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Annual Performance Report April 2013 Through March 2014 for the Shiprock, New Mexico, Site

October 2014

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Abbreviations

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
kg	kilogram
lb	pounds
MCL	maximum concentration limit
mg/L	milligrams per liter
msl	mean sea level
N	nitrogen
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 2013 through March 2014. 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, 116 monitoring wells (59 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. COC concentrations in central floodplain near-river wells 0857 and 1136–1139 have been variably increasing over the past few years, and this trend continued for sulfate and uranium in early 2014. COC concentrations in surface water samples collected from the San Juan River are at or below established benchmarks and are comparable to upstream (background) results.

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 12.3 million gallons of groundwater were extracted from the floodplain aquifer system during this performance period. Approximately 107 million gallons have been extracted from the floodplain since DOE initiated active remediation in March 2003.

Groundwater in the terrace system is currently being extracted from two drainage trenches (in Bob Lee and Many Devils Washes) and nine wells. From April 2013 through March 2014, approximately 3.4 million gallons of groundwater were extracted from the terrace system; the total cumulative volume extracted is approximately 36 million gallons. The cumulative volume removed from both the terrace and the floodplain combined (as of April 1, 2014) is over 143 million gallons. Estimated masses of sulfate, nitrate, and uranium removed from the floodplain and terrace well fields during this performance period were (rounded) 688,350 pounds; 18,800 pounds; and 40 pounds, respectively.

Recommendations

Based on the current status of remediation progress and recent monitoring results, the major recommendations presented in this report are as follows:

- Continue to monitor the fluid level in the evaporation pond and operate the enhanced evaporation system as necessary to maintain sufficient freeboard. If necessary, temporarily cease pumping at Trenches 1 and 2 during periods of high snowmelt runoff in the river.
- Update the compliance strategy for the terrace and floodplain.
- Implement the recommendations in the report *Optimization of Sampling at the Shiprock, New Mexico, Site* (DOE 2013b).

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 2013 through March 2014. 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 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.

A detailed description of Shiprock site conditions is presented in the Site Observational Work Plan (SOWP; DOE 2000), and the compliance strategy is documented in the Groundwater Compliance Action Plan (GCAP; DOE 2002). 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 mid-term 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.

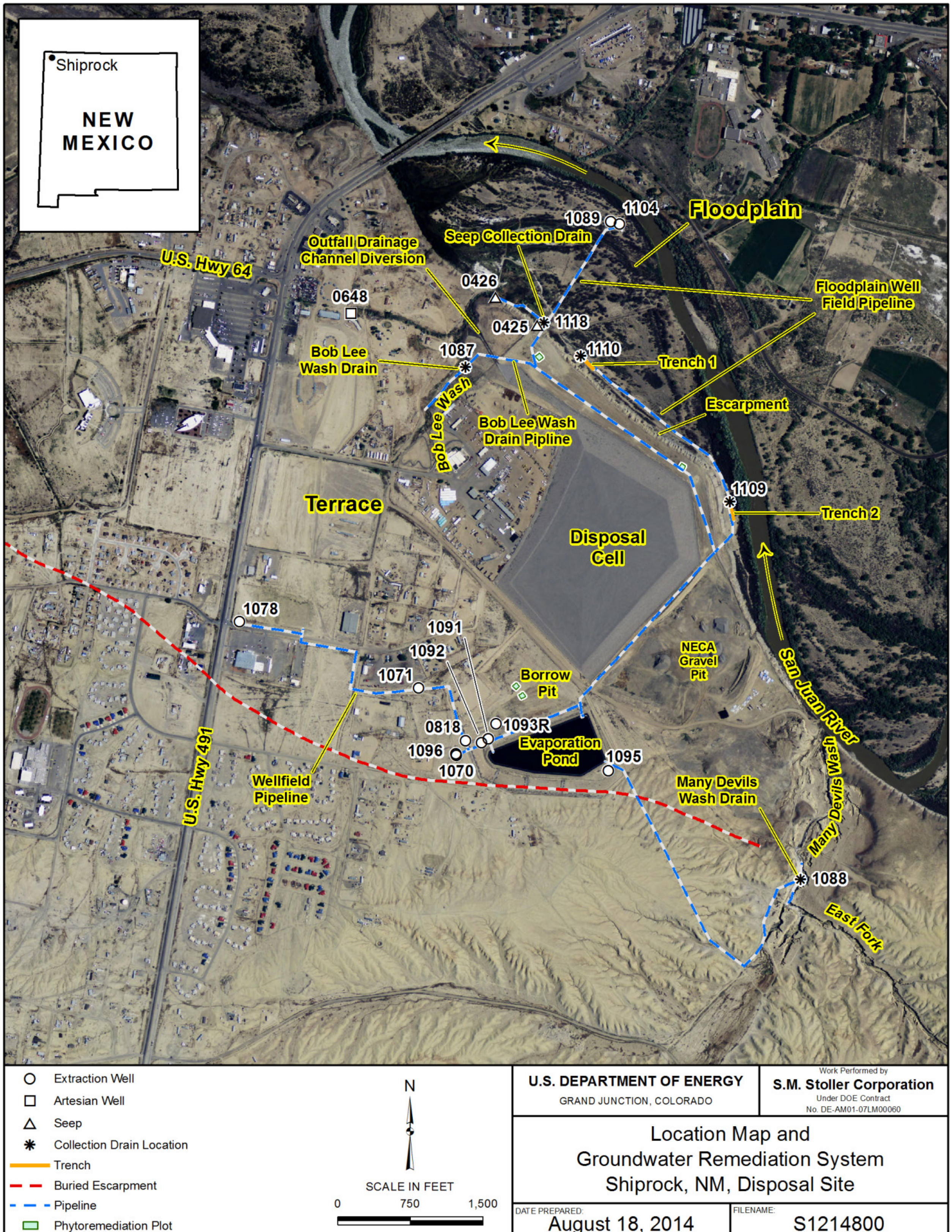

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Figure 1. Location Map and Groundwater Remediation System

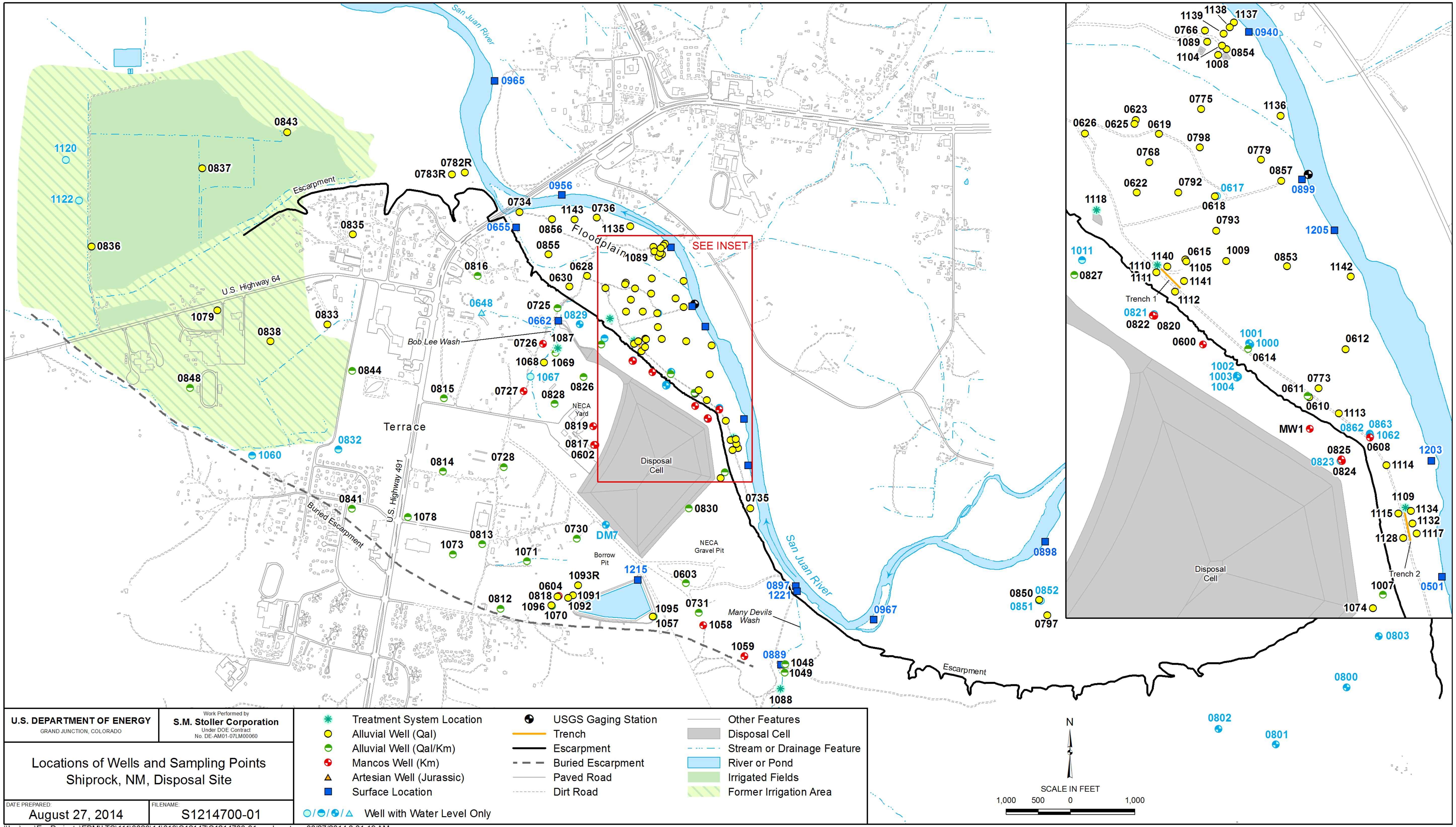

Figure 2. Locations of Wells and Sampling Points at the Shiprock Site

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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) 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 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)	Historical Range in Floodplain Background Wells[a]	Comments
Ammonia as N (mg/L)	NA	0.074–0.11	Most ammonia results for floodplain background wells have been nondetects (<0.1 mg/L).
Manganese (mg/L)	NA	0.001–7.2	Compliance standard and cleanup goal for the floodplain is 2.74 mg/L, as identified in the GCAP (DOE 2002).
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, the MCL and compliance standard cited in the GCAP (DOE 2002).
Selenium (mg/L)	0.01	0.0001–0.02	Compliance standard and 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)	NA	0.18–10	EPA's Drinking Water Equivalent Level for lifetime exposure is 20 mg/L (EPA 2012).
Sulfate (mg/L)	NA	210–5,200	Given elevated levels in artesian well 0648 (1,810–2,340 mg/L), an alternate cleanup goal of 2000 mg/L for the floodplain 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
NA = Not applicable (contaminant does not have an MCL in 40 CFR 192)

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 2,340 mg/L), the GCAP proposed an alternate cleanup goal for sulfate of 2,000 mg/L for the floodplain. This alternate goal is conservative, given the elevated levels measured in floodplain background wells (4,300–4,700 mg/L in well 0797 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 2013–2014 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, 2012, through March 31, 2013)		Current Period (April 1, 2013, through March 31, 2014)	
	Average Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)	Average Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)
1089	4.4	2,324,600	5.6	2,941,600
1104	0.91	468,176	1.5	795,274
Trench 1	8.3	4,356,120	10.2	5,362,680
Trench 2	3.6	1,911,800	5.6	2,964,700
Seep (1118)	0.43	226,050	0.55	290,600
Total	**17.7** (cum. avg.)	**9,286,746**	**23.5** (cum. avg.)	**12,354,854**

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 2013 through March 2014, approximately 2.9 million gallons of water were removed from well 1089 at an average pumping rate of about 5.6 gpm (Table 2). Pumping rates at well 1104 averaged about 1.5 gpm; the cumulative extracted volume was about 796,000 gallons. During the period since the start of operations in March 2003 through the end of March 2014, totals of approximately 30.1 and 6.3 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 2013 through March 2014, approximately 5.4 million gallons of water were removed from Trench 1 at an average pumping rate of 10.2 gpm. In 2013–2014, approximately 3 million gallons of water were removed from Trench 2 at an average pumping rate of 5.6 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. An extended period of non-pumping between March 28, 2014, and April/May 2014 was due to a shutdown of the entire remediation system while safety concerns related to access at the site were resolved.

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 2013 through March 2014, the average discharge rate from the seep collection drain was 0.55 gpm, similar to the average rates reported in the last several years. Approximately 290,600 gallons were pumped from the seeps during this period (Table 2), yielding a total cumulative volume of about 2.2 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 (Figure 1). Table 3 compares the average pumping rate and total groundwater volume removed from each terrace extraction well and drain location for the current (2013–2014) and previous (2012–2013) reporting periods. The production rate from wells 1070, 1071, 1091, and 1092 does not and has not exceeded 0.1 gpm, the minimum production to be considered an aquifer under 10CFR192; therefore, additional pumping from these wells is unwarranted.

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

Terrace Well or Drain	Previous Period (April 1, 2012, through March 31, 2013)		Current Period (April 1, 2013, through March 31, 2014)	
	Average Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)	Average Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)
0818[a]	0.91	480,461	1.0	527,143
1070	0.035	18,349	0.019	9,870
1071	0.012	6,523	0.010	5,283
1078	1.116	586,320	0.93	489,360

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

Terrace Well or Drain	Previous Period (April 1, 2012, through March 31, 2013)		Current Period (April 1, 2013, through March 31, 2014)	
	Average Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)	Average Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)
1091	0.003	1,816	0.037	19,427
1092	0.004	2,167	0.001	523
1093R	0.883	464,210	0.665	349,710
1095	0.328	172,587	0.30	157,283
1096	0.305	160,318	0.52	273,772
Subtotal	**3.6** (cum. avg.)	**1,892,751**	**3.5** (cum. avg.)	**1,832,371**
1087[b]	2.158	1,134,500	2.99	1,571,700
1088[b]	0.170	89,391	0.07	38,372
Total	**5.93** (cum. avg.)	**3,116,642**	**6.55** (cum. avg.)	**3,442,443**

[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.

As shown in Table 3, the current-period average pumping rates for terrace extraction wells ranged from 0.003 gpm to 1.0 gpm. The total groundwater volume removed from each well during this period ranged from about 520 gallons to 527,140 gallons. The cumulative total volume removed from pumping the terrace extraction wells (about 1.8 million gallons) is about 3 percent less than the volume extracted during the 2012–2013 reporting period.

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, 2002). 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 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 2013−2014, the average pumping rate from Bob Lee Wash was 3.0 gpm (vs. 2.2 gpm in 2012−2013), and the groundwater interceptor drain removed about 1.1 million gallons of water (Table 3). During the current performance period, the average pumping rate from Many Devils Wash was 0.07 gpm, and the groundwater interceptor drain removed approximately 38,370 gallons of water. This intercepted discharge from Many Devils Wash possibly comprises a portion of the natural base flow. At 0.07 gpm it does not meet the definition of an aquifer under 40CFR192 and further pumping from this interceptor drain is unwarranted.

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). Prior to the March 28 treatment system shutdown, the average water level in the evaporation pond was 5.7 ft in March 2014 (measured as the distance above transducers), leaving approximately 2.3 ft of unfilled pond capacity.

From April 2013 through March 2014, close to 15.8 million gallons of extracted groundwater were pumped to the evaporation pond. The majority (about 12.4 million gallons, or 78 percent) of the influent liquids entering the pond were from the floodplain aquifer. About 22 percent (3.4 million gallons) of the inflow originated from the terrace groundwater system (Table 4).

As shown in Figure 3, at the end of the 2013–2014 reporting period, slightly over 36 million gallons have been extracted from the terrace and about 107 million gallons from the floodplain since DOE initiated active remediation in March 2003. This yields a cumulative extracted volume of about 143.4 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 2013–2014 performance period were approximately 19,000 pounds nitrate (as N), 688,350 pounds sulfate, and 40.5 pounds uranium. These mass estimates (rounded to nearest thousand) 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.

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

Location	Annual Cumulative Volume (gal)[a]	Percent Contribution	Nitrate—Average Concentration (mg/L)	Nitrate Mass Contribution per Location (kg)[b]	Nitrate Mass Contribution per Location (lb)[c]	Sulfate—Average Concentration (mg/L)	Sulfate Mass Contribution per Location (kg)[b]	Sulfate Mass Contribution per Location (lb)[c]	Uranium—Average Concentration (mg/L)	Uranium Mass Contribution per Location (kg)[b]	Uranium Mass Contribution per Location (lb)[c]
Terrace											
0818	527,143	3.3	1000	1995	4399	14,000	27,933	61,582	0.13	0.259	0.572
1070	9870	0.06	630	23.5	51.9	16,000	598	1,318	0.080	0.003	0.007
1071	5283	0.03	755	15.1	33.3	14,000	280	617.2	0.125	0.0025	0.006
1078	489,360	3.1	495	917	2021	14,500	26,857	59,210	0.13	0.241	0.531
1091	19,427	0.12	915	67.3	148.3	14,500	1,066	2,351	0.115	0.0085	0.019
1092	523	0.003	1045	2.1	4.6	15,500	30.7	67.6	0.105	0.0002	0.0005
1093R	349,710	2.2	655	867	1911	7,950	10,523	23,199	0.114	0.151	0.333
1095	157,283	1.0	1650	982	2,166	5,200	3,096	6,825	0.052	0.031	0.068
1096	273,772	1.7	640	663	1462	15,000	15,543	34,267	0.089	0.092	0.203
1087 (BLW)	1,571,700	10.0	245	1457	3213	6,400	38,073	83,935	0.445	2.647	5.836
1088 (MDW)	38,372	0.24	390	56.6	125	17,500	2,542	5,603	0.175	0.025	0.056
Floodplain											
1089	2,941,600	18.6	1.13	12.6	27.7	4,300	47,876	105,547	0.205	2.28	5.03
1104	795,274	5.0	2.57	7.7	17.1	5,600	16,857	37,162	0.38	1.14	2.52
Trench 1 (1110)	5,362,680	34.0	31.0	629	1387	4,700	95,399	210,318	0.405	8.22	18.1
Trench 2 (1109)	2,964,700	18.8	68.0	763	1682	1,665	18,684	41,190	0.243	2.72	6.0
Seep sump (1118)	290,600	1.8	56.5	62	137	6,250	6,875	15,156	0.485	0.53	1.18
			Total Masses:	**8,521**	**18,786**		**312,232**	**688,347**		**18.4**	**40.5**
Total Terrace	3,442,443	21.8									
Total Floodplain	12,354,854	78.2									
Total to Pond	15,797,297										

[a] Annual cumulative volumes are for this reporting period: April 1, 2013, through March 31, 2014.
[b] Mass in kilogram (kg) derived = annual volume × 3.785 (liters to gallons) × average concentration × (1/1,000,000).
[c] Conversion to pounds (lb) = kg × 2.2046.
BLW = Bob Lee Wash
MDW = Many Devils Wash

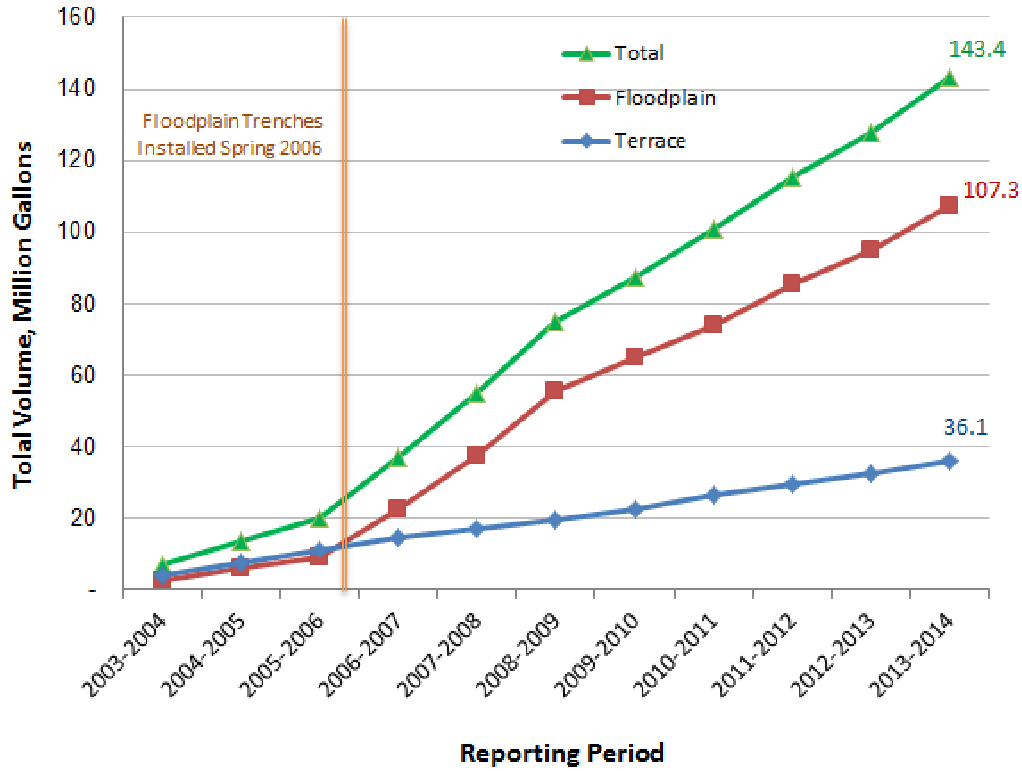

Figure 3. Total Groundwater Volume Pumped to the Evaporation Pond

3.0 Current Conditions

This section summarizes salient water quality and hydraulic characteristics of the floodplain and terrace groundwater systems for the April 2013 through March 2014 reporting period. For this reporting period, 116 monitoring wells were sampled (59 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. Prior to the March 2013 sampling effort, 13 surface/seep locations were eliminated because the locations had been historically dry.

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 2014a, 2014b).

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.

Nitrate (as N)

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.

Sulfate

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 show a decrease in sulfate concentrations in the area between Trench 1 and Trench 2, this may be an artifact stemming from the lack of baseline data for the Trench 2 region. During this reporting period, sulfate has been most elevated in alluvial wells 0734 and 0735, wells 1137–1139 near the 1089 area, and central floodplain well 0779 (Appendix A). Sulfate concentrations in central floodplain near-river wells 0857 and 1136–1138 have been variably increasing over the past few years as shown in Appendix A, Figure A-4. The reason for this trend is not known.

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 sulfate trends, uranium levels have increased in near-river wells 1137 and 1138 to current maximum floodplain-wide levels (1.9 and 2.3 mg/L, respectively).

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 2014a, 2014b). Except for declines noted in certain areas of the floodplain for the primary COCs, in general, spatial distributions of contaminants 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.

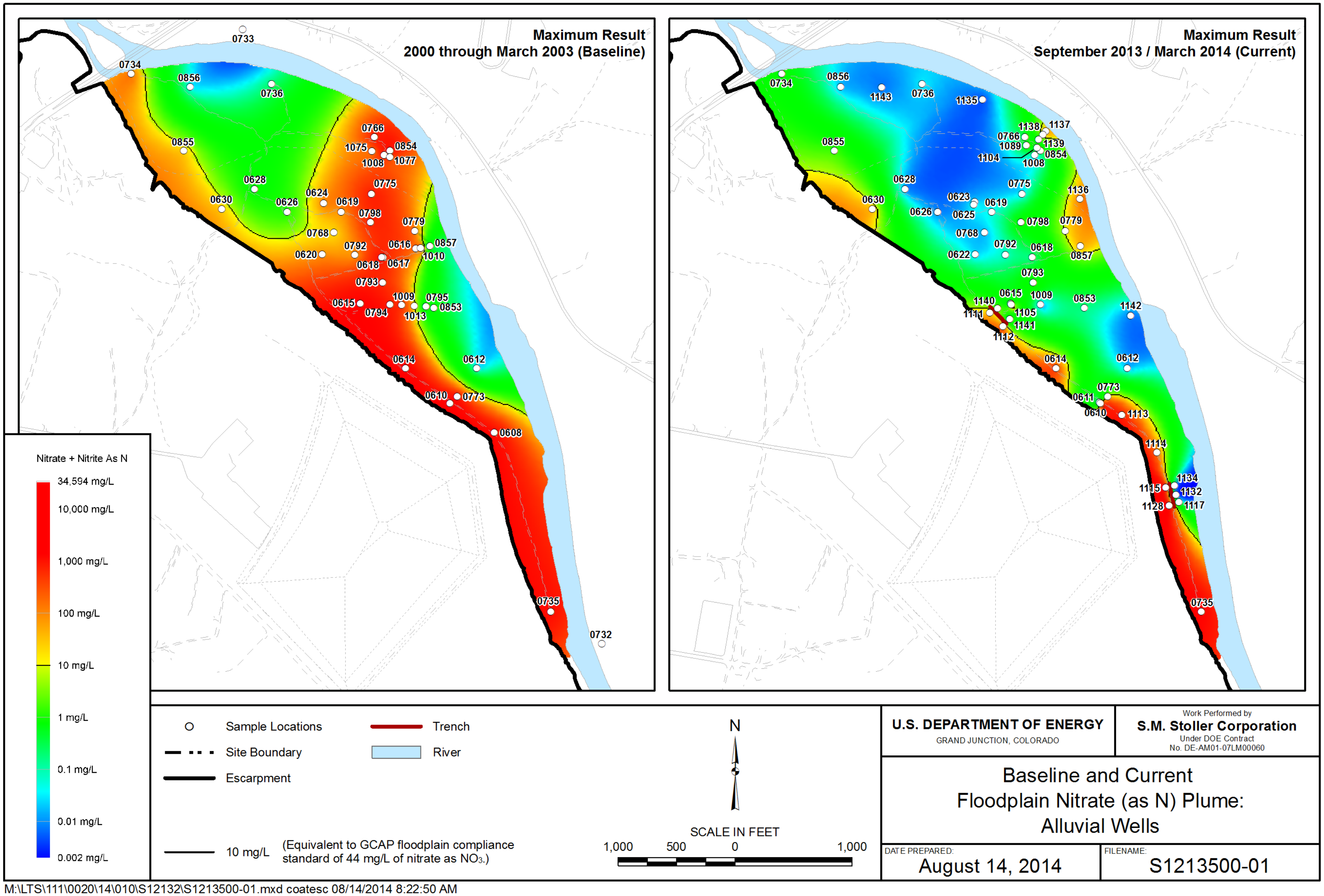

Figure 4. Baseline (2000–2003) and September 2013 through March 2014 Floodplain Nitrate Plumes

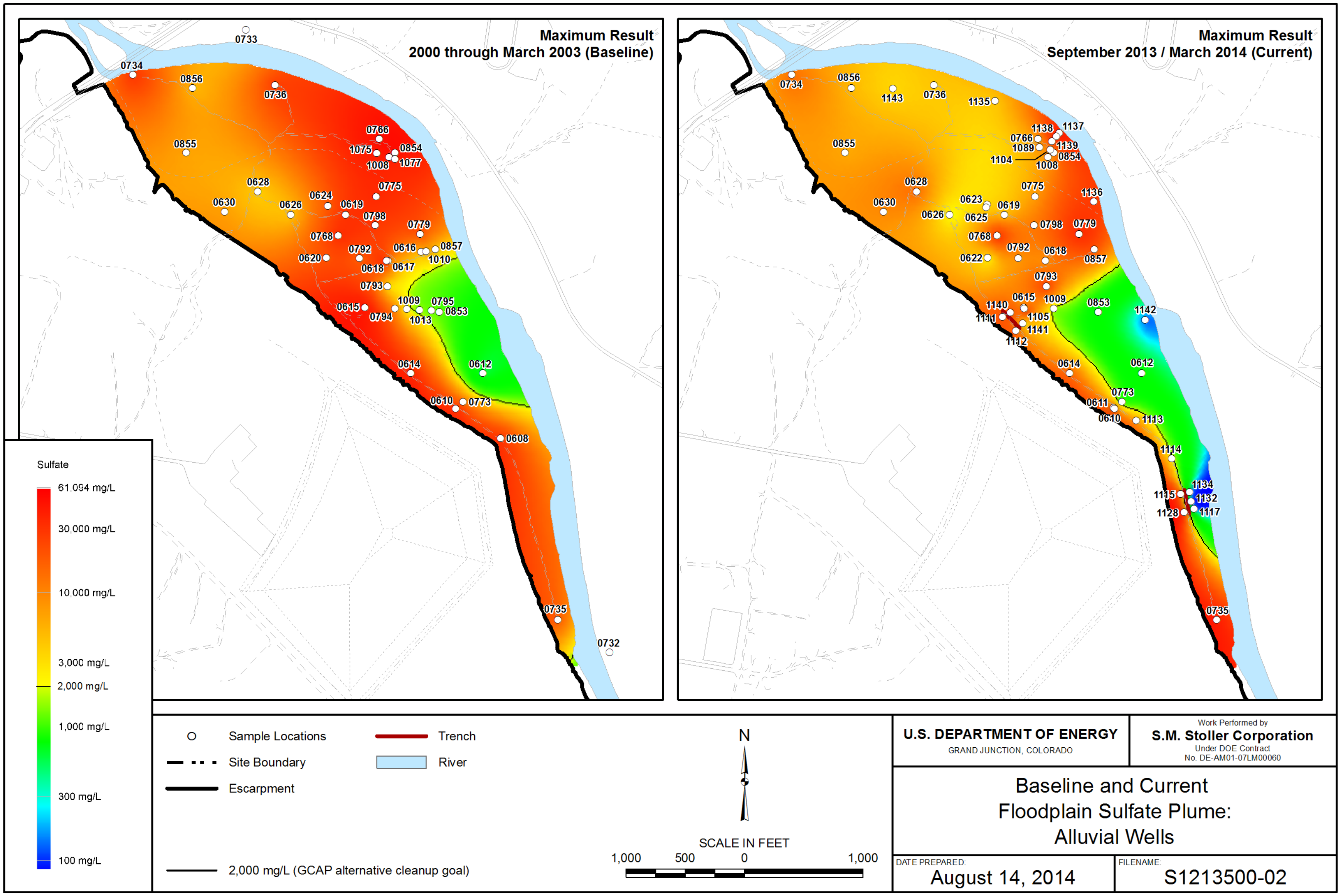

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Figure 5. Baseline (2000–2003) and September 2013 through March 2014 Floodplain Sulfate Plumes

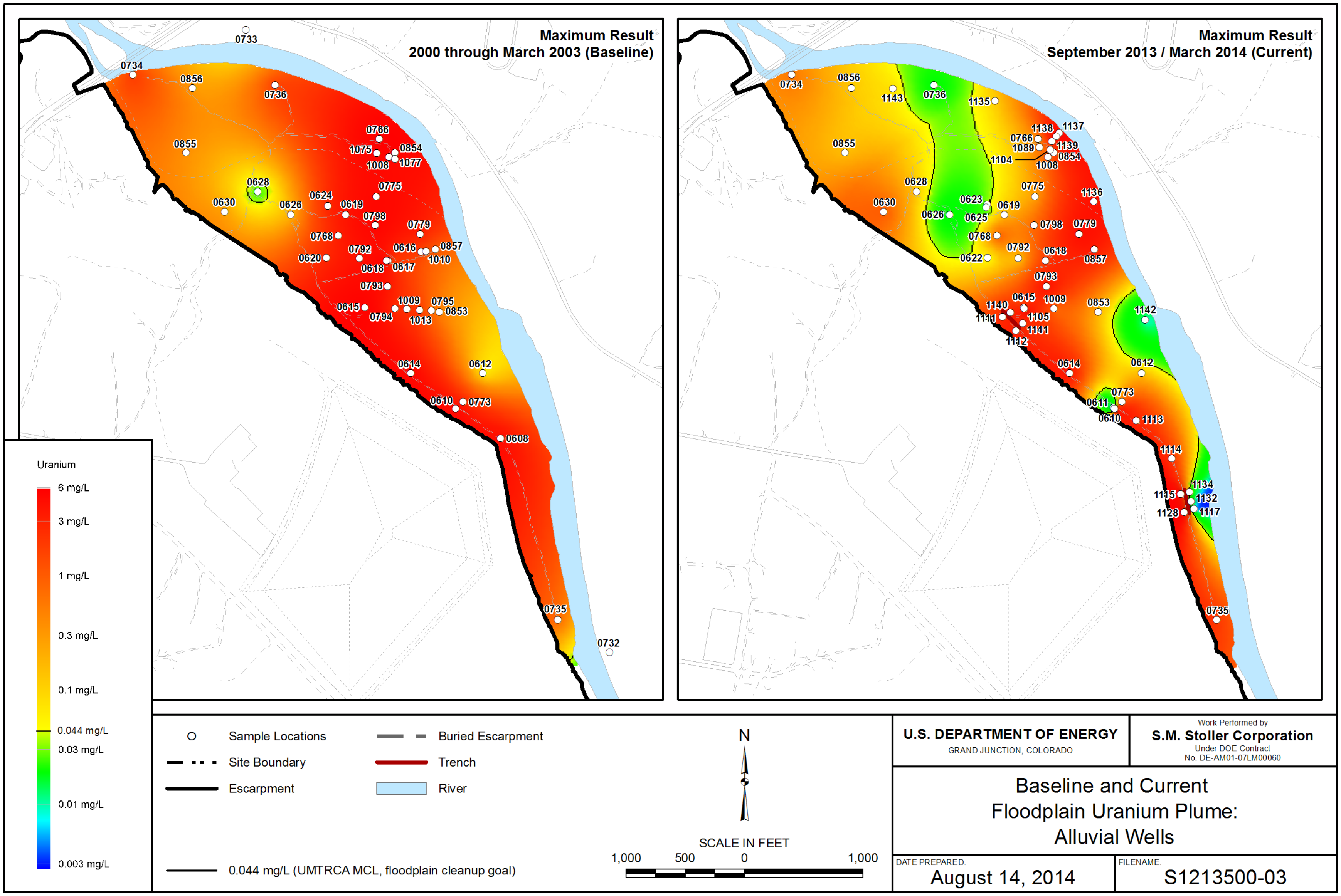

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Figure 6. Baseline (2000–2003) and September 2013 through March 2014 Floodplain Uranium Plumes

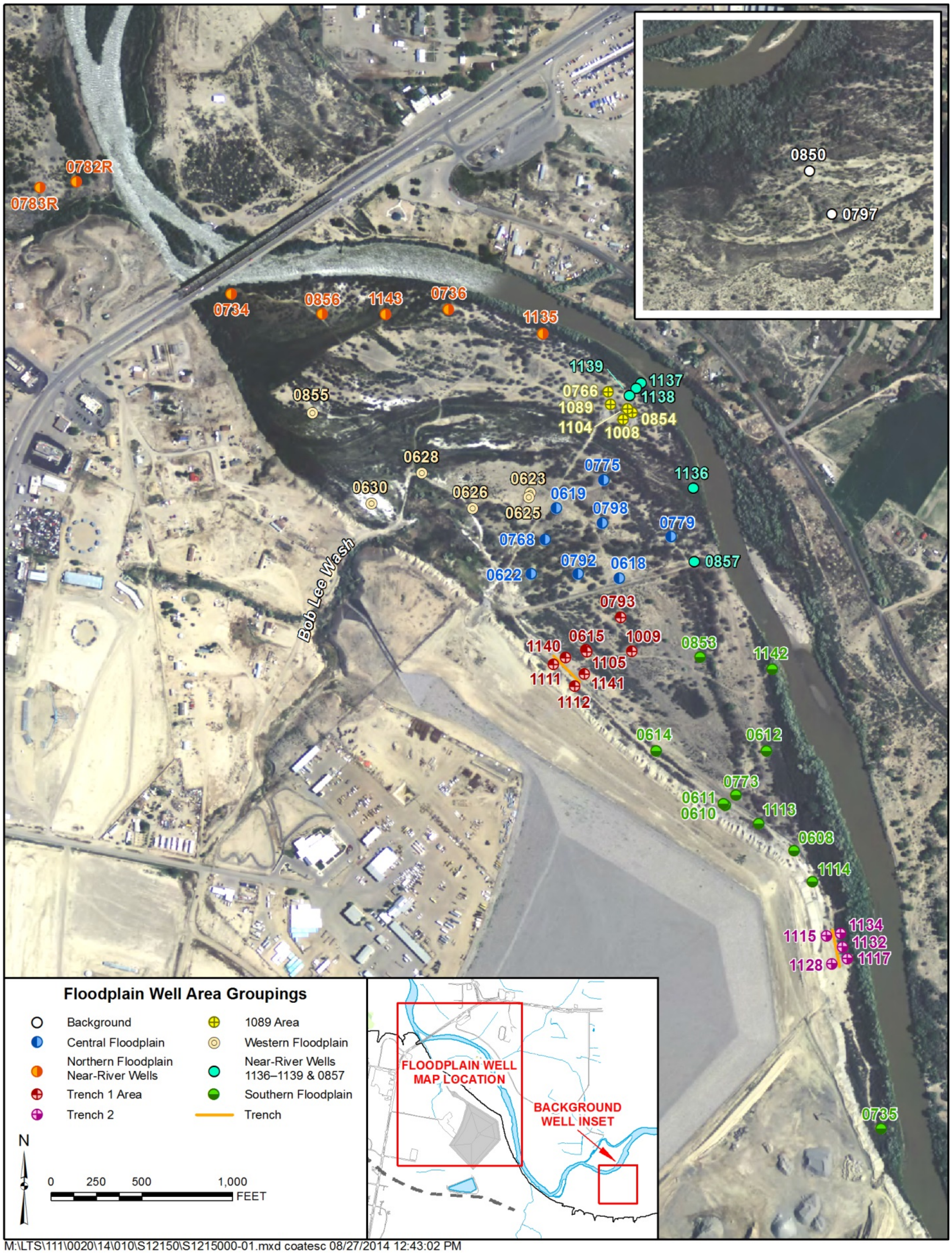

Figure 7. Shiprock Site Floodplain Area Well Groupings

3.2 San Juan River Monitoring

DOE regularly monitors eight San Juan River locations, including one upgradient background location. Between 2003 and March 2013, 0898 was the representative upgradient location. In 2014, surface location 0967 (Figure 2) was sampled instead for safety reasons. In the future, 0967 will be used as 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 2014b). BTV values are calculated using ProUCL version 5.0 as provided by the EPA and are revised each time additional background results are received and validated.

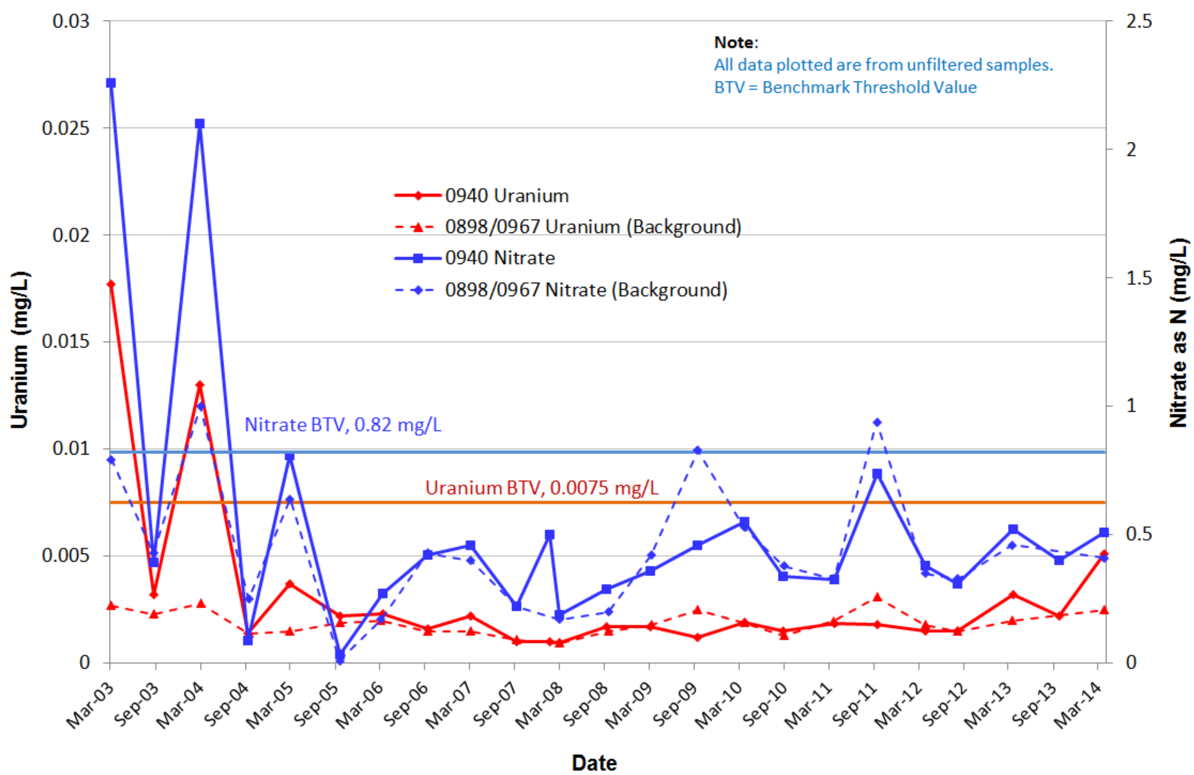

Figure 8. Uranium and Nitrate Concentrations in Samples from San Juan River Location 0940 and Background Locations

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. Uranium and nitrate concentrations at location 0940 have been below corresponding BTVs since 2004.

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 2014. 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

As of April 1, 2014, the cumulative volume of water removed from the terrace extraction system since pumping began was approximately 36 million gallons (Figure 3). Pumping records indicate that approximately 3.4 million gallons were removed from the terrace between April 2013 and April 2014 (Table 3). Groundwater level data from the terrace collected during the March 2014 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. To support the presentation in Figure 9, Figure 10 plots groundwater elevations in terrace alluvial wells (only), showing contours for both baseline (March 2003) and current (March 2014) periods. As has been the case in the last several annual reports, this figure demonstrates that groundwater elevations have declined across much of the terrace groundwater system. Of the 29 water level measurements taken in September 2013 or March 2014 at wells screened in alluvium beneath the terrace, the majority showed declines relative to the baseline period of March 2003. Declines ranged from 0.26 ft to maximum decreases of close to 9 ft in west terrace wells 0836 and 0837. The average decrease in terrace alluvial wells was about 2 ft.

Four alluvial west terrace wells (0832, 1060, 1120, and 1122) were dry at the time of the March 2014 sampling event. Southwest terrace wells 0832 and 1060 have 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.

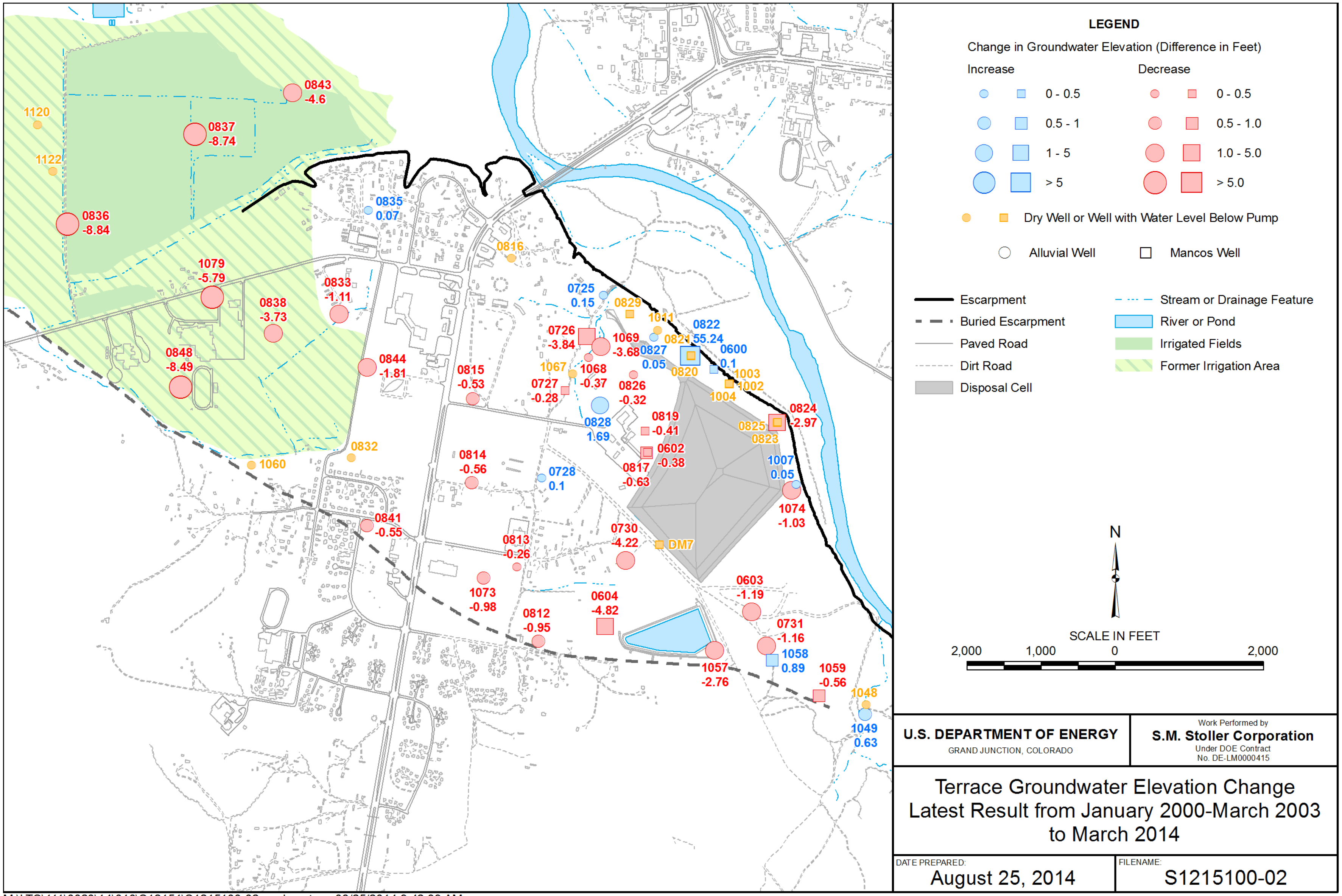

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Figure 9. Terrace Groundwater Elevation Changes from Baseline (2000–2003) to Current (March 2014) Conditions

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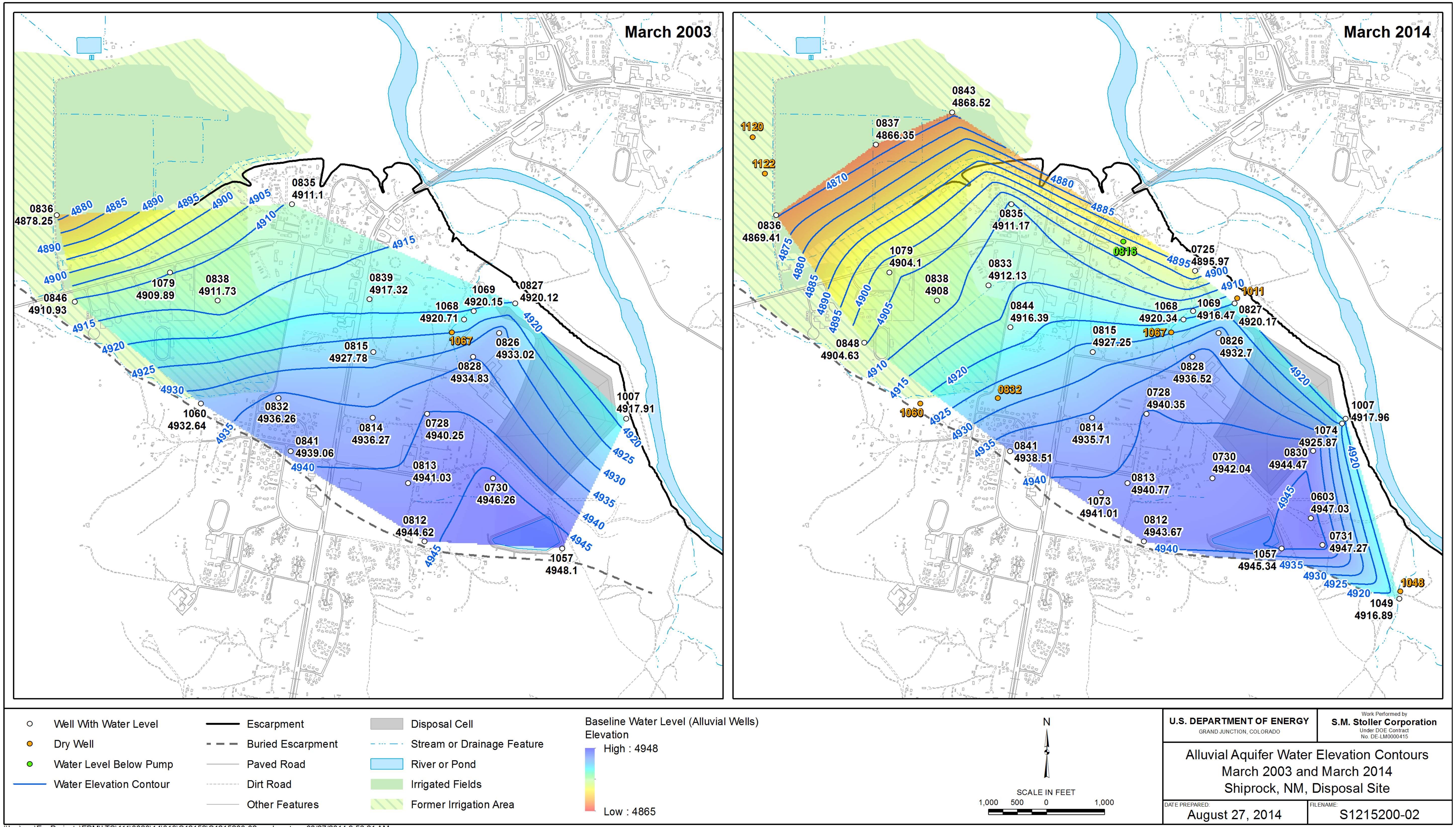

Figure 10. Groundwater Elevation Contours in Terrace Alluvial Wells: March 2003 (Baseline) vs. March 2014 (Current)

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4.0 Performance Summary

This section summarizes the findings of the most recent (April 2013 through March 2014) assessment of the floodplain and terrace groundwater remediation systems at the Shiprock site, marking the end of the 10th 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 12.3 million gallons of groundwater were extracted from the floodplain aquifer system during this performance period, yielding a cumulative total of about 107 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 wells. From April 2013 through March 2014, approximately 3.4 million gallons of groundwater were extracted from the terrace system, yielding a total cumulative volume (extracted since March 2003) of close to 36 million gallons. The cumulative volume removed from both terrace and floodplain combined (as of April 1, 2014) is just over 143 million gallons.
- 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 10); average and maximum decreases were 2.0 ft and 8.8 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 2014 sampling event. Also, many 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 688,350 pounds, 18,800 pounds, and 40 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. Based on monitoring results and findings documented in the Trench 2 evaluation (DOE 2009), 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. COC concentrations in central floodplain near-river wells 0857 and 1136−1139 have been variably increasing over the past few years, and this trend continued for some COCs during 2014. The increases over the past few years are being monitored and evaluated. Finally, COC concentrations in samples collected from the San Juan River are still below established benchmarks and are comparable to upstream (background) results.

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5.0 Recommendations

Based on the current status of remediation progress and recent monitoring results, DOE recommends the following activities to improve the performance and evaluation of the Shiprock remediation system and to minimize potential risks to human health and the environment.

- Continue to monitor the fluid level in the evaporation pond and operate the enhanced evaporation system as necessary to maintain sufficient freeboard. If necessary, temporarily cease pumping at Trenches 1 and 2 during periods of high snowmelt runoff in the river.
- Because pumping of the terrace alluvial aquifer has achieved the objectives proposed in the GCAP, namely that the terrace seeps are no longer posing a risk to human health and environment, develop a letter to NRC seeking concurrence to cease active remediation of the terrace alluvial aquifer, consistent with the GCAP. Concurrent with this action, continue active treatment to enhance the flushing of the floodplain alluvial aquifer.
- Implement a number of recommendations cited in the recently issued report *Optimization of Sampling at the Shiprock, New Mexico, Site* (DOE 2013b).
- Solicit concurrence from NRC to initiate annual, rather than semiannual, groundwater monitoring of the Shiprock site, consistent with the scheduled long-term monitoring frequency presented in the GCAP.
- The production rate from wells 1070, 1071, 1091, and 1092 does not and has not exceeded 0.1 gpm, the minimum production to be considered an aquifer under 10CFR192; therefore, additional pumping from these wells is unwarranted.
- The intercepted discharge from Many Devils Wash possibly comprises a portion of the natural base flow. At 0.07 gpm it does not meet the definition of an aquifer under 40CFR192 and further pumping from this interceptor drain is unwarranted.

DOE continues to underscore the importance of institutional controls and seeks cooperation and assistance from the Navajo Nation Environmental Protection Agency, the Navajo Nation Department of Justice, and the Navajo UMTRA Office to maintain protection of human health and the environment.

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6.0 References

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Appendix A

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

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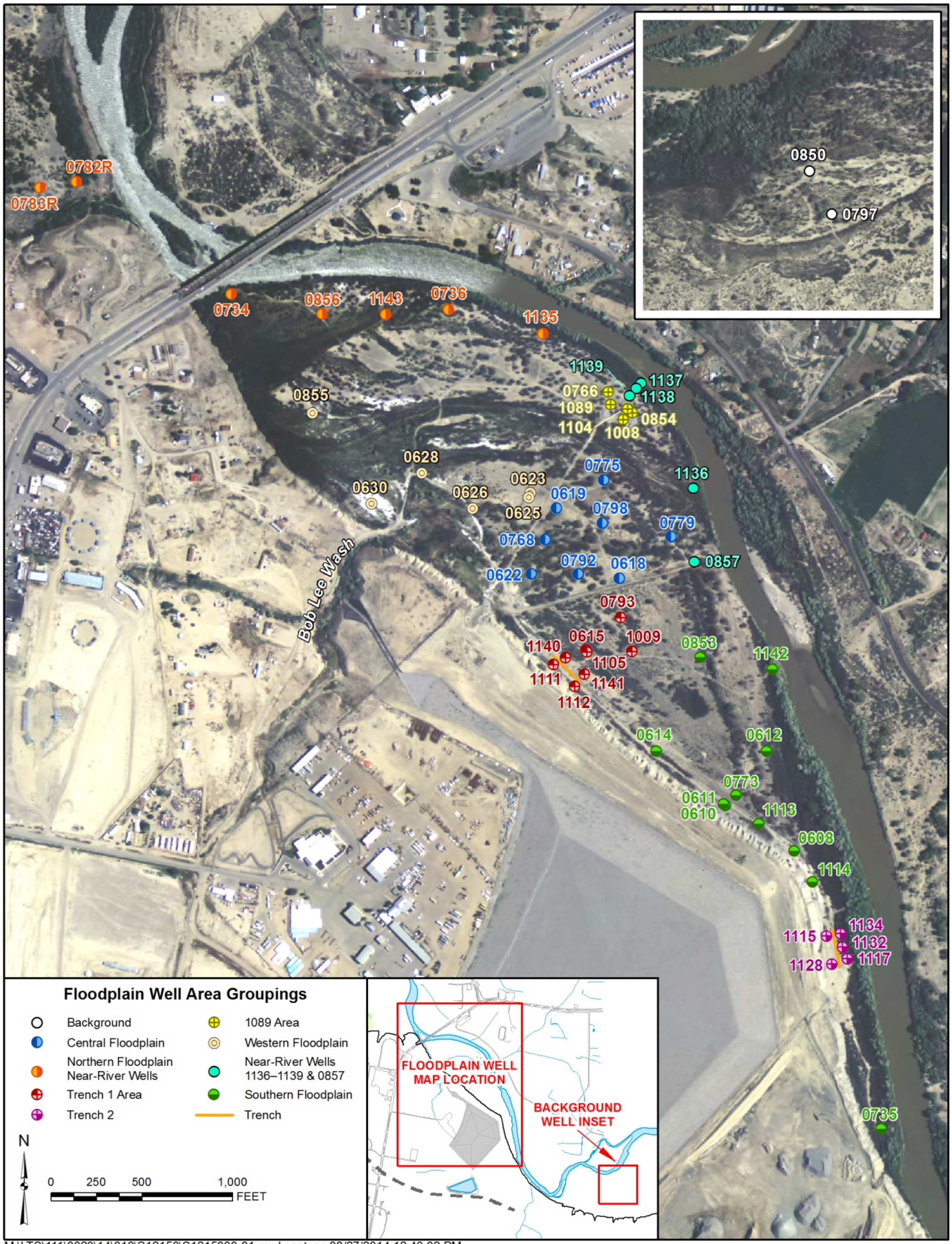
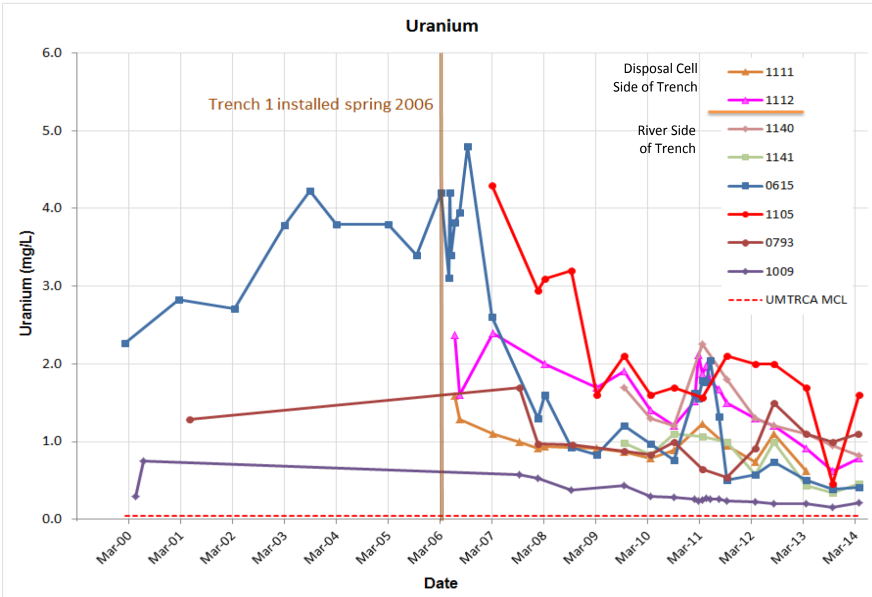
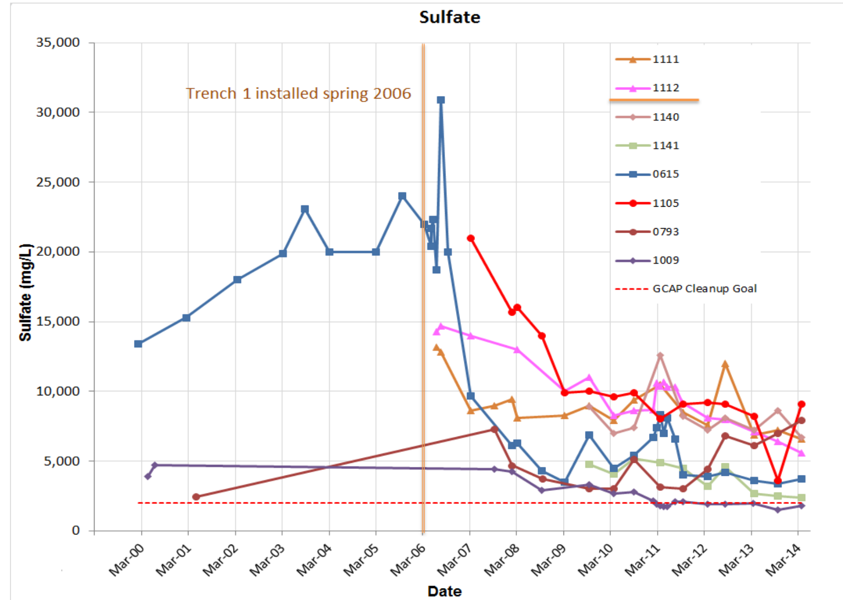
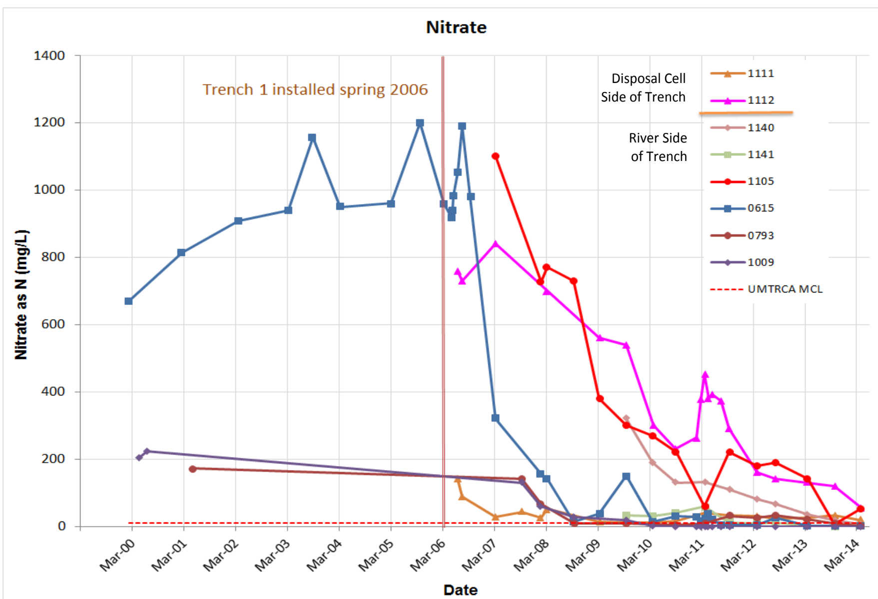


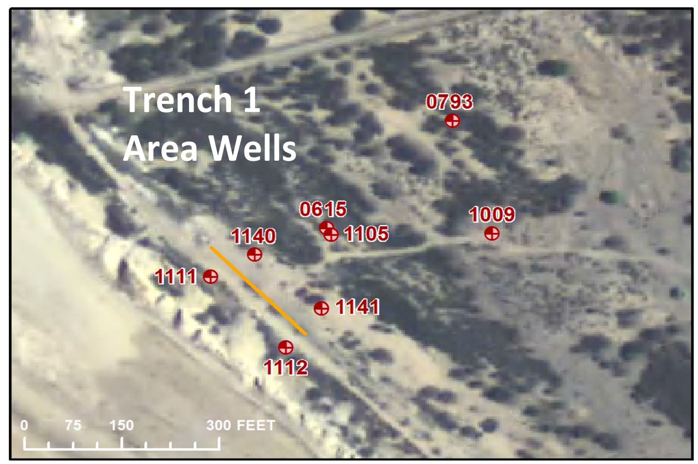
Figure A-1. Shiprock Site Floodplain Well Groupings

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



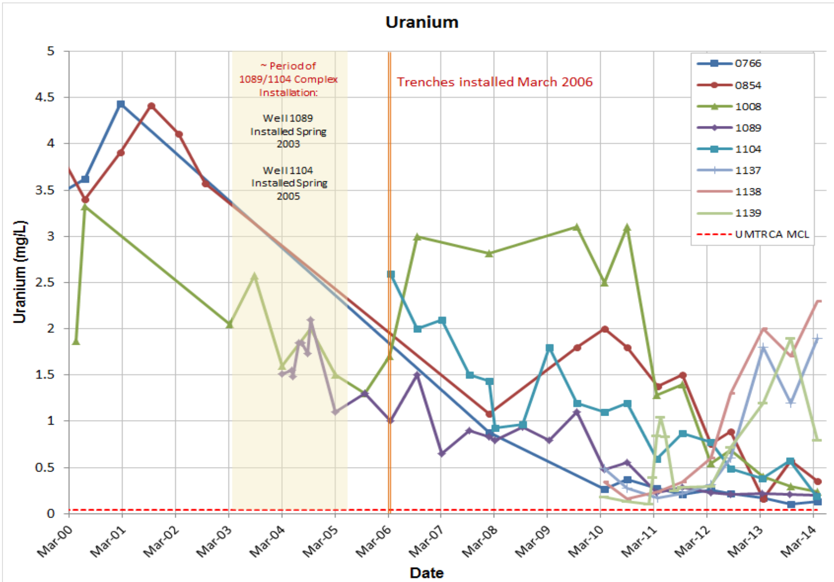


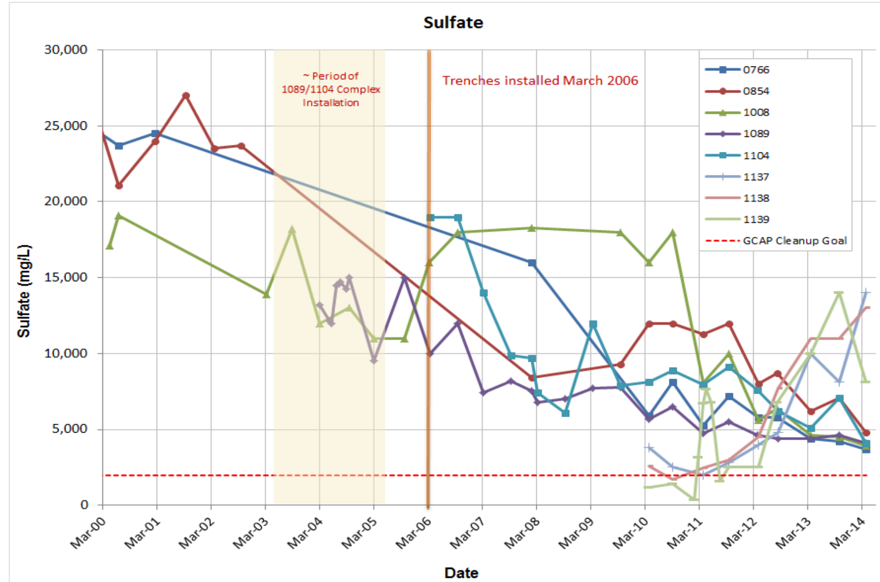


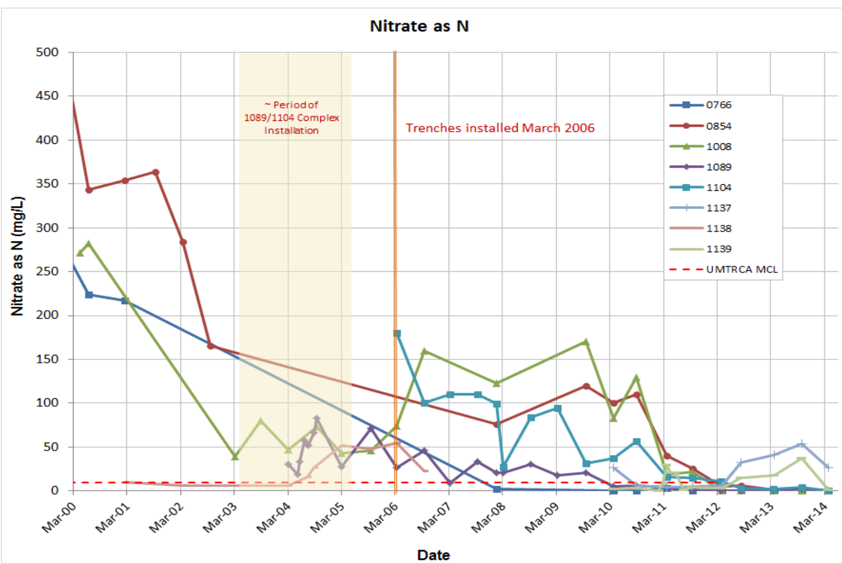


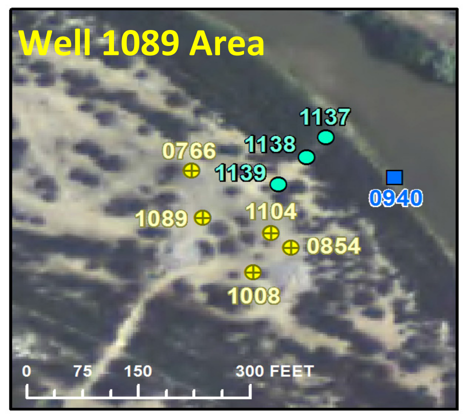
Note:
In each plot legend, wells are listed in order of increasing distance from the disposal cell—e.g., wells 1111 and 1112, on the disposal cell side of the trench, are listed first.

Figure A-2. Uranium, Nitrate, and Sulfate Concentration Trends in Trench 1 Area Wells



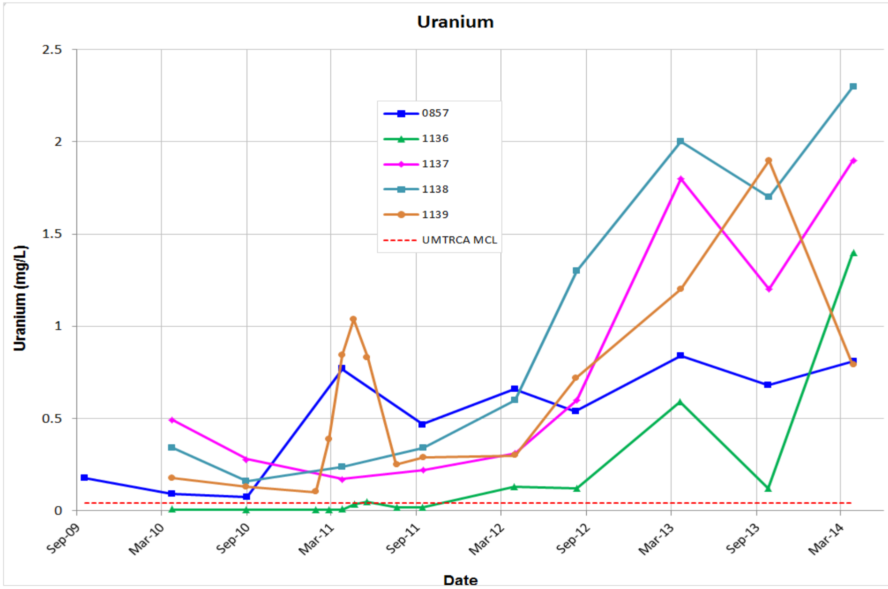


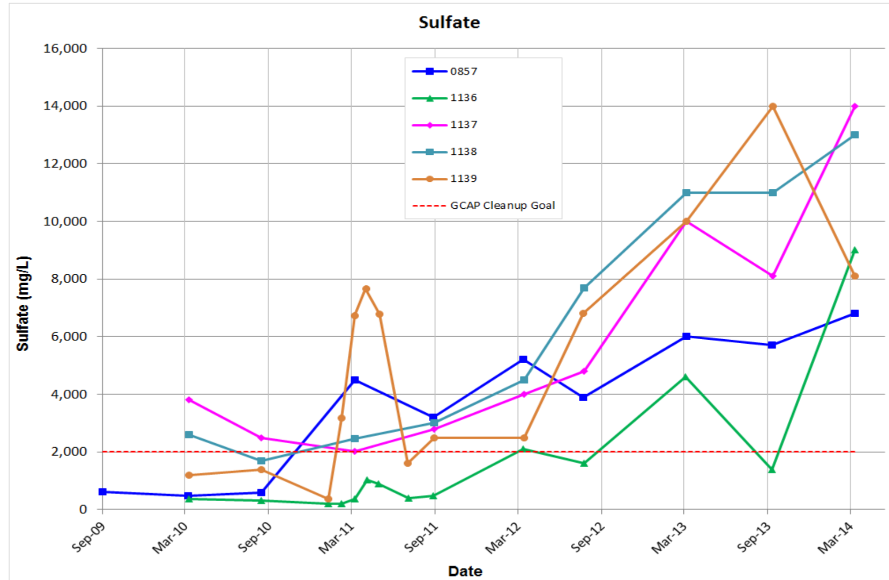


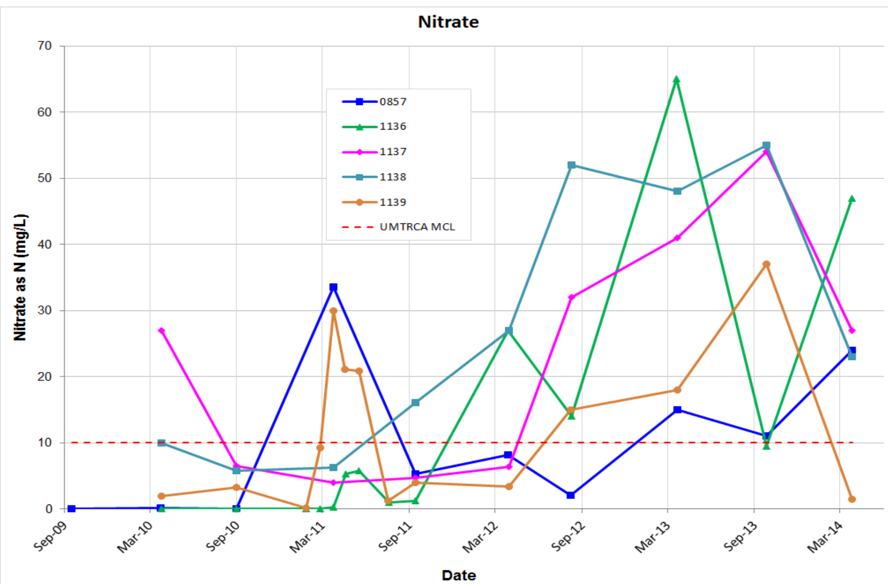


Note:
In addition to wells in the immediate vicinity of the well 1089 area, this inset also shows the locations of nearby wells 1137, 1138, and 1139. Although data from these wells are also plotted in Figure A-4 (near-river wells), they are shown here to allow comparison of trends with nearby 1089 area pumping wells. Sample point 0940 (■), also shown, is the nearest San Juan River monitoring location (see Figure 8 of main report).

Figure A-3. Uranium, Nitrate, and Sulfate Trends in the Well 1089 Area

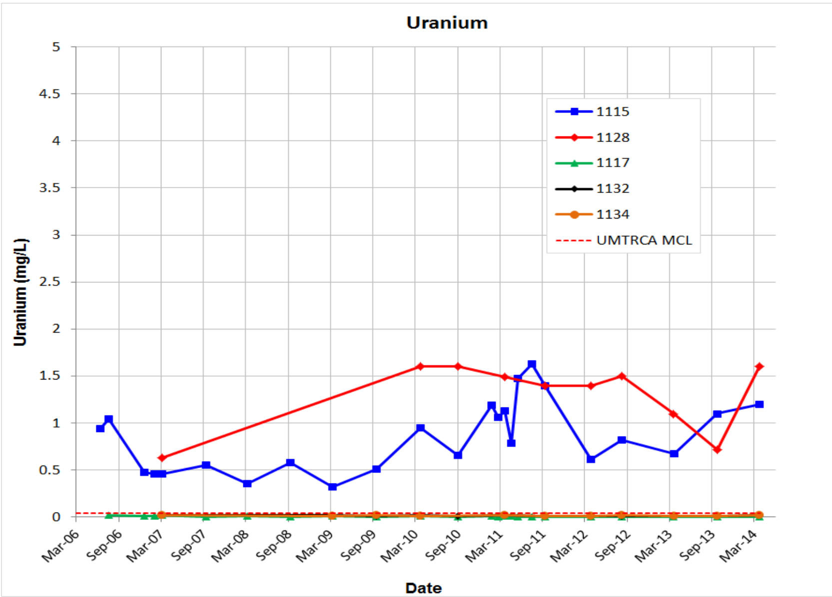


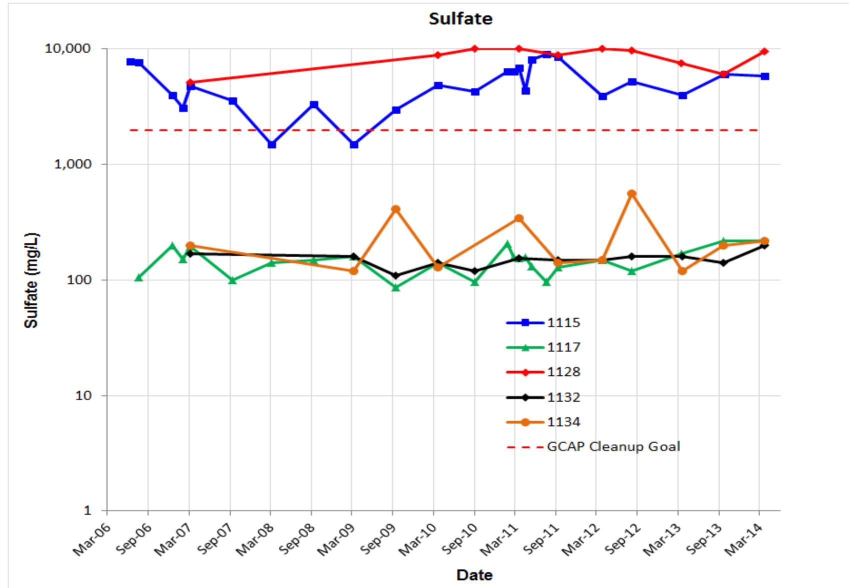


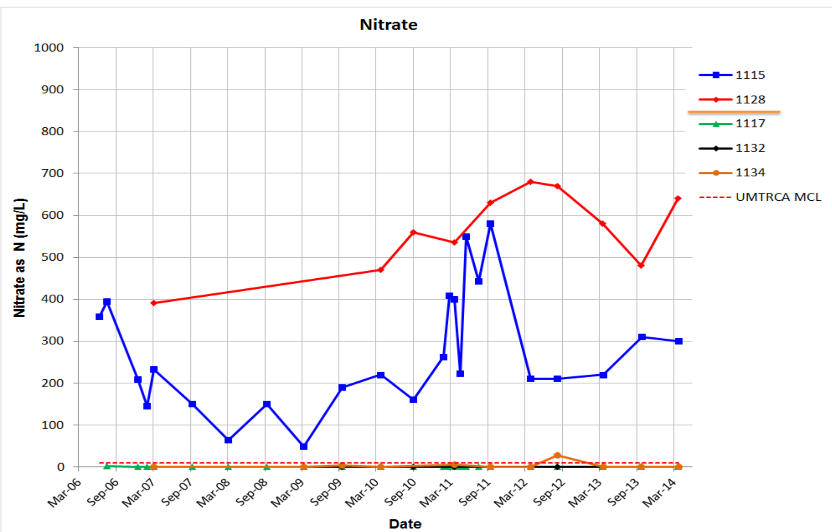


Note:
These near-river wells were grouped separately because of recent increases in contaminant concentrations in the last few years, in particular uranium and sulfate. Data for wells 1137, 1138, and 1139 are also plotted in the preceding figure (Figure A-3) given proximity to 1089 area pumping wells.

Figure A-4. Uranium, Sulfate, and Nitrate Trends in Near-River Wells 1136–1139 and 0857

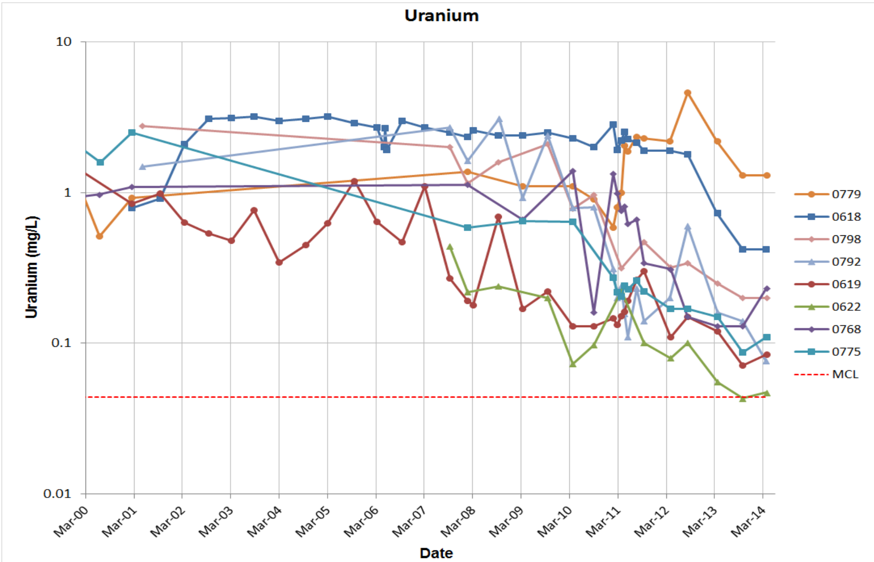


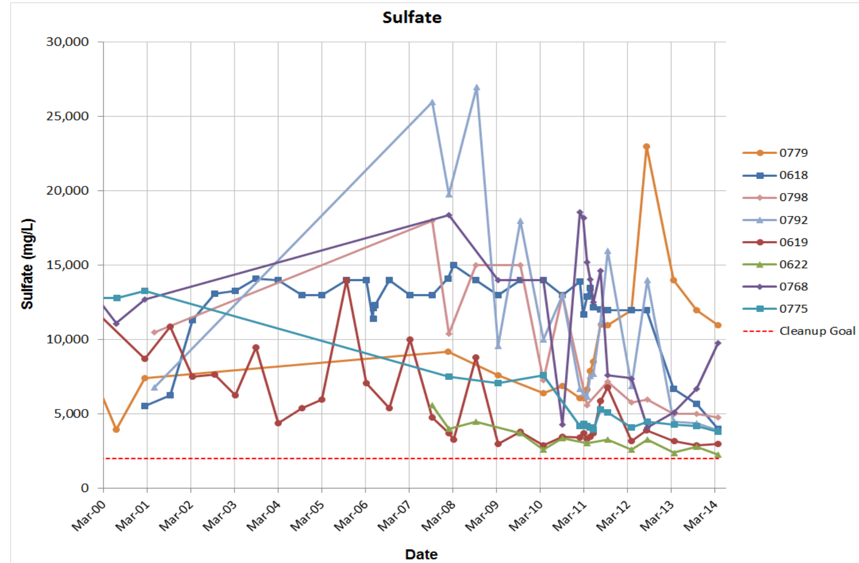


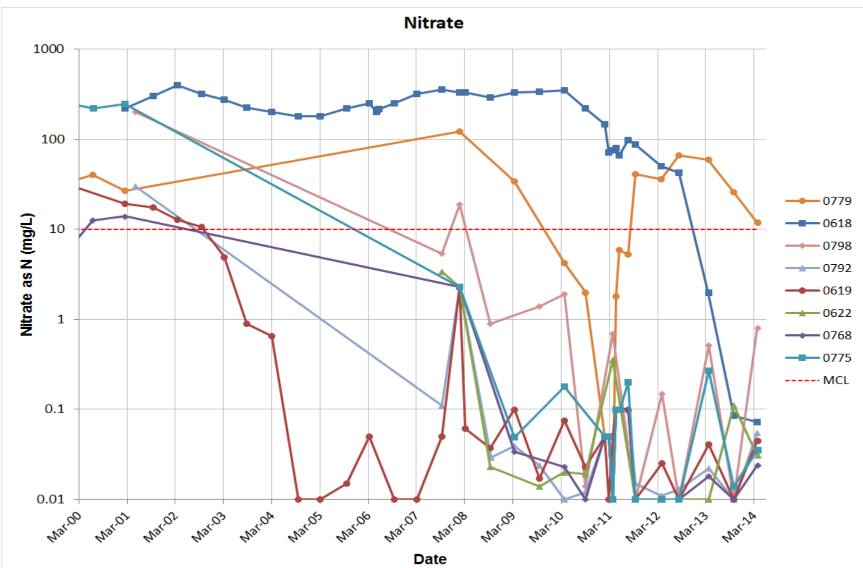


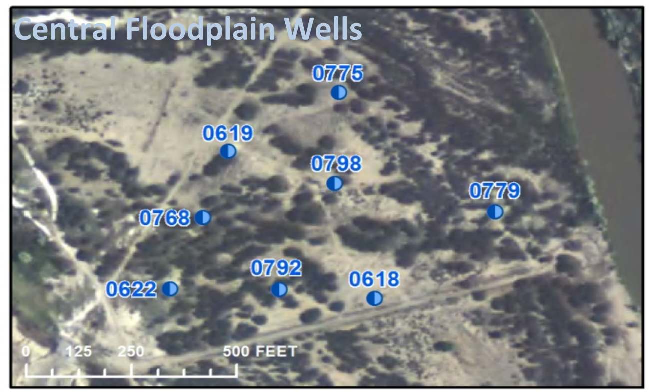
Note:
COC concentrations in wells on the river side of the trench have been below corresponding compliance standards except for the Aug-2012 nitrate result (28 mg/L). Given the discrepancies between COC magnitudes for western vs. eastern trench 2 wells, graphs here are presented in log scale (base 10).

Figure A-5. Uranium, Nitrate, and Sulfate Trends in Trench 2 Area Wells



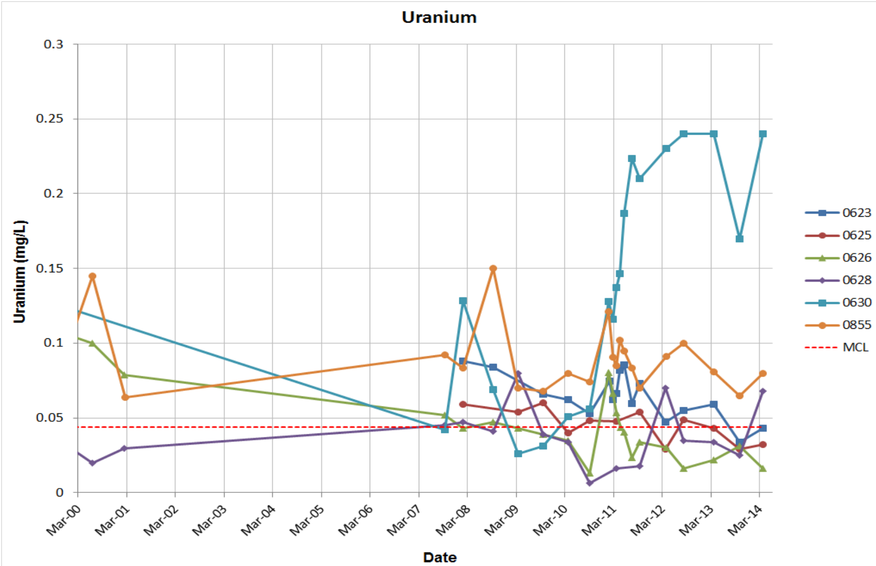


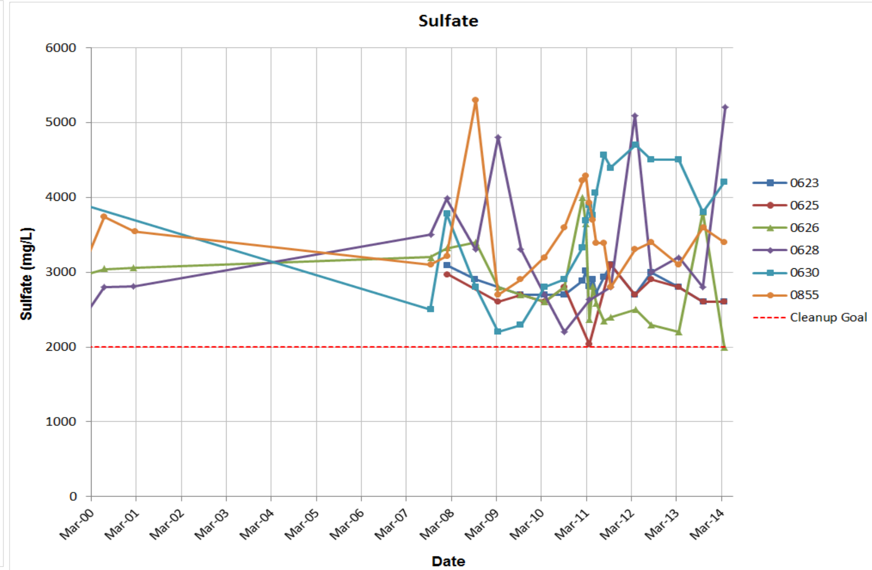


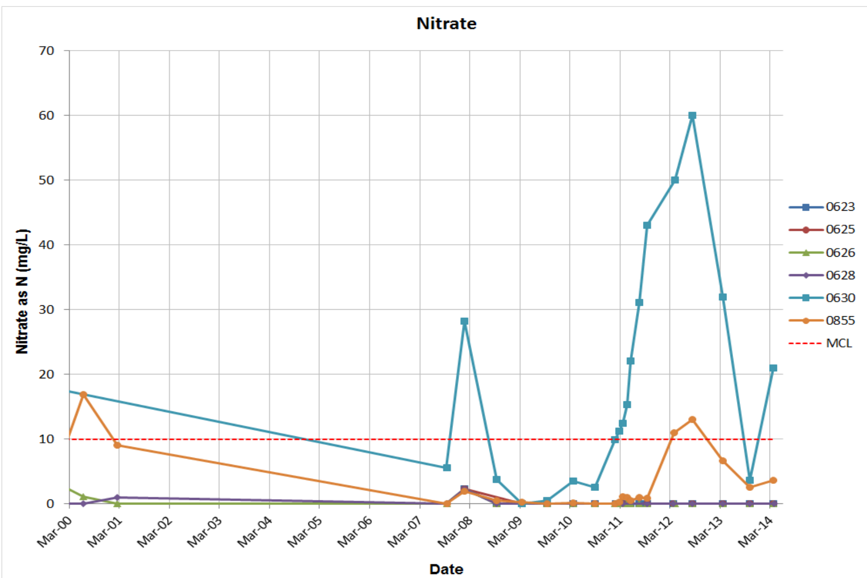


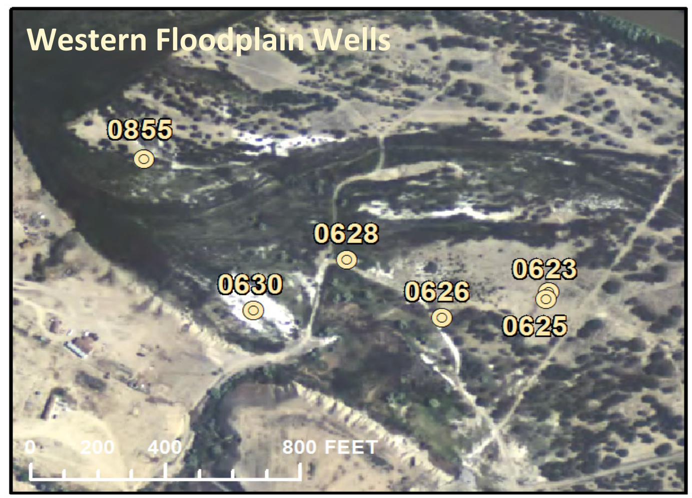
Note:
As shown in these plots, contaminant concentrations in central floodplain wells have varied widely. Because of this variation, results for uranium and nitrate are plotted in log scale. In each figure, the wells with the highest historical COC concentrations (0779, 0618, 0798, and 0792) are listed first in the legend.

Figure A-6. Uranium, Nitrate, and Sulfate Trends in Central Floodplain Wells



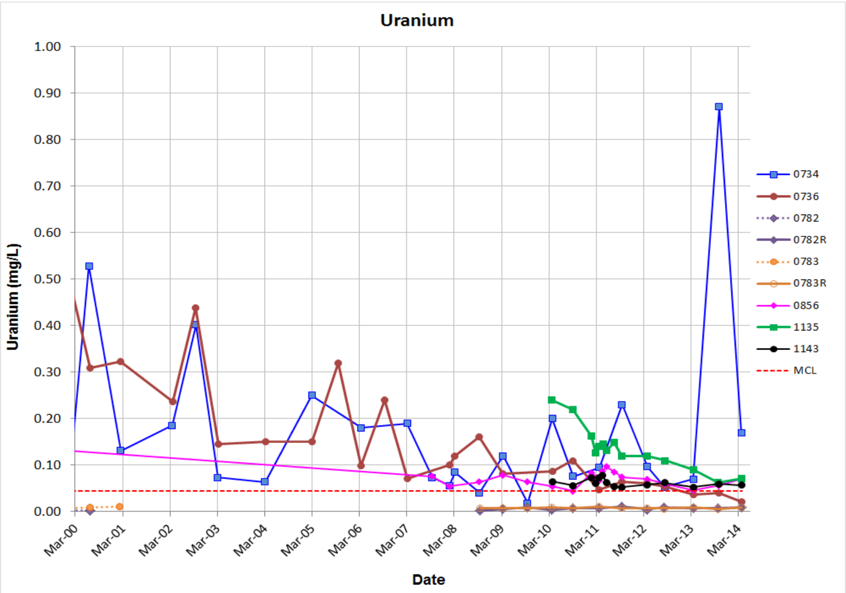


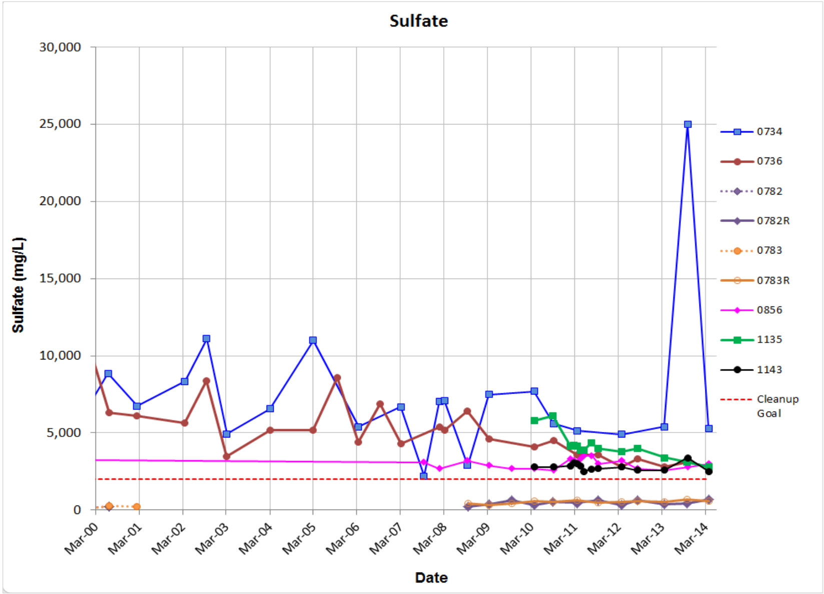


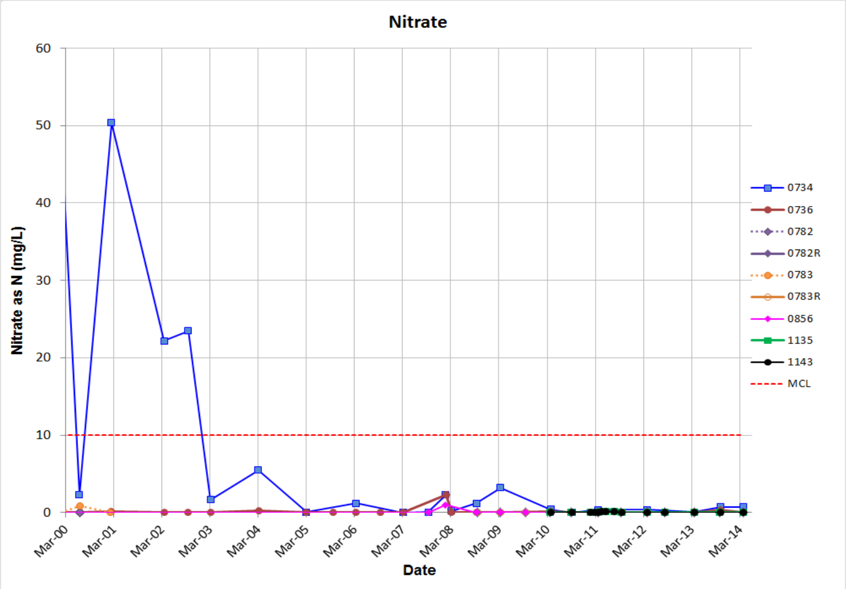


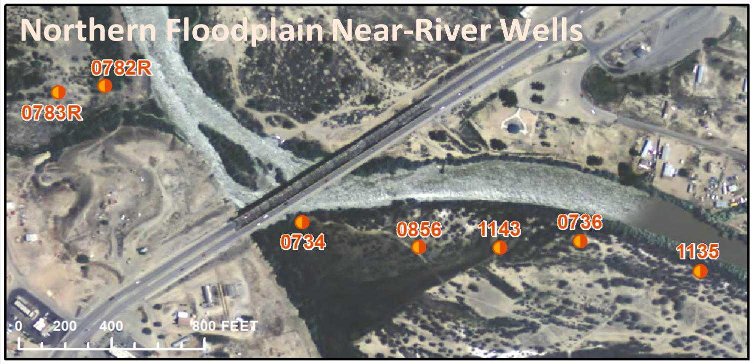
Note recent increases in uranium and sulfate concentrations in well 0630 at base of Bob Lee Wash.

Figure A-7. Uranium, Nitrate, and Sulfate Trends in Western Floodplain Wells



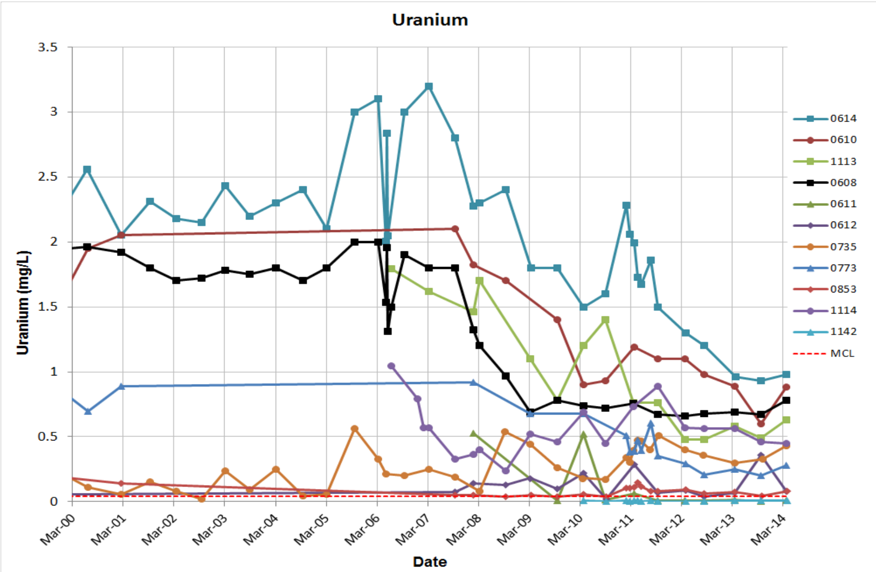


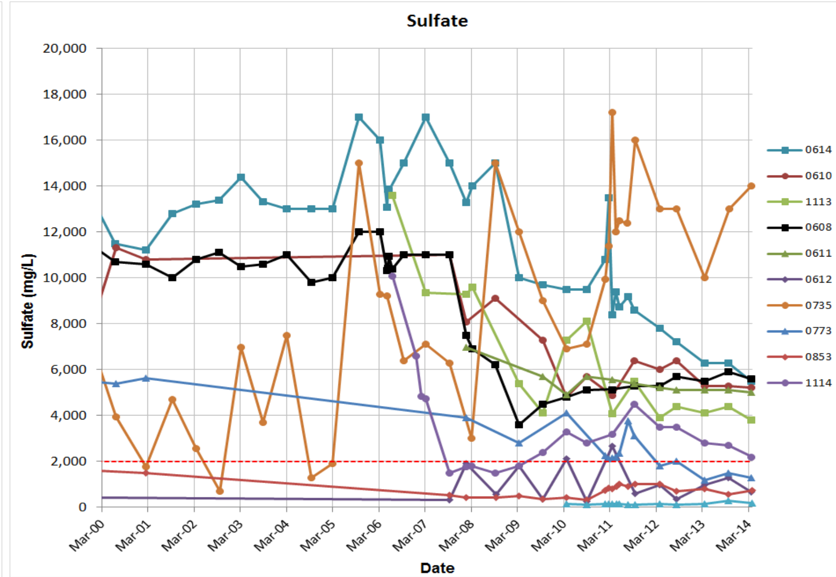


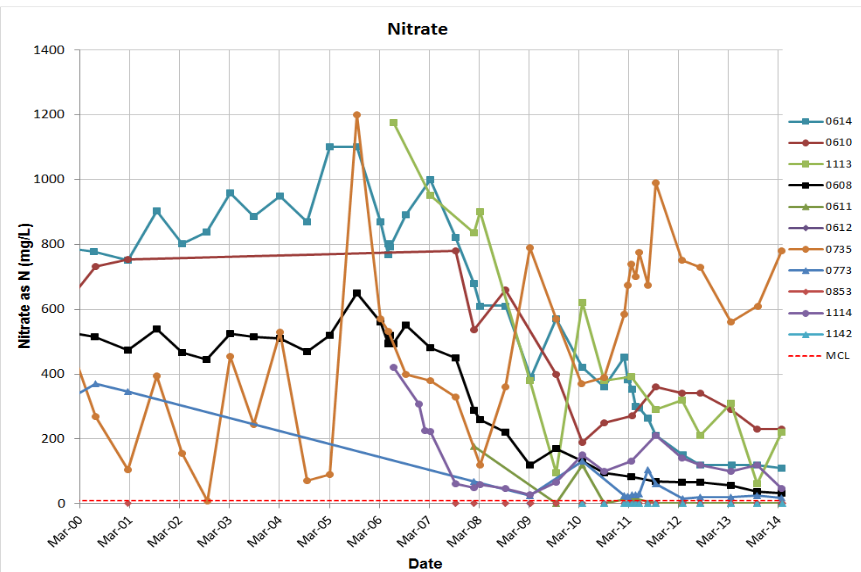


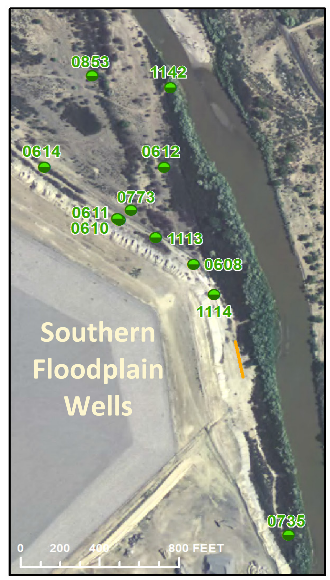
Note:
As shown in the uppermost plots, trends for sulfate and uranium in this subset of floodplain wells are very similar. Levels of these two COCs have fluctuated widely in shallow (7-ft deep) well 0734. The reason for the spike in sulfate and uranium in September 2013 is not known at this time. Apart from elevated levels prior to 2003, nitrate concentrations in all wells in this region have been well below the 10 mg/L MCL. Concentrations of all COCs in westernmost wells 0782(R) and 0783(R) have historically been well below GCAP compliance goals or standards.

Figure A-8. Uranium, Nitrate, and Sulfate Trends in Northern Floodplain Near-River Wells







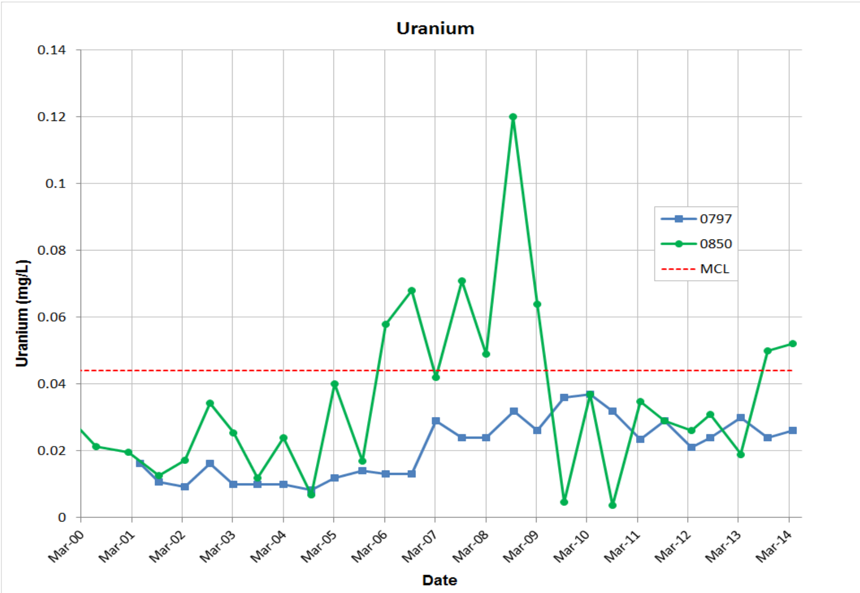


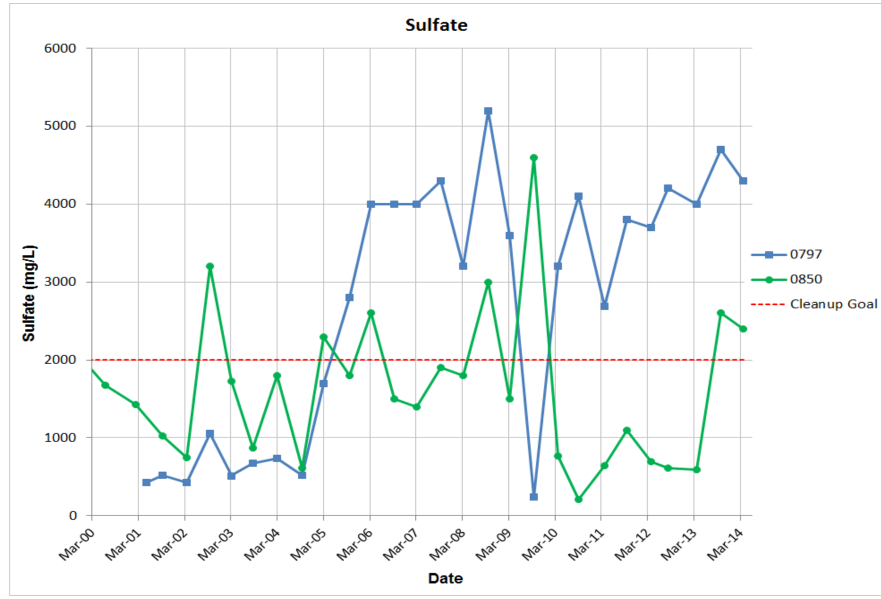
Note:
In each figure, the wells with the highest historical uranium concentrations—0614, 0610, 1113, and 0608, all at the base of the escarpment—are listed first in the legend.

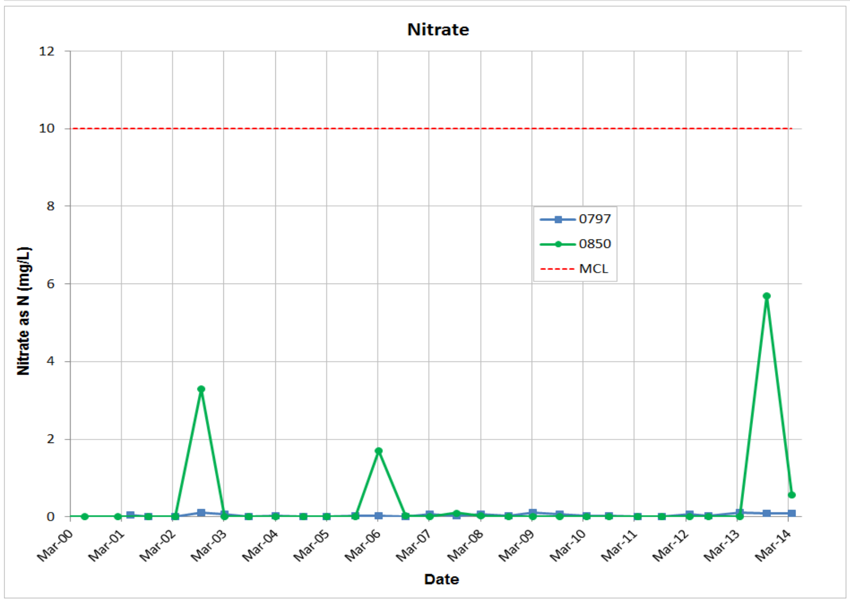
COC concentrations in this region are highest in wells at the base of the escarpment. Those in more distal wells (0612, 0853, and 1142) are much lower. COC concentrations in well 1142 closest to the San Juan River have been well below compliance standards or goals.

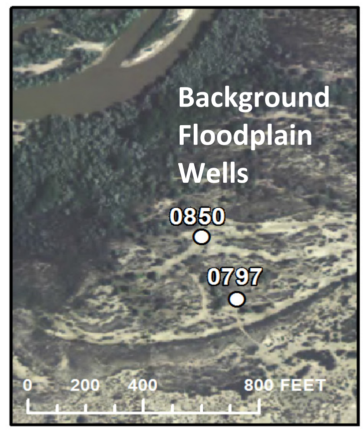
Sulfate and nitrate concentrations in southernmost well 0735 have fluctuated widely. The reason for recent increases is not known.

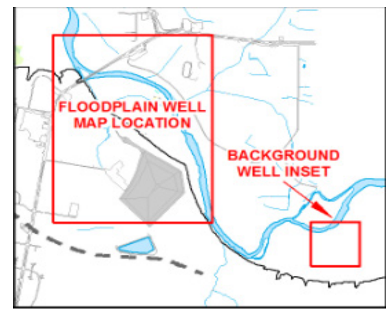
Figure A-9. Uranium, Nitrate, and Sulfate Trends in Southern Floodplain Wells











Note:
Uranium concentrations in well 0850 have at times, including the last two sampling rounds, exceeded the 0.044 mg/L UMTRCA standard. Sulfate concentrations in well 0797 have fluctuated widely and since 2006 have exceeded the 2000 mg/L cleanup goal. Nitrate concentrations in both wells have been below the 10 mg/L MCL.

Figure A-10. Uranium, Nitrate, and Sulfate Trends in Background Floodplain Wells

Appendix B

Hydrographs for Terrace Alluvial Wells

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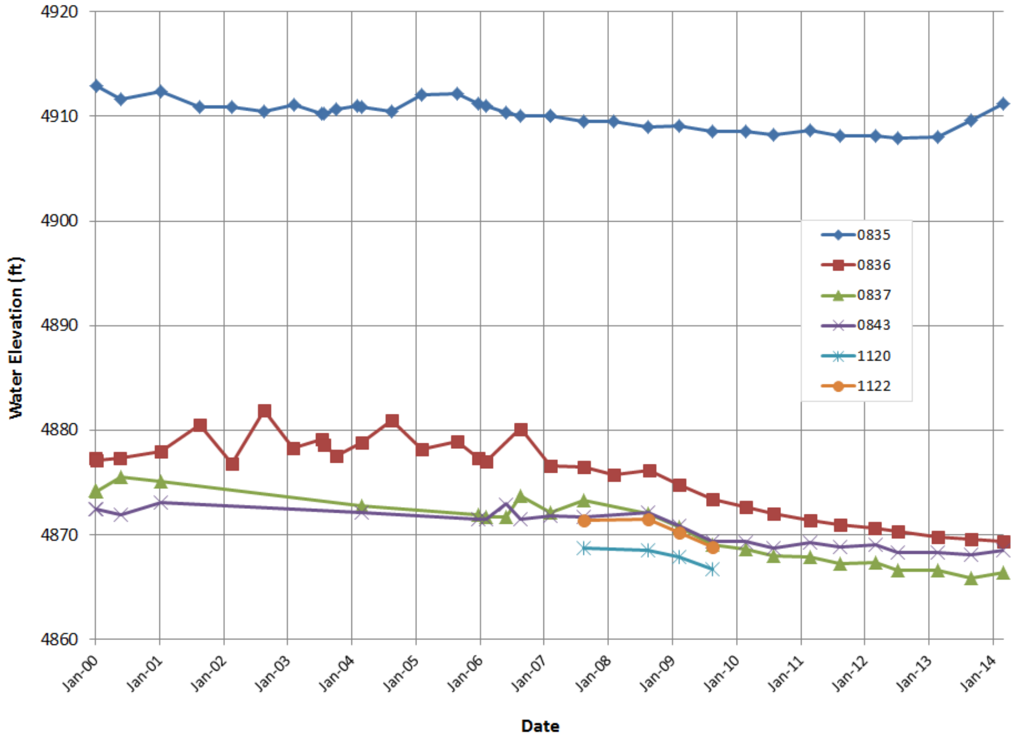


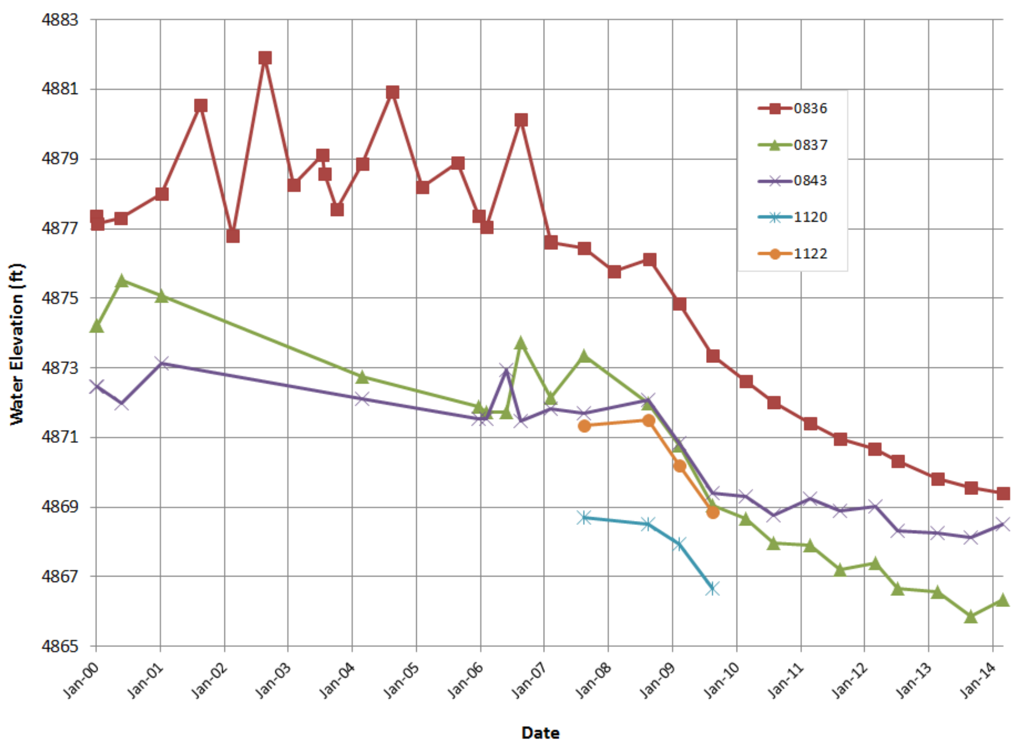
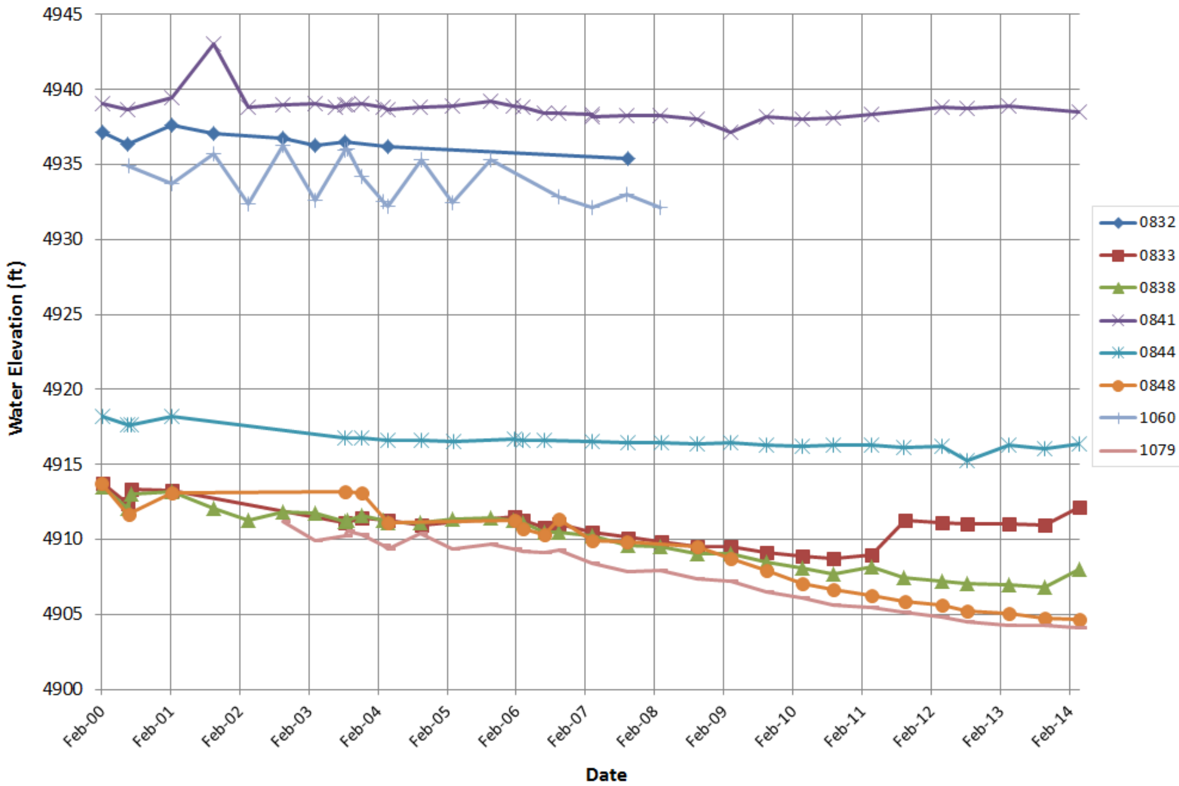


Figure B-1. Hydrographs for Northwest Terrace Alluvial Wells North of Highway 64

Upper plot shows all wells in this area; lower plot excludes well 0835 for scaling purposes. Wells 1120 and 1122 have been dry since September 2009.



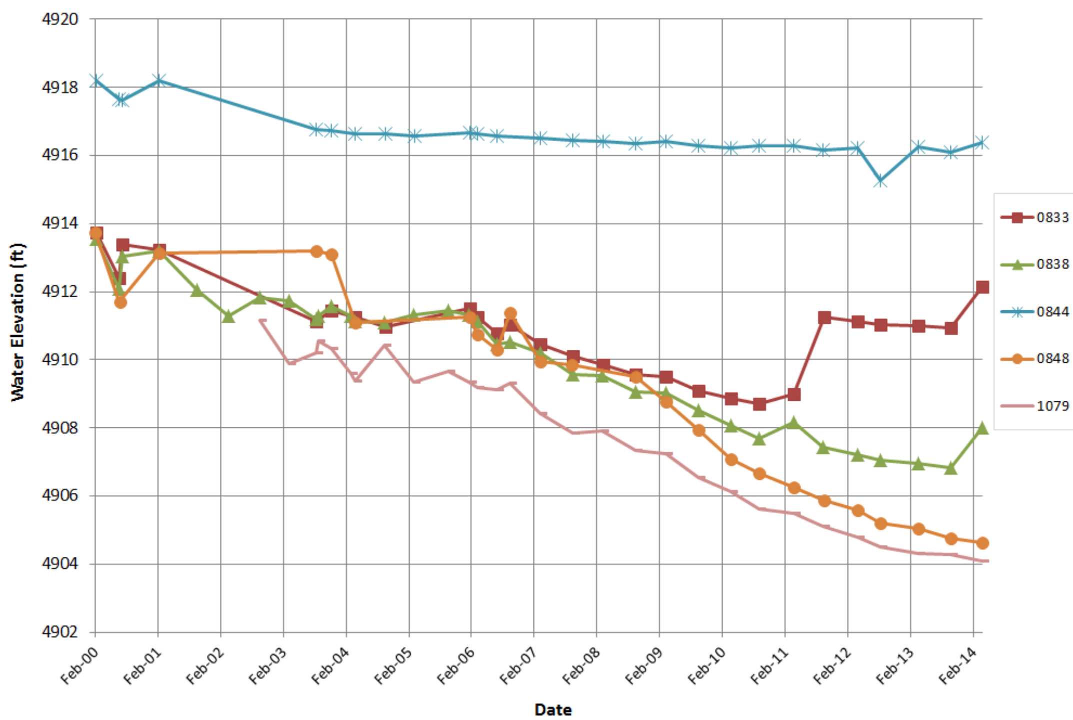


Figure B-2. Hydrographs for Southwest Terrace Alluvial Wells South of Highway 64 and West of Highway 491

Upper plot shows all wells in this area; lower plot excludes wells with elevations >4,920 ft.

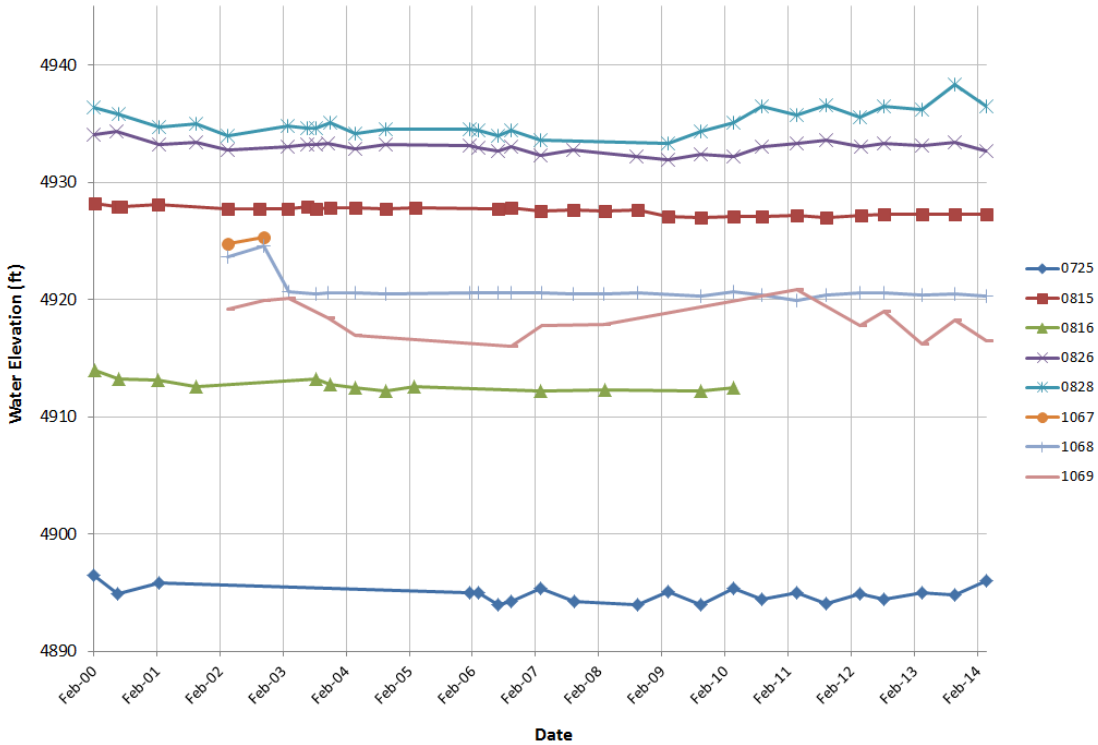


Figure B-3. Hydrographs for Terrace Alluvial Wells West of the Disposal Cell

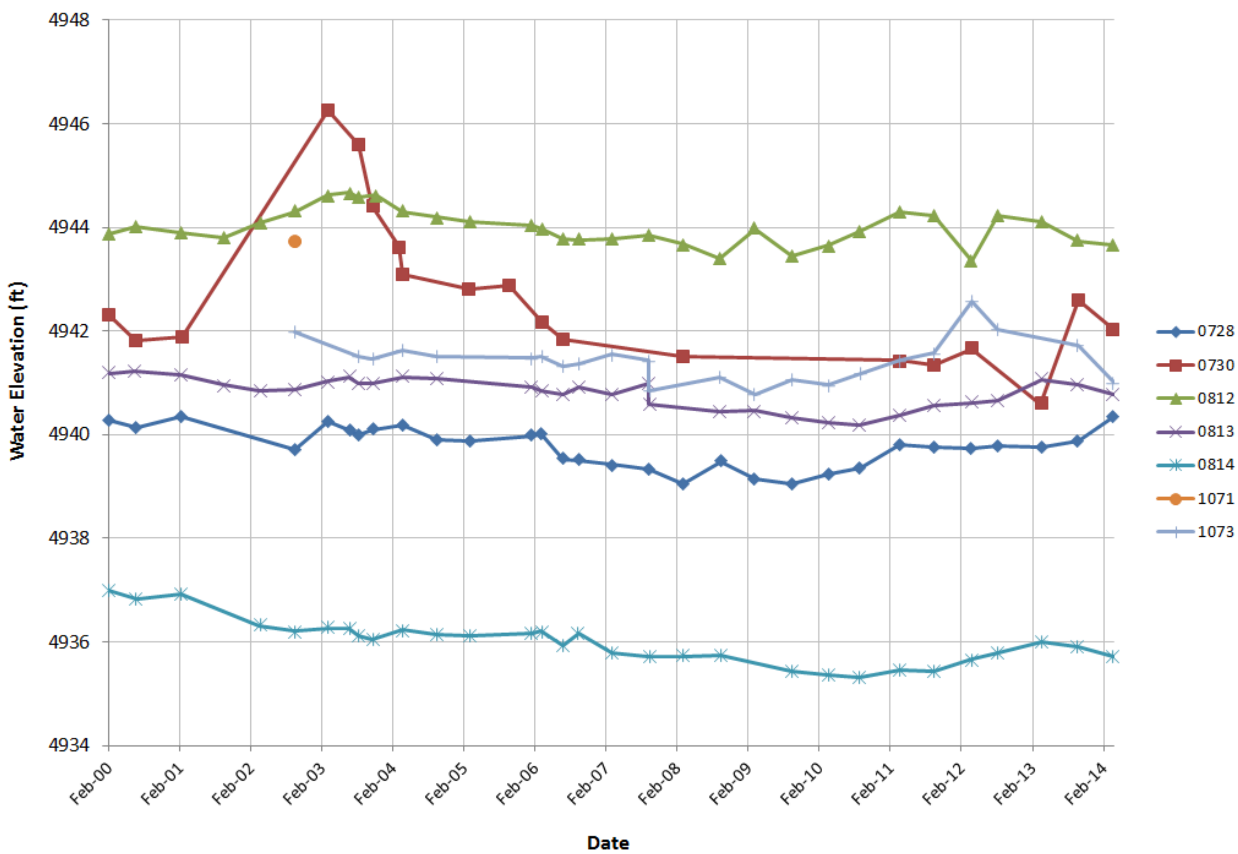


Figure B-4. Hydrographs for Terrace Alluvial Wells in Borrow Pit and Swale Area

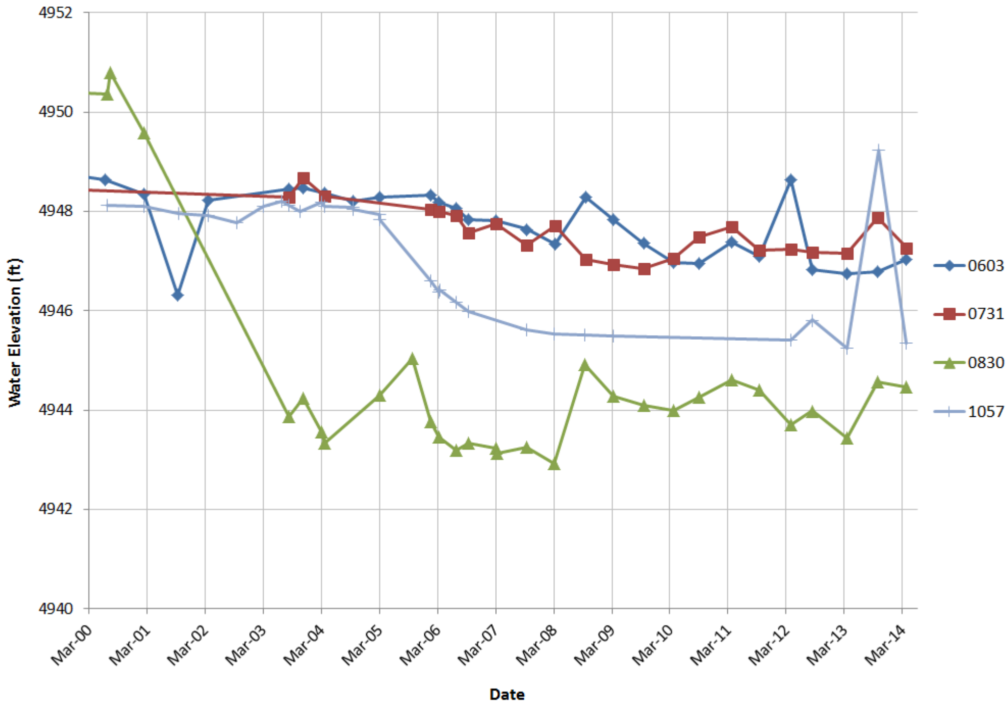


Figure B-5. Hydrographs for Terrace Alluvial Wells East of the Disposal Cell and Evaporation Pond: Wells with Water Elevations above 4,940 ft msl

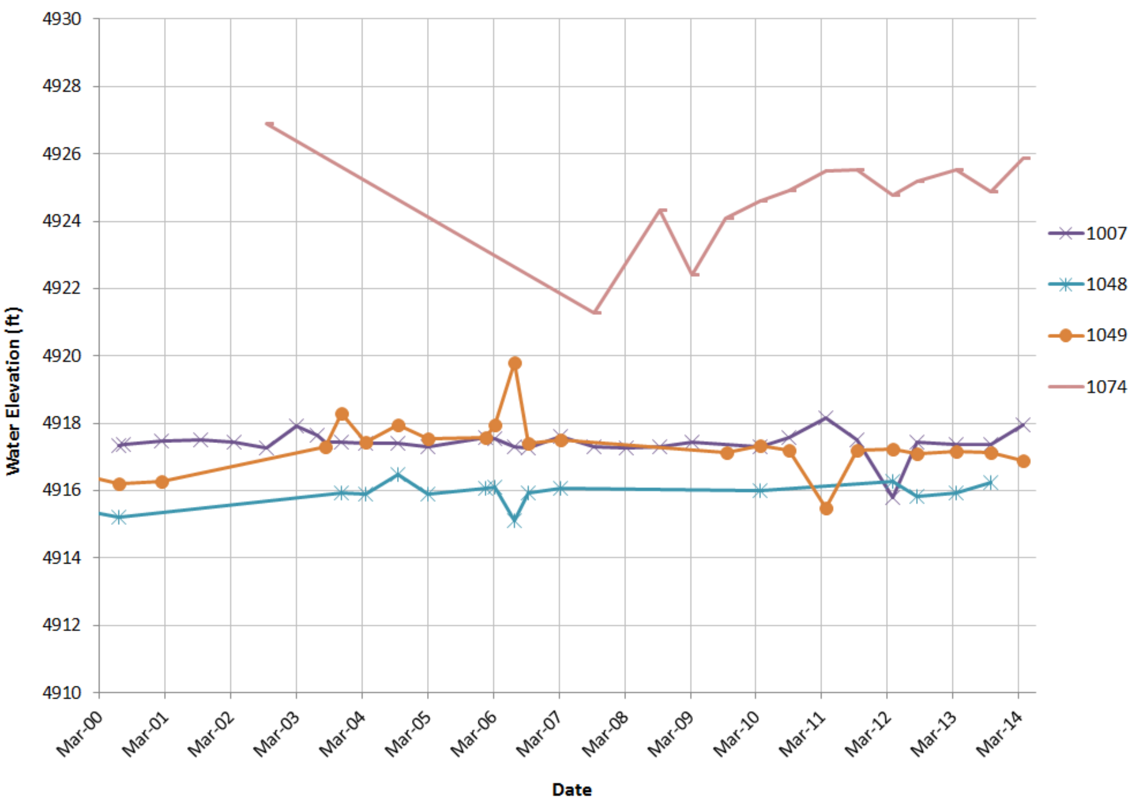


Figure B-6. Hydrographs for Terrace Alluvial Wells East of the Disposal Cell and Evaporation Pond: Wells with Water Elevations less than 4,940 ft msl

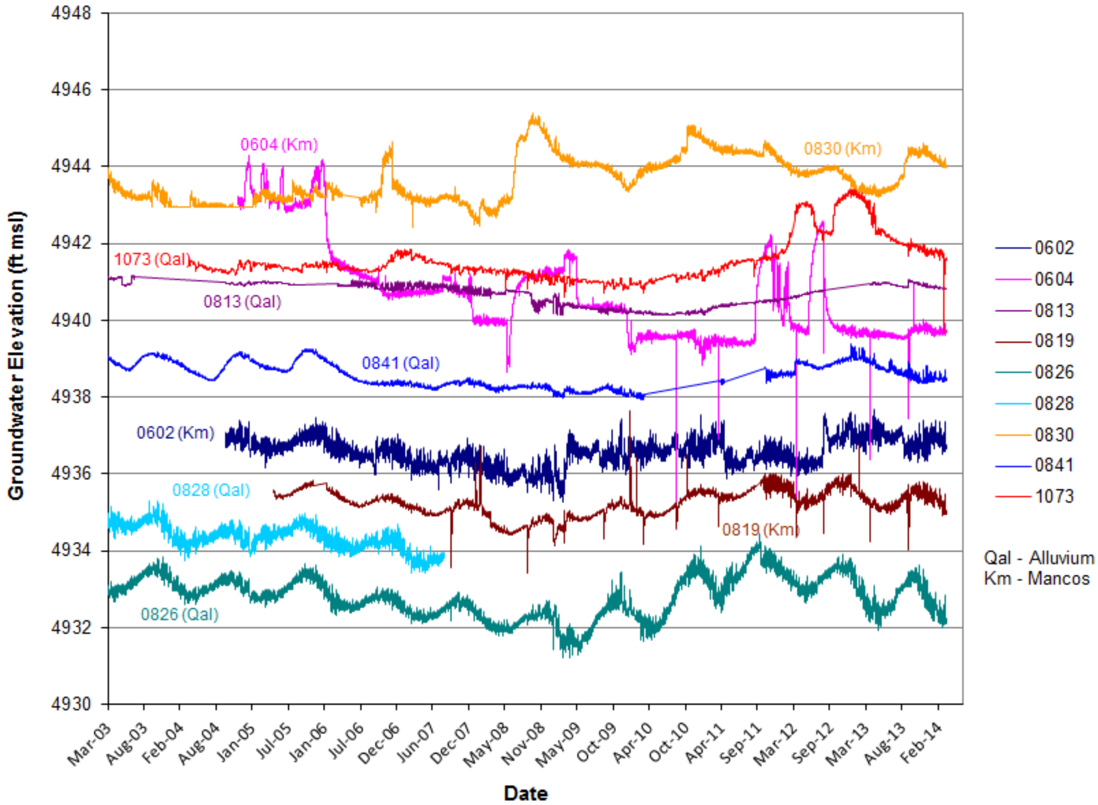


Figure B-7. Terrace Datalogger Measurements, Wells with Water Elevations above 4,930 ft msl

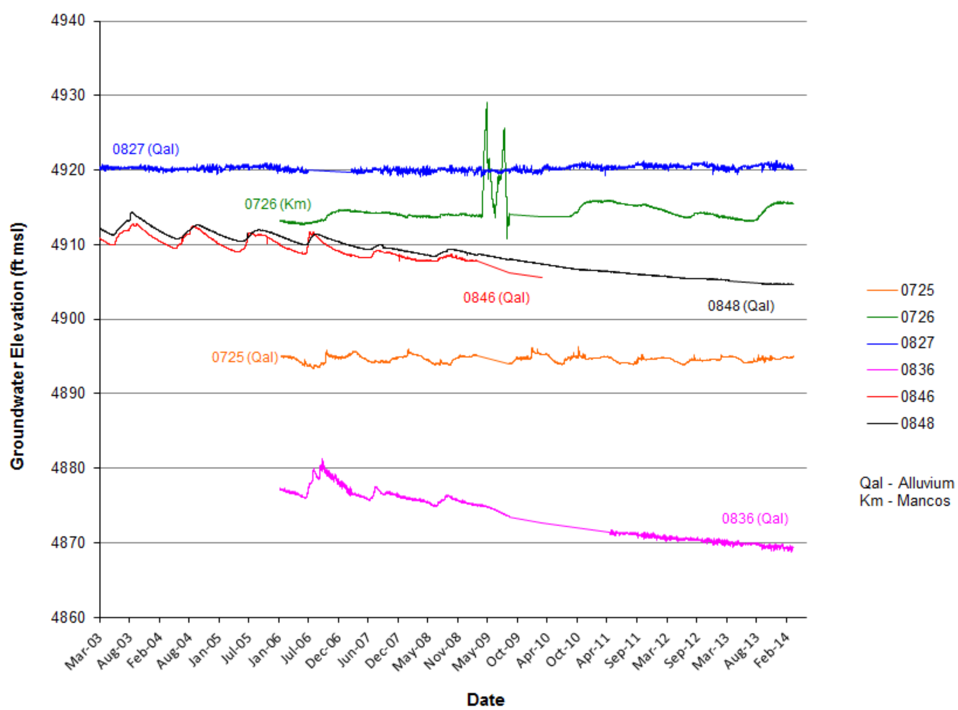


Figure B-8. Terrace Datalogger Measurements, Wells with Water Elevations less than 4,930 ft msl

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