LMS/SHP/S13080

Annual Performance Report April 2014 Through March 2015 for the Shiprock, New Mexico, Site

August 2015

U.S. DEPARTMENT OF ENERGY | Legacy Management

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Abbreviations

BTV	background threshold value
COC	contaminant of concern
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	feet
GCAP	Groundwater Compliance Action Plan
gpm	gallons per minute
lb	pounds
MCL	maximum concentration limit
mg/L	milligrams per liter
N	nitrogen
SOARS	System Operation and Analysis at Remote Sites
SOWP	Site Observational Work Plan
UMTRA	Uranium Mill Tailings Remedial Action (Project)
UMTRCA	Uranium Mill Tailings Radiation Control Act

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Executive Summary

This annual report evaluates the performance of the groundwater remediation system at the Shiprock, New Mexico, Disposal and Processing Site (Shiprock site) for the period April 2014 through March 2015. The Shiprock site, a former uranium-ore processing facility remediated under the Uranium Mill Tailings Radiation Control Act, is managed by the U.S. Department of Energy (DOE) Office of Legacy Management. This annual report is based on an analysis of groundwater quality and groundwater level data obtained from site monitoring wells and the groundwater flow rates associated with the extraction wells, drains, and seeps.

Background

The Shiprock mill operated from 1954 to 1968 on property leased from the Navajo Nation. Remediation of surface contamination, including stabilization of mill tailings in an engineered disposal cell, was completed in 1986. During mill operation, nitrate, sulfate, uranium, and other milling-related constituents leached into underlying sediments and resulted in contamination of groundwater in the area of the mill site. In March 2003, DOE initiated active remediation of groundwater at the site using extraction wells and interceptor drains. At that time, DOE developed a baseline performance report that established specific performance standards for the Shiprock groundwater remediation system.

The Shiprock site is divided into two distinct areas: the floodplain and the terrace. The floodplain remediation system consists of two groundwater extraction wells, a seep collection drain, and two collection trenches (Trench 1 and Trench 2). The terrace remediation system consists of nine groundwater extraction wells, two collection drains (Bob Lee Wash and Many Devils Wash), and a terrace drainage channel diversion structure. All extracted groundwater is pumped into a lined evaporation pond on the terrace.

Compliance Strategy and Remediation Goals

As documented in the Groundwater Compliance Action Plan (DOE 2002), the U.S. Nuclear Regulatory Commission–approved compliance strategy for the floodplain is natural flushing supplemented by active remediation. The contaminants of concern (COCs) at the site are ammonia (total as nitrogen), manganese, nitrate (nitrate + nitrite as nitrogen), selenium, strontium, sulfate, and uranium. The compliance standards for nitrate, selenium, and uranium are listed in Title 40 *Code of Federal Regulations* Part 192. Regulatory standards are not available for ammonia, manganese, and sulfate; remediation goals for these constituents are either risk-based alternate cleanup standards or background levels. These standards and background levels apply only to the compliance strategy for the floodplain. The compliance strategy for the terrace is to eliminate exposure pathways at the washes and seeps and to apply supplemental standards in the western section (DOE 2002).

Semiannual Sampling Results

For this reporting period, 115 monitoring wells (58 on the floodplain and 57 on the terrace) and 17 surface water locations (8 from the San Juan River), were sampled. Contaminant distributions of nitrate, sulfate, and uranium (the primary COCs at the site) are generally the same as those observed in previous years. Contaminant concentrations have decreased in several floodplain wells in response to pumping—most notably in the Trench 1 area. COC concentrations in the easternmost Trench 2 area wells (closest to the San Juan River) are still lower than those nearer the escarpment, demonstrating the effectiveness of the Trench 2 system. Decreases in COC concentrations in the well 1089 area since remediation pumping began in 2003 are also evident.

Although concentrations of uranium, sulfate, and nitrate have decreased in most floodplain wells, especially in areas near the pumping regions, exceptions are found at several near-river locations—wells 1137, 1138, 1139 in the well 1089/1104 remediation area, central floodplain wells 0857 and 1136, and southernmost well 0735. At these locations, contaminant concentrations, in particular sulfate and uranium, appear to be increasing. Recent increases are also apparent in wells 0628 and 0630 at the base of Bob Lee Wash. The reason for these increases is not known at this time, but these trends will be evaluated. No measurable impacts to the San Juan River have resulted from these increases.

In general, COC concentrations in samples collected from the San Juan River have been below established benchmarks. Exceedances of threshold values for nitrate and uranium in October 2014 are considered unrelated to historical milling activities, as comparable exceedances also occurred during that time at the upstream (background) location.

Summary of Remediation Performance and Site Evaluation Progress

Groundwater in the floodplain system is currently being extracted from two wells (wells 1089 and 1104) adjacent to the San Juan River north of the disposal cell, two collection trenches, and a seep collection sump. Approximately 10.2 million gallons of groundwater were extracted from the floodplain aquifer system during this performance period. Approximately 119.5 million gallons have been extracted from the floodplain since DOE began active remediation in March 2003.

Groundwater in the terrace system is currently being extracted from a drainage trench (Bob Lee Wash) and nine extraction wells. During this reporting period, no groundwater was pumped from a second drainage trench in Many Devil Wash, given the need for extensive repairs of the interceptor drain. From April 2014 through March 2015, approximately 2.7 million gallons of groundwater were extracted from the terrace system; the total cumulative volume extracted is approximately 39.6 million gallons. The cumulative volume removed from both the terrace and the floodplain combined (as of April 1, 2015) is over 159 million gallons. Estimated masses of sulfate, nitrate, and uranium removed from the floodplain and terrace well fields during this performance period were (rounded) 472,190 pounds; 20,000 pounds; and 27.7 pounds, respectively.

Previous annual reports have concluded with a recommendations section, but since the inception of the technical working group, consisting of the various stakeholders, that section is no longer included in this report. Rather, recommendations for future actions and a technically sound and protective "path forward" are discussed on a regular basis and implemented as soon as feasible.

1.0 Introduction

This report evaluates the performance of the groundwater remediation system at the Shiprock, New Mexico, Disposal and Processing Site for the period April 2014 through March 2015. The Shiprock site, a former uranium-ore processing facility remediated under the Uranium Mill Tailings Radiation Control Act (UMTRCA), is managed by the U.S. Department of Energy (DOE) Office of Legacy Management.

The Shiprock mill operated from 1954 to 1968; mill tailings were stabilized in an engineered disposal cell in 1986. As a result of milling operations, groundwater in the mill site area was contaminated with uranium, nitrate, sulfate, and associated constituents. In March 2003, DOE initiated active remediation of the groundwater using extraction wells and interceptor drains. At that time, DOE developed a baseline performance report (DOE 2003) that established specific performance standards for the Shiprock groundwater remediation system and documented the site conditions that form the basis for comparisons drawn herein.

The Shiprock site is divided into two distinct areas: the floodplain and the terrace; an escarpment forms the boundary between these two areas. The floodplain remediation system consists of two groundwater extraction wells, a seep collection drain, and two collection trenches (Trench 1 and Trench 2). The terrace remediation system consists of nine groundwater extraction wells, two collection drains (Bob Lee Wash and Many Devils Wash), and a terrace drainage channel diversion structure. All extracted groundwater is pumped into a lined evaporation pond on the terrace. Figure 1 shows the site layout and the major components of the floodplain and terrace groundwater remediation systems. Figure 2 shows all monitoring locations at the site, including groundwater monitoring wells, surface water sampling locations, and treatment system sample locations.

The Site Observational Work Plan (SOWP; DOE 2000) presents a detailed description of Shiprock site conditions, and the Groundwater Compliance Action Plan (GCAP; DOE 2002) documents the compliance strategy. Since these initial reports were developed, DOE has undertaken additional evaluations, including the *Refinement of Conceptual Model and Recommendations for Improving Remediation Efficiency at the Shiprock, New Mexico, Site* (DOE 2005), evaluations of the Trench 1 and Trench 2 groundwater remediation systems (DOE 2009, DOE 2011d), a midterm evaluation of the site remediation strategy (DOE 2011a), and the *Optimization of Sampling at the Shiprock, New Mexico, Site* (DOE 2013b).

1.1 Remediation System Performance Standards

This performance assessment is based on an analysis of groundwater quality and water level data obtained from site monitoring wells and groundwater flow rates measured at the extraction wells, drains, and seeps. Specific performance standards or metrics established for the Shiprock floodplain groundwater remediation system in the Baseline Performance Report (DOE 2003) are:

- Groundwater flow directions in the vicinity of the extraction wells should be toward the extraction wells to maximize the zones of capture.
- Groundwater contaminant concentrations should be monitored and compared to the baseline concentrations to provide an indication as to whether the floodplain extraction system is effective and contaminant levels are decreasing.

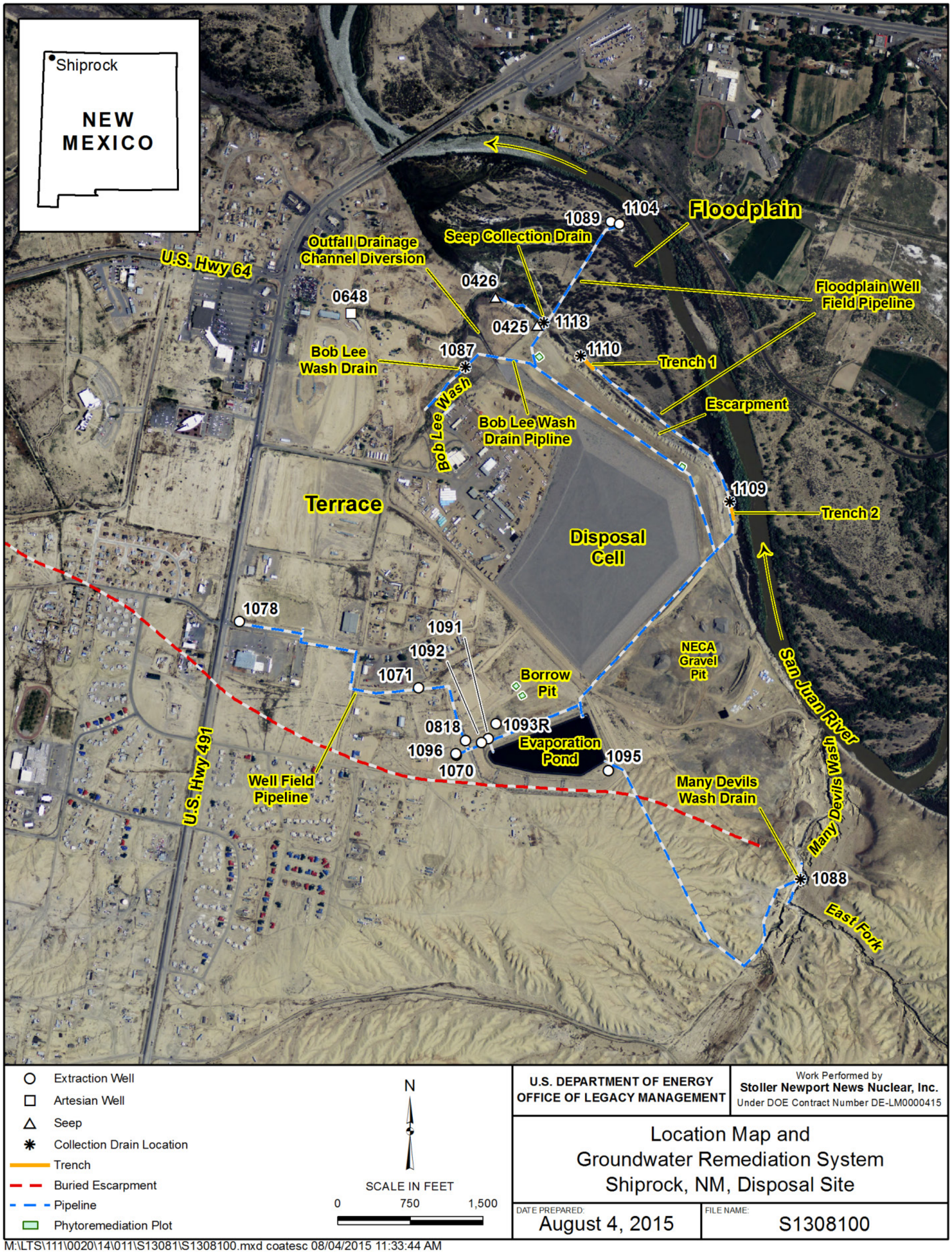

Figure 1. Location Map and Groundwater Remediation System

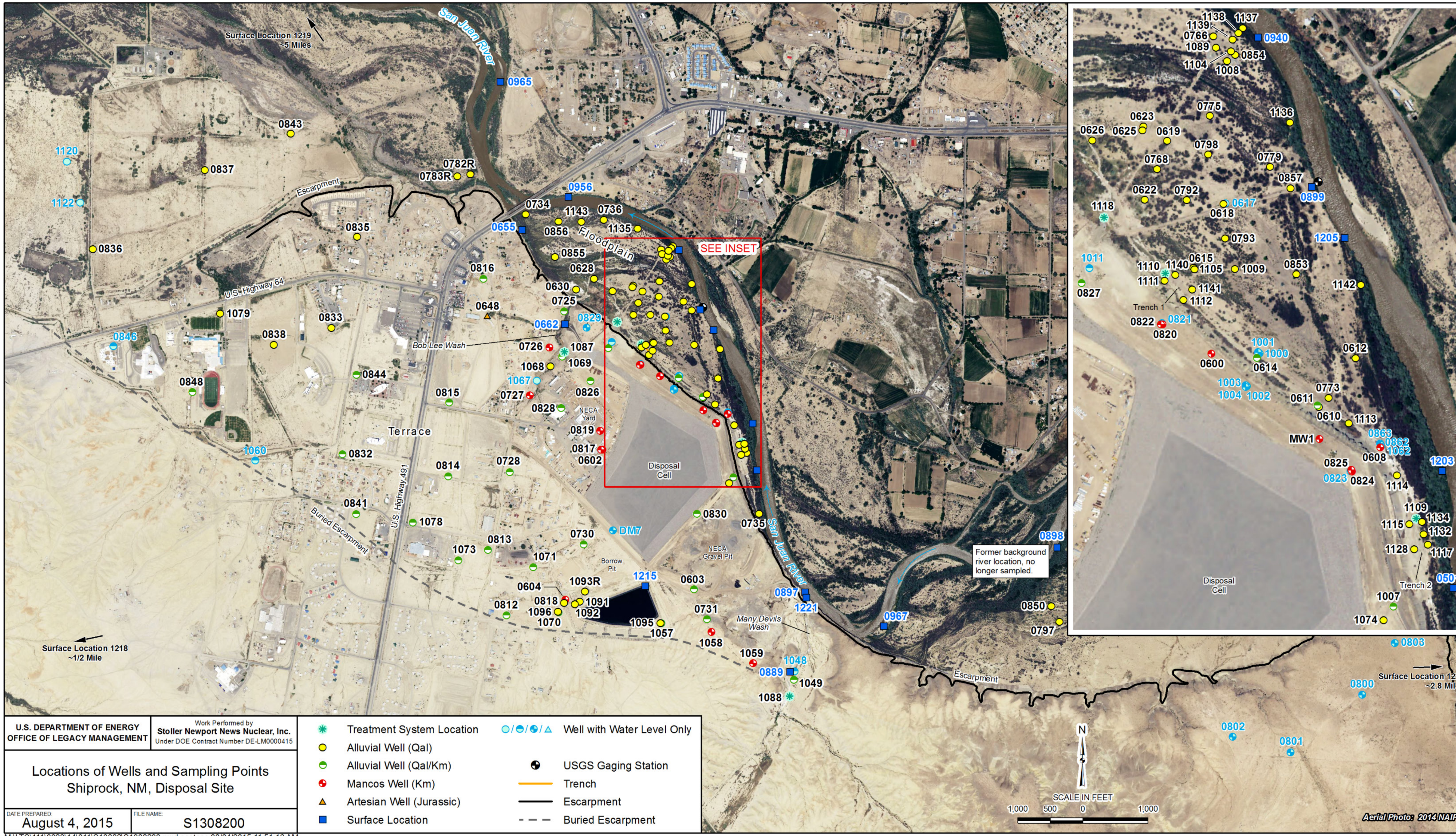

Figure 2. Locations of Wells and Sampling Points at the Shiprock Site

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Specific performance standards established for the terrace groundwater remediation system in the Baseline Performance Report (DOE 2003) are:

- Terrace groundwater elevations should decrease as water is removed from the terrace system.
- The volume of water discharging to the interceptor drains located in Bob Lee Wash and Many Devils Wash should decrease over time as groundwater levels on the terrace decline.
- The flow rates of seeps located at the base of the escarpment face (locations 0425 and 0426, represented by measurements from seep collection drain 1118) should decrease over time as groundwater levels on the terrace decline.

The performance standards summarized above (from DOE 2003) are based on the active remediation aspects of the compliance strategies documented in the GCAP (DOE 2002).

1.2 Contaminants of Concern and Remediation Goals

The contaminants of concern (COCs) for both the floodplain and the terrace, defined in the GCAP, are ammonia (total as nitrogen), manganese, nitrate (nitrate + nitrite as nitrogen), selenium, strontium, sulfate, and uranium. These constituents are listed in Table 1 along with corresponding floodplain background data and maximum concentration limits (MCLs) established in Title 40 *Code of Federal Regulations* Part 192 (40 CFR 192), which apply to UMTRCA sites.

Table 1. Groundwater COCs for the Shiprock Site

Contaminant	40 CFR 192 MCL (mg/L)	Cleanup Goal (mg/L)	Historical Range in Floodplain Background Wells[a]	Comments
Ammonia as N (mg/L)	–	–	0.074–0.11	Most ammonia results for floodplain background wells have been nondetects (<0.1 mg/L).
Manganese (mg/L)	–	2.74	0.001–7.2	2.74 mg/L alternate cleanup goal established in the GCAP (DOE 2002, Table 3-2).
Nitrate as N (mg/L)	10	–	0.01–5.7	10 mg/L nitrate as N is equivalent to 44 mg/L nitrate as NO_3.
Selenium (mg/L)	0.01	0.05	0.0001–0.02	Cleanup goal for the floodplain is 0.05 mg/L as identified in the GCAP (DOE 2002). This is also the U.S. Environmental Protection Agency (EPA) Safe Drinking Water Act maximum contaminant level.
Strontium (mg/L)	–	–	0.18–10	EPA's Drinking Water Equivalent Level for lifetime exposure is 20 mg/L (EPA 2012).
Sulfate (mg/L)	–	2000	210–5200	Given elevated levels in artesian well 0648 (1810–2340 mg/L), a cleanup goal of 2000 mg/L was proposed in the GCAP (DOE 2002).
Uranium (mg/L)	0.044	–	0.004–0.12	Uranium levels measured in floodplain background wells have varied widely and have exceeded the MCL at times.

[a] Data are from floodplain background wells 0797 and 0850 (locations shown in Figure 2).
mg/L = milligrams per liter
– not applicable (contaminant does not have an MCL in 40 CFR 192, or alternate cleanup goal not relevant)

As listed in Table 1, the compliance standards for nitrate, uranium, and selenium are the respective 40 CFR 192 standards of 10 milligrams per liter (mg/L), 0.044 mg/L, and 0.01 mg/L. If the relatively high selenium concentrations in floodplain groundwater originate on the terrace, it may be unlikely that the 40 CFR 192 standard of 0.01 mg/L for this constituent can be met. Therefore, an alternate concentration limit for selenium of 0.05 mg/L was proposed for the floodplain in the GCAP (DOE 2002), which is the maximum contaminant level for drinking water established under the U.S. Environmental Protection Agency (EPA) Safe Drinking Water Act. This alternate level may still be too conservative, given the potential influence from natural sources addressed in recent DOE evaluations (DOE 2011b, 2011c).

Regulatory standards are not available for ammonia and manganese (Table 1). An alternate cleanup standard has not been established for ammonia because EPA has not developed any toxicity values upon which to base an associated risk-based standard. Ammonia levels measured in floodplain background wells have been low and mostly below detection limits. The cleanup goal for manganese is 2.7 mg/L for the floodplain, as specified in the GCAP.

Regulatory standards are also not available for strontium, a constituent typically not associated with uranium-milling sites. Strontium was selected as a COC in the Baseline Risk Assessment (DOE 1994) primarily because of concentrations measured in sediment (rather than groundwater) and a conservatively modeled agricultural uptake scenario. The form present at the Shiprock site is stable (nonradioactive) strontium, a naturally occurring element, and is distinguished from the radioactive and much more toxic isotope strontium-90, a nuclear fission product (ATSDR 2004). EPA's Drinking Water Equivalent Level for lifetime exposure is 20 mg/L (EPA 2012).

Because sulfate levels have also been elevated in groundwater entering the floodplain from flowing artesian well 0648 (up to 2340 mg/L), the GCAP proposed an alternate cleanup goal for sulfate of 2000 mg/L for the floodplain. This alternate goal is conservative, given the elevated level measured in floodplain background well 0797 (4,500 mg/L for this reporting period).

1.3 Hydrogeological Setting

This section presents a brief summary of the floodplain and terrace groundwater systems. More-detailed descriptions are provided in the SOWP (DOE 2000), the refinement of the site conceptual model (DOE 2005), and the Trench 1 and Trench 2 floodplain remediation system evaluations (DOE 2011d, DOE 2009).

1.3.1 Floodplain Alluvial Aquifer

The thick Mancos Shale of Cretaceous age forms the bedrock underlying the entire site. A floodplain alluvial aquifer occurs in unconsolidated medium- to coarse-grained sand, gravel, and cobbles that were deposited in former channels of the San Juan River above the Mancos Shale. The floodplain aquifer is hydraulically connected to the San Juan River; the river is a source of groundwater recharge to the floodplain aquifer in some areas, and it receives groundwater discharge in other areas. In addition, the floodplain aquifer receives some inflow from groundwater in the terrace area. The floodplain alluvium is up to 20 feet (ft) thick and overlies Mancos Shale, which is typically soft and weathered for the first several feet below the alluvium.

Most groundwater contamination in the floodplain lies close to the escarpment east and north of the disposal cell. Contaminant distributions in the alluvial aquifer are best characterized by elevated concentrations of sulfate and uranium. Lower levels of contamination occur along the escarpment base in the northwest part of the floodplain because relatively uncontaminated surface water from Bob Lee Wash discharges to the floodplain at the wash's mouth. Surface water in Bob Lee Wash originates primarily as deep groundwater from the Morrison Formation that flows to the land surface via artesian well 0648. Well 0648 flows at approximately 65 gallons per minute (gpm) and drains eastward into lower Bob Lee Wash. Historically, background groundwater quality in the floodplain aquifer has been defined by the water chemistry observed at monitoring wells 0797 and 0850, installed in the floodplain approximately 1 mile upriver from the site (Figure 2).

1.3.2 Terrace Groundwater System

The terrace groundwater system occurs partly in unconsolidated alluvium in the form of medium- to coarse-grained sand, gravel, and cobbles deposited in the floodplain of the ancestral San Juan River. Terrace alluvial material is Quaternary in age; it varies from 0 to 20 ft in thickness and caps the Mancos Shale. Although less well mapped, some terrace groundwater also occurs in weathered Mancos Shale underlying the alluvium. The Mancos Shale is exposed in the escarpment adjacent to the San Juan River floodplain.

The terrace groundwater system is bounded on its south side by an east-west-trending buried bedrock (Mancos Shale) escarpment, about 1,500 ft south of the southernmost tip of the disposal cell. The terrace system extends more than a mile west and northwestward, to more than 4,000 ft west of Highway 491. Terrace alluvial material is exposed at ground surface in the vicinity of the terrace–floodplain escarpment; south and southwest of the former mill, the terrace alluvium is covered by eolian silt (deposited by wind), or loess, which increases in thickness with proximity to the buried bedrock escarpment. Up to 40 ft of loess overlies the alluvium along the base of the buried escarpment. Terrace alluvium consists of coarse-grained ancestral San Juan River deposits, primarily in the form of coarse sands and gravels.

Mancos Shale underlying the alluvium in the terrace area is soft and weathered. The weathered Mancos Shale is typically 2 to 10 ft thick, but some characteristics of weathering below the shale-alluvium contact occur as deep as 30 ft in places (DOE 2000). Groundwater is known to occur in the weathered shale and, in some areas, possibly flows through deeper portions of the shale, within fractures and along bedding surfaces.

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2.0 Remediation System Performance

This section describes the key components of the floodplain and terrace groundwater remediation systems and summarizes their performance for the 2014–2015 reporting period.

2.1 Floodplain Remediation System

The floodplain remediation system consists of three major components shown in Figure 1: two extraction wells (wells 1089 and 1104); two drainage trenches (horizontal wells), Trench 1 and Trench 2; and a sump (collection drain location 1118) used to collect discharges from seeps 0425 and 0426 on the escarpment. The main objective of the floodplain groundwater extraction system is to supplement the natural flushing process by reducing the contaminant mass and volume within the floodplain alluvial aquifer. All groundwater collected from the floodplain extraction wells and trenches is piped south to the terrace and discharged into the evaporation pond. Average pumping rates and cumulative volumes of groundwater extracted from floodplain remediation system locations are summarized in Table 2 for the current and previous reporting periods.

Table 2. Floodplain Remediation System Locations: Average Pumping Rates and Total Groundwater Volume Removed

Floodplain Location	Previous Period (April 1, 2013, through March 31, 2014)		Current Period (April 1, 2014, through March 31, 2015)	
	Average Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)	Average Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)
1089	5.9	3,115,198	4.3	2,270,327
1104	1.6	819,015	1.4	733,359
Trench 1	10.8	5,662,661	6.95	3,653,552
Trench 2	6.2	3,240,211	6.3	3,288,298
Seep (1118)	0.55	289,755	0.51	268,619
Total	**25.0** (cum. avg.)	**13,126,840**	**19.5** (cum. avg.)	**10,214,155**

Note: Since the last annual performance report was issued, an extensive effort was taken to verify and correct all pumping and flow data obtained through SOARS (System Operation and Analysis at Remote Sites), the telemetry system used to record all active treatment 5-minute and daily flow data. As a result, some historical flow data have changed.

2.1.1 Extraction Well Performance

The floodplain extraction well system consists of wells 1089 and 1104 (Figure 1). These wells were constructed using slotted culverts placed in trenches excavated to bedrock. From April 2014 through March 2015, approximately 2.3 million gallons of water were removed from well 1089 at an average pumping rate of about 4.3 gpm (Table 2). Pumping rates at well 1104 averaged about 1.4 gpm; the cumulative extracted volume was about 733,400 gallons. During the period since the start of operations in March 2003 through the end of March 2015, totals of approximately 33 and 7 million gallons of water have been removed from wells 1089 and 1104, respectively.

2.1.2 Floodplain Drain System Performance

In spring 2006, two drainage trenches—Trench 1 (1110) and Trench 2 (1109)—were installed in the floodplain just below the escarpment to enhance the extraction of groundwater from the alluvial system. Pumping began in April 2006. From April 2014 through March 2015, approximately 3.65 million gallons of water were removed from Trench 1 at an average pumping rate of 6.95 gpm. In 2014–2015, approximately 3.3 million gallons of water were removed from Trench 2 at an average pumping rate of 6.3 gpm (Table 2).

As has been the case in the last several years, during this reporting period, pumping from floodplain locations was shut down periodically for maintenance and repairs and to increase evaporation pond capacity and maintain pond water levels.

2.1.3 Floodplain Seep Sump Performance

In August 2006, seeps 0425 and 0426 were incorporated into the remediation system. Groundwater discharge from these two seeps is piped into a collection drain (location 1118) and then pumped to the evaporation pond. From April 2014 through March 2015, the average discharge rate from the seep collection drain was 0.51 gpm, similar to the average rates reported in the last several years. Approximately 268,600 gallons were pumped from the seeps during this period (Table 2), yielding a total cumulative volume of about 2.5 million gallons.

2.2 Terrace Remediation System

The objective of the terrace remediation system is to remove groundwater from the southern portion of the terrace area so that potential exposure pathways at seeps and at Bob Lee Wash and Many Devils Wash are eventually eliminated, and the flow of groundwater from the terrace to the floodplain is reduced. The terrace remediation system consists of four major components shown in Figure 1: the extraction wells, the evaporation pond, the terrace drains (Bob Lee Wash and Many Devils Wash), and the terrace outfall drainage channel diversion.

2.2.1 Extraction Well Performance

During the current period, the terrace remediation well field consisted of wells 0818, 1070, 1071, 1078, 1091, 1092, 1093R, 1095, and 1096. Table 3 compares the average pumping rate and total groundwater volume removed from each terrace extraction well and drain location for the current (2014–2015) and previous (2013–2014) reporting periods. The production rate from wells 1070, 1071, 1091, and 1092 (all less than 0.03 gpm this reporting period) has not exceeded 0.1 gpm, the minimum production to be considered an aquifer under 10 CFR 192.

As shown in Table 3, the current-period average pumping rates for terrace extraction wells ranged from 0.002 gpm to 0.93 gpm. The total groundwater volume removed from each well during this period ranged from 1,220 gallons to 491,109 gallons. The cumulative total volume removed from pumping the terrace extraction wells (about 1.64 million gallons) is about 11 percent less than the volume extracted during the 2013–2014 reporting period.

Table 3. Terrace Extraction Wells and Drains: Average Pumping Rates and Total Groundwater Volume Removed

Terrace Well or Drain	Previous Period (April 1, 2013, through March 31, 2014)		Current Period (April 1, 2014, through March 31, 2015)	
	Average Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)	Average Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)
0818[a]	1.0	527,106	0.77	405,481
1070	0.019	10,058	0.020	10,437
1071	0.01	5,282	0.007	3,700
1078	0.93	490,104	0.73	383,929
1091	0.037	19,659	0.004	2,323
1092	0.001	687	0.002	1,220
1093R	0.67	352,443	0.93	491,109
1095	0.32	166,765	0.30	158,532
1096	0.52	273,810	0.34	180,016
Subtotal	**3.5** (cum. avg.)	**1,845,914**	**3.1** (cum. avg.)	**1,636,747**
1087[b]	3.0	1,574,426	2.02	1,059,596
1088[b]	0.072	37,712	0	0
Total	**6.58** (cum. avg.)	**3,458,052**	**5.12** (cum. avg.)	**2,696,343**

[a] Well 0818 was identified in the GCAP as a performance assessment well.
[b] Locations 1087 and 1088 are Bob Lee Wash and Many Devils Wash drains, respectively.

Note: Since the last annual performance report was issued, an extensive effort was taken to verify and correct all pumping and flow data obtained through SOARS. As a result, some historical flow results have changed, affecting the volumes and flow rates reported here (see more detailed note following Table 2).

One of the initial objectives for the terrace remediation system was attainment of a cumulative 8 gpm extraction rate, a goal based on groundwater modeling conducted for the SOWP (DOE 2000). To help meet this objective, two wells (1095 and 1096) were installed near the evaporation pond in March 2005. In September 2007, DOE installed a new large-diameter well (1093R) to increase the probability of collecting a larger volume of water. Despite these enhancements, the 8 gpm objective has still not been achieved and likely will not be achieved. Historically, the combined pumping rate from terrace extraction wells has ranged between 2 and 4.3 gpm.

2.2.2 Terrace Drain System Performance

The terrace extraction system collects seepage from Bob Lee Wash and Many Devils Wash using subsurface interceptor drains. These drains, which consist of perforated pipe surrounded by drain rock and lined with geotextile filter fabric, are offset from the centerline of each wash to minimize the infiltration of surface water. All water collected by these drains is pumped through a pipeline to the evaporation pond. In 2014−2015, the average pumping rate from Bob Lee Wash was 2 gpm (vs. 3 gpm in 2013−2014), and the groundwater interceptor drain removed about 1.1 million gallons of water (Table 3). No water was pumped from the Many Devils Wash groundwater interceptor drain during this reporting period, given the need for extensive repairs of the system. These repairs have not been addressed yet because the origins of the groundwater in Many Devils Wash are being explored and may form the basis for decommissioning the interceptor drain system.

2.2.3 Evaporation Pond

The selected method for handling groundwater from the interceptor drains and extraction wells is solar evaporation. Contaminated groundwater is pumped to an 11-acre lined evaporation pond in the south part of the radon cover borrow pit area (Figure 1). At the close of this reporting period (March 31, 2015), the average water level in the evaporation pond was 4.9 ft (measured as the distance above transducers), leaving approximately 3.1 ft of unfilled pond capacity.

From April 2014 through March 2015, about 12.9 million gallons of extracted groundwater were pumped to the evaporation pond. The majority (10.2 million gallons, or 79 percent) of the influent liquids entering the pond were from the floodplain aquifer. About 21 percent (2.7 million gallons) of the inflow originated from the terrace groundwater system (Table 4). As shown in Figure *3*, at the end of the 2014–2015 reporting period, about 39.6 million gallons have been extracted from the terrace and 119.5 million gallons from the floodplain since DOE began active remediation in March 2003. This yields a cumulative extracted volume of just over 159 million gallons of water pumped to the evaporation pond from all sources (cumulative contributions of 25 percent and 75 percent from the terrace and floodplain, respectively).

As shown in Table 4, the estimated masses of nitrate, sulfate, and uranium pumped to the evaporation pond from the floodplain extraction wells and trenches and terrace groundwater extraction system during the 2014–2015 performance period were approximately 20,000 pounds nitrate (as N), 472,190 pounds sulfate, and 27.7 pounds uranium. These mass estimates were computed using the average concentrations measured in each extraction well and the corresponding annual cumulative volume pumped. In terms of mass, sulfate is the dominant COC that enters the evaporation pond because of its high concentrations in both the floodplain and terrace groundwater systems.

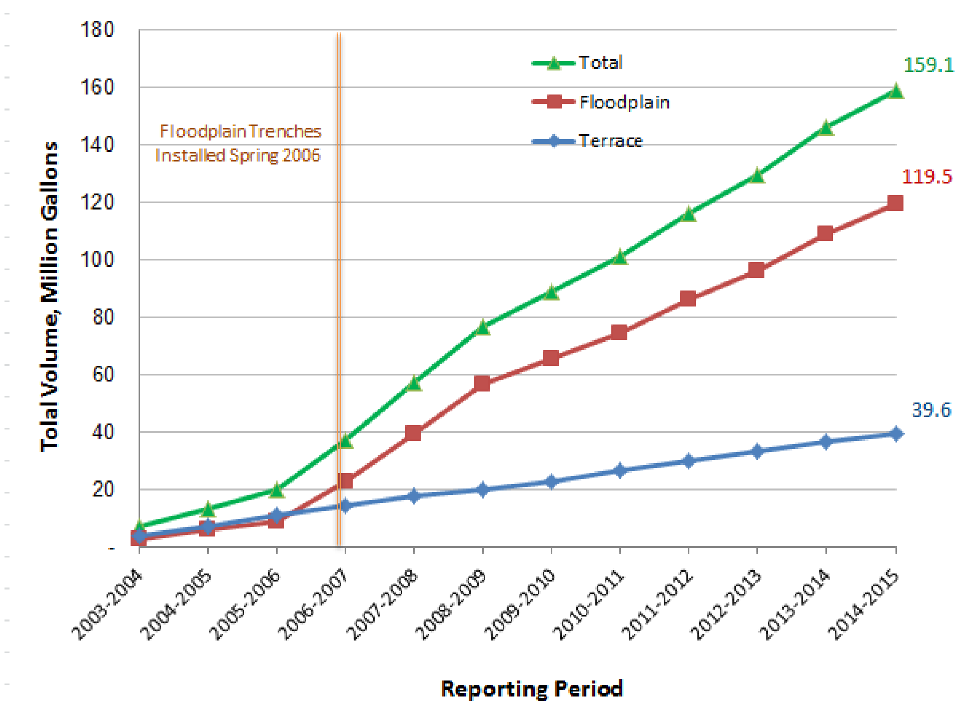

Figure 3. *Total Groundwater Volume Pumped to the Evaporation Pond*

Table 4. Estimated Total Mass of Selected Constituents Pumped from Terrace and Floodplain

Location	Annual Cumulative Volume (gal)[a]	Total Cumulative Volume (gal)[a]	Percent of Total Cum. Volume Pumped (%)	Nitrate as N Average Concentration, 2014–2015 (mg/L)	Nitrate Mass Removed, 2014-2015 (lb)[b]	Cumulative Mass of Nitrate Removed (lb)[c]	Sulfate Average Concentration, 2014–2015 (mg/L)	Sulfate Mass Removed, 2014-2015 (lb)[b]	Cumulative Mass of Sulfate Removed (lb)[c]	Uranium Average Concentration, 2014–2015 (mg/L)	Uranium Mass Removed, 2014-2015 (lb)[b]	Cumulative Mass of Uranium Removed (lb)[c]
Terrace												
0818	405,481	4,664,327	2.9	705	2,386	49,819	13,000	43,991	490,016	0.12	0.406	4.88
1070	10,437	517,437	0.3	590	51.4	3,792	15,000	1,307	72,285	0.086	0.0075	0.528
1071	3,700	106,169	0.1	585	18.1	1,730	12,500	386	5,585	0.150	0.005	0.136
1078	383,929	3,673,594	2.3	535	1,714	19,343	13,000	41,652	422,579	0.125	0.401	4.113
1091	2,323	219,304	0.1	740	14.3	2,838	14,500	262	22,244	0.113	0.002	0.214
1092	1,220	225,322	0.1	505	5.1	2,879	14,000	143	24,867	0.099	0.001	0.220
1093R[d]	491,109	3,612,929	2.3	1633	6,694	64,664	8,733	35,793	163,658	0.12	0.492	3.096
1095	158,532	2,499,362	1.6	1700	2,249	33,442	5,100	6,747	127,758	0.054	0.072	1.239
1096	180,016	2,647,820	1.7	545	818.8	14,081	14,000	21,032	313,160	0.086	0.130	2.299
1087 (BLW)	1,059,596	18,032,636	11.3	215	1,901	49,879	6,200	54,825	1,147,288	0.49	4.333	89.43
1088 (MDW)	0	3,403,357	2.1	570	0	18,637	19,000	0	535,247	0.15	0	4.994
Floodplain												
1089	2,270,327	32,854,850	20.7	1.8	45.7	5,500	2,915	75,787	2,126,306	0.138	3.60	211.3
1104	733,359	6,983,531	4.4	2.3	15.6	2,784	5,149	35,191	529,951	0.36	2.48	62.35
Trench 1 (1110)	3,653,552	34,674,699	21.8	45.2	2,134	34,924	2,226	105,191	2,177,395	0.219	10.37	259.97
Trench 2 (1109)	3,288,298	41,668,223	26.2	67.0	1,811	20,175	1,269	34,303	457,640	0.157	4.25	66.14
Seep sump (1118)	268,619	2,476,719	1.6	58.9	142.3	1,048	6,443	15,580	124,687	0.473	1.143	10.20
				Total Masses:	**20,000**	325,535		**472,190**	8,740,666		**27.7**	721.1
Total Terrace[d]	2,696,343	39,617,886	24.9	–	15,852	261,628	–	206,138	3,324,999	–	5.85	111.15
Total Floodplain[d]	10,214,155	119,470,470	75.1	–	4,149	65,545	–	266,052	5,532,389	–	21.84	626.79
Total to Pond[d]	12,910,498	159,088,356	–	–	20,001	327,173	–	472,190	8,857,388	–	27.69	737.94

[a] Annual cumulative volumes are for this reporting period: April 1, 2014 through March 31, 2015.
[b] Mass in pounds (lb) removed = annual volume (gal) × average concentration (mg/L) × (3.7854 L/gal) × $(453{,}592.37\ \text{mg/lb})^{-1}$
[c] Cumulative volumes and masses are totals since March 2003. Cumulative volumes and masses listed for 1093R combine flow and sampling data for former smaller-diameter well 1093 (2003–2007) with those for well 1093R (2008–present). Average contaminant concentrations listed for well 1093R (2014–2015) include analytical results from May 1, 2014.
[d] Total cumulative volumes and masses include data from former terrace pumping well 1094 (15,628 gal, 2003–2004) and floodplain well 1077 (812,449 gal, 2003–2005).

BLW - Bob Lee Wash; gal - gallon(s); MDW - Many Devils Wash

Note: This table has been modified since the last and preceding annual reports to include cumulative flows and masses, as well as those for the current reporting period.

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3.0 Current Conditions

This section summarizes water quality and hydraulic characteristics of the floodplain and terrace groundwater systems for the April 2014 through March 2015 reporting period. For this reporting period, 115 monitoring wells were sampled (58 on the floodplain and 57 on the terrace). Seventeen surface water locations, including eight San Juan River sampling points and various seeps, were also sampled. In the last several years, 13 surface/seep locations have been eliminated because the locations had been historically dry (refer to Figure 10).

Detailed information, including time-concentration graphs for both terrace and floodplain monitoring locations for all COCs, along with supporting quality assurance documentation, is provided in the corresponding Data Validation Package reports (DOE 2015a, 2015b).

3.1 Floodplain Contaminant Distributions and Temporal Trends

This discussion and supporting figures (Figure 4 through Figure 6) presented in this section focus on nitrate, sulfate, and uranium because these contaminants are most widespread on the floodplain and are used to gauge the effectiveness of the remediation system at the Shiprock site. For these COCs, the alluvial plume maps in Figure 4 through Figure 6 compare baseline and current conditions using all alluvial wells that were sampled during both periods. Interpolations of COC concentrations at unsampled areas (i.e., between well locations) are based on measurements made at the closest surrounding sites. The color scale for the plume maps was determined based on the compliance standard or cleanup goal established in the GCAP—the break between blue/green and yellow/red was set at this value (highlighted by a black outline).

Corresponding time-concentration graphs for the primary COCs are provided in Appendix A using the spatial groupings shown in Figure 7 (see Figures A-1 through A-9). As demonstrated in this appendix, concentrations of uranium, sulfate, and nitrate have decreased in most floodplain wells, especially in areas near the pumping regions. Exceptions are found at several near-river locations—wells 1137, 1138, 1139 in the well 1089/1104 remediation area (Figure A-3), wells 0857 and 1136 in the central floodplain (Figure A-5), and southernmost well 0735 (Figure A-7). At these locations, contaminant concentrations, in particular sulfate and uranium, appear to be increasing. Recent increases are also apparent in wells 0628 and 0630 at the base of Bob Lee Wash (Figure A-8). The reason for these increases is not known at this time but will be evaluated.

<u>Nitrate (as N)</u>

Although still elevated on the floodplain relative to the 10 mg/L GCAP compliance standard, nitrate concentrations are much lower since the installation of trenches in 2006. The plume maps (Figure 4) show demonstrable progress on the floodplain (reductions in nitrate concentrations) in a comparison of baseline to current results. This is most evident in the Trench 1 and well 1089 areas. Nitrate concentrations in most areas of the floodplain are below the 10 mg/L cleanup goal.

<u>Sulfate</u>

Reductions in sulfate concentrations since the baseline period are evident in floodplain wells, particularly in the Trench 1 and well 1089 areas (Appendix A, Figures A-2 and A-3). Although the plume maps in Figure 5 indicate a decrease in sulfate concentrations in the area near the river between Trench 1 and Trench 2, this may be an artifact stemming from the lack of baseline data for the Trench 2 region. As discussed above, sulfate concentrations in central floodplain near-river wells 0857 and 1136–1139 have been variably increasing over the past few years as shown in Appendix A, Figures A-3 and A-5. Increases are also apparent in southernmost near-river well 0735 (Figure A-7) and wells 0628 and 0630 at the base of Bob Lee Wash (Figure A-8).

Exceptions are found at several near-river locations—wells 1137, 1138, 1139 in the well 1089/1104 remediation area (Figure A-3), wells 0857 and 1136 in the central floodplain (Figure A-5), and southernmost well 0735 (Figure A-7). At these locations, contaminant concentrations, in particular sulfate and uranium, appear to be increasing. Recent increases are also apparent in wells 0628 and 0630 at the base of Bob Lee Wash (Figure A-8). The reason for these increases is not known at this time but will be evaluated. As discussed in Section 3.2 (Figure 8), no measurable impacts to the San Juan River have resulted from these increases.

Uranium

As observed for nitrate and sulfate, reductions in uranium concentrations in some portions of the floodplain are evident in a comparison of the baseline to current plume maps (Figure 6). Despite these reductions, uranium concentrations in most floodplain wells still exceed the 0.044 mg/L MCL. Uranium concentrations have decreased in Trench 1 area wells since installation of the trench in 2006; decreases are also apparent in the well 1089 area (Appendix A, Figures A-2 and A-3). However, similar to the trends found for sulfate, uranium levels have increased in a number of near-river wells (0735, 0857, 1136–1139) as well as wells 0628 and 0630 near the base of Bob Lee Wash (refer to figures in Appendix A).

Other COCs

Previous annual reports (e.g., DOE 2013a) provide a more complete discussion of the spatial distribution of remaining COCs. The following summary is based largely on those characterizations and on recent data presented in the data validation packages (DOE 2015a, 2015b). In general, spatial distributions of the secondary COCs—ammonia, manganese, selenium, and strontium—have not changed significantly over the years.

Historically, ammonia concentrations have been highest on the floodplain in the area of the trenches and at the base of the escarpment. In contrast, most manganese concentrations have been within the 0–7.2 mg/L background range listed in Table 1.

Selenium concentrations on the floodplain are most elevated in the Trench 1 area and, southeast of Trench 1, in wells located at the base of the escarpment. With few exceptions, selenium concentrations in wells near the river have been below the 0.05 mg/L GCAP compliance standard.

Historically, strontium concentrations have been fairly uniform (most less than 10 mg/L). Apart from a possible association with Mancos wells, no spatial pattern indicative of site-related contamination has ever been apparent.

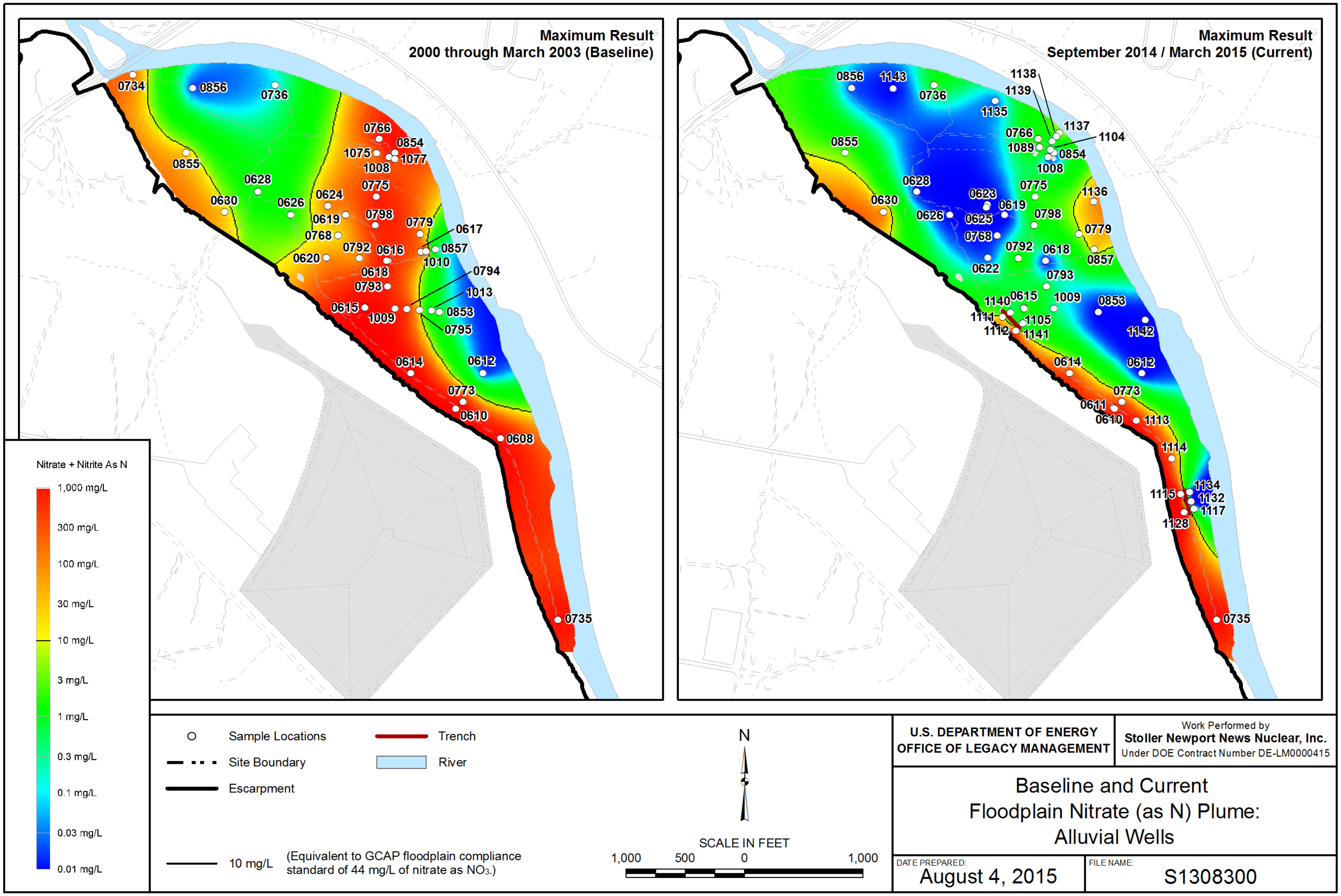

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Figure 4. Baseline (2000–2003) and September 2014 through March 2015 Floodplain Nitrate Plumes

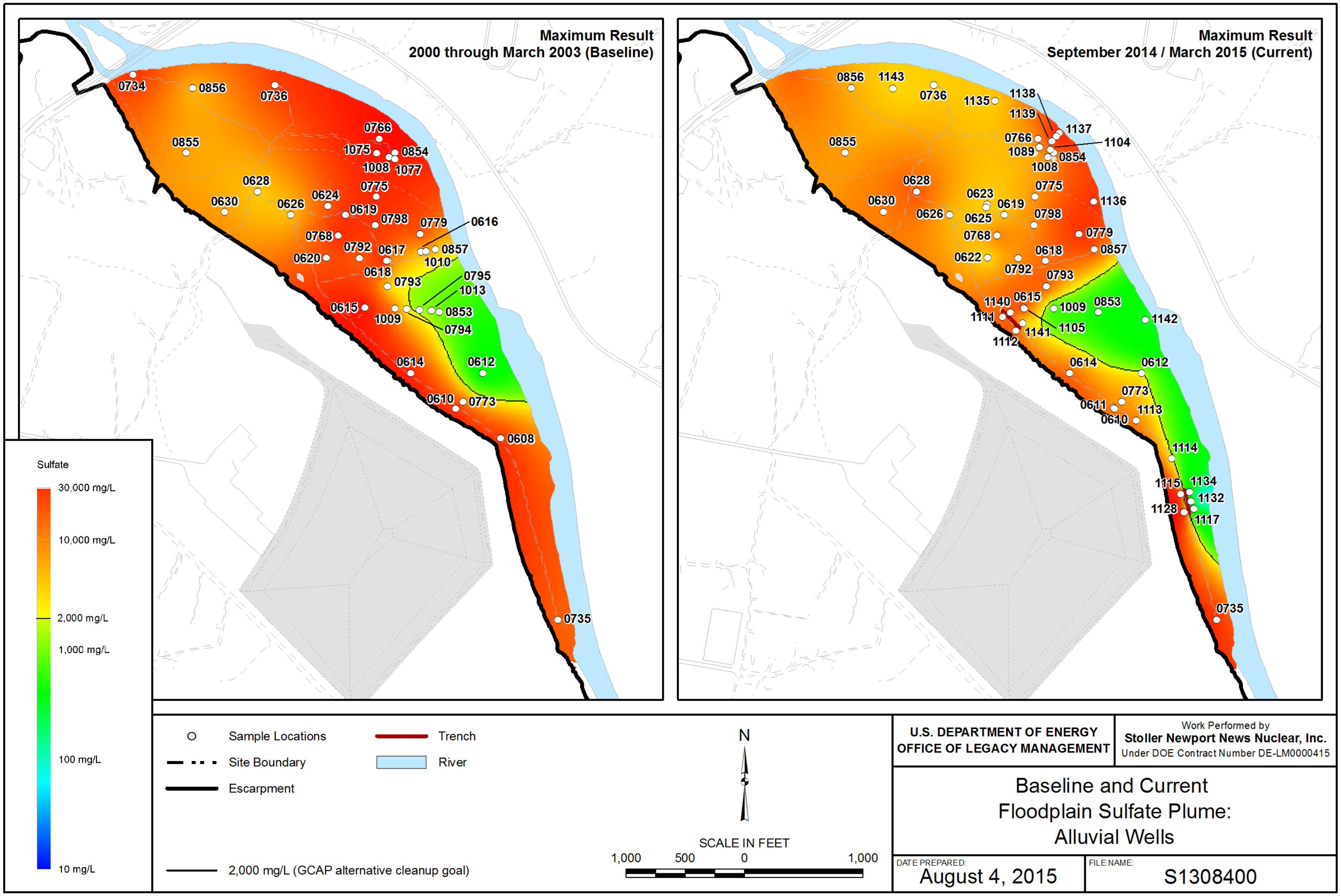

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Figure 5. Baseline (2000–2003) and September 2014 through March 2015 Floodplain Sulfate Plumes

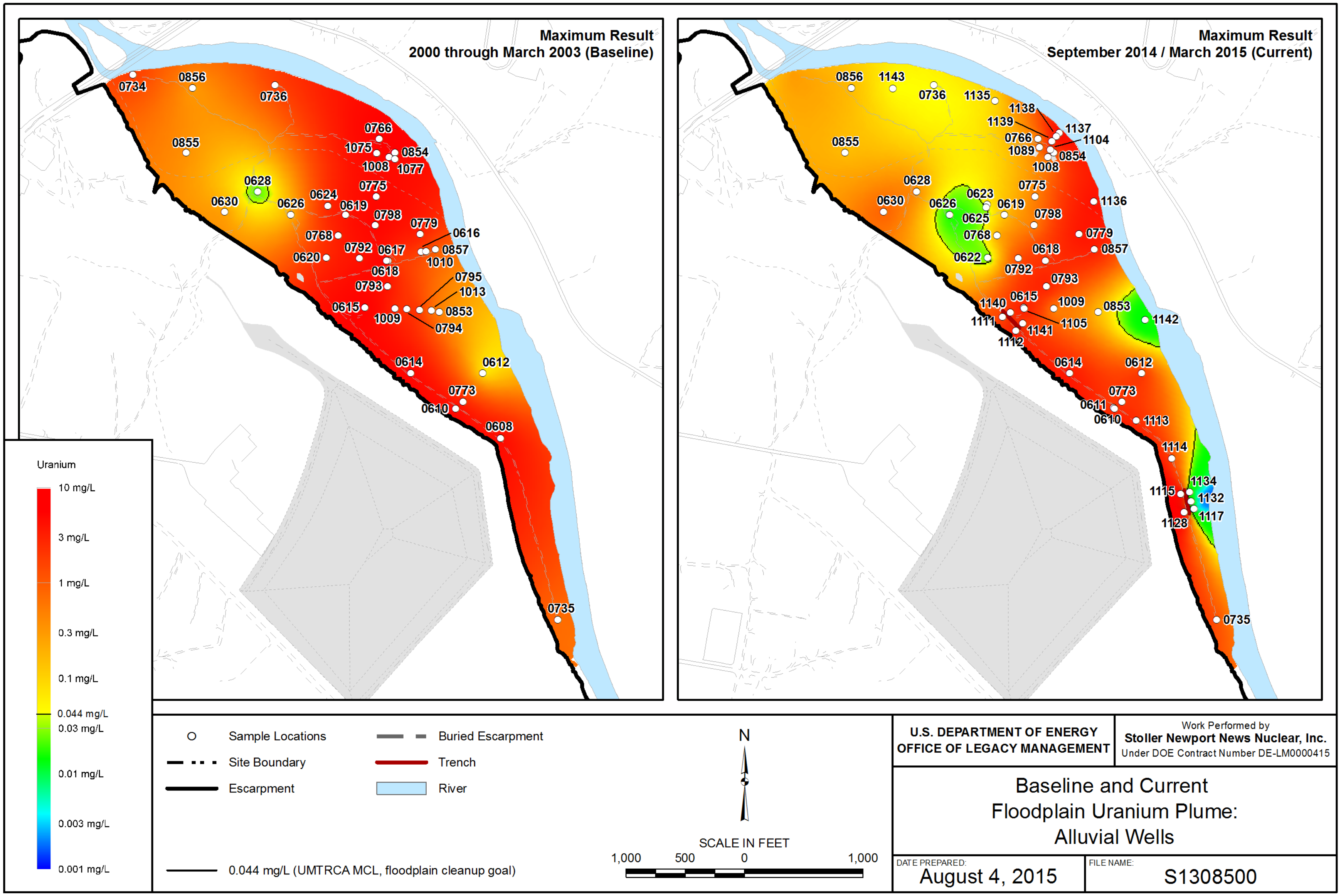

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Figure 6. Baseline (2000–2003) and September 2014 through March 2015 Floodplain Uranium Plumes

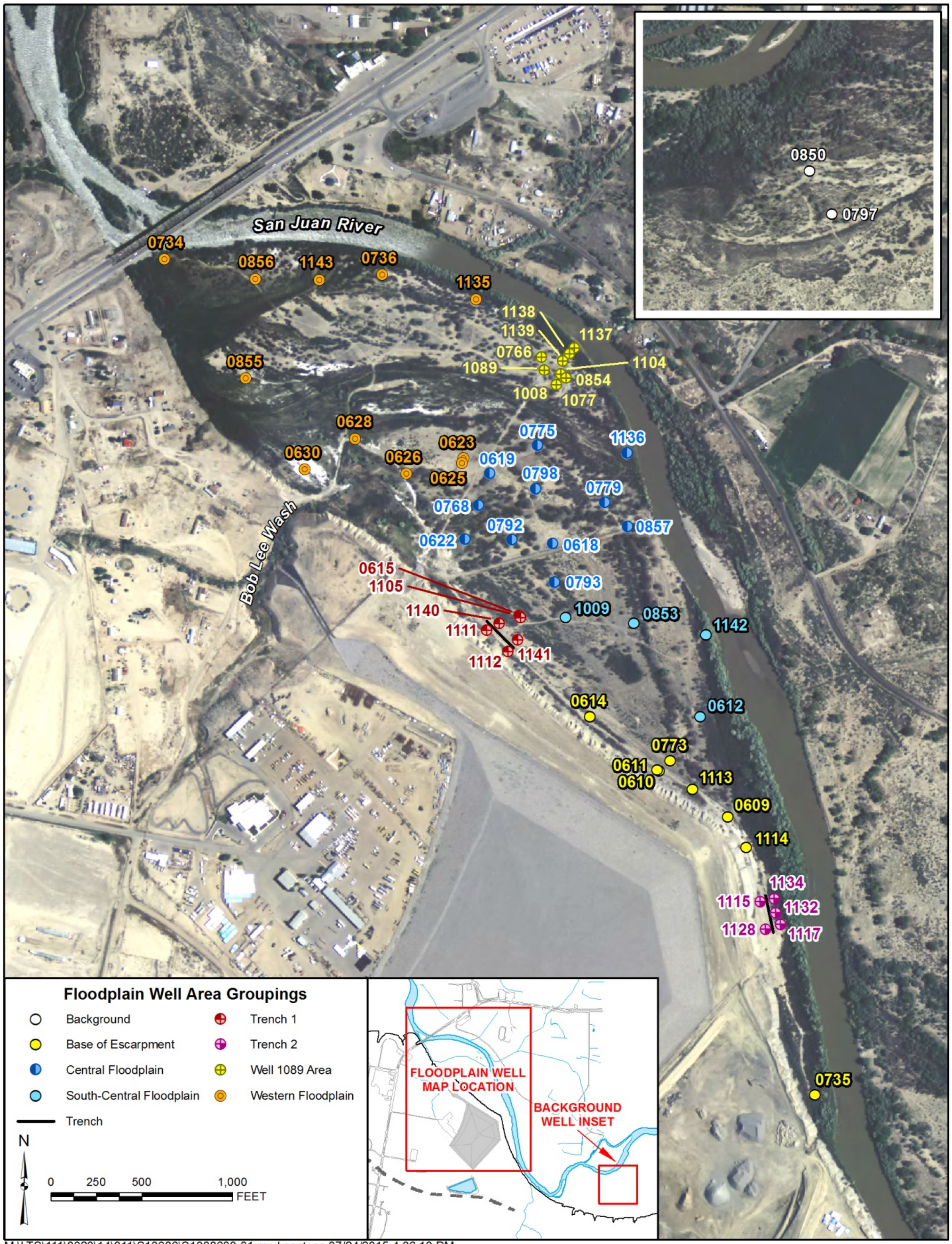

Figure 7. Shiprock Site Floodplain Area Well Groupings

3.2 San Juan River Monitoring

DOE regularly monitors eight San Juan River locations, including one upgradient background location. Between 2003 and March 2013, surface 0898 (farther upgradient) was the representative upgradient location. More recently, in 2014 and 2015, surface location 0967 (Figure 2) has been sampled instead because of difficulty in accessing location 0898. Location 0967 is now considered to be the representative upgradient San Juan River monitoring location.

Figure 8 plots concentrations of uranium (left *y*-axis) and nitrate (right *y*-axis) for location 0940 along with corresponding background (0898 or 0967) results. Sampling point 0940, located just north of pumping wells 1089 and 1104, was identified as a key river monitoring location in the GCAP because this area is where contaminant plumes in the alluvial aquifer likely discharge to the river (DOE 2002). Additionally, it is the only location where measured concentrations have exceeded background concentrations for a COC.

Background threshold values (BTVs) are benchmarks for comparing upgradient (background) concentrations to concentrations from other downgradient locations. The BTVs of 0.0075 and 0.82 mg/L for uranium and nitrate, respectively, were statistically derived based on historical results from background location 0898 (DOE 2015b). BTV values are calculated using EPA's ProUCL version 5.0 and are revised each time additional background results are received and validated. As shown in Figure 8, uranium and nitrate trends in 0940 river samples are generally correlated with each other and with trends at the upstream 0898 (or 0967) background location. Although BTVs for both nitrate and uranium were exceeded in October 2014 at location 0940, the BTVs were also exceeded at background/upgradient location 0967.

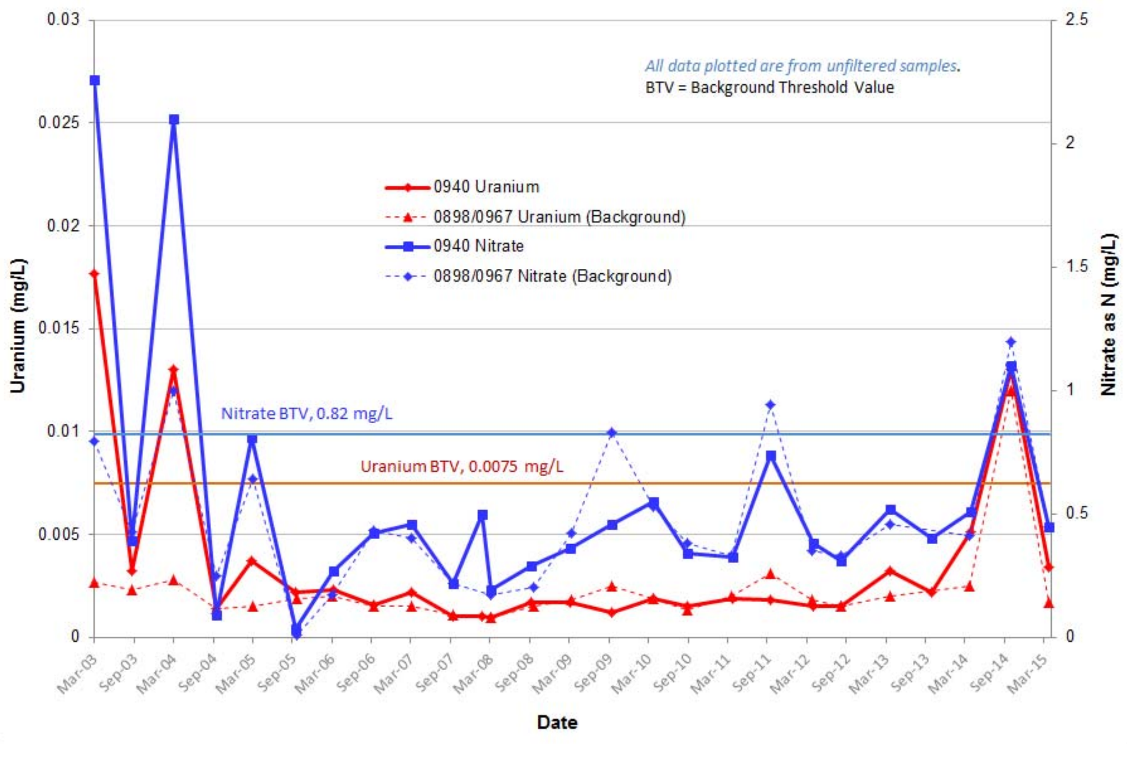

Figure 8. Uranium and Nitrate Concentrations in Samples from San Juan River Location 0940 and Background Locations

3.3 Terrace System Subsurface Conditions

The discussion of current subsurface conditions on the terrace is based on collection and analysis of groundwater level data through March 2015. Analyses of water level trends and drain flow rates associated with the terrace are discussed below. Results are compared to baseline conditions established in the Baseline Performance Report (DOE 2003) to evaluate the effectiveness of the terrace treatment system.

Currently, there are no concentration-driven performance standards for the terrace system because the compliance strategy is active remediation to eliminate exposure pathways at escarpment seeps and at Bob Lee and Many Devils Washes. As a best management practice, however, contaminant concentrations are measured at each extraction well, drain, and seep.

3.3.1 Terrace Groundwater Level Trends

Approximately 1.6 million gallons of groundwater was pumped from the nine terrace extraction wells between April 2014 and March 2015. As of April 1, 2015, the cumulative volume of water removed from the terrace (excluding Bob Lee and Many Devils washes) is approximately 18 million gallons (Table 3). Groundwater level data from the terrace collected during the March 2015 sampling event were compared to corresponding groundwater elevation data for the baseline period (most recent from 2000 to March 2003). Figure 9 shows a qualitative map view of some of the changes in groundwater elevations during this period for both alluvial and Mancos wells. Of the 32 water level measurements taken in September/October 2014 or March 2015 at terrace wells screened in alluvium, the majority showed declines relative to the baseline period of March 2003. Declines ranged from 0.02 ft to maximum decreases of more than 9 ft in west terrace wells 0836 and 0837. The average decrease in terrace alluvial wells was about 2 ft.

Three alluvial west terrace wells (1060, 1120, and 1122) were dry at the time of the March 2015 sampling event. Southwest terrace well 1060 has been dry for 6 to 7 years (see Appendix B hydrographs), while northwest terrace wells 1120 and 1122 have been dry since September 2009. Also, many seeps on the west terrace have been dry since 2008 (Figure 10).

To support the presentation in Figure 9, Figure 11 depicts groundwater saturated thickness in terrace alluvium, using (automated) contours for both (February 2000 and current March 2015) periods. Table 5 includes an estimate of liquid volume for both dates based on these depictions and a volumetric reduction of about 59 percent in the south terrace vicinity with active remediation. Volumetric reduction approximated with this method (approximately 16 million gallons) was relatively close to the 18 million gallons (cumulative) measured entering the evaporation pond from terrace alluvium pumping. These findings demonstrate that groundwater elevations have declined across much of the terrace groundwater system.

Table 5. Estimated Liquid Volume Present and Removed in the Terrace Alluvium Active Remediation Vicinity

	Volume of Solid (ft^3)	Porosity (assumed)	Volume of Liquid (ft^3)	Volume of Liquid (gallons)	Percent Reduction
February 2000 Depiction	11,975,132	30%	3,592,540	26,874,061	
March 2015 Depiction	4,855,371	30%	1,456,611	10,896,209	59%

Notes: Only south terrace shaded areas from Figure 11 used in calculations. ft^3 = cubic feet

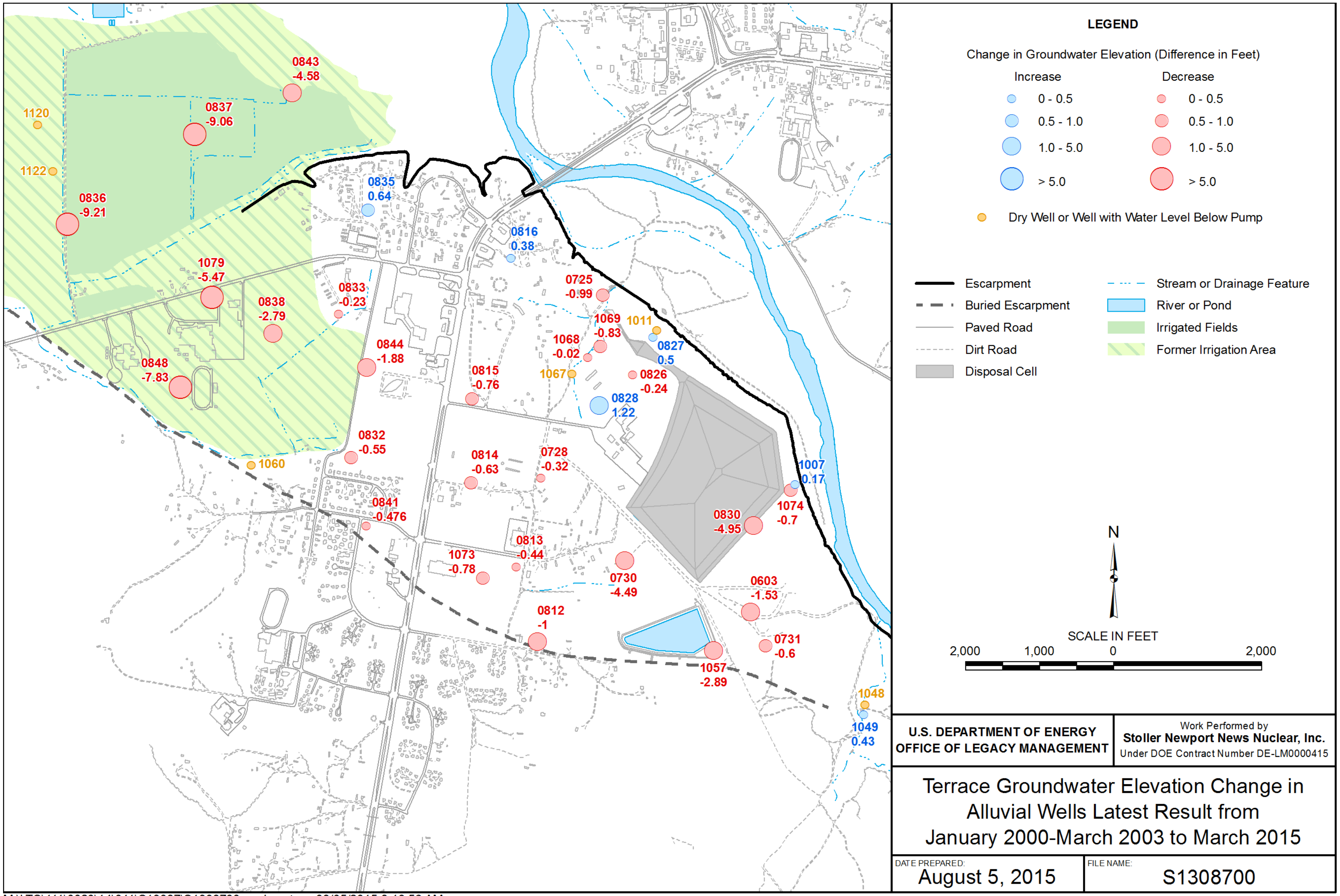

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Figure 9. Terrace Groundwater Elevation Changes from Baseline (2000–2003) to Current (March 2015) Conditions

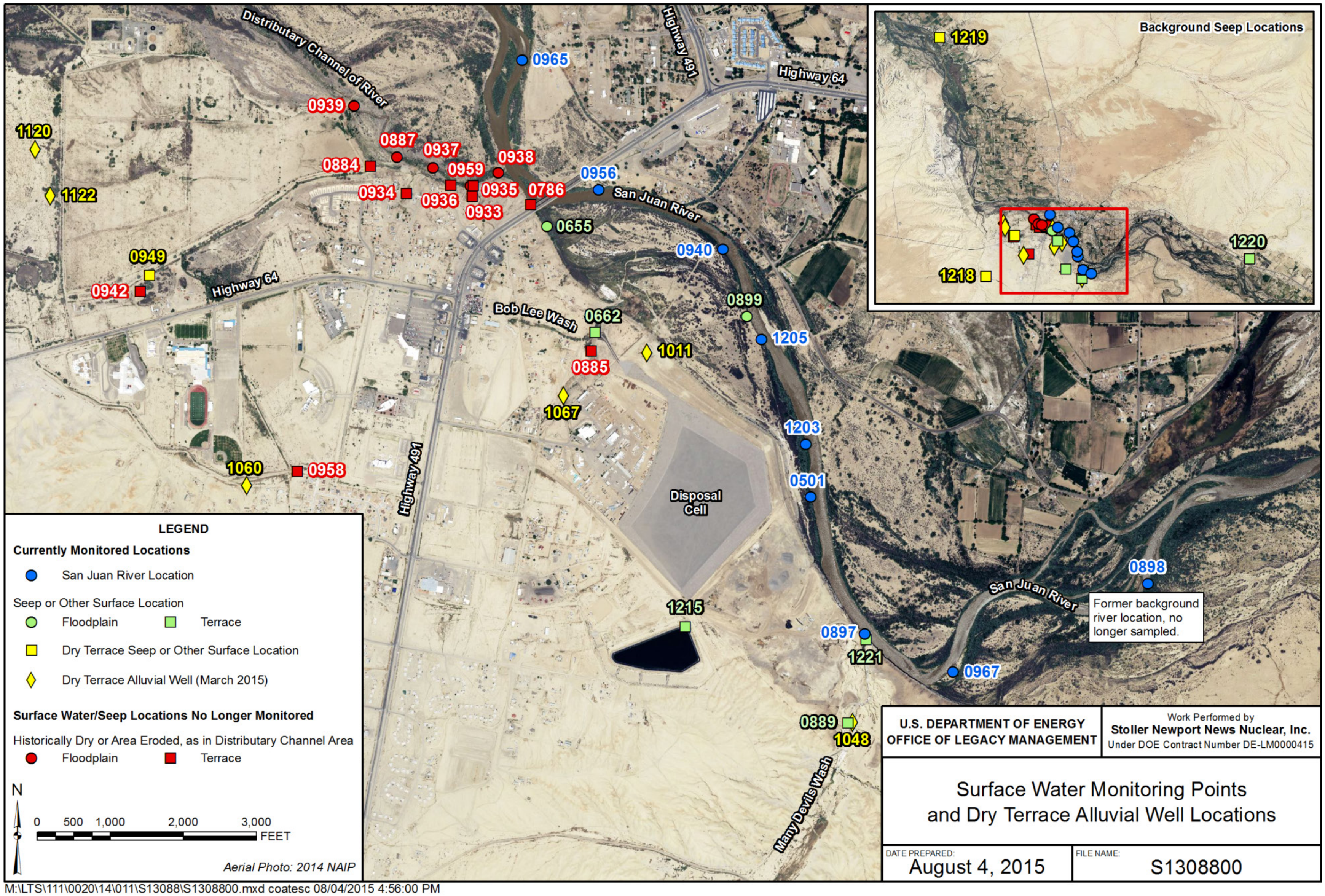

Figure 10. Current and Previous (2003–2013) Surface Water Monitoring Locations at the Shiprock Site
Locations of Current Dry Wells Also Shown to Allow Comparison with Dry Seep Locations

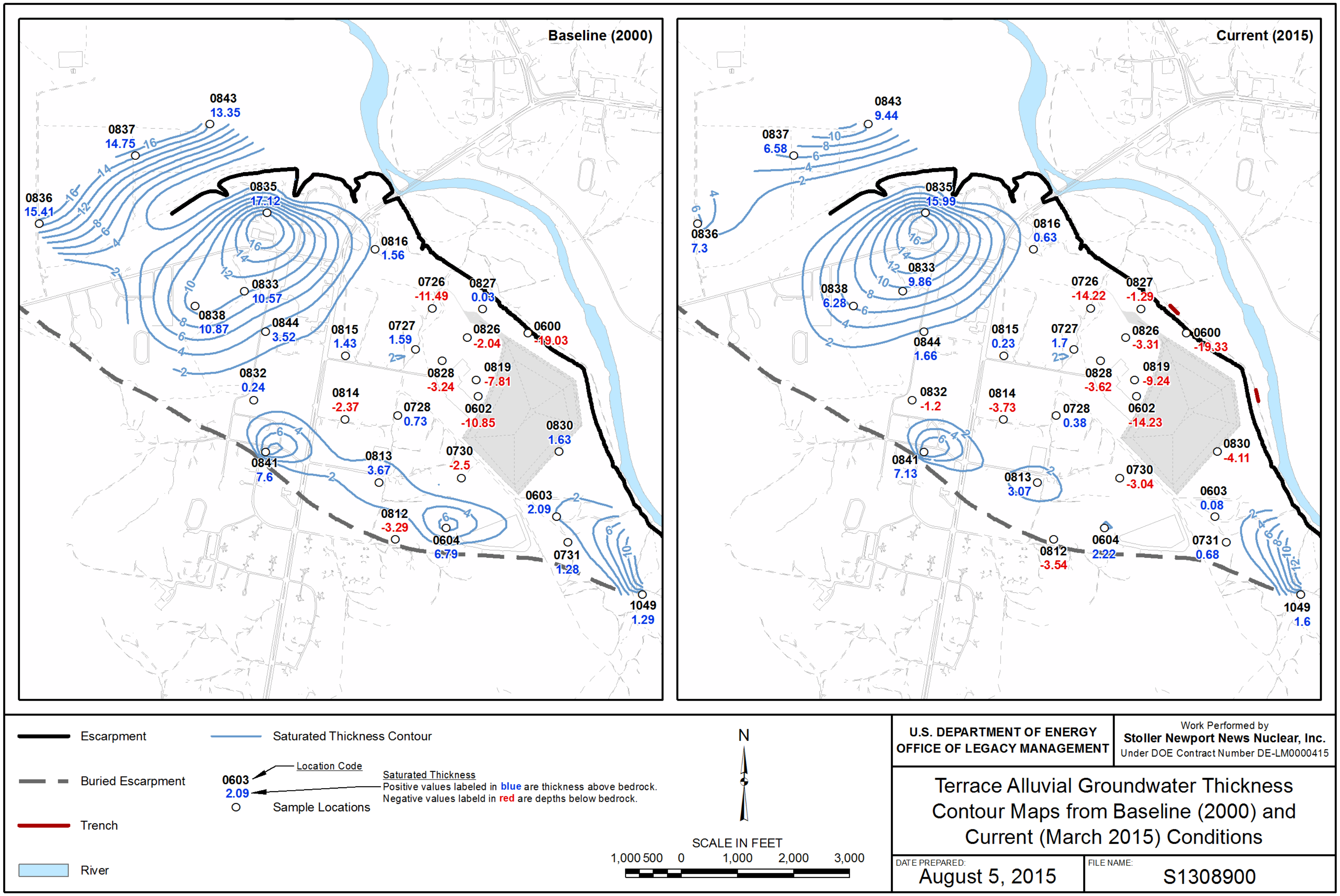

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Figure 11. Terrace Alluvial Groundwater Thickness Contour Maps from Baseline (2000) and Current (March 2015) Conditions

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4.0 Performance Summary

This section summarizes the findings of the most recent (April 2014 through March 2015) assessment of the floodplain and terrace groundwater remediation systems at the Shiprock site, marking the end of the 12th year of active groundwater remediation.

- Groundwater in the floodplain system is currently being extracted from two wells (wells 1089 and 1104) adjacent to the San Juan River north of the disposal cell, two collection trenches (Trench 1 and Trench 2), and a seep collection sump. Approximately 10.2 million gallons of groundwater were extracted from the floodplain aquifer system during this performance period, yielding a cumulative total of about 119.5 million gallons extracted from the floodplain since March 2003.
- Groundwater in the terrace system is currently being extracted from two drainage trenches (in Bob Lee and Many Devils Washes) and nine extraction wells. From April 2014 through March 2015, approximately 2.7 million gallons of groundwater were extracted from the terrace system, yielding a total cumulative volume (extracted since March 2003) of about 39.6 million gallons. The cumulative volume removed from both terrace and floodplain combined (as of April 1, 2015) is just over 159 million gallons.
- During this reporting period, no groundwater was pumped from Many Devil Wash, given the need for extensive repairs of the interceptor drain.
- Terrace-wide, groundwater levels in the majority of alluvial wells sampled during this performance period declined relative to the baseline period (2000–2003) (Figure 9 and Figure 11); average and maximum decreases were 2.0 ft and 9.2 ft, respectively. Relative to baseline conditions, decreases in the eastern portion of the terrace are negligible. Four alluvial west terrace wells were dry during the March 2015 sampling, and several seeps on the west terrace have been dry since 2008.
- The remediation system is effectively removing contaminant mass from the floodplain alluvial aquifer and accelerating the natural flushing process. This contaminated groundwater is pumped to the evaporation pond on the terrace just south of the disposal cell. The estimated masses of sulfate, nitrate, and uranium removed from the floodplain and terrace well fields during this performance period were 472,190 pounds, 20,000 pounds, and 27.7 pounds, respectively.

As observed for the last several years, decreases in contaminant concentrations are evident in selected floodplain wells—most notably in the Trench 1 area. Since Trench 1 was installed in 2006, reductions in concentrations of the primary COCs (nitrate, sulfate, and uranium) are apparent in surrounding wells, especially those on the river side of the trench. Trench 2, when pumped, appears to be lowering the concentration of COCs near the base of the escarpment. Decreases in COC concentrations in the well 1089 area since remediation pumping began in 2003 are also evident. However, COC concentrations (primarily uranium and sulfate) have been variably increasing in a number of central floodplain near-river wells (0857, 1136–1139), southernmost well 0735, and wells 0628 and 0630 near the base of Bob Lee Wash. No measurable impacts to the San Juan River have resulted from these increases. In general, COC concentrations in samples collected from the San Juan River have been below established benchmarks. Exceedances of threshold values for nitrate and uranium in October 2014 are considered unrelated to historical milling activities, as comparable exceedances also occurred during that time at the upstream (background) location.

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5.0 References

ATSDR (Agency for Toxic Substances and Disease Registry), 2004. *Toxicological Profile for Strontium*, U.S. Department of Health and Human Services, Public Health Service, April.

DOE (U.S. Department of Energy), 1994. *Baseline Risk Assessment of Ground Water Contamination at the Uranium Mill Tailings Site at Shiprock, New Mexico*, DOE/AL/62350-48F, Rev. 1, Albuquerque Operations Office, Albuquerque, New Mexico, April.

DOE (U.S. Department of Energy), 2000. *Final Site Observational Work Plan for the Shiprock, New Mexico, UMTRA Project Site*, GJO-2000-169-TAR, Rev. 2, Grand Junction, Colorado, November.

DOE (U.S. Department of Energy), 2002. *Final Groundwater Compliance Action Plan for Remediation at the Shiprock, New Mexico, UMTRA Project Site*, GJO-2001-297-TAR, Grand Junction, Colorado, July.

DOE (U.S. Department of Energy), 2003. *Baseline Performance Report for the Shiprock, New Mexico, UMTRA Project Site*, GJO-2003-431-TAC, Grand Junction, Colorado, September.

DOE (U.S. Department of Energy), 2005. *Refinement of Conceptual Model and Recommendations for improving Remediation Efficiency at the Shiprock, New Mexico, Site*, GJO-2004-579-TAC, Office of Legacy Management, Grand Junction, Colorado, July.

DOE (U.S. Department of Energy), 2009. *Evaluation of the Trench 2 Groundwater Remediation System at the Shiprock, New Mexico, Legacy Management Site*, LMS/SHP/S05037, Office of Legacy Management, Grand Junction, Colorado, March.

DOE (U.S. Department of Energy), 2011a. *2010 Review and Evaluation of the Shiprock Remediation Strategy,* LMS/SHP/S05030, Office of Legacy Management, Grand Junction, Colorado, January.

DOE (U.S. Department of Energy), 2011b. *Geology and Groundwater Investigation, Many Devils Wash, Shiprock Site, New Mexico*, LMS/SHP/S06662, ESL-RPT-2011-02, Office of Legacy Management, Grand Junction, Colorado, April.

DOE (U.S. Department of Energy), 2011c. *Natural Contamination from the Mancos Shale*, LMS/S07480, ESL-RPT-2011-01, Office of Legacy Management, Grand Junction, Colorado, April.

DOE (U.S. Department of Energy), 2011d. *Preliminary Evaluation of the Trench 1 Collection Drain Floodplain Area of the Shiprock, New Mexico, Site*, LMS/SHP/S07374, ESL-RPT-2011-03, Office of Legacy Management, Grand Junction, Colorado, June.

DOE (U.S. Department of Energy), 2013a. *Annual Performance Report, April 2012 through March 2013 for the Shiprock, New Mexico, Site*, LMS/SHP/S10301, Office of Legacy Management, Grand Junction, Colorado, November.

DOE (U.S. Department of Energy), 2013b. *Optimization of Sampling at the Shiprock, New Mexico, Site*, LMS/SHP/S08223, Office of Legacy Management, Grand Junction, Colorado, March.

DOE (U.S. Department of Energy), 2015a. *September and October 2014 Groundwater and Surface Water Sampling at the Shiprock, New Mexico, Disposal Site*, LMS/SHP/S00914, Office of Legacy Management, Grand Junction, Colorado, January.

DOE (U.S. Department of Energy), 2015b. *March 2015 Groundwater and Surface Water Sampling at the Shiprock, New Mexico, Disposal Site*, LMS/SHP/S00315, Office of Legacy Management, Grand Junction, Colorado, June.

EPA (U.S. Environmental Protection Agency), 2012. *2012 Edition of the Drinking Water Standards and Health Advisories*, EPA 822-S-12-001, Office of Water, April.

Appendix A

Time-Concentration Graphs for Nitrate, Sulfate, and Uranium in Floodplain Monitoring Wells

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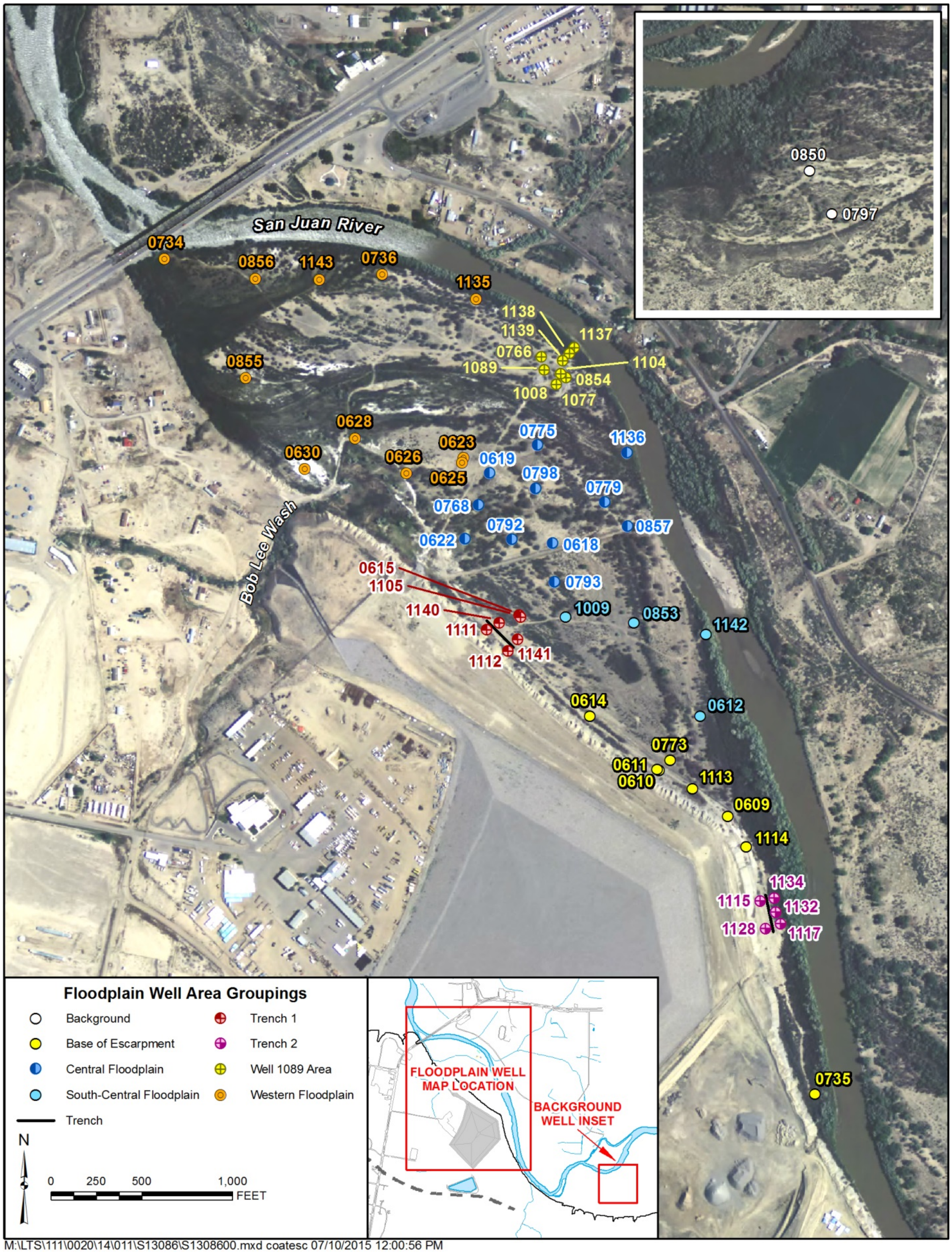

Figure A-1. Shiprock Site Floodplain Well Groupings

Figure repeated from Figure 7 of main report. The groups shown here are used as the basis for subsequent time-concentration plots.

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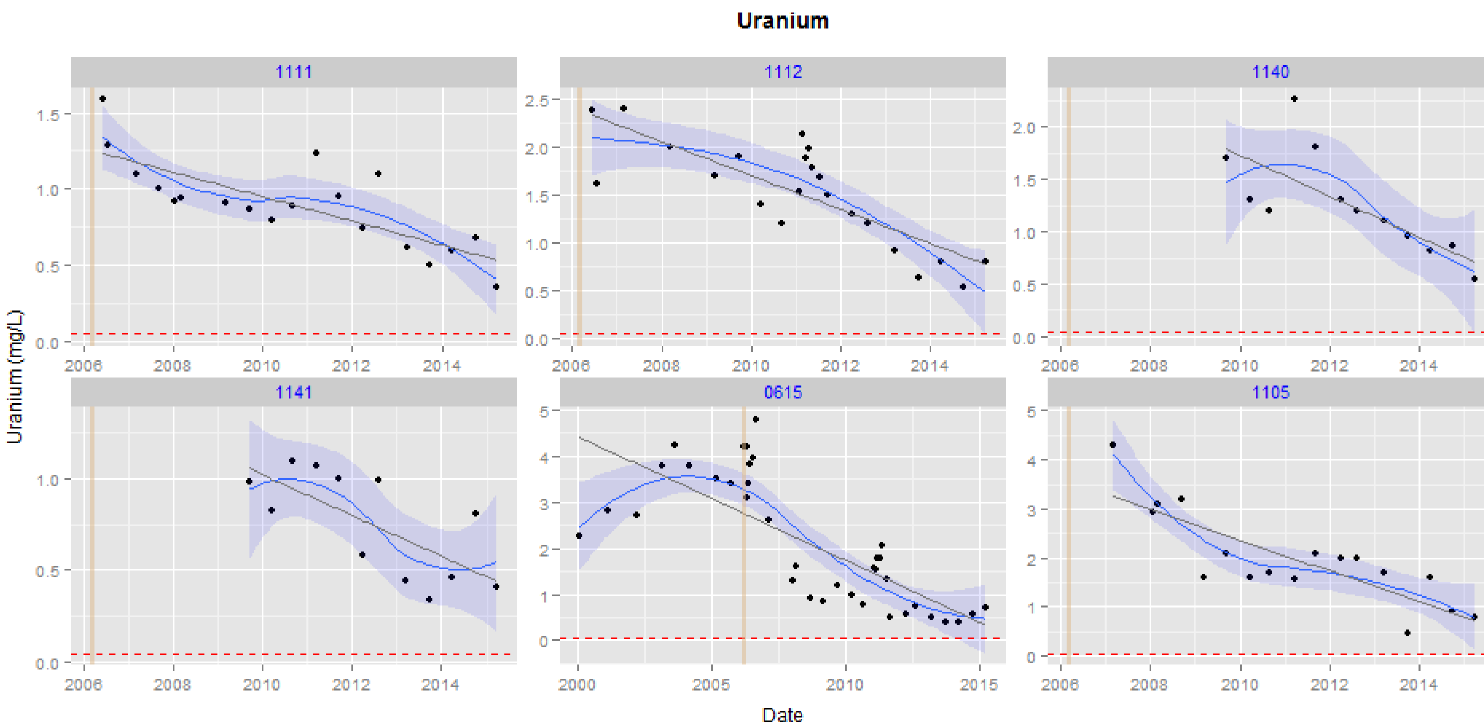
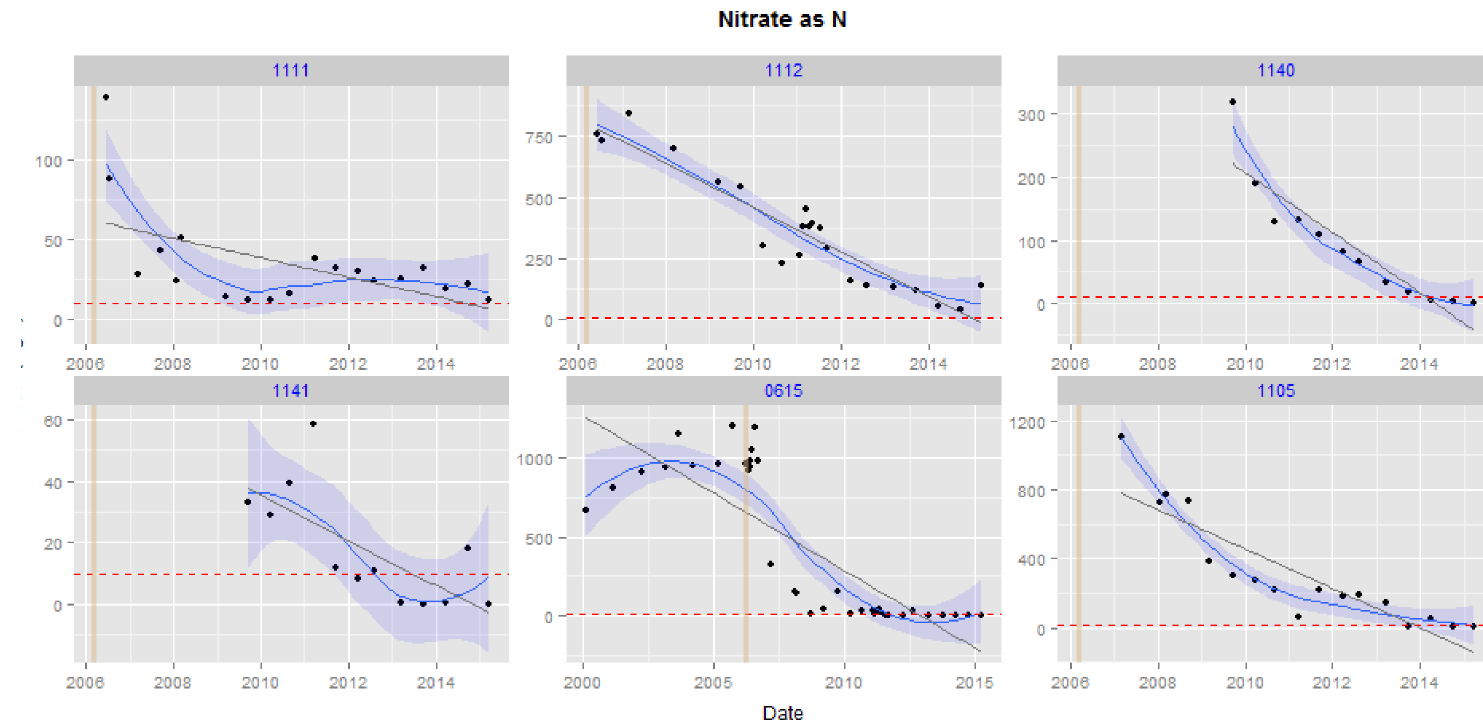
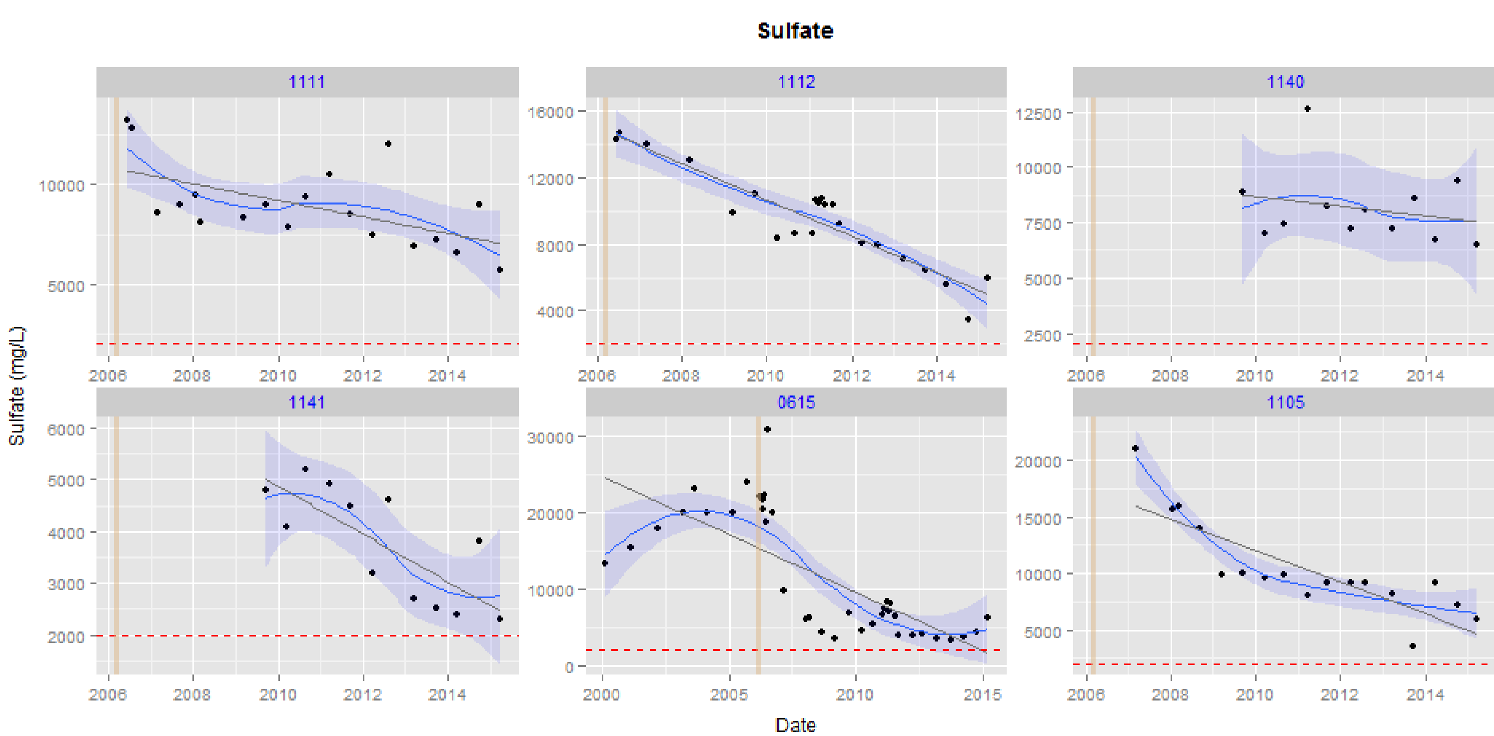






Time-Trend Plot Explanation. In contrast to traditional grouped line plots provided in previous annual reports, data for each well are plotted separately to facilitate understanding of well-specific trends. In this and subsequent figures, a non-parametric smoothing method or locally weighted regression—"loess" (not to be confused with the geologic term)—is used.† With this approach, overall trends in the data are more apparent and not obscured by "noise." For reference, trend lines based on a standard linear model are also shown. In each plot, wells are listed in order of increasing distance from the disposal cell, shown in the inset below.

- blue line is loess locally weighted regression line; shaded area is the 95% confidence interval about that line
- standard linear regression trendline
- denotes the 40 CFR 192 MCL or cleanup goal: 0.044 mg/L uranium; 10 mg/L nitrate as N; 2000 mg/L sulfate

Vertical line denotes time when Trench 1 was installed, in spring 2006.

† See http://www.inside-r.org/r-doc/stats/loess, http://docs.ggplot2.org/0.9.3.1/stat_smooth.html and W.S., E. Grosse and W. M. Shyu. 1992. Local regression models. Chapter 8 of *Statistical Models in S*, eds. J.M. Chambers and T.J. Hastie, Wadsworth & Brooks/Cole.

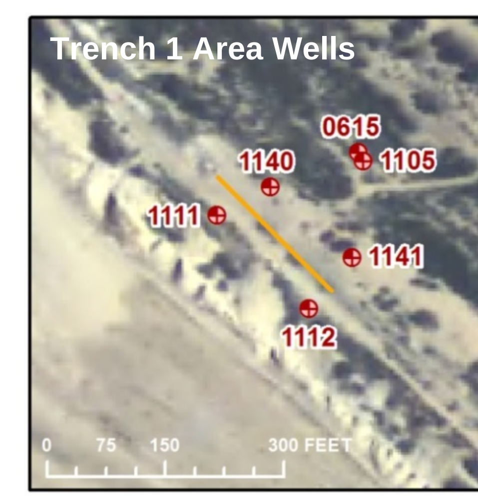
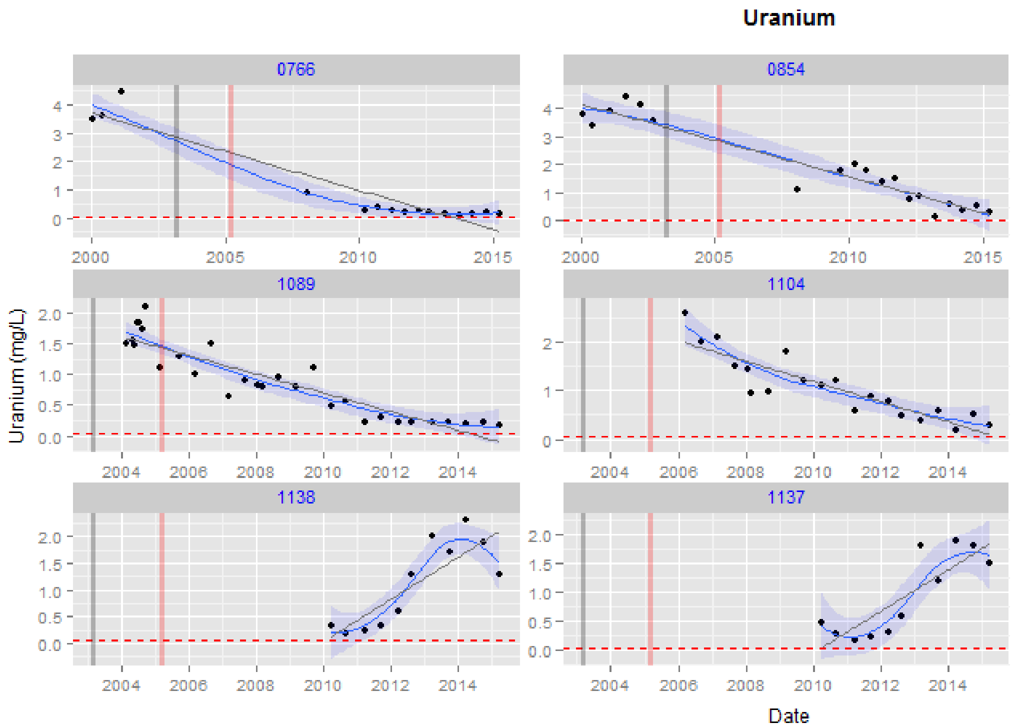
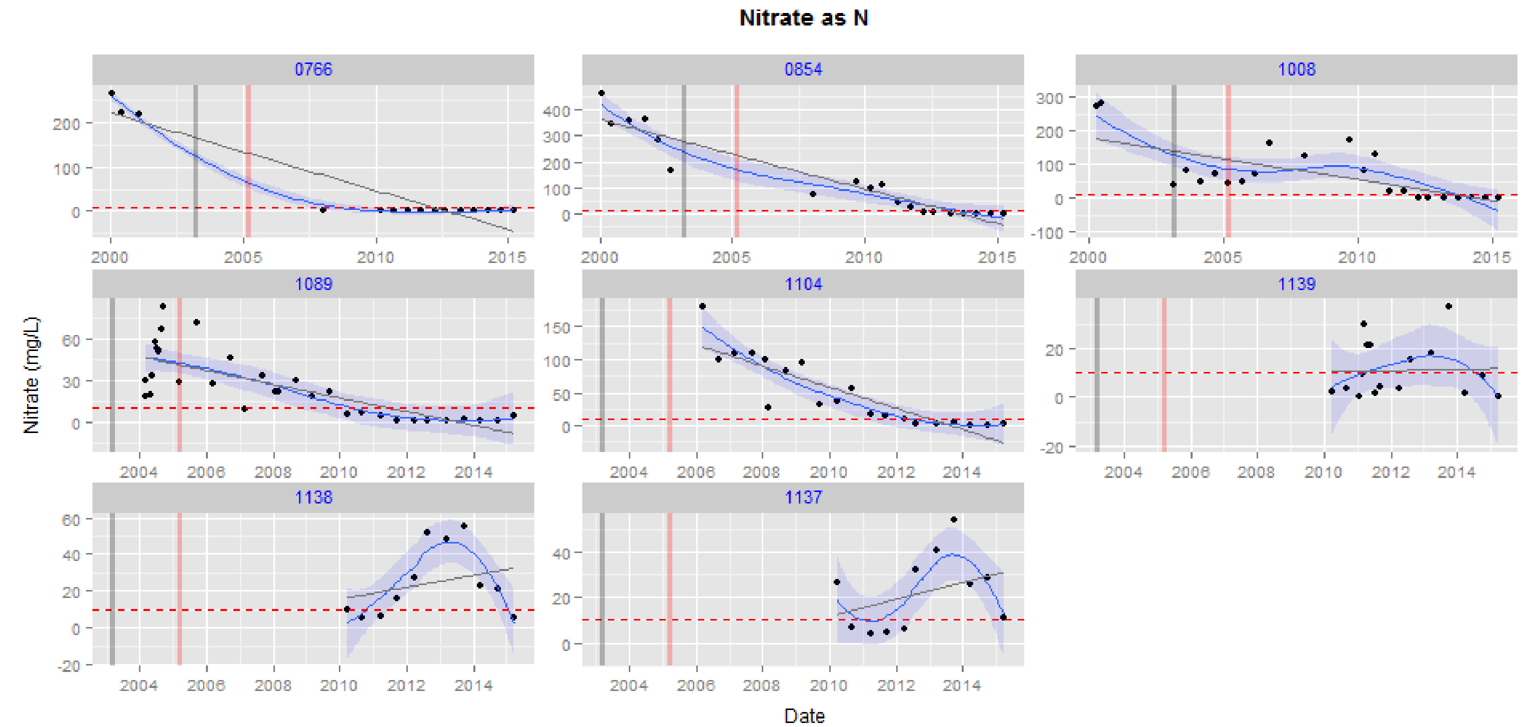
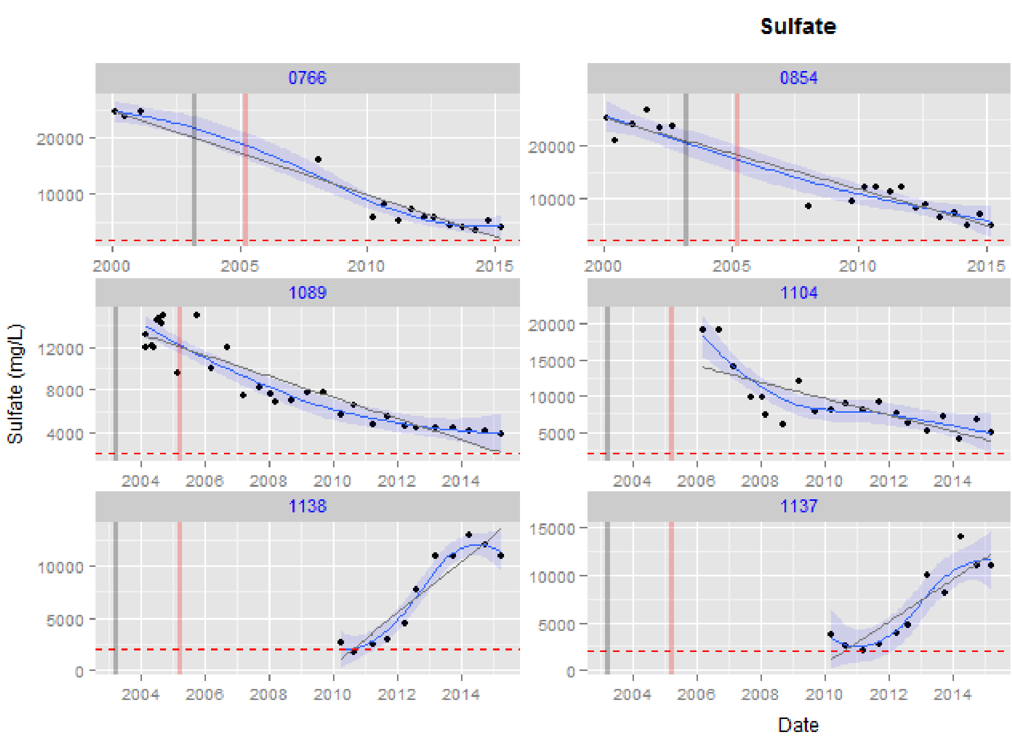


Figure A-2. Uranium, Nitrate, and Sulfate Concentration Trends in Trench 1 Area Wells: 2000–March 2015







Time-Trend Plot Explanation. In contrast to traditional group line plots (provided in previous annual reports), data for each well are plotted separately to facilitate understanding of well-specific trends. In each plot, near-river wells 1137, 1138, and 1139 are listed in order of increasing distance from the remediation area (see inset below).

blue line is loess local regression line; shaded area is the 95% confidence interval about that line

standard linear regression trendline

denotes the 40 CFR 192 MCL or cleanup goal: 0.044 mg/L uranium; 10 mg/L nitrate as N; 2000 mg/L sulfate

Vertical lines | | denote periods corresponding to installation of well 1089 (spring 2003) and well 1104 (spring 2005).

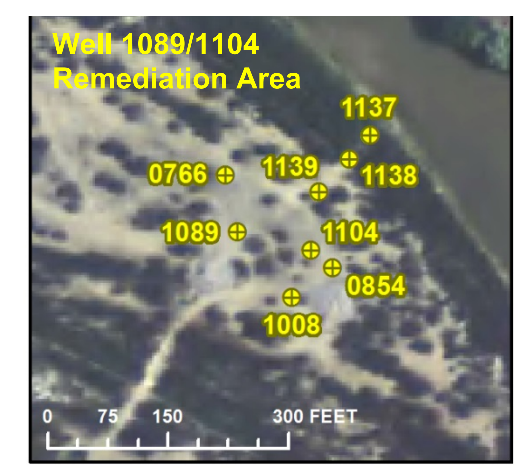
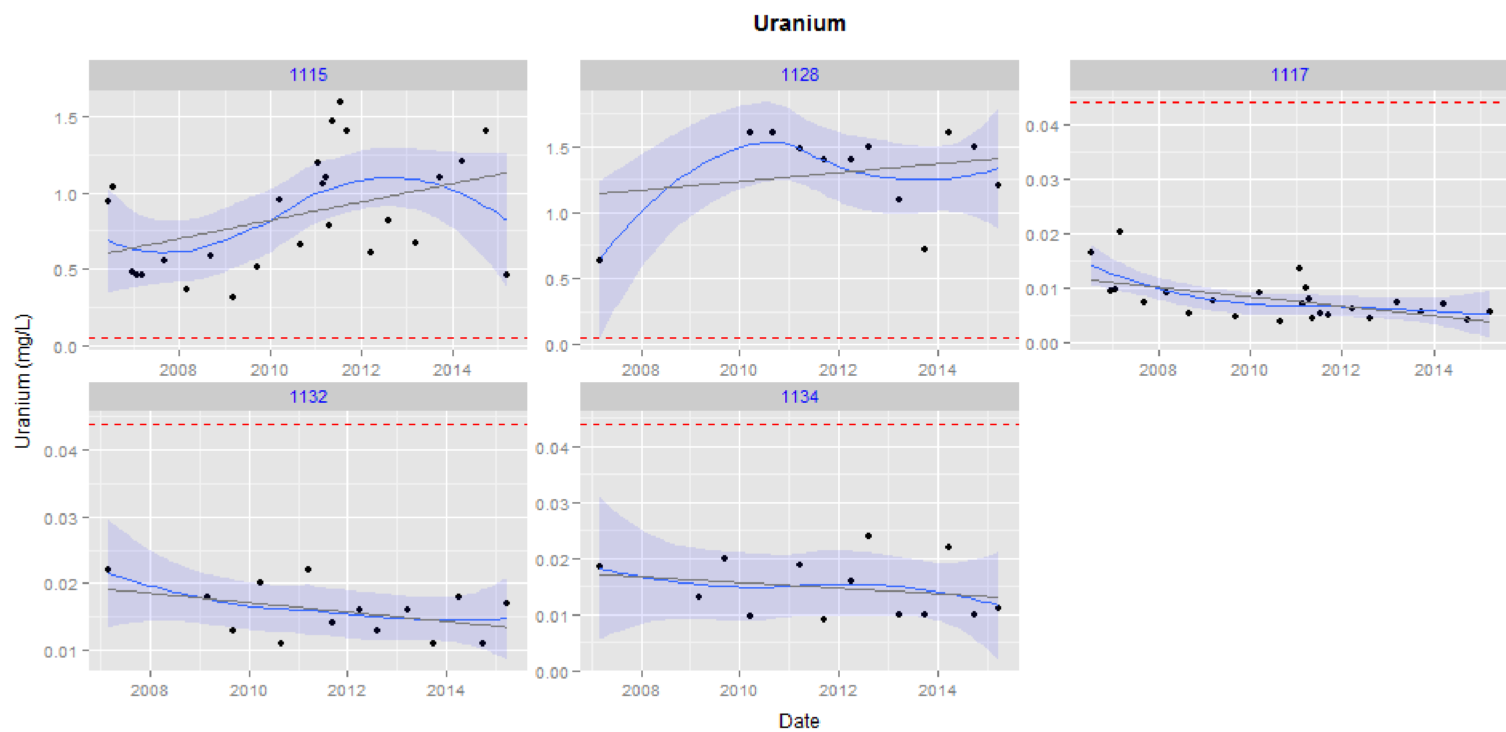
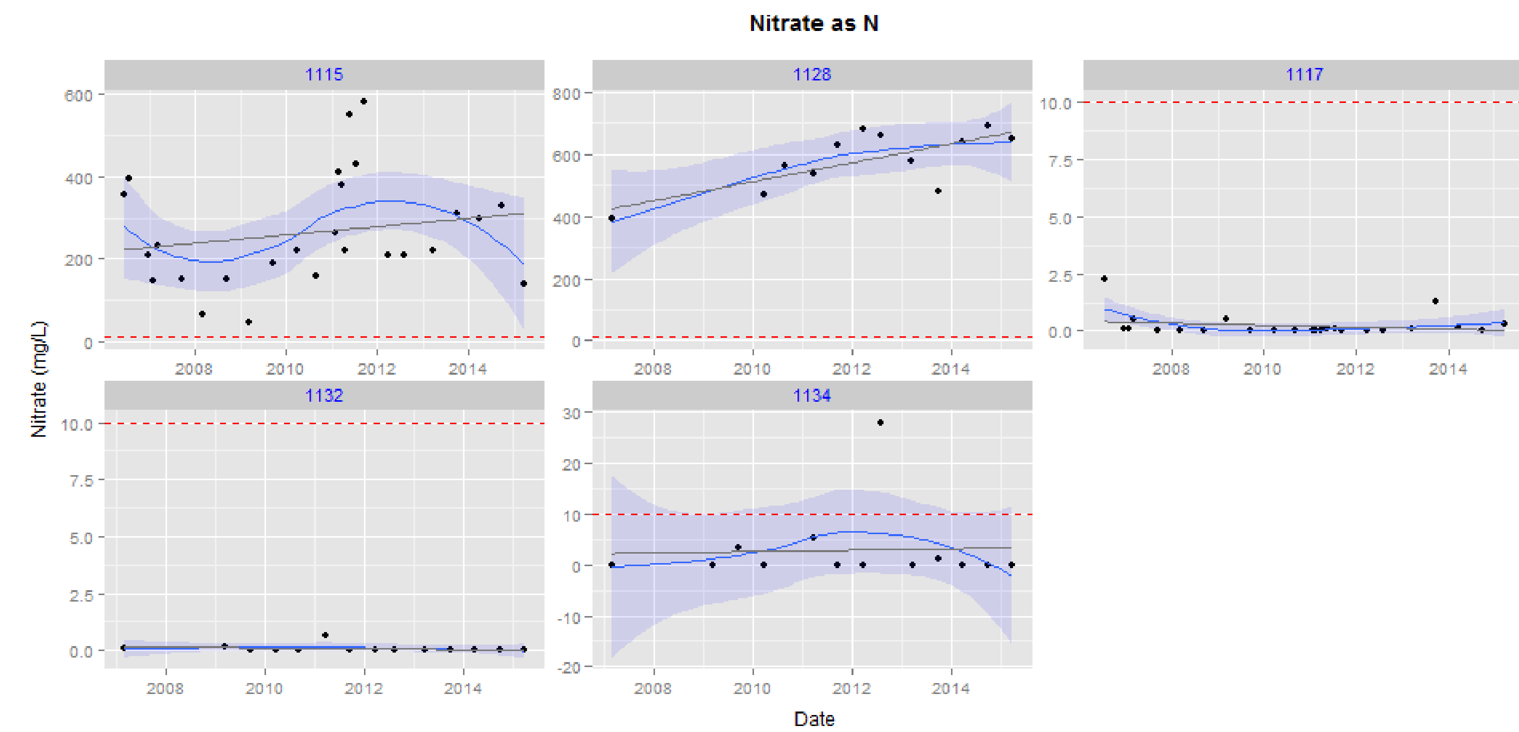
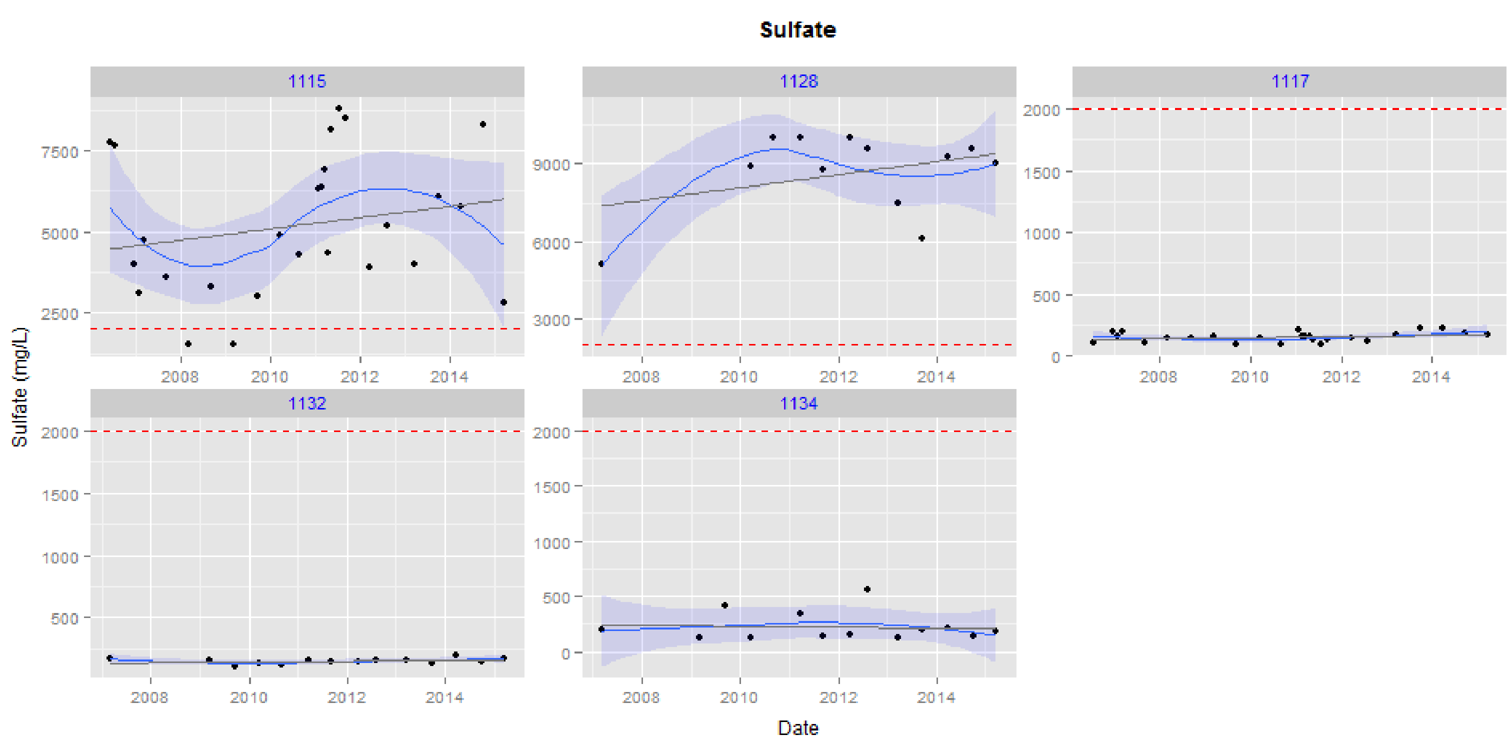


Figure A-3. Uranium, Nitrate, and Sulfate Concentration Trends in the Well 1089/1104 Remediation Area: 2000–March 2015







Time-Trend Plot Explanation. In contrast to traditional group line plots (provided in previous annual reports), data for each well are plotted separately to facilitate understanding of well-specific trends. In each plot, wells with the highest contaminant concentrations, on the escarpment side of Trench 2, are listed first (see inset below).

- blue line is loess local regression line; shaded area is the 95% confidence interval about that line
- standard linear regression trendline
- denotes the 40 CFR 192 MCL or cleanup goal: 0.044 mg/L uranium; 10 mg/L nitrate as N; 2000 mg/L sulfate

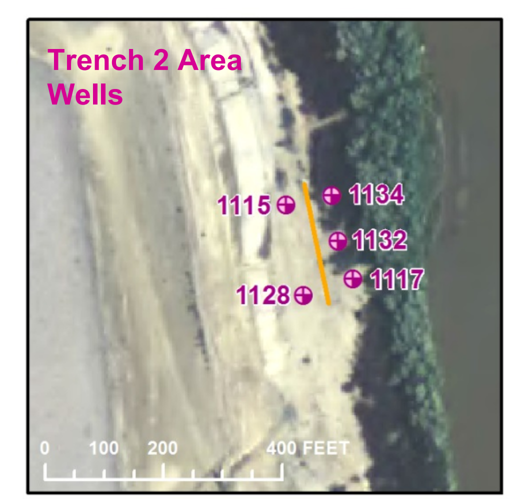
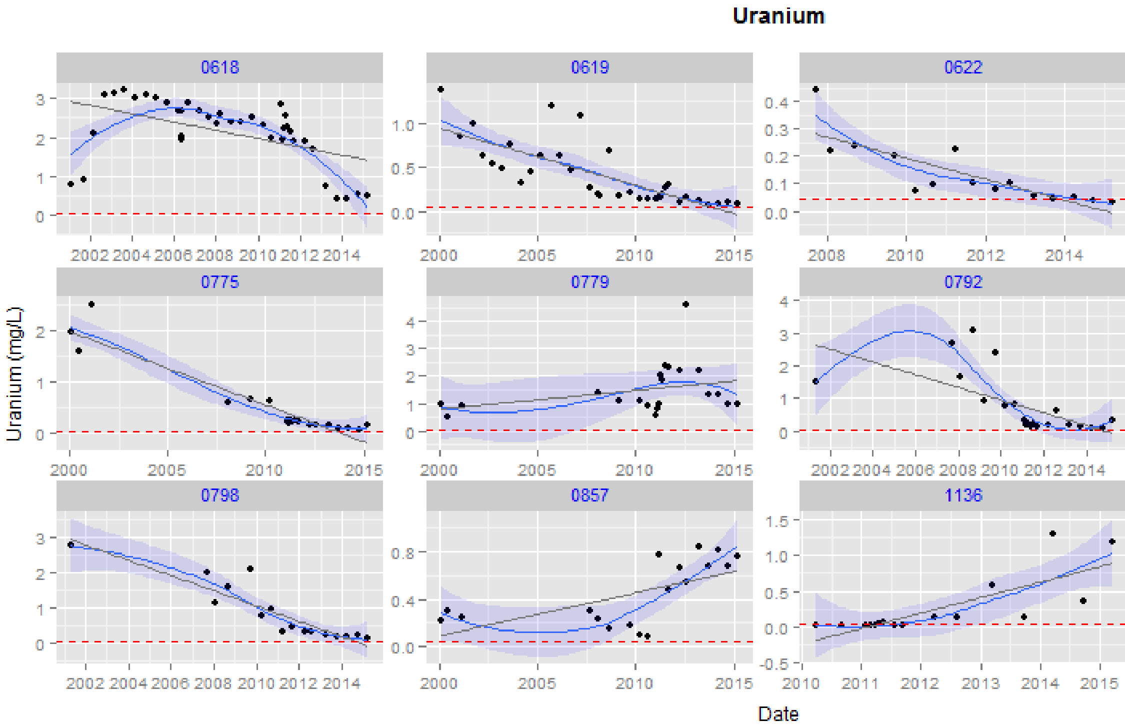
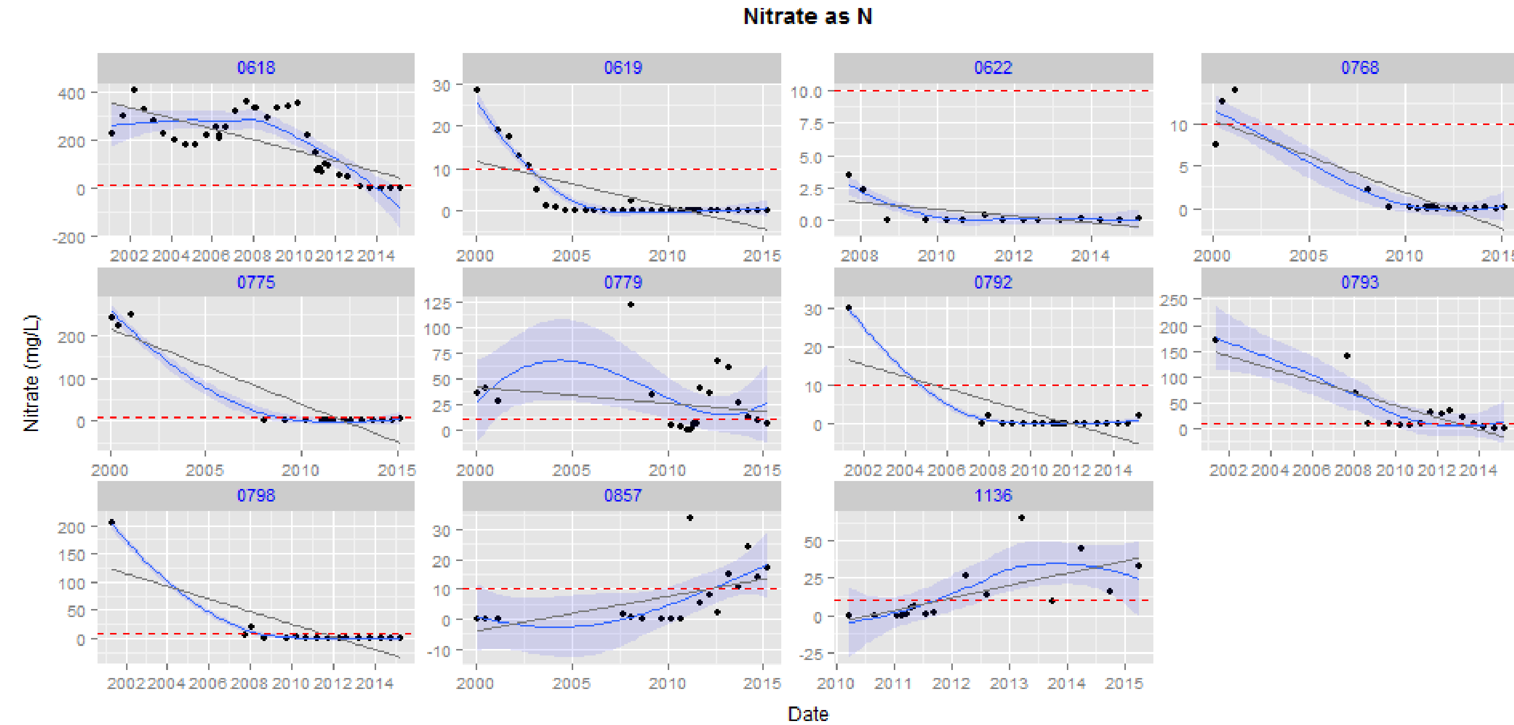
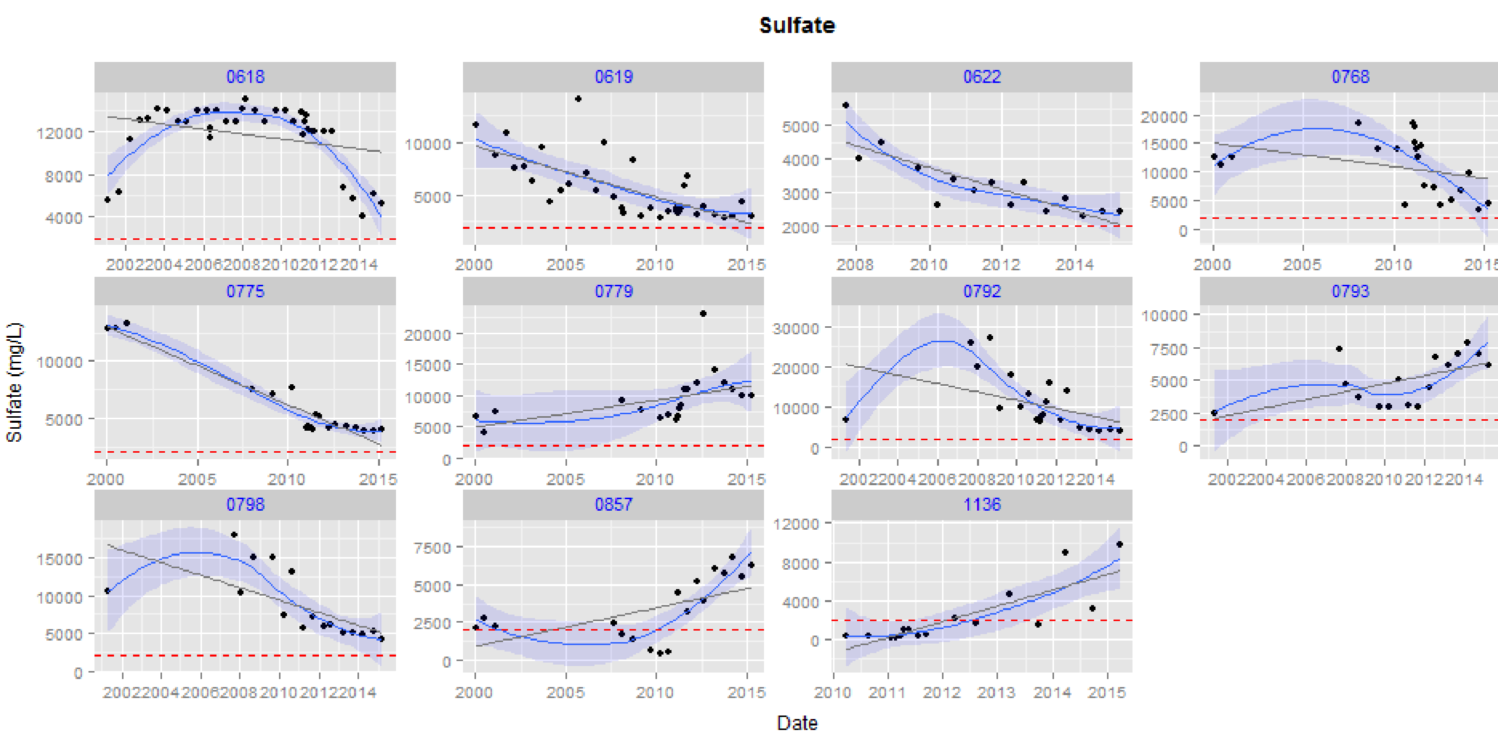


Figure A-4. Uranium, Nitrate, and Sulfate Concentration Trends in Trench 2 Area Wells: 2000–March 2015







Time-Trend Plot Explanation. In contrast to traditional group line plots (provided in previous annual reports), data for each well are plotted separately to facilitate understanding of well-specific trends.

- blue line is loess local regression line; shaded area is the 95% confidence interval about that line
- standard linear regression trendline
- denotes the 40 CFR 192 MCL or cleanup goal: 0.044 mg/L uranium; 10 mg/L nitrate as N; 2000 mg/L sulfate

Central Floodplain Wells

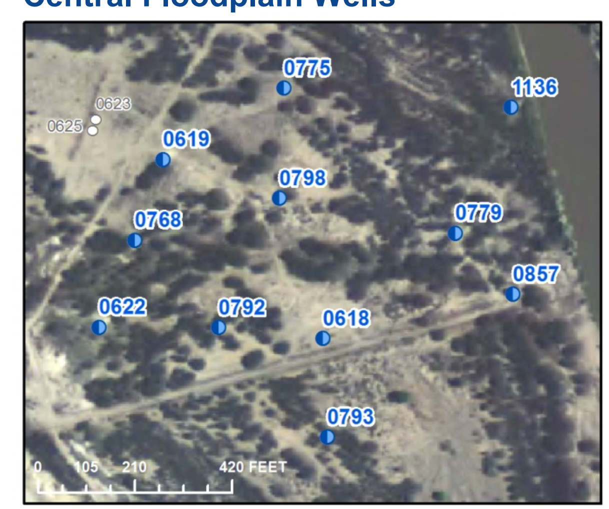
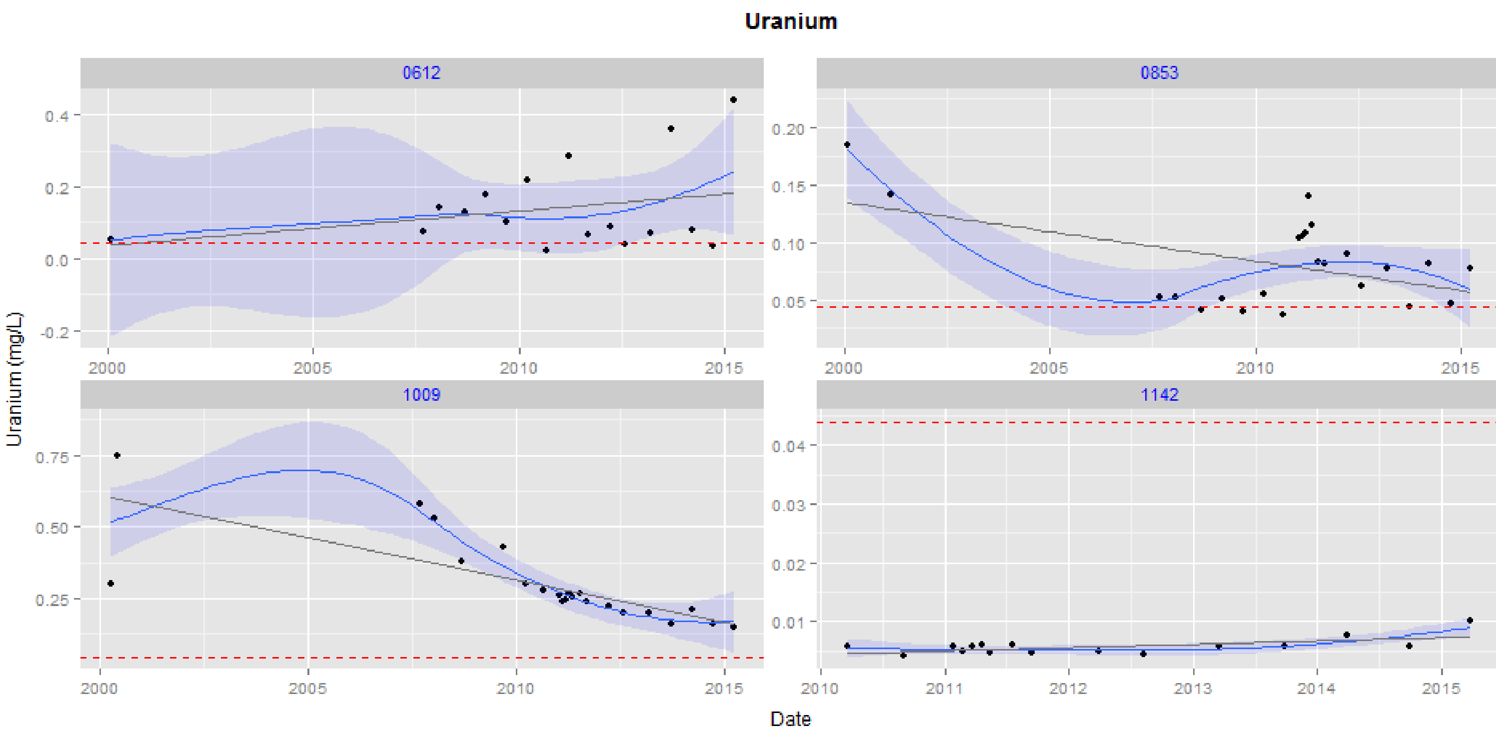
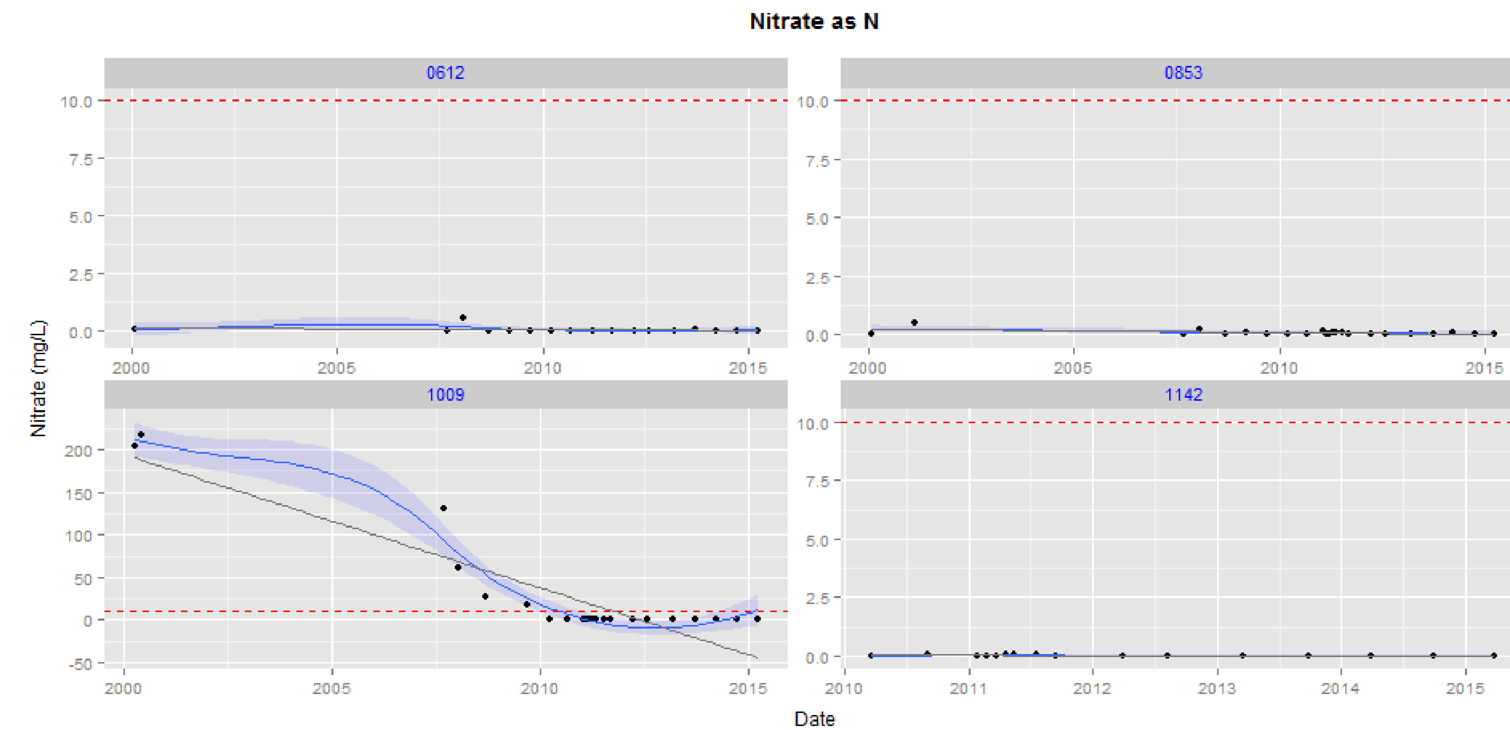
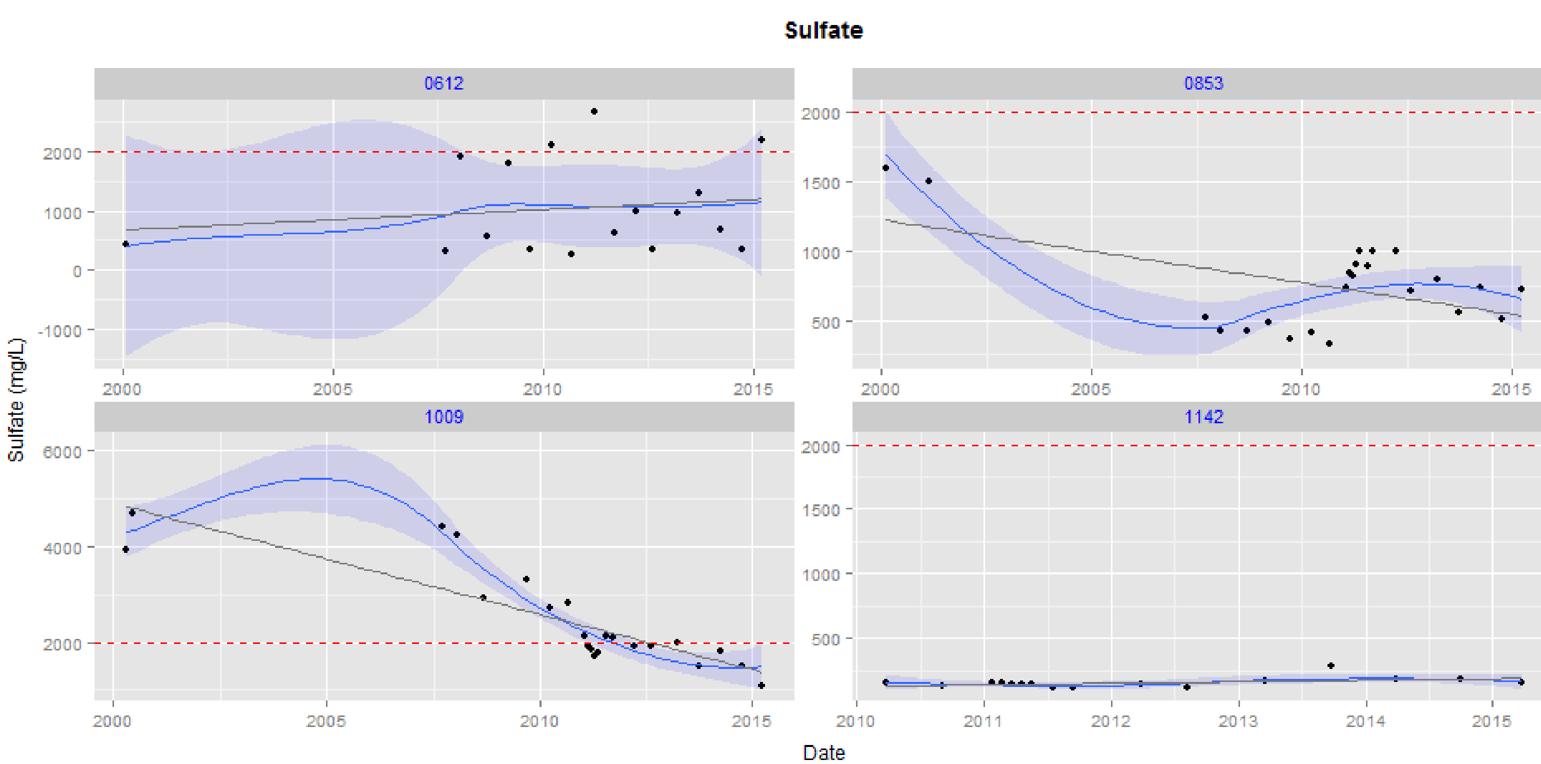


Figure A-5. Uranium, Nitrate, and Sulfate Concentration Trends in Central Floodplain Wells: 2000–March 2015







Time-Trend Plot Explanation. In contrast to traditional group line plots (provided in previous annual reports), data for each well are plotted separately to facilitate understanding of well-specific trends. The area represented in this figure is considered a river loss area (i.e., an area where the river contributes water to the aquifer).

- blue line is loess local regression line; shaded area is the 95% confidence interval about that line
- standard linear regression trendline
- denotes the 40 CFR 192 MCL or cleanup goal: 0.044 mg/L uranium; 10 mg/L nitrate as N; 2000 mg/L sulfate

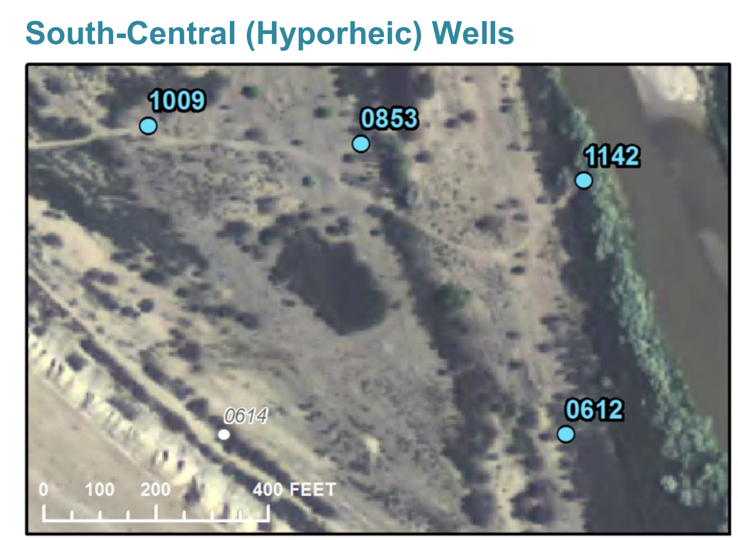
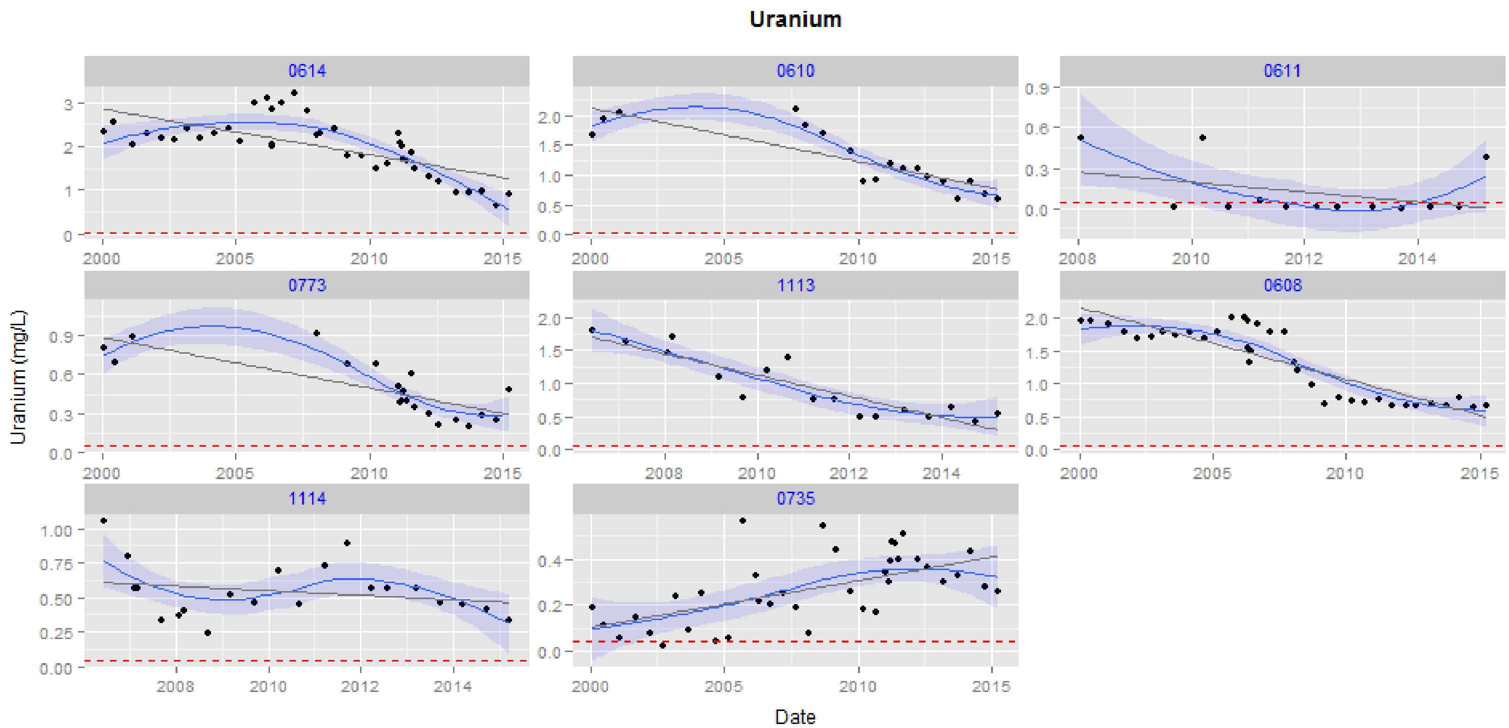
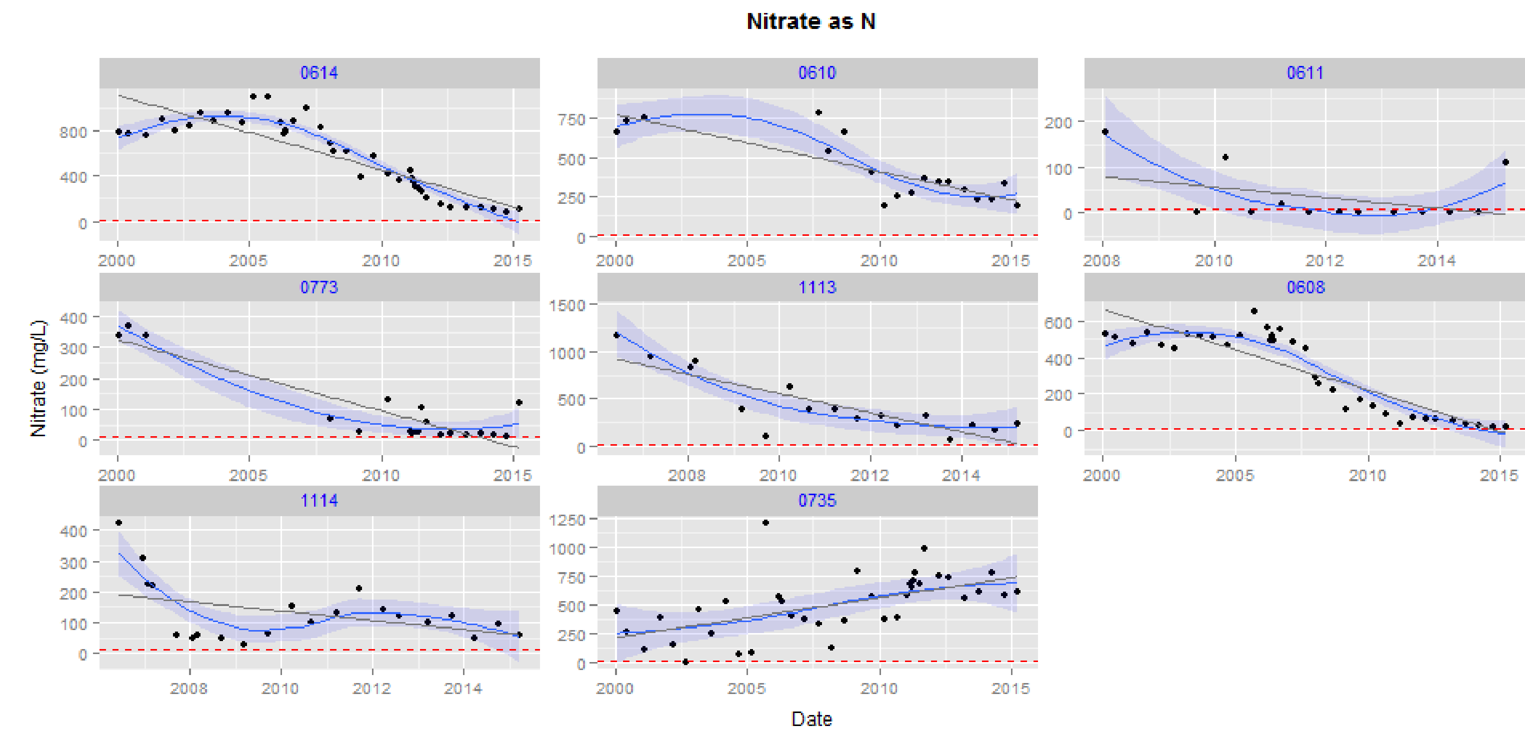
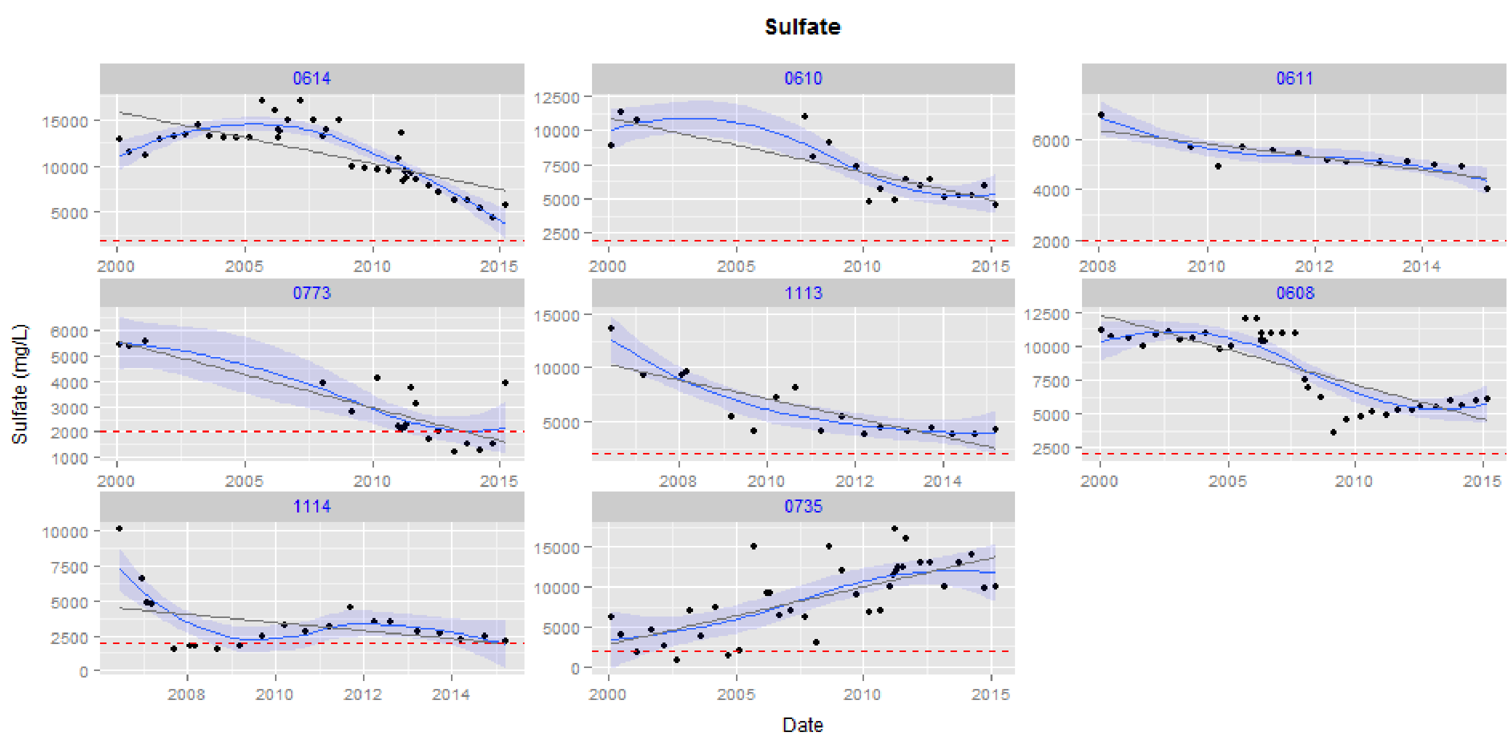
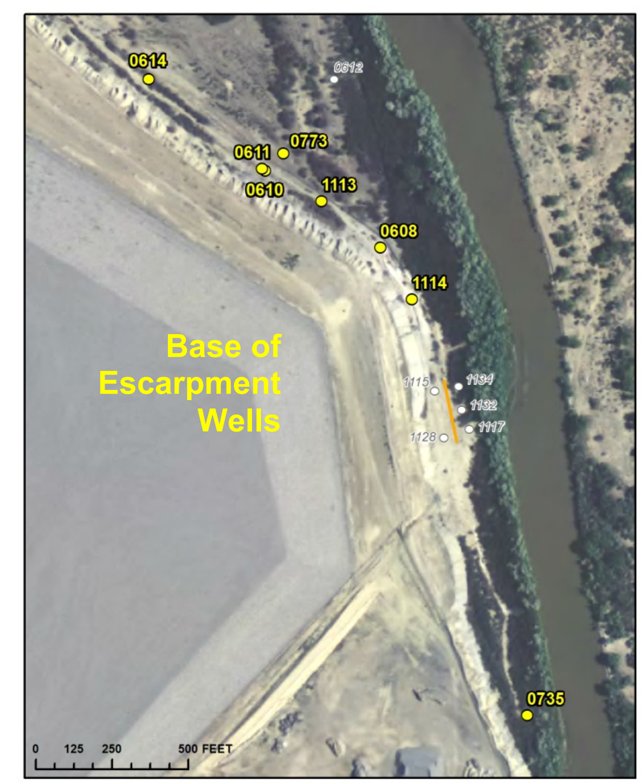


Figure A-6. Uranium, Nitrate, and Sulfate Concentration Trends in South-Central Floodplain Wells: 2000–March 2015









Time-Trend Plot Explanation. In contrast to traditional group line plots (provided in previous annual reports), data for each well are plotted separately to facilitate understanding of well-specific trends. In each plot, wells are listed in order of northeast to southwest direction (see inset to the left).

blue line is loess local regression line

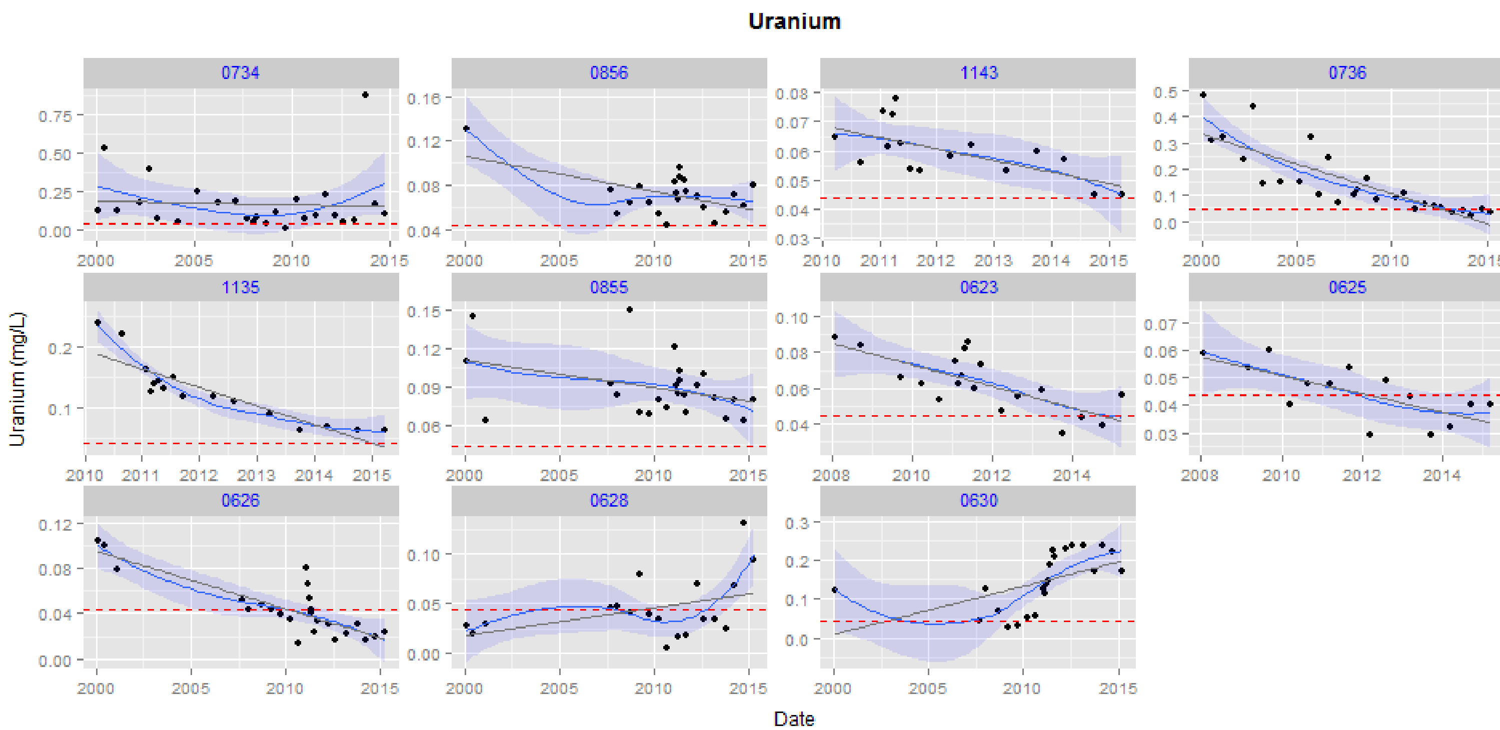
shaded area is the 95% confidence interval about that line

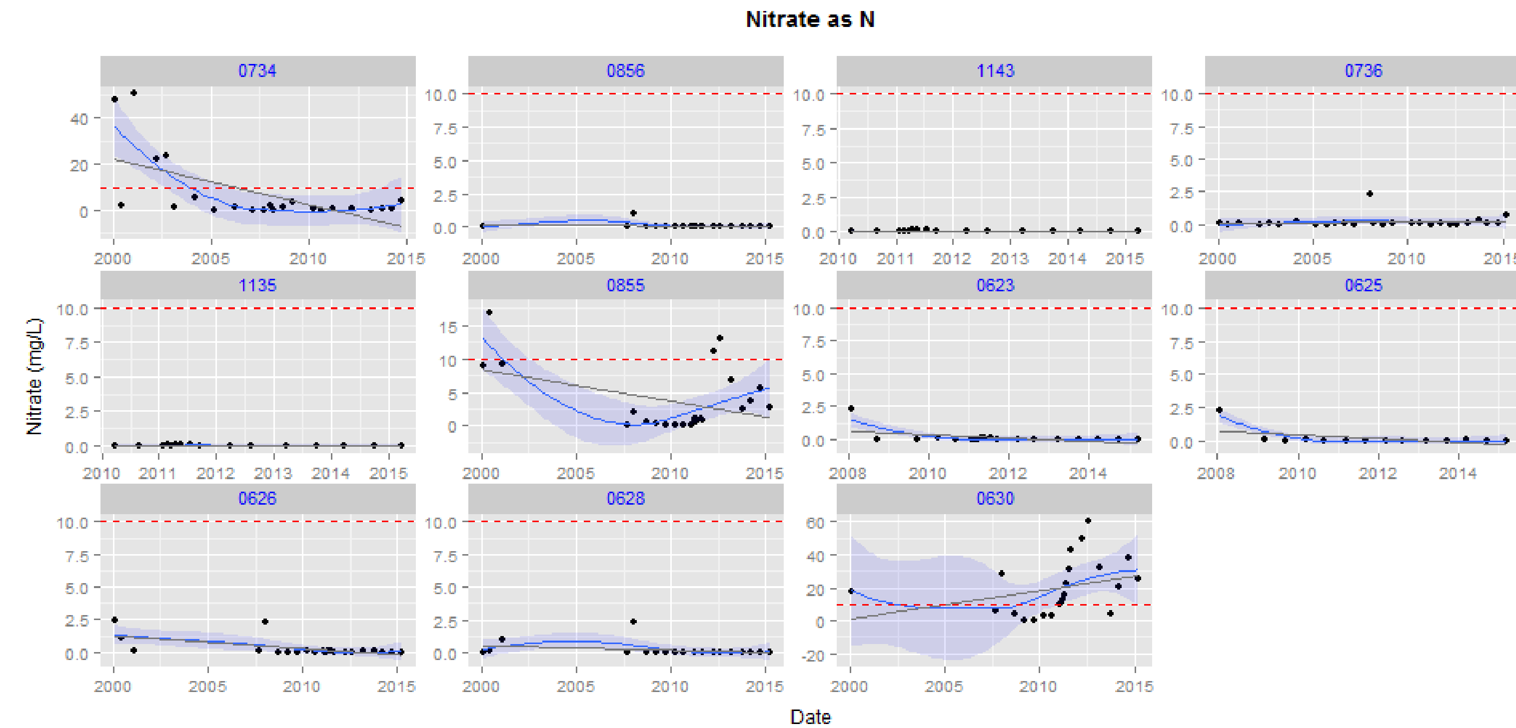
standard linear regression trendline

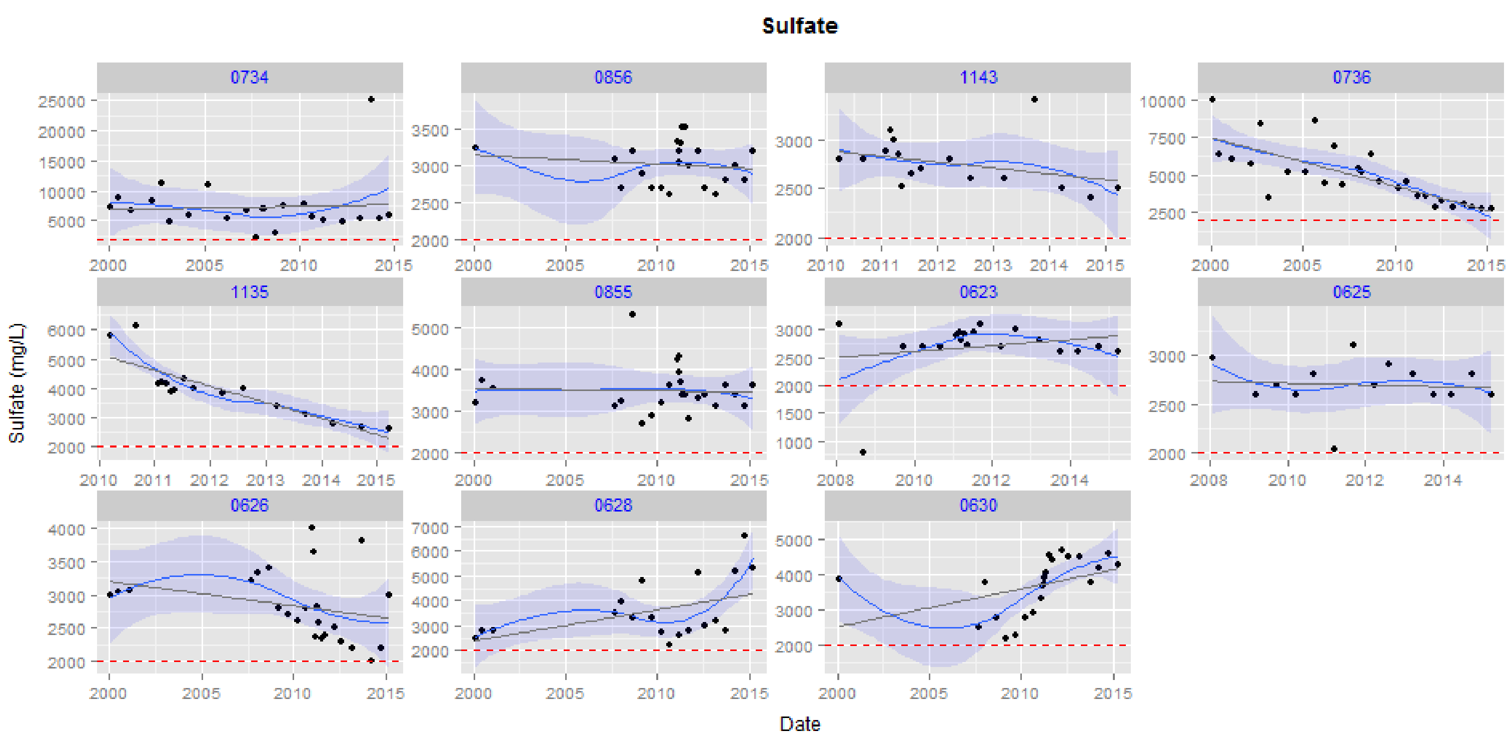
denotes the 40 CFR 192 MCL or cleanup goal:

- 0.044 mg/L uranium
- 10 mg/L nitrate as N
- 2000 mg/L sulfate

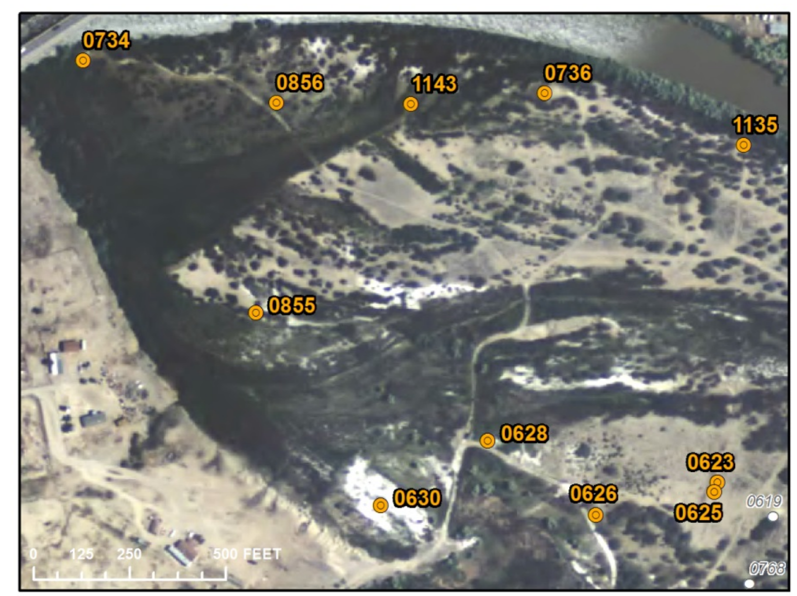
Figure A-7. Uranium, Nitrate, and Sulfate Concentration Trends in Base of Escarpment Floodplain Wells: 2000–March 2015







Western Floodplain Wells



Time-Trend Plot Explanation. In contrast to traditional group line plots (provided in previous annual reports), data for each well are plotted separately to facilitate understanding of well-specific trends. In each plot, western floodplain wells nearest the river are listed first (west to east direction), followed by well 0855. Remaining wells to the south are listed in numeric order.

blue line is loess local regression line

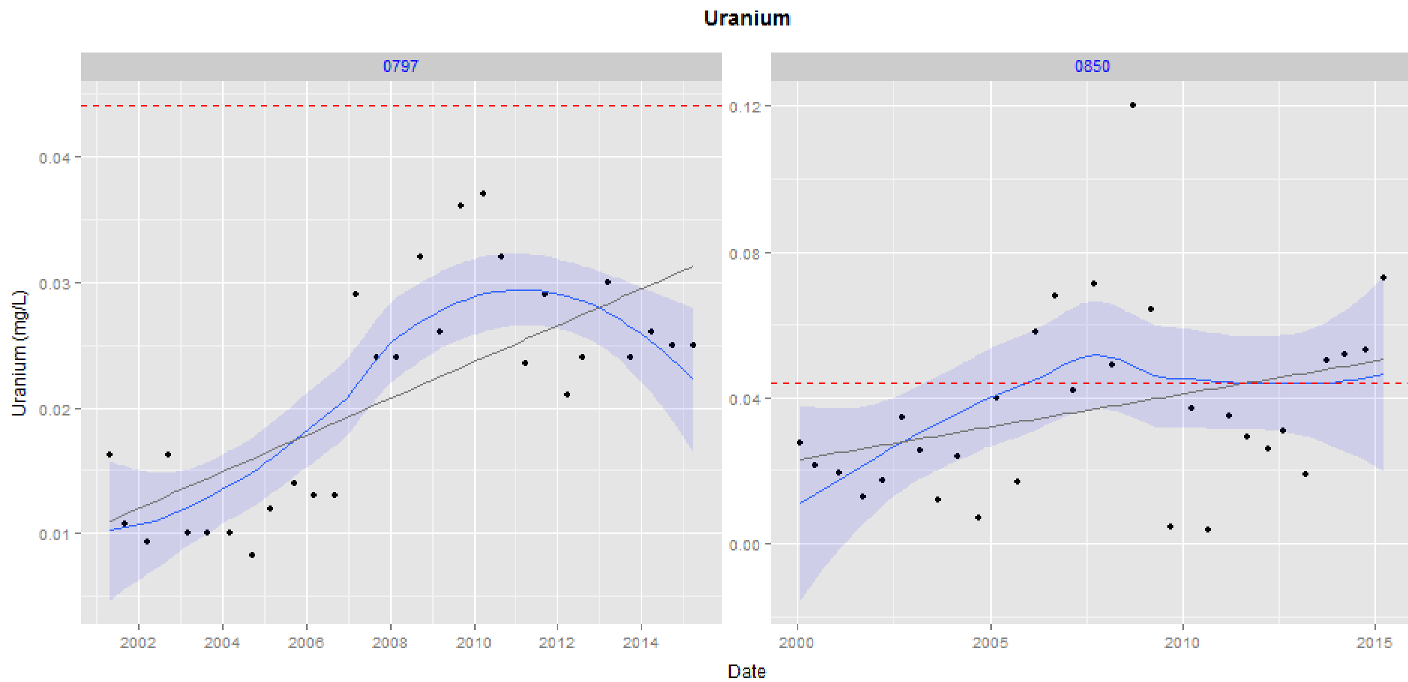
shaded area is the 95% confidence interval about that line

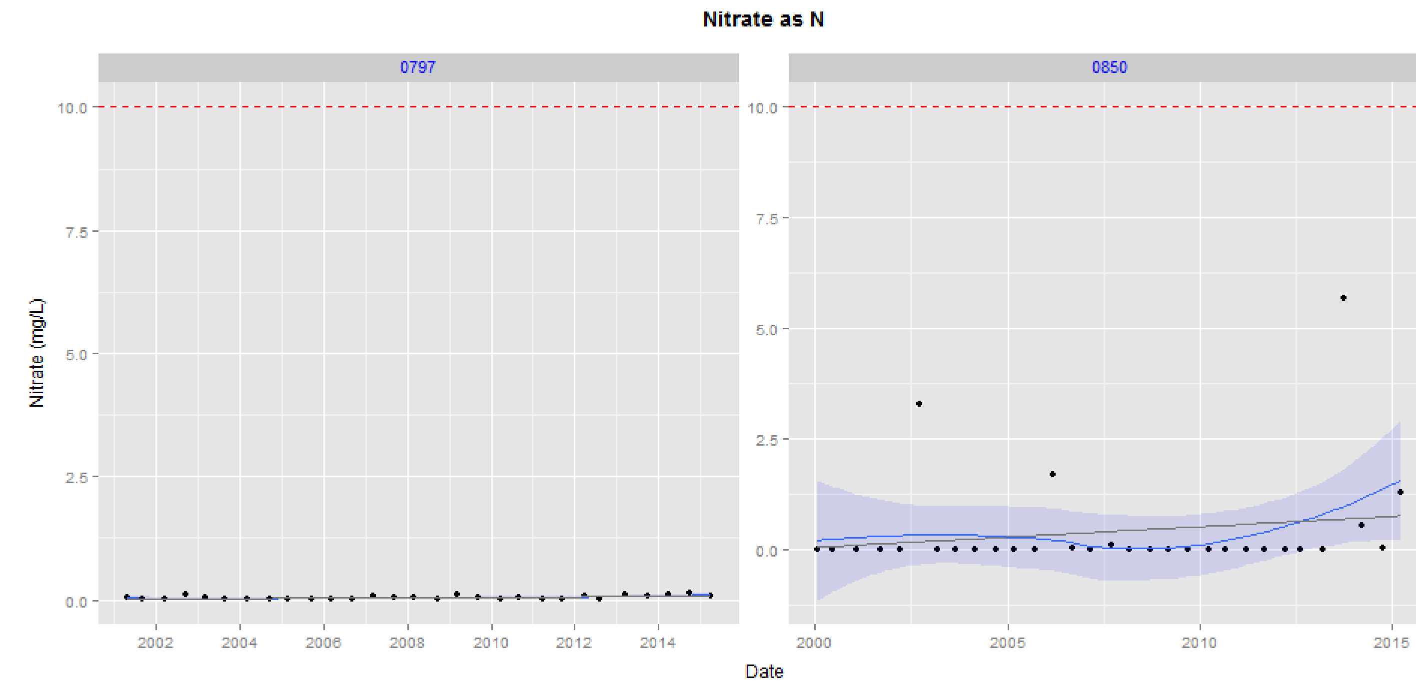
standard linear regression trendline

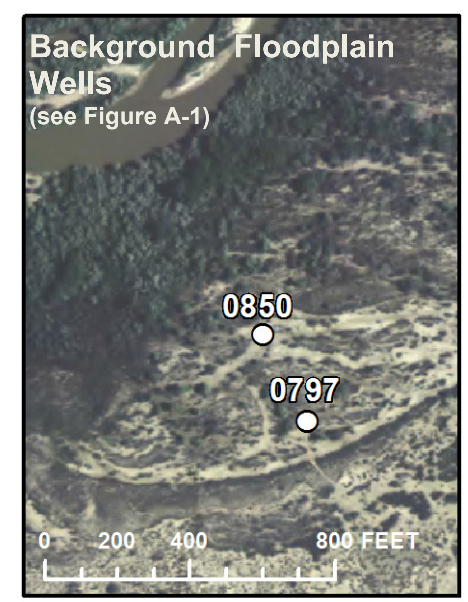
denotes the 40 CFR 192 MCL or cleanup goal:

- 0.044 mg/L uranium
- 10 mg/L nitrate as N
- 2000 mg/L sulfate

Figure A-8. Uranium, Nitrate, and Sulfate Concentration Trends in Western Floodplain Wells: 2000–March 2015







Time-Trend Plot Explanation. In contrast to traditional group line plots (provided in previous annual reports), data for each well are plotted separately to facilitate understanding of well-specific trends.

blue line is loess local regression line

shaded area is the 95% confidence interval about that line

standard linear regression trendline

denotes the 40 CFR 192 MCL or cleanup goal:

- 0.044 mg/L uranium
- 10 mg/L nitrate as N
- 2000 mg/L sulfate

Figure A-9. Uranium, Nitrate, and Sulfate Concentration Trends in Background Floodplain Wells: 2000–March 2015

Appendix B

Hydrographs for Terrace Alluvial Wells

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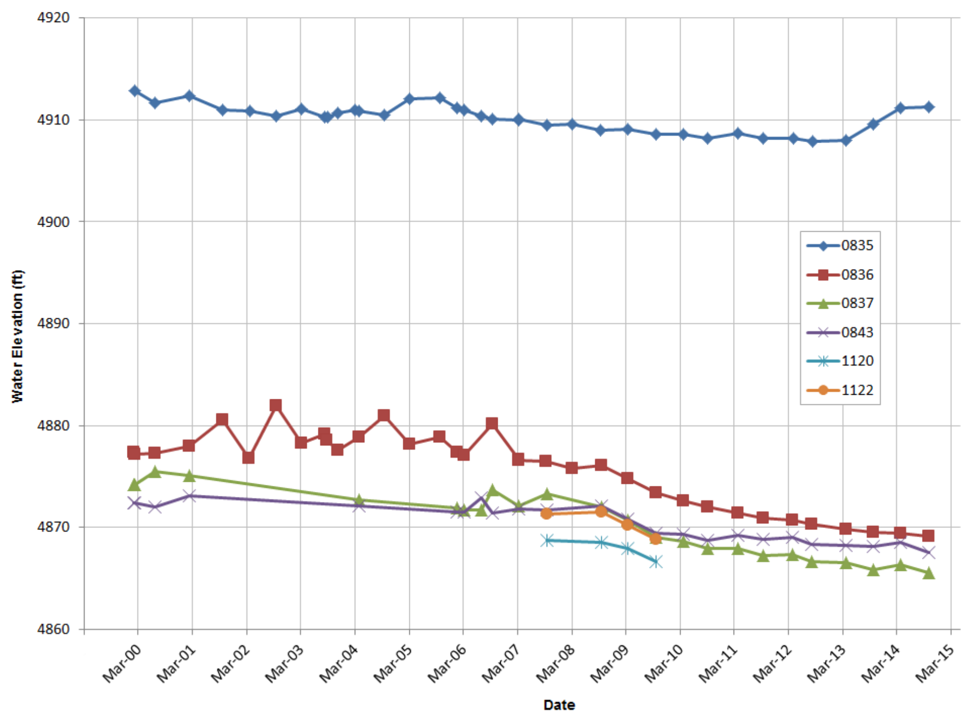
Plot a. Standard Line Plot with Common Scales



Plot b. Facet Plot with Unique Scales

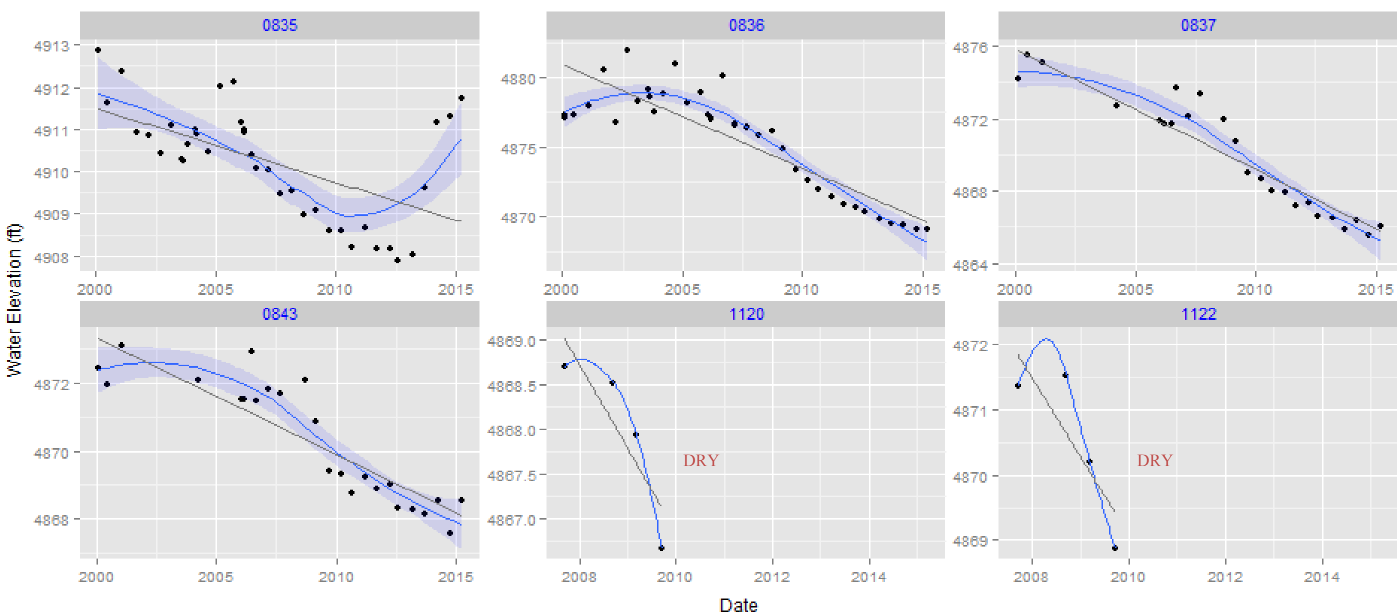


Figure B-1. Hydrographs for Northwest Terrace Alluvial Wells North of Highway 64

In this figure, the upper plot is consistent with the presentation used in previous reports. The lower plot presents the same water level results using a different data visualization approach. In the lower plot, water level data are plotted separately for each well. In each of these plots, the blue line is a loess local regression line, the shaded area is the 95% confidence interval about that line, and the straight line is the trendline using the standard linear regression model. Wells 1120 and 1122 have been dry since September 2009.

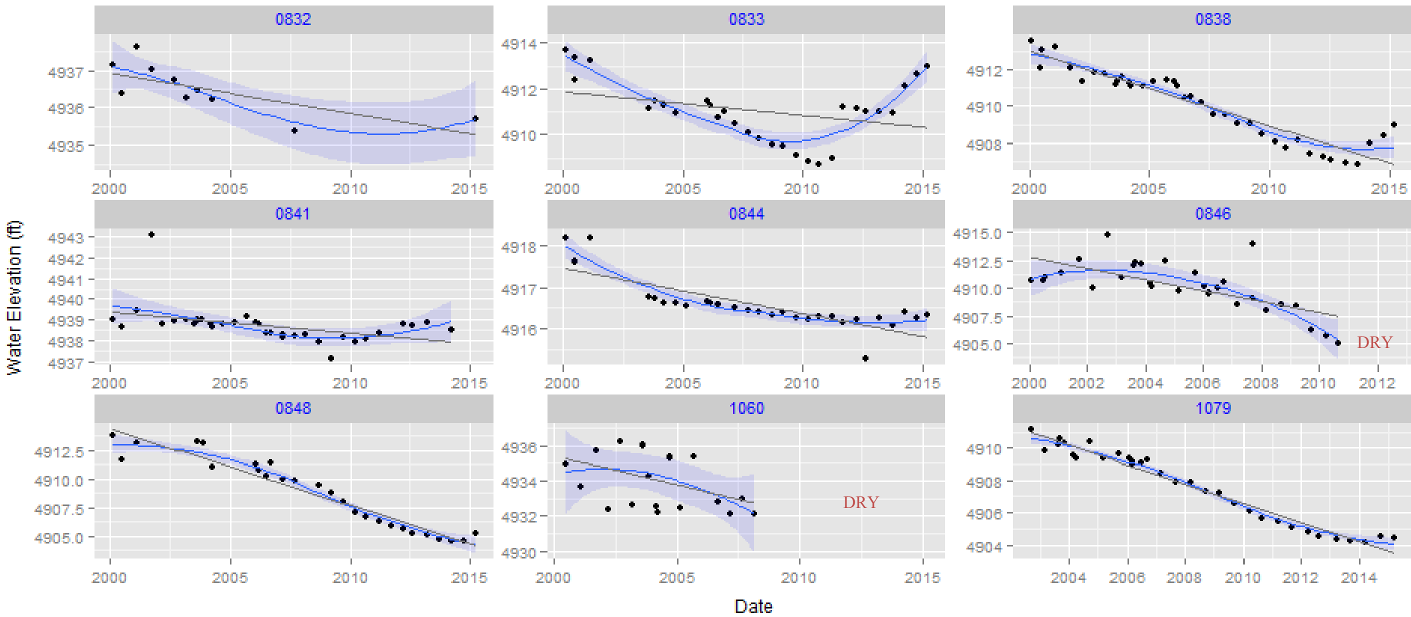


Figure B-2. Hydrographs for Southwest Alluvial Wells South of Highway 64 and West of Highway 491

Well 0832 has been consistently monitored but has been dry at the time of most of the 18 sampling events since January 2006. At well 0841, the water level was below the top of the pump at the time of the last two sampling events. Well 0846 was dry at the time of the four 2011–2012 sampling events; this well has not been monitored since August 2012. Well 1060 has been dry since March 2009.

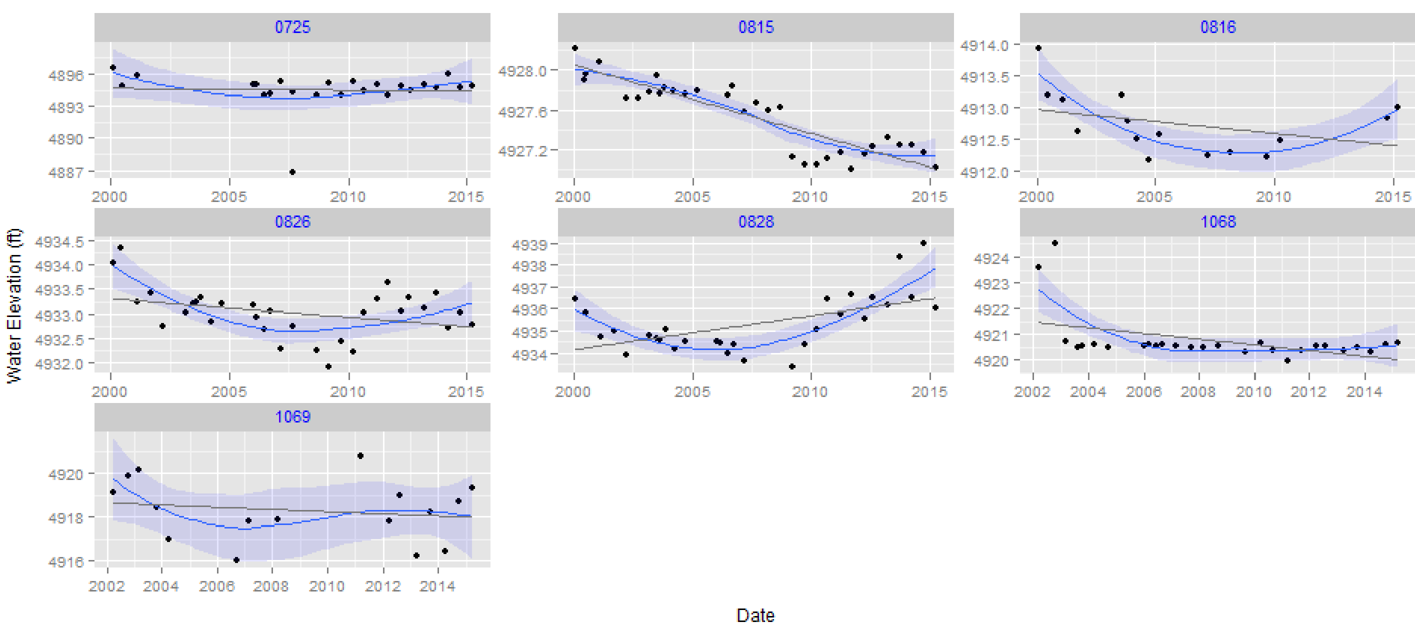


Figure B-3. Hydrographs for Terrace Alluvial Wells West of the Disposal Cell

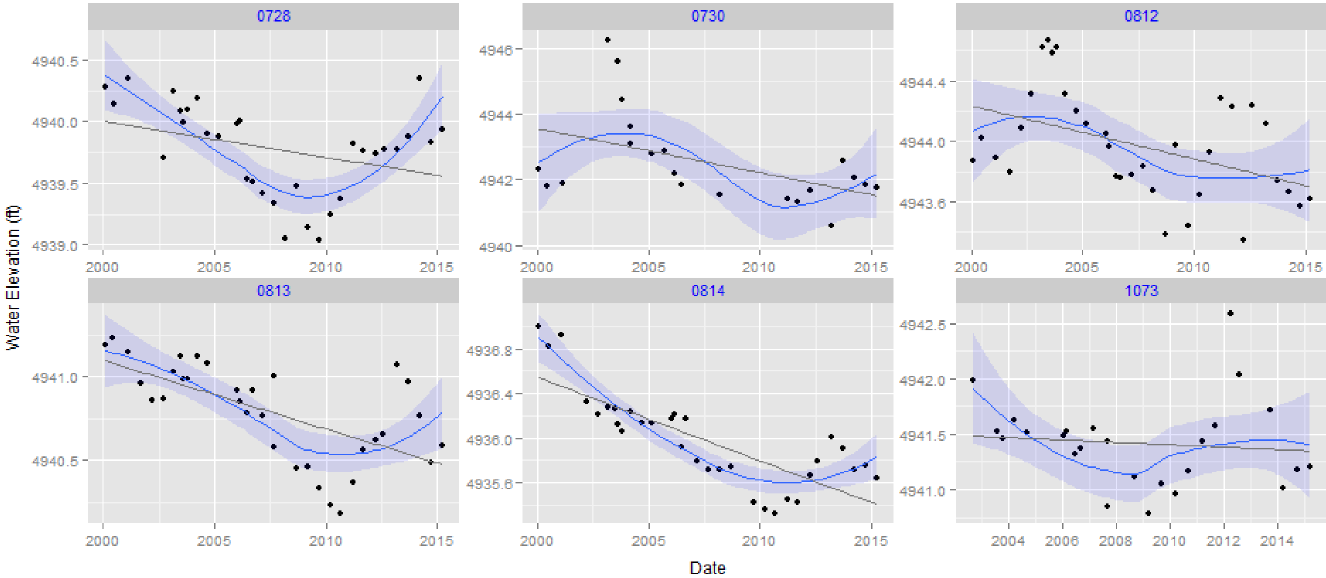


Figure B-4. Hydrographs for Terrace Alluvial Wells in Borrow Pit and Swale Area

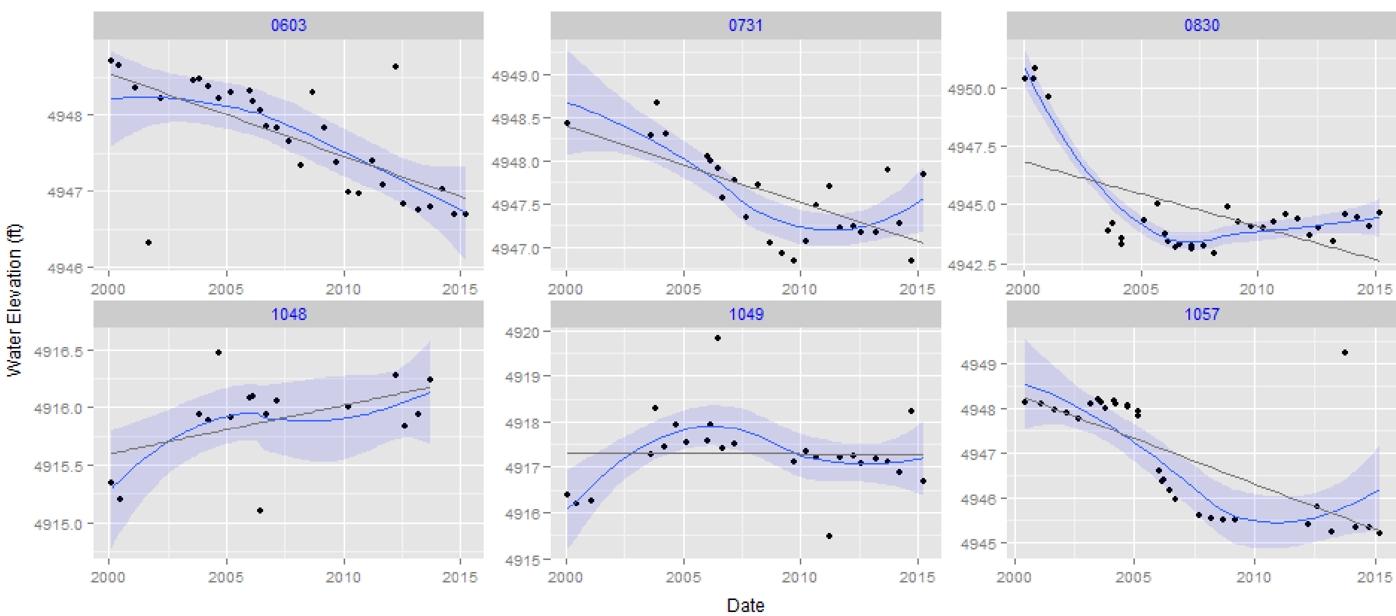


Figure B-5. Hydrographs for Terrace Alluvial Wells East of the Disposal Cell and Evaporation Pond

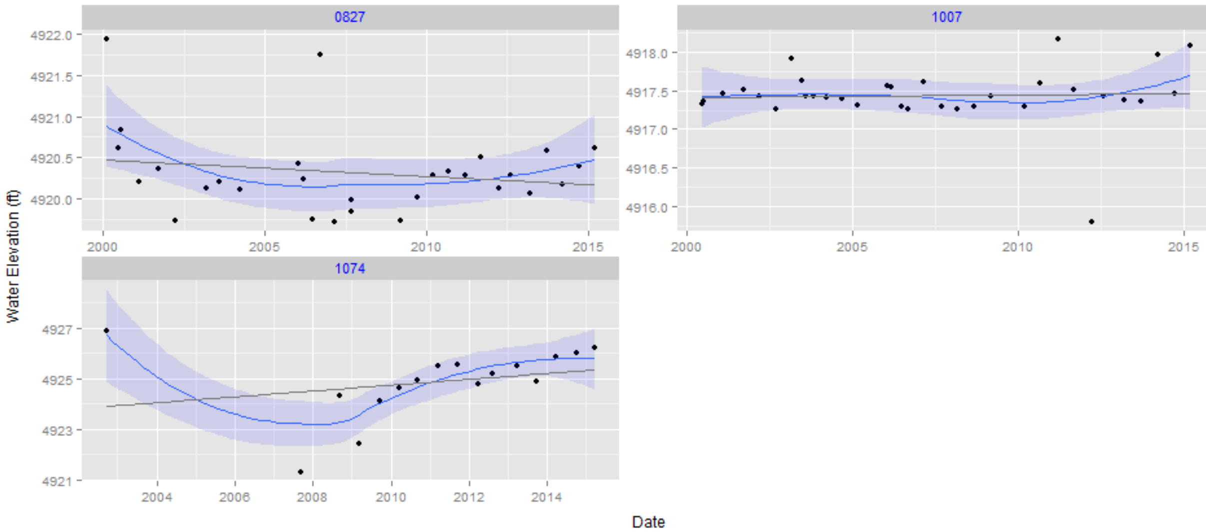


Figure B-6. Hydrographs for Terrace Alluvial Wells North of the Disposal Cell (Top of Escarpment)

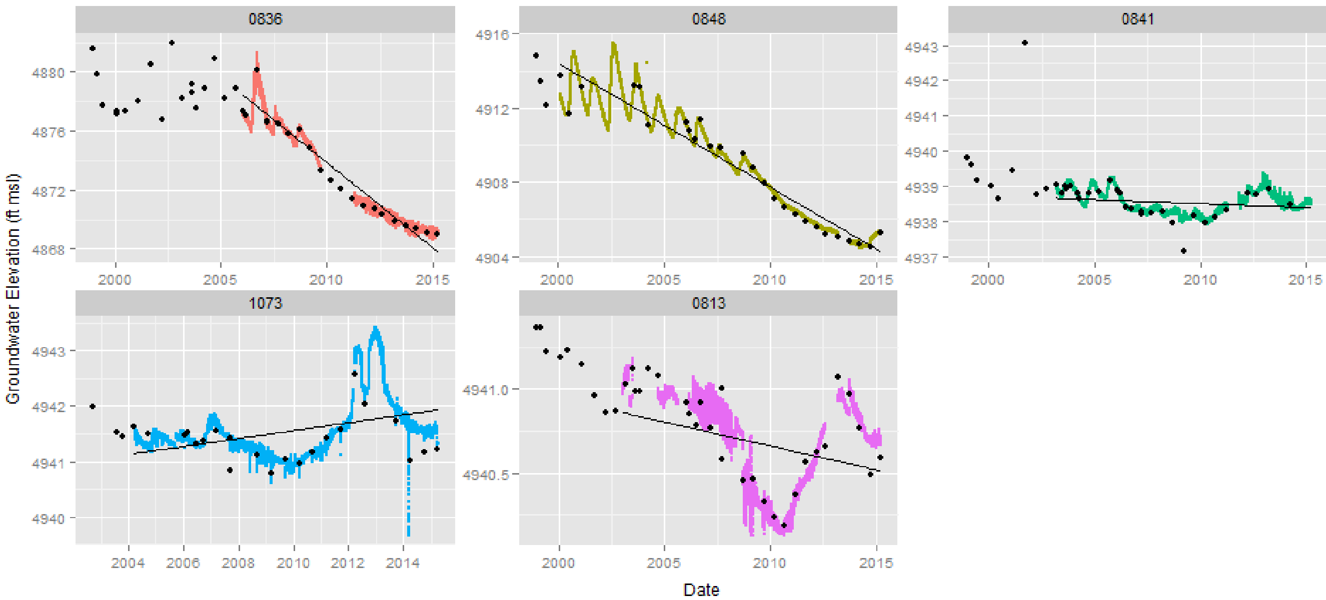


Figure B-7. Terrace Datalogger Measurements: West Terrace and Swale Area Alluvial Wells

In each plot, line (—) is linear trend line on datalogger measurements; • denotes manual measurement.

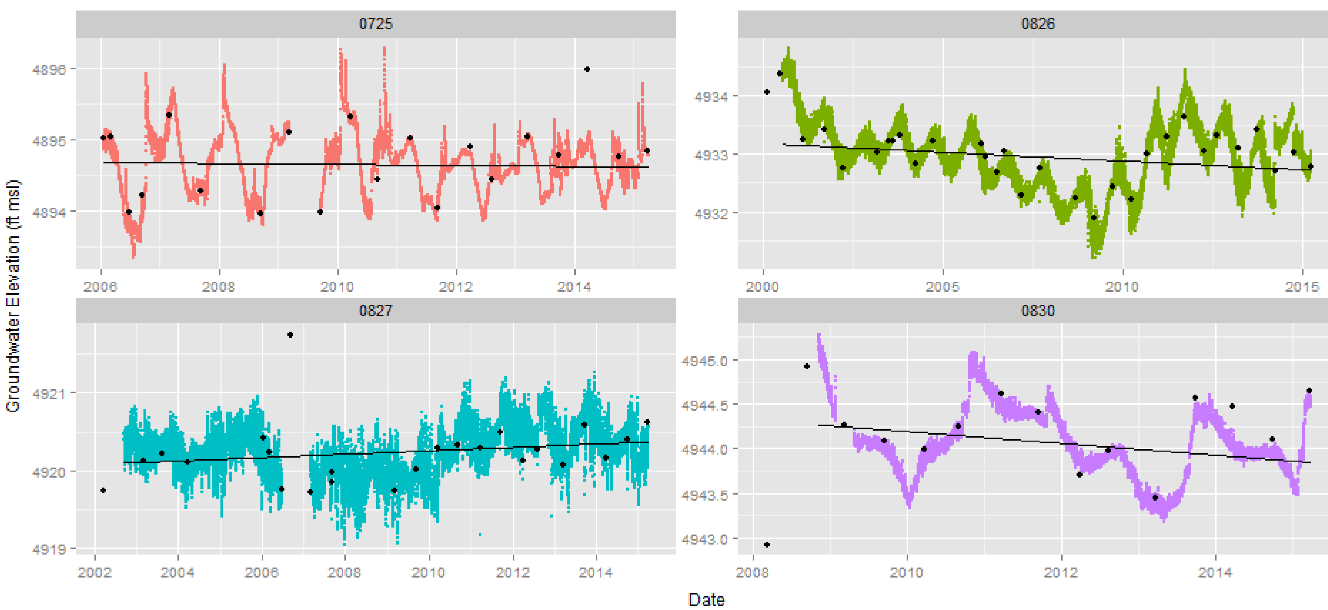


Figure B-8. Terrace Datalogger Measurements: Alluvial Wells East of Highway 64

In each plot, line (—) is linear trend line on datalogger measurements; • denotes manual measurement.

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