DOE/EIS–0355

Remediation of the Moab Uranium Mill Tailings, Grand and San Juan Counties, Utah, Final Environmental Impact Statement

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Introduction

This appendix has been prepared by the U.S. Department of Energy (DOE) to comply with requirements set forth in Section 7 of the Endangered Species Act (ESA) (16 U.S.C. 1531 et seq.) and the National Environmental Policy Act (NEPA) (40 CFR 1502.25). It includes the following documents:

- Biological Assessment, including DOE's determinations (Appendix A1)
- A screening-level risk assessment (Appendix A2)
- The U.S. Fish and Wildlife Service (USF&WS) Biological Opinion (Appendix A3)

This appendix addresses the potential effects of remediation alternatives on listed threatened and endangered species and on critical habitat for the Moab, Utah, Uranium Mill Tailings Radiation Control Act (UMTRCA) site. The alternatives are discussed in detail in the *Remediation of the Moab Uranium Mill Tailings, Grand and San Juan Counties, Utah, Draft Environmental Impact Statement* (DOE/EIS-0355D). The analyses focus on contaminated ground water that is currently affecting the Colorado River. The alternatives evaluated in the environmental impact statement (EIS) address both surface remediation and ground water remediation under the proposed on-site and off-site disposal alternatives. All alternatives except the No Action alternative would include active ground water remediation at the Moab site, because this medium presents the greatest potential to adversely affect threatened and endangered aquatic species. Less emphasis is placed in this appendix on terrestrial species, because preliminary investigations and consultations do not indicate an imminent adverse effect to threatened and endangered terrestrial species for any of the proposed disposal cell locations.

Background

In 1978, Congress passed UMTRCA, 42 U.S.C. §§ 7901 et seq., in response to public concern regarding potential health hazards of long-term exposure to radiation from uranium mill tailings. Title I of UMTRCA requires DOE to establish a remedial action program and authorizes DOE to stabilize, dispose of, and control uranium mill tailings at 24 uranium-ore processing sites and associated vicinity properties (properties where uranium mill tailings were used as construction or fill material before the potential hazards associated with this material were known). In October 2000, the Floyd D. Spence National Defense Authorization Act (Floyd D. Spence Act) for fiscal year (FY) 2001 (Public Law 106–398) added the Moab site to the list of UMTRCA Title I sites and gave DOE responsibility for remediation of the site.

Prior to its transfer to DOE, the site had been owned and operated by the Uranium Reduction Company and later the Atlas Minerals Corporation under a license issued by the U.S. Nuclear Regulatory Commission (NRC). The processing facility no longer operates and has been dismantled except for one building that is currently used by DOE for maintenance and storage space. During its years of operation, the facility accumulated approximately 11.8 million tons of uranium mill tailings. Uranium mill tailings are the naturally radioactive residue from the processing of uranium ore. The tailings at the Moab site contain constituents that have contaminated the nearby soil and ground water at levels that exceed U.S. Environmental Protection Agency (EPA) standards in 40 CFR 192, "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings."

Decommissioning of the mill began in 1988, and an interim cover was placed on the tailings pile between 1989 and 1995. In 1996, Atlas submitted a reclamation plan and an application to NRC for an amendment to its existing NRC license (No. SUA-917) to allow for reclamation of the site. In May 1994, USF&WS provided comments to NRC on its Notice of Intent to prepare an EIS for site reclamation, stating concerns that included water depletion and contaminant effects on endangered fish. A biological assessment was prepared in 1995 and supplemented in 1997. USF&WS issued a Final Biological Opinion in 1998. The opinion was based on a proposed action of stabilizing the contaminated materials in place, and it concluded that continued leaching of existing concentrations of ammonia (and other constituents) would jeopardize the continued existence of endangered fish species in the Colorado River. In addition, depletion of Colorado River water (associated with remedial actions) would jeopardize four endangered species. The action would also affect critical river habitat for the razorback sucker and Colorado pikeminnow. In its Final Biological Opinion, USF&WS proposed mitigative measures that would be protective of endangered fish species and critical habitat. Because USF&WS considered ground water remediation an “interrelated action,” the opinion included a request for an expedited ground water compliance action plan. DOE is addressing ground water remediation within the scope of the EIS.

Stakeholders, including federal and state agencies, have expressed concern that elevated levels of site-related ground water contaminants, primarily ammonia, are reaching the Colorado River. The USF&WS and Utah Division of Wildlife Resources (UDWR), among others, are concerned because the segment of the Colorado River near the Moab site is also designated critical habitat for four endangered fish species. The Columbia Environmental Research Center of the U.S. Geological Survey conducted a study in 1998. The study was updated in 2002 and concluded that ammonia concentrations entering the river from the Moab site may present a risk to endangered fish species (USGS 1999, 2002). The study also concluded that current Utah surface water quality standards for ammonia would be protective of fish species. DOE has identified, through a screening level risk assessment, four other contaminants of concern that could adversely affect aquatic receptors; manganese, copper, sulfate, and uranium. Appendix A2 summarizes the analyses that identified these contaminants of potential concern.

By letter dated February 8, 2001, during transition of ownership of the site to DOE, USF&WS withdrew its Biological Opinion pending additional consultation. Since acquiring the site, DOE has undertaken informal consultation and short-term actions to mitigate impacts to endangered fish. In 2002, 2003, and 2004, DOE consulted with USF&WS to implement initial and interim actions that are anticipated to reduce the influence of contamination on designated critical habitat. These actions are discussed in more detail in the attached Biological Assessment (BA).

Appendix A1

Biological Assessment

BIOLOGICAL ASSESSMENT
REMEDIATION OF THE MOAB URANIUM MILL TAILINGS

U.S. DEPARTMENT OF ENERGY
Grand Junction, Colorado

CONTACT PERSON: Don Metzler Phone Number: (970) 248-7612

LOCATION: Grand and San Juan Counties, Utah

Activities are contemplated in portions of the following townships, depending on the alternative selected in the *Remediation of the Moab Uranium Mill Tailings, Grand and San Juan Counties, Utah, Environmental Impact Statement* (EIS):

T 21 S	R 19, 20 E	T 30 S	R 23, 24 E
T 22 S	R 19, 20 E	T 31 S	R 23, 24 E
T 23 S	R 18, 19, 20 E	T 32 S	R 23, 24 E
T 24 S	R 19, 20 E	T 33 S	R 23, 24 E
T 25 S	R 20, 21 E	T 34 S	R 23, 24 E
T 26 S	R 21, 22 E	T 35 S	R 23, 24 E
T 27 S	R 22, 23 E	T 36 S	R 22, 23 E
T 28 S	R 22, 23 E	T 37 S	R 22 E
T 29 S	R 23 E	T 38 S	R 22 E

U.S. Geological Survey (USGS) Quadrangles: Crescent Junction, Klondike Bluffs, Valley City, Merrimac Butte, Golden Bar Canyon, Moab, Rill Creek, Kane Springs, La Sal Junction, La Sal West, Hatch Rock, Sandstone Draw, Church Rock, Monticello North, Monticello South, Abajo Peak, Blanding North, Blanding South.

A1−1.0 Introduction

This Biological Assessment (BA) documents and assesses the proposed surface and ground water remedial actions for disposition of the uranium mill tailings pile and mill-related contamination on vicinity properties located near Moab, Utah (Figure A1−1). Sufficient information is provided to determine the potential effects on federal threatened or endangered species of the proposed alternatives addressed in the U.S. Department of Energy's (DOE's) EIS. This BA also documents initial and interim actions implemented to date to mitigate ongoing impacts to aquatic species in the Colorado River caused by elevated ground water concentrations of mill-related contaminants (Section A1−4.3).

For some terrestrial species, site-specific investigations may need to be conducted prior to a final determination of effects. This BA is prepared in accordance with requirements in Section 7 of the Endangered Species Act (ESA) (16 U.S.C. 1531) and complies with the requirements established in U.S. Fish and Wildlife Service (USF&WS) regulations (50 CFR 402) and DOE's National Environmental Policy Act (NEPA) regulations (10 CFR 1021).

A1−2.0 Species Evaluated

Three plant, six bird, four fish, and two mammal species that may occur near the Moab site or at alternative proposed disposal sites are federally protected under the ESA. This list of species was based on consultation with the USF&WS (Table A1−1) during April 2003 (USF&WS 2003a, 2003b) and information obtained from the Utah Division of Wildlife Resources (UDWR) and the Bureau of Land Management (BLM), Moab and Monticello Offices.

Table A1−1. Species Considered in the 2004 BA for the Moab Site, Moab, Utah

Common Name	Scientific Name	Federal Status
PLANTS		
Navajo sedge	*Carex specuicola*	T
Jones cycladenia	*Cycladenia humilis* var. *jonesii*	T
Clay phacelia	*Phacelia argillacea*	E
BIRDS		
Bald eagle	*Haliaeetus leucocephalus*	T
Mexican spotted owl	*Strix occidentalis lucida*	T
California condor	*Gymnogyps californianus*	E
Southwestern willow flycatcher	*Empidonax traillii extimus*	E
Yellow-billed cuckoo	*Coccyzus americanus*	C
Gunnison sage grouse	*Centrocercus minimus*	C
FISH		
Humpback chub	*Gila cypha*	E
Bonytail	*Gila elegans*	E
Colorado pikeminnow	*Ptychocheilus lucius*	E
Razorback sucker	*Xyrauchen texanus*	E
MAMMALS		
Black-footed ferret	*Mustela nigripes*	E
White-tailed prairie dog	*Cynomys leucurus*	*

T = federal threatened, E = federal endangered, C = federal candidate, * = Petition Under Review

A1−2.1 Critical Habitat

The USF&WS has designated the floodplain and Colorado River segment adjacent to the Moab site as critical habitat for the humpback chub, bonytail, Colorado pikeminnow, and razorback sucker (50 CFR 17.95). Critical habitat is defined as "…specific areas on which are found those physical or biological features essential to the conservation of the species and which may require special management considerations or protection" (USF&WS 1998b). Activities associated with the disposal site and alternative disposal sites would occur in the vicinity of this designated critical habitat. No critical habitat for terrestrial species exists in the vicinity of the Moab, Klondike Flats, Crescent Junction, or White Mesa Mill disposal site locations. Likewise, no critical terrestrial habitat has been identified within the transportation corridors. The proposed pipeline transportation route to the White Mesa Mill site is within 2 miles of designated critical habitat for Mexican spotted owl and is in the vicinity of a Gunnison sage grouse conservation area (not designated critical habitat).

A1−3.0 Consultation to Date

The U.S. Nuclear Regulatory Commission (NRC) initiated consultation on the remediation of the Moab uranium mill tailings pile during preparation of a previous EIS (NRC 1999). For that EIS, NRC prepared a BA in 1995 that concluded endangered fish species could be exposed to potentially toxic levels of site-related contaminants. The BA also concluded that remediation of the tailings pile could disturb breeding activities for the southwestern willow flycatcher, if this species were present in the vicinity of the millsite.

NRC updated its BA in 1997. In this revision, it was determined that ammonia was at potentially toxic levels where site ground water entered the river and that this constituent could adversely affect endangered fish. The updated BA further evaluated the potential for the southwestern willow flycatcher and peregrine falcon to be adversely affected by selenium and mercury. The results were inconclusive.

USF&WS issued its Final Biological Opinion in July 1998. At that time, it was the Service's opinion that capping the pile in place would jeopardize the continued existence of the razorback sucker and Colorado pikeminnow due to continued leaching of contaminants (primarily ammonia) into the Colorado River, water depletion in the river, and adverse modification of designated critical habitat. This opinion was based primarily on the lack of a ground water corrective action plan. It provided a set of reasonable and prudent measures that would help to minimize these adverse impacts. USF&WS also concluded that the proposed action would not jeopardize the southwestern willow flycatcher and provided prudent measures to minimize take of that species. The peregrine falcon was not addressed in the Biological Opinion.

NRC published its final EIS in 1999. However, responsibility for cleanup of the Moab tailings pile was transferred, by act of Congress, to DOE in October 2000 (Floyd D Spence Act, Public Law 106-398). In February 2001, based on circumstances that pre-dated transfer of the site to DOE, USF&WS rescinded its Final Biological Opinion. Since DOE acquired responsibility for the Moab site, many activities, including characterization, maintenance and operational activities, and interim actions, have taken place. Before implementing these actions, DOE consulted regularly with USF&WS concerning threatened and endangered species that may be affected by these activities. These consultations, and DOE determinations, resulted in concurrences by USF&WS dated March 23, 2001, September 12, 2001, January 22, 2002, and April 5, 2004. In all cases, it was determined that these actions would not jeopardize the continued existence of any aquatic or terrestrial threatened or endangered species.

In support of the preparation of the draft EIS for remediation of the Moab site, DOE sent a request for information to USF&WS in March 2003. USF&WS responded in April 2003 with an updated list of threatened, endangered, proposed, and candidate species that may occur in the potentially affected areas under the various alternatives.

On April 24, 2003, DOE and USF&WS met in Salt Lake City to discuss the BA approach and scope. This meeting also included discussions regarding options for preparing a biological opinion (BO) prior to identifying preferred alternatives for soil and ground water remediation.

A teleconference with USF&WS, DOE, the U.S. Environmental Protection Agency (EPA), and the Utah Department of Environmental Quality took place on July 9, 2003, to discuss the applicable numeric ammonia criteria.

On August 25, 2003, USF&WS and DOE met in Salt Lake City to further discuss applicable risk-based criteria and standards that would be protective of endangered fish. On November 3, 2003, the draft BA was forwarded to USF&WS for comment. DOE received initial comments on the BA in early December 2003. Following receipt of the comments, a meeting was held on December 15, 2003. Additional comments were received in early January 2004, followed by telephone conferences to clarify issues and concerns.

On April 14, 2004, DOE submitted the final draft BA to USF&WS. In June through August 2004, DOE and USF&WS consulted extensively to resolve final comments on this document.

On August 10, 2004, DOE received formal comments on the final draft BA.

On May 26, 2005, based on the identification of off-site disposal at Crescent Junction using mostly rail and active ground water remediation as DOE's preferred alternatives, USF&WS submitted the final BO, which is included as Appendix A3.

A1−4.0 Description of the Proposed Action

DOE is proposing to remediate contaminated soils and materials and contaminated ground water at the Moab site. Three disposal alternatives are presented in the EIS:

- On-site disposal of tailings
- Off-site disposal of tailings (three locations, three transportation options considered)
- No action

On-site disposal of tailings is discussed in Section A1−4.1. Off-site disposal of tailings is discussed in Section A1−4.2. Active ground water remediation is proposed for both the on-site and off-site alternatives (Section A1−4.3.1). This BA places emphasis on ground water remediation due to contamination entering the Colorado River, which is designated critical habitat for four endangered fish species. The remediation goals (Section A1−4.3.2) are to reduce concentrations of five contaminants reaching the Colorado River to acceptable risk levels within 10 years of the ROD. Emphasis is placed on remediation of ammonia, which is the primary contaminant of concern. DOE implemented initial and interim actions (Section A1−4.3.3) in 2003 and 2004 in an attempt to begin reducing ammonia concentrations prior to full implementation of proposed ground water remediation.

DOE also analyzes the No Action alternative (Section 2.4 of the EIS), which serves as a baseline for comparing all alternatives, as required by NEPA regulation.

Although this BA assesses all of the alternatives included in the EIS to support final decision-making for remediation of the Moab mill tailings, the BO (Appendix A3) is limited in its scope to DOE's preferred alternatives of off-site disposal at Crescent Junction using mostly rail and active ground water remediation.

Appendix A2

Screening of Contaminants to Aquatic and Terrestrial Resources

A2−1.0 Introduction

Environmental consequences to aquatic and terrestrial species near the Moab site northwest of Moab, Utah, were assessed using data collected to estimate contaminant concentrations in the surface waters of the nearshore environment adjacent to and immediately downstream of the tailings pile. Contaminant data from the freshwater aquifer that underlies the tailings pile were also used to understand the source of contaminants in the surface water.

The assessment involved determining which contaminants of potential concern exceed detection limits and background samples, assessing the relevance of the sample location to biotic exposure, and comparing the contaminant concentrations to ecotoxicological screening benchmarks. Environmental consequences to aquatic biota are discussed first, followed by terrestrial biota.

Results of this assessment are used to support the BA of federally listed threatened and endangered species (Appendix A1). However, the species evaluated here are relatively common species of wildlife and fish for which toxicological benchmarks were available. Similar toxicity data are generally not available for threatened and endangered species. Consequently, in cases where threatened or endangered species may be exposed to contaminants, the BA utilizes species evaluated here as surrogates.

Results of this assessment are also used to support alternative evaluations of environmental consequences in Chapter 4.0 of the EIS.

A2−1.1 Screening of Contaminant Data for Aquatic Biota Assessment

The aquatic environment at the Moab site is mainly associated with the Colorado River. The Moab site is a former uranium-ore processing facility located on the west bank of the Colorado River at the confluence with Moab Wash, an ephemeral stream that runs from the northwest to the southeast, bisecting the site (Figure A2−1). The wash is adjacent to or near the eastern edge of the tailings pile on the site. The tailings pile and other decommissioned facilities on the site are the source of chemical contamination discharging into the Colorado River.

There are two principal plumes in the ground water from past activities at the Moab site: the millsite area plume, and the tailings area plume. The millsite plume is contaminated from mill wastes buried near the river upstream of the Moab Wash. The tailings area plume moves contaminants to the ground water from leachate that comes from the pile. The primary exposure route for contaminants to the aquatic environment is through the ground water.

The analysis for screening of contaminants for impacts to aquatic biota is divided into chemical and radiological impacts. Chemical contaminants have toxicological effects based on the activity of the contaminant in the organism. Radiological impacts have effects based on the energy released from the radioisotope when the organism uptakes that element. A contaminant may have both a chemical and radiological impact.

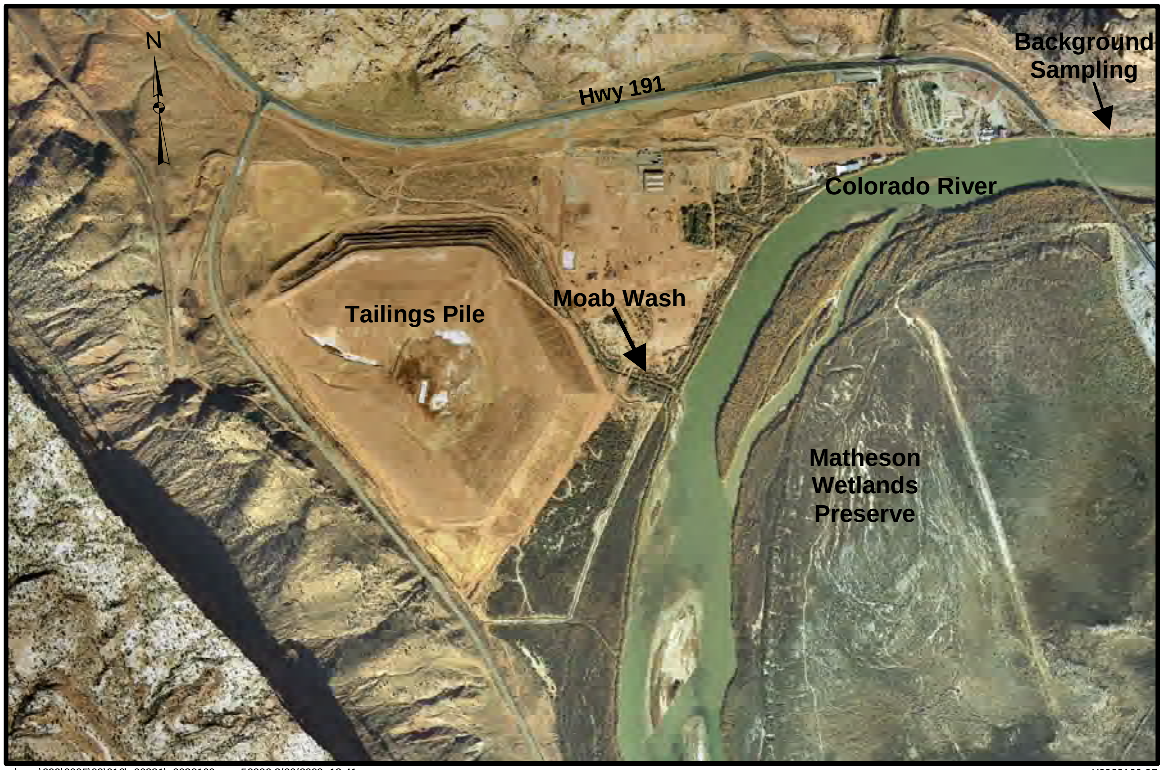

Figure A2−1. Aerial view of the Moab site in 2001 identifying the locations of the tailings pile, Moab Wash, Colorado River, upstream background sampling location, and the Matheson Wetlands Preserve

Chemical Impacts. The aquatic environment near the site has been characterized (Chapter 3.0). Monitoring programs have included sampling sediment, fish tissue, and surface water near the Moab site and upstream environment. Sediment samples of the Colorado River were collected from 1995 through 1997; however, those samples were not considered in this analysis based on comments in the Final Biological Opinion in NRC's final EIS (NRC 1999) concerning the quality of the data for evaluation of impacts. Concerns for the quality of the sediment data include inappropriate procedures and protocols for sample collection and inadequate collection of samples for statistical evaluation. Fish were collected for tissue analyses from 1995 through 1997, and the fish tissue samples also were not considered in this analysis based on comments of data quality similar to those made about sediment samples in the Final Biological Opinion of NRC's final EIS (NRC 1999). Based on an evaluation of the means and standard deviation for all the combined fish tissue data, the results do not show a strong statistical difference in concentrations in the tissues collected upstream of the Moab site compared to those collected downstream.

The screening of contaminants presented in this section is based on surface water samples collected by SMI, DOE, and USGS. Samples were collected by SMI and DOE from 2000 through 2002. These data are presented in Appendix D of the *Site Observational Work Plan for the Moab, Utah, Site* (SOWP) (DOE 2003). USGS collected water sample data from 1998 through 2000; these data are presented in *A Site-Specific Assessment of the Risk of Ammonia to Endangered Colorado Pikeminnow and Razorback Sucker Populations in the Upper Colorado River Adjacent to the Atlas Mill Tailings Pile, Moab, Utah* (USGS 2002). Many of the samples from other studies were considered, but quality issues were discovered during data evaluation.

These issues included insufficient information to determine the location of the analyzed sample and laboratory quality control and quality assurance questions. Contaminants of potential concern for the Moab site were identified from institutional knowledge about the uranium milling processes used during operation of the Atlas mill, the NRC EIS (NRC 1999), and the Notice of Intent for this EIS published in the *Federal Register* (67 FR 77969 [2003]). Surface water monitoring data were evaluated to determine if estimated concentrations were above detection limits, background levels, and federal and state criteria for surface water quality (i.e., benchmarks) (Figure A2−2). Data on background ground water samples were taken from information provided in Chapter 5.0 and Appendix C of the SOWP (DOE 2003).

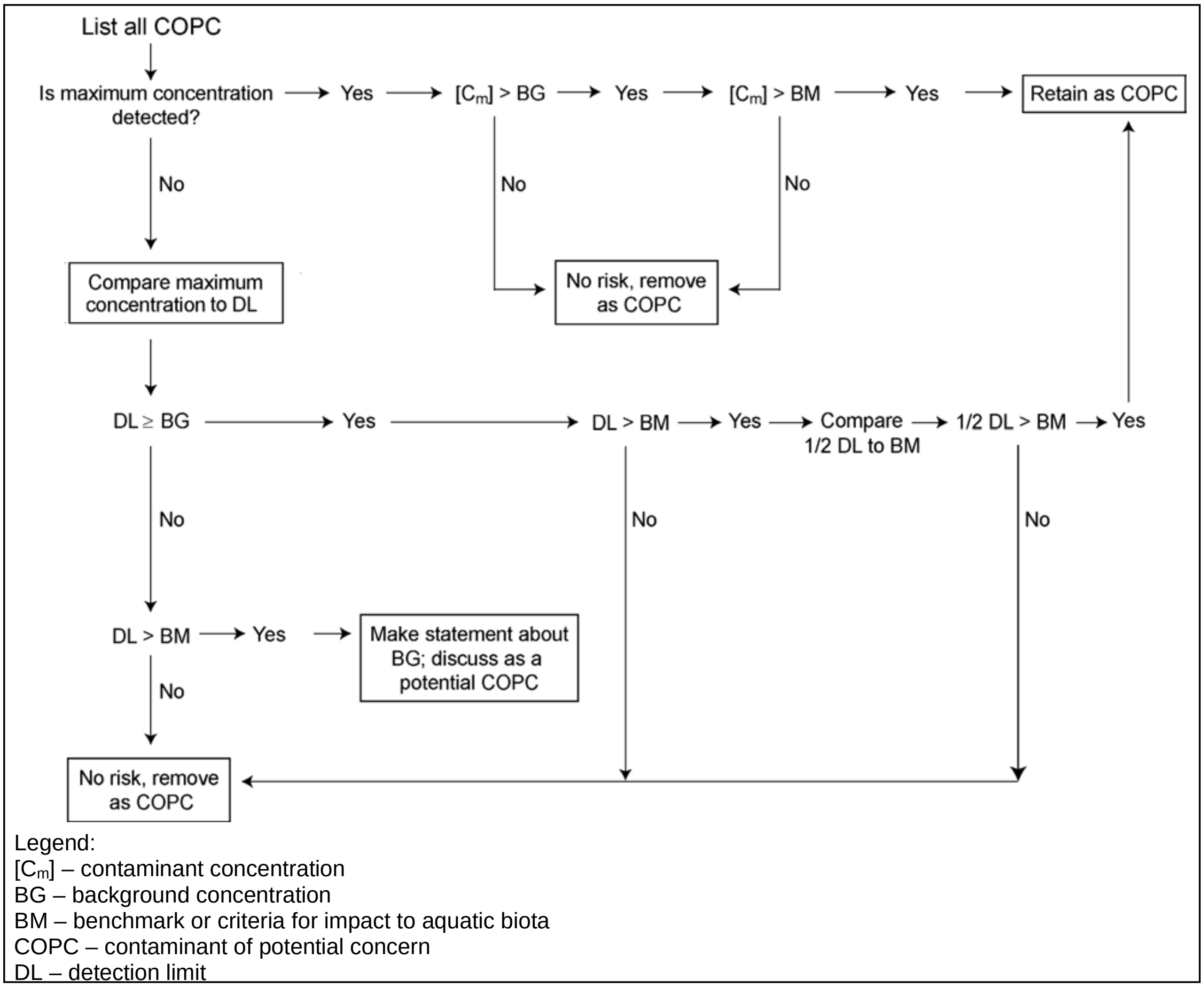

Figure A2−2. Evaluation of Contaminants of Potential Concern for Chemical Impacts to Aquatic Biota at the Moab Site

The 2000 through 2002 chemical constituent surface water data set was examined first to determine which sample results exceeded the detection limit set by the laboratory (Figure A2−2). If an analyte was not detected, the laboratory reported a value equal to the method detection limit. Analytes not detected were assessed using values corresponding to one-half the method detection limit, based on EPA protocol (EPA 2001a, 2001b). The maximum concentration for the contaminant at any location or time was then compared to the maximum background concentration (Table A2−1). Two upstream locations were considered as background stations for the Moab site. These background stations were within 15 ft of each other (see Figure A2−1). If a given contaminant was not detected in any background sample, then one-half the reported detection limit was used in the evaluation. Finally, the maximum concentration above background was compared to benchmarks for evaluating impacts to aquatic biota (Table A2−2).

Benchmarks for the contaminants at the Moab site included the NWQC (EPA 2002) and proposed State of Utah water quality criteria (UAC 2003). Water quality standards are the foundation of a water-quality-based control program. Standards are mandated by the Clean Water Act (33 U.S.C. 1251 et seq.). Water quality standards define the goals for a water body by designating its uses, setting criteria to protect those uses, and establishing provisions to protect water quality from pollutants. Utah's water quality standards are applicable to "waters of the State." Utah water quality standards apply to all waters within the state, with the exception of those waters that are within Indian Country, as defined in 18 U.S.C. Section 1151. Thus, the standards set for Utah, including the federal standards, were used for this assessment. However, the contaminants of potential concern included contaminants for which neither federal nor state criteria are established; therefore, criteria established by Suter and Tsao (1996) for aquatic biota were used. Suter and Tsao (1996) provide a compilation of aquatic toxicity values, including National Ambient Water Quality Criteria, derived Tier II values (secondary chronic and acute values), and chronic values from a variety of other government sources.

Impacts to aquatic organisms can result from either acute or chronic exposures to contaminants of potential concern. An acute exposure is defined as "the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect" (EPA 2002). A chronic exposure is defined as "the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect" (EPA 2002). Currently, the State of Utah criteria include an acute, 1-hour exposure and a chronic, 4-day exposure. As mentioned above, Suter and Tsao (1996) were used where state and federal standards were not available. However, they used a method, referred to as Tier II, to establish criteria for aquatic benchmarks using a smaller data set than required by EPA in the NWQC. Also, they developed estimated lowest chronic values for fish extrapolated from laboratory studies. Therefore, the standards from Suter and Tsao (1996) can be overly conservative and could not always be used for this analysis. These limits are discussed within the constituent-by-constituent discussions that follow.

The 2000 through 2002 surface water data were compared to the ecotoxicological screening benchmarks (Table A2−3). This comparison further pared the list of contaminants of potential concern for assessing potential impacts to aquatic biota. Contaminants were not considered further when (1) the maximum concentration and maximum background concentration were below detection and below all benchmarks, and (2) the maximum concentration was less than all the benchmarks (Table A2−3). The contaminants that were retained were further evaluated based on the number of samples, location of the samples, and the relevance of the flow regime at the time of sampling in comparison to the potential for exposure to aquatic biota.

Table A2−1. Minimum, Maximum, Background Range, Total Number of Samples, and Number of Samples Above Detection Limit for Contaminants of Potential Concern at the Moab Site, Utah (2000–2002 data)

Contaminant of Potential Concern	Minimum Concentration (mg/L)	Maximum Concentration (mg/L)	Background Concentration Range (mg/L)	Total Number of Samples	Number of Samples above Detection Limit
Aluminum	0.005	0.348[a]	0.008–0.14	182	84
Ammonia[b]	0.05	1440	0.05–0.134	266	266
Antimony	<0.001	0.0005[c]	0.0005[c]	62	0
Arsenic	<0.006	0.002[d]	<0.0006–0.002	71	42
Barium	0.002	0.211	0.051–0.14	186	185
Beryllium	<0.0001	0.00005[c]	0.00005[c]	3	0
Bismuth	<0.001	0.0005[c]	0.0005[c]	3	0
Boron	0.064	1.74	<0.0801–0.123	76	65
Cadmium	<0.0001	0.004	<0.00005[c]	114	11
Chloride	22	17300	25–172	301	301
Chromium	<0.0005	0.0005[c]	<0.0005–<0.0013	62	1
Copper	<0.00049	0.051[a]	<0.0006–<0.0014	182	61
Gross Alpha	1.1	665.45	7.31–13.82	93	
Iron	<0.003	7.23	0.0075–4.17	119	73
Lead	<0.0008	0.0005[c]	0.00005[c]	104	0
Lithium	0.0552	0.31[d]	0.057[d]	18	15
Manganese	0.0005	12	<0.003–0.076	260	147
Mercury	<0.0002	0.002[a]	0.00005[c]	96	1
Molybdenum	<0.001	1.91	<0.0028–0.007	290	275
Nickel	<0.0006	0.052	<.0006–0.002	56	19
Nitrate	0.829	21.7	1.86–5.51	76	75
pH	6.83	8.89	7.38–8.6	423	NA
Selenium	<0.0005	0.026	0.0013–0.0079	216	206
Silver	<0.00005	0.0025[c]	0.000025–0.00005[c]	63	0
Strontium	0.005	10.2	0.965–1.63	136	133
Sulfate	72	14400	84.1–439	301	290
Thallium	<0.001	0.0005[c]	0.0005[c]	63	21
Uranium	0.0013	5.12	0.0023–0.008	331	331
Vanadium	0.0003	0.249	0.00073–0.0031	148	132
Zinc	<0.0008	0.023	<0.0017–0.006	112	50

[a]Analyte is estimated, based on laboratory qualifier.
[b]All ammonia samples were converted for this assessment to total ammonia as nitrogen.
[c]All analytes were below detection; maximum value based on one-half of detection limit.
[d]Analytes in data set represent multiple detection limits. Analytes above this value are below detection limits.

Table A2−2. Chemical Benchmarks for Assessing Potential Impacts to Aquatic Organisms From Inorganic Contaminants of Potential Concern at the Moab Site, Utah (2000–2002 data)

Contaminant of Potential Concern	National Recommended Water Quality Criteria[a]		Utah State Water Quality Criteria[b]		Suter and Tsao (1996)		
	Acute	Chronic	Aquatic Wildlife 3B-Acute	Aquatic Wildlife 3B-Chronic	Tier II Acute	Tier II Chronic	Lowest Chronic
Milligrams per liter (mg/L) unless otherwise noted							
Aluminum	0.75[c]	0.087[c]	0.75[c]	0.087[c]			3.288
Ammonia	[d]	[e]	[d]	[e]			1.7
Antimony					0.18	0.03	1.6
Arsenic	0.34[g]	0.15[g]	0.34[f,g]	0.15[f,g]	0.066	0.0031	0.892
Barium					0.11	0.004	
Beryllium					0.035	0.00066	0.057
Bismuth							
Boron					0.03	0.0016	
Cadmium	0.002[g,h]	0.00025[g,h]	0.0039[g,h]	0.0011[g,h]			0.0017
Chloride	860	230					
Chromium[i]	0.016[g]	0.011[g]	0.016	0.011			0.07318
Copper	0.013[g,h]	0.009[g,h]	0.018[g,h]	0.012[g,h]			0.0038
Gross Alpha			15 pCi/L	15 pCi/L			
Iron[j]		1	1	1			1.3
Lead	0.065[g,h]	0.0025[g,h]	0.082[g,h]	0.0032[g,h]			0.01888
Lithium					0.26	0.014	
Manganese					2.3	0.12	1.78
Mercury	0.0014[g]	0.00077[g]	0.0024	0.000012		0.0013	< 0.00023
Molybdenum					16	0.37	
Nickel	0.47[g,h]	0.052[g,h]	1.40[g,h]	0.16[g,h]			< 0.035
Nitrate			4	4			
pH			6.5–9.0	6.5–9.0			
Selenium		0.005[k]	0.0184[g]	0.0046[g]			0.08832
Silver	0.0032[g,h]		0.0041[g,h]			0.00036	0.00012
Strontium					15	1.5	
Sulfate							
Thallium					0.11	0.012	
Uranium					0.046	0.0026	0.142
Vanadium					0.28	0.02	0.08
Zinc	0.12	0.12	0.12	0.12			0.03641

[a]National Recommended Water Quality Criteria are based on EPA 2002 except for ammonia, which is based on EPA 1999.
[b]Changes and updates to the Utah State Water Quality Standards as of November 2003 (UAC 2003).
[c]Aluminum is expressed in terms of total recoverable metal in the water column.
[d]Refer to EPA 1999 and UAC 2003 for calculation of pH and life-stage-dependent chronic ammonia benchmarks.
[e]Refer to EPA 1999 and UAC 2003 for calculation of pH, temperature, and life-stage-dependent chronic ammonia benchmarks.
[f]Arsenic values based on arsenic V.
[g]Criteria for metals are expressed in terms of dissolved metal in the water column.
[h]Criteria are expressed as a function of hardness. The value listed corresponds to a hardness of 100 mg/L.
[i]Chromium values based on chromium (VI).
[j]Criteria are for dissolved iron.
[k]Criteria for selenium are expressed in terms of total recoverable metal in the water column.

Table A2−3. Comparison of Contaminants of Concern to Associated Benchmarks for Aquatic Biota at the Moab Site (page 1 of 2)

Contaminant of Potential Concern	Sample Location for Maximum Concentration	Maximum Concentration (in mg/L)	Number of samples above Acute NWQC Benchmark [a]	Number of samples above Chronic NWQC Benchmark [a]	Number of Samples above Utah Wildlife 3B-Acute Benchmark [b]	Number of Samples above Utah Wildlife 3B-Chronic Benchmark [b]	Number of samples above Acute Tier II Benchmark [c]	Number of samples above Chronic Tier II Benchmark [c]	Number of samples above Lowest Chronic Benchmark [c]	Comments on Contaminant of Potential Concern
Aluminum	CR2-BX	0.348[d]	0	2	0	2	NA	NA	0	Measured Concentration above background and NWQC chronic benchmark. Background above Chronic Tier II. Retain as COPC.
Ammonia	CR2-BX	1440	[e]	[f]	[e]	[f]	NA	NA	[f]	Measured concentrations above background and benchmarks. Retain as COPC.
Antimony	NA	0.0005[g]	NA	NA	NA	NA	0	0	NA	Measured concentration and background are below detection limits. Half detection limit is below all benchmarks. Not retained as COPC.
Arsenic	CR2-BX	0.002[h]	0	0	0	0	0	0	0	Two samples above detection limit and background. Measured concentration below all benchmarks. Not retained at COPC.
Barium	Moab Wash	0.211	NA	NA	NA	NA	4	4	NA	Measured concentration above background and Tier II acute and chronic benchmark. Background above Acute and Chronic Tier II. Retain as COPC.
Beryllium	NA	0.00005[g]	NA	NA	NA	NA	0	0	NA	Measured concentration and background are below detection limits. Half detection limit is below all benchmarks. Not retained as COPC.
Bismuth	NA	0.0005[g]	NA	NA	NA	NA	NA	NA	NA	Measured concentration and background are below detection limits. Measured concentration detection limit is the same as the background detection limit. Not retained as COPC.
Boron	0206	1.74	NA	NA	NA	NA	9	9	NA	Measured concentration above background and Tier II acute and chronic benchmark. Background above Acute and Chronic Tier II. Retain as COPC.
Cadmium	CR2BX	0.004	3	10	1	4	NA	NA	3	Measured concentration above background and multiple acute and chronic benchmarks. All background is below detection limit. Half detection limit for background samples is below all benchmarks. Retain as COPC.
Chloride	0206	17300	13	13	NA	NA	NA	NA	NA	Measured Concentration above background and NWQC acute and chronic benchmark. Retain as COPC.
Chromium	NA	0.0005[g]	0	0	0	0	NA	NA	0	Measured concentrations below detection limit and below background. Not retained as COPC.
Copper	CR2-BX	0.051[d]	9	16	5	9	NA	NA	21	Measured concentration above background and multiple acute and chronic benchmarks. Retain as COPC.
Iron	CRD	7.23	NA	13	13	13	NA	NA	13	Measured Concentration above background and all benchmarks. Background above all benchmarks. Retain as COPC.
Lead	NA	0.0005[g]	0	0	0	0	NA	NA	0	Measured concentration and background are below detection limits. Half detection limit is below all benchmarks. Not retained as COPC.
Lithium	CR2B	0.31[h]	NA	NA	NA	NA	1	11	NA	Measured concentration above background and Tier II acute and chronic benchmark. Background above Chronic Tier II. Retain as COPC.
Manganese	CR2B	12	NA	NA	NA	NA	10	15	10	Measured concentration above background and all benchmarks. Retain as COPC.

[a]NWQC (National Recommended Water Quality Criteria) is based on EPA 2002 except for Ammonia, which is based on EPA 1999.
[b]Utah State Water Quality Criteria is based on UAC 2003.
[c]Suter and Tsao, 1996
[d]Refer to references for calculation of pH and life-stage-dependent chronic ammonia benchmarks.
[e]Refer to references for calculation of pH, temperature and life-stage-dependent chronic ammonia benchmarks.
[f]Analyte is estimated, based on laboratory qualifier.
[g]All analytes were below detection; maximum value based on one-half of detection limit.
[h]Analytes in data set represent multiple detection limits. Analytes above this value are below detection limits.

Contaminant of Potential Concern	Sample Location for Maximum Concentration	Maximum Concentration (in mg/L)	Number of samples above Acute NWQC Benchmark[a]	Number of samples above Chronic NWQC Benchmark[a]	Number of Samples above Utah Wildlife 3B-Acute Benchmark[b]	Number of Samples above Utah Wildlife 3B-Chronic Benchmark[b]	Number of samples above Acute Tier II Benchmark[c]	Number of samples above Chronic Tier II Benchmark[c]	Number of samples above Lowest Chronic Benchmark[c]	Comments on Contaminant of Potential Concern
Mercury	NA	0.002[f]	NA	NA	1	85	NA	1	1	One sample with a measured concentration above the detection limit, background and all benchmarks. Measured concentration in all other samples and background are below detection limits. Half detection limit is above Utah State Chromic wildlife benchmark. Retain as COC.
Molybdenum	CR2-BX	1.91	NA	NA	NA	NA	0	10	NA	Measured concentration above background and Tier II chronic benchmark. Retain as COC.
Nickel	CR2-BX	0.052	0	1	0	0	NA	NA	1	Measured concentration above background and NWQC chronic benchmark. Retain as COC.
Nitrate	CR2B	21.7	NA	NA	36	36	NA	NA	NA	Measured concentration above background and Utah State acute and chronic benchmark. Background above Utah State acute and chronic benchmark. Retain as COC.
Selenium	CR3-10	0.026	NA	7	1	7	NA	NA	0	Measured Concentration above background and above NWQC chronic benchmark and Utah State chronic and acute benchmarks. Background above NWQC chronic and Utah state chornic benchmarks. Retain as
Silver	NA	0.0025[g]	1	NA	1	NA	NA	2	33	Measured concentrations and background are below detection limit. Half detection limit for one sample is above Tier II chronic and lowest chronic benchmarks. Half detection limit in remaining samples and background are below all benchmarks. Retain as COC.
Strontium	CR3-001	10.2	NA	NA	NA	NA	0	19	NA	Measured concentration above background and Tier II chronic benchmark. Background above chronic Tier II. Retain as COC.
Sulfate	CR2-BX	14400	NA	NA	NA	NA	NA	NA	NA	Measured concentration above background. Retain as COC
Thallium	CRBA	0.0005[g]	NA	NA	NA	NA	0	0	NA	Measured concentration and background are below detection limits. Half detection limit is below all benchmarks. Not retained as COC.
Thorium	CR4	1.7[i]	NA	NA	NA	NA	NA	NA	NA	Measured concentration is below background and all benchmarks. Not retained as COC.
Uranium	Moab Wash	5.12	NA	NA	NA	NA	42	263	16	Measured Concentration above background and above Tier II acute and chronic benchmarks and lowest chronic benchmark. Background above Tier II chronic benchmark. Retain as COC.
Vanadium	MWSeep	0.249	NA	NA	NA	NA	0	2	2	Measured concentration above background and above Tier II chronic and lowest chronic benchmarks. Retain as COC.
Zinc	CR2-BX	0.023	0	0	0	0	NA	NA	0	Measured concentration above background and below all benchmarks. Not retained as COC.

[a]NWQC (National Recommended Water Quality Criteria) is based on EPA 2002 except for ammonia, which is based on EPA 1999.
[b]Utah State Water Quality Criteria is based on UAC 2003.
[c]Suter and Tsao 1996
[d]Refer to references for calculation of pH and life-stage-dependent chronic ammonia benchmarks.
[e]Refer to references for calculation of pH, tenperature and life stage dependent chronic ammonia benchmarks.
[f]Analyte is estimated, based on laboratory qualifier.
[g]All analytes were below detection; maximum value based on one-half of detection limit.
[h]Analytes in data set represent multiple detection limits. Analytes above this value are below detection limits.
[i]Analyte detected in both the sample and the associated blank.

Table A2−3. Comparison of Contaminants of Concern to Associated Benchmarks for Aquatic Biota at the Moab Site (page 2 of 2)

The 1998 through 2000 data summarized in *A Site-Specific Assessment of the Risk of Ammonia to Endangered Colorado Pikeminnow and Razorback Sucker Populations in the Upper Colorado River Adjacent to the Atlas Mill Tailings Pile, Moab, Utah* (USGS 2002) were also examined. Results presented in the USGS report indicate that the pile represents a localized source of ground water input containing elevated levels of contaminants, including copper, manganese, zinc, and radiochemicals. These contaminants were measured at levels that exceeded benchmarks during the low-water hydrologic period ranging from August through March. Based on the results of this study, USGS summary data for copper, manganese, zinc, and total alpha were evaluated using the process previously described (see Figure A2−2). These results are discussed where applicable within the constituent-by-constituent discussions that follow.

Toxicity of contaminants of potential concern is often related to water quality. The following discussions summarize water quality parameters that are considered in further discussions on the contaminants of potential concern.

Water Quality Parameters

pH. The measure of pH is an indicator of overall water quality. Aquatic organisms can be sensitive to large fluctuations in pH. However, gradual changes in pH may not affect organisms except to change the potential toxicity of other contaminants (e.g., ammonia). Twenty-nine surface water samples were collected at background locations; sample pH ranged from 7.38 to 8.6. Surface water samples near the Moab site had a pH between 6.83 and 8.89. The range of pH is within the State of Utah water quality criteria (UAC 2003). Continued monitoring of pH during the collection of surface water would be necessary to ensure protection of aquatic biota.

Temperature. Surface water temperature varies seasonally and diurnally, especially at low-flow conditions. There were 269 measures of temperature for surface water samples collected from 2000 to 2002. The temperature measurements ranged from 3.0 to 34.6 ^{o}C (37.4 to 94.3 ^{o}F). The maximum temperature for the Moab reach of the Colorado River was 27 ^{o}C (UAC 2003). Forty-two measurements along the shoreline near the tailings pile were above the standard for maximum temperatures. Most measurements were recorded during a 2-day period in July 2000; a few were made in April through August. The measurements were often in shallow pools along the edge of the river and islands in the river (e.g., CRBBY1; see locations in Figure A2–3). Continued monitoring of temperature during the collection of surface water samples would be necessary to ensure protection of aquatic biota.

Hardness. In general, hardness is a measure of the divalent metallic ions in surface water. The primary contributors to hardness are typically calcium and magnesium; however, the geological system can contribute other ions that are measured by a total hardness analysis. Hardness is related to the toxicity of many heavy metals; as hardness increases, the effect of the toxicity due to the metal decreases (EPA 2002). Examples of such metals include cadmium, copper, and nickel. USGS measured total hardness as part of its site-specific assessment of the effect of ammonia on endangered fish in the Colorado River adjacent to the Moab site. The measurements were made during three sampling events in September 1999, February 2000, and August 2000. The background locations had a range of total hardness from 140 to 700 mg/L as $CaCO_3$, and an average of 416 mg/L as $CaCO_3$. Total hardness as $CaCO_3$ in samples collected along the shoreline near the Moab site ranged from 320 to 512 mg/L and averaged 378 mg/L. Continued monitoring of hardness during the collection of surface water samples would be necessary to ensure protection of aquatic biota.

Total Dissolved Solids. Salinity alone can be toxic to many aquatic species. Total dissolved solids in excess of 15,000 mg/L are considered unsuitable for freshwater fish (NRC 1999). The toxicity of salinity depends on the ionic composition that produces the salinity (NRC 1999). Pimentel and Bulkley (1983) reported salinity concentrations that were avoided by juvenile Colorado pikeminnow, humpback chub, and bonytail. They found that Colorado pikeminnow avoided total dissolved solids above 4,400 mg/L, humpback chub avoided concentrations above 5,100 mg/L, and bonytail avoided concentrations above 6,600 mg/L. The background surface water concentration for total dissolved solids ranges from 430 to 1,060 mg/L (12 samples). Background ground water concentrations range from 677 to 97,014 mg/L total dissolved solids. The mean ground water concentration in the fresh Qal facies is 4,450 mg/L, and the mean concentration in the brine Qal facies is 51,400 mg/L. Concentrations of total dissolved solids in 29 of the 76 surface water samples collected near the Moab site were above the maximum background surface water concentration. Four of the 29 samples had concentrations that were above the levels found to cause avoidance behavior. The proposed State of Utah water quality standards (UAC 2003) provide for total dissolved solids in the surface water to be at background. Continued monitoring of total dissolved solids during active ground water remediation would be necessary to ensure protection of aquatic biota.

Contaminants of Potential Concern

The following is an evaluation of each contaminant of potential concern retained after the evaluation of surface water sampling results (Table A2−3).

Aluminum. Aluminum is a heavy metal with numerous valence states that vary according to the environment (e.g., pH and oxygen concentration). At a pH similar to that of Colorado River water near the Moab site (ranging from 6.8 to 8.9), aluminum is not very toxic to aquatic biota such as fish and amphibians (Hoffman et al. 1995). Aluminum was not detected in background ground water samples. Twelve background surface water samples were collected from 2000 to 2002 with values ranging from 0.008 to 0.14 mg/L (DOE 2003 and Chapter 3.0 of the EIS). Only two of 182 surface water samples had aluminum concentrations that exceeded the NWQC and State of Utah chronic benchmarks; the maximum background concentration also exceeded the State of Utah chronic benchmark. The State of Utah chronic criterion does not apply to waters with a pH equal to or greater than 7.0 and hardness equal to or greater than 50 mg/L as $CaCO_3$ in the receiving water after mixing. The pH and hardness values for Colorado River water near the Moab site indicate that aluminum is regulated by the acute aluminum criteria, which were not exceeded. Based on (1) the lower toxicity of aluminum in waters with high pH and hardness, (2) the low number of samples with aluminum concentrations that exceeded chronic benchmarks, and (3) the background surface water concentration, an acute or chronic effect resulting from aluminum only from the Moab site is not likely. Thus, the potential impacts to aquatic resources from exposure to aluminum are small, and further assessment is not warranted.

Ammonia. Ammonia is a form of nitrogen that is highly toxic to aquatic biota. The toxicity of ammonia is related to the ammonia ionization, which is a function of pH and temperature. Ionized ammonia (NH_4^+) is not as toxic as the un-ionized form (NH_3) (Hoffman et al. 1995). Short exposures of fish to high concentrations of ammonia (acute conditions) can cause increased gill ventilation, hyperexcitability, convulsions, and death. These effects are likely a direct effect of ammonia on the central nervous system. Long-term exposure of fish to lower concentrations of ammonia (chronic conditions) can cause histological changes, decreased reproductive capacity, decreased growth and morphological development, and increased susceptibility to disease in fish (Rand and Petrocelli 1985). Ammonia in the ground water at the Moab site is from operations associated with the extraction of uranium.

Concentrations of ammonia in surface water samples exceed acute and chronic benchmarks at numerous locations along the shoreline at the Moab site. Acute criteria for ammonia vary as a function of pH, and the chronic criteria for ammonia vary as a function of pH and temperature. The federal and state criteria are calculated on the basis of the presence or absence of salmonids (i.e., salmon or trout) and early life stages of fish. The most applicable calculations for ammonia and aquatic organisms in the Colorado River are for the absence of salmonids and the presence of early life stages of fish. Table A2−2 does not include numerical values for federal or state criteria because the benchmark for ammonia can vary greatly according to temperature and pH, which can change dramatically during even a 1-day period. Temperature and pH measurements taken simultaneously with samples for ammonia analysis from 2000 to 2002 produced federal acute criteria that ranged from 1.06 to 39.0 mg/L total ammonia. The same process resulted in federal chronic criteria that ranged from 0.29 to 5.34 mg/L total ammonia. Further information on the calculation of ammonia criteria is discussed in Appendix D of the SOWP (DOE 2003). Figure A2−3 shows the distribution of total ammonia in the surface water at the Moab site.

USGS conducted a site-specific risk assessment to determine if ground water entering the Colorado River from beneath the tailings pile could affect the endangered Colorado pikeminnow and razorback sucker (USGS 2002). Results indicate that during the low-flow period from August to March, ammonia levels exceed State of Utah standards. The area of contamination varies with hydrologic regime but in general is confined to an area less than 6,000 square yards (yd^2). USGS found that the highest observed concentrations of ammonia occur at river flows of less than 5,000 cfs during the late summer, fall, and winter months. Flows above 5,000 cfs dilute ammonia concentrations to levels below those of toxicological concern.

Toxicity tests performed as part of the USGS risk assessment indicated that Colorado pikeminnow, razorback sucker, and fathead minnow had a 28-day lowest observed effect concentration (LOEC) value for mortality ranging from 2.19 to 4.35 mg/L total ammonia (pH = 8.25 and temperature = 25 °C). USGS estimated effects on individuals at concentrations as low as 0.17 mg/L un-ionized ammonia. Toxicity tests also indicate there were no differences in toxicity across pH within a given temperature. They found that Colorado pikeminnow were more sensitive to ammonia at lower temperatures (8 °C) than at an average condition (18 °C). On-site toxicity tests demonstrated that site waters were directly toxic to both the endangered Colorado pikeminnow and the fathead minnow.

USGS also conducted surveys above and below Moab Wash to determine if ammonia or other ground water constituents were influencing the invertebrate food resources. Results indicate that the benthic invertebrate community distribution was not affected by ammonia concentrations.

Comparisons of laboratory and field results indicate that ammonia is the primary contaminant of concern due to high exposure and rapid onset of toxicity. Metals and radiochemicals, although sometimes elevated above benchmarks, did not contribute to toxicity. Continued monitoring of ammonia levels during ground water remediation would be necessary to ensure protection of aquatic biota. Ammonia would be assessed further during proposed active ground water remediation.

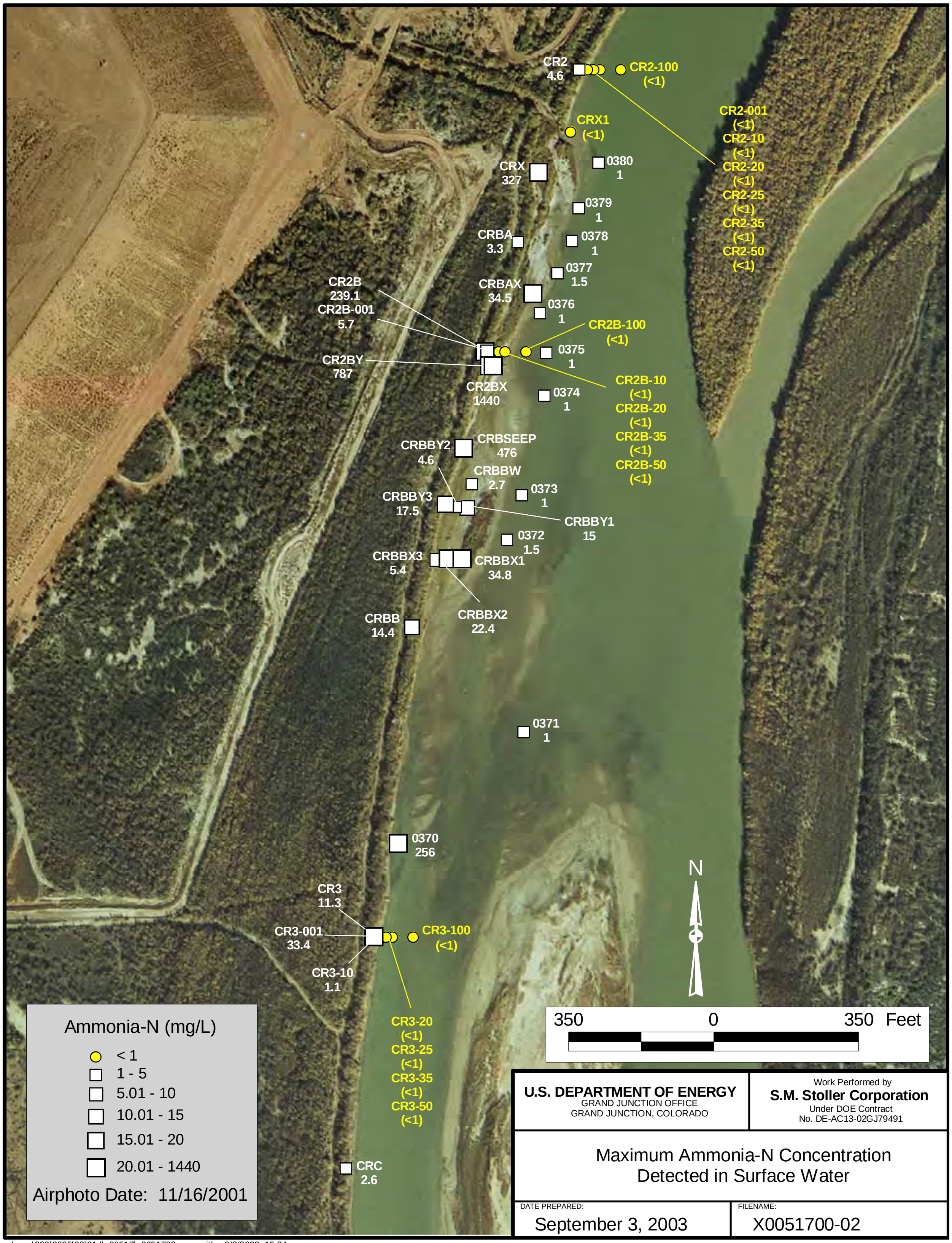

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Figure A2−3. Sampling Results for Ammonia in Surface Water at the Moab Site

Barium. Barium is a silvery-white metal that reacts readily with water to form barium hydroxide ($Ba(OH)_2$) and hydrogen gas. The toxicity of barium to fish is not well documented. The toxicity of barium to mammals ranges from muscular paralysis to cardiovascular effects (EPA 2003). Barium is concentrated in the bone, the choroids of the eye, and the lung of mammals (Hope et al. 1996). Background ground water concentrations near Moab range from 0.0222 to 0.121 mg/L. The mean concentration in the fresh Qal facies is 0.028 mg/L, and the mean concentration in the brine Qal facies is 0.076 mg/L (DOE 2003 and Chapter 3.0 of the EIS). There are no federal or state surface water quality criteria for protection of aquatic species for barium. Maximum background ground water concentrations exceed Tier II chronic criteria. Background surface water concentrations range from 0.051 to 0.14 mg/L. All 13 of the background surface water samples exceed Tier II chronic criteria, and one of the samples exceeds Tier II acute criteria. Four of the 186 surface water samples taken near Moab had barium concentrations that were above background and Tier II acute and chronic criteria. Of these four samples, three were taken from the river and one was taken from a seep. One of the river samples (0.182 mg/L) was taken from a 4-ft by 5-ft pool with no flow. The remaining two samples were found near backwater areas during the time when juvenile endangered fish might be in the region. However, the conditions necessary for aquatic biota to be exposed to elevated levels of barium that would cause a chronic impact are unlikely due to changes in river flow. Also, the concentrations in these two samples (0.152 mg/L and 0.155 mg/L) were not substantially different from maximum background concentrations (0.14 mg/L). Based on the background ground water and surface water concentrations, an acute or chronic effect resulting from barium only from the Moab site is not likely. Thus, the potential impacts to aquatic resources from exposure to barium are small, and further assessment is not warranted.

Boron. Boron is widely distributed in the environment and has been found to be essential for the early embryonic development of frogs and may be required for reproduction in some fish (Loewengart 2001). At high doses, it has been reported to be teratogenic in mammals; at lower doses, it has been shown to be an essential micronutrient in vascular plants and lower vertebrate animals (Loewengart 2001). Surface water concentrations in the United States, Canada, and the United Kingdom have mean concentrations from 0.10 to 0.16 mg/L boron (Loewengart 2001). In the western United States, 5 to 15 mg/L may be found in surface waters because of weathering of boron-rich formations and deposits (Loewengart 2001). Background ground water concentrations near the Moab site range from 0.106 to 1.33 mg/L (DOE 2003). Background surface water samples near the Moab site have boron concentrations that range from 0.0801 to 0.123 mg/L. One of the 10 background surface water samples (0.123 mg/L) is above Tier II acute and chronic criteria. Nine of the 76 surface water samples near the Moab site were above background and Tier II acute and chronic criteria. The highest concentration of boron (1.74 mg/L) was collected in January in a seep downstream of the tailings pile. Three of the samples were collected near backwater areas during the time when juvenile endangered fish might be in the region. The five remaining samples were in areas not considered backwater habitat. The conditions necessary for aquatic biota to be exposed to elevated levels of boron that would cause a chronic impact are unlikely due to changes in river flow. Hamilton examined the acute toxicity of boron on swim-up fry and juvenile Colorado pikeminnow, razorback sucker, and bonytail (Hamilton 1995). He found a mean 96-hour lethal concentration 50 (LC_{50}) of 337 mg/L boron. The most sensitive fish life stage was juvenile fish (0.4 to 2.0 grams) of all species with 96-hour LC_{50}s of greater than 100 mg/L boron. Based on the background ground water and surface water concentrations, as well as species-specific laboratory testing, an acute or chronic effect resulting from boron only from the Moab site is not likely. Thus, the potential impacts to aquatic resources from exposure to boron are small, and further assessment is not warranted.

Cadmium. Cadmium is a silvery-white metal that is relatively rare in the environment. It is an essential micronutrient for plants but can be toxic to aquatic organisms at concentrations just slightly higher (EPA 2001c). Toxic effects include pericardial and abdominal edema, reduced growth, and poor yolk utilization in larval and juvenile fish (Rand and Petrocelli 1985). A variety of factors modify the toxicity of cadmium to aquatic organisms. These factors include the species, size, and age of the organism; water hardness; pH; and the other constituents in the water (EPA 2001c). Background ground water concentrations at the Moab site range from less than 0.0001 to 0.014 mg/L. Background surface water concentrations are below detection limits (12 samples collected). Six of the 114 surface water samples collected have cadmium levels above benchmarks. Three of these were above acute NWQC and the State of Utah acute criteria, and six were above the NWQC and State of Utah chronic criteria. Two of the samples above the acute and chronic criteria were collected in the river during July and August. The other sample above acute criteria was collected in a seep in April. The remaining three samples above chronic criteria were collected in the river and in seeps during January and April.

If the NWQC acute criteria for cadmium were corrected for the minimum total hardness determined by USGS from 1999 to 2000 (320 mg/L as $CaCO_3$), then the acute cadmium criteria would increase from 0.002 to 0.006 mg/L cadmium. The State of Utah acute criteria would increase from 0.0039 to 0.013 mg/L cadmium (UAC 2003). A correction for the minimum total hardness for the NWQC chronic criteria would increase from 0.00025 to 0.00055 mg/L cadmium (EPA 2002). The State of Utah chronic criteria would increase from 0.0011 to 0.0024 mg/L cadmium. With these criteria corrected for total hardness, none of the samples collected exceeded the NWQC or State of Utah acute criteria. Five of the samples exceeded the corrected NWQC chronic criteria, and one exceeded the corrected State of Utah chronic criteria. The conditions necessary for aquatic biota to be exposed to elevated levels of cadmium that would cause a chronic impact are unlikely due to changes in river flow.

The mean background ground water concentration measured in the brine Qal facies of the aquifer is 0.004 mg/L cadmium, which is equal to the highest surface water sample concentration. The mean background ground water concentration measured in the fresh Qal facies is 0.0017 mg/L. These ground water concentrations are likely to be contributing to the surface water sample concentrations. Studies have shown that pre-exposure to cadmium leads to an elevation of the acute toxic concentration (Wicklund et al. 1990). Aquatic organisms in the Colorado River have likely been pre-exposed to these elevated levels of cadmium from natural levels in the ground water. The natural ground water concentration, small number of samples with concentrations above benchmarks, and the sample locations and dates indicate that impacts to aquatic resources from cadmium are likely to be small. Thus, the potential impacts to aquatic resources from exposure to cadmium are small, and further assessment is not warranted.

Chloride. Chloride is an anion. The effects of chloride are primarily associated with the complexes of chloride and heavy metals, and in high concentrations, as the main contributor to salinity. The background ground water concentration for chloride ranges from 135 to 52,388 mg/L. The mean background concentration in the fresh Qal facies is 1,990 mg/L, and the mean background concentration in the brine Qal facies is 29,200 mg/L. A shallow ground water sample in the Matheson Wetlands Preserve across the river from the site has concentrations of chloride exceeding 29,000 mg/L (DOE 2003). These concentrations occurring naturally in the ground water are well above the acute NWQC. Chloride was detected in all 20 background surface water samples, with concentrations ranging from 25 to 172 mg/L. Fifty-one surface water samples collected near the Moab site had concentrations above background surface water concentrations. Thirteen of these samples had concentrations above the acute NWQC, and concentrations in 27 are above the chronic NWQC. Fourteen of the samples with concentrations that exceed benchmarks were collected in pools with little or no flow. The sample with the maximum concentration (17,300 mg/L) was collected in January from a seep. This high concentration indicates that ground water near the Moab site and the Matheson Wetlands Preserve may be influencing surface water concentrations. In the Colorado River Basin, the influence of chloride from natural sources is likely (DOE 2003). Studies indicate that aquatic biota acclimate to increased salinity due to high concentrations of chloride or other anions (Buttner et al. 1993). Aquatic organisms in the Colorado River have likely been pre-exposed to these elevated levels of chloride from natural levels in the ground water. Impacts to aquatic resources from chloride are likely to be small. Thus, the potential impacts to aquatic resources from exposure to chloride are small, and further assessment is not warranted.

Copper. Copper is a micronutrient and an essential component of numerous metabolic pathways and enzymes (Rand and Petrocelli 1985, Magos and Suzuki 1996). Ingestion of copper in excess of nutritional needs can lead to accumulation in the liver, anorexia, edema, disorientation, and scale protrusion (Rand and Petrocelli 1985, Wedemeyer et al. 1976). A variety of factors modify the toxicity of copper to aquatic organisms. These factors include the species, size and age of the organism, water hardness, pH, and the other constituents in the water. Fish, invertebrates, and aquatic plants appear to be equally sensitive to chronic toxicity (EPA 2003). Copper was detected in three of the 13 background surface water samples, with concentrations ranging from 0.0006 to 0.0014 mg/L. Background concentrations in the ground water range from 0.0004 to 0.007 mg/L. Background surface water and ground water concentrations are below all benchmarks. Five of the 182 samples collected for copper had concentrations above acute NWQC and State of Utah acute criteria. Eight had concentrations above chronic NWQC and State of Utah chronic criteria. Three of the samples above the benchmarks were collected in seeps, and the remaining five were collected in the river. The samples were collected near backwater areas during the time when juvenile endangered fish might be in the region.

If the criteria for copper were corrected for the minimum total hardness determined by USGS from 1999 to 2000 (320 mg/L as $CaCO_3$), then the NWQC acute copper criteria would increase from 0.013 to 0.040 mg/L copper (EPA 2002). The State of Utah acute criteria would increase from 0.018 to 0.051 mg/L copper (UAC 2003). A correction for the minimum total hardness for the NWQC chronic criteria would increase from 0.009 to 0.024 mg/L copper (EPA 2002). The State of Utah chronic criteria would increase from 0.012 to 0.030 mg/L copper. With these criteria corrected for total hardness, only one of the samples exceeded the NWQC and State of Utah acute or chronic criteria.

USGS analyzed surface water samples for metals in August 1998, February 1999, and 2000. Results indicate that copper concentrations exceeded the State of Utah water quality criteria at several locations during each sampling event. However, USGS concluded that "concentrations of these constituents [copper and zinc] are transient and do not approach levels demonstrated in the laboratory as acutely toxic to razorback suckers or Colorado pikeminnow" (USGS 2002).

Copper has been found to be the primary toxic component of mixtures of contaminants similar to those found at the Moab site (Buhl and Hamilton 1996). Copper has also been implicated as a potential site-related contaminant in previous discussions and in correspondences with USF&WS (NRC 1999). In addition, process knowledge from the site indicates that copper was likely a contaminant in the pile and waste areas (DOE 2003). Continued monitoring of copper levels during ground water remediation would be necessary to ensure protection of aquatic biota. Copper would be assessed further during active ground water remediation.

Iron. Iron is a micronutrient and is essential in a variety of biochemical reactions. However, in higher concentrations, iron can be toxic to aquatic biota (Magos and Suzuki 1996). Ingestion of iron in excess of nutritional needs can lead to accumulation in the liver (Magos and Suzuki 1996). A variety of factors modify the toxicity of iron to aquatic organisms. These factors include the species, size and age of the organism, water hardness, pH, and the other constituents in the water. Background surface water concentrations range from 0.0075 to 4.17 mg/L (nine samples collected). Background concentrations in the ground water range from 0.0008 to 22.3 mg/L. The mean concentration in the fresh Qal facies is 0.009 mg/L and from the brine Qal facies is 9.14 mg/L. The mean concentration in the brine Qal facies is above the chronic NWQC and the acute and chronic State of Utah water quality criteria. Fourteen of the 119 surface water samples collected had copper concentrations that were above the chronic NWQC and the acute and chronic State of Utah water quality criteria. These samples were taken in August 2002 during a sampling event where paired samples (one filtered and one unfiltered) were collected. Results indicate that the iron is bound to a particulate that can be removed with a filter. Iron was the only analyte from that sampling event in which filtering the sample before analysis lowered the concentration by more than an order of magnitude. In the state of Utah, filtered samples are the only samples that should be used for comparison to benchmarks (UAC 2003). The one filtered sample above benchmarks was collected from the river in August. Though it was collected in the river during a time when juvenile endangered fish might be in the region, it was not in an area with backwater habitat. Conditions necessary for fish to be exposed to chronic conditions are unlikely. Natural ground water concentrations and the small number of samples with concentrations above the benchmarks indicate that impacts to fish resulting from iron contamination related to the Moab site are unlikely. Thus, the potential impacts to aquatic resources from exposure to iron are small, and further assessment is not warranted.

Lithium. There is very little in the literature on the toxicity of lithium to aquatic organisms. A study by Hamilton (1995) indicated that lithium is as toxic to fish as selenite and uranium, especially at early life stages. Background ground water concentrations range from 0.0278 to 1 mg/L. The mean concentration in samples from the fresh Qal facies is 0.0873 mg/L, and the mean concentration in samples from the brine Qal facies is 0.143 mg/L, which is above the Tier II chronic benchmark. Three background surface water samples have been collected; lithium concentrations in two were below detection limit and the other had a concentration of 0.057 mg/L. One of the 18 surface water samples collected near the Moab site had a lithium concentration above the Tier II acute benchmark, and 14 samples had concentrations above the Tier II chronic benchmark. All of these samples were collected in the river during the time when juvenile endangered fish might be in the region. However, the conditions necessary for aquatic biota to be exposed to elevated levels of lithium that would cause a chronic impact are unlikely due to changes in river flow.

Hamilton (1995) examined the acute toxicity of lithium on swim-up fry and juvenile Colorado pikeminnow, razorback sucker, and bonytail. He found a mean 96-hour LC_{50} of 42 mg/L lithium. The most sensitive fish life stage was the swim-up fry (10 to 31 days old) of all species, with 96-hour LC_{50}s ranging from 17 to 25 mg/L lithium. Background ground water concentrations, as well as species-specific laboratory testing, indicate that impacts to fish resulting from lithium contamination related to the Moab site are not likely. Thus, the potential impacts to aquatic resources from exposure to lithium are small, and further assessment is not warranted.

Manganese. Manganese is a metallic element that occurs naturally in rock and soils/sediments weathered from rock. It is most abundant in areas of metamorphic and sedimentary rock. Dissolution from rock and soils/sediments into ground water and surface water has resulted in the presence of varying levels of manganese in natural waters (Reimer 1999). It is an essential trace element for microorganisms, plants, and animals and is therefore present in almost all organisms (Magos and Suzuki 1996). Manganese is a constituent in a variety of enzymes and is an essential part of enzyme systems that metabolize proteins and energy in all animals (Reimer 1999, Magos and Suzuki 1996). A variety of factors modify the toxicity of manganese to aquatic organisms. These factors include the species, size and age of the organism, water hardness, pH, and the other constituents in the water. Toxic effects include anemia, reduced growth, reduction in reproductive potential in fish, and anemia (Srivastava and Agrawal 1983, Stubblefield et al. 1997, Reimer 1999).

Background ground water concentrations range from 0.0001 to 38.5 mg/L. The mean ground water concentration in the fresh Qal facies is 0.0057 mg/L, and the mean concentration in the brine Qal facies is 11.7 mg/L, which is above the Tier II acute benchmark. Eight of the 18 background surface water samples had concentrations above detection, ranging from 0.003 to 0.076 mg/L. Ten of the 260 surface water samples collected had concentrations above the Tier II acute benchmark and the lowest chronic benchmark. Twenty-six of the samples had concentrations above the Tier II chronic benchmark. Thirteen of the samples with concentrations above the benchmarks were collected in pools with little or no flow. The two samples with the highest concentration of manganese were collected from a 4-ft by 5-ft pool with no flow. The ground water concentrations are likely to be contributing to the surface water sample concentrations.

USGS analyzed surface water samples for metals in August 1998, February 1999, and 2000. Results indicate that manganese concentrations exceeded the State of Utah water quality criteria at several locations during each sampling event. However, the concentrations varied spatially with no obvious relationship to the location of the tailings pile (USGS 2002).

Studies have shown that pre-exposure of fish to manganese leads to an elevation of the acute toxic concentration (Stubblefield et al. 1997, Reimer 1999). Aquatic organisms in the Colorado River have likely been pre-exposed to these elevated levels of manganese from natural levels in the ground water.

At least half of the manganese samples were collected in the river during the time when juvenile endangered fish might be in the region. In addition, manganese has been implicated as a potential site-related contaminant in previous discussions and correspondences with USF&WS (NRC 1999). Manganese is known to be part of process knowledge and is likely in high concentrations in the waste and tailings pile (DOE 2003). Continued monitoring of manganese levels during ground water remediation would be necessary to ensure protection of aquatic biota. Manganese would be assessed further during active ground water remediation.

Mercury. Mercury is a dense silver-white metal that is liquid at room temperature (Hoffman et al. 1995). The environmental effects of mercury vary with its form, dose, pathway of exposure, and life stage of the affected organism (EPA 2003). Mercury concentrations in all background ground water, background surface water, and surface water samples near the Moab site were below the detection limit. DOE reviewed existing data for mercury in preparation for additional sampling during July 2002. Mercury was detected in 3 of 30 ground water samples collected in previous monitoring rounds. Only one ground water sample had a concentration (0.003 mg/L) that exceeded the maximum concentration limit of 0.002 mg/L. Review of historical process data and experience at other Uranium Mill Tailings Radiation Control Act (UMTRCA) sites indicate that mercury is not used in the milling process (Stoller 2002). On the basis of process knowledge and the low frequency of detection in ground water, it is unlikely that mercury is a site-related contaminant. The potential impacts to aquatic resources from exposure to mercury are small, and further assessment is not warranted.

Molybdenum. Molybdenum is a cofactor to many enzymes essential to aquatic organisms (Magos and Suzuki 1996; Reid 2002). It is generally considered nontoxic to aquatic organisms. In aquatic systems, it readily forms organometallic complexes (Reid 2002). Toxicity estimates of molybdenum to freshwater fish range from 70 to greater than 3,000 mg/L, depending on the species, size of fish, and test conditions (Reid 2002). Acute sublethal effects include increased ventilation, fused gill lamellae, and hemorrhaging of the gut and pyloric caeca (Reid 2002). The background ground water concentration in the fresh Qal facies ranges from 0.0018 to 0.01 mg/L (mean concentration = 0.0037 mg/L). The ground water concentration in the brine Qal facies was below detection limits. Seventeen of the 18 background surface water samples had concentrations above detection limits, ranging from 0.0028 to 0.007 mg/L. Ten of the 290 surface water samples collected had concentrations above the chronic Tier II benchmark. Three of these samples were collected from seeps, and seven were collected from the river. Two of the samples collected from the river were taken from a 4-ft by 5-ft pool with no flow. The river samples were all collected during a time when juvenile endangered fish might be in the region. However, the conditions necessary for aquatic biota to be exposed to elevated levels of molybdenum (e.g., to cause a chronic impact) are unlikely due to changes in river flow. The low toxicity of molybdenum as well as the surface water sample locations indicate that impacts to fish resulting from molybdenum contamination are not likely. Thus, the potential impacts to aquatic resources from exposure to molybdenum are small, and further assessment is not warranted.

Nickel. Pure nickel is a hard, silvery-white metal and is abundant in the environment. Nickel combined with other elements occurs naturally in the earth's crust, primarily combined with oxygen (oxides) or sulfur (sulfides), and is found in all soils (EBI 2003). Toxic effects in aquatic systems include tissue damage, genotoxicity, and growth reduction (EPA 2003). A variety of factors modify the toxicity of nickel to aquatic organisms. These factors include the species, size and age of the organism, water hardness, pH, and the other constituents in the water. Background ground water concentrations range from 0.0006 to 0.0647 mg/L. The mean ground water concentration in the fresh Qal facies is 0.0022 mg/L, and the mean concentration in the brine Qal facies is 0.0327 mg/L. The background surface water concentration ranges from 0.003 to 0.076 mg/L (10 samples collected). Ground water and surface water concentrations are below all benchmarks. One of the 56 surface water samples collected had a concentration above the chronic NWQC, State of Utah chronic criteria, and the lowest chronic benchmark.

If the criteria for nickel were corrected for the minimum total hardness determined by USGS from 1999 to 2000 (320 mg/L as $CaCO_3$), then the NWQC acute nickel criteria would increase from 0.47 to 1.25 mg/L nickel (EPA 2002). The State of Utah acute criteria would increase from 1.40 to 3.79 mg/L nickel (UAC 2003). A correction for the minimum total hardness for the NWQC chronic criteria would increase from 0.052 to 0.139 mg/L nickel (EPA 2002). The State of Utah chronic criteria would increase from 0.16 to 0.420 mg/L nickel. With these criteria corrected for total hardness, none of the samples had concentrations that exceeded the NWQC and State of Utah acute or chronic criteria for nickel.

The one sample that exceeded the chronic benchmark without a correction for hardness was collected in the river during a time when juvenile endangered fish might be in the region. However, the conditions necessary for aquatic biota to be exposed to elevated levels of nickel that would cause a chronic impact are unlikely due to changes in river flow. The low number of samples with concentrations that are above benchmarks indicates that impacts to fish resulting from nickel related to the Moab site are not likely. Thus, the potential impacts to aquatic resources from exposure to nickel are small, and further assessment is not warranted.

Nitrate. Ammonia, nitrite, and nitrate are interrelated through the process of nitrification. Nitrification is the biological process during which nitrifying bacteria convert toxic ammonia to less harmful nitrate. Nitrate is considered essentially nontoxic to aquatic organisms (Rand and Petrocelli 1985). Toxic effects include disruption of normal osmoregulatory ability (Rand and Petrocelli 1985). Background ground water concentrations range from 1.22 to 15.9 mg/L. The mean ground water concentration in the fresh Qal facies is 7.58 mg/L, and the mean concentration in the brine Qal facies is 0.0346 mg/L. The mean concentration in the fresh Qal facies is above the acute and chronic State of Utah water quality criteria. The background surface water concentration ranges from 1.86 to 5.51 mg/L. Two of the five background surface water samples had concentrations above the acute and chronic State of Utah water quality criteria. Thirty-eight of the 76 surface water samples collected had concentrations above the acute and chronic State of Utah water quality criteria. At least half of these samples were collected in the river during the time when juvenile endangered fish might be in the region. However, the conditions necessary for aquatic biota to be exposed to elevated levels of nitrate such as to cause a chronic impact are unlikely due to changes in river flow. Background ground water concentrations, background surface water concentrations, and the relatively low toxicity of nitrate indicate that impacts to fish resulting from nitrate related to the Moab site are not likely. Thus, the potential impacts to aquatic resources from exposure to nitrate are small, and further assessment is not warranted.

Selenium. Selenium is a metalloid that occurs ubiquitously in nature but is rarely found in concentrations over 100 mg/L in aquatic systems (Cleveland et al. 1993). Selenium is required in the diet of fish at concentrations of 1.0 to 0.5 micrograms per gram (μg/g) dry weight (Lemly 1998). It is necessary for the formation of enzymes involved in normal cellular and organ metabolism (Lemly 1998). At dietary concentrations 7 to 39 times those required, it becomes toxic (Lemly 1998). Toxic effects include reduced growth, reproductive failure, liver damage, and chromosomal aberrations (Cleveland et al. 1993, EPA 2003).

Background ground water concentrations range from 0.0091 to 0.0266 mg/L. The mean ground water concentration in the fresh Qal facies is 0.0164 mg/L, and the mean concentration in the brine Qal facies is 0.00171 mg/L. The mean concentration in the fresh Qal facies is above the chronic NWQC and the chronic State of Utah water quality criteria. The background surface water concentration ranges from 0.0013 to 0.0079 mg/L. Six of the 15 background surface water samples had concentrations above the chronic NWQC and chronic State of Utah water quality criteria. Seven of the 216 surface water samples collected near the Moab site had concentrations above background, the chronic NWQC, and chronic State of Utah water quality criteria. The selenium level in one of these samples exceeded the acute State of Utah water quality criteria.

Four of these seven samples were collected in pools with little or no flow, and two were collected from seeps.

USGS analyzed surface water samples for metals in August 1998, February 1999, and 2000. Results indicate that selenium concentrations range from 0.001 to 0.004 mg/L as total selenium. However, USGS concluded that the data "provides no indication that selenium from the Atlas Mill Tailings Pile is elevated to levels of localized concern" (USGS 2002).

Background ground water and surface water concentrations, the sample locations, and low number of samples with concentrations above benchmarks indicate that impacts to fish resulting from selenium related to the Moab site are not likely. Thus, the potential impacts to aquatic resources from exposure to selenium are small, and further assessment is not warranted.

Silver. Silver may biomagnify in some aquatic invertebrates and is highly toxic to aquatic organisms. Elevated levels of silver can cause larval mortality, developmental abnormalities, and reduced larval growth in fish (EPA 2003). Silver concentrations in all background ground water, background surface water, and surface water samples near the Moab site were below the analytical detection limits. One-half the reported detection limit (EPA 2001a, 2001b) was used to assess these samples. A variety of factors modify the toxicity of nickel to aquatic organisms. These factors include the species, size and age of the organism, water hardness, pH, and the other constituents in the water. One sample collected in the surface water near the Moab site could be above the acute NWQC and State of Utah acute criteria. Two samples could be above the chronic Tier II benchmark, and 33 could be above the lowest chronic benchmarks. The mean concentration of silver in the tailings pore water is 0.0009 mg/L (DOE 2003). This value is below all benchmarks except the "lowest chronic" benchmark.

If the criteria for silver were corrected for the minimum total hardness determined by USGS from 1999 to 2000 (320 mg/L as $CaCO_3$), then the NWQC acute silver criteria would increase from 0.0032 to 0.024 mg/L silver (EPA 2002). The State of Utah acute criteria would increase from 0.0041 to 3.79 mg/L silver (UAC 2003). With these criteria corrected for total hardness, none of the samples had concentrations that exceeded the NWQC and State of Utah acute criteria for silver.

The lack of elevated silver in the tailings pore water and the low number of samples with concentrations above benchmarks indicate that impacts to fish resulting from silver related to the Moab site are not likely. Thus, the potential impacts to aquatic resources from exposure to silver are small, and further assessment is not warranted.

Strontium. Strontium is a soft, silver-gray metal that is commonly found in soils. It behaves similarly to calcium in living organisms (Peterson et al. 2002). The uptake of strontium through an organism and through the food chain is affected by the presence of calcium in the system (Driver 1994). The concentration of strontium in the bone and muscle of trout was found to be inversely related to calcium concentrations in the water. Because of its chemical similarity to calcium, strontium is deposited in the bones of vertebrates (Driver 1994). Background ground water concentrations at the Moab site range from 2.25 to 65 mg/L. The mean ground water concentration in the fresh Qal facies is 3.79 mg/L, and the mean concentration in the brine Qal facies is 36.8 mg/L. The mean concentration in the fresh Qal facies is above the chronic Tier II benchmark, and the mean concentration in the brine Qal facies is above the acute and chronic Tier II benchmarks. The background surface water concentration ranges from 0.965 to

1.63 mg/L. Concentrations in two of the 10 background surface water samples are above the chronic Tier II benchmark. Twenty of the 136 surface water samples collected near the Moab site had concentrations above the maximum background surface water concentration and the chronic Tier II benchmark. Sixteen of these samples were collected from pools with little or no flow. The natural ground water concentrations are likely to be contributing to the surface water sample concentrations. At least half of these samples were collected in the river during a time when juvenile endangered fish might be in the region. However, the conditions necessary for aquatic biota to be exposed to elevated levels of strontium that would cause a chronic impact are unlikely due to changes in river flow. Elevated natural ground water concentrations, elevated background surface water concentration, and surface water sample locations indicate that impacts to fish resulting from strontium related to the Moab site are not likely. Thus, the potential impacts to aquatic resources from exposure to strontium are small, and further assessment is not warranted.

Sulfate. Sulfate is an anion, and the effects of sulfate are primarily associated with the complexes of sulfate and heavy metals. There are no established benchmarks for sulfate. The background ground water concentrations for sulfate range from 180 to 6,000 mg/L. The mean background concentration in the fresh Qal facies is 772 mg/L, and the mean background concentration in the brine Qal facies is 3,520 mg/L. The surface water background concentrations range from 84.1 to 439 mg/L (20 samples). Fifty-three of the 301 surface water samples collected near the Moab site had concentrations above background. Four of the 53 samples with above background concentrations were collected in seeps. Twenty-eight of the 53 samples were collected in pools with little or no flow, and these samples also had elevated levels of other contaminants of potential concern. Sulfate was used extensively in processing the ore at the Moab site and is a common contaminant at other UMTRCA sites (DOE 2003). Continued monitoring of sulfate levels during ground water remediation would be necessary to ensure protection of aquatic biota. Sulfate would be assessed further during active ground water remediation.

Uranium. Uranium is a silver-colored heavy metal that is nearly twice as dense as lead. It is the heaviest naturally occurring element in nature. Uranium can pose a hazard from its chemical toxicity as well as from its radiological toxicity (internal alpha emission) in biota. However, because of its low specific activity, uranium primarily poses a chemical hazard rather than a radiological hazard in biota (Wrenn et al. 1985; Bosshard et al. 1992). The toxicity of uranium to fish varies with water quality, particularly total hardness and alkalinity (Driver 1994). It accumulates in soils and sediments and enters the food chain by adsorption on surfaces of plants and animals and by ingestion of sediments and contaminated food (Driver 1994; Cooley and Klaverkamp 2000; Swanson 1983). Therefore, bottom-feeding fish species have been found to accumulate the highest concentration of uranium, relative to piscivorous fish (Waite et al. 1988; Swanson 1983, 1985).

Information regarding the accumulation and distribution of uranium in freshwater fish is limited. Available data indicate that the primary sites of uranium accumulation are the bones, scales, gonads, gills, gastrointestinal tract, kidney, and liver (Cooley and Klaverkamp 2000; Swanson 1985; Waite et al. 1988; Holdway 1992). Studies by Cooley et al. (2000) and Holdway (1992) suggest that the liver and kidney may be a significant site for uranium toxicity in fish, causing lesions and malformations.

Uranium in samples from 2000 to 2002 ranged from 0.0013 to 5.12 mg/L (Figure A2−4). Background ground water concentrations range from 0.0042 to 0.0269 mg/L uranium. The mean ground water concentration in the fresh Qal facies is 0.0127 mg/L, and the mean concentration in the brine Qal facies is 0.00768 mg/L. The mean uranium concentrations in the fresh Qal facies and the brine Qal facies are above the Tier II chronic benchmark. The background surface water concentration ranges from 0.0023 to 0.008 mg/L uranium. Eighteen of the 20 background surface water samples had concentrations above the Tier II chronic benchmark. One hundred seventy-four of 331 surface water samples collected near the Moab site had concentrations above the maximum background surface water concentration and the Tier II chronic benchmark. Forty-two surface water samples had concentrations above the Tier II acute benchmark. Sixteen samples had concentrations above the lowest chronic benchmark.

The calculated criteria by Suter and Tsao (1996) were used to evaluate uranium in surface water because there are no federal or State of Utah standards. The values for the Tier II acute and chronic benchmarks appear to be very low and not reproducible when the published data are recalculated using their methodology. They also developed estimated lowest chronic values for fish extrapolated from laboratory studies. The lowest chronic value is considered conservative in comparison to results of studies on swim-up fry and juvenile Colorado pikeminnow, razorback sucker, and bonytail (Hamilton 1995).

Hamilton (1995) examined the acute toxicity of uranium on swim-up fry and juvenile Colorado pikeminnow, razorback sucker, and bonytail. He found a mean 96-hour LC_{50} of 46 mg/L of uranium for all species. Results do not indicate a difference in uranium sensitivity between life stages or species.

Continued monitoring of uranium levels during ground water remediation would be necessary to ensure protection of aquatic biota. Uranium would be assessed further during active ground water remediation.

Vanadium. Vanadium is a steel-gray, corrosion-resistant metal that is likely an essential element to living organisms (Barceloux 1999). There is little information about the toxicity of vanadium to aquatic resources. Background ground water concentrations range from 0.00061 to 0.135 mg/L vanadium. The mean ground water concentration in the fresh Qal facies is 0.00534 mg/L, and the mean concentration in the brine Qal facies is 0.0418 mg/L, which is above the Tier II chronic benchmark. The background surface water concentration ranges from 0.00073 to 0.0031 mg/L. Two of the 148 surface water samples collected near the Moab site had concentrations above the Tier II acute and chronic benchmarks. These two samples were collected from seeps in April, when juvenile endangered fish are not likely to be in the region. The conditions necessary for aquatic biota to be exposed to elevated levels of vanadium that would cause a chronic impact are unlikely due to changes in river flow. Thus, the potential impacts to aquatic resources from exposure to vanadium are small, and further assessment is not warranted.

Synergistic Effects. The list of analytes for the Moab site monitoring of surface water from 2000 to 2002 includes chemicals that may act together to cause synergistic impacts to the listed fish. Mixtures of inorganic metals can be hazardous because metals in a mixture may be present at concentrations below their individual toxic thresholds but sufficiently high to interact additively or synergistically with other inorganics and cause a toxic response in aquatic organisms (Hamilton 1995). Numerous studies have documented additive effects on aquatic organisms,

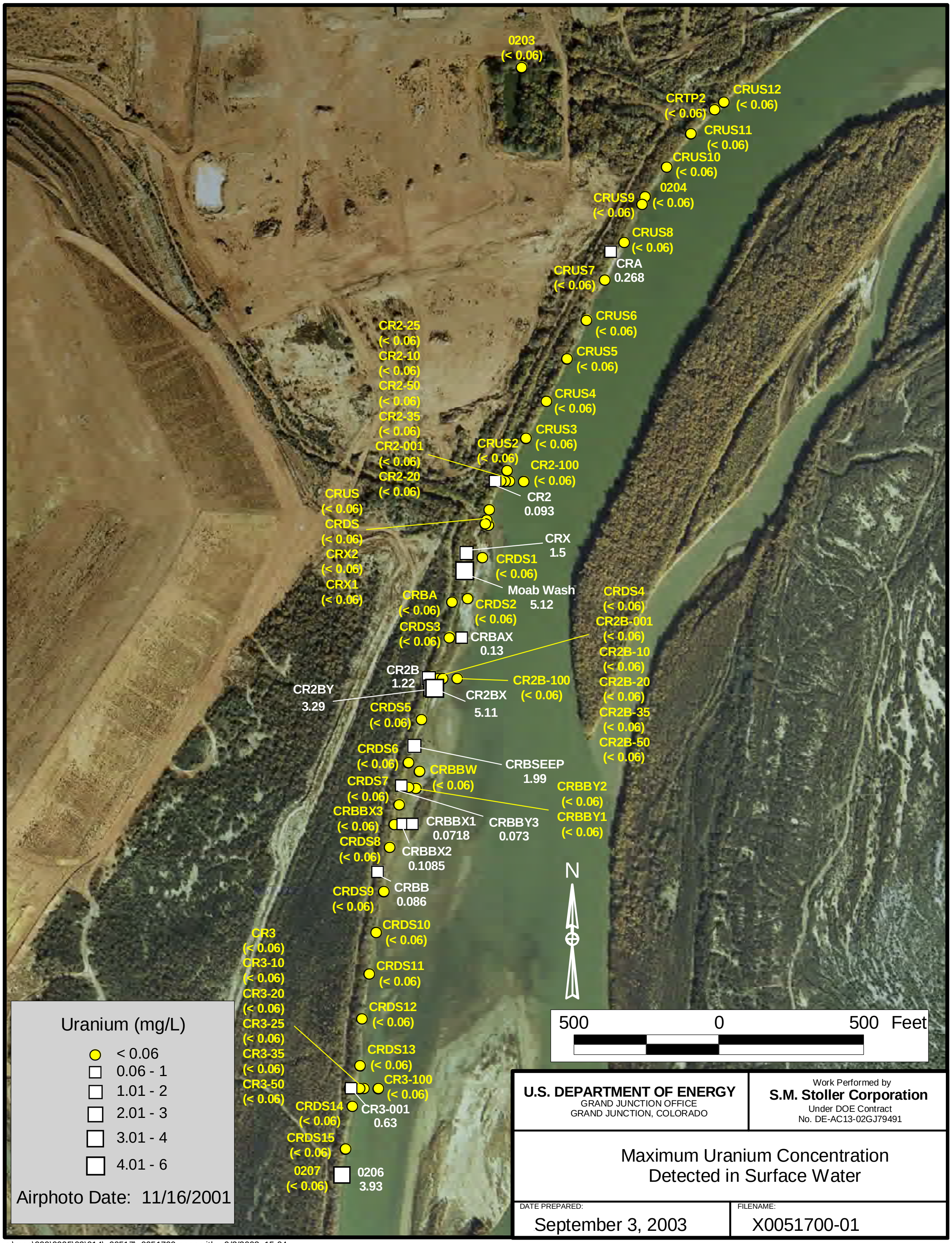

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Figure A2−4. Sampling Results for Uranium in Surface Water at the Moab Site including the Colorado pikeminnow, razorback sucker, and bonytail. Hamilton (1995) found that waterborne concentrations of boron, selenium, and zinc each cause an adverse effect in young Colorado pikeminnows, razorback suckers, and bonytails. In addition, the mixture of these metals with vanadium and uranium increased the toxicity to the fish, yet by themselves, vanadium and uranium were not hazardous. Buhl and Hamilton (1996) considered effects from waterborne mixtures of arsenate, boron, copper, molybdenum, selenate, selenite, uranium, vanadium, and zinc to early life stages of Colorado pikeminnow, razorback sucker, and bonytail. Results indicate that chronic exposure to the mixtures showed a synergistic effect that was species- and life-stage specific. Hamilton et al. (2000) found that mixtures of copper, selenium, and zinc have toxic effects on razorback suckers and bonytails. The results of the USGS site-specific study with the Colorado pikeminnow and the razorback sucker indicate that ammonia toxicity was not affected when ammonia was mixed with other contaminants found in the Colorado River (USGS 2002). Potential impacts to aquatic resources from synergistic effects of ammonia with other contaminants are not likely. Synergistic effects between other metals are possible but are difficult to quantify.

Chemical Impacts to Aquatic Biota. Based on the evaluation of contaminants of potential concern, the chemical contaminants that would require future assessment and continued monitoring during proposed active ground water remediation activities for the Moab site are ammonia, copper, manganese, sulfate, and uranium. The proposed ground water extraction near the Colorado River and the use of freshwater injection would decrease the maximum concentrations of these contaminants of concern in the nearshore environment to levels below acute and chronic benchmarks. Potential synergistic effects between contaminants would be reduced through ground water remediation. For these contaminants of concern, for both acute and chronic benchmarks, continued monitoring during ground water remediation activities would be necessary to ensure acceptable conditions for protection of aquatic biota.

Radiological Impacts to Aquatic Biota. The primary route by which radioactive contamination enters the aquatic environment at the Moab site is through ground water. The routes of exposure for the radioactive contaminants are the same as those for chemical impacts. The contributors to radiological dose to the aquatic organisms at the Moab site that have been monitored include lead-210, polonium-210, radium-226, radium-228, radon-222, thorium-230, uranium-234, and uranium-238, and the general indicator of radionuclides, gross alpha and gross beta.

The RESRAD Biota Code (Version 1.0 Beta 3, June 3, 2003) was used to screen the dose rate to aquatic organisms based on the maximum observed concentrations of uranium-238, uranium-234, and radium-226 (DOE 2002). These isotopes represent the highest values analyzed for radionuclides in 2000 to 2002. The protocol for screening assessment includes multiple tiers. The first-tier screening assessment using the maximum observed concentrations had a sum of fractions that equaled 3.16, which exceeded the DOE guidance level of 1.0 for aquatic biota. A second-tier analysis based on mean concentrations of these three radionuclides of those values above detection resulted in a sum of fractions value of 0.29. The results of the second-tier analysis indicate that dose rates are below the guidance level associated with the 1.0-rad-per-day criterion adopted by DOE for screening dose rates to aquatic organisms.

The results of the RESRAD assessment indicate that the actual dose rates to aquatic organisms are below a population effect level. There are no guidelines for radiological effects to individuals, which is important in evaluating impacts to threatened and endangered species. The studies that were completed for the 1.0-rad-per-day criterion were based on exposures to organisms for 1 year, and then normalized to a dose rate based on a day. One can interpret these results to mean that a dose rate of 1.0 rad per day, if sustained for a year, would have an effect on some individuals but not on the population as a whole. Based on monitoring results from 2000 to 2002 and on the life styles of the endangered fish around the Moab site, radiological effects currently are not expected to adversely affect the aquatic environment.

Ground water extraction near the Colorado River and the use of freshwater injection would further decrease the maximum concentrations of radionuclides along the shoreline of the Moab site. These activities would be necessary to reduce impacts from chemical contaminants. They would also reduce the potential for radiological effects to individuals, which is important to endangered species as well as populations.

Long-term impacts would depend on the cover design and cover effectiveness to maintain radioactive contaminants below their current concentrations. As long as the dose rate to aquatic biota from radioactive contaminants remained below that measured from 2000 to 2002, there would be no impacts to individuals or populations.

Gross Alpha. Gross alpha is a screening assay to measure all the alpha activity present in a sample, regardless of the specific radionuclide source. Such measurements are used as a method to screen samples for relative levels of radioactivity (INEEL 2001). The alpha-emitting radionuclides at the Moab site are uranium-238, radon-222, radium-226, and polonium-210. The State of Utah water quality standard for gross alpha is 15 pCi/L (UAC 2003). A total of 93 surface water samples were analyzed for gross alpha from 2000 to 2002; seven samples were collected at background locations; concentrations ranged from <7.3 to 13.82 pCi/L. Gross alpha activity in surface water samples near the Moab site ranged from 8 to 665 pCi/L; the maximum activity was detected in a sample from location CR2B (Figure A2–4). Samples with gross alpha activity that exceeded the State of Utah water quality standard (37 samples) were located in regions where uranium concentrations were highest. Overall, radiochemicals do not appear to be a concern to aquatic biota in the Colorado River adjacent to the site. USGS concluded that there would be “no significant biological impacts to fish populations caused by radionuclide concentrations sampled in the Colorado River and sediments.” They found that “radiochemical concentrations are elevated in ground water below the Moab pile; however, these waters do not result in a high radiation exposure to fish” (USGS 2002). Continued monitoring of uranium levels would be appropriate for addressing impacts to the aquatic biota and directly evaluating proposed activities to remediate the site.

A2−2.0 Screening for Terrestrial Biota

Chemical Impacts to Wildlife. Samples of nonradiological constituents in surface water were collected by SMI and USGS between 2000 and 2002. The rationale for screening the original 28 contaminants to select two contaminants of potential concern for wildlife (mercury and selenium) was the same as the process described above for aquatic biota (involving comparison of maximum contaminant concentrations in surface water with detection limits, background concentrations, and toxicological benchmarks), except that different toxicological benchmarks were used.

Wildlife could be exposed to contaminants through ingestion of prey and water and through incidental soil ingestion, inhalation of airborne contaminants, and dermal uptake. The primary pathway for wildlife exposure to contaminants would likely be through ingestion of prey in the riparian zone and of prey and water in the surface waters of the nearshore environment.

The selection of contaminants of potential concern could not be based on ingestion of prey in the riparian zone because contaminant data for local riparian biota were not available for comparison with tissue concentration benchmarks (milligrams per kilogram [mg/kg]) based on ingestion. Consequently, in addition to the process described above for aquatic biota, the selection of contaminants of potential concern was based on the potential for chronic effects via ingestion of prey and water within the surface waters of the nearshore environment. This was evaluated by comparing contaminant concentrations in surface water with mammalian and avian drinking water benchmarks (mg/L) that would result in NOAELs (mg/kg/day) and LOAELs (mg/kg/day), and with piscivorous mammalian and avian food/water benchmarks (mg/L) that would result in NOAELs (mg/kg/day) and LOAELs (mg/kg/day). NOAEL benchmarks are values believed to be nonhazardous. LOAEL benchmarks are threshold values for which chronic adverse effects are likely to become evident.

Sample et al. (1996) provides drinking water benchmarks for 9 mammalian wildlife species (cottontail rabbit, little brown bat, meadow vole, mink, red fox, river otter, short-tailed shrew, white-footed mouse, and whitetail deer) and 11 avian wildlife species (American robin, American woodcock, barn owl, barred owl, belted kingfisher, Cooper's hawk, great blue heron, osprey, red-tailed hawk, rough-winged swallow, and wild turkey). The lowest mammal and bird NOAEL- and LOAEL-based drinking water benchmarks (Tables A2−4 and A2−5, respectively) were used to select contaminants of potential concern. In addition, Sample et al. (1996) provides food/water benchmarks for two piscivorous mammals (river otter and mink) and three piscivorous birds (belted kingfisher, great blue heron, and osprey). The lowest of the piscivorous mammal and the lowest of the piscivorous bird NOAEL- and LOAEL-based food/water benchmarks were also used to select contaminants of potential concern (Tables A2−4 and A2–5, respectively).

Drinking water and/or food/water toxicity benchmarks that were exceeded by maximum contaminant concentrations are identified by an asterisk in tables A2-4 and A2-5 (i.e., aluminum, cadmium, mercury, molybdenum, and selenium). However, for some constituents (i.e., iron, molybdenum, and silver), there were no existing drinking water or food/water toxicity benchmarks (Sample et al. (1996). For these constituents, these benchmarks were derived using the methodology presented in Sample et al. (1996) and supporting data from the toxicological literature, where such was available. However, for some of these constituents (i.e., ammonia, chloride, nitrate, and sulfate), there was insufficient data from the toxicological literature to support derivation of the benchmarks. In such cases, these constituents were evaluated on the basis of other rationale, such as exceedance of livestock drinking water standards. These 11 constituents are considered preliminary contaminants of potential concern and are identified by an asterisk in Table A2−6. The evaluation of these preliminary contaminants of concern are discussed in the following paragraphs in terms of their exclusion or retention as final contaminants of concern (i.e., mercury and selenium).

Table A2−4. Surface Water Concentrations of Contaminants With Minimum Mammal NOAEL- and LOAEL-Based Drinking Water Benchmarks and Piscivorous Mammal NOAEL- and LOAEL-Based Food/Water Benchmarks.

(All mammal NOAEL- and LOAEL-based drinking water benchmarks were for the white-tailed deer, except for mercury, which was for the river otter, with multiple benchmarks separated by commas. Piscivorous mammal NOAEL- and LOAEL-based food/water benchmarks are provided, in order, for river otter and mink, with multiple benchmark values for each species separated by commas and enclosed in parentheses. Benchmark values exceeded by maximum concentrations are denoted with an asterisk and are of potential concern and are therefore discussed in the text.)

Constituent	Min. (mg/L or pCi/L)	Mean (mg/L or pCi/L)	Max. (mg/L or pCi/L)	Background range or maximum (mg/L or pCi/L)	Lowest mammal NOAEL-based drinking water benchmark (mg/L)	Lowest mammal LOAEL-based drinking water benchmark (mg/L)	Piscivorous mammal NOAEL-based food/water benchmarks (mg/L)	Piscivorous mammal LOAEL-based food/water benchmarks (mg/L)
Aluminum	0.005	0.02164	0.348[a]	0.008–0.14	4.474	44.738	0.018*, 0.025*	0.183*, 0.253*
Ammonia[b]	0.05		1,440	0.05–0.134	N/A[c]	N/A	N/A	N/A
Antimony			0.0005[d]	0.0005[d]	0.290	2.898	0.161, 0.220	1.607, 2.204
Arsenic			0.002[e]	<0.0006–0.002	0.292	2.921	0.016, 0.022	0.156, 0.216
Barium	0.002		0.211	0.051–0.14	23.1	84.8	N/A	N/A
Beryllium			0.00005[d]	0.00005[d]	N/A	N/A	N/A	N/A
Bismuth			0.0005[d]	0.0005[d]	N/A	N/A	N/A	N/A
Boron	0.064		1.74	<0.0801–0.123	120	401	N/A	N/A
Cadmium	<0.0001	0.00095	0.004	<0.00005[d]	4.132, 68.135	41.323	3.162E-04*, 4.367E-04*	3.162E-03*, 4.367E-03
Chloride	22		17,300	25–172	N/A	N/A	N/A	N/A
Chromium			0.0005[d]	<0.0005–<0.0013	14.05 (Cr+6), 11725 (Cr+3)	56.29 (Cr+6)	3.593 (Cr+6), 4.947 (Cr+6)	14.394 (Cr+6), 19.817 (Cr+6)
Copper	<0.00049		0.051[a]	<0.0006–<0.0014	65.2	85.8	0.213, 0.294	0.280, 0.387
Iron[f]	<0.003	0.098	3.08	0.0075–0.0178	N/A	N/A	N/A	N/A
Lead			0.0005[d]	0.00005[d]	34.27	342.72	0.711, 0.982	7.115, 9.823
Lithium	0.0552		0.31[e]	0.057[e]	40.3	80.5	N/A	N/A
Manganese	0.0005		12	<0.003–0.076	377	1217	N/A	N/A
Mercury	<0.0002	N/A	0.002[a]	0.00005[d]	0.111	0.186	1.576E-06*, 3.924E-06*	2.626E-06*, 6.540E-06*
Molybdenum	<0.001	0.05195	1.91	<0.0028–0.007	0.6*	6.03	N/A	N/A
Nickel	<0.0006		0.052	<.0006–0.002	171.36	342.72	1.524-2.104	3.048-4.209
Nitrate	0.829		21.7	1.86–5.51	2719	6061	N/A	N/A
Selenium	<0.0005	0.00446	0.026	0.0013–0.0079	0.857	1.414	2.363E-04*, 4.318E-04*	3.899E-04*, 7.12E-04*
Silver	<0.005		0.0025[d]	0.00005[d]	N/A	N/A	N/A	N/A
Strontium	0.005		10.2	0.965–1.63	1127	N/A	N/A	N/A
Sulfate	72		14400	84.1–439	N/A	N/A	N/A	N/A
Thallium			0.0005[d]	0.0005[d]	0.032	0.320	0.001	0.009, 0.012
Uranium	0.0013		5.12	0.0023–0.008	6.995	13.996	N/A	N/A
Vanadium	0.0003		0.249	0.00073–0.0031	0.835	8.352	N/A	N/A
Zinc			0.023	<0.0017–0.006	685.4	1370.9	0.673, 0.929	1.346, 1.858

[a]Concentration is estimated, based on laboratory qualifier.
[b]All ammonia samples were converted for this assessment to total ammonia as nitrogen.
[c]N/A = not available.
[d]All concentrations were below detection; maximum value based on one-half of detection limit.
[e]Values in data set represent multiple detection limits. This is the highest value in the data that was above its respective detection limit.
[f]Values reported for this constituent are based only on unfiltered samples in order to conform to UAC (2003).
*Benchmark exceeded by maximum contaminant concentration.

Table A2−5. Surface Water Concentrations of Contaminants with Minimum Bird NOAEL- and LOAEL-Based Drinking Water Benchmarks and Piscivorous Bird NOAEL- and LOAEL-Based Food/Water Benchmarks.

(All bird NOAEL- and LOAEL-based drinking water benchmarks were for the rough-winged swallow, with multiple benchmarks separated by commas. Piscivorous bird NOAEL- and LOAEL-based food/water benchmarks are provided, in order, for belted kingfisher, osprey, and great blue heron, with multiple benchmarks values for each species separated by commas and enclosed in parentheses. Benchmark values exceeded by maximum concentrations are denoted with an asterisk and are of potential concern and are therefore discussed in the text.)

Constituent	Min. (mg/L or pCi/L)	Mean (mg/L or pCi/L)	Max. (mg/L or pCi/L)	Background mg/L or pCi/L)	Lowest bird NOAEL-based drinking water benchmark (mg/L)	Lowest bird LOAEL-based drinking water benchmark (mg/L)	Piscivorous bird NOAEL-based food/water benchmarks (mg/L)	Piscivorous bird LOAEL-based food/water benchmarks (mg/L)
Aluminum	0.005	0.02164	0.348[a]	0.008–0.14	471.4	191.2	0.936, 2.372, 2.699	0.380, 0.962, 1.095
Ammonia[b]	0.05		1440	0.05–0.134	N/A[c]	N/A	N/A	N/A
Antimony			0.0005[d]	0.0005[d]	N/A	N/A	N/A	N/A
Arsenic			0.002[e]	<0.0006–0.002	10.6, 22.1	31.7, 55.2	(0.282, 0.589), (0.713, 1.489), (0.811, 1.695)	(0.846, 1.472), (2.138, 3.720), (2.434, 4.235)
Barium	0.002		0.211	0.051–0.14	89.4	179.2	N/A	N/A
Beryllium			0.00005[d]	0.00005[d]	N/A	N/A	N/A	N/A
Bismuth			0.0005[d]	0.0005[d]	N/A	N/A	N/A	N/A
Boron	0.064		1.74	<0.0801–0.123	124	430	N/A	N/A
Cadmium	<0.0001	0.00095	0.004	<0.00005[d]	6.23	85.95	2.307E-04*, 0.001*, 0.001*	3.183E-03*, 8.0E-03, 9.0E-03
Chloride	22		17300	25–172	N/A	N/A	N/A	N/A
Chromium			0.0005[d]	<0.0005–<0.0013	4.30 (Cr+3)	21.49 (Cr+3)	N/A	N/A
Copper	<0.00049		0.051[a]	<0.0006–<0.0014	202	265.1	0.32, 0.81, 0.921	0.420, 1.063, 1.210
Iron[f]	<0.003	0.098	3.08	0.0075–0.0178	N/A	N/A	N/A	N/A
Lead			0.0005[d]	0.00005[d]	4.86, 16.54	48.56	0.049, 0.125, 0.142	0.493, 1.248, 1.421
Lithium	0.0552		0.31[e]	0.057[e]	N/A	N/A	N/A	N/A
Manganese	0.0005		12	<0.003–0.076	4284	N/A	N/A	N/A
Mercury	<0.0002	N/A	0.002[a]	0.00005[d]	0.028, 1.93	0.275, 3.87	4.527E-07*, 1.147E-06*, 1.305E-06*	4.527E-06*, 1.147E-05*, 1.305E-05*
Molybdenum	<0.001	0.05195	1.91	<0.0028–0.007	15.04	151.69	N/A	N/A
Nickel	<0.0006		0.052	<.0006–0.002	332.61	459.81	1.438, 3.642, 4.145	1.988, 5.035, 5.731
Nitrate	0.829		21.7	1.86–5.51	N/A	N/A	N/A	N/A
Selenium	<0.0005	0.00446	0.026	0.0013–0.0079	1.719, 2.149	3.438, 4.297	3.795E-04*, 9.614E-04*, 1.094E-03*	7.589E-04*, 1.923E-03*, 2.188E-03*
Silver	<0.005		0.0025[d]	0.00005[d]	N/A	N/A	N/A	N/A
Strontium	0.005		10.2	0.965–1.63	N/A	N/A	N/A	N/A
Sulfate	72		14400	84.1–439	N/A	N/A	N/A	N/A
Thallium			0.0005[d]	0.0005[d]	N/A	N/A	N/A	N/A
Uranium	0.0013		5.12	0.0023–0.008	68.8	N/A	N/A	N/A
Vanadium	0.0003		0.249	0.00073–0.0031	48.989	N/A	N/A	N/A
Zinc			0.023	<0.0017–0.006	62.3	562.9	0.030, 0.075, 0.085	0.268, 0.678, 0.771

[a]Concentration is estimated, based on laboratory qualifier.
[b]All ammonia samples were converted for this assessment to total ammonia as nitrogen.
[c]N/A = not available.
[d]All concentrations were below detection; maximum value based on one-half of detection limit.
[e]Values in data set represent multiple detection limits. This is the highest value in the data that was above its respective detection limit.
[f]Values reported for this constituent are based only on unfiltered samples in order to conform to UAC (2003).
*Benchmark exceeded by maximum contaminant concentration.

Table A2−6. Maximum Concentrations of Contaminants in Surface Water With the Number of Sample Values (not including background) at or Above Minimum Mammalian and Avian NOAEL- and LOAEL-Based Drinking Water Benchmarks and Minimum Piscivorous Mammal and Bird NOAEL- and LOAEL-Based Food/Water Benchmarks

Constituent	Max. (mg/L or pCi/L)	Lowest bird NOAEL-based drinking water benchmark (mg/L)	Lowest bird LOAEL-based drinking water benchmark (mg/L)	Piscivorous bird NOAEL-based food/water benchmarks (mg/L)	Piscivorous bird LOAEL-based food/water benchmarks (mg/L)	Lowest mammal NOAEL-based drinking water benchmark (mg/L)	Lowest mammal LOAEL-based drinking water benchmark (mg/L)	Piscivorous mammal NOAEL-based food/water benchmarks (mg/L)	Piscivorous mammal LOAEL-based food/water benchmarks (mg/L)	Approach for the EIS and BA
Aluminum	0.348[a]	0	0	0	0	0	0	17*	2*	Maximum concentration is above background and piscivorous mammal NOAEL- and LOAEL-based benchmarks. Retained as preliminary COPC.*
Ammonia	1440	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Maximum concentration above background. No wildlife benchmarks available. Retained as preliminary COPC.*
Antimony	0.0005[b]	N/A	N/A	N/A	N/A	0	0	0	0	Maximum concentration is equal to background and both are below detection limits. Half detection limit is below all benchmarks. Not retained as preliminary COPC.
Arsenic	0.002[c]	0	0	0	0	0	0	0	0	Maximum concentration is equal to highest background concentration. Maximum and background concentrations are both below all benchmarks. Not retained as preliminary COPC.
Barium	0.211	0	0	N/A	N/A	0	0	N/A	N/A	Maximum concentration is above background concentration. Maximum and background concentrations are both below all benchmarks. Not retained as preliminary COPC.
Beryllium	0.00005[b]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Measured concentrations and background concentrations are below detection limits. Measured concentration detection limit is equal to background detection limit. (No wildlife benchmarks available.) Not retained as preliminary COPC.

Table A2−6. Maximum Concentrations of Contaminants in Surface Water With the Number of Sample Values (not including background) at or Above Minimum Mammalian and Avian NOAEL- and LOAEL-Based Drinking Water Benchmarks and Minimum Piscivorous Mammal and Bird NOAEL- and LOAEL-Based Food/Water Benchmarks (continued)

Constituent	Max. (mg/L or pCi/L)	Lowest bird NOAEL-based drinking water benchmark (mg/L)	Lowest bird LOAEL-based drinking water benchmark (mg/L)	Piscivorous bird NOAEL-based food/water benchmarks (mg/L)	Piscivorous bird LOAEL-based food/water benchmarks (mg/L)	Lowest mammal NOAEL-based drinking water benchmark (mg/L)	Lowest mammal LOAEL-based drinking water benchmark (mg/L)	Piscivorous mammal NOAEL-based food/water benchmarks (mg/L)	Piscivorous mammal LOAEL-based food/water benchmarks (mg/L)	Approach for the EIS and BA
Bismuth	0.0005[b]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Measured concentrations and background concentrations are below detection limits. Measured concentration detection limit is equal to background detection limit. (No wildlife benchmarks available.) Not retained as preliminary COPC.
Boron	1.74	0	0	N/A	N/A	0	0	N/A	N/A	Maximum concentration above background. Maximum concentration and background below all benchmarks. Not retained as preliminary COPC.
Cadmium	0.004	0	0	8*	1*	0	0	8*	1*	Maximum concentration above background and above picscivorous bird and picscivorous mammal NOAEL- and LOAEL-based benchmarks. Retained as preliminary COPC.*
Chloride	17300	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Maximum concentration above background. No wildlife benchmarks available. Retained as preliminary COPC.*
Chromium	0.0005[b]	0	0	N/A	N/A	0	0	0	0	Maximum concentration equal to low background. Maximum concentration and background below all Cr+6 and Cr+3 benchmarks. Not retained as preliminary COPC.
Copper	0.051[a]	0	0	0	0	0	0	0	0	Maximum concentration is above background. Maximum concentration is below all benchmarks. Not retained as preliminary COPC.

Table A2−6. Maximum Concentrations of Contaminants in Surface Water With the Number of Sample Values (not including background) at or Above Minimum Mammalian and Avian NOAEL- and LOAEL-Based Drinking Water Benchmarks and Minimum Piscivorous Mammal and Bird NOAEL- and LOAEL-Based Food/Water Benchmarks (continued)

Constituent	Max. (mg/L or pCi/L)	Lowest bird NOAEL-based drinking water benchmark (mg/L)	Lowest bird LOAEL-based drinking water benchmark (mg/L)	Piscivorous bird NOAEL-based food/water benchmarks (mg/L)	Piscivorous bird LOAEL-based food/water benchmarks (mg/L)	Lowest mammal NOAEL-based drinking water benchmark (mg/L)	Lowest mammal LOAEL-based drinking water benchmark (mg/L)	Piscivorous mammal NOAEL-based food/water benchmarks (mg/L)	Piscivorous mammal LOAEL-based food/water benchmarks (mg/L)	Approach for the EIS and BA
Iron	3.08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Maximum concentration above background. No wildlife benchmarks available. Retained as preliminary COPC.*
Lead	0.0005[b]	0	0	0	0	0	0	0	0	Maximum concentration is above background and both are below detection limits. Half detection limit of maximum concentration is below all benchmarks. Not retained as preliminary COPC.
Lithium	0.31[c]	0	0	N/A	N/A	N/A	N/A	N/A	N/A	Maximum concentration is above background. Maximum concentration is below detection limits. Half detection limit is below all benchmarks. Not retained as preliminary COPC.
Manganese	12	0	N/A	N/A	N/A	0	0	N/A	N/A	Maximum concentration is above background. Maximum concentration is below all benchmarks. Not retained as preliminary COPC.
Mercury	0.002[a]	0	0	85*	85*	0	0	85*	85*	Maximum concentration is above background. Maximum concentration is above piscivorous mammal and piscivorous bird NOAEL- and LOAEL-based benchmarks. Retained as preliminary COPC.*
Molybdenum	1.91	0	0	N/A	N/A	8*	0	N/A	N/A	Maximum concentration is above background and above mammal NOAEL-based drinking water benchmark. No piscivorous wildlife benchmarks available. Retained as preliminary COPC.*

Table A2−6. Maximum Concentrations of Contaminants in Surface Water With the Number of Sample Values (not including background) at or Above Minimum Mammalian and Avian NOAEL- and LOAEL-Based Drinking Water Benchmarks and Minimum Piscivorous Mammal and Bird NOAEL- and LOAEL-Based Food/Water Benchmarks (continued)

Constituent	Max. (mg/L or pCi/L)	Lowest bird NOAEL-based drinking water benchmark (mg/L)	Lowest bird LOAEL-based drinking water benchmark (mg/L)	Piscivorous bird NOAEL-based food/water benchmarks (mg/L)	Piscivorous bird LOAEL-based food/water benchmarks (mg/L)	Lowest mammal NOAEL-based drinking water benchmark (mg/L)	Lowest mammal LOAEL-based drinking water benchmark (mg/L)	Piscivorous mammal NOAEL-based food/water benchmarks (mg/L)	Piscivorous mammal LOAEL-based food/water benchmarks (mg/L)	Approach for the EIS and BA
Nickel	0.052	0	0	0	0	0	0	0	0	Maximum concentration is above background. Maximum concentration is below all benchmarks. Not retained as preliminary COPC.
Nitrate	21.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Maximum concentration is above background. No wildlife benchmarks available. Retained as preliminary COPC.*
Selenium	0.026	0	0	193*	193*	0	0	201*	193*	Maximum concentration is above background. Maximum concentration is above piscivorous mammal and piscivorous bird NOAEL- and LOAEL-based benchmarks. Retained as preliminary COPC.*
Silver	0.0025[b]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Maximum concentration is above background. No wildlife benchmarks available. Retained as preliminary COPC.*
Strontium	10.2	N/A	N/A	N/A	N/A	0	N/A	N/A	N/A	Maximum concentration above background. Maximum concentration below all benchmarks. Not retained as preliminary COPC.
Sulfate	14400	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Maximum concentration above background. No wildlife benchmarks available. Retained as preliminary COPC.*
Thallium	0.0005[b]	N/A	N/A	N/A	N/A	0	0	0	0	Maximum concentration equal to background. Maximum concentration is below all benchmarks. Not retained as preliminary COPC.
Uranium	5.12	0	N/A	N/A	N/A	0	0	N/A	N/A	Maximum concentration above background. Maximum concentration below all benchmarks. Not retained as preliminary COPC.

Table A2−6. Maximum Concentrations of Contaminants in Surface Water With the Number of Sample Values (not including background) at or Above Minimum Mammalian and Avian NOAEL- and LOAEL-Based Drinking Water Benchmarks and Minimum Piscivorous Mammal and Bird NOAEL- and LOAEL-Based Food/Water Benchmarks (continued)

Constituent	Max. (mg/L or pCi/L)	Lowest bird NOAEL-based drinking water benchmark (mg/L)	Lowest bird LOAEL-based drinking water benchmark (mg/L)	Piscivorous bird NOAEL-based food/water benchmarks (mg/L)	Piscivorous bird LOAEL-based food/water benchmarks (mg/L)	Lowest mammal NOAEL-based drinking water benchmark (mg/L)	Lowest mammal LOAEL-based drinking water benchmark (mg/L)	Piscivorous mammal NOAEL-based food/water benchmarks (mg/L)	Piscivorous mammal LOAEL-based food/water benchmarks (mg/L)	Approach for the EIS and BA
Vanadium	0.249	0	N/A	N/A	N/A	0	0	N/A	N/A	Maximum concentration above background. Maximum concentration below all benchmarks. Not retained as preliminary COPC.
Zinc	0.023	0	0	0	0	0	0	0	0	Maximum concentration above background. Maximum concentration below all benchmarks. Not retained as preliminary COPC.

[a]Analyte is estimated, based on laboratory qualifier.
[b]All analytes were below detection; maximum value based on one-half of detection limit.
[c]Analytes in data set represent multiple detection limits. This is the highest value in the data that was below its respective detection limit.
*Number of samples whose concentrations exceeded the corresponding wildlife toxicity benchmarks. Asterisks also identify contaminants retained as contaminants of potential concern

Aluminum. The maximum aluminum concentration was about 2 to 3 times the uppermost background value and exceeded by about 1 order of magnitude the food/water benchmarks, resulting in NOAELs for the river otter and mink (Table A2–4). A total of 17 sample values (excluding background) exceeded the river otter NOAEL-based food/water benchmark (Table A2–6). The maximum aluminum concentration exceeded slightly the food/water benchmarks resulting in LOAELs for the river otter and mink (Table A2–4), and only two sample values exceeded the river otter LOAEL-based food/water benchmark (Table A2–6).

Adverse effects would be unlikely to result from food/water consumption at these two sample locations, because the river otter and mink very likely consume food and water over a much larger area. The average aluminum concentration in the sampled area slightly exceeds the food/water benchmarks resulting in NOAELs for the river otter and is slightly less than the food/water benchmarks resulting in NOAELs for the mink (Table A2–4). Consequently, adverse effects would also be unlikely to result from food/water consumption over the entire sampled area. Thus, the potential impacts, if any, to piscivorous mammalian wildlife from exposure to aluminum in surface water would be small, and further assessment is not warranted.

The maximum aluminum concentration did not exceed either the avian drinking water or piscivorous bird food/water benchmarks. Thus, further assessment of avian exposure to aluminum in surface water is not warranted.

Ammonia. The maximum ammonia concentration was 4 to 5 orders of magnitude above background and the mean concentration (19.39 mg/L) was about 2 orders of magnitude above background (Table A2–4). There are currently no wildlife drinking water or food/water benchmarks (the only types of benchmarks that can be compared with contaminant concentrations in surface water) available for this constituent (Tables A2–4 and A2–5). Sample et al. (1996) provide methodology for deriving such benchmarks from other types of toxicological data. However, most experimental toxicological work concerning the oral route of administration has centered on ammonium chloride (Arnold et al. 1997, Crookshank et al. 1973, Fukushima et al. 1986, Goldman and Yakovac 1964, Shibata et al. 1989). Few studies have attempted to identify the role of ammonia in the effects (World Health Organization 1986). Consequently, no benchmarks could be derived for ammonia using the methodology provided in Sample et al. (1996) due to the lack of other toxicological data in the literature. Further, EPA has not provided an oral reference dose factor (for humans) for ammonia (http://www.epa.gov/iris/subst/0422.htm#reforal), nor is there a human drinking water standard. The lack of toxicological data suggests that the occurrence of ammonia in food and drinking water is generally considered not to pose potentially significant toxic effects for terrestrial organisms. This precludes further screening of wildlife exposure to ammonia in surface water.

Cadmium. The maximum cadmium concentration was about 2 orders of magnitude above background and exceeded the food/water benchmarks that resulted in NOAELs for the river otter and mink by about 1 order of magnitude (Table A2–4). A total of eight sample values exceeded the river otter NOAEL-based food/water benchmark (Table A2–6). The maximum cadmium concentration was slightly greater than the food/water benchmarks that resulted in LOAELs for the river otter and slightly less than the food/water benchmarks that resulted in LOAELs for the mink (Table A2–4). No sample values other than the maximum exceeded the LOAEL-based river otter food/water benchmark (Table A2–6).

The maximum cadmium concentration exceeded by about 1 order of magnitude the food/water benchmark resulting in a NOAEL for the belted kingfisher and exceeded by about one-half an order of magnitude that of the osprey and great blue heron (Table A2–5). A total of eight sample values exceeded the belted kingfisher NOAEL-based food/water benchmark (Table A2–6). The maximum concentration exceeded only slightly the food/water benchmark resulting in a LOAEL for the belted kingfisher and was less than that of the osprey and great blue heron (Table A2–5). No sample values other than the maximum exceeded the LOAEL-based belted kingfisher food/water benchmark (Table A2–6).

Adverse effects to the river otter and belted kingfisher would be unlikely to result from food/water consumption at the location of the maximum sample value, because these species very likely consume food and water over a much larger area. The average cadmium concentration in the sampled area slightly exceeds the river otter and belted kingfisher NOAEL-based food/water benchmarks but does not exceed associated LOAEL-based food/water benchmarks (Tables A2–4 and A2–5). Consequently, adverse effects would also be unlikely to result from food/water consumption by these species over the entire sampled area. Thus, the potential impacts, if any, to piscivorous mammalian and avian wildlife from exposure to cadmium in surface water would be small, and further assessment is not warranted.

Chloride. The maximum chloride concentration was about 2 orders of magnitude above background concentration, and the mean concentration (255.08 mg/L) ranged from about 1.5 to 10 times background (Table A2–4). There are currently no wildlife drinking water or food/water benchmarks available for this constituent (Tables A2−4 and A2−5). Sample et al. (1996) provide methodology for deriving such benchmarks from other types of toxicological data. However, no benchmarks could be derived for chloride using this methodology due to the lack of other toxicological data in the literature. Further, there is also no human drinking water standard for chloride. The lack of toxicological data suggests that the occurrence of chloride in drinking water is generally considered not to pose potentially significant toxic effects for terrestrial organisms (compounds that include chloride are likely to be more toxic to terrestrial organisms than chloride alone). This precludes further screening of wildlife exposure to chloride in surface water.

Iron. The August 2002 samples include some that were not filtered. In the state of Utah, only filtered samples should be used for comparison to benchmarks (UAC 2003). Thus, the unfiltered August 2002 samples were removed and only filtered iron samples (Tables A2−4 and A2−5) are used in this analysis.

The maximum and mean iron concentrations were about 2 orders and about 1 order of magnitude, respectively, above the highest background concentration (Table A2−4). There are currently no published wildlife drinking water or food/water benchmarks available for this constituent. Consequently, drinking water benchmarks were derived for the 9 mammal and 11 bird species listed above using the methodology provided in Sample et al. (1996). The derived NOAEL-based drinking water benchmarks were then used to derive food/water benchmarks for piscivorous mammals and birds. A brief outline of the methodology used for deriving drinking water benchmarks follows.

First, mammal and bird NOAELs were either obtained from the results of laboratory experiments summarized in the literature or estimated from acute toxicity benchmarks summarized in the literature. A mammalian NOAEL of 120 mg/kg/day, with mice as test organisms and weight loss as the endpoint, was obtained from Parametrix (2001). Because an avian NOAEL was unavailable, an avian LD_{50} of greater than 4,500 mg/kg/day, with quail as the test organism and no endpoint specified, was used (Parametrix 2001). Because the precise avian LD_{50} was not specified but was given as being an unknown value greater than 4,500 mg/kg/day, 4,500 mg/kg/day was used to be conservative. No standardized mathematical relationship exists between an LD_{50} and a NOAEL (Sample et al. 1996). Exposure levels associated with NOAELs may range from 1/10 to 1/10,000 of the acutely toxic dose (Sample et al. 1996). Consequently, a high and a low NOAEL were estimated by applying these factors to the avian LD_{50}, resulting in high and low avian NOAELs of 450 and 0.45 mg/kg/day, respectively.

The literature-based mammalian and avian NOAELs were used to derive NOAELs for the 9 mammal and 11 bird species listed above by adjusting for differences in body weight (kg) between the test organism and target species (Sample et al. 1996). These derived NOAELs (mg/kg/day) were then used to derive drinking water equivalents (mg/L) using the body weight of the target species and its rate of water consumption (L/day) (Sample et al. 1996). The lowest mammal drinking water benchmark was for white-tailed deer (278 mg/L), 2 orders of magnitude above the maximum iron surface water concentration (3.08 mg/L) (Table A2−4). The lowest of the high and low avian drinking water benchmarks were for the rough-winged swallow (3,517 and 3.5 mg/L, respectively). These values were 3 orders of magnitude above and just slightly above the maximum iron surface water concentration (Table A2−4), respectively, and about 2 orders of magnitude above the mean concentration (0.098 mg/L) (Table A2−4). Thus, adverse impacts to the 9 mammalian and 11 avian receptors are not expected from consumption of iron in surface water via drinking only. No further evaluation of wildlife exposure to iron in surface water via drinking is warranted.

The above derived NOAEL-based drinking water benchmarks were then used to derive NOAEL-based food/drinking water benchmarks for the two piscivorous mammals (mink and river otter) and three piscivorous birds (belted kingfisher, great blue heron, and osprey) using the body weight of the species, its rate of water and food (kg/day) consumption, and biological accumulation factor (BAF) (Sample et al. 1996). The BAF is the ratio of the concentration of a contaminant in tissue (mg/kg) to its concentration in water (mg/L), where both the organism and its prey are exposed, and is expressed as liters per kilogram. For most inorganic compounds, the BAF is assumed to equal the biological concentration factor (BCF). The BCF is the ratio of the concentration of a contaminant in food to its concentration in water (i.e., [mg/kg]/[mg/L] = L/kg) (Sample et al. 1996). A BAF of 200 reported for the edible parts of fish in a critical review of bioaccumulation factors in aquatic systems by Karlsson et al. (2002) was used in this analysis.

The lowest NOAEL-based piscivorous mammal food/drinking water benchmark was 18.18 mg/L for mink. The maximum iron concentration (3.08 mg/L) (Table A2-4) is about six times lower than this benchmark. Consequently, since this derived NOAEL was not exceeded by the maximum iron concentration, piscivorous mammals would be unlikely to be adversely affected by consumption of iron in surface water and associated prey. No further evaluation of piscivorous mammal exposure to iron in surface water and associated prey is warranted.

The low NOAEL-based piscivorous bird food/drinking water benchmarks were 0.04 mg/L for the belted kingfisher, 0.13 mg/L for the osprey, and 0.15 mg/L for the great blue heron. The maximum iron concentration (3.08 mg/L) (Table A2-4) is about 2 orders of magnitude higher than the kingfisher benchmark, and about a factor of 20 higher than the osprey and heron benchmarks. However, since piscivorous birds would integrate their exposure by foraging over a much larger area than the point where the maximum surface water concentration was taken, the average iron concentration is more applicable than the maximum. The average iron concentration (0.098 mg/L) (Table A2-4) is only about two times higher than the kingfisher benchmark and is slightly lower than the osprey and heron benchmarks.

Thus, the kingfisher is the only species of the three whose NOAEL-based food/drinking water benchmark was exceeded by the average iron concentration. However, it is exceedance of a LOAEL, not a NOAEL, that implies potential adverse effects. There is no LOAEL-based food/water benchmark for piscivorous bird species, and one cannot be derived because there is no standard relationship that applies when extrapolating from a NOAEL and a LOAEL (because the LOAEL is the point where adverse effects begin, and the NOAEL could be anywhere below it). Consequently, it is uncertain whether exceedance of the low kingfisher NOAEL-based food/drinking water benchmark by the average iron concentration could result in potential adverse effects. The following two discussion points serve to diminish such a possibility.

First, the high NOAEL-based food/drinking water benchmark for the belted kingfisher was 42.72 mg/L. The average iron concentration (0.098 mg/L) (Table A2-4) is about 2.5 orders of magnitude below this benchmark. Thus, in this case, adverse effects would be very unlikely. Second, the fact that the maximum iron concentration is suspect further diminishes the possibility of potential adverse effects under the low NOAEL-based food/drinking water benchmark, as follows.

The maximum iron concentration (3.08 mg/L) (Table A2−4) is somewhat anomalous in that it is the only sample that is 2 to 3 orders of magnitude above the rest of the values, including background. When this value is removed, the new maximum from the sampled area becomes 0.04 mg/L and the new mean (0.007 mg/L [N=33, SD=0.006]) is slightly less than the mean background concentration (0.012 mg/L [N=3, SD=0.005]). This new mean iron concentration is about 1 and 4 orders of magnitude below the low and high kingfisher food/drinking water benchmarks, respectively. In summary, potential adverse effects to the kingfisher from iron in surface water and associated prey appear unlikely, and further assessment of this species is not warranted.

Mercury. The maximum mercury concentration was about 2 orders of magnitude above background and exceeded by about 3 orders of magnitude the food/water benchmarks resulting in NOAELs and LOAELs for the river otter and mink (Table A2–4).

The maximum mercury concentration exceeded by about 4 orders of magnitude the food/water benchmark resulting in a NOAEL for the belted kingfisher and exceeded by about 3 orders of magnitude the food/water benchmarks resulting in NOAELs for the osprey and great blue heron (Table A2–5). Further, the maximum mercury concentration exceeded by about 3 orders of magnitude the food/water benchmark resulting in a LOAEL for the belted kingfisher and exceeded by about 2 orders of magnitude the food/water benchmarks resulting in LOAELs for the osprey and great blue heron (Table A2–5).

Mercury was undetected in the rest of the mercury samples other than the maximum, including background, some of the samples had a detection limit of 0.0002 mg/L and the others had a detection limit of 0.0001 mg/L. Results of these samples in which mercury was undetected were assigned a value of one-half the corresponding detection limit. Eighty-five of these sample values (excluding background sample values) exceeded all the piscivorous mammal and bird

LOAEL-based food/water benchmarks (Table A2–6) by 1 to 2 orders of magnitude (Tables A2–4 and A2–5). The 15 background sample values similarly exceeded all the piscivorous mammal and bird LOAEL-based food/water benchmarks.

Adverse effects would be unlikely to result from food/water consumption at the location where the maximum mercury concentration was obtained, because the river otter, mink, belted kingfisher, osprey, and great blue heron very likely consume food and water over a much larger area. However, adverse effects to these species could potentially result if food/water consumption occurred largely within the sampled area, based on the above evaluation of samples in which mercury was undetected. Nonetheless, because the actual concentrations of mercury are unknown over most of the sampled area, further assessment is warranted. This might include analytical methods and instrumentation that provide lower detection limits.

Molybdenum. The maximum molybdenum concentration was about 3 orders of magnitude above the uppermost background value and was about 3 times greater than the drinking water benchmark resulting in a NOAEL for white-tailed deer (Table A2–4). A total of eight sample values exceeded the white-tailed deer NOAEL-based drinking water benchmark, but none, including the maximum, exceeded the associated LOAEL-based drinking water benchmark (Table A2–6). The maximum molybdenum concentration did not exceed the avian NOAEL- or LOAEL-based drinking water benchmarks (Table A2–5). Thus, adverse impacts to the 9 mammalian and 11 avian receptors are not expected from consumption of molybdenum by drinking surface water, and further assessment is not warranted.

There are currently no published piscivorous wildlife food/water benchmarks available for this constituent (Tables A2−4 and A2−5). Consequently, piscivorous mammal (mink and river otter) and bird (belted kingfisher, great blue heron, and osprey) food/water benchmarks were derived using the methodology provided in Sample et al. (1996). A brief outline of the methodology used for deriving these benchmarks follows.

First, piscivorous mammal and bird drinking water NOAELs were obtained from Sample et al. (1996). These drinking water NOAELs were used to derive the piscivorous mammal and bird food/water NOAELs using the species' body weight (kg), its rate of food (kg/day) and water (L/day) consumption, and BAF (Sample et al. 1996). A BAF of 10, with a 10-fold error likely according to other data, was reported for the edible parts of fish in a critical review of BAFs in aquatic systems by Karlsson et al. (2002). Consequently, three food/drinking water NOAELs were derived for each piscivorous mammal and bird species, one for each BAF of 1, 10, and 100.

The lowest NOAEL-based piscivorous mammal food/drinking water benchmark was 0.08 mg/L for mink, derived using a BAF of 100. The maximum molybdenum concentration (1.91 mg/L) (Table A2-4) is more than 1 order of magnitude higher than this benchmark. However, since piscivorous mammals would integrate their exposure by foraging over a much larger area than the point where the maximum surface water concentration was detected, the average molybdenum concentration is more applicable. The average molybdenum concentration (0.05 mg/L) (Table A2-4) is slightly less than this benchmark. Consequently, since this derived NOAEL was not exceeded by the average molybdenum concentration, piscivorous mammals would not likely be adversely affected by consumption of molybdenum in surface water and associated prey.

The lowest NOAEL-based piscivorous bird food/drinking water benchmark was 0.64 mg/L for belted kingfisher, derived using a BAF of 100. The maximum molybdenum concentration (1.91 mg/L) (Table A2-4) is about three times higher than this benchmark. However, since piscivorous birds would integrate their exposure by foraging over a much larger area than the point where the maximum surface water concentration was detected, the average molybdenum concentration is more applicable. The average molybdenum concentration (0.05 mg/L) (Table A2-4) is about 1 order of magnitude below this benchmark. Consequently, since this derived NOAEL was not exceeded by the average molybdenum concentration, piscivorous birds would not likely be adversely affected by consumption of molybdenum in surface water and associated prey.

Further assessment of piscivorous avian and mammalian exposure to molybdenum in surface and associated prey is not warranted.

Nitrate. The maximum nitrate concentration was about 4 times the maximum background concentration (Table A2−4). There are currently no published wildlife drinking water or food/water benchmarks available for this constituent (Tables A2−4 and A2−5). Sample et al. (1996) provide methodology for deriving such benchmarks from other types of toxicological data. However, no benchmarks could be derived for nitrate using this methodology due to the lack of other toxicological data in the literature.

Consequently, drinking water standards for livestock were used. Guidelines for levels of nitrate in drinking water for livestock are as follows: 0 to 440 mg/L is considered safe; 440 to 1,300 mg/L is a cautionary level where the additive effect of nitrate in feed should also be considered; and over 1,300 mg/L is considered potentially toxic (Bagley et al. 1997). The maximum nitrate concentration (Table A2−4) falls near the bottom of the range of values considered safe for livestock. Thus, based on livestock drinking water standards, further assessment of wildlife exposure to nitrate in surface water is not warranted.

Selenium. The maximum selenium concentration was about 1 order of magnitude above background and exceeded by about 2 orders of magnitude the food/water benchmarks resulting in NOAELs and LOAELs for the river otter and mink (Table A2–4). The maximum selenium concentration exceeded by about 1 to 2 orders of magnitude the food/water benchmarks resulting in NOAELs and LOAELs for the belted kingfisher, osprey, and great blue heron (Table A2–5). The mean selenium concentration exceeded the river otter and mink NOAEL and LOAEL food/water benchmarks by 1 order of magnitude (Table A2–4), and the belted kingfisher, osprey, and great blue heron NOAEL and LOAEL food/water benchmarks by 1 order of magnitude or less (Table A2–5).

Thus, adverse effects to these species would be unlikely to result from food/water consumption at the location where the maximum selenium concentration was obtained because they would not obtain all their food/water from one location. However, adverse effects could potentially result from the mean selenium concentration if food/water consumption occurred largely within the sampled area. However, the mean selenium concentration (0.00446 mg/L [N=193, SD=0.0026]) in this area is virtually the same as the mean background concentration (0.00441 mg/L [N=15, SD=0.0021]). Thus, any adverse effects may not be attributable to the Moab site. Nevertheless, two samples (0.012 and 0.014 mg/L) from the contaminated portion of the river have selenium concentrations that are greater than two standard deviations above the mean (Table A2−4), and one sample concentration (0.026 mg/L) is greater than eight standard deviations above the mean. These three samples were all collected on April 12, 2000, and there is no detection limit reported for them. Because of the uncertainty surrounding these high values and the associated potential for adverse effects to piscivorous mammals and birds at the three locations where they were obtained, further assessment is warranted.

Silver. Silver was undetected in all of the samples, and various silver detection limits were associated with the samples. The maximum silver detection limit (0.005 mg/L) was associated with only one sample, and it was higher than the maximum background silver detection limit (0.0001 mg/L) by a factor of 50 (Table A2–4). There are currently no published wildlife drinking water or food/water benchmarks available for this constituent (Tables A2–4 and A2–5). Consequently, as was done above for iron, drinking water benchmarks were derived for 9 mammal and 11 bird species using the methodology provided in Sample et al. (1996). The derived NOAEL-based drinking water benchmarks were then used to derive food/water benchmarks for piscivorous mammals and birds. A brief outline of the methodology used for deriving drinking water benchmarks follows.

First, mammal and bird NOAELs were either obtained from the results of laboratory experiments summarized in the literature or estimated from acute toxicity benchmarks summarized in the literature. A mammalian NOAEL of 222.2 mg/kg/day, with rats as test organisms and weight loss as the endpoint, was obtained from Ratte (1999) and Parametrix (2001). Because an avian NOAEL was unavailable, an avian LD_{50} of greater than 4,500 mg/kg/day, with quail as the test organism and no endpoint specified, was used (Parametrix 2001). Because the precise avian LD_{50} was not specified but was given as being an unknown value greater than 4,500 mg/kg/day, 4,500 mg/kg/day was used to be conservative. No standardized mathematical relationship exists between an LD_{50} and a NOAEL (Sample et al. 1996). Exposure levels associated with NOAELs may range from 1/10 to 1/10,000 of the acutely toxic dose (Sample et al. 1996). Consequently, a high and a low NOAEL were estimated by applying these factors to the avian LD_{50}, resulting in high and low avian NOAELs of 450 and 0.45 mg/kg/day, respectively.

The literature-based mammalian and avian NOAELs were used to derive NOAELs for the 9 mammal and 11 bird species listed above by adjusting for differences in body weight (kg) between the test organism and target species (Sample et al. 1996). These derived NOAELs (mg/kg/day) were then used to derive drinking water equivalents (mg/L) using the body weight of the target species and its rate of water consumption (L/day) (Sample et al. 1996). The lowest mammal drinking water benchmark was for white-tailed deer (952 mg/L), at least 5 orders of magnitude above the maximum silver detection limit (0.005 mg/L) (Table A2−4). The lowest of the high and low avian drinking water benchmarks were for the rough-winged swallow (3,517 and 3.5 mg/L, respectively). These values were between 5 and 6 and between 2 and 3 orders of magnitude, respectively, above the maximum silver detection limit (0.005 mg/L) (Table A2−4). Thus, adverse impacts to the 9 mammalian and 11 avian receptors are not expected from consumption of silver in surface water via drinking alone. No further evaluation of wildlife exposure to silver in surface water via drinking is warranted.

The above derived NOAEL-based drinking water benchmarks were then used to derive NOAEL-based food/drinking water benchmarks for the two piscivorous mammals (mink and river otter) and three piscivorous birds (belted kingfisher, great blue heron, and osprey) listed using the body weight of the species, its rate of water and food (kg/day) consumption, and BAF (Sample et al. 1996). Two BAFs of 5 and 10, each with a 10-fold error likely according to other data, were reported for the edible parts of fish in a critical review of BAFs in aquatic systems by Karlsson et al. (2002). Consequently, five food/drinking water NOAELs were derived for each piscivorous mammal and bird species, one for each BAF of 0.5, 1, 5, 10, and 100.

The lowest NOAEL-based piscivorous mammal food/drinking water benchmark was 123.97 mg/L for mink. The maximum silver detection limit (0.005 mg/L) (Table A2–4) is about 4 orders of magnitude lower than this benchmark. Consequently, since this derived NOAEL was not exceeded by the maximum silver detection limit, piscivorous mammals would be unlikely to be adversely affected by consumption of silver in surface water and associated prey. No further evaluation of piscivorous mammal exposure to silver in surface water and associated prey is warranted.

The lowest of the low NOAEL-based piscivorous bird food/drinking water benchmarks was 0.09 mg/L for the belted kingfisher. The maximum silver detection limit (0.005 mg/L) (Table A2–4) is about 1 order of magnitude lower than this benchmark. Consequently, since this derived NOAEL was not exceeded by the maximum silver detection limit, piscivorous birds would be unlikely to be adversely affected by consumption of silver in surface water and associated prey. No further evaluation of piscivorous bird exposure to silver in surface water and associated prey is warranted.

Sulfate. The maximum sulfate concentration was about 2 orders of magnitude above background (Table A2–4). There are currently no wildlife drinking water or food/water benchmarks available for this constituent (Tables A2–4 and A2–5). Sample et al. (1996) provide methodology for deriving such benchmarks from other types of toxicological data. However, no benchmarks could be derived for sulfate using this methodology due to the lack of other toxicological data in the literature.

Consequently, drinking water standards for livestock were used. Guidelines for levels of sulfate in drinking water for livestock are as follows. Sulfate levels up to 1,500 mg/L produce slight effects on livestock (objectionable taste); levels from 1,500 to 2,500 mg/L produce temporary diarrhea; and levels above 4,500 mg/L should not be used (Bagley et al. 1997).

The maximum sulfate concentration (Table A2−4) is about 3 times this maximum level (4,500 mg/L). Wildlife species would likely consume their water over a much broader area than from the location where the maximum sulfate sample was obtained. Thus, any effects would more likely be incurred by water consumption over the entire sampled area. The mean sulfate concentration (609.65 mg/L) in the sampled area could therefore produce slight effects on wildlife, based on the above guidance. This precludes further screening of wildlife exposure to sulfate in surface water. (Note that compounds that include sulfate are likely to be more toxic to terrestrial organisms than sulfate alone).

Summary of Chemical Impacts to Wildlife. From the 28 original contaminants, 11 preliminary contaminants of potential concern (aluminum, ammonia, cadmium, chloride, iron, mercury, molybdenum, nitrate, selenium, silver, and sulfate) were selected for further assessment. From these, nine were excluded and two potential contaminants of concern were selected: mercury and selenium. These two were selected because they could potentially cause chronic adverse effects to piscivorous mammalian and avian species consuming food/water within the surface waters of the nearshore environment within the contaminated portion of the river.

Chemical Impacts to Plants. Plants may be exposed to contaminants via root or dermal uptake of contaminants. Of these, root uptake would likely be the primary exposure pathway. Soil contaminant data were available for only a limited area of the Moab site, at some temporary monitoring wells just northeast of the tailings pile. The soil samples were taken at a depth of from 0 to 1 ft at these locations (DOE 2003). It is currently estimated that 309 acres of contaminated soils at an average depth of from 12 to 18 inches would be removed (under the on-site and off-site disposal alternatives) from the Moab site and be replaced with 6 inches of borrowed reclamation soil. Thus, the sampled soil layer would be excluded as a source of potential impacts to plants, which themselves would be absent until the site was revegetated or otherwise recolonized following reclamation. Consequently, the existing soil contaminant data were not used to evaluate chemical impacts to plants. Instead, contaminants in the freshwater aquifer were used because they were considered more representative of the entire Moab site and because they will remain as a source of potential impacts to plants much longer than the top layer of soil.

Only root uptake is considered, since only phytotoxicity benchmarks based on root uptake were available. Maximum and mean concentrations of contaminants in the freshwater aquifer were obtained from Chapter 5.0 of the SOWP (DOE 2003) and screened based on their exceedance of available phytotoxicity benchmarks (Table A2–7). Soil solution phytotoxicity benchmarks were available only for the metals (Efroymson et al. 1997).

The following nine metals had maximum concentrations that exceeded maximum background concentrations and were slightly less than or exceeded phytoxicity benchmarks: aluminum, arsenic, cobalt, copper, iron, manganese, mercury, molybdenum, and vanadium (Table A2–7). Four of these metals had mean concentrations that were slightly below or above phytotoxicity benchmarks: arsenic, manganese, molybdenum, and vanadium. These nine metals, but particularly the latter four, could cause phytotoxic effects, assuming that plants had root access to the freshwater aquifer or associated soil water above it. In addition, these metals could become translocated to plant parts consumed by herbivorous wildlife or by terrestrial invertebrates that are in turn consumed by wildlife. Consequently, these metals could potentially cause toxic effects to wildlife. However, the nature and extent of such effects, if any, are unknown.

Radiological Impacts to Wildlife and Plants. Samples of radioactive constituents in surface water were collected by SMI, DOE, and the USGS between 2000 and 2002. Of the 10 radioactive contaminants sampled (excluding gross alpha and gross beta), 3 are evaluated here (uranium-238, uranium-234, and radium-226), since only these were included in the library of constituents of the RESRAD Biota Code (Version 1.0 Beta 3, June 3, 2003) (DOE 2002) used in this evaluation.

The RESRAD Biota Code was used to screen the radiological dose rate to generic (not species-specific) riparian animals and generic terrestrial plants based on the maximum observed concentrations of uranium-238, uranium-234, and radium-226 in surface water. The total radiological dose was estimated using the default parameters (e.g., BAFs) provided in the RESRAD Biota Code, since such site-specific data were lacking.

The total estimated radiological dose was divided by the applicable DOE dose limits or standards designed to protect the terrestrial (including riparian) environment, including populations of animals and plants. These dose limits or standards are 0.1 rad/day for terrestrial (including riparian) animals and 1 rad/day for terrestrial (including riparian) plants (DOE 2002). A quotient greater than 1 indicates exceedence of such a dose limit or standard and thus a potential risk of radiotoxic effects. Where a quotient exceeded 1, the RESRAD Biota Code was used to screen the dose rate based on the mean observed concentrations of uranium-238, uranium-234, and radium-226, since vertebrates integrate their exposure over a much larger area than the location from which the maximum concentration was obtained. Input maximum and mean concentrations and the corresponding quotients are provided in Table A2–8.

Table A2−7. Background Range and On-Site and Downgradient Range and Mean Concentrations of Metals in the Freshwater Aquifer and Soil Solution Phytoxicity Benchmarks

Constituent	Background Range (mg/L)	On-Site and Downgradient Range (mg/L)	On-Site and Downgradient Mean (mg/L)	Soil Solution Phytoxicity Benchmark (mg/L)
Aluminum	<0.0076–<0.051	0.002–0.29	0.0207	0.3
Antimony	<0.0001–<0.011	<0.0001–<0.0029	0.000534	N/A[a]
Arsenic	0.00018–0.0015	<0.0001–0.361	0.0109	0.001
Barium	0.0222–0.033	<0.01–0.108	0.0362	N/A
Beryllium	0.002–0.002	<0.001–0.0021	0.000775	0.5
Bismuth	<0.011–<0.011	<0.001–<0.011	0.00158	20
Cadmium	<0.0001–<0.0017	<0.0001–0.0208	0.0018	0.1
Chromium	<0.0005–<0.011	<0.0005–<0.003	0.000638	0.05
Cobalt	<0.0013–0.002	0.00055–0.064	0.00755	0.06
Copper	<0.0004–0.005	<0.0004–0.068	0.0102	0.06
Iron	<0.0008–<0.05	<0.0008–17.1	1.28	10
Lead	<0.0001–<0.0055	<0.0001–<0.0055	0.000355	0.02
Lithium	0.0278–1	0.0201–1.71	0.373	3
Manganese	<0.0001–0.0157	<0.01–14.5	3.1	4
Mercury	<0.0001–<0.0002	<0.0001–0.003	0.000488	0.005
Molybdenum	<0.0018–0.01	<0.001–10.8	0.844	0.5
Nickel	<0.0006–0.015	<0.0006–0.089	0.0185	0.5
Selenium	0.0091–0.0266	<0.0001–0.205	0.032	0.7
Silver	<0.0001–<0.0055	<0.0001–<0.0055	0.000309	0.1
Thallium	<0.0001–<0.011	<0.0001–<0.011	0.000451	0.05
Uranium	0.0042–0.0259	<0.0001–23.3	2.76	40
Vanadium	0.00061–0.0164	<0.0003–7.1	0.154	0.2
Zinc	<0.0006–0.011	<0.0006–0.16	0.0129	0.4

N/A = not available.

Table A2−8. Maximum and Mean Concentrations of Radioactive Constituents Evaluated Using the RESRAD Biota Code and Corresponding Quotients

Constituent	Maximum Concentration (pCi/L)	Riparian Animal Quotient	Riparian Plant Quotient	Mean Concentration (pCi/L)	Riparian Animal Quotient	Riparian Plant Quotient
Uranium-238	413	1.4	9.87E-06	28.7	1.3E-01	[a]
Uranium-234	396			29.5		
Radium-226	1.27			0.21		

[a]The terrestrial plant quotient was not calculated for the mean concentrations of the radionuclide constituents, since the terrestrial plant quotient calculated for the maximum concentrations did not exceed 1.

The quotient of riparian plants based on maximum surface water concentrations was 6 orders of magnitude below 1 (Table A2–8). The quotient for riparian animals based on maximum concentrations slightly exceeded 1 and thus could be of minor concern if riparian organisms were to get all their exposure at the location where the maximum sample was taken. However, riparian vertebrates integrate their exposure over a much larger area, and the quotient for riparian animals based on mean concentrations was about 1 order of magnitude below 1 (Table A2–8). Consequently, there is no potential risk of radiotoxic effects for either riparian vertebrates or plants from these radiological constituents in surface water.

A2−3.0 References

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Appendix A3

Biological Opinion

United States Department of the Interior
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UTAH FIELD OFFICE
2369 WEST ORTON CIRCLE, SUITE 50
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In Reply Refer To
6-UT-04-F-008

Mr. Don Metzler, Moab Project Manager
U.S. Department of Energy
2597 B¾ Road
Grand Junction, Colorado 81503

Dear Mr. Metzler:

Subject: Biological Opinion on the Surface and Ground Water Remediation at the Moab, Utah. Uranium Mill Tailings Radiation Control Act (UMTRCA) Site

In accordance with section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.), and the Interagency Cooperation Regulations (50 CFR 402), this transmits the Fish and Wildlife Service's final biological opinion for impacts to federally listed endangered species for Department of Energy's (DOE) proposed action to remediate surface and ground water contamination at the Moab Site. Reference is made to your August 30, 2004, correspondence (received in our Utah Field office on August 31, 2004) which transmitted a biological assessment for our approval and requested initiation of formal consultation for the subject project. Our letter of September 20, 2004 approved the biological assessment as final and initiated formal consultation.

This biological opinion is based on information presented in the August 2004 biological assessment, the November 2004 Draft Environmental Impact Statement, the December 2003 Site Observational Work Plan, and other sources of information. I concur that aspects of the ground water remediation component of the proposed action may adversely affect the endangered Colorado pikeminnow *(Ptychocheilus lucius*), humpback chub (*Gila cypha*), bonytail (*Gila elegans*), and razorback sucker (*Xyrauchen texanus*) and critical habitat.

This biological opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the Act to complete the following analysis with respect to critical habitat. Section 3(5)(A) of the Act defines critical habitat as: (i) the specific areas within the geographic area occupied by a species, at the time it is listed in accordance with the Act, on which are found those physical or biological features, (I) essential to the conservation of the species, and (II) that may require special management considerations or protection; and (ii) specific areas outside the geographic area occupied by a species at the time it is listed, upon a determination that such areas are essential for the conservation of the species. "Conservation" means the use of all methods and procedures that are necessary to bring an endangered or a threatened species to the point at which listing under the Act is no longer necessary.

Based on the information provided in the biological assessment, I concur that the proposed action may affect but is not likely to adversely affect, the threatened bald eagle (*Haliaeetus leucocephalus*), the endangered southwestern willow flycatcher (*Empidonax traillii extimus*), the threatened Mexican spotted owl (*Strix occidentalis lucida*), the endangered Black-footed ferret (*Mustela nigripes*), the candidate yellow-billed cuckoo (*Cocyzus americanus*), and the candidate Gunnison sage grouse (*Centrocercus minimus*). The bald eagle, southwestern willow flycatcher, and western yellow-billed cuckoo have been reported near the Moab Site, but their presence is seasonal and likely infrequent due to their migratory nature. Potential habitat exists for the Mexican spotted owl west of the site, although not close to the site. Therefore, potential effects on these species would be considered discountable. At the Crescent Junction disposal site location, the only species of concern are the bald eagle and black-footed ferret due to the possible occurrence of associated suitable habitat. Based on available information, it is unlikely that these species are present; therefore, potential adverse effects would be considered discountable.

In addition, I concur with the determination of no effect for the threatened Jones' cycladenia (*Cycladenia jonesii*), the threatened Navajo sedge (*Carex specuicola*), and the endangered clay phacelia (*Phacelia argillosa*) as these species are not known to occur in the project areas.

CONSULTATION HISTORY

The Atlas Moab Mill is located on the west bank of the Colorado River about 3.7 km (2.3 mi) northwest of Moab, Utah. The property and facilities were originally owned by the Uranium Reduction Company and regulated by the Atomic Energy Commission, precursor to the NRC. The mill and site were acquired by Atlas Corporation in 1962. Atlas activities at the Moab Mill site were covered by NRC Source Material License SUA-917, which was renewed in 1988. The mill ceased ore milling operations in 1984 and has been dismantled except for one building that DOE currently uses for maintenance and storage.

The USFWS=s Utah Field Office has been involved with the proposed reclamation of the Atlas mill tailings since 1979. At that time, the Department of Interior provided comments which were included in the Final Environmental Statement for the Atlas site. These comments included reference to the proposed critical habitat designation for two endangered fish, the humpback chub and Colorado pikeminnow.

In 1983, the USFWS identified in a letter to the Assistant Regional Director regarding a review of the Emergency and Remedial Response Information System Inventory, that the only site which may aversely affect threatened or endangered species was the Atlas Mineral Corporation mill tailings pile at Moab, Utah. The USFWS identified likely effects to Colorado pikeminnow and razorback sucker.

On August 28, 1992, the USFWS provided the Nuclear Regulatory Commission (NRC) with a letter identifying the presence of four endangered fishes in the Colorado River. This letter recommended that reclamation plans ensure that mill tailings material never enter the Colorado

River system, particularly over the long term when there may not be personnel or equipment to deal with problem situations. For example, in the middle 1980's the river level rose to the base of the tailings pile and equipment operators were barely able to keep the pile from sloughing into the river. At that time the USFWS advised the NRC that any depletion of water from the Colorado River system, including water used in dust suppression, is considered a Amay affect@ on the endangered Colorado River fish.

On May 13, 1994, the USFWS sent a letter to the Secretary, NRC, providing review and comment on the Notice of Intent to prepare an Environmental Impact Statement. In this letter, the USFWS identified and attached our August 1993 memoradum from our Regional Office in Denver that provided extensive comments on the Environmental Assessment. Issues included water depletion from the Colorado River; groundwater contamination; release of toxic elements; the lack of a discussion of laboratory practices for chemical analyses of toxic elements; selenium in surface water; radiological hazards to wildlife and Atake@ under the Migratory Bird Treaty Act; the lack of contaminant studies in fish, and whether the area would truly be a maintenance free closed system for 200--1,000+ years.

On November 2, 1994, the USFWS provided an updated list of species that may be affected by the reclamation of the Atlas mill tailings, this time to Oak Ridge National Laboratory, Tennessee. Oak Ridge was a consultant working for the NRC on preparation of the Environmental Impact Statement for the proposed action. In this letter the USFWS identified that, not only were four endangered Colorado River fishes (Colorado pikeminnow, razorback sucker, humpback chub, and bonytail chub) likely to occur in the vicinity of the proposed project site, but that the peregrine falcon (*Falco peregrinus*) and Jones cycladenia (*Cycladenia humilis* var. *jonesii*) also may be present. The USFWS reiterated that indirect effects could result from water depletions associated with the project. Water depletions, including water used for construction activities such as dust suppression, drilling, and mixing of concrete, from the upper Colorado River Basin is considered a jeopardy and an adverse modification of designated critical habitat for the endangered Colorado River fishes.

On January 11, 1995, the USFWS provided comments on the Preliminary Draft Environmental Impact Statement (PDEIS). In these comments the USFWS identified that it did not agree with the conclusions drawn in the PDEIS regarding tailings contamination of the Colorado River. The PDEIS concluded minimal impact on water quality and minimal toxicity effects to wildlife. The USFWS identified that some contaminants of concern can bioaccumulate to harmful levels in wildlife even when contaminant levels remain below water quality standards, and that sampling of aquatic biota is the best way to determine if contaminants are bioaccumulating in the food chain. Dilution by the Colorado River was not an effective means of mitigation for contaminants being carried into the river from the Atlas mill tailings pile. Selenium contamination was a concern and the literature indicated detrimental effects on fish and waterfowl from selenium levels of 1-3 Fg/L in water (Peterson and Nebeker 1992; Hamilton and Waddell 1994; Skorupa and Ohlendorf 1991). Furthermore, USFWS comments identified inadequate sediment and biota sampling in the river and in the Scott M. Matheson Wetlands Preserve across the river channel and recommended sampling benthic invertebrates, aquatic plants, and nonendangered fish. The PDEIS provided inadequate radiological hazard evaluation, and an inadequate examination of the environmental impacts of a tailings pile failure.

In April 1995, contaminants staff from the USFWS=s Utah Field Office participated in a 2-day meeting in Moab to determine necessary studies to characterize the tailings pile constituents and to determine what leachates, if any, were escaping from the pile into the Colorado River. At this meeting the Federal representatives developed a list of recommended objectives and protocols for the Atlas/NRC study of the Colorado River below the Atlas tailings pile. The USFWS expressed a need for additional data at the site in order to make informed decisions on environmental impacts. These recommendations were submitted to the NRC and their consultants. For a variety of reasons, most of the recommended data collections were not conducted.

On November 2, 1995, the USFWS received the biological assessment on the proposed reclamation of the Atlas mill tailings from the NRC with a request for formal consultation pursuant to the Endangered Species Act of 1973, as amended. Review of the biological assessment prompted the USFWS to request additional materials and analysis in a letter dated February 15, 1996. The limited data did not accurately assess potential impacts to the endangered fish species in the Colorado River, and required additional analyses.

On March 28, 1996, the USFWS forwarded comments on the Draft Environmental Impact Statement to the National Park Service. The National Park Service coordinated Department of the Interior comments on the Draft document. After having fully reviewed the Draft Environmental Impact Statement and the Biological Assessment and receiving the results of some additional analyses, the USFWS provided the NRC with a letter, on July 22, 1996, which related its ongoing concerns regarding the paucity of data on toxic elements released into the Colorado River system from the Atlas mill tailings pile, as well as the inconsistency in data results. Additionally, the USFWS recommended a meeting between the USFWS, the NRC, and Atlas Corporation to discuss additional data needs.

On August 15, 1996, the USFWS met with the NRC and Atlas Corporation to discuss data needs and USFWS comments on the Draft Environmental Impact Statement. The Atlas consultants, Harding-Lawson Associates, presented some additional data concerning the hydrology of the region and the studies that had been conducted to date.

On October 21, 1996, USFWS staff again met with Atlas Corporation and the NRC to discuss regional hydrogeology, surface water quality issues, the potential effects of the tailings pile on the Colorado River and NRC requirements for the Ground Water Corrective Action Plan.

One additional meeting was held with USFWS staff, Atlas Corporation, NRC, and Department of Interior personnel to discuss the Departments= comments on the Draft Environmental Impact Statement and Atlas=s response to these comments. This meeting was held on December 17 and 18, 1996.

On January 14, 1997, the USFWS provided the NRC with a letter which detailed ongoing issues relating to the section 7 consultation and the National Environmental Policy Act process including: completion of the National Environmental Policy Act process prior to completion of the section 7 consultation; the possible impacts to endangered species from the contaminated groundwater underneath the tailings pile; impacts to listed species from the relocation of Moab Wash; evaluation of the analytical methods used to characterize the leachate from the pile; the lack of data characterizing the tailings pile itself; high concentrations of ammonia at and below the Atlas site, and the presence of southwestern willow flycatcher habitat at the site. The southwestern willow flycatcher had not been included in earlier species lists provided by the USFWS because the species was not listed as endangered until February 27, 1995.

On January 30, 1997, the USFWS received the supplemental biological assessment on the proposed reclamation of the Atlas mill tailings, with a cover letter requesting formal section 7 consultation pursuant to the Act.

On February 3, 1997, the USFWS received a letter from Atlas Corporation transmitting Atlas=s perspective on several of the procedural or process and technical issues identified in the USFWS=s January 14, 1997, letter to the NRC.

On February 6, 1997, the USFWS received a revised letter from Atlas Corporation requesting that the USFWS replace the February 3, 1997, letter with this new letter. There were no substantive changes or alterations.

On February 18, 1997, the USFWS sent a letter to the NRC acknowledging receipt of the supplemental biological assessment and request for formal consultation. In that letter the USFWS identified that it would provide the NRC with a biological opinion by June 15, 1997.

On March 27, 1997, the USFWS received a letter from Atlas Corporation providing Colorado River water depletions information and proposed actions for the Ground Water Corrective Action Plan.

On June 26, 1997, the USFWS released its Draft Jeopardy Biological Opinion for the proposed reclamation of the Atlas mill tailings site in Moab, Utah. Comments on the Draft Biological Opinion were received from the NRC, dated August 12, 1997, and Atlas Corporation and their consultants, dated August 6, 1997.

On September 9, 1997, USFWS staff participated in a meeting arranged by the Grand Canyon Trust, with staff from Oak Ridge National Laboratory/Grand Junction, the National Park Service, USFWS, the State of Utah (by phone), and Grand Canyon Trust, to discuss the potential effects of contaminated groundwater discharge to the Colorado River from the Atlas pile. The Oak Ridge National Laboratory/Grand Junction was assigned the task of developing a sampling scheme to more accurately delineate the content and width of the contaminant plume. A proposal was distributed September 19, 1997.

Given the differing opinions concerning the USFWS=s Draft Jeopardy Biological Opinion, the entire matter was elevated to the Council of Environmental Quality and the Office of the Secretary of Interior. The Council of Environmental Quality approved the Oak Ridge National Laboratory/Grand Junction study proposal.

On October 23, 1997, a meeting was held in the USFWS=s Denver office to address the status of the Oak Ridge National Laboratory/Grand Junction study proposal and refine the work plan. Participants included the USFWS, Oak Ridge National Laboratory/Grand Junction, NRC, Atlas Corporation, and Atlas=s consultants, Harding-Lawson Associates. At the meeting Oak Ridge

National Laboratory/Grand Junction agreed to perform the work and provide a report 60 days following the awarding of funds. Subsequently, Atlas Corporation, the NRC, and the USFWS agreed that following receipt of the Oak Ridge National Laboratory/Grand Junction report, the USFWS would issue a revised draft biological opinion within 30 days. The NRC and Atlas Corporation would have 10 days to review the revised draft biological opinion and provide comments to the USFWS. The USFWS would then have an additional 30 days to finalize the biological opinion. On November 10, 1997, Oak Ridge National Laboratory/Grand Junction began work on the approved study and on January 9, 1998, submitted the final report to the USFWS (received on January 12, 1998) and the NRC.

Upon receipt and review of the January 9, 1998, Oak Ridge National Laboratory/Grand Junction (1998a, 1998b) studies, the USFWS determined that additional modeling would be necessary to determine the long term impacts of leaving the tailings pile in place as opposed to moving it. An additional study that supplemented the earlier modeling effort was agreed to by the NRC and Atlas Corporation and conducted by Oak Ridge National Laboratory/Grand Junction (1998c). Shortly into this modeling effort, the NRC decided that a further modeling effort, one which modeled the long term contaminant levels in the Colorado River, was necessary. On February 5, 1998, USFWS staff met with the NRC, Atlas Corporation, Harding-Lawson Associates, and Oak Ridge National Laboratory/Grand Junction to discuss future modeling needs. At this meeting Oak Ridge National Laboratory/Grand Junction presented the completed supplemental modeling requested by the USFWS. After hearing the presentation, the NRC determined that additional future modeling was not necessary. All parties agreed to proceed with a revised draft biological opinion, to be delivered to the NRC by March 2, 1998.

In a letters to NRC dated March 2, 1998 and March 11, 1998, Atlas Corporation granted a 30-day extension for issuance of the USFWS=s revised draft biological opinion. The letter from Atlas Corporation stated that the length of this extension would be determined pursuant to discussions to be immediately undertaken among Atlas, the NRC, and the USFWS. This consultation timeline was in part dependent on a response from the USFWS whether the NRC could require Atlas Corporation to move the tailings pile out of the Colorado River floodplain. The USFWS provided said response in a letter dated March 11, 1998, which stated that the NRC did not have the authority to make Atlas Corporation move the pile.

On April 14, 1998, the USFWS issued a Revised Draft Biological Opinion. Numerous comments were received on the Revised Draft Biological Opinion from the NRC and Atlas Corporation. These comments facilitated a meeting that was held between the NRC, the USFWS, and Atlas Corporation on May 21 and 22, 1998 followed by subsequent conference calls. All parties agreed that upon receipt of a letter from Atlas Corporation identifying several specific time frames for completion of proposed actions, the USFWS would issue a final biological opinion within 30 days. The USFWS received said letter on May 29, 1998.

In a letter dated June 30, 1998, the parties agreed to an additional extension. The USFWS agreed to complete and transmit a draft final biological opinion to the NRC and Atlas Corporation by July 10, 1998, and the final biological opinion by July 20, 1998. On July 9, 1998, the USFWS completed and transmitted the draft final biological opinion.

In a conference call on July 16, 1998, the parties agreed to extend the date of issuance of the final biological opinion to July 24, 1998. Letters from Atlas and the NRC agreeing to the extension were received by the USFWS on July 20, 1998.

The USFWS issued its Final Biological Opinion on July 29, 1998. At that time, it was the USFWS's opinion that capping the pile in place would jeopardize the continued existence of the razorback sucker and Colorado pikeminnow due to continued leaching of contaminants (primarily ammonia) into the Colorado River, water depletion in the river, and adverse modification of designated critical habitat. This opinion was based primarily on the lack of a ground water corrective action plan; a reasonable and prudent alternative is summarized below:

1. Develop a revised groundwater corrective action plan necessary to reduce leaching from the pile and other sources such that the fish are no longer jeopardized and the habitat is no longer adversely modified.
2. Assure that ammonia levels will be reduced to levels avoiding future jeopardy to the endangered fish. The NRC shall incorporate, whether by order or through the request of Atlas Corporation, ammonia as a new constituent in the license held by Atlas Corporation.
3. In order to more effectively determine cleanup levels required to remove jeopardy to listed species, the Service initiated previously planned bioassay studies. These bioassay studies will be conducted by the Columbia Laboratory of the Biological Resources Division, U.S. Geological Survey and shall be initiated in July 1998. In order to effectively conduct these studies the Service, and other personnel participating in the study, will require access to the Atlas property to carry out the study. The NRC shall ensure that access is permitted to the site for purposes of conducting the study.
4. The NRC shall consult with the Service, pursuant to section 7, before establishing alternate concentration limits, and exceptions thereto, at the site.
5. Depletion impacts for 154.3 ac-ft (ac-ft) of Colorado River water were addressed through the Recovery Program.

The Final Biological Opinion provided a set of reasonable and prudent measures that would help to minimize take. The USFWS also concluded that the proposed action would not jeopardize the southwestern willow flycatcher and provided reasonable and prudent measures and terms and conditions to minimize take of that species. The peregrine falcon was not addressed in the Biological Opinion.

NRC published its final EIS in 1999. In March 1999, a trust was created to fund future reclamation and site closure. Atlas was released from all future liability with respect to the uranium mill facilities and tailings impoundment at the Moab Site. The bankruptcy court appointed NRC and the Utah Department of Environmental Quality (UDEQ) beneficiaries of the Atlas bankruptcy trust. Later, the beneficiaries selected PricewaterhouseCoopers to serve as trustee. In October 2000, the Floyd D. Spence National Defense Authorization Act (Floyd D. Spence Act) for fiscal year (FY) 2001 (Public Law 106-398) amended UMTRCA Title I (which expired in 1998 for all other sites except for ground water remediation and long-term radon management), giving DOE responsibility for remediation of the Moab Site. That act also mandates that the Moab Site be remediated in accordance with UMTRCA Title I "subject to the availability of appropriations for this purpose" and requires that DOE prepare a remediation plan to evaluate the costs, benefits, and risks associated with various remediation alternatives. The act further stipulates that the draft plan be presented to the National Academy of Sciences (NAS) for review. NAS is directed to provide "technical advice, assistance, and recommendations" for remediation of the Moab Site.

Under the act, the Secretary of Energy is required to consider NAS comments before making a final recommendation on the selected remedy. If the Secretary prepares a remediation plan that is not consistent with NAS recommendations, the Secretary must submit a report to Congress explaining the reasons for deviating from those recommendations. DOE's *Preliminary Plan for Remediation* (DOE 2001) for the Moab Site was completed in October 2001 and forwarded to NAS. After reviewing the draft plan, NAS provided a list of recommendations on June 11, 2002, for DOE to consider during its assessment of remediation alternatives for the Moab Site. DOE addressed the NAS recommendations in their internal scoping for the project EIS and in their draft EIS which was made available for public comment on November 5, 2004. Ultimately, DOE will need to finalize their RAP, which will need to be approved by the NRC. The RAP would provide the detailed engineering reclamation design and incorporate a ground water compliance strategy and corrective actions. DOE indicates that the RAP would likely follow issuance of a NEPA Record of Decision.

In letters dated, April 25, 2000 and June 28, 2000, the USFWS requested the NRC to reinitiate Endangered Species Act Section 7 consultation based on new information relating to higher than anticipated fish mortality from contaminated ground water entering the Colorado River and delays in submitting a ground water corrective action and dewatering plans. NRC responded on May 25, 2000 and September 22, 2000, with a request that the USFWS answer questions and issues raised by counsel for the trustee including the necessity and appropriateness for the reinitiation. On December 7, 2000 the USFWS again requested the NRC to reinitiate consultation due to the profound and fundamental changes in the proposed remediation plan resulting from passage of the Floyd D. Spence Act, which required that the site be turned over to the DOE and authorized the trustee to undertake ground water remediation at the Atlas site in the interim. In their final response dated December 20, 2000, NRC declined to reinitiate consultation with USFWS and instead requested informal Section 7 consultation.

In a letter dated February 8, 2001, the USFWS indicated that they could not engage in informal consultation once formal consultation has been completed and withdrew the Final Biological Opinion. In that same letter the USFWS informally consulted on actions the NRC and the DOE had agreed needed to be accomplished prior to official transfer of the site. Responsibility for the mill site was officially transferred to DOE prior to October 30, 2001.

Since DOE acquired responsibility for the Moab Site, many activities, including characterization, maintenance and operational activities, and interim actions, have taken place. Before implementing these actions, DOE consulted regularly with USFWS concerning threatened and endangered species that may be affected by these activities. These consultations, and DOE determinations, resulted in concurrences by USFWS dated March 23, 2001, September 12, 2001, January 22, 2002, and April 5, 2004. In all cases, it was determined that these actions would not adversely affect the continued existence of any aquatic or terrestrial threatened or endangered species.

In support of the preparation of the draft EIS for remediation of the Moab Site, DOE sent a request for information to USFWS in March 2003. USFWS responded in April 2003 with an updated list of threatened, endangered, proposed, and candidate species that may occur in the potentially affected areas under the various alternatives.

On April 24, 2003, DOE and USFWS met in Salt Lake City to discuss the BA approach and scope. This meeting also included discussions regarding options for preparing a biological opinion prior to identifying a preferred alternative.

A teleconference with USFWS, DOE, the U.S. Environmental Protection Agency (EPA), and the Utah Department of Environmental Quality took place on July 9, 2003, to discuss the applicable numeric ammonia criteria.

On August 25, 2003, USFWS and DOE met in Salt Lake City to further discuss applicable risk-based criteria and standards to ensure the protection of endangered fish. On November 3, 2003, the draft BA was forwarded to USFWS for comment. DOE received initial comments on the BA in early December 2003. Following receipt of the comments, a meeting occurred on December 15, 2003. Additional comments were transmitted by USWFS in early January 2004, followed by telephone conferences to clarify issues and concerns.

On April 14, 2004, DOE submitted the final draft BA to USFWS. In June through August 2004, DOE and USFWS consulted extensively to resolve final comments on this document.

On August 10, 2004, USFWS provided formal comments to DOE on the final draft BA. DOE incorporated those comments and on August 30, 2004, sent a BA and a cover letter requesting our approval of that version as final. USFWS responded with a letter on September 20, 2004 accepting the latest version of the BA as final and committed to having a draft BO to DOE by January 31, 2005.

On January 31, 2005 the USFWS sent a letter requesting an extension on the draft BO due date until March 17, 2005. DOE agreed to that extension, via email on February 14, 2005.

On April 6, 2005, DOE announced their preferred alternatives for tailings disposition and ground water remediation. Off-site disposal at the Crescent Junction site was selected as the preferred disposal location for the tailings, and transportation by rail was the preferred transportation mode. DOE also selected active ground water remediation at the Moab site as its preferred ground water compliance strategy.

BACKGROUND

The Atlas tailings pile is about 0.8 km (0.5 mile) in diameter and 28.65 m (94 feet) high. It rises to an elevation of 1237 m (4058 ft) above mean sea level. The pile is located 3.7 km (2.3 mi) northwest of Moab, Utah and occupies about 53 ha (130 acres) of land about 230 m (750 ft) from the Colorado River. It consists of an outer compact embankment of coarse tailings and an inner impoundment of both coarse and fine tailings. An interim cover of uncontaminated earth covers the tailings. The amount of tailings is estimated to total 9.5 million metric tons (10.5 million tons).

Initial tailings pond construction was completed in 1956, and with the exception of brief periods, tailings were disposed in the pond continuously from initial startup in October 1956 until the mill ceased operations and was placed on standby status in 1984. The pile has five embankments that were raised to their present elevation of 1,237 m (4,058 feet) above mean sea level after Atlas's 1979 license renewal. A 5.5 m (18 foot) raise in embankment elevation to a projected final elevation of 1,242 m (4,076 feet) was reviewed and approved under License Amendment No. 7 dated June 30, 1982. However, the embankment raise was never initiated because the added capacity was not needed when the mill subsequently entered a long-term shutdown status.

During early operations Atlas utilized an acid leach process for uranium milling. During this period, lime was added to the mill tailings to help neutralize the tailings. In 1961 an alkaline leach process was initiated. In 1967 a new acid leach circuit was installed and, for a period of time, both the acid circuit and an alkaline circuit were operated. From 1982 through 1984, only an acid leach process was used with no neutralization of process water because a recycle process was in use.

To collect water draining from the tailings pile embankments, two sump pits were excavated in the 1980's, one on the northeast side of the pile and the other on the south end of the pile. Pumps were installed to collect the seepage water and pump it to an evaporation pond on top of the tailings pile. Water did not collect in the pits for several years, and the pumps were subsequently removed. The NRC amended Atlas=s license to allow disposal of radioactive contaminated solid waste in the south sump pit.

The 1982-1984 phase of operations appears to have resulted in increased metals mobilization as a result of the lower pH of the water and tailings associated with the acid leach circuit. After the NRC conformed its groundwater regulations to the Environmental Protection Agency=s, they required Atlas to initiate a compliance monitoring and corrective action program by July 1990. A revised program was prepared by Atlas and found acceptable with modification. The program included the establishment of groundwater quality standards, point-of-compliance wells, a background well, sampling frequency, groundwater sampling points, selected constituents for which the groundwater was to be analyzed, and enhanced drying of the tails. Wells were drilled into the tailings to pump water to an evaporative pond on the top of the tailings pile.

Atlas conducted cleanup of windblown tailings and other contaminated soils in several areas on the site. These areas were along the west side of State Route (S.R.) 279, between the tailings pile and the highway, an area northwest of the tailings pile, and an area of about 3 ha (7 acres) southeast of the tailings pile. Cleanup involved excavating the windblown tailings and contaminated soil and placing them on the tailings pile.

Since DOE took over responsibility for the site in 2001, they have instituted environmental controls and interim actions to minimize potential adverse effects to human health and the environment in the short term. Controls have included storm water management, dust suppression, pile dewatering activities, and placement of an interim cover on the tailings to prevent movement of contaminated and windblown materials from the pile. Interim actions have included restricting site access, monitoring ground water and surface water, and managing and disposing of legacy chemicals. A pilot-scale ground water extraction system was implemented in summer 2003, which has intercepted a portion of the ground water contaminants discharging into the Colorado River. Contaminated ground water is pumped to the top of the pile for evaporation.

DESCRIPTION OF THE PROPOSED ACTION

DOE is proposing to remediate contaminated soils and materials and contaminated ground water at the Moab Site. In addition, DOE has determined properties in the vicinity of the Moab Site (vicinity properties) may contain contamination and require remediation. These properties include portions of the state highway and railroad rights-of-way, BLM property, and Arches National Park. Surface contamination at the Moab Site and vicinity properties would be consolidated at the Moab Site prior to transportation by railroad to a disposal site near Crescent Junction, Utah. The ground water remediation goal is to reduce concentrations of five contaminants reaching the Colorado River to acceptable risk levels within 10 years of the ROD. Ground water remediation, as proposed, seeks to reduce concentrations of ammonia reaching the Colorado River surface waters to protective levels. DOE presumes that by reducing ammonia concentrations the other contaminants will be reduced to protective levels as well. Following informal consultation with the Utah Field Office in 2003 and 2004 DOE implemented initial and interim actions to begin reducing ammonia concentrations prior to full implementation of proposed ground water remediation.

The following description of the proposed action is based on information provided in the biological assessment, the DEIS and the SOWP (DOE 2003a) and technical appendices to those documents.

Disposal Cell Recountouring, Stabilization, and Capping – Figure 1 provides a conceptual cross-section of the final condition of the disposal cell. The figure also illustrates the types and approximate dimensions of the materials that would be placed on the sides and top of the pile to contain radon emissions and stabilize the cell. This is a conceptual design and diagram only. The conceptual design is strictly intended to establish a reasonable basis for evaluating environmental impacts between the alternatives associated with this component of site remediation and reclamation. This assumed design is not intended to commit DOE to any specific cover design. A detailed design would be developed in DOE’s Remedial Action Plan (RAP) following the ROD.

Should the final design differ substantially from the design considered here, DOE would assess the significance of these changes as they relate to the decision-making process and the requirements of NEPA and ESA.

Remediation of Surface Contamination: Disposal at the Crescent Junction Site

The tailings pile, contaminated on-site soils and materials not yet in the existing pile, and contaminated materials from the vicinity properties would be transported to the Crescent Junction Site. Contaminated materials would be transported by rail. Activities under the proposed action will therefore occur at the Moab Site as well as at the off-site disposal site: Crescent Junction.

Activities at the Moab Site would include grading and removing vegetation over almost the entire 439-acre site, both to prepare the site for subsequent activities and to remove surface contamination. These activities would remove remaining wildlife habitat (approximately 50 acres, primarily tamarisk) from the Moab Site. Other site activities would include removing any existing structures and creating temporary construction support facilities (such as laydown yards, material stockpiles, vehicle maintenance and refueling areas, and vehicle decontamination facilities).

In the past, tailings material was removed from the Moab Site and taken to off-site locations for a variety of purposes, such as backfill. In many cases, ore was stockpiled at various locations in the Moab area. For the purposes of analysis in the EIS, and based on available information and past experience, DOE has estimated that about 98 vicinity properties, may require remediation. All are relatively small (about 2,500 square feet [ft^2] and 300 cubic yards [yd^3]of material per site). These sites would be excavated and the materials transported by truck to the Moab Site, where they would be stockpiled for eventual disposal at the Crescent Junction Site.

In addition to the surface disturbance at the Moab Site, an additional 1200 acres would be subject to disturbance at the Crescent Junction site, borrow areas and for transportation. Additional activities at the disposal site would include preparing the disposal cell and constructing similar support facilities as at the Moab Site.

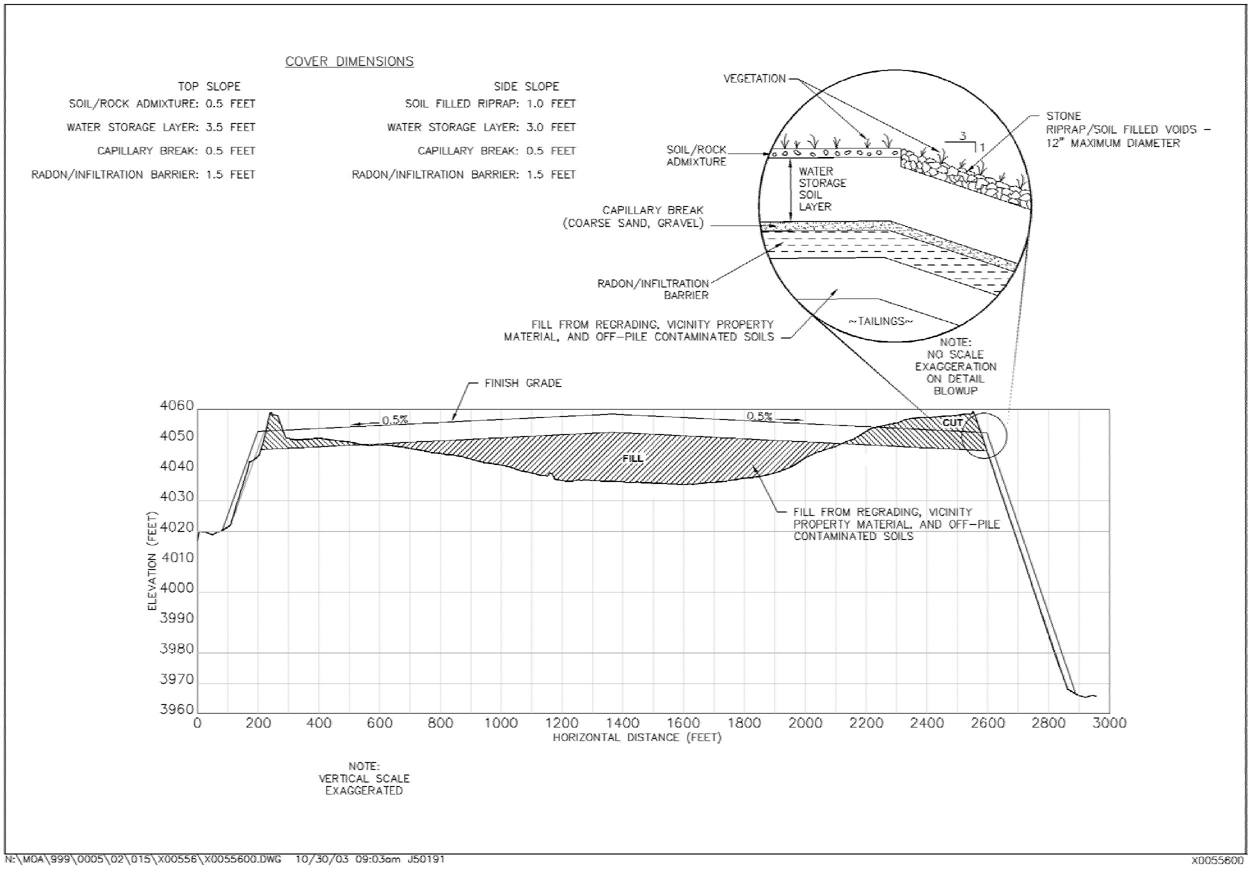

Figure 1. Cross Section of Disposal Cell designed for the Moab Site. Presented here as a conceptual design for the Crescent Junction Site. (reproduced from DEIS)

Table 1 shows areas of disturbance at borrow areas. The degree of disturbance would depend upon the borrow areas actually used and would be included in the RAP.

Rail transport would require construction of a loading facility at the Moab Site and some additional track and unloading facilities at the Crescent Junctin site.

Information provided in DOE's DEIS offers a more detailed description of activities associated with surface remediation: construction and operation at the Moab Site, characterization and remediation of vicinity properties, construction and operation at the borrow areas, preparation of contaminated materials for transport, final site reclamation and water depletions. These project details were reproduced from the DEIS.

Construction and Operations at the Moab Site -

Contaminated materials from vicinity properties would be transported to the Moab Site, stockpiled on site and prepared for transportation to an off-site disposal site. DOE projects surface remediation activities at the Moab Site would be complete in the year 2012 provided construction begins as proposed in 2007.

Preparation of contaminated materials for transport off-site - Before it could be transported by rail, the material in the tailings pile would have to be excavated and dried to a specified moisture content by drying in a process bed and mixing with drier material. To accomplish this, approximately 32 acres at the northwest and east base of the pile and an additional 14 acres around the top perimeter of the pile would be used as drying or processing areas. These areas would be accessed by temporary haul roads. There would be approximately seven separate 6- to 7-acre process beds in the areas. DOE has previous experience successfully moving wet tailings, including saturated slimes, at other UMTRCA sites such as at the Riverton (Wyoming), Rifle (Colorado), Monument Valley (Arizona), and Grand Junction (Colorado) sites.

Once the process beds and haul roads were constructed, pile excavation would begin. An excavating machine located on the perimeter of the pile would excavate from the center of the pile outward. The excavating machine would drag slimes from the center and pull them over and into the perimeter sands, providing some mixing during the excavation. The coarser tailings sands at the outer perimeter of the pile would be excavated and moved to the process beds using scrapers. This method would allow a progressive top-down excavation sequence that would maintain the stability of the perimeter tailings dike surrounding slimes and also allow continuous use of the perimeter area material for processing. As saturated slimes were excavated from the center of the pile, the material would be loaded onto trucks and taken to the process beds for mixing and drying. A tractor would turn and dry the graded material until it reaches a consistent moisture content suitable for truck or rail transport. Assuming dry tailings were available for mixing with wet tailings, the mixing and drying process for a load of excavated material would take approximately 3 days; if dry tailings were not available for mixing, the material would be processed for 7 days prior to shipment. The approximate maximum daily volume of material that could be placed for processing would be 15,500 yd^3 in each process bed of approximately 6 to 7 acres. Should tailings drying take additional time, slightly greater areas for drying would be necessary to allow sufficient inventory of tailings to be dried and transported according to the planned schedule. Once the material was sufficiently dry, it would transported by a conveyor system and loaded onto waiting gondola cars.

After excavation of the pile reached the assumed original grade, it would continue until the cleanup criterion had been met. On the basis of limited existing data, DOE estimates that subpile excavation to a depth of 2 ft would be required.

Final Site Reclamation - Release of portions of the site for future uses would depend on the success of site remediation. DOE's ultimate goal would be to remediate to unrestricted surface use standards. However, DOE would defer its decisions on the release and future use of the Moab Site pending an evaluation of the success of surface and ground water remediation. Some fencing would be required at least for the 75 years during which ground water remediation would be ongoing. Before backfill and site reclamation and following the removal of the temporary infrastructure, structures, and controls, DOE's contractor would verify that radium-226 concentrations in soil within the Moab Site boundary did not exceed EPA standards in 40 CFR 192. The entire site would then be graded and re-contoured. The water storage ponds would be backfilled to original grades prior to reclamation. Approximately 425,000 yd^3 of fine grained silty- to sandy-loam reclamation soil excavated from the selected borrow area (e.g. Floy Wash) borrow area would be imported as backfill for the Moab Site. Soils would be prepared for planting by scarifying with a disk harrow. Moisture conditioning would be performed and the area seeded with native or adapted plant species.

Moab Wash would be reconstructed in its general present alignment. After removal of the tailings impoundment and contaminated soils, site topography and future land use are uncertain. Thus, to minimize costs and achieve fluvial stability, the channel would be re-established in its current location. Additional meanders may be added to increase travel distance of the water and reduce slope to mitigate future erosion caused by higher water flow velocity. The channel would be lined with riprap and designed to carry the estimated runoff volume for a 200-year flood. Larger flows would be allowed to flood into channel overbank areas.

DOE estimates that all 8,867,400 yd^3 of source materials (uranium mill tailings, pile surcharge, subpile soils, off-pile contaminated soils, and vicinity property materials) weighing approximately 12,000,000 tons would need to be hauled off site. Estimates of the time to transport contaminant offsite range from: 3.3. years if four round trips are completed per day to 1.6 years if 8 round trips are completed daily. DOE provides preliminary details addressing the wide ranging considerations of infrastructure needed at the Moab Site, at the Crescent Junction Site and points between in their DEIS.

<u>Water Depletions -</u> DOE estimates that on average of 130 - 235 ac-ft would be depleted annually for approximately 5 years to implement the preferred alternatives and transportation mode.

Conservation Measures:

1. Moab Wash would be reconstructed in its general present alignment. The channel would be lined with riprap and designed to carry the estimated runoff volume for a 200-year flood. Larger flows would be allowed to flood into channel overbank areas.
2. DOE's contractor would verify that radium-226 concentrations in soil within the Moab Site boundary did not exceed EPA standards in 40 CFR 192. The entire site would then be graded and re-contoured. The water storage ponds would be backfilled to original grades prior to reclamation. Approximately 425,000 yd^3 of fine-grained silty- to sandy-loam reclamation soil excavated from the Floy Wash borrow area (or other suitable site) would be imported as backfill for the Moab Site.

<u>Remediation of Ground Water Contamination:</u>

DOE's proposed action for ground water remediation at the Moab Site is to design and implement an active remediation system and also apply ground water supplemental standards (see below). These actions would be in addition to the initial and interim actions described below. Ground water remediation would be implemented under both the on-site and off-site tailings disposal alternatives. The remediation system would be designed to intercept contaminated ground water that is currently discharging into the near-bank, shoreline area of the Colorado River, which is designated critical habitat for endangered fish species. It is estimated that up to 5 years may be required to design and construct the remediation system. Once the system is implemented, up to 5 years of operation may be required before the action becomes completely effective and provides the requisite protection in the adjacent surface waters. DOE claims these time frames are conservative, and the time needed to design, implement, and achieve protective levels may be substantially less. In addition, the proposed action would, at a minimum, meet the protective surface water criteria. It is possible that effects of the interim action and the proposed action may achieve background surface water quality conditions in less than the estimated 10 years after the ROD. The system would be operated until ground water contaminant concentrations decreased to a level that would no longer present a risk to aquatic species. This is predicted to be 75 years for DOE's preferred ground water remediation alternative (Figure 2). More detailed information is presented in Section 2.3 of the EIS.

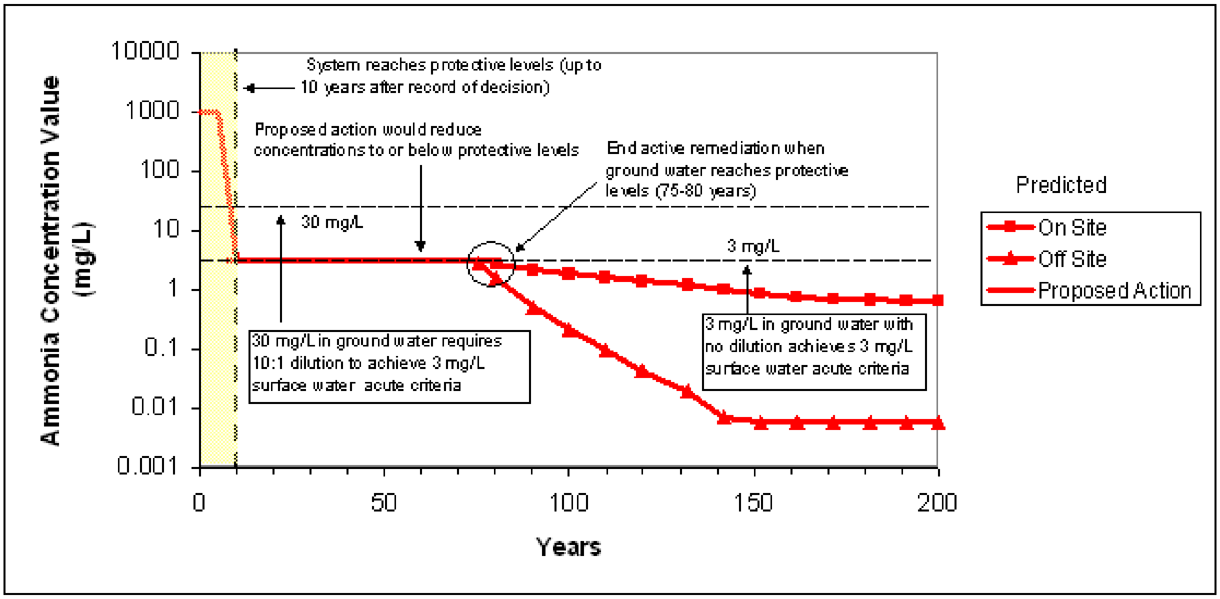

Figure 2. Predicted Maximum Ammonia Concentrations in Ground Water for Active Remediation

Supplemental standards (40 CFR 192), would also be applied to ground water at the site. The uppermost aquifer at the Moab Site contains a highly saline (salty) water, often referred to as brine, which can be as thick as 400 ft, overlain with a thin layer of less salty water. Because ground water in the major portion of the uppermost aquifer has a TDS content exceeding 10,000 milligrams per liter (mg/L), the aquifer meets the definition of a limited-use aquifer as described in EPA's *Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy* (EPA 1988). Supplemental standards are regulatory standards that may be applied when the concentration of certain constituents (in this case, total dissolved solids [TDS]) exceeds the normally applicable standards (e.g., MCLs; see 40 CFR 192, Subpart C for further explanation) for reasons unrelated to site contamination.

Remediation Goals for Contaminants of Concern: Aquatic goals - Remediation goals are based on the contaminants of concern identified in Appendix A2 of the EIS (refer to Table 2). In Appendix A2 of the EIS, *Screening of Contaminants to Aquatic and Terrestrial Resources,* DOE identified ammonia, copper, manganese, sulfate, and uranium as the chemical contaminants of concern. The primary contaminant of concern that would require ground water remediation is ammonia. The area of contamination varies with hydrologic regime but in general is confined to an area less than 53,800 ft^2 (approximately 1.25 acres) (USGS 2002).

Remediation goals for ammonia include the acute and chronic benchmarks based on ambient pH and temperature conditions in compliance with the National Recommended Water Quality Criteria (NWQC) (EPA 2002) and currently proposed Utah Water Quality Standards (UAC 2003, UDEQ 2003). The approach for setting the goals is discussed in Section 2.3 of the EIS. It is DOE's position that achieving a target goal of approximately 3 milligrams per liter (mg/L) for ammonia in ground water would result in compliance with the range of surface water standards in the Colorado River. The 3-mg/L target goal represents the low end of the reasonable range of acute standards. The 3-mg/L concentration represents a 2- to 3-order-of-magnitude decrease in the center of the ammonia plume and would be expected to result in a corresponding decrease in surface water. In addition, based on analysis of collocated samples of interstitial ground water (pore water) and surface water, additional dilution occurs as the ammonia moves from the bank of the river into the water column. The dilution is estimated to be an average of 10-fold (DOE 2003a, 2005a). The combination of active remediation, dilution into surface water, and the tendency for ammonia to volatilize should result in compliance with both acute and chronic ammonia standards in the river everywhere adjacent to the site. It is anticipated that ground water remediation would decrease and maintain the concentrations of all contaminants of concern at levels protective of aquatic species.

Table 2 . Minimum, Maximum, Background Range, Total Number of Samples, and Number of Samples Above Detection Limit for Contaminants of Potential Concern at the Moab Site, Utah (2000–2002 data)

Contaminant of Potential Concern	Minimum Concentration (mg/L)	Maximum Concentration (mg/L)	Background Concentration Range (mg/L)	Total Number of Samples	Number of Samples above Detection Limit
Aluminum	0.005	0.348[a]	0.008–0.14	182	84
Ammonia[b]	**0.05**	**1440**	**0.05–0.134**	**266**	**266**
Antimony	<0.001	0.0005[c]	0.0005 [c]	62	0
Arsenic	<0.006	0.002[d]	<0.0006–0.002	71	42
Barium	0.002	0.211	0.051–0.14	186	185
Beryllium	<0.0001	0.00005	0.00005 [c]	3	0
Bismuth	<0.001	0.0005 [c]	0.0005 [c]	3	0
Boron	0.064	1.74	<0.0801–0.123	76	65
Cadmium	<0.0001	0.004	<0.00005 [c]	114	11
Chloride	22	17300	25–172	301	301
Chromium	<0.0005	0.0005 [c]	<0.0005–<0.0013	62	1
Copper	**<0.00049**	**0.051 [a]**	**<0.0006–<0.0014**	**182**	**61**
Gross Alpha	1.1	665.45	7.31–13.82	93	
Iron	<0.003	7.23	0.0075–4.17	119	73
Lead	<0.0008	0.0005 [c]	0.00005 [c]	104	0
Lithium	0.0552	0.31 [d]	0.057 [d]	18	15
Manganese	**0.0005**	**12**	**<0.003–0.076**	**260**	**147**
Mercury	<0.0002	0.002 [a]	0.00005 [c]	96	1
Molybdenum	<0.001	1.91	<0.0028–0.007	290	275
Nickel	<0.0006	0.052	<.0006–0.002	56	19
Nitrate	0.829	21.7	1.86–5.51	76	75
pH	6.83	8.89	7.38–8.6	423	NA
Selenium	<0.0005	0.026	0.0013–0.0079	216	206
Silver	<0.00005	0.0025 [c]	0.000025–0.00005 [c]	63	0
Strontium	0.005	10.2	0.965–1.63	136	133
Sulfate	**72**	**14400**	**84.1–439**	**301**	**290**
Thallium	<0.001	0.0005 [c]	0.0005 [c]	63	21
Uranium	**0.0013**	**5.12**	**0.0023–0.008**	**331**	**331**
Vanadium	0.0003	0.249	0.00073–0.0031	148	132
Zinc	<0.0008	0.023	<0.0017–0.006	112	50

[a]Analyte is estimated, based on laboratory qualifier.
[b]All ammonia samples were converted for this assessment to total ammonia as nitrogen.
[c]All analytes were below detection; maximum value based on one-half of detection limit.
[d]Analytes in data set represent multiple detection limits. Analytes above this value are below detection limits.

Remediation Goals for Contaminants of Concern: Terrestrial goals -
Remediation goals for terrestrial or avian species have not been established. This is due to limited potential for threatened or endangered receptors (both plant and animal) to be adversely affected by contaminated surface water or ground water. Limited potential is based on the risk analysis in Appendix A2 of the EIS and includes potential exposure pathways, potential presence of species, and potential use of ground water or surface water. Although specific goals are not established, concentrations of contaminants of concern would be reduced by proposed ground water remediation, which would reduce concentrations in surface water.

As a result of remediation, contaminants may concentrate in an evaporation pond. If concentrations presented a risk to threatened or endangered species DOE would inform USFWS, and reasonable and prudent measures would be agreed upon and implemented in order to minimize take. If adverse effects could not be avoided, DOE has committed to additional Section 7 consultation.

Initial and Interim Actions at the Moab Site as Related to the Proposed Action - Upon accepting responsibility for the Moab Site, DOE initiated consultations with USFWS. Based on these consultations, and after reviewing historical surface water quality studies and data, DOE and USFWS both agreed that an immediate risk was posed to endangered fish and designated critical habitat. The source of the risk was identified as elevated concentrations of site-related ground water contaminants (primarily ammonia) reaching the Colorado River.

On April 30, 2002, USFWS concurred with DOE's determination to implement an initial action, followed by an interim action. The goal of the initial action was to dilute ammonia concentrations at the ground water–surface water interface in areas that presented the greatest potential for fish to be present, when backwater habitat has developed. It was estimated that backwater habitat would most likely be present from June through August at flows of 5,000 to 15,000 cubic feet per second (cfs). The action focused on the segment of the Colorado River from Moab Wash extending approximately 800 feet (ft) downriver; that segment contributes the highest concentrations of contaminants to the river. The initial action was designed to take fresh water upstream of the site and pump it through a distribution system to backwater areas. The system was not installed in 2003 due to low flows. The system was installed and tested in 2004 but not fully implemented because the targeted backwater areas never held water. This was due to low river flows caused by drought. It is anticipated that the initial action would be phased out as the interim and subsequent ground water remediation actions reduce ammonia to safe concentrations.

The goal of the interim action is to extract contaminated ground water near the Colorado River, thereby reducing the amount of contamination reaching the river. DOE funded, designed, and implemented the system (Phase 1) in 2003, which included 10 extraction wells aligned parallel to the Colorado River. The system is designed to withdraw ground water at the rate of approximately 30 gallons per minute (gpm) and pump it to an evaporation pond on top of the existing tailings pile. On April 4, 2004, USFWS concurred with DOE's determination to construct a land-applied sprinkler system designed to increase evaporation rates. The system was installed in the existing evaporation pond area. In July 2004, DOE added another 10 extraction wells (Phase 2) near the first 10 wells to increase the rates of ground water extraction and to test the effects of freshwater injection on surface water concentrations. If the interim actions are successful, a reduction in contaminant concentrations in surface water could be observed significantly sooner than the 10-year time frame considered under the proposed action.

As reported in DOE's *Fall 2004 Performance Assessment of the Ground Water Interim Action Well Fields at the Moab, Utah, Project Site* (DOE 2005b) the Phase 1 well field removed an estimated total volume of 5,246,106 gallons of ground water between June and October of 2004. The estimated total masses of ammonia and uranium removed by Phase 2 wells during this period were 16,700 and 55 kg, respectively. During September and the first week in October of 2004, Phase 2 extraction wells removed an estimated total ground water volume of 821,583 gallons. The mass withdrawals of ammonia and uranium associated with this extraction volume were 3,130 and 7 kg, respectively.

Ground Water Remediation Options – DOE proposes that active ground water remediation would consist of one or a combination of the options described below. All proposed remediation options would occur within the footprint of historical millsite activities and areas requiring surface remediation. Figure 3 shows the area of proposed ground water remediation. Final selection of the most appropriate option(s) would be documented in DOE's remedial action plan (RAP) and would depend upon which surface disposal alternative is selected. These options, which are described in detail in Section 2.3 of the EIS include:

- Ground water extraction, treatment, and disposal
- Ground water extraction and deep well injection (without treatment)
- In situ ground water treatment
- Clean water application

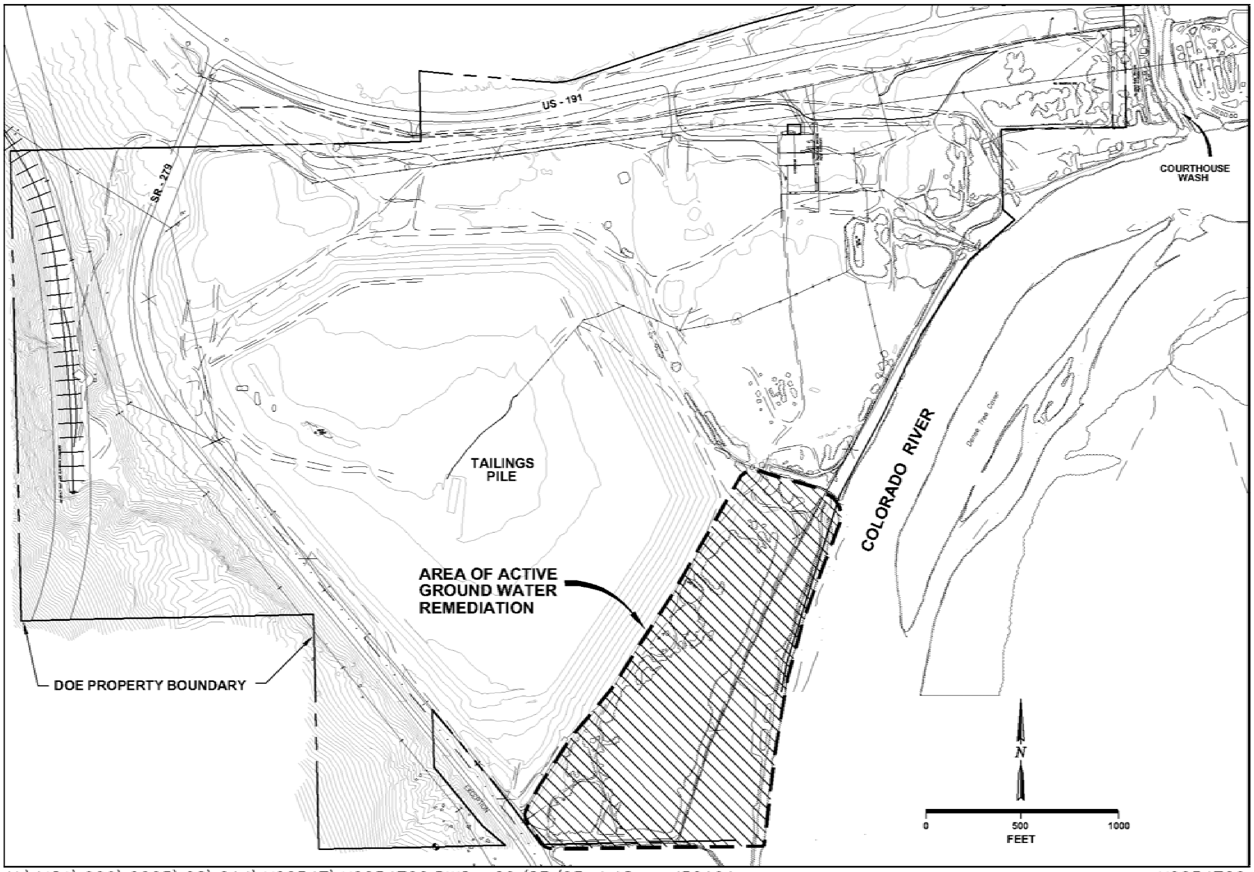

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Figure 3. Area of Proposed Active Ground Water Remediation

Ground Water Extraction: The two proposed methods for extracting contaminated ground water are extraction wells or interception trenches.

If extraction wells were used, between 50 and 150 wells would be installed to depths of up to 50 ft using conventional drilling equipment. This design would allow for extracting up to 150 gpm of contaminated ground water. The water would be pumped from the wells to a treatment collection point (e.g., evaporation pond) via subsurface piping. The system would be installed between the current tailings pile location and the Colorado River to intercept the plume before it discharged to the river and would require up to 50 acres of land for the duration of ground water remediation. The proposed locations are within the area of historical site disturbances and areas requiring remediation of contaminated soils. It is expected that the system would be installed after any remediation of surface soils required in these areas. It is possible that some extraction wells would need to be installed adjacent to the river in areas northeast of the tailings pile in the vicinity of the old millsite.

If shallow trenches were used, they would be constructed to intercept shallow ground water, which would be piped via shallow subsurface piping to a collection point for treatment (e.g., evaporation pond). This design would allow for extracting up to 150 gpm of contaminated ground water. It is estimated that the system would require from 1,500 to 2,000 lineal ft of trenches and could affect up to 50 acres of land for the duration of ground water remediation. The proposed locations are within the area of historical site disturbances and areas requiring remediation of contaminated soils.

Treatment Options: DOE has screened potential treatment technologies, which would be applicable for treatment of ammonia and other contaminants of concern (DOE 2003a). The treatment options and technologies described below are meant to bound the range of viable possibilities. All treatment options would require construction of infrastructure. The level of treatment would depend largely on the selected method of effluent discharge. Therefore, specific treatment goals could not be established until the specific discharge method(s) were selected. The treatment goals would have to consider risk analysis and regulatory requirements.

Additional testing, characterization, or pilot studies may be required before the optimum system could be selected and designed. This level of design would be developed in a RAP following publication of the ROD. The Site Observational Work Plan (SOWP) (DOE 2003a) presents more detailed descriptions and discussion of the screening process for the following treatment options.

- Standard evaporation
- Enhanced evaporation
- Distillation
- Ammonia stripping
- Ammonia recovery
- Chemical oxidation
- Zero-valent iron
- Ion exchange
- Membrane separation
- Sulfate coagulation

Because evaporation is a primary treatment consideration and is also considered a disposal option, it was included in more detail in the BA. Evaporation treats extracted ground water by allowing the water to evaporate due to the dry conditions of the site and warm temperatures during part of the year. Influent rates to the ponds would match the rate of natural evaporation. Nonvolatile contaminants would be contained and allowed to concentrate, which would require provisions for disposal of the accumulated solids. Evaporation could also be used to treat concentrated wastewater from treatment processes such as distillation and ion-exchange that produce a wastewater stream. Passive evaporation would not require any mixing after disposal in the ponds. If it were determined that concentrations would present a risk to avian or terrestrial species, a wildlife management plan would be submitted to the USFWS.

Solar evaporation would consist of putting the water into large, double-lined outdoor ponds built in the floodplain to withstand 100-year precipitation and flood events. In the absence of enhanced methods, a sufficiently large pond or ponds would need to be constructed in order to achieve evaporation rates that could keep up with extraction rates and complete remediation in a reasonable time frame. Estimated pond areas could range up to 40 acres, and a total of 60 acres of land would need to be disturbed. This would also require some type of small support facility. Devices such as spray nozzles could considerably enhance evaporation rates.

Disposal Options: If ground water were treated by a method other than evaporation, the treated water would require disposal by one of the following methods: discharge to surface water, shallow injection, or deep well injection. The Colorado River is a boundary to the Moab Site, and it would be the natural repository of the site ground water if effluent were discharged to surface water. Based on water quality standards and designation as critical habitat for endangered fish, it is likely that this option would require extensive water treatment for all contaminants of concern. If discharge to the river was considered a viable alternative for dealing with treatment effluent, appropriate permits would need to be obtained from the state, and compliance with conditions such as discharge rates and effluent composition would be required.

If shallow injection were selected, injection wells would be used to return the treated ground water directly back into the alluvial aquifer. Treated ground water could potentially be used to recharge the aquifer at different points to allow manipulation of hydraulic gradients. This could facilitate extraction of the lower quality water and faster removal of the contaminant source. This option would require treatment of ammonia.

If deep well injection were selected, treated ground water would be disposed of by deep well injection into the Paradox Formation, Leadville Limestone, or deep brine aquifer. Ground water hydrology beneath the site includes a deep salt formation called the Paradox Formation overlain by a deep aquifer with a high salt concentration (brine water). This method would likely require an underground injection control permit from the State of Utah.

Ground Water Extraction and Deep Well Injection (without treatment): Under this scenario, ground water would be extracted using a system and infrastructure similar to that described above, and untreated water would be pumped into a geologically isolated zone. This option would likely require an underground injection control permit from the State of Utah and concurrence from NRC.

In Situ Remediation: If this option were selected, it would include some form of biodegradation, including but not limited to phytoremediation. This option would require minimal infrastructure and could require state or federal permits, depending on the method of biodegradation.

Clean Water Application: Another aspect of the active remediation system could involve some form of application of clean water to dilute ammonia concentrations in the backwater areas along the Colorado River where potentially suitable habitat for endangered fish may exist. This would likely take either or both of two possible configurations. The first configuration would consist of diverting uncontaminated water from the Colorado River through a screened intake at the nearest location just upstream of Moab Wash. A water delivery system consisting of a pump and aboveground piping would redistribute the water to the backwater areas along a section of the sandbar of up to 1,200 ft beginning just south of Moab Wash. Flow meters and valves would be used to measure and control the rate of upstream river water released at each distribution point to minimize turbidity and velocities. The components and operation would be similar to the 1,360-gpm system originally planned as an initial action for the sandbar area adjacent to the site (DOE 2002a) or some alternative system design.

A variation of the clean water application could consist of using injection wells or an infiltration trench to deliver uncontaminated river water indirectly to the backwater areas. For this second configuration, clean water would be collected from the Colorado River and pumped to the site water storage ponds to control suspended sediment and prevent system clogging. The storage pond water would then be introduced to the shallow ground water system by a series of injection wells or infiltration trenches located along the bank adjacent to the backwater areas. The clean water would enter the backwater areas by bank discharge of ground water to provide dilution of ammonia concentrations. This clean water application system could also be combined with the extraction wells discussed earlier to control drawdown and minimize the potential for brine upconing. For this case, up to 150 gpm of uncontaminated river water would be needed to balance the amount of plume water extracted.

DOE will fully describe their final approach to ground water remediation in the RAP, which the Service will review to determine the need for additional Section 7 consultation.

Implementation and Operation - DOE estimates that design, procurement, testing, construction, and implementation of an active ground water remediation system would be complete within 5 years of issuance of the ROD. Design criteria and specifications would depend upon whether the on-site or off-site alternative is selected for tailings disposal.

After the system begins operation, DOE estimates that as much as an additional 5 years would be required to reduce concentrations of contaminants in the surface water to levels that are protective of aquatic species in the Colorado River, if protective levels were not already achieved as a result of interim actions. However, it is possible that considerably less time may be required to reach protective levels. The active remediation system would extract and treat ground water for 75 to 80 years (depending on whether the off-site or on-site surface remediation alternative were implemented) to maintain surface water quality goals. Contaminant concentrations in ground water would thus be reduced to acceptable risk levels prior to entry into the Colorado River. Active remediation would cease only after ground water and surface water monitoring confirmed that long-term remediation goals were achieved and after appropriate consultation and concurrence with USFWS. The uncertainties and assumptions associated with the success of active remediation are discussed below.

DOE would monitor the progress of remedial actions to determine if goals are being met and would commit to ongoing consultation with USFWS. In addition, DOE would provide monitoring data and remediation results annually to USFWS.

DOE's Groundwater Remediation Uncertainties

DOE does not have a quantitative estimate of uncertainty associated with the ground water modeling predictions estimating the time for ground water concentrations to reach levels protective of aquatic species. Specifically, transport parameters (e.g., tailings seepage concentration and the natural degradation of ammonia in the subsurface) were found to have a much greater impact on predicted concentrations than did flow parameters (e.g., hydraulic conductivity and effective porosity). The sensitivity analysis performed indicates that perturbing the key transport parameters from the calibrated values could result in either significantly higher or significantly lower contaminant concentrations in the ground water adjacent to the river: it did not indicate the probability or likelihood of any one outcome.

Many variables affect prediction accuracy, and the system of contaminant transport and the interaction between ground water and surface are complex, largely due to the dynamic nature of river stage and backwater area morphology. To compensate for the inherent uncertainties, DOE has assumed a conservative protective water quality goal of meeting the lowest possible acute aquatic standard (based on the range of observed pH and temperature conditions in the river) in the ground water with no consideration of dilution. DOE's model predictions, supported by site-specific data, indicate that long-term ground water concentrations adjacent to the river would be protective for chronic exposure scenarios for all but the worst-case pH and temperature conditions without any consideration of dilution from the surface water.

Ground Water Remediation Conservation Measures

On the basis of site-specific data and its study of site conditions, DOE claims, in their BA, to possess a reasonable degree of confidence that protective conditions would be met and maintained during both the operation of the corrective action and following achievement of water quality goals. To ensure that protective conditions were met:

1. DOE would monitor the ground water and surface water systems, and report the results to the USFWS annually, by January 30 for the preceding year.
2. DOE would hold regular consultations with USFWS, on at least an annual basis.
3. DOE commits to conduct active remediation, which would continue throughout the projected 75-year remedial action period to achieve the target goal of 3 mg/L ammonia or less in ground water and into the post-remedial action confirmation monitoring period. This is anticipated to meet acute and chronic standards in surface water, combined with 10-fold dilution.
4. If an evaporation pond were used as part of ground water remediation, DOE commits to qualitative monitoring for general wildlife use. If any listed species frequented the evaporation pond, DOE would consult with USFWS to develop reasonable and prudent

Description of the Project Area

DOE's preliminary consultations and investigations indicate that listed threatened or endangered terrestrial wildlife species are not known to occur, nor are they strongly expected to occur, at the Crescent Junction site. However, before developing any disposal site, DOE, in consultation with USFWS, would determine the need for additional habitat evaluations and surveys for species that could be affected. If threatened or endangered species or critical habitats were identified at a selected site, a mitigation plan would be developed to minimize potential adverse impacts. If impacts could not be avoided, additional Section 7 consultation would be required.

Moab Site: Terrestrial Setting - Historically, the entire Moab Site has been created and altered by natural events such as floods and, more recently, by the activities related to milling operations. At present, significant vegetation does not occur on approximately 380 acres of the site; this severely limits use of this area by terrestrial wildlife. Mature tamarisk, with minimal understory, covers approximately 50 acres of the site east of the tailings pile on the Colorado River floodplain. This area provides some habitat for birds and small mammals. Steep rock mesas dominate the area just west of the site. Low-growing desert shrub communities and low-density piñon-juniper forest are the predominant vegetation types to the west and north of the site along the transportation routes.

The upland soils at the site are Nakai sandy loam. The potential indigenous vegetation that might occur if the site were not disturbed from past mill operations includes grasses such as Indian ricegrass (*Achnatherum hymenoides*) and galleta (*Pleuraphis jamesii*) and the desert shrubs fourwing saltbush (*Atriplex canescens*), shadscale (*Atriplex confertifolia*), and winterfat (*Krascheninnikovia lanata*). This potential vegetation could provide habitat for small mammals, including white-tailed prairie dog (*Cynomys leucurus*), desert cottontail (*Sylvilagus audubonii*), and black-tailed jackrabbit (*Lepus californicus*). Fourwing saltbush, shadscale, and galleta may be used to some extent by mule deer (*Odocoileus hemionus*) as forage.

The existing vegetation reflects a history of disturbance. Plants observed during April 2003 include spike dropseed (*Sporobolus contractus*), sand dropseed (*Sporobolus cryptandrus*), tamarisk (*Tamarix parviflora*), black greasewood (*Sarcobatus vermiculatus*), gray rabbitbrush (*Ericameria nauseosa*), Douglas rabbitbrush (*Chrysothamnus viscidiflorus*), big sagebrush (*Artemisia tridentata*), and galleta. The presence of tamarisk and low-density black greasewood indicates that ground water occurs within 20 to 50 ft of the surface.

A narrow strip of riparian habitat along the eastern site boundary between the upper floodplain terrace and the Colorado River also contains wetland plants and soils. This area includes the sandbar areas downstream of Moab Wash. The area was assessed but not formally delineated in February 2002. The presence of wetland vegetation and soils and predominance of water would likely qualify at least a portion (estimated at approximately 1 acre) of this area as U.S. Army Corps of Engineers jurisdictional wetlands. Seedling tamarisk is the predominant plant in these wetland areas; other wetland plants include saltgrass *(Distichlis spicata)*, cattail *(Typha sp.*), rush (*Juncus sp.*), bulrush *(Scirpus sp.)*, spikerush (*Eleocharis sp.*), redroot flat sedge (*Cyperus erythrorhizos*), and sandbar willow (*Salix exigua*).

Other riparian areas at the Moab Site do not meet the criteria for classification as jurisdictional wetlands. These include the wooded areas of tamarisk and other species on the floodplain and an area of woody and emergent vegetation surrounding a holding pond for water pumped from the river.

Vegetation across the Colorado River, including the Scott M. Matheson Wetlands Preserve (Matheson Wetlands Preserve) on the river's east bank, includes habitat that consists of riparian woodland, grassland, and shadscale (saltbush) communities. Woodland, dominated by tree species such as black willow (*Salix nigra*) and Fremont cottonwood (*Populus fremontii*), is present in the preserve. Other plants include tamarisk, sedges (*Carex* spp.), bulrush, and cattail (NRC 1999). More than 175 species of birds have been observed at the Matheson Wetlands Preserve, and a great blue heron (*Ardeaherodias*) rookery is present in its lower end (NRC 1999). The Matheson Wetlands Preserve has a variety of wetland types that include emergent wetlands, shrub wetlands, cottonwood stands, and ponds. It is the only sizable wetland remaining on the Colorado River in Utah and serves multiple environmental functions, including water quality preservation, flood protection, erosion control, and biological productivity and diversity.

Moab Site: Aquatic Setting - The Moab Site lies immediately adjacent to the Colorado River, the principal surface water resource for the area. The tailings pile is approximately 700 ft west of the river. The site is located on an alluvial terrace, which historically floods through the area, along the Moab Wash and into the Colorado River. The tailings pile is located within the 100-year recurrence interval storm floodplain of the Colorado River and within the floodplain of the probable maximum flood (PMF) of both the Colorado River and Moab Wash. Mussetter and Harvey (1994) identified two Colorado River flows that are significant for the Moab Site. At a flow of approximately 40,000 cfs, the river elevation exceeds its banks and floods the Matheson Wetlands Preserve. There were a total of seven years from 1959 to 2002 when flows were greater than 40,000 cfs. The other critical flow occurs at about 70,000 cfs, which, according to Mussetter and Harvey (1994), produces a river elevation such that river water comes in contact with the toe of the tailings pile. Based on an analysis of the flow data from the gaging station upstream at Cisco, there has only been one day (in 1984) since 1959 in which the flow has exceeded 70,000 cfs. Section 3.1.8 of the EIS and Section 5.2 of the SOWP (DOE 2003a) provide further discussion of the floodplains and hydrology. The major tributaries of the Colorado River near the site include the Dolores River (located upstream) and the Green River (located downstream). The Matheson Wetlands Preserve is on the east bank of the Colorado River, across from the Moab Site. Sections 3.1.1 and 3.1.7 of the EIS and Gardner and Solomon (2004) describe the geology and surface water further.

The aquatic species within the vicinity of the Moab Site are associated with the Colorado River. The Colorado River has seasonal variations in flow and temperature following a snowpack-driven hydrograph (DOE 2003b). Aquatic species in the river have adapted to physical and chemical conditions that fluctuate naturally, both seasonally and daily. These conditions include river flow and flooding of intermittent backwaters and elevated floodplains, bottom scouring by sand and silt, temperature, sediment loading, chemical composition, and salinity (NRC 1999).

The Moab Site is located at approximately river mile 64 on the Colorado River (NRC 1999) in a transition zone between two geomorphically distinct reaches. River miles on the Colorado River have been designated for the purposes of research programs; the beginning of the designation is at the confluence of the Green River into the Colorado River (Belknap and Belknap 1991; Osmundson et al. 1997). The immediate reach of the Colorado River upstream of the site is predominantly sand-bedded with a few cobble bars. Directly downstream of the site, the river is sand-bedded with sandbars and stabilized islands. A portion of the shoreline near the site has been stabilized by tamarisk, an invasive species, or stabilized with riprap. The tamarisk can form cut banks that erode to some degree with each large flood. The shoreline at the Matheson Wetlands Preserve opposite the site has been diked and is heavily colonized by tamarisk (NPS 2003).

The State of Utah has classified the river segment adjacent to the Moab Site as protected for warm-water species of game fish and other warm-water aquatic life, including necessary aquatic organisms in their food chain. Macroinvertebrate samples were collected at six locations in the vicinity of the site in 1999 (USGS 2002). At each location, a sample was collected 3 ft, 15 ft, and 30 ft from the shoreline. Over 40 macroinvertebrate taxa, including chironomids and oligochaetes, were found during this sampling effort. Rooted macrophytes (i.e., plants), along with algae and zooplankton, have been found in the intermittent backwater areas but are almost nonexistent in the main channel (NRC 1999). The backwaters and inundated floodplains often serve as important nurseries and forage suppliers for fish, including the endangered Colorado pikeminnow (Valdez and Wick 1983). Both native and non-native species are present in this reach of the Colorado River, including four federal endangered species (NRC 1999). Trammell and Chart found twelve non-native species and only five native species in surveys conducted from 1992 through 1996 (Trammell and Chart 1998).

Many components of the upper Colorado River ecosystem have changed over the last several decades. One change that affects the aquatic life of the river near Moab is the establishment of introduced, or non-native, fish species. The upper basin contains about 20 species of warm-water, non-native fish (USFWS 2002a). The red shiner (*Cyprinella lutrensis*), common carp (*Cyprinus carpio*), fathead minnow (*Pimephales promelas*), channel catfish (*Ictalurus punctatus*), northern pike (*Esox lucius*), and green sunfish (*Lepomis cyanellus*) are the non-natives considered by Colorado River Basin researchers to be of greatest concern because of their suspected or documented negative interactions with native fishes (USFWS 2002a). These introductions, in concert with the physical and chemical alterations of the river, may have contributed to the decline of the native fish populations (Trammell and Chart 1999, NRC 1999, Muth et al. 2000; USFWS 2002a). Chapter 3.0 of the EIS describes the aquatic setting further.

Off-Site Disposal Site: Crescent Junction - The proposed Crescent Junction disposal site is located on BLM-administered lands about 2 miles north of the town of Crescent Junction, which is an interchange on I-70 and US-191. The site is about 30 miles north of the Moab Site and covers several square miles of largely desert terrain that is bordered on the north by the prominent Book Cliffs. No perennial streams are present, but ephemeral streams may carry high flows during heavy rains. Because no perennial streams or other surface water bodies are present on the Crescent Junction site, aquatic ecological resources and wetlands would not be adversely affected by activities at this site. The State of Utah Division of Wildlife Resources in their DEIS comment letter to DOE, dated January 31, 2005, identified concerns for several state sensitive species at this site, including the white tailed prairie dog. In addition, some herpetile species may be dependent on ephemeral wash habitats.

In most areas of the site, vegetation is indicative of disturbance and varies from the potential native vegetation. About 50 percent of the Crescent Junction site is covered by very sparse low-growing vegetation. The northern part of the site is covered with a gray veneer of debris from a recent outwash originating in the nearby Mancos Shale hills. The outwash area is mostly bare with some prickly pear cactus, cheatgrass (*Bromus tectorum*), and Russian thistle (*Salsola kali*). Vegetation in the south-central and southeast portions of the site also consists primarily of these three species with a few native shrubs and perennial grasses, including gardner saltbush, galleta, and Indian ricegrass. Range condition in this area would probably rate as poor to fair.

Vegetation in the southwest portion of the site is probably influenced by a shallow aquifer and consists of sparse shrubs, including black greasewood, shadscale, and gardner saltbush. Understory vegetation consists primarily of annual weeds, such as cheatgrass and Russian thistle, with a few perennial grasses (galleta, Indian ricegrass). Tamarisk occurs occasionally in the drainages.

Water bodies in the vicinity of the Crescent Junction site consist of ephemeral washes that are dry most of the year. The water from these washes eventually flows into the Green River. There are no known wetlands in the area.

Transportation to the Crescent Junction site would be along US-191 or the Union Pacific Railroad. A slurry pipeline would follow existing natural gas pipeline rights-of-way. Transportation to the Crescent Junction site would also pass through the canyon area north of Moab.

Borrow Areas – DOE's preliminary consultations and investigations do not indicate the presence of threatened or endangered species at borrow sites. However, the proposed borrow areas may need further evaluation to determine habitat, species presence, and other ecological characteristics. Preliminary evaluations of these areas indicate that no aquatic resources are present. Before developing any borrow area, DOE, in consultation with USFWS and BLM, would determine the need for habitat evaluations and surveys for species that may be affected. If threatened or endangered species or critical habitats were identified on a selected area, a mitigation plan would be developed or a different borrow area would be selected, in order to minimize or eliminate impacts. If impacts could not be avoided, additional Section 7 consultation would be required. See the DEIS for a contemporary description of ten proposed borrow areas.

STATUS OF THE SPECIES/CRITICAL HABITAT

Colorado Pikeminnow

Species/Critical Habitat Description

The Colorado pikeminnow is the largest cyprinid fish (minnow family) native to North America and evolved as the main predator in the Colorado River system. It is an elongated pike-like fish that during predevelopment times may have grown as large as 6 feet in length and weighed nearly 100 pounds (Behnke and Benson 1983). Today, Colorado pikeminnow rarely exceed 3 feet in length or weigh more than 18 pounds; such fish are estimated to be 45-55 years old (Osmundson et al. 1997). The mouth of this species is large and nearly horizontal with long slender pharyngeal teeth (located in the throat), adapted for grasping and holding prey. The diet of Colorado pikeminnow longer than 3 or 4 inches consists almost entirely of other fishes (Vanicek and Kramer 1969). Males become sexually mature earlier and at a smaller size than do females, though all are mature by about age 7 and 500 mm (20 inches) in length (Vanicek and Kramer 1969, Seethaler 1978, Hamman 1981). Adults are strongly countershaded with a dark, olive back, and a white belly. Young are silvery and usually have a dark, wedge-shaped spot at the base of the caudal fin.

Critical habitat, as defined in section 3(5)(A) of the Act, means: A(I) the specific areas within the geographical area occupied by the species at the time it is listed . . . , on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographic area occupied by a species at the time it is listed . . . , upon a determination by the Secretary that such areas are essential for the conservation of the species.@

Designated critical habitat for the endangered Colorado River fishes includes those portions of the 100-year floodplain that contain constituent elements. The constituent elements are those physical and biological features that the USFWS considers essential for the conservation of the species and include, but are not limited to, the following items: (1) Space for individual and population growth, and for normal behavior; (2) Food, water, air, light, minerals, or other nutritional or physiological requirements; (3) Cover or shelter; (4) Sites for breeding, reproduction, rearing of offspring, germination, or seed dispersal; and generally (5) Habitats that are protected from disturbance or are representative of the historical geographical and ecological distributions of the species. The primary constituent elements determined necessary for the survival and recovery of the four endangered Colorado River fishes include, but are not limited to:

> Water - A quantity of water of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, turbidity, etc.) that is delivered to a specific location in accordance with a hydrologic regime that is required for the particular life stage for each species;
>
> Physical Habitat - Areas of the Colorado River system that are inhabited or potentially habitable by fish for use in spawning, nursing, feeding, and rearing, or corridors between these areas. In addition to river channels these areas also include bottom lands, side channels, secondary channels, oxbows, backwaters, and other areas in the 100-year floodplain, which when inundated provide spawning, nursery, feeding, and rearing habitats, or access to these habitats;
>
> Biological Environment - Food supply, predation, and competition are important elements of the biological environment and are considered components of this constituent element. Food supply is a function of nutrient supply, productivity, and availability to each life stage of the species. Predation and competition, although considered normal components of this environment, are out of balance due to introduced nonnative fish species in many areas.

Designated critical habitat makes up about 29% of the species' original range and occurs exclusively in the Upper Colorado River Basin. Critical habitat has been designated within the 100-year floodplain of the Colorado pikeminnow's historical range in the following sections of the Upper Basin, excluding the San Juan River Basin (59 FR 13374).

> Colorado, Moffat County. The Yampa River and its 100-year floodplain from the State Highway 394 bridge in T. 6 N., R. 91 W., section 1 (6th Principal Meridian) to the confluence with the Green River in T. 7 N., R. 103 W., section 28 (6th Principal Meridian).
>
> Utah, Uintah, Carbon, Grand, Emery, Wayne, and San Juan Counties; and Colorado, Moffat County. The Green River and its 100-year floodplain from the confluence with the Yampa River in T. 7 N., R. 103 W., section 28 (6th Principal Meridian) to the confluence with the Colorado River in T. 30 S., R. 19 E., section 7 (Salt Lake Meridian).
>
> Colorado, Rio Blanco County; and Utah, Uintah County. The White River and its 100-year floodplain from Rio Blanco Lake Dam in T. 1 N., R. 96 W., section 6 (6th Principal Meridian) to the confluence with the Green River in T. 9 S., R. 20 E., section 4 (Salt Lake Meridian).
>
> Colorado, Delta and Mesa Counties. The Gunnison River and its 100-year floodplain from the confluence with the Uncompahgre River in T. 15 S., R. 96 W., section 11 (6th Principal Meridian) to the confluence with the Colorado River in T. 1 S., R. 1 W., section 22 (Ute Meridian).
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> Colorado, Mesa and Garfield Counties; and Utah, Grand, San Juan, Wayne, and Garfield Counties. The Colorado River and its 100-year floodplain from the Colorado River Bridge at exit 90 north off Interstate 70 in T. 6 S., R. 93 W., section 16 (6th Principal Meridian) to North Wash, including the Dirty Devil arm of Lake Powell up to the full pool elevation, in T. 33 S., R. 14 E., section 29 (Salt Lake Meridian).

Status and Distribution

Based on early fish collection records, archaeological finds, and other observations, the Colorado pikeminnow was once found throughout warmwater reaches of the entire Colorado River Basin down to the Gulf of California, and including reaches of the upper Colorado River and its major tributaries, the Green River and its major tributaries, and the Gila River system in Arizona (Seethaler 1978). Colorado pikeminnow apparently were never found in colder, headwater areas. The species was abundant in suitable habitat throughout the entire Colorado River Basin prior to the 1850s (Seethaler 1978). By the 1970s they were extirpated from the entire lower basin (downstream of Glen Canyon Dam) and portions of the upper basin as a result of major alterations to the riverine environment. Having lost some 75 to 80 percent of its former range due to habitat loss, the Colorado pikeminnow was federally listed as an endangered species in 1967 (Miller 1961, Moyle 1976, Tyus 1991, Osmundson and Burnham 1998). Full protection under the Act of 1973 occurred on January 4, 1974.

Colorado pikeminnow are presently restricted to the Upper Colorado River Basin and inhabit warmwater reaches of the Colorado, Green, and San Juan rivers and associated tributaries. The Colorado pikeminnow recovery goals (USFWS 2002a) identify occupied habitat of wild Colorado pikeminnow as follows: the Green River from Lodore Canyon to the confluence of the Colorado River; the Yampa River downstream of Craig, Colorado; the Little Snake River from its confluence with the Yampa River upstream into Wyoming; the White River downstream of Taylor Draw Dam; the lower 89 miles of the Price River; the lower Duchesne River; the upper Colorado River from Palisade, Colorado, to Lake Powell; the lower 34 miles of the Gunnison River; the lower mile of the Dolores River; and 150 miles of the San Juan River downstream from Shiprock, New Mexico, to Lake Powell.

Recovery goals for the Colorado pikeminnow (USFWS 2002a) were approved on August 1, 2002. According to these recovery goals, downlisting can be considered if, over a 5-year period:

- a genetically and demographically viable, self-sustaining population is maintained in the Green River subbasin such that (a) the trends in separate adult (age 7+; > 450 mm total length) point estimates for the middle Green River and the lower Green River do not decline significantly, and (b) mean estimated recruitment of age-6 (400–449 mm total length) naturally produced fish equals or exceeds mean annual adult mortality for the Green River subbasin, and (c) each population point estimate for the Green River subbasin exceeds 2,600 adults (2,600 is the estimated minimum viable population needed to ensure long-term genetic and demographic viability); and

- a self-sustaining population of at least 700 adults (number based on inferences about carrying capacity) is maintained in the upper Colorado River subbasin such that (a) the trend in adult point estimates does not decline significantly, and (b) mean estimated recruitment of age-6 naturally produced fish equals or exceeds mean annual adult mortality; and

- a target number of 1,000 age-5+ fish (> 300 mm total length; number based on estimated survival of stocked fish and inferences about carrying capacity) is established through augmentation and/or natural reproduction in the San Juan River subbasin; and

- certain site-specific management tasks to minimize or remove threats have been identified, developed, and implemented.

Delisting can be considered if, over a 7-year period beyond downlisting:

- a genetically and demographically viable, self-sustaining population is maintained in the Green River subbasin such that (a) the trends in separate adult point estimates for the middle Green River and the lower Green River do not decline significantly, and (b) mean estimated recruitment of age-6 naturally produced fish equals or exceeds mean annual adult mortality for the

Green River subbasin, and (c) each population point estimate for the Green River subbasin exceeds 2,600 adults; and

- either the upper Colorado River subbasin self-sustaining population exceeds 1,000 adults or the upper Colorado River subbasin self-sustaining population exceeds 700 adults and San Juan River subbasin population is self-sustaining and exceeds 800 adults (numbers based on inferences about carrying capacity) such that for each population (a) the trend in adult point estimates does not decline significantly, and (b) mean estimated recruitment of age-6 naturally produced fish equals or exceeds mean annual adult mortality; and

- certain site-specific management tasks to minimize or remove threats have been finalized and implemented, and necessary levels of protection are attained.

Life History

The Colorado pikeminnow is a long-distance migrator; adults move hundreds of miles to and from spawning areas, and require long sections of river with unimpeded passage. Adults require pools, deep runs, and eddy habitats maintained by high spring flows. These high spring flows maintain channel and habitat diversity, flush sediments from spawning areas, rejuvenate food production, form gravel and cobble deposits used for spawning, and rejuvenate backwater nursery habitats. Spawning occurs after spring runoff at water temperatures typically between 18 and 23ºC. After hatching and emerging from spawning substrate, larvae drift downstream to nursery backwaters that are restructured by high spring flows and maintained by relatively stable base flows. Flow recommendations have been developed that specifically consider flow-habitat relationships in habitats occupied by Colorado pikeminnow in the upper basin, and were designed to enhance habitat complexity and to restore and maintain ecological processes. The following is a description of observed habitat uses in the Upper Colorado River Basin.

Colorado pikeminnow live in warm-water reaches of the Colorado River mainstem and larger tributaries, and require uninterrupted stream passage for spawning migrations and dispersal of young. The species is adapted to a hydrologic cycle characterized by large spring peaks of snow-melt runoff and low, relatively stable base flows. High spring flows create and maintain in-channel habitats, and reconnect floodplain and riverine habitats, a phenomenon described as the spring flood-pulse (Junk et al. 1989; Johnson et al. 1995). Throughout most of the year, juvenile, subadult, and adult Colorado pikeminnow use relatively deep, low-velocity eddies, pools, and runs that occur in nearshore areas of main river channels (Tyus and McAda 1984; Valdez and Masslich 1989; Tyus 1990, 1991; Osmundson et al. 1995). In spring, however, Colorado pikeminnow adults use floodplain habitats, flooded tributary mouths, flooded side canyons, and eddies that are available only during high flows (Tyus 1990, 1991; Osmundson et al. 1995). Such environments may be particularly beneficial for Colorado pikeminnow because other riverine fishes gather in floodplain habitats to exploit food and temperature resources, and may serve as prey. Such low-velocity environments also may serve as resting areas for Colorado pikeminnow. River reaches of high habitat complexity appear to be preferred.

Because of their mobility and environmental tolerances, adult Colorado pikeminnow are more widely distributed than other life stages. Distribution patterns of adults are stable during most of the year (Tyus 1990, 1991; Irving and Modde 2000), but distribution of adults changes in late spring and early summer, when most mature fish migrate to spawning areas (Tyus and McAda 1984; Tyus 1985, 1990, 1991; Irving and Modde 2000). High spring flows provide an important cue to prepare adults for migration and also ensure that conditions at spawning areas are suitable for reproduction once adults arrive. Specifically, bankfull or much larger floods mobilize coarse sediment to build or reshape cobble bars, and they create side channels that Colorado pikeminnow sometimes use for spawning (Harvey et al. 1993).

Colorado pikeminnow spawning sites in the Green River subbasin have been well documented. The two principal locations are in Yampa Canyon on the lower Yampa River and in Gray Canyon on the lower Green River (Tyus 1990, 1991). These reaches are 42 and 72 km long, respectively, but most spawning is believed to occur at one or two short segments within each of the two reaches. Another spawning area may occur in Desolation Canyon on the lower Green River (Irving and Modde 2000), but the location and importance of this area has not been verified. Although direct observation of Colorado pikeminnow spawning was not possible because of high turbidity, radiotelemetry indicated spawning occurred over cobble-bottomed riffles (Tyus 1990). High spring flows and subsequent post-peak summer flows are important for construction and maintenance of spawning substrates (Harvey et al. 1993). In contrast with the Green River subbasin, where known spawning sites are in canyon-bound reaches, currently suspected spawning sites in the upper Colorado River subbasin are at six locations in meandering, alluvial reaches (McAda 2000).

After hatching and emerging from the spawning substrate, Colorado pikeminnow larvae drift downstream to backwaters in sandy, alluvial regions, where they remain through most of their first year of life (Holden 1977; Tyus and Haines 1991; Muth and Snyder 1995). Backwaters and the physical factors that create them are vital to successful recruitment of early life stages of Colorado pikeminnow, and age-0 Colorado pikeminnow in backwaters have received much research attention (e.g., Tyus and Karp 1989; Haines and Tyus 1990; Tyus 1991; Tyus and Haines 1991; Bestgen et al. 1997). It is important to note that these backwaters are formed after cessation of spring runoff within the active channel and are not floodplain features. Colorado pikeminnow larvae occupy these in-channel backwaters soon after hatching. They tend to occur in backwaters that are large, warm, deep (average, about 0.3 m in the Green River), and turbid (Tyus and Haines 1991). Recent research (Day et al. 1999a, 1999b; Trammell and Chart 1999) has confirmed these preferences and suggested that a particular type of backwater is preferred by Colorado pikeminnow larvae and juveniles. Such backwaters are created when a secondary channel is cut off at the upper end, but remains connected to the river at the downstream end. These chute channels are deep and may persist even when discharge levels change dramatically. An optimal river-reach environment for growth and survival of early life stages of Colorado pikeminnow has warm, relatively stable backwaters, warm river channels, and abundant food (Muth et al. 2000).

Threats to the Species

Major declines in Colorado pikeminnow populations occurred during the dam-building era of the 1930s through the 1960s. Behnke and Benson (1983) summarized the decline of the natural ecosystem, pointing out that dams, impoundments, and water use practices drastically modified the river's natural hydrology and channel characteristics throughout the Colorado River Basin. Dams on the mainstem broke the natural continuum of the river ecosystem into a series of disjunct segments, blocking native fish migrations, reducing temperatures downstream of dams, creating lacustrine habitat, and providing conditions that allowed competitive and predatory nonnative fishes to thrive both within the impounded reservoirs and in the modified river segments that connect them. The highly modified flow regime in the lower basin coupled with the introduction of nonnative fishes decimated populations of native fish.

The primary threats to Colorado pikeminnow are stream flow regulation and habitat modification; competition with and predation by nonnative fishes; and pesticides and pollutants (USFWS 2002a). The existing habitat, altered by these threats, has been modified to the extent that it impairs essential behavior patterns, such as breeding, feeding, and sheltering. These impairments are described in further detail below.

Stream flow regulation includes mainstem dams that cause the following adverse effects to Colorado pikeminnow and its habitat:

- block migration corridors,
- changes in flow patterns, reduced peak flows and increased base flows,
- release cold water, making temperature regimes less than optimal,
- change river habitat into lake habitat, and
- retain sediment that is important for forming and maintaining backwater habitats

In the Upper Basin, 435 miles of Colorado pikeminnow habitat has been lost by reservoir inundation from Flaming Forge Reservoir on the Green River, Lake Powell on the Colorado River, and Navajo Reservoir on the San Juan River. Cold water releases from these dams have eliminated suitable habitat for native fishes, including Colorado pikeminnow, from river reaches downstream for approximately 50 miles below Flaming Gorge Dam and Navajo Dam. In addition to main stem dams, many dams and water diversion structures occur in and upstream from critical habitat that reduce flows and alter flow patterns, which adversely affect critical habitat. Diversion structures in critical habitat divert fish into canals and pipes where the fish are permanently lost to the river system. It is unknown how many endangered fish are lost in irrigation systems, but in some years, in some river reaches, majority of the river flow is diverted into unscreened canals. High spring flows maintain habitat diversity, flush sediments from spawning habitat, increase invertebrate food production, form gravel and cobble deposits important for spawning, and maintain backwater nursery habitats (McAda 2000; Muth et al. 2000). Peak spring flows in the Green River at Jensen, Utah, have decreased 13–35 percent and base flows have increased 10–140 percent due to regulation by Flaming Gorge Dam (Muth et al. 2000).

Predation and competition from nonnative fishes have been clearly implicated in the population reductions or elimination of native fishes in the Colorado River Basin (Dill 1944, Osmundson and Kaeding 1989, Behnke 1980, Joseph et al. 1977, Lanigan and Berry 1979, Minckley and Deacon 1968, Meffe 1985, Propst and Bestgen 1991, Rinne 1991). Data collected by Osmundson and Kaeding (1991) indicated that during low water years nonnative minnows capable of preying on or competing with larval endangered fishes greatly increased in numbers.

More than 50 nonnative fish species were intentionally introduced in the Colorado River Basin prior to 1980 for sportfishing, forage fish, biological control and ornamental purposes (Minckley 1982, Tyus et al. 1982, Carlson and Muth 1989). Nonnative fishes compete with native fishes in several ways. The capacity of a particular area to support aquatic life is limited by physical habitat conditions. Increasing the number of species in an area usually results in a smaller population of most species. The size of each species population is controlled by the ability of each life stage to compete for space and food resources and to avoid predation. Some life stages of nonnative fishes appear to have a greater ability to compete for space and food and to avoid predation in the existing altered habitat than do some life stages of native fishes. Tyus and Saunders (1996) cite numerous examples of both indirect and direct evidence of predation on razorback sucker eggs and larvae by nonnative species.

Threats from pesticides and pollutants include accidental spills of petroleum products and hazardous materials; discharge of pollutants from uranium mill tailings; and high selenium concentration in the water and food chain (USFWS 2002a). Accidental spills of hazardous material into critical habitat can cause immediate mortality when lethal toxicity levels are exceeded. Pollutants from uranium mill tailings cause high levels of ammonia that exceed water quality standards. High selenium levels may adversely affect reproduction and recruitment (Hamilton and Wiedmeyer 1990; Stephens et al. 1992; Hamilton and Waddell 1994; Hamilton et al. 1996; Stephens and Waddell 1998; Osmundson et al. 2000a).

Management actions identified in the recovery goals for Colorado pikeminnow (USFWS 2002a) to minimize or remove threats to the species included:

- provide and legally protect habitat (including flow regimes necessary to restore and maintain required environmental conditions) necessary to provide adequate habitat and sufficient range for all life stages to support recovered populations;
- provide passage over barriers within occupied habitat to allow adequate movement and, potentially, range expansion;
- investigate options for providing appropriate water temperatures in the Gunnison River;
- minimize entrainment of subadults and adults in diversion canals;
- ensure adequate protection from overutilization;
- ensure adequate protection from diseases and parasites;
- regulate nonnative fish releases and escapement into the main river, floodplain, and tributaries;
- control problematic nonnative fishes as needed;
- minimize the risk of hazardous-materials spills in critical habitat; and
- remediate water-quality problems.

Razorback sucker

Species/Critical Habitat Description

Like all suckers (family Catostomidae, meaning "down mouth"), the razorback sucker has a ventral mouth with thick lips covered with papillae and no scales on its head. In general, suckers are bottom browsers, sucking up or scraping off small invertebrates, algae, and organic matter with their fleshy, protrusible lips (Moyle 1976). The razorback sucker is the only sucker with an abrupt sharp-edged dorsal keel behind its head. The keel becomes more massive with age. The head and keel are dark, the back is olive-colored, the sides are brownish or reddish, and the abdomen is yellowish white (Sublette et al. 1990). Adults often exceed 3 kg (6 pounds) in weight and 600 mm (2 feet) in length. Like Colorado pikeminnow, razorback suckers are long-lived, living 40-plus years.

Critical habitat was designated for razorback sucker on March 21, 1994 (59 FR 13374). Designated critical habitat makes up about 49% of the species' original range and occurs in both the Upper and Lower Colorado River Basins (USFWS 1994). The primary constituent elements are the same as those described for Colorado pikeminnow.

Critical habitat has been designated within the 100-year floodplain of the razorback sucker's historical range in the following sections of the Upper Basin, excluding the San Juan River Basin (59 FR 13374).

> Colorado, Moffat County. The Yampa River and its 100-year floodplain from the mouth of Cross Mountain Canyon in T. 6 N., R. 98 W., section 23 (6th Principal Meridian) to the confluence with the Green River in T. 7 N., R. 103 W., section 28 (6th Principal Meridian).
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> Utah, Uintah County; and Colorado, Moffat County. The Green River and its 100-year floodplain from the confluence with the Yampa River in T. 7 N., R. 103 W., section 28 (6th Principal Meridian) to Sand Wash in T. 11 S., R. 18 E., section 20 (6th Principal Meridian).
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> Utah, Uintah, Carbon, Grand, Emery, Wayne, and San Juan Counties. The Green River and its 100-year floodplain from Sand Wash at river mile 96 at T. 11 S., R. 18 E., section 20 (6th Principal Meridian) to the confluence with the Colorado River in T. 30 S., R. 19 E., section 7 (6th Principal Meridian).
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> Utah, Uintah County. The White River and its 100-year floodplain from the boundary of the Uintah and Ouray Indian Reservation at river mile 18 in T. 9 S., R. 22 E., section 21 (Salt Lake Meridian) to the confluence with the Green River in T. 9 S., R 20 E., section 4 (Salt Lake Meridian).
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> Utah, Uintah County. The Duchesne River and its 100-year floodplain from river mile 2.5 in T. 4 S., R. 3 E., section 30 (Salt Lake Meridian) to the confluence with the Green River in T. 5 S., R. 3 E., section 5 (Uintah Meridian).
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> Colorado, Delta and Mesa Counties. The Gunnison River and its 100-year floodplain from the confluence with the Uncompahgre River in T. 15 S., R. 96 W., section 11 (6th Principal Meridian) to Redlands Diversion Dam in T. 1 S., R. 1 W., section 27 (Ute Meridian).

Colorado, Mesa and Garfield Counties. The Colorado River and its 100-year floodplain from Colorado River Bridge at exit 90 north off Interstate 70 in T. 6 S., R. 93 W., section 16 (6th Principal Meridian) to Westwater Canyon in T. 20 S., R. 25 E., section 12 (Salt Lake Meridian) including the Gunnison River and its 100-year floodplain from the Redlands Diversion Dam in T. 1 S., R. 1 W., section 27 (Ute Meridian) to the confluence with the Colorado River in T. 1 S., R. 1 W., section 22 (Ute Meridian).

Utah, Grand, San Juan, Wayne, and Garfield Counties. The Colorado River and its 100-year floodplain from Westwater Canyon in T. 20 S., R. 25 E., section 12 (Salt Lake Meridian) to full pool elevation, upstream of North Wash, and including the Dirty Devil arm of Lake Powell in T. 33 S., R. 14 E., section 29 (Salt Lake Meridian).

Status and Distribution

On March 14, 1989, the USFWS was petitioned to conduct a status review of the razorback sucker. Subsequently, the razorback sucker was designated as endangered under a final rule published on October 23, 1991 (56 FR 54957). The final rule stated "Little evidence of natural recruitment has been found in the past 30 years, and numbers of adult fish captured in the last 10 years demonstrate a downward trend relative to historic abundance. Significant changes have occurred in razorback sucker habitat through diversion and depletion of water, introduction of nonnative fishes, and construction and operation of dams" (56 FR 54957). Recruitment of razorback suckers to the population continues to be a problem.

Historically, razorback suckers were found in the mainstem Colorado River and major tributaries in Arizona, California, Colorado, Nevada, New Mexico, Utah, Wyoming, and in Mexico (Ellis 1914; Minckley 1983). Bestgen (1990) reported that this species was once so numerous that it was commonly used as food by early settlers and, further, that commercially marketable quantities were caught in Arizona as recently as 1949. In the Upper Basin, razorback suckers were reported in the Green River to be very abundant near Green River, Utah, in the late 1800s (Jordan 1891). An account in Osmundson and Kaeding (1989) reported that residents living along the Colorado River near Clifton, Colorado, observed several thousand razorback suckers during spring runoff in the 1930s and early 1940s. In the San Juan River drainage, Platania and Young (1989) relayed historical accounts of razorback suckers ascending the Animas River to Durango, Colorado, around the turn of the century.

Currently, the largest concentration of razorback sucker remaining in the Colorado River Basin is in Lake Mohave on the border of Arizona and California. Estimates of the wild stock in Lake Mohave have fallen precipitously in recent years from 60,000 as late as 1991, to 25,000 in 1993 (Marsh 1993, Holden 1994), to about 9,000 in 2000 (USFWS 2002b). Until recently, efforts to introduce young razorback sucker into Lake Mohave have failed because of predation by non-native species (Minckley et al. 1991, Clarkson et al. 1993, Burke 1994). While limited numbers of razorback suckers persist in other locations in the Lower Colorado River, they are considered rare or incidental and may be continuing to decline.

In the Upper Colorado River Basin, above Glen Canyon Dam, razorback suckers are found in limited numbers in both lentic (lake-like) and riverine environments. The largest populations of razorback suckers in the upper basin are found in the upper Green and lower Yampa rivers (Tyus

1987). In the Colorado River, most razorback suckers occur in the Grand Valley area near Grand Junction, Colorado; however, they are increasingly rare. Osmundson and Kaeding (1991) reported that the number of razorback sucker captures in the Grand Junction area has declined dramatically since 1974. Between 1984 and 1990, intensive collecting effort captured only 12 individuals in the Grand Valley (Osmundson and Kaeding 1991). The wild population of razorback sucker is considered extirpated from the Gunnison River (Burdick and Bonar 1997).

Razorback suckers are in imminent danger of extirpation in the wild. As Bestgen (1990) pointed out:

> "Reasons for decline of most native fishes in the Colorado River Basin have been attributed to habitat loss due to construction of mainstream dams and subsequent interruption or alteration of natural flow and physio-chemical regimes, inundation of river reaches by reservoirs, channelization, water quality degradation, introduction of nonnative fish species and resulting competitive interactions or predation, and other man-induced disturbances (Miller 1961, Joseph et al. 1977, Behnke and Benson 1983, Carlson and Muth 1989, Tyus and Karp 1989). These factors are almost certainly not mutually exclusive, therefore it is often difficult to determine exact cause and effect relationships."

The virtual absence of any recruitment suggests a combination of biological, physical, and/or chemical factors that may be affecting the survival and recruitment of early life stages of razorback suckers. Within the Upper Basin, recovery efforts endorsed by the Recovery Program include the capture and removal of razorback suckers from all known locations for genetic analyses and development of discrete brood stocks. These measures have been undertaken to develop refugia populations of the razorback sucker from the same genetic parentage as their wild counterparts such that, if these fish are genetically unique by subbasin or individual population, then separate stocks will be available for future augmentation. Such augmentation may be a necessary step to prevent the extinction of razorback suckers in the Upper Basin.

Recovery goals for the razorback sucker (USFWS 2002b) were approved on August 1, 2002. According to these recovery goals, downlisting can be considered if, over a 5-year period:

- genetically and demographically viable, self-sustaining populations are maintained in the Green River subbasin and either in the upper Colorado River subbasin or the San Juan River subbasin such that (a) the trend in adult (age 4+; > 400 mm total length) point estimates for each of the two populations does not decline significantly, and (b) mean estimated recruitment of age-3 (300–399 mm total length) naturally produced fish equals or exceeds mean annual adult mortality for each of the two populations, and (c) each point estimate for each of the two populations exceeds 5,800 adults (5,800 is the estimated minimum viable population needed to ensure long-term genetic and demographic viability); and

- a genetic refuge is maintained in Lake Mohave of the lower basin recovery unit; and

- two genetically and demographically viable, self-sustaining populations are maintained in the lower basin recovery unit (e.g., mainstem and/or tributaries) such that (a) the trend in adult point estimates for each population does not decline significantly, and (b) mean estimated recruitment of age-3 naturally produced fish equals or exceeds mean annual adult mortality for each population, and (c) each point estimate for each population exceeds 5,800 adults; and

- certain site-specific management tasks to minimize or remove threats have been identified, developed, and implemented.

Delisting can be considered if, over a 3-year period beyond downlisting:

- genetically and demographically viable, self-sustaining populations are maintained in the Green River subbasin and either in the upper Colorado River subbasin or the San Juan River subbasin such that (a) the trend in adult point estimates for each of the two populations does not decline significantly, and (b) mean estimated recruitment of age-3 naturally produced fish equals or exceeds mean annual adult mortality for each of the two populations, and (c) each point estimate for each of the two populations exceeds 5,800 adults; and

- a genetic refuge is maintained in Lake Mohave; and

- two genetically and demographically viable, self-sustaining populations are maintained in the lower basin recovery unit such that (a) the trend in adult point estimates for each population does not decline significantly, and (b) mean estimated recruitment of age-3 naturally produced fish equals or exceeds mean annual adult mortality for each population, and (c) each point estimate for each population exceeds 5,800 adults; and

- certain site-specific management tasks to minimize or remove threats have been finalized and implemented, and necessary levels of protection are attained.

Life History

McAda and Wydoski (1980) and Tyus (1987) reported springtime aggregations of razorback suckers in off-channel habitats and tributaries; such aggregations are believed to be associated with reproductive activities. Tyus and Karp (1990) and Osmundson and Kaeding (1991) reported off-channel habitats to be much warmer than the mainstem river and that razorback suckers presumably moved to these areas for feeding, resting, sexual maturation, spawning, and other activities associated with their reproductive cycle. Prior to construction of large mainstem dams and the suppression of spring peak flows, low velocity, off-channel habitats (seasonally flooded bottomlands and shorelines) were commonly available throughout the Upper Basin (Tyus and Karp 1989; Osmundson and Kaeding 1991). Dams changed riverine ecosystems into lakes by impounding water, which eliminated these off-channel habitats in reservoirs. Reduction in spring peak flows eliminates or reduces the frequency of inundation of off-channel habitats.

The absence of these seasonally flooded riverine habitats is believed to be a limiting factor in the successful recruitment of razorback suckers in their native environment (Tyus and Karp 1989; Osmundson and Kaeding 1991). Wydoski and Wick (1998) identified starvation of larval razorback suckers due to low zooplankton densities in the main channel and loss of floodplain habitats which provide adequate zooplankton densities for larval food as one of the most important factors limiting recruitment.

While razorback suckers have never been directly observed spawning in turbid riverine environments within the Upper Basin, captures of ripe specimens (in spawning condition), both males and females, have been recorded (Valdez et al. 1982a; McAda and Wydoski 1980; Tyus 1987; Osmundson and Kaeding 1989; Tyus and Karp 1989; Tyus and Karp 1990; Osmundson and Kaeding 1991; Platania 1990) in the Yampa, Green, Colorado, and San Juan rivers. Sexually mature razorback suckers are generally collected on the ascending limb of the hydrograph from mid-April through June and are associated with coarse gravel substrates (depending on the specific location).

Outside of the spawning season, adult razorback suckers occupy a variety of shoreline and main channel habitats including slow runs, shallow to deep pools, backwaters, eddies, and other relatively slow velocity areas associated with sand substrates (Tyus 1987; Tyus and Karp 1989; Osmundson and Kaeding 1989; Valdez and Masslich 1989; Osmundson and Kaeding 1991; Tyus and Karp 1990).

Habitat requirements of young and juvenile razorback suckers in the wild are not well known, particularly in native riverine environments. Prior to 1991, the last confirmed documentation of a razorback sucker juvenile in the Upper Basin was a capture in the Colorado River near Moab, Utah (Taba et al. 1965). In 1991, two early juvenile (36.6 and 39.3 mm total length (TL)) razorback suckers were collected in the lower Green River near Hell Roaring Canyon (Gutermuth et al. 1994). Juvenile razorback suckers have been collected in recent years from Old Charley Wash, a wetland adjacent to the Green River (Modde 1996). Between 1992 and 1995 larval razorback suckers were collected in the middle and lower Green River and within the Colorado River inflow to Lake Powell (Muth 1995). In 2002, eight larval razorback suckers were collected in the Gunnison River (Osmundson 2002b). No young razorback suckers have been collected in recent times in the Colorado River.

<u>Threats to the Species</u>

A marked decline in populations of razorback suckers can be attributed to construction of dams and reservoirs, introduction of nonnative fishes, and removal of large quantities of water from the Colorado River system. Dams on the mainstem Colorado River and its major tributaries have segmented the river system, blocked migration routes, and changed river habitat into lake habitat. Dams also have drastically altered flows, temperatures, and channel geomorphology. These changes have modified habitats in many areas so that they are no longer suitable for breeding, feeding, or sheltering. Major changes in species composition have occurred due to the introduction of numerous nonnative fishes, many of which have thrived due to human-induced changes to the natural riverine system. These nonnative fishes prey upon and compete with razorback suckers.

The primary threats to razorback sucker are stream flow regulation and habitat modification; competition with and predation by nonnative fishes; and pesticides and pollutants (USFWS 2002b). The existing habitat, altered by these threats, has been modified to the extent that it impairs essential behavior patterns, such as breeding, feeding, and sheltering. The threats to razorback sucker are essentially the same threats identified for Colorado pikeminnow.

Management actions identified in the recovery goals for razorback sucker (USFWS 2002b) to minimize or remove threats to the species included:

- provide and legally protect habitat (including flow regimes necessary to restore and maintain required environmental conditions) necessary to provide adequate habitat and sufficient range for all life stages to support recovered populations;
- provide passage over barriers within occupied habitat to allow unimpeded movement and, potentially, range expansion;
- investigate options for providing appropriate water temperatures in the Gunnison River;
- minimize entrainment of subadults and adults in diversion/out-take structures;
- ensure adequate protection from overutilization;
- ensure adequate protection from diseases and parasites;
- regulate nonnative fish releases and escapement into the main river, floodplain, and tributaries;
- control problematic nonnative fishes as needed;
- minimize the risk of hazardous-materials spills in critical habitat;
- remediate water-quality problems; and
- minimize the threat of hybridization with white sucker.

Humpback chub

Species/Critical Habitat Description

The humpback chub is a medium-sized freshwater fish (less than 500 mm) of the minnow family. The adults have a pronounced dorsal hump, a narrow flattened head, a fleshy snout with an inferior-subterminal mouth, and small eyes. It has silvery sides with a brown or olive colored back.

The humpback chub is endemic to the Colorado River Basin and is part of a native fish fauna traced to the Miocene epoch in fossil records (Miller 1946; Minckley et al. 1986). Humpback chub remains have been dated to about 4000 B.C., but the fish was not described as a species until the 1940s (Miller 1946), presumably because of its restricted distribution in remote white water canyons (USFWS 1990). Because of this, its original distribution is not known. The humpback chub was listed as endangered on March 11, 1967.

Until the 1950s, the humpback chub was known only from Grand Canyon. During surveys in the 1950s and 1960s humpback chub were found in the upper Green River including specimens from Echo Park, Island Park, and Swallow Canyon (Smith 1960, Vanicek et al. 1970). Individuals were also reported from the lower Yampa River (Holden and Stalnaker 1975b), the White River in Utah (Sigler and Miller 1963), Desolation Canyon of the Green River (Holden and Stalnaker 1970) and the Colorado River near Moab (Sigler and Miller 1963).

Critical habitat was designated for humpback chub on March 21, 1994 (59 FR 13374). Designated critical habitat makes up about 28% of the species' original range and occurs in both the Upper and Lower Colorado River Basins. The primary constituent elements are the same as those described for Colorado pikeminnow.

Critical habitat has been designated within the humpback chub's historical range in the following sections of the Upper Basin (59 FR 13374).

> Colorado, Moffat County. The Yampa River from the boundary of Dinosaur National Monument in T. 6 N., R. 99 W., section 27 (6th Principal Meridian) to the confluence with the Green River in T. 7 N., R. 103 W., section 28 (6th Principal Meridian).
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> Utah, Uintah County; and Colorado, Moffat County. The Green River from the confluence with the Yampa River in T. 7 N., R. 103 W., section 28 (6th Principal Meridian) to the southern boundary of Dinosaur National Monument in T. 6 N., R. 24 E., section 30 (Salt Lake Meridian).
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> Utah, Uintah and Grand Counties. The Green River (Desolation and Gray Canyons) from Sumners Amphitheater in T. 12 S., R. 18 E., section 5 (Salt Lake Meridian) to Swasey's Rapid in T. 20 S., R. 16 E., section 3 (Salt Lake Meridian).
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> Utah, Grand County; and Colorado, Mesa County. The Colorado River from Black Rocks in T. 10 S., R. 104 W., section 25 (6th Principal Meridian) to Fish Ford in T. 21 S., R. 24 E., section 35 (Salt Lake Meridian).
>
> Utah, Garfield and San Juan Counties. The Colorado River from Brown Betty Rapid in T. 30 S., R. 18 E., section 34 (Salt Lake Meridian) to Imperial Canyon in T. 31 S., R. 17 E., section 28 (Salt Lake Meridian).

Status and Distribution

Failure to recognize *Gila cypha* as a species until 1946 complicated interpretation of historic distribution of humpback chubs in the Green River (Douglas et al. 1989, 1998). Best available information suggests that before Flaming Gorge Dam, humpback chubs were distributed in canyon regions throughout much of the Green River, from the present site of Flaming Gorge Reservoir downstream through Desolation and Gray canyons (Vanicek 1967; Holden and Stalnaker 1975a; Holden 1991). In addition, the species occurred in the Yampa and White rivers. Pre-impoundment surveys of the Flaming Gorge Reservoir basin (Bosley 1960; Gaufin et al. 1960; McDonald and Dotson 1960; Smith 1960) reported both humpback chubs and bonytails from the Green River near Hideout Canyon, now inundated by Flaming Gorge Reservoir.

Historic collection records of humpback chub exist from the Yampa and White rivers, both tributaries to the Green River. Tyus (1998) verified the presence of seven humpback chubs in collections of the University of Colorado Museum, collected from the Yampa River in Castle Park between 19 June and 11 July 1948. A single humpback chub was found in the White River near Bonanza, Utah, in June 1981 (Miller et al. 1982b), and a possible bonytail-humpback chub intergrade was also captured in July 1978 (Lanigan and Berry 1981).

Present concentrations of humpback chub in the Upper Basin occur in canyon-bound river reaches ranging in length from 3.7 km (Black Rocks) to 40.5 km (Desolation and Gray Canyons). Humpback chubs are distributed throughout most of Black Rocks and Westwater Canyons (12.9 km), and in or near whitewater reaches of Cataract Canyon (20.9 km), Desolation and Gray Canyons (65.2 km), and Yampa Canyon (44.3 km), with populations in the separate canyon reaches ranging from 400 to 5,000 adults (see population dynamics). The Utah Division of Wildlife Resources has monitored the fish community in Desolation and Gray Canyons since 1989 and has consistently reported captures of age-0, juvenile, and adult *Gila,* including humpback chub, indicating a reproducing population (Chart and Lentsch 1999b). Distribution of humpback chubs within Whirlpool and Split Mountain Canyons is not presently known, but it is believed that numbers of humpback chub in these sections of the Green River are low.

The Yampa River is the only tributary to the Green River presently known to support a reproducing humpback chub population. Between 1986 and 1989, Karp and Tyus (1990) collected 130 humpback chubs from Yampa Canyon and indicated that a small but reproducing population was present. Continuing captures of juveniles and adults within Dinosaur National Monument indicate that a population persists in Yampa Canyon (T. Modde, U.S. Fish and Wildlife USFWS, personal communication). Small numbers of humpback chub also have been reported in Cross Mountain Canyon on the Yampa River and in the Little Snake River about 10 km upstream of its confluence with the Yampa River (Wick et al. 1981; Hawkins et al. 1996).

Recovery goals for the humpback chub (USFWS 2002c) were approved on August 1, 2002. According to these recovery goals, downlisting can be considered if, over a 5-year period:

- the trend in adult (age 4+; > 200 mm total length) point estimates for each of the six extant populations does not decline significantly; and

- mean estimated recruitment of age-3 (150–199 mm total length) naturally produced fish equals or exceeds mean annual adult mortality for each of the six extant populations; and

- two genetically and demographically viable, self-sustaining core populations are maintained, such that each point estimate for each core population exceeds 2,100 adults (2,100 is the estimated minimum viable population needed to ensure long-term genetic and demographic viability); and

- certain site-specific management tasks to minimize or remove threats have been identified, developed, and implemented.

Delisting can be considered if, over a 3-year period beyond downlisting:

- the trend in adult point estimates for each of the six extant populations does not decline significantly; and

- mean estimated recruitment of age-3 naturally produced fish equals or exceeds mean annual adult mortality for each of the six extant populations; and

- three genetically and demographically viable, self-sustaining core populations are maintained, such that each point estimate for each core population exceeds 2,100 adults; and

- certain site-specific management tasks to minimize or remove threats have been finalized and implemented, and necessary levels of protection are attained.

Life History

Unlike Colorado pikeminnow and razorback sucker, which are known to make extended migrations of up to several hundred miles to spawning areas in the Green and Yampa rivers, humpback chubs in the Green River do not appear to make extensive migrations (Karp and Tyus 1990). Radio-telemetry and tagging studies on other humpback chub populations have revealed strong fidelity by adults for specific locations with little movement to areas outside of home canyon regions. Humpback chubs in Black Rocks (Valdez and Clemmer 1982), Westwater Canyon (Chart and Lentsch 1999a), and Desolation and Gray Canyons (Chart and Lentsch 1999b) do not migrate to spawn.

Generally, humpback chub show fidelity for canyon reaches and move very little (Miller et al. 1982a; Archer et al. 1985; Burdick and Kaeding 1985; Kaeding et al. 1990). Movements of adult humpback chub in Black Rocks on the Colorado River were essentially restricted to a 1-mile reach. These results were based on the recapture of Carlin-tagged fish and radiotelemetry studies conducted from 1979 to 1981 (Valdez et al. 1982) and 1983 to 1985 (Archer et al. 1985; USFWS 1986; Kaeding et al. 1990).

In the Green River and upper Colorado River, humpback chubs spawned in spring and summer as flows declined shortly after the spring peak (Valdez and Clemmer 1982; Valdez et al. 1982; Kaeding and Zimmerman 1983; Tyus and Karp 1989; Karp and Tyus 1990; Chart and Lentsch 1999a, 1999b). Similar spawning patterns were reported from Grand Canyon (Kaeding and Zimmerman 1983; Valdez and Ryel 1995, 1997). Little is known about spawning habitats and behavior of humpback chub. Although humpback chub are believed to broadcast eggs over mid-channel cobble and gravel bars, spawning in the wild has not been observed for this species. Gorman and Stone (1999) reported that ripe male humpback chubs in the Little Colorado River aggregated in areas of complex habitat structure (i.e., matrix of large boulders and travertine masses combined with chutes, runs, and eddies, 0.5–2.0 m deep) and were associated with deposits of clean gravel.

Chart and Lentsch (1999b) estimated hatching dates for young *Gila* collected from Desolation and Gray Canyons between 1992 and 1995. They determined that hatching occurred on the descending limb of the hydrograph as early as 9 June 1992 at a flow of 139 m^3/s and as late as 1 July 1995 at a flow of 731 m^3/s. Instantaneous daily river temperatures on hatching dates over all years ranged from 20 to 22ºC.

Newly hatched larvae average 6.3–7.5 mm TL (Holden 1973; Suttkus and Clemmer 1977; Minckley 1973; Snyder 1981; Hamman 1982; Behnke and Benson 1983; Muth 1990), and 1-month-old fish are approximately 20 mm long (Hamman 1982). Unlike Colorado pikeminnow and razorback sucker, no evidence exists of long-distance larval drift (Miller and Hubert 1990; Robinson et al. 1998). Upon emergence from spawning gravels, humpback chub larvae remain in the vicinity of bottom surfaces (Marsh 1985) near spawning areas (Chart and Lentsch 1999a).

Backwaters, eddies, and runs have been reported as common capture locations for young-of-year humpback chub (Valdez and Clemmer 1982). These data indicate that in Black Rocks and Westwater Canyon, young utilize shallow areas. Habitat suitability index curves developed by Valdez et al. (1990) indicate young-of-year prefer average depths of 2.1 feet with a maximum of 5.1 feet. Average velocities were reported at 0.2 feet per second.

Valdez et al. (1982) Wick et al. (1979) and Wick et al. (1981) found adult humpback chub in Black Rocks and Westwater Canyons in water averaging 50 feet in depth with a maximum depth of 92 feet. In these localities, humpback chub were associated with large boulders and steep cliffs.

Threats to the Species

Although historic data are limited, the apparent range-wide decline in humpback chubs is likely due to a combination of factors including alteration of river habitats by reservoir inundation, changes in stream discharge and temperature, competition with and predation by introduced fish species, and other factors such as changes in food resources resulting from stream alterations (USFWS 1990).

The primary threats to humpback chub are stream flow regulation and habitat modification; competition with and predation by nonnative fishes; parasitism; hybridization with other native *Gila* species; and pesticides and pollutants (USFWS 2002c). The existing habitat, altered by these threats, has been modified to the extent that it impairs essential behavior patterns, such as breeding, feeding, and sheltering. The threats to humpback chub in relation to flow regulation and habitat modification, predation by nonnative fishes, and pesticides and pollutants are essentially the same threats identified for Colorado pikeminnow.

The humpback chub population in the Grand Canyon is threatened by predation from nonnative trout in the Colorado River below Glen Canyon Dam. This population is also threatened by the Asian tapeworm reported in humpback chub in the Little Colorado River (USFWS 2002c). No Asian tapeworms have been reported in the upper basin populations.

Hybridization with roundtail chub (*Gila robusta*) and bonytail, where they occur with humpback chub, is recognized as a threat to humpback chub. A larger proportion of roundtail chub have been found in Black Rocks and Westwater Canyon during low flow years (Kaeding et al. 1990; Chart and Lentsch 2000), which increase the chances for hybridization.

Management actions identified in the recovery goals for humpback chub (USFWS 2002c) to minimize or remove threats to the species included:

- provide and legally protect habitat (including flow regimes necessary to restore and maintain required environmental conditions) necessary to provide adequate habitat and sufficient range for all life stages to support recovered populations,
- investigate the role of the mainstem Colorado River in maintaining the Grand Canyon population,
- investigate the anticipated effects of and options for providing warmer water temperatures in the mainstem Colorado River through Grand Canyon,
- ensure adequate protection from overutilization,
- ensure adequate protection from diseases and parasites,
- regulate nonnative fish releases and escapement into the main river, floodplain, and tributaries,
- control problematic nonnative fishes as needed,
- minimize the risk of increased hybridization among *Gila* spp, and
- minimize the risk of hazardous-materials spills in critical habitat.

Bonytail

Species/Critical Habitat Description

Bonytail are medium-sized (less than 600 mm) fish in the minnow family. Adult bonytail are gray or olive colored on the back with silvery sides and a white belly. The adult bonytail has an elongated body with a long, thin caudal peduncle. The head is small and compressed compared to the rest of the body. The mouth is slightly overhung by the snout and there is a smooth low hump behind the head that is not as pronounced as the hump on a humpback chub.

The bonytail is endemic to the Colorado River Basin and was historically common to abundant in warm-water reaches of larger rivers of the basin from Mexico to Wyoming. The species experienced a dramatic, but poorly documented, decline starting in about 1950, following construction of several mainstem dams, introduction of nonnative fishes, poor land-use practices, and degraded water quality (USFWS 2002d).

Currently, no self-sustaining populations of bonytail are known to exist in the wild, and very few individuals have been caught anywhere within the basin. An unknown, but small number of wild adults exist in Lake Mohave on the mainstem Colorado River. Since 1977, only 11 wild adults have been reported from the upper basin (Valdez et al. 1994).

A total of 499 km (312 miles) of river has been designated as critical habitat for the bonytail in the Colorado River Basin, representing about 14% of the species' historic range (59 FR 13374). The primary constituent elements are the same as those described for the Colorado pikeminnow.

Critical habitat has been designated within the bonytail's historical range in the following sections of the Upper Basin (59 FR 13374).

> Colorado, Moffat County. The Yampa River from the boundary of Dinosaur National Monument in T. 6 N., R. 99 W., section 27 (6th Principal Meridian) to the confluence with the Green River in T. 7 N., R. 103 W., section 28 (6th Principal Meridian).
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> Utah, Uintah County; and Colorado, Moffat County. The Green River from the confluence with the Yampa River in T. 7 N., R. 103 W., section 28 (6th Principal Meridian) to the boundary of Dinosaur National Monument in T. 6 N., R. 24 E., section 30 (Salt Lake Meridian).
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> Utah, Uintah and Grand Counties. The Green River (Desolation and Gray Canyons) from Sumner's Amphitheater (river mile 85) in T. 12 S., R. 18 E., section 5 (Salt Lake Meridian) to Swasey's Rapid (river mile 12) in T. 20 S., R. 16 E., section 3 (Salt Lake Meridian).
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> Utah, Grand County; and Colorado, Mesa County. The Colorado River from Black Rocks in T. 10 S., R. 104 W., section 25 (6th Principal Meridian) to Fish Ford in T. 21 S., R. 24 E., section 35 (Salt Lake Meridian).
>
> Utah, Garfield and San Juan Counties. The Colorado River from Brown Betty Rapid in T. 30 S., R. 18 E., section 34 (Salt Lake Meridian) to Imperial Canyon in T. 31 S., R. 17 E., section 28 (Salt Lake Meridian).

Status and Distribution

The bonytail is the rarest native fish in the Colorado River. Little is known about its specific habitat requirements or cause of decline, because the bonytail was extirpated from most of its historic range prior to extensive fishery surveys. It was listed as endangered on April 23, 1980. Currently, no documented self-sustaining populations exist in the wild. Formerly reported as widespread and abundant in mainstem rivers (Jordan and Evermann 1896), its populations have been greatly reduced. Remnant populations presently occur in the wild in low numbers in Lake Mohave and several fish have been captured in Lake Powell and Lake Havasu (USFWS 2002d). The last known riverine area where bonytail were common was the Green River in Dinosaur National Monument, where Vanicek (1967) and Holden and Stalnaker (1970) collected 91 specimens during 1962-1966. From 1977 to 1983, no bonytail were collected from the Colorado or Gunnison rivers in Colorado or Utah (Wick et al. 1979, 1981; Valdez et al. 1982; Miller et al. 1984). However, in 1984, a single bonytail was collected from Black Rocks on the Colorado River (Kaeding et al. 1986). Several suspected bonytail were captured in Cataract Canyon in 1985-1987 (Valdez 1990). Current stocking plans for bonytail identify the middle Green River and the Yampa River in Dinosaur National Monument as the highest priority for stocking in Colorado and the plan calls for 2,665 fish to be stocked per year over the next six years (Nesler et al. 2003).

Recovery goals for the bonytail (USFWS 2002d) were approved on August 1, 2002. According to these recovery goals, downlisting can be considered if, over a 5-year period:

- genetically and demographically viable, self-sustaining populations are maintained in the Green River subbasin and upper Colorado River subbasin such that (a) the trend in adult (age 4+; > 250 mm total length) point estimates for each of the two populations does not decline significantly, and (b) mean estimated recruitment of age-3 (150–249 mm total length) naturally produced fish equals or exceeds mean annual adult mortality for each of the two populations, and (c) each point estimate for each of the two populations exceeds 4,400 adults (4,400 is the estimated minimum viable population needed to ensure long-term genetic and demographic viability); and

- a genetic refuge is maintained in a suitable location (e.g., Lake Mohave, Lake Havasu) in the lower basin recovery unit; and

- two genetically and demographically viable, self-sustaining populations are maintained in the lower basin recovery unit (e.g., mainstem and/or tributaries) such that (a) the trend in adult point estimates for each population does not decline significantly, and (b) mean estimated recruitment of age-3 naturally produced fish equals or exceeds mean annual adult mortality for each population, and (c) each point estimate for each population exceeds 4,400 adults; and

- certain site-specific management tasks to minimize or remove threats have been identified, developed, and implemented.

Delisting can be considered if, over a 3-year period beyond downlisting:

- genetically and demographically viable, self-sustaining populations are maintained in the Green River subbasin and upper Colorado River subbasin such that (a) the trend in adult point estimates for each of the two populations does not decline significantly, and (b) mean estimated recruitment of age-3 naturally produced fish equals or exceeds mean annual adult mortality for each of the two populations, and (c) each point estimate for each of the two populations exceeds 4,400 adults; and

- a genetic refuge is maintained in the lower basin recovery unit; and

- two genetically and demographically viable, self-sustaining populations are maintained in the lower basin recovery unit such that (a) the trend in adult point estimates for each population does not decline significantly, and (b) mean estimated recruitment of age-3 naturally produced fish equals or exceeds mean annual adult mortality for each population, and (c) each point estimate for each population exceeds 4,400 adults; and

- certain site-specific management tasks to minimize or remove threats have been finalized and implemented, and necessary levels of protection are attained.

Life History

The bonytail is considered a species that is adapted to mainstem rivers, where it has been observed in pools and eddies (Vanicek 1967; Minckley 1973). Spawning of bonytail has never been observed in a river, but ripe fish were collected in Dinosaur National Monument during late June and early July suggesting that spawning occurred at water temperatures of about 18ºC (Vanicek and Kramer 1969). Similar to other closely related *Gila* species, bonytail probably spawn in rivers in spring over rocky substrates; spawning has been observed in reservoirs over rocky shoals and shorelines. It has been recently hypothesized that flooded bottomlands may provide important bonytail nursery habitat. Of five specimens captured most recently in the upper basin, four were captured in deep, swift, rocky canyons (Yampa Canyon, Black Rocks, Cataract Canyon, and Coal Creek Rapid), but the fifth was taken in Lake Powell. Since 1974, all bonytails captured in the lower basin were caught in reservoirs.

Threats to the Species

The primary threats to bonytail are stream flow regulation and habitat modification; competition with and predation by nonnative fishes; hybridization with other native *Gila* species; and pesticides and pollutants (USFWS 2002d). The existing habitat, altered by these threats, has been modified to the extent that it impairs essential behavior patterns, such as breeding, feeding, and sheltering. The threats to bonytail in relation to flow regulation and habitat modification, predation by nonnative fishes, and pesticides and pollutants are essentially the same threats identified for Colorado pikeminnow. Threats to bonytail in relation to hybridization are essentially the same threats identified for humpback chub.

Management actions identified in the recovery goals for bonytail (USFWS 2002d) to minimize or remove threats to the species included:

- provide and legally protect habitat (including flow regimes necessary to restore and maintain required environmental conditions) necessary to provide adequate habitat and sufficient range for all life stages to support recovered populations;
- provide passage over barriers within occupied habitat to allow unimpeded movement and, potentially, range expansion;
- investigate options for providing appropriate water temperatures in the Gunnison River;
- minimize entrainment of subadults and adults at diversion/out-take structures;
- investigate habitat requirements for all life stages and provide those habitats;
- ensure adequate protection from overutilization;
- ensure adequate protection from diseases and parasites;
- regulate nonnative fish releases and escapement into the main river, floodplain, and tributaries;
- control problematic nonnative fishes as needed;

- minimize the risk of increased hybridization among *Gila* spp.;
- minimize the risk of hazardous-materials spills in critical habitat; and
- remediate water-quality problems.

Analysis of the species/critical habitat likely to be affected

In summary, the four species of endangered Colorado River fish and their critical habitat are likely to be adversely affected by components of the proposed action. These species will be considered further in the remaining sections of this biological opinion.

ENVIRONMENTAL BASELINE

The environmental baseline includes the status of the species within the action area (the Colorado River near Moab, Utah) as well as the factors affecting the environment of the species or critical habitat in the action area. The baseline includes; State, tribal, local and private actions already affecting the species or that will occur contemporaneously with the consultation in progress; unrelated Federal actions affecting the same species or critical habitat that have completed formal or informal consultation; and Federal and other actions within the action area that may benefit listed species or critical habitat. The environmental baseline does not include the effects of the action under review in the consultation.

Status of the Species Within the Action Area

Colorado pikeminnow

Colorado pikeminnow are distributed throughout the Colorado River from Price Stubb Dam, an impassible barrier at the upper end of the Grand Valley (RM 188.3), downstream to Lake Powell (Osmundson and Burnham 1998). The Recovery Program is scheduled to provide passage at the structure, but it currently remains an obstacle to fish movement.

Although Colorado pikeminnow use the entire river, there are distinct differences in distribution among age classes. In general, most adults are found in the upper reaches of the river and most subadults, juveniles, and YOY are found in the lower reaches (Valdez et al. 1982a; Archer et al. 1985; McAda and Kaeding 1991b; Osmundson et al. 1997). This corresponds to the general distribution of different age classes in the Green River as well (Tyus 1991). Osmundson and Burnham (1998) conducted an intensive river-wide study using mark-recapture to estimate the population size of subadult (250–500 mm long) and adult Colorado pikeminnow (>500 mm long) in the Colorado River. They divided the river into two subreaches — Westwater Canyon to Price Stubb Dam (RM 125–188) and confluence with Green River to Westwater Canyon (RM 0–113; Westwater Canyon itself was not sampled). They estimated that the average population size in 1991–1994 was 253 (95% CI, 161–440) for the upper reach and 344 (95% CI, 196–604) for the lower reach. They noted that almost all fish captured in the upper reach were adults (i.e. >500 mm), whereas most fish captured from the lower reach were subadults.

Although most adults were captured from the upper river, they were not distributed equally throughout the reach. Catch rates in two segments of the upper reach — known as the 18-mile reach (RM 154–171) and the 15-mile reach (RM 171–185) — were five to six times higher than in the lower third of the reach (Osmundson 2000). These reaches contain 8 to 10 times more adult Colorado pikeminnow per mile than the lower 100 mile of the Colorado River.

Osmundson (2002a) repeated the population estimate for the 1998–2000 period using the same techniques used by Osmundson and Burnham (1998). He also revised the previous estimate using length criteria for adults corresponding to recovery goals established in 2002 (USFWS 2002c; ≥450 mm total length [TL]) and provided a river-wide estimate. Average population size for the Colorado River was 503 adult Colorado pikeminnow for 1992–1994 and 604 for 1998–2000 (Osmundson 2002a). Although the average point estimate increased for the second period, the difference was not significant because of wide confidence intervals. An increase in the adult population during the 1990s was also suggested by an increasing catch rate during spring ISMP electrofishing (Figure 3.6; McAda 2002a). However, electrofishing catch rates dropped off in 1999 and 2000, whereas population estimates did not.

Density and distribution of YOY Colorado pikeminnow have been monitored in the Colorado River since 1982 (McAda and Ryel 1999). Density has been highly variable over that period, but YOY have been captured every year since monitoring began. Highest density of YOY Colorado pikeminnow occurred in 1985, 1986, and 1996 and lowest density occurred in 1984, 1995, and 1997. Young-of-the-year Colorado pikeminnow were found throughout the Colorado River downstream from the confluence with the Gunnison River, but were most abundant in the 65 mile between Moab and the mouth of the Green River. Although larval Colorado pikeminnow were collected upstream of the mouth of the Gunnison River in 1982 (McAda and Kaeding 1991b) and in 1995 (Anderson 1999), no YOY and only one yearling have ever been captured there (Osmundson and Burnham 1998). The number of YOY captured in the river between the mouth of the Gunnison River and Westwater Canyon has decreased since the mid 1980s, with no YOY Colorado pikeminnow captured upstream from Westwater Canyon during autumn ISMP surveys since 1992 and only one captured each year from 1988 to 1992 (McAda and Ryel 1999). However, more intensive seining collections than done under ISMP captured one YOY Colorado pikeminnow in 1997 and one in 1998 in the Grand Valley downstream from the Gunnison River (K. Bestgen, personal communication).

Density of YOY Colorado pikeminnow was greatest in the lowest gradient reaches of the Colorado River, similar to distributional patterns in the Green River (Tyus and Haines 1991). This lower 60 miles of the river has a large number of backwaters and embayments (although not the largest, or the highest concentration of backwaters) and the warmest water temperatures in the Colorado River upstream from Lake Powell (Osmundson 1999). Backwaters are warmer and more productive than the rest of the river (Wydoski and Wick 1998), and they provide important nursery habitat for small Colorado pikeminnow during the first year of their life (Tyus and Haines 1991).

On December 19, 2001, UDWR personnel identified backwater areas that may be used by larval and juvenile pikeminnows beginning at the mouth of Moab Wash and extending approximately 1,200 ft south. Within this area, three locations extending about 600 to 800 ft south of the wash were tentatively identified as having the greatest potential for suitable nursery habitat at river flows that inundate these areas each year.

As part of the ISMP, pikeminnow nursery habitat was sampled each fall (1986 to 2002) between river mile 53.5 and 63.5. The purpose of this sampling was to determine relative abundance and distribution of young-of-the-year Colorado pikeminnow. The sampling protocol required sampling two habitats every 5 miles. Sixty backwater locations were sampled between 1986 and 2002, of which 13 were between river mile 61 and 63.5. Five of the 13 backwater areas sampled contained a total of 83 young-of-the-year pikeminnow comprising 24 percent of the total pikeminnow captured between river mile 53.5 and 63.5 during ISMP sampling (UDWR 2003a).

In the spring of 2003, USF&WS captured 8 stocked adult pikeminnow between river miles 60 and 64, 4 between river miles 64 and 70, and 20 between river miles 50 and 60 (USF&WS 2004b).

Razorback Sucker

In the Colorado River upstream from Lake Powell, most razorback suckers have been captured in the Grand Valley (Loma, Colorado to Palisade, Colorado) near the confluence of the Gunnison and Colorado rivers. However, their abundance has decreased to the point that they are only infrequently captured there. During intensive efforts specifically targeted at known concentration areas, Kidd (1977) and McAda and Wydoski (1980) captured a combined total of 54 razorback suckers in 1974 and 204 in 1975 from two gravel-pit ponds connected to the Colorado River near Grand Junction. These numbers reflect the combined total of independent collections, but probably include some recaptures of the same fish because sampling was done in the same areas and Kidd (1977) did not mark fish before release. All of these fish were adults that exhibited signs of old age such as large size, missing eyes, and heavy scarring (C. McAda, personal observation).

A variety of investigators have sampled the Colorado River in subsequent years, but sampling effort varied considerably and sampling did not always target razorback sucker. The high numbers of razorback suckers captured in 1975 were not repeated in subsequent years (summarized by Osmundson and Kaeding 1991). The highest number captured in later years was 30 fish that were collected in 1982 from the same gravel-pit ponds sampled by Kidd (1977) and McAda and Wydoski (1980). Total fish captured declined dramatically after 1975, and few wild razorback suckers have been captured in recent years. Only 11 wild razorback suckers have been collected in the Grand Valley since 1990 despite intensive sampling in some years (Osmundson and Kaeding 1991; CDOW and USFWS, unpublished data). All of these fish were removed from the river to support propagation activities for the Recovery Program (M. Baker, unpublished data).

Although most razorbacks suckers have been collected in the Grand Valley, they have also been collected both up and downstream of the area. Kidd (1977) reported 22 razorback suckers from the Colorado River near DeBeque, Colorado (RM 209.7) in 1974–1975. No razorbacks have been collected from that reach since then (Valdez et al. 1982b; Burdick 1992). Burdick (1992) captured one razorback sucker from a gravel pit pond along the river at RM 234.8 and discovered a small population in another gravel-pit pond at RM 204.5. About 75 razorback suckers were captured from the second pond, but DNA analysis revealed that they were siblings. They were probably offspring from two or three razorback suckers trapped in the pond during the high-water years of 1983 or 1984. Three razorback suckers from this pond were incorporated into the propagation program, but their close relationship precluded extensive use in the brood-stock program. Forty-five razorback suckers from this pond were equipped with radio transmitters and stocked into the Colorado and Gunnison rivers as part of an experimental stocking; six of those fish were confirmed alive at the end of the 2-yr study (Burdick and Bonar 1997).

Few razorback suckers have been captured downstream from the Grand Valley, between Loma and Lake Powell. Taba et al. (1965) captured eight juveniles in backwaters of the Colorado River downstream of Moab. One adult was captured near Salt Wash (RM 144.2) in 1988 (McAda et al. 1994b). Further downstream, Valdez et al. (1982b) captured two razorback suckers within 2 mileof the confluence with the Green River, and Valdez (1990) captured one more in the same area.

The only small razorback suckers reported from the Colorado River were captured by Taba et al. (1965), who found eight juveniles (90–115 mm TL) in “quiet backwater areas” during a 2-yr survey of the river between Moab and Dead Horse Point. That observation is consistent with collections of juveniles from the Green River. Gutermuth et al. (1994) captured two age-0 juveniles in backwaters along the lower Green River in 1991, and Modde (1996) found two in similar habitats in the middle Green River in 1993. Most recently, Modde (1996) found age-0 juveniles in an experimental flooded bottomland (Old Charlie Wash) along the middle Green River when it was drained at the end of the growing season — 28 in 1995 and 45 in 1996.

Although razorback suckers have declined dramatically in abundance in recent years, the Recovery Program considers the Colorado and Gunnison rivers to be suitable habitat for razorback suckers and has begun a reintroduction program to restore populations in the two rivers (Burdick 1992; Nesler 1998; Hudson, et al. 1999).

The Recovery Program is still building a broodstock for future use, but about 19,000 razorback suckers have been stocked into the Gunnison River near Delta and about 44,000 razorbacks have been stocked into the Colorado River upstream from Grand Junction (Burdick 2003; C. McAda, personal communication). Initial surveys indicate that some of the stocked fish are surviving in the Gunnison and Colorado rivers near their stocking location, and others have moved and are surviving further downstream in the Colorado River (Burdick 2003). In 2003, USFWS captured 3 stocked adult razorback suckers between river miles 60 and 64, 10 between river miles 64 and 70, and 8 between river miles 50 and 60 (USFWS 2004b). USFWS sampled this stretch of river in the spring of 2004 and captured 6 stocked adults between river miles 64 and 70, 2 between river miles 60 and 64, and 3 between river miles 45 and 60 (USFWS 2004c). This reintroduction program is scheduled to continue until a self-sustaining population of at least 5,800 individuals is established in the Gunnison and upper Colorado Rivers (USFWS 2002d). Some of the stocked razorback suckers have survived to adulthood and spawned successfully — a total of eight larval razorback suckers were captured from the Gunnison River in 2002 (Osmundson 2002b).

Bonytail

Few bonytails have been captured from the upper Colorado River since intensive sampling began in the 1970s, even though anecdotal and photographic evidence suggest that they were common in the river early in this century (Quartarone 1993). Valdez et al. (1982b) did not capture bonytails during an intensive 3-yr study of the Colorado River between Rifle and Lake Powell. Kaeding et al. (1986) captured one adult at Black Rocks near the Colorado-Utah state line, and Valdez (1990) captured 14 *Gila* spp. from Cataract Canyon that were suspected to be bonytails (1 YOY, 7 juveniles, and 6 adults).

The Recovery Program began a reintroduction program in 1996 and has stocked about 84,600 bonytails into the Colorado River since then (Badame and Hudson 2003). Developing a self-sustaining bonytail population in the upper Colorado River will require accomplishments in all phases of the Recovery Program including nonnative fish control, habitat restoration, and instream flow protection. Recaptures of these stocked individuals have been increasing in recent years throughout the river, including near the Moab Site (USFWS 2004a). In 2003, a stocked adult bonytail was captured by USFWS at river mile 66.2, just upstream of the Moab Site (USFWS 2004b). In 2004, a stocked adult was captured at river mile 69.2. (USFWS 2004c). Recovery goals call for a self-sustaining population of 4,400 adults in the upper Colorado River (USFWS 2002a).

Because of its extreme rarity, little is known about the habitat requirements of bonytail in the upper Colorado River. However, all four of the endangered fish evolved together in the Colorado River ecosystem, and flow recommendations and water quality needs based on habitat requirements of the more common species and basic river restoration principals (Stanford et al. 1996) should also benefit bonytail.

Humpback Chub

Two major populations of humpback chub are found in the upper Colorado River — Black Rocks, a 1-mile long reach just upstream from the Colorado-Utah state line, and Westwater Canyon, an 18-mile long canyon-bound reach of rapids, deep pools, and violent eddies. The two populations are generally considered to be distinct because they are separated by about 11 mi, but movement between the two populations has been documented (Valdez and Clemmer 1982; Kaeding et al. 1990; Chart and Lentsch 1999a; McAda 2002b).

Both populations have been sampled regularly since the late 1970's and were generally considered to be stable, with annual reproduction and regular recruitment of young fish to the adult population (Valdez and Clemmer 1982; Kaeding et al. 1990; McAda et al. 1994b; Chart and Lentsch 1999a). However, quantitative population estimates have not been attempted until recently. Chart and Lentsch (1999a) sampled Westwater Canyon during 1993–1996 and made population estimates based on year-to-year recaptures at three discrete sites within the canyon. Sampling was restricted to the three sites because rapids and violent eddies made sampling very difficult in the rest of the canyon. The average annual population estimate for the three sites combined was 6,985 adults (Chart and Lentsch 1999a). A more intensive, mark recapture estimate conducted from 1998–2000 period determined the population declined from 4,744 adults to 2,201 adults in 2001 (Hudson and Jackson 2003). The average adult population size for Black Rocks during 1998–2000 was estimated to be about 740 individuals (McAda 2002b). Decline in catch rates suggest that the population has decreased, but annual population estimates are not significantly different from each other (McAda 2002b).

Adult humpback chubs in the upper Colorado River are relatively sedentary and generally remain within a small area (Valdez and Clemmer 1982; Kaeding et al. 1990; Chart and Lentsch 1999a). Displacement of radiotagged humpback chubs in Black Rocks averaged 0.5– 0.9 mile (Valdez and Clemmer 1982; Kaeding et al. 1990), and displacement of fish tagged with carlin tags averaged 0.7–1.0 mile(Valdez and Clemmer 1982; Kaeding et al. 1990).

Thirty-two percent of the humpback chubs tagged and recaptured by Kaeding et al. (1990) were recaptured at their release site, and 80% were recaptured within 0.3 mile of it. However, they recaptured two humpback chubs that had originally been tagged in Westwater Canyon, about 14 mile downstream. Valdez and Clemmer (1982) also reported movement of a humpback chub from Westwater Canyon upstream to Black Rocks.

The majority (82%) of fish tagged and recaptured by Chart and Lentsch (1999a) in Westwater Canyon showed no net movement, although some fish moved among the three sampling sites. Among others, they recaptured two fish only 2 d after being tagged at Black Rocks. The abrupt downstream movement may have been precipitated by handling stress (Chart and Lentsch 1999a). In addition, seven humpback chubs originally tagged in Westwater Canyon by Chart and Lentsch (1999a) were recaptured in Black Rocks (McAda 2002b). Intervals between tagging and recapture varied from 1 to 6 yr; there is no way to determine how long the fish had been in Black Rocks or how long it took them to move 14 mile upstream. One of these fish was recaptured a second time in Black Rocks 1 yr after its first recapture (C. McAda, unpublished data).

A third population, the Cataract Canyon population is located some 70 miles downstream in Canyonlands National Park. Densities of humpback chubs in Cataract Canyon are much lower than those reported from Black Rocks or Westwater Canyon. Three weeks of sampling in Cataract Canyon during the fall of 2003 resulted in the capture of 32 individual humpback chub (Valdez et al 2003).

Young-of-the-year humpback chubs have been collected from a variety of low-velocity habitats within Westwater Canyon, including shorelines, backwaters, and embayments (Chart and Lentsch 1999a). They used low-velocity habitats as they were available with very little selection of specific habitats (Chart and Lentsch 1999a). In Black Rocks, small humpback chubs were collected from backwaters as well as small, quiet pockets along the steep rock walls (Valdez and Clemmer 1982).

Factors Affecting the Species Environment Within the Action Area

Designated critical habitat for both Colorado pikeminnow and razorback sucker includes the Colorado River and its 100-year floodplain throughout the project area. Designated critical habitat for the humpback chub and bonytail is located approximately 50 miles upstream of the project and approximately 60 miles downstream. Primary constituent elements include, but are not limited to, water (in sufficient quantity and quality to sustain all life stages), physical habitat, and the biological environment (including competition and predation with nonnative species).

Impoundments and diversions have reduced peak discharges in various river reaches throughout the Upper Colorado River Basin since the 1890's, while increasing base flows in other reaches. These depletions, along with a number of other factors, including the introduction of nonnative fishes and increases in salinity and contaminants in the system, have resulted in such drastic reductions in populations of Colorado pikeminnow, humpback chub, razorback sucker and bonytail chub that the USFWS has listed these species as endangered, designated their critical habitats, and has implemented programs to prevent them from becoming extinct.

The numerous impoundments in the upper Colorado River, including Granby, Dillon, Blue Mesa and McPhee Reservoirs, have altered the natural hydrograph of the Colorado River. Reductions in water quantity and changes in flow regime have resulted from upstream developments (USFWS 1993a). A comparison of the frequency of the $Q_{1.5}$ peak flow (a river flow that was equaled or exceeded in 2 out of 3 years) at the Colorado River at the USGS gage near Cisco, Utah (the closest upstream gage) for three development periods (1914-1936, 1937-1965, and 1966-1997) declined from 37,200 cfs to 27,900 cfs to 21,600 cfs (summarized in McAda 2003). Changes in the hydrologic regime through the closure of main stem impoundments has altered sediment transport and resulted in channel degradation (Lyons 1989). Changes in the hydrograph can also lead to changes in the channel geometry. Reduction in channel width has increased the average velocity in the main channel and decreased the number of low-velocity backwaters (Wick et al. 1982). Important backwater habitats and low-velocity shoreline habitats have been eliminated through siltation and subsequent vegetative growth (Wick et al. 1982). In particular, river shorelines have been altered by establishment of the exotic plant tamarisk (*Tamarisk chinensis*). For example, in Canyonlands National Park, the establishment of tamarisk on islands, sandbars, and river shorelines has decreased channel width by an average of 25 percent (Graff 1978). All these species can be found to varying degrees in the project area.

The impoundment of tributaries and mainstem waters also has led to the stocking of a number of nonnative sport and bait fishes for use by local residents and visitors to the basin. While the acceptance of these fishes has been generally favorable to the public, their presence has led to predation, competition, and the general demise of native species (Tyus 1990, Tyus and Saunders 1996). The stocking of nonnative warm water fishes such as channel catfish (*Ictalurus punctatus*), smallmouth bass (*Micropterus dolomieu*), and walleye (*Stizostedion vitreum*) have resulted in the continuing high probability of predation on native fishes. Red shiners (*Cyprinella lutrensis*), for example, have been documented as preying on larval suckers, including razorbacks (Rupert et al. 1993, Modde 1997). Other exotics such as sand shiners (*Notropis stramineus*) and fathead minnows (*Pimephales promelas*) compete for food and space in remaining habitats. Some scientists believe (Tyus and Saunders 1996) that changes in the biological environment as a result of fish introductions may currently be the most significant threat to the native fish fauna of the Colorado River basin.

Water quality has been altered in the Colorado River Basin and also has been identified as a factor resulting in the decline of the endangered fishes. Both the Draft Razorback Sucker Recovery Plan (USFWS 1997) and Colorado Squawfish (name later changed to Colorado pikeminnow) Recovery Plan (USFWS 1991) identify changes in water quality and introduction of environmental contaminants as factors in the decline of the endangered fish. While several general trends in water quality changes have been identified for the Colorado River system (for example, increasing pH and decreasing turbidity), the water quality parameters and environmental contaminants of concern to the endangered fish tend to be site specific. In the USFWS's Recovery Goals for the Colorado pikeminnow, razorback sucker, and bonytail (USFWS 2002a-c) the Atlas Mill tailings are recognized as posing two significant threats: a). toxic discharge of pollutants, particularly ammonia, and b). the risk of catastrophic pile failure that could bury important nursery areas. Quantifiable criteria required to downlist these species include:

> Task E-2.1.- Identify actions to remediate groundwater contamination from the Atlas Mills tailings pile located near Moab, Utah, in order to restore water quality of the Colorado River in the vicinity of the pile in accordance with State of Utah and Environmental Protection Agency (EPA) water quality standards for fish and wildlife.

Quantifiable criteria required to delist these species include:

> Task E-2.2.- Implement actions (as determined under Task E-2.1) to remediate groundwater contamination from the Atlas Mill tailings pile.

The nearest U.S. Geological Survey water quality monitoring station on the mainstem Colorado River to the Atlas site is approximately 31 river miles upstream near Cisco, Utah. The site is located on the left bank of the Colorado River one mile downstream of the Dolores River confluence, 11 miles south of Cisco, Utah, 36 miles downstream from the Utah-Colorado state line. This site has been continuously monitored by the U.S. Geological Survey since 1928. Baseline water quality data for the Colorado River upstream of the Atlas site, at the Cisco station, is included in Table 3 below. While the data is included as baseline, it should be noted that several washes (Salt, Negro Bill, and Courthouse), and Creeks (Onion, Professor, Stearns, and Castle) contribute flows to the Colorado River between the Cisco station and the Atlas site. Therefore, water quality in the Colorado River just above the Atlas site may, at times, be slightly different than that reported for Cisco.

Table 3. Baseline water quality data for the Colorado River, recorded at Cisco, Utah (Water Year 2000).

Date	Discharge (Inst. CFS)	Sulfate Dissolved (mg/l as SO4)	Chloride Dissolved (mg/l as CL)	Nitrogen NO2+NO3 Dissolved (mg/l as N)	Nitrogen Ammonia Dissolved (mg/l as NH4)	Arsenic Dissolved (ug/l as AS)	Beryllium Dissolved (ug/l as BE)	Cadmium Dissolved (ug/l as CD)	Manganese Dissolved (ug/l as MN)	Molybdenum Dissolved (ug/l as MO)	Selenium Dissolved (ug/l as SE)	Uranium Natural Dissolved (ug/l as U)
11/02/99	5920	240	72	0.289	--	<2	--	--	--	--	4	--
12/01/99	3900	260	100	0.500	--	--	--	--	--	--	4	--
12/16/99	3770	250	95	0.530	--	<2	<1.0	<1.0	17.0	5.6	3	5.7
03/29/00	3970	240	110	0.356	0.05	<2	<1.0	<1.0	1.5	6.8	4	4.4
04/27/00	8080	120	41	0.317	--	--	--	--	--	--	<2	--
05/23/00	10200	120	36	0.270	--	<2	<1.0	<1.0	<1.0	2.8	--	2.6
06/27/00	5950	170	59	0.319	--	<2	--	--	--	--	3	--
07/20/00	3930	250	83	0.668	0.03	<2	--	--	--	--	4	--
08/28/00	3760	310	75	0.784	--	--	<1.0	<1.0	<1.0	7.2	5	6.6
09/07/00	3760	290	81	0.700	--	--	--	--	--	--	4	--

The following constituents were detected at DOE's background monitoring site CR-1(located upstream of the Moab Site and upstream of the Hwy 191 bridge; at the cement boat ramp): aluminum, ammonia, arsenic (very low), barium, boron, calcium, chloride, fluoride, gross alpha, gross beta, iron (unfiltered only), lithium, magnesium, manganese, molybdenum (very low), nickel (very low), nitrate, polonium-210, potassium, radium-226 (low), selenium, sodium, strontium, sulfate, TDS, uranium, vanadium, and zinc (very low). Constituents that were analyzed but not detected included antimony, beryllium, bismuth, cadmium, chromium, cobalt, elemental lead, lead-210, mercury, radium-228, radon-222, silver, thallium, thorium-230, phosphate, and tungsten. Detectable constituents and concentration ranges at background locations for samples collected during SMI and DOE sampling events from April 2000 through December 2002 are presented in Table 4 (reproduced from DOE 2003).

Table 4. Constituent concentration ranges collected immediately upstream of the Moab Site.

Constituent	Frequency of Detection	Range (mg/L except as noted)
Major Ions		
Calcium	16/16	46.3–141
Chloride	20/20	25.1–172
Magnesium	16/16	12.9–41
Potassium	16/16	2.1–5.3
Sodium	17/17	30.5–125
Sulfate	20/20	84.1–439
Total Dissolved Solids	12/12	430–1060
Minor Constituents		
Aluminum	9/12	0.008–0.14
Ammonia, total as N	9/20	Nd–0.134
Arsenic	8/11	Nd–0.002
Barium	13/13	0.051–0.14
Boron	4/10	Nd–0.123
Copper	3/13	Nd–0.0014
Fluoride	3/3	0.3–0.504
Gross Alpha	1/7	Nd–13.82*pCi/L
Gross Beta	2/7	Nd–13.78**pCi/L
Iron	6/9	Nd–4.17**
Lithium	1/3	Nd–0.0557
Manganese	8/18	Nd–0.076
Molybdenum	17/18	Nd–0.007
Nickel	7/10	Nd–0.002
Nitrate as NO3	6/6	0.776–5.51
Polonium-210	2/5	Nd–0.1142 pCi/L
Radium-226	5/5	0.12–0.23 pCi/L
Selenium	15/15	0.0013–0.0079
Strontium	10/10	0.965–1.63
Uranium	20/20	0.0023–0.008
Vanadium	11/11	0.0007–0.0031
Zinc	5/12	Nd–0.006

EFFECTS OF THE PROPOSED ACTION

Current Conditions

Surface contamination

In 2001, DOE began radiometric characterization of soils on the millsite. To date, the area north and northeast of the tailings pile have been assessed. Most of the site exhibits soil contamination exceeding EPA standards for radium-226. Exceptions are some small areas north of the tailings pile and one larger area northwest of the pile where a borrow pit was excavated and soils were used for pile surcharge (i.e., weight on the pile to squeeze out moisture) and for the interim cover. Shallow contamination was also identified north of US-191 on DOE property extending to the property line with Arches National Park.

Depths of contamination range from 6 to 120 inches. The area outside the tailings pile (i.e., the area of windblown contamination) is estimated to contain 71,000 yd^3 of contaminated soils. Measuring the depth of contamination with surface scanning and downhole logging instruments has inherent uncertainties; experience at other UMTRCA sites suggests that the final volume could exceed the volume characterized by a range of 50 to 100 percent.

On the basis of site knowledge and past UMTRCA site experience, DOE estimates that 11.9 million tons (8.9 million yd^3) of contaminated materials exist at the Moab Site and vicinity properties. Table 5 presents a summary of the contaminated materials and quantities present at the Moab Site and nearby vicinity properties. Additional investigations confirmed that most of the slimes are located in the center of the pile and are surrounded by sandy tailings.

Table 5. Contaminated Material Quantities

Source Material	**Volume (yd^3)**	**Weight (dry short tons)**
Uranium mill tailings	7,800,000	10,500,000
Pile surcharge	445,000	600,000
Subpile soil	420,000	566,000
Off-pile contaminated site soils	173,000	234,000
Vicinity property material	29,400	39,700
Total	**8,867,400**	**11,939,700**

The tailings pile at the Moab Site contains waste residuals from the milling operation. Milling involved both acid and carbonate processing methods (i.e., circuits). Lime was added to the tailings to neutralize the acid-milled tailings. Chemicals used in the processing, including acids, ammonia, and solvents, are incorporated with the silicate grains. Many other minerals, including sulfates and sulfides, are also present in lesser amounts. It is difficult to determine the residence time of the contaminants, although there is evidence that some exist as siliceous mixtures, and others may exist as sulfides, selenides, molybdates, and uranium minerals. Contaminants are also likely to be adsorbed to minerals, especially iron oxyhydroxides.

Bulk chemical analysis of the tailings solids indicates that high concentrations of ammonia, uranium, and radium-226 are present. The mean radium-226, ammonia (as N), and uranium concentrations for the tailings are 516 pCi/g, 423 milligrams per kilogram (mg/kg), and 84 mg/kg, respectively. The finer grained (slimes and silt) fractions have more radium-226 and uranium but less ammonia as (N) than the sand fraction. Other constituents, including iron, manganese, copper, lead, molybdenum, selenium, and vanadium, are present in lesser amounts. The pH values of the tailings are near neutral but have zones of pH values as low as 2.5 and as high as 10. The tailings have a small amount of acid-generating capacity in the form of sulfide minerals. The oxidation-reduction potential is not well defined by existing data, and conditions may vary spatially from relatively oxidizing to relatively reducing.

Mean tailings pore water concentrations for radium-226 and uranium are 61.1 picocuries per liter (pCi/L) and 15.1 mg/L, respectively. The average tailings pore water concentration for ammonia (as N) is 1,100 mg/L. Pore water is a mixture of residual milling fluids and water that infiltrated later into the tailings. The pore water appears to be relatively oxidized, although few data are available to assess oxidation-reduction potential. The pH value of the pore water is near neutral, and the mean TDS concentration is 23,500 mg/L. Values of pH, oxidation state, and availability of soluble minerals in the tailings are the main parameters that affect the composition of pore water. Concentrations of organic constituents used in the mill processing circuit are negligible in the pore water. Concentrations of all constituents are much higher in samples of water collected in a shallow-depth sump fed by pore water extracted from the tailings through wick drains than in any of the pore water samples collected from deeper SRK (2000) wells. Analyses of samples collected from the sump indicate the presence of a salt layer in the upper portion of the pile (DOE 2003).

Two underground septic tanks (size unknown) that supported past operations but are no longer used are located inside the radioactively contaminated portion of the site northeast of the historical warehouse. It is unknown if there are buried leach fields associated with these tanks. Organic contamination in soil and ground water samples was not detected by DOE in an analysis performed as part of the site characterization for the SOWP (DOE 2003a).

<u>Ground water contamination</u>

Ground water occurs in the bedrock formations and unconsolidated Quaternary material deposited on the floor of Moab and Spanish Valleys. The Navajo Sandstone, Kayenta Formation, and Wingate Sandstone of the Glen Canyon Group contain the principal bedrock aquifer in the region and locally are present only upgradient at the northern boundary of the site. The Navajo Sandstone of the Glen Canyon aquifer ranges in thickness from 300 to 700 ft (Doelling et al. 2002) and is the shallowest and most permeable formation in the Glen Canyon Group. Wells located 7 to 8 miles southeast of the site produce in excess of 1,000 gpm of high-quality water from the Navajo Sandstone for the city of Moab water supply.

Most of the freshwater in the basin-fill aquifer enters the site from Moab Wash and along geologic contacts between the alluvium and the Glen Canyon Group bedrock present at the north boundary of the site. The bedrock in this area is highly fractured and faulted from incipient collapse of the Moab anticline caused by dissolution of the underlying Paradox Formation salt core of the anticline.

Ground water elevation contours east of the Colorado River in the Matheson Wetlands Preserve based on March 2003 water elevation measurements indicate ground water flow toward the river. Elevation contours indicate that freshwater entering the site at the northern boundary flows south toward the river over the top of a deeper natural brine zone.

The deeper brine water results mostly from dissolution of the underlying salt beds of the Paradox Formation present beneath most of the site. Figure 4 presents a conceptual model of the subsurface hydrogeology along a representative streamline showing the interface between the deeper saltwater system and the overlying freshwater system. The saltwater interface is defined at the 35,000-mg/L TDS boundary. The transition from the saltwater to the freshwater system occurs over a short vertical distance and is, therefore, referred to as being "sharp." The vertical position of the interface is in equilibrium because the buoyant force exerted by the brine is balanced by the weight of the overlying freshwater. In natural systems, little, if any, freshwater penetrates saltwater at the interface. The freshwater can be thought of as a liquid that "floats" upon a buoyant saltwater liquid. At the Moab Site, the interface extends across the site in a wedge shape, in which the deepest part of the interface is near the northwest boundary, and the shallowest depth is near the river. The position of the interface near the river is in dynamic equilibrium and probably shifts laterally and vertically in response to evapotranspiration by the tamarisk plant communities and the stage of the Colorado River. The interface may also shift vertically upward as a result of pumping from the shallow freshwater (e.g., during a pump-and-treat remediation) and cause the saltwater to rise to a higher elevation and intrude the freshwater. Saltwater intrusion would result in degradation of the overlying freshwater, which could adversely affect the tamarisk plant communities which are presumed to provide some beneficial phytoremediation at the site.

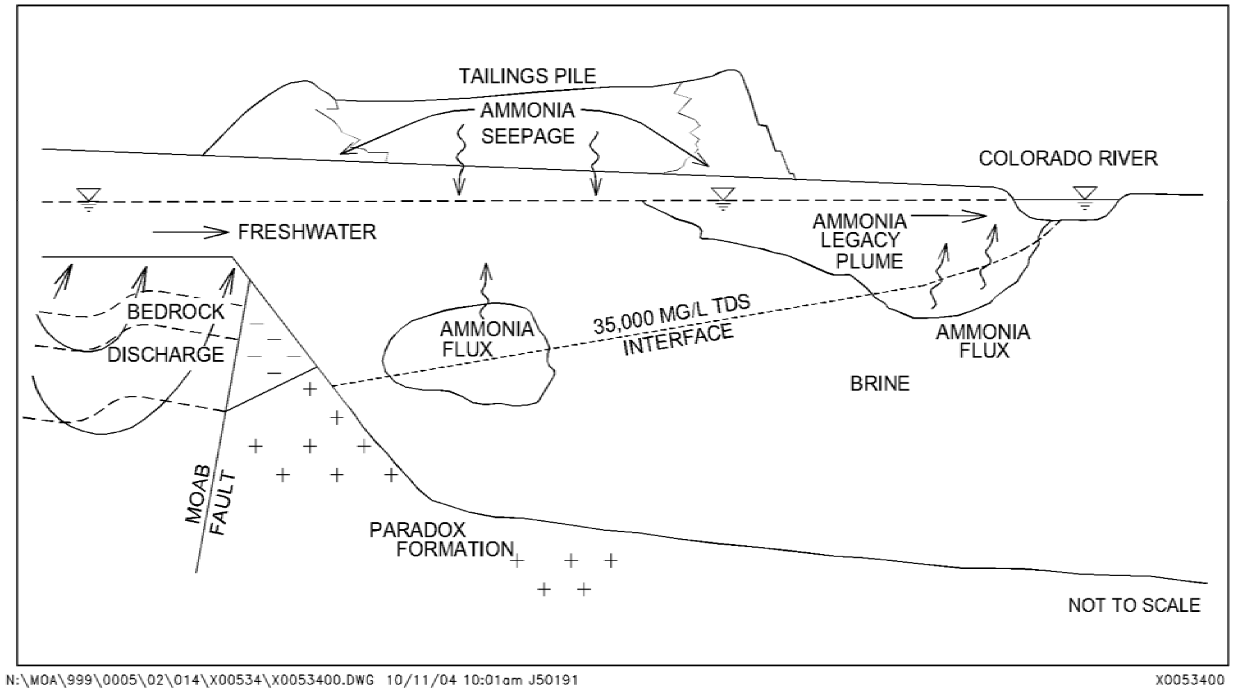

Figure 4. Conceptual Model, Saltwater/Freshwater Interface

Rising saltwater may also bring higher ammonia and salt concentrations to the surface and cause added contamination flux to the river. Low pumping rates and proper extraction well construction and pump location may prevent saltwater intrusion. Additional information on the hydrogeology of the site is presented in the SOWP (DOE 2003a).

Additional recharge to the site occurs through precipitation. The Paradox Formation is believed to be an impermeable boundary (bedrock aquitard) and does not contribute to the site water budget. An estimate of the annual steady-state water budget for each hydrologic component of the system is presented in Table 6. Short-term transient effects such as the small positive contribution to bank storage by recharge from the Colorado River during periods of high flow are not included. The estimates are represented with a large range of individual values, and the ranges of the total inflow and total outflow do not overlap, reflecting the uncertainty of the values and suggesting that the true water budget might lie between the two ranges. The SOWP (DOE 2003a) provides additional discussion of the ground water hydrology and water budget of the site.

Table 6**. Estimated Annual Water Budget for the Moab Site**

Flow Component	**Inflow (gpm)**	**Outflow (gpm)**
Areal Precipitation	16–65	N/A
Moab Wash	0.5–33	N/A
Glen Canyon Group	28–280	N/A
Tailings Pile	20	N/A
Evapotranspiration	N/A	200–500
Colorado River	N/A	300–600
Total	**65–400**	**500–1,100 (rounded)**

N/A = not applicable.

Ground Water Quality - The basin-fill aquifer underlying the site is divided into three hydrochemical facies: (1) an upper fresh to moderately saline facies (fresh Quaternary alluvium [Qal]) that has concentrations of TDS up to 10,000 mg/L, (2) an intermediate facies of very saline water (saline Qal), having TDS concentrations between 10,000 and 35,000 mg/L, and (3) a lower briny facies (brine Qal) that has TDS concentrations greater than 35,000 mg/L. All three facies existed beneath the site prior to milling activities. The SOWP (DOE 2003a) provides additional discussion of ground water geochemistry and water quality at the site.

The freshwater quickly becomes mixed with more saline water in the basin-fill aquifer as it enters the site from Moab Wash and flows toward the Colorado River. Salinity naturally increases with depth and distance from the freshwater source contribution from Moab Wash. Mixing of the two background water types (fresh upgradient water with the deeper depth saline water) influences the background water quality at the site. The result is a background water quality in the basin-fill aquifer that is highly variable both vertically and horizontally across the site.

Background conditions in the upper fresh Qal facies are characterized by low concentrations of uranium and other trace metals that are all below the EPA standards in 40 CFR 192. TDS concentrations range from 677 to 7,820 mg/L, which classifies the water quality as fresh to slightly saline. Background alkalinity as calcium carbonate ranges from 137 to 189 mg/L. There is no EPA standard for ammonia in 40 CFR 192. Ammonia–N concentrations are less than 1 mg/L. Sulfate concentrations range from 180 to 1,140 mg/L. Calcium concentrations range from 47 to 294 mg/L. Magnesium concentrations range from 31 to 188 mg/L. On average, the pH value of the upper fresh Qal facies is near neutral (7.7), and the redox condition is slightly oxidizing (oxidation-reduction potential is 186 millivolts [mV]).

Ground water concentration limits for arsenic, barium, cadmium, chromium, lead, mercury, molybdenum, nitrate, selenium, silver, uranium (combined U-234 and U-238), gross alpha (excluding radon and uranium), and radium (combined radium-226 and radium-228) are regulated by EPA standards (40 CFR 192). Of these constituents, the maximum concentrations detected for arsenic, cadmium, uranium, radium, gross alpha, nitrate, selenium, and molybdenum exceed EPA standards. The remaining regulated constituents (barium, chromium, lead, mercury, and silver) are all present at relatively low concentrations below EPA standards.

The areal distribution of uranium concentrations greater than 0.044 mg/L, interpolated and contoured on the upper surface of the ground water, were presented in the DEIS and depicted in Figure 3-10 of that document. The highest uranium concentrations are in the shallow ground water in the former millsite area. Cross-sectional views of the uranium plume and additional isoconcentration maps of uranium as a function of depth are provided in the SOWP (DOE 2003a). SMI (2001) suggested that the high uranium concentrations beneath the millsite are caused by waste leaking from the former wood chip disposal areas. Although the uranium plume is in an area where wood chip disposal was likely to have occurred, lithologic logs of borings installed in this area of the site do not indicate that they penetrated through the wood chip pits. Another possible source of the high uranium concentrations is the uranium ore stockpiles; however, samples collected from monitor wells nearest the largest known ore stockpiles have lower uranium concentrations. Whether the source of the high uranium concentrations in ground water samples is the wood chip pits, the ore stockpiles, or some other millsite-related release, it seems that some of the ground water contamination originates in the millsite area, independently of the tailings pile.

Although ammonia has no EPA standard in 40 CFR 192, it occurs at concentrations significantly greater than natural background, is one of the most prevalent contaminants in the ground water, and is the constituent of greatest ecological concern that is discharging to the Colorado River in backwater areas adjacent to the site. The areal distribution of ammonia concentrations greater than 50 mg/L, interpolated and contoured on the upper surface of the ground water, is presented in the DEIS and depicted in Figure 3-11 of that document. The highest concentrations in the shallow ground water, greater than 500 mg/L, appear near the down gradient edge of the pile and extend to and discharge to the Colorado River. The highest ammonia concentrations in surface water samples are detected in samples collected closest to the riverbank adjacent to the tailings pile and immediately downstream of Moab Wash. A comparison of ground water data with surface water data shows that, with few exceptions, concentrations of site-related constituents are much lower in the surface water than in the ground water. Ammonia concentrations in the river are approximately 2 orders of magnitude lower than in the ground water. Although available data are not adequate to establish an accurate dilution factor, these data do suggest that at least order-of-magnitude decreases in constituent concentrations can be expected as ground water discharges to the river. DOE recognizes that isolated pools or very shallow areas may be exceptions to this dilution, and claim that these may not be important aquatic habitats, as they are frequently cut off from the river and dry up, and fish mortality would be as likely from habitat limiting factors (e.g. physical factors and predation). The USFWS considers shallow areas ($\geq$2.5cm in depth) in backwaters and along the margin of flowing channels as habitats used by young native fish. If these shallow habitats are not subject to habitat limiting factors, they can potentially be very important to early life stages of endangered fish and therefore lower dilution rates could be harmful.

Relatively high ammonia concentrations in ground water also occur at depth beneath the tailings pile. During milling operations, the tailings pond contained fluids with TDS concentrations ranging from 50,000 to 150,000 mg/L. Because these salinities exceed 35,000 mg/L, they had sufficient density to migrate vertically downward through the freshwater system and into the brine. This downward migration of the tailings pond fluids into the saltwater system is believed to have created a reservoir of ammonia that now resides below the saltwater interface. This ammonia plume below the interface probably came to rest at an elevation where it was buoyed by brine having a similar density. Under present conditions, the ammonia plume beneath the saltwater interface represents a potential long-term source of ammonia to the freshwater system. The conceptual model presented in Figure 4 illustrates the ammonia source at the saltwater interface (basal flux), the legacy plume, and seepage of ammonia from tailings pore fluids.

Surface water contamination

Analytical results of samples collected adjacent to the site were compared to background concentrations and aquatic benchmarks to develop a list of contaminants of potential concern. The analytical results confirmed that ground water discharge from the Moab Site has caused localized degradation of surface water quality. As a result of that evaluation, ammonia, copper, manganese, sulfate, and uranium are considered contaminants of concern.

Concentrations of contaminants of potential concern in surface water samples vary widely, depending on sampling locations and river flow conditions. Concentrations are most likely to be elevated during periods of average to low river stages in areas where water is shallow and slow moving or pooled. Concentrations are also highest immediately adjacent to the riverbank. The constituents with concentrations that are most consistently elevated in samples from the Colorado River are ammonia and uranium. These will be discussed as indicators of site-related contamination. DOE reports ammonia concentrations as high as 300 mg/l detected in samples from areas next to the riverbank immediately downstream of Moab Wash.

Low river flows expose greater portions of the Moab Wash sandbar, creating increased backwater areas that allow for higher concentrations of ammonia in the surface water. However, a study completed in 2000 (SMI 2001) determined that during high flows, backwater areas are eliminated near the site, and ammonia concentrations near the shore are diluted to protective levels (within EPA's recommended total ammonia protection criteria), or loading is temporarily stopped by river water flowing into the aquifer because of the seasonally high river stage. This finding suggests that snowmelt runoff periods (May and June) may temporarily reduce the ammonia concentration in the Colorado River.

Because ground water gradients on both sides flow toward the river, it is likely that the presence of the ground water brine affects surface water quality. However, because process fluids disposed of in the former tailings pond contained some of the same constituents that occur in natural brines, distinguishing between naturally occurring constituents and site-related constituents in surface water is not straightforward. Increases in sodium, chloride, or dissolved solids content of river water (among other constituents) in the vicinity of the site, compared to background concentrations, could be a result of discharge of either site-related contaminated ground water or natural brines.

Toxic effects of ammonia

The toxic effects of ammonia to aquatic species are well documented. Thurston et al. (1983) documented that acute toxicity, as the 96-hour median lethal concentration (LC50), occurred in fathead minnow (*Pimephales promelas*) at ammonia concentrations ranging from 0.75 to 3.4 mg/l un-ionized ammonia (34-108 mg/l total ammonia nitrogen). DeGraeve et al. (1980) reported a 96-hour LC50 of 1.59 mg/l un-ionized ammonia for fathead minnow. Ammonia toxicity has been reported for numerous other nonsalmonid fishes. LC50's ranged from 0.14 to 4.2 mg/l un-ionized ammonia for these fishes (Thurston et al. 1983).

The documented chronic effects of ammonia toxicity include reduced growth rate (Rice and Bailey 1980, Burkhalter and Kaya 1977, Broderius and Smith 1979, McCormick et al. 1984, Robinette 1976, Smith 1972, Smith and Piper 1975, Smith et al. 1984, Swigert and Spacie 1983), reduced gamete production, body deformities and malformations (Smith 1984), and degenerative gill and kidney appearance and function (Burkhalter and Kaya 1977, Fromm 1970, Smart 1976, Thurston et al. 1978). Reported ammonia concentrations found to reduce growth rates, retard growth, reduce gamete production, or decrease body weight, ranged from 0.0024 mg/l, to 0.49 mg/l.

USGS conducted a site-specific risk assessment to determine if ground water entering the Colorado River from beneath the tailings pile could affect the endangered Colorado pikeminnow and razorback sucker (USGS 2002). Results indicate that during the low-flow period from August to March, ammonia levels exceed State of Utah standards. The area of contamination varies with hydrologic regime but in general is confined to an area less than 6,000 square yards (yd2). USGS found that the highest observed concentrations of ammonia occur at river flows of less than 5,000 cfs during the late summer, fall, and winter months. Flows above 5,000 cfs dilute ammonia concentrations to levels below those of toxicological concern.

Toxicity tests performed as part of the USGS risk assessment indicated that Colorado pikeminnow, razorback sucker, and fathead minnow had a 28-day lowest observed effect concentration (LOEC) value for mortality ranging from 2.19 to 4.35 mg/L total ammonia (pH = 8.25 and temperature = 25 ^{o}C). USGS estimated effects on individuals at concentrations as low as 0.17 mg/L un-ionized ammonia. Toxicity tests also indicate there were no differences in toxicity across pH within a given temperature. They found that Colorado pikeminnow were more sensitive to ammonia at lower temperatures (8^{o} C) than at an average condition (18^{o} C). On-site toxicity tests in low or no flow areas demonstrated that site waters were directly toxic to both the endangered Colorado pikeminnow and the fathead minnow.

Analyses for Effect of the Action and Species Response to the Proposed Action

DOE has indicated that many of the details of their preferred alternative will be determined after filing a Record of Decision and therefore the following effects analysis is based on DOE’s characterization of project effects as presented in their biological assessment.

We relied heavily on supplemental information presented in the EIS (DOE 2004) and SOWP (DOE 2003a) documents to assist in our analysis. In addition, we relied on information provided through the Upper Colorado River Endangered Fish Recovery Program, studies conducted by USGS (USGS 2002), University of Utah (Gardner and Solomon 2003, 2004) and comments provided by various agencies on the DEIS to complete our analyses.

Actions at the Moab Site:

Mechanical Disturbance. The impact to aquatic species due to construction and operations at the Moab Site would be from mechanical disturbances and loss of vegetation along the shoreline of the Moab Wash and Colorado River. Activities at the Moab Site would likely disturb about 8,100 ft of Colorado River shoreline. The vegetation along the shoreline of the tailings pile, consisting primarily of tamarisk, would be removed in order to excavate and remove contaminated materials (i.e., soils contaminated with residual radioactive material). The tamarisk along the banks of Moab Wash as it enters the Colorado River would likely be removed as well.

The effects of mechanical disturbance would include the loss of shade and cover over the shoreline and potentially a loss of surface stability that could lead to increased erosion and siltation into the wash and river. Impacts to threatened and endangered species due to these changes would be minimal. The shade and cover provided by the tamarisk is only along the edge of the river during high and moderate flows of the river. At low river flows, the shoreline vegetation provides no shade, and the flow into the wash is cut off. The potential also exists for water intake structures in the river to result in mortality to eggs, larvae, young-of-the-year, and juvenile life stages. DOE would minimize this potential by using one-quarter to three-eighths-inch screened mesh on water intake structures.

Effects from siltation and erosion into the river and wash could fill in backwater areas that may be important to macroinvertebrates and fish. Moab Wash has been documented as potential pikeminnow nursery habitat that could be affected by siltation and erosion (NPS 2003). Erosion along the river shoreline could create new backwater areas, but these would likely be temporary based on river stage.

Federally listed species that could be affected by the changes to the shoreline include the endangered Colorado pikeminnow, razorback sucker, humpback chub, and bonytail. The Colorado River reach near the Moab Site has been designated as critical habitat (50 CFR 17.95) for two of the endangered fish: Colorado pikeminnow and razorback sucker. Juvenile and adult Colorado pikeminnow and stocked adult razorback sucker and bonytail have been collected near the Moab Site. Moab Wash and the riparian vegetation adjacent to the Colorado River potentially provide nursery habitat for young-of-the-year fish (NRC 1999, NPS 2003, UDWR 2003a). Erosion and siltation events that change the depth and configuration of these backwater areas are likely to diminish the quantity and quality (amount of available food items) of nursery habitats for endangered fish. Other fish, macroinvertebrates, and emergent plants associated with the backwater areas are also likely to be affected by erosion and siltation. DOE intends to prevent or reduce the effects of erosion by minimizing shoreline disruption, replacing vegetation, and installing erosion control devices. The USFWS sees these effects to physical habitat as short term in nature. Whereas, a temporary loss of a specific nursery habitat could result in some level of take of the species, we would assume displacement downstream to the next suitable habitat alone (i.e. without the added impact of exposure to elevated levels of surface water contamination) would not adversely affect these early life stages.

Noise. Noise from site construction and operations is not expected to affect the aquatic environment. Activities along the shoreline are likely to be of short duration and are not likely to cause macroinvertebrate or fish communities to avoid the area.

Other Human Disturbances. Aspects of human presence such as personnel or vehicle movement and supplemental lighting are not expected to affect the aquatic environment.

Water Depletions. Water depletion in the Colorado River as a result of remediation of the Moab Site would jeopardize the endangered Colorado River fishes. In accordance with the Cooperative Agreement to implement the "Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin" (USFWS 1987) all Section 7 consultations address depletion impacts. A key element of the program requires a one-time contribution of $16.30 per ac-ft (adjusted annually for inflation) based on the average annual depletion through activities at the site, to be paid to USFWS. DOE has identified an average annual depletion of 235 ac-ft / year. Depletions less than 4500 ac-ft/yr are considered "small depletions" by the Recovery Implementation Program. Depletion impacts to the Colorado River endangered fish from the proposed action will be addressed in the Conclusion section of this biological opinion.

<u>Effects of Off-site Disposal at the Crescent Junction Site</u>

We concur with DOE's determination that their off-site disposal alternative (excluding the ground water remediation component) may affect but is not likely to adversely affect the Colorado River fish with the exception of the effects associated with the Colorado River depletions. Water depletions reduce the ability of the river to create and maintain important habitats and reduce the frequency and duration of availability of these habitats. Food supply, predation, and competition are important elements of the biological environment. Food supply is a function of nutrient supply and productivity. High spring flows inundate bottomland habitats and increase the nutrient supply and productivity of the river environment. Reduction of high spring flows from water storage reservoirs that store water during spring peak flows may reduce food supply. The effects of Colorado River depletions will be addressed separately in the Conclusion section.

DOE compared and contrasted the relative effects to the environment from disposing surface contamination on-site versus off-site in their DEIS. Several uncertainties were associated with capping the mill tailings onsite, including: the threat of the release of contaminants due to river flooding and river migration; the future dissolution of ammonia salts associated with the pile. As portrayed in the DEIS those uncertainties would be significantly reduced under an off-site disposal alternative. The USFWS recognizes that even after surface contaminants at the Moab Site were removed and the Moab Site was reclaimed to EPA standards future river channel avulsion could result in the release of some contamination to the surface flows of the Colorado River. However the USFWS believes that off-site disposal of surface contamination at the Moab Site, as proposed by DOE, represents the most conservative approach to protecting listed species and their habitat.

In their biological assessment, DOE indicates that further study of the site and the transportation method selected would be required to fully address all endangered species concerns. As DOE continues to develop their RAP, the USFWS will determine if further Section 7 consultation is needed.

Effects Associated with the Ground Water Remediation Program

DOE proposes an active ground water remediation program as part of their preferred alternative. All remediation activities would occur within the existing millsite boundary. DOE estimates that the active remediation system would extract and treat ground water for 75 years to maintain surface water quality goals.

DOE and the USFWS, in discussions during the summer of 2003, agreed to an ammonia-based groundwater remediation goal of 3mg/l. The USFWS conferred with the USGS on this ground water remediation target in January, 2004. In his email response to our inquiry dated January 8, 2004, Mr. James Fairchild, USGS, Research Ecologist, concurred that the 3mg/l ammonia target was reasonable based on information that suggested the ground water pH would be around 7.2 which should decrease the uninonzed fraction. In addition there should be some microbial activity to oxidize the ammonia to nitrate. Mr. Fairchild's concern, however, was that a "goal" is not the same as a statutory criteria. The 3-mg/L concentration represents a 2- to 3-order-of-magnitude decrease in the center of the ammonia plume and is expected to result in a corresponding decrease in surface water concentrations. The overall groundwater remediation goal is expected to put DOE in compliance with the acute and chronic benchmarks based on ambient pH and temperature as stipulated in the National Recommended Water Quality Criteria (NWQC) (EPA 2002) and currently proposed Utah Water Quality Standards (UAC 2003, UDEQ 2003). The groundwater target, coupled with DOE's estimated average 10-fold dilution as groundwater mixes with surface water is expected to result in compliance with both acute and chronic ammonia standards in the river everywhere adjacent to the site. Potential synergistic effects between contaminants would be reduced through ground water remediation. Continued monitoring during active ground water remediation would be necessary to verify that contaminant concentrations remained below both acute and chronic benchmarks for aquatic species.

DOE has determined, and the Service concurs, that during the pre-remediation phase, critical habitat for the Colorado pikeminnow and the razorback sucker would likely continue to be adversely modified by historical contamination. The following endangered fish species and their life stages are most likely to be directly and adversely affected by site-related contamination: Colorado pikeminnow (all life stages with emphasis on drifting larvae and young-of-the-year), razorback sucker (stocked juveniles and adults, and naturally produced larvae and young-of-the-year) and bonytail (stocked juveniles and adults, and naturally produced larvae and young-of-the-year) (USFWS 2004a). The closest population of humpback chub occurs 60 miles downriver in Cataract Canyon and could be affected by a large release of surface contaminants. Under the most extreme catastrophic release of surface contaminants (prior to completion of off-site disposal) the USFWS believes there could be lethal effects in Cataract Canyon. Conversely, we do not believe current levels of ground water contamination are causing measureable effects there.

DOE, in consultation with USFWS, has implemented and will continue to implement initial and interim actions to reduce the potential for “take” until the selected remedial action and methods are fully implemented. The time frame required for the selection and implementation of remedial actions and methods, during which the take could occur, is anticipated to be a maximum of 10 years from the date of the ROD. A reduction in contaminant concentrations in surface water could be observed significantly sooner than the 10-year time frame as a result of interim actions.

DOE predicts that during the remediation and post-remediation phases of ground water remediation effects on fish species and associated critical habitat would likely be insignificant or neutral. The USFWS will rely on ground water and surface water monitoring to determine if remediation goals are met. USFWS would be consulted at least annually on the results of monitoring.

In their biological assessment, DOE addressed the effects of flooding on ground water remediation. Catastrophic flooding could affect the aquatic environment by flooding the ground water remediation systems. The interim action and proposed ground water remediation includes wells or shallow trenches located between the foot of the pile and the river’s edge. The location for these systems is in the 100-year floodplain. If a flood were to inundate the remediation systems, ground water with contaminant concentrations exceeding the aquatic benchmarks could pass through the region toward the river. DOE expects that remediation and monitoring systems would be quickly restored after the flood waters receded. In the event of any disruption in groundwater remediation operations DOE will notify the USFWS and both agencies will determine how to proceed.

The Service and DOE recognize several areas of uncertainty associated with ground water remediation. DOE’s conceptual model does not account for site related contaminants affecting habitats on the south side of the river, i.e. the Matheson Wetland Preserve. In a recent effort to describe the water budget at the Scott M. Matheson Wetland Preserve, Gardner and Solomon (2004) developed studies to quantify and investigate: (1) sources of water to the wetland, (2) seasonal changes in hydrologic patterns, (3) bulk wetland evapotranspiration, and (4) the hydrologic connection between the wetland an the Moab Mill Tailings. Field studies were conducted from the fall of 2002 to the spring of 2004. Uranium and ammonia concentrations were sampled along with an analysis of tritium, oxygen, and deuterium isotopic ratios to explore groundwater connectivity between the wetland and the mill tailings directly across the river. Gardner and Solomon concluded that brines sourced from across the river had migrated beneath the river in the highly permeable channel gravels. They claimed that brine migration was further substantiated by the uranium distribution, which was coincident with equivalent freshwater head gradients (EFH) during the summer of 2003. Dr. Solomon (personal communication via electronic mail of May 3, 2005) recognized uncertainty in their EFH analysis and in their report the authors were uncertain whether the passage of fluids beneath the river through highly conductive channel deposits is ongoing or a response to discontinuous driving forces (seasonal or otherwise). Regardless, they concluded that fluids, at some point in time, migrated from north to south beneath the Colorado River.

The DOI referenced Gardner and Solomon's report in our comments to DOE on their draft EIS. DOE provided a critique of Gardner and Solomon (2004) in their response to DOI's comments. In their critique, DOE took exception to the author's conclusions based on their own investigations into groundwater flow at the Moab Site. DOE does, however, agree with the authors of the report and the USFWS that this is an area of uncertainty that warrants further investigation.

The State of Utah DEQ maintains that there is sufficient information currently available to support a ground water remediation goal that is consistent with the chronic ammonia standard of 0.6 mg/l total N as opposed to the acute standard of 3 mg/l. In their EIS comment letter to DOE dated February 17, 2005, they explain their position as follows:

> *Mixing Zone Premise: Lack of Turbulent Flow – acute standards are applied to surface water quality problems under the assumption that 1) open channel turbulence will provide for a mixing zone to dilute or otherwise reduce the contaminant concentrations from a point source discharge, and 2) the mixing zone will be limited in its dimensions relative to the river's channel, i.e., less wide than the river channel and limited in longitudinal length (see Utah Water Quality Rules, UAC R317-2-5). However, the backwater areas in question only access the river channel at the habitat's downstream end. Hence, there is no open channel turbulence inside the backwater area. Instead, the backwater areas are recharged by infiltrating groundwater from the bank, or by river water infiltrating thru the barrier sand bar. Both of these sources of recharge constitute laminar flow and not turbulent conditions. Hence the acute standard is not applicable to an environment where water flow is largely laminar.*
>
> *Avoidance Behavior Assumption – another critical assumption in the application of acute standards to surface water quality problems is that adult fish can avoid the toxicity of the mixing zone by swimming around it (avoidance behavior). However in the case of the backwater areas in questions, larval fish that will be deposited there by the currents do not have the capability to resist moving water. Consequently, they cannot exhibit any avoidance behavior. Given these circumstances only the chronic standard is appropriate, 0.6 mg/l.*
>
> *Exposure Time and Dilution Criteria – the acute standards are designed for a 1-hour exposure to the fish (see Utah Water Quality Rules, UAC R317-6-2, Table 2.14.2). In contrast the chronic standard is designed for a 4-hour exposure period (ibid.). In the case of the backwater areas, the habitat will serve as a nursery for the larval fish in question. Consequently, they will reside there for weeks if not months. As a result, only the chronic standard, 0.6 mg/l, is applicable. For these reasons, the chronic ammonia-nitrogen*

> *standard must be applied to the backwater habitats in question. We understand that water quality monitoring of these backwater areas is challenging, largely due to their transient nature; and that therefore it is preferred to monitor groundwater quality as a means of verifying compliance. We have also concluded that the DOE evaluation of the transfer mechanism between groundwater and the backwater areas is incomplete. Errors have also been found in DOE's claim for a 10-fold groundwater to surface water dilution factor. These errors are discussed in detail below. Until these errors are resolved, and without confirmation on how dilution, dispersion, retardation, or biologic decay will reduce the ammonia concentrations during this groundwater to surface water transition, it is conservative and protective of the environment to apply the chronic (0.6 mg/l) standard as a groundwater cleanup goal.*

In their EIS comments, UDEQ called into question DOE's calculations of the dilution factor. UDEQ suggested that a better understanding of the time dependent dynamic between ground water / surface water interactions as a function of river stage is required. It was UDEQ's contention that insufficient quality assurances were applied to the data used to develop the dilution factor. UDEQ further cautioned that the amount of variability associated with the data used to develop the dilution factor in backwater habitats was considerable and suggested non-normal distribution. They advised further study of these issues.

The USFWS has considered all of UDEQ's comments in our analysis of the effects to listed species associated with ground water remediation and we agree that many warrant further study (see Incidental Take Statement). Based on our review of the available information, and with recognition that there are uncertainties in both DOE's and UDEQ's analyses, the Service has determined that DOE's premise that 3mg/l ammonia in groundwater will result in protective concentrations in all surface water habitats presents a reasonable approach to the problem.

Another basic premise of DOE's groundwater remediation program is the assumption that if ammonia concentrations are reduced to protective levels the other contaminants of concern will be reduced as well. In their comments on the EIS, USEPA points out that this assumption remains relatively untested and that the other constituents of concern have different solution chemistries and sorptive characteristics and consequently are likely to have different fate and transport projections. The USFWS agrees that this assumption warrants further investigation, which we address in our Incidental Take Statement.

Cumulative Effects

Cumulative effects include the effects of future State, local or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to secton 7 of the Endangered Species Act. In the action area, the Colorado River flows mostly through federal land. We are unaware of future state or private actions that are in the planning that would not require Section 7 consultation. For this reason, no cumulative effects are anticipated on the endangered species or designated critical habitat in the action area.

CONCLUSION

Project Depletions of the Colorado River

After reviewing the current status of the Colorado River fish, the environmental baseline for the action area, the effects of the proposed action and the cumulative effects, it is the USFWS's biological opinion that average annual depletions of 235 ac-ft of Colorado River water will jeopardize the continued existence of the Colorado pikeminnow, humpback chub, bonytail, and razorback sucker will likely result in destruction or adverse modification of critical habitat. The USFWS has developed the following reasonable and prudent alternative to deal with water depletion impacts to the four endangered Colorado River fishes.

Reasonable and Prudent Alternative

On January 21-22, 1988, the Secretary of the Interior; the Governors of Wyoming, Colorado, and Utah; and the Administrator of the Western Area Power Administration were cosigners of a Cooperative Agreement to implement the "Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin" (USFWS 1987). An objective of the Recovery Program was to identify reasonable and prudent alternatives that would ensure the survival and recovery of the listed species while providing for new water development in the Upper Basin.

The following excerpts are pertinent to the consultation because they summarize portions of the Recovery Program that address depletion impacts, section 7 consultation, and project proponent responsibilities:

"All future Section 7 consultations completed after approval and implementation of this program (establishment of the Implementation Committee, provision of congressional funding, and initiation of the elements) will result in a one-time contribution to be paid to the USFWS by water project proponents in the amount of $10.00 per ac-ft based on the average annual depletion of the project . . . . This figure will be adjusted annually for inflation [the current figure is $16.30 per ac-ft] . . . . Concurrently with the completion of the Federal action which initiated the consultation, e.g., . . . issuance of a 404 permit, 10 percent of the total contribution will be provided. The balance will be …due at the time the construction commences . . . ."

It is important to note that these provisions of the Recovery Program were based on appropriate legal protection of the instream flow needs of the endangered Colorado River fishes. The Recovery Program further states:

". . . it is necessary to protect and manage sufficient habitat to support self-sustaining populations of these species. One way to accomplish this is to provide long term protection of the habitat by acquiring or appropriating water rights to ensure instream flows . . . . Since this program sets in place a mechanism and a commitment to assure that the instream flows are protected under State law, the USFWS will consider these elements under Section 7 consultation as offsetting project depletion impacts."

Thus, the USFWS has determined that project depletion impacts, which the USFWS has consistently maintained are likely to jeopardize the listed fishes, can be offset by (a) the water project proponent's one-time contribution to the Recovery Program in the amount of $16.30 per ac-ft of the project's average annual depletion, (b) appropriate legal protection of instream flows pursuant to State law, and accomplishment of activities necessary to recover the endangered fishes as specified under the Recovery Implementation Program Recovery Action Plan. The USFWS believes it is essential that protection of instream flows proceed expeditiously, before significant additional water depletions occur.

With respect to (a) above (i.e., depletion charge), the applicant will make a one-time payment which has been calculated by multiplying the project's average annual depletion (235 ac-ft) by the depletion charge in effect at the time payment is made. At the time of this consultation, DOE has identified a range of depletions (130-235 ac-ft) associated with the proposed action; a final depletion figure will be developed as they develop their RAP. We recommend that DOE pay the depletion charges as soon as the final depletion amount is determined. For Fiscal Year 2005 (October 1, 2004, to September 30, 2005), the depletion charge is $16.30 per ac-ft for the average annual depletion which equals a total payment of $ 3,830.50 for this project. This amount will be adjusted annually for inflation on October 1 of each year based on the previous year's Composite Consumer Price Index. The USFWS will notify the applicant of any change in the depletion charge by September 1 of each year. Ten percent of the total contribution ($383), or total payment, will be provided to the USFWS's designated agent, the National Wildlife Foundation at the time of issuance of the Federal approvals from the Department of Energy. The balance will be due at the time the construction commences. The payment will be included by the DOE as a permit stipulation. Fifty percent of the funds will be used for acquisition of water rights to meet the instream flow needs of the endangered fishes (unless otherwise recommended by the Implementation Committee); the balance will be used to support other recovery activities for the Colorado River endangered fishes. All payments should be made to the National Fish and Wildlife Foundation.

National Fish and Wildlife Foundation
28 Second Street, 6th Floor
San Francisco, California 94105

Each payment is to be accompanied by a cover letter that identifies the project and biological opinion that requires the payment, the amount of payment enclosed, check number, and any special conditions identified in the biological opinion relative to disbursement or use of the funds (there are none in this instance). The cover letter also shall identify the name and address of the payor, the name and address of the Federal Agency responsible for authorizing the project, and the address of the USFWS office issuing the biological opinion. This information will be used by the Foundation to notify the payor, the lead Federal Agency, and the USFWS that payment has been received. The Foundation is to send notices of receipt to these entities within 5 working days of its receipt of payment.

In order to further define and clarify processes outlined in sections 4.1.5, 4.1.6, and 5.3.4 of the Recovery Program, an additional section 7 agreement and Recovery Plan addressing section 7 consultation on depletion impacts was developed (USFWS 1993b). The section 7 agreement establishes a framework for conducting all future section 7 consultations on depletion impacts related to new projects and those associated with historic projects in the Upper Basin. Procedures outlined in the section 7 agreement will be used in conjunction with the Recovery Plan to determine if sufficient progress is being accomplished in the recovery of the endangered fishes to enable the Recovery Program to serve as a reasonable and prudent alternative to avoid jeopardy. The Recovery Plan was finalized on October 15, 1993, and is reviewed annually.

In accordance with the agreement, the USFWS has agreed to assess impacts of projects that require section 7 consultation and determine if progress toward recovery has been sufficient for the Recovery Program to serve as a reasonable and prudent alternative. If sufficient progress is being achieved, biological opinions will be written to identify activities and accomplishments of the Recovery Program that support it as a reasonable and prudent alternative. If sufficient progress in the recovery of the endangered fishes has not been achieved by the Recovery Program, actions from the Recovery Plan will be identified which must be completed to avoid jeopardy to the endangered fishes. For historic projects, these actions will serve as the reasonable and prudent alternative as long as they are completed according to the schedule identified in the Recovery Plan. For new projects, these actions will serve as the reasonable and prudent alternative so long as they are completed before the impact of the project occurs. The Atlas mill tailings reclamation project is considered a new project.

The evaluation by the USFWS to determine if sufficient progress has been achieved considered (a) actions which result in a measurable population response, a measurable improvement in habitat for the fishes, legal protection of flows needed for recovery, or a reduction in the threat of immediate extinction; (b) status of fish populations; adequacy of flows; and (d) magnitude of the project impact. In addition, the USFWS considered support activities (funding, research, information and education, etc.) of the Recovery Program if they help achieve a measurable population response, a measurable improvement in habitat for the fishes, legal protection of flows needed for recovery, or a reduction in the threat of immediate extinction. The USFWS evaluated progress separately for the Colorado River and Green River subbasins; however, it gave due consideration to progress throughout the Upper Basin in evaluating progress toward recovery.

Based on current Recovery Program accomplishments and the expectation that the Recovery Plan will be fully implemented in a timely manner, the USFWS determined that sufficient progress has been achieved under the Recovery Program so that it could serve as the reasonable and prudent alternative to avoid jeopardy to the endangered fishes by the impacts caused by the water depletion associated with this permit. For historic projects, the responsibility for implementation of all elements of the reasonable and prudent alternative rests with the Recovery Program participants, not the individual project proponent. All actions must be implemented according to the time schedule specified in the Plan. For new projects, the responsibility for implementation of elements of the reasonable and prudent alternative is shared by the Recovery Program and the applicant. Recovery Program participants are responsible for carrying out activities outlined in the Recovery Plan.

The USFWS should condition the permit to retain jurisdiction in the event that the Recovery Program is unable to implement the Recovery Plan in a timely manner. In that case, as long as the lead Federal Agency has discretionary authority over the project, reinitiation of section 7 consultation may be required so that a new reasonable and prudent alternative can be developed by the USFWS.

The above Reasonable and Prudent Alternative involves time frames that must be met to avoid jeopardy to the endangered fish. Because these time frames are critical to meeting the stipulations for removing the jeopardy to the endangered fish, the DOE shall reinitiate consultation if any of the time frames are not met.

<u>Off-Site Disposal of Surface Contamination at the Crescent Junction Site and Ground Water Remediation at the Moab Site</u>

After reviewing the current status of the Colorado River fish, the environmental baseline for the action area, the effects of the proposed action and the cumulative effects, it is the USFWS's biological opinion that this proposed action alternative will not likely jeopardize the continued existence of the Colorado pikeminnow, humpback chub, bonytail, and razorback sucker and is not likely to result in destruction or adverse modification of critical habitat. The USFWS concludes that the proposed action to dispose of tailings (i.e. surface contamination) off-site would reduce negative effects associated with the ongoing contamination of the Colorado River near the Moab Site, and eliminate the potential for future catastrophic events associated with river flooding and river migration The proposed action for ground water remediation at the Moab Site would address the effects of ground water contaminants impacting endangered fish in the Colorado River. There would be adverse effects associated with the current levels of groundwater contamination until ground water remediation is fully implements, assuming the effects are not minimized by existing interim actions. The USFWS has determined that the amount of take that is occurring in the near shore habitats will not jeopardize the Colorado River fish. Previous research has shown that drifting larval Colorado River fish are equally distributed throughout the river channel. The Service believes that only a small percentage of the drifting larval contingent would be exposed to unsafe contaminant levels, and that DOE has already reduced impacts through implementation of the interim remedial actions.

INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by the USFWS to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns including breeding, feeding, or sheltering. Harass is defined by the USFWS as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to breeding, feeding or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are nondiscretionary, and must be undertaken so that they become binding conditions of any Federal discretionary activity, for the exemption in section 7(o)(2) to apply. The participating Federal Agencies have a continuing duty to monitor the activity covered by this Incidental Take Statement. If the DOE 1) fails to assume and implement the terms and conditions or 2) fails to retain oversight to ensure compliance with the terms and conditions, the protective coverage of section 7(o)(2) may lapse for the projects covered by this Incidental Take Statement.

AMOUNT OR EXTENT OF TAKE

The listed Colorado River fish (Colorado pikeminnow, humpback chub, bonytail, and razorback sucker) are the only species covered under this Incidental Take Statement and only take associated with the groundwater remediation component of the proposed action is covered. Recent studies have demonstrated that ammonia concentrations in near shore habitats exceed acute and chronic standards for the protection of aquatic species from ammonia toxicity. A report of dead and dying fish (nonnative cyprinids) in a backwater immediately downstream of Moab Wash was transmitted to the USFWS in November, 2004. DOE was not able to make a strong cause /effect relationship based on available water quality data, but we (DOE and USFWS) assume the incident was contaminant related.

DOE has proposed the development and implementation of a groundwater remediation program that will reduce ammonia concentrations to protective levels in all surface water habitats. Based on data collected and analyzed by DOE and others, DOE assumes that by reducing near surface groundwater ammonia concentrations to 3 mg/l they will be able to achieve chronic standards (0.6 mg/l ammonia) in all habitats. The USFWS is operating under the same assumption.

DOE has projected that within 5 years of issuing a Record of Decision that design, procurement, testing, construction, and implementation of an active ground water remediation system would be complete. Following implementation of the system, DOE estimates that as much as an additional 5 years would be required to reduce concentrations of contaminants in the surface water to levels that are protective of aquatic species in the Colorado River. In this Incidental Take Statement, the USFWS is covering incidental take of Colorado River fish associated with exposure to non-protective concentrations of contaminants in near shore habitats along the north bank of the Colorado River at and downstream of the Moab Site for ten years from finalization of the biological opinion. In their compliance documents DOE suggests, based on preliminary results from their interim ground water remediation program, that contaminant levels may be reduced to protective levels in less than 10 years. The USFWS will work closely with DOE to implement an effective ground water remediation program sooner than 10 years if possible.

During each year of this ten year period, the USFWS anticipates that as many as three (3) Age-0 Colorado pikeminnow, one (1) Age-0 humpback chub, one (1) Age-0 razorback sucker, and one (1) Age-0 bonytail could be taken in low velocity shoreline habitats within a 0.5 five mile reach of the Colorado River (Moab Wash as the upstream terminus) as result of this proposed action. The Service considers Age-0 to be $\leq$ 40 mm Total Length. The incidental take is expected to be in the form of harm (death or injury) due to exposure to non-protective levels of contamination (most likely ammonia) or due to entrainment at DOE's Colorado River pumps. No take of older life stages is anticipated, based on data that indicate harmful concentrations are most likely to occur in backwater or other low velocity habitats and larger fish would be more capable of avoiding entrainment. Low velocity habitats are used preferentially by early life stages of the endangered species, and less so by older / larger fish.

EFFECT OF THE TAKE

In the accompanying biological opinion, the USFWS determined that the anticipated and declining level of incidental take associated with groundwater contamination at the Moab Site for ten years following finalization of this biological opinion is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

REASONABLE AND PRUDENT MEASURES

Based on DOE's analyses, our review of the subject documents and recent comments from the DOI and other agencies on the DEIS, the USFWS recognizes several uncertainties associated with the proposed ground water remediation program. Until protective levels of contamination are achieved in all surface water habitats in the Colorado River the Service believes some level of take of the endangered Colorado River fish species will occur. The Service believes the following reasonable and prudent measures are necessary and appropriate to minimize impacts of incidental take of the endangered Colorado River fishes:

1. Monitor backwater habitats near the Moab Site for any indication of fish being affected by surface water contamination.

2. Evaluate the effectiveness of their initial action (diluting non-protective contaminant concentrations in backwater habitats by pumping clean river water).

3. Address uncertainties associated with the ground water remediation program.

4. Reduce effects of surface water contamination in habitats along the south bank of the Colorado River if necessary.

5. Reduce the effects of entrainment at all project pumping sites.

TERMS AND CONDITIONS

In order to be exempt from the prohibitions of section 9 of the Act, the DOE must comply with the following terms and conditions, which implement the reasonable and prudent measures described above and outline required reporting/monitoring requirements. These terms and conditions are non-discretionary.

1. To implement Reasonable and Prudent Measure (1): DOE in coordination with the USFWS will develop a biota monitoring plan (within six months of the ROD) for the purpose of observing and reporting dead or stressed fish to state and federal fish and wildlife offices (contact information below). Observations should occur from Moab Wash downstream approximately 1200 feet. If professional biologists are unavailable we require DOE or other on-site personnel to preserve specimens (25 fish or 10% of the total estimated number of dead fish; whichever is greater) in alcohol (50% isopropyl – rubbing alcohol) or on ice, but not frozen. Contact information:

   Utah Division of Wildlife Resources
   Moab Field Station
   1165 South HWY 191
   Moab, Utah 84532
   435-259-3780

   USFWS Utah Field Office
   2369 West Orton Circle, Suite 50
   West Valley City, Utah 84119
   801-975-3330

2. To implement Reasonable and Prudent Measure (2): DOE has the infrastructure in place to implement an "initial action" (pumping water from the flowing river into affected backwaters), which the USFWS agrees may be a reasonable, immediate measure to minimize take should water quality monitoring data indicate non-protective levels of contamination in backwater habitats during critical period of the summer. DOE will develop protocols and parameters (within 12 months of the ROD) that address timing and field techniques to implement the initial action. These protocols shall seek to minimize potential adverse effects associated with the initial action itself: temperature shock, re-suspension of fine sediments, elevated BOD, turbulence, etc. The development of these protocols and any field studies needed to support them shall be identified in the Water Quality Study Plan (see RPM #3; T&C #3).

3. To implement Reasonable and Prudent Measure (3): DOE, in coordination with USFWS, will develop data quality objectives within 6 months of the ROD, and will develop a Water Quality Study Plan (WQSP) within 18 months of the finalization of the ROD that evaluates / determines: 1) the effectiveness of current and expanded ground water remediation efforts; 2) the validity of the purported 10-fold ground water to surface water dilution factor; 3) compliance with achieving the target goal of 3 mg/L acute in ground water which is anticipated to meet chronic ammonia standards (0.6 mg/l) in all habitats

adjacent to the Moab site; assuming background does not exceed 0.6 mg/L. Background concentrations will be defined as those found in habitats upstream of the Hwy 191 bridge; 4) the validity of the assumption that by reducing concentrations of ammonia the other constituents of concern (manganese, sulfate, uranium, copper, and selenium) will also be reduced to protective levels; 5) the requirements and schedule for DOE's reporting to the USFWS; 6) if refinement of the conceptual model is necessary; and 7) issues identified in T&C No. 2 and 4. The Service will require a third party review of the WQSP.

4. To implement Reasonable and Prudent Measure (4): Independent studies conducted by Gardner and Solomon (University of Utah) do not support DOE's data and studies regarding the effects of Moab site contaminants on the Matheson Wetland Preserve. DOE will continue to investigate the potential for contaminants to be affecting the Matheson Wetland Preserve. Should data indicate that contaminants are, or are likely to affect surface water habitats on the south side of the river, DOE would consult with the USFWS concerning the need to expand ground water remediation efforts. Monitoring of the south side of the river will need to be addressed in the WQSP (see T&C No. 3).

5. To implement Reasonable and Prudent Measure (5): To reduce the likelihood of entraining young of the year native fish, DOE will continue to screen all pump intakes with ¼" diameter mesh material. DOE will avoid drawing water from low velocity habitats from June 1 through August 31.

CONSERVATION RECOMMENDATIONS

If the USFWS determines that ground water remediation as proposed is not effective in achieving the targeted goal, alternative approaches to reduce take may need to be considered. In preparation for that unlikely event, the USFWS recommends that DOE work closely with USFWS to evaluate the following options.

1. Reduce threats associated with surface water contamination at the Moab Site through dilution, i.e. increased base flows. The USFWS believes that a plausible alternative solution to the threat of ground water contamination would be to increase Colorado River flows upstream of the Moab Site throughout the summer, autumn and winter base flow period. DOE would need to identify an upstream source(s) of water and then secure that flow to the Moab Site through purchase, lease, or other agreement (if available). By increasing base flows secondary and primary productivity would presumably increase throughout the river. Increased productivity could potentially result in increased larval endangered fish production. In addition, an increase in base flows, over the baseline conditions would result in some dilution effect at the Moab Site.

2. If river dilution were pursued, DOE should also explore options to reduce threats of surface water contamination in low velocity habitats adjacent to the Moab Site by reducing endangered fish access to those habitats. DOE and the Service should consider, among other options, manipulating access to potentially dangerous habitats near the

Moab Site and compensate for that loss of nursery habitat area on a 1:1 basis at a nearby location.

REINITIATION NOTICE

This concludes formal consultation on the subject action. As provided in 50 CFR sec. 402.16, reinitiation of formal consultation is required for projects where discretionary Federal Agency involvement or control over the action has been retained (or is authorized by law) and under the following conditions:

1. The amount or extent of take specified in the Incidental Take Statement for this opinion is exceeded.

2. New information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion. In preparing this opinion, the USFWS describes the positive and negative effects of the action it anticipates and considered in the section of the opinion entitled "EFFECTS OF THE ACTION." New information would include, but is not limited to, not achieving contaminant levels that are protective of aquatic life.

3. The section 7 regulations (50 CFR 402.16 (c)) state that reinitiation of consultation is required if the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion.

4. The USFWS lists new species or designates new or additional critical habitat, where the level or pattern of depletions covered under this opinion may have an adverse impact on the newly listed species or habitat. If the species or habitat may be adversely affected by depletions, the USFWS will reinitiate consultation on the biological opinion as required by its section 7 regulations.

If we can be of any further assistance, please contact me at Tom Chart at (801)975-3330 extension 124 or extension 144, respectively.

Sincerely,

Henry R. Maddux
Field Supervisor

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On August 25, 2003, USF&WS and DOE met in Salt Lake City to further discuss applicable risk-based criteria and standards that would be protective of endangered fish. On November 3, 2003, the draft BA was forwarded to USF&WS for comment. DOE received initial comments on the BA in early December 2003. Following receipt of the comments, a meeting was held on December 15, 2003. Additional comments were received in early January 2004, followed by telephone conferences to clarify issues and concerns.

On April 14, 2004, DOE submitted the final draft BA to USF&WS. In June through August 2004, DOE and USF&WS consulted extensively to resolve final comments on this document.

On August 10, 2004, DOE received formal comments on the final draft BA.

On May 26, 2005, based on the identification of off-site disposal at Crescent Junction using mostly rail and active ground water remediation as DOE's preferred alternatives, USF&WS submitted the final BO, which is included as Appendix A3.

A1−4.0 Description of the Proposed Action

DOE is proposing to remediate contaminated soils and materials and contaminated ground water at the Moab site. Three disposal alternatives are presented in the EIS:

- On-site disposal of tailings
- Off-site disposal of tailings (three locations, three transportation options considered)
- No action

On-site disposal of tailings is discussed in Section A1−4.1. Off-site disposal of tailings is discussed in Section A1−4.2. Active ground water remediation is proposed for both the on-site and off-site alternatives (Section A1−4.3.1). This BA places emphasis on ground water remediation due to contamination entering the Colorado River, which is designated critical habitat for four endangered fish species. The remediation goals (Section A1−4.3.2) are to reduce concentrations of five contaminants reaching the Colorado River to acceptable risk levels within 10 years of the ROD. Emphasis is placed on remediation of ammonia, which is the primary contaminant of concern. DOE implemented initial and interim actions (Section A1−4.3.3) in 2003 and 2004 in an attempt to begin reducing ammonia concentrations prior to full implementation of proposed ground water remediation.

DOE also analyzes the No Action alternative (Section 2.4 of the EIS), which serves as a baseline for comparing all alternatives, as required by NEPA regulation.

Although this BA assesses all of the alternatives included in the EIS to support final decision-making for remediation of the Moab mill tailings, the BO (Appendix A3) is limited in its scope to DOE's preferred alternatives of off-site disposal at Crescent Junction using mostly rail and active ground water remediation.

A1−4.1 On-Site (Moab) Remedial Actions

Under the on-site disposal alternative (Section A1−2.1 of the EIS), the existing tailings pile would be converted into a permanent, engineered, disposal cell into which all on-site and vicinity property contaminated material would be encapsulated. Upon completion of excavation and placement of all contaminated material, the disposal cell would be stabilized, recontoured, and covered (Figure A1−2). With the exception of specific engineering design changes, this alternative is similar to that proposed by the Atlas Corporation and described in Section A1−2.1 of NRC's 1999 EIS (NRC 1999). No on-site contaminated materials would be transported off the site. However, contaminated materials at vicinity properties would be transported to the Moab site on public roads.

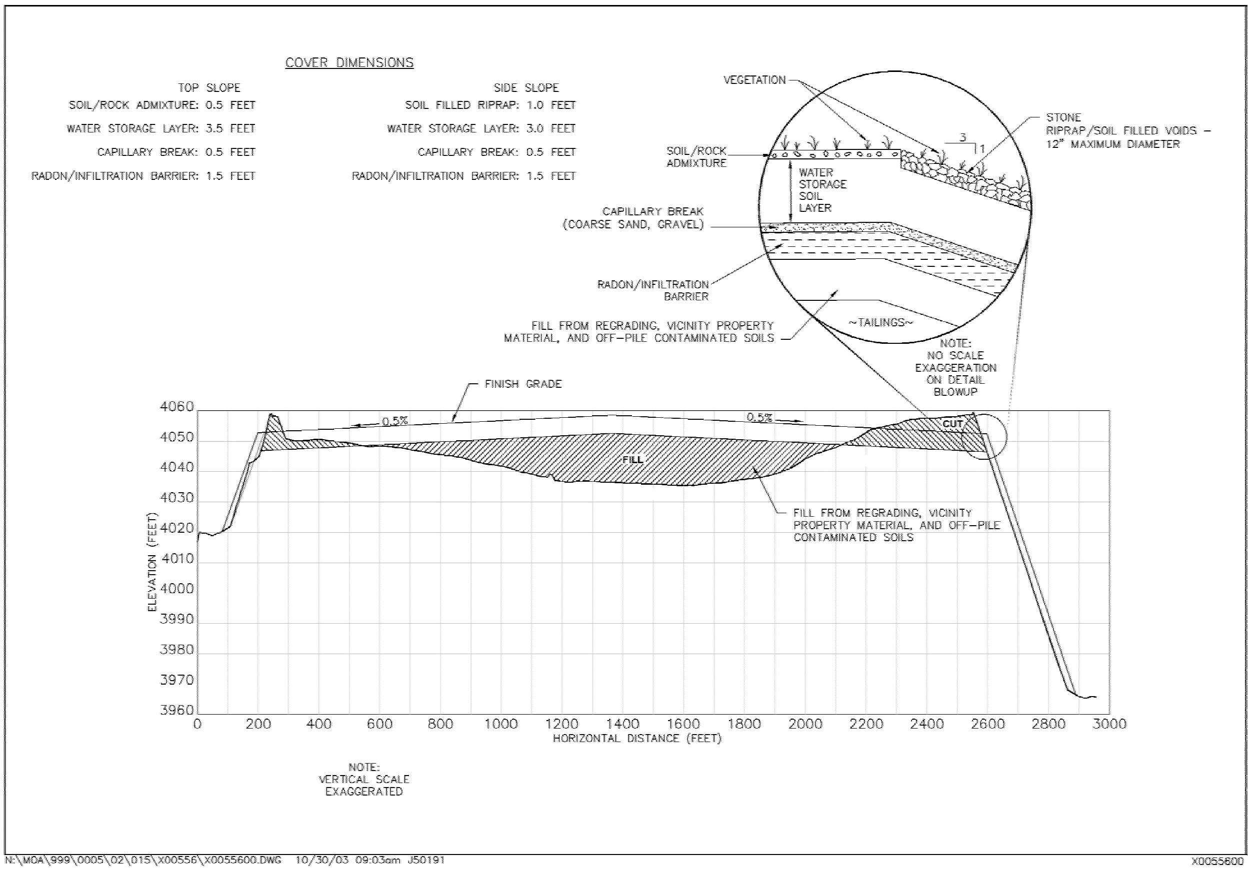

Figure A1−2. Typical Cross Section of Disposal Cell, On-Site Disposal Alternative

Activities would include grading and removing vegetation over almost the entire 439-acre site, both to prepare the site for subsequent activities and to remove surface contamination. These activities would remove remaining wildlife habitat (approximately 50 acres, primarily tamarisk) from the Moab site. Other site activities would include removing any existing structures and creating temporary construction support facilities (such as laydown yards, material stockpiles, vehicle maintenance and refueling areas, and vehicle decontamination facilities).

In the past, tailings material was removed from the Moab site and taken to off-site locations for a variety of purposes, such as backfill. In many cases, ore was stockpiled at various locations in the Moab area. For the purposes of analysis in the EIS, and based on available information and past experience, it has been estimated that about 98 locations, known as vicinity properties, may require remediation. All are relatively small (about 2,500 square feet [ft^2] and 300 cubic yards [yd^3]of material per site). These sites would be excavated and the materials transported by truck to the Moab site, where they would be stockpiled for eventual disposal at the selected disposal site.

If the on-site disposal alternative were selected, the route of Moab Wash (currently adjacent to the north and east sides of the tailings pile) would be altered to minimize potential damage to the tailings pile that could occur in the event of flooding. An engineered cover (Figure A1−2) consisting of a clay radon barrier, riprap, gravels, sands, and fine-grained soils would be constructed using materials obtained from several borrow areas (Figure A1−3, Table A1−2). Borrow materials would be transported to the Moab site by truck. Some improvements to existing roads may be required for access to some of the proposed borrow areas. Normal construction best management practices would be followed to limit wind and water erosion at the Moab site and borrow areas.

Table A1−2. Estimated Area of Disturbed Land at Borrow Areas for the Remediation Activities at the Moab Site, Moab, Utah

Borrow Material / Area	Estimated Area of Disturbance (Excavated acres or quarried volumes)	Estimated Available Area/Volume
Cover and Reclamation Soils		
Floy Wash	178–380 acres	1,035 acres
Crescent Junction	70–100 acres	4,925 acres
Tenmile	115–250 acres	1,480 acres
Courthouse Syncline	70–155 acres	4,925 acres
Blue Hills Road	70–185 acres	900 acres
Radon Barrier		
Klondike Flats	100–170 acres	10,000 acres
Crescent Junction	70–100 acres	4,925 acres
Sand and Gravel		
LeGrand Johnson	43,000–140,000 yd^3	13,000,000 yd^3
Riprap		
Papoose Quarry	185,000–257,000 yd^3	3,500,000 yd^3
Blanding	8–10 acres[a]	1,355 acres
Soils and Clay		
White Mesa Mill site	63–83 acres	300,000–400,000 yd^3

[a]Assumes rock layer thickness of 12 ft at the borrow area.

Upon completion of remediation activities at the Moab site (under either the on-site or off-site disposal alternatives), the site would be graded and prepared for replanting, including any seedbed preparation activities. Replanting with native species would take place as early as practicable following completion of these activities, ideally at the onset of the next growing season. Areas of the Moab site currently dominated by tamarisk would be replanted with native riparian species that are of equal or higher functional value for wildlife, particularly for the southwestern willow flycatcher. Methods would be employed to maximize the competitive advantage of the replacement vegetation against encroachment of non-native species. DOE would use such means to ensure the establishment of the native vegetation but would not be required to maintain it in perpetuity.

A1−4.2 Off-Site Remedial Actions

Under the off-site disposal alternative (Section A1−2.2 of the EIS), the tailings pile, contaminated on-site soils and materials that are not yet in the existing pile, and contaminated materials from the vicinity properties would be transported to one of three proposed off-site disposal alternative locations: Klondike Flats, Crescent Junction, or White Mesa Mill (see Figure A1−3). Contaminated materials would be transported using one of three possible modes of transportation: truck, rail, or slurry pipeline; however, rail transportation is not an option for transportation to the White Mesa Mill site.

In addition to the activities at the Moab site described in Section A1–4.1, if the off-site disposal alternative were selected, approximately 346 to 489 acres of land would be disturbed at the selected disposal site, depending on the site and transportation option selected. Additional activities at the off-site disposal site would include preparing the disposal cell and constructing support facilities such as laydown areas, stockpile areas, vehicle maintenance and refueling facilities, temporary offices, and material-handling facilities. Depending on the transportation option selected, some infrastructure improvements would be performed. An engineered barrier cap would be constructed over the tailings using materials obtained from borrow areas that would most likely be located near the selected disposal site. Table A1−2 shows areas of disturbance at borrow areas. The degree of disturbance would depend upon the borrow areas actually used.

If the off-site disposal alternative were selected, the tailings and vicinity property materials would be prepared for transport to the selected disposal site. Truck transport would require minor construction to allow for more efficient entrance onto and exit from US-191 at the Moab site and at the alternative disposal sites. Rail transport would require construction of a loading facility at the Moab site and some additional track and unloading facilities at the selected disposal site.

If a slurry pipeline were chosen as the means to transport materials, the pipeline would primarily be aligned close to existing roads (primarily US-191) or existing natural gas or utility rights-of-way, although some new rights-of-way would be required.

A1−4.3 Moab Site Ground Water Remedial Actions

A1−4.3.1 Proposed Action

DOE's proposed action for ground water remediation at the Moab site is to design and implement an active remediation system and also apply ground water supplemental standards. These actions would be in addition to the initial and interim actions (described in Section A1−4.3.3) that have already been implemented. Ground water remediation would be implemented under both the on-site and off-site tailings disposal alternatives. The remediation system would be designed to intercept contaminated ground water that is currently discharging into the near-bank, shoreline area of the Colorado River, which is designated critical habitat for endangered fish species. It is estimated that up to 5 years may be required to design and construct the remediation system. Once the system is implemented, up to 5 years of operation may be required before the action becomes completely effective and provides the requisite protection in the adjacent surface waters (Figure A1−4). However, these time frames are conservative, and the time needed to design, implement, and achieve protective levels may be substantially less. In addition, the proposed action would, at a minimum, meet the protective surface water criteria. It is possible that effects of the interim action and the proposed action may achieve background surface water quality conditions in less than the estimated 10 years after the ROD. This is discussed in more detail in Section A1–4.3.3. The system would be operated until ground water contaminant concentrations decreased to a level that would no longer present a risk to aquatic species. This is predicted to be 75 years for the off-site disposal alternative, and 80 years for the on-site disposal alternative (Figure A1−4). More detailed information is presented in Section 2.3 of the EIS.

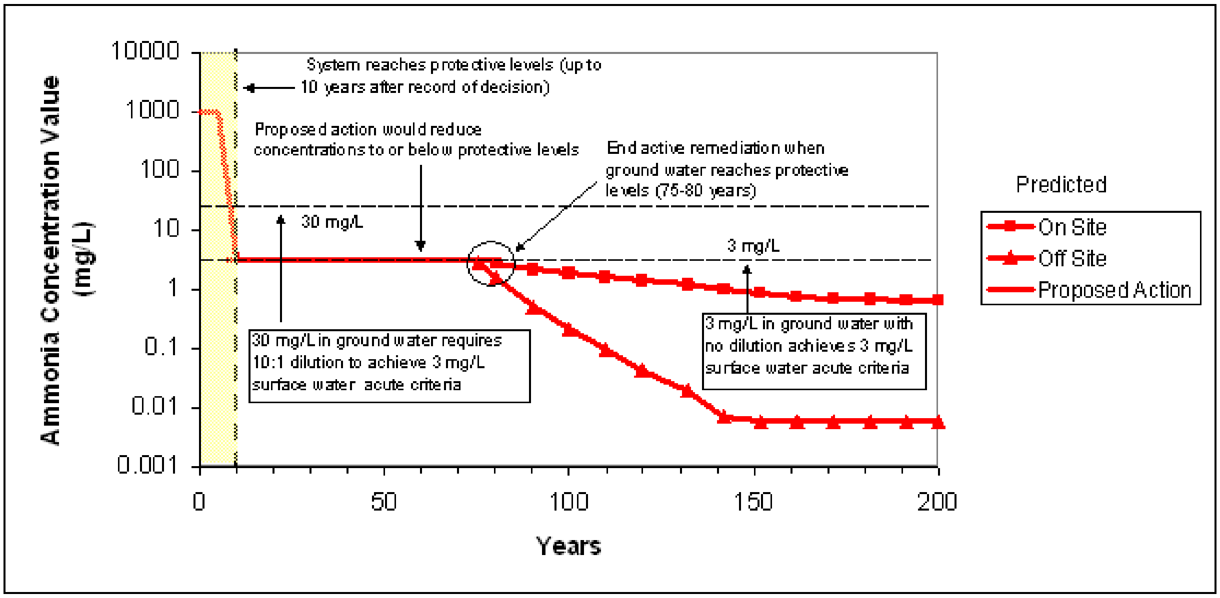

Figure A1−4. Predicted Maximum Ammonia Concentrations in Ground Water for Active Remediation

Supplemental standards (40 CFR 192), would also be applied to ground water at the site. Ground water beneath the site qualifies for supplemental standards because it meets the criteria for limited use ground water. Section 2.3 of the EIS discusses ground water standards in more detail. These standards apply to human health and would not affect the active remediation goals discussed in the preceding sections.

A1−4.3.2 Remediation Goals for Contaminants of Concern

<u>*Aquatic Goals*</u>

Remediation goals are based on the contaminants of concern identified in Appendix A2 of the EIS, as summarized in Section A1−7.2 of this BA. Appendix A2 of the EIS, *Screening of Contaminants to Aquatic and Terrestrial Resources*, identified ammonia, copper, manganese, sulfate, and uranium as the chemical contaminants of concern. The primary contaminant of concern that would require ground water remediation is ammonia. The area of contamination varies with hydrologic regime but in general is confined to an area less than 53,800 ft^2 (approximately 1.25 acres) (USGS 2002).

Remediation goals for ammonia include the acute and chronic benchmarks based on ambient pH and temperature conditions in compliance with the National Recommended Water Quality Criteria (NWQC) (EPA 2002) and currently proposed Utah Water Quality Standards (UAC 2003, UDEQ 2003). The approach for setting the goals is discussed in Section 2.3 of the EIS. It is DOE's position that achieving a target goal of approximately 3 milligrams per liter (mg/L) for ammonia in ground water would result in compliance with the range of surface water standards in the Colorado River. The 3-mg/L target goal represents the low end of the reasonable range of acute standards. The 3-mg/L concentration represents a 2- to 3-order-of-magnitude decrease in the center of the ammonia plume and would be expected to result in a corresponding decrease in surface water. In addition, based on analysis of collocated samples of interstitial ground water (pore water) and surface water, additional dilution occurs as the ammonia moves from the bank of the river into the water column. The dilution is estimated to be an average of 10-fold (DOE 2003a). The combination of active remediation, dilution into surface water, and the tendency for ammonia to volatilize should result in compliance with both acute and chronic ammonia standards in the river everywhere adjacent to the site. It is anticipated that ground water remediation would decrease and maintain the concentrations all of contaminants of concern at levels protective of aquatic species.

Terrestrial Goals

Contaminants of concern are identified in Appendix A2 of the EIS, and the potential effects of these contaminants are summarized in Section A1−8.2 of this BA. Appendix A2 of the EIS, *Screening of Contaminants to Aquatic and Terrestrial Resources,* identified mercury and selenium as contaminants of concern.

Remediation goals for terrestrial or avian species have not been established. This is due to limited potential for threatened or endangered receptors (both plant and animal) to be adversely affected by contaminated surface water or ground water, which is discussed in detail in Section A1−8.2 of this BA. Limited potential is based the risk analysis in Appendix A2 of the EIS and includes potential exposure pathways, potential presence of species, and potential use of ground water or surface water. Although specific goals are not established, concentrations of contaminants of concern would be reduced by proposed ground water remediation, which would reduce concentrations in surface water.

As a result of remediation, contaminants may concentrate in an evaporation pond. If concentrations presented a risk to threatened or endangered species, mitigation may be required as discussed in Section A1–8.1 of this BA.

A1−4.3.3 Initial and Interim Actions Related to the Proposed Action

As stated in Section A1−3.0, DOE, upon accepting responsibility for the site, initiated consultations with USF&WS. Based on these consultations, and after reviewing historical surface water quality studies and data, DOE and USF&WS both agreed that an immediate risk was posed to endangered fish and designated critical habitat. The source of the risk was identified as elevated concentrations of site-related ground water contaminants (primarily ammonia) reaching the Colorado River.

On April 30, 2002, USF&WS concurred with DOE's determination to implement an initial action, followed by an interim action. The goal of the initial action was to dilute ammonia concentrations at the ground water–surface water interface in areas that presented the greatest potential for fish to be present, when backwater habitat has developed. It was estimated that backwater habitat would most likely be present from June through August at flows of 5,000 to 15,000 cubic feet per second (cfs). The action focused on the segment of the Colorado River from Moab Wash extending approximately 800 feet (ft) downriver; that segment contributes the highest concentrations of contaminants to the river. The initial action was designed to take fresh water upstream of the site and pump it through a distribution system to backwater areas. The system was not installed in 2003 due to low flows. The system was installed and tested in 2004 but not fully implemented because the targeted backwater areas never held water. This was due to low river flows caused by drought.

The goal of the interim action is to extract contaminated ground water near the Colorado River, thereby reducing the amount of contamination reaching the river. DOE funded, designed, and implemented the system (Phase I) in 2003, which included 10 extraction wells aligned parallel to the Colorado River. The system is designed to withdraw ground water at the rate of approximately 30 gallons per minute (gpm) and pump it to an evaporation pond on top of the existing tailings pile. On April 4, 2004, USF&WS concurred with DOE's determination to construct a land-applied sprinkler system designed to increase evaporation rates. The system was installed in the existing evaporation pond area. In July 2004, DOE added another 10 extraction wells (Phase II) near the first 10 wells to increase the rates of ground water extraction and to test the effects of freshwater injection on surface water concentrations. If the interim actions are successful, a reduction in contaminant concentrations in surface water could be observed significantly sooner than the 10-year time frame considered under the proposed action. DOE will monitor surface water quality and provide the reports to USF&WS annually at a minimum.

A1−4.3.4 Ground Water Remediation Options

For purposes of this BA, active ground water remediation would consist of one or a combination of the options described below. All proposed remediation options would occur within the footprint of historical millsite activities and areas requiring surface remediation. Figure A1−5 shows the area of proposed ground water remediation. Final selection of the most appropriate option(s) would be documented in a remedial action plan (RAP) and would depend upon which surface disposal alternative is selected.

- Ground water extraction, treatment, and disposal
- Ground water extraction and deep well injection (without treatment)
- In situ ground water treatment
- Clean water application

Section 2.3 of the EIS describes these remediation options in detail.

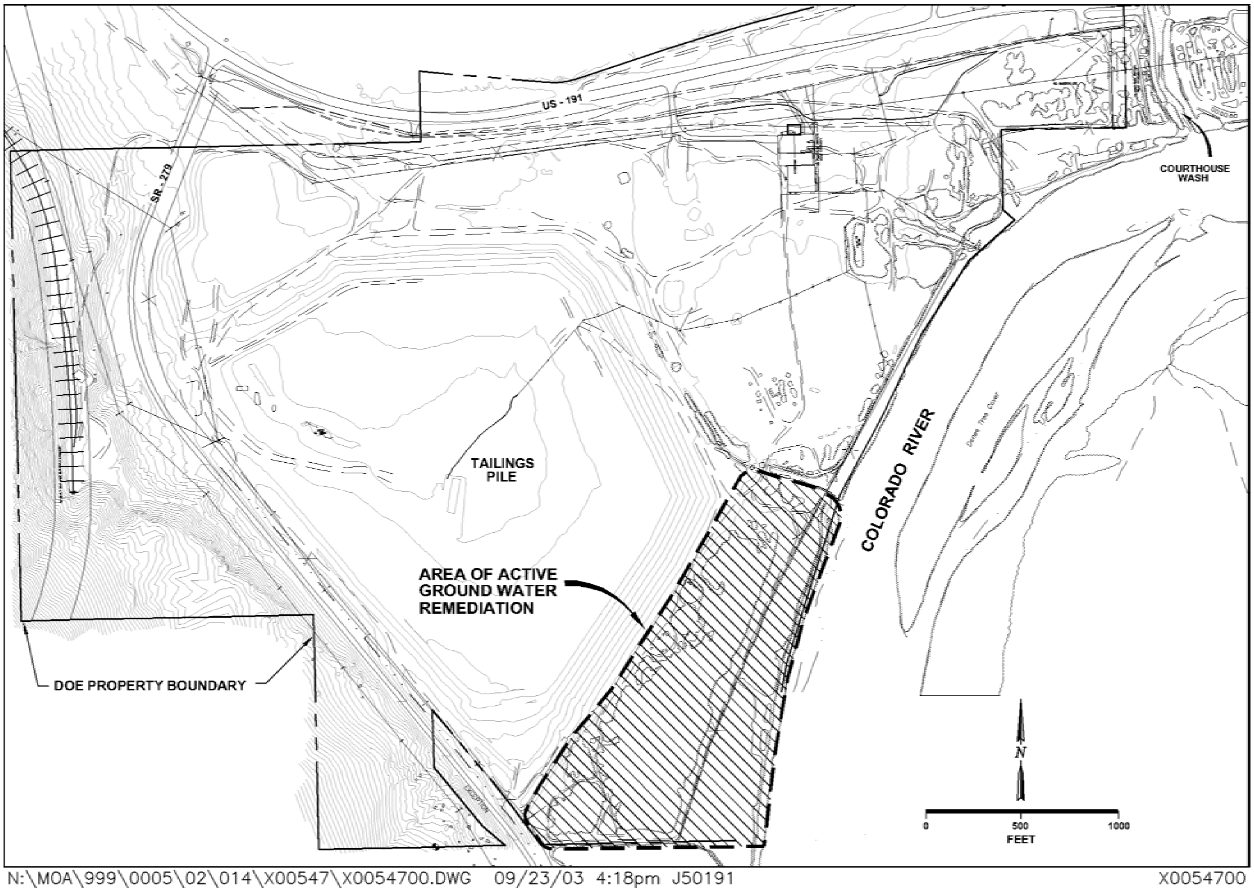

Figure A1−5. Area of Proposed Active Ground Water Remediation

Ground Water Extraction, Treatment, and Disposal

Ground Water Extraction: The two proposed methods for extracting contaminated ground water are extraction wells or interception trenches.

If extraction wells were used, between 50 and 150 wells would be installed to depths of up to 50 ft using conventional drilling equipment. This design would allow for extracting up to 150 gpm of contaminated ground water. The water would be pumped from the wells to a treatment collection point (e.g., evaporation pond) via subsurface piping. The system would be installed between the current tailings pile location and the Colorado River to intercept the plume before it discharged to the river and would require up to 50 acres of land for the duration of ground water remediation. The proposed locations are within the area of historical site disturbances and areas requiring remediation of contaminated soils. It is expected that the system would be installed after any remediation of surface soils required in these areas. It is possible that some extraction wells would need to be installed adjacent to the river in areas northeast of the tailings pile in the vicinity of the old millsite.

If shallow trenches were used, they would be constructed to intercept shallow ground water, which would be piped via shallow subsurface piping to a collection point for treatment (e.g., evaporation pond). This design would allow for extracting up to 150 gpm of contaminated ground water. It is estimated that the system would require from 1,500 to 2,000 lineal ft of trenches and could affect up to 50 acres of land for the duration of ground water remediation. The proposed locations are within the area of historical site disturbances and areas requiring remediation of contaminated soils.

Treatment Options: DOE has screened potential treatment technologies, which would be applicable for treatment of ammonia and other contaminants of concern (DOE 2003a). The treatment options and technologies described below are meant to bound the range of viable possibilities. All treatment options would require construction of infrastructure. The level of treatment would depend largely on the selected method of effluent discharge. Therefore, specific treatment goals could not be established until the specific discharge method(s) were selected. The treatment goals would have to consider risk analysis and regulatory requirements.

Additional testing, characterization, or pilot studies may be required before the optimum system could be selected and designed. This level of design would be developed in a RAP following publication of the ROD. The Site Observational Work Plan (SOWP) (DOE 2003a) presents more detailed descriptions and discussion of the screening process for the following treatment options.

- Standard evaporation
- Enhanced evaporation
- Distillation
- Ammonia stripping
- Ammonia recovery
- Chemical oxidation
- Zero-valent iron
- Ion exchange
- Membrane separation
- Sulfate coagulation

Because evaporation is a primary treatment consideration and is also considered a disposal option, it is included in more detail in this BA. Evaporation treats extracted ground water by allowing the water to evaporate due to the dry conditions of the site and warm temperatures during part of the year. Influent rates to the ponds would match the rate of natural evaporation. Nonvolatile contaminants would be contained and allowed to concentrate, which would require provisions for disposal of the accumulated solids. Evaporation could also be used to treat concentrated wastewater from treatment processes such as distillation and ion-exchange that produce a wastewater stream. Passive evaporation would not require any mixing after disposal in the ponds. If it were determined that concentrations would present a risk to avian or terrestrial species, a wildlife management plan would be submitted to the USF&WS.

Solar evaporation would consist of putting the water into large, double-lined outdoor ponds built in the floodplain to withstand 100-year precipitation and flood events. In the absence of enhanced methods, a sufficiently large pond or ponds would need to be constructed in order to achieve evaporation rates that could keep up with extraction rates and complete remediation in a reasonable time frame. Estimated pond areas could range up to 40 acres, and a total of 60 acres of land would need to be disturbed. This would also require some type of small support facility. Devices such as spray nozzles could considerably enhance evaporation rates.

Disposal Options: If ground water were treated by a method other than evaporation, the treated water would require disposal by one of the following methods:

- Discharge to surface water
- Shallow injection
- Deep well injection

The Colorado River is a boundary to the Moab site, and it would be the natural repository of the site ground water if effluent were discharged to surface water. Based on water quality standards and designation as critical habitat for endangered fish, it is likely that this option would require extensive water treatment for all contaminants of concern. If discharge to the river was considered a viable alternative for dealing with treatment effluent, appropriate permits would need to be obtained from the state, and compliance with conditions such as discharge rates and effluent composition would be required.

If shallow injection were selected, injection wells would be used to return the treated ground water directly back into the alluvial aquifer. Treated ground water could potentially be used to recharge the aquifer at different points to allow manipulation of hydraulic gradients. This could facilitate extraction of the lower quality water and faster removal of the contaminant source. This option would require treatment of ammonia.

If deep well injection were selected, treated ground water would be disposed of by deep well injection into the Paradox Formation or deep brine aquifer. Ground water hydrology beneath the site includes a deep salt formation called the Paradox Formation overlain by a deep aquifer with a high salt concentration (brine water). This method would likely require an underground injection control permit from the State of Utah.

Ground Water Extraction and Deep Well Injection (without treatment)

If this option were selected, ground water would be extracted using a system and infrastructure similar to that described above, and untreated water would be pumped into a geologically isolated zone. This option would likely require an underground injection control permit from the State of Utah and concurrence from NRC.

In Situ Remediation

If this option were selected, it would include some form of biodegradation, including but not limited to phytoremediation. This option would require minimal infrastructure and could require state or federal permits, depending on the method of biodegradation.

Clean Water Application

Another aspect of the active remediation system could involve some form of application of clean water to dilute ammonia concentrations in the backwater areas along the Colorado River where potentially suitable habitat for endangered fish may exist. This would likely take either or both of two possible configurations. The first configuration would consist of diverting uncontaminated water from the Colorado River through a screened intake at the nearest location just upstream of

Moab Wash. A water delivery system consisting of a pump and aboveground piping would redistribute the water to the backwater areas along a section of the sandbar of up to 1,200 ft beginning just south of Moab Wash. Flow meters and valves would be used to measure and control the rate of upstream river water released at each distribution point to minimize turbidity and velocities. The components and operation would be similar to the 1,360-gpm system originally planned as an initial action for the sandbar area adjacent to the site (DOE 2002a) or some alternative system design.

A variation of the clean water application could consist of using injection wells or an infiltration trench to deliver uncontaminated river water indirectly to the backwater areas. For this second configuration, clean water would be collected from the Colorado River and pumped to the site water storage ponds to control suspended sediment and prevent system clogging. The storage pond water would then be introduced to the shallow ground water system by a series of injection wells or infiltration trenches located along the bank adjacent to the backwater areas. The clean water would enter the backwater areas by bank discharge of ground water to provide dilution of ammonia concentrations. This clean water application system could also be combined with the extraction wells discussed earlier to control drawdown and minimize the potential for brine upconing. For this case, up to 150 gpm of uncontaminated river water would be needed to balance the amount of plume water extracted.

A1−4.3.5 Implementation and Operation

DOE estimates that design, procurement, testing, construction, and implementation of an active ground water remediation system would be complete within 5 years of issuance of the ROD. Design criteria and specifications would depend upon whether the on-site or off-site alternative is selected for tailings disposal.

After the system begins operation, DOE estimates that as much as an additional 5 years would be required to reduce concentrations of contaminants in the surface water to levels that are protective of aquatic species in the Colorado River, if protective levels were not already achieved as a result of interim actions. However, it is possible that considerably less time may be required to reach protective levels. The active remediation system would extract and treat ground water for 75 to 80 years (depending on whether the off-site or on-site surface remediation alternative were implemented) to maintain surface water quality goals. Contaminant concentrations in ground water would thus be reduced to acceptable risk levels prior to entry into the Colorado River. Active remediation would cease only after ground water and surface water monitoring confirmed that long-term remediation goals were achieved and after appropriate consultation and concurrence with USF&WS. The uncertainties and assumptions associated with the success of active remediation are discussed below.

DOE would monitor the progress of remedial actions to determine if goals are being met and would commit to ongoing consultation with USF&WS. In addition, DOE would provide monitoring data and remediation results annually to USF&WS.

Uncertainties

DOE does not have a quantitative estimate of uncertainty associated with the ground water modeling predictions estimating the time for ground water concentrations to reach levels protective of aquatic species. Sections 7.3.5.5, 7.6, and 7.8.3 of the SOWP (DOE 2003a) discuss the sensitivity of the ground water flow and transport model to specific modeling input parameters as well as modeling uncertainty. Specifically, transport parameters (e.g., tailings seepage concentration and the natural degradation of ammonia in the subsurface) were found to have a much greater impact on predicted concentrations than did flow parameters (e.g., hydraulic conductivity and effective porosity). The sensitivity analysis performed indicates that perturbing the key transport parameters from the calibrated values could result in either significantly higher or significantly lower contaminant concentrations in the ground water adjacent to the river: it did not indicate the probability or likelihood of any one outcome.

Many variables affect prediction accuracy, and the system of contaminant transport and the interaction between ground water and surface are complex, largely due to the dynamic nature of river stage and backwater area morphology. To compensate for the inherent uncertainties, DOE has assumed a conservative protective water quality goal of meeting the lowest possible acute aquatic standard (based on the range of observed pH and temperature conditions in the river) in the ground water with no consideration of dilution. Model predictions, supported by site-specific data, also indicate that long-term ground water concentrations adjacent to the river (background for the off-site disposal alternative and 0.7 mg/L ammonia for the on-site disposal alternative) would be protective for chronic exposure scenarios for all but the worst-case pH and temperature conditions without any consideration of dilution from the surface water.

On the basis of site-specific data and a study of site conditions, DOE has a reasonable degree of confidence that protective conditions would be met and maintained during both the operation of the corrective action and following achievement of water quality goals. To ensure that protective conditions were met, DOE would monitor the ground water and surface water systems and would hold regular consultations with USF&WS. In addition, the active remediation system would continue throughout the 75- to 80-year remedial action period and into the post-remedial action confirmation monitoring period.

A1−5.0 Description of Project Areas

Preliminary consultations and investigations indicate that listed threatened or endangered terrestrial wildlife species are not known to occur, nor are they strongly expected to occur, at the Moab, Klondike Flats, Crescent Junction, or White Mesa Mill sites. The proposed pipeline corridor to the White Mesa Mill site provides the greatest potential for terrestrial threatened or endangered species to be present. However, before developing any disposal site, DOE, in consultation with USF&WS, would determine the need for additional habitat evaluations and surveys for species that could be affected. If threatened or endangered species or critical habitats were identified at a selected site, a mitigation plan would be developed to minimize potential adverse impacts. If impacts could not be avoided, additional Section 7 consultation would be required.

Uncertainties

DOE does not have a quantitative estimate of uncertainty associated with the ground water modeling predictions estimating the time for ground water concentrations to reach levels protective of aquatic species. Sections 7.3.5.5, 7.6, and 7.8.3 of the SOWP (DOE 2003a) discuss the sensitivity of the ground water flow and transport model to specific modeling input parameters as well as modeling uncertainty. Specifically, transport parameters (e.g., tailings seepage concentration and the natural degradation of ammonia in the subsurface) were found to have a much greater impact on predicted concentrations than did flow parameters (e.g., hydraulic conductivity and effective porosity). The sensitivity analysis performed indicates that perturbing the key transport parameters from the calibrated values could result in either significantly higher or significantly lower contaminant concentrations in the ground water adjacent to the river: it did not indicate the probability or likelihood of any one outcome.

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On the basis of site-specific data and a study of site conditions, DOE has a reasonable degree of confidence that protective conditions would be met and maintained during both the operation of the corrective action and following achievement of water quality goals. To ensure that protective conditions were met, DOE would monitor the ground water and surface water systems and would hold regular consultations with USF&WS. In addition, the active remediation system would continue throughout the 75- to 80-year remedial action period and into the post-remedial action confirmation monitoring period.

A1−5.0 Description of Project Areas

Preliminary consultations and investigations indicate that listed threatened or endangered terrestrial wildlife species are not known to occur, nor are they strongly expected to occur, at the Moab, Klondike Flats, Crescent Junction, or White Mesa Mill sites. The proposed pipeline corridor to the White Mesa Mill site provides the greatest potential for terrestrial threatened or endangered species to be present. However, before developing any disposal site, DOE, in consultation with USF&WS, would determine the need for additional habitat evaluations and surveys for species that could be affected. If threatened or endangered species or critical habitats were identified at a selected site, a mitigation plan would be developed to minimize potential adverse impacts. If impacts could not be avoided, additional Section 7 consultation would be required.

A1−5.1 Moab Site

A1−5.1.1 Terrestrial Setting

Historically, the entire Moab site has been created and altered by natural events such as floods and, more recently, by the activities related to milling operations. At present, significant vegetation does not occur on approximately 380 acres of the site; this severely limits use of this area by terrestrial wildlife. Mature tamarisk, with minimal understory, covers approximately 50 acres of the site east of the tailings pile on the Colorado River floodplain. This area provides some habitat for birds and small mammals. Steep rock mesas dominate the area just west of the site. Low-growing desert shrub communities and low-density piñon-juniper forest are the predominant vegetation types to the west and north of the site along the transportation routes.

The upland soils at the site are Nakai sandy loam. The potential indigenous vegetation that might occur if the site were not disturbed from past mill operations includes grasses such as Indian ricegrass (*Achnatherum hymenoides*) and galleta (*Pleuraphis jamesii*) and the desert shrubs fourwing saltbush (*Atriplex canescens*), shadscale (*Atriplex confertifolia*), and winterfat (*Krascheninnikovia lanata*). This potential vegetation could provide habitat for small mammals, including white-tailed prairie dog (*Cynomys leucurus*), desert cottontail (*Sylvilagus audubonii*), and black-tailed jackrabbit (*Lepus californicus*). Fourwing saltbush, shadscale, and galleta may be used to some extent by mule deer (*Odocoileus hemionus*) as forage.

The existing vegetation reflects a history of disturbance. Plants observed during April 2003 include spike dropseed (*Sporobolus contractus*), sand dropseed (*Sporobolus cryptandrus*), tamarisk (*Tamarix parviflora*), black greasewood (*Sarcobatus vermiculatus*), gray rabbitbrush (*Ericameria nauseosa*), Douglas rabbitbrush (*Chrysothamnus viscidiflorus*), big sagebrush (*Artemisia tridentata*), and galleta. The presence of tamarisk and low-density black greasewood indicates that ground water occurs within 20 to 50 ft of the surface.

A narrow strip of riparian habitat along the eastern site boundary between the upper floodplain terrace and the Colorado River also contains wetland plants and soils. This area includes the sandbar areas downstream of Moab Wash. The area was assessed but not formally delineated in February 2002. The presence of wetland vegetation and soils and predominance of water would likely qualify at least a portion (estimated at approximately 1 acre) of this area as U.S. Army Corps of Engineers jurisdictional wetlands. Seedling tamarisk is the predominant plant in these wetland areas; other wetland plants include saltgrass *(Distichlis spicata)*, cattail *(Typha sp.*), rush (*Juncus sp.*), bulrush *(Scirpus sp.)*, spikerush (*Eleocharis sp.*), redroot flat sedge (*Cyperus erythrorhizos*), and sandbar willow (*Salix exigua*).

Other riparian areas at the Moab site do not meet the criteria for classification as jurisdictional wetlands. These include the wooded areas of tamarisk and other species on the floodplain and an area of woody and emergent vegetation surrounding a holding pond for water pumped from the river.

Vegetation across the Colorado River, including the Scott M. Matheson Wetlands Preserve (Matheson Wetlands Preserve) on the river's east bank, includes habitat that consists of riparian woodland, grassland, and shadscale (saltbush) communities. Woodland, dominated by tree species such as black willow (*Salix nigra*) and Fremont cottonwood (*Populus fremontii*), is present in the preserve. Other plants include tamarisk, sedges (*Carex* spp.), bulrush, and cattail (NRC 1999). More than 175 species of birds have been observed at the Matheson Wetlands Preserve, and a great blue heron (*Ardeaherodias*) rookery is present in its lower end (NRC 1999). The Matheson Wetlands Preserve has a variety of wetland types that include emergent wetlands, shrub wetlands, cottonwood stands, and ponds. It is the only sizable wetland remaining on the Colorado River in Utah and serves multiple environmental functions, including water quality preservation, flood protection, erosion control, and biological productivity and diversity.

A1−5.1.2 Aquatic Setting

The Moab site lies immediately adjacent to the Colorado River, the principal surface water resource for the area. The tailings pile is approximately 700 ft west of the river. The site is located on an alluvial terrace, which historically floods through the area, along the Moab Wash and into the Colorado River. The tailings pile is located within the 100-year recurrence interval storm floodplain of the Colorado River and within the floodplain of the probable maximum flood (PMF) of both the Colorado River and Moab Wash. Mussetter and Harvey (1994) identified two Colorado River flows that are significant for the Moab site. At a flow of approximately 40,000 cfs, the river elevation exceeds its banks and floods the Matheson Wetlands Preserve. There were a total of seven years from 1959 to 2002 when flows were greater than 40,000 cfs. The other critical flow occurs at about 70,000 cfs, which, according to Mussetter and Harvey (1994), produces a river elevation such that river water comes in contact with the toe of the tailings pile. Based on an analysis of the flow data from the gaging station upstream at Cisco, there has only been one day (in 1984) since 1959 in which the flow has exceeded 70,000 cfs. Section 3.1.8 of the EIS and Section 5.2 of the SOWP (DOE 2003a) provide further discussion of the floodplains and hydrology. The major tributaries of the Colorado River near the site include the Dolores River (located upstream) and the Green River (located downstream). The Matheson Wetlands Preserve is on the east bank of the Colorado River, across from the Moab site. Sections 3.1.1 and 3.1.7 of the EIS describe the geology and surface water further.

The aquatic species within the vicinity of the Moab site are associated with the Colorado River. The Colorado River has seasonal variations in flow and temperature following a snowpack-driven hydrograph (DOE 2003b). Aquatic species in the river have adapted to physical and chemical conditions that fluctuate naturally, both seasonally and daily. These conditions include river flow and flooding of intermittent backwaters and elevated floodplains, bottom scouring by sand and silt, temperature, sediment loading, chemical composition, and salinity (NRC 1999).

The Moab site is located at approximately river mile 64 on the Colorado River (NRC 1999) in a transition zone between two geomorphically distinct reaches. River miles on the Colorado River have been designated for the purposes of research programs; the beginning of the designation is at the confluence of the Green River into the Colorado River (Belknap and Belknap 1991; Osmundson et al. 1997). The immediate reach of the Colorado River upstream of the site is predominantly sand-bedded with a few cobble bars. Directly downstream of the site, the river is sand-bedded with sandbars and stabilized islands. A portion of the shoreline near the site has been stabilized by tamarisk, an invasive species, or stabilized with riprap. The tamarisk can form cut banks that erode to some degree with each large flood. The shoreline at the Matheson Wetlands Preserve opposite the site has been diked and is heavily colonized by tamarisk (NPS 2003).

The State of Utah has classified the river segment adjacent to the Moab site as protected for warm-water species of game fish and other warm-water aquatic life, including necessary aquatic organisms in their food chain. Macroinvertebrate samples were collected at six locations in the vicinity of the site in 1999 (USGS 2002). At each location, a sample was collected 3 ft, 15 ft, and 30 ft from the shoreline. Over 40 macroinvertebrate taxa, including chironomids and oligochaetes, were found during this sampling effort. Rooted macrophytes (i.e., plants), along with algae and zooplankton, have been found in the intermittent backwater areas but are almost nonexistent in the main channel (NRC 1999). The backwaters and inundated floodplains often serve as important nurseries and forage suppliers for fish, including the endangered Colorado pikeminnow (Valdez and Wick 1983). Both native and non-native species are present in this reach of the Colorado River, including four federal endangered species (NRC 1999). Trammell and Chart found twelve non-native species and only five native species in surveys conducted from 1992 through 1996 (Trammell and Chart 1998).

Many components of the upper Colorado River ecosystem have changed over the last several decades. One change that affects the aquatic life of the river near Moab is the establishment of introduced, or non-native, fish species. The upper basin contains about 20 species of warm-water, non-native fish (USF&WS 2002a). The red shiner (*Cyprinella lutrensis*), common carp (*Cyprinus carpio*), fathead minnow (*Pimephales promelas*), channel catfish (*Ictalurus punctatus*), northern pike (*Esox lucius*), and green sunfish (*Lepomis cyanellus*) are the non-natives considered by Colorado River Basin researchers to be of greatest concern because of their suspected or documented negative interactions with native fishes (USF&WS 2002a). These introductions, in concert with the physical and chemical alterations of the river, may have contributed to the decline of the native fish populations (Trammell and Chart 1999, NRC 1999, Muth et al. 2000; USF&WS 2002a). Chapter 3.0 of the EIS describes the aquatic setting further.

A1−5.2 Klondike Flats

The proposed Klondike Flats disposal site is located on land administered by BLM about 18 miles north of the Moab site and just west of US-191 (Figure A1−6). The Klondike Flats site is remote and is located behind a low bluff such that the site is not visible from the highway. There are no perennial streams or other surface water features in or near this area; therefore, there are no significant aquatic ecological resources or wetlands that would be affected at the site. A portion of the site under consideration is designated for disposal in BLM's resource management plan (BLM 1983). The Grand County landfill is located within the area identified for disposal. The Canyonlands Field Airport is located immediately southeast of the Klondike Flats site. Access to the Grand County landfill is approximately 1 mile north of the Klondike Flats site and 1 mile west of US-191 on CR-236. Crescent Junction and the I-70 interchange are approximately 10 miles north of the site along US-191.

Plant abundance and diversity are generally very low, even for arid rangeland, because the low-permeability soils promote rapid runoff, have low water-holding capacity, and are often highly saline. Rooting depths vary from 5 to 20 inches. Extant vegetation on Chipeta soil within the Klondike Flats site is similar to the potential natural vegetation described in the Grand County Soil Survey (USDA 1989), which has limited value for grazing because of low productivity and poor palatability of dominant species. In upland areas, vegetation is dominated by low saltbushes (mat and Gardner saltbush [*Atriplex corrugata* and *Atriplex gardneri*]) with scattered shadscale, bud sagebrush (*Picrothamnus desertorum*), galleta, Indian ricegrass, and desert trumpet (*Eriogonum inflatum*). Maximum vegetative cover is about 50 percent. Prickly pear cactus, a grazing increaser that occurs in upland areas, is evidence of past overgrazing. A few hedgehog cacti (*Echinocereus* spp.) were also observed in upland areas. At the confluence of drainages where greater amounts of moisture occur seasonally, vegetation consists of abundant rubber rabbitbrush with a relatively dense understory of galleta, indicating that a slight increase in moisture can significantly increase plant abundance.

Water bodies in the vicinity of the Klondike Flats site consist primarily of ephemeral washes that are dry most of the year. The water from these washes eventually flows into either the Green River or the Colorado River. There are no wetlands in the area; however, there are several springs and wells nearby. These water sources are small, and nearby vegetation is primarily tamarisk.

The area surrounding and including the Klondike Flats site is available for recreation and other uses; however, existing access is limited to several dirt roads that are used for recreational access. Favorable weather allows off-road access for hikers, campers, mountain bikers, and off-highway vehicles during most of the year. Most recreational activities occur south of the Klondike Flats site along CR-138, also known as the Blue Hills Road. This road provides access to desirable areas to the west that are used mainly for mountain biking and off-highway vehicles. Although the amount of recreational use west of the site is unknown, it is possible that as many as 53,000 recreational use visits occurred during 2002. In addition to recreation, BLM allows grazing, oil and gas leasing, and mining claims. The Klondike Flats site area is part of the Big Flat grazing allotment, which is currently under a grazing permit until 2013.

Transportation of materials between the Moab site and the Klondike Flats site would occur along the US-191/Union Pacific Railroad corridor. An existing natural gas pipeline right-of-way would be followed if a slurry pipeline were selected to transport materials. From the Moab site to the north for approximately 7 miles, this transportation route climbs through a relatively broad but steep-walled canyon with many side canyons.

A1−5.3 Crescent Junction

The proposed Crescent Junction disposal site is located on BLM-administered lands about 2 miles north of the town of Crescent Junction, which is an interchange on I-70 and US-191 (Figure A1−7). The site is about 30 miles north of the Moab site and covers several square miles of largely desert terrain that is bordered on the north by the prominent Book Cliffs. No perennial streams are present, but ephemeral streams may carry high flows during heavy rains. Because no perennial streams or other surface water bodies are present on the Crescent Junction site, aquatic ecological resources and wetlands would not be adversely affected by activities at this site.

In most areas of the site, vegetation is indicative of disturbance and varies from the potential native vegetation. About 50 percent of the Crescent Junction site is covered by very sparse low-growing vegetation. The northern part of the site is covered with a gray veneer of debris from a recent outwash originating in the nearby Mancos Shale hills. The outwash area is mostly bare with some prickly pear cactus, cheatgrass (*Bromus tectorum*), and Russian thistle (*Salsola kali*). Vegetation in the south-central and southeast portions of the site also consists primarily of these three species with a few native shrubs and perennial grasses, including gardner saltbush, galleta, and Indian ricegrass. Range condition in this area would probably rate as poor to fair.

Vegetation in the southwest portion of the site is probably influenced by a shallow aquifer and consists of sparse shrubs, including black greasewood, shadscale, and gardner saltbush. Understory vegetation consists primarily of annual weeds, such as cheatgrass and Russian thistle, with a few perennial grasses (galleta, Indian ricegrass). Tamarisk occurs occasionally in the drainages.

Water bodies in the vicinity of the Crescent Junction site consist of ephemeral washes that are dry most of the year. The water from these washes eventually flows into the Green River. There are no known wetlands in the area.

Although not designated by BLM as a recreational area, the site has no access controls and the area is used for hiking, biking, and camping. While the Crescent Junction area is designated as access-limited, it can be accessed by secondary dirt roads and may thus incur off-road vehicle use. The site is part of the Crescent Canyon grazing allotment, which is currently under a grazing permit until 2010. Currently, all sections of interest for the potential Crescent Junction site are held by oil and gas leases, although none are in production.

Transportation to the Crescent Junction site would be along US-191 or the Union Pacific Railroad. A slurry pipeline would follow existing natural gas pipeline rights-of-way. Transportation to the Crescent Junction site would also pass through the canyon area north of Moab.

A1−5.4 White Mesa Mill

The proposed White Mesa Mill disposal site is located in San Juan County, Utah, approximately 5 miles south of Blanding, Utah. The proposed disposal cell site (Figure A1−8) is situated within 5,415 acres of property owned primarily by International Uranium (USA) Corporation (IUC). Existing facilities at the site consist of a mill, ore storage pad, and four lined tailings cells with leak detection systems and ground water monitor wells. The mill itself occupies approximately 50 acres, and the tailings disposal ponds occupy approximately 450 acres. The site is accessible from a half-mile-long private road connected to US-191. Other than the tailings disposal ponds, no perennial surface water is present at the White Mesa Mill site. Wetlands at the site are restricted to very small areas where perched ground water discharges to springs and seeps along Westwater Creek Canyon and Cottonwood Creek Canyon to the west-southwest of the site and along Corral Canyon to the east of the site near the Burro Canyon Formation. Ruin Spring, about 2 miles southwest of the millsite, is the only spring that is known to flow on a consistent basis. The other springs and seeps have not been known to flow year-round, although plants such as cattails have been observed around the seep in Cottonwood Canyon.

At the White Mesa Mill site, several areas were chained (to remove unwanted vegetation) to support an active cattle ranch prior to mill operations. These areas were reseeded but are now mostly void of vegetation due to overgrazing. Current vegetation consists primarily of crested wheatgrass and invasive weeds. Annual weeds, rabbitbrush, snakeweed, sagebrush, and cheatgrass dominate vegetation in the surrounding areas, which include some abandoned dry farms. Areas that were neither cultivated nor chained support sagebrush communities with a sparse understory of grasses, including galleta and crested wheatgrass. Forbs are rarely found. Potential vegetation consists of more than 50 percent palatable grasses such as western wheatgrass, Indian ricegrass, needle-and-thread grass, and squirreltail; 15 to 20 percent increaser grasses, including galleta and blue grama; 25 percent decreaser browse plants, including winterfat; and 5 to 10 percent big sagebrush, ephedra, and other shrubs.

Truck transportation between Moab and the White Mesa Mill site would be along US-191. There is no existing rail route south of Moab; therefore, rail transport to White Mesa Mill is not considered an option. A slurry pipeline would follow mostly existing rights-of-way through federally administered lands. However, approximately 29 miles of new rights-of way would be required, which would occur in an area that likely supports a greater diversity and abundance of vegetation and wildlife than the other pipeline routes. For example, the region near Monticello, Utah, north of the White Mesa Mill site where the new right-of-way would pass, supports piñon-juniper forests, and scattered ponderosa pine stands dominate this zone at higher elevations.

Recent NRC environmental assessments for the White Mesa Mill site concluded that no threatened or endangered species were being adversely affected by current mill operations (IUC 2003).

A1−6.0 Borrow Areas

Preliminary consultations and investigations do not indicate the presence of threatened or endangered species at borrow sites. However, the proposed borrow areas may need further evaluation to determine habitat, species presence, and other ecological characteristics. Preliminary evaluations of these areas indicate that no aquatic resources are present. Before developing any borrow area, DOE, in consultation with USF&WS and BLM, would determine the need for habitat evaluations and surveys for species that may be affected. If threatened or endangered species or critical habitats were identified on a selected area, a mitigation plan would be developed or a different borrow area would be selected, in order to minimize or eliminate impacts. If impacts could not be avoided, additional Section 7 consultation would be required. Figure A1−3 shows the borrow area locations.

A1−6.1 Crescent Junction Borrow Area

The Crescent Wash borrow area is located within the Crescent Junction disposal site and shares the same environmental features.

A1−6.2 Floy Wash Borrow Area

The Floy Wash borrow area is within an area that has been previously used by the State of Utah Department of Transportation for borrow materials. It is located about 7 miles west of Crescent Junction and I-70. The Floy Wash borrow area includes a small reservoir with tamarisk as the main vegetative component. This area is subject to flooding and is also bordered by Floy Wash, located half a mile to the northwest and west. Floy Wash has 80 acres of native and exotic riparian and wetland habitats, including lentic wetlands and tamarisk and willow areas (BLM 2003a). BLM has rated the wash as a "functioning at risk" system, meaning that it fulfills some, but not all, of the definitions of a properly functioning riparian system (BLM 2002).

Potential vegetation of Mesa-Trook complex soils (USDA 1989), found on the Floy Wash borrow area, consists of shadscale, galleta grass, Indian ricegrass, and fourwing saltbush. Phacelia (another phacelia species, not the endangered clay phacelia [*Phacelia argillosa*] described in Section A1−8.1.3) and prickly pear cacti dominated vegetation observed during a site visit in April 2003, which reflects the history of the site as a gravel quarry. Other species observed include milkvetch, kochia, Gardner saltbush, mat saltbush, bud sagebrush, galleta, globemallow, and cheatgrass.

A1−6.3 Courthouse Syncline Borrow Area

The Courthouse Syncline borrow area is located several miles northwest of the Klondike Flats disposal site. This borrow area is located about 1 mile from Thompson Wash and Crescent Wash, both of which are intermittent and support tamarisk totaling approximately 34 acres. Otherwise, vegetation on the Courthouse Syncline borrow area is similar to that of the Klondike Flats disposal site.

A1−6.4 Klondike Flats Borrow Area

The Klondike Flats borrow area is located within the Klondike Flats disposal site and shares the same environmental features.

A1−6.5 Tenmile Borrow Area

The Tenmile borrow area is located about 7 miles west of the Klondike Flats site. No ephemeral or perennial surface water features have been identified in this area. Soils and potential natural vegetation at the Tenmile borrow area are classified as Nakai fine sandy loam; however, approximately 25 percent of the Tenmile borrow area consists of stabilized and active parabolic dunes of fine sand. Ephedra is the common dune stabilizer in the area. Other common plants are sand sage, hopsage, Indian ricegrass, and wild buckwheat in fine sand areas and fourwing saltbush, jimmyweed, rabbitbrush, galleta, and yucca in sandy loam areas. Tamarisk and greasewood occur in areas with relatively shallow ground water. The Tenmile borrow area is located within one-half mile of Tenmile Wash, an ephemeral wash system dominated by tamarisk.

Land in the area is administered by BLM. Blue Hills Road provides major access to the Tenmile borrow area, and the area is laced with interconnecting backcountry roads and trails. There is high recreational use of the general area.

A1−6.6 Blue Hills Road Borrow Area

The Blue Hills Road borrow area is located about 4 miles south of the Klondike Flats site. Soils at the Blue Hills Road borrow area are classified as Nakai fine sandy loam and the Toddler-Ravola-Glenton association. These soils and the potential natural vegetation are similar to that described for the Klondike Flats disposal site.

Land in the area is administered by BLM. Blue Hills Road provides major access to the Blue Hills Road borrow area, and the vicinity is laced with interconnecting backcountry roads and trails. There is high recreational use of the general area.

A1−6.7 LeGrand Johnson Borrow Area

This privately owned commercial gravel pit is located about 8 miles south of Moab along US-191 in Spanish Valley. The site is surrounded by other past or present quarry and borrow sites and other developments. Obtaining borrow materials from this site would not be expected to greatly alter the effects of current borrow area operations on the terrestrial environment.

A1−6.8 Papoose Quarry Borrow Area

This existing commercial quarry, owned by the Cotter Corporation, is located in Lisbon Valley south of SR-46 and at the intersection of CR-113 and CR-370. Obtaining borrow materials from this site would not be expected to greatly alter the effects of current quarry operations on the terrestrial environment.

A1−6.9 Blanding Borrow Area

The Blanding borrow area, located north of the White Mesa Mill site and northeast of Blanding, is near existing sand and gravel pits. This site can be readily accessed from US-191 and is on land administered by BLM. It lies within a designated transportation and utility corridor and is open to off-road vehicle use. Recapture Creek, a perennial stream, and an intermittent stream are located within the Blanding borrow area. Both watercourses are dominated by tamarisk, cottonwood, willow, and shrub oak (BLM 2002). Compared to other borrow areas under consideration, this site is believed to support greater wildlife diversity and abundance.

A1−6.10 White Mesa Mill Borrow Area

The White Mesa Mill borrow area is located south of Blanding at the head of a broad, heavily dissected canyon within the IUC property boundary. Sparse piñon-juniper, saltbush, and sagebrush communities currently dominate the area.

A1−7.0 Analysis for Aquatic Species

A1−7.1 Species Accounts and Status in the Proposed Action Area

The major portions of the upper Colorado and Green rivers, including tributaries, have been designated by USF&WS as critical habitat for the Colorado pikeminnow, razorback sucker, humpback chub, and bonytail (Table A1−3). The segment of the Colorado River near the Moab site is within this designated critical habitat. These fish species are considered endangered by USF&WS. Conservation of these species requires the identification and management of water resources and habitat that are important for their survival and propagation (i.e., spawning areas, nursery grounds, and interactions with predators and competitors) (50 CFR 17.95).

Table A1−3. Status of Aquatic Species

Common Name	Scientific Name	Status
Humpback chub	*Gila cypha*	Endangered
Bonytail	*Gila elegans*	Endangered
Colorado pikeminnow	*Ptychocheilus lucius*	Endangered
Razorback sucker	*Xyrauchen texanus*	Endangered

The Colorado pikeminnow, razorback sucker, humpback chub, and bonytail are included in the Upper Colorado River Endangered Fish Recovery Program (USF&WS 2002a, 2002b, 2002c, 2002d). The program goal is "to recover the endangered fishes while water development proceeds in compliance with State and Federal laws, including the ESA, State water law, interstate compacts, and Federal trust responsibilities to American Indian Tribes" (USF&WS 2002a, 2002b, 2002c, 2002d). Management actions identified as part of the recovery goals for these species include "minimizing the risk of hazardous-materials spills in critical habitats and remediation of water-quality problems." Contaminants of concern, primarily ammonia, pose a threat to the Colorado pikeminnow and razorback sucker. There is also the risk of "catastrophic pile failure that could affect important nursery areas and destroy other fish habitat" (USF&WS 2002a, 2002b). Disposal cell or pile failure is discussed further in Section A1−7.2.

A1−7.1.1 Colorado Pikeminnow

Habitat/Reproduction. Colorado pikeminnow, a large, predatory fish belonging to the minnow family, was once abundant and widely distributed in the Colorado River basin. Wild populations of Colorado pikeminnow currently occupy only about 25 percent of their historical range in the basin, including the upper Colorado River from Palisade, Colorado, to Lake Powell, Utah (USF&WS 2002a). Natural reproduction of Colorado pikeminnow is known to occur in the upper Colorado, Green, Yampa, Gunnison and San Juan Rivers (USF&WS 2002a). Although adult and juvenile fish move intermittently through the reach of the Colorado adjacent to the Moab Site, the entire reach is considered occupied habitat at all times. Exposure of pikeminnow to Moab site-related contamination is related to the presence of suitable habitat and to the presence or absence of contamination in those suitable areas. The areal extent and type of pikeminnow habitat near Moab changes with the time of the year, water temperature, pH, changes in river morphology, water level, and water quality. The interaction and connections among these habitat characteristics and the exact location of suitable habitat can change over time. These changes can occur over very short periods of less than a day to seasonal, annual, and even decadal periods of time.

Throughout most of the year, juvenile, subadult, and adult pikeminnow use relatively deep, low-velocity eddies, pools, and runs that occur in the nearshore areas of main river channels (USF&WS 2002a). During the spring and early summer, the adults use shorelines, floodplain habitats, flooded tributary mouths, and flooded side canyons that are available only during high flows (Tyus 1990, USF&WS 2002a). These high spring flows provide an important cue to prepare adults for spawning migration (USF&WS 2002a). During the spawning season, adults have been reported to migrate up to 200 miles upstream or downstream to reach spawning areas (Tyus 1990). By late August or September, most adults return to home ranges occupied the previous spring (Muth et al. 2000). Juvenile pikeminnow, which are more commonly collected in the lower reaches of the river, are more wide-ranging in their habitat preference compared to adults. Juveniles feed on small-bodied fishes that spend much of their life in or associated with low velocity habitats. Whereas adult pikeminnow are found in the lower Colorado River, the greatest concentration of adults (spawning population) occurs upstream of the Moab site in Colorado (USF&WS 2004a).

Pikeminnows spawn on cobble bars in the upper reaches of the river, upstream of Westwater Canyon (USF&WS 2004a). Spawning occurs during period of declining flows during June, July, or August (Tyus and Haines 1991, Muth et al. 2000, Tyus 1990). After hatching, larvae passively drift downstream to settle into relatively low-velocity river reaches where they are entrained in backwater nursery habitats. Larvae develop paired fins and are then classified as young-of-the-year. They remain in these backwater habitats throughout most of their first year of life (USF&WS 2002a). Backwater areas are vital to successful recruitment of early life stages of Colorado pikeminnow. The pikeminnow larvae occupy these in-channel backwaters soon after hatching. They tend to occur in backwaters that are large, warm, deep (approximately 1 ft) and turbid (USF&WS 2002a). Larval and juvenile pikeminnow (0 to 1 year) show a preference for secondary channel habitats (Trammell and Chart 1998, Rakowski and Schmidt 1997, Day et al. 1999, USF&WS 2002a), and they are primarily found in low-velocity waters, which include backwaters (Tyus and Haines 1991, Trammell and Chart 1998). During the fall, they utilize backwater habitats that are deeper and more persistent than other habitats (Trammell and Chart 1998, Day et al. 1999). These backwaters are created when a secondary channel is cut off at the upper end but remains connected to the river at the downstream end. These areas are considered crucial for over-winter survival of the larval and juvenile fish (Trammell and Chart 1998). The backwater areas are considered primary, preferred habitat for juveniles; however, both adults and juveniles can occur in a variety of habitats throughout the year. Young Colorado pikeminnow remain near the nursery areas for the first 2 to 4 years of life, then move upstream and establish home ranges (Osmundson et al. 1998).

Aerial observations of the Colorado River were conducted between 1992 and 1996 to estimate backwater habitat from river mile 53.5 to 64.0. In addition, Colorado River flow data (in cubic feet per second) were recorded from the U.S. Geological Survey (USGS) Cisco, Utah, gaging station (Station No. 09180500) for each observation. Flows recorded during the observations ranged from 2,490 to 9,260 cfs. Base river flow typically ranges from 3,000 to 5,000 cfs for most of the year. Between April and July, the river discharge and stage dramatically increase in response to snowmelt runoff. On average, the river stage rises approximately 7 ft during peak flows at the Cisco gaging station (DOE 2003b). The average total backwater area for flows under

5,000 cfs was 2.3 acres (ranging from 0.4 to 4.4 acres). The average total backwater area for flows over 5,000 cfs was 1.2 acres (ranging from 0.9 to 2.0 acres).

Backwater areas were also quantified for areas adjacent to and immediately downstream of the Moab site (river mile 61 to 64). The average total backwater area in river mile 61 to 64 was 1.2 acres (ranging from 0.2 to 2.1 acres) for flows under 5,000 cfs and 0.9 acre (ranging from 0.4 to 1.9 acres) for flows over 5,000 cfs. Fifty to 70 percent of the backwater areas from river mile 53.5 to 64.0 were found in the stretch of the Colorado River in the vicinity of the Moab site (river mile 61 to 64).

A field visit with UDWR on December 19, 2001, identified backwater areas that may be used by larval and juvenile pikeminnows beginning at the mouth of Moab Wash and extending approximately 1,200 ft south. Within this area, three locations extending about 600 to 800 ft south of the wash were tentatively identified as having the greatest potential for suitable nursery habitat at river flows that inundate these areas each year.

Based on multiple studies of young-of-the-year pikeminnow habitat, researchers have established a protocol for sampling backwater areas to monitor pikeminnow recovery efforts (Trammell and Christopherson 1999). The protocol calls for sampling backwaters with a minimum surface area of 322 ft^2 and a minimum depth of 0.98 ft for the Interagency Standardized Monitoring Program (ISMP). The relatively permanent “average” secondary channel backwater areas have mean surface areas of 10,749 ft^2 and mean depths of 1.38 ft (Trammell and Christopherson 1999). Besides area and depth requirements, quality pikeminnow habitat must also be sufficiently turbid to provide adequate cover. Recent studies of pikeminnow in the Green River found a positive correlation of pikeminnow with higher turbidity; it was therefore recommended that a minimum depth for sampling in these turbid areas be reduced to 0.7 to 0.8 ft (Day et al. 1999).

Known Occurrences in the Project Area. There are estimated to be 600 to 900 adult pikeminnows in the upper Colorado River (USF&WS 2002a). The two known spawning areas in this reach of the river are near Grand Junction, Colorado, and in the lower Gunnison River (USF&WS 2002a). Age 0–1 fish and juveniles are found in the upper Colorado River downstream of Palisade to Lake Powell (USF&WS 2002a). The Moab site is located on river mile 64 and is within the habitats documented to contain current populations of Colorado pikeminnow. Both adults and subadults have been collected in Moab Wash and directly downstream from the tailings pile (USGS 2002). Up to 53 young-of-the-year pikeminnow were captured between river mile 48 and 84 (Osmundson et al. 1997). In a mark-recapture study of adult pikeminnow in this reach (river mile 48 to 84), 21 of 51 (41 percent) fish were caught between river mile 57 and 65 (Osmundson et al. 1997). Surveys in 1992 to 1996 by Trammell and Chart (1998) found adult and larval pikeminnow between river mile 55 and 65.

As part of the ISMP, pikeminnow nursery habitat was sampled each fall (1986 to 2002) between river mile 53.5 and 63.5. The purpose of this sampling was to determine relative abundance and distribution of young-of-the-year Colorado pikeminnow. The sampling protocol required sampling two habitats every 5 miles. Sixty backwater locations were sampled between 1986 and 2002, of which 13 were between river mile 61 and 63.5. Five of the 13 backwater areas sampled contained a total of 83 young-of-the-year pikeminnow comprising 24 percent of the total pikeminnow captured between river mile 53.5 and 63.5 during ISMP sampling (UDWR 2003a).

In the spring of 2003, USF&WS captured 8 stocked adult pikeminnow between river miles 60 and 64, 4 between river miles 64 and 70, and 20 between river miles 50 and 60 (USF&WS 2004b).

UDWR sampled three locations within 1,000 ft of the Moab Wash in April 2004. Each site was sampled using seines. Red shiner and plains killifish were collected. However, Colorado pikeminnow were not collected during these sampling events (UDWR 2004).

Diet. Pikeminnow less than 2.0 inches total length prey on small aquatic invertebrates in side channels and backwaters; juveniles between 2.0 and 4.0 inches total length still in the backwater nursery habitat eat invertebrates and other fish; and pikeminnow greater than 4.0 inches total length prey mainly on other fish (Muth and Snyder 1995; USF&WS 2002a).

Threats. Threats to this species include streamflow regulation, habitat modification, competition with and predation by non-native fish species, and pesticides and pollutants (USF&WS 2002a). The Moab site poses two significant threats to the Colorado pikeminnow: "toxic discharges of pollutants, particularly ammonia, through ground water to the Colorado River and the risk of catastrophic pile failure, that could affect important nursery areas and destroy other fish habitat" (USF&WS 2002a).

A1−7.1.2 Razorback Sucker

General Distribution. The endangered razorback sucker is one of the most imperiled fishes in the basin and exists naturally as only a few disjunct populations of scattered individuals (Minckley et al. 1991; Muth et al. 2000). Lack of recruitment sufficient to sustain populations has been mainly attributed to the cumulative effects of habitat loss and modification caused by water and land development and predation on early life stages by non-native fishes (Hamilton 1998; USF&WS 1998a; Muth et al. 2000). Wild populations of razorback sucker were virtually extirpated from the Colorado River system by 1990. Since the mid-1990s, the recovery program has been reintroducing hatchery-reared fish in the Colorado and Gunnison rivers (USF&WS 2004a).

Habitat. Razorback suckers are known to spawn on gravel bars and may also spawn in backwaters (NRC 1999). In the past, they have been observed spawning in early and mid-summer within 2 miles upstream of the tailings pile (NRC 1999). The razorback sucker may be found almost anywhere in the river, including slow runs in the main channel, inundated floodplains and tributaries, eddies and backwaters, sandy bottom riffles, and gravel pits (50 CFR 17.95). Young razorback suckers require nursery habitat with warm, shallow water such as tributary mouths, backwaters, or inundated floodplains (Modde 1996, Muth et al. 2000). Stocked juvenile and adult razorback sucker actively seek out flooded habitat in the Colorado River system and are likely using flooded habitats available at the mouth of Courthouse Wash, Moab Wash, the mouth of Mill Creek and Kane Springs (USF&WS 2004a). During periods of inundations, the lower Moab Wash and the riparian woodland near the toe of the pile potentially provide habitat for pikeminnow and razorback suckers (NRC 1999). The Matheson Wetlands Preserve area is also potential nursery habitat for the razorback sucker (NPS 2003). For purposes of this BA, it is assumed that the razorback sucker may be present in the project area.

Known Occurrences in the Project Area. A limited number of adults have been found in the upper Colorado River since 1974 (USF&WS 2002b). Many of the adults captured during studies have been found in two abandoned gravel pits in the Grand Valley, near Grand Junction, Colorado, just upstream and downstream of the confluence with the Gunnison River (USF&WS 2002b). Recaptures of stocked individuals have been increasing in recent years throughout the river, including near the Moab site (USF&WS 2004a). In 2003, USF&WS captured 3 stocked adult razorback suckers between river miles 60 and 64, 10 between river miles 64 and 70, and 8 between river miles 50 and 60 (USF&WS 2004b). USF&WS sampled this stretch of river in the spring of 2004 and captured 6 stocked adults between river miles 64 and 70, 2 between river miles 60 and 64, and 3 between river miles 45 and 60 (USF&WS 2004c). No young razorback suckers have been captured anywhere in the upper Colorado River since the mid-1960s (USF&WS 2002b; USGS 2002; NPS 2003). However, in recent years, stocked razorback sucker have reproduced in the Gunnison River, and naturally produced larvae are now in the Colorado River system (USF&WS 2004a).

Diet. The diet of all life stages is varied and includes invertebrates, zooplankton, phytoplankton, algae, and detritus (Behnke and Benson 1980, Muth et al. 1998, Marsh 1987, Muth et al. 2000).

Threats. Threats to this species include streamflow regulation, habitat modification, competition with and predation by non-native fish species, and pesticides and pollutants (USF&WS 2002b). The Moab site poses two significant threats to the razorback sucker: "toxic discharges of pollutants, particularly ammonia, through ground water to the Colorado River and the risk of catastrophic pile failure, that could affect important nursery areas and destroy other fish habitat" (USF&WS 2002b).

A1−7.1.3 Humpback Chub

Habitat/Distribution. The humpback chub, a large cyprinid fish, prefers deep canyons with swift water and rapids (USF&WS 2002c; Muth et al. 2000). Historical abundance of the humpback chub is unknown, and historical distribution is incomplete (Muth et al. 2000; USF&WS 2002c). The species primarily inhabits relatively inaccessible canyons of the Colorado River Basin and was rare in early collections (USF&WS 2002c). Adults require eddies and sheltered shoreline habitats maintained by high spring flows. These high spring flows maintain channel and habitat diversity, flush sediments from spawning area, rejuvenate food production, and form gravel and cobble deposits used during spawning. Young require low-velocity shoreline habitats, including eddies and backwaters, that are more prevalent under base-flow conditions (USF&WS 2002c).

Humpback chub are more sedentary than other native Colorado River fishes and are capable of completing their life cycle in relatively short stretches of the river. Radiotelemetry and tagging studies consistently show high fidelity by humpback chub for specific river locations occupied by respective populations. Six extant wild populations are known in the Upper Colorado Basin: (1) Black Rocks, Colorado River, Colorado; (2) Westwater Canyon, Colorado River, Utah; (3) Yampa Canyon, Yampa River, Colorado; (4) Desolation/Gray Canyons, Green River, Utah; (5) Cataract Canyon, Colorado River, Utah; and (6) mainstem Colorado River in Marble and Grand Canyons and the little Colorado River, Arizona (USF&WS 2002c). The nearest downstream population occurs in Cataract Canyon (over 50 miles downstream of the Moab site) (USF&WS 2002c). The population in Cataract Canyon consists of about 500 adults (USF&WS 2003c). Populations in the Upper Colorado River Basin appear healthy and stable. The population at Black Rocks and Westwater Canyon, near the Colorado-Utah state line, is estimated at about 2,900 adults (USF&WS 2003c).

Known Occurrences in the Project Area. Five individuals were collected from a reach about 19 river miles downstream of the Moab site, possibly associated with populations upstream of the Moab site in Westwater Canyon and Black Rocks (NRC 1999, Valdez and Williams 1993).

Threats. Threats to this species include streamflow regulation, habitat modification, predation by non-native fish species, parasitism, hybridization with other native *Gila*, and pesticides and pollutants (USF&WS 2002c).

A1−7.1.4 Bonytail

Habitat/Distribution/Known Occurrences in the Project Area. Little is known about the specific habitat requirements of bonytail because this species was extirpated from most of its historical range prior to extensive fishery surveys (USF&WS 2002d). The bonytail uses mainstem river channels, where it has been observed in pools and eddies, as well as inundated riparian areas. Available distribution data show that flooded bottomland habitats are important growth and conditioning areas for bonytail, particularly as nursery habitats for young (USF&WS 2002d). Potential habitat for both adult and juvenile fish exists in the reach of the Colorado River near the Moab site.

Currently, no self-sustaining populations of bonytail exist in the wild, and very few individuals have been caught throughout the Upper Colorado Basin (USF&WS 2002d). Since the mid-1990s, the recovery program has been reintroducing hatchery-reared fish in the Colorado River. Some of the stocked fish have been recaptured, indicating at least short-term survival (USF&WS 2002d). Recaptures of these stocked individuals have been increasing in recent years throughout the river, including near the Moab site (USF&WS 2004a). In 2003, a stocked adult bonytail was captured by USF&WS at river mile 66.2, just upstream of the Moab site (USF&WS 2004b). In 2004, a stocked adult was captured at river mile 69.2. (USF&WS 2004c).

Threats. Threats to this species include streamflow regulation, habitat modification, competition with and predation by non-native fish species, hybridization, and pesticides and pollutants (USF&WS 2002d).

A1−7.2 Potential Effects of Proposed Actions on Aquatic Species

The impacts described below would be applicable at the Moab site, under either on-site or off-site disposal alternatives.

Mechanical Disturbance. The impact to aquatic species due to construction and operations at the Moab site would be from mechanical disturbances and loss of vegetation along the shoreline of the Moab Wash and Colorado River. Activities at the Moab site would likely disturb about 8,100 ft of Colorado River shoreline. The vegetation along the shoreline, consisting primarily of tamarisk, would be removed in order to excavate and remove contaminated materials (i.e., soils contaminated with residual radioactive material). The vegetation along the shoreline, consisting primarily of tamarisk, would be removed in order to complete remediation of the tailings pile. The tamarisk along the banks of Moab Wash as it enters the Colorado River would likely be removed as well.

The effects of mechanical disturbance would include the loss of shade and cover over the shoreline and potentially a loss of surface stability that could lead to increased erosion and siltation into the wash and river. Impacts to threatened and endangered species due to these changes would be minimal. The shade and cover provided by the tamarisk is only along the edge of the river during high and moderate flows of the river. At low river flows, the shoreline vegetation provides no shade, and the flow into the wash is cut off. The potential also exists for water intake structures in the river to result in mortality to eggs, larvae, young-of-the-year, and juvenile life stages. DOE would minimize this potential by using one-quarter to three-eighths-inch screened mesh on water intake structures.

Effects from siltation and erosion into the river and wash could fill in backwater areas that may be important to macroinvertebrates and fish. Moab Wash has been documented as potential pikeminnow nursery habitat that could be affected by siltation and erosion (NPS 2003). Erosion along the river shoreline could create new backwater areas, but these would likely be temporary based on river stage.

Federally listed species that could be potentially affected by the changes to the shoreline include the endangered Colorado pikeminnow, razorback sucker, humpback chub, and bonytail. The Colorado River reach near the Moab site has been designated as critical habitat (50 CFR 17.95) for all four federal endangered fish species. Juvenile and adult Colorado pikeminnow and stocked adult razorback sucker and bonytail have been collected near the Moab site. Moab Wash and the riparian vegetation adjacent to the Colorado River potentially provide nursery habitat for young-of-the-year fish (NRC 1999, NPS 2003, UDWR 2003a). Erosion and siltation events that change the depth and configuration of these backwater areas are likely to have an effect on the extent of nursery habitat for endangered fish. Other fish, macroinvertebrates, and emergent plants associated with the backwater areas are also likely to be affected by erosion and siltation. The effects of erosion and siltation would be prevented or reduced by minimizing shoreline disruption, replacing vegetation, and installing erosion control devices.

Noise. Noise from site construction and operations is not expected to affect the aquatic environment. Activities along the shoreline are likely to be of short duration and are not likely to cause macroinvertebrate or fish communities to avoid the area.

Other Human Disturbances. Aspects of human presence such as personnel or vehicle movement and supplemental lighting are not expected to affect the aquatic environment.

Water depletion in the Colorado River as a result of remediation of the Moab site would be in accordance with the Cooperative Agreement to implement the “Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin” (USF&WS 1987). The Cooperative Agreement was signed by the Secretary of the Interior and by the governors of the states of Colorado, Utah, and Wyoming. The recovery program requires that all Section 7 consultations address depletion impacts. A key element of the program requires a one-time contribution of $10 per acre-foot (adjusted annually for inflation) based on the average annual depletion through activities at the site, to be paid to USF&WS. The balance of the payment would be due at the commencement of construction at the site. The impacts due to water depletion can be offset by the one-time contribution, appropriate legal protection of instream flows pursuant to state law, and accomplishments of activities necessary to recover the endangered fish as specified in the recovery plan (NRC 1999). Further consultation to determine the financial contribution based on water depletion, and required permits, if any, would be necessary.

Disposal Cell Failure from Natural Phenomena. This section addresses the potential natural processes that could cause a failure of the disposal cell at the Moab site and the expected consequences and potential risks associated with a contaminant release. The degree of contaminant impact to endangered species would depend upon (1) the type, duration, and areal extent of the failure event, and (2) the mass and concentrations of contaminants released into the Colorado River. Due to uncertainties associated with a contaminant release, and cumulative effects that are not contaminant-related, specific impacts to endangered species are difficult to assess.

Two basic types of failures could occur: catastrophic and long-term. These are described in more detail in Section 4.1.17 of the EIS. A catastrophic (i.e., sudden and unexpected) failure could occur as a result of a major flood or seismic event and would likely affect the entire Moab region. The analysis of a catastrophic failure considered the following assumptions to estimate the concentrations of uranium and ammonia as nitrogen in Colorado River water (DOE 2003c):

- Volumes of 20 and 80 percent of the tailings eroded into the river at a constant rate over a period of 10 hours (NRC 1999).
- Disposal cell failure occurs during a PMF, and the average river flux over the 10-hour period is 150,000 cfs, or half the 300,000 cfs maximum flux (NRC 1999).
- Concentrations of uranium and ammonia in tailings pore fluids and solid phases are the geometric means of all tailings samples.
- Uranium partitions between solid-phase tailings and river water according to a linear relationship with a distribution ratio of 3.0 milliliters per gram.
- All ammonia is dissolved into the river water (based on its common occurrence in soluble salts at the Moab site).
- Colorado River water mixes with Green River water at a ratio of 1.2:1.0, a 30-year average value determined from river gage stations at Cisco, Utah (Colorado River), and Green River, Utah (Green River) (USGS 2004).
- There is no dispersion of the dissolved phase.
- Colorado River water mixes uniformly with 50 percent of the water in Lake Powell; Lake Powell contains 6.85 trillion gallons (USBR 2004).
- There is no sorption of dissolved contaminants to clean suspended load in the river.

While engineering design of the disposal cell could compensate somewhat for this type of catastrophic event, planned mitigation would, at best, be speculative. A long-term, slow release could occur as a result of river migration, basin settling, or periodic erosion of the cell cover. Long-term failures assume smaller-quantity releases over an extended period (many years); a continuation of this type of release would also require a failure of long-term management (a scenario that assumes no repairs to the damaged cell would be done). This type of release, which is possible at all Uranium Mill Tailings Radiation Control Act (UMTRCA) Title I sites, can be mitigated. DOE's newly created (2003) Office of Legacy Management is responsible for monitoring and mitigating this type of release.

The focus of this analysis is to evaluate the potential qualitative consequences of contaminants in the water and sediments of the Colorado River based on a significant (catastrophic) release of tailings. DOE has evaluated the hydrologic and geologic conditions of the northwestern portion of Spanish Valley and the Colorado River corridor at Moab (see Sections 3.1.1, 3.1.6, and 3.1.7 of the EIS). DOE has determined that catastrophic failure of the pile from sudden or catastrophic lateral migration of the Colorado River into the Moab site for the disposal cell design period of 200 to 1,000 years does not pose a realistic hazard. Given the known geologic and hydrologic context, the likelihood of catastrophic failure, though not statistically quantified, is considered extremely unlikely. Although the probability of a significant release would be very small over the design life of the on-site disposal cell, this type of failure was assumed to occur in order to qualitatively evaluate the potential consequences (risks).

The hypothetical catastrophic failure could release a large quantity of tailings into a relatively small volume of water compared to long-term releases, which would release a small quantity of tailings into a large volume of water (river flow over many years). Consequently, the assumptions associated with the hypothetical catastrophic event would yield the worst-case situation (more tailings released and higher contaminant concentrations in water).

For purposes of analysis, a large disposal cell failure (20 to 80 percent of the tailings eroded) was assumed to occur over a short duration (10 hours). Although such a large event would be unlikely, the analysis is useful in projecting potential environmental consequences of a worst-case scenario. The Colorado River was assumed to be at high flood stage during the tailings release. Concentrations of uranium, ammonia as nitrogen, and radium-226, the most prevalent contaminants, were estimated for the failure scenarios.

Sediment released during a catastrophic event would deposit in the river bottom or along banks or become part of the suspended load. Fine-grained portions of the sediment would remain in suspension and rapidly transport downstream. Where the river overflowed its banks, fine-grained sediment would be deposited by settling in standing water. The concentrations of contamination in backwater areas would depend on (1) the proportion of fine-grained tailings to clean suspended load, (2) concentration in the suspended tailings, and (3) the mass deposited over a given area. During periods of low flow, fine-grained sediment would be deposited; during high flow, these deposits would be remobilized and transported farther downstream. The sediment would be dispersed and mixed with clean sediment during transport, causing a continuous decrease in contaminant load. Detailed studies of deposition of radioactive sediment in the Colorado River Basin have shown that very small amounts of contamination would be expected to accumulate in the main river channel (HEW 1963).

After a catastrophic failure, contaminants would likely cause short-term adverse impacts to aquatic receptors in surface waters and sediments adjacent to the site. These negative impacts would likely decrease as the contaminant concentrations were reduced through dilution and dispersion downstream. Impacts from elevated ammonia levels at the Moab site downstream to Lake Powell would likely be short-term. Ammonia degrades and volatilizes and would not be expected to persist in the environment. Although the uranium surface water benchmarks would be exceeded, impacts would more likely occur from elevated concentrations in the sediment. Uranium accumulates in sediments and enters the food chain by adsorption on surfaces of plants and animals and by ingestion of sediments and contaminated food (Driver 1994; Cooley and Klaverkamp 2000; Swanson 1983). Thus, impacts from uranium in the sediments may be longer term because it complexes with sediments where it is likely to be more persistent.
Catastrophic disposal cell failure as a result of an unexpected event could also cause negative impacts to aquatic habitat within areas that are relatively close to the site. Habitat loss could

include degradation of backwater nursery areas as a result of elevated concentrations of contaminants and sediment loading. This loss could be extensive in the short term. Once the river dynamics normalized, newly created fish habitat, including backwater areas, could be adversely affected, depending on the duration and concentrations of the contaminant release.

Catastrophic disposal cell failure would also result in increased turbidity and sediment, which could affect the aquatic and benthic producers. The loss of primary producers would affect the entire food chain.

If mitigated, long-term failure would not likely result in negative impacts to aquatic biota. DOE's Office of Legacy Management is responsible for monitoring and mitigating this type of release. In addition, all currently available evaluations of the site's geologic and hydrologic conditions suggest that future lateral migration of the river will tend toward the east, away from the site (see Table 2−33, No.10 in the EIS). Also, DOE has incorporated a buried riprap diversion wall into the on-site disposal design to mitigate potential impacts should lateral river migration occur. It has been estimated that this engineering control could easily be enhanced, expanded, or modified in the future should river migration encroach on the site and the disposal cell.

Effects of Flooding on Ground Water Remediation. Catastrophic flooding could also affect the aquatic environment by flooding the ground water remediation systems. The interim action and proposed ground water remediation includes wells or shallow trenches located between the foot of the pile and the river's edge (Section A1−4.3). As discussed in Section 3.1.8 of the EIS, the location for these systems is in the 100-year floodplain. If a flood were to inundate the remediation systems, ground water with contaminant concentrations exceeding the aquatic benchmarks could pass through the region toward the river. DOE expects that remediation systems would be quickly restored after the flood waters receded. USF&WS would be notified if ground water remediation systems were shut down due to flooding, and the river environment would be monitored to determine if the concentrations of contaminants of concern exceed benchmark.

Temperature. Temperature can influence the development, metabolism, motility, and mobility of fish; effect the expression of other environmental factors; and destroy the integrity of a fish, causing its death (Beitinger et al. 2000). Colorado pikeminnow spawn when the water temperature reaches 16 to 22 °C (61 to 72 °F), and the humpback chub spawns at temperatures greater than 17 °C (63 °F) (Muth et al. 2000). The Colorado pikeminnow, humpback chub, bonytail, and razorback sucker prefer temperatures between 24 and 25 °C (75 and 77 °F) (Bulkley and Pimentel 1983). Razorback suckers avoid temperatures above 27.4 °C (81 °F) and below 14.7 °C (58 °F) (Bulkley and Pimentel 1983). Young-of-the-year pikeminnow stop growing at temperatures less than 13 °C (55 °F) (Trammell and Chart 1998). During the fall and early winter, as the water temperature cools to less than 13°C (55 °F), the habitat available for overwintering become very important (Trammell and Chart 1998). A preference for temperatures somewhat warmer than the main river channel may also be important. However, in a study of the Colorado River pikeminnow nursery habitat, it was noted that fluctuations of temperature in backwater areas result in a lower mean daily temperature than in the main channel and that if pikeminnow closely follow temperature gradients, movement in and out of backwaters would be more frequent that previously assumed (Trammell and Chart 1998). The season of year, turbidity, and the temperature of the ground water can affect the fluctuation of temperature in the backwater relative to the main channel.

Impacts associated with activities related to remediation would not be expected to influence the temperature of the Colorado River. Leachate from the pile travels through the ground water pathway into the river, and the temperature gradient is not expected to affect the aquatic environment.

Chemical Impacts to Aquatic Species. The tailings pile on the Moab site is the source of chemical contamination to ground water, which in turn is the source of contamination influencing the Colorado River.

Characterization of the aquatic environment near the site is described in Chapter 3.0 of the EIS. Characterization has included sampling sediment, fish tissue, and surface water near the Moab site and upstream background surface water. Sediment samples of the Colorado River were collected from 1995 through 1997; however, those samples were not considered in this analysis because of comments in the USF&WS 1998 Final Biological Opinion (NRC 1999) concerning the quality of the data for evaluation of impacts. Concerns for the quality of the sediment data include inappropriate procedures and protocols for sample collection and inadequate collection of samples for statistical evaluation. Fish were collected for tissue analyses from 1995 through 1997, and the fish tissue samples also were not considered in this analysis because of comments on data quality that were similar to those made about sediment samples in the USF&WS 1998 Final Biological Opinion. An evaluation of the means and standard deviations for all the combined fish tissue data does not show a strong statistical difference in concentrations in the tissues collected upstream of the Moab site compared to those collected downstream.

The screening of contaminants is presented in Appendix A2 of the EIS and summarized here. The screening is based on surface water samples collected by Shepherd Miller, Inc. (SMI), DOE, and USGS. Samples were collected by SMI and DOE from 2000 through 2002. These data are presented in Appendix D of the SOWP (DOE 2003a). Water sample data were collected by USGS from 1998 through 2000 and are presented in *A Site-Specific Assessment of the Risk of Ammonia to Endangered Colorado Pikeminnow and Razorback Sucker Populations in the Upper Colorado River Adjacent to the Atlas Mill Tailings Pile, Moab, Utah* (USGS 2002). Many of the samples from other studies were considered, but quality issues were discovered during the evaluation of data for surface water samples taken prior to 2000. These issues included insufficient information to determine the location of the analyzed sample and laboratory quality control and quality assurance questions. Contaminants of potential concern for the Moab site were identified from institutional knowledge about the uranium milling processes used during operation of the Atlas mill and from the NRC EIS (NRC 1999). Surface water monitoring data were evaluated to determine if maximum concentrations were above detection limits, background levels, and federal and state criteria (i.e., benchmarks) for surface water quality.

The 2000 through 2002 surface water sampling data set was examined first to determine which sample results were above the detection limit set by the laboratory (Appendix A2 of the EIS). If an analyte was not detected, the laboratory reported a value equal to the method detection limit. Analytes not detected were assessed using values corresponding to one-half the method detection limit, based on EPA protocol (EPA 2001a, 2001b). The maximum concentration for the contaminant at any location or time was then compared to the maximum background concentration. Three upstream locations were considered as background stations for the Moab site. If a constituent was undetected in all background samples, then one-half the reported detection limit was used in the evaluation. Finally, the maximum concentration above background was compared to benchmarks for evaluating impacts to aquatic biota.

Benchmarks for the contaminants at the Moab site included the NWQC (EPA 2002) and proposed State of Utah water quality criteria (UAC 2003). The benchmarks used in the contaminant screening are listed in Appendix A2 of the EIS. Narrative and numeric water quality criteria are the foundation of a water-quality-based control program. The Clean Water Act standards mandate that water standards be established (33 U.S.C. 1251 et seq.). Water quality standards define the goals for a waterbody by designating its uses, setting criteria to protect those uses, and establishing provisions to protect water quality from pollutants. Utah's water quality standards are applicable to “waters of the State.” Utah water quality standards apply to all waters within the state of Utah, with the exception of those waters that are within Indian Country, as defined in 18 U.S.C. Section 1151. DOE notes that the ground water discharge at the Moab site is not a point source water discharge requiring a permit and that residual radioactive material is not considered a “pollutant” under the Clean Water Act (40 CFR § 122.2; see also Utah Administrative Code Section R317-8-1.5[34] and [35]). However, DOE is proposing to remediate ground water discharging from the Moab site under 40 CFR 192. DOE recognizes the need to comply with surface water quality criteria to the extent practical, including the need to minimize, and preferably eliminate, risks to human health and the environment. Thus, the surface water standards set by Utah, including federal and state water quality criteria, were used for this assessment.

In some cases, federal or state criteria have not been established for contaminants of potential concern in surface water. Therefore, criteria established by Suter and Tsao (1996) for aquatic biota were used. Suter and Tsao (1996) provide a compilation of aquatic toxicity values, including National Ambient Water Quality Criteria, derived Tier II values (secondary chronic and acute values), and chronic values from a variety of other government sources.

Impacts to aquatic organisms can result from either acute or chronic exposures to contaminants of potential concern (Appendix A2 of the EIS). An acute exposure is defined as “the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect” (EPA 2002). A chronic exposure is defined as “the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect” (EPA 2002). Currently, the State of Utah criteria include an acute, 1-hour exposure and a chronic, 4-day exposure. As mentioned, Suter and Tsao (1996) were used where state and federal standards were not available. However, they used a method referred to as Tier II to establish criteria for aquatic benchmarks using fewer data than required by EPA in the NWQC. Also, they developed estimated lowest chronic values for fish extrapolated from laboratory studies. The standards are discussed further in Appendix A2 of the EIS.

The 2000 through 2002 surface water sampling data were compared to the ecotoxicological screening benchmarks (Appendix A2 of the EIS). This comparison further pared the list of contaminants of potential concern for assessing potential impacts to aquatic biota. Contaminants were not considered further when (1) the maximum concentration and maximum background concentration were below detection limits and below all benchmarks, or (2) the maximum concentration was less than all the benchmarks. These contaminants were further evaluated on the basis of the number of samples, location of the samples, and relevance of the flow regime at the time of sampling in comparison to the potential for exposure to aquatic biota.

The 1998 through 2000 data summarized in *A Site-Specific Assessment of the Risk of Ammonia to Endangered Colorado Pikeminnow and Razorback Sucker Populations in the Upper Colorado River Adjacent to the Atlas Mill Tailings Pile, Moab, Utah* (USGS 2002) were also examined. Results presented in the USGS report indicate that the pile represents a localized source of ground water input containing elevated levels of contaminants, including copper, manganese, zinc, and radiochemicals. These contaminants were measured at levels that exceeded benchmarks during the low-water hydrologic period ranging from August through March. Based on the results of this study, USGS summary data for copper, manganese, zinc, and total alpha were evaluated using the process previously described. These results are discussed where applicable within the constituent-by-constituent discussions in Appendix A2 of the EIS.

Based on the evaluation of contaminants of potential concern in Appendix A2 of the EIS, the contaminants that would require further assessment and continued monitoring during ground water remediation for the Moab site are ammonia, copper, manganese, sulfate, and uranium. If active remediation of the ground water near the Colorado River were conducted, the maximum concentrations of these contaminants of concern in the region where the ground water enters the river (nearshore environment) would decrease to levels below acute and chronic benchmarks. It is DOE's position that if acute criteria can be met everywhere, then chronic criteria can be met outside the mixing zone. (Section A1–4.3.2 of this BA, and Section 2.3.2.1 of the EIS). In addition, available data regarding interaction of ground water and surface water indicate that concentrations of most constituents decrease significantly as ground water discharges to and mixes with surface water (a 10-fold decrease is observed on average). Consequently, there is a reasonable assurance that protective surface water concentrations could be achieved by meeting less conservative goals than chronic standards in ground water. DOE believes that a target goal of 3 mg/L in ground water (the low end of the reasonable acute range) would provide adequate surface water protection. The 3-mg/L concentration represents a 2- to 3-order-of-magnitude decrease in the center of the ammonia plume and would be expected to result in a corresponding decrease in surface water concentrations. Coupled with the average 10-fold dilution, and the tendency for ammonia to volatilize, this concentration should result in compliance with both acute and chronic ammonia standards in the river everywhere adjacent to the site. Therefore, DOE proposes to use the 3-mg/L concentration of ammonia as a target goal for evaluating ground water cleanup options. Potential synergistic effects between contaminants would be reduced through ground water remediation. Continued monitoring during active ground water remediation would be necessary to verify that contaminant concentrations remained below both acute and chronic benchmarks for aquatic species.

Radiological Impacts to Aquatic Species. The primary source of radiological contamination to enter the aquatic environment at the Moab site is ground water. The routes of exposure for the radiological contaminants are the same as those for chemical contaminants. The contributors to radiological dose to the aquatic organisms at the Moab site that have been monitored include lead-210, polonium-210, radium-226, radium-228, radon-222, thorium-230, uranium-234, and uranium-238, and the general indicator of radionuclides, gross alpha and gross beta.

The RESRAD Biota Code (Version 1.0 Beta 3, June 3, 2003) was used to screen the dose rate to aquatic organisms based on the maximum observed concentrations of uranium-238, uranium-234, and radium-226 (DOE 2002b). These isotopes represent the highest values analyzed for radionuclides from 2000 to 2002. The protocol for screening assessment includes multiple tiers. The first-tier screening assessment using the maximum observed concentrations had a sum of fractions that equaled 3.16, which exceeded the DOE guidance level of 1.0 for aquatic biota. A second-tier analysis based on mean concentrations of these three radionuclides of those values above detection resulted in a sum of fractions value of 0.29. The results of the second-tier analysis indicate that dose rates are below the guidance level associated with the 1.0-rad-per-day criterion adopted by DOE for screening dose rates to aquatic organisms.

The results of the RESRAD assessment indicate that the actual dose rates to aquatic organisms are below a population-effect level. There are no guidelines for radiological effects to individuals, which is important in evaluating impacts to threatened and endangered species. The studies that were completed for the 1.0-rad-per-day criterion were based on exposures to organisms for 1 year, and then normalized to a dose rate based on a day. One can interpret these results to mean that a dose rate of 1.0 rad per day, if sustained for a year, would have an effect on some individuals but not on the population as a whole. Based on monitoring results from 2000 to 2002 and on the life styles of the endangered fish around the Moab site, radionuclides in ground water discharging to the river currently are not expected to adversely affect the aquatic environment.

In its site-specific assessment, the USGS concluded that there would be "no significant biological impacts to fish populations caused by radionuclide concentrations sampled in the Colorado River and sediments." It found that "radiochemical concentrations are elevated in ground water below the Moab pile; however, these waters do not result in a high radiation exposure to fish" (USGS 2002).

Ground water extraction near the Colorado River and the use of freshwater injection would further decrease the maximum concentrations of radionuclides in the shoreline of the Moab site. These activities would be necessary for reducing impacts from chemical contaminants. They would also reduce the potential for radiological effects to individuals, which is important to endangered species as well as populations.

A1−8.0 Analysis for Terrestrial Species

A1−8.1 Species Accounts and Status in the Proposed Action Area

Spatial data for federally listed plant and animal species were obtained from the Utah Conservation Data Center (UCDC). This data set was compiled by the Utah Natural Heritage Program (UNHP) of the UDWR, in which species occurrences are depicted as points at a scale of 1:24,000 on 7.5-minute topographic quad maps. Spatial data depicting the project areas were overlaid on the spatial data depicting the occurrence of species of concern. Table A1−4 summarizes the listing status for terrestrial species discussed in this BA.

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Table A1−4. Status of Terrestrial Species

Common Name	Scientific Name	Status	Federal Register Citation
Plants			
Jones' cycladenia	*Cycladenia jonesii*	Threatened	51 FR 16526–16530 (1986)
Navajo sedge	*Carex specuicola*	Threatened	50 FR 19370–19374 (1985)
Clay phacelia	*Phacelia argillosa*	Endangered	43 FR 44810–44812 (1978)
Birds			
Bald eagle	*Haliaeetus leucocephalus*	Threatened, but proposed for delisting	64 FR 36454–36464 (1999)
California condor	*Gymnogyps californianus*	Endangered	61 FR 54043–54060 (1996)
Mexican spotted owl	*Strix occidentalis lucida*	Threatened	66 FR 8530–8553 (2001)
Southwestern willow flycatcher	*Empidonax traillii extimus*	Endangered	62 FR 39129–39147 (1997)
Gunnison sage grouse	*Centrocercus minimus*	Candidate	67 FR 40657–40679 (2002)
Western yellow-billed cuckoo	*Coccyzus americanus*	Candidate	66 FR 38611–38626 (2001)
Mammals			
Black-footed ferret	*Mustela nigripes*	Endangered	67 FR 57558–57567 (2002)
White-tailed prairie dog	*Cynomys leucurus*	Species of Concern	67 FR 57558–57567 (2002)

A1−8.1.1 Jones' Cycladenia

Jones' cycladenia is an herbaceous perennial 4 to 6 inches tall and is the only member of its genus in the Intermountain West.

Distribution. Jones' cycladenia has a disjunct distribution, occurring in the canyonlands of the Colorado Plateau in four counties in Utah: Emery, Garfield, Grand, and Kane, and in Coconino County, Arizona (UDWR 2003b). There is a cluster of known populations on BLM land in Grand County approximately 11 to 17 miles northeast of Moab (UDWR 2003b).

Soils and Community Associations. Jones' cycladenia grows in gypsiferous soils that are derived from the Summerville, Cutler, and Chinle Formations; they are shallow, fine-textured, and intermixed with rock fragments. The species can be found in eriogonum-ephedra, mixed desert shrub, and scattered piñon-juniper communities, at elevations ranging from 4,000 to 6,800 ft (UDWR 2003b). The Grand County populations in Castle Valley and along Onion Creek are growing in mixed desert shrub and in the lower edge of the piñon-pine and juniper community at 4,920 to 5,580 ft on sparsely vegetated hills derived from arkosic (containing unweathered feldspar) sandstone of the Cutler Formation.

Threats. The primary threat to Jones' cycladenia is habitat disturbance.

Critical Habitat. No critical habitat has been designated for this species (USF&WS 2003b).

Known Occurrences in the Project Area. There were no occurrences of Jones' cycladenia in any of the quads that contain project areas.

Findings. Jones' cycladenia would be most affected by habitat destruction. This species is not known to exist at or near any of the proposed disposal sites, transportation routes, or borrow areas. However, many of the potential project areas have not been well surveyed for this or other rare species. Therefore, prior to development of any disposal site, borrow area, or transportation route, a thorough survey of the area should be performed. If Jones' cycladenia were found, an alternate site would be considered or a mitigation plan would be developed to prevent adverse effects.

A1−8.1.2 Navajo Sedge

Distribution. Navajo sedge occurs in the canyons of Kane and San Juan counties in Utah, and in immediately adjacent Coconino County, Arizona (UDWR 2003b).

Soils and Community Associations. Navajo sedge is restricted to seep, spring, and hanging garden habitats in Navajo Sandstone, at elevations ranging from 3,770 to 5,980 ft (UDWR 2003b).

Critical Habitat. Critical habitat designated for this species consists of about 6,460 ft^2. This area contains the entire habitat occupied by the species where it occurs near Inscription House Ruin on the Navajo Indian Reservation in Coconino County, Arizona.

Threats. The primary threats to Navajo sedge and its critical habitat are spring development and sheep grazing (UDWR 2003b).

Known Occurrences in the Project Area. All of the known populations in Utah are located at least 20 miles southwest of the White Mesa Mill disposal site and associated borrow areas (UDWR 2003b).

Findings. Navajo sedge would be most affected by habitat destruction. This species is not known to exist at or near any of the proposed disposal sites, transportation routes, or borrow areas. However, many of the potential project areas have not been well surveyed for this or other rare species. Therefore, prior to development of any disposal site, borrow area, or transportation route; a thorough survey of the area should be performed. If Navajo sedge were found, an alternate site would be considered or a mitigation plan would be developed to prevent adverse effects.

A1−8.1.3 Clay Phacelia

Distribution. This species was included at the suggestion of BLM. Clay phacelia is thought to be restricted to Green River shales in Spanish Fork Canyon in Utah County, Utah (UDWR 2003b). However, UDWR (1998) suggests that specimens collected from Green River shales in Grand and Uinta counties, Utah, and in adjacent Colorado that were previously identified as *P. glandulosa* may properly belong to the endangered *P. argillosa*, based on seed morphology.

Findings. Based on current knowledge, it is unlikely that clay phacelia exists in the vicinity of any of the project sites. However, many of the potential project areas have not been well surveyed for this or other rare species. Therefore, prior to development of any disposal site, borrow area, or transportation route, a thorough survey of the area should be performed. In particular, areas that may have Green River shale should be examined for clay phacelia. In the unlikely event that this species were found, an alternate site would be considered or a mitigation plan would be developed, in cooperation with USF&WS and BLM, to prevent adverse effects.

A1−8.1.4 Bald Eagle

Habitat and Diet. The bald eagle is a bird of aquatic ecosystems. It frequents estuaries, large lakes, reservoirs, major rivers, and some seacoast habitats. Fish is the major component of its diet, but waterfowl, seagulls, and carrion are also eaten. The species may also use prairies if adequate food is available. Bald eagles usually nest in trees near water but are known to nest on cliffs; they rarely nest on the ground. Nest sites are usually in large trees along shorelines in relatively remote areas that are free of disturbance. In winter, bald eagles often congregate at specific wintering sites that are generally close to open water and offer good perch trees and night roosts.

Critical Habitat. No critical habitat has been designated for this species (USF&WS 2003b).

Known Occurrences in the Project Area. Only four nest sites were known in Utah as of 2000, three of them in the southeastern part of the state (UDWR 2003b). The nearest nest is at Cisco Landing on the Colorado River approximately 19 miles upriver from the Moab site. Utah has a large wintering bald eagle population scattered throughout the state. They are known to occur in winter and spring in the Matheson Wetlands Preserve (UDWR 2003b, Seglund 2004). The Utah Gap Analysis indicates that potential high-quality wintering habitat occurs in the vicinity of almost all the potential disposal sites and borrow areas (UDWR 1999). However, more recent information provided by UDWR (UDWR 2003b, Seglund 2004) indicates that bald eagles are not known to occur near any of these project sites.

Findings—Habitat and Human Disturbance. Bald eagles are not likely to be greatly affected by habitat destruction or by noise, lights, and human presence, since they do not nest at or near any of the project sites and may roost only occasionally in the vicinity of the Moab site. Activities at the Moab site would not remove any known bald eagle roost trees. Further, as indicated above, eagles probably rely more heavily on the large Matheson Wetlands Preserve than on the 50 acres of tamarisk at the Moab site.

The Utah Gap Analysis indicates that potential high-quality wintering habitat exists throughout the other project areas. Indeed, bald eagles could be found temporarily and infrequently using such areas when there are opportunities to feed on carrion, such as in big-game wintering areas or in prairie dog colonies. Therefore, it is possible that if traffic-related wildlife mortality increased due to the project, an increased number of eagles could be hit on highways. Although no data on this relationship are available, it is reasonable to assume that the number of eagles hit on highways would be proportional to the number of carrion available. The increase in the number of traffic-related wildlife mortalities would likely be small. Consequently, the potential increase in associated eagle deaths would also likely be small.

Findings—Exposure to Contaminants in Surface Water. If the bald eagle inhabits the vicinity of the Moab tailings pile, the most prevalent route of exposure to chemical and radioactive constituents would likely be from ingestion of prey and surface water in the nearshore environment. The potential for chronic effects from ingestion of chemical contaminants in food and surface water was evaluated for the No Action alternative using the osprey (*Pandion haliaetus*) as a surrogate (see Appendix A2 of the EIS). The maximum surface water concentrations of mercury and selenium exceeded no observed adverse effect level (NOAEL)- and lowest observed adverse effect level (LOAEL)-based food/drinking water benchmarks for the osprey (Sample et al. 1996). NOAEL benchmarks are values believed to represent nonhazardous concentrations. LOAEL benchmarks are threshold values for which chronic adverse effects are likely to become evident at the level of the individual.

Implicit in this benchmark is the assumption that the diet of the benchmark species (osprey) consists entirely of contaminated food/drinking water. In the context of the BA, this means that the food/water consumption of the analogous consultation species (i.e., the species for which the benchmark species is a reasonable surrogate—the bald eagle) would need to occur entirely within the surface waters of the nearshore environment within the contaminated portion of the river in order for the toxicological benchmark to be valid.

It is possible that eagles could consume fish from surface waters contaminated by ground water flowing beneath the tailings pile. However, because bald eagles generally forage over much larger areas and are present in the vicinity only during winter and spring, it is unlikely that enough contaminated food material would be obtained from the contaminated area to result in adverse toxicological effects.

Any potential effects to the bald eagle that could arise from exposure to radionuclides would be discountable (i.e., extremely unlikely to occur) (see Section A1–8.2 of this BA and Appendix A2 of the EIS).

Findings—Exposure to Contaminants at the Evaporation Pond(s). The bald eagle could potentially be affected by contaminant exposure at the evaporation pond(s) via ingestion of contaminated prey and water, dermal uptake of contaminated water and airborne contaminants, and inhalation of airborne contaminants.

As indicated above, eagles would probably rely more heavily on the large Matheson Wetlands Preserve than on habitat at the site of the Moab tailings pile, including the evaporation pond(s). The evaporation pond(s) would also be located in an area where project activities and site maintenance operations would create continual disturbance. Further, because of distance, disturbance, and the fact that the evaporation pond(s) would be located in an area that has been previously disturbed and is generally devoid of vegetation (which could provide perch and roost sites), the likelihood of visits from bald eagles would be small.

The evaporation pond(s) would be qualitatively monitored for general wildlife use, regardless of the potential presence of the bald eagle. Consequently, if it were determined that bald eagles were frequenting the evaporation pond(s), techniques to minimize or eliminate use would be identified and implemented. Techniques could include noise (e.g., propane boom cannons) or obstruction (e.g., netting).

If, during the course of the proposed actions, bald eagles were observed in the vicinity of any of the project sites, DOE would inform USF&WS, and reasonable and appropriate mitigation measures would be agreed upon and implemented in order to minimize or avoid potential impacts to the species. If impacts could not be avoided, additional Section 7 consultation would be required.

A1−8.1.5 California Condor

Historical Information. By the time Europeans arrived in western North America, California condors occurred in a narrow Pacific coastal strip from British Columbia, Canada, to Baja

California Norte, Mexico. By 1987, the California condor's range was reduced to a wishbone-shaped area encompassing six counties in southern California. Mortality factors include habitat loss; however, the factors that have been most important in decline of the species have not been determined. In 1987, the last wild condor was captured and taken to the San Diego Wild Animal Park. Beginning with the first successful captive breeding of California condors in 1988, the total population increased annually and stood at 121 individuals in 1996: 104 in the captive flock and 17 in the wild (USF&WS 1998b).

Habitat, Diet, and Reproduction. California condors lay only one egg every other year, on the floor of a cliff cavity or cave or in a crevice among boulders on a steep slope (UDWR 2003b). Cliffs and tall conifers, including dead snags, are generally used as roost sites in nesting areas. The California condor is an opportunistic scavenger, feeding only on carcasses. Although most roost sites are near nesting or foraging areas, scattered roost sites are located throughout its range.

Distribution in Utah. In Utah, condor sightings were historically rare, noted only twice by pioneers in the 1800s. A nonessential experimental population of California condors was established in northern Arizona in 1996 (61 FR 54043–54060 [1996]). However, sightings of birds that were released in northern Arizona have been made almost statewide in the late 1990s. The known distribution of the California condor in Utah currently consists of the southern third of the state, including most of San Juan County (UDWR 2003b).

Critical Habitat. Critical habitat has been designated for this species only within the state of California (42 FR 47840–47845 [1977]).

Known Occurrences in the Project Area. California condors are not known to regularly occur within the project area. Occasional transient individuals may be possible.

Findings. In addition to the lack of known occurrences in the project area, the sites that could be disturbed by project activities are minute compared to the apparently large areas required for foraging by California condors. Further, the proposed project areas include no known habitat features in particular that would be sought out or used by condors.

A1−8.1.6 Mexican Spotted Owl

Distribution. The Mexican spotted owl inhabits canyon and montane forest habitats across its range, which extends from southern Utah and Colorado, through Arizona, New Mexico, and west Texas, to the mountains of central Mexico (66 FR 8530–8553 [2001]).

Diet, Reproduction, and Migration. Mexican spotted owls do not nest every year and average about one young per pair (66 FR 8530–8553 [2001]). Their diet includes a variety of mammals, birds, reptiles, and insects (58 FR 14248–14271 [1993]) but consists most commonly of small- and medium-sized rodents, such as woodrats, peromyscid mice, and microtine voles. Some individuals are year-round residents within an area, some remain in the same general area but show shifts in habitat use patterns, and some migrate short distances (12 to 31 miles) during winter, generally migrating to more open habitat at lower elevations (66 FR 8530–8553 [2001]).

Habitat. At the northern edge of their range in northeastern Arizona, southwestern Colorado, and Utah, Mexican spotted owls may occur year-round at 4,400 to 6,800 ft within the piñon-juniper zone below mixed-conifer forests (58 FR 14248–14271 [1993]). Within this zone, canyon habitats are used for nesting and roosting and are typically characterized by the cooler conditions found in steep, narrow canyons, often containing crevices, ledges, and/or caves (typically used for nest placement). These canyons frequently contain small clumps or stringers of ponderosa pine, Douglas fir, white fir, and/or piñon-juniper. Deciduous riparian and upland trees may also be present (66 FR 8530–8553 [2001]). However, Mexican spotted owls may also nest, but less frequently so, in arid, rocky, mostly unvegetated canyons (Romin 2004). Adjacent uplands are usually vegetated by a variety of plant associations, including piñon-juniper woodland, desert scrub vegetation, ponderosa pine-Gambel oak, ponderosa pine, or mixed conifer (66 FR 8530–8553 [2001]).

Threats. The Mexican spotted owl is threatened by destruction and modification of habitat caused by timber harvest and fires and increased predation associated with habitat fragmentation (58 FR 14248–14271 [1993]).

Critical Habitat. In 2001, approximately 4.6 million acres of critical habitat in Utah, Arizona, Colorado, and New Mexico were designated, with the majority occurring in Utah (3.2 million acres) (66 FR 8530–8553 [2001]). The critical habitat in Utah consists of five units, two of which (CP-13 and CP-14) are located in San Juan County (USF&WS 2003a).

Known Occurrences in the Project Area. Data provided by UDWR (2003a) indicated that there were no occurrences of the Mexican spotted owl in any of the quads that contained project areas. However, designated critical habitat occurs within 2 miles of the transportation corridor just south (within 25 miles) of the Moab site. Habitat models (BLM 2003b) also indicate that potential habitat areas may exist in the canyons near US-191 over the first 7 miles north from the Moab tailings pile. Nonetheless, these models are primarily based on physical and topographic features and do not consider vegetation requirements. Mexican spotted owls nest, roost, and forage in an array of different community types, but mixed-conifer forests dominated by Douglas fir and/or white fir are most common (58 FR 14248–14271 [1993]). However, as noted above, they may also nest, but less frequently so, in arid, rocky, mostly unvegetated canyons (Romin 2004). Although there are no forested areas in the vicinity of US-191 north of Moab, there are arid canyons that largely or altogether lack forest-type vegetation.

Findings. There are no known Mexican spotted owl occurrences or critical habitat within any of the project areas. However, owls could occur along US-191 over the first 7 miles north from the Moab tailings pile and, if present, could be disturbed by noise from increased truck traffic or from construction of a slurry pipeline.

The area in the vicinity of this section of transportation corridor constitutes a very popular recreation area, with heavy use by off-highway vehicles and mountain bikes. Although the increase in truck traffic noise could be detectable up to several miles from the highway, the existing off-highway vehicle noise and associated human presence would likely have a greater and more direct impact on the owls.

If a slurry pipeline option were selected, the route should be surveyed for Mexican spotted owls prior to construction. If any owls or potential habitat areas were identified, an appropriate mitigation plan would be developed to minimize potential adverse impacts, including scheduling activities such that owl nesting and fledging would not be disturbed. If impacts could not be avoided, additional Section 7 consultation would be required.

A1−8.1.7 Southwestern Willow Flycatcher

Range-Wide Distribution. The southwestern willow flycatcher's breeding range includes southern California, Arizona, New Mexico, western Texas, southwestern Colorado, southern portions of Nevada and Utah, and extreme northwestern Mexico. The subspecies most likely winters in Mexico, Central America, and perhaps northern South America (USF&WS 2002e).

Distribution in Utah. The recovery plan for the southwestern willow flycatcher places the northern limit of its breeding range in Utah south of the Moab site (USF&WS 2002e). In addition, UDWR (UDWR 2003a) specified only the southern parts of the state as the known distribution of this subspecies in Utah. However, the range line specified in the recovery plan (USF&WS 2002e) was recently extended to well north of the Moab site (USF&WS 2003d) because the subspecific identity of willow flycatchers remains unresolved in central Utah (due to the occurrence of a similar subspecies, *E.t. adastus*, at higher elevations in the central and northern part of the state) (USF&WS 2002e) and because it is believed that the Colorado and Green river systems may provide travel corridors and suitable habitat for the subspecies (USF&WS 2003d).

General Nesting Habitats. The southwestern willow flycatcher breeds in different types of dense riparian habitats, across a large elevational and geographic area. It usually breeds in patchy to dense riparian habitats along streams or other wetlands, near or adjacent to surface water or underlain by saturated soil. Common tree and shrub species comprising nesting habitat include willows (*Salix* spp.), seepwillow (aka mulefat; *Baccharis* spp.), boxelder (*Acer negundo*), stinging nettle (*Urtica* spp.), blackberry (*Rubus* spp.), cottonwood (*Populus* spp.), arrowweed (*Tessaria sericea*), tamarisk (*Tamarix ramosissima*, also known as saltcedar), and Russian olive (*Eleagnus angustifolia*) (USF&WS 2002e).

Habitat characteristics such as plant species composition, size and shape of habitat patch, canopy structure, vegetation height, and vegetation density vary across the subspecies' range. However, general unifying characteristics of flycatcher habitat can be identified. Regardless of the plant species composition or height, occupied sites usually consist of dense vegetation in the patch interior, or an aggregate of dense patches interspersed with openings. In most cases, this dense vegetation occurs within the first 10 to 13 ft above the ground. These dense patches are often interspersed with small openings, open water, or shorter/sparser vegetation, creating a mosaic that is not uniformly dense. In almost all cases, slow-moving or still surface water and/or saturated soil is present at or near breeding sites during wet or nondrought years (USF&WS 2002e).

Thickets of trees and shrubs used for nesting range in height from 6 to 98 ft. Lower-stature thickets (6 to 13 ft) tend to be found at higher elevation sites; tall-stature habitats are at middle- and lower-elevation riparian forests. Nest sites typically have dense foliage from the ground level up to approximately 13 ft above the ground, although dense foliage may exist only at the shrub level, or as a low dense canopy. Nest sites typically have a dense canopy, but nests may be placed in a tree at the edge of a habitat patch, with sparse canopy overhead. The diversity of nest site plant species may be low (e.g., monocultures of willow or tamarisk) or comparatively high. Nest site vegetation may be even- or uneven-aged, but is usually dense (USF&WS 2002e).

Historically, the southwestern willow flycatcher nested in native vegetation such as willows, buttonbush, boxelder, and *Baccharis*, sometimes with a scattered overstory of cottonwood. Following modern changes in riparian plant communities, the flycatcher still nests in native vegetation where available, but it also nests in thickets dominated by tamarisk and Russian olive and in habitats where native and non-native trees and shrubs are present in essentially even mixtures (USF&WS 2002e).

Nesting Habitats Dominated by Exotic Plants. Southwestern willow flycatchers nest in some riparian habitats dominated by exotics, primarily tamarisk and Russian olive. Most such exotic habitats range below 3,940 ft elevation and are nearly monotypic, dense stands of tamarisk or Russian olive that form a nearly continuous, closed canopy with no distinct overstory layer. Canopy height generally averages 16 to 33 ft, with canopy density uniformly high. The lower 6.5 ft of vegetation often consists of dense, dead branches. Thus, live foliage density may be relatively low from 0 to 6.5 ft above the ground but increases higher in the canopy (USF&WS 2002e).

Forty-seven percent of southwestern willow flycatcher territories occurred in mixed native/exotic habitat (more than 10 percent exotic), and 25 percent were at sites where tamarisk was dominant. Flycatchers nest in tamarisk at many river sites and, in many cases, use tamarisk even if native willows are present. Southwestern willow flycatchers nest in tamarisk at sites along the Colorado, Verde, Gila, San Pedro, Salt, Bill Williams, Santa Maria, and Big Sandy rivers in Arizona; Tonto Creek in Arizona; the Rio Grande and Gila rivers in New Mexico; the San Dieguito, lower San Luis Rey, and Sweetwater rivers in California; and Meadow Valley Wash and the Virgin River in Nevada. Rangewide, 86 percent of nests in mixed and exotic habitats were in tamarisk. In Arizona, 93 percent of the 758 nests documented from 1993 to 1999 in mixed and exotic habitats were in tamarisk. Tamarisk nests are at least as successful as nests in other substrates (USF&WS 2002e).

Because the physical and structural characteristics of tamarisk stands vary widely, not all have the same value as flycatcher breeding habitat. Among sites with tamarisk, suitable flycatcher breeding habitat usually occurs where the tamarisk is tall and dense, with surface water and/or wet soils present, and where it is intermixed with native riparian trees and shrubs. However, flycatchers breed in a few patches consisting of more than 90 percent tamarisk, with dry soils and surface water more than 600 ft away from some of their territories (USF&WS 2002e).

Suitable Nesting Habitat. “Suitable habitat” for southwestern willow flycatchers is defined as a riparian area with all the components needed to provide conditions suitable for breeding. These conditions are generally dense, mesic riparian shrub and tree communities 0.25 acre (minimum nest patch size) or greater in size within floodplains large enough to accommodate riparian patches at least 33 ft wide (USF&WS 2002e).

Diet and Reproduction. The nesting period of the southwestern willow flycatcher may vary depending on altitude and latitude. However, it generally begins in May with its arrival at breeding grounds and terminates with fledging in July and early August (USF&WS 2002e).

The southwestern willow flycatcher is an insectivore that forages within and occasionally above dense riparian vegetation, taking insects on the wing and gleaning them from foliage (USF&WS 2002e). According to DeLay et al. (2002) and Drost et al. (2001), southwestern willow flycatchers consume a variety of prey items, but the most prevalent included true bugs, bees and wasps, true flies, beetles, leafhoppers, and some spiders and dragonfly/damselflies. The southwestern willow flycatcher also may consume berries and seeds (USF&WS 2002e, UDWR 2003b).

Range-Wide Population Status and Nesting Areas in Utah. The total population of southwestern willow flycatchers across the species' range was estimated at 1,200 to 1,300 pairs in 2002. The population as a whole consists of extremely small, widely separated breeding groups. In Utah, for example, the willow flycatcher has been described as a common summer resident. However, there are few records concerning the breeding range in the southern portion of the state. Historically, southern Utah's largest flycatcher populations may have been those along the Colorado River and its tributaries in Glen Canyon; these are now inundated by Lake Powell. The flycatcher also bred along the Virgin River in the St. George area and along the San Juan River. Recent surveys have found the flycatcher absent as a breeding species on the Green and Colorado rivers in the Canyonlands National Park area, on the San Juan River (west of the New Mexico state line), and in portions of the Manti-La Sal National Forest. Flycatchers have recently bred in small numbers along the Virgin River near St. George, and single territories have been located at sites in the Panguitch Lake area and within Bryce Canyon National Park (USF&WS 2002e).

Threats. The reasons for the decline of the southwestern willow flycatcher and the current threats it faces are numerous, complex, and interrelated. The primary cause of the flycatcher's decline is loss and modification of habitat. Its riparian nesting habitat tends to be uncommon, isolated, and widely dispersed. Historically, these habitats have always been dynamic and unstable in place and time, due to natural disturbance and regeneration events such as floods, fire, and drought. With increasing human populations and the related industrial, agricultural, and urban developments, these habitats have been modified, reduced, and destroyed by mechanisms such as dams and reservoirs, diversions and ground water pumping, channelization and bank stabilization, phreatophyte control, livestock grazing, recreation, fire, agricultural development, and urbanization. Other factors include changes in abundance of other species (i.e., exotic plant species and brood parasitism), vulnerability of small populations (i.e., demographic effects and genetic effects), and migration and winter range stresses (USF&WS 2002e).

Critical Habitat. Critical habitat has been designated for this species in Arizona, California, and New Mexico (62 FR 39129–39147 [1997]); there is no designated critical habitat in Utah.

Occurrences in the Project Area. The UDWR database contained two records of southwestern willow flycatchers in two areas potentially affected by project activities. There was a reported but unconfirmed sighting of the southwestern willow flycatcher in 1998 in Grand County within the Moab quad that contains the Moab site (UDWR 2003b). There was a reported sighting in San Juan County in the vicinity of the slurry pipeline corridor in the La Sal West quad (UDWR 2003b). There is no information on the date of the reported sighting or on whether the sighting was confirmed.

The southwestern willow flycatcher has been identified as potentially occurring in the Matheson Wetlands Preserve and also several miles downstream from the Moab site. No nesting activity was observed in these areas, and the species has not been observed on the Moab site proper (NRC 1999). Surveys of potentially suitable habitat were conducted along the Colorado River, approximately 6 river miles south of the site in 2002. Willow flycatchers (subspecies not specified) were present during one survey in May (USGS 2002). The survey report concluded, after 3 years of study (1999 to 2001), that willow flycatchers were migrating through the area but were not breeding, and continued monitoring was recommended. On May 12, June 24, and July 10, 2004, DOE and UDWR conducted field surveys in the tamarisk habitat located along the easternmost boundary of the Moab site. This area had been historically identified as the only area on site containing potentially suitable flycatcher habitat. No flycatchers were detected, and UDWR concluded that this tamarisk constitutes only marginal nesting habitat at best (UDWR 2004).

Findings—Nesting Habitat. Based on the above studies, willow flycatchers occur in the vicinity of the Moab tailings pile and may occur in the vicinity of the White Mesa Mill site. Although it is unclear whether these birds belong to the listed southwestern, or *traillii*, subspecies, the former should be assumed in order to be conservative. Based on the above descriptions of nesting habitat dominated by exotic plants (USF&WS 2002e) and the 2004 field surveys conducted by DOE and UDWR (UDWR 2004), the tamarisk at the Moab tailings site should be considered marginally suitable nesting habitat.

Because riparian vegetation typically occurs in floodplain areas that are prone to periodic disturbance, suitable habitats will be ephemeral and their distribution dynamic in nature. Suitable habitat patches may become “unsuitable” (habitat that does not have the potential for developing into suitable habitat, even with extensive management) through maturation or disturbance (though this may be only temporary, and patches may cycle back into suitability). Therefore, it is not realistic to assume that any given suitable habitat patch (occupied or unoccupied) will remain continually occupied and/or suitable over the long term. Unoccupied suitable habitat will therefore play a vital role in the recovery of the flycatcher, because it will provide suitable areas for breeding flycatchers to (1) colonize as the population expands (numerically and geographically) and (2) colonize following loss or degradation of existing breeding sites. Indeed, many sites will likely pass through a stage of being suitable but unoccupied before they become occupied. “Potential” habitats (habitat that does not currently have all the components needed to provide suitable nesting habitat, but could, if managed appropriately, develop these components over time) that are not currently suitable will also be essential for flycatcher recovery, because they are the areas from which new suitable habitat develops as existing suitable sites are lost or degraded; in a dynamic riparian system, all suitable habitat starts as potential habitat. Further, even unsuitable habitats used as migration stopover areas may be critically important resources affecting productivity and survival (USF&WS 2002e).

Consequently, based on the above discussion of the dynamic nature of habitat suitability, removal of the currently marginally suitable tamarisk at the Moab site would result in temporary habitat loss for the southwestern willow flycatcher. However, this would not be the case if it were determined in the future (USF&WS 2003d) that the breeding range of the subspecies lies south of the Moab site (USF&WS 2002e). However, once remediation was completed, the lost tamarisk would be replaced with native riparian plant species of equal or higher functional value for the southwestern willow flycatcher. This would compensate for the habitat loss on the site.

Further, the size of the tamarisk stand at the Moab site (50 acres) is close to the mean patch size of breeding sites supporting 10 or more southwestern willow flycatcher territories (62.2 acres) (USF&WS 2002e). Consequently, the tamarisk habitat at the Moab site could be utilized by one or more pairs of the subspecies for nesting and/or during migration. Use of this habitat should be determined by field surveys during the most recent nesting and/or migration period(s) prior to its removal. If southwestern willow flycatchers were present during nesting and/or migration, and if impacts to the subspecies could not be avoided by removing habitat outside these periods, additional Section 7 consultation would be required.

Findings—Exposure to Contaminants in Surface Water. If the southwestern willow flycatcher occurs in the near vicinity of the Moab tailings pile, the most prevalent route of exposure to chemical and radioactive constituents would likely be from ingestion of prey and surface water in the nearshore environment. The potential for chronic effects from ingestion of chemical contaminants in surface water was evaluated for the No Action alternative using the rough-winged swallow (*Stelgidopteryx serripennis*) as a surrogate species (see Appendix A2 of the EIS). None of the maximum surface water concentrations of any of the chemical constituents exceeded NOAEL-based drinking water benchmarks for the rough-winged swallow (Sample et al. 1996). Consequently, no adverse effects to the southwestern willow flycatcher would be expected from surface water consumption within the nearshore environment of the contaminated portion of the river.

Any potential effects to the southwestern willow flycatcher that could arise from exposure to radionuclides in surface water would be negligible (see Section A1–8.2 of this BA and Appendix A2 of the EIS).

Findings—Exposure to Contaminants in Soils. Because the known diet of the southwestern willow flycatcher consists primarily of insects without aquatic life stages, exposure to chemical contaminants originating in surface water via ingestion of prey would be relatively minor. In contrast, some of these insects could have extensive contact with contaminants in surface soils. However, potential impacts associated with this route of exposure cannot be evaluated in the absence of soil contaminant data.

Exposure to chemical contaminants originating in soils could also arise from consumption of the berries and seeds of plants that accumulate such contaminants (see the evaluation of the potential effects of metals in the freshwater aquifer to terrestrial plants in Section A1−8.2). Further, exposure could arise from consumption of the terrestrial invertebrates that feed on the berries and seeds. However, potential impacts associated with these two routes of exposure cannot be evaluated in the absence of soil contaminant data.

Findings—Exposure to Contaminants at the Evaporation Pond(s). The southwestern willow flycatcher could be affected due to contaminant exposure at the evaporation pond(s) via ingestion of contaminated prey and water, dermal uptake of contaminated water and airborne contaminants, and inhalation of airborne contaminants.

The evaporation pond(s) would be built sufficiently high on the floodplain to withstand a 100-year flood event. The evaporation pond(s) would thus be located away from the river shoreline at an as-yet-unspecified distance. For this reason, and because estimated breeding territory sizes for the southwestern willow flycatcher are relatively small (generally from approximately 0.25 to 5.7 acres) (USF&WS 2002e), the evaporation pond(s) would likely be located well outside any breeding territories that could be located in association with riparian shoreline vegetation. The evaporation pond(s) would also be located in an area where project activities and site maintenance operations would create continual disturbance. Because of distance, disturbance, and the fact that the evaporation pond(s) would be located in an area that has been previously disturbed and is generally devoid of vegetation (in and over which the species generally forages [USF&WS 2002e]), the likelihood of visits from the southwestern willow flycatcher would be small. However, during the nesting period, adult southwestern willow flycatchers are known to sometimes fly outside their territory to gather food for their nestlings. Southwestern willow flycatchers may also use a larger area than their initial territory after their young are fledged and may use nonriparian habitats adjacent to the breeding area (USF&WS 2002e).

The evaporation pond(s) would be qualitatively monitored for general wildlife use, regardless of the potential presence of the southwestern willow flycatcher. Consequently, if it were determined that southwestern willow flycatchers were frequenting the evaporation pond(s), techniques to minimize or eliminate use would be identified and implemented. Techniques could include noise (e.g., propane boom cannons), visual deterrents (e.g., reflectors, silhouettes, effigies, water color), or obstruction (e.g., netting).

A1−8.1.8 Black-Footed Ferret

Historical Information. The black-footed ferret is the only ferret species native to North America. The historical range of the species, based on specimen collections, extends over 12 western states (Arizona, Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming) and the Canadian provinces of Alberta and Saskatchewan.

Significant reductions in prairie dog numbers and distribution occurred during the last century due to widespread poisoning of prairie dogs, the conversion of native prairie to farmlands, and outbreaks of sylvatic plague. This resulted in near extinction of the black-footed ferret in the wild by the early 1970s. The species was believed extinct until 1981, when a small population was discovered near Meeteetse, Wyoming. In 1985 and 1986, the Meeteetse population declined to only 18 animals. Following this decline, the remaining individuals were taken into captivity in 1986 and 1987 to serve as founders for a captive propagation program.

Reintroductions. Since the late 1980s, highly successful captive breeding efforts have provided the basis for ferret reintroductions over a broad area of their formerly occupied range (Wyoming in 1991, South Dakota and Montana in 1994, Arizona in 1996, Montana in 1997, Colorado/Utah in 1999, South Dakota in 2000, and Mexico in 2001). The only black-footed ferrets currently occurring in the wild are believed to be the result of these reintroductions. Of all these reintroduction efforts, populations may have become self-sufficient at only one site in South Dakota.

The only ferret reintroduction in Utah was a nonessential experimental population in 1999. The experimental population area consisted of all of Uinta and Duchesne counties. (For purposes of Section 7 of the ESA, nonessential experimental populations are treated as species proposed for listing if they are located outside the National Wildlife Refuge System or National Park System). It was considered highly unlikely that ferrets could disperse outside the experimental area due to the area's large size, the absence of suitable surrounding habitat (lack of prairie dog towns), and the presence of vegetative and topographical barriers (63 FR 52824–52841 [1998]).

Dependence on Prairie Dogs. Black-footed ferrets depend almost exclusively on prairie dog colonies for food, shelter, and denning. The range of the ferret coincides with that of prairie dogs, and ferrets with young have been documented only in the vicinity of active prairie dog colonies. Historically, ferrets have been reported from black-tailed prairie dog (*Cynomys ludovicianus*), white-tailed prairie dog (*Cynomys leucurus*), and Gunnison's prairie dog (*Cynomys gunnisoni*) towns (67 FR 57558–57567 [2002]). Black-footed ferrets require prairie dog colonies of at least 100 to 150 acres in size (USF&WS 1988). Some of the white-tailed prairie dog colonies found from the Crescent Junction area southward toward the Klondike Flats alternative disposal site satisfy this size requirement (see Section A1−8.1.11).

Critical Habitat. No critical habitat has been designated for this species (USF&WS 2003a).

Known Occurrences in the Project Area. For reasons stated above, it is highly unlikely that black-footed ferrets reintroduced in Uinta and Duchesne counties in 1999 could occur on or in the vicinity of any of the project areas. However, unconfirmed sightings of naturally occurring ferrets persist throughout eastern Utah (UDWR 2003b). UDWR reported numerous but unconfirmed sightings of the black-footed ferret in the vicinity of the following project sites, with the year of the most recent observation provided parenthetically: Floy Wash Borrow Area (1989), Crescent Junction disposal site and Crescent Flat borrow area (1989), Courthouse Syncline borrow area and Klondike Flats disposal site (1989), and at five locations along the pipeline between the Moab site and the north IUC borrow area (1968 [Rill Creek quad], 1967 [Photograph Gap quad], 1996 [Monticello North quad], and 1996 [Monticello South quad]) (UDWR 2003b). Finally, there were confirmed sightings in the vicinity of the White Mesa Mill site in 1937 (UDWR 2003b).

Not all of the potential project areas have been fully surveyed for prairie dogs. However, surveys were conducted at the Klondike Flats site (BLM 1995). At that time, it was determined that all the colonies were relatively small and isolated, such that they would not support black-footed ferrets. It is believed that the colonies at the other proposed project sites are also too small to support ferrets.

Findings. It is unlikely that there are prairie dog colonies of sufficient size to support black-footed ferrets at any of the proposed project locations. However, this would be determined on a site-specific basis, since all project locations would be surveyed for white-tailed prairie dogs prior to disturbance (see Section A1−8.1.11). In addition, despite occasional unconfirmed sightings, it is believed that all black-footed ferrets currently in the wild are the result of the federal reintroduction program, and none of the reintroduced ferrets or their offspring are likely to now reside within the project areas.

A1−8.1.9 Western Yellow-Billed Cuckoo

General Distribution. The historical range of the western yellow-billed cuckoo included all states west of the Rocky Mountains and extended into southern British Columbia at the northern extent and into the northwestern states of Mexico at the southern limit. The cuckoo's population and range have been largely diminished since the subspecies was first described in 1877. Currently, the range of the cuckoo is limited to disjunct fragments of riparian habitats from northern Utah, western Colorado, southwestern Wyoming, and southeastern Idaho southward into northwestern Mexico and westward into southern Nevada and California.

Distribution in Utah. Historically, cuckoos were probably a common to uncommon summer resident in Utah and across the Great Basin. The current distribution of yellow-billed cuckoos in Utah is poorly understood, though they appear to be an extremely rare breeder in lowland riparian habitats statewide (UDWR 2003b). There are at least two recent breeding records in Utah: one from the Ouray National Wildlife Refuge on the Green River in 1992 and one from the Matheson Wetlands Preserve in 1994.

Reproduction. The western yellow-billed cuckoo is one of the latest migrants to arrive and breed in Utah. They arrive in late May or early June, breed in late June through July, and start their southerly migration to northern South America by late August or early September. Yellow-billed cuckoo nesting behavior may be closely tied to food abundance. In years of low food abundance, cuckoos may forgo nesting; in years when the food supply is abundant, cuckoos may lay a large number of eggs (UDWR 2003b). Clutch size may consist of up to eight eggs but is usually two or three, and development of the young is very rapid, with a breeding cycle of 17 days from egg-laying to fledging. Although yellow-billed cuckoos usually raise their own young, they are facultative brood parasites, occasionally laying eggs in nests of other yellow-billed cuckoos or of other bird species.

Diet. Yellow-billed cuckoos feed almost entirely on large insects gleaned from tree and shrub foliage. They feed primarily on caterpillars, including tent caterpillars. They also feed frequently on grasshoppers, cicadas, beetles, and katydids, occasionally on lizards, frogs, and eggs of other birds, and rarely on berries and fruits (UDWR 2003b).

Nesting Habitat. Nesting habitat is classified as dense lowland riparian woodlands characterized by a dense subcanopy or shrub layer (regenerating canopy trees, willows, or other riparian shrubs) within 333 ft of water. Overstory in these habitats may be either large, gallery-forming trees (33 to 90 ft) or developing trees (10 to 27 ft), usually cottonwoods. Nesting habitats are found at low to mid-elevations (2,500 to 6,000 ft) in Utah. Cuckoos may require large tracts (100 to 200 acres) of contiguous riparian nesting habitat. The yellow-billed cuckoo is thus considered a riparian obligate (UDWR 2003b).

Threats. Threats to the yellow-billed cuckoo and its habitat in Utah include habitat loss and fragmentation from flooding and dewatering, encroachment by non-native tamarisk, grazing, recreational impacts, and oil and gas development.

Known Occurrences in the Project Area. Yellow-billed cuckoos have been known to nest in the Matheson Wetlands Preserve across the river from the Moab site (66 FR 38611–38626 [2001]). However, the UDWR (2003a) does not have records of cuckoo occurrence near any of the project sites, and other recent surveys (Johnson 2002) have not detected cuckoos near the Moab site. There are no known stands of suitable habitat large enough to support nesting cuckoos at or near any of the alternate disposal sites, borrow areas, or transportation corridors, except in the Matheson Wetlands Preserve near the Moab site. Habitat at the Moab site is probably insufficient to support nesting cuckoos, although cuckoos could forage on the Moab site.

Findings—Foraging Habitat and Human Disturbance. Yellow-billed cuckoos may occur in the Matheson Wetlands Preserve across the river from the Moab tailings pile. Removal of the approximately 50 acres of tamarisk on the Moab site may reduce the value of the area for foraging but would not likely remove suitable nesting habitat. Increased noise and lighting could affect yellow-billed cuckoos. However, the nearest nesting sites (Matheson Wetlands Preserve) would probably be at least one-half mile from the construction activities at the Moab site. At that point, the maximum noise levels would be approximately 65 dBA, which is comparable to normal daytime noise levels in the town of Moab.

Findings—Exposure to Contaminants in Surface Water. The yellow-billed cuckoo is unlikely to spend much time near the Moab tailings pile, since it nests across the river in the Matheson Wetlands Preserve. However, if it does occur near the tailings pile, the most prevalent route of exposure to chemical and radioactive constituents would likely be from ingestion of prey and surface water in the nearshore environment. The potential for chronic effects from ingestion of chemical contaminants in surface water was evaluated for the No Action alternative using the American robin (*Turdus migratorius*) as a surrogate. Of the surrogate species available (Sample et al. 1996), the robin most closely approximated the diet and body size of the yellow-billed cuckoo. None of the maximum surface water concentrations of any of the chemical constituents exceeded NOAEL-based drinking water benchmarks for the robin (Sample et al. 1996). Consequently, no adverse effects to the yellow-billed cuckoo would be expected from surface water consumption within the nearshore environment.

Any potential effects to the yellow-billed cuckoo that could arise from exposure to radioactive constituents would be discountable (see Section A1–8.2 of this BA and Appendix A2 of the EIS).

Findings—Exposure to Contaminants in Soils. Because the known diet of the yellow-billed cuckoo consists of insects without aquatic life stages, there would be no exposure to chemical contaminants originating in surface water through ingestion of prey. In contrast, some of these food items could have extensive contact with contaminants in surface soils. Further exposure to chemical contaminants originating in soils could also arise from consumption of the berries and seeds of plants that accumulate such contaminants. However, the nature and extent of any effects that could result from exposure by the latter two pathways that are linked to soils are unknown and probably are relatively unimportant compared with the potential effects of habitat destruction.

Findings—Exposure to Contaminants at the Evaporation Pond(s). The yellow-billed cuckoo could potentially be affected by contaminant exposure at the evaporation pond(s) through ingestion of contaminated prey and water, dermal uptake of contaminated water and airborne contaminants, and inhalation of airborne contaminants.

The evaporation pond(s) would be located well outside any yellow-billed cuckoo breeding territories, since nesting would occur in the Matheson Wetlands Preserve on the opposite side of the river. Thus, it is unlikely that yellow-billed cuckoos would spend much time in the vicinity of the evaporation pond(s). Further, the evaporation pond(s) would also be located in an area where project activities and site maintenance operations would create continual disturbance. Because of distance, disturbance, and the fact that the evaporation pond(s) would be located in an area that has been previously disturbed and is generally devoid of vegetation (from which the species generally gleans its prey [UDWR 2003b]), the likelihood of visits from the yellow-billed cuckoo would be small.

The evaporation pond(s) would be qualitatively monitored for general wildlife use, regardless of the potential presence of the yellow-billed cuckoo. Consequently, if it were determined that yellow-billed cuckoos were frequenting the evaporation pond(s), techniques to minimize or eliminate use would be identified and implemented. Techniques could include noise (e.g., propane boom cannons), visual deterrents (e.g., reflectors, silhouettes, effigies, water color), or obstruction (e.g., netting).

A1−8.1.10 Gunnison Sage Grouse

Distribution. The Gunnison sage grouse is a newly identified species that is rare in Utah. It formerly occurred in areas of Utah, Colorado, Arizona, New Mexico, and Oklahoma (UDWR 2003b). The distribution of the species has been reduced to less than 25 percent of its historical range (67 FR 40657–40679 [2002]). It now occurs only in parts of southeastern Utah and southwestern Colorado. In Utah, the Gunnison sage grouse currently occurs only in eastern San Juan County near the Colorado state line.

Habitat, Diet, and Reproduction. The Gunnison sage grouse prefers sagebrush and sagebrush/grassland habitats. It feeds primarily on sagebrush and other plant material, although it also consumes insects. It is a colonial breeder that mates in the spring. Females lay a clutch of approximately eight eggs that hatch in about 1 month, and young can fly at 1 to 2 weeks of age (UDWR 2003b).

Threats. The distribution of the Gunnison sage grouse and quality of its habitat has been reduced in part by habitat loss and fragmentation (67 FR 40657–40679 [2002]); habitat loss appears to be the major threat (UDWR 2003b).

Known Occurrences in the Project Area. The Gunnison sage grouse has been observed in San Juan County in the vicinity of the proposed pipeline corridor between Moab and the White Mesa Mill site. Occurrences have been documented in the Monticello North and Monticello South quads in 1999 (UDWR 2003b), and there was a confirmed sighting with no date in the Devil Mesa quad in the vicinity of the proposed pipeline corridor (UDWR 2003b). Much of the area near the proposed slurry pipeline route between Moab and White Mesa is part of a Gunnison sage grouse conservation area (Sage Grouse Working Group 2000).

Findings. Habitat destruction is the greatest potential impact of the proposed project activities on the Gunnison sage grouse. However, most of the proposed pipeline route follows existing, already disturbed rights-of-way; therefore, relatively little habitat would likely be lost in those areas. Portions of the proposed pipeline that are not part of existing rights-of-way would be surveyed prior to development. If significant sage grouse habitat features were identified, an appropriate mitigation plan would be developed to minimize impacts. Sage grouse could also be disturbed by noise or human presence during critical periods of the year, especially during courtship, breeding, and nesting. To minimize these impacts, if a slurry pipeline option were selected, construction within potential sage grouse habitat would be scheduled to occur during portions of the year when these activities would not be disrupted.

A1−8.1.11 White-Tailed Prairie Dog

A petition to list the white-tailed prairie dog as threatened or endangered under the ESA was submitted by a group of environmental organizations in July 2002 (Center for Native Ecosystems 2002). USF&WS is currently evaluating this petition and is considering adding this species to the list of candidates for ESA protection. This species is considered here both because it is under candidate review and because another species considered here (the black-footed ferret) is closely tied to the white-tailed prairie dog in Utah.

Habitat and Distribution. The white-tailed prairie dog inhabits grasslands and shrublands ranging from southern Montana through Wyoming and into Colorado and eastern Utah. In Utah, the Gap Analysis indicates that critical value habitat is located in Rich County, much of Uinta County, southeastern Duchesne County, and the central portions of Grand and Emory counties.

Threats. Major threats to the white-tailed prairie dog are habitat loss, poisoning, and sylvatic plague (UDWR 2003b).

Known Occurrences in the Project Area. White-tailed prairie dog colonies are known to occur at the Crescent Junction alternative disposal site. Numerous colonies occur around the Crescent Junction area and extend south toward the Klondike Flats alternative disposal site, forming a complex of colonies ranging in size from 10 to 2,445 acres (Seglund 2004). BLM (1995) reported a number of colonies at the Klondike Flats site, most of which were fairly small and concentrated in drainage bottoms with more silt soil and more vegetation. White-tailed prairie dogs are also likely to occur at Floy Wash, Tenmile, Courthouse Syncline, and Blue Hills Road borrow areas, and potentially in the general vicinity of the Moab site, as well as along transportation corridors between the sites. The area from Moab south along US-191 toward the White Mesa Mill site supports colonies of Gunnison’s prairie dog (Seglund 2004); this area could also support white-tailed prairie dogs, since their ranges overlap in this region.

Findings. Development of any of the sites north of Moab would likely disturb some white-tailed prairie dog colonies. Impacts would be possible, but apparently less likely, if sites south of Moab were developed for this project.

Prior to development of any of the proposed project sites or transportation routes, the areas would be surveyed and the potential effects to white-tailed prairie dogs evaluated. DOE, in coordination with BLM, USF&WS, and UDWR, would develop reasonable and appropriate mitigation plans to minimize adverse impacts. If the white-tailed prairie dog became listed as threatened or endangered under the ESA prior to completion of project activities, and if impacts were identified and could not be avoided, additional Section 7 consultation would be required.

A1−8.2 Potential Effects of Proposed Actions on Terrestrial Species

The impacts described below would be applicable at the Moab site, under either on-site or off-site disposal alternatives.

Habitat Destruction. Habitat loss would likely be the greatest and most obvious impact to terrestrial species under any of the EIS alternatives, the extent of which would depend on the alternative selected. At the Moab site, approximately 439 acres would be directly affected. However, only approximately 50 acres currently support vegetation, and most of this is dominated by tamarisk. Development of borrow areas could disturb 100 to 550 acres of desert vegetation spread over at least three locations. If an alternative disposal site were selected, an additional 350 to 500 acres of desert vegetation could be affected. Under the on-site or off-site disposal alternatives, up to 60 acres of land could be affected by construction of one or more evaporation ponds and an associated small support facility near the Moab tailings pile. However, it is likely that the evaporation pond(s) would be located in an area that has been previously disturbed and thus supports little vegetation.

Traffic Mortality. Truck transportation of tailings materials from the Moab site to one of the alternative disposal sites would significantly increase the amount of truck traffic on US-191 either north or south of Moab. Normal traffic on US-191 north of Moab consists of approximately 2,800 to 3,000 vehicles per day, of which approximately 30 percent (840 to 1,000) are trucks. Transporting tailings would add another 200 to 400 truck round trips per day, an increase of from about 7 to 15 percent over the normal number of vehicles. This increase in traffic would likely lead to a marginal increase in traffic-related wildlife mortalities in the vicinity of US-191.

Noise. Noise from site construction and operations and from increased truck or rail transport could have adverse impacts on terrestrial biota in the vicinity of the Moab site as well as at the alternate disposal sites, borrow areas, and transportation corridors. Man-made noise can affect wildlife by inducing physiological changes, nest or habitat abandonment, or behavioral modifications. It may also disrupt communications required for breeding or defense (Larkin 1996). However, wildlife may also habituate to man-made noise (Larkin 1996). Much of the available data on noise effects focus on noise sources that are much more extreme than construction activities, such as aircraft overflights (Efroymson et al. 2000), and most of the existing data are species-specific. Consequently, only a general evaluation of potential noise impacts due to the proposed activities is possible without specific knowledge about the locations of species relative to the noise source and without specific data on the responses of these same species to construction noises.

The maximum noise level generated by construction equipment at the Moab site or at an alternative disposal site is estimated to be approximately 95 dBA measured at 49 ft. This noise level would decrease with distance, until it reached a level of approximately 65 dBA at 1,476 ft from the source (65 dBA is the normal daytime background level in Moab). At the more isolated sites, this noise level would attenuate over a distance of approximately 6 miles until it reached the quiet desert background level of approximately 30 dBA. At the Moab site, noise effects on local wildlife would likely be minimal, because the available habitat would be removed during the remediation process. However, there could be detectable elevated sound levels in habitats downstream and across the Colorado River resulting from work near the periphery of the Moab site.

The increased truck traffic along US-191 resulting from transport of materials from the Moab site to an alternative disposal site would likely increase ambient noise levels by approximately 5 dB (measured at 49 ft). Although the highway noise (average baseline approximately 70 dBA) may be detected over distances of 6 to 7 miles, the additional noise due to the additional trucks would not be perceptible (at least to humans) beyond several hundred yards.

Other Disturbances. Other potential impacts could result from increased human presence during remediation activities, such as those from supplemental lighting that could be employed for dual-shift or 24-hour operations at the Moab and alternative disposal sites. To the extent practicable, activities and worker presence near the periphery of the sites should be limited to minimize potential harassment of wildlife. If supplemental lighting were employed, the lights would be directed and/or sheltered to minimize the amount of light escaping the work site.

Chemical/Radiological Impacts. The potential for adverse effects resulting from wildlife and plant exposures to chemical and radiological constituents would be greater under the No Action alternative, which does not include ground water treatment, than under the on-site or off-site disposal alternatives that include ground water treatment. Consequently, the following summary of potential impacts to wildlife focuses on chemical and radiological constituents in surface water under the No Action alternative. A small section discussing potential impacts at the evaporation pond(s) is also included.

Chemical Impacts—Wildlife. At the Moab site, wildlife could be exposed to contaminants through ingestion of prey, water, and soil; dermal uptake; and inhalation of airborne contaminants. The primary pathway for wildlife exposure to contaminants would likely be through ingestion of prey in the riparian zone and prey and water in the surface waters of the nearshore environment.

The potential for chronic effects through ingestion of prey and water within the surface waters of the nearshore environment was evaluated as part of the process of selecting preliminary contaminants of potential concern in surface water. The selection process involved comparing maximum concentrations of 28 contaminants with detection limits, background concentrations, and toxicological benchmarks. Toxicological benchmarks consisted of drinking water and food/water benchmarks that would result in NOAEL and LOAEL for selected wildlife species (Sample et al. 1996).

Two of the 28 original contaminants, mercury and selenium, were identified as preliminary contaminants of potential concern because they had maximum concentrations that exceeded detection limits, background concentrations, and wildlife toxicological benchmarks (Sample et al. 1996) (see Appendix A2 of the EIS). The bald eagle, southwestern willow flycatcher, and western yellow-billed cuckoo are the only consultation species considered to be potentially present at the Moab site. The bald eagle, southwestern willow flycatcher, and western yellow-billed cuckoo are similar in lifestyle to three of the benchmark species. Consequently, potential impacts to the bald eagle, southwestern willow flycatcher, and western yellow-billed cuckoo are discussed in relation to these benchmark species in Sections A1−8.1.4, A1−8.1.7, and A1−8.1.9, respectively. In addition, the nine metals in the freshwater aquifer that are of potential concern to plants (discussed below) could become translocated to plant parts consumed by wildlife or terrestrial invertebrates that are in turn consumed by wildlife. The only consultation species that could be exposed to contaminants via this route are the southwestern willow flycatcher and western yellow-billed cuckoo. Potential impacts to the southwestern willow flycatcher and western yellow-billed cuckoo from this route of exposure are discussed briefly in Sections A1−8.1.7 and A1−8.1.9, respectively.

Chemical Impacts—Plants. Plants may be exposed to contaminants through root or dermal uptake of contaminants. Of these, root uptake would likely be the primary exposure pathway. Further, only root uptake is considered, since only phytotoxicity benchmarks based on root uptake were available. Of the contaminants listed for the freshwater aquifer in the SOWP (DOE 2003a), soil solution phytotoxicity benchmarks were available only for the metals (Efroymson et al. 1997). Maximum and mean concentrations of metals in the freshwater aquifer were obtained from the SOWP (DOE 2003a) and screened on the basis of their exceedance of these phytotoxicity benchmarks (see Appendix A2 of the EIS).

The following nine metals had maximum concentrations that exceeded maximum background concentrations and were slightly less than or exceeded phytoxicity benchmarks: aluminum, arsenic, cobalt, copper, iron, manganese, mercury, molybdenum, and vanadium (Appendix A2 of the EIS). Four of these metals had mean concentrations that were slightly below or above phytotoxicity benchmarks: arsenic, manganese, molybdenum, and vanadium (Appendix A2 of the EIS). These nine metals, but particularly the latter four, could cause phytotoxic effects, assuming that plants had root access to the freshwater aquifer or associated soil water above it.

However, there would be no potential phytotoxic effects to consultation plant species (Jones' cycladenia, Navajo sedge, and clay phacelia), since these are not known to occur at or near the Moab tailings pile (see Sections A1−8.1.1, A1−8.1.2, and A1−8.1.3, respectively).

Radiological Impacts—Wildlife and Plants. The following constituents have been monitored as contributors to radiological dose to terrestrial organisms in surface waters at the Moab site: lead-210, polonium-210, radium-226, radium-228, radon-222, thorium-230, uranium-234, and uranium-238, and the general indicators of radionuclides, gross alpha and gross beta. The RESRAD Biota Code (Version 1.0 Beta 3, June 3, 2003) was used to screen the total radiological dose to populations of generic (not species-specific) terrestrial (including riparian) animals and generic terrestrial (including riparian) plants based on maximum and mean concentrations of uranium-238, uranium-234, and radium-226 in surface water (DOE 2002b). These isotopes represent the highest values analyzed for radionuclides from 2000 to 2002.

The total radiological dose was estimated using the default parameters (e.g., bioaccumulation factors) provided in the RESRAD Biota Code, since such site-specific data were lacking. The total estimated radiological dose was compared to the applicable DOE dose limits or standards designed to protect populations of generic terrestrial animals and generic terrestrial plants.

The total radiological dose to a population of generic terrestrial plants based on maximum surface water concentrations was 9.87×10^{-6} rad/day, about 6 orders of magnitude below the DOE dose standard of 1 rad/day. The total radiological dose to a population of generic terrestrial animals based on maximum concentrations was 0.14 rad/day, slightly above the DOE dose standard of 0.1 rad/day. This could be of potential concern if riparian animals' total exposure occurred at the location where the maximum-concentration sample was taken. However, riparian vertebrates integrate their exposure over a much larger area. The total radiological dose to a population of generic terrestrial animals based on mean concentrations was 0.013 rad/day, about 1 order of magnitude below the DOE dose standard.

Consequently, there is no potential risk of radiotoxic effects to a population of generic riparian plants, and the risk of potential radiotoxic effects to a population of generic riparian vertebrates would be minimal from these radioactive constituents in surface water. Consequently, it follows that there would be minimal risk to the bald eagle, southwestern willow flycatcher, and western yellow-billed cuckoo, the only consultation species thought to be potentially present at the Moab site (see Sections A1−8.1.4, A1−8.1.7, and A1−8.1.9, respectively).

The results of the RESRAD assessment indicate that the actual dose rates to terrestrial animals are below a population-level effect. There are no guidelines for radiological effects to individuals, which is important in evaluating impacts to threatened and endangered species. The studies resulting in the 0.1-rad/day criterion for terrestrial animals were based on exposures to organisms for 1 year, and then normalized to a dose rate based on a day. One could interpret these results to mean that a dose rate of 0.1 rad/day, if sustained for a year, would have an effect on some individuals but not on the population as a whole. Based on the results of the RESRAD assessment and on the fact that the bald eagle, southwestern willow flycatcher, and western yellow-billed cuckoo would be present at the Moab site only seasonally, if at all, radionuclides are not expected to adversely affect these species.

Evaporation Pond(s). Potential impacts that could result from the construction and operation of one or more evaporation ponds include contaminant impacts to wildlife. The evaporation pond(s) could attract wildlife that could be affected due to contaminant exposure through ingestion of contaminated prey and water, dermal uptake of contaminated water and airborne contaminants, and inhalation of airborne contaminants. The bald eagle, southwestern willow flycatcher, and western yellow-billed cuckoo are the only terrestrial consultation species considered to be potentially present at the Moab site. Potential impacts to these species in connection with the evaporation pond(s) are discussed in Sections A1−8.1.4, A1−8.1.7, and A1−8.1.9, respectively.

A1−9.0 Determinations and Conclusions

The potential impacts of the action alternatives and the No Action alternative include physical, chemical, and/or radiological impacts as assessed in Sections A1−7.2 and A1−8.2. The degree and duration of the impacts would vary depending upon location, remediation methods, remediation goals, remediation period, transportation modes, and the potential presence of species and habitats.

DOE has made determinations regarding effects to federal threatened, endangered, and candidate species based on the information and assessment presented in Sections A1−7.0 and A1−8.0. This information was obtained in consultation with USF&WS and other federal and State agencies (e.g., BLM, UDWR). Because DOE's on-site and off-site remediation alternatives propose improvements to the existing environment, the determinations are made based on DOE's proposed actions and not on the effects of existing impacts (No Action alternative). It is emphasized that DOE's proposed action alternatives would mitigate existing risks to endangered species caused by historical surface and ground water contamination.

The determinations were made using the guidance provided in Chapter 3 of the USF&WS *Endangered Species Consultation Handbook* (USF&WS 1998b). These determinations serve as the basis for USF&WS to reach a jeopardy, or no jeopardy, finding in the Biological Opinion

Consequently, there is no potential risk of radiotoxic effects to a population of generic riparian plants, and the risk of potential radiotoxic effects to a population of generic riparian vertebrates would be minimal from these radioactive constituents in surface water. Consequently, it follows that there would be minimal risk to the bald eagle, southwestern willow flycatcher, and western yellow-billed cuckoo, the only consultation species thought to be potentially present at the Moab site (see Sections A1−8.1.4, A1−8.1.7, and A1−8.1.9, respectively).

The results of the RESRAD assessment indicate that the actual dose rates to terrestrial animals are below a population-level effect. There are no guidelines for radiological effects to individuals, which is important in evaluating impacts to threatened and endangered species. The studies resulting in the 0.1-rad/day criterion for terrestrial animals were based on exposures to organisms for 1 year, and then normalized to a dose rate based on a day. One could interpret these results to mean that a dose rate of 0.1 rad/day, if sustained for a year, would have an effect on some individuals but not on the population as a whole. Based on the results of the RESRAD assessment and on the fact that the bald eagle, southwestern willow flycatcher, and western yellow-billed cuckoo would be present at the Moab site only seasonally, if at all, radionuclides are not expected to adversely affect these species.

Evaporation Pond(s). Potential impacts that could result from the construction and operation of one or more evaporation ponds include contaminant impacts to wildlife. The evaporation pond(s) could attract wildlife that could be affected due to contaminant exposure through ingestion of contaminated prey and water, dermal uptake of contaminated water and airborne contaminants, and inhalation of airborne contaminants. The bald eagle, southwestern willow flycatcher, and western yellow-billed cuckoo are the only terrestrial consultation species considered to be potentially present at the Moab site. Potential impacts to these species in connection with the evaporation pond(s) are discussed in Sections A1−8.1.4, A1−8.1.7, and A1−8.1.9, respectively.

A1−9.0 Determinations and Conclusions

The potential impacts of the action alternatives and the No Action alternative include physical, chemical, and/or radiological impacts as assessed in Sections A1−7.2 and A1−8.2. The degree and duration of the impacts would vary depending upon location, remediation methods, remediation goals, remediation period, transportation modes, and the potential presence of species and habitats.

DOE has made determinations regarding effects to federal threatened, endangered, and candidate species based on the information and assessment presented in Sections A1−7.0 and A1−8.0. This information was obtained in consultation with USF&WS and other federal and State agencies (e.g., BLM, UDWR). Because DOE’s on-site and off-site remediation alternatives propose improvements to the existing environment, the determinations are made based on DOE’s proposed actions and not on the effects of existing impacts (No Action alternative). It is emphasized that DOE’s proposed action alternatives would mitigate existing risks to endangered species caused by historical surface and ground water contamination.

The determinations were made using the guidance provided in Chapter 3 of the USF&WS *Endangered Species Consultation Handbook* (USF&WS 1998b). These determinations serve as the basis for USF&WS to reach a jeopardy, or no jeopardy, finding in the Biological Opinion

(Appendix A3). They also serve as the basis for USF&WS to authorize a "take," if applicable. A "take" may be authorized if an action will not jeopardize the continued existence of a species.

As defined in the guidance (USF&WS 1998b), the three categories of effects that are considered in this BA are:

No Effect—There is sufficient evidence that the species and habitat (including critical and potentially suitable habitat) would not be affected. This determination is based on consultation with USF&WS and other federal and State agencies (e.g., BLM, UDWR).

May affect, not likely to adversely affect—Effects to species and critical habitat are discountable, insignificant, or completely beneficial. In most cases, in this BA, this determination would be a result of discountable effects. Discountable effects are those that are extremely unlikely to occur.

May affect, likely to adversely effect—Adverse effects to species and critical habitat are direct or indirect, including interrelated and interdependent actions.

Three plant species (Navajo sedge, Jones' cycladenia, and clay phacelia), and the California condor are not known or suspected to occur at any of the proposed project sites or within transportation corridors. DOE has determined that the proposed alternatives, including the No Action alternative, would have "no effect" on these species. DOE has not made a determination for the white-tailed prairie dog based on the current status (candidate review) of this species. Therefore, these species are not discussed further.

In addition, DOE has made a determination of "no effect" for all species for proposed remediation of vicinity properties. These locations have been historically disturbed and are located in urbanized areas (e.g., private residences and commercial properties) in the vicinity of the Moab site. No aquatic species would be present on vicinity properties, and suitable habitat does not exist for avian or terrestrial species at vicinity property locations.

Section A1−9.1 discusses determinations for the on-site surface disposal alternative. Section A1−9.2 discusses determinations for the off-site surface disposal alternatives. Section A1−9.3 discusses determinations for the ground water remediation aspects of both the on-site and off-site alternatives. Section A1−9.4 discusses determinations for the No Action alternative. Section A1−9.5 summarizes the conclusions and determinations.

A1−9.1 Determinations for the On-Site Disposal Alternative

Table A1−5 summarizes DOE's determinations for aquatic and terrestrial species for the on-site disposal alternative and the effects at borrow locations and haul routes for borrow materials.

These determinations would be associated with short-term surface remediation activities (within 5 to 10 years of the ROD). Once remediation was complete, there would be "no adverse effect" to any of these species. Effects associated with ground water remediation are addressed in Section A1−9.3.

Table A1−5. Summary of DOE Determinations for the On-Site Surface Disposal Alternative

Species	Scientific Name	On-Site Effects	Borrow Location and Haul Route Effects
BIRDS			
Bald eagle	*Haliaeetus leucocephalus*	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Gunnison sage grouse	*Centrocercus minimus*	No effect	No effect
Mexican spotted owl	*Strix occidentalis lucida*	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Southwestern willow flycatcher	*Empidonax traillii extimus*	May affect, not likely to adversely affect	No effect
Western yellow-billed cuckoo	*Coccyzus americanus*	May affect, not likely to adversely affect	No effect
MAMMALS			
Black-footed ferret	*Mustela nigripes*	No effect	May affect, not likely to adversely affect
FISH			
Bonytail	*Gila elegans*	May affect, not likely to adversely affect	No effect
Colorado pikeminnow	*Ptychocheilus lucius*	May affect, not likely to adversely affect	No effect
Humpback chub	*Gila cypha*	May affect, not likely to adversely affect	No effect
Razorback sucker	*Xyrauchen texanus*	May affect, not likely to adversely affect	No effect

On-site Effects

The bald eagle, southwestern willow flycatcher, and western yellow-billed cuckoo have been reported near the Moab site, but their presence is seasonal and likely infrequent due to their migratory nature. Potential habitat exists for the Mexican spotted owl west of the site, although not close to the site. Therefore, potential effects on these species would be considered discountable.

Endangered fish species are not likely to be affected by physical or mechanical disturbances and noise associated with the preparation of the on-site disposal cell. Therefore, potential effects would be discountable.

Borrow Locations and Haul Routes

Bald eagles are not known to occur close to the borrow locations and haul routes, although potential high-quality wintering habitat is reported to be in the vicinity. Although potentially suitable habitat for the Mexican spotted owl has been identified to the west of the haul routes, it is of sufficient distance to preclude disturbance above that caused by common recreational vehicle use in the area. Therefore, potential effects on these species would be considered discountable.

The black-footed ferret has been confirmed as not being present at the Moab site. However, there is potentially suitable habitat, based on the location and size of prairie dog colonies, relatively close to some borrow locations and haul routes. Final selection of borrow areas would exclude any sites that would adversely affect endangered species.

Endangered fish species are not present at the borrow locations. Some of the haul routes do cross the Colorado River, and accidental spills could introduce a small quantity of borrow material into the Colorado River. However these effects would be discountable or insignificant.

Disposal Cell Failure From Natural Phenomena

DOE has determined that catastrophic failure of the disposal cell from sudden or catastrophic lateral migration of the Colorado River into the Moab site for the pile design period of 200 to 1,000 years does not pose a realistic hazard. DOE has evaluated the hydrologic and geologic conditions of the northwestern portion of Spanish Valley and the Colorado River corridor at Moab (See Sections 3.1.1, 3.1.6, and 3.1.7 of the EIS). Given the known geologic and hydrologic context, the likelihood of catastrophic failure, though not statistically quantified, is considered extremely unlikely. Consequently, on-site disposal may affect, but is not likely to adversely affect, endangered fish species in the Colorado River. However, in the extremely unlikely event that a catastrophic failure occurred, the impacts would likely adversely affect endangered fish species in the Colorado River from the Moab site to Lake Powell (see Section A1−7.2).

If mitigated, long-term failure would not likely result in negative impacts to aquatic biota. DOE's Office of Legacy Management is responsible for monitoring and mitigating this type of release. In addition, all currently available evaluations of the site's geologic and hydrologic conditions suggest that future lateral migration of the river will tend toward the east, away from the site (see Table 2−33, No.10 in the EIS). Further, DOE has incorporated a buried riprap diversion wall into the on-site disposal design to mitigate potential impacts should lateral river migration occur. It has been estimated that this engineering control could easily be enhanced, expanded, and/or modified in the future should river migration encroach on the site and the disposal cell. Consequently, on-site disposal may affect, but is not likely to adversely affect, endangered fish species in the Colorado River. However, in the unlikely event that long-term failure occurred, the impacts would likely adversely affect endangered fish species in the Colorado River adjacent to the Moab site.

There would be short-term adverse effects to the endangered fish if natural processes caused a catastrophic failure of the on-site disposal cell at the Moab site. Long-term failure of the on-site disposal alternative may affect, but is not likely to adversely affect, the endangered fish. While the contaminant load to the water and sediment is likely to increase, the effects of sediment loading is likely to be offset by new habitat being created in other locations.

A1−9.2 Determinations for the Off-Site Disposal Alternative

Table A1−6 summarizes DOE's determinations for terrestrial and aquatic species for the off-site disposal alternative. The determinations consider on-site effects related to preparation of tailings for transportation, effects associated with transportation to the off-site disposal location, and effects at the off-site disposal location. If a species may be affected either at the Moab site, at an off-site disposal location, or along a transportation route, a "may affect" determination is indicated.

Table A1−6. Summary of DOE Determinations for the Off-Site Surface Disposal Alternative

Species	Scientific Name	On-Site Effects	Off-Site Effects		
			Klondike Flats	Crescent Junction	White Mesa
BIRDS					
Bald eagle	*Haliaeetus leucocephalus*	May affect, not likely to adversely affect	May affect, not likely to adversely affect	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Gunnison sage grouse	*Centrocercus minimus*	No effect	No effect	No effect	May affect, not likely to adversely affect
Mexican spotted owl	*Strix occidentalis lucida*	May affect, not likely to adversely affect	May affect, not likely to adversely affect	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Southwestern willow flycatcher	*Empidonax traillii extimus*	May affect, not likely to adversely affect	No effect	No effect	May affect, not likely to adversely affect
Western yellow-billed cuckoo	*Coccyzus americanus*	May affect, not likely to adversely affect	No effect	No effect	No effect
MAMMALS					
Black-footed ferret	*Mustela nigripes*	No effect	May affect, not likely to adversely affect	May affect, not likely to adversely affect	May affect, not likely to adversely affect
FISH					
Bonytail	*Gila elegans*	May affect, not likely to adversely affect	No effect	No effect	May affect, not likely to adversely affect
Colorado pikeminnow	*Ptychocheilus lucius*	May affect, not likely to adversely affect	No effect	No effect	May affect, not likely to adversely affect
Humpback chub	*Gila cypha*	May affect, not likely to adversely affect	No effect	No effect	May affect, not likely to adversely affect
Razorback sucker	*Xyrauchen texanus*	May affect, not likely to adversely affect	No effect	No effect	May affect, not likely to adversely affect

These determinations would be associated with short-term surface remediation activities (within 5 to 10 years of the ROD). Once remediation was complete, there would be “no adverse effect” to any of these species. Effects associated with borrow locations and borrow haul routes have been addressed in Section A1−9.1 and are not addressed again in this section. Effects associated with ground water remediation are addressed in Section A1−9.3.

<u>On-site Effects Associated with Tailings Preparation</u>

If an off-site disposal site were selected in the ROD, remediation activities would still occur at the Moab site (i.e., those associated with preparing the tailings for transportation). The potential effects to the bald eagle, Mexican spotted owl, southwestern willow flycatcher, and western yellow-billed cuckoo, as well as for the endangered fish species, would be similar to those described for the on-site surface disposal alternative under Section A1−9.1 and are therefore considered discountable.

Klondike Flats Alternative

At this proposed disposal cell location, the only species of concern are the bald eagle and black-footed ferret due to the possible occurrence of associated suitable habitat. Based on available information, it is unlikely that these species are present; therefore, potential adverse effects would be considered discountable.

The bald eagle, Mexican spotted owl, and black-footed ferret are the species of concern along the three proposed transportation corridors (truck, rail, and pipeline) due to the possible occurrence of associated suitable habitat. Based on available information, it is unlikely that these species are present; therefore, potential adverse effects would be considered discountable.

Endangered fish species are not present at Klondike Flats, and the routes for transporting material to the location do not cross critical habitat. Therefore, there would be “no effect.”

Crescent Junction Alternative

At this proposed disposal cell location, the only species of concern are the bald eagle and black-footed ferret due to the possible occurrence of associated suitable habitat. Based on available information, it is unlikely that these species are present; therefore, potential adverse effects would be considered discountable.

For the three transportation corridors, the potential effects would be similar to those described for the Klondike Flats alternative and would therefore be considered discountable.

Endangered fish species are not present at Crescent Junction, and the routes for transporting material to the location do not cross critical habitat. Therefore, there would be “no effect.”

White Mesa Mill Alternative

At the White Mesa Mill disposal cell location, no effects are anticipated because the White Mesa mill is an operating site under an NRC license. The “may effect” determinations in Table A1−6 are based on potential effects associated with the two transportation corridors (truck and pipeline). Transportation by rail is not included as an alternative in the EIS and therefore was not considered in making the determinations in Table A1−6.

The species listed in Table A1−6 are not expected to be adversely affected by use of the truck corridor, since it is currently a state highway. If species were present close to the highway, the effects would be considered discountable.

With the exception of the western yellow-billed cuckoo, all the species listed in Table A1−6, or associated suitable habitat, could be present along the pipeline corridor. Because of the diversity of vegetation and life zones, this corridor presents the greatest potential for species presence or the presence of potentially suitable habitat. As a result, this corridor presents the greatest potential for adverse effects.

The potential for adverse impacts to the bald eagle and southwestern willow flycatcher exists wherever riparian areas are present along the slurry pipeline corridor, particularly where the route would cross the Colorado River. Based on available information, it is unlikely that these species are present; therefore, potential adverse effects would be considered discountable. There is the potential for the Gunnison sage grouse and associated habitat to be present along the pipeline corridor. However, there is no indication that the route would cross any essential habitat areas (e.g., “leks”). Therefore, if the species was present, these effects would be considered insignificant. Potentially suitable habitat for the Mexican spotted owl also exists in the vicinity of the pipeline corridor. Based on available information, it is unlikely that this species is present; therefore, potential adverse effects would be considered discountable.

Although the potential exists for black-footed ferret habitat to occur in the vicinity of some segments of the pipeline corridor, such occurrence is unlikely. Therefore, potential effects are considered discountable.

Endangered fish species are not present at the White Mesa Mill. However, the routes for transporting material to the location cross critical habitat in the Colorado River. There is the possibility that an accidental spill of contaminated soil could introduce material into the river. However, these effects would be discountable.

A1−9.3 Determinations for Ground Water Remediation

Active ground water remediation is proposed for the on-site and the three off-site alternatives. All remediation activities would occur within the existing millsite boundary. Determinations are based on meeting the remediation goals stated in Section A1−4.3.2 and implementation and operation schedules stated in Section A1−4.3.5. The active remediation system would extract and treat ground water for 75 to 80 years (depending on whether an off-site or on-site remediation alternative were implemented) to maintain surface water quality goals. The length of the remediation period required to achieve compliance under off-site disposal would be about 5 years shorter than under on-site disposal (Table A1−7). The contaminant concentrations in the ground water would thus be reduced to acceptable risk levels prior to entry into the Colorado River. Active remediation would cease only after ground water and surface water monitoring confirmed that long-term remediation goals were achieved and after appropriate consultation and concurrence with USF&WS. This information is summarized in Table A1−7 for the three major post-ROD project phases. It assumes that remediation goals would not be fully met as a result of the initial and interim actions described in Section A1−4.3.3.

Table A1−7. Schedule for Meeting Ground Water Remediation Goals

Post-ROD Project Phase	Remediation Goals Achieved ?	
	On-site Alternative	Off-site Alternative
Pre-remediation (within 10 years of the ROD)	No	No
Remediation – On-site disposal (within 80 years of the ROD)	Yes	NA
Remediation – Off-site disposal (within 75 years of the ROD)	NA	Yes
Post-remediation	Yes	Yes

Table A1−8 summarizes DOE determinations for effects to terrestrial and aquatic species, as a result of ground water remediation, for both the on-site and off-site disposal alternatives. For terrestrial receptors, determinations are based on (1) disturbances associated with ground water remediation activities and (2) exposure to concentrated contaminants that could occur in an evaporation pond if a pond were used during ground water remediation.

Table A1−8. Summary of DOE Ground Water Remediation Determinations

Common Name	Scientific Name	Pre-Remediation	During Remediation	Post-Remediation
BIRDS				
Bald eagle	*Haliaeetus leucocephalus*	May affect, not likely to adversely affect	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Gunnison sage grouse	*Centrocercus minimus*	No effect	No effect	No effect
Mexican spotted owl	*Strix occidentalis lucida*	May affect, not likely to adversely affect	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Southwestern willow flycatcher	*Empidonax traillii extimus*	May affect, not likely to adversely affect	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Western yellow-billed cuckoo	*Coccyzus americanus*	May affect, not likely to adversely affect	May affect, not likely to adversely affect	May affect, not likely to adversely affect
FISH				
Bonytail	*Gila elegans*	May affect, **likely** to adversely affect	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Colorado pikeminnow	*Ptychocheilus lucius*	May affect, **likely** to adversely affect	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Humpback chub	*Gila cypha*	May affect, **likely** to adversely affect	May affect, not likely to adversely affect	May affect, not likely to adversely affect
Razorback sucker	*Xyrauchen texanus*	May affect, **likely** to adversely affect	May affect, not likely to adversely affect	May affect, not likely to adversely affect
MAMMALS				
Black-footed ferret	*Mustela nigripes*	No effect	No effect	No effect

There would be no effect on the Gunnison sage grouse or black-footed ferret from ground water remediation construction and operation or from an evaporation pond, since neither of these species or associated suitable habitat is present at the Moab site.

The bald eagle, southwestern willow flycatcher, and western yellow-billed cuckoo are the only consultation species considered to be potentially present at the Moab site. If present, they could be affected by ground water remediation construction and operation and by an evaporation pond. However, disturbance resulting from ground water remediation would probably be less than that resulting from surface remediation under the on-site disposal alternative. Because the potential effects of surface remediation under the on-site disposal alternative are considered discountable (see Section A1−9.1), the potential effects of ground water remediation should also be considered discountable. Potential effects on the bald eagle, southwestern willow flycatcher, and yellow-billed cuckoo from an evaporation pond would be considered discountable due primarily to a lack of habitat nearby for these species, as explained in Sections A1−8.1.4, A1−8.1.7, and A1−8.1.9, respectively.

The Mexican spotted owl is not considered to be potentially present at the Moab site, based solely on distance to critical habitat (located a few miles south of the site) and potential habitat (located within the first 7 miles north of the site). Further, in the very unlikely event that the spotted owl were to occur at the Moab site, it would be unlikely to use the area where ground water remediation construction and operation would occur (within the millsite boundary) and the environs of the evaporation pond. The spotted owl primarily consumes rodents, and these would be unlikely to occur within the millsite boundary and the area where the evaporation pond would be constructed, since both areas have been previously disturbed and support little to no vegetation. Consequently, potential effects on the Mexican spotted owl due to ground water remediation activities and the presence of an evaporation pond are considered discountable.

If an evaporation pond were used as part of ground water remediation, it would be qualitatively monitored for general wildlife use. If any species that are the subject of this BA frequented the evaporation pond, DOE would consult with USF&WS to develop reasonable and prudent measures to discourage or prevent those species from using the pond. There would be no adverse evaporation pond effects upon completion of remediation (see “post-remediation” in Table A1−8).

During the pre-remediation phase (Table A1−8)), critical habitat for all four endangered fish species would likely continue to be adversely affected by historical contamination. As discussed in Section A1−7.2. As discussed in Section A1−7.1, the following endangered fish species and their life stage are most likely to be directly and adversely affected by site-related contamination: pikeminnow (all life stages with emphasis on drifting larvae and young-of-the-year), razorback sucker (stocked juveniles and adults, and naturally produced larvae and young-of-the-year) and bonytail (stocked juveniles and adults, and naturally produced larvae and young-of-the-year) (USF&WS 2004a). The closest population of humpback chub is downriver in Cataract Canyon and would be affected in the event of disposal cell failure, but this population is not affected by site-related contamination.

DOE, in consultation with USF&WS, has implemented and will continue to implement initial and interim actions to reduce the potential for “take” until the selected remedial action and methods are fully implemented. The time frame required for the selection and implementation of remedial actions and methods, during which the take could occur, is anticipated to be a maximum of 10 years from the date of the ROD (see pre-remediation phase in Table A1−7). As stated in Section A1−4.3.3, a reduction in contaminant concentrations in surface water could be observed significantly sooner than the 10-year time frame as a result of interim actions.

During the remediation and post-remediation phases in Table A1−8, effects on fish species and associated critical habitat would likely be insignificant or beneficial. Ground water and surface water would be monitored to determine if remediation goals were being met. USF&WS would be consulted at least annually on the results of monitoring. Long-term effects are consistent with the goals of the Upper Colorado River Endangered Fish Recovery Program.

A1−9.4 Determinations for the No Action Alternative

Selection of the No Action alternative would result in the continued contamination of the Colorado River at the Moab site, which is critical habitat for four endangered fish species. Terrestrial species that use riparian areas along the eastern boundary of the site would continue to be exposed to elevated contaminant concentrations in surface water.

Potential impacts to the bald eagle, southwestern willow flycatcher, and western yellow-billed cuckoo from elevated contaminant concentrations in surface water are discussed in Sections A1−8.1.4, A1−8.1.7, and A1−8.1.9, respectively. Under the No Action alternative, potential effects on all three species are considered unlikely and therefore discountable.

Elevated contaminant concentrations in the Colorado River are likely to adversely affect the Colorado pikeminnow, razorback sucker, bonytail, humpback chub, and designated critical habitat for all four species under the No Action alternative. Adverse impacts would continue to occur until ground water concentrations naturally attenuate to acceptable risk levels in the river. This is estimated to be 75–80 years after the ROD (Figure A1−9).

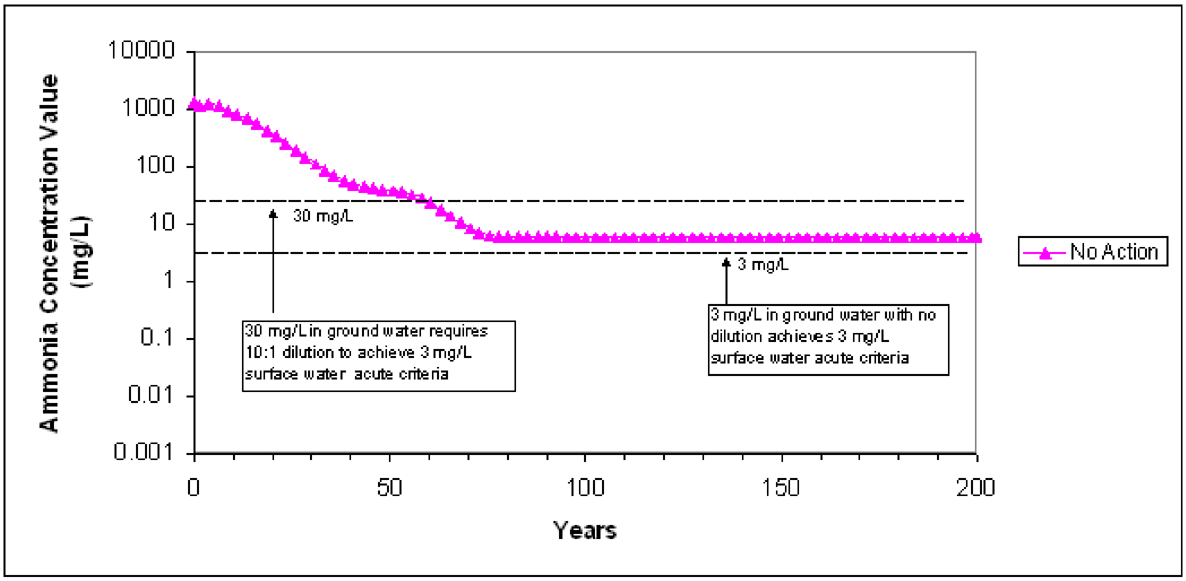

Figure A1−9. Predicted Maximum Ammonia Concentrations in Ground Water for the No Action Alternative

No species would be adversely affected at proposed off-site disposal locations, at borrow areas, or in the proposed transportation corridors under the No Action alternative.

A1−9.5 Conclusions

When the Moab site was assigned to DOE (October 2000) for remediation under UMTRCA, DOE considered the effects of existing contaminated media at the Moab site and determined that ground water is the only medium providing an exposure pathway. DOE further determined that ground water contamination reaching the Colorado River is presenting unacceptable risk to endangered species and critical habitat—in this case, four endangered fish species. Therefore, the conclusions presented below compare remediation alternatives considered in this BA and in the EIS in light of the determinations presented in Sections A1−9.1 through A1−9.4 for aquatic and terrestrial species.

On-Site and Off-Site Surface Disposal Alternatives

For the on-site surface disposal alternative, DOE has concluded that the proposed action would have no effect, or would be unlikely to adversely affect, terrestrial and aquatic consultation species.

For the off-site surface disposal alternatives, DOE has concluded that remediation activities at the proposed disposal locations and along transportation routes would result in no effect, or would be unlikely to adversely affect, terrestrial and aquatic consultation species. DOE may need to complete additional biological investigations and field surveys for terrestrial species, depending on the disposal location and transportation corridor selected in the ROD.

Of the off-site disposal locations, the White Mesa Mill site would be the least likely to affect terrestrial consultation species. The Klondike Flats site also would present minimal potential impacts. BLM has conducted extensive studies in this area, and none of the consultation species are known to occur in the vicinity. Further, placing a disposal facility at the Klondike Flats site would be consistent with existing land uses (e.g., county landfill). The Crescent Junction site is similar to the Klondike Flats site in that none of the consultation species are known to occur in the vicinity.

Of the transportation options, the slurry pipeline would present the greatest potential for affecting terrestrial consultation species, due to the need for new disturbance associated with pipeline construction, operation, and removal. Of the three pipeline corridors, the corridor to the White Mesa Mill site would present the greatest potential for adverse effects due to the diversity of habitat types present (see Section A1−8.1). It would also be the corridor requiring the greatest level of effort for additional field surveys and biological investigations.

In a comparison of the disposal alternatives, the on-site alternative would be less likely to affect terrestrial and aquatic consultation species. In the near term (75–80 years), the effect on aquatic species is similar for the on-site and off-site disposal alternatives; ammonia concentrations in ground water will exceed ammonia criteria unless ground water remediation takes place. By moving the tailings pile to an off-site location, ground water concentrations are predicted to fall below federal and state criteria in 75 years, about 5 years sooner than if the pile remains on site.

Ground Water Remediation

DOE is proposing ground water remediation under both the on-site and off-site disposal alternatives. Based on consultation with USF&WS and other cooperating agencies, the long-term benefits to endangered fish species as a result of remediation would outweigh the potential discountable short-term effects on terrestrial consultation species.

During the pre-remediation phase (within 10 years of the ROD), DOE would continue interim actions to reduce the risk to endangered fish. DOE projects that remedial actions would reduce concentrations of contaminants to levels that would no longer pose a risk that could result in a "take." This would require from 10 to 80 years following the ROD for on-site disposal, and from 10 to 75 years following the ROD for off-site disposal. Remedial actions would continue until contaminant concentrations no longer posed a risk under natural conditions. This post-remediation phase is currently projected to commence at approximately 80 years after the ROD for on-site disposal and approximately 75 years after the ROD for off-site disposal.

In a comparison of ground water remediation under the disposal alternatives, off-site disposal would be slightly more favorable for aquatic consultation species.

No Action Alternative

No adverse effects on terrestrial species would be likely to occur at off-site disposal or borrow locations or along transportation routes under this alternative. No adverse impacts to terrestrial species would be likely to occur as a result of historical site operations (i.e., elevated contaminant concentrations in surface water). However, adverse impacts caused by historical site operations would continue to affect endangered fish species and critical habitat. This unmitigated effect would likely result in a long-term "take" and would not be consistent with USF&WS recovery plans.

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- Bureau of Land Management, Monticello
- National Parks Service, Canyonlands National Park
- National Parks Service, Arches National Park
- Utah Department of Wildlife Resources, Moab

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- U.S. Fish and Wildlife Service, Salt Lake City
- Utah Department of Wildlife Resources, Price

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Appendix B

Assumed Disposal Cell Cover Conceptual Design and Construction

B1.0 Introduction

This appendix describes the technical basis for the disposal cell cover conceptual design assumed for the purposes of this environmental impact statement (EIS) at the Moab, Klondike Flats, and Crescent Junction, Utah, sites. The design is strictly pre-conceptual and is intended to develop a basis for comparing impacts between the alternatives. This assumed design is not intended to commit the U.S. Department of Energy (DOE) to any specific cover design but rather to establish a reasonable basis for evaluating environmental impacts associated with this component of site remediation and reclamation.

The design for the White Mesa Mill site disposal cell cover is different from the design described here because it is based on an unsolicited proposal submitted to DOE. The White Mesa Mill cover approach reflects an alternative design more typical of Title II (Uranium Mill Tailings Radiation Control Act [UMTRCA]) uranium mill tailings reclamation similar to that proposed in the U.S Nuclear Regulatory Commission's (NRC's) *Final Environmental Impact Statement Related to Reclamation of the Uranium Mill Tailings at the Atlas Site, Moab, Utah* (NRC 1999). A brief description of the White Mesa Mill cover design is included in Section B4.0.

By including both design approaches, DOE has attempted to support decision-making by presenting a range of potential cover design approaches and a sense of the associated impacts related to the cover component selected for the final remedy.

B2.0 Current Design Concept

Engineered covers are the accepted remedial action to achieve containment (DOE 1989). In the case of uranium mill tailings, the engineering process must address the regulatory requirement that the cover remain effective for 1,000 years where reasonably achievable, and in no case for less than 200 years (EPA 1983).

In the semiarid Moab environment, ground water recharge is naturally limited where thick, fine-grained soils store precipitation until soil evaporation and plant transpiration seasonally return it to the atmosphere. The current assumed design mimics and enhances this natural water conservation. The design includes a water storage soil layer consisting of thick, fine-grained soil. This water storage soil layer overlies a coarse-grained capillary break layer that limits downward water movement and increases the water storage capacity of the water storage soil layer. High tensions in the small pores of the water storage soil layer impede movement of water into the larger pores of the underlying coarse-grained layer. Drainage into the capillary break layer occurs only if water accumulation at the sponge/capillary break layer interface approaches saturation and tensions decrease sufficiently for water to enter the larger pores (Ho and Webb 1998; Stormont and Morris 1998; Hillel 1980).

Evapotranspiration prevents excessive water accumulation above the textural break (Waugh et al. 1991; Anderson et al. 1993; Link et al. 1994; Sackschewsky et al. 1995; Waugh et al. 2004; Anderson and Forman 2002). In short, the water storage soil layer stores water while plants are dormant, then plants extract stored water during the growing season and return it to the atmosphere. Performance monitoring data for similar water balance designs have shown that flux rates are considerably less than 1×10^{-7} centimeters per second (cm/s) (Waugh 2004).

The assumed design relies on management of the water balance as the primary means for limiting water infiltration. Figure 2–6 of DOE's current draft EIS is a conceptual cross section of the final condition of the proposed disposal cell. The figure also illustrates the types and cover dimensions of the materials that would be placed on the sides and top of the cell to contain radon emissions and stabilize the cell. Variations of this design would be used for both the on-site and off-site alternatives analyzed in the draft EIS.

The assumed cover system's top slope**,** described from the base upward, would consist of

- A 1.5-foot-thick radon/infiltration barrier consisting of basal clay.
- A 0.5-foot-thick capillary break layer consisting of coarse sand/fine gravel.
- A 3.5-foot-thick water storage soil layer consisting of fine-grained soil.
- A 0.5-foot-thick surface erosion protection layer (called the soil/rock admixture) consisting of 80 percent soil and 20 percent limestone riprap.
- A vegetated surface for water balance control.

The assumed cover system's side slope would be identical to the top slope system with the exception of the soil/rock admixture. Because the side slope would be steep, a much greater erosion potential would exist compared to the top slope. A 1-foot-thick riprap rock surface would be designed and constructed in accordance with NUREG-1623, *Design of Erosion Protection for Long-Term Stabilization* (NRC 2002). To facilitate water-balance control, voids in the riprap would be filled with soil and planted.

Table B–1 lists the basis for each component of the assumed design.

Table B–1. Technical Basis and Assumptions for Components of the Assumed Cover Design

Compacted Soil Layer
• Layer thickness would be based on calculations of radon flux at the surface of the compacted soil layer. • Soil type (e.g., clay loam) would be selected from available borrow sources that can satisfy performance requirements for permeability and radon attenuation. • Compaction requirements would be determined with tests and calculations of saturated hydraulic conductivity and radon attenuation. • Soil conditioning requirements would consider the morphology and structure of borrow soils.
Capillary Break Layer
• Grain size and gradation requirements would be based on tests and calculations of (1) unsaturated flow (e.g., Richard's equation) between the water storage soil layer and capillary break layer, and (2) saturated hydraulic conductivity. • The layer thickness would be based on the design (monolayer or graded filter) and constructability.

Table B–1 (continued). Technical Basis and Assumptions for Components of the Assumed Cover Design

Water Storage Soil Layer ***Materials:*** • The soil type would be selected from available borrow sources that can satisfy water balance and revegetation performance standards. • Soil selection criteria would include soil hydraulic properties and water storage capacity. • Soil materials would have adequate fertility and nominal phytotoxicity (e.g., low salinity and sodicity) for establishing and sustaining a diverse plant community. ***Thickness*****:** The thickness would be based on evaluations of • Current and possible future climates. • Water storage capacity. • Plant evapotranspiration rates and seasonality. • Plant root ecology, depths, and distribution. • Burrowing animal ecology, habitat conditions, and burrow characteristics. • Frost protection requirements for the underlying compacted soil layer.
Soil/Rock Admixture • Rock mixed into the soil/rock admixture on the top slope and side slope would satisfy NRC criteria for size and durability. • The hydraulic properties of interstitial soil would match the underlying water storage soil layer. • The interstitial soil would be live topsoil with favorable fertility, microbiology, propagules, and nominal phytotoxicity. • The admixture layer would be placed to act as a mulch, to reduce evaporation, and to hold plant-available water near the surface. • No credit would be taken for erosion protection provided by plants.
Vegetation • Revegetation goals would include rapid establishment; ability to adapt to soil/rock admixture habitat; ample and spatially uniform evapotranspiration rates; sustainability; resilience to disturbance (e.g., fire, drought, disease); and consistency with future land use. • The revegetation design would be based on current and future climate, potential natural vegetation, and borrow soil hydrology, chemistry, fertility, and biology.

B3.0 Construction

After all the contaminated materials from the site and vicinity properties were relocated to the top of the tailings pile and the consolidation process was under way, the final side slope would be graded and recontoured to a 3:1 horizontal:vertical slope. The top would be contoured to slope (less than 0.5 percent) outward toward the side slopes.

B3.1 Side Slope Construction

Side slope cover construction would start with placement of the compacted soil layer that would form the radon barrier. Clayey soil borrow material would be transported to the site by truck or tandem trailers, dumped at the base of the pile, and pushed up the recontoured slopes with a dozer. A similar procedure would be used to place the capillary break layer’s sand/gravels and the water storage soil layer’s fine-grained soils. The soil/rock admixture would be the final layer placed on the side slopes. For this layer, erosion control limestone riprap would be placed to the required thickness, and interstitial voids would be loosely filled with soils.

B3.2 Top Slope Construction

Top slope cover construction would begin when pore pressure readings indicated that the slimes were 90 percent consolidated. Construction would follow the same order as side slope construction described above. A surface layer consisting of a soil/rock admixture 0.5 foot thick would protect the underlying layers from the effects of erosion. This layer would be constructed by creating a 20 percent–80 percent mixture of rock-soil by volume. Rock would be sized to resist wind and water erosion. Soil would promote plant growth, which is crucial for a successful water-balance cover. The soil/rock admixture would be planted with vegetation for water extraction and infiltration control.

B3.3 Construction-Related Features and Objectives

B3.3.1 Vegetation

A diverse mixture of native plants on the cover would maximize water removal by evapotranspiration (Link et al. 1994) and remain more resilient to major disturbances and fluctuations in the environment. Revegetation efforts would attempt to emulate the structure, diversity, dynamics, and function of native plant communities occurring on deep, fine-grained soils in the area. The native vegetation at Moab is a mosaic of species that structurally and functionally change in response to disturbances and climatic fluctuations (Tausch et al. 1993). Similarly, biological diversity in the cover vegetation would be important to plant community stability and resilience, given variable and unpredictable changes in the environment resulting from pest outbreaks, disturbances (overgrazing, fire, etc.), and climatic fluctuations.

B3.3.2 Erosion Control

A primary erosion control issue for vegetated cover designs is whether vegetation alone adequately limits soil loss or if gravel and rock admixtures are necessary to armor the soil when vegetation is sparse or less dependable. Vegetation and organic litter disperse raindrop energy, slow flow velocity, bind soil particles, filter sediment from runoff, increase infiltration, and reduce surface wind velocity (Wischmeier and Smith 1978). However, vegetation alone may be inadequate, particularly in the first years after construction. To achieve the benefits of a combination of rock for erosion protection and plants for evapotranspiration, DOE's assumed cover design includes mixing rock into the upper soil layer. Erosion studies (Finely et al. 1985; Ligotke 1994) and soil-water balance studies (Waugh et al. 1994; Sackschewsky et al. 1995) suggest that rock mixed into the cover topsoil would control both water and wind erosion and act as a mulch to enhance plant establishment and growth. As wind and water passed over the surface, some winnowing of fines from the admixture would be expected, leaving a vegetated erosion-resistant pavement.

B3.3.3 Frost Protection

The 3.5-foot-thick water storage soil layer would provide more than adequate depth to isolate the capillary break layer and compacted soil layer from frost damage. The estimated maximum frost depth in the topsoil layer would be less than 3 feet given historical climatic conditions. A modified Berggren approach (DOE 1989; Smith and Rager 2002) would be used to calculate the maximum frost depth for a range of possible future climate changes.

B3.3.4 Biointrusion Control

The current assumed design includes measures to limit biological intrusion by plant roots and burrowing vertebrates. By retaining soil water close to the surface, the water storage soil layer and capillary break layer would create a habitat for relatively shallow-rooted plant species; root growth would generally be limited to regions within the soil where extractable water was available. The thickness of the water storage soil layer is expected to exceed the burrow depths of most vertebrates in the Moab area. If deeper burrowing were likely for either current conditions or for a future climate scenario, a layer of rock would be mixed into the water storage soil layer as an added deterrent. Loosely aggregated gravel and rock have been shown to deter burrowing mammals (Cline et al. 1980; Hakonson 1986; Bowerman and Redente 1998). A rock biointrusion layer would be placed immediately above the capillary break layer.

B4.0 White Mesa Mill Site Disposal Cell Cover

The White Mesa Mill site cover design consists of an erosion-protection layer consisting of 3-inch-diameter riprap, a 2-foot frost barrier, a 12-inch compacted clay radon barrier, and 3 feet of platform fill. Side slopes would consist of random fill covered by riprap. The cover design is consistent with other Title II cell designs approved by NRC. DOE has determined that at the conceptual stage, the design appears to be reasonable.

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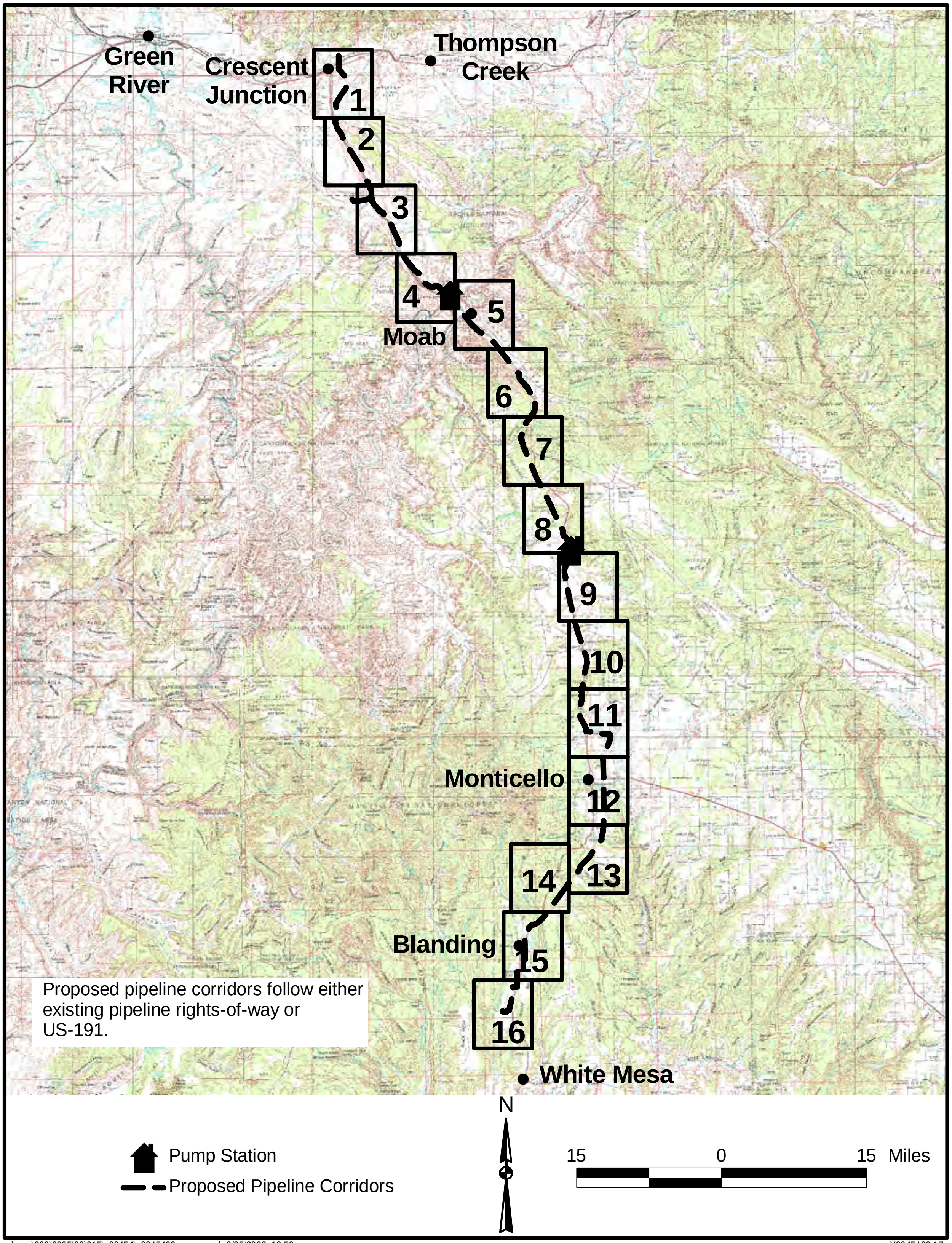
Appendix C

Slurry Pipeline Route Maps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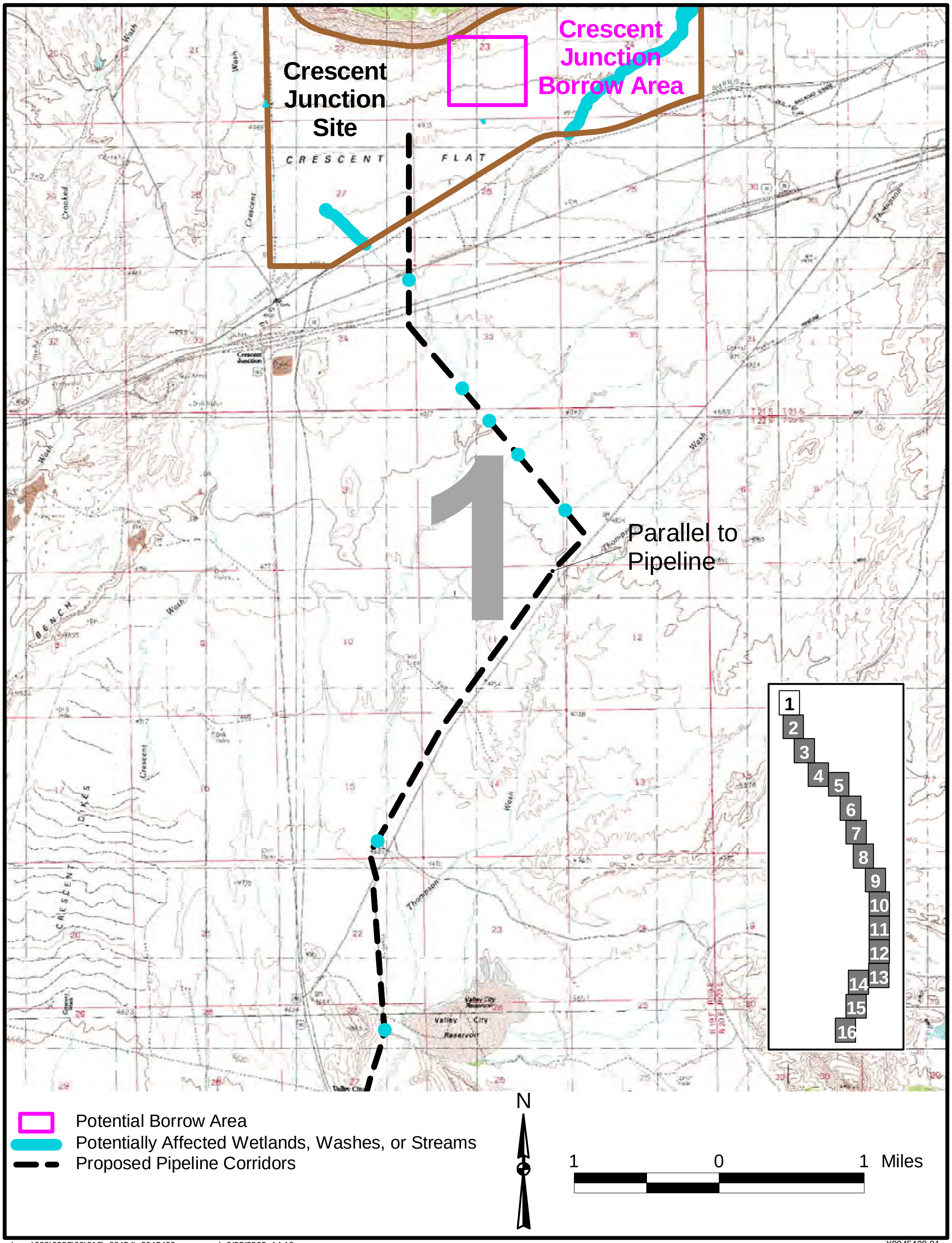

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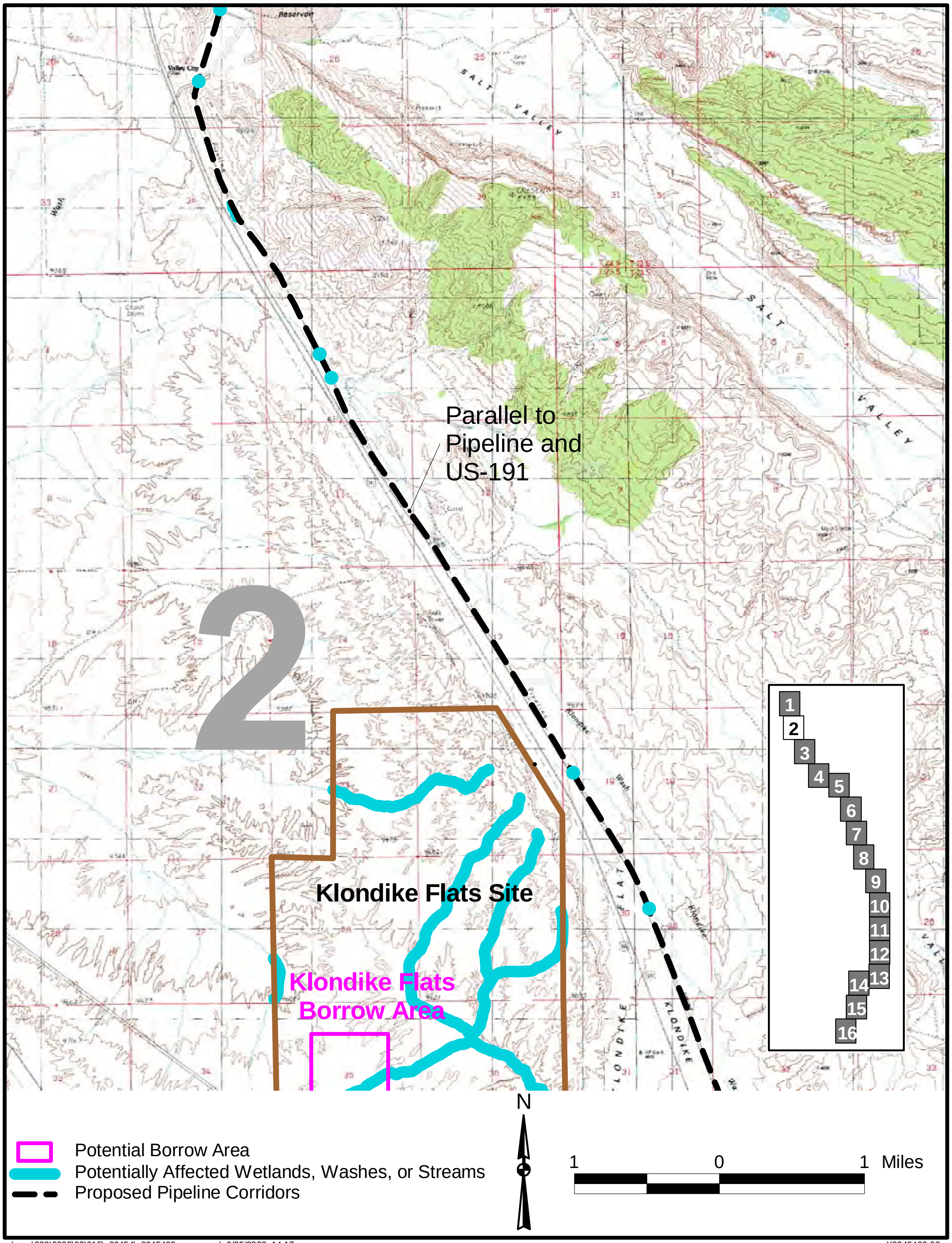
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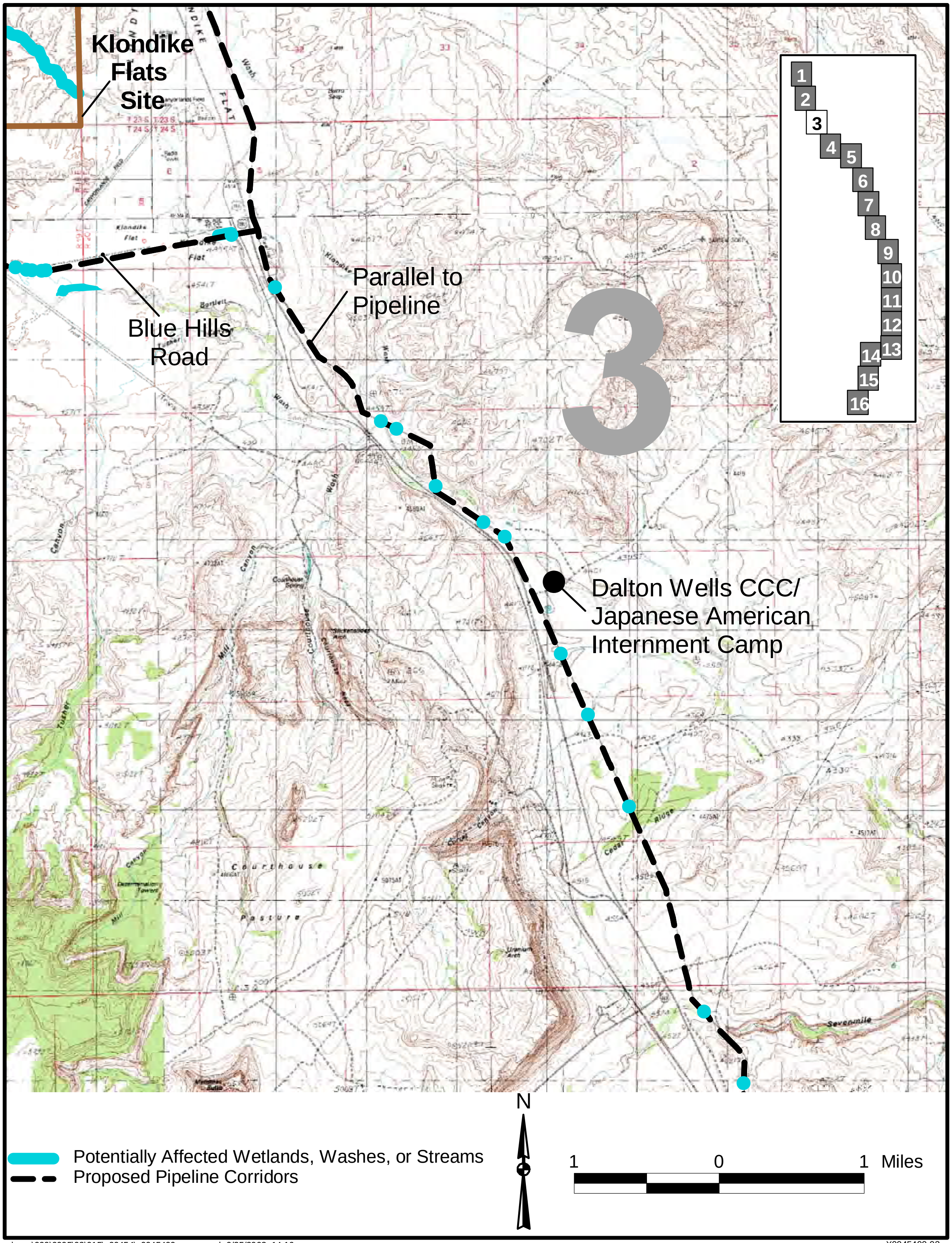

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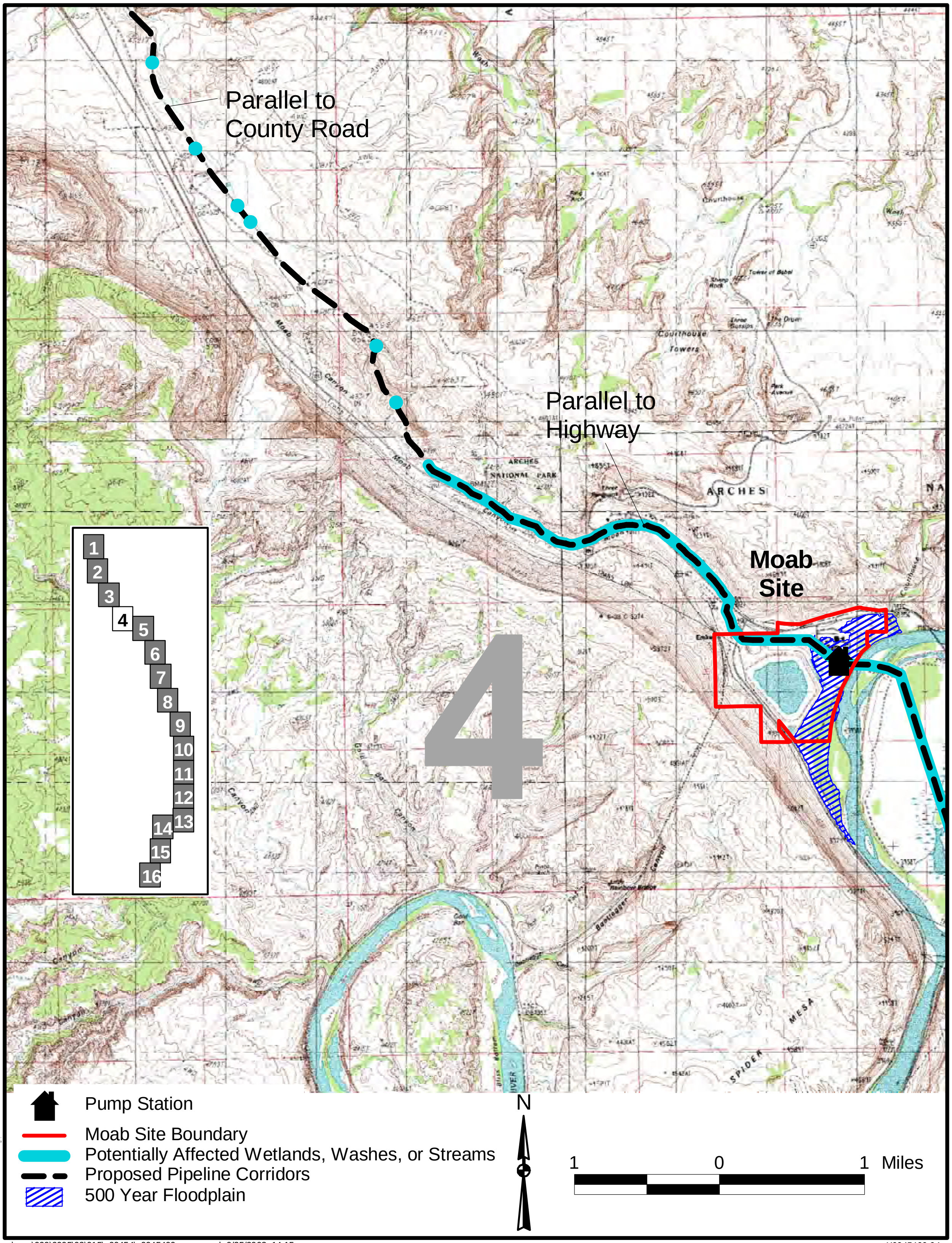

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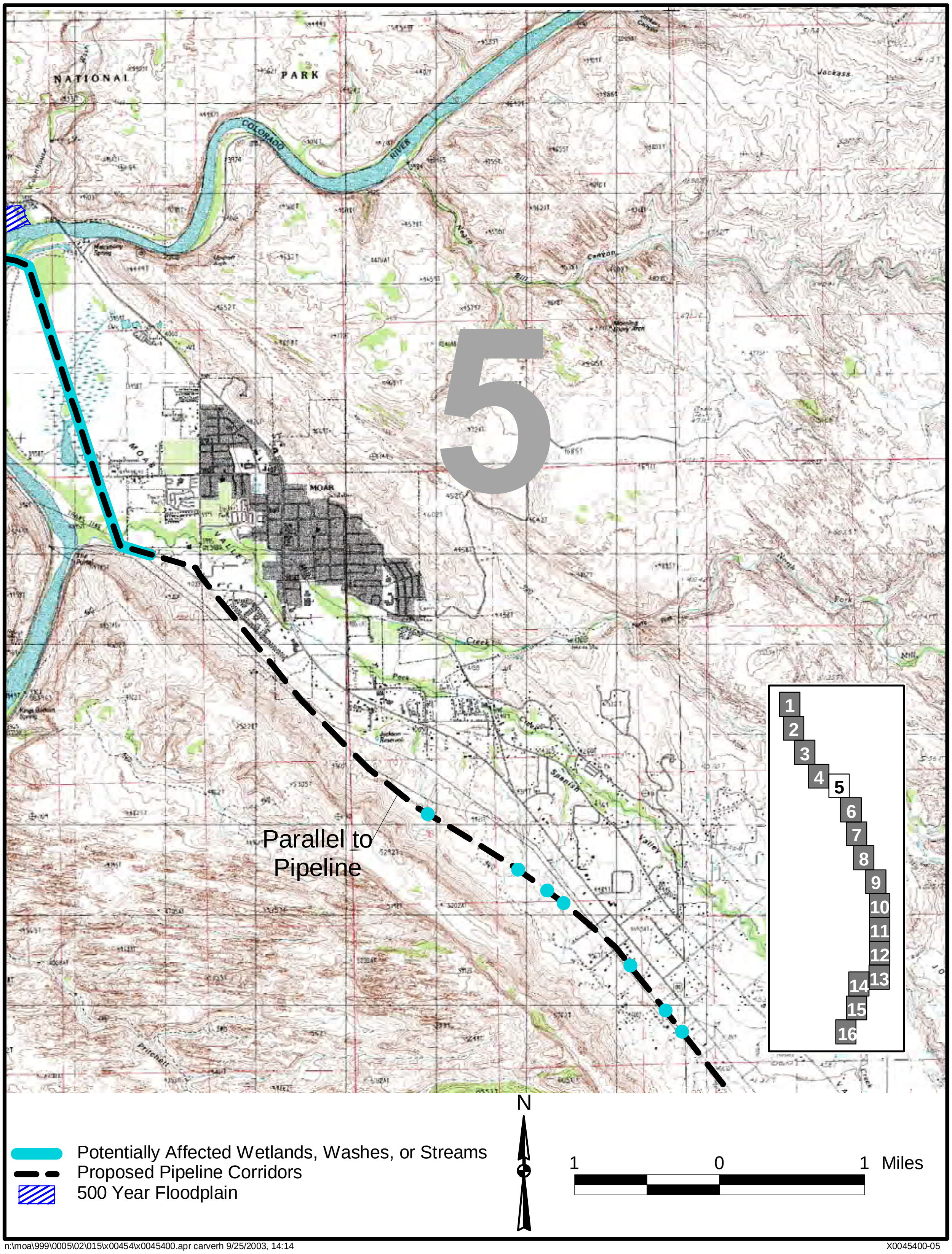
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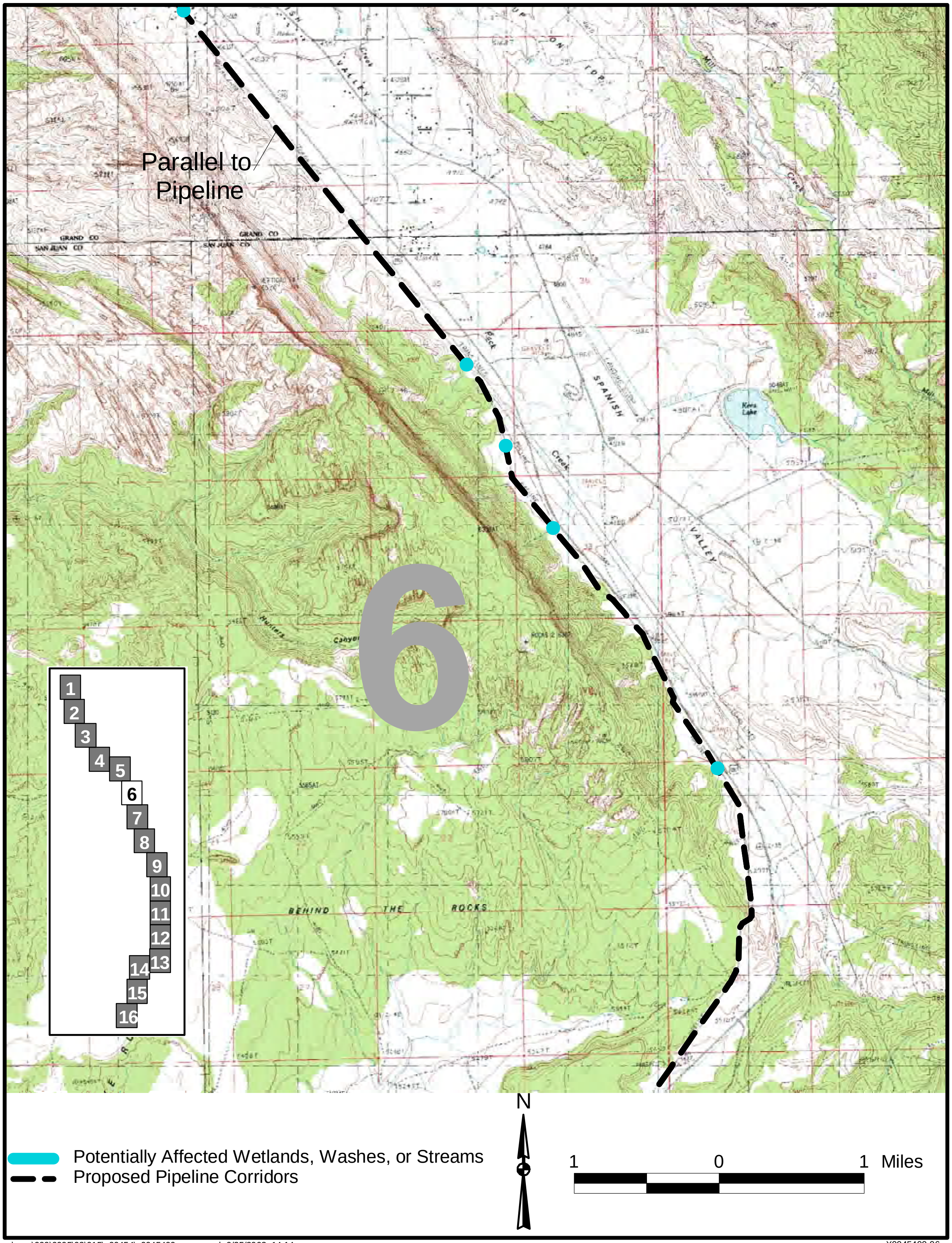

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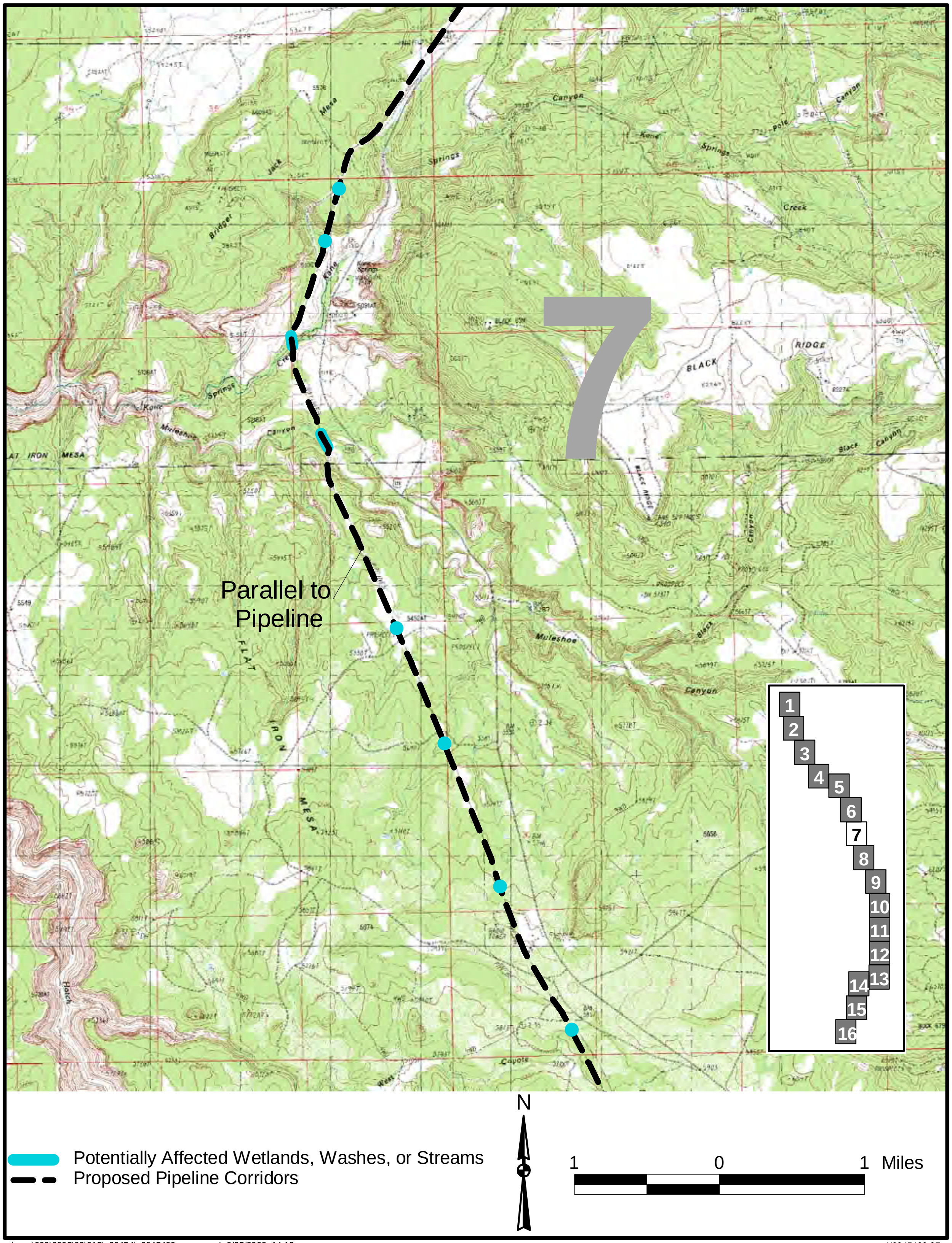

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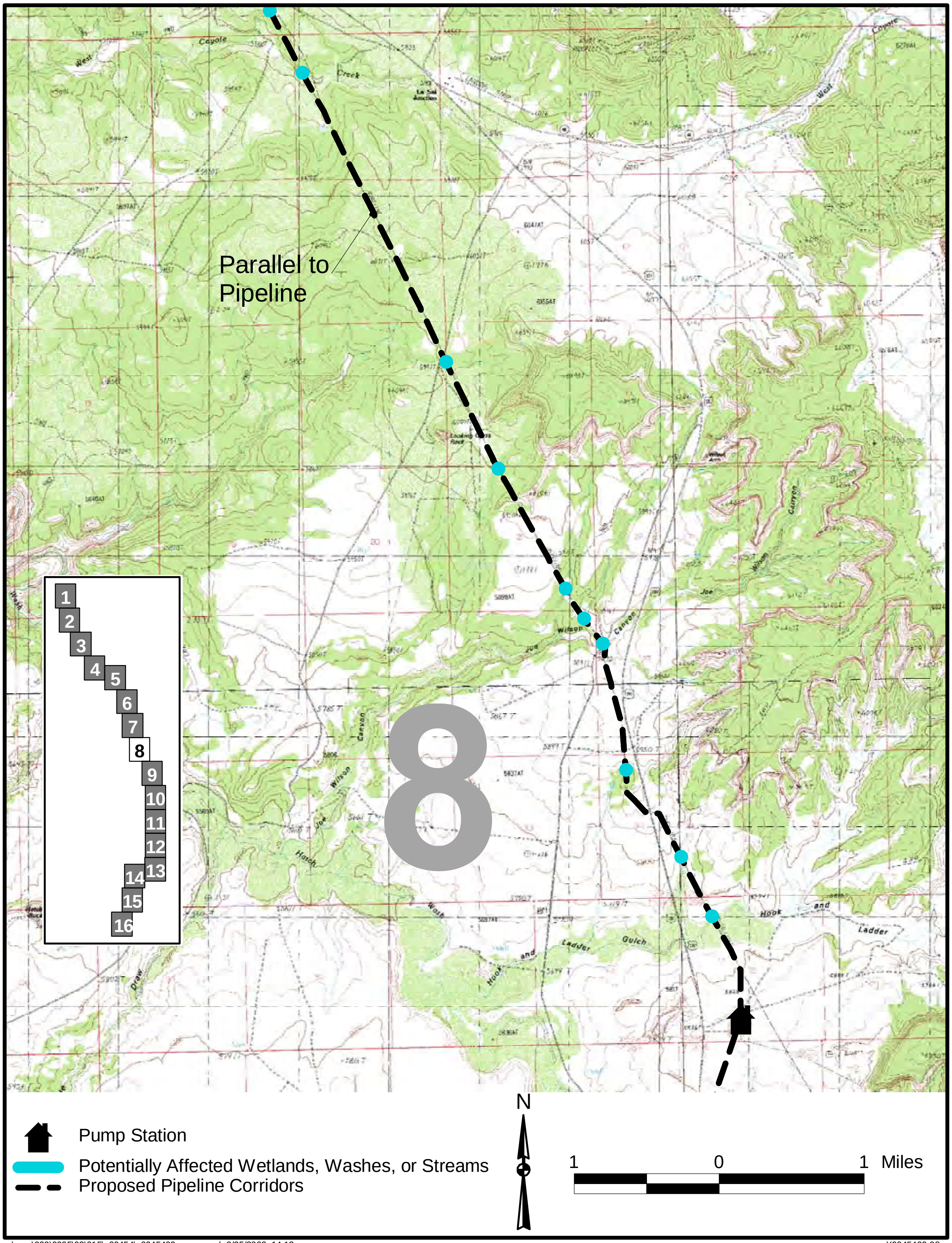

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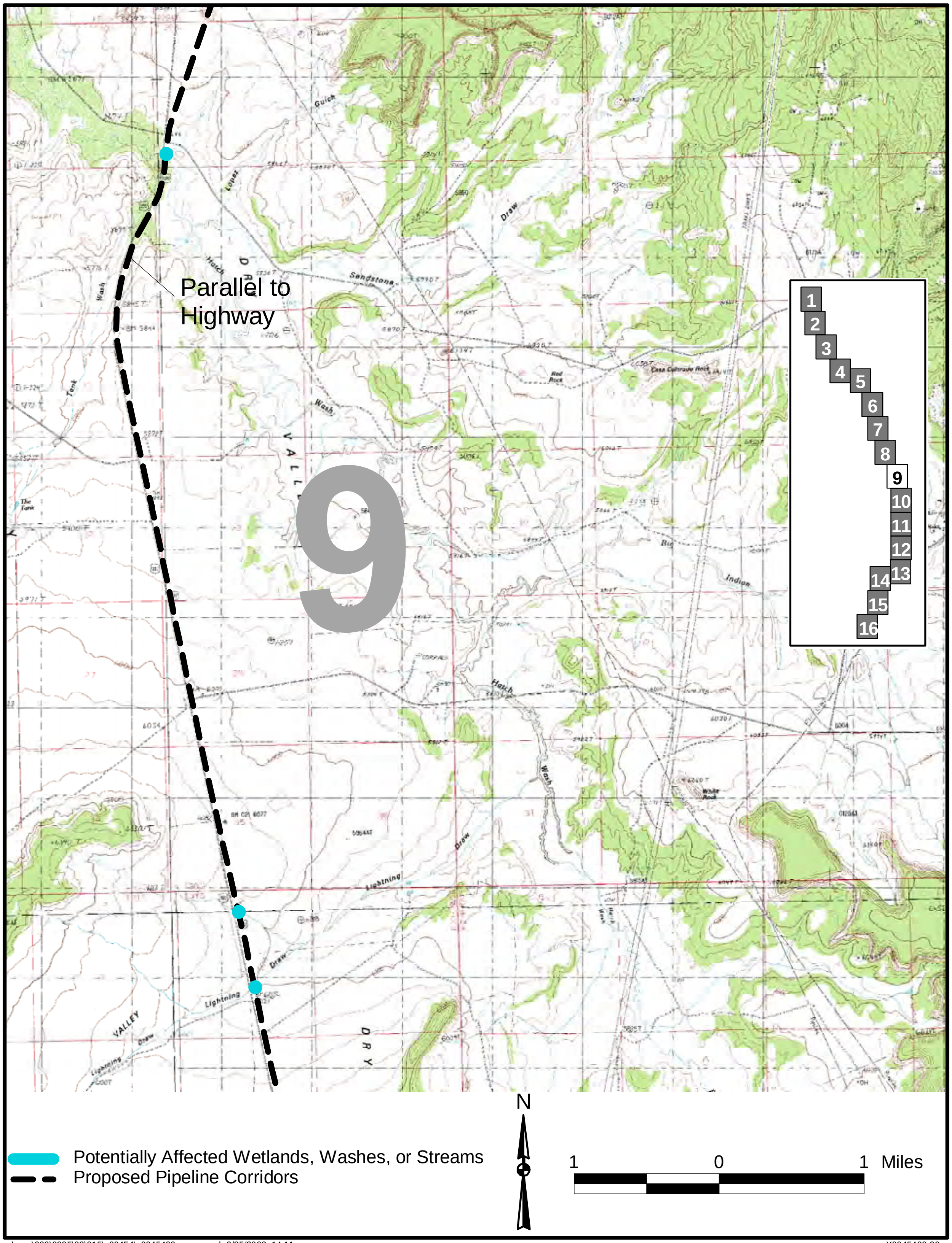

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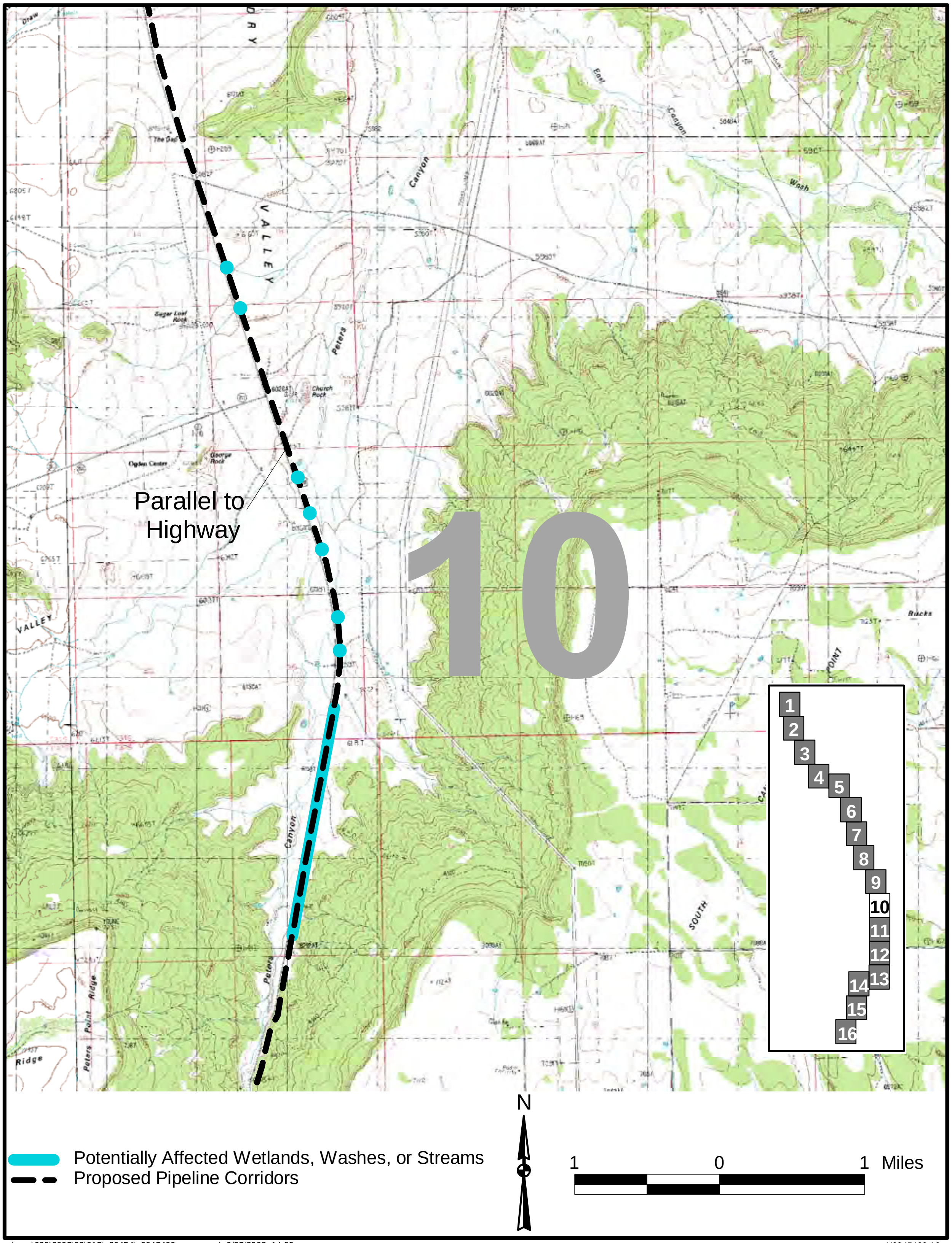

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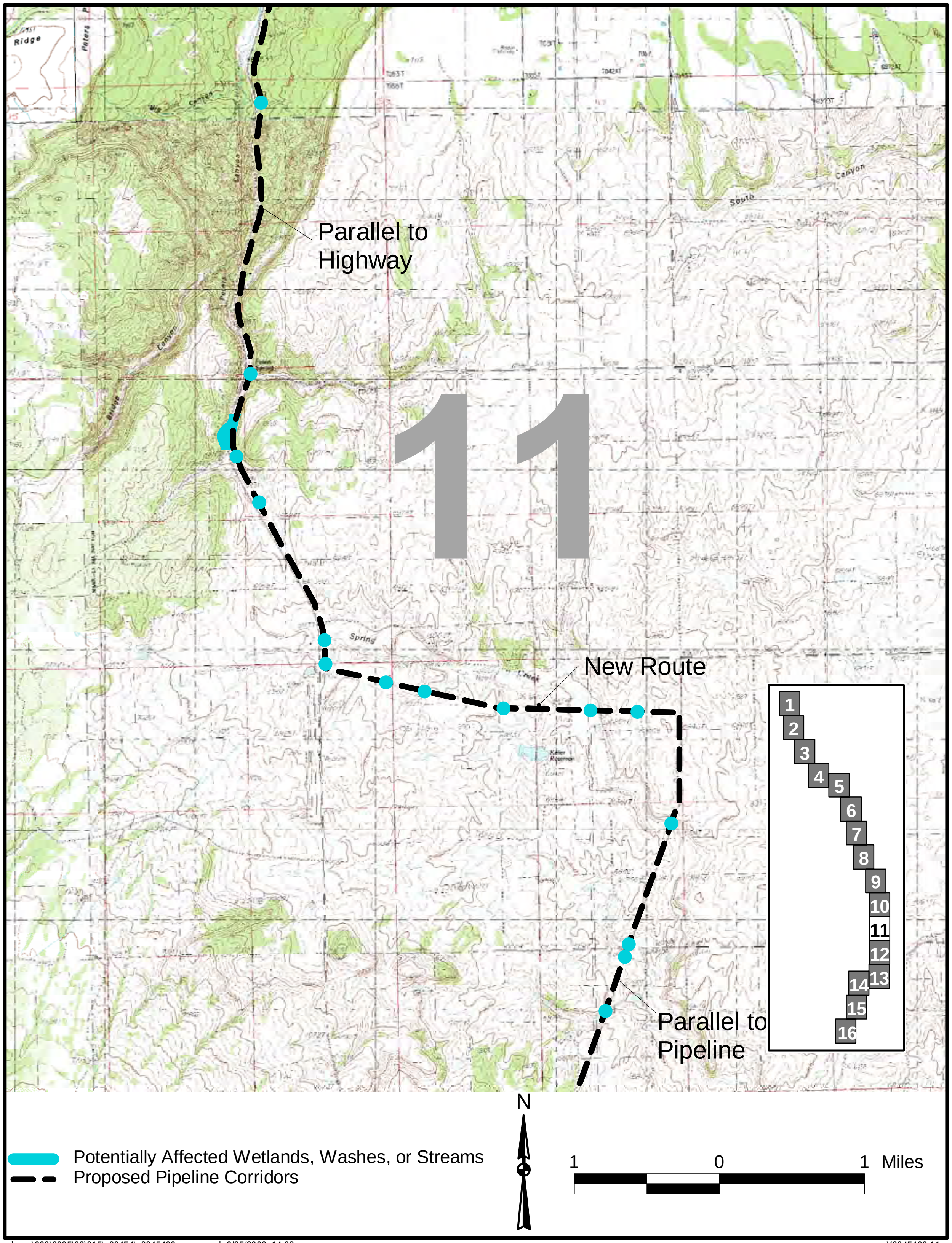
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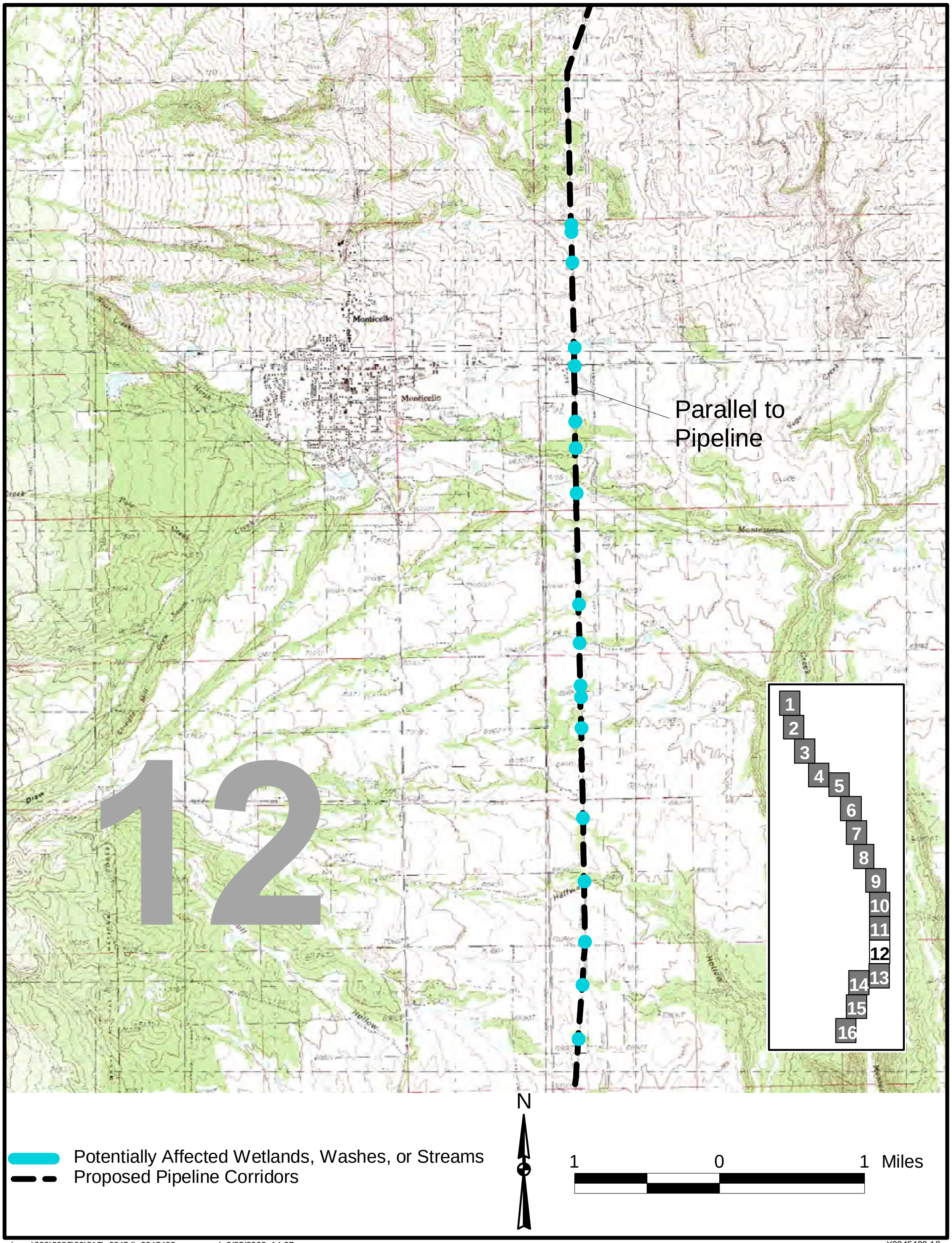

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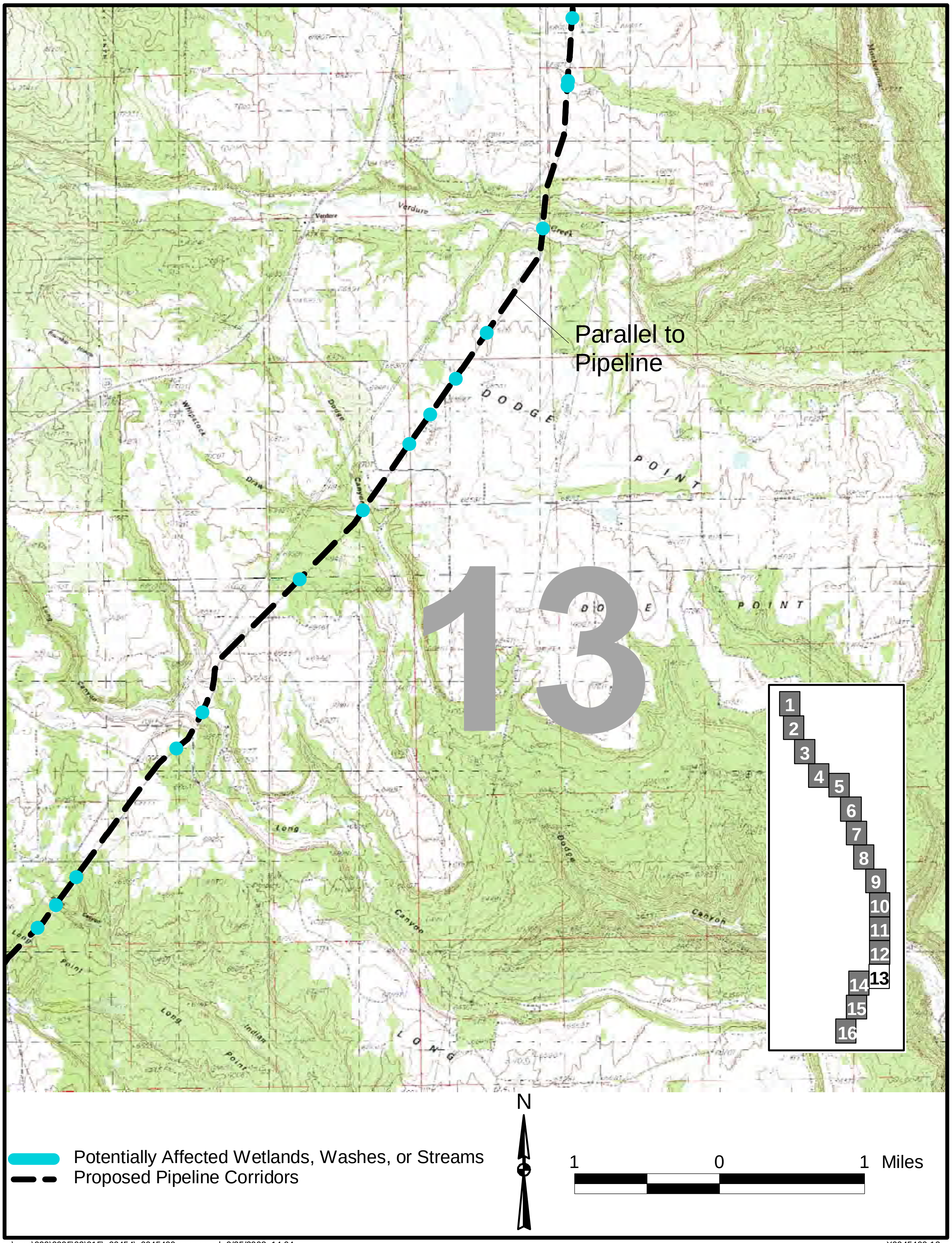

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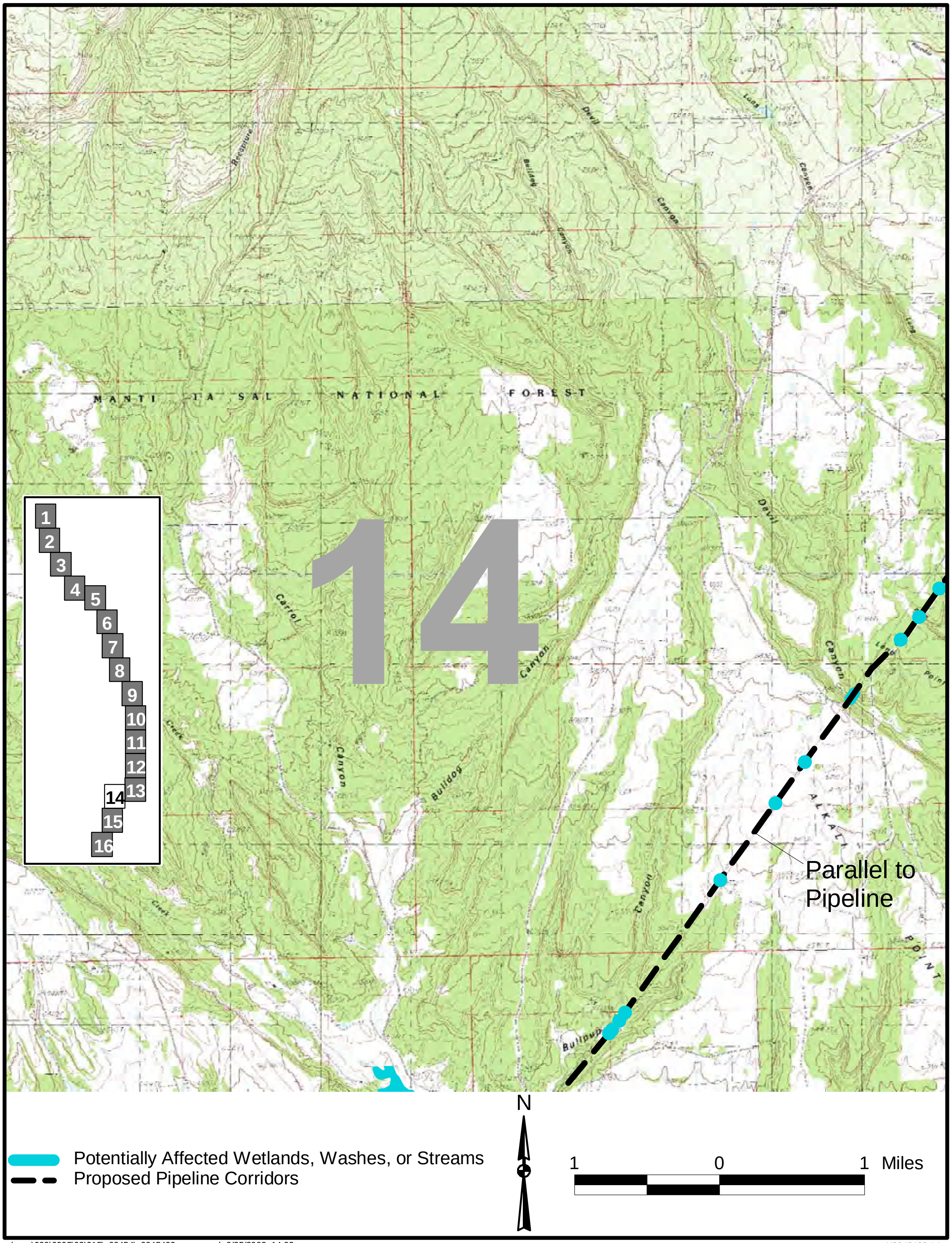

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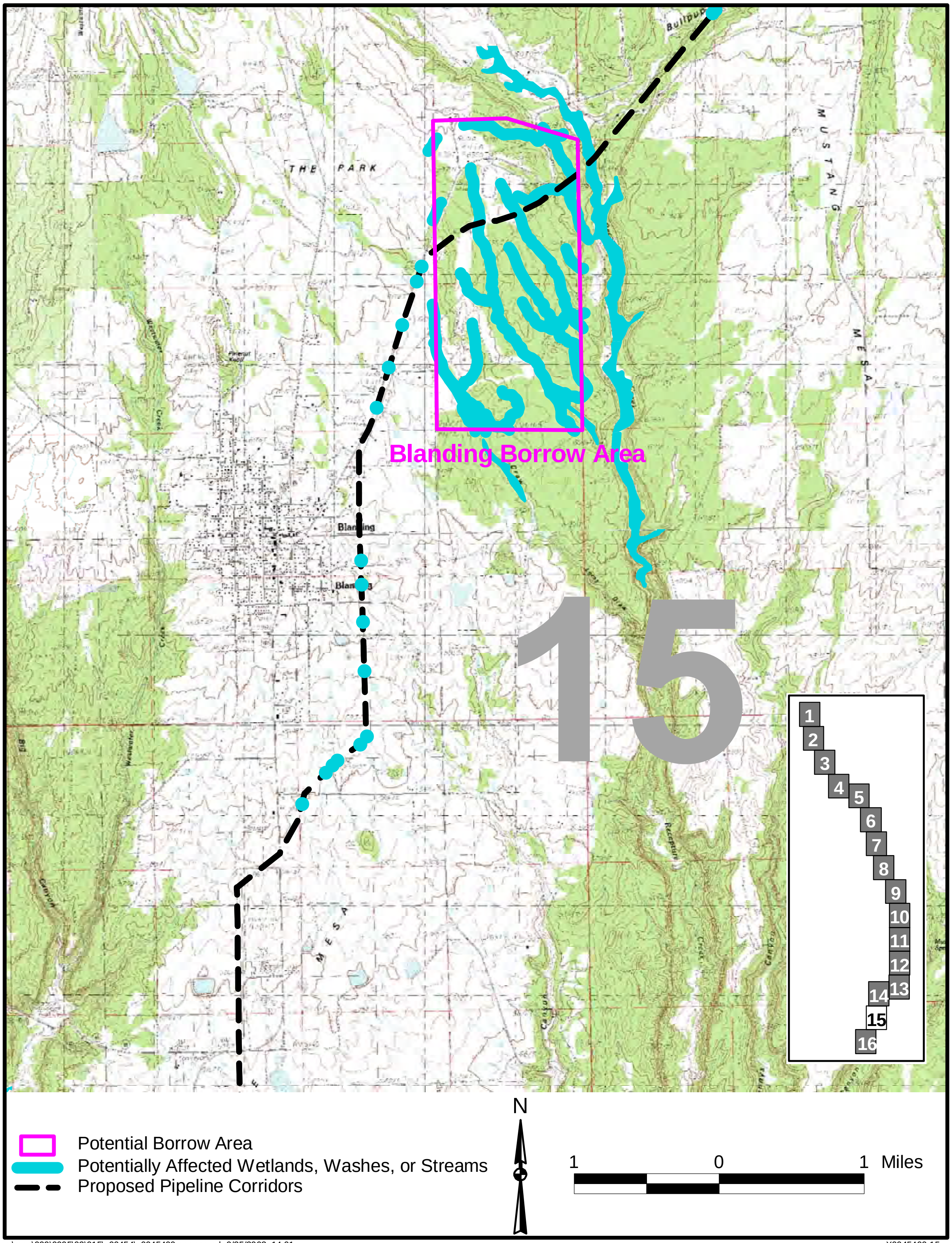

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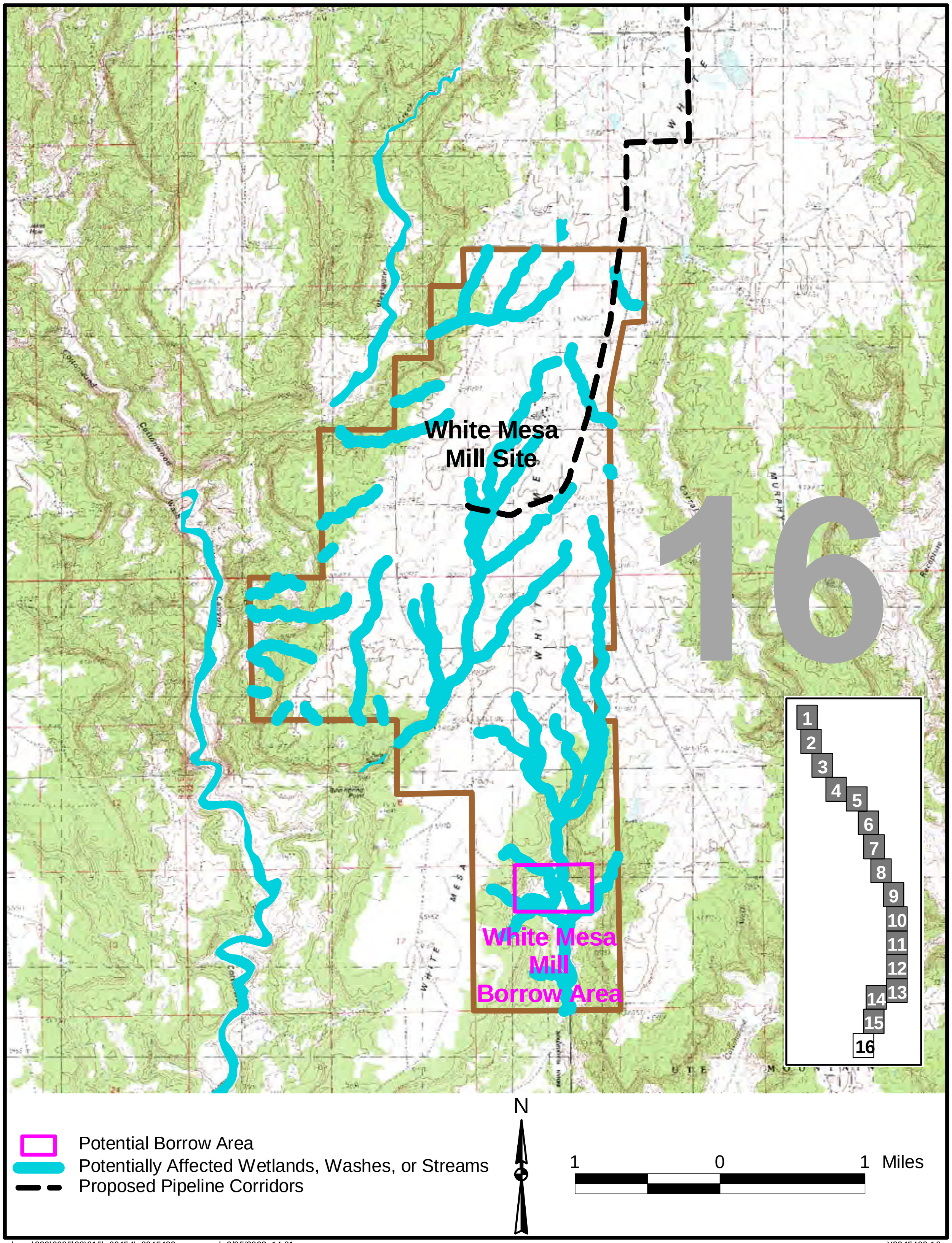
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Appendix D

Human Health

D1.0 Introduction

This appendix is organized into the following sections:

D2.0 Radiation and Human Health—This section provides a general overview of how radiation affects the human body.

D3.0 Future Potential Risks—This section presents the assumptions and calculation methods used to estimate risks from possible future uses of the Moab site. Most of this information is presented in the form of calculation spreadsheets that include the assumptions. A complete set of calculation spreadsheets is presented for the No Action alternative; only the different exposure point concentrations and results are presented for the off-site alternatives and the on-site alternative.

D4.0 Construction Risks—This section provides information on potential risks from construction accidents and the approach used to estimate radiological risks to workers and members of the public during construction activities.

D2.0 Radiation and Human Health

Radiation is the emission and propagation of energy through space or through a material in the form of waves or bundles of energy called photons or in the form of high-energy subatomic particles. Radiation generally results from atomic or subatomic processes that occur naturally. The most common kind of radiation is electromagnetic radiation, which is transmitted as photons. Electromagnetic radiation is emitted over a range of wavelengths and energies. We are most commonly aware of visible light, which is part of the spectrum of electromagnetic radiation. Radiation of longer wavelengths and lower energy includes infrared radiation, which heats material when the material and the radiation interact, and radio waves. Electromagnetic radiation of shorter wavelengths and higher energy (which are more penetrating) includes ultraviolet radiation (which causes sunburn), X-rays, and gamma radiation.

Ionizing radiation is radiation that has sufficient energy to displace electrons from atoms or molecules to create ions. It can be electromagnetic (for example, X-rays or gamma radiation) or subatomic particles (for example, alpha and beta radiation). The ions have the ability to interact with other atoms or molecules; in biological systems, this interaction can cause damage in the tissue or organism.

Radioactivity is the property or characteristic of an unstable atom to undergo spontaneous transformation (to disintegrate or decay) with the emission of energy as radiation. Usually the emitted radiation is ionizing radiation. The result of the process, called radioactive decay, is the transformation of an unstable atom (a radionuclide) into a different atom, accompanied by the release of energy (as radiation) as the atom reaches a more stable, lower-energy configuration. Radioactive decay produces three main types of ionizing radiation—alpha particles, beta particles, and gamma or X-rays—but our senses cannot detect them. These types of ionizing radiation can have different characteristics and levels of energy and, thus, varying abilities to penetrate and interact with atoms in the human body. Because each type has different characteristics, each requires different amounts of material to stop (shield) the radiation. Alpha particles are the least penetrating and can be stopped by a thin layer of material such as a single sheet of paper. However, if radioactive atoms (called radionuclides) emit alpha particles in the body when they decay, there is a concentrated deposition of energy near the point where the radioactive decay occurs. Shielding for beta particles, depending on their energies, may require thicker layers of material such as several reams of paper or several inches of wood or water. Shielding from gamma rays, which are highly penetrating, requires very thick material such as several inches to several feet of heavy material (for example, concrete or lead). Deposition of the energy by gamma rays is dispersed across the body in contrast to the local energy deposition by an alpha or a beta particle. In fact, some gamma radiation will pass through the body without interacting with it.

Radiation that originates outside of an individual's body is called external or direct radiation. Such radiation can come from an X-ray machine or from radioactive materials (materials or substances that contain radionuclides), such as radioactive waste or radionuclides in soil. Internal radiation originates inside a person's body following intake of radioactive material or radionuclides through ingestion or inhalation. Once in the body, the fate of a radioactive material is determined by its chemical behavior and how it is metabolized. If the material is soluble, it might be dissolved in bodily fluids and transported to and deposited in various body organs; if it is insoluble, it might move rapidly through the gastrointestinal tract or be deposited in the lungs.

Exposure to ionizing radiation is expressed in terms of absorbed dose, which is the amount of energy imparted to matter per unit mass. Often simply called dose, it is a fundamental concept in measuring and quantifying the effects of exposure to radiation. The unit of absorbed dose is the rad. The different types of radiation mentioned above have different effects in damaging the cells of biological systems. Dose equivalent is a concept that considers the absorbed dose and the relative effectiveness of the type of ionizing radiation in damaging biological systems, using a radiation-specific quality factor. The unit of dose equivalent is the rem. In quantifying the effects of radiation on humans, other concepts are also used. The concept of effective dose equivalent is used to relate absorbed dose in a single part or limited volume of the body to an equivalent risk of effect on the whole body. It involves estimating the susceptibility of the different tissue in the body to radiation to produce a tissue-specific weighting factor. The weighting factor is based on the susceptibility of that tissue to cancer. The sum of the products of each affected tissue's estimated dose equivalent multiplied by its specific weighting factor is the effective dose equivalent. The potential effects from a one-time ingestion or inhalation of radioactive material are calculated over a period of 50 years to account for radionuclides that have long half-lives and long residence time in the body. The result is called the committed effective dose equivalent. The unit of effective dose equivalent is also the rem. Total effective dose equivalent is the sum of the committed effective dose equivalent from radionuclides in the body plus the dose equivalent from radiation sources external to the body (also in rem). All estimates of dose presented in this environmental impact statement (EIS), unless specifically noted as something else, are total effective dose equivalents, which are quantified in terms of rems or millirems (mrem), which is one one-thousandth of a rem.

More detailed information on the concepts of radiation dose and dose equivalent are presented in publications of the National Council on Radiation Protection and Measurements (NCRP) (1993) and the International Commission on Radiological Protection (ICRP) (1991).

The factors used to convert estimates of radionuclide intake (by inhalation or ingestion) to dose are called dose conversion factors (DCFs). The ICRP and federal agencies such as the U.S. Environmental Protection Agency (EPA) publish these factors (Eckerman and Ryman 1993; Eckerman et al. 1988). They are based on original recommendations of the ICRP (1977).

The radiation dose to an individual or to a group of people can be expressed as the total dose received or as a dose rate, which is dose per unit time (usually an hour or a year). Collective dose is the total dose to an exposed population. Person-rem is the unit of collective dose. Collective dose is calculated by summing the individual dose to each member of a population. For example, if 100 workers each received 0.1 rem, the collective dose would be 10 person-rem (100 × 0.1 rem).

Exposures to radiation or radionuclides are often characterized as being acute or chronic. Acute exposures occur over a short period of time, typically 24 hours or less. Chronic exposures occur over longer periods of time (months to years); they are usually assumed to be continuous over a period, even though the dose rate might vary. For a given dose of radiation, chronic radiation exposure is usually less harmful than acute exposure because the dose rate (dose per unit time, such as rem per hour) is lower, providing more opportunity for the body to repair damaged cells.

On average, members of the public nationwide are exposed to approximately 300 mrem per year from natural sources (NCRP 1987). Natural sources that contribute the most to the public collective effective dose equivalent are radon-222 and its radioactive decay products in outside air and in air in homes, buildings, and other enclosed spaces, which contribute about 200 mrem per year. Additional natural sources include radioactive material in the earth (primarily the uranium and thorium decay series and potassium-40), radioactive material in our bodies (primarily potassium-40), and cosmic rays from space filtered through the atmosphere. With respect to exposures resulting from human activities, the combined doses from weapons testing fallout, consumer and industrial products, and air travel (cosmic radiation) account for the remainder (approximately 3 percent) of the total annual dose. Nuclear fuel cycle facilities contribute less than 0.1 percent (0.05 mrem per year) of the total dose.

Cancer is the principal potential risk to human health from exposure to low or chronic levels of radiation. This EIS expresses radiological health impacts as the incremental changes in the number of expected fatal cancers (latent cancer fatalities) for populations and as the incremental increases in lifetime probabilities of contracting a fatal cancer for an individual. The estimates are based on the dose received and on dose-to-health effect conversion factors recommended by the Interagency Steering Committee on Radiation Standards (DOE 2002). The committee estimated that, for the general population, a collective dose of 1 person-rem would yield 6×10^{-4} excess latent cancer fatality. For radiation workers, a collective dose of 1 person-rem would yield an estimated 5×10^{-4} excess latent cancer fatality. The higher risk factor for the general population is primarily due to the inclusion of children in the population group, while the radiation worker population includes only people older than 18 (see Table D−1).

For radon-222 and its short-lived radioactive progeny polonium-218, lead-214, bismuth-214, and polonium-214, the Working Level (WL) is the common unit for expressing exposure rates.

Table D−1. Risk of Latent Cancer Fatalities and Other Health Effects from Exposure to Radiation[a]

Population	Latent Cancer Fatality (per rem)	Nonfatal Cancer (per rem)	Genetic Effects (per rem)	Total Detriment (per rem)
Workers	4.0×10^{-4}	8.0×10^{-5}	8.0×10^{-5}	5.6×10^{-4}
General Population	5.0×10^{-4}	1.0×10^{-4}	1.3×10^{-4}	7.3×10^{-4}

Source: ICRP 1991. The latent cancer fatality, nonfatal cancer, and genetic risks for workers and the public from ICRP (1991) have not been revised to include the latent cancer fatality risks from DOE (2002).
[a]Epidemiological studies of human radiation exposure are not sufficiently sensitive to determine the actual level of risk. There is scientific uncertainty about cancer risk in the low-dose region, and the dose-incidence curve at low doses still remains highly uncertain. The data do not suffice to rule out the possible existence of a threshold (ICRP 1991).

Numerically, the WL is any combination of the short-lived radioactive progeny of radon-222 in 1 liter of air that will result in the emission of 1.3×10^5 million electron volts of potential alpha energy. When radon-222 is in complete equilibrium with its short-lived radioactive progeny polonium-218, lead-214, bismuth-214, and polonium-214, one WL equals 100 picocuries per liter (pCi/L) of radon-222. Differences in the activity concentrations between radon-222 and its short-lived radioactive progeny are considered using an equilibrium factor; the WL considers this factor. The advantage of the WL concept is that different equilibrium levels and different concentrations of radon progeny can be expressed and compared using a common unit.

The exposure of workers and the public to radon-222 and its short-lived radioactive progeny polonium-218, lead-214, bismuth-214, and polonium-214 are expressed in units of Working Level Months (WLMs), which is an exposure rate of 1 WL for 170 hours. WLMs are converted to units of effective dose equivalent using a conversion factor of 400 mrem per WLM for the public or 500 mrem per WLM for workers (ICRP 1994). WLMs are converted to the risk of a latent cancer fatality using a conversion factor of 5.38×10^{-4} latent cancer fatalities per WLM (EPA 2003).

Other health effects such as nonfatal cancers and genetic effects can occur as a result of chronic exposure to radiation. Inclusion of the incidence of nonfatal cancers and severe genetic effects from radiation exposure increases the total detriment by 40 to 50 percent, compared to the change for latent cancer fatalities (ICRP 1991). As is the general practice for any U.S. Department of Energy (DOE) EIS, estimates of the total change have not been included in this EIS.

Exposures to high levels of radiation at high dose rates over a short period (less than 24 hours) can result in acute radiation effects. Minor changes in blood characteristics might be noted at doses in the range of 25 to 50 rad. The external symptoms of radiation sickness begin to appear following acute exposures of about 50 to 100 rad and can include anorexia, nausea, and vomiting. More severe symptoms occur at higher doses and can include death at doses higher than 200 to 300 rad of total body irradiation, depending on the level of medical treatment received. Information on the effects of acute exposures on humans was obtained from studies of the survivors of the Hiroshima and Nagasaki bombings and from studies following a multitude of acute accidental exposures. Factors to relate the level of acute exposure to health effects exist but are not applied in this EIS because effective dose equivalents during normal operations and accidents would be well below 50 rem.

The standards for inactive uranium mill tailings sites are in 40 CFR 192, *Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings*, and were issued in 1983. The environmental impact statement issued for these standards was the *Final Environmental Impact Statement for Remedial Action Standards for Inactive Uranium and Thorium Processing Sites (40 CFR 192)* (EPA 1982).

For radon releases from a remediated mill tailings site, these standards specify that the radon release rate may not exceed 20 pCi/m^2-s. Also, the annual average atmospheric radon concentration from radon releases from the site may not exceed 0.5 pCi/L at any location outside the site. These standards must be met for a time period of 200 to 1,000 years. These standards are estimated to reduce the residual risk of cancer to 1 in 1,000 (EPA 1982).

For vicinity properties, these standards specify a radon decay product concentration objective of 0.02 WL (including background), with an upper bound of 0.03 WL (including background), and an external gamma exposure rate of 20 microroentgens per hour above background. The estimated residual risk of cancer for this level of radon and external gamma exposure is 1.3 in 100 (EPA 1982).

These standards also specify radium-226 concentration limits of 5 picocuries per gram (pCi/g) above background in surface soil (0–15 cm) and 15 pCi/g above background for subsurface soil (more than 15 cm below the surface). The residual risk of cancer for this level of radium-226 contamination is 2 in 100 (EPA 1982). This residual risk does not include background concentrations of radium-226 in soil, which typically range from 1 to 2 pCi/g in the Moab area.

D3.0 Future Potential Risks

This assessment of future potential risks generally follows the format recommended by EPA (1989); additional narrative is provided on the assessment of exposure and toxicity and the characterization of risks.

D3.1 Exposure Assessment

The objectives of the exposure assessment are to identify potential human populations that may be exposed to millsite-related contaminants, to determine the potential pathways through which exposure may occur, and to identify the exposure assumptions that will be used to estimate risks. Exposure is defined as the contact of an organism (i.e., humans for this assessment) with a chemical or physical agent. Information presented in the exposure assessment will be used to estimate pathway-specific chronic daily intakes (CDIs) for the potentially exposed populations. CDIs are then combined with chemical-specific toxicity information to characterize potential risks.

A complete exposure pathway comprises the following four elements:

- A contamination source and mechanism for release;
- Environmental retention of the contamination or transport mechanism to disperse contaminants;
- A point of potential human contact with the contaminated media; and

- A route of exposure (i.e., inhalation, ingestion, dermal absorption) at the point of contact.

An exposure pathway is incomplete when one or more of these elements are missing. No exposure is possible for incomplete pathways as long as the pathways remain incomplete into the future.

D3.1.1 Current Site Conditions

The perimeter of the Moab site is fenced (except adjacent to the Colorado River and "no trespassing" signs have been posted; the main access points have locked gates or chains when representatives from DOE are not present. Nevertheless, the perimeter of the site is not actively patrolled, and unauthorized access by the public has occurred. DOE contract personnel are on the site Mondays through Thursdays, except on holidays.

On-site personnel are conducting maintenance activities and environmental characterization activities. Maintenance activities include dust control using calcium chloride or water spraying, repairing the tailing pile after major precipitation events, constructing and operating interim ground water corrective action measures, and removing legacy chemicals and other process-related material from the site.

The property south of the site boundary, which is bounded by the Colorado River and SR-279, is privately owned. This property is mostly vegetated with tamarisk and has numerous dirt roads; it is frequently used for camping. This property occupies approximately 44 acres.

The other section of private property adjacent to the site is located to the northwest; it is bounded by the Colorado River and US-191. This property covers 10 to 13 acres and has two habitable structures. One structure, which is occupied by the property owners, is located next to the Colorado River approximately 350 feet from the DOE property boundary. The owners are retired; however, the structure is occupied only 6 to 8 months of the year because the owners typically spend the winter months in Arizona. The house is built on a concrete slab. Two other residents currently occupy the second habitable structure. This structure is a trailer set on concrete blocks with skirting. Because of a misunderstanding on property easements, part of this trailer is located on DOE property. No children live on the property. The full-time residents have jobs in Moab and are, therefore, not usually on the property during normal working hours. Both residents bring in potable water from off-site for drinking and cooking. The owners use Colorado River water (piped from a location upstream of the Moab site) for bathing and irrigation water. The water used for bathing is stored in a cistern to settle out particulates, and chorine is added before it is used.

The next closest residents are west of the private property described above, and within one-half mile of the site boundary. A trailer park (Moab Valley RV Park) is located on the east side of the Colorado River near US-191. Water from the Moab municipal water system is used at this location. On the basis of radon and gamma monitoring data, this area does not appear to be significantly affected by site contamination. Less than 1 mile northwest of the site, employees of the National Park Service (NPS) and their families live in NPS-supplied housing near the entrance to Arches National Park. From February to October, approximately 13 people live in this housing; only 4 to 6 people live in this area during the winter season (November to January) (NPS 2003). The drinking water is supplied by the well Arches 1978, which is upgradient of the Moab site and is considered a background well with respect to the Moab site. Other areas near the site are not inhabited and will not likely be inhabited in the near future, either because the

U.S. Government owns most of the nearby land or because the lands are located in a floodplain or wetlands.

The closest population center is the city of Moab, which is approximately 3 miles southeast of the site. According to the U.S. Census Bureau, the population of Moab was 4,779 in 2000 (Governor's Office of Planning and Budget 2001). During the spring and summer months, a large number of tourists visit the area because of the nearby national parks and other recreation and tourist attractions. No other communities are within 25 miles of the site; the nearest large city is Grand Junction, Colorado, about 120 miles to the northeast.

The primary individuals exposed to the contaminants at the Moab site are the nearby residents and recreational users of land adjacent to the site. Recreational users include Moab residents and tourists. The major recreational activities occurring near the site are rafting on the Colorado River and camping on adjacent lands.

D3.1.2 Future Site Conditions

In the future, it is plausible that some future development of the site may occur. A comparison of the census data from 1990 and 2000 showed an increase of more than 20 percent (808 people) (Governor's Office of Planning and Budget, 2001). Because of limited private land in the Moab area, some future residential or commercial development of the Moab site is possible. The site offers nearby access to Moab, river frontage, easy access to US-191, and excellent views. On the basis of these assumptions, the following future scenarios are assumed:

- Residential use—Although this has a low probability of occurrence in the short term, future residential use was assumed as the worst-case scenario. This scenario assumes that a future residence that includes children in the household would be established in the relatively level area northeast of the tailings pile and west of the adjacent private property. Because the water quality is poor and supplemental standards are being applied to the site, it is assumed that contaminated ground water would not be used for domestic purposes. The residents are assumed to have a vegetable garden. The assumption of future residential use is consistent with previous risk assessments done under the Uranium Mill Tailings Remedial Action (UMTRA) Ground Water Project.
- Outside worker—It is becoming more common to use former industrial sites for some type of recreational purpose. Accordingly, it was assumed that this location could be used for a park or a golf course and that an adult maintenance worker, who is typically outdoors, is the primary receptor.

D3.1.3 Summary

In identifying the potentially exposed populations, DOE had considered previous land uses, land ownership, local zoning, and precedents used at other Uranium Mill Tailings Radiation Control Act (UMTRCA) sites. On the basis of this information, the following populations are the most likely to be exposed to the contaminants at the Moab site:

- Future recreational users that may camp adjacent to the site or stop next to the site during rafting trips
- Future residents who may be exposed to contaminated soil

- Future outdoor workers exposed to contaminated ground water used for irrigation (adults only)

Other populations could be exposed to on-site contamination in the future; however, because of limited exposure duration and/or frequency, their exposures would be lower than the populations listed above. Examples include recreational users that trespass on DOE property and other recreational users of land adjacent to the site such as bikers.

D3.1.4 Exposure Assumptions

Pathway-specific exposures (CDIs) are estimated using exposure-point concentrations and exposure assumptions specific to the activities being conducted by the receptor population. Two types of exposure assumptions are used to provide risk managers with a range of potential exposures: reasonable maximum exposure (RME) and central tendency (CT). RME is defined as an exposure well above the average but still within the range of possible values. EPA guidance (EPA 1992) suggests that RME is analogous to "high end" exposure estimates corresponding to an approximate 90th percentile of the population distribution. CT uses exposure assumptions that result in an average or best-estimate exposure to an individual (approximately 50th percentile of possible exposures). While generally considered to be average estimates, CT still tends to provide somewhat conservative exposure estimates. CT provides additional information for risk management decisions by showing a plausible range of risks and by highlighting the sensitivity of the risk estimates to the exposure factors.

As suggested in EPA risk assessment guidance (EPA 1989) and as was commonly done in UMTRA Ground Water Project risk assessments, exposure assumptions based on site-specific data and conditions are used whenever possible to more accurately reflect actual exposures. Because most of the exposure scenarios are associated with the conditions at or adjacent to the Moab site, numerous site-specific exposure assumptions are used. These have been based on professional judgment, and they will be adjusted if more accurate information is obtained from members of the public or other interested individuals. When standard scenarios are evaluated and site-specific data are not appropriate, standard EPA default assumptions for both RME and CT exposures were used. Please note that because no site-specific data were available for the camping and the rafting scenarios, exposure frequency and durations were assumed to be 1. If additional information is available, this should be adjusted, as risks will be proportional.

D3.2 Toxicity Assessment

A toxicity assessment involves assessing the potential for the identified contaminants of concern to cause adverse effects in exposed individuals. The toxicity assessment also seeks to develop a reasonable assessment of the associations between the degree of exposure to a contaminant and the possibility of adverse health effects. A chemical or radionuclide may not cause adverse effects in biological systems unless the agent, or its metabolic by-products, reach critical receptor sites in the body at specific levels and for a period of time sufficient to elicit an effect. Whether or not an adverse response occurs depends on the chemical and physical properties of the chemical or radionuclide, the degree of exposure, and the susceptibility of an individual to the particular effect.

Toxicants are divided into two categories on the basis of their health effects. This division is based on the different mechanisms of action associated with each category. Chemicals posing cancer risks may also produce noncancer effects. These chemicals are assessed in both categories. In the discussion of carcinogenic effects, the assessment will be further divided into nonradionuclides and radionuclides (because of distinct differences in mechanisms).

D3.2.1 Noncancer Effects

Noncancer or systemic effects are assumed to be associated with a level of exposure exceeding some threshold value that can be tolerated by the organism (e.g., a human) without causing an adverse health effect. Noncancer health effects include a variety of toxicological endpoints and may include effects on specific organs or systems, such as the kidney (nephrotoxicants), the liver (hepatotoxicants), the nervous system (neurotoxicants), the lungs (pulmonary toxicants), and the reproductive system. The systemic toxicity of a chemical is assessed through a review of toxic effects noted in long-term animal studies and epidemiological investigations describing observed effects on humans.

A "toxic response" depends on the degree of exposure to a substance. Toxicity endpoints (severity and incidence) are quantitative expressions of the dose-response relationship for a chemical. For noncarcinogens, reference doses (RfDs) are used to quantitatively express toxicological impacts. RfDs are derived from the lowest end of a dose-response relationship for noncancer health effects (also referred to as the no observed adverse effect level [NOAEL]); RfDs are the chemical-specific NOAEL divided by uncertainty factors. EPA (1989) defines the RfD as ". . .an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime." The RfD is generally expressed in units of milligrams per kilogram of body weight per day (mg/kg-day).

D3.2.2 Carcinogenic Effects

D3.2.2.1 Nonradionuclides

Some chemical exposures result in, or are suspected of resulting in, the development of cancer. On the basis of available data, EPA assumes a nonthreshold mechanism for carcinogens (for example, a small number of molecular events can cause changes in a single cell that can eventually lead to cancer). Therefore, EPA conservatively assumes there is essentially no level of exposure to a carcinogenic chemical that does not pose a finite probability, however small, of generating a corresponding carcinogenic response in the exposed organism (i.e., dose-response holds true because the lower or higher the dose, the lower or higher the response).

The dose-response relationship for cancer effects for nonradionuclides is usually expressed as a cancer slope factor (CSF). Generally, the slope factor is a plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. The response predicted is cancer incidence (the number of cases in a defined population at a point in time). The slope factor is usually, but not always, the 95 percent upper confidence limit of the slope of the dose-response curve and is expressed as the inverse of milligrams of chemical per kilogram of body weight per day $(mg/kg\text{-}day)^{-1}$(EPA 1989). EPA also notes that the slope factor could be zero, thus indicating no carcinogenic response from exposure (EPA 1989).

D3.2.2.2 Radionuclides

EPA categorically classifies all radionuclides as human carcinogens, based on their property of emitting ionizing radiation and on the weight of evidence provided by epidemiological studies of radiogenic cancers in humans (EPA 1989, 1995a). Radiation produces damage in biological systems through ionization of molecules. Damage may occur directly, as when a chromosome breaks into smaller pieces after absorption of energy from radiation. Damage may also occur indirectly through ionization of water molecules to produce highly reactive oxygen-free radicals. The free radicals may react with other cellular compounds and cause damage through abnormal oxidation reactions. Chronic exposure to ionizing radiation falls into three categories: (1) carcinogenic effects, (2) mutagenic (genetic damage) effects, and (3) teratogenic effects (embryonic or fetal damage).

In accordance with EPA guidelines, the risk associated with radiation exposure is evaluated using maximum likelihood estimates (MLEs) of CSFs that represent lifetime excess cancer incidence per picocurie of intake for each radionuclide.

The slope factors are the average risk per unit intake or exposure for an individual in a stationary population with vital statistics (mortality rates) typical of the United States. Radionuclide ingestion and inhalation slope factors are not expressed as a function of body weight and time and do not require corrections for gastrointestinal absorption or lung-transfer efficiencies (EPA 1995a)[1].

D3.3 Risk Characterization

D3.3.1 Risk Characterization Methods

Risk characterization methods used in this section are based on the approach used for UMTRA risk assessments, *Human Health Risk Assessment Methodology for the UMTRA Ground Water Project* (DOE 1994), which is based on conventional EPA guidance (EPA 1989). Two overall approaches were used to estimate risk. First, the traditional estimation approach presented in EPA (1989) was used to estimate risks from chemical exposures (see exposure assumptions for the simplified approach used to estimate risks for camper and rafter scenarios) and exposures to radionuclides in ground water. Second, the computer code RESRAD was used to estimate risks from exposure to radon gas, gamma radiation, and inhalation of radioactive particulates. RESRAD was developed at Argonne National Laboratory for DOE to estimate radiation dose and excess cancer risk for chronically exposed individuals (ANL 2001, 2003). It is an established method to estimate risks from these pathways. Included in this appendix are the detailed spreadsheets of the risk characterization calculations.

[1]Although similar to the nonradionuclide approach, this approach differs in three significant ways: (1) the CSF is an MLE estimate, which is analogous to an average (e.g., "the expected value"); in the nonradionuclide evaluation, an upper-bound estimate of the slope factor is used; (2) radionuclide risk is estimated from total intake; nonradionuclide cancer risk is estimated from the average daily intake—normalized to body weight; and (3) radionuclide cancer-risk estimates are for mortality; nonradionuclide cancer-risk estimates are for incidence. Thus, radionuclide and nonradionuclide risk estimates are fundamentally different and should not be added together.

D3.3.1.1 Exposure Estimation

Intakes for Noncarcinogenic Contaminants of Concern

The CDI is the appropriate intake estimator for exposure to noncarcinogenic contaminants of concern at the Moab site because exposures are assumed to be recurrent and long-term (e.g., 30 years in the RME case). According to EPA (1989), the CDI for assessing noncarcinogenic effects is computed as:

$$CDI\ (mg/kg-day) = \frac{(C \times IR \times EF \times ED \times f)}{(BW \times AT)}$$

where

C	=	media concentration,
IR	=	daily intake rate (grams or liters per day),
EF	=	exposure frequency (days per year),
ED	=	exposure duration (years),
f	=	fraction of intake from the contaminated source,
BW	=	body weight (kilograms), and
AT	=	averaging time (365 days per year × ED).

Chronic Intakes for Carcinogenic Contaminants of Concern

Arsenic and cadmium are the only carcinogens identified as contaminants of concern. According to EPA (1989), the CDI for assessing carcinogenic effects is computed as:

$$CDI\ (mg/kg-day) = \frac{(C \times IR \times EF \times ED \times f)}{(BW \times AT)}$$

where

C	=	media concentration,
IR	=	daily intake rate (liters or grams per day),
EF	=	exposure frequency (days per year),
ED	=	exposure duration (years),
f	=	fraction of intake from the contaminated source,
BW	=	body weight (kilograms), and
AT	=	averaging time (days).

This is the same equation used to calculate intakes for noncarcinogenic compounds (presented above) with the exception that intake is averaged over a 70-year lifetime (*AT* = 25,550 days [EPA 1989]) as opposed to a 1-year (365 days) averaging period used to estimate CDIs for assessing noncarcinogenic effects.

Intakes for Radionuclides (soils)

The CDI is not the appropriate intake estimator for exposure to radionuclides at the Moab site. Instead, EPA recommends use of a total radionuclide intake over the exposure period (EPA 1989, Chapter 10). According to EPA (1989), the total intake for assessing the carcinogenic effects of radionuclides is computed as

$$\text{Total intake (pCi)} = C \times IR \times EF \times ED \times f,$$

where

C	=	media concentration,
IR	=	daily intake rate (liters or grams per day),
EF	=	exposure frequency (days per year),
ED	=	exposure duration (years), and
f	=	fraction of intake from the contaminated source.

Unlike the previous intake estimates, exposure to radionuclides is neither normalized to body weight nor averaged over time. Exposure is considered chronic and routine for the consumption of ground water. However, the time-dependent modifications in the discussion of intakes for noncarcinogenic compounds are made to reflect an intermittent exposure that would occur for the recreational exposures.

D3.3.1.2 Risk Characterization

Noncarcinogenic Risks

Hazard quotient (HQ) is the ratio of a single-substance exposure level over a specified time period to an RfD for a substance derived from a similar exposure (EPA 1989).

HQ is computed using the following formula:

$$HQ = CDI/RfD$$

where

CDI = chronic daily intake for noncarcinogens in milligrams per kilograms-day and
RfD = reference dose in milligrams per kilograms-day.

This approach assumes the individual HQs can be summed into a hazard index (HI), as specified by EPA (1989). The HI is computed using the following formula:

$$HI = HQ1 + HQ2 + \ldots + HQn,$$

where

HQ1 through *HQn* are individual *HQs*.

When the HI exceeds 1.0, it is a numerical indicator of the transition between acceptable and unacceptable exposure levels, and there may be concern for potential health effects (EPA 1989).

The assumption that HQs are additive is applied most appropriately to chemicals that induce the same effect by the same mechanism or act on the same target organ at similar levels of exposure. If no individual HQ exceeds 1.0, but the HI exceeds 1.0, the chemicals in the mixture may be segregated by critical organ effect or target organ, and separate indices may be derived for each effect or organ.

Carcinogenic Nonradionuclide Risks

The method of using CSFs to estimate potential cancer risks from nonradionuclides also comes from EPA guidance (EPA 1989). The cancer slope factor equation is

$$\text{Added cancer risk} = CDI_C \times SF$$

where

Added cancer risk is the probability of cancer incidence attributable to exposure,
CDI_C = chronic daily intake for nonradionuclide carcinogens in units of milligrams per kilograms-day, and
SF = cancer dose-response slope factor in units of kg-day/mg

Added cancer risk, computed in this manner, is a dimensionless probability of cancer incidence. It can also be used to estimate population risk metrics such as cancer incidence per 100,000 exposed persons or to gauge the magnitude of attributable risk relative to other sources of cancer risk, such as the background incidence rate. For example, an added cancer risk of 0.0001 is an added chance of cancer incidence of 1 in 10,000 attributable to exposure. On a population basis, 0.0001 implies one additional case of cancer in 10,000 persons exposed under the conditions of the exposure scenario. An added cancer risk of 0.0001, when appended to the background cancer incidence rate in the United States of about 0.25, produces an overall individual cancer risk of 0.2501, which represents a 0.04 percent increase in the overall total (i.e., absolute) cancer risk.

Carcinogenic Radionuclide Risks from Soils

The method used to estimate potential cancer risks from exposure to radionuclides also uses a CSF approach detailed in EPA guidance (EPA 1989). The CSF equation for radionuclides is

$$\text{Added cancer risk} = TI \times SF,$$

where

Added cancer risk is the probability of cancer incidence attributable to exposure,
TI = total exposure period radionuclide intake in units of picocuries (exposure periods are 30 years for the RME case and 9 years in the CT case), and
SF = cancer intake slope factor in units of liters per picocurie.

As with the nonradionuclides, added cancer risk computed in this manner is a dimensionless probability of cancer mortality that can be compared to EPA's benchmark range and can be used to estimate population-risk metrics or to gauge the attributable risk from exposure relative to other sources. Radionuclide-added cancer risks can also be added to give a summed risk for all compounds in a mixture. Because there are multiple radionuclide contaminants of concern, cancer risks will be summed to give an aggregate cancer risk for this mixture, as appropriate.

Radionuclide and nonradionuclide cancer risk will not be added together because (1) nonradionuclide cancer risks express incidence, and radionuclide risks express risk of mortality, and (2) the slope factors for nonradionuclide cancer risks are "upper-bound estimates" of the dose response function (i.e., potency), and radionuclide slope factors are MLEs of radionuclide cancer potency (MLE estimates are similar to CT estimates).

Carcinogenic Radionuclide Risks from Radon and Particulates in Air and Gamma Exposures

RESRAD (Version 6.0) was used to estimate risks from airborne contamination and from gamma exposures (ANL 2001, 2003). Among the advantages that RESRAD brings to a radiological dose or risk assessment is its ability to derive values for exposure parameters based on built-in fate and transport computations using well-defined site-specific data. It is widely accepted as an industry standard tool for performing radiological dose assessments and specifically for deriving concentration guideline values. A few of the key points that should be recognized about the RESRAD modeling code and the algorithms it uses are

- Default DCFs used in RESRAD 6.0 were taken from FGR #13 (the data library for FGR #13 was added to this version of RESRAD) and EPA's 1997 Health Effects Assessment Summary Tables (HEAST) (EPA 1997a) and are derived using the ICRP 30 dosimetry model. The bio-kinetic dosimetry model accounts for particle fractioning that might occur following exposure. For example, the DCFs for particle inhalation account for the dose to the gastrointestinal tract from the fraction of respired particles that are ingested. As a result, there is no need to independently account for biological fractioning in the dose calculations.
- RESRAD integrates and normalizes exposure factors based on the fraction of time a receptor is exposed during the exposure period. For example, a soil ingestion rate of 100 mg/day for a receptor who is exposed on the site for only 50 percent of 1 day would result in an ingestion intake of 50 mg.
- RESRAD requires that the risk assessor input single-point estimates for values of every parameter required to evaluate complete pathways in the deterministic module of the code. RESRAD uses the single-point deterministic value for a specific parameter to calculate dose or risk unless the risk assessor specifies that the value be evaluated with a range of possible values selected from a specified distribution. It is not necessary to evaluate the uncertainty in every parameter, as variability (perhaps stemming from uncertainty) in many parameters does not contribute to variability or uncertainty in the resulting dose.

The RESRAD modeling code is recognized as an industry standard and is accepted for use by the U.S. Nuclear Regulatory Commission (NRC), DOE, and EPA for modeling dose and risk to individuals exposed to radioactivity originating in soils.

Conservatism has been built into the modeling by conscientiously selecting exposure factor values that err on the side of safety when confronted with uncertainty in the selection of input parameters.

D3.4 Risk Evaluations for the On-Site and Off-Site Disposal Alternatives

This section examines risks to human health after remediation of the tailings pile is completed. This assumes that the site has been remediated and the surface soils are clean (i.e., no risks from soils, air [including radon] or gamma exposure). It was assumed that contaminated ground water would not be used as the primary source of drinking water for the on-site residential scenario because the site is close to Moab, which has municipal water. However, it was assumed that contaminated water could be used for irrigation. The off-site locations do not have and are not expected to have contaminated ground water, so the use of ground water at those locations does not add to the risks.

D3.5 Backup Calculations

This section presents the detailed calculation spreadsheets used to develop the estimated risks for scenarios and pathways that did not use RESRAD. The detailed RESRAD calculation backup will be furnished on request via paper copy or compact disc.

The following tables present calculation spreadsheets:

Table D−2. Scenarios, Exposure Facts, Abbreviations, References (Overview Sheet)

Scenarios

Current	**Adults**	**Children**	**Notes**
-Off Site Resident	x	x	Air and dust only; evaluated with RESRAD
-Rafter		x	Worst-case scenarios with children; current/future
-Camper	x	x	Current and future could occur
Future			
-Residential	x	x	Low probability
-Office Worker	x		
-Outdoor Worker	x		

Exposure Factors (See Exposure Factor Worksheet for Values)

Factor	**Abbreviation**	**Units**
Exposure Frequency	EF	days/year
Exposure Duration	ED	years
Averaging Time-Cancer	AT-c	days
Averaging Time-Non Cancer	AT-NC	days
Soil-Sediment Ingestion Rate	IR-S	mg/day
Fraction Intake From Source	FI	fraction
Inhalation Rate	IR-A	m^3/day
Surface Water Ingestion Rate	IR-SW	L/day
Ground Water Ingestion Rate	IR-GW	L/day
Body Weight	BW	kg
Hours per Day	HpD	hours/day
Conversion Factor-Solids	CF	mg/kg
Conversion Factor-Water	CF	µg/mg
Conversion Factor- Solids rad	CF	mg/gr
Conversion Factor-Dermal	CF	L/cm^3
gamma exposure fraction	gef	fyear exposed
gamma shield & roughness factor	Se	ftransmitted

-

Equations

Nonradionuclides

1) $CDI_{\text{soil ingestion carcinogenic}}$ (mg/kg-day) = (Cs [mg/kg] * 1 kg/1E 6 mg * EF * IR-S * ED * FI) / (BW * AT-c)
2) $CDI_{\text{soil ingestion non cancer}}$ (mg/kg-day) = (Cs [mg/kg] * 1kg/1E 6 * mg * EF* IR* ED *) /(BW * AT-NC)
3) $CDI_{\text{sw ingestion carcinogenic}}$ (mg/kg-day) = (Cw [mg/L] * IR-SW * EF * ED * FI)/(BW * AT-c)
4) $CDI_{\text{sw ingestion non cancer}}$ (mg/kg-day) = (Cw [mg/L] * IR-SW * EF * ED * FI)/(BW * AT-NC)
5) $CDI_{\text{Dermal contact with water carcinogenic}}$ (mg/kg-day) = (Cw [mg/L] * SA * EF * PC * ED * EF * ET * CF) / (BW * AT-c)
6) $CDI_{\text{Dermal contact with water non carcinogenic}}$ (mg/kg-day) = (Cw [mg/L] * SA * PC* EF * ED * ET *CF) / (BW * AT-NC)
7) $CDI_{\text{ground water ingestion carcinogenic}}$ (mg/kg-day) = (Cw [mg/L] * IR-GW * EF * ED * FI)/(BW * AT-c)
8) $CDI_{\text{ground water ingestion non carcinogenic}}$ (mg/kg-day) = (Cw [mg/L] * IR-GW * EF * ED * FI)/(BW * AT-NC)

9) HQ (unitless) = CDI/RfD
10) HI (unitless) = $HQ_1 + HQ_2 + \ldots + HQ_i$
11) Risk (unitless probability) = CDI * SF (Chemical)
12) Risk (fatal and nonfatal cancer) = TI * SF (Radionuclide)

Radionuclides

13) $TI_{\text{ground water ingestion}}$ (pCi) = Cw * IR-GW * EF * FI * ED

Table D−2. Scenarios, Exposure Facts, Abbreviations, References (overview sheet) (continued)

Abbreviations

Abbreviation	Description
EF	Exposure Frequency (days per year)
DEP	Daily Exposure Period
ED	Exposure Duration (years)
AT-c	Averaging Time-Cancer (days)
AT-NC	Averaging Time-Non-Cancer (days)
IR-S	Soil-Sediment Ingestion Rate
FI	Fraction Intake From Source
IR-A	Inhalation Rate
IR-SW	Surface Water Ingestion Rate (liters per day)
IR-GW	Ground Water Ingestion Rate (liters per day)
IR -Play	Water ingestion rate during play at the edge of the river (liters per day)
BW	Body Weight (kilograms)
HpD	Hours per Day
CF	Conversion factor (media dependant)
CDI	Chronic Daily Intake (milligrams per kilograms-day)
mg	milligrams
L	liters
Cw	Chemical concentration in water (milligrams per liter or picocuries per liter)
Cs	Chemical concentration in soil (milligrams per kilograms or picocuries per kilograms)
SA	Skin surface area available for contact (square centimeter)
cm	centimeters
PC	Chemical-specific dermal permeability constant (centimeters per hour)
HQ	Hazard Quotient (unitless)
HI	Hazard Index (unitless)
SF	Slope Factor (kilograms-day per milligram or risk/pCi)
ET	Exposure Time (dermal) (hours per day)
RME	Reasonable Maximum Exposure
CT	Central Tendency
Cf	Chemical concentration in food (milligrams per kilogram)
IR-F	Ingestion rate for food (grams per day)
TI	Total Intake (picocurie)

Table D−3. No Action—Future Incidental Ingestion of Contaminated Soil by a Resident

Description - A future residence is established on the Moab site and incidental ingestion of contaminated soil occurs. Exposure occurs to children only, mostly while playing outside, although estimates include some indoor dust ingestion.

Exposure Factors					
			Parameters		
Factor	**Abbreviation**	**Units**	**CT**	**RME**	**Notes**
Exposure Frequency	EF	days/year	350	365	RME from EPA 1989; CT assumes 2 weeks away from residence
Exposure Duration—Child	ED	years	7	9	RME over entire period, CT based on typical 50% from Table 15-168 in EPA 1997b
Averaging Time—Cancer	AT-c	days	25,550	25,550	Default from EPA 1989
Averaging Time—Non Cancer Child	AT-NC	days	2,450	3,285	Default with child EDs
Body Weight—Child	BW	kg	22	22	Mean for 1-10 year olds, Table 7-3 EPA 1997b
Soil Ingestion Rate—Child	IR-S	mg/day	100	400	EPA 1997b, Table 4-23, defaults
Fraction Intake From Source	FI	fraction	0.8	1	CT based on professional judgment
Conversion Factor (1)	CF1	kg/mg	1.00E-06	1.00E-06	1 kg/1,000,000 mg
Conversion Factor (2)	CF2	g/mg	1.00E-03	1.00E-03	1 kg/1,000 g

Note: Ingestion rates centered around a 6-year-old child but include other age children. The same range of ages was assumed in the calculations for this pathway as other pathways for the residential scenario.

Equations

Exposure - Nonradionuclides

$CDI\ soil_{ingestion\ non\ carcinogenic}$ (mg/kg-day) = (Cs [mg/kg] * IR-S * CF1 * EF * ED * FI)/(BW * AT-Nc)

$CDI\ soil_{ingestion\ carcinogenic}$ (mg/kg-day) = (Cs [mg/kg] * IR-S * CF1 * EF * ED * FI)/(BW * AT-c)

Risk - Nonradionuclides

HQ (unitless) = CDI/RfD

HI (unitless) = $HQ_1 + HQ_2 + \ldots + HQ_i$

Risk (unitless probability) = CDI * SF

Exposure - Radionuclides

$TI_{soil\ ingestion}$ (pCi) = Cs (pCi/g) * IR-S * EF * FI * ED *CF2

Risk - Radionuclides

Risk (unitless probability) = TI*SF

Estimated CDI and Risks-Child				
	Central Tendency		**RME**	
	CDI	**HQ**	**CDI**	**HQ**
Chemicals as Noncarcinogens	**(mg/kg-day)**	**(Unitless)**	**(mg/kg-day)**	**(Unitless)**
Ammonium	0.00	NA	0.00	NA
Arsenic	0.00	0.09	0.00	0.45
Uranium (mg/kg)	0.00	0.19	0.00	0.93
Vanadium	0.00	0.32	0.01	1.61
Sulfate	0.02	NA	0.12	NA
Total		0.60		3.00
	Central Tendency		**RME**	
	CDI	**Risk**	**CDI**	**Risk**
Chemicals as Carcinogens	**(mg/kg-day)**	**(Unitless)**	**(mg/kg-day)**	**(Unitless)**
Arsenic	2.58E-06	3.87E-06	1.73E-05	2.59E-05
Total		3.87E-06		2.59E-05
Radionuclides				
Radium-226	4.47E+03	3.26E-06	3.00E+04	2.19E-05
Thorium-230	2.61E+04	5.27E-06	1.75E+05	3.53E-05
Uranium-234	9.43E+03	1.49E-06	6.32E+04	9.99E-06
Uranium-238	1.18E+04	2.47E-06	7.90E+04	1.66E-05
Total	5.18E+04	1.25E-05	3.47E+05	8.38E-05

Table D−4. No Action—Future Exposure to Contaminated Produce Grown Adjacent to a Residence

Description - A future residence is established on the Moab site and a vegetable garden is located adjacent to the residence. Vegetables from the garden are used as a source of food, and ground water is used as an irrigation source.

Exposure Factors					
			Parameters		
Factor	**Abbreviation**	**Units**	**CT**	**RME**	**Notes**
Exposure Frequency	EF	days/year	350	365	RME from EPA 1989; CT assumes 2 weeks away from residence
Exposure Duration - Adult	ED	years	9	30	EPA 1997b, Chapter 15.4.3; 50th and 95th %
Exposure Duration - Child	ED	years	7	9	RME over entire period, CT based on typical 50% from Table 15-168 in EPA 1997b
Averaging Time-Cancer	AT-c	days	25,550	25,550	Default from EPA 1989
Averaging Time-Non Cancer Adult	AT-NC	days	3,150	10,950	Default from EPA 1989
Averaging Time-Non Cancer Child	AT-NC	days	2,450	3,285	Default with child EDs
Body Weight -Adult	BW	kg	70	70	EPA 1989, average of US population
Body Weight - Child	BW	kg	22	22	Mean for 1-10 year olds, Table 7-3 EPA 1997b
Ingestion Rate - Food Adult	IR-F	g/day	74.9	434.7	Table 13-17 in EPA 1997b adjusted by body weight, homegrown vegetables only; households that garden in the western U.S.
Ingestion Rate - Food Child	IR-F	g/day	23.54	136.62	Table 13-17 in EPA 1997b adjusted by body weight, homegrown vegetables only; households that garden in the western U.S.
Fraction Intake for Source	F	Unitless	1	1	RME and CT values were adjusted in the ingestion rate, home produce is assumed to be contaminated.
Conversion Factor (Food)	CF	kg/g	1.00E-03	1.00E-03	1 kg/1,000 g

Equations

Exposure – Nonradionuclides
$CDI_{\text{vegetable ingestion non carcinogenic}}$ (mg/kg-day) = (Cf [mg/kg] * IR-F * EF * ED * FI* CF)/(BW * AT-Nc)
$CDI_{\text{vegetable ingestion carcinogenic}}$ (mg/kg-day)= (Cf [mg/kg] * IR-F * EF * ED * FI * CF)/(BW * AT-c)

Risk – Nonradionuclides
HQ (unitless) = CDI/RfD
HI (unitless) = $HQ_1 + HQ_2 + \ldots + HQ_i$
Risk (unitless probability) = CDI * SF

Exposure – Radionuclides
$TI_{\text{vegetable ingestion}}$ (pCi) = Cf (pCi/kg) *IR-F * EF * FI * ED *CF

Risk – Radionuclides
Risk (unitless probability) = TI*SF

Table D−4. No Action—Future Exposure to Contaminated Produce Grown Adjacent to a Residence (continued)

Estimated CDI and Risks-Adult				
	Central Tendency		**RME**	
	CDI	**Risk**	**CDI**	**Risk**
Chemicals as Carcinogens	**(mg/kg-day)**	**(Unitless)**	**(mg/kg-day)**	**(Unitless)**
Arsenic	6.33E-04	9.50E-04	3.68E-03	2.45E-03
Total		9.50E-04		2.45E-03
	Central Tendency		**RME**	
	CDI	**HQ**	**CDI**	**HQ**
Chemicals as Noncarcinogens	**(mg/kg-day)**	**(Unitless)**	**(mg/kg-day)**	**(Unitless)**
Arsenic	0.001	2.11	0.004	12.25
Uranium	0.000	0.14	0.002	0.80
Vanadium	0.005	0.66	0.027	3.86
Total		2.91		16.91
Estimated CDI and Risks-Children				
	Central Tendency		**RME**	
	CDI	**Risk**	**CDI**	**Risk**
Chemicals as Carcinogens	**(mg/kg-day)**	**(Unitless)**	**(mg/kg-day)**	**(Unitless)**
Arsenic	1.99E-04	2.99E-04	1.16E-03	7.70E-04
Total		2.99E-04		7.70E-04
	Central Tendency		**RME**	
	CDI	**HQ**	**CDI**	**HQ**
Chemicals as Noncarcinogens	**(mg/kg-day)**	**(Unitless)**	**(mg/kg-day)**	**(Unitless)**
Arsenic	0.001	2.11	0.004	12.25
Uranium	0.000	0.14	0.002	0.80
Vanadium	0.005	0.66	0.027	3.86
Total		2.91		16.91

Note: Risks to children and adults are the same for noncarcinogens because the intake rate was proportioned based on body weight.
Uptake factors are unknown for radionuclides; this exposure pathway also results in much lower risks compared to other pathways.

Table D−5. No Action—Future Dermal Exposure to Contaminated Ground Water for an Outside Worker

Description - A future golf course is established on the Moab site and contaminated ground water is used as the primary source of irrigation water. Exposure occurs during watering and maintenance activities at the golf course.

Exposure Factors					
			Parameters		
Factor	**Abbreviation**	**Units**	**CT**	**RME**	**Notes**
Exposure Frequency	EF	days/year	230	250	RME assumes 50 weeks, 5 days/week; CT assumes 46 weeks, 5 days /week
Exposure Duration - Adult	ED	years	7	20	EPA 1997b, Table 15-158, Tenure of employment, CT is average, RME range for older workers
Exposure Time	ET	hours/day	4	8	RME assumes exposure for the full work day; CT assumes water contact for 1/2 day
Averaging Time-Cancer	AT-c	days	25,550	25,550	Default from EPA 1989
Averaging Time-Non Cancer Adult	AT-NC	days	2,555	7,300	Default from EPA 1989
Body Weight -Adult	BW	kg	70	70	EPA 1989, average of US population
Dermal Permeability Constant	PC	cm/hour	Chemical Specific	Chemical Specific	See below
Skin Surface Available for Contact-Adult	SA	cm^2	361	432	EPA 1997b, Table 6-2, assumes hands, forearms, and feet exposure only.
Conversion Factor	CF	L/cm^3	0.001	0.001	1L/1,000 cm^3

Equations

Exposure – Nonradionuclides

$CDI_{\text{ground water ingestion non carcinogenic}}$ (mg/kg-day) = (Cw [mg/L] * SA * PC - EF * ED * ET * CF)/(BW * AT-Nc)
$CDI_{\text{ground water ingestion carcinogenic}}$ (mg/kg-day)= (Cw [mg/L] * SA * PC * EF * ED * ET * CF)/(BW * AT-c)

Risk – Nonradionuclides

HQ (unitless) = CDI/RfD
HI (unitless) = HQ_1+ HQ_2 +….+ HQ_i
Risk (unitless probability) = CDI * SF

Exposure – Radionuclides

TI_{dermal} (pCi) = Cw (pCi/L) * SA* PC* EF * FI * ED * CF

Risk – Radionuclides

Risk (unitless probability) = TI*SF

Dermal Permeability Constants (PC)

Chemical Name	**PC (K_p) cm/h**	**Notes**
Ammonia	NA	Inhalation route
Arsenic	1.0E-03	Not listed; default assumed, Exhibit 3-1
Boron	1.0E-03	Not listed; default assumed, Exhibit 3-1
Cadmium	1.0E-03	Experimental
Fluoride	1.0E-03	Not listed; default assumed, Exhibit 3-1
Iron	1.0E-03	Not listed; default assumed, Exhibit 3-1
Lithium	1.0E-03	Not listed; default assumed, Exhibit 3-1
Manganese	1.0E-03	Not listed; default assumed, Exhibit 3-1
Molybdenum	1.0E-03	Not listed; default assumed, Exhibit 3-1
Nitrate	NA	
Selenium	1.0E-03	Not listed; default assumed, Exhibit 3-1
Strontium	1.0E-03	Not listed; default assumed, Exhibit 3-1
Uranium	1.0E-03	Not listed; default assumed, Exhibit 3-1
Vanadium	1.0E-03	Not listed; default assumed, Exhibit 3-1

Source: EPA (2001)

Table D–5. No Action—Future Dermal Exposure to Contaminated Ground Water for an Outside Worker (continued)

Estimated CDI and Risks-Adult	**Central Tendency**		**RME**	
	CDI	**HQ**	**CDI**	**HQ**
Chemicals as Noncarcinogens	**(mg/kg-day)**	**(Unitless)**	**(mg/kg-day)**	**(Unitless)**
Ammonia	NA	NA	NA	NA
Arsenic	0.000	0.00	0.000	0.01
Boron	0.000	0.00	0.000	0.00
Cadmium (water)	0.000	0.00	0.000	0.00
Fluoride	0.000	0.00	0.000	0.00
Iron	0.000	0.00	0.000	0.00
Lithium	0.000	0.00	0.000	0.00
Manganese (nonfood)	0.000	0.00	0.000	0.00
Molybdenum	0.000	0.00	0.000	0.00
Nitrate	NA	NA	NA	NA
Selenium	0.000	0.00	0.000	0.00
Strontium	0.000	0.00	0.000	0.00
Uranium	0.000	0.02	0.000	0.06
Vanadium	0.000	0.00	0.000	0.01
Total		0.03		0.09
		Added		**Added**
Chemicals as Carcinogens		**Cancer**		**Cancer**
Arsenic	9.03E-08	1.36E-07	6.71E-07	1.01E-06
Total		1.36E-07		1.01E-06

Note: Estimations of dermal exposure require a contaminant mass and the contribution to risk from dermal exposure to radionuclides is expected to be much less than other pathways (ingestion, direct exposure). Therefore, dermal exposure to radionuclides was not estimated.

Table D−6. No Action—Future Incidental Ingestion of Contaminated Soil During Camping

Description – The Moab site is used for camping in the future and incidental ingestion of contaminated soil occurs. Exposure occurs to children only mostly while playing around the camping site. Exposures are based on a one night camping event. The camping trip is assumed to occur over one 24-hour period.

Exposure Factors

			Parameters		
Factor	**Abbreviation**	**Units**	**Central Tendency**	**RME**	**Notes**
Exposure Frequency	EF	days/year	1	1	Unit estimate based on one event per year (see note)
Exposure Duration - Child	ED	years	1	1	Unit estimate based on one event per year (see note)
Averaging Time-Cancer	AT-c	days	25,550	25,550	Default from EPA 1989
Averaging Time-Non Cancer Child	AT-NC	days	365	365	Default with child EDs
Body Weight - Child	BW	kg	22	22	Mean for 1-10 year olds, Table 7-3 EPA 1997b
Soil Ingestion Rate - Child	IR-S	mg/day	100	400	EPA 1997b, Table 4-23, defaults
Fraction Intake From Source	FI	fraction	1	1	CT based on professional judgment
Conversion Factor	CF1	kg/mg	1.00E-06	1.00E-06	1 kg/1,000 mg
Conversion Factor	CF2	kg/mg	1.00E-03	1.00E-03	1 g/1,000 mg

Note: Ingestion rates centered on a 6-year-old child but include other age children. The same range of ages was assumed in the calculations for this pathway as other pathways for the residential scenario.
Actual exposures may be greater. Site-specific data should be used if available. Results will be linear. For example, camping for 5 days will increase risks by a factor of 5.

Equations

Exposure – Nonradionuclides

CDI soil $_{\text{ingestion non carcinogenic}}$ (mg/kg-day) = (Cs [mg/kg] * IR-S * CF * EF * ED * FI)/(BW * AT-Nc)

CDI soil $_{\text{ingestion carcinogenic}}$ (mg/kg-day) = (Cs [mg/kg] * IR-S * CF * EF * ED * FI)/(BW * AT-c)

Risk – Nonradionuclides

HQ (unitless) = CDI/RfD

HI (unitless) = $HQ_1 + HQ_2 + \ldots + HQ_i$

Risk (unitless probability) = CDI * SF

Exposure – Radionuclides

TI $_{\text{soil ingestion}}$ (pCi) = Cs (pCi/g) * IR-S * EF * FI * ED

Risk – Radionuclides

Risk (unitless probability) = TI*SF

Table D–6. No Action—Future Incidental Ingestion of Contaminated Soil During Camping (continued)

Exposure - Radionuclides				
	Central Tendency		**RME**	
	CDI	**HQ**	**CDI**	**HQ**
Chemicals as Noncarcinogens	**(mg/kg-day)**	**(Unitless)**	**(mg/kg-day)**	**(Unitless)**
Arsenic	9.22E-08	0.000307	3.69E-07	0.001229
Uranium	1.92E-06	6.39E-04	7.67E-06	2.56E-03
Vanadium	7.74E-06	1.11E-03	3.10E-05	4.42E-03
Total	9.75E-06	2.05E-03	3.90E-05	8.21E-03
	Central Tendency		**RME**	
Chemicals as Carcinogens	**CDI**	**Risk**	**CDI**	**Risk**
	(mg/kg-day)	(Unitless)	(mg/kg-day)	(Unitless)
Arsenic	1.32E-09	1.97E-09	5.27E-09	7.90E-09
Total	1.32E-09	1.97E-09	5.27E-09	7.90E-09
Radionuclides				
Radium-226	2.28E+00	1.66E-09	9.12E+00	6.66E-09
Thorium-230	1.33E+01	2.69E-09	5.32E+01	1.08E-08
Uranium-234	4.81E+00	7.60E-10	1.92E+01	3.04E-09
Uranium-238	6.01E+00	1.26E-09	2.40E+01	5.05E-09
	2.64E+01	6.38E-09	1.06E+02	2.55E-08

Table D−7. No Action—Future Dermal Exposure to Contaminated Ground Water During Camping

Description – The Moab site is used for camping and dermal exposure to contaminated surface water occurs. Ground water entering the Colorado River is assumed to be where exposure occurs. Exposure is assumed to children while playing by the edge of the Colorado River. The camping trip is assumed to occur over one 24-hour period.

Exposure Factors					
			Parameters		
Factor	**Abbreviation**	**Units**	**Central Tendency**	**RME**	**Notes**
Exposure Frequency	EF	days/year	1	1	Unit estimate based on one event per year (see note)
Exposure Duration - Child	ED	years	1	1	Unit estimate based on one event per year (see note)
Exposure Time	ET	hours/day	2	4	Based on professional judgment for play time in river
Averaging Time-Cancer	AT-c	days	25,550	25,550	Default from EPA 1989
Averaging Time-Non Cancer Child	AT-NC	days	365	365	Default with child EDs
Body Weight - Child	BW	kg	22	22	Mean for 1-10 year olds, Table 7-3 EPA 1997b
Dermal Permeability Constant	PC	cm/hour	Chemical Specific	Chemical Specific	See Below
Skin Surface Available for Contact-Child	SA	cm^2	486	591	Total for 6-9 old male, % for arms, legs, hands, feet for 6-7 year old (52%), Table 6-8, EPA 1997b
Conversion Factor	CF	L/cm^3	0.001	0.001	$1L/1{,}000\ cm^3$

Note: Actual exposures may be greater. Site-specific data should be used if available. Results will be linear. For example, camping for 5 days will increase risks by a factor of 5.

Equations

Exposure - Nonradionuclides
$CDI_{\text{ground water ingestion non carcinogenic}}$ (mg/kg-day) = (Cw [mg/L] * SA * * PC - EF * ED * ET * CF)/(BW * AT-Nc)
$CDI_{\text{ground water ingestion carcinogenic}}$ (mg/kg-day)= (Cw [mg/L] * SA * PC * EF * ED * ET * CF)/(BW * AT-c)

Risk - Nonradionuclides
HQ (unitless) = CDI/RfD
HI (unitless) = $HQ_1 + HQ_2 + \ldots + HQ_i$
Risk (unitless probability) = CDI * SF

Exposure - Radionuclides
TI_{dermal} (pCi) = Cw (pCi/L) * SA* PC* EF * FI * ED * CF

Risk - Radionuclides
Risk (unitless probability) = TI*SF

Dermal Permeability Constants (PC)

Chemical Name	**PC (K_p) cm/hr**	**Notes**
Ammonia	NA	Inhalation route
Arsenic	1.0E-03	Not listed; default assumed from Exhibit 3-1
Boron	1.0E-03	Not listed; default assumed from Exhibit 3-1
Cadmium	1.0E-03	Listed in Exhibit 3-1
Fluoride	1.0E-03	Not listed; default assumed from Exhibit 3-1
Iron	1.0E-03	Not listed; default assumed from Exhibit 3-1
Lithium	1.0E-03	Not listed; default assumed from Exhibit 3-1
Manganese	1.0E-03	Not listed; default assumed from Exhibit 3-1
Molybdenum	1.0E-03	Not listed; default assumed from Exhibit 3-1
Nitrate	NA	
Selenium	1.0E-03	Not listed; default assumed from Exhibit 3-1
Strontium	1.0E-03	Not listed; default assumed from Exhibit 3-1
Uranium	1.0E-03	Not listed; default assumed from Exhibit 3-1
Vanadium	1.0E-03	Not listed; default assumed from Exhibit 3-1

Source: EPA 2001

Table D–7. No Action—Future Dermal Exposure to Contaminated Ground Water During Camping (continued)

Estimated CDI and Risks-Children				
	Central Tendency		**RME**	
	CDI	**HQ**	**CDI**	**HQ**
Chemicals as Noncarcinogens	**(mg/kg-day)**	**(Unitless)**	**(mg/kg-day)**	**(Unitless)**
Ammonia	NA	NA	NA	NA
Arsenic	0.000	0.00	0.000	0.00
Boron	0.000	0.00	0.000	0.00
Cadmium (water)	0.000	0.00	0.000	0.00
Fluoride	0.000	0.00	0.000	0.00
Iron	0.000	0.00	0.000	0.00
Lithium	0.000	0.00	0.000	0.00
Manganese (nonfood)	0.000	0.00	0.000	0.00
Molybdenum	0.000	0.00	0.000	0.00
Nitrate	NA	NA	NA	NA
Selenium	0.000	0.00	0.000	0.00
Strontium	0.000	0.00	0.000	0.00
Uranium	0.000	0.00	0.000	0.00
Vanadium	0.000	0.00	0.000	0.00
Total		0.00		0.00
Chemicals as Carcinogens				
Arsenic	1.20E-10	1.80E-10	5.34E-09	8.01E-09
Total		1.80E-10		8.01E-09

Note: Estimations of dermal exposure require a contaminant mass and the contribution to risk from dermal exposure to radionuclides is expected to be much less than other pathways (ingestion, direct exposure). Therefore, dermal exposure to radionuclides was not estimated.

Table D−8. No Action—Future Ingestion of Contaminated Ground Water by a Camper

Description – The Moab site is used for camping and ingestion of contaminated surface water occurs. Ground water entering the Colorado River is assumed to used as the drinking water source. The camping trip is assumed to occur over one 24-hour period.

Exposure Factors					
			Parameters		
Factor	**Abbreviation**	**Units**	**Central Tendency**	**RME**	**Notes**
Exposure Frequency	EF	days/year	1	1	Unit estimate based on one event per year (see note)
Exposure Duration - Adult	ED	years	1	1	Unit estimate based on one event per year (see note)
Exposure Duration - Child	ED	years	1	1	Unit estimate based on one event per year
Averaging Time-Cancer	AT-c	days	25,550	25,550	Default from EPA 1989
Averaging Time-Non Cancer Adult	AT-NC	days	365	365	Default from EPA 1989
Averaging Time-Non Cancer Child	AT-NC	days	365	365	Default with child EDs
Body Weight -Adult	BW	kg	70	70	EPA 1989, average of US population
Body Weight - Child	BW	kg	22	22	Mean for 1-10 year olds, Table 7-3 EPA 1997b
Ground water Ingestion Rate - Adult	IR-GW	L/day	1.4	2	EPA 1997b, Section 3.6
Ground water Ingestion Rate - Child	IR-GW	L/day	0.74	1.29	Age 1-10 mean and 90 %, Table 3-33 EPA 1997b
Fraction Intake From Source	FI	fraction	0.8	1	CT based on professional judgment

Note: Actual exposures may be greater. Site-specific data should be used if available. Results will be linear. For example, camping for 5 days will increase risks by a factor of 5.

Equations

Exposure - Nonradionuclides

$CDI_{\text{ground water ingestion non carcinogenic}}$ (mg/kg-day) = (Cw [mg/L] * IR-GW * EF * ED * FI)/(BW * AT-Nc)

$CDI_{\text{ground water ingestion carcinogenic}}$ (mg/kg-day)= (Cw [mg/L] * IR-GW * EF * ED * FI)/(BW * AT-c)

Risk - Nonradionuclides

HQ (unitless) = CDI/RfD

HI (unitless) = $HQ_1 + HQ_2 + \ldots + HQ_i$

Risk (unitless probability) = CDI * SF

Exposure - Radionuclides

$TI_{\text{ground water ingestion}}$ (pCi) =Cw (pCi/L) * IR-GW * EF * FI * ED

Risk - Radionuclides

Risk (unitless probability) = TI*SF

Estimated CDI and Risks-Adults	**Central Tendency**		**RME**	
	CDI	**HQ**	**CDI**	**HQ**
Chemicals as Noncarcinogens	**(mg/kg-day)**	**(Unitless)**	**(mg/kg-day)**	**(Unitless)**
Ammonia	NA	NA	NA	NA
Arsenic	0.000	0.00	0.000	0.00
Boron	0.000	0.06	0.000	0.10
Cadmium (water)	0.000	0.00	0.000	0.00
Fluoride	0.000	0.00	0.000	0.00
Iron	0.000	0.00	0.000	0.00
Lithium	0.000	0.00	0.000	0.00
Manganese (nonfood)	0.000	0.00	0.000	0.00
Molybdenum	0.000	0.00	0.000	0.01
Nitrate	0.006	0.00	0.012	0.01
Selenium	0.000	0.00	0.000	0.00
Strontium	0.001	0.00	0.001	0.00
Uranium	0.000	0.08	0.000	0.15
Vanadium	0.000	0.01	0.000	0.01
Total		0.16		0.28
Chemicals as Carcinogens		**Added Cancer**		**Added Cancer**
Arsenic	4.35E-08	6.53E-08	5.44E-06	8.16E-06
Total		6.53E-08		8.16E-06
Radionuclides				
Radon-222	247.632	0.00E+00	442.2	0.00E+00
Radium-226+D	1.71472	6.62E-10	3.062	1.18E-09
Radium-228+D	3.36	3.49E-09	6	6.24E-09
Uranium-234	2,021.6	1.43E-07	3610	2.55E-07
Uranium-238+D	2,129.12	1.85E-07	3802	3.31E-07
Total		3.33E-07		5.94E-07

Table D–8. No Action—Future Ingestion of Contaminated Ground Water by a Camper (continued)

Estimated CDI and Risks-Children				
	Central Tendency		**RME**	
	CDI	**HQ**	**CDI**	**HQ**
Chemicals as Noncarcinogens	**(mg/kg-day)**	**(Unitless)**	**(mg/kg-day)**	**(Unitless)**
Ammonia	NA	NA	NA	NA
Arsenic	0.000	0.02	0.000	0.04
Boron	0.000	0.00	0.000	0.00
Cadmium (water)	0.000	0.00	0.000	0.00
Fluoride	0.000	0.00	0.000	0.00
Iron	0.000	0.00	0.000	0.00
Lithium				
Manganese (nonfood)	0.000	0.00	0.000	0.00
Molybdenum	0.000	0.01	0.000	0.01
Nitrate	0.011	0.01	0.024	0.01
Selenium	0.000	0.00	0.000	0.00
Strontium	0.001	0.00	0.002	0.00
Uranium	0.000	0.14	0.001	0.31
Vanadium	0.000	0.01	0.000	0.03
Total		0.19		0.42
Chemicals as Carcinogens				
Arsenic	7.32E-08	1.10E-07	1.60E-07	2.39E-07
Total		1.10E-07		2.39E-07
Radionuclides				
Radon-222	130.8912	0.00E+00	285.219	0.00E+00
Radium-226+D	0.906352	3.50E-10	1.97499	7.62E-10
Radium-228+D	1.776	1.85E-09	3.87	4.02E-09
Uranium-234	1,068.56	7.55E-08	2,328.45	1.65E-07
Uranium-238+D	1,125.392	9.80E-08	2,452.29	2.14E-07
Total		1.76E-07		3.83E-07

Table D−9. No Action—Current Dermal Exposure to Contaminated Ground Water During Rafting

Description – The sandbars adjacent to the Moab site could be used as a stopping (lunch) area for rafters. Children playing at the edge of the river could be dermally exposed to contaminated water. Ground water entering the Colorado River is assumed to be the source of the water. Rafters are assumed to stop at this location for 1 hour.

Exposure Factors					
			Parameters		
Factor	**Abbreviation**	**Units**	**Central Tendency**	**RME**	**Notes**
Exposure Frequency	EF	days/year	1	1	Unit estimate based on one event per year (see note)
Exposure Duration - Child	ED	years	1	1	Unit estimate based on one event per year (see note)
Exposure Time	ET	hours/day	1	1	Exposure occurs for only 1 hour/day
Averaging Time-Cancer	AT-c	days	25,550	25,550	Default from EPA 1989
Averaging Time-Non Cancer Child	AT-NC	days	365	365	Default with child EDs
Body Weight - Child	BW	kg	22	22	Mean for 1-10 year olds, Table 7-3 EPA 1997b
Dermal Permeability Constant	PC	cm/hour	Chemical Specific	Chemical Specific	See Below
Skin Surface Available for Contact-Child	SA	cm^2	486	591	Total for 6-9 old male, % for arms, legs, hands, feet for 6-7 year old (52%), Table 6-8, EPA 1997b
Conversion Factor	CF	L/cm^3	0.001	0.001	$1L/1{,}000\ cm^3$

Note: Actual exposures may be greater. Site-specific data should be used if available. Results will be linear. For example, camping for 5 days will increase risks by a factor of 5.

Equations

Exposure - Nonradionuclides

$CDI_{\text{ground water ingestion non carcinogenic}}$ (mg/kg-day) = (Cw [mg/L] * SA * PC - EF * ED * ET * CF)/(BW * AT-Nc)

$CDI_{\text{ground water ingestion carcinogenic}}$ (mg/kg-day)= (Cw [mg/L] * SA * PC * EF * ED * ET * CF)/(BW * AT-c)

Risk - Nonradionuclides

HQ (unitless) = CDI/RfD

HI (unitless) = $HQ_1 + HQ_2 + \ldots + HQ_i$

Risk (unitless probability) = CDI * SF

Exposure - Radionuclides

TI_{dermal} (pCi) = Cw (pCi/L) * SA* PC* EF * FI * ED * CF

Dermal Permeability Constants (PC)

Chemical Name	**PC (K_p) cm/hr**	**Notes**
Ammonia	NA	Inhalation route
Arsenic	1.0E-03	Not listed; default assumed from Exhibit 3-1
Boron	1.0E-03	Not listed; default assumed from Exhibit 3-1
Cadmium	1.0E-03	Listed in Exhibit 3-1
Fluoride	1.0E-03	Not listed; default assumed from Exhibit 3-1
Iron	1.0E-03	Not listed; default assumed
Lithium	1.0E-03	Not listed; default assumed from Exhibit 3-1
Manganese	1.0E-03	Not listed; default assumed from Exhibit 3-1
Molybdenum	1.0E-03	Not listed; default assumed
Nitrate	NA	
Selenium	1.0E-03	Not listed; default assumed from Exhibit 3-1
Strontium	1.0E-03	Not listed; default assumed from Exhibit 3-1
Uranium	1.0E-03	Not listed; default assumed
Vanadium	1.0E-03	Not listed; default assumed from Exhibit 3-1

Source: EPA (2001)

Table D–9. No Action—Current Dermal Exposure to Contaminated Ground Water During Rafting (continued)

Estimated CDI and Risks-Children				
	Central Tendency		**RME**	
	CDI	**HQ**	**CDI**	**HQ**
Chemicals as Noncarcinogens	**(mg/kg-day)**	**(Unitless)**	**(mg/kg-day)**	**(Unitless)**
Ammonia	NA	NA	NA	NA
Arsenic	0.000	0.00	0.000	0.00
Boron	0.000	0.00	0.000	0.00
Cadmium (water)	0.000	0.00	0.000	0.00
Fluoride	0.000	0.00	0.000	0.00
Iron	0.000	0.00	0.000	0.00
Lithium	0.000	0.00	0.000	0.00
Manganese (nonfood)	0.000	0.00	0.000	0.00
Molybdenum	0.000	0.00	0.000	0.00
Nitrate	NA	NA	NA	NA
Selenium	0.000	0.00	0.000	0.00
Strontium	0.000	0.00	0.000	0.00
Uranium	0.000	0.00	0.000	0.00
Vanadium	0.000	0.00	0.000	0.00
Total		0.00		0.00
Chemicals as Carcinogens				
Arsenic	6.01E-11	9.01E-11	7.31E-11	1.10E-10
Total		9.01E-11		1.10E-10

Note: Estimations of dermal exposure require a contaminant mass, and the contribution to risk from dermal exposure to radionuclides is expected to be much less than other pathways (ingestion, direct exposure). Therefore, dermal exposure to radionuclides was not estimated.

Table D−10. No Action—Current Incidental Ingestion of Contaminated Ground Water by a Rafter

Description – The sandbars adjacent to the Moab site could be used as a stopping (lunch) area for rafters. Children playing at the edge of the river could inadvertently ingest contaminated water. Ground water entering the Colorado River is assumed to be the source of the water. Rafters are assumed to stop at this location for one hour.

Exposure Factors					
			Parameters		
Factor	**Abbreviation**	**Units**	**Central Tendency**	**RME**	**Notes**
Exposure Frequency	EF	days/year	1	1	Unit estimate based on one event per year (see note)
Exposure Duration - Child	ED	years	1	1	Unit estimate based on one event per year (see note)
Averaging Time-Cancer	AT-c	days	25,550	25,550	Default from EPA 1989
Averaging Time-Non Cancer Child	AT-NC	days	365	365	Default with child EDs
Body Weight - Child	BW	kg	22	22	Mean for 1-10 year olds, Table 7-3 EPA 1997b
Ground water Ingestion Rate - Child	IR-Play	L/day	0.05	0.05	Based on Incidental Ingestion while swimming, EPA 1989, Page 6-34.
Fraction Intake From Source	FI	fraction	0.8	1	CT assumes some play occurs in the main channel of the river (minimal site influence)

Note: Actual exposures may be greater. Site-specific data should be used if available. Results will be linear. For example, camping for 5 days will increase risks by a factor of 5.

Equations

Exposure - Nonradionuclides
CDI $_{\text{ground water ingestion non carcinogenic}}$ (mg/kg-day) = (Cw [mg/L] * IR-Play * EF * ED * FI)/(BW * AT-Nc)
CDI $_{\text{ground water ingestion carcinogenic}}$ (mg/kg-day)= (Cw [mg/L] * IR-Play * EF * ED * FI)/(BW * AT-c)

Risk - Nonradionuclides
HQ (unitless) = CDI/RfD
HI (unitless) = $HQ_1 + HQ_2 + \ldots + HQ_i$
Risk (unitless probability) = CDI * SF

Exposure - Radionuclides
TI $_{\text{ground water ingestion}}$ (pCi) = Cw (pCi/L) * IR-Play * EF * FI * ED

Risk - Radionuclides
Risk (unitless probability) = Ti*SF

Estimated CDI and Risks-Children				
	Central Tendency		**RME**	
	CDI	**HQ**	**CDI**	**HQ**
Chemicals as Noncarcinogens	**(mg/kg-day)**	**(Unitless)**	**(mg/kg-day)**	**(Unitless)**
Ammonia	NA	NA	NA	NA
Arsenic	0.000	0.00	0.000	0.00
Boron	0.000	0.00	0.000	0.00
Cadmium (water)	0.000	0.00	0.000	0.00
Fluoride	0.000	0.00	0.000	0.00
Iron	0.000	0.00	0.000	0.00
Lithium	0.000	0.00	0.000	0.00
Manganese (nonfood)	0.000	0.00	0.000	0.00
Molybdenum	0.000	0.00	0.000	0.00
Nitrate	0.001	0.00	0.001	0.00
Selenium	0.000	0.00	0.000	0.00
Strontium	0.000	0.00	0.000	0.00
Uranium	0.000	0.01	0.000	0.01
Vanadium	0.000	0.00	0.000	0.00
Total		0.01		0.02
Chemicals as Carcinogens				
Arsenic	4.95E-09	7.42E-09	6.18E-09	9.27E-09
Total		7.42E-09		9.27E-09
Radionuclides				
Radon-222	8.844	0.00E+00	11.055	0.00E+00
Radium-226+D	0.061	2.36E-11	0.077	2.95E-11
Radium-228+D	0.120	1.25E-10	0.150	1.56E-10
Uranium-234	72.200	5.10E-09	90.250	6.38E-09
Uranium-238+D	76.040	6.62E-09	95.050	8.28E-09
Total		1.19E-08		1.48E-08

Table D−11. On-Site—Exposure Point Concentrations

Presents contaminant concentrations by medium for each exposure scenario.		
Residential Scenario		
	Ground Water Concentrations (Northeast area)	
Chemicals (mg/L)	**95 % UCL**	**Notes**
Ammonia	11.41	Ammonia, total reported as N; Reduced by an order of magnitude based on general modeling results
Arsenic	0.00695	Reduced by an order of magnitude based on general modeling results
Boron	0.127	Reduced by an order of magnitude based on general modeling results
Cadmium	0.00011	Reduced by an order of magnitude based on general modeling results
Fluoride	0.1768	Reduced by an order of magnitude based on general modeling results
Iron	0.2397	Reduced by an order of magnitude based on general modeling results
Lithium	0.02485	Reduced by an order of magnitude based on general modeling results
Manganese (nonfood)	0.1662	Reduced by an order of magnitude based on general modeling results
Molybdenum	0.03589	Reduced by an order of magnitude based on general modeling results
Nitrate	14.77	Reduced by an order of magnitude based on general modeling results
Selenium	0.00733	Reduced by an order of magnitude based on general modeling results
Strontium	1.44	Reduced by an order of magnitude based on general modeling results
Uranium	0.5738	Reduced by an order of magnitude based on general modeling results
Vanadium	0.1324	Reduced by an order of magnitude based on general modeling results
Radionuclides		
Radon-222	23.01	Unfiltered; Reduced by an order of magnitude based on general modeling results
Radium-226	0.04618	Reduced by an order of magnitude based on general modeling results
Radium-228	0.3237	Reduced by an order of magnitude based on general modeling results
Uranium-234	209.5	Reduced by an order of magnitude based on general modeling results
Uranium-238	221.1	Reduced by an order of magnitude based on general modeling results
	Soil concentrations	
Chemicals (mg/kg)	**95 % UCLs**	
Ammonium	0	Clean fill; assumed to be 0
Arsenic	0	Clean fill; assumed to be 0
Uranium (mg/kg)	0	Clean fill; assumed to be 0
Vanadium	0	Clean fill; assumed to be 0
Sulfate	0	Clean fill; assumed to be 0
Radionuclides (pCi/g)	**95 % UCLs**	
Radium-226	0	Clean fill; assumed to be 0
Thorium-230	0	Clean fill; assumed to be 0
Uranium-234	0	Clean fill; assumed to be 0
Uranium-238+D	0	Clean fill; assumed to be 0
	NH_3 in Air	
		Notes
NH_3 (mg/m^3)	0.01	Based on NH_3 conc. In water; default from EPA 1991a of 0.0005; conversion factor of 1,000 L/m^3, conversion from NH_4 to NH_3
		NH_3 conc. in air = water conc. x water-to-air volatilization factor x conversion factor
		NH_3 available in water based on a temperature of 20 °C and a pH of 7.5 from Emerson 1975. 1.24 % is unionized NH_3.
		Reduced by an order of magnitude for the on-site alternative compared to the no action
Food Concentrations (Vegetables)		
Chemicals (mg/kg)		Notes
Arsenic	0.00	Uptake value of 0.08; default from Resrad (ANL 1993), Table C.3
Uranium	0.00	Uptake value of 0.0025; default from Resrad (ANL 1993), Table C.3
Vanadium	0.00	Uptake value of 0.007; 90 % UCL from the Weinberg Group, Inc. 2000, Table C-1

Table D–11. On Site—Exposure Point Concentrations (continued)

Camper and Rafter Scenarios		
	Ground Water (assumed surface water) Concentrations	
Chemicals (mg/L)	**95 % UCL**	**Notes**
Ammonia	11.41	Ammonia, total reported as N; Reduced by an order of magnitude based on general modeling results
Arsenic	0.00695	Reduced by an order of magnitude based on general modeling results
Boron	0.127	Reduced by an order of magnitude based on general modeling results
Cadmium (water)	0.00011	Reduced by an order of magnitude based on general modeling results
Fluoride	0.1768	Reduced by an order of magnitude based on general modeling results
Iron	0.2397	Reduced by an order of magnitude based on general modeling results
Lithium	0.02485	Reduced by an order of magnitude based on general modeling results
Manganese (nonfood)	0.1662	Reduced by an order of magnitude based on general modeling results
Molybdenum	0.03589	Reduced by an order of magnitude based on general modeling results
Nitrate	14.77	Reduced by an order of magnitude based on general modeling results
Selenium	0.00733	Reduced by an order of magnitude based on general modeling results
Strontium	1.44	Reduced by an order of magnitude based on general modeling results
Uranium	0.5738	Reduced by an order of magnitude based on general modeling results
Vanadium	0.1324	Reduced by an order of magnitude based on general modeling results
Radionuclides		
Radon-222	23.01	Unfiltered; Reduced by an order of magnitude based on general modeling results
Radium-226	0.04618	Reduced by an order of magnitude based on general modeling results
Radium-228	0.3237	Reduced by an order of magnitude based on general modeling results
Uranium-234	209.5	Reduced by an order of magnitude based on general modeling results
Uranium-238	221.1	Reduced by an order of magnitude based on general modeling results
	Soil concentrations	
Chemicals (mg/kg)	**95 % UCLs**	**Notes**
Ammonium	0	Clean fill; assumed to be 0
Arsenic	0	Clean fill; assumed to be 0
Uranium (mg/kg)	0	Clean fill; assumed to be 0
Vanadium	0	Clean fill; assumed to be 0
Sulfate	0	Clean fill; assumed to be 0
Radionuclides (pCi/g)	**95 % UCLs**	**Notes**
Radium-226	0	Clean fill; assumed to be 0
Thorium-230	0	Clean fill; assumed to be 0
Uranium-234	0	Clean fill; assumed to be 0
Uranium-238+D	0	Clean fill; assumed to be 0
Worker Scenarios		
	Ground Water Concentrations	
Chemicals (mg/L)	**95 % UCL**	**Notes**
Ammonia	11.41	Ammonia, total reported as N; Reduced by an order of magnitude based on general modeling results
Arsenic	0.00695	
Boron	0.127	
Cadmium (water)	0.00011	
Fluoride	0.1768	
Iron	0.2397	
Lithium	0.02485	
Manganese (nonfood)	0.1662	
Molybdenum	0.03589	
Nitrate	14.77	Reduced by an order of magnitude based on general modeling results
Selenium	0.00733	
Strontium	1.44	

Table D–11. On Site–Exposure Point Concentrations (continued)

Uranium	0.5738	
Vanadium	0.1324	
Radionuclides (pCi/L)		
Radon-222	221.1	
Radium-226	1.531	
Radium-228	3	
Uranium-234	1805	
Uranium-238	1901	
	Soil concentrations	
Exposure is assumed not to occur to adults under a worker scenario.		
	NH_3 in Air	
		Notes
NH_3 (mg/m^3)	0.01	Based on NH_3 conc. In water; default from EPA 1991a of 0.0005; conversion factor of 1,000 L/m^3, conversion from NH_4 to NH_3.
		NH_3 conc. in air = water conc. × water-to-air volatilization factor × conversion factor
		NH_3 available in water based on a temperature of 20 C and a pH of 7.5 from Emerson 1975. 1.24 % is un-ionized NH_3
		Reduced by an order of magnitude for the on-site alternative compared to the no action

Table D−12. On-Site—Risk Summary for the Residential Scenario (Adult)

	Added Cancer Risk							
					Residential Scenario Combined Pathways			
	Soil Ingestion		**Vegetable Ingestion**		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Arsenic	NA	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	NA
Total	NA	NA	0.00E+00	0.00E+00	0.00E+00		0.00E+00	
	Soil Ingestion		**Vegetable Ingestion**		**Compound Contribution**		**Compound Contribution**	
Radionuclide	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Radon-222	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226+D	NA	NA	NA	NA	NA	NA	NA	NA
Radium-228+D	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-234	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-238+D	NA	NA	NA	NA	NA	NA	NA	NA
Total	NA	NA	NA	NA	NA	NA	NA	NA
Pathway Contribution %								
	Noncarcinogenic Risks							
					Residential Scenario Combined Pathways			
	Soil Ingestion		**Vegetable Ingestion**		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Ammonia	NA	NA	NA	NA	NA	NA	NA	NA
Arsenic	NA	NA	0.00	0.00	0.00	NA	0.00	NA
Boron	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	NA	NA	NA	NA	NA	NA	NA	NA
Fluoride	NA	NA	NA	NA	NA	NA	NA	NA
Iron	NA	NA	NA	NA	NA	NA	NA	NA
Lithium	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	NA	NA	NA	NA	NA	NA	NA	NA
Molybdenum	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate	NA	NA	NA	NA	NA	NA	NA	NA
Selenium	NA	NA	NA	NA	NA	NA	NA	NA
Strontium	NA	NA	NA	NA	NA	NA	NA	NA
Uranium	NA	NA	0.00	0.00	0.00	NA	0.00	NA
Vanadium	NA	NA	0.00	0.00	0.00	NA	0.00	NA
Total	0.00	0.00	0.00	0.00	0.00	NA	0.00	NA

Table D−13. On-Site—Risk Summary for the Residential Scenario (Children)[a]

	Added Cancer Risk							
	Soil Ingestion		Vegetable Ingestion		Compound Contribution		Compound Contribution	
Chemical	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Arsenic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	NA
Total	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	
					Residential Scenario Combined Pathways			
	Soil Ingestion		**Vegetable Ingestion**		**Compound Contribution**		**Compound Contribution**	
Radionuclide	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Radon-222	0	0	NA	NA	NA	NA	NA	NA
Radium-226+D	0.00E+00	0.00E+00	NA	NA	0.00E+00	NA	0.00E+00	NA
Radium-228+D	0.00E+00	0.00E+00	NA	NA	0.00E+00	NA	0.00E+00	NA
Uranium-234	0.00E+00	0.00E+00	NA	NA	0.00E+00	NA	0.00E+00	NA
Uranium-238+D	0.00E+00	0.00E+00	NA	NA	0.00E+00	NA	0.00E+00	NA
Total	0.00E+00	0.00E+00	NA	NA	0.00E+00	NA	0.00E+00	NA
Pathway Contribution %								
	Noncarcinogenic Risks							
					Residential Scenario Combined Pathways			
	Soil Ingestion		**Vegetable Ingestion**		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Ammonia	NA	NA	NA	NA	NA	NA	NA	NA
Arsenic	0.00	0.00	0.00	0.00	0.00	NA	0.00	NA
Boron	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	NA	NA	NA	NA	NA	NA	NA	NA
Fluoride	NA	NA	NA	NA	NA	NA	NA	NA
Iron	NA	NA	NA	NA	NA	NA	NA	NA
Lithium	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	NA	NA	NA	NA	NA	NA	NA	NA
Molybdenum	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate	NA	NA	NA	NA	NA	NA	NA	NA
Selenium	NA	NA	NA	NA	NA	NA	NA	NA
Strontium	NA	NA	NA	NA	NA	NA	NA	NA
Uranium	0.00	0.00	0.00	0.00	0.00	NA	0.00	NA
Vanadium	0.00	0.00	0.00	0.00	0.00	NA	0.00	NA
Total	0.00	0.00	0.00	0.00	0.00	NA	0.00	NA

[a]Assumes a clean source of domestic water and that all contaminated soil is isolated in the repository.

Table D−14. On-Site—Risk Summary for the Rafting Scenario (Children)[a]

	Added Cancer Risk							
					Rafter Scenario Combined Pathways			
	SW Ingestion		**Dermal**		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Arsenic	7.42E-10	9.27E-10	9.01E-12	1.10E-11	7.51E-10	100%	9.38E-10	100%
Total	7.42E-10	9.27E-10	9.01E-12	1.10E-11	7.51E-10		9.38E-10	
Pathway Contribution %	98.8%	98.8%	1.2%	1.2%				
	SW Ingestion		**Dermal**		**Compound Contribution**		**Compound Contribution**	
Radionuclide	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Radon-222	0.00	0.00	NA	NA	0.00E+00	0.0%	0.00E+00	0.0%
Radium-226+D	0.00	0.00	NA	NA	7.13E-13	0.1%	8.91E-13	0.1%
Radium-228+D	0.00	0.00	NA	NA	1.35E-11	1.0%	1.68E-11	1.0%
Uranium-234	0.00	0.00	NA	NA	5.92E-10	43.0%	7.41E-10	43.0%
Uranium-238+D	0.00	0.00	NA	NA	7.70E-10	55.9%	9.63E-10	55.9%
Total	0.00	0.00	NA	NA	1.38E-09	100.0%	1.72E-09	100.0%
Pathway Contribution %								
	Noncarcinogenic Risks							
					Rafter Scenario Combined Pathways			
	SW Ingestion		**Dermal**		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Ammonia	NA	NA	NA	NA	NA	NA	NA	NA
Arsenic	0.00	0.00	0.00	0.00	0.00	8.9%	0.00	8.9%
Boron	0.00	0.00	0.00	0.00	0.00	0.5%	0.00	0.5%
Cadmium	0.00	0.00	0.00	0.00	0.00	0.1%	0.00	0.1%
Fluoride	0.00	0.00	0.00	0.00	0.00	1.1%	0.00	1.1%
Iron	0.00	0.00	0.00	0.00	0.00	0.3%	0.00	0.3%
Lithium	0.00	0.00	0.00	0.00	0.00	0.5%	0.00	0.5%
Manganese	0.00	0.00	0.00	0.00	0.00	0.1%	0.00	0.1%
Molybdenum	0.00	0.00	0.00	0.00	0.00	2.8%	0.00	2.8%
Nitrate	0.00	0.00	NA	NA	0.00	3.5%	0.00	3.5%
Selenium	0.00	0.00	0.00	0.00	0.00	0.6%	0.00	0.6%
Strontium	0.00	0.00	0.00	0.00	0.00	0.9%	0.00	0.9%
Uranium	0.00	0.00	0.00	0.00	0.00	73.4%	0.00	73.4%
Vanadium	0.00	0.00	0.00	0.00	0.00	7.3%	0.00	7.3%
Total	0.00	0.00	0.00	0.00	0.00	100.0%	0.00	100.0%
Pathway Contribution %								

[a]Assumes no contaminated soil is available for exposure.

Table D−15. On-Site—Risk Summary for the Camping Scenario (Adult)

		Added Cancer Risk				
			Camping Scenario Combined Pathways			
	SW Ingestion		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Arsenic	6.53E-09	8.16E-07	6.53E-09	100%	8.16E-07	100%
Total	6.53E-09	8.16E-07	6.53E-09		8.16E-07	
	SW Ingestion		**Compound Contribution**		**Compound Contribution**	
Radionuclide	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Radon-222	0.00E+00	0.00E+00	0.00E+00	0.0%	0.00E+00	0.0%
Radium-226+D	2.00E-11	3.57E-11	2.00E-11	0.1%	3.57E-11	0.1%
Radium-228+D	3.77E-10	6.73E-10	3.77E-10	1.0%	6.73E-10	1.0%
Uranium-234	1.66E-08	2.96E-08	1.66E-08	43.0%	2.96E-08	43.0%
Uranium-238+D	2.16E-08	3.85E-08	2.16E-08	55.9%	3.85E-08	55.9%
Total	3.86E-08	6.88E-08	3.86E-08		6.88E-08	100.0%
		Noncarcinogenic Risks				
			Camping Scenario Combined Pathways			
	SW Ingestion		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Ammonia	NA	NA	NA	NA	NA	NA
Arsenic	0.00	0.00	0.00	0.0%	0.00	0.0%
Boron	0.01	0.01	0.01	35.0%	0.01	35.0%
Cadmium	0.00	0.00	0.00	0.1%	0.00	0.1%
Fluoride	0.00	0.00	0.00	0.8%	0.00	0.8%
Iron	0.00	0.00	0.00	0.2%	0.00	0.2%
Lithium	0.00	0.00	0.00	0.3%	0.00	0.3%
Manganese	0.00	0.00	0.00	0.1%	0.00	0.1%
Molybdenum	0.00	0.00	0.00	2.0%	0.00	2.0%
Nitrate	0.00	0.00	0.00	2.5%	0.00	2.5%
Selenium	0.00	0.00	0.00	0.4%	0.00	0.4%
Strontium	0.00	0.00	0.00	0.7%	0.00	0.7%
Uranium	0.01	0.01	0.01	52.7%	0.01	52.7%
Vanadium	0.00	0.00	0.00	5.2%	0.00	5.2%
Total	0.02	0.03	0.02	100%	0.03	100.0%

Table D−16. On-Site—Risk Summary for the Camping Scenario (Children)

	Added Cancer Risk							
					Camping Scenario Combined Pathways			
	SW Ingestion		**Dermal**		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Arsenic	1.10E-08	2.39E-08	1.80E-11	8.01E-10	1.10E-08	100%	2.47E-08	100%
Total	1.10E-08	2.39E-08	1.80E-11	8.01E-10	1.10E-08		2.47E-08	
Pathway Contribution %	99.8%	96.8%	0.2%	3.2%				
					Camping Scenario Combined Pathways			
	SW Ingestion		**Dermal**		**Compound Contribution**		**Compound Contribution**	
Radionuclide	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Radon-222	0.00E+00	0.00E+00	NA	NA	0.00E+00	0.0%	0.00E+00	0.0%
Radium-226+D	1.06E-11	2.30E-11	NA	NA	1.06E-11	0.1%	2.30E-11	0.1%
Radium-228+D	1.99E-10	4.34E-10	NA	NA	1.99E-10	1.0%	4.34E-10	1.0%
Uranium-234	8.77E-09	1.91E-08	NA	NA	8.77E-09	43.0%	1.91E-08	43.0%
Uranium-238+D	1.14E-08	2.48E-08	NA	NA	1.14E-08	55.9%	2.48E-08	55.9%
Total	2.04E-08	4.44E-08	NA	NA	2.04E-08	100.0%	4.44E-08	100.0%
Pathway Contribution %								
	Noncarcinogenic Risks							
					Camping Scenario Combined Pathways			
	SW Ingestion		**Dermal**		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Ammonia	NA	NA	NA	NA	NA	NA	NA	NA
Arsenic	0.00	0.00	0.00	0.00	0.00	8.9%	0.00	8.9%
Boron	0.00	0.00	0.00	0.00	0.00	0.5%	0.00	0.5%
Cadmium	0.00	0.00	0.00	0.00	0.00	0.1%	0.00	0.1%
Fluoride	0.00	0.00	0.00	0.00	0.00	1.1%	0.00	1.1%
Iron	0.00	0.00	0.00	0.00	0.00	0.3%	0.00	0.3%
Lithium	0.00	0.00	0.00	0.00	0.00	0.0%	0.00	0.0%
Manganese	0.00	0.00	0.00	0.00	0.00	0.1%	0.00	0.1%
Molybdenum	0.00	0.00	0.00	0.00	0.00	2.8%	0.00	2.8%
Nitrate	0.00	0.00	NA	NA	0.00	3.6%	0.00	3.6%
Selenium	0.00	0.00	0.00	0.00	0.00	0.6%	0.00	0.6%
Strontium	0.00	0.00	0.00	0.00	0.00	0.9%	0.00	0.9%
Uranium	0.01	0.03	0.00	0.00	0.01	73.8%	0.03	73.8%
Vanadium	0.00	0.00	0.00	0.00	0.00	7.3%	0.00	7.3%
Total	0.02	0.04	0.00	0.00	0.02	100.0%	0.04	100.0%
Pathway Contribution %	99.8%	99.8%	0.2%	0.2%				

Table D−17. On-Site—Risk Summary for the Outside Worker Scenario (Adult)[a]

	Added Cancer Risk					
			Outside Worker Scenario Combined Pathways			
	Dermal		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Arsenic	1.36E-08	1.01E-07	1.36E-08	100.0%	1.01E-07	100.0%
Total	1.36E-08	1.01E-07	1.36E-08		1.01E-07	
			Outside Worker Scenario Combined Pathway			
	Dermal		**Compound Contribution**		**Compound Contribution**	
Radionuclide	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Radon-222	NA	NA	NA	NA	NA	NA
Radium-226+D	NA	NA	NA	NA	NA	NA
Radium-228+D	NA	NA	NA	NA	NA	NA
Uranium-234	NA	NA	NA	NA	NA	NA
Uranium-238+D	NA	NA	NA	NA	NA	NA
Total	NA	NA	NA	NA	NA	NA
	Noncarcinogenic Risks					
			Outside Worker Scenario Combined Pathway			
	Dermal		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Ammonia	NA	NA	NA	NA	NA	NA
Arsenic	0.00	0.00	0.00	9.2%	0.00	9.2%
Boron	0.00	0.00	0.00	0.6%	0.00	0.6%
Cadmium	0.00	0.00	0.00	0.1%	0.00	0.1%
Fluoride	0.00	0.00	0.00	1.2%	0.00	1.2%
Iron	0.00	0.00	0.00	0.3%	0.00	0.3%
Lithium	0.00	0.00	0.00	0.5%	0.00	0.5%
Manganese	0.00	0.00	0.00	0.1%	0.00	0.1%
Molybdenum	0.00	0.00	0.00	2.9%	0.00	2.9%
Nitrate	NA	NA	NA	NA	NA	0.00
Selenium	0.00	0.00	0.00	0.6%	0.00	0.6%
Strontium	0.00	0.00	0.00	1.0%	0.00	1.0%
Uranium	0.00	0.01	0.00	76.1%	0.01	76.1%
Vanadium	0.00	0.00	0.00	7.5%	0.00	7.5%
Total	0.00	0.01	0.00	100.0%	0.01	100.0%

[a]Assumed clean fill material and an alternate clean water source.

Table D−18. On-Site—Overall Summary for All Receptors and Pathways

	Added Cancer (Unitless Probability)				**Noncarcinogenic Risks (HI)**		**Notes**
	Chemical		**Radionuclides**				
Receptor	**CT**	**RME**	**CT**	**RME**	**CT**	**RME**	
Resident							Assumes clean, municipal source of domestic water
Adult	0.00E+00	0.00E+00	NA	NA	0.00	0.00	Assumes clean fill at the site from borrow areas
Child	0.00E+00	0.00E+00			0.00	0.00	
Rafter							Assumes one day of exposure per year
Child	7.51E-10	9.38E-10	1.38E-09	1.72E-09	0.00	0.00	Exposure is from child playing in water
Camper							Assumes one day of exposure per year
Adult	6.53E-09	8.16E-07	3.86E-08	6.88E-08	0.02	0.03	Clean soil in areas of exposure
Child	1.10E-08	2.47E-08	2.04E-08	4.44E-08	0.02	0.04	
Outside Worker							Assumes clean, municipal source of domestic water
Adult	1.36E-08	1.01E-07	NA	NA	0.00	0.01	

Table D−19. Off-Site—Exposure Point Concentrations

Presents contaminant concentrations by medium for each exposure scenario.		
Residential Scenario		
	Ground Water Concentrations (Northeast area)	
Chemicals (mg/L)	**95 % UCL**	**Notes**
Ammonia	1.141	Ammonia, total reported as N; Reduced by two orders of magnitude based on general modeling results
Arsenic	0.000695	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Boron	0.0127	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Cadmium	0.000011	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Fluoride	0.01768	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Iron	0.02397	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Lithium	0.002485	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Manganese (nonfood)	0.01662	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Molybdenum	0.003589	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Nitrate	1.477	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Selenium	0.000733	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Strontium	0.144	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Uranium	0.05738	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Vanadium	0.01324	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Radionuclides		
Radon-222	2.301	Unfiltered; Reduced by an order of magnitudes based on general modeling results
Radium-226	0.004618	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Radium-228	0.03237	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Uranium-234	20.95	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Uranium-238	22.11	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
	Soil concentrations	
Chemicals (mg/kg)	**95 % UCLs**	
Ammonium	0	Clean fill; assumed to be 0
Arsenic	0	Clean fill; assumed to be 0
Uranium (mg/kg)	0	Clean fill; assumed to be 0
Vanadium	0	Clean fill; assumed to be 0
Sulfate	0	Clean fill; assumed to be 0
Radionuclides (pCi/g)	**95 % UCLs**	
Radium-226	0	Clean fill; assumed to be 0
Thorium-230	0	Clean fill; assumed to be 0
Uranium-234	0	Clean fill; assumed to be 0
Uranium-238+D	0	Clean fill; assumed to be 0

Table D–19. Off Site—Exposure Point Concentrations (continued)

	NH_3 in Air	
		Notes
NH_3 (mg/m^3)	0.00	Based on NH_3 conc. In water; default form EPA 1991a of 0.0005; conversion factor of 1,000 L/ m^3, conversion from NH_4 to NH_3.
		NH_3 conc. in air = water conc. x water-to-air volatilization factor x conversion factor
		NH_3 available in water based on a temperature of 20 C and a pH of 7.5 from Emerson 1975. 1.24 % is un-ionized NH_3
		Reduced by an order of magnitude over the no action for the cap in place
	Food Concentrations (Vegetables)	
Chemicals (mg/kg)		Notes
Arsenic	0.00	Uptake value of 0.08; default from RESRAD (ANL 1993), Table C.3
Uranium	0.00	Uptake value of 0.0025; default from RESRAD (ANL 1993), Table C.3
Vanadium	0.00	Uptake value of 0.007; 90 % UCL from the Weinberg Group, Inc. 2000, Table C-1
Camper and Rafter Scenarios		
	Ground Water (assumed surface water) Concentrations	
Chemicals (mg/L)	**95 % UCL**	**Notes**
Ammonia	1.141	Ammonia, total reported as N; Reduced by two orders of magnitude based on general modeling results
Arsenic	0.000695	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Boron	0.0127	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Cadmium (water)	0.000011	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Fluoride	0.01768	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Iron	0.02397	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Lithium	0.002485	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Manganese (nonfood)	0.01662	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Molybdenum	0.003589	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Nitrate	1.477	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Selenium	0.000733	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Strontium	0.144	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Uranium	0.05738	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Vanadium	0.01324	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Radionuclides		
Radon-222	2.301	Unfiltered; Reduced by an order of magnitudes based on general modeling results
Radium-226	0.004618	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Radium-228	0.03237	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Uranium-234	20.95	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Uranium-238	22.11	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
	Soil concentrations	
Chemicals (mg/kg)	**95 % UCLs**	**Notes**
Arsenic	0	Clean fill; assumed to be 0
Uranium (mg/kg)	0	Clean fill; assumed to be 0
Vanadium	0	Clean fill; assumed to be 0

Table D–19. Off Site—Exposure Point Concentrations (continued)

Radionuclides (pCi/g)	**95 % UCLs**	**Notes**
Radium-226	0	Clean fill; assumed to be 0
Thorium-230	0	Clean fill; assumed to be 0
Uranium-234	0	Clean fill; assumed to be 0
Uranium-238+D	0	Clean fill; assumed to be 0
Worker Scenarios		
	Ground Water Concentrations	
Chemicals (mg/L)	**95 % UCL**	**Notes**
Ammonia	1.141	Ammonia, total reported as N; Reduced by two orders of magnitude based on general modeling results
Arsenic	0.000695	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Boron	0.0127	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Cadmium (water)	0.000011	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Fluoride	0.01768	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Iron	0.02397	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Lithium	0.002485	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Manganese (nonfood)	0.01662	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Molybdenum	0.003589	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Nitrate	1.477	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Selenium	0.000733	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Strontium	0.144	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Uranium	0.05738	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Vanadium	0.01324	Reduced by two orders of magnitude compared to the no action alternative based on general modeling results
Radionuclides (pCi/L)		
Radon-222	221.1	
Radium-226	1.531	
Radium-228	3	
Uranium-234	1805	
Uranium-238	1901	
	Soil concentrations	
Exposure is assumed not to occur to adults under a worker scenario.		
	NH_3 in Air	
		Notes
NH_3 (mg/m^3)	0.00	Based on NH_3 conc. In water; default form EPA 1991a of 0.0005; conversion factor of 1,000 L/ m^3, conversion from NH_4 to NH_3.
		NH_3 conc. in air = water conc. × water-to-air volatilization factor × conversion factor
		NH_3 available in water based on a temperature of 20 C and a pH of 7.5 from Emerson 1975. 1.24 % is un-ionized NH_3
		Reduced by two orders of magnitude compared to the no action alternative based on general modeling results

Table D−20. Off-Site—Risk Summary for the Residential Scenario (Adult)

					Residential Scenario Combined Pathways			
	Added Cancer Risk							
	Soil Ingestion		Vegetable Ingestion		Compound Contribution		Compound Contribution	
Chemical	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Arsenic	NA	NA	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	NA
Total	NA	NA	0.00E+00	0.00E+00	0.00E+00		0.00E+00	
	Soil Ingestion		**Vegetable Ingestion**		**Compound Contribution**		**Compound Contribution**	
Radionuclide	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Radon-222	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226+D	NA	NA	NA	NA	NA	NA	NA	NA
Radium-228+D	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-234	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-238+D	NA	NA	NA	NA	NA	NA	NA	NA
Total	NA	NA	NA	NA	NA	NA	NA	NA
Pathway Contribution %								
	Noncarcinogenic Risks							
					Residential Scenario Combined Pathways			
	Soil Ingestion		**Vegetable Ingestion**		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Ammonia	NA	NA	NA	NA	NA	NA	NA	NA
Arsenic	NA	NA	0.00	0.00	0.00	NA	0.00	NA
Boron	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	NA	NA	NA	NA	NA	NA	NA	NA
Fluoride	NA	NA	NA	NA	NA	NA	NA	NA
Iron	NA	NA	NA	NA	NA	NA	NA	NA
Lithium	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	NA	NA	NA	NA	NA	NA	NA	NA
Molybdenum	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate	NA	NA	NA	NA	NA	NA	NA	NA
Selenium	NA	NA	NA	NA	NA	NA	NA	NA
Strontium	NA	NA	NA	NA	NA	NA	NA	NA
Uranium	NA	NA	0.00	0.00	0.00	NA	0.00	NA
Vanadium	NA	NA	0.00	0.00	0.00	NA	0.00	NA
Total	0.00	0.00	0.00	0.00	0.00	NA	0.00	NA

Table D−21. Off-Site—Risk Summary for the Residential Scenario (Children)[a]

	Added Cancer Risk							
					Residential Scenario Combined Pathways			
	Soil Ingestion		**Vegetable Ingestion**		**Compound**	**Contribution**	**Compound**	**Contribution**
Chemical	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Arsenic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA	0.00E+00	NA
Total	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.00E+00	
	Soil Ingestion		**Vegetable Ingestion**		**Compound**	**Contribution**	**Compound**	**Contribution**
Radionuclide	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Radon-222	0	0	NA	NA	NA	NA	NA	NA
Radium-226+D	0.00E+00	0.00E+00	NA	NA	0.00E+00	NA	0.00E+00	NA
Radium-228+D	0.00E+00	0.00E+00	NA	NA	0.00E+00	NA	0.00E+00	NA
Uranium-234	0.00E+00	0.00E+00	NA	NA	0.00E+00	NA	0.00E+00	NA
Uranium-238+D	0.00E+00	0.00E+00	NA	NA	0.00E+00	NA	0.00E+00	NA
Total	0.00E+00	0.00E+00	NA	NA	0.00E+00	0.0%	0.00E+00	0.00%
Pathway Contribution %								
	Noncarcinogenic Risks							
					Residential Scenario Combined Pathways			
	Soil Ingestion		**Vegetable Ingestion**		**Compound**	**Contribution**	**Compound**	**Contribution**
Chemical	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Ammonia	NA	NA	NA	NA	NA	NA	NA	NA
Arsenic	0.00	0.00	0.00	0.00	0.00	NA	0.00	NA
Boron	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	NA	NA	NA	NA	NA	NA	NA	NA
Fluoride	NA	NA	NA	NA	NA	NA	NA	NA
Iron	NA	NA	NA	NA	NA	NA	NA	NA
Lithium	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	NA	NA	NA	NA	NA	NA	NA	NA
Molybdenum	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate	NA	NA	NA	NA	NA	NA	NA	NA
Selenium	NA	NA	NA	NA	NA	NA	NA	NA
Strontium	NA	NA	NA	NA	NA	NA	NA	NA
Uranium	0.00	0.00	0.00	0.00	0.00	NA	0.00	NA
Vanadium	0.00	0.00	0.00	0.00	0.00	NA	0.00	NA
Total	0.00	0.00	0.00	0.00	0.00	NA	0.00	NA

[a]Assumes a clean source of domestic water and that all contaminated soil is isolated in the repository.

Table D−22. Off-Site—Risk Summary for the Rafting Scenario (Children)[a]

			Added Cancer Risk					
					Rafter Scenario Combined Pathways			
	SW Ingestion		**Dermal**		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Arsenic	7.42E-11	9.27E-11	9.01E-13	1.10E-12	7.51E-11	100%	9.38E-11	100%
Total	7.42E-11	9.27E-11	9.01E-13	1.10E-12	7.51E-11		9.38E-11	
Pathway Contribution %	98.8%	98.8%	1.2%	1.2%				
Radionuclide	**SW Ingestion**		**Dermal**		**Compound Contribution**		**Compound Contribution**	
	CT	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Radon-222	0.00	0.00	NA	NA	0.00E+00	0.0%	0.00E+00	0.0%
Radium-226+D	0.00	0.00	NA	NA	7.13E-14	0.1%	8.91E-14	0.1%
Radium-228+D	0.00	0.00	NA	NA	1.35E-12	1.0%	1.68E-12	1.0%
Uranium-234	0.00	0.00	NA	NA	5.92E-11	43.0%	7.41E-11	43.0%
Uranium-238+D	0.00	0.00	NA	NA	7.70E-11	55.9%	9.63E-11	55.9%
Total	0.00	0.00	NA	NA	1.38E-10	100.0%	1.72E-10	100.0%
Pathway Contribution %								
			Noncarcinogenic Risks					
					Rafter Scenario Combined Pathways			
Chemical	**SW Ingestion**		**Dermal**		**Compound Contribution**		**Compound Contribution**	
	CT	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Ammonia	NA	NA	NA	NA	NA	NA	NA	NA
Arsenic	0.00	0.00	0.00	0.00	0.00	8.9%	0.00	8.9%
Boron	0.00	0.00	0.00	0.00	0.00	0.5%	0.00	0.5%
Cadmium	0.00	0.00	0.00	0.00	0.00	0.1%	0.00	0.1%
Fluoride	0.00	0.00	0.00	0.00	0.00	1.1%	0.00	1.1%
Iron	0.00	0.00	0.00	0.00	0.00	0.3%	0.00	0.3%
Lithium	0.00	0.00	0.00	0.00	0.00	0.5%	0.00	0.5%
Manganese	0.00	0.00	0.00	0.00	0.00	0.1%	0.00	0.1%
Molybdenum	0.00	0.00	0.00	0.00	0.00	2.8%	0.00	2.8%
Nitrate	0.00	0.00	NA	NA	0.00	3.5%	0.00	3.5%
Selenium	0.00	0.00	0.00	0.00	0.00	0.6%	0.00	0.6%
Strontium	0.00	0.00	0.00	0.00	0.00	0.9%	0.00	0.9%
Uranium	0.00	0.00	0.00	0.00	0.00	73.4%	0.00	73.4%
Vanadium	0.00	0.00	0.00	0.00	0.00	7.3%	0.00	7.3%
Total	0.00	0.00	0.00	0.00	0.00	100.0%	0.00	100.0%
Pathway Contribution %								

[a]Assumes no contaminated soil is available for exposure.

Table D−23. Off-Site—Risk Summary for the Camping Scenario (Adult)

	Added Cancer Risk					
			Camping Scenario Combined Pathways			
	SW Ingestion		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Arsenic	6.53E-10	8.16E-08	6.53E-10	100%	8.16E-08	100%
Total	6.53E-10	8.16E-08	6.53E-10		8.16E-08	
	SW Ingestion		**Compound Contribution**		**Compound Contribution**	
Radionuclide	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Radon-222	0.00E+00	0.00E+00	0.00E+00	0.0%	0.00E+00	0.0%
Radium-226+D	2.00E-12	3.57E-12	2.00E-12	0.1%	3.57E-12	0.1%
Radium-228+D	3.77E-11	6.73E-11	3.77E-11	1.0%	6.73E-11	1.0%
Uranium-234	1.66E-09	2.96E-09	1.66E-09	43.0%	2.96E-09	43.0%
Uranium-238+D	2.16E-09	3.85E-09	2.16E-09	55.9%	3.85E-09	55.9%
Total	3.86E-09	6.88E-09	3.86E-09		6.88E-09	100.0%
	Noncarcinogenic Risks					
			Camping Scenario Combined Pathways			
	SW Ingestion		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Ammonia	NA	NA	NA	NA	NA	NA
Arsenic	0.00	0.00	0.00	0.0%	0.00	0.0%
Boron	0.00	0.00	0.00	35.0%	0.00	35.0%
Cadmium	0.00	0.00	0.00	0.1%	0.00	0.1%
Fluoride	0.00	0.00	0.00	0.8%	0.00	0.8%
Iron	0.00	0.00	0.00	0.2%	0.00	0.2%
Lithium	0.00	0.00	0.00	0.3%	0.00	0.3%
Manganese	0.00	0.00	0.00	0.1%	0.00	0.1%
Molybdenum	0.00	0.00	0.00	2.0%	0.00	2.0%
Nitrate	0.00	0.00	0.00	2.5%	0.00	2.5%
Selenium	0.00	0.00	0.00	0.4%	0.00	0.4%
Strontium	0.00	0.00	0.00	0.7%	0.00	0.7%
Uranium	0.00	0.00	0.00	52.7%	0.00	52.7%
Vanadium	0.00	0.00	0.00	5.2%	0.00	5.2%
Total	0.00	0.00	0.00	100%	0.00	100.0%

Table D−24. Off-Site—Risk Summary for the Camping Scenario (Children)[a]

	Added Cancer Risk									
							Camping Scenario Combined Pathways			
	SW Ingestion		**Dermal**		**Soil Ingestion**		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Arsenic	1.10E-09	2.39E-09	1.80E-12	8.01E-11	0.00E+00	0.00E+00	1.10E-09	100%	2.47E-09	100%
Total	1.10E-09	2.39E-09	1.80E-12	8.01E-11	0.00E+00	0.00E+00	1.10E-09		2.47E-09	
Pathway Contribution %	99.8%	96.8%	0.2%	3.2%	0.0%	0.0%				
Radionuclide	**SW Ingestion**		**Dermal**		**Soil Ingestion**		**Compound Contribution**		**Compound Contribution**	
	CT	**RME**	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Radon-222	0.00E+00	0.00E+00	NA	NA	0	0	0.00E+00	0.0%	0.00E+00	0.0%
Radium-226+D	1.06E-12	2.30E-12	NA	NA	0.00E+00	0.00E+00	1.06E-12	0.1%	2.30E-12	0.1%
Radium-228+D	1.99E-11	4.34E-11	NA	NA	0.00E+00	0.00E+00	1.99E-11	1.0%	4.34E-11	1.0%
Uranium-234	8.77E-10	1.91E-09	NA	NA	0.00E+00	0.00E+00	8.77E-10	43.0%	1.91E-09	43.0%
Uranium-238+D	1.14E-09	2.48E-09	NA	NA	0.00E+00	0.00E+00	1.14E-09	55.9%	2.48E-09	55.9%
Total	2.04E-09	4.44E-09	NA	NA	0.00E+00	0.00E+00	2.04E-09	100.0%	4.44E-09	100.0%
Pathway Contribution %										
	Noncarcinogenic Risks									
							Camping Scenario Combined Pathways			
Chemical	**SW Ingestion**		**Dermal**		**Soil Ingestion**		**Compound Contribution**		**Compound Contribution**	
	CT	**RME**	**CT**	**RME**	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Ammonia	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Arsenic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.9%	0.00	8.9%
Boron	0.00	0.00	0.00	0.00	NA	NA	0.00	0.5%	0.00	0.5%
Cadmium	0.00	0.00	0.00	0.00	NA	NA	0.00	0.1%	0.00	0.1%
Fluoride	0.00	0.00	0.00	0.00	NA	NA	0.00	1.1%	0.00	1.1%
Iron	0.00	0.00	0.00	0.00	NA	NA	0.00	0.3%	0.00	0.3%
Lithium	0.00	0.00	0.00	0.00	NA	NA	0.00	0.0%	0.00	0.0%
Manganese	0.00	0.00	0.00	0.00	NA	NA	0.00	0.1%	0.00	0.1%
Molybdenum	0.00	0.00	0.00	0.00	NA	NA	0.00	2.8%	0.00	2.8%
Nitrate	0.00	0.00	NA	NA	NA	NA	0.00	3.6%	0.00	3.6%
Selenium	0.00	0.00	0.00	0.00	NA	NA	0.00	0.6%	0.00	0.6%
Strontium	0.00	0.00	0.00	0.00	NA	NA	0.00	0.9%	0.00	0.9%
Uranium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	73.8%	0.00	73.8%
Vanadium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.3%	0.00	7.3%
Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.0%	0.00	100.0%
Pathway Contribution %	99.8%	99.8%	0.2%	0.2%	0.0%	0.0%				

[a]Assumes no contaminated soil available for exposure.

Table D−25. Off-Site—Risk Summary for the Outside Worker Scenario (Adult)[a]

	Added Cancer Risk					
			Outside Worker Scenario Combined Pathways			
	Dermal		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Arsenic	1.36E-09	1.01E-08	1.36E-09	100.0%	1.01E-08	100.0%
Total	1.36E-09	1.01E-08	1.36E-09		1.01E-08	
	Dermal		**Compound Contribution**		**Compound Contribution**	
Radionuclide	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Radon-222	NA	NA	NA	NA	NA	NA
Radium-226+D	NA	NA	NA	NA	NA	NA
Radium-228+D	NA	NA	NA	NA	NA	NA
Uranium-234	NA	NA	NA	NA	NA	NA
Uranium-238+D	NA	NA	NA	NA	NA	NA
Total	NA	NA	NA	NA	NA	NA
	Noncarcinogenic Risks					
			Outside Worker Scenario Combined Pathways			
	Dermal		**Compound Contribution**		**Compound Contribution**	
Chemical	**CT**	**RME**	**CT**	**%**	**RME**	**%**
Ammonia	NA	NA	NA	NA	NA	NA
Arsenic	0.00	0.00	0.00	9.2%	0.00	9.2%
Boron	0.00	0.00	0.00	0.6%	0.00	0.6%
Cadmium	0.00	0.00	0.00	0.1%	0.00	0.1%
Fluoride	0.00	0.00	0.00	1.2%	0.00	1.2%
Iron	0.00	0.00	0.00	0.3%	0.00	0.3%
Lithium	0.00	0.00	0.00	0.5%	0.00	0.5%
Manganese	0.00	0.00	0.00	0.1%	0.00	0.1%
Molybdenum	0.00	0.00	0.00	2.9%	0.00	2.9%
Nitrate	NA	NA	NA	NA	NA	0.00
Selenium	0.00	0.00	0.00	0.6%	0.00	0.6%
Strontium	0.00	0.00	0.00	1.0%	0.00	1.0%
Uranium	0.00	0.00	0.00	76.1%	0.00	76.1%
Vanadium	0.00	0.00	0.00	7.5%	0.00	7.5%
Total	0.00	0.00	0.00	100.0%	0.00	100.0%

[a]Assumed clean fill material and an alternate clean water source.

Table D−26. Off-Site—Overall Summary for All Receptors and Pathways

	Added Cancer (Unitless Probability)				Noncarcinogenic Risks (HI)		
	Chemical		Radionuclides				
Receptor	**CT**	**RME**	**CT**	**RME**	**CT**	**RME**	**Notes**
Resident							Assumes clean, municipal source of domestic water
Adult	0.00E+00	0.00E+00	NA	NA	0.00	0.00	Assumes clean fill at the site from borrow areas
Child	0.00E+00	0.00E+00			0.00	0.00	
Rafter							Assumes one day of exposure per year
Child	7.51E-11	9.38E-11	1.38E-10	1.72E-10	0.00	0.00	Exposure is from child play in water
Camper							Assumes one day of exposure per year
Adult	6.53E-10	8.16E-08	3.86E-09	6.88E-09	0.00	0.00	Clean soil in areas of exposure
Child	1.10E-09	2.47E-09	2.04E-09	4.44E-09	0.00	0.00	
Outside Worker							Assumes clean, municipal source of domestic water
Adult	1.36E-09	1.01E-08	NA	NA	0.00	0.00	Dermal exposure to contaminated ground water used for irrigation

D4.0 Construction Risks

This section provides additional information on the worksheets used to estimate fatalities from construction accidents and risks to workers and members of the public from exposure to radiological contamination that would occur during implementation of the various alternatives.

The following tables present calculation spreadsheets:

Table D−27. Klondike Flats Disposal Alternative–Truck

Moab Operations								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	25	52.5	4.5	236.25	2.16E-04	Scott et al. 2001	5.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	19	39.9	4.5	179.55	7.47E-05	Hoskin et al. 1994	1.34E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	1	2.1	4.5	9.45	3.88E-04	Scott et al. 2001	3.67E-03	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	22	46.2	4.5	207.90	3.29E-04	Scott et al. 2001	6.84E-02	
Mechanics	0	0	4.5	0.00	5.40E-05	Scott et al. 2001	0.00E+00	
Total							1.37E-01	
Vicinity Property								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	6	12.6	3	37.80	2.16E-04	Scott et al. 2001	8.16E-03	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	4	8.4	3	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	3	63.00	3.29E-04	Scott et al. 2001	2.07E-02	
Mechanics	0	0	3	0.00	5.40E-05	Scott et al. 2001	0.00E+00	
Total							3.08E-02	

Table D−27. Klondike Flats Disposal Alternative–Truck (continued)

Borrow Areas								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	7	14.7	4	58.80	2.16E-04	Scott et al. 2001	1.27E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	3	6.3	4	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	4	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	4	84.00	3.29E-04	Scott et al. 2001	2.76E-02	
Mechanics	0	0	4	0.00	5.40E-05	Scott et al. 2001	0.00E+00	
Total							4.22E-02	
Disposal Cell Operations								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	28	58.8	4.8	282.24	2.16E-04	Scott et al. 2001	6.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	16	33.6	4.8	161.28	7.47E-05	Hoskin et al. 1994	1.21E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	8	16.8	4.8	80.64	3.88E-04	Scott et al. 2001	3.13E-02	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	18	37.8	4.8	181.44	3.29E-04	Scott et al. 2001	5.97E-02	
Mechanics	0	0	4.8	0.00	5.40E-05	Scott et al. 2001	0.00E+00	
Total							1.64E-01	

Table D−27. Klondike Flats Disposal Alternative–Truck (continued)

Transportation Related Labor								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	0	0	3.5	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	9	18.9	3.5	66.15	7.47E-05	Hoskin et al. 1994	4.94E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3.5	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	0	0	3.5	0.00	3.29E-04	Scott et al. 2001	0.00E+00	
Mechanics	3	6.3	3.5	22.05	5.40E-05	Scott et al. 2001	1.19E-03	
Total							6.13E-03	

Table D−28. Klondike Flats Disposal Alternative–Truck Summary

	Moab Operations	Vicinity Properties	Borrow Areas	Disposal Cell	Transportation	Worker Total
Equipment Operators	25	6	7	28	0	66
Site Support	19	4	3	16	9	51
Truck Drivers	1	0	0	8	0	9
General Labor	22	10	10	18	0	60
Mechanics	0	0	0	0	3	3
Total	67	20	20	70	9	186

Table D−29. Klondike Flats Disposal Alternative–Rail

			Moab Operations					
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	25	52.5	4.5	236.25	2.16E-04	Scott et al. 2001	5.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	19	39.9	4.5	179.55	7.47E-05	Hoskin et al. 1994	1.34E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	1	2.1	4.5	9.45	3.88E-04	Scott et al. 2001	3.67E-03	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	22	46.2	4.5	207.90	3.29E-04	Scott et al. 2001	6.84E-02	
Conveyor Operators	0	0	4.5	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Assume fatality rate the same as operating engineer
Total							1.37E-01	
			Vicinity Property					
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	6	12.6	3	37.80	2.16E-04	Scott et al. 2001	8.16E-03	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	4	8.4	3	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	3	63.00	3.29E-04	Scott et al. 2001	2.07E-02	
Conveyor Operators	0	0	3	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Assume fatality rate the same as operating engineer
Total							3.08E-02	

Table D−29. Klondike Flats Disposal Alternative–Rail (continued)

			Borrow Areas					
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	7	14.7	3.5	51.45	2.16E-04	Scott et al. 2001	1.11E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	3	6.3	3.5	22.05	7.47E-05	Hoskin et al. 1994	1.65E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3.5	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	3.5	73.50	3.29E-04	Scott et al. 2001	2.42E-02	
Conveyor Operators	0	0	3.5	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Assume fatality rate the same as operating engineer
Total							3.69E-02	
			Disposal Cell Operations					
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	28	58.8	4.8	282.24	2.16E-04	Scott et al. 2001	6.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	16	33.6	4.8	161.28	7.47E-05	Hoskin et al. 1994	1.21E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	8	16.8	4.8	80.64	3.88E-04	Scott et al. 2001	3.13E-02	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	18	37.8	4.8	181.44	3.29E-04	Scott et al. 2001	5.97E-02	
Conveyor/Operators	0	0	4.8	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Assume fatality rate the same as operating engineer
Total							1.64E-01	

Table D−29. Klondike Flats Disposal Alternative–Rail (continued)

			Transportation Related Labor					
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	0	0	3.5	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Labor is from Section 2 and is based on a 3,600-hour year because of the 6 day work schedule for rail transport
Site Support	9	16.2	3.5	56.70	7.47E-05	Hoskin et al. 1994	4.24E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3.5	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	0	0	3.5	0.00	3.29E-04	Scott et al. 2001	0.00E+00	
Conveyor Operators	6	10.8	3.5	37.80	2.16E-04	Hoskin et al. 1994	8.16E-03	Assume fatality rate the same as operating engineer
Track Maintenance	1	1.8	3.5	6.30	7.62E-04	Scott et al. 2001	4.80E-03	Assume railroad worker fatality rates
Total							1.72E-02	

Table D−30. Klondike Flats Disposal Alternative–Rail Summary

	Moab Operations	Vicinity Properties	Borrow Areas	Disposal Cell	Transportation	Worker Total
Equipment Operators	25	6	7	28	0	66
Site Support	19	4	3	16	9	51
Truck Drivers	1	0	0	8	0	9
General Labor	22	10	10	18	0	60
Conveyor operators	0	0	0	0	6	6
Track Maintenance	0	0	0	0	1	1
Total	67	20	20	70	16	193

Table D−31. Klondike Flats Disposal Alternative–Slurry

Moab Operations								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	25	52.5	4.5	236.25	2.16E-04	Scott et al. 2001	5.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	19	39.9	4.5	179.55	7.47E-05	Hoskin et al. 1994	1.34E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	1	2.1	4.5	9.45	3.88E-04	Scott et al. 2001	3.67E-03	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	22	46.2	4.5	207.90	3.29E-04	Scott et al. 2001	6.84E-02	
System Operators	0	0	4.5	0.00	5.40E-05	Scott et al. 2001	0.00E+00	Operating engineer risk values
Total							1.37E-01	
Vicinity Property								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	6	12.6	3	37.80	2.16E-04	Scott et al. 2001	8.16E-03	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	4	8.4	3	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	3	63.00	3.29E-04	Scott et al. 2001	2.07E-02	
System Operators	0	0	3	0.00	5.40E-05	Scott et al. 2001	0.00E+00	Operating engineer risk values
Total							3.08E-02	

Table D−31. Klondike Flats Disposal Alternative–Slurry (continued)

Work Category	Labor	Labor/2000 h/yr	Years Worked	Person Years	Fatality Rate	Rate Reference	Fatalities	Notes
Borrow Areas								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	7	14.7	4	58.80	2.16E-04	Scott et al. 2001	1.27E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	3	6.3	4	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	4	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	4	84.00	3.29E-04	Scott et al. 2001	2.76E-02	
System Operators	0	0	4	0.00	5.40E-05	Scott et al. 2001	0.00E+00	Operating engineer risk values
Total							4.22E-02	
Disposal Cell Operations								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	28	58.8	4.8	282.24	2.16E-04	Scott et al. 2001	6.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
								Disposal cell is 4 and 10 months
Site Support	16	33.6	4.8	161.28	7.47E-05	Hoskin et al. 1994	1.21E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	8	16.8	4.8	80.64	3.88E-04	Scott et al. 2001	3.13E-02	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	18	37.8	4.8	181.44	3.29E-04	Scott et al. 2001	5.97E-02	
System Operators	0	0	4.8	0.00	5.40E-05	Scott et al. 2001	0.00E+00	Operating engineer risk values
Total							1.64E-01	

Table D−31. Klondike Flats Disposal Alternative–Slurry (continued)

Transportation Related Labor								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	0	0	3.5	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Labor is from Section 2 and is based on a 3,600-hour year because of the 6-day work schedule for rail transport
Site Support	4	7.2	3.5	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3.5	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	0	0	3.5	0.00	3.29E-04	Scott et al. 2001	0.00E+00	
System Operators	21	37.8	3.5	132.30	5.40E-05	Hoskin et al. 1994	7.14E-03	Operating engineer risk values
Pipeline Construction	250	450	0.5	225.00	2.32E-04	Scott et al. 2001	5.22E-02	Fatality rate is based on 50% general laborer, 25% mechanic and 25% equipment operator. General laborer has higher fatality rates
Total							6.12E-02	

Table D−32. Klondike Flats Disposal Alternative–Slurry Summary

	Moab Operations	**Vicinity Properties**	**Borrow Areas**	**Disposal Cell**	**Transportation**	**Worker Total**
Equipment Operators	25	6	7	28	0	66
Site Support	19	4	3	16	9	51
Truck Drivers	1	0	0	8	0	9
General Labor	22	10	10	18	0	60
System Operators	0	0	0	0	3	3
Pipeline Construction	67	20	20	70	9	186
Total	134	40	40	140	21	375

Table D−33. Crescent Junction Disposal Alternative–Truck

Work Category	Labor	Labor/2000 h/yr	Years Worked	Person Years	Fatality Rate	Rate Reference	Fatalities	Notes
Moab Operations								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	25	52.5	4.5	236.25	2.16E-04	Scott et al. 2001	5.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	19	39.9	4.5	179.55	7.47E-05	Hoskin et al. 1994	1.34E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	1	2.1	4.5	9.45	3.88E-04	Scott et al. 2001	3.67E-03	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	22	46.2	4.5	207.90	3.29E-04	Scott et al. 2001	6.84E-02	
Mechanics	0	0	4.5	0.00	5.40E-05	Scott et al. 2001	0.00E+00	
Total							1.37E-01	
Vicinity Property								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	6	12.6	3	37.80	2.16E-04	Scott et al. 2001	8.16E-03	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	4	8.4	3	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	3	63.00	3.29E-04	Scott et al. 2001	2.07E-02	
Mechanics	0	0	3	0.00	5.40E-05	Scott et al. 2001	0.00E+00	
Total							3.08E-02	

Table D−33. Crescent Junction Disposal Alternative–Truck (continued)

Borrow Areas								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	7	14.7	4	58.80	2.16E-04	Scott et al. 2001	1.27E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	3	6.3	4	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	4	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	4	84.00	3.29E-04	Scott et al. 2001	2.76E-02	
Mechanics	0	0	4	0.00	5.40E-05	Scott et al. 2001	0.00E+00	
Total							4.22E-02	
Disposal Cell Operations								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	28	58.8	4.8	282.24	2.16E-04	Scott et al. 2001	6.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	16	33.6	4.8	161.28	7.47E-05	Hoskin et al. 1994	1.21E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	8	16.8	4.8	80.64	3.88E-04	Scott et al. 2001	3.13E-02	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	18	37.8	4.8	181.44	3.29E-04	Scott et al. 2001	5.97E-02	
Mechanics	0	0	4.8	0.00	5.40E-05	Scott et al. 2001	0.00E+00	
Total							1.64E-01	

Table D−33. Crescent Junction Disposal Alternative–Truck (continued)

Transportation Related Labor								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	0	0	3.5	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	9	18.9	3.5	66.15	7.47E-05	Hoskin et al. 1994	4.94E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3.5	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	0	0	3.5	0.00	3.29E-04	Scott et al. 2001	0.00E+00	
Mechanics	4	8.4	3.5	29.40	5.40E-05	Scott et al. 2001	1.59E-03	
Total							6.53E-03	

Table D−34. Crescent Junction Disposal Alternative–Truck Summary

	Moab Operations	**Vicinity Properties**	**Borrow Areas**	**Disposal Cell**	**Transportation**	**Worker Total**
Equipment Operators	25	6	7	28	0	66
Site Support	19	4	3	16	9	51
Truck Drivers	1	0	0	8	0	9
General Labor	22	10	10	18	0	60
Mechanics	0	0	0	0	4	4
Total	67	20	20	70	9	186

Table D−35. Crescent Junction Disposal Alternative–Rail

Work Category	Labor	Labor/2000 h/yr	Years Worked	Person Years	Fatality Rate	Rate Reference	Fatalities	Notes
Moab Operations								
Equipment Operators	25	52.5	4.5	236.25	2.16E-04	Scott et al. 2001	5.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	19	39.9	4.5	179.55	7.47E-05	Hoskin et al. 1994	1.34E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	1	2.1	4.5	9.45	3.88E-04	Scott et al. 2001	3.67E-03	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	22	46.2	4.5	207.90	3.29E-04	Scott et al. 2001	6.84E-02	
Conveyor Operators	0	0	4.5	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Assume fatality rate the same as operating engineer
Total							1.37E-01	
Vicinity Property								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	6	12.6	3	37.80	2.16E-04	Scott et al. 2001	8.16E-03	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	4	8.4	3	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	3	63.00	3.29E-04	Scott et al. 2001	2.07E-02	
Conveyor Operators	0	0	3	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Assume fatality rate the same as operating engineer
Total							3.08E-02	

Table D−35. Crescent Junction Disposal Alternative–Rail (continued)

Work Category	Labor	Labor/2000 h/yr	Years Worked	Person Years	Fatality Rate	Rate Reference	Fatalities	Notes
Borrow Areas								
Equipment Operators	7	14.7	3.5	51.45	2.16E-04	Scott et al. 2001	1.11E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	3	6.3	3.5	22.05	7.47E-05	Hoskin et al. 1994	1.65E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3.5	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	3.5	73.50	3.29E-04	Scott et al. 2001	2.42E-02	
Conveyor Operators	0	0	3.5	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Assume fatality rate the same as operating engineer
Total							3.69E-02	
Disposal Cell Operations								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	28	58.8	4.8	282.24	2.16E-04	Scott et al. 2001	6.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	16	33.6	4.8	161.28	7.47E-05	Hoskin et al. 1994	1.21E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	8	16.8	4.8	80.64	3.88E-04	Scott et al. 2001	3.13E-02	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	18	37.8	4.8	181.44	3.29E-04	Scott et al. 2001	5.97E-02	
Conveyor Operators	0	0	4.8	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Assume fatality rate the same as operating engineer
Total							1.64E-01	

Table D−35. Crescent Junction Disposal Alternative–Rail (continued)

Transportation Related Labor								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	0	0	3.5	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Labor is from Section 2 and is based on a 3,600-hour year because of the 6-day work schedule for rail transport
Site Support	9	16.2	3.5	56.70	7.47E-05	Hoskin et al. 1994	4.24E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3.5	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	0	0	3.5	0.00	3.29E-04	Scott et al. 2001	0.00E+00	
Conveyor Operators	6	10.8	3.5	37.80	2.16E-04	Hoskin et al. 1994	8.16E-03	Assume fatality rate the same as operating engineer
Track Maintenance	1	1.8	3.5	6.30	7.62E-04	Scott et al. 2001	4.80E-03	Assume railroad worker fatality rates
Total							1.72E-02	

Table D−36. Crescent Junction Disposal Alternative–Rail Summary

	Moab Operations	**Vicinity Properties**	**Borrow Areas**	**Disposal Cell**	**Transportation**	**Worker Total**
Equipment Operators	25	6	7	28	0	66
Site Support	19	4	3	16	9	51
Truck Drivers	1	0	0	8	0	9
General Labor	22	10	10	18	0	60
Conveyor/operators	0	0	0	0	6	6
Track Maintenance	0	0	0	0	1	1
Total	67	20	20	70	16	193

Table D−37. Crescent Junction Disposal Alternative–Slurry

Work Category	Labor	Labor/2000 h/yr	Years Worked	Person Years	Fatality Rate	Rate Reference	Fatalities	Notes
Moab Operations								
Equipment Operators	25	52.5	4.5	236.25	2.16E-04	Scott et al. 2001	5.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	19	39.9	4.5	179.55	7.47E-05	Hoskin et al. 1994	1.34E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	1	2.1	4.5	9.45	3.88E-04	Scott et al. 2001	3.67E-03	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	22	46.2	4.5	207.90	3.29E-04	Scott et al. 2001	6.84E-02	
System Operators	0	0	4.5	0.00	5.40E-05	Scott et al. 2001	0.00E+00	Operating engineer risk values
Total							1.37E-01	
Vicinity Property								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	6	12.6	3	37.80	2.16E-04	Scott et al. 2001	8.16E-03	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	4	8.4	3	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	3	63.00	3.29E-04	Scott et al. 2001	2.07E-02	
System Operators	0	0	3	0.00	5.40E-05	Scott et al. 2001	0.00E+00	Operating engineer risk values
Total							3.08E-02	

Table D−37. Crescent Junction Disposal Alternative–Slurry (continued)

Borrow Areas								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	7	14.7	4	58.80	2.16E-04	Scott et al. 2001	1.27E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	3	6.3	4	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	4	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	4	84.00	3.29E-04	Scott et al. 2001	2.76E-02	
System Operators	0	0	4	0.00	5.40E-05	Scott et al. 2001	0.00E+00	Operating engineer risk values
Total							4.22E-02	
Disposal Cell Operations								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	28	58.8	4.8	282.24	2.16E-04	Scott et al. 2001	6.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
								Disposal cell is 4 and 10 months
Site Support	16	33.6	4.8	161.28	7.47E-05	Hoskin et al. 1994	1.21E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	8	16.8	4.8	80.64	3.88E-04	Scott et al. 2001	3.13E-02	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	18	37.8	4.8	181.44	3.29E-04	Scott et al. 2001	5.97E-02	
System Operators	0	0	4.8	0.00	5.40E-05	Scott et al. 2001	0.00E+00	Operating engineer risk values
Total							1.64E-01	

Table D−37. Crescent Junction Disposal Alternative–Slurry (continued)

Transportation Related Labor								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	0	0	3.5	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Labor is from Section 2 and is based on a 3,600-hour year because of the 6-day work schedule for rail transport
Site Support	4	7.2	3.5	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3.5	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	0	0	3.5	0.00	3.29E-04	Scott et al. 2001	0.00E+00	
System Operators	21	37.8	3.5	132.30	5.40E-05	Hoskin et al. 1994	7.14E-03	Operating engineer risk values
Pipeline Construction	330	594	0.6	356.40	2.32E-04	Scott et al. 2001	8.27E-02	Fatality rate is based on 50% general laborer, 25% mechanic, and 25% equipment operator. General laborer has higher fatality rates
Total							9.17E-02	

Table D−38. Crescent Junction Disposal Alternative–Slurry Summary

	Moab Operations	Vicinity Properties	Borrow Areas	Disposal Cell	Transportation	Worker Total
Equipment Operators	25	6	7	28	0	66
Site Support	19	4	3	16	4	46
Truck Drivers	1	0	0	8	0	9
General Labor	22	10	10	18	0	60
System Operators	0	0	0	0	21	21
Pipeline Construction	0	0	0	0	330	330
Total	67	20	20	70	355	532

Table D−39. White Mesa Mill Disposal Alternative–Truck

Work Category	Labor	Labor/2000 h/yr	Years Worked	Person Years	Fatality Rate	Rate Reference	Fatalities	Notes
Moab Operations								
Equipment Operators	25	52.5	4.5	236.25	2.16E-04	Scott et al. 2001	5.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	19	39.9	4.5	179.55	7.47E-05	Hoskin et al. 1994	1.34E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	1	2.1	4.5	9.45	3.88E-04	Scott et al. 2001	3.67E-03	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	22	46.2	4.5	207.90	3.29E-04	Scott et al. 2001	6.84E-02	
Mechanics	0	0	4.5	0.00	5.40E-05	Scott et al. 2001	0.00E+00	
Total							1.37E-01	

Work Category	Labor	Labor/2000 h/yr	Years Worked	Person Years	Fatality Rate	Rate Reference	Fatalities	Notes
Vicinity Property								
Equipment Operators	6	12.6	3	37.80	2.16E-04	Scott et al. 2001	8.16E-03	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	4	8.4	3	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	3	63.00	3.29E-04	Scott et al. 2001	2.07E-02	
Mechanics	0	0	3	0.00	5.40E-05	Scott et al. 2001	0.00E+00	
Total							3.08E-02	

Table D−39. White Mesa Mill Disposal Alternative–Truck (continued)

Work Category	Labor	Labor/2000 h/yr	Years Worked	Person Years	Fatality Rate	Rate Reference	Fatalities	Notes
Borrow Areas								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	7	14.7	4	58.80	2.16E-04	Scott et al. 2001	1.27E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	3	6.3	4	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	4	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	4	84.00	3.29E-04	Scott et al. 2001	2.76E-02	
Mechanics	0	0	4	0.00	5.40E-05	Scott et al. 2001	0.00E+00	
Total							4.22E-02	
Disposal Cell Operations								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	28	58.8	4.8	282.24	2.16E-04	Scott et al. 2001	6.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	16	33.6	4.8	161.28	7.47E-05	Hoskin et al. 1994	1.21E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	8	16.8	4.8	80.64	3.88E-04	Scott et al. 2001	3.13E-02	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	18	37.8	4.8	181.44	3.29E-04	Scott et al. 2001	5.97E-02	
Mechanics	0	0	4.8	0.00	5.40E-05	Scott et al. 2001	0.00E+00	
Total							1.64E-01	

Table D‒39. White Mesa Mill Disposal Alternative–Truck (continued)

Transportation Related Labor								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	0	0	3.5	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	10	21	3.5	73.50	7.47E-05	Hoskin et al. 1994	5.49E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3.5	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	0	0	3.5	0.00	3.29E-04	Scott et al. 2001	0.00E+00	
Mechanics	8	16.8	3.5	58.80	5.40E-05	Scott et al. 2001	3.18E-03	
Total							8.67E-03	

Table D−40. White Mesa Mill Disposal Alternative–Truck Summary

	Moab Operations	Vicinity Properties	Borrow Areas	Disposal Cell	Transportation	Worker Total
Equipment Operators	25	6	7	28	0	66
Site Support	19	4	3	16	10	52
Truck Drivers	1	0	0	8	0	9
General Labor	22	10	10	18	0	60
Mechanics	0	0	0	0	8	8
Total	67	20	20	70	10	187

Table D−41. White Mesa Mill Disposal Alternative–Slurry

Work Category	Labor	Labor/2000 h/yr	Years Worked	Person Years	Fatality Rate	Rate Reference	Fatalities	Notes
Moab Operations								
Equipment Operators	25	52.5	4.5	236.25	2.16E-04	Scott et al. 2001	5.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	19	39.9	4.5	179.55	7.47E-05	Hoskin et al. 1994	1.34E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	1	2.1	4.5	9.45	3.88E-04	Scott et al. 2001	3.67E-03	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	22	46.2	4.5	207.90	3.29E-04	Scott et al. 2001	6.84E-02	
System Operators	0	0	4.5	0.00	5.40E-05	Scott et al. 2001	0.00E+00	Operating engineer risk values
Total							1.37E-01	
Vicinity Property								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	6	12.6	3	37.80	2.16E-04	Scott et al. 2001	8.16E-03	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	4	8.4	3	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	3	63.00	3.29E-04	Scott et al. 2001	2.07E-02	
System Operators	0	0	3	0.00	5.40E-05	Scott et al. 2001	0.00E+00	Operating engineer risk values
Total							3.08E-02	

Table D−41. White Mesa Mill Disposal Alternative–Slurry (continued)

Work Category	Labor	Labor/2000 h/yr	Years Worked	Person Years	Fatality Rate	Rate Reference	Fatalities	Notes
Borrow Areas								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	7	14.7	4	58.80	2.16E-04	Scott et al. 2001	1.27E-02	Labor is from Section 2 and is based on a 4,200-hour year
Site Support	3	6.3	4	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	4	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	10	21	4	84.00	3.29E-04	Scott et al. 2001	2.76E-02	
System Operators	0	0	4	0.00	5.40E-05	Scott et al. 2001	0.00E+00	Operating engineer risk values
Total							4.22E-02	
Disposal Cell Operations								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	28	58.8	4.8	282.24	2.16E-04	Scott et al. 2001	6.10E-02	Labor is from Section 2 and is based on a 4,200-hour year
								Disposal cell is 4 and 10 months
Site Support	16	33.6	4.8	161.28	7.47E-05	Hoskin et al. 1994	1.21E-02	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	8	16.8	4.8	80.64	3.88E-04	Scott et al. 2001	3.13E-02	On-site truck drivers only; off-site truck driver risks are addressed under transportation risks
General Labor	18	37.8	4.8	181.44	3.29E-04	Scott et al. 2001	5.97E-02	
System Operators	0	0	4.8	0.00	5.40E-05	Scott et al. 2001	0.00E+00	Operating engineer risk values
Total							1.64E-01	

Table D−41. White Mesa Mill Disposal Alternative–Slurry (continued)

Transportation Related Labor								
Work Category	**Labor**	**Labor/2000 h/yr**	**Years Worked**	**Person Years**	**Fatality Rate**	**Rate Reference**	**Fatalities**	**Notes**
Equipment Operators	0	0	3.5	0.00	2.16E-04	Scott et al. 2001	0.00E+00	Labor is from Section 2 and is based on a 3,600-hour year because of the 6-day work schedule for rail transport
Site Support	4	7.2	3.5	25.20	7.47E-05	Hoskin et al. 1994	1.88E-03	Fatality rate is based on 50% inspector, 25% surveyor, and 25% civil engineer
Truck Drivers	0	0	3.5	0.00	3.88E-04	Scott et al. 2001	0.00E+00	Truck drivers are on public roads and are addressed under transportation risks
General Labor	0	0	3.5	0.00	3.29E-04	Scott et al. 2001	0.00E+00	
System Operators	25	45	3.5	157.50	5.40E-05	Hoskin et al. 1994	8.51E-03	Operating engineer risk values
Pipeline Construction	502	903.6	0.75	677.70	2.32E-04	Scott et al. 2001	1.57E-01	Fatality rate is based on 50% general laborer, 25% mechanic, and 25% equipment operator. General laborer has higher fatality rates
Total							1.68E-01	

Table D−42. White Mesa Mill Disposal Alternative–Slurry Summary

	Moab Operations	**Vicinity Properties**	**Borrow Areas**	**Disposal Cell**	**Transportation**	**Worker Total**
Equipment Operators	25	6	7	28	0	66
Site Support	19	4	3	16	4	46
Truck Drivers	1	0	0	8	0	9
General Labor	22	10	10	18	0	60
System Operators	0	0	0	0	25	25
Pipeline Construction	0	0	0	0	502	502
Total	67	20	20	70	531	708

Table D−43. Summary of Construction and Transportation Fatality Estimates for the Disposal Alternatives

Alternative	Construction Fatalities	Transportation Fatalities	Total Fatalities	Notes
Cap-in Place	1.57E-01	6.45E-02	2.22E-01	
Klondike Flats-Rail	1.93E+02	1.05E-01	1.93E+02	Higher than Crescent Junction because of cover soil transport
Klondike Flats -Truck	1.86E+02	3.62E-01	1.86E+02	
Klondike Flats -Slurry	4.35E-01	9.92E-02	5.34E-01	Higher than Crescent Junction because of cover soil transport
Crescent Junction-Rail	1.93E+02	7.16E-02	1.93E+02	
Crescent Junction-Truck	1.86E+02	4.90E-01	1.86E+02	
Crescent Junction-Slurry	5.32E+02	6.06E-02	5.32E+02	
White Mesa -Truck	1.87E+02	1.25E+00	1.88E+02	
White Mesa - Slurry	7.08E+02	7.12E-02	7.08E+02	

Table D−44. On-Site Worker Summary

Used in Sections 4.1.15.1, 4.1.15.2

23 = Vicinity Property Workers
47 = Moab Workers
3 = Duration for VPs (yr)
2.5 = Duration for Moab (yr)

Worker	Site	Radon LCFs	External LCFs	Total LCFs	Rounded Totals: Radon LCFs	Rounded Totals: External LCFs	Rounded Totals: Total LCFs	
Annual:								
Individual	Moab	2.6E-4	3.5E-4	6.1E-4	2.6E-4	3.5E-4	6.1E-4	
Individual	Vicinity Properties	2.9E-4	1.2E-4	4.2E-4	2.9E-4	1.2E-4	4.1E-4	
Population	Moab	1.2E-2	1.6E-2	2.9E-2	1.2E-2	1.6E-2	2.8E-2	
Population	Vicinity Properties	6.7E-3	2.9E-3	9.5E-3	6.7E-3	2.9E-3	9.6E-3	
Total		1.9E-2	1.9E-2	3.8E-2	1.9E-2	1.9E-2	3.8E-2	
Duration:								
Individual	Moab	6.5E-4	8.8E-4	1.5E-3	6.5E-4	8.8E-4	1.5E-3	
Individual	Vicinity Properties	8.7E-4	3.7E-4	1.2E-3	8.7E-4	3.7E-4	1.2E-3	
Population	Moab	3.0E-2	4.1E-2	7.2E-2	3.0E-2	4.1E-2	7.1E-2	
Population	Vicinity Properties	2.0E-2	8.6E-3	2.9E-2	2.0E-2	8.6E-3	2.9E-2	
Total		5.1E-2	5.0E-2	1.0E-1	5.0E-2	5.0E-2	1.0E-1	
Annual:								
Individual	Moab	241	700	941	240	700	940	<== mrem/yr
Individual	Vicinity Properties	271	248	519	270	250	520	<== mrem/yr
Population	Moab	11,335	32,900	44,235	11,000	33,000	44,000	<== person-mrem/yr
Population	Vicinity Properties	6,224	5,704	11,928	6,200	5,700	12,000	<== person-mrem/yr
Total		17,559	38,604	56,163	17,000	39,000	56,000	<== person-mrem/yr
Duration:								
Individual	Moab	603	1,750	2,353	600	1,800	2,400	<== mrem over duration
Individual	Vicinity Properties	812	744	1,556	810	740	1,600	<== mrem over duration
Population	Moab	28,338	82,250	110,588	28,000	82,000	110,000	<== person-mrem over duration
Population	Vicinity Properties	18,671	17,112	35,783	19,000	17,000	36,000	<== person-mrem over duration
Total		47,009	99,362	146,371	47,000	99,000	150,000	<== person-mrem over duration

Table D−45. Cap-In-Place Workers

Used in Section 4.1.15.1

5.00E-7	= Worker LCF/mrem	
5.38E-4	= Nominal fatality coefficient (lung cancer fatalities/WLM)	
500	= Worker mrem/WLM	
2,000	= Exposure time (hr/yr)	
4.10E-2	= WL	<== Average of MPS-0114, -0115, -0116
4.8E-1	= WLM per year	
241	= Radon dose (mrem/yr)	
2.6E-4	= Radon risk (lifetime probability of lung cancer per year of exposure)	
350.0	= External exposure rate (µR/hr)	<== Average of external gamma for data >= 200 µR/hr
0.350	= External exposure rate (mR/hr)	
700	= External dose (mR/yr)	
3.5E-4	= External risk (LCFs per year)	
941	= Total annual dose (mrem/yr)	
6.1E-4	= Total annual LCFs	
7.0E-1	= Equilibrium factor (unitless)	
5.9	= Radon concentration (pCi/L)	

Table D−46. Klondike Flats, Crescent Junction, White Mesa Mill Worker Summary

Used in Sections 4.2.15.1, 4.3.15.1, 4.4.15.1

23 = Vicinity Property Workers
67 = Moab Workers
70 = Disposal Site Workers
3 = Duration for VPs (yr)
5 = Duration for Moab (yr)
5 = Duration for disposal site (yr)

					Rounded Totals			
Worker	Site	Radon LCFs	External LCFs	Total LCFs	Radon LCFs	External LCFs	Total LCFs	
Annual:								
Individual	Moab	6.1E-4	6.0E-4	1.2E-3	6.1E-4	6.0E-4	1.2E-3	
Individual	Disposal Site	6.1E-4	6.0E-4	1.2E-3	6.1E-4	6.0E-4	1.2E-3	
Individual	Vicinity Properties	2.9E-4	1.2E-4	4.2E-4	2.9E-4	1.2E-4	4.1E-4	
Population	Moab	4.1E-2	4.0E-2	8.1E-2	4.1E-2	4.0E-2	8.1E-2	
Population	Disposal Site	4.3E-2	4.2E-2	8.5E-2	4.3E-2	4.2E-2	8.5E-2	
Population	Vicinity Properties	6.7E-3	2.9E-3	9.5E-3	6.7E-3	2.9E-3	9.6E-3	
Total		9.0E-2	8.5E-2	1.7E-1	9.1E-2	8.5E-2	1.8E-1	
Duration:								
Individual	Moab	3.0E-3	3.0E-3	6.0E-3	3.0E-3	3.0E-3	6.0E-3	
Individual	Disposal Site	3.0E-3	3.0E-3	6.0E-3	3.0E-3	3.0E-3	6.0E-3	
Individual	Vicinity Properties	8.7E-4	3.7E-4	1.2E-3	8.7E-4	3.7E-4	1.2E-3	
Population	Moab	2.0E-1	2.0E-1	4.0E-1	2.0E-1	2.0E-1	4.0E-1	
Population	Disposal Site	2.1E-1	2.1E-1	4.2E-1	2.1E-1	2.1E-1	4.2E-1	
Population	Vicinity Properties	2.0E-2	8.6E-3	2.9E-2	2.0E-2	8.6E-3	2.9E-2	
Total		4.4E-1	4.2E-1	8.6E-1	4.3E-1	4.2E-1	8.5E-1	
Annual:								
Individual	Moab	565	1,200	1,765	560	1,200	1,800	<== mrem/yr
Individual	Disposal Site	565	1,200	1,765	560	1,200	1,800	<== mrem/yr
Individual	Vicinity Properties	271	248	519	270	250	520	<== mrem/yr
Population	Moab	37,835	80,400	118,235	38,000	80,000	120,000	<== person-mrem/yr
Population	Disposal Site	39,529	84,000	123,529	40,000	84,000	120,000	<== person-mrem/yr
Population	Vicinity Properties	6,224	5,704	11,928	6,200	5,700	12,000	<== person-mrem/yr
Total		83,588	170,104	253,692	84,000	170,000	250,000	<== person-mrem/yr
Duration:								
Individual	Moab	2,824	6,000	8,824	2,800	6,000	8,800	<== mrem over duration
Individual	Disposal Site	2,824	6,000	8,824	2,800	6,000	8,800	<== mrem over duration
Individual	Vicinity Properties	812	744	1,556	810	740	1,600	<== mrem over duration
Population	Moab	189,176	402,000	591,176	190,000	400,000	590,000	<== person-mrem over duration
Population	Disposal Site	197,647	420,000	617,647	200,000	420,000	620,000	<== person-mrem over duration
Population	Vicinity Properties	18,671	17,112	35,783	19,000	17,000	36,000	<== person-mrem over duration
Total		405,494	839,112	1,244,606	410,000	840,000	1,200,000	<== person-mrem over duration

Table D−47. Tailings Piles Worker Risks

Used in Sections 4.2.15.1, 4.3.15.1, 4.4.15.1
Used for off-site disposal scenarios

5.00E-7	= Worker LCF/mrem	
5.38E-4	= Nominal fatality coefficient (lung cancer fatalities/WLM)	
500	= Worker mrem/WLM	
2,000	= Exposure time (hr/yr)	
9.6E-2	= WL	<== Highest measurement when pile opened
1.1E+0	= WLM per year	
565	= Radon dose (mrem/yr)	
6.1E-4	= Radon risk (lifetime probability of lung cancer per year of exposure)	
600	= External exposure rate (µR/hr)	<== Highest measurement when pile opened
0.60	= External exposure (mR/hr)	
1200	= External dose (mR/yr)	
6.0E-4	= External risk (LCFs per year)	
1,765	= Total annual dose (mrem/yr)	
1.2E-3	= Total annual LCFs	
4.5E-1	= Equilibrium factor (unitless)	
21.3	= Radon concentration (pCi/L)	

Table D−48. Vicinity Property Workers

Used in Section 4.1.15.2

5.00E-7	= Worker LCF/mrem
5.38E-4	= Nominal fatality coefficient (lung cancer fatalities/WLM)
500	= Worker mrem/WLM
2000	= Worker exposure time (hours/yr)
0.046	= WL at VPs
0.54	= WLM per year
271	= Radon dose (mrem/yr)
2.9E-4	= Radon risk (lifetime probability of lung cancer per year of exposure)
124	= External exposure rate at VPs (µR/hr)
0.124	= External exposure rate at VPs (mR/hr)
248	= External dose (mrem/yr)
1.2E-4	= External risk (LCFs per year)
519	= Total annual dose (mrem/yr)
4.2E-4	= Total annual LCFs
0.7	= F for indoors
6.6	= Indoor radon concentration (pCi/L)

Table D−49. Vicinity Property Public Risks—On-Site, Klondike Flats, Crescent Junction, and White Mesa Mill Disposal Alternatives

Used in Section 4.1.15.2

6.00E-7	= Public LCF/mrem		
5.38E-4	= Nominal fatality coefficient (lung cancer fatalities/WLM)		
400	= Public mrem/WLM		
8760	= Exposure time (hours/yr)		
0.02	= WL at VPs		
1.03	= WLM per year		
412	= Annual radon dose (mrem/yr)		
5.5E-4	= Annual radon LCF		
20	= External radiation rate at VPs (µR/hr)		
0.020	= External radiation rate at VPs (mR/hr)		
175	= Annual external exposure dose (mrem/yr)		
1.1E-4	= Annual external exposure LCF		
0.7	= F for indoors		
2.9	= Indoor radon concentration (pCi/L)		
587	= Total annual dose (mrem/yr)		
6.6E-4	= Total annual LCF		
392	= Number of VP people	4	= p/VP; 98 = Number of VPs
30	= Exposure duration (yrs) After Remediation		
5	= Exposure duration (yrs) Before Remediation		

After Remediation:
Annual:
Individual at VP:

1.1E-4	= Annual external exposure LCF	175	= Annual individual external exposure dose (mrem/yr)
5.5E-4	= Annual radon LCF	412	= Annual individual radon dose (mrem/yr)
6.6E-4	= Total annual LCF	587	= Total annual individual dose (mrem/yr)

Collective Public at VP:

4.1E-2	= Annual external exposure LCF	68.7	= Annual collective external exposure dose (person-rem/yr)
2.2E-1	= Annual radon LCF	162	= Annual collective radon dose (person-rem/yr)
2.6E-1	= Total annual LCF	230	= Total annual collective dose (person-rem/yr)

Duration:
Individual at VP:

30	= Exposure Duration (yrs)		
3.2E-3	= External exposure LCF	5,256	= Duration individual external exposure dose (mrem)
1.7E-2	= Radon LCF	12,367	= Duration individual radon dose (mrem)
2.0E-2	= Total LCF	17,623	= Total duration individual dose (mrem)

Collective Public at VP:

30	= Exposure Duration (yrs)		
1.2E+0	= External exposure LCF	2,060	= Duration collective external exposure dose (person-rem)
6.5E+0	= Radon LCF	4,848	= Duration collective radon dose (person-rem)
7.8E+0	= Total LCF	6,908	= Total duration collective dose (person-rem)

Table D–49. Vicinity Property Public Risks—On-Site, Klondike Flats, Crescent Junction, and White Mesa Mill Disposal Alternatives (continued)

Before Remediation:
Annual:
Individual at VP:
6.5E-4 = Annual external exposure LCF
1.3E-3 = Annual radon LCF
1.9E-3 = Total annual LCF

Collective Public at VP:
2.6E-1 = Annual external exposure LCF
5.0E-1 = Annual radon LCF
7.6E-1 = Total annual LCF

Duration:
Individual at VP:
5 = Exposure Duration (yrs)
3.3E-3 = External exposure LCF
6.4E-3 = Radon LCF
9.6E-3 = Total LCF

Collective at VP:
5 = Exposure Duration (yrs)
1.3E+0 = External exposure LCF
2.5E+0 = Radon LCF
3.8E+0 = Total LCF

Total (Before and After Remediation):

2.9E-2 = Total VP (Individual)
12 = Total VP (Collective)

Table D−50. Vicinity Property Public Risks–No Action Alternative

Used in Section 4.6.15

6.00E-7	= Public LCF/mrem
5.38E-4	= Nominal fatality coefficient (lung cancer fatalities/WLM)
400	= Public mrem/WLM
8760	= Exposure time (hours/yr)
0.046	= WL at VPs
2.37	= WLM per year
948	= Annual radon dose (mrem/yr)
1.3E-3	= Annual radon LCF
124	= External radiation rate at VPs (µR/hr)
0.124	= External radiation rate at VPs (mR/hr)
1,086	= Annual external exposure dose (mrem/yr)
6.5E-4	= Annual external exposure LCF
0.7	= F for indoors
6.6	= Indoor radon concentration (pCi/L)
2,034	= Total annual dose (mrem/yr)
1.9E-3	= Total annual LCF

392	= Number of VP people	4	= p/VP	98	= Number of VPs
35	= Exposure duration (yrs)				

Annual:

Individual at VP:

6.5E-4	= External exposure LCF	1,086	= Annual individual external exposure dose (mrem/yr)
1.3E-3	= Annual radon LCF	948	= Annual individual radon dose (mrem/yr)
1.9E-3	= Total LCF	2,034	= Total annual individual dose (mrem/yr)

Collective Public at VP:

2.6E-1	= External exposure LCF	426	= Annual collective external exposure dose (person-rem/yr)
5.0E-1	= Radon LCF	372	= Annual collective radon dose (person-rem/yr)
7.6E-1	= Total LCF	797	= Total annual collective dose (person-rem/yr)

Duration:

Individual at VP:

2.3E-2	= External exposure LCF	38,018	= Duration individual external exposure dose (mrem)
4.5E-2	= Radon LCF	33,185	= Duration individual radon dose (mrem)
6.7E-2	= Total LCF	71,203	= Total duration individual dose (mrem)

Collective Public at VP:

8.9E+0	= External exposure LCF	14,903	= Duration collective external exposure dose (person-rem)
1.7E+1	= Radon LCF	13,008	= Duration collective radon dose (person-rem)
2.6E+1	= Total LCF	27,912	= Total duration collective dose (person-rem)

Table D−51. Off-Site MEI

Used in Sections 4.2.15.1, 4.3.15.1, 4.4.15.1, 4.2.15.3, 4.3.15.3, 4.4.15.3, 4.6.15

8,760 = Exposure time (hr/yr)
5.38E-4 = Nominal fatality coefficient (lung cancer fatalities/WLM)
400 = Public mrem/WLM

Site	Ra-226 Concentration (pCi/g)	Ra-226 Concentration (Bq/g)	Rn-222 Specific Flux Bq/m2-s per Bq/g	Area (m^2)	Rn-222 Release (Ci/yr)	CAP88-PC WL (WL/Ci released)	WLM	Annual LCFs	Time Duration (yr)	Total LCFs	Annual Dose (mrem/yr)	Duration Dose (mrem)
Pile is Open:												
Klondike	516	19.1	0.948	129,504	1997.8	6.42E-08	6.6E-3	3.6E-6	5	1.8E-5	2.6E+0	1.3E+1
Crescent Junction	516	19.1	0.948	129,504	1997.8	2.72E-07	2.8E-2	1.5E-5	5	7.5E-5	1.1E+1	5.6E+1
White Mesa	516	19.1	0.948	146,704	2263.1	2.49E-08	2.9E-3	1.6E-6	5	7.8E-6	1.2E+0	5.8E+0
Moab (Pile)	516	19.1	0.948	526,110	8116.0	6.14E-06	2.6E+0	1.4E-3	5	6.9E-3	1.0E+3	5.1E+3
Moab (Drying Areas)	516	19.1	0.948	194,256	2996.7	4.48E-06	6.9E-1	3.7E-4	5	1.9E-3	2.8E+2	1.4E+3
Moab Total								1.8E-3		8.8E-3	1.3E+3	6.5E+3
Moab (Pile) (Used For No-Action)	516	19.1	0.948	526,110	8116.0	6.14E-06	2.6E+0	1.4E-3	30	4.1E-2	1.0E+3	3.1E+4
Moab (Pile) (Used For No-Action) (assumes cover erodes)	516	19.1	0.948	526,110	8116.0	6.14E-06	2.6E+0	1.4E-3	35	4.8E-2	1.0E+3	3.6E+4

Site	Rn-222 Flux (pCi/m2-s)	Area (m^2)	Rn-222 Release (Ci/yr)	CAP88-PC WL (WL/Ci released)	WLM	Annual LCFs	Time Duration (yr)	Total LCFs	Annual Dose (mrem/yr)	Duration Dose (mrem)
Pile is Closed:										
Klondike	20	129,504	81.7	6.42E-08	2.7E-4	1.5E-7	30	4.4E-6	1.1E-1	3.2E+0
Crescent Junction	20	129,504	81.7	2.72E-07	1.1E-3	6.2E-7	30	1.8E-5	4.6E-1	1.4E+1
White Mesa	20	146,704	92.5	2.49E-08	1.2E-4	6.4E-8	30	1.9E-6	4.7E-2	1.4E+0

Site	Total LCFs
Totals (Operations + After NRC cover installed)	
Klondike	2.2E-5
Crescent Junction	9.4E-5
White Mesa	9.7E-6

Table D−52. Off-Site Population Public

Used in Sections 4.2.15.1, 4.3.15.1, 4.4.15.1, 4.2.15.3, 4.3.15.3, 4.4.15.3, 4.6.15

8,760 = Exposure time (hr/yr)
5.38E-4 = Nominal fatality coefficient (lung cancer fatalities/WLM)
400 = Public mrem/WLM

Site	Ra-226 Concentration (pCi/g)	Ra-226 Concentration (Bq/g)	Rn-222 Specific Flux Bq/m2-s per Bq/g	Area (m2)	Rn-222 Release (Ci/yr)	CAP88-PC WL (person-WL/ Ci released)	WLM	Annual LCFs	Time Duration (yr)	Total LCFs	Annual Dose (person-rem/yr)	Duration Dose (person-rem)
Pile is Open:												
Klondike	516	19.1	0.948	129,504	1997.8	4.090E-05	4.2E+0	2.3E-3	5	1.1E-2	1.7E+0	8.4E+0
Crescent Junction	516	19.1	0.948	129,504	1997.8	2.980E-05	3.1E+0	1.7E-3	5	8.3E-3	1.2E+0	6.1E+0
White Mesa	516	19.1	0.948	146,704	2263.1	3.870E-05	4.5E+0	2.4E-3	5	1.2E-2	1.8E+0	9.0E+0
Moab (Pile)	516	19.1	0.948	526,110	8116.0	6.570E-04	2.7E+2	1.5E-1	5	7.4E-1	1.1E+2	5.5E+2
Moab (Drying Areas)	516	19.1	0.948	194,256	2996.7	6.570E-04	1.0E+2	5.5E-2	5	2.7E-1	4.1E+1	2.0E+2
Moab Total								2.0E-1		1.0E+0	1.5E+2	7.5E+2
Moab (Pile) (Used for No-Action)	516	19.1	0.948	526,110	8116.0	6.570E-04	2.7E+2	1.5E-1	30	4.4E+0	1.1E+2	3.3E+3
Moab (Pile) (Used for No-Action)	516	19.1	0.948	526,110	8116.0	6.570E-04	2.7E+2	1.5E-1	35	5.2E+0	1.1E+2	3.8E+3
Moab (Pile) (Used for No-Action, Long-Term) (assumes cover erodes)	516	19.1	0.948	526,110	8116.0	6.570E-04	2.7E+2	1.5E-1	1000	1.5E+2	1.1E+2	1.1E+5

Site	Rn-222 Flux (pCi/m2-s)	Area (m2)	Rn-222 Release (Ci/yr)	CAP88-PC WL (WL/Ci released)	WLM	Annual LCFs	Time Duration (yr)	Total LCFs	Annual Dose (person-rem/yr)	Duration Dose (person-rem)
Pile is Closed:										
Klondike	20	129,504	81.7	4.090E-05	1.7E-1	9.3E-5	30	2.8E-3	6.9E-2	2.1E+0
Crescent Junction	20	129,504	81.7	2.980E-05	1.3E-1	6.7E-5	30	2.0E-3	5.0E-2	1.5E+0
White Mesa	20	146,704	92.5	3.870E-05	1.8E-1	9.9E-5	30	3.0E-3	7.4E-2	2.2E+0
Totals (Operations + After NRC cover installed)										
Klondike								1.4E-2		
Crescent Junction								1.0E-2		
White Mesa								1.5E-2		
Pile is Closed (Long-Term):										
Klondike	20	129,504	81.7	4.090E-05	1.7E-1	9.3E-5	1000	9.3E-2	6.9E-2	6.9E+1
Crescent Junction	20	129,504	81.7	2.980E-05	1.3E-1	6.7E-5	1000	6.7E-2	5.0E-2	5.0E+1
White Mesa	20	146,704	92.5	3.870E-05	1.8E-1	9.9E-5	1000	9.9E-2	7.4E-2	7.4E+1

Table D−53. On-Site Disposal MEI

Used in Sections 4.1.15.1, 4.6.15

Before Remediation (Before NRC Cover Installed):

1.9	= Radon concentration (pCi/L)
0.45	= Equilibrium factor (unitless)
8,760	= Exposure time (hr/yr)
5.38E-4	= Nominal fatality coefficient (lung cancer fatalities/WLM)
400	= Public mrem/WLM
4.41E-1	= WLM
176	= Annual individual radon dose (mrem/yr)
2.4E-4	= Annual individual radon risk (LCFs)
5	= Exposure time (yrs)
881	= Lifetime individual radon dose (mrem)
1.2E-3	= Lifetime individual radon risk (LCFs)

After Remediation (After NRC Cover Installed):

1.66E-1	= WLM
66.5	= Annual individual radon dose (mrem/yr)
8.9E-5	= Annual individual radon risk (LCFs)
30	= Exposure time (yrs)
1,994	= Lifetime individual radon dose (mrem)
2.7E-3	= Lifetime individual radon risk (LCFs)

Total (Before + After Remediation):

2,876	= Total individual radon dose (mrem)
3.9E-3	= Total individual radon risk (LCFs)

No-Action (assumes current conditions):

4.41E-1	= WLM
176	= Annual individual radon dose (mrem/yr)
2.4E-4	= Annual individual radon risk (LCFs)
35	= Exposure time (yrs)
6,168	= Lifetime individual radon dose (mrem)
8.3E-3	= Lifetime individual radon risk (LCFs)

Table D−54. On-Site Disposal Alternative Radon Risks (Off-Site Population)

Used in Sections 4.1.15.1, 4.6.15

Before Remediation (Before NRC Cover Installed):

1.9	= MEI radon concentration (pCi/L)
2.16E-03	= Calculated MEI concentration per Ci released (pCi/L per Ci released)
8.80E+02	= Calculated radon release (Ci)
526,110	= Area of Moab pile (m^2)
53.0	= Radon release rate (pCi/m^2-s)
6.570E-04	= CAP88-PC WL (person-WL/Ci released)
8,760	= Exposure time (hr/yr)
5.38E-4	= Nominal fatality coefficient (lung cancer fatalities/WLM)
400	= Public mrem/WLM
29.8	= person-WLM
11.9	= Annual population radon dose (person-rem/yr)
1.6E-2	= Annual population radon risk (LCFs)
5	= Time duration (yrs)
59.6	= Lifetime population radon dose (person-rem)
8.0E-2	= Lifetime population radon risk (LCFs)

After Remediation (After NRC Cover Installed):

11.2	= person-WLM
4.49	= Annual population radon dose (person-rem/yr)
6.0E-3	= Annual population radon risk (LCFs)
30	= Time Duration (yrs)
135	= Lifetime population radon dose (person-rem)
1.8E-1	= Lifetime population radon risk (LCFs)

Total (Before + After Remediation):

194	= Total population radon dose (person-rem)
2.6E-01	= Total population radon risk (LCFs)

No-Action (assumes current conditions):

29.8	= person-WLM
11.9	= Annual population radon dose (person-rem/yr)
1.6E-2	= Annual population radon risk (LCFs)
35	= Time Duration (yrs)
417	= Lifetime population radon dose (person-rem)
5.6E-1	= Lifetime population radon risk (LCFs)

Long-Term (After NRC Cover Installed):

11.2	= person-WLM
4.49	= Annual population radon dose (person-rem/yr)
6.0E-3	= Annual population radon risk (LCFs)
1000	= Time Duration (yrs)
4494	= Lifetime population radon dose (person-rem)
6.0E+0	= Lifetime population radon risk (LCFs)

Table D−55. Moab Post NRC Cover

Used in Section 4.1.15.4	1.9	= Measured radon concentration (pCi/L)
	2.16E-3	= Calculated MEI concentration per Ci released (pCi/L per Ci released)
	879.6	= Calculated radon release (Ci/yr)
	526,110	= Area of Moab pile (m^2)
	53.0	= Radon release rate (pCi/m^2-s)
	20.0	= Maximum allowable radon release rate (pCi/m^2-s)
	331.8	= Maximum allowable radon release rate (Ci/yr)
	6.570E-04	= CAP88-PC WL (person-WL/Ci released)
	8,760	= Exposure time (hr/yr)
	5.38E-4	= Nominal fatality coefficient (lung cancer fatalities/WLM)
	400	= Public mrem/WLM
	0.45	= Equilibrium factor (unitless)
	MEI:	
	0.72	= MEI radon concentration (pCi/L)
	0.166	= WLM
	66.5	= Annual individual dose (mrem/yr)
	8.9E-05	= Annual individual radon risk (LCFs)
	5	= Time duration (yrs)
	332	= Lifetime individual radon dose (mrem)
	4.5E-04	= Lifetime individual radon risk (LCFs)
	30	= Time duration (yrs)
	1,994	= Lifetime individual radon dose (mrem)
	2.7E-03	= Lifetime individual radon risk (LCFs)
	Population:	
	11.2	= person-WLM
	4.5	= Annual population radon dose (person-rem/yr)
	6.0E-03	= Annual population radon risk (LCFs)
	5	= Time duration (yrs)
	22.5	= Lifetime population radon dose (person-rem)
	3.0E-02	= Lifetime population radon risk (LCFs)
	30	= Time Duration (yrs)
	135	= Lifetime population radon dose (person-rem)
	1.8E-1	= Lifetime population radon risk (LCFs)

D5.0 Air Quality

The SCREEN3 computer code (EPA 1995b) was used to estimate the potential impacts to air quality from emissions from the Moab site, borrow areas, and off-site disposal locations. Tailpipe emissions were calculated using the equipment lists in Table D−56 and Table D−57 and the emission factors in Supplement A to the *Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources* (EPA 1991b). These emission factors are presented in Table D−58. For dust emissions from construction activities, an emission factor of 2.69×10^6 grams per hectare-month (1.2 tons per acre-month) was used from Section 13.2.3, "Heavy Construction Operations," in *Compilation of Air Pollutant Emission Factors, Volume I: Stationary and Point Sources* (EPA 1995c). Dust emissions were estimated using a 90-percent efficiency for dust suppression activities. In addition, it was assumed that 25 percent of the area would be actively worked at any one time.

Table D−56. Equipment List for On-Site Disposal Alternative

Equipment	Moab	Floy Wash Borrow Area	Klondike Flats Borrow Area
Tractor	1	0	0
Backhoe	2	0	0
Grader	3	0	0
Trackhoe	0	0	0
Front-end loader	1	1	1
Water truck	2	1	1
Crane	0	0	0
21-yd^3 scrapers	2	0	0
Dozer	2	0	0
Sheepfoot compactor	1	0	0
Smooth drum roller	1	0	0
Pickup truck	2	3	3
Welding rig	0	0	0
End dump truck	1	0	0
Skidsteer	0	0	0
16-yd^3 dragline	0	0	0
Tandem truck	0	0	0
Total	18	5	5

Table D−57. Equipment List for Off-Site Disposal Alternative

Equipment	Moab	Disposal Cell	Floy Wash Borrow Area	Klondike Flats Borrow Area	Crescent Junction Borrow Area
Tractor	2	1	0	0	0
Backhoe	1	2	1	1	1
Grader	1	2	1	1	1
Trackhoe	1	1	0	0	0
Front-end loader	2	2	1	1	1
End dump truck	0	1	0	0	0
Water truck	1	2	1	1	1
Crane	1	0	0	0	0
21-yd^3 scrapers	3	6	1	1	1
Dozer	3	2	1	1	1
Sheepfoot compactor	1	2	0	0	0
Smooth drum roller	0	0	0	0	0
Pickup truck	4	4	1	1	1
Welding rig	1	0	0	0	0
End dump truck	0	0	0	0	0
Skidsteer	0	1	0	0	0
16-yd^3 dragline	2	0	0	0	0
Tandem truck	0	0	0	0	0
Total	23	26	7	7	7

Table D−58. Emission Factors Used for Construction Equipment

Equipment	CO (g/h)	NOX (g/h)	SOX (g/h)	Particulate (g/h)
Tractor	157.01	570.7	62.3	50.7
Backhoe	306.37	767.3	64.7	63.2
Grader	68.46	324.43	39	27.7
Trackhoe	306.37	767.3	64.7	63.2
Front-end loader	91.15	375.22	34.4	26.4
Water truck	306.37	767.3	64.7	63.2
Crane	306.37	767.3	64.7	63.2
21-yd^3 scrapers	568.19	1740.14	210	184
Dozer	157.01	570.7	62.3	50.7
Sheepfoot compactor	306.37	767.3	64.7	63.2
Smooth drum roller	137.97	392.9	30.5	22.7
Pickup truck	306.37	767.3	64.7	63.2
Welding rig	306.37	767.3	64.7	63.2
End dump truck	816.81	1889.16	206	116
Skidsteer	306.37	767.3	64.7	63.2
16-yd^3 dragline	306.37	767.3	64.7	63.2
Tandem truck	306.37	767.3	64.7	63.2

Source: Supplement A to the *Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources* (EPA 1991b).

Table D−59 presents the emissions predicted for the Moab site, the Floy Wash borrow area, and the Klondike Flats borrow area for the on-site disposal alternative. Table D−60 presents the predicted emissions for the Moab site, the Floy Wash borrow area, the Klondike Flats borrow area, and the Crescent Junction borrow area for the off-site disposal alternatives. Table D−61 and Table D−62 contain the emissions from the Klondike Flats, Crescent Junction, and White Mesa Mill disposal areas for the truck, rail, and slurry pipeline transportation options.

Table D−59. Emissions for On-Site Disposal Alternative

Pollutant	Moab[a] (g/h)	Floy Wash[b] Borrow Area (g/h)	Klondike Flats[c] Borrow Area (g/h)
Tailpipe Emissions			
CO	2,400	630	630
NOX	6,800	1,700	1,700
SOX	690	140	140
Particulate	580	130	130
Construction Activities			
Particulate (dust)	2,400	2,000	910

[a]Moab site = 441 acres.
[b]Floy Wash borrow area = 380 acres.
[c]Klondike Flats borrow area = 170 acres.

Table D−60. Emissions for the Moab Site, the Floy Wash Borrow Area, the Klondike Flats Borrow Area, and the Crescent Junction Borrow Area for the Off-Site Disposal Alternatives

Pollutant	Moab[a] (g/h)	Floy Wash[b] Borrow Area (g/h)	Klondike Flats[c] Borrow Area (g/h)	Crescent Junction[d] Borrow Area (g/h)
Tailpipe Emissions				
CO	3,100	860	860	860
NOX	8,800	2,500	2,500	2,500
SOX	880	260	260	260
Particulate	790	230	230	230
Construction Activities				
Particulate (Dust)	2,400	2,000	910	540

[a]Moab site = 442 acres.
[b]Floy Wash borrow area = 380 acres.
[c]Klondike Flats borrow area = 170 acres.
[d]Crescent Junction borrow area = 100 acres.

Table D−61. Tailpipe Emissions at the Klondike Flats, Crescent Junction, and White Mesa Mill Disposal Sites

Tailpipe Pollutants	Klondike Flats Truck/Rail/Slurry (g/h)	Crescent Junction Truck/Rail/Slurry (g/h)	White Mesa Mill Truck/Slurry (g/h)
CO	4,200	4,200	4,200
NOX	12,000	12,000	12,000
SOX	1,200	1,200	1,200
Particulate	1,100	1,100	1,100

Table D−62. Dust Emissions from Construction Activities at the Klondike Flats, Crescent Junction, and White Mesa Mill Disposal Sites

Dust Pollutants	Klondike Flats[a,b,c] (g/h)	Crescent Junction[d,e,f] (g/h)	White Mesa Mill[g,h] (g/h)
Particulate - Truck	2,500	2,400	1,900
Particulate - Rail	2,600	2,600	--
Particulate – Slurry	2,500	2,400	1,900

[a]Klondike Flats Truck Disposal Site = 475 acres.
[b]Klondike Flats Rail Disposal Site = 489 acres.
[c]Klondike Flats Slurry Disposal Site = 459 acres.
[d]Crescent Junction Truck Disposal Site = 448 acres.
[e]Crescent Junction Rail Disposal Site = 477 acres.
[f]Crescent Junction Slurry Disposal Site = 446 acres.
[g]White Mesa Mill Truck Disposal Site = 348 acres.
[h]White Mesa Mill Slurry Disposal Site = 346 acres.

Table D−63 through Table D−70 present the estimated concentrations at 1 mile from each site. In each case, the stability class was assumed to be Class F and the wind speed was assumed to be 1 meter per second. This combination of atmospheric conditions would tend to provide an upper bound on potential impacts.

Table D−63. Criteria Pollutant Concentrations from Emissions at the Moab Site for the On-Site Disposal Alternative

Pollutant	Averaging Period	Standard ($\mu g/m^3$)[a]	Concentration from Emissions ($\mu g/m^3$)
Carbon monoxide	1-hour	40,000	31
	8-hour	10,000	22
Nitrogen dioxide	Annual	100	7.0
Sulfur dioxide	Annual	80	0.71
	24-hour	365	3.6
	3-hour	1,300	8.0
PM_{10}[b]	Annual	50	3.0
	24-hour	150	15

[a]$\mu g/m^3$ = micrograms per cubic meter.
[b]PM_{10} includes fugitive dust emissions from construction activities.

Table D−64. Criteria Pollutant Concentrations from Emissions at the Floy Wash Borrow Area for the On-Site Disposal Alternative

Pollutant	Averaging Period	Standard ($\mu g/m^3$)[a]	Concentration from Emissions ($\mu g/m^3$)
Carbon monoxide	1 hour	40,000	8.6
	8 hours	10,000	6.0
Nitrogen dioxide	Annual	100	1.8
Sulfur dioxide	Annual	80	0.15
	24 hours	365	0.77
	3 hours	1,300	1.7
PM_{10}	Annual	50	0.15
	24 hours	150	0.73

[a]$\mu g/m^3$ = micrograms per cubic meter.

Table D−65. Criteria Pollutant Concentrations from Emissions at the Klondike Flats Borrow Area for the On-Site Disposal Alternative

Pollutant	Averaging Period	Standard (µg/m³)[a]	Concentration from Emissions (µg/m³)
Carbon monoxide	1 hour	40,000	12
	8 hours	10,000	8.5
Nitrogen dioxide	Annual	100	2.5
Sulfur dioxide	Annual	80	0.22
	24 hours	365	1.1
	3 hours	1,300	2.4
PM_{10}	Annual	50	0.20
	24 hours	150	1.0

[a]µg/m³ = micrograms per cubic meter.

Table D−66. Criteria Pollutant Concentrations from Emissions at the Moab Site for the Klondike Flats, Crescent Junction, and White Mesa Mill Disposal Alternatives

Pollutant	Averaging Period	Standard (µg/m³)[a]	Concentration from Emissions (µg/m³)
Carbon monoxide	1 hour	40,000	40
	8 hours	10,000	28
Nitrogen dioxide	Annual	100	9.1
Sulfur dioxide	Annual	80	0.90
	24 hours	365	4.5
	3 hours	1,300	10
PM_{10}[b]	Annual	50	3.2
	24 hours	150	16

[a]µg/m³ = micrograms per cubic meter.
[b]PM_{10} includes fugitive dust emissions from construction activities.

Table D−67. Criteria Pollutant Concentrations from Emissions at the Klondike Flats Site for the Klondike Flats Disposal Alternative

Pollutant	Averaging Period	Standard (µg/m³)[a]	Concentration from Emissions (µg/m³)		
			Truck	Rail	Slurry
Carbon monoxide	1 hour	40,000	52	52	53
	8 hours	10,000	37	36	37
Nitrogen dioxide	Annual	100	12	12	12
Sulfur dioxide	Annual	80	1.2	1.2	1.3
	24 hours	365	6.2	6.1	6.3
	3 hours	1,300	14	14	14
PM_{10}[b]	Annual	50	3.6	3.7	3.6
	24 hours	150	18	18	18

[a]µg/m³ = micrograms per cubic meter.
[b]PM_{10} includes fugitive dust emissions from construction activities.

Table D−68. Criteria Pollutant Concentrations from Emissions at the Crescent Junction Site for the Crescent Junction Disposal Alternative

Pollutant	Averaging Period	Standard (µg/m³)[a]	Concentration from Emissions (µg/m³)		
			Truck	Rail	Slurry
Carbon monoxide	1 hour	40,000	53	52	53
	8 hours	10,000	37	36	37
Nitrogen dioxide	Annual	100	12	12	12
Sulfur dioxide	Annual	80	1.3	1.2	1.3
	24 hours	365	6.3	6.2	6.3
	3 hours	1,300	14	14	14
PM_{10}[b]	Annual	50	3.6	3.6	3.6
	24 hours	150	18	18	18

[a]µg/m³ = micrograms per cubic meter.
[b]PM_{10} includes fugitive dust emissions from construction activities.

Table D−69. Criteria Pollutant Concentrations from Emissions at the White Mesa Mill Site for the White Mesa Mill Disposal Alternative

Pollutant	Averaging Period	Standard (µg/m³)[a]	Concentration from Emissions (µg/m³)	
			Truck	Slurry
Carbon monoxide	1 hour	40,000	59	59
	8 hours	10,000	41	41
Nitrogen dioxide	Annual	100	13	13
Sulfur dioxide	Annual	80	1.4	1.4
	24 hours	365	7.0	7.0
	3 hours	1,300	16	16
PM_{10}[b]	Annual	50	3.3	3.3
	24 hours	150	17	17

[a]µg/m³ = micrograms per cubic meter.
[b]PM_{10} includes fugitive dust emissions from construction activities.

Table D−70. Criteria Pollutant Concentrations from Emissions at the Floy Wash, Klondike Flats, and Crescent Junction Borrow Areas for the Klondike Flats, Crescent Junction, and White Mesa Mill Disposal Alternatives

Pollutant	Averaging Period	Standard (µg/m³)[a]	Concentration from Emissions (µg/m³)		
			Floy Wash	Klondike Flats	Crescent Junction
Carbon monoxide	1 hour	40,000	12	17	21
	8 hours	10,000	8.3	12	15
Nitrogen dioxide	Annual	100	2.8	3.9	4.9
Sulfur dioxide	Annual	80	0.28	0.40	0.50
	24 hours	365	1.4	2.0	2.5
	3 hours	1,300	3.2	4.5	5.6
PM_{10}	Annual	50	0.25	0.35	0.44
	24 hours	150	1.3	1.8	2.2

[a]µg/m³ = micrograms per cubic meter.

Table D−71 presents the estimated concentrations at the Arches National Park entrance, located about 1.25 miles northwest of the Moab site. These concentrations were estimated using the same atmospheric conditions (Class F stability class and 1 meter per second wind speed) as the concentrations at 1 mile and are lower than the concentrations at 1 mile.

Table D−71. Criteria Pollutant Concentrations at the Arches National Park Entrance from Emissions at the Moab Site

Pollutant	Averaging Period	Standard ($\mu g/m^3$)[a]	Concentration from Emissions ($\mu g/m^3$)	
			On-Site Disposal	Off-Site Disposal
Carbon monoxide	1 hour	40,000	26	33
	8 hours	10,000	18	23
Nitrogen dioxide	Annual	100	5.9	7.6
Sulfur dioxide	Annual	80	0.60	0.76
	24 hours	365	3.0	3.8
	3 hours	1,300	6.8	8.5
PM_{10}[b]	Annual	50	2.5	2.7
	24 hours	150	13	14

[a]$\mu g/m^3$ = micrograms per cubic meter.
[b]PM_{10} includes fugitive dust emissions from construction activities.

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Appendix E

Evaluation of Disposal of Moab Tailings in Salt Caverns Within the Paradox Formation

E1.0 Introduction

In late 2003, the U.S. Department of Energy (DOE) considered an option to dispose of the Moab mill tailings in solution-mined salt caverns either at the DOE-owned Moab site or off-site at two potential locations. From the initial analysis, disposal of uranium mill tailings in solution mined salt caverns appeared to have potential advantages in terms of long-term risk reduction over the more conventional methods of capping tailings or disposal at off-site locations. Consequently, DOE took a closer look at this option. Potential advantages of salt cavern disposal might include greater long-term isolation, reduced long-term commitment of surface acreage, and dual usage of injection wells for contaminated ground water disposal. Further analysis shows that this option's advantages do not outweigh the disadvantages. Technical uncertainty, cost, schedule, and the demand on river water are among disadvantages for this option as compared to the other alternatives in this EIS.

Conceptually, solution-mining techniques would be used to create disposal caverns in the salt beds of the Paradox Formation beneath the Moab site or at other potential locations, such as the commercial potash mine site approximately 6 air miles downstream from Moab or in the area of Sevenmile Canyon; both areas are controlled by private entities. The use of off-site locations would entail DOE acquiring the necessary lands, leases, mineral rights, and associated permits for Federal ownership in perpetuity.

This option would involve withdrawal of significant quantities of Colorado River water, on the order of 1,700 gallons per minute (gpm) for 20 years (880 million gallons per year, or 73 million gallons per month). The water would be used as part of the solution mining process and would become saturated with salt, generating brine that would require disposal by deep well injection or solar evaporation or perhaps could be used in the future by commercial potash mining operations.

Other disadvantages of this option include:

- The potential need to purchase water rights and pay water depletion fees associated with compensation of existing water right holders because of impairment;
- Uncertainties of implementing a complex, first-of-a-kind disposal technique for radioactive waste;
- The long projected completion time of surface remediation under this alternative that could be 3 or 4 times as long as all other alternatives (up to a few decades to go operational with a 20-year operations time frame, culminating in a project life cycle range of multiple decades);
- Life-cycle cost range for this salt cavern alternative ranges from $892 million to $1.3 billion;
- The potential for substantial schedule and cost growth over the estimates generated in this evaluation based on the existing technical, geological, hydrological, seismological, legal, economic, and operational uncertainties;
- DOE would need to invest several years and millions of dollars to study this option to resolve uncertainties with no guarantee of success;
- Lease or purchase fees for extractive resource rights, land, and infrastructure;

- Uncertainty in obtaining multiple leases from the State of Utah and drilling multiple wells to determine the presence of oil, gas, potash, and mineral resources;
- Processing of brine and acquisition of specialty materials necessary to work in a highly corrosive environment.

Section E2.0 of this appendix further defines the conceptual approach to this option and identifies uncertainties relevant to the ability to execute this option. Section E3.0 provides a preliminary estimate of the potential cost of this option and compares that cost to the other alternatives evaluated in this EIS. Section E4.0 describes advantages and disadvantages of salt cavern disposal. Section E5.0 evaluates this option in the context of its viability and resonableness or lack thereof under NEPA.

E2.0 Conceptual Approach

Three potentially geologically suitable sites in the Moab area where the Paradox Formation is several thousand feet thick were examined. The sites include the following options: (1) the on-site option using the DOE-owned Moab millsite, (2) the off-site option near the potash mine site that is privately owned by Intrepid Mining, LLC (Intrepid) and located approximately 6 air miles southwest of the Moab millsite, and (3) the off-site option of using the Sevenmile Canyon site that is also privately owned by Intrepid and located approximately 7 air miles northwest of the Moab millsite. The two off-site locations considered might not be available to DOE. Consultation with the Army Corp of Engineers would be needed to estimate the magnitude of the site acquisition process A location and land ownership map, geologic cross sections, and brief descriptions of each of the three potential disposal sites are presented in Attachment 1, Figures 1 through 7.

The Paradox Formation consists of a sequence of salt beds several thousand feet thick in the Moab area (see geologic cross sections in Attachment 1, Figure 3). Caverns within the salt formation would be created by solution-mining techniques similar to those used extensively in the United States to store liquid and gas products. Solution mining would consist of injecting fresh water into the Paradox Formation to dissolve the salt until each of the multiple caverns is developed to the required size (about 200 feet in diameter by 2,000 feet in height). The mining solutions would become saturated with dissolved salts (brine) and would be pumped to the surface for disposal (880 million gallons per year, or 73 million gallons per month) by any one or a combination of methods, including (1) deep underground injection into the underlying Leadville Limestone; (2) multiple solar evaporation ponds up to 500 acres in size; and (3) consumption by the Intrepid potash mining operation. Tailings would be slurried several thousand feet below ground surface into the caverns for disposal and geologic isolation. Issues examined in the evaluation of this conceptual approach include constructing the caverns, disposal of the brine solution, slurrying the tailings into the salt caverns for disposal; relationship to oil, gas, and potash resources; property ownership; and permitting. The existing underground workings at the potash mine (large rooms with pillars) are not available for tailings disposal because of ongoing solution-mining operations in the old workings to prolong mine life.

E2.1 Cavern Construction

Both solution mining and conventional mining techniques have been used to create disposal caverns in nonradioactive environments. Conventional underground mining to develop disposal caverns was not considered further because those costs would be substantially higher than solution-mining methods.

Solution mining is a proven technology that has been used by DOE as part of the Strategic Petroleum Reserve (SPR) to create caverns for the storage of 700 million barrels of petroleum. Solution mining to create salt caverns is also used extensively in the United States by private industry to store liquid and gas products. Ferrell Gas Company developed a relatively small (about 267,000 cubic feet; considerably smaller cavern than those required for tailings disposal) salt cavern for natural gas storage in the Paradox Formation approximately 1.5 miles southeast of the Moab site in the 1960s.

The conceptual approach for disposal of approximately 8.9 million cubic yards of Moab tailings (equivalent to 11.9 million tons, assuming 101 pounds per cubic foot of moist tailings) presumes 6 caverns are created during a 20year period. Assuming the waste volume will bulk by 20 percent, an estimated 10.5 million cubic yards of salt would be mined to create the caverns. The caverns would need to be filled with brine or gas (a volume equivalent of 10.5 million cubic yards) to keep them open until the tailings are deposited. Caverns would be mined sequentially with each cavern being developed in 3 years then filled with mill tailings during the following 3 years. The total life of the project would depend on the permitting, initial cavern startup, and the time to fill the last cavern with the last of the mill tailings. This schedule from obtaining approvals and regulatory permits to the end of tailings disposal could be up to multiple decades with the associated technical, legal, economic, and regulatory uncertainties.

Each cavern would be approximately 200 feet in diameter and 2,000 feet in height, similar to the dimensions of the caverns used at the SPR. The top of the caverns would be encased at least 500 feet beneath the top of the salt formation and at least 2,000 feet beneath ground surface. The conceptual cavern locations would be (1) on-site, underneath the DOE Moab millsite or (2) on privately owned land (Sevenmile Canyon site or Intrepid potash mine area), where adequate thickness of the Paradox Formation is assumed to exist at reasonable depths beneath the ground surface. An illustration of the caverns for this conceptual approach is shown in the geologic cross sections provided in Attachment 1, Figures 3, 5 and 7, for each of the three potential disposal sites. Characterization of the geological, hydrological, seismological, biological, and climate change conditions would be required.

E2.2 Brine Disposal

According to the solution-mining engineers with whom DOE consulted, brine disposal is considered one of the most significant technical challenges to this concept. The estimated rate of brine production from solution mining the caverns would be approximately 1,700 gpm for a 20-year production period. This amounts to an estimated total water consumption of 15 billon gallons over the life of the project. Deep-sea disposal of the brine was the option selected for expansion of the SPR program, but that disposal option is not available for this project. Because salt is generally in oversupply, it is not easily marketable without significant disruption of markets for existing commercial producers. Other sites in the United States use underground injection wells as the option for brine disposal. The U.S. Bureau of Reclamation (USBR) is currently using deep well injection for disposal of brine at its Paradox Valley, Colorado, site adjacent to the Dolores River. USBR operating costs are high; injection pressures are also high and lead to some technical and operational difficulties. The design life of the wells is 100 years, the injection depth is 16,000 feet below ground surface and cost is $2 million per year to inject 230 gpm through one well screened at 16,000 feet below ground surface.

Because of the limited options for brine disposal, deep well injection into a permeable geologic formation is the primary method of choice to dispose of the brine solutions for this conceptual approach. The option of brine disposal solely by injection into the Leadville Limestone offers the possibility of minimizing overall costs, but this option has a higher technical uncertainty associated with (1) locating the desirable aquifer characteristics (no hydraulic connection to ground water or surface water and high porosity); (2) inherent possibilities of generating micro-seismicity; (3) potentially high surface wellhead pressures; (4) corrosivity to wells and equipment; (5) a relatively large subsurface footprint (see Attachment 1, Figures 3, 5, and 7); and (6) potential impacts to oil, gas, or potash resources that may be present in the injection horizon (Leadville Formation).

Other brine disposal methods available include (1) evaporation of the brine solution at multiple ponds constructed (up to 500 acres in size) at on-site or off-site locations; (2) transport and surface storage of the salt at the Intrepid potash site for future mining operations, and (3) consumption of the brine solution by ongoing Intrepid mining operations. Intrepid's potash site includes a salt storage area that once stored 4 to 5 million tons of salt. The company is consuming the remaining stockpiled salt at a rate of 650 gpm of brine that will be depleted in 2 to 3 years. The salt storage facility is nearly empty but could be reused for long-term storage of salt from the evaporation ponds. The opportunity exists for Intrepid to consume approximately the equivalent amount of brine (650 gpm) developed during solution mining of the disposal caverns. This consumption rate is optimally only one-third the total rate that would be required and may not be constant during the year; therefore, the alternate disposal options of deep aquifer injection and pond storage together would be necessary to potentially allow management of the brines developed during cavern growth.

Brine disposal cost based on evaporation and storage is higher than for deep aquifer disposal or for consumption by the ongoing potash mining operations. The cost for disposal via consumption by the ongoing Intrepid mining operation appears attractive but may be unreliable if Intrepid should curtail potash production or transfer ownership to an uncooperative owner. In addition, developing appropriate and durable contractual commitments with Intrepid for storage and/or consumption of salt and/or brine may be problematic because this model is untried and unproven.

The availability of three brine disposal options —(1) deep injection, (2) evaporation and storage, and (3) consumptive use, each with the potential to accept a third or more of the brine stream — provides flexibility to optimize the approach both during design and operations. Likely, DOE would have to implement all three options. Costs for brine disposal are, therefore, based on a combination of the three disposal options. For example, sole reliance on deep well injection and reduced ability of subsurface formations to accept the requisite flow rates could substantially increase the operational life of the project and increase the cost of brine disposal. The uncertainties could only be evaluated through extensive field studies.

E2.3 Tailings Slurry

The slurry system would involve screens, ball mill, thickener, and a pumping station and is assumed to require essentially the same site infrastructure for both on-site and off-site salt-cavern tailings disposal. Slurry transport is detailed in the EIS as a transportation mode for the conventional off-site disposal alternatives. The tailings would be conveyed through a slurry pipeline to the off-site locations, only nominal pipeline lengths would be required for on-site disposal. The pipeline to the Intrepid site or Sevenmile Canyon site is assumed to be above ground along the railroad bed. A pipeline would have to be constructed at least 8 miles to transport contaminated slurry to the off-site locations. If this pipeline route is not acceptable to the railroad and/or State of Utah, the other option is to bury the pipeline in State Highway 279 or Highway 191 right-of-way at a higher capital cost of installation and decommissioning. A leak-detection system would have to be installed to isolate the system if a leak or line break occurs. For the on-site salt cavern option, the same tailings preparation system is required, but only a short pipeline would be required on-site to convey tailings to the injection points.

For the purpose of estimating cost, the oversized material is assumed to be trucked and disposed of at a licensed disposal cell. Cost estimate for this scope is the same as that identified in the EIS for the off-site alternatives using the slurry pipeline method of transportation.

E2.4 Tailings Disposal

This concept proposes that the Moab site tailings would be slurry injected into the caverns. The multiple cavern volumes (approximately 8.9 million cubic yards is based on the known quantities of tailings plus a 20 percent bulk addition to make the slurry) assume the mill tailings will settle in the cavern and separate out from the water used to slurry the tailings. If tailings do not settle out and separate from the water, a larger cavern volume will be required to accommodate the tailings and slurry water. Studies would have to be completed to characterize the ability of slurry water to separate from the tailings. Brine displaced during injection of the mill tailings slurry into the caverns would be radioactively contaminated with fine uranium mill tailings. This overflow could be recycled back to the slurry plant by constructing an additional return 8-mile pipeline or could be permanently disposed of in a dedicated well permitted for deep injection of the radioactive contaminated brine. The return pipeline would be co-located with the pipeline discussed in Section E2.3. Because the brine-disposal injection well would be underutilized once cavern mining is completed, the well could be used to dispose of radioactively contaminated ground water from the Moab site. For both the on-site and off-site options, it is assumed that radioactively contaminated ground water would be mixed with slurry material during tailings placement and then later disposed of by deep well injection for the remainder of the 75 to 80 years of pumping the contaminant plume in the alluvial aquifer.

E2.5 Oil, Gas, Potash, and other Mineral Resources

Oil, gas, potash, and other minerals are known to exist in the vicinity of the two off-site locations. Studies and well drilling would have to be completed to characterize and verify mineral occurrences. Whether or not these mineral resources exist in the vicinity area, State of Utah well drilling permits and mineral lease tracts would be required. Potash ore has been produced by underground and solution mining since 1964 at the Intrepid site from a large block of land under active potash leases. Unlike the other site options, small amounts of oil and gas have been produced from the Long Canyon and Cane Creek fields near the Intrepid site. Production at these fields has been from the Cane Creek zone near the base of the Paradox Formation. This zone is approximately 1,000 feet below the bottom of solution-mined caverns in the Paradox Formation that are proposed for the Intrepid site. The Cane Creek zone is also present in the subsurface at the Sevenmile Canyon site and is in a similar position in relation to solution-mined caverns proposed at that site.

Issuance of oil and gas leases in areas that have active potash leases has been a concern in the Intrepid area where commercial mining is ongoing. To avoid conflict, the State of Utah Division of Oil, Gas, and Mining, has allowed oil and gas leases in potash-leased areas to occur with precautionary stipulations if they otherwise meet Utah's applicable requirements. Specific oil and gas well locations are considered on a case-by-case basis to determine horizontal and vertical buffer zones and appropriate fluid injection pressures that would prevent fluid communication and seismic effects to the solution-mining operation. Similar regulations and stipulations would need to be formulated to allow exploration for oil and gas at the sites where solution-mined caverns and deep injection into Leadville Limestone are proposed. Establishment of horizontal and vertical buffer zones and appropriate restrictions for oil and gas leases that may be required could alter the locations and costs of the solution-mined caverns as currently conceptualized. A large cost contingency would have to be estimated to cover this uncertainty.

In the Moab Valley, several caverns in the Paradox Formation have been created by salt dissolution for storage of natural gas. These operations are at least 1.5 miles southeast of the solution-mined caverns proposed for the Moab millsite and are assumed to be located a sufficient distance from the millsite so that storage of natural gas would not be affected. However, geologic, hydrological, biological, and seismic studies would have to be completed to support this assumption.

E2.6 Property Ownership

Approximately 1,700 gpm of fresh water (880 million gallons per year, or 73 million gallons per month) would be required for a 20-year period to perform solution-mining activities. In addition, state and privately owned lands exist in the immediate vicinity of the proposed operations. Obstacles associated with this approach include:

- Transfer existing 1,360 gpm of surface water rights (currently owned by DOE for the millsite, with a current consumption of 50 gpm annually) to a different intended use;
- Acquire the existing additional 340 gpm of water rights (solution mining would require 25 instead of 20 years if additional water rights were unavailable);
- Demonstrate maintenance of sufficient stream flow in the Colorado River to comply with Threatened and Endangered Species Act requirements; and
- Purchase private property (from Intrepid and potentially other private parties) to develop required infrastructure.

E2.7 Permitting

This conceptual approach would require State of Utah Class IV underground injection permits for the tailings, contaminated ground water, and disposal of brine solutions. Rights-of-way and various Federal and State permits would be required for access to and use of the potential disposal sites. A legal agreement would be required with the railroad and/or State of Utah to permit DOE placement of the aboveground slurry line on its property or right-of-way and with Intrepid for the off-site disposal options.

Potential additional environmental permits that would be required include, but may not be limited to,

- Air emission permit (NSR, NESHAPS);
- State wastewater disposal permit (evaporative lagoons);
- State solid waste permit (salt disposal);
- State mining permit;
- Federal storm water permit; and
- Pollution prevention permit.

Concurrence and/or approval from the U.S. Nuclear Regulatory Commission (NRC) would be required for disposal of the Moab tailings in the salt caverns and for the underground injection of contaminated brine and ground water. NRC concurrence and/or approval would also be required for disposal of the 35,000 cubic yards of contaminated solid debris that would not be disposed of in the salt cavern.

E3.0 Cost Estimates

This section provides a preliminary estimate of cost for the salt cavern disposal option and compares that cost to the other alternatives analyzed in this EIS. Several assumptions and tasks are not included in the preliminary cost estimate. Items omitted from the preliminary cost estimate because of the difficulty in estimating costs, but accounted for in contingency include, but may not be limited to:

- Site characterization requirements to demonstrate feasibility of this option;
- Lease or purchase fees for extractive resource rights, land, and infrastructure;
- Access fees;
- Processing of brine and acquisition of specialty materials necessary to work in a highly corrosive environment;
- Purchase of water rights and fees associated with compensation of existing water right holders related to impairment;
- Identification of suitable geologic and hydrologic locations for activities;
- Special design requirements;
- Permitting requirements;
- Cavern construction;

- Brine disposal; and
- Cost impacts related to adjacent extractive industry leases.

The cost estimates included are based on the same basic assumptions used in the EIS for the analyzed alternatives. The basic cost components include

- Infrastructure;
- Excavation of tailings;
- Slurry system;
- Solution mining;
- Disposal of brine; and
- Project management/oversight.

The range of costs is presented in Table E−1. Table E–2 provides the major components of the salt cavern scenario. The life-cycle cost range for the salt cavern alternative is $892 million to $1.3 billion. The low end reflects the simplest method of injecting the tailings into salt caverns below the Moab millsite and injecting the uncontaminated brine and radioactive contaminated brine into the Leadville Limestone below the salt caverns. The higher cost reflects conveying the tailings by slurry pipeline approximately 8 miles to an off-site location and a worse-case scenario of building multiple evaporation ponds (500 acres) to dispose of the salt brine on site or off site. Both on-site and off-site tailings disposal options require approximately 75 to 80 years of active ground water restoration. It is assumed that contaminated ground water will be mixed with slurry during tailings placement and then later injected into the deep disposal wells for the necessary 75 to 80 years of pumping the contaminant plume in the alluvial aquifer.

Table E−1. Preliminary Estimated Costs for Disposal of the Moab Tailings in Salt Caverns and Comparison to On-Site and Off-Site Alternatives in the EIS

	On-Site Cap-In-Place	IUC White Mesa Mill		Crescent Junction		Klondike Flats		Salt Cavern	
		Truck	Slurry	Truck	Slurry	Truck	Slurry	On-Site	Off-Site
Construction Costs									
	$151M	$382M	$423M	$304M	$366M	$300M	$359M	$445M[a]	$683M[a]
Long-Term Costs (Long-Term Surveillance and Maintenance, Ground Water Construction and Operations)									
	$75M[b]	$70M[b]	$70M[b]	$70M[b]	$70M[b]	$70M[b]	$70M[b]	$60M[b,c]	$60M[b,c]
Subtotal	**$226M**	**$452M**	**$493M**	**$374M**	**$436M**	**$370M**	**$429M**	**$505M**	**$743M**
Contingency	10%	10%	10%	10%	10%	10%	10%	[d]	[d]
Subtotal	**$22.6M**	**$45.2M**	**$49.3M**	**$37.4M**	**$43.6M**	**$37.0M**	**$42.9M**	**$387M**	**$578M**
Total	**$249M**	**$497M**	**$542M**	**$411M**	**$480M**	**$407M**	**$472M**	**$892M**	**$1,321M**

[a] Represents all pre-contingency costs minus surveillance and maintenance costs from Table E–2, below.
[b] Cap-in-place ground water remediation costs are slightly greater than off-site alternatives due to an estimated 5 additional years of ground water restoration efforts. Ground water remediation costs for the salt cavern disposal scenario are less than the other alternatives due to dual usage of injection wells for brine and contaminated ground water disposal.
[c] Represents surveillance and maintenance costs from Table E–2, below
[d] Salt cavern approach cost contingencies developed as per Table E–2, below.

Table E−2. Major Cost Components for Disposal of the Moab Tailings in Salt Caverns

Major Cost Components	Costs ($ Millions)		Comments
	On-site	Off-site	
Site characterization	$4	$15	Test cavern and brine disposal wells
Environmental H&S/NEPA	$16	$35	UIC Permit
Remedial action design	$3	$5	
Site acquisition	$1	$4	For brine/tailings disposal areas
Remedial action field management	$70	$81	Double shift for 20 years
Site preparation	$6	$20	Temp facilities, electricity
Tailings handling	$73	$170	Slurry Prep, Disposal
Cover material	N/A	N/A	
Erosion protection	N/A	N/A	
Site restoration	$12	$30	Reclaim millsite, Moab Wash, wells
All other construction costs	$237	$300	Well stimulation, salt transport
Surveillance and maintenance	$60	$60	Includes long-term ground water costs
Subtotal	**$482**	**$720**	
Contingency (80%)	$385	$576	
Vicinity property design	$1	$1	
Vicinity property construction	$10	$10	
TAC project management	$12	$12	For 6-year period - pre-remediation
Subtotal	$**23**	$**23**	
Contingency (10%)	$2	$2	
Grand Total	$**892**	$**1,321**	

Note: Vicinity property (VP) design, VP construction, and project management have lower uncertainty and, therefore, lower contingency values (10 percent). Eighty percent contingency for other costs based on guidance in DOE Order 413.3. Costs for this approach are pre-conceptual and represent rough order of magnitude.

Preliminary cost estimates for tailings disposal in salt caverns mined beneath the Moab millsite and for off-site disposal in salt caverns mined beneath the Intrepid site or beneath the Sevenmile Canyon site are significantly higher than for the alternatives presented in the EIS because of high capital costs, high operations and maintenance requirements, and high risk contingency. Risk management principles are applied in this case as a major input cost factor for predicting the probability of successfully defining and implementing the disposal concept of slurrying the Moab uranium tailings into salt caverns. Life-cycle costs of remediating and disposing of remaining waste, both uncontaminated and contaminated, in the ponds and with the slurry pipeline will increase the cost of the off-site options. The application of risk management increases the estimated costs and schedule significantly to the $892 million to $1.3 billion range.

E4.0 Advantages and Disadvantages of Salt Cavern Disposal

Relative advantages and disadvantages of tailings disposal in solution-mined salt caverns as compared to the on-site and off-site alternatives presented in the EIS are summarized below.

Advantages of salt cavern disposal include the following points:

- Provides the potential for longer term isolation and more protection than other alternatives;

- Offers the least long-term environmental impact because no surface footprint would remain at the conclusion of the disposal period;
- Provides disposal option for contaminated ground water for 50 of the 75 to 80 years of required ground water remediation.

Disadvantages of salt cavern disposal include the following points:

- Withdrawal of large quantities of Colorado River water that could impact the river and protected aquatic species;
- Technical uncertainties associated with both the uncontaminated brine and radioactively contaminated brine disposal are greater;
- Remediation time frame to complete the tailings disposal phase of the project is greater;
- Potential contractual uncertainty for use of privately owned sites and operations;
- Substantial technical, legal, operational, and life-cycle cleanup cost uncertainties.

E5.0 Conclusions

Disposal of uranium mill tailings in underground salt formations has never been attempted in the United States or elsewhere.

Because of the unproven concept, a large contingency factor must be applied to the total estimated cost. This contingency may not sufficiently account for the uncertainties and unknowns. Resolving these uncertainties sufficiently so that the decision-makers could be sure that this concept can be validated as technically feasible and implementable would require a considerable investment in time and money for additional studies, including injection well testing, subsurface characterization, salt cavern performance assessment, and permitting, all of which are required for a proof of concept. Such studies could require millions of dollars and years to complete, with no guarantee that the investment would demonstrate that this alternative is viable.

DOE has considered the salt cavern disposal option in view of guidance on evaluating alternatives in the Council on Environmental Quality's NEPA regulations (40 CFR 1500–1508). Given the technical, legal, and economic uncertainties associated with this approach, the time and cost needed to resolve the uncertainties and the potential disadvantages, DOE has concluded that this option is not "practical or feasible" and, therefore, is not a reasonable alternative that should be analyzed in detail in this EIS.

Attachment 1

Characterization of Potential Salt Cavern Disposal Sites

Attachment 1

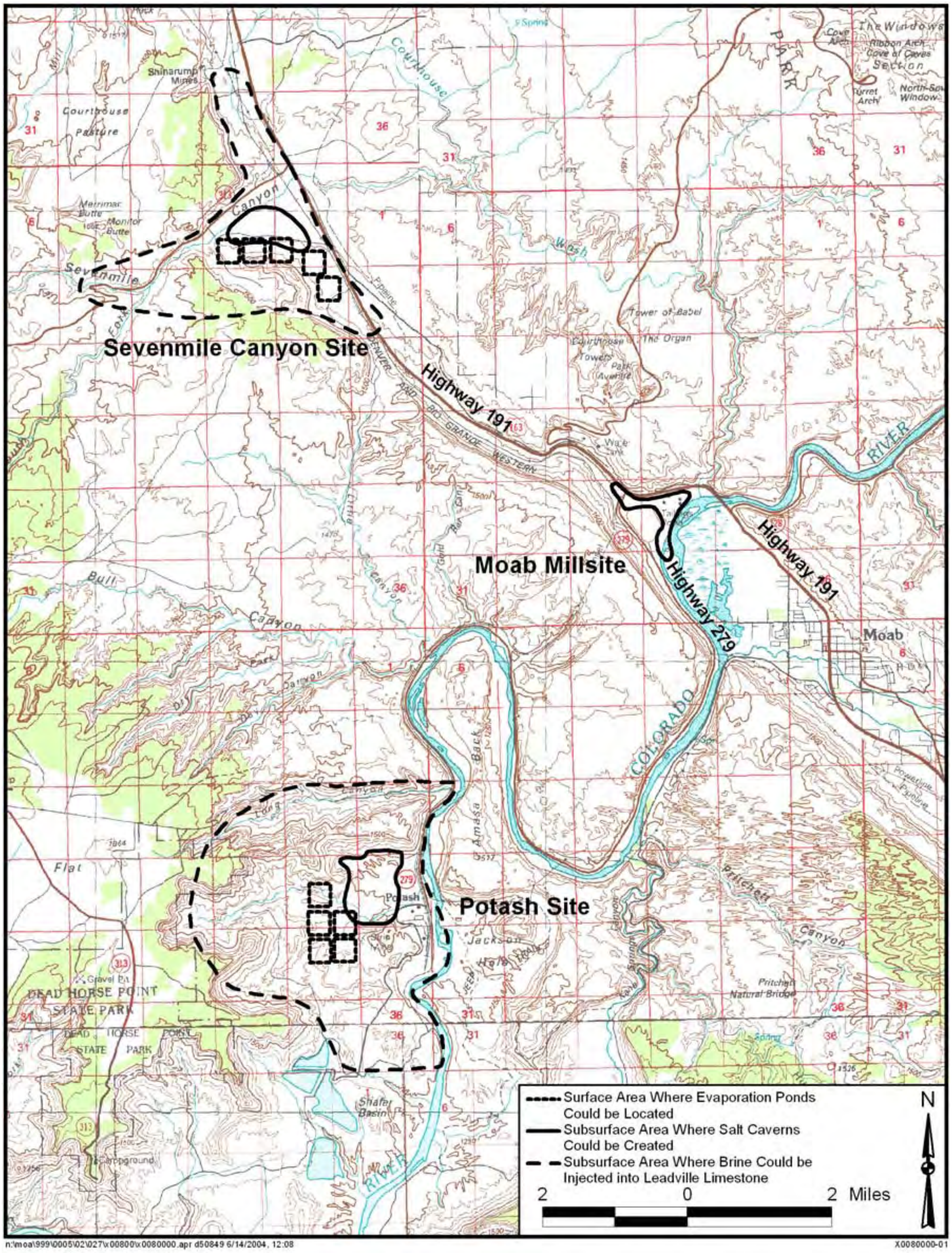

Figure 1. Location Map of Three Geologically Potential Sites

Attachment 1

Description of the Moab Millsite

The thick Paradox Formation composing the Moab Valley salt diapir beneath the Moab millsite might provide solution-mined caverns for tailings disposal. Original beds in the Paradox Formation have been disturbed by salt flowage during creation of the salt diapir. Because of this, beds in the Paradox Formation below the site are expected to be highly contorted or indistinct, or both. This salt flowage and its creation of indistinct or contorted beds in the formation is analogous to conditions in salt domes along the U.S. Gulf of Mexico coastal area, where numerous solution-mined caverns have been developed for storage of liquid and gas products but never for radioactive waste.

The thickness of the Paradox Formation decreases from southwest to northeast across the project site (Figures 2 and 3). At the southwest end of the site (Figure 3), the formation thickness is estimated at 6,000 to 7,000 feet and at the northeast end of the site along the Colorado River; the formation thickness may reach up to 9,000 feet. The northwest-striking Moab normal fault (Figure 3) with a displacement of approximately 2,500 feet is in the northwest end of the site; a larger thickness of the Paradox Formation is on the southwest, or upthrown, side of the fault. The Moab Fault disappears to the southeast, in the area northeast and east of the tailings pile, in the main part of the thick diapir forming the Moab Valley salt-cored anticline.

Multiple solution-mined caverns at the Moab millsite would potentially be situated in an arc-shaped area starting east of the tailings pile and extending north and northwest near State Highway 279 (Figure 2). Spacing of approximately 1,000 feet between each cavern would allow enough area for six caverns. The top of each cavern would be at depths of between 2,000 and 3,000 feet. In the northwest part of the millsite, approximately 1,000 feet of bedrock overlying the Paradox Formation occurs southwest of the Moab Fault. In the southeast part of the millsite (and in all locations), approximately 500 feet of cap rock, the insoluble residue on top of the leached salt diapir, occurs at the top of the Paradox Formation. With these conditions, the base of the 2,000-foot-high caverns would be at depths of between 4,000 and 5,000 feet across the millsite.

Brine disposal at the Moab millsite could be achieved by deep well injection into the Leadville Limestone or sent to large multiple evaporation ponds. The Leadville is approximately 400 feet thick in this area and at a depth below the effects of salt movement. The estimated depths to Leadville Limestone vary across the Moab millsite from 8,000 feet at the northwest end of the site to 9,000 to 10,000 feet in the southeast part of the site. However, the surface area at the Moab site is sufficiently large to allow only one or two brine injection wells. These injection wells would be used for disposal of brine contaminated with fine-grained mill tailings or contaminated ground water. The majority of brine solutions from cavern development could be disposed of by deep well injection into the Leadville Limestone at the potash site or the Sevenmile Canyon site or by evaporation in large evaporation ponds up to 500 acres in size.

Attachment 1

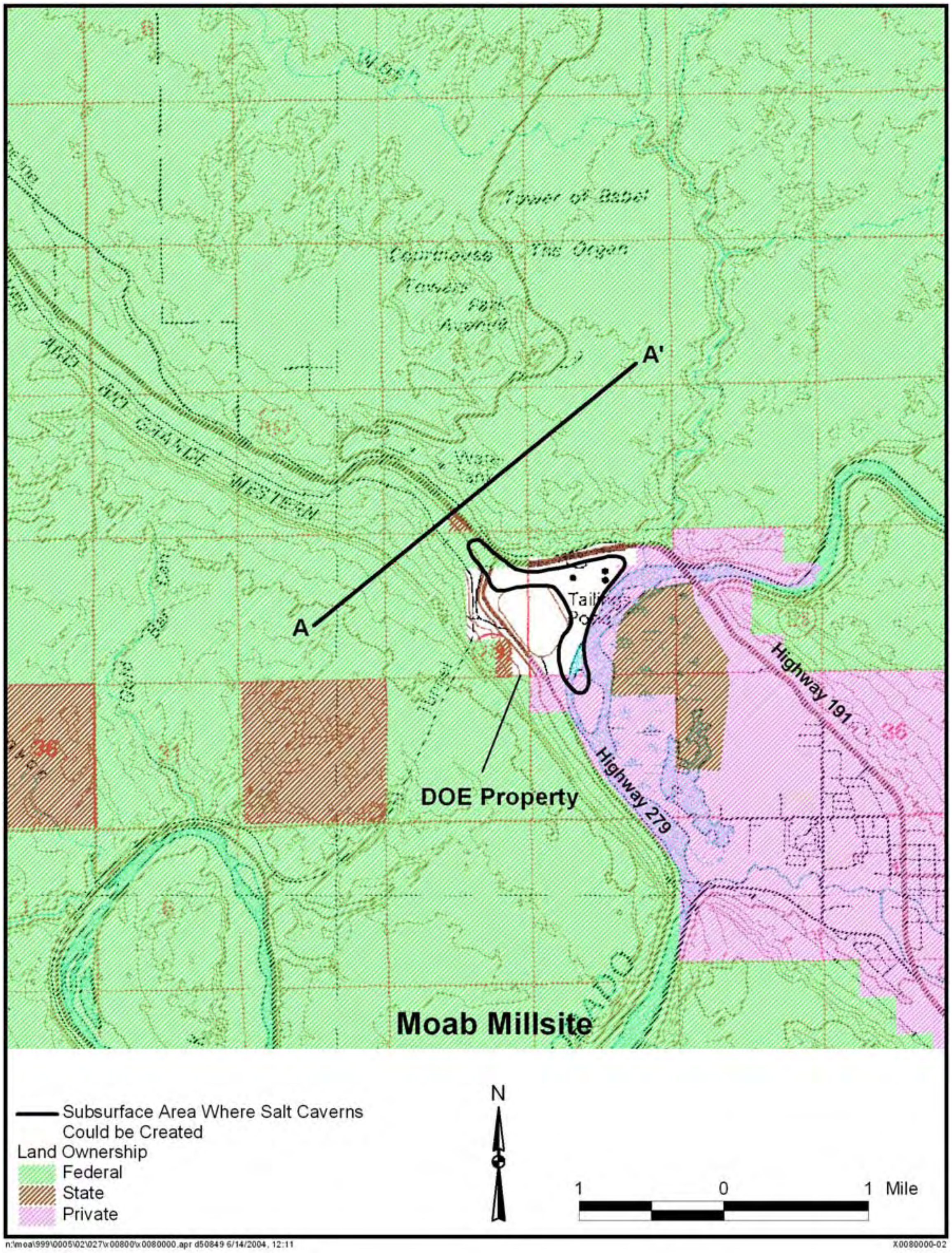

Figure 2. Property Ownership and Location of the Geologic Cross Section for the Moab Millsite

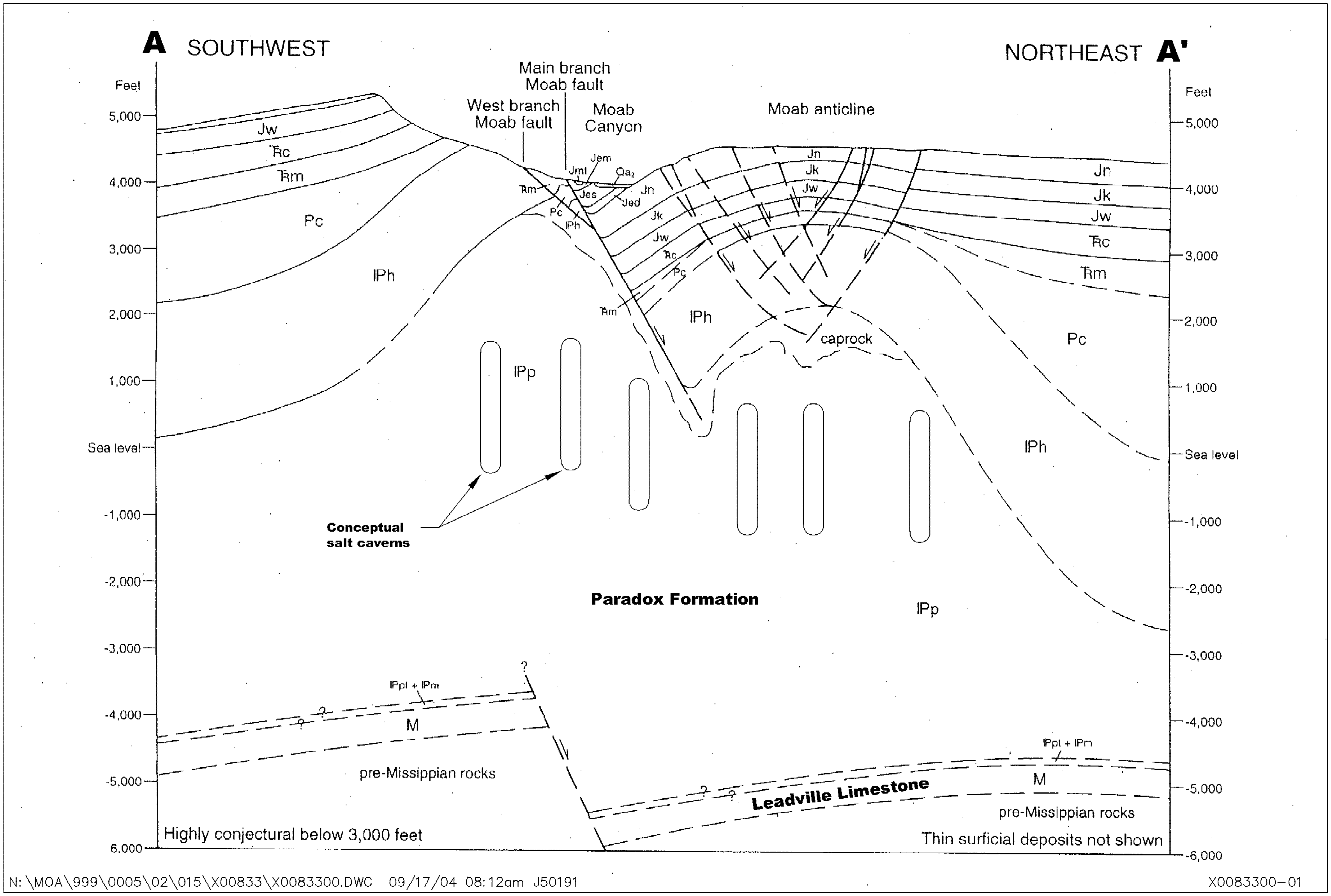

Figure 3. Geologic Cross Section for the Moab Millsite

<u>Attachment 1</u>

Description of the Potash Site

The thick Paradox Formation underlying the Intrepid potash site could provide solution-mined caverns for tailings disposal. The proposed disposal area under which the caverns could be situated is on the northeast flank of the northwest-striking Cane Creek Anticline (Figure 4) approximately 6 air miles southwest of the Moab millsite. This area is about 0.5 to 1 mile north to northwest of the offices and loading facilities of Intrepid Mining, LLC, the present solution-mining and evaporation operator at the Intrepid potash site. Also, the area is at least 0.5 mile north of the underground potash mine workings.

Road distance from the Moab millsite to the potash site along State Highway 279, which is mostly along the bank of the Colorado River, is 15.4 miles (from the junction of U.S. Highway 191). Distance along the railroad spur to the potash site, starting from the road west of the tailings pile that goes to the railroad tunnel entrance, is much shorter at 8.4 miles. The elevation at the proposed disposal area is about 4,000 feet, the same as at the Moab millsite. Elevation difference along the railroad varies from about 4,220 feet at the north end of the tunnel (west of the Moab millsite) to approximately 3,950 feet about 0.5 mile north of the potash site.

A 3,500-foot thickness is estimated for the Paradox Formation in the proposed disposal area (Figure 5) where the formation consists of cyclically interbedded evaporite and clastic beds; 29 cycles of paired evaporite and clastic sequences have been identified. These evaporite/clastic beds are expected to be distinct and underformed or only slightly deformed.

The six solution-mined caverns, spaced approximately 1,000 feet apart, could be situated (in the subsurface) in the low, amphitheatre-like area extending from the railroad westward for about 0.75 mile (Figure 4). The top of the Paradox Formation in this area is at a depth of about 2,500 feet. The top of each cavern would be well within the Paradox at a depth of about 3,500 feet. The base of the 2,000-foot-high caverns would then be at a depth of about 5,500 feet (Figure 5).

Brine disposal at the potash site would be through deep well injection into the Leadville Limestone, estimated to be about 400 feet thick in this area and/or send to large multiple evaporation ponds about 500 acres in size. The depth to the top of the Leadville is approximately 6,500 feet at its shallowest point (where the surface elevation in the area is lowest). Depths for injection could range to about 8,000 feet.

Attachment 1

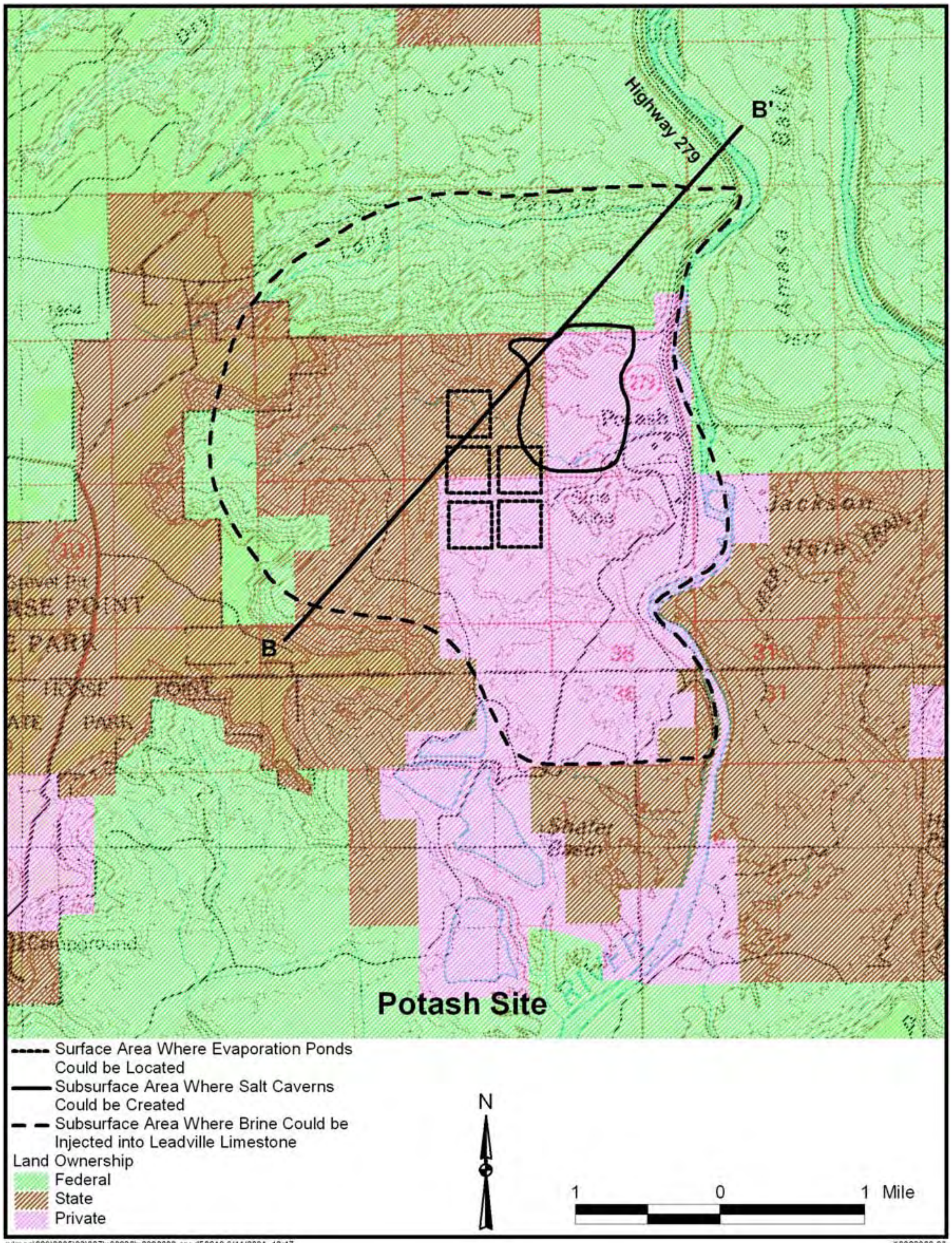

Figure 4. Property Ownership and Location of the Geologic Cross Section for the Potash Site

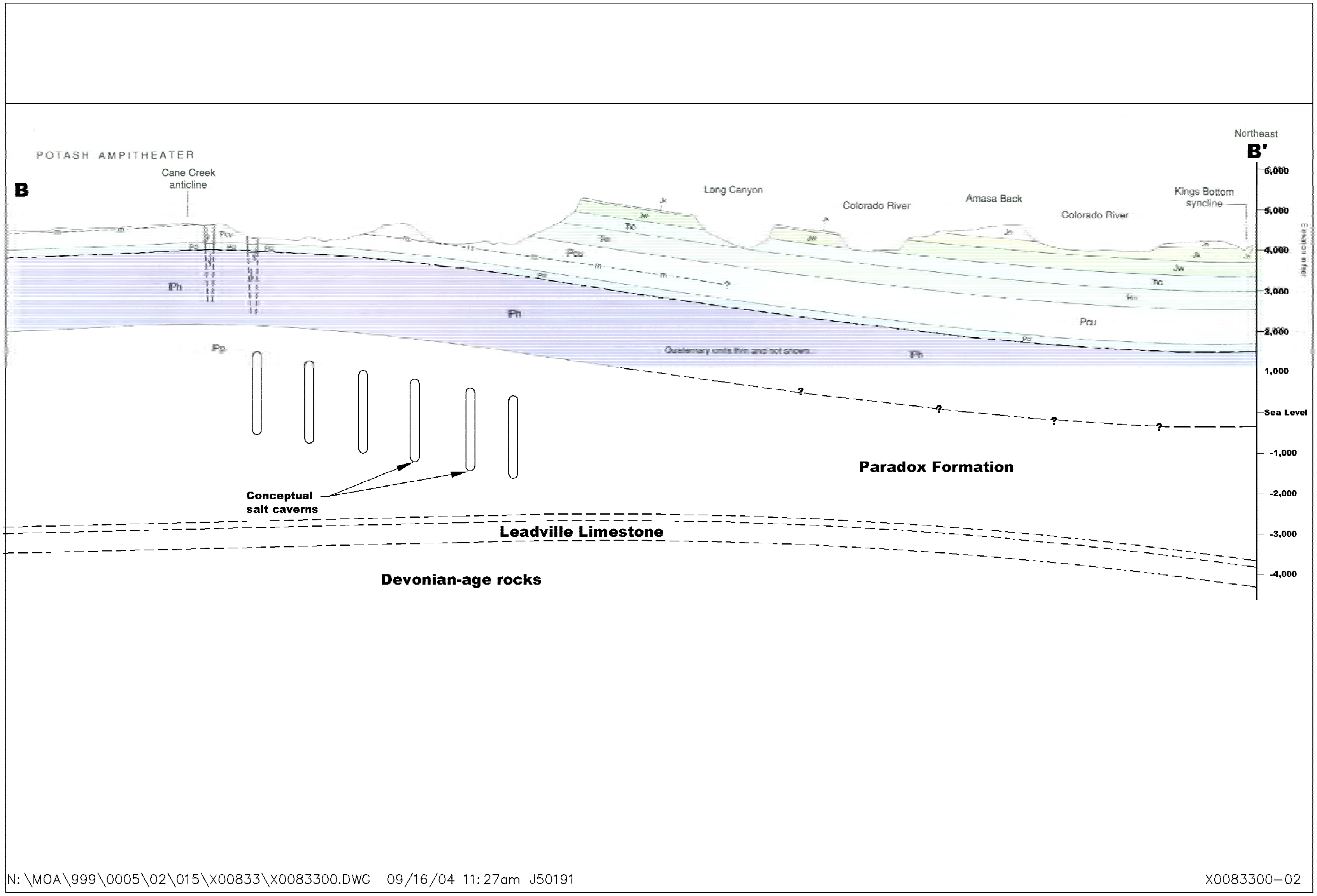

Figure 5. Geologic Cross Section for the Potash Site

Attachment 1

Description of the Sevenmile Canyon Site

The greatly thickened section of Paradox Formation underlying the Sevenmile Canyon area could provide solution-mined caverns for tailings disposal. This area is at the mouth of Sevenmile Canyon, south of the junction of U.S. Highway 191 and State Highway 313 (Figure 6), approximately 7 miles northwest of the Moab millsite. Elevation of this area is approximately 4,500 feet; U.S. Highway 191 rises northwest through Moab Canyon to about 4,600 feet en route to this area from the millsite, which is at an elevation of about 4,000 feet.

The Sevenmile Canyon area is 0.5 to 1.5 miles southwest (on the upthrown side) of the northwest-striking Moab normal fault, which has approximately 3,000 feet of displacement (Figure 7). In this area southwest of the Moab Fault where beds dip gently to the southwest, the Paradox Formation is estimated to be as much as 7,000 feet thick. Because this area is northwest of the Moab Valley salt diapir, original evaporite beds in the Paradox Formation are expected to be distinct and underformed or only slightly deformed.

Spaced approximately 1,000 feet apart, six solution-mined caverns could be situated (in the subsurface) in the flat area south of the junction of the two highways. Here, the top of the Paradox Formation is at a depth of approximately 2,500 feet. The caverns would be situated below any cap rock that might occur in the uppermost Paradox Formation, and the top of each cavern would be at a depth of about 4,500 feet. The base of the 2,000-foot-high caverns would be at a depth of about 6,500 feet (Figure 7).

Brine disposal at the Sevenmile Canyon area would be through deep well injection into the Leadville Limestone or large multiple evaporation ponds approximately 500 acres in size. The depth to the top of the approximately 500-foot-thick Leadville Limestone in this area is about 8,000 feet.

Attachment 1

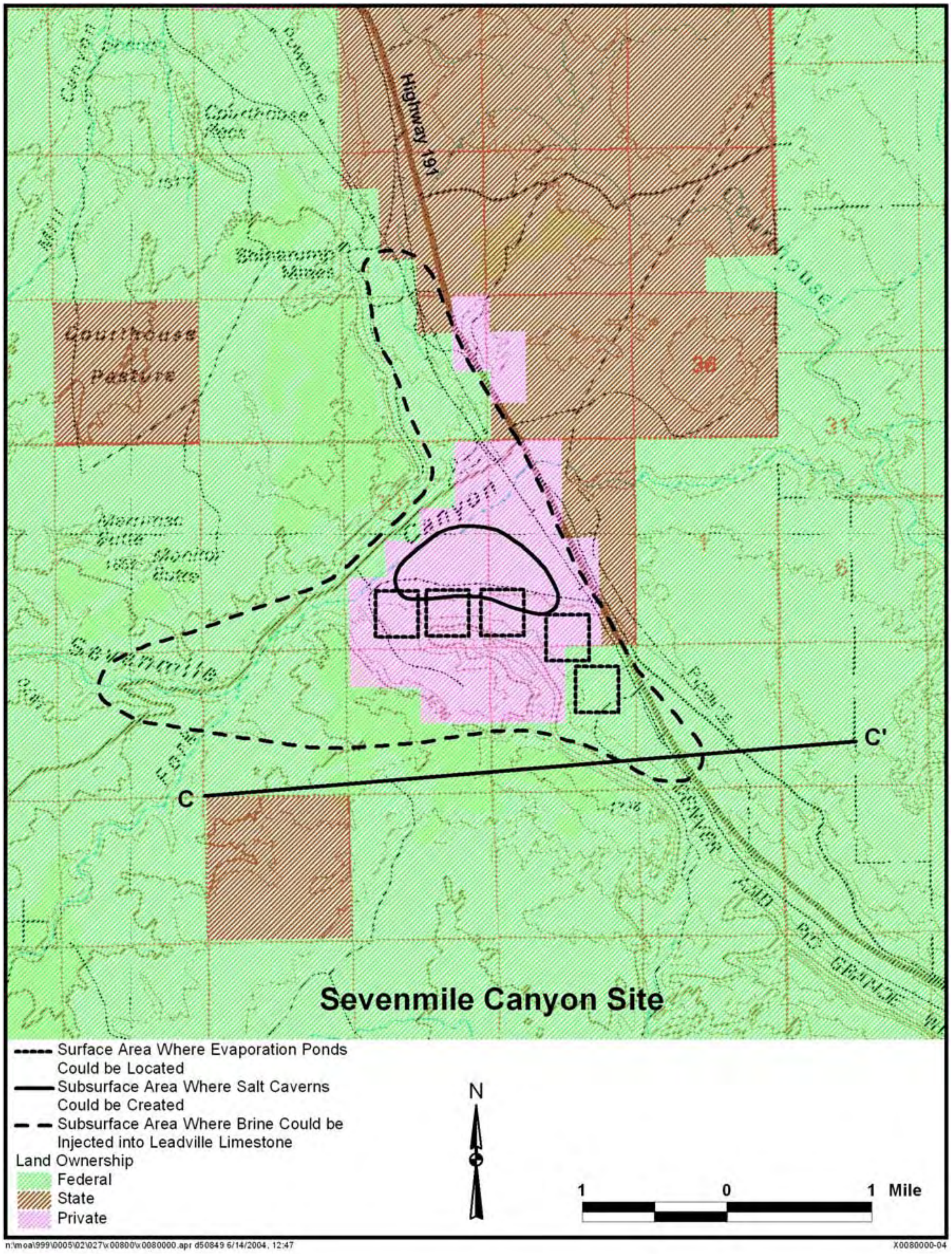

Figure 6. Property Ownership and Location of the Geologic Cross Section for the Sevenmile Canyon Site

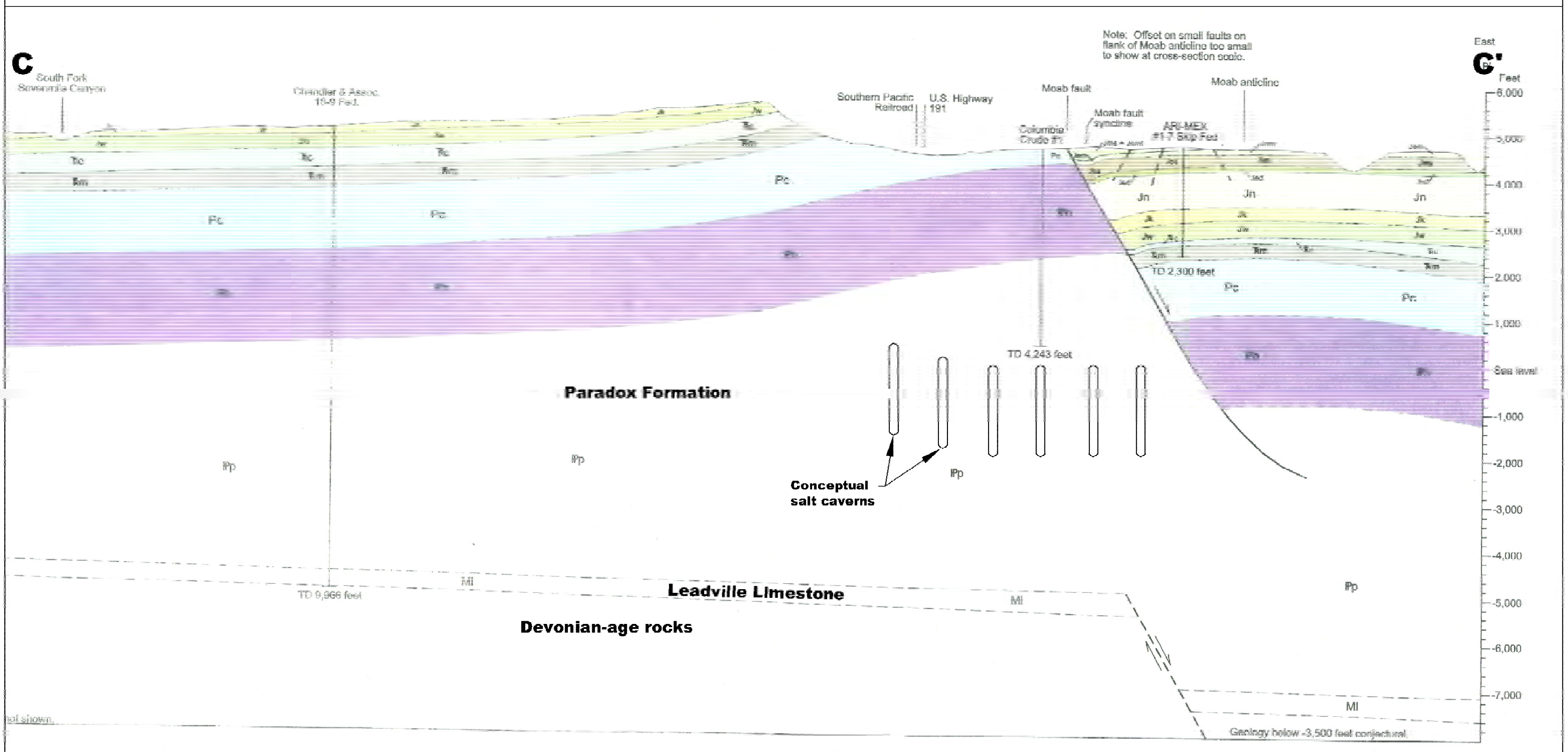

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Figure 7. Geologic Cross Section for the Sevenmile Canyon Site

Appendix F

Floodplain and Wetlands Assessment and Floodplain Statement of Findings for Remedial Action at the Moab Site

F1.0 Introduction

The Moab uranium mill tailings site (Moab site) is located 3 miles northwest of Moab, Utah, on the west bank of the Colorado River. Historical processing of uranium ore at the site has resulted in a 130-acre mill tailings pile and contamination of surface water and ground water. The entire site covers approximately 439 acres, 150 of which are in the 100-year floodplains of the Colorado River and Moab Wash (an ephemeral stream that bisects the site) and the 500-year floodplain of the Colorado River. The site also contains wetlands along the border of the Colorado River (Figure F–1).

Remediation of the Moab site is mandated by the Floyd D. Spence National Defense Authorization Act, which transferred the title for the site and responsibility for cleanup to the U.S. Department of Energy (DOE). The Act also specified that the site be remediated in accordance with Title I of the Uranium Mill Tailings Radiation Control Act of 1978. Custody of the site was transferred to DOE in 2001 for remediation and long-term stewardship. Executive Order 11988, *Floodplain Management*, and Executive Order 11990, *Protection of Wetlands*, requires that each federal agency evaluate the impacts of proposed actions on floodplains and wetlands and consider flood hazards and floodplain management. Regulations in 10 CFR 1022 mandate this assessment, which includes a description of the proposed action for remediation, a description of floodplains and wetlands, a discussion of the effects on floodplains and wetlands, and a consideration of alternatives.

Pursuant to the National Environmental Policy Act of 1969 (NEPA), DOE announced its intent to prepare this environmental impact statement and published a Notice of Floodplain and Wetlands Involvement for remediation of the Moab site (67 FR 77969, December 20, 2002). This notice requested comments from the public regarding potential impacts on floodplains and wetlands associated with remediation of the Moab site.

In 10 CFR 1022.4, a floodplain is defined as "…lowlands adjoining inland or coastal waters …including at a minimum, that area inundated by a 1.0 percent or greater chance flood in any given year." The area meeting this definition is referred to as the base floodplain or the 100-year floodplain. The *critical action floodplain*, also referred to as the 500-year floodplain, is the area inundated by a flood having a 0.2 percent chance of occurring in any given year. Within this floodplain, any activity for which even a slight chance of flooding would be too great (a *critical action*) is prohibited. Because petroleum, lubricants, and other hazardous materials would be used during the construction phase of this project, both the base floodplain and the critical action floodplain are considered in this assessment.

National Flood Insurance maps have not been updated recently, do not reflect current site conditions, and do not include the 500-year floodplain boundary, so they were not used for floodplain boundaries for this assessment. Therefore, flood and rainfall data, including an extensive backwater analysis (Mussetter and Harvey 1994) were used with the U.S. Army Corps of Engineers (USACE) HEC-2 model to determine the current 100-year and 500-year floodplains at the site.

A wetland is defined in 10 CFR 1022.4 as "an area that is saturated by surface or ground water at a frequency and duration sufficient to support a prevalence of vegetation typically adapted to life in saturated soil conditions." Wetlands can serve a variety of functions in an ecosystem, including water quality preservation, flood protection, erosion control, biological productivity, and wildlife habitat. The presence of riparian vegetation such as cottonwood (*Populus* spp.), willow (*Salix* spp.), and tamarisk (*Tamarix ramosissima*) does not necessarily indicate the presence of wetlands because such plants have deep root systems that enable them also to grow in upland areas with a sufficient water table.

To gather information about other possible floodplains and wetlands in the project areas, several resources were examined:

- *U.S. Fish and Wildlife Service National Wetlands Inventory.* The inventory contained no information on wetlands in or near the sites.
- *U.S. Department of Agriculture, Natural Resources Conservation Service* (NRCS). Local offices of the NRCS have not conducted any wetland delineations near any of the sites. Current soil surveys did not indicate hydric soils at any of the locations being considered.
- *U.S. Geological Survey Topographic Maps.* Topographic maps of the areas involved were examined for evidence of springs and streams in the project area. These areas were further investigated by contacting local, state, and federal agency personnel and by making site visits when possible.

F2.0 Project Description

This section briefly describes the proposed project. For more detailed descriptions, see Chapter 2.0 of the *Remediation of the Moab Uranium Mill Tailings, Grand and San Juan Counties, Utah, Final Environmental Impact Statement* (DOE/EIS-0355). Both on-site and off-site disposal alternatives are under consideration; in either case, ground water remedial action would take place at the Moab site for an estimated 75 to 80 years after remediation. The on-site disposal alternative would be completed in 7 to 8 years and would involve stabilizing the existing tailings, along with contaminated materials to be identified and removed from the remainder of the Moab site and any affected vicinity properties, at the Moab site. Alternatively, the tailings and all other contaminated materials could be transported and disposed of in an off-site cell. This alternative would be completed in an estimated 5 years and would include transportation methods of truck, rail, or slurry pipeline.

This section is divided into two parts. Section F2.1 describes the proposed on-site disposal alternative at the Moab site, including ground water remediation and vicinity properties. Section F2.2 discusses off-site disposal alternatives at Klondike Flats (approximately 18 miles northwest of Moab), Crescent Junction (approximately 30 miles northwest of Moab), and White Mesa Mill (approximately 80 miles south of Moab).

F2.1. Proposed Actions at the Moab Site—On-Site Disposal Alternative

F2.1.1 Remediation of Contaminated Materials

In areas with surface contamination, large earth-moving equipment would be used to excavate soil from the top layer. Existing contaminated vegetation, consisting mostly of tamarisk, would be cleared and chipped for disposal in the cell. Disturbed areas would be revegetated with native species.

Remediation of vicinity properties in the Moab area would include excavating and transporting contaminated materials from affected properties. Disturbed areas would be reclaimed.

F2.1.2 On-Site Disposal Cell

Construction of an on-site disposal cell would involve stabilizing and capping the tailings pile in place. The activities would take place outside wetlands and floodplains with the following exceptions. Interim storage of uncontaminated borrow materials for the disposal cell would occur within the 100-year floodplain. Storm water management measures, including the construction of berms, drainage ditches and basins, hay bales, sediment traps, and silt fence fabric, would also occur on the floodplain. Under the on-site disposal alternative, Moab Wash would be rechanneled. The wash would be moved north of its current location, away from the base of the tailings pile. It would be designed to carry runoff for an approximate 200-year flood and would discharge into the Colorado River at its historical (pre-millsite) location. To further protect the disposal cell, a buried riprap wall would be installed in the Colorado River floodplain. The wall would protect the stabilized tailings pile from river migration and erosion to meet the design life of the disposal cell. DOE would also perform additional flood analyses at Courthouse Wash to determine the best alignment and design requirements.

Long-term maintenance and monitoring of the disposal cell would include inspecting the floodplain and river boundary and the buried riprap wall.

F2.1.3 Ground Water Remediation

Ground water remediation could involve installation of up to 50 wells or 1,500 to 2,000 linear feet (ft) of shallow trenches in the floodplain to intercept contaminated ground water before discharge to the river. The wells or trenches would be installed in areas already disturbed by surface remediation.

There are several options for treating collected ground water. Evaporation ponds could be installed in the floodplain and isolated by berms from the 100-year flood level to evaporate the water, resulting in a concentrated brine or sludge for disposal. Injection of the water into a hydrologically separate deep saline aquifer is another possibility. Currently, tamarisk on the site is removing a significant quantity of ground water and plays a phytoremediation role. Similar deep-rooted plants could be placed on the floodplain after remediation. Alternatively, salt-tolerant native or agricultural plants could be irrigated for uptake.

F2.1.4 Borrow Areas

Seven proposed borrow areas for soil, sand, gravel, and rock are being investigated for the on-site disposal alternative. LeGrand Johnson and Papoose Quarry are existing commercial quarries. Floy Wash, Crescent Junction, Tenmile, Courthouse Syncline, and Blue Hills Road borrow areas would be new excavations, requiring new transportation routes. Disturbed areas would be reclaimed with native vegetation.

F2.2. Off-Site Disposal Alternative

Construction, vicinity properties remediation, and ground water remediation activities at the Moab site would be similar to those described in Section F2.1, with several changes:

- Moab Wash would not be rechanneled. It could be reconfigured with meanders to slow the water velocity and erosion potential of high flows. It would be lined with riprap and designed to carry a 200-year flood.
- Storm water management structures would be removed when remediation was complete.
- There would not be a buried riprap wall in the floodplain.
- Storage of borrow materials at the Moab site would not be necessary.
- Maintenance and monitoring of an alternative disposal cell would occur off-site.

All of the off-site alternatives would involve constructing a new disposal cell; preparing tailings for transport; transporting the tailings to the cell by rail, truck, or slurry pipeline; excavating borrow areas; and constructing borrow material transportation routes. All transportation options would require activity within the floodplain at the Moab site. Rail and truck options would require processing and/or drying areas within the floodplain. The slurry pipeline option would require the construction of temporary facilities to mix the slurry. All processing areas would be protected by berms against a 100-year flood event.

The White Mesa Mill alternative does not include rail transport because no rail lines go to that disposal location. This alternative also proposes the use of two additional borrow areas, Blanding and White Mesa Mill. If the White Mesa Mill option were chosen and a slurry pipeline were used, the pipeline would cross the 100-year floodplain at the Moab site. It would also cross the Colorado River, Matheson Wetlands Preserve, and numerous streams and dry washes. Under the Klondike Flats and Crescent Junction disposal alternatives, a slurry pipeline would not cross these areas. Floodplains and wetlands associated with individual borrow areas or transportation routes are described in Sections F3.0 and F4.0.

F3.0 Floodplain and Wetlands Descriptions

F3.1. Moab Site

The 100-year and 500-year floodplains for Moab Wash and the Colorado River occupy 150 acres, or the easternmost third of the Moab site (see Figure F–1). Floodplain alluvium consists of shallow sandy sediments and deeper gravelly sediments. Thickness of the shallow alluvium ranges from 8 to 30 ft. Coarse sand and gravel with occasional silt and clay pockets make up the deeper alluvium layer. The water table is within 5 feet of the surface in the floodplain through most of the year (SMI 2001).

Base flow for the river ranges from 3,000 to 4,000 cubic feet per second (cfs); the average peak between April and July (based on flows from 1914 to 1999) is 22,000 cfs. The river stage increases by approximately 7 feet during average peak flow. Currently, the river accesses the floodplain at the Moab site when it reaches 48,900 cfs. Because tamarisk has stabilized the soils and flow has been altered by upstream water diversions, the floodplain is not accessed by a 5-year or less flood event. Therefore, it is not considered an active floodplain. During a 100-year flood, flow would reach 99,500 cfs (NRC 1997). The 500-year flood discharge for the river was estimated by the U.S. Geological Survey to be 123,500 cfs (Jacoby and Gonzales 1993). These discharges are based on flows at the Cisco gaging station, which is 35 miles upstream from Moab; the flows at the Cisco station are considered representative of the flows at the Moab site because there are no significant tributaries between the gage and the site. One of the highest recorded discharges of the river was in 1984, when the flow reached 70,300 cfs. This flow flooded part of Moab and rose about 4 ft above the toe of the tailings pile (NRC 1999). The U.S. Nuclear Regulatory Commission (NRC) calculated a 300,000-cfs discharge applicable to the Moab site during the probable maximum flood (PMF). This flow would correspond to a water depth of 29 feet above the toe of the tailings pile (Mussetter and Harvey 1994).

Moab Wash runs through the middle of the site to the Colorado River. The wash drains approximately 5 square miles and is located north and east of the tailings pile (NRC 1997). Its original configuration was altered during milling operations. It is an ephemeral stream with infrequent, brief runoff periods during rainstorms and snowmelt. The 100-year flow for Moab Wash is 9,480 cfs, based on precipitation of 2.6 inches in 24 hours (USACE 1995). The PMF flow for Moab Wash was estimated at approximately 16,000 cfs (NRC 1997). Practices implemented as a result of the *Moab Project Site Storm Water Pollution Prevention Plan* (DOE 2002) limit the amount of runoff entering the wash from the millsite.

Vegetation on the floodplain is dominated by tamarisk, which is dense in the areas adjacent to the river and sparse or patchy in other areas. There are approximately 50 acres of mature tamarisk, with patches of cottonwood and Russian olive at the Moab site. Milling operations and remedial activities have disturbed much of the floodplain in recent years and have limited its use by wildlife. The tamarisk areas on the floodplain are not jurisdictional wetlands.

Several areas below the tamarisk next to the Colorado River were investigated in February 2002 and were found to contain wetland plants and soils. These areas include sandbars downstream of Moab Wash that are critical habitat for sensitive fish species. Seedling tamarisk is the predominant plant in these wetland areas; other wetland plants include saltgrass *(Distichlis spicata)*, cattail *(Typha* sp.), rush (*Juncus* sp.), bulrush *(Scirpus* sp.*)*, spikerush (*Eleocharis* sp.), redroot flat sedge (*Cyperus erythrorhizos*), and sandbar willow (*Salix exigua*). Formal wetlands delineations indicate that 4.7 acres of USACE jurisdictional wetlands exist immediately adjacent to the Colorado River, at the Moab Site's eastern boundary. Although wetland vegetation exists on the margins of an on-site holding pond for irrigation water, this area is not a jurisdictional wetland because the water source is artificial.

The Matheson Wetlands Preserve is an 875-acre conservation area that occupies the floodplain across the river from the site. The preserve has a variety of wetland types that include emergent wetlands, shrub wetlands, cottonwood stands, and ponds. It is the only sizable wetland remaining on the Colorado River in Utah and is important in serving multiple functions, including water quality preservation, flood protection, erosion control, and biological productivity and diversity. A levee along the northwest edge of the wetland failed in 1984 and now allows water into the wetland when the flow reaches 40,000 cfs (Mussetter and Harvey 1994). This levee possibly affects flooding potential at the Moab site; if the entire levee were removed, floodwaters would inundate the Matheson Wetlands Preserve in a shorter time. Currently, floodwaters inundate the Matheson Wetlands Preserve at a lower stage than at the DOE site (40,000 cfs vs. 48,900 cfs).

In the desert environment, it is common for very small wetlands to occur at numerous seeps, springs, and areas of rainfall collection. The presence of riparian vegetation such as tamarisk, willow, or cottonwood may indicate the presence of such small wetlands, but because riparian trees and shrubs have very deep roots, they usually occur alone, without associated wetlands. Because it is difficult to locate all the small emergent wetlands throughout large geographical areas, there is incomplete knowledge regarding their location and size. Although they are very small, these wetlands have ecological importance. It is known that no such wetlands occur on the Moab site. All other areas to be remediated or disturbed by construction, including vicinity properties, would be examined thoroughly for small wetlands prior to construction. If such wetlands were found, they would be protected (Section F4.1.2).

F3.2. Klondike Flats Site

No perennial streams or rivers exist at the Klondike Flats site (Figure F–2). The site contains numerous ephemeral washes in which surface flooding occurs, but these areas are not floodplains. Northern portions of the Klondike Flats site drain into the Green River (approximately 23 river miles) via tributaries to Tenmile Wash. Southern portions of the site drain into the Colorado River (approximately 15 river miles) via Courthouse Wash. Several areas of wetland riparian vegetation are present in or near the southern portion of the Klondike Flats site. Two occur near small ephemeral reservoirs north of the site and are vegetated primarily by tamarisk. In all, 66 acres of land containing some riparian vegetation exist in five locations near the site (BLM 2003).

No wetland areas are known to exist at the Klondike Flats site. However, if the Klondike Flats disposal alternative were chosen, areas vegetated with riparian species would be investigated for any small, isolated wetlands.

F3.3. Crescent Junction Site

Although no floodplains exist at the Crescent Junction site, due to its location at the base of the Book Cliffs and adjacent to Crescent Wash, it is subject to extreme surface water flooding potential (BLM 2003).

There are no known wetlands on or near the Crescent Junction site; therefore, a map of the site is not included in this document. Three small water collection structures exist on the site, but they have no associated riparian vegetation (BLM 2003). Two other collection structures near the site are vegetated by tamarisk and grasses. Although it is unlikely that wetland areas occur in these areas or along the proposed transportation and pipeline routes, they would be thoroughly investigated for small, isolated wetlands.

F3.4. White Mesa Mill Site

The White Mesa Mill site is situated near four intermittent streams, all of which contain cottonwood and tamarisk, valuable riparian resources. Corral Creek, to the east, has a 5-square-mile drainage and is a tributary to Recapture Creek. Westwater Creek to the west drains 27 square miles into Cottonwood Creek. Both Cottonwood and Recapture Creeks flow into the San Juan River. PMF estimates for Cottonwood Creek, Westwater Creek, and Corral Creek are 66,000 cfs, 18,000 cfs, and 14,000 cfs, respectively (Dames and Moore 1978). The existing watercourses for these creeks have capacities that exceed their PMF values. The White Mesa Mill site is located beyond the floodplains of these creeks.

Water resources in and near the White Mesa Mill site have not been assessed in detail; such an assessment would be required if this alternative were chosen. Topographic maps of the area potentially indicate 10 riparian or wetland areas within the boundaries of the site, 2 of which occur within the borrow area. The following resources are known to exist:

- Perched ground water discharges in springs and seeps along Westwater Creek Canyon, Cottonwood Creek, and Corral Canyon where the Burro Canyon Formation crops out.
- Ruin Spring, approximately 2 miles southwest of the millsite, flows on a consistent basis, and riparian species (including cottonwood and tamarisk) grow near the discharge. The other springs and seeps have not been known to flow year-round, although plants such as cattails have been observed around a seep in Cottonwood Canyon.
- Two small, ephemeral catch basins are located near the millsite; these ponds are filled by the mill to provide water and habitat for local wildlife, and it is assumed that they have associated wetland vegetation.

Figure F−3 shows potential wetland and riparian areas on and near the White Mesa Mill site.

The White Mesa Mill pipeline would cross 11 perennial streams and at least 21 intermittent drainages. The perennial streams contain riparian and wetland vegetation such as cottonwoods, willows, tamarisk, and bulrush. Some of the intermittent washes also have wetland vegetation and could be considered valuable riparian resources. The pipeline would also cross the Colorado River and the Matheson Wetlands Preserve.

F3.5. Borrow Areas

F3.5.1 Areas with No Floodplains or Wetlands

Of the 10 proposed borrow areas, 5 have no associated floodplain or wetland areas: the commercial quarries (LeGrand Johnson and Papoose Quarry), and the Klondike Flats, Crescent Junction, and Blanding borrow areas. Some transportation routes to these areas may cross dry washes, and though no wetlands are known to exist, the areas would be investigated for small, isolated wetlands.

F3.5.2 Blue Hills Road Borrow Area

Near the southwest corner of this site, a small spring provides water to maintain cottonwoods and bulrush. As this small potential wetland area approaches the edge of the borrow area, the vegetation changes to more drought-tolerant species such as skunkbush and serviceberry, reflecting the drier, nonriparian conditions. Figure F–2 shows the location of the spring relative to the proposed borrow area.

F3.5.3 Courthouse Syncline Borrow Area

Courthouse Syncline borrow area contains portions of Thompson Wash and Crescent Wash. Both washes are intermittent streams that contain potential wetlands. It is unlikely that any wetlands occur in the area, but because they contain some tamarisk populations, these areas would be investigated for small, isolated wetlands.

F3.5.4 Floy Wash Borrow Area

The Floy Wash borrow area is bordered by Floy Wash, an intermittent stream that lies to the west of the proposed borrow area (Figure F–4). Though not located within a floodplain, this wash is prone to extreme surface flooding (BLM 2003).

The whole of Floy Wash has 80 acres of native and exotic riparian and wetland resources, including lentic wetlands, tamarisk, and willow areas (BLM 2003). Farther downstream, the wash supports additional riparian areas containing cottonwood, willow, bulrush, and tamarisk. The wash has been rated by BLM as a "functioning at risk" system, meaning that it fulfills some, but not all, of the definitions of a properly functioning riparian system (BLM 2002). Known lentic wetlands lie approximately 0.5 mile north and 1 mile south of the borrow area. Portions of Floy Wash and a small water impoundment structure in the southeast corner of the area contain tamarisk, but they are not likely to contain jurisdictional wetlands. However, they would be investigated for small, isolated wetlands.

F3.5.5 Tenmile Borrow Area

The Tenmile borrow area is within one-quarter mile of Tenmile Wash, an ephemeral wash system dominated by tamarisk. BLM has rated it as a non-functioning riparian system, meaning that improvements must be made to restore the riparian values of this system (BLM 2002). The channel is deeply incised with bank collapse and gullying. There are a total of 99 acres of wetland areas in the whole of Tenmile Wash, and its drainage also supports a network of 125 acres of developed cattail and bulrush wetlands downstream (BLM 2003). Such lentic wetlands are rare in desert environments. Figure F−5 shows the location of Tenmile Wash relative to the borrow area.

F3.5.6 White Mesa Borrow Area

The borrow areas associated with the White Mesa Mill site contain some drainages with riparian vegetation that may also contain associated wetlands (see Figure F−3). These would need a more detailed water resource inventory should this alternative be chosen.

F4.0 Floodplain and Wetlands Impacts

F4.1. Moab Site—On-Site Disposal Alternative

F4.1.1 Floodplains

Removal of contaminated materials during surface remediation at the Moab site may permanently lower the base elevation of the floodplain. The depth of soil removed may be greater than the 6 inches of topsoil proposed for reclamation. This would result in flooding of the site at a slightly lower river stage, increasing the capacity of the floodplain, and possibly minimally affecting flooding patterns at the Matheson Wetlands Preserve. Although the capacity of the floodplain would increase, the boundary would not change significantly.

Rechanneling Moab Wash would permanently affect features within the floodplain by changing drainage patterns and the river discharge point. Fortification of the wash with riprap to withstand 200-year flows would make it less likely to overflow or to carry sediment into the river. More water could be discharged to the river, but this would be somewhat mitigated by storm water management measures that would decrease runoff to Moab Wash. The wash would enter the river farther upstream and could change flow patterns; this could alter fish habitat and possibly affect wetlands over time. Critical fish habitat is discussed in the Biological Assessment (Appendix A1).

The buried riprap wall would permanently alter the floodplain by stabilizing soils in the floodplain.

Vegetation loss would result from remedial action. Currently, the tamarisk located on the floodplain plays a significant role in reducing the amount of ground water reaching the river. Removal of the tamarisk could cause more contaminated ground water to migrate to the river unless additional interim actions were implemented. Another effect of vegetation removal is a greater potential for erosion from the floodplain. This short-term effect would be mitigated by storm water management measures, described in Section F2.1.2. Because the area would be revegetated, these effects would be temporary.

Wastes generated from construction activities would be evaluated and managed according to the site waste management plan to ensure protection of public health, safety, and the environment. The use of petroleum, oil, lubricants, and other hazardous materials during construction would be controlled, spills would be promptly cleaned up, and any affected surface would be remediated. Fuel storage and refueling facilities would not be located in the floodplain.

With some ground water remediation strategies, trenches and/or evaporation ponds would be constructed in the floodplain. These structures would be bermed for a 100-year flood event. No long-term negative effects would be expected as a result of ground water remediation. Disturbance would take place in areas already disturbed by surface remediation. Removal of contaminated surface soils and ground water would improve water quality in the Colorado River adjacent to and downstream of the site.

Impacts to floodplains caused by vicinity property remediation would likely be short-term. Vicinity property remediation would be on a much smaller scale than at the Moab site.

The proposed floodplain actions would result in no significant effects to lives or property.

F4.1.2 Wetlands

At the Moab site and on vicinity properties, impacts to wetlands would be avoided whenever possible. Unavoidable excavation of contaminated soils along waterways would result in a temporary increase in sedimentation downstream. A temporary loss of wetland soils and vegetation would occur in all excavated wetlands, but these would be replaced during reclamation. Reclamation of wetlands would be in accordance with USACE Section 404 permitting requirements. The USACE regulates activities in wetlands and issues permits that require mitigation for any temporary or permanent disturbances. Its permitting requirements, both general and site-specific, would ensure that the size, quality, and function of wetlands are preserved.

F4.2. Off-Site Disposal–Klondike Flats

Impacts from remediation at the Moab site would be similar under the Klondike Flats off-site disposal alternative, with several changes. Because there would be no rechanneling of Moab Wash to a new location, effects associated with rechanneling would not apply. There would not be a buried riprap wall in the floodplain, and storage of materials for disposal cell construction would not be necessary. Also, effects from storm water management measures would be temporary because storm water management structures would be removed after remediation.

At the Moab site, tailings processing areas would be constructed in several locations on the floodplain during remediation. Depending on the mode of transportation, these areas would be used to dry tailings for transport or to mix tailings with water to form slurry. The tailings processing areas would be bermed to protect against a 100-year event and removed after remediation.

If the Klondike Flats site alternative were chosen, a formal survey would be undertaken to identify any small, isolated wetlands that may exist in the area. All impacts to such wetlands, including disturbance or sedimentation due to runoff, would be avoided.

No impacts to floodplains and wetlands would be expected from monitoring and maintenance of this facility.

F4.3. Off-Site Disposal–Crescent Junction

Under the Crescent Junction off-site disposal alternative, impacts at the Moab site would be the same as those described in Section F4.2. The Crescent Junction site is more susceptible to surface flooding than the Klondike Flats site, and construction of a disposal cell could add more sediment to the Crescent Wash drainage. However, because of the distance between Crescent Wash and the Colorado River, impacts to distant floodplains and wetlands would be unlikely.

There are no floodplains at the Crescent Junction site. If this alternative were chosen, areas containing riparian vegetation would be surveyed to identify any small isolated wetlands that may exist in the area. All impacts to such wetlands, including disturbance or sedimentation due to runoff, would be avoided.

No impacts to floodplains and wetlands would be expected from monitoring and maintenance of this facility.

F4.4. Off-Site Disposal–White Mesa Mill

Under the White Mesa Mill off-site disposal alternative, impacts at the Moab site would be the same as those described in Section F4.2. If a slurry pipeline were installed, it would be within the 100-year floodplain.

Construction on the White Mesa Mill site has a potential for sediment loading or surface water runoff into adjacent streams and wetlands. This effect would be temporary and would be mitigated with a storm water management system and revegetation.

The slurry pipeline transportation option would involve crossing the Colorado River and the Matheson Wetlands Preserve, along with 11 perennial streams and at least 21 intermittent drainages. There have been previous utility crossings in the Matheson Wetlands Preserve, and the pipeline for this project would follow these as closely as possible. Construction of the pipeline would involve an estimated 3,500 ft of directional drilling under the streams and wetlands. A small potential exists for leakage of drilling fluids into the ground water beneath the wetlands. Up to 1 mile of open-cut buried crossings would introduce sediment into the stream during the period of construction. To reduce sediment impacts, crossings would be constructed during low-flow periods, and sediment control measures would be implemented. Unavoidable disturbance to wetlands along waterways would be mitigated in accordance with USACE Section 404 guidelines (see Section F4.1.2).

Some of the springs or seeps adjacent to the White Mesa Mill site may be hydrologically connected to the site, and there could be a potential for ground water contamination due to spills, pipeline rupture, or other accidents. Mitigation to minimize the possibility of exposure would be implemented.

No impacts to floodplains and wetlands would be expected from monitoring and maintenance of this facility.

F4.5. Borrow Area Impacts

Removal of materials from borrow areas would involve the use of large earth-moving equipment. Borrow areas and their associated transportation routes would be chosen to avoid any impacts to wetlands, including sedimentation.

F5.0 Summary

Disturbance to floodplains at the Moab site and on any potential vicinity properties would be unavoidable where soils within the floodplains are contaminated. The ground water treatment system described in Section F2.1.3 must be located in the floodplain at the Moab site. Because of space constraints, materials must be stored within the floodplain (Section F2.1.2), and tailings processing areas (Section F2.2), excluded by berms, must be located within the floodplain boundary.

Disturbance to wetlands would be unavoidable where wetland soils are contaminated. In all other areas except in construction of a slurry pipeline to White Mesa Mill, wetlands could be avoided. Disturbance to wetlands would be unavoidable if a slurry pipeline were constructed because there is no alternative route.

The only alternative to remediation is a No Action alternative. Under this alternative, DOE would not remediate contaminated materials or ground water. No short-term or long-term site controls to protect human health or the environment would be in place. This alternative is analyzed to provide a basis for comparison to the action alternatives and is required by NEPA regulations.

F6.0 References

10 CFR 1022. U.S. Department of Energy, "Compliance with Floodplain and Wetland Environmental Review Requirements."

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42 FR 26961, *Protection of Wetlands*, Executive Order 11990, May 24, 1977.

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Jacoby, D.L., and R.O. Gonzales, 1993. *Proposed Amendment to Source Material License SUA-917 for Reclamation and Closure of Atlas Corporation's Moab Mill Disposal Area near Moab, Utah,* Memorandum for Docket File No. 40-3453, U.S. Nuclear Regulatory Commission, Region IV, Uranium Recovery Field Office, Denver, July 7.

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Attachment 1

Floodplain and Wetland Statement of Findings

Floodplain and Wetland Statement of Findings

AGENCY: U.S. Department of Energy (DOE)

SUMMARY:

The Moab site is a Title I site under the Uranium Mill Tailings Radiation Control Act, as amended by the Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001. A Floodplain and Wetlands Assessment was prepared to assess on-site and off-site alternatives to remediate residual radioactive material (RRM) in accordance with 10 CFR 1022.12 and Executive Orders 11988 and 11990; this assessment is included in the Moab site environmental impact statement (EIS) as Appendix F. On April 6, 2005, DOE announced its preferred alternatives for remediation of the Moab site: (1) offsite disposal of the tailings pile and other contaminated materials at the Crescent Junction site, and (2) active ground water remediation at the Moab site. This Statement of Findings is included in the final EIS in accordance with 10 CFR 1022.15 for the preferred alternatives only.

DESCRIPTION OF PROPOSED ACTION:

The major actions associated with implementing the preferred alternatives are briefly outlined below. For more detailed descriptions of the proposed actions, see Sections 2.2 and 2.3 of the EIS; for a floodplain map, see Figure 3–16 of the EIS.

- Construction and operations at the Moab site: Activities located within or adjacent to the base floodplain would include those associated with both surface and ground water remediation. Surface remediation activities would include constructing temporary staging areas, access roads, haul roads, and a conveyor system to transport tailings to a loadout station; enhancing and repairing the water pumping station, including piping and ponds; applying water for dust control; implementing a storm water management system; excavating contaminated soils; regrading and recontouring remediated areas; backfilling deep excavations; revegetating disturbed areas; and reconstructing Moab Wash. Activities located within or adjacent to wetlands would include excavating contaminated soils and enhancing the intake structure to the water pumping station. Fuel storage areas and tailings processing areas would be located outside the base floodplain with berms designed to protect against a 100-year flood.

  Active ground water remediation at the Moab site could include installing multiple extraction wells, injection wells, trenches, and/or evaporation ponds. If evaporation ponds were constructed within the floodplain, they would be bermed to protect against a 100-year flood.

- Characterization and remediation of vicinity properties could include excavating contaminated materials within floodplains or wetland areas, followed by reclamation.
- Construction and operations at the borrow areas would include excavating and transporting soils or other materials and reclaiming disturbed areas after excavation. Excavation would not be done within wetlands or floodplains, but floodplains and wetlands exist near several potential borrow areas.
- Activities associated with transporting contaminated materials to the proposed Crescent Junction site by rail and constructing and operating the proposed Crescent Junction disposal cell would not occur within floodplains or wetlands.

REASON FOR LOCATION WITHIN FLOODPLAIN AND WETLANDS:

As a result of historical ore processing activities, contaminated soils and ground water exist within the floodplain and wetlands at the Moab site and possibly at vicinity properties. Contamination that is affecting, or may affect, these resources must be remediated to protect human health and the environment. Therefore, remediation activities must be temporarily located, and must occur, within the 100-year floodplain, and possibly within the wetlands located along the eastern boundary of the site.

ALTERNATIVES CONSIDERED:

In the EIS, DOE considered (1) stabilizing and capping the tailings pile in place at the Moab site (the on-site disposal alternative), and (2) relocating and disposing of the tailings at one of three off-site locations (the off-site disposal alternative). Both alternatives would include remediating vicinity properties, remediating ground water, and transporting borrow materials for reclamation of disturbed areas. The on-site disposal alternative assessed consolidating on-site contaminated soils into the existing tailings pile before capping the pile in place. The off-site disposal alternative considered transporting (by rail, truck, or slurry pipeline) the unconsolidated contaminated soils and existing tailings pile to a newly constructed disposal cell at Klondike Flats, Crescent Junction, or White Mesa Mill. In addition, DOE assessed the No Action alternative. Detailed descriptions of all the alternatives considered for remediation of the Moab site are included in Chapter 2.0 of the EIS. .

CONFORMANCE WITH APPLICABLE STATE AND LOCAL FLOODPLAIN PROTECTION STANDARDS:

All activities associated with DOE’s preferred alternatives would conform to applicable state and local floodplain protection standards and would be coordinated with appropriate federal and state agencies.

STEPS TO MINIMIZE POTENTIAL HARM TO OR WITHIN THE FLOODPLAIN AND WETLANDS:

All remediation activities would be conducted in a manner that would minimize potential adverse impacts to the floodplain and wetlands. Activities would include removing unconsolidated RRM-contaminated soils from the floodplain and protecting wetlands that could be affected by remediation activities. Specific activities would include locating remediation activities, to the extent practical, outside the floodplain; constructing temporary berms to minimize the potential for floodwaters to come in contact with contaminated soils; implementing a storm water management plan; and implementing best management practices for soil remediation, control of invasive plant species, and native plant revegetation. Activities would also include ground water remediation to reduce the contaminant concentrations within the floodplain. Detailed actions to minimize potential effects on the floodplain and wetlands would be included in the remedial action plan and the mitigation action plan that would be developed following issuance of the Record of Decision for the EIS.

Appendix G

White Mesa Mill Operations

G1.0 Introduction

White Mesa Mill is a U.S. Nuclear Regulatory Commission (NRC)-licensed mill that produces uranium for commercial nuclear power plants. The White Mesa uranium/vanadium mill was developed in the late 1970s by Energy Fuels Nuclear, Inc. (EFN) as an outlet for the many small mines that are located in the Colorado Plateau and for the possibility of milling Arizona Strip ores. Although the White Mesa Mill facility is a candidate site for possible permanent disposal of the Moab tailings, the facility also operates periodically as an NRC-licensed mill under Source Material License SUA-1358. White Mesa Mill's Source Material License allows the mill to create and dispose of uranium by-product materials from mill operations. Because of the recent history of periodic operations, the continued operations of the mill into future years is considered a reasonably foreseeable action with respect to cumulative impact analysis for the Moab tailings project. Although it is not known how long into the future the mill will operate, it is reasonable to assume that continued operations similar to those of the past 10 years are possible, since the facility's license does not expire until March 31, 2007.

G2.0 Background

The Source Material License application for the White Mesa Mill was submitted to NRC on February 8, 1978. Construction on the tailings area began on August 1, 1978, with the removal of earth from the area of Cell 2. Cell 2 was completed on May 4, 1980, Cell 1 on June 29, 1981, and Cell 3 on September 2, 1982. In January 1990, an additional cell, designated 4A, was completed and placed into use solely for solution storage and evaporation. The first ore was fed to the mill grizzly on May 6, 1980 (IUC 2000).

At the time of the mill's construction, it was anticipated that high uranium prices would stimulate ore production. However, prices started to decline about the same time as mill operations commenced. As uranium prices fell, producers in the region were affected and mine output declined. After about two and one-half years, the White Mesa Mill ceased ore-processing operations altogether, began solution recycle, and entered a total shutdown phase. In 1984, a majority ownership interest was acquired by Union Carbide Corporation's (UCC) Metals Division, which later became UMETCO Minerals Corporation (UMETCO), a wholly-owned subsidiary of UCC. From 1985 through 1990, the mill was active again in receiving and processing uranium ores. The partnership between UMETCO and EFN continued until May 26, 1994, when EFN reassumed complete ownership. Beginning in the mid- to late- 1990s, the mill began to process uranium-bearing material other than natural ores from off-site locations. These "alternative feed materials" generally have consisted of uranium-bearing residues from uranium-ore processing facilities or other metal-processing facilities as well as soils contaminated with natural uranium, most of which has come from Formerly Utilized Sites Remedial Action Program sites managed by the Army Corps of Engineers (NRC 1999). In May 1997, International Uranium (USA) Corporation (IUC) purchased the assets of EFN and is the current owner of the facility.

G3.0 Facility

The White Mesa Mill is located in San Juan County, Utah, approximately 5 miles south of Blanding, Utah. Facilities consist of a mill, ore storage pad, and four lined tailings cells with leak detection systems and ground water monitor wells. The facilities are situated within a 5,415-acre private property mostly owned by IUC. The mill itself occupies approximately 50 acres, and the tailings disposal ponds occupy approximately 450 acres. A one-half-mile-long private road off US-191 provides access to the site.

The ore storage pad at the site covers an area of approximately 20 acres. The pad is underlain by compacted, mostly fine-grained material. Crushed limestone was reported to have been incorporated into the pad at the time of construction. The surface of the pad is sloped to promote drainage and prevent off-site movement of drainage.

The tailings facilities at White Mesa Mill consist of four cells:

- Cell 1, constructed with a 1.2-inch polyvinyl chloride (PVC) earthen-covered liner, is used to store the process solution.
- Cell 2, constructed with a 1.2-inch PVC earthen-covered liner, is used to store the barren tailings sands.
- Cell 3, constructed with a 1.2-inch PVC earthen-covered liner, is used to store the barren tailings sands and solutions.
- Cell 4A, constructed with a 1.6-inch high-density polyethylene liner, is currently not used.

Total estimated design capacity of Cells 2, 3, and 4A is approximately 6 million cubic yards (IUC 2000).

G4.0 Operations

Although originally designed for a capacity of 1,500 dry tons per day, the mill capacity was boosted to the present rated design of 1,980 dry tons per day prior to commissioning. Under current and recent operations, alternative feed materials are received at the site by truck and temporarily staged until a sufficient quantity is received to run the mill.

Feed materials for the mill are temporarily stockpiled on the ore pad. The period that materials are stockpiled varies but is typically about 2 years. Feeds currently stored on the site in piles typically cover an area of approximately 0.1 to 1.5 acres and often merge. Pile thicknesses vary but may exceed 30 feet (ft). Mill operations are periodic; when operations are under way, the mill typically employs between 70 and 100 full-time employees.

Once operations commence, the feed materials are either passed through the ore-receiving hopper and semiautogenous grinding mill or run through an existing trammel before being pumped into pulp storage tanks, where a leaching process is initiated by addition of sulfuric acid. The mill currently uses propane to fire all process and heating boilers.

The mill uses an atmospheric hot acid leach followed by countercurrent decantation (CCD). This in turn is followed by a clarification stage, then a solvent extraction (SX) circuit. Kerosene containing isodecanol and tertiary amines extracts the uranium and vanadium from the solution in the SX circuit. Salt and soda ash are then used to strip the uranium and vanadium from the organic phase.

After extraction from the SX solution, uranium is precipitated with anhydrous ammonia, dissolved, and reprecipitated to improve product quality. The resulting precipitate is then washed and dewatered using centrifuges to produce a final product called “yellowcake.” The yellowcake is dried in a multiple-hearth dryer and packaged in drums weighing approximately 800 pounds for shipping to conversion plants. The current NRC license for the facility specifies a maximum production rate of 4,380 tons of yellowcake per year.

After the uranium is stripped from the pregnant SX solution, the vanadium in the remaining solution is transferred to tertiary amines contained in kerosene and concentrated into an intermediate product called vanadium product liquor (VPL). An intermediate product, ammonium metavanadate (AMV), is precipitated from the VPL using ammonium sulfate in batch precipitators. The AMV is then filtered on a belt filter and, if necessary, dried. Normally, the AMV cake is fed to fusion furnaces where it is converted to the mill’s primary vanadium product, vanadium pentoxide (V_2O_5).

Tailings produced by the mill typically contain 30 percent moisture by weight, have an in-place dry density of 86.3 pounds per cubic foot (Cell 2), have a particle size distribution that is predominantly a −325 mesh size fraction, and have a high acid and flocculent content (IUC 2000).

Constructed in shallow valleys or swale areas, the lined tailings cells provide storage below the existing grade and reduce potential exposure. Because the cells are separate, individual cells may be reclaimed as they are filled to capacity. This phased reclamation approach attempts to minimize the amount of tailings exposed at any time.

Slurry is disposed of in both Cells 2 and 3. Tailings in Cell 2 were placed using the perimeter discharge method. Perimeter discharge involves setting up discharge points around the east, north, and west boundaries of the cell. This method results in low-cost disposal at first, followed by higher disposal costs toward the end of the cell's life. In Cell 3, a process called the final grade method has been used, whereby the slurry is discharged until the tailings surface reaches final grade. The discharge points are set up in the east end of the cell, and the final grade surface is advanced to the slimes pool area. When the slimes pool is reached, the discharge points are then moved to the west end of the cell and worked back to the middle. As described by IUC in its reclamation plan, an advantage to using the final grade method is that maximum stability is achieved by (1) allowing water to drain from the sands to the maximum extent, and (2) allowing coarse sand deposition to help provide stable beaches. Another advantage is that radon release and dust prevention measures (through the placement of the initial layer of the final cover) are applied as expeditiously as possible.

As a zero-discharge facility, the White Mesa Mill must evaporate all of the liquids used during processing. This evaporation takes place in two areas: Cell 1, which is used for solutions only, and Cell 3, in which tailings and solutions exist.

The original engineering design indicated that a net water gain into the cells would occur during mill operations. In addition to natural evaporation, spray systems have been used occasionally to enhance evaporation rates and control dust. To minimize net water gain, solutions are recycled from the active tailings cells to the maximum extent possible. Solutions from Cells 1 and 3 are brought back to the CCD circuit, where additional extraction can be realized. Recycling to other parts of the mill circuit is not feasible due to the acid content of the solution.

G5.0 Air and Radioactive Emissions

Air emissions from the White Mesa Mill are regulated by the State of Utah in accordance with the mill's air quality permit issued in 1997 (Utah DAQE-884-97). The air quality permit establishes annual emissions limits for the yellowcake dryers and vanadium circuit scrubber. The permit also describes emission controls for sources in the mill and general procedures for controlling dust from roads and fugitive sources. Specifically, the permit requires that particulate (PM_{10}) emissions to the atmosphere shall not exceed 0.40 pound per hour for each yellowcake dryer and 2.50 pounds per hour for the vanadium circuit scrubber. The mill is also required to submit to the Utah Department of Environmental Quality an annual emissions inventory (Table G−1). Table G−1 is based on the 5 years of operation from 1997 through 2002 and shows the amounts of emissions that might be expected from future mill operations.

Table G–1. Air Emission Inventory for Key Criteria Emissions (tons per year)

Year	PM_{10}	Sulfur Dioxide	Nitrogen Dioxide	Volatile Organic Compounds	Carbon Monoxide
1997	0.775	0.255	3.859	2.120	7.257
1998[a]	–	–	–	–	–
1999	2.57	1.15	18.11	2.16	14.14
2000	1.9	1.47	14.61	2.76	11.78
2001[a]	–	–	–	–	–
2002	0.68	0.98	9.04	1.80	11.49

[a]IUC was not required to file an air emission inventory for these years because it was determined that the mill did not realize a change of 5 percent or more in emissions for any criteria pollutant reported in the previous year.
Source: IUC 2003
Note: PM_{10} = particulate matter less than 10 micrometers in diameter.

As required by 10 CFR 20.1101, the mill employs procedures and engineering controls, to the extent practicable, to achieve occupational radiological doses and doses to members of the public as low as reasonably achievable. Under 10 CFR 20.1301, NRC has adopted the U.S. Environmental Protection Agency's (EPA's) annual dose limit of 25 millirem (mrem) (exclusive of radon) for members of the public for doses attributable to licensed operations. Doses from natural background or medical radiation are excluded. In addition, the highest dose any individual member of the public should receive from direct air emissions of radioactive material to the environment should not exceed 10 mrem/year from plant emissions. On the basis of past analyses by NRC, the predicted total effective dose equivalent to a receptor at the potential nearest residence would have been a small fraction of the 25-mrem standard (IUC 2003).

G6.0 Past and Recent Production

From May 6, 1980, to February 4, 1983, the mill processed 1,511,544 tons of ore and other materials. During a second operational period from October 1, 1985, through December 7, 1987, 1,023,393 tons were processed. During a third operational period from July 1988 through November 1990, 1,015,032 tons were processed. During the fourth operational period from August 1995 through January 1996, 203,317 tons were processed. The fifth operational period from May 1996 through September 1996 processed 3,868 tons of calcium fluoride material. Since early 1997, the mill has processed over 100,000 tons from several additional feed stocks. The total amount of materials processed from the beginning of milling operations through 2002 is 4,083,144 tons. The highest annual production of yellowcake was 3.75 million pounds per year in the 1985−1990 period.

G7.0 Transportation

The original plan for the mill was to process up to 680,000 tons of ore per year, which, using 25-ton trucks, would be 27,500 truck loads per year (78 per day based on a 7-day work week, or 109 per day based on a 5-day work week). To serve the mill with process materials, it was anticipated there would be over 20 truck trips per day bringing loads of anhydrous ammonia, sulfuric acid, and other supplies.

Yellowcake refined at the mill is shipped in 55-gallon drums that weigh an average of 800 pounds. Drums are shipped an average of 1,300 miles to conversion plants, where the yellowcake is converted to uranium hexafluoride and then to enrichment-grade uranium suitable as a fuel source for nuclear power plants. An average truck shipment contains approximately 40 drums, or 17.5 tons of yellowcake. Based on licensed production capacity of 4,380 tons of yellowcake per year, a maximum of 8,760,000 pounds of yellowcake could require shipment from the mill in a given year, or 275 truck shipments per year.

A more typical recent mill operation can be characterized by the license amendments that allowed the mill to process materials from the Molycorp's Lanthanide Division Facility in Mountain Pass, California. For the year 2002, it was estimated that the mill would receive and process up to 17,750 tons of alternative feed materials, in this case consisting of lead sulfide containing approximately 0.15 percent uranium. For this mill run, an estimated 60 to 70 trucks per week would bring the materials from California to the mill over a 60- to 90-day period, representing a 2-percent increase in truck traffic on regional roads for a 3-month period. Based on the recent past history of mill operations, it can be expected that the White Mesa Mill would undertake milling operations on a scale similar to the Molycorp project approximately every 3 years.

Each periodic operation of the mill can have adverse environmental consequences from mill operations, including transportation. These effects could be in the form of health effects for workers at the mill, air or ground water pollution, or a transportation accident resulting in the release of process chemicals or source materials into streams or other sensitive areas along the travel route to the mill. These potential adverse environmental effects would be in addition to environmental effects contributed from the permanent disposal of Moab uranium tailings at the White Mesa Mill facility. The direct, indirect, and cumulative effects of Moab tailings disposal at the White Mesa Mill site are discussed in Chapters 4.0 and 5.0.

G8.0 References

10 CFR 20. U.S. Nuclear Regulatory Commission, "Standards for Protection Against Radiation."

IUC (International Uranium [USA] Corporation), 2000. *White Mesa Mill Reclamation Plan*, International Uranium (USA) Corporation, Revision 3, July 17, Denver.

IUC (International Uranium [USA] Corporation), 2003. *Description of the Affected Environment, White Mesa Mill, Blanding, Utah*, International Uranium (USA) Corporation, May 5, Denver.

NRC (U.S. Nuclear Regulatory Commission), 1999. *Environmental Assessment for International Uranium Corporation's Uranium Mill Site, White Mesa, San Juan County, Utah*, in consideration of an Amendment to Source Material License SUA-1358 for the Approval of the Proposed Reclamation Plan. U.S. Nuclear Regulatory Commission, Division of Waste Management, Office of Nuclear Safety and Safeguards, Washington, D.C., December 23.

Appendix H

Transportation Impact Analysis

H1.0 Introduction

This appendix summarizes the methods and results of analyses for determining the environmental impacts of shipping uranium mill tailings and borrow materials by truck and rail. The impacts are presented by alternative and include doses and health effects.

The transportation impacts of shipping contaminated materials from vicinity properties, mill tailings from the Moab site, and borrow material from the proposed borrow areas would be from two sources: radiological impacts and nonradiological impacts. Radiological impacts would be from incident-free transportation and from transportation accidents that released contaminated material or uranium mill tailings. There would be no radiological impacts from moving borrow material because it is not contaminated. Nonradiological impacts would be from the engine and fugitive dust emissions from the truck or train moving the contaminated material, uranium mill tailings, and the borrow material, and from fatalities from traffic accidents during the transport of these materials. The total transportation impacts would be the sum of the radiological and nonradiological impacts.

H1.1 Incident-Free Transportation Impacts

Radiological dose during normal, incident-free transportation of contaminated material or uranium mill tailings would result from exposure to the external radiation field that surrounds the truck or rail car containing the contaminated material or uranium mill tailings. The dose is a function of the number of people exposed, their proximity to the containers, their length of time of exposure, and the intensity of the radiation field surrounding the truck or rail car.

Radiological impacts were determined for workers and the general population during normal, incident-free transportation. For truck shipments, the workers were drivers of the trucks carrying the contaminated material or uranium mill tailings. The radiation dose rate for the driver of a truck carrying contaminated material from vicinity properties was estimated to be 0.13 millirem (mrem) per hour using the MICROSHIELD computer code (Grove Engineering 1996). The radiation dose rate for the driver of a truck carrying uranium mill tailings from the Moab site was estimated to be 0.22 mrem per hour. For rail shipments, the workers would be individuals who inspected the train carrying the uranium mill tailings. The radiation dose rate for the inspectors was estimated to be 0.44 mrem per hour.

For truck shipments, the general population consisted of those individuals within 2,625 feet (ft) of the road (off-link) and individuals sharing the road (on-link). Because the trucks would drive directly to the disposal sites, no individuals were assumed to be exposed at stops. For rail shipments, the general population consisted of those individuals within 2,625 ft of the road (off-link). Because the train would not share the track with other trains at the same time and would not be in a classification yard, no individuals were assumed to be exposed at stops or on-link. Radiation doses for the general population were calculated using the RADTRAN 5 computer code (Neuhauser and Kanipe 2000, Neuhauser et al. 2000). The radiation dose rate for the vicinity property truck was estimated to be 0.17 mrem per hour at 3 ft from the truck. For the truck carrying uranium mill tailings, the radiation dose rate was estimated to be 0.30 mrem per hour. The radiation dose rate for the rail cars was estimated to be 0.44 mrem per hour at 3 ft from a rail car.

H1.1.1 Incident-Free Collective Dose Scenarios

Calculating the collective doses is based on developing unit risk factors. Unit risk factors provide an estimate of the impact from transporting one shipment of radioactive material over a unit distance of travel in a given population density zone. The unit risk factors may be combined with routing information such as the shipment distances in various population density zones to estimate the risk for a single shipment (a shipment risk factor) between a given origin and destination. Cashwell et al. (1986) contains a detailed explanation of the use of unit risk factors. Table H–1 contains the unit risk factors for truck and rail shipments.

Table H–1. Incident-Free Unit Risk Factors

Receptor	Zone	Truck	Rail
General population (public)			
Vicinity property off-link (person-rem/km per persons/km^2)	Rural	1.92E-09	0
	Suburban	1.92E-09	0
	Urban	1.92E-09	0
Vicinity property on-link (person-rem/km)	Rural	9.11E-07	0
	Suburban	9.11E-07	0
	Urban	9.11E-07	0
Off-link (person-rem/km per persons/km^2)	Rural	1.85E-09	4.42E-09
	Suburban	6.38E-09	4.42E-09
	Urban	6.38E-09	4.42E-09
On-link (person-rem/km)	Rural	1.65E-07	0
	Suburban	4.56E-07	0
	Urban	2.14E-06	0
Workers			
Vicinity property truck drivers (person-rem/km)	Rural	3.34E-06	0
	Suburban	3.34E-06	0
	Urban	3.34E-06	0
Mill tailings truck drivers (person-rem/km)	Rural	2.50E-06	0
	Suburban	3.93E-06	0
	Urban	3.93E-06	0
Rail inspector (person-rem/shipment)	Rural	0	7.99E-04
	Suburban	0	7.99E-04
	Urban	0	7.99E-04

km = kilometer

Incident-free nonradiological fatalities (pollution health effects) were also evaluated using unit risk factors. These fatalities would result from exhaust and fugitive dust emissions from highway and rail traffic and are associated with 10-micrometer (µm) particles. The nonradiological unit risk factor for truck transport used in this analysis was 1.5×10^{-11} fatalities per kilometer per persons per square kilometer; for train transport, the nonradiological unit risk factor was 2.6×10^{-11} fatalities per kilometer per persons per square kilometer. These unit risk factors were estimated from the data in Biwer and Butler (1999) and have been adjusted to account for more current diesel exhaust emission factors, a fleet average fugitive dust emission factor for roads, an age-adjusted mortality rate, and an average 10-µm particle risk factor. The distances used in the nonradiological analyses were doubled to reflect the round-trip distances, because these impacts could occur whether or not the shipments contain radioactive material. In addition, the impacts from pollution health effects included shipments from borrow areas.

H1.1.2 Incident-Free Maximally Exposed Individual Exposure Scenarios

Maximum individual doses were calculated using the RISKIND computer code (Yuan et al. 1995). The maximum individual doses for the routine transport off-site were estimated for transportation workers and for members of the public. For truck shipments, two scenarios were evaluated for members of the public:

- A person caught in traffic next to a truck containing uranium mill tailings for 30 minutes. The distance between the two vehicles was assumed to be 3 ft.
- A resident living 98 ft from the highway used to transport the uranium mill tailings. For shipments from vicinity properties, the resident lived 26 ft from the road. This person was assumed to be exposed to all shipments over the course of a year.

For rail shipments, two scenarios were evaluated for members of the public:

- A resident living 98 ft from the railroad used to transport the uranium mill tailings. This person was assumed to be exposed to all shipments over the course of a year.
- A person in a car stopped at a railroad crossing while a 30-car train passes. This person was assumed to be 9 ft from the train.

For truck shipments of uranium mill tailings, the maximally exposed worker would be the driver, who would be exposed for 1,000 hours per year. The radiation dose rate for the driver was estimated to be 0.22 mrem per hour, or 0.13 mrem per hour for a vicinity property truck driver. For rail shipments, the maximally exposed worker would be an individual who inspected the loaded rail cars for 1,000 hours per year. This individual would be 3 ft from a railcar, and the radiation dose rate for this individual was estimated to be 0.44 mrem per hour. The inspector would inspect rail cars prior to departure from the Moab site or after arrival at the disposal site.

H2.0 Transportation Accident Impacts

The transportation accident analysis considers the impacts of accidents during the transportation of uranium mill tailings and contaminated material by truck or rail. Under accident conditions, impacts to human health and the environment may result from the release and dispersal of radioactive material. Transportation accident impacts have been assessed using accident analysis methods developed by the U.S. Nuclear Regulatory Commission (NRC 1977). In addition, the nonradiological impacts from transportation accidents involving traffic fatalities were evaluated.

Two types of analyses were performed for accidents involving the dispersal of uranium mill tailings and contaminated material. First, an accident risk assessment was performed that takes into account the probabilities and consequences of a spectrum of potential accident severities. For the spectrum of accidents considered in the analysis, accident consequences in terms of collective dose to the population within 50 miles were multiplied by the accident probabilities to yield collective dose risk using the RADTRAN 5 computer code (Neuhauser and Kanipe 2000, Neuhauser et al. 2000).

Second, to represent the maximum reasonably foreseeable impacts to individuals and populations should an accident occur, radiological consequences were calculated for an accident of maximum credible severity. An accident is considered credible if its probability of occurrence is greater than 1×10^{-7} per year (1 in 10 million per year). The accident consequence assessment for maximally exposed individuals and population groups was performed using the RISKIND computer code (Yuan et al. 1995).

The radiological impacts were calculated in units of dose (rem or person-rem). Impacts are further expressed as health risks in terms of estimated latent cancer fatalities in exposed populations.

H2.1 Transportation Accident Rates

Utah-specific accident rates and fatality rates taken from data provided in Saricks and Tompkins (1999) for rail and heavy combination trucks were used to estimate accident risks and consequences, and traffic fatalities. These rates are presented in Table H–2.

Table H–2. Utah-Specific Accident and Fatality Rates

Type	Mode	Accident Rate	Fatality Rate
State Highway	Truck	3.05×10^{-7} accidents/km	1.60×10^{-8} fatalities/km
Interstate	Truck	2.90×10^{-7} accidents/km	1.19×10^{-8} fatalities/km
Other	Truck	9.04×10^{-7} accidents/km	2.27×10^{-8} fatalities/km
Rail	Rail	5.87×10^{-8} accidents/railcar-km	2.54×10^{-8} fatalities/railcar-km

H2.1.1 Severity Categories, Conditional Probabilities, and Release Fractions

Transportation accidents have different severities and would result in the release of different amounts of uranium mill tailings or contaminated materials. Therefore, accidents are grouped into severity categories. Each severity category has a different conditional probability of occurrence and release fraction. In this analysis, the release fraction is the fraction of material released that is respirable. The respirable release fractions considered the large particle size of uranium mill tailings (45 to 75 µm for slimes and 75 to 500 µm for sands), with 10 µm as the upper bound for a respirable particle. The severity categories, conditional probabilities, and release fractions for truck and rail accidents are presented in Tables H–3 and H−4, respectively.

Table H–3. Severity Categories, Conditional Probabilities, and Respirable Release Fractions for Truck Accidents

Severity Category	Conditional Probability	Respirable Release Fraction
1	0.80	0.0
2	0.10	5.0×10^{-6}
3	0.05	2.5×10^{-5}
4	0.05	5.0×10^{-5}

Table H–4. Severity Categories, Conditional Probabilities, and Respirable Release Fractions for Rail Accidents

Severity Category	Conditional Probability	Respirable Release Fraction
1	0.60	0.0
2	0.20	5.0×10^{-6}
3	0.20	5.0×10^{-5}

H2.1.2 Shipment Inventories

Based on data from the Moab site, the average radium-226 (Ra-226) concentration in the uranium mill tailings was 516 picocuries per gram (pCi/g), and the density of the tailings was 1.6 grams per cubic centimeter (cm^3). In order to calculate the radionuclide inventory contained in a truck or train, it was assumed that Ra-226 was in secular equilibrium with its radioactive progeny. In addition, thorium-230 (Th-230) was assumed to be present in equilibrium with Ra-226. A 44-ton tandem truck was assumed to be used for truck shipments of uranium mill tailings. A 10-cubic-yard (yd^3) truck was assumed to be used for shipments from vicinity properties. A 100-ton gondola car was assumed to be used for rail shipments of uranium mill tailings. Table H–5 shows the estimated radionuclide inventories for truck and rail shipments.

Table H–5. Radionuclide Inventory in Uranium Mill Tailings Shipments

Radionuclide	Concentration (pCi/g)	Truck Inventory (Ci)	Railcar Inventory (Ci)	Vicinity Property Truck Inventory (Ci)
Th-230	516.00	0.021	0.047	0.0063
Ra-226	516.00	0.021	0.047	0.0063
Radon-222 (Rn-222)[a]	516.00	0.021	0.047	0.0063
Polonium-218 (Po-218)	516.00	0.021	0.047	0.0063
Lead-214 (Pb-214)	515.90	0.021	0.047	0.0063
Bismuth-214 (Bi-214)	516.00	0.021	0.047	0.0063
Polonium-214 (Po-214)	515.89	0.021	0.047	0.0063
Lead-210 (Pb-210)	516.00	0.021	0.047	0.0063
Bismuth-210 (Bi-210)	516.00	0.021	0.047	0.0063
Polonium-210 (Po-210)	516.00	0.021	0.047	0.0063

[a]Rn-222 through Po-210 are radioactive progeny of Ra-226.
Ci = curies; pCi/g = picocuries per gram.

H2.1.3 Atmospheric Conditions

Because it is impossible to predict the specific location of a transportation accident, generic atmospheric conditions were selected for the risk and consequence assessments. For the accident risk assessment, neutral weather conditions (Pasquill Stability Class D) were assumed. Neutral weather conditions are typified by moderate wind speeds, vertical mixing within the atmosphere, and good dispersion of atmospheric contaminants. For the accident consequence assessment, doses were assessed under neutral (Class D with 14.67-ft-per-second wind speed) atmospheric conditions.

H2.1.4 Exposure Pathways

Radiological doses were calculated for an individual located near the scene of the accident and for populations within 50 miles of the accident. Rural, suburban, and urban population densities were assessed. Dose calculations considered a variety of exposure pathways, including inhalation and direct exposure from the passing cloud (cloudshine), direct exposure from radioactivity deposited on the ground (groundshine), and inhalation of resuspended radioactive particles from the ground.

H2.1.5 Health Risk Conversion Factors

The following health risk conversion factors used to estimate latent cancer fatalities from radiological exposures were from the Interagency Steering Committee on Radiation Standards (DOE 2002): 6×10^{-4} and 5×10^{-4} latent cancer fatalities per person-rem for members of the public and workers, respectively. Although latent cancer fatalities are the predominant health risk associated with low-level radiation doses (that is, doses below the thresholds for acute effects), they are not the only potential detrimental health effect. Risks of other delayed health effects such as nonfatal cancers and hereditary effects should also be acknowledged. International Commission on Radiological Protection Publication 60 (ICRP 1991) has estimated that the total risk of detrimental health effects are 7.3×10^{-4} and 5.6×10^{-4} total detrimental health effects per person-rem for members of the public and workers, respectively.

H3.0 Shipments

For each alternative, there would be shipments of contaminated material from vicinity properties, uranium mill tailings, and borrow material. The borrow material would consist of cover soils, radon barrier soils, sand and gravel, riprap, and Moab site reclamation soils. The numbers of shipments are listed for each alternative in Tables H−6 through H−9. The distances for the shipments are listed in Table H–10.

Table H–6. Number of Shipments for the On-Site Disposal Alternative

Material	Truck Shipments
Vicinity property material	2,940
Borrow material	
Cover soils[a]	25,030
Radon barrier soils[b]	11,200
Sand and gravel[c]	4,200
Riprap[d]	6,363
Moab site reclamation soils[a]	9,670
Total	**59,403**

[a]Cover soils and reclamation soils were assumed to be from the Floy Wash borrow area.
[b]Radon barrier soils were assumed to be from the Klondike Flats borrow area.
[c]Sand and gravel was assumed to be from the LeGrand Johnson borrow area.
[d]Riprap was assumed to be from the Papoose Quarry borrow area.

Table H–7. Shipments for Klondike Flats Disposal Alternative

Material	Truck Option		Rail Option		Slurry Pipeline Option	
	Shipments	Mode	Shipments	Mode	Shipments	Mode
Vicinity property material	2,940	Truck	2,940	Truck	2,940	Truck
Borrow material						
Cover soils[a]	37,800	Truck	37,800	Truck	37,800	Truck
Radon barrier soils[b]	0		0		0	Truck
Sand and gravel[c]	6,538	Truck	6,538	Truck	6,538	Truck
Riprap[d]	1,973	Truck	1,973	Truck	1,973	Truck
Moab site reclamation soils[a]	12,875	Truck	12,875	Truck	12,875	Truck
Uranium mill tailings	268,800	Truck	3,840 2,188	Rail[e] Truck	2,188	Truck
Total	**330,926**		**68,154**		**64,314**	

[a]Cover soils and reclamation soils were assumed to be from the Floy Wash borrow area.
[b]Radon barrier soils were assumed to be from the Klondike Flats borrow area.
[c]Sand and gravel was assumed to be from the LeGrand Johnson borrow area.
[d]Riprap was assumed to be from the Papoose Quarry borrow area.
[e]Each rail shipment would consist of 30 rail cars of uranium mill tailings.

Table H–8. Shipments for Crescent Junction Disposal Alternative

Material	Truck Option		Rail Option		Slurry Pipeline Option	
	Shipments	Mode	Shipments	Mode	Shipments	Mode
Vicinity property material	2,940	Truck	2,940	Truck	2,940	Truck
Borrow material						
Cover soils[a]	0		0		0	
Radon barrier soils[a]	0		0		0	
Sand and gravel[b]	6,300	Truck	6,300	Truck	6,300	Truck
Riprap[c]	1,973	Truck	1,973	Truck	1,973	Truck
Moab site reclamation soils[d]	12,875	Truck	12,875	Truck	12,875	Truck
Uranium mill tailings	268,800	Truck	3,840 2,188	Rail[e] Truck	2,188	Truck
Total	**292,888**		**30,116**		**26,276**	

[a]Cover soils and radon barrier soils were assumed to be from the Crescent Junction borrow area.
[b]Sand and gravel was assumed to be from the LeGrand Johnson borrow area.
[c]Riprap was assumed to be from the Papoose Quarry borrow area.
[d]Reclamation soils were assumed to be from the Floy Wash borrow area.
[e]Each rail shipment would consist of 30 rail cars of uranium mill tailings.

Table H–9. Shipments for White Mesa Mill Disposal Alternative

Material	Truck Option		Slurry Pipeline Option	
	Shipments	Mode	Shipments	Mode
Vicinity property material	2,940	Truck	2,940	Truck
Borrow material				
Cover soils[a]	0		0	
Radon barrier soils[a]	0		0	
Sand and gravel[b]	6,300	Truck	6,300	Truck
Riprap[c]	1,973	Truck	1,973	Truck
Moab site reclamation soils[d]	12,875	Truck	12,875	Truck
Uranium mill tailings	268,800	Truck	2,188	Truck
Total	**292,888**		**26,276**	

[a]Cover soils and radon barrier soils were assumed to be from the White Mesa borrow area.
[b]Sand and gravel was assumed to be from the LeGrand Johnson borrow area.
[c]Riprap was assumed to be from the Papoose Quarry borrow area.
[d]Reclamation soils were assumed to be from Floy Wash borrow area.

Table H–10. Shipment Distances

Origin	Destination	Truck Distance (miles)[a]	Rail Distance (miles)[a]
Vicinity Properties	Moab	5.0	N/A
Moab	Klondike Flats	19	16
Moab	Crescent Junction	31	30
Moab	White Mesa Mill	85	N/A
Floy Wash borrow area	Moab	35	N/A
Klondike Flats borrow area	Moab	18	N/A
LeGrand Johnson borrow area	Moab	6.0	N/A
Papoose Quarry borrow area	Moab	28	N/A
Floy Wash borrow area	Klondike Flats	25	N/A
LeGrand Johnson borrow area	Klondike Flats	24	N/A
Papoose Quarry borrow area	Klondike Flats	53	N/A
LeGrand Johnson borrow area	Crescent Junction	39	N/A
Papoose Quarry borrow area	Crescent Junction	68	N/A
LeGrand Johnson borrow area	White Mesa Mill	91	N/A
Papoose Quarry borrow area	White Mesa Mill	10	N/A

[a]All distances are one-way distances.

H4.0 Results

H4.1 Transportation Impacts

H4.1.1 On-Site Disposal Alternative

Table H–11 lists the transportation impacts for the on-site disposal alternative. The transportation impacts would be from shipping contaminated materials from vicinity properties to the Moab site and shipping borrow materials. Borrow materials would consist of cover soils and reclamation soils shipped from the Floy Wash borrow area, radon barrier soils shipped from the Klondike Flats borrow area, sand and gravel shipped from the LeGrand Johnson borrow area, and riprap shipped from the Papoose Quarry borrow area. For this alternative, there would less than one fatality.

Table H–11. Transportation Impacts for the On-Site Disposal Alternative

Alternative	Radiological			Nonradiological		Total Fatalities
	Incident-Free		Accident Risk	Pollution Health Effects Fatalities	Traffic Fatalities	
	Public LCFs	Worker LCFs				
Truck option						
Vicinity properties	2.7E-5	3.9E-5	6.9E-9	3.7E-4	1.1E-3	1.5E-3
Borrow material	0	0	0	1.1E-3	8.1E-2	8.2E-2
Mill tailings	0	0	0	0	0	0
Total	2.7E-5	3.9E-5	6.9E-9	1.5E-3	8.2E-2	8.4E-2

LCFs = latent cancer fatalities

H4.1.2 Klondike Flats Off-Site Disposal Alternative

Table H–12 lists the transportation impacts for the Klondike Flats off-site disposal alternative. Transportation impacts would be from shipping contaminated materials from vicinity properties to the Moab site, shipping uranium mill tailings and vicinity property material from the Moab site to Klondike Flats, and shipping borrow materials. Borrow materials would consist of cover soils shipped from the Floy Wash borrow area to Klondike Flats, reclamation soils shipped from the Floy Wash borrow area to the Moab site, sand and gravel shipped from the LeGrand Johnson borrow area to Klondike Flats, and riprap shipped from Papoose Quarry borrow area to Klondike Flats. For this alternative, there would less than one fatality.

Table H–12. Transportation Impacts for the Klondike Flats Off-Site Disposal Alternative

Alternative	Radiological			Nonradiological		Total Fatalities
	Incident-Free		Accident Risk	Pollution Health Effects Fatalities	Traffic Fatalities	
	Public LCFs	Worker LCFs				
Truck option						
Vicinity properties	2.7E-5	3.9E-5	6.9E-9	3.7E-4	1.1E-3	1.5E-3
Borrow material	0	0	0	9.3E-4	8.1E-2	8.2E-2
Mill tailings	1.6E-3	1.0E-2	2.0E-9	9.6E-5	2.6E-1	2.7E-1
Total	1.6E-3	1.0E-2	8.9E-9	1.4E-3	3.4E-1	3.5E-1
Rail option						
Vicinity properties	2.7E-5	3.9E-5	6.9E-9	3.7E-4	1.1E-3	1.5E-3
Borrow material	0	0	0	9.3E-4	8.1E-2	8.2E-2
Mill tailings	1.6E-5	1.6E-3	3.5E-9	6.1E-5	1.5E-1	1.5E-1
Total	4.3E-5	1.6E-3	1.0E-8	1.4E-3	2.3E-1	2.3E-1
Slurry option						
Vicinity properties	2.7E-5	3.9E-5	6.9E-9	3.7E-4	1.1E-3	1.5E-3
Borrow material	0	0	0	9.3E-4	8.1E-2	8.2E-2
Mill tailings	1.3E-5	8.4E-5	1.6E-11	7.8E-7	2.1E-3	2.2E-3
Total	4.0E-5	1.2E-4	6.9E-9	1.3E-3	8.4E-2	8.6E-2

LCFs = latent cancer fatalities

H4.1.3 Crescent Junction Off-Site Disposal Alternative

Table H–13 lists the transportation impacts for the Crescent Junction off-site disposal alternative. Transportation impacts would be from shipping contaminated materials from vicinity properties to the Moab site, shipping uranium mill tailings and vicinity property material from the Moab site to Crescent Junction, and shipping borrow materials. Borrow materials would consist of reclamation soils shipped from the Floy Wash borrow area to the Moab site, sand and gravel shipped from the LeGrand Johnson borrow area to Crescent Junction, and riprap shipped from the Papoose Quarry borrow area to Crescent Junction. For this alternative, there would less than one fatality.

Table H–13. Transportation Impacts for the Crescent Junction Off-Site Disposal Alternative

Alternative	Radiological			Nonradiological		Total Fatalities
	Incident-Free		Accident Risk	Pollution Health Effects Fatalities	Traffic Fatalities	
	Public LCFs	Worker LCFs				
Truck Option						
Vicinity properties	2.7E-5	3.9E-5	6.9E-9	3.7E-4	1.1E-3	1.5E-3
Borrow material	0	0	0	8.9E-4	4.2E-2	4.3E-2
Mill tailings	2.7E-3	1.7E-2	3.3E-9	1.6E-4	4.3E-1	4.5E-1
Total	2.7E-3	1.7E-2	1.0E-8	1.4E-3	4.7E-1	4.9E-1
Rail Option						
Vicinity properties	2.7E-5	3.9E-5	6.9E-9	3.7E-4	1.1E-3	1.5E-3
Borrow material	0	0	0	8.9E-4	4.2E-2	4.3E-2
Mill tailings	2.7E-5	1.7E-3	6.5E-9	1.1E-4	2.9E-1	2.9E-1
Total	5.4E-5	1.7E-3	1.3E-8	1.4E-3	3.3E-1	3.3E-1
Slurry Option						
Vicinity properties	2.7E-5	3.9E-5	6.9E-9	3.7E-4	1.1E-3	1.5E-3
Borrow material	0	0	0	8.9E-4	4.2E-2	4.3E-2
Mill tailings	2.2E-5	1.4E-4	2.7E-11	1.3E-6	3.5E-3	3.7E-3
Total	4.9E-5	1.8E-4	6.9E-9	1.3E-3	4.7E-2	4.8E-2

LCFs = latent cancer fatalities

H4.1.4 White Mesa Mill Off-Site Disposal Alternative

Table H–14 lists the transportation impacts for the White Mesa Mill off-site disposal alternative. Transportation impacts would be from shipping contaminated materials from vicinity properties to the Moab site, shipping uranium mill tailings and vicinity property material from the Moab site to White Mesa Mill, and shipping borrow materials. Borrow materials would consist of reclamation soils shipped from the Floy Wash borrow area to the Moab site, sand and gravel shipped from the LeGrand Johnson borrow area to White Mesa Mill, and riprap shipped from the Papoose Quarry borrow area to White Mesa Mill. For this alternative, there would be about one fatality.

Table H–14. Transportation Impacts for the White Mesa Mill Off-Site Disposal Alternative

Alternative	Radiological			Nonradiological		Total Fatalities
	Incident-Free		Accident Risk	Pollution Health Effects Fatalities	Traffic Fatalities	
	Public LCFs	Worker LCFs				
Truck option						
Vicinity properties	2.7E-5	3.9E-5	6.9E-9	3.7E-4	1.1E-3	1.5E-3
Borrow material	0	0	0	1.2E-3	5.3E-2	5.4E-2
Mill tailings	2.6E-2	4.9E-2	1.4E-6	6.7E-2	1.2E+0	1.3E+0
Total	2.6E-2	4.9E-2	1.4E-6	6.9E-2	1.3E+0	1.4E+0
Slurry option						
Vicinity properties	2.7E-5	3.9E-5	6.9E-9	3.7E-4	1.1E-3	1.5E-3
Borrow material	0	0	0	1.2E-3	5.3E-2	5.4E-2
Mill tailings	2.1E-4	4.0E-4	1.1E-8	5.4E-4	9.6E-3	1.1E-2
Total	2.4E-4	4.4E-4	1.8E-8	2.1E-3	6.4E-2	6.7E-2

LCFs = latent cancer fatalities

H4.2 Incident-Free Radiation Doses to Maximally Exposed Individuals

H4.2.1 On-Site Disposal Alternative

Table H–15 lists the incident-free radiation doses for the maximally exposed individual scenarios for the on-site disposal alternative. For truck shipments of contaminated materials from vicinity properties to the Moab site, the maximally exposed transportation worker would be the driver of the truck. This person would receive a radiation dose of 26 mrem per year, which is equivalent to a probability of a latent cancer fatality of about 1.3×10^{-5}.

For truck shipments of contaminated materials from vicinity properties to the Moab site, the maximally exposed member of the public would be a person who happened to be stuck in a traffic jam next to a truck containing contaminated materials. This person would receive a radiation dose of 0.084 mrem, which is equivalent to a probability of a latent cancer fatality of about 5.0×10^{-8}.

H4.2.2 Klondike Flats Off-Site Disposal Alternative

Table H–15 lists the incident-free radiation doses for the maximally exposed individual scenarios for the Klondike Flats off-site disposal alternative. For truck shipments of mill tailings from Moab to Klondike Flats, the maximally exposed transportation worker would be the driver of the truck. This person was assumed to drive the truck containing mill tailings for 1,000 hours per year. For the other 1,000 hours per year, the truck would be empty. This driver would receive a radiation dose of 220 mrem per year, which is equivalent to a probability of a latent cancer fatality of about 1.1×10^{-4}. This represents an upper bound to potential radiation impacts, because it includes no wait times, training times, etc.

For rail shipments of mill tailings from Moab to Klondike Flats, the maximally exposed transportation worker would be an individual who inspected the rail cars. This person would receive a radiation dose of 440 mrem per year, which is equivalent to a probability of a latent cancer fatality of about 2.2×10^{-4}. This also represents an upper bound on potential radiation impacts, because it assumes that the individual inspects rail cars for 1,000 hours per year, and includes no wait times, training times, etc.

Table H–15. Incident-Free Radiation Doses for the Maximally Exposed Individual Scenarios

Scenario	On-Site Disposal	Klondike Flats Disposal	Crescent Junction Disposal	White Mesa Mill Disposal
Truck				
Nearby resident (member of the public)	0.0058 mrem/yr (3.5E-9 LCFs)	1.0 mrem/yr (6.3E-7 LCFs)	1.0 mrem/yr (6.3E-7 LCFs)	1.0 mrem/yr (6.3E-7 LCFs)
Individual in traffic jam (member of the public)	0.084 mrem/yr (5.0E-8 LCFs)	0.15 mrem/yr (9.0E-8 LCFs)	0.15 mrem/yr (9.0E-8 LCFs)	0.15 mrem/yr (9.0E-8 LCFs)
Driver (occupational)	26 mrem/yr (1.3E-5 LCFs)	220 mrem/yr (1.1E-4 LCFs)	220 mrem/yr (1.1E-4 LCFs)	220 mrem/yr (1.1E-4 LCFs)
Rail				
Nearby resident (member of the public)	N/A	0.53 mrem/yr (3.2E-7 LCFs)	0.53 mrem/yr (3.2E-7 LCFs)	N/A
Individual at railroad crossing (member of the public)	N/A	1.4E-6 mrem/yr (8.5E-13 LCFs)	1.4E-6 mrem/yr (8.5E-13 LCFs)	N/A
Inspector (occupational)	N/A	440 mrem/yr (2.2E-4 LCFs)	440 mrem/yr (2.2E-4 LCFs)	N/A

LCFs = latent cancer fatalities

For truck shipments of mill tailings from Moab to Klondike Flats, the maximally exposed member of the public would be a resident who lived along the road on which the tailings were shipped. This person would receive a radiation dose of 1.0 mrem per year, which is equivalent to a probability of a latent cancer fatality of about 6.3×10^{-7}.

For rail shipments of mill tailings from Moab to Klondike Flats, the maximally exposed member of the public would also be a resident who lived along the rail line on which the tailings were shipped. This person would receive a radiation dose of 0.53 mrem per year, which is equivalent to a probability of a latent cancer fatality of about 3.2×10^{-7}.

H4.2.3 Crescent Junction Off-Site Disposal Alternative

Table H–15 lists the incident-free radiation doses for the maximally exposed individual scenarios for the Crescent Junction off-site disposal alternative. For truck shipments of mill tailings from Moab to Crescent Junction, the maximally exposed transportation worker would be the driver of the truck. This person was assumed to drive the truck containing mill tailings for 1,000 hours per year. For the other 1,000 hours per year, the truck would be empty. This driver would receive a radiation dose of 220 mrem per year, which is equivalent to a probability of a latent cancer fatality of about 1.1×10^{-4}. This represents an upper bound to potential radiation impacts, because it includes no wait times, training times, etc.

For rail shipments of mill tailings from Moab to Crescent Junction, the maximally exposed transportation worker would be an individual who inspected the rail cars. This person would receive a radiation dose of 440 mrem per year, which is equivalent to a probability of a latent cancer fatality of about 2.2×10^{-4}. This also represents an upper bound on potential radiation impacts, because it assumes that the individual inspects rail cars for 1,000 hours per year, and includes no wait times, training times, etc.

For truck shipments of mill tailings from Moab to Crescent Junction, the maximally exposed member of the public would be a resident who lived along the road on which the tailings were shipped. This person would receive a radiation dose of 1.0 mrem per year, which is equivalent to a probability of a latent cancer fatality of about 6.3×10^{-7}.

For rail shipments of mill tailings from Moab to Crescent Junction, the maximally exposed member of the public would also be a resident who lived along the rail line on which the tailings were shipped. This person would receive a radiation dose of 0.53 mrem per year, which is equivalent to a probability of a latent cancer fatality of about 3.2×10^{-7}.

H4.2.4 White Mesa Mill Off-Site Disposal Alternative

Table H–15 lists the incident-free radiation doses for the maximally exposed individual scenarios for the White Mesa Mill off-site disposal alternative. For truck shipments of mill tailings from Moab to White Mesa Mill, the maximally exposed transportation worker would be the driver of the truck. This person was assumed to drive the truck containing mill tailings for 1,000 hours per year. For the other 1,000 hours per year, the truck would be empty. This driver would receive a radiation dose of 220 mrem per year, which is equivalent to a probability of a latent cancer fatality of about 1.1×10^{-4}. This represents an upper bound to potential radiation impacts, because it includes no wait times, training times, etc.

For truck shipments of mill tailings from Moab to White Mesa Mill, the maximally exposed member of the public would be a resident who lived along the road on which the tailings were shipped. This person would receive a radiation dose of 1.0 mrem per year, which is equivalent to a probability of a latent cancer fatality of about 6.3×10^{-7}.

H4.3 Impacts from Severe Transportation Accidents

In addition to analyzing the radiological and nonradiological risks of transporting contaminated material from vicinity properties, shipping uranium mill tailings and vicinity property material from the Moab site, and shipping borrow materials, DOE assessed the consequences of severe transportation accidents, known as maximum reasonably foreseeable transportation accidents. These severe accidents have a probability of about 1×10^{-7} per year. The consequences of these accidents were determined through the inhalation, groundshine, and immersion pathways.

The following assumptions were used to estimate the consequences of maximum reasonably foreseeable accidents:

- The release height of the plume is 3.3 ft.
- The breathing rate for individuals is assumed to be 10,500 yd^3 per year.
- The short-term exposure to airborne contaminants is assumed to be 2 hours.
- The long-term exposure to contamination deposited on the ground is assumed to be 1 year for the maximally exposed individual and the population, with no interdiction or cleanup.
- The accident was assumed to occur in either a rural area or near Moab, Monticello, or Blanding.
- Impacts were determined using moderate wind speeds and neutral atmospheric conditions (a wind speed of 14.67 ft per second and Class D stability).
- The release fractions used in the analysis were for Severity Category 4 truck accidents or Severity Category 3 rail accidents (see Tables H−3 and H−4).
- The shipment inventories used in the analysis are listed in Table H–5.

H4.3.1 On-Site Disposal Alternative

The maximally exposed individual would receive a radiation dose of 4.8×10^{-5} rem from the maximum reasonably foreseeable transportation accident involving a shipment of mill tailings from a vicinity property to the Moab site. This is equivalent to a probability of a latent cancer fatality of about 2.9×10^{-8}. The probability of this accident is about 4×10^{-4} per year. The population would receive a collective radiation dose of 5.6×10^{-4} person-rem from this accident, which is equivalent to a probability of a latent cancer fatality of about 3.3×10^{-7}.

H4.3.2 Klondike Flats Off-Site Disposal Alternative

If trucks were used to transport the mill tailings from Moab to Klondike Flats, the maximally exposed individual would receive a radiation dose of 1.6×10^{-4} rem from the maximum reasonably foreseeable transportation accident involving a shipment of mill tailings, which is equivalent to a probability of a latent cancer fatality of about 9.6×10^{-8}. The probability of this accident is about 0.06 per year.

If this accident occurred near Moab, the population would receive a collective radiation dose of 0.0018 person-rem. This is equivalent to a probability of a latent cancer fatality of about 1.1×10^{-6}. If this accident occurred in a rural area, the population would receive a collective radiation dose of 2.9×10^{-6} person-rem, which is equivalent to a probability of a latent cancer fatality of about 1.7×10^{-9}.

If rail were used to transport the mill tailings from Moab to Klondike Flats, the maximally exposed individual would receive a radiation dose of 0.0014 rem from the maximum reasonably foreseeable transportation accident involving a shipment of mill tailings, which is equivalent to a probability of a latent cancer fatality of about 8.5×10^{-7}. The probability of this accident is about 0.3 per year.

If this accident occurred near Moab, the population would receive a collective radiation dose of 0.017 person-rem. This is equivalent to a probability of a latent cancer fatality of about 1.0×10^{-5}. If this accident occurred in a rural area, the population would receive a collective radiation dose of 2.7×10^{-5} person-rem, which is equivalent to a probability of a latent cancer fatality of about 1.6×10^{-8}.

H4.3.3 Crescent Junction Off-Site Disposal Alternative

If trucks were used to transport the mill tailings from Moab to Crescent Junction, the maximally exposed individual would receive a radiation dose of 1.6×10^{-4} rem from the maximum reasonably foreseeable transportation accident involving a shipment of mill tailings, which is equivalent to a probability of a latent cancer fatality of about 9.6×10^{-8}. The probability of this accident is about 0.1 per year.

If this accident occurred near Moab, the population would receive a collective radiation dose of 0.0018 person-rem. This is equivalent to a probability of a latent cancer fatality of about 1.1×10^{-6}. If this accident occurred in a rural area, the population would receive a collective radiation dose of 2.9×10^{-6} person-rem, which is equivalent to a probability of a latent cancer fatality of about 1.7×10^{-9}.

If rail were used to transport the mill tailings from Moab to Crescent Junction, the maximally exposed individual would receive a radiation dose of 0.0014 rem from the maximum reasonably foreseeable transportation accident involving a shipment of mill tailings, which is equivalent to a probability of a latent cancer fatality of about 8.5×10^{-7}. The probability of this accident is about 0.5 per year.

If this accident occurred near Moab, the population would receive a collective radiation dose of 0.017 person-rem. This is equivalent to a probability of a latent cancer fatality of about 1.0×10^{-5}. If this accident occurred in a rural area, the population would receive a collective radiation dose of 2.7×10^{-5} person-rem, which is equivalent to a probability of a latent cancer fatality of about 1.6×10^{-8}.

H4.3.4 White Mesa Mill Off-Site Disposal Alternative

If trucks were used to transport the mill tailings from Moab to White Mesa Mill, the maximally exposed individual would receive a radiation dose of 1.6×10^{-4} rem from the maximum reasonably foreseeable transportation accident involving a shipment of mill tailings, which is equivalent to a probability of a latent cancer fatality of about 9.6×10^{-8}. The probability of this accident is about 0.3 per year.

If this accident occurred near Moab, Monticello, or Blanding, the population would receive a collective radiation dose of 0.0018 person-rem, which is equivalent to a probability of a latent cancer fatality of about 1.1×10^{-6}. If this accident occurred in a rural area, the population would receive a collective radiation dose of 2.9×10^{-6} person-rem. This is equivalent to a probability of a latent cancer fatality of about 1.7×10^{-9}.

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