6.0 Summary of Human Health and Ecological Risk

6.1 Human Health Risks

A baseline risk assessment (BLRA, DOE 1995) was previously prepared for the Naturita site. Most of the methodology used in that risk assessment followed standard EPA risk assessment protocol (EPA 1989a), though the BLRA did not calculate potential risks for noncarcinogenic constituents. Instead, calculated exposure intakes were compared with a range of contaminant doses associated with various adverse effects. Data used in that report were collected from 1989 to 1994. Since that time, additional data have been collected to more completely characterize the site and to represent more recent site conditions. Updated and revised toxicological data are also available for some site-related constituents. These new data were used to reevaluate the identified contaminants of potential concern (COPCs) and assessment of associated risks.

6.1.1 Summary of 1995 BLRA Methodology and Results

6.1.1.1 Ground Water

The BLRA identified 27 constituents at the Naturita site as being present at levels statistically above background concentrations. This initial list was screened to first eliminate constituents with concentrations within nutritional ranges and then to eliminate constituents of low toxicity and high dietary ranges. These two steps eliminated four and ten constituents, respectively, resulting in the following COPC list: antimony, arsenic, lead-210, manganese, molybdenum, polonium-210, radium-226, radium-228, selenium, sodium, sulfate, uranium, and vanadium. These contaminants were retained for further risk analysis.

A number of potential routes of exposure were evaluated: ingestion of ground water as drinking water in a residential setting, dermal contact with ground water while bathing, ingestion of meat and milk from ground-water-fed livestock, and contact with surface water and sediment where ground water discharges at the seep. Risks from ingestion of ground-water-irrigated produce were not calculated due to lack of sufficient data. Results of the exposure assessment indicated that intakes for all constituents were negligible from exposure routes other than drinking water. Therefore, only exposure through ingestion of ground water as drinking water was retained for more detailed evaluation. Both children and adults were considered as likely receptors.

Calculated exposure intakes were presented along with contaminant intakes associated with a range of adverse health effects. Potential risks associated with exposure to noncarcinogenic constituents were discussed qualitatively; carcinogenic risks were quantified and compared to EPA's acceptable risk range of 1×10^{-4} to 1×10^{-6}.

For sulfate, the most sensitive receptor population is infants. Results of the BLRA showed that infants exposed to the levels of sulfate in ground water at the Naturita site could experience significant adverse health effects due to severe diarrhea and dehydration.

Exposure intakes for the other noncarcinogenic contaminants in ground water were calculated for the receptors with the highest intake to body weight ratio—children between the ages of 1 and 10. Vanadium, manganese, and molybdenum were associated with the highest risks; concentrations of those constituents were consistently higher than recommended levels. Arsenic, uranium, and antimony concentrations exceeded EPA's acceptable intake levels (reference doses,

or RfDs) but were below levels known to produce adverse health effects. (The RfDs are generally established at levels below known toxicity values to account for uncertainty in toxicity studies and data.) Sodium and selenium concentrations were also typically below the dietary intake range. The BLRA (DOE 1995) provides detailed information on toxicity studies and effects.

Carcinogenic risks were calculated for adult exposure. Carcinogenic risks from to exposure to uranium and its daughter products exceeded the upper bound of EPA's acceptable risk range of 1×10^{-4} by approximately 1 order of magnitude. Risks from arsenic exposure were also more than an order of magnitude above this upper bound of the risk range.

6.1.1.2 Surface Water

It was assumed that children aged 9 to 10 years old could ingest and experience dermal contact with contaminated surface water and sediment at the seep downgradient of the site. No adverse health effects would be expected through this incidental exposure.

6.1.1.3 Meat and Milk Ingestion

Intakes were calculated for adult exposure to beef and milk from cattle watered with contaminated ground water and fed on contaminated forage. Intakes were determined to be negligible compared with direct ingestion of ground water, and associated risks were assumed to be insignificant.

6.1.2 BLRA Update

The original BLRA considered several potential routes of exposure to contaminants and eliminated as insignificant all except ingestion of ground water in a residential setting. Overall concentrations have declined for all COPCs since the time the BLRA was completed. Therefore, for this BLRA update, it is assumed that any pathway that was insignificant based on the original BLRA is still insignificant; risks will not be recalculated for those pathways (e.g., ingestion of meat and milk). Though not considered a likely scenario, risks from drinking water in a residential setting are recalculated using more recent monitoring data. In addition, to represent a more reasonable and likely exposure scenario, recreational use is considered, and risks are calculated assuming that the site becomes a golf course in the future. A scenario with children playing in the vicinity of the seep also is reevaluated using updated data from a location where exposure is more likely.

Risk calculations presented here follow EPA's *Risk Assessment Guidance for Superfund Methodology* (EPA 1989a), which involves determining a point estimate for excess cancer risk from current or potential carcinogenic exposures (risk is equal to lifetime intake times cancer slope factor) and a hazard quotient (HQ) for noncarcinogenic exposures (HQ is equal to exposure intake divided by reference dose). EPA's acceptable carcinogenic risk range is 1×10^{-4} to 1×10^{-6}, which is an excess cancer risk of 1 in 10,000 to 1 in 1,000,000 compared to the general population. Risks exceeding this range are potentially unacceptable. For noncarcinogenic exposures, an HQ exceeding 1 is potentially unacceptable. HQs from multiple contaminants and/or pathways are often summed to estimate cumulative noncarcinogenic risks; these summed HQs are referred to as a hazard index (HI). HIs greater than 1 also represent potentially unacceptable exposures. Therefore, it is possible for a number of individual contaminants to each

have "acceptable" HQs of less than 1 that, when summed, represent a potentially unacceptable cumulative risk. Figure 6-1 provides exposure intake equations and default assumptions used in intake calculations for this BLRA update.

Equations used in calculations

Chemicals: Ingestion from water: Intake (mg/kg-day) = (Cw × IRw × EF × ED)/(BW × AT)
Absorption from water: Intake (mg/kg-day) = (Cw × SA × PC × ET × EF × ED × CF)/(BW ×A T)
Ingestion from sediment (mg/kg-day) = (Cs × Csf × Irs × FI × EF × ED)/(BW × AT)

Radionuclides: Ingestion from water : Intake(lifetime in picocuries) = Cw × IRw × EF × ED
Absorption from water: Intake (mg/kg-day) = Cw × SA × PC × ET × EF × ED × CF
Ingestion from sediment (mg/kg-day) = Cs × Csf × Irs × FI × EF × ED

Residential Exposure Scenario—Ground Water Ingestion

Where

Cw = contaminant concentration in water
IRw = ingestion rate for water (2 L/day default for adults; 1.5 L/day for children 6-12 years; 0.64 L/day for infants)
EF = exposure frequency (350 days per year)
ED = exposure duration (30 years for adults, 7 years for children, and 1 year for infants for noncarcinogens; 30 years for carcinogens)
BW = body weight (70 kg for adults; 38.3 kg for children; 4 kg for infants)
AT = averaging time (365 days × ED for noncarcinogens; 365 days × 70 years for carcinogens)

Incidental Exposure Scenario—Surface Water and Sediment

Where

Cw = contaminant concentration in water
Cs = contaminant concentration in sediment
Csf = conversion factor (10^{-6} kg/mg)
IRw = ingestion rate for water (0.05 L/day for children and adults)
IRs = ingestion rate for sediments (100 mg/day for children and adults)
EF = exposure frequency (3 months per year at 7 days per week = 90 days, plus 3 months per year on weekends = 24 days; total = 114 days per year for children playing. 250 days per year for golf course worker)
ED = exposure duration (7 years for children aged 6–12 years playing on the floodplain; 30 years for golf course worker)
ET = Exposure time (1 h/day for children playing; 8 h/day for golf course worker)
BW = body weight (38.3 kg for children aged 6–12 years; 70 kg for adult)
AT = averaging time (365 days × ED for noncarcinogens; 365 days × 70 years for carcinogens)
SA = skin surface area available for contact (497 cm^2 body surface area for children 6–12 years old; 312 cm^2 for adult's arms and hands)
PC = dermal permeability constant (0.001 cm/h; same rate as water)
CF = volumetric conversion factor for water (1 L/1000 cm^3)
FI = fraction ingested from sediment (1.0, unitless; assumes all contaminant is ingested)

RfD = reference dose (chemical specific; mg/kg-day); HQ = Intake/RfD
SF = slope factor (chemical specific; unitless); Risk = intake × slope factor

All exposure factors from EPA 1989b unless otherwise noted.

Figure 6-1. Exposure Intake, Risk Equations, and Default Assumptions

In Figure 6-1, toxicological values used to estimate risks (reference doses and slope factors) are conservative values with uncertainty factors built in to be protective of sensitive populations.

Therefore, risks presented here are reasonable worst-case estimates and are likely much higher than those that actually exist.

In this update, which uses point-exposure doses, single values are used for each parameter required in the risk calculations. Calculations to determine contaminant intakes use standard exposure factors (EPA 1989b). The ground water and surface water data used to assess risks in this document are from the last two rounds of sampling at the site—November/December 2000 and February/March 2001. These data were used to give an up-to-date look at the site. Risk calculations performed for ground water use the 95 percent upper confidence level (UCL_{95}) on the mean concentrations to provide reasonable worst-case risk estimates for probable future ground water uses. Exposure to surface water represents the only potentially complete pathway that currently exists. Surface water concentrations used in the risk calculations are from sample location 0567, an area where seep water has ponded adjacent to the San Miguel River. This location is probably one of the most attractive locations along the river for children to play because of its accessibility and lack of thick vegetation and steep banks. Based on data collected in February 2001, it appears that constituents have concentrated in the pooled area due to evaporation; concentrations are typically higher than in the ground water that feeds the pool. Use of data from this location represents a most-likely and worst-case situation for evaluation of exposure to surface water. For sediment calculations, concentrations were the maximum obtained from all locations. No data from location 0567 were available.

The same methodology was used to calculate carcinogenic risks for this BLRA update as was used in the original BLRA (i.e., receptors are adults with exposure averaged over 70 years). For all risk calculations, benchmarks for acceptable contaminant intakes (e.g., reference doses and slope factors) are the best available data from standard EPA sources (e.g., Integrated Risk Information System, Region III Risk-Based Concentration Table).

6.1.2.1 Ground Water

This BLRA update uses the COPC list from the original BLRA as a starting point to evaluate current data for ground water. These constituents are antimony, arsenic, lead-210, manganese, molybdenum, polonium-210, radium-226, radium-228, selenium, sodium, sulfate, uranium, and vanadium.

Historical data indicate that concentrations of antimony have declined through time to near the detection limit in most wells, with few exceptions. Monitoring for this constituent was discontinued upon completion of the original BLRA. It is assumed that antimony is still close to background concentrations and can be eliminated as a COPC. Monitoring for all radionuclides other than uranium was also discontinued after completion of the original BLRA. At that time most radionuclides (except uranium) had declined in concentration to levels that posed little incremental risk over background. Because most of the risk is associated with uranium, and most of the other radionuclides represent uranium daughter products, it is assumed that any compliance strategy that is protective of exposure to uranium will result in acceptable levels of exposure to all other radionuclides. The COPCs retained for further evaluation in this BLRA update are arsenic, manganese, molybdenum, selenium, sodium, sulfate, uranium, and vanadium.

Table 6–1 summarizes background, current plume, and historical plume data for each COPC in the alluvial ground water. Also included for comparison are the applicable UMTRA ground water standards (if available) and risk-based concentrations (RBCs; EPA 2001). The RBC for a given contaminant represents a concentration in drinking water that would be protective of human health provided

- Residential exposure is appropriate.
- Ingestion of contaminated drinking water is the only exposure pathway.
- The contaminant contributes nearly all the health risk.
- EPA's risk level of 1×10^{-6} for carcinogens and an HQ of 1 for noncarcinogens is appropriate.

If any of these assumptions is *not* true, contaminant levels at or below RBCs cannot automatically be assumed to be protective. For example, if multiple contaminants are present in drinking water, a single contaminant may be below its RBC but still be a significant contributor to the total risk posed by drinking the water. However, if an RBC is exceeded, it is an indication that further evaluation of the contaminant is warranted. RBCs are intended for use in screening-level evaluations.

No standards or benchmarks have been established for sodium based on human health concerns. The secondary standard of 250 mg/L for sulfate is based on considerations of taste and odor and not on effects to human health. Because of the lack of toxicity data, potential risks from exposure to these two contaminants cannot be quantified. Exposure intakes are calculated for these constituents, but potential adverse effects are considered only qualitatively.

For the residential ground water pathway evaluated quantitatively in this BLRA update, both children and adults were evaluated as receptors. Children would be more sensitive receptors than adults due to higher intake to body weight ratios. Infants were also evaluated for exposure to sulfate in a residential scenario because they represent the most sensitive receptor population. Adults only were evaluated for the occupational exposure scenario (hypothetical golf course worker). Carcinogenic risks were calculated for adults only based on the much longer exposure duration and because risks are averaged over a lifetime.

6.1.2.2 Surface Water and Sediment

Two scenarios are evaluated for exposure to surface water and sediment in this BLRA update. Children are evaluated for exposure to contaminated surface water and sediment at location 0567. In addition, based on the likely future use of the Naturita site as a golf course, exposures and risks were calculated for a hypothetical golf course worker that could be exposed to contaminated ground water used for irrigation, water hazards, or some similar purpose. Conservative exposure assumptions were used in both instances. Carcinogenic risks were calculated for adults only.

Table 6–1. Naturita Alluvial Ground Water Data Summary 2000–2001

Contaminant	FOD[a]	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	UCL_{95} (mg/L)	UMTRA std (mg/L)	RBC (mg/L)
Arsenic						0.05	0.011N[e]
Background[b]	2/2	0.0006	0.0009	NA			0.000045C[f]
Current plume[c]	53/53	0.0005	0.064	0.013	0.017		
Historical Plume[d]	11/13	0.007	0.08	0.03			
Manganese						0.05[g]	1.7N
Background	5/5	0.18	0.32	0.26			
Current plume	51/54	<0.04	2.06	0.871	0.99		
Historical Plume	6/6	1.9	7.5	5.1			
Molybdenum						0.1	
Background	0/5	<0.02	NA	NA			
Current plume	20/54	<0.02	0.16	0.038	0.046		
Historical Plume	6/6	0.25	0.38	0.29			
Selenium						0.01	
Background	0/3	<0.0003	NA	NA			
Current plume	44/53	<0.0003	0.014	0.002	0.002		
Historical Plume	11/13	<0.005	0.08	0.01			
Sodium							
Background	5/5	18.2	25.1	23.7			
Current plume	54/54	29.8	1,050	210	257		
Historical Plume	6/6	801	1,080	997			
Sulfate						250[g]	
Background	4/4	131	282	229			
Current plume	54/54	260	1,700	697	774		
Historical Plume	6/6	1,030	1,450	1,200			
Uranium						0.044?	
Background	5/5	0.004	0.009	0.007			
Current plume	54/54	0.004	2.49	0.773	0.91		
Historical Plume	13/13	1.0	5.2	2.2			
Vanadium							0.33N
Background	0/5	<0.019	NA	NA			
Current plume	26/54	<0.02	5.73	1.11	1.49		
Historical Plume	6/6	1.5	10.0	6.4			

Background well DM1
Plume wells: (USGS analyses) wells 0547, 0548, MAU03 through MAU08, NAT01-1, 02, 03, 04-1, 06-1, 08, 10, 11, 15-1, 16-1, 16, 20, 23 through 26, 27-2, 29, and 30-1.
[a]Frequency of detection
[b]Current background data collected 6/2000 through 3/2001
[c]Current plume data collected 11/2000 through 3/2001
[4]Historical data collected 1989 through 1994; wells 0616 and 0632 (as reported in DOE 1995)
[e]N= noncarcingenic risks
[f]C= carcinogenic risks
[g] Secondary drinking water standard

6.1.3 Results

6.1.3.1 Ground Water—Residential

Table 6–2 provides results of calculations for ingestion of ground water through residential use. Noncarcinogenic risks were calculated for both children and adults; risks are slightly higher for children because of their lower body weights. The greatest risks for both children and adults are from exposure to uranium, vanadium, and arsenic. Manganese, molybdenum, and selenium collectively make up only about 5 percent of the risk. From a risk perspective, selenium and molybdenum, and possibly manganese, could probably be eliminated as COPCs, though selenium and molybdenum exceed their respective UMTRA standards in at least one location. Background concentrations of manganese are approximately an order of magnitude higher than the Colorado secondary drinking water standard. Carcinogenic risks for both arsenic and uranium exceed the high end of EPA's acceptable risk range of 1×10^{-4} by factors of approximately 3 and 7, respectively.

Sodium and sulfate could not be evaluated quantitatively due to lack of toxicity data. A recent survey by EPA (1999a) indicated that no adverse affects resulted from exposures to sulfate of 500 mg/L or less in drinking water in any study conducted. Some studies of adult populations showed that negligible effects were associated with concentrations up to 1,200 mg/L. Infants are the receptors most sensitive to sulfate exposure. Sulfate levels present at the Naturita site could result in diarrhea and dehydration if ingested by infants on a regular basis. Only minor and temporary effects, if any, would be expected for adults exposed to those levels of sulfate.

Intakes of sodium based on concentrations at the Naturita site are well within typical dietary ranges. The National Research Council recommends that most healthy adults consume at least 500 mg/day and that sodium intake be limited to 2,400 mg/day. A Food and Drug Administration publication, *Scouting for Sodium and Other Nutrients Important to Blood Pressure* (FDA 95-2284), indicates that most adults tend to eat between 4,000 and 6,000 mg of sodium per day. Therefore, levels associated with the Naturita site, even with a residential scenario, would not be expected to result in significant adverse affects. The level of sodium ingested by children would be slightly less than 400 mg/day and for adults would be slightly higher than 500 mg/day.

6.1.3.2 Ground Water—Occupational

Table 6–3 provides calculations on exposure to ground water through occupational use. The assumption is made that a well is installed into the alluvial aquifer and used for drinking water in an occupational setting. Risks are calculated for a full-time worker exposed 5 days a week for the work year. One-half the daily intake of drinking water is consumed at work. Calculations show that risks for use of ground water in this manner would be unacceptable. The HI for that exposure route is approximately 6, and most of the risk is accounted for by uranium and vanadium. Carcinogenic risks are 5 times the high end of EPA's acceptable risk range; contributions from uranium and arsenic are approximately equal.

Table 6–2. Intake/Risk Calculation Spreadsheet (ground water ingestion pathway)

Naturita Site—Residential Exposure

Noncarcinogens—Ground Water Ingestion Only (children)

Contaminant	Cw[a]	Irw	EF	ED	BW	AT	Intake	RfD	HQ
Arsenic	0.017	1.5	350	7	38.3	2,555	0.0006	0.0003	2.128
Manganese	0.99	1.5	350	7	38.3	2,555	0.0372	0.047	0.791
Molybdenum	0.046	1.5	350	7	38.3	2,555	0.0017	0.005	0.346
Selenium	0.002	1.5	350	7	38.3	2,555	0.0001	0.005	0.015
Sodium	257	1.5	350	7	38.3	2,555	9.6516		
Sulfate	774	1.5	350	7	38.3	2,555	29.0676		
infants	774	0.64	350	1	4	365	118.7507		
Uranium	0.91	1.5	350	7	38.3	2,555	0.0342	0.003	11.392
Vanadium	1.49	1.5	350	7	38.3	2,555	0.0560	0.007	7.994

HI= 22.665

Noncarcinogens—Ground Water Ingestion Only (adults)

Contaminant	Cw	Irw	EF	ED	BW	AT	Intake	RfD	HQ
Arsenic	0.017	2	350	30	70	10,950	0.00047	0.0003	1.553
Manganese	0.99	2	350	30	70	10,950	0.02712	0.047	0.577
Molybdenum	0.046	2	350	30	70	10,950	0.00126	0.005	0.252
Selenium	0.002	2	350	30	70	10,950	5.47945E-05	0.005	0.011

Table 6–2 (continued). Intake/Risk Calculation Spreadsheet (ground water ingestion pathway)

Contaminant	Cw	Irw	EF	ED	BW	AT	Intake	RfD[2]	HQ
Sodium	257	2	350	30	70	10950	7.04109		
Sulfate	774	2	350	30	70	10950	21.20547		
Uranium	0.91	2	350	30	70	10950	0.02493	0.003	8.311
Vanadium	1.49	2	350	30	70	10950	0.04082	0.007	5.832
								HI =	16.535

Carcinogens—Ground Water Ingestion Only (adults)

Contaminant	Cw	Irw	EF	ED	BW	AT	Intake	SF	Risk
Arsenic	0.017	2	350	30	70	25,550	0.00019	1.5	2.99E-04
U-234+238[b] (pCi/L)	624.26	2	350	30	na	na	1.31E+07	5.32E-11	6.97E-04
								Total risk	9.97E-04

[a]Water concentrations used are UCL_{95} milligrams per liter

[b]Assumes equilibrium; 1 mg = 686 pCi; slope factor is average of U-234 and U-238

Cw = contaminant concentration in water
Irw = ingestion rate for water (L/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (365 days × ED)
Intake = mg/kg-day per chemicals; pCi for radionuclides
SF = slope factor (chemical specific; unitless)
Risk = intake × slope factor

6.1.3.3 Surface Water and Sediment—Incidental Exposure

Table 6–3 and Table 6–4 present results of exposure to surface water and sediment. The surface water and sediment pathway assumes incidental exposure through surface water and sediment ingestion as well as dermal contact with surface water. Conservative assumptions are made regarding absorption and ingestion of contaminants and about exposure frequencies and durations. For both scenarios considered, risks summed for all contaminants and all pathways were well below the threshold HI of 1. Carcinogenic risks associated with the golf course worker scenario were within EPA's acceptable risk range. Because infants would not be exposed to sulfate through incidental exposure, sulfate intakes are not of concern for the surface water pathway. Sodium intakes are also acceptable given the more limited exposure compared to a residential scenario.

6.1.3.4 Uncertainty in the BLRA

Any risk assessment includes many sources of uncertainty, such as limited site characterization, uncertainty of future land use, and uncertainty in toxicity values used. Because of the conservative assumptions used in calculating risks, risks are most often overestimated for an exposure scenario. Some of the sources of uncertainty specific to this BLRA update are listed below along with their overall effect on estimates of site-related risks.

- *Toxicity data and contaminant interactions.* The toxicity values were obtained from EPA's Integrated Risk Information System (IRIS) database and represent the best data available. However, these values are often extrapolated from animal data or from laboratory tests conducted under conditions that differ from those under which actual exposure to environmental contaminants occurs. Most of the studies do not include data on more sensitive populations (e.g., children, the elderly). Uncertainly factors are often applied to these values to account for such circumstances. The RfDs for arsenic and selenium were developed using an uncertainty factor of 3; the RfD for molybdenum includes an uncertainty factor of 30. Uncertainty factors of 100 and 1,000 were applied in developing the RfDs for vanadium and uranium, respectively. Thus, the actual risks associated with vanadium and uranium are least understood. The application of highly conservative uncertainty factors may overestimate the risks.

- *Chemical interaction.* To get hazard indices and total carcinogenic risks, HQs and risks for all chemicals were simply summed. In reality, certain chemicals can have interactions that are synergistic or antagonistic. This is not accounted for by summing risks. Lack of data on chemical interaction could either overestimate or underestimate actual risks.

- *Future water and land use.* Risks were calculated assuming residential, occupational, and recreational exposure to ground water, surface water, and sediment. A residence is currently located in the contaminant plume for uranium, but ground water is not being used for drinking water. The presumed future use for the rest of the property associated with the plume is a golf course, but currently there are no complete pathways to ground water. The only potentially complete exposure pathway at present is exposure to surface water, though it is unlikely that this is actually occurring. Uses of the land could change in the future and would dictate the possible exposure scenarios. Risks presented here, particularly for a residential scenario, are overestimates based on current ground water and surface water exposures.

Table 6–3. Occupational Exposure Scenario, Hypothetical Golf Course Worker at the Naturita Site

Dermal Exposure Pathway

Noncarcinogens	Cw mg/L	SA cm^2	PC cm/h	CF L/cm^3	ET h/day	EF days/yr	ED yr	BW kg	AT days	Intake absorbed mg/kg-day	RfD mg/kg-day	HQ mg/kg-day
Arsenic	0.017	312	0.001	0.001	8	250	30	70	10,950	4.15E-07	0.0003	0.00138
Manganese	0.99	312	0.001	0.001	8	250	30	70	10,950	2.42E-05	0.047	0.00051
Molybdenum	0.046	312	0.001	0.001	8	250	30	70	10,950	1.12E-06	0.005	0.00022
Selenium	0.002	312	0.001	0.001	8	250	30	70	10,950	4.88E-08	0.005	0.00001
Sodium	257	312	0.001	0.001	8	250	30	70	10,950	6.28E-03		
Sulfate	774	312	0.001	0.001	8	250	30	70	10,950	1.89E-02		
Uranium	0.91	312	0.001	0.001	8	250	30	70	10,950	2.22E-05	0.003	0.00741
Vanadium	1.49	312	0.001	0.001	8	250	30	70	10,950	3.64E-05	0.007	0.00520
											HI =	0.01474

Carcinogens	Cw	SA	PC	Cf	ET	EF	ED	BW	AT	Intake absorbed	SF	Risk
Arsenic	0.017	312	0.001	0.001	8	250	30	70	10,950	4.15E-07	1.5	6.23E-07
Uranium (pCi/L)	624.26	312	0.001	0.001	8	250	30	na	na	1.17E+04	5.32E-11	6.22E-07
											Total risk	1.24E-06

Surface Water Ingestion—Incidental Exposure

Noncarcinogens	Cw	Irw	EF	ED	BW	AT	Intake	RfD	HQ
Arsenic	0.017	0.05	250	30	70	10,950	8.317E-06	0.0003	0.028
Manganese	0.99	0.05	250	30	70	10,950	0.00048	0.047	0.010
Molybdenum	0.046	0.05	250	30	70	10,950	2.25E-05	0.005	0.005
Selenium	0.002	0.05	250	30	70	10,950	9.785E-07	0.005	0.000
Sodium	257	0.05	250	30	70	10,950	0.12573		
Sulfate	774	0.05	250	30	70	10,950	0.37866		
Uranium	0.91	0.05	250	30	70	10,950	0.00044	0.003	0.148
Vanadium	1.49	0.05	250	30	70	10,950	0.00072	0.007	0.104

Table 6–3 (continued). Occupational Exposure Scenario, Hypothetical Golf Course Worker at the Naturita Site

Surface Water Ingestion—Incidental Exposure

Carcinogens	Cw	Irw	EF	ED	BW	AT	Intake	SF	Risk
Arsenic	0.017	0.05	250	30	70	10950	8.317E-06	1.5	1.25E-05
U-234+238	624.26	0.05	250	30	na	na	234,097.5	5.32E-11	1.25E-05
								Total Risk	2.49E-05

Sediment Ingestion—Incidental Exposure

Noncarcinogens	Csf	Cs-max	Irs	EF	ED	BW	AT	Intake	RfD	HQ
Arsenic	1.00E-05	2.83	100	250	30	70	10950	2.769E-05	0.0003	0.0923
Manganese	1.00E-05	498	100	250	30	70	10950	0.0048728	0.047	0.1037
Molybdenum	1.00E-05	2.19	100	250	30	70	10950	2.143E-05	0.005	0.0043
Selenium	1.00E-05	0.27	100	250	30	70	10950	2.642E-06	0.005	0.0005
Sodium	1.00E-05	244	100	250	30	70	10950	0.0023875		
Sulfate	1.00E-05	2464	100	250	30	70	10950	0.0241096		
Uranium	1.00E-05	12.5	100	250	30	70	10950	0.0001223	0.003	0.0408
Vanadium	1.00E-05	9.74	100	250	30	70	10950	9.53E-05	0.007	0.0136
									HI=	0.255

Carcinogens		Cw	Irw	EF	ED	BW	AT	Intake	SF	Risk
Arsenic	1.00E-05	2.83	100	250	30	70	10950	2.769E-05	1.5	1.85E-05
Uranium (pCi/L)	1.00E-05	8575	100	250	30	na	na	64,312.5	5.32E-11	3.42E-06
									Total risk	2.19E-05

Cumulative HI, all pathways = 0.56518

Cumulative risk, all pathways = 4.81E-05

Table 6–3 (continued). Occupational Exposure Scenario, Hypothetical Golf Course Worker at the Naturita Site

Ground Water Ingestion—Drinking Water

Nonarcinogens	Cw	Irw	EF	ED	BW	AT	Intake	RfD	HQ
Arsenic	0.017	1	250	30	70	10,950	0.00016	0.0003	0.554
Manganese	0.99	1	250	30	70	10,950	0.00968	0.047	0.206
Molybdenum	0.046	1	250	30	70	10,950	0.00045	0.005	0.090
Selenium	0.002	1	250	30	70	10,950	1.957E-05	0.005	0.004
Sodium	257	1	250	30	70	10,950	2.51467		
Sulfate	774	1	250	30	70	10,950	7.57338		
Uranium	0.91	1	250	30	70	10,950	0.00890	0.003	2.968
Vanadium	1.49	1	250	30	70	10,950	0.01457	0.007	2.083
								HI=	5.905

Carcinogens	Cw	Irw	EF	ED	BW	AT	Intake	SF	Risk
Arsenic	0.017	1	250	30	70	10950	0.00016	1.5	2.50E-04
U-234+238 (pCi/L)	624.26	1	250	30	na	na	4,681,950	5.32E-11	2.49E-04
								Total Risk	4.99E-04

[a]Based on 2000 & 2001 data; UCL_{95}

[b]Carcinogenic risks for uranium assumes 1 mg U = 686 pCi of U-234 + U-238; SF is average of U-234 and U-238

Table 6–4. Intake/Risk Calculation Spreadsheet (Surface Water/Sediment)

Naturita Site—Incidental Exposure at Location 0567

Noncarcinogens—Surface Water Ingestion Only (children)

	Cw	Irw	EF	ED	BW	AT	Intake	RfD	HQ
Arsenic	0.001	0.05	114	7	38.3	2,555	4.0774E-07	0.0003	0.001
Manganese	1.76	0.05	114	7	38.3	2,555	0.00071	0.047	0.015
Molybdenum	0	0.05	114	7	38.3	2,555	0	0.005	0.000
Selenium	0	0.05	114	7	38.3	2,555	0	0.005	0.000
Sodium	698	0.05	114	7	38.3	2,555	0.28460		
Sulfate	1,710	0.05	114	7	38.3	2,555	0.69723		
Uranium	1.06	0.05	114	7	38.3	2,555	0.00043	0.003	0.144
Vanadium	0	0.05	114	7	38.3	2,555	0	0.007	0.000
								HI=	0.161

Noncarcinogens—Sediment Ingestion Only (children)

	Csf	Cs-max	Irs	EF	ED	BW	AT	Intake	RfD	HQ
Arsenic	1.00E-05	2.83	100	114	7	38.3	2,555	2.30781E-05	0.0003	0.0769
Manganese	1.00E-05	498	100	114	7	38.3	2,555	0.00406	0.047	0.0864
Molybdenum	1.00E-05	2.19	100	114	7	38.3	2,555	1.7859E-05	0.005	0.0036
Selenium	1.00E-05	0.27	100	114	7	38.3	2,555	2.2018E-06	0.005	0.0004
Sodium	1.00E-05	244	100	114	7	38.3	2,555	0.00198		
Sulfate	1.00E-05	2,464	100	114	7	38.3	2,555	0.02009		
Uranium	1.00E-05	12.5	100	114	7	38.3	2,555	0.00010	0.003	0.0340
Vanadium	1.00E-05	9.74	100	114	7	38.3	2,555	7.94277E-05	0.007	0.0113
									HI=	0.2127

Table6–4 (continued). Intake/Risk Calculation Spreadsheet (Surface Water/Sediment)

Naturita Incidental Exposure—Dermal Exposure Pathway (child)

Noncarcingens	Cw mg/L	SA cm^2	PC cm/h	CF L/cm^3	ET h/day	EF days/yr	ED yr	BW kg	AT days	Intake absorbed mg/kg-day	RfD mg/kg-day	HQ mg/kg-day
Arsenic	0.001	497	0.001	0.001	1	114	7	38.5	2,555	0.00000	0.0003	1.34396E-05
Manganese	1.76	497	0.001	0.001	1	114	7	38.5	2,555	0.00001	0.047	0.00015
Molybdenum	0	497	0.001	0.001	1	114	7	38.5	2,555	0.00000	0.005	0
Selenium	0	497	0.001	0.001	1	114	7	38.5	2,555	0.00000	0.005	0
Sodium	698	497	0.001	0.001	1	114	7	38.5	2,555	0.00281		
Sulfate	1,710	497	0.001	0.001	1	114	7	38.5	2,555	0.00689		
Uranium	1.06	497	0.001	0.001	1	114	7	38.5	2,555	0.00000	0.003	0.00142
Vanadium	0	497	0.001	0.001	1	114	7	38.5	2,555	0.00000	0.007	0
											HI=	0.00158

Total risk from all pathways = 0.3750

Data used are from the February/March 2001 sampling round

Cw = contaminant concentration in water
Irw = ingestion rate for water (L/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (365 days × ED)
Intake = mg/kg-day per chemicals; pCi for radionuclides
SF = slope factor (chemical specific; unitless)
Risk = intake × slope factor

- *Exposure parameters.* Exposure parameters for the residential scenario are default parameters used regularly by EPA. Most of the parameters are based on statistical analyses of population data. Actual exposures vary considerably. Numbers used represent values from the high end of the actual exposure distribution and are therefore conservative estimates. Because each parameter is set at the high end of its respective distribution, overall risks are probably overestimated.

6.1.4 Summary and Recommendations

Risk calculations show that the only unacceptable exposure pathway is ingestion of ground water as drinking water. Risks are unacceptable for both a residential and an occupational setting. This indicates that controls should be put in place to prevent use of alluvial ground water for drinking water until contamination is reduced to acceptable levels. Most of the risk is contributed by uranium and vanadium, and to a lesser degree by arsenic. The other constituents combined contribute only about 5 percent of the total risk. In both residential and occupational settings, carcinogenic and noncarcinogenic risk thresholds are exceeded. Risks could not be calculated quantitatively for sodium and sulfate, but it appears that the only potential adverse effect would be associated with infant exposure to ground water as drinking water.

Incidental exposure to ground water through non-drinking-water use in an occupational setting does not result in any unacceptable risks. This suggests that the aquifer could be used for irrigation or possibly some other type of industrial use. However, before the ground water is used for such a purpose, it is recommended that calculations be completed based on process-specific exposures.

Exposure of children to surface water and sediment while playing adjacent to the San Miguel River would not result in any unacceptable risks. This indicates that restrictions on access to the river and adjacent areas are not required based on discharge of ground water to the river.

Uranium, vanadium, and arsenic concentrations should continue to be monitored. Monitoring requirements for the remaining constituents is a risk management decision. Presumably any compliance strategy that prevents exposure to uranium, vanadium, and arsenic will be likewise be protective of exposure to the remaining contaminants.

6.2 Ecological Risk Assessment

6.2.1 Introduction

Ecological risk assessment is a process that evaluates the likelihood that adverse ecological effects are occurring or may occur in the future as a result of exposure to one or more environmental stressors. A stressor is defined as any physical, chemical, or biological entity that can induce an adverse ecological response. The risk assessment process is outlined in EPA guidance documents, particularly the *Guidelines for Ecological Risk Assessment* (EPA 1998) and the *Framework for Ecological Risk Assessment* (EPA 1992). The Ecological Risk Assessment (ERA) for the Naturita site generally follows this EPA framework and guidance.

The overall goal of this risk assessment is to identify ecological COPCs (E-COPCs) that can be related to the dispersal of contaminants in the ground water underlying the millsite and to

characterize the potential for adverse effects of these E-COPCs on the ecosystem at the Naturita site. In particular, potential effects on special status species and sensitive environments are considered. This assessment is an update and expansion of the BLRA screening-level assessment conducted in 1995 (DOE 1995). However, it is still primarily a screening assessment to identify E-COPCs and areas in which future monitoring may be necessary. This section summarizes the BLRA findings and evaluates any data collected since the BLRA. This section will also apply data from new studies as well as updated ecological benchmarks and regulatory requirements that have been developed since completion of the BLRA.

Predicting the effects of chemicals on ecological receptors is complicated because of variable interactions and influences within an ecosystem. To a great extent, ecological risk assessment is an emerging science. Little data exist for most chemicals and their effects on ecological receptors. Therefore, attempting to integrate and evaluate individual and synergistic chemical effects with other stressors (predation, drought, disease, etc.) is problematic.

For ecological risks to occur, both a source and a pathway must exist for exposure of ecological receptors to contaminated ground water. The simplified ecological risk scenario gives a generalized overview of the ecological risk assessment process:

Source	→	Release	→	Contaminated Media	→	Pathway	→	Receptor	→	Effect
(mill tailings, RRM)		(into soil and ground water)		(ground water, surface water, and sediments)		(ingestion or absorption)		(plants and wildlife		(no effect, mortality, or nonlethal effects),

The following sections provide a summary of the BLRA and evaluation of potential risks based on a review of all relevant data, with emphasis on the 1998–2001 data.

6.2.2 Ecological Risk Assessment Process

As shown in Figure 6-2, the framework of the ERA contains three main components: (1) problem formulation, (2) analysis, and (3) risk characterization. The overall goal of the problem formulation is to "set the stage" for the analysis and risk characterization phases. In the problem formulation, the need for a risk assessment is identified and the scope of the problem is defined. Available data are evaluated to identify potential stressors (in this case, the potential stressors are COPCs associated with the ground water at the Naturita millsite), key ecological receptors, and potential exposure pathways linking the receptors to the stressors. This information is used to develop a site conceptual model and risk hypotheses. Finally, assessment and measurement endpoints are defined for the specific determination of risk to these receptors and the environmental resources they represent. These endpoints are directly tied to overall management goals for the site.

The analysis phase of the ERA includes two concurrent steps—the exposure assessment and the effects characterization. In the exposure assessment, the potential for each receptor to be exposed to each stressor is evaluated and, where possible, quantified. The effects characterization describes the potential for the stressor to adversely affect the receptors that are exposed to it. Because the stressors at the Naturita site are chemical, the principal effects to ecological receptors will be toxicological; however, they may also include physical effects, such as those related to radiation.

The risk characterization phase evaluates (either qualitatively or quantitatively) the combined results of the exposure assessment and effects characterization to determine the potential for risk to the receptors due to their exposure to the stressors. A critical aspect of the risk characterization is the analysis of uncertainties associated with predictions of potential risk. Typically, uncertainties result from data gaps that necessitate the incorporation of assumptions into the analysis and risk characterization phases. In general, these assumptions are conservatively biased toward results that will lead to overestimations rather than underestimations of risk. The uncertainty analysis provides an analysis of these assumptions in terms of their potential for introducing significant bias in the risk estimation.

As described in the EPA guidance (EPA 1998), ecological risk assessment is an iterative process in which the evaluation of potential risks to ecological receptors is refined as additional data are collected to fill data gaps and reduce uncertainties. At the conclusion of each iteration (or "tier") in the process, decisions are made whether sufficient data have been collected and analyzed to proceed with risk management actions (if required), or whether additional data should be collected. Such a tiered approach to the ecological risk assessment process began at the Naturita site in 1995 with the screening-level BLRA (DOE 1995).

Subsequently, additional data have been collected from key environmental media specifically to characterize potential ecological risk. The ERA presented here provides an analysis of these new data as a refinement of the screening-level assessment. Sampling of ground water, surface water, and sediments for chemical analysis was conducted between 1998 and 2001 as discussed in Section 4.10.2, "Ecological Field Investigations."

6.2.2.1 Problem Formulation

The problem formulation phase in this risk assessment is represented in part by the information presented in the BLRA (DOE 1995). The BLRA was based on analytical data collected at the Naturita site before 1995. These data were reviewed to determine if concentrations of analytes in ground water, surface water, and sediment may pose a potential ecological risk. Information on the geologic setting, ground water hydrology, geochemistry, and habitats of the Naturita site were incorporated in the BLRA evaluation. Principal results of the BLRA included an initial screening of chemical analytes as E-COPCs and an assessment of potential risk to biota, including livestock and irrigated crops. The assessment of potential risk, however, was primarily qualitative. The BLRA provided a basis for the preparation of a characterization work plan (DOE 1998b).

Since the completion of the BLRA, additional samples have been collected at Naturita and at upgradient reference areas. These new analytical data are limited to data obtained from USGS. All available data gathered specifically for the ERA, which include the 1998–2001 sampling efforts, have been included in this update. Any other surface data collected after July 2001 will be addressed in the environmental assessment for the Naturita site as necessary.

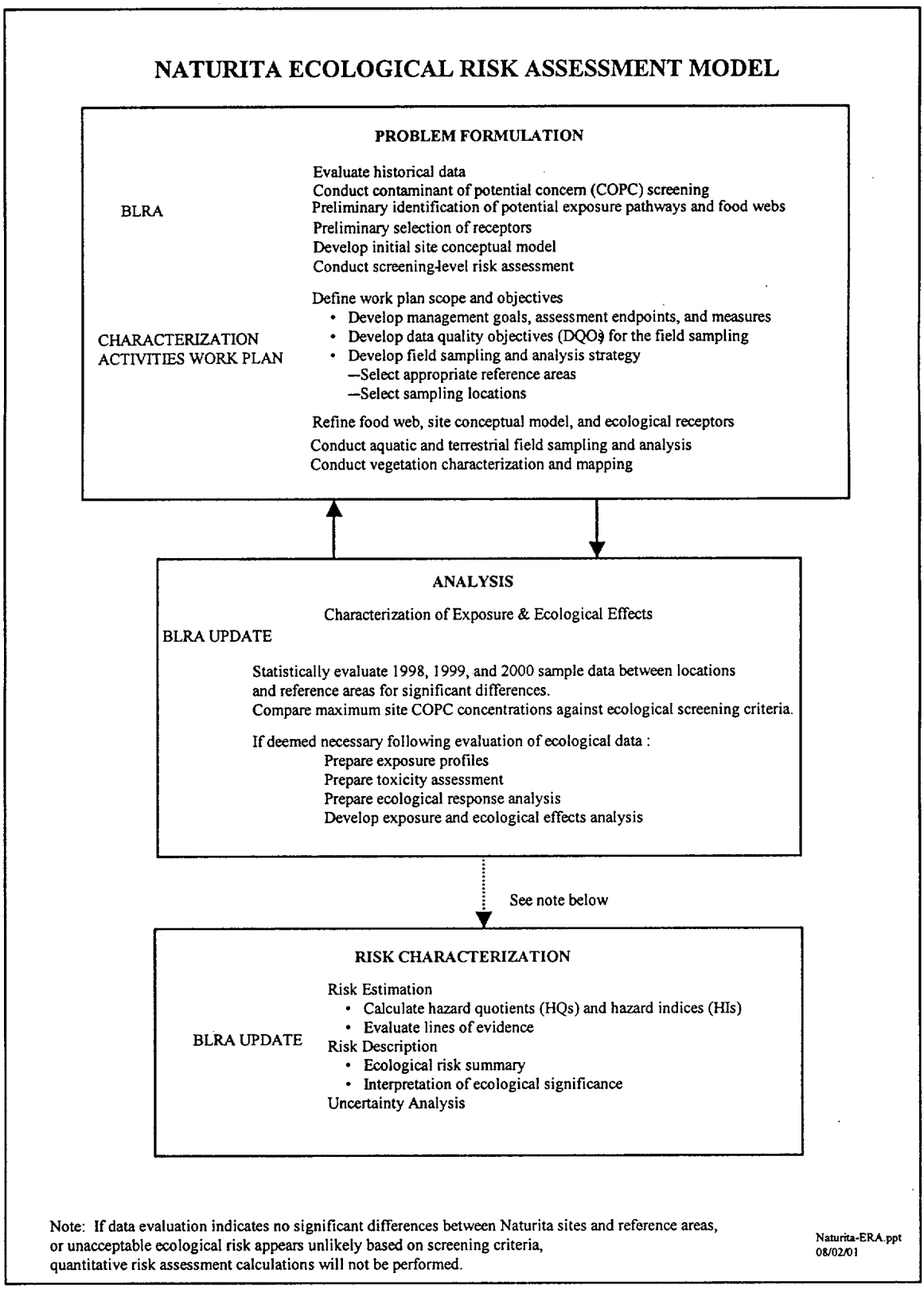

Figure 6-2. Naturita Ecological Risk Assessment Model

Potentially Affected Habitats and Populations

The millsite area is dominated by disturbed pastureland and a riparian community along the San Miguel River. Surrounding habitats are generally characterized as semiarid, influenced by the low to moderate annual precipitation. Flora and fauna of the Naturita millsite and surrounding areas were investigated between 1986 and 1994. Detailed information is provided in the *Environmental Assessment of Remedial Action at the Naturita Uranium Processing Site Near Naturita, Colorado* (DOE 1994), which documents the results of the investigations and lists the potential ecological receptors, including threatened or endangered species. Ecological characterization and surveys targeted terrestrial ecological receptors, with an emphasis on riparian plant communities and associated wildlife along the San Miguel River. Terrestrial wildlife such as foxes, coyotes, skunks, raccoons, deer, and rodents likely use the riparian habitats for foraging, resting, denning, and other activities. The area is also known to provide winter range for large mammals, including deer and elk. Drinking water sources such as the San Miguel River and tributaries are commonly available in or near these habitats, adding to their attractiveness to wildlife. Most, if not all, of the area (including riparian areas) is currently used as pastureland for livestock (primarily horses). Birds of the riparian habitats include resident and migratory species (e.g., bald eagle). The aquatic habitat of the San Miguel River is also used by waterfowl such as ducks and geese. The area is also suitable habitat for cold water game fish, primarily various trout species.

The BLRA identified several federally threatened or endangered species that may inhabit the former millsite area. Of the species originally listed, the only one for which there appears to be suitable habitat (located on private land) is the southwestern willow flycatcher. This is based on visual observations and the degree of human and livestock use of the site. Surveys were conducted at the site for this species through 1994, but no observations were documented.

A seep at location 0538 provides a small pond and criteria wetland of approximately one acre at the northeast end of the site. It is likely that amphibians, primarily frogs, inhabit this pond. This area is thought to be the most downgradient extent of contamination and will be the primary focus of ecological assessment. Because surface and near-surface expressions of the contaminated ground water are limited to this area, emphasis will be placed on receptors that may be present in this area. The areas and media currently considered to have potential ecological pathways also include the millsite (ground water), and surface water and sediments in and along the San Miguel River.

Summary of the 1995 Ecological Risk Assessment Results

In the 1995 BLRA (DOE 1995), the list of ground water constituents that were present in elevated levels in ground water (based on statistical comparisons between on-site and background well data) was used a starting point for identifying E-COPCs in those media for which ecological exposure pathways may exist. The water quality of samples from upgradient wells was considered to be representative of background conditions for the floodplain aquifer. The BLRA initially identified 27 ground-water-based constituents as E-COPCs for further evaluation. Additional media of concern included surface water, sediments, and vegetation (Figure 4–25). Based on this information, a screening-level assessment of ecological risks at the site evaluated potential exposure pathways, receptors, and potential adverse effects related to these constituents and media. No other contaminated media and subsequent pathways or effects were addressed in the BLRA. Of 27 initial E-COPCs, the list was reduced in Sections 3.0 and 7.0 of the BLRA to those constituents with concentrations that were elevated above background in affected media. These media-specific E-COPCs are indicated in Table 6–5. Concentrations of

E-COPCs in ground water, surface water, sediments, and vegetation were then compared to toxicity standards and guidelines (if available) for various ecological receptors.

In some cases the BLRA identified E-COPCs and media that required further evaluation. However, no sampling of any media was conducted between 1995 and 1997. Sampling resumed in 1998 for selected constituents in ground water, surface water, and sediments. Sampling from 1998 to the present will be discussed in subsequent sections of this document, with an emphasis on 2000 and 2001 data.

Table 6–5. Summary of Ecological Contaminants of Potential Concern in Ground Water, Surface Water, Sediments, and Vegetation from the BLRA (DOE 1995)

Constituents with Concentration Above Background in Ground Water[a]	Concentration Above Background in the San Miguel River Channel[b]	Concentration Elevated in San Miguel River Sediments[b]	Concentration Elevated in Vegetation[c]
Aluminum			
Ammonium			
Antimony			
Arsenic		X	X
Barium			
Boron			
Calcium			
Chloride			
Fluoride			
Magnesium			
Manganese		X	X
Molybdenum			
Nitrate			
Phosphate			
Potassium			
Selenium			X
Silica			
Silver			
Sodium			
Strontium			
Sulfate		X	
Uranium		X	
Vanadium		X	X
Radionuclides			
Lead-210			
Polonium-210			
Radium-226	X		
Radium-228			

[a]Ground water constituents with concentrations that exceeded background (reference area concentrations).
[b]Surface water constituents that exceeded background surface water areas (river and location 0531). Constituents were excluded that were either not detected in surface water or the maximum concentrations adjacent to and downgradient from the site were less than concentrations upgradient of the site.
[c]Selection of constituents was based on a screening benchmarks for plants where available (river channel and location 0531) because background samples were not taken.

Section 3.6 of the BLRA states that a statistical evaluation of water samples at surface locations identified no statistically significant elevated concentrations in downstream locations, indicating that ground water is not adversely affecting the San Miguel River. The one exception was a slight increase in radium-226 at one location adjacent to the site. Other radionuclides could not be thoroughly evaluated due to the lack of data. Mass balance calculations were also completed to further document that ground water was not influencing surface waters. The results indicated that only sodium, sulfate, and uranium had the potential to be detected in the San Miguel River. However, in all cases, the concentrations would be below standards for surface waters and would not affect the quality of the surface water in the San Miguel River under low-flow conditions. Therefore, the river was not considered an exposure point for environmental receptors. However, analysis of location 0538, referred to as a small pond in the BLRA, does show signs that ground water is reaching this location. The pond, which is within the river floodplain, has an outflow that empties into the San Miguel River. The BLRA states that water quality in the pond does not exceed any water quality criteria or available screening benchmarks for terrestrial plants or wildlife.

On the basis of one round of sediment sampling in 1994, concentrations of a few constituents (uranium, sulfate, and zinc) were higher in downstream river locations than upstream locations. (Zinc was not included in the original list of 27 E-COPCs, and is therefore not included in Table 6–5.) The BLRA indicates that the differences in upstream and downstream concentrations of uranium and sulfate in sediments are difficult to attribute to site contamination.

Sediments at location 0538 showed elevated levels of arsenic, manganese, sulfate, uranium, vanadium, and zinc. Arsenic, manganese, and zinc concentrations exceeded National Oceanic and Atmospheric Administration (NOAA) sediment screening benchmarks. The case is made that zinc concentrations at location 538 (the seep), although elevated an order of magnitude above background, are unlikely to be attributed to site influence due to low zinc concentrations in site-related ground water. No sediment benchmarks were available for sulfate, uranium, and vanadium. In the case of both surface water and sediments, the BLRA states that insufficient water and sediment data were available to draw firm conclusions, and further data and evaluation were recommended.

Update of the 1995 Ecological COPCs

For the current risk assessment, additional data collected and information received subsequent to the 1995 BLRA are used to reevaluate the list of E-COPCs that are further assessed for potential ecological risk. Due to uncertainties associated with previous analyses, the initial list of 27 constituents identified as ground water E-COPCs in the 1995 BLRA are reconsidered in this update. Iron, tin, zinc, and thorium-230 are added, bringing the total number of constituents to 31 for preliminary risk evaluation. These 31 constituents are listed in Table 6–6. For the constituents for which sampling was not conducted during the 1998–2001 sampling events, the evaluation is based on pre-1995 data. Current benchmarks and assessment methodologies are applied as applicable to the evaluation of potential risk from identified E-COPCs.

Table 6–6. Preliminary Ecological Contaminants of Potential Concern in Ground Water

Constituents Considered For Preliminary Evaluation[a]	Exceed Background[b]	Retained As E-COPC	Rationale
Aluminum	Y	N	Only slightly elevated based on current data.
Ammonium	Y	N	Only slightly elevated based on 89–94 data.
Antimony	Y	N	Only slightly elevated based on 89–94 data.
Arsenic	Y	Y	Exceeds background by an order of magnitude.
Barium	Y	Y	Exceeds background by an order of magnitude.
Boron	Y	Y	Exceeds background by an order of magnitude.
Calcium	Y	N	Essential nutrient, not typically associated with/RRM.
Chloride	Y	N	Low potential toxicity.
Fluoride	Y	N	Not typically associated with RRM.
Iron	Y	Y	Elevated by two orders of magnitude.
Magnesium	Y	N	Considered an essential nutrient.
Manganese	Y	Y	Elevated above background.
Molybdenum	Y	Y	Elevated above background.
Nitrate	Y	Y	Elevated above background.
Phosphate	Y	N	Low potential toxiciy.
Potassium	Y	N	Essential nutrient, not associated with/RRM.
Selenium	Y	Y	Slightly elevated above background.
Silica	Y	N	Not typically associated with RRM.
Silver	Y	N	Small number of detects based on 89–94 data.
Sodium	Y	N	Considered an essential nutrient.
Strontium	Y	Y	Elevated at 4 times background.
Sulfate	Y	Y	Elevated at 8 times background.
Tin	Y	N	Small number of detects based on 89-94 data.
Uranium	Y	Y	Elevated above background.
Vanadium	Y	Y	Elevated above background.
Zinc	Y	Y	Elevated above background.
Radionuclides			
Lead-210	Y	Y	Based on 89–94 data.
Polonium-210	Y	Y	Based on 89–94 data.
Radium-226	Y	Y	Based on 89–94 data.
Radium-228	N	N	Based on 89–94 data.
Thorium-230	Y	Y	Based on 89–94 data.

[a]Ground water constituents that require further evaluation because they were E-COPCs under the BLRA, they were not fully evaluated under the BLRA, or current data justifies consideration as an E-COPC because maximum concentrations exceed background.

[b]Based on maximum concentrations of most recent (through March 2001) sampling. If no sampling was completed after 1994, then 89–94 data are used.

Constituents that are considered to be essential nutrients (as recognized in EPA 1989a) were excluded as E-COPCs. These included calcium, magnesium, potassium, and sodium. Chloride and phosphate were excluded from consideration as E-COPCs in the BLRA because of their low potential toxicities and are still excluded as E-COPCs for the same reason. However, at high concentrations in water, these anions and the four cations considered to be essential nutrients can contribute to adverse ecological effects due to high osmotic potentials, and some can affect the use of water by wildlife and livestock by imparting strong tastes to the water. These types of effects are not addressed in this risk assessment.

Sulfate is also an anion of relatively low potential toxicity in biota. High sulfate levels in water is known to cause diarrhea in humans and livestock; however, some evidence indicates that this effect is temporary, and the individual will acclimate to the high sulfate ingestion without long-term adverse effect (EPA 1999a). Sulfate-based salts are commonly used to test the toxicity of cationic elements, indicating a general lack of toxic potential of the sulfate anion, which would otherwise interfere with the test results. However, because of its high concentrations in the ground water associated with the millsite, sulfate has not been excluded from consideration as an E-COPC.

The radioactive elements in the decay chain of uranium-238 that have sufficiently long half-lives to accumulate at detectable levels in the environment are not specifically included in this evaluation. The maximum concentrations of these radionuclides, which include thorium-230, radium-226, polonium-210, and lead-210, exceed the maximum concentrations from background wells and are therefore identified as E-COPCs. Radium-228, which was also detected in ground water, did not exceed the maximum background concentration. The principal risk to ecological receptors from the radionuclides is from radiation resulting from their decay rather than their individual chemical toxicities.

E-COPCs were identified from the remaining list of constituents on the basis of their detection in recent samples from the Naturita site and comparisons of these concentrations to background values. The comparisons to background were performed separately for the San Miguel River, locations 0538/0560 seep and pond, sediments, and vegetation areas where ecological pathways may exist. "Recent" data were considered to be data from samples collected in 2000 and 2001, or the most recent year for which data are available for the analyte. In some cases only a small number of data points were available and statistical comparisons were not possible. Therefore, a comparison of maximum values was used to identify E-COPCs. A constituent was retained as an E-COPC if the maximum concentration detected in the surface water or sediment was greater than the maximum detected reference site concentration. Because the seep and pond near locations 0538 and 0560 are within the river floodplain but are distinct surface water features from the river, they are addressed separately from other river locations. In the case of vegetation, no additional sampling or reference samples were obtained. In some cases, a lack of detections was the criterion for eliminating a constituent from further consideration as an E-COPC.

Because nitrate and zinc were detected in less than 25 percent of samples collected during the 2000–2001 sampling of the floodplain alluvial ground water, their identification as millsite-related contaminants is questionable.

The 2000 and 2001 data from upstream sampling location 0531 were used as reference data for surface water and sediment samples from both the San Miguel River and the seep/pond.

For the vegetation samples, 1994 data were used because no samples have been taken since that time. These data are not evaluated as a separate medium, but are incorporated in the evaluation of risk associated with the E-COPCs identified for the areas in question.

E-COPCs Associated with Ground Water

Of the 31 constituents considered in this update, 13 nonradionuclides and 4 radionuclides are retained for evaluation to determine risks associated with ground water (Table 6–6). Based on the shallow depth to contaminated ground water at the site, it is possible that some plant roots could intercept ground water. Phreatophytes, including cottonwood, willow, and greasewood, have the potential to root into the shallow ground water. These plants grow at the site and are discussed in more detail in Section 4.10.1. The BLRA evaluated the potential for phytotoxic effects by comparing the UCL_{95} of the ground water concentrations to published plant toxicity benchmarks based on contaminant concentrations in solution. Because phytotoxicity comparison data were unavailable for 15 of the 24 E-COPCs, the potential for risk to phreatophytes could not be completely evaluated. However, the results indicated that plant concentrations did not exceed phytotoxicity standards for six of the nine constituents for which benchmark values were available. The three exceptions were arsenic, manganese, and vanadium.

The BLRA evaluated potential effects to wildlife using contaminated ground water in a livestock pond (i.e., animals drinking from the pond) and to fish stocked in the pond. The UCL_{95} ground water concentrations of the E-COPCs were compared with available water quality criteria. The UCL_{95} exceeded the water quality values, indicating that the water would be unacceptable for aquatic organisms because of chloride, manganese, selenium, and silver concentrations. Vanadium was also found to potentially pose a risk to organisms exposed to ground water in such a pond. No water quality criteria were available for 16 of the ground water E-COPCs.

The BLRA evaluated the effect of hypothetical use of ground water for irrigating agricultural crops. The UCL_{95} ground water concentrations for manganese, molybdenum, selenium, and silver exceeded the comparison criteria. No comparison criteria were available for 13 of the E-COPCs (excluding the four radionuclides).

E-COPCs Associated with Surface Water

The 13 nonradiological and 4 radiological constituents in ground water that were retained as E-COPCs were further evaluated as possible E-COPCs in surface water at the Naturita site based on the 2000–2001 data. Surface water data from the seep and pond (locations 0538 and 0560) were evaluated separately from the river data. Upstream river sampling location 0531 was used as the reference location for both areas. If concentrations in the downstream or pond samples exceeded the reference (background) concentrations, the E-COPC was retained for surface water evaluation. If the constituent was not detected, or the downstream concentration was less than or equal to the upstream location, it was eliminated as an E-COPC. The results of these evaluations for the river and the seep/pond location are presented in Table 6–7 and Table 6–8, respectively. Barium concentration in the river only marginally exceeded the background value and did not exceed background in the pond sample. Barium is questionably retained as an E-COPC in the river surface water.

Table 6–7. Constituents Retained for Evaluation in the San Miguel River Surface Water

Constituent	Maximum Concentration in Surface Water[a]		Selected as E-COPC?	Reason
	Site	Ref.		
Nonradiological Constituents				
Arsenic	0.0017	<0.0002	Yes	Exceeds background range
Barium	0.09	0.08	Yes	Exceeds background range
Boron	0.14	0.09	Yes	Exceeds background range
Iron	0.48	<0.03	Yes	Exceeds background range
Manganese	0.78	<0.04	Yes	Exceeds background range
Molybdenum	ND	<0.04	No	Not detected
Nitrate	0.11	0.05	Yes	Exceeds background range
Selenium	0.0018	0.001	Yes	Exceeds background range
Strontium	1.74	1.23	Yes	Exceeds background range
Sulfate	459	239	Yes	Exceeds background range
Uranium	0.44	0.002	Yes	Exceeds background range
Vanadium	ND	<0.04	No	Not detected
Zinc	0.1	<0.041	Yes	Exceeds background range
Radiological Constituents				
Lead-210	1.2	0.2	Yes	Exceeds background range
Polonium-210	ND	0.2	No	Not detected
Radium-226	0.6	0.1	Yes	Exceeds background range
Radium-228	23	1.1	Yes	Exceeds background range
Thorium-230	0.5	0.1	Yes	Exceeds background range

[a]In mg/L for nonradiological constituents and pCi/L for radiological constituents.
ND = not detected
Results are from the 2000–2001 sampling data.

Table 6–8. Constituents Retained for Evaluation for the 0567/0538 Seep and Pond Surface Water

Constituent	Maximum Concentration in Surface Water, mg/L		Selected as E-COPC?	Reason
	Site	Ref.		
Arsenic	0.001	<0.0002	Yes	Exceeds background range
Barium	0.04	0.08	No	Does not exceed background
Boron	0.17	0.09	Yes	Exceeds background range
Iron	0.22	<0.03	Yes	Exceeds background range
Manganese	1.76	<0.04	Yes	Exceeds background range
Molybdenum	<0.04	<0.04	No	Not detected
Nitrate	<0.02	0.05	No	Does not exceed background
Selenium	0.002	0.001	Yes	Exceeds background range
Strontium	4.37	1.23	Yes	Exceeds background range
Sulfate	1,710	239	Yes	Exceeds background range
Uranium	1.06	0.002	Yes	Exceeds background range
Vanadium	<0.04	<0.04	No	Not detected
Zinc	0.08	<0.041	Yes	Exceeds background range

Results are from the 2000–2001 sampling data.

Radiological analyses for surface water were limited to the San Miguel River. Of the four radionuclides identified as E-COPCs for ground water (lead-210, polonium-210, radium-226, and thorium-230), concentrations of all except polonium-210 exceeded the upstream concentration in the San Miguel River. In addition, the concentrations of radium-228 also exceeded its upstream concentration in the river; however, concentrations of this radionuclide have not exceeded background in ground water. Therefore, its identification as an E-COPC is questionable.

E-COPCs Associated with Sediments

As with the surface water, the sediment data from the 2000–2001 samples were evaluated for E-COPCs based on comparisons to data from the upstream river sampling location. Because of the lower number of data points, however, the sediment data were not segregated by the pond and river locations. Therefore, sediment is assessed as a single unit at the Naturita site. As described for the surface water evaluation, E-COPCs in sediment were defined as those constituents that exceeded the maximum reference site (location 0531) concentration. As Table 6–9 shows, this was true for 12 of the 13 constituents that were evaluated (the exception was nitrate, which was not analyzed in the sediment samples).

Table 6–9. Constituents Retained for Evaluation in Sediments

Constituent	Maximum Concentration in Surface Water, mg/kg		Selected as E-COPC?	Reason
	Site	Ref.		
Arsenic	2.83	1.83	Yes	Exceeds background range
Barium	97	75	Yes	Exceeds background range
Boron	5.83	4.45	Yes	Exceeds background range
Iron	3,519	2,307	Yes	Exceeds background range
Manganese	721	367	Yes	Exceeds background range
Molybdenum	2.19	<0.04	Yes	Exceeds background range
Nitrate	–	–	–	No data
Selenium	0.27	0.18	Yes	Exceeds background range
Strontium	195	112	Yes	Exceeds background range
Sulfate	2,464	1,150	Yes	Exceeds background range
Uranium	12.5	0.53	Yes	Exceeds background range
Vanadium	9.54	6.56	Yes	Exceeds background range
Zinc	171	117	Yes	Exceeds background range

Results are from the 2000–2001 sampling data.

Summary of E-COPCs for All Media

Table 6–10 presents a summary of the reevaluation of E-COPCs.

Table 6–10. Summary of Ecological Contaminants of Potential Concern at the Naturita Millsite

Alluvial Ground Water	Surface Water in the San Miguel River	Surface Water at Locations 0538 and 0560	River, Seep, and Pond Sediment
Arsenic	Arsenic	Arsenic	Arsenic
Barium	Barium	Boron	Barium
Boron	Boron	Iron	Boron
Iron	Iron	Manganese	Iron
Manganese	Manganese	Selenium	Manganese
Molybdenum	Nitrate	Strontium	Molybdenum
Nitrate	Selenium	Sulfate	Selenium
Selenium	Strontium	Uranium	Strontium
Strontium	Sulfate	Zinc	Sulfate
Sulfate	Uranium		Uranium
Uranium	Zinc		Vanadium
Vanadium	Lead-210		Zinc
Zinc	Radium-226		
Lead-210	Radium-228		
Polonium-210	Thorium-230		
Radium-226			
Thorium-230			

6.2.3 Ecological Site Conceptual Model

The conceptual model for an ERA is developed from information about stressors, predicted exposure pathways, and the potential effects of exposure on ecological receptors. Conceptual models consist of two principal components (EPA 1998):

- A set of risk hypotheses that provide descriptions of predicted relationships among stressor, exposure, and assessment endpoint response, along with the rationale for their selection.
- A diagram that illustrates the relationships presented in the risk hypotheses.

A complete exposure pathway is the mechanism by which a contaminant in an environmental medium (i.e., the source) can contact an ecological receptor. A complete exposure pathway includes

- A contaminant source.
- A release mechanism that allows contaminants to become mobile or accessible.
- A transport mechanism that moves contaminants away from the release.
- An ecological receptor.
- A route of exposure (e.g., dermal or direct contact, inhalation, or ingestion).

Because the stressors at the Naturita site are chemical contaminants, the risk hypotheses are considered to be stressor-initiated.

As part of the initial problem formulation in the BLRA, a generalized site conceptual model was developed for the Naturita site. That model has since been revised to address current and potential exposure pathways based on all the available data (Figure 6-3). The movement of contaminated ground water from the millsite in various directions has resulted in surface and near-surface expressions of this ground water in the seep at location 0538. For this reason, risk hypotheses are developed separately for the San Miguel River and the seep and pond at locations 0538 and 0560.

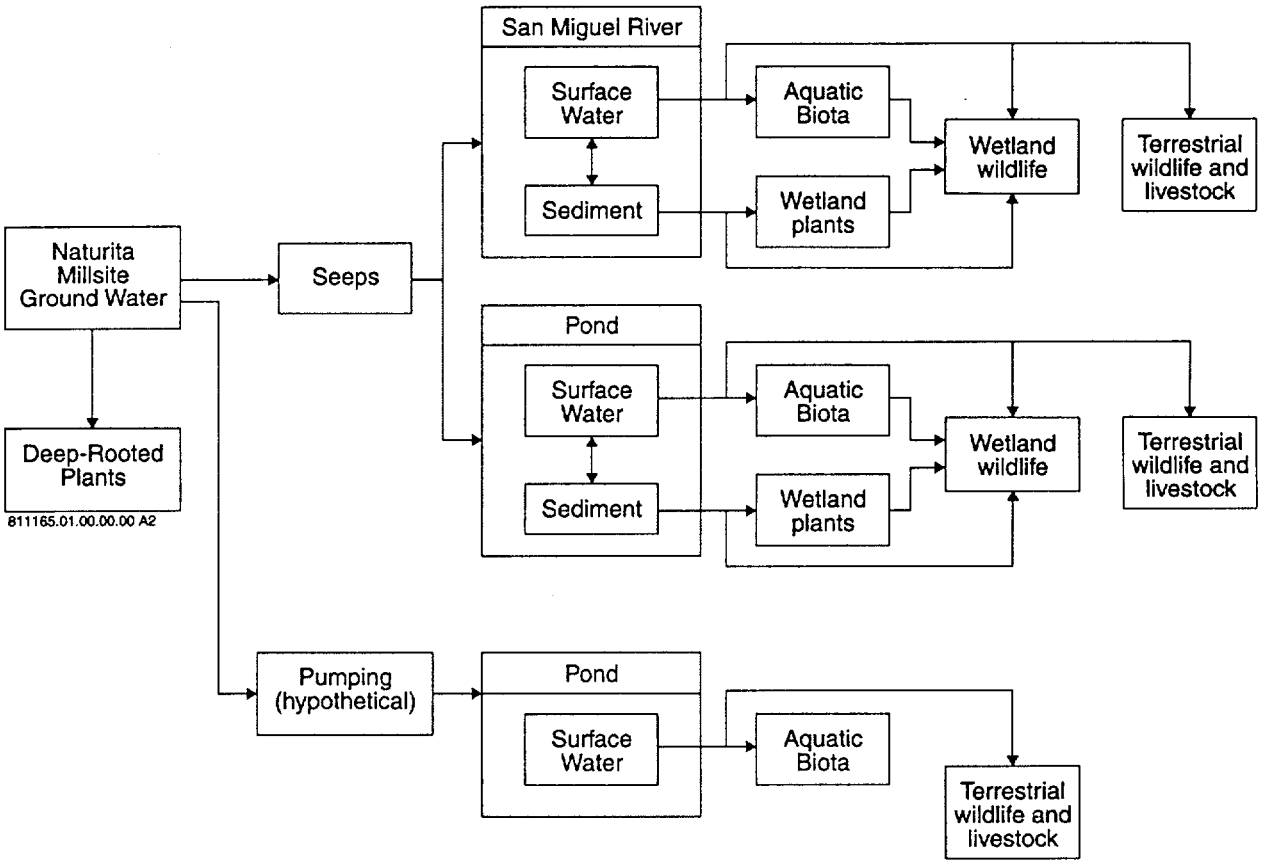

Figure 6-3. Naturita Ecological Site Conceptual Model

6.2.3.1 Risk Hypotheses Based on Current Exposure Scenarios

The following risk hypotheses are proposed for the Naturita site where complete exposure pathways to ecological receptors may exist based on the current site conditions. Roots of phreatophytes may take up contaminants in the shallow ground water of the San Miguel River floodplain. These contaminants may result in phytotoxic effects and they may be transported to plant tissues that are accessible to wildlife and foraging livestock. Contaminated ground water may be discharging at seeps (e.g., the seep feeding the pond at location 0538) and directly into the San Miguel River, thereby adversely affecting surface water and sediment quality of the area. Aquatic organisms in direct contact with these media may be affected and may provide a link for bioaccumulation of the contaminants up the food chain. Wildlife and livestock may be directly exposed to these contaminants through ingestion of this water and the food items exposed to the water and sediment and through incidental ingestion of the sediment.

6.2.3.2 Risk Hypotheses Based on Hypothetical Future Exposure Scenario

Without institutional controls, ground water could possibly be pumped and used for irrigation, livestock watering, or industry. This practice would create a source for ground water and surface water ingestion, direct contact with terrestrial vegetation, and deposition of ground water and surface water on the soil. The soil would then represent an additional source medium for ingestion and direct contact. Large-scale irrigation with ground water is not considered a likely future pathway because surface water is the main source of irrigation water in the Naturita area. As long as there is the possibility of pumping ground water for agricultural purposes, it is assumed that the potential exists for these two exposure pathways.

6.2.3.3 Ecological Receptors

Ecological receptors that could potentially be exposed to E-COPCs were identified in the BLRA (DOE 1995) and include mammalian and avian species. Section 6.2.2.1. summarizes the habitats and populations that may be affected by exposures to E-COPCs at the Naturita site. The food web for the Naturita site (Figure 6-4) illustrates the significant dietary interactions among the wetland and aquatic receptors. The food web also depicts the major trophic interactions and shows nutrient flow and transfer of matter and energy through the trophic levels. This food web model was developed from the species lists and the exposure pathways. The food web diagram portrays potential routes of E-COPCs from the ground water to biota at various trophic levels; potential receptor species are in specific areas identified as having potentially complete ecological exposure pathways. These areas and potential receptors are as follows:

The San Miguel River and Seep/Pond. The habitat of the river channel is primarily riparian. The potential receptors of these areas include

- Riparian plants that grow along the channel course and around the pond and seep.
- Aquatic receptors, including fish, aquatic invertebrates, and aquatic plants.
- Wetland wildlife, which may be exposed to E-COPCs in the seep/pond area and along the river as a result of drinking surface water and feeding on the aquatic organisms and wetland plants. Potential receptors include insectivorous birds, such as swallows, flycatchers, and

shorebirds; and piscivorous birds, such as belted kingfishers and herons. Mammals associated with wetland habitats include muskrats and raccoons.

- Terrestrial wildlife, which may be attracted to the surface water of the river and pond for drinking and may be exposed to E-COPCs in the seep/pond area and along the river as a result of drinking surface water. These may include small, local species and large, wide-ranging species.

Based on habitat conditions along the San Miguel River channel, the endangered southwestern willow flycatcher is considered a potential receptor at this location.

The San Miguel River Floodplain. The habitats of the San Miguel River floodplain are primarily terrestrial; however, many of the wildlife receptors in these habitats live and feed in close association with the aquatic habitats of the river and pond. These receptors include

- Terrestrial herbivores—The terrestrial wildlife that may be exposed to E-COPCs through the consumption of phreatophytes and wetland plants include rodents (e.g., white-footed mice, voles, and ground squirrels), lagomorphs (cottontails and jackrabbits), and mule deer. Evidence of beaver along the San Miguel River indicates that this herbivorous rodent is a potential receptor in the riparian habitat of the floodplain. Additional exposure in these receptors may result from the ingestion of water from the site.

- Terrestrial predators—Predators that may be exposed to E-COPCs through the consumption of terrestrial herbivorous prey include foxes, coyotes, skunks, snakes, and raptors. Many mammalian predators will also consume plant material, making them omnivores rather than strict carnivores.

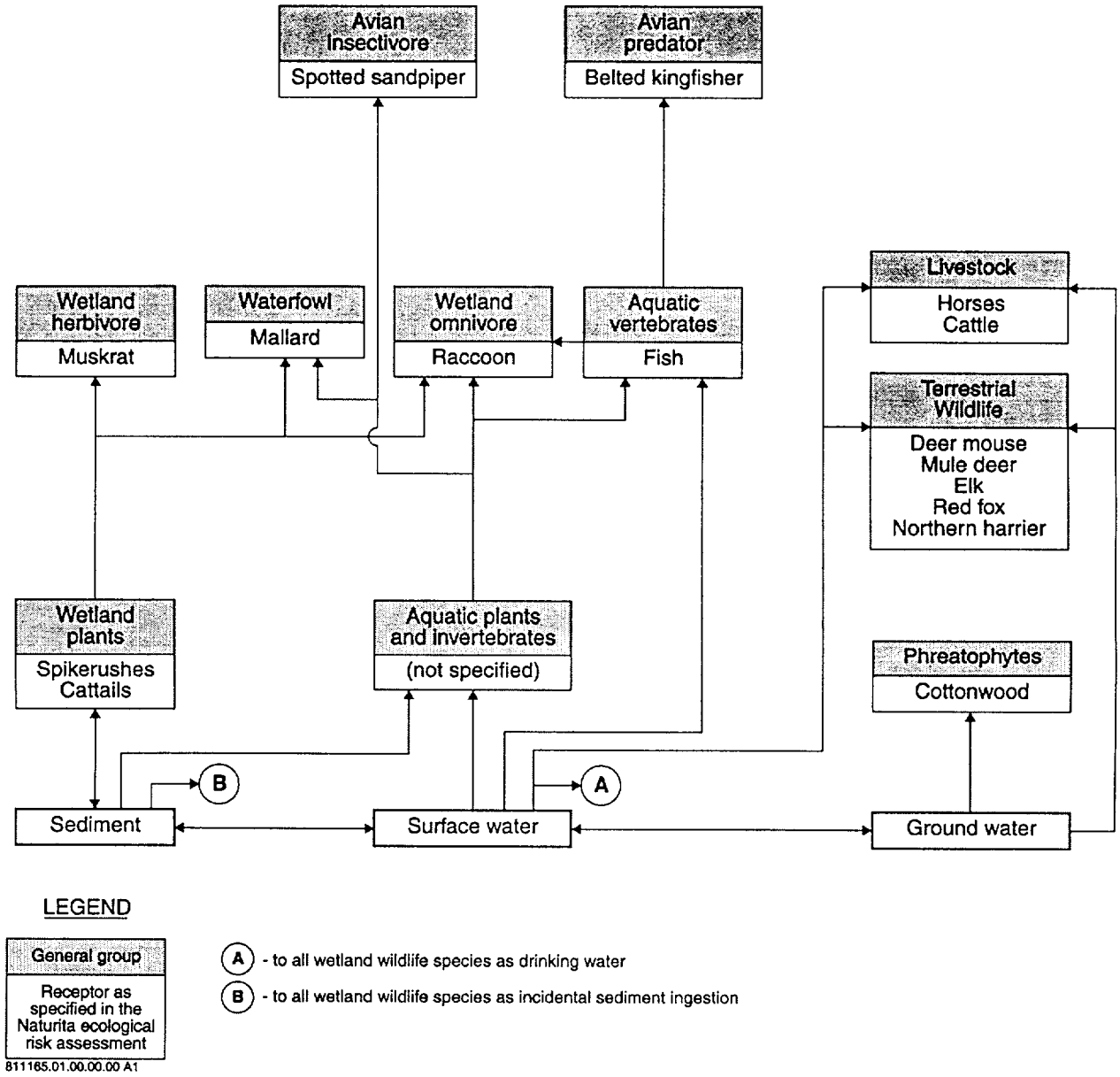

Figure 6-4. Generalized Food Web for Naturita Ecological Receptors

6.2.3.4 Management Goals and Endpoints

Table 6–11 presents the primary goals for protection of ecological resources at the Naturita site with respect to contaminants associated with ground water, and the assessment and measurement endpoints that will be used to evaluate potential risk to these resources in support of achieving these goals.

Table 6–11. Management Goals, Assessment Endpoints, and Measurement Endpoints for the Evaluation of Ecological Risks at the Naturita Site

Management Goals	Assessment Endpoints	Measurement Endpoints
Maintain the quality of aquatic habitats in the San Miguel River	Surface water quality of the San Miguel River	Concentrations of ecological COPCs in the surface water of the San Miguel River meet applicable water quality criteria or equivalent benchmarks for the protection of aquatic life.
	Sediment quality of the San Miguel River	Concentrations of ecological COPCs in the sediment of the San Miguel River meet applicable sediment quality benchmarks for the protection of benthic organisms.
Maintain habitat quality of the floodplain for the protection of wildlife diversity	Potential for adverse effects on survival and reproduction in wildlife from exposures to COPCs in various environmental media of the San Miguel River floodplain	Hazard quotients comparing estimated exposure to toxicity benchmarks for key indicator receptor species are less than unity.
	Surface water quality of the San Miguel River floodplain	Concentrations of ecological COPCs in the surface water of the San Miguel River floodplain meet applicable water quality criteria or equivalent benchmarks for the protection of aquatic life.
	Sediment quality of the San Miguel River floodplain	Concentrations of ecological COPCs in the sediment of the San Miguel River floodplain meet applicable sediment quality benchmarks for the protection of benthic organisms.
	Ground water quality of the San Miguel River floodplain	Concentrations of ecological COPCs in the ground water of the San Miguel River floodplain meet benchmarks for the protection of riparian plants.

6.2.4 Analysis

6.2.4.1 Exposure Assessment

Exposure Modeling and Assumptions

Only complete exposure pathways are quantitatively and qualitatively evaluated in an ecological risk assessment. In this assessment, the following potential exposure pathways were considered for evaluation:

- Surface water—ingestion and direct contact
- Soil—ingestion and direct contact
- Sediment—ingestion and direct contact
- Dietary—ingestion of forage or prey, as appropriate, by receptor

The contaminants associated with the Naturita site are inorganics and are principally associated with water (in dissolved form) and sediments (adsorbed to particles in these media). Estimations of potential exposures to key ecological receptors are based on the dominant pathways to these media for the specific receptor. Exposures in plants (both terrestrial plants and emergents) are dominated by direct contact with the soil or sediment in which they are rooted. Exposures to aquatic organisms (those that live within the water column) and benthic organisms (those that live within the sediment) are dominated by direct contact with the external media (water and sediment) in which they live, but in the cases of aquatic and benthic animals also include the ingestion of food associated with these media. In all these cases (plants and animals), potential exposure to an E-COPC is based on the concentration of that E-COPC in the media of principal contact (water, sediment, or soil).

Exposures in wildlife involve multiple potential pathways that may include ingestion of food, water, and sediment; direct contact and dermal absorption; and inhalation. In this assessment, the inhalation and dermal absorption pathways are assumed to be minor with respect to the combined exposures based on ingestion (food, water, and sediment ingestion). Most wildlife of the area have very little and infrequent direct dermal contact with potentially contaminated media due to their protective covers of feathers or fur and their habits and behaviors, such as preening and grooming, and (in the cases of most birds) living principally in trees and shrubs. Because the E-COPCs are not highly volatile, their occurrence in the air is principally related to dust particles. For the assessment of exposures to wildlife, however, dust inhalation was considered a minor exposure pathway relative to sediment ingestion. Although both dermal absorption and inhalation will contribute to the overall exposure in these receptors, these contributions are assumed to be included within the conservatisms incorporated in the estimation of exposures through the ingestion pathways.

In the estimation of ingestion-related exposure for the wildlife receptors, the E-COPCs are assumed to be 100 percent bioavailable and the receptors are assumed to be exposed only at the selected exposure point concentration, regardless of home range size or seasonal use patterns. The exposure through multiple ingestion pathways is modeled using the methods described in the EPA's *Wildlife Exposure Factors Handbook* (EPA 1993). The basic model for estimating the daily intake of an E-COPC per kilogram of body weight (i.e., the estimated daily dose of the E-COPC) through these ingestion pathways is

$$D_x = \frac{\sum_{k=1}^{m}(C_k \cdot F_k \cdot I_k) + C_s \cdot F_s \cdot I_s + C_w \cdot F_w \cdot I_w}{W}$$

where

D_x = the estimated daily dose (mg/kg-day) of E-COPC x,
C_k = the concentration of E-COPC x in the k_{th} food type (mg/kg dry weight),
F_k = the fraction of the k_{th} food type that comes from the site,
I_k = the ingestion rate of the k_{th} food type (kg dry weight/day),
m = the number of food items in the receptor's diet,
C_s = the concentration of E-COPC x in the sedimentl (mg/kg dry weight),
F_s = the fraction of ingested sediment that comes from the site,
I_s = the ingestion rate of sediment (kg dry weight/day),

C_w = the concentration of E-COPC x in water (mg/L),
F_w = the fraction of the ingested water that comes from the site,
I_w = the ingestion rate of water (L/day), and
W = the body weight of the receptor (kg wet weight).

F_k, F_s, and F_w are commonly assumed to be the area use factor (the area of the site divided by the home range of the receptor or 1, whichever is smaller) but may also be modified by a seasonal use factor (number of days at the site divided by 365 days per year) if the home range is used for only part of the year. For estimating risk in this assessment, both area use and seasonal use are conservatively assumed to be 100 percent; therefore, F_k, F_s, and F_w are assumed to be 1.

For the purposes of estimating exposure in wildlife, the E-COPC concentrations in plants and small mammals were principally based on the empirically derived uptake models (nonlinear or linear) as recommended by Oak Ridge National Laboratory (Bechtel Jacobs Company 1998a, Sample and others 1998). The nonlinear form of the uptake model is

$$C_{organism} = B_0 \cdot C_{soil}^{B_1}$$

where

$C_{organism}$ = the concentration of the E-COPC in the plant or small mammal (mg/kg dry weight),
C_{soil} = the soil concentration of the E-COPC (mg/kg dry weight), and
B_0 and B_1 = empirically derived model parameters for the E-COPC and organism.

In the linear form of this model, B_1 is assumed to be exactly 1 and B_0 becomes a soil-to-organism transfer factor, where

$$C_{organism} = B_0 \cdot C_{soil}$$

In cases where parameters were not available in the Oak Ridge National Laboratory uptake model documents, soil-to-plant transfer factors from other literature sources (e.g., Baes and others 1984) were used in this linear model. For small mammals, soil-to-mammal transfer factors based on modeling information available in Sample and others (1998) were primarily used. Sandia National Laboratories data (IT Corporation 1999) was used as a secondary source of soil-to-mammal transfer factors. In some cases, small mammal concentrations were modeled from plant concentrations using food-to-mammal transfer factors from Baes and others (1984), NCRP (1989), and IAEA (1994). In this case, the model is of the form

$$C_{mammal} = B_0 \cdot C_{plant}$$

where

C_{mammal} = the concentration of the E-COPC in an herbivorous mammal (mg/kg dry weight),
C_{plant} = the concentration of the E-COPC in the plant material eaten by the mammal (mg/kg dry weight), and
B_0 = the food-to-mammal transfer factor (converted as necessary to be on a dry-weight to dry-weight basis).

For aquatic prey species (invertebrates and fish), linear uptake models based on bioaccumulation factors (BAFs) were used to estimate concentrations of E-COPCs in tissues. These models are of the form

$$C_{organism} = BAF \cdot C_{water}$$

where:

$C_{organism}$ = the concentration of the E-COPC in the invertebrate or fish prey species(mg/kg dry weight),
C_{water} = the concentration of the E-COPC in the water (mg/L), and
BAF = the bioaccumulation factor for the E-COPC.

BAFs account for all exposure pathways (dermal absorption, uptake through respiratory organs, and ingestion). In contrast, bioconcentration factors (BCFs) account for uptake through pathways other than ingestion. However, for most inorganic constituents, uptake through ingestion of water is insignificant, and BAFs are considered to be equal to BCFs. Therefore, BCFs are used as BAFs in this assessment when the latter values are not available. Whenever possible, however, BAFs and BCFs specific to either invertebrates or fish were used to model the concentrations in these respective prey types. Table 6–12 presents the uptake model parameters (B_0, B_1, BAF, and/or BCF values) used in modeling the concentrations of E-COPCs through the food chain at the Naturita site.

Key Indicator Receptors

Receptors used to evaluate risks were selected on the basis of their potential presence in the habitats of the site, their potential for exposure to E-COPCs in the media at the site, and their potential for conservatively representing potential exposures to a range of other receptors at the site. Potential receptors for the habitats identified as having potentially complete ecological pathways are discussed in Section 6.2.3.3. The indicator receptors are representative of key links in the food webs associate with these habitats.
These indicator receptors are as follows:

- Terrestrial habitats—deep-rooted plant (phreatophyte), deer mouse (herbivorous), red fox, mule deer, elk, northern harrier, cattle, horses
- Wetland habitats—wetland plant, muskrat, raccoon, mallard, spotted sandpiper, belted kingfisher
- Aquatic habitats—aquatic and benthic organisms

Terrestrial exposure pathways are on the floodplain. Deep-rooted plants (e.g., cottonwood) are considered to be the only potential receptors for E-COPCs in the ground water underlying the floodplain. For the terrestrial wildlife and livestock on the floodplain, surface water is the primary medium for E-COPC exposures, and therefore, risks to all terrestrial receptors are evaluated on the basis of potential consumption of drinking water from the various sources, including ground water being pumped to the surface. The terrestrial wildlife receptors used represent both mammals and birds; the mammals are represented by a range of body sizes, from a deer mouse to an elk. In addition, two classes of livestock (horses and cattle) are also used to evaluate potential risk from drinking water on the floodplain.

Table 6–12. Uptake Model Parameters and Bioaccumulation Factors for Ecological Contaminants of Potential Concern

Contaminant of Potential Concern	Uptake Model Parameters				Bioaccumulation Factors	
	Plants		Small mammals		Invertebrates	Fish
	B_0	B_1	B_0	B_1		
Arsenic	0.136[a]	0.564[a]	0.00351[b]	1.14[b]	73.0[n]	17.0[d]
Barium	0.15[e]	1.0[f]	0.0566[b]	1.0[f]	4.0[c]	4.0[g]
Boron	4.0[e]	1.0[f]	0.0008[e,h]	1.0[f]	1.0[i]	1.0[i]
Iron	0.004[e]	1.0[f]	0.621[b]	0.621[b]	200[c]	200[g]
Manganese	3.0[j]	1.0[f]	0.0205[b]	1.0[f]	65[k]	17.8[k]
Molybdenum	0.8[g]	1.0[f]	0.001[g,h]	1.0[f]	10[c]	10[g]
Nitrate	1.0[i]	1.0[i]	1.0[i]	1.0[i]	1.0[i]	1.0[i]
Selenium	0.508[a]	1.10[a]	0.660[b]	0.376[b]	269[l]	129[m]
Strontium	2.5[e]	1.0[f]	0.008[e,h]	1.0[f]	9.5[c]	9.5[f]
Sulfate	1.0[i]	1.0[i]	1.0[i]	1.0[i]	1.0[i]	1.0[i]
Uranium	0.023[g]	1.0[f]	0.033[n]	1.0[f]	27.1[c]	27.1[k]
Vanadium	0.0055[e]	1.0[f]	0.0123[b]	1.0[f]	3,000[o]	3,000[p]
Zinc	4.831[a]	0.555[a]	87.5[b]	0.0738[b]	1,130[q]	161[r]

[a]From Bechtel Jacobs Company (1998 a).
[b]From Sample and others (1998).
[c]Invertebrate bioaccumulation factor based on fish bioaccumulation factor.
[d]From Sample and others (1996).
[e]From Baes and others (1984).
[f]The uptake model is linear; therefore, B_1 = 1.0.
[g]From IAEA (1994).
[h]Based on uptake from food.
[i]Default value.
[j]From NCRP (1989).
[k]From EPA (2000).
[l]Geometric mean of selenite bioaccumulation factors for water fleas based on 14-day exposure from AQUIRE (2000).
[m]From NMED (2000).
[n]From SNL (1999).
[o]From Neumann (1985).
[p]Fish bioaccumulation factor based on invertebrate bioaccumulation factor.
[q]From Eisler (1993).
[r]From EPA (1995)

For the wetland habitats, emergent plants, such as spikerush, are considered to be the primary producers and the muskrat and mallard are considered to be representative of herbivores that may consume such plants (both will also eat some animal prey). The raccoon represents an omnivore in this habitat. The spotted sandpiper represents an insectivorous bird, and the belted kingfisher represents an piscivorous bird. All animal prey of these wildlife receptors (the muskrat is the only one to be assumed to be purely herbivorous) are assumed to be aquatic invertebrates or fish.

Receptors in the aquatic habitats are not specified. Risk to these receptors is based on comparisons of the E-COPC concentrations in surface water and sediment to broad-based benchmark values, such as ambient water quality criteria (AWQC), that are protective of a wide range of aquatic and benthic organisms. For the San Miguel River, fish are assumed to be included as potential aquatic receptors within this broad categorization. All wildlife receptors are

modeled as potential receptors of E-COPCs in surface water through the consumption of that water at all sites where surface water is present as a medium of concern.

The species-specific parameters used to model exposures to these key indicator receptors (wildlife only) are presented in Table 6–13.

6.2.4.2 Effects Characterization

The potential for adverse effects to ecological receptors resulting from exposures to E-COPCs at the Naturita site was evaluated through the comparison of the potential exposure in the receptor to a toxicity-based benchmark of exposure representing the threshold of potential adverse effects.

For aquatic and benthic receptors and plants, the exposure to an E-COPC is characterized by the concentration of that constituent in the medium (water, sediment, or soil) with which the receptor is principally in direct contact. Therefore, the benchmarks by which the potential for adverse effects is evaluated are also based on media concentrations. For surface water, either AWQC (EPA 1999b, Buchman 1999) or Colorado Department of Public Health and Environment (CDPHE) Water Quality Standards (whichever was lower) were used as the principal benchmarks for evaluating potential risk to aquatic life. When neither was available for an E-COPC, Tier II secondary values (Suter and Tsao 1996) or other values (e.g., Haines and others 1994) were used. Sediment benchmarks were principally based on the lowest threshold effect levels (TELs) as presented in Buchman (1999), and supplemented from other sources (e.g., EPA 1996, Jones and others 1997, and Haines and others 1994). Table 6–14 presents these water quality benchmarks.

Table 6–13. Exposure Parameters for Livestock and Wildlife Receptors

Receptor	Body Weight (kg)[a]	Food Ingestion Rate (kg [dry wt.]/day)[b]	Soil/Sediment Ingestion Rate (percent of food ingestion)[c]	Water Ingestion Rate (L/day)[d]	Dietary Composition (percent)[e]
Deer mouse (*Peromyscus maniculatus*)	0.0239[f]	NA	NA	0.00344	NA
Red fox (*Vulpes vulpes*)	4.54	NA	NA	0.386	NA
Mule deer (*Odocoileus hemionus*)	65[f]	NA	NA	4.24	NA
Elk (*Cervus canadensis*)	210[f]	NA	NA	12.2	NA
Northern harrier (*Circus cyaneus*)	0.180[g]	NA	NA	0.0187	NA
Muskrat (*Ondatra zibethicus*)	1.135	0.0772[h]	9.4[i]	0.111	Plant: 100
Raccoon (*Procyon lotor*)	5.74	0.289	9.4	0.477	Plant: 40 Invertebrate: 50 Fish: 10
Mallard (*Anas platyrhynchos*)	1.134	0.0592	3.3	0.0642	Plant: 90 Invertebrate: 10
Spotted sandpiper (*Actitis macularia*)	0.0425	0.00503	18[j]	0.0711	Invertebrate: 100
Belted kingfisher (*Ceryle alcyon*)	0.147	0.0128	2.0[k]	0.0163	Invertebrate: 20 Fish: 80

[a]From EPA (1993), except where noted.
[b]Based on allometric equations from Nagy (1987), as presented in EPA (1993), except where noted.
[c]From Beyer and others (1994). Data are species-specific except where noted.
[d]Based on allometric equations from Calder and Braun (1983), as presented in EPA (1993), except where noted.
[e]Diets are generalized to emphasize specific trophic levels. Dietary compositions of the raccoon, mallard, and belted kingfisher are based on species-specific information presented in EPA (1993) and Martin and others (1951) and have been rounded to incremerts of 10 percent.
[f]From Silva and Downing (1995).
[g]From Dunning (1993).
[h]Based on species-specific food intake rate from EPA (1993), with assumed water content of food of 80 percent.
[i]Based on soil/sediment ingestion for raccoon from Beyer and others (1994).
[j]Based on the mean soil/sediment ingestion rate of four species of sandpipers as reported by Beyer and others (1994).
[k]No data available. Assumed value of 2 percent is based on the detection limit of the method used by Beyer and others (1994).

Table 6–14. Surface Water and Sediment Quality Benchmarks for Ecological Contaminants of Potential Concern for the Protection of Freshwater Aquatic Life

Contaminant of Potential Concern	Water Quality Benchmarks (mg/L)				Sediment Quality Benchmarks (mg/kg)	
	AWQC[a]	CDPHE SWQS[b]	Tier II[c]	Other	TEL[d]	Other
Arsenic	0.15	0.10	–	–	5.9	–
Barium	–	–	0.0039	50[e]	–	0.7[f]
Boron	–	0.75	0.0016	1.0[g]	–	–
Iron	1.0	1.0	–	–	188,400[h]	–
Manganese	–	1.0	0.08	–	630[h]	–
Molybdenum	–	–	0.24	–	–	4.0[i]
Nitrate	–	10[j]	–	177[k]	–	2,440[l]
Selenium	0.005	0.0046	–	–	–	5.0[m]
Strontium	–	–	1.5	–	–	49[f]
Sulfate	–	250[j]	–	100[n]	–	–
Uranium	–	1.5	0.0026	0.30[o]	–	–
Vanadium	–	–	0.019	–	–	50[f]
Zinc	0.12	0.118	–	–	123.1	–

[a]EPA ambient water quality criteria (EPA 1999b, Buchman 1999). Hardness of 100 mg/L $CaCO_3$ was used for all hardness-dependent values.
[b]Colorado Department of Public Health and Environment Surface Water Quality Standard for aquatic life.
[c]Tier II secondary chronic value from Suter and Tsao (1996).
[d]Threshold effect level from Buchman (1999).
[e]Chronic criterion from Quebec (Haines and others 1994), presented in contrast to the Tier II secondary chronic value.
[f]Background value from Buchman (1999).
[g]From Eisler (1994).
[h]Lowest threshold effect levels from Buchman (1999).
[i]Sediment quality guideline for the protection of agricultural uses (from Haines and others 1994).
[j]Standard for the San Miguel River above Naturita Creek (mg/L as N).
[k]Guideline from British Columbia (Haines and others 1994) converted from µg N/L to mg NO_3/L.
[l]Lowest effect level (Ontario) for total kjeldahl nitrogen (from Haines and others 1994) and converted from mg N/L to mg NO_3/L.
[m]Sediment quality criterion from British Columbia (Haines and others 1994).
[n]Maximum concentration value (tentative) from British Columbia for the protection of aquatic life (Haines and others 1994).
[o]Maximum concentration value (British Columbia) for total uranium (from Haines and others 1994), presented in contrast to the Tier II secondary chronic value.
– = No value available.

For plants, toxicity benchmarks are based primarily on the information provided in Efroymson and others (1997). These benchmarks are based on lowest-observed-adverse-effect levels (LOAELs) using 20 percent reduction in growth as the endpoint. Both the soil-based and solution-based benchmarks were used. Soil-based benchmarks were used to evaluate risk to wetland plants exposed to sediments, and solution-based benchmarks were used to evaluate potential risk to phreatophytes that may be in contact with ground water. Although based on LOAELs, these benchmarks are considered conservative. The endpoint is sublethal, and reductions in plant growth may have no significant effect on the reproductive potential or the continued existence of a plant population. Further, these benchmarks are primarily based on studies in which the chemical of interest is added freshly to a soil (often as a soluble salt) and is

typically more bioavailable than the COPCs in field situations where they have had time to bind more strongly with soil particles. Table 6–15 presents the plant toxicity benchmarks.

Table 6–15. Plant Toxicity Benchmarks for Ecological Contaminants of Potential Concern

Contaminant of Potential Concern	Plant Toxicity Benchmark[a]	
	Soil (mg/kg)	Solution (mg/L)
Arsenic	10	0.001
Barium	500	–
Boron	0.5	1.0
Iron	–	10
Manganese	500	4.0
Molybdenum	2.0	0.5
Nitrate	–	–
Selenium	1.0	0.7
Strontium	–	–
Sulfate	–	–
Uranium	5.0	40
Vanadium	2.0	0.2
Zinc	50	0.4

[a]From Efroymson and others (1997).
– = No benchmark available.

For the wildlife receptors, no-observed-adverse-effect levels (NOAELs) for chronic oral exposure are used as benchmarks for toxic effects. The endpoints of particular interest in this assessment are those associated with reproductive health, development, and mortality. Therefore, NOAELs are defined as the maximum dosage tested that produced no effect that would be considered adverse to the receptor's survival, growth, or reproductive capacity. Because the NOAELs for the wildlife receptor species are based on NOAELs from test species, the latter are scaled to NOAELs specific to the wildlife receptor species using a power function of the ratio of body weights, as described by Sample and others (1996) and Sample and Arenal (1999). This scaling is based on the equation

$$NOAEL_W = NOAEL_T \left(\frac{BW_T}{BW_W}\right)^s$$

where

$NOAEL_W$ = the no-observed-adverse-effect level for the wildlife receptor species (mg/kg-day),
$NOAEL_T$ = the no-observed-adverse-effect level for the test species (mg/kg-day),
BW_T = the body weight of the test species (kg),
BW_W = the body weight of the wildlife receptor species (kg), and
s = the body weight scaling factor; (s = 0.06 for mammals –0.2 for birds (Sample and Arenal 1999).

Toxicity studies were considered to be chronic if they were conducted over a period of 26 weeks (one-half year) or more. This period represents the period of seasonal use by migratory and hibernating species and is sufficient time for small animals to complete their reproductive cycles.

Studies of lesser duration (i.e., 1 to 25 weeks) are considered subchronic, unless they specifically included reproductive effects as endpoints (Sample and others 1996). When only subchronic oral $NOAEL_T$ values were available, these are converted to chronic $NOAEL_T$ values by applying an uncertainty factor of 0.1 (Sample and others 1996).

When only a chronic LOAEL value was available for test data, an uncertainty factor of 0.1 was used to convert it to the chronic $NOAEL_T$. If only a subchronic LOAEL was available, then an uncertainty factor of 0.01 was used to estimate the chronic $NOAEL_T$. This uncertainty factor is the product of two uncertainty factors of 0.1, one to convert the subchronic value to a chronic value and the other to convert the LOAEL to an NOAEL.

When possible, NOAELs for the wildlife receptor species are derived from test species that are taxonomically close to the target receptor. NOAELs were not determined if toxicity data could not be found for test species within the same class. Therefore, NOAELs for mammalian receptors are derived only from mammalian test species data and NOAELs for avian receptors are derived only from avian test species data. These data are presented in Table 6–16 and Table 6–17

6.2.5 Risk Characterization

The potential for risk to ecological receptors is determined through HQs, which are specific to a particular receptor for exposure to a particular E-COPC. An HQ is defined by

$$HQ = \frac{Exposure}{Benchmark}$$

For aquatic and benthic organisms and plants, exposures are equivalent to media concentrations (surface water or sediment) with which the organism is in contact. For wildlife and livestock, exposures are modeled from multiple pathways by the methods described in Section 6.2.4.1. The methods for determining toxicity benchmark values for these receptors are discussed in Section 6.2.4.2.

The value of the HQ is greater than 1.0 if the magnitude of the exposure is greater than the corresponding benchmark, and conversely, the HQ is less than or equal to 1.0 if the exposure is less than or equal to the benchmark. An HQ value less than or equal to 1.0 is interpreted as evidence of no potential risk to that receptor for that E-COPC. If the HQs for an E-COPC are less than unity for all receptors, that E-COPC is eliminated from further consideration as a potential ecological risk driver. However, because exposure for the screening of E-COPCs is conservatively estimated, an HQ value greater than unity is not interpreted as evidence of risk, but only as evidence that the potential for risk cannot be ruled out.

For the purposes of this evaluation, potential exposures were conservatively based on the maximum measured E-COPC in each medium of ecological concern (surface water, sediment, and soil), as appropriate to each area. In addition, the UCL_{95} concentrations were used to calculate HQs that better reflect average (yet still conservatively estimated) risks to receptors in these areas. Measured concentrations of E-COPCs in wetland plants as presented in the BLRA (DOE 1995) were used in the calculation of exposures to herbivores when such data were available. Sections 6.2.5.1 through 6.2.5.5 are summaries of the risk assessment results for specific media and associated receptor groups.

Table 6–16. Mammal Toxicity Benchmarks for Ecological Contaminants of Potential Concern

Contaminant of Potential Concern	Mammalian Test Data[a]			Mammalian Receptor NOAELs (mg/kg-day)							
	Test Species	Body weight (kg)	NOAEL (mg/kg-day)	Deer mouse	Red fox	Mule deer	Elk	Muskrat	Raccoon	Horse	Cow
Arsenic	Rabbit	4.40	0.396	0.541	0.395	0.337	0.314	0.430	0.390	0.298	0.298
Barium	Rat	0.435	5.1	6.07	4.43	3.78	3.52	4.81	4.37	3.34	3.34
Boron	Rat	0.35	28.0	32.9	24.0	20.5	19.1	26.1	23.7	18.1	18.1
Iron	–	–	–	–	–	–	–	–	–	–	–
Manganese	Rat	0.35	88.0	103	75.5	64.3	60.0	82.0	74.4	56.9	56.9
Molybdenum	Mouse	0.03	0.26	0.264	0.192	0.164	0.153	0.209	0.190	0.145	0.145
Nitrate	Guinea pig	0.86	507	629	459	391	365	499	452	346	346
Selenium	Rat	0.35	0.20	0.235	0.171	0.146	0.136	0.186	0.169	0.129	0.129
Strontium	Rat	0.35	263	309	226	192	179	245	222	170	170
Sulfate	–	–	–	–	–	–	–	–	–	–	–
Uranium	Mouse	0.028	3.07	3.10	2.26	1.93	1.80	2.46	2.23	1.71	1.71
Vanadium	Rat	0.26	0.21	0.242	0.177	0.151	0.141	0.192	0.174	0.133	0.133
Zinc	Rat	0.35	160	188	137	117	109	149	135	103	103

[a]From Sample and others (1996).

Table 6–17. Avian Toxicity Benchmarks for Ecological Contaminants of Potential Concern

Contaminant of Potential Concern	Avian Test Data[a]			Avian Receptor NOAELs (mg/kg-day)			
	Test Species	Body weight (kg)	NOAEL (mg/kg-day)	Northern harrier	Mallard	Spotted sandpiper	Belted kingfisher
Arsenic	Mallard	1.0	5.14	3.65	5.27	2.73	3.50
Barium	Chicken	0.121	20.8	22.5	32.5	16.9	21.6
Boron	Mallard	1.0	28.8	20.4	29.5	15.3	19.6
Iron	–	–	–	–	–	–	–
Manganese	Japanese quail	0.072	977	1,170	1,700	879	1,130
Molybdenum	Chicken	1.5	3.53	2.31	3.34	1.73	2.22
Nitrate	–	–	–	–	–	–	–
Selenium	Mallard	1.0	0.40	0.284	0.410	0.213	0.273
Strontium	–	–	–	–	–	–	–
Sulfate	–	–	–	–	–	–	–
Uranium	Black duck	1.25	16.0	10.9	15.7	8.14	10.4
Vanadium	Mallard	1.17	11.4	7.84	11.3	5.87	7.53
Zinc	Chicken	1.935	14.5	9.02	13.0	6.76	8.66

[a]From Sample and others (1996).
– = no benchmark value available

6.2.5.1 Risk to Aquatic Community Receptors

Table–6–18 presents the comparison of water concentrations from the San Miguel River, from the seep and pond at location 0538, and from the alluvial aquifer to water quality benchmarks for the protection of aquatic life. The river and the pond data represent existing surface water features at the Naturita site that contain aquatic communities. The comparisons with the ground water data are presented to evaluate the potential for ecological risk if ground water were to be used to feed a surface pond. In all three cases, comparisons are made with both the maximum measured concentration and (when data allowed) the UCL_{95} or an estimated mean value. The UCL_{95} or mean value was not estimated when 50 percent or more of the data points were nondetections. For both the San Miguel River and ground water, sufficient data points were available to calculate the UCL_{95}, which was used as a conservative estimate of the sample mean. In the case of the pond location, only two sample points were available. Therefore, the midpoint between these two values (providing both were detections) was used as the estimate of the sample mean.

Maximum concentrations measured in surface water samples from the San Miguel River exceeded water quality benchmarks for barium, strontium, and sulfate. Although the HQ for barium was 23.1, those for strontium and sulfate were both less than 2. In all three cases, the UCL_{95} values were within the range of upstream (background) concentrations. Although the HQs for strontium and sulfate decreased to values less than 1 based on the UCL_{95} concentrations, the HQ for barium only decreased to 13.3. This indicates that the Tier II secondary chronic value (0.0039 mg/L) used as the benchmark for this element probably significantly overestimates the potential risk from barium exposure. Also, the maximum barium concentration (0.09 mg/L) is only slightly above the maximum upstream measured value of 0.08 mg/L. Overall, the risk to aquatic communities in the San Miguel River near the site is insignificant.

Table–6–18. Hazard Quotients for Aquatic Communities Based Upon Comparison of Water Concentrations to Water Quality Benchmarks for the Protection of Aquatic Life

Contaminant of Potential Concern	Water Quality Benchmark (mg/L)	San Miguel River Surface Water				Seep/Pond Surface Water				Ground water[a]			
		Maximum		UCL_{95}		Maximum		Mean		Maximum		UCL_{95}	
		Conc. (mg/L)	Hazard Quotient	Conc. (mg/L)	Hazard Quotient	Conc. (mg/L)	Hazard Quotient	Conc. (mg/L)	Hazard Quotient	Conc. (mg/L)	Hazard Quotient	Conc. (mg/L)	Hazard Quotient
Arsenic	0.10[b]	0.0017	0.0170	0.0009	0.00900	0.001	0.0100	0.001	0.0100	0.064	0.640	0.017	0.170
Barium	0.0039[c]	0.09	**23.1**	0.052[d]	**13.3**	Not a COPC for this area and medium				0.1	**25.6**	0.030[d]	**7.69**
Boron	0.75[b]	0.14	0.187	0.068[d]	0.0907	0.17	0.227	0.097	0.129	0.45	0.600	0.141	0.188
Iron	1.0[b]	0.48	0.480	NC	NA	0.22	0.220	NC	NA	2.03	**2.03**	0.51	0.510
Manganese	1.0[b]	0.78	0.780	NC	NA	1.76	**1.76**	1.01	**1.01**	2.06	**2.06**	0.99	0.990
Molybdenum	0.24[c]	Not a COPC for this area and medium				Not a COPC for this area and medium				0.16	0.667	0.046	0.192
Nitrate	10[b]	0.11	0.0110	NC	NA	Not a COPC for this area and medium				3.56	0.356	0.31	0.0310
Selenium	0.0046[b]	0.0018	0.391	0.0009[d]	0.196	0.002	0.435	NC	NA	0.014	**3.04**	0.002	0.435
Strontium	1.5[c]	1.74	**1.16**	1.13[d]	0.753	4.37	**2.91**	2.23	**1.49**	4.65	**3.10**	2.56	**1.71**
Sulfate	250[b]	459	**1.84**	237[d]	0.948	1,710	**6.84**	793	**3.17**	1,700	**6.80**	774	**3.10**
Uranium	1.5[b]	0.44	0.293	0.081	0.0540	1.06	0.707	0.51	0.340	2.49	**1.66**	0.91	0.607
Vanadium	0.019[c]	Not a COPC for this area and medium				Not a COPC for this area and medium				5.73	**302**	1.49	**78.4**
Zinc	0.118[b]	0.1	0.847	NC	NA	0.08	0.678	NC	NA	0.09	0.763	NC	NA

[a]Ground water comparisons are made to evaluate potential risk associated with the use of ground water in a surface pond.
[b]Colorado Department of Public Health and Environment surface water quality Standard for aquatic life.
[c]Tier II secondary chronic value from Suter and Tsao (1996).
[d]Concentration is within background range.

ND = Not detected.
NC = Not calculated (frequency of detection less than 50%).
NA = Not applicable.
COPC = Contaminant of potential concern.
Hazard quotient values in **bold** are greater than 1.

Surface water from the seep and pond at location 0538 had maximum and mean concentrations exceeding water quality benchmarks for manganese, strontium, and sulfate. For manganese, the maximum HQ was less than 2 and the HQ for the mean was nearly equal to 1, indicating that the potential for risk from exposure to this element is very small. Strontium and sulfate also had relatively low HQs for the mean concentrations at this location (1.49 and 3.17, respectively).

Maximum concentrations for ground water exceeded the water quality benchmarks for barium, iron, manganese, selenium, strontium, sulfate, uranium, vanadium, and zinc. All of these HQs except those for barium and vanadium were less than 7. Based on the UCL_{95} concentrations, only barium, strontium, sulfate, and vanadium had HQs greater than unity. As described for the San Miguel River, the HQs for barium are probably overestimated by the Tier II secondary chronic value used as the benchmark. The maximum concentration for barium (0.1 mg/L) is only slightly above the concentration range measured in the San Miguel River upstream of the site, and the UCL_{95} concentration was within this range. The concentrations (and consequent HQs) for strontium and sulfate in the ground water are similar to those in the seep and pond at location 0538. Vanadium concentration appears to be significantly elevated in the ground water and may be the limiting factor in the use of ground water to feed surface ponds.

6.2.5.2 Risk to Benthic Community Receptors

Table–6–19 presents a comparison of the combined sediment concentration data from the San Miguel River and seep/pond at location 0538 to the available sediment quality benchmarks. Comparisons are made with both the maximum measured concentrations and the UCL_{95}s. The maximum sediment concentrations measured at the Naturita site exceeded corresponding sediment quality benchmarks for manganese and zinc. In both cases, as indicated by the low HQ values, the exceedances were relatively low. The maximum manganese concentration in sediment was from a sample collected at the seep/pond location, where manganese concentration in water also slightly exceeded the corresponding benchmark value. However, neither of the HQs for these two elements exceeded unity when based on the UCL_{95} sediment concentrations. Overall, risk to benthic communities associated with the site is insignificant.

6.2.5.3 Risk to Plant Receptors

Table–6–20 presents a comparison of the sediment concentration data and the ground water data to the available soil-based and solution-based plant toxicity benchmarks, respectively. Comparisons are made with both the maximum measured concentration and the UCL_{95}s. The sediment-based comparison evaluates potential risk to wetland plants that are in direct contact with the near-surface sediments along the shorelines of the river and seep/pond. The ground-water-based comparison evaluates potential risk to phreatophytes on the floodplain of the river that are direct contact with alluvial ground water.

The maximum sediment concentrations measured at the Naturita site exceeded corresponding plant toxicity benchmarks for boron, manganese, molybdenum, uranium, vanadium, and zinc. However, based on the UCL_{95} concentrations, only boron, vanadium, and zinc exceeded plant toxicity benchmarks. In all three cases, the plant benchmark was also less than the upstream (background) sediment concentration. Boron, had a maximum measured concentration of 5.83 mg/kg and a UCL_{95} of 4.98; the corresponding HQs were 11.7 and 9.96, respectively. The background concentration was 4.45 mg/kg, which would produce an HQ of 8.90. Therefore, the magnitude of potential risk to plants from boron in site sediments is probably exaggerated by

Table–6–19. Hazard Quotients for Benthic Communities Based on Comparison of Sediment Concentrations to Sediment Quality Benchmarks

Contaminant of Potential Concern	Sediment Quality Benchmark (mg/kg)	Sediment[a]			
		Maximum		UCL_{95}	
		Concentration (mg/kg)	Hazard Quotient	Concentration (mg/kg)	Hazard Quotient
Arsenic	5.9	2.83	0.480	2.17	0.368
Barium	–	97	–	87	–
Boron	–	5.83	–	4.98	–
Iron	188,400	3,519	0.0187	2,948	0.0156
Manganese	630	721	**1.14**	459	0.729
Molybdenum	4.0	2.19	0.548	1.03	0.258
Nitrate	2,440	Not a COPC for this medium			
Selenium	5.0	0.27	0.0540	0.24	0.0480
Strontium	–	195	–	174	–
Sulfate	–	2,464	–	1,785	–
Uranium	–	12.5	–	4.29	–
Vanadium	–	9.54	–	5.90[b]	–
Zinc	123.1	171	**1.39**	121	0.983

[a]Sediment data are combined for the San Miguel River and the seep/pond location.
[b]Concentration is within background range.

– = No benchmark value available.
COPC = Contaminant of potential concern.
Hazard quotient values in **bold** are greater than 1.

the plant benchmark value. Similarly, the UCL_{95} of zinc (121 mg/kg) is only slightly above the background concentration value of 117 mg/kg, and that for vanadium is less than its corresponding background value of 6.56 mg/kg. Overall, the risk to wetland plants rooted in the near-surface sediments at the Naturita site is insignificant.

The maximum and UCL_{95} ground water concentrations measured at the Naturita site exceeded corresponding solution-based plant toxicity benchmarks for arsenic and vanadium. In both cases, the background concentration ranges for ground water were less than the corresponding plant benchmark. Therefore, contact with contaminated ground water at this site may pose a risk to phreatophytic plants growing on the floodplain.

6.2.5.4 Risk to Wetland Wildlife Receptors

Table–6–21 and Table–6–22 present the hazard quotients for the five wetland wildlife receptors based on exposures to E-COPCs in various media (surface water, sediment, and food) associated with the San Miguel River and seep/pond area, respectively. As available, exposures were estimated on the basis of maximum measured concentrations in each medium and the UCL_{95}s for each medium. Surface water and vegetation data were specific to the two areas. The sediment data used in the exposure estimations were combined as a single unit. Because only one vegetation sample was collected from the pond area, the same data were used in both the maximum and UCL_{95} exposure estimates for this area. Plant concentrations estimated from the sediment concentrations were used when no site-specific plant data were available.

Table–6–20. Hazard Quotients for Plants Based on Comparison of Sediment and Ground Water Concentrations to Plant Toxicity Benchmarks

Contaminant of Potential Concern	Soil-based Plant Benchmark (mg/kg)	Sediment				Solution-based Plant Benchmark (mg/L)	Ground water[a]			
		Maximum		UCL_{95}			Maximum		UCL_{95}	
		Conc. (mg/kg)	Hazard Quotient	Conc. (mg/kg)	Hazard Quotient		Conc. (mg/L)	Hazard Quotient	Conc. (mg/L)	Hazard Quotient
Arsenic	10	2.83	0.283	2.17	0.217	0.001	0.064	**64.0**	0.017	**17.0**
Barium	500	97	0.194	87	0.174	8.33	0.1	0.0120	0.030[b]	0.00360
Boron	0.5	5.83	**11.7**	4.98	**9.96**	1.0	0.45	0.450	0.141	0.141
Iron	–	3,519	–	2,948	–	10	2.03	0.203	0.51	0.0510
Manganese	500	721	**1.44**	459	0.918	4.0	2.06	0.515	0.99	0.248
Molybdenum	2.0	2.19	**1.10**	1.03	0.515	0.5	0.16	0.320	0.046	0.0920
Nitrate	–	Not a COPC for this area and medium				–	3.56	–	0.31	–
Selenium	1.0	0.27	0.270	0.24	0.240	0.7	0.014	0.0200	0.002	0.00286
Strontium	–	195	–	174	–	–	4.65	–	2.56	–
Sulfate	–	2,464	–	1,785	–	–	1,700	–	774	–
Uranium	5.0	12.5	**2.50**	4.29	0.858	40	2.49	0.0623	0.91	0.0228
Vanadium	2.0	9.54	**4.77**	5.90[b]	**2.95**	0.2	5.73	**28.7**	1.49	**7.45**
Zinc	50	171	**3.42**	121	**2.42**	0.4	0.09	0.225	NC	NA

[a]Ground water comparisons are made to evaluate potential risk to deep-rooted plants (phreatophytes) in direct contact with ground water.
[b]Concentration is within background range.

– = No plant toxicity benchmark available.
NC = Not calculated (frequency of detection less than 50%).
NA = Not applicable.
COPC = Contaminant of potential concern.
Hazard quotient values in **bold** are greater than 1.

Table–6–21. Hazard Quotients for Wetland Wildlife Along the San Miguel River[a]

Contaminant of Potential Concern	Muskrat		Raccoon		Mallard		Spotted Sandpiper		Belted Kingfisher	
	Maximum	UCL_{95}	Maximum	UCL_{95}	Maximum	UCL_{95}	Maximum	UCL_{95}	Maximum	UCL_{95}
Arsenic	**1.61**	**1.17**	0.556	0.404	0.0894	0.0650	0.0275	0.0198	0.00437	0.00265
Barium	0.336	0.301	0.178	0.158	0.0264	0.0236	0.126	0.112	0.0132	0.0101
Boron	0.0627	0.0534	0.0218	0.0183	0.0378	0.0321	0.0107	0.00820	0.00342	0.00185
Iron	–	–	–	–	–	–	–	–	–	–
Manganese	0.526	0.406	0.221	0.150	0.0166	0.0129	0.0244	0.0111	0.00540	0.000708
Molybdenum	0.717	0.397	0.267	0.145	0.0293	0.0164	0.0270	0.0127	0.00172	0.000807
Nitrate	0.0000216	NC	0.0000312	NC	–	–	–	–	–	–
Selenium	0.339	0.200	0.215	0.120	0.111	0.0644	0.298	0.159	0.270	0.136
Strontium	0.0543	0.0439	0.0240	0.0190	–	–	–	–	–	–
Sulfate	–	–	–	–	–	–	–	–	–	–
Uranium	0.271	0.194	0.357	0.115	0.0309	0.0210	0.215	0.0448	0.345	0.0638
Vanadium	**11.6**	**10.4**	**3.95**	**3.48**	0.134	0.120	0.0346	0.0214	0.00220	0.00136
Zinc	0.0456	0.0367	0.0419	0.0145	0.371	0.266	**2.52**	0.381	0.779	0.0243

[a]Exposure media include surface water specific to the San Miguel River, sediment from all potentially contaminated areas, and vegetation. Vegetation concentrations were based on site-specific data when available or were estimated from sediment concentrations.

– = No toxicity benchmark available.
NC = UCL not calculated (frequency of detection less than 50%).
Hazard quotient values in **bold** are greater than 1.

Table–6–22. Hazard Quotients for Wetland Wildlife at the Seep/Pond Area[a]

Contaminant of Potential Concern	Muskrat		Raccoon		Mallard		Spotted Sandpiper		Belted Kingfisher	
	Maximum	UCL_{95}	Maximum	UCL_{95}	Maximum	UCL_{95}	Maximum	UCL_{95}	Maximum	UCL_{95}
Arsenic	**7.80**	**7.79**	**2.57**	**2.56**	0.438	0.438	0.0253	0.0201	0.00315	0.00282
Barium	0.335	0.300	0.175	0.154	0.0263	0.0235	0.124	0.110	0.0102	0.00699
Boron	0.0628	0.0535	0.0219	0.0185	0.0378	0.0322	0.0113	0.00874	0.00404	0.00245
Iron	–	–	–	–	–	–	–	–	–	–
Manganese	**1.92**	**1.90**	0.704	0.666	0.0635	0.0631	0.0332	0.0201	0.0108	0.00625
Molybdenum	0.899	0.845	0.433	0.291	0.0376	0.0357	0.0582	0.0127	0.0570	0.000807
Nitrate	0.0000039	NC	0.0000057	NC	–	–	–	–	–	–
Selenium	0.339	0.337	0.226	0.114	0.111	0.104	0.328	0.0240	0.300	0.00153
Strontium	0.0401	0.0387	0.0251	0.0197	–	–	–	–	–	–
Sulfate	–	–	–	–	–	–	–	–	–	–
Uranium	0.683	0.640	0.848	0.507	0.0807	0.0728	0.472	0.223	0.827	0.398
Vanadium	**19.8**	**19.7**	**37.8**	**6.5**	0.285	0.229	**2.45**	0.0214	**4.71**	0.00136
Zinc	0.0456	0.0367	0.0372	0.0145	0.362	0.266	**2.12**	0.381	0.630	0.0243

[a]Exposure media include surface water specific to the seep and pond near location 0538, sediment from all potentially contaminated areas, and vegetation. Vegetation concentrations were based on site-specific data when available or were estimated from sediment concentrations.

– = No toxicity benchmark available.
NC = UCL not calculated (frequency of detection less than 50%).
Hazard quotient values in **bold** are greater than 1.

For wetland wildlife exposed along the San Miguel River, concentrations of arsenic, vanadium, and zinc resulted in HQs greater than unity for one or more receptors based on the maximum estimated exposures. For zinc, this was limited to exposure in the spotted sandpiper and did not extend to the UCL_{95}-based exposure estimation for this species. Vanadium concentration resulted in the highest HQs (maximum HQ = 11.6), which exceeded unity for both the muskrat and raccoon at both exposure levels. The high measured concentrations of vanadium in wetland plant tissues is the principal contributor to this exposure. Although arsenic had lower HQs (maximum HQ = 1.61) than vanadium, and those exceeding unity were limited to the muskrat, the exposure to this herbivorous mammal was dominated by the contribution of arsenic from plants. Again, the arsenic concentration in plants was based on measured values.

The HQ results for the seep/pond area were somewhat similar to those for the San Miguel River. The zinc results were almost identical, showing some potential risk to the spotted sandpiper at the maximum exposure, but none at the UCL_{95}. The pond/seep area HQs for arsenic and vanadium for the muskrat and raccoon were higher than those for the river; potential risk to the spotted sandpiper and belted kingfisher from exposure to vanadium is indicated at the maximum concentration levels but not at the UCL_{95} levels. In addition, potential risk to the raccoon was indicated for arsenic, and potential risk to the muskrat was also indicated from exposure to manganese at the site.

6.2.5.5 Risk to Terrestrial Wildlife and Livestock Receptors

Table–6–23 through Table–6–25 present the hazard quotients for the five terrestrial wildlife receptors and two livestock receptors based on exposures to E-COPCs in drinking water taken from the San Miguel River, the seep/pond area, and ground water that is assumed to have been pumped to the surface and made available to these receptors. Exposures were estimated on the basis of the maximum measured concentrations in water samples from each area and the UCL_{95}s of these data, if available. It was assumed that the specified area was the only source of drinking water for these receptors. As shown in Table–6–23 and Table–6–24, neither the San Miguel River nor the seep/pond pose potential risks to these receptors as drinking water sources. However, the high concentrations of vanadium in the ground water could pose a risk to both wildlife and livestock if used as a drinking water source.

Table–6–23. Hazard Quotients for Terrestrial Wildlife and Livestock from Drinking Water Along the San Miguel River[a]

Contaminant of Potential Concern	Deer Mouse		Red Fox		Mule Deer		Elk		Northern Harrier		Horse		Cow	
	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}
Arsenic	4.52E-04	2.39E-04	3.66E-04	1.94E-04	3.29E-04	1.74E-04	3.14E-04	1.66E-04	4.84E-05	2.56E-05	3.03E-04	1.61E-04	6.84E-04	3.62E-04
Barium	2.13E-03	1.23E-03	1.73E-03	9.99E-04	1.55E-03	8.98E-04	1.48E-03	8.57E-04	4.15E-04	2.40E-04	1.43E-03	8.28E-04	3.23E-03	1.87E-03
Boron	6.12E-04	2.97E-04	4.96E-04	2.41E-04	4.46E-04	2.17E-04	4.26E-04	2.07E-04	7.12E-04	3.46E-04	4.11E-04	2.00E-04	9.28E-04	4.51E-04
Iron	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Manganese	1.09E-03	NC	8.80E-04	NC	7.91E-04	NC	7.55E-04	NC	6.91E-05	NC	7.29E-04	NC	1.64E-03	NC
Molybdenum	Not a COPC for this medium and location													
Nitrate	2.52E-05	NC	2.04E-05	NC	1.83E-05	NC	1.75E-05	NC	–	–	1.69E-05	NC	3.81E-05	NC
Selenium	1.10E-03	5.51E-04	8.93E-04	4.47E-04	8.03E-04	4.02E-04	7.66E-04	3.83E-04	6.59E-04	3.29E-04	7.40E-04	3.70E-04	1.67E-03	8.35E-04
Strontium	8.10E-04	5.26E-04	6.57E-04	4.26E-04	5.90E-04	3.83E-04	5.63E-04	3.66E-04	–	–	5.44E-04	3.53E-04	1.23E-03	7.97E-04
Sulfate	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Uranium	2.04E-02	3.76E-03	1.66E-02	3.05E-03	1.49E-02	2.74E-03	1.42E-02	2.61E-03	4.21E-03	7.75E-04	1.37E-02	2.52E-03	3.09E-02	5.70E-03
Vanadium	Not a COPC for this medium and location													
Zinc	7.65E-05	NC	6.20E-05	NC	5.58E-05	NC	5.32E-05	NC	1.15E-03	NC	5.14E-05	NC	1.16E-04	NC

[a]Exposure limited to surface water specific to the San Miguel River.

– = No toxicity benchmark available.
NC = UCL not calculated (frequency of detection less than 50%).

Table–6–24. Hazard Quotients for Terrestrial Wildlife and Livestock from Drinking Water at the Seep/Pond Area[a]

Contaminant of Potential Concern	Deer Mouse		Red Fox		Mule Deer		Elk		Northern Harrier		Horse		Cow	
	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}
Arsenic	2.66E-04	2.66E-04	2.15E-04	2.15E-04	1.94E-04	1.94E-04	1.85E-04	1.85E-04	2.85E-05	2.85E-05	1.78E-04	1.78E-04	4.03E-04	4.03E-04
Barium	Not a COPC for this medium and location													
Boron	7.43E-04	4.24E-04	6.03E-04	3.44E-04	5.42E-04	3.09E-04	5.17E-04	2.95E-04	8.64E-04	4.93E-04	4.99E-04	2.85E-04	1.13E-03	6.43E-04
Iron	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Manganese	2.45E-03	1.41E-03	1.98E-03	1.14E-03	1.78E-03	1.02E-03	1.70E-03	9.77E-04	1.56E-04	8.94E-05	1.64E-03	9.44E-04	3.71E-03	2.13E-03
Molybdenum	Not a COPC for this medium and location													
Nitrate	Not a COPC for this medium and location													
Selenium	1.22E-03	NC	9.92E-04	NC	8.92E-04	NC	8.51E-04	NC	7.32E-04	NC	8.22E-04	NC	1.86E-03	NC
Strontium	2.03E-03	1.04E-03	1.65E-03	8.42E-04	1.48E-03	7.57E-04	1.41E-03	7.22E-04	–	–	1.37E-03	6.97E-04	3.08E-03	1.57E-03
Sulfate	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Uranium	4.92E-02	2.37E-02	3.99E-02	1.92E-02	3.58E-02	1.72E-02	3.42E-02	1.65E-02	1.01E-02	4.88E-03	3.30E-02	1.59E-02	7.46E-02	3.59E-02
Vanadium	Not a COPC for this medium and location													
Zinc	6.12E-05	NC	4.96E-05	NC	4.46E-05	NC	4.26E-05	NC	9.22E-04	NC	4.11E-05	NC	9.28E-05	NC

[a]Exposure limited to surface water specific to the seep and pond near location 0538.

– = No toxicity benchmark available.
NC = UCL not calculated (frequency of detection less than 50%).

Table–6–25. Hazard Quotients for Terrestrial Wildlife and Livestock from Drinking Pumped Ground Water[a]

Contaminant of Potential Concern	Deer Mouse		Red Fox		Mule Deer		Elk		Northern Harrier		Horse		Cow	
	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}
Arsenic	1.70E-02	4.52E-03	1.38E-02	3.66E-03	1.24E-02	3.29E-03	1.18E-02	3.14E-03	1.82E-03	4.84E-04	1.14E-02	3.03E-03	2.58E-02	6.84E-03
Barium	2.37E-03	7.11E-04	1.92E-03	5.76E-04	1.73E-03	5.18E-04	1.65E-03	4.94E-04	4.61E-04	1.38E-04	1.59E-03	4.77E-04	3.59E-03	1.08E-03
Boron	1.97E-03	6.16E-04	1.60E-03	5.00E-04	1.43E-03	4.49E-04	1.37E-03	4.29E-04	2.29E-03	7.17E-04	1.32E-03	4.14E-04	2.98E-03	9.34E-04
Iron	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Manganese	2.87E-03	1.38E-03	2.32E-03	1.12E-03	2.09E-03	1.00E-03	1.99E-03	9.58E-04	1.82E-04	8.77E-05	1.92E-03	9.25E-04	4.34E-03	2.09E-03
Molybdenum	8.73E-02	2.51E-02	7.08E-02	2.03E-02	6.36E-02	1.83E-02	6.07E-02	1.75E-02	7.20E-03	2.07E-03	5.86E-02	1.69E-02	1.32E-01	3.80E-02
Nitrate	8.14E-04	7.09E-05	6.60E-04	5.75E-05	5.94E-04	5.17E-05	5.66E-04	4.93E-05	–	–	5.47E-04	4.76E-05	1.23E-03	1.07E-04
Selenium	8.57E-03	1.22E-03	6.95E-03	9.92E-04	6.25E-03	8.92E-04	5.96E-03	8.51E-04	5.12E-03	7.32E-04	5.76E-03	8.22E-04	1.30E-02	1.86E-03
Strontium	2.16E-03	1.19E-03	1.75E-03	9.66E-04	1.58E-03	8.68E-04	1.51E-03	8.29E-04	–	–	1.45E-03	8.00E-04	3.28E-03	1.81E-03
Sulfate	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Uranium	1.16E-01	4.22E-02	9.37E-02	3.42E-02	8.42E-02	3.08E-02	8.03E-02	2.94E-02	2.38E-02	8.71E-03	7.76E-02	2.84E-02	1.75E-01	6.40E-02
Vanadium	**3.40E+00**	8.84E-01	**2.76E+00**	7.17E-01	**2.48E+00**	6.44E-01	**2.36E+00**	6.15E-01	7.59E-02	1.97E-02	**2.28E+00**	5.94E-01	**5.15E+00**	**1.34E+00**
Zinc	6.89E-05	NC	5.58E-05	NC	5.02E-05	NC	4.79E-05	NC	1.04E-03	NC	4.63E-05	NC	1.04E-04	NC

[a]Exposure limited to ground water under the assumption that is it pumped to the surface and made available to livestock and wildlife.

– = No toxicity benchmark available.
NC = UCL not calculated (frequency of detection less than 50%).
Hazard quotient values in **bold** are greater than 1.

Potential Risks from Radionuclides

Potential risks from radionuclides were evaluated using the screening-level benchmarks for aquatic biota (specifically large and small fish) derived for Oak Ridge National Laboratory (Bechtel Jacobs 1998b), based on the methodology for estimating dose rates for aquatic biota developed by Blaylock and others (1993). Radiological analyses in surface water and ground water samples from the Naturita site between 1989 and 1994 have included four uranium-238 daughters (radium-226, thorium-230, lead-210, and polonium-210), as well as radium-228. As shown in Table 6–26, these five radionuclides have been identified as E-COPCs in the San Miguel River surface water, and all except radium-228 have been identified as E-COPCs in the ground water (based on comparisons to background or upstream sample results). Table 6–26 presents the comparison (as HQs) of the maximum concentrations of these radionuclides to their screening benchmark values. Although no benchmark was available for radium-228, it is clear from the HQs for the other radiological COPCs that doses to aquatic biota (specifically to fish) from uranium-238 daughters at the Naturita site are negligible.

Table 6–26. Hazard Quotients for Radiological E-COPCs

Contaminant of Potential Concern	Surface Water (San Miguel River)			Ground Water		
	Benchmark Value[a] (pCi/L)[b]	Maximum Measured Activity (pCi/L)	Hazard Quotient	Benchmark Value[a] (pCi/L)[b]	Maximum Measured Activity (pCi/L)	Hazard Quotient
Lead-210	30,600	1.2	3.92×10^{-5}	30,600	13.5	4.41×10^{-4}
Polonium-210	725	ND	–	725	4.5	0.00620
Radium-226	160	0.6	0.00375	160	28.6	0.17
Radium-228	NB	23	NB	Not an E-COPC for ground water		
Thorium-230	413	0.5	0.00121	413	0.9	0.00218

[a]Benchmark is the minimum for large and small fish (from Bechtel Jacobs 1998b)
[b]Picocuries per liter
NB = No benchmark available
ND = Not detected

Potential Risks to Sensitive Species

As stated in Section 6.2.2.1, the endangered southwestern willow flycatcher has the potential for occurring in the riparian habitat along the San Miguel River at or near the Naturita site. The diet of this species consists principally of flying insects, at least some of which possibly are being exposed to water or sediment at the site during their development. The spotted sandpiper, modeled as having a diet consisting entirely of invertebrates exposed to surface water at either the San Miguel River or the seep/pond area, conservatively represents potential exposure and risk to the southwestern willow flycatcher, should it occur at the site. Because the HQs for the spotted sandpiper are low at both of these areas (maximum HQs not exceeding 3, and all HQs based on the UCL_{95} concentration or mean concentration being less than unity), the potential for risk to the southwestern willow flycatcher is also expected to be very low.

Ecological Risk Summary

For the purpose of summarization, the receptors are categorized into six groups: aquatic organisms, benthic organisms, upland plants, wetland plants, terrestrial wildlife and livestock, and wetland wildlife. Further, the potential risk to each group based on the HQs was categorized as follows:

- None: HQs are less than or equal to 1 for both the maximum and UCL_{95} concentrations.
- Very low: Maximum HQs are less than 10 but greater than 1; UCL_{95}-based HQs are less than 1.
- Low: Both maximum and UCL_{95}-based HQs are less than 10, but greater than 1.
- Medium-Low: Maximum HQ is greater than or equal to 10 but less than 100; UCL_{95}-based HQs are less than 10.
- Medium: Both maximum and UCL_{95}-based HQs are greater than or equal to 10 but less than 100.
- High: Maximum HQ is greater than or equal to 100 but less than 1,000; UCL_{95}-based HQs are greater than 10.
- Very high: Maximum HQs are greater than or equal to 1,000.

Table 6–27 presents the results of this categorization of potential risk. In the cases where multiple receptors are included in the receptor group (i.e., the terrestrial and wetland wildlife groups), the risk is based on the highest worst-case risk result among the receptors. Because many conservatisms were incorporated in the calculation of these HQs, including the use of maximum and UCL_{95} values as exposure point concentrations, the use of conservative toxicity benchmarks, such as water quality criteria and NOAELs, and the assumption of 100 percent area and seasonal use, the HQs are expected to overestimate actual risk to most individual receptors, and therefore, risks categorized as medium-low to none are not expected to represent significant potential risks to populations of nonsensitive species. However, for those receptor groups that may include sensitive species, risk categorizations of medium-low to low are still considered to be of concern.

In the San Miguel River, the highest potential ecological risk may be associated with barium in surface water. However, the maximum concentration of barium measured in surface water from the river at the site (0.09 mg/L) only slightly exceeded the maximum concentration measured at the upstream reference location (0.08 mg/L). The latter concentration also exceeded the Tier II value that was used as the benchmark for potential risk (0.0016 mg/L). Therefore, a similar level of risk would be predicted for the reference area as was predicted for the site. For this reason, it is highly likely that the Tier II value for barium is highly conservative and overestimates potential risk to aquatic receptors, and it is likely that barium in the river water is not significantly above background levels.

Table 6–27. Summary of Potential Ecological Risks at the Naturita Site[a]

Contaminant of Potential Concern	Aquatic Organisms	Benthic Organisms	Deep-Rooted Plants	Wetland Plants	Terrestrial Wildlife and Livestock	Wetland Wildlife
(principal exposure media)	surface water	sediment	ground water	sediment	ground water	surface water sediment food
San Miguel River						
Arsenic	none	none	NA	none	none	low
Barium	medium	–	NA	none	none	none
Boron	none	–	NA	medium-low	none	none
Iron	none	none	NA	–	–	–
Manganese	none	very low	NA	very low	none	none
Molybdenum	NA	none	NA	very low	NA	none
Nitrate	none	NA	NA	NA	none[b]	none[b]
Selenium	none	none	NA	none	none	none
Strontium	very low	–	NA	–	none[b]	none[b]
Sulfate	very low	–	NA	–	–	–
Uranium	none	–	NA	very low	none	none
Vanadium	NA	–	NA	low	NA	low
Zinc	none	very low	NA	low	none	very low
Seep/Pond						
Arsenic	none	none	NA	none	none	low
Barium	NA	–	NA	none	NA	none
Boron	none	–	NA	medium-low	none	none
Iron	none	none	NA	–	–	–
Manganese	low	very low	NA	very low	none	low
Molybdenum	NA	none	NA	very low	NA	none
Nitrate	NA	NA	NA	NA	NA	none[b]
Selenium	none	none	NA	none	none	none
Strontium	low	–	NA	–	none[b]	none[b]
Sulfate	low	–	NA	–	–	–
Uranium	none	–	NA	very low	none	none
Vanadium	NA	–	NA	low	NA	medium
Zinc	none	very low	NA	low	none	very low
Ground Water						
Arsenic	none	NA	medium	NA	none	NA
Barium	medium-low	NA	none	NA	none	NA
Boron	none	NA	none	NA	none	NA
Iron	very low	NA	none	NA	–	NA
Manganese	very low	NA	none	NA	none	NA
Molybdenum	–	NA	none	NA	none	NA
Nitrate	none	NA	–	NA	none[b]	NA
Selenium	very low	NA	none	NA	none	NA
Strontium	low	NA	–	NA	none[b]	NA
Sulfate	low	NA	–	NA	–	NA
Uranium	very low	NA	none	NA	none	NA
Vanadium	high	NA	medium-low	NA	low	NA
Zinc	none	NA	none	NA	none	NA

[a]See text for definition of risk categories.
[b]Avian benchmark not available. Risk based on mammalian receptors only.
– = No hazard quotients available
NA = Not applicable to this area

For the seep/pond area at sampling location 0538, the potential exposure of wetland wildlife to vanadium is the principal ecological risk concern. This is primarily due to the risks predicted for the two mammalian receptors, the muskrat and raccoon. Vanadium was also the primary risk driver associated with ground water if it were to be pumped to a surface pond. In addition, the levels of arsenic in ground water may adversely affect deep-rooted plants on the floodplain area.

Risks were considered low if all HQs based on maximum concentrations were less than 10, very low if all HQs based on UCL_{95} concentrations were less than 1, and none if all HQs (based on maximum and UCL_{95} concentrations) were less than 1. E-COPCs showing no or very low risk are dropped from further consideration, and those with low risks are also dropped provided that the receptors showing the low risk do not include or represent potential risks to endangered or threatened species. Because conservative assumptions and values have been incorporated into the exposure models and toxicity benchmarks, HQs are expected to overestimate the actual risks posed by these E-COPCs. Therefore, HQs less than 10 are expected to be protective of populations and communities, but may not be protective of individuals in the cases where threatened or endangered species may be exposed. Of the E-COPCs that have HQs greater than 10, barium at the San Miguel River and boron are only marginally above background levels, and risk may be exaggerated by the corresponding benchmark values used in the assessment. Incremental risks above background posed by these constituents are insignificant; therefore further monitoring is not warranted. Vanadium in the ground water, which may be reflected in the seep/pond area, is the principal constituent of ecological concern at the Naturita site. High arsenic concentrations in ground water is also of concern with respect to potential effects on plants. Continued monitoring of vanadium and arsenic is recommended. The potential for risk to the endangered southwestern willow flycatcher is considered to be very low at this site; exposures to vanadium and zinc are of primary concern for this species.

7.0 Ground Water Compliance Strategy

7.1 Compliance Strategy Selection Process

The framework defined in the PEIS (DOE 1996) governs selection of the strategy to achieve compliance with EPA ground water standards. Stakeholder review of the final PEIS is documented and supported by the Record of Decision (CFR v. 62, No. 18, 1997). Figure 7–1 and Figure 7–2 present summaries of the framework used to determine the appropriate ground water compliance strategies for the Naturita site. The framework considers human health and environmental risk, stakeholder input, and cost. A step-by-step approach in the PEIS results in the selection of one of three general compliance strategies:

- *No remediation*—Compliance with the EPA ground water protection standards would be met without altering the ground water or cleaning it up in any way. This strategy could be applied for those constituents at or below maximum concentration limits (MCLs) or background levels or for those constituents above MCLs or background levels that qualify for supplemental standards or alternate concentration limits (ACLs), as defined in Section 2.2, "EPA Ground Water Protection Standards." A site could qualify for no remediation by application of supplemental standards based on a determination of technical impracticability (TI).

- *Natural flushing*—This strategy would allow natural ground water movement and geochemical processes to decrease contaminant concentrations to regulatory limits. The natural flushing strategy can be applied where ground water compliance could be achieved within 100 years, where effective monitoring and institutional controls can be maintained, and where the ground water is not currently and is not projected to be a source for a public water system.

- *Active ground water remediation*—This strategy would require engineered ground water remediation methods such as gradient manipulation, ground water extraction and treatment, land application, phytoremediation, and in situ ground water treatment to achieve compliance with EPA standards.

7.2 Naturita PEIS Compliance Selection Framework Analysis

The UMTRA Project regulations provide for several ways to comply with the ground water protection standards for Subpart B of 40 CFR 192.12(c). These include meeting the provisions of 40 CFR 192.02(c)(3) or a supplemental standard established under 40 CFR 192.22. The provisions of 40 CFR 192.02(c)(3) include (1) the background level of the constituent in ground water, (2) the MCL for any constituents listed in Table 1 to Subpart A, or (3) an ACL established pursuant to paragraph (c)(3)(ii) of that section.

UMTRCA requires DOE to establish standards under Title I that provide protection consistent, to the maximum extent practicable, with the requirements of RCRA (CFR 1995, v. 60, No. 7, p. 2855). No guidance is available from NRC and DOE for implementing criterion (f) of the supplemental standards criteria, technical impracticability. As such, and consistent with the approach discussed in the UMTRCA preamble, this SOWP uses several EPA documents for guidance. They include the *Handbook of Groundwater Policies for RCRA Corrective Action* (EPA 2000), *Presumptive Response Strategy and Ex-Situ Treatment Technologies for*

Contaminated Ground Water at CERCLA Sites (EPA 1996), and *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (EPA 1993).

Section 6.0 established arsenic, uranium, and vanadium as the COPCs for the Naturita site. Section 6.3 summarizes this evaluation and provides explanations for eliminating other constituents. Only the final COPCs for the Naturita site are discussed further in this section.

Proposed compliance strategies for the Naturita site

Two compliance strategies are proposed for the Naturita site.

- Natural flushing with application of institutional controls and monitoring for arsenic.

- No action and the application of supplemental standards for uranium and vanadium. Specifically, Section 192.21(f) of 40 CFR 192 applies because of the following circumstances: "The restoration of groundwater quality at any designated processing site under §192.12(c) is technically impracticable from an engineering perspective." To a lesser extent, paragraph 192.21 (b) also applies, due to its previous application during the surface program. It states that "Remedial actions to satisfy cleanup standards for land and groundwater...would, notwithstanding reasonable measures to limit damage, directly produce health and environmental harm that is clearly excessive compared to the health and environmental benefits... A clear excess of health and environmental harm is harm that is long-term, manifest, and grossly disproportionate to the health and environmental benefits that may reasonably be anticipated."

Figure 7–1 and Table 7–1 for arsenic and Figure 7–2 and Table 7–2 for uranium and vanadium show these strategies as outlined by the PEIS framework.

7.3 Detailed Explanation of Compliance Strategies

7.3.1 Natural Flushing for Arsenic with Institutional Controls

Arsenic presents only a marginal risk because of its limited extent. However, because it is highly toxic to organisms in small quantities, it has been retained as a COPC. Only two ground water locations, NAT03 at 0.052 mg/L and NAT08 at 0.057 mg/L, contain average arsenic levels above the UMTRA MCL of 0.05 mg/L, although levels at location NAT11 rose to 0.052 during the February 2001 sampling event. The area with elevated arsenic concentrations is within the vanadium and uranium plumes. It is also located beneath the former tailings pile and is considered to be milling-related contamination. The plume map for arsenic (Figure 7–3) shows a very small area where the concentration is thought to be above the MCL. Well 0548 is the only well in the plume for which pre- and post-remedial action data are available. A time/concentration graph shows relatively low levels of arsenic (around 0.01 mg/L) until 1997 and 1998, when the concentrations increased several times to a maximum of 0.04 mg/L and decreased back to 0.01 mg/L (Figure 7–4). The time/concentration plots for vanadium and, to a lesser degree, uranium show similar trends (Figure 7–5). The increased concentrations in ground water occurred during or just after surface remedial action and are thought to be related to mobilization of constituents during this disturbance. Therefore, arsenic concentrations in the small plume area may decrease to pre-surface remediation concentrations over the next few years to levels below MCLs.

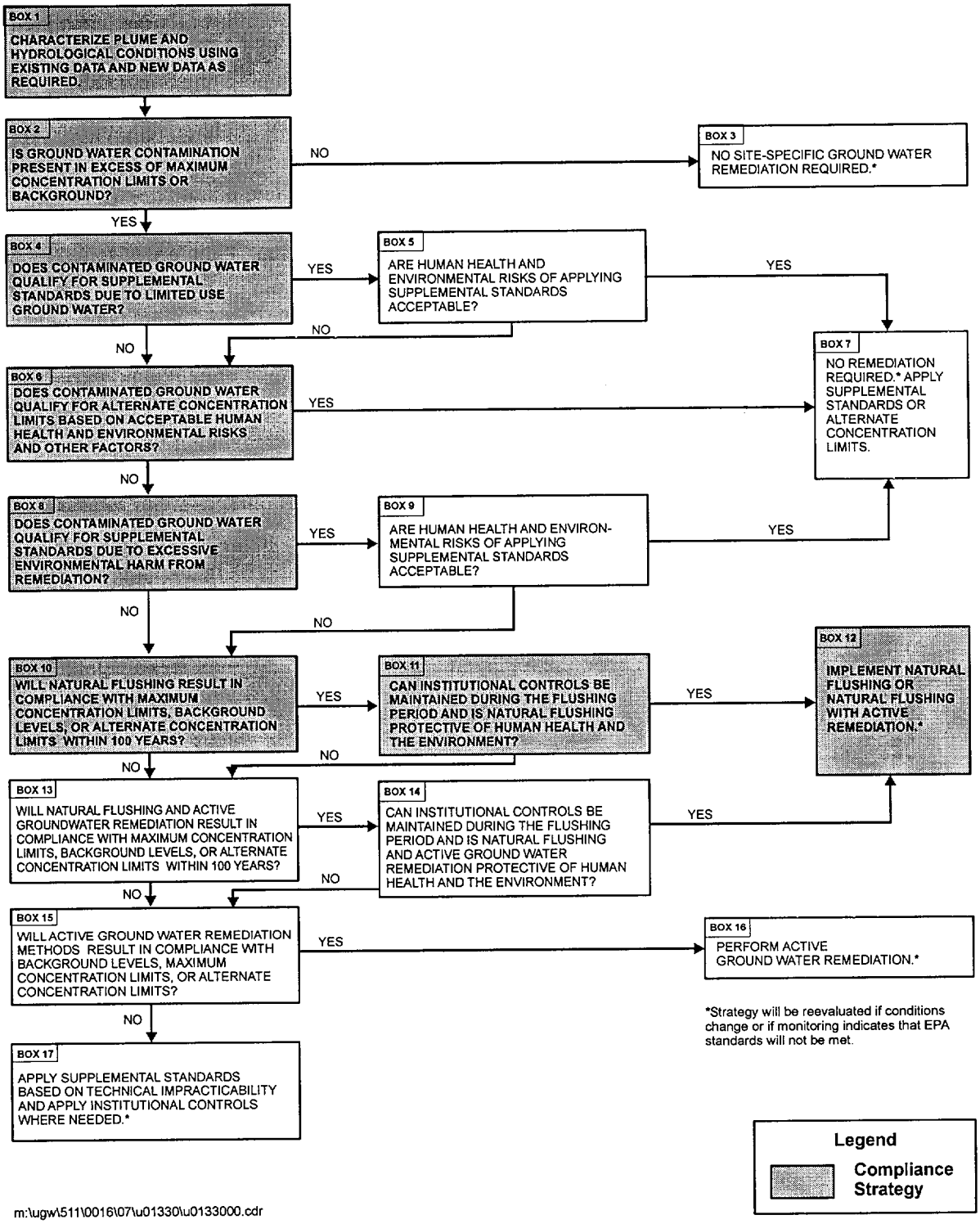

Figure 7–1. Summary of Natural Flushing Compliance Strategy for Arsenic in Ground Water.

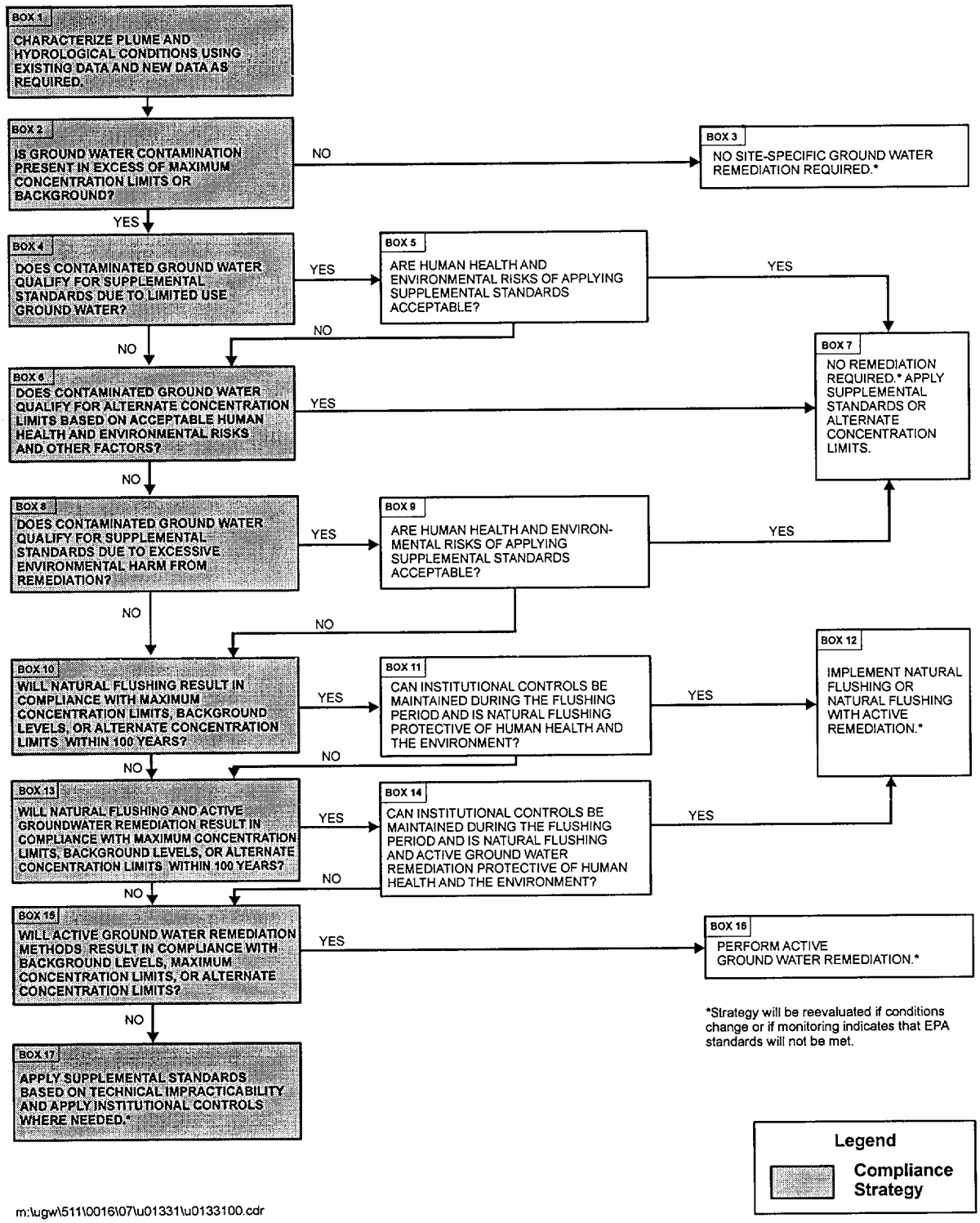

Figure 7–2. Summary of Technical Impracticability Compliance Strategy for Uranium and Vanadium in Ground Water.

Table 7–1. Explanation of the Natural Flushing Strategy for Arsenic at the Naturita Site

Box Figure 7–1	Action or Question	Result of Decision
Box 1	Characterize plume and hydrologic conditions.	See Site Conceptual Model in Section 5. Move to Box 2.
Box 2	Is ground water contamination present in excess of UMTRA MCLs or background?	Arsenic concentration exceeds UMTRA MCLs or risk based concentrations. Move to Box 4.
Box 4	Does ground water qualify for supplemental standards due to limited use ground water?	Alluvial ground water does not meet any criteria for limited use. Move to Box 6.
Box 6	Does ground water qualify for alternate concentration limits based on acceptable human health and environmental risks and other factors?	No, not at this time.
Box 8	Does contaminated ground water qualify for supplemental standards due to excessive environmental harm from remediation?	No.
Box 10	Will natural flushing result in compliance with UMTRA MCLs, background, or ACLs within 100 years?	Ground water modeling shows that arsenic will flush to concentrations below the UMTRA MCL within 100 years. Move to Box 11.
Box 11	Can institutional controls be maintained during the flushing period and is the compliance strategy protective of human health and the environment?	The final compliance strategy is protective of human health and the environment. Institutional controls will be in place soon and will prevent the use of ground water for human consumption. After 100 years, ground water will have levels of arsenic that will be below UMTRA MCLs. Move to Box 12 and implement natural flushing for arsenic.
Box 12		Implement natural flushing for arsenic.

Table 7–2. Explanation of the Technical Impracticability Compliance Strategy for Uranium and Vanadium at the Naturita Site

Box Figure 7–2	Action of Question	Result of Decision
Box 1	Characterize plume and hydrologic conditions.	See Site Conceptual Model in Section 5. Move to Box 2.
Box 2	Is ground water contamination present in excess of UMTRA MCLs or background?	Uranium, and vanadium concentrations exceed UMTRA MCLs or risk based concentrations. Move to Box 4.
Box 4	Does ground water qualify for supplemental standards due to limited use ground water?	Alluvial ground water does not meet any criteria for limited use. Move to Box 6.
Box 6	Does ground water qualify for alternate concentration limits based on acceptable human health and environmental risks and other factors?	Questionable. At this time, DOE considers another strategy (TI) more favorable. Move to Box 8.
Box 8	Does contaminated ground water qualify for supplemental standards due to excessive environmental harm from remediation?	DOE considers this to be an important and subordinate consideration for ground water remediation due to the large areas of supplemental standards left during the surface program, which used this criterion. This is currently considered a secondary strategy. Move to Box 10.
Box 10	Will natural flushing result in compliance with UMTRA MCLs, background, or ACLs within 100 years?	Ground water modeling shows that uranium and vanadium will not flush to concentrations below the UMTRA MCLs, background, or ACLs within 100 years. Move to Box 13.
Box 13	Will natural flushing and active ground water remediation result in compliance with MCLs, background, or ACLs within 100 years?	Based on modeling data for removal of ground water and continued source material at the site, DOE believes it is doubtful that levels of vanadium and uranium would be reduced to MCLs or background within 100 years. ACLs are not proposed. Costs of active remedial actions do not outweigh the benefits, considering the limited potential negative impacts to human health and the environment. Move to Box 15.
Box 15	Will active ground water remediation methods result in compliance with MCLs, background, or ACLs?	Same answer as Box 13. Move to Box 17.
Box 17	Apply supplement standards based on technical impracticability and apply institutional controls where needed.	DOE plans to apply for a TI Determination and apply institutional controls in the TI zone. Human health and the environment will be protected.

To quantify this assumption, modeling of arsenic was also performed. Ground water flow is toward the north to northeast in this area, and application of MODFLOW software indicates that transport and attenuation of arsenic to levels below 0.05 mg/L will occur in approximately 10 years, well within the 100-year period allowed for natural flushing. Even if the flushing action is inhibited by extraction of ground water at the upgradient gravel mining operation, the arsenic plume is so limited in size and the 100-year timeframe is long enough that natural flushing should achieve cleanup goals. The future monitoring will be ongoing until cleanup objectives are met. Figure 7–3 shows the current plume for arsenic will probably flow northeast toward the San Miguel River before concentrations decrease to acceptable levels. Contamination will not leave the site area during the flushing period and should dissipate to levels below the MCL before entering the San Miguel River. Proposed ICs for the site will ensure safety to humans and the environment during this period.

7.3.2 Supplemental Standards Based on Technical Impracticability

Unlike arsenic, modeling of uranium and vanadium indicates they will not flush to acceptable levels during the 100-year natural flushing period. In addition, as discussed in Section 8.3, any reasonable active remediation compliance strategy is also unlikely to be effective. Therefore, no remediation by reason of technical impracticability is proposed as the compliance strategy for uranium and vanadium. Additional justification for this strategy is provided in Section 8.0.

(Figure 7–6) shows that uranium has the most extensive areal distribution of the three COPCs. Concentrations above 0.044 mg/L extend from the former location of milling buildings northward into the vicinity property, to the northern terminus of the floodplain where it intersects the San Miguel River. However, the highest concentrations of uranium, located below the former tailings pile, have apparently migrated only as far north as the northern boundary of the site and have begun to encroach on the southernmost side of the vicinity property. The plume map for vanadium (Figure 7–7) shows a much smaller areal distribution. It is confined to the southern half of the area within the footprint of the former tailings pile and has shown little, if any, migration in the 60 years since vanadium milling first began. This distribution of uranium and vanadium is consistent with measured K_ds, ground water modeling predictions, and observations at other UMTRA ground water sites. All indicators are that vanadium is more immobile than uranium and is more strongly adsorbed by alluvial materials. Therefore, it is unlikely that removal of vanadium from the alluvial aquifer will be effective.

Evidence exists that mill tailings from the site have been eroded by the San Miguel River over time and redeposited downstream of the site. These deposits may serve as a continuing source of ground water contamination. Figures 3–1 and 3–2 are aerial photographs from 1954 and 1966 that show a distributary channel for the San Miguel River cutting through the vicinity property floodplain. Repeated spring runoff and periods of flooding probably deposited tailings in this area. This millsite contamination apparently contained sufficient concentrations of uranium and has had sufficient residence time in contact with ground water to produce some of the elevated uranium concentrations detected in the vicinity property ground water. Analysis of uranium from wells on the site and vicinity property suggests that the plume of uranium migrating off the site toward the vicinity property may be a combination of millsite related and vicinity property related contamination (see Figure 7–6).

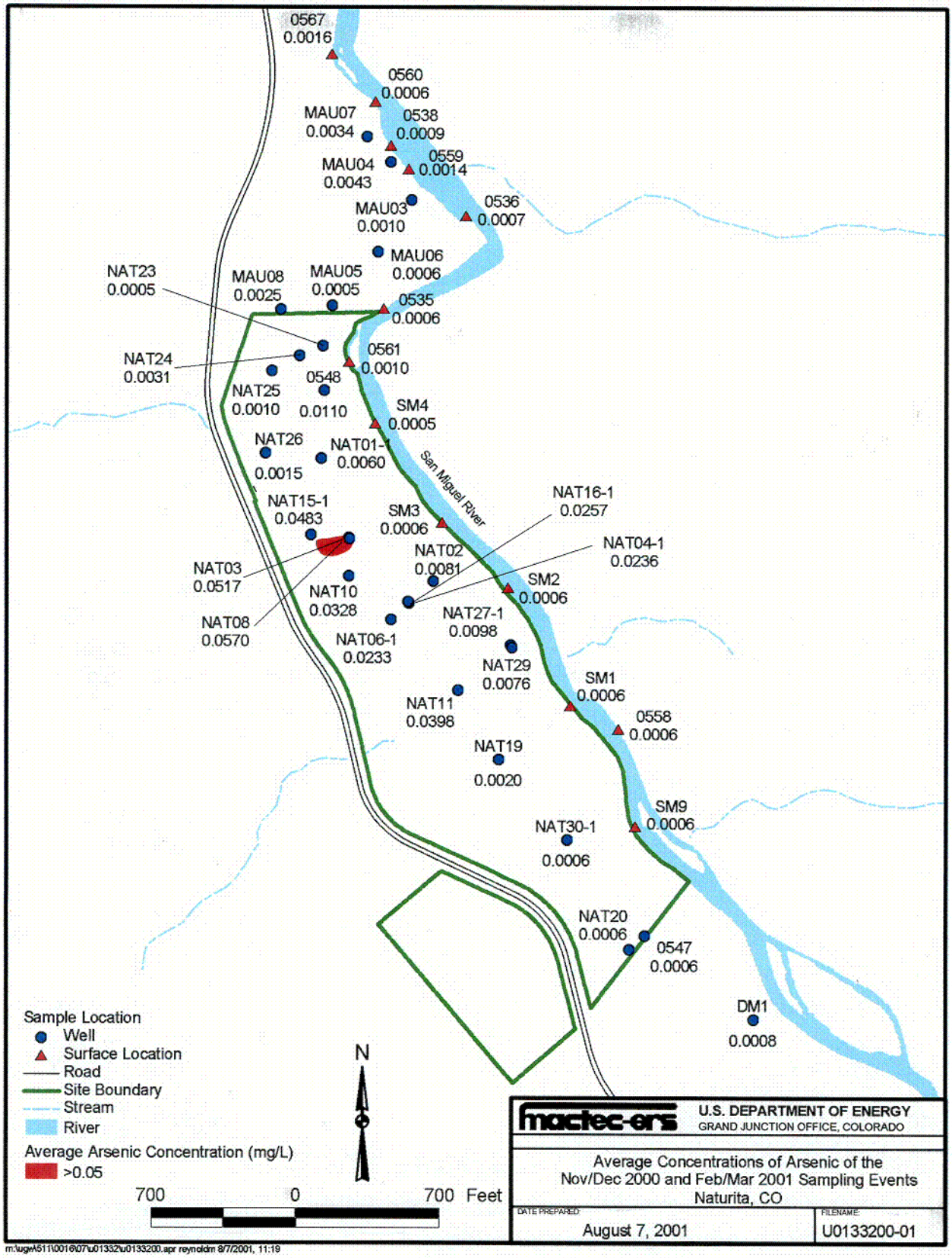

Figure 7–3. Average Concentrations of Arsenic from the Nov/Dec 2000 and Feb/Mar 2001 Samples

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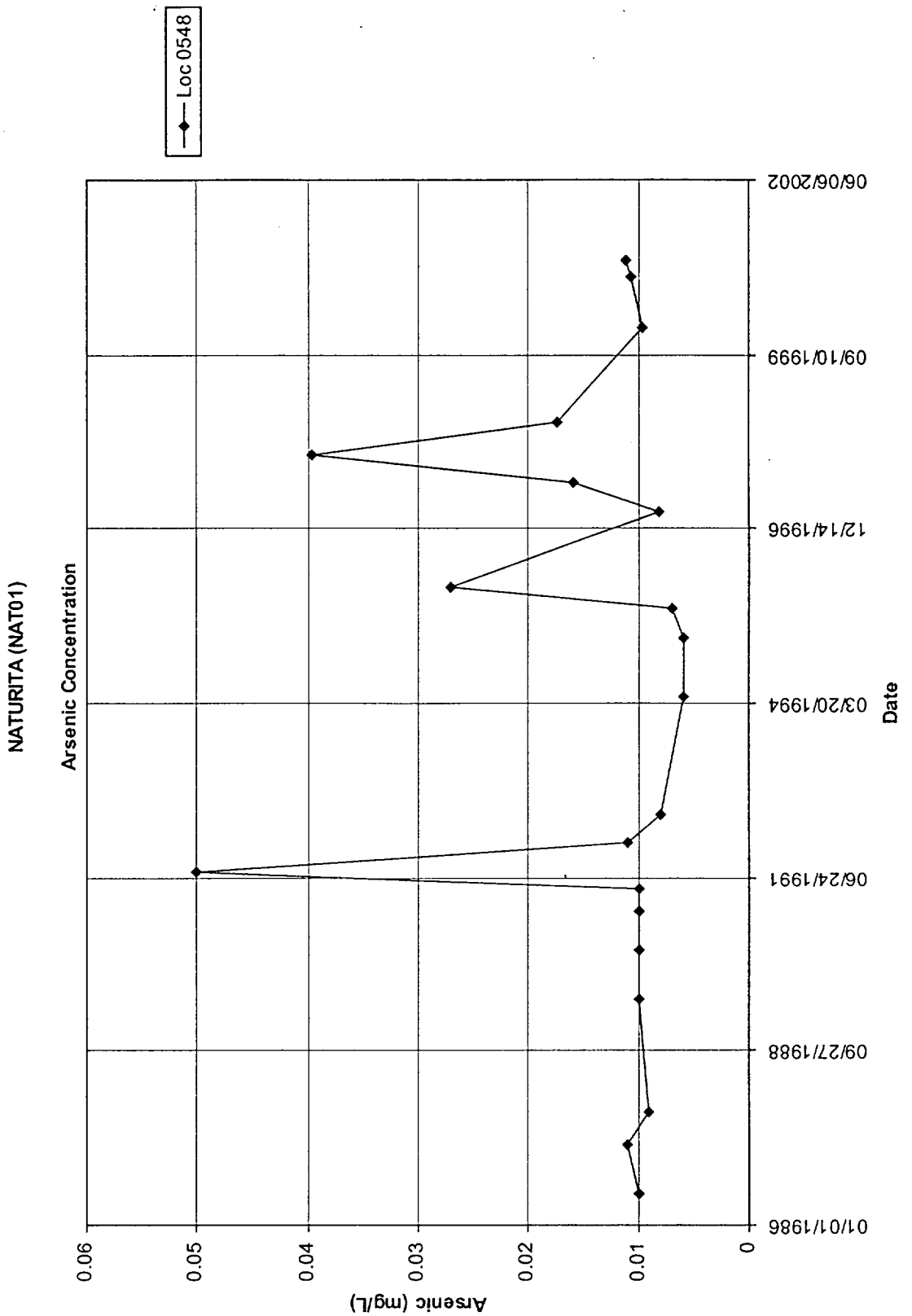

Figure 7–4. Time/Concentration Graph of Arsenic

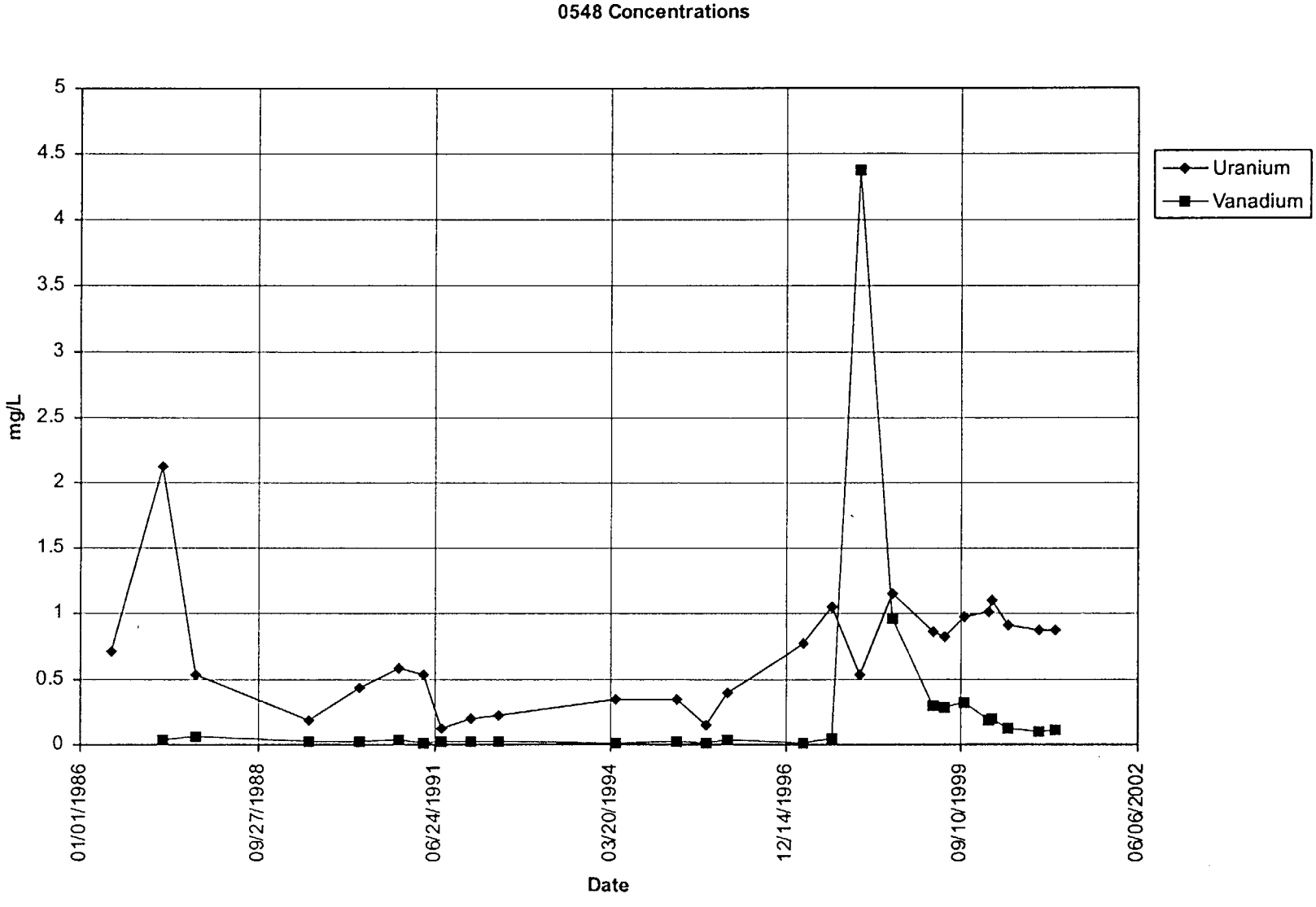

Figure 7–5. Time/Concentration Graph of Uranium and Vanadium

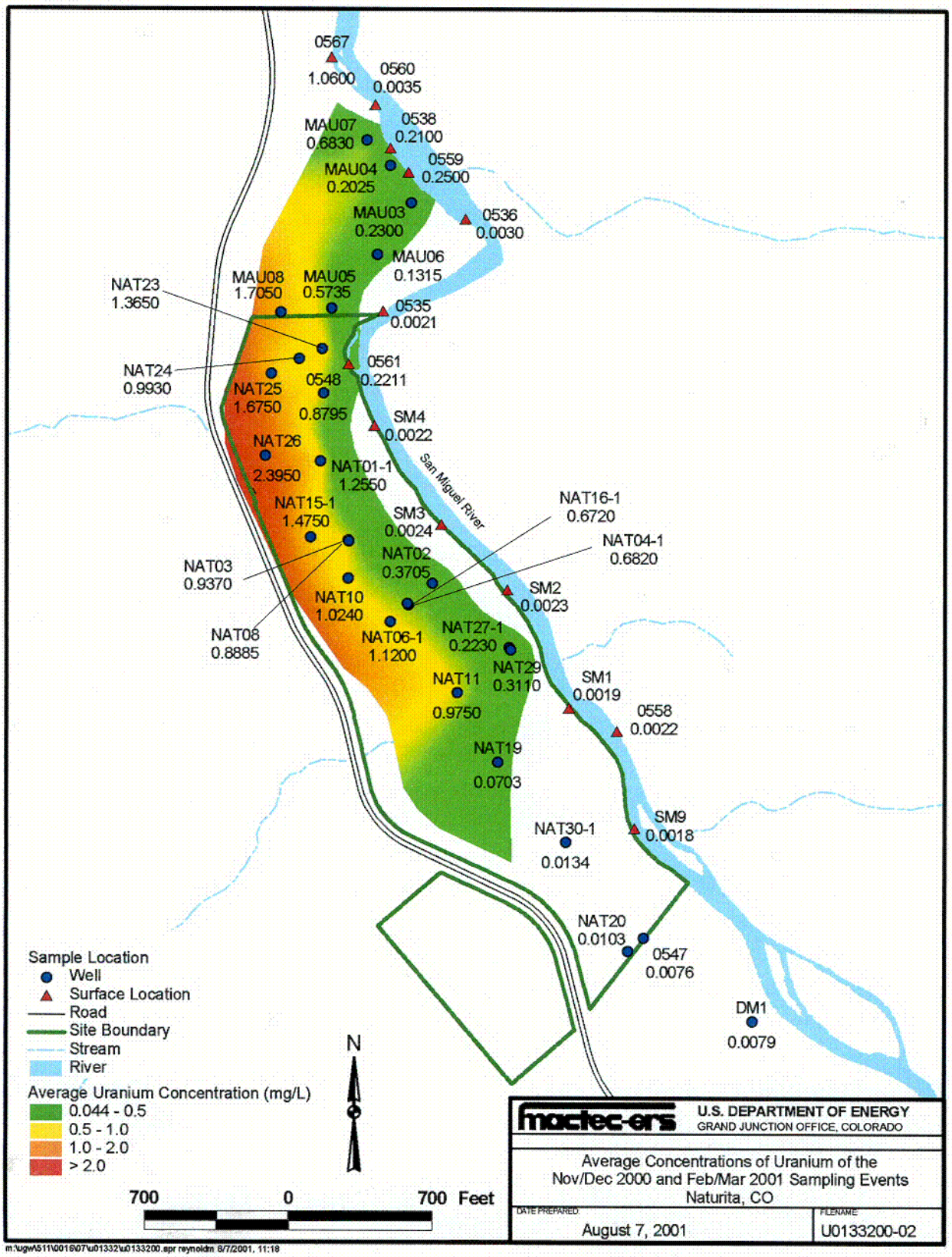

Figure 7–6. Average Concentrations of Uranium from the Nov/Dec 2000 and Feb/Mar 2001 Samples

C02

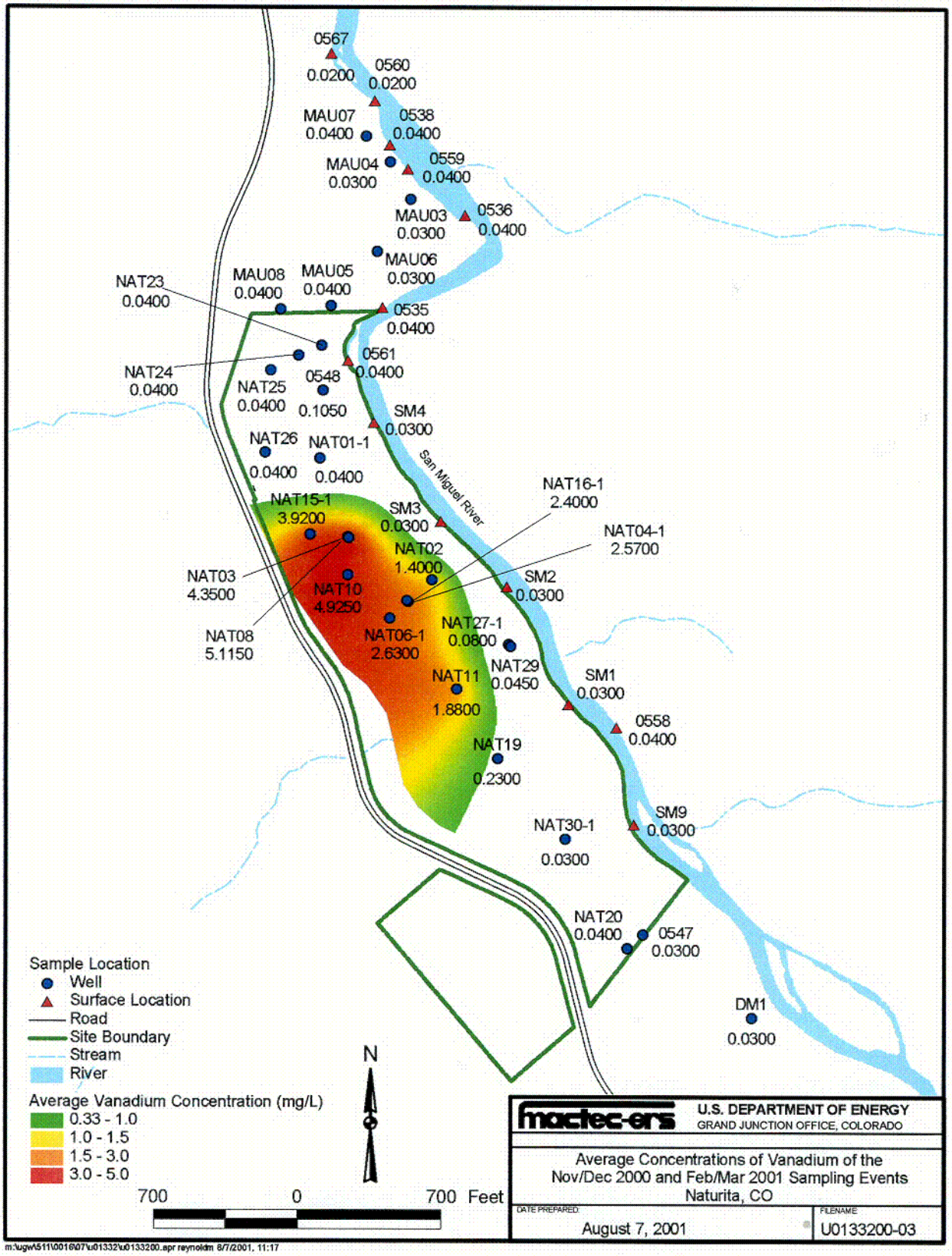

Figure 7–7. Average Concentrations of Vanadium from the Nov/Dec 2000 and Feb/Mar 2001 Samples

C03

7.3.2.1 Technical Impracticability (TI)

According to guidance from EPA (1993b), cleanup of ground water may be technically impracticable if the "restoration potential" is low and the "remediation difficulty" is high.

Three well-defined remediation problems contribute to the impracticability of restoring ground water at the Naturita site. In order to complete ground water restoration, all three issues would have to be addressed.

1. The thin alluvial aquifer in the area of the plumes would hamper removal of large quantities of contamination because pumping draws down the aquifer near the pumping well and does not allow flushing of constituents; some form of gradient manipulation would be required to overcome this problem.

2. The removal of continued sources of uranium and vanadium left in five locations on the site and the vicinity property under application of supplemental standards would be required to remove the continuing contamination source, which would probably cause excessive environmental harm.

3. The high adsorptive affinity of vanadium to clays and other sediments would require an extremely long period of time to perform a typical pump-and-treat cleanup.

Because of the difficulty involved in dealing with these site-related issues and the questionable benefit in doing so, the application of supplemental standards by reason of TI is believed to be justified. To demonstrate and evaluate TI at a site, EPA prepared guidance in the *Handbook of Groundwater Policies for RCRA Corrective Action* (EPA 2000b) and *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (EPA 1993b).

The Handbook (EPA 2000b) indicates that a TI demonstration should include the following information:

- Spatial area (TI zone) over which the TI decision would apply.
- Specific ground water cleanup objectives that are considered technically impracticable to achieve.
- A site conceptual model that describes geology, hydrogeology, ground water contamination sources, transport, and fate.
- Evaluation of the "restoration potential" of the TI zone.
- Cost estimates.
- Any additional information the regulatory agencies deem necessary.
- Description of an alternative remedial strategy.

Section 8.0 contains the formal discussion of these points as they apply to the remediation of the Naturita ground water.

7.3.2.2 Description of Alternative Remedial Strategy

An alternative remedial strategy is required for a TI application and must protect human health and the environment. This strategy should have at least the following attributes:

- It should be technically practicable.
- It should control the sources of contamination and prevent migration of contamination beyond the zone associated with the TI application.
- It should achieve the ground water cleanup objectives outside the zone associated with the TI application.
- It should be consistent with the overall cleanup goals for the facility.

The alternative remedial strategy proposed for the Naturita site consists of limiting exposure to contamination (as a best management practice) and providing institutional controls and maintaining a monitoring program to ensure that levels of contaminants reaching the surface do not produce unacceptable levels in springs or in the San Miguel River. The family living on the vicinity property underlain by contaminated ground water currently hauls drinking water to their property. As part of this TI application, DOE proposes to drill and complete a well into the Entrada Formation, which contains potable water, and pipe the water into the household.

Short-term protectiveness goals are already in place for the site. At the present time, no one is drinking ground water from the site and no one is anticipated to be drinking it. Only one family is living in the area where contamination occurs; no other residents are anticipated to move into the area.

7.4 Interim Actions

Several interim actions were completed during 2001. DOE provided 200 cubic yards of riprap and 500 cubic yards of clean dirt to the site and stored it along the southwest corner at the request of Montrose County. This material is to be used by the county in case the San Miguel River floods the site during spring runoff or a storm event.

A second interim action was to armor the riverbank with riprap along a stretch of the adjoining vicinity property to prevent future erosion and prohibit exposure of RRM left on the property. This was considered important to protect monitoring wells that may have become flooded during spring runoff or storm events if the riverbank failed. A third action was to repair and armor an eroded culvert on the west side of the site that passes under Highway 141 and drains valleys to the west. Plate 1 shows the locations of these interim action areas.

7.5 Future Land Use

Growth in this part of western Colorado has been very slow and has historically been linked with mining production. Mining is not expected to experience significant regrowth, but tourism may become increasingly important. Ranching is the other industry of western Colorado that has been and will be important. The millsite is currently safe for livestock grazing, and part of it is used for this purpose. The town of Naturita is several miles south of the site and is not expected to expand to the area of the millsite in the near future.

The City of Naturita has expressed considerable interest in the old millsite as the future location of a municipal golf course. The City owns the central portion of the site and is actively pursuing ownership or transfer of property at the north and south ends of the site, owned by Chemetall Foote Corporation. This mining company has not developed plans for their property and is currently considering transferring it to state or local government. DOE is facilitating discussions between the landowners to expedite this decision.

It is likely that the gravel mining operation upgradient of the former millsite will expand. This expansion could affect alluvial ground water flow in an increasingly pronounced manner. Withdrawal and evaporation of alluvial ground water would be expected to inhibit any natural flushing of the ground water system.

The Maupin family, who owns the downgradient vicinity property, plans to continue ranching. DOE would provide a drinking water well for their use.

7.6 Institutional Controls

Montrose County has agreed to apply a zone overlay for properties affected by contaminated ground water. This will prohibit the use of ground water for drinking purposes. Other potential uses, such as irrigation, may be permissible under this restriction. The IC boundary will overlay the TI zone on the east side of State Highway 141.

7.7 Future Monitoring

Monitoring is planned to ensure continued protection of human health and the environment. Monitoring wells DM1, NAT08, NAT26, MAU08, MAU07, the domestic well to be installed on the Maupin property, and surface locations 0531, 0538, and 0533 will be monitored for arsenic, uranium, and vanadium (Table 7–3, Figure 7–8). If DM1 is destroyed by expansion of the gravel operation, a suitable location for a new background well will be selected.

Table 7–3. Summary of Future Monitoring Requirements

Location	Monitoring Purpose	Analytes	Frequency
Well DM1	Background ground water	Arsenic, uranium, vanadium, TDS, field parameters	Annually for 5 years; afterwards every 3 years for 30 years
Well NAT08	Maximum V conc.		
Well NAT26	Maximum U conc.		
Well MAU08	U plume		
Well MAU07	Last well before ground water enters the San Miguel River		
Maupin water well	Only private well on site		
Surface 531	Upgradient San Miguel River		
Surface 538	Seep near San Miguel River		
Surface 533	Downgradient San Miguel River		

The sampling frequency is once every year for the first 5 years following NRC's acceptance of the Ground Water Compliance Action Plan. Thereafter, sampling would be conducted every 3 years for the next 30 years. During this period, the site will be evaluated at 5-year increments to determine if new or better remediation technologies could be used to expedite cleanup. The total duration of the monitoring is unknown at this time but may be up to 100 years.

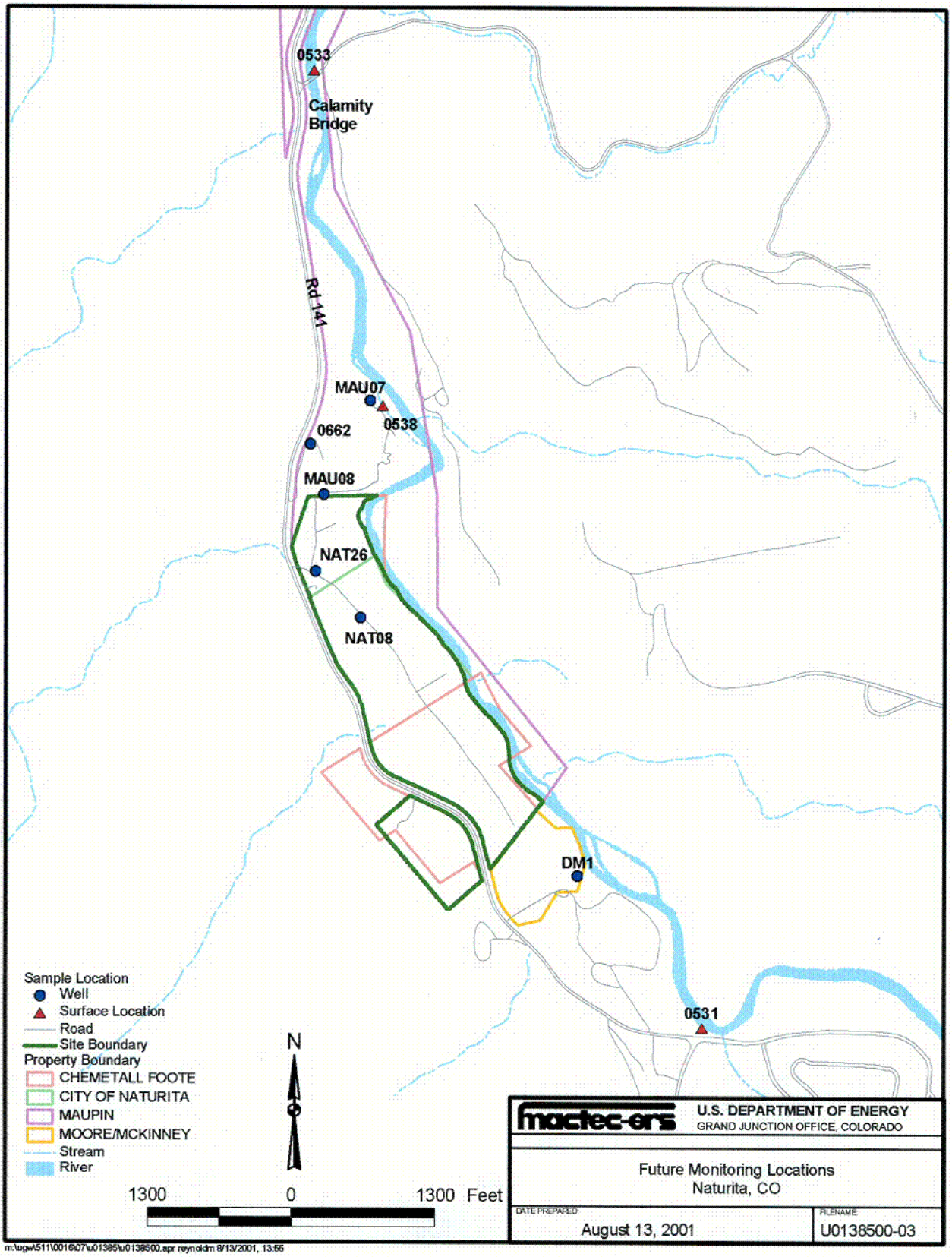

Figure 7–8. Future Monitoring Locations

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8.0 Development and Evaluation of Active Remediation Alternatives

8.1 Background Information

Tailings and other RRM have been removed from the Naturita site, first to extract uranium from the tailings, and second to mitigate exposure to contaminated soils. From 1977 to 1979, mill tailings were removed and taken to the Coke Oven site several miles south and leached to extract residual uranium. Surface remedial action was performed from fall 1994 until fall of 1998, when approximately 771,400 cubic yards of RRM was removed and placed in the Upper Burbank engineered repository near Uravan, 15 miles to the northwest.

Uranium dissolved in ground water beneath the former millsite has been migrating downgradient to the north and has begun to intercept the southern boundary of the adjoining vicinity property. The vanadium plume has not moved or has moved very little since milling ceased over 40 years ago. Transport modeling predicts that concentrations of uranium will require 135 years to reach the UMTRA MCL of 0.044 mg/L, and concentrations of vanadium will require more than 1,000 years to reach a human health risk-based concentration of 0.33 mg/L.

8.2 Area of the TI Application

The area of the TI application extends from the southern boundary of the site, past the northern site boundary, to a point where the vicinity property pinches out against the San Miguel River (Figure 8-1). Ground water exits the system into the San Miguel River at this northern terminus. For a detailed discussion, see Section 5, "Site Conceptual Model."

8.3 Cleanup Objectives that are Considered Technically Impracticable

Human heath and ecological risk assessments have demonstrated that there is currently no potential adverse impact to human health or the environment because of site-related contamination in ground water on or downgradient from the Naturita site. This situation is not expected to change in the future. The application of supplemental standards requires consideration of practicable corrective measures for controlling, reducing, mitigating, or eliminating ground water contamination. These include (1) conventional pump-and-treat technology, plus (2) the physical removal of RRM left on the site under surface supplemental standards application. These two active measures are compared with the no remediation alternative.

A permeable reactive treatment (PeRT) wall along the downgradient boundary of the site was considered to prevent off-site contaminant migration but was dismissed because the sorption rate differential between uranium and vanadium results in a lag of hundreds of years between the maximum concentrations of their respective plumes. In addition, ground water flow along the western side of the site is slower than along the eastern side, and a damming effect could result from high flows along the eastern side of a PeRT wall.

Pump and Treat

The most common approach to mitigating ground water contamination is an active ground water withdrawal and ex situ treatment process (commonly referred to as the pump-and-treat method). One or more pumping wells are typically installed to hydraulically capture the contaminant plume, and the water is pumped through some type of treatment system. The ground water must be treated until contaminant concentrations are below acceptable limits and the treated water can be reinjected or allowed to mix with surface water, or until concentrations are reduced so that natural flushing will decrease ground water contaminants to acceptable concentrations. This scenario is considered for the Naturita site. Pump-and-treat methods are typically time consuming and costly because of the complex nature of contaminant transport processes in heterogeneous media. Two methods—treatment with zero valent iron (ZVI) and distillation—will be discussed. Depending on the cleanup criteria, some pump-and-treat operations have not been able to meet their technical objectives because of heterogeneity and sorption characteristics of the aquifer matrix. Despite the potential shortcomings, it is still considered the baseline technology for a comparison of alternatives.

Evaporation as a treatment option was dismissed because this method would require a large evaporation pond, and no land in the nearby area is available for this purpose, assuming all current and future land use plans do not change.

Surface Remediation

Mill-related materials were left in place at some locations, both on and off site, through the application of supplemental standards during surface remediation. Though transport modeling for vanadium and uranium did not include this additional source material, its presence would further contribute to the inability to effectively perform ground water remediation. Therefore, removal of the remaining source material, especially in the areas left on site that are 1 ft below the water table and areas near the San Miguel River on site and on the vicinity property, would be required in addition to a pump-and-treat remedy.

No Remediation

An alternative to active remediation is no remediation in conjunction with an application for supplemental standards, based on Technical Impracticability, for vanadium and uranium. Since there is no current or projected risk to human health and the environment because of site-related contamination in ground water or surface water at the Naturita site, this alternative would comply with the ground water protection standards. Also, ground water in the uppermost aquifer is not a current or potential source of drinking water, and it is proposed that access to ground water will be prohibited by ICs.

8.3.1 Details of Pump and Treat

Pumping

A pumping scenario can often be formulated as a classical optimization problem. Optimization modeling problems inherently require considerable time and effort. Before developing an optimization model, DOE took a much simpler approach to determine if there was any reasonable possibility that this strategy would succeed.

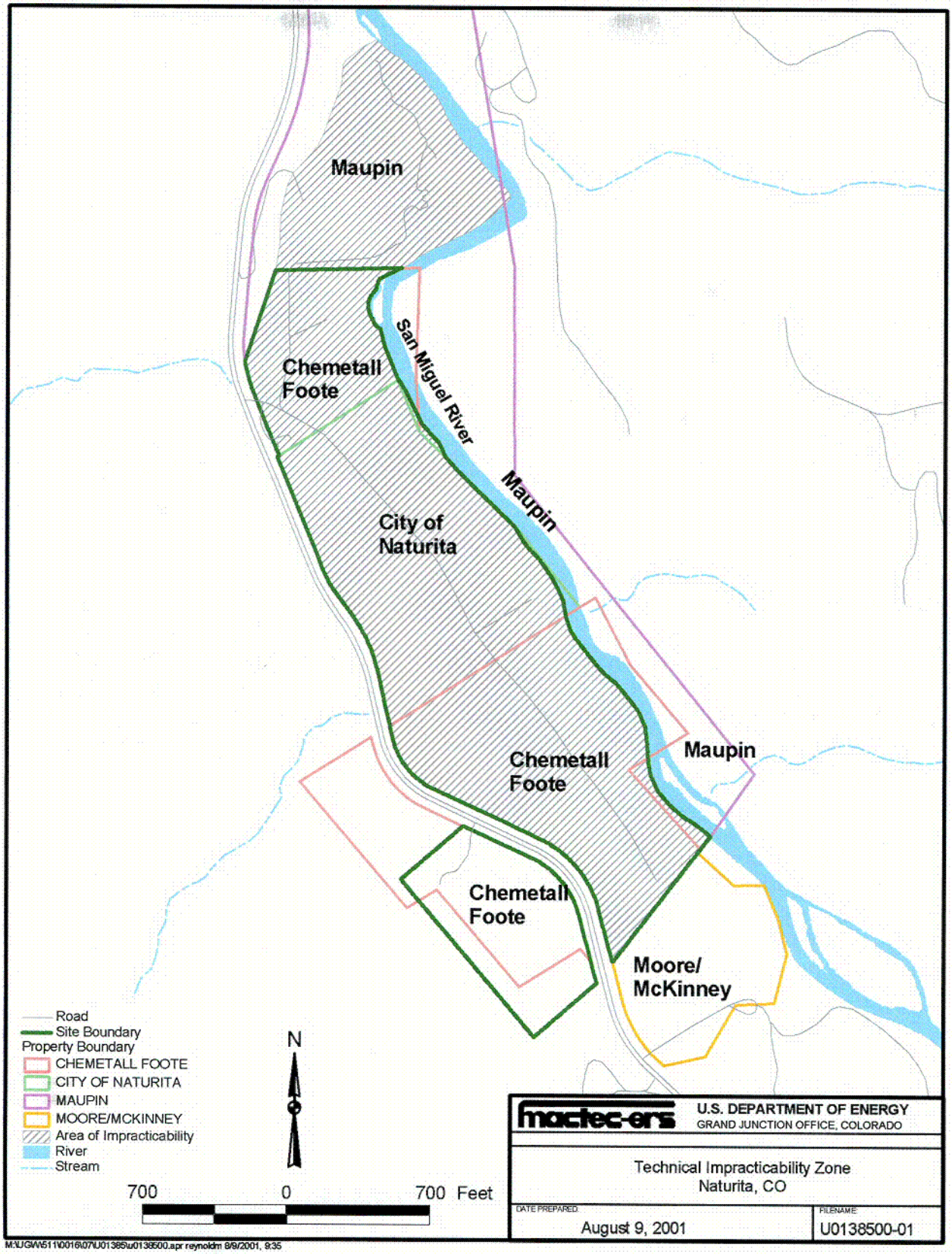

Figure 8-1. Technical Impracticability Zone

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Modeling the pumping of water from the shallow alluvial aquifer at the Naturita site presented the first unexpected problem of a pump-and-treat scenario. Details of the modeling are presented in Appendix F.

Four existing wells that show high concentrations of either uranium or vanadium were selected as potential pumping locations. These wells (MAU08, NAT01-1, NAT03, and NAT06-1) were to be pumped at the highest sustainable rate.

Modeling determined the maximum pump rate that could be sustained, with all wells pumped simultaneously, without drying up the area in the vicinity of any of the wells. These values are shown in Table 8-1.

Table 8–1. Maximum Simultaneous Pump Rates

Well	Pump Rate	
	Gpm	ft^3/day
MAU08	0.5	96.25
NAT01-1	5	962.5
NAT03	2	385.
NAT06-1	3	577.5

Three scenarios were modeled to determine if pumping could reduce the uranium levels to those required for natural flushing to complete the cleanup. Only the results of pumping each well at the maximum sustainable rate shown in Table 8-1 are presented here. Table 8-2 shows the maximum remaining concentration at selected years for natural flushing (i.e., no pumping) and the maximum pumping rate scenarios.

Table 8–2. Maximum Remaining Uranium Concentration

Years	Maximum Remaining Concentration (mg/L)			
	Natural Flushing	Run 1	Run 2	Run 3
0	2.5220	2.5220	2.5220	2.5220
5	2.4266	2.4358	2.4476	2.5043
10	2.3683	2.3797	2.3954	2.4873
15	2.2993	2.3285	2.3519	2.4594
25	2.0257	2.1147	2.1884	2.4077
50	1.3047	1.3527	1.4707	2.0998
60	1.0439	1.0400	1.1552	1.9028
70	0.78606	0.75038	0.85610	1.6842
80	0.55612	0.51044	0.60078	1.4563
90	0.37134	0.33101	0.40296	1.2332
100	0.23654	0.20698	0.26095	1.0258

The results were unexpected and somewhat counterintuitive. Intuitively, it would seem that if the aquifer is pumped, the maximum remaining concentration would decrease with time and would be less than if the aquifer were not pumped. However, the results predict just the opposite. As more water is extracted from the aquifer, the higher the maximum remaining concentration.

Two factors, the saturated thickness and the low hydraulic conductivity, are thought to cause the unexpected results. If pumping draws down the aquifer water level to the point that the aquifer around a well is almost dry, no water is moving through the aquifer matrix. All the water that

flows toward the well is extracted from the well. The cone of depression that develops around each well will leave much of the aquifer matrix dry. With no water moving through the aquifer near the well, contaminants remain adsorbed to the matrix.

If these modeling results are accurate, pumping for even 100 years will not reduce the concentration of uranium and vanadium to the required levels such that 100 years of natural flushing would complete the cleanup.

A possible solution to this pumping problem is some type of gradient manipulation. To achieve an effective solution, water would be introduced along the western side of the floodplain and would be allowed to percolate into the ground. Another possible aid would be irrigation of the floodplain as would be accomplished if a golf course were established on the site. A golf course has been proposed as a possible land use. Both scenarios were considered during initial modeling, but both were ultimately ineffective toward achieving contaminant concentrations that would allow natural flushing. The effectiveness of any form of gradient manipulation is complicated by water loss at the gravel mining operation and its influence on ground water flow. Nonetheless, some other form of gradient manipulation would be necessary to achieve effective pumping at the site.

Treatment by Zero Valent Iron

The most feasible treatment technology would use zero valent iron (ZVI) to reduce the uranium and vanadium concentrations in the ground water. Assuming that an adequate stream of contaminated ground water could be extracted from the aquifer, it would be pumped through a piping collection gallery to the treatment facility. Because of the cold climate, the treatment unit would need to be housed to prevent the extracted water from freezing.

A pilot study currently being conducted at the New Rifle UMTRA site near Rifle, Colorado, is using ZVI to treat vanadium contamination (DOE 2000). To date about 1.7 million gallons of ground water have been treated (K. Karp, personal communication, 2001). A treatment system similar to the one at Rifle could be used at Naturita. The treatment unit would consist of very fine grained ZVI filings (–6,100 mesh) inside of a steel tank. The ZVI would remove the uranium and vanadium in a reaction similar to the dynamics that occur in a PeRT wall. Uranium and vanadium are removed through reductive precipitation as the contaminated water contacts the ZVI. Because carbonates precipitate onto the ZVI and lower the iron's hydraulic conductivity, the ZVI filings need to be replaced periodically. Results from Rifle indicate that about 650 pounds of ZVI are required to treat 100,000 gallons of water. One pore volume of contaminated water for the uranium plume (which is larger than the vanadium plume) is estimated to be 22,700,000 gallons, requiring about 35,000 pounds of ZVI for treatment.

Cleanup may require several pore volumes, especially for the smaller vanadium plume, which is estimated to be 9.5 million gallons. (A pore volume is only one method to estimate the amount of water to be treated. In reality, many pore volumes would need to be withdrawn from a small radius around extraction wells before other areas of the plume contribute sufficient contaminant mass to reduce the total contaminant load.)

Results of Phase I of the Rifle pilot test are not yet final, but Figure 8-2 shows a time/ concentration plot for the action, and the results to date compared to predicted values. The rate at which uranium and vanadium are removed from the ground water depends on the constituent's K_d. The three predicted curves in Figure 8-2 show the anticipated decreases in vanadium concentration over time using several K_d values. A K_d value of 4.9 mL/g was the average value determined for the Rifle site; other values were used for comparison. The actual decrease in vanadium concentration (from an extraction well sampled in the plume) was matching the predicted values, at a K_d of 4.9 mL/g, until about 7 months into the test. At this time, these values stopped decreasing and showed a slight increasing trend. The reason for this trend is not yet understood, but could result from spring runoff raising the water table and mobilizing vanadium, or pumping could be intersecting a different part of the plume, or some other factor.

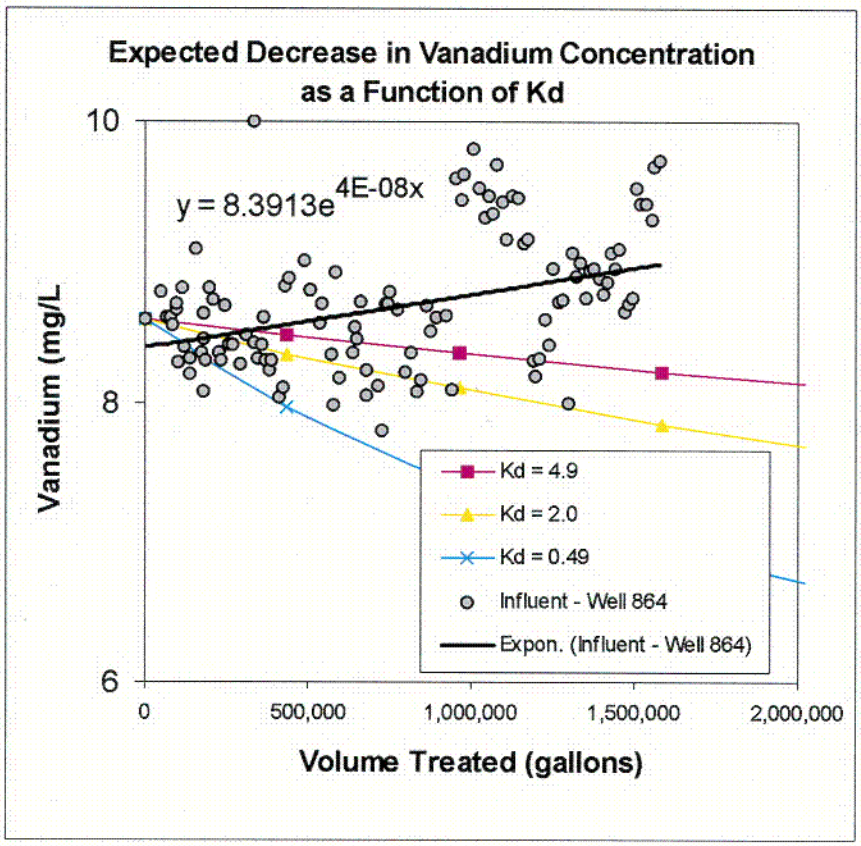

Figure 8-2. Time-Concentration Plot

At this time and without additional information, it is conservatively estimated that if vanadium behavior at Naturita is similar to the Rifle site, at least six pore volumes would need to be removed from the Naturita uranium/vanadium plume before the system would naturally flush to acceptable concentrations. This is the volume used in estimates at other sites and is the volume on which cost estimates are based. Spent ZVI would be treated as RRM and would be transported to the Cheney Disposal Cell near Grand Junction.

Treatment by Distillation

Alternatives evaluations for other UMTRA sites typically include distillation as one of the treatment alternatives. This method recovers more treated water than any other technology, and the treated water is of higher quality than that produced by any other technology. Volumes of water to be treated are the same as those for the ZVI alternative.

In a simple distillation process, water is vaporized by heating it to its boiling point. The water vapors are then condensed and recovered as clean water. Nonvolatile contaminants such as nitrates, sulfates, uranium, vanadium, and other components of TDS will not evaporate. Instead, they concentrate in the evaporation chamber and must be removed at an appropriate rate. If no volatile contaminants are present, the condensed water will be of high quality and can be used for nearly any purpose. The concentrate, or brine, may be taken off site for disposal; or, it may be evaporated to dryness, and the residue can then be disposed of as a solid.

Distillation is an expensive treatment technology to implement because of the significant capital costs of distillation equipment. However, distillation does recover almost all the water, and the product water is of high quality. Because the Naturita ground water does not contain volatile contaminants, the condensate from a distillation system would be of such high quality that the concentrations of contaminants would be orders of magnitude below regulatory standards for drinking water.

Commercial distillation units are self-contained and include all instrumentation required for monitoring and controlling the operation. The units are designed for outdoor operation, and no building is required other than the control building for the operators.

In general, commercial distillation systems are reliable and require a low level of oversight and only scheduled maintenance during their operating life. Operation of the distillation system would require a minimum of managerial and technical supervision. The acid pretreatment system can operate unattended, although periodic replenishing of the acid would be required. The cost estimate for operation of the distillation system allows for two full-time employees 7 days a week on day shift for operation and maintenance.

For optimal performance, the distillation system should be operated as continuously as possible. However, it is expected that the flow rate produced by the extraction system would be variable. To dampen variations in the extraction rate and produce a constant flow rate of feed to the distillation unit, a feed tank of approximately 10,000-gallon capacity would be erected at the site immediately adjacent to the treatment unit. Water from the extraction system would flow into the feed tank, and the distillation unit would take its feed from the tank; the level in the feed tank would be allowed to vary as needed.

The distillation process generates concentrated brine continuously. The brine discharged from the distillation unit is expected to contain no more than about 10-percent suspended solids. Because a 10-percent solids-loading is low enough that disposal is impractical without further concentration, the brine must be evaporated to dryness. Preliminary calculations indicate that a small, spray-enhanced solar evaporation pond would be more cost-effective than a larger solar evaporation pond for this purpose.

The proposed location of the distillation unit is somewhere on the southwestern flank of the site, above the 500-year flood level. It should be in an area that would not conflict with proposed future land use because it will be in place for an estimated 10 years. The location of the evaporation pond is problematic. Its size should be minimized, and its location would probably be on the site toward the south end.

Limiting Factor for ZVI and Distillation Remedies

Extraction of vanadium contamination from the subsurface is extremely difficult. The high K_d for this constituent causes it to be tightly adsorbed to the substrate and requires large amounts of water to flush through the system before it is removed. Other methods of vanadium extraction may be tried at the Rifle test, but analysis of the current test suggests that pumping will be required for an indeterminate time. The unknown duration of pumping required to remove vanadium from the alluvial system is the single most important factor of this TI proposal.

8.3.2 Details of Surface Remediation

During surface remediation from 1994 to 1998, approximately 771,400 cubic yards of RRM was removed to the Upper Burbank Repository near Uravan (DOE 1998). This material originated from 52 acres on the site, 195 acres off the site from windblown areas, and at least 11 acres from the contiguous vicinity property to the north. An estimated 93,602 cubic yards of RRM was removed from this vicinity property (DOE 1999). However, a large amount of RRM was left on site and on the adjacent vicinity property.

Table 8–3 lists the five general areas where RRM was known to be left on site and on the vicinity property under applications for supplemental standards (DOE 1998b) (Figure 8–3). The rationale for leaving the materials in place is specific to each application but generally includes (1) low radiological hazard, (2) increased risk of injury to workers along steep slopes and near high voltage lines, (3) environmental harm to wetland areas, and (4) low radiological hazard from contaminants remaining below the water table and associated high cost of pumping, storing, and treating contaminated water. The rationale for leaving contamination on the vicinity property adjoining the millsite, downgradient and to the north, was the same as (1), (2), and (3) above, but the property owner also requested that mature trees on the property along the river be left undisturbed (DOE 1999).

Table 8–3. Surface Supplemental Standards Areas and Volumes

Area	Description	Area (acres)	Volume (cubic yards)
Area A	On site, steep slopes	6.5	5,243
Area B	Wetland areas along the river	1.1	4,350
Area C	Steep areas along the highway	0.2	190
Area D	Power poles	0.2	1,260
Area E	On site, >1 ft below the water table	0.4	1,200
Vicinity Property	Near the San Miguel River	5.1	50,000[a]

[a]Based on an estimate from the vicinity property completion report. All RRM remaining was estimated at 37,520 cubic yards, and because the volume removed was twice the estimate, 75,000 cubic yards is probably left. This is considered a conservative volume estimate. A small part of this volume is along the highway and most is in the floodplain.

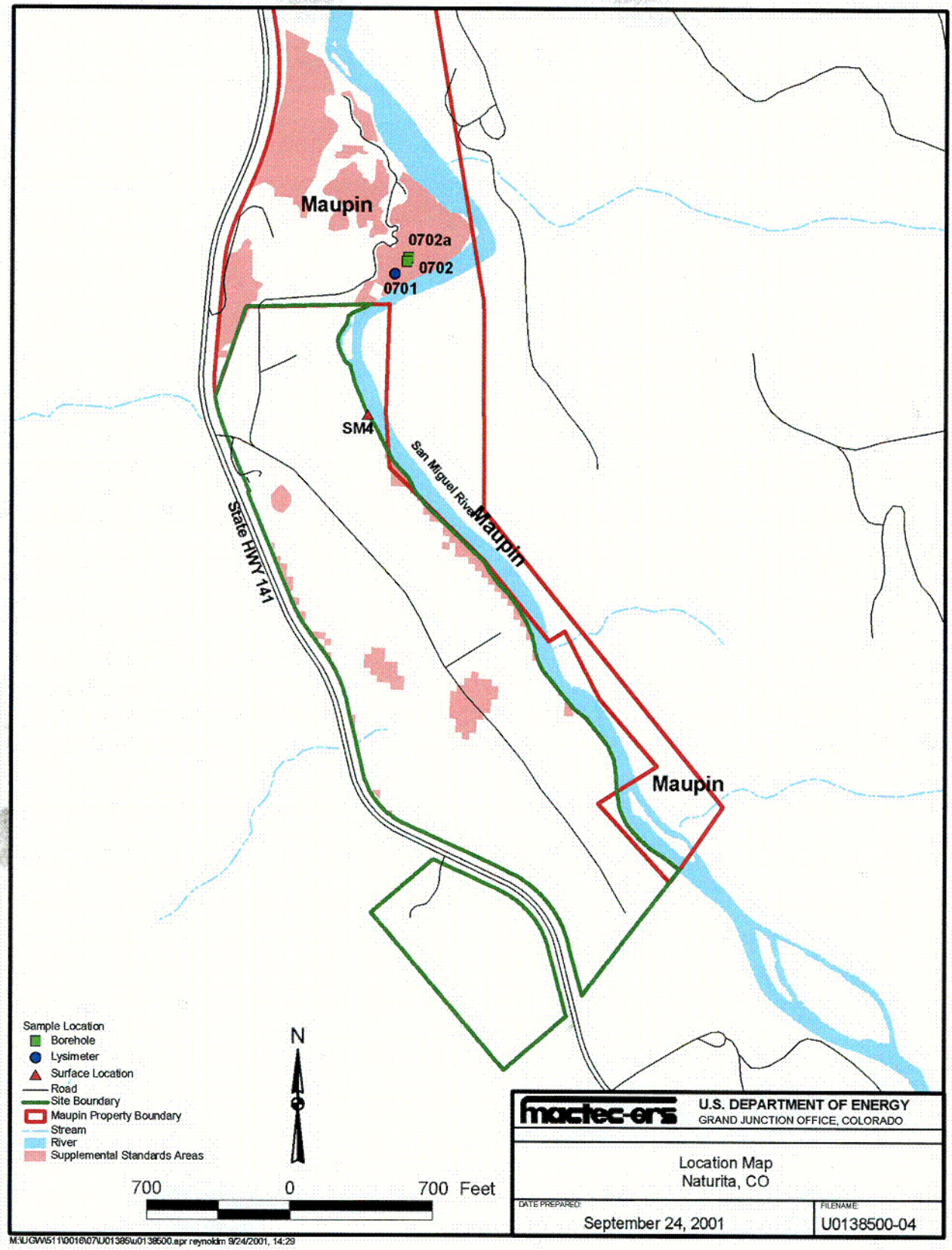

Figure 8-3. Locations of Surface Project Supplemental Standards

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The proposed surface action would invoke criterion (b) in 40 CFR 192.21, Criteria for Applying Supplemental Standards, whereby "... remedial actions... would directly produce health and environmental harm that is clearly excessive compared to health and environmental benefits, now or in the future..." In other words, the same criteria for leaving RRM under application of supplemental standards 3 years ago would still apply. The potential danger to laborers working along the high voltage power line still exists, the potential harm to riparian areas and habitats along the San Miguel River has not changed, and the low risk to people and the environment from contaminated ground water associated with the RRM is still low and is expected to remain low. Also, the owner of the vicinity property would still like to preserve the trees along the San Miguel River.

If the material were removed, the Cheney Disposal Cell, located 105 miles from the site, would be the repository for the 57,000 cubic yards of tailings from the site and vicinity property. The truck haul along Colorado Highway 141 to the Cheney Disposal Cell presents an additional hazard. This is a standard 24-ft-wide highway, which is also a scenic byway, that passes through 40 miles of deep, sinuous, redrock canyons, heavily traveled by tourists. The estimated number of loads from standard 22-cubic-yard belly-dump trucks is 2,600 round trips. This translates into an estimated 23,400 highway hours assuming a 9-hour round trip, or 546,000 miles assuming a 210-mile round trip. Based on tables from the U.S. Department of Transportation (DOT 1999), this might be expected to cause 0.01 fatal accidents and 0.4 injuries to people driving the large trucks in average terrain. This estimate does not account for persons in passenger cars or other vehicles that might be associated with potential accidents and does not account for permitting and permission from the State of Colorado to haul RRM along this stretch of highway. Hazards presented by transporting the tailings support the application of supplemental standards to the contaminated materials remaining on site and on the vicinity property.

8.3.3 No Remediation

This alternative would require few additional activities at the site. Monitoring as a best management practice would be continued. Institutional controls, also as a best management practice, would be imposed to prevent access to contaminated ground water for drinking purposes. Providing the landowner downgradient of the site with a reliable source of drinking water is proposed to ensure a safe source of domestic water.

8.4 Site Conceptual Model

The Site Conceptual Model is discussed in Section 5 of this SOWP. It covers topics such as geology, hydrology, ground water contamination sources, and contaminant fate and transport.

8.5 Evaluation of "Restoration Potential" of the TI Zone

EPA's *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (EPA 1993b) discusses "Restoration Potential" for RCRA sites, and further EPA guidance (EPA 1996b) discusses relevance to CERCLA sites. Figure 8-4 shows a flow diagram from EPA's guidance that shows factors contributing to the restoration potential of an aquifer. The two factors most relevant to ground water at Naturita are the Chemical Properties and Hydraulics/Flow.

Modeling results indicate that pumping at strategic wells within the plumes for vanadium and uranium will decrease the mobility of the constituents. This is because the saturated zone of the alluvial aquifer (where the contamination is located) is thin, and removal of water will decrease the degree of saturation in the plume and thereby decrease the desorption rate of remaining uranium. Modeling indicates that pumping for 100 years will still not remove adequate uranium to allow natural flushing to achieve the UMTRA MCL of 0.044 mg/L in 100 years, after remedial action is completed. A possible remedy is to add additional water to the aquifer by some form of gradient manipulation. However, vanadium is tightly sorbed to soils and this enhancement to ground water flow may still not be feasible for vanadium removal.

Other issues such as source control measures, remedial action performance appraisal, restoration time frames analysis, other applicable technologies, and additional considerations are discussed in Sections 8.2 and 8.8.

8.6 Estimated Costs

Cost estimates are provided in this section for pumping, treatment by ZVI, treatment by distillation, additional surface remediation, and no remediation.

8.6.1 Pump and Treat

Pumping

Regardless of whether treatment is by distillation or by ZVI, pumping and gradient manipulation systems would be required to effectively remove ground water. A system of four 4-inch-diameter 15-ft-deep extraction wells with pumps, associated electrical infrastructure, and buried piping would be required to remove contaminated water from the ground to a treatment facility on the southwestern portion of the site. The estimated cost, based these elements and engineering support, is $125,000.

An additional cost of pumping would be gradient manipulation of the aquifer to successfully extract contamination from the floodplain. The simplest method to achieve this would be diversion of water from the San Miguel River to a channel along the base of the scarp on the west side of the site. The infiltration zone would need to extend from the southern end of the site to a point near the northern terminus in the vicinity property (Maupin property) where the floodplain intersects the river. This is about 6,000 ft of infiltration trench. Costs of engineering and construction are estimated to be $250,000.

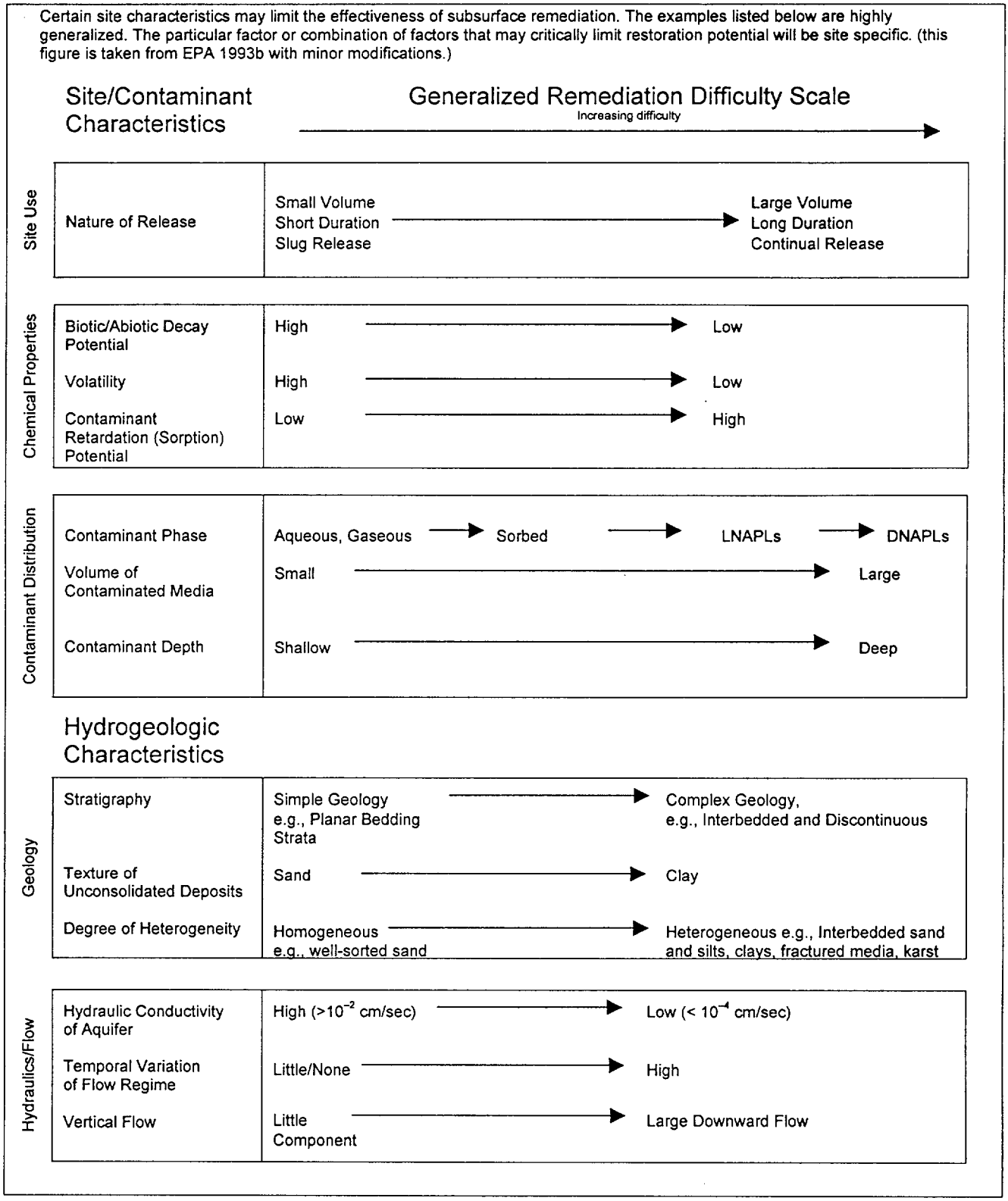

Figure 8-4. Flow Diagram

Discussions with the Colorado State Engineer's Office and the U.S. Army Corps of Engineers would be held to determine the need for a permit to withdraw water from the San Miguel River and to evaluate the substance of a 404 Nationwide Permit. Work plans, permitting, and discussions with key regulators are estimated to cost $50,000.

The costs for pumping the gradient manipulation are shown with the discussions of Treatment by Distillation and Treatment by ZVI. See Table 8–4 and Table 8–5.

Treatment by Distillation

The cost estimate for this analysis includes

- Remedial design/permitting/procurement/construction management; includes preparing permits for discharge to the river, developing a hydrologic model of the plume, bidding and awarding a contract, and construction oversight of subcontractors hired to install the system.
- Construction of a 1.5-acre evaporation pond.
- A treatment facility— garage style building, electrical controls, distillation system, associated piping and valves.
- Operation and maintenance costs: utilities for the building, electricity for well pumps, part-time labor to operate the system, and professional labor to assess the plume.
- Monitoring and sampling costs: labor to sample the wells and discharge effluent and analytical laboratory costs.

Table 8–4 shows a summary breakdown of the cost estimate for the distillation option. Operating and monitoring costs are shown as the present worth value of operating the system for 10 years.

Table 8–4. Cost Estimate for Pump and Treat, Distillation Operation

Item	Cost
Remedial design/permitting/construction management	$150,000
Well installation/piping/permitting	$125,000
Gradient manipulation/permitting	$300,000
Treatment facility	$2,500,000
Operation and maintenance (10 years at $82,000/yr)	$820,000
Monitoring/sampling costs (10 years at $1,500/yr)	$15,000
Subtotal	$3,910,000
Contingency @ 30%	$1,173,000
Total cost	$5,083,000

Treatment by ZVI

The cost estimate for this analysis includes

- Remedial design/permitting/construction management; includes preparing permits for discharge to the river, developing a hydrologic model of the plume, and construction oversight of subcontractors hired to install the system.
- Well installation and piping—includes well development, vaults, electrical service to each well, and discharge piping from the wells to the treatment facility.
- Treatment facility—garage style building, electrical controls, steel tank containing ZVI filings, 10-year supply of ZVI, piping, and valves.
- Operation and maintenance costs: utilities for the building, electricity for well pumps, purchase and disposal of ZVI, part-time labor to operate the system, and professional labor to assess the plume.
- Monitoring and sampling costs: labor to sample wells and discharge effluent and analytical laboratory costs.

Table 8–5. Cost Estimate for Pump and Treat, ZVI Operation

Item	Cost
Remedial design/permitting/construction management	$150,000
Well installation/piping/permitting	$125,000
Gradient manipulation/permitting	$300,000
Treatment facility	$800,000
Cost of ZVI @ $0.40/pound (@ 650 lb/100,000 gallons for 80 million gallons	$208,000
Operation and maintenance (10 years at $50,000/yr)	$500,000
Monitoring/sampling costs (10 years at $1,500/yr)	$15,000
Subtotal	$1,915,000
Contingency @ 30%	$574,500
Total cost	$2,672,500

Vanadium Removal

This analysis applies for a 10-year period, a normal and reasonable duration for active treatment of most ground water problems. The actual duration required to pump and treat vanadium is unknown at this time. Results from the Rifle pilot test are incomplete. Therefore, the costs for distillation or ZVI treatment could be many times the amount shown in this analysis.

8.6.2 Surface Remediation

Removing remaining source material would be required in addition to one of the pump and treat scenarios if the ground water restoration is to be successful. The estimated cost of removing the source material is based on an extrapolation of costs from previous surface removal and also includes the cost of hauling RRM to the Cheney Disposal Cell near Grand Junction. The time

that would be spent acquiring Department of Transportation permits and dealing with political issues of moving RRM along a scenic byway are difficult to calculate.

The best information about the costs of removing RRM is from the Naturita vicinity property completion report (DOE 1999b). The cost estimate was based on partial removal of RRM from the open areas. Supplemental standards were used to justify leaving RRM along the river and along steep slopes of the highway. The estimated cost to remove this "easily accessible" RRM was $1,567,000 based on removal of 56,690 cubic yards of contaminated materials (the estimated remaining volume was 37,520 cubic yards). The actual volume of material removed was 93,602 (DOE 1999b). The volume of RRM removed was twice the estimated volume and nearly equal to the total estimated volume of tailings at the site under a complete removal scenario (94,210 cubic yards), which had an estimated cost of $4,492,000. Therefore, an estimated cost to remove the remaining tailings from the site could be between $4.5 million and $9 million. This range is based on (1) doubling the estimated volume of remaining tailings, (2) greater difficulty in accessing and removing the remaining RRM, the increased cost of moving the material to the Cheney Disposal Cell instead of the cell at Uravan (an estimated $40/cubic yard transportation cost for an estimated 75,000 cubic yards = $3,000,000), and (4) inflation of 3.3 percent per year since 1996. This cost would probably be closer to the higher estimate because of the labor intensive methods required for removing tailings from the steep embankments along the highway and the costs of dealing with political issues of transporting RRM along the highway. Even the removal of materials only along the San Miguel River could be close to the lower number because the depth of tailings is greater than originally estimated. The estimated total cost of removing RRM from the vicinity property floodplain is $7,000,000.

The cost of cleaning up the wetland area along the millsite would probably be about one fifth the cost for the vicinity property because the wetland has approximately one fifth the area (48,627 square feet versus 221,129 square feet). Therefore, the cost might range from $900,000 to $1,800,000. If the riprap along the river and flood control dike were replaced, the cost might be closer to this higher number. The estimated cost of cleaning up the wetland is $1,200,000.

The cost of digging up RRM below the water table in the 0.4-acre area on site considers removal and storage of about 4,000 cubic yards of clean fill, excavation of RRM for an additional 3 ft below the water table to include a minimum of 1,800 cubic yards of RRM, drying saturated RRM sediments before shipment, piping and treatment of contaminated water through the same ZVI facility discussed in Section 8.6.1, and transportation of RRM to the Cheney Disposal Cell. These estimated costs are shown in Table 8–6.

Table 8–6. Estimated Costs for Removal of RRM from 1 Ft Below the Water Table on the 0.4 Acre Area

Description	Cost
Excavation of 4,000 cy clean fill ($10/cy)	$40,000
Excavation of 1,800 cy of RRM (+10%) ($12/cy)	$24,000
Drying (windrow) of 1,800 cy of RRM before shipment ($10/cy)	$18,000
Pumping/piping system to treatment facility for contaminated ground water	$20,000
Transportation of 1,800 cy (+10%) RRM to disposal cell @ $40/cy	$79,000
Haul clean fill and place in site (1,980 cy @ $15/cy)	$30,000
Contingency at 30%	$63,000
Total cost	$274,000

cy = cubic yard

The cost of removing RRM left around power poles would be similar to the previous estimate except for treatment of contaminated water. Table 8–7 shows the cost breakdown.

Table 8–7. Cost Breakdown of Removing RRM Left Around Power Poles

Description	Cost
Excavation of 1,260 cy of RRM (+10%) ($12/cy)	$17,000
Transportation of 1,260 cy RRM (+10%) to disposal cell at $40/cy	$55,000
Haul clean fill and place in site (1,260 cy +10% @ $15/cy)	$21,000
Contingency at 30%	$30,000
Total cost	$123,000

cy = cubic yards

The total cost for removing RRM from the site and the vicinity property is summarized in Table 8–8.

Table 8–8. Total Cost for Removing RRM

Description	Cost
Vicinity property	$7,000,000
Wetlands	$1,200,000
Greater than 1 ft below ground water	$274,000
Power poles	$123,000
Total	$8,597,000

Total Costs for Pump and Treat and Remediation alternatives

The total costs for both cleanup strategies are shown in Table 8–9.

Table 8–9. Total Cost for Both Cleanup Strategies

Description	Cost
Pump and treat, distillation	$5,083,000
Surface remediation	$8,597,000
Total	**$13,680,000**
Pump and treat, ZVI	$2,489,500
Surface remediation	$8,597,000
Total	**11,086,500**

8.6.3 No Remediation

Few costs are associated with the no remediation alternative. Monitoring of ground water at several monitoring wells and surface water locations along the San Miguel River would be ongoing. The estimated cost for six samples, collected once per year, for 5 years and subsequently every 3 years for the following 30 years, and analyses for the three COPCs is $1,500 per sample round, or $22,500.

A second, one-time cost would be the installation of a drinking water well for the family in the adjoining vicinity property. This area is or will be in the plume migrating off the site, and the occupants currently haul water from a public source in Naturita. The well would be drilled into potable water in the Entrada Formation approximately 600 ft below the surface. The cost includes drilling, completion, development, and plumbing of a well for drinking water into the home. The estimated cost is $25,000.

8.7 Description of the Alternative Remedial Strategy

8.7.1 Introduction

If TI is appropriate at a site, implementation of an alternate remedial strategy is still required.

The *Handbook of Groundwater Policies* (EPA 2000b) cites several criteria necessary for implementing a successful alternative remedial strategy. The strategy must be protective of human health and the environment and should

- Be technically practicable.
- Control the sources of contamination and prevent migration of contamination beyond the zone associated with the technical impracticability determination.
- Achieve the ground water objectives outside the zone associated with the technical impracticability.
- Be consistent with the overall cleanup goals for the facility.
- Demonstrate that monitoring will be protective of human health and the environment for a length of time needed.
- Demonstrate that the TI will show protection for current and future ground water use.

A successful TI demonstration also shows how conditions at a facility prevent the achievement of ground water cleanup objectives. This is based partly on the high costs compared to the benefit of performing ground water cleanup.

The two active corrective action alternatives evaluated for the Naturita site are (1) a conventional pump-and-treat scenario based on a ZVI collection gallery and a distillation process for active cleanup of the aquifer, and (2) surface remedial action to remove uranium and vanadium from ground water. If the cost of implementing a corrective action is greater than the benefits of the outcome, the alternative may be inappropriate or inefficient. The costs for implementing a pump-and-treat system using distillation with surface remediation is approximately $13.7 million (for 10 years); the cost of implementing a pump-and-treat system using ZVI and surface remediation is approximately $11 million (for 10 years). Current and future risks to human health and the environment are minimal and are lower than the risk to workers that would result from implementing these remedial actions.

Based on current and predicted conditions at the Naturita site and evaluation of alternatives, the preferred alternative is no remediation and implementation of supplemental standards based on criteria (b) and (f) of 40 CFR 192.21.

8.7.2 Alternative Remedial Strategy

The alternative remedial strategy proposed for the Naturita site is to restrict access to ground water in the TI area and to continue monitoring to ensure that no harm is occurring to humans and the environment. The TI zone, shown in Figure 8–1, follows the site boundary and extends northward into the vicinity property (Maupin property). There it is bounded on the east by the San Miguel River and on the west by the outcrops of bedrock until they intersect the San Miguel River to the north. The owners of property in the TI zone are Chemetall-Foote (a mining company), the City of Naturita, and the Maupin family. DOE would request that Montrose County provide a zone overlay of the TI zone to exclude use of ground water for human consumption. Discussions have already begun with the County. DOE will also facilitate transfer of Chemetall-Foote's property to Montrose County. These discussions have also begun. Members of the Maupin family are living in the TI zone. Currently, they haul drinking water from a city well in Naturita. Part of their property within the zone will receive the proposed zone overlay and they would not be able to drill a domestic well in the alluvial aquifer. Therefore, DOE proposes to drill a deep well into pristine water about 600 ft beneath the site and provide the family with a clean source of drinking water. An upward hydraulic gradient in the underlying Brushy Basin sediments would prevent any downward migration of contaminants. Monitoring would be conducted annually for the next 5 years and every 3 years after that for the next 30 years. During this time, DOE would conduct a review approximately every 5 years to determine if new or modified technologies have been developed that might be used to expedite site cleanup. Monitoring will continue past the 35-year period until concentrations of uranium and vanadium demonstrate they are decreasing to acceptable levels or until another strategy is adopted. Acceptable levels are defined as 0.044 mg/L for uranium and 0.33 mg/L for vanadium. According to modeling, this could require up to 135 years for uranium and more for vanadium.

Contaminants will not migrate beyond the TI zone because (1) the San Miguel River provides effective flushing and prevents eastward migration, (2) impermeable bedrock mudstones from the Brushy Basin Member of the Morrison Formation are effective barriers to westward migration, and (3) the upward hydraulic gradient in the Brushy Basin sediments beneath the site prevent downward migration. Ground water flow is to the north and east; therefore, contaminants eventually flush into the San Miguel River to the east and finally to a point where the bedrock intersects the river at the northern end of the site.

Ground water outside of the TI zone is not contaminated from past milling activities and no action is required beyond the TI zone.

The cleanup goal for arsenic, the other COPC, is 0.05 mg/L. Arsenic will naturally flush to acceptable levels in less than 100 years and is not part of this TI application.

Monitoring is planned to ensure continued protection of human health and the environment. Section 7 presents the details of the monitoring plan. Monitoring wells DM1, NAT08, NAT26, MAU08, MAU07, and the domestic well to be installed on the Maupin property along with surface locations 0531, 0538, and 0533 will be monitored for arsenic, uranium, and vanadium. DM1 is a background ground water location; if it is removed by expansion of the gravel mining

operation, a suitable location will be selected for installation of a new background well. NAT08 contains the maximum vanadium concentration (2.47 mg/L), NAT26 contains the maximum uranium concentration 2.39 mg/L, MAU08 shows the maximum northern concentration for uranium, and the proposed Maupin well will be monitored to verify that no contaminants have migrated into the deeper aquifer. Surface location 0531 is upgradient on the San Miguel River, 0538 is a seep on the Maupin property, and 0533 is the downgradient location on the San Miguel River.

The strategy will be protective of current and future water use. Currently, there is no use of the ground water in the TI zone. Calculations in the 1995 BLRA (DOE 1995) considered the effect of contaminated ground water seeping into the San Miguel River. The highest concentrations of contaminants were used in the calculation and were assumed to attenuate slightly before they entered the river near surface location 0538. A statistical 20-year low flow for the river was also used in the estimate. Results showed that increases of COPC concentrations in the river water were 0.00002 mg/L arsenic, 0.001 mg/L uranium, and 0.002 mg/L vanadium. These increases are insufficient to cause an increase in ecological risks. The City of Naturita and Montrose County are considering construction of a golf course on the site if adequate land is obtained. This is only in the discussion stages at this time, and the proposed zone overlay would prevent anyone from using ground water under the TI zone for drinking purposes. One family is living in the area of contaminated ground water. They haul water from a public water source in Naturita. DOE proposes to drill and install a well for the family as a permanent source of drinking water.

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