LMS/SHP/S10301

Annual Performance Report April 2012 Through March 2013 for the Shiprock, New Mexico, Site

November 2013

U.S. DEPARTMENT OF ENERGY | Legacy Management

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Abbreviations

COC	contaminant of concern
DOE	U.S. Department of Energy
DWEL	Drinking Water Equivalent Level
EPA	U.S. Environmental Protection Agency
ESL	Environmental Sciences Laboratory
ft	feet
GCAP	Groundwater Compliance Action Plan
GEMS	Geospatial Environmental Mapping System
gpm	gallons per minute
kg	kilogram
Km	Mancos Shale
lb	pounds
LM	DOE Office of Legacy Management
MCL	maximum concentration limit
mg/L	milligrams per liter
msl	mean sea level
N	nitrogen
Qal	Quaternary alluvium
SDWA	Safe Drinking Water Act
SOARS	System Operation and Analysis at Remote Sites
SOWP	Site Observational Work Plan
UMTRA	Uranium Mill Tailings Remedial Action
UMTRCA	Uranium Mill Tailings Radiation Control Act

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 2012 through March 2013. 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 (LM). 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, a baseline performance report was developed which 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 (GCAP; DOE 2002), the U.S. Nuclear Regulatory Commission–approved compliance strategy for the floodplain is natural flushing supplemented by active remediation. However, active remediation (pumping from extraction wells and trenches) is now considered the dominant strategy for the floodplain, (see DOE 2011a). 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 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 are generally the same as those observed in previous years. Contaminant concentrations continue to decrease 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 increased since the last reporting period. The reason for these recent increases is not clear and is being investigated. Finally, COC concentrations in surface water samples collected from the San Juan River are still well 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 9.3 million gallons of groundwater were extracted from the floodplain aquifer system during this performance period. Nearly 95 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 2012 through March 2013, approximately 3 million gallons of groundwater were extracted from the terrace system; the total cumulative volume extracted is approximately 33 million gallons. The cumulative volume removed from both the terrace and the floodplain combined (as of April 1, 2013) is nearly 128 million gallons. Estimated masses of sulfate, nitrate, and uranium removed from the floodplain and terrace well fields during this performance period were (rounded) 596,000 pounds; 25,000 pounds; and 38 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 (see DOE 2011a).
- Implement the recommendations in the report titled *Optimization of Sampling at the Shiprock, New Mexico, Site* (DOE 2013c).

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 2012 through March 2013. The Shiprock site, a former uranium-ore processing facility under the Uranium Mill Tailings Radiation Control Act (UMTRCA), is managed by the U.S. Department of Energy (DOE) Office of Legacy Management (LM).

The mill operated from 1954 to 1968; mill tailings were contained 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, a baseline performance report was developed (DOE 2003). That report 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 the locations of monitoring wells and surface water sampling locations at the site. Figure 3 shows surface water monitoring locations only.

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), and a mid-term evaluation of the site remediation strategy (DOE 2011a).

1.1 Remediation System Performance Standards

This performance assessment is based on an analysis of groundwater quality and groundwater level data obtained from site monitoring wells, in addition to groundwater flow rates associated with 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 summarized as follows:

- Groundwater flow directions in the vicinity of the extraction wells should be toward the extraction wells to maximize the zones of capture; and
- Pumping on the floodplain should intercept contaminants of concern (COCs) that would otherwise discharge to the San Juan River.

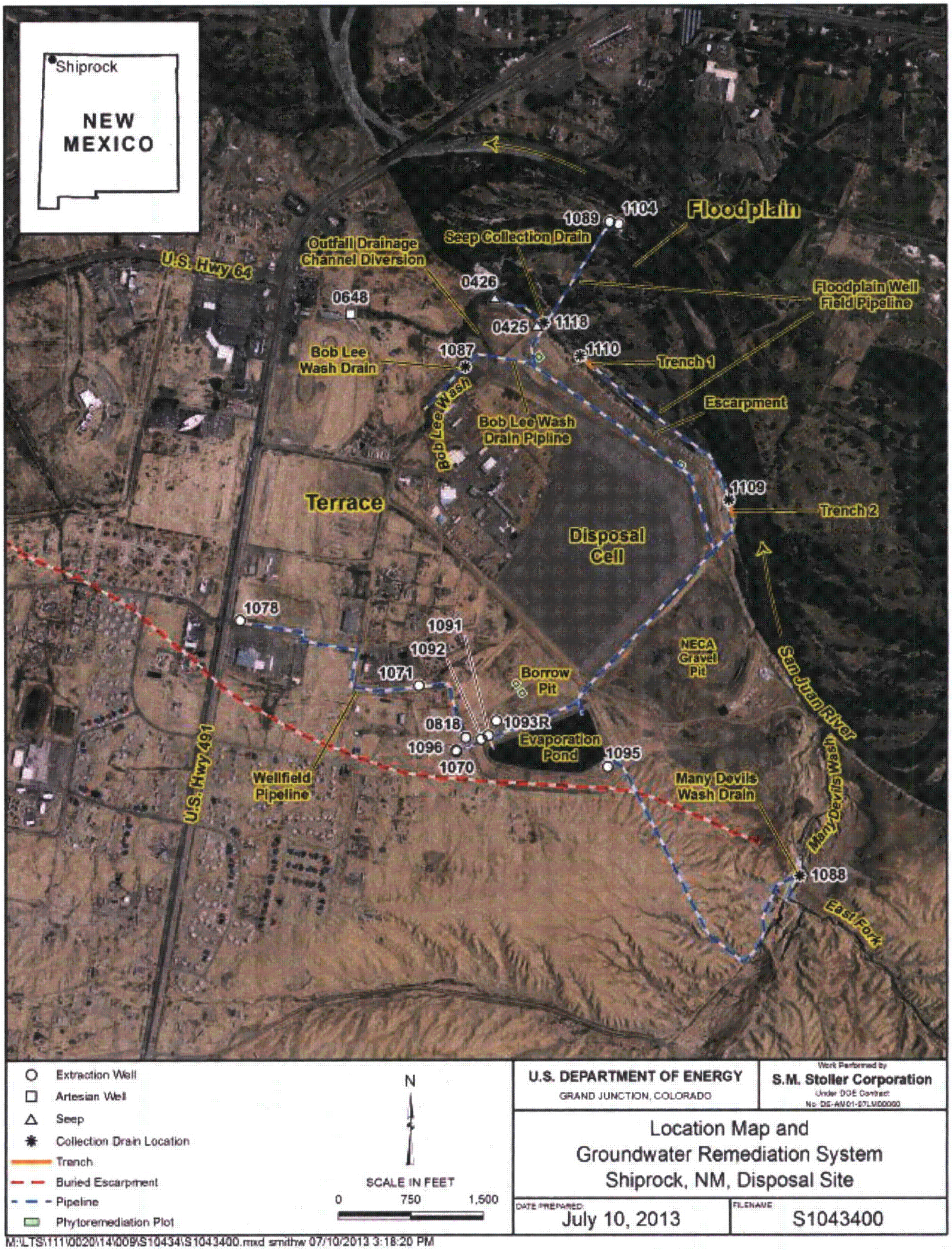

Figure 1. Location Map and Groundwater Remediation System

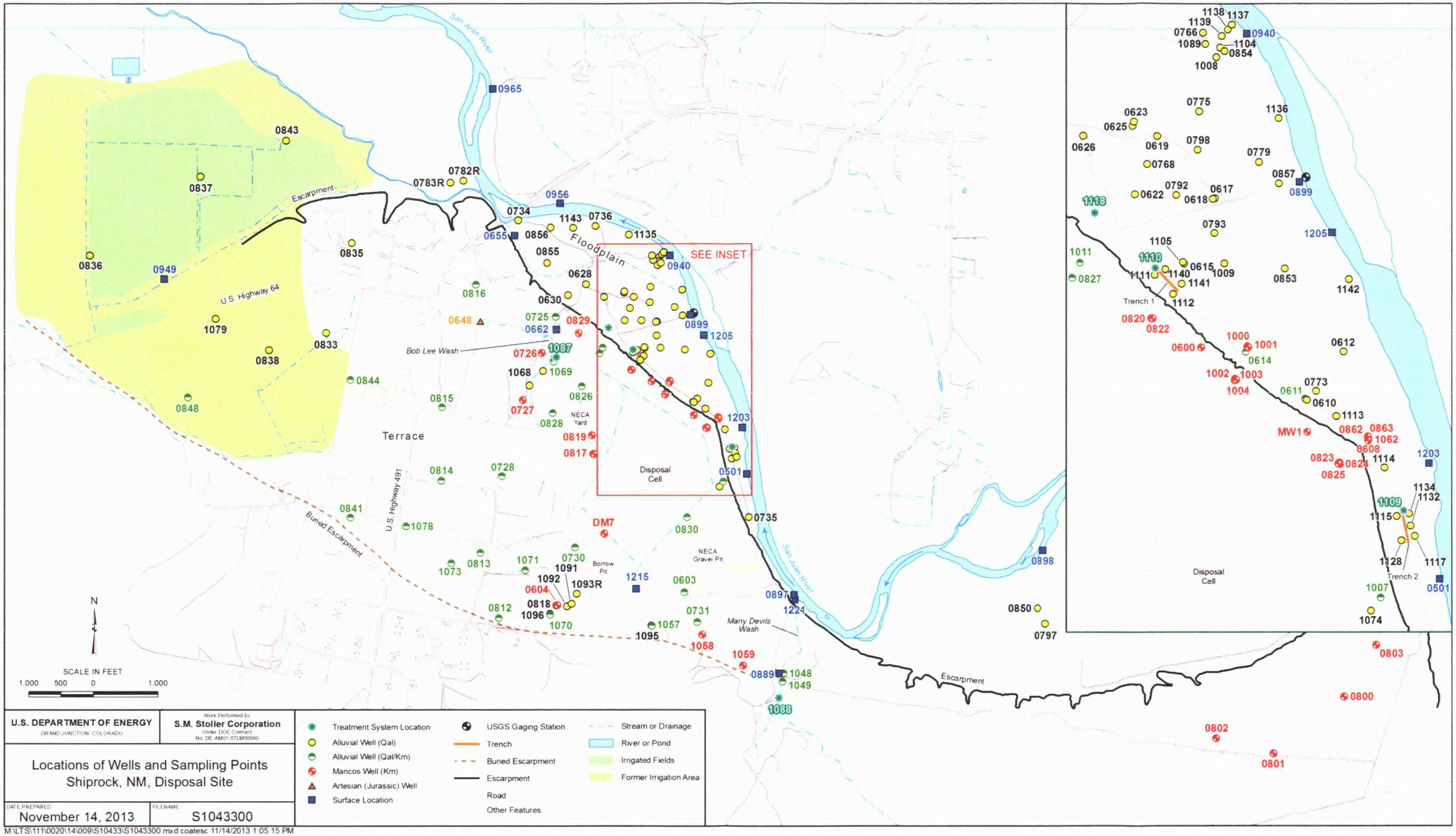

Figure 2. Locations of Wells and Sampling Points at the Shiprock Site

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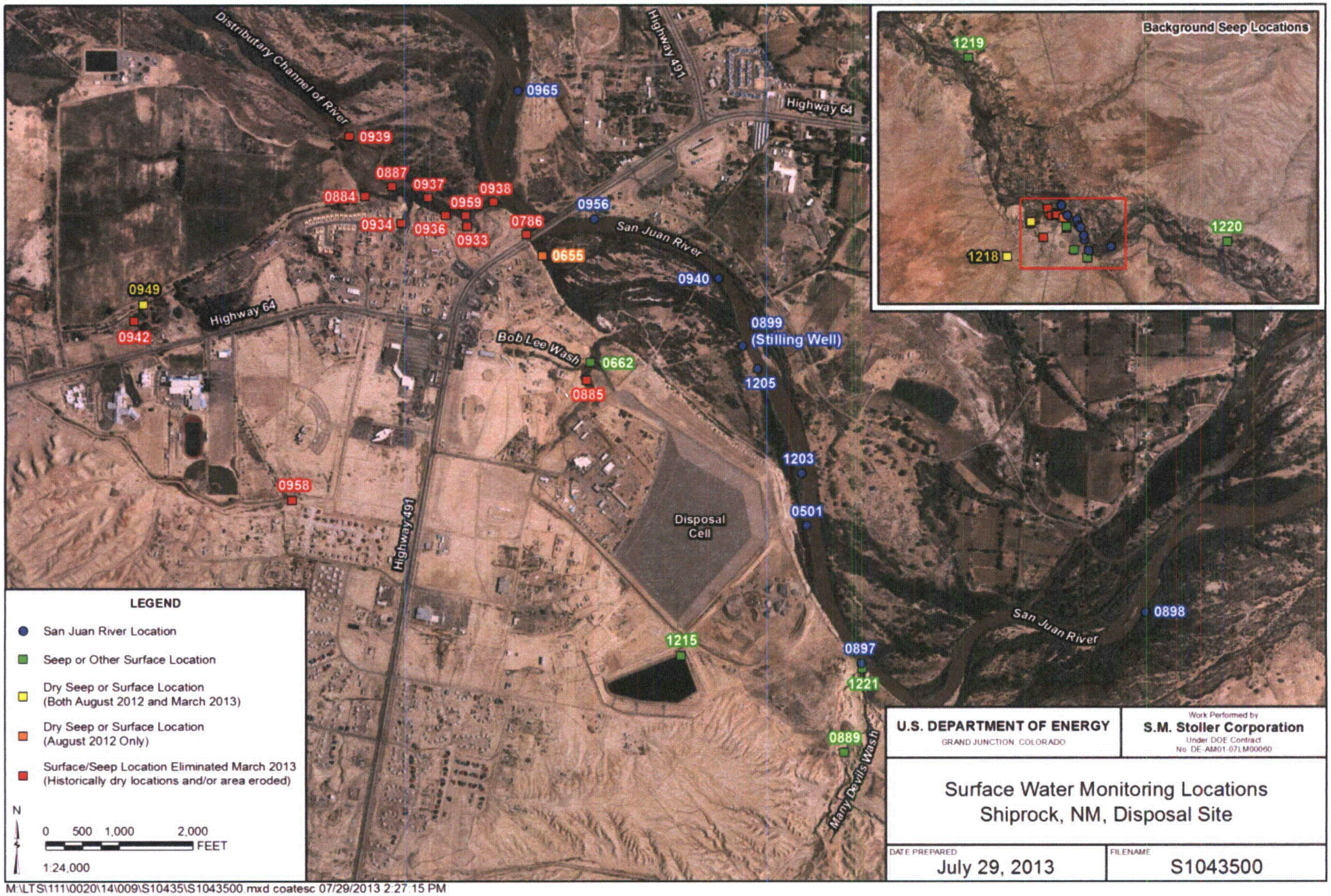

Figure 3. Current and Historical Shiprock Site Surface Water Monitoring Locations

Specific performance standards established for the terrace groundwater remediation system in the 2003 baseline 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 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 (DOE 2002), 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	All results for floodplain background wells have been nondetects (<0.1 mg/L) except for 2 results from well 797.
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	0.01–3.3	As identified in the GCAP (DOE 2002), the compliance standard for nitrate (as NO_3) in the floodplain is 44 mg/L. This is equivalent to 10 mg/L of nitrate (as N), which is the UMTRA standard (40 CFR 192).
Selenium (mg/L)	0.01	0.0001–0.018	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 2,000 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 (0.004–0.12 mg/L) 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 could 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 (SDWA). This alternate level may still be too conservative, given the potential influence from natural sources addressed in recent DOE ESL 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 (EPA has not developed any toxicity values upon which to base an associated risk-based standard), and levels measured in floodplain background wells have been low or non-detect results. 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 (DWEL) 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 in floodplain background wells.

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 recent (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 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, 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, flows through deeper portions of the shale, within fractures and along bedding surfaces.

1.4 Contaminant Distributions

The objective of the floodplain remediation strategy is to reduce COC concentrations and decrease the contaminant mass discharging to the San Juan River. Therefore, subsequent discussions of contaminant distributions and temporal trends focus primarily on floodplain wells. Contamination trends on the terrace receive less focus in this annual report because the compliance strategy is based on hydrologic control—active remediation to reduce groundwater elevations, with the ultimate goal of eliminating potential exposure pathways (e.g., in seeps and washes). Therefore, concentration-driven performance standards for the terrace system have not been developed. However, as a best management practice, contaminant concentrations are measured at each extraction well, drain, and seep.

Figure 4 through Figure 10 plot concentrations of COCs in terrace and floodplain groundwater and surface water based on results of the most recent sampling event (August 2012 or March 2013). Monitoring well locations in these figures are distinguished by the formation in which the well is completed; Qal is the geologic symbol for alluvial deposits and Km is the geologic symbol for the Mancos Shale formation. Figure 11 presents a side-by-side comparison of relative contaminant distributions for the primary COCs. Figure 12 through Figure 25 plot changes in the floodplain contaminant plumes in the alluvial aquifer since active remediation began in 2003. These plume maps plot interpolated data for alluvial wells sampled between 2000 and 2003 (representing baseline conditions) alongside interpolations of the maximum result for this evaluation period (August 2012 or March 2013).

Two alluvial plume map figures are provided for each COC. The first map compares baseline and current conditions using only those alluvial wells that were sampled during both periods. The second map shows the current conditions using all alluvial wells that were sampled August 2012 through March 2013. Interpolations of COC concentrations at unsampled sites (i.e., in between well locations) are based on measurements made at the closest surrounding sites. For most COCs, 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 and green was set at this value. All floodplain locations or areas with interpolated results that are below the compliance standard or cleanup goal are colored blue. In contrast, all locations/areas with interpolated results that exceed the standard are colored green, yellow, or red depending on the magnitude of the concentration. Strontium and ammonia do not have compliance standards or cleanup goals in the GCAP. The EPA Drinking Water Equivalent Level for lifetime exposure to strontium discussed in Section 1.2.1 was used for the strontium maps. Ammonia has no comparable benchmark value; therefore, plume maps for ammonia (Figures 12 and 13) have no set value for the blue to green color break.

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 location had been historically dry or, in the case of the floodplain distributary channel, the area has since eroded (Figure 3).

In general, the contaminant-specific characterizations provided below are similar to those in previous annual reports, as spatial distributions and overall trends have been generally consistent over the last several years. Detailed information, including time-concentration graphs for both terrace and floodplain monitoring locations and supporting quality assurance documentation, is provided in the corresponding Data Validation Package reports (DOE 2013a, 2013b).

<u>Ammonia</u>

Ammonia concentrations are highest in the radon cover borrow pit/evaporation pond area, in Mancos wells west of the disposal cell (0602, 0817, and 0819), and on the floodplain in the area of the trenches and at the base of the escarpment (Figure 4 and Figure 11). On the floodplain, ammonia concentrations continue to be most elevated in Trench 2 wells 1115 and 1128, located on the disposal cell side of the trench (most recent results of 140 and 290 mg/L, respectively). Ammonia concentrations on the eastern (river) side of the trench are much lower. The maximum ammonia concentration of 970 mg/L for this reporting period was measured in terrace Mancos well 0817, just west of the disposal cell. Except for slight decreases in the central floodplain, the plume maps in Figure 12 show no notable differences between baseline and current periods. Apparent increases in the Trench 2 area (Figure 13) are attributable to the fact that no data (wells) were available for this area during the baseline (2000–2003) period.

Manganese

Manganese, which is at or near background concentrations across much of the site, is elevated only in the borrow pit/evaporation pond area (Figure 5 and Figure 11). Concentrations in terrace well 0603 nearly doubled between September 2008 and March 2009—from about 27 to 55 mg/L, consistent with an early (1990) measurement (69 mg/L). The reason for the 2008-2009 increase is not known, but could be related to large volumes of water introduced into the alluvial aquifer during the nearby gravel pit operations beginning in 2008. Since 2009, manganese levels in well 0603 have been relatively stable, ranging from about 50 to 60 mg/L. The only other wells with elevated manganese concentrations are terrace extraction wells 1093 and 1095 (28 and 34 mg/L, respectively) and well 0730 (26 mg/L) south of the disposal cell. On the floodplain, most manganese concentrations in groundwater are within the historical floodplain background range listed in Table 1. The plume maps in Figure 14 show slight decreases in manganese concentrations in the central portion of the floodplain along the base of the escarpment and near the river.

Nitrate (as N)

As has been historically, nitrate concentrations are most elevated in the terrace radon cover borrow pit and paleochannel areas (i.e., along the buried escarpment), as well as in Many Devils Wash (Figure 6 and Figure 11). 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 in Figure 16 show demonstrable progress on the floodplain (reductions in nitrate concentrations) when comparing baseline versus 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 (Figure 17).

Selenium

Selenium's spatial distribution is similar to that observed for nitrate in that concentrations are most elevated along the terrace buried escarpment and in Many Devils Wash (Figure 7 and Figure 11). The plume maps in Figure 18 indicate some reductions in selenium concentrations in the central portion of the floodplain. 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 (Figure 19). With few exceptions (e.g., well 0779), selenium concentrations in wells near the river are below the 0.05 mg/L GCAP compliance standard (or cleanup goal for the floodplain), and a number of results are below detection limits.

Strontium

As discussed in Section 1.2, strontium is not typically associated with uranium milling sites but was selected as a COC based on a conservative risk assessment. The symbol categories used in Figure 8 are based on historical floodplain background concentrations (0–10 mg/L). Strontium concentrations appear to be fairly uniform within this range except for Mancos wells and alluvial wells in the swale area and west terrace. Apart from a possible association with Mancos wells, no spatial pattern appears. Given these observations, strontium may be naturally occurring at the Shiprock site rather than associated with former milling processes. The plume maps in Figure 20 show no notable changes in strontium concentrations when comparing baseline to current conditions for the common set of wells shown. Figure 21 shows that strontium concentrations on the floodplain are at or below EPA's 20 mg/L DWEL for lifetime exposure referenced in Table 1.

Sulfate

Sulfate concentrations are elevated at most locations at the Shiprock site. However, like nitrate and selenium, sulfate is most concentrated in the swale area and in Many Devils Wash (Figure 9 and Figure 11). Sulfuric acid was used during milling and this likely contributed to elevated concentrations at the tailings and escarpment areas. However, sulfate concentrations in Many Devils Wash are much higher than those measured in the tailings and escarpment areas. Reductions in sulfate concentrations since the baseline period are evident in floodplain wells, particularly in the Trench 1 and well 1089 areas (Figure 22). Sulfate is most elevated in central floodplain well 0779 and near the well 1089 area (Figures 9 and 23).

Uranium

Uranium's distribution differs from that of the other COCs in that it is most concentrated in terrace Mancos wells near the disposal cell and on the floodplain (Figure 10 and Figure 11). The highest concentration portions of the uranium plume are located in the terrace alluvium and weathered Mancos close to the disposal cell, on the floodplain near the southern portion of the escarpment, and in a zone traversing the floodplain in a line trending northward from the disposal cell. As observed for nitrate and sulfate, reductions in uranium concentrations in the central portion of the floodplain are evident in the baseline vs. current plume maps (Figure 24). Currently, uranium concentrations in most portions of the floodplain exceed the 0.044 mg/L UMTRCA standard (Figure 25). Uranium concentrations are highest in the area of the trenches nearest the escarpment, in the central floodplain at wells 0779 and 0857, and north of the well 1089 area.

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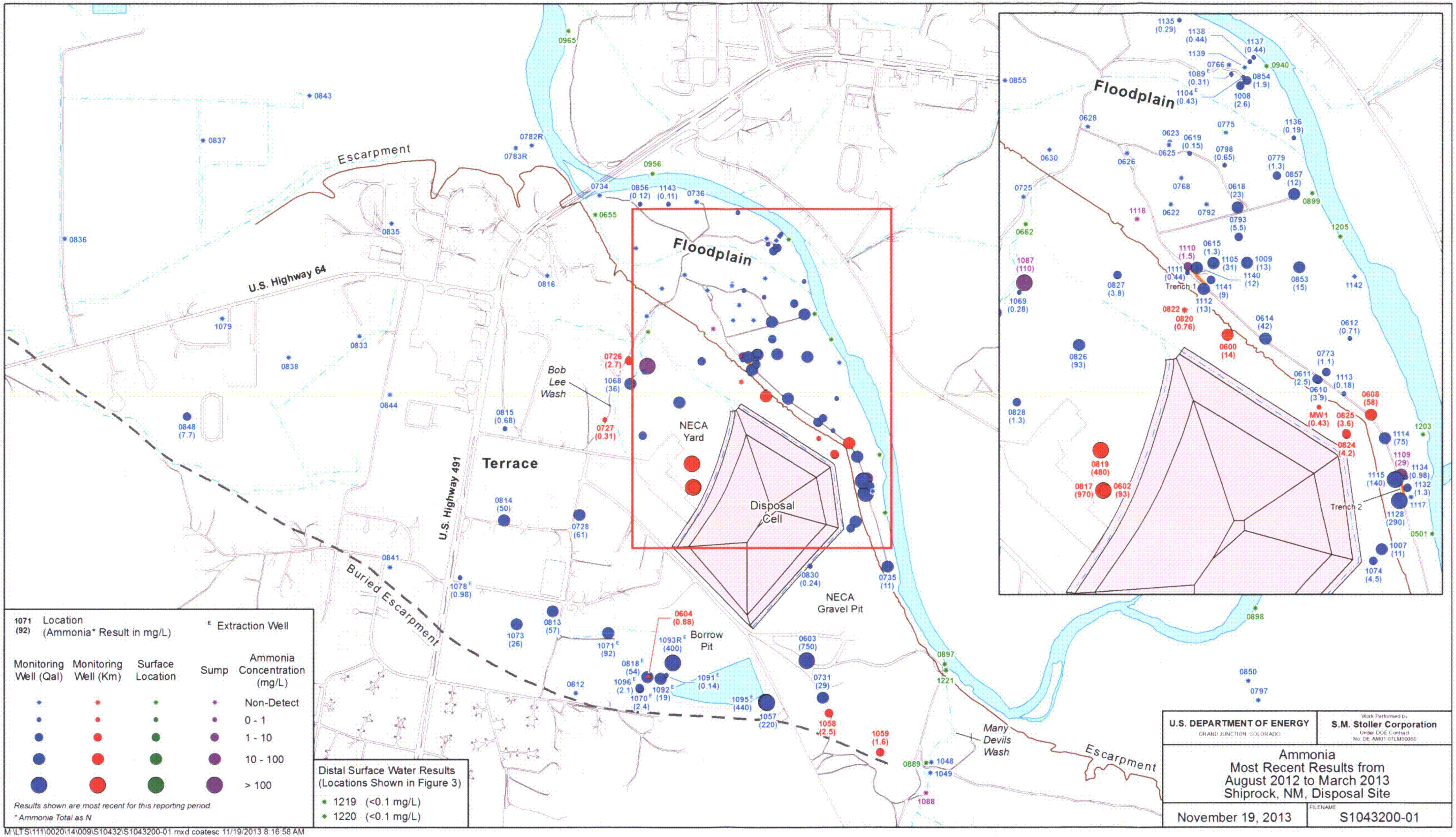

Figure 4. Ammonia Concentrations in Groundwater and Surface Water Samples, August 2012–March 2013

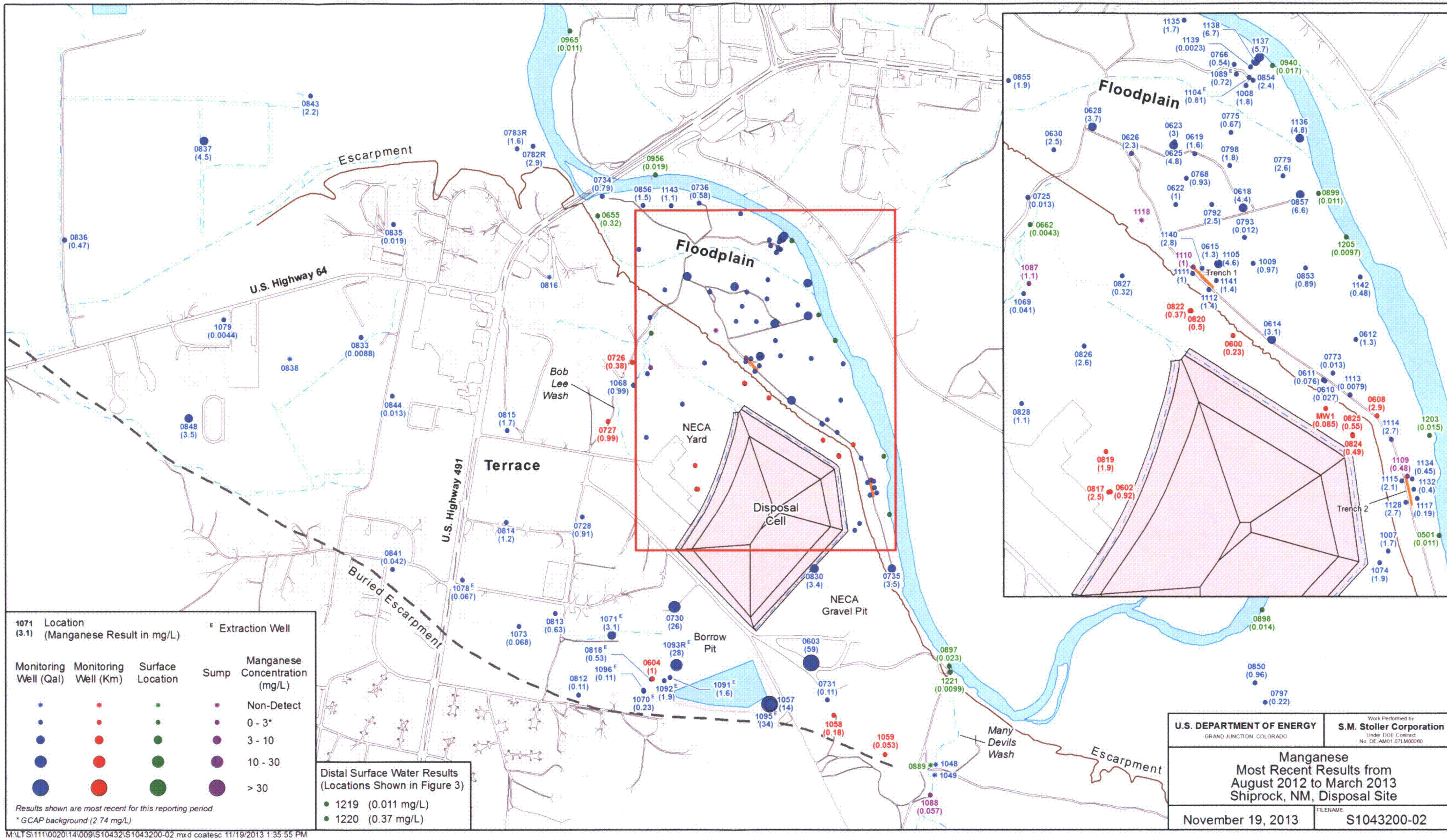

Figure 5. Manganese Concentrations in Groundwater and Surface Water Samples, August 2012–March 2013

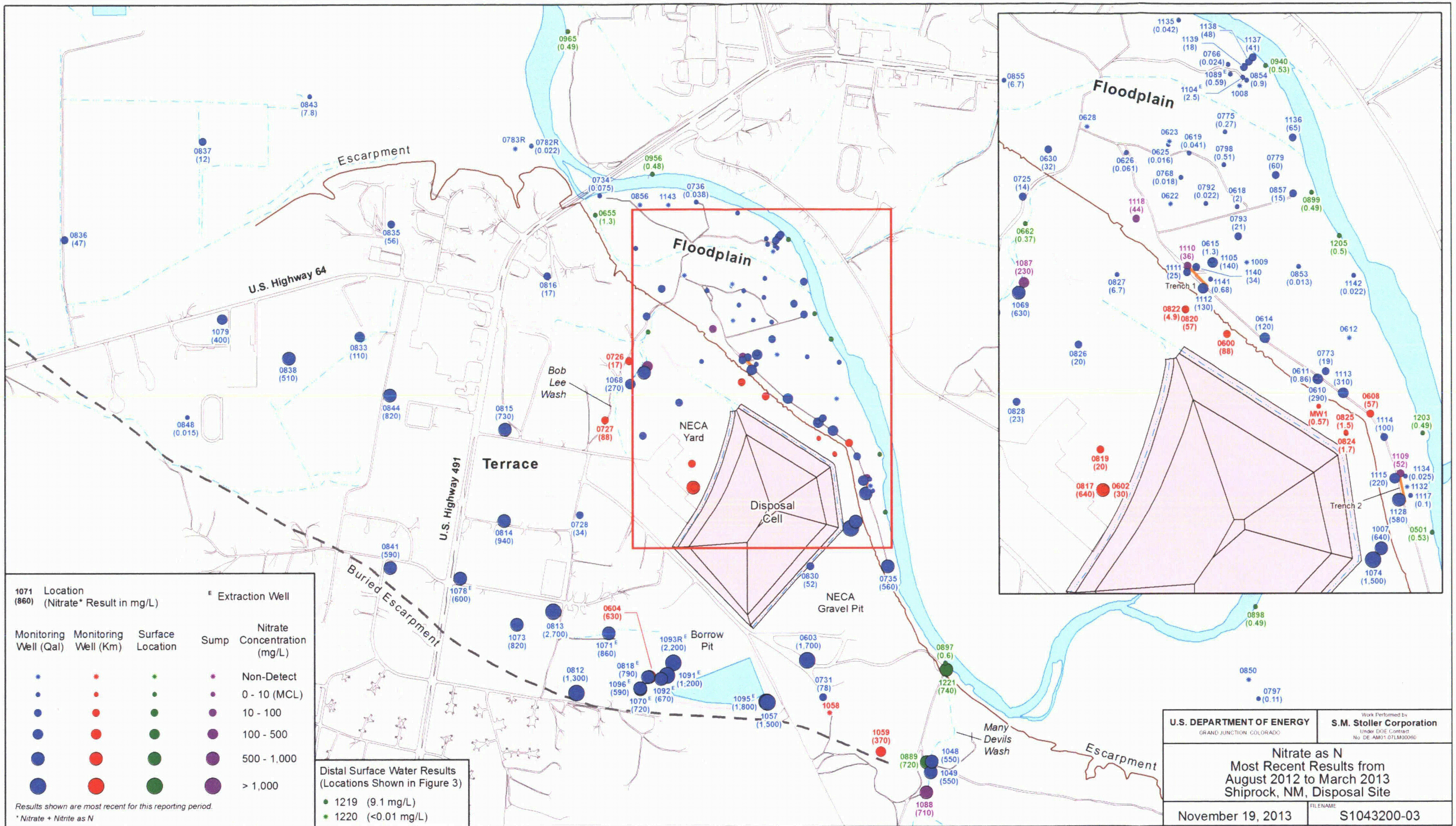

Figure 6. Nitrate Concentrations in Groundwater and Surface Water Samples, August 2012–March 2013

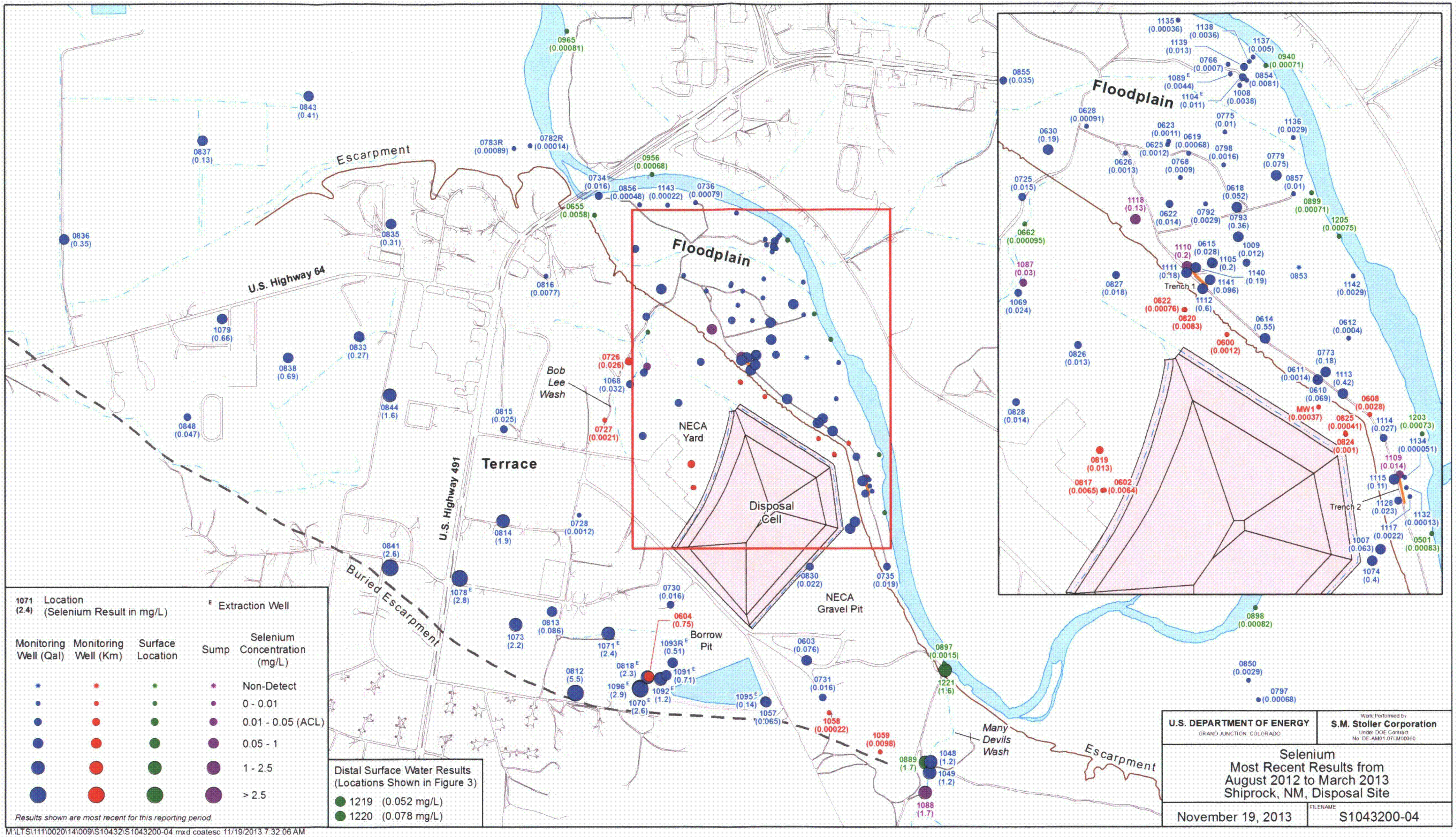

Figure 7. Selenium Concentrations in Groundwater and Surface Water Samples, August 2012–March 2013

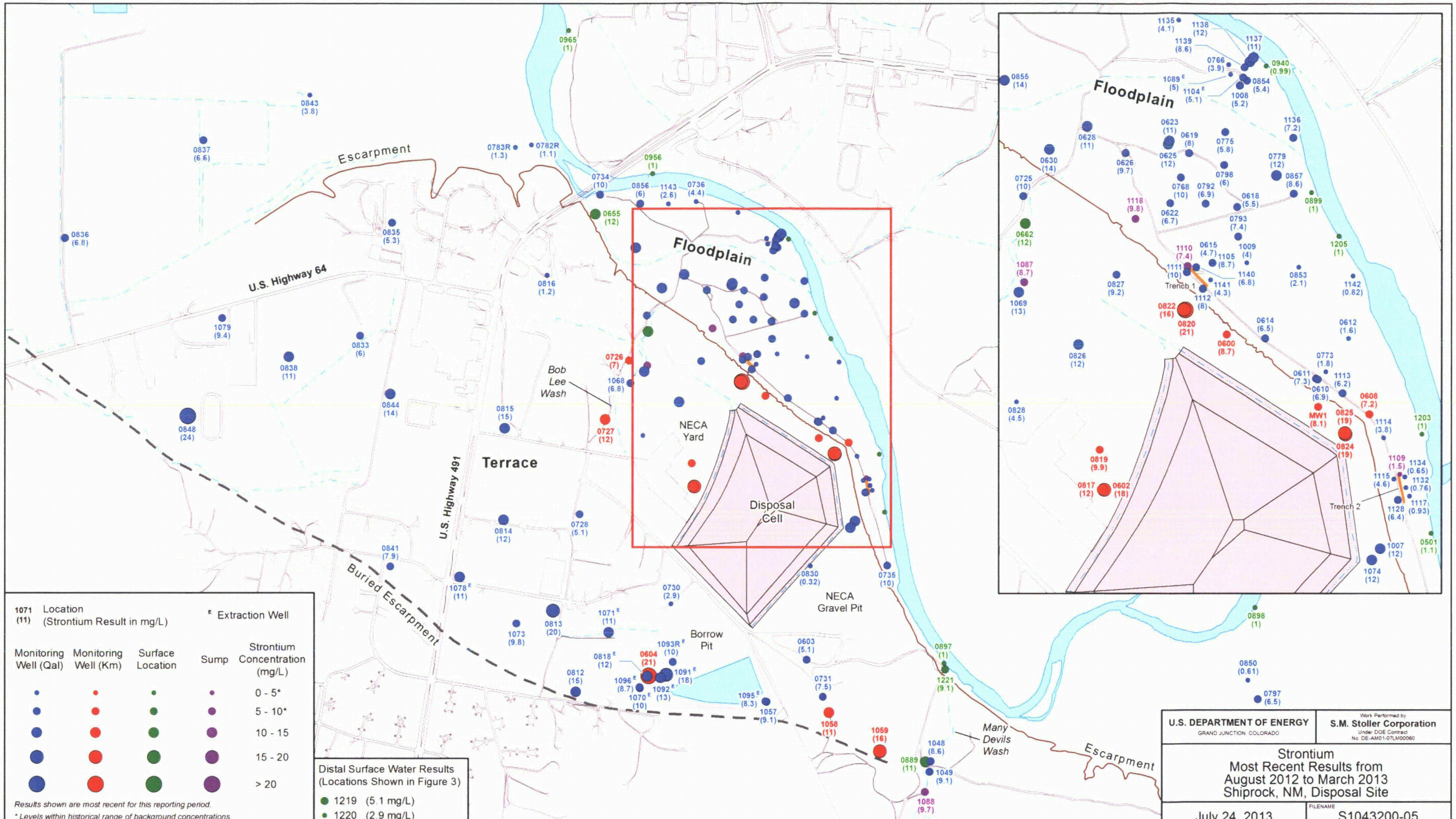

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Figure 8. Strontium Concentrations in Groundwater and Surface Water Samples, August 2012–March 2013

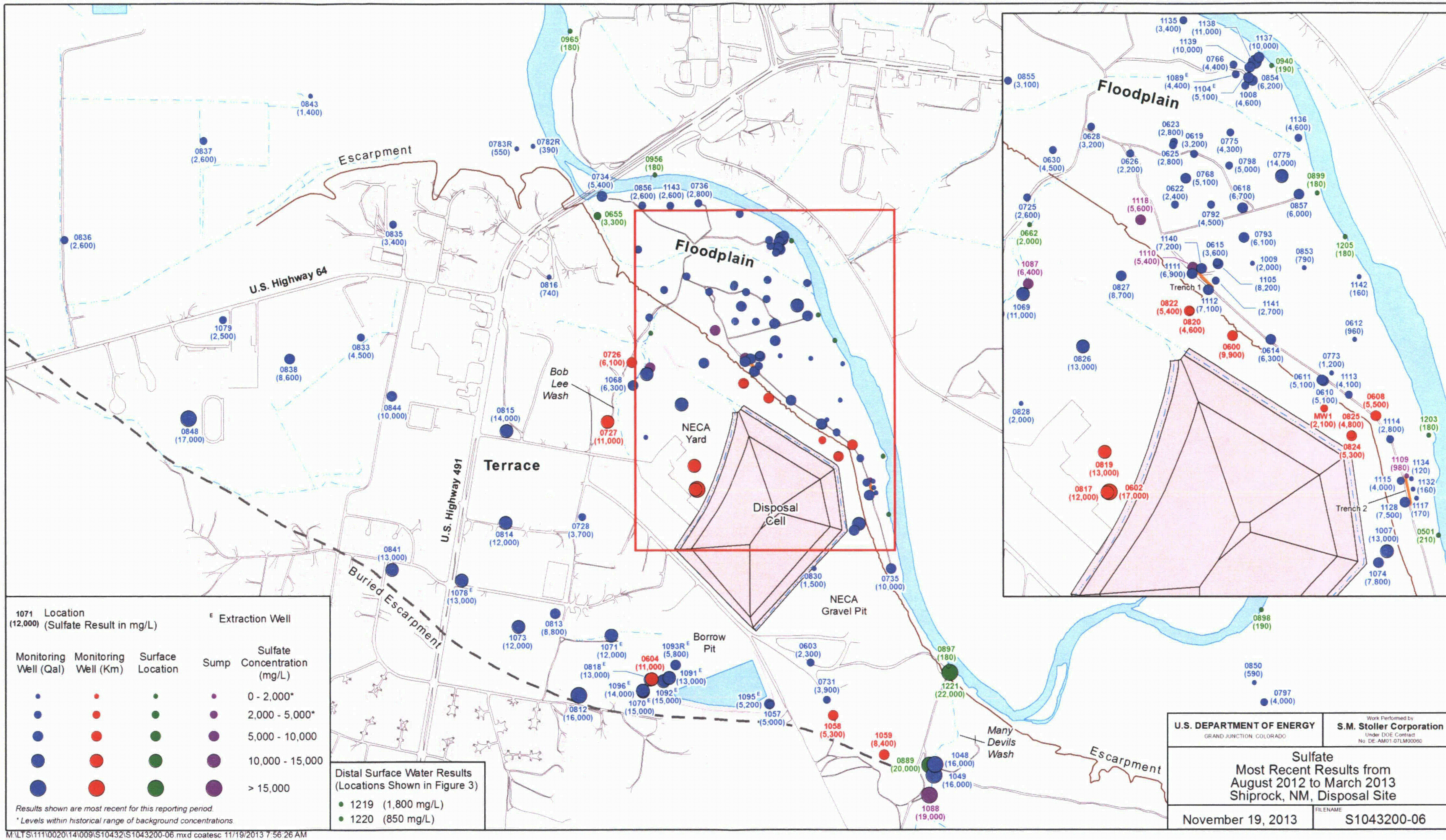


Figure 9. Sulfate Concentrations in Groundwater and Surface Water Samples, August 2012–March 2013

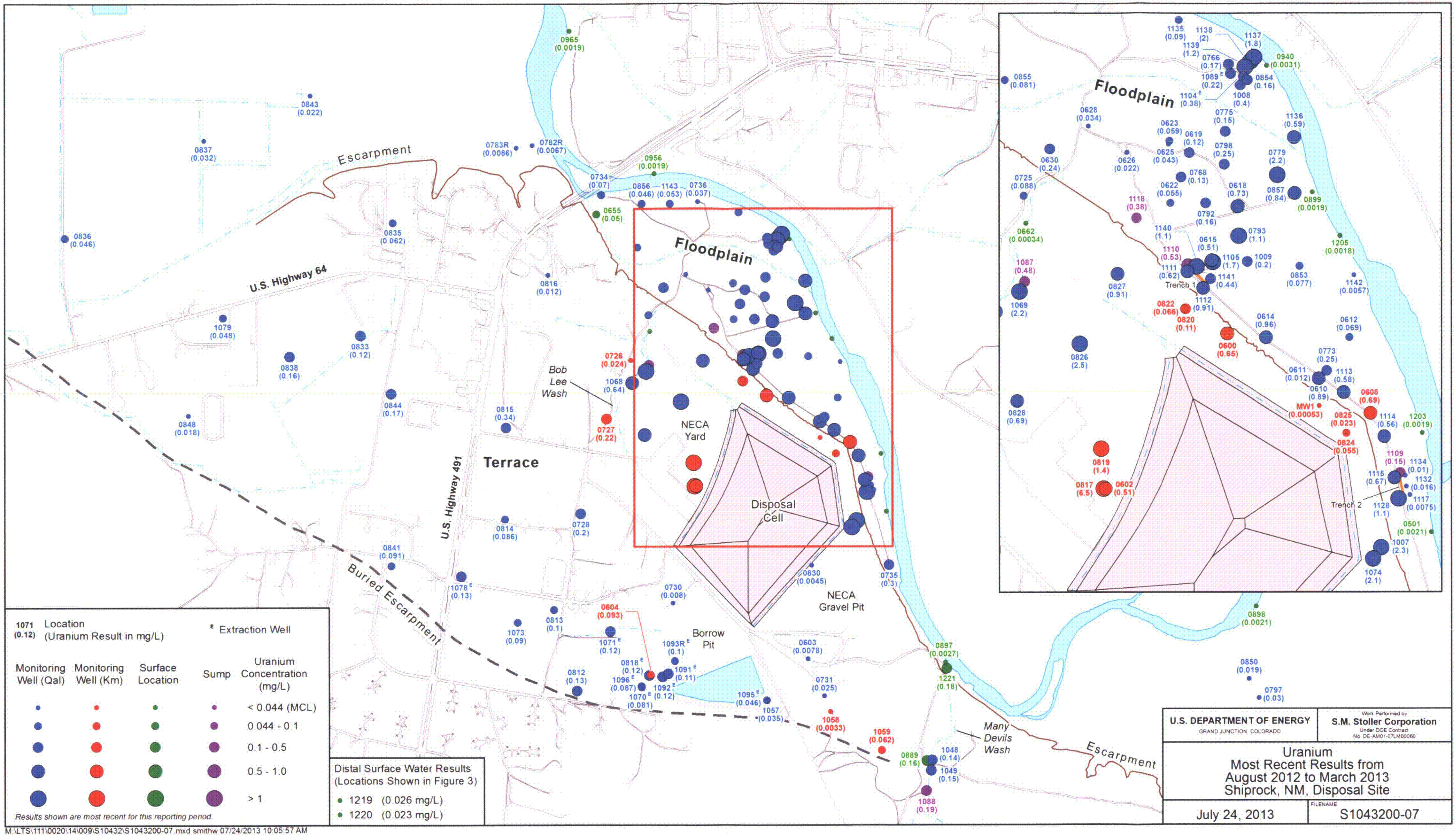
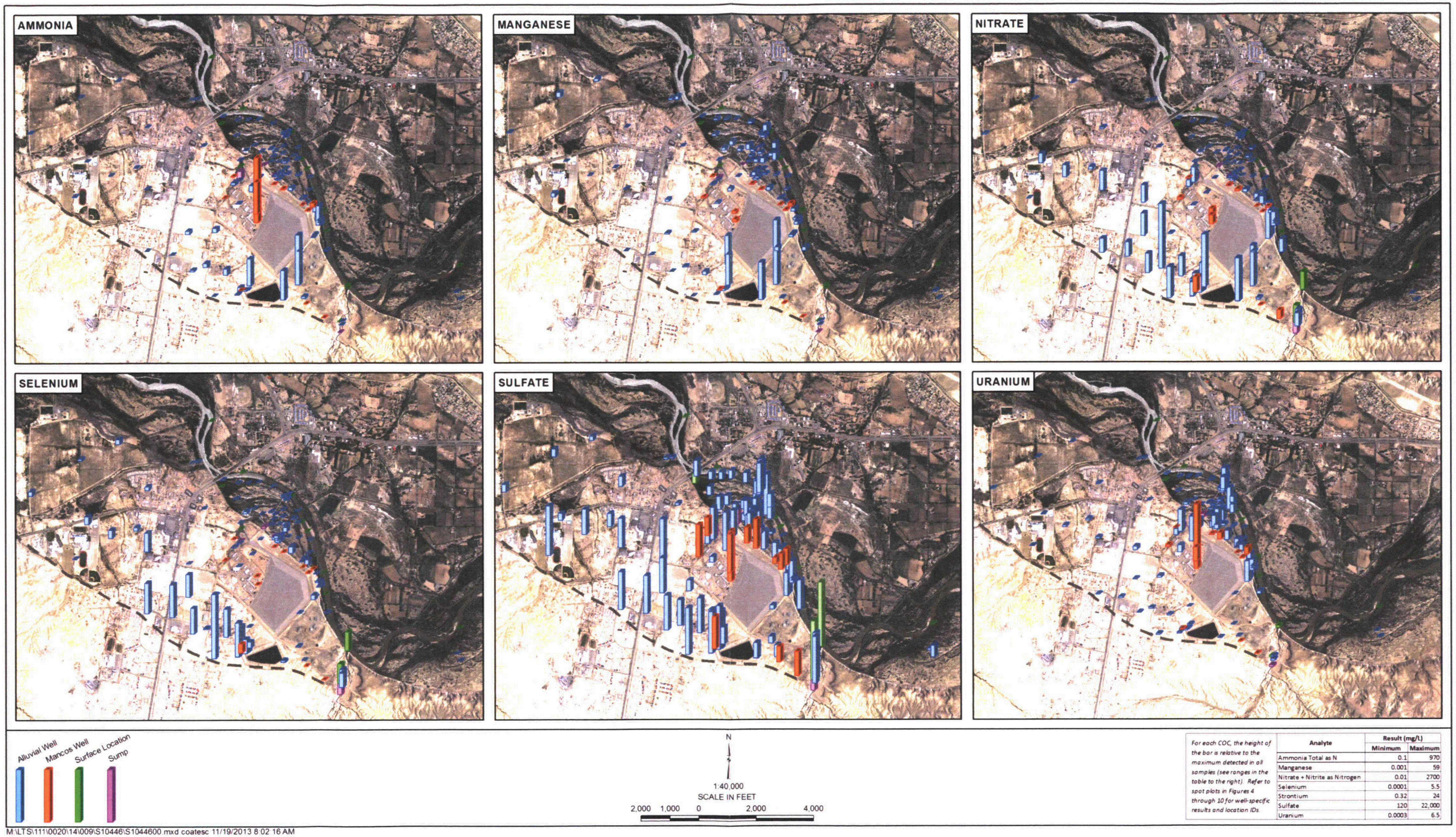


Figure 10. Uranium Concentrations in Groundwater and Surface Water Samples, August 2012–March 2013



Analyte	Result (mg/L)	
	Minimum	Maximum
Ammonia Total as N	0.1	970
Manganese	0.001	59
Nitrate + Nitrite as Nitrogen	0.01	2700
Selenium	0.0001	5.5
Strontium	0.32	24
Sulfate	120	22,000
Uranium	0.0003	6.5

Figure 11. Comparison of Relative Contaminant Distributions for the Primary COCs, August 2012–March 2013

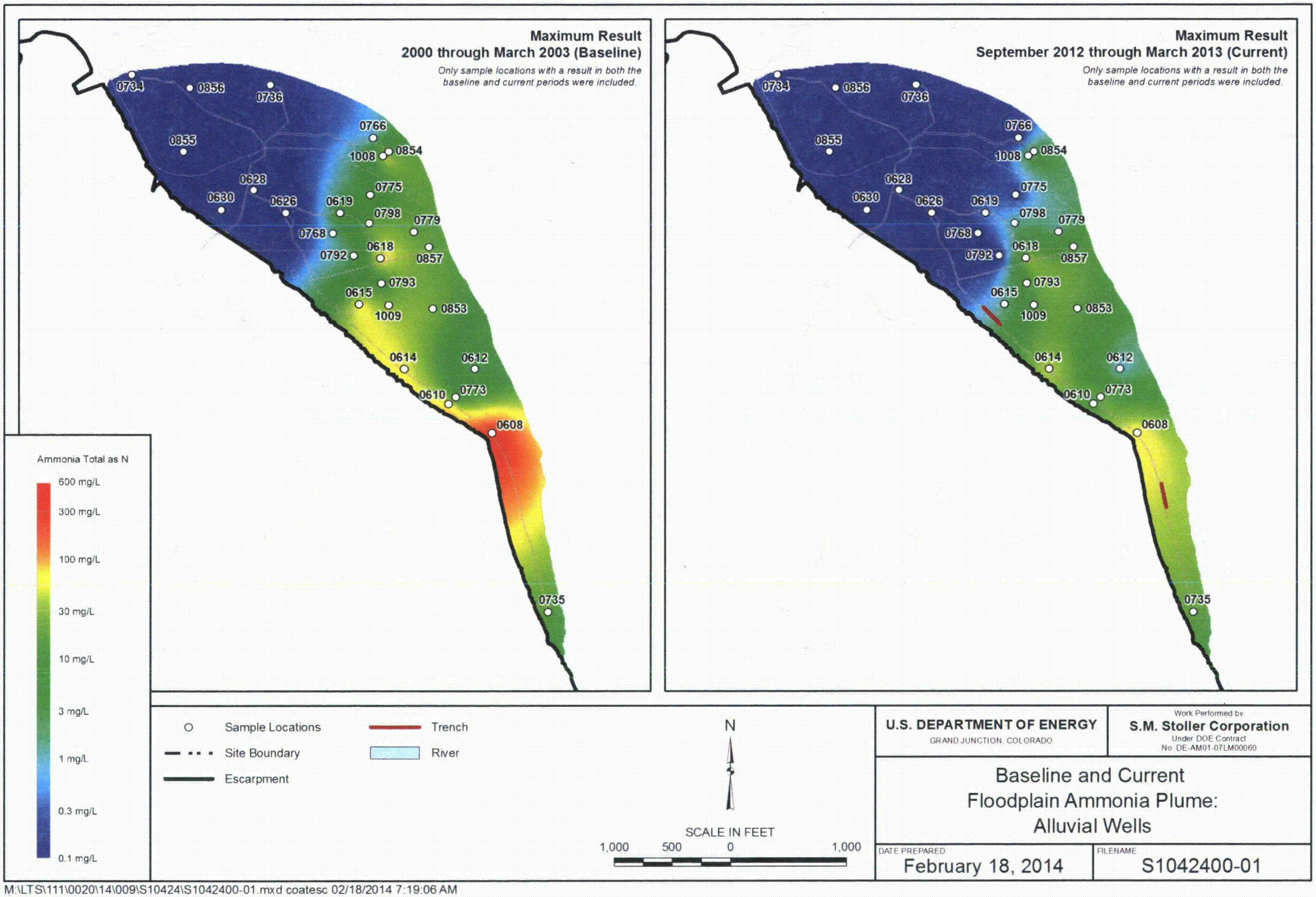


Figure 12. Baseline (2000–2003) and August 2012 through March 2013 Floodplain Ammonia Plumes

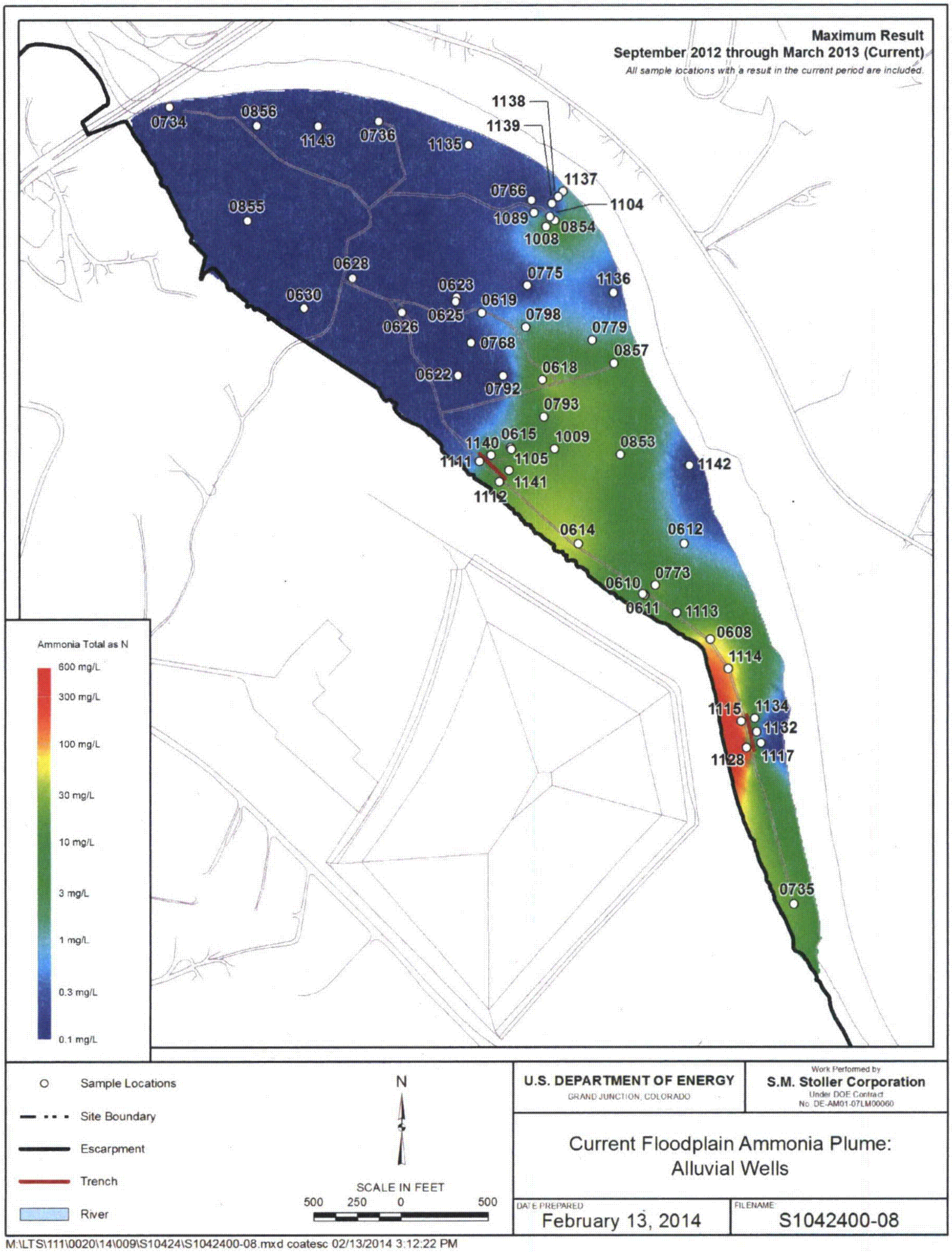


Figure 13. August 2012 through March 2013 Floodplain Ammonia Plume—All Sampled Wells

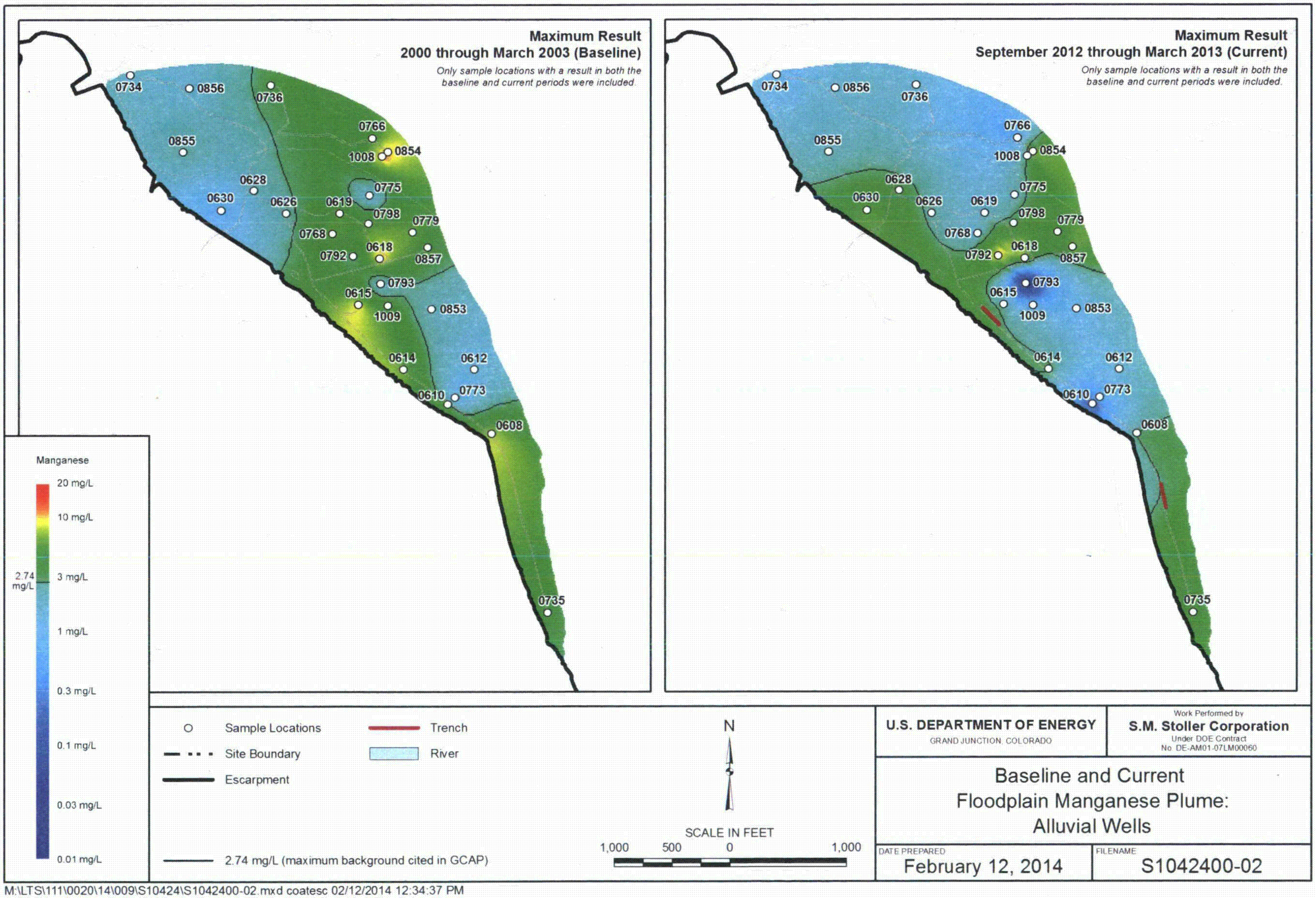


Figure 14. Baseline (2000–2003) and August 2012 through March 2013 Floodplain Manganese Plumes

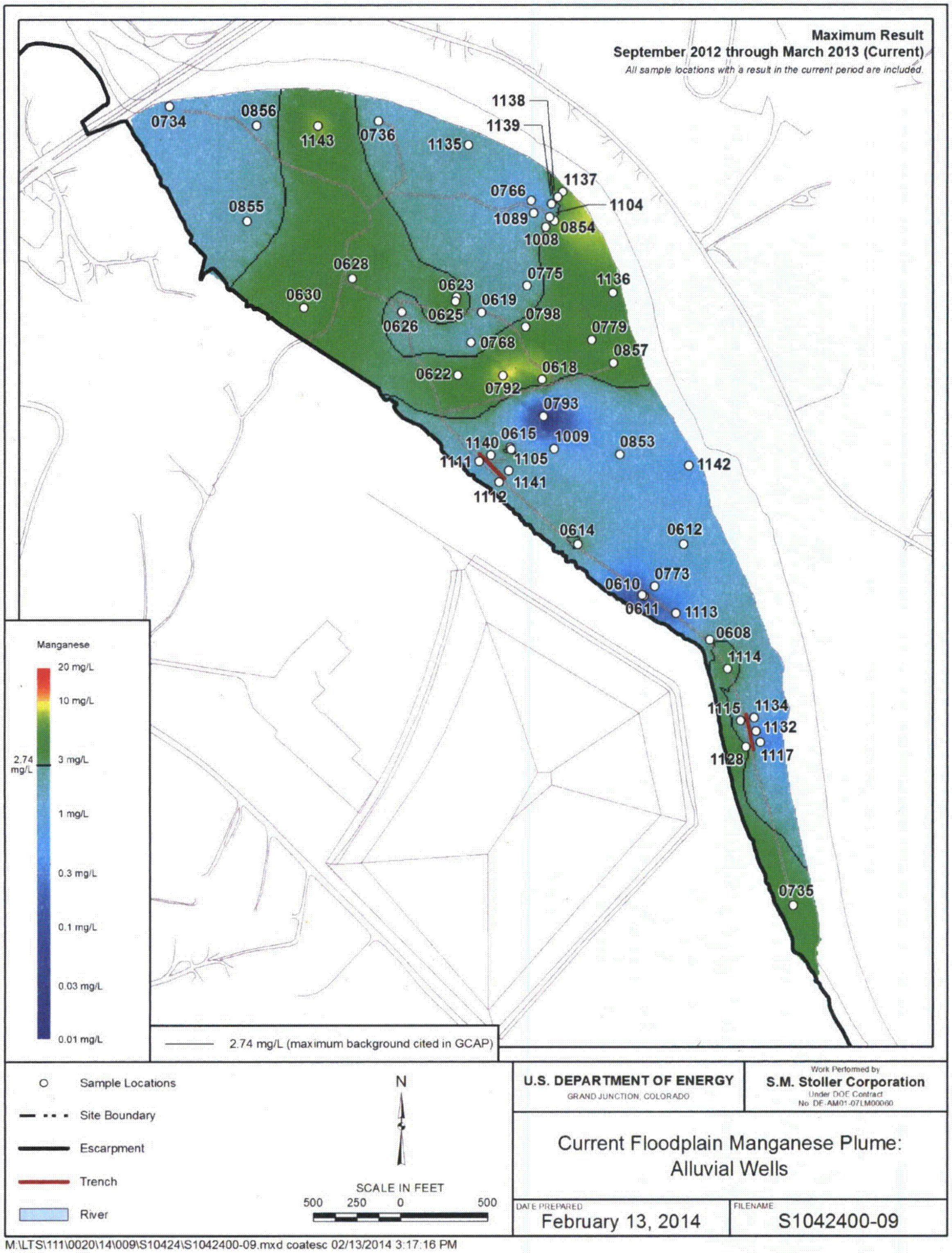


Figure 15. August 2012 through March 2013 Floodplain Manganese Plume—All Sampled Wells

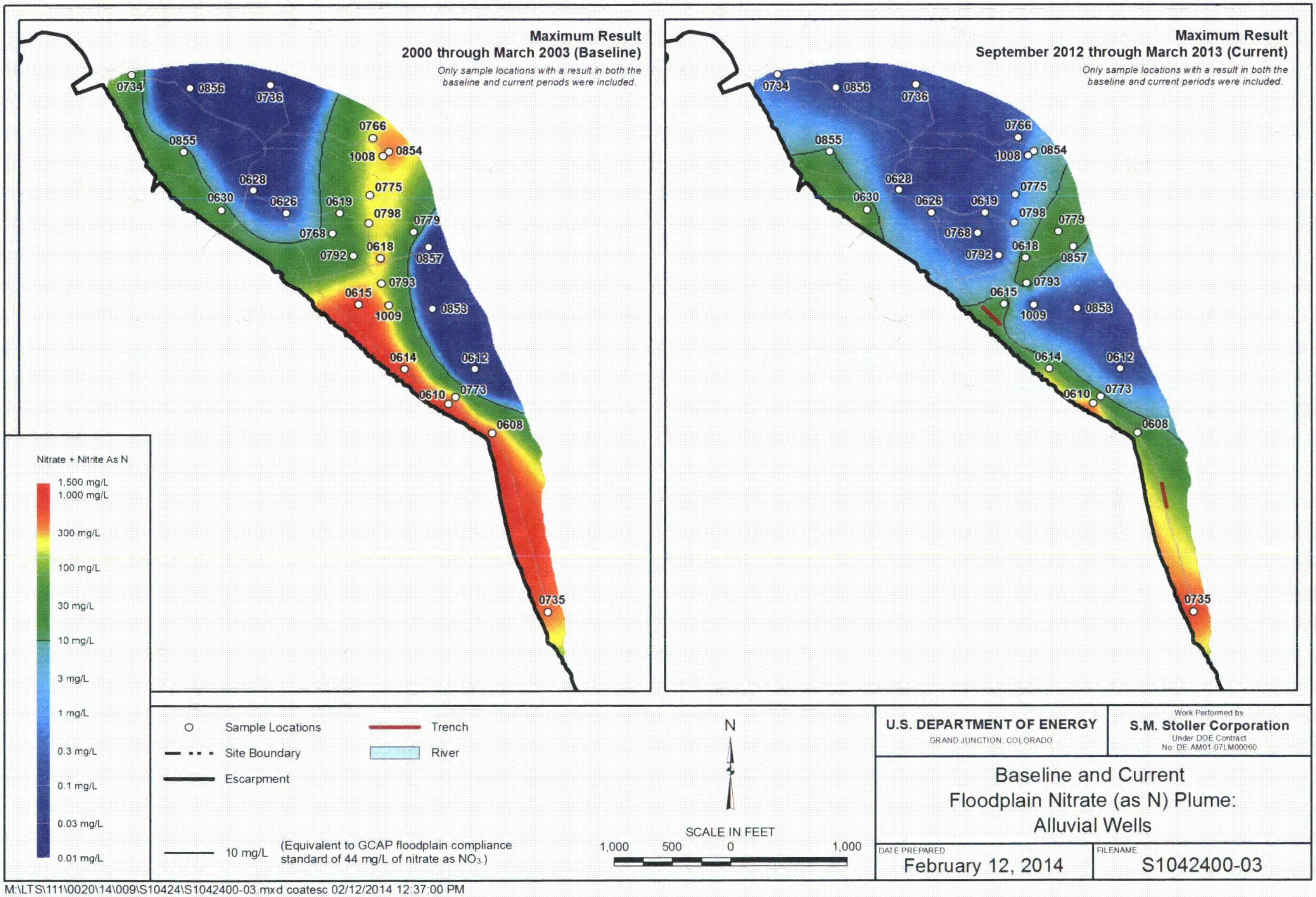


Figure 16. Baseline (2000–2003) and August 2012 through March 2013 Floodplain Nitrate Plumes

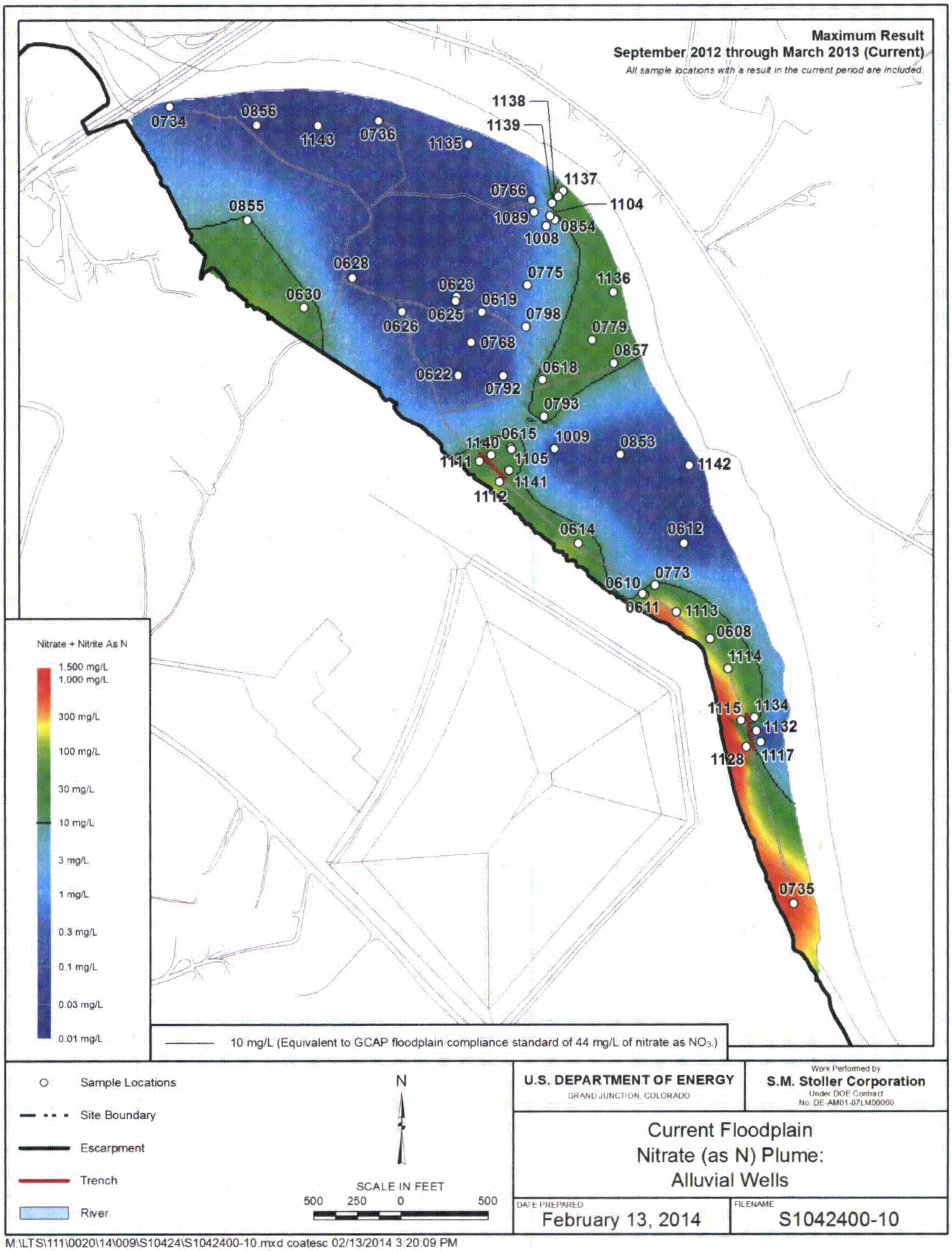


Figure 17. August 2012 through March 2013 Floodplain Nitrate Plume—All Sampled Wells

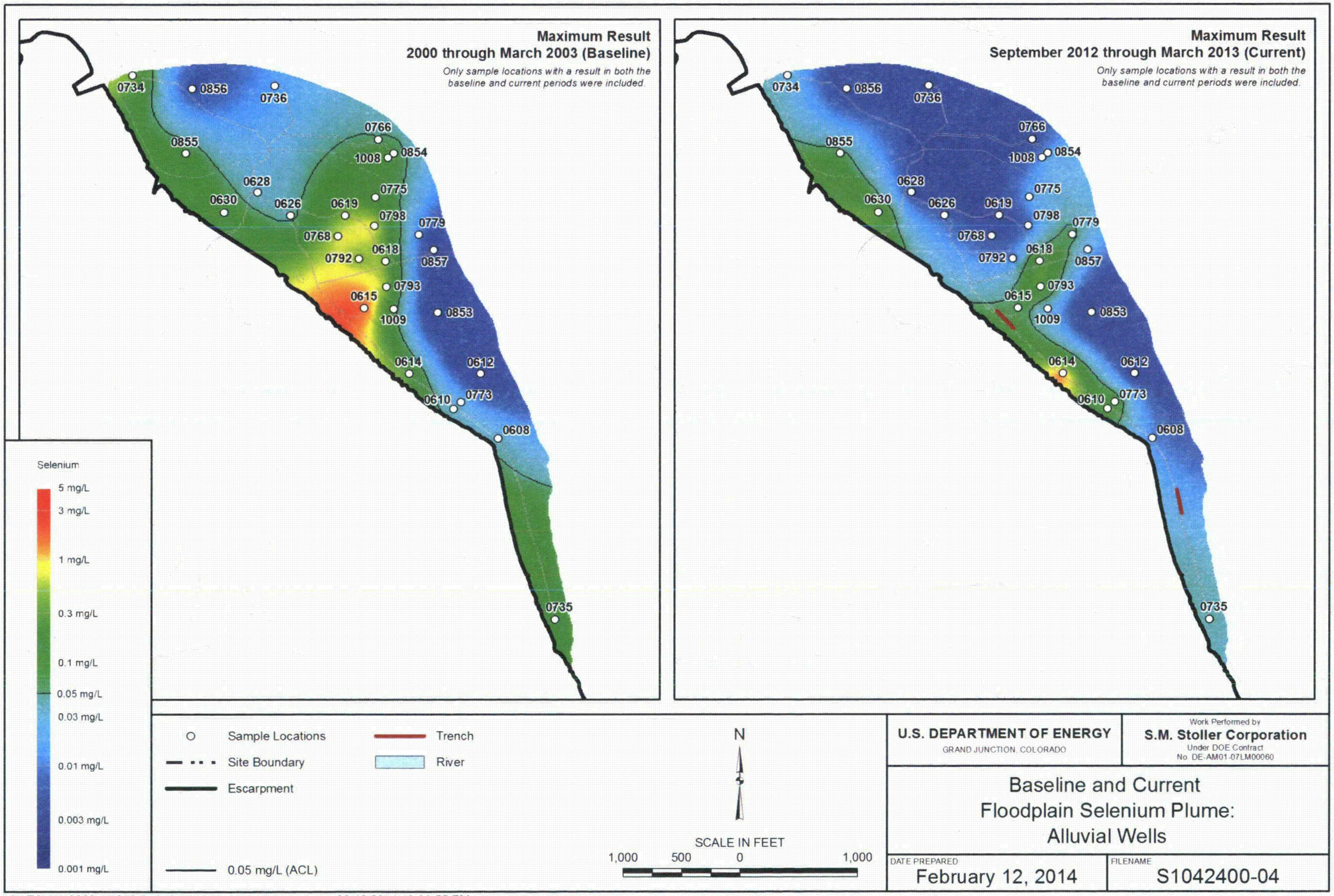


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Figure 18. Baseline (2000–2003) and August 2012 through March 2013 Floodplain Selenium Plumes

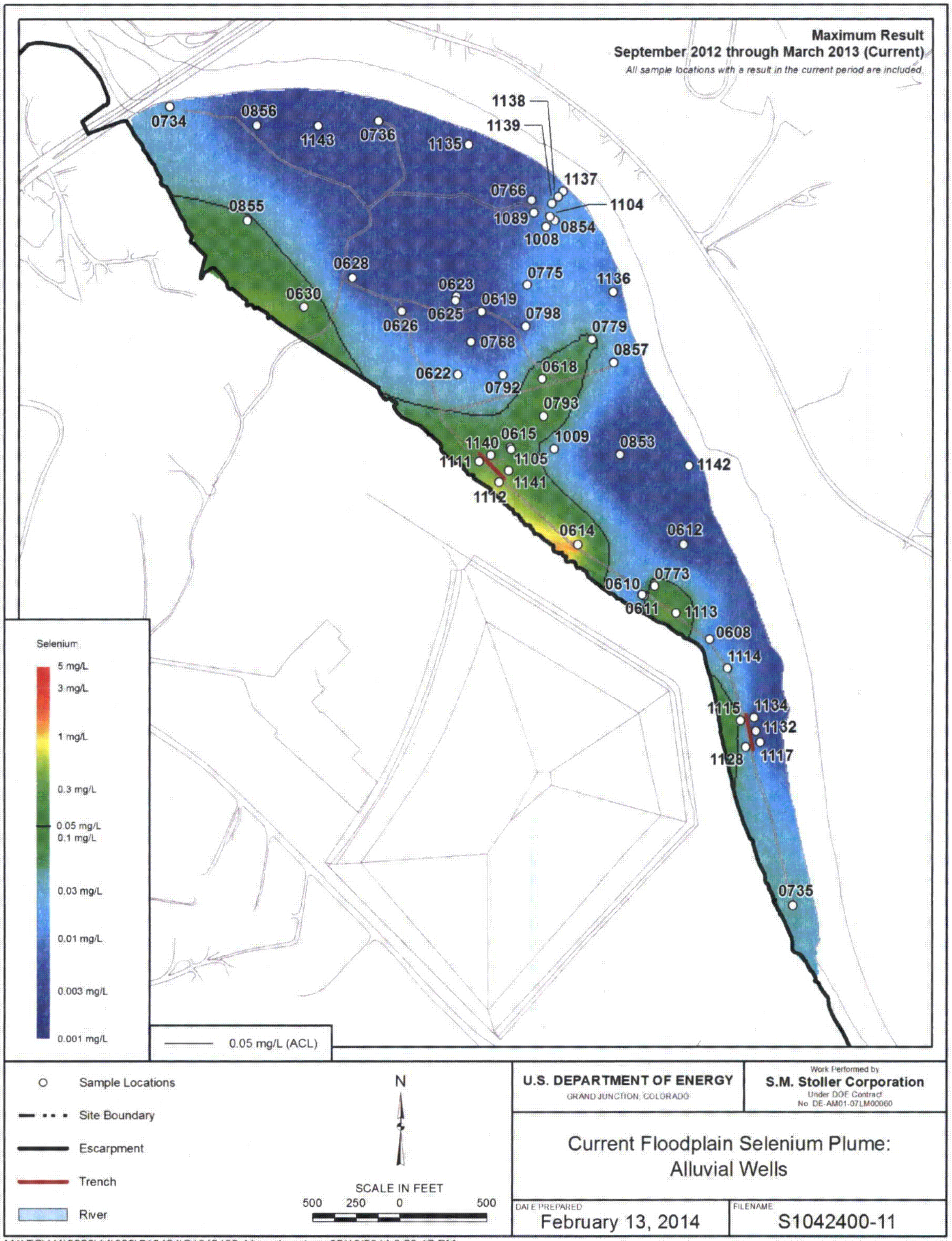

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Figure 19. August 2012 through March 2013 Floodplain Selenium Plume—All Sampled Wells

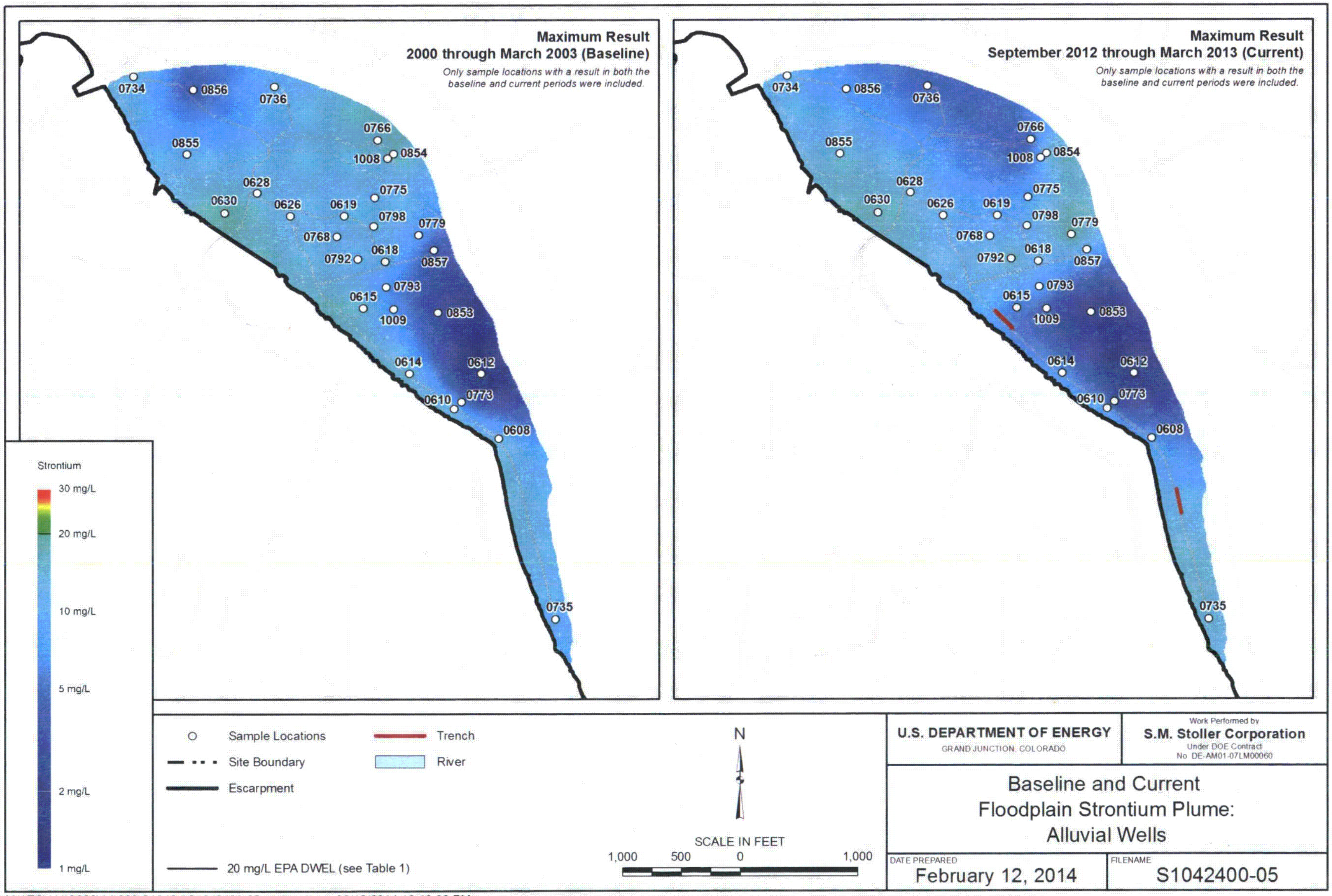

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Figure 20. Baseline (2000–2003) and August 2012 through March 2013 Floodplain Strontium Plumes

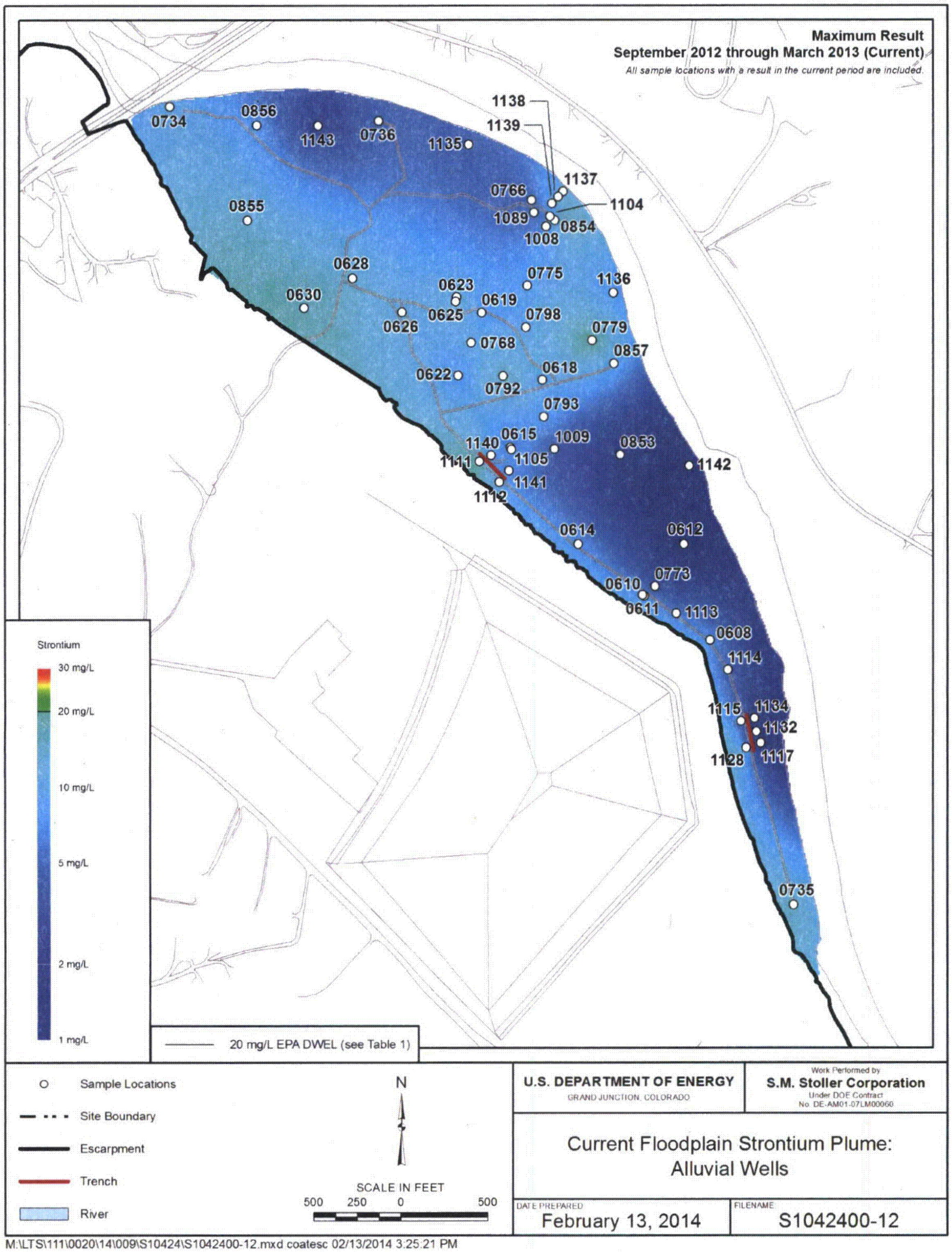

Figure 21. August 2012 through March 2013 Floodplain Strontium Plume—All Sampled Wells

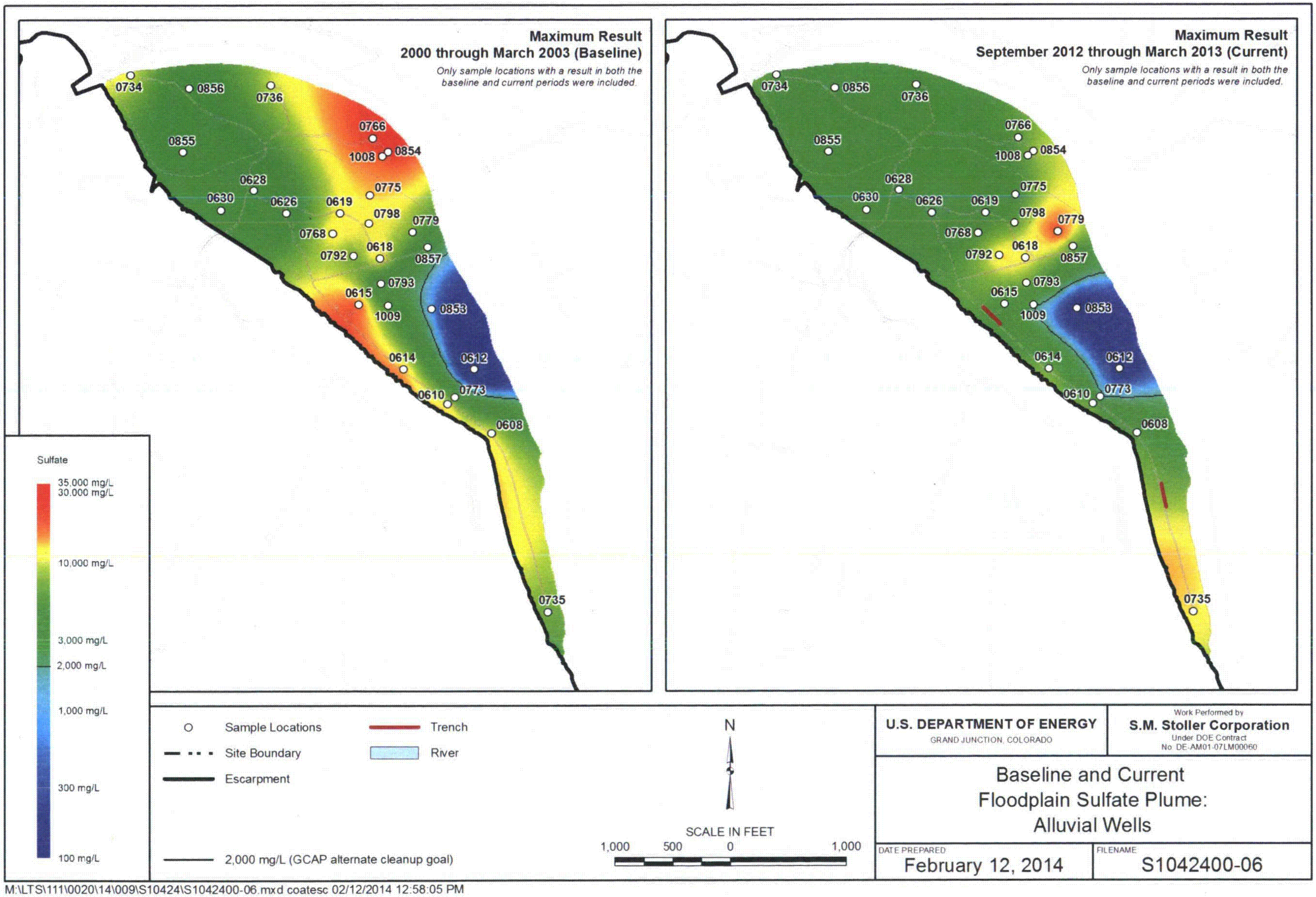

Figure 22. Baseline (2000–2003) and August 2012 through March 2013 Floodplain Terrace Sulfate Plumes

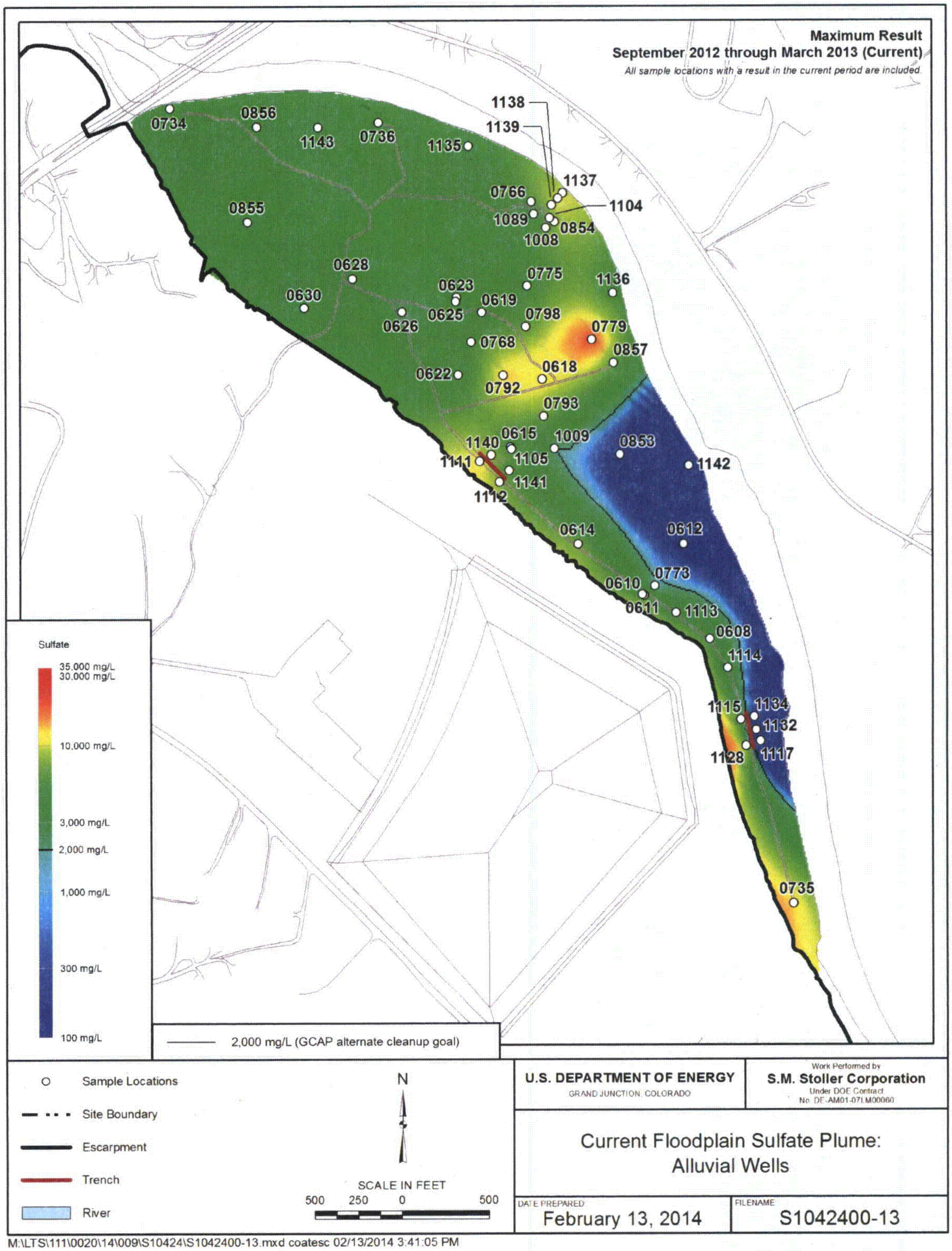

Figure 23. August 2012 through March 2013 Floodplain Sulfate Plume—All Sampled Wells

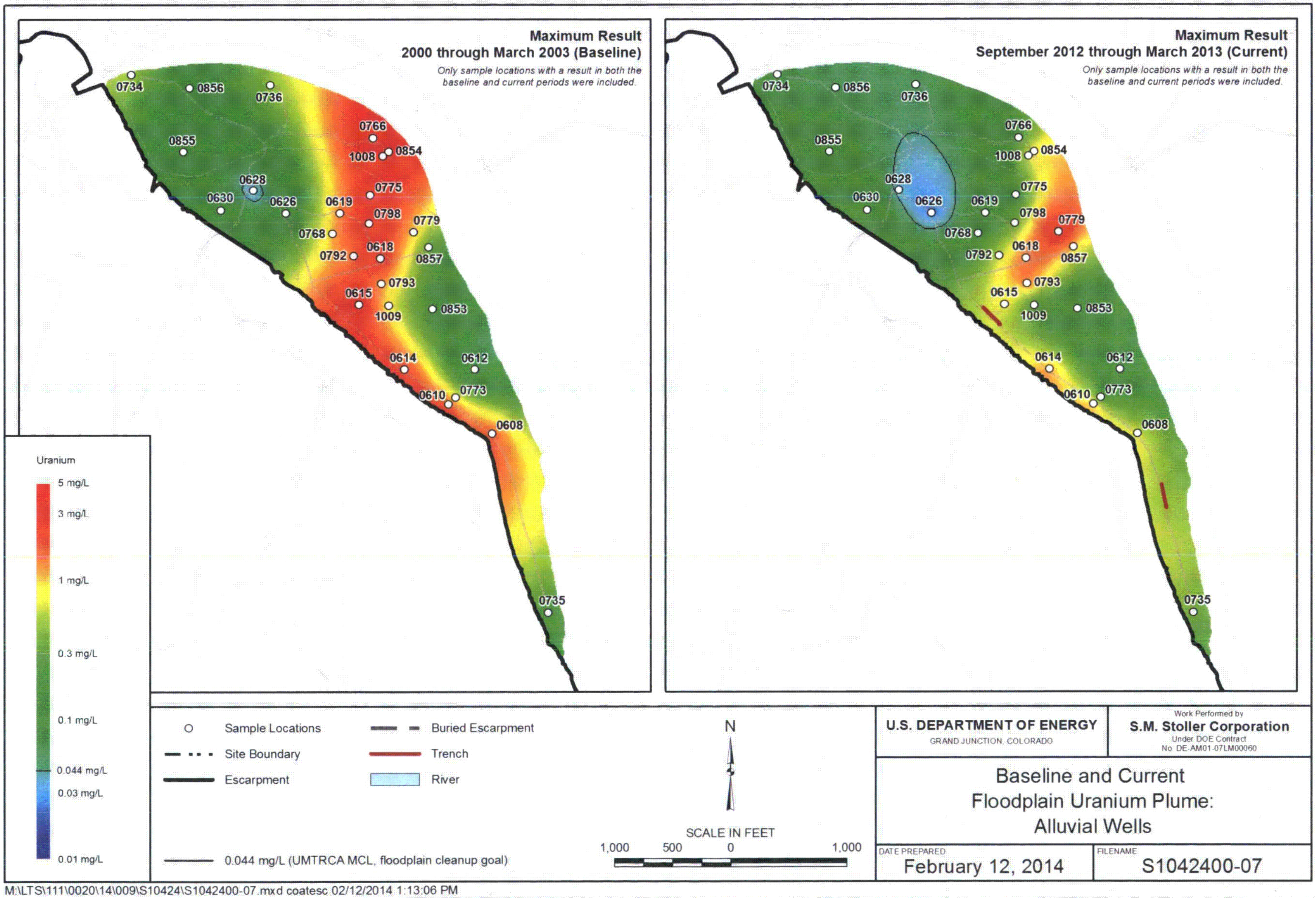

Figure 24. Baseline (2000–2003) and August 2012 through March 2013 Floodplain Uranium Plumes

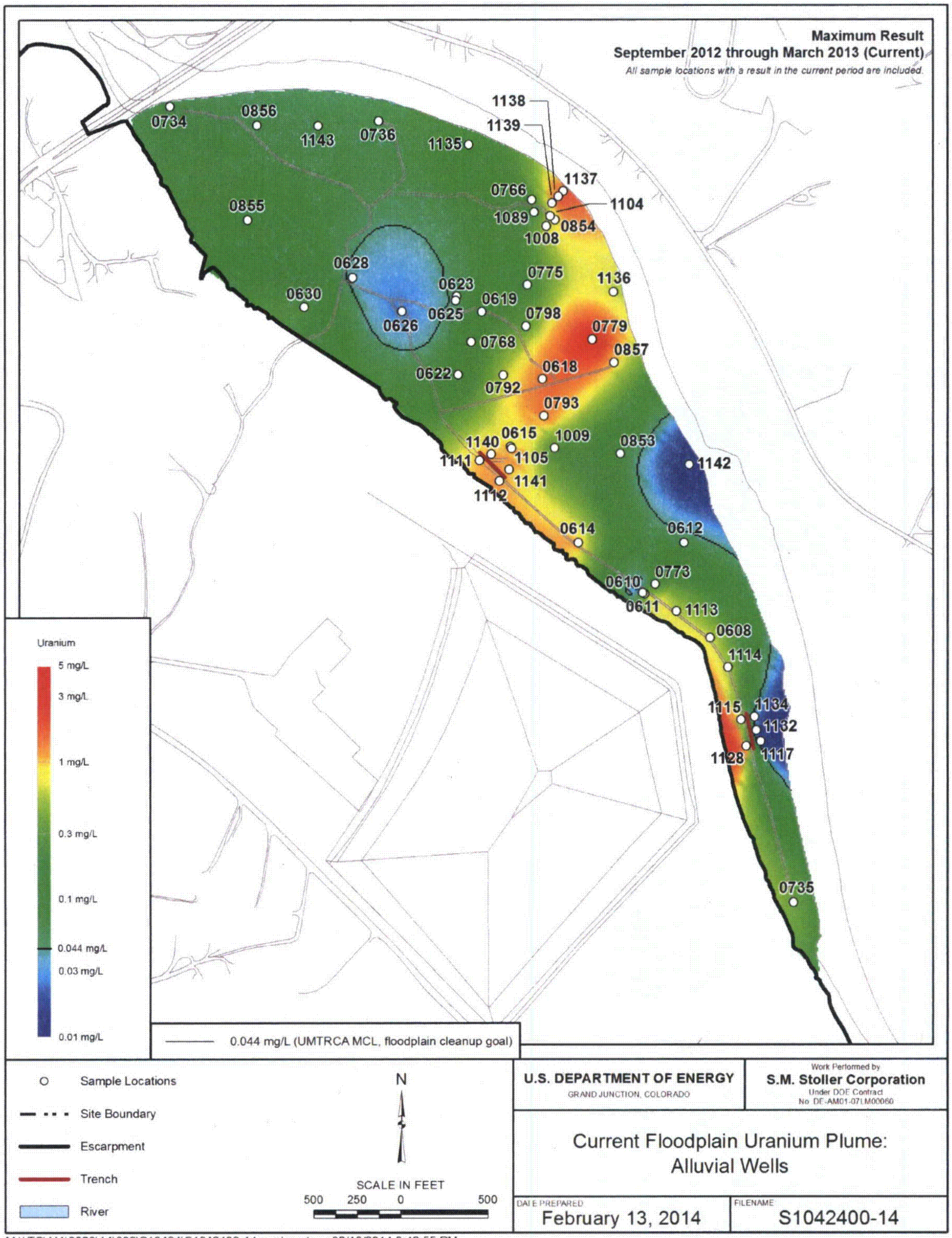

Figure 25. August 2012 through March 2013 Floodplain Uranium Plume—All Sampled Wells

2.0 Subsurface Conditions

This section summarizes hydraulic and water-quality characteristics of the floodplain and terrace groundwater systems for the April 2012 through March 2013 reporting period, approximately 10 years after startup of the treatment system.

2.1 Floodplain Subsurface Conditions

The following discussion of current subsurface conditions in the floodplain is based on the collection and analysis of groundwater samples and groundwater level data through March 2013. Analyses of groundwater level trends, groundwater flow directions, and contaminant distributions in the floodplain are presented below. Results are compared to baseline conditions established in the *Baseline Performance Report* (DOE 2003) to evaluate the effectiveness of the floodplain treatment system.

2.1.1 Floodplain Groundwater Level Trends

Analysis of groundwater-level data is important for evaluating flow in the floodplain aquifer, including changes in flow direction induced by variable flows in the San Juan River. Historically, three-point analyses, based on water levels collected semiannually (September and March), were used to ascertain flow directions. The analyses did demonstrate that flow in the floodplain generally behaves as expected in response to pumping from extraction wells and remediation trenches; that is, the flow of groundwater is predominantly toward these pumping locations (DOE 2008). A previous, detailed evaluation of the Trench 2 remediation system (DOE 2009) and a more recent evaluation of the Trench 1 system (DOE 2011d) supported this observation.

Groundwater levels in the floodplain aquifer continue to be manually recorded during routine semiannual groundwater sampling events in March and September. Figure 26, which plots groundwater elevations for a representative subset of the floodplain wells, indicates that annual groundwater level fluctuations over the past 10 years have been on the order of 2 ft, with the March elevations generally being higher than those measured in September.

In addition to manual measurements, relatively continuous groundwater elevations are measured in a subset of floodplain monitoring wells. Both the datalogger information and SOARS water-level data indicate a close correlation between subsurface water levels and the San Juan River's flow cycles, indicating relatively rapid responses of groundwater to changes in river flow and river stage.

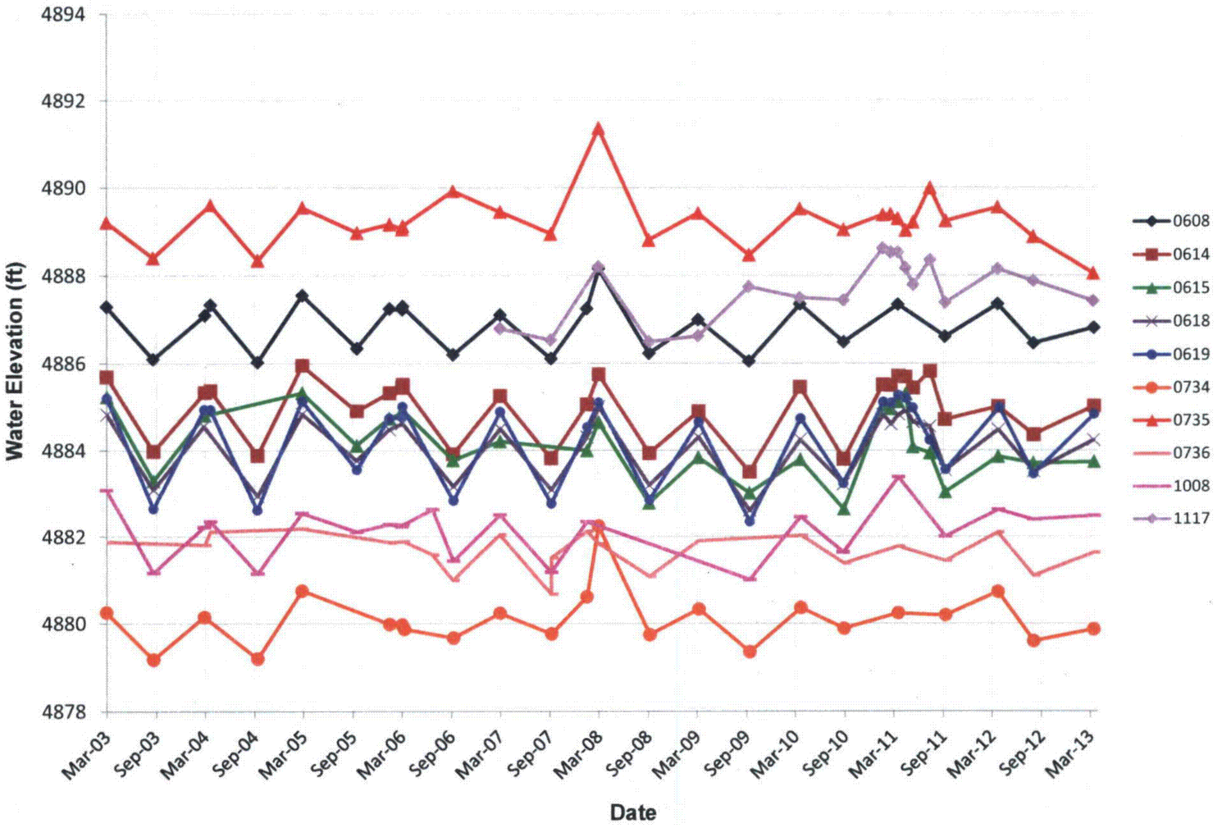

Figure 26. Floodplain Groundwater Elevations from Manual Measurements

2.1.2 Floodplain Contaminant Temporal Trends

Groundwater samples were collected from 59 floodplain monitoring wells in August 2012 and March 2013. The discussion in the remainder of this section uses the floodplain well groupings shown in Figure 27 to describe the changes that have occurred in the concentrations of floodplain contaminants since the last annual performance report. Emphasis is placed on those areas that best reflect remediation progress and those with some of the highest COC concentrations—namely, Trenches 1 and 2 and the well 1089 area (Figure 28 through Figure 31).

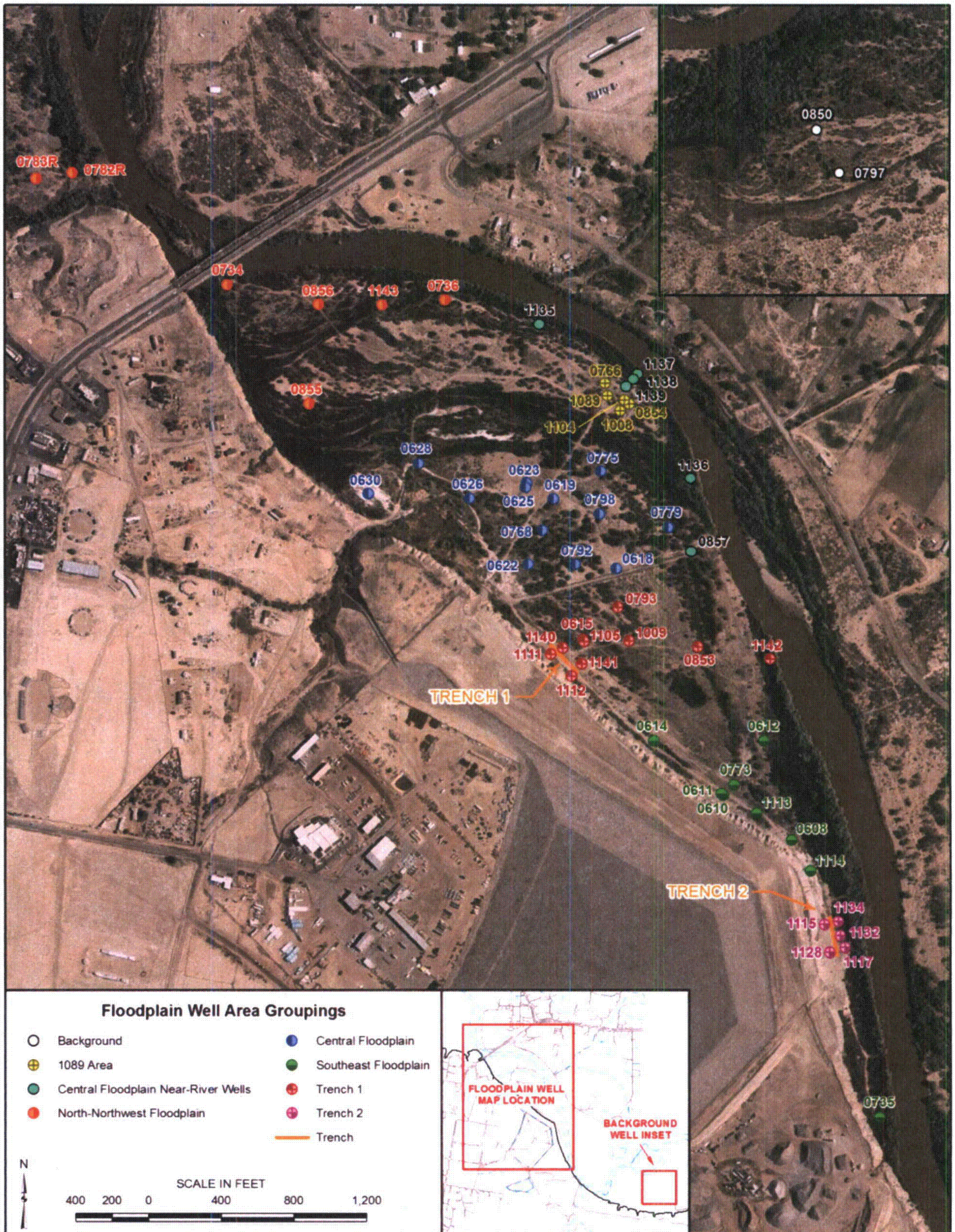

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Figure 27. Shiprock Site Floodplain Area Well Groupings

Trench 1 Area

Figure 28 presents time-concentration plots of uranium, nitrate, and sulfate concentrations in Trench 1 area wells. Reductions in levels of all three constituents (since the trench was installed in 2006) are apparent at wells 0615 and 1105, about 150 ft from the trench on its river side. At wells closer to the river, contaminant levels are much lower and appear relatively stable since the start of trench pumping. COC concentrations, especially nitrate, have also decreased in well 1112, between the trench and the escarpment.

Well 1089 Area

Figure 29 plots uranium, nitrate, sulfate, and selenium concentrations in well 1089 area wells. Uranium concentrations have decreased 1 to 2 mg/L in several wells, and sulfate concentrations have more than halved in wells 0766 and 0854 since the baseline period. Declines are also apparent for nitrate and selenium. For this reporting period, selenium concentrations in all wells in this area were $\leq$ 0.01 mg/L, below the 0.05 mg/L GCAP cleanup goal for the floodplain.

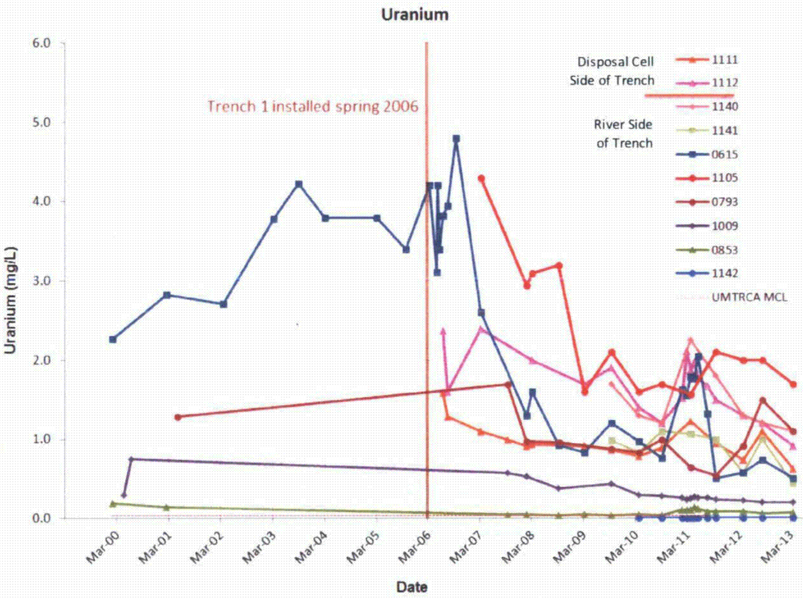
Central Floodplain Wells 0857 and 1135–1139

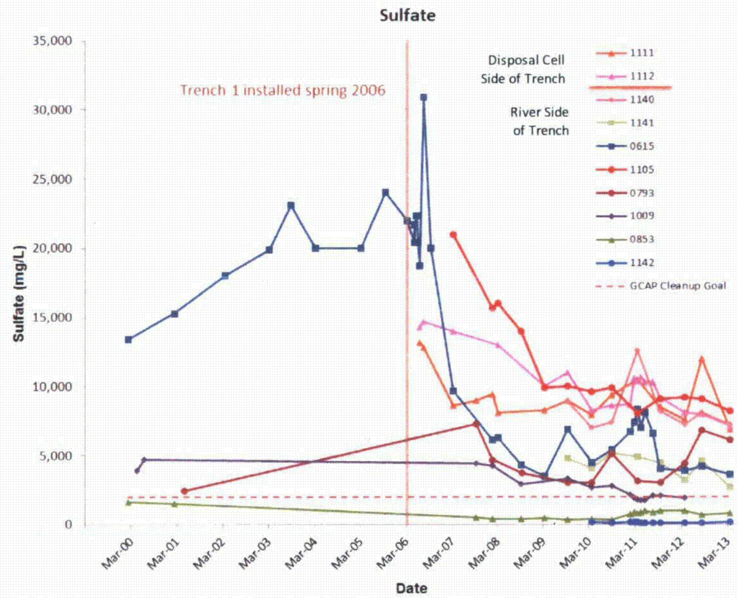
Figure 30 plots uranium, sulfate, and nitrate concentrations in central floodplain wells 0857 and 1135–1139, located near the San Juan River (Figure 27). This figure also shows corresponding hydrographs, based on manual measurements and daily (SOARS) measurements from well 1137, along with a plot of daily average river flows (right *y*-axis). Except for well 1135 (located north of the well 1089 area), COC concentrations in these central floodplain near-river wells have more than doubled since the last reporting period (Figure 30). The reason for these recent increases is not clear at this time and is being investigated.

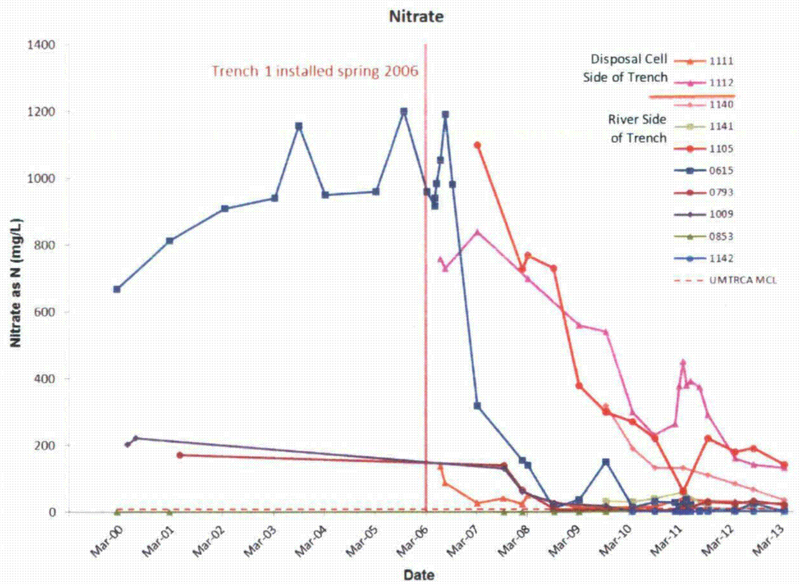
Trench 2 Area

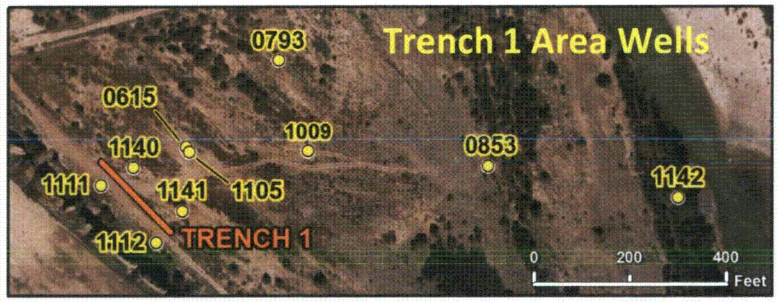
Figure 31 plots uranium, nitrate, and sulfate concentrations in the wells surrounding Trench 2. In this set of plots, all data are plotted in logarithmic scale because of the marked differences in contaminant magnitude between wells on the escarpment side of the trench and wells on the river side of the trench. While uranium concentrations in wells 1115 and 1128 have generally ranged from 0.5 to 1 mg/L, levels in wells located on the river side of the trench have remained stable at about
0.01–0.02 mg/L, below the 0.044 mg/L UMTRCA MCL.

As observed for uranium, sulfate and nitrate concentrations in wells between Trench 2 and the escarpment are several orders of magnitude higher than levels measured in wells located on the river side of the trench. For example, sulfate concentrations in wells between the trench and the escarpment generally range from 3,000 to 10,000 mg/L. In contrast, levels in wells on the river side of the trench have been at or below 560 mg/L, well below the 2,000 mg/L floodplain cleanup goal. The 10 mg/L nitrate (as N) UMTRCA MCL was exceeded in well 1134 in August 2012 (28 mg/L). However, the most recent result (0.025 mg/L), is well below the cleanup goal.









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. Although not technically part of the Trench 1 area, wells 0793, 1009, 0853, and 1142 are included to show trends for wells closer to the San Juan River.

Figure 28. Uranium, Nitrate, and Sulfate Concentration Trends in Trench 1 Area Wells

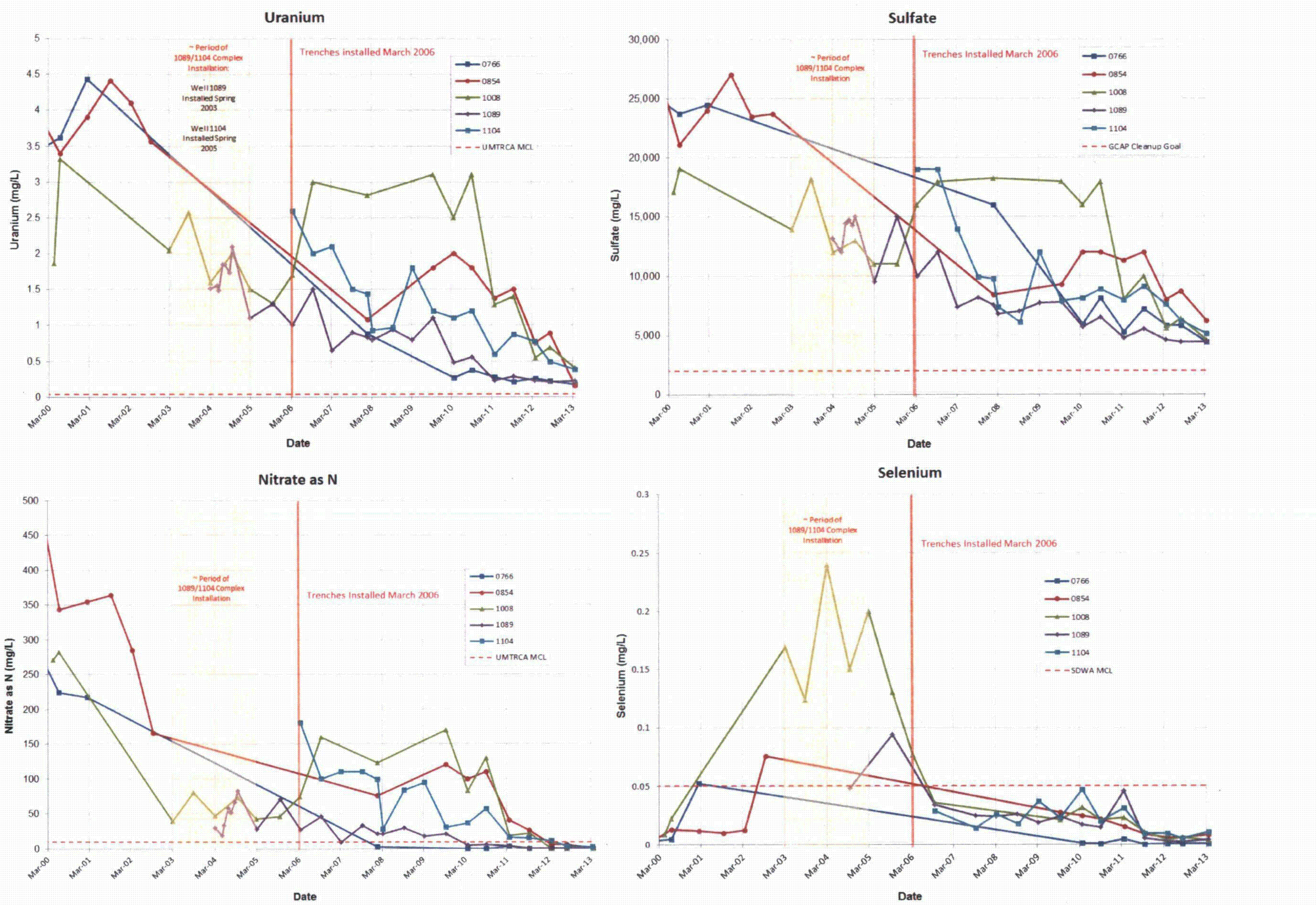


Figure 29. Uranium, Nitrate, Sulfate, and Selenium Trends in the Well 1089 Area

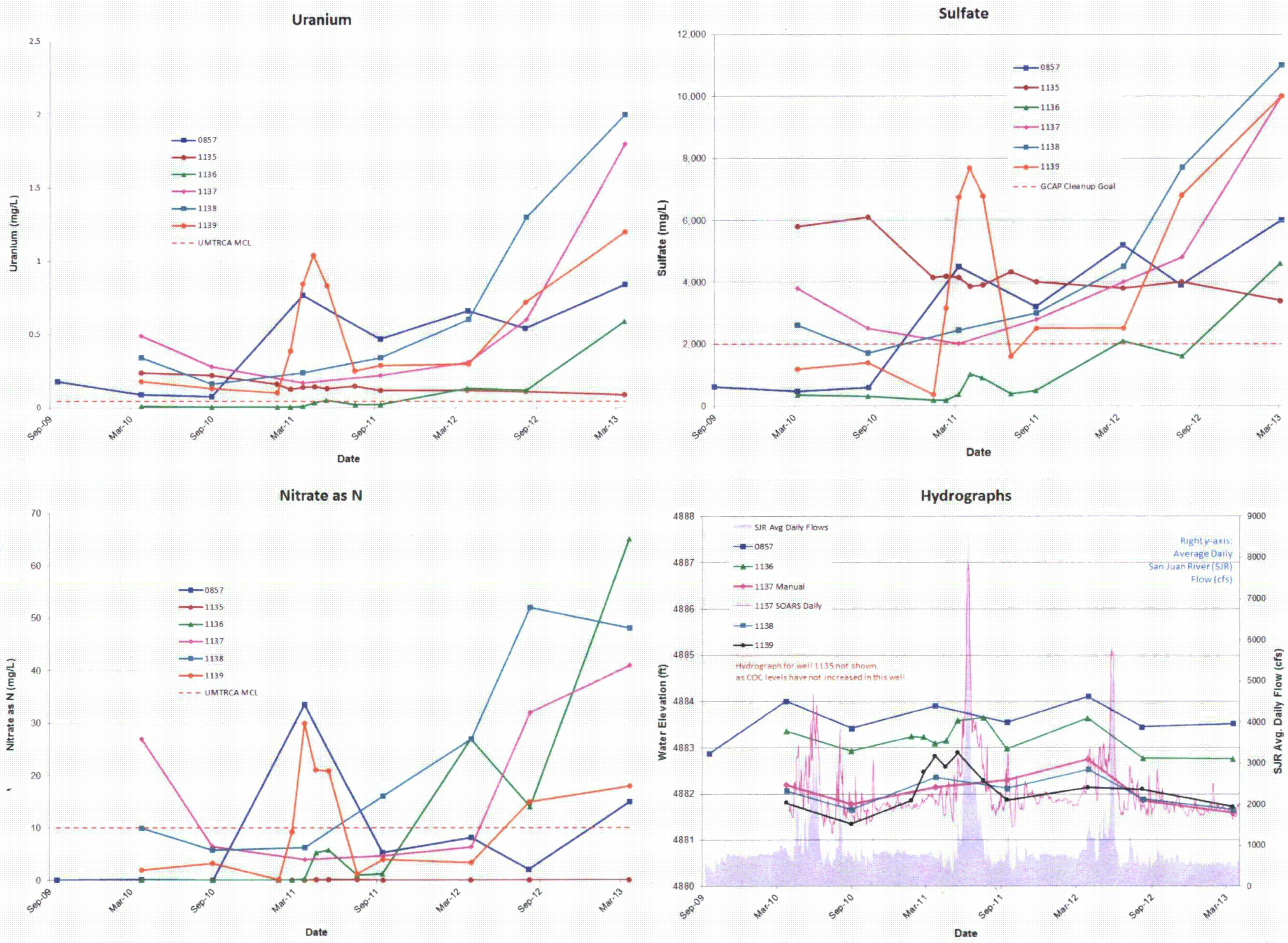


Figure 30. Uranium, Sulfate, and Nitrate in Central Floodplain Wells 1135–1139 and 0857

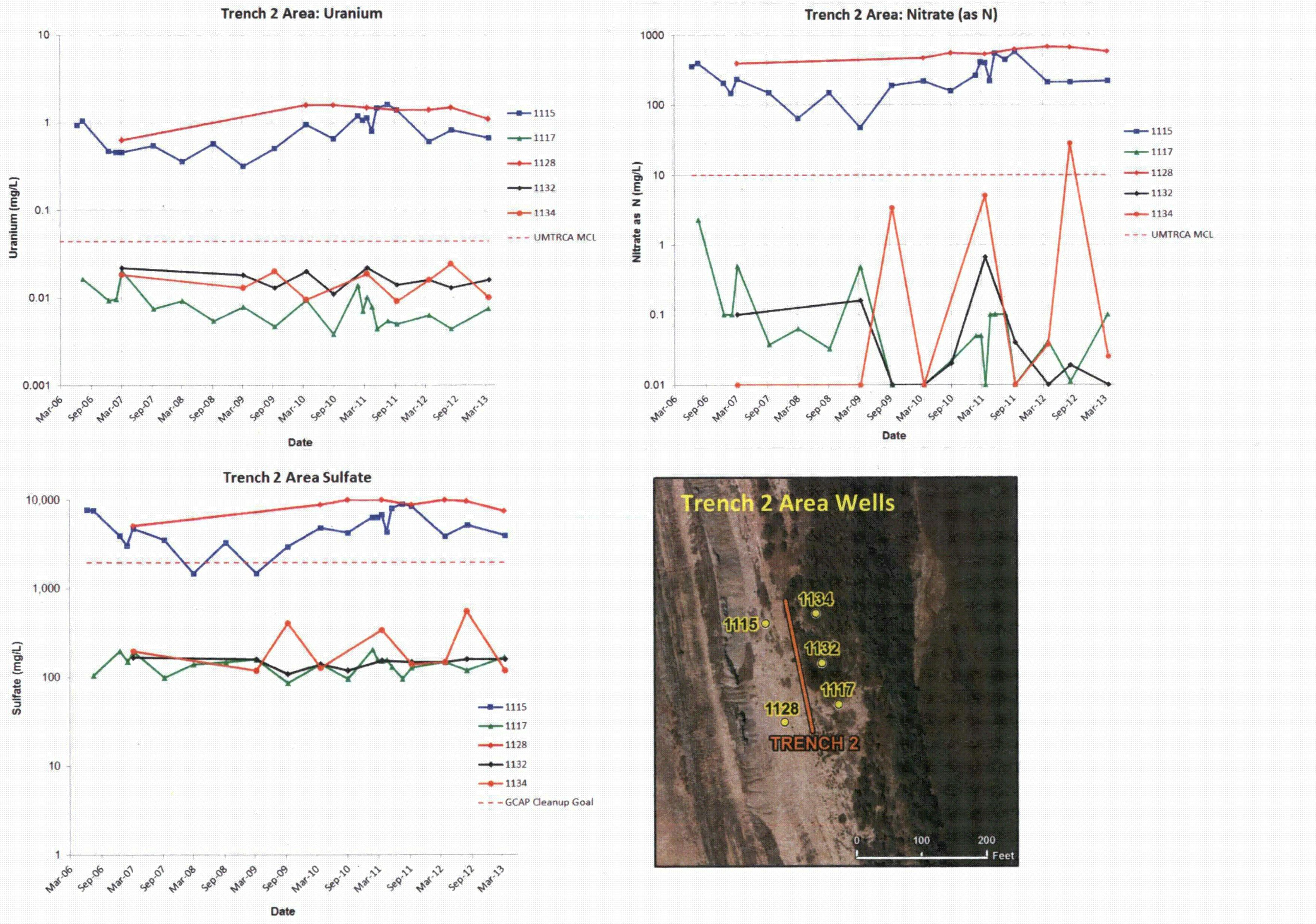


Figure 31. Uranium, Nitrate, and Sulfate Trends in Trench 2 Area Wells

Southeast Floodplain

Figure 32 plots uranium concentrations in the southeast well subset shown in Figure 27. Temporal trends in concentrations in this set of wells, particularly at the base of the escarpment, are important because they may indicate decreases, if any, of contaminant discharge from the terrace to the floodplain via fractures in the Mancos Shale. In Figure 32, declines are evident for well 0608 (screened in shallow Mancos Shale) and alluvial wells 0610, 0614, 0773, and 1113, all located at the base of the escarpment. Trending is not apparent for the remaining wells in this subset.

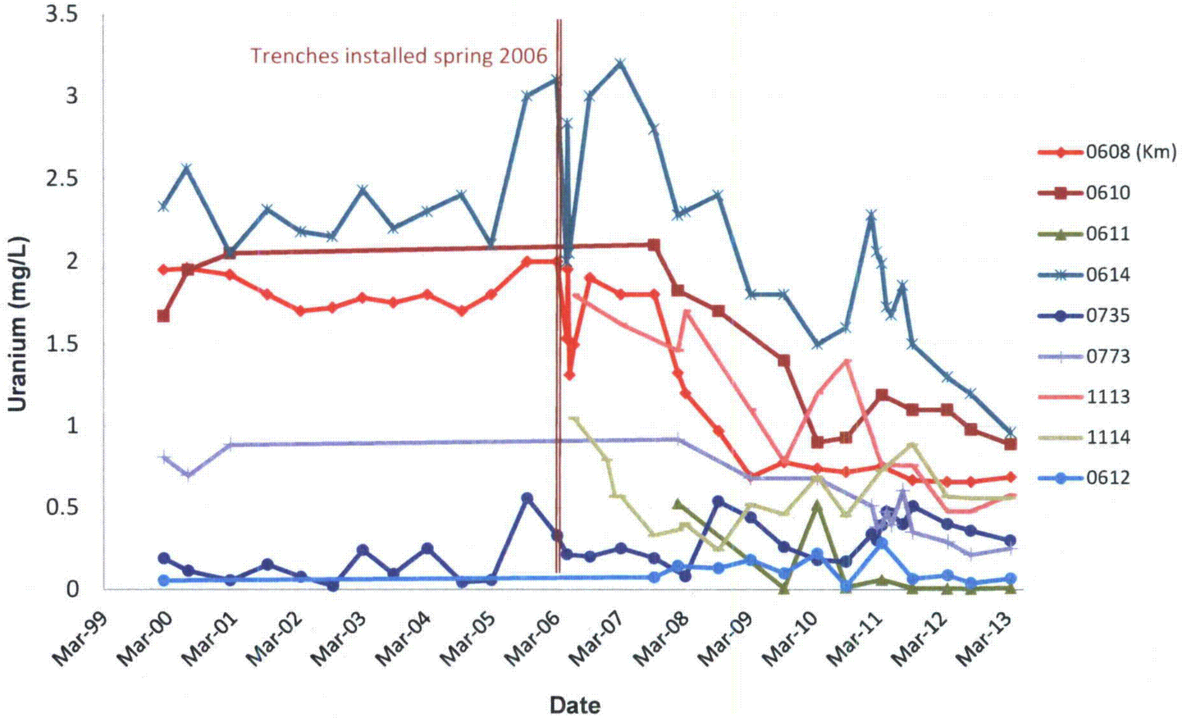


Figure 32. Uranium Trends in Southeastern Floodplain Wells

Other Floodplain Areas and COCs

This section has focused primarily on uranium because, of all the COCs, it is most prevalent on the floodplain and it is a reliable indicator of remediation progress. Additional data and information regarding contaminant trends for all COCs is provided in the corresponding Data Validation Packages (DOE 2012c, DOE 2012d) and is also available in the Geospatial Environmental Mapping System (GEMS) on the LM website.

2.1.3 Floodplain Contaminant Removal

The floodplain trenches, wells 1089 and 1104, and seep sump 1118 removed approximately 351,000 pounds of contaminants from the floodplain groundwater system during the 2012–2013 reporting period (refer to Table 3 in Section 3.2.3). As prescribed in the GCAP (DOE 2002), DOE currently monitors eight river locations, including one upgradient background location.[1] Consistent with previous annual reports, Figure 33 plots concentrations of uranium (left *y*-axis) and nitrate (right *y*-axis) for location 0940, which was identified as a key river monitoring location in the GCAP. This sampling point is located just north of pumping wells 1089 and 1104, where contaminant plumes in the alluvial aquifer likely discharge to the river under background, nonpumping conditions (DOE 2002).

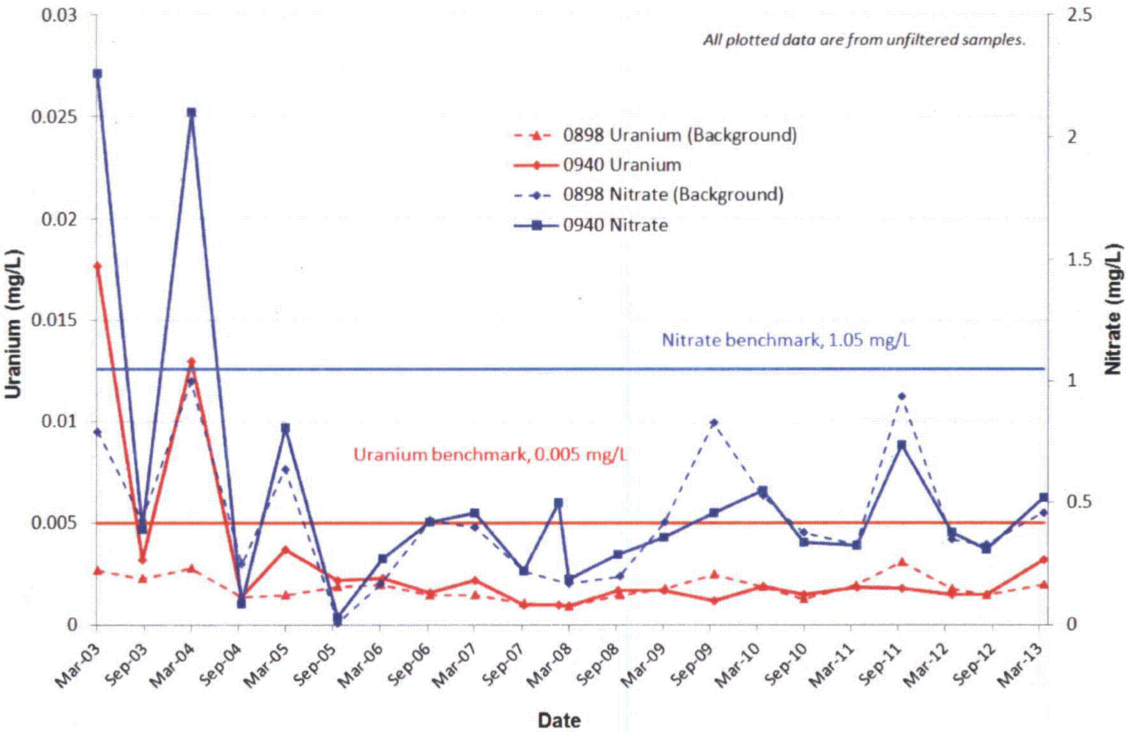


Figure 33. Uranium and Nitrate Concentrations in San Juan River Location 0940 and Background Location 0898

At location 0940, uranium and nitrate trends are correlated with each other and with trends at the upstream (background) 0898 location. Of all surface water sampling points on the west bank of the river in the floodplain area, 0940 is the only location where measured concentrations have exceeded background benchmarks for a COC. Background benchmarks were statistically derived based on historical results from background location 0898 (DOE 2002). As shown in Figure 33, uranium and nitrate concentrations at this location have remained below these benchmarks (0.005 and 1.05 mg/L, respectively) since 2004.

[1] Surface location 0899 (Figure 3) has been sampled in recent years for chemical analysis but it is not a designated GCAP monitoring location.

2.2 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 2013. 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, selected contaminant concentrations are measured at each extraction well, drain, and seep. Estimates of mass removal via the terrace remediation system, compiled for this performance period, are presented in Section 3.2.3 of this report.

2.2.1 Terrace Groundwater Level Trends

As of April 1, 2013, the cumulative volume of water removed from the terrace extraction system since pumping began was close to 33 million gallons. Pumping records indicate that approximately 3.1 million gallons were removed from the terrace between April 2012 and April 2013. Groundwater-level data from the terrace collected during the March 2013 sampling event were compared to corresponding groundwater elevation data for the baseline period (most recent from 2000 to March 2003). Figure 34 presents a qualitative map view of some of the changes in groundwater elevations during this period. 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 30 water-level measurements taken in August 2012 or March 2013 at wells screened in alluvium beneath the terrace, the majority showed declines relative to the baseline period of March 2003. Declines ranged from 0.05 ft to maximum decreases of 8.4–8.5 ft in west terrace wells 0836 and 0837, the average decrease was about 3 ft. Five alluvial west terrace wells (0832, 0846, 1060, 1120, and 1122) were dry at the time of the March 2013 sampling event.

Water levels have also been monitored using pressure transducers connected to dataloggers in selected wells on the terrace. Plots of datalogger-based water elevations versus time are shown in Figure 35 and Figure 36. Figure 35 plots water level elevations for wells greater than 4,930 ft msl; most of the wells in this category are east of Highway 491. Although some of the hydrographs in Figure 35 indicate that groundwater levels near the former mill and tailings pile generally decreased between 2003 and early 2009, upward trends are apparent at most locations in following years.

Figure 36 presents datalogger-derived water elevations for wells with water elevations below 4,930 ft msl. Three of the wells in this category (0836, 0846, and 0848) are located west of Highway 491, in a part of the terrace that was irrigated in earlier years. The hydrographs for wells 0836 and 0848 indicate that water levels at these locations have gradually declined; well 0846 has been dry since August 2010. Water levels in wells 0725, 0726, and 0827, located just west of the disposal cell near Bob Lee Wash, have been generally stable.

2.2.2 Drain Flow Rates

As discussed in the Baseline Performance Report (DOE 2003), the flow rates of the pumps removing water from the drains installed in Bob Lee Wash and Many Devils Wash were expected to decrease as groundwater levels in the terrace declined. Between April 2012 and March 2013, the average pumping rate from Bob Lee Wash was 3.1 gpm (refer to Figure 51). The average pumping rate from the drain in Many Devils Wash during the performance period was about 0.6 gpm (see Figure 52).

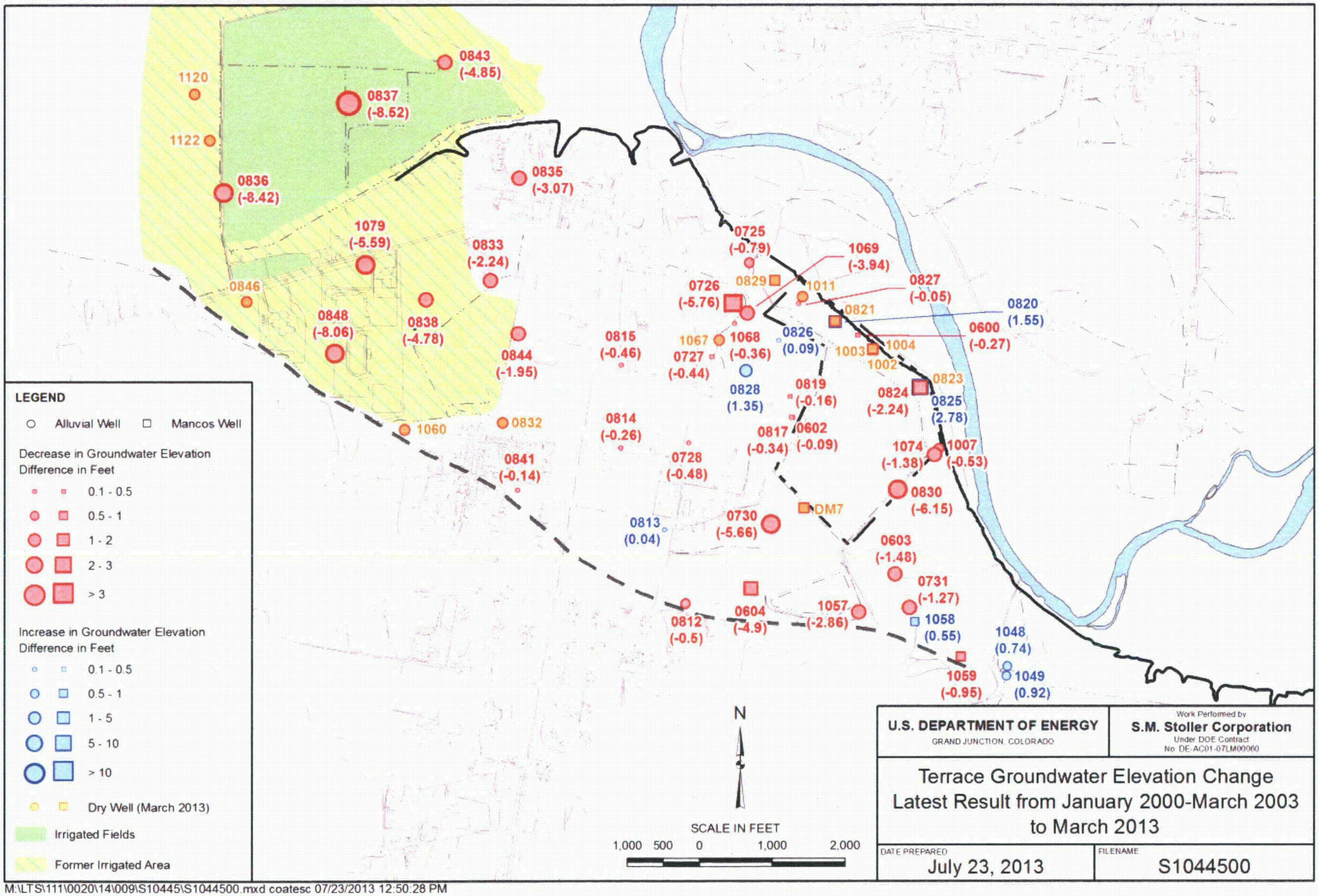


Figure 34. Terrace Groundwater Elevation Changes from Baseline (2000–2003) to Current (March 2013) Conditions

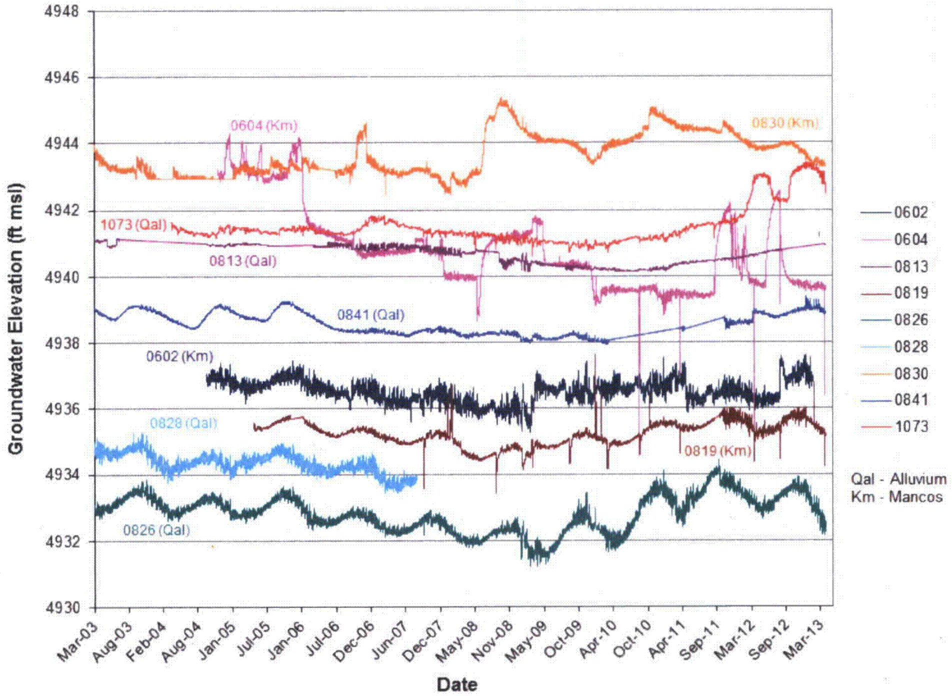


Figure 35. Terrace Datalogger Measurements, Wells with Water Elevations above 4,930 ft msl

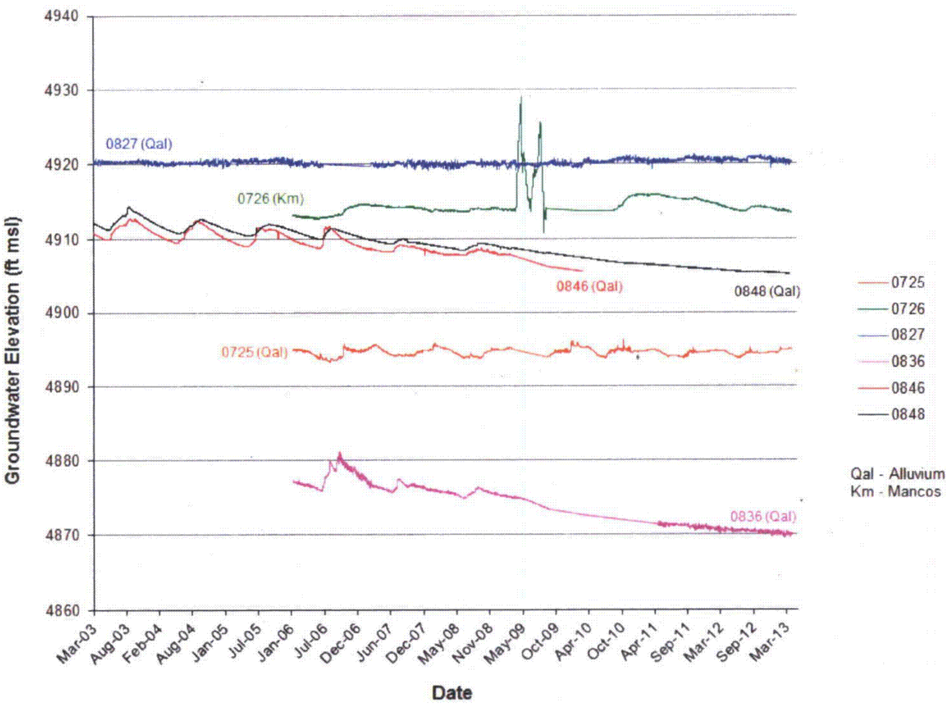


Figure 36. Terrace Datalogger Measurements, Wells with Water Elevations less than 4,930 ft msl

3.0 Remediation System Performance

This section describes the key components of the floodplain and terrace groundwater remediation systems and summarizes their performance for the 2012–2013 reporting period.

3.1 Floodplain Remediation System

The floodplain remediation system consists of the 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) used to collect discharges from seeps 0425 and 0426 on the escarpment. The objective of the floodplain groundwater extraction system is to reduce the mass of COCs in alluvial groundwater near the San Juan River and to lessen exposure and potential risks. All groundwater collected from the floodplain extraction wells and trenches is piped south to the terrace and discharged into the evaporation pond.

3.1.1 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. Corresponding pumping rates and cumulative volumes of groundwater extracted are plotted in Figure 35 and Figure 36. From April 2012 through March 2013, approximately 2.3 million gallons of water were removed from well 1089 at an average effective pumping rate of about 6 gpm.[2] Pumping rates at well 1104 averaged about 0.9 gpm; the cumulative extracted volume was about 470,000 gallons. During the 10-year period since the start of operations in March 2003 through the end of March 2013, totals of approximately 27.2 and 5.5 million gallons of water have been removed from wells 1089 and 1104, respectively.

3.1.2 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 2012 through March 2013, approximately 4.4 million gallons of water were removed from Trench 1 at an average pumping rate of 8.3 gpm (Figure 39). In 2012–2013, about 1.9 million gallons of water were removed from Trench 2 at an average effective pumping rate of 6.8 gpm (Figure 40).

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

[2] In the text of this report, total volumes are rounded (e.g., to the nearest thousand or larger); corresponding non-rounded values are shown in the figures and are listed in Table 3.

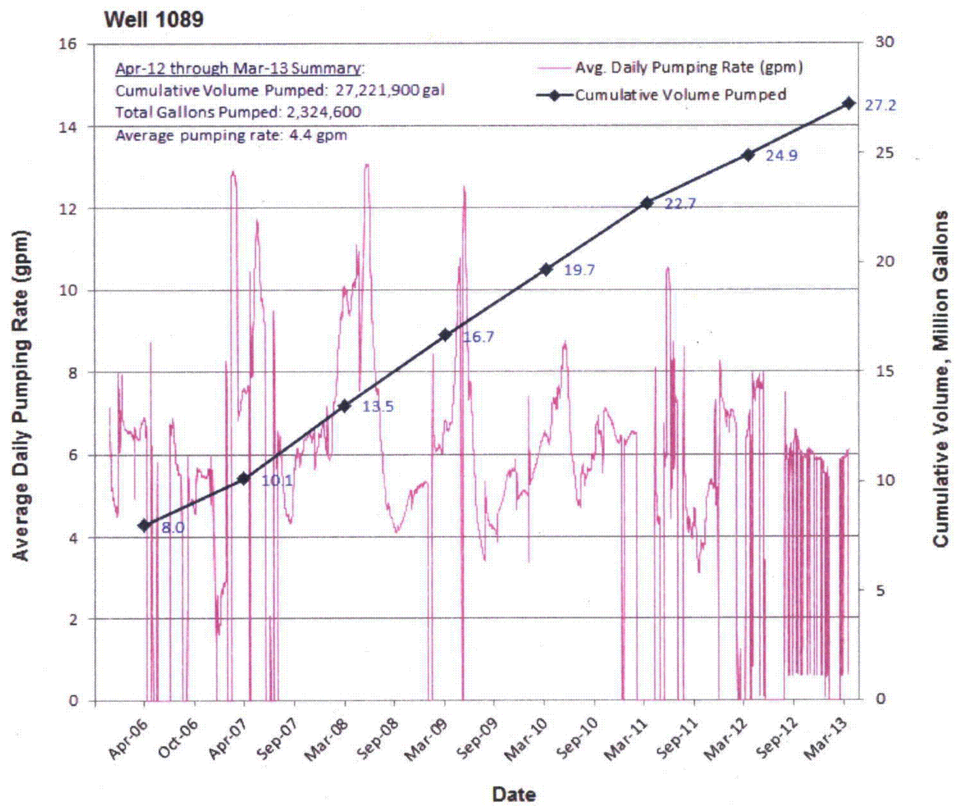


Figure 37. Floodplain Well 1089 Pumping Rate and Cumulative Groundwater Volume Extracted

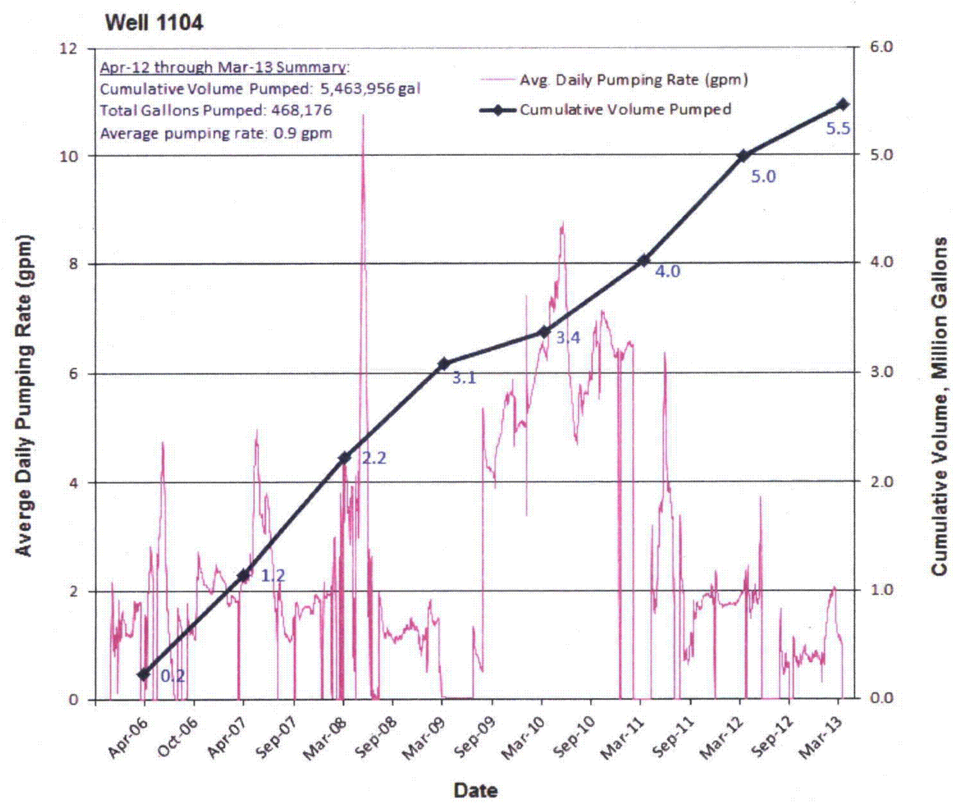


Figure 38. Floodplain Well 1104 Pumping Rate and Cumulative Groundwater Volume Extracted

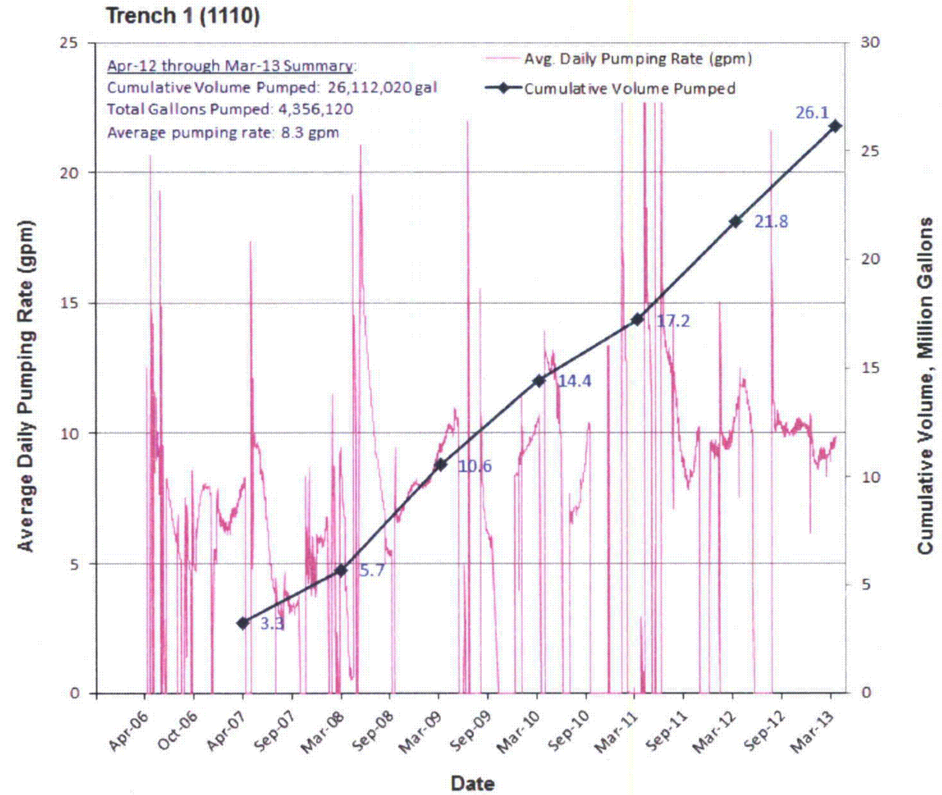


Figure 39. Floodplain Trench 1 Pumping Rate and Cumulative Groundwater Volume Extracted

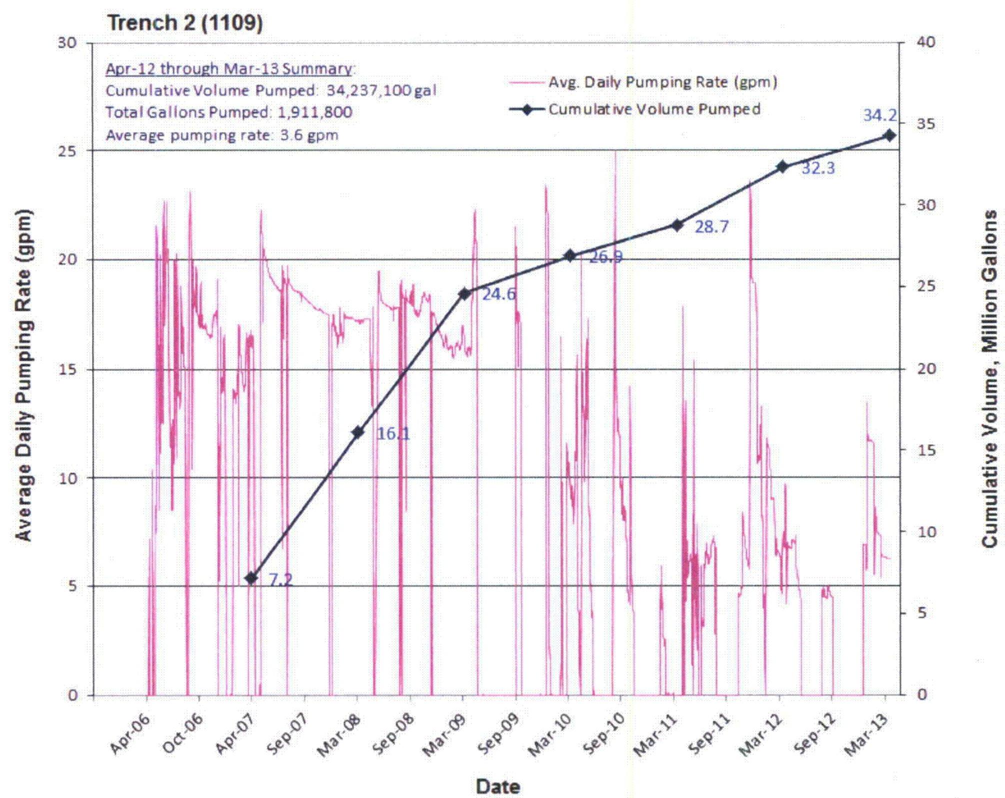


Figure 40. Floodplain Trench 2 Pumping Rate and Cumulative Groundwater Volume Extracted

3.1.3 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 2012 through March 2013, the average discharge rate from the seep collection drain was 0.43 gpm, similar to the average rates reported in the last several years. Approximately 226,000 gallons were pumped from the seeps during this period, yielding a total cumulative volume of about 1.87 million gallons. Figure 41 plots the historical rates of groundwater discharge from the escarpment seeps.

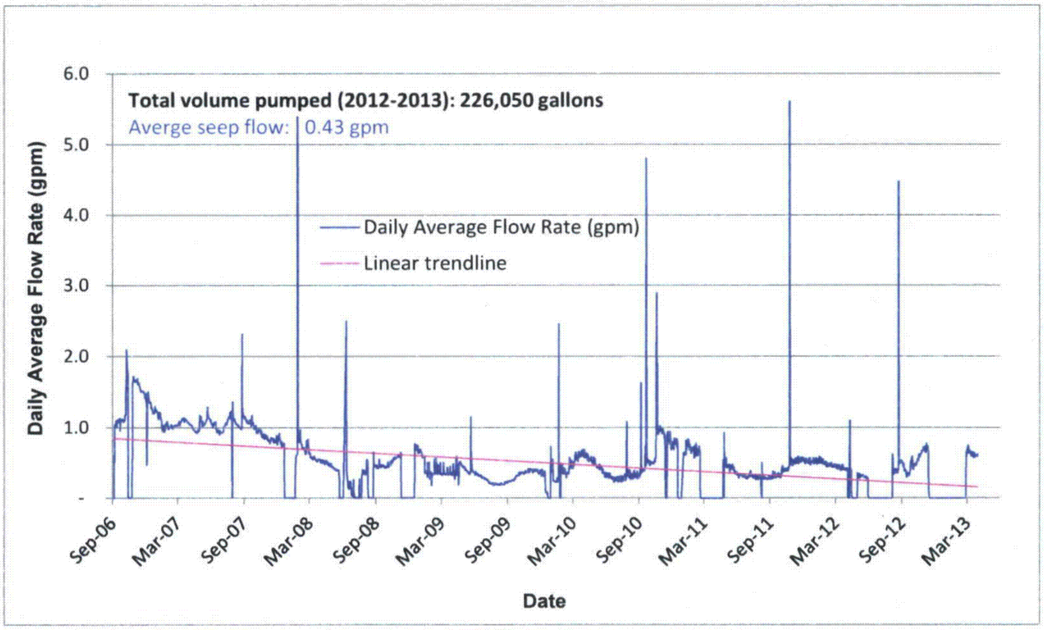


Figure 41. Historical Seep Flows (Seeps 0425 and 0426)

3.2 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.

3.2.1 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 2 compares the average pumping rate and total groundwater volume removed from each extraction well for the current (2012–2013) and previous (2011–2012) reporting periods.

Table 2. Terrace Extraction Wells: Average Pumping Rates and Total Groundwater Volume Removed

Well	Previous Period (April 1, 2011, through March 31, 2012)		Current Period (April 1, 2012, through March 31, 2013)	
	Average Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)	Average Pumping Rate (gpm)	Total Groundwater Volume Removed (gallons)
0818[1]	0.68	357,381	0.91	480,461
1070	0.022	11,355	0.035	18,349
1071	0.007	3,553	0.012	6,523
1078	0.59	311,880	1.1	586,320
1091	0.016	8,665	0.003	1,816
1092	0.002	933	0.004	2,167
1093R	0.57	301,580	0.88	464,210
1095	0.59	215,230	0.33	172,587
1096	0.42	222,790	0.31	160,318
Total	**2.9**	**1,433,367**	**3.6**	**1,892,751**

[1] Well 818 was identified in the GCAP as a performance assessment well.

As shown in Table 2, the current-period average pumping rates for terrace extraction wells ranged from 0.003 gpm to 1.1 gpm, and the total groundwater volume removed from each well during this period ranged from 1,800 gallons to about 586,300 gallons. The cumulative total volume removed from pumping the terrace extraction wells (about 1.9 million gallons) is about 30 percent higher than the volume extracted during the 2011–2012 reporting period (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, 2002, 2005, 2011a). 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, below the 8 gpm objective.

Pumping rates and corresponding cumulative groundwater volumes removed from individual terrace extraction wells are presented in Figure 42 through Figure 50. Although active remediation began in March 2003, these figures only plot data after 2004–2005, when site remediation system wells and drains were instrumented with LM's automated telemetry data collection system (SOARS).

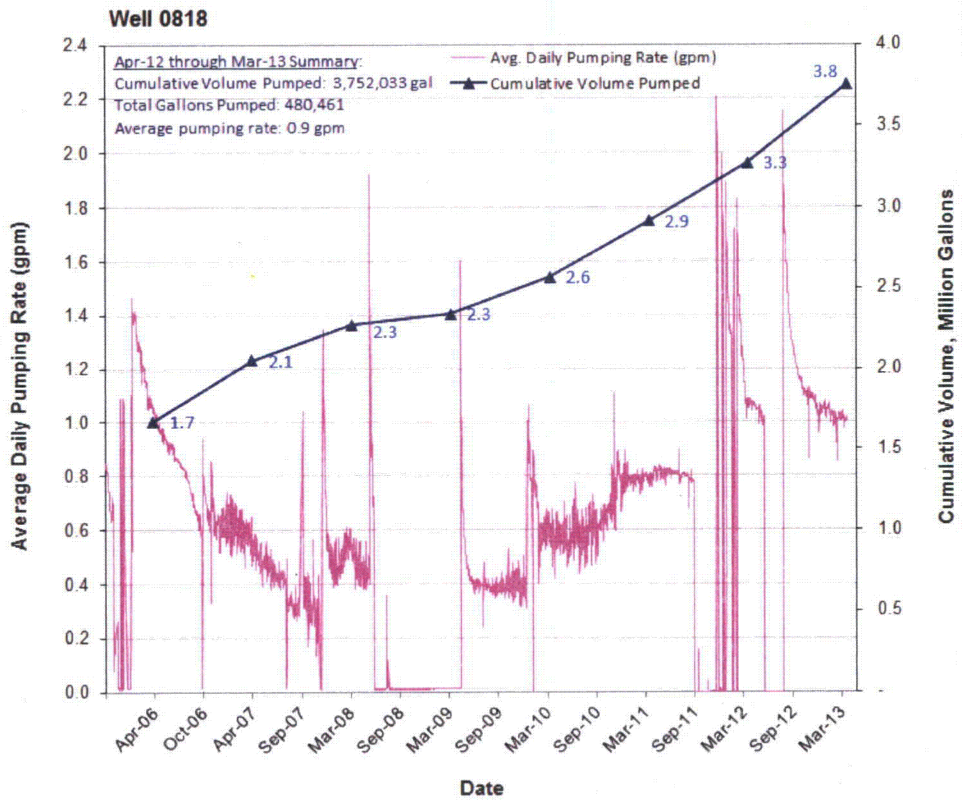


Figure 42. Terrace Well 0818 Pumping Rate and Cumulative Groundwater Volume Extracted

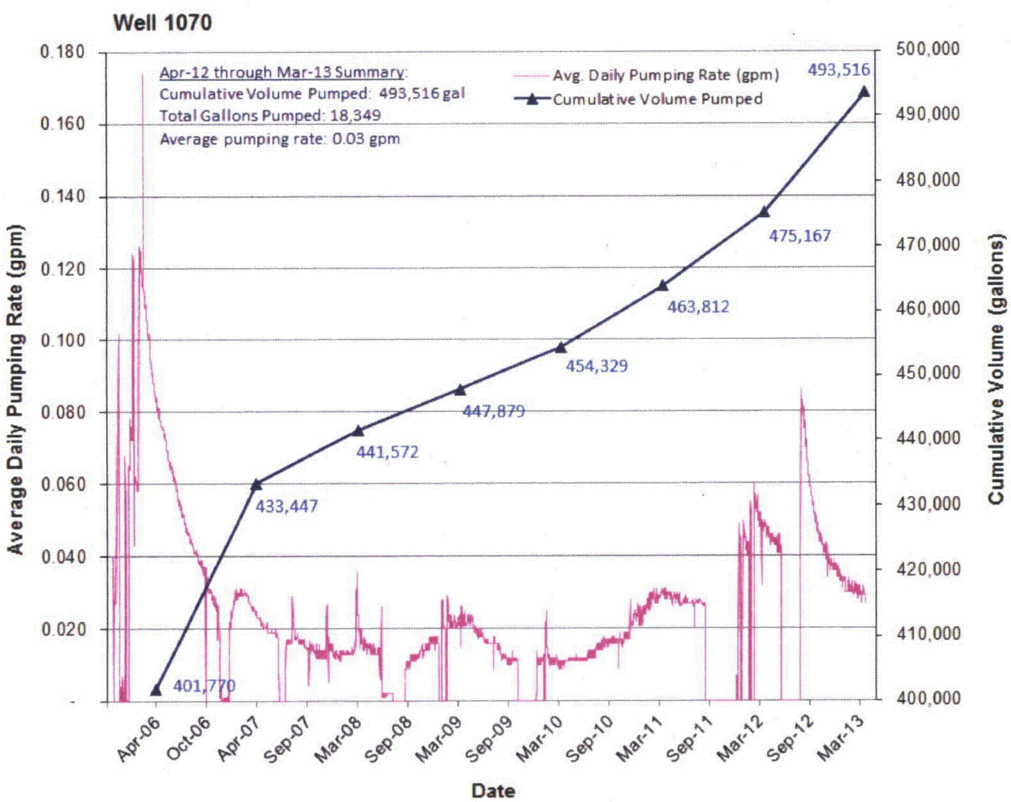


Figure 43. Terrace Well 1070 Pumping Rate and Cumulative Groundwater Volume Extracted

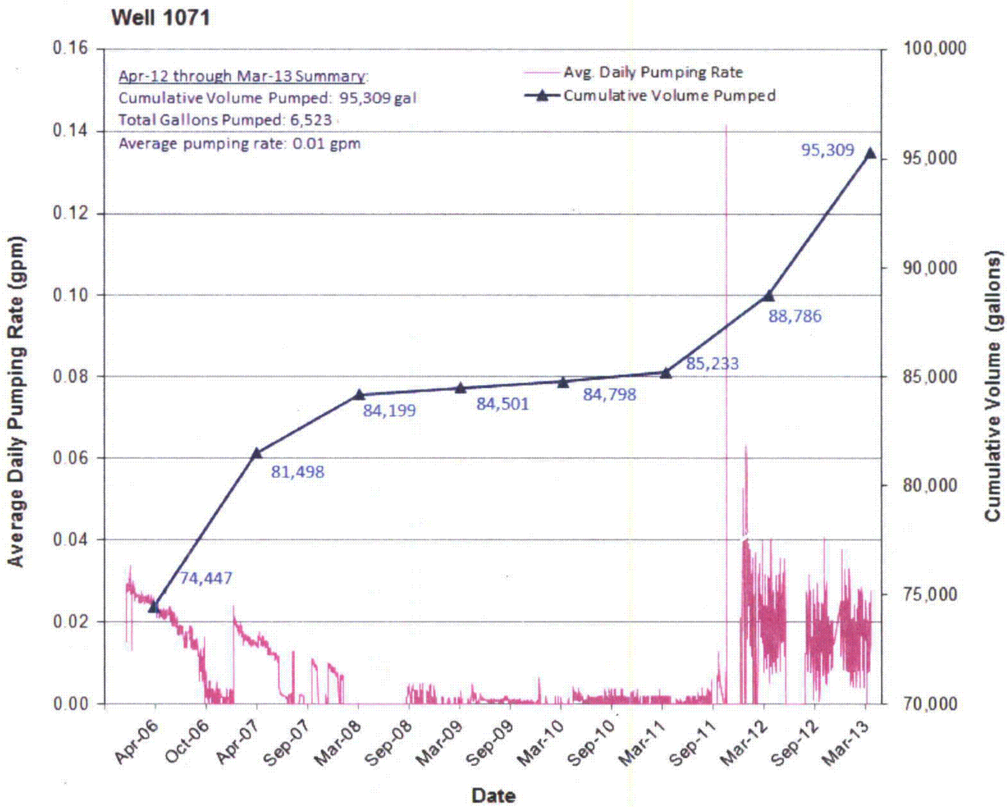


Figure 44. Terrace Well 1071 Pumping Rate and Cumulative Groundwater Volume Extracted

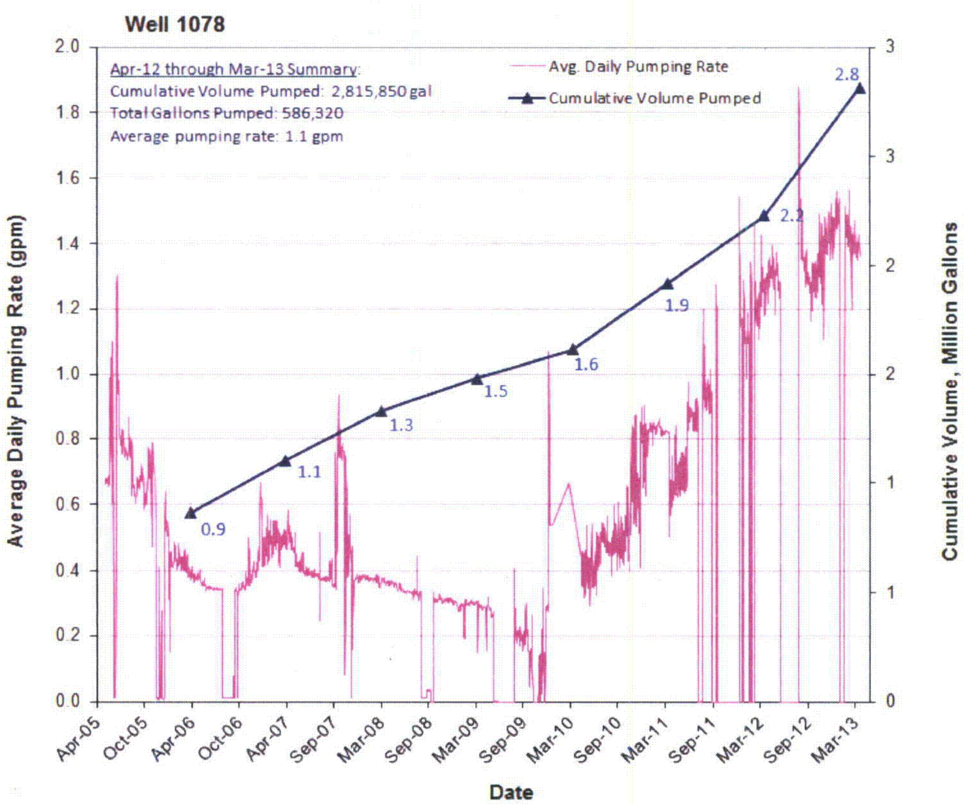


Figure 45. Terrace Well 1078 Pumping Rate and Cumulative Groundwater Volume Extracted

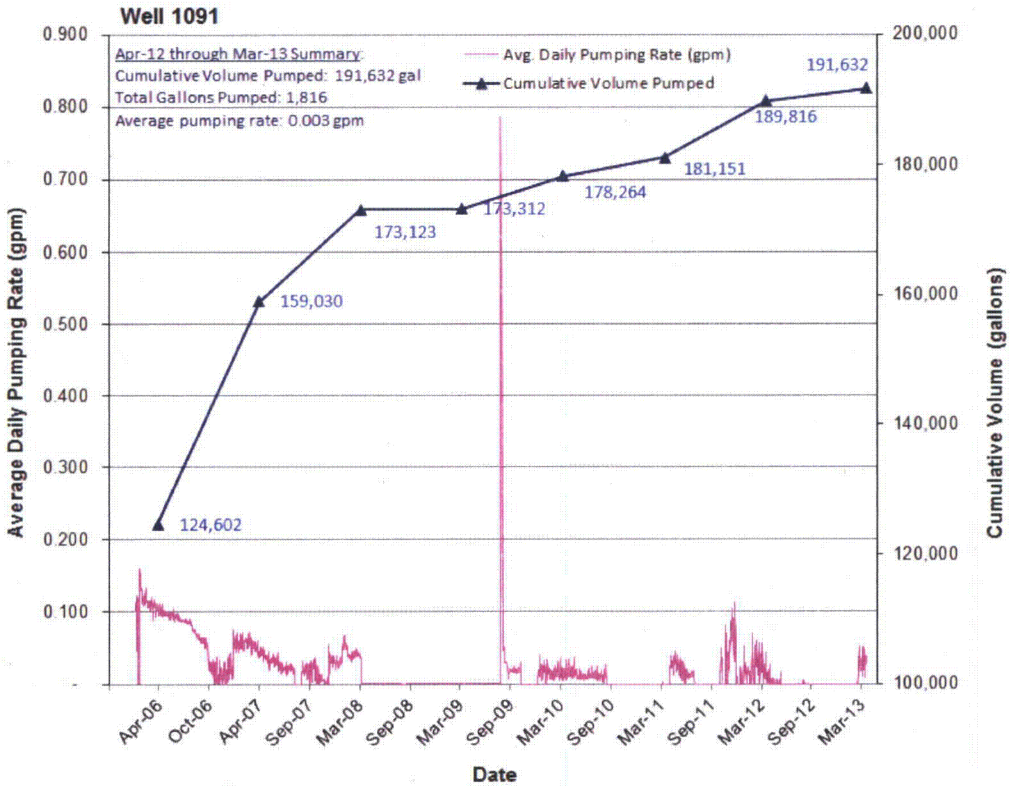


Figure 46. Terrace Well 1091 Pumping Rate and Cumulative Groundwater Volume Extracted

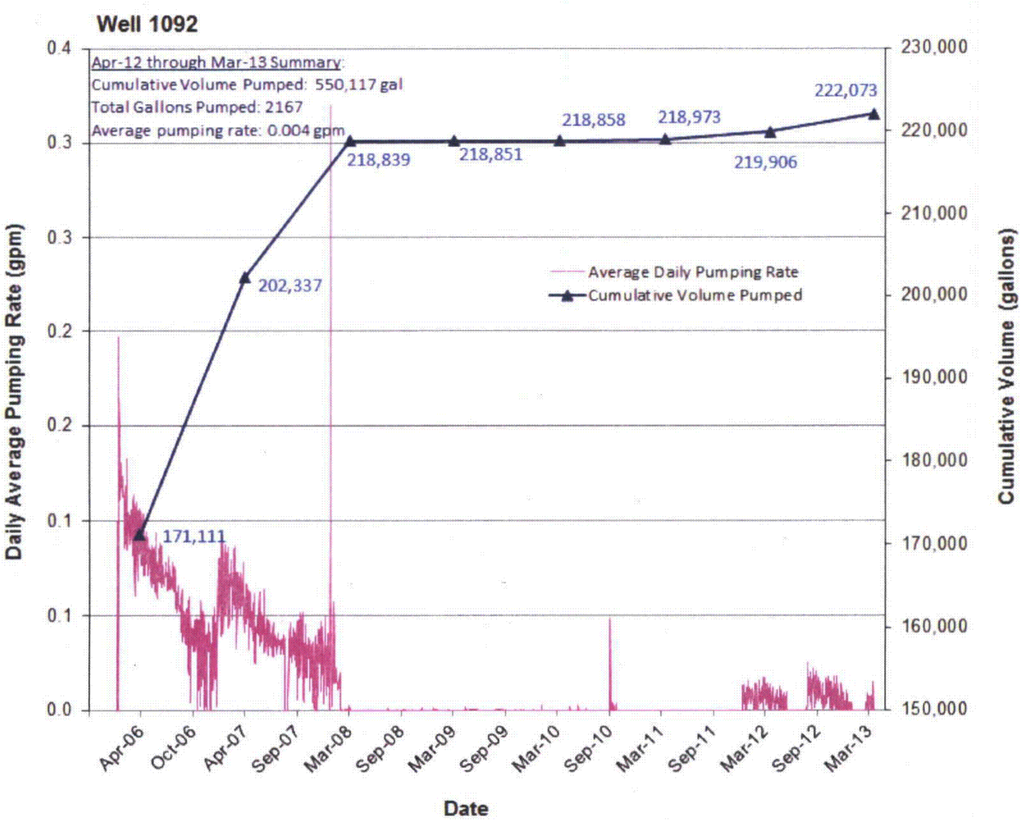


Figure 47. Terrace Well 1092 Pumping Rate and Cumulative Groundwater Volume Extracted

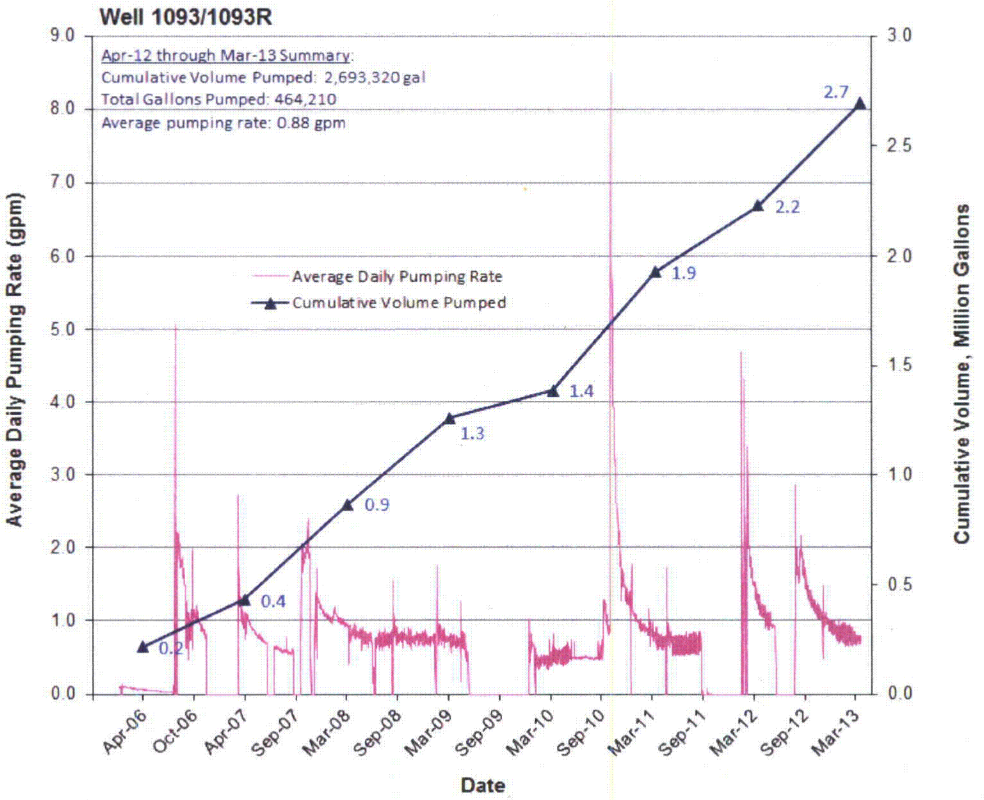


Figure 48. Terrace Well 1093R Pumping Rate and Cumulative Groundwater Volume Extracted

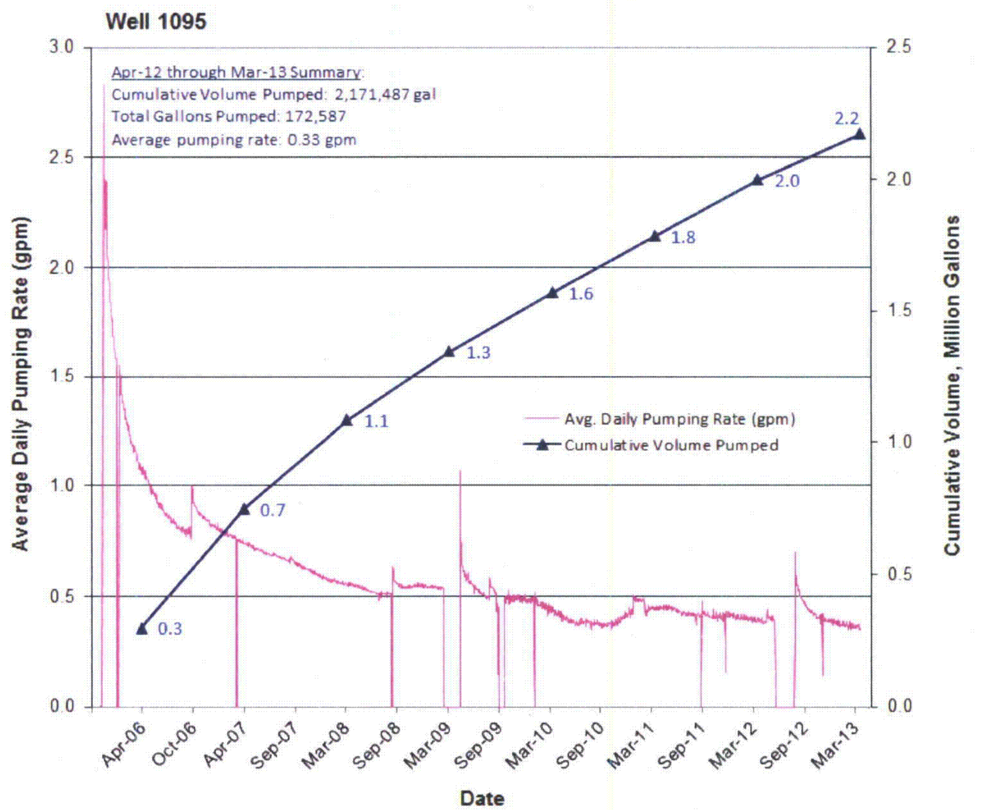


Figure 49. Terrace Well 1095 Pumping Rate and Cumulative Groundwater Volume Extracted

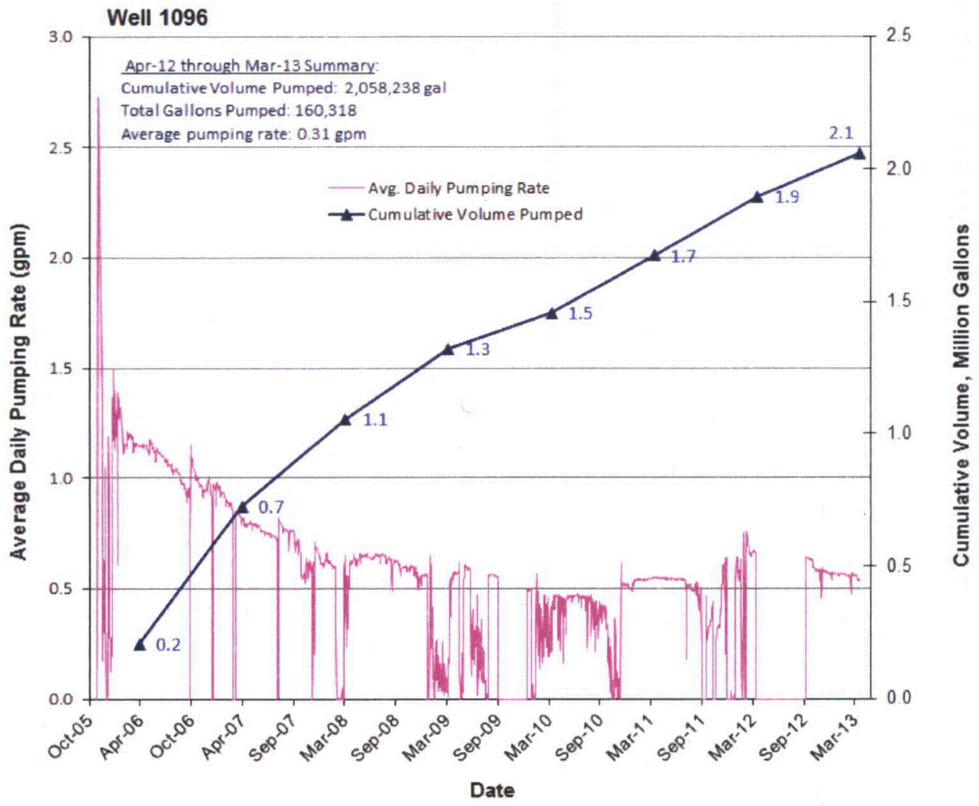


Figure 50. Terrace Well 1096 Pumping Rate and Cumulative Groundwater Volume Extracted

3.2.2 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.

Extraction rates and cumulative flow volumes for the pump installed in the Bob Lee Wash drain (location 1087) are plotted in Figure 51. In 2012–2013, the average pumping rate from Bob Lee Wash was 2.2 gpm (vs. 3.1 gpm in 2011–2012), and the groundwater interceptor drain removed approximately 1.1 million gallons of water.

The pumping rates and volume of water removed from the groundwater interceptor drain in Many Devils Wash (location 1088) are plotted in Figure 52. During the current performance period, the average pumping rate from Many Devils Wash was about 0.17 gpm, and the groundwater interceptor drain removed approximately 89,400 gallons of water.

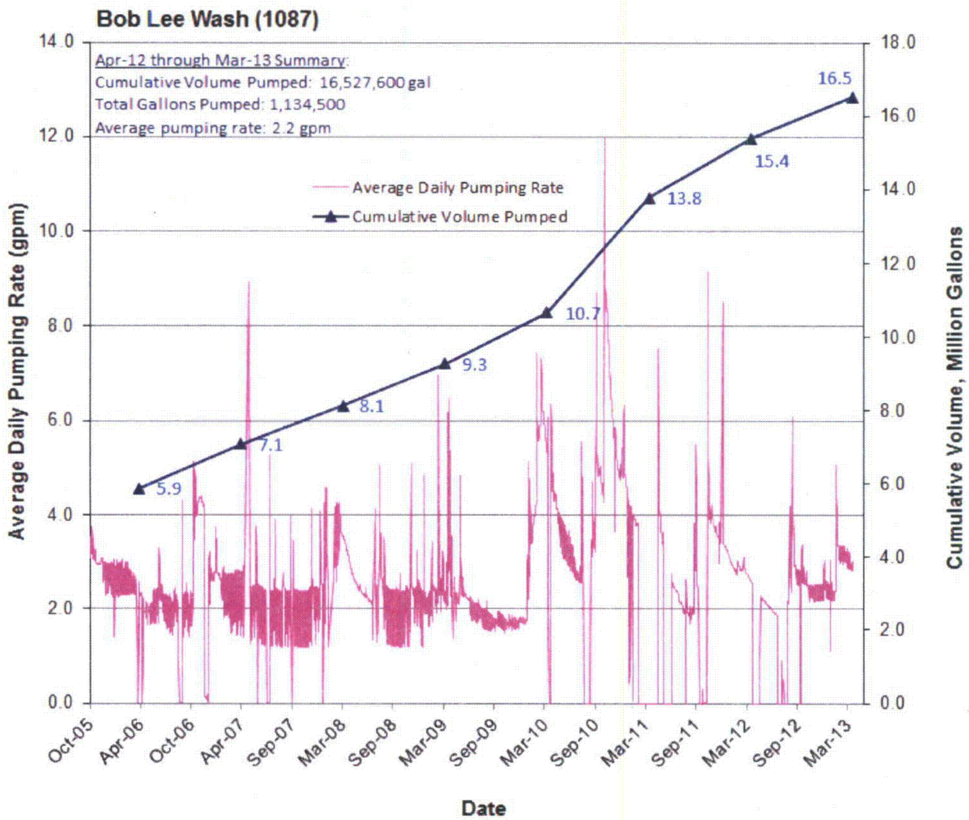


Figure 51. Bob Lee Wash Pumping Rate and Cumulative Groundwater Volume Extracted

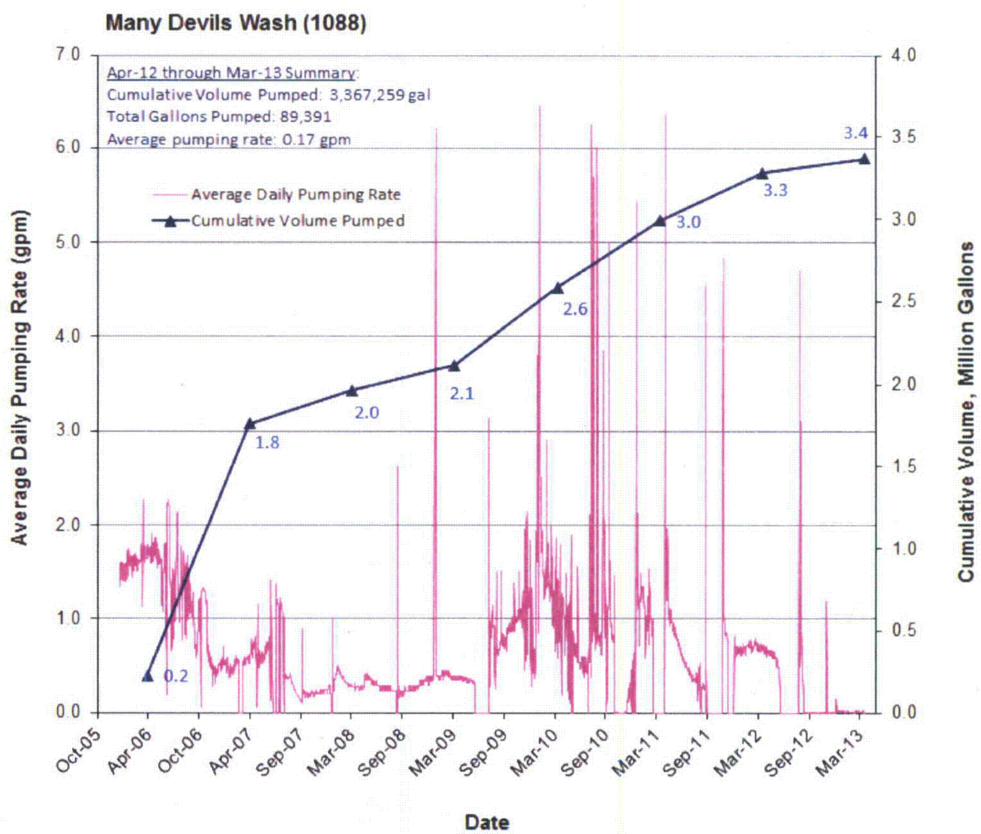


Figure 52. Many Devils Wash Pumping Rate and Cumulative Groundwater Volume Extracted

3.2.3 Evaporation Pond

The selected method for handling groundwater from the interceptor drains and extraction wells is solar evaporation. The contaminated groundwater is pumped to an 11-acre lined evaporation pond in the south part of the radon cover borrow pit area (Figure 1). The average water level in the evaporation pond was 4.6 ft in March 2013 (measured as the distance above transducers), leaving approximately 3.4 ft of unfilled pond capacity.

From April 2012 through March 2013, over 12 million gallons of extracted groundwater were pumped to the evaporation pond. The majority (close to 9.3 million gallons, 75 percent) of the influent liquids entering the pond were from the floodplain aquifer. About 25 percent (3.1 million gallons) of the inflow originated from the terrace groundwater system (Table 3). As shown in Figure 53, at the end of the 2012–2013 reporting period, a cumulative volume of about 127.6 million gallons of water had been pumped to the evaporation pond from all sources since the start of operations in March 2003 (cumulative contributions of 25.6 percent and 74.4 percent from the terrace and floodplain, respectively).

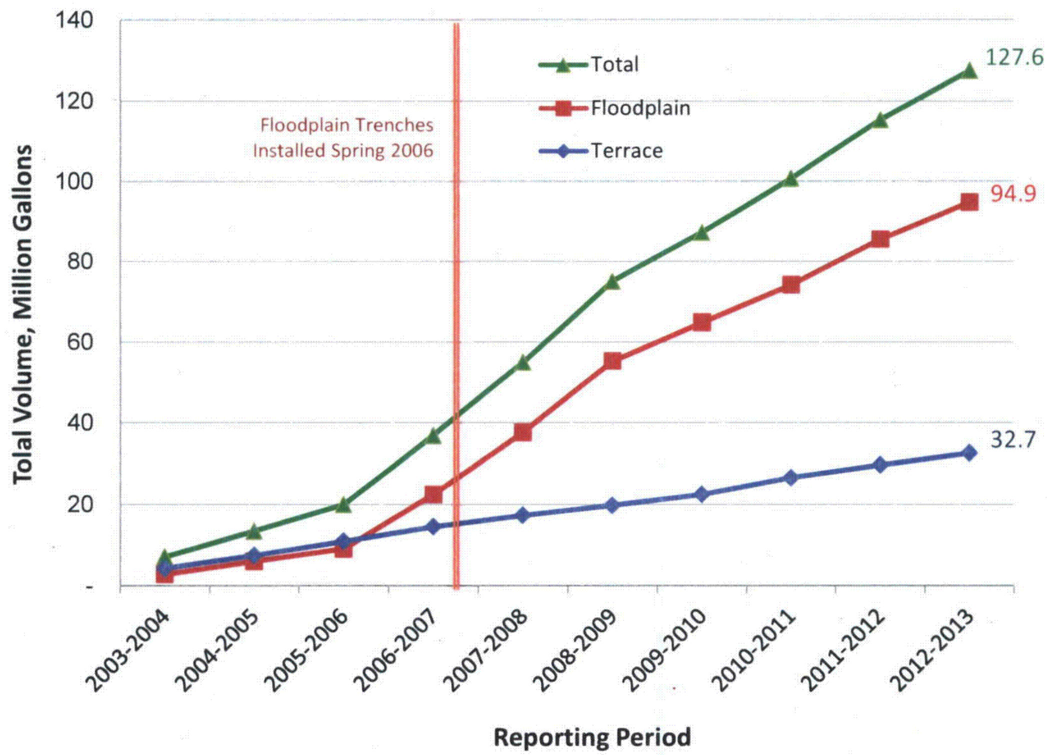


Figure 53. Total Groundwater Volume Pumped to the Evaporation Pond

Table 3. 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	480,461	3.87	795	1,446	3,187	13,500	24,550	54,124	0.135	0.246	0.541
1070	18,349	0.15	690	47.9	105.6	14,500	1,007	2,220	0.080	0.006	0.012
1071	6,523	0.05	780	19.3	42.5	13,000	321	707.6	0.140	0.0035	0.008
1078	586,320	4.73	595	1,320	2,911	13,000	28,850	63,602	0.135	0.300	0.660
1091	1,816	0.01	1,030	7.1	15.61	13,500	92.8	204.6	0.105	0.0007	0.002
1092	2,167	0.017	640	5.2	11.6	14,500	118.9	262.2	0.115	0.0009	0.002
1093	464,210	3.74	2,300	4,041	8,909	5,000	8,785	19,368	0.125	0.220	0.484
1095	172,587	1.39	1,850	1,208	2,664	4,700	3,070	6,769	0.052	0.034	0.075
1096	160,318	1.29	605	367	809	14,000	8,495	18,729	0.087	0.053	0.116
1087 (BLW)	1,134,500	9.15	285	1,224	2,698	7,250	31,132	68,634	0.525	2.254	4.97
1088 (MDW)	89,391	0.72	705	239	526	18,500	6,259	13,799	0.185	0.063	0.138
Floodplain											
1089	2,324,600	18.74	0.7	5.9	12.9	4,400	38,714	85,349	0.215	1.89	4.170
1104	468,176	3.77	2.7	4.8	10.5	5,650	10,012	22,073	0.435	0.77	1.699
Trench 1 (1110)	4,356,120	35.12	48.5	800	1,763	5,600	92,332	203,556	0.570	9.40	20.719
Trench 2 (1109)	1,911,800	15.41	96.0	695	1,531	1,590	11,505	25,365	0.225	1.63	3.589
Seep sump (1118)	226,050	1.82	54.0	46	102	6,000	5,134	11,318	0.455	0.39	0.858
			Total Masses:	**11,476**	**25,300**		**270,379**	**596,079**		**17.3**	**38.0**
Total Terrace	3,116,642	25.1									
Total Floodplain	9,286,746	74.9									
Total to Pond	12,403,388										

[a] Annual cumulative volumes derived from data used to generate plots in Figure 37 through Figure 52 (data from April 1, 2012, through March 31, 2013).
[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.
MDW = Many Devils Wash; BLW = Bob Lee Wash

As shown in Table 3, 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 2012–2013 performance period were approximately 25,000 pounds nitrate (as N), 596,000 pounds sulfate, and 38 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.

3.2.4 Passive and Enhanced Phytoremediation

A pilot study of natural phytoremediation (no human intervention) and hydraulic control is ongoing at the Shiprock site. DOE began the pilot studies in 2006 to evaluate the feasibility of enhancing natural phytoremediation by planting native phreatophytes on the terrace between the disposal cell and the escarpment north of the disposal cell, where a uranium plume enters the floodplain, and in the radon cover borrow pit south of the disposal cell, where nitrate levels are elevated in alluvial sediments. The potential goal of phytoremediation in these areas would be hydraulic control (as opposed to contaminant removal), to enhance plant transpiration of groundwater, thereby limiting the spread of contaminants in groundwater. The four irrigated 15-square-meter phytoremediation test plots were established in 2006; locations are shown on Figure 1. To date, all work has been done in concert with the Diné Environmental Institute at Diné College in Shiprock. The status of phytoremediation has not changed significantly in the last several years. Changes since 2011 include:

- Only half of each test plot has been irrigated.
- Diné College students measured plant growth (height, canopy area, canopy volume) for irrigated and non-irrigated treatments in October 2012.
- Diné College students sampled plant tissue for irrigated treatments, non-irrigated treatments, and reference areas in October 2012. Samples were taken to assess potential uptake of contaminants, including uranium and other metals, by the plants. Plant stems, soils, and alluvial groundwater were also sampled for stable water isotopes (oxygen/deuterium isotope ratios) in July 2013 to assess whether plants have rooted in groundwater. Analyses from these two sampling events are underway.

4.0 Performance Summary

This section summarizes the findings of the most recent (April 2012 through March 2013) assessment of the floodplain and terrace groundwater remediation systems at the Shiprock site, marking the end of the tenth 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 9.3 million gallons of groundwater were extracted from the floodplain aquifer system during this performance period, yielding a cumulative total of about 95 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 2012 through March 2013, approximately 3 million gallons of groundwater were extracted from the terrace system, yielding a total cumulative volume (extracted since March 2003) of close to 33 million gallons. The cumulative volume removed from both terrace and floodplain combined (as of April 1, 2013) approaches 128 million gallons (Figure 53).
- Terrace-wide, groundwater levels in the majority of alluvial wells sampled during this performance period declined relative to the baseline period (2000–2003) (Figure 34); average and maximum decreases were 2.95 ft and 8.5 ft, respectively. Relative to baseline conditions, decreases in the eastern portion of the terrace are negligible. Five alluvial west terrace wells were dry during the March 2013 sampling event. Also, many seeps on the west terrace have been dry since 2008.
- The remediation system is intercepting contaminated groundwater that could discharge to the San Juan River. 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 596,000 pounds; 25,000 pounds; and 38 pounds, respectively.

As observed for the last several years, marked 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 successfully intercepting contaminated groundwater emanating from the terrace across the escarpment, thereby preventing the contamination from discharging to the river in areas farther to the north. 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 increased since the last reporting period. These recent increases are being monitored and evaluated. Finally, COC concentrations in samples collected from the San Juan River are still well 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.
- Update the compliance strategy for the terrace.
- Implement a number of recommendations in the recently issued document titled *Optimization of Sampling at the Shiprock, New Mexico, Site* (DOE 2013c).

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

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 Office, 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 Office, 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), 2008. *Annual Performance Report, April 2007 through March 2008, for the Shiprock, New Mexico, Site*, LMS/SHP/S04378, Office of Legacy Management, Grand Junction, Colorado, September.

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, U.S. Department of Energy 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), 2012. *Application of Environmental Isotopes to the Evaluation of the Origin of Contamination in a Desert Arroyo: Many Devils Wash, Shiprock, New Mexico* (draft), LMS/SHP/S09197, ESL-RPT-2012-01, Office of Legacy Management, Grand Junction, Colorado, July.

DOE (U.S. Department of Energy), 2013a. *August 2012 Groundwater and Surface Water Sampling at the Shiprock, New Mexico, Disposal Site*, LMS/SHP/S00812, Office of Legacy Management, Grand Junction, Colorado, January.

DOE (U.S. Department of Energy), 2013b. *March 2013 Groundwater and Surface Water Sampling at the Shiprock, New Mexico, Disposal Site*, LMS/SHP/S00313, Office of Legacy Management, Grand Junction, Colorado, June.

DOE (U.S. Department of Energy), 2013c. *Optimization of Sampling at the Shiprock, New Mexico, Site*, LMS/SHP/S008223, Office of Legacy Management, Grand Junction, Colorado, March.

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.

Annual Performance Report
April 2012 through March 2013
for the Shiprock, New Mexico, Site

The U.S. Department of Energy (DOE) has prepared the *Annual Performance Report, April 2012 through March 2013 for the Shiprock, New Mexico, Site*. **At your request, you are receiving a hard copy of the report.**

The report is also available for your review on the Internet at the DOE Legacy Management (LM) website, http://energy.gov/lm. From the LM website home page, select the LM SITES MAP. Then select Shiprock Site from the LM SITES list in the right column. The report will be available on the Shiprock Disposal Site page of the LM website under Site Documents and Links.

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