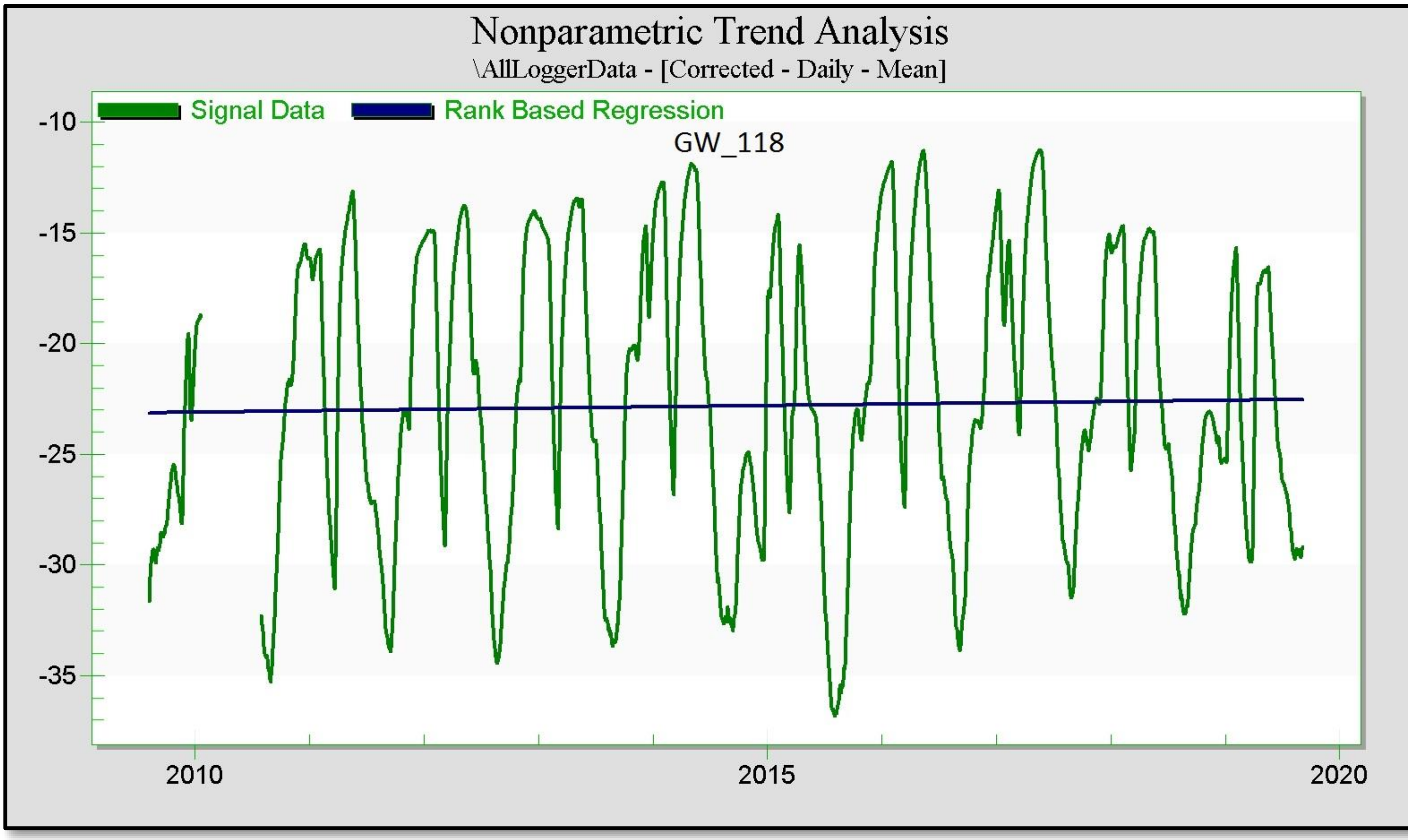


Figure 43. Pressure transducer data (green line) in feet below ground surface for the well GW_118 located near the Johnson aquifer recharge site. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

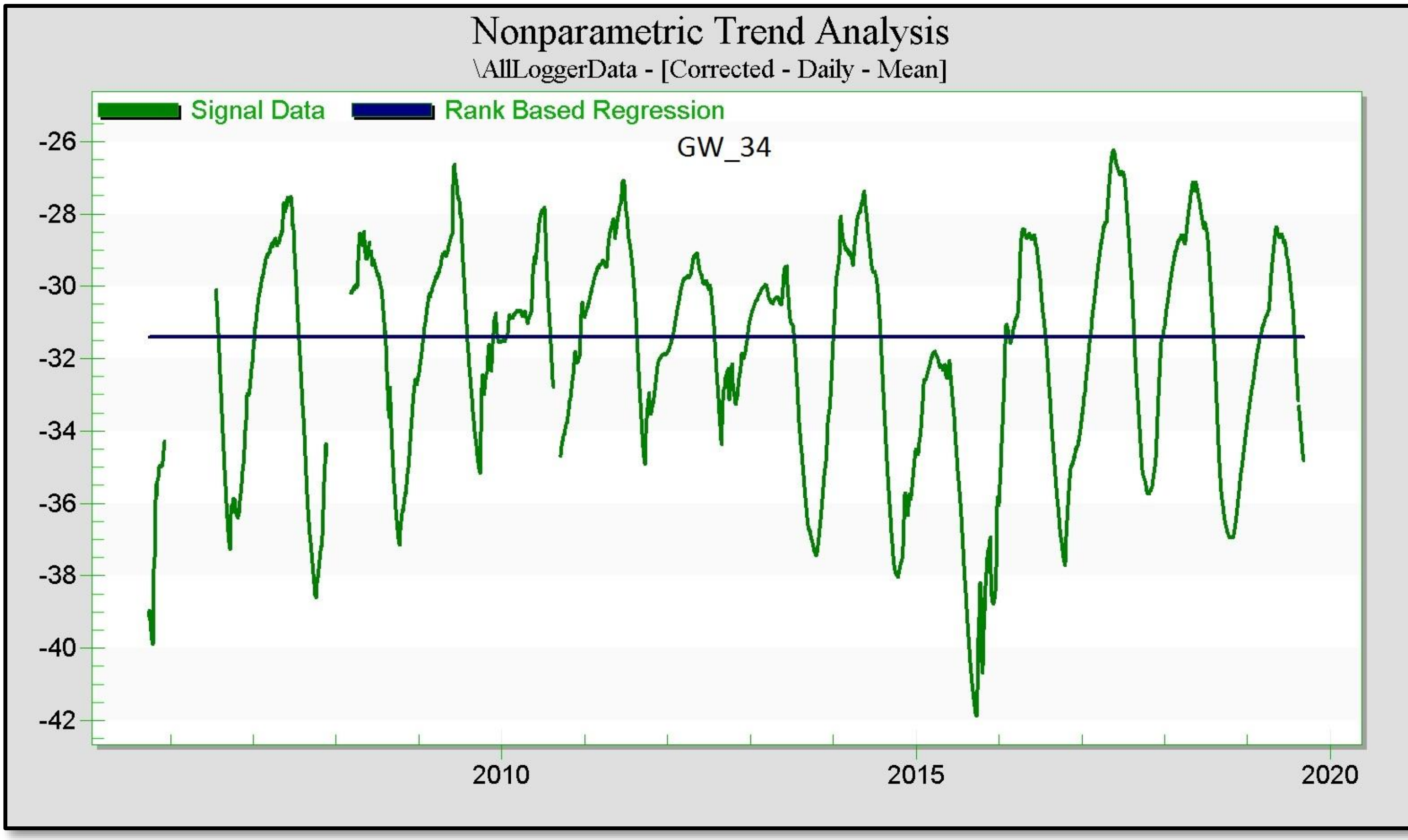


Figure 44. Pressure transducer data (green line) in feet below ground surface for the well GW_34 located near the Northwest Umapine aquifer recharge site. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

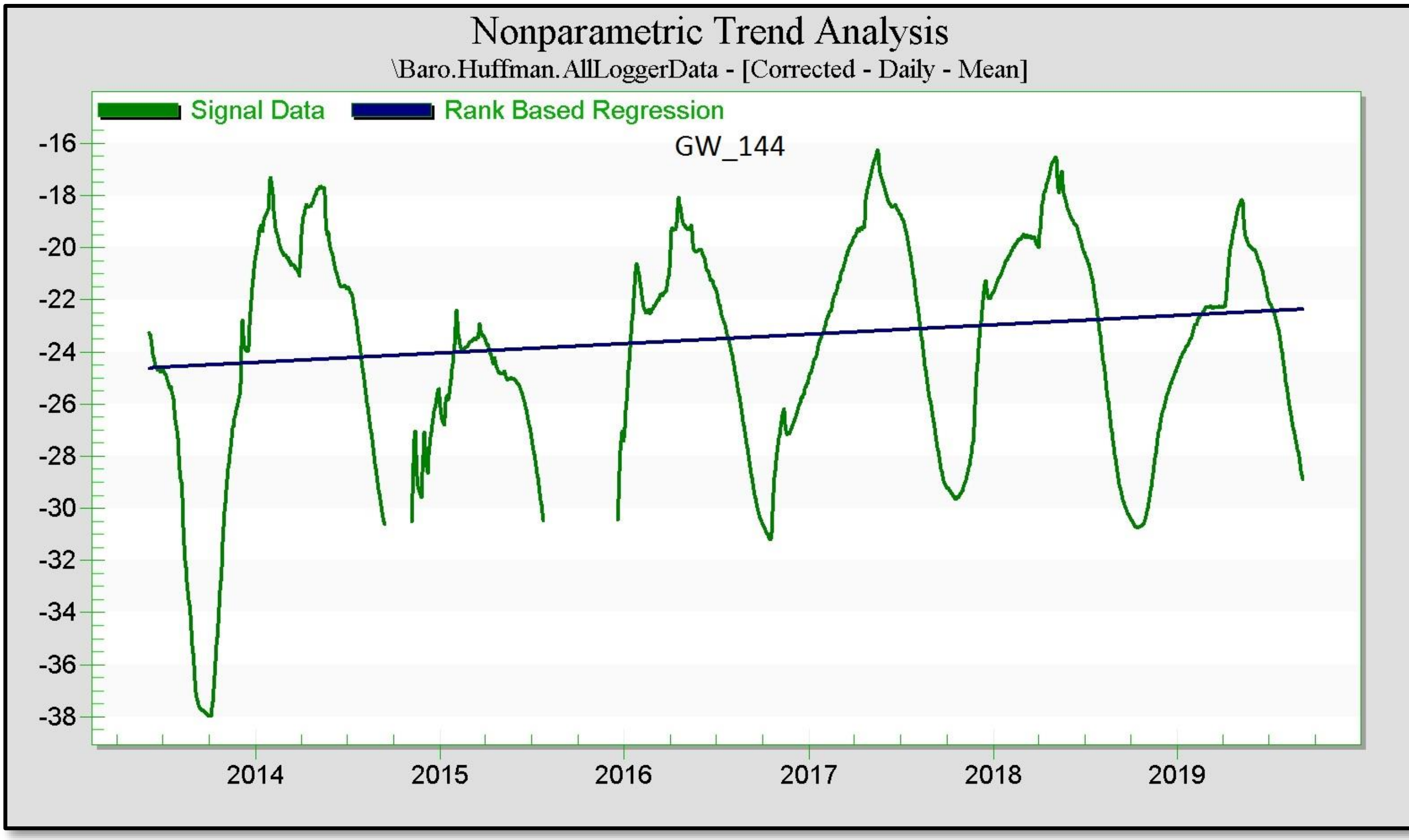


Figure 45. Pressure transducer data (green line) in feet below ground surface for the well GW_144 located near the Northwest Umapine aquifer recharge site. This is a Mann-Kendall (M-K) Nonparametric trend analysis.

## APPENDIX B

### GPS coordinates for wells currently monitored in the Walla Walla Basin Shallow Aquifer.

Note: GPS coordinates are in UTM (Datum = NAD83 and NAVD88 for Elevation)

| WELL_ID | Easting | Northing | Well Elevation in Meters | Well Elevation in Feet | Horizontal Confidence in Meters | Vertical Confidence in Meters |
|---|---|---|---|---|---|---|
| GW_03 | 393477.08 | 5091165.361 | 273.745 | 898.114 | 0.016 | 0.012 |
| GW_05 | 393764.617 | 5094403.253 | 248.064 | 813.920 | 0.022 | 0.015 |
| GW_06 | 392664.181 | 5092403.474 | 262.960 | 867.425 | 0.015 | 0.011 |
| GW_07 | 392787.583 | 5091551.116 | 271.717 | 891.460 | 0.012 | 0.012 |
| GW_09 | 392658.605 | 5088806.697 | 306.631 | 1006.007 | 0.014 | 0.01 |
| GW_10 | 392132.402 | 5091372.824 | 273.696 | 897.950 | 0.022 | 0.019 |
| GW_13 | 390667.86 | 5093232.622 | 250.852 | 823.004 | 0.013 | 0.015 |
| GW_14 | 392157.683 | 5089568.006 | 295.488 | 969.449 | 0.012 | 0.009 |
| GW_15 | 388945.465 | 5089304.752 | 272.057 | 892.575 | 0.003 | 0.003 |
| GW_18 | 386647.989 | 5093698.759 | 225.360 | 739.367 | 0.005 | 0.006 |
| GW_19 | 391225.116 | 5092022.761 | 265.289 | 870.369 | 0.014 | 0.018 |
| GW_20 | 393114.775 | 5092400.73 | 264.392 | 867.428 | 0.096 | 0.101 |
| GW_23 | 390432.546 | 5088757.822 | 292.342 | 959.125 | 0.006 | 0.007 |
| GW_27 | 391245.146 | 5088811.531 | 298.777 | 980.239 | 0.008 | 0.009 |
| GW_28 | 390083.217 | 5090403.42 | 274.565 | 900.803 | 0.005 | 0.004 |
| GW_31 | 385163.051 | 5093209.972 | 218.535 | 716.976 | 0.006 | 0.007 |
| GW_33 | 387947.465 | 5093853.935 | 230.034 | 754.702 | 0.008 | 0.006 |
| GW_34 | 383288.818 | 5093418.243 | 201.734 | 661.855 | 0.011 | 0.008 |
| GW_36 | 384946.272 | 5091616.019 | 220.534 | 723.534 | 0.01 | 0.012 |
| GW_37 | 384227.715 | 5092519.703 | 208.416 | 683.780 | 0.008 | 0.01 |
| GW_38 | 392985.262 | 5094932.606 | 248.083 | 812.122 | 0.021 | 0.014 |
| GW_39 | 388823.228 | 5090045.31 | 266.394 | 873.993 | 0.004 | 0.002 |
| GW_40 | 388846.149 | 5089945.789 | 266.979 | 875.913 | 0.004 | 0.002 |
| GW_41 | 388830.34 | 5090133.816 | 265.537 | 871.182 | 0.004 | 0.002 |
| GW_45 | 388555.543 | 5090167.255 | 262.553 | 861.394 | 0.003 | 0.003 |
| GW_46 | 388325.733 | 5090362.964 | 259.118 | 850.123 | 0.004 | 0.002 |
| GW_47 | 388335.675 | 5090331.38 | 259.507 | 851.400 | 0.003 | 0.002 |
| GW_48 | 388432.429 | 5090413.757 | 259.608 | 851.732 | 0.004 | 0.002 |
| GW_58 | 387261.534 | 5091269.173 | 245.655 | 805.953 | 0.005 | 0.004 |
| GW_60 | 388039.791 | 5090041.577 | 257.473 | 844.726 | 0.003 | 0.003 |
| GW_61 | 387730.609 | 5089747.583 | 255.862 | 839.440 | 0.003 | 0.003 |
| GW_62 | 389834.806 | 5089059.234 | 283.305 | 929.478 | 0.006 | 0.004 |
| GW_63 | 383280.245 | 5091893.17 | 203.980 | 669.226 | 0.014 | 0.01 |
| GW_64 | 383657.595 | 5091641.274 | 208.550 | 684.218 | 0.011 | 0.013 |
| GW_65 | 387239.855 | 5090936.276 | 246.133 | 807.520 | 0.005 | 0.003 |
| GW_66 | 384016.598 | 5091700.048 | 209.851 | 688.485 | 0.014 | 0.01 |
| GW_67 | 378968.413 | 5093403.081 | 175.056 | 574.330 | 0.019 | 0.02 |

| | | | | | | |
|---|---|---|---|---|---|---|
| GW_68 | 379255.547 | 5092242.311 | 181.305 | 594.831 | 0.022 | 0.018 |
| GW_69 | 383991.427 | 5091254.854 | 212.394 | 696.829 | 0.013 | 0.013 |
| GW_73 | 390621.47 | 5095033.16 | 232.761 | 763.651 | | |
| GW_74 | 390649.10 | 5094642.92 | 234.943 | 770.811 | | |
| GW_75 | 390474.91 | 5095093.45 | 230.702 | 756.897 | | |
| GW_92 | 372892.083 | 5095185.179 | 170.620 | 559.775 | 0.017 | 0.016 |
| GW_98 | 388276.158 | 5089528.166 | 263.425 | 864.255 | 0.021 | 0.014 |
| GW_115 | 392743.234 | 5086919.977 | 326.984 | 1072.780 | 0.072 | 0.106 |
| GW_116 | 391304.129 | 5091322.097 | 272.050 | 892.550 | 0.022 | 0.015 |
| GW_117 | 389825.547 | 5090864.475 | 268.409 | 880.607 | 0.004 | 0.004 |
| GW_118 | 387655.395 | 5090858.899 | 250.210 | 820.898 | 0.004 | 0.003 |
| GW_119 | 384949.15 | 5092104.046 | 217.173 | 712.508 | 0.01 | 0.011 |
| GW_120 | 380094.16 | 5094289.865 | 172.605 | 566.289 | 0.019 | 0.013 |
| GW_135 | 390848.356 | 5088932.953 | 294.177 | 965.146 | 0.01 | 0.01 |
| GW_140 | 388116.677 | 5092574.411 | 243.582 | 799.154 | 0.006 | 0.007 |
| GW_141 | 390842.948 | 5088970.697 | 293.484 | 962.874 | 0.011 | 0.01 |
| GW_142 | 388923.795 | 5091216.075 | 258.721 | 848.822 | 0.003 | 0.003 |
| GW_143 | 388395.621 | 5091633.293 | 252.996 | 830.039 | 0.005 | 0.003 |
| GW_144 | 383287.34 | 5092945.899 | 200.103 | 656.506 | 0.012 | 0.018 |
| GW_150 | 389352.667 | 5089573.785 | 274.086 | 899.232 | 0.003 | 0.003 |
| GW_151 | 389744.387 | 5094445.287 | 234.767 | 770.233 | 0.015 | 0.009 |
| GW_152 | 393286.724 | 5089571.48 | 296.604 | 973.110 | 0.015 | 0.011 |
| GW_160 | 393147.417 | 5089956.004 | 290.045 | 951.591 | 0.003 | 0.003 |
| GW_161 | 393734.325 | 5090589.237 | 278.018 | 912.133 | 0.003 | 0.004 |
| GW_162 | 393090.749 | 5090347.905 | 284.768 | 934.278 | 0.003 | 0.003 |
| GW_163 | 393084.789 | 5090347.965 | 284.814 | 934.429 | 0.003 | 0.003 |
| GW_164 | 386472.034 | 5092250.3 | 230.158 | 755.112 | 0.01 | 0.006 |
| GW_165 | 387848.965 | 5091049.631 | 251.695 | 825.771 | 0.004 | 0.002 |
| GW_166 | 386644.834 | 5090448.375 | 243.503 | 798.894 | 0.006 | 0.004 |
| GW_167 | 386674* | 5090444* | 244* | 801* | * | * |
| GW_168 | 386698* | 5090444* | 244* | 802* | * | * |
| GW_169 | 390001.583 | 5088453.461 | 290.135 | 951.887 | 0.006 | 0.006 |
| GW_170 | 389307.391 | 5092050.988 | 255.411 | 837.963 | 0.007 | 0.004 |
| GW_171 | 388106.856 | 5094086.999 | 228.983 | 751.257 | 0.013 | 0.008 |

* Well locations not yet surveyed.  Values shown here were obtained from Google Earth.

# Appendix C

## Explanation of Data Gaps during the 2019 Water Year

| Well ID | Gap Dates | Explanation |
|---|---|---|
| GW_07 | 6-24-19 to now | Datalogger is stuck in the well |
| GW_23 | 9-4-19 | Port opening is sealed, no access. Landowner says he'll unseal the port opening by next visit |
| GW_28 | 6-24-19 to 9-4-19 | Datalogger programming error |
| GW_37 | 6-25-19 to now | Door is screwed shut, no access. Decommissioned well |
| GW_40 | 9-7-18 to 12-4-18 | Datalogger failure, couldn't communicate |
| GW_40 | 2-13-19 to 3-23-19 | Water dropped below level of datalogger. Dry data were deleted |
| GW_58 | 7-19-18 to 1-20-19 | Water dropped below level of datalogger. Dry data were deleted |
| GW_58 | 2-26-19 to 4-12-19 | Water dropped below level of datalogger. Dry data were deleted |
| GW_58 | 6-22-19 to 9-4-19 | Water dropped below level of datalogger. Dry data were deleted |
| GW_60 | 7-2-18 to 10-10-18 | Water dropped below level of datalogger. Dry data were deleted |
| GW_60 | 2-22-19 to 3-30-19 | Water dropped below level of datalogger. Dry data were deleted |
| GW_60 | 6-3-19 to 6-23-19 | Water dropped below level of datalogger intermittently. Dry data were deleted |
| GW_60 | 6-24-19 to 9-4-19 | Water dropped below level of datalogger. Dry data were deleted |
| GW_73 | 12-6-18 to 3-19-19 | Datalogger failure, couldn't connect |
| GW_74 | 11-11-18 to now | Datalogger filled up due to no access to well. New landowner doesn't want us to monitor. Decommissioned well |
| GW_92 | 10-2-18 to 10-10-18 | Water dropped below level of datalogger. Dry data were deleted |
| GW_92 | 10-17-18 to 10-29-18 | Water dropped below level of datalogger. Dry data were deleted |
| GW_92 | 8-29-19 to 9-5-19 | Datalogger failure, internal clock went out of calibration |
| GW_115 | 9-6-18 to 12-3-18 | Datalogger failure, couldn't communicate |
| GW_116 | 6-24-19 to 9-3-19 | Datalogger programming error |
| GW_142 | 2-24-19 to 3-31-19 | Water dropped below level of datalogger. Dry data were deleted |
| GW_150 | 11-22-18 to 1-11-19 | Water dropped below level of datalogger. Dry data were deleted |
| GW_150 | 1-14-19 to 1-17-19 | Water dropped below level of datalogger. Dry data were deleted |
| GW_150 | 2-3-19 to 3-27-19 | Water dropped below level of datalogger. Dry data were deleted |
| GW_163 | 9-23-18 to 12-3-18 | Water dropped below level of datalogger. Dry data were deleted |
| GW_163 | 12-3-18 to now | Datalogger is stuck in the well |
| GW_164 | 12-6-19 to now | Port opening is sealed, no access. Decommissioned well |
| GW_169 | 3-10-19 to 3-11-19 | Water dropped below level of datalogger. Dry data were deleted |
| GW_169 | 3-13-19 to 3-14-19 | Water dropped below level of datalogger. Dry data were deleted |