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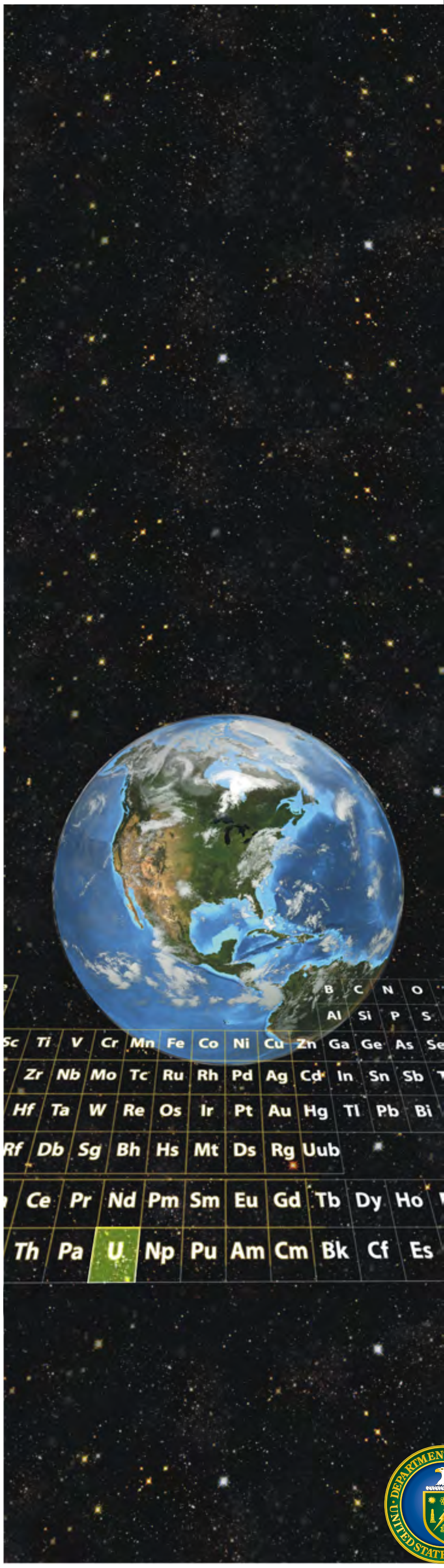

Preliminary Evaluation of the Trench 1 Collection Drain Floodplain Area of the Shiprock, New Mexico, Site

June 2011

Prepared for

U.S. DEPARTMENT OF ENERGY | Legacy Management

Cover Photo: Trench 1 Collection Drain on Floodplain

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Appendix B Data Quality Assessment of Specific Conductivity (SOARS Data)
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Abbreviations

AS&T	Applied Science and Technology
COC	contaminant of concern
DOE	U.S. Department of Energy
DTW	depth-to-water
ESL	Environmental Sciences Laboratory
ft	feet
ft msl	feet above mean sea level
g	grams
gpm	gallons per minute
HDPE	high-density polyethylene
LM	Office of Legacy Management
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter
mg/L	milligrams per liter
mS/cm	millisiemens per centimeter
ppm	parts per million
%meq/l	percent of total milliequivalents per liter
SOARS	System Operation and Analysis at Remote Sites
TDS	total dissolved solids
TOC	top of the well casing
UMTRA	Uranium Mill Tailings Remedial Action

Executive Summary

This investigation examines the effectiveness of the Trench 1 collection drain at the Shiprock, New Mexico, Disposal Site. The collection drain was installed in 2006 and had removed 16,746,300 gallons of contaminated groundwater from the floodplain by December 1, 2010. The collection drain and surrounding wells are monitored by System Operation and Analysis at Remote Sites (SOARS), a remote monitoring system that measures water level, temperature, and specific conductivity. A detailed assessment of SOARS data was conducted, and data that were inaccurate due to field-related interferences were omitted. SOARS was useful in assessing the performance of the collection drain as specific conductivity and water level readings allow for real-time monitoring of groundwater system behavior. Water levels show the effects of pumping, and specific conductivity correlates to uranium concentrations. The collection drain is performing as designed and is having an effect on contaminant removal and plume interception. An estimated 58.7 kilograms of uranium had been removed through pumping of Trench 1 by December 1, 2010.

This study showed that pumping at Trench 1 and two additional floodplain extraction wells creates a groundwater flow divide in the floodplain aquifer, with water on its respective sides migrating to Trench 1 and the extraction wells. Changes in pumping at Trench 1 and the extraction wells could affect the location of the divide, which in turn would influence movement of the contaminant plume in the aquifer. Further analysis of groundwater processes is recommended to determine whether the floodplain remediation system could be altered or amended in ways that would improve groundwater cleanup. Possible improvements include manipulation of pumping rates and times or adding an additional collection drain in the central area of the floodplain.

Further studies, including a holistic groundwater flow model, that make use of findings in this report are being conducted to prepare an assessment of the entire floodplain groundwater system. The SOARS monitoring system provides data collected on 5-minute intervals. These data provide a detailed display of responses of the groundwater table to pumping and non-pumping events. The responses of wells near Trench 1 and near the extraction wells 1089 and 1104 are dependent on aquifer properties. As such these data provide a valuable set of data with which to check the accuracy of flow modeling.

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1.0 Introduction

Using funding from the U.S. Department of Energy's (DOE's) Office of Legacy Management (LM) Applied Science and Technology (AS&T) subtask under Task Order 501, two collection drains at the Shiprock, New Mexico, Disposal Site (Trench 1 and Trench 2) were instrumented with equipment to monitor flow rates, water levels, and water chemistry. Data from these measurements have been collected in real time using LM's System Operation and Analysis at Remote Sites (SOARS) telemetry system. Wells near the Trench 2 system were instrumented in April 2006 to study the collection drain performance. The results of data collected through SOARS were used in a groundwater flow model that improved understanding of groundwater flow and transport in the portion of the floodplain near the Trench 2 collection drain (DOE 2009). Conclusions from the Trench 2 study included: (1) the collection drain was improving the groundwater cleanup effort and (2) the detailed SOARS-based monitoring system was useful for identifying and quantifying key groundwater system processes. To better understand the impacts of the remediation system in other areas of the floodplain, additional instrumentation was installed in wells near Trench 1 and near extraction wells 1089 and 1104. This report presents preliminary results of monitoring with these detailed systems.

The purpose of this report is to evaluate the quality of the data from SOARS and to conduct a preliminary evaluation of the performance of the Trench 1 collection drain using these data and semiannual groundwater monitoring data. Findings in this report will assist Shiprock site personnel who are currently using information collected from all components of the floodplain remediation system and data collected at numerous wells to conduct a "holistic" study of groundwater processes beneath the entire floodplain.

The evaluation presented in this report is based on data collected through SOARS. SOARS instrumentation was installed in December 2005 at two floodplain extraction wells (1089 and 1104), in April 2006 at Trench 1, and in October 2009 at additional wells near well 1089, well 1104, and Trench 1. The results of groundwater sampling conducted from February 2000 through September 2010 are also used.

The following items are evaluated in this report: (1) the effects of pumping on groundwater flow and direction, (2) the quantities of water and contaminant mass removed through pumping, (3) the efficiency and accuracy of the SOARS monitoring system, and (4) chemical changes in the groundwater plume.

2.0 Site Description

2.1 Site Background

The Trench 1 collection drain is part of the groundwater remediation system at the Shiprock, New Mexico, Disposal Site located in the northwest corner of New Mexico, about 28 miles west of the city of Farmington (Figure 1). A uranium-vanadium ore processing mill operated on the site from 1954 to 1968. By September 1986, all tailings and associated materials at the former millsite were encapsulated in a disposal cell built on top of the two existing tailings piles. The Shiprock site is divided into two distinct areas, the floodplain and the terrace; an escarpment forms the boundary between the two areas. Groundwater in the area of the millsite was

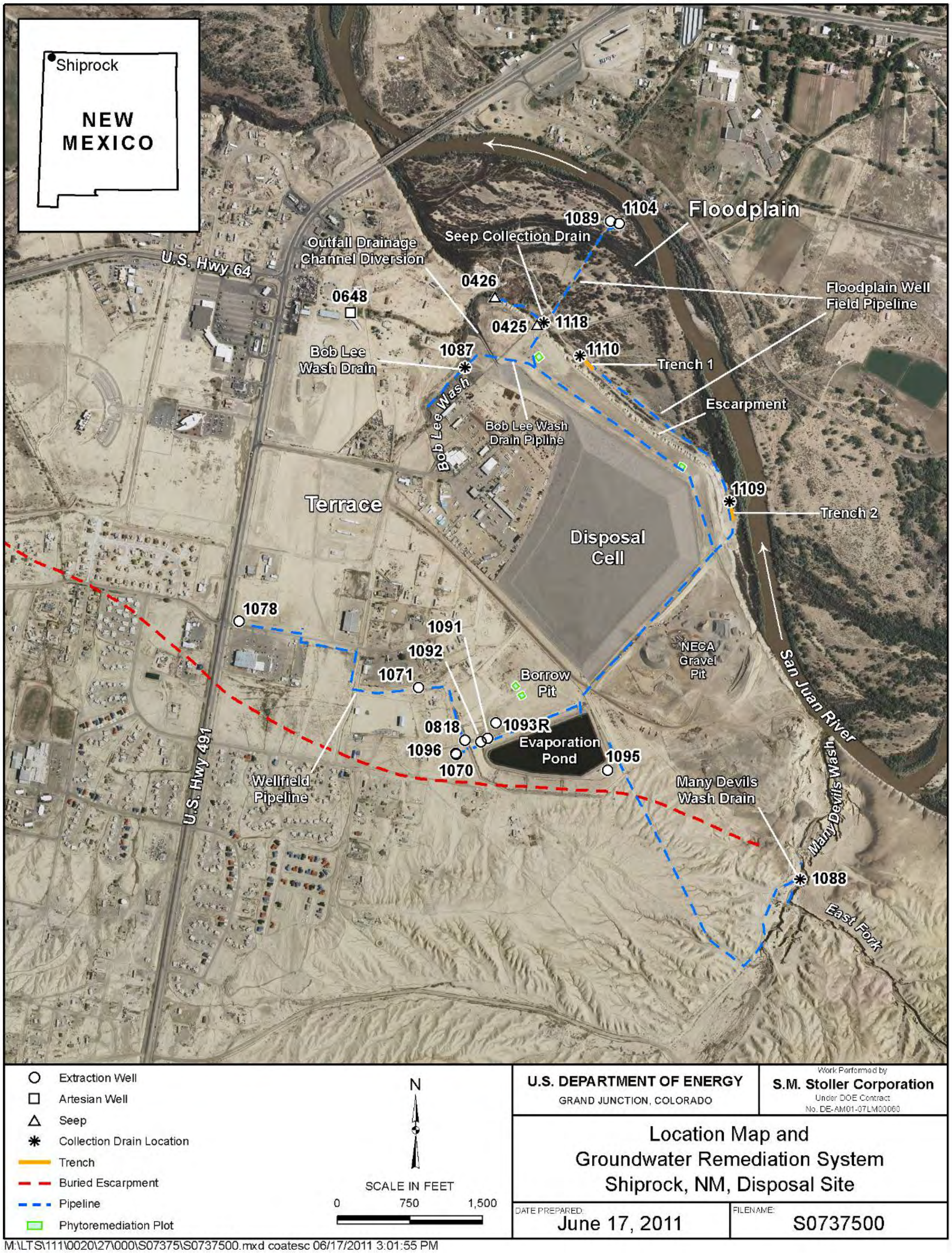

Figure 1. Site Location and Groundwater Remediation System

contaminated by uranium, nitrate, sulfate, and associated constituents as a result of the milling operations. The DOE Uranium Mill Tailings Remedial Action (UMTRA) Ground Water Project was responsible for characterizing and remediating groundwater at the Shiprock site (DOE 1996).

2.2 Site Conditions

Mancos Shale of Cretaceous age forms the bedrock underlying the entire site. A floodplain alluvial aquifer, consisting of unconsolidated medium- to coarse-grained sand, gravel, and cobbles, was deposited in former channels of the San Juan River over the Mancos Shale. The alluvium is up to 20 feet (ft) thick and the upper few feet of Mancos Shale below the alluvium is typically soft and weathered. The floodplain aquifer is hydraulically connected to the San Juan River.

Contamination (from milling operations and transient drainage from the disposal cell) in the terrace groundwater system subsequently flows to the floodplain groundwater system. Historically the most concentrated portion of the floodplain contaminant plume parallels the base of the escarpment from the narrow part of the floodplain near Trench 2 to the area near Trench 1 and continues north across the floodplain to the 1089 Area. The groundwater system in the northwest portion of the floodplain is influenced by surface water originating from artesian well 0648 and flowing down Bob Lee Wash (Figure 1). The northeast portion of the plume adjacent to the San Juan River is influenced by the river recharging the aquifer. The influence from surface water sources is evident by lower groundwater contaminant concentrations observed in these areas.

2.3 Remediation System

In March 2003, DOE initiated pump-and-treat remediation of groundwater at the Shiprock site as prescribed in the final Groundwater Compliance Action Plan (DOE 2002). The system included a network of extraction wells and drains, which pumped water to an 11-acre evaporation pond. The terrace extraction system consisted of eight extraction wells and two interceptor drains (Bob Lee Wash and Many Devils Wash); the floodplain extraction system consisted of two extraction wells (1075 and 1077). The rate of groundwater extraction during the first 10 months (March through December 2003) of operation was less than the design rate. The wells and interceptor drains were expected to produce 20 gallons per minute (gpm) but were only producing about 13 gpm. Additional extraction wells and collection drains were added from 2005 to 2007 to address the low extraction rate. The current terrace system consists of nine groundwater extraction wells, two collection drains (Bob Lee Wash and Many Devils Wash), and a terrace drainage channel diversion structure. The floodplain remediation system consists of two groundwater extraction wells (1089, 1104), a seep collection drain (1118), and two groundwater collection drains (Trench 1 and Trench 2). Figure 1 shows the site layout and the major components of the floodplain and terrace groundwater remediation systems. The current remediation system has improved the groundwater extraction rates. The average total flow rate to the pond from all sources as calculated in the SOARS system from December 1, 2006, through December 1, 2010, was approximately 28 gpm.

3.0 Methods

The study area consists of floodplain alluvial wells and surface locations. For this discussion, the wells have been divided based on location within the study area. The Trench 1 Area consists of the trench collection sump (1110), trench ports 1110-A and 1110-C, and wells 0615, 1105, 1111, 1112, 1140, and 1141. The 1089 Area consists of extraction wells 1089 and 1104; wells 0766, 0854, 1008, 1075, 1077, 1137, 1138, and 1139; and river location 0940. The remaining locations are the floodplain wells between the Trench 1 and 1089 areas (0618, 0619, 0622, 0623, 0625, 0768, 0775, 0779, 0792, 0793, 0798, 0853, 0857, 1009, and 1136), the river location 1205, and stilling well 0899. Figure 2 shows the study area on the floodplain.

3.1 Trench 1 Installation

The Trench 1 collection drain was installed in the spring of 2006. Trench 1 is a horizontal well constructed in the alluvial aquifer at the base of the escarpment (Figure 2). It was designed to intercept contaminated water migrating across the Mancos Shale escarpment, and to increase the extraction rate over the existing vertical wells. The collection drain is approximately 200 ft in length, 2 ft wide, and 15 ft deep with a 4-inch diameter perforated high-density polyethylene (HDPE) pipe on the bottom connected to a 12-inch diameter HDPE sump (Figure 3). Two 4-inch diameter HDPE riser pipes are connected to the bottom pipe and four 6-inch diameter access ports are set into the gravel layer of the trench.

The collection drain was constructed via the bio-polymer slurry excavation method in which guar gum slurry is used to keep the trench open during construction. The bio-polymer slurry consists of a solution of guar gum in water plus additives. Soda ash was added when the slurry was first mixed to raise the pH to discourage biological activity. Dazomet, an FDA-approved biodegradable biostat, was added to delay biological attack on the slurry, and lime was added to raise the pH while the slurry was in use. An enzyme breaker was added after the collection drain was installed to cause a biological breakdown of the slurry into low-molecular weight sugars and starches, which then dissolved into the groundwater. Calcium hypochlorite was also added to ensure complete breakdown of the Dazomet and to minimize the generation of anaerobic odors from microorganism decay.

The slurry was prepared with approximately 7,000 parts per million (ppm) guar gum, 2,500 ppm soda ash, and less than 300 ppm Dazomet in river water. The slurry was pumped into the open trench to prevent the trench walls from caving during construction. The HDPE pipe and sump were assembled outside of the trench, weighted with concrete pipe weights every 15 ft, and placed in the trench through the slurry starting with the sump and moving down the length of the trench. Gravel was placed in the trench through the slurry to within 3 ft of the ground surface and the remainder was backfilled with native alluvium. Ports (open pipes) were placed in the trench to convey the enzyme breaker into the trench. Enzyme breaker was added at 2 to 3 times the minimum but below the maximum of 200 ppm, and calcium hypochlorite was added at 100–200 ppm.

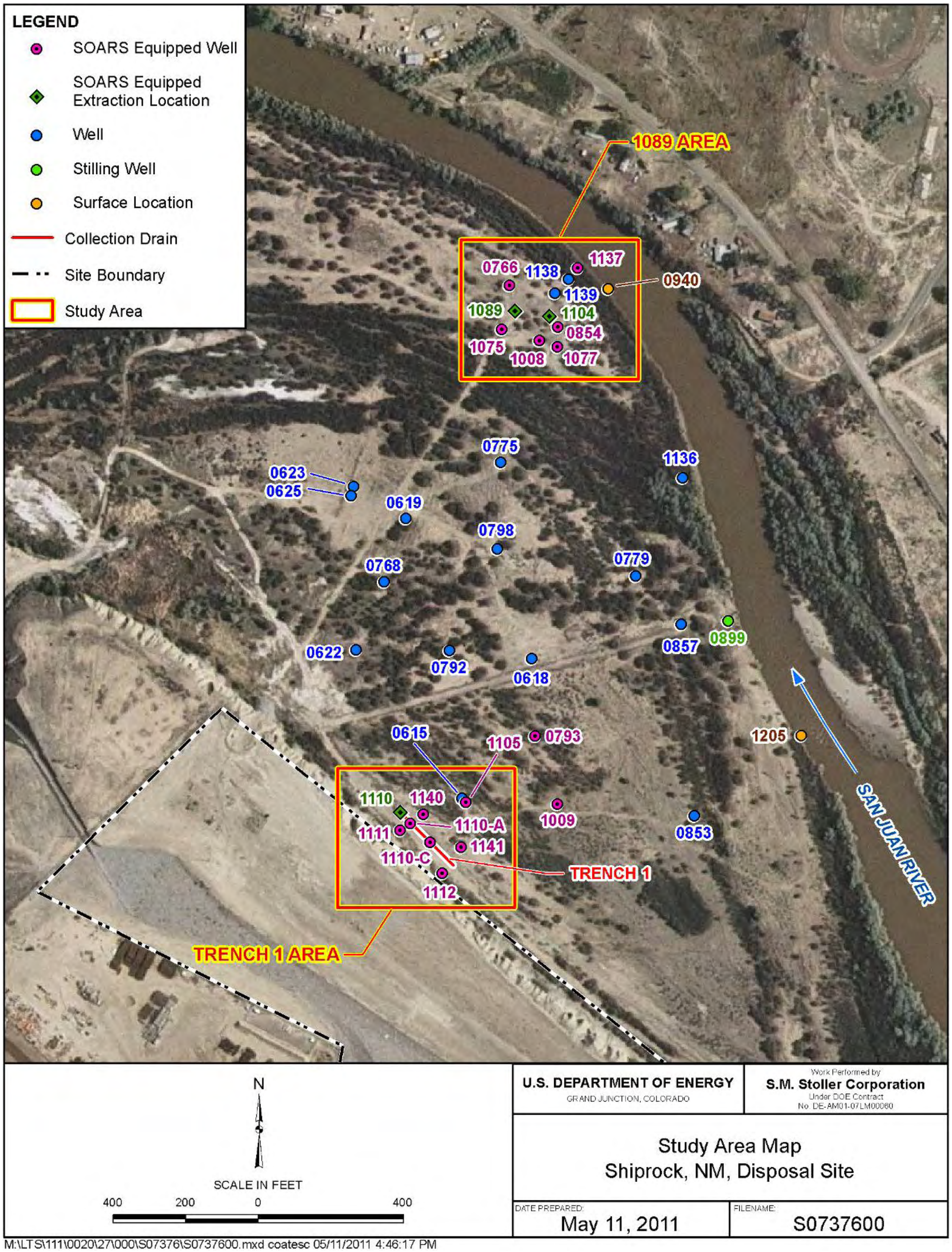

Figure 2. Study Area for the Trench 1 Collection Drain

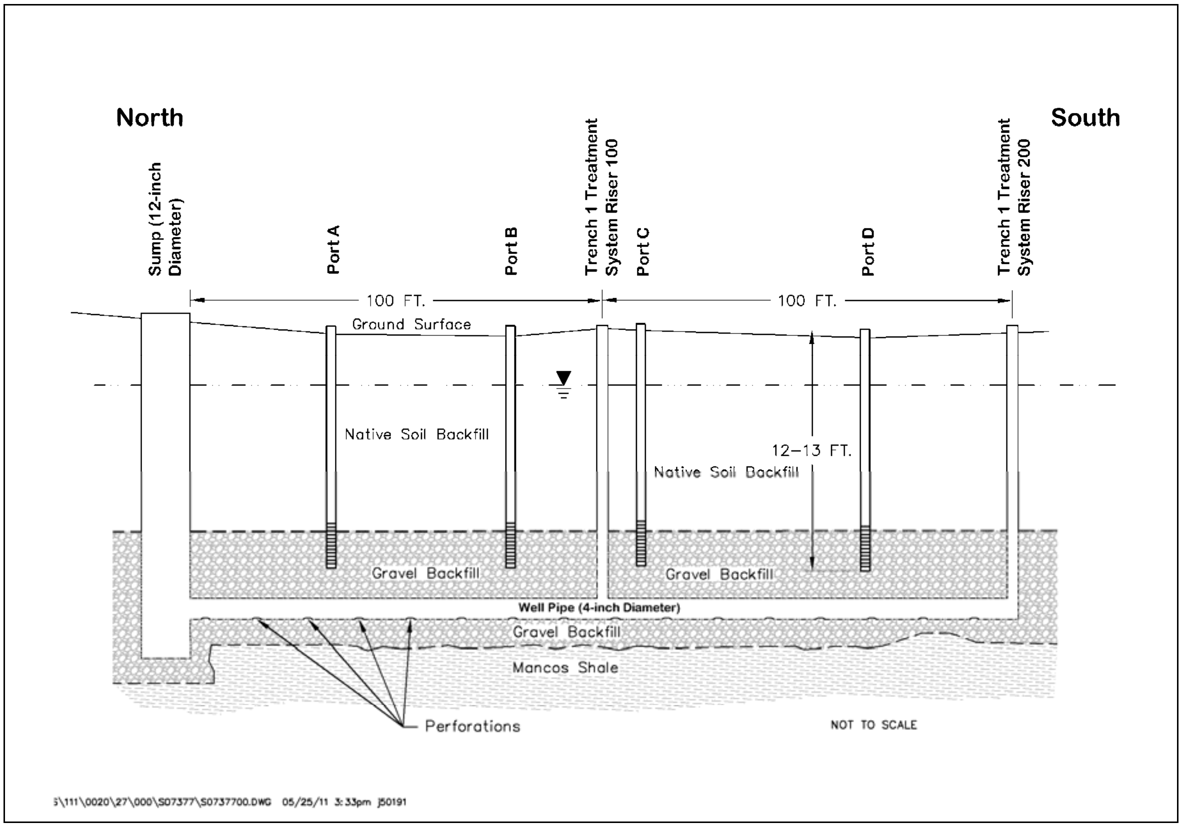

Figure 3. Cross-Section View of the Trench 1 Collection Drain

Trench 1 was designed to extract contaminated groundwater from the floodplain and pump it to an evaporation pond. It was placed in a highly contaminated portion of the plume to maximize the interception of contaminated groundwater. During pumping groundwater flows toward Trench 1 from surrounding areas. The efficiency at extracting contamination is based on the evolution of the groundwater system as pumping progresses. Observed groundwater levels in the study area indicate that surface water from the San Juan River enters the floodplain aquifer to replace some of the groundwater removed by Trench 1.

3.2 Extraction Well Installation

Wells 1089 and 1104 were constructed from 24-inch steel culverts placed in trenches dug by backhoe. Slots were cut into the culverts by torch to form the screened intervals for each well. Well 1089 was installed in June 2003 and added to the remediation system in place of extraction well 1075, which was performing poorly (DOE 2003). Well 1104 was installed in April 2005 to replace extraction well 1077. Wells 1075 and 1077 remain as monitoring wells.

3.3 SOARS System

The detailed SOARS-based monitoring program was installed to monitor flow and chemical changes in the groundwater system during operation of the extraction system. The goal was to track the groundwater flow and chemical changes to predict the long-term effects of pumping and to determine if additions to the extraction system would be beneficial.

Trench 1 locations (1110, 1110-A, 1110-C), Trench 1 Area wells (1105, 1111, 1112, 1140, 1141), floodplain wells (0793, 1009), extraction wells (1089, 1104), and 1089 Area wells (0766, 0854, 1008, 1075, 1077, 1137) are equipped with monitoring instruments (Figure 2). Data are typically collected at 5-minute intervals and automatically downloaded and graphed via SOARS. Specific conductivity, temperature, and water level measurements are made using in situ sensors placed in the wellbores below the water table. Appendixes A, B, and C provide a data quality assessment of the SOARS instruments.

3.4 Groundwater Analyses

Groundwater samples at the Shiprock site are currently collected semiannually. Historically, the number of locations sampled at the site has varied (Figure 4). This study focuses on groundwater samples collected in the study area and the surrounding floodplain in February 2000 as a baseline because a large number of locations were sampled at this time, and active remediation had not yet begun. Subsequent sampling events in March 2006 (just before the collection drains were installed) and in September 2010 are used for comparison to the baseline. March 2006 was chosen because it was after active remediation had begun, but before the collection drains were installed. September 2010 was chosen to represent current conditions because it was the last sampling event before Trench 1 was temporarily shut down in December 2010. Pumping at Trench 1 was discontinued on December 14, 2010, to establish baseline conditions for the ongoing holistic floodplain study.

The September 2010 data were analyzed separately for three areas within the study area. This approach allows for a more focused analysis of smaller data sets and allows for observation of trends and relationships within a smaller area of the floodplain. The first area is the 1089 Area, the second area consists of the wells in the floodplain that fall between the 1089 and Trench 1 areas (wells 0618, 0619, 0622, 0623, 0625, 0768, 0775, 0779, 0792, 0798, 0857, and 1136), and the third area is the Trench 1 Area plus monitoring locations east of the Trench 1 Area (wells 0793, 0853, and 1009, and river location 1205).

3.5 Groundwater Elevations

Groundwater elevation data were gathered from the SOARS system as well as manual measurements taken during sampling and for this evaluation. The groundwater flow directions were analyzed during different times and site conditions to show the effectiveness of the Trench 1 collection drain. Based on a comparison of manual measurements to the automated SOARS measurements, water elevations are typically accurate to within 0.05 ft (Appendix A). Groundwater elevations are measured from the top of the well casing (TOC). Table 1 shows the TOC elevations used in this study.

Table 1. Top of Well Casing (TOC) Elevations Used in This Study

Well	TOC (ft)	Well	TOC (ft)
0615	4892.23	1009	4892.1
0618	4891.51	1075	4893.06
0619	4892.19	1077	4893.8
0622	4890.06	1089	4891.9
0623	4891.19	1104	4891.95
0625	4891.23	1105	4892.4
0766	4892.55	1110	4891.11
0768	4892.33	1110-A	4889.08
0775	4892.2	1110-C	4888.31
0779	4893.86	1111	4889.85
0792	4891.52	1112	4890.01
0793	4891.05	1136	4892.47
0798	4891.55	1137	4891.3
0853	4891.41	1138	4891.48
0854	4890.09	1139	4890.44
0857	4894.02	1140	4891.53
1008	4890.8	1141	4892.48

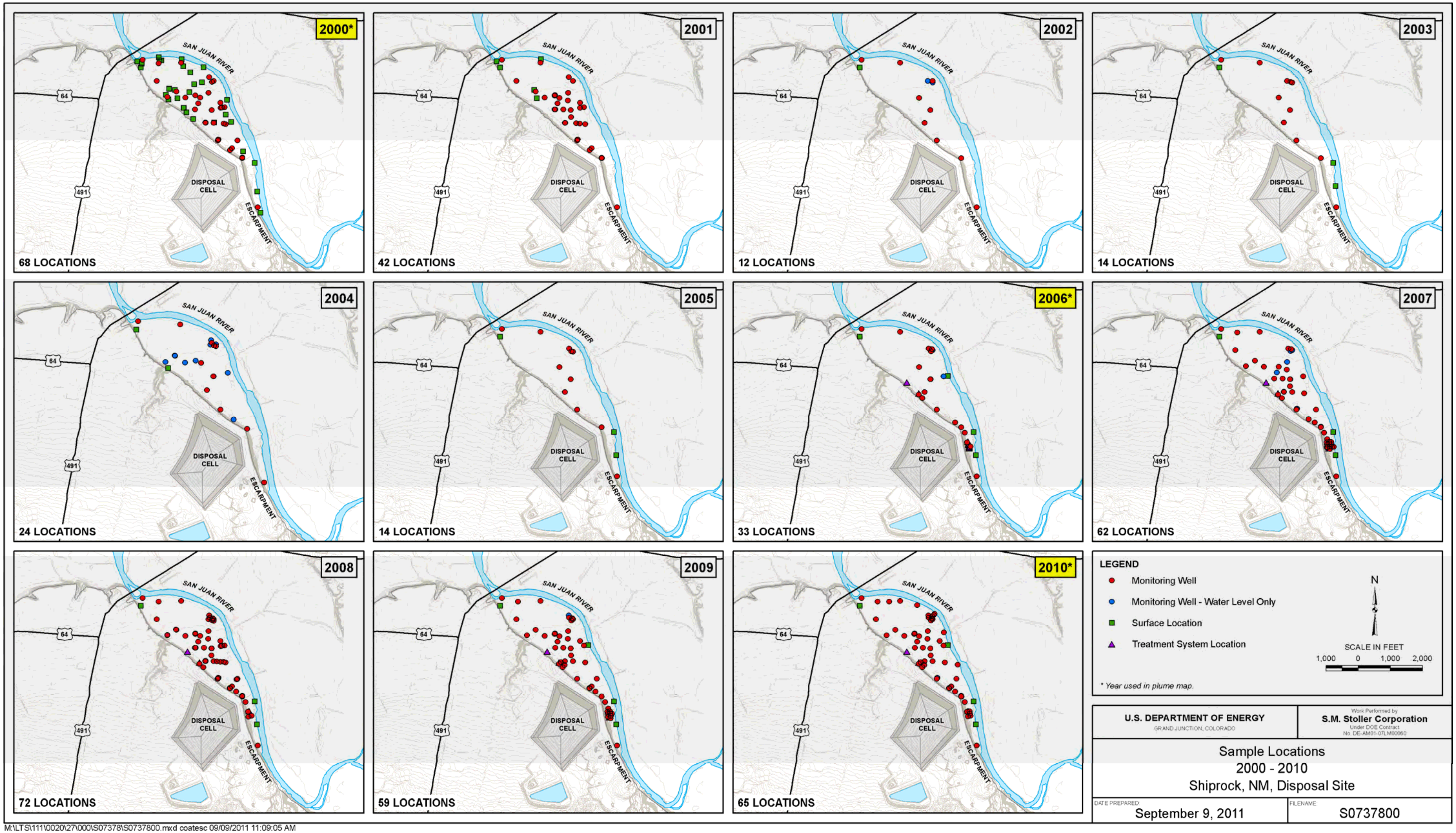

Figure 4. Floodplain Sampling Locations

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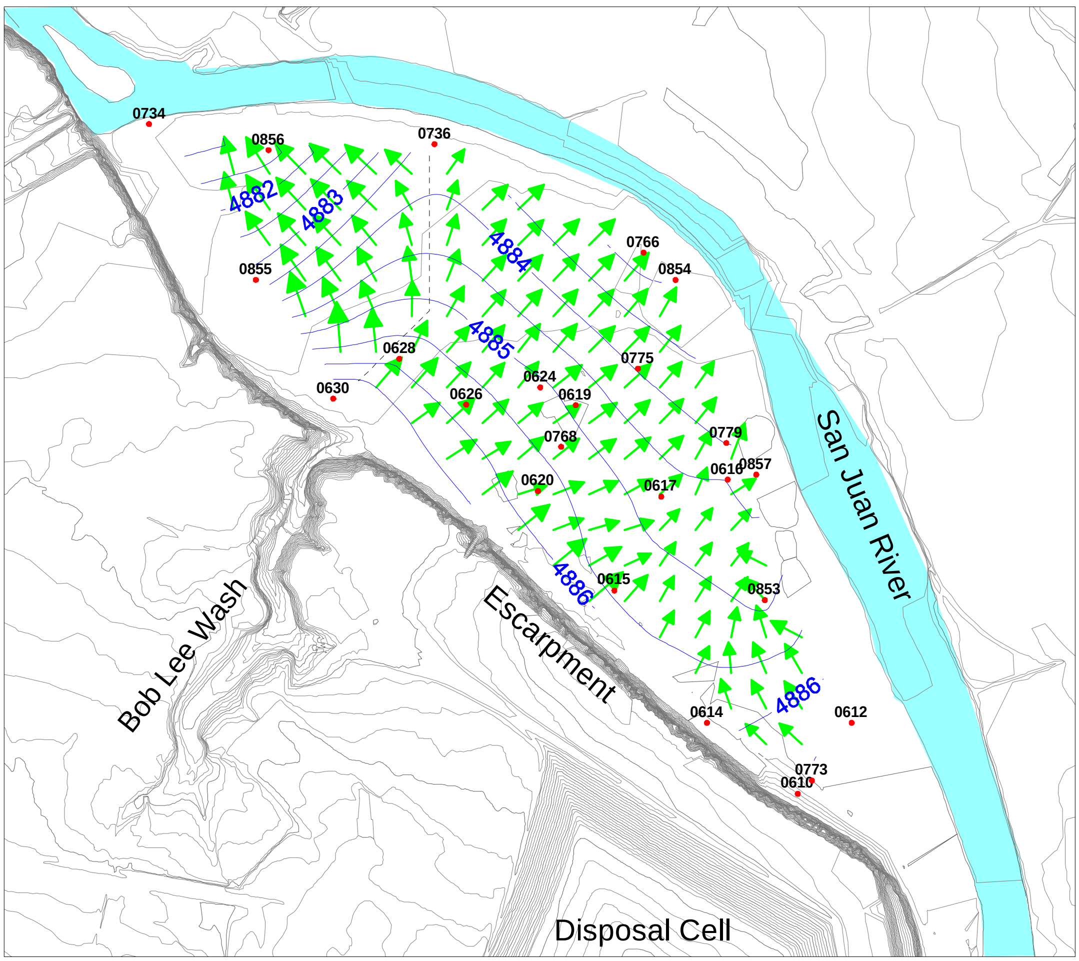
4.0 Results

4.1 Groundwater Flow

Groundwater flow direction was determined with Surfer software using the natural neighbor gridding method and water level elevations in the wells. Figure 5 shows groundwater flow directions in the floodplain based on water levels from the February 2000 sampling event. This shows the groundwater flows in the floodplain before active remediation began. Groundwater flows north between the escarpment and the river near well 0614 and then flows northeast away from the escarpment toward the river north of the disposal cell. Groundwater north of the mouth of Bob Lee Wash flows radially toward the river. Division of the flow between northeast and northwest is observed directly south of well 0736 (see the dashed line in Figure 5). This suggests that a groundwater divide occurs along a groundwater ridge in this area. However, such a divide might just be a result of the contouring method as no groundwater level data were available for the mapped ridge area.



Notes:
Dashed line indicates position of a perceived groundwater divide.
Groundwater flow originates at arrow tails.

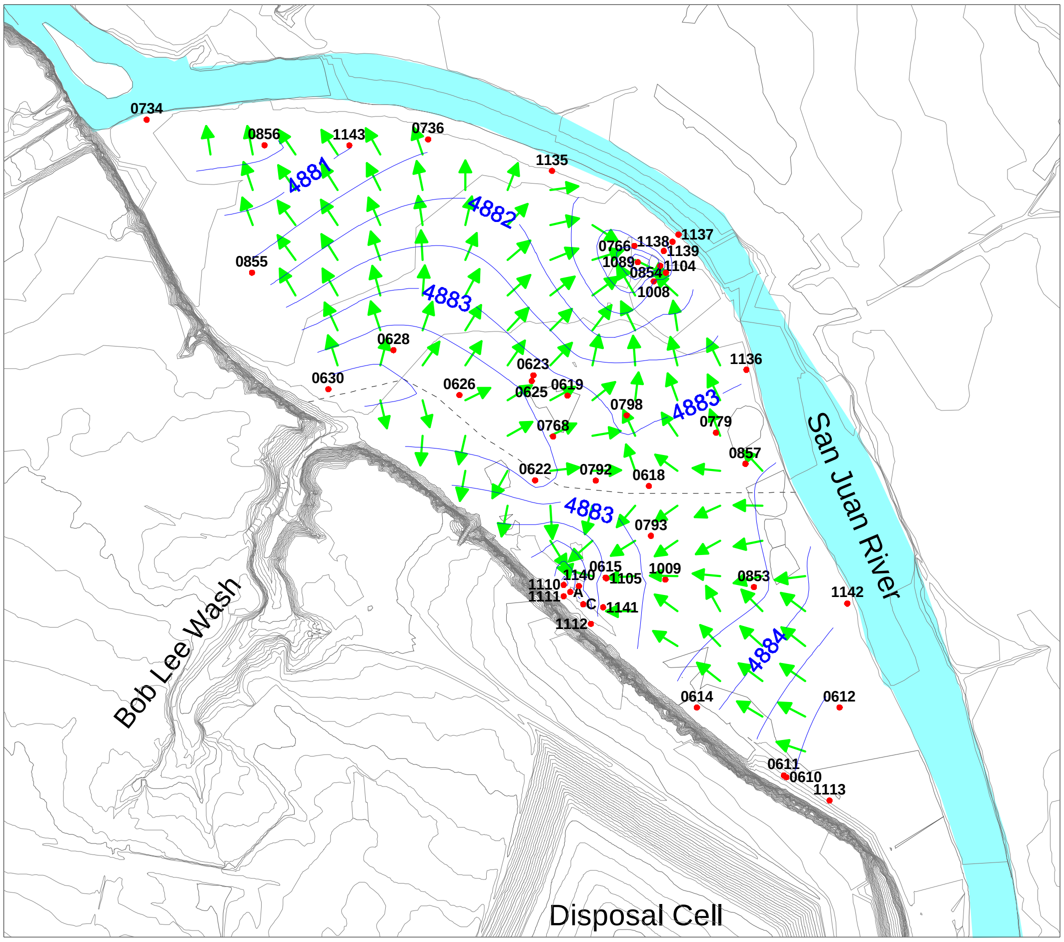
Figure 5. Groundwater Flow Baseline Conditions February 2000

Figure 6 shows the groundwater flow direction in the floodplain based on the September 2010 sampling as well as on measurements from SOARS. Wells 1089 and 1104 (in the 1089 Area) and Trench 1 were all pumping at this time. There is a northwest-to-southeast flow divide on the floodplain (see the dashed line in Figure 6). Water north of the divide flows toward the 1089 Area or northwest to the river and water south of the divide flows toward Trench 1. The perceived flow divide discussed earlier for the area located north of the mouth of Bob Lee Wash in 2000 (Figure 5) is less apparent in the groundwater flow patterns illustrated in Figure 6. This observation appears to stem partly from the fact that water-level data were available from more wells than were present in 2000 and partly from the tendency of the pumping in the 1089 Area to alter flow patterns south of well 0736. Regardless, as shown in Figure 6, a large amount of the groundwater originating near the mouth of the wash continues to flow north and northwest toward the river, thereby avoiding capture by pumping at either Trench 1 or wells 1089 and 1104. The opposing flow patterns on either side of the flow divide illustrate the respective areas of influence for Trench 1 compared to wells 1089 and 1104. Wells 1089 and 1104 seem to draw in water from both the mouth of Bob Lee Wash and nearby parts of the San Juan River. Pumping at Trench 1 also pulls in groundwater from the wash mouth and the river, but the river reach affected by the trench is located farther south and upstream of the river reach that is impacted by pumping at wells 1089 and 1104. It would be beneficial to test if Trench 1 has the capacity to draw in water from north of the flow divide shown in Figure 6 when the 1089 Area extraction wells are not pumping. If it could be shown that Trench 1 has an effect on the plume further out on the floodplain, that could alleviate the need for pumping at well 1089 and well 1104, which would also reduce pumping-induced river losses.

4.1.1 Pumping and Non-Pumping Conditions

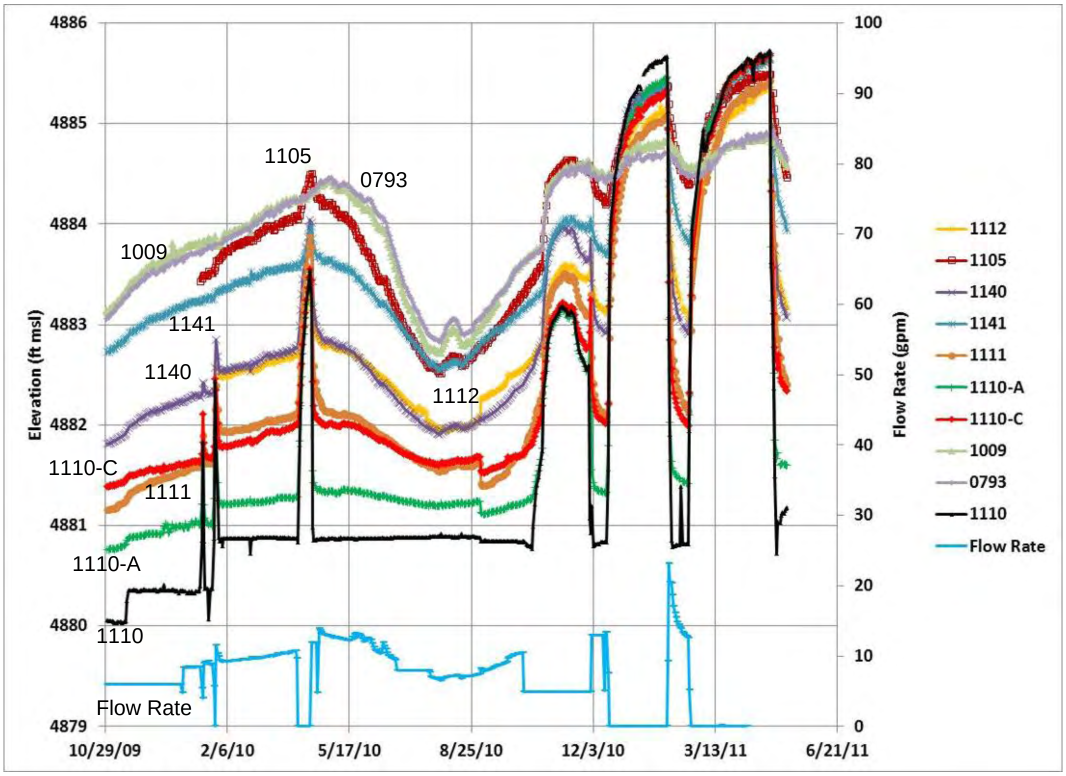
During the period from September 2009 through April 2011, pumping from Trench 1 was interrupted on six occasions, either intentionally or due to equipment malfunctions. The groundwater system changed substantially during the relaxation periods, as indicated by the response of groundwater elevations collected by the SOARS system on 5-minute intervals. The responses were likely dictated by (1) the hydraulic conductivity distribution in the aquifer and (2) the nature of boundary areas (including the elevations of the San Juan River). This section presents the groundwater elevation data from wells near Trench 1 and discusses the effects of the six relaxation periods, which ranged from 21 hours to 55 days (Figures 7 through 13). This information will be critical for optimizing the extraction system and for developing the holistic representation of the groundwater flow system.

The greater detail provided by the SOARS system (Figure 7) is evident when compared with the occasional manual measurements made during routine sampling (Figure 8). However, the data provided during routine sampling cover a much longer time period and provide information about the system prior to the installation of Trench 1. During the last relaxation period, which lasted 67 days ending April 27, 2011, the groundwater elevations in wells 0793 and 1009 (Figure 7) nearly regained their pre-pumping (2000) levels (Figure 8).



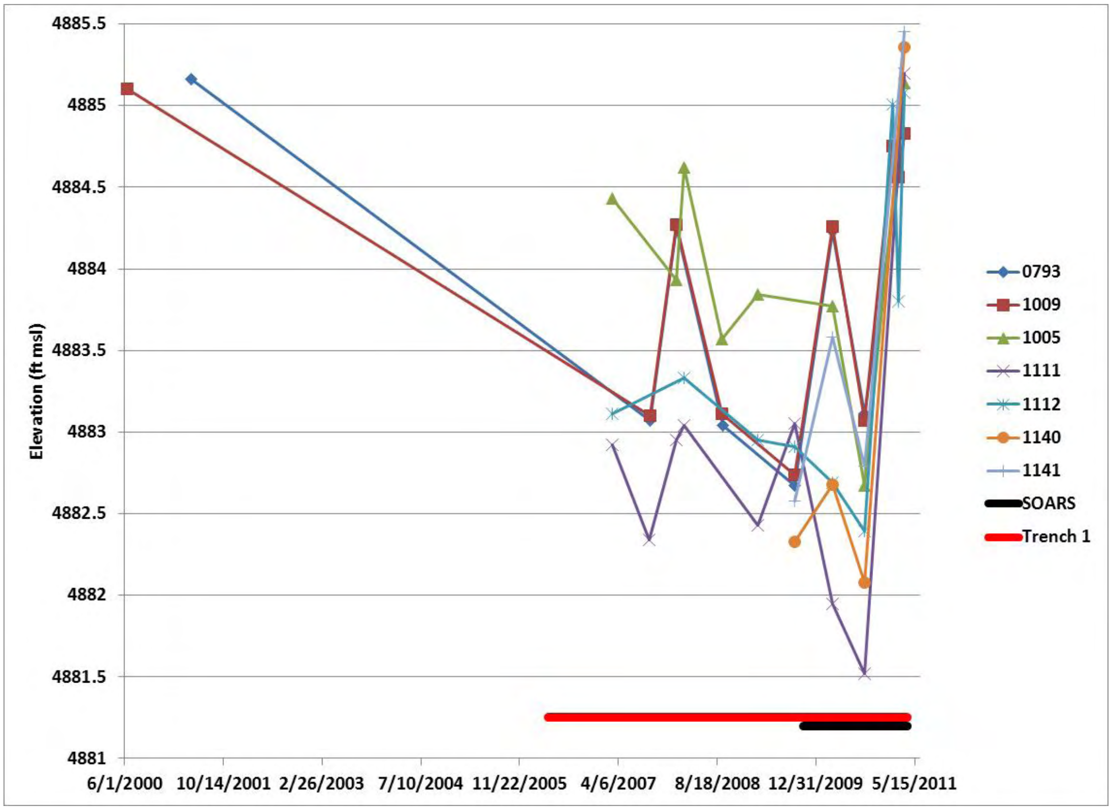
Notes:
Dashed line indicates position of a groundwater divide.
Groundwater flow originates at arrow tails.

Figure 6. Groundwater Flow September 2010 Trench 1 and 1089 Areas Pumping



Abbreviations:
ft msl = feet above mean sea level

Figure 7. Groundwater Elevations for Wells Close to Trench 1, Showing the Effects of Pumping and Relaxation Cycles



Notes:

Data are based on manual depth-to-water measurements made during routine water sampling events.
The red horizontal line shows the time period that Trench 1 has been operating.
The black line shows the time period that the detailed SOARS system on the wells near Trench 1 has been collecting water levels and corresponds to the period shown in Figure 7.

Figure 8. Groundwater Elevation Data from Routine Manual Measurements

During relaxation period 1 in January 2010, the Trench 1 pump was off for 21 hours (Figure 9). Groundwater elevation at the pumping well increased by 1.7 ft to an elevation of 4,882.3 ft, while collection drain port A (1110-A) increased by 1.2 ft. During this relatively short shutdown, the water level in the collection drain nearly equalized as indicated by the nearly same elevations for the pumping well (1110), and ports A and C (1110-A and 1110-C) indicating that groundwater flows efficiently from the surrounding areas to the collection drain. The rapid responses at ports A, B and the pumping well also indicate high efficiency of the collection drain to convey the water to the sump. Well 1111 which is located near the pumping well was affected by the relaxation period, but other wells in the nearby vicinity were not affected.

Relaxation period 2, initiated about 10 days later than relaxation period 1, was slightly longer (39 hours) in duration (Figure 10). The groundwater elevation in the pumping well (1110) increased by the same amount (1.7 ft) as in relaxation period 1 and reached a maximum elevation of 4,882.7 ft, just slightly higher than during relaxation period 1. The ports in the collection drain (1110-A and 1110-C) also showed a similar response to relaxation period 1, and reached the same level as the pumping well. The only obvious difference between relaxation period 1 and relaxation period 2 was that well 1140, which is located close to the pumping well on the river side, was more affected during period 2.

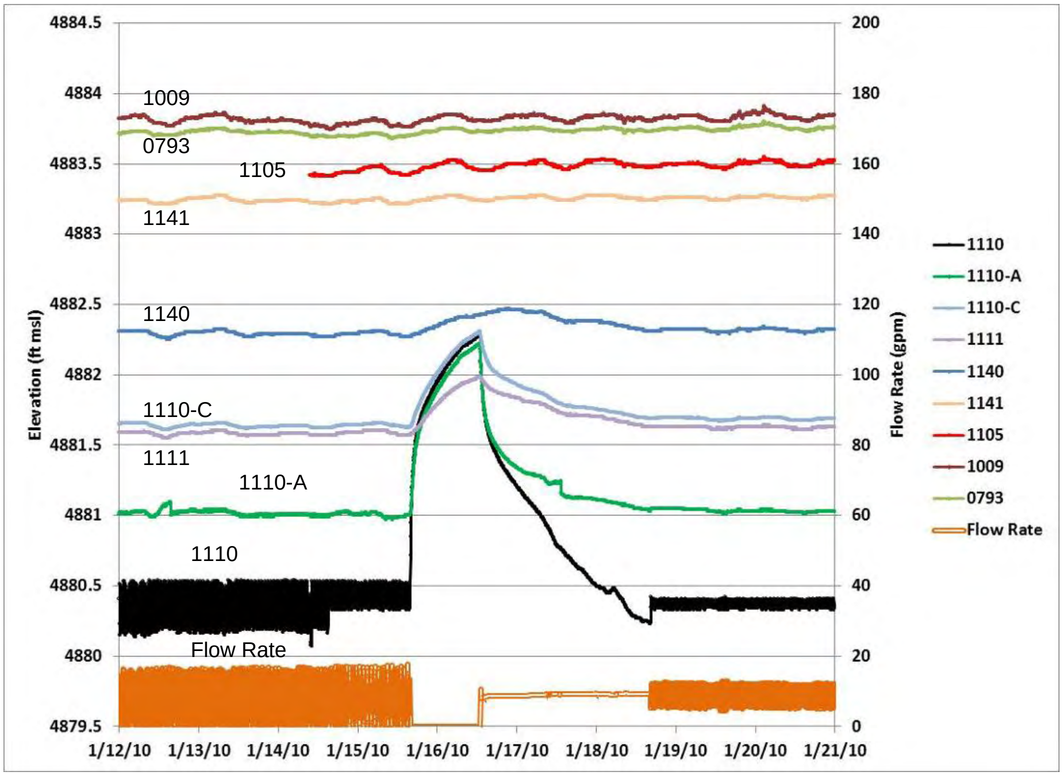


Figure 9. Groundwater Elevations near Trench 1 During Relaxation Period 1: January 15–16, 2010 (The pump was off for 21 hours)

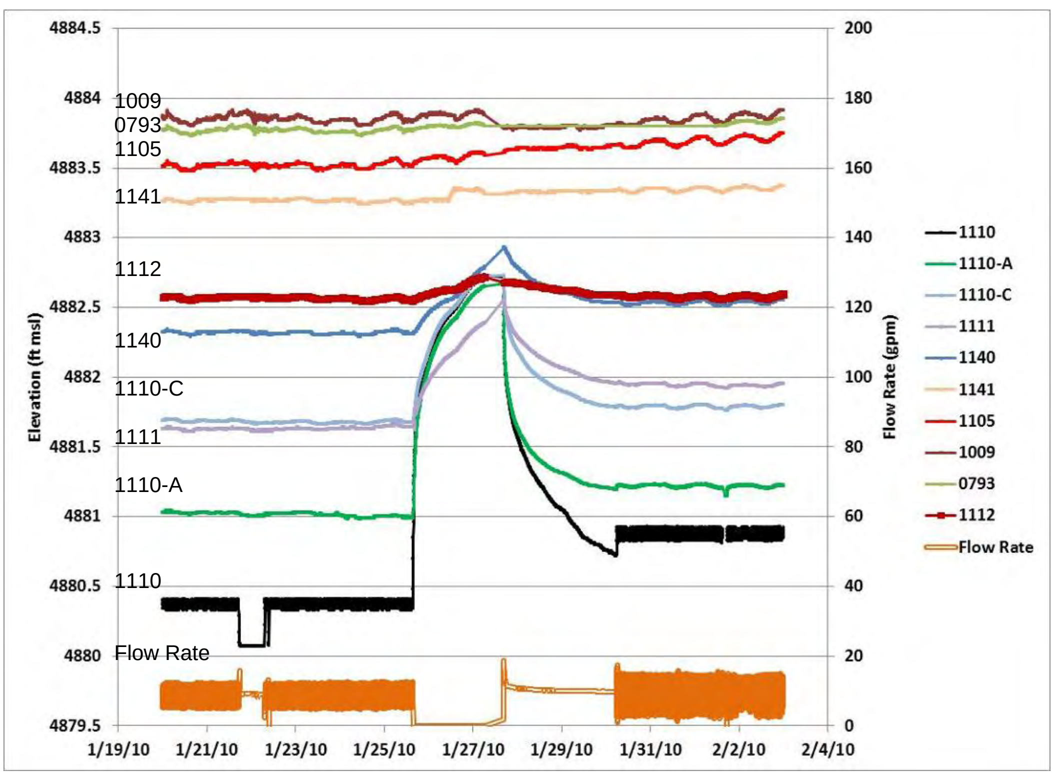


Figure 10. Groundwater Elevations near Trench 1 During Relaxation Period 2: January 25–27, 2010 (The pump was off for 39 hours)

Relaxation period 3 in April 2010 lasted 11.6 days during which the water level in the pumping well increased 2.6 ft to an elevation of 4,883.5 ft, nearly a ft higher than in relaxation period 2 (Figure 11). The higher elevation could be due to two factors, (1) a longer period of relaxation that allowed more rebound of the groundwater system, and (2) a response to higher groundwater levels typical of the spring months. The groundwater elevations in wells 1111 and 1140 responded more during relaxation period 3 than during relaxation period 2. Unlike relaxation periods 1 or 2, groundwater elevations in wells 1112 and 1140 were strongly affected during relaxation period 3. Well 1105 also showed a weak response during relaxation period 3. The responses observed during relaxation period 3 indicate that the longer the pump is off, the further away the groundwater table is affected. When pumping resumed following relaxation period 3, the groundwater elevations in the wells rapidly decreased (about 3 days) to near their pre-relaxation levels.

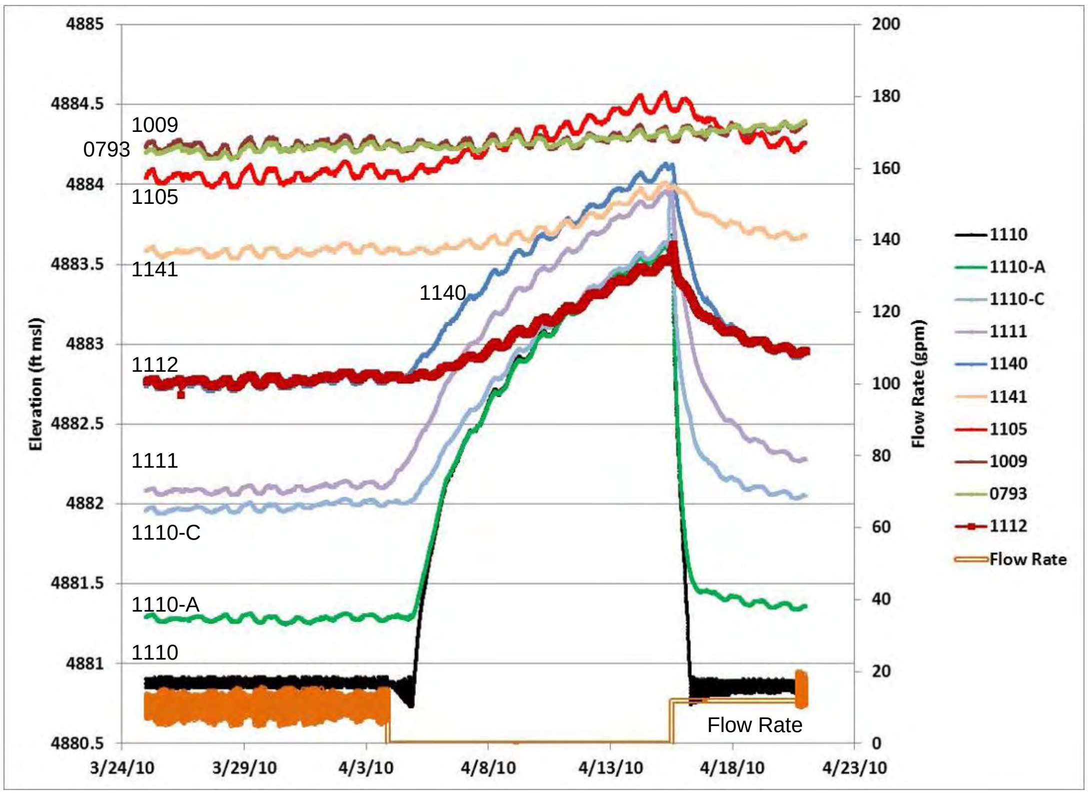


Figure 11. Groundwater Elevations near Trench 1 During Relaxation Period 3: April 3–15, 2010 (The pump was off for 11.6 days)

During relaxation period 4 the pump was at low flow (about 5 gpm) for 55 days (Figure 12). During this time, groundwater elevation in the pumping well (1110) increased to 4,883.2 ft, similar to relaxation period 3. All of the Trench 1 wells showed some influence of pumping and relaxation during this event.

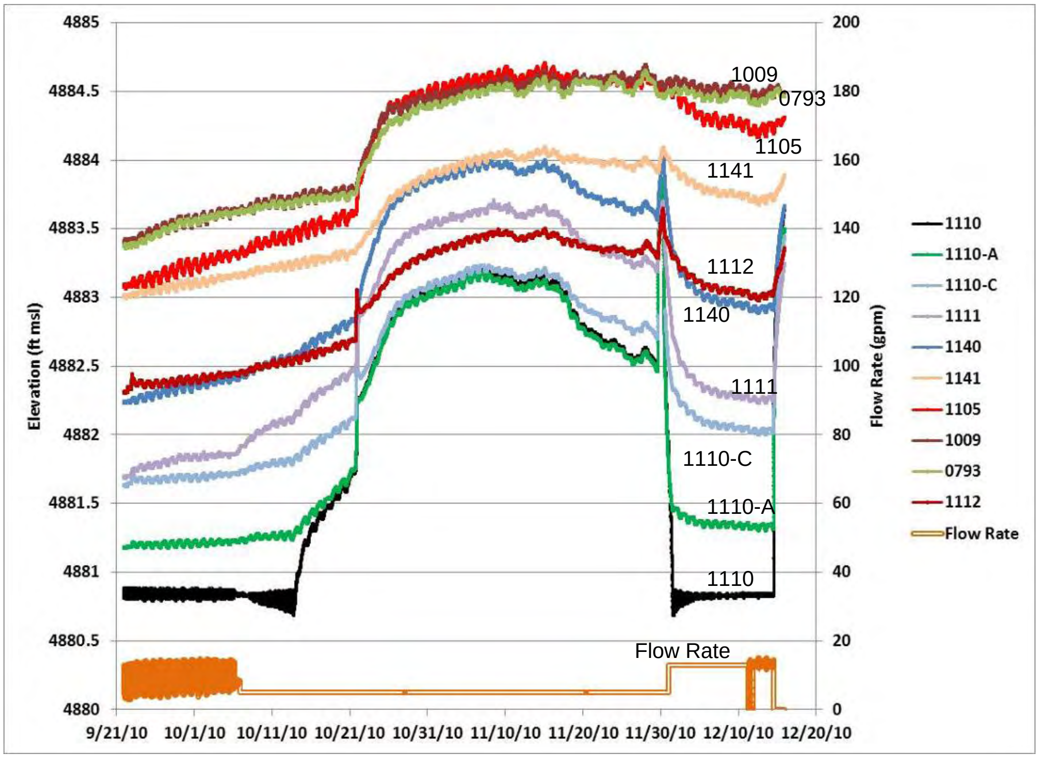


Figure 12. Groundwater Elevations near Trench 1 During Relaxation Period 4: October 6 through December 1, 2010 (The pump was at low flow [<5 gpm?] for 55 days)

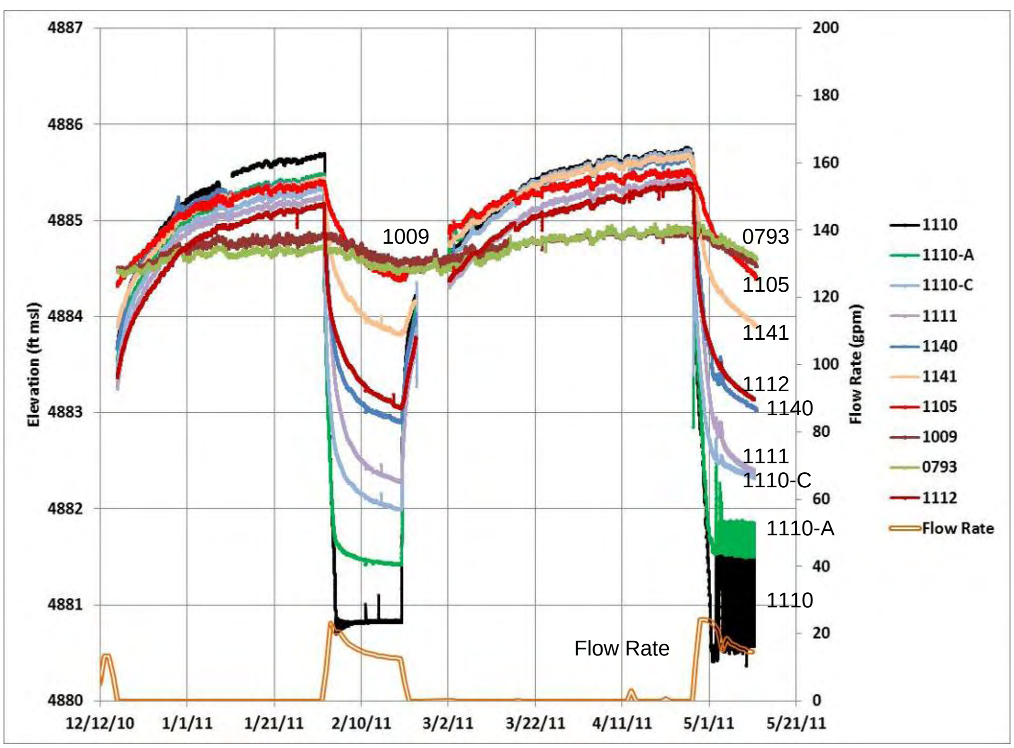
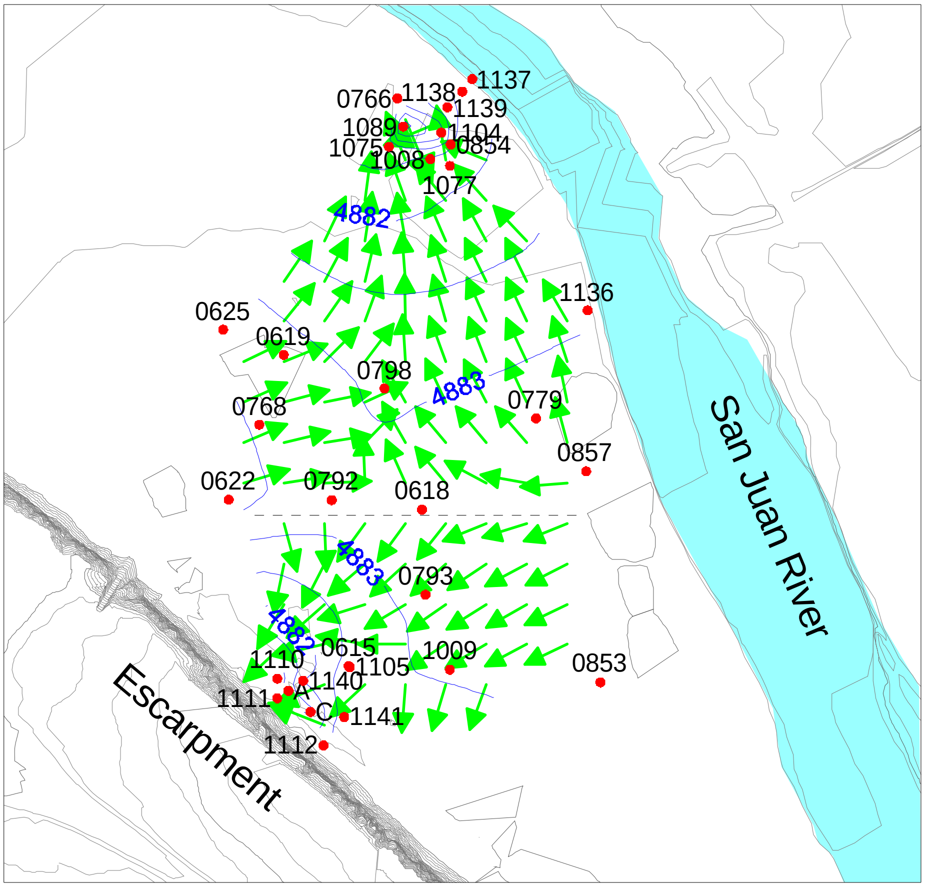


Figure 13. Groundwater Elevations near Trench 1 During Relaxation Period 5 (December 14, 2010, through February 1, 2011) and Relaxation Period 6 (February 19 through April 27, 2011); (The pump was off for 49 and 67 days for Relaxation Periods 5 and 6, respectively)

During relaxation periods 5 and 6 in January and March 2011, the pump was off for 49 and 67 days, respectively. During each of these two events, groundwater elevations in the pumping well increased to about 4,885.6 ft, about 2 ft higher than previous events and nearly back to elevations prior to installation of Trench 1. During the intermediate pumping in February 2011, groundwater elevations decreased rapidly to pre-relaxation levels in about 2 to 3 weeks. All wells showed effects from these events; however, wells 0793 and 1009 were only slightly affected. Thus, it appears that the greatest influence from pumping at Trench 1 over a time scale of months, is in the area between wells 0793 and 1009, Trench 1. Longer term effects appear to influence the groundwater table to greater distances as indicated by water level contouring described in the following paragraphs.

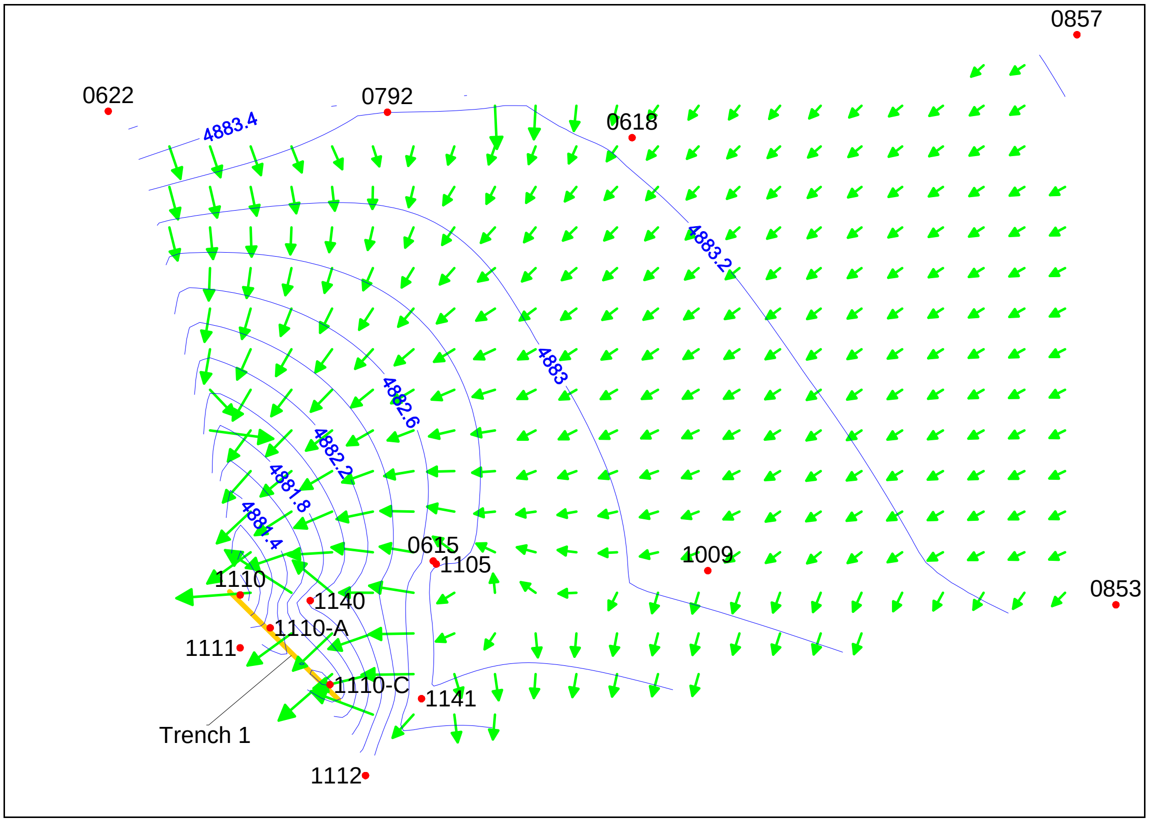
The groundwater flow directions during September 2010 and January 2011 were determined using the Surfer software natural neighbor gridding method to show the difference in flow between pumping and non-pumping conditions. The flow directions are based only on data collected at wells in the study area. The 2010 data are from semiannual sampling and SOARS measurements, and the 2011 data are from manual measurements conducted specifically for this study and SOARS measurements.

Figure 14 shows the groundwater flow direction while Trench 1 and wells 1089 and 1104 are actively pumping. A flow divide is apparent south of well 0618. Water north of the divide is flowing toward wells 1089 and 1104, and water south of the divide is flowing toward Trench 1. To show the flow detail near Trench 1, a Surfer plot was prepared using only the wells from the flow divide south to the collection drain. Groundwater velocity is highest in the vicinity of Trench 1, the result of convergent flow on the collection drain (Figure 15). Though Figure 15 does not show it, water is also flowing into the drain from the escarpment.



Notes:
Dashed line indicates position of a groundwater divide.
Flows originate at arrow tails.

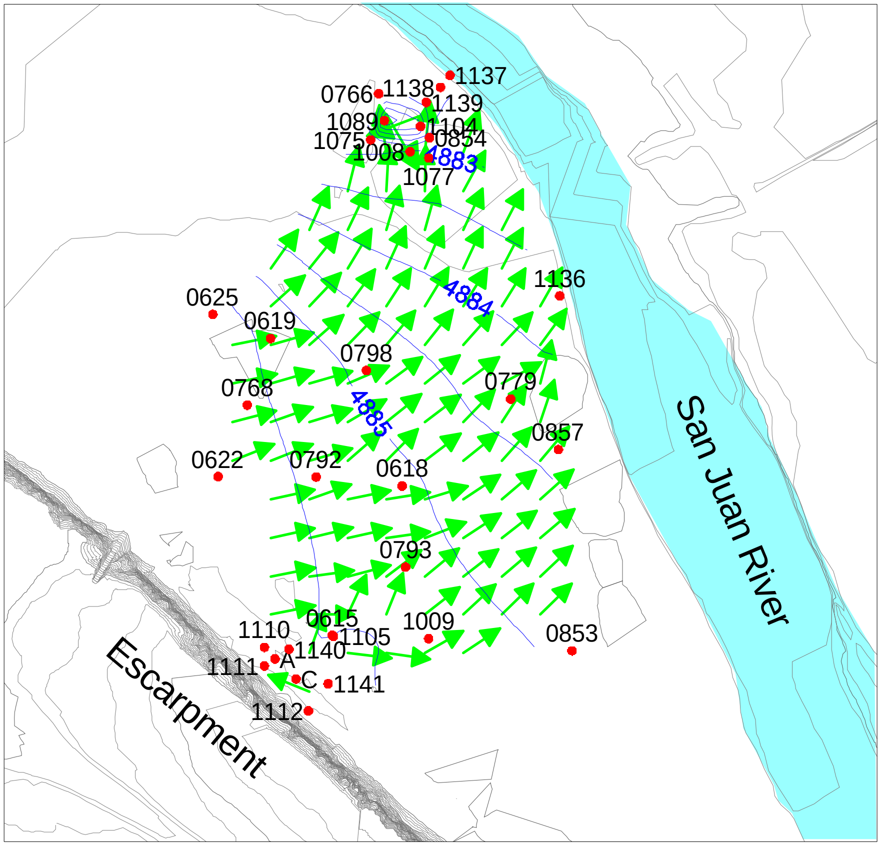
Figure 14. Groundwater Flow Directions Under Pumping Conditions in the Trench 1 Study Area: September 2010



Notes:
Size of arrow is relative to the rate of groundwater flow.
Groundwater flow originates at arrow tails.

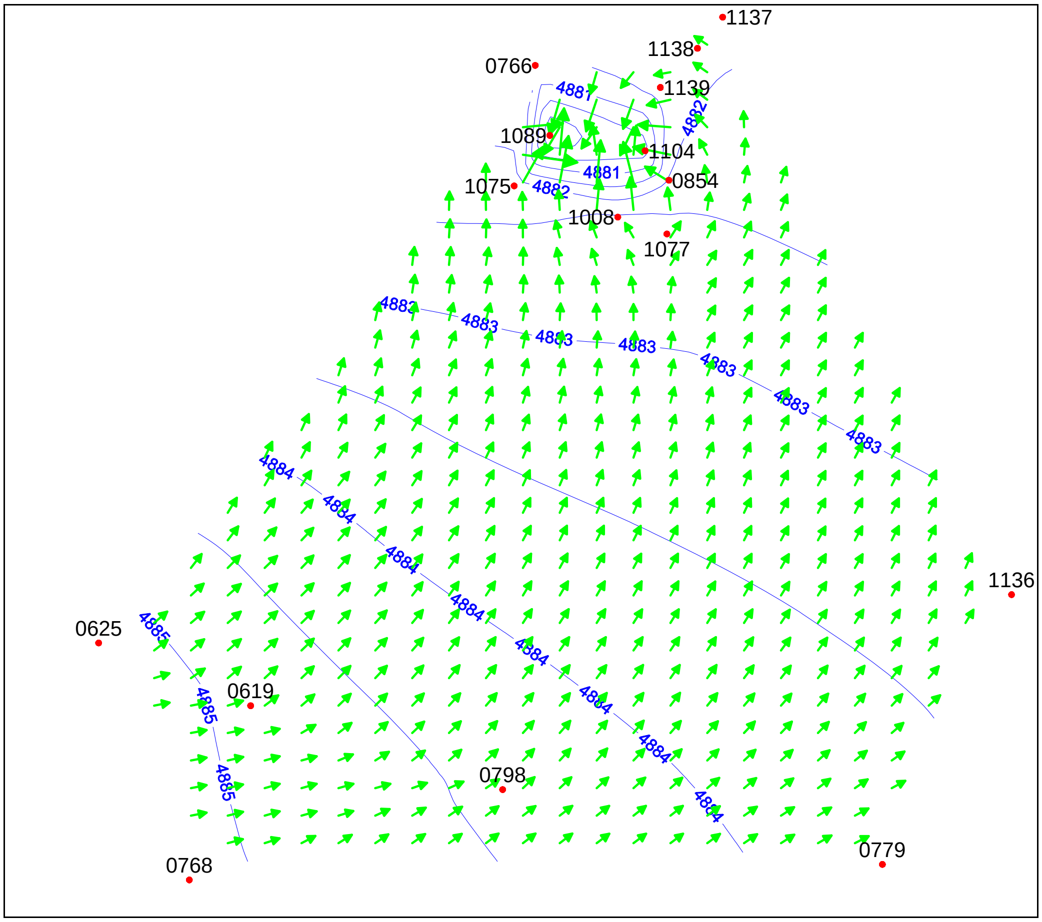
Figure 15. Groundwater Flow Directions Under Pumping Conditions South of the Flow Divide to Trench 1: September 2010

Figure 16 shows the groundwater flow directions while Trench 1 is off and wells 1089 and 1104 are pumping. Under these conditions, groundwater is generally flowing away from the escarpment and toward the river. Groundwater southeast of wells 1089 and 1104 appears to be unaffected by the pumping as groundwater in this area appears to avoid capture and is discharging directly to the river. This is probably attributable to the increased amount of water flowing through the floodplain aquifer when Trench 1 is not intercepting it. To show flow details in the 1089 Area during January 2011, Surfer diagrams were prepared using only the data collected at wells located north of the flow divide (Figure 17). Comparison of this flow system with equivalent patterns observed in September 2010 (Figure 18) indicates that wells 1089 and 1104 have a much larger capture zone when pumping occurs at Trench 1. This effect could also be attributed to seasonal changes as pumping conditions are based on measurements taken August 30–September 2, and non-pumping conditions are based on measurements taken January 13. The lower river elevations typical in winter may be a factor in directing more groundwater toward the river than toward the pumping wells.



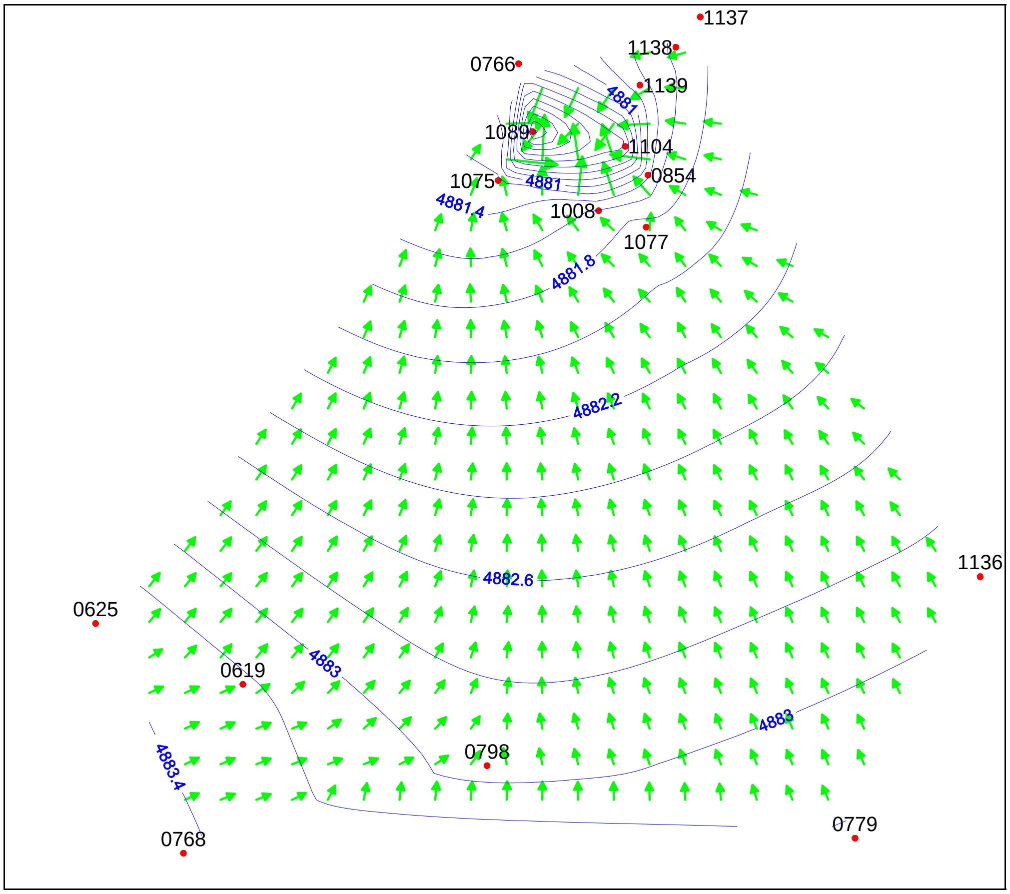
Notes:
Size of arrow is relative to the rate of groundwater flow.
Groundwater flow originates at arrow tails.

Figure 16. Groundwater Flow Directions Under Trench 1 Non-Pumping Conditions in the Trench 1 Study Area: January 2011



Notes:
Size of arrow is relative to the rate of groundwater flow.
Groundwater flow originates at arrow tails.

Figure 17. Groundwater Flow Directions Under Trench 1 Non-Pumping Conditions, North of the Flow Divide to the 1089 Area: January 2011



Notes:
Size of arrow is relative to the rate of groundwater flow.
Groundwater flow originates at arrow tails.

Figure 18. Groundwater Flow Directions Under Trench 1 Pumping Conditions, North of the Flow Divide to the 1089 Area: September 2010

4.2 Groundwater Pumping Rates

The collection drains were installed to intercept contaminated water flowing from the terrace and to collect contaminated groundwater in the floodplain alluvium. Figures 19 through 21 show the extraction rate and volume extracted from Trench 1, well 1089, and well 1104, from the time pumping began at each location until December 1, 2010. Manual readings from flow meters on the wells were added in to SOARS for the time period before the wells were instrumented. SOARS monitoring began at wells 1089 and 1104 in December 2005 and at Trench 1 in April 2006. Since pumping began until December 1, 2010, Trench 1 removed 16,746,300 gallons, well 1089 removed 21,986,300 gallons, and well 1104 removed 3,909,470 gallons. Trench 1 has the highest average pumping rate at 7.69 gpm and should be able to remove more contaminated water from the floodplain than either of the vertical extraction wells. Well 1089 has an average pumping rate of 6.3 gpm, which is close to the rate of Trench 1 and greater than the rate at well 1104 (1.6 gpm). Section 4.3 examines the difference in the pumping rates at wells 1089 and 1104.

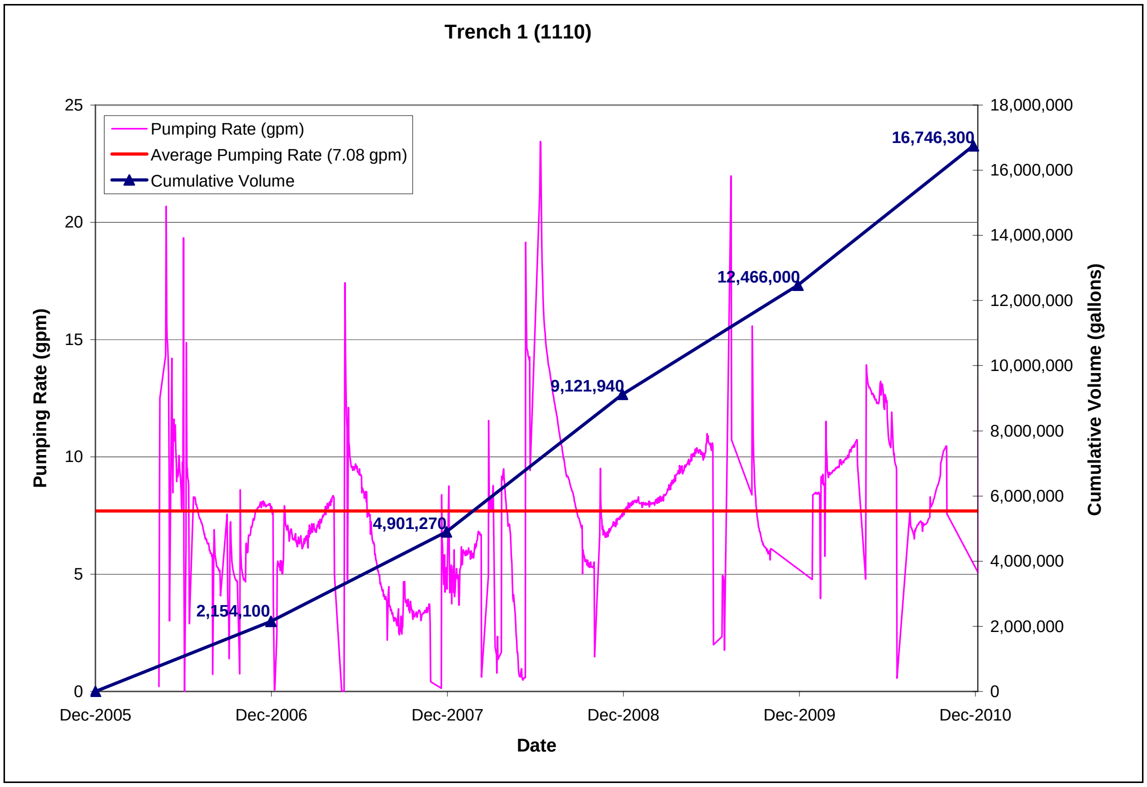


Figure 19. Trench 1 Pumping Rate and Cumulative Volume Extracted

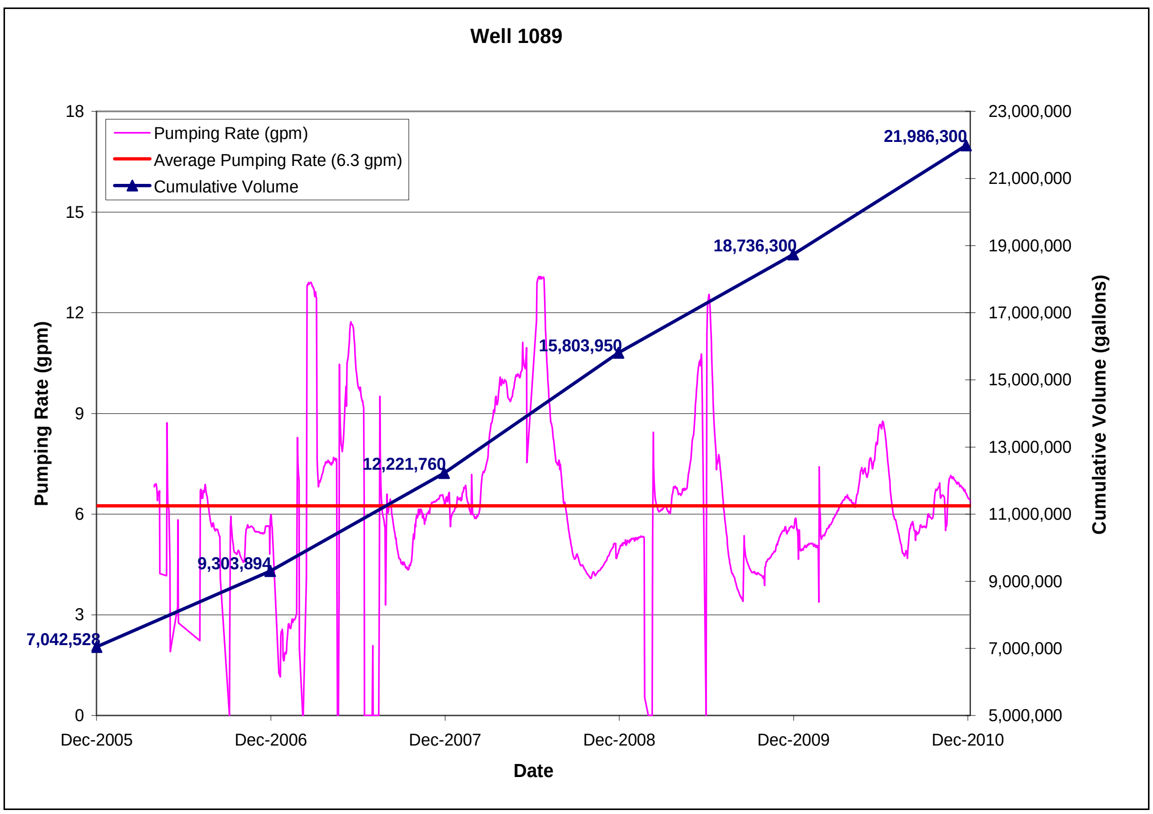


Figure 20. Well 1089 Pumping Rate and Cumulative Volume Extracted

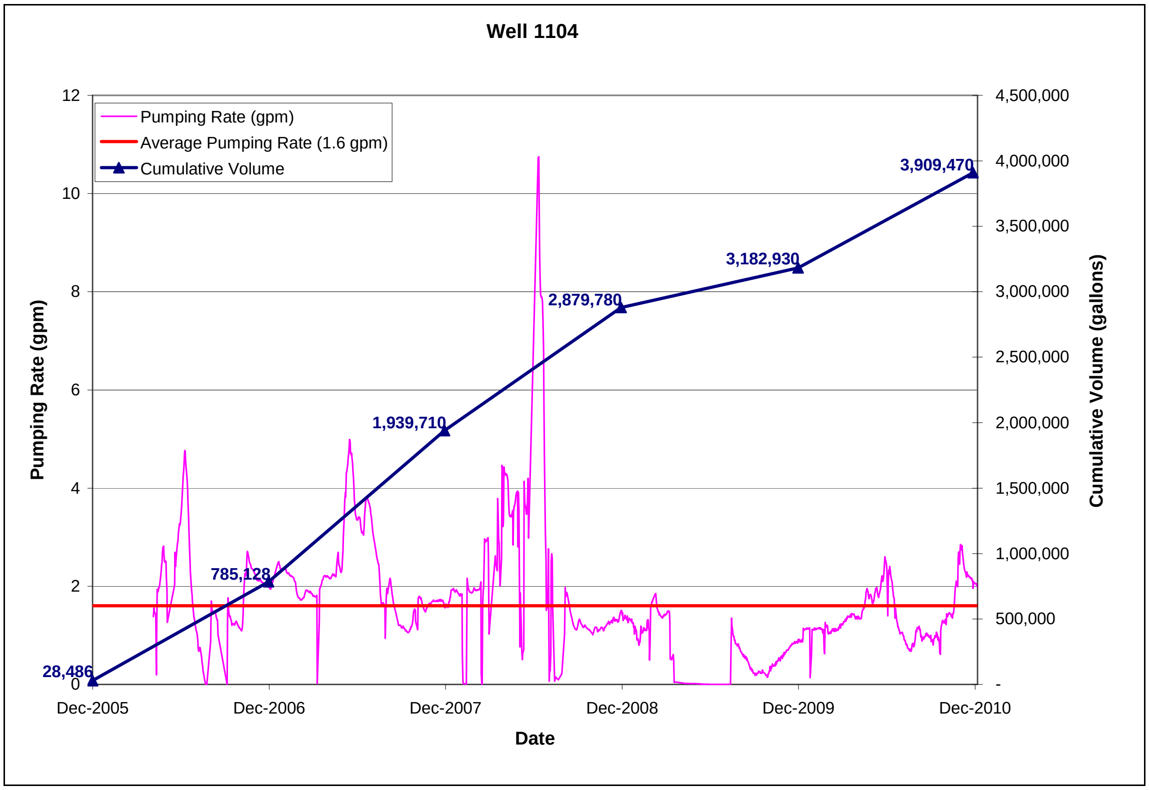


Figure 21. Well 1104 Pumping Rate and Cumulative Volume Extracted

4.3 Effects of Pumping in the 1089 Area

Pumping from the two extraction wells (1104 and 1089) in the 1089 Area was continuous from October 30, 2009, through February 1, 2011 (Figure 22). Pumping from extraction well 1104 was discontinued when a pipe ruptured on February 1, 2011. Pumping continued from extraction well 1089 through February 19, 2011, when flow from this well was also discontinued due to another pipe rupture. Pumping was resumed at both extraction wells on April 27, 2011. During the pumping periods, the average flow rates were 6.2 and 1.4 gpm for extraction wells 1089 and 1104, respectively. The wells are only about 100 ft apart; however, water has been consistently pumped at a higher rate from well 1089 as compared to well 1104. The difference in pumping rates may be caused by the increased drawdown maintained in extraction well 1089. The water levels at the end of individual pump cycles were typically about 0.8 ft lower in 1089 than in 1104 (Figure 22). Variable well efficiency may also be a factor in the contrasting extraction rates.

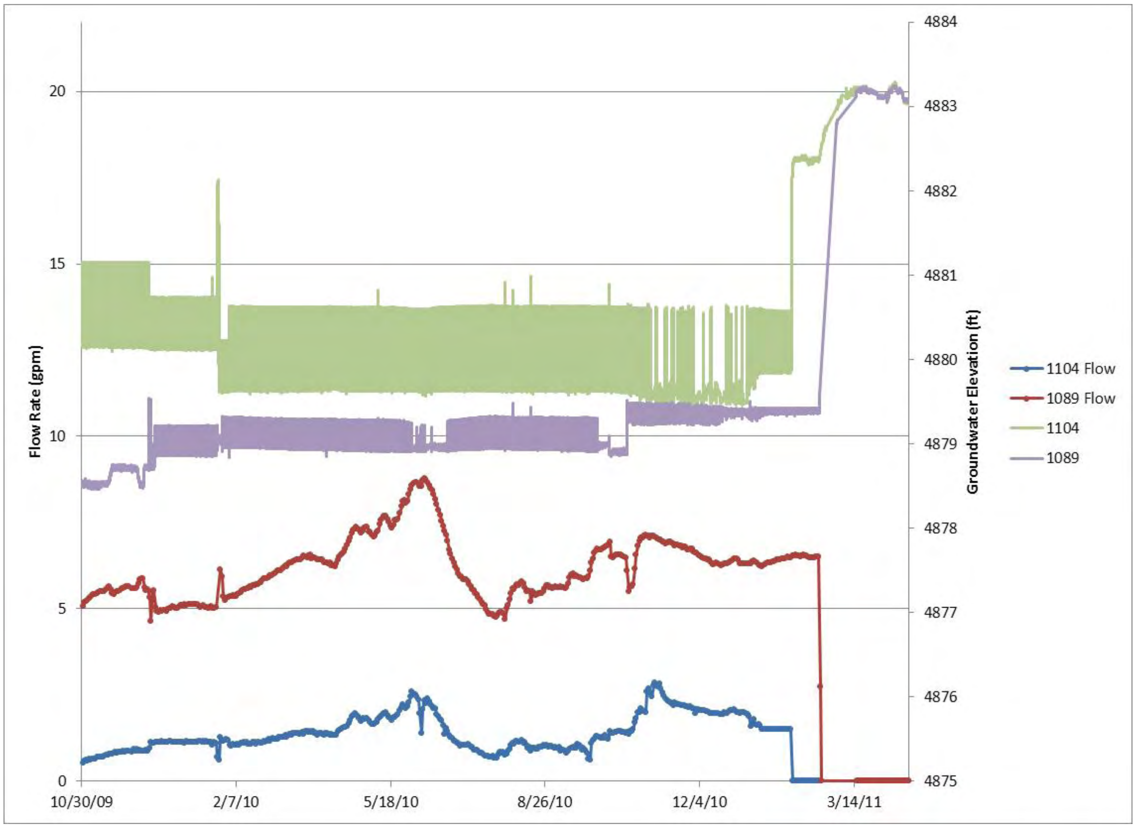


Figure 22. Pumping Rates (gpm) and Groundwater Elevations in the Two Extraction Wells (1089 and 1104) in the 1089 Area

When pumping was discontinued at wells 1089 and 1104 in spring 2011, groundwater elevations soon increased (Figure 23). About 1 month elapsed before water elevations rebounded to a nearly constant value (Figure 24), with most of the rebound occurring in the first week following cessation of pumping. With the exception of well 1137, all wells in the area showed a significant amount of rebound. The maximum rebound at non-pumping wells was about 1.3 ft (wells 1075 and 0766) and the rebound in other wells ranged from about 0.5 to 0.8 ft.

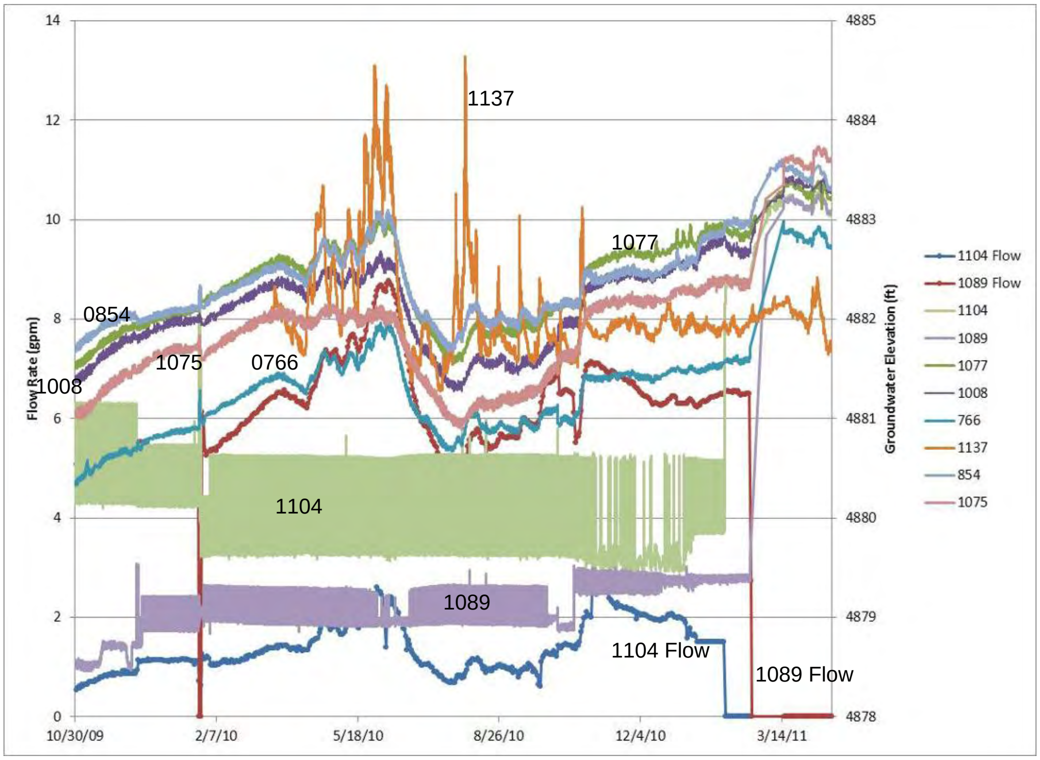


Figure 23. Groundwater Elevations in the 1089 Area Since October 30, 2009

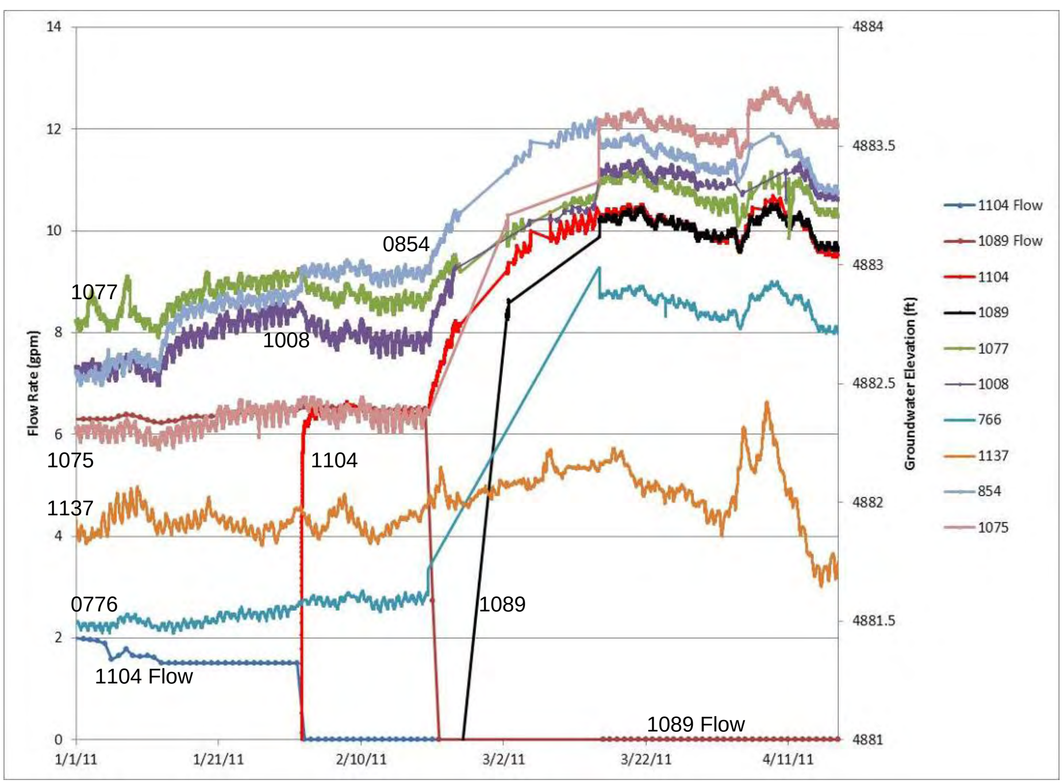


Figure 24. Effect of Groundwater Elevations Before and After Discontinuation of Pumping in the 1089 Area

Well 1137 had minimal response to pumping in the 1089 Area, but it did experience numerous short-term water elevation spikes. The largest spike shown on Figure 23 occurred on August 2, 2010, when the water elevation increased by 1.7 ft in 3 hours. The water level in well 1137 was responding to fluctuating levels in the San Juan River as evidenced by close correlation of the spikes with those recorded in stilling well 0899 located in the river about 1,000 ft upstream (Figure 25). Note that the water elevations displayed for the stilling well have not been adjusted to accurately comport with measured groundwater elevations at the Shiprock site. As a consequence, the difference in water levels observed at wells 1137 and 0899 is considerably less that the approximate 4.7 ft of difference suggested by water elevations shown in Figure 25.

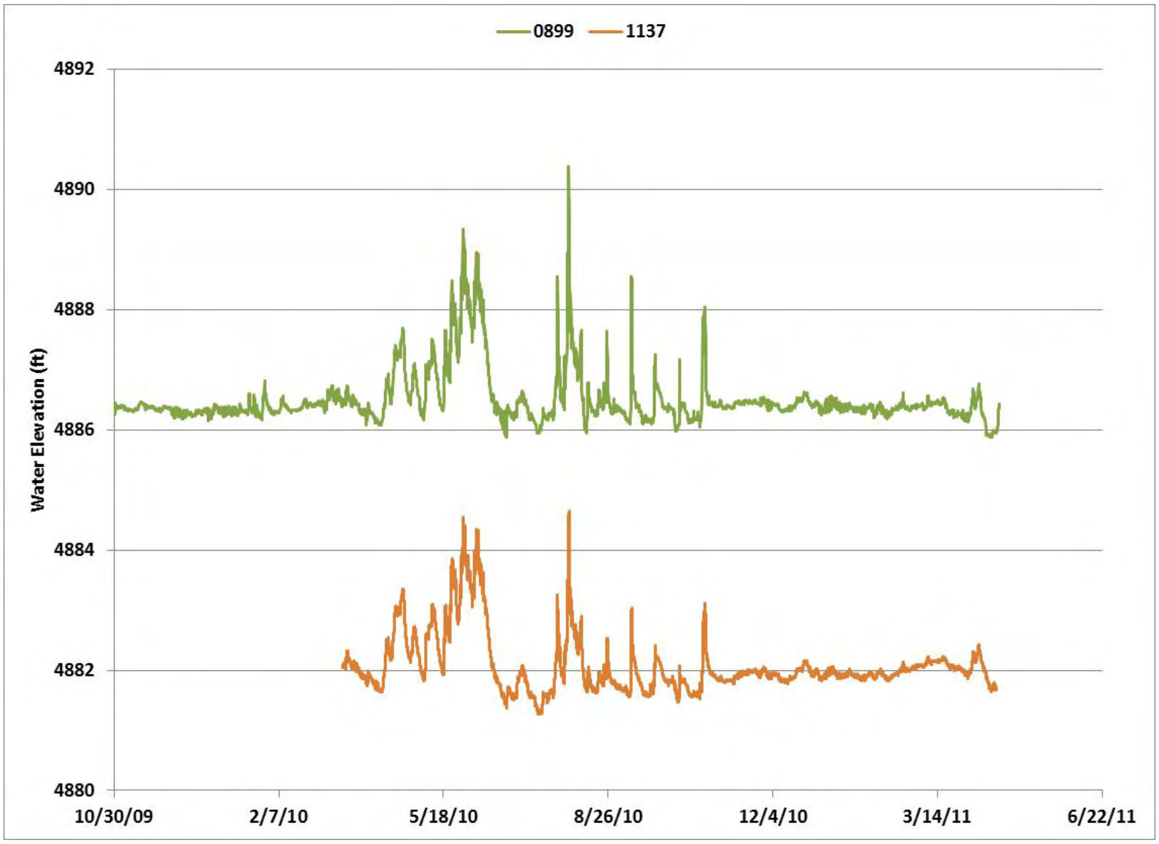
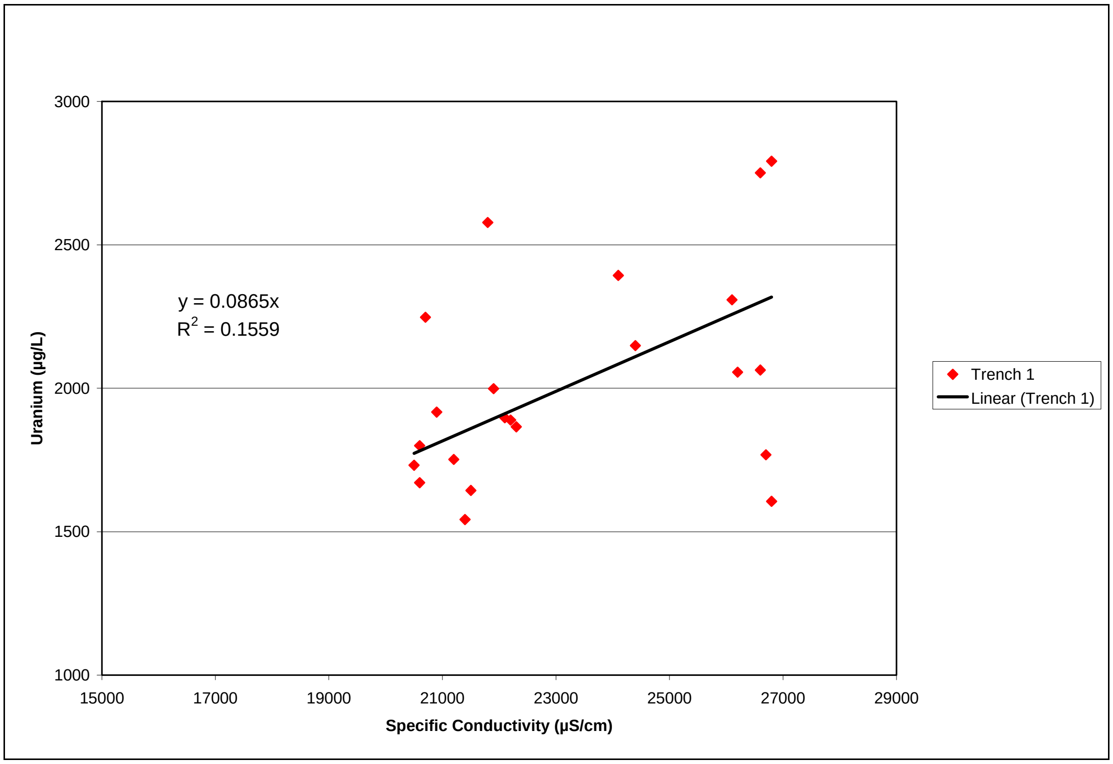


Figure 25. Comparison of Groundwater Elevations in Well 1137 with Water Elevations in the San Juan River from Nearby Stilling Well 0899

4.4 Contaminant Removal

The SOARS system contains an algorithm that calculates the amount of uranium removed by Trench 1 based on a correlation of specific conductivity and uranium concentration. This correlation was calculated using data collected by Environmental Sciences Laboratory (ESL) personnel from April through December 2006. The uranium concentration and specific conductivity were graphed and linear regression analysis was performed (Figure 26).



Abbreviations:
µg/L = micrograms per liter
µS/cm = microsiemens per centimeter

Figure 26. Uranium and Specific Conductivity Correlation for SOARS

The resulting correlation is as follows:
uranium concentration (µg/L) = 0.0865 × specific conductivity (µS/cm)

Converting to the units used in SOARS yields the following:
uranium concentration (mg/L) = 0.0865 × specific conductivity (mS/cm)

where:
mg/L = milligrams per liter
mS/cm = millisiemens per centimeter

The correlation based on these early data is not strong as indicated by the low R^2 value (see Figure 26). However, the R^2 value shows that a correlation between specific conductivity and uranium exists, and it provides a useful estimate of the uranium removal. Based on this correlation and using the daily specific conductivity reading on December 1, 2010, from SOARS and the cumulative volume of water pumped, an estimated 58.0 kg of uranium was removed by Trench 1 by December 1, 2010, as calculated below:

U (mg/L) = (0.0865) (10.58) = 0.91517 mg/L
U g removed = (0.91517 mg/L) (1 gram/1,000 mg) (3.785 L/gal) (16,746,300 gal) = 58,007 g.

The semiannual sampling data show a stronger correlation between specific conductivity and uranium. The data from 2006 through 2010 were graphed with the 2006 ESL data and linear regression analysis performed (Figure 27). The higher R^2 value indicates a stronger correlation between uranium and specific conductivity. Substituting this new relationship in to the previous calculation estimates the uranium removed at 58.7 kg, which is similar to the previous value. The SOARS calculation is good as a rough estimate of uranium removed and is useful to monitor the performance of the collection drain. The SOARS system has been updated to include the slightly better correlation.

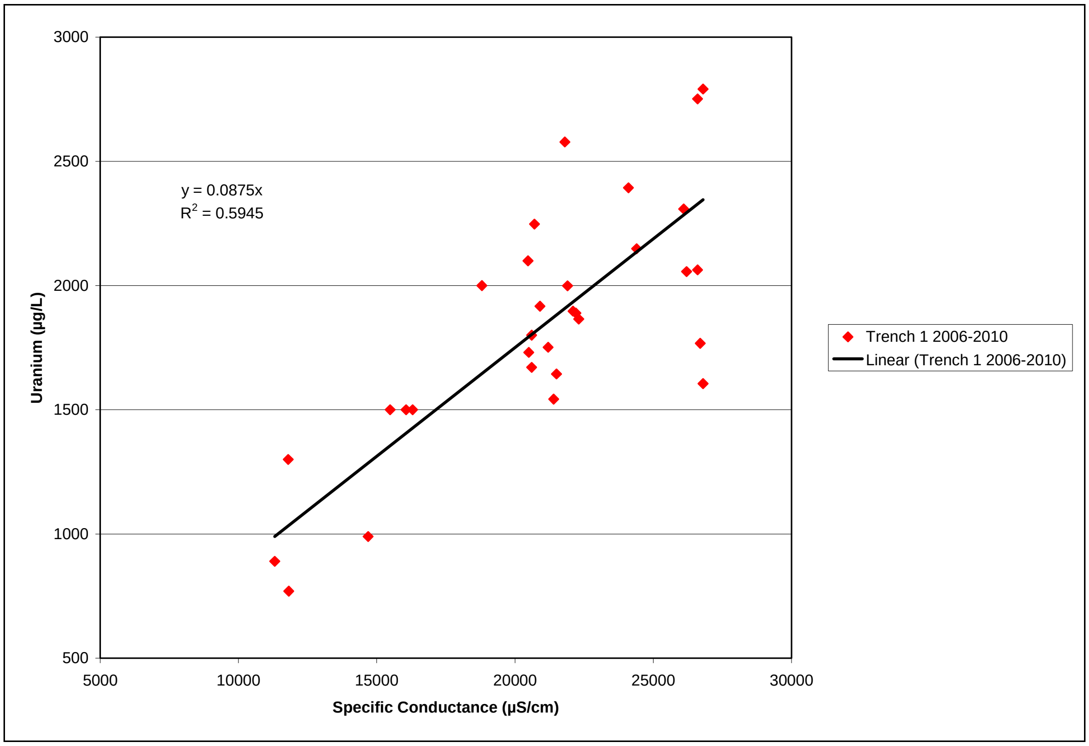


Figure 27. Updated Uranium and Specific Conductivity Correlation for SOARS

4.5 Uranium in Groundwater

Uranium is one of the main contaminants of concern (COC) in the study area and is used to show the effect that Trench 1 has had on cleaning up groundwater. Figure 28 shows the uranium plume in the floodplain during the baseline period (February 2000), after remediation began but before installation of the collection drains (March 2006), and under current conditions (August and September 2010). The baseline plume shows uranium concentrations are highest along the base of the escarpment and in the 1089 Area prior to the installation of any extraction wells. The 2006 plume shows more uranium had migrated off the terrace to the base of the escarpment and that groundwater extraction was reducing the levels of uranium in the 1089 Area. The 2010 plume shows that the trench has intercepted the uranium migrating from the terrace and has had an effect on reducing the levels of uranium on the floodplain. The cleanup effects are further supported by time concentration trends of the wells in the study area from 2000 through 2010.

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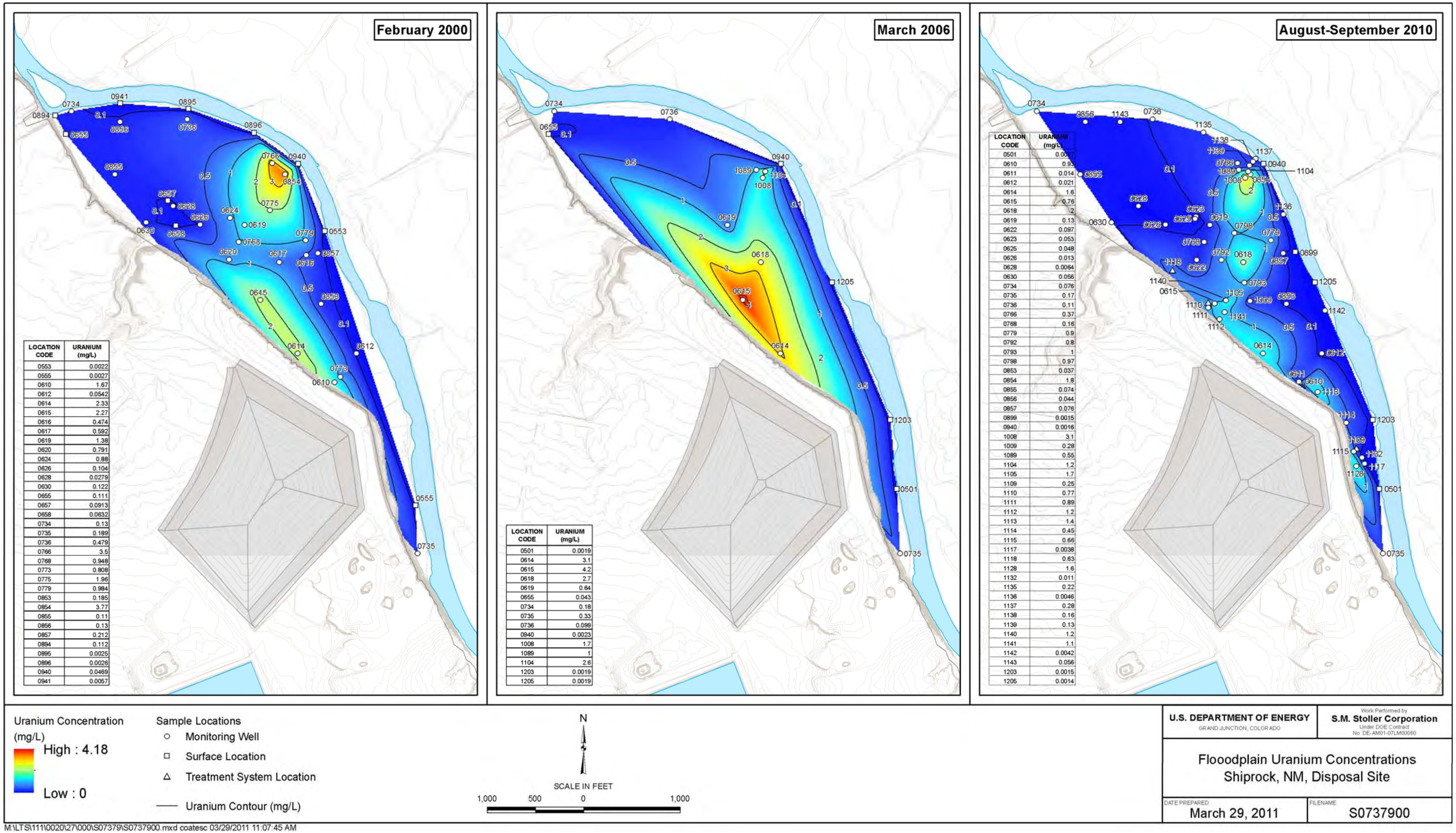

February 2000

LOCATION CODE	URANIUM (mg/L)
0553	0.0022
0555	0.0027
0610	1.67
0612	0.0542
0614	2.33
0615	2.27
0616	0.474
0617	0.592
0619	1.38
0620	0.791
0624	0.88
0626	0.104
0628	0.0279
0630	0.122
0655	0.111
0657	0.0913
0658	0.0632
0734	0.13
0735	0.189
0736	0.479
0766	3.5
0768	0.948
0773	0.808
0775	1.96
0779	0.984
0853	0.185
0854	3.77
0855	0.11
0856	0.13
0857	0.212
0894	0.112
0895	0.0025
0896	0.0026
0940	0.0469
0941	0.0057

March 2006

LOCATION CODE	URANIUM (mg/L)
0501	0.0019
0614	3.1
0615	4.2
0618	2.7
0619	0.64
0655	0.043
0734	0.18
0735	0.33
0736	0.099
0940	0.0023
1008	1.7
1089	1
1104	2.6
1203	0.0019
1205	0.0019

August-September 2010

LOCATION CODE	URANIUM (mg/L)
0501	0.0017
0610	0.93
0611	0.014
0612	0.021
0614	1.6
0615	0.76
0618	2
0619	0.13
0622	0.097
0623	0.053
0625	0.048
0626	0.013
0628	0.0064
0630	0.056
0734	0.076
0735	0.17
0736	0.11
0766	0.37
0768	0.16
0779	0.9
0792	0.8
0793	1
0798	0.97
0853	0.037
0854	1.8
0855	0.074
0856	0.044
0857	0.076
0899	0.0015
0940	0.0016
1008	3.1
1009	0.28
1089	0.55
1104	1.2
1105	1.7
1109	0.25
1110	0.77
1111	0.89
1112	1.2
1113	1.4
1114	0.45
1115	0.66
1117	0.0038
1118	0.63
1128	1.6
1132	0.011
1135	0.22
1136	0.0046
1137	0.28
1138	0.16
1139	0.13
1140	1.2
1141	1.1
1142	0.0042
1143	0.056
1203	0.0015
1205	0.0014

Figure 28. Floodplain Uranium Plume in 2000, 2006, and 2010

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Figure 29 shows the uranium concentrations from 2000 to 2010 for multiple wells in the 1089 Area and the river (surface location 0940). The majority of the wells show a decreasing trend for uranium concentrations. Well 1008, however, increased in 2006 and then remained elevated through 2010. Well 1008 is screened deeper than the other wells in the area. Well 1008 could be intercepting a stratification of the groundwater, or it could be receiving less influence from the influx of river water because it is located on the terrace side of the extraction wells. Two additional competing explanations are (1) that well 1008 is affected by the inflow of more contaminated water from the south, which is drawn northward by the pumping of wells 1089 and 1104, and (2) that contaminated water is reaching the 1089 area near well 1008 via fracture flow in the Mancos extending from the former mill site area.

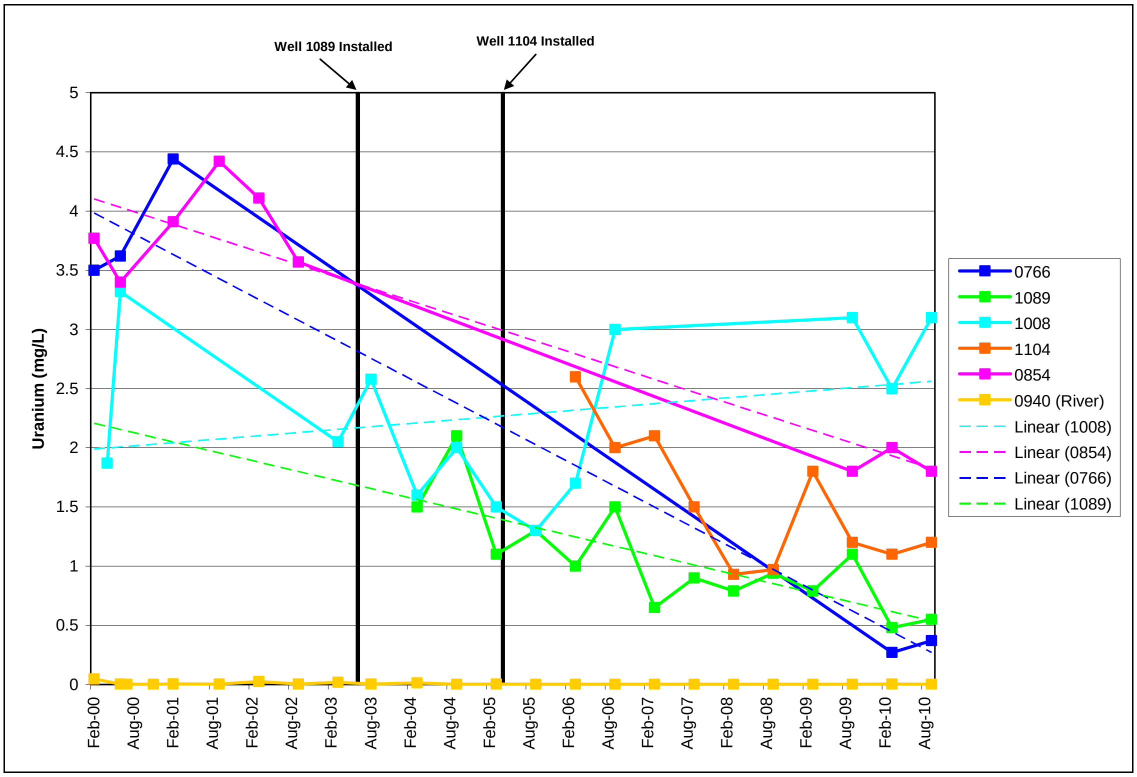


Figure 29. Uranium Concentrations in the 1089 Area, February 2000–September 2010

Figures 30 and 31 show the uranium concentrations from 2000 to 2010 at wells in the floodplain between the 1089 Area and the Trench 1 Area. Figure 30 shows the wells that are influenced by extraction wells 1089 and 1104 as indicated by the flow divide observed in groundwater (see Figures 6 and 14). These wells show either decreasing trends or relatively flat trends; data from wells that are closer to the 1089 Area show decreasing trends. The trends appear to show that the extraction wells are impacting contaminant concentrations. Figure 31 shows the data from wells along the flow divide. Wells 0618 and 0792 have more variation in uranium concentration than wells 0622 and 0857. Linear trends show a slightly increasing trend for 0618; however, it has been decreasing since late 2002. Well 0792 exhibits a slightly decreasing trend, well 0857 exhibits a slightly decreasing trend, and well 0622 exhibits a decreasing trend. The variability in wells 0618 and 0792 is likely due to their location in an area that is influenced by both Trench 1 and 1089/1104 pumping, by the influx of river water, and by water flowing from Bob Lee Wash.

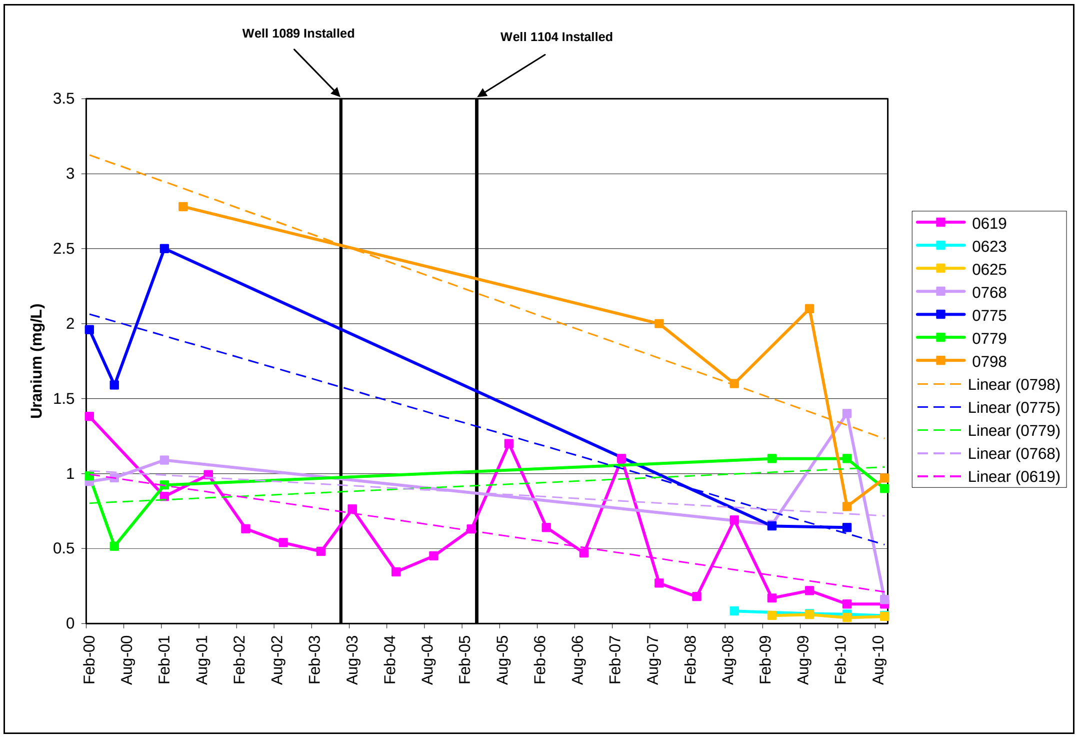


Figure 30. Uranium Concentrations in Floodplain Wells Influenced by Extraction Wells 1089 and 1104, February 2000–September 2010

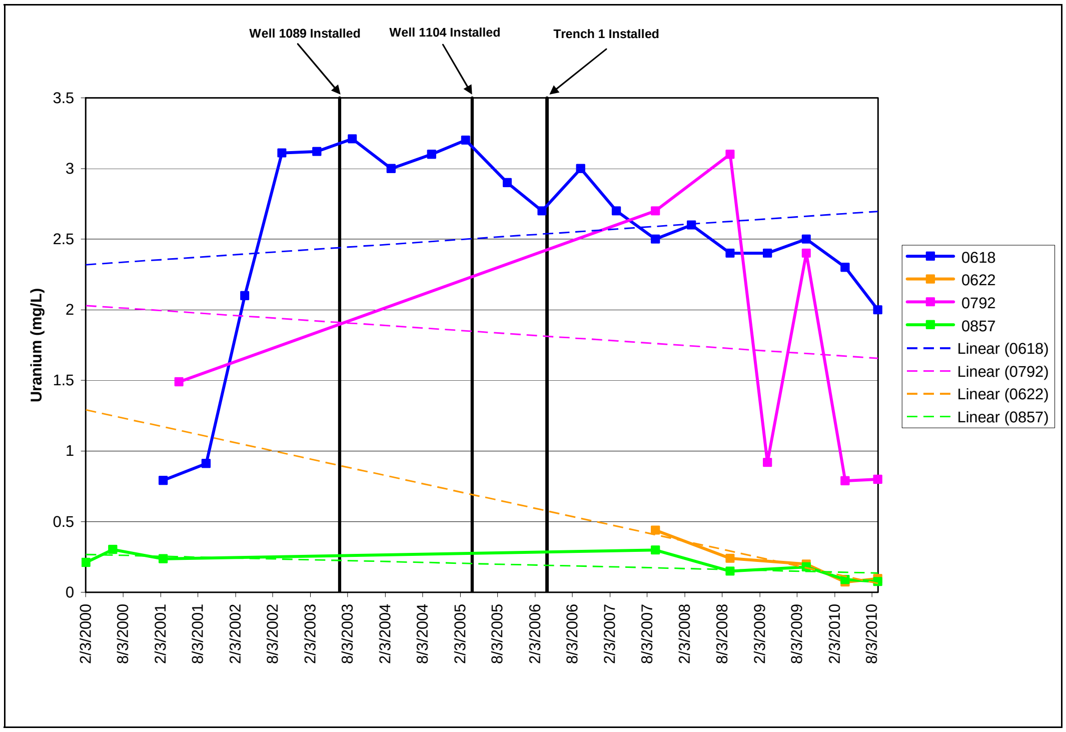


Figure 31. Uranium Concentrations in Floodplain Wells along the Flow Divide, February 2000–September 2010

Figure 32 shows the uranium concentrations in the area extending from the Trench 1 Area eastward to the San Juan River. The uranium concentrations in this area exhibit decreasing trends. The wells in the Trench 1 Area show larger decreases in concentration, as would be expected due to their proximity to the collection drain. The wells between the Trench 1 Area and the river have stayed steadier but still show a slightly decreasing trend. The relatively low and constant uranium concentrations at well 0853 suggest that this well is strongly affected by inflows from the San Juan River, which are likely increased due to pumping of Trench 1. These data show that the collection drain is capturing contaminants flowing from the terrace before the plume can migrate toward the river, as can be seen by the lower concentrations in the wells as they get closer to the river (1105 > 1009 > 0853).

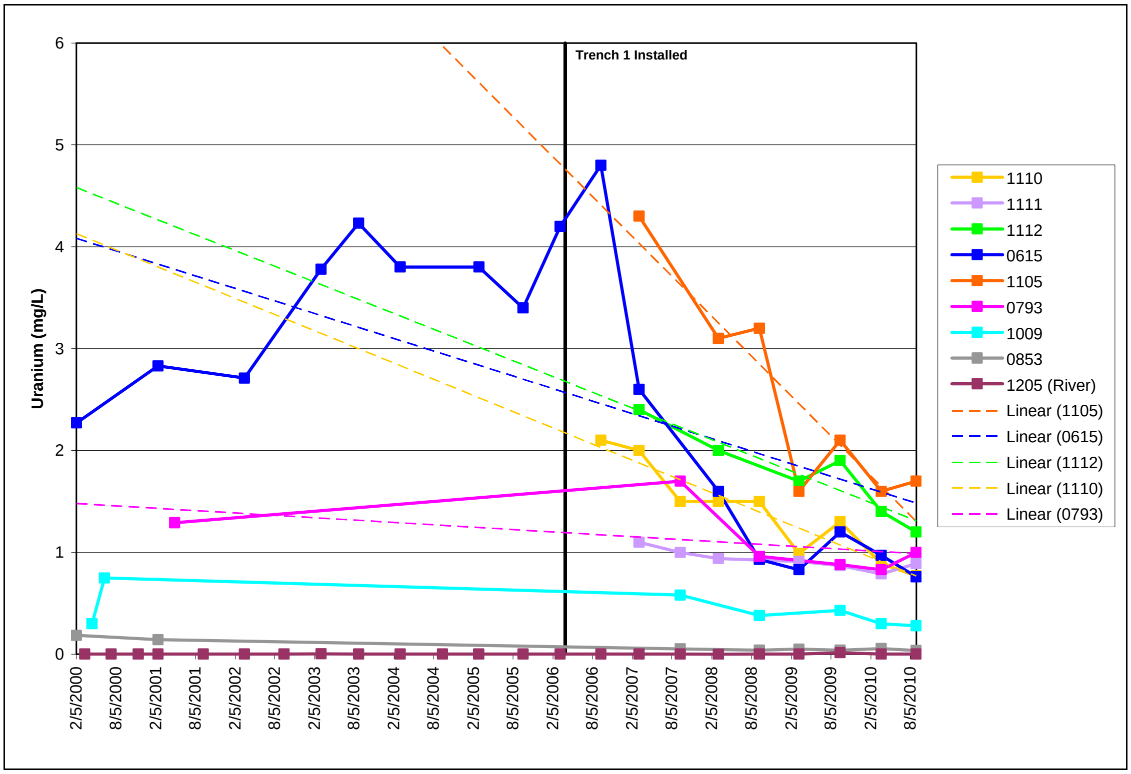


Figure 32. Uranium Concentrations from the Trench 1 Area to the River, February 2000–September 2010

Well 0615 is located downgradient of Trench 1, and it was installed before remediation began, so data from this well best represents the effects of Trench 1. Concentrations were increasing in well 0615 from February 2000 to September 2006 then decreased sharply after Trench 1 had been pumping for a year. The sharp concentration decrease is also evident in adjacent well 1105.

4.6 Groundwater Major Ion Chemistry

Influences on groundwater chemistry include influx from the San Juan River, local recharge, and contamination from the mill site. As noted above, data from well 0615 best reflect the impacts of Trench 1. The ion chemistry in this well was fairly stable and began decreasing once Trench 1 was installed and pumping (Figure 33). When pumping is stopped, a slight rebound in ion levels is observed.

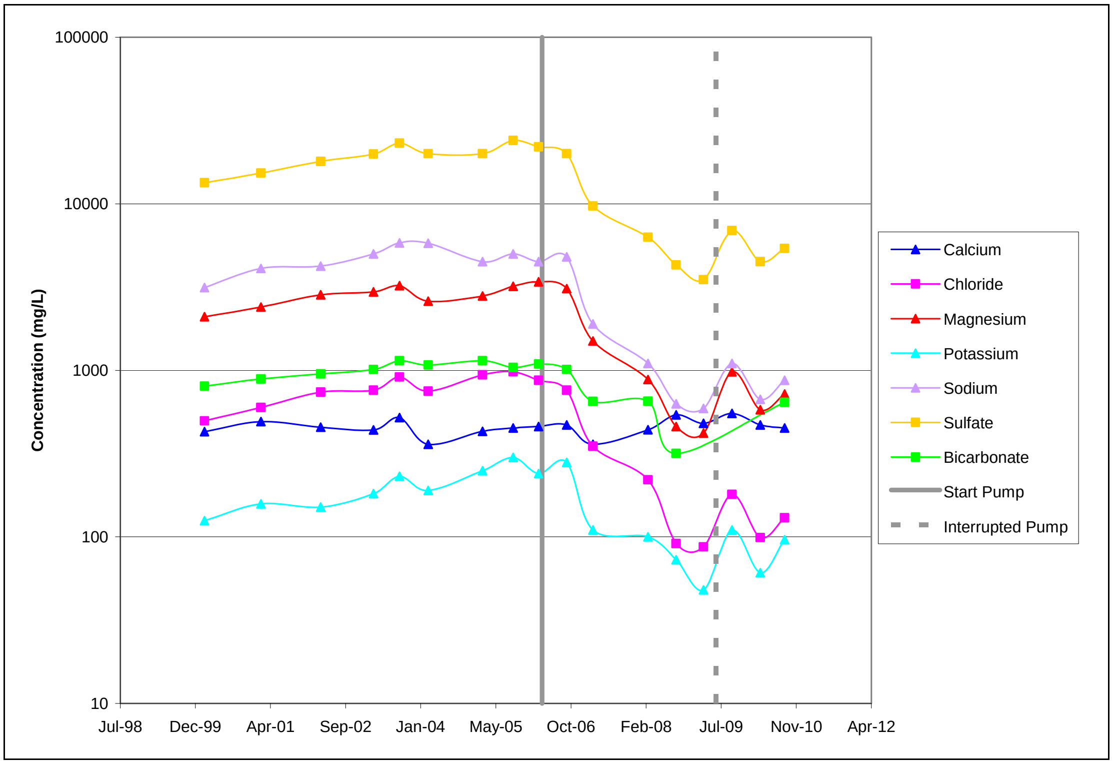
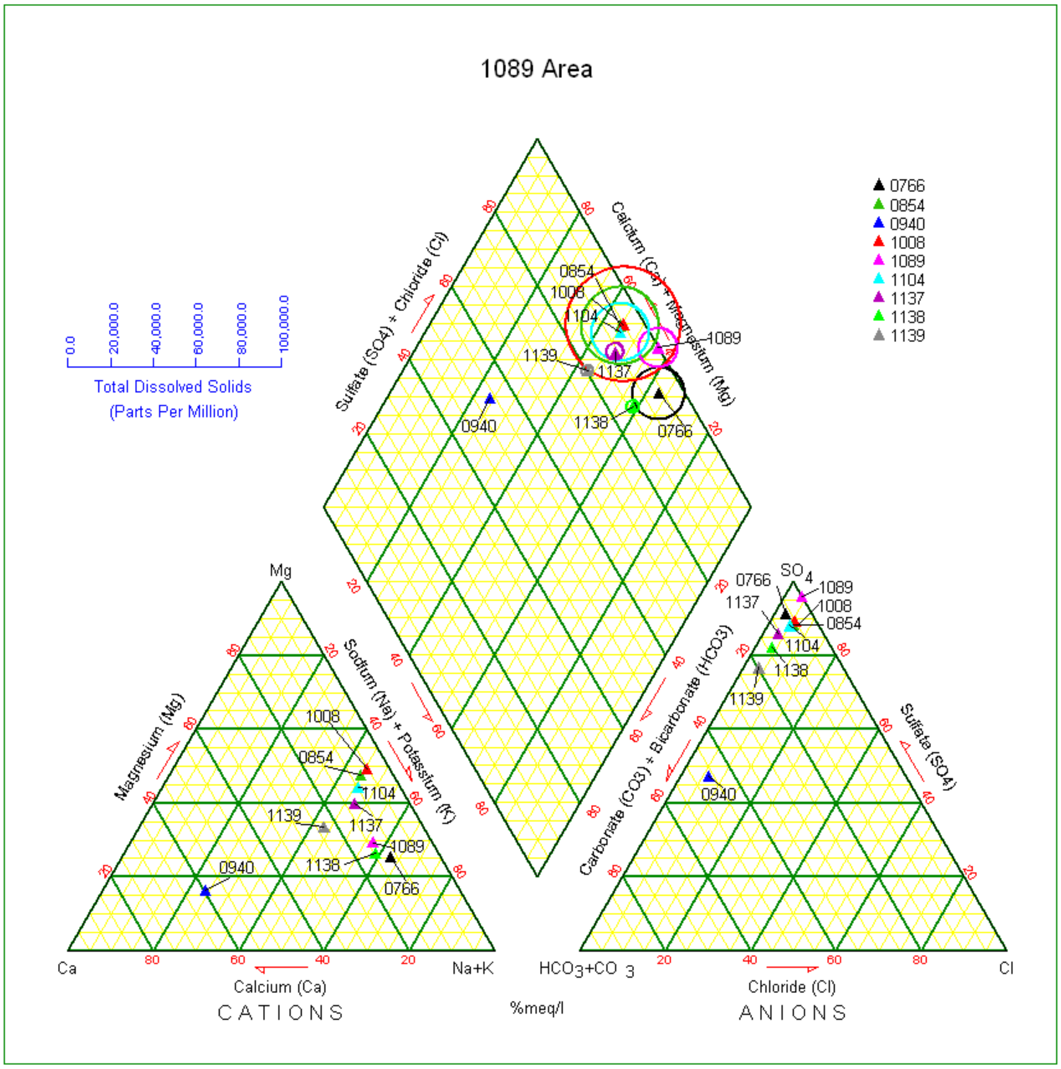


Figure 33. Major Ions in Well 0615, 2000–2010

Water chemistry is often classified by the ratios of major ions using a Piper diagram (Freeze and Cherry 1979). Piper diagrams were prepared using the September 2010 data to show the groundwater chemistry in three areas within the study area.

Figure 34 is a Piper diagram showing the ion chemistry in the 1089 Area. The majority of the wells show no dominant type on the cation chart, three wells (0766, 1089 and 1138) are sodium plus potassium dominant, and calcium dominates the cations in the river sample (0940). All of the wells show sulfate dominance for the anions, with the river (0940) showing no dominant type. The three wells closest to the river (1137, 1138, and 1139) show a slight trending in ion chemistry away from the cluster of other wells toward river like chemistry. Interestingly, the wells trend opposite of their locations; the well closest to the river (1137) is more sulfate type dominant than the other two wells. One explanation is that there is stratification in the groundwater and the wells are screened to different depths, and therefore the wells are capturing different layers of groundwater. Alternatively, it is possible that wells 1138 and 1139 are impacted by inflowing river water from the south to a greater degree than well 1137, even though water levels in well 1137 mimics river water levels (Figure 25).



Notes:
Location 0940 is river water
Abbreviations:
%meq/L = percent of total milliegivalents per liter

Figure 34. Piper Diagram of the 1089 Area Wells, September 2010

Figure 35 is a Piper diagram showing the ion chemistry of floodplain wells located between the 1089 Area and the Trench 1 Area. Anions in these wells are dominated by sulfate with the two wells closest to the river (0857 and 1136) trending toward no dominant type (similar to surface location 0940, as shown in Figure 34). Cations in the majority of the wells are dominated by sodium plus potassium with four wells having no dominance. The data shows a shift in cation dominance from sodium type toward magnesium type for the wells in the middle of the floodplain (0618, 0779, 0798) and toward calcium type for the wells closer to the river (0857, 1136).

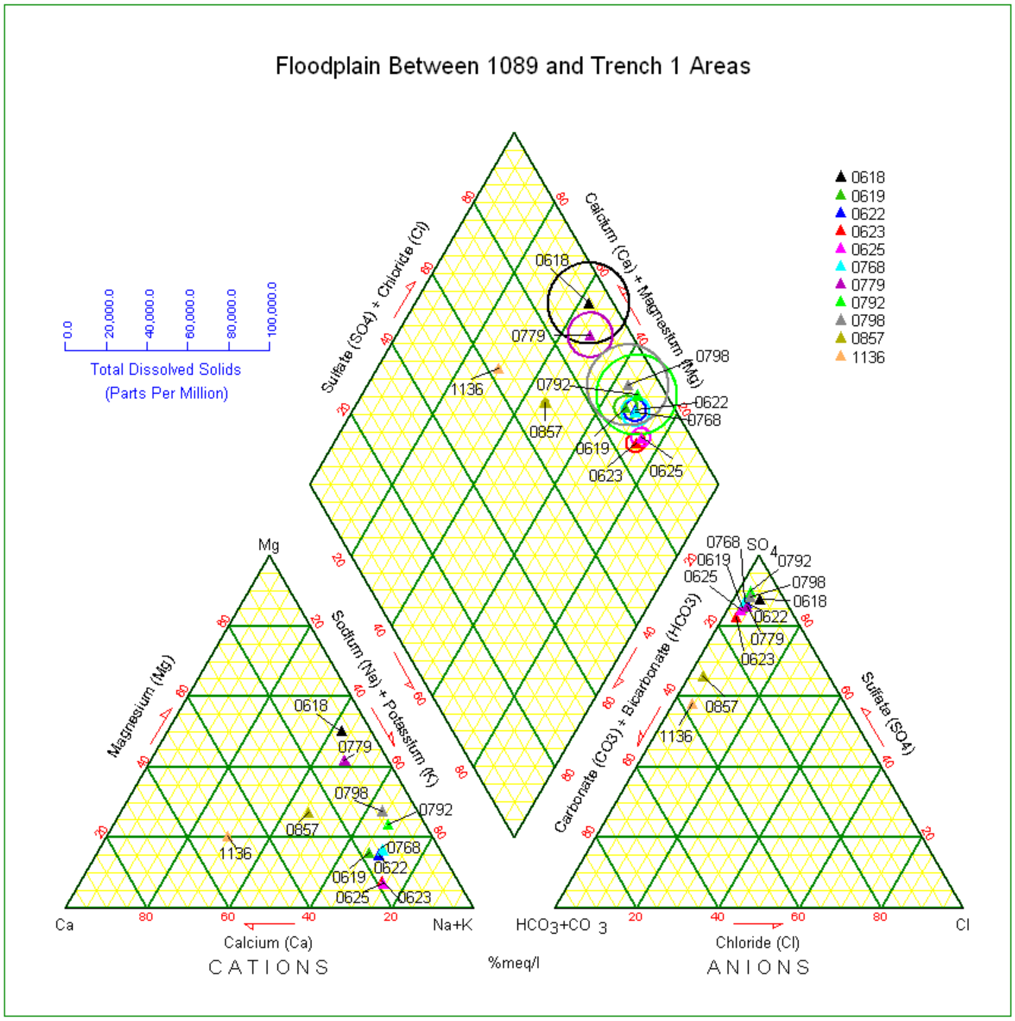
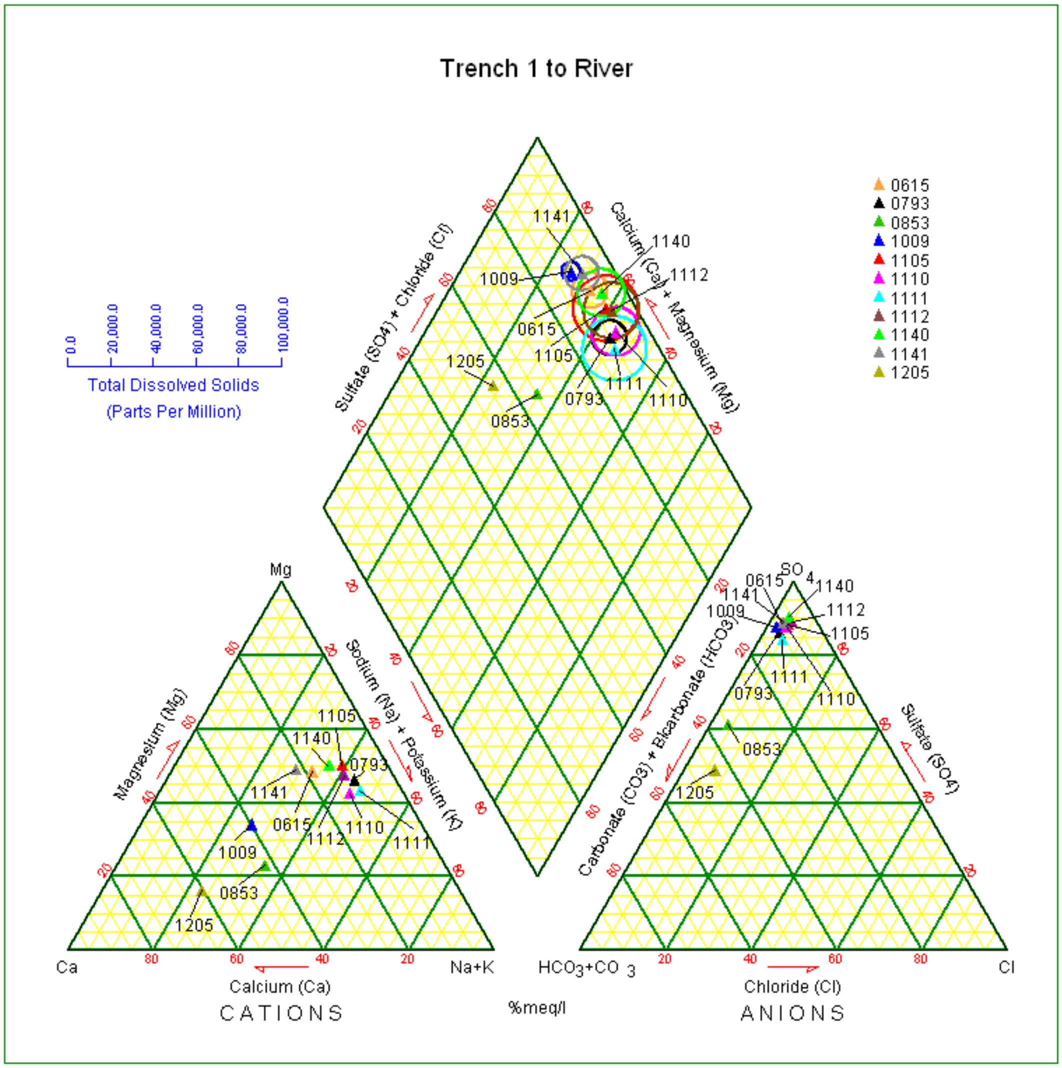


Figure 35. Piper Diagram of the Floodplain Wells between the 1089 Area and the Trench 1 Area, September 2010

Figure 36 is a Piper diagram showing the ion chemistry in the area extending from the Trench 1 Area to the river. In this area all of the wells are sulfate type for anions, with the river location (1205) having no dominant type, and the well closer to the river (0853) trending toward the river location. All of the wells show no dominant type for cations, with a trend toward river like chemistry, which is calcium type (location 1205).



Notes:
Location 1205 is river water

Figure 36. Piper Diagram of the Wells in the Area Extending from the Trench 1 Area to the River September 2010

Piper diagrams also indicate total dissolved solids (TDS) for the wells by the radii of the circles around the sample points on the diamond shaped portion of the diagram. In the 1089 Area (Figure 34), the wells ranked from highest to lowest TDS are as follows: 1008 > 0854 > 1104 > 0766 > 1089 > 1137 > 1138 > 1139. The same trend is observed with the September 2010 uranium concentrations, except that 1089 and 0766 are switched: 1008 (3.1 mg/L) > 854 (1.8 mg/L) > 1104 (1.2 mg/L) > 1089 (0.55 mg/L) > 0766 (0.37 mg/L) > 1137 (0.28 mg/L) > 1138 (0.16 mg/L) > 1139 (0.13 mg/L).

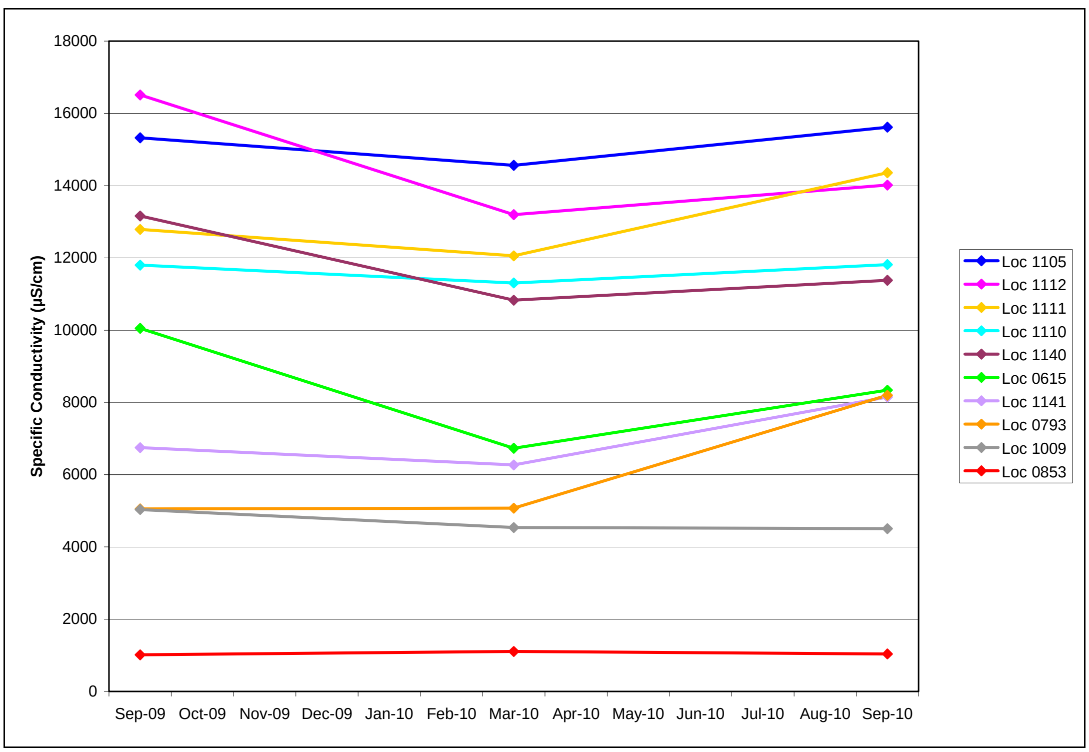
In the floodplain between the 1089 and Trench 1 areas (Figure 35), the TDS from highest to lowest for the wells north of the flow divide is as follows: 0798 > 0779 > 0768 = 0619 > 0623 = 0625 > 1136. For the wells at the flow divide, the TDS from highest to lowest is as follows: 0618 = 0792 > 0622 > 0857. For this area the same trends can be seen in uranium concentration: 0798 (0.97 mg/L) > 0779 (0.9 mg/L) > 0768 (0.16 mg/L) > 0619 (0.13 mg/L) > 0623

(0.053 mg/L) > 0625 (0.048 mg/L) > 1136 (0.0046 mg/L), and 0618 (2 mg/L) > 0792 (0.8 mg/L) > 0622 (0.097 mg/L) > 0857 (0.076 mg/L).

In the Trench 1 Area to the river (Figure 36), TDS from highest to lowest is as follows: 1105 = 1111 > 1112 > 1140 = 1110 > 1141 = 0793 = 0615 > 1009. In this area the uranium levels trend with the TDS rankings except for wells 1111 and 1110, which fall lower in the uranium ranking, as follows: 1105 (1.7 mg/L) > 1112 (1.2 mg/L) = 1140 (1.2 mg/L) > 1141 (1.1 mg/L) > 0793 (1.0 mg/L) > 1111 (0.89 mg/L) > 1110 (0.77 mg/L) > 0615 (0.76 mg/L) > 1009 (0.28 mg/L). These trends are expected since TDS correlates well to specific conductivity and a correlation exists between uranium and specific conductivity, as discussed in Section 4.4.

4.7 Specific Conductivity

Specific conductivity is the electrical conductance of a body of unit length and unit cross-sectional area at a specific temperature (Hem 1985). Measurement of specific conductivity is straightforward and is readily integrated into remote monitoring systems. The instrumentation used in the SOARS system is robust and holds calibration well. Specific conductivity of pure water is very low and increases with increasing concentrations of charged ions. Thus, specific conductivity values directly correlate with dissolved salt content. Specific conductivity values are useful in depicting plume-river interaction because contaminated groundwater is typically high in salts while river water is lower. This trend can be seen in data from the wells in and around the Trench 1 Area. Figure 37 is a graph of the specific conductivity data from the semiannual sampling events that occurred from September 2009 through September 2010. The specific conductivity values decrease from Trench 1 to the river.



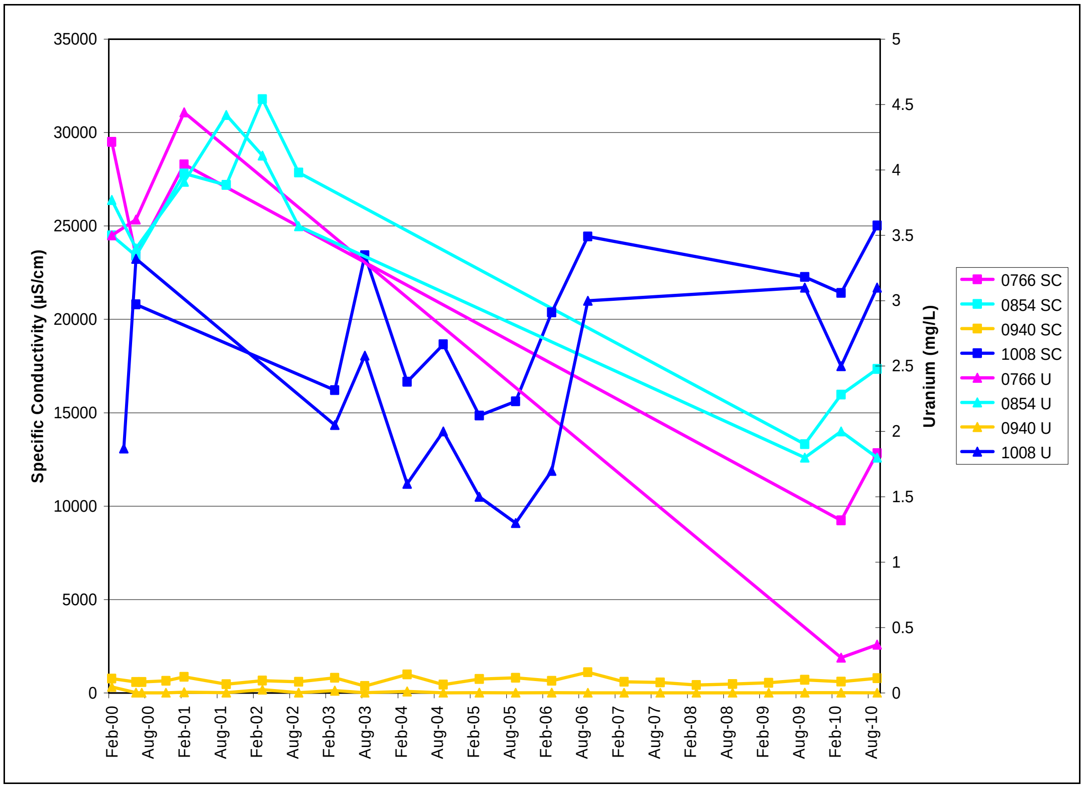
Notes:
Wells are ordered in legend by March result (highest to lowest)

Figure 37. Semiannual Sampling Specific Conductivity

4.7.1 Specific Conductivity and Uranium

Temporal plots of specific conductivity and uranium concentration at study area wells between 2000 and 2010 were prepared for the purpose of identifying correlation of trends in salinity and contaminant concentration.

Figure 38 shows the wells and river location in the 1089 Area. All of the wells show a matching trend between uranium and specific conductivity. A higher uranium result typically correlates with higher specific conductivity. There are a few incidences where the correlation is not observed. For example, in the September 2001 results for well 0854, uranium increased and specific conductivity slightly decreased, and the opposite was observed for September 2010, when uranium decreased and specific conductivity increased.



Abbreviations:
SC = Specific Conductivity
U = Uranium

Figure 38. 1089 Area Wells Uranium and Specific Conductivity, February 2000–September 2010

Figure 39 shows the extraction wells 1089 and 1104; both wells show a matching trend between uranium increase and specific conductivity increase. The uranium and specific conductivity data from the two extraction wells were graphed together and linear regression analysis was performed to look for a direct correlation (Figure 40).

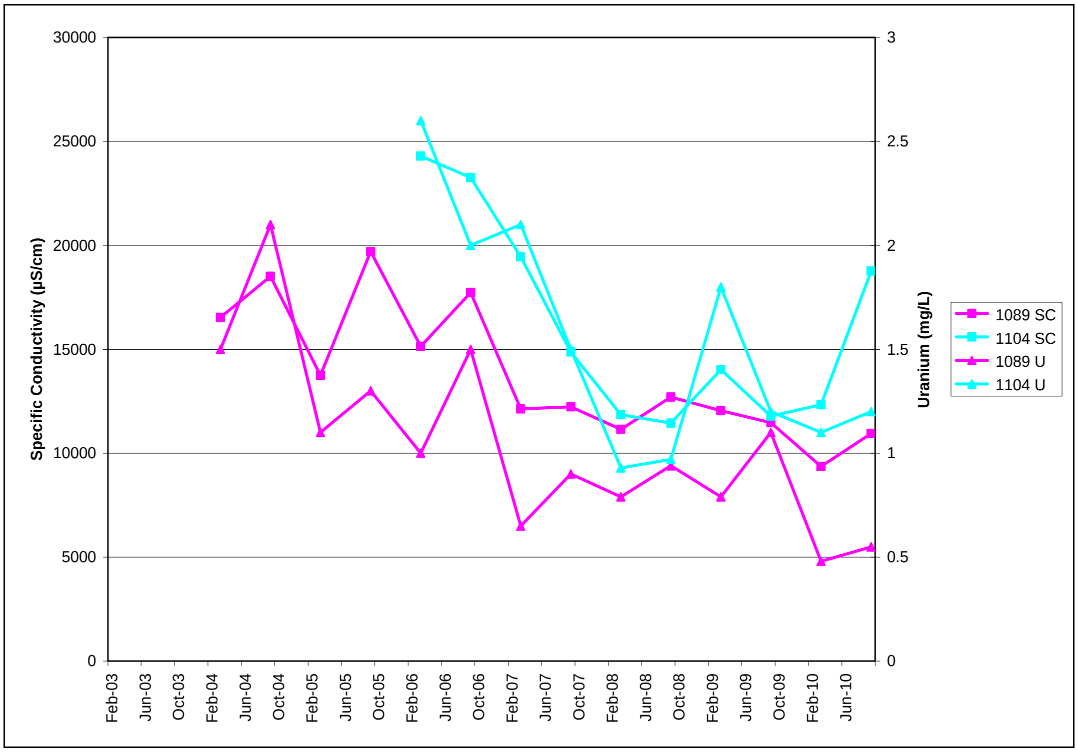


Figure 39. Uranium and Specific Conductivity in Extraction Wells 1089 and 1104, 2003–2010

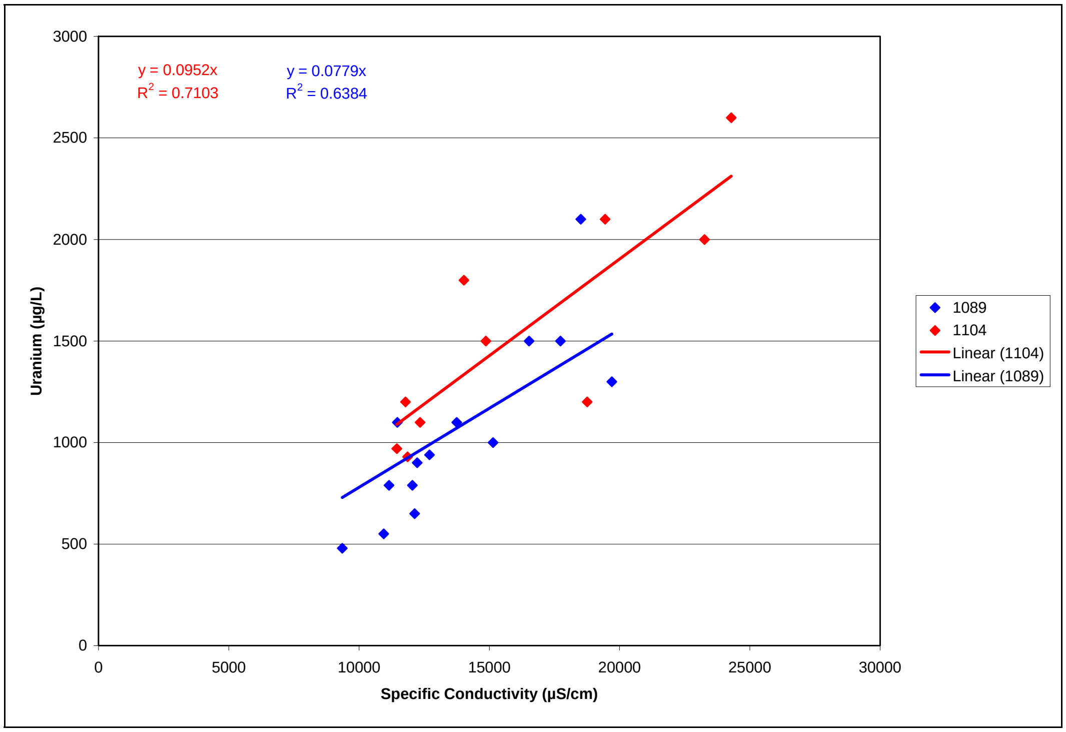


Figure 40. Extraction Wells 1089 and 1104 Analyte Correlation

The R^2 values are fairly high, showing a good correlation between uranium and specific conductivity. These correlations have been programmed into the SOARS software to monitor uranium removal at these wells. Using the daily specific conductivity reading on December 1, 2010, from SOARS and the cumulative volume of water pumped, the estimated amount of uranium removed by the extraction wells can be calculated. Well 1089 removed approximately 59.6 kg of uranium since pumping began until December 1, 2010, and 1104 removed approximately 8.3 kg. Comparing these estimates to the estimated 58.7 kg that Trench 1 removed in a shorter time frame shows that Trench 1 has the potential to remove more contaminants than either of the vertical wells.

Figure 41 shows newer Trench 1 Area wells and Figure 42 shows older Trench 1 Area wells and the floodplain wells between Trench 1 and the river. The wells all show matching trends between uranium and specific conductivity.

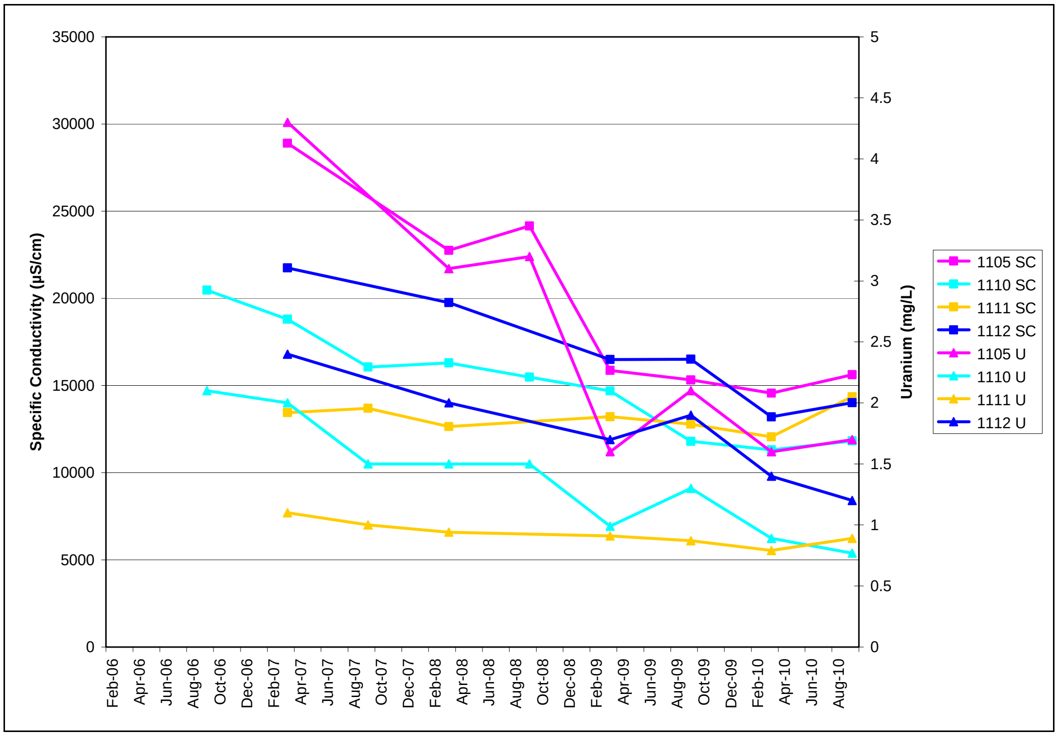


Figure 41. Uranium and Specific Conductivity in Trench 1 Area Wells, 2006–2010

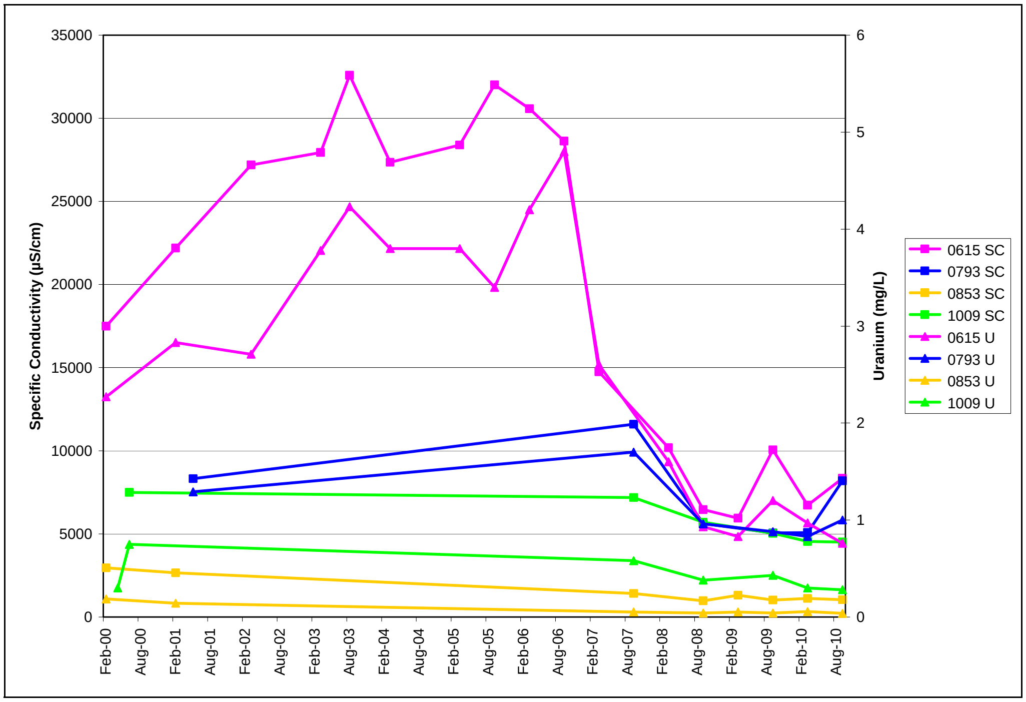


Figure 42. Uranium and Specific Conductivity in Trench 1 Area to River Wells, 2000–2010

Analyte correlation analysis was performed for the Trench 1 Area wells (Figure 43). Wells 615 and 1105 show the strongest correlation and well 1111 the weakest. The stronger correlations may be due more to larger data sets than to a truly higher correlation. The validity of calculating the amount of uranium using these correlations can be checked by using the SOARS specific conductivity measurements to calculate uranium concentration and then comparing it to the measured uranium value (Table 2). Interestingly, the correlation with the weakest R^2 value calculated uranium levels closest to the actual measured value. Even though the calculated values do not exactly match the measured values, the approximation in SOARS is still valuable as a tool to monitor contaminant removal.

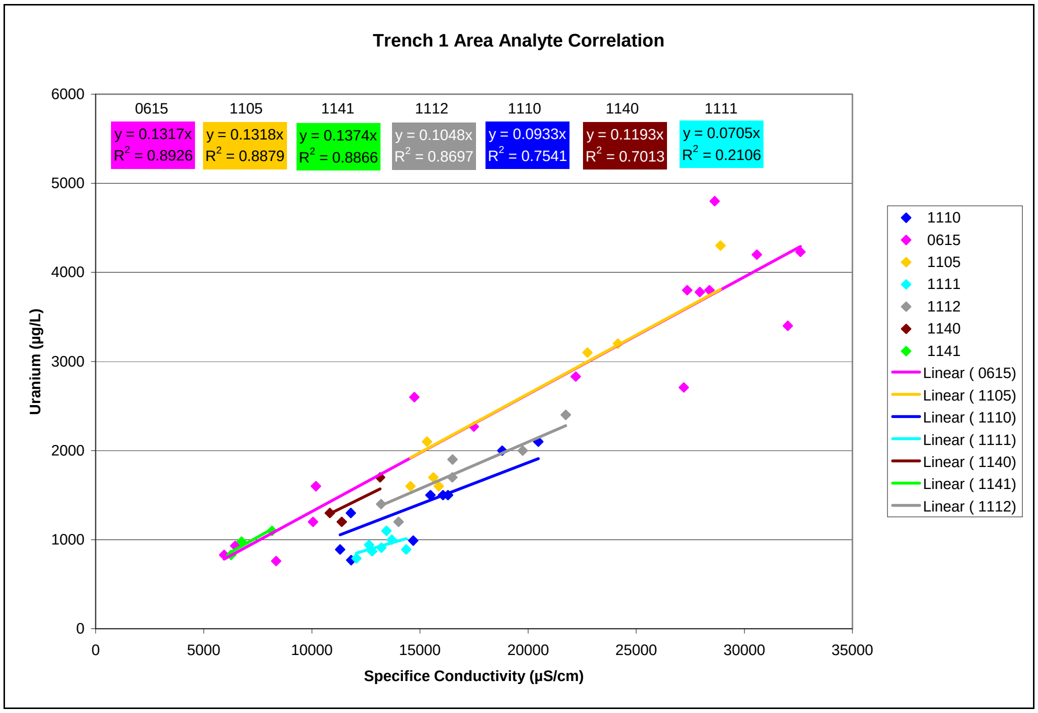


Figure 43. Trench 1 Area Wells Analyte Correlation

Table 2. Calculated and Measured Uranium Concentrations in Trench 1 Area SOARS Equipped Wells

Well	SOARs Daily Data 9/1/2010	Calculated U (mg/L)	Measured U (mg/L)	Difference	Correlation R^2 Value
1111	12.88	0.91	0.89	0.02	0.2106
1110	10.69	1.00	0.77	0.23	0.7541
1105	14.73	1.94	1.70	0.24	0.8879
1141	7.61	0.54	1.10	0.56	0.8866
1112	19.86	2.08	1.20	0.88	0.8697
1140	20.22	2.41	1.20	1.21	0.7013

4.7.2 Specific Conductivity and Pumping

Trench 1 daily specific conductivity data from SOARS was graphed for the month of December 2010 to show the effect that pumping has on contaminant concentrations. The specific conductivity increases almost immediately after pumping stops and continues to increase over time (Figure 44). This effect is likely due to the collection of lower specific conductivity water during pumping.

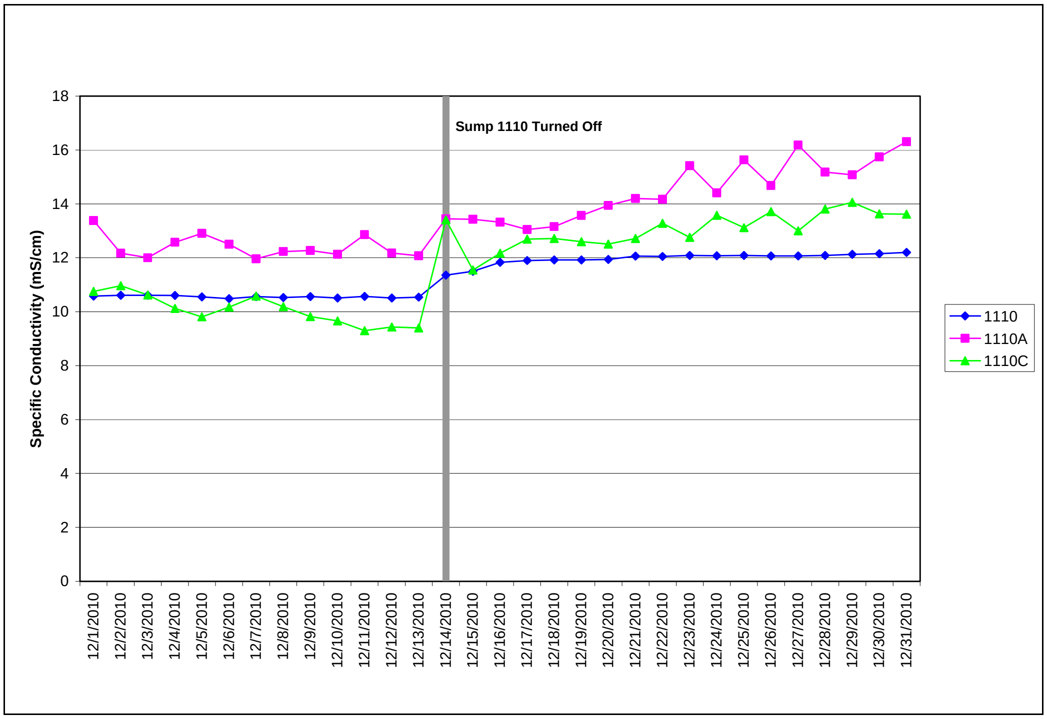


Figure 44. Trench 1 Daily Specific Conductivity Readings from SOARS

5.0 Discussion and Recommendations

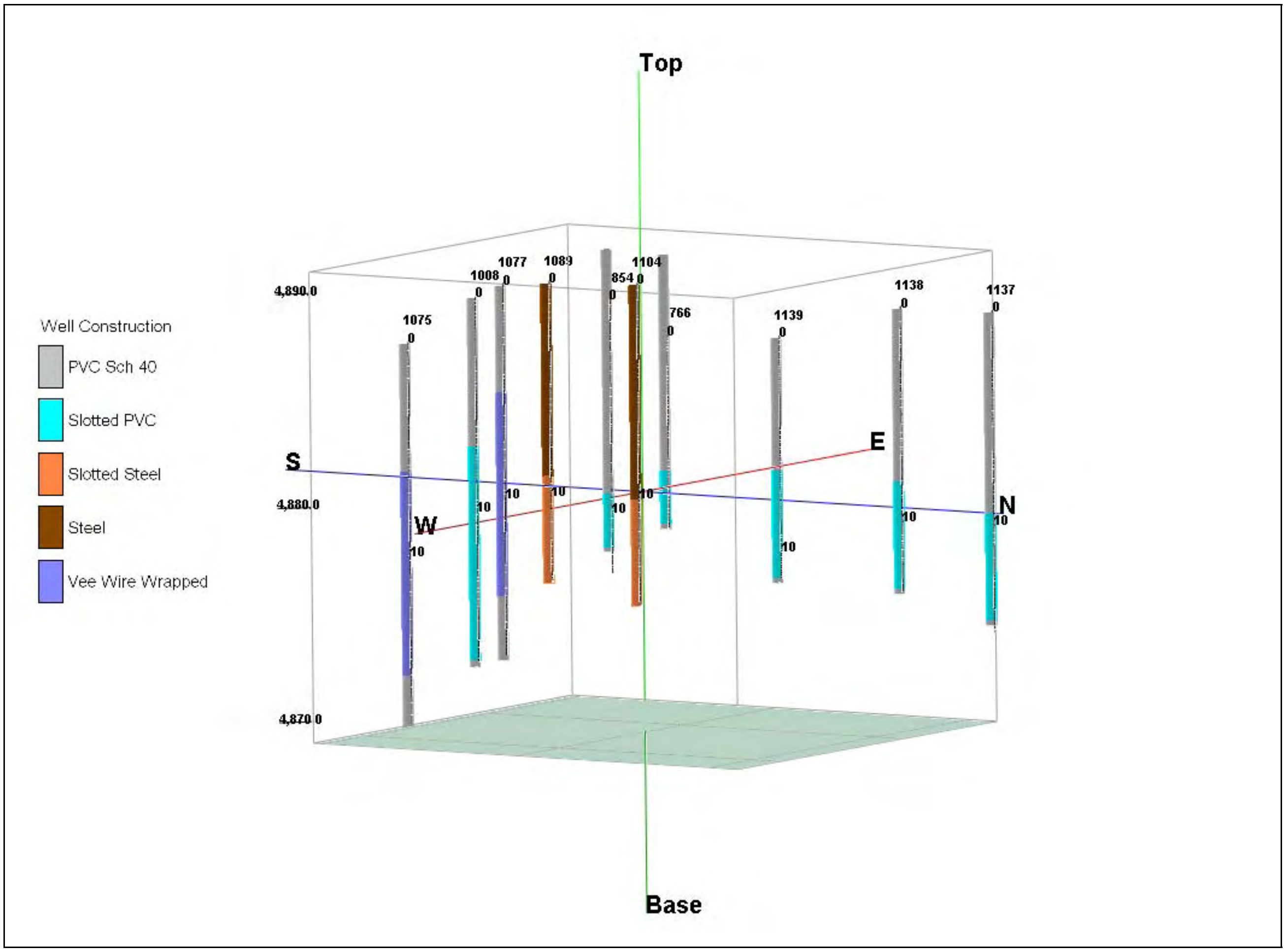
The collection drain is reducing the mass of contaminants that are reaching the river by intercepting contaminated water inflowing from the terrace as well as having an influence on groundwater flow away from the river. The capture zone created by the Trench 1 system is influenced by groundwater mounding at the mouth of Bob Lee Wash and by river elevations east of the Trench 1 Area. Currently, the highest levels in the uranium plume occur in the area between Trench 1 and the 1089 Area, with the highest concentration being observed in well 1008 (Figure 28). The groundwater flow on the floodplain, before remediation was implemented, was naturally toward the river and the 1089 Area (Figure 5). Pumping at wells 1089 and 1104 has decreased the contaminant concentrations in the 1089 Area, but also may be drawing more contaminants into the area. Trench 1 has reduced the mass of contaminants and volume of groundwater that the vertical extraction wells can draw, however the general flow of the plume is still toward the 1089 Area.

The objective of instrumenting and studying the Trench 1 collection drain was not only to assess the performance, but also to determine if the performance indicates that additions or modifications to the remediation system would be beneficial. One such addition could be to install another collection drain. Based on the areas of influence of the extraction wells and Trench 1, one might consider adding another collection drain in the central area of the floodplain between the Trench 1 and the 1089 areas near well 0798. A collection drain in that area would remove more contamination and prevent it from reaching the 1089 Area and the river. It could also reduce the area of influence of the extraction wells and pull the plume back from the 1089 Area. The same effect might be achieved if it is possible to increase the area of influence of Trench 1. Extraction wells 1089 and 1104 would need to be shut down while Trench 1 was pumping to see what effect Trench 1 has on groundwater flow when not competing with the vertical extraction wells. Shiprock site personnel, working on the holistic study, are preparing a model of the floodplain groundwater system, and they should be able to test this scenario in the model. If discontinuing pumping at wells 1089 and 1104 and only pumping at the collection drains is shown to have an increased effect in the model and the effect can also be corroborated by field measurements, then this change in the operation of the remediation system may be warranted. If Trench 1 can influence a greater area, then it could pull the plume back in toward the escarpment as well as preventing further migration of contaminants toward the river. This approach would also reduce the volume of water being removed and evaporated.

A focus of this study was on performance of the Trench 1 collection drain as compared to the vertical extraction wells in the 1089 Area. Additional studies in the 1089 Area would be useful to evaluate the following: (1) the large difference in pumping rates between the vertical extraction wells 1089 and 1104, (2) the interaction of the river with the 1089 Area as seen with the new wells 1137–1139, and (3) the increase in uranium levels in well 1008.

A 3D well log was prepared using Rockworks software as a preliminary attempt to understand the interactions in the 1089 Area. Figure 45 shows the well construction and depth below surface of the wells in the 1089 Area.

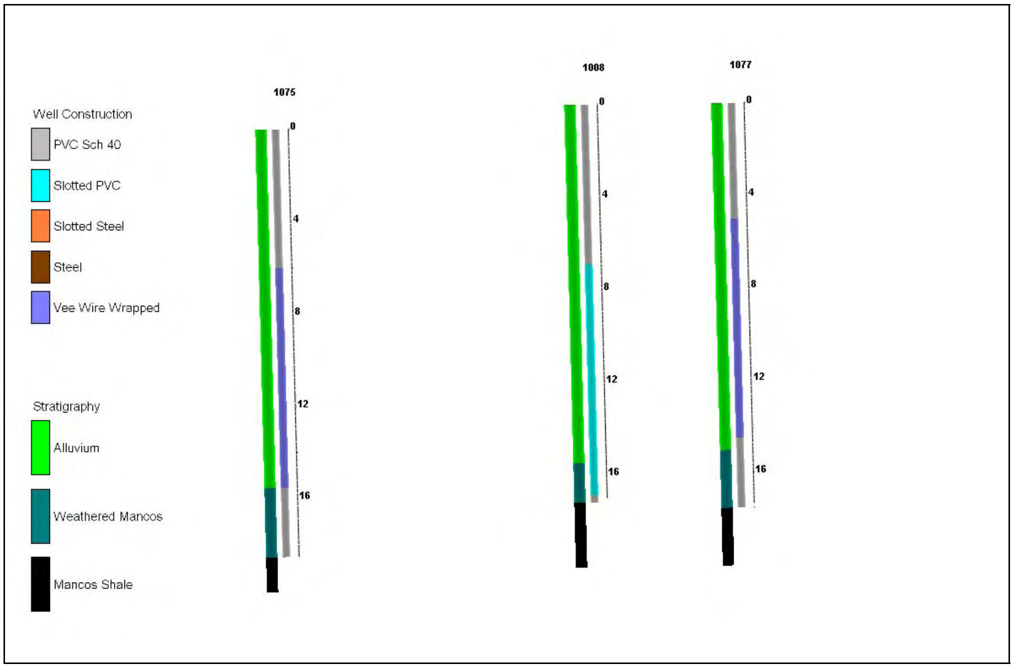
Wells 1075, 1077, and 1008 are the deepest wells in the area. Well 1008 is screened the deepest and is partially screened in weathered Mancos (Figure 46). The well depth and screened interval may be a factor in the differing uranium concentrations observed. Further studies in this area and on the flow of contaminates in the floodplain to the 1089 are recommended, as many theories have been suggested as explanation of the elevated uranium concentrations in well 1008 (Section 4.5). Additional investigation in the area of well 1008 should include sampling at wells 1075 and 1077, which are currently not included in semiannual sampling except for water levels. A better understanding of the plume in this area would be useful to determine if the suggested changes to the remediation system would remain protective of the river and continue to reduce the contaminant levels in the 1089 Area.



Notes:
Units are in feet below ground surface.
Elevation in feet is shown on the left side of the grid.

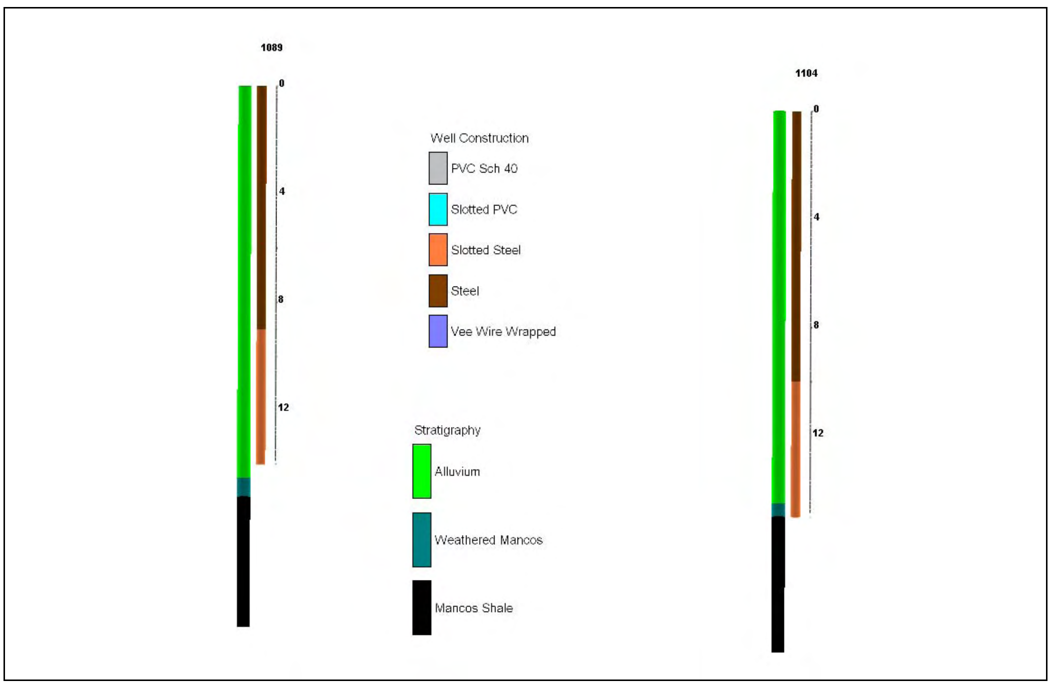
Figure 45. 3D Well Logs of the 1089 Area

Figure 47 shows the well logs and a simplified stratigraphy near the extraction wells 1089 and 1104. Additional investigation on the current condition of these wells could potentially help in determining causes for the lower pumping rates from well 1104.



Notes:
Units are in feet below ground surface.

Figure 46. Well Logs and Simplified Stratigraphy for Wells 1075, 1077, and 1008



Notes:
Units are in feet below ground surface.

Figure 47. Well Logs and Simplified Stratigraphy for Wells 1089 and 1104

Wells 1137, 1138, and 1139 were installed to determine if contaminants are reaching the river, and well 1137 was instrumented as part of this study. Even though a preliminary assessment shows that well 1137 is hydraulically connected to the river (Figure 25), the water chemistry shows well 1139 to be most river-like in composition. In the short time (about 1 year) that well 1137 has been sampled concentrations of major ions and uranium have decreased by about 50 percent from the values at the time of well installation (Figure 48). In contrast the uranium concentration in well 1139 has increased from 180 µg/L to 850 µg/L in the same time period. Further studies on these wells, including continuing to monitor well 1137 using the SOARS system, will be key in understanding the interaction of the river with the 1089 Area.

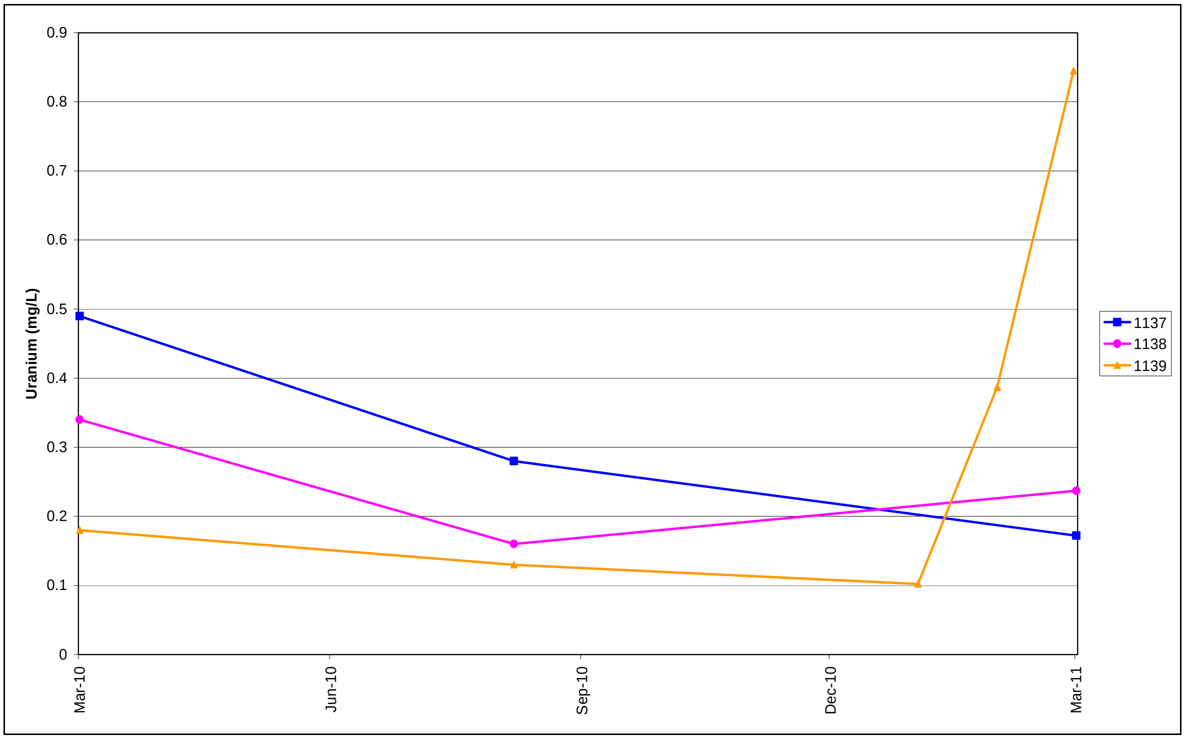


Figure 48. Uranium in Wells 1137, 1138, and 1139

The SOARS instrumentation installed for the Trench 1 Area and 1089 Area systems has been effective in helping to understand the effects of pumping on the groundwater aquifer system. Sensors that measure specific conductivity have now been field tested at the site for several years with good results; however, in some cases the results were inaccurate due to electrical noise and other issues that interfered with the readings. These issues are being addressed and can likely be overcome. Careful notes were incorporated into the SOARS logs, including comments about disturbances that affected the system. Technical personnel need to continue to carefully observe the SOARS data, conduct frequent calibrations, fix problems in a timely manner, and make needed adjustments in order to collect a high-quality data set. The specific conductivity data provide a continuous record of data that mimic contamination levels, and for this reason provide valuable information for making decisions about groundwater remediation.

6.0 Conclusions

This preliminary evaluation of the Trench 1 collection drain has shown that the floodplain remediation system is having a positive effect on contaminant removal and plume control. The concentration of uranium in the floodplain groundwater has been reduced by pumping at Trench 1 as well as at the extraction wells 1089 and 1104. From when it was installed in the spring of 2006 through December 2010, Trench 1 has removed 16,746,300 gallons of water and an estimated 58.7 kg of uranium. Trench 1 has the potential to remove more water from the floodplain than the vertical extraction wells 1089 and 1104 because Trench 1 has a higher average pumping rate. The groundwater flows produced by pumping are reducing the groundwater plume and limiting contaminants from reaching the river. The SOARS system has been shown to be a valuable tool in monitoring remediation system performance, and upgrades to SOARS based on recommendations in this report are being implemented. This study has identified areas that require further study, some of which will be addressed by the groundwater model being prepared by site personnel conducting a holistic study of the floodplain.

7.0 References

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Appendix A

Data Quality Assessment of SOARS Depth-to-Water (DTW) Measurements

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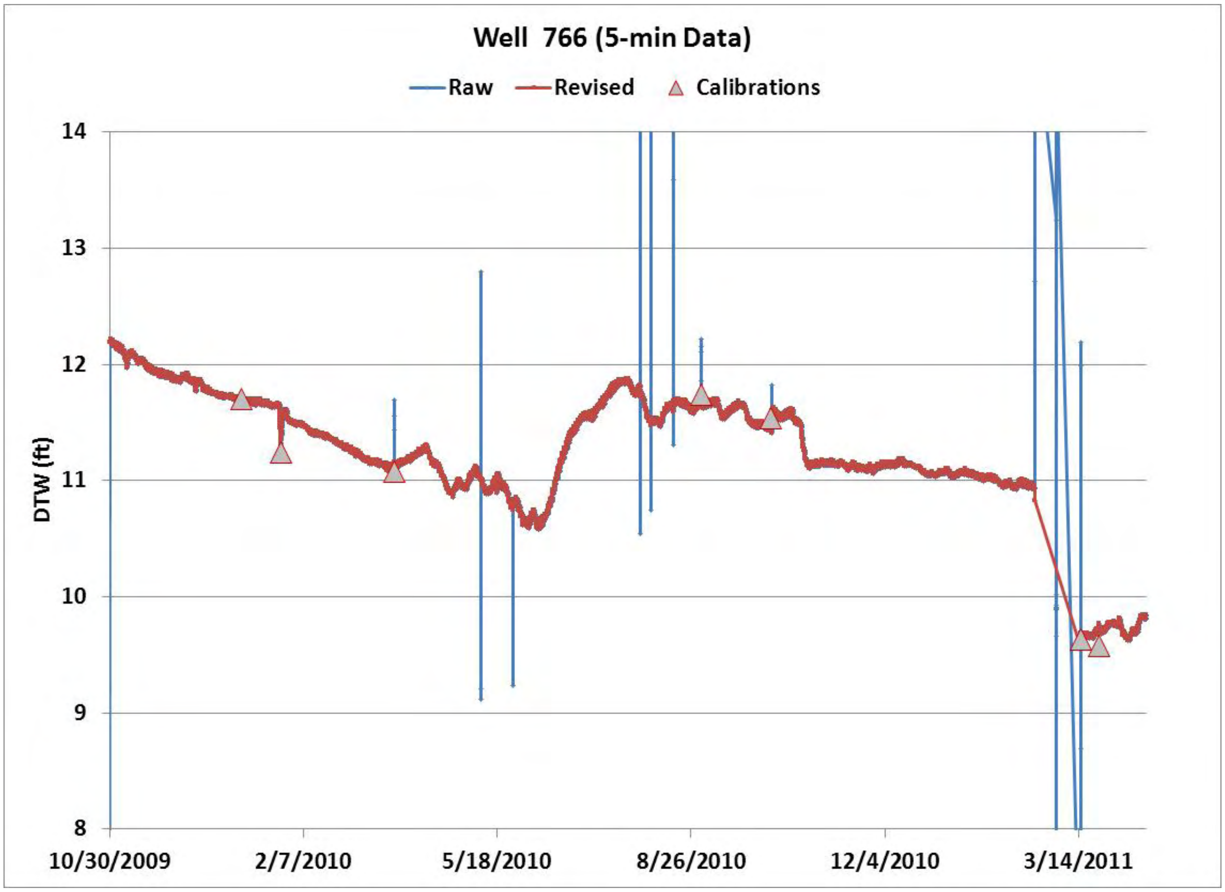
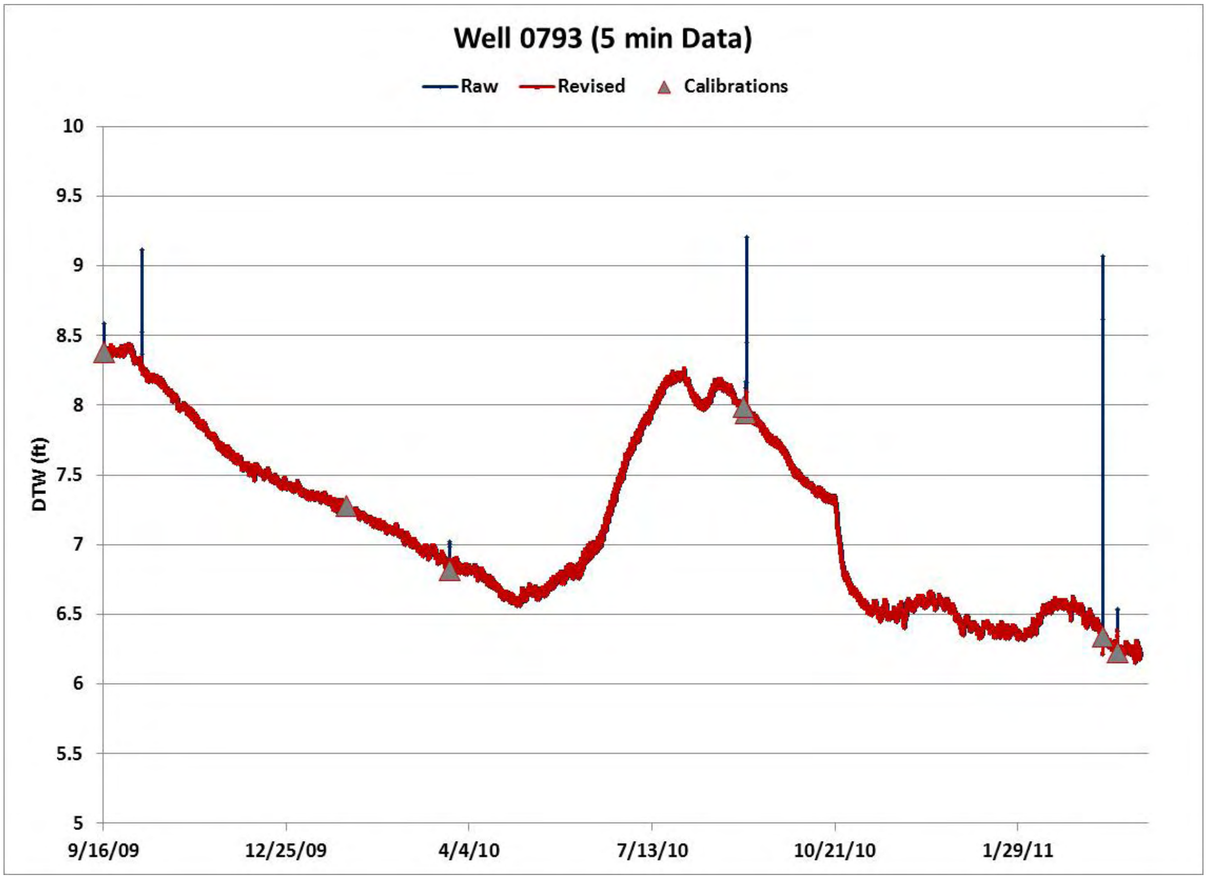
In this appendix, depth-to-water (DTW) data from the SOARS system are compared to calibration points to assess their accuracy. In cases where data were known to be erroneous from entries in field notes, the data have been transformed to corrected values. Details of these transformations are provided. The transformed values are used in the body of the report for interpretive purposes. Data were collected on 5-minute intervals to provide a detailed examination of the water table responses to pumping and non-pumping conditions. At this collection frequency, for the period October 30, 2009, through April 1, 2011, there were about 150,000 depth-to-water measurements for each well.



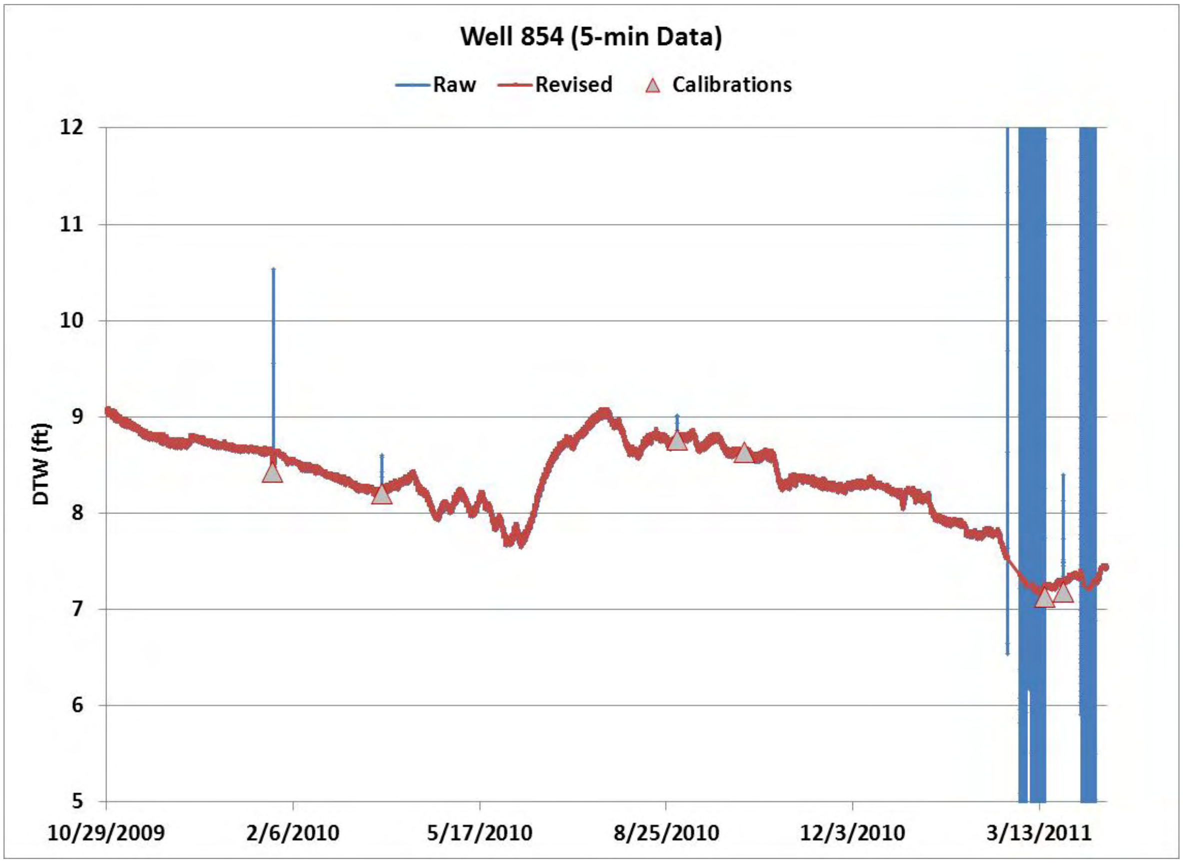
Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data include removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same.
Data from 10:05 on February 19, 2011, through 08:40 on March 15, 2011, were omitted due to a power outage.

Figure A–1. SOARS DTW Values for Well 0766



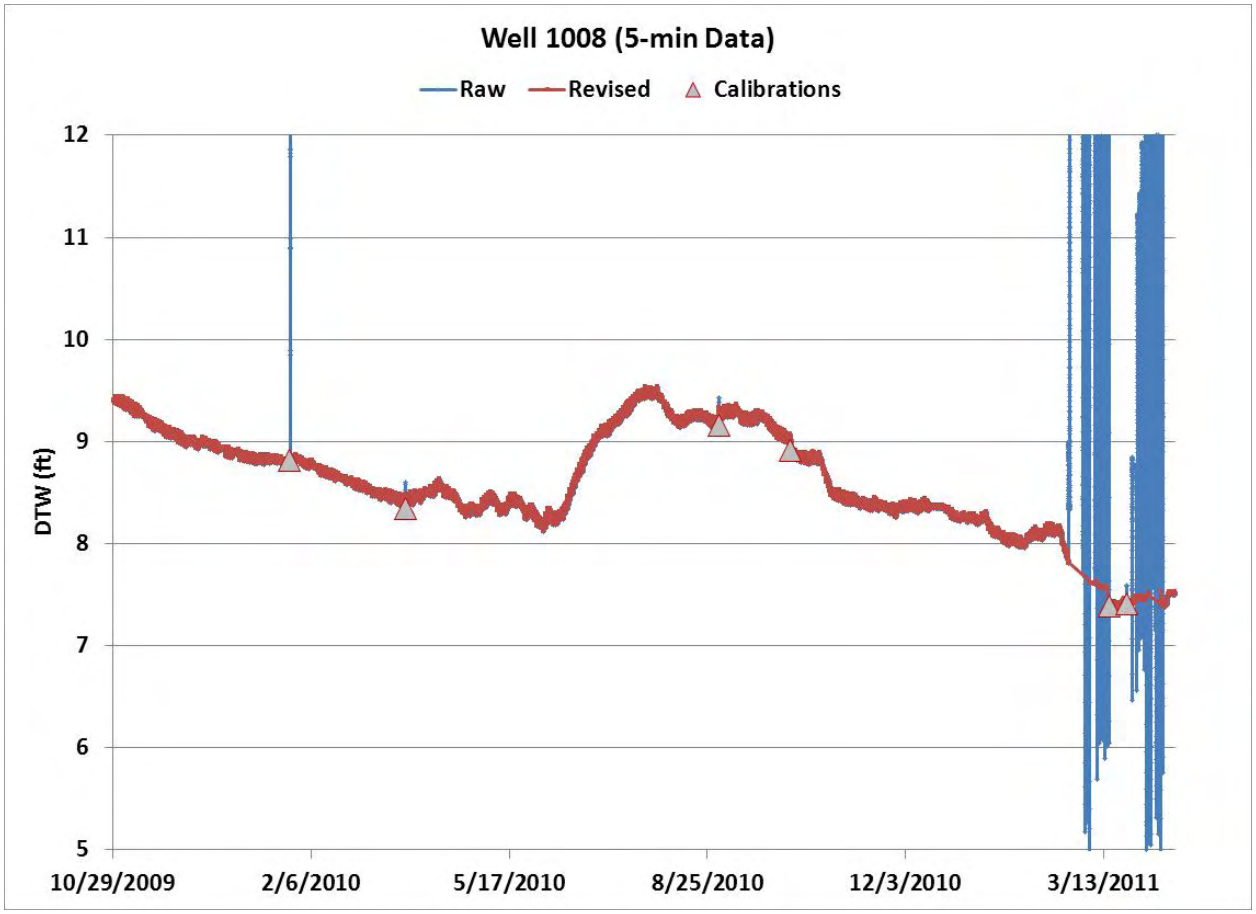
Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data include removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same.

Figure A–2. SOARS DTW Values for Well 0793



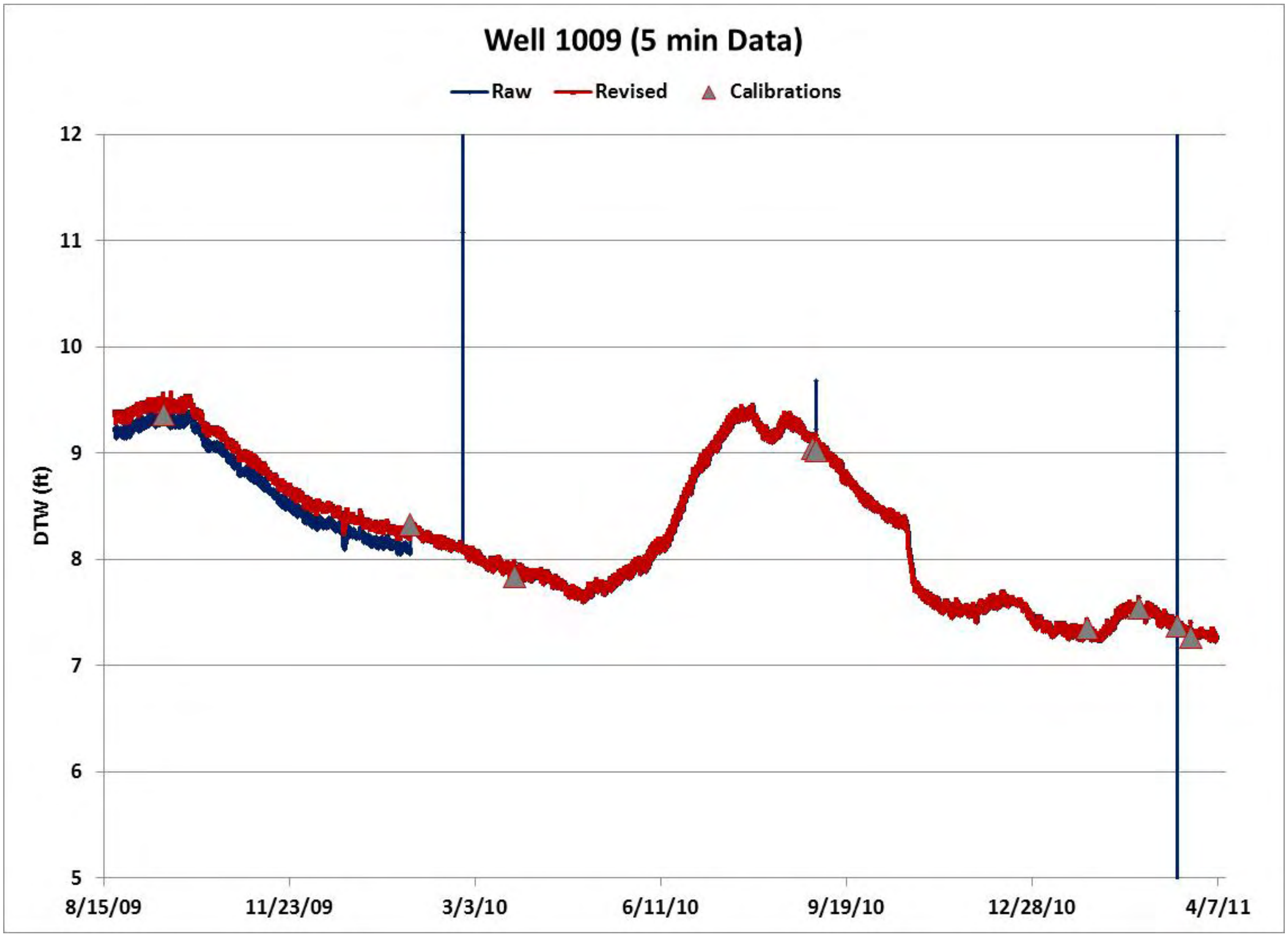
Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data include removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same. Power was low during the nights from about February 23 through April 4, 2011; those low-power-related erroneous data were omitted, but valid data from the daytime (when battery power was good) were retained.

Figure A–3. SOARS DTW Values for Well 0854.



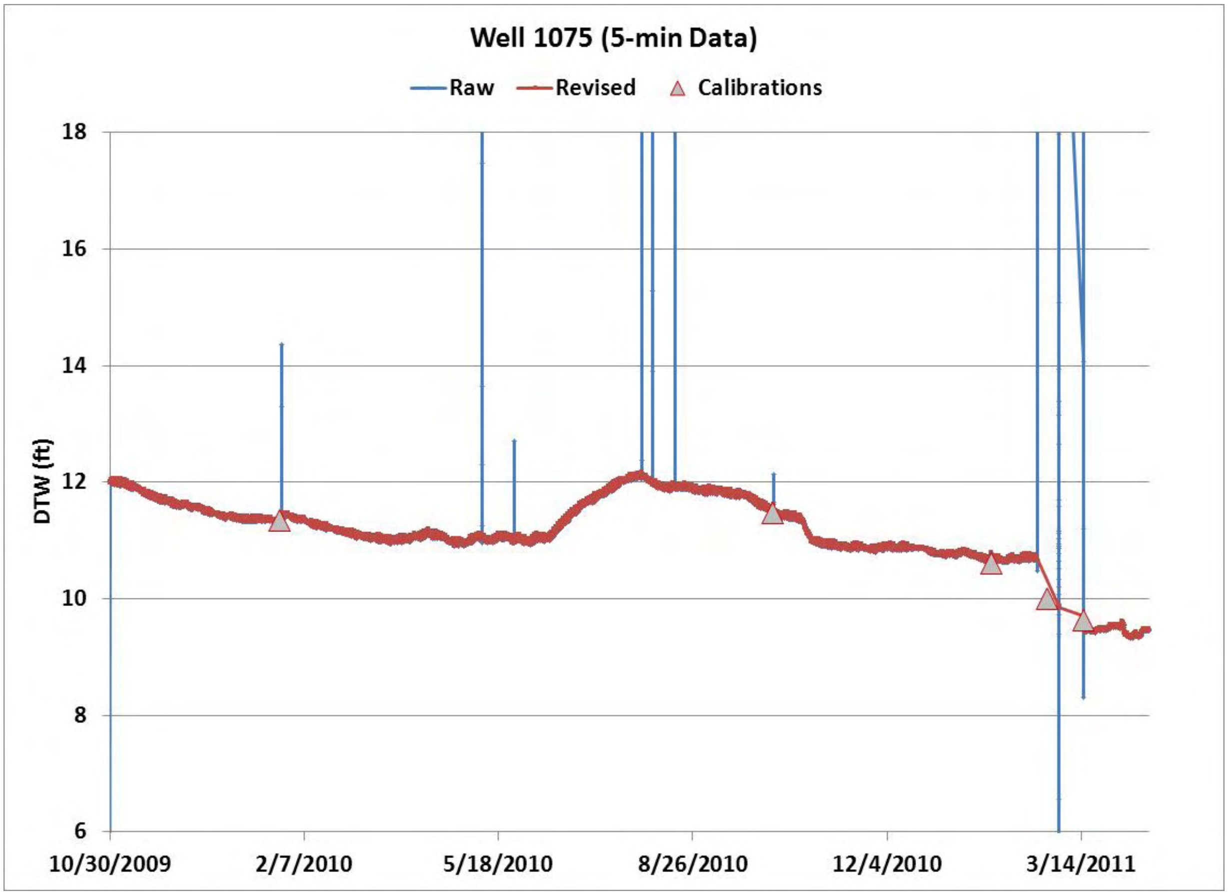
Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data include removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same. Power was low during the nights from about February 23 through April 4, 2011; that low-power-related erroneous data were omitted, but valid data from the daytime (when battery power was good) were retained.

Figure A–4. SOARS DTW Values for Well 1008



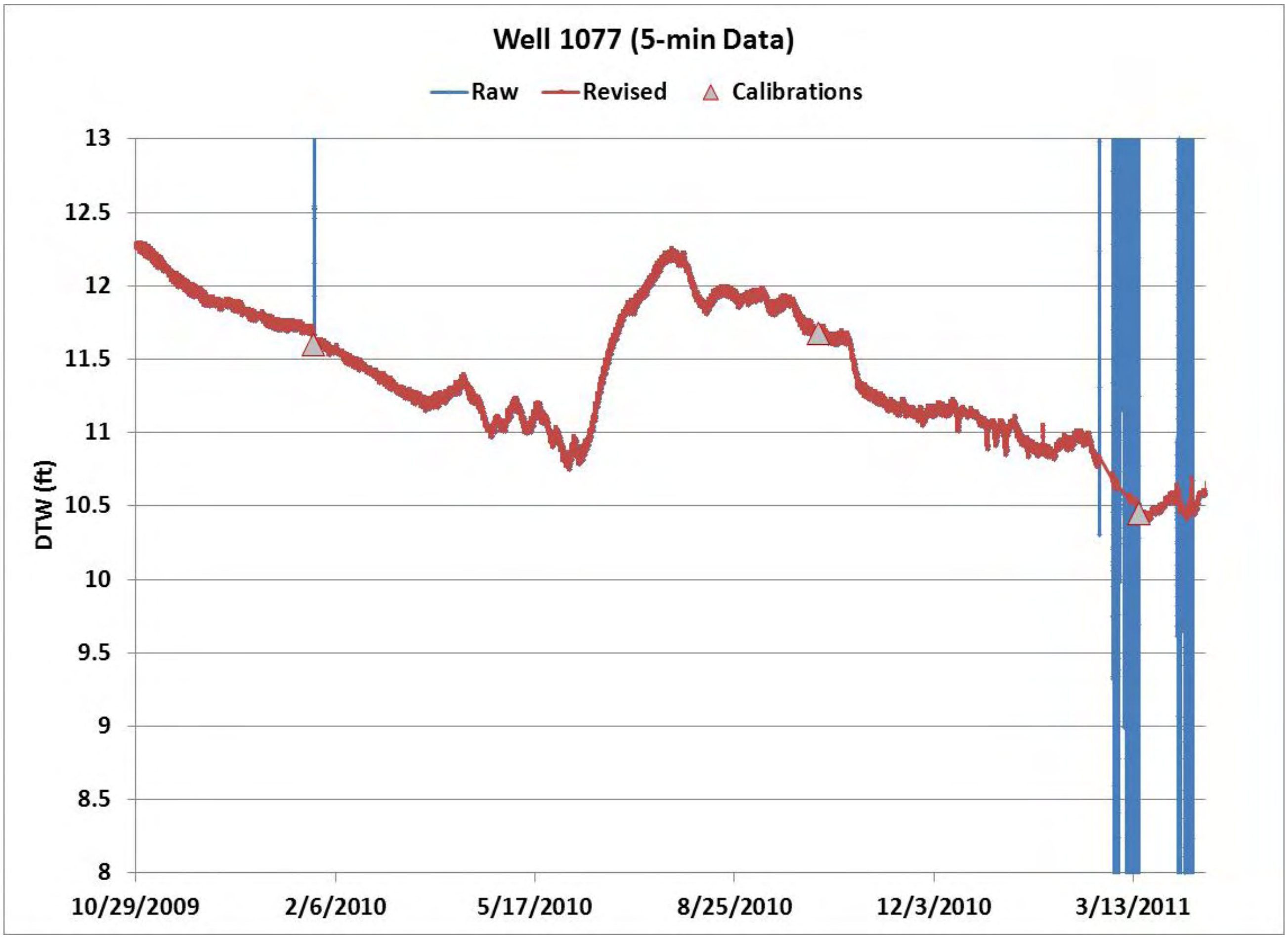
Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data include removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same. Added 0.14 ft to DTW data for the period from 10:50 on August 21, 2009, through 17:00 on January 27, 2010, to match calibrations.

Figure A–5. SOARS DTW Values for Well 1009



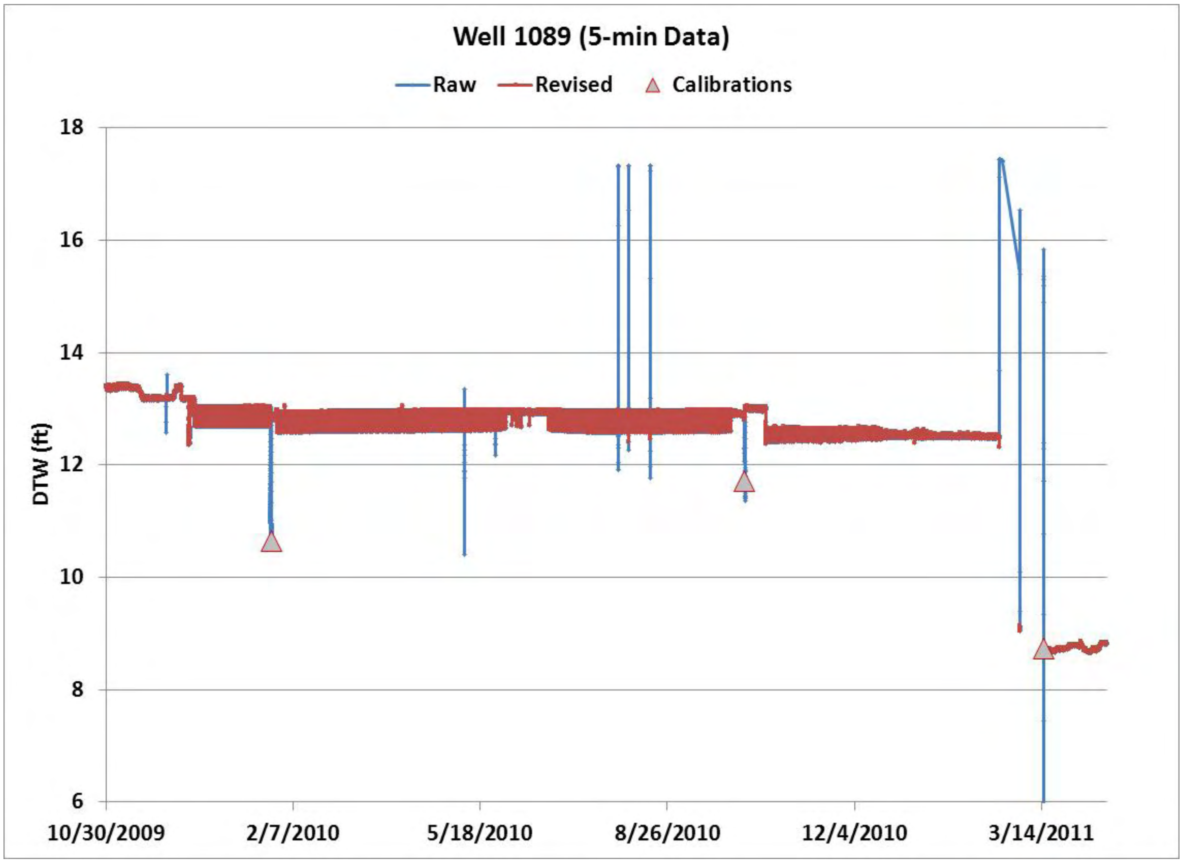
Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data include removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same.

Figure A–6. SOARS DTW Values for Well 1075



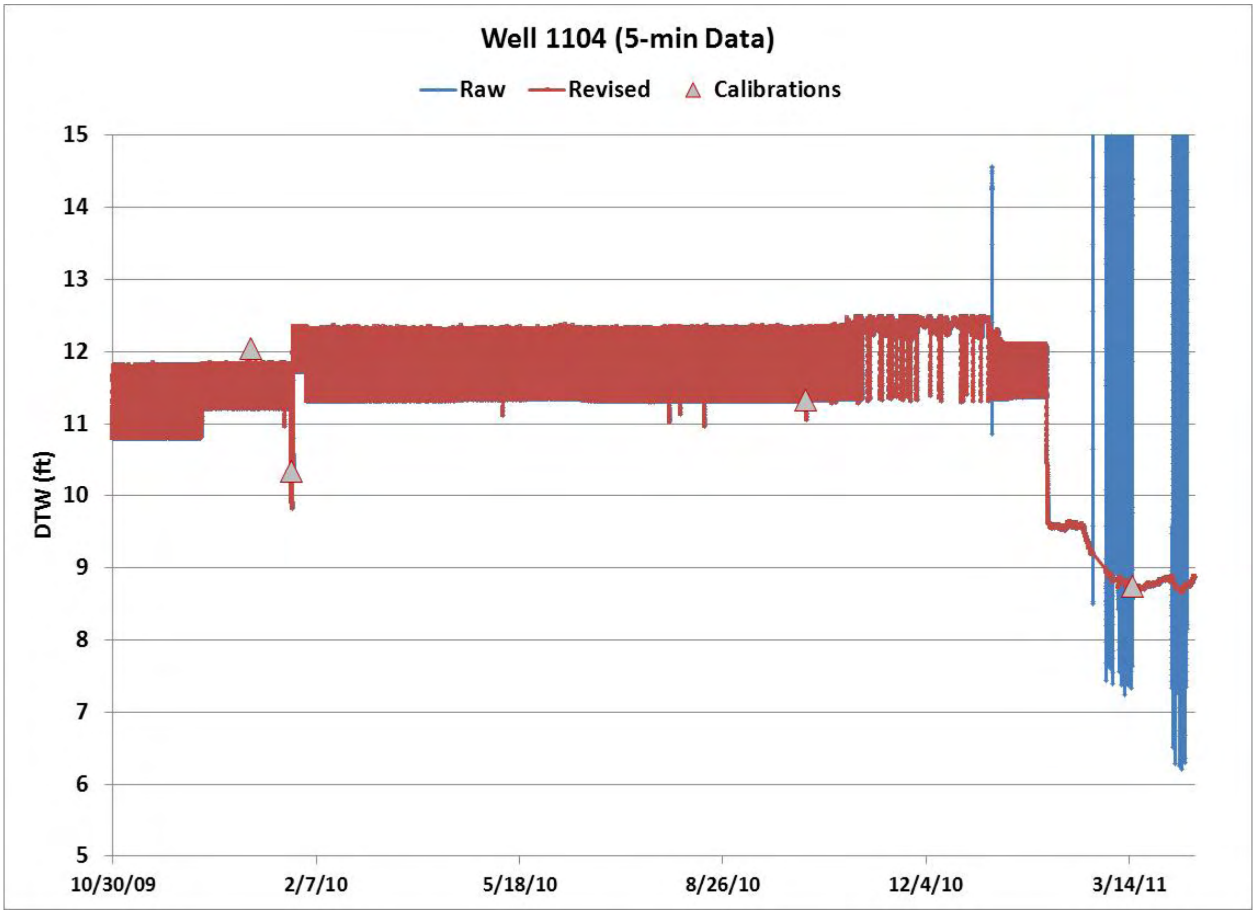
Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data include removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same. Power was low during the nights from about February 23 through April 4, 2011; that low-power-related erroneous data were omitted, but valid data from the daytime (when battery power was good) were retained.

Figure A–7. SOARS DTW Values for Well 1077



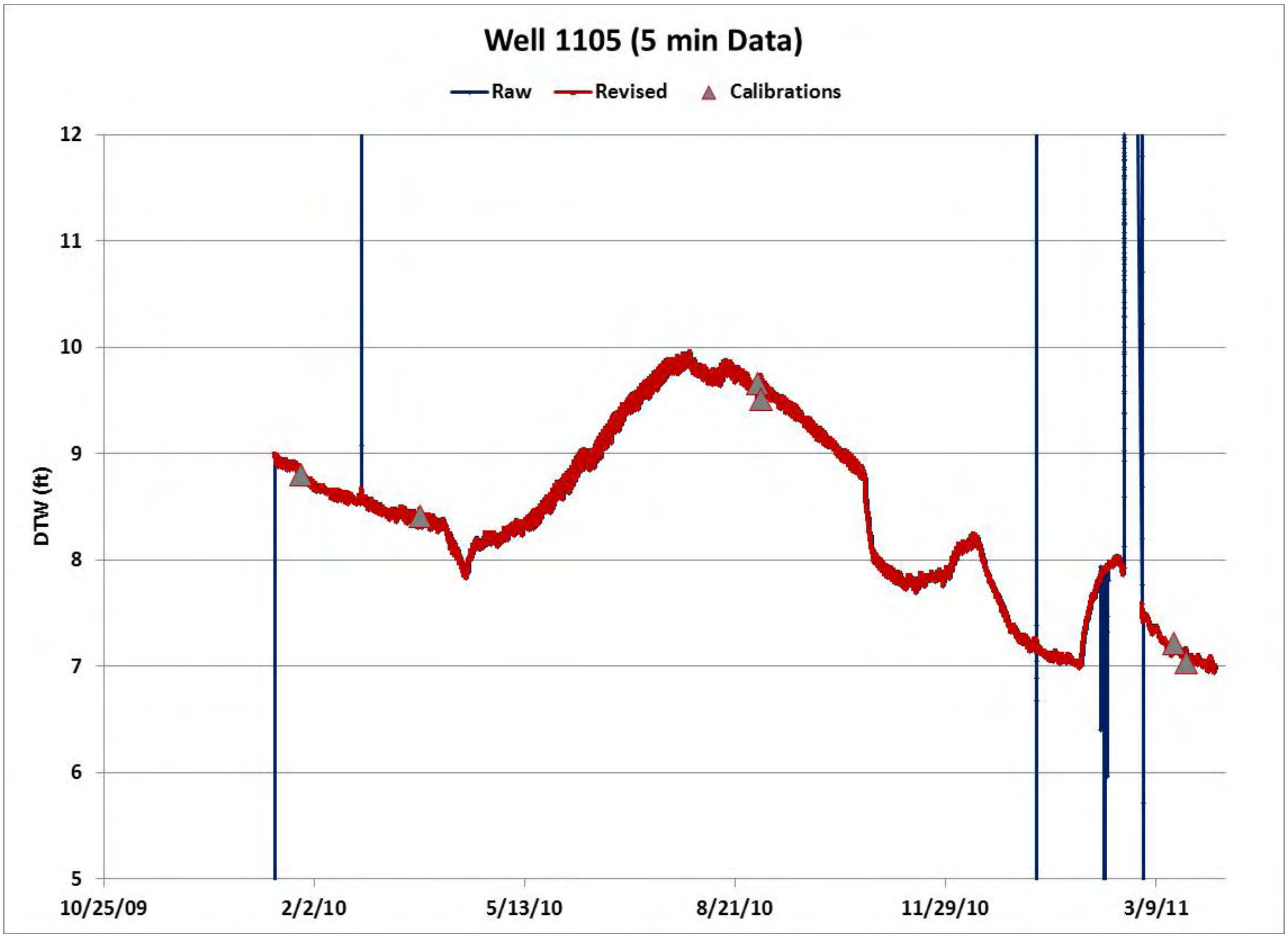
Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data include removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same. Data from 10:05 on February 19, 2011, through 11:00 on March 15, 2011, are missing due to a shutdown associated with a pipe break.

Figure A–8. SOARS DTW Values for Well 1089



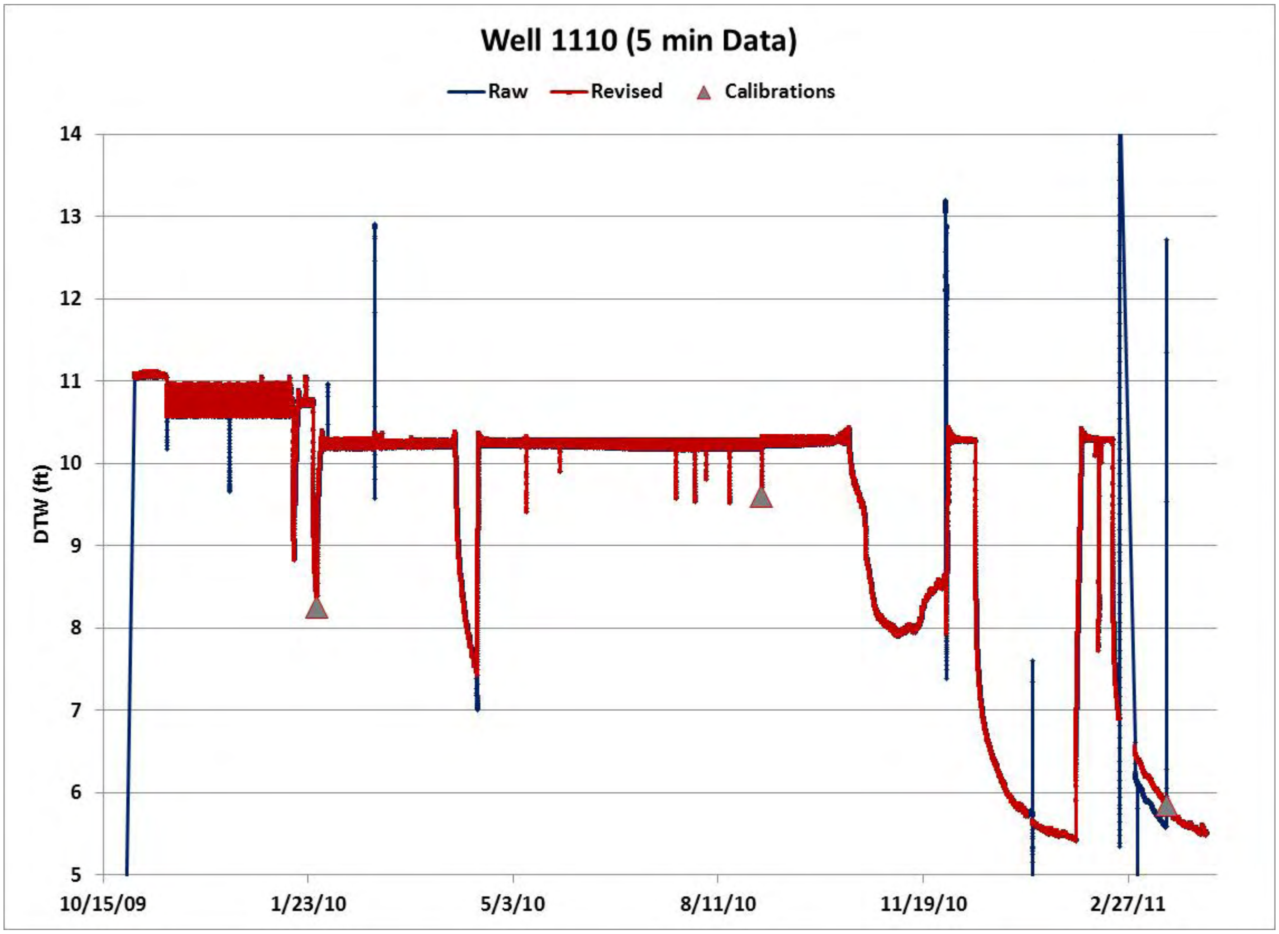
Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data include removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same. Power was low during the nights from about February 20 through April 11, 2011; those low-power-related erroneous data were omitted, but valid data from the daytime (when battery power was good) were retained.

Figure A–9. SOARS DTW Values for Well 1104



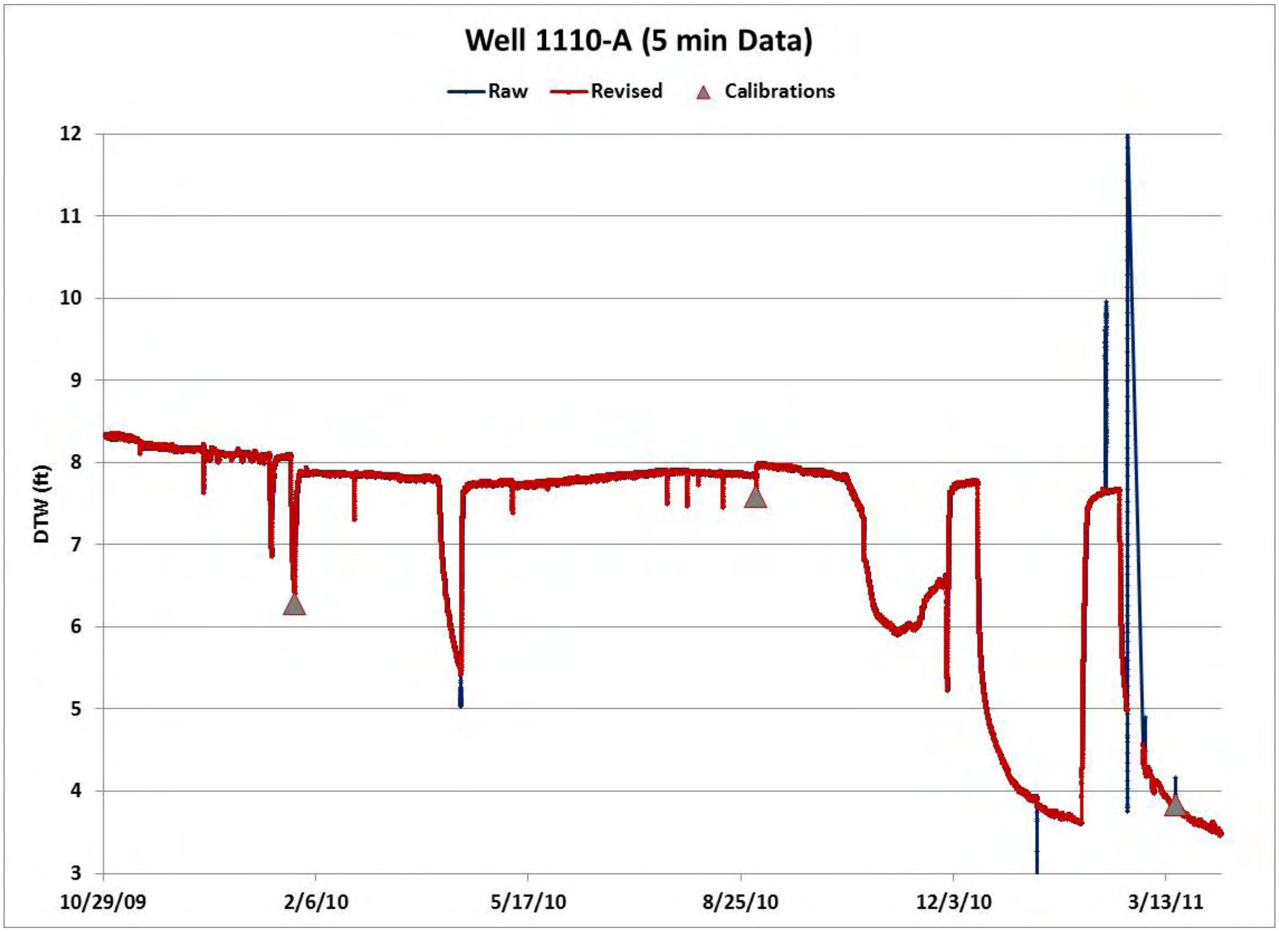
Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data includes removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same. Data from 10:45 on October 30, 2009, through 09:00 on January 14, 2010, were omitted due to system startup errors.

Figure A–10. SOARS DTW Values for Well 1105



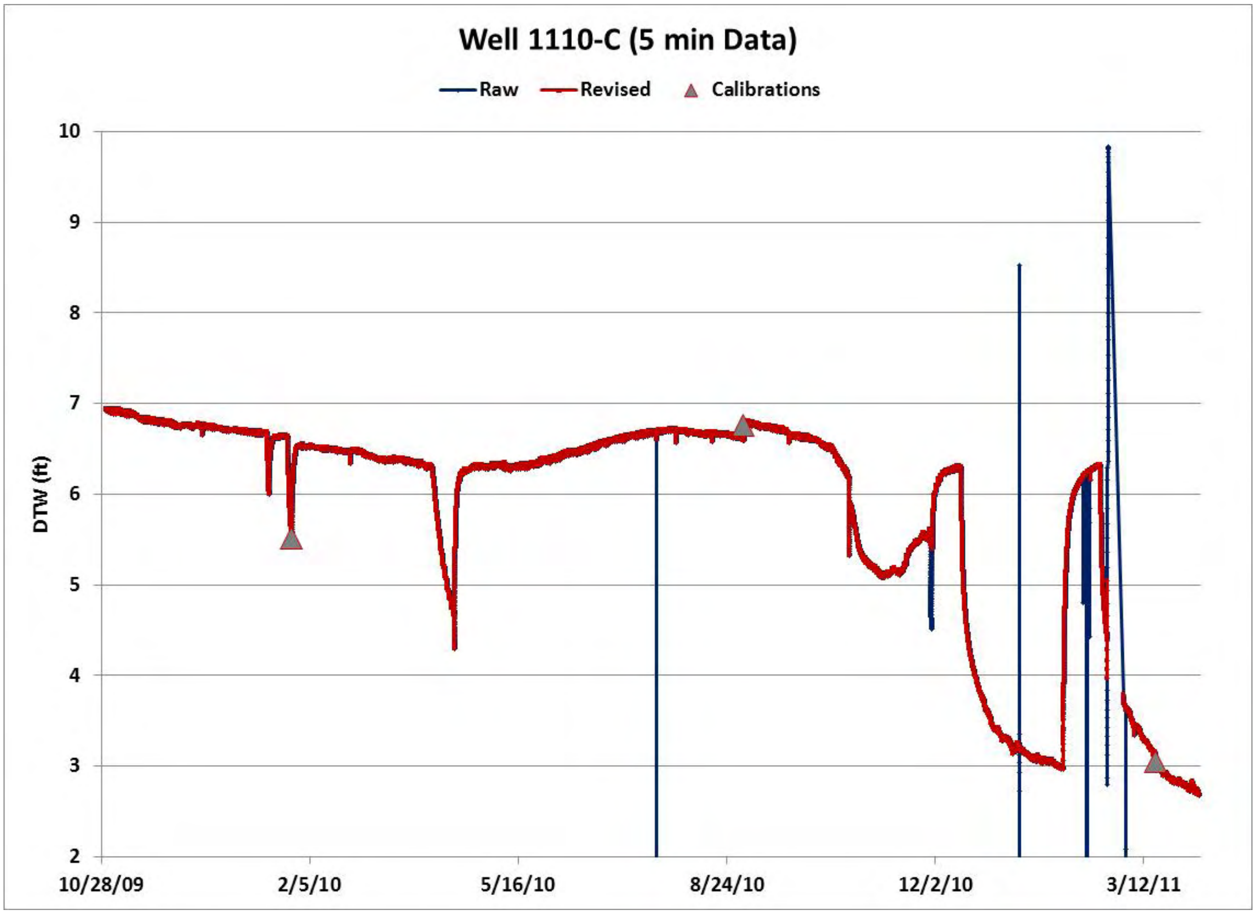
Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data include removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same. Only three calibration checks were conducted. The first two were subject to uncertainty because they were made during pumping. The third was made on March 17, 2011, during a non-pumping period. Based on observations of water levels and the higher level of certainty for this third check, 0.297 ft was added to the DTW data in SOARS from 10:15 on March 3 through 10:15 on March 17, 2011.

Figure A–11. SOARS DTW Values for Well 1110 (Pumping Well)



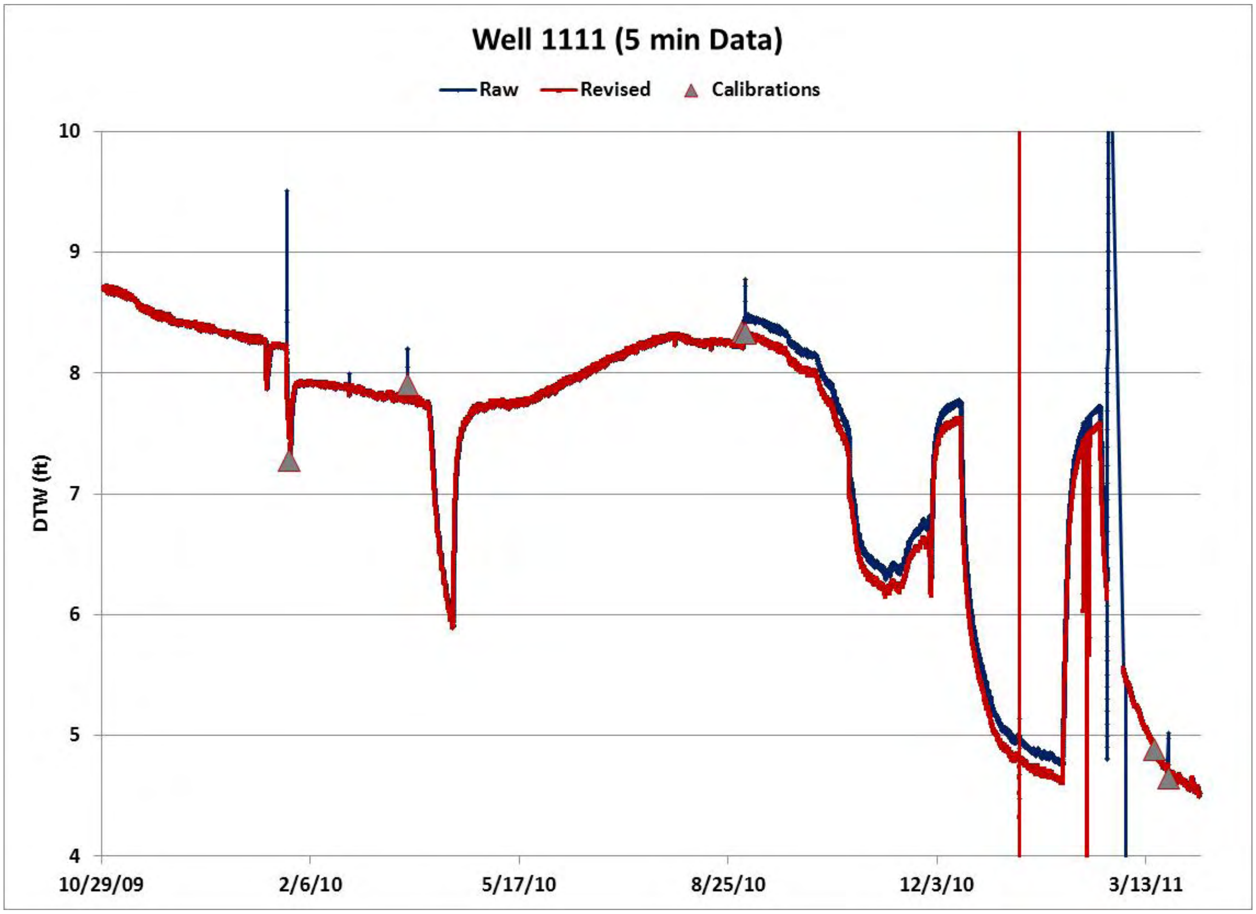
Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data include removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same.

Figure A–12. SOARS DTW Values for Well 1110-A



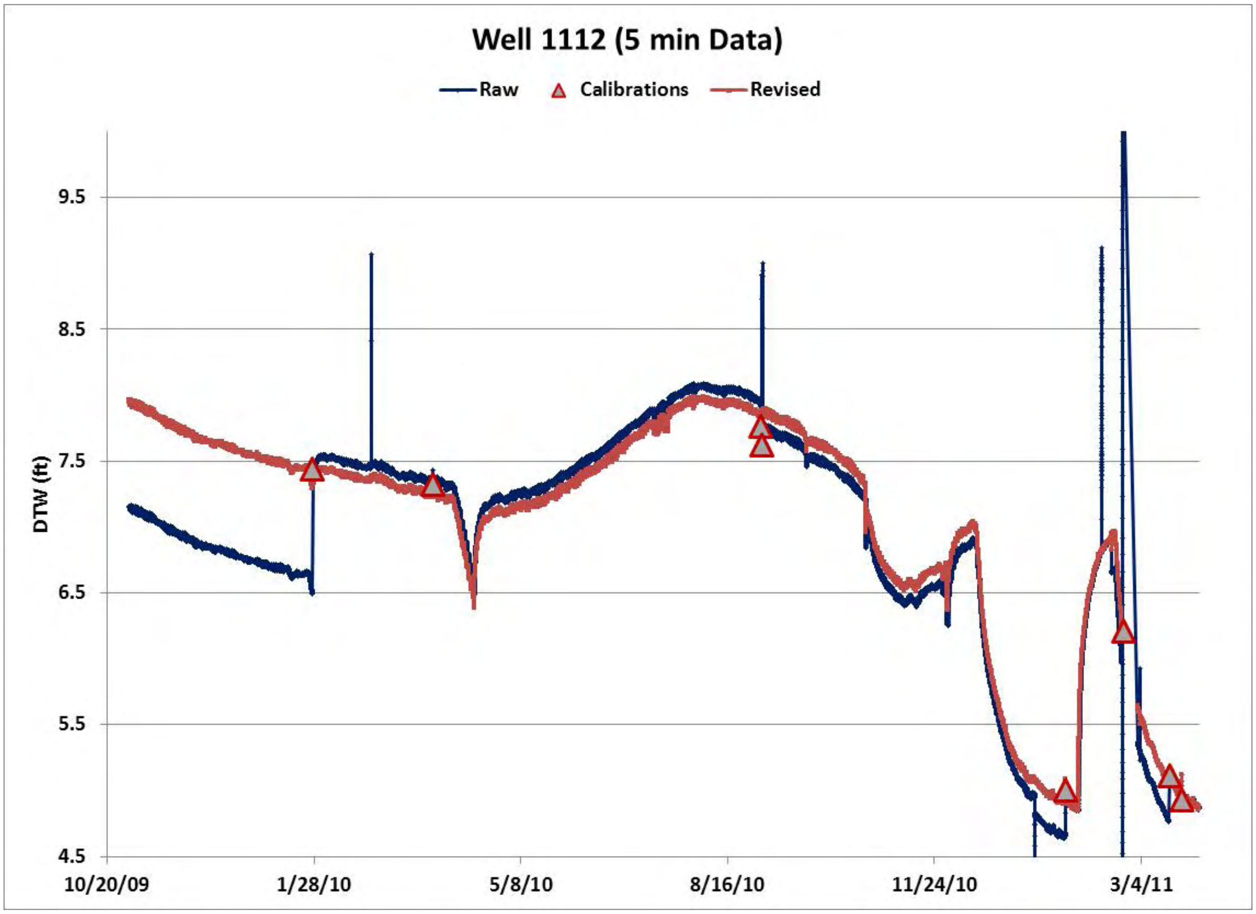
Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data include removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same.

Figure A–13. SOARS DTW Values for Well 1110-C



Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data include removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same. Subtracted 0.15 ft from DTW for data from 18:20 on September 1, 2010, through 16:50 on February 22, 2011, to best match calibration data.

Figure A–14. SOARS DTW Values for Well 1111

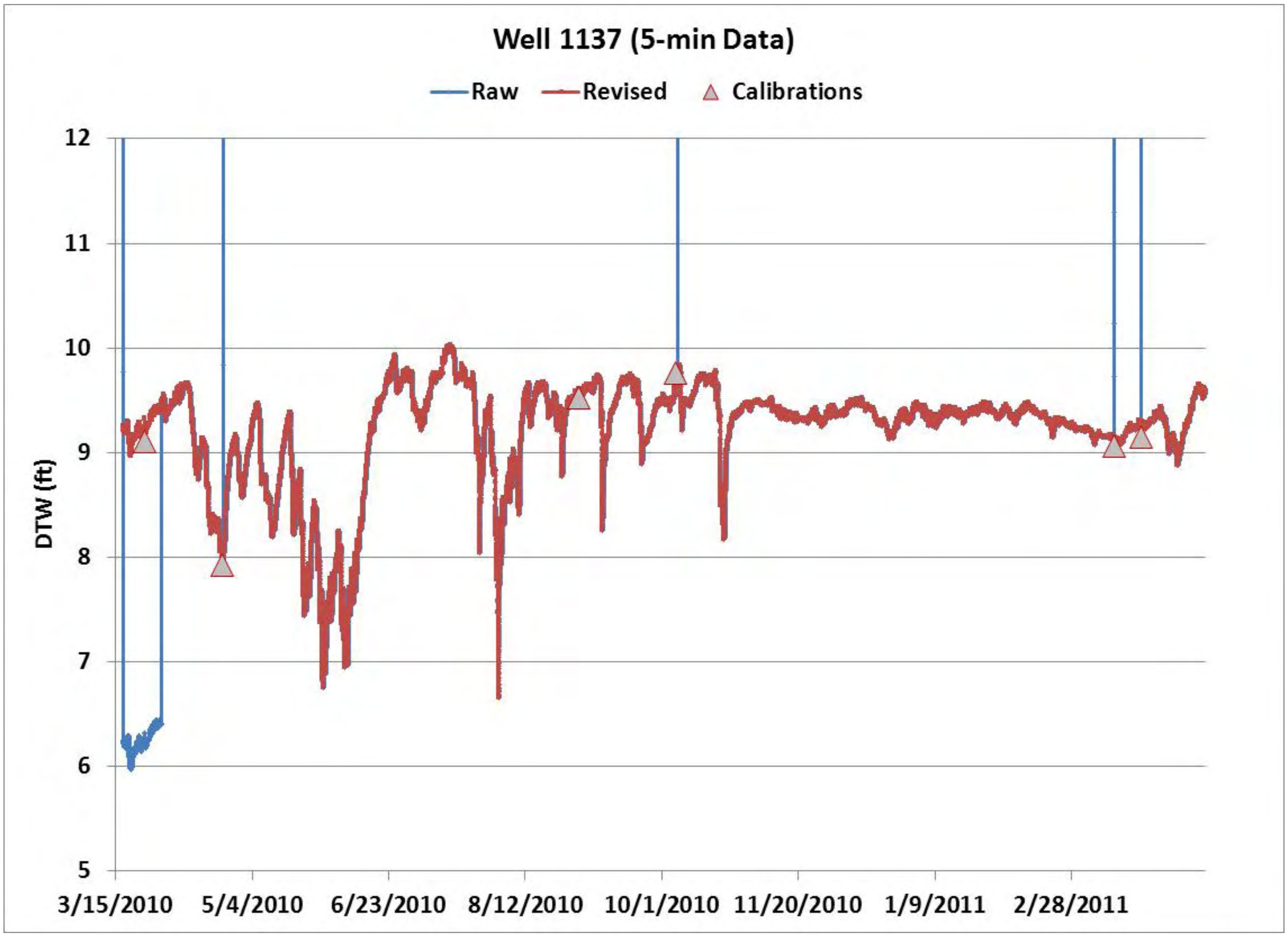


Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data include removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same. The following adjustments were made to the DTW data, based on fitting to calibration data:

- 10:45 on October 30, 2009, to 06:30 on January 27, 2010, added 0.8 ft
- 16:35 on January 27, 2019, to 18:15 on September 1, 2010, subtracted 0.1 ft
- 19:00 on September 1, 2010, to 10:15 on January 11, 2011, added 0.12 ft
- 11:05 on January 11, 2011, to 08:30 on January 26, 2011, added 0.257 ft
- 12:50 on February 17, 2011, to 10:30 on March 17, 2011, added 0.28 ft

Less emphasis was placed on the calibration points on September 1, 2010, because they were possibly in error due to difficulties with wiring in the well (based on review of field notes).

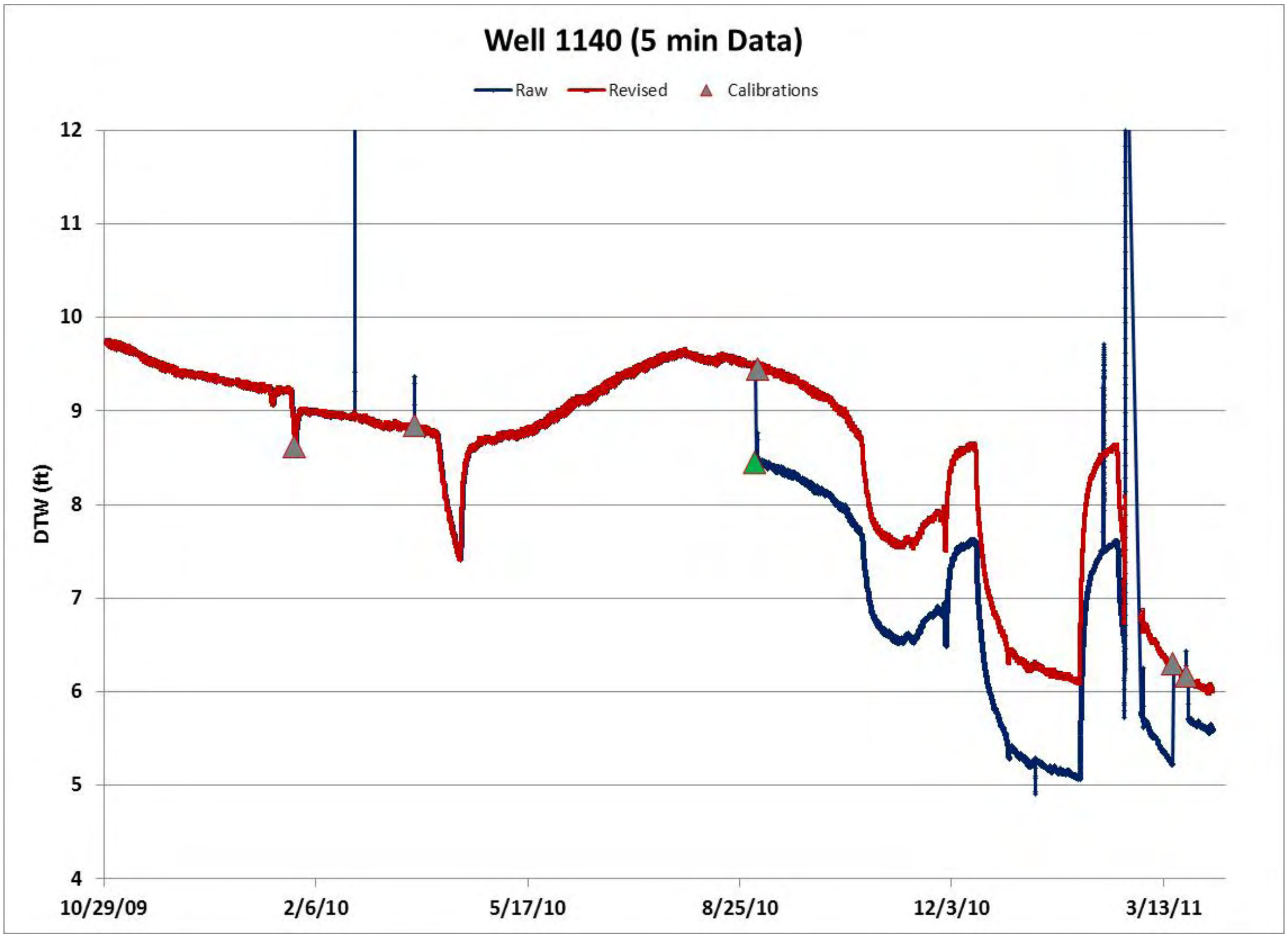
Figure A–15. SOARS DTW Values for Well 1112



Notes:

This well was not monitored in SOARS until March 17, 2010. Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Revised data include removal of erroneous outliers caused by instrument malfunctions. Where there is no blue curve, the raw and revised data are the same. To best match calibration data, 3.0 ft was added to data from 15:20 on March 17, 2010, to 16:25 on March 31, 2011.

Figure A–16. SOARS DTW Values for Well 1137

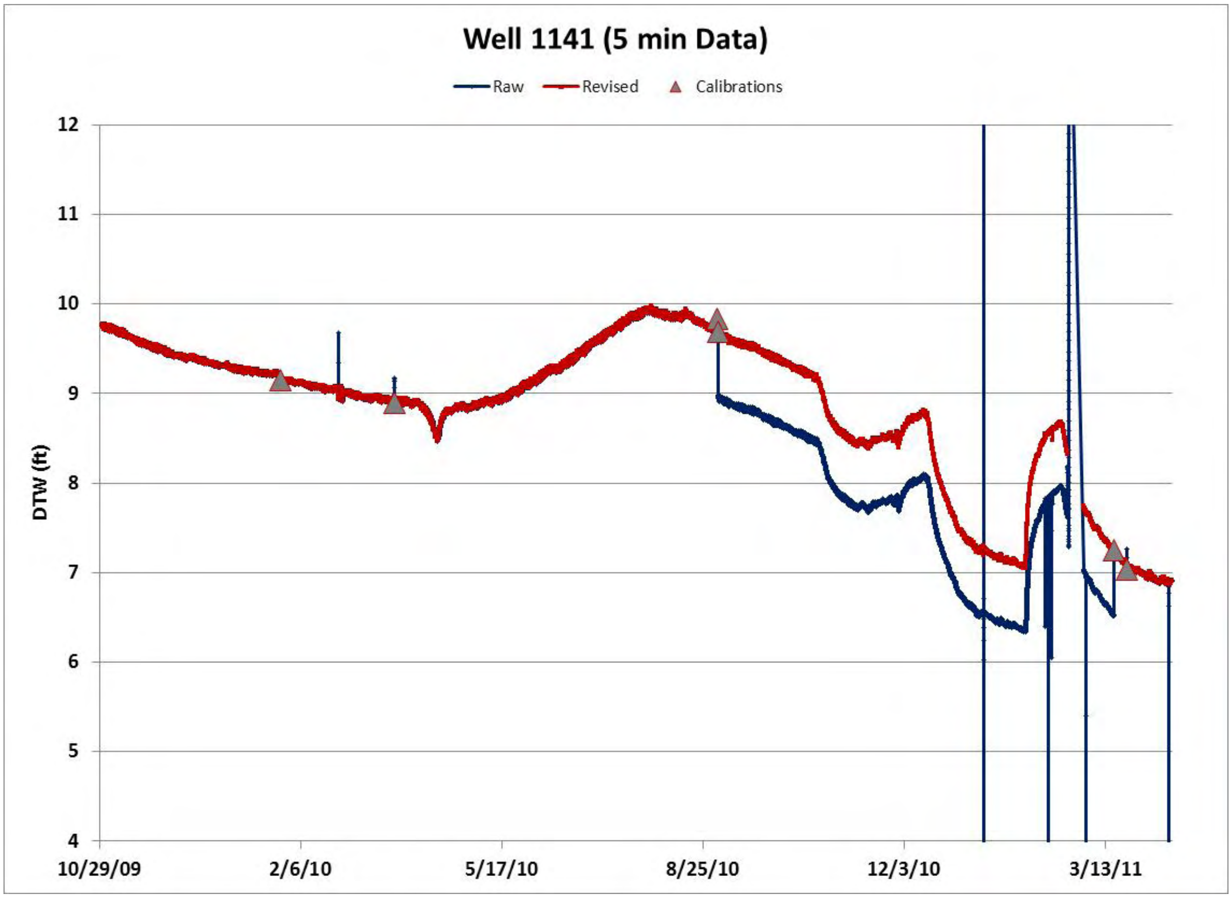


Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Where there is no blue curve, the raw and revised are the same. Revised data include the following modifications:

- Erroneous outliers caused by instrument malfunctions were removed
- Addition of 1.02 ft to the data from 18:10 on September 1, 2010, to 10:30 on March 17, 2011, to correct an erroneous datalogger setting
- Addition of 0.42 ft to DTW data from 14:20 on March 24, 2011, to 15:00 on April 11, 2011, (i.e., to the end of data set) due to surveyor inadvertently moving transducer

The calibration point from September 1, 2010 (i.e., the green triangle) was measured incorrectly and is an error.

Figure A–17. SOARS DTW Values for Well 1140



Notes:
Raw depth-to-water (DTW) values in the SOARS system are shown in blue, revised data are shown in red, and calibration points are shown as triangles. Where there is no blue curve, the raw and revised data are the same. Revised data include the following modifications:

- Erroneous outliers caused by instrument malfunctions were removed
- Addition of 0.71 ft to the data from 18:10 on September 1, 2010, to 10:30 on March 17, 2011, to correct an erroneous datalogger setting

Figure A–18. SOARS DTW Values for Well 1141

Appendix B

Data Quality Assessment of Specific Conductivity (SOARS Data)

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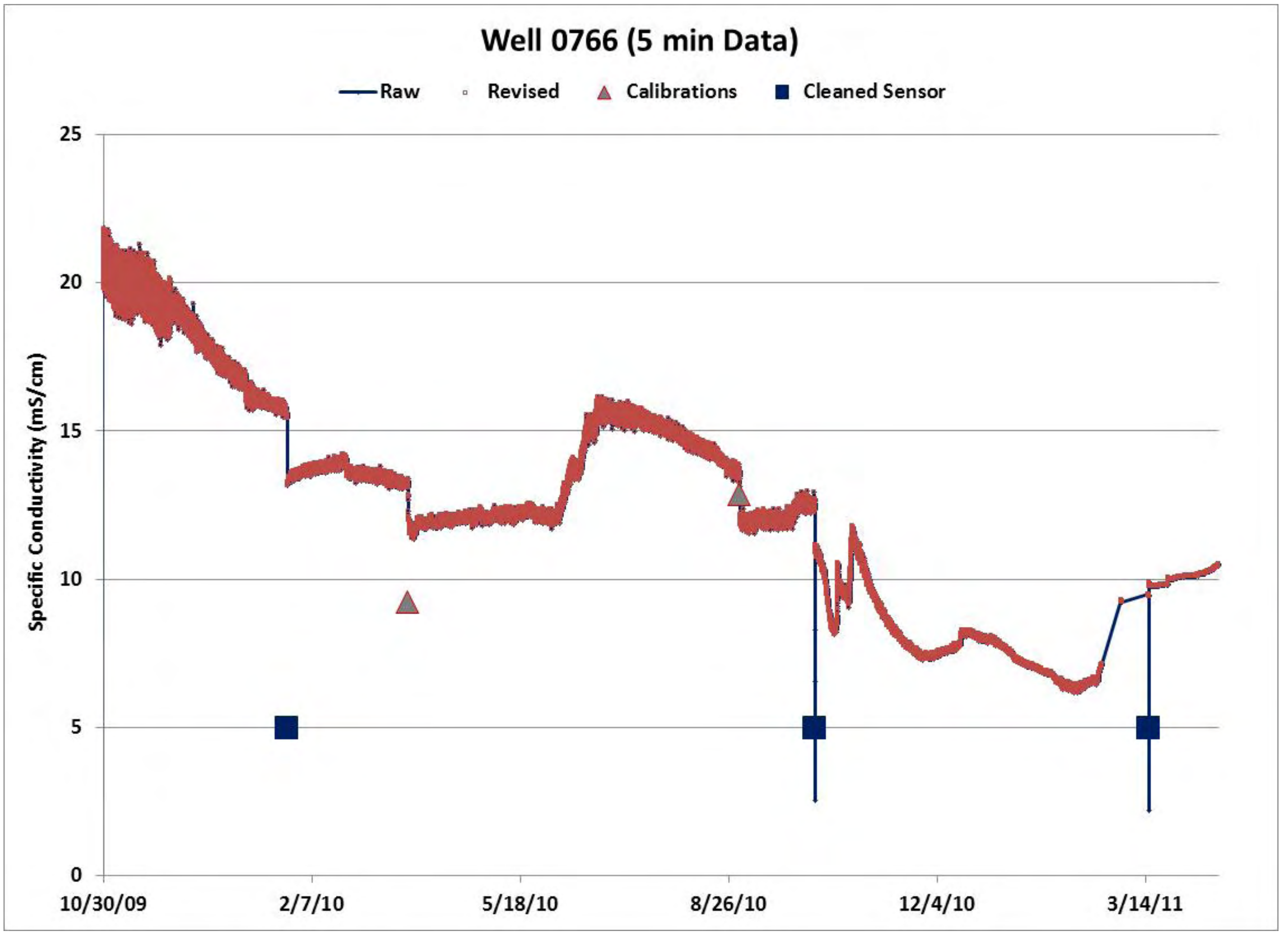
In this appendix, revisions to the specific conductivity data collected throught the SOARS system are presented. In cases where data were known to be erroneous based on entries in field notes, the data were revised accordingly. Details of these revisions are provided. The revised values are used in the body of the report for interpretive purposes.

Manual field measurements of specific conductivity (labeled “Calibrations” on the figures in this section) are compared to the SOARS data. The manual field measurements were made with a calibrated conductivity sensor in a flow-through cell. Thus, the manual measurements may have been made on groundwater collected at a different level in the water column than that of the SOARS sensor. Stratification in the groundwater may account for some of the variation between (1) the specific conductivity values measured in SOARS and (2) those measured manually. Improvements are being made in the procedures used for making calibration checks on these sensors.

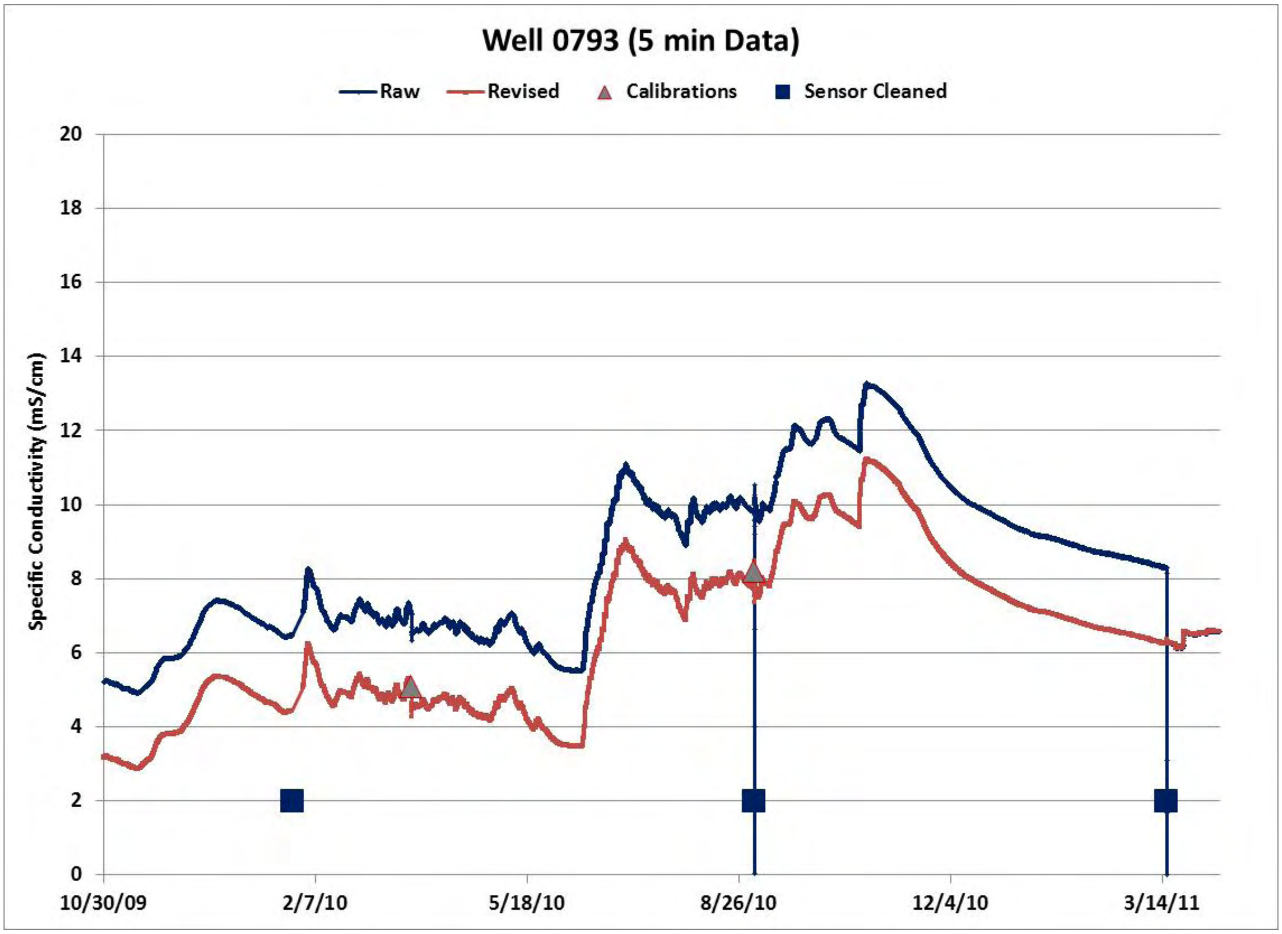
As part of regular maintenance, the SOARS sensors were inspected several times during the course of this study and were often found to have accummulated dirt and plant roots. The sensors were cleaned using a manufacturer-supplied nylon brush. The sensor response often showed a different response following cleaning, so cleaning events are also shown on the figures.

On the figures in this appendix, the blue curves are raw data (i.e., directly from SOARS, with no revisions) and the red curves are revised data. The red is superimposed on top of the blue, which means (1) where there is blue only, no revisions were needed, and (2) where there is red showing, the data have been revised.



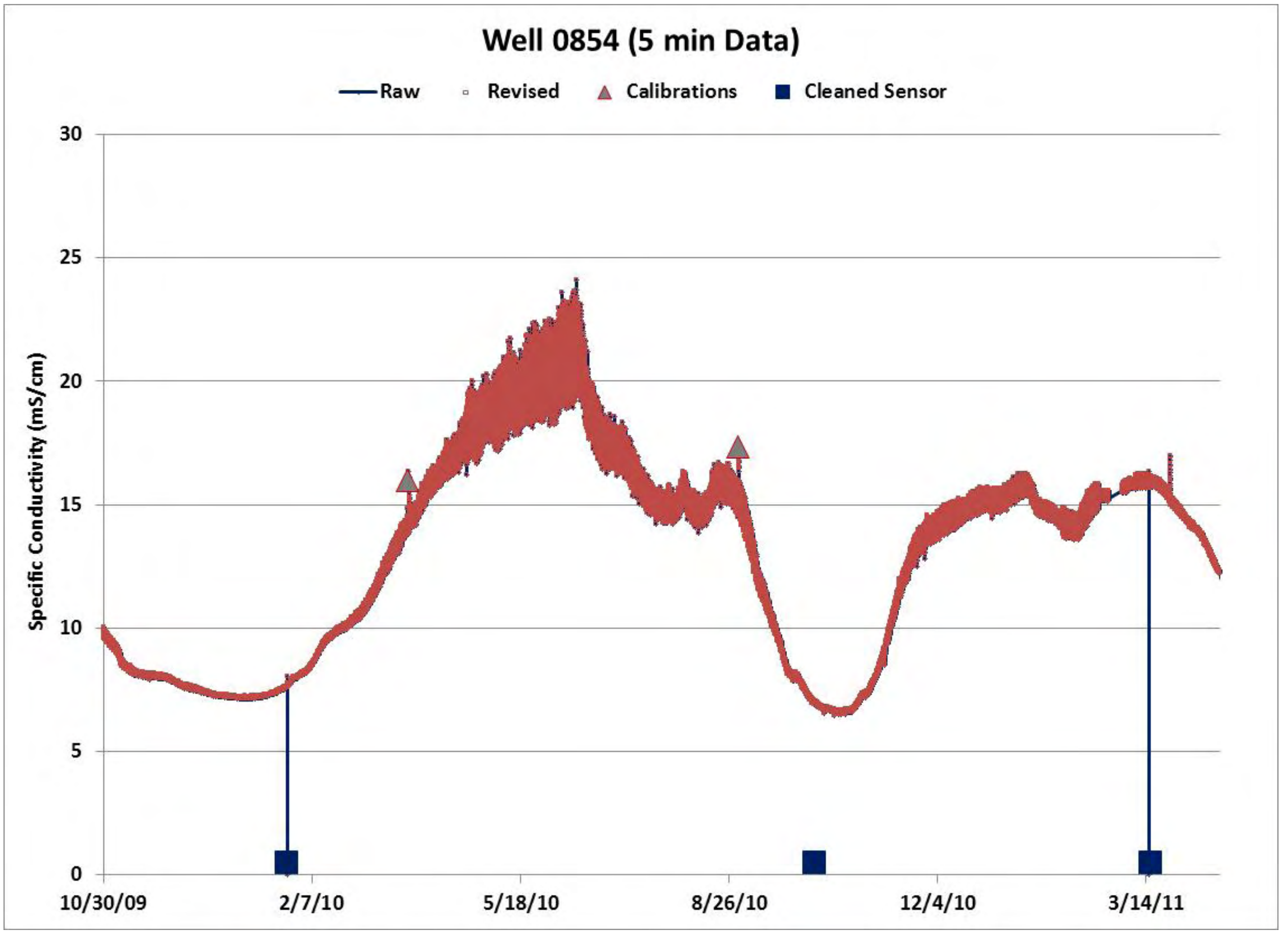
Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for well 0766, compared to measurements made in a flow-through cell at the field site (calibrations). Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. Data were not collected from February 19 through March 15, 2011, due to a power outage. Calibration of the conductivity sensor was checked several times against standard solutions and the results indicated reasonable agreement.

Figure B–1. Specific Conductivity for Well 0766



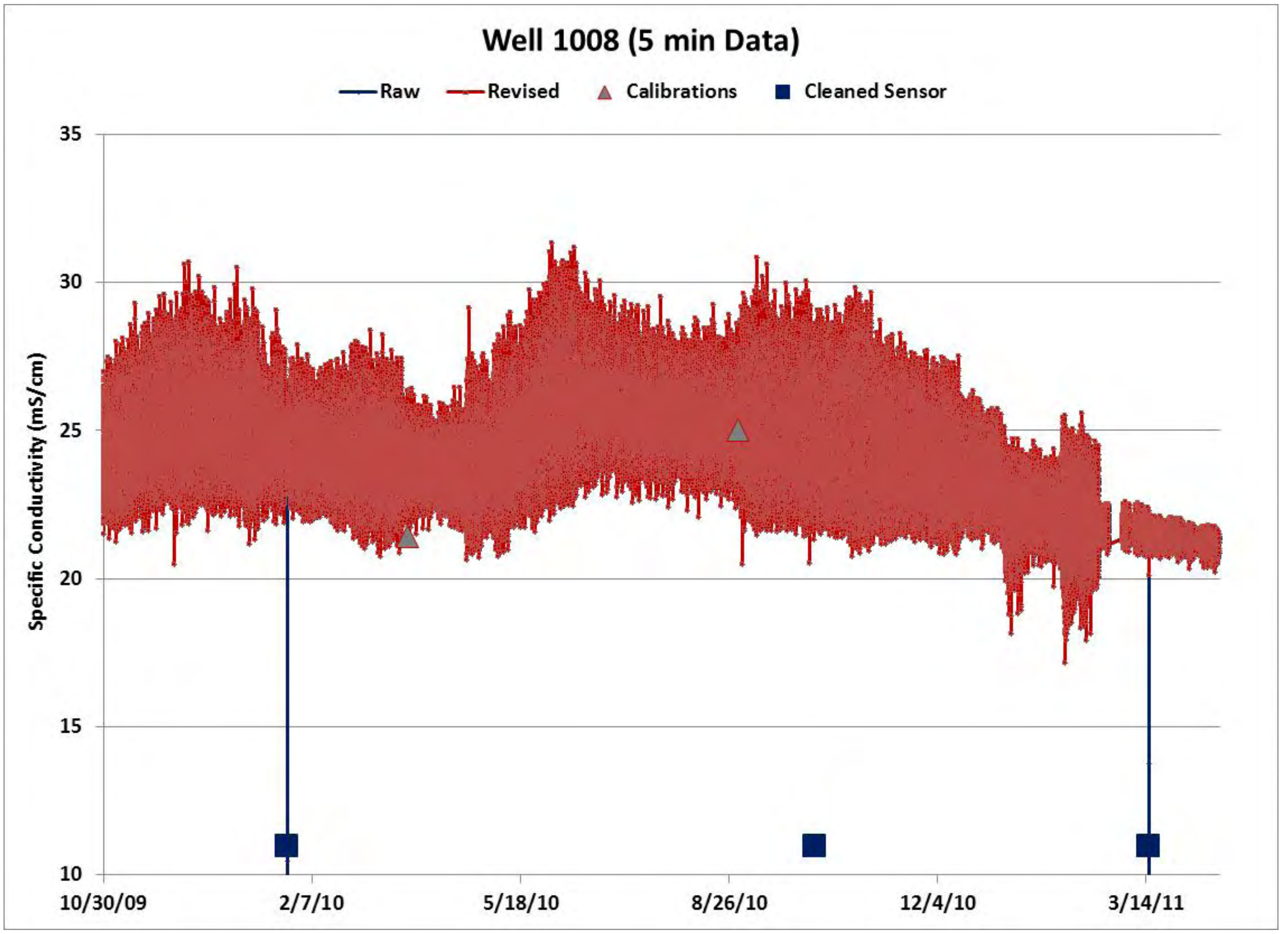
Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for well 0793, compared to measurements made in a flow-through cell at the field site (calibrations). Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. Also, the revised data include the addition of 2.05 mS/cm for the period from August 21, 2009, through March 16, 2011, to match calibration data and to reflect a better match to data after sensor cleaning. Calibration of the conductivity sensor was checked several times against standard solutions and the results indicated reasonable agreement.

Figure B–2. Specific Conductivity for Well 0793



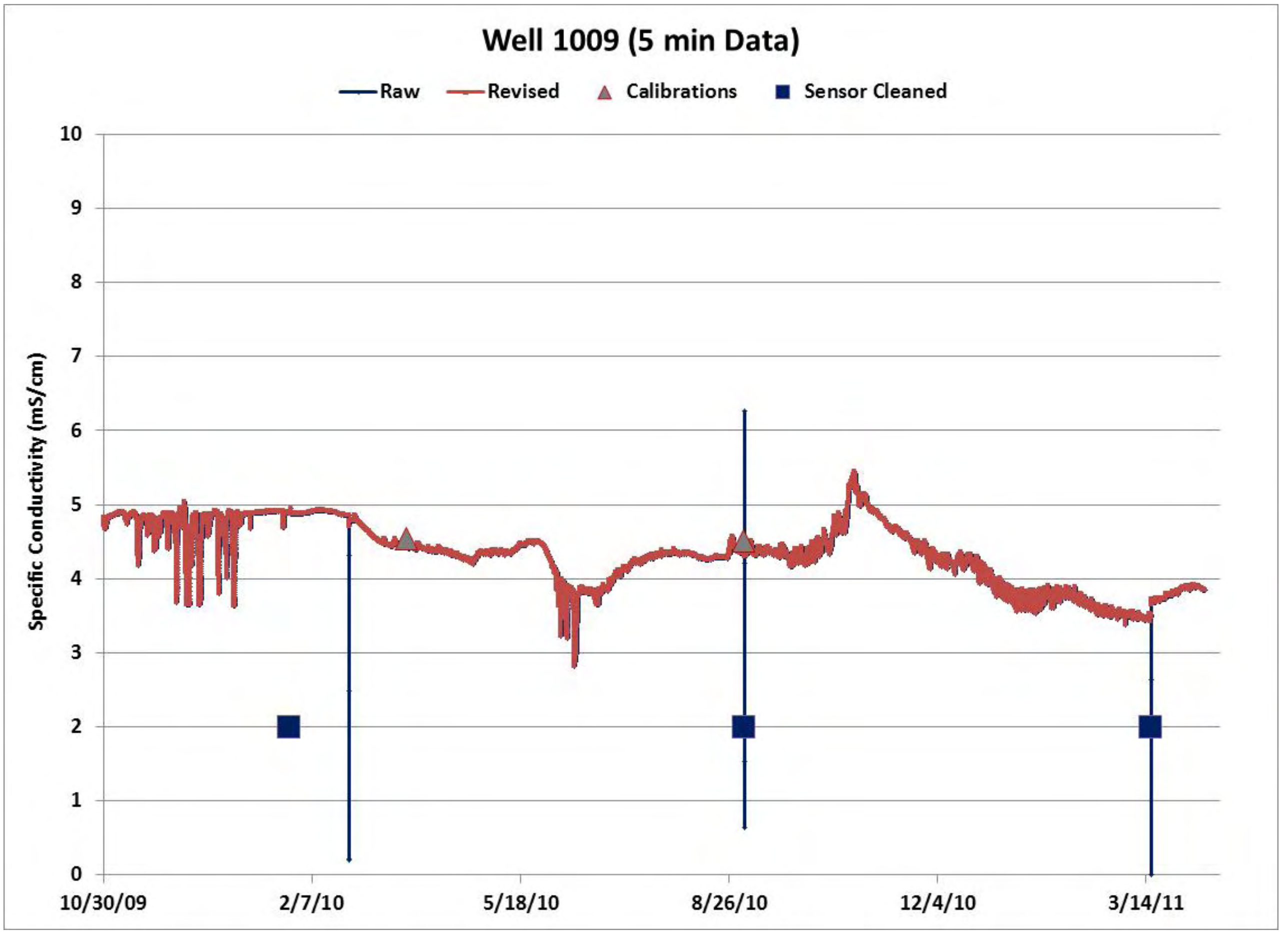
Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for extraction well 0854, compared to measurements made in a flow-through cell at the field site (calibrations). Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. Calibration of the conductivity sensor was checked several times against standard solutions and the results indicated reasonable agreement.

Figure B–3. Specific Conductivity for Well 0854



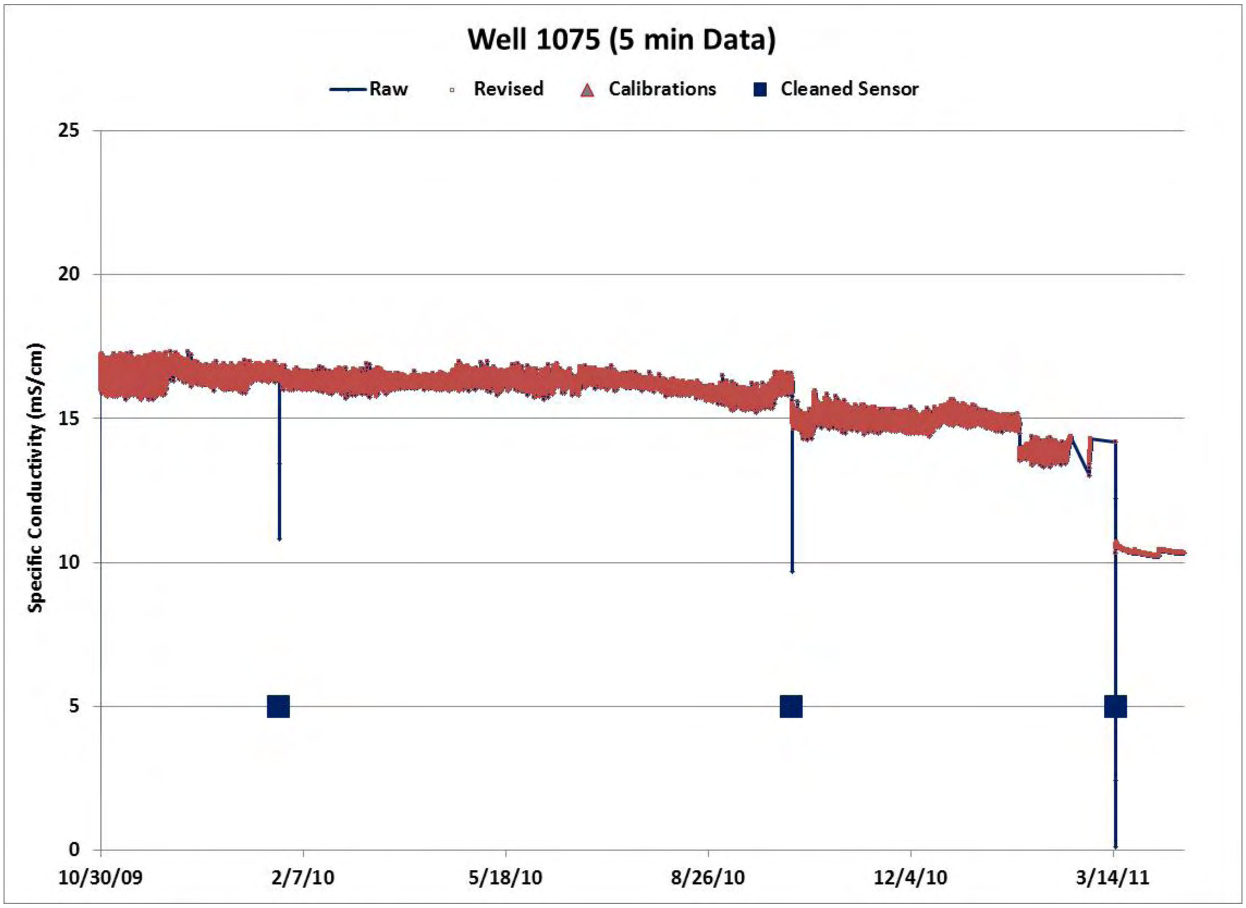
Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for extraction well 1008, compared to measurements made in a flow-through cell at the field site (calibrations). Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. Calibration of the conductivity sensor was checked several times against standard solutions and the results indicated reasonable agreement.

Figure B–4. Specific Conductivity for Well 1008



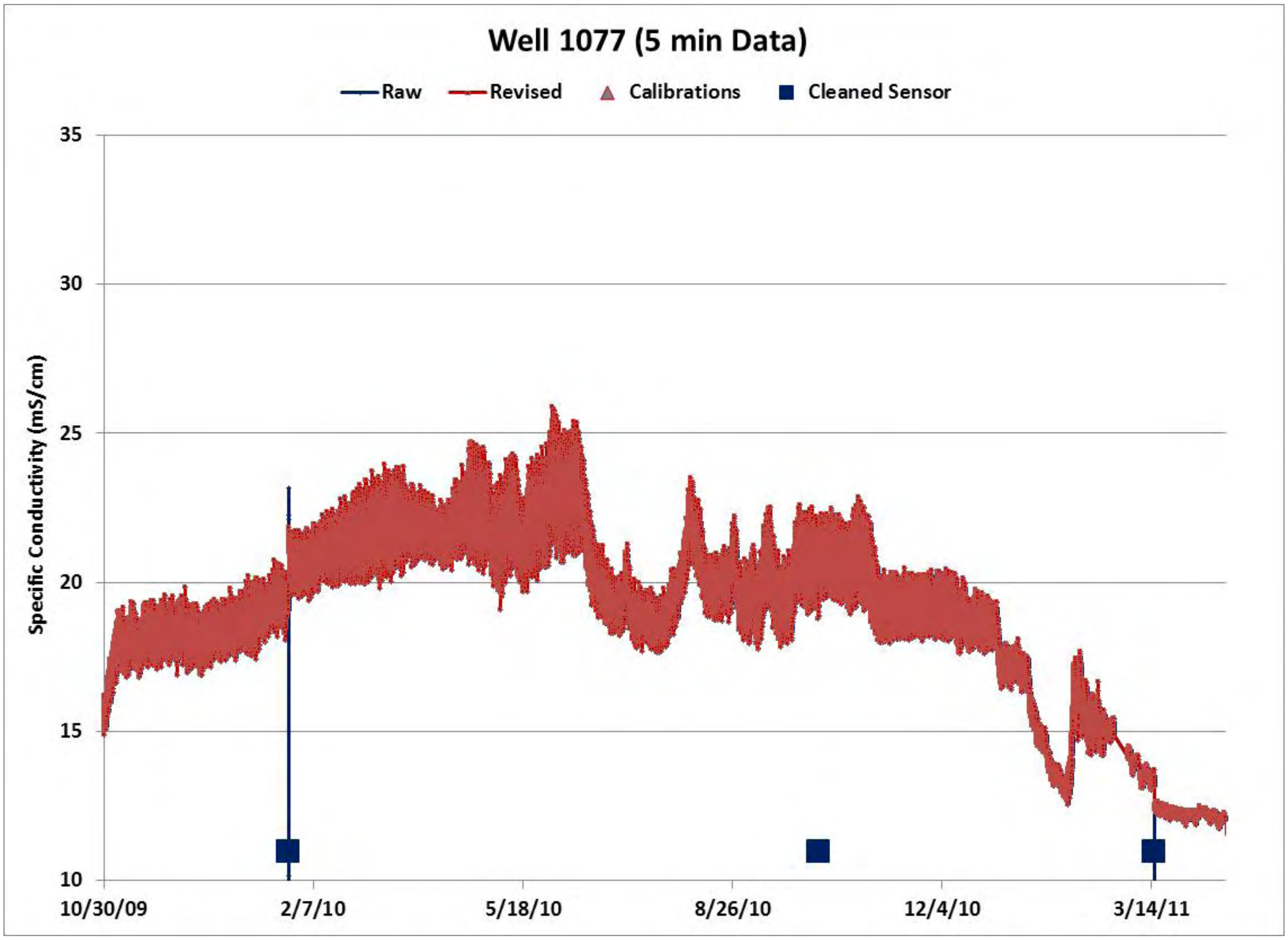
Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for well 1009, compared to measurements made in a flow-through cell at the field site (calibrations). Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. Calibration of the conductivity sensor was checked several times against standard solutions and the results indicated reasonable agreement.

Figure B–5. Specific Conductivity for Well 1009



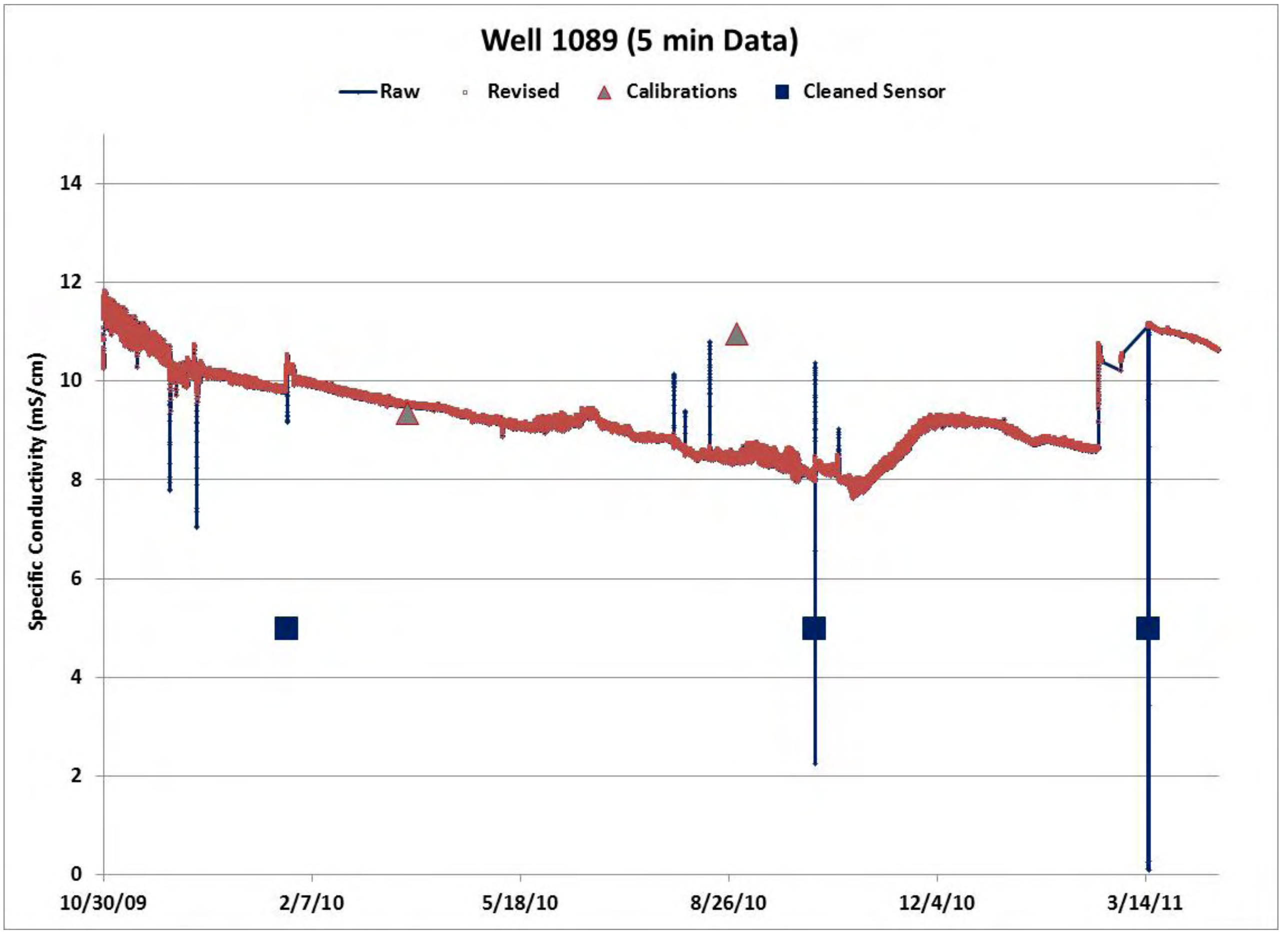
Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for well 1075. There were no measurements of specific conductivity for this well to use as calibration checks. Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. Data were not collected from February 19 through March 15, 2011, due to a power outage. Calibration of the conductivity sensor was checked several times against standard solutions and the results indicated reasonable agreement.

Figure B–6. Specific Conductivity for Well 1075



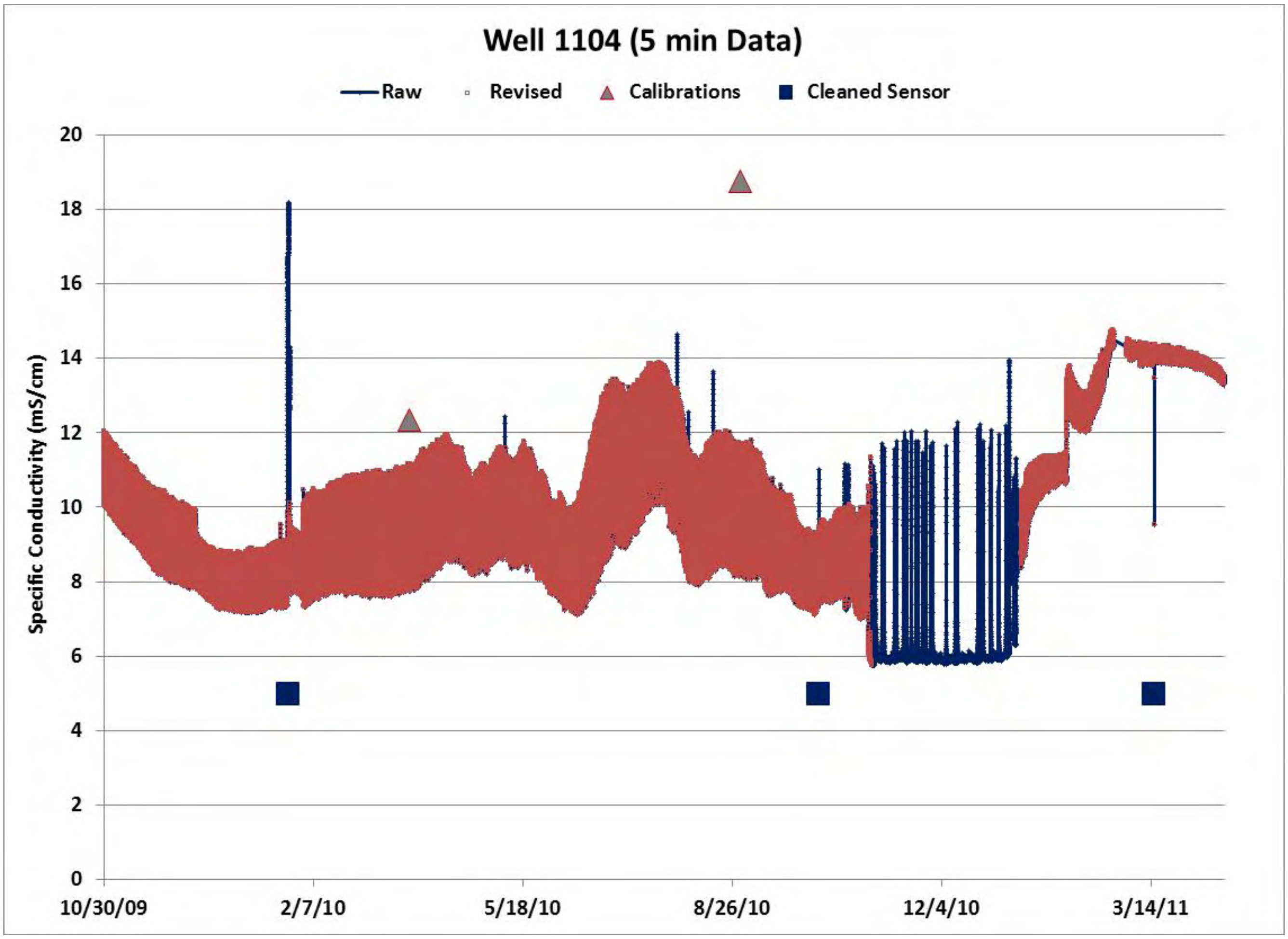
Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for well 1077. There were no measurements of specific conductivity for this well to use as calibration checks. Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. Calibration of the conductivity sensor was checked several times against standard solutions and the results indicated reasonable agreement.

Figure B–7. Specific Conductivity for Well 1077



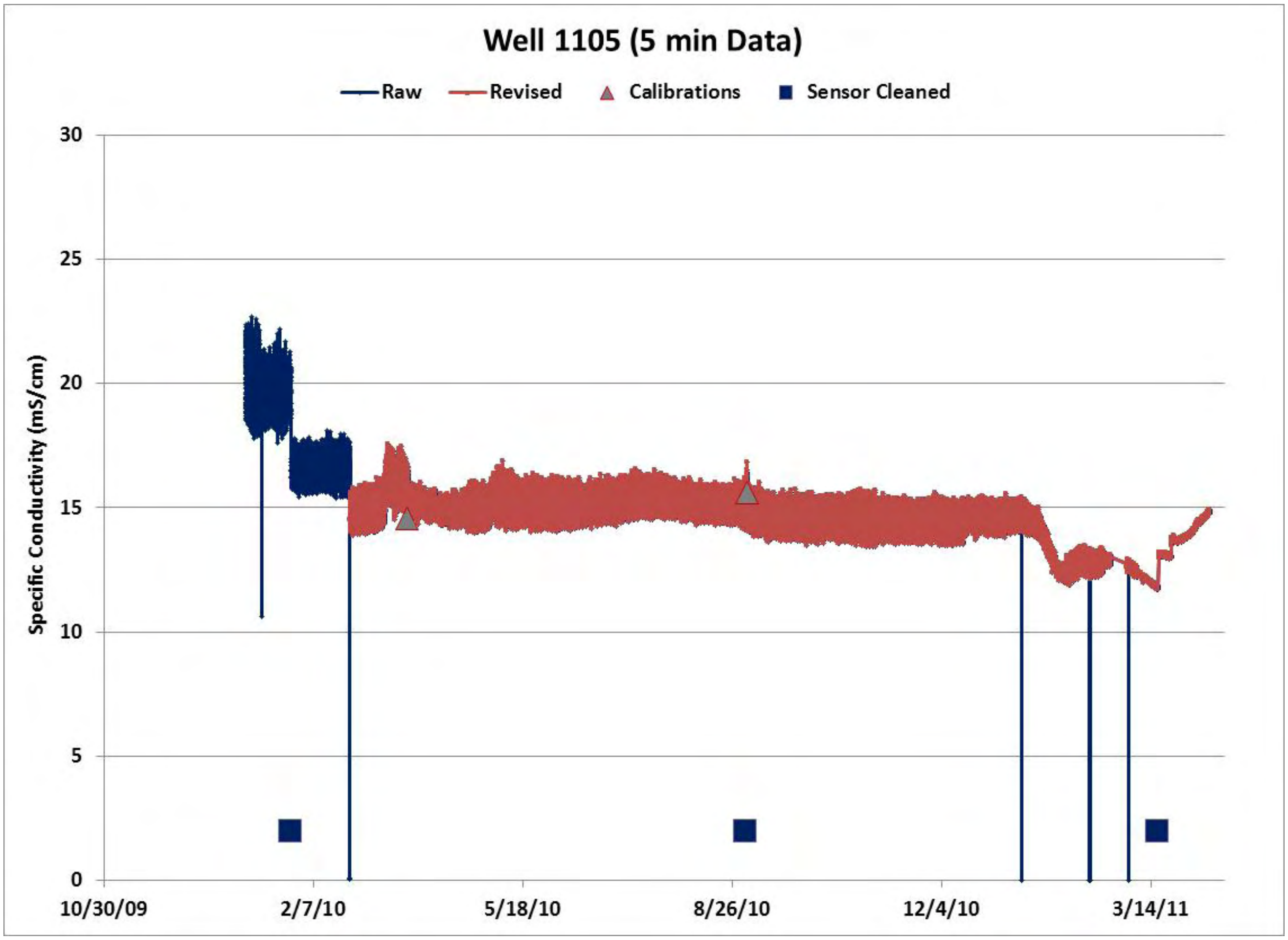
Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for extraction well 1089, compared to measurements made in a flow-through cell at the field site (calibrations). Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. Data were not collected from February 19 through March 15, 2011, due to a power outage. Calibration of the conductivity sensor was checked several times against standard solutions and the results indicated reasonable agreement.

Figure B–8. Specific Conductivity for Well 1089



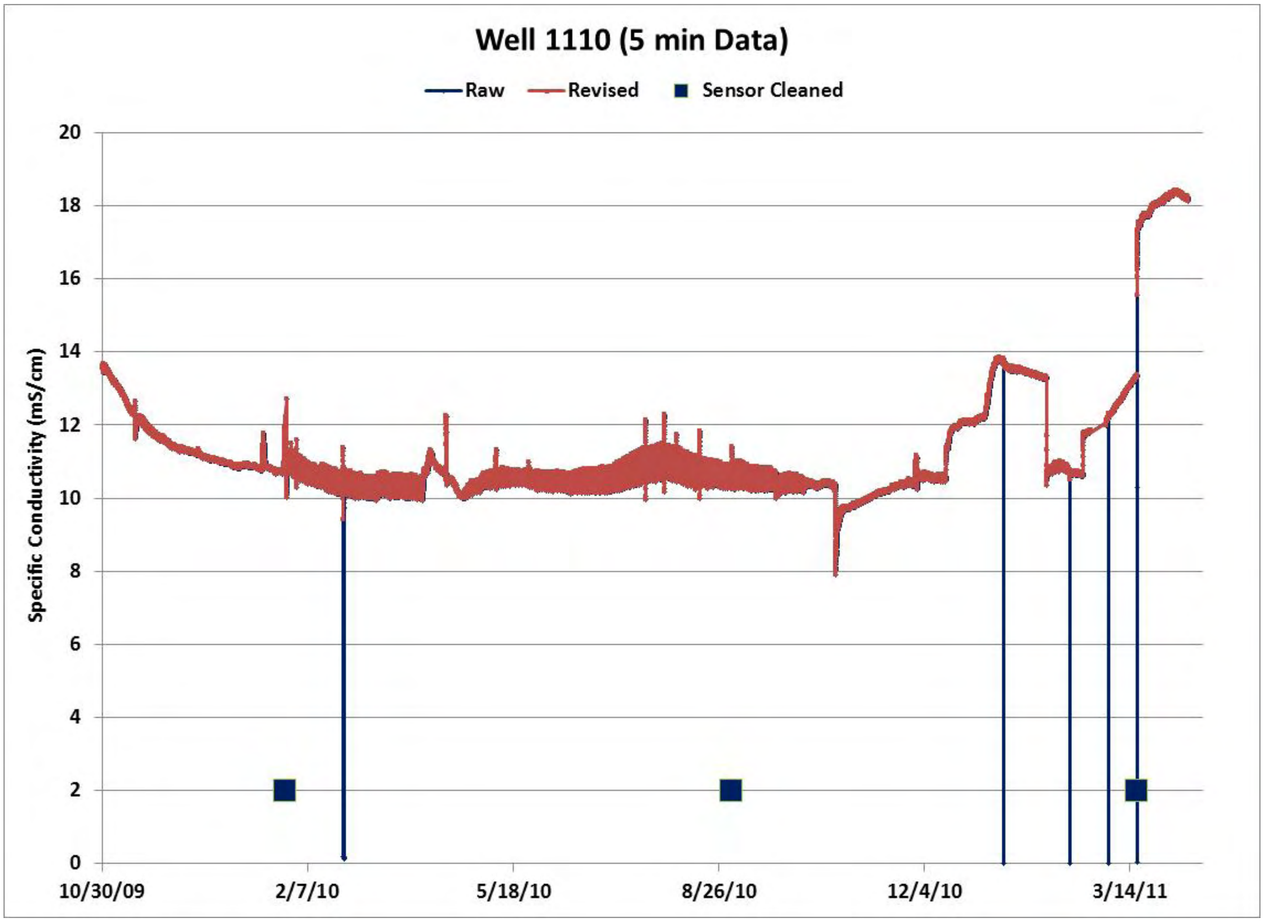
Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for extraction well 1104, compared to measurements made in a flow-through cell at the field site (calibrations). Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. Data were not collected from February 19 through March 15, 2011, due to a power outage. Data from November 1, 2010, through January 10, 2011, were omitted because the data were noisy and likely erroneous. Calibration of the conductivity sensor was checked several times against standard solutions and the results indicated reasonable agreement.

Figure B–9. Specific Conductivity for Well 1104



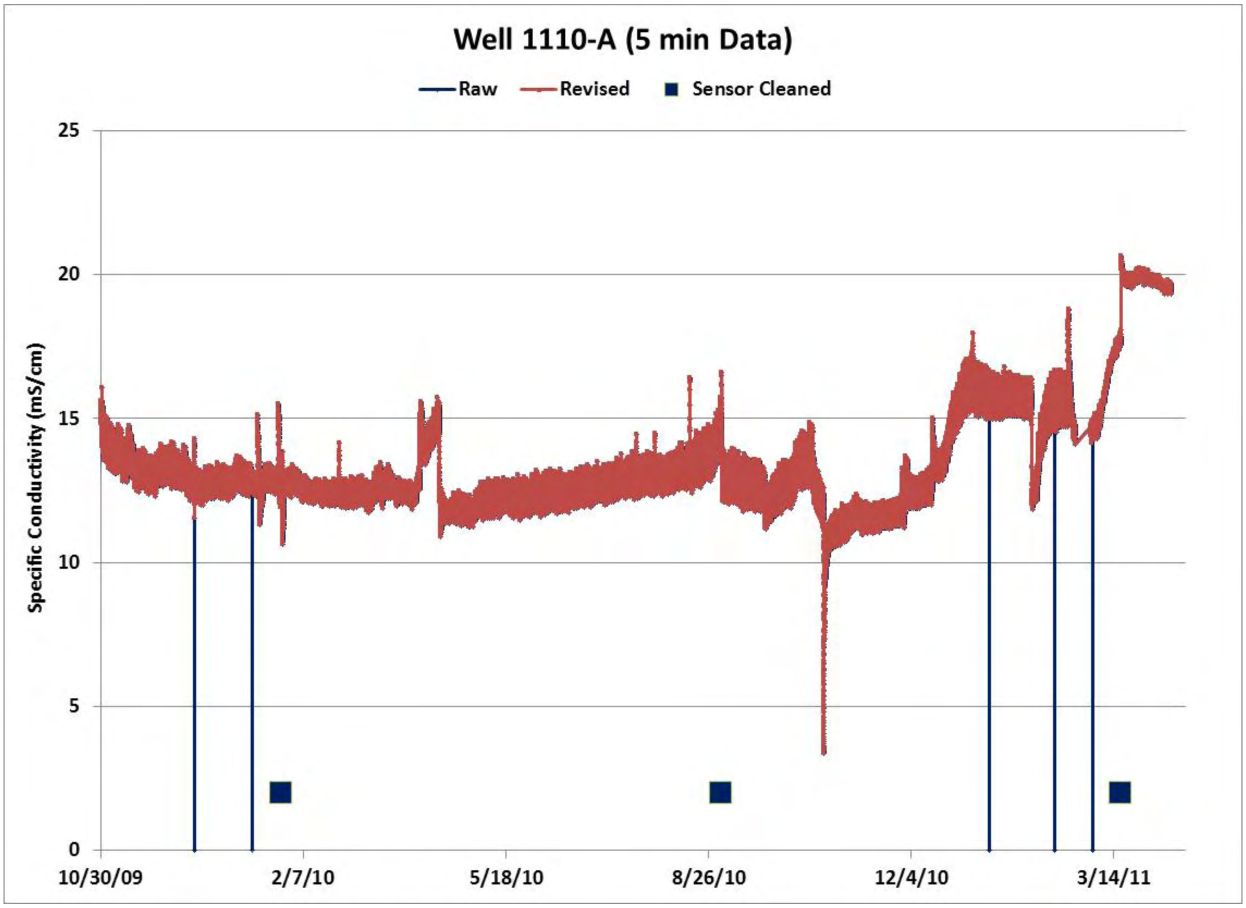
Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for well 1105, compared to measurements made in a flow-through cell at the field site (calibrations). Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. Data from 16:30 on January 5, 2010, through 15:55 on February 24, 2010, were omitted due to start-up errors. Calibration of the conductivity sensor was checked several times against standard solutions and the results indicated reasonable agreement.

Figure B–10. Specific Conductivity for Well 1105



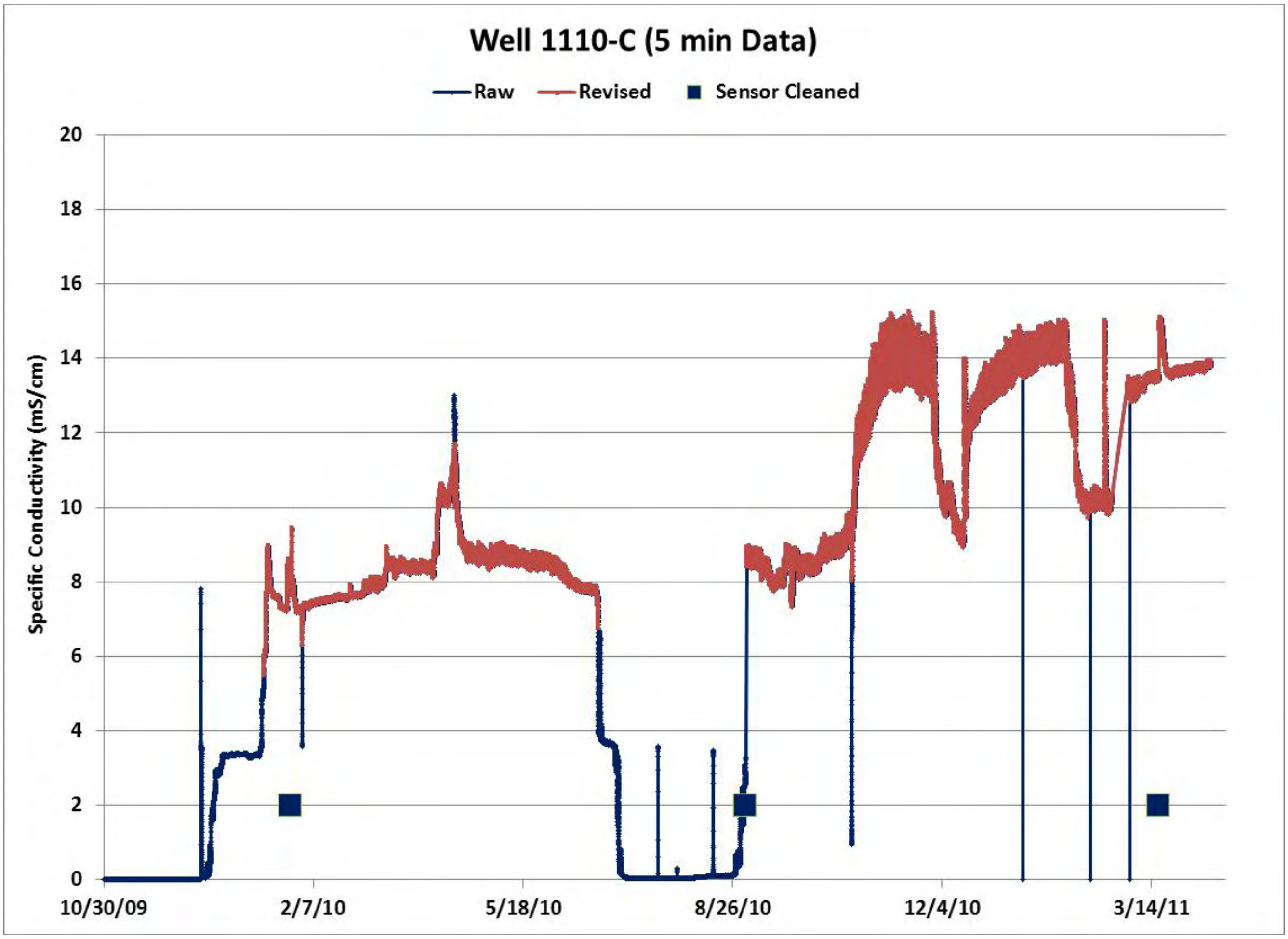
Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for extraction well 1110. Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. No calibration checks were made using an independent calibrated instrument; however, the sensor was checked several times against standard solutions and the results indicated reasonable agreement.

Figure B–11. Specific Conductivity for Well 1110



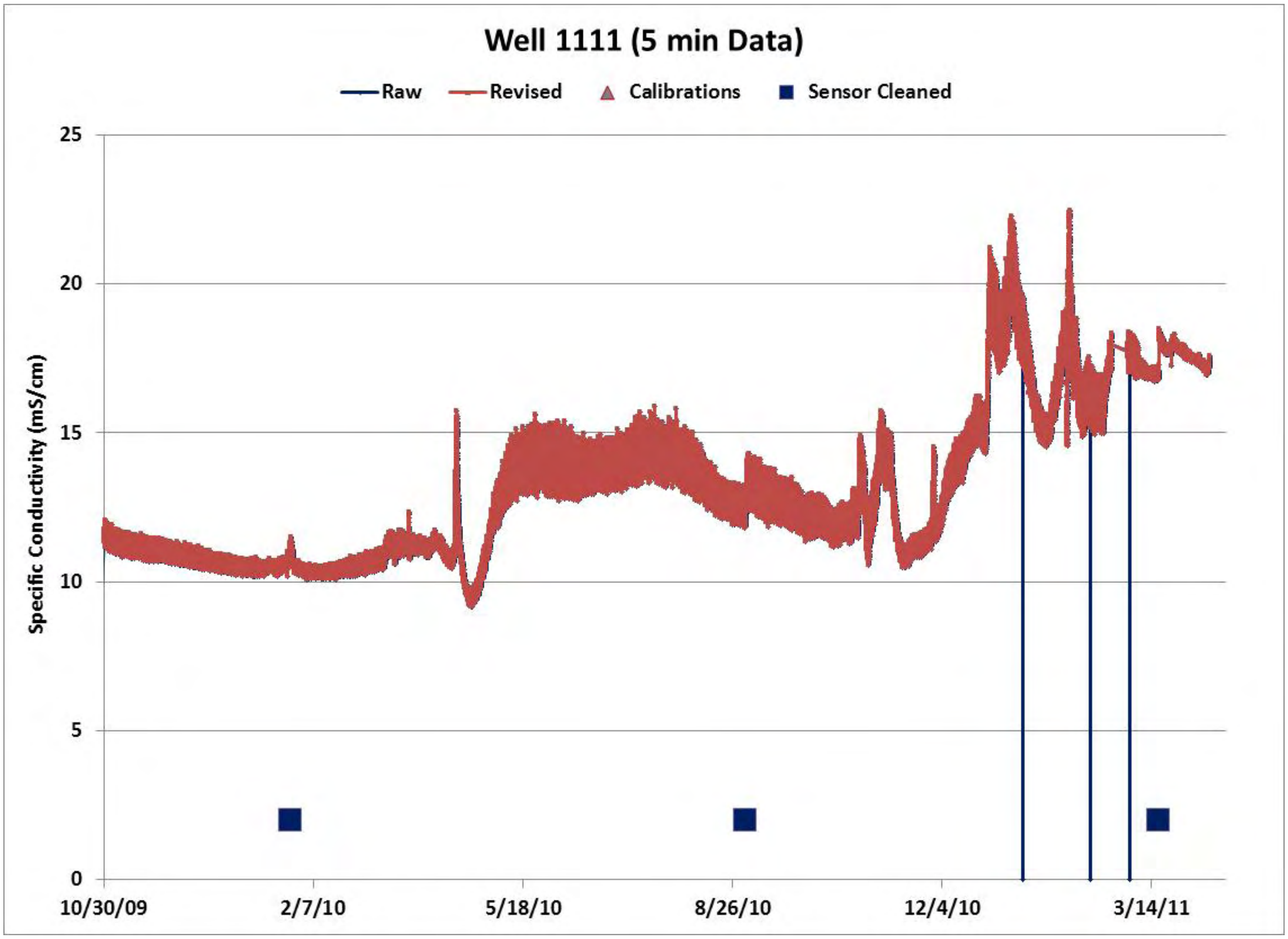
Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for well 1110-A. Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. No calibration checks were made using an independent calibrated instrument; however, the sensor was checked several times against standard solutions and the results indicated reasonable agreement.

Figure B–12. Specific Conductivity for Well 1110-A



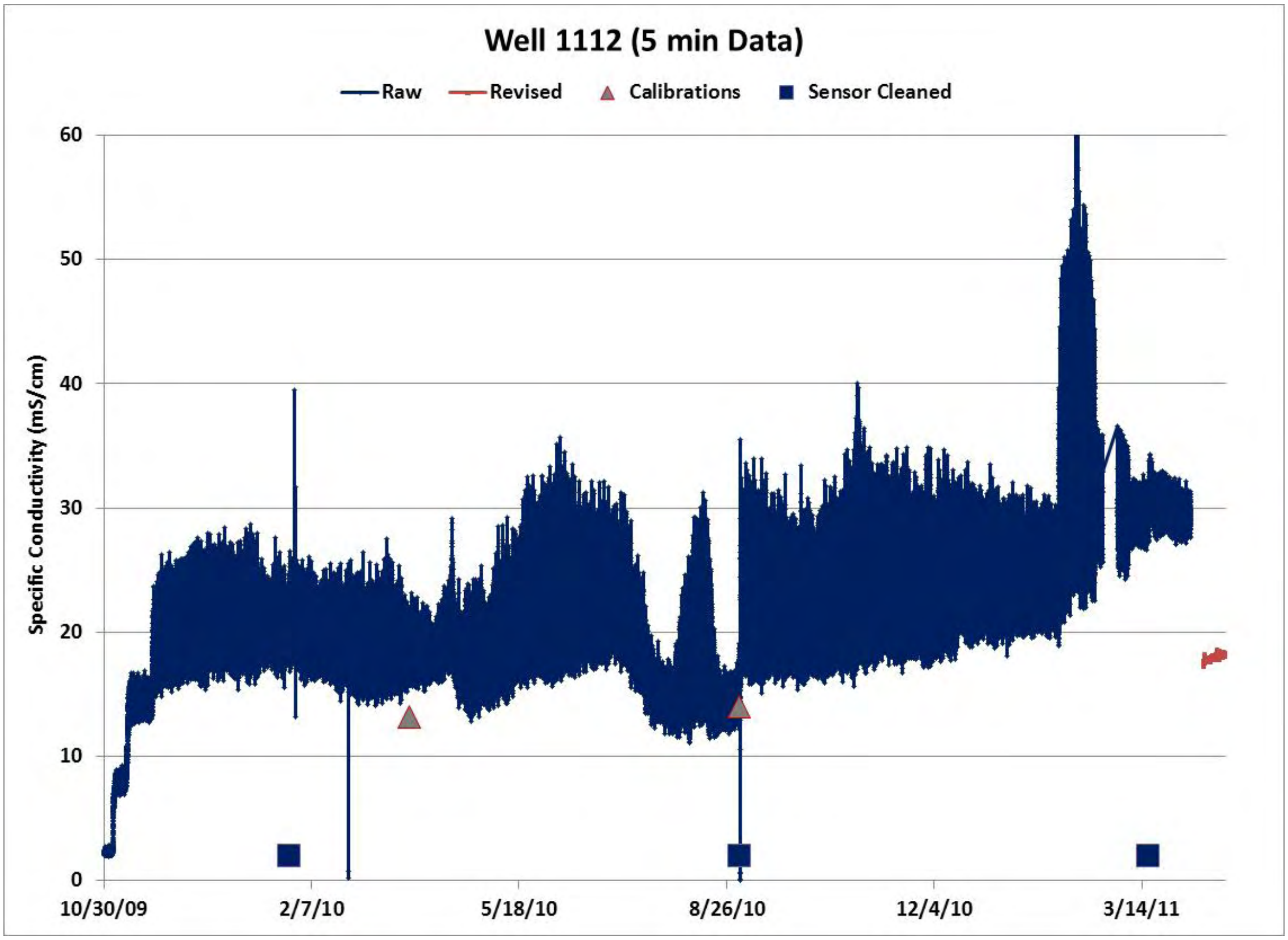
Notes:
This figure shows the specific Conductivity (mS/cm) measured by the SOARS system for well 1110-C. Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. Data from 11:00 on October 7, 2009, through 14:35 on January 14, 2010, were omitted due to start-up errors. Data from 00:30 on June 23 through 18:10 on September 9, 2010, were omitted because data were likely erroneous based on trends. No calibration checks were made using an independent calibrated instrument; however, the sensor was checked several times against standard solutions and the results indicated reasonable agreement.

Figure B–13. Specific Conductivity for Well 1110-C



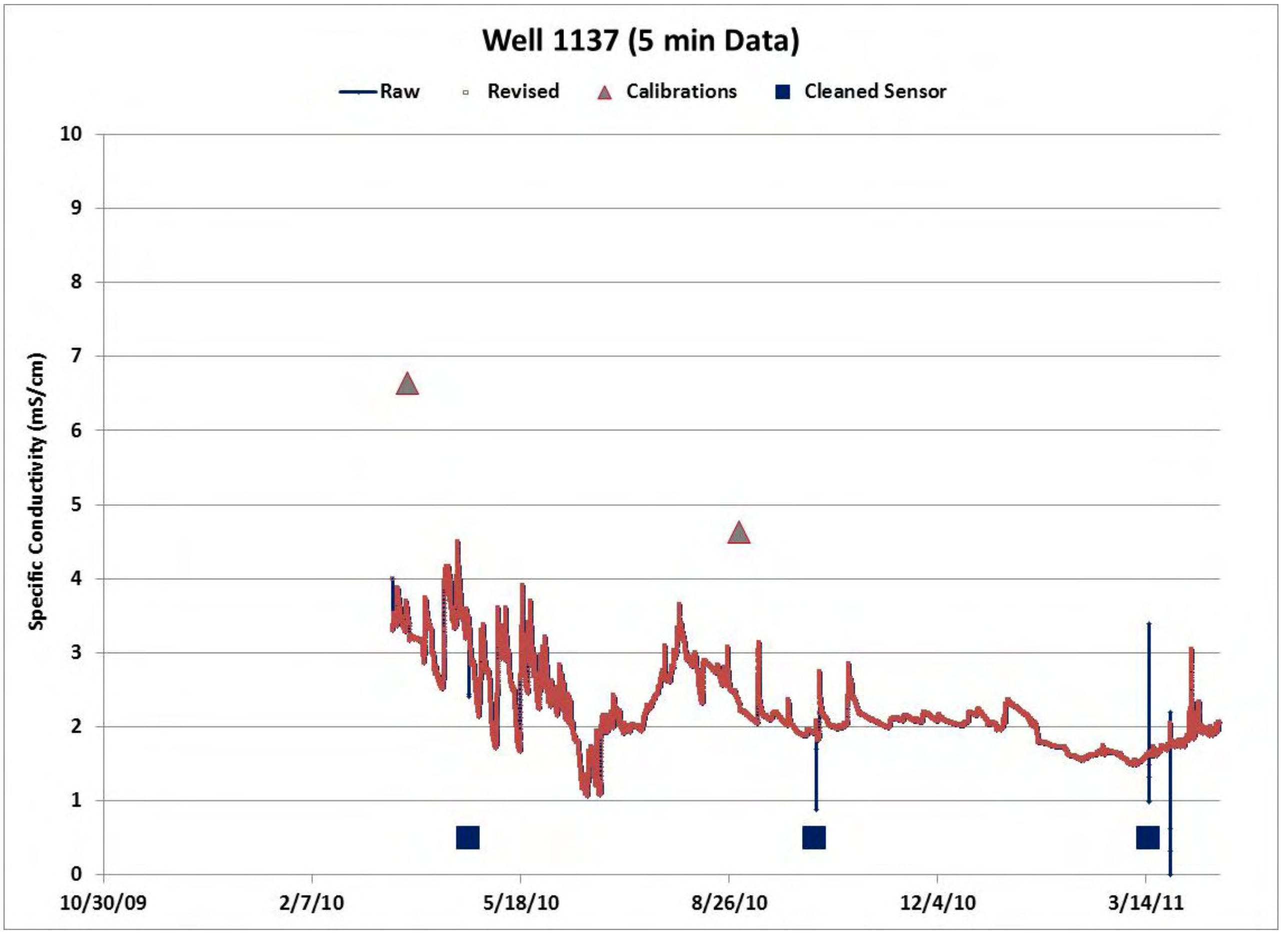
Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for well 1111. Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. No calibration tests were conducted during the time period with SOARS data; however, a test conducted on September 16, 2009, just prior to SOARS instrumentation, showed good agreement with projected SOARS data. Calibrations conducted on standard solutions at several times showed good agreement.

Figure B–14. Specific Conductivity for Well 1111



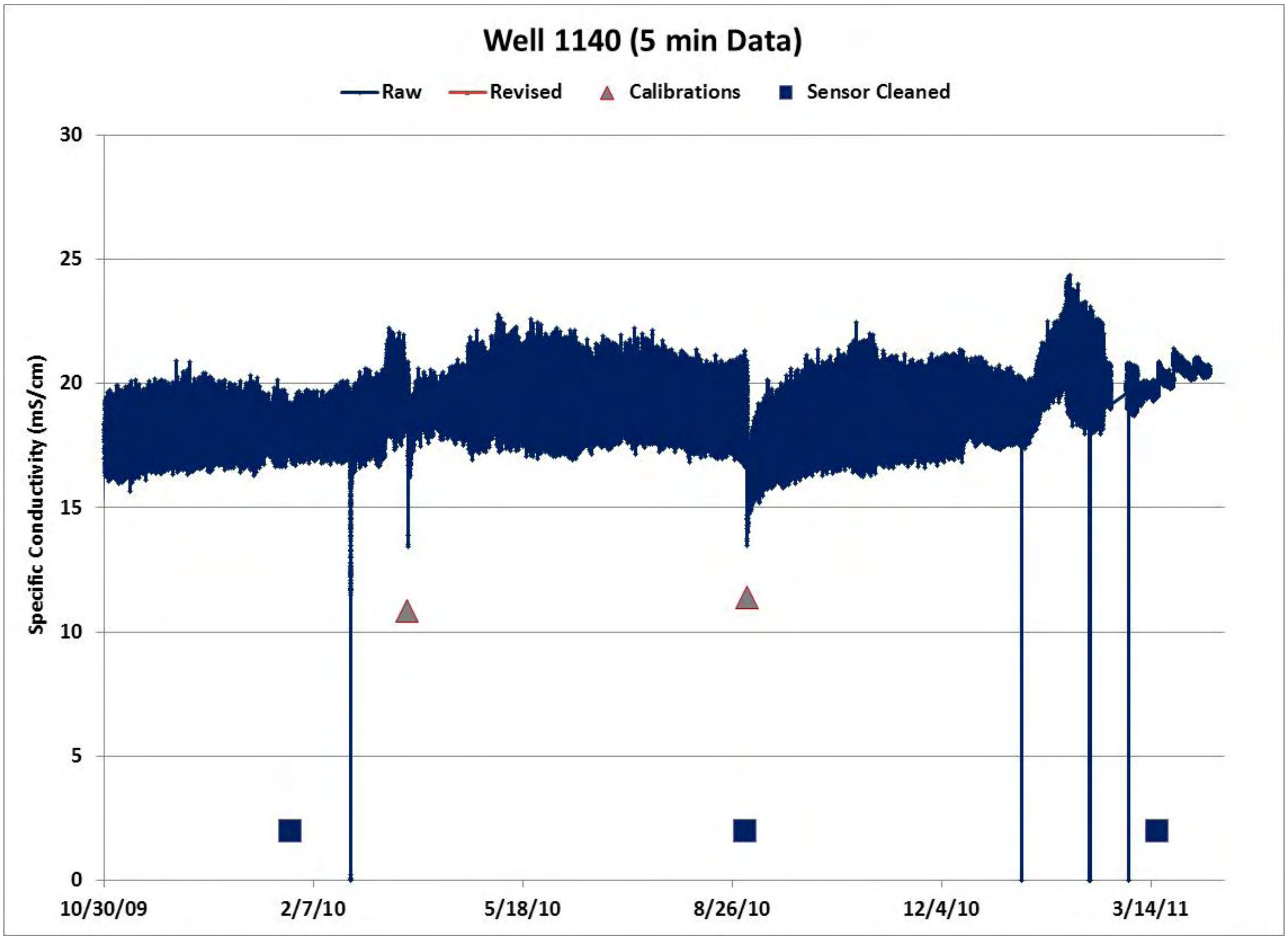
Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for well 1112, compared to measurements made in a flow-through cell at the field site (calibrations). A calibration test conducted on April 12, 2011, indicated that the sensor was not functioning correctly; at this time the wiring was replaced and the problem corrected. The reading decreased by about 2 mS/cm and the noise was eliminated by the new wiring. Thus, all data prior to this date (including most of the data on this figure) were omitted. Note, however, that calibrations conducted on standard solutions at several times showed good agreement, which means the overall data trends might have some meaning.

Figure B–15. Specific Conductivity for Well 1112



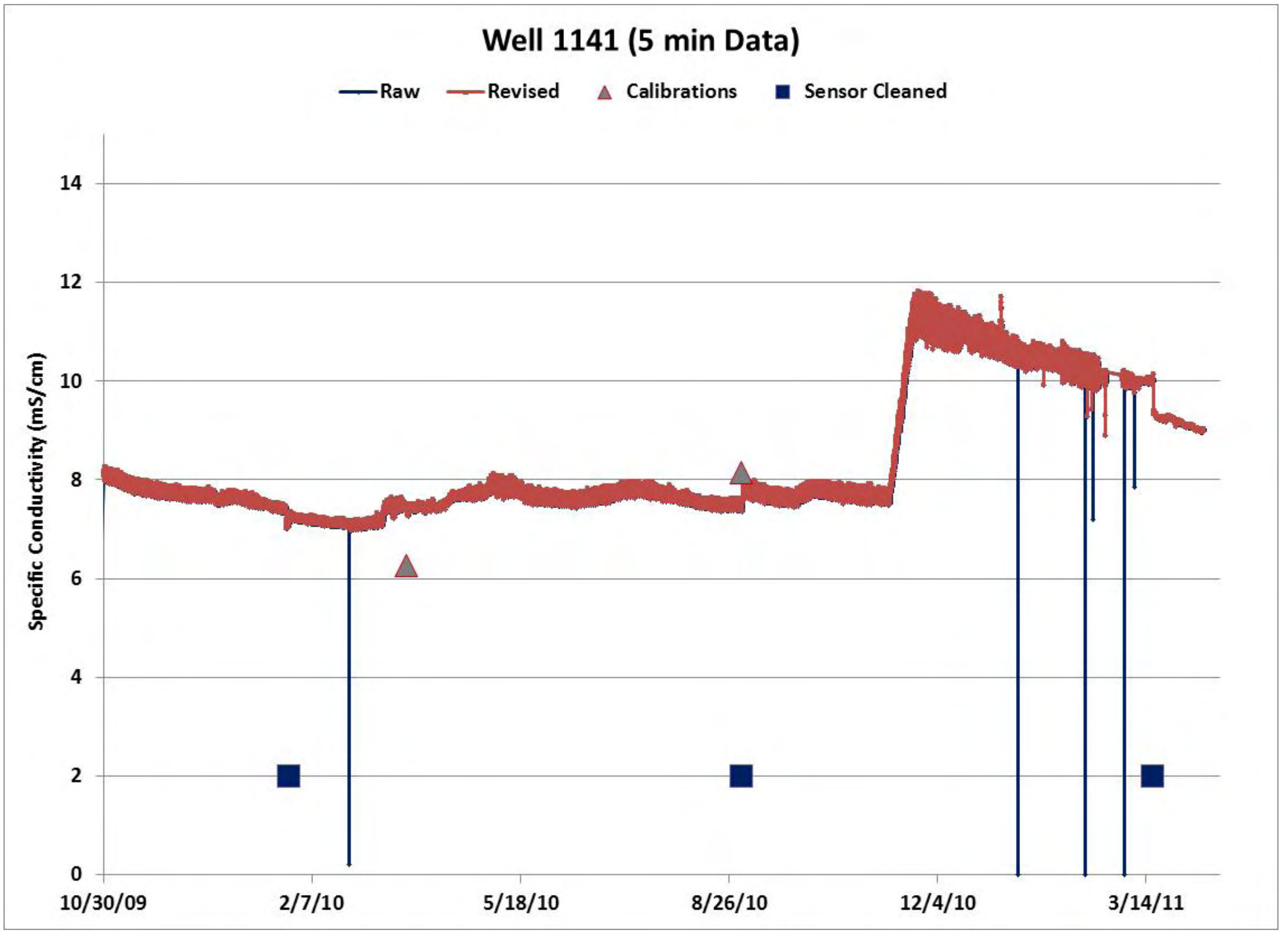
Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for extraction well 1137, compared to measurements made in a flow-through cell at the field site (calibrations). Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. Calibration of the conductivity sensor was checked several times against standard solutions and the results indicated reasonable agreement.

Figure B–16. Specific Conductivity for Well 1137



Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for well 1140, compared to measurements made in a flow-through cell at the field site (calibrations). Due to the high noise level in the data and poor correspondence to the calibration checks, all specific conductivity data from this well were omitted. Calibration of the conductivity sensor was checked several times against standard solutions and the results indicated good agreement.

Figure B–17. Specific Conductivity for Well 1140



Notes:
This figure shows the specific conductivity (mS/cm) measured by the SOARS system for well 1141, compared to measurements made in a flow-through cell at the field site (calibrations). Outliers (such as data collected while the sensor was out of the well during sampling and maintenance events) were removed in the revised data. Calibration of the conductivity sensor was checked several times against standard solutions and the results indicated good agreement.

Figure B–18. Specific Conductivity for Well 1141

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Appendix C

Data Quality Assessment: Flow Rates

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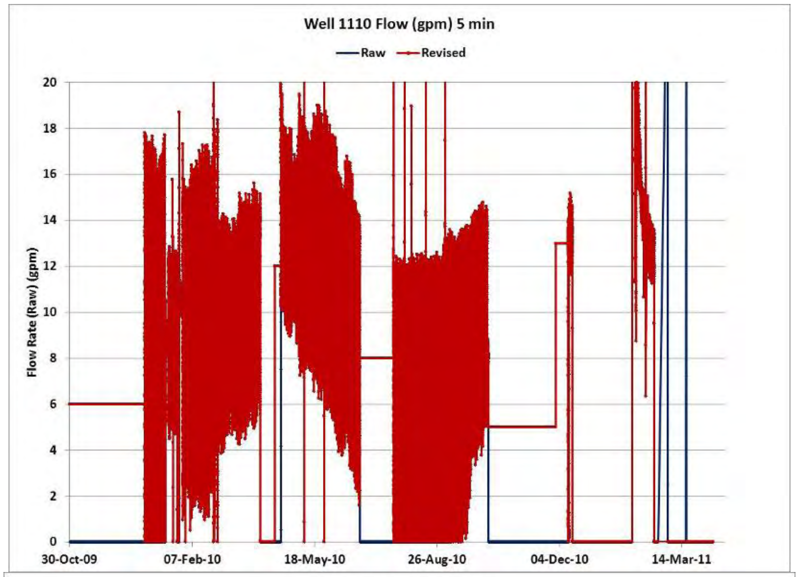
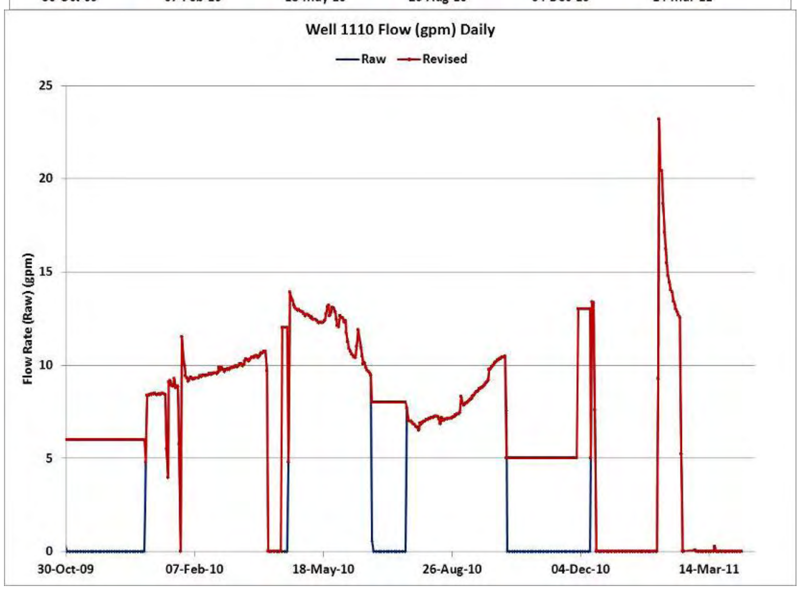
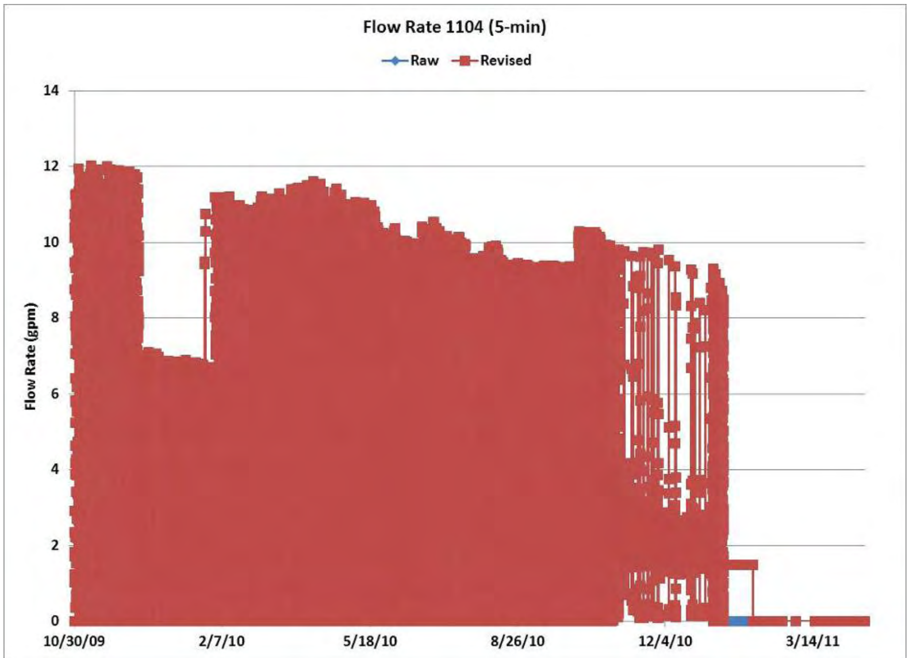
In this appendix, the accuracy of flow rate data from the extraction wells in the SOARS system are assessed for the period October 30, 2009, through April 18, 2011. In cases where data were known to be erroneous (by interpreting entries in field notes and results from pressure and water level sensors), the data were revised. Details of these revisions are provided. The revised values are used in the body of the report for interpretive purposes.

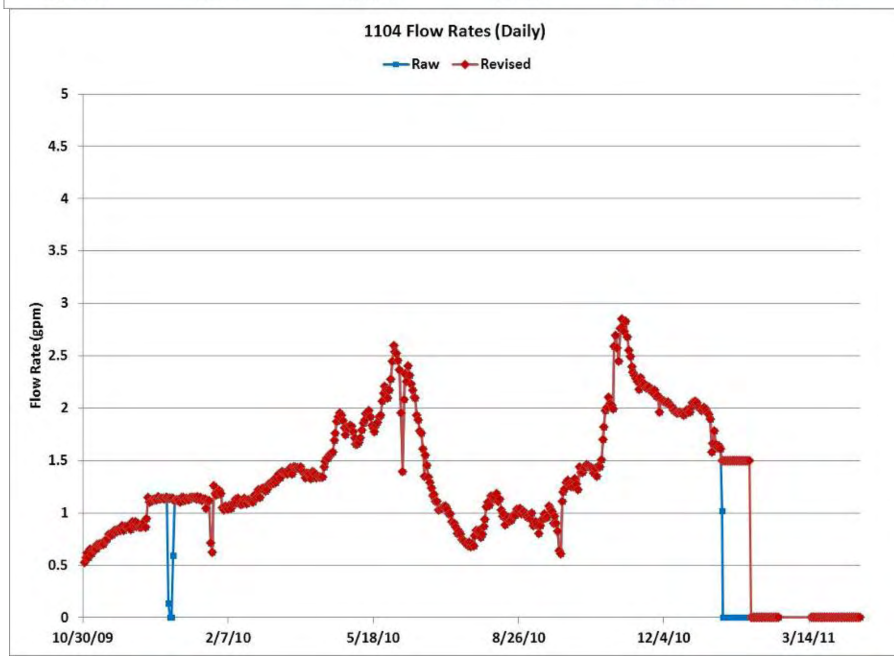




Notes:
Instruments at Well 1110 (Trench 1 Sump) provided 5-minute data and daily data for gallons per minute (gpm) flow rates. The raw flow rates in the SOARS system are shown in blue and revised data are shown in red. Revised data include estimates of flow rates for periods when the pump was on but the flow meter was not working. Interpretations of these flow rates for these periods are based on water level and in-line pressure measurements. From October 7 through December 30, 2009, the system was assumed to have been pumping at an average of 6 gpm. From April 15 through April 20, 2010, the system was assumed to have been pumping at an average of 12 gpm. From June 24 through July 20, 2010, the system was assumed to have been pumping at an average of 8 gpm. From October 6 through December 10, 2010, the system was assumed to have been pumping at an average of 5 gpm.

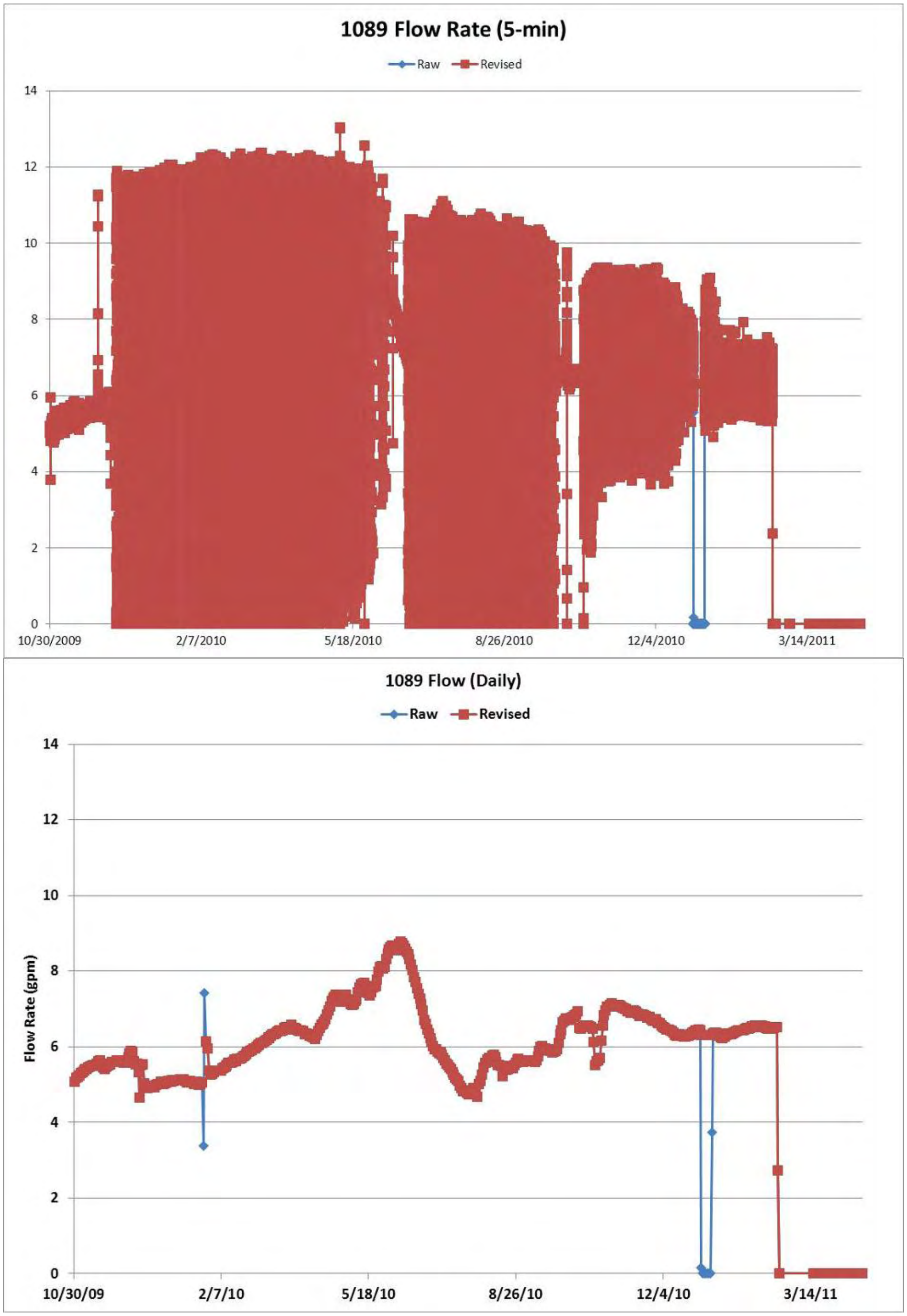
Figure C–1. Flow Rate Data for Well 1110





Notes:
Instruments at Well 1104 (Pumping Well) provided 5-minute data and daily data for gallons per minute (gpm) flow rates. The raw flow rates in the SOARS system are shown in blue and revised data are shown in red. The flow meter was not working from 03:25 on December 12 through 10:40 on December 30, 2009, due to dead batteries; it was assumed, based on trending, that flow during this period was 1.14 gpm. The flow meter was not working from 15:25 on January 12 through 15:10 on February 1, 2011; it was assumed, based on the trending of existing data, that the flow was 1.5 gpm for this period.

Figure C–2. Flow Rate Data for Well 1104



Notes:
Instruments at Well 1089 (Pumping Well) provided 5-minute data and daily data for gallons per minute (gpm) flow rates. The raw flow rates in the SOARS system are shown in blue and revised data are shown in red. The flow meter was not working from 00:30 on December 29, 2010, through 09:45 on January 5, 2011; it was assumed, based on trending, that flow during this period was 6.3 gpm.

Figure C–3. Flow Rate Data for Well 1089