Development of a Groundwater Monitoring System Protocol and Determination of Baseline Surface and Groundwater Water-Level Conditions

For

The Barrington Area Council of Governments

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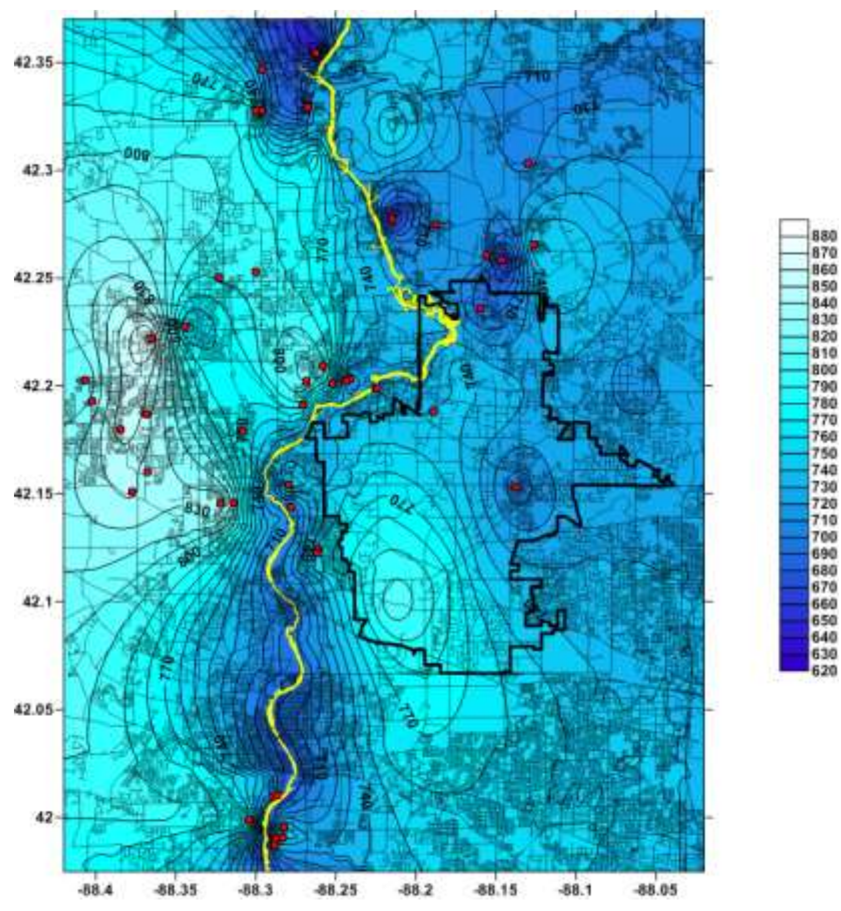

KOT ENVIRONMENTAL CONSULTING, INC.

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1.0 INTRODUCTION

Barrington area residents are reliant on groundwater from the shallow aquifer system for their water supply. Recent work completed by the Illinois State Water Survey (ISWS) has indicated that the availability of groundwater as a water source and as discharge to local streams may be adversely impacted by the year 2050. The Barrington Area Council of Governments (BACOG) has initiated a water resource initiative to study and monitor groundwater conditions in the area. As part of this initiative BACOG has authorized the development of a groundwater monitoring system protocol and the determination of baseline groundwater water-level conditions.

The BACOG groundwater monitoring system protocol, when completed, will be composed of several data collection elements the resulting analysis of which, when combined, will provide information on the state of the shallow aquifer system and the interaction of groundwater with the surface. Additionally, the protocol will include provisions for collecting water quality data in the future. The robustness of planning decisions made using the results of analysis of the collected data will increase as the amount of data collected increases with time.

Baseline surface and groundwater water-level conditions will be determined upon implementation of the groundwater monitoring system protocol during the initial data collection and analysis effort. The results of subsequent data collection efforts will be compared to the baseline conditions to establish any positive or negative changes to these conditions.

The surface monitoring system elements include:

Data Collection

- Stream Gages with Recorders
- Lake-Level Measurements

The groundwater monitoring system elements include:

- Municipal Wells
- Monitoring Wells with Recorders
- Illinois State Geologic Survey (ISGS) Monitoring Wells

Data Management

Data Analysis

- Water Table/Potentiometric Surface Generation
- Lake-Level Measurements

- Statistical Data Analysis
- Wells with Water-Level Recorders
- Streamflow

2.0 DATA COLLECTION

The initial monitoring effort consists of collecting water-level data from the data collection elements listed above and analyzing these data to establish baseline conditions. The required analytical effort will increase as the groundwater monitoring system protocol matures and more data are collected that will allow for the establishment of trends.

It is expected that all data will be collected annually in June. June has been selected because it has been established that the hydrologic conditions in the area are stable and represent average annual conditions at this time. Due to an extended period of wet weather, data collection took place on July 9th. During this initial monitoring period the data were used to establish baseline conditions including a baseline groundwater surface map.

2.1Municipal Wells

To establish what effect municipal wells drawing water from the shallow aquifer system have on the system, municipal wells operating during the data collection period were identified and pumping levels and pumping rates were provided by public works officials representing the municipalities. Contact information is provided in the database.

Seventeen municipalities, each with a number of wells, draw water from the shallow aquifer system within the study area. Fourteen of these municipalities are located along the Fox River and these wells impact the amount of water that flows through the BACOG area since the groundwater flows from west to east.

The municipalities listed below were contacted by telephone before the data collection effort to determine if they would be willing to provide the project with wells being pumped, pumping rates and pumping levels for the July 9th date. All of the municipalities agreed to cooperate. Telephone contacts were followed by e-mails containing a short project description and a reiteration of the information being requested. Another e-mail was sent out two days before the event as a reminder.

Algonquin	East Dundee	Lake in the Hills	Wauconda
Barrington	Elgin	Lake Zurich	West Dundee
Carpentersville	Fox River Grove	McHenry	

Cary	Island Lake	South Elgin	
Crystal Lake	Lake Barrington	Tower Lakes	

During the telephone conservations, it was determined that the municipalities of Elgin, Lake Zurich, and West Dundee were not pumping from the shallow aquifer system but rely solely on wells in the deep aquifer system. During the collection period, East Dundee decided not to participate. Data were collected from 12 municipalities having 52 wells in the shallow aquifer system. The locations of these wells are presented in Table 1 along with the data collected. Figure 1 shows the distribution of these wells in the Barrington area.

2.2 Monitoring Wells with Recorders

Twelve existing monitoring wells in nine locations within the study area are currently equipped with water-level recorders that take hourly readings. Data collected from these wells were used to determine water levels during the data collection effort and subsequent annual data records were used to establish water-level trends. Six of these wells are owned by McHenry County, two by the Illinois State Geological Survey (ISGS) and one each by the Village of Barrington Hills (VBH), Deer Park ((VDP), Lake Barrington (VLB) and North Barrington (VNB). With the exception of the VBH recorder, the water-level recorders are operated by the United States Geological Survey.(USGS). Eight of the recorders have been recording water-level data since 2009. The other three locations within the BACOG area were installed in June 2014. Data from wells (USGS) are collected by the USGS, subjected to quality assurance checks and made available on the National Water Information System web interface. VBH data are collected by the village engineer and require conversion, quality assurance and reformatting. Figure 2 shows the locations of the monitoring wells with recorders. Table 2 lists the wells with recorders, their locations and the water level data collected.

2.3 ISGS Monitoring Wells

Groundwater water-level data were collected from existing ISGS monitoring wells. There are 18 ISGS monitoring wells at 15 locations within the BACOG area. Three of these monitoring wells were equipped with water-level recorders that are operated and maintained by the USGS. Two wells were not located during the field data collection effort. Water levels in the other 13 wells were measured by hand. The collected data are presented in Table 3 and the locations of the ISGS monitoring wells are presented in Figure 3.

2.4 Stream Gages with Recorders

Stream gages with recorders collect stream flow data on an hourly basis throughout the year. These data are used to estimate the base-flow of the stream. The stream base-flow is an indicator of the groundwater discharge within the watershed. This groundwater discharge (base-flow) will be monitored annually. The base-flow is representative of the groundwater levels in the area. A decrease in the base-flow is equivalent to a decrease of the groundwater levels in the area.

Therefore, monitoring the base-flow reflects the condition of the groundwater system.
The USGS maintains seven stream gages in the BACOG area. The gages are located along the Fox River in pairs (up and down stream) at McHenry, Algonquin, and South Elgin. An additional gage is located on Poplar Creek near the confluence of Poplar Creek and the Fox River. Data from the USGS gages are collected by the USGS, subjected to quality assurance checks and made available on the National Water Information System web interface.

Two stream gages with recorders were installed on the Flint Creek by the Flint Creek Watershed Partnership (FCWP) to establish baseline conditions in the future. It is expected that three more gages will be installed on the Flint Creek and three on Spring Creek in the future. Data collected from these gages will be incorporated into this monitoring system when these gages come online. Locations of the stream gages are presented in Figure 4.

2.5 Lake-Level Measurements

Lake-level measurements were taken in the 15 lakes listed below. A surveyor was engaged by the consultant to measure these lake levels. The resulting measurements were compared to the groundwater levels in the area to determine if the lakes are connected to the groundwater system. If ascertained that the lakes are connected to the groundwater system, installation of a staff gage will be recommended at each such identified lake location prior to the next data collection effort to facilitate future lake-level readings.

Baker's Lake	Hawley Lake	Lake of the Coves
Crabtree Lake	Hawthorn Lake	Lake Zurich
Echo Lake	Honey Lake	Penny Road Pond
Galvin's Lake	Keene Lake	Mud Lake/Spring Lake
Grassy Lake	Lake Barrington	Tower Lake

2.6 Data Management

Water-level data were collected and stored on portable external hard drives. All collected data remains the property of BACOG. The portable external hard drives will be stored with the consultant and at the BACOG office.

Water-level data were collected using both electronic and manual means. Data from the automatic water-level recorders were downloaded directly from the USGS web site by the consultant and the files were stored on portable hard drives. Data collected manually were recorded on field data sheets at the collection site, the data were then transferred to a spreadsheet and the transfer verified by an independent individual. Once the data were verified the files containing the spreadsheet(s) were also stored on the portable hard drive.

3.0 DATA ANALYSIS

Water-level data were analyzed to produce the groundwater surface map (potentiometric-surface map) for determining groundwater flow directions and for establishing baseline characteristics that will be used as a basis for future comparisons. In addition, statistical analyses were performed on both ground and surface-water data. This section briefly describes the techniques employed for these analyses; it also describes how the results of water-level monitoring are reported for the purpose of continuity of the program

3.1 Potentiometric Surface

Annual groundwater and surface-water level measurements will be used to create a potentiometric map for that year. Maps from successive years or (when enough data are available) from previous years will be compared. Maps will be prepared that will show the changes resulting from the comparisons. These maps will define the areas of decreasing or increasing water levels and their magnitude. There will be differences when doing comparisons. When making the comparisons a difference that occurs at the same place and grows smaller or larger over time is something that needs to be explained by a hydrogeologist.

To generate a contour map, the water level measurements to be contoured are selected and a map showing the area to be contoured along with the measurements is generated using Geographic Information System (GIS) software called Surfer, a 3D visualization, contouring and modeling software. These maps are then reviewed by a hydrogeologist. Any changes to the contours are then digitized and stored where they are made available for final map production.

Figure 5 shows the distribution of all 92 sampling points. The data points are not evenly distributed, therefore, the areas that have the denser population of data points will generate a more realistic map than areas that have lesser data points. For instance the area in the southeast portion of the area has no data points because most of the area is served by Lake Michigan water. A large area around the BACOG footprint was used to generate enough data so that the groundwater characteristics within the BACOG area would have the most detail. Figure 6 is the potentiometric map generated from the data collected during this effort. The municipal well locations are shown to demonstrate the effect of pumping. A break (a computer technique used to account for rivers and faults) was used during the modeling to show the influence of the Fox River in the area. This is particularly important in the area between Algonquin and South Elgin since there is a 32-foot drop in elevation. As mentioned before, the southeastern portion of the map is probably not accurately depicted because there is so little data. This also holds true for the northeast and northwest corners. The area between Algonquin and South Elgin is probably a relatively good depiction of the circumstances, but it would have been more detailed if information from East Dundee which is situated on the river near the southern portion of the BACOG footprint were available. There is a groundwater high spot in the southwestern corner of the BACOG footprint. This area coincides with the recharge area. Recharge areas are areas where precipitation readily supplies the ground water system resulting in higher groundwater levels.

The geology of the high spot area is composed of mostly sands and gravels that are highly permeable that extend to a depth of 35 to 40 feet before encountering relatively impermeable material consisting of silts and clay. The area is classified as having highly sensitive to sensitive recharge characteristics. Highly sensitive recharge areas capture about 48.2 percent of the annual rainfall and the relative time of travel for the rainfall to enter the ground and reached the water table is less than approximately 20 days. Sensitive recharge characteristics capture about 30.3 percent of the annual rainfall and the relative time of travel for this water to reach the water table is about somewhere between 20 days and 1.5 years. Although it doesn't seem that the water travels fast from the surface to the water table in the recharge areas it is significantly faster than in the surrounding less permeable areas. Therefore, water in the recharge areas reaches the water table faster than elsewhere causing a mounding on the groundwater surface. This mounding shows up as a groundwater high on a groundwater surface map.

Another high spot is located at the western edge of the map between latitudes 42.15 and 42.25. The geology of this area was not available but it is probably very similar to that described above. This high spot area has a significant number of municipal wells yet it has high groundwater levels. The fact that these municipal wells are located in an area of high groundwater levels indicates that the water supply is so great that there are no effects of the pumping visible at the scale of the map.

Figure 7 is the potentiometric map overlain on the recharge map. It is evident that most of the municipal wells are located in areas that have moderately sensitive to highly sensitive recharge areas. Further review shows that the high spot located in the southwestern corner of the BACOG footprint also coincides with a recharge area as does the area located at the western edge of the map.

BACOG's water-level measurements next year and in future years will be used to construct potentiometric change maps that will be used to show how the potentiometric surface has changed annually or between previous years. These maps also are prepared using the software and techniques referenced above. To generate these maps digital grids of the potentiometric surfaces are electronically compared. Manual editing of the resulting grid is performed where necessary, but the addition of the digitized potentiometric contours provides a data point density suitable to overcome many problems associated with using a computer algorithm. Surfer is then used to calculate new grids showing the areas that exhibit increases/decreases in water levels.

3.2 Lake-Level Measurements

Water-levels were taken in 15 area lakes on July 9th (Table 4). The objective was to learn which lakes interacted with the major aquifer. Comparison of the lake levels to the potentiometric surface indicated that only the Spring Creek watershed lakes (Penny Road Pond, Galvin's Lake and Mud Lake/Spring Lake) interacted with the main aquifer. The geology information was generated from a database of water well logs. Not many wells were constructed near lakes and wetlands. Therefore, little is known of the shallow geology in the areas of lakes and wetlands. The lakes that are not obviously connected to the potentiometric surface probably have localized perched aquifers associated with them. The original plan was to install staff gages in the lakes that were connected to the main aquifer. This will be unnecessary in that installation of recording stream gages in the area will serve the purpose and provide additional information on the interactions between groundwater and surface water.

4.0 STATISTICAL DATA ANALYSIS

Statistical data analysis was required on wells having recorders and on streamflow records. Trend analyses were conducted on the well data. Streamflow data required the establishment of the base-flow and conducting a trend analysis on the resulting data.

4.1 Well Recorder Data

Unlike the annual generation of potentiometric maps, statistical analysis of the water-level data requires a significantly longer period of record. Usually ten plus years of data are required at a minimum for meaningful statistical analysis. Summary statistics of the water-level data from the individual monitoring wells and stream gage stations will be produced annually. Frequency analysis and time series analysis such as trends and seasonality require larger databases to be effective. Preliminary frequency and time series analysis will be conducted on early data to establish procedures and to get a sense of the expected outcomes.

Table 2 lists all the wel1s that have water level recorders. The first eight wells are part of the McHenry County groundwater monitoring program. These wells are located in the Western buffer zone of our study area. The wells were installed in 2009 and a review of the data collected determined that the data were good enough for preliminary statistical analysis. The wells at Lake Barrington, North Barrington and Deer Park had recording devices installed by the USGS in June and are functioning very well as evidenced by their short-term hydrographs that are presented as Figures 8 to 10 respectively. With the exception of the Barrington Hills well, all of the wells in the McHenry County program have five years of data. For each of these wells a hydrograph was prepared of the groundwater levels over a five-year period. Once the data were prepared they were subjected to a trend analysis using the Seasonal Kendall test (Hensel,et.al.,2005). The program used was developed by the USGS and has become the most frequently used test for trend in the environmental sciences.

Figure 11 and 12 are the hydrographs for the monitoring wells in the Algonquin area (17-ALG -S & 17-ALG-D). Two wells were constructed at this location, one shallow and one deep. The individual well hydrographs with the statistical results are shown in the figures. Subjecting both sets of data to Seasonal Kendall testing indicates a positive trend at a 95 percent level over the course of a five-year period. The trend slope in the deep well is significantly greater than that in the upper well. Analysis of the slope of the trend line indicates that the water level increased 9.7 feet over the course of five years. This means that 9.7 feet of storage has been added to the area aquifer. It is not known the volume of water this change in storage equates to because the configuration of the affected portion of the aquifer is unknown. The shallow aquifer also had a positive trend which resulted in an increase of 1.2 feet in the water levels over to five-year period. This also translates into an increase in groundwater storage. The data are interesting in that it is been reported by the ISWS that the Algonquin area is going to experience groundwater shortages in the near future, yet here we have monitoring wells that seem to imply that the opposite is true. The results of the tests on the Algonquin wells could be an anomaly due to extremely complex geology of the shallow aquifer system in the immediate area. Figure 13 shows the two Algonquin hydrographs in the same figure. There is an approximately 80-foot difference between the water levels in the shallow aquifer and that in the deep aquifer. Shallow aquifer is obviously a water table aquifer (an aquifer near the land surface) while the deep aquifer is the regional aquifer. Because the water level in the shallow aquifer is at a higher elevation than the water level in the lower aquifer gravity will pull the water in the upper aquifer downward, therefore, a downward vertical gradient is present.

The Grafton area also has two monitoring wells (16-GRF-I and 16-GRF-D), one is at an intermediate depth and the other is a deep well. Hydrographs with their statistical results are presented in Figures 14 and 15 respectively. Seasonal Kendall testing for trends indicate that both hydrographs have negative trends. Figure 16 shows both hydrographs together. The closeness of the two hydrographs indicates that they are connected to the same aquifer system. The negative trends indicate that they are both losing water out of storage. The intermediate aquifer seems to be losing water at a faster rate than the deep aquifer. The intermediate aquifer has lost 6.2 feet as opposed the deep aquifer losing 2.6 feet out of storage. The location of the trend line in the intermediate aquifer being above the trend line in the deep aquifer indicates a vertical downward gradient between the two aquifers.

Wells 13-NUN-I and 13-NUN-D R intermediate and deep wells are located in Nunda Township. The hydrographs for these two wells are presented as Figures 17 and 18 respectively. Both hydrographs exhibited negative trend lines after the data analysis. Figure 19 shows the two hydrographs together. For all practical purposes the two hydrographs are the same. Statistically, there is only a small difference between the two trend lines. One line indicates a loss of 1.3 feet over a five-year period and the other show a loss of 1.4 feet out of storage. This shows that the intermediate level and the deep level aquifers at that location act is one aquifer.

Two wells are located in the Wauconda area (WAUC-02-12 and WAUC-08-13) Figures 20 and 21 respectively. The hydrograph for WAUC–02–12 shows significant 20-foot swings in the water level in addition to two data gaps. Statistical analysis was run on the data and it resulted in a negative trend that was significant and indicated a 3.6-foot loss in the water level over the five-year period. Since the response of the hydrograph is so erratic, it would require more study to understand the cause of these 20-foot swings. Monitoring well WAUC-08-13 is a hydrograph that also exhibits a negative trend line. In this case there is a 1.8 foot decrease in the water level over the five-year period.

The Barrington Hills well is operated by Barrington Hill's personnel. It is also been in operation since 2009 but was out of commission for most of 2013 because of technical difficulties. Enough data were collected before the shutdown that a preliminary statistical analysis could be conducted. The Barrington Hills well is an active well that is used three or four times a day for short periods of time. Before analyzing the well data a filtering process was instituted to remove the effects of the intermittent pumping. Figure 22 is the Barrington Hills hydrograph showing a slightly positive trend. Statistical analysis indicated that the trend was not significant at the 95 percent level. The results of all the statistical analyses presented in this section are summarized in Table 5.

4.2 Stream Flow

Stream flow information is important to groundwater studies because analysis of stream flow data can provide an estimate of base-flow which is the equivalent of groundwater discharge to the stream. The BACOG area has seven stream recording gauges in the immediate area operated by the USGS. Two are located in McHenry, two are located in Algonquin, two are located at South Elgin and the seventh is located on Poplar Creek just before the confluence with the Fox River. The PARK model (Rutledge, A.T., 1998) was used to separate the base flow from the stream data. The major requirement of the PARK model is that the data be consistent. The process consists of analyzing the stream flow data using the PARK model to establish a base flow hydrograph. The base flow hydrograph data is then subjected to the Seasonal Kendall Trend analysis to establish a trend. Data for each of the seven gages were analyzed to find data suitable for analysis using the PARK program. The data needed to be consistent over a long period of time. Consistent data were found at only two locations: Algonquin's upper gage and the gage on Poplar Creek.

Figure 23 shows the results of the data analysis performed on the Algonquin well data. The data were downloaded from USGS database and was graphed. The PARK model was applied to the data and the base-flow hydrograph was overlain on the stream flow hydrograph. The base-flow hydrograph is in red it is interesting that the base-flow hydrograph mimics the stream flow hydrograph. Usually the base-flow peaks are significantly smaller than the stream flow peaks. This indicates a very rapid response of groundwater returning to the stream. This makes sense allowing that all the good recharge areas are in the Fox River Valley and adjacent to the river. Running a Seasonal Kendall trend analysis on the base-flow data yields a base-flow trendline that is significantly positive at the 95 percent level. At this time limited knowledge is available about the characteristics of the near river hydrogeology, but it's possible that some of the decreases in the well water levels are responsible for a portion of the increase of the base flow of the river.

Figure 24 shows the base-flow and the trend line for the Poplar Creek data. The period of record for Poplar Creek is January 1997 through December 2012. Poplar Creek data goes all the way back to 1952. This period of record was chosen because 15 years was the limitation of the model. The PARK model was run on the original data that resulted in a base-flow hydrograph that is seen in Figure 24. The normal hydrograph of the streamflow was excluded because it interfered with the presentation of the base-flow and the trendline determined by the Seasonal Kendall Trend test. It was discovered that the base-flow had a positive trendline but that it was not significant at the 95 percent level.

In the future base-flow data that is more suited to our needs will be available. Eight stream gages will be installed on the Flint Creek and on the Spring Creek by FCWP. Once these gages are installed we will have expert coverage of base-flow information in the BACOG area. Five gages are planned for the Flint Creek and the other three are planned for the Spring Creek. At this time, two gages have been installed on the Flint Creek, one at the head of Flint Lake (FC3) and the other (FC5) in the Grassy Lake Forest Preserve just downstream of the Kelsey road bridge. The gages have been in operation since September but they already are collecting good data as can be seen by their short-term hydrographs in Figures 25 and 26 respectively for FC3 and FC5. Both hydrograph have recorded two storm events that can be isolated for further study as shown in Figure 27.

5.0 SUMMARY

In this effort a potentiometric map that accurately reflects the groundwater conditions in place in the BACOG area on July 9. 2014 was developed. Because of the effect that it has had on shaping the surface and subsurface features, the Fox River is an important characteristic in the development of the potentiometric surface. Discharge to the river flows from the east and west. The southern portion of the Fox River is particularly important in that between Algonquin and South Elgin there is 32 foot drop in elevation causing steep groundwater gradients. There are two groundwater highs of note, one is located on the western boundary between latitudes 42.15 and 42.25 the other is located in the southwest corner of the BACOG area boundary. Because of the higher groundwater levels both of these areas are good recharge areas. A review of the recharge figure indicates that most of the area west of the river is a very good recharge area. This is probably the reason why the large amount of pumping going on the western side of the river is not having a greater effect than would be expected. The potentiometric map that was developed during this project is an excellent baseline map for comparison of annual potentiometric surfaces and to identify areas of no change in groundwater levels as well as areas that indicate groundwater losses and groundwater gains.

The statistical analyses conducted on the USGS maintained well data in McHenry County seem to support the ISWS conclusion that water levels will be declining over the near future. With the exception of the monitoring well nest in the Algonquin area, each well had trends of lowered water levels over a five-year period of analysis. The Algonquin area well nest seems to be an anomaly because they have exhibited increasing groundwater levels over the last five years. Without further study, this phenomenon may be due to certain hydrogeologic conditions in the immediate area. The Lake Barrington, North Barrington and Deer Park wells will probably exhibit the same characteristics as the other USGS monitored wells once enough data has been collected to conduct an analysis.

Establishing a baseline base flow of a river or stream and comparing it to future measurements is another excellent way of monitoring the health of the groundwater system. As part of this study the streamflow data for six stations of the Fox River and one on Poplar Creek were studied. In most cases the data were too inconsistent to analyze using the available model. An acceptable set of data from the Algonquin gage was found. The data were analyzed to separate the base-flow from the rest of the flow. Once base-flow was available, trend analysis was conducted to see if the base-flow was increasing or decreasing. As it turned out, base flow was increasing. It is interesting to note that there is an increase in groundwater discharge to the Fox River and an apparent decrease in the water levels in the monitoring wells. It is something that would require additional study and may be of interest to the ISWS. The other streamflow record available was that of the Poplar Creek. Poplar Creek has a 52 year record that has no inconsistencies. Analysis of the popular Creek record indicated that it had a increasing base-flow trend but that the trend was not statistically significant. Using Fox River and the Poplar Creek for base-flow information would be adequate if nothing else were available. Fortunately a stream gage system is being installed in the Flint and Spring Creek watersheds by FCWP. When completed there will be five gages in the Flint Creek watershed and three gages in the Spring Creek watershed. This summer two gages were installed on the Flint Creek. Two short-term hydrographs were produced as examples for this report.

The relationship between groundwater and surface water was established as well as possible with available data. Our surface water is beginning the get a closer look in that the FCWP developed a water quality monitoring plan that will be implemented next summer. Thirty water samples will be collected and analyzed to determine baseline conditions for both the Flint and the Spring Creeks. Conducting a similar sampling program by BACOG for the ISGS wells located within the BACOG footprint would provide important information. Information of this type would go a long way to establishing the interaction between groundwater and surface water in the local area.

6.0 REFERENCES

Hensel, D. R.,D.K. Meuller and J.R.Stack,2005. Computer Program for the Kendall Family of Trend Tests. Scientific Investigations Report 2005-5275, U.S. Department of the Interior, U.S. Geological Survey, Reston, VA.

Rutledge, A.T., 1998. Computer Programs for Describing the Recession of Ground-Water Discharge and for Estimating Mean Ground-Water Recharge and Discharge from Streamflow Records-Update, U.S. Geological Survey, Water-Resource Investigations Report 98-4148, Reston, VA.

USGS Real-Time Data for Illinois-Streamflow, National Water Information System: Web Interface, http://waterdata.usgs.gov/il/nwis/current/?type=flow.

Tables

Table 1 Municipal Well

Operating Municipal Well	Location Longitude (NAD83)	Latitude (NAD83)	Reference Point Elevation (ft NAVD88)	Pumping Rate (GPM)	Pumping Level 070914 (feet)	Pumping Level 071014 Elevation (ft NAVD88
ALGONQUIN_5	-88.279644	42.154021	787	570	25	762
ALGONQUIN_7	-88.278322	42.144017	752	1260	52	700
ALGONQUIN_8	-88.314327	42.145912	882	900	64	818
ALGONQUIN_9	-88.322174	42.145652	913	1100	76	837
ALGONQUIN_13	-88.367783	42.160315	901	930	66	835
ALGONQUIN_15	-88.377586	42.150825	894	1130	52	842
BARRINGTON_1	-88.137617	42.152929	NS	1048	NS	702
CARPENTERSVILLE_5	-88.261084	42.123990	879	811	112	767
CARPENTERSVILLE_6	-88.261824	42.122606	880	1114	128	752
CARY_3	-88.252329	42.201124	881	143	51	782
CARY_8	-88.241270	42.203220	767	312	113	713
CARY_9	-88.243118	42.202090	764	408	148	701
CARY_10	-88.270574	42.191420	906	427	89	787
CARY_11	-88.258159	42.209300	863	487	108	805
CARY_12	-88.268074	42.202127	881	562	246	811
CRYSTAL_LAKE_9	-88.344010	42.227139	898	180	143	755
CRYSTAL_LAKE_10	-88.323054	42.250173	924	452	132	792
CRYSTAL_LAKE_11	-88.323054	42.250173	924	453	120	804
CRYSTAL_LAKE_14	-88.299763	42.253090	904	382	109	795
CRYSTAL_LAKE_15	-88.365472	42.221866	899	599	24	875
FOX_RIVER_GROVE_1	-88.225287	42.198720	741	462	20	741
FOX_RIVER_GROVE_2	-88.224589	42.198614	742	464	19	742
ISLAND LAKE_4-6	-88.214953	42.277272	743	123.3	93	650
ISLAND LAKE_4-10	-88.214964	42.277260	743	110	95	648
ISLAND_LAKE_5	-88.187638	42.274925	804	221.5	84	720
LAKE BARRINGTON 1	-88.188683	42.188239	781	544	40	741
LAKE_IN_THE_HILLS_6	-88.368653	42.187042	888	62	45	843
LAKE_IN_THE_HILLS_9	-88.307958	42.178758	791	279	24	767
LAKE_IN_THE_HILLS_10	-88.384753	42.179892	897	184	42	855
LAKE_IN_THE_HILLS_12	-88.406625	42.202764	868	191	59	809
LAKE_IN_THE_HILLS_16	-88.402319	42.192822	880	234	58	822
LAKE_IN_THE_HILLS_17	-88.307958	42.178758	791	222	64	727
MCHENRY_2	-88.267785	42.329116	766	325	31	735
MCHENRY_3	-88.267859	42.329114	766	275	97	669
MCHENRY_5	-88.296233	42.346661	760	500	49	711
MCHENRY_6	-88.296028	42.346656	760	475	56	704
MCHENRY_7	-88.296640	42.327576	825	350	114	711
MCHENRY_8	-88.300167	42.327542	818	200	31	787
MCHENRY_9	-88.263044	42.354317	774	700	127	647
MCHENRY_10	-88.262772	42.354372	744	400	133	611
SOUTH_ELGIN_3	-88.287635	41.989822	734	500	57	734

Table 1 Municipal Well Data

Operating Municipal Well	Location Longitude (NAD83)	Latitude (NAD83)	Reference Point Elevation (ft NAVD88)	Pumping Rate (GPM)	Pumping Level 070914 (feet)	Pumping Level 071014 Elevation (ft NAVD88
SOUTH_ELGIN_4	-88.304289	41.998742	776	268	41	776
SOUTH_ELGIN_5	-88.288796	42.009419	710	410	12	710
SOUTH_ELGIN_6	-88.287994	41.987554	731	425	44	731
SOUTH_ELGIN_10	-88.283398	41.990661	739	864	56	739
SOUTH_ELGIN_11	-88.282761	41.995255	743	892	38	743
SOUTH_ELGIN_12	-88.286782	42.010171	707	979	58	707
TOWER_LAKES_5	-88.159832	42.236172	768	76	75	693
WAUCONDA_3	-88.146048	42.258362	785	NS	135	650
WAUCONDA_5	-88.126315	42.265435	808	NS	57	751
WAUCONDA_6	-88.155930	42.260303	765	NS	48	717
WAUCONDA_10	-88.129989	42.302842	796	NS	89	707

Well Identification	Location (NAD83)		Reference Elevation (ft NAVD88)	Depth to Water (feet)	Water Level Elevation (ft NAVD88)
	Latitude	Longitude			
17-ALG-S	42.1958	-88.3300	880.03	-1.15	881.18
17-ALG-D	42.1958	-88.3300	880.03	98.61	781.42
16-GRF-I	42.1894	-88.3744	879.51	15.52	863.99
16-GRF-D	42.1894	-88.3744	879.51	20.14	859.37
13-NUN-I	42.3056	-88.2625	785.32	46.98	738.34
13-NUN-D	42.3056	-88.2625	785.32	46.66	738.66
WAUC-02-12	42.2633	-88.2400	835.00	93.37	741.63
WAUC-08-13	42.3206	-88.2148	766.00	21.44	744.56
Lake Barrington	42.2113	-88.1717	764.27	23.03	744.21
North Barrington	42.1923	-88.1499	804.26	65.65	738.61
Deer Park	42.1768	-88.0958	875.39	151.48	723.91
Barrington Hills	42.1129	-88.1813			781.92

Table 2 Data from Monitoring Wells That Have Water-Level Recorders

Well Identification	Location (NAD83)		Reference Elevation (ft NAVD88)	Depth to Water (feet)	Water Level Elevation (ft NAVD88)
	Latitude	Longitude			
BARR-06-01	42.1390	-88.2189	846.90	65.52	780.88
BARR-06-02A	42.2337	-88.2133	784.90	46.35	738.30
BARR-06-02B	42.2337	-88.2133	784.90	32.25	752.40
BARR-06-03	42.2286	-88.1985	775.61	Not Found	
BARR-06-04A	42.1441	-88.2074	776.46	4.91	771.26
BARR-06-04B	42.1441	-88.2074	776.46	Not Found	
BARR-07-06B	42.2110	-88.1712	764.27	23.03	742.03
LZUR-04-01	42.2450	-88.1190	840.10	95.30	746.72
LZUR-05-02	42.1712	-88.1007	856.98	70.20	789.20
LZUR-05-03	42.1360	-88.0920	853.15	123.76	728.87
LZUR-06-04	42.2071	-88.0705	867.99	153.00	717.28
LZUR-07-07	42.1691	-88.1086	827.40	102.59	727.16
STRM-05-01	42.1144	-88.1595	869.65	121.49	747.81
STRM-06-02	42.0992	-88.2151	837.43	28.34	808.76
STRM-06-03	42.0306	-88.2132	800.46	34.25	765.79

Table 3 ISGS Monitoring Well Data

Lake	Latitude	Longitude	Elevation
	(feet NAD83)		(feet NAVD88)
Baker’s	42.1468	-88.1231-	843.2
Crabtree	42.1141	-88.1639	868.9
Echo	42.2114	-88.0896	841.9
Galvin’s	42.1173	-88.2113	790.0
Grassy	42.2044	-88.1464	750.9
Hawley	42.1364	-88.1542	831.7
Hawthorne	42.1368	-88.1475	819.1
Honey	42.1976	-88.1309	783.3
Keene	42.1328	-88.1536	827.1
Lake Barrington	42.2127	-88.1458	781.0
Lake of the Cloves	42.0840	-88.1558	842.4
Lake Zürich	42.1954	-88.0962	844.6
Penny Road Pond	42.0976	-88.2073	804.1
Mud Lake/Spring Lake	42.1541	-88.2118	768.6
Tower Lake	42.2348	-88.1581	747.9

Table 4 Lake Water Elevations 070914

Well Identification	Well Depth	Borehole Depth	Aquifer	Trend	Vertical Gradient	Storage Loss/Gain (feet)
17-ALG-S	47.3	189	Sand & Gravel	Positive	Downward ↓	+1.2
17-ALG-D	187.8	189	Sand & Gravel	Positive		+9.7
16-GRF-I	99	171	Sand & Gravel	Negative	Downward ↓	-6.2
16-GRF-D	139.1	171	Sand & Gravel	Negative		-2.6
13-NUN-I	113	153	Sand & Gravel	Negative	Downward ↓	-1.3
13-NUN-D	152.2	153	Sand & Gravel	Negative		-1.4
WAUC-02-12	192.2	2/17	Sand & Gravel	Negative	ID	-3.6
WAUC-08-13	105.3	158	Sand & Gravel	Negative	ID	-1.8
Lake Barrington	71	139	Sand & Gravel	ID	ID	ID
North Barrington	109	203	Sand & Gravel	ID	ID	ID
Deer Park	169.7	282.6	Sand & Gravel	ID	ID	ID
Barrington Hills			Sand & Gravel	Positive	ID	+0.23

ID Insufficient Data

Table 5 Summary of Trend Analysis Results

Figures

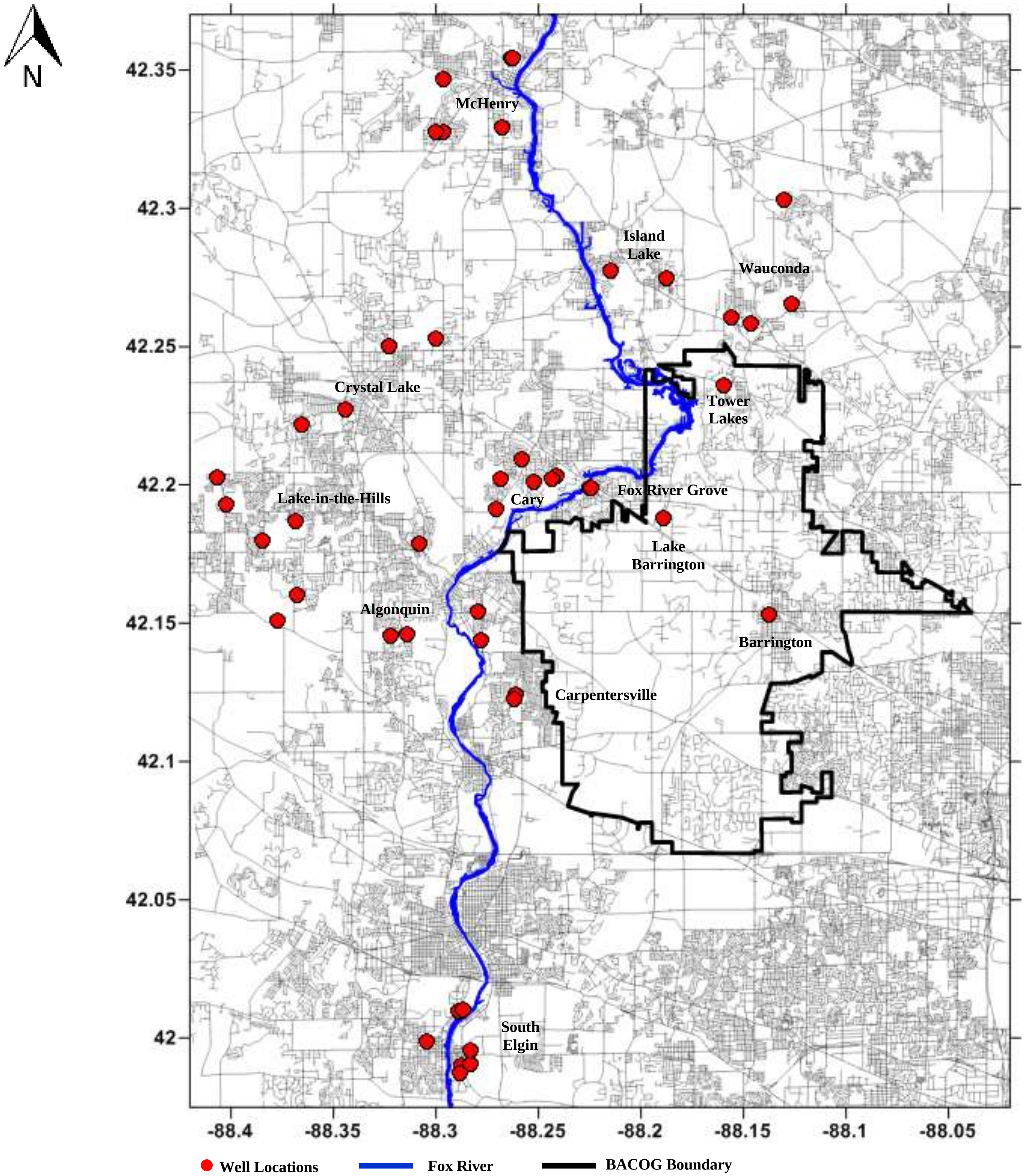

Figure 1 Municipal Well Locations

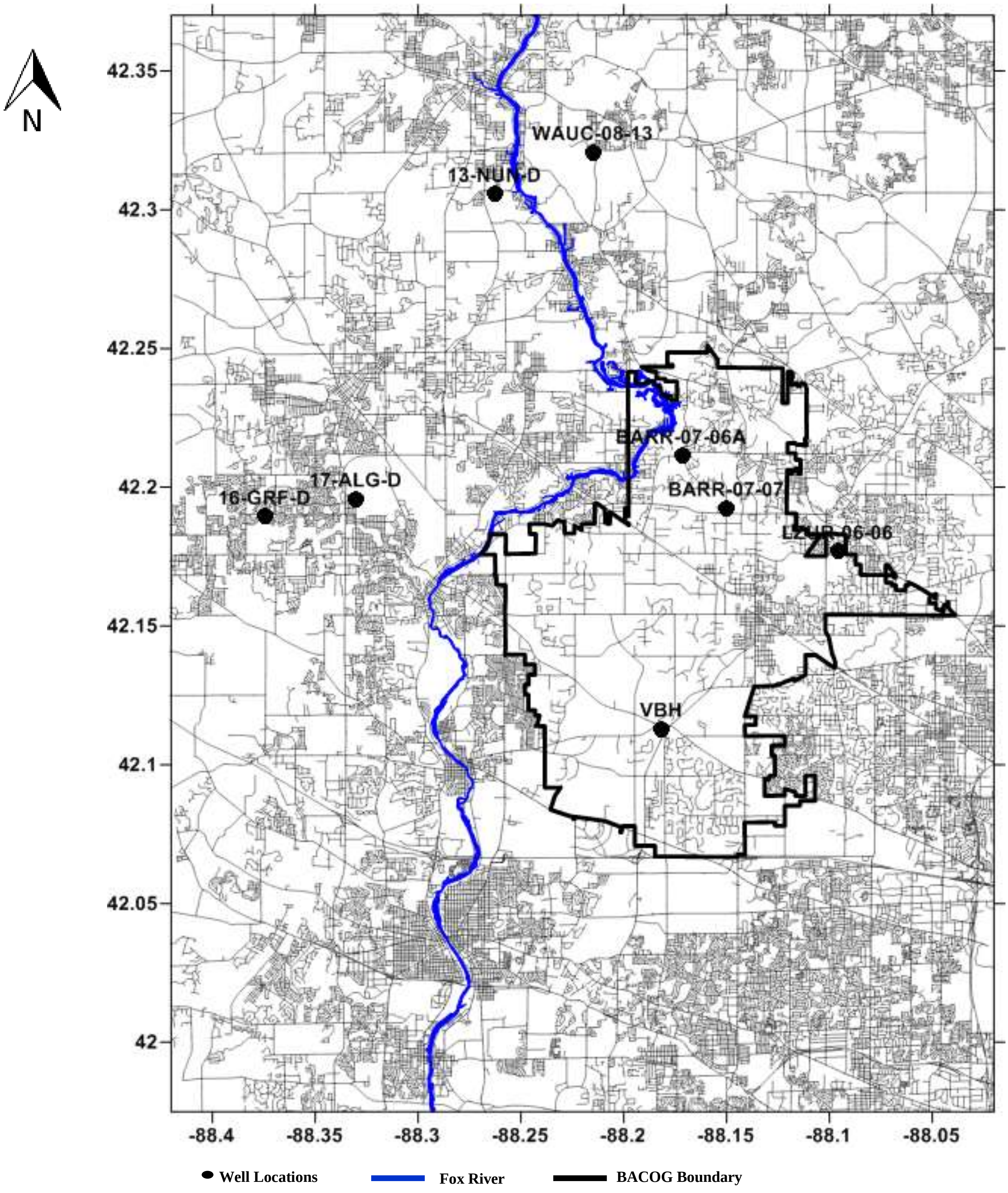

Figure 2 Locations of Wells Having Automatic Water-Level Recording

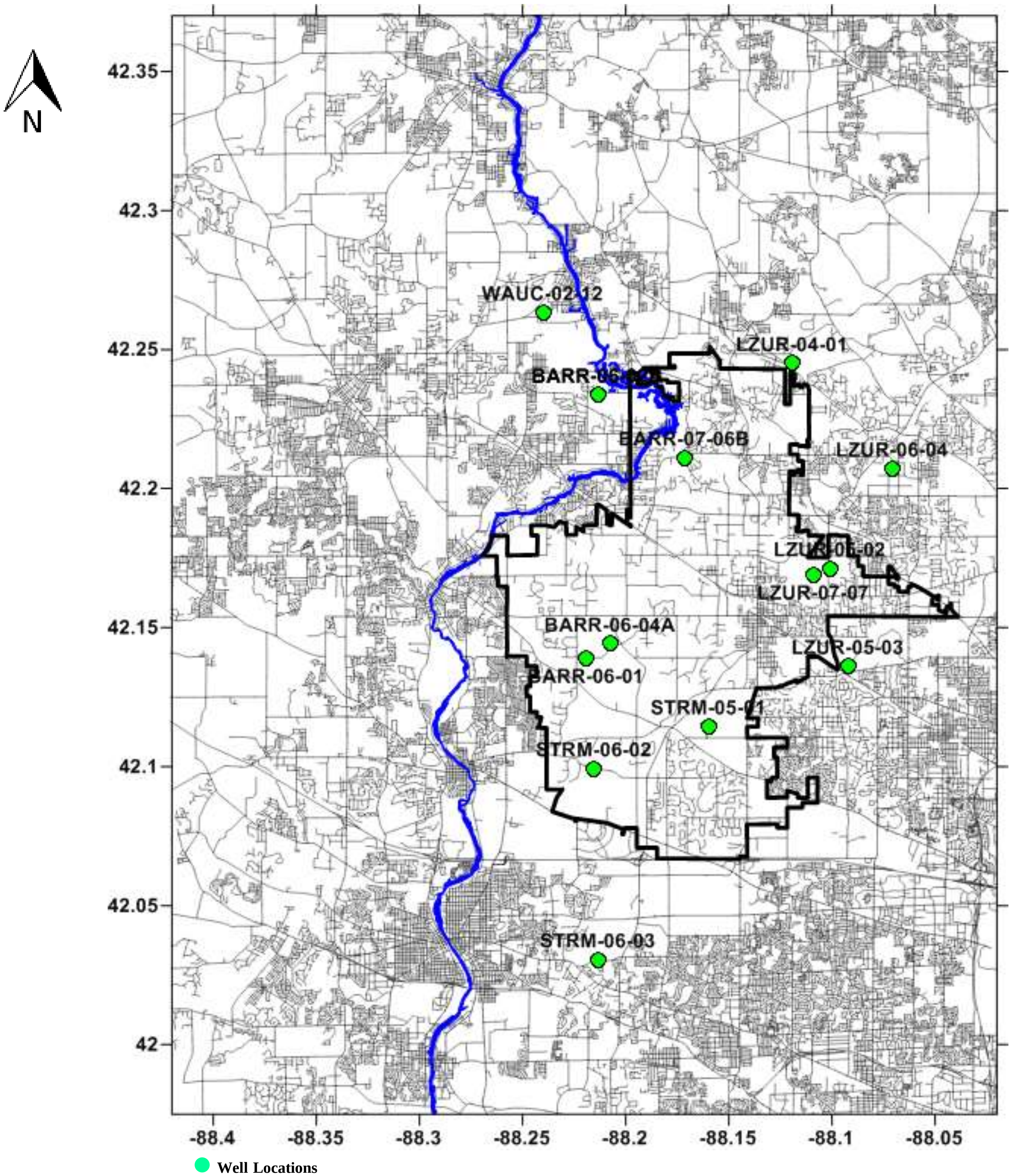

Figure 3 Locations of ISGS Monitoring Wells

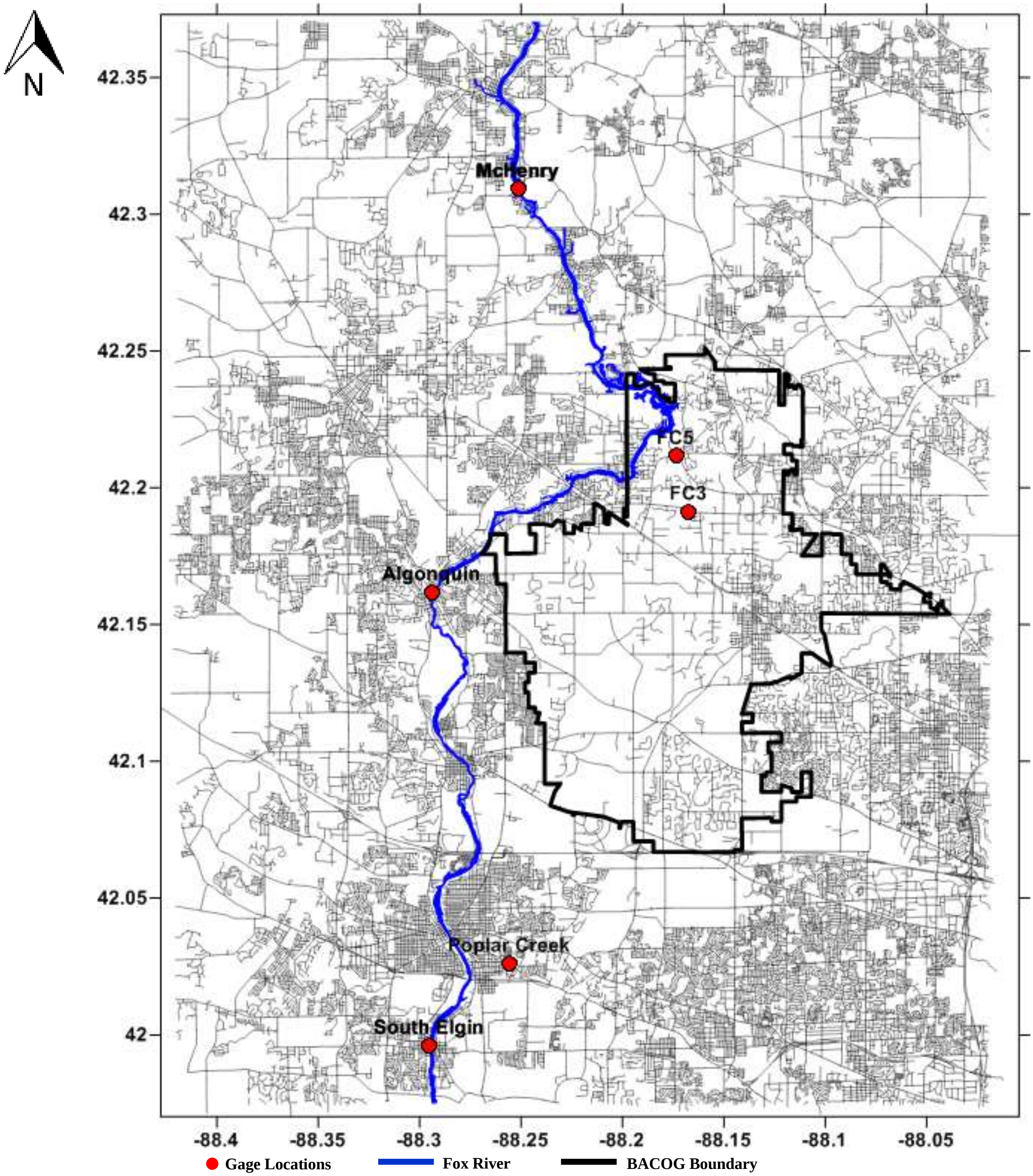

Figure 4 Locations Recording Stream Gages

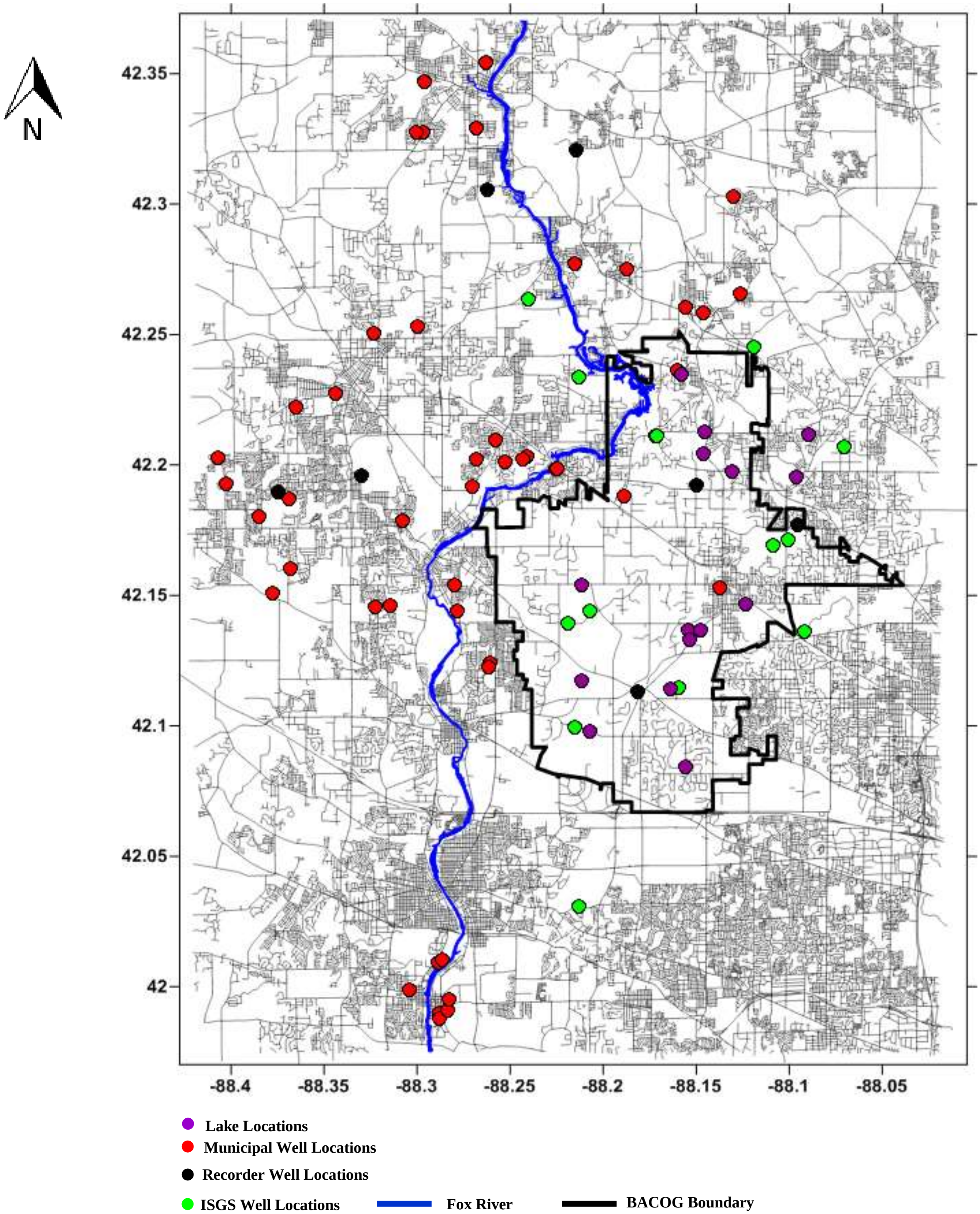

Figure 5 All Data Collection Point Locations

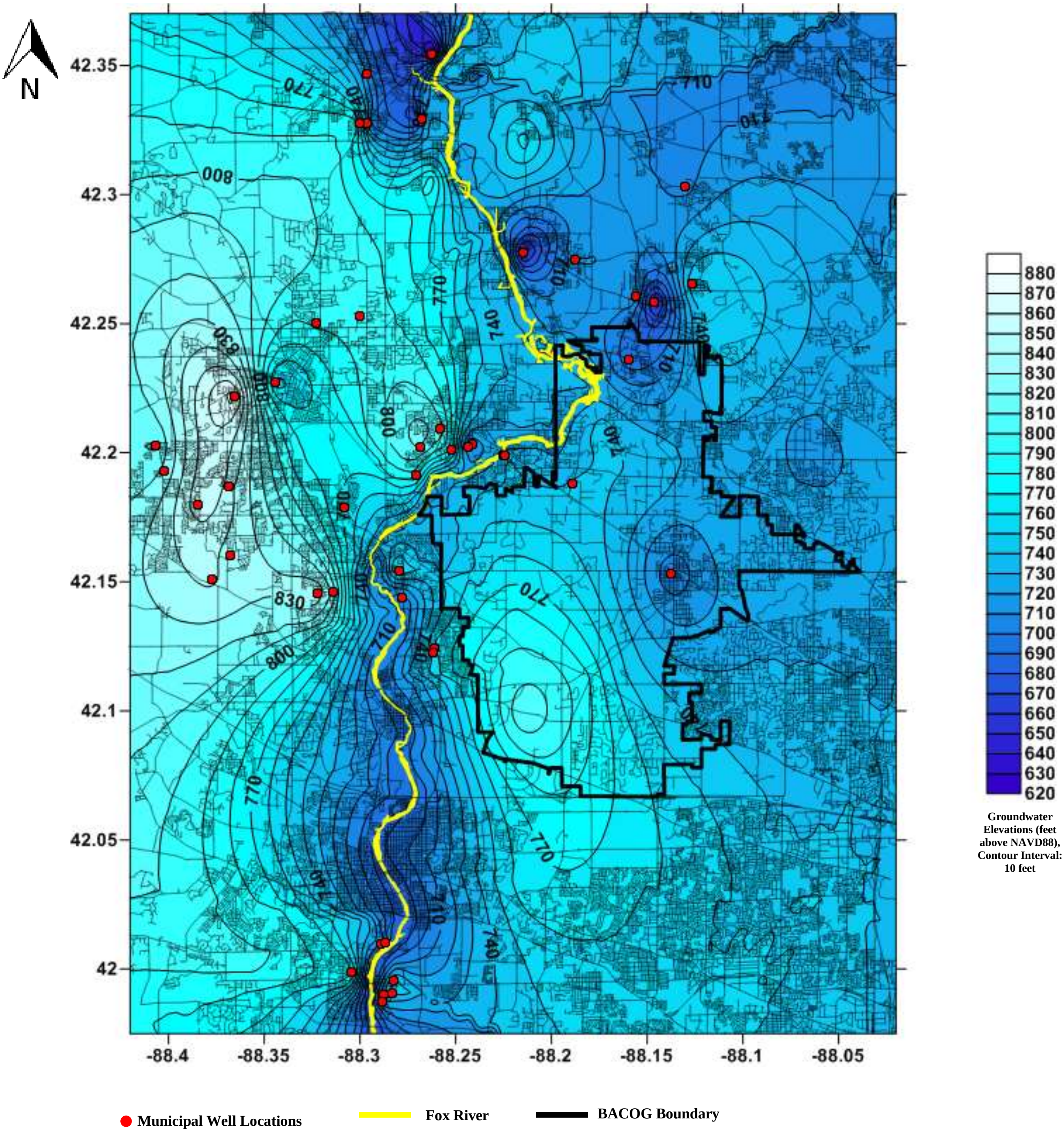

Figure 6 Potentiometric Surface, July 9, 2014

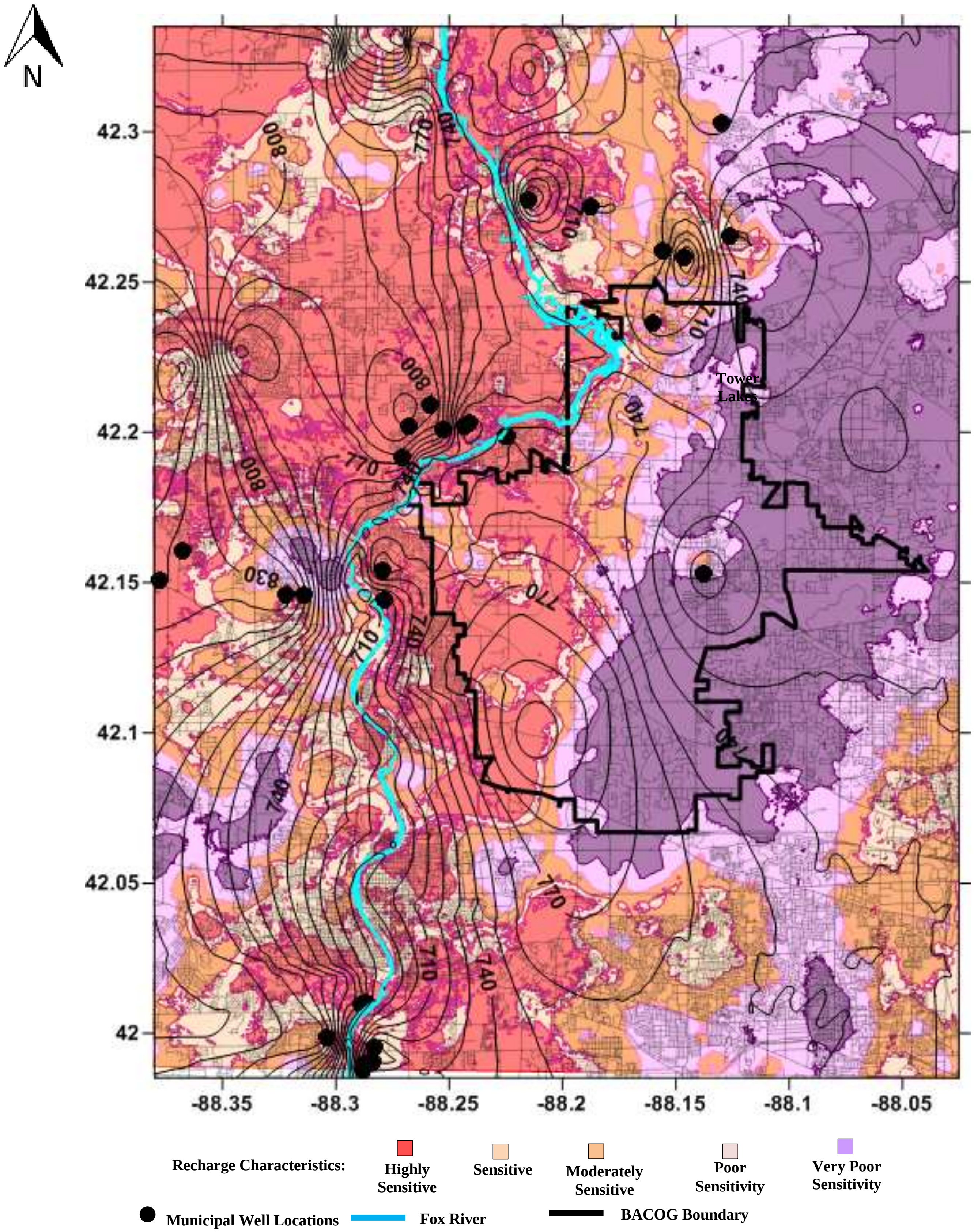

Figure 7 Potentiometric Surface over Recharge Areas

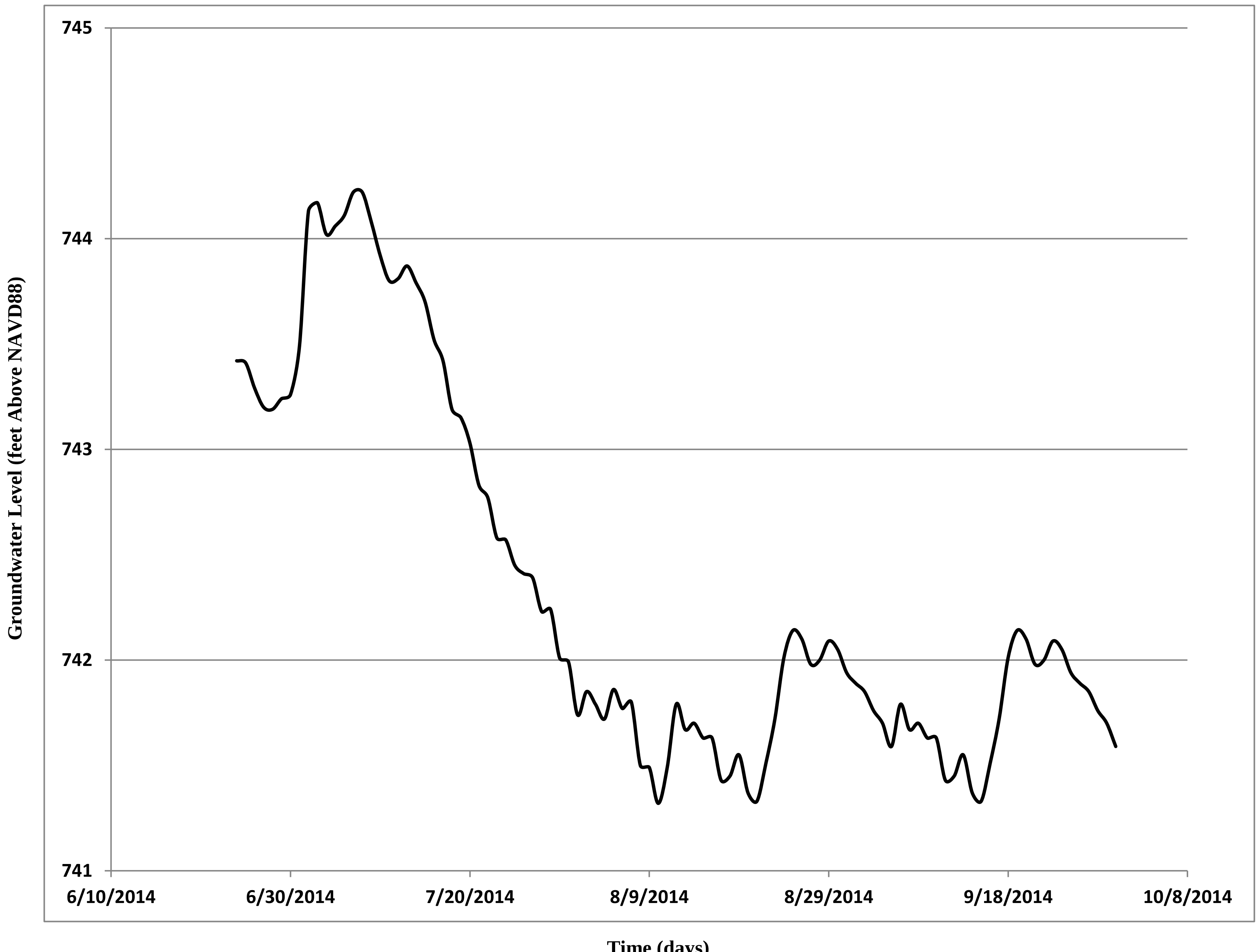

Figure 8 Lake Barrington Monitoring Well Hydrograph

Period of Record: 062414 through 093014

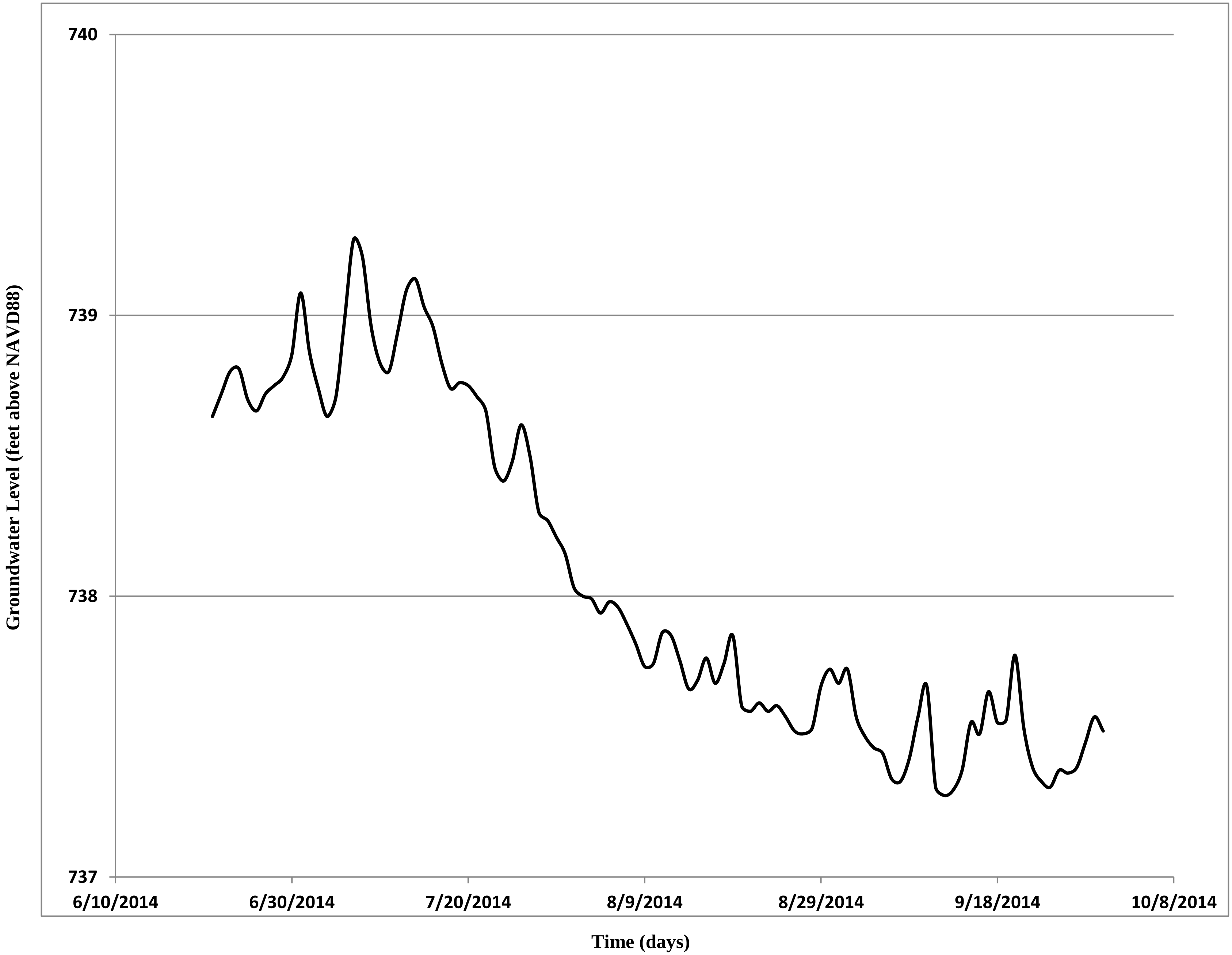

Figure 9 North Barrington Monitoring Well Hydrograph

Period of Record: 062414 through 093014

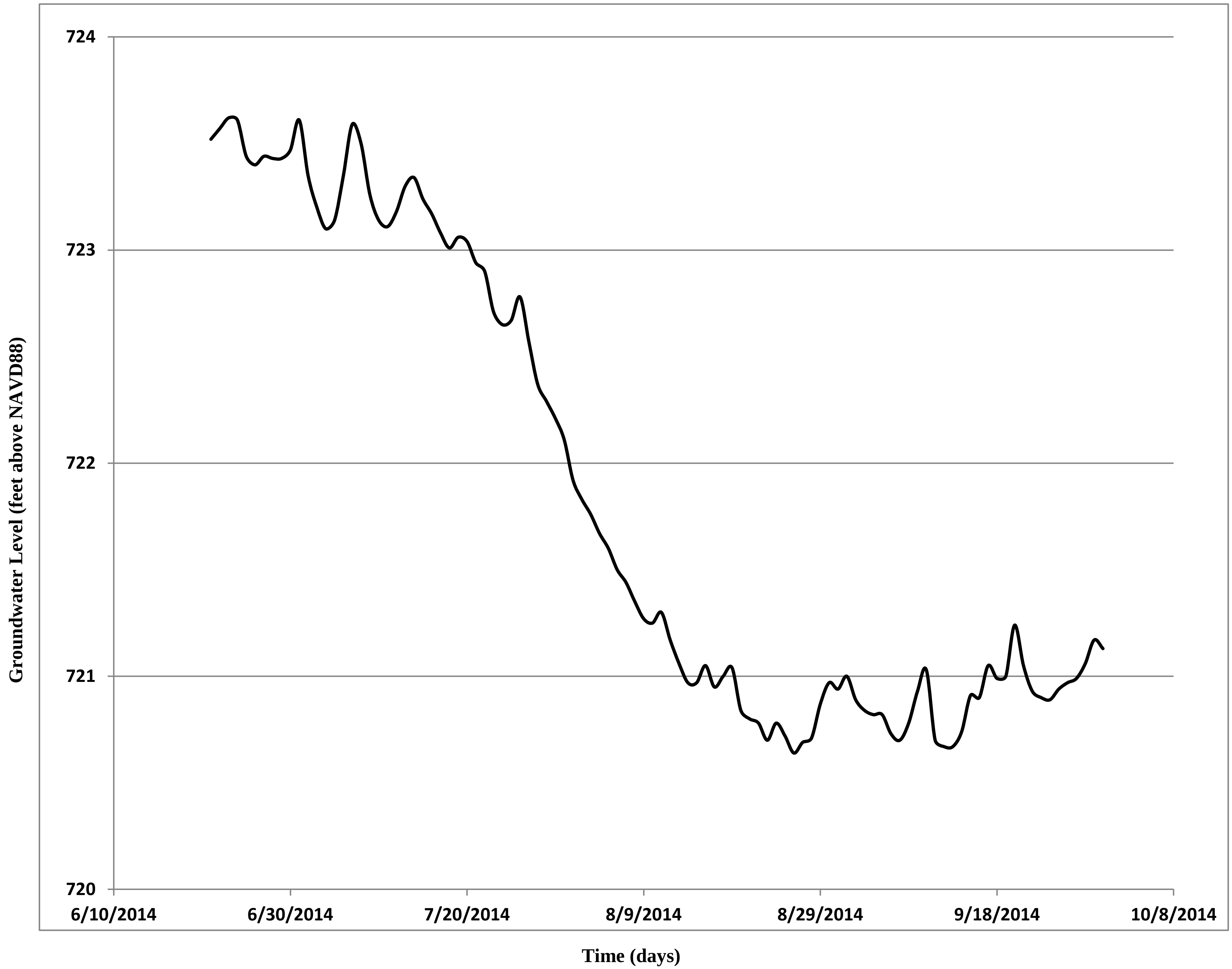

Figure 10 Deer Park Monitoring Well Hydrograph

Period of Record: 062414 through 093014

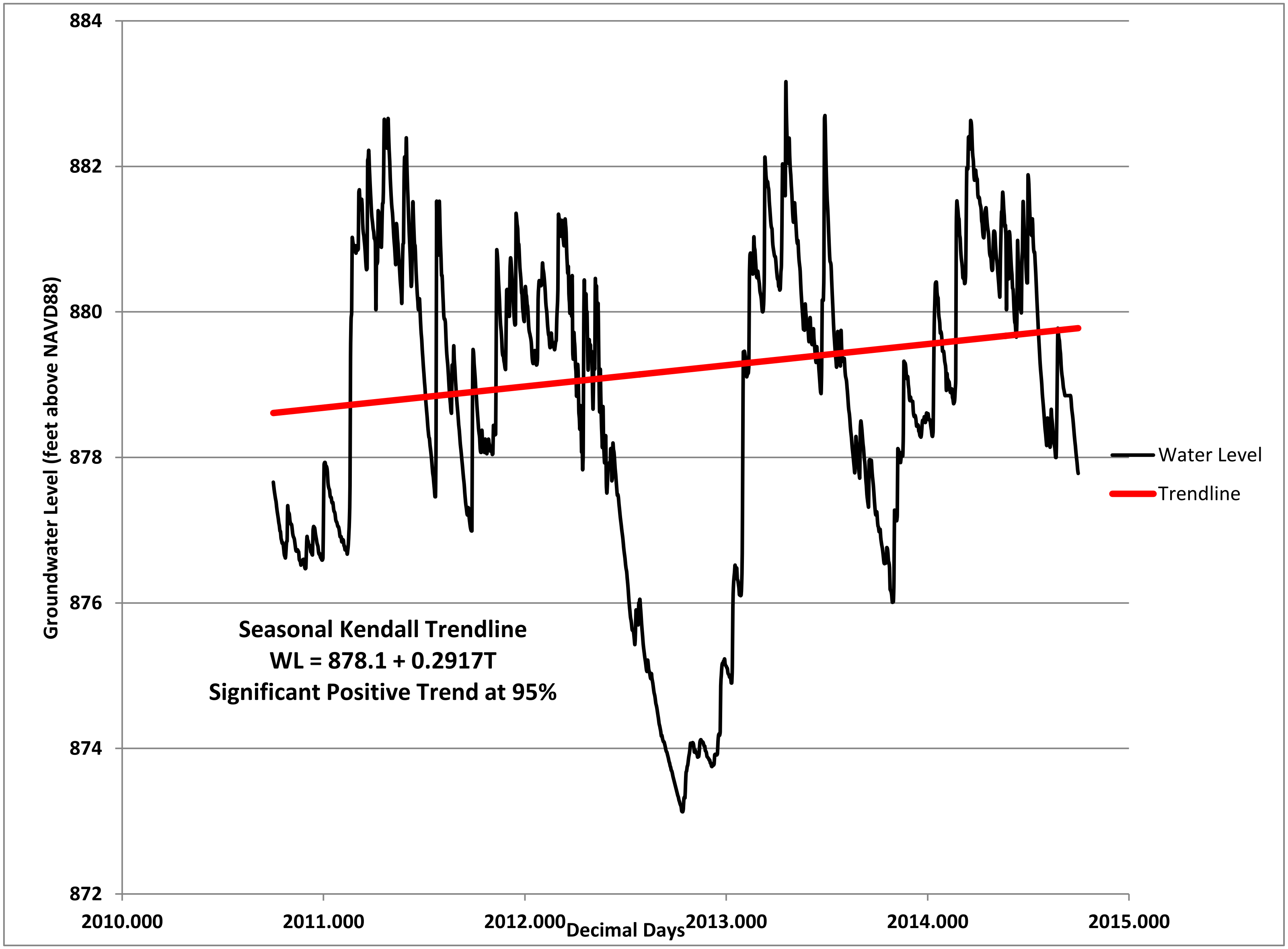

Figure 11 Monitoring Well 17-ALG-S Hydrograph

Period of Record: 100109 through 093014

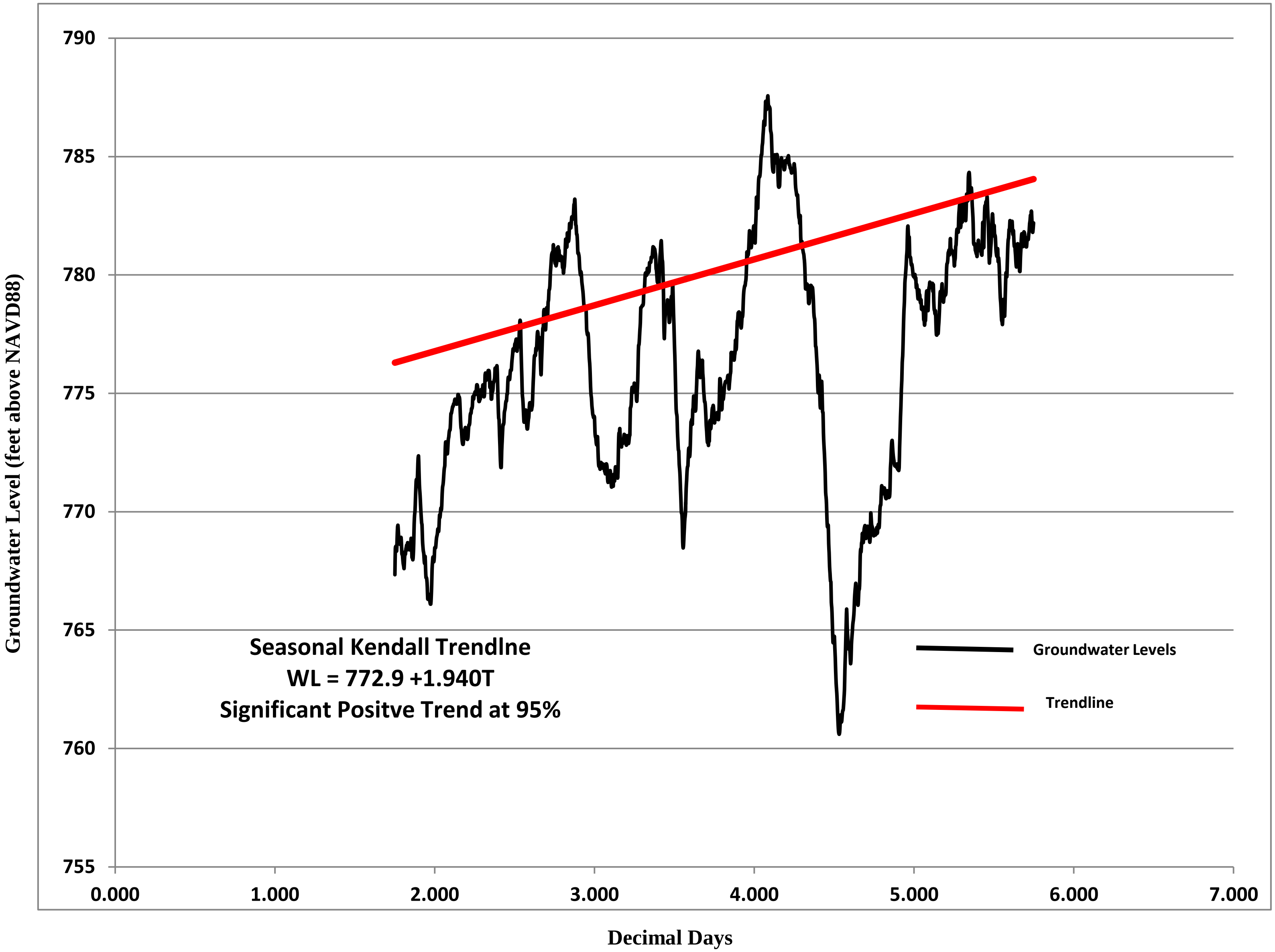

Figure 12 Monitoring Well 17-ALG-D Hydrograph

Period of Record: 100109 through 093914

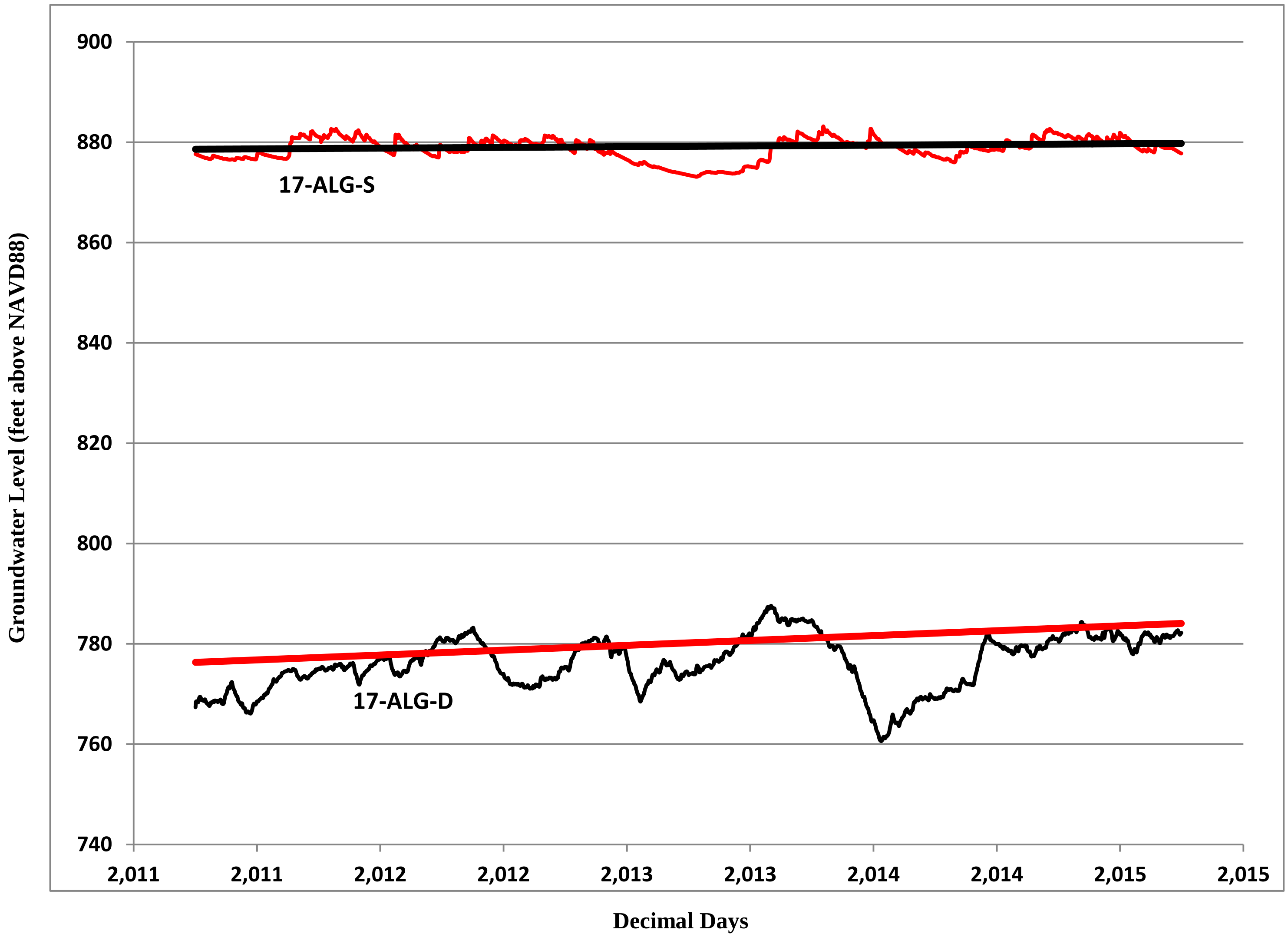

Figure 13 Combined 17-ALG-S and 17-ALG-D Hydrographs

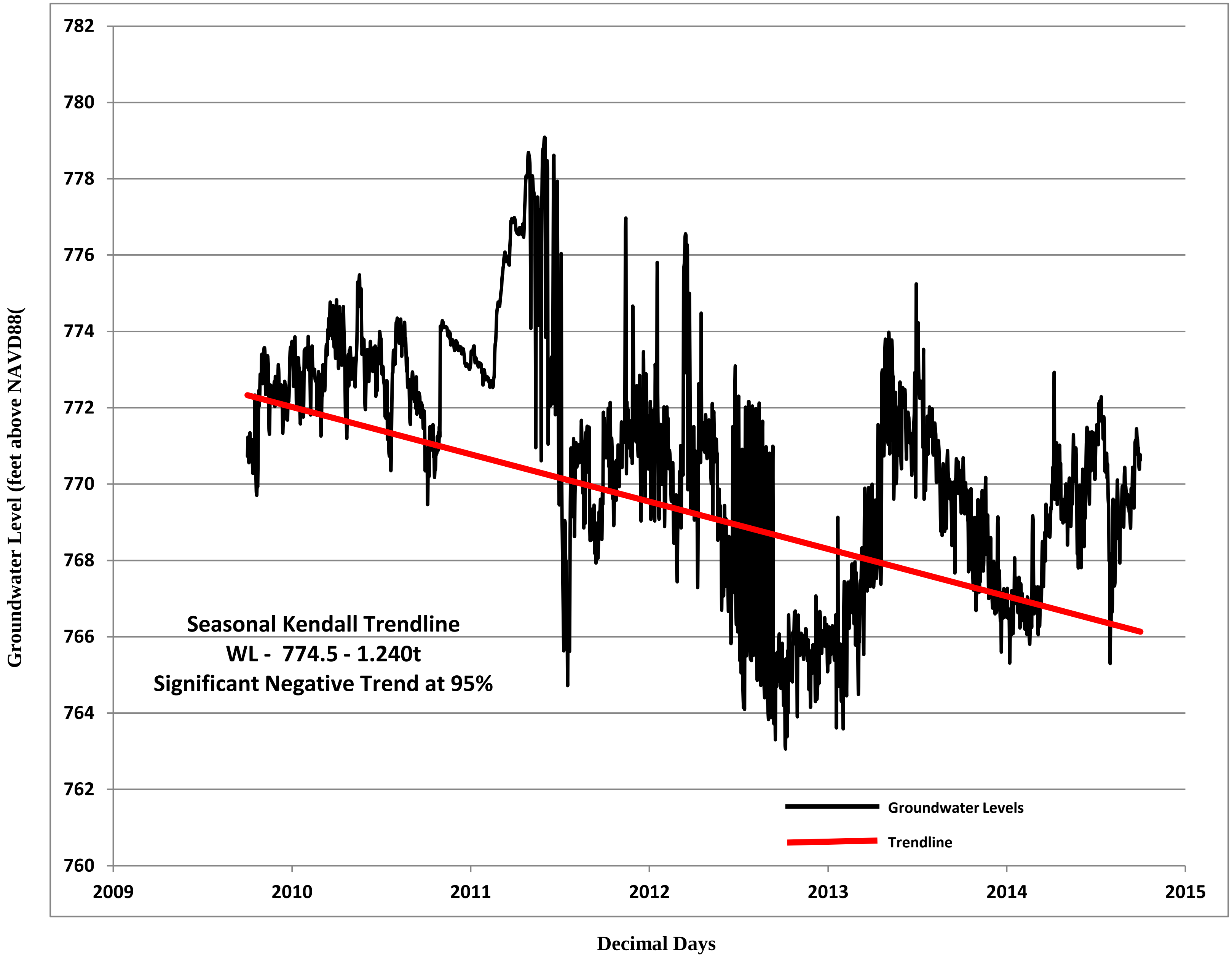

Figure 14 Monitoring Well 16-GRF-I Hydrograph

Period of Record: 100109 through 093014

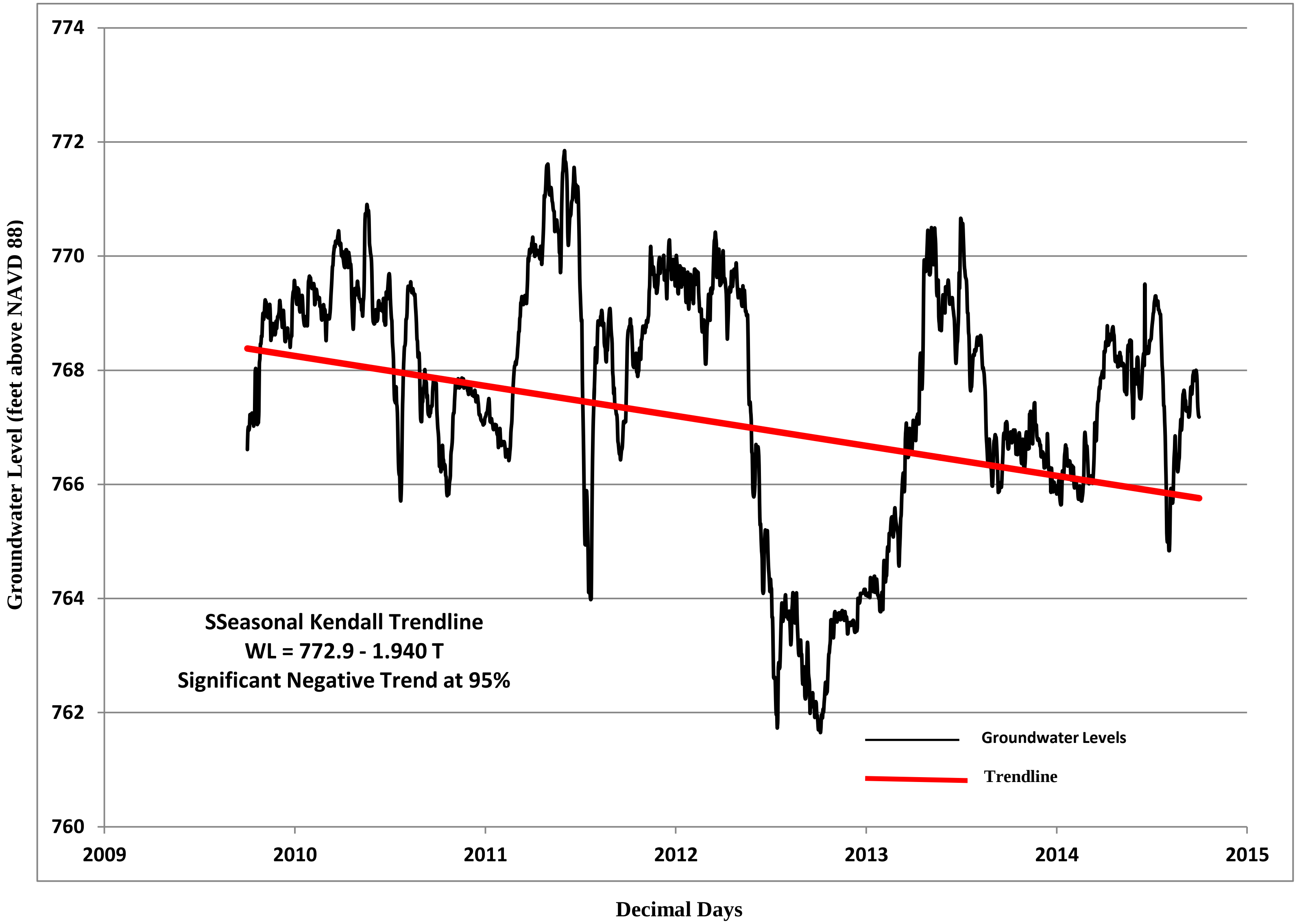

Figure 15 Monitoring Well 16-GRF-D Hydrograph

Period of Record: 100109 through 0939224

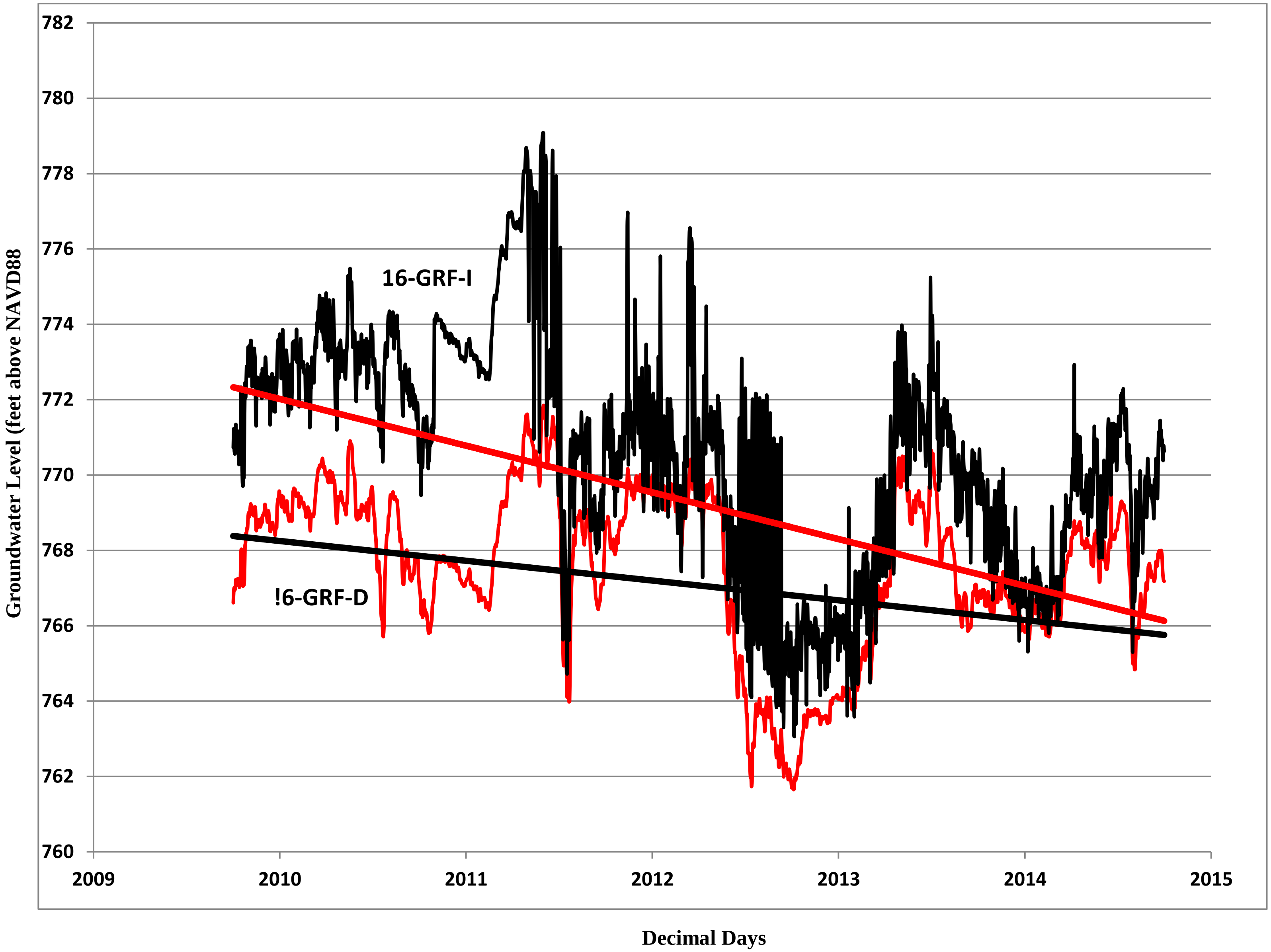

Figure 16 Combined 16-GRF-I and 16-GRF-D

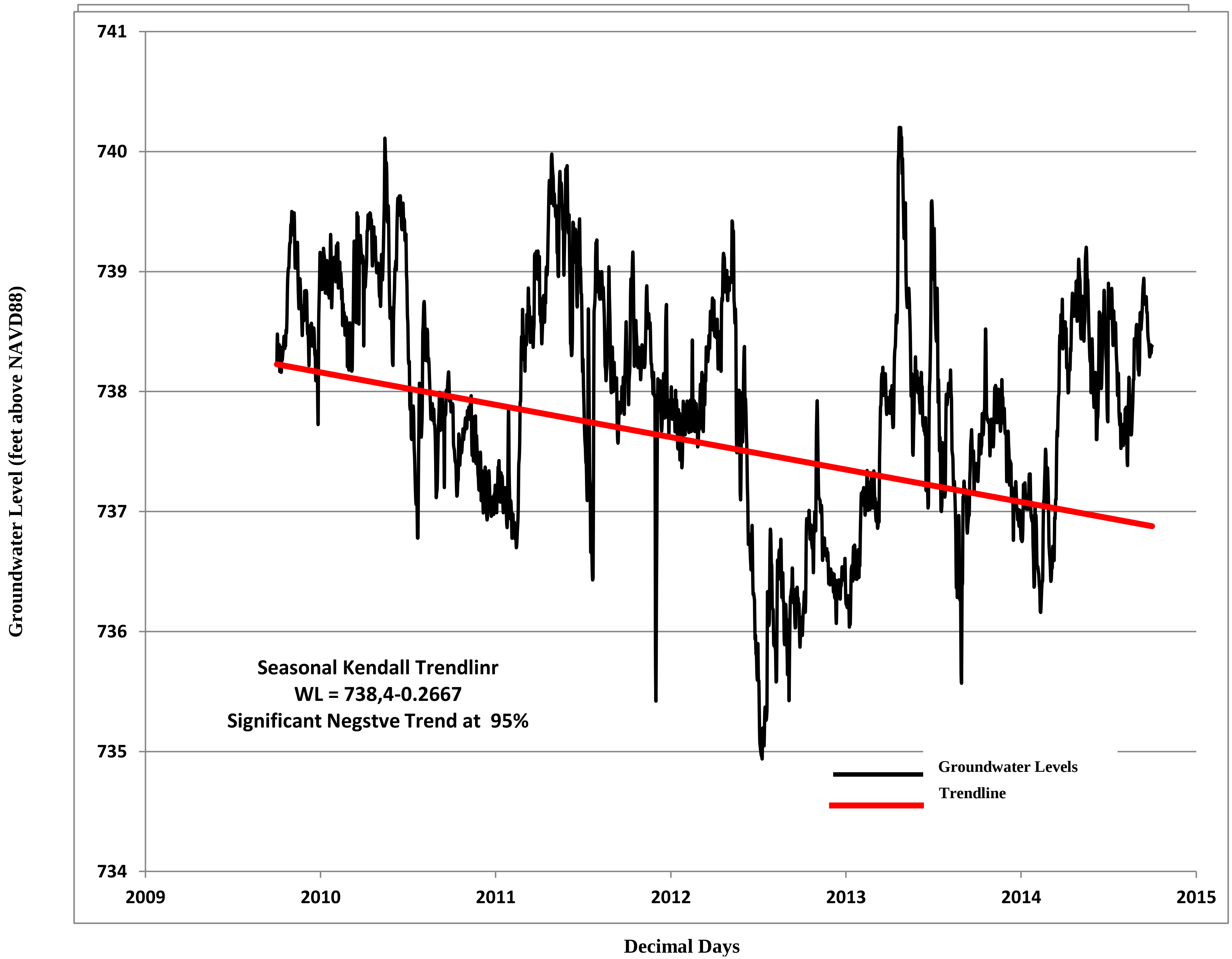

Figure 17 Monitoring Well 13-NUN-I Hydrograph

Period of Record: 100109 through 093014

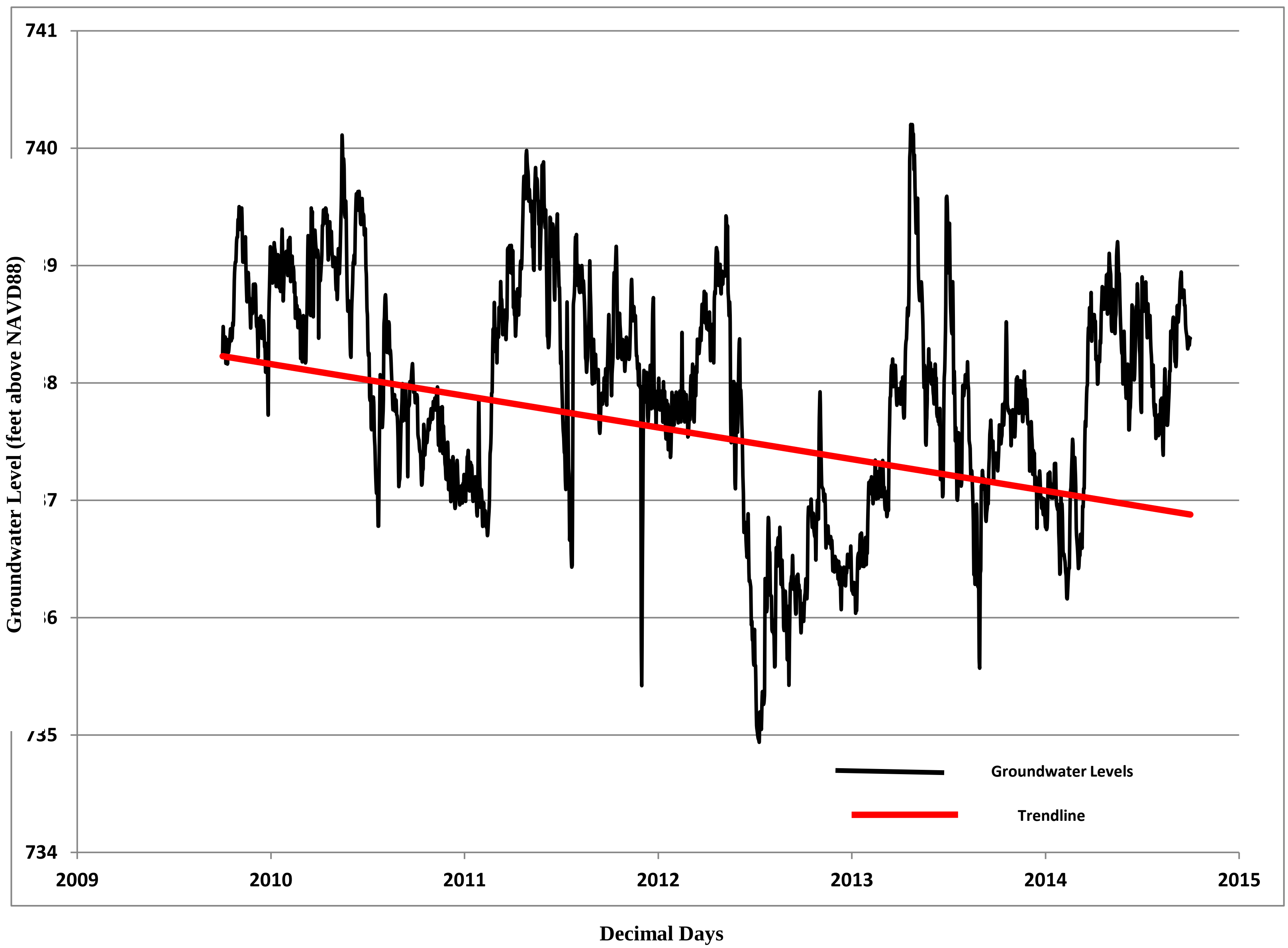

Figure 18 Monitoring Well 13-NUN-D Hydrograph

Period Of Record: 100109 through 093014

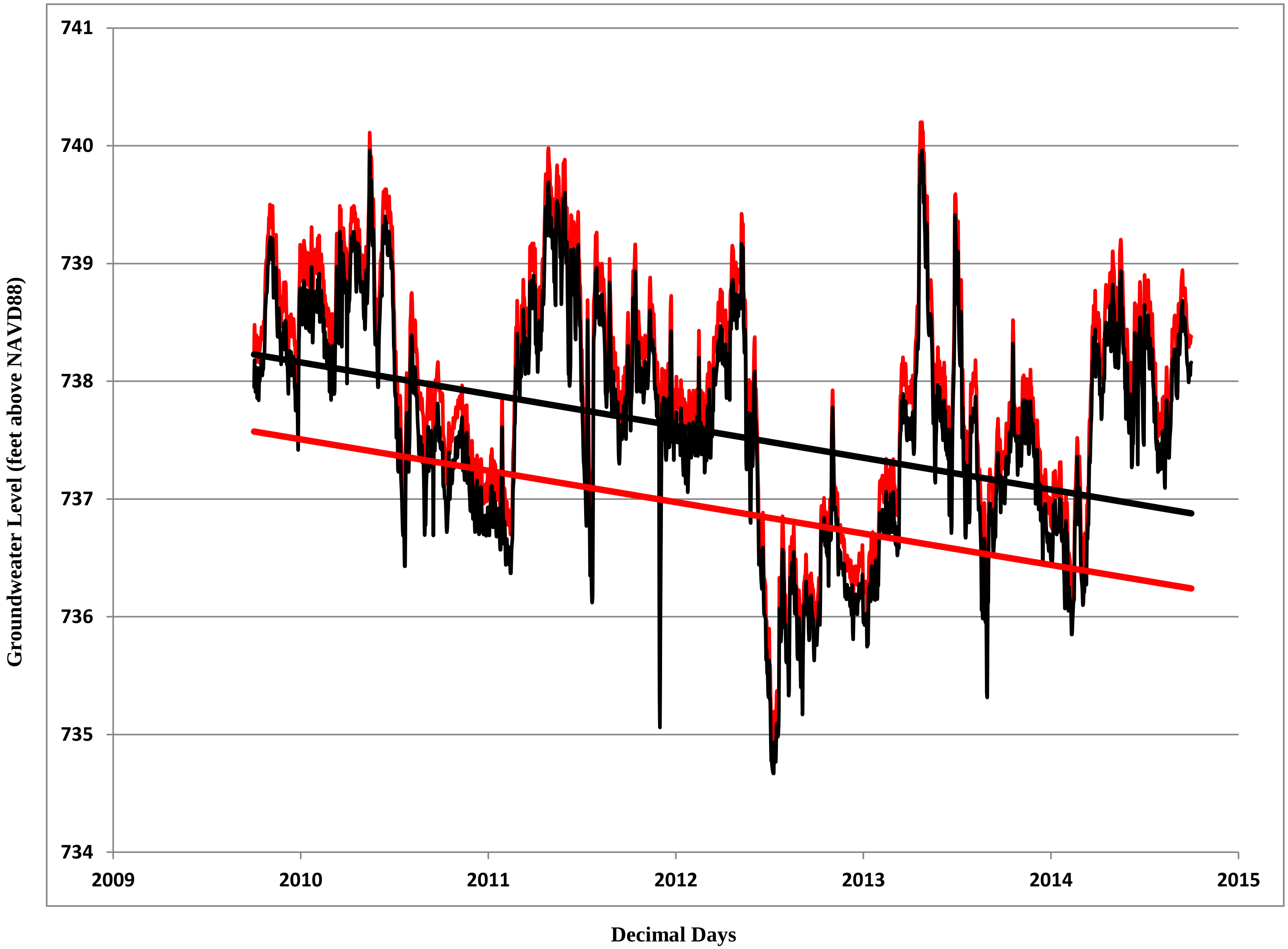

Figure 19 Combined 13-NUN-I and 13-NUN-D Hydrographs

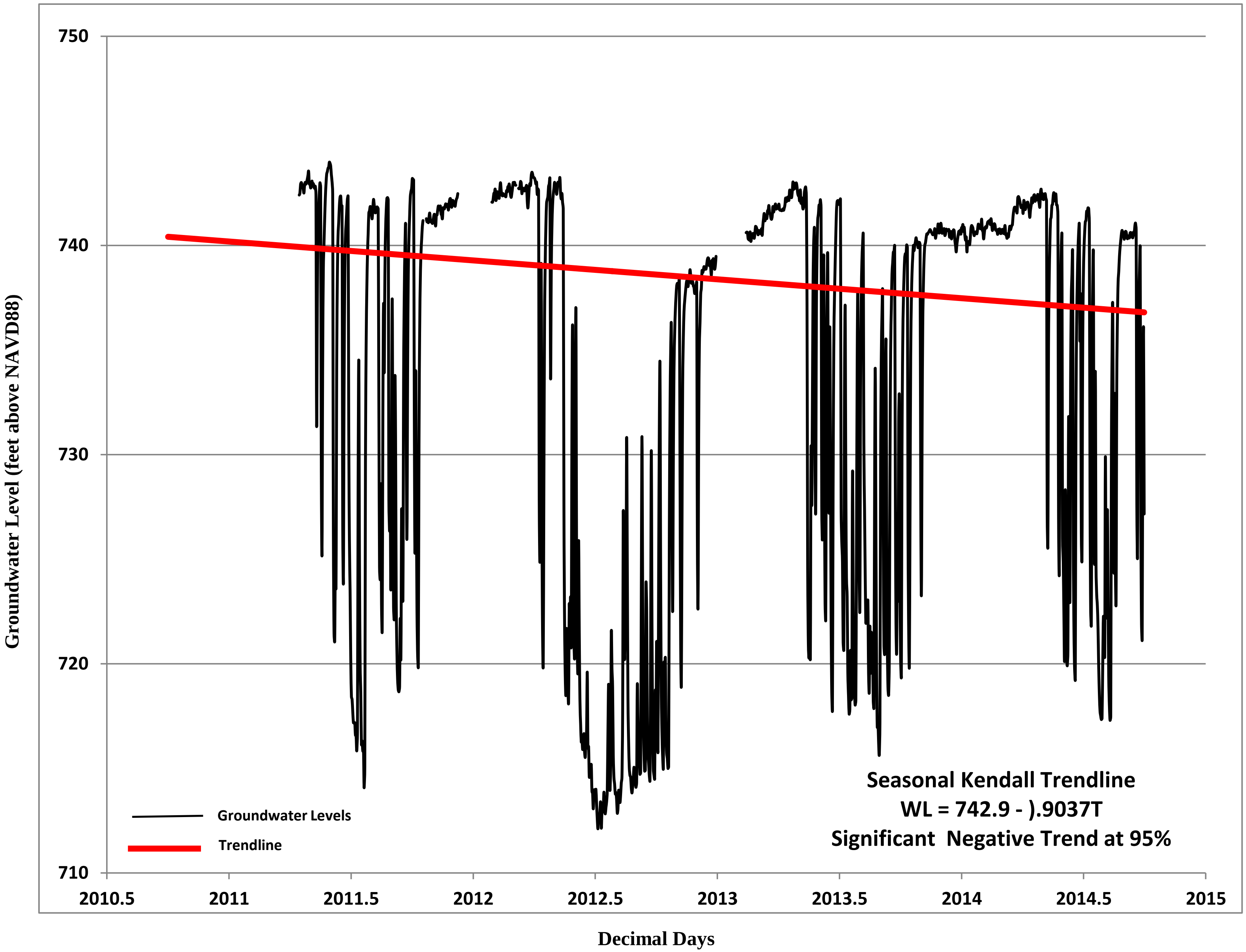

Figure 20 Monitoring Well WAUC-02-12 Hydrograph

Period of Record: 100109 through 093014

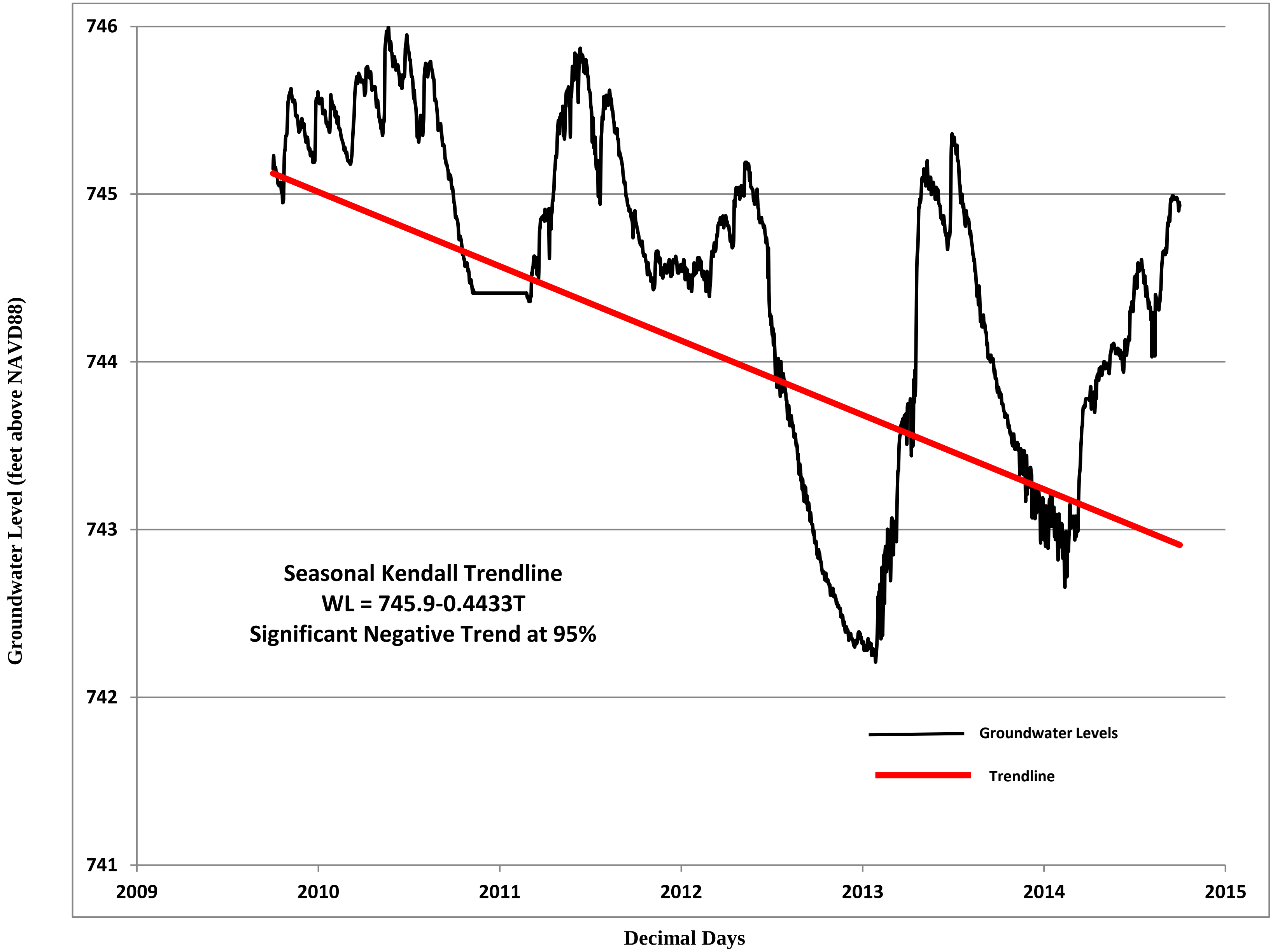

Figure 21 Monitoring Well WAUC-08-13 Hydrograph

Period of Record: 100109 through 093014

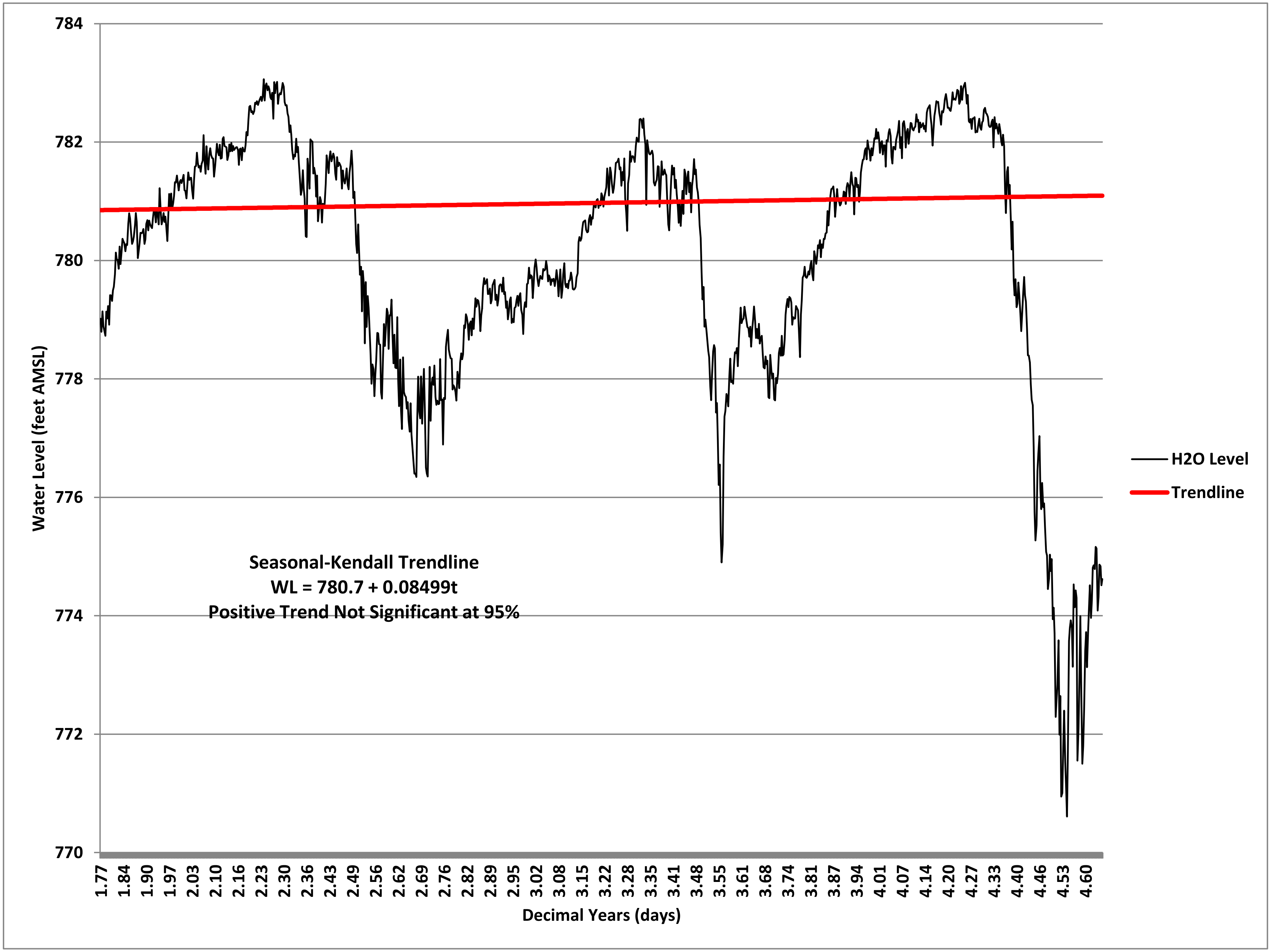

Figure 22 Barrington Hills Monitoring Well Hydrograph

Period of Record: 100809 through 093012

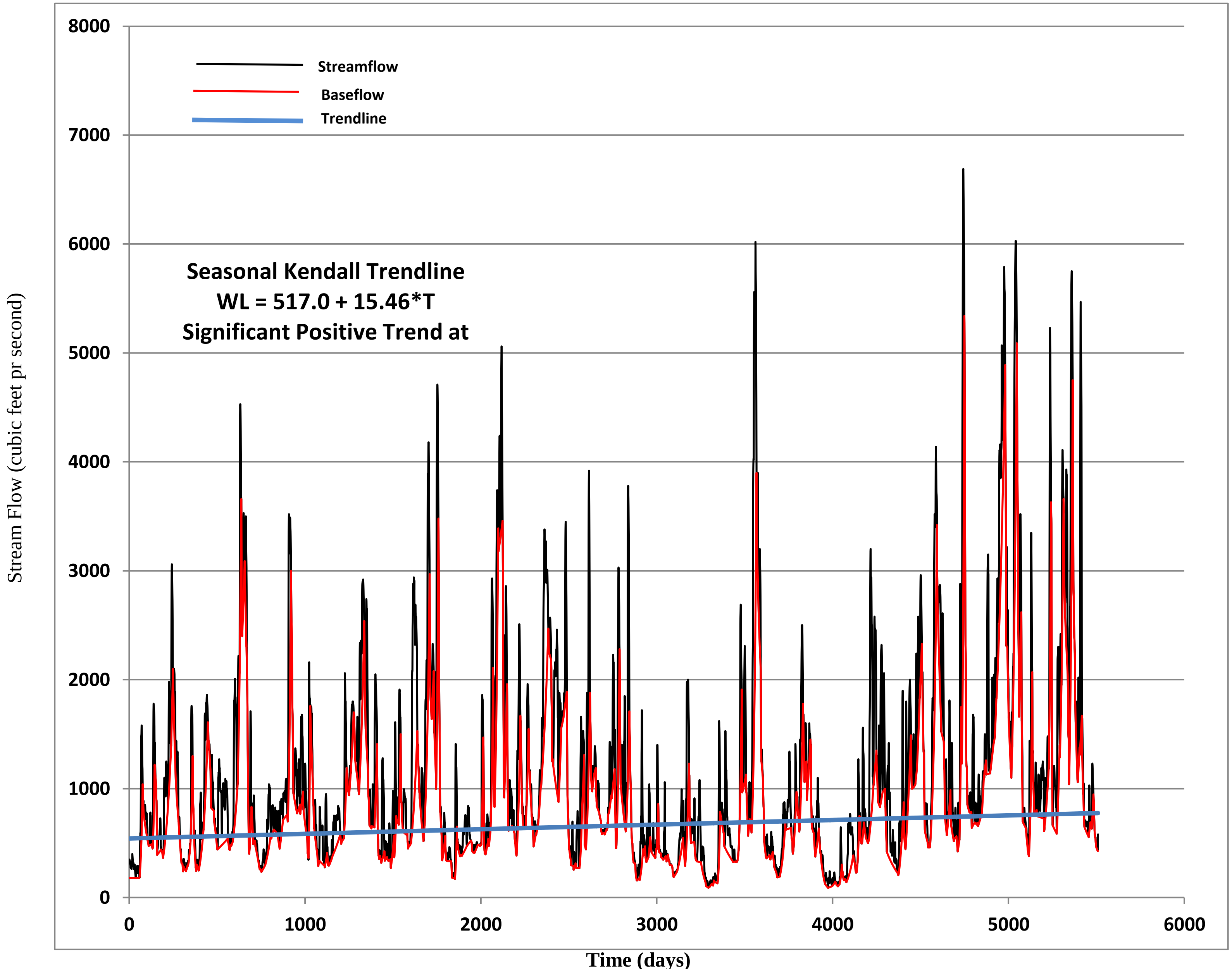

Figure 23 Fox River at Algonquin Stream Flow and Base-Flow Hydrographs

Period of Record: 100192 through 093014

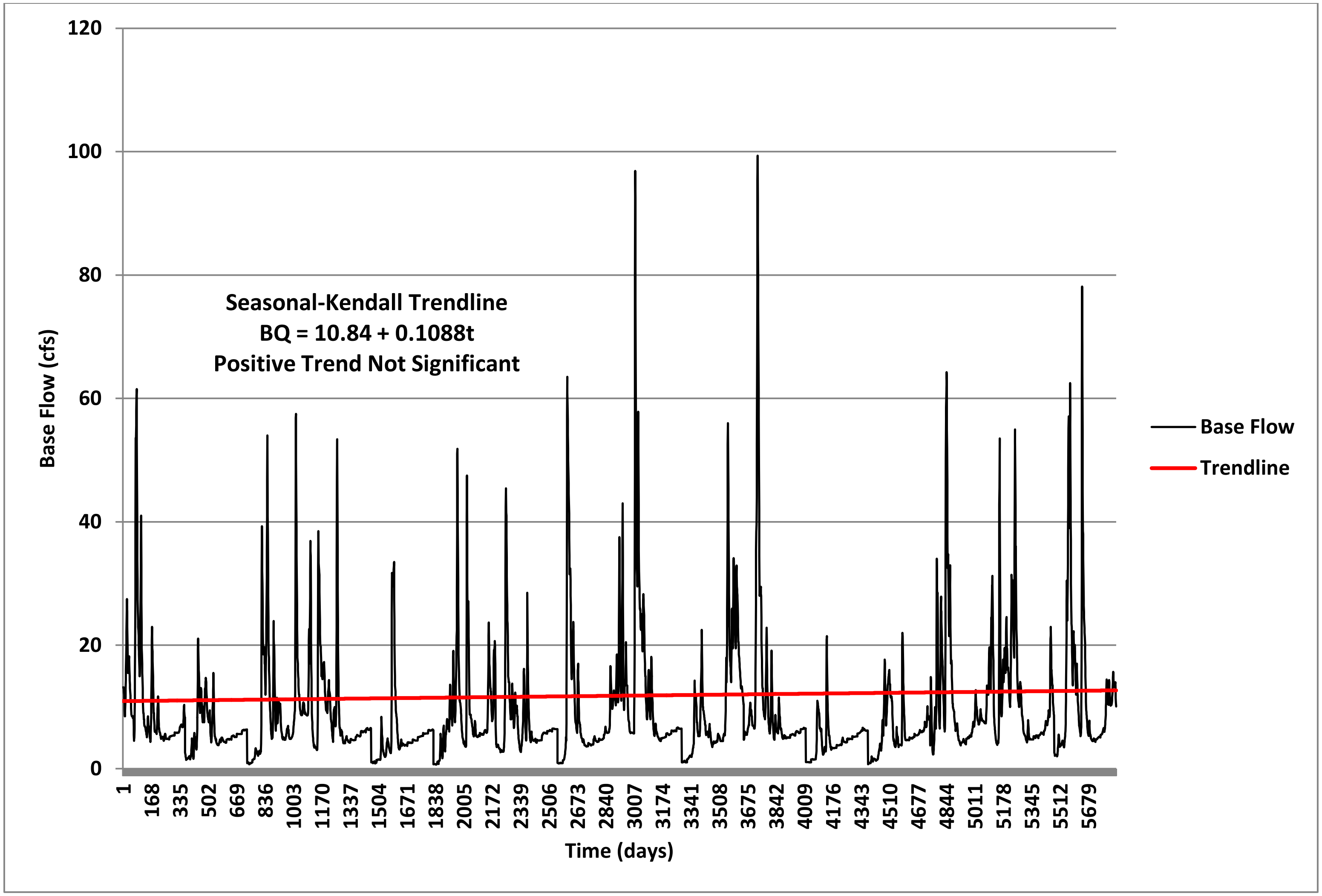

Figure 24 Poplar Creek Base-Flow Hydrograph with Trendline

Period of Record: 010197 through 123112

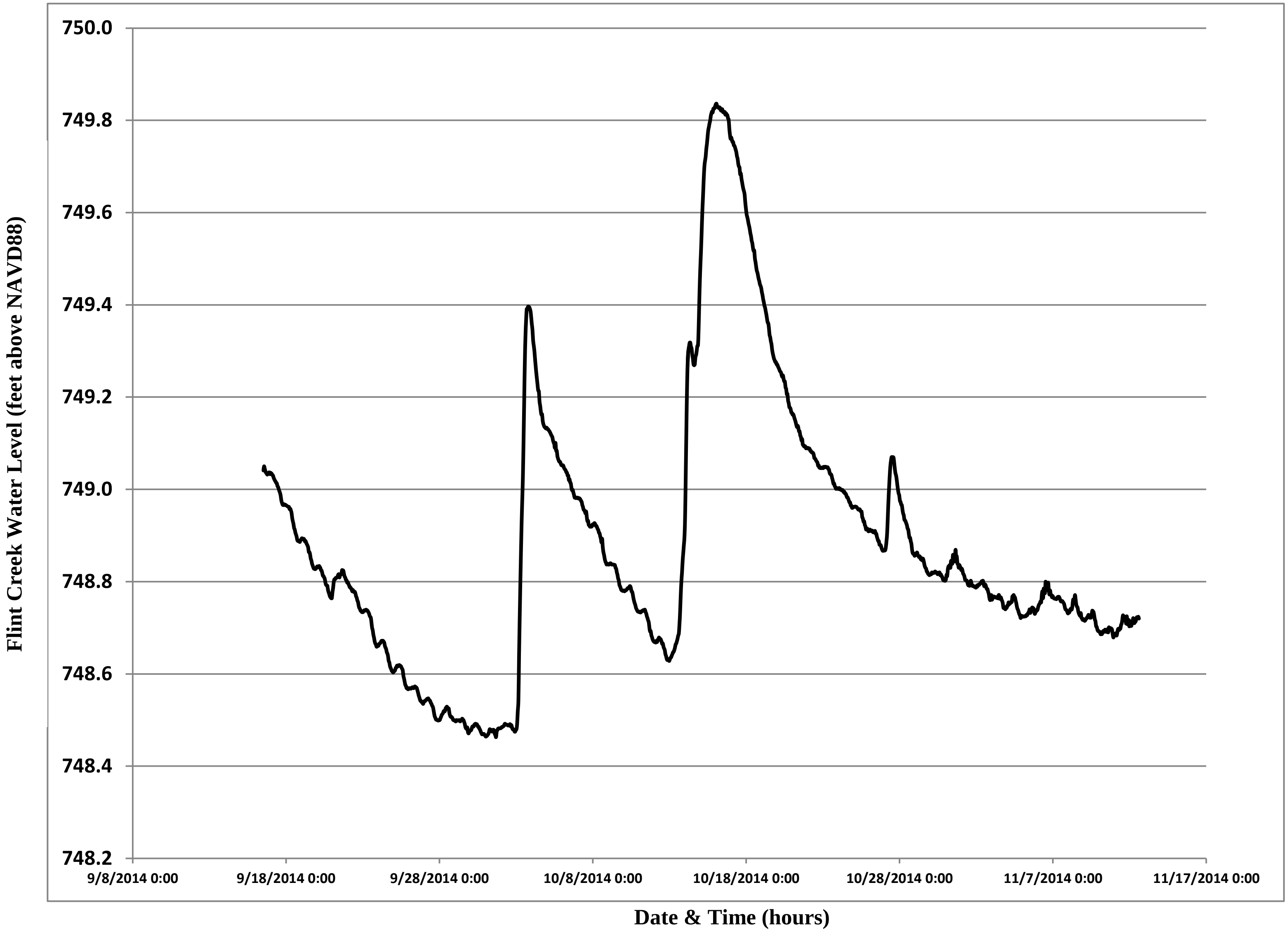

Figure 25 Preliminary FC3 Stream-Level Hydrograph

Period of Record: 091614 through 111214

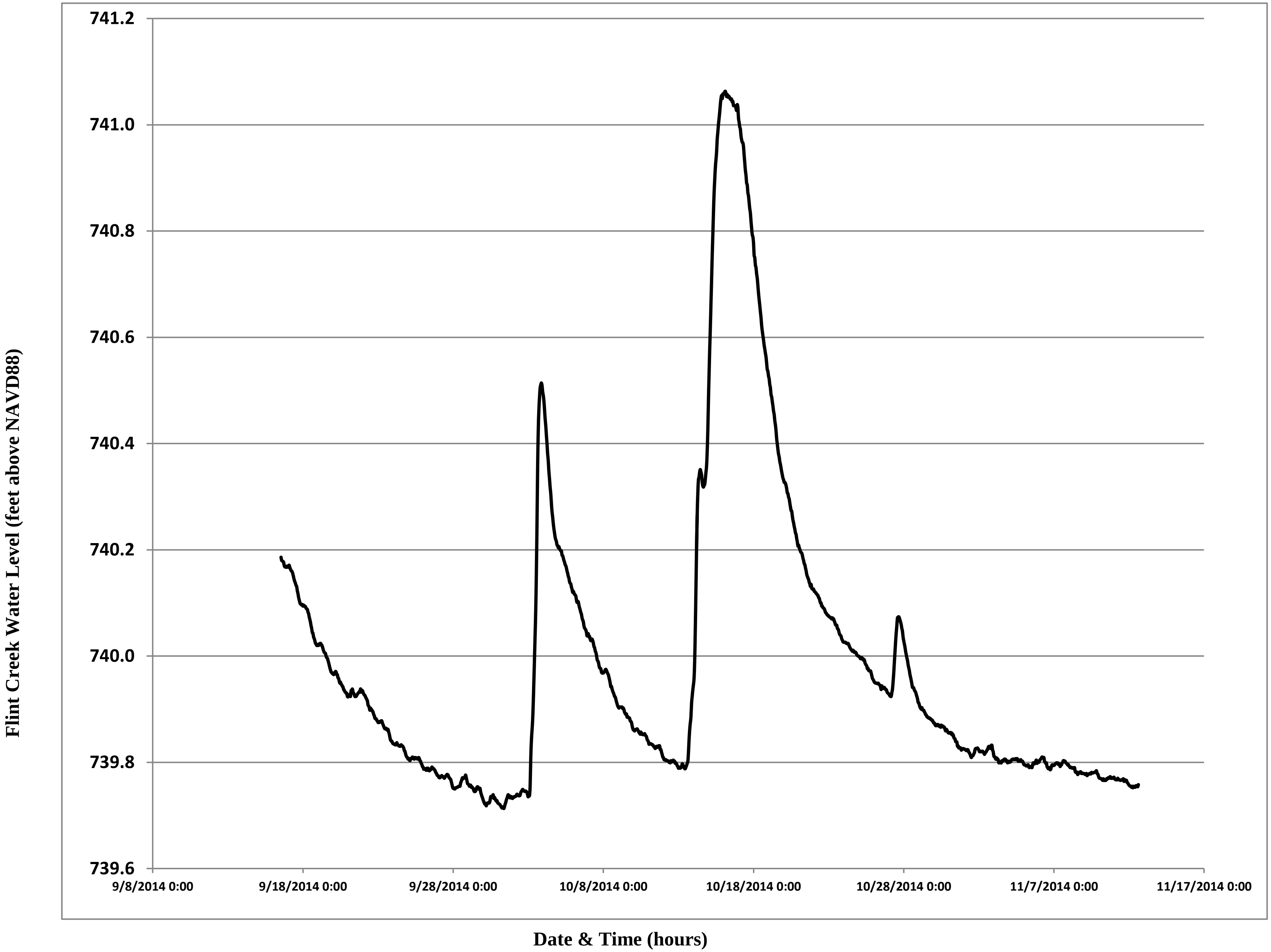

Figure 26 Preliminary FC5 Stream Level Hydrograph

Period of Record: 091614 through 111214

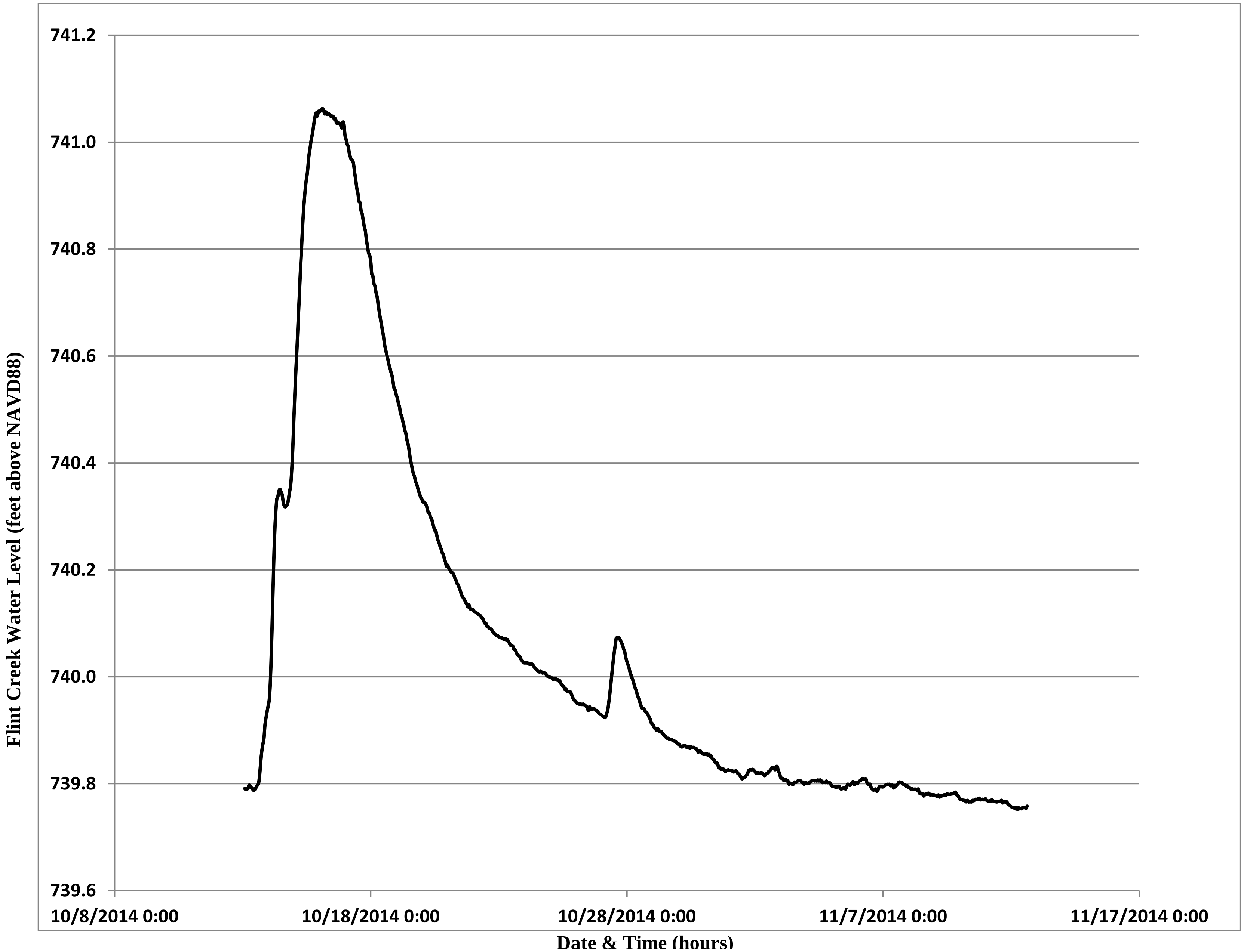

Figure 27 Example of Stormwater Hydrograph – Flint Creek at FC5

Period of Record: 101314 through 111214