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UMTRA Ground Water Project

Baseline Performance Report for the Shiprock, New Mexico, UMTRA Project Site

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Prepared by
U.S. Department of Energy
Grand Junction Office
Grand Junction, Colorado

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Foreward

This document describes baseline hydrogeologic conditions for the Shiprock site prior to startup of the site remediation system. The terrace remediation system began operation in February 2003, and the floodplain remediation system became operational in March 2003. While the ground water elevation and contaminant concentration data presented in this report are considered representative of baseline conditions, the hydraulic and transport processes that have led to these data and, consequently, the site hydrogeologic conceptual model, are only partly understood. Much of the uncertainty regarding the conceptual model derives from a discrepancy between expected and actual extraction well production during the past 6 months.

A component of the conceptual model as described in the Shiprock Site Observational Work Plan and the Ground Water Compliance Action Plan is a swale in the underlying Mancos Shale bedrock in the south part of the terrace east area of the site. This swale, bounded abruptly to the south by a buried bedrock escarpment, was thought to have been eroded by a channel of the ancestral San Juan River. Though information collected during site investigations suggests the existence of such a feature, the limited data set indicating its presence make it very difficult to accurately define its extent and morphometry. It is possible that the swale may not have been formed by a broad ancestral river channel, but rather a series of small-scale former river channels, parallel elongated bedrock depressions, or some other unknown features dependent upon detailed topography of the bedrock surface. If limited hydraulic connection occurs between these latter types of features in comparison to the connection occurring throughout a broad former river channel, pumping rates from these features would tend to be similarly limited.

The terrace remediation system initially included four ground water extraction wells located in the south part of terrace east. After 6 months of pumping, it was apparent that ground water removal from this region of the site was not meeting expectations based on the previously developed conceptual model. Four more extraction wells were installed in August 2003 in an attempt to increase the production, and initially-limited pumping rates from them has confirmed the difficulty in removing ground water from this part of the site. Assuming extraction well efficiency is not an issue, these results suggest that the subsurface thickness of alluvium may be variable over short distances, reflecting more variation in the bedrock topography than previously thought.

There is also significant amount of uncertainty regarding the ground water flow path between the saturated alluvium in the south part of terrace east and two seeps located at the base of the escarpment (0425 and 0426). The site conceptual model indicates that withdrawing water from the south part of the terrace would over time ultimately reduce the volume of water feeding the seeps. While this represents one potential scenario, other possibilities exist. The apparent source of water in the seeps is ground water contained within Mancos Shale bedrock, which is the same bedrock underlying the south part of the terrace. While there is evidence of a hydraulic connection between terrace alluvial material and the underlying Mancos in some areas of the site, a direct hydrologic connection between the south part of terrace east and the seeps (a distance of over 4,000 feet) has not been confirmed.

Removal of ground water from the floodplain has also proven to be more difficult than expected based on the site conceptual model. An aquifer test in one region of the floodplain (just west of the San Juan River) sustained over 50 gallons per minute (gpm); however, shorter-term tests completed in May 2003 using other wells installed during the same drilling event have sustained considerably lower pumping rates (pumping rates at two wells located near the center of the floodplain varied from 2 to 10 gpm).

Even with uncertainties associated with ground water pumping, both on the terrace and floodplain, additional effort will be expended to evaluate and reduce ground water contaminant migration from the terrace to the floodplain. This will reduce exposure risks to humans and wildlife where contaminated ground water surfaces and to aquatic life along the San Juan River. During this process, more information will become available regarding site hydrogeologic conditions. This information will be incorporated into the site conceptual model. Subsequent semiannual performance reports on the remediation system may provide site conceptual model updates when appropriate.

1.0 Introduction

Ground water at the Shiprock, New Mexico, Uranium Mill Tailings Remedial Action (UMTRA) Project site has been contaminated as a result of uranium-vanadium milling activities from 1954 to 1968. The Shiprock site is on Navajo Nation land in San Juan County, in the northwest corner of New Mexico (Figure 1). Located south of the San Juan River about one mile south of the center of the town of Shiprock, the site includes a floodplain area and a terrace area. An escarpment approximately 50 to 60 feet (ft) high separates the elevated terrace from the river floodplain.

Sitting on the terrace, just east of the former milling area, is the 76-acre UMTRA disposal cell. The cell, completed in 1986, encapsulates two former tailings piles at this location and other surface and near-surface radiologically contaminated soil that was collected during cleanup of the site. Ground water contamination remained on the site around the former millsite area and disposal cell, both in the floodplain and on the terrace. Characterization of the nature and extent of this contamination consisted of several phases extending from the early 1990s to 2000, culminating in the Final Site Observational Work Plan (SOWP) that was completed in late 2000 (DOE 2000). The millsite-related contaminants of concern (COCs) in ground water at the site are ammonium, manganese, nitrate, selenium, strontium, sulfate, and uranium.

The Final Ground Water Compliance Action Plan (GCAP) describes the ground water compliance strategies at the site for remediation of COCs attributable to milling activities (DOE 2002). To comply with the compliance strategies for the terrace and floodplain areas of the site, a remediation system was constructed in late 2002 and early 2003. The system infrastructure for the terrace, shown in Figure 1, consists of four ground water extraction wells and ground water interceptor drains in Bob Lee and Many Devils Washes. The system for the floodplain consists of two ground water extraction wells close to the San Juan River (Figure 1). Ground water removed by the extraction wells and collected in the interceptor drains is pumped through pipelines to an 11-acre pond on the terrace just south of the disposal cell where it is evaporated. The remediation system began full operation in March 2003.

1.1 Objectives and Scope

One objective of this report is to establish baseline (prior to remediation) hydrologic conditions for the areas in the floodplain and terrace that will be affected by ground water remediation activities. Another report objective is to establish performance metrics that will be used to gauge the effectiveness of the remediation system. Performance reports will be prepared semiannually using these metrics to assess how well the remediation system is working.

The scope of this report includes the following:

1. Site hydrogeologic conditions and hydrogeologic complexities/uncertainties in Sections 1.2 and 1.3, respectively
2. Compliance strategies for the terrace ground water system and the floodplain ground water system in Section 2.0
3. Terrace ground water baseline conditions (including flow gradients, water levels, and water volume), remediation system design, and performance metrics in Section 3.0

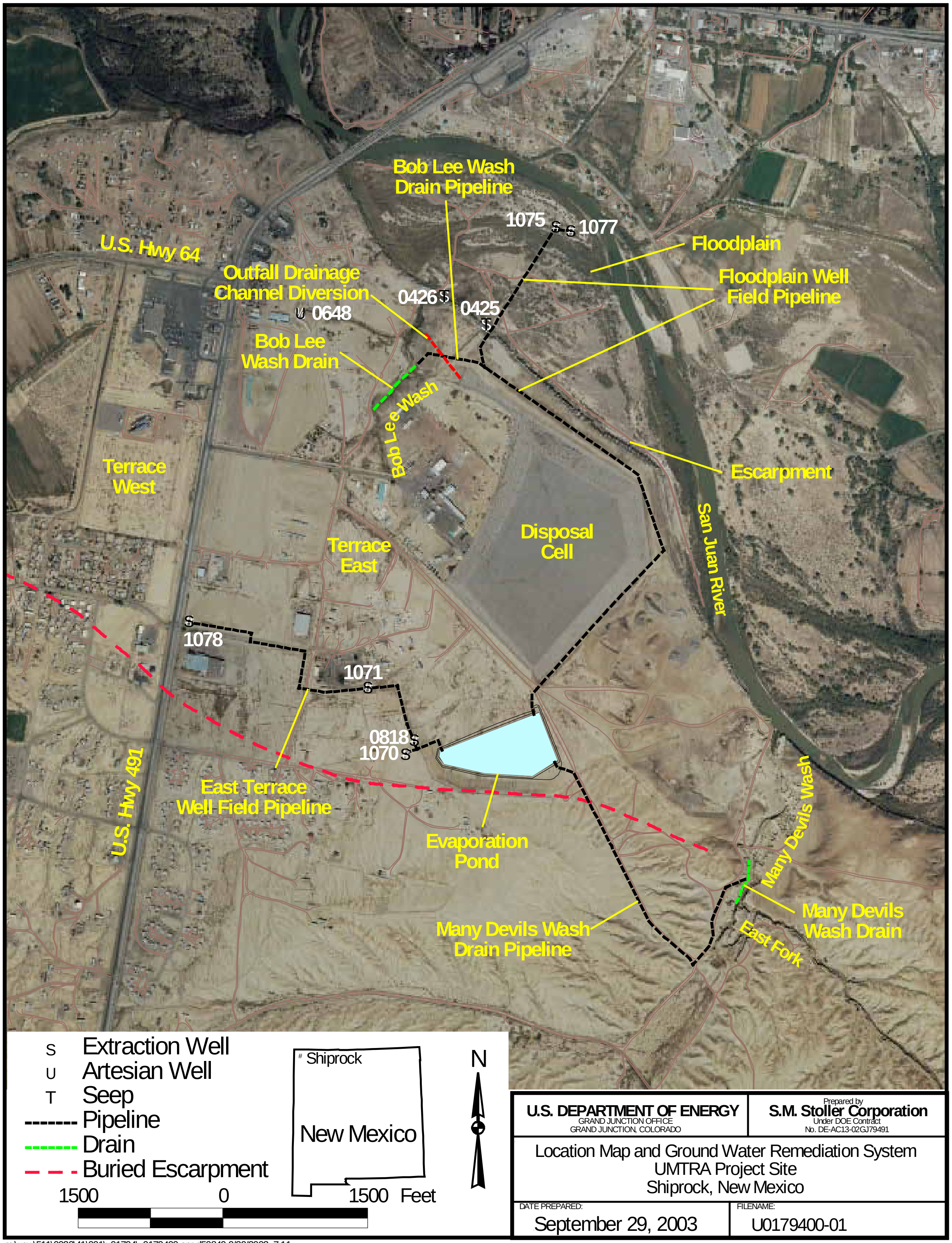

Figure 1. Location Map

4. Floodplain ground water baseline conditions (including flow gradients, volume estimates, and contaminant concentrations), remediation system design, and performance metrics in Section 4.0

1.2 Site Hydrogeologic Conditions

1.2.1 Floodplain Aquifer

The thick Mancos Shale of Cretaceous age forms the bedrock underlying the entire site. Floodplain ground water (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 contributes water to the floodplain in some areas, and receives ground water discharges in others. The floodplain aquifer also receives inflow from an artificial ground water system in the terrace area created during milling activities. 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 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 two floodplain extraction wells (Figure 1). 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 uncontaminated surface water from Bob Lee Wash discharges into the floodplain, recharging local ground water and then flowing to the north and west. Water that enters the floodplain from Bob Lee Wash consists mainly of deep nonpotable ground water from flowing (65 gallons per minute) artesian well 0648 (Figure 1) that 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 about 1 mile upriver from the site.

1.2.2 Terrace Ground Water System

The terrace ground water system occurs mainly 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, typically 10 to 20 ft thick, and caps the Mancos Shale. Though less well known, 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 alluvial ground water system extends southwestward from the escarpment for up to 1 mile where it is abruptly bounded by a buried escarpment (Figure 1). Terrace alluvial material is exposed at the escarpment edge, but southwestward from there it is covered by an increasing thickness of silt, which was deposited by wind as 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. The east end of the terrace alluvial ground water system is just east of the evaporation pond where terrace gravel has been removed during former gravel pit operations.

Mancos Shale in the terrace area is weathered (fractured and soft) for up to several feet below its contact with alluvium. Ground water is known to occur in the weathered shale, and may flow through deeper portions of the shale that might be fractured. Jointing (fracturing) is common in weathered Mancos Shale exposed along the escarpment; the principal joint strike direction is northeast (DOE 2000).

Just north of the buried escarpment that forms the south boundary of the terrace alluvium, bedrock data indicate the existence of a west-trending elongate swale cut by one or more channels of the ancestral San Juan River. The apparent north boundary of this bedrock swale is a subtle west-striking bedrock ridge. Much uncertainty exists regarding the configuration of the bedrock swale, particularly its extent, morphometry, and ability of alluvial material overlying the bedrock to yield ground water to pumping. In the Shiprock SOWP (DOE 2000) and GCAP (DOE 2002), this bedrock swale feature was referred to as a sump because it was believed that elevated bedrock near U.S. Highway 491 impeded ground water stored east of it from flowing west. Recently, questions have been raised regarding the areal extent of the feature because pumping from wells screened in the local alluvium overlying bedrock have repeatedly produced much less water than was expected from an areally extensive subsurface ground water system. This in turn has raised the possibility that the subsurface here does not actually comprise a large, wide, laterally continuous ancestral channel filled with river deposits, but rather a series of much smaller features, such as short-length bedrock depressions with limited hydraulic connection between them. Regardless of the subsurface topography and spatial distribution of permeable alluvium (up to 7 ft of saturation – greatest thickness in the terrace ground water system) in this area, the swale area in this report is simply referred to as the south part of the terrace east area. Future investigations of the site will result in a better understanding of this area and a more accurate description of the occurrences of ground water.

In earlier documents, the terrace was divided into two areas referred to as terrace east and terrace west. The approximate boundary between the two areas was a line lying just east of U.S. Highway 491. This line was defined on the basis of ground water modeling of the site. At that time, it was believed that pumping in the previously mentioned area of the bedrock swale area for a period of 5 to 7 years would create a ground water divide just east of the highway. In other words, the line indicated where ground water from the east part of the terrace would no longer flow to the west part of the terrace. Based on the present understanding of the south part of the terrace east area and information from four extraction wells east of U.S. Highway 491, the boundary between terrace east and terrace west is arbitrarily placed along U.S. Highway 491.

Ground water is present in parts of the terrace system other than in the south part of terrace east, but the saturated thickness of alluvial material in these other areas is less. The ground water surface drops down into the Mancos Shale in parts of these other terrace areas such as around the disposal cell and in the areas of Bob Lee and Many Devils Washes. Discharges to these washes are expressions of ground water that has traveled through weathered portions of Mancos Shale, and possibly along fractures or bedding features in the shale.

Water that emerges from the escarpment between the terrace and floodplain at Seeps 0425 and 0426 (Figure 1) is an expression of ground water that has traveled northward from the former milling area through the Mancos Shale. The water feeding the seeps may be in part from water that pooled at the toe of the outfall channel of the disposal cell. A drainage channel diversion was constructed to facilitate drainage of this outfall (Figure 1) and to expedite flow of surface water from storm events into lower Bob Lee Wash. Ground water that flows southeastward to Many Devils Wash from the south part of the terrace east area moves down into the Mancos Shale and likely flows on top of a thin, resistant, east-dipping, calcareous siltstone bed in the Mancos Shale. This siltstone bed occurs throughout the east part of the site and crops out as a knickpoint in Many Devils Wash. Most ground water that reaches Many Devils Wash is believed to have traveled downdip along this siltstone bed and, at or near the wash, the water finds additional pathways downward along fractures and joints to seepage points along the wash.

No ground water has been found in the terrace system east of the Many Devils Wash area. Terrace materials about 2 miles east of the site that are geologically equivalent to both terrace alluvial material and underlying Mancos Shale are also dry. This lack of background ground water and the dryness indicated for the terrace area by early aerial photos before milling operations implies that the site terrace ground water system is artificial or anthropogenic. Process water from the milling area, disposal cell construction, and raffinate ponds is believed to have created the terrace ground water system. Water from these sources moved radially away to the locations on the terrace where ground water presently occurs. Besides the locations already discussed in terrace east, ground water has moved west of U.S. Highway 491 into the terrace west area where several wells contain millsite-related ground water contamination. Contaminant levels decrease westward, particularly in the part of terrace west that has been irrigated by the Helium Lateral Canal system. Elevated levels of some constituents, particularly selenium, sulfate, and uranium in the west and north parts of the terrace west area, are thought to be partly attributable to natural occurrences of these constituents in Mancos Shale. Ground water, slightly contaminated by milling constituents, comes to the surface in the northwest part of terrace west in several small drainages and in seeps near the San Juan River floodplain.

1.3 Terrace Hydrogeologic Complexities/Uncertainties

Ground water flow in the terrace ground water system is not completely understood due to several geologic uncertainties. Though characterization efforts have identified the main elements of the system, uncertainties include:

1. The exact position of the buried escarpment forming the south boundary of the bedrock swale on the terrace is not known in several areas, particularly in terrace west.
2. The configuration of the bedrock swale in the south part of terrace east is based upon the limited available data associated with that area of the site. Updates to the conceptual model may include a paleofeature with a significantly different configuration.
3. Top of bedrock in the south part of the terrace east area is known only in a limited number of locales containing deep wells.
4. The amount of water leaking from sewer and water lines on the terrace (and contributing to terrace ground water) is incompletely known; continued monitoring and observations will likely identify additional leaks.
5. The contribution of water to the terrace ground water system from the disposal cell is incompletely understood; continued monitoring will improve quantification of this contribution.
6. Estimates of the amount of ground water flowing from the terrace to the floodplain can be improved through continued monitoring.
7. Ground water flow paths to Many Devils Wash in the terrace east area are only partly understood. Ground water may flow to the wash from areas other than the south part of terrace east.
8. Ground water paths to seeps 0425 and 0426 are only partly understood. Ground water in the Mancos Shale is the apparent water source for the seeps, but it is unclear how the water migrates from the terrace alluvium to the Mancos Shale and ultimately to the seeps.

Because of these uncertainties, the reader is cautioned to treat implied projections of terrace ground water system behavior presented in this report as preliminary estimates.

2.0 Compliance Strategies

2.1 Terrace Ground Water System

As previously mentioned, terrace west ground water represents the distal part of more contaminated ground water in terrace east. Current remediation on the terrace is focused on terrace east; removal of ground water from terrace east should ultimately decrease ground water contaminant concentrations in terrace west.

The compliance strategy for terrace west ground water is application of supplemental standards with monitoring. Terrace west ground water qualifies as limited use water based on the existence of widespread ambient contamination (particularly in Mancos Shale underlying the western half of terrace west) not related to milling activities; this ground water cannot be cleaned up using treatment methods normally applied in public water systems. The monitoring plan in the GCAP (DOE 2002) calls for measurement of water levels and sampling for water quality in wells in terrace west immediately west of U.S. Highway 491. The water level measurements will be used to evaluate the effectiveness of water extraction in terrace east, and the water quality sampling will detect contaminant movement westward and the anticipated decrease in contaminant concentrations through time.

The objective of remediation in terrace east is to remove ground water from the south part of the system so that current exposure pathways at seeps and at Bob Lee and Many Devils Washes are eventually eliminated and flow of ground water from the terrace to the floodplain is reduced. The compliance strategy for terrace east ground water is active remediation until potential risks to human health and the environment have been eliminated. This strategy of removing anthropogenic ground water to eliminate surface exposure (thereby eliminating risks to human health and the environment) voids the application of cleanup standards such as maximum concentration limits (MCLs). Previous modeling results indicate that, after extracting ground water in the south part of terrace east for approximately 7 years, ground water levels will be drawn to such low levels that ground water flow to terrace west will no longer occur (DOE 2000).

Elements of the remediation system for terrace east include four extraction wells and interceptor drains along the upper parts of Bob Lee and Many Devils Washes (Figure 1). Several additional extraction wells are planned to be installed in the south part of terrace east area to better optimize ground water recovery. The removal of anthropogenic ground water by the wells and interceptor drains is expected to assist in drying the seeps and curtail surface expression of ground water in the washes. All water from the extraction wells and water collected in the sump at each interceptor drain in the washes is piped to an 11-acre pond east of the extraction wells where it is evaporated.

2.2 Floodplain Ground Water System

The objective of remediation in the floodplain is to remove contaminated ground water from the contaminant plume before it discharges to the San Juan River, thereby alleviating exposure risk for aquatic life. The compliance strategy for the floodplain aquifer is natural flushing supplemented by removal of ground water from two extraction wells in the contaminant plume where it is close to the San Juan River (Figure 1). The ground water extraction is considered a best management practice. Pumping of ground water may continue for up to 20 years, as needed, to reduce contaminant concentrations to acceptable levels.

The COCs for human health in the floodplain aquifer are ammonium, manganese, nitrate, selenium, strontium, sulfate, and uranium. Compliance standards for uranium and nitrate are their UMTRA standards of 0.044 and 44 milligrams per liter (mg/L), respectively. The cleanup objective for manganese is the maximum background concentration, which is currently 2.74 mg/L. No cleanup standards or background concentrations have been established for ammonium and strontium.

For sulfate, a secondary standard of 250 mg/L 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 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 the presence of high background sulfate concentrations (up to 1,920 mg/L) at the site and the high sulfate concentration (up to 2,340 mg/L) of water entering the floodplain from flowing artesian well 0648, the proposed cleanup goal for floodplain sulfate is 2,000 mg/L.

Relatively high selenium concentrations in the floodplain make it unlikely that the UMTRA standard of 0.01 mg/L for this constituent can be met. An alternate concentration limit of 0.05 mg/L is proposed for selenium, which is a MCL established by EPA.

3.0 Baseline Ground Water Conditions in the Terrace

This section describes the ground water flow system of both terrace west and terrace east at the Shiprock site. The majority of the discussion is focused on ground water flow gradients and water levels for the terrace (Section 3.1), terrace east ground water volumes (Section 3.2), the terrace ground water remediation system (Section 3.3), and remediation system performance metrics (Section 3.4).

3.1 Terrace East and Terrace West Horizontal Ground Water Flow Gradients

Historical water levels and data logger information indicate the ground water surface of the terrace ground water system does not fluctuate seasonally. The baseline ground water surface contour map (Figure 2), as generated from primarily March 2003 data presented in Table 1, indicates that subsurface water in terrace west flows toward the northwest. The ground water flow direction in terrace east ranges from northwest (in the south part of terrace east) to northeast.

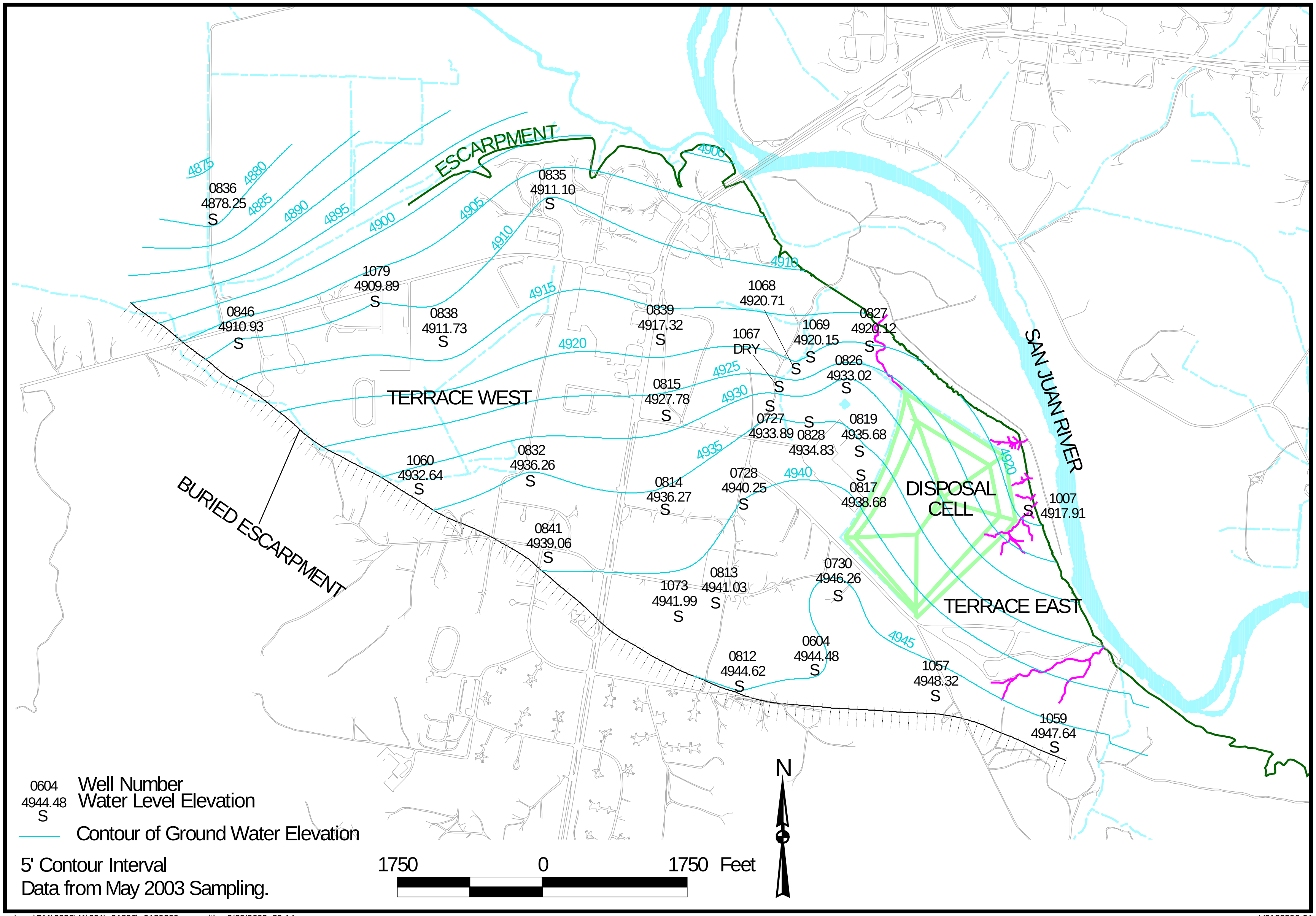

Figure 2. Terrace Ground Water Surface Contour Map

Table 1. Water Level Data Used to Generate the Terrace Ground Water Surface Contour Map

Well	Zone of Completion	Baseline Ground Water Elevation (ft msl)	Date of Baseline Measurement
0604	Mancos	4,944.48	3/3/03
0727	Mancos	4,933.89	3/5/03
0728*	Alluvium / Mancos	4940.25	3/4/03
0730	Alluvium / Mancos	4946.26	3/5/03
0812*	Alluvium / Mancos	4,944.62	3/5/03
0813*	Alluvium / Mancos	4,941.03	3/4/03
0814*	Alluvium / Mancos	4,936.27	3/5/03
0815*	Alluvium / Mancos	4,927.78	3/4/03
0817*	Mancos	4,938.68	3/4/03
0819*	Mancos	4,935.68	3/4/03
0826*	Alluvium / Mancos	4,933.02	3/4/03
0827	Alluvium / Mancos	4,920.12	3/5/03
0828*	Alluvium / Mancos	4,934.83	3/4/03
0832*	Alluvium / Mancos	4,936.26	3/4/03
0835*	Alluvium	4,911.10	3/5/03
0836*	Alluvium	4,878.25	3/4/03
0838*	Alluvium	4,911.73	3/4/03
0839*	Alluvium / Mancos	4,917.32	3/5/03
0841*	Alluvium	4,939.06	3/4/03
0846*	Alluvium / Mancos	4,910.93	3/4/03
1007*	Alluvium / Mancos	4,917.91	3/3/03
1057*	Alluvium	4,948.32	3/5/03
1059*	Mancos	4,947.64	3/4/03
1060*	Alluvium / Mancos	4,932.64	3/4/03
1067*	Alluvium / Mancos	Dry	3/5/03
1068*	Alluvium / Mancos	4,920.71	3/5/03
1069*	Alluvium / Mancos	4,920.15	3/5/03
1073	Alluvium	4,941.99	9/17/02
1079*	Alluvium	4,909.89	3/4/03

Notes: *designates a well included in the long-term monitoring plan.
Mancos – Well screened within the Mancos Shale
Alluvium – Well screened within the alluvium
Alluvium/Mancos – Well screened across the alluvium – Mancos Shale contact
ft msl is feet above mean sea level

Ground water elevation data for the terrace have historically been collected during the February/March and September/October timeframes. The majority of the data presented in Table 1 were collected during the March 2003 sampling period. An additional water level collected in September 2002 (well 1073) was used to supplement the data set and provide a more extensive ground water surface contour map. Table 1 also lists the wells that will be measured in the future according to the long-term monitoring plan in the GCAP (DOE 2002).

Horizontal gradient vectors under recent conditions were calculated for the terrace using three-point analyses. This was accomplished using V3PP, a computer code developed by Laase et al. (2002) that provides graphical representation of the computed vectors. Figure 3 presents the results of the three-point analyses. In general, the vectors indicate horizontal flow directions that are similar to those discerned from the ground water surface contour map (Figure 2). However,

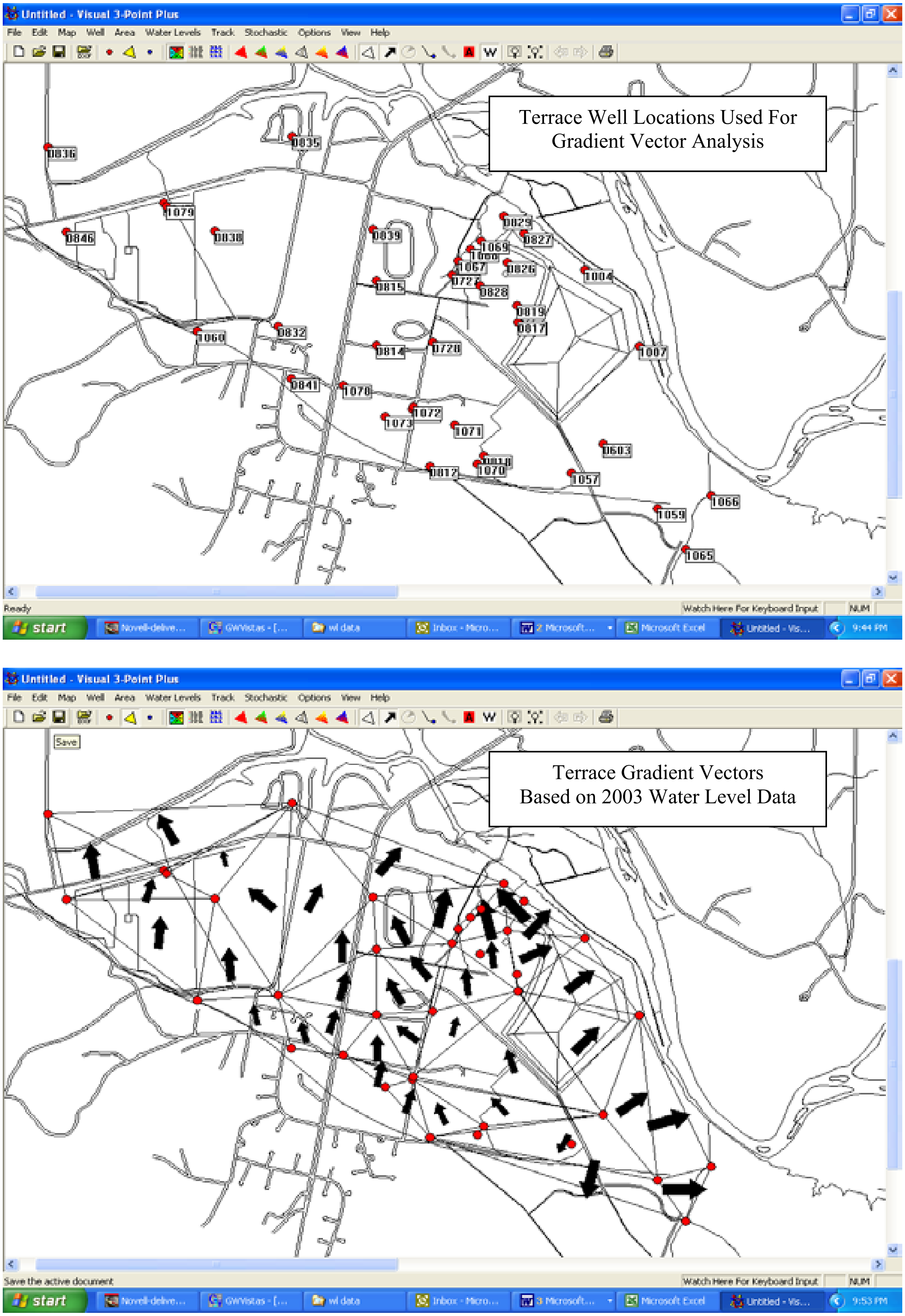

Figure 3. Three-Point Analysis of the Terrace Ground Water Surface

two vectors indicating southward flow toward the buried escarpment near the southeast corner are likely erroneous. These latter vectors appear to result from anomalous data.

3.1.1 Historical Ground Water Elevation Trends

Terrace east ground water is conceptualized as comprising an anthropogenic ground water system created by milling. Consequently, water levels have probably declined here since the termination of milling and will continue to decline in the future. Baseline water level measurements should serve as a basis to indicate future declining water levels.

To examine the hypothesis that terrace water levels are naturally declining, a linear regression analysis was conducted using historical ground water elevation data for a number of wells in the terrace east area. This analysis, in Appendix A, indicates that water levels have decreased in a majority of the wells.

3.2 Terrace East Ground Water Volumes

In the SOWP (2000), the volume of ground water in alluvial material overlying the broad bedrock swale in the south part of terrace east was estimated as 38 million gallons. Ground water in alluvial material is spread more widely over the terrace east area than just in the bedrock swale area. Estimates of ground water volume in alluvium over the entire area of terrace east (the terrace area east of U.S. Highway 491) are considerably higher than the estimated volume in the SOWP. Using a porosity of 30 percent, the volume of ground water for each foot of saturated thickness of alluvial material in the terrace east area is approximately 56 million gallons.

3.3 Terrace Ground Water Remediation System

The Shiprock remediation system consists of five main components, four of which are associated with the terrace: the terrace drain system (Bob Lee and Many Devils Washes), the terrace outfall drainage channel diversion, the terrace extraction well system, and the evaporation pond (Figure 1). Brief descriptions of each of these four components are presented in the following sections. A more detailed discussion of the system is presented in the Shiprock GCAP (DOE 2002).

3.3.1 Terrace Drain System

The terrace remedial system is designed to collect seepage along Bob Lee and Many Devils Washes using subsurface interceptor drains. These drains, which consist of perforated pipe surrounded by drain rock and are lined with impermeable geomembrane and geotextile filter fabric, are offset from the centerline of each wash to minimize infiltration of surface water.

Water collected in the Bob Lee Wash drain flows northward along the wash to a sump. Water collected by this sump is pumped northward to intersect the pipeline carrying water from the floodplain wells. This water is transported east and south to the evaporation pond. The drain in Many Devils Wash discharges to a sump, and this water is transported through a pipeline to the evaporation pond (Section 3.3.4).

3.3.2 Terrace Outfall Drainage Channel Diversion

During infrequent high-intensity rainfall events, surface water shed from the disposal cell has historically drained northwest to a rock-lined dissipation area, eventually reaching upper Bob Lee Wash. In some instances the water has become ponded in the rock-lined dissipation area, and this water potentially recharged the aquifer and fed the escarpment seeps.

The outfall drainage channel diversion has been re-designed to better drain surface water from the dissipation area and convey it northwest to the lower part of Bob Lee Wash. It is located such that it will not interfere with the interceptor drain in upper Bob Lee Wash.

3.3.3 Terrace Extraction System

Three wells installed for ground water extraction (1070, 1071, and 1078) along with converted monitor well 0818 comprise the terrace extraction system (Figure 1). Each of the wells, (whose total depths range from 40 to 60 ft below ground surface [bgs]) is located in the south part of the terrace east area. Saturated thickness in the wells ranges from 3 to 7 ft. Ground water extracted from these wells is collected in a pipeline and transported eastward to the evaporation pond.

3.3.4 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). This pond, with a surface area of approximately 11 acres, has a geosynthetic liner underlain by a compacted soil base.

The amount of water that can be evaporated in the pond was calculated by determining the annual net evaporation rate at the site, taking into account such factors as pan evaporation rates corrected for pan effects, salinity, and natural precipitation. Assuming an average reliability of 95 percent for the extraction system, a pond with an area of 11 acres and a depth of approximately 10 ft can treat a total influent rate of up to 25 gallons per minute (gpm) for up to 7 years, or up to 20 gpm for 40 years.

3.4 Terrace Remediation System Performance Metrics

The main objective of the terrace remediation system is to lower the alluvial ground water surface such that its contributions of water to the escarpment seeps and to Many Devils and Bob Lee Washes are effectively removed. To determine the effectiveness of the remedial system, semiannual water levels, seep flow rate data, and drain flow rate data will be compared to the following performance metrics.

3.4.1 Terrace Ground Water Elevation Trends

Ground water elevations over terrace east and terrace west are expected to decline over time. Assuming a constant rate of ground water withdrawal, the rate of water level decrease is expected to be gradual at first and to increase as pumping continues. Subsequent elevation data will be compared to the data presented in Table 1 to discern ground water elevation trends across the terrace.

3.4.2 Seep Flow Rate Comparison

Because one of the purposes of the terrace remediation system is to potentially reduce flows along the escarpment seeps, discharges measured during recent years are documented in this baseline evaluation. Table 2 presents historical ground water flow rates for seeps 0425 and 0426 (locations shown on Figure 1) prior to the initiation of the extraction system.

Table 2. Seep Flow Rate Data

Date	Seep 0425 (gpm)	Seep 0426 (gpm)
January 1991	0.25−0.5	1.0
June 1998	2 to 2.5	0.08
June 2000	1.5	0.13
March 2002	0.5−0.7	0.25−0.5
October 2002	0.8	2.1
February 2003	0.4	1.25
March 2003	0.5	1.8

The table shows a change in seep flow trends after June 2000. Seep 0425 had flow rates higher than seep 0426 from June 1998 to June 2000. After March 2002, seep 0426 attained a higher flow rate than seep 0425. This latter change is believed to be the result of modifications made in the spring of 2002 to the seep collection basins to facilitate flow measurements. In this report, seep flow rate data from October 2002 through March 2003 are considered representative of the baseline conditions.

Future flows at seeps 0425 and 0426 will be compared to historical flow rates (Table 2) to determine if ground water is feeding the seeps at decreasing rates with continuation of terrace remediation.

3.4.3 Bob Lee and Many Devils Washes Drain Flow Rate Comparison

Ground water flows into the interceptor drains in Bob Lee and Many Devils Washes (which were installed in December 2002 and November 2002, respectively) will be monitored and compared with historical flows in these areas. Since their installation, flow rate data have been collected at both drains (Table 3). These data were collected prior to the installation of pumps that remove water from the drains, and exclusively represent the amount of inflow coming into the drains. Subsequent flow data collected from Bob Lee and Many Devils Washes will comprise the discharges from pumps removing water from the drains. As a consequence, the data presented in Table 3 might be of limited utility in assessing future reductions in drain collection.

Table 3. Interceptor Drain Flow (gpm) Data for Bob Lee and Many Devils Washes

Location	Date						
	1/3/03	1/8/03	1/20/03	1/31/03	2/5/03	2/7/03	2/14/03
Bob Lee Wash	14.9	9.4	9.0	8.6	8.3	5.7	7.3
Many Devils Wash	na	na	12 to 15*	na	na	0.5	0.5

Notes: * − Flows impacted by standing water above the drain and may not be representative of actual ground water flow into the drain.

na – not applicable, no data collected

During early stages of active remediation, it is expected that ground water flow to the drains will be greater than pump outflow. However, continued operation of the remedial system will likely lead to a situation where drain inflow rates are less than the rates at which pumps could remove water. Accordingly, water removal rates from Bob Lee and Many Devils Washes are expected to decrease over time.

4.0 Floodplain Ground Water Conditions

4.1 Horizontal Ground Water Flow Gradient

Ground water elevation data for the floodplain have historically been collected during the February/March and September/October timeframes. Table 4 presents water level data collected in March 2003, which represents the most recent monitoring period prior to startup of the ground water remediation system. Wells whose water levels will be measured in the future according to the long-term monitoring plan (DOE 2002) are identified in the table.

Table 4. Water Level Data Used to Generate the Floodplain Alluvial Aquifer Ground Water Surface Contour Map

Well	Ground Water Elevation (ft msl)	Date
0608*	4,887.30	3/5/2003
0614*	4,885.70	3/6/2003
0615*	4,885.24	3/6/2003
0618*	4,884.83	3/6/2003
0619*	4,885.21	3/6/2003
0734*	4,880.27	3/5/2003
0735*	4,889.22	3/5/2003
0736*	4,881.89	3/6/2003
0797	4,900.43	3/5/2003
0850	4,900.09	3/5/2003
1008*	4,883.09	3/5/2003

Notes: *designates a well included in the long-term monitoring plan.

The floodplain alluvial aquifer ground water surface contour map (Figure 4) indicates that ground water flow is generally toward the northwest. Floodplain ground water levels change seasonally with the alluvial aquifer surface reaching a maximum elevation in response to high levels of the San Juan River during spring runoff. The contours in Figure 4 suggest that the San Juan River loses water to the aquifer east of the disposal cell and receives ground water to the north of the cell.

Floodplain horizontal ground water flow directions and gradients were also examined using the V3PP program for generating gradient vectors (Figure 5). The vectors suggest that ground water flow direction varies across the floodplain. In the part of the floodplain where Bob Lee Wash (which transports water flowing from flowing artesian well 0648, see Figure 1) drains into the floodplain, the vectors indicate that ground water flows radially from the discharge point at the mouth of Bob Lee Wash toward the San Juan River.

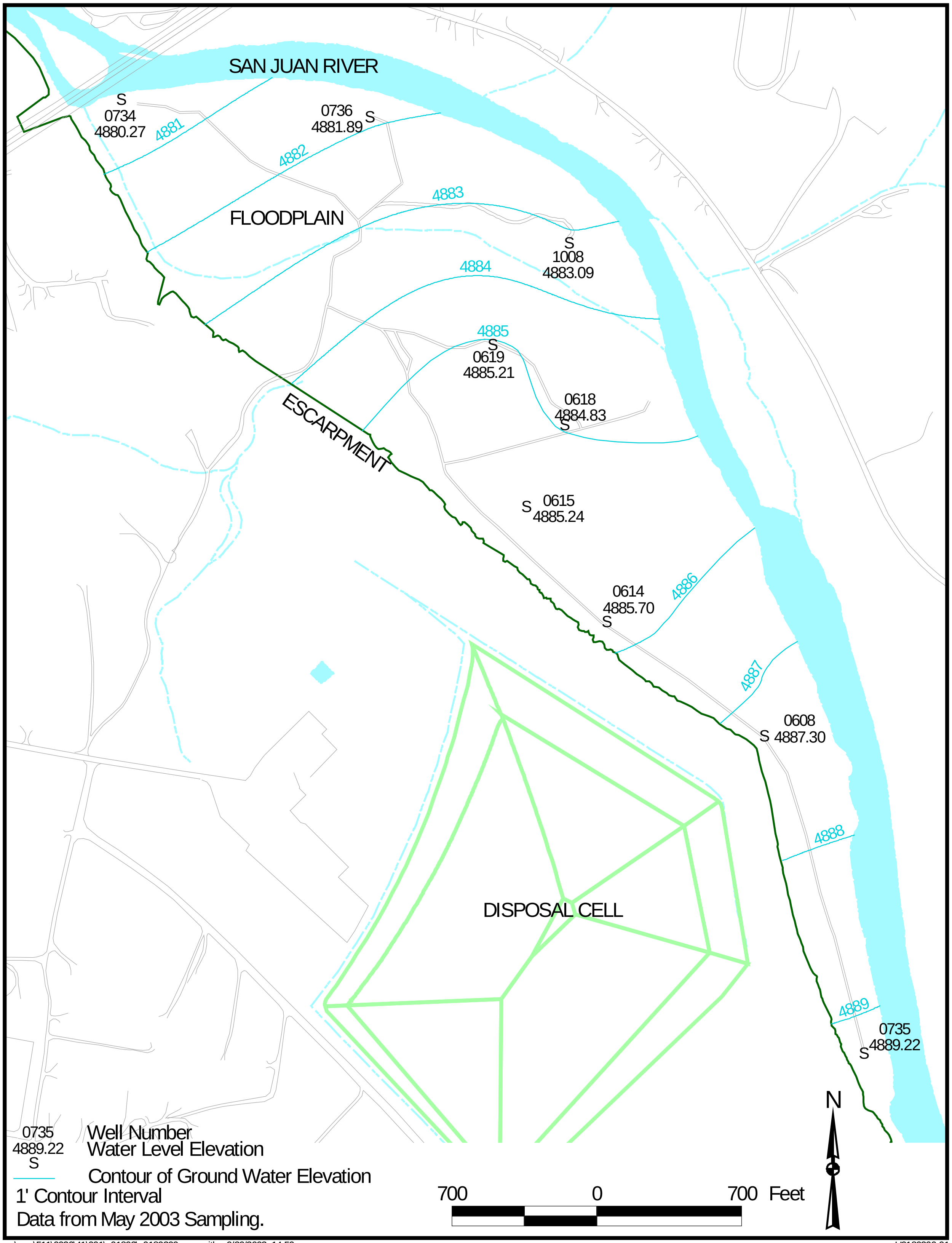

Figure 4. Floodplain Alluvial Aquifer Ground Water Surface Contour Map

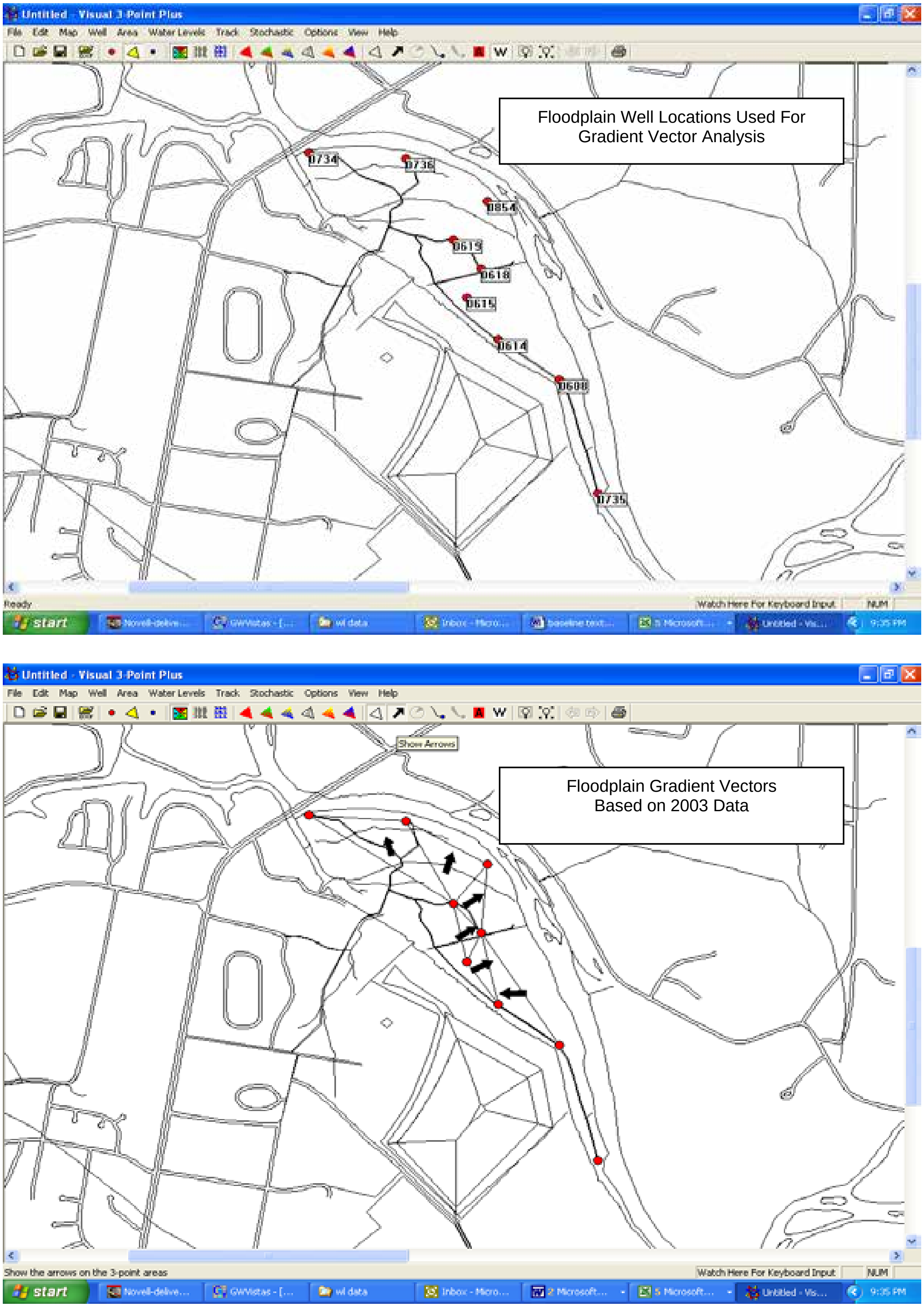

Figure 5. Three-Point Analysis of the Floodplain Alluvial Aquifer Ground Water System

4.1.1 Seasonal Fluctuations

Because of the hydraulic connection between floodplain ground water and the nearby San Juan River, ground water levels fluctuate in response to the river stage. During 2001, the San Juan River stage varied approximately 5 ft. In response to this variation, the water level in well 0857, located approximately 150 ft from the river, fluctuated 2.5 ft. The water level in well 0617, located approximately 550 ft from the river, fluctuated approximately 2 ft during the year.

4.2 Floodplain Ground Water Volume Estimate

The volume of ground water contained within the floodplain was estimated using a computer program that takes into account ground water elevations, bedrock surface data, and porosity. Ground water elevation data were translated into a Surfer (Golden Software 1996) grid file generated using 2003 water level data (Table 4). This grid file was imported into the Shiprock MODFLOW (McDonald and Harbaugh 1988) ground water model, and subsequently exported as a head file. The bedrock surface data required for estimating the water volume were obtained from the MODFLOW block-centered flow file. Assuming a porosity of 30 percent, the computed volume was 141,429,700 gallons (Figure 6).

An estimate of the floodplain ground water volume has previously been developed for the SOWP (DOE 2000), assuming an average saturated thickness, a total floodplain area, and an assumed porosity of 30 percent. This approach produced a total volume of approximately 150 million gallons, which is very close to the volume generated by this computer program.

4.3 Floodplain Ground Water Contaminants

Several dissolved contaminants occur in floodplain ground water. The primary source for the contaminants is historical mill-related activities at the site. However, the concentrations of some contaminants may be enhanced by interactions of ground water with Mancos Shale, particularly in the terrace area. The effectiveness of the floodplain remediation system will be gauged by comparing measured contaminant levels in the future with baseline concentrations of these constituents presented in this report. To provide representative baseline conditions, ground water concentration data from March 2003 (Table 5) are used. Figure 7 through Figure 13 illustrate resulting concentration distributions for the seven floodplain COCs: ammonium, manganese, nitrate, selenium, strontium, sulfate, and uranium, respectively.

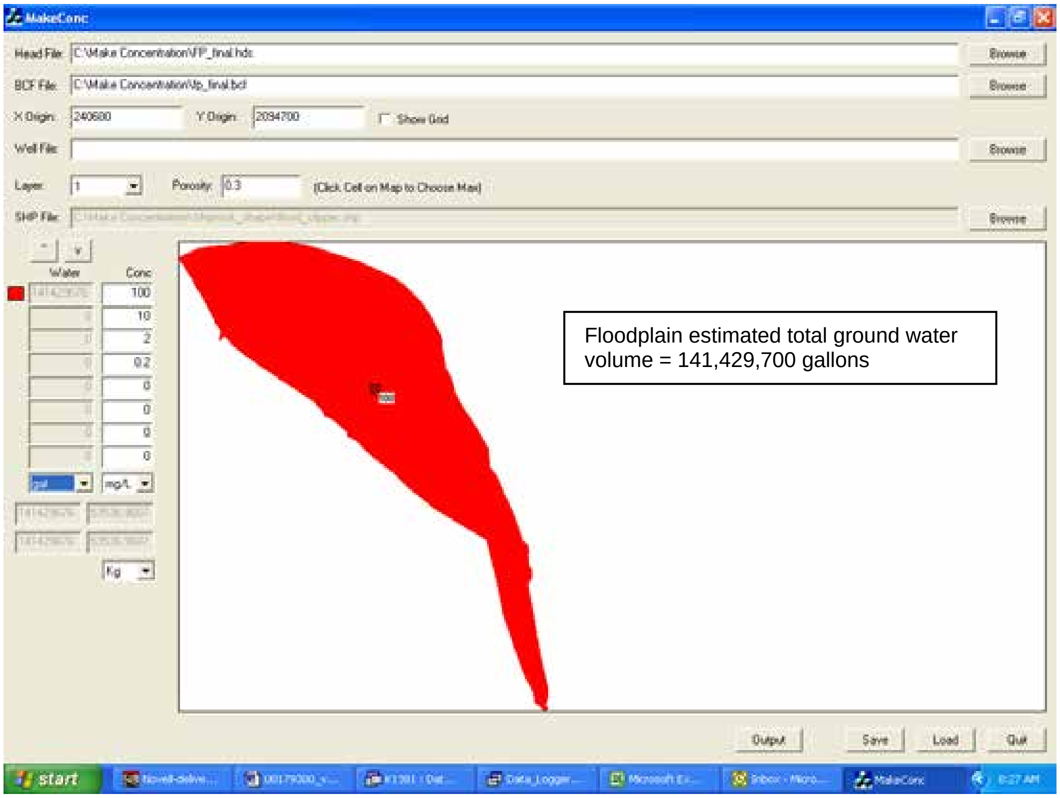

Figure 6. Floodplain Ground Water Volume Estimate

Table 5. Floodplain Ground Water Baseline Contaminant Concentrations

Well	Ammonium		Manganese		Nitrate		Selenium		Strontium		Sulfate		Uranium	
	Result mg/L	Date	Result mg/L	Date	Result mg/L	Date	Result mg/L	Date	Result mg/L	Date	Result mg/L	Date	Result mg/L	Date
0608	389	3/5/2003	7.8	3/5/2003	2320	3/5/2003	0.0065	3/5/2003	10.7	3/5/2003	10,500	3/5/2003	1.78	3/5/2003
0614	50.5	3/6/2003	6.01	3/6/2003	4240	3/6/2003	0.291	3/6/2003	13.1	3/6/2003	14,400	3/6/2003	2.43	3/6/2003
0615	51	3/6/2003	5.56	3/6/2003	4160	3/6/2003	1.16	3/6/2003	14.4	3/6/2003	19,900	3/6/2003	3.78	3/6/2003
0618	776	3/6/2003	11.3	3/6/2003	1230	3/6/2003	0.352	3/6/2003	11.2	3/6/2003	13,300	3/6/2003	3.12	3/6/2003
0619	2.9	3/6/2003	3.13	3/6/2003	21.9	3/6/2003	0.213	3/6/2003	7.32	3/6/2003	6,280	3/6/2003	0.48	3/6/2003
0734	0.004	3/5/2003	0.656	3/5/2003	7.43	3/5/2003	0.0086	3/5/2003	6.63	3/5/2003	4,940	3/5/2003	0.0735	3/5/2003
0735	14.8	3/5/2003	3.47	3/5/2003	2010	3/5/2003	0.159	3/5/2003	9.3	3/5/2003	6,980	3/5/2003	0.24	3/5/2003
0736	0.0921	3/6/2003	1.54	3/6/2003	0.0831	3/6/2003	0.0007	3/6/2003	6.79	3/6/2003	3,480	3/6/2003	0.146	3/6/2003
1008	28.6	3/5/2003	6.61	3/5/2003	172	3/5/2003	0.169	3/5/2003	10.2	3/5/2003	13,900	3/5/2003	2.05	3/5/2003
1075	20.3	3/6/2003	6.58	3/6/2003	198	3/6/2003	0.054	3/6/2003	12.1	3/6/2003	17,800	3/6/2003	2.71	3/6/2003
1077	21.3	3/6/2003	4.52	3/6/2003	304	3/6/2003	0.134	3/6/2003	10.3	3/6/2003	14,900	3/6/2003	2.05	3/6/2003

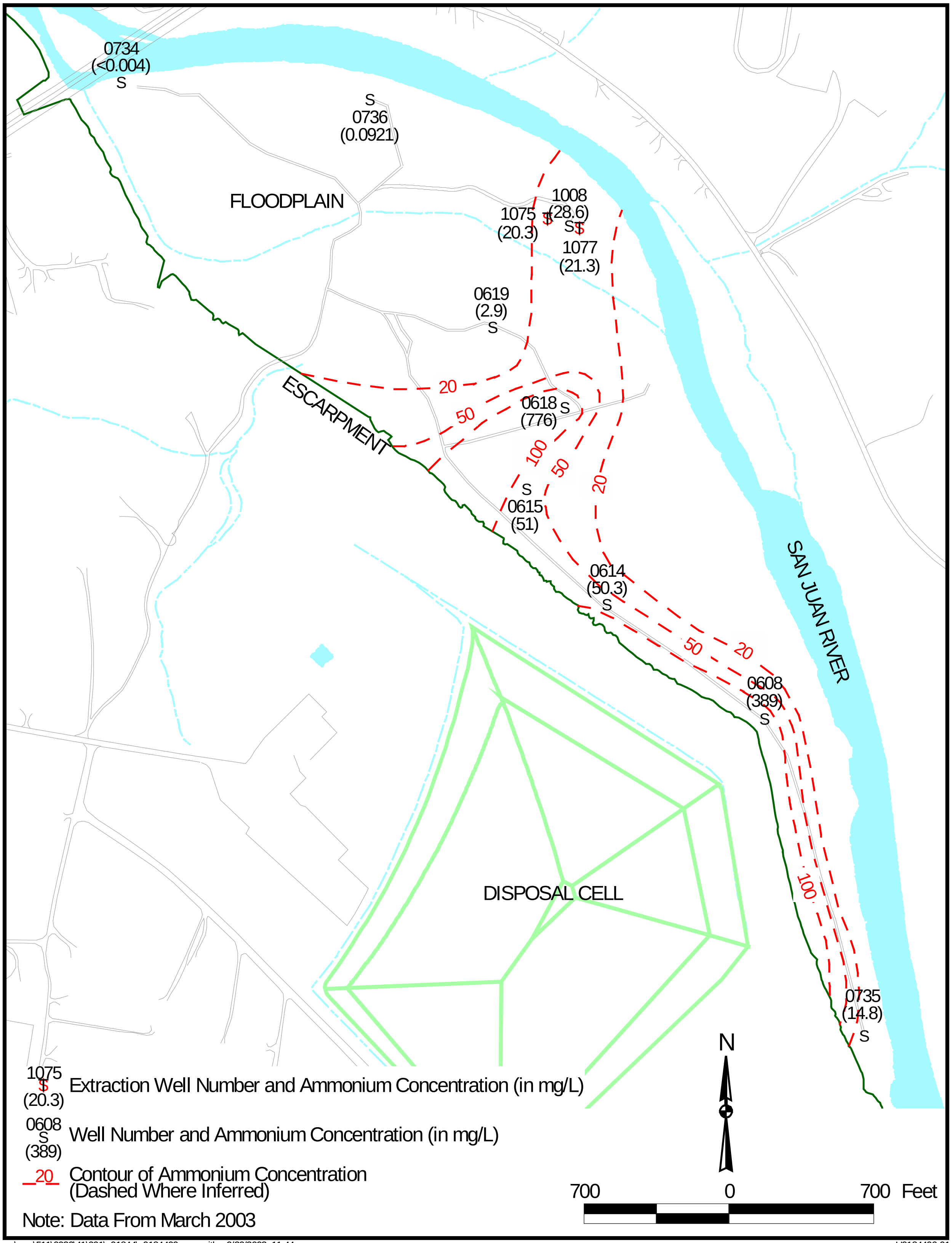

Figure 7. Floodplain Ammonium Ground Water Concentrations

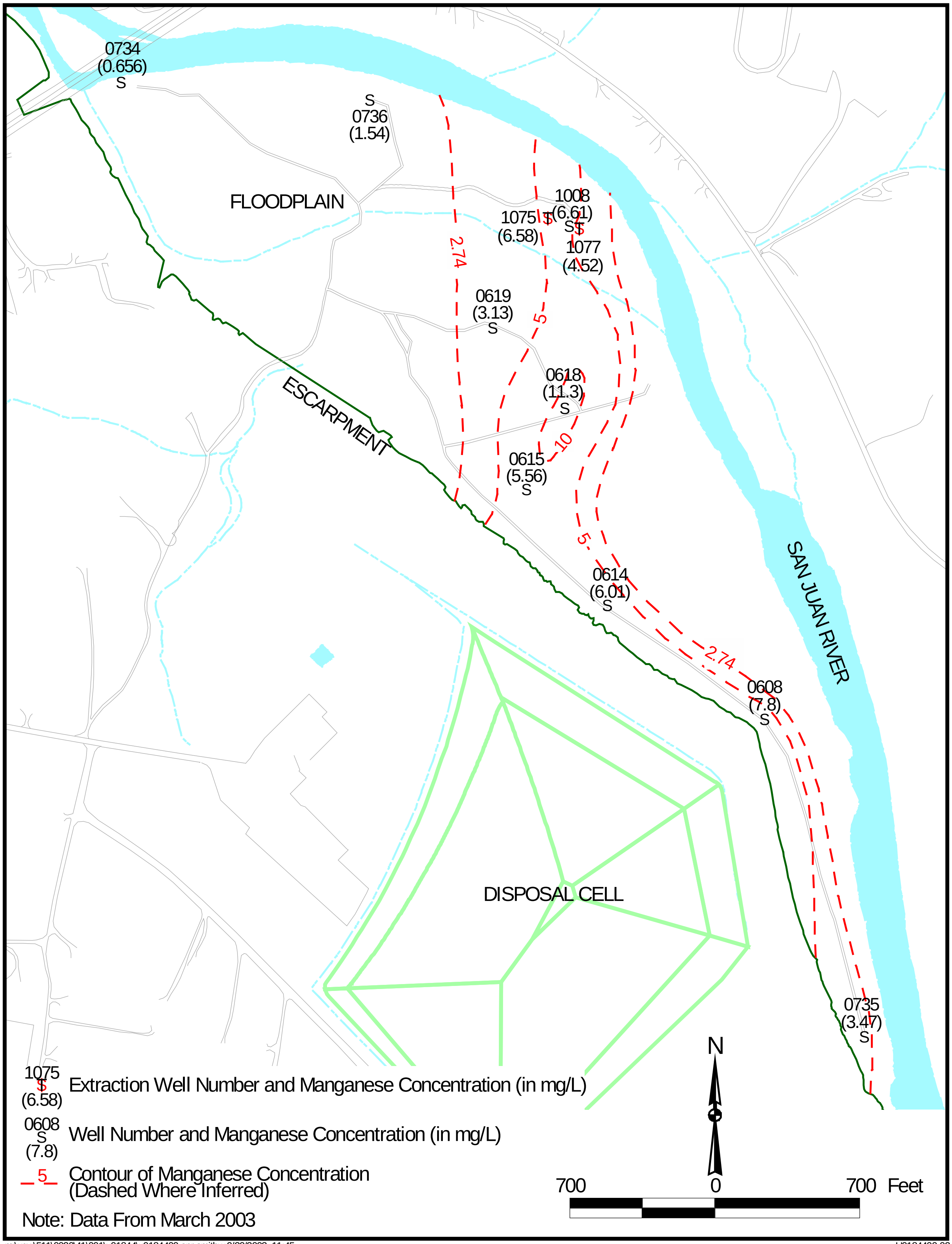

Figure 8. Floodplain Manganese Ground Water Concentrations

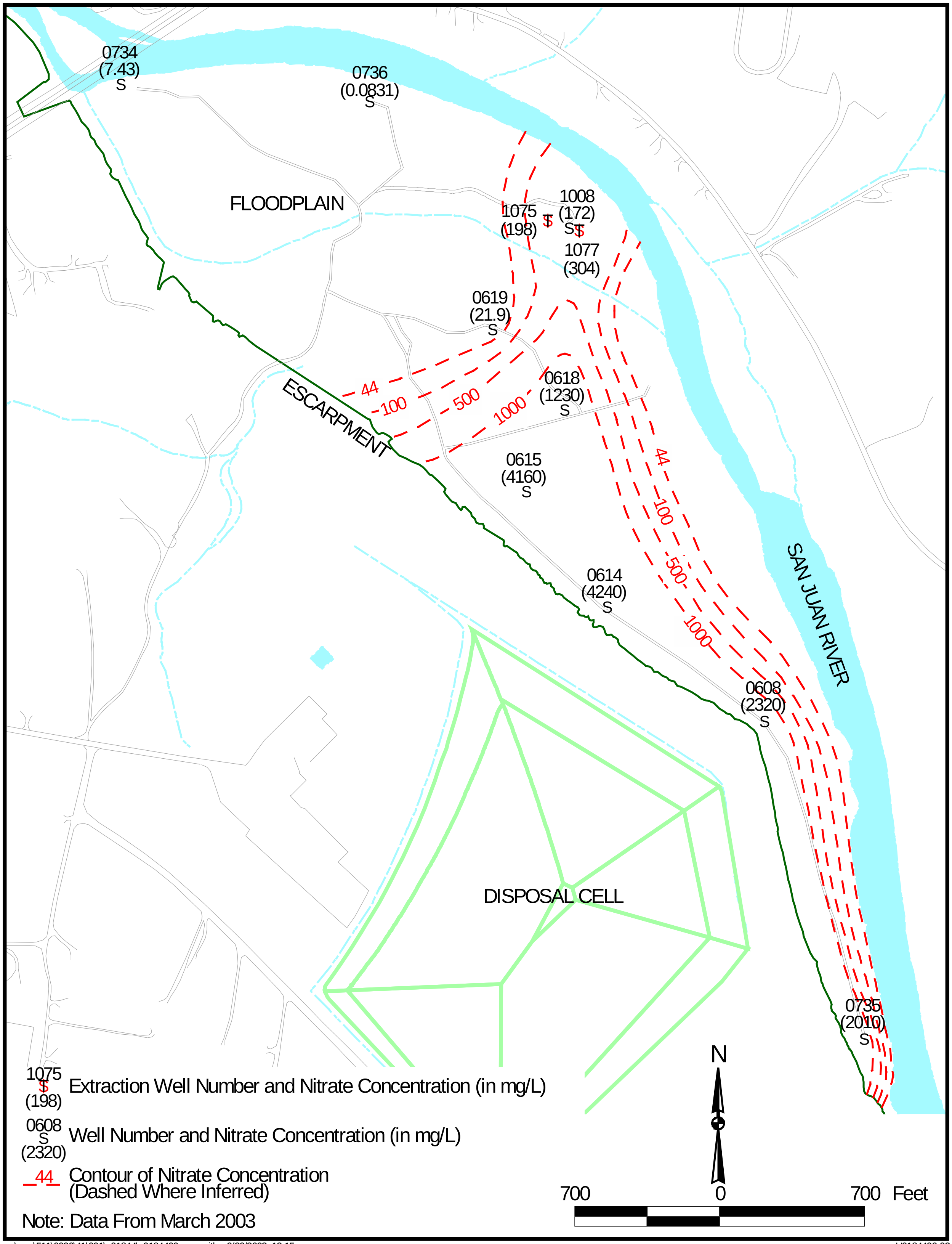

Figure 9. Floodplain Nitrate Ground Water Concentrations

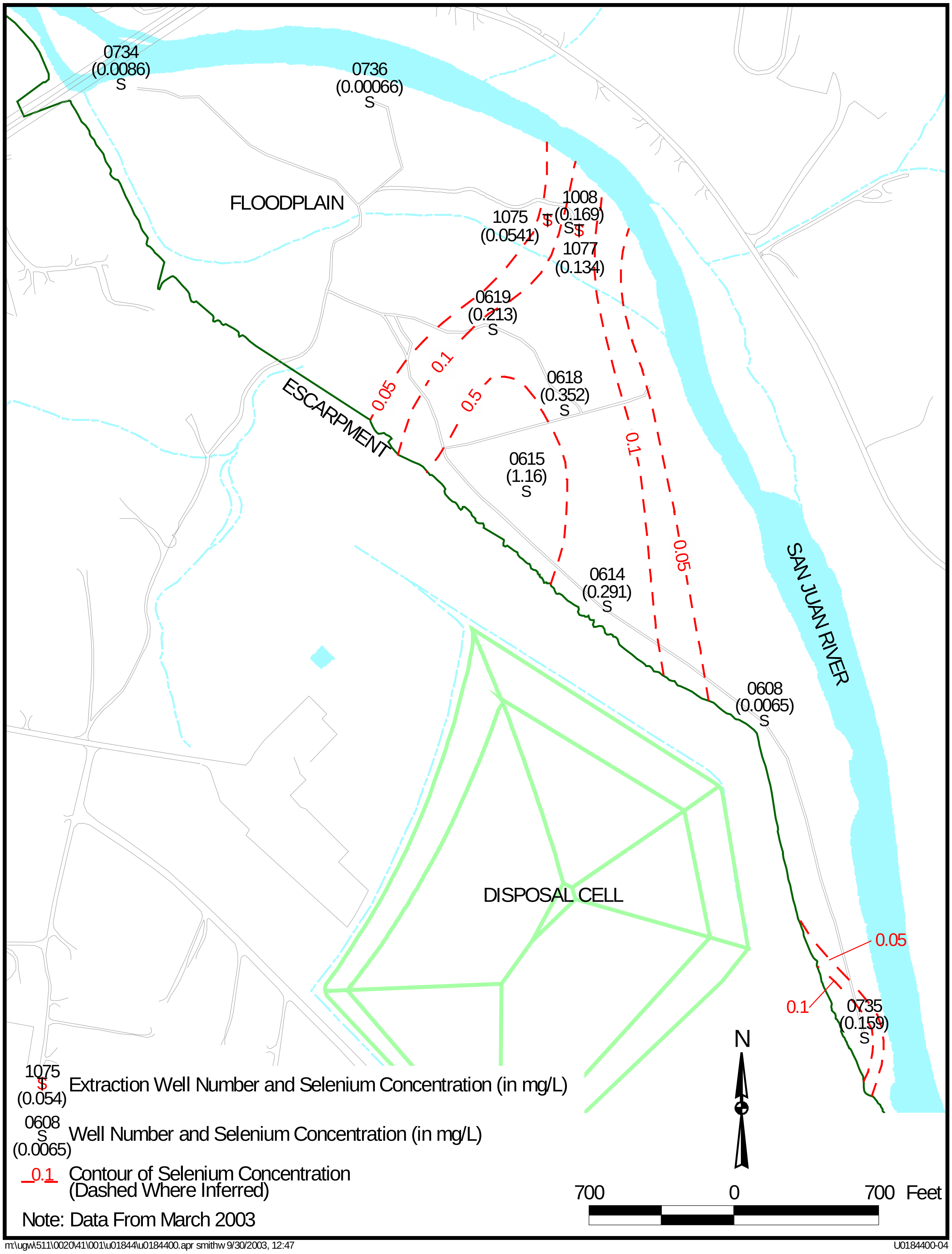

Figure 10. Floodplain Selenium Ground Water Concentrations

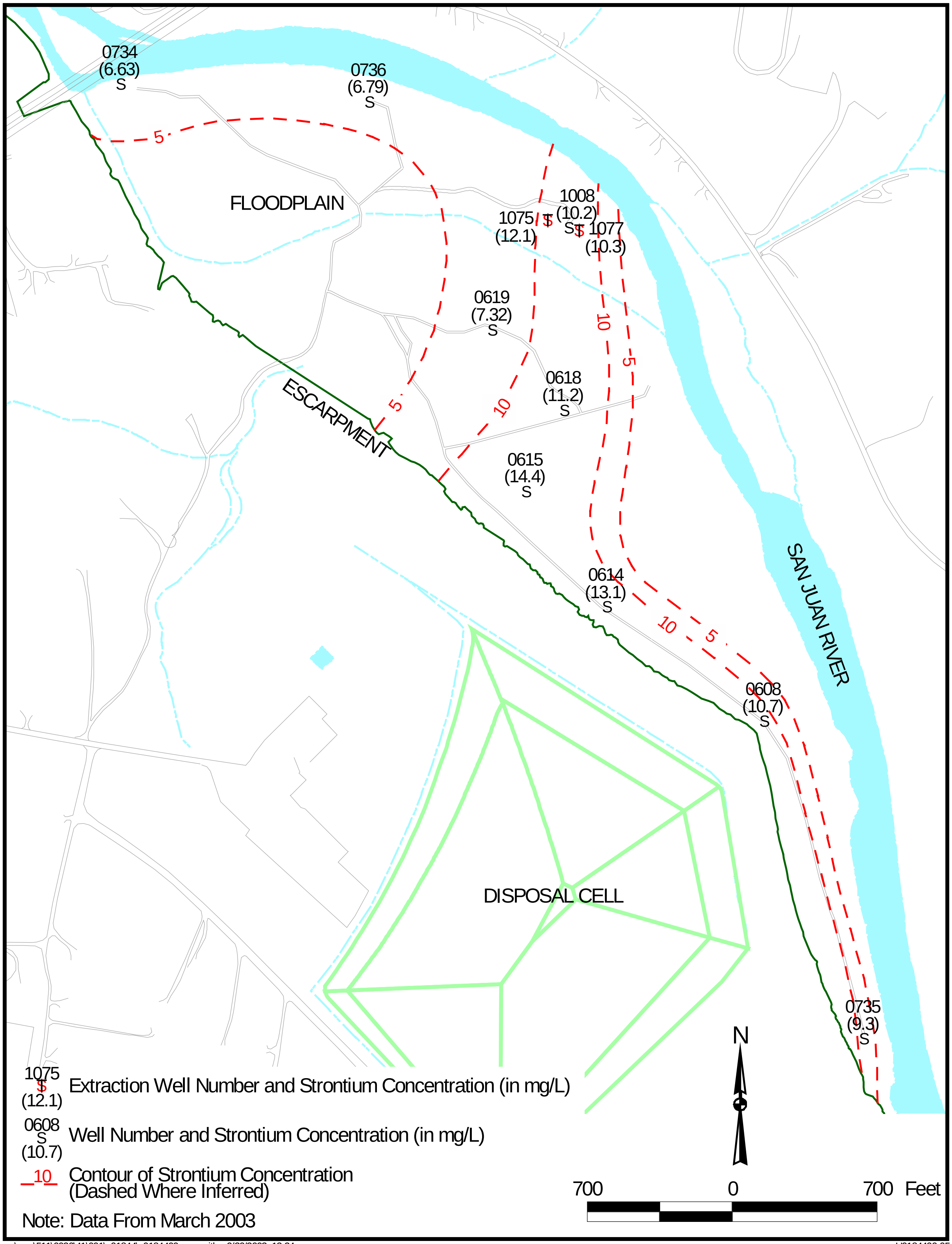

Figure 11. Floodplain Strontium Ground Water Concentrations

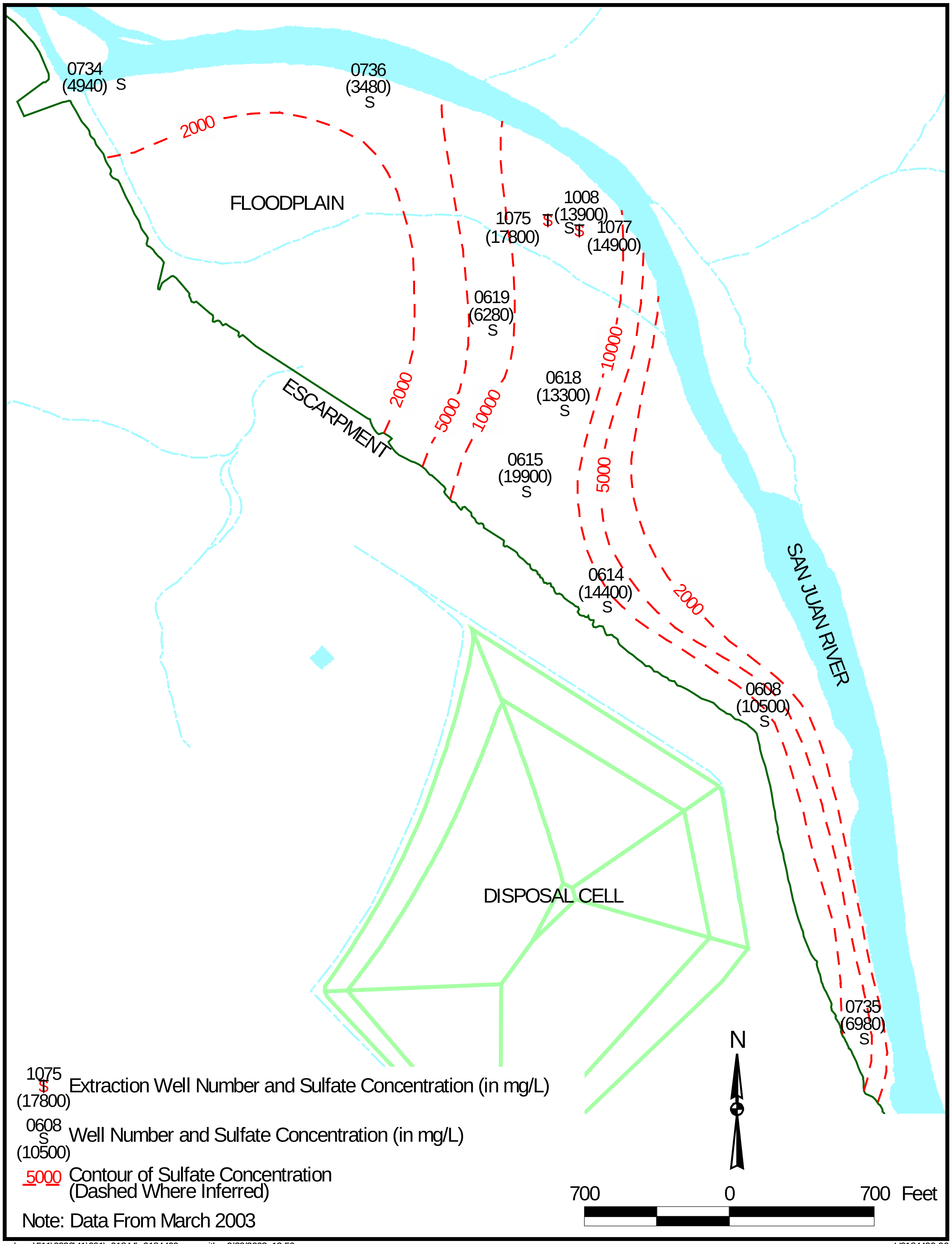

Figure 12. Floodplain Sulfate Ground Water Concentrations

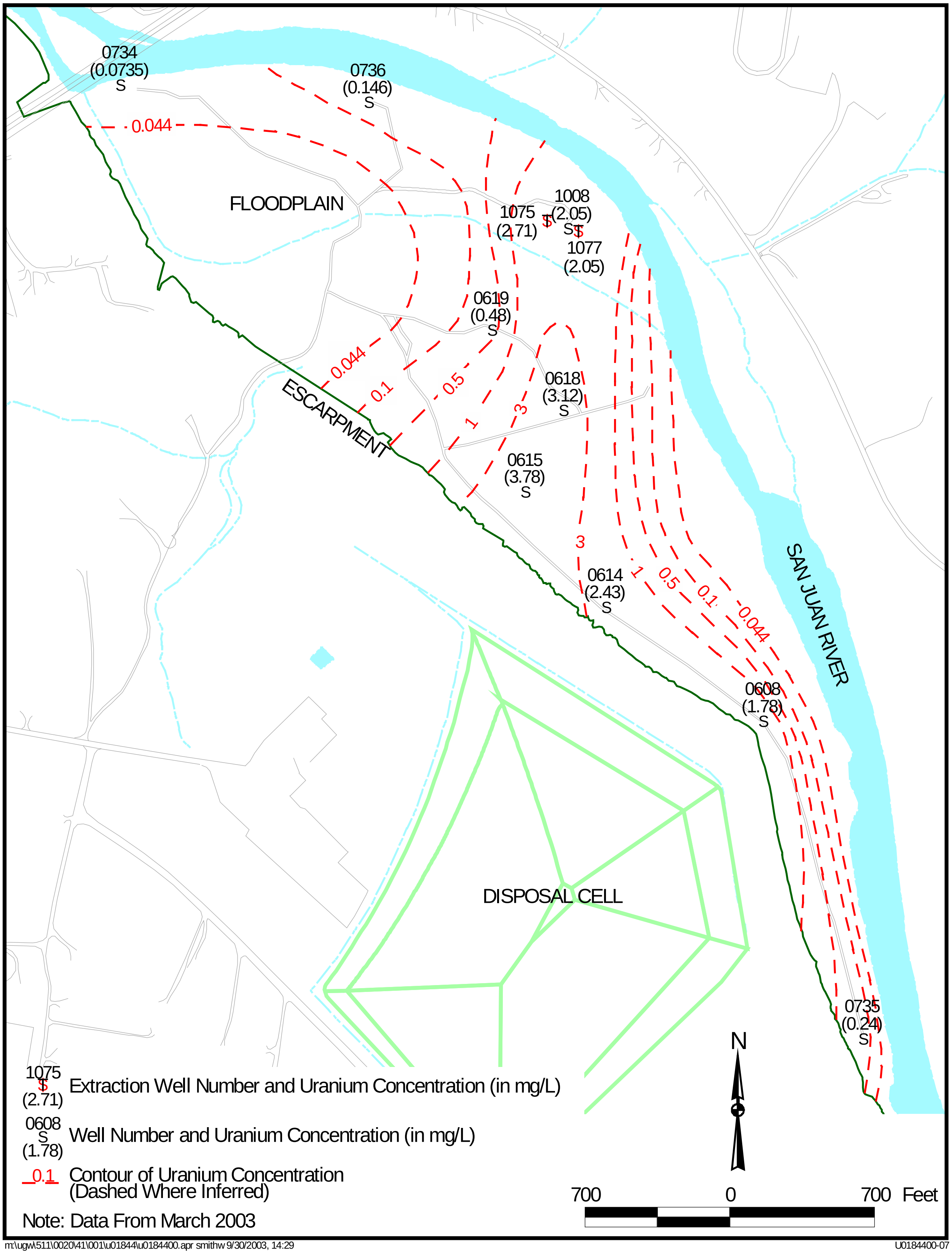

Figure 13. Floodplain Uranium Ground Water Concentrations

The plume maps presented in this report using 2003 data may vary somewhat from previous plume maps for several reasons. For one, floodplain contaminant distribution maps presented in the GCAP (DOE 2002) were mainly based on samples collected in September 2001, with some additional data for concentrations from March 1999 through March 2001 being used to provide a more comprehensive plume configuration. It should also be noted that, subsequent to the September 2001 sampling, wells were sampled using a new micro-purge sampling method and the number of wells sampled on a routine basis was significantly reduced.

4.4 Floodplain Ground Water Remediation System

The floodplain ground water extraction system consists of two wells, 1075 and 1077 (Figure 1). These wells were drilled to approximately 20 ft bgs, and have saturated alluvial thicknesses of 8 to 10 ft. The goal for total pumping rate from the floodplain is from 10 to 20 gpm. Ground water collected from the extraction wells is piped south to the terrace and eventually discharges into the evaporation pond. The objectives of this extraction system are to extract ground water from the most contaminated part of the plume where it is near the San Juan River to lessen exposure risk to aquatic life and to provide adequate water to cover the floor of the evaporation pond.

4.5 Floodplain Remediation System Performance Metrics

The main objective of the floodplain remediation system is to supplement the natural flushing process by reducing contaminant mass and volume within the floodplain alluvial aquifer. The following performance metrics will be used to assess the degree to which this objective is being met.

4.5.1 Expected Ground Water Gradients

Computed horizontal hydraulic gradients will be compared to those determined for baseline conditions (Figure 5) to identify possible flow regime changes in the vicinity of the extraction wells. For effective contaminant capture during pumping, the horizontal vectors should point toward extraction well locations.

Pressure transducers designed to monitor depth to ground water have been installed in monitor wells 0854 and 1008, each of which is located within 150 ft of the extraction wells. These data will be reviewed to determine if there has been a significant change in ground water elevation since start-up of the remediation system. The pumping rate from floodplain extraction wells may not be sufficient to produce significant drawdown, particularly given the relatively coarse material comprising the floodplain alluvial aquifer. Consequently, it is possible that no significant changes in ground water elevations will be measured.

4.5.2 Comparison to Contaminant Baseline Concentrations

Ground water contaminant concentrations will be monitored and compared to the baseline concentrations presented in Table 5. This comparison will provide indication as to whether the floodplain extraction system is effective and contaminant levels are decreasing.

5.0 Summary and Conclusions

This baseline performance evaluation describes the hydrogeology of both the terrace and floodplain areas at the Shiprock Project site, the ground water remediation steps that are being applied in each, and performance metrics by which the success of remediation can be evaluated. The ground water system in the terrace area is conceptualized as an anthropogenic system that resulted from historical water uses at the site when milling took place. Ground water observed below the terrace area today occurs in both relatively thin alluvial sediments and underlying Mancos Shale, the latter of which is weathered in its shallowest portions and possibly fractured in others. Because of several uncertainties inherent in the characterization of the terrace alluvium and Mancos Shale, estimates of the quantities of ground water currently stored in them and the manner in which contaminated water will eventually be transported from the terrace are considered as preliminary estimates.

The conceptual model of the terrace ground water system includes a swale in the underlying Mancos Shale in the south part of terrace east. Alluvium overlying the Mancos Shale in this area contains up to 7 ft of saturation. Uncertainties exist regarding the extent of this thick saturation and its ability to yield ground water to extraction wells.

The objective of remediation in the eastern half of the terrace ground water system is to remove local ground water with the intent of reducing the discharge of contaminated ground water to the adjacent floodplain alluvial aquifer and ultimately eliminating surface exposures of this water at Bob Lee and Many Devils Washes. Ground water removal is accomplished with four extraction wells in the south part of terrace east and collector drains in Bob Lee and Many Devils Washes. The extracted ground water is pumped to an 11-acre evaporation pond located south of the disposal cell.

Metrics used to assess the efficacy of terrace ground water remediation are based on future monitored water levels in terrace east and terrace west, measured flow rates in two seeps occurring along the escarpment that separates the terrace from the floodplain, and flows in the collector drains installed in the two washes.

The ground water system in the floodplain comprises an alluvial aquifer overlying Mancos Shale adjacent to the San Juan River. The river and aquifer interact with one another, with the river appearing to lose water to the aquifer east of the disposal cell and gain from ground water discharge farther to the north. Water also enters the floodplain alluvium via subsurface seepage through the Mancos Shale along the escarpment separating the terrace from the floodplain. This latter process is the mechanism by which site-related contaminated water feeds the contaminant plume in the floodplain aquifer.

Seven COCs occur in the plume in the floodplain aquifer. The remediation system in the floodplain aquifer consists of two extraction wells near the west bank of the San Juan River where the plume contacts the river. Water pumped from these wells is piped to the evaporation pond on the terrace south of the disposal cell.

An important objective of the floodplain remediation system is to remove ground water in the most contaminated part of the plume where it is adjacent to the river such that the risk to aquatic life is minimized. Parameters indicative of ground water flow direction along with contaminant concentrations will be monitored in the future to assess the degree to which the remediation system is effective. The degree to which contaminant concentrations can be expected to decrease in future years is dependent on remedial measures that will ultimately be employed in the floodplain.

6.0 References

Golden Software, 1996. Surfer User's Guide.

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McDonald, M.G., and A.W. Harbaugh, 1988. "A Modular Three-Dimensional Finite-Difference Ground Water Flow Model," *U.S. Geological Survey Techniques of Water-Resources Investigations*, Book 6, Chapter A1.

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Appendix A

Historical Ground Water Elevation Data Regression Analysis

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Monitor wells in terrace east are screened either in the terrace alluvium or the Mancos Shale, or both of these hydrogeologic units. Using MS-Excel, water level records from terrace east wells for the complete period of record were assembled and plotted. A linear–regression trend line was plotted through the data for each well and the equation of the linear regression trend line was calculated to quantify the magnitude of the trend. A negative coefficient for the x-variable in the tables and figures presented in this appendix indicates that a water level has been declining. Conversely, if the x-variable coefficient is positive, the water level has been rising.

Table A-1 presents the equations of trend lines generated from the water-level data for several terrace wells. Color shading is used to indicate the geologic materials in which the wells are screened. Only two wells are screened exclusively in the terrace alluvium. Of the remaining wells, 10 are screened across the both the terrace alluvium and the Mancos Shale, and the remaining 13 wells are screened only in Mancos Shale. Approximately two thirds of the wells in terrace east show that water levels have been declining during recent years.

Figure A-1 shows the locations of wells used in the regression analysis. Visual observation of the posted data suggests that declining water levels are uniformly distributed throughout terrace east. The rising water levels in wells 0725 through 0728, all of which are located within the Bob Lee Wash area, could be attributed to a leaking water line near well 0728. The rising water levels in these wells are, therefore, not considered representative of natural trends in the terrace ground water system.

Falling water levels in wells 0817, 0819, 0820, and 0826 through 0829 may indicate that stored water possibly feeding seeps 0425 and 0426 is being depleted. If so, seep flows should decrease naturally with time.

Overall, the regression analysis shows that the magnitude of changes in the water levels is only marginal, at best. Because the changes are subtle, it might be appropriate to look for changes in trends as monitoring proceeds. The objective of such monitoring would be to see if the baseline trends continue, or possibly reverse themselves. Extraction of ground water from the terrace east flow system is projected to result in an overall decline in ground water levels.

Table A-1. Summary of Water Level Trends in the Terrace East Portion of the Shiprock Terrace

Well	Equation of Trend Line	Well	Equation of Trend Line
603	y = -0.0002x + 4955.3	602	y = 0.0005x + 4917.3
728	y = 0.0003x + 4928.1	604	y = -0.0073x + 5211.1
725	y = 0.0006x + 4872.4	726	y = 0.0015x + 4862.7
730	y = 0.0003x + 4930.1	727	y = 6E-05x + 4931.6
731	y = 0.0002x + 4941.5	817	y = -0.0005x + 4957.8
812	y = 0.0002x + 4936.4	819	y = -0.0007x + 4963.2
813	y = -0.0004x + 4954.9	820	y = -0.0137x + 5307
814	y = -0.0008x + 4967.9	823	y = -0.0011x + 4895.7
815	y = -0.0004x + 4943.8	824	y = -0.0882x + 8012.
816	y = -0.0011x + 4954	825	y = 0.0074x + 4536.4
826	y = -0.001x + 4970.2	829	y = -0.0026x + 4987.6
827	y = -0.0021x + 4999.3	830	y = -0.0025x + 5042.2
828	y = -0.0014x + 4984.9	1002	y = -0.2462x + 13954
839	y = -0.0009x + 4952	1003	y = -0.0647x + 7256.1
1007	y = -2E-05x + 4918.2	1004	y = -0.001x + 4952
818	y = 0.0004x + 4931.2	1058	y = -0.0154x + 5515.2
1057	y = -0.0041x + 5101	1059	y = -0.0007x + 4972.5
600	y = 6E-05x + 4920.6	DM-7	y = 0.0014x + 4873.9
Overall, 24 of 36 wells (0.67) have negative slope, or declining water levels			
Shading indicates that these wells are completed in Terrace Alluvium and Mancos Shale. 10 of 15 (0.67) have negative slope, or declining water levels			
Shading indicates that these wells are completed in Terrace Alluvium only.			
Shading indicates that these wells are completed in Mancos Shale only. 13 of 19 (0.68) have negative slope, or declining water levels.			

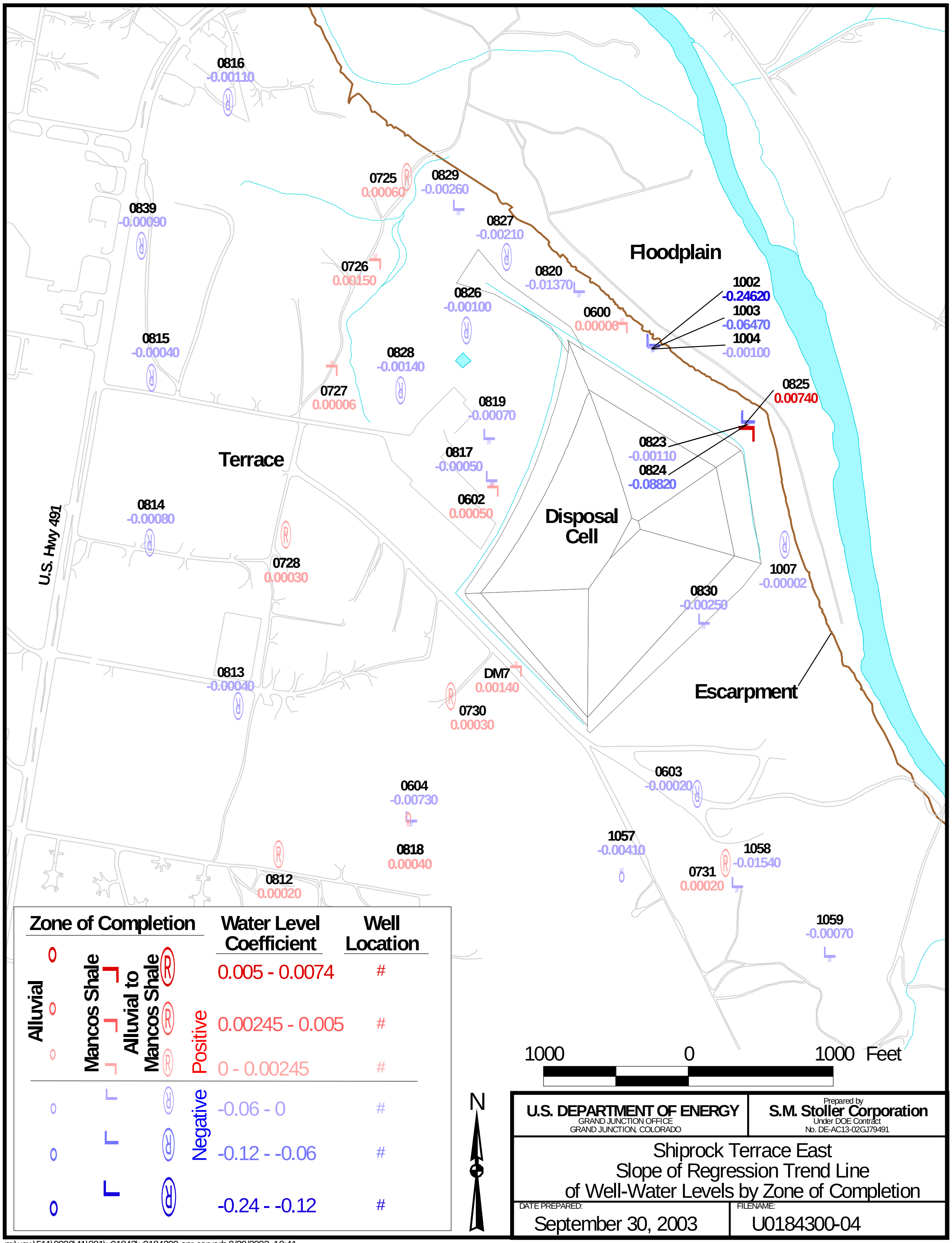
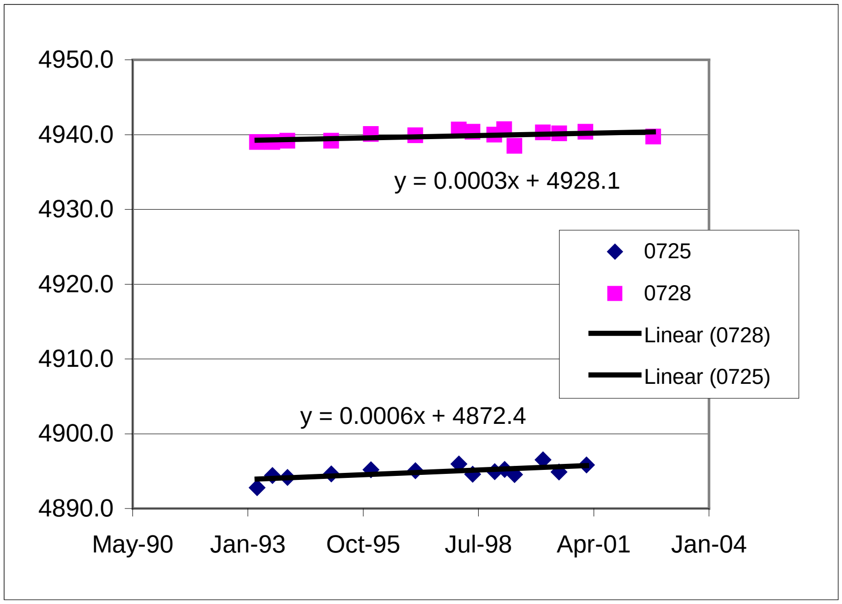
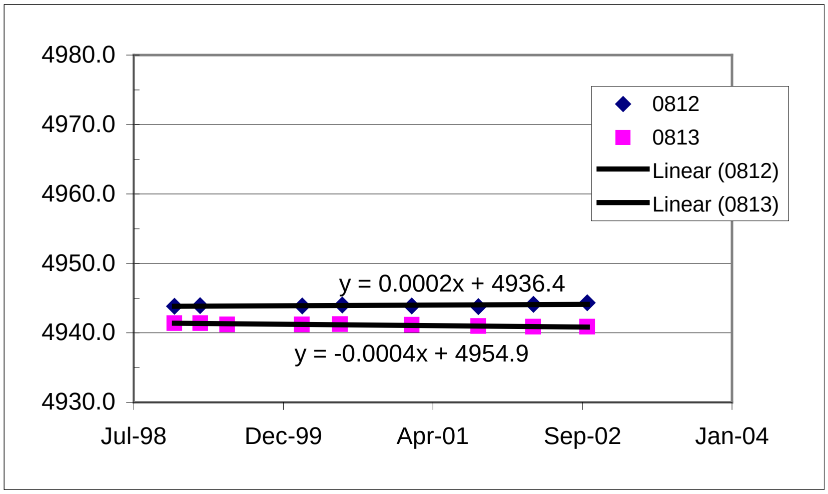


Figure A−1. Terrace Ground Water Elevation Historical Trend Regression Analysis


4950.0
4940.0
4930.0
4920.0
4910.0
4900.0
4890.0
y = 0.0003x + 4928.1
y = 0.0006x + 4872.4
0725
0728
Linear (0728)
Linear (0725)
May-90
Jan-93
Oct-95
Jul-98
Apr-01
Jan-04


4980.0
4970.0
4960.0
4950.0
4940.0
4930.0
0812
0813
Linear (0812)
Linear (0813)
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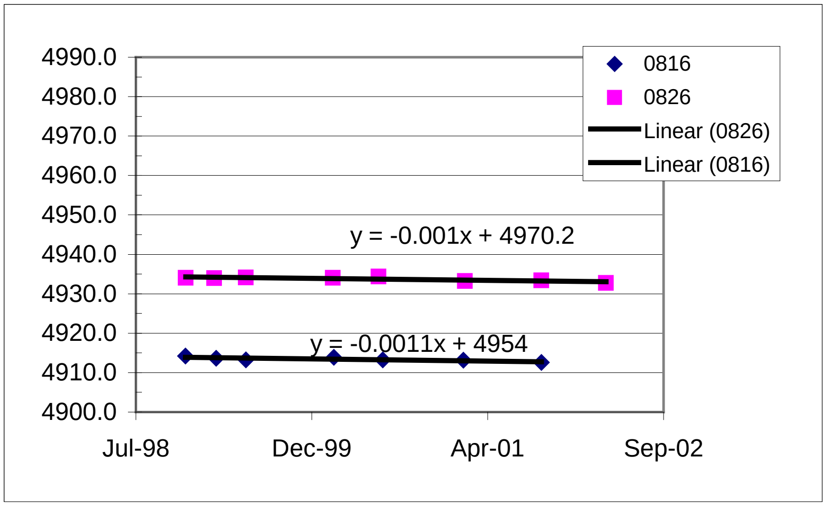
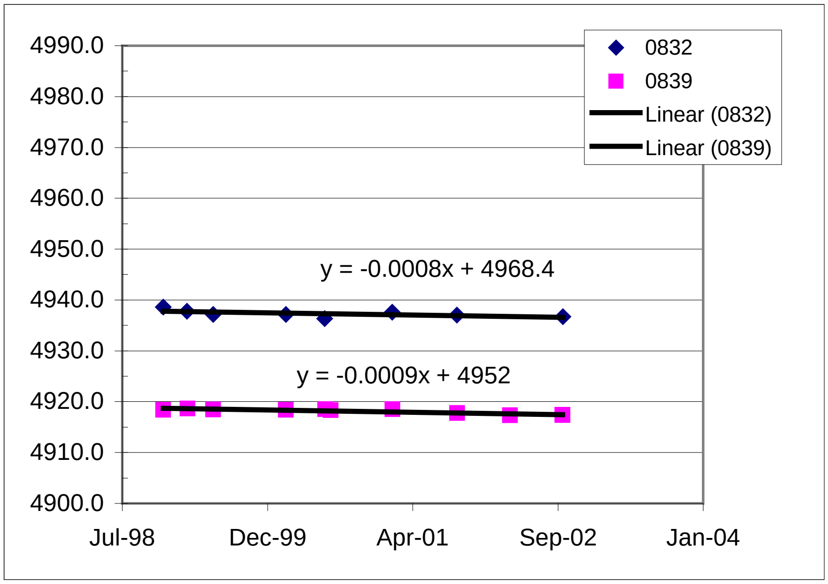
y = -0.0004x + 4954.9
Jul-98
Dec-99
Apr-01
Sep-02
Jan-04


4990.0
4980.0
4970.0
4960.0
4950.0
4940.0
4930.0
4920.0
4910.0
4900.0
0816
0826
Linear (0826)
Linear (0816)
y = -0.001x + 4970.2
y = -0.0011x + 4954
Jul-98
Dec-99
Apr-01
Sep-02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4950.0
4940.0
4930.0
4920.0
4910.0
4900.0
Jul-98
Dec-99
Apr-01
Sep-02
Jan-04
0832
0839
Linear (0832)
Linear (0839)
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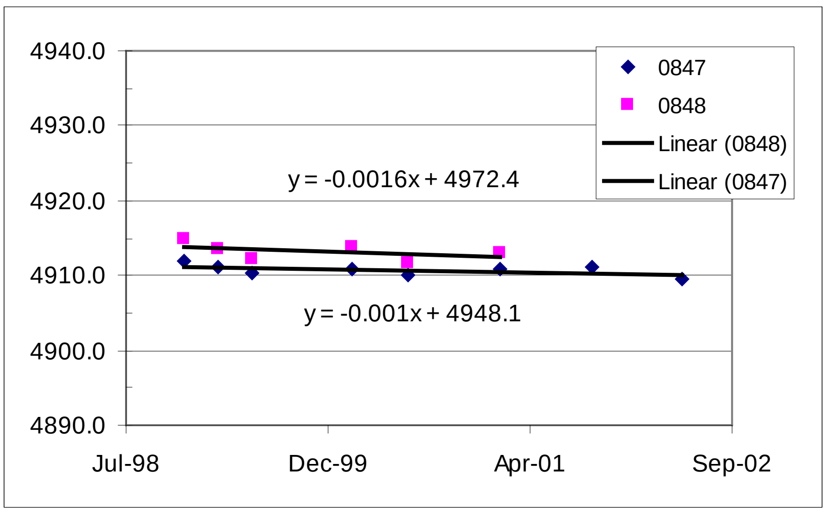
y = -0.0009x + 4952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4920.0
4910.0
4900.0
4890.0
Jul-98
Dec-99
Apr-01
Sep-02
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0848
Linear (0848)
Linear (0847)
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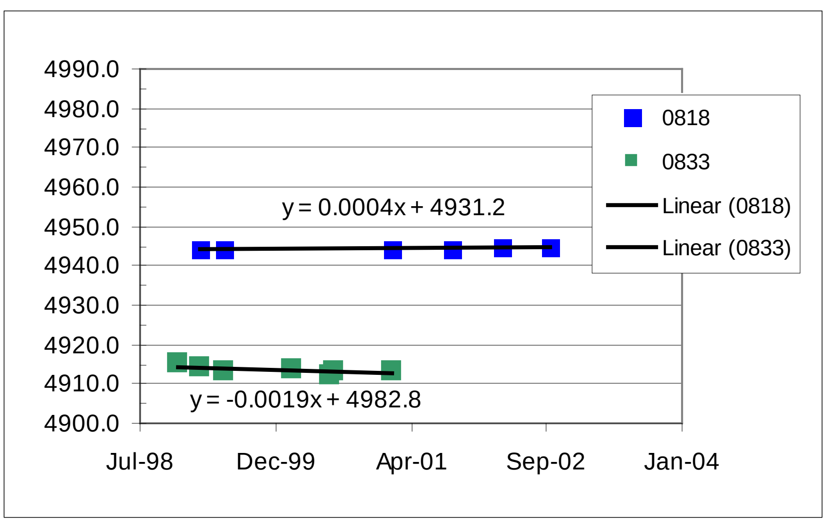
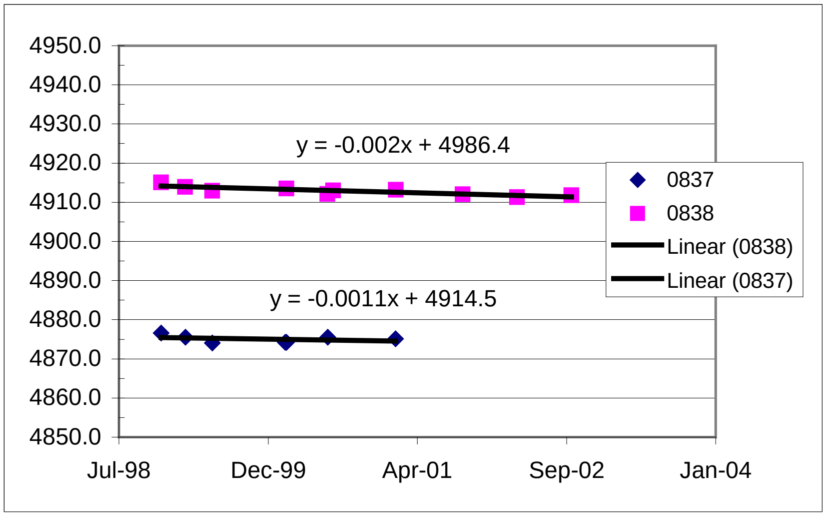
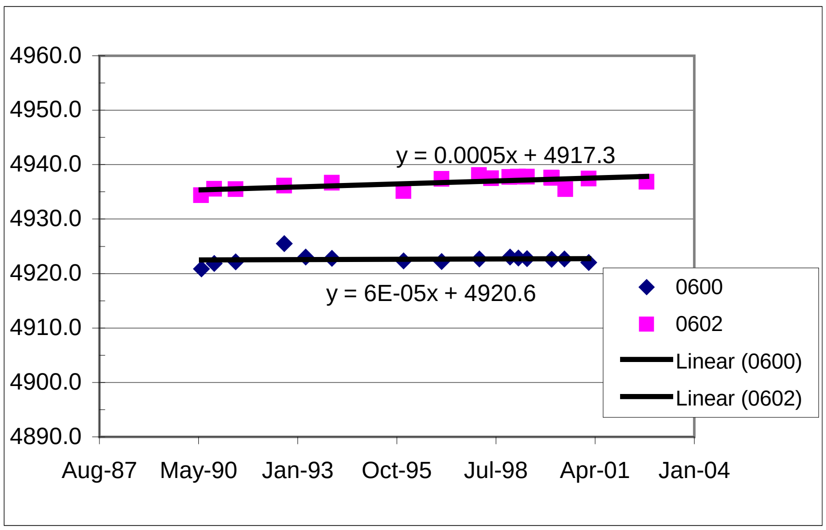
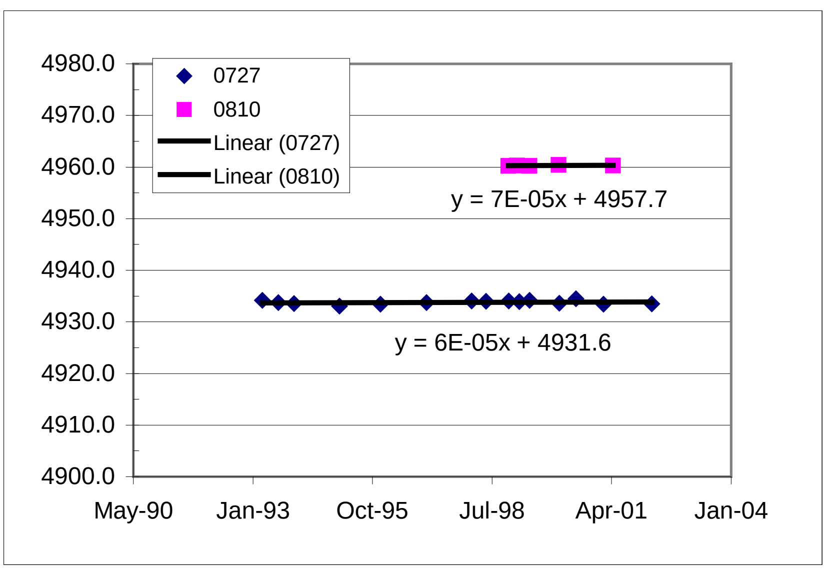
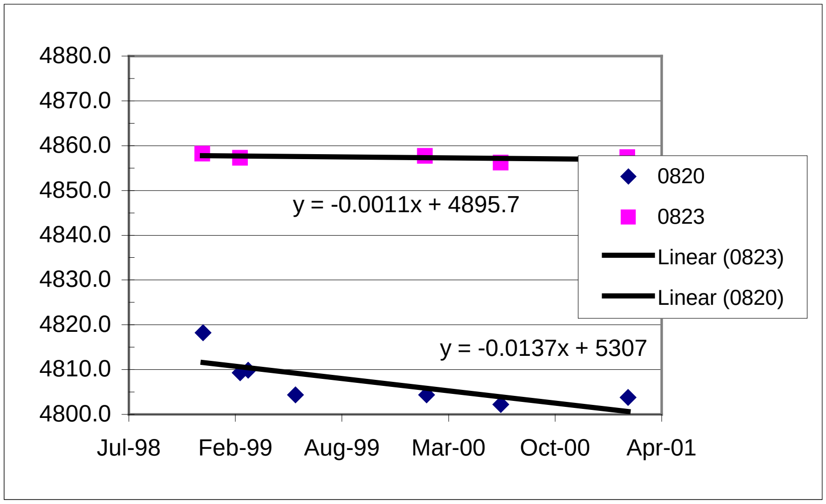
y = -0.001x + 4948.1

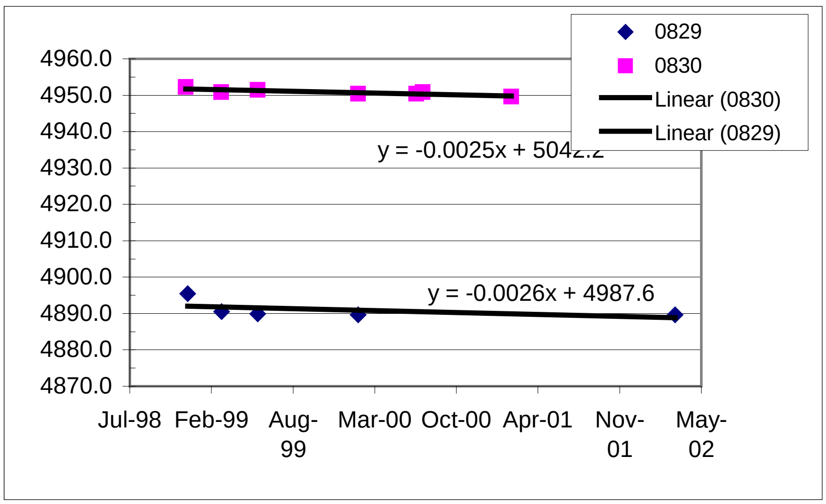

4990.0
4980.0
4970.0
4960.0
4950.0
4940.0
4930.0
4920.0
4910.0
4900.0
Jul-98
Dec-99
Apr-01
Sep-02
Jan-04
0818
0833
Linear (0818)
Linear (0833)
y = 0.0004x + 4931.2
y = -0.0019x + 4982.8

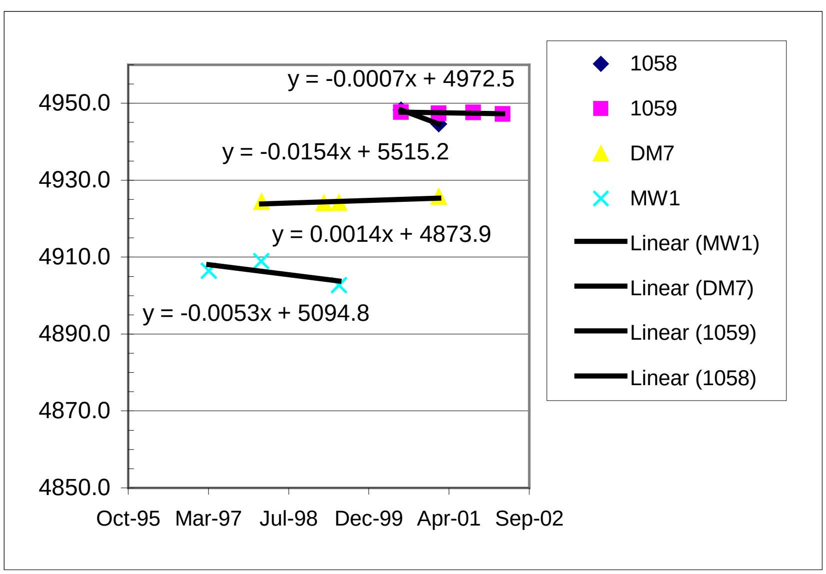

4950.0
4940.0
4930.0
4920.0
4910.0
4900.0
4890.0
4880.0
4870.0
4860.0
4850.0
Jul-98
Dec-99
Apr-01
Sep-02
Jan-04
y = -0.002x + 4986.4
y = -0.0011x + 4914.5
0837
0838
Linear (0838)
Linear (0837)


4960.0
4950.0
4940.0
4930.0
4920.0
4910.0
4900.0
4890.0
Aug-87
May-90
Jan-93
Oct-95
Jul-98
Apr-01
Jan-04
y = 0.0005x + 4917.3
y = 6E-05x + 4920.6
0600
0602
Linear (0600)
Linear (0602)


4980.0
4970.0
4960.0
4950.0
4940.0
4930.0
4920.0
4910.0
4900.0
May-90
Jan-93
Oct-95
Jul-98
Apr-01
Jan-04
0727
0810
Linear (0727)
Linear (0810)
y = 7E-05x + 4957.7
y = 6E-05x + 4931.6


4880.0
4870.0
4860.0
4850.0
4840.0
4830.0
4820.0
4810.0
4800.0
Jul-98
Feb-99
Aug-99
Mar-00
Oct-00
Apr-01
y = -0.0011x + 4895.7
y = -0.0137x + 5307
0820
0823
Linear (0823)
Linear (0820)


4960.0
4950.0
4940.0
4930.0
4920.0
4910.0
4900.0
4890.0
4880.0
4870.0
Jul-98
Feb-99
Aug-99
Mar-00
Oct-00
Apr-01
Nov-01
May-02
y = -0.0025x + 5042.2
y = -0.0026x + 4987.6
0829
0830
Linear (0830)
Linear (0829)


4950.0
4930.0
4910.0
4890.0
4870.0
4850.0
Oct-95
Mar-97
Jul-98
Dec-99
Apr-01
Sep-02
y = -0.0007x + 4972.5
y = -0.0154x + 5515.2
y = 0.0014x + 4873.9
y = -0.0053x + 5094.8
1058
1059
DM7
MW1
Linear (MW1)
Linear (DM7)
Linear (1059)
Linear (1058)

End of current text