DOE–LM/1461–2007

Annual Performance Report April 2006 Through March 2007 for the Shiprock, New Mexico, Site

June 2007

U.S. Department of Energy

Office of Legacy Management

Work Performed Under DOE Contract No. DE–AC01–02GJ79491
for the U.S. Department of Energy Office of Legacy Management.
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Annual Performance Report
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Work Performed by S.M. Stoller Corporation under DOE Contract No. DE–AC01–02GJ79491
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1.0 Introduction

This report evaluates the performance of the ground water remediation system at the disposal and processing site in Shiprock, New Mexico, for the period of April 2006 through March 2007. The Shiprock site, a former uranium mill tailings facility under the Uranium Mill Tailings Radiation Control Act (UMTRCA), is currently managed by the U.S. Department of Energy Office of Legacy Management (DOE−LM). This evaluation is based on comparison of the site conditions in March 2007 to the baseline site conditions presented in the Baseline Performance Report (DOE 2003). The baseline conditions were established using data collected primarily from March 2003. A detailed description of the site conditions is presented in the Site Observational Work Plan (SOWP) (DOE 2000), and the compliance strategy is presented in the Ground Water Compliance Action Plan (GCAP) (DOE 2002).

The Shiprock site is divided into two distinct areas, the floodplain and the terrace. An escarpment forms the boundary between the two areas. The terrace is further divided into terrace west and terrace east. The floodplain remediation system currently consists of two ground water extraction wells, a seep collection drain, and two collection trenches. The terrace remediation system currently consists of nine ground water extraction wells, two collection drains (Bob Lee Wash and Many Devils Wash), an open pit sump system, and a terrace drainage channel diversion structure. All extracted ground water goes into a lined evaporation pond on the terrace. The entire ground water remediation system is shown in Figure 1–1.

1.1 Remediation System Performance Standards

This performance assessment is based on the analysis of ground water quality and ground water level data obtained from site monitor wells in addition to ground water flow rates associated with the extraction wells, drains, and seeps.

Specific performance standards as established for the Shiprock floodplain ground water remediation system in the Baseline Performance Report (DOE 2003) are summarized as follows:

- Ground water flow directions in the vicinity of the extraction wells should be toward the extraction wells.
- Pumping on the floodplain should intercept contaminants of concern (COC) that would otherwise discharge to the San Juan River.

Figure 1–1. Location Map and Ground Water Remediation System

Specific performance standards as established for the Shiprock terrace ground water remediation system in the Baseline Performance Report (DOE 2003) are summarized as follows:

- Terrace ground water surface elevations should decrease as water is removed from the terrace system.
- Ground water flow directions in the vicinity of the extraction wells should be toward the extraction wells.
- The volume of water discharging to the interceptor drains located in Bob Lee Wash and Many Devils Wash should decrease over time as ground water levels on the terrace decline.
- The flow rates of seeps located at the escarpment face (locations 0425 and 0426) should decrease over time as ground water levels on the terrace decline.

1.2 Contaminants of Concern and Remediation Goals

Ground water at the site is contaminated as a result of uranium milling activities between 1954 and 1968. The COCs for both the floodplain and terrace are ammonia (total as nitrogen), manganese, nitrate (nitrate + nitrite as nitrogen), selenium, strontium, sulfate, and uranium. Distribution of concentrations of nitrate, sulfate, and uranium in terrace and floodplain ground water, based on the March 2007 sampling event, are shown in Figure 1–2, Figure 1–3, and Figure 1–4, respectively.

Floodplain compliance standards for uranium and nitrate are their respective UMTRCA standards of 0.044 and 10 milligrams per liter (mg/L). A secondary standard of 250 mg/L for sulfate exists under the Safe Drinking Water Act. However, studies conducted by the Centers for Disease Control in conjunction with the U.S. Environmental Protection Agency (EPA) have shown that no adverse effects from sulfate ingestion occur at concentrations of up to 1,200 mg/L (EPA 1999). The report notes that other studies have shown that concentrations of sulfate exceeding 2,000 mg/L may have little to no adverse effect on humans and animals. Because of high background sulfate concentrations at the site in floodplain ground water (up to 1,920 mg/L) and the high sulfate concentration of water entering the floodplain from flowing artesian well 0648 (up to 2,340 mg/L), the proposed cleanup goal for floodplain sulfate is 2,000 mg/L. Relatively high selenium concentrations in the floodplain make it unlikely that the UMTRCA standard of 0.01 mg/L for this constituent can be met while contaminated terrace water is still providing a source. DOE proposed an alternate concentration limit for selenium of 0.05 mg/L (DOE 2003), which is the EPA maximum contaminant level for drinking water. The cleanup objective for manganese is the maximum background concentration for the floodplain, which is currently 2.74 mg/L. There are no cleanup standards or background concentrations established for ammonia and strontium.

Ground water compliance for the terrace is based on hydrologic control, and concentration standards do not apply.

1.3 Hydrogeological Setting

This section summarizes the floodplain and terrace ground water systems. A more detailed description is available in the SOWP (DOE 2000).

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 ground water recharge to the floodplain aquifer in some areas and receives ground water discharge in other areas. In addition, the floodplain aquifer almost certainly receives some inflow from a ground water system 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 ground water contamination in the floodplain lies close to the escarpment east and north of the disposal cell. A plume extends northward from this contaminated area in an arc-shape as it crosses the floodplain and reaches the San Juan River near the floodplain extraction wells (Figure 1–1, Figure 1–2, Figure 1–3, and Figure 1–4). This plume configuration is best characterized by elevated concentrations of sulfate and uranium. Contamination does not occur along the escarpment base in the northwest part of the floodplain because relatively uncontaminated surface water from Bob Lee Wash discharges into the floodplain, recharging local ground water and then flowing to the north and west. Surface water in Bob Lee Wash originates primarily as deep ground water 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. Background ground water quality in the floodplain aquifer has been defined by monitor wells installed in the floodplain approximately 1 mile upriver from the site.

1.3.2 Terrace Ground Water System

The terrace ground water 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 thick and caps the Mancos Shale. Though less well mapped, some terrace ground water also occurs in weathered Mancos Shale underlying the alluvium. The Mancos Shale is exposed in the escarpment overlooking the present floodplain.

The terrace ground water system extends southwestward from the escarpment separating the terrace from the floodplain for up to one mile, where it is abruptly bounded by a buried escarpment. Terrace alluvial material is exposed at the terrace/floodplain escarpment, but southwestward from there it is covered by an increasing thickness of eolian silt, or loess. At the southwest edge of the terrace aquifer, along the base of the buried escarpment, up to 40 ft of loess overlies the alluvium. The alluvium in this latter area consists of coarse, ancestral San Juan River deposits.

Mancos Shale in the terrace area is weathered (fractured and soft) several feet below its contact with the alluvium. Ground water is known to occur in the weathered shale and may flow through deeper portions of the shale that might be fractured and along bedding surfaces.

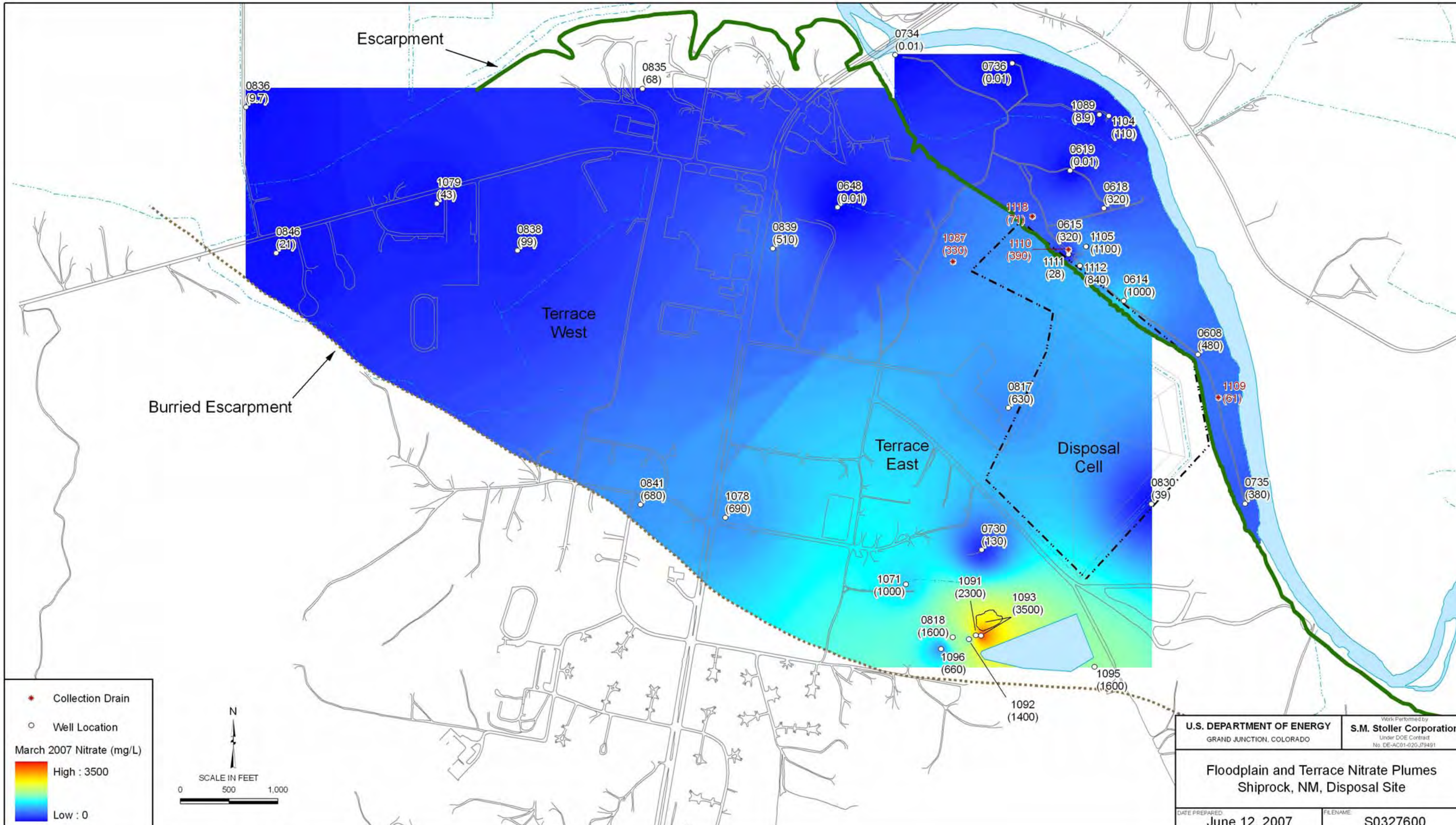

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Figure 1–2. Nitrate Concentrations in Terrace and Floodplain Ground Water

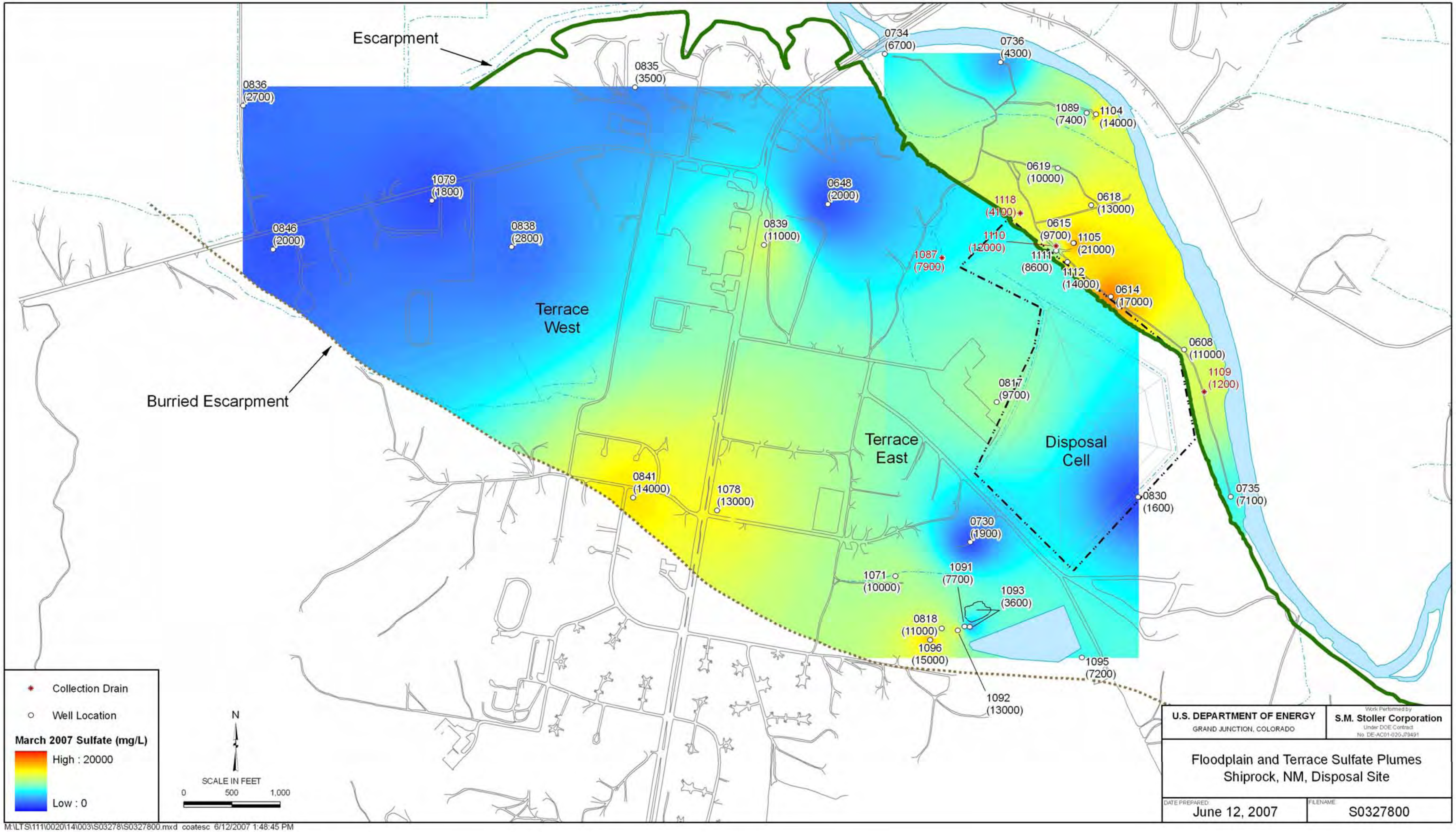

Figure 1–3. Sulfate Concentrations in Terrace and Floodplain Ground Water

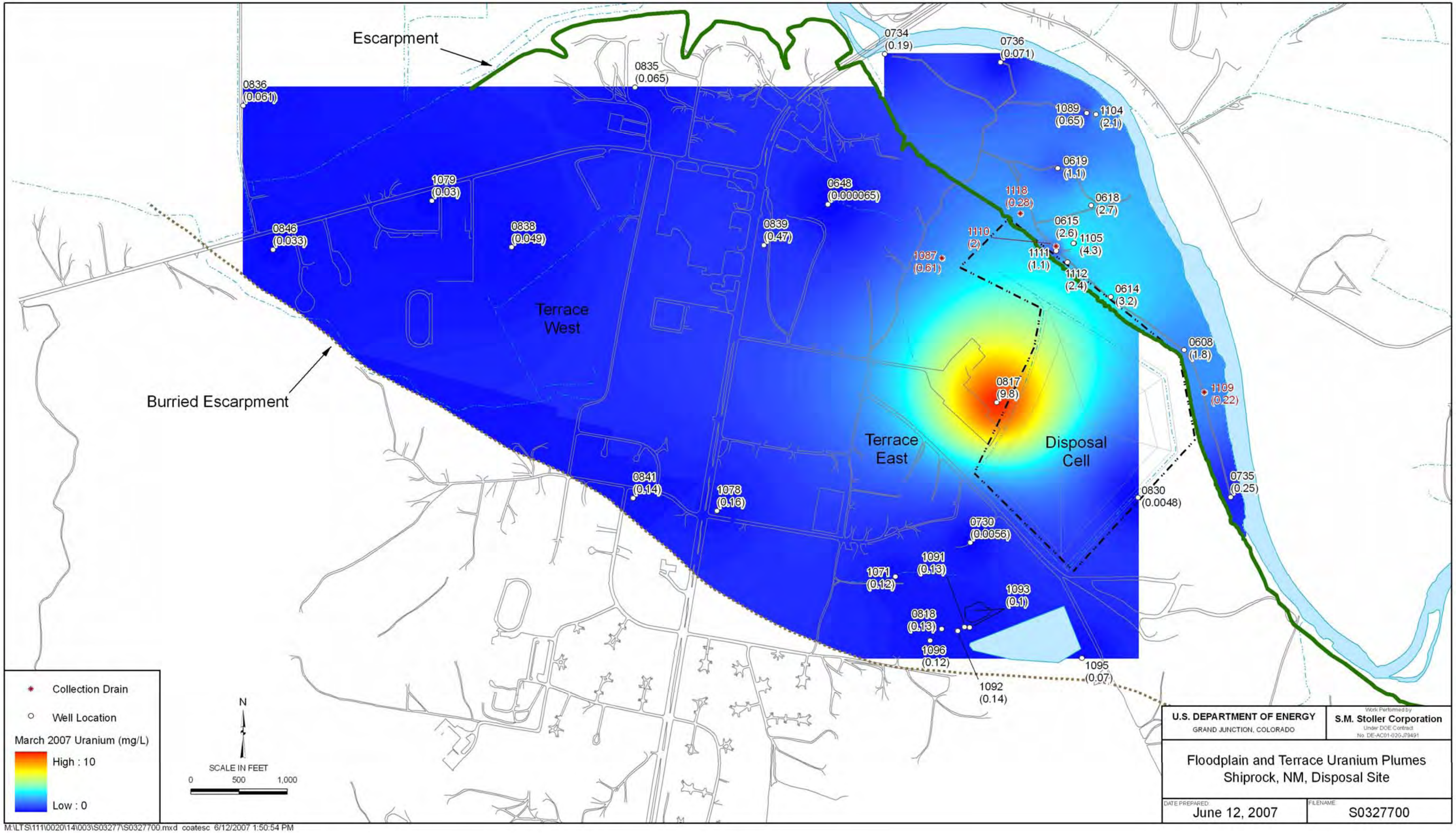

Figure 1–4. Uranium Concentrations in Terrace and Floodplain Ground Water

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2.0 Subsurface Conditions

This section summarizes hydraulic and water quality characteristics of the floodplain and terrace ground water systems in March 2007, approximately 4 years after startup of the treatment system. Figure 2–1 shows the locations of all wells and sampling locations that are discussed in this report.

2.1 Floodplain Subsurface Conditions

The discussion of current subsurface conditions of the floodplain is based on collection and analysis of ground water samples and ground water level data through March 2007. Analyses of ground water level trends and flow directions, and contaminant distributions in the floodplain are discussed below. Results are compared to baseline conditions established in March 2003 in the Baseline Performance Report (DOE 2003) to evaluate the effectiveness of the floodplain treatment system.

2.1.1 Ground Water Level Trends and Flow Directions

Three-point analyses of ground water level data were initiated using March 2003 information, which were subsequently compared to March 2004 and March 2005 data, to determine horizontal gradients and flow directions across the floodplain system and to demonstrate that the flow of ground water was predominantly toward the extraction wells. Analysis of ground water level and flow data was also important to observe recharge and discharge effects of the floodplain aquifer caused by interaction with flow dynamics of the San Juan River and seasonal variability of river flow and precipitation. Results of the three-point analyses over the 2-year period showed very little change in ground water flow directions and demonstrated that the flow system in the floodplain was operating as expected, taking into account the variabilities mentioned above. There was also adequate indication that flow was toward the extraction wells.

Ground water levels in the floodplain aquifer are manually recorded during routine ground water sampling events (Figure 2–2). Ground water level fluctuations in the floodplain wells over the past 4-year period have been on the order of 2 ft. Higher ground water levels appear to have coincided with elevated flows in the San Juan River during the March sampling event.

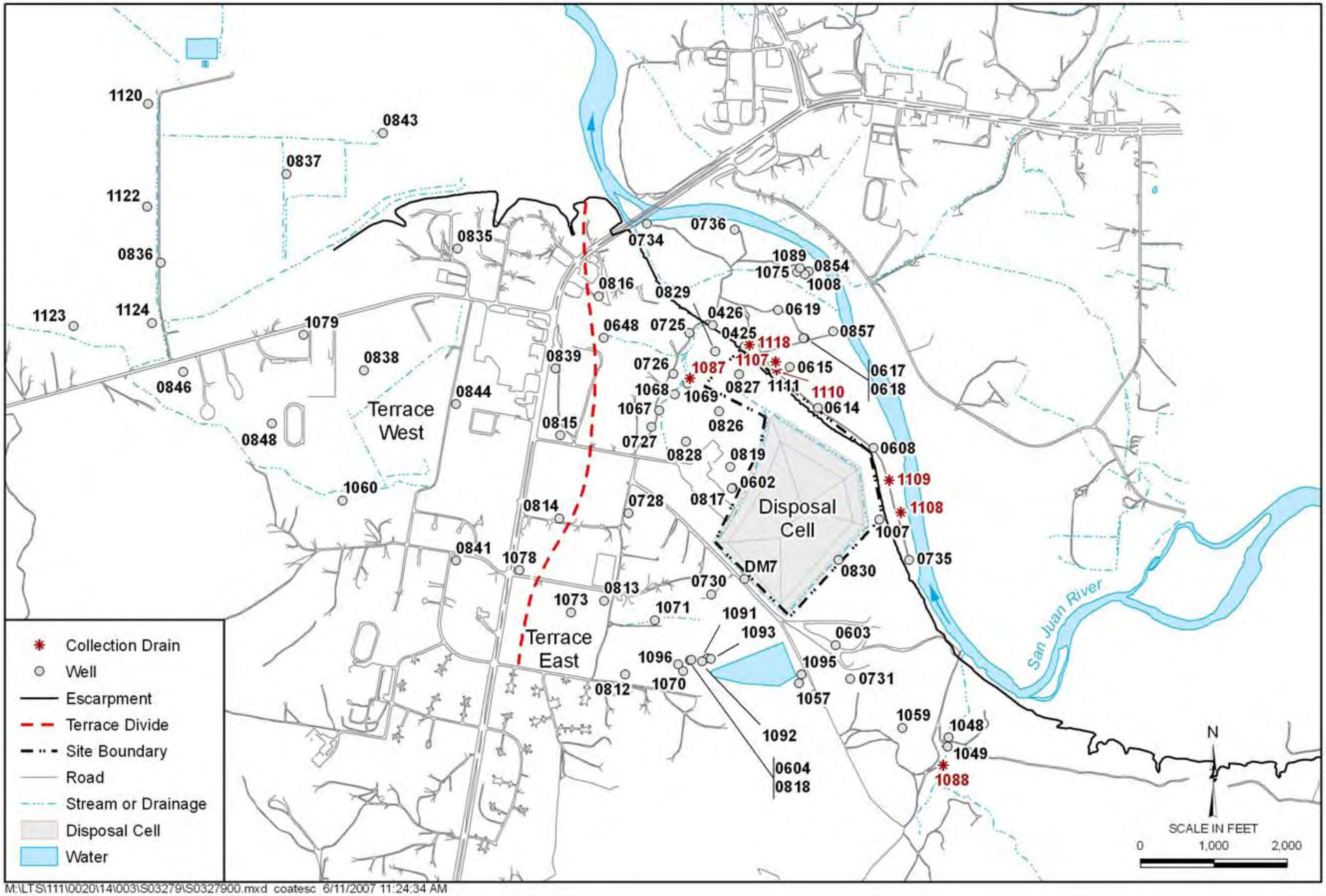

Figure 2–1. Locations of Wells and Sampling Points Discussed in This Report

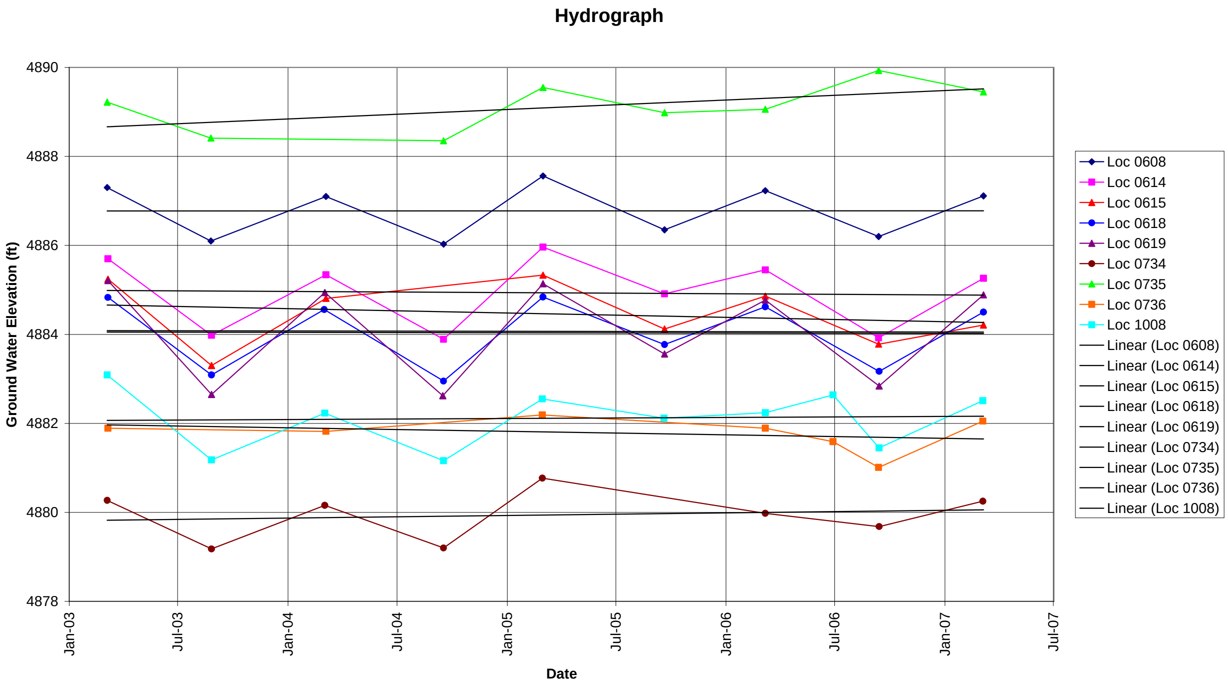

Figure 2–2. Floodplain Ground Water Elevations From Manual Measurements

Ground water elevations in the floodplain aquifer are also measured every 4 hours by pressure transducers installed in 4 monitor wells (0617, 0736, 0857, and 1008) and connected to dataloggers. These data for the reporting period are shown in Figure 2–3 along with streamflow in the San Juan River for comparison.

Flow data from the U.S. Geological Survey Gaging Station 09368000 in the San Juan River at Shiprock, New Mexico, are plotted in Figure 2–3 and Figure 2–4. The river flow on the day the March 2003 water level data were measured was 649 cubic feet per second (cfs), while the flow on the day the March 2007 data were measured was 784 cfs. In terms of stage, or water surface elevation, the San Juan River flows measured in 2007 and the 2003 flows are approximately the same.

Precipitation data showing the influence of rainfall in the area are available from weather stations at the Farmington, New Mexico, and the Durango, Colorado airports. These data are available at: http://www.wunderground.com/history/airport/KFMN/2006/4/1/MonthlyHistory.html and http://www.wunderground.com/history/airport/KDRO/2006/4/1/MonthlyHistory.html, and are shown in Figure 2–4. Precipitation data from the meteorological station at the Shiprock site were not consistently available during this reporting period.

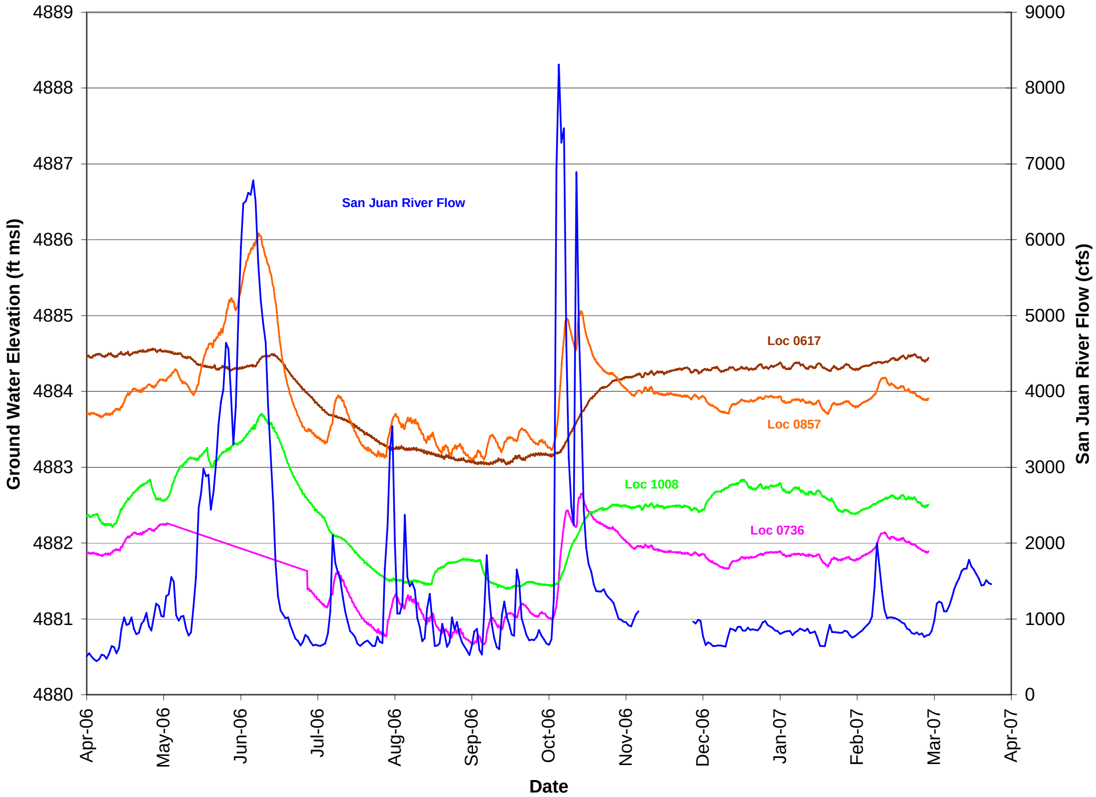

Figure 2–3. Floodplain Ground Water Elevations From Datalogger Measurements

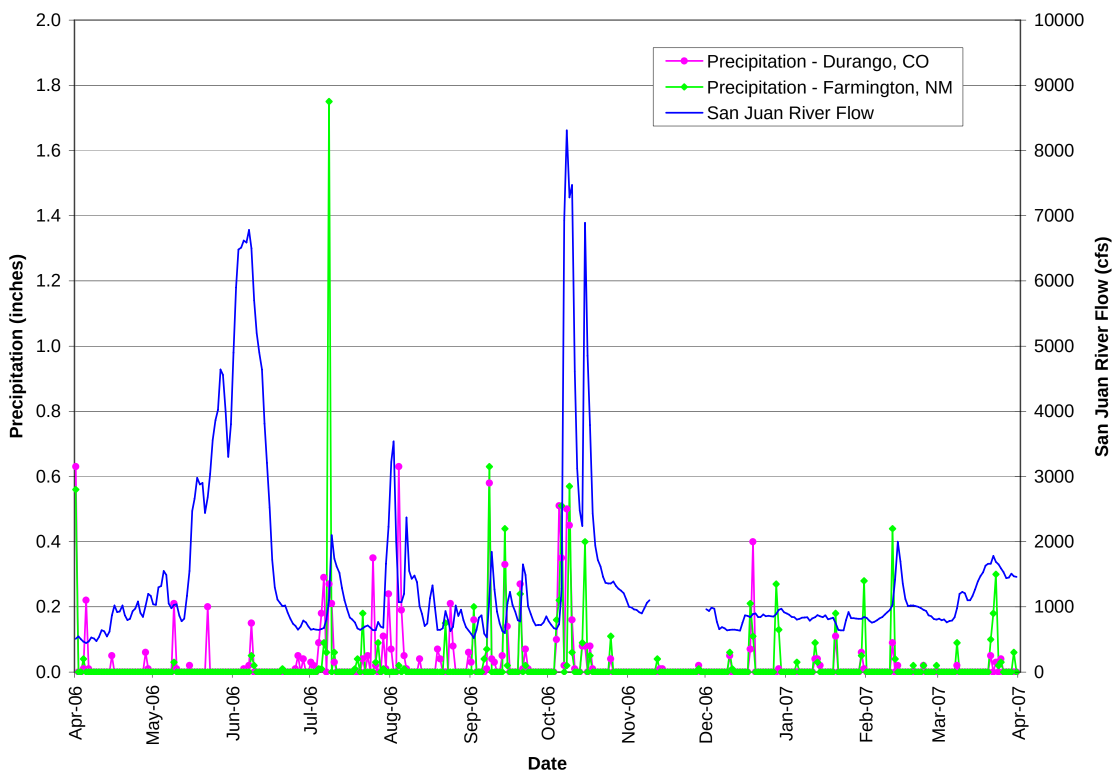

Figure 2–4. Precipitation and San Juan River Flow

The datalogger plots show very close correlation between ground water levels with the flow patterns of the San Juan River, indicating relatively rapid recharge and discharge of the aquifer related to change in river flow and surface water levels (Figure 2–3). It is known that most of the water entering the floodplain aquifer does so via San Juan River losses along the southernmost tip of the aquifer. Thus, it is logical to assume that inflow from the river increases during high runoff, and that this produces flow directions east of the disposal cell that are in a more northward to northwestward direction than normal. The potential for greater mixing of relatively clean water from the river with contaminated ground water emanating from the Mancos Shale would likely increase under such circumstances, which possibly leads to greater dilution of ground water contaminants in the aquifer and enhances natural flushing of contaminants from the floodplain aquifer.

2.1.2 Contaminant Distributions

Ground water samples were collected from selected floodplain monitor wells in September 2006 and March 2007. Locations of the wells sampled are shown in Figure 2–5 through Figure 2–11, which illustrate the spatial distribution of concentrations measured in March 2007 for ammonia, manganese, nitrate, selenium, strontium, sulfate, and uranium, respectively.

Variations in concentration versus time of these constituents from March 2003 (baseline) through March 2007 are shown in Figure 2–12 through Figure 2–18. Linear trendlines are shown on the graphs to indicate changes in concentrations over the past 4 years. There is a certain amount of periodic variation in concentrations of constituents that is not necessarily indicative of the overall longer-term trend. Concentrations of constituents in ground water in the floodplain alluvium are affected by seasonal changes in climate, river stage influence, discharge of ground water from the artesian well that flows into Bob Lee Wash and then onto the floodplain, and pumping rates of the extraction wells and drainage trenches.

Ammonium concentrations in ground water have generally decreased over the past 4 years (Figure 2–12). The maximum concentration in monitor well 0608 adjacent to the disposal cell has decreased from 240 mg/L to 190 mg/L over the past year; this compares with 303 mg/L in March 2003 (Figure 2–12). Concentrations in all other wells are less than 50 mg/L and generally stable.

Concentrations of manganese have been variable over the past 4 years, ranging from 0.01 mg/L to 8.70 mg/L during the March 2007 sampling event (Figure 2–6). There is noticeable but inconsistent variation on a seasonal basis in some of the wells. Over the past 4 years there has been a downward trend in manganese concentrations in ground water in four of the nine wells (Figure 2–13).

Nitrate concentrations in ground water ranged from less than 1 mg/L to 1,000 mg/L and have increased slightly in three of the nine monitor wells over the past 4 years (Figure 2–7). Concentrations remained relatively stable at five of the locations. Again, there has been seasonal variation in some of the wells contrary to the longer-term trends (Figure 2–14).

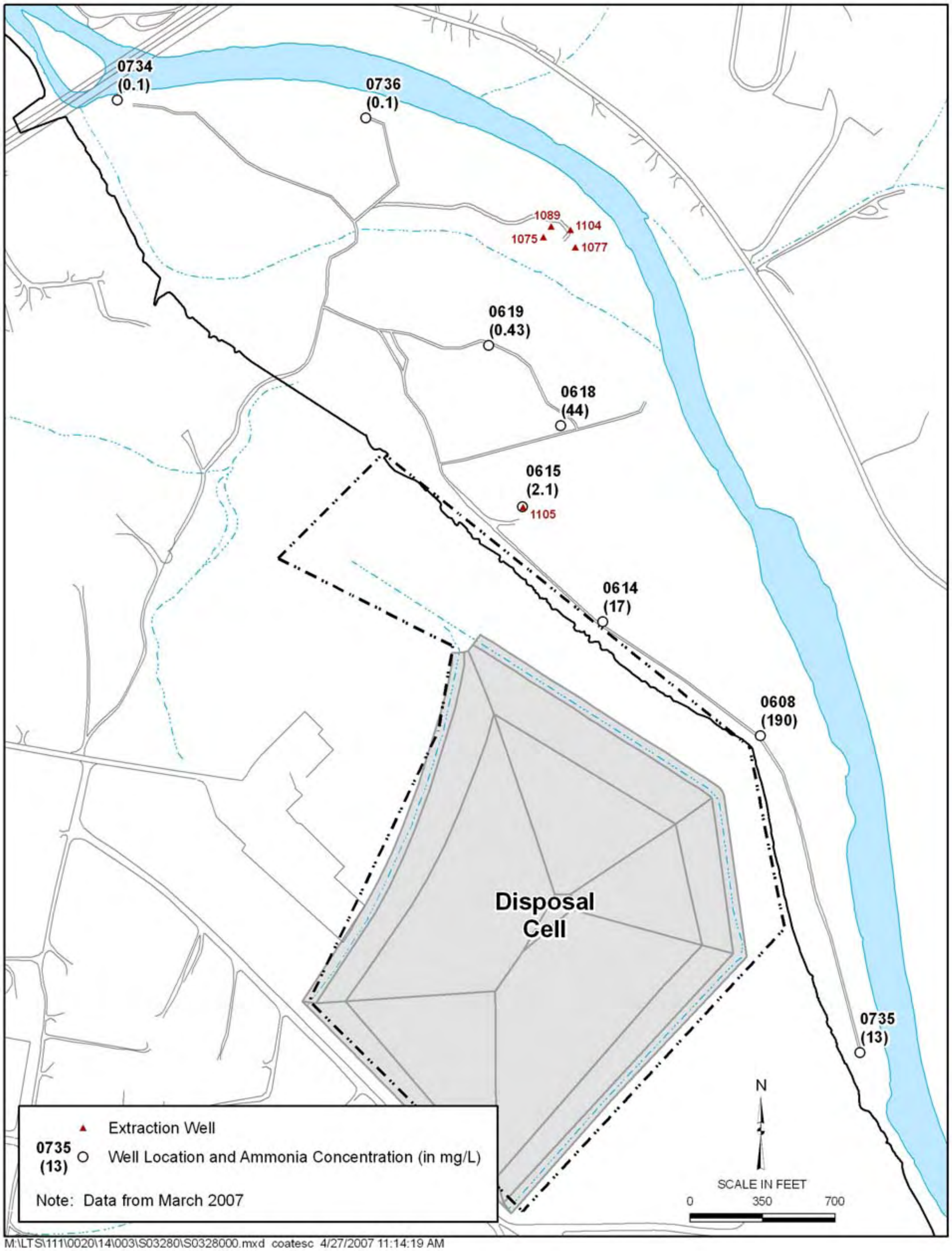

Figure 2–5. Floodplain Ammonia (Total as Nitrogen) Ground Water Concentrations

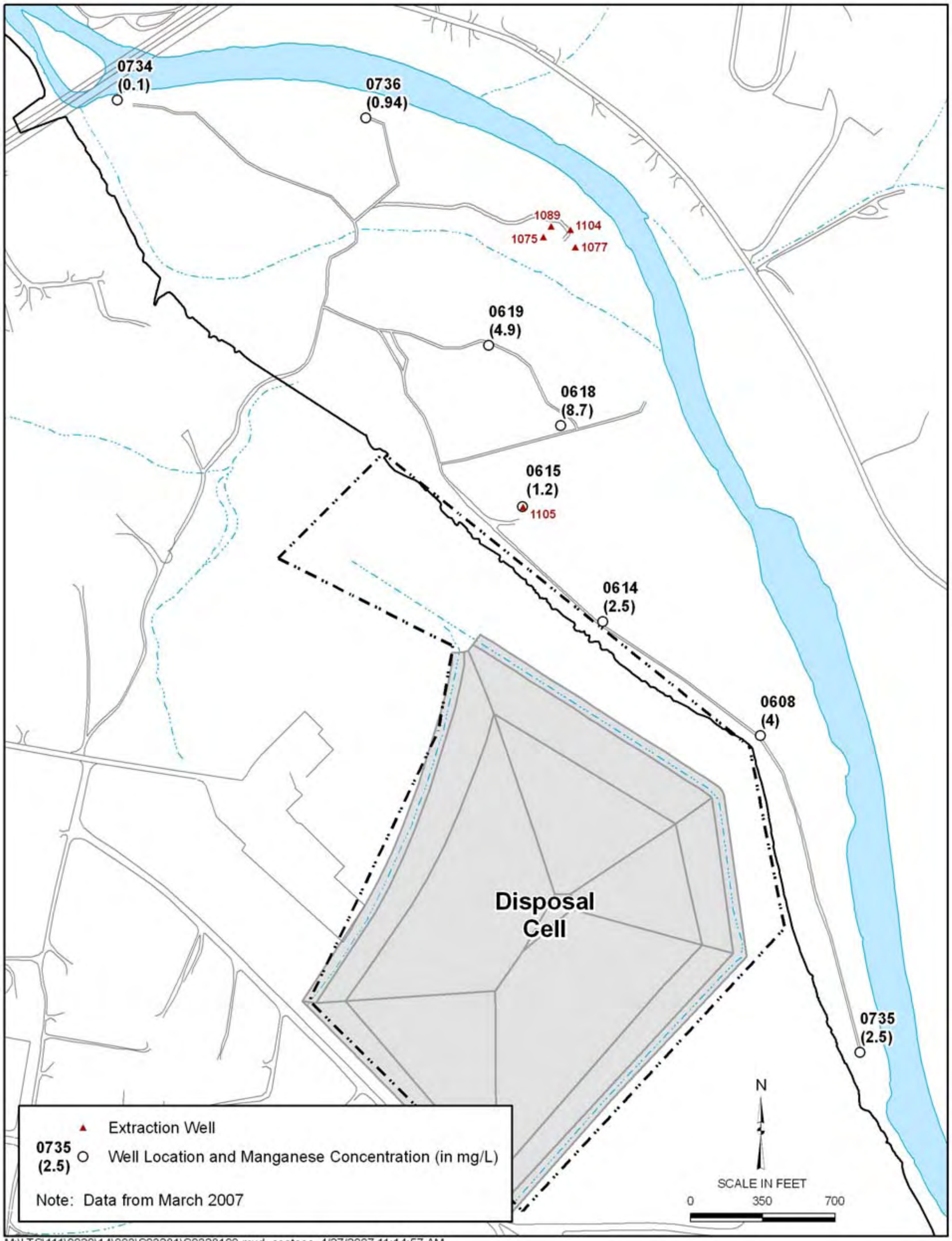

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Figure 2–6. Floodplain Manganese Ground Water Concentrations

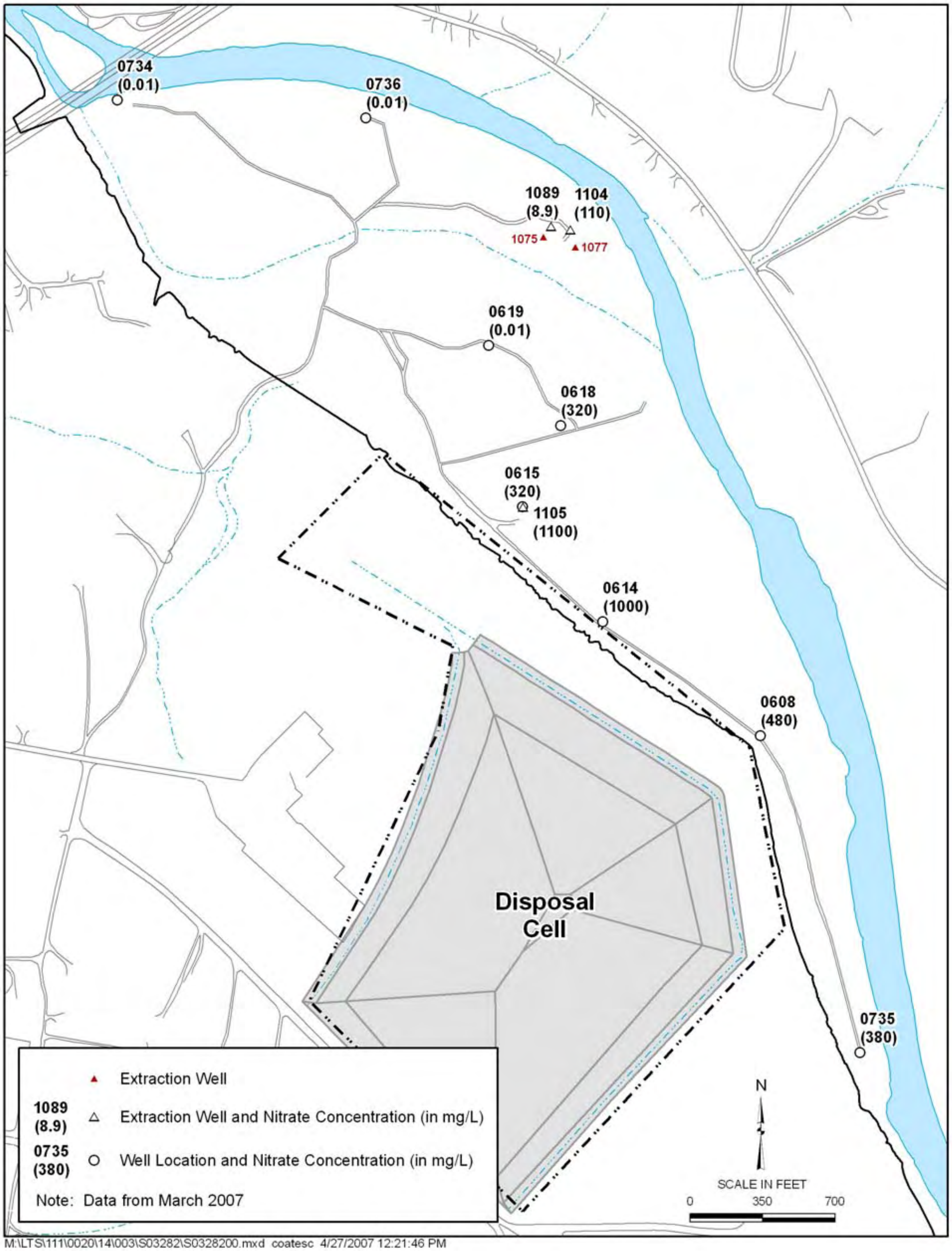

Figure 2–7. Floodplain Nitrate + Nitrite (as Nitrogen) Ground Water Concentrations

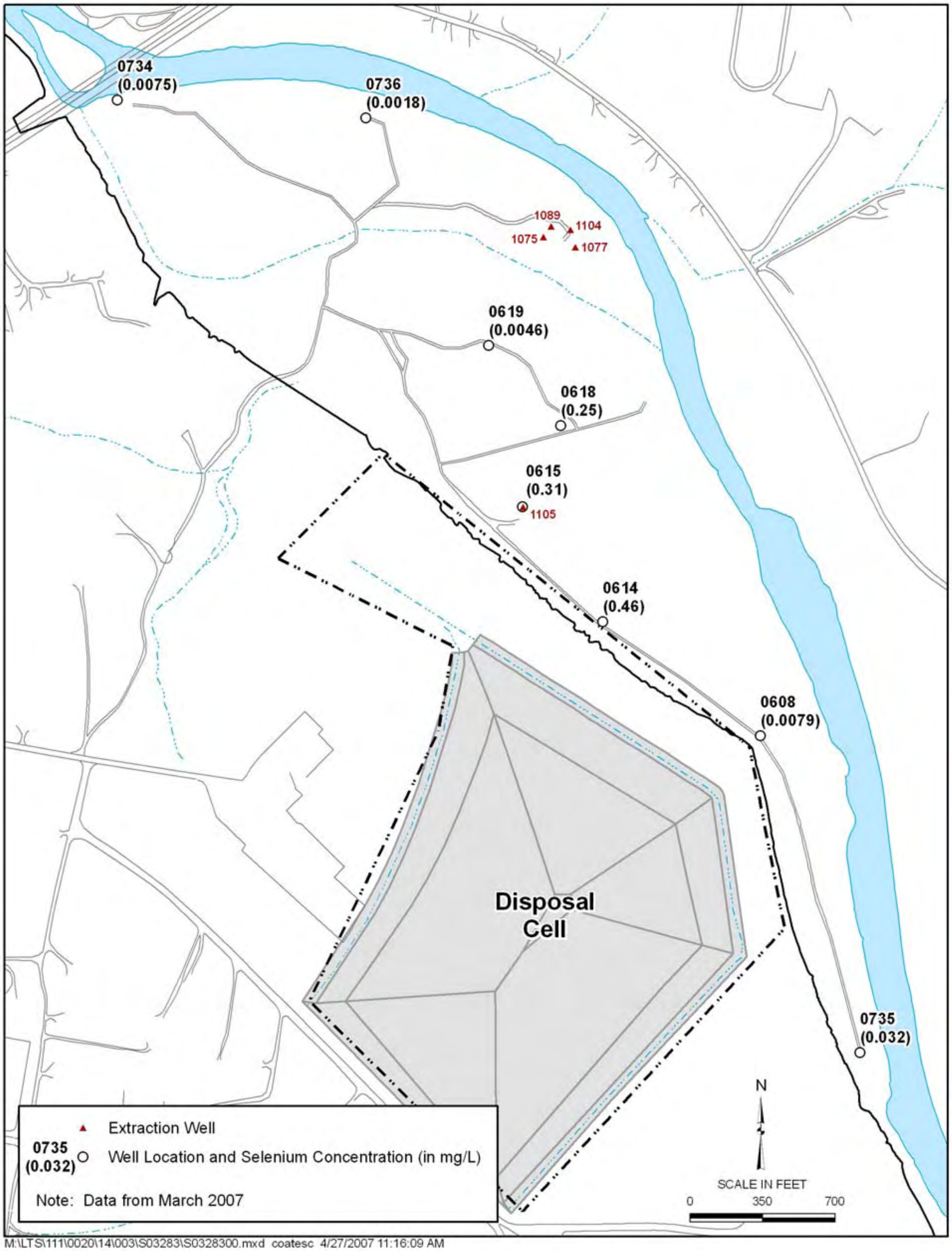

Figure 2–8. Floodplain Selenium Ground Water Concentrations

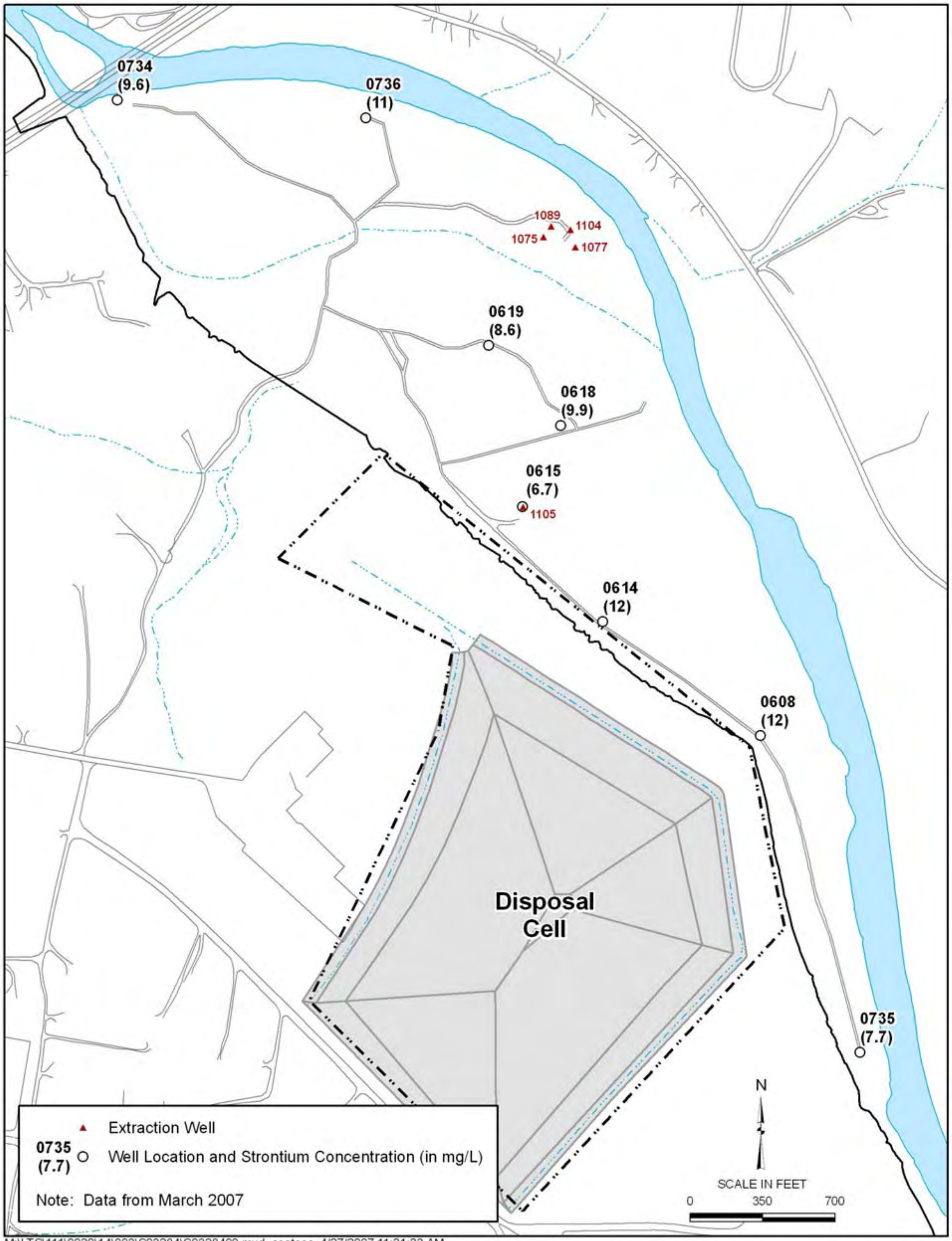

Figure 2–9. Floodplain Strontium Ground Water Concentrations

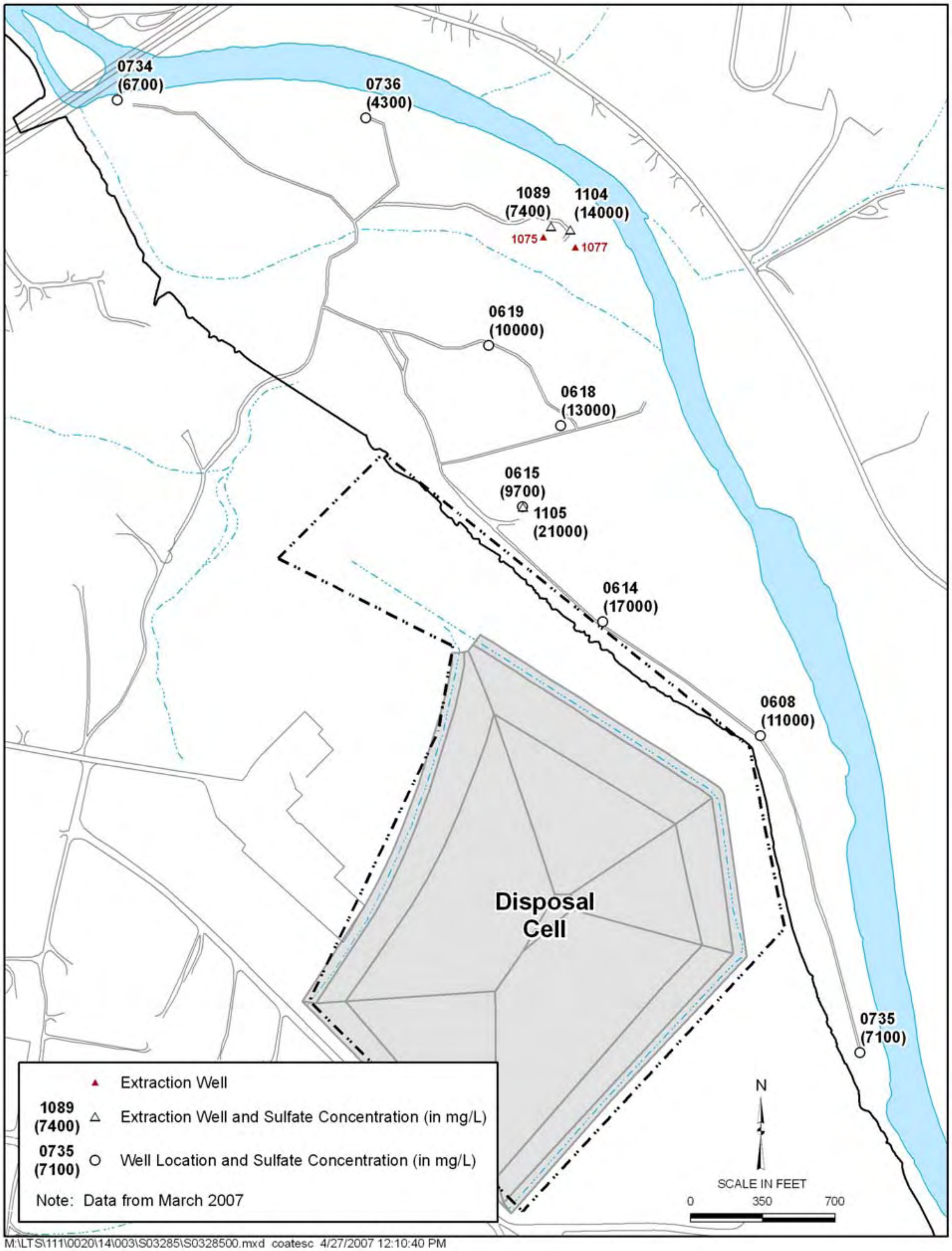

Figure 2–10. Floodplain Sulfate Ground Water Concentrations

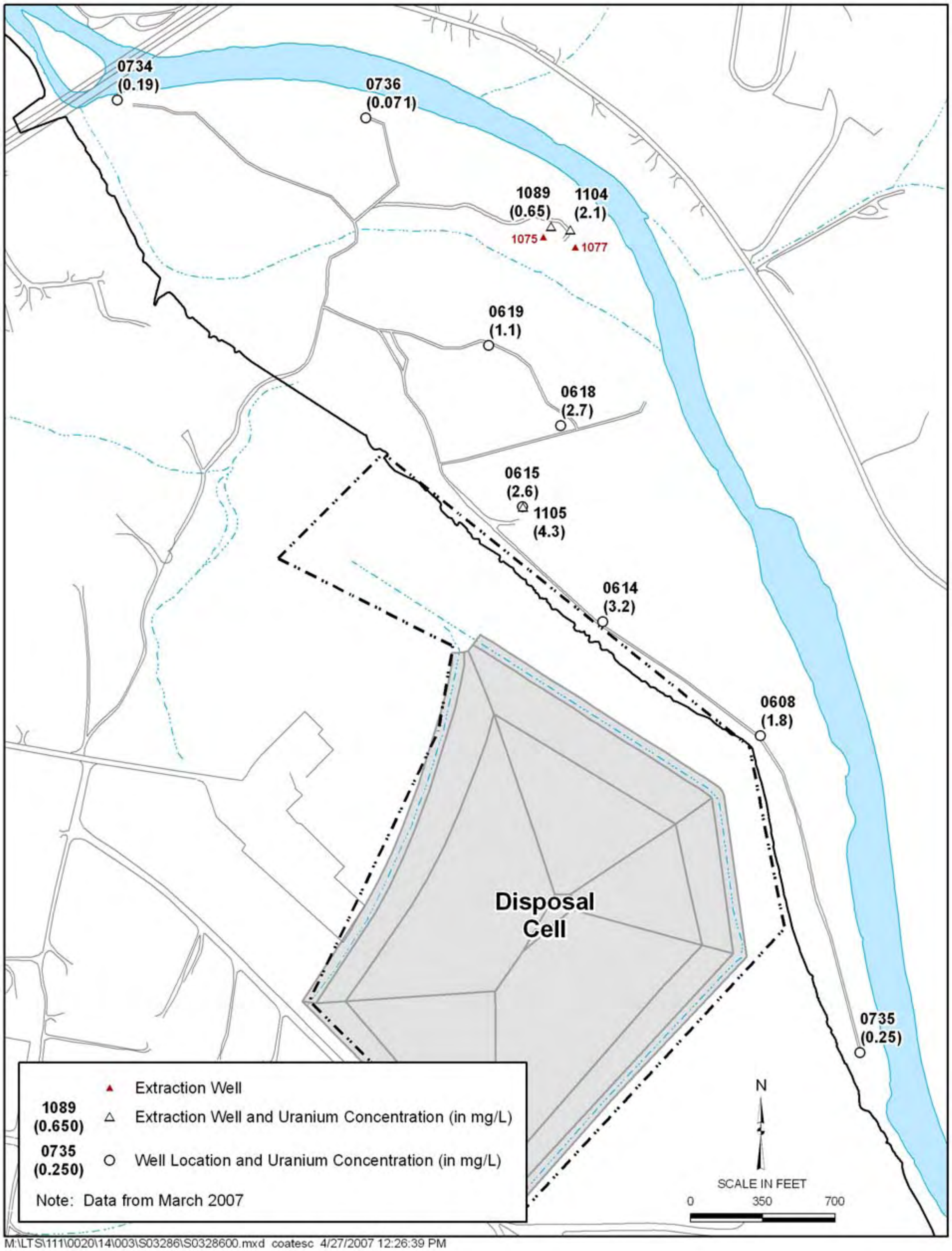

Figure 2–11. Floodplain Uranium Ground Water Concentrations

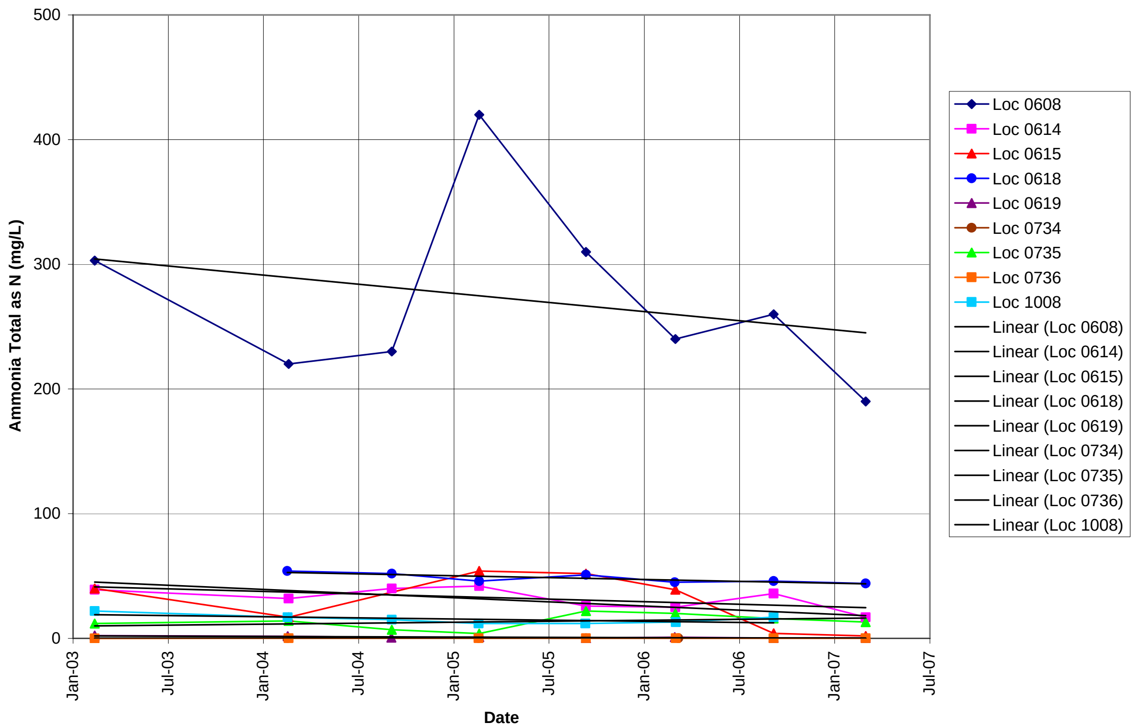

Figure 2–12. Floodplain Ammonia (Total as Nitrogen) Ground Water Concentrations Versus Time

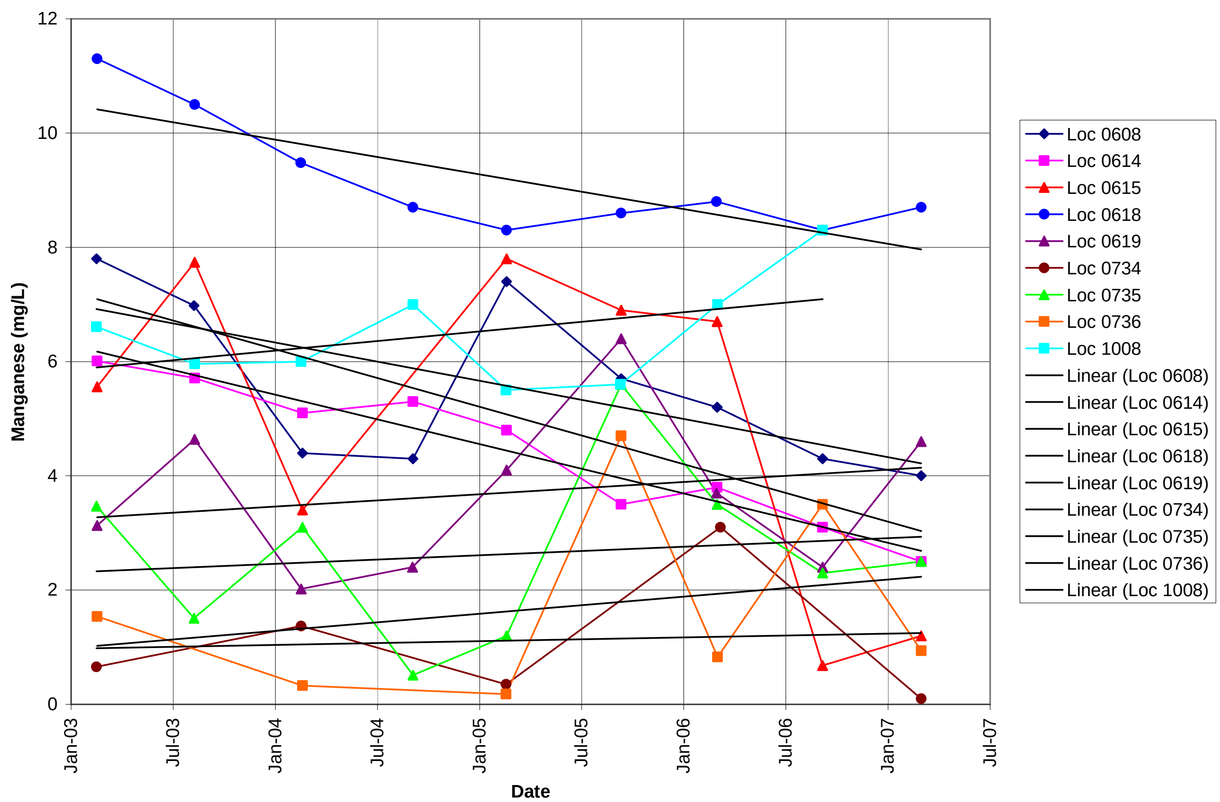

Figure 2–13. Floodplain Manganese Ground Water Concentrations Versus Time

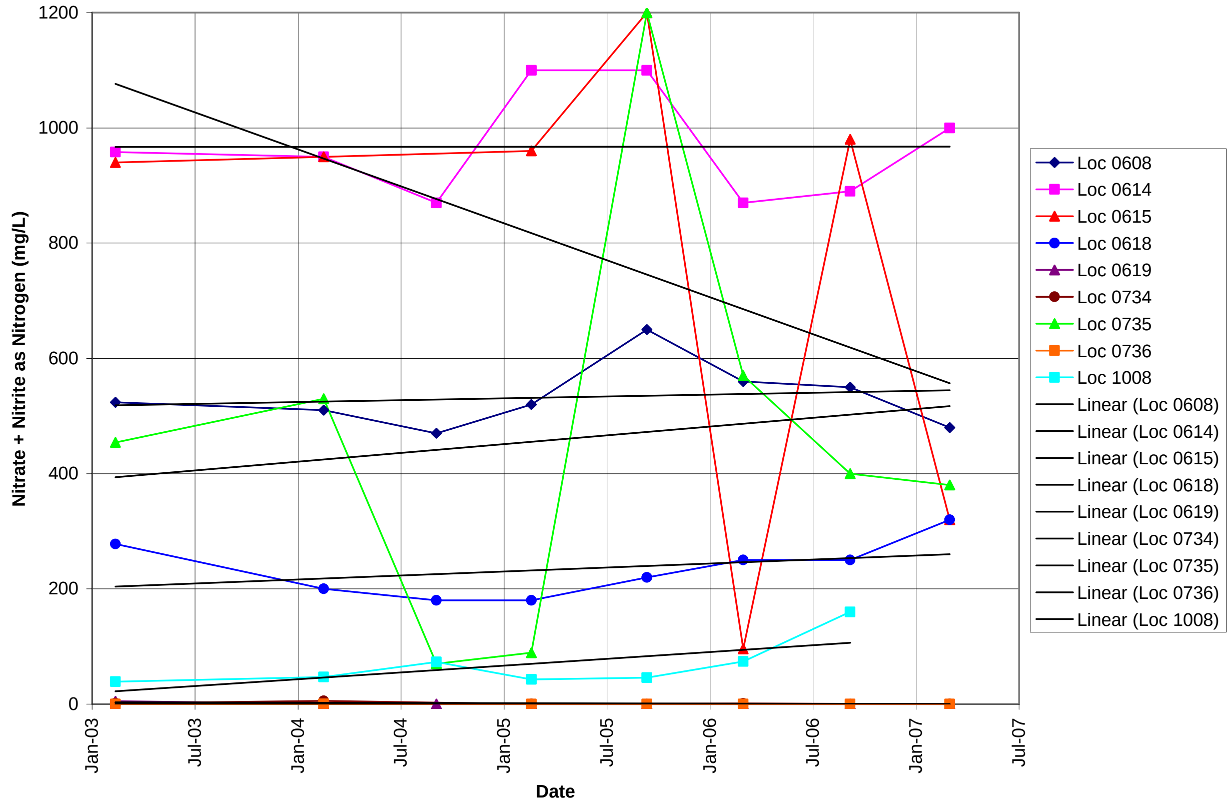

Figure 2–14. Floodplain Nitrate + Nitrite (as Nitrogen) Ground Water Concentrations Versus Time

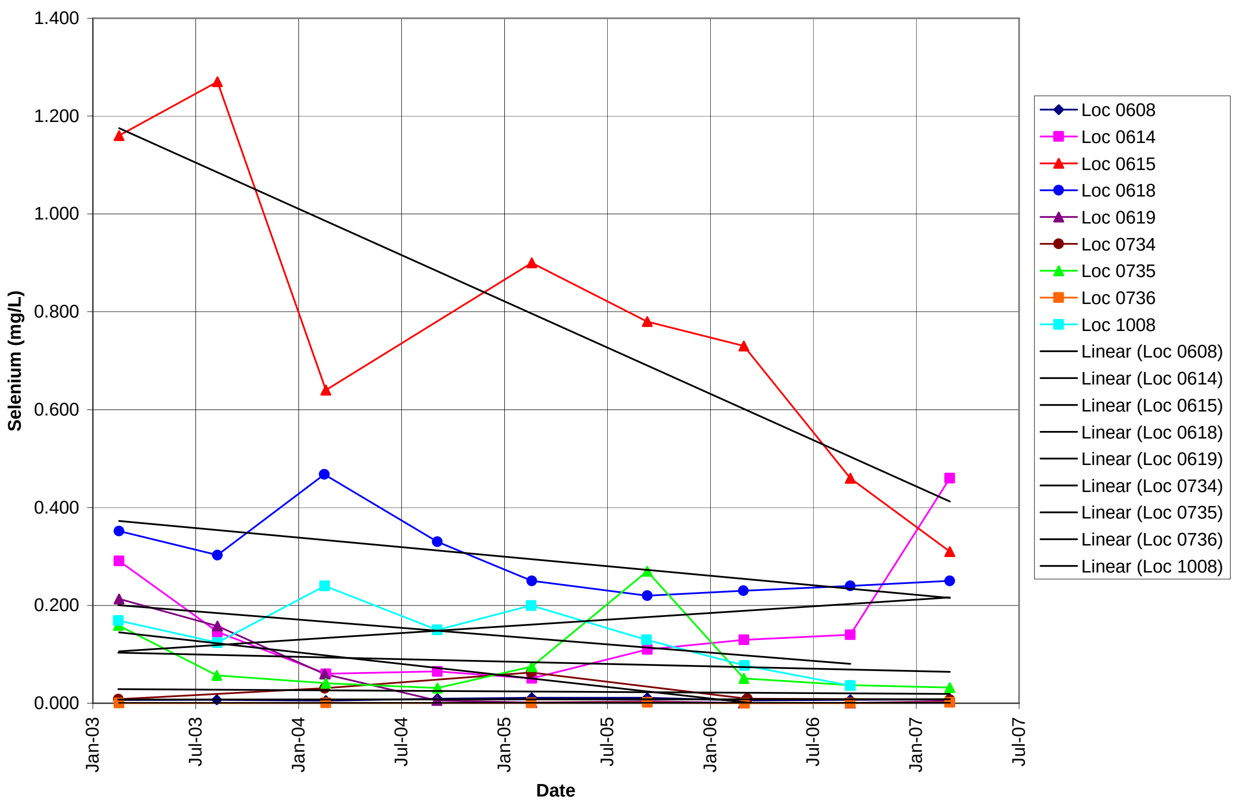

Figure 2–15. Floodplain Selenium Ground Water Concentrations Versus Time

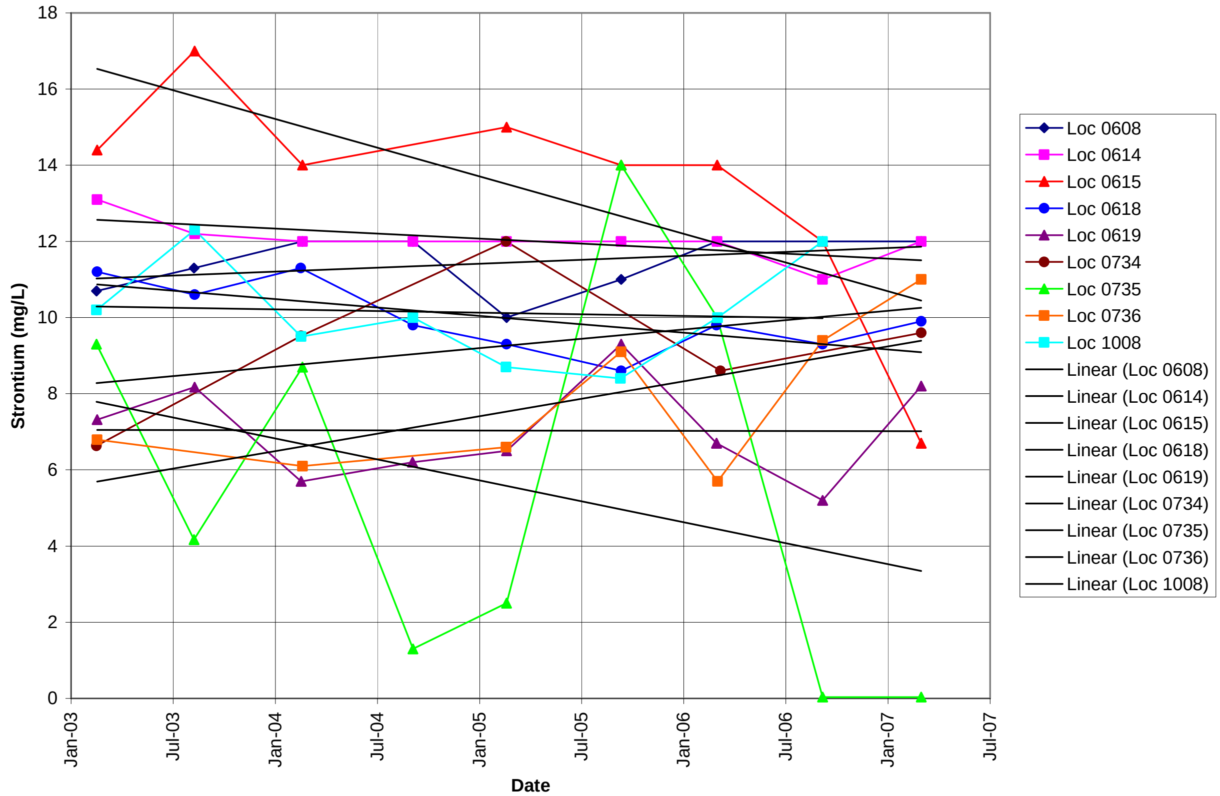

Figure 2–16. Floodplain Strontium Ground Water Concentrations Versus Time

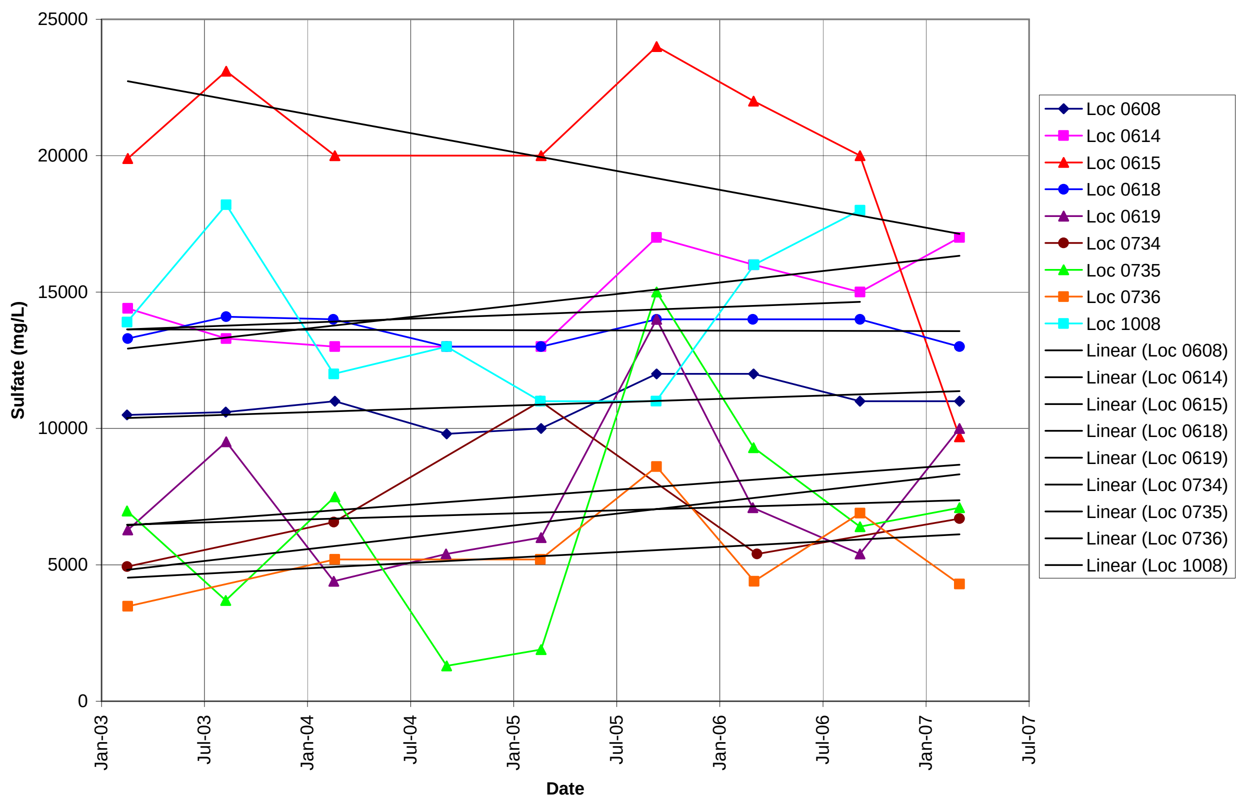

Figure 2–17. Floodplain Sulfate Ground Water Concentrations Versus Time

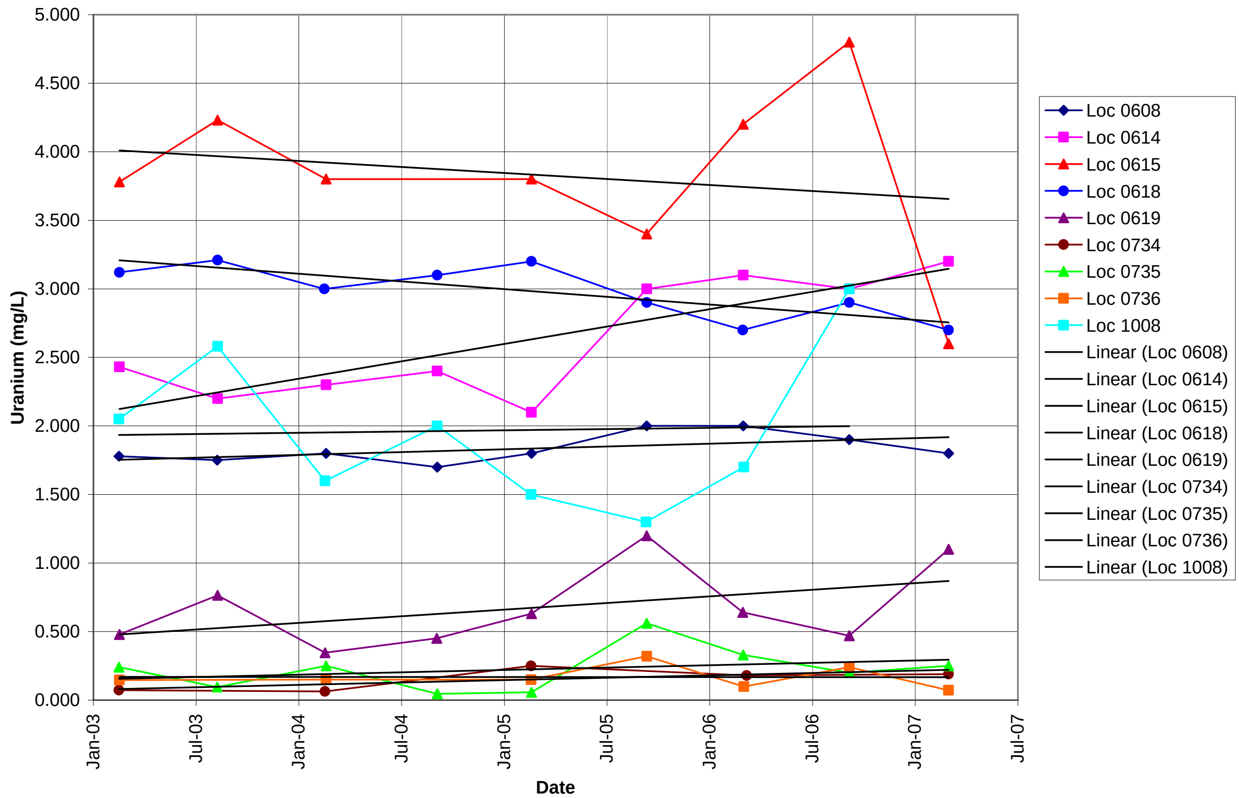

Figure 2–18. Floodplain Uranium Ground Water Concentrations Versus Time

Concentrations of selenium in ground water have generally been decreasing over the past 4 years (Figure 2–8). The maximum concentration during the March 2007 sampling event was 0.46 mg/L; levels were greater than 0.05 mg/L in only three of the nine monitor wells (Figure 2–15).

Concentrations of strontium have generally decreased over the past 4 years (Figure 2–9). Concentrations decreased or were stable in six of the nine monitor wells and ranged from less than 1 mg/L to 12 mg/L during the March 2007 sampling event (Figure 2–16).

Sulfate concentrations in ground water have generally increased over the past 4 years (Figure 2–10). Again, variability is noted in some wells with recent decreases but overall upward trends, which may be the effect of seasonal variation and interaction with surface water from the San Juan River (Figure 2–17).

Uranium concentrations in ground water ranged from 0.071 mg/L to 3.200 mg/L during the March 2007 sampling event (Figure 2–11). Trends over the past 4 years have been variable; concentrations increased in some wells and decreased in others. Again, seasonal variations may be contrary to longer-term trends (Figure 2–18).

During the first 4 years of operation of the remediation system at the Shiprock site a significant mass of contaminants has been removed from the alluvial ground water system by the extraction wells and trenches (see Section 3.2.4). Also, natural flushing is having an effect, as the floodplain system is dynamic with the interaction of recharge and discharge of surface water from the San Juan River, precipitation, and the influx of ground water from the artesian well discharging into Bob Lee Wash. The recent addition of two drainage trenches at the base of the escarpment (Figure 1–1) has enhanced the amount of ground water and mass of constituents removed from the alluvial system.

Another indication that pumping of ground water from the floodplain system is having an effect is the fact that concentrations of nitrate and uranium in surface water in the San Juan River (location 0940) have remained below the upgradient background benchmark values (statistically derived), even during low flow periods, since 2004 (Figure 2–19 and Figure 2–20).

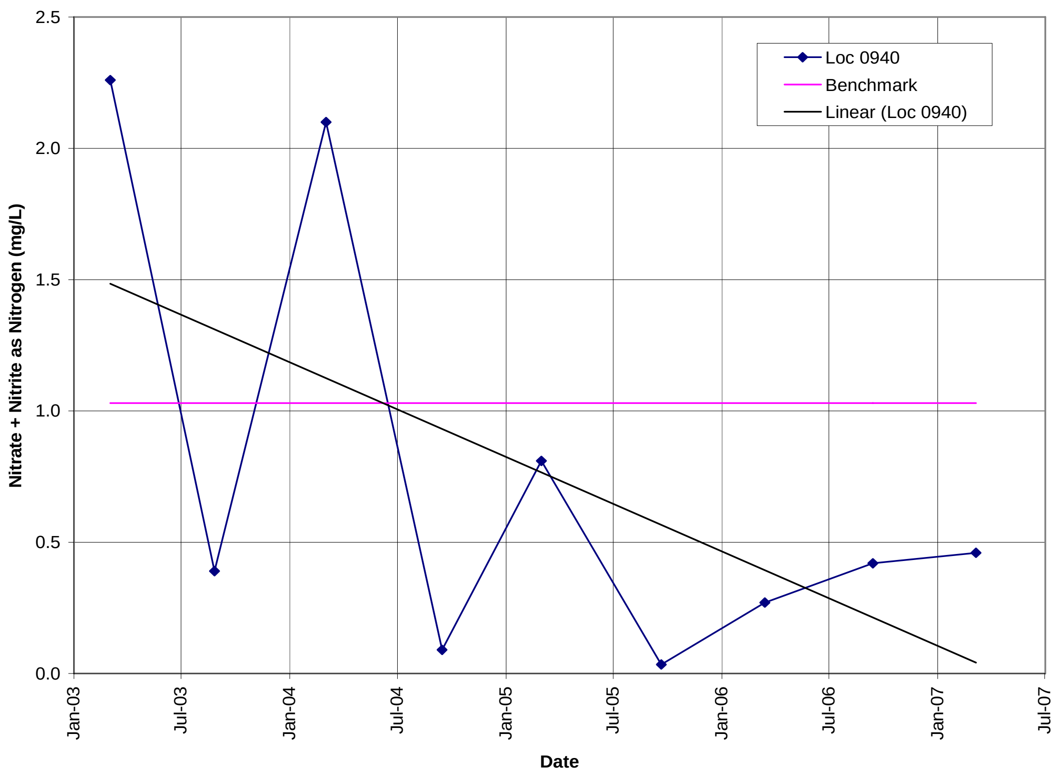

Figure 2–19. Nitrate + Nitrite (as Nitrogen) Concentrations in the San Juan River

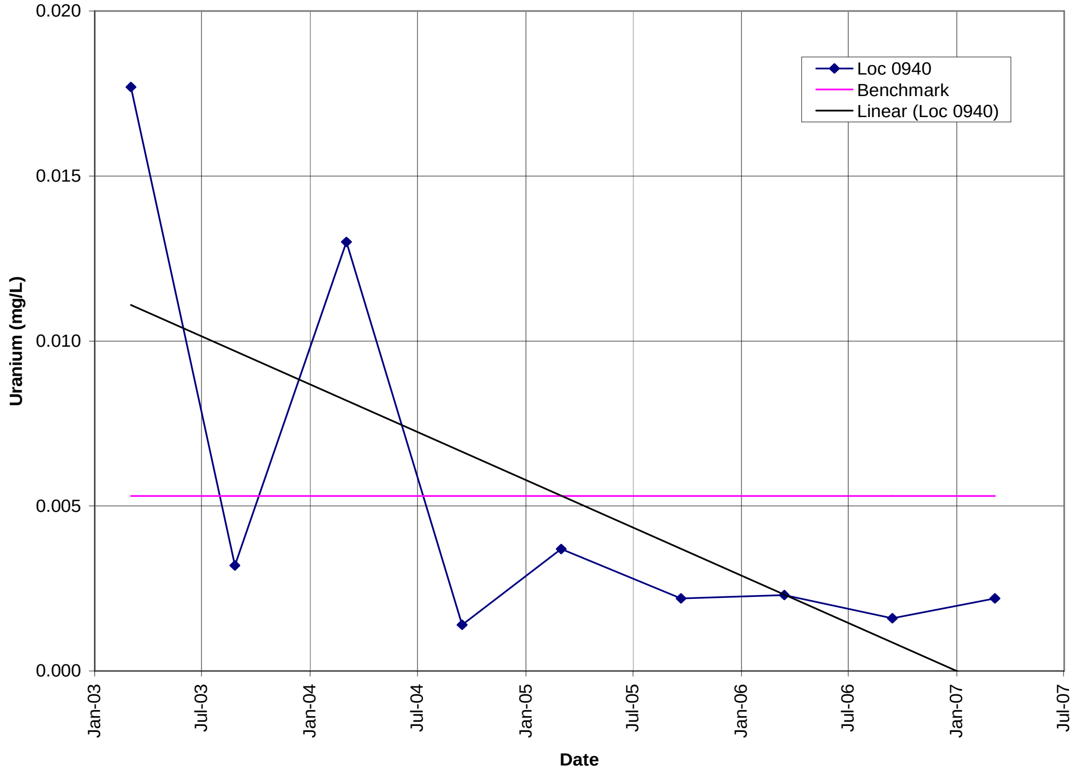

Figure 2–20. Uranium Concentrations in the San Juan River

2.2 Terrace System Subsurface Conditions

The discussion of current subsurface conditions of the terrace is based on collection and analysis of ground water level data through March 2007. Analyses of ground water level trends and flow directions, drain flow rates, and seep flow rates associated with the terrace are discussed below. Results are compared to baseline conditions established in March 2003 in the Baseline Performance Report (DOE 2003) to evaluate the effectiveness of the terrace treatment system.

There are no concentration-driven performance standards for the terrace system because compliance is based on hydrologic control. However, as a best management practice, selected contaminant concentrations are measured at each extraction well, drain, and seep. Estimates of mass removal from the terrace system, compiled during this performance period, are presented in Section 3.2.4 of this report.

2.2.1 Ground Water Level Trends and Flow Directions

Three-point analyses of ground water level data were initiated using March 2003 information, which were subsequently compared to March 2004 and March 2005 data, to determine horizontal gradients and flow directions across the terrace system and to demonstrate that the flow of ground water was predominantly toward the extraction wells. Results of the three-point analyses over the 2-year period showed very little change in ground water flow directions and demonstrated that the flow system beneath the terrace was operating as expected. At the scale of the three-point vector plots, the pumping rates on the terrace over the period of observation had a negligible impact on ground water flow directions near the extraction wells.

Ground water level data from the terrace collected during the March 2007 sampling event were compared to baseline ground water elevations from March 2003 as presented in the Baseline Performance Report (DOE 2003). Figure 2–21 presents a qualitative map view of some of the changes in ground water elevation during this period. Ground water elevations appear to be declining across the entire terrace ground water system. Of the 20 measurements of ground water levels taken in March 2007, all showed declines relative to the baseline period of March 2003. The observation wells nearest the extraction well field are 0604, 0812, and 1057. The greatest ground water level decrease was 3.68 ft at well 0604, which is just west of the evaporation pond. As of March 2007, the cumulative volume of water removed from the terrace extraction system since pumping began was approximately 14,700,000 gallons, and pumping records showed that approximately 3,600,000 gallons were removed during the period April 2006 through March 2007. The water levels in each of these wells in 2007 had declined both relative to baseline conditions and relative to water level measurements made in 2006. Thus, it can generally be concluded that the extraction well field is beginning to have the desired effect on ground water levels in terrace east.

Water levels have also been monitored using pressure transducers that have been installed in selected wells on the terrace. Plots of ground water elevation data versus time collected from pressure transducers connected to dataloggers in terrace east wells 0602, 0604, 0725, 0726, 0813, 0819, 0826, 0827, 0828, 0830, and 1073 are shown in Figure 2–22. Linear trendlines on these data show a decrease in water levels during the time of observation in 7 of the 11 wells. Decreases range from approximately 3.6 ft in well 0604 to 0.1 ft in well 0827. Increases range from 2.1 ft in well 0726 to 0.2 ft in well 1073. The increases in ground water level may be associated with local phenomena and will continue to be monitored. The datalogger in well 0604 indicates how the pumping at wells 0818 and 1096 has affected neighboring ground water elevations during 2006 and 2007. The average pumping rates for these wells for the period were 0.76 and 1.02 gpm, respectively.

Plots of ground water elevation data versus time collected by dataloggers in terrace west wells 0836, 0841, 0846, 0848, and 1060 are shown in Figure 2–23. Although water levels have generally decreased during the past 4 years, ground water elevations are also influenced by irrigation practices in the terrace west area. Therefore, information from these dataloggers does not appear to be as relevant to assessing performance of the remediation system at the Shiprock site.

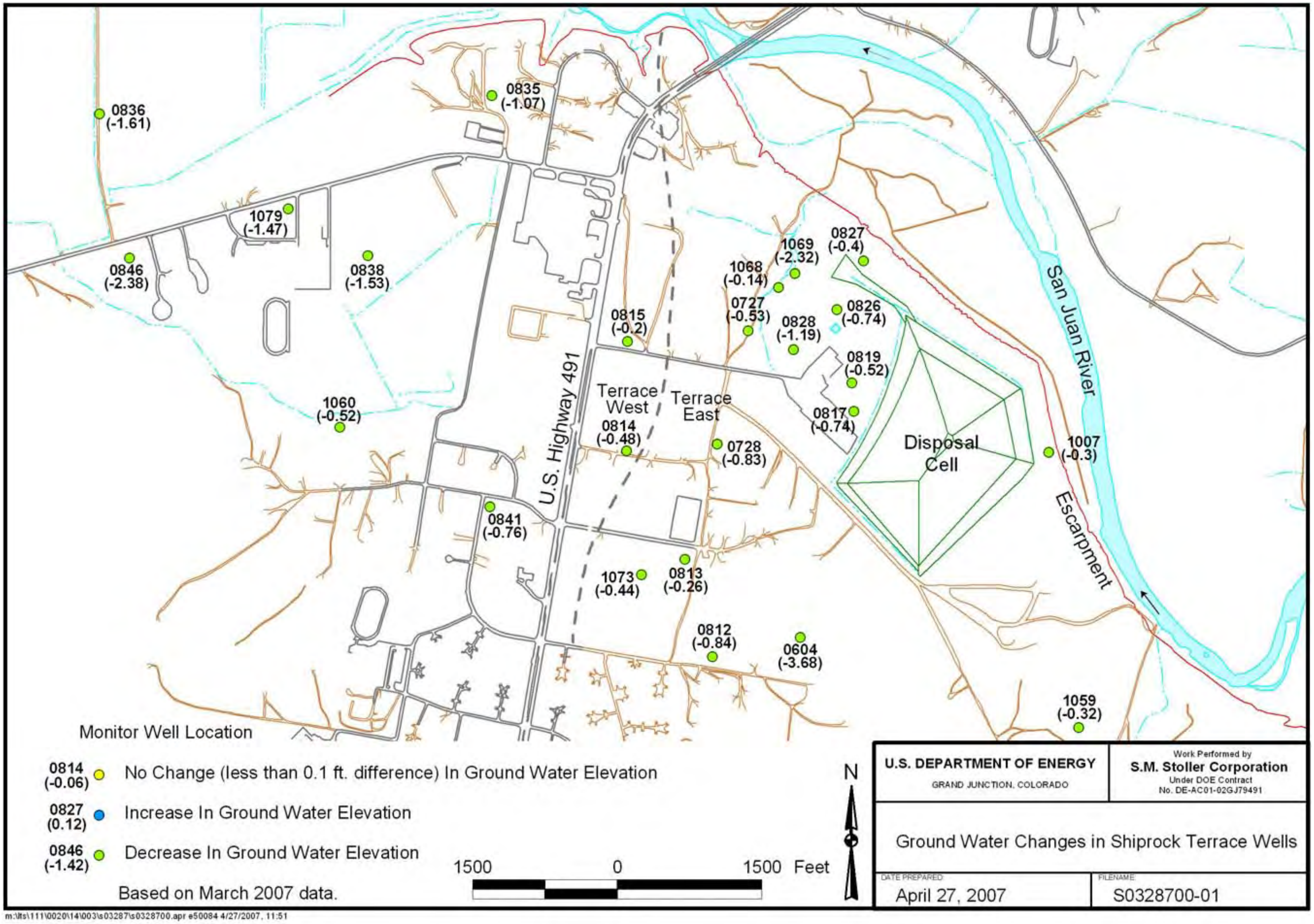

Figure 2–21. Terrace Ground Water Elevation Changes From Baseline (March 2003) to Current (March 2007) Conditions

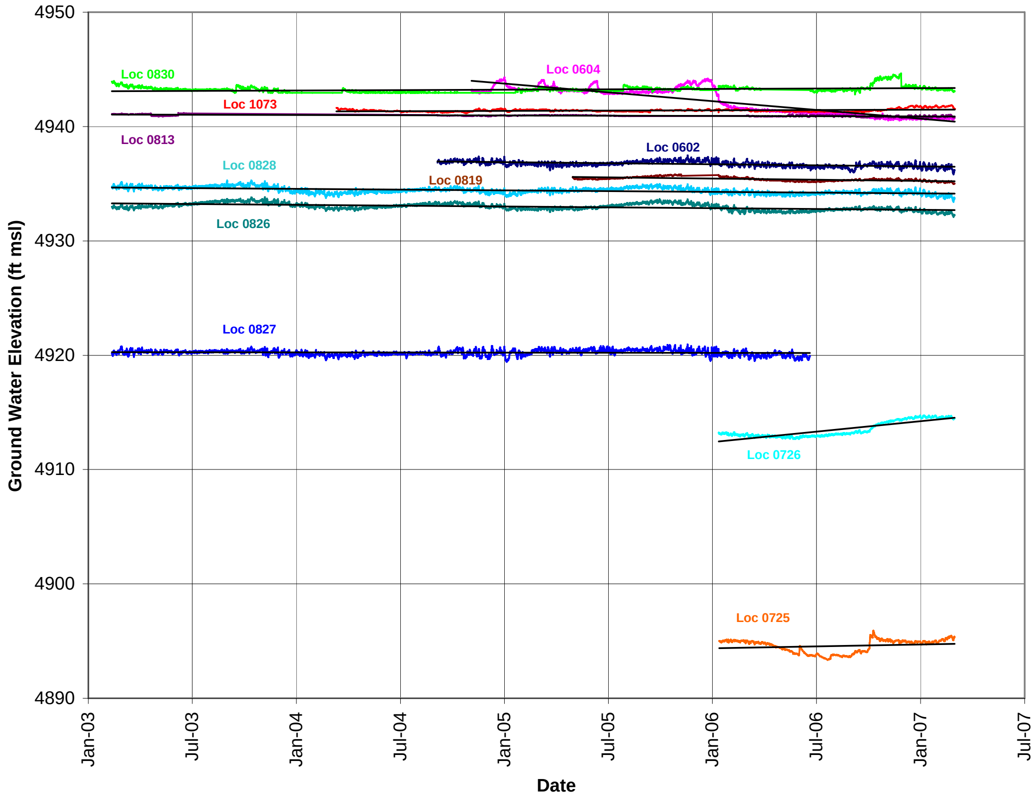

Figure 2–22. Terrace East Datalogger Ground Water Elevations

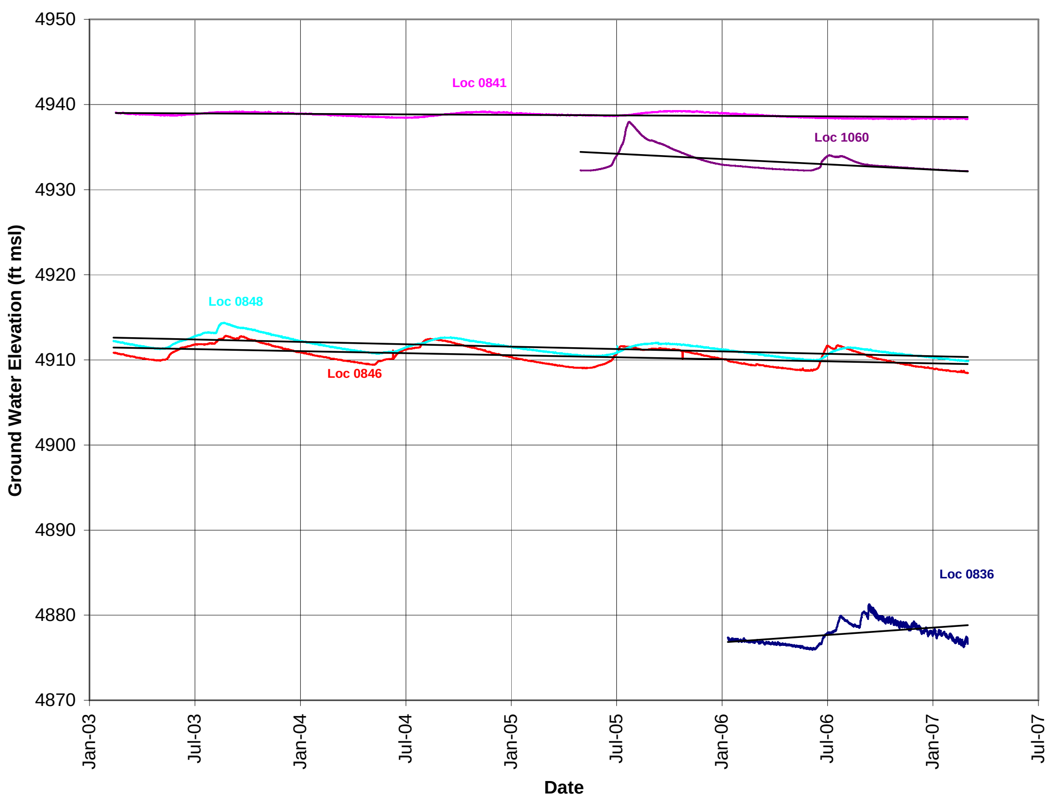

Figure 2–23. Terrace West Datalogger Ground Water Elevations

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 ground water levels in the terrace declined. The average pumping rate from Bob Lee Wash during the performance period was 2.27 gpm. The average pumping rate from Many Devils Wash during the performance period was 1.09 gpm. Average pumping rates decreased at both locations during this period by 32 percent at Bob Lee Wash and 10 percent at Many Devils Wash.

2.2.3 Seep Flow Rates

Rates of ground water discharge at seeps 0425 and 0426 have previously been measured twice a year at the discharge pipes. The flow rate at seep 0425 was 0.08 gpm in March 2006, which was significantly lower than the flow rate of 0.5 gpm measured in March 2003. Seep 0426 was not flowing in March 2006, which compares with a measured rate of 1.8 gpm in March 2003. It has been previously noted that flow measurements at the seeps are subject to considerable temporal variability. During this performance period, these seeps have been incorporated into the remediation system, with discharge from the two seeps piped into a sump, and then transported to the evaporation pond. The average discharge rate from the seep sump during March 2007 was 1.08 gpm.

3.0 Remediation System Performance

The following sections provide a brief description of the components of the floodplain and terrace ground water remediation systems and summarize their performance during the current reporting period.

3.1 Floodplain Remediation System

The objective of the floodplain ground water extraction system is to reduce the mass of COCs in alluvial ground water near the San Juan River. Pumping is focused at this location to lessen exposure risk to aquatic life. All ground water collected from the floodplain extraction wells and trenches is piped south to the terrace where it feeds into the evaporation pond.

3.1.1 Extraction Well Performance

During the current period, the floodplain remediation extraction system consisted of wells 1089 and 1104 (Figure 1–1). These wells were constructed using slotted culvert placed in trenches excavated to bedrock. The cumulative volume of extracted ground water and measured pumping rates at wells 1089 and 1104, from April 2006 to March 2007, are shown in Figure 3–1 and Figure 3–2. During this performance period approximately 1,980,000 gallons of water were removed from well 1089 at an average pumping rate of 3.83 gallons per minute, and approximately 906,000 gallons of water were removed from well 1104 at an average pumping rate of 1.73 gallons per minute. During the 4-year period since the start of operations in March 2003 through the end of March 2007, a total of just over 10,000,000 gallons of water have been removed from well 1089 and just over 1,000,000 gallons of water have been removed from well 1104.

3.1.2 Floodplain Drain System Performance

Two drainage trenches were recently installed in the floodplain just below the escarpment to enhance extraction of ground water from the alluvial system (Figure 1–1). Pumping of ground water from Trench 1 (1110) and Trench 2 (1109) commenced in late April 2006. The cumulative volume of extracted ground water and measured pumping rates at Trench 1 and Trench 2, from April 2006 to March 2007, are shown in Figure 3–3 and Figure 3–4. During this performance period approximately 3,200,000 gallons of water were removed from Trench 1 at an average pumping rate of 5.94 gallons per minute, and approximately 6,980,000 gallons of water were removed from Trench 2 at an average pumping rate of 12.35 gallons per minute.

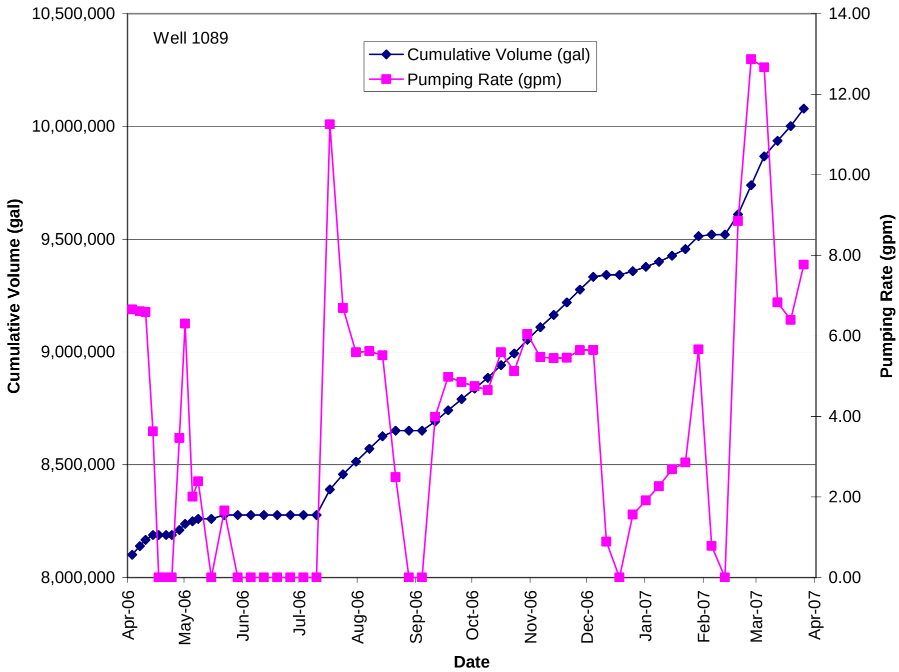

Figure 3–1. Well 1089 Pumping Rate and Cumulative Ground Water Volume Extracted

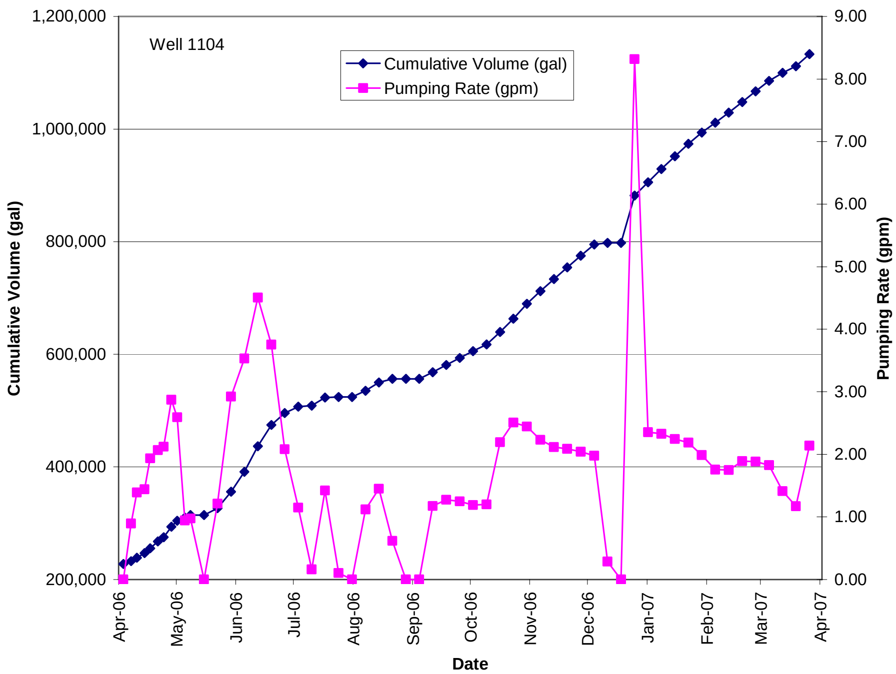

Figure 3–2. Well 1104 Pumping Rate and Cumulative Ground Water Volume Extracted

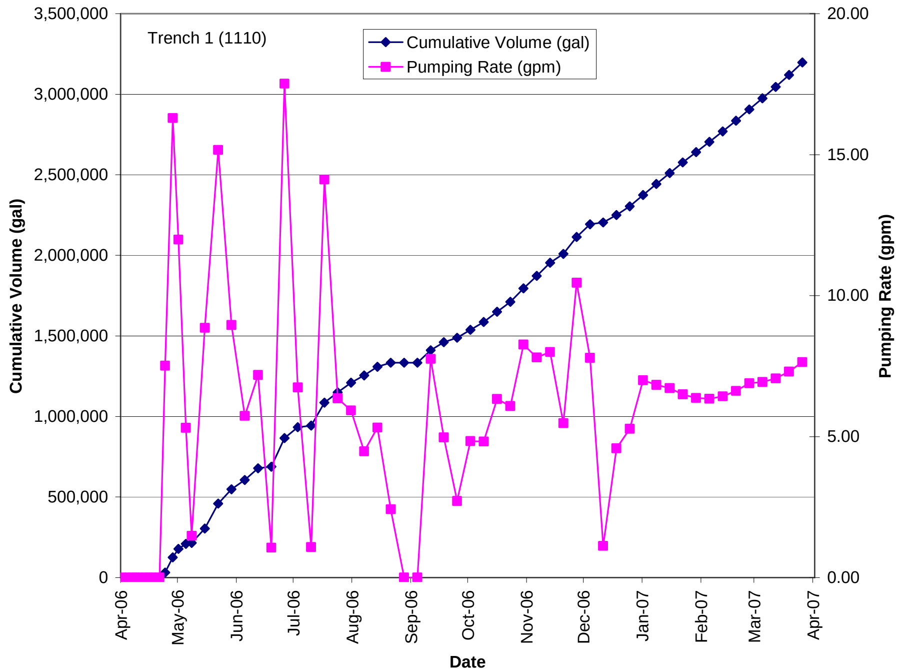

Figure 3–3. Trench 1 Pumping Rate and Cumulative Ground Water Volume Extracted

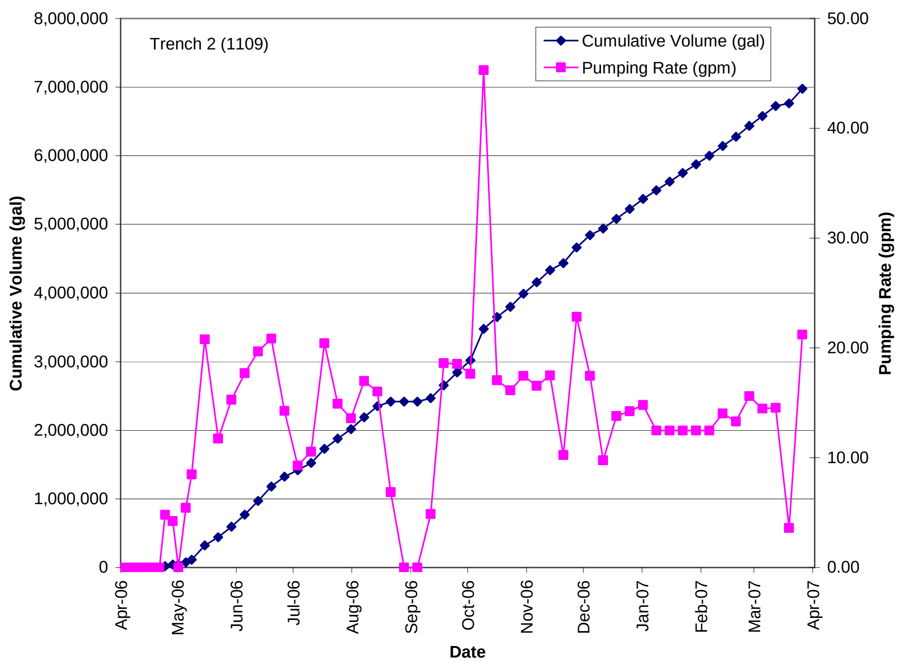

Figure 3–4. Trench 2 Pumping Rate and Cumulative Ground Water Volume Extracted

3.2 Terrace Remediation System

The objective of the terrace remediation system is to remove ground water from the south part of the area so that current exposure pathways at seeps and at Bob Lee Wash and Many Devil Wash are eventually eliminated and flow of ground water from the terrace to the floodplain is reduced. Since ground water compliance for the terrace is based on hydrologic control, concentration standards for COCs do not apply. The terrace remediation system consists of four components: the extraction wells, the terrace drains (Bob Lee Wash and Many Devils Wash), the evaporation pond, and the terrace outfall drainage channel diversion (Figure 1–1).

3.2.1 Extraction Well Performance

During the current period, the terrace remediation well field consisted of wells 0818, 1070, 1071, 1078, 1091, 1092, 1093, 1095, and 1096 (Figure 1–1). The average pumping rates and corresponding cumulative ground water volumes removed from these wells from April 2006 through March 2007 are presented in Figure 3–5 through Figure 3–13, respectively. Measured pumping rates and corresponding volumes of ground water removed from the terrace ground water extraction wells during the recent performance period are available in the database at the DOE Office in Grand Junction, Colorado. Table 3–1 compares the current-period and previous-period average pumping rate and total ground water volume removed from each of the extraction wells. The current-period average pumping rates ranged from 0.01 (well 1071) to 1.02 gpm (well 1096), and the total ground water volume removed from each well during this period ranged from 6,715 gallons (well 1071) to 516,370 gallons (well 1096). The cumulative total volume removed during the current period was approximately 58 percent more than during the previous reporting period. This increase is attributed to the contribution from extraction wells 1095 and 1096.

Table 3–1. Terrace Extraction Well Average Pumping Rate and Total Ground Water Volume Removed

Well	Previous Period (April 1, 2005, through March 31, 2006)		Current Period (April 1, 2006, through March 31, 2007)	
	Average Pumping Rate (gpm)	Total Ground Water Volume Removed (gallons)	Average Pumping Rate (gpm)	Total Ground Water Volume Removed (gallons)
0818	0.69	348,931	0.76	372,754
1070	0.12	60,868	0.05	21,314
1071	0.02	12,411	0.01	6,715
1078	0.45	241,098	0.53	237,046
1091	0.06	30,381	0.15	30,976
1092	0.11	58,285	0.06	29,037
1093	0.09	49,141	0.38	206,248
1095	1.37	193,204	0.88	439,154
1096	1.35	182,918	1.02	516,370
Total	**4.26**	**1,177,237**	**3.84**	**1,859,614**

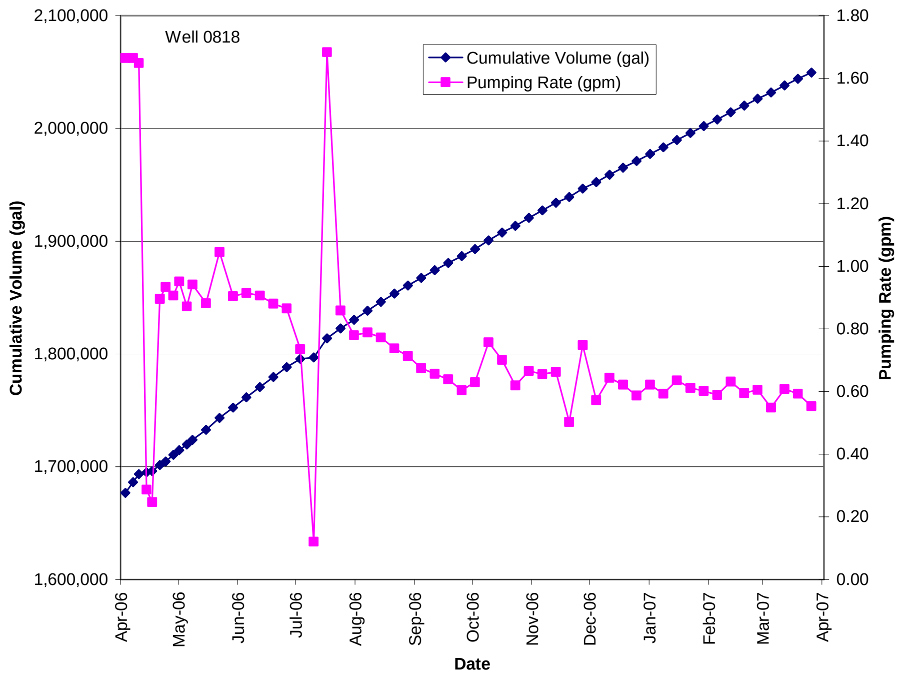

Figure 3–5. Well 0818 Pumping Rate and Cumulative Ground Water Volume Extracted

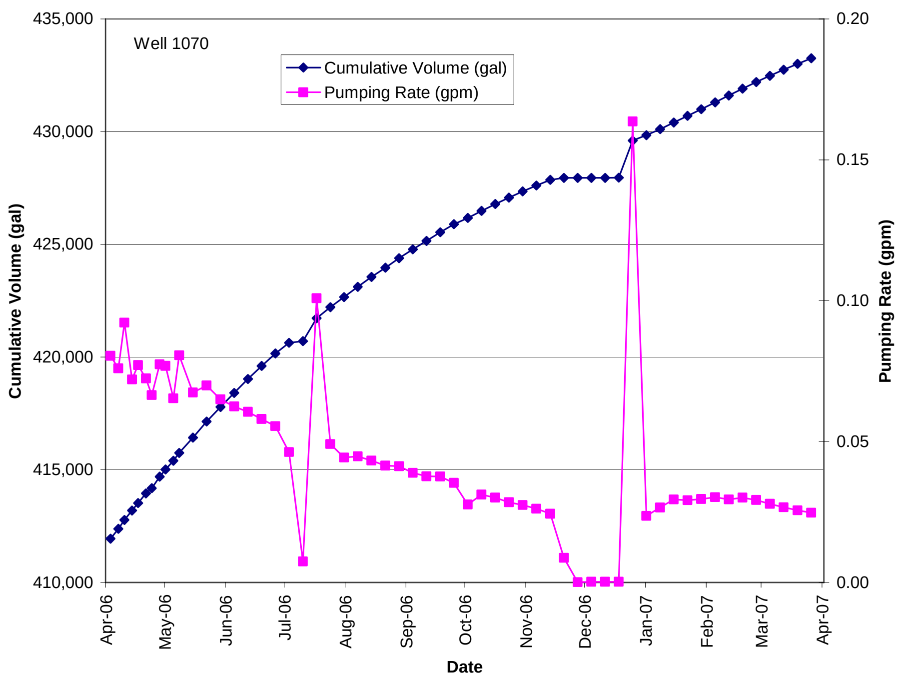

Figure 3–6. Well 1070 Pumping Rate and Cumulative Ground Water Volume Extracted

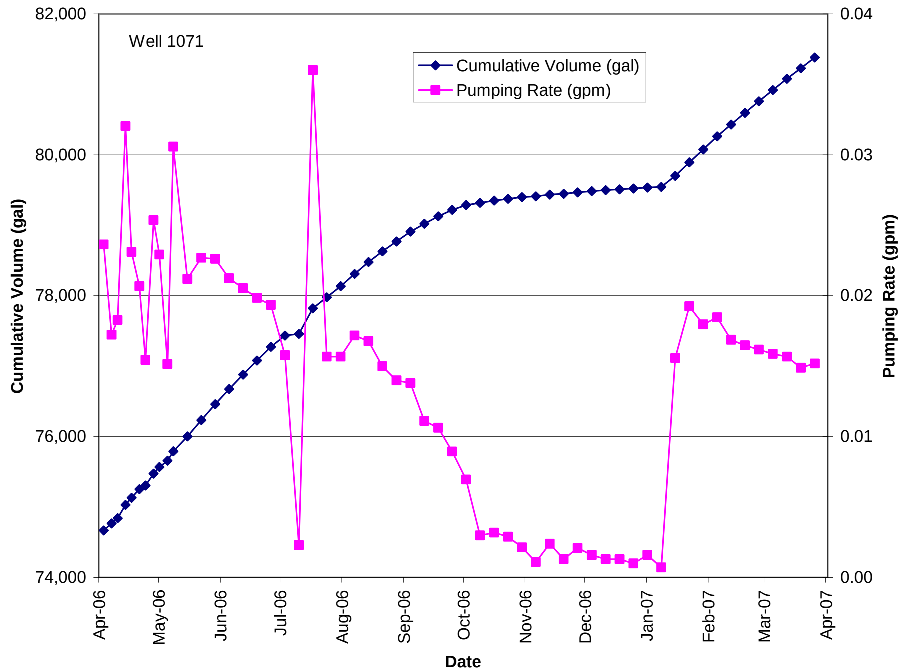

Figure 3–7. Well 1071 Pumping Rate and Cumulative Ground Water Volume Extracted

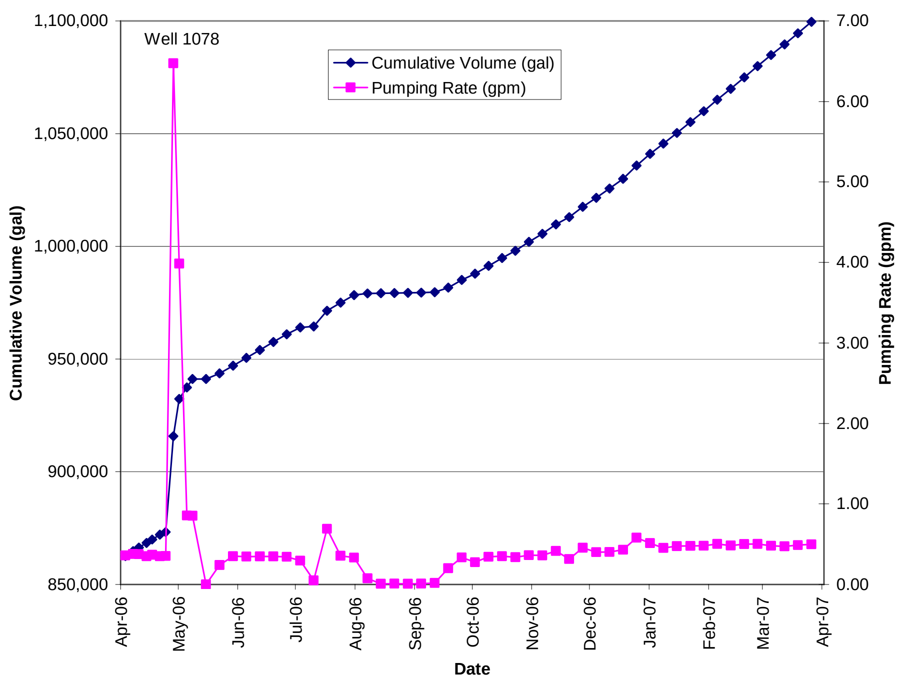

Figure 3–8. Well 1078 Pumping Rate and Cumulative Ground Water Volume Extracted

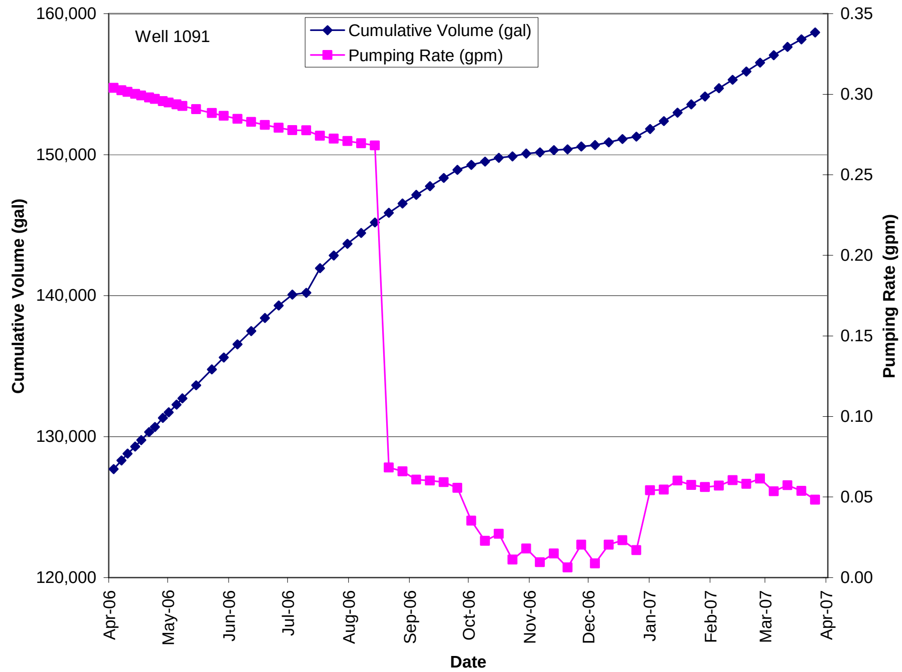

Figure 3–9. Well 1091 Pumping Rate and Cumulative Ground Water Volume Extracted

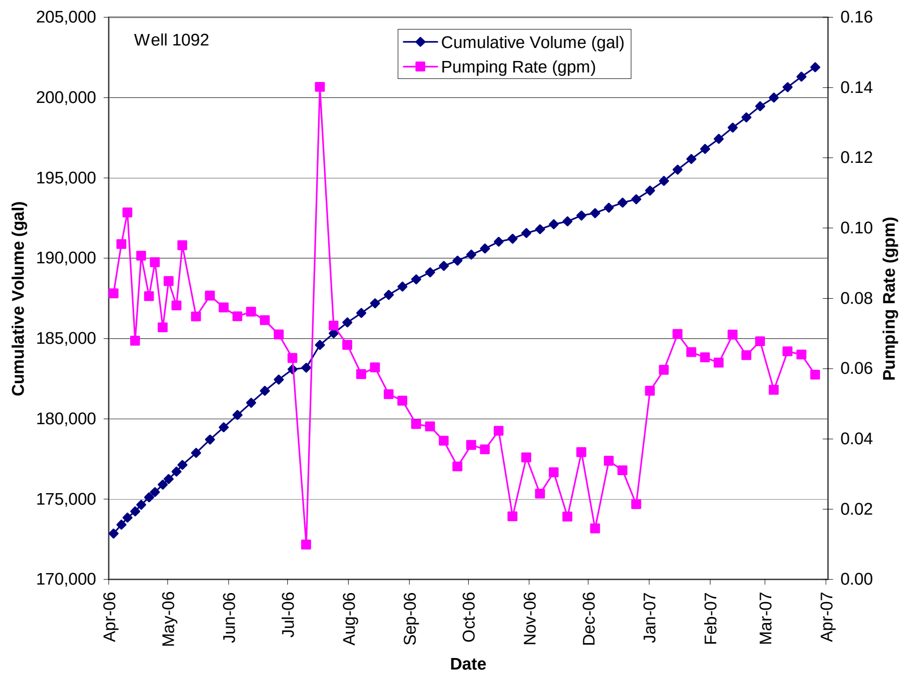

Figure 3–10. Well 1092 Pumping Rate and Cumulative Ground Water Volume Extracted

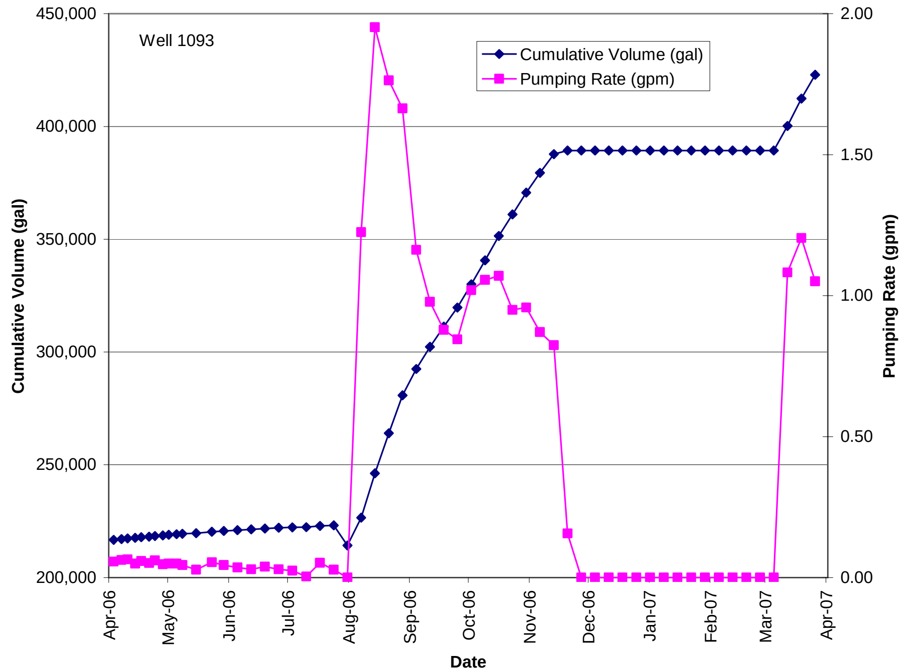

Figure 3–11. Well 1093 Pumping Rate and Cumulative Ground Water Volume Extracted

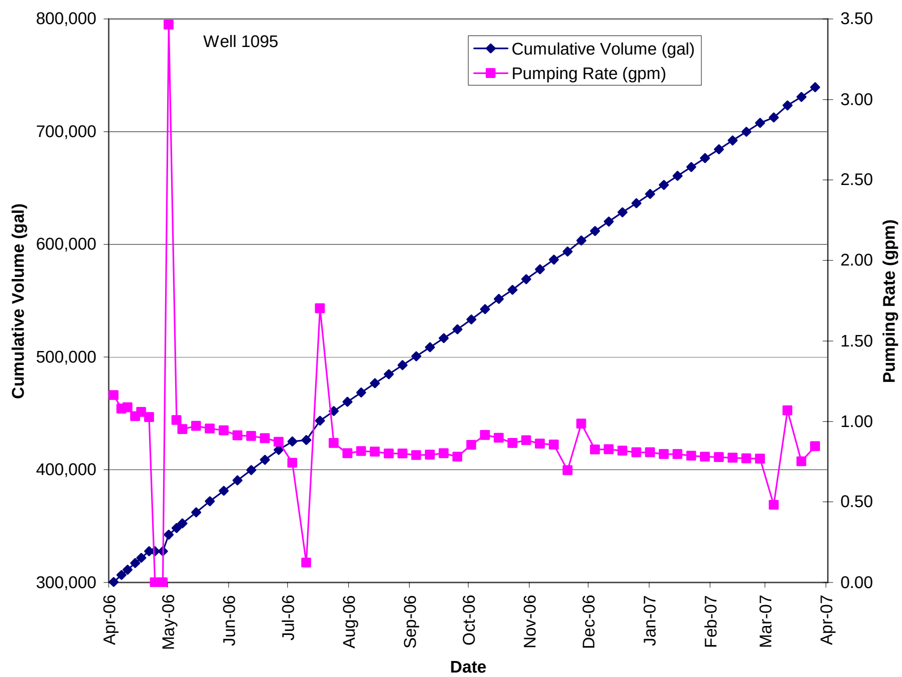

Figure 3–12. Well 1095 Pumping Rate and Cumulative Ground Water Volume Extracted

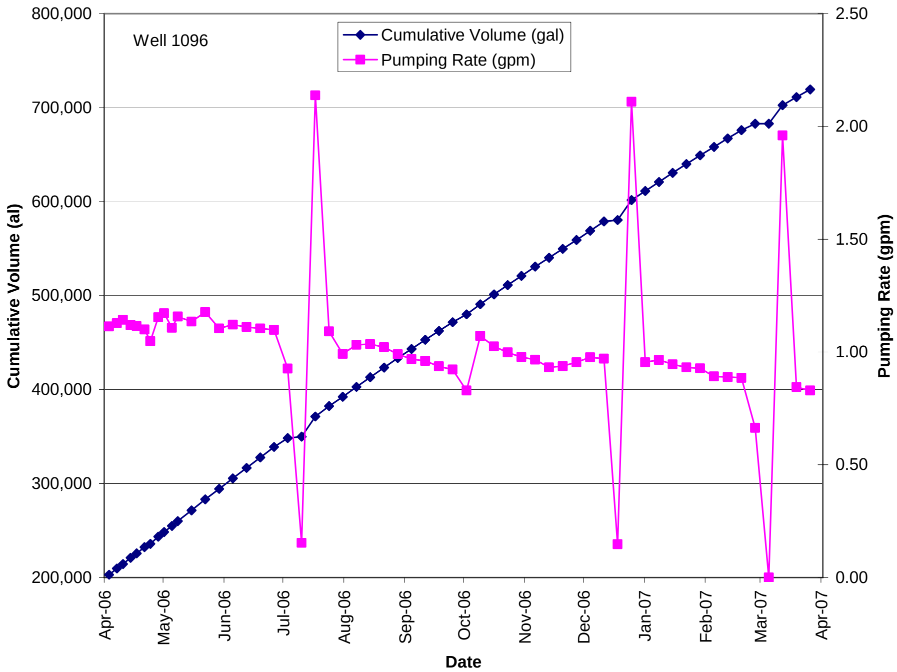

Figure 3–13. Well 1096 Pumping Rate and Cumulative Ground Water Volume Extracted

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 impermeable geomembrane and geotextile filter fabric, are offset from the centerline of each wash to minimize 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 (location 1087) drain are presented in Figure 3–14. During the current performance period, the average pumping rate from Bob Lee Wash was 2.27 gpm, and approximately 1,191,000 gallons of water were removed by the ground water interceptor drain.

The pumping rates and volume of water removed from the ground water interceptor drain in Many Devils Wash (location 1088) are presented in Figure 3–15. During the current performance period, the average pumping rate from Many Devils Wash was 1.09 gpm, and approximately 526,000 gallons of water were removed by the ground water interceptor drain.

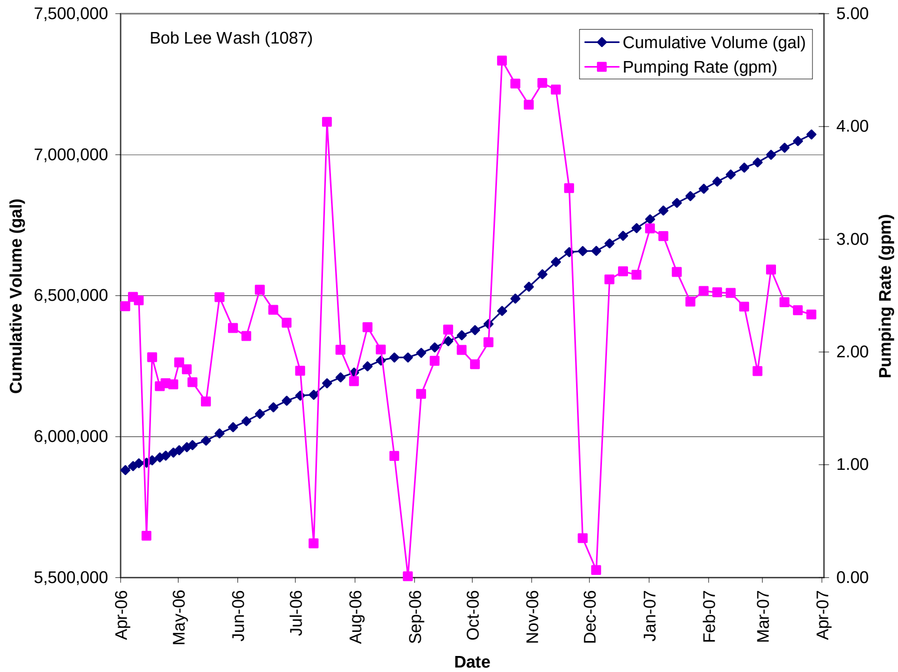

Figure 3–14. Bob Lee Wash Pumping Rate and Cumulative Ground Water Volume Extracted

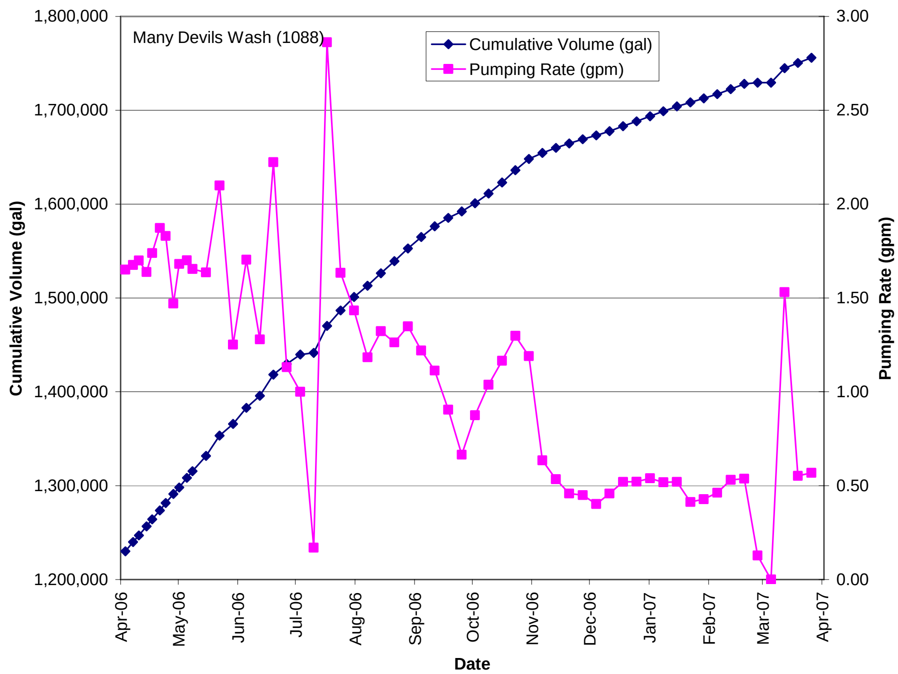

Figure 3–15. Many Devils Wash Pumping Rate and Cumulative Ground Water Volume Extracted

3.2.3 Terrace Seep Sump Performance

Rates of ground water discharge at seeps 0425 and 0426, which have previously been measured twice a year where they flowed out of the pipes, have decreased since March 2003. During this performance period, these seeps have been incorporated into the remediation system, with discharge from the two seeps piped into a sump, and then transported to the evaporation pond. The average discharge rate from the seep sump during March 2007 is 1.08 gpm. The total volume of water produced since pumping began is 365,606 gallons.

3.2.4 Evaporation Pond

The selected method for treating ground water from the interceptor drains and extraction wells is solar evaporation. The contaminated ground water is pumped to a lined evaporation pond in the south part of the radon cover borrow pit area (Figure 1–1). Depth of water in this 11-acre pond was approximately 2.5 ft in March 2007, leaving approximately 5.5 ft of unfilled pond capacity. With the additional input to the pond from the floodplain, it is anticipated that the evaporation pond will fill by the winter of 2008.

During this performance period, approximately 77 percent of the influent liquids entering the evaporation pond come from the floodplain aquifer, leaving approximately 23 percent of the inflow to come from the terrace ground water system. At the end of this reporting period, approximately 36,500,000 gallons of water had been pumped to the evaporation pond from all sources since start of operations in March 2003. The floodplain contribution includes two extraction wells and the two trenches. The terrace contribution includes nine extraction wells, Bob Lee Wash, Many Devils Wash, and the seep sump. Figure 3–16 presents the total volume of water transported to the pond, and the relative contributions from the floodplain and terrace systems.

The estimated masses of nitrate, sulfate, and uranium entering the evaporation pond from the alluvial extraction wells and trenches, and the terrace ground water extraction system are summarized in Table 3–2. Because of its high concentration in both the alluvial and terrace ground water systems, sulfate is the dominant COC (in terms of mass) that enters the evaporation pond. During the current performance period the estimated mass of selected COCs pumped to the evaporation pond was 1,022,282 pounds of sulfate, 42,543 pounds of nitrate, and 114 pounds of uranium. The estimate was computed from the average COC concentrations and the monthly flows at each well.

3.2.5 Terrace Drainage Channel Diversion

Storm-water runoff from the disposal cell is designed to drain northwest to a rock-lined energy dissipation area, eventually reaching upper Bob Lee Wash. The so-called “outfall drainage channel diversion” conveys surface water to the lower part of Bob Lee Wash from the energy dissipation area. The extent to which the energy dissipation area functions as a point source of recharge to the terrace is unclear.

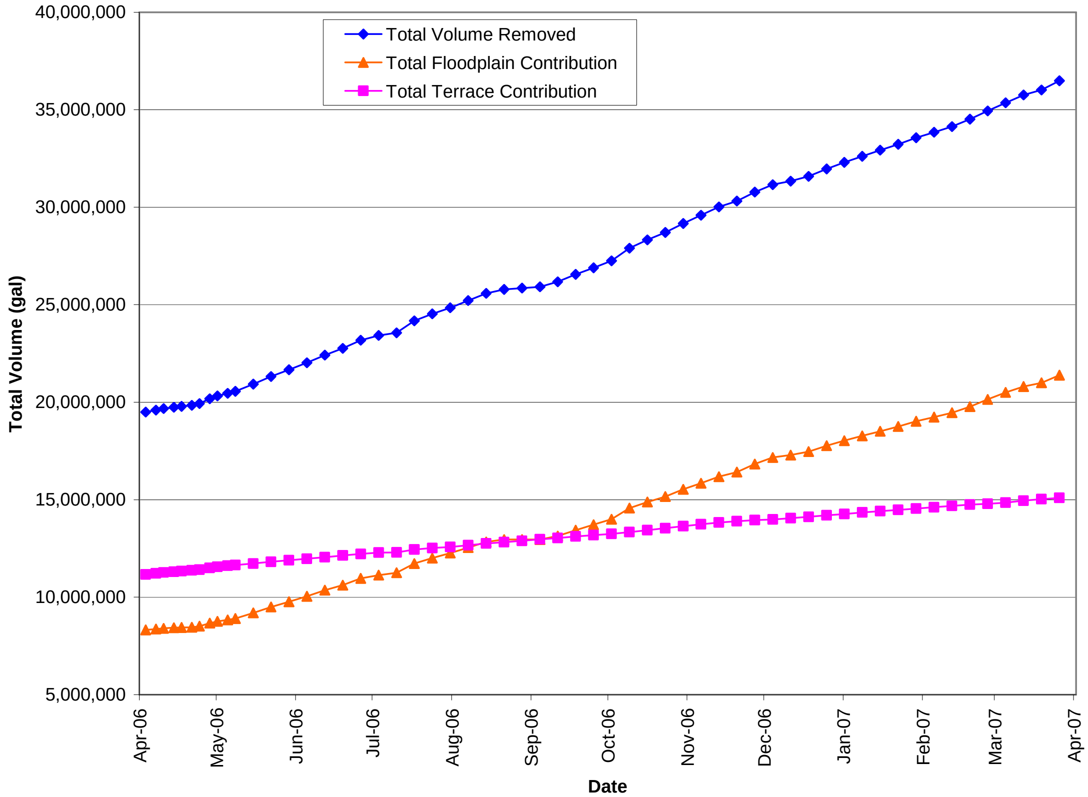

Figure 3–16. Total Ground Water Volume Transported to the Evaporation Pond

Table 3–2. Estimated Total Mass of Selected Constituents Pumped From Terrace and Floodplain

Location	Annual Cumulative volume (gal) (1)	Percent Contribution	Nitrate - Average Concentration (mg/L)	Nitrate Mass Contribution per Location (kg)	Nitrate Mass Cumulative (kg) (2)	Nitrate Mass Cumulative (lb) (2)	Sulfate - Average Concentration (mg/L)	Sulfate Mass Contribution per Location (kg)	Sulfate Mass Cumulative (kg) (2)	Sulfate Mass Cumulative (lb) (2)	Uranium Average Concentration (mg/L)	Uranium Mass Contribution Per Location (kg)	Uranium Mass Cumulative (kg) (2)	Uranium Mass Cumulative (lb) (2)
0818	372754	9	1650	2328	2328	5132	11000	15520	15520	34215	0.135	0.190	0.190	0.419
1070	21314	1	680	55	2383	5253	14500	1170	16690	36794	0.120	0.010	0.200	0.440
1071	6715	0	840	21	2404	5300	11500	292	16982	37439	0.130	0.003	0.203	0.448
1078	237046	6	665	597	3001	6616	13000	11664	28646	63153	0.150	0.135	0.338	0.744
1091	30976	1	2050	240	3241	7146	9350	1096	29742	65570	0.125	0.015	0.352	0.777
1092	29037	1	1400	154	3395	7485	13000	1429	31171	68719	0.135	0.015	0.367	0.809
1093	206248	5	2950	2303	5698	12562	3250	2537	33708	74313	0.090	0.070	0.437	0.964
1095	439154	11	1550	2576	8274	18242	7350	12217	45925	101247	0.700	1.164	1.601	3.529
1096	516370	13	680	1329	9603	21172	14500	28340	74265	163724	0.120	0.235	1.835	4.046
1087 (blw)	1191168	30	330	1488	11091	24452	7900	35618	109883	242247	0.610	2.750	4.586	10.109
1088 (mdw)	526016	13	650	1294	12385	27305	18000	35837	145720	321254	0.180	0.358	4.944	10.900
Seep sump	365606	9	28	39	12424	27390	8600	11901	157621	347491	1.100	1.522	6.466	14.255
1089	1978126	15	28	210	12634	27852	9700	72626	230247	507602	1.075	8.049	14.515	32.000
1104	905692	7	105	360	12994	28646	16500	56563	286809	632300	2.050	7.027	21.542	47.492
Trench 1	3197060	24	390	4719	17713	39050	12000	145210	432020	952431	2.000	24.202	45.744	100.848
Trench 2	6975840	53	60	1584	19297	42543	1200	31684	463704	1022282	0.220	5.809	51.553	113.654
Total terrace	**3942404**	23												
Total floodplain	**13056718**	77												
Total pond	**16999122**													

Notes:
(1) Annual cumulative volumes derived from data used to generate plots in Figures 3-1 through 3-15 from April 1, 2006 through March 31, 2007.
(2) Mass in kg derived = annual volume x 3.785 x average concentration x (1/1000000). Conversion to pounds = kg x 2.2046.

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4.0 Performance Summary

This report contains an assessment of the floodplain and terrace ground water remediation systems at the DOE−LM site in Shiprock, New Mexico, for the performance period of April 2006 through March 2007. This performance period marks the end of the fourth year of operation of the ground water remediation system.

- Ground water in the floodplain system is currently being extracted from two wells adjacent to the San Juan River north of the disposal cell. Two collection trenches were added to the system in 2006 to enhance extraction of contaminated ground water from the alluvial system.
- Approximately 13,000,000 gallons of ground water were extracted from the floodplain aquifer system during this performance period for a total of approximately 21,400,000 gallons extracted since March 2003.
- A significant mass of COCs is being intercepted by the remediation system that would otherwise discharge to the San Juan River. This contaminated ground water is being transported to the evaporation pond on the terrace just south of the disposal cell.
- Relative to baseline conditions, levels of some COCs in ground water in the floodplain aquifer appear to be decreasing, although there is a certain amount of periodic variation in concentrations of constituents that is not necessarily indicative of the overall longer-term trend. Concentrations of constituents in ground water in the floodplain alluvium are affected by seasonal changes in climate, river stage influence, discharge of ground water from the artesian well that flows into Bob Lee Wash and then onto the floodplain, and pumping rates of the extraction wells.
- Concentrations of nitrate and uranium in surface water in the San Juan River adjacent to the site have remained below background benchmark levels during this performance period.
- Ground water in the terrace system is currently being extracted from nine wells, two drainage trenches in Bob Lee Wash and Many Devils Wash, and a seep collection sump.
- Approximately 3,900,000 gallons of ground water were extracted from the terrace system during this performance period for a total of approximately 15,100,000 gallons extracted since March 2003.
- The estimated dissolved masses of sulfate, nitrate, and uranium removed from the floodplain and terrace well fields were 1,022,282 pounds, 42,543 pounds, and 114 pounds, respectively.

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5.0 Recommendations

The following recommendations are provided to help improve the performance and evaluation of the Shiprock remediation system:

- The floodplain extraction system appears to be functioning as anticipated. The addition of the two trenches at the base of the escarpment enhances removal of contaminant mass from ground water in the alluvium. No additions to the floodplain system are deemed necessary at this time.
- The terrace extraction system is operating adequately and water levels are gradually declining over time. No additions to this system are recommended at this time.
- As the pumping capability of the remediation system increases, it will become more important to monitor the fluid level in the evaporation pond. The pond depth is currently monitored by SOARS.
- The performance of the terrace remedial action is currently tied to the reduction of flow from seeps 0425 and 0426 (which are now part of the remediation system) and from other seeps on the terrace, some of which are currently dry. Discharge from these seeps will continue to be monitored and included as part of the annual performance evaluation. Given the temporal variability in hydrologic conditions at the site, long-term trends in annual combined flow rates from the seeps may be discernible.

End of current text

6.0 References

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