

# 2010 Review and Evaluation of the Shiprock Remediation Strategy

January 2011



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of the Shiprock Remediation Strategy**

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## Abbreviations

AML	Abandoned Mine Lands (as in Navajo AML/UMTRA)
CFR	<i>Code of Federal Regulations</i>
COCs	contaminants of concern
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	feet
GCAP	Groundwater Compliance Action Plan
gpm	gallons per minute
ICs	Institutional Controls
mg/L	milligram(s) per liter
NECA	Navajo Engineering and Construction Authority
NN	Navajo Nation
NN AML/ UMTRA	Navajo Nation Abandoned Mine Lands/UMTRA Department
NNEPA	Navajo Nation Environmental Protection Agency
NRC	U.S. Nuclear Regulatory Commission
SOARS	System Operation and Analysis at Remote Sites
SOWP	Site Observational Work Plan
UMTRA	Uranium Mill Tailings Remedial Action (Project)
UMTRCA	Uranium Mill Tailings Radiation Control Act
USFWS	U.S. Fish and Wildlife Service

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## 1.0 Introduction

The Shiprock, New Mexico, Disposal Site (Shiprock site) is the location of a former uranium and vanadium ore-processing mill that operated from 1954 to 1968 on property leased from the Navajo Nation. During mill operation, nitrate, sulfate, uranium, and other milling-related constituents leached into underlying sediments and resulted in contamination of groundwater in the area of the mill site. The site was designated for remedial action as an inactive uranium-ore processing site under Title I of the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978. Remediation of surface contamination, including decommissioning the mill buildings and infrastructure and impounding the tailings, was completed in 1986 under the U.S. Department of Energy (DOE) Uranium Mill Tailings Remedial Action (UMTRA) Project. The mill tailings were stabilized in an engineered disposal cell built on top of the two existing tailings piles on the site. The disposal cell occupies approximately 77 acres and contains about 1.9 million cubic yards of tailings and related materials.

DOE was responsible for characterizing and remediating groundwater at the site under the Programmatic Environmental Impact Statement for the UMTRA Groundwater Project (DOE 1996). These early characterization efforts culminated in the submittal of the Site Observational Work Plan (SOWP, DOE 2000), a comprehensive report documenting the technical aspects of the site and the corresponding site conceptual model. The SOWP also established the foundation for defining an overall compliance strategy, later documented in the Ground Water Compliance Action Plan (GCAP, DOE 2002a).

In March 2003, DOE began active remediation of groundwater using extraction wells and interceptor drains; baseline conditions were documented in the Baseline Performance Report (DOE 2003a). A year later, DOE completed a performance evaluation of the remediation system, as documented in the *Refinement of Conceptual Model and Recommendations for Improving Remediation Efficiency at the Shiprock, New Mexico, Site* (DOE 2004). This report was reissued in 2005 to include an addendum that established a framework and decision process for future evaluations of the groundwater remediation strategy (DOE 2005).<sup>1</sup> To allow for the implementation of contingencies or adjustments, the addendum recommended that the performance of the groundwater remediation system be reviewed in two phases: a near-term review (3 years, or 2008) and a long-term review (7 years, or 2012).

This strategy evaluation represents the first of the two recommended performance and remedial strategy reviews. Given the timing, it is more aptly referred to as a midterm (rather than a near-term) review.<sup>2</sup> An initial abbreviated version of this report—titled *2009 Evaluation of the Shiprock Remediation Strategy: Annotated Outline*—was submitted in January 2009 (DOE 2009b). DOE sought input from stakeholders on the 2009 draft report and considered this input in developing this revised evaluation. DOE's responses to comments on the abbreviated report are provided in Appendix A.

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<sup>1</sup> With the exception of the addendum, the document was unchanged from the initial March 2004 version. That document, a major catalyst for this strategy evaluation, is referred to herein as the Conceptual Model Report.

<sup>2</sup> A reason for the delay in assessing the status of the near-term endpoints is that new activities to improve the remediation system and to mitigate potential risks (discussed herein) were ongoing, and DOE had not reached a logical evaluation point for the initial strategy review.

## 1.1 Scope, Content, and Organization of this Report

The purpose of this document is to provide an update on the status of the remediation activities and a path forward at the Shiprock site based on discussions with the Navajo Nation and other stakeholders. Unlike the 2005 Conceptual Model Report, this midterm review is not intended to provide a comprehensive technical evaluation of the site conceptual model. Rather, it is intended to inform stakeholders of the status of DOE's progress toward resolving the two fundamental issues that lie at the core of this evaluation: (1) increasing the effectiveness of the groundwater remediation system; and (2) the ultimate goal, reduction of potential human health and ecological risks.

Section 2 provides an overview of the compliance strategies for the terrace and floodplain underlying this evaluation and summarizes previous investigations and key submittals. Section 3 summarizes the refinements recommended in the 2005 Conceptual Model Report and revisits the decision process—"Process for Selecting Ground Water Remediation Strategy"—provided in the report addendum. Section 4 describes the site characterization and remediation activities undertaken since the 2005 report was developed, the progress made in terms of risk mitigation and performance of the groundwater remediation system, and the status of study endpoints. This report culminates in a description of DOE's ongoing and planned activities and studies that are intended to evaluate unresolved issues and ensure protection of human health and the environment (Section 5). Section 6 provides a brief synopsis of the strategy evaluation. References are provided in Section 7.

The area-specific matrix provided in Attachment 1 represents a tabular executive summary of the material presented in this strategy evaluation; as such, it is intended for use as a stand-alone document. Appendix A presents DOE's responses to stakeholder comments on the initial draft (DOE 2009b) version of this strategy evaluation.

Although contaminant concentration trends are summarized briefly in this report, for more detailed information, the reader is referred to the performance reports DOE has prepared annually since submitting the initial Baseline Performance Report in 2003. These annual performance reports document the results of semiannual monitoring and provide updated assessments of the floodplain and terrace groundwater remediation systems. The most recent report (DOE 2009a) presents data for the performance period April 2008 through March 2009, marking the end of the sixth year of operation of the groundwater remediation system.

## 1.2 Site Description

The Shiprock site is divided physiographically and hydrologically into two regions, terrace and floodplain, that are separated by an escarpment. Although the groundwater systems in these regions are interrelated (some terrace groundwater flows to the floodplain), each region has unique groundwater features and compliance strategies. Since 2005 (when the Conceptual Model Report was issued), DOE has expanded the groundwater remediation system and continues to remove contaminated groundwater.

The terrace remediation system currently consists of nine groundwater extraction wells, two collection drains (Bob Lee Wash and Many Devils Wash), and a terrace drainage channel diversion structure. All extracted groundwater is pumped into a lined evaporation pond on the

terrace. The floodplain remediation system currently consists of two groundwater extraction wells, a seep collection drain, and two collection trenches (Trench 1 and Trench 2). Figure 1 shows the site layout and the major components of the floodplain and terrace groundwater remediation systems.

### **1.3 Regulatory Framework**

UMTRCA directed the U.S. Environmental Protection Agency (EPA) to develop standards for remedial action at designated inactive uranium-ore processing sites. Groundwater remediation at the Shiprock site (and other UMTRCA sites) is regulated by Subparts B and C of Title 40 *Code of Federal Regulations* Part 192 (40 CFR 192). To document DOE's proposed strategies for complying with this mandate, DOE issued the site GCAP in 2002 (DOE 2002a). The GCAP proposed a phased approach that was documented in the Conceptual Model Report. The compliance strategy requires formal concurrence from the U.S. Nuclear Regulatory Commission (NRC) and consultation with the Navajo Nation. NRC conditionally approved the GCAP (and the SOWP) in 2003 (NRC 2003). DOE may reissue the GCAP to better reflect the data and observations obtained since active remediation began in 2003.

In developing a revised compliance strategy, DOE will continue to consult with stakeholders, including the Navajo Nation Environmental Protection Agency (NNEPA), the Navajo Nation Abandoned Mine Lands/UMTRA Department (NN AML/UMTRA), the Navajo Water Code Administration, Diné College, and the residents of Shiprock. Given the proximity of the San Juan River, nearby drainages, and other factors potentially affecting wildlife habitat, DOE also consults with the U.S. Fish and Wildlife Service (USFWS).

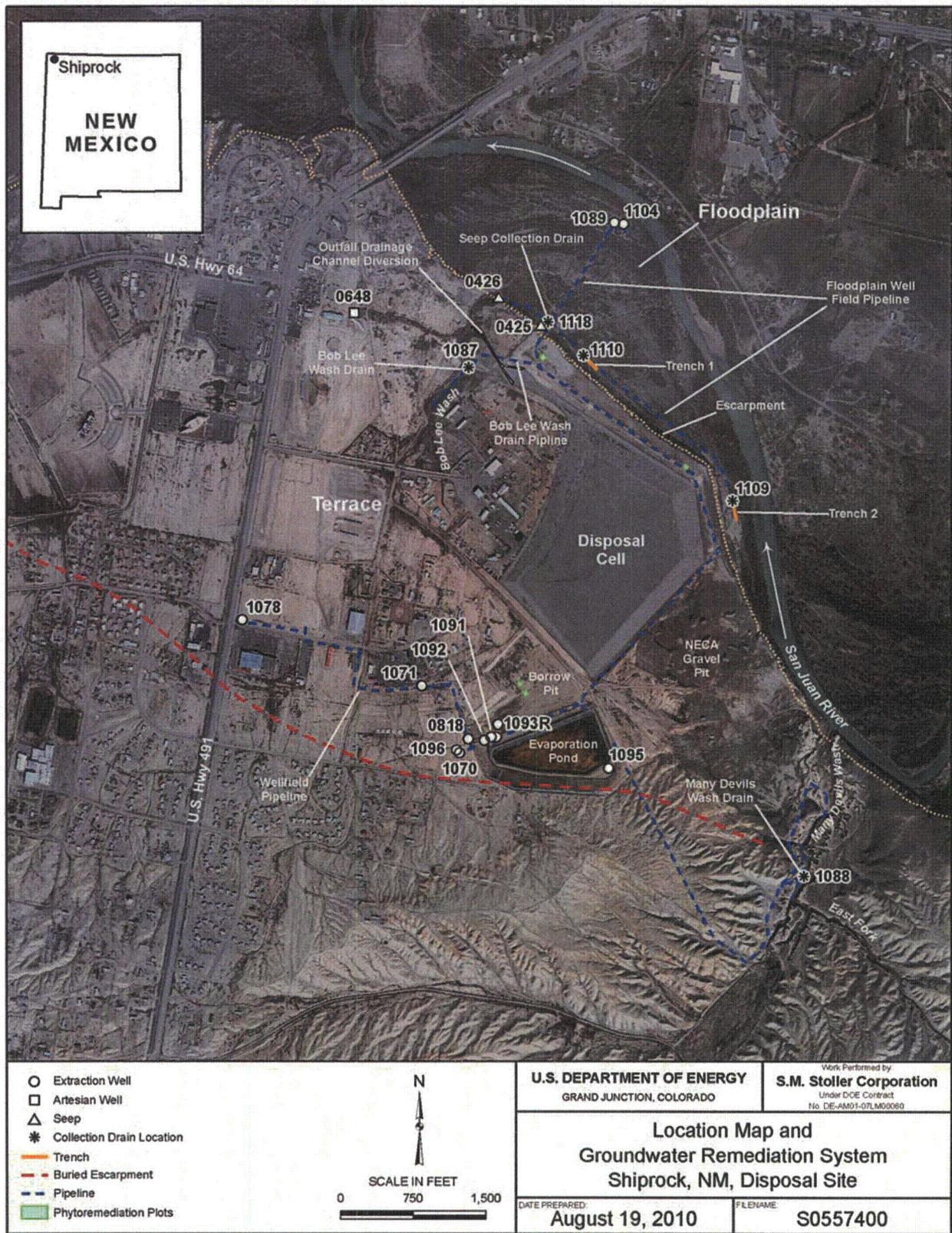


Figure 1. Location Map and Groundwater Remediation System

## 2.0 Background and Overview

As a prelude to this strategy evaluation, Section 2.1 presents an overview of the compliance strategy developed for the Shiprock site, as documented in the GCAP (DOE 2002a). To capture the breadth and scope of related characterization and remediation efforts DOE has undertaken, Section 2.2 summarizes the key site documents, investigations, and activities conducted to date.

### 2.1 Summary of Initial Compliance Strategy

The site compliance strategy and the remediation strategy are interrelated—in some respects, the compliance strategy is the umbrella under which the remediation strategy is formulated. Table 1 provides an overview of the Shiprock compliance strategy established in the GCAP for the terrace and floodplain, the two primary site regions. The fourth column in the table provides a synopsis of DOE's current thinking and recommended modifications to the strategy.

Table 1. Shiprock Compliance Strategy Overview

Project Area	Initial Compliance Strategy	Rationale	Recommended Updates to Site Compliance Strategy
Terrace East	Active remediation with monitoring	Active remediation at the base of the escarpment will intercept and remove contaminated water moving from the terrace east area to the floodplain. Active remediation on the terrace will reduce the concentrations of constituents entering the washes and seeps and will dry up the seeps.	Active remediation is the compliance strategy for the terrace. As discussed later in this report, progress is evident in terms of dewatering and drying up seeps.  DOE proposes to eliminate the distinction between the east and west terrace areas because this distinction is no longer relevant or technically defensible (see discussion following this table for elaboration).
Terrace West	Supplemental standards with monitoring (40 CFR 192)	Widespread ambient contamination not related to uranium-milling processes.	Evidence suggests that constituents naturally occurring in the Mancos shale account for some of the contamination observed on site. The proportion of constituents from natural vs. man-made sources is difficult to discern. DOE continues to evaluate the origin of this source of contamination.
Floodplain	Natural flushing with monitoring, supplemented with some active remediation	During the initial 10 to 20 years, active remediation from one or more wells will remove constituents from the most-contaminated area of the floodplain. Consistent with the requirement in 40 CFR 192, the goal is that natural flushing will remove mill-related constituents within 100 years.	Active remediation, augmented by natural flushing. Essentially, the strategy is unchanged; except that active remediation (pumping from extraction wells and trenches) is the preferred strategy for contaminant removal. The effects of natural flushing cannot be accurately assessed or quantified.

NRC conditionally approved the GCAP (NRC 2003). However, because refinement of the site compliance and remedial strategies is an ongoing process, DOE may reissue the GCAP to better reflect the data and observations obtained since active remediation began in 2003. The following sections elaborate upon the overview provided in Table 1 and summarize the current terrace and floodplain compliance strategies. The overall goal of these strategies is to reduce or eliminate exposures to the site contaminants of concern (COCs) determined in the Baseline Risk Assessment (DOE 1994). These COCs are nitrate, sulfate, and uranium (the primary COCs), and ammonium, manganese, selenium,<sup>3</sup> and strontium.

### 2.1.1 Overview of Terrace Compliance Strategy

In the 2002 GCAP, two distinct compliance strategies were proposed for the terrace, assuming a hydraulic separation between the eastern terrace (historically referred to as terrace east, located east of the fairgrounds and closest to the disposal cell) and terrace west (i.e., areas west of Highway 491).

The compliance strategy for terrace east is active remediation by extraction of groundwater from the terrace alluvium until potential risks to humans and the environment have been eliminated by removal of exposure pathways. Meeting this objective requires drying of seeps in Bob Lee Wash and Many Devils Wash and at the base of the escarpment (seeps 425 and 426; see Figure 1). Numerical standards for COCs do not apply because exposure pathways would be eliminated under active remediation.

The compliance strategy for terrace west is groundwater monitoring and the application of supplemental standards based on limited use groundwater (defined in 40 CFR 192.11[e]) due to low yield (volume) and the existence of widespread ambient aquifer contamination, thought to be related to irrigation water leaching contaminants from the Mancos Shale or, in the case of nitrate, derived from fertilizer use and septic field drainage.

Several aspects or assumptions underlying the terrace compliance strategies described above warrant clarification. First, the distinction between terrace east and terrace west is no longer relevant. This distinction was based on modeling conducted for the SOWP (DOE 2000), the results of which suggested that a hydraulic divide separated westward-moving groundwater from all other water in the terrace alluvium. More than a decade has passed since this distinction was postulated, and it is now difficult to identify a divide between the areas. If a divide does exist, it has likely been altered by the significant dewatering that has occurred since groundwater extraction began. Therefore, any references to terrace east and west in this evaluation correspond to geographical (rather than hydrogeological) distinctions only—terrace east corresponds to the area east of Highway 491, including the disposal cell and former mill site, and terrace west encompasses monitored areas west of Highway 491. Therefore, DOE will adopt a single compliance strategy for the terrace (active remediation, as described in Table 1).

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<sup>3</sup> Although concentrations are clearly elevated in some areas at the Shiprock site, the extent to which selenium is attributable to former milling processes vs. natural sources is not clear. Selenium concentrations are highest in distal areas—e.g., the paleochannel south of the site and in Many Devils Wash (e.g., see DOE 2009a)—and evidence suggests that selenium could have been leached from the Mancos Shale or soils derived from the shale. Concurrently with ongoing efforts to find representative terrace background locations, DOE plans to further evaluate the distribution of naturally occurring selenium in areas away from the disposal cell to help determine the origin of selenium in groundwater at the Shiprock site.

A second point of clarification relates to the semantics surrounding the compliance strategy, which originate in 40 CFR 192. Even though DOE considers active remediation the dominant strategy for the terrace, in many respects, the conditions that support the application of supplemental standards (the strategy initially proposed for terrace west) still apply. The term "supplemental standards"<sup>4</sup> implies the existence of numerical standards when in fact there are none. In other words, background conditions and/or the low potential for exposure obviate the need for application of numerical standards. Essentially, the term "supplemental standards" means that the numerical limits established under 40 CFR 192 cannot be achieved, but conditions are protective and no additional remedial action is required.

The 40 CFR 192 regulation lists eight criteria for applying supplemental standards (§192.21); one of these criteria states that the groundwater meets the definition of limited use groundwater, meaning that groundwater that is not a current or potential source of drinking water based on either poor background quality (i.e., not affected by contamination from milling operations) or low yield. Section 11(e) in 40 CFR 192 lists three criteria for satisfying the conditions of limited use groundwater:

- (1) The concentration of total dissolved solids is in excess of 10,000 milligrams per liter (mg/L). *This condition applies to about half the wells on the west terrace based on the most recent measurements;*
- (2) Widespread, ambient contamination not due to milling or processing-related activities exists that cannot be remediated. *DOE believes this is the case due to naturally occurring constituents in the Mancos shale, but this has yet to be definitively established;* and
- (3) The quantity of water reasonably available for sustained continuous use is less than 150 gallons per day (or 0.1 gallon per minute [gpm]). *This low-yield criterion is supported based on the poor performance of the terrace extraction wells (see Section 3).*

Irrespective of the applicability of any of the above provisions, 40 CFR 192 *does* require assurances that human health and the environment are protected, consistent with DOE's primary mission. The town of Shiprock is served by a public water supply and the local groundwater in the Mancos Shale is of poor quality; therefore, groundwater at the Shiprock site is not a current source of drinking water. As discussed in Section 2.1.3, DOE continues to work with NN AML/UMTRA to ensure implementation of institutional controls that will effectively provide long-term protection to human health and the environment by preventing exposure to contaminated site groundwater.

### **2.1.2 Overview of Floodplain Compliance Strategy**

The compliance strategy proposed in the GCAP for the floodplain is natural flushing, supplemented by active remediation by extraction of groundwater from the floodplain aquifer adjacent to the San Juan River. Besides reduced flow to the floodplain through the pumping of the terrace, additional extraction of groundwater in the floodplain was expected to accelerate reduction in contaminant concentrations. As described in Table 1, DOE does not currently propose any significant modifications to the floodplain compliance strategy. Essentially, the strategy is the same as that initially proposed, except that active remediation (pumping from

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<sup>4</sup>The application of supplemental standards has been the subject of previous stakeholder comments, so some of the explanation above is repeated in DOE's responses to stakeholder comments provided in Appendix A.

extraction wells and trenches) is now considered the dominant strategy in concert with natural flushing.<sup>5</sup>

### 2.1.3 Role of Institutional Controls

In their letter approving the 2002 GCAP, one of the conditions of NRC's concurrence was that DOE works to finalize institutional controls (ICs)<sup>6</sup> at the site (NRC 2003). Due to the existence of the disposal cell, associated contaminated groundwater, and the presence of elevated levels of COCs in seeps and nearby washes, DOE and the Navajo Nation have identified the need for long-term ICs that are enduring and enforceable. It is important to emphasize that ICs are to be used in conjunction with, and not in lieu of, remedial action measures. DOE intends to apply ICs in a layered fashion (e.g., using multiple ICs), thereby providing overlapping assurances of protection.

Examples of ICs applied on the terrace include fencing around the disposal cell and monitoring for disturbance, erosion, and other signs of encroachment. The evaporation pond and portions of Many Devils Wash are also fenced to prevent access, and warning signs have been posted in numerous areas (particularly in Many Devils Wash). DOE has also placed netting over the seeps to limit environmental risks and is evaluating the feasibility of additional remediation options for Many Devils Wash.

Examples of ICs applied on the floodplain include grazing restrictions, intended to eliminate risks to livestock from ingestion of vegetation that may have been exposed to contaminated groundwater. In 2003, DOE negotiated an agreement to establish a restriction and to compensate those with rights to graze on the floodplain. This restricted grazing agreement was recently renewed and has a termination date of May 2, 2013.<sup>7</sup> DOE also installed fencing to restrict access and monitors the area for evidence of encroachment; locked gates prevent access. Additional measures DOE is undertaking to reduce or eliminate risks on both the terrace and the floodplain are discussed in Sections 4 and 5.

## 2.2 Summary of Previous Investigations and Key Submittals

As stated in the introduction to this report, this evaluation is the fourth in a series of key submittals addressing the Shiprock site conceptual model and/or compliance and remediation strategies. The three previous submittals are the SOWP (DOE 2000), the GCAP (DOE 2002a), and the 2005 Conceptual Model Report (DOE 2005), considered the springboard to this evaluation. However, numerous other investigations have been conducted to attempt to better understand the complex hydrogeology and technical aspects of the site. The historical overview provided in Table 2 demonstrates the evolving nature of site activities and the significant work that has been done to date.

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<sup>5</sup> The term "natural flushing" refers to a combination of natural physical, chemical, and biological processes that reduce contaminant concentrations in soil or groundwater over time. Provisions in 40 CFR 192 allow for natural flushing as a compliance strategy if contaminant concentrations will decrease to acceptable levels within 100 years and if institutional controls (discussed in Section 2.1.3) are applied.

<sup>6</sup> ICs, which rely on local acceptance and enforcement, are defined as non-engineered instruments such as administrative and/or legal controls that maintain protection of human health and the environment by limiting land or resource use.

<sup>7</sup> Agreement DE-RO01-04LM70007, effective June 16, 2004, was renewed for 5 more years in May 2008 and will be effective until May 2013.

Table 2. Summary of Key Site Documents, Previous Investigations, and Remediation Activities

Evaluation or Activity	Date <sup>a</sup>	Summary (Description)
Baseline Risk Assessment of Groundwater Contamination at the Uranium Mill (DOE 1994)	April 1994	Detailed evaluation of potential risks to both human and ecological receptors. Based on this evaluation, seven COCs were identified: nitrate, sulfate, uranium, selenium, ammonium, manganese, and strontium.
Programmatic Environmental Impact Statement (DOE 1996)	1996	Sets the stage for compliance strategy development and the observational approach used to evaluate Shiprock site conditions.
Composition of Salt Deposits (DOE 1999)	July 1999	Study involved collection and analysis of salt deposits at the site (terrace, floodplain, and Bob Lee Wash), Many Devils Wash, and background areas. Thirty-six samples of salt deposits were collected. Results confirmed elevated levels of uranium, nitrate, and sulfate at the site; uranium levels at Many Devils Wash were comparable to background. Nitrate, selenium, and sulfate levels were also elevated in background samples. In fact, the highest selenium concentration (67 milligrams per kilogram) was from a background location approximately 1.5 miles east of the site (along the escarpment). Overall, results affirmed that some groundwater contamination may be attributable to natural sources.
Final Site Observational Work Plan (SOWP) (DOE 2000)	November 2000	Finalized in November 2000, this document was developed over a period of years based on numerous studies and investigations. Most of the field investigations supporting the SOWP took place in 1999. A comprehensive technical report documenting the site characterization and modeling efforts underlying the selection of the initial site compliance strategy, the SOWP lays the groundwork for subsequent investigations and initial assumptions underlying the 2005 Conceptual Model Report.
Biological Assessment for Groundwater Remediation (DOE 2001a)	April 2001	Developed for the USFWS, this report evaluates potential impacts associated with planned remediation in relation to the Endangered Species Act.
Disposal Cell Cover Moisture Content and Hydraulic Conductivity (DOE 2001b)	May 2001	Because percolation of precipitation through the disposal cell cover and tailings is a potential source of continuing groundwater contamination, this study (requested by the Navajo Nation) was conducted to evaluate evidence of water movement through the Shiprock disposal cell cover. The 2001 report presents methods and results of physical property tests of cover materials, hydroprobe monitoring results of soil moisture profiles in the cover from June 1999 through September 2000, and in situ measurements of the saturated hydraulic conductivity. This study served as a catalyst for revisiting assumptions about disposal cell design and performance.
Environmental Assessment (EA) (DOE 2001c)	September 2001	Contains details of the selected compliance strategy and environmental impacts.
Piezocone Investigation (DOE 2002b)	February 2002	As part of a screening-level investigation of in situ moisture conditions within the disposal cell, 29 piezocone soundings were made on the disposal cell. Results of the investigation indicated that moisture is present in both saturated and unsaturated conditions. This report recommended a second investigation phase to: (1) quantify the extent of the saturated slimes; (2) determine soil moisture characteristics of the cover and tailings; and (3) physically measure in situ moisture conditions.

Table 2 (continued). Summary of Key Site Documents, Previous Investigations, and Remediation Activities

Evaluation or Activity	Date <sup>a</sup>	Summary (Description)
Hydrologic Evaluation of Landfill Performance (HELP) Modeling (Knight Piesold and Company 2002)	2002	To refine estimates of cell leakage and to evaluate optimal methods for remediation of groundwater at the site, the HELP model was used to simulate infiltration of precipitation through the disposal cell. Results of this modeling yielded flux estimates ranging from 2.5 to 4.8 gpm. As discussed later in this report, the seepage flux draining from the disposal cell remains uncertain.
Ground Water Compliance Action Plan (GCAP) (DOE 2002a)	2002	Documents DOE's initial compliance strategy, which is still evolving. Nearly a decade has passed since the assumptions underlying the GCAP were initially formulated. DOE expects to reissue the GCAP to better reflect the data obtained and observations made since active remediation began in March 2003.
Active groundwater remediation begins and Baseline Performance Report prepared (DOE 2003a).	2003	DOE initiates active remediation of groundwater on the terrace and floodplain using extraction wells and interceptor drains. The Baseline Performance Report documented the site conditions at that time.
Wildlife Management Plan (DOE 2003b)	2003	Developed in consultation with the USFWS and the Navajo Nation, the plan describes DOE's proposed measures for minimizing potential adverse effects to wildlife associated with the evaporation pond.
Refinement of Conceptual Model (DOE 2004, March)	2004	This document, a major predecessor to this strategy evaluation, was developed from data obtained and observations made during the first year of remediation system operation. The report evaluates the prior conceptual model described in the SOWP and proposes refinements to both the site conceptual model and the remedial strategy.
Reissue of Conceptual Model Report (DOE 2005)	2005	Same as the previous report (DOE 2004), except that it was reissued to incorporate an addendum documenting DOE's proposed decision process for evaluating the effectiveness of the remediation strategy.
Instrumentation of remediation system wells and drains with automated data collection system, referred to as System Operation and Analysis at Remote Sites (SOARS).	2004–2005 (ongoing)	Critical to monitoring the remediation system performance, this real-time data collection system allows personnel to remotely identify problems so they can be quickly remedied and facilitates the quantitative evaluation of system component performance.
Initiation of phytoremediation (DOE 2008)	2006	Four 15-meter × 15-meter irrigated phytoremediation test plots were established in 2006—two on the terrace above the escarpment and two in the radon-cover borrow pit.
Enhancement to the floodplain remediation system; see DOE 2009c for evaluation of initial findings (studies are ongoing).	2006	In spring 2006, two additional groundwater withdrawal systems consisting of horizontal wells in excavated trenches (Trench 1 and Trench 2) were installed in the alluvial aquifer near the base of the escarpment.
Detailed (One-Time) Sampling on Floodplain	January 2008	In January 2008, all existing floodplain wells were sampled and analyzed for contaminants, major ions, and field parameters. A line of seven wells on the terrace, just at the top of the floodplain escarpment, was also sampled. This effort was aimed primarily at delineating the distribution of contaminants at the time and to provide a baseline for future remediation efforts at Trenches 1 and 2.

Table 2 (continued). Summary of Key Site Documents, Previous Investigations, and Remediation Activities

Evaluation or Activity	Date <sup>a</sup>	Summary (Description)
Pilot Study Status Report of Natural and Enhanced Attenuation (DOE 2008)	June 2008	Documents initial findings and observations at Shiprock phytoremediation test plots and natural and enhanced attenuation of soil and groundwater contaminants at the Shiprock site.
Trench 2 Evaluation (DOE 2009c)	March 2009	This comprehensive evaluation of Trench 2 concluded that the Trench 2 remediation system successfully intercepts contamination discharging across the Mancos Shale escarpment and creates a zone of non-contaminated water between the trench and the river. Thus, Trench 2 is meeting its design objectives. (A similar evaluation is planned for Trench 1.)
Initial submittal of the midterm strategy evaluation (DOE 2009b)	January 2009	The initial (outline) version of the updated strategy evaluation presented herein. DOE sought input from stakeholders on this initial draft; responses to comments are provided in Appendix A.
Many Devils Wash Investigations	2010 (in preparation)	DOE recently initiated several studies aimed at reducing exposure in Many Devils Wash and intended to further investigate the source and nature of elevated levels of constituents (nitrate, selenium, and sulfate) in the wash.

<sup>a</sup> In the case of documented investigations, the date field in the second column corresponds to the date the report was issued (as noted in reference citation), even though underlying investigations may have spanned a period of years.

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### 3.0 Summary of Previous Recommendations and Refinements

As discussed in Section 1, DOE's first performance evaluation of the remediation system was performed in 2004, as documented in the Conceptual Model Report (DOE 2005). The purpose of that report was to assess the design of the groundwater treatment system based on a reevaluation of the site conceptual model<sup>8</sup> and to provide recommendations for improvement of the system. The addendum to that report established a framework and decision process for future evaluations of the groundwater remediation strategy. This section summarizes those recommendations and refinements. The bulk of this summary is provided in the flow diagrams in Figures 2 and 3, which represent a graphical version of the decision process documented in the addendum for the terrace and floodplain, respectively. The figures also present an overview of the current status of remediation (as of 2010), which is discussed in more detail in Section 4. The matrix table in Attachment 1, which is organized by site area, summarizes past, ongoing, and planned future activities.

#### 3.1 Terrace

The compliance strategy for the terrace is active remediation with the objective of dewatering the alluvial portion of the terrace system. As a result of this dewatering, (1) migration of site-related contamination to the western portion of the terrace would be curtailed, (2) flow of contaminated water to Bob Lee Wash and Many Devils Wash would be significantly reduced, (3) flow to seeps along the escarpment and along the distributary channel would be reduced, and (4) discharge of contaminated groundwater to the floodplain would decrease (DOE 2000, DOE 2002a, DOE 2005). As shown in Figure 2, the extraction objectives for the terrace decision process presented in the July 2005 addendum followed four determinations:

- Near-term—Can new wells and the existing extraction system achieve extraction objectives (8 gpm)?<sup>9</sup>
- Near-term—If "No" to (1), can a combination of wells and vegetation achieve extraction objectives (8 gpm)?
- Longer-term—Is extraction curtailing flow to the west terrace as predicted?; and
- Longer-term—Is pumping reducing contaminant discharges to the washes and seeps?

Recommendations intended to meet these objectives are discussed in Section 6 of the 2005 Conceptual Model Report. These recommendations, addressed in detail in Attachment 1, are summarized only briefly here.

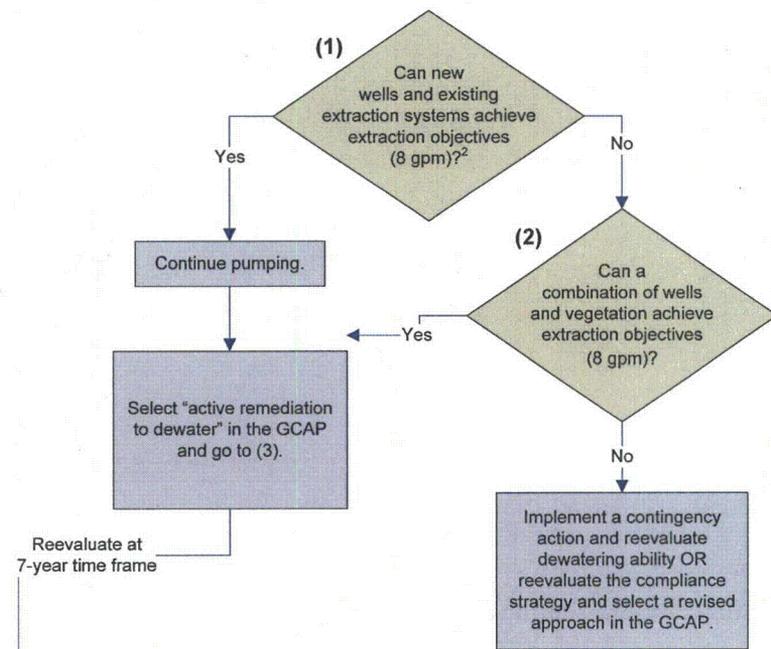
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<sup>8</sup> The 2005 Conceptual Model Report described refinements to the site conceptual model and modifications to the previous understanding of the groundwater system. The reader is referred to that document for details, as this strategy evaluation is focused on the remedial strategy.

<sup>9</sup> The 8 gpm terrace extraction objective was based on groundwater modeling results presented in the SOWP, Section 4.5.5 (DOE 2000). This modeling effort was designed to evaluate the time required for Many Devils Wash and Bob Lee Wash to become hydraulically isolated from the buried channel south of the disposal cell and the groundwater that originates as drainage from the disposal cell. At that time, the model included an extraction system for the terrace consisting of a combination of two extraction wells and two interceptor trenches and the total groundwater extraction rate for the terrace system was expected to stabilize at 8 gpm.

**Terrace Decision Process**  
 Source: DOE 2005 (Addendum 1, Exhibit 1)

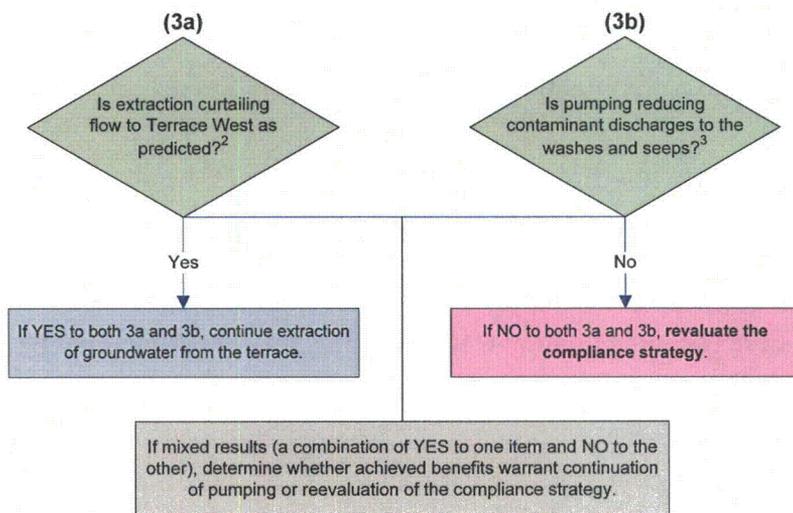
**(1 and 2)  
 Near-Term (3 Years) Decisions Based on Current Field Effort:<sup>1</sup>**



**Overview of Current Status (2010, approximately 5 years)**

- As of October 2010, despite expansion of the extraction system, the 8 gpm objective has not been achieved. For the last 2 years, total combined terrace extraction rates have been about 2 gpm, well short of the 8 gpm goal.
- Although the 8 gpm extraction objective has not been attained, progress has been made in terms of the overall dewatering objective (see below). The extent to which this is due to pumping or other influences (e.g., cessation of irrigation on the west terrace and/or drought conditions) is not clear.

**(3) Longer-Term Decisions (7 Years; 2012) Based on Presumed System Operation:**



**Preliminary Overview of Current Status for 2012 Decision Endpoints:**

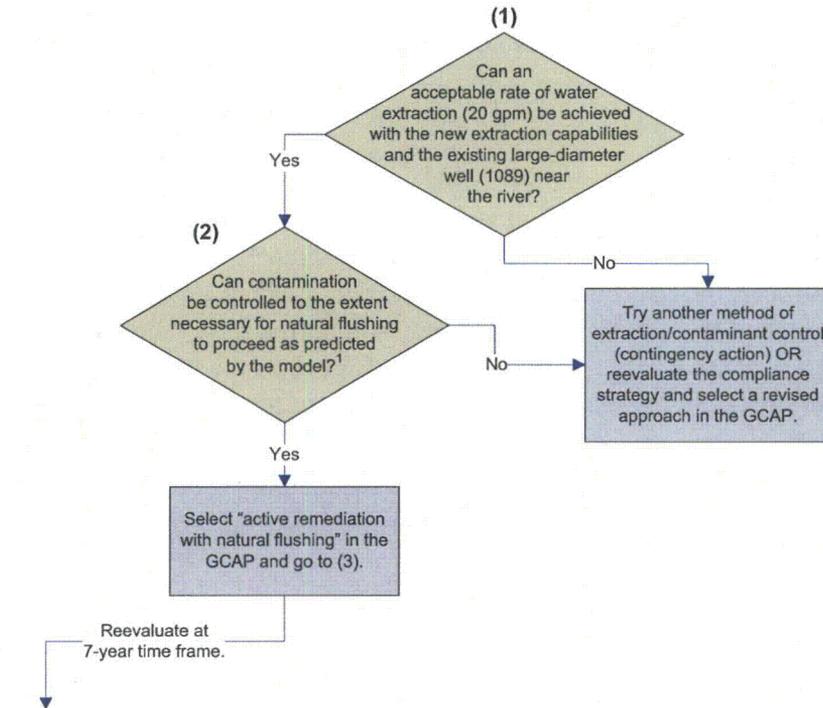
- Although it is premature to evaluate the long-term decision endpoints at this time, some interim observations can be made:
- As shown in Figure 5, water levels have declined, particularly in the western portion of the terrace. However, the extent to which flow to the west terrace has been "curtailed" is not clear.
  - Many seeps on the west terrace have dried up. Also, flows at escarpment seeps 0425 and 0426 have been below the 0.9 gpm goal (see Note 3); now at ~0.3 gpm; contaminant concentrations have not declined, however.
  - It is not clear if flow reductions, if any, at Bob Lee and Many Devils Washes, are attributable to remediation, as there are several influences on wash flows—e.g., precipitation, engineering issues (clogging of drains), and natural variations in groundwater flows.
  - Despite the drying up of some seeps and/or reduced flow rates, no significant decline in contaminant concentrations is apparent at terrace monitoring locations.

<sup>1</sup> October 2010 (date of this report) marks the midpoint between the near-term and long-term evaluation points.  
<sup>2</sup> The 2005 addendum established a criterion of a 1-ft water level drop over a period of 7 years (as evidence of significant progress). As discussed in the text, there is no longer any technical basis to support the presence of a groundwater divide between Terrace East and Terrace West.  
<sup>3</sup> To satisfy this condition, the addendum stated that the average combined flow from seeps 426 and 427 during the 7th year of the evaluation must decrease to 0.9 gpm or less. Also note that the seep 427 location no longer applies; seeps 425 and 426 are now the representative escarpment seeps.

Figure 2. Terrace Decision Process

**Floodplain Decision Process**  
 Source: DOE 2005 (Addendum 1, Exhibit 2)

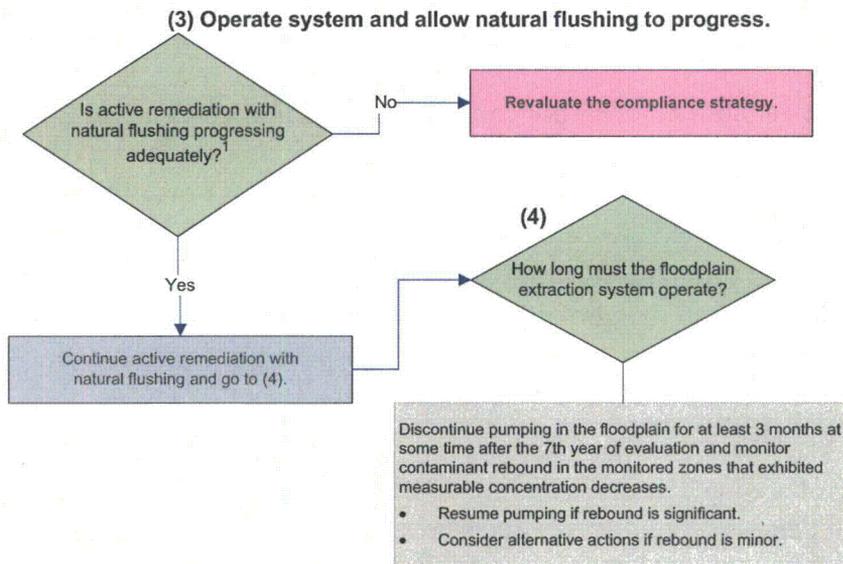
**(1 and 2)**  
 Near-Term (3 Years) Decisions Based on Current Field Effort:



**Overview of Current Status (2010, ~5 years)**

- At the time this decision matrix was developed, it was recognized that wells 1089 and 1104 were not meeting objectives. In 2006, DOE installed two trenches at the base of the escarpment to improve extraction rates. The 20-gpm rate is now being achieved.
- Decreases in contaminant concentrations (uranium, sulfate, nitrate) are apparent in a number of floodplain wells (DOE 2009a).
- In large part, because of the two trenches, progress has been made in terms of extraction rates and contamination control.

**(3 and 4)**  
 Longer-Term Decisions (7 Years; 2012) Based on Presumed System Operation:



**Preliminary Overview of Current Status for 2012 Decision Endpoints:**

- Although it is premature to evaluate the long-term decision endpoints at this time, some interim observations can be made:
- Significant declines in contaminant concentrations are evident in trench area wells.
  - Contaminant concentrations in well 1089 area are variable, and no clear conclusions can be drawn at this time.
  - Although studies are ongoing, the trenches appear to be effective in extracting contaminated water from the floodplain and reducing contaminant concentrations in nearby groundwater (DOE 2009c).

<sup>1</sup> To satisfy this criterion, the addendum stated that the arithmetic average of measured concentrations of nitrate, sulfate, and uranium in selected floodplain monitoring wells would have to be noticeably reduced from the arithmetic average of measured concentrations in these same wells during the first year of evaluation. Wells slated for evaluation were to be located hydraulically downgradient of extraction wells and trenches relatively close to the escarpment, and upgradient of the two large-diameter wells close to the river. Consequently, there is some subjectivity in the determination as to whether the floodplain remediation is progressing adequately and/or meeting the model predictions.

Figure 3. Floodplain Decision Process

To increase groundwater extraction rates from the terrace, improve the efficiency of extraction wells, and reduce or eliminate potential exposures to contaminated groundwater discharging at seeps, the following measures were recommended: installation of new extraction and monitoring wells (refer to Attachment 1 for details); development and plumbing of seeps 425 and 426; and well restoration activities. In addition, the report recommended that DOE design and conduct a pilot-scale investigation using deep-rooted plants to enhance evapotranspiration in the radon-cover borrow pit. DOE's progress toward meeting these objectives is discussed in Section 4.

## 3.2 Floodplain

The compliance strategy for the floodplain is active remediation, supplemented by natural flushing. At the time both the GCAP and the 2005 Conceptual Model Report were developed, active remediation (i.e., extraction of groundwater from the contaminant plume on the floodplain close to the San Juan River) was considered a best management practice (see DOE 2005, Section 5.2). DOE has since modified its position on this point, and active remediation is now considered the dominant strategy (refer to Table 1). As shown in Figure 3, the extraction objectives for the terrace decision process presented in the July 2005 addendum followed four determinations:

- Near-term—Can an acceptable rate of water extraction (20 gpm) be achieved with the new extraction capabilities and the existing large-diameter well (1089) near the river?
- Near-term—Can contamination be controlled to the extent necessary for natural flushing to proceed as predicted by the model?
- Longer-term—Is active remediation with natural flushing progressing adequately?
- Longer-term—How long must the floodplain extraction system operate?

Recommendations intended to meet these objectives are discussed in Section 6 of the 2005 Conceptual Model Report. These recommendations, addressed in detail in Attachment 1, are summarized briefly here.

- To increase groundwater extraction in the highly contaminated portion of the plume near the San Juan River, install an extraction well near extraction well 1077 and another well near monitoring well 0615 in the heart of the contaminant plume (for specific existing well locations, refer to Figure 6 in this report).
- To capture highly contaminated groundwater from the escarpment area to prevent it from migrating to the floodplain, construct two groundwater collection drains along the base of the escarpment.

## 3.3 Recommended Contingencies

In addition to the possibility of adding extraction and treatment capacities, the 2005 Conceptual Model Report recommended that other contingency measures be considered if groundwater cleanup was not expected within a reasonable time period. Possible contingencies included: (1) remediation of groundwater contaminants using chemical reactants; (2) installation of an interceptor drain and a permeable reactive barrier at the base of the escarpment; (3) installation of a flow barrier and interceptor drain at the base of the escarpment; and (4) extraction of contaminated groundwater beneath the disposal cell. It is still premature to evaluate these contingencies; this evaluation will be undertaken as part of the assessment of the long-term decisions in 2012.

## 4.0 Summary of Actions Since Last Review/Current Status

This section describes the site characterization and remediation activities performed since the Conceptual Model Report was developed, the progress made in terms of risk mitigation and performance of the groundwater remediation system, and the status of study endpoints. The reader is again referred to Figures 2 and 3 in the previous section and to the tabular summary in Attachment 1.

### 4.1 Terrace

This section begins by addressing the endpoints and recommendations discussed in the previous section—specifically, DOE's progress in attaining the terrace extraction objectives (Section 4.1.1). Sections 4.1.2 through 4.1.5 address related endpoints for terrace subareas where significant work has been done to either reduce risks or to provide further characterization.

#### 4.1.1 Terrace Remediation System—Progress Toward Meeting Extraction Objectives

As recommended in the Conceptual Model Report, DOE expanded the terrace extraction well network between 2005 and 2007. Two new wells (1095 and 1096) were installed near the evaporation pond in March 2005, and in September 2007, DOE installed a new large-diameter well (1093R) to increase the probability of collecting a larger volume of water (see Attachment 1). As of September 2010, despite expansion and enhancement of the terrace extraction system, the 8 gpm objective has not been achieved. The combined pumping rate from terrace extraction wells has ranged between 2 and 4 gpm since remediation started (2 gpm in the last 2 years), well short of the 8 gpm objective (Figure 4).

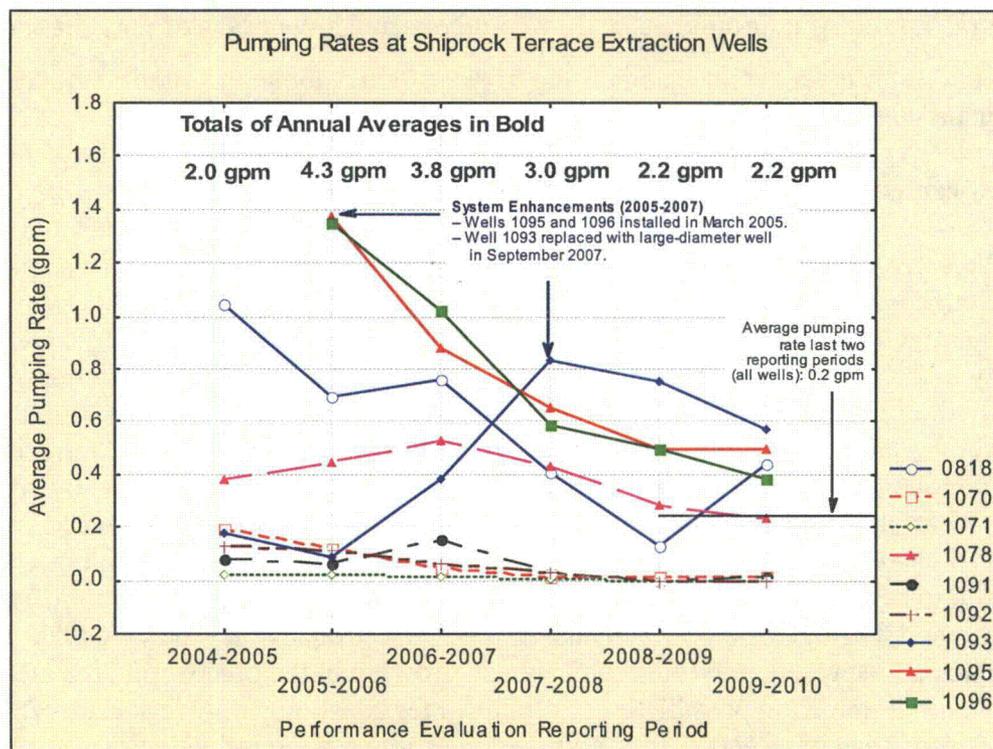


Figure 4. Pumping Rate Summary for Terrace Extraction Wells

Since 2005, DOE has also redeveloped several wells on the terrace to improve well yields. These and other well restoration methods proved ineffective. During pumping tests performed in 2008, the wells evaluated in the immediate vicinity of the current system did not produce enough water to justify adding any additional infrastructure.

Although the 8 gpm extraction objective has not been attained, progress has been made in terms of the overall dewatering objective (see below). The extent to which this is due to pumping or other influences—such as cessation of irrigation on the west terrace (which was phased out between 2003 and 2004) and/or drought conditions—is not clear. As shown in the decision process in Figure 2, although it is premature to evaluate the long-term decision endpoints at this time (curtailing of flow to the west terrace and reducing contaminant discharges to the washes and seeps), some interim observations can be made:

- As shown in Figure 5, water levels on the terrace declined, particularly in the western portion of the terrace. Groundwater elevations measured in 26 groundwater wells in March 2010 have decreased relative to the baseline period of January 2000 to March 2003. A corresponding decrease in flow from seeps along the floodplain and in areas of the western portion of the terrace has also been observed. However, the extent to which flow to the west terrace has been curtailed is not clear.
- Many seeps on the west terrace are now dry, and have been for the last several years (Figure 5). Also, flows at escarpment seeps 0425 and 0426 have been below the 0.9 gpm goal (see Figure 2, Note 3) for some time (current flows are about 0.3 gpm); contaminant concentrations in these seeps have not declined, however.
- It is not clear whether flow reduction at Bob Lee Wash is attributable to remediation or to natural variations in groundwater flow. There has been no observed decrease in flow in Many Devils Wash, and influences such as precipitation, engineering issues (clogging of drains), and natural variations in groundwater flow could obscure any effects of remediation.
- Despite the water level declines and drying of seeps noted above, no significant decline in contaminant concentrations is apparent at terrace monitoring locations.

#### **4.1.2 Phytoremediation (Groundwater Extraction by Plants)**

As discussed above, active remediation (pumping) is not extracting as much terrace plume water as expected; this was anticipated in the decision process for the terrace groundwater remediation strategy (Figure 2, decision endpoint 2). Therefore, as recommended (DOE 2005), DOE initiated a pilot study in 2006 to evaluate the feasibility of phytoremediation (groundwater extraction by plants) for hydraulic control (DOE 2008). Four irrigated 15-meter by 15-meter phytoremediation test plots were established in 2006. Two test plots have been maintained on the terrace above the escarpment on the northeast side of the disposal cell, and two in the radon-cover borrow pit (Figure 1). Water isotope signatures, a major endpoint of the pilot study, can be used as evidence of whether volunteer phreatophytes have rooted into the shallow groundwater plumes and can thus be useful to assess the feasibility of enhancing phytoremediation and hydraulic control. In 2007, oxygen and hydrogen isotope analysis of plants and groundwater indicated that volunteer tamarisk, black greasewood, and fourwing saltbush growing in the borrow pit area are likely extracting water, nitrate, and possibly other groundwater constituents. A few scattered black greasewood plants that have established on the terrace above the floodplain are also likely removing water that might otherwise surface in contaminated seeps at the base of the escarpment.

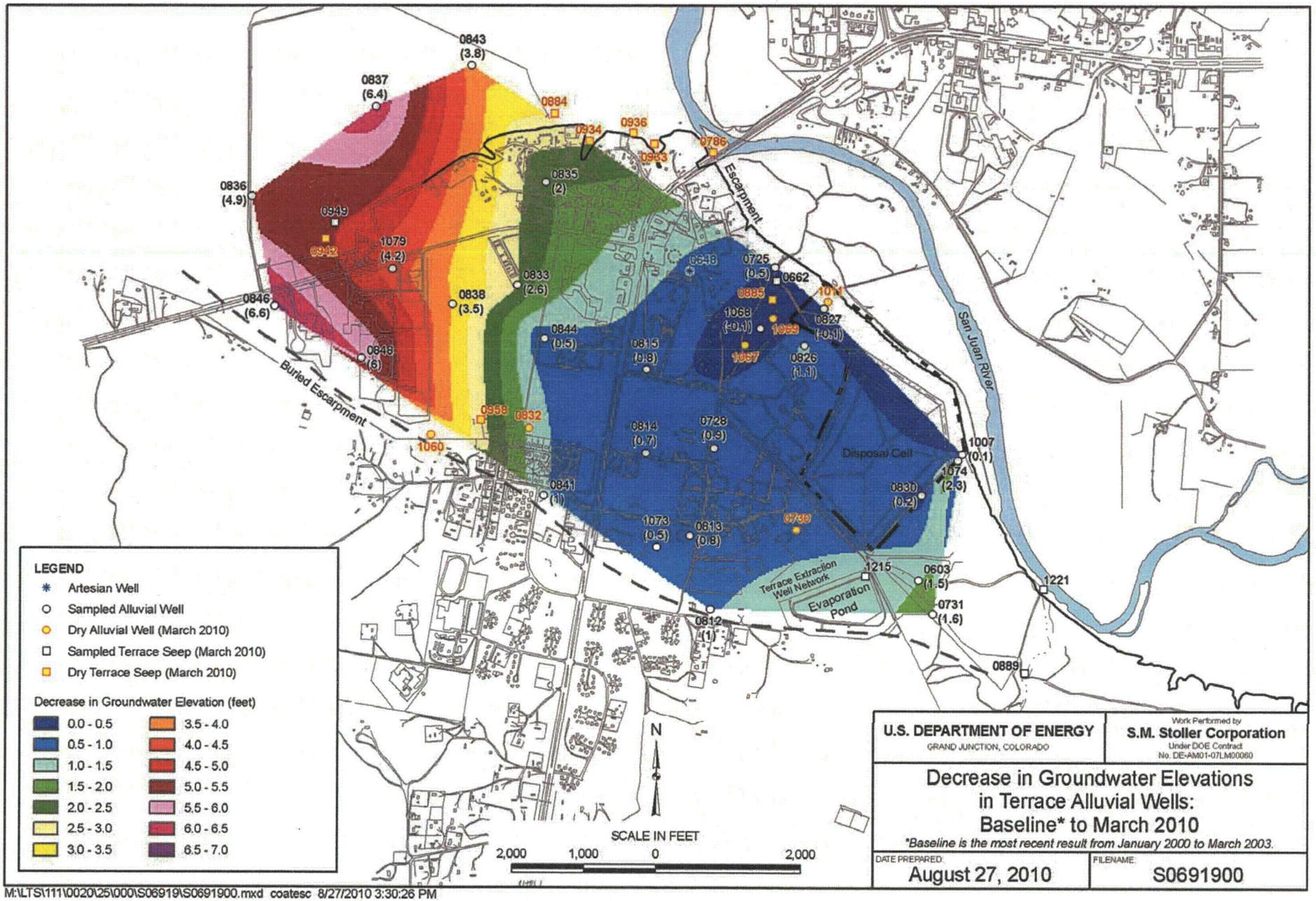


Figure 5. Decrease in Groundwater Elevations in Terrace Alluvial Wells (March 2003—March 2010)

### **4.1.3 Evaporation Pond**

A key component of the terrace remediation system, the 11-acre evaporation pond is the collection point for contaminated groundwater from extraction wells on the terrace and the two collection trenches and extraction wells on the floodplain. The volume of contaminated water being sent to the evaporation pond has increased significantly since the floodplain trenches were installed in the spring of 2006 (see Section 4.2). This increased volume of water has allowed algae to develop in the pond, which could potentially attract migratory birds.

When active remediation began in 2003, in consultation with USFWS and the Navajo Nation, DOE developed a Wildlife Management Plan (DOE 2003b). This plan established a phased approach for minimizing potential adverse effects to wildlife based on systematic observation of the pond and the surrounding area. The three phases established were monitoring, deterrence, and contingency. The monitoring component was greatly enhanced in 2004–2005, when the pond was instrumented with DOE's automated data collection system, referred to as System Operation and Analysis at Remote Sites (SOARS). This technology, applied at key features of the Shiprock site remediation network, allowed monitoring of water levels in the pond and, later, installation of cameras instrumented with telemetry.

Based on pond monitoring in the last several years, USFWS indicated that elevated concentrations of selenium in the pond may be bioconcentrating in the algae, which is a food source for the migratory birds. Selenium is toxic to wildlife, particularly migratory birds. Although very few birds have been observed (using both telemetry cameras and human observation) visiting the pond, USFWS expressed concern about migratory birds consuming algae as a food source. DOE reviewed information provided by the USFWS on the uptake of selenium in migratory birds and concluded that the most effective way to mitigate the exposure to selenium is to eliminate the food source (algae) from the pond. The proposed approach to remove the algae was to add dye to pond, which greatly reduces that amount of sunlight available to the algae, killing most of the plants. In June 2010, after coordinating with NN AML/UMTRA and local residents, DOE began adding dye to the evaporation pond to block sunlight as a way to kill the algae. DOE will continue adding dye to the pond on a semiannual basis.

Water levels in the pond continue to be monitored using the SOARS telemetry system, and actions to maintain pond elevations are being implemented, such as alternate pumping of floodplain trenches.

### **4.1.4 Disposal Cell/Cover Investigations**

Although not addressed in the Conceptual Model Report in the context of the terrace remediation strategy, the disposal cell has been an ongoing concern of stakeholders. For example, in their conditional concurrence with the GCAP, NRC stated that continued monitoring and study of the contaminant flux from the disposal cell was required and that groundwater geochemistry should be monitored at a few additional wells around the disposal cell (NRC 2003).

To address these concerns, DOE is currently investigating water balance issues associated with the disposal cell and the terrace. Historical records of the milling operations have been reviewed to estimate water use while the site was operational and to evaluate the potential residual or

transient water present in the tailings when the cell was constructed. Historically, DOE has funded several investigations of the disposal cell cover as an indicator of cell performance. Results of these studies are summarized below:

- Neutron hydroprobe ports in the top slope of the disposal cell were monitored between 1999 and 2001. Results showed that standing water in the bottom of the probe ports throughout the monitoring period indicated saturation in the upper tailings where the hydroprobes were inserted in the cell.
- In 2005, DOE measured the saturated hydraulic conductivity, a measure of soil permeability, at five locations on the cover top slope using air-entry permeameters; 20 tests were conducted. The results indicated that saturated hydraulic conductivity was highly variable, ranging between  $10^{-8}$  and  $10^{-4}$  centimeters per second (cm/s). However, in 1989 disposal cell designers assumed that the saturated hydraulic conductivity was  $10^{-7}$  cm/s (DOE 1989a; DOE 1989b).
- In 2007 (part of the same study noted above, but sampled from the top of the tailings), oxygen and hydrogen isotope analysis of water extracted from neutron hydroprobe ports in the upper tailings suggested that the tailings water is likely local rainwater, both summer and winter rainwater, percolating through the upper disposal cell cover.

These limited studies have indicated a high variability in measurements of soil hydraulic properties and large uncertainty in calculations of percolation flux. Although no specific studies are currently planned, DOE will continue to investigate cell performance as a best management practice.

#### **4.1.5 Many Devils Wash**

Located about one-half mile east of the disposal cell, Many Devils Wash drains an area of about 11.5 square miles and enters the San Juan River just upstream of Shiprock. Although a focus of previous site investigations in terms of site characterization, the wash had not been specifically targeted for remediation until recently. This area is now a major focus of DOE's ongoing investigations because groundwater seepage and ponded water containing elevated concentrations of nitrate, selenium, sulfate, and uranium occur in many places along the wash. The ponding occurs from the drain sump south to the confluence of the East Fork of the wash and along the main channel. Although variable in volume, water is consistently present. Furthermore, reduction of contaminant discharges to the wash was a major criterion established for the longer-term terrace decision process (Figure 2). However, unlike trends observed at Bob Lee Wash, flows at Many Devils Wash have not decreased. Despite several attempts at engineering controls (summarized below and in Attachment 1), decreased flows in the wash and at seeps have not been observed.

To limit exposure to the surface water in Many Devils Wash, two interim actions were conducted in the summer and fall of 2000. The wash was fenced to prevent access by cattle, and a cobble blanket was used to cover contaminated pools. In July 2001, flooding caused major removal of the cobble blanket, rendering it ineffective for exposure control. In November 2002, a 400-ft-long collection drain was installed in the wash to capture surface water and shallow groundwater; it began operating in March 2003. Captured contaminated water is removed from the wash by pumping to the evaporation pond.

Flow rates and water levels in the collection sump were instrumented in December 2005 and connected to SOARS for real-time monitoring. The efficiency of the collection drain decreased over time in part because accumulation of fines is limiting the infiltration of surface water. To help capture the contaminated surface water, a diversion dam was built in August 2009. The wash has since dried up for about 300 ft downstream of the diversion dam. However, perennial pools of water persist upstream of the diversion structure and downstream of the knickpoint, an erosion resistant outcrop of bedrock that forms a small waterfall.

Recent (non-engineered) controls undertaken to limit exposure and reduce risks include the repair of fencing and installation of warning signs. In April 2010, approximately 20 new warning signs were posted in the area of the wash. Additional characterization or risk reduction measures are documented in Attachment 1.

To investigate the source of elevated contaminant levels in the wash, in spring 2010 DOE began a detailed investigation of the geology and groundwater chemistry in Many Devils Wash in an attempt to determine the source of contaminants in the wash. The contaminants—nitrate, sulfate, selenium, and uranium—are similar to those found in groundwater near the disposal cell. However, paradoxically, the seeps occur on the east wall of the incised wash but not on the west side of the wash, which is closer to the disposal cell and in a position hydrologically that is more likely to receive site groundwater. The extent to which these are naturally occurring cannot be determined at this time, because lack of groundwater in candidate background locations has prevented characterization of background conditions on the terrace (see Attachment 1 for further discussion). As a result, the origin of contaminants in Many Devils Wash—whether mill-related, reflecting background conditions and characteristics of Mancos Shale, or a combination of both—remains unclear.

## **4.2 Status of Floodplain Remediation**

Efforts undertaken on the floodplain since the Conceptual Model Report was issued are detailed in Attachment 1. These efforts included installation of 26 additional floodplain monitoring wells since 2005 (Figure 6). Most notable is the installation of two additional groundwater withdrawal systems consisting of horizontal wells in excavated trenches—Trench 1 and Trench 2—in spring 2006. These trenches were installed in the alluvial aquifer near the base of the escarpment. It was believed that the pumping of these horizontal wells would result in greater groundwater extraction rates than had previously been achieved at either of the two vertical wells on the floodplain, particularly given that the length of each horizontal well is 200 ft. Trench 1 and Trench 2 were expected to intercept much, if not all, of the contaminated water migrating across the Mancos Shale escarpment, thereby reducing the contaminant mass reaching portions of the alluvial aquifer between the bedrock escarpment and the river. The detailed Trench 2 evaluation indicates a large capture zone exists around this trench.

### **4.2.1 Recent Floodplain Assessment (Trench 2 Study)**

DOE issued a report in March 2009 that evaluated the effectiveness of the Trench 2 remediation system in the southern part of the floodplain (DOE 2009c). The trench and the horizontal collection well installed in it are located near the base of the Mancos Shale escarpment.

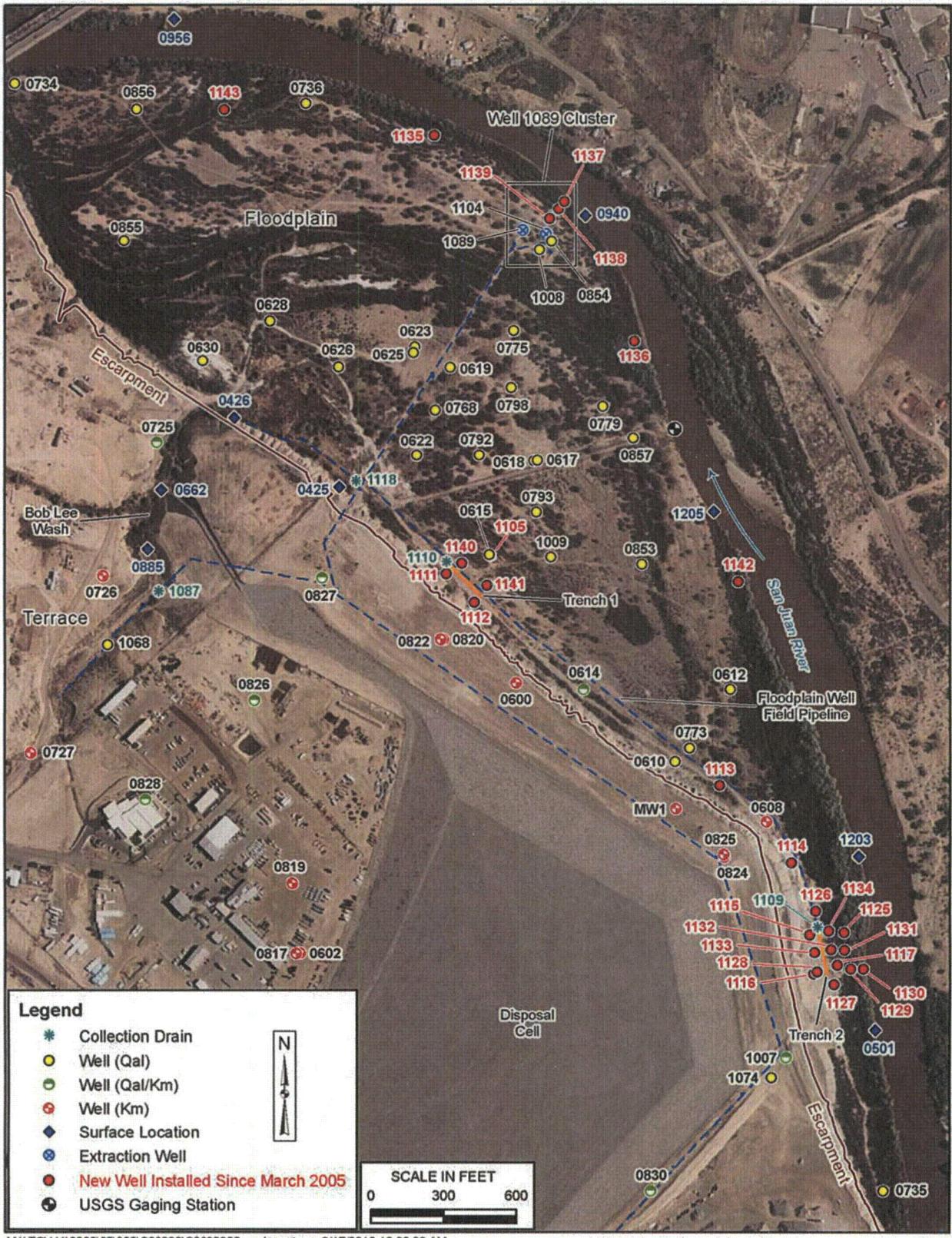


Figure 6. Subset of Shiprock Sampling Network Showing Floodplain Wells Installed Since 2005

The report concludes that the Trench 2 remediation system has met its design objectives, which are to:

- Intercept contamination in groundwater that may be flowing across the Mancos Shale escarpment to prevent it from migrating eastward and discharging to the San Juan River;
- Remove large quantities of dissolved contaminant mass from floodplain groundwater; and
- Create a zone of uncontaminated water between the trench and the river as well as at substantial distances north and south of the trench.

The report shows that much of the success of the Trench 2 remediation system can be attributed to its ability to induce inflow of river water into the alluvial aquifer underlying the floodplain. Accordingly, the freshwater zone created between the trench and the river consists almost solely of river-derived water. Observed decreases of contaminant concentration in groundwater lying between the trench and the Mancos Shale escarpment since pumping at the trench began suggest that river water is also drawn into this area, diluting the water discharging across the escarpment.

The Trench 2 system has been monitored since spring 2006; monitoring consisted primarily of pumping rate, water level, and specific conductance data from 15 monitoring locations that are part of the SOARS data collection and analysis system. Since groundwater extraction began at Trench 2 in spring 2006, the pumping rate has typically ranged between 12 and 20 gpm and has averaged about 17 gpm. The average rate comes very close to meeting the objective of reaching a long-term pumping rate of 20 gpm from all wells and trenches on the floodplain, as established in the 2005 Conceptual Model Report.

#### **4.2.2 Status of Floodplain Remediation**

As indicated in Figure 3, at the time the decision matrix was developed<sup>10</sup> (DOE 2005 addendum), it was recognized that wells 1089 and 1104 were not meeting objectives. In 2006, DOE installed the two trenches at the base of the escarpment to improve extraction rates. The 20-gpm rate is now being achieved, and decreases in contaminant concentrations (uranium, sulfate, nitrate) are apparent in a number of floodplain wells (DOE 2009a). In large part, because of the two trenches, progress has been made in terms of extraction rates and contamination control.

Although it is premature to evaluate the long-term decision endpoints at this time, some interim observations can be made: Significant declines in contaminant concentrations are evident in trench area wells. Contaminant concentrations in well 1089 area are variable, and no clear conclusions can be drawn at this time. Although studies are ongoing, the trenches appear to be effective in extracting contaminated water from the floodplain and reducing contaminant concentrations in nearby groundwater (DOE 2009c).

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<sup>10</sup> It is important to note that the decision process language (Figure 3) assumed natural flushing as the dominant remediation strategy. Observations since then, particularly since installation of Trenches 1 and 2 in 2006, clearly indicate that active remediation, the preferred strategy on the floodplain, is effective.

## 5.0 Summary of Ongoing Activities and Proposed Future Actions

The previous section demonstrated the progress and extensive enhancements undertaken since development of the 2005 Conceptual Model Report. Investigations are clearly ongoing and evolving. This section describes DOE's ongoing and planned activities and studies that are intended to evaluate unresolved issues and ensure protection of human health and the environment.

### 5.1 Terrace

#### 5.1.1 Terrace Extraction System

##### Ongoing

- Groundwater extraction on the terrace and monitoring of water levels will continue.
- Phytoremediation (groundwater extraction by plants) is ongoing; DOE will analyze the overall findings and data when the pilot studies end. An evaluation of the feasibility of phytoremediation on the terrace will continue, using deep-rooted plants to enhance evapotranspiration in the borrow pit area south of the disposal cell and also between the disposal cell and the escarpment above the San Juan River floodplain.

##### Planned

No activities or modifications are planned for the terrace extraction system at this time. The present system is not achieving demonstrable success. However, given that extraction rates have stabilized at about 2 gpm, well short of the 8 gpm goal, DOE is shifting the focus to other areas of the site where greater benefits may be achieved, as described below.

- DOE will further investigate the disposal cell as a continuing source of contaminants to the terrace and floodplain and will issue a report describing the results.
- DOE plans to develop a report documenting what is known about how the cell is performing, including approximations regarding the water balance. Drawing upon previous studies (including the initial cell design), this report will evaluate water balance estimates (and all assumptions and uncertainties associated with those estimates) and will also address potential risks if a complete exposure pathway is identified. The report will be a starting point; DOE does not expect to fully define the extent to which the cell is a continuing source of contamination. The issue is complex, and even with considerable additional site characterization, the extent of the contribution may never be definitively quantified.

#### 5.1.2 Many Devils Wash

##### Ongoing Activities

DOE will continue to implement measures to reduce risks in Many Devils Wash. Approximately 20 warning signs were posted on the fence surrounding the wash in spring 2010.

##### Planned Investigations at Many Devils Wash

Several areas of Many Devils Wash have surface water with elevated levels of nitrate, selenium, and sulfate. A primary focus is the mitigation of any potential exposures in the wash. To develop

a more holistic construction solution for the wash, DOE recently initiated a comprehensive study of the geology, groundwater movement, and water chemistry of the wash. Potential construction options from this study could include (1) installing a water collection system in the East Fork of the wash to curtail groundwater flows down the wash; (2) installing a water collection and pumping system in areas with surface water downstream of the existing water collection system; and/or (3) placing large rock in areas with surface water to reduce potential exposures.

DOE will also explore installing fencing at the East Fork of Many Devils Wash to keep livestock out of seeps. NN AML/UMTRA will coordinate with the grazing official for the Shiprock Chapter to determine if any access is restricted.

### **5.1.3 Terrace Background Characterization**

The inability to characterize background conditions has hindered the derivation of alternate concentration limits (usually required for an active remediation program) and also constitutes a data gap in DOE's attempts to identify a contaminant source in the wash. DOE has made numerous attempts to locate a representative background location for the terrace, and a representative area has not yet been identified. With additional consultation from representatives of the Navajo Nation, DOE plans to continue to search for a suitable background location for the terrace. Two additional (candidate) seep background locations were sampled during the spring 2010 sampling event: location 1218, about 2 miles southwest of the site, and Eagles Nest Arroyo (location 1220), about 5 miles northeast of the site.

### **5.1.4 Other Study Endpoints**

DOE is considering a pilot groundwater hot-spot remediation study at locations where concentrations of one or more contaminants (especially selenium, nitrate, and uranium) are higher. An aspect that confounds the implementation of this study is the fact that maximum concentrations of individual COCs do not occur in the same location.

## **5.2 Floodplain**

### **5.2.1 Well 1089/1104 Area**

#### Ongoing

DOE will continue to monitor groundwater chemistry and water levels in the floodplain.

#### Planned

A planned study will use river gauging station data and water temperatures to evaluate the interaction between the San Juan River and the alluvial aquifer. A study of the Trench 1 remediation system and pumping wells 1089 and 1104 near the San Juan River will include monitoring surface water levels and water temperatures in the river. Groundwater levels will be measured concurrently to evaluate flow directions between the river and the alluvial aquifer. Groundwater levels, water temperature, and specific conductance at multiple wells between Trench 1 and the San Juan River and from one location in the river itself are being measured continuously. Analysis of these types of data at three wells between the river and extraction wells 1089 and 1104 will be used to determine if the wells are inducing water losses from the

river. Temperature measurements will be compared during and shortly after flow events on the river that lead to significant, short-term variations in surface water temperature. It is also possible that pumping at Trench 1 could induce some of the river loss at upstream locations.

### 5.2.2 Trenches

#### Ongoing

DOE will continue to monitor Trench 2 and the well 1089 area.

#### Planned

Due to the success of the Trench 2 study, similar instrumentation is proposed for the Trench 1 horizontal well and for the well 1089 area. Measurements of groundwater specific conductance in Trench 2 have provided useful estimates of contaminant levels. All instrumented wells will feed conductivity and water level data to the SOARS system. Instruments in two alluvial wells in Trench 1 provide data to estimate horizontal well efficiency, and instruments in two alluvial wells on the escarpment side of Trench 1 monitor contamination entering the floodplain from the disposal cell area. Alluvial wells 1140 and 1141 were installed in May 2009 about 50 ft from Trench 1 and are also equipped with SOARS instrumentation (see Figure 6 for locations).

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## 6.0 Summary

The addendum to the Conceptual Model Report provided a process for selecting groundwater remediation and management activities in future years. It prescribed that site decisions on the groundwater strategy for both the terrace and the floodplain should be reevaluated in the near-term (3 years) and long-term (7 years). Long-term time frame decisions cannot be evaluated until approximately 2013, using data from 2012. However, those in the near-term time frame can be evaluated using data from 2008 to 2010.

The primary criterion used for the near-term terrace evaluation was to meet a groundwater extraction rate of 8 gpm or greater from pumping wells or a combination of pumping wells and phytoremediation. This has not been achieved, which, according to the 2005 addendum (DOE 2005), would imply it may be appropriate to reconsider the compliance strategy for the terrace.

The water levels in the terrace have decreased approximately 50 percent since pumping began. The reduction in terrace water levels has reduced the number of seeps and the flow rate from the active seeps in the escarpment. Contaminated surface water is present in Many Devils Wash, although additional water is being collected after the diversion structure was installed in the wash. DOE's highest priority is to continue to reduce the potential for exposure to contaminants at the site.

The goals for the floodplain in the near-term were to meet a groundwater extraction rate of 20 gpm and to control contamination for four key constituents (nitrate, selenium, sulfate, and uranium) to the extent necessary for natural flushing to proceed as predicted by the model. The 20 gpm extraction rate has been achieved, and concentrations of the three key constituents have decreased in some wells. This implies that DOE should continue extracting contaminated groundwater from the floodplain, and the groundwater compliance strategy for the floodplain does not need to be reevaluated at this time.

Seven years after initiation of active remediation in 2003, contaminant concentrations in floodplain groundwater are decreasing, and the installation of the two collection trenches appears to have enhanced the cleanup rate.

DOE's historical interpretation of site conditions led to the conclusion that more benefit would be derived from stressing the system through continued remediation than from additional characterization efforts (DOE 2005). That interpretation has changed somewhat as additional data became available, and the present approach is to continue remediation, but conduct a targeted characterization to address key issues, such as Many Devils Wash, to better understand site conditions and reduce uncertainty. The current interpretation is likely to continue to evolve as ongoing and planned studies yield additional data.

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**Attachment 1**

**Area-Specific Matrix Summarizing Key Aspects of the 2010 Midterm  
Strategy Evaluation**

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Attachment 1. Area-Specific Matrix Summarizing Key Aspects of the 2010 Midterm Strategy Evaluation<sup>a,b</sup>

Site Area	2005 Conceptual Model Report Recommendations and Previous Actions to Mitigate Risks	Summary of DOE Activities Since 2004–2005 and Current Status <sup>c</sup>	Ongoing or Planned DOE Activities	Comment(s)
Terrace <sup>d</sup> Groundwater Remediation System—Extraction Well Network	<ul style="list-style-type: none"> <li>Install three 6-inch-diameter extraction wells using a casing-advance drilling method—two near the evaporation pond and one farther west in the swale area. <i>Purpose:</i> To increase groundwater extraction rates on the terrace in the swale area.</li> <li>Improve efficiency of extraction wells using modern well-restoration methods.</li> </ul> <p><u>From Addendum (Terrace Decision Tree)</u></p> <ul style="list-style-type: none"> <li>Extract 8 gpm from new and existing wells</li> <li>Curtail flow to western portion of terrace</li> </ul>	<ul style="list-style-type: none"> <li>Extraction wells 1095 and 1096 were installed near the evaporation pond in March 2005 within 50 ft of wells 1057 and 1070, respectively. DOE delayed installation of the third-recommended well (planned for an area farther west in the swale area) pending evaluation of the performance of the enhanced well network.</li> <li>In September 2007, DOE replaced well 1093 with a new large-diameter well to increase the probability of collecting a larger volume of water. Initial flows were favorable but have decreased over time.</li> <li>DOE has redeveloped several wells on the terrace to improve well yields. Unfortunately, these efforts have had little impact on improving the extraction rates. Several well treatment/restoration methods were also attempted but proved ineffective.</li> <li>Two new wells—1120 and 1122—were installed in February 2007 in the northwest portion of the terrace to assess the nitrate concentrations at the leading edge of the nitrate plume. Nitrate concentrations in these wells were fairly low (&lt;1 mg/L), so although DOE had considered a phytoremediation test plot in this area, this was later deemed unnecessary.</li> </ul> <p>In terms of progress, the 8 gpm extraction rate proposed in the Addendum has not been achieved. However, water levels have declined, particularly on the western terrace, and most of the terrace seeps are now dry (see Figure 5 in the 2010 Review and Evaluation of the Shiprock Remediation Strategy report).</p>	<p><u>Ongoing</u></p> <p>Groundwater extraction on the terrace will continue.</p> <p><u>Planned</u></p> <p>No more well restoration attempts or expansion/refinements to terrace extraction well system are planned at this time (combined total pumping rates have stabilized at 2 gpm; see comment).</p> <p>DOE's focus has shifted to other areas where exposure is occurring (see planned activities in other areas below).</p>	<ul style="list-style-type: none"> <li>Experience gained from well installation, well development, low initial extraction rates, and decreasing extraction rates over time indicate limited continuity of saturated alluvium. Results so far suggest that much of the subsurface water occurs within low-permeability Mancos Shale.</li> <li>Options to collect significant volumes of groundwater from the terrace are limited, as demonstrated by the significant effort and cost to install the large-diameter well (1093), which currently yields less than 1 gpm. The remaining eight traditional extraction wells have yielded limited volumes of water even when water is initially intersected.</li> <li>DOE is awaiting input from the Navajo Nation as to whether the artesian well on the terrace above Bob Lee Wash can be decommissioned. Any remediation strategy would be adjusted to accommodate either option (plugging of the well or allowing continued flow).</li> </ul>
Terrace Seeps and Bob Lee Wash	<ul style="list-style-type: none"> <li>Develop and plumb seeps 425 and 426 to the evaporation pond. <i>Purpose:</i> To increase groundwater extraction from the terrace and to limit exposures to the environment.</li> <li>Install two new wells immediately upgradient of the Bob Lee Wash interceptor drain (1087) using a track hoe to key the wells into the Mancos Shale. <i>Purpose:</i> To increase collection of contaminated groundwater from the drain, which initially was not intercepting all the groundwater available in the lowermost part of the alluvium.</li> </ul>	<ul style="list-style-type: none"> <li>Developed and added collection piping to seeps 425 and 426, as planned.</li> <li>As recommended, two wells (1097 and 1098) were installed upgradient of the Bob Lee Wash interceptor drain and close to monitoring well 1068. These wells are not monitored but are instrumented with a solar pump to increase groundwater collection.</li> </ul>	<p>No planned activities—the seeps have been dry for several years, and Bob Lee Wash is also dry.</p>	<p>Given these findings, the major focus has shifted to Many Devils Wash (see following row).</p>

<sup>a</sup> To facilitate review, this table represents a cross-tab of the material provided in the 2010 Review and Evaluation of the Shiprock Remediation Strategy. It summarizes previous commitments and recommendations, all activities undertaken since the 2005 Conceptual Model Report was developed (both completed and ongoing), and identifies activities and evaluations that DOE is considering.

<sup>b</sup> Chapter 8 of the 2005 Conceptual Model Report mentions potential contingency options for the Shiprock site to be considered after 5 to 7 years. This table presents the current status of activities, which in some cases is not progressing as outlined in the 2005 Conceptual Model Report addendum. It is still premature to evaluate potential contingency options; DOE will delay this evaluation until the longer-term (2012) scheduled review.

<sup>c</sup> The 2005 Conceptual Model Report was first issued in March 2004 but was reissued in July 2005 to incorporate an addendum documenting the process for selecting remediation and management activities in future years. With the exception of the addendum, the document was unchanged from the initial March 2004 version. Therefore, some of the activities recommended in that document (e.g., installation of new terrace extraction wells) had already been accomplished by the time the final 2005 report was issued.

<sup>d</sup> Historically, the terrace has been divided into two areas, terrace east and terrace west. This distinction was based on modeling conducted for the SOWP, the results of which suggested that a hydraulic divide separated westward-moving groundwater from all other water in the terrace alluvium. As discussed in the text, a decade has passed since that postulate was made. Based on groundwater level measurements and observations of groundwater geochemistry, the existence of such a divide cannot be verified under current conditions. Any references to terrace east and west in this evaluation correspond to geographical (rather than hydrogeological) distinctions only—i.e., terrace east corresponds to the area east of Highway 491, including the disposal cell and former mill site, and terrace west encompasses monitored areas west of U.S. Highway 491.

Site Area	2005 Conceptual Model Report Recommendations and Previous Actions to Mitigate Risks	Summary of DOE Activities Since 2004–2005 and Current Status <sup>c</sup>	Ongoing or Planned DOE Activities	Comment(s)
Terrace—Many Devils Wash	<p>It was initially predicted that, after approximately 7.5 years of pumping, exposure pathways at escarpment seeps and at Bob Lee and Many Devils Washes would be eliminated. The report also recommended continued observation of the locations and fluxes from seeps in Many Devils Wash.</p> <p><u>Previous Actions to Mitigate Exposures and Risks</u></p> <p>To limit exposure to the surface water in Many Devils Wash, two interim actions were conducted in the summer and fall of 2000. The wash was fenced to prevent access by cattle, and a cobble blanket was emplaced to cover contaminated pools. However, flooding in July 2001 removed the majority of the cobble blanket, rendering it ineffective for exposure control.</p> <p>In November 2002, a 400-ft-long collection drain was installed in Many Devils Wash to capture surface water and shallow groundwater; it began operating in March 2003.</p>	<ul style="list-style-type: none"> <li>Flow rates and water levels in the collection sump were instrumented in December 2005 and connected to SOARS for real-time monitoring.</li> <li>Efficiency of the collection drain gradually decreased due to accumulation of fine-grained material around the drain. To help capture the contaminated surface water, a diversion dam was built in August 2009 to increase water collection/flows to the sump (rationale being to collect additional water in the upper portion of the wash to limit downstream exposures).</li> <li>In response to stakeholder concerns that large storm events could generate runoff from Many Devils Wash resulting in contaminant loading to the San Juan River, DOE installed an automated sampling system in the lower end of the wash in May 2009.</li> <li>Despite lowering of water elevations on the terrace and drying of seeps, concomitant decreases in the wash have not been observed. Water/pooling is consistently present.</li> <li>DOE 2010 (in preparation) evaluates the geology and groundwater chemistry in Many Devils Wash. This report showed similar groundwater chemistry in all portions of Many Devils Wash as far as 1,000 ft upstream of the seeps.</li> <li>Repaired fencing and installed warning signs (new signs installed in spring 2010).</li> <li>New surface location in wash near river sampled in spring 2010 (location 1221; see Figure 5).</li> <li>New characterization in the East Fork of Many Devils Wash (spring 2010).</li> </ul>	<p><u>Ongoing</u></p> <ul style="list-style-type: none"> <li>Given the core objective of reducing risk, DOE is evaluating possible engineering solutions for Many Devils Wash.</li> <li>DOE recently initiated studies focused on understanding more effective ways to control surface water flows.</li> </ul> <p><u>Planned</u></p> <p>DOE will conduct additional studies to further evaluate Many Devils Wash, particularly the potential of a single source of water in the wash and a single point of groundwater entry into the system.</p>	<p>Many Devils Wash has complex hydrogeology. DOE is evaluating options to reduce potential exposures that may occur from contamination in the surface water of the wash.</p> <p>The initial remediation program at the site focused mainly on groundwater extraction on the floodplain and terrace. DOE has since expanded the focus, as demonstrated by the ongoing and planned activities and evaluations at Many Devils Wash.</p>
Terrace—Evaporation Pond	<p>Not addressed in the 2005 Conceptual Model Report except in an ancillary capacity (focus on groundwater extraction).</p> <p>However, the pond was addressed in the 2003 Wildlife Management Plan (DOE 2003b), which focused on the evaporation pond as a potential threat to wildlife because it constitutes a fairly large body of still water. The plan follows a phased approach based on systematic observation of the pond and the surrounding area, organized in three phases: (1) monitoring, (2) deterrence, and (3) contingency.</p>	<p>DOE developed a risk evaluation (comparing levels in pond water and algae with corresponding wildlife standards) to evaluate the potential impacts to birds (particularly migratory birds) visiting the evaporation pond. This study indicated that selenium and uranium levels exceeded wildlife standards. However, for contaminants to pose a risk to wildlife, there must be exposure. Based on observations (using both telemetry cameras and human observation), very few birds are visiting the evaporation pond. Although very few birds have been observed visiting the pond, USFWS expressed a concern about migratory birds consuming algae as a food source. Selenium tends to concentrate in algae to levels that can be harmful to birds. To address this issue, in June 2010 DOE began adding dye to the evaporation pond to block sunlight as way to kill algae and thus remove a potential food source to birds.</p>	<p><u>Ongoing</u></p> <p>SOARS monitoring continues. Very little visitation by migratory birds is apparent.</p> <p><u>Planned</u></p> <p>In response to USFWS concerns, DOE will add dye to the pond to control the growth of algae.</p>	<p>Because of the increased collection rates of contaminated water being pumped to the evaporation pond from the floodplain, there has been a recent concern about the pond becoming too full. To address this issue, DOE has been shutting down the pumps in Trench 2 during high flows of the San Juan River, which typically last 2 to 3 months (higher river flows force cleaner river water toward Trench 2).</p>
Terrace—Disposal Cell	<p>Not addressed in the 2005 Conceptual Model Report in the context of any remedial strategy. However, in their concurrence on the GCAP and the SOWP, NRC did state that continued monitoring and study of the contaminant flux from the disposal cell is required and that groundwater geochemistry should be monitored at a few additional wells around the disposal cell.</p>	<p>Currently investigating water balance issues associated with the cell cover and the terrace; this includes an evaluation of the disposal cell as a continuing source of groundwater contamination.</p>	<p><u>Planned</u></p> <p>Finalize the cell cover study; discuss with NRC and the Navajo Nation.</p>	<p>The evaluation includes an examination of water use during milling and potential residual or transient water in the tailings.</p>

Site Area	2005 Conceptual Model Report Recommendations and Previous Actions to Mitigate Risks	Summary of DOE Activities Since 2004–2005 and Current Status <sup>c</sup>	Ongoing or Planned DOE Activities	Comment(s)
Terrace—Borrow Pit and Phytoremediation	As a recommended refinement to the remediation system, the 2005 Conceptual Model Report recommended the use of deep-rooted plants to enhance evapotranspiration in the radon-cover borrow pit.	DOE is conducting a phytoremediation study on the terrace using deep-rooted plants to enhance evapotranspiration. Although the study was initially recommended only for the borrow pit area, DOE expanded the proposed study area. Four phytoremediation test plots were established in 2006—two in the borrow pit area and two on the terrace between the disposal cell and the escarpment above the San Juan River floodplain (DOE 2008).	<p><u>Ongoing</u> The pilot study will continue. This is part of the overall phased approach DOE is using to address issues at the site.</p> <p><u>Planned</u> DOE is reserving any specific plan for phytoremediation pending analysis of overall findings and data when pilot studies end.</p>	<p>Although established in 2006, the phytoremediation study is still in the pilot study stage. Some applications are not easily quantified, and the extent to which plants contribute to extraction rates is not clear. (Note: Students from Diné College have assisted with this effort.)</p> <p>DOE is investigating the feasibility of a pilot groundwater hot-spot remediation study. The borrow pit is an initial candidate for such a study, as selenium, nitrate, and sulfate levels are highest in this area (uranium concentrations are lower, however).</p>
Terrace—Monitoring Program and Background Characterization	<p>At the time the 2005 Conceptual Model Report was prepared, an extensive monitoring network was already established on the terrace. Table 7–1 of that report summarized the monitoring requirements (for both chemistry and water levels) and identified deviations from the GCAP.</p> <p>Proposed monitoring to be semiannual through the 7-year extraction period (2010), then annually through year 12 (2015), and every 5 years thereafter.</p> <p><u>Background Characterization</u></p> <p>To evaluate the nature and extent of terrace background groundwater, four boreholes were drilled by Geoprobe in December 1999 in the main branch of Many Devils Wash south of its confluence with the West Fork. All boreholes were drilled through loess and into Mancos Shale; no groundwater was found.</p> <p>The Conceptual Model Report recommended measurement of water levels at the four terrace background wells established during initial site characterization activities conducted for development of the SOWP: 0800, 0801, 0802, and 0803.</p>	<ul style="list-style-type: none"> <li>• Collection of semiannual samples to evaluate groundwater chemistry and monitoring of water levels at 56 terrace wells (September 2009 to March 2010).</li> <li>• Water levels measured at 37 alluvial wells and 26 wells screened in the Mancos Shale.</li> <li>• Although several nearby washes have been visited, and DOE has attempted to find background groundwater by drilling in suitable areas, to date background conditions on the terrace have not been characterized because groundwater in candidate background locations could not be found.</li> </ul>	<p><u>Ongoing</u></p> <p>Continued monitoring of chemistry and water levels in terrace wells.</p> <p>DOE is evaluating possible analogs in areas similar to the disposal cell terrace to investigate contaminant (e.g., selenium) contributions from Mancos Shale.</p> <p><u>Planned</u></p> <p>DOE will select new background locations in consultation with the Navajo Nation and other stakeholders.</p>	For wells showing consistent contaminant trends, DOE may reduce the sampling frequency to annual sampling.
Floodplain—Trench Excavation and Evaluation	Construct two groundwater collection drains along the base of the escarpment. Each drain will be approximately 200 ft long and 25 ft deep.	In spring 2006, two additional groundwater withdrawal systems consisting of horizontal wells in excavated trenches—Trench 1 and Trench 2—were installed in the alluvial aquifer near the base of the escarpment. It was believed that the pumping of these horizontal wells would result in greater groundwater extraction rates than had previously been achieved at either of the two vertical wells on the floodplain, particularly given that the length of each horizontal well is 200 ft. Trench 1 and Trench 2 were expected to intercept much, if not all, of the contaminated water migrating across the Mancos Shale escarpment, thereby reducing the contaminant mass reaching portions of the alluvial aquifer between the bedrock escarpment and the river. The detailed Trench 2 evaluation indicates a large capture zone exists around this trench.	<p><u>Planned</u></p> <p>Given the success of the Trench 2 evaluation (in terms of providing evidence of declining contaminant concentrations), a study evaluating the effectiveness of Trench 1 is being planned.</p> <p>Trenches 1 and 2 were both installed in spring 2006. Trench 2 was studied first because its proximity to the river, smaller area of influence, and higher pumping rate caused concentrations to change more rapidly than at Trench 1, facilitating evaluation of river intrusion.</p>	The trenches have been successful in collecting contaminated alluvial groundwater in greater volumes than was possible with traditional extraction wells.

Site Area	2005 Conceptual Model Report Recommendations and Previous Actions to Mitigate Risks	Summary of DOE Activities Since 2004–2005 and Current Status <sup>c</sup>	Ongoing or Planned DOE Activities	Comment(s)
Floodplain—Well Installation	<ul style="list-style-type: none"> <li>• Install an extraction well using a track hoe near extraction well 1077 (<i>Note:</i> Wells 1089 and 1104, which replaced previous wells 1075 and 1077, were installed in 2003, but this information was not included in the 2005 Conceptual Model Report).</li> <li>• Install an extraction well using a track hoe near monitoring well 0615 in the heart of the contaminant plume.</li> </ul>	<ul style="list-style-type: none"> <li>• Well 1105, a 6-inch-diameter well, was installed in March 2005 adjacent to well 0615.</li> <li>• Since then, 26 additional floodplain monitoring wells were installed: <ul style="list-style-type: none"> <li>➤ Trench 1 area (four wells)—1111 and 1112 in June 2006 and 1140 and 1141 in May 2009</li> <li>➤ Trench 2 area (13 wells)—1115–1117 (June 2006) and 1125–1134 (February 2007)</li> <li>➤ Well 1089 Area (three wells)—1137–1139 in January 2010</li> <li>➤ Near San Juan River (four wells)—1135, 1136, 1142, 1143 in January 2010</li> <li>➤ Near base of escarpment (two wells)—1113 and 1114 (installed in June 2006) roughly downgradient from terrace well MW1</li> </ul> </li> </ul>	<p><u>Ongoing</u></p> <ul style="list-style-type: none"> <li>• DOE will continue to monitor and evaluate contaminant concentrations and water levels on the floodplain.</li> <li>• Continued evaluation of Trench 2 and well 1089 area.</li> </ul> <p><u>Planned</u></p> <ul style="list-style-type: none"> <li>• Trench 1 study—to be commensurate in scope with the Trench 2 evaluation (see DOE 2009c).</li> <li>• Study of river/aquifer interaction using river gaging station data and water temperatures.</li> </ul>	Demonstrated success on the floodplain—the remedial objectives set forth in the 2005 Conceptual Model Report (and addendum) are being met.
Floodplain—Monitoring and Characterization Efforts	Update monitoring requirements for the east and west terrace areas (see Table 7-1 of the Conceptual Model Report).	<p>In January 2008, all existing floodplain wells were sampled and analyzed for contaminants, major ions, and field parameters. A line of seven wells on the terrace, just at the top of the floodplain escarpment, was also sampled. This effort was aimed primarily at delineating the distribution of contaminants at the time and providing a baseline for future remediation efforts at Trenches 1 and 2.</p> <p>Numerous new wells were installed in the well 1089 and Trenches 1 and 2 areas, so the monitoring program was greatly expanded (see Figure 6 in the <i>2010 Review and Evaluation of the Shiprock Remediation Strategy</i>).</p>	<p><u>Ongoing</u></p> <p>Continued monitoring of groundwater chemistry and water levels.</p>	Refer to rows above regarding planned evaluations of the floodplain remediation system.

**Appendix A**

**Responses to Stakeholder Comments**

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## Preface

This appendix presents DOE's responses to the following stakeholder comments on the *2009 Evaluation of the Shiprock Remediation Strategy: Annotated Outline*<sup>1</sup> (DOE 2009b):

- NNEPA comments on the 2009 Evaluation of the Shiprock Remediation Strategy Annotated Outline (March 6, 2009);
- Navajo AML Reclamation /UMTRA Department comments (March 13, 2009); and
- Comments from U.S. Fish and Wildlife Service (March 5, 2009).

DOE has attempted to address these comments as thoroughly as possible; however, some cannot be answered completely because several studies designed to better understand the complexity of the site are ongoing (e.g., the Many Devils Wash investigation, evaluation of floodplain trenches, phytoremediation pilot studies, and the disposal cell water balance evaluation). Therefore, some responses are necessarily brief because the issues they address cannot be resolved at this time, and any attempt at more detailed responses would be premature. In other cases, preliminary conclusions may be drawn; but again, the complex setting of the site and the evolving nature of the site remedial action approach and strategy could continue to affect these conclusions.

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<sup>1</sup> Since the draft annotated outline was first developed in early 2009, DOE has revised both the organization and the content of the strategy evaluation substantially. Therefore, in most cases the references to specific sections in the following comments do not correspond directly to the current document format. However, where the comments and/or responses warrant a change or revision, the document does reflect these required changes.

**Navajo Nation Environmental Protection Agency (NNEPA) Comments on the 2009  
Evaluation of the Shiprock Remediation Strategy Annotated Outline**

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**Comment 1.** Page 2, Section 3.0, last sentence: If all of the sources of water in the Terrace mentioned here are insufficient to sustain a water table, then why is one still present 40 years after the biggest source (the mill) was stopped?

The hydrologic characteristics of the terrace groundwater system are such that several decades may be required before groundwater levels reach a new equilibrium. The water recharging the groundwater system is now limited to natural infiltration of rainfall, remnant seepage from the base of the disposal cell, and NECA gravel yard activities. DOE still expects that water levels will fluctuate (e.g., due to recharge from rainfall events) but gradually decline, primarily because groundwater is being removed as part of the site remediation system. As shown in Figure 5 of the revised strategy evaluation, water levels have decreased about 1 to 2 feet in the eastern terrace and even more (generally 2 to 4 feet, but as much as 7 feet) in the western terrace (i.e., west of Highway 491).<sup>2</sup> Some terrace wells have been dry. The extent to which these declines are attributable to pumping from terrace extraction wells versus other influences (e.g., cessation of mill activities and/or irrigation) is not known.

**Comment 2.** Page 2, Section 3.1, first paragraph: One of the stated objectives is to “reduce” flow from the Terrace to the Floodplain. How will the floodplain ever be remediated if this isn’t cut off completely?

It is not certain how much of the flow can be reduced. DOE will continue implementing the approach recommended in the 2005 Conceptual Model Report (removing contaminated groundwater), and alternative strategies may also be considered to meet the overall objective of risk reduction and contaminant control. Groundwater migrating from the terrace system to the floodplain will continue to be contaminated because of remnant seepage from the base of the cell, entrainment of residual contamination in terrace soils, and dissolution of contamination in the matrix clays of Mancos Shale. However, contamination in the terrace groundwater from anthropogenic or natural sources will have less impact on groundwater in the floodplain as flows from the terrace decrease. Therefore, DOE intends to continue pumping on the terrace and at the floodplain trenches and extraction wells, as contaminant levels in many floodplain wells appear to be decreasing in recent years in response to site remedial actions (e.g., see DOE 2009a).

**Comment 3.** Page 2, Section 3.1, first paragraph:

**Comment 3A.** Navajo EPA and Navajo DOJ requested a legal opinion from DOE regarding the question of whether or not 40 CFR 192 allows the use of “hydrologic controls” in lieu of numeric water standards in April of 2008. This question has never been answered. It is the opinion of Navajo EPA that a “hydrologic control” is not allowed as the final solution in Terrace East under 40 CFR 192 because it leaves many contaminants in place under the ground that can be mobilized in the future by recharge, washing of gravel or equipment by NECA in unlined areas, broken water lines, etc.

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<sup>2</sup> As discussed in the text, any references to terrace east and west in this evaluation correspond to geographical (rather than hydrogeologic) distinctions only.

DOE acknowledges that 40 CFR 192 does not explicitly allow for the use of hydrologic controls, but this is because references to remedial action in the regulation are general (as is fitting, given the evolving nature of remedial technologies). However, under parts (b) and (c) of §192.01 (Definitions), the option for this approach is alluded to as follows: "(b) *Remedial* action means any action performed under section 108 of the Act; (c) *Control* means any remedial action intended to stabilize, inhibit future misuse of, or reduce emissions or effluents from residual radioactive materials." And, if numerical standards are not applied—i.e., if supplemental standards are invoked<sup>3</sup>—under §192.22(d), DOE is still ultimately mandated to assure, at a minimum, protection of human health and the environment, which the use of hydrologic controls (i.e., groundwater extraction on the terrace) is intended to address.

Provisions in 40 CFR 192 allow for several possible compliance strategies that may be used to address groundwater contamination. Possible strategies include no action, natural flushing with institutional controls, and active remediation. In all cases, the primary objective is to be protective of human health and the environment. The strategy for the terrace, which was developed in conjunction with NN AML/UMTRA, is a variation of an active remediation strategy. The rationale for not requiring numerical standards with hydrologic control was that there would be no complete exposure pathways (seeps would dry up, groundwater use restrictions on terrace)—therefore, concentrations were not relevant.

The town of Shiprock is served by a public water supply; groundwater is not a current source of drinking water. DOE continues to work with NN AML/UMTRA to ensure implementation of institutional controls that will effectively protect public health and the environment.

**Comment 3B.** The “Refinement of Conceptual Model and Recommendations for Improving Remediation Efficiency at the Shiprock, New Mexico, Site (July 2005)” indicates that supplemental standards will be used as the compliance strategy for Terrace West. There is no mention of this strategy in the draft Evaluation document. If a change in strategy has been made for Terrace West, why was Navajo EPA not involved? If the strategy has not changed, why haven’t the supplemental standards been set for Terrace West? It seems like the compliance strategy for Terrace West is the same as it is for the floodplain: namely reducing flow from Terrace East and let flushing take care of the rest. The problem is that no significant water source exists to flush the contaminants out of Terrace West. This compliance strategy needs to be reevaluated.

DOE concurs with NNEPA’s suggestion and is currently reevaluating the terrace compliance strategy. This strategy was proposed in the GCAP (DOE 2002), which was developed before the site remedial action program was started and was based on assumptions stemming from predictions in the SOWP, some of which no longer apply (e.g., the presence of a hydrologic divide separating the east and west terrace). Eight years of additional data collection and 7 years after active remediation began, DOE is now in a better position to refine the compliance strategy and to redefine objectives, which will be done in consultation with the Navajo Nation and NRC.

<sup>3</sup> The provision for supplemental standards allows the current and potential future use of groundwater as a drinking water source to be taken into account, allowing a groundwater to be classified as limited use based on either poor background quality (i.e., not affected by contamination from milling operations) or low yield. The term “supplemental standards” is counterintuitive because it implies the existence of numerical standards, when in fact it means that background conditions and/or the low potential for exposure obviate the need for application of numerical standards at all. Nonetheless, 40 CFR 192 *does* require assurances that human health and the environment are protected, consistent with DOE’s primary objective.

**Comment 4.** Page 2, Section 3.1.1, first paragraph: It seems like the point of dewatering the Terrace is not to stop flows to the perimeter, but to reduce them. Again how are any of the compliance strategies going to be met if the flows from Terrace East to the seeps, washes, floodplain, and Terrace West are not stopped? This strategy also needs to be reevaluated.

Water levels on the terrace have declined, in some areas markedly. Also the majority of seeps monitored on the terrace are now dry (see DOE 2005, Table 7-1). Recharge to the terrace system from infiltration of rainfall on the terrace is expected to continue even if recharge from other sources (seepage of remnant moisture from the base of the cell, NECA gravel yard activities) is completely cut off. Though this flow pattern significantly extends the time for complete flushing of residual contamination beneath the terrace, continued pumping of floodplain groundwater from two wells and two trenches is recommended. DOE will continue to monitor the dewatering progress on the terrace and the potential impacts on other areas of the site.

**Comment 5.** Page 3, Section 3.1.1, first paragraph (on that page): It is the opinion of Navajo EPA that 40 CFR 192 requires the establishment of concentration limits for Terrace East now and that the remediation strategy reflect the goal of reducing contaminants to a point where they will never be a potential threat to human health and the environment in the future. This will only be done if the contaminated material left in the subsurface is removed instead of being left in place through the current “hydrologic control” strategy. If alternate concentration limits are a potential future option, then there is no reason why that better alternative is not put into place at this time.

DOE is willing to discuss changes in the compliance strategy on the terrace based on guidance in 40 CFR 192.

**Comment 6.** Page 3, Section 3.2: Why was the rate of 8 gpm chosen for the minimal extraction goal on the Terrace? How long will it take to dry up the seeps at this rate? Would it be more effective to strategically place extraction wells near the seeps in Terrace West?

As discussed in Section 3 of the revised document, the 8 gpm extraction rate (and the initial time estimate of 7.5 years to reach remediation goals) was estimated based on the information available at the time—groundwater modeling conducted for the SOWP indicated that the total extraction rate of water from the east portion of the terrace would have to average 8 gpm over multiple years to achieve the compliance objectives<sup>4</sup> (see Section 4.5.5 of the SOWP [DOE 2000]).

Although DOE has attempted to increase the extraction rate of groundwater from the terrace, rates approaching 8 gpm have not been achieved. Because of the complexity of the groundwater system at the Shiprock site, DOE can not accurately predict how long it will take for the seeps to dry up. However, progress is evident, as many of the seeps on the terrace, particularly in the northern and western terrace, are now dry. DOE is further investigating the groundwater system

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<sup>4</sup> The model included an extraction system for the terrace consisting of a combination of two extraction wells and two interceptor trenches. The extraction rates of the two terrace wells were set at 1 and 3 gpm. The extraction rates of the two interceptor trenches that were assumed to be keyed into the weathered Mancos Shale bedrock were expected to stabilize to 1 and 3 gpm as well. As a result, the total ground water extraction rate for the terrace system was expected to stabilize at 8 gpm.

(e.g., water balance), including potential impacts from the terrace and the disposal cell. The outcome of this investigation may result in adjustments to the approach of extracting contaminated groundwater from the terrace.

**Comment 7.** Page 5, Section 3.6, last sentence: The water ponding in Many Devils Wash is not “highly variable”. In fact, it is consistently present.

DOE has installed two water collection systems in Many Devils Wash; the most recent was completed in August 2009. Nevertheless, perennial water still exists in Many Devils Wash (water ponding in the wash, although variable in quantity/volume, is consistently present). As reflected in the revised (September 2010) strategy evaluation report, a primary focus for DOE is to mitigate any potential exposures in Many Devils Wash. Therefore, DOE has recently initiated a comprehensive study of the geology, groundwater movement, and water chemistry of Many Devils Wash. (When issued, the study will be posted on the LM website.) Potential construction options from this study may include (1) installation of a water collection system in the East Fork of Many Devils Wash to cut off groundwater flows down the wash, (2) installation of a water collection and pumping system in areas with surface water downstream of the existing water collection system, and/or (3) placement of large rock in areas with surface water to reduce potential exposures. DOE has installed fencing to restrict access; additional fencing may be placed if necessary.

**Comment 8.** Page 5, Section 3.6.2, mid-paragraph: The concern is not that large storms “could” cause salt deposits from Many Devils Wash to enter the San Juan River. It is that they do cause the salts to enter the San Juan.

DOE concurs that this is the case—i.e., salts from Many Devils Wash are entering the river. Based on previous studies of efflorescence deposits in upstream areas of many Devils Wash, it is likely that runoff is transporting contaminants, whether from Mancos Shale leachate or prior mill activities, to the San Juan River. To date, elevated concentrations of site-related COCs have not been detected in the San Juan River (at outfall surface location 0897); however, as discussed in the updated strategy evaluation, DOE will continue to investigate this issue.

**Comment 9.** Page 6, Section 3.7: Who with the Navajo Nation helped the DOE to identify the need for long-term institutional controls and how long is “long-term”?

DOE has been working with NN AML Reclamation/UMTRA Department. Institutional controls can be established for up to 100 years (the time frame established in 40 CFR 192).

**Comment 10.** Page 6, Section 3.8: Additional recommendations: 1) develop supplemental standards for Terrace West; 2) develop a strategy to meet the supplemental standards for Terrace West.

DOE is willing to discuss adjustments to the compliance strategy for the terrace based on the guidance presented in 40 CFR 192.

**Comment 11.** Page 6, Section 4.0, second paragraph: How small does the flux have to be from the Terrace in order for natural flushing in the floodplain to work?

As long as contaminant flux from the terrace to the floodplain occurs, some contaminant mass will be present in the floodplain alluvium. Accordingly, the degree to which natural flushing is successful at limiting contaminant concentrations in the floodplain alluvium depends upon influx to the alluvium from the terrace and the San Juan River. In general, as groundwater flow from the terrace to the floodplain decreases, dilution by river-derived groundwater in the floodplain alluvium would cause contaminant concentrations to decrease. It is difficult, however, to project how contaminant attenuation will progress with time because the spatial and temporal behaviors of the groundwater fluxes from the terrace and the river losses to the floodplain alluvium are very uncertain. DOE will continue to collect hydraulic and groundwater chemistry data in an effort to better characterize reductions in contaminant discharge from the terrace and the process of dilution by river water. Moreover, DOE will continue extracting contaminated groundwater from the terrace and evaluating the effectiveness of phytoremediation in reducing the volume of groundwater on the terrace, as part of the ongoing pilot studies.

**Comment 12.** Page 7, Section 4.1.1, first paragraph, last sentence: It's not clear how the fact that there is a dynamic interaction between rainfall, discharge and recharge with the San Juan River, and flow from the artesian well means that "natural flushing is having an effect". This sentence needs clarification, indicating what that effect is and how it is known that these interactions are having an effect.

This sentence has been deleted from the revised strategy evaluation.

**Comment 13.** Page 8, Section 4.3, second paragraph: The statement that "15.2 million gallons of groundwater are removed from the floodplain alluvial aquifer before it can enter the San Juan River" is misleading as indicated by the next sentence which states that "a great deal of clean water from the river is being captured" in this volume.

DOE will revise this to clarify that some of the water removed from the floodplain is from the San Juan River.

**Comment 14.** Page 9, Section 4.4.1: Because the report has not been finalized, it's premature to state that the Trench 2 remediation system has met its design objectives.

The Trench 2 report is now finalized and is available on the LM website. As stated in the report, the purpose of the Trench 2 system is to intercept contaminated groundwater emanating from the escarpment and pipe it to the evaporation pond while simultaneously drawing river water into the aquifer, thereby creating a freshwater zone between the trench and the river. The data and analyses presented in the report demonstrate that this purpose has been met.

**Comment 15.** Page 9, Section 4.4.2: The data from this sampling event are not yet available from GEMS. Is there any correlation between the terrace wells used for this study and the wells in the floodplain near the terrace? It seems like those floodplain wells nearest the terrace are generally much higher than these terrace wells.

These data are now available on GEMS. The concentrations of COCs in the wells nearest the terrace may be influenced by contaminants associated with the milling and those found naturally in the Mancos Shale. DOE plans to further investigate the influence of the terrace groundwater on the floodplain groundwater system.

**Comment 16.** Page 10, Section 4.4.2, top of page: After looking at some of the wells in the floodplain it appears that those located east of Bob Lee Wash all seemed to have substantial increases in COC concentrations over time between the late 1980s and early 2000s. Any idea why this would occur? Those wells checked west of the wash tended to decrease over the same time period.

The increases in COC concentrations east of Bob Lee Wash between the late 1980s and the 2000s can be explained by natural transport processes. Specifically, the concentrations increase over time because of the slow rate at which contaminants are being fed from the Mancos Shale to the floodplain alluvium relative to the rate at which groundwater is migrating in the floodplain parallel to the Mancos Shale escarpment.

This can be explained by natural transport processes in groundwater, some of which are addressed in the Trench 2 Evaluation report (DOE 2009c). These will be investigated in future reports as well.

**Comment 17.** Page 10, Section 4.5.3: The water elevation surveys are a good idea.

No response necessary.

**Comment 18.** Page 11, Section 4.7: Additional recommendations: 1) investigate why the concentrations in floodplain wells near the terrace are so much higher than those along the edge of the terrace; 2) investigate why concentrations in the floodplain east of Bob Lee Wash increased so much after the surface remediation was completed; 3) investigate what would happen if artesian well 648 were shut off because of high salts, sulfate, and mercury (which exceeds Navajo Nation Surface Water Quality Standards); and 4) install permanent fencing at the Many Devils Wash crossing.

*(1) Investigate why the concentrations in the floodplain wells near the terrace are so much higher than those along the edge of the terrace:* The fact that contaminant concentrations in floodplain wells at the base of the escarpment are much higher than those in terrace groundwater is explained by the likelihood that few of the terrace wells intercept the areas of highest contamination within the Mancos Shale, whether at wells close to the escarpment or at some distance from the escarpment. Because most groundwater flow and, therefore, contaminant transport through the shale occurs within fractures that are difficult to delineate and monitor, it is not surprising that contaminant levels in terrace wells near the escarpment appear lower than those in the nearby floodplain where contaminant discharge is concentrated.

*(2) Investigate why concentrations in the floodplain east of Bob Lee Wash increased so much after the surface remediation was completed:* The conceptual model presented in the response to Comment 16 has bearing on this issue. Specifically, the concentration of any contaminant in Mancos Shale water feeding the floodplain alluvium must be larger than the concentrations seen in the floodplain alluvium. This means that actual contaminant concentrations in deeper parts of the Mancos Shale are higher than are typically observed in existing wells on the terrace. DOE believes that natural transport processes were responsible for the observed increases and that there is no direct correlation between the completion of surface remediation activities and significant changes in floodplain concentrations.

*(3) Investigate what would happen if artesian well 648 were shut off because of high salts, sulfate, and mercury (which exceeds Navajo Nation Surface Water Quality Standards):* As part of a future modeling assessment of the impacts of Trench 1 pumping, DOE is considering a future investigation of the potential effects of terminating well 648 discharge.

*(4) Install permanent fencing at the Many Devils Wash crossing:* As discussed in the strategy document, DOE is planning installation of additional fencing to restrict access to the wash.

## Responses to Navajo AML Reclamation/UMTRA Department Comments

### Navajo AML Reclamation /UMTRA Department Comments Dated March 13, 2009

**Comment 1.** Will my previous comments to the “Plan for Instrumentation of Areas Around Trench 1 and Well 1089” Floodplain Ground Water Remediation System be incorporated into that document and into this current Annotated Outline?

These comments and recommendations have been addressed, as reflected in the installation of 26 new wells on the floodplain since the 2005 Conceptual Model Report was issued. DOE continues to evaluate the Trenches 1 and 2 and well 1089 areas using a combination of existing wells, some of which are instrumented.

**Comment 2. (Section 3.0, Terrace):** States in the paragraph the terrace remediation system receives natural recharge from precipitation, the Navajo Engineering and Construction Authority gravel pit,.... How was impact from the gravel pit determined and would there be a need to construct additional wells on the NECA property? What are the contaminants in the water or is it just a recharge issue?

A study of the specific effects of recharge at the NECA property has not been conducted. Data collected during semiannual sampling events suggest that recharge has the capacity to increase water levels in alluvium and the underlying Mancos Shale at the Shiprock site, but no attempts have been made to measure recharge rates or quantify the relation between recharge and local groundwater levels. Measurement of recharge to the Mancos Shale is particularly challenging given that it is difficult, if not impossible, to identify fractures in the shale where seepage of infiltrated water occurs.

Based on results of previous sampling, the contaminants in Mancos Shale beneath the NECA property appear to be the same as the inorganic chemicals observed in wells both at the former mill site and in the floodplain alluvium at the base of the escarpment (e.g., sulfate, nitrate, uranium). However, it is uncertain whether these constituents are a legacy of Shiprock mill activities or the result of leaching of natural Mancos Shale materials by oxidized recharge water. The chemical similarity between recharge-related Mancos Shale leachates and mill-related contamination would make it difficult to identify the source.

**Comment 3. 3.1 Terrace Remediation System Operation Status:** In paragraph 1 states the concentration standards for the contaminants of concerns (COCs) do not apply for terrace groundwater compliance and decline in the terrace water levels, is this DOE’s overall approach for the remediation system compliance strategy?

The rationale for not pursuing numerical standards with hydrologic control was that there would be no complete exposure pathways—i.e., seeps would dry up (largely true except for Many Devils Wash), and the surface aquifer would not meet the production requirements of a usable aquifer (DOE's response to NNEPA Comment 3A provides further elaboration on this point). Since these situations are still valid, DOE will continue with this strategy unless a more feasible alternative is identified.

**Comment 4.** In paragraph 3 states that several monitoring wells and the environmental sampling data was utilized to evaluate the potential of adding wells to the remediation system, regardless of the past environmental data the DOE should have obtained water level measurements at all ground water monitoring wells prior to stating water levels are declining in the terrace.

DOE monitors water levels at most wells on a semiannual basis. Figure 5 of the revised strategy evaluation demonstrates the declines in terrace water levels for the subset of alluvial wells for which baseline (before March 2003) measurements are available.

**Comment 5. 3.1.1 Terrace Compliance Strategy Status:** In paragraph 1 states the Terrace dewatering in the SOWP (DOE 2000) the decrease of “(2) *flow of contaminated water to Bob Lee Wash and Many Devils Wash*” my site observations seems to indicate the flow of water to the Many Devils Wash is constant without major reduction. My concerns with the surface flow in Many Devils Wash and discharging into the San Juan River is still the issue at hand.

DOE has installed two water collection systems in Many Devils Wash; the most recent was completed within the last year. Nevertheless, perennial water still exists in Many Devils Wash. DOE is currently evaluating options to collect additional water from the wash and prevent any potential exposures.

**Comment 6. 3.2 Terrace Compliance Strategy Assessment:** The documented two determinations are based on current field efforts as stated, could a third determination be included that combines the documented two into a third determination?

The second option was intended to be the combination of pumping and water uptake from plants. The overall compliance strategy for the terrace will be revisited because DOE has not been able to achieve the goal of removing 8 gpm of water from the terrace groundwater system. DOE plans to work closely with NRC and the Navajo Nation in developing any adjustments to the compliance strategy for the terrace.

**Comment 7. 3.3 Risk Assessment:** The outlined bullets as noted needs to spell out the introduction of a low-flow check dam, automated water sampler, and the feasibility of a stream flow measurement system needs to be incorporated into this risk assessment scenario. The U.S Fish and Wildlife Service (March 05, 2009, Consultation #2-22-00-I-169) has raised potential effects with exposure concerns to listed species and their critical habitat, and contaminated loading into the San Juan River.

These issues are discussed in Section 4 of the updated report. In addition, DOE is currently investigating ways to mitigate any risks from the contaminated water in Many Devils Wash.

**Comment 8. 3.5 Cover Evaluation:** Any need to mention the annual re-evaluation for the radon and gamma radiation exposure rate currently ongoing at the site? Any future plans to transplant shallow rooted species on the disposal cover to address the continued percolation of water down into the cell?

The radon and gamma radiation monitoring initiated by NN AML/UMTRA is not immediately germane to the groundwater compliance and remediation issues that represent the primary scope of the strategy evaluation. Radon monitoring results provided by NN AML/UMTRA (1999/2000

and 2009) indicate that radon fluxes for all monitored periods are comparable to background and are therefore below established standards (where standards correspond to an increment above background).

DOE has recently initiated an investigation of the internal water balance and disposal cell performance. To improve the water balance of the disposal cell, one option that may be evaluated in the future is renovation of the cover. Renovation in this context would be to accommodate or enhance the natural transformation of a low-permeability cover to an evapotranspiration (ET) cover. The latter evaluation may include an assessment of the potential effects of soil drying on radon flux.

**Comment 9. 3.7 Institutional Controls:** Based on lessons learned and environmental data, where are additional areas within the community of Shiprock will the DOE request for institutional control applications not previously identified?

The areas requiring institutional controls have not changed since the previous discussions with stakeholders. If any changes are proposed, DOE will coordinate with NN AML/UMTRA and other stakeholders. DOE does not expect that this will be necessary because groundwater is not being used at the site for drinking, irrigation, or any other purpose. DOE continues to work with NN AML/UMTRA to establish institutional controls on the floodplain, and much of the success of this implementation requires cooperation of stakeholders. DOE has identified information needs, including the provision of well records. NN AML/UMTRA conducted a records search, which verified that groundwater is not being used in the site vicinity. DOE has received verbal notification of the search results and is awaiting written confirmation.

**Comment 10. 4.4.1 Trench 2 Study:** When will the Trench 2 Study be available for review or is it displayed on SOARS?

The Trench 2 report, titled *Evaluation of the Trench 2 Groundwater Remediation System at the Shiprock, New Mexico, Legacy Management Site*, dated March 2009, has been finalized and is now available on the LM website at <http://www.lm.doe.gov/Shiprock/Documents.aspx>.

**Comment 11. 4.4.1 New Well Installation:** Incorporates comments from a previous DOE document "Plan for Instrumentation of Areas Around Trench 1 and Well 1089.

No response necessary.

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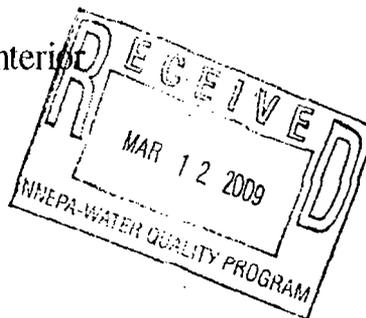
## Comments from the U.S. Fish and Wildlife Service (USFWS)



### United States Department of the Interior

#### FISH AND WILDLIFE SERVICE

New Mexico Ecological Services Field Office  
2105 Osuna NE  
Albuquerque, New Mexico 87113  
Phone: (505) 346-2525 Fax: (505) 346-2542



March 5, 2009

Ms. Tracy Ribeiro  
U.S. Department of Energy  
Shiprock UMTRA Site Manager  
2597 B ¼ Road  
Grand Junction, Colorado 81503

Consultation #2-22-00-I-169

Dear Ms. Ribeiro:

Thank you for your correspondence regarding plans for upgrading the seepage interception system in the Many Devils Wash drainage adjacent to the Shiprock Department of Energy (DOE) UMTRA site. We consider this another related action to the overall site remedial efforts that have been ongoing for quite some time. These current actions are thus considered another ongoing component of the informal endangered species consultation (2-22-00-I-169) initiated in 2000.

As you know, we have expressed concerns since the beginning of our consultation that the contaminated water in Many Devils Wash may be adversely affecting wildlife, listed species, and their critical habitat within the wash and/or in the San Juan River. In response to these and other concerns, DOE installed a seepage collection system in Many Devils Wash, covered exposed water and soils with textile liner material and heavy rip-rap, and fenced the area to restrict livestock access. At the time, we concurred with this relatively low-cost/low-tech course of action because remedial planning documents anticipated that the site-wide groundwater extraction and seepage interception systems would eliminate the contaminated groundwater seeps flowing into Many Devils Wash. Unfortunately, these seeps continue to flow, and because the existing seepage interception system is now largely inoperable, these flows enter the San Juan River. In addition, wildlife throughout the area can access open pools and streams of highly contaminated water.

The current project is to install a fairly robust low-flow check dam to intercept and collect this contaminated water, which DOE anticipates will prevent continued flow of contaminated water into the San Juan River. Although we believe that a more robust and costly storm-water retention dam and retention structure may be needed to fix this issue and prevent storm-water loading of contaminants to the San Juan River, we are willing to accept the proposed project as a step forward, or perhaps even a solution, to this ongoing problem.

However, to better understand pre- and post-project effects of contaminants from Many Devils Wash to the San Juan River, DOE agreed to install an automated water sampler in the wash just above the confluence with the San Juan River. Our understanding is that this sampler will be operational in the near future, and will be programmed to collect samples several times during

Ms. Tracy Ribeiro

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storm flow events. If feasible, stream flow measurements will also be collected to estimate total discharge, so that contaminant loading to the San Juan River can be predicted. After project completion, data from this sampler can be used to estimate the effectiveness of remedial measures in the wash. Potential effects to listed species and their critical habitat can then be reassessed to determine if any additional remedial measures will be necessary. Thus, if this new project is not considerably effective in reducing potential adverse effects to listed species and their habitat, alternative and/or additional approaches must be examined.

Since your original submittal, Steve Austin with the Navajo Environmental Protection Agency has provided comments on the structure's construction, and it appears that these suggestions were largely accepted and incorporated into your most current plans. Given Mr. Austin's expertise in this area, we are comfortable that his comments adequately address issues related to the installation and stability of this structure (given current knowledge of the hydrodynamics of the drainage). Consequently, we do not anticipate any adverse effects to listed species or their critical habitat as a result of the installation and operation of this structure in Many Devils Wash.

If you have any questions, please contact Russell MacRae at (505) 761-4724 ([russ\\_macrae@fws.gov](mailto:russ_macrae@fws.gov)).

Sincerely,



Wally Murphy  
Field Supervisor

cc:

Navajo Nation UMTRA Program, Window Rock, AZ (Attn: M. Roanhorse)

Navajo Nation Environmental Protection Agency, Window Rock, AZ (Attn: S. Austin)

U.S. Corps of Engineers, Albuquerque, NM (Attn: D. Cummings)

Comments on the Shiprock Cell:

- 1) Page 5, Section 3.5: "...the disposal cell may be a continuing source of groundwater contamination..."—I didn't know that there was still some doubt about the cell being a continuing source of groundwater contamination.
- 2) Page 5, Section 3.5: It's my understanding that hydroprobe ports are supposed to be free from water because it can interfere with readings from the probe. That said, the fact that the upper tailings and lower cover are saturated by rainwater is very interesting. Has any water been sampled from the middle or lower tailings to determine the source of that water? I'd be curious to know if it is of recent rainwater origin as well.
- 3) Page 6, Section 3.8: Additional recommendations: 1) develop plan to deal with leaking cell; 2) investigate the source of water in the lower tailings to determine if this is still drainage from the original slurry or if precipitation recharge is more significant than previously stated.
- 4) Page 6, Section 4.0, second paragraph: I'm not sure you can say that drainage from the cell is residual and transient if the upper tailings and lower cell are saturated with rainwater (section 3.5).
- 5) Page 6, Section 4.0, second paragraph: If the flux through the cell is steady state (comment 14 above), and the "concentrations of COCs immediately below the escarpment have not changed significantly over time", then how can natural flushing work in the floodplain?
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## Responses to USFWS General Comments

The following are responses to specific comments on the Shiprock disposal cell. Regarding statements in the body of the letter (e.g., regarding the Many Devils Wash automated sampler), the reader is referred to the revised strategy evaluation report.

### Comments on the Shiprock Cell:

1. Page 5, Section 3.5: "...the disposal cell may be a continuing source of groundwater contamination..." I didn't know that there was still some doubt about the cell being a continuing source of groundwater contamination. Based on data collected to date, DOE believes that the cell is a continuing source of groundwater contamination. The two main questions are (1) How much contaminated water is draining from the cell? and (2) What effect is it having on the contaminant concentrations in the groundwater? The cell was designed to allow water to migrate from the tailings. Water in the tailings at the time the cell was capped (i.e., transient drainage) will continue to seep for many years. Even if the cell was performing as designed with a saturated hydraulic conductivity of  $1 \times 10^{-7}$  cm/s, a small volume of precipitation would continue to percolate through the tailings and seep from the cell. The questions DOE is pursuing answers to are:
  - (1) How much transient drainage will occur and for how long?
  - (2) How much water percolates through the cover?; and
  - (3) What impact will the drainage from the cell have on the contaminant concentrations in groundwater and (ultimately) the ability to meet compliance goals?

The drainage rate from the disposal cell is not known because of the numerous variables that influence seepage rates and the inability to directly measure the volume of water draining from the cell, an accurate estimate of the rate can not be obtained. DOE is investigating this issue, including reexamining the historical records, to better understand the potential range of drainage rates from the cell and their impact on groundwater.

2. Page 5, Section 3.5: It's my understanding that hydroprobe ports are supposed to be free from water because it can interfere with readings from the probe. This is true. During this study, water was encountered only at the bottom of the probe port, so water in the port likely influenced only the lowest readings. That said, the fact that the upper tailings and lower cover are saturated by rainwater is very interesting. Has any water been sampled from the middle or lower tailings to determine the source of that water? No. I'd be curious to know if it is of recent rainwater origin as well. Oxygen and deuterium isotope data suggest that some of the water in the bottom of the neutron hydroprobe ports was recent precipitation.
3. Page 6, Section 3.8: Additional recommendations: (1) develop plan to deal with leaking cell; DOE is currently investigating the cell performance; some recommendations may follow this investigation. DOE is currently conducting a cover renovation pilot study at the Grand Junction Disposal Site that might have DOE-wide implications; (2) investigate the source of water in the lower tailings to determine if this is still drainage from the original slurry or if precipitation recharge is more significant than previously stated. As discussed in the strategy

evaluation document, DOE is investigating water balance issues with the cell (augmentation of the oxygen/deuterium isotope study previously conducted may provide useful data).

4. Page 6, Section 4.0, second paragraph: I'm not sure you can say that drainage from the cell is residual and transient if the upper tailings and lower cell are saturated with rainwater (section 3.5). DOE agrees; it cannot be said definitively how much water is percolating through the cover, how much residual water remains and may continue to drain, or how much water has drained and is currently draining from the disposal cell. Some, if not most, of the water is likely residual, considering how wet the tailings were when the tailings were capped and considering the hydraulic properties of the tailings. Some of the water is likely cover percolation, given evidence from oxygen and deuterium isotope data, neutron hydroprobe monitoring, in situ saturated hydraulic conductivity measurements with air-entry permeameters, and piezocene tests. However, overall, we do not know the relative contributions of water to the drainage.
  
5. Page 6, Section 4.0, second paragraph: If the flux through the cell is steady state (comment 14 above [actually refers to comment 4 above], and the "concentrations of COCs immediately below the escarpment have not changed significantly over time," then how can natural flushing work in the floodplain?

This question cannot be answered conclusively at this time. DOE recognizes that a continuing source exists, although the extent to which this is occurring is not clear or quantifiable. DOE will continue active remediation on both the terrace and the floodplain and concomitant monitoring of the progress of groundwater cleanup.