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Engineering Evaluation/Cost Analysis for the Proposed Management of Contaminated Water in the Weldon Spring Quarry

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January 1989

prepared by

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prepared for

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FOREWORD

This engineering evaluation/cost analysis (EE/CA) report has been prepared to support the proposed removal action for management of contaminated water in the Weldon Spring quarry, located near Weldon Spring, Missouri. The water became chemically and radioactively contaminated as a result of contact with various wastes that were disposed of in the quarry between 1942 and 1968. The U.S. Department of Energy is responsible for cleanup activities at the Weldon Spring site, which includes the quarry, under its Surplus Facilities Management Program (SFMP). The major goals of SFMP are to eliminate potential hazards to the public and the environment that are associated with contamination at SFMP sites and to make surplus real property available for other uses, to the extent possible.

The EE/CA report is required to document the proposed removal action because the action is a non-time-critical response (i.e., it need not be implemented within 6 months). This requirement is identified in guidance from the U.S. Environmental Protection Agency (EPA) that addresses removal actions at sites subject to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986. Actions at the Weldon Spring quarry are subject to CERCLA requirements because the site is listed on EPA's National Priorities List.

The objectives of the EE/CA report are to identify the cleanup as a removal action, to document the selection of response activities that will mitigate the potential for release of radioactive or chemical contaminants from the quarry water into the nearby environment, and to address environmental impacts associated with the proposed action. Pursuant to the evaluation of potential alternatives in this report, it is proposed that the water be pumped from the quarry pond to a newly constructed treatment plant for removal of the contaminants of concern. This removal action is necessary for and consistent with the overall response action being planned to minimize potential threats to the public and the environment associated with the current contamination at the quarry.

NOMENCLATURE

The following is a list of the acronyms, initialisms, and abbreviations (including units of measure) used in this document.

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
ARAR	applicable or relevant and appropriate requirement
As	arsenic
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended
DNR	(Missouri) Department of Natural Resources
DNT	dinitrotoluene
DOE	U.S. Department of Energy
EE/CA	engineering evaluation/cost analysis
EPA	U.S. Environmental Protection Agency
GAC	granular activated carbon
GW	groundwater (monitoring well)
ICRP	International Commission on Radiological Protection
k	hydraulic conductivity
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MKT	Missouri-Kansas-Texas (railroad)
Mn	manganese
MSL	mean sea level
MW	monitoring well
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act of 1969, as amended
NESHAP	National Emission Standards for Hazardous Air Pollutants
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
O&M	operation and maintenance
OSHA	Occupational Safety and Health Act
PAC	powdered activated carbon
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
pH	negative logarithm of the hydrogen ion concentration
r	radius
RCRA	Resource Conservation and Recovery Act of 1976, as amended
RMW	St. Charles County monitoring well
R.R.	railroad
SARA	Superfund Amendments and Reauthorization Act of 1986
SFMP	Surplus Facilities Management Program
SPCC	Spill Prevention, Control and Countermeasures
SS	suspended solids

ACRONYMS, INITIALISMS, AND ABBREVIATIONS (Cont'd)

SW	surface water (monitoring well)
TBC	to-be-considered (requirements)
TNT	trinitrotoluene
U	uranium
UMTRCA	Uranium Mill Tailings Radiation Control Act
USGS	U.S. Geological Survey
WS	Weldon Spring (monitoring well)
WSS	Weldon Spring Site
WSSRAP	Weldon Spring Site Remedial Action Project

UNITS OF MEASURE

°C	degrees Celsius
cc	cubic centimeter(s)
Ci	curie(s)
cm	centimeter(s)
ft	foot (feet)
g	gram(s)
gal	gallon(s)
gpd	gallon(s) per day
gpm	gallon(s) per minute
h	hour(s)
ha	hectare(s)
Hz	hertz
in.	inch(es)
km	kilometer(s)
L	liter(s)
μCi	microcurie(s)
μg	microgram(s)
m	meter(s)
mCi	millicurie(s)
mg	milligram(s)
mgd	million gallon(s) per day
mi	mile(s)
mL	milliliter(s)
MPa	megapascal(s)
mph	mile(s) per hour
pCi	picocurie(s)
ppb	part(s) per billion
ppm	part(s) per million
psi	pound(s) per square inch
rem	roentgen equivalent man
s	second(s)
V	volt(s)
yd	yard(s)
yr	year(s)

1 SITE CHARACTERIZATION

1.1 SITE DESCRIPTION

The Weldon Spring site is located near Weldon Spring, Missouri, about 48 km (30 mi) west of St. Louis (Figure 1). The site consists of two noncontiguous areas: (1) the raffinate pits and chemical plant area and (2) the quarry. The raffinate pits and chemical plant are about 3.2 km (2 mi) southwest of the junction of Missouri (State) Route 94 and U.S. Route 40/61. The quarry is located about 6.4 km (4 mi) south-southwest of the raffinate pits and chemical plant area and about 8 km (5 mi) southwest of the city of Weldon Spring in St. Charles County, Missouri. Both the raffinate pits and chemical plant area and the quarry are accessible from State Route 94 and are fenced and closed to the public.

The Weldon Spring quarry was excavated into a limestone ridge that borders the Missouri River alluvial floodplain; prior to 1942, it was mined for limestone to support various construction activities. The quarry is about 300 m (1,000 ft) long and covers approximately 3.6 ha (9 acres). The floor and rim of the quarry are at elevations of about 146 and 170 m (480 and 550 ft) mean sea level (MSL), respectively. The main floor of the quarry covers approximately 0.8 ha (2 acres) and contains ponded water covering about 0.2 ha (0.5 acres). Although there is seasonal variation, the pond holds an estimated 11,000 m^3 (3,000,000 gal) of water at its fullest, with an average surface elevation of about 142 m (465 ft) MSL, and a maximum depth of about 6.1 m (20 ft) (U.S. Dept. Energy 1987a). A pyramid-shaped limestone hill rises from the quarry floor northeast of the pond to an elevation of about 158 m (518 ft) MSL. A 12-m (40-ft) wooden pier extends into the pond, which is the only surface water body within the quarry.

The abandoned Missouri-Kansas-Texas (MKT) railroad line is located to the south of the quarry, and a rail spur enters the quarry at its lower level from the west and extends approximately one-third of its length. The spur is overgrown with vegetation and is in a state of disrepair. (The MKT line itself was recently dismantled, and most of the track has been removed.) A water treatment plant that is owned by the county, but not in use, is located north of the quarry adjacent to State Route 94. A second county water treatment plant is currently operating about 1.6 km (1 mi) northeast of the quarry. The layout of the quarry is shown in Figure 2.

The quarry lies about 1.6 km (1 mi) west of the Missouri River and about 29 km (18 mi) south of the Mississippi River at its closest point. The drainage divide between the two rivers transects the east-southeast portion of the raffinate pits and chemical plant area of the Weldon Spring site; surface runoff to the south of the divide, including the quarry area, flows into the Missouri River (Bechtel Natl. 1987). Drainage in the quarry occurs primarily through the subsurface, with limited surface drainage on the southern rim; the drainage flows to the Missouri River through Femme Osage Creek and Little Femme Osage Creek. Surface hydrological features in the vicinity of the Weldon Spring site are shown in Figure 3. The high quarry rim prevents entry of surface flow from the surrounding area; therefore, water influent from outside the quarry is limited to direct rainfall or subsurface flow.

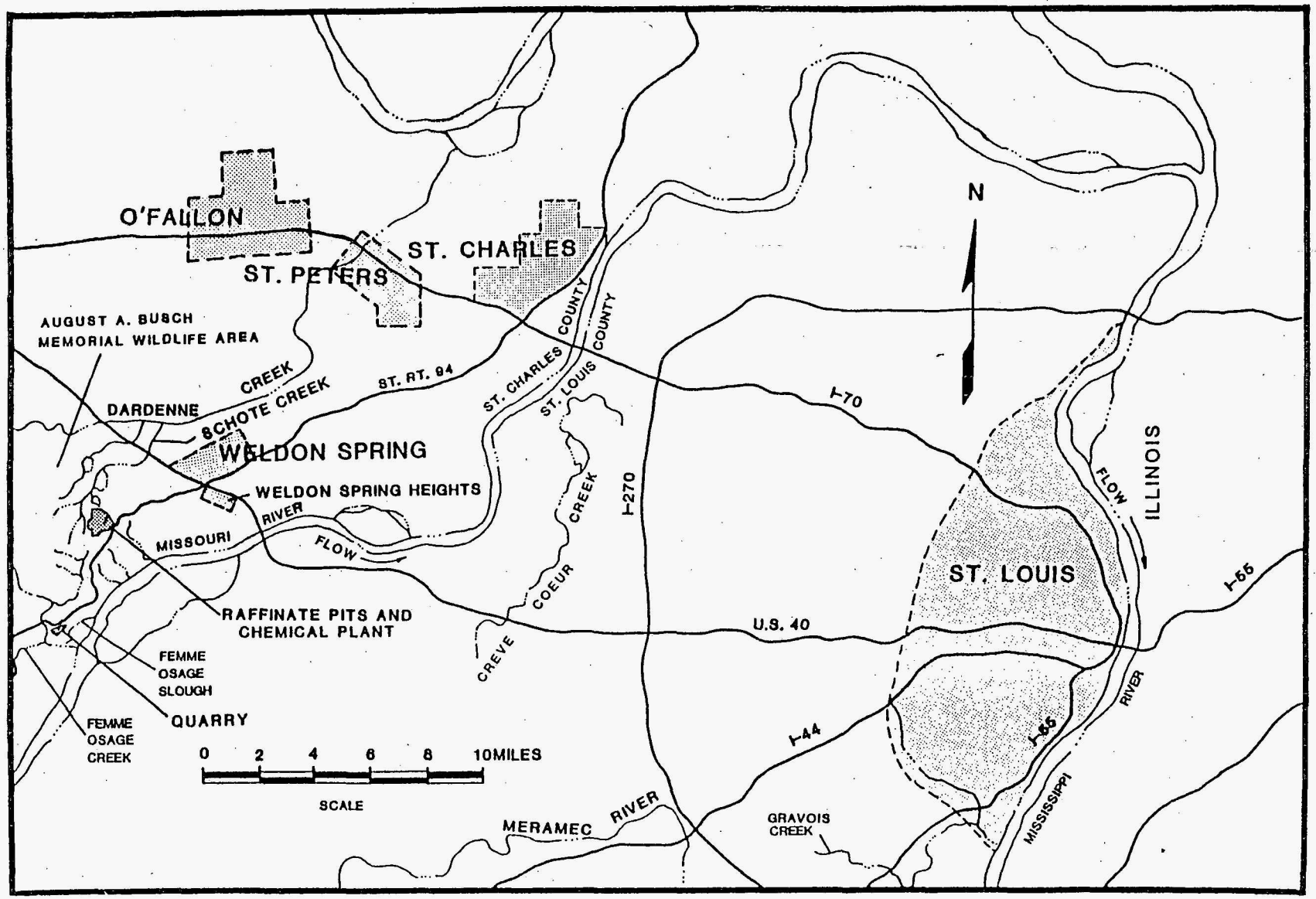

FIGURE 1 Area and Vicinity Map of the Weldon Spring Site, Weldon Spring, Missouri

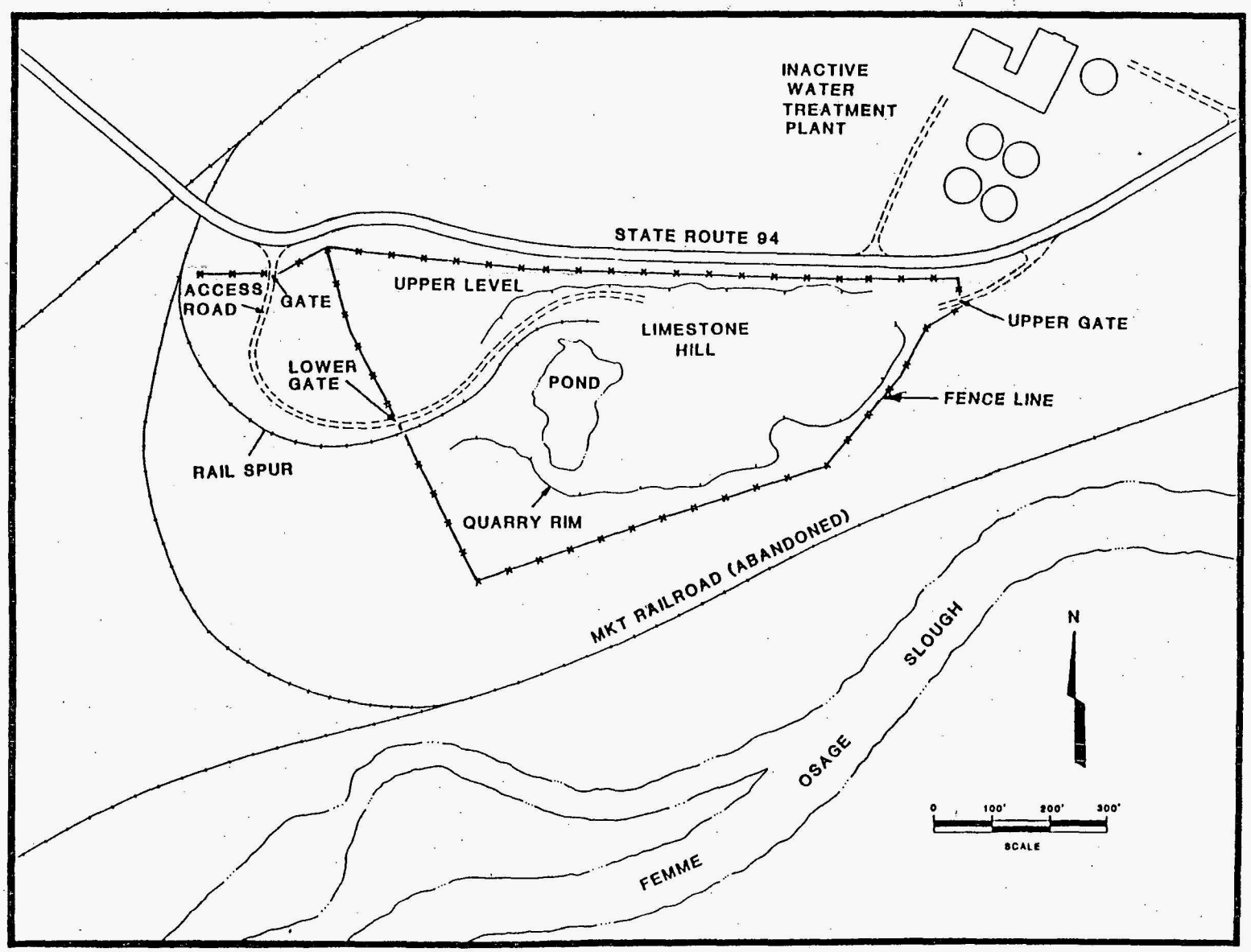

FIGURE 2 Layout of the Weldon Spring Quarry

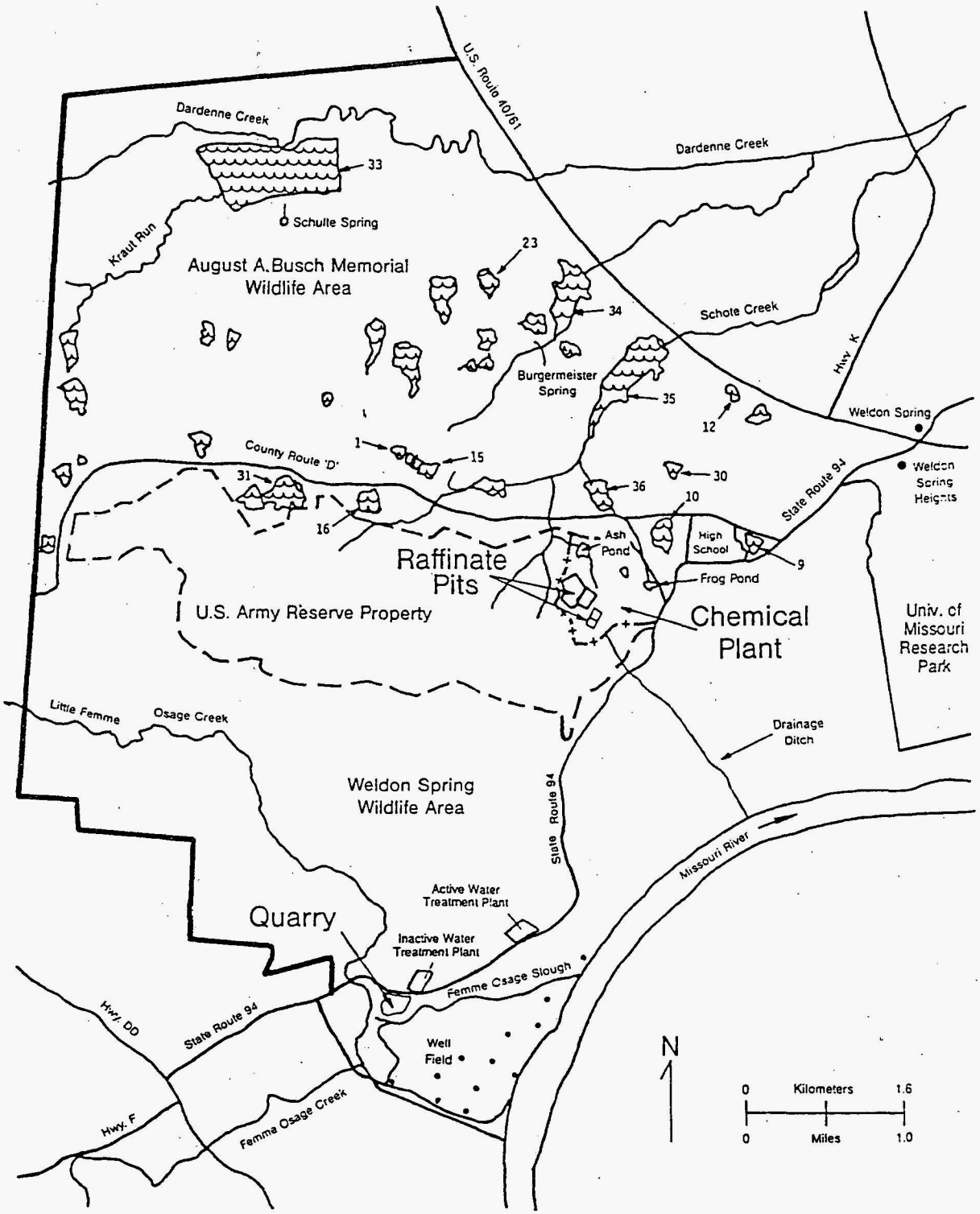

FIGURE 3 Surface Hydrological Features in the Vicinity of the Weldon Spring Site (the numbers refer to lakes in the Busch Wildlife Area) (Source: Modified from U.S. Department of Energy 1987a)

Although the floodplain below the quarry is partially surrounded by a levee, the area floods occasionally to a depth of about 1 m (3-4 ft). This area is drained by a 41-cm (16-in.) diameter pipe through the levee and takes 1 to 2 months to dry following a flood (U.S. Dept. Energy 1987a). Approximately 210 m (700 ft) south of the quarry is a 2.4-km (1.5-mi) section of the original Femme Osage Creek that was dammed at both ends by the University of Missouri between 1960 and 1963. This body of water lies parallel to the quarry bluffs and is called Femme Osage Slough. The water level of the slough averages about 140 m (450 ft) MSL and is affected by the levels of the Missouri River and the alluvial groundwater. The Missouri River bottom in the vicinity of the quarry is at an elevation of about 129 m (422 ft) MSL. The St. Charles County well field is located between the Femme Osage Slough and the Missouri River; the location of production wells in the well field is shown in Figure 4 (U.S. Dept. Energy 1987a).

The uppermost geological stratum at the quarry is Kimmswick limestone, and the quarry floor is Decorah shale. Exposed rock on the quarry walls and on the steep bluffs along the Missouri River is predominantly Ordovician limestone, shale, dolomite, and sandstone. The upper layers of limestone in the quarry consist of a complex system of solution channels, joints, and fractures through which groundwater movement occurs. Groundwater in the vicinity of the quarry occurs in the alluvium, the limestone bedrock, and the deeper layers of dolomite and sandstone. A hydraulic connection exists between the quarry groundwater and the Femme Osage Slough, but the slough appears to present a hydrogeologic barrier to further contaminant migration from the quarry toward the well field to the south (Berkeley Geosci. Assoc. 1984).

Vegetation in the quarry consists mainly of grasses, shrubs, and small trees. With the exception of the floodplain area to the south, the surrounding topography is rugged and heavily wooded and is characterized by deeply dissected hills and deep ravines. The Weldon Spring site is located within the Bluestem Prairie, Oak-Hickory Forest Mosaic (northern) subsection of the Prairie Parkland province. The quarry supports old-field and slope and bottomland forest vegetation, with the predominant species being eastern cottonwood. Based on habitat preferences and ranges of Missouri mammals, over 30 species could be common to abundant in the area (including eastern cottontail rabbit, opossum, raccoon, white-tailed deer, and several species of mouse, vole, shrew, squirrel, bat, and fox). The area is also within the range of more than 50 species of reptiles and amphibians. The quarry pond provides habitat suitable for waterfowl, about 10 species of which are common to abundant in the area during periods of spring and fall migration; in addition, a few species nest and/or overwinter in the area. No designated critical habitats currently exist at or near the quarry (U.S. Dept. Energy 1987a).

The climate in the vicinity of the Weldon Spring site is continental, with moderately cold winters and warm summers. Temperatures above 38°C (100°F) or below -18°C (0°F) are infrequent. Annual precipitation in the area totals approximately 94 cm (37 in.). The heaviest rainfalls occur in the spring and early summer; as much as 25 cm (10 in.) has been recorded in 24 hours during a heavy storm. Prevailing winds in the vicinity of the site are from the south during the summer and fall and from the northwest and west-northwest during the winter and early spring. Wind speeds average 13.9 km/h (8.7 mph) in the summer and fall and 17.6 km/h (11 mph) during the winter (U.S. Dept. Energy 1987b).

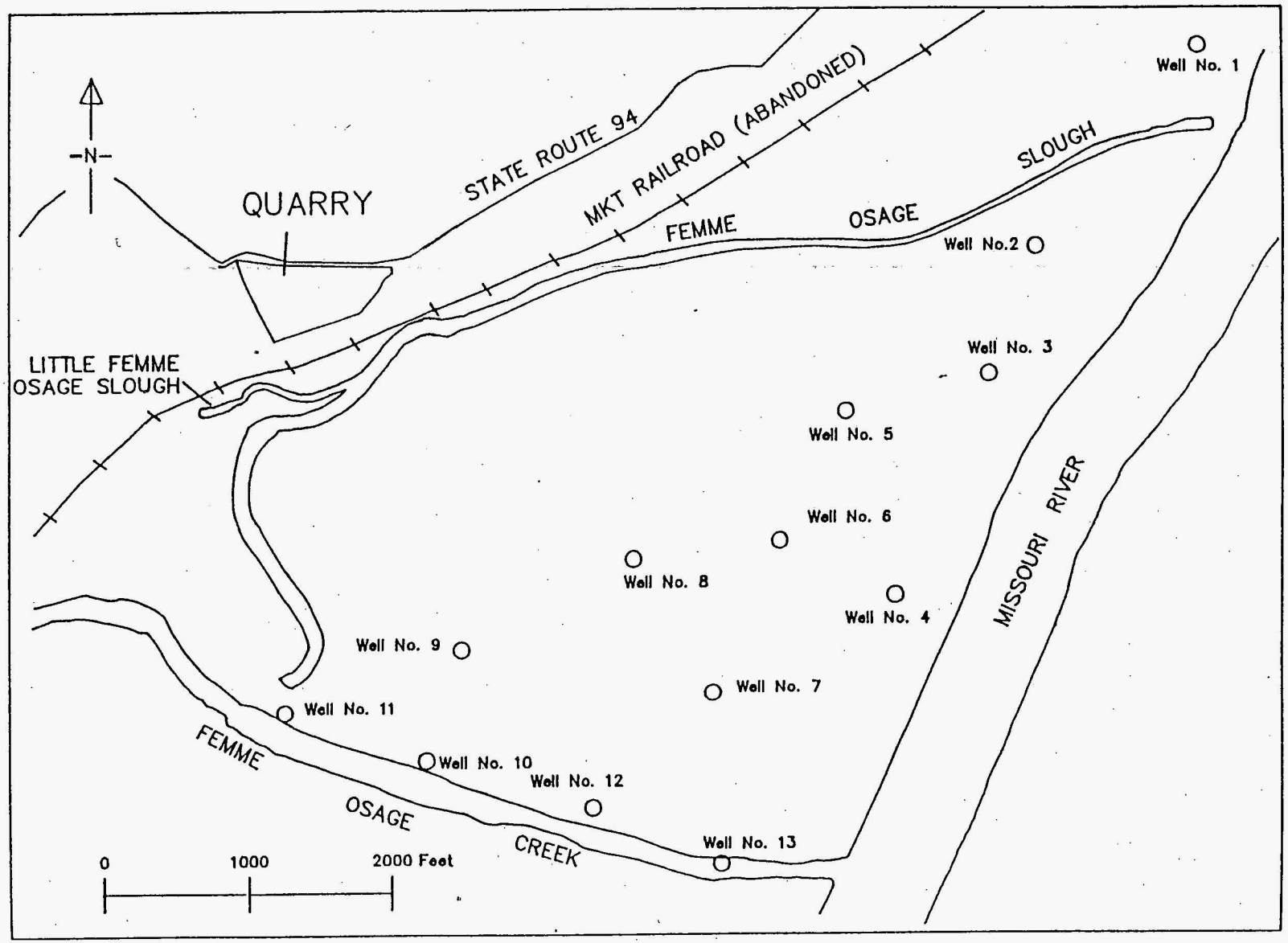

FIGURE 4 Surface Hydrological Features in the Vicinity of the Quarry and Location of Production Wells in the St. Charles County Well Field

The Weldon Spring site is located in St. Charles County (see Figure 1) but is also considered part of the St. Louis metropolitan area, which has a population in excess of 2.5 million. The communities of Weldon Spring and Weldon Spring Heights are located approximately 3.2 km (2 mi) east-northeast of the raffinate pits and chemical plant area and have a combined population of about 800. St. Charles, the largest city in the county, is located about 29 km (18 mi) northeast of the raffinate pits and chemical plant area and has a population of about 40,000. St. Charles County is currently experiencing strong residential and commercial/industrial growth. The county population has increased continuously over the past six decades, and the 1980 population of 144,000 represents a 55% increase over the 1970 population. Local development is expected to continue, with an estimated 70% growth rate projected for the region from 1980 to the year 2000 (U.S. Dept. Energy 1987a).

The Weldon Spring quarry is located in a relatively unpopulated portion of the county, and most of the surrounding land consists of wildlife areas operated by the Missouri Department of Conservation. The nearest residence is about 0.8 km (0.5 mi) west of the quarry on State Route 94, and a limestone quarry is currently operating about 1.2 km (0.75 mi) west of the residence. Francis Howell High School is located about 7.2 km (4.5 mi) northeast of the quarry on State Route 94, and a university extension center is located just west of the high school. A highway maintenance facility is located west of the school and adjacent to the northeast boundary of the raffinate pits and chemical plant area. An active water treatment plant is located about 1.6 km (1 mi) northeast of the quarry adjacent to State Route 94.

1.2 SITE BACKGROUND

In April 1941, the U.S. Department of the Army acquired about 7,000 ha (17,000 acres) of land in St. Charles County, Missouri, for construction of the Weldon Spring Ordnance Works. The Atlas Powder Company operated the ordnance works for the Army as a production facility for trinitrotoluene (TNT) and dinitrotoluene (DNT) explosives from November 1941 through January 1944. The ordnance works was closed and declared surplus to Army needs in April 1946. By 1949, all but about 810 ha (2,000 acres) had been transferred to the state of Missouri (August A. Busch Memorial Wildlife Area) and the University of Missouri (agricultural land). Much of the land transferred to the University of Missouri has since been developed into the Weldon Spring Wildlife Area. Except for several small parcels transferred to St. Charles County, the remaining property became the U.S. Army Reserve and National Guard Training Area.

The U.S. Atomic Energy Commission (AEC, a predecessor of the DOE) acquired 83 ha (205 acres) of the former ordnance works property from the Army by permit in January 1955, and the property transfer was approved by Congress in August 1956. The AEC constructed a feed materials plant -- now referred to as the chemical plant -- on the property for the purpose of processing uranium and thorium ore concentrates. The quarry, which had been used by the Army since the early 1940s for disposal of chemically contaminated (explosive) material, was transferred to the AEC in July 1960 for use as a disposal site for radioactively contaminated material (Niedermeyer 1976).

The feed materials plant was operated for the AEC by the Uranium Division of Mallinckrodt Chemical Works from 1957 to 1966. During this operational period, the quarry was used by the AEC for the disposal of uranium and thorium residues (drummed and uncontained), radioactively contaminated building rubble and process equipment, and TNT and DNT residues from cleanup of the former ordnance works.

Following closure by the AEC, the Army reacquired the chemical plant in 1967 and began converting the facility for herbicide production. The buildings were partially decontaminated, and some equipment was dismantled. In 1969, prior to becoming operational, the herbicide project was canceled. Since that time, the plant has remained essentially unused and in caretaker status.

The last instance of waste disposal at the quarry was planned for 1969, when the AEC contracted to use it for the disposal of contaminated barium sulfate residues from the St. Louis Airport Storage Site (Niedermeyer 1976). However, these residues were deposited instead in a local landfill (U.S. Nucl. Reg. Comm. 1988). A summary of disposal activities at the quarry is presented in Table 1.

In 1971, the Army returned the 21-ha (51-acre) portion of the ordnance works property containing the raffinate pits to the AEC but retained control of the chemical plant buildings. As successor to the AEC, DOE assumed responsibility for the raffinate pits. During 1984, the Army repaired several of the chemical plant buildings; decontaminated some of the floors, walls, and ceilings; and removed some contaminated equipment to areas outside of the buildings. (Despite these efforts, none of the structures met the DOE criteria for release to the general public, due to the presence of elevated levels of alpha contamination.) In May 1985, DOE designated the control and decontamination of the Weldon Spring site as a major federal project under its Surplus Facilities Management Program (SFMP). In October 1985, custody of the chemical plant was transferred to DOE. In May 1988, DOE redesignated the Weldon Spring site as a major system acquisition.

On October 15, 1985, the U.S. Environmental Protection Agency (EPA) proposed to include the Weldon Spring quarry on its National Priorities List (NPL); the listing occurred on July 30, 1987. On June 24, 1988, EPA proposed to expand this listing to include the raffinate pits and chemical plant area.

1.3 EXISTING ANALYTICAL DATA

Based on historical data and characterization results, an estimated 73,000 m^3 (95,000 yd^3) of contaminated material is present in the quarry. This total consists of approximately 31,000 m^3 (40,000 yd^3) of contaminated rubble, 39,000 m^3 (51,000 yd^3) of contaminated soil and clay, and 3,000 m^3 (4,000 yd^3) of contaminated pond sediment. An estimated 11,000 m^3 (3,000,000 gal) of water in the quarry pond has become contaminated as a result of contact with these wastes (U.S. Dept. Energy 1987a). The characterization results for the quarry area, including local groundwater and surface water, are discussed in Appendix A.

TABLE 1 History of Disposal Activities at the Weldon Spring Quarry

Time Period	Waste Type	Estimated Volume[a] m^3	Estimated Volume[a] yd^3
1942-1945	TNT and DNT process waste (burn areas)	-	-
1946	TNT and DNT process waste (burn areas)	b	b
1946-1957	TNT and DNT residues and contaminated rubble from cleanup of the ordnance works (in deepest part and in northeast corner of quarry)	-	-
1959	3.8% thorium residues (drummed, currently below water level)	150	200
1960-1963	Uranium- and radium-contaminated rubble from demolition of the St. Louis Destrehan Street feed plant (covering 0.4 ha [1 acre] to a 9-m [30-ft] depth in deepest part of quarry)	38,000	50,000
1963-1965	High-thorium-content waste (in northeast corner of quarry)[c]	760	1,000
1963-1966	Uranium and thorium residues from the chemical plant and off-site facilities; building rubble and process equipment (both drummed and uncontained)	-	-
1966	3.0% thorium residues (drummed, placed above water level in northeast corner of quarry);	460	600
	TNT residues from cleanup of the ordnance works (placed to cover the drums)	-	-
1968-1969	Uranium- and thorium-contaminated rubble and equipment from interior of some chemical plant buildings (101, 103, and 105)	4,600	6,000

[a]A hyphen indicates that the waste volume estimate is not available.

[b]An estimated 90 tons of TNT/DNT waste was burned in 1946.

[c]This was a portion of the waste originally stored at the Army Arsenal in Granite City, Illinois; most of this material was subsequently removed from the quarry for the purpose of recovering rare earth elements.

Sources: Morrison-Knudsen Engineers (1988a); Lenhard et al. (1967); Pennak (1975); Weidner and Boback (1982); Bechtel National (1983); Berkeley Geosciences Associates (1984); Kleeschulte and Emmett (1986).

1.4 SITE CONDITIONS THAT JUSTIFY A REMOVAL ACTION

The threats posed by the contamination in the quarry pond are of a non-time-critical nature, i.e., no imminent or substantial endangerment of the public or the environment related to pond contaminants currently exists that would necessitate initiation of a response within 6 months. The site conditions do meet certain criteria listed in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) for categorization of specific cleanup efforts as removal actions. The eight factors to be considered in determining the appropriateness of a removal action, as listed in Section 300.65(b)(2) of the NCP, are:

1. Actual or potential exposure to hazardous substances or pollutants or contaminants by nearby populations, animals, or food chains;

2. Actual or potential contamination of drinking water supplies or sensitive ecosystems;

3. Hazardous substances or pollutants or contaminants -- in drums, barrels, tanks, or other bulk storage containers -- that may pose a threat of release;

4. High levels of hazardous substances or pollutants or contaminants in soils, largely at or near the surface, that may migrate;

5. Weather conditions that may cause hazardous substances or pollutants or contaminants to migrate or be released;

6. Threat of fire or explosion;

7. Availability of other appropriate federal or state response mechanisms to respond to the release;

8. Other situations or factors that may pose threats to public health or welfare and the environment.

A number of hazardous contaminants, both drummed and uncontained, are present in the Weldon Spring quarry and in the pond. Chemically contaminated material consists primarily of DNT- and TNT-contaminated rubble and soil. Radioactively contaminated material consists of wastes from uranium- and thorium-processing activities previously carried out at the chemical plant and at other facilities off-site, as well as rubble and debris from decontamination of processing facilities. Some of the quarry wastes may be classified as *mixed wastes*, i.e., radioactive wastes that also meet the criteria for classification as hazardous wastes under the Resource Conservation and Recovery Act (RCRA).

Plant and animal populations in the quarry are currently being exposed to radioactive and chemical contaminants from the quarry pond. Characterization results indicate that these contaminants are being released from the pond into the local

environment through groundwater transport. Although Femme Osage Slough appears to act as a barrier to contaminant migration from the quarry pond to the county well field, contamination of the county drinking water supply could potentially occur in the future if no response action is taken at the quarry. Weather conditions (e.g., rain or drought) may affect the potential for contaminant release into the local environment by increasing or decreasing the gradient for migration.

Groundwater transport from the quarry pond is believed to occur through two distinct hydrological regimes: the bedrock and the alluvial aquifer. The bedrock regime involves the limestone walls and floor of the quarry. It is suspected that contaminated leachate seeps out of the quarry through solution-enlarged joints and cracks. After passing through this first medium, contaminants are transported through the alluvium into the alluvial aquifer system. The mechanisms and pathways of transport at the interface between the bedrock and alluvial systems are not yet clearly defined.

By contrast, the alluvial aquifer system is fairly well understood. Past characterization and monitoring efforts have involved the drilling of a number of wells throughout the quarry. This has resulted in a well-documented subsurface lithology, and the aquifer transport characteristics have been modeled with a reasonable degree of confidence. Thus, although contaminant transport through the quarry bedrock into the alluvium has not yet been defined, once the contaminants reach the alluvial system, contaminant transport is generally understood.

The transport of contaminants from the quarry into the alluvial system need not be characterized as part of the proposed action. In fact, an understanding of the nature and extent of fracture joints and cracks can only be established after the bulk wastes have been removed from the quarry and the limestone walls and floors have been exposed for study. In turn, bulk waste removal cannot be completed until the ponded water has been pumped from the quarry. The removal of bulk wastes and the management of residual contamination in joints and cracks of the quarry -- and in the groundwater -- will be addressed separately, following the removal and treatment of ponded water as currently proposed (see Section 5.4). Therefore, the proposed removal and treatment of the quarry water is a stand-alone action that represents an important, discrete critical-path element of the overall response action planned for the quarry.

The potential risks associated with the final alternatives for the proposed action (see Section 4.2) will be evaluated as part of the comprehensive evaluation of those alternatives (see Chapter 5). The following factors will be considered in this risk evaluation: release mechanisms, environmental fate, population exposure, potential risks, potential receptors, and contaminants of concern.

1.4.1 Release Mechanisms

The potential for migration of radionuclides and chemicals is related to the physical and chemical characteristics of the contaminants, the chemistry of the local environment, and the nature of the groundwater or surface water movement. Release of contaminants from the quarry pond can affect the quality of the local sediment/soil,

groundwater, surface water, and air. Possible release mechanisms associated with the quarry pond are:

- Dissolution, runoff, leaks, or spills that contaminate surface water;
- Contact of sediment/soil with the contaminated surface water;
- Leaching of contaminated surface and/or subsurface material to the groundwater;
- Internal gas generation (e.g., radon) and emission to the atmosphere;
- Release of suspended solids (e.g., asbestos) to the atmosphere; and
- Direct ingestion by animals and uptake by plants, with subsequent entry into the animal food chain.

1.4.2 Environmental Fate

The potential fate of contaminants released into the environment must be evaluated in order to determine the exposure of potential receptors. Exposure can be either direct or indirect. Direct human exposure could result from contact with the contaminated water during cleanup activities or during recreational activities in the pond area. Indirect exposure involves the transport of the contaminants through various media to potentially affected receptors and could occur in the absence of a response action at the quarry.

The environmental fate of a released contaminant depends on both its physical/chemical properties and the nature of the environmental medium in which it occurs. The primary contaminant transport media are the atmosphere, surface water, groundwater, and sediment/soil. At the quarry pond, the environmental fate of contaminants in these media may be affected by the following factors:

- Atmospheric dispersion,
- Surface water dilution,
- Groundwater transfer to surface water,
- Surface water transfer to groundwater,
- Groundwater dilution,
- Sediment/soil transfer to water, and
- Water transfer to sediment/soil.

1.4.3 Population Exposure

The assessment of population exposure consists of (1) developing scenarios of human activities that give rise to exposure, (2) assessing the transport of contaminants from the source through environmental media to potential receptors, and (3) assessing the biological uptake of these contaminants by all potential receptors. This assessment evaluates the following means of exposure:

- Ingestion of contaminated surface water and groundwater,
- Ingestion of contaminated flora and fauna,
- Direct contact with contaminated water, and
- Inhalation of contaminants.

1.4.4 Potential Risks

Transient or permanent populations of animals that occupy the quarry may currently be exposed to contaminants from the pond water through (1) direct contact, (2) inhalation, or (3) ingestion of the water or local biota (e.g., aquatic or shoreline vegetation contaminated by the uptake of radionuclides or chemicals). Also, the release of contaminants from the pond could impact local ecosystems, and exposure of animal populations could result from contact with affected vegetation, soil, or groundwater.

Human exposure to pond contaminants could occur through similar pathways. Direct contact with the contaminated water would occur if a trespasser swam in the quarry pond. However, this pathway is not expected to be significant based on the existence of access restrictions at the quarry. Nor is the inhalation pathway expected to be a significant source of human exposure at the pond because most of the contamination is entrained in and/or below the surface of the water and the release of radioactive gases is minor. The primary pathway of human exposure to contaminants from the quarry pond is considered to be ingestion of contaminated surface water and/or groundwater. Elevated concentrations of radionuclides have been detected in the pond, and a person (i.e., trespasser) drinking this water directly could incur measurable radiation doses. In addition, elevated levels of radionuclides and chemicals have been detected in the groundwater, and exposure through ingestion of this groundwater as it recharges the pond in the quarry could also occur. Ingestion of quarry biota that have been contaminated by the pond water could result in human exposure as well. However, little, if any, trespasser activity is expected at the quarry; therefore, the ingestion pathway within the quarry is not expected to play a major role in human exposure.

Potential human exposure is more likely to result from the ingestion of surface water or groundwater in the vicinity of the quarry, i.e., if contaminants migrate from the pond to a public or private drinking water supply. This represents the most significant pathway of concern with regard to the contaminants in the quarry pond. Human exposure could also occur through ingestion of wildlife (e.g., waterfowl or game animals) that have been contaminated by the pond water. In addition, if contaminants migrate from the

pond into nearby surface waters, the potential exists for direct contact with or inadvertent ingestion of contaminants (e.g., while swimming). Fishing and swimming activities do occur in these waters, and there is a potential for associated exposure.

1.4.5 Potential Receptors

Potential receptors of the radioactive and chemical contaminants that may migrate from the Weldon Spring quarry pond include:

- Persons who live in the area, drink local surface water or groundwater, consume locally grown plant or animal food products, and/or consume wildlife that inhabit the quarry area. (The closest residence is about 0.8 km [0.5 mi] west of the quarry on State Route 94.)

- Visitors and staff at the adjacent wildlife areas (attendance at the August A. Busch Wildlife Area alone has averaged 710,000 persons per year over the last 10 years [U.S. Dept. Energy 1987a]).

- Persons who fish or swim in nearby surface waters.

- Trespassers who gain entry to the quarry in spite of existing access restrictions (e.g., fences and locked gates).

1.4.6 Contaminants of Concern

Based on the results of sampling at the quarry, the primary contaminants of concern in the quarry pond are manganese, arsenic, uranium, and 2,4-dinitrotoluene (hereafter referred to as 2,4-DNT). The associated potential exposure hazards of these contaminants are discussed below; additional details regarding these contaminants are addressed in Chapters 5 and 6 of this report.

The chemical toxicity of manganese depends on its form. Its reduced form, e.g., the divalent manganous ion, may exist in groundwater inflows to the pond because reducing environments are typical of subsurface regions. The adverse health effects of exposure to manganous oxide are not fully known, and in fact this compound is used as a dietary supplement. Manganous sulfate is also used as a food additive in trace amounts, but exposure to very high concentrations of this compound may be toxic. (Acute toxicity for manganous sulfate [mouse data] is defined by an intraperitoneal LD_{50} -- i.e., the lethal dose for half the test group -- of 120 mg/kg [Sax 1979].) Based on the high concentrations of sulfate in the quarry pond and local groundwater, this compound may be present near the sediments or in groundwater inflows. Oxidized forms of manganese, e.g., the trivalent and tetravalent ions, are likely to predominate in the surface water of the quarry. The ingestion of such manganese compounds can lead to potential adverse health effects related to the dysfunction of blood and protein chemistry, e.g., in terms of oxygen transport and enzyme activity.

Manganese dioxide is considered highly toxic via the intravenous route (Sax 1979), and exposure to manganese compounds through inhalation can also result in adverse health effects. However, these two routes are not expected to be significant at the quarry. Chronic manganese poisoning resulting from inhalation affects primarily the central nervous system. Permanent disability, e.g., in terms of gait and speech can result from long-term exposure, although symptoms may improve if the source of exposure is removed. Other adverse health effects of long-term exposure to manganese compounds include upper respiratory infections, weakness, and parkinsonism (Sax 1979).

Arsenic is a recognized chemical carcinogen of the skin, lungs, and liver, and it is considered highly toxic when exposure occurs through the intramuscular and subcutaneous routes. Pentavalent arsenic, which is likely to be the primary form of this element in the surface water of the quarry, is less toxic than the trivalent form. However, groundwater inflows may contain trivalent arsenic if a subsurface reducing environment is present. Chronic arsenic poisoning can result from the ingestion or inhalation of arsenic compounds, giving rise to a wide range of symptoms that include liver damage, dermal abnormalities, and disturbances of the blood, kidneys, digestive system, and nervous system (Sax 1979).

Uranium is a recognized carcinogen and poses both a radiological and a chemical hazard. Insoluble compounds, e.g., uranium oxides, pose primarily a radiological hazard resulting from inhalation and lung irradiation. Chemical toxicity is considered the controlling hazard for soluble uranium compounds, e.g., uranium oxynitrates, and ingestion of these compounds can lead to kidney damage and arterial lesions (Sax 1979). Other potential adverse health effects that can result from the ingestion of soluble uranium compounds include damage to the cardiovascular, hematopoietic, endocrine, and immunological systems. Soluble uranium compounds exist in the quarry water, whereas insoluble compounds are present in the sediments and in the local soil/waste matrix; the insoluble compounds will serve as a continuous equilibrium source of dissolved uranium until their removal. Therefore, both types of hazards associated with this radionuclide currently exist at the quarry.

The chemical toxicity of 2,4-DNT is considered high, with an acute toxicity defined by an oral LD_{50} of 1,625 mg/kg (mouse data). Exposure to this organic compound through ingestion, inhalation, or dermal contact could result in such adverse health effects as anemia, methemoglobinemia, cyanosis, and liver damage (Sax 1979).

2 REMOVAL ACTION OBJECTIVES

The objectives of the proposed removal action at the Weldon Spring quarry are to eliminate, reduce, or otherwise mitigate the potential for release of radioactive and chemical contaminants from the quarry pond and to minimize threats to the public and the environment resulting from these contaminants. The overall objectives are defined in Sections 2.1 through 2.4 in terms of statutory limits, scope and purpose of the proposed action, schedule, and compliance with applicable or relevant and appropriate requirements.

2.1 STATUTORY LIMITS

Authority for responding to releases or threats of releases from a hazardous waste site is addressed in Section 104 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Executive Order 12580 delegates to DOE the response authority for DOE sites. Under CERCLA Section 104(b), DOE is authorized to undertake such investigations, surveys, testing, or other data gathering deemed necessary to identify the existence, extent, and nature of the contaminants involved at the Weldon Spring site, including the extent of danger to public health or welfare and the environment. In addition, DOE is authorized to undertake planning, engineering, and other studies or investigations appropriate to directing response actions to prevent, limit, or mitigate the risk to public health or welfare and the environment. The statutory limits of Superfund-financed removal actions are 1 year and $2 million, as specified in Section 104(e)(1) of the Superfund Amendments and Reauthorization Act (SARA). However, these limits do not apply to removal actions authorized under CERCLA Section 104(b) that are not financed by Superfund monies, such as the proposed action at the Weldon Spring quarry.

2.2 SCOPE AND PURPOSE

The scope of the proposed removal action can be broadly defined as management of radioactively and chemically contaminated surface water in the Weldon Spring quarry. The primary purpose of the proposed action is to limit the release of contaminants from the quarry pond, thereby minimizing the potential for associated impacts to the public and the environment. This could be achieved by removing the source of contaminant migration, i.e., the pond water. Removing the pond water would alter the associated hydraulic head, which would result in reversing the direction of groundwater flow at the quarry and therefore the gradient for contaminant migration. However, the water could not be discharged directly upon removal because levels of certain contaminants exceed pertinent release limits (see Sections 2.4 and 5.1). Thus, the water would require treatment prior to being released off-site.

The specific objectives of the proposed removal action are to:

- Eliminate or reduce public and environmental hazards associated with the contaminated water,

- Minimize potential health hazards to on-site personnel performing the removal action, and

- Facilitate subsequent response activities at the quarry.

These objectives can be achieved by the alternatives that meet the screening criteria for the proposed action (see Section 4.2). The general scope of these alternatives, as defined by their components, is to:

- Remove the ponded water from the quarry,

- Collect and remove storm water and groundwater inflow from the quarry pond, and

- Treat the water to remove radioactive and chemical contaminants.

The timely removal and treatment of the contaminated water from the quarry would contribute to the efficient performance of comprehensive response actions being planned for the quarry.

2.3 SCHEDULE

The proposed removal action at the Weldon Spring quarry is scheduled to begin in fiscal year 1989 (October 1, 1988, to September 30, 1989). The primary activities associated with this action, i.e., removal and treatment of the pond water, are expected to be completed in fiscal year 1991. To ensure protection of the public and the environment, removal and treatment of subsequent groundwater inflows and of precipitation and construction water would continue throughout the course of response activities at the quarry. The primary scheduling objective is to complete the removal and treatment of existing surface water within a limited period, in order to permit the timely implementation of subsequent response actions at the quarry.

2.4 COMPLIANCE WITH RELEVANT REQUIREMENTS

The proposed removal action at the Weldon Spring quarry would be carried out in accordance with all applicable or relevant and appropriate requirements (ARARs), based on EPA interim guidance regarding compliance with ARARs (U.S. Environ. Prot. Agency 1987a). The EPA guidance defines *applicability* as implying that the proposed action or site circumstances satisfy all of the jurisdictional prerequisites of the requirement. *Relevant and appropriate requirements* are defined as those that address problems or situations sufficiently similar to those encountered at the site in question that their use is well suited to the particular site.

The ARARs can be divided into three categories: (1) contaminant-specific, (2) location-specific, and (3) action-specific. Contaminant-specific ARARs address certain chemical species or a class of contaminants, e.g., radium or halogenated organic

compounds, respectively, and relate to the level of contamination allowed for a specific pollutant in various environmental media (i.e., soil, water, and air). Location-specific ARARs are based on the specific setting and nature of the site, e.g., location in a floodplain and proximity to wetlands or the presence of archeological resources and historic properties. Action-specific ARARs relate to specific response actions (i.e., removal or remedial actions) that are proposed for implementation at a site, e.g., incineration of organically contaminated soil. Thus, a determination of the potential ARARs for proposed action(s) at a site is based on factors specific to that site and the individual action(s).

The preliminary identification of potential ARARs for the proposed removal action at the Weldon Spring quarry is based on the nature of the contamination (radioactively and chemically contaminated surface water), the location of the quarry (near a floodplain that contains a county well field), and the general scope of the applicable alternatives (see Section 4.2). In addition to ARARs, other requirements that may play a role in the selection and implementation of a preferred alternative are "to-be-considered (TBC)" requirements. These TBC requirements, e.g., individual agency or departmental standards, are not promulgated by law but may be significant for the proposed action.

The potential requirements for the proposed action at the Weldon Spring quarry are presented in Table 2. These requirements can be divided into two major groups. The first group contains those laws and orders that are generically applicable to the authorization, objectives, planning, or implementation of policies or actions related to environmental response (e.g., the Atomic Energy Act and a number of federal orders). Because many of the components of this group have led to the establishment of standard policies and procedures for undertaking response actions, they will not be discussed in detail in this report. All aspects of the proposed action would fully comply with these laws and orders. The second group of laws and orders contains those that have specific applicability to the management of contaminated water in the quarry (e.g., CERCLA and the Safe Drinking Water Act).

A detailed discussion of relevant requirements is not possible at this stage of the analysis because the final alternatives for the proposed action have not yet been identified. Therefore, the action-specific requirements cannot yet be discussed. In addition, although certain contaminant- and location-specific requirements could be addressed, much of the discussion would be intimately tied to the nature of the selected action (e.g., what specific environmental media would be affected by what specific contaminants and in what specific location). Thus, in order to reduce duplication and provide a single, comprehensive discussion, the potential requirements for the proposed action will be addressed in Section 5.1 following identification of the final alternatives.

TABLE 2 Laws and Orders Potentially Relevant to Response Actions at the Weldon Spring Site

Federal Laws

Archeological and Historic Preservation Act of 1974
Archeological Resources Protection Act of 1979
Atomic Energy Act of 1954, as amended
Clean Air Act of 1963, as amended
Clean Water Act, as amended (also referred to as Federal Water Pollution Control Act of 1972, as amended)
Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986
Department of Energy Organization Act of 1977
Endangered Species Act of 1973, as amended
Fish and Wildlife Coordination Act of 1934, as amended
Hazardous Materials Transportation Act of 1974, as amended
National Environmental Policy Act of 1969, as amended
National Historic Preservation Act of 1966, as amended
Noise Control Act of 1972, as amended
Noise Pollution and Abatement Act of 1970
Occupational Safety and Health Act of 1970
Safe Drinking Water Act of 1974, as amended
Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of 1976, as amended by the Hazardous and Solid Waste Amendments of 1984
Toxic Substances Control Act of 1976
Uranium Mill Tailings Radiation Control Act of 1978, as amended

Executive Orders

Executive Order 11490, Assigning Emergency Preparedness Functions to Federal Departments and Agencies
Executive Order 11514, Protection and Enhancement of Environmental Quality
Executive Order 11738, Providing for Administration of the Clean Air and the Federal Water Pollution Control Act with Respect to Federal Contracts, Grants, or Loans
Executive Order 11807, Occupational Safety and Health Programs for Federal Employees
Executive Order 11988, Floodplain Management
Executive Order 11990, Protection of Wetlands
Executive Order 11991, Relating to the Protection and Enhancement of Environmental Quality
Executive Order 12088, Federal Compliance with Pollution Control Standards
Executive Order 12146, Management of Federal Legal Resources
Executive Order 12580, Superfund Implementation

TABLE 2 (Cont'd)

Department of Energy Orders

Order 1540.1 Materials Transportation and Traffic Management
Order 4240.1H Designation of Major System Acquisitions and Major Projects
Order 4320.1A Site Development and Facility Utilization Planning
Order 4700.1 Project Management System
Order 5440.1C Implementation of the National Environmental Policy Act
Order 5480.1B Environment, Safety, and Health Program for Department of Energy Operations -- Note: Chapter XI of Order 5480.1B has been amended (see Vaughan [1985] and subsequent updates of Derived Concentration Guides)
Order 5480.4 Environmental Protection, Safety, and Health Protection Standards
Order 5480.14 Comprehensive Environmental Response, Compensation, and Liability Act Program
Order 5481.1B Safety Analysis Review System
Order 5482.1B Environmental Protection, Safety, and Health Protection Appraisal Program
Order 5483.1A Occupational Safety and Health Program for Government-Owned Contractor-Operated Facilities
Order 5484.1 Environmental Protection, Safety, and Health Protection Information Reporting Requirements
Order 5000.3 Unusual Occurrence Reporting System
Order 5500.2 Emergency Planning, Preparedness, and Response for Operations
Order 5700.6B Quality Assurance
Order 5820.2 Radioactive Waste Management

Missouri State Environmental Laws

Governor's Executive Order 82-19 on Flood Plain Management
Missouri Abandoned Mine Reclamation and Restoration Rules
Missouri Air Conservation Law
Missouri Air Pollution Control Regulations and Air Quality Standards
Missouri Clean Water Law
Missouri Hazardous Substances Rules
Missouri Hazardous Waste Management Law
Missouri Public Drinking Water Regulations
Missouri Safe Drinking Water Act
Missouri Solid Waste Law
Missouri Solid Waste Rules
Missouri Water Pollution Control Regulations
Missouri Water Quality Standards and Effluent Limitations Standards

3 REMOVAL ACTION TECHNOLOGIES

The following discussion summarizes the procedures and rationale for identifying alternative removal actions by assembling technologies that may be implemented to achieve the objectives of the proposed action (see Chapter 2). Due to the nature of the proposed removal action, i.e., management of the ponded water in the quarry, the number of practicable and suitable treatment technologies that can be applied is limited. The technologies considered in selecting response action alternatives include those identified in the NCP. Additional technologies addressed in the following discussion are based on experience and information gained as a result of response action planning and implementation at similar sites.

Section 121 of SARA identifies a strong statutory preference for remedies that are highly reliable and provide long-term protection. The principal requirements for a selected remedy are that it both protect human health and the environment and be cost-effective. Additional selection criteria include the following:

- Preferred remedies are those in which the principal element is treatment to permanently or significantly reduce the volume, toxicity, or mobility of hazardous substances, pollutants, or contaminants.

- Where practical treatment technologies are available, off-site transport and disposal without treatment is the least preferred alternative.

- Permanent solutions and alternative treatment technologies or resource recovery technologies should be assessed and used to the maximum extent practicable.

A broad overview of technologies that could be used to protect public health or welfare and the environment, based on the current understanding of contamination in the surface water at the quarry and on the potential for population exposure, is presented in Sections 3.1 and 3.2. The following discussion is divided into two general categories as prescribed in the NCP: source control and migration control.

3.1 SOURCE CONTROL TECHNOLOGIES

The objective of source control technologies is to protect the public and the environment by altering the nature of the waste source (i.e., the radioactively or chemically hazardous constituents) to reduce its toxicity, mobility, and/or volume. Source control technologies that are potentially applicable to the proposed action include access restrictions, waste removal, waste treatment, temporary storage, and disposal.

3.1.1 Access Restrictions

Access restrictions involve the use of physical barriers (e.g., fences) and/or institutional controls (e.g., deed restrictions) to reduce the potential for public exposure to contaminated material. Such restrictions are currently in place at the quarry to limit access to and use of the quarry and its surroundings. The improvement of existing barriers and continued control of property use would be relatively easy to implement and could protect the public and the environment when used in conjunction with other response actions. Therefore, access restrictions are considered applicable to the proposed action.

3.1.2 Removal

Removal of contaminated material may involve decontamination, demolition, excavation, and/or pumping. The first three technologies are applicable to the management of contaminated soils, structures, and bulk wastes. Therefore, they are not appropriate for the proposed action and will not be considered further. Pumping is used to remove a contaminated solution from its current location, and it permits subsequent removal of contaminants from the solution (i.e., through treatment of surface water or groundwater). Therefore, pumping is considered applicable to the proposed action.

3.1.3 Treatment

Treatment includes a wide range of technologies, only a limited number of which can be implemented where radioactive contamination is present. Radioactive waste reprocessing/treatment technologies can be divided into two general categories:

- Those that remove the radioactive materials from the waste matrix, and
- Those that change the form of the waste, thereby reducing its toxicity, mobility, and/or volume.

These objectives can be achieved by chemical, physical, and/or biological methods.

Chemical treatment technologies are typically used to alter the nature of hazardous constituents and can reduce their toxicity, mobility, and/or volume. Processes for the chemical treatment of contaminated liquids include coagulation/precipitation, oxidation/reduction, and ion exchange.

Physical treatment technologies are used to alter the structure of waste constituents to facilitate stabilization and management. Physical treatment can reduce waste toxicity, mobility, and/or volume. Processes for the physical treatment of contaminated liquids include clarification, filtration, vapor recompression/distillation, and thermal destruction.

Biological treatment technologies can be used to alter the nature of a waste and/or to remove contaminants from a waste matrix. Such technologies are typically employed in conventional wastewater treatment systems and can reduce waste toxicity, mobility, and/or volume. Processes for the biological treatment of contaminated liquids include activated sludge treatment, trickling filters, and surface impoundments.

Treatment has the capacity to permanently and significantly reduce the toxicity, mobility, and/or volume of contaminants in the quarry water. Therefore, treatment is considered applicable to the proposed action.

3.1.4 Temporary Storage

Temporary storage can involve the temporary placement of contaminated material on an engineered pad and covering the waste pile with a synthetic membrane or clay cap. Storage can also involve placing contaminated material in an existing engineered structure or in a structure newly constructed to provide containment. As a source control measure, temporary storage is considered potentially applicable to the proposed action.

3.1.5 Disposal

Disposal typically involves the placement of contaminated material in a confined environment for permanent containment, which can be an extremely effective means of reducing contaminant mobility and the associated potential for population exposure. However, unless the waste is treated before disposal, this technology reduces neither the volume of the waste nor the toxicity of its constituents. In addition, because of institutional concerns related to the confined disposal of contaminated liquids (e.g., regarding transportation and the preference for treatment), this option is considered generally unacceptable and is not considered further for the proposed action. In the case of liquids, disposal could also involve direct discharge onto land, e.g., using spray irrigation or evaporation ponds. This form of disposal would do little to reduce the toxicity, mobility, or volume of the wastes. Because of the associated concerns regarding implementability (e.g., land availability and subsurface hydrogeology at the quarry, as well as the need for treatment to meet relevant requirements), direct disposal is considered generally unacceptable and is not considered further for the proposed action.

3.2 MIGRATION CONTROL TECHNOLOGIES

Migration control technologies are designed to mitigate exposure of the population to contaminants that are transported via any of the pathways described in Section 1.4. An additional objective of migration control measures for the proposed removal action is to limit human activity that could result in the migration of contaminated material. Migration control technologies that are potentially applicable to the proposed action include access restrictions and waste containment/treatment.

3.2.1 Access Restrictions

Access restrictions, which involve the use of physical barriers and/or institutional controls, are considered applicable to the proposed action. However, they generally serve as a reliable means of protecting the public and the environment only when used as support for other response actions. Improvements could be made in the existing barriers at the quarry, e.g., by closing gaps in the fence and posting signs. Such improvements would reduce the potential for contaminant migration by human activities and would limit contact with areas to which contaminants have already migrated.

Institutional controls are not generally effective in preventing contact with contaminants that have migrated, nor do they limit the effect of natural forces (e.g., wind and precipitation) on contaminant migration. However, institutional controls are retained as an option for the proposed action in support of physical barriers, provided that these access restrictions are used only in conjunction with other response activities.

3.2.2 Containment/Treatment

The purpose of containment is to reduce waste mobility and the potential for contaminant migration and associated population exposure. Containment technologies, in and of themselves, do not typically reduce waste toxicity or volume. Containment can be implemented following removal of contaminated material, or it can be achieved without removal by media-specific, in-situ stabilization techniques for migration control. Containment technologies for migration control of contaminated water that may be applicable to the proposed action include:

- Surface water -- dikes, terraces, channels, downpipes, grading, and surface seals (with containment of runoff); and

- Groundwater -- slurry/cutoff walls, grout curtains, subsurface drains or other leachate containment systems, and groundwater pumping. (Groundwater is included because it can recharge the surface water at the pond.)

When used in conjunction with containment technologies, treatment technologies for migration control can reduce waste volume as well as waste toxicity and mobility. Treatment technologies for migration control of contaminated water include:

- Surface water -- runoff collection (e.g., with dikes or channels) in conjunction with physical/chemical/biological treatment systems; and

- Groundwater -- groundwater pumping/leachate collection in conjunction with physical/chemical/biological treatment systems.

As a migration control measure, containment/treatment is considered potentially applicable to the proposed action.

The identification and preliminary screening of the broad categories of potential source control and migration control technologies for the proposed action are summarized in Tables 3 and 4, respectively.

3.3 ASSEMBLY OF TECHNOLOGIES INTO PRELIMINARY REMOVAL ACTION ALTERNATIVES

Preliminary removal action alternatives are developed and assessed according to the categories specified for remedial actions in the current NCP, as follows:

- No action;
- Alternatives for treatment or disposal at an off-site facility, as appropriate;
- Alternatives that attain applicable or relevant and appropriate public health and environmental requirements;
- Alternatives that exceed applicable or relevant and appropriate public health and environmental requirements; and
- Alternatives that do not attain applicable or relevant and appropriate public health and environmental requirements but will reduce the likelihood of present or future threats from the hazardous substances and will provide significant protection to public health or welfare and the environment. This must include an alternative that closely approaches the level of protection provided by those alternatives that attain the applicable or relevant and appropriate requirements.

Section 105 of SARA required the President (who subsequently delegated this responsibility to the EPA) to propose amendments to the NCP by April 17, 1988. The EPA is currently drafting revisions to the NCP, but the statutory deadline was not met. Nevertheless, publication of the proposed revisions is expected within the next few months. In the interest of addressing those requirements that may be promulgated before the proposed removal action is complete, categories of remedial action alternatives that are recommended by the EPA in the draft revisions to the NCP are also considered in the current evaluation; these categories are:

- No action;
- Containment (migration control) -- involving little or no treatment, but protective of human health and the environment by causing a reduction in waste mobility and related exposure risks; and

TABLE 3 Summary of General Response Technology Screening: Source Control

Source Control Technology	Media	Evaluation Result	Comments
Access Restrictions			
Physical barriers	Soils, sludges, structures, surface water, groundwater	Retained	Temporarily limits exposure to contaminants; may be effective when used in conjunction with other technologies.
Institutional controls	Soils, sludges, structures, surface water, groundwater	Retained	Temporarily limits exposure to contaminants; may be effective when used in conjunction with other technologies.
Removal			
Pumping	Surface water, groundwater	Retained	Reduces exposure to contaminants by reducing waste mobility and/or volume; allows subsequent treatment. Requires pumping/collection facility and access restrictions.
Treatment			
Chemical treatment			
Leaching/extraction	Soils, bulk wastes, sludges, liquids	Rejected	Not applicable due to nature of the contamination (e.g., relatively large volume of dilute surface water and groundwater inflow).
Precipitation, coagulation, ion exchange, adsorption, etc.	Surface water, groundwater	Retained	May reduce toxicity, mobility, or volume of waste; requires treatment facility; may require bench-scale testing and access restrictions.

TABLE 3 (Cont'd)

Source Control Technology	Media	Evaluation Result	Comments
Treatment (Cont'd)			
Physical treatment			
Filtration, reverse osmosis, thermal destruction, etc.	Surface water, groundwater	Retained	May reduce toxicity, mobility, or volume of waste; requires treatment facility; may require bench-scale testing and access restrictions.
Biological treatment			
Activated sludge, surface impoundments, land treatment, etc.	Surface water, groundwater, sludges	Retained	May reduce toxicity, mobility, or volume of waste; requires treatment facility and/or area; may require bench-scale testing and access restrictions.
Temporary Storage			
On-site	Soils, sludges, bulk wastes, liquids	Retained	May reduce waste mobility and exposure to contaminants while a more permanent remedy is developed. Limits near-term land use; requires storage facility (e.g., engineered structure) and access restrictions during the storage period.
Off-site	Soils, sludges, bulk wastes, liquids	Rejected	Not currently available and not practical due to institutional factors (e.g., siting, transportation requirements, and public acceptance).

TABLE 3 (Cont'd)

Source Control Technology	Media	Evaluation Result	Comments
Disposal			
Direct disposal in land-based facility	Soils, sludges, bulk wastes, liquids	Rejected	Not applicable due to institutional factors (e.g., compliance with ARARs and public/regulatory preference for treatment).
Direct application to land	Sludges, liquids	Rejected	Not applicable due to institutional factors (e.g., compliance with ARARs and public/regulatory preference for treatment).
Direct discharge to surface water	Sludges, liquids	Rejected	Not applicable due to institutional factors (e.g., compliance with ARARs and public/regulatory preference for treatment).
Ocean disposal	Soils, sludges, bulk wastes, liquids	Rejected	Not currently available and not expected to become available in the near future, due to institutional factors. Also, transportation would be expensive and difficult to arrange.

TABLE 4 Summary of General Response Technology Screening: Migration Control

Migration Control Technology	Media	Evaluation Result	Comments
Access Restrictions			
Physical barriers	Soils, sludges, bulk wastes, surface water, groundwater	Retained	Temporarily limits exposure to contaminants. Limits near-term land use; may have negative impact on property values; may be effective when used in conjunction with other technologies.
Institutional controls	Soils, sludges, bulk wastes, surface water, groundwater	Retained	Temporarily limits exposure to contaminants. Limits near-term land use; may have negative impact on property values; may be effective when used in conjunction with other technologies.
Containment/Treatment			
Engineered system or in situ	Soils, sludges, bulk wastes, surface water, groundwater	Retained	Reduces waste mobility and, when containment is used in conjunction with treatment, may also reduce toxicity or volume of waste. Requires containment/treatment system(s); requires monitoring, maintenance, and access restrictions during the containment/treatment period; limits near-term land use; and may have a negative impact on property values.

- Treatment (source control) -- ranging from (a) treatment, as the principal element of the alternative, that will reduce the principal threat(s) posed by a site (i.e., may not involve the highest degree of treatment or the treatment of all wastes) to (b) treatment that will minimize the need for long-term management of the wastes (including monitoring).

The general technologies described in Sections 3.1 and 3.2 have been screened on the basis of the characteristics of the quarry pond water with regard to applicability and institutional considerations. This preliminary screening, summarized in Tables 3 and 4, has identified the following control technologies as potential components of alternatives for the proposed action: access restrictions, pumping, in-situ containment, treatment, and temporary storage of process wastes on-site.

These control technologies have been grouped into the following preliminary removal action alternatives:

Alternative 1:	No action.
Alternative 2:	Access restrictions, i.e., improvement of existing controls.
Alternative 3:	Access restrictions with in-situ containment, e.g., using channels and a grout system.
Alternative 4:	Access restrictions; pumping and treatment, with temporary storage of process wastes at the quarry; and discharge of the treated water to Femme Osage Creek.
Alternative 5:	Access restrictions; pumping and treatment, with temporary storage of process wastes at the quarry; and discharge of the treated water to the Missouri River.
Alternative 6:	Access restrictions; pumping and treatment, with temporary storage of process wastes at the quarry; and discharge of the treated water on land at the quarry, through spray irrigation or evaporation ponds.

4 PRELIMINARY REMOVAL ACTION ALTERNATIVES

4.1 SCREENING OF PRELIMINARY ALTERNATIVES

The six removal action alternatives identified in Section 3.3 are screened for applicability to the proposed action according to four criteria: (1) effectiveness, in terms of protecting the public and the environment, (2) timeliness, (3) technical feasibility, and (4) institutional considerations. The results of this screening are summarized in Tables 5 through 8.

Criterion 1 considers the ability of an alternative to provide a permanent solution; reduce toxicity, mobility, and/or volume of the contaminated pond water; reduce exposure potential; and provide effective protection. Criterion 2 considers the time required to achieve start-up and a permanent solution. The timeliness criterion for initiation of the response action at the quarry pond has been identified as 1 year following approval, i.e., 1 year is the maximum allowable start-up time for retaining an alternative. Criterion 3 considers factors such as constructibility, adverse effects of site environment, reliable performance, and useful life. Criterion 4 considers factors such as the ability of an alternative to reliably meet relevant requirements, its relative effect on local land use and property values, and its potential impact on archeological sites and cultural resources. With regard to the latter, no structures that might be eligible for inclusion in the *National Register of Historic Places* are expected to be impacted by any of the six removal action alternatives because none of these alternatives would involve the destruction or alteration of potentially eligible structures. An archeological survey of the quarry area affected by the proposed action would be conducted prior to the initiation of any response activities at the quarry. If results of the survey identified a potential for impact to archeological sites, either a determination would be made to relocate the activity or other mitigative measures would be taken, as appropriate, in compliance with the requirements of the National Historic Preservation Act.

4.1.1 Alternative 1

Alternative 1, no action, is not affected by either the timeliness criterion or technical feasibility considerations. However, this alternative could confront institutional obstacles based on DOE's commitment to ensure protection of the public and the environment under the National Environmental Policy Act (NEPA), CERCLA, and other relevant requirements. The institutional obstacles could include perceived health risks and negative effects on land use and property values. Adverse environmental impacts include a continuance of, and possible increase in, local exposure to contaminants; the continued potential for contamination of groundwater through leaching; and the possible spread of contamination to a larger area -- through leaching, biouptake, and/or ingestion — with an increased potential for exposure of both humans and local biota.

TABLE 5 Screening of Preliminary Alternatives for the Proposed Action: Criterion 1, Effectiveness

Alternative	Provides Permanent Solution	Reduces Toxicity, Mobility, and/or Volume of Contaminated Water	Reduces Exposure Potential		Provides Effective Protection of the Public and the Environment	Additional Comments
			Short Term	Long Term		
1	No.	No.	No.	No.	No.	Provides baseline for comparison with other alternatives.
2	No.	No.	No.	No.	No.	Although inadequate alone, improvement of existing access restrictions could be used to support primary response actions.
3	No.	Mobility.	Somewhat; entry by trespassers and wildlife still possible.	Uncertain; system integrity difficult to ensure due to fractured nature of subsurface.	Uncertain; monitoring and maintenance required.	Construction activities could result in minor, temporary releases of airborne contaminants. Good engineering practices and mitigative measures would be implemented as appropriate.
4	Yes.	Toxicity, mobility, and volume.	Probably yes, but uncertain because the nature of subsurface pathways is not completely characterized and base flow may be low.	Probably yes, but uncertain; same as short term.	Uncertain (see comments for exposure potential).	Construction, pumping, treatment, and storage activities could result in minor, temporary releases of airborne contaminants. Mitigative measures would be implemented as appropriate.
5	Yes.	Toxicity, mobility, and volume.	Yes.	Yes.	Yes.	Same as Alternative 4.
6	Yes.	Toxicity, and volume, and possibly mobility (spray irrigation may not effect mobility reduction).	Probably yes, but uncertain because the nature of subsurface pathways is not completely characterized.	Probably yes, but uncertain; same as Alternative 4.	Uncertain; same as Alternative 4.	Same as Alternative 4.

TABLE 6 Screening of Preliminary Alternatives for the Proposed Action: Criterion 2, Timeliness

Alternative	Start-up Time	Time for Permanent Solution	Additional Comments
1	Not applicable.	Not applicable.	Because there is no long-term resolution of the contaminated-water issue, Alternative 1 is considered to be untimely in the overall analysis.
2	Weeks.	Not applicable.	Same as Alternative 1.
3	Several months to 1 year.	Not applicable.	Same as Alternative 1.
4	1 year.	2 to 5 years.	Alternative 4 provides a permanent solution to the contaminated-water issue in the near term, so it is considered timely in the overall analysis.
5	1 year.	2 to 5 years.	Same as Alternative 4.
6	1 year.	2 to 5 years.	Same as Alternative 4.

TABLE 7 Screening of Preliminary Alternatives for the Proposed Action: Criterion 3, Technical Feasibility

Alternative	Constructibility	Adverse Effects of Site Environment	Reliable Performance	Useful Life	Additional Comments
1	Not applicable.	Not applicable.	Not applicable.	Not applicable	Technical feasibility is not applicable to "no action."
2	Straightforward and simple, because access restrictions are currently in place at the quarry.	No.	No, based on experience (repairs of existing system are needed) and inability to control trespassers or wildlife.	Inadequate as the sole response.	Although technically feasible, the useful life of Alternative 2 is expected to be low, based on its inherently limited usefulness.
3	Difficult, due to the nature of the terrain within the quarry and the subsurface geology (fractured) in addition to the presence of buried wastes.	Yes (see comments for constructibility).	Uncertain, due to the difficulty inherent in ensuring system integrity (see Table 5).	Uncertain (see comments for reliable performance).	The performance and longevity of Alternative 3 cannot be reliably determined because the complex nature of the pond's subsurface is not yet understood.
4	Straightforward, but somewhat resource-intensive.	No.	Yes.	Adequate, because the components can be designed to provide the appropriate length of service.	As a broad category, treatment is technically feasible (specific treatment technologies for the proposed action are considered in Appendixes B and C), as are pumping and storage. For discharge performance, the construction and use of a pipe to the receiving surface water are also technically feasible.
5	Straightforward, but somewhat resource-intensive.	No.	Yes.	Adequate; same as Alternative 4.	Same as Alternative 4.
6	Potentially difficult, specifically in terms of the discharge component, for which sufficient land may not be available; for the pumping, treatment, and storage components, construction is expected to be straightforward but somewhat resource-intensive.	Possible, due to the limited availability of land, the meteorological conditions, and the subsurface geology as related to the discharge component; the other components are not expected to be adversely affected.	Uncertain (see comments for effects of site environment).	Adequate; same as Alternative 4.	Although the pumping, treatment, and storage components are considered reliable, the performance of the discharge component is uncertain. This performance depends on such factors as available land, weather conditions, and surface soils/subsurface geology.

TABLE 8 Screening of Preliminary Alternatives for the Proposed Action: Criterion 4, Institutional Considerations

Alternative	Compliance with ARARs	Relative Effect on Local Land Use/Property Values	Potential Impact on Archeological Sites/ Cultural Resources	Additional Comments
1	Inadequate, because levels of specific contaminants in the quarry water do not meet certain requirements.	Negative, because the contaminated water would remain in the quarry, as would the associated potential for migration.	None.	Perceived health risks and the public and regulatory preference for treatment are likely to be factors influencing public acceptance.
2	Inadequate; same as Alternative 1.	Negative; same as Alternative 1.	Unlikely, because the activities would only affect limited areas that had previously been disturbed.	Same as Alternative 1.
3	Uncertain, because the integrity of the containment system would be difficult to ensure, making possible the migration of contaminants at levels that do not meet certain requirements.	Somewhat negative, because the migration potential would not be eliminated, so the long-term fate of contaminants would remain uncertain.	Uncertain, because the area to be affected has not yet been surveyed for the presence of such sites or resources.	Same as Alternative 1, but to a lesser degree because of the inclusion of migration control.
4	Uncertain, because water flow in the creek may be intermittently low.	Somewhat positive, because the strong positive effect associated with water treatment would be tempered by the potential for impacting local soil and water resources.	Uncertain; same as Alternative 3.	The preference for treatment would be satisfied by Alternative 4.
5	Full compliance.	Positive, because the strong positive effect associated with water treatment would be supported by the effect of discharging to a large-volume body of water at a considerable distance from the nearest downstream intake (see Section 5.2).	Uncertain; same as Alternative 3.	Same as Alternative 4.
6	Uncertain, because the affected surface and subsurface is not fully characterized.	Somewhat positive; same as Alternative 4.	Uncertain; same as Alternative 3.	Same as Alternative 4.

4.1.2 Alternative 2

Alternative 2 involves improving existing access restrictions and is both timely and technically feasible. However, this alternative does little to address public health and institutional concerns. Related impacts would effectively be the same as those for Alternative 1.

4.1.3 Alternative 3

Alternative 3 consists of in-situ containment with access restrictions and is a viable alternative in terms of timeliness and technical feasibility. During the effective containment period, this alternative would reduce the potential for adverse public and environmental impacts associated with the migration of contaminants from the quarry pond; the potential adverse impacts would be similar to those identified for Alternative 1 and would probably increase with time. In addition, Alternative 3 could encounter institutional problems similar to those for Alternative 1.

4.1.4 Alternatives 4, 5, and 6

Alternatives 4, 5, and 6 would employ timely, technically feasible methods to implement activities associated with access restrictions, pumping, treatment, temporary storage, and effluent discharge. Potential environmental impacts associated with these alternatives include temporary disturbance of local soils, temporary increases in airborne contaminants (e.g., radon-222 and asbestos), and short-term displacement and loss of vegetation and wildlife due to noise and other impacts related to construction and operation activities. In addition, construction activities associated with these alternatives could increase concentrations of suspended solids in nearby surface waters (e.g., Little Femme Osage Creek) in the short term. Good engineering practices and mitigative measures would be implemented as appropriate, e.g., to control erosion, in order to minimize the potential for such impact. Alternatives 4, 5, and 6 would also have positive impacts on water resources related to removing and treating the contaminated surface water from the quarry, thereby removing a source of and gradient for contaminant migration. No impacts to endangered or threatened species are anticipated at the quarry from any of these alternatives because the quarry does not provide habitat for such species. The timely removal of contaminated surface water from the quarry is the primary consideration for protection of the public and the environment. Thus, the most protective and responsible action in terms of minimizing potential adverse impacts to the public and the environment would be achieved by Alternative 4, 5 or 6. Institutional issues associated with action-specific requirements (e.g., release levels) would be resolved through consultation between the departments and agencies involved.

It is important to note that the impacts associated with Alternatives 4, 5, and 6 are likely to be applicable to the other three alternatives in the long term. If a permanent solution for the pond water is not implemented at this time, the pond would be remediated in the future as part of the overall response action for the Weldon Spring site.

4.2 IDENTIFICATION OF FINAL ALTERNATIVES

On the basis of the screening/evaluation and comparative analysis of alternatives in Section 4.1, Alternatives 4, 5, and 6 -- access restrictions; pumping and treatment of the pond water, with temporary storage of the process wastes at the quarry; and discharge of the treated water to Femme Osage Creek, to the Missouri River, or on land at the quarry -- have passed the screening step of the process for selecting a preferred alternative for the proposed action. These alternatives are effective, timely, technically feasible, and responsive to institutional considerations. In addition, they are consistent with the preference specified in Section 121(b)(2) of SARA for remedies that include treatment as a permanent solution. Finally, Alternatives 4, 5, and 6 are consistent with and would contribute to the overall performance of remedial action at the Weldon Spring site.

5 EVALUATION OF FINAL ALTERNATIVES

The following removal action alternatives are retained for further consideration on the basis of the screening discussed in Chapter 4:*

- Alternative 1: Access restrictions; pumping and treatment of the pond water, with temporary storage of process wastes at the quarry; and discharge of the treated water to Femme Osage Creek.

- Alternative 2: Access restrictions; pumping and treatment of the pond water, with temporary storage of process wastes at the quarry; and discharge of the treated water to the Missouri River.

- Alternative 3: Access restrictions; pumping and treatment of the pond water, with temporary storage of process wastes at the quarry; and discharge of the treated water on land at the quarry, through spray irrigation or evaporation ponds.

The potentially relevant requirements associated with the proposed action are discussed in Section 5.1. The three final alternatives are evaluated in Section 5.2 according to effectiveness, implementability, and cost. The alternatives are compared in Section 5.3, and the preferred alternative is identified in Section 5.4.

Implementation of any one of these alternatives would require the design and construction of a water treatment plant to treat the quarry pond water. The design bases for the proposed treatment of contaminated water from the quarry pond are discussed in Section 5.5 and Appendixes B and C. No features would be incorporated into the treatment plant design beyond those required for treatment of the quarry water; however, the design would permit operational flexibility and the modification of unit processes to respond to variations in influent flow and/or concentrations, as appropriate. The proposed water treatment plant would be constructed adjacent to the quarry, as shown in Figure 5.

5.1 REQUIREMENTS POTENTIALLY RELEVANT TO THE PROPOSED ACTION

The final alternatives identified for the proposed action are assessed on the basis of three interrelated categories of requirements: contaminant-specific, location-specific, and action-specific requirements. These requirements are discussed according

*The numbering of these final alternatives differs from that of the preliminary alternatives due to the elimination of three alternatives as a result of the screening process.

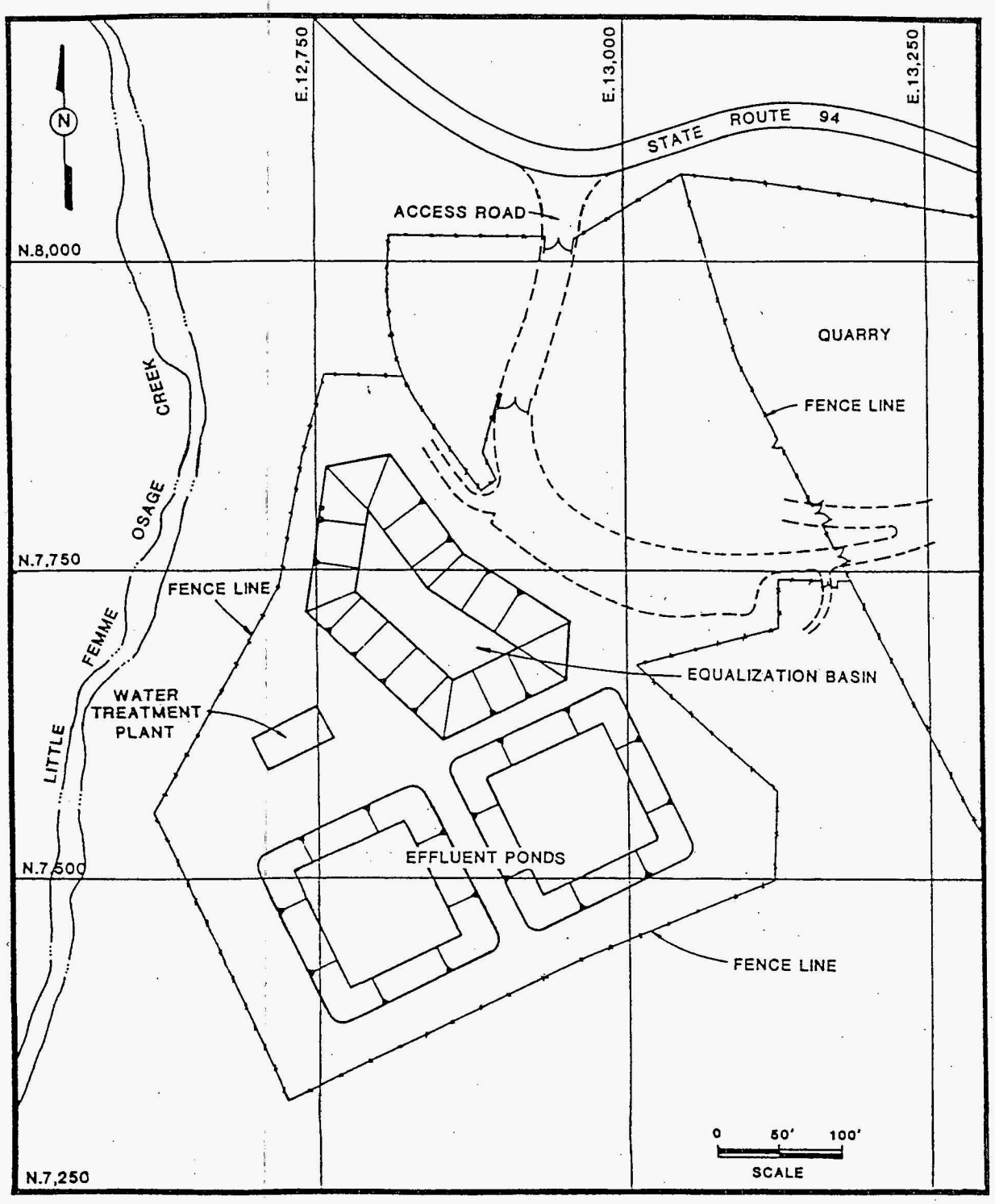

FIGURE 5 Location and Layout of the Proposed Water Treatment Plant

to their grouping in Table 2, i.e., federal laws (Section 5.1.1), federal orders (Section 5.1.2), and state requirements (Section 5.1.3).

It is important to note that the proposed removal action is an intermediate action, the purpose of which is to improve near-term environmental and safety conditions at the quarry. Therefore, the determination of specific effluent limits will be dictated by the conditions of this action alone; no general applicability to other response actions at the Weldon Spring site is implied. Levels of contaminants in the quarry water and potential effluent limits are listed in Table 9; the contaminant levels are based on average concentrations obtained from the characterization results for the quarry pond (see Appendix A). The specific contaminants identified as requiring treatment, the potential effluent limits, and the estimated percent reductions necessary to meet these limits are listed in Table 10.

5.1.1 Federal Laws

The federal laws that may have primary significance to the proposed action at the quarry pond are summarized briefly in Sections 5.1.1.1 through 5.1.1.14.

5.1.1.1 Archeological and Historic Preservation Act; Archeological Resources Protection Act; National Historic Preservation Act, as Amended

The Archeological and Historic Preservation Act, Archeological Resources Protection Act, and National Historic Preservation Act address the preservation, protection, and/or recovery of scientific, prehistorical, historical, or archeological data. Although no historical structures exist at the quarry (see Section 4.1), archeological artifacts may be present because of the quarry's location in an area of little urban disturbance and its close proximity to surface waters, i.e., where prehistoric and later communities typically became established (see Section 5.2.2). Therefore, the requirements regarding archeological resources may apply specifically to the proposed action.

5.1.1.2 Clean Air Act, as Amended

The Clean Air Act establishes National Ambient Air Quality Standards for certain pollutants, including particulate matter, i.e., not to exceed a 24-hour average concentration of 150 $\mu g/m^3$ and an annual arithmetic mean of 50 $\mu g/m^3$. Additional air standards include (1) National Emission Standards for Hazardous Air Pollutants (NESHAPs) for nonambient contaminants such as asbestos and (2) standards for radionuclide emissions from DOE facilities. The asbestos NESHAP requires inactive waste disposal sites to display warning signs indicating that asbestos is present and to prevent the occurrence of visible asbestos emissions to the outside air. The radionuclide emissions standards limit atmospheric releases of radionuclides other than radon-220 and radon-222 and their decay products to amounts resulting in an annual dose equivalent not to exceed 25 mrem to the whole body or 75 mrem to a critical organ of any member of the general public.

TABLE 9 Water Quality of the Quarry Pond and Potential Effluent Limits

Chemical Species	Concentration[a] (mg/L, except as noted) Range	Average	Potential Effluent Limit[b] (mg/L, except as noted)
Aluminum	<0.1-0.08	0.045	-
Arsenic	<0.001-0.15	0.075	0.05
Barium	0.04-0.36	0.11	1
Boron	0.52-0.60	0.54	-
Cadmium	<0.001-0.01	<0.006	0.01
Calcium	70-100	86	-
Chromium	<0.001-0.02	0.013	0.05
Copper	<0.001-<0.02	<0.01	1.0
Iron	0.003-0.33	0.068	0.3
Lead	0.002-<0.05	<0.05	0.05
Lithium	<0.01-0.036	0.025	-
Magnesium	16-26	22	-
Manganese	0.003-0.26	0.07	0.05
Mercury	<0.0001-0.0006	0.0004	0.002
Molybdenum	<0.01-0.07	0.035	-
Phosphorus (as P_2O_5)	0.5	0.5	-
Potassium	11-18	15	-
Selenium	<0.005	<0.005	0.01
Silicon (as SiO_2)	13-21	16	-
Silver	<0.003-0.015	<0.015	0.05
Sodium	14-29	22	-
Strontium	0.37-0.54	0.47	-
Tin	<0.05	<0.05	-
Zinc	0.005-0.31	0.068	5
Chloride	14-200	44	250
Fluoride	0.9-1.1	1.0	2
Nitrate (as N)	<1-9	3.7	10
Sulfate	150-240	200	250
Bicarbonate	190-220	210	-
pH (in units)	7.3-8.2	7.7	6.5-8.5
Asbestos (fibers/L)[c]	-	1.9×10^6	7.1×10^6
Organics (μg/L)			
Cyanide	3	3	5
Toluene	5	5	-
Bis (2-ethylhexyl) phthalate	2	2	-
Di-n-butyl phthalate	3	3	-
Diethyl phthalate	2	2	-
2-Amino-4,6-dinitrotoluene	26	26	-

TABLE 9 (Cont'd)

Chemical Species	Concentration[a] (mg/L, except as noted) Range	Average	Potential Effluent Limit[b] (mg/L, except as noted)
2,4,6-Trinitrotoluene	9	9	-
4-Amino-2,6-dinitrotoluene	15	15	-
2,4-Dinitrotoluene	10	10	0.11[d]
2,4-Diamino-6-nitrotoluene	6	6	-
2,6-Diamino-4-nitrotoluene	3	3	-
6-Amino-hexanoic acid	254	254	-
Suspended solids	50-100	75	-
Gross alpha (pCi/L)	1100	1100	15, minus radon and uranium
Radionuclides (pCi/L)			
Radium-226	-	0.8	5, combined
Radium-228	-	<5	
Thorium-230 (as gross alpha)	-	1.5	15, minus radium-226
Thorium-232 (as gross alpha)	-	0.5	15, minus radium-228
Total uranium	620-3500	2314	550[e]

[a]ND means none detected, i.e., concentration is below the analytical detection limit; a hyphen indicates that data are not available; for those entries having only one value, only one sample was analyzed.

[b]Limits taken from federal drinking water standards (40 CFR Parts 141 and 143, established pursuant to the Safe Drinking Water Act) and state of Missouri drinking water supply limits, unless otherwise noted; a hyphen indicates inapplicability.

[c]Potential effluent limit taken from the EPA proposed recommended maximum contaminant level (goal) (U.S. Environ. Prot. Agency 1985a).

[d]Limit taken from the ambient water quality criteria for federal priority pollutants, corresponding to a 10^{-6} risk level for cancer (U.S. Environ. Prot. Agency 1980).

[e]Limit derived from DOE radiation protection standards (DOE Order 5480.1B and associated guidelines; U.S. Dept. Energy 1987c).

Sources: U.S. Department of Energy (1987a); Bechtel National (1985); Morrison-Knudsen Engineers (1987).

TABLE 10 Contaminants Requiring Treatment for Reducing Concentrations to Potential Effluent Limits

Contaminant	Unit	Average Influent Concentration	Potential Effluent Limit	Percent Removal Required
Arsenic	mg/L	0.075	0.05[a]	33
Manganese	mg/L	0.07	0.05[a]	29
2,4-DNT	µg/L	10	0.11[b]	99
Total uranium	pCi/L	2,314	550[c]	76

[a]Taken from Missouri drinking water supply limits, which are at least as stringent as the EPA drinking water standards (40 CFR Parts 141 and 143).

[b]Taken from the ambient water quality criteria for federal priority pollutants, corresponding to a 10^{-6} risk level for cancer (U.S. Environ. Prot. Agency 1980).

[c]Derived from DOE guidelines (DOE Order 5480.1B and associated guidelines; U.S. Dept. Energy 1987c).

Asbestos and radionuclides are present in the quarry pond, and proposed construction, pumping, and treatment activities in the area could generate particulate matter, asbestos, and/or radionuclide emissions. All air quality and emission requirements would be complied with throughout the course of the proposed action by implementing mitigative measures as necessary (e.g., wetting surfaces to minimize dust generation and controlling vehicular traffic, as well as wearing personal protective equipment). Monitoring would be conducted during the response action to ensure compliance with air quality requirements (see Section 5.2.1.1).

5.1.1.3 Clean Water Act, as Amended

For direct discharges to surface waters, the Clean Water Act establishes National Pollutant Discharge Elimination System (NPDES) permitting requirements that identify water quality standards and effluent limitations that are based on the best available technology that is economically achievable. Included are discharge limits for certain chemicals (not including uranium), monitoring requirements, and best management practices (e.g., proper operation and maintenance of treatment systems). Pursuant to the act, limits were established under 40 CFR Part 440 for radium and uranium in surface water discharges from uranium mines (i.e., for uranium, a 30-day average concentration of 2 mg/L and a 24-hour maximum concentration of 4 mg/L; for dissolved and total radium-226, 30-day average concentrations of 3 and 10 pCi/L and 24-hour

maximum concentrations of 10 and 30 pCi/L, respectively). In addition, the act requires the preparation of spill prevention, control, and countermeasures (SPCC) plans to address the accidental release of oils in quantities that may be harmful to waters.

Certain chemicals (not including radium) in the quarry pond are in excess of the discharge limits regulated under the Clean Water Act (see Table 9). The proposed action would reduce the levels of these contaminants to those levels promulgated under the act, as appropriate. (Uranium limits are discussed in Section 5.1.2.2.) Although the SPCC plan under this act applies specifically to oils, the SPCC plan in place for the Weldon Spring site covers accidental releases of hazardous materials as well, and the requirements of the act with regard to releases would be implemented for all actions proposed for the site, including those at the quarry.

5.1.1.4 Comprehensive Environmental Response, Compensation, and Liability Act, as Amended

The authority and responsibilities for implementing environmental response actions, including procedural requirements, are identified in CERCLA. Because the quarry is listed on the NPL, the proposed action is subject to and would comply with CERCLA requirements (see Section 1.2).

5.1.1.5 Endangered Species Act

The Endangered Species Act establishes a policy to avoid either jeopardizing species that are listed as endangered or threatened or modifying their critical habitats. No endangered or threatened species, nor critical habitats, have been identified at the quarry (see Sections 1.1 and 4.1.4). Therefore, this act is neither applicable nor relevant and appropriate to the proposed action.

5.1.1.6 Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act addresses the protection of fish and wildlife from actions that modify streams or areas affecting streams (e.g., diversion or channeling). No modification of streams or stream areas is planned as part of the proposed action. However, minor, temporary (mitigable) disturbances of Little Femme Osage Creek could occur in terms of suspended solids loading during proposed construction activities (see Section 4.1.4). In addition, if Femme Osage Creek is the receiving body for the treated water (Alternative 4), some adverse impacts may occur to the ecosystem it supports. The pertinent requirements of this act would be followed during implementation of the proposed action.

5.1.1.7 Hazardous Materials Transportation Act, as Amended

The Hazardous Materials Transportation Act establishes standards for shipping, packaging, marking, labeling, and recording associated with the transport of hazardous

materials, as well as requirements for spill contingency and response, i.e., generic requirements for minimizing the environmental impacts of spills or releases that address neither specific contaminants nor classes of contaminants (e.g., asbestos or radioactive material). This act is applicable to the proposed action because transportation of process wastes is a component of each of the final alternatives (see Section 4.2). All pertinent requirements of the act would be followed during the transportation phase. An SPCC plan to address spill contingency and response activities is in place for the Weldon Spring site, which includes the quarry (see also Sections 5.1.1.3 and 5.1.1.10).

5.1.1.8 National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires consideration of environmental impacts at every stage of the process for making decisions and implementing actions that may affect the quality of the environment. The proposed action is subject to and would comply with all NEPA requirements.

5.1.1.9 Noise Control Act, as Amended; Noise Pollution and Abatement Act

The Noise Control Act and Noise Pollution and Abatement Act address protection of the public from noise that jeopardizes their health or welfare (e.g., from machinery or transportation vehicles), primarily sources of noise in interstate commerce. (Most of the responsibility for noise control was vested in state and local governments; see also Section 5.1.1.10.) Pursuant to the acts, standards have been established for certain equipment and vehicles such as air compressors and trucks/tractors. Because equipment and vehicles would be involved in certain aspects of the proposed action (e.g., construction, operation, and transportation), all pertinent requirements of the acts would be followed.

5.1.1.10 Occupational Safety and Health Act

The Occupational Safety and Health Act (OSHA) establishes worker protection requirements in occupational situations, such as the storage and handling of contaminated materials, including materials containing inorganic arsenic and asbestos. (For example, the exposure standard for inorganic arsenic is 0.5 mg/m^3 air, and the standard for asbestos identifies an 8-hour time-weighted average of 2.0 fibers and an upper limit of 10.0 fibers >5 $\mu m/cm^3$ air.) In addition, OSHA identifies requirements for noise exposure and for the ventilation and operation of open-surface tanks. The proposed action would involve the potential for worker exposure (mitigable) to regulated contaminants at the quarry, such as arsenic and asbestos, as well as to noise; also, the treatment plant would include open-surface tanks (see Sections 4.1.4, 5.2.1, and 5.5 and Appendix C). All pertinent requirements of the act would be followed.

5.1.1.11 Safe Drinking Water Act, as Amended

The Safe Drinking Water Act establishes National Primary and Secondary Drinking Water Standards and led to the identification of maximum contaminant levels (MCLs) for contaminants in surface water or groundwater (not including uranium), which should be met where the water is used for drinking. Subsequent to the act, maximum contaminant level goals (MCLGs) — i.e., nonenforceable limits for which to strive -- were also identified for specific contaminants (e.g., asbestos). Certain contaminants in the quarry pond are in excess of drinking water standards. The proposed action would reduce the levels of these contaminants to appropriate limits. In addition, because no MCL has been promulgated for asbestos, the level of asbestos in the quarry water would be reduced to comply with the proposed MCLG (see Table 9).

5.1.1.12 Solid Waste Disposal Act, as Amended

The Solid Waste Disposal Act addresses the treatment, storage, management, and disposal of certain contaminated materials and establishes requirements for permits and licenses. The act also prohibits the land disposal of certain liquids (e.g., those containing over 500 mg/L arsenic), but the levels of regulated contaminants in the pond are less than those at which land disposal is precluded (see Table 9). Certain substantive requirements of the act, e.g., those pertaining to the management of contaminated materials and tank/container storage, may be relevant and appropriate to the proposed action. All pertinent, substantive requirements of this act would be followed.

5.1.1.13 Toxic Substances Control Act

The Toxic Substances Control Act addresses PCB contamination and establishes inspection and testing requirements for materials contaminated at certain levels (e.g., 50-500 ppm PCBs). Subsequent rulemaking addresses asbestos contamination (i.e., in schools). Based on characterization results, the act does not apply to PCB contamination in the quarry pond (see Appendix A). The ARARs for asbestos are derived from other regulatory requirements (see Sections 5.1.1.2, 5.1.1.10, and 5.1.1.11).

5.1.1.14 Uranium Mill Tailings Radiation Control Act, as Amended

The Uranium Mill Tailings Radiation Control Act (UMTRCA) establishes limits for the release of radon from inactive uranium mill tailings sites (see 40 CFR Part 192). Following remedial activities, radon releases to the atmosphere from uranium mill tailings piles should not exceed an average rate of 20 pCi/m^2-s or increase the annual average concentration in air outside the disposal site by more than 0.5 pCi/L. (In any occupied or habitable building, the concentration of radon and decay products [including background] should not exceed an annual average of 0.02 working level [WL] or a maximum of 0.03 WL, where 1 WL equals any concentration of short-lived radon decay products in 1 L of air that will result in the ultimate emission of alpha particles with a total energy of 130 billion electron volts.) In addition, gamma exposure should not exceed background levels by more than 20 μR/h in any occupied or habitable building,

combined radium-226 and radium-228 in water should not exceed 5 pCi/L, gross alpha (excluding radon and uranium) in water should not exceed 15 pCi/L, and the annual dose equivalent from sources other than radon and its short-lived decay products should not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ of any member of the general public.

Although not applicable to the proposed action (because the quarry is not an inactive uranium mill tailings disposal site), these requirements may be considered relevant and appropriate because of the presence of similar contaminants. All pertinent requirements of this act would be followed (e.g., those for the occupied building as pertaining to any enclosed portion of the treatment plant). The DOE basic dose limit for the general public from all sources of radiation is 100 mrem/yr above background, with further reductions as practical and appropriate to levels "as low as reasonably achievable" (ALARA) (see Section 5.1.2.2). The derivation of the DOE limit is based on a 50-year committed effective dose equivalent, whereas the limit identified in UMTRCA is based strictly on an annual dose resulting from exposure via the inhalation pathway alone. The proposed action would comply with both requirements (DOE and EPA).

5.1.2 Federal Orders

In addition to those federal orders that relate to the general policies and implementation of certain of these federal laws, the orders discussed in Sections 5.1.2.1, 5.1.2.2, and 5.1.2.3 may have primary significance to the proposed action.

5.1.2.1 Executive Orders 11988 and 11990

Executive Orders 11988 and 11990 establish a policy to avoid adverse impacts to wetlands and adverse effects related to the direct and indirect development of floodplains, to the extent possible. The orders apply to managing and disposing of federal lands, providing construction and improvements, and conducting programs and activities that affect land use. First, the proposed action would not have an adverse effect on development of the nearby floodplain but, by limiting contaminant migration, would in fact improve the long-term conditions in the floodplain if future development of the floodplain should be planned. In addition, the proposed treatment plant would not be constructed in the floodplain or in the quarry pond (see Figure 5). Finally, the quarry pond is a man-made wetland (i.e., it was created after the quarry was excavated to considerable depths for limestone mining), and the intent of the proposed action is to clean up contaminated water, not to directly place fill materials in an existing wetland (see Chapter 2). Therefore, these requirements are not pertinent to the proposed action.

5.1.2.2 DOE Order 5480.1B (Chapter XI, as Amended) and Subsequent Updates of Derived Concentration Guides

The requirements of DOE Order 5480.1B and subsequent updates of the Derived Concentration Guides establish a basic dose limit for nonoccupationally exposed individuals of 100 mrem/yr committed effective dose equivalent above background. The

requirements also identify health-based aqueous concentration limits for uranium-238 and uranium-234 at the point of discharge to a surface water (i.e., not to exceed 600 pCi/L and 500 pCi/L, respectively). Additionally, all radiation exposures must be reduced to ALARA levels (see Chapter 6).

These are established requirements that have been implemented numerous times, and because they represent standards for DOE releases of uranium to water in uncontrolled areas, they are directly applicable to the proposed action. For total uranium, the discharge limit derived from the above concentration limits is 550 pCi/L plus ALARA. An additional standard for uranium has been promulgated and implemented by the EPA (40 CFR Part 440) to regulate uranium mine discharges. This standard identifies a 30-day average concentration limit of 2 mg/L, which translates to about 670 pCi/L for uranium-238 or 1,360 pCi/L for total uranium. However, this limit is neither applicable nor relevant or appropriate to the proposed action because the proposed quarry treatment plant discharge is not a uranium mine discharge. (In addition, this limit is substantially higher than the DOE limit.) Therefore, the DOE standards represent the uranium ARAR for the proposed action.

5.1.2.3 DOE Order 5480.3

DOE Order 5480.3 establishes requirements for the packaging and transportation of hazardous materials, hazardous substances, and hazardous wastes. All pertinent requirements of the order would be followed, as appropriate, during the proposed action.

5.1.3 State Requirements

The state laws, rules, and regulations discussed in Sections 5.1.3.1 through 5.1.3.10 may have primary significance to the proposed action. Many of the state requirements are either similar to federal requirements that have been discussed in this section or are pertinent only to state-lead actions.

5.1.3.1 Missouri Abandoned Mine Reclamation and Restoration Rules

The Missouri Abandoned Mine Reclamation and Restoration Rules address restoration of the environment and protection of the public from adverse effects of past mining practices (including noncoal mining). Rules are established for rights of entry, acquisition of land or water for reclamation, and reclamation of private lands. The proposed action would achieve the goals identified in these rules, e.g., protection of the public and the environment, and would thus comply with the pertinent requirements (see Chapter 2 and Section 4.1.4).

5.1.3.2 Missouri Air Conservation Law

The Missouri Air Conservation Law addresses the preservation of air quality by such means as requiring construction permits. The proposed action would comply with

the pertinent, substantive requirements of this law, i.e., to preserve air quality (see Section 5.1.1.2).

5.1.3.3 Missouri Air Pollution Control Regulations and Air Quality Standards

The Missouri Air Pollution Control Regulations and Air Quality Standards establish limits for ambient air quality, i.e., an annual arithmetic mean and a 24-hour average for particulate matter in air of 50 and 150 $\mu g/m^3$, respectively. In addition, these regulations establish permitting requirements and regulations for the St. Louis Metropolitan Area (and four other state areas) that impose restrictions on the emission of visible air contaminants, including those from internal combustion engines, as well as restrictions to limit the emission of fugitive particulate matter. The proposed action would comply with the pertinent, substantive requirements of these regulations, e.g., during periods of potential dust generation, such as during construction of the treatment plant (see Section 5.1.1.2).

5.1.3.4 Missouri Clean Water Law

The Missouri Clean Water Law establishes procedural requirements, including proper operation and maintenance of treatment facilities. Because a treatment facility is an essential component of the proposed action, pertinent aspects of this law would be followed.

5.1.3.5 Missouri Hazardous Substance Rules

The Missouri Hazardous Substance Rules address emergency reporting for releases of hazardous substances. The requirements established in these rules would be followed, as appropriate, i.e., if a release of hazardous substances occurs (see Section 5.1.1.7).

5.1.3.6 Missouri Hazardous Waste Management Law

The Missouri Hazardous Waste Management Law addresses procedural requirements, such as for transportation, storage, and permits. Permitted discharges to waters and radioactive wastes that are governed under Section 42.2011 of the U.S. Code are excluded from this law. Pertinent requirements of this law would be followed, as appropriate, during the proposed action, e.g., during transportation of the process wastes (see Section 5.1.1.7).

5.1.3.7 Missouri Public Drinking Water Regulations

The Missouri Public Drinking Water Regulations establish requirements for drinking water supply systems, including requirements for permits, monitoring, laboratory procedures, reporting, record maintenance, plant construction, grants, and operator

certification. In addition, these regulations specify maximum contaminant levels for drinking water systems. Except for fluoride, the specified levels for contaminants relevant to the proposed action are the same as levels identified in federal requirements (see Section 5.1.1.3); for fluoride, the specified value of 2.2 mg/L is slightly higher than the federal standard of 2.0 mg/L. The proposed action would reduce levels of contaminants in the quarry water to comply with the levels specified in these regulations.

5.1.3.8 Missouri Safe Drinking Water Act

The Missouri Safe Drinking Water Act establishes procedural requirements for drinking water supply systems, including requirements for rulemaking, authorization for testing, reporting, and record maintenance. Pertinent, substantive requirements of this act would be followed, as appropriate, during the proposed action.

5.1.3.9 Missouri Solid Waste Law

The Missouri Solid Waste Law addresses procedural requirements for waste processing and disposal facilities, including permits and postclosure monitoring. Pertinent requirements of this law would be followed, as appropriate, during the proposed action.

5.1.3.10 Missouri Solid Waste Rules

The Missouri Solid Waste Rules establish certain policies and procedures, including those for the design and operation of sanitary and demolition landfills and permitting and postclosure monitoring of disposal areas. Pertinent requirements identified in these rules would be followed, as appropriate, during the proposed action.

5.1.3.11 Missouri Water Pollution Control Regulations

The Missouri Water Pollution Control Regulations establish procedural requirements, such as permitting, to control the release of contaminants into state waters. All pertinent, substantive requirements of these regulations would be followed, as appropriate, during the proposed action.

5.1.3.12 Missouri Water Quality Standards and Effluent Limitations Standards

The Missouri Water Quality Standards and Effluent Limitations Standards establish water quality standards for certain pollutants — including arsenic, manganese, and lead — for different water-use categories. For example, for the protection of aquatic life, arsenic is limited to 20 μg/L and lead is limited to 50 μg/L; for drinking water supplies (i.e., for Alternative 3), arsenic, lead, and manganese are each limited to 50 μg/L; and for irrigation supplies, arsenic is limited to 100 μg/L. Effluent limitations standards are established for discharges from point sources, water contamination sources, and wastewater treatment facilities. These standards apply to common

parameters such as pH, biological oxygen demand, total suspended solids, and fecal coliform. Additional procedural requirements are addressed for monitoring and sludge management. Certain of the established standards are applicable to the proposed action (e.g., for metals, pH, and total suspended solids) and would be followed, as would pertinent procedural requirements (see Table 9).

5.2 DETAILED EVALUATION OF FINAL ALTERNATIVES

The three final alternatives identified in Section 4.2 are evaluated according to three broad criteria:

- Effectiveness, in terms of protecting the public and the environment from potential impacts;
- Implementability, in terms of
  - Time required for implementation (i.e., timeliness),
  - Technical feasibility (technology-specific and site-specific factors and applicability to project goals), and
  - Responsiveness to institutional considerations such as public acceptance, acquisition of permits, compliance with ARARs, need for cooperation with other agencies or organizations, and compliance with specific project requirements (e.g., budget, schedule, and efficient performance of the overall remedial action planned for the site); and
- Reasonable cost, in terms of capital costs and operation and maintenance (O&M) costs -- both short-term and long-term.

5.2.1 Effectiveness

The effectiveness of an alternative is defined by its effectiveness in ensuring protection of and minimizing impacts to the public and the environment. Potential impacts of the final alternatives are addressed in Sections 5.2.1.1 and 5.2.1.2. Each of the three alternatives would reduce long-term impacts by removing and treating the source of contaminated surface water at the quarry, thereby eliminating the potential for uncontrolled releases of contaminants from the quarry pond into the local environment. All three alternatives would also be effective in terms of health and safety because the treatment system inherent to each alternative could be safely constructed and operated. However, the alternatives differ in terms of the risks associated with their respective discharge points, i.e., into Femme Osage Creek (Alternative 1), into the Missouri River (Alternative 2), or onto the land at the quarry via spray irrigation or evaporation ponds (Alternative 3).

For the spray-irrigation option of Alternative 3, the area of land available to receive the treated water may not be sufficient. Land within the quarry rim is excluded from consideration (runoff would refill the pond and could increase contaminant levels due to flow over bulk wastes), and the availability of external land is limited. In addition, the soil dedicated to spray irrigation may be intermittently unable to receive the water at the required rate, e.g., due to saturated or frozen conditions. If the soil were able to receive the land application of treated water, the ultimate fate of residual contaminants in the water could not be ascertained. The subsurface hydrogeology could include interconnections with aquifers or discrete lenses that may now or in the future be a source of ingested water, or it could contain conduits for the direct transport of undiluted effluent to potential receptors.

Similar difficulties are associated with implementation of the evaporation-pond option of Alternative 3. The availability of land at the quarry is limited and may be insufficient to provide the evaporation capacity required for the proposed action. In addition, the success of evaporation is strongly dependent on meteorological conditions such as temperature, amount of cloud cover, and relative humidity. Based on the environmental conditions in the area -- including low net lake/pan evaporation rates, relatively cold winters, and humid summers -- and based on the estimated volume of treated water that could be produced (see Section 5.5), the pond option is not appropriate for the proposed action.

In summary, because of site-specific factors, it may not be feasible to implement Alternative 3, and it cannot be demonstrated that this alternative would ensure protection of the public and the environment. Therefore, Alternative 3 is eliminated from further consideration for the proposed action. Only Alternatives 1 and 2 will be addressed in the remaining detailed evaluation of alternatives. The differences between Alternative 1 (effluent discharge to Femme Osage Creek) and Alternative 2 (effluent discharge to the Missouri River) in terms of potential impacts to the public and the environment are identified in the following analyses of risks to human health and the environment.

5.2.1.1 Health Risk Analysis

Impacts to the local population could result from exposure to contaminants during pumping, treatment, and temporary storage activities at the quarry under either Alternative 1 or 2. The planned improvement of access restrictions at the quarry would limit public (i.e., trespasser) exposure through direct contact or ingestion, or through inhalation at the enclosed storage facility. However, potential population exposure could result through inhalation of airborne contaminants, such as radon gas or asbestos, released during pumping and treatment of the contaminated pond water. Existing monitoring data indicate that radon exposure would not be significant because radon concentrations decrease with increasing distance from the quarry such that, beyond a radius of about 0.4 km (0.25 mi), the concentration of radon is indistinguishable from background levels; the nearest residence to the quarry is about 0.8 km (0.5 mi) distant. Similarly, asbestos levels beyond the quarry are expected to be insignificant. No volatile organics have been detected in the quarry water, so chemical exposure through inhalation of organics during the action period is also expected to be minimal. Monitoring for radon

and asbestos would be conducted during the action period, and mitigative measures would be taken, as needed, to ensure public safety. Therefore, the potential for inhalation exposure of the local population is expected to be minimal. In summary, the impacts to public health from pumping, treatment, and temporary storage activities at the quarry are expected to be insignificant for both alternatives.

Impacts to workers could occur during pumping, treatment, and storage activities at the quarry under either alternative. All activities associated with the proposed action would be conducted in accordance with health and safety plans for the Weldon Spring site to ensure the health and safety of the workers. Therefore, the potential for occupational exposure to contaminants by direct contact, ingestion, or inhalation is expected to be minimal. Removal of water from the quarry pond is not expected to result in any measurable increase in the levels of radon gas or gamma radiation from the bulk wastes in the quarry because the pond covers only a relatively small portion of these wastes. The potential for exposure to radon or asbestos resulting from emissions during pumping and treatment activities is expected to be greater for workers than for the general public. Levels of radon and asbestos at the quarry would be monitored during the removal action period. If monitoring results indicated a potential occupational exposure threat, additional mitigative measures (such as use of personal air filters) would be implemented to ensure the health and safety of the workers. Based on experience with safe practices that have been implemented for similar activities in the field, handling of process wastes (such as sludges and spent resins) is not expected to pose an occupational threat to workers. The treatment facility would be ventilated, as necessary, to limit the buildup of gaseous contaminants, e.g., radon. Work procedures have been developed to ensure that doses to workers would be kept to levels that are less than those specified by relevant regulations. Workers would receive training with regard to radiation risks and proper health-physics procedures. Based on the nature of the proposed action and the implementation of proper procedures, the health impacts to workers from implementing either of the proposed alternatives are expected to be insignificant.

The primary difference between potential impacts associated with Alternative 1 and Alternative 2 is related to where the treated water would be discharged. The nature of the discharge, i.e., the levels of residual contaminants in the effluent, would be the same for both alternatives. The EPA and the state of Missouri have established drinking water requirements for arsenic, manganese, and 2,4-DNT; these requirements would be met prior to effluent release (see Table 9). Because there are no similar EPA or state requirements for uranium, the following analysis is limited to the risks associated with residual uranium in the release of treated water to either Femme Osage Creek (Alternative 1) or the Missouri River (Alternative 2).

Under Alternative 1, the concentration of uranium in the effluent that would be discharged to Femme Osage Creek would be maintained below 100 pCi/L (see Chapter 6). Because flow in the creek is sometimes quite low, no credit is taken for further dilution that may occur. Therefore, it is conservatively assumed that water containing uranium at a concentration of 100 pCi/L could be consumed by an individual passing through the area, e.g., a hiker or hunter. The likelihood of incidental ingestion is expected to be low because warning signs would be posted along the creek during the action period to preclude such an occurrence. However, for completeness, the dose and risk associated

with this one-time accidental exposure scenario is assessed, and it is assumed that the maximally exposed individual ignores posted signs and consumes an incidental volume of 1 L of water from the creek. Other exposure pathways associated with the creek, such as ingestion of contaminated plant foods or inhalation, would be insignificant contributors to the total dose relative to the water-ingestion pathway.

In this analysis, the dose and risk resulting from the accidental exposure scenario are treated separately and are not combined with the doses and risks from the other (routine) exposure scenarios because the likelihood that this accidental exposure would occur is low. Routine exposures are those exposures considered likely to occur, e.g., through ingestion of fish and/or drinking water from the Missouri River.

The incremental radiation dose (i.e., the dose received from action-related exposure in addition to the dose from background radiation) that would result from ingesting 1 L of water containing 100 pCi/L of uranium is estimated to be 2.7×10^{-5} rem, using the 50-year committed effective dose equivalent conversion factors of the International Commission on Radiological Protection (ICRP 1979). Applying the ICRP risk factor of 1.65×10^{-4}/person-rem for the induction of fatal cancers and serious genetic effects in the first two generations following radiation exposure, the incremental health risk to the maximally exposed individual from this incidental ingestion is about 4.5×10^{-9}. This value represents a lifetime incremental risk because the dose results from a single accidental exposure.

In addition to this accidental-exposure assessment, the dose and risk to the maximally exposed individual resulting from routine exposures under Alternative 1 must also be assessed. These routine exposures are associated with the Missouri River because Femme Osage Creek empties into the Missouri River. The two pathways that are expected to contribute to radiation exposure after the effluent flows from the creek into the river are ingestion of drinking water and ingestion of fish.

When the creek empties into the Missouri River, the uranium concentration would be rapidly reduced because of dilution. The concentration of uranium in the river is determined by its concentration in the creek effluent and by the flow rate of both the effluent and the river. The average uranium concentration of the effluent is expected to be maintained below 100 pCi/L, and the effluent flow rate is expected to average 0.002 m^3/s (0.07 ft^3/s) (see Section 5.5). Using these average values, the annual inventory of uranium that would be received by the Missouri River during one year of plant operation (i.e., 300 days, see Section 5.5) is estimated to be 0.005 Ci. Measurements of the river's flow rate documented from 1970 to 1985 range from about 420 to 11,200 m^3/s (15,000 to 400,000 ft^3/s) and consistently exceed 280 m^3/s (10,000 ft^3/s) (by 1970, the last of the current upstream dams had been put in place on the river). In fact, over 99% of these recorded flow rates exceed 700 m^3/s (25,000 ft^3/s) (Bedan 1988). For this risk analysis, the volumetric flow rate of the Missouri River is conservatively assumed to be 280 m^3/s (10,000 ft^3/s). Thus, the average incremental uranium concentration in the river following its receipt of the effluent flow would be about 0.0007 pCi/L.

Femme Osage Creek flows into the Missouri River at river mile 49 from the confluence with the Mississippi River. The nearest water-supply intakes are located

about 19 km (12 mi) downstream, at mile 37 from the confluence and on the opposite (eastern) side of the Missouri River. These intakes serve two water treatment plants that are adjacent to each other at mile 37: (1) Hog Hollow Water Treatment Plant of St. Louis County, a private water supply, and (2) Howard Bend Water Treatment Plant of the city of St. Louis, a municipal system. A third intake is located about 45 km (28 mi) downstream from the effluent release, at mile 21 from the confluence with the Mississippi River. This is the intake of the Florissant Water Treatment Plant of St. Louis County, a private water supply. A fourth water treatment plant that may be affected by the release of residual uranium to the Missouri River is the municipal Chain of Rocks plant, which is located on the Missouri side of the Mississippi River about 6.4 km (4 mi) downstream of its confluence with the Missouri River. Although the intake for this plant is located on the Mississippi River, it is conservatively assumed that due to its proximity to the Missouri River, the two flows have not yet mixed. Therefore, the uranium concentration at this intake is assumed to be the same as that at the three intakes on the Missouri River. The combined population that could be served by these four treatment plants is about 1.5 million persons (Mazur 1988). Thus, the total population potentially affected by the proposed action through ingestion of drinking water is conservatively estimated to be two million persons.

For the drinking-water ingestion pathway, it is assumed that neither entrainment nor settling of uranium on the river banks or bed occurs, so that all of the uranium discharged to the river contributes to the concentration in the water that is withdrawn downstream for use as drinking water. However, some entrainment/deposition of uranium is likely because the Missouri River is fairly turbid and traverses a convoluted path; also, the effluent is discharged across the width of the river from the intakes and at the bank rather than at mid river. Therefore, the uranium concentration at the intakes of the water treatment plants could be significantly lower than the 0.0007 pCi/L derived from the above assumptions. However, neither these factors nor the potential of the lime-softening process used in these treatment plants to provide additional uranium-removal capability have been incorporated in the analysis. Thus, the assumptions upon which the river drinking-water risk estimate is based are conservative.

The incremental dose to the maximally exposed individual is calculated for an individual ingesting drinking water from the river that contains 0.0007 pCi/L of uranium, at a typical rate of 410 L/yr (U.S. Dept. Energy 1988a). The incremental dose received from this ingestion is about 7.7×10^{-8} rem/yr. The incremental health risk corresponding to this dose is about 1.3×10^{-11}/yr, and the incremental lifetime risk is about 1.3×10^{-10}, based on the assumption that the quarry treatment plant would operate for 10 years.

For the fish-ingestion pathway, it is assumed that the maximally exposed individual annually consumes 5.4 kg of fish (U.S. Dept. Energy 1988a) whose habitat was restricted to an area of the Missouri River near the creek outflow. The uranium concentration in this area could be somewhat greater than 0.0007 pCi/L due to incomplete dilution. Also, any suspended material that was entrained in the effluent could settle to the river bottom in the immediate area and subsequently become re-entrained. Thus, it is assumed for this analysis that the fish inhabited water containing a uranium concentration 100 times greater than that of the fully mixed flow, or 0.07 pCi/L. Using the

bioaccumulation factor of 2 L/kg for freshwater fish (Gilbert et al. 1983), the maximally exposed individual would receive an incremental dose of 2.0×10^{-7} rem/yr from this pathway. The incremental annual risk associated with this dose is 3.3×10^{-11}/yr, and the incremental lifetime risk is 3.3×10^{-10}, assuming 10 years of plant operation.

Under Alternative 1, the maximally exposed individual would receive an annual dose of about 2.8×10^{-7} rem/yr from routine exposure through the ingestion of fish (2.0×10^{-7} rem/yr) and drinking water from the river (7.7×10^{-8} rem/yr). Combining the incremental annual risk from fish ingestion (3.3×10^{-11}/yr) with the risk for ingestion of drinking water supplied from the river (1.3×10^{-11}/yr), the total incremental annual risk to the maximally exposed individual from routine exposure under Alternative 1 is about 4.6×10^{-11}/yr. This risk is a very small fraction (1/10,000) of the risk that an individual will be struck by lightning in a given year. Combining the incremental lifetime risks associated with these two exposure scenarios, the total incremental lifetime risk to the maximally exposed individual under Alternative 1 is about 4.6×10^{-10}.

To estimate population doses for Alternative 1, the contributive exposure scenarios are (1) ingestion of drinking water from the water treatment plants with intakes on the Missouri River and on the Mississippi River near the confluence of the rivers and (2) ingestion of fish from the Missouri River. For the river drinking-water pathway, it is assumed that the population of 2 million supplied by the four treatment plants downstream of the effluent release would ingest a total of 820 million liters of water, resulting in a population dose of about 1.5×10^{-1} person-rem/yr. The incremental annual risk to the population corresponding to this dose is about 2.5×10^{-5}/yr, and the incremental lifetime risk is about 2.5×10^{-4}.

To estimate the population dose that could result from ingesting fish harvested from the Missouri River, it is assumed that the population consumes all of the fish caught downstream of the effluent release (i.e., between the discharge point and the confluence with the Mississippi River). It is also assumed that the uranium concentration in this 78-km (49-mi) stretch of river averages 0.0007 pCi/L and that the fish have inhabited this water throughout their lifespans. Approximately 136,500 fish/yr are harvested from the Missouri River between mile 144 and the confluence with the Mississippi River due to recreational and commercial fishing combined (Fleener 1988). From this total, it is estimated that 46,500 fish are harvested from the Missouri River between the Femme Osage Creek outflow (mile 49) and the Mississippi River (mile 0). Conservatively assuming that the average edible portion of these fish is about 2.5 kg (5 to 6 lb), the total edible amount of fish harvested over this distance is estimated to be 116,000 kg (255,000 lb). Using the uranium bioaccumulation factor of 2 L/kg for freshwater fish, the estimated population dose resulting from fish ingestion is 4.4×10^{-5} person-rem/yr. This dose corresponds to an incremental annual risk of about 7.3×10^{-9}/yr and an incremental lifetime risk of about 7.3×10^{-8}. Combining the incremental annual population risk from the ingestion of drinking water (2.5×10^{-5}/yr) and the ingestion of fish (7.3×10^{-9}/yr) associated with the Missouri River, the total incremental annual risk to the exposed population is about 2.5×10^{-5}. The total incremental lifetime risk to the population under Alternative 1 is about 2.5×10^{-4}, assuming 10 years of plant operation.

Under Alternative 2 -- discharge of the effluent from the quarry treatment plant to the Missouri River -- the effluent uranium concentration, which would be maintained

below 100 pCi/L, would rapidly decrease upon reaching the river because of dilution. The two primary pathways of potential radiation exposure associated with the river for both the maximally exposed individual and the exposed population are (1) ingestion of drinking water and (2) ingestion of fish. As for Alternative 1, exposure pathways such as ingestion of irrigated plant foods and inhalation would be minor contributors to the total dose relative to these two primary pathways. Although the discharge point for Alternative 2 is about 1.6 km (1 mi) downstream of the Femme Osage Creek outflow, this small distance does not affect the risk assessment relative to Alternative 1 (i.e., for the fish-ingestion population-exposure scenario).

The total incremental dose to the maximally exposed individual under Alternative 2 is the same as that calculated under Alternative 1 for the combined ingestion of fish from the discharge area and of drinking water supplied from the river, i.e., about 2.8×10^{-7} rem/yr. The corresponding incremental annual risk to this individual is about 4.6×10^{-11}/yr, and the incremental lifetime risk is about 4.6×10^{-10}, assuming 10 years of plant operation. The population dose that could result from ingesting fish and drinking water from the river is also the same for Alternative 2 as for Alternative 1. Thus, the incremental population dose for Alternative 2 is about 1.5×10^{-1} person-rem/yr. The total incremental annual risk to the population associated with this dose is about 2.5×10^{-5}/yr, and the incremental lifetime risk is about 2.5×10^{-4}.

The doses and risks estimated for Alternatives 1 and 2 are summarized in Table 11. For the accidental-exposure scenario under Alternative 1, the dose and incremental lifetime risk associated with incidental ingestion of undiluted effluent from the creek are 2.7×10^{-5} rem and 4.5×10^{-9}, respectively. For routine exposures, the dose to the maximally exposed individual associated with Alternative 1 is the same as that for Alternative 2, i.e., about 2.8×10^{-7} rem/yr. If the quarry treatment plant effluent were discharged to Femme Osage Creek (Alternative 1) or the Missouri River (Alternative 2), the resultant incremental lifetime risk to the maximally exposed individual from routine exposure would be about 4.6×10^{-10}. The EPA-recommended target value for an incremental individual lifetime risk for all cancers is 1×10^{-6}, and the target risk range is 1×10^{-4} to 1×10^{-7} (U.S. Environ. Prot. Agency 1986). It is estimated that about 60% of all cancers are fatal (American Cancer Society 1988).

In addition to considering the EPA-recommended target risk value, it may be useful and appropriate to compare the incremental individual radiation risks associated with the proposed action to the risks resulting from background environmental radiation. Exposure to natural sources of radiation -- such as radon, terrestrial radiation, and cosmic rays -- results in a background effective dose equivalent of about 300 mrem/yr (Natl. Counc. Radiat. Prot. Measure. 1987), which translates to a lifetime individual radiation risk of about 3×10^{-3}. Thus, under Alternative 1 or 2, the estimated incremental lifetime risk to the maximally exposed individual resulting from routine exposure is a very small fraction (about 1/6,000,000) of the individual risk due to background radiation. Under either alternative, the estimated incremental lifetime risk to the exposed population is about 1/23,000,000 of the risk to that population from background radiation.

TABLE 11 Estimated Incremental Radiation Doses and Incremental Risks for Alternatives 1 and 2

Alternative/Receptor	Exposure Scenario	Annual Dose[a]	Incremental Annual Risk	Incremental Lifetime Risk
Alternative 1: Effluent Discharge to Femme Osage Creek				
Accidental exposure of the maximally exposed individual	Drinking water from creek	2.7×10^{-5}	–[b]	4.5×10^{-9}
Routine exposure				
Maximally exposed individual	Drinking water from river	7.7×10^{-8}	1.3×10^{-11}	1.3×10^{-10}
	Ingesting fish from discharge area	2.0×10^{-7}	3.3×10^{-11}	3.3×10^{-10}
	Total	2.8×10^{-7}	4.6×10^{-11}	4.6×10^{-10}
Population	Drinking water from river	1.5×10^{-1}	2.5×10^{-5}	2.5×10^{-4}
	Ingesting fish from river	4.4×10^{-5}	7.3×10^{-9}	7.3×10^{-8}
	Total	1.5×10^{-1}	2.5×10^{-5}	2.5×10^{-4}

TABLE 11 (Cont'd)

Alternative/Receptor	Exposure Scenario	Annual Dose[a]	Incremental Annual Risk	Incremental Lifetime Risk
Alternative 2: Effluent Discharge to Missouri River				
Routine exposure				
Maximally exposed individual	Drinking water from river	7.7×10^{-8}	1.3×10^{-11}	1.3×10^{-10}
	Ingesting fish from discharge area	2.0×10^{-7}	3.3×10^{-11}	3.3×10^{-10}
	Total	2.8×10^{-7}	4.6×10^{-11}	4.6×10^{-10}
Population	Drinking water from river	1.5×10^{-1}	2.5×10^{-5}	2.5×10^{-4}
	Ingesting fish from river	4.4×10^{-5}	7.3×10^{-9}	7.3×10^{-8}
	Total	1.5×10^{-1}	2.5×10^{-5}	2.5×10^{-4}

[a]For the maximally exposed individual, the units are mrem/yr; for the exposed population, the units are person-rem/yr.

[b]No annual risk is estimated for the accidental-exposure scenario; the risk results from a single exposure and therefore represents a lifetime risk.

5.2.1.2 Environmental Risk Analysis

The environmental impacts associated with construction of the proposed treatment plant, pumping of pond water to the plant, and storage of plant process wastes at the quarry would be the same for Alternatives 1 and 2. However, potential impacts associated with the discharge of treated water would differ for the two alternatives.

For both Alternative 1 and Alternative 2, the potential impact to soils would involve temporary disturbance of localized areas dedicated to the construction of the water treatment facility, including laydown areas. The total affected area is estimated to be about 5.6 ha (14 acres), much of which has been disturbed as a result of past mining and disposal activities at the quarry. The impact of pumping activities is expected to be insignificant.

The implementation of either alternative would improve the current condition of water resources at the quarry by limiting the potential for contaminant migration from the quarry into local groundwater. The associated construction activities could result in increased concentrations of suspended solids in nearby surface waters (e.g., Little Femme Osage Creek) in the short term. To minimize the potential for such impact, good engineering practices and mitigative measures would be implemented, as appropriate, to control erosion.

The construction, pumping, and storage activities at the quarry could impact air quality under both alternatives. The potential for dust generation would be minimized by limiting vehicular traffic and by implementing good engineering practices, such as wetting exposed soil surfaces during the construction period. Some disturbance of the contaminated water would occur during pumping and treatment activities and could result in airborne releases of contaminants. However, these releases are expected to be minimal (see Section 5.2.1.1). Animals and vegetation are not likely to receive any significant exposure to airborne contaminants at the quarry because airborne releases are not expected to be significant.

Adverse impacts to vegetation and wildlife related to noise, visual disturbance, and construction dust during the proposed response activities at the quarry are expected to be minimal. Disturbance of habitats could displace mobile wildlife and destroy local vegetation. However, the quarry area does not provide unique wildlife habitats, and its plant species are not restricted in distribution. In addition, the disturbed habitats could be readily repopulated following the action period, and the surrounding areas are expected to be able to support displaced individuals. The approximately 5.6-ha (14-acre) area that would be affected by the proposed treatment plant is negligible in size relative to the 6,000 ha (15,000 acres) of surrounding wildlife area. Thus, any mobile wildlife displaced by this action would not overcrowd adjacent habitats. Finally, no impacts to endangered or threatened species are anticipated at the quarry for either alternative because the quarry does not provide any critical habitat for such species.

Although no distinction can be made between the two alternatives in terms of potential environmental impacts related to pumping, treatment, or storage activities, those impacts related to the discharge of treated water differ because the respective discharge points differ. Under Alternative 1, effluent from the treatment plant would be

discharged to Femme Osage Creek about 1.6 km (1 mi) from its outflow to the Missouri River. Under Alternative 2, the effluent would be released directly to the Missouri River. Because the creek empties into the Missouri River, potential impacts associated with the river would be similar for both alternatives (see Section 5.2.1.1 for conservative assumptions regarding creek flow). However, additional impacts would be associated with Alternative 1, e.g., relative to treatment residuals in the creek flow, that would not be associated with Alternative 2.

For the river component of both alternatives, the impacts in terms of soils, water resources, air quality, vegetation, and wildlife are expected to be minimal. The flow rate and volume of the effluent are negligible relative to the river (see Section 5.2.1.1), so no significant channeling or chemical changes are expected to occur when the flows combine. Limited deposition of suspended solids may occur at the discharge point (i.e., the creek outflow for Alternative 1 or the pipe outfall for Alternative 2), but based on the sedimentation, filtration, and adsorption processes of the treatment plant (see Section 5.5 and Appendixes B and C), the effluent solids content is not expected to be significant. In terms of residual contaminant levels, the treated water would meet effluent requirements that are based on ensuring protection of human health and the environment, including biotic populations (see Sections 5.2.1.1 and 5.5). In addition, the large dilution factor associated with the river (about 100,000) would serve to reduce these levels to far below the established limits. No impacts to air quality are expected to result from effluent discharge because the associated release of airborne contaminants would be negligible.

For the creek component unique to Alternative 1, adverse impacts could occur to soils, water resources, vegetation, and wildlife. The potential for air-quality impacts is expected to be negligible. Impacts to soils could include (1) incremental channeling of the creek bed, due to the additional flow volume, and (2) alteration of existing bed soils, due to the deposition of particulates that were either entrained in the effluent or formed following chemical transformations that occurred when the effluent flow reached the creek. For assessment of impacts to water resources, it is important to note that the potential for impact at any time is affected by the flow in Femme Osage Creek at that time. Because this flow can sometimes be quite low, it is conservatively assumed that the effluent flow represents the total flow; on this basis, the quality of the creek water is defined by the effluent quality, and impacts could occur to vegetation and wildlife that rely on this water resource. For example, rabbits or deer drinking water from the creek could receive radiation doses resulting from an average uranium concentration of 100 pCi/L. In addition, uranium could be taken up by vegetation growing along the creek, which in turn could be taken up by animals feeding on this vegetation. Thus, adverse environmental impacts could occur under Alternative 1 relative to the transfer of residual contaminants from the effluent to biotic populations. If flow in the creek were zero, effluent release to the creek bed would be inappropriate because, in addition to the potential impacts from uptake (e.g., biota ingesting undiluted water), considerable deposition of residual contaminants would likely occur and the effluent flow could be transported to subsurface soils before reaching the river. In any case, Alternative 1 would result in the limited contamination of an off-site area that is not currently contaminated, i.e., Femme Osage Creek, whereas Alternative 2 would preclude the contamination of this additional area.

In summary, the potential for adverse environmental impacts is considerably greater for Alternative 1 than for Alternative 2, based on the additional affected area, i.e., Femme Osage Creek.

5.2.2 Implementability

Implementability of an alternative is defined by its timeliness, technical feasibility, and responsiveness to institutional considerations. No distinction can be made between Alternative 1 and Alternative 2 on the basis of timeliness. Both alternatives could be implemented within 1 year. Similarly, no distinction can be made on the basis of technical feasibility. The difference between the alternatives is related to the discharge of effluent from the quarry treatment plant. Both alternatives would require a pipe to transport the treated water from the effluent pond to the discharge point. The length of pipe required for Alternative 1 (about 0.6 km [0.4 mi]) would be about four times less than that required for Alternative 2. However, no technical impact is associated with this minor difference.

Institutional considerations related to local land use and property values and to regulatory and project requirements are expected to be minimal for the two alternatives. Both Alternative 1 and Alternative 2 are expected to have a positive impact on local land use and property values in the long term because these alternatives would reduce the potential for contaminant migration and associated impacts to local drinking water supplies. In addition, the treatment component of both alternatives provides consistency with the preference for permanent solutions that is identified in the NCP, and both would be conducted in compliance with specific ARARs (see Section 5.1) and permit requirements. Finally, both alternatives are consistent with and would contribute to the overall remedial action planned for the quarry.

The primary institutional considerations associated with the two alternatives are related to public perception and the potential for impacts to archeological sites and cultural resources. Under Alternative 1, the effluent from the quarry treatment plant would flow through the lower 1.6 km (1 mi) of Femme Osage Creek, in close proximity to certain wells of the county well field. Thus, although the creek flow itself is not tapped by the drinking water wells, the public might perceive an impact to the drinking water supplied by the well field. No such perception would exist for Alternative 2 because no effluent would be released to the creek under this alternative and the direct discharge of effluent to the Missouri River would be downstream of the county well field. The potential for impacts to archeological sites and cultural resources is considerably greater for Alternative 1 than for Alternative 2 because Alternative 1 would impact a greater area in which the presence of such sites or resources is quite likely (i.e., the length of the creek that would carry the effluent flow). Historically, individuals and communities have based their activities in close proximity to water resources such as lakes and streams. Therefore, it is possible that remnants of such sites exist along Femme Osage Creek and may be affected by channeling or other potential impacts associated with Alternative 1.

In summary, the potential for institutional concerns is greater for Alternative 1 than for Alternative 2, and therefore the implementation of Alternative 1 could be less straightforward than the implementation of Alternative 2.

5.2.3 Cost

The estimated capital and O&M costs for the two alternatives are essentially the same. The only cost difference between the alternatives is related to the construction and maintenance of an incremental segment of pipe that is required for the greater distance over which treated water would be transported for Alternative 2. The incremental cost for this segment is estimated to be $106,000, which is low relative to the total estimated cost of the quarry treatment plant (about $1.5 million; see Appendix B).

5.3 SUMMARY AND COMPARATIVE ANALYSIS OF ALTERNATIVES

Based on the evaluation of Alternative 1 (effluent discharge to Femme Osage Creek) and Alternative 2 (effluent discharge to the Missouri River) according to effectiveness, implementability, and cost, the following comparisons can be made. No significant difference exists between the alternatives in terms of either cost or the timeliness and technical feasibility components of implementability. However, Alternative 1 could be somewhat more difficult to implement than Alternative 2 because of institutional considerations related to public perception and the potential for incremental impacts to archeological sites and cultural resources. Finally, the effectiveness of Alternative 1 would be less than that of Alternative 2 due to the potential for incremental impacts to human health and the environment associated with effluent flow in the creek. The incremental lifetime health risks to the maximally exposed individual (about 4.6×10^{-10}) and to the exposed population (about 2.5×10^{-4}) from routine exposure would be essentially the same for both alternatives. However, an accidental-exposure scenario exists for Alternative 1 that does not exist for Alternative 2. This scenario (incidental ingestion of creek water) would result in an incremental lifetime health risk to the exposed individual of about 4.5×10^{-9}. These individual risks represent very small fractions (about 1/6,000,000 and 1/600,000, respectively) of the lifetime risk from background radiation (3×10^{-3}). Adverse environmental impacts associated with Alternative 1, but not Alternative 2, include biotic uptake of contaminants from the effluent flow and deposition of residual contaminants on the creek bed. Most importantly, Alternative 1 would result in the contamination of an off-site area that is currently uncontaminated, whereas this incremental contamination would be precluded by Alternative 2.

5.4 IDENTIFICATION OF THE PREFERRED ALTERNATIVE

On the basis of the evaluation of alternatives proposed for the management of contaminated water at the Weldon Spring quarry, the preferred alternative has been identified as Alternative 2 -- access restrictions; pumping and treatment of the pond water, with temporary storage of the process wastes at the quarry; and discharge of the treated water to the Missouri River. Consistent with the preference identified in Section 121(b)(1) of SARA, Alternative 2 utilizes treatment technologies to provide a permanent solution to the problem of contaminated water in the quarry by reducing waste toxicity, mobility, and volume. Discharge from the treatment plant would be piped directly to the Missouri River, downstream of the county well field.

Based on the conventional nature of the proposed treatment system (see Section 5.5 and Appendix B) and the demonstrated performances of its component processes, it is expected that implementation of Alternative 2 would result in effectively reducing the contaminants of concern in the quarry water to consistently meet the associated effluent limits. These limits, which are based on public and environmental protection, are arsenic, 0.05 mg/L; manganese, 0.05 mg/L; 2,4-DNT, 0.11 μg/L; and total uranium, 100 pCi/L. Treatability tests of the quarry water would be conducted to assess the performance of the proposed treatment system. Detailed design of the treatment plant would begin following approval of the proposed action and would be based on the results of these treatability tests.

In addition to being implementable and cost-effective, Alternative 2 would minimize adverse impacts to the public and the environment that are associated with the contaminated water in the quarry. Finally, Alternative 2 is consistent with and would contribute to the efficient performance of the overall remedial action being planned for the Weldon Spring site. In conclusion, it is recommended that a water treatment plant, as defined by Alternative 2 (pending the success of planned treatability tests), be constructed at the Weldon Spring quarry to manage the contaminated water therein.

5.5 TREATMENT PLANT SPECIFICATIONS

The actual design of the quarry treatment plant cannot be developed prior to a decision on the proposed action. Thus, the discussion of likely unit operations in this section and in Appendix B must be considered preliminary. Detailed design of the quarry treatment plant would begin following approval of the proposed removal and treatment of contaminated water from the quarry. The design would be specific to the pond water and would rely on results of treatability tests using the unit operations discussed herein. The processes that are proposed to comprise the treatment system are equalization/density separation, lime addition, clarification, granular media filtration, activated alumina adsorption, granular activated carbon adsorption, and ion exchange (see Appendix B).

Design-flow information for the treatment plant is summarized in Table 12. Potential sources of contaminated water at the quarry pond include surface water currently in the pond, groundwater inflow to the pond area, water from construction and decontamination activities, water from showers and washbasins, and storm water and snowmelt. For the proposed action, the water currently in the pond would be removed and treated during the first 2 years of plant operation; during this time, the rate of influent derived from the potential sources is estimated to be about 170 m^3/day (31 gpm). For years 2 through 5 of plant operation, all but the pond water would continue to be treated, and the influent rate for this period is estimated to be about 140 m^3/day (26 gpm). After 5 years from start-up, the plant would be operated only on an as-needed basis (e.g., if it were determined that local surface water or groundwater required treatment [Morrison-Knudsen Engineers 1988b]).

The design safety factor for the proposed tr~~eatment plant is identified as~~ 2.5. This safety factor would compensate for (1) the unknown potential for higher uranium levels due to a lower dilution factor relative to current pond conditions, e.g., as

TABLE 12 Estimated Influent Flows to the Treatment Plant

Water Source	Influent Rate (gpm) Years 0-2	Years 2-5	Design Basis
Pond	3.5	0	11,000 m^3 (3,000,000 gal) over 600 days of treatment; completed by the end of 2 years.
Storm water	6.7	6.7	94 cm (37 in.) annual precipitation over 3.6 ha (9 acres), with a retention coefficient of 40%, over 1,500 days of treatment.
Groundwater	16	16	Characterization results and Theis nonequilibrium equation (conical structure with r = 15 m [50 ft], face thickness = 5 m [17 ft], k = 0.03 cm/s, and storage coefficient = 0.1) for 6 m (20 ft) of drawdown and 1,500 days of treatment.
Sink and shower water	0.6	0.6	Sink, 1.5 gal per wash at 100 washes per day; shower, 25 gal per shower at 30 showers per day.
Equipment decontamination water	2	1.2	12 gpm for 8 hours/day at a subutilization rate of 50% for the first 2 years and 30% for the next 3 years.
Quarry wash water	2.5	1.7	50 gpm for 8 hours/day at a subutilization rate of 15% for the first 2 years and 10% for the next 3 years.
Total	31.3	26.2	

groundwater flows into the emptied pond through the contaminated sediments; (2) the potential for large, temporary increases in storm-water runoff (e.g., during a major thunderstorm or following spring snowmelt); (3) uncertainty with regard to the rate of groundwater inflow over time, i.e., as the drawdown depth increases; and (4) the capacity for follow-on surface water/groundwater treatment, if necessary.

Using this safety factor, the nominal treatment plant capacity would therefore be 440 m^3/day (80 gpm), and the plant would be designed to meet the potential effluent limits at maximum flows of 550 m^3/day (100 gpm). This treatment capacity translates to a 39% utilization of the plant for the first 2 years of operation and 33% for the following 3 years. A schedule of the activities and percent utilization of the proposed treatment plant during its operational period is presented in Table 13.

The treatment plant influent would be a mixture of several streams. However, the plant design is based on average contaminant levels in the pond because the pond water is the best characterized of the various streams, it has higher contaminant levels than local surface water and groundwater, and it is expected to contain the highest equilibrium concentrations of contaminants by virtue of its continuous contact with the quarry wastes. Also, the equalization/detention pond is expected to limit concentration variability.

Influent values for the treatment plant are derived from the data in Table 9. These values indicate that levels of uranium, arsenic, manganese, and 2,4-DNT in the pond exceed discharge limits. Thus, these four contaminants have been identified as the primary contaminants of concern. Although the upper ranges of other contaminants such as iron and sulfate may also exceed the appropriate limits, the plant design is based on average influent concentrations, and these averages are less than the limits. However, if it were determined during plant operation that effluent levels for other contaminants were not within the limits specified for the proposed action, the treatment system could

TABLE 13 Schedule of Proposed Activities and Treatment Plant Utilization

Period in Years	Activities	Percent Utilization
0-2	Pond water, storm water, groundwater inflows, and construction water are processed.	39
2-5	Pond water treatment has been completed; storm water, groundwater inflows, and construction water are processed.	33
>5	Plant operates on an as-needed basis.	As required

be modified relatively easily to accommodate the removal of these secondary contaminants (see Appendix B, Section B.3.2). Because these modifications would be relatively inexpensive and straightforward to implement, the selection of a specific alternative for the proposed action is not affected by their exclusion from the current treatment plant design.

The quality of water leaving the treatment plant would be monitored for compliance with the discharge limits specified for the proposed action. Effluent would be discharged to one of two lined effluent ponds. When the first pond became filled, the flow would be redirected to the second pond, and water in the full pond would be sampled and analyzed for contaminants. If levels were found to be within the specified effluent limits, the water would be discharged from the pond into the Missouri River (Figure 6); if any specific effluent limit was exceeded, the water would be returned to the equalization basin for recycle through the treatment plant. Each effluent pond would have a storage capacity of about 10 days, to allow for the receipt of and response to analytical testing results (i.e., to accommodate recycle, if necessary). It is expected that treated water would be released from the pond at the rate of about 0.002 m^3/s (0.07 ft^3/s).

Recent characterization of the area proposed for construction of the quarry treatment plant has identified limited, low-level contamination of soil along the abandoned rail spur and access road adjacent to the quarry (U.S. Dept. Energy 1988b). Prior to initiation of construction activities for the proposed action, this radioactively contaminated soil -- estimated to total about 650 m^3 (850 yd^3) -- would be excavated and placed in the quarry for subsequent removal under the separate response action planned for the quarry (i.e., removal of bulk wastes, with transport to the raffinate pits and chemical plant area for temporary storage). This would minimize the potential for adverse impacts associated with disturbance of contaminated soil during the action period.

The designs for site preparation, concrete pads for plant construction, metal building enclosures, lined ponds, piping, and power supply -- as well as for other support activities such as procurement specifications -- would be prepared, as required, pending approval of the proposed action. Electric power (480 V, 3-phase, 60 Hz) would be supplied to the treatment plant from commercial utility sources. Manpower and schedule requirements for these activities would be developed prior to the initiation of detailed design.

An estimated 1.0 m^3/day (1.3 yd^3/day) of solid wastes would be generated by the treatment processes (Morrison-Knudsen Engineers 1988b). This volume, consisting primarily of lime sludge, would be reduced by a factor of six through a dewatering process (e.g., filter press). This follow-on process is expected to increase the solids content of the sludge from about 10% to about 40%. Thus, the daily volume of dewatered wastes generated by the treatment system would be about 0.17 m^3 (0.22 yd^3); the annual waste volume would total about 22 m^3 (28 yd^3).

The process resins, adsorbents, and dewatered sludges would be containerized (e.g., in 55-gal drums) and temporarily placed in the quarry near the treatment plant. These containers would subsequently be removed from the quarry, e.g., during removal operations currently being planned for the quarry bulk wastes.

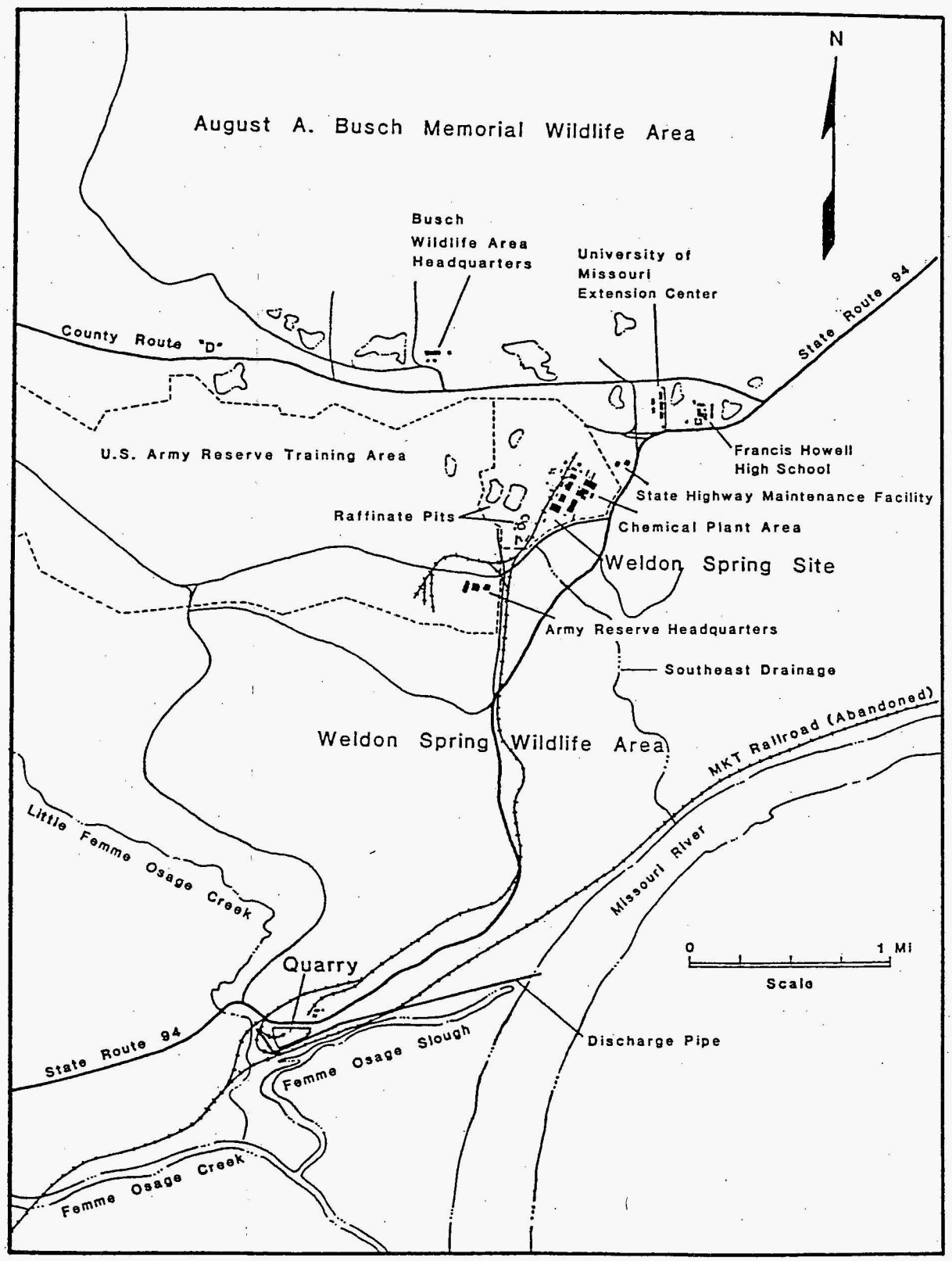

FIGURE 6 Location of the Discharge Pipe for the Treatment Plant Effluent

6 ALARA CONSIDERATIONS

"As low as reasonably achievable" (ALARA) is a phrase used to describe an approach to radiation exposure control or management whereby the exposures and resulting doses to affected individuals and populations are maintained as far below the specified limits as technical, economic, and social considerations permit. The DOE requires that all radiation exposures be limited to ALARA levels in order to minimize the total risk to potential receptors. The ALARA process is based on the conservative assumptions that the probability of an occurrence of health effects from irradiation exhibits no threshold and that the response is linearly proportional to the received dose. The ALARA process therefore requires that every effort should be made to reduce radiation exposure as much as is reasonably achievable. Consistent with the ALARA process, the proposed action would be undertaken in a manner that minimizes the potential for incremental radiation exposure.

Contaminants have migrated from the quarry pond into the nearby groundwater. Removal of the pond water from the quarry would limit additional contaminant migration and would permit the implementation of other response actions at the quarry (e.g., bulk waste removal). Hence, the net benefit to the public and the environment resulting from the proposed action would be considerable. It has been shown that the preferred alternative (1) would be protective of the public and the environment by minimizing potential impacts associated with the current contamination in the quarry water, (2) could be implemented, and (3) would be cost-effective (see Chapter 5).

The average concentration of uranium in the quarry pond, about 2,300 pCi/L, exceeds the DOE limit of 550 pCi/L for discharge to uncontrolled areas; therefore, the water must be treated prior to its release. The analysis of a combination of various treatment technologies (see Section 5.5 and Appendixes B and C) indicates that treating this water to attain a uranium concentration of 550 pCi/L could be achieved by the following conventional processes: chemical (lime) addition, granular media filtration, and adsorption onto both activated alumina and granular activated carbon. Adding an ion-exchange process to the treatment system would provide the capacity to reliably reduce the uranium concentration to 100 pCi/L. This would also increase capital costs over those for achieving 550 pCi/L by about $124,000 to a total of $1,157,000, and O&M costs would be increased by about $100/day to a total of about $580/day, based on the design flow rate. Finally, inclusion of the ion-exchange process would increase the total capital and O&M costs of the treatment system by about $172,000 (based on a 5-year present worth) to a total of $1,445,000 (Morrison-Knudsen Engineers 1988b).

Although it is more expensive, ion exchange would be incorporated in the proposed treatment system because the additional costs incurred to reduce the uranium concentration by 450 pCi/L (from 550 to 100 pCi/L) are not prohibitive. This reduction in the uranium concentration by a factor of about five would reduce the resultant dose and risk estimates by the same factor (see Section 5.2.1.1). Using the 5-year present worth value of total costs, the dose reduction corresponding to 5 years of operation results in a relationship between incremental cost and incremental reduction in population dose of about $64,000/person-rem. This is considerably greater than the value

of $1,000/person-rem that has been used by the U.S. Nuclear Regulatory Commission to assess the reasonableness of costs for effecting incremental dose reductions (i.e., for radioactive waste treatment systems at nuclear power plants; see 10 CFR Part 50, Appendix I). Thus, despite the fact that its inclusion results in a cost increment that is quite high relative to the dose reduction, ion exchange has been included in the quarry treatment system in order to implement the project's commitment to minimizing potential impacts to the public and the environment.

The uranium level could be reliably reduced below 100 pCi/L by constructing and operating a vapor recompression/distillation system rather than a conventional, multistage treatment process. This system would increase capital costs to more than $1,650,000 and O&M costs to over $1,000/day, and the combined costs for the 5-year operational period (5-year present worth) would increase to about $2,150,000 (Morrison-Knudsen Engineers 1988b). The reduction in effluent uranium concentration associated with this significant cost increment would only be about 15% of the reduction realized for inclusion of ion exchange. In addition, decreasing the uranium concentration from 100 to 30 pCi/L -- a three-fold reduction -- would reduce the incremental dose and risk estimates by the same factor, but total costs (5-year present worth) would increase by about $705,000 relative to costs for the conventional system. Thus, under the vapor recompression/distillation process, it would cost an additional $1.8 million/person-rem to effect dose reduction. This cost-benefit ratio far exceeds the value of $1,000/person-rem historically used to assess reasonable costs, and it is considered highly unreasonable.

Based on these ALARA considerations, it is proposed that the treatment system for the contaminated water in the quarry consist of the following processes: chemical (lime) addition, granular media filtration, adsorption on activated alumina, adsorption on granular activated carbon, and ion exchange. The treatment plant would be constructed and operated in a manner to ensure not only that the effluent uranium concentration would meet the limit of 100 pCi/L, but that it would be further reduced as much below 100 pCi/L as could reasonably be achieved, i.e., by optimizing the performance of unit operations. To provide a conservative safety factor that would address the potential for variable influent flow and uranium concentration over time, the design goal of the plant would be 30 pCi/L. Thus, the level of uranium in the treatment plant effluent would range from 30 to 100 pCi/L. As identified in Section 5.2.1.1, routine exposures associated with a uranium effluent concentration of 100 pCi/L discharged to the Missouri River would result in very low incremental risks to the exposed population. The incremental lifetime risk to the maximally exposed individual from routine exposures would be about 4.6×10^{-10}, and the incremental lifetime risk to the exposed population would be about 2.5×10^{-4}. These incremental risks to both the individual and the exposed population are very small fractions (about 1/6,000,000 and 1/23,000,000, respectively) of the risk from exposure to background radiation in the environment.

In summary, the proposed action would implement DOE's ALARA process through a commitment to minimize the potential for radiation exposure of the public. This would be achieved by treating the quarry water to a uranium concentration of 30 to 100 pCi/L. Concerted efforts would be made throughout the operational period of the treatment plant to minimize the release of uranium to the environ~~ment as far below 100 pCi/L~~ as is reasonably achievable.

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APPENDIX A:

CHARACTERIZATION RESULTS FOR THE QUARRY AREA

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A.1 QUARRY SOIL

Studies of soil in the Weldon Spring quarry have confirmed the presence of radioactive and chemical contaminants predicted from the quarry's burial history (see Section 1.2 of this report). Natural-series radionuclides have been detected at concentrations typical of uranium-processing wastes, and metals have been measured at concentrations typical of plant rubble and thorium wastes. In addition to polychlorinated biphenyls (PCBs), organic compounds have been identified that can be expected from past TNT disposal activities (e.g., combustion and decomposition products). The chemical and radiological species in the quarry are not found in discrete, homogeneous areas, but are intermixed in a soil/rubble matrix at varying concentrations.

The concentration of chemically contaminated material in the quarry varies with depth, and most of the volume is contained within 3 to 4 m (12 ft) of the surface. The general location of chemically contaminated areas is depicted in Figure A.1. The PCBs typically occur near the surface, whereas nitroaromatics and volatile and semivolatile compounds are detected at greater depths. Over 30% of the mass of volatile compounds has been detected at depths exceeding 5.5 m (18 ft). (However, these volatile compounds were probably introduced to the quarry samples during collection and/or analysis, based on their presence in field and sample blanks [Kaye and Davis 1987].)

The actual volumes and concentrations of TNT and DNT wastes in the quarry are unknown. Surficial discoloration of soils in the eastern portion of the quarry is due to nitroaromatic compounds at levels of 1 to 2%; the maximum concentration of subsurface nitroaromatic compounds that has been detected is 1,600 ppm TNT (Kaye and Davis 1987). No distribution pattern was identified for nitroaromatics during characterization efforts, but the areas of contamination are consistent with records that identify burning of ordnance wastes near the quarry pond and the disposition of nitroaromatic wastes in the eastern portion of the quarry.

Likewise, the volumes and concentrations of PCBs, phthalates, naphthalene, and other organics are unknown, and their areal distribution has no consistent pattern. The maximum concentration of PCBs that has been detected is 120 ppm Aroclor 1254. Volatile organics detected in one or more boreholes include methylene chloride, xylene, and ethyl benzene at concentrations ranging from 1 to 50 ppm. Semivolatile organic compounds detected in one or more boreholes include the polynuclear aromatic hydrocarbons (PAHs) phenanthrene, fluoranthene, and benzo(b)fluoranthene at maximum concentrations of 150, 190, and 110 ppm, respectively (Kaye and Davis 1987).

Radioactively contaminated wastes on the main floor of the quarry cover an area of about 2,800 m^2 (3,300 yd^2) and extend to a depth of about 12 m (40 ft) (see Figure A.2). Radioactive contamination in the entire quarry covers a surface area of about 18,400 m^2 (22,000 yd^2) and extends to an average depth of about 4 m (13 ft). The concentrations and inventories of radionuclides in the quarry wastes are summarized

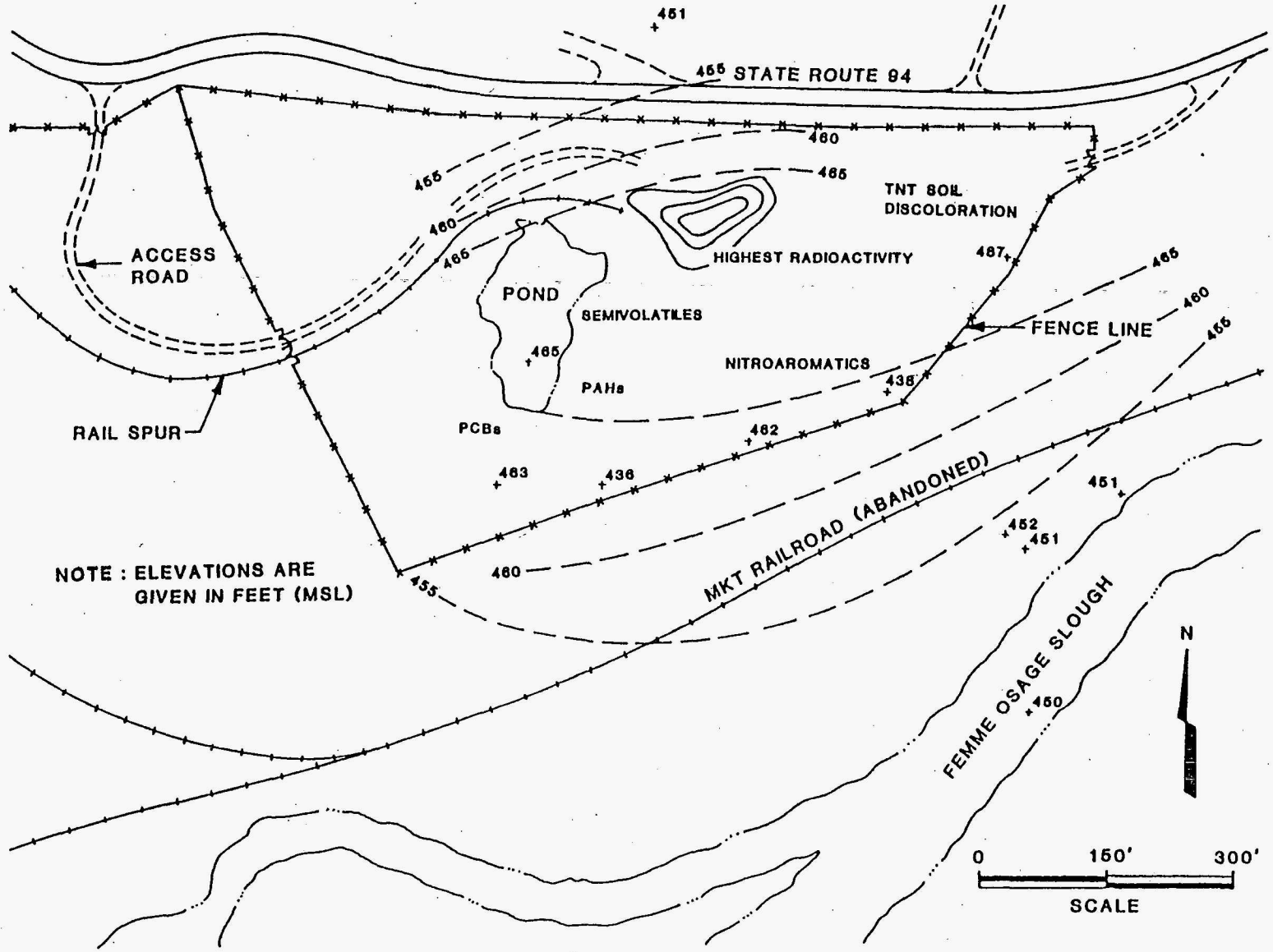


FIGURE A.1 General Location of Chemically Contaminated Areas in the Quarry

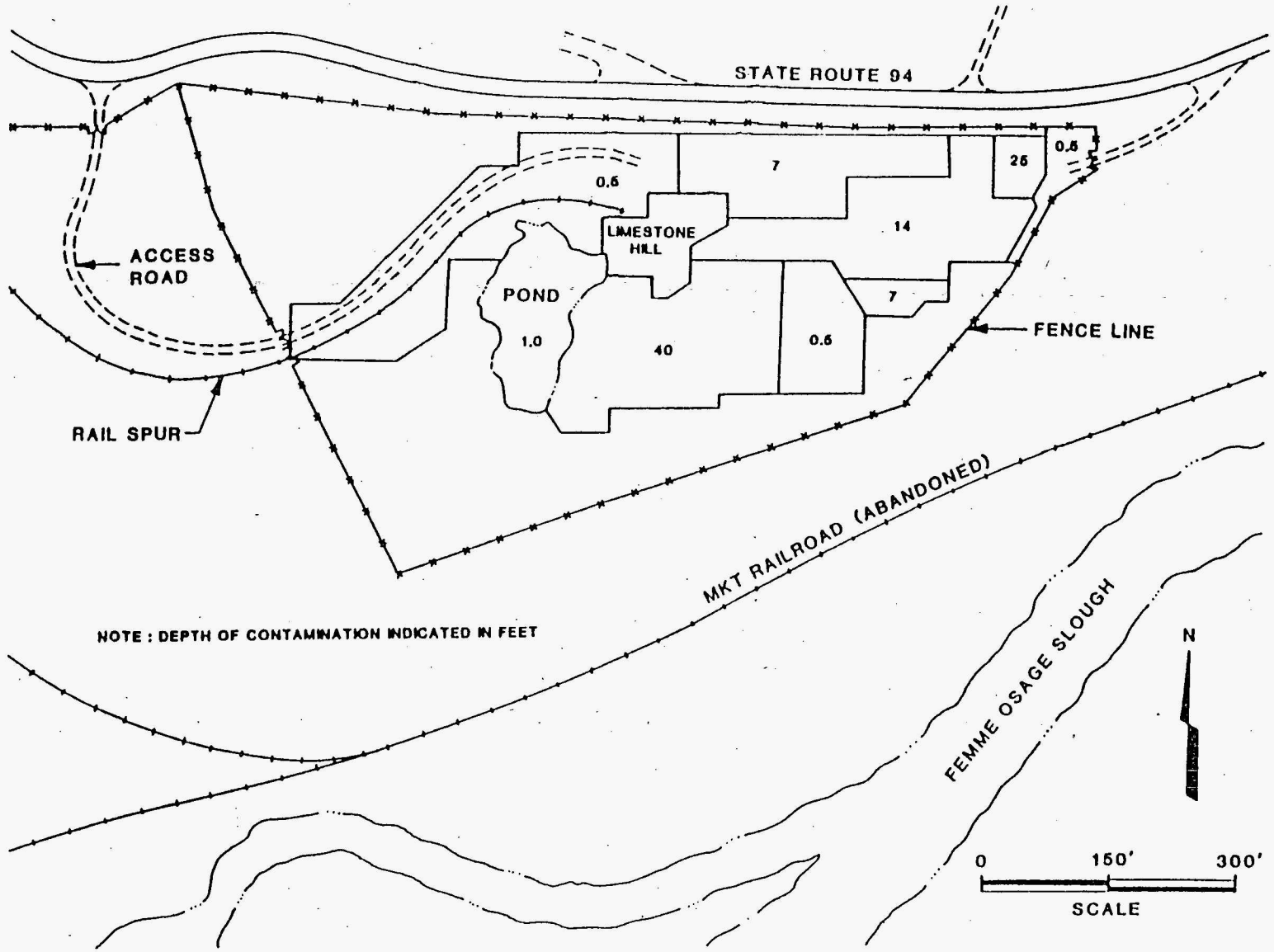


FIGURE A.2 Depth of Contamination in the Quarry

in Table A.1. Concentrations of radionuclides in boreholes drilled into the quarry wastes vary as a function of both depth within a borehole and borehole location (Bechtel Natl. 1985b). The concentrations and inventories of radionuclides with depth are summarized in Table A.2.

Three areas of localized radioactive contamination -- the red area, the yellow area, and the high bench level area -- have been identified in the quarry (Figure A.3). The red area has the highest levels of total alpha radiation and is believed to have been used for the disposal of drummed thorium residues. The total volume of these wastes is estimated at 1,100 m^3 (1,400 yd^3), and the predominant radioactive contaminants are uranium-238 and radium-226. The yellow area was used for the disposal of contaminated rubble and has intermediate levels of alpha radiation. The rubble covers an area of approximately 0.8 ha (2 acres) and extends to an average depth of 11 m (33 ft). Uranium-238 and radium-226 are the predominant radioactive contaminants in the yellow area. The high bench level area contains an estimated 7,100 m^3 (9,000 yd^3) of drummed wastes at an elevation of about 150 m (500 ft) MSL. The wastes cover an area of about 0.2 ha (0.5 acre) and extend to an average depth of 4 m (12 ft). The predominant radioactive contaminants in the high bench level area are uranium-238 and thorium-232. The high bench level area and the remainder of the quarry have generally low levels of radioactivity (Morrison-Knudsen Engineers 1988).

TABLE A.1 Summary of Radioactive Concentrations and Inventories of the Quarry Wastes

Radionuclide	Concentration (pCi/g) Average	Concentration (pCi/g) Range	Inventory[a] (Ci)
Uranium-238[b]	170	4-460	30
Thorium-232	16	1-414	3
Thorium-230	540	1-5,500	90
Radium-226	63	1.3-560	10

[a]Estimated to one significant figure.

[b]The amounts of uranium-234, uranium-235, and uranium-238 are assumed to be present in their natural activity ratio, 234:235:238 = 1:0.046:1.

Source: Data from U.S. Department of Energy (1987a).

TABLE A.2 Summary of Radioactive Concentrations of the Quarry Wastes with Depth

	Average Concentration (pCi/g)			
Region[a]	Uranium-238	Radium-226	Thorium-230	Thorium-232
40-ft	190	64	475	3.0
25-ft	155	54	400	73
14-ft	155	54	400	73
7-ft	77	90	1,860	24
0.5-ft	20	7.9	29	3.4
	Inventory (Ci)			
Region[a]	Uranium-238	Radium-226	Thorium-230	Thorium-232
40-ft	24.7	8.3	61.7	0.39
25-ft	0.9	0.3	2.3	0.43
14-ft	3.8	1.3	9.7	1.77
7-ft	0.8	0.9	19.1	0.24
0.5-ft	0.03	0.01	0.05	0.005
Total	30	11	93	2.8

[a]"Region" corresponds to the location of contamination delineated according to depth (see Figure A.3).

Source: Data from U.S. Department of Energy (1987a).

Exposure rates from gamma-emitting radionuclides are elevated above background in certain areas of the quarry. Radon measurements taken at the quarry since 1980 have been at above-background concentrations in several locations that are associated with areas of ore and rubble disposal. In addition, the topography of the quarry results in the temporary accumulation of radon along its perimeter during episodes of meteorological inversion, which typically occur at night during the summer and fall (U.S. Dept. Energy 1988). Radon concentrations decrease with increasing distance from the quarry such that, beyond a radius of approximately 0.4 km (0.25 mi), the concentration of radon is indistinguishable from background levels (Bechtel Natl. 1983a).

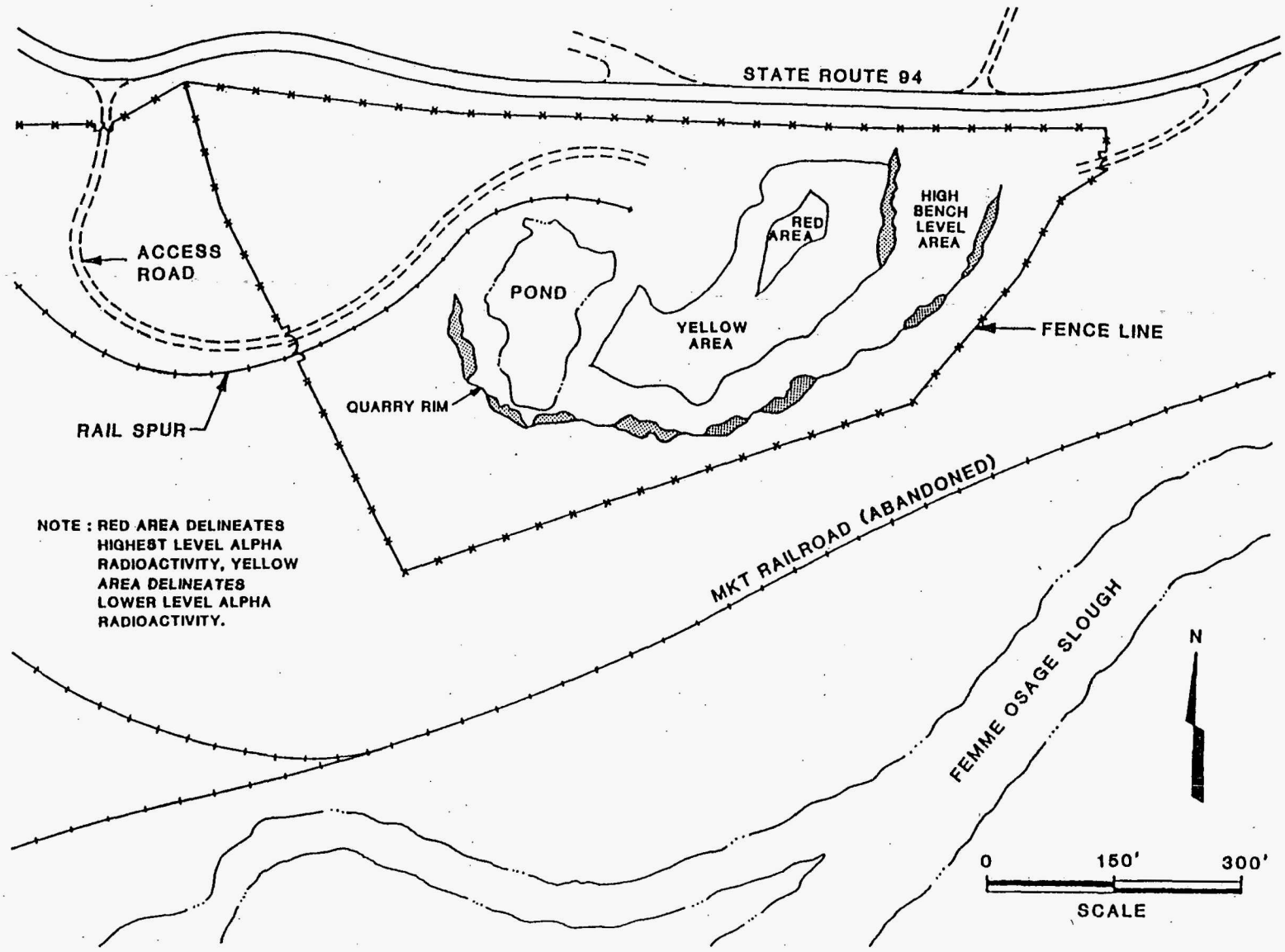


FIGURE A.3 Three Major Areas of Radioactive Contamination in the Quarry

A.2 SURFACE WATER

Surface water monitoring locations in and near the quarry are shown in Figure A.4. Concentrations of organic species detected in the quarry are tabulated in Table A.3, and concentrations of additional chemical parameters are tabulated in Table A.4. Chemical parameters measured in surface waters near the quarry are summarized in Table A.5. Radiological parameters measured in the quarry pond are presented in Table A.6, and those measured in nearby surface waters are presented in Table A.7. Average uranium concentrations in Femme Osage Slough have ranged from about 20 to 80 pCi/L. The primary contaminant in the quarry pond (sampling location SW-1008) is uranium. Results of sample analyses for uranium in the pond water from 1960 through 1987 are presented in Table A.8. Measured concentrations of radionuclides in samples taken from the pond sediment are summarized in Table A.9.

A.3 GROUNDWATER

Groundwater monitoring locations near the quarry are shown in Figure A.5. Results obtained during the Phase I water quality assessment of the quarry and from routine environmental monitoring are presented in Table A.10 (radiological parameters), Table A.11 (nitroaromatics), Table A.12 (metals), and Table A.13 (inorganic anions and water quality parameters). Nitroaromatic compounds were detected in wells completed in the Decorah limestone and in certain alluvial wells north of Femme Osage Slough. Three volatile organic compounds -- ethyl benzene, toluene, and xylene -- were detected in two alluvial wells (MW-1008 and MW-1009) at concentrations ranging from 8 to 20 ppb. These are the same volatile organic compounds identified in the quarry wastes. Although subsequent quarterly sampling of these and other alluvial wells failed to detect these three compounds, sampling for volatile organic compounds continues. (As noted above, volatile compounds were probably introduced into field samples during collection or analysis, based on their presence in test and sample blanks.) Semivolatile organic compounds, PCBs, and pesticides have not been detected in any of the quarry monitoring wells. The metal concentrations in samples collected from both the limestone and alluvial aquifers appear consistent with respective background levels.

A.4 VICINITY SOILS

Analysis of water samples from wells in the limestone bluff and in the alluvium between the quarry and the slough indicate that uranium has migrated from the quarry (Kleeschulte and Emmett 1987). Results of recent radiological sampling of soils in the vicinity of the quarry and Femme Osage Slough are summarized in Table A.14. Contaminant migration from the quarry into the alluvium and Femme Osage Slough was investigated in 1987, using uranium as an indicator element (Marutzky et al. 1988). Samples were collected in 0.3-m (1-ft) increments along the two geologic cross sections shown in Figure A.6. Results of the analysis are shown in Figure A.7. Because the water table in the area is 0.6 to 1.5 m (2 to 5 ft) below the ground surface, most of the soil samples

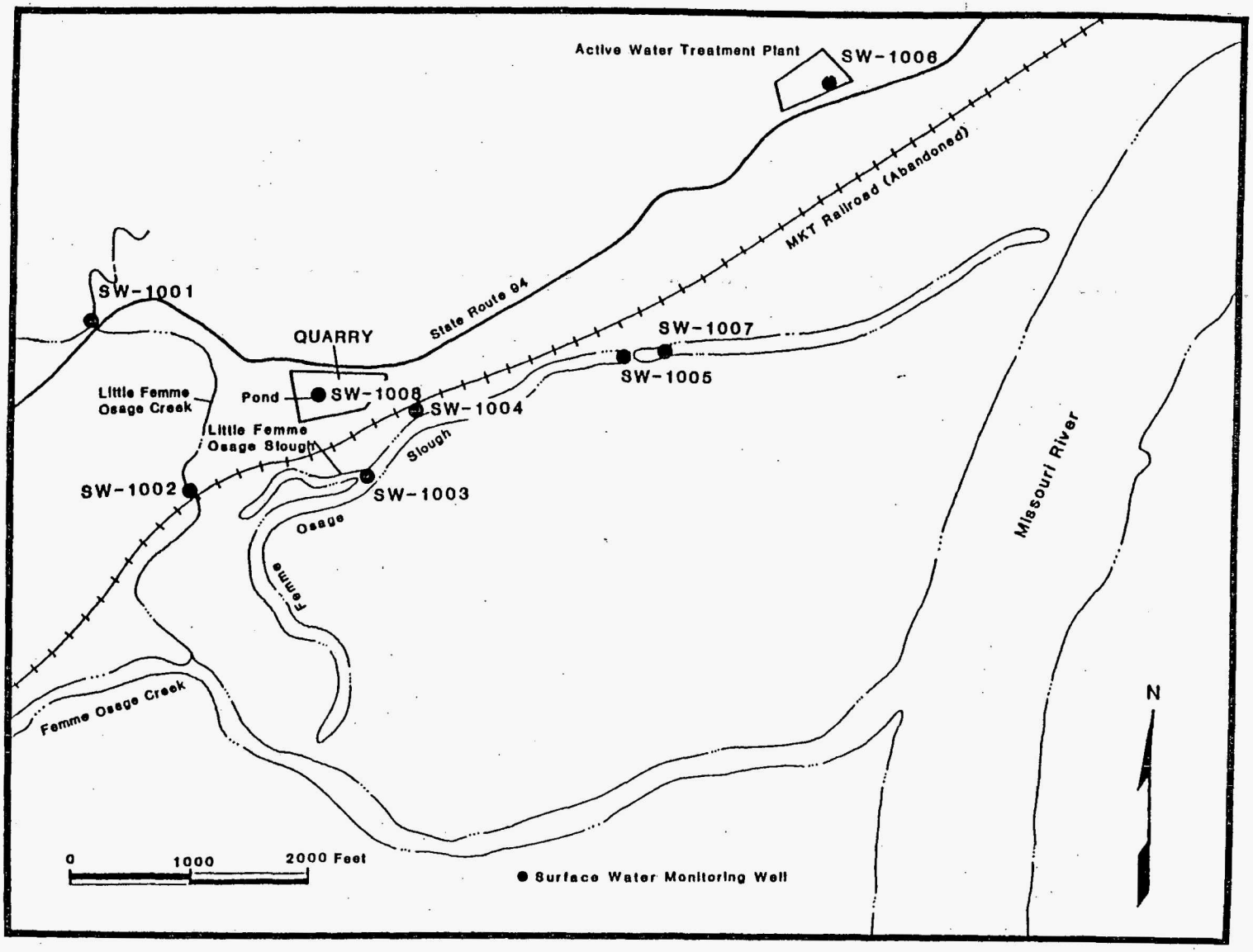


FIGURE A.4 Surface Water Sampling Locations near the Quarry (Source: U.S. Department of Energy 1987c)

TABLE A.3 Organic Compounds Detected in the Quarry Pond

Organic Compound	Concentration (μg/L)
Cyanide	3
Toluene	5
Bis(2-ethylhexyl) phthalate	2
Di-n-butyl phthalate	3
Diethyl phthalate	2
2-Amino-4,6-dinitrotoluene	26
2,4,6-Trinitrotoluene	9
4-Amino-2,6-dinitrotoluene	15
2,4-Dinitrotoluene	10
2,4-Diamino-6-nitrotoluene	6
2,6-Diamino-4-nitrotoluene	3
6-Amino-hexanoic acid	254

Source: Data from Morrison-Knudsen Engineers (1987).

were saturated when collected. Thus, the uranium results reflect both soil and groundwater contributions. Based on typical concentrations of dissolved uranium in the quarry groundwater, which range from 1,000 to 8,000 pCi/L, the overall contribution of groundwater uranium to levels of dissolved uranium in the alluvium adjacent to the quarry ranges from 5 to 20%. No samples were collected from directly beneath the slough; therefore, little can be inferred about the presence of uranium in this area, and the isopleths for cross section A-A' in Figure A.7 have been dashed to indicate that the uranium distribution in close proximity to the slough is only estimated. No elevated levels of uranium were detected in samples collected from boreholes immediately south of the slough.

Radiological surveys along the southern quarry wall and adjacent to the right-of-way of the recently abandoned MKT railroad failed to identify any surface contamination that, via surface runoff, could contribute to the uranium contamination detected between the slough and the quarry. Rather, the uranium contamination present in the slough area appears to have resulted from transport via groundwater movement and deposition along preferential flow pathways. Groundwater elevations in the vicinity of the quarry are known to fluctuate in response to changing river stages. During high stages, the water table has been observed at the ground surface. Characterization data indicate that uranium carried into the area via groundwater remains in the upper alluvial

TABLE A.4 Chemical Parameters in the Quarry Pond

Parameters	Concentration[a] (mg/L) Average	Range	Concentration[b] (mg/L)
Aluminum	0.045	<0.1-0.08	0.17
Arsenic	0.075	<0.001-0.15	ND[c]
Barium	0.11	0.04-0.36	0.05
Boron	0.54	0.52-0.60	-[c]
Calcium	86	70-100	83
Chromium	0.013	<0.001-0.02	0.051
Copper	<0.01	<0.001-0.02	0.013
Iron	0.068	0.003-0.33	0.071
Lead	<0.05	0.002-<0.05	ND
Lithium	0.025	<0.01-0.036	ND
Magnesium	22	16-26	17
Manganese	0.07	0.003-0.26	0.038
Mercury	0.0004	<0.0001-0.0006	ND
Molybdenum	0.035	<0.01-0.07	-
Phosphorus (as P_2O_5)	0.5	0.5	-
Potassium	15	11-18	10
Silicon (as SiO_2)	16	13-21	-
Silver	<0.015	<0.003-0.015	0.015
Sodium	22	14-29	15
Strontium	0.47	0.37-0.54	-
Tin	<0.05	<0.05	-
Zinc	0.068	<0.005-0.31	0.007
Chloride	44	14-200	8
Fluoride	1.0	0.9-1.1	0.43
Nitrate (as N)	3.7	<1-9	10
Sulfate	200	150-240	202
Bicarbonate	210	190-220	-
Suspended solids	75	50-100	-
pH (units)	7.7	7.3-8.2	-
Asbestos[d] (fibers/L)	-	-	1.9×10^6

[a]Sources: Bechtel National (1985b); U.S. Department of Energy (1987a); Morrison-Knudsen Engineers (1987).

[b]Source: U.S. Department of Energy (1987c), except as noted.

[c]ND = not detected; a hyphen indicates that data are not available.

[d]Source: Bechtel National (1985b).

TABLE A.5 Chemical Parameters in Surface Water in the Vicinity of the Quarry

Parameter	Concentration (mg/L)[a]		
	Little Femme Osage Creek	Femme Osage Slough	Little Femme Osage Slough
Aluminum	0.2	0.3	-
Arsenic	0.1	0.002-0.14	0.17
Boron	0.05	0.083	0.09
Barium	0.1	0.1-0.17	-
Cadmium	-	0.001	-
Calcium	33-136	52-78	73
Chromium	0.05	0.001-0.03	-
Copper	0.1	0.001-0.009	-
Iron	2.3	0.01-0.5	-
Lithium	0.01	0.003-0.012	0.005
Lead	-	0.001	-
Magnesium	8-17	12-18	21
Manganese	0.04-0.4	0.056-0.4	0.003
Molybdenum	0.03	0.01-0.04	0.05
Phosphorus	0.2	0.23	0.2
Potassium	1.5-2.9	5.3-7.5	6
Selenium	-	0.001	-
Silicon	12	5.5-9.3	6
Sodium	10-17	9.1-11	15
Strontium	0.1	0.24-0.29	0.27
Tin	-	-	-
Zinc	0.01	0.006-0.014	0.01
Chloride	1.8-9.3	3.6-10.3	-
Fluoride	0.25	0.25-0.3	-
Nitrate (as N)	0.1-7.0	0.1-8.1	-
Nitrate (as NO_3)	0.55	0.44-2.5	-
Nitrite (as NO_2)	-	0.033	-
Sulfate	45-50.2	12-33	-
Bicarbonate	126	238	-
pH (in units)	7.8	7.7-8.2	-

[a]A hyphen indicates that data are not available.

Sources: Weidner and Boback (1982); Bechtel Natl. (1983a, 1983b, 1984, 1985a, 1986); Berkeley Geosciences Associates (1984); Kleeschulte and Emmett (1986); U.S. Department of Energy (1987c, 1988).

TABLE A.6 Radiological Data from Surface Water Sampling at the Quarry

Sampling Location	Date Sampled	Concentration ± Error[a] (pCi/L)						
		Gross Alpha	Gross Beta	Natural Uranium[b]	Radium -226	Radium -228	Thorium -230	Thorium -232
SW-1001	3/12/87	<4	<8	3.7 ± 1.1	<1	I	<2	<2
SW-1002	3/12/87	<4	<8	<1	<1	<2	<3	<3
SW-1003	3/23/87	26 ± 5	26 ± 4	45 ± 7	<1	<2	<4	<4
SW-1004	3/13/87	26 ± 5	56 ± 7	47 ± 7	<1	<3	<2	<2
SW-1005	3/10/87	19 ± 5	19 ± 5	39 ± 4	<1	<4	<2	<2
SW-1006	3/9/87	<5	<8	<1	<1	<5	<2	<2
SW-1007	3/11/87	<3	<6	25 ± 3	<1	<10	<2	<2
SW-1008	3/11/87	1100 ± 200	1200 ± 200	2100 ± 200	3.9 ± 0.4	<3	<2	<2

[a]The less than (<) symbol indicates that the measurement is less than the analysis-specific detection limit; I = interference.

[b]Natural uranium is the sum of all uranium isotopes assumed to be present in their natural activity ratio.

Source: U.S. Department of Energy (1987c).

TABLE A.7 Radiological Data from Surface Water Sampling in the Vicinity of the Quarry

	Average Concentration (pCi/L)[a]		
Parameter	Little Femme Osage Creek	Femme Osage Slough	Little Femme Osage Slough
Uranium	<1-71	22-82	28-334
Radium-226	0.1-<2	0.1-<1	0.1-<1
Radium-228	<0.5-<2.3	<0.5-<2.5	<0.5-<2.3
Thorium-230	<0.2-<1	<0.2-<1	<0.1-<1
Thorium-232	<1	<1	<1

[a]A hyphen indicates that data are not available.

Sources: Pennak (1975); Weidner and Boback (1982); Bechtel Natl. (1983a, 1983b, 1984, 1985a, 1986); Berkeley Geosciences Associates (1984); U.S. Department of Energy (1987a, 1987b, 1987c, 1988); Morrison-Knudsen Engineers (1988).

soils as the water table falls. Migration of uranium from the quarry in the direction of the Missouri River appears to be limited to an area between the quarry and the slough, with the slough acting as a barrier to further groundwater migration. It is likely that groundwater north of Femme Osage Slough discharges into the slough, where it becomes subject to natural dilutional effects. In addition, the adsorptive nature of clayey soils at this location probably serves to limit the migration of contaminants beyond the slough (Berkeley Geosci. Assoc. 1984).

TABLE A.8 Historical Uranium Measurements for Quarry Pond Water

Year	Number of Samples	Total Uranium Concentration (pCi/L)[a] Range	Average
1960	1[b]	-	2
1961	8	60-4,500	1,680
1962	12	290-8,000	3,670
1963	6	2,100-12,500	8,350
1964	6	30-4,100	2,200
1967	1	-	16,000
1974	1	-	1,500
1976	1	-	3,200
1977	6	2,860-4,350	3,650
1979	3	3,130-3,260	3,220
1980	2	2,240-2,580	2,410
1981	1	-	2,040
1984	1	-	1,400
1985	1	-	1,240
1987	1	-	2,100

[a]Data reported in units of mg/L, µCi/mL, µCi/cc, µg/L, or ppm were converted to pCi/L total uranium using the conversion factors: 1 cc = 1 mL; 1 µCi/cc = 1 mCi/L, and 1 mg/L = 1 ppm = 680 pCi/L.

[b]Single sample collected prior to USGS pumping tests from the quarry pond to Femme Osage Slough.

Sources: 1960-1964, Mallinckrodt Chemical Works (1960, 1961a, 1961b, 1961c, 1962a, 1962b, 1963, 1964); 1967, Lenhard et al. (1967); 1974, Pennak (1975); 1976-1977, Huey (1978); 1979-1981, Berkeley Geosciences Associates (1984); 1984, Kleeschulte et al. (1986); 1985, Bechtel National (1985b); 1987, U.S. Department of Energy (1987c).

TABLE A.9 Radionuclide Concentrations in Samples of Sediment from the Quarry Pond[a]

Radionuclide	*Source A* Concentration[b] (pCi/g) Range	Average	*Source B* Concentration[b] (pCi/g) Range	Average	*Source C* Average Concentration[c] (pCi/g)
Total uranium[d]	1558-2412	1901	57-449	235	2.5
Uranium-234	765-1180	912	-	-	1.3
Uranium-235	31-227	107	-	-	0.4
Uranium-238	735-1170	890	-	-	1.2
Radium-226	3-11	7	-	-	<2
Thorium-230	220-405	320	-	-	1.6
Thorium-232	0.2-3.9	2.3	-	-	-
Actinium-228	2.3-2.7	2.5	-	-	-

[a]Source A, Bechtel National (1985b); Source B, Berkeley Geosciences Associates (1984); Source C, Bechtel National (1986). Data for Source B were reported in ppm and converted to pCi/g using the conversion factor 1 ppm = 0.68 pCi/g. A hyphen indicates that data are not available.

[b]Wet/dry weight not reported.

[c]Dry weight.

[d]Total uranium is the sum of uranium-234, uranium-235, and uranium-238, which are assumed to be present in their natural activity ratio of 1:0.046:1.

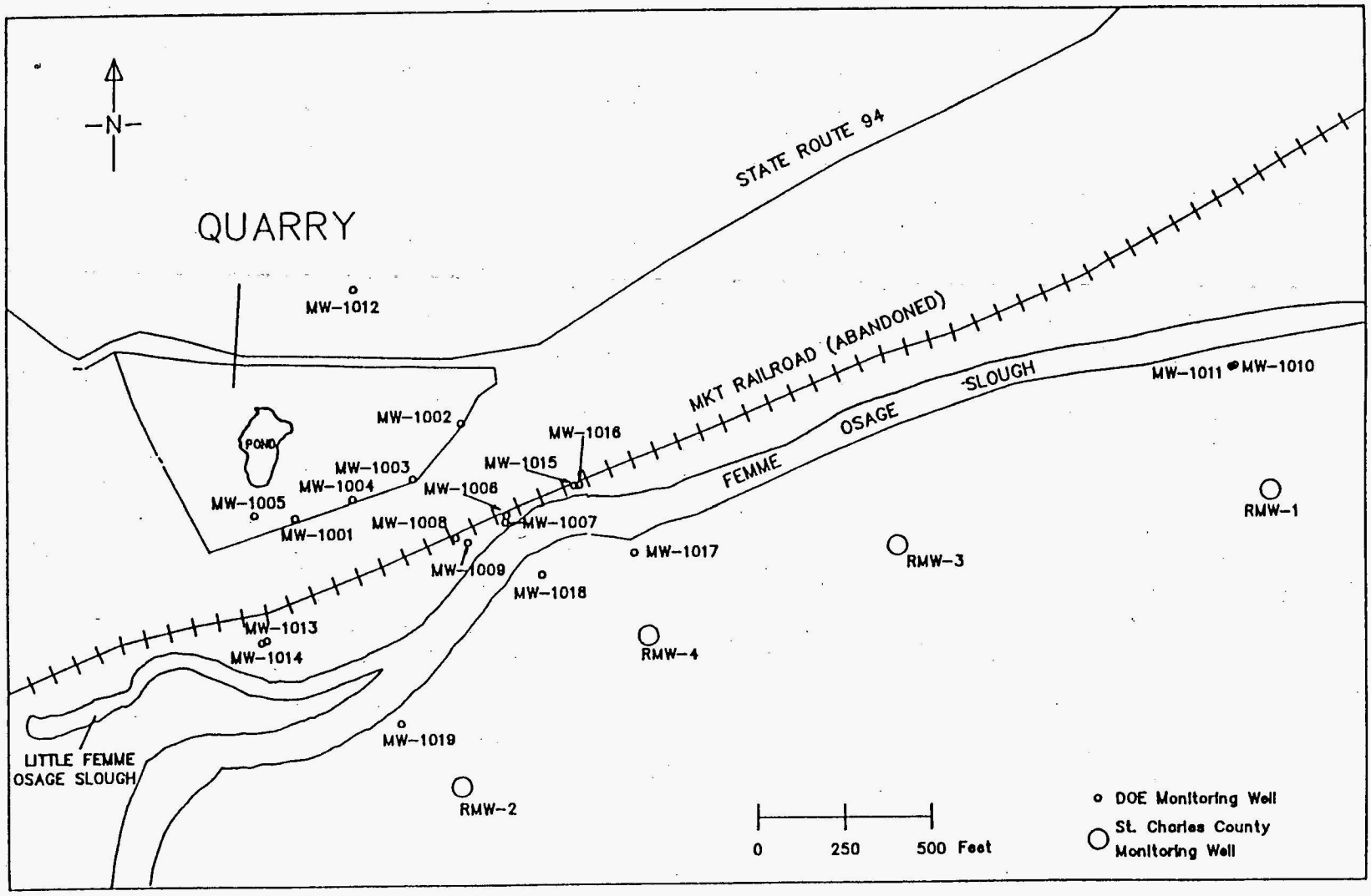


FIGURE A.5 Groundwater Monitoring Locations near the Quarry

TABLE A.10 Radiological Data from Groundwater Sampling at the Quarry

Sampling Location[a]	Date Sampled	Concentration ± Error (pCi/L)						
		Gross Alpha	Gross Beta	Natural Uranium[b]	Radium -226	Radium -228	Thorium -230	Thorium -232
GW-1002	3/12/87	<4[c]	<8	3.8 ± 1.1	<1	<3	<2	<2
GW-1004	3/11/87	2600 ± 300	2500 ± 300	3900 ± 400	<1	32 ± 6	<1	<1
GW-1005	3/11/87	460 ± 50	490 ± 50	420 ± 50	<1	<2	<1	<1
GW-1006	3/13/87	640 ± 50	850 ± 90	1300 ± 200	1.0 ± 0.1	<5	<2	<2
GW-1007	3/13/87	78 ± 9	120 ± 20	360 ± 40	1.8 ± 0.2	<3	<2	<2
GW-1008	3/13/87	500 ± 50	280 ± 30	770 ± 80	3.7 ± 0.1	<4	<2	<2
GW-1009	3/13/87	<8	<15	12 ± 2.0	<1	<3	<1	<1
GW-1010	3/10/87	<3	<8	<1	<1	<2	<2	<2
GW-1011	3/10/87	<3	<8	<1	<1	<2	<2	<2
GW-1012	3/2/87	<9	28 ± 9	2.9 ± 1.0	<1	<10	12 ± 1	<4
GW-1013	9/28/87	300 ± 30	290 ± 30	1200 ± 200	<1	<8	<1	<1
GW-1014	9/28/87	650 ± 70	490 ± 50	1200 ± 200	<1	<5	<1	<1
GW-1015	9/24/87	310 ± 40	180 ± 20	470 ± 50	<1	<1	<1	<1
GW-1015-D	9/24/87	320 ± 40	170 ± 20	470 ± 50	<1	3.5 ± 1.2	<1	<1
GW-1016	9/24/87	26 ± 6	<6	32 ± 4	<1	<1	<1	<1
GW-1017	9/22/87	<5	<8	1.2 ± 0.6	<1	<4	<1	<1
GW-1018	9/23/87	<3	<7	<1	<1	<1	<1	<1
GW-1019	9/23/87	<3	<6	<1	<1	<1	<1	<1

[a]D refers to duplicate sample analysis.

[b]Natural uranium is the sum of all uranium isotopes assumed to be present in their natural activity ratio.

[c]The less than (<) symbol indicates that the measurement is less than the analysis-specific detection limit.

TABLE A.11 Nitroaromatics Data from Groundwater Sampling at the Quarry

Sampling Location	Date Sampled	Concentration (μg/L)					
		2,4,6-TNT	2,4-DNT	2,6-DNT	Nitro-benzene	1,3,5-Trinitro-benzene	1,3-Dinitro-benzene
GW-1001	10/2/87	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
GW-1002	10/1/87	<0.5	<0.2	<0.6	2.2	0.48	<0.4
GW-1004	10/2/87	<0.5	0.33	<0.6	<0.6	0.16	<0.4
GW-1005	10/1/87	<0.5	0.61	<0.6	1.7	0.52	<0.4
GW-1006	9/28/87	7.6	<0.2	1.0	8.5	1.5	<0.4
GW-1007	9/29/87	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
GW-1008	9/29/87	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
GW-1009	9/22/87	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
GW-1010	9/22/87	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
GW-1011	9/22/87	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
GW-1012	9/30/87	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
GW-1013	9/28/87	<0.5	0.56	<0.6	0.95	0.23	<0.4
GW-1014	9/28/87	<0.5	0.33	<0.6	1.6	0.25	<0.4
GW-1015	9/24/87	28.9	<0.2	<0.6	44.0	8.3	<0.4
GW-1016	9/24/87	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
GW-1017	9/22/87	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
GW-1018	9/23/87	<0.5	0.33	<0.6	<0.6	<0.03	<0.4
GW-1019	9/23/87	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4

TABLE A.12 Metals Data from Groundwater Sampling at the Quarry

Sampling Location	Date Sampled	Concentration[a] (μg/L)											
		Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb
GW-1002	3/12/87	132	U	U	150	U	U	120,000	38	U	7	40	U
GW-1004	3/11/87	370	97	U	95	U	U	103,900	76	U	20	220	U
GW-1005	3/11/87	132	U	U	74	U	U	103,900	47	U	10	23	U
GW-1006	3/13/87	260	77	U	103	U	U	224,400	75	U	20	24	U
GW-1007	3/13/87	203	82	U	512	U	U	208,200	67	U	14	5,130	U
GW-1008	3/13/87	224	79	U	191	U	U	177,700	66	U	14	296	U
GW-1009	3/13/87	186	78	U	328	U	U	198,100	70	U	15	4,570	U
GW-1010	3/10/87	U	U	27	533	U	U	57,200	28	U	9	883	U
GW-1011	3/10/87	U	U	U	170	U	U	69,000	32	U	9	2,250	U
GW-1012	3/2/87	219	86	10	171	U	U	145,600	54	U	18	80	U
GW-1013	9/28/87	121	44	U	159	1	U	126,000	49	10	15	1,860	U
GW-1014	9/28/87	132	47	U	158	1	U	130,000	49	10	15	2,360	U
GW-1015	9/24/87	103	40	U	92	1	U	137,000	45	7	17	118	U
GW-1016	9/24/87	122	-	U	138	U	U	139,000	45	7	15	104	U
GW-1017	9/22/87	110	46	32	962	1	11	139,000	46	18	15	20,190	U
GW-1018	9/23/87	100	60	32	890	1	12	137,000	47	18	14	26,400	U
GW-1019	9/23/87	149	41	48	852	1	U	100,000	33	12	12	9,600	U
EPA standard[b]		c	c	50	1,000	c	10	c	50	c	1,000	300	50
RDL[b]		200	60	10	200	5	5	5,000	10	50	25	100	5

TABLE A.12 (Cont'd)

Sampling Location	Date Sampled	Concentration[a] (μg/L)											
		Li	Mg	Mn	Hg	Ni	K	Se	Ag	Na	Tl	V	Zn
GW-1002	3/12/87	U	20,800	620	U	36	6,350	U	U	27,600	U	U	12
GW-1004	3/11/87	U	46,700	840	U	52	8,660	U	23	27,700	U	28	29
GW-1005	3/11/87	U	24,200	64	U	37	7,680	U	U	25,800	U	U	7
GW-1006	3/13/87	U	33,150	3,690	U	39	3,400	U	26	79,370	U	33	30
GW-1007	3/13/87	U	34,100	7,170	U	38	3,290	U	19	67,740	U	30	12
GW-1008	3/13/87	U	32,600	6,180	U	41	3,640	U	19	39,000	U	29	23
GW-1009	3/13/87	U	34,600	4,330	U	39	2,850	U	18	50,800	U	31	17
GW-1010	3/10/87	U	12,800	5,915	U	U	3,310	U	U	15,500	U	U	21
GW-1011	3/10/87	U	15,800	4,240	U	U	2,060	U	U	21,700	U	U	38
GW-1012	3/2/87	U	41,000	380	U	43	8,340	U	22	187,600	U	25	21
GW-1013	9/28/87	U	31,000	633	U	20	3,990	U	U	19,900	U	35	8
GW-1014	9/28/87	U	30,500	786	U	21	4,760	U	U	21,400	U	36	21
GW-1015	9/24/87	U	30,700	39	U	14	2,370	U	U	26,200	U	34	37
GW-1016	9/24/87	U	27,400	206	0.2	26	1,030	U	U	17,900	U	33	16
GW-1017	9/22/87	U	38,500	690	U	24	5,800	U	U	23,900	U	35	U
GW-1018	9/23/87	U	40,400	1,230	U	25	6,550	U	U	24,900	U	36	34
GW-1019	9/23/87	U	31,000	503	U	10	4,490	U	U	11,400	U	27	7
EPA standard[b]		c	c	50	2[e]	c	c	10	50	c	c	c	5,000
RDL[b]		-	5,000	15	0.2	40	5,000	5	10	5,000	10	50	20

[a]U means undetected at the contract-required detection limit; a hyphen indicates that the data are not available.

[b]EPA standard = primary/secondary drinking water standard unless otherwise noted; RDL = contract laboratory program required detection limits.

[c]No drinking water standard has been promulgated for these parameters.

TABLE A.13 Inorganic Anion and Water Quality Data from Groundwater Sampling at the Quarry

Sampling Location[a]	Date Sampled	Concentration[b] (mg/L)								
		Nitrate (as N)	Sulfate	Chloride	Fluoride	Hardness	Total Dissolved Solids	Total Organic Carbon	Cyanide	Phenol
GW-1002	3/12/87	0.4	62.7	9.06	<0.25	313	404	3	U	U
GW-1004	3/11/87	537	329	7.0	0.97	530	872	3.48	U	U
GW-1005	3/11/87	579	379	125	0.62	372	600	11.2	U	U
GW-1006	3/13/87	2.2	377	50.9	<0.25	777	1,108	6.28	0.014	U
GW-1007	3/13/87	3.2	132	71.0	<0.25	784	968	8.63	0.013	U
GW-1008	3/13/87	<0.1	238	24.3	<0.25	784	816	6.06	U	U
GW-1009	3/13/87	<0.1	160	28.5	<0.25	740	870	5.01	U	U
GW-1010	3/10/87	<0.25	4.40	7.91	<0.25	215	278	4.17	U	U
GW-1011	3/10/87	<0.25	20	9.64	<0.25	267	318	4.00	U	U
GW-1012	3/2/87	0.8	479	11.4	0.76	528	1,156	13	U	U
GW-1013	9/28/87	<0.1	112	24.5	0.9	444	1,002	3.8	0.008	<0.005
GW-1014	9/28/87	25.2	106	21.5	1.0	524	720	2.3	0.012	<0.005
GW-1015	9/24/87	1.3	160	31.4	1.0	568	727	2.55	<0.005	<0.005
GW-1015-D	9/24/87	1.5	156	30.6	1.0	556	599	6.58	<0.005	<0.005
GW-1016	9/24/87	<0.1	154	14.6	0.9	544	670	2.63	<0.005	<0.005
GW-1017	9/22/87	<0.1	1.3	24.4	1.0	630	715	15	<0.005	<0.005
GW-1018	9/23/87	<0.1	51.4	33.4	0.9	614	701	6	<0.005	<0.005
GW-1019	9/23/87	<0.1	1.05	8.5	0.8	440	483	12	<0.005	<0.005
EPA standard[c]		10	250	250	2	d	500	d	d	0.001[e]

[a]D refers to duplicate sample analysis.

[b]U means undetected at the contract-required detection limits.

[c]Primary/secondary drinking water standard.

[d]No drinking water standard has been promulgated for these parameters.

[e]Missouri drinking water standard.

TABLE A.14 Range of Values in Samples Taken between the Quarry and Femme Osage Slough

Area	Maximum Years Sampled for an Individual Well	Range[a] (pCi/L)	
		Uranium	Radium-226
Bedrock surrounding quarry	14	ND-18,676	0.1-31.6
Alluvium between quarry and Femme Osage Slough	7	<1.3-7,014	0.1-6
Alluvium south of Femme Osage Slough	6	<1.3-402	ND-7

[a]Detection limits varied throughout the sampling period; ND = not detected.

Sources: Berkeley Geosciences Associates (1984); Morrison-Knudsen Engineers (1988).

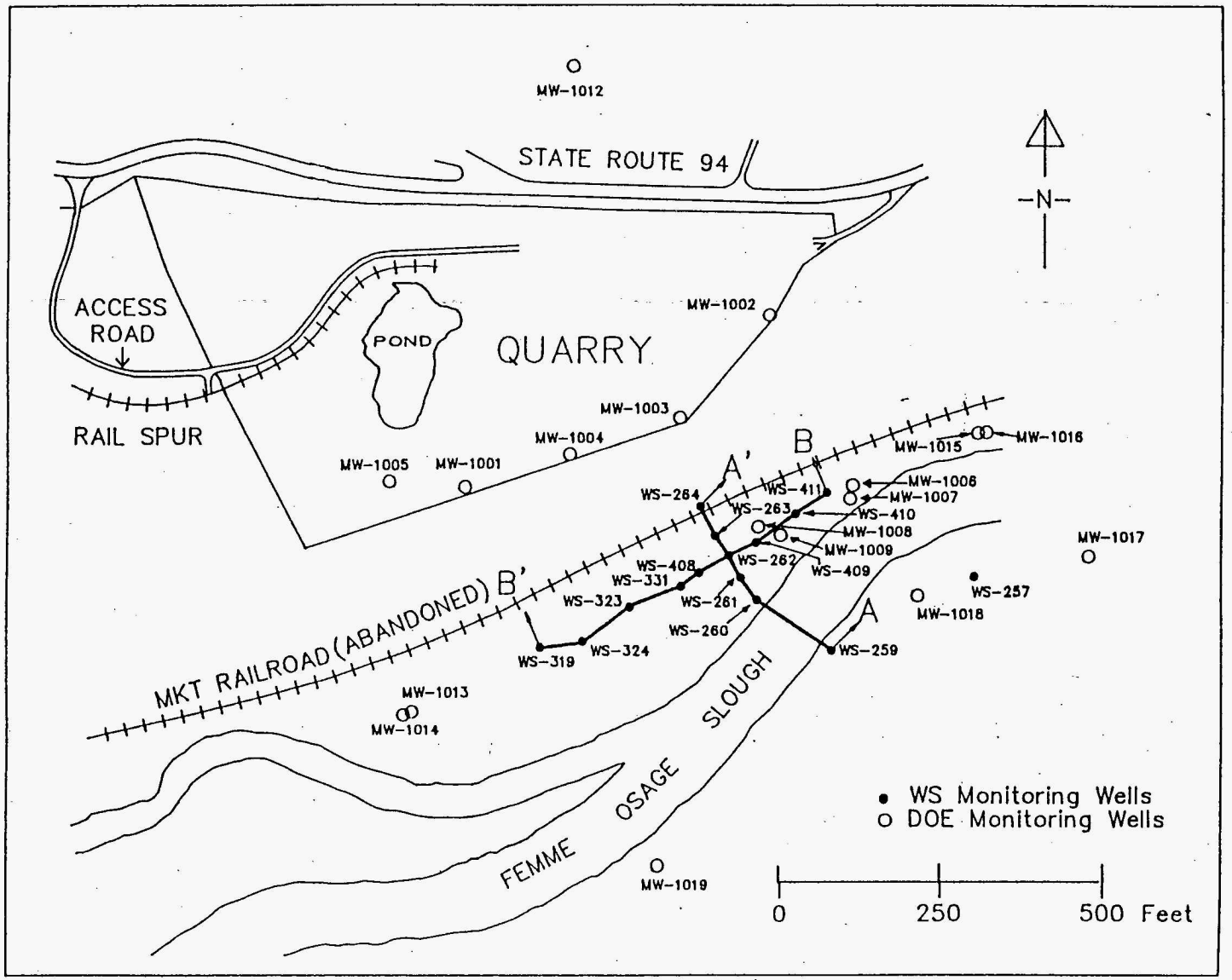
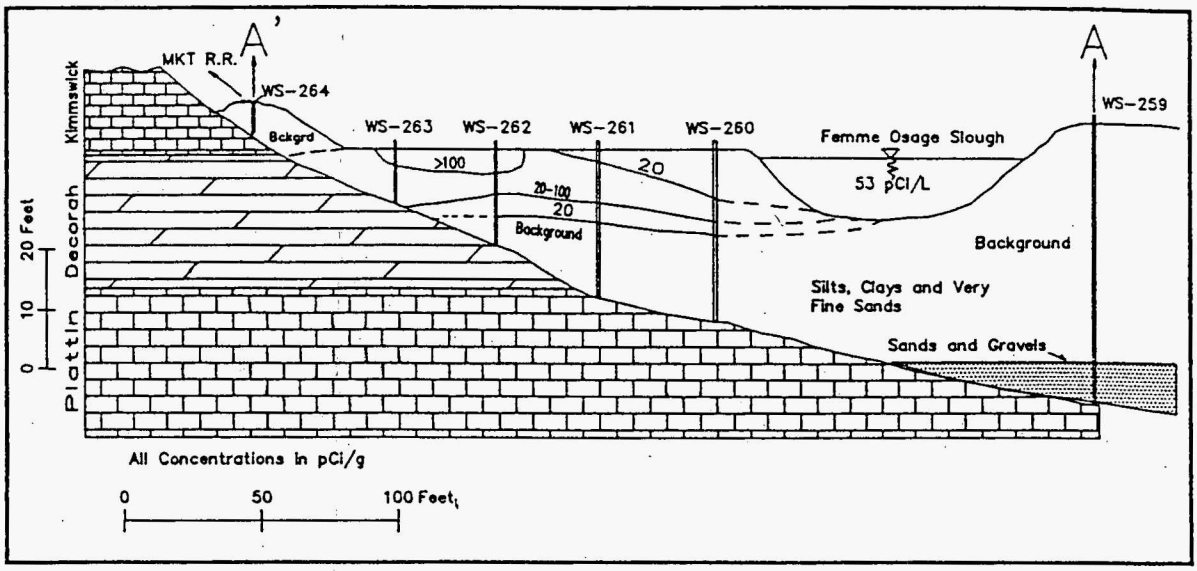


FIGURE A.6 Locations Sampled in the Alluvium near the Quarry to Assess Contaminant Migration



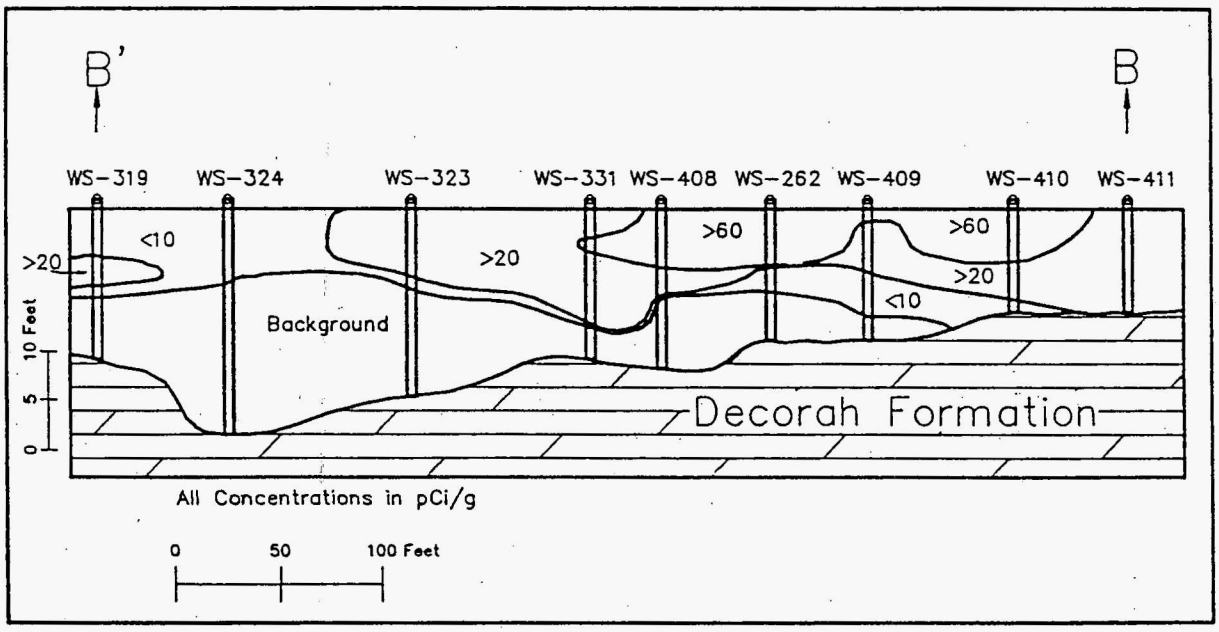


FIGURE A.7 Uranium Concentrations (pCi/g) in the Alluvium near the Quarry, Cross Sections A-A' and B-B'

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APPENDIX B:

TREATMENT TECHNOLOGIES AND SYSTEMS THAT ARE APPLICABLE TO THE PROPOSED ACTION

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TREATMENT TECHNOLOGIES AND SYSTEMS THAT ARE APPLICABLE TO THE PROPOSED ACTION

Treatment technologies that might be used to support the final alternatives identified in Section 4.2 of this report are listed in Table B.1. The potential applicability of each specific technology to the treatment objectives of the proposed action is also identified, i.e., in terms of removing the contaminants of concern from the quarry water; these contaminants, as identified in Chapter 5, are arsenic, manganese, uranium, and 2,4-DNT. Although potential technologies are listed singly, most must be integrated with other technologies to form a treatment system for the contaminated water in the quarry pond. Each of the listed technologies is screened in Appendix C for applicability to the proposed action in terms of technical feasibility and implementation considerations. Results of this screening are summarized in Section B.1. In Section B.2, those technologies that are identified as potentially applicable are combined into specific alternatives for treatment of the contaminated water. General considerations for the screened technologies, as assembled into specific treatment alternatives, are addressed in Section B.3. Based on a comparative analysis of these alternatives, the specific treatment system for the proposed action is identified in Section B.4.

B.1 SCREENING OF POTENTIAL TREATMENT TECHNOLOGIES

Based on the screening of potential treatment technologies, the following treatment technologies are considered applicable to the proposed action:

- Equalization/detention
- Density separation (clarification, flotation)
- Flocculation
- Filtration (granular media, tubular membrane, and filter press)
- Adsorption (granular activated carbon, activated alumina)
- Vapor recompression/distillation
- Neutralization
- Coagulation/precipitation
- Ion exchange

These potential treatment technologies are described and screened for applicability to the proposed action in Appendix C.

TABLE B.1 Potential Technologies for Treatment of the Quarry Water

Technology[a]	Potential Applicability[b]
Physical	
Equalization/detention	General
Density separation	
Clarification	General
Flotation	General
Centrifugation	General
Flocculation	General
Filtration	
Granular media	General
Tubular membrane	General
Rotary drum	Follow-on
Filter press	Follow-on
Microscreening	General
Dialysis (osmosis)	General
Ultrafiltration (reverse osmosis)	General
Electrolysis	Manganese, arsenic, uranium
Electrodialysis	Manganese, arsenic, uranium
Adsorption	
Powdered activated carbon	Arsenic, 2,4-DNT
Granular activated carbon	Arsenic, 2,4-DNT
Activated alumina	Arsenic, uranium
Stripping (air, steam)	2,4-DNT
Vapor recompression/distillation	General
Thermal destruction	
Incineration	2,4-DNT
Pyrolysis	2,4-DNT
Thermal oxidation	2,4-DNT
Freeze crystallization	General
Chemical	
Neutralization	General
Coagulation/precipitation	General
Oxidation/reduction	
Ozonation	General
Chlorination	General
Wet air oxidation	General
Ion exchange	Manganese, arsenic, uranium
Chlorinolysis	Other
Dechlorination	Other

TABLE B.1 (Cont'd)

Technology[a]	Potential Applicability[b]
Chemical (Cont'd)	
Solvent extraction	2,4-DNT
Stabilization/solidification	General
In-situ permeable treatment beds	General
In-situ injection	General
Biological	
Activated sludge	2,4-DNT
Trickling filter	2,4-DNT
Rotating biological disc	2,4-DNT
Surface impoundment	2,4-DNT
Land treatment	2,4-DNT

[a]Although many of these are physical-chemical treatment technologies, they are listed here on the basis of their controlling element.

[b]"General" implies broad applicability, e.g., for the removal of any of the four contaminants or of suspended solids either present in the influent or generated during a primary treatment process for the removal of dissolved contaminants. "Other" implies potential applicability as a secondary treatment process, e.g., to destroy contaminants that are not now present in the quarry water but could be generated during a primary treatment process. "Follow-on" implies potential applicability as a follow-on process, e.g., to dewater waste sludges generated by unit operations of the treatment system.

B.2 ASSEMBLY OF TECHNOLOGIES INTO SPECIFIC TREATMENT ALTERNATIVES

Specific treatment alternatives for the proposed action have been developed on the basis of the screened treatment technologies and the following considerations:

- Concentrations of the contaminants of concern are reduced to meet the effluent limits identified in Section 5.1 of this report (see Table 10).

- Distillation is generally considered a single-stage process, i.e., pretreatment is not identified separately. However, the distillation

alternative includes an ion-exchange step, which makes this alternative a two-stage process. Except for the distillation alternatives, each specific alternative has three general process stages:

- Chemical addition for coagulation or precipitation,
- Solids/liquid separation for the removal of suspended solids, and
- Ion exchange and/or adsorption for the removal of residual contaminants.

- Flocculation, neutralization, and oxidation/reduction are considered part of the coagulation/precipitation process because they involve chemical addition for solids separation.
- Lime treatment and coagulation for precipitation are considered separately.
- Each alternative includes a pretreatment step of solids separation, i.e., sedimentation in an equalization/detention basin.
- Two additional process methods of solids separation for treatment of the quarry water are addressed:
  - Clarification followed by granular media filtration, and
  - Tubular membrane filtration.
- To minimize plugging, the filtration step precedes the ion-exchange and adsorption steps.
- Two adsorption processes are addressed:
  - Granular activated carbon adsorption, and
  - Activated alumina adsorption.
- Filter press filtration is considered as a follow-on process for each alternative to reduce the volume of waste sludges generated by the preceding unit operations.

Five treatment alternatives have been developed to achieve the treatment objectives identified in Table 10 of this report. These alternatives, which are composed of different process options, are identified in Table B.2. The three treatment stages and the removals targeted by component technologies are identified in Table B.3.

The major differences between the five alternatives are as follows. Alternative 5 is a single-stage distillation process. Alternatives 1 through 4 differ from each

TABLE B.2 Treatment Alternatives and Component Technologies

	Component Technology			
	Precipitation		Filtration	
Alternative	Coagulant Addition	Lime Addition	Granular Media	Tubular Membrane
1	X	-	X	-
2	X	-	-	X
3	-	X	X	-
4	-	X	-	X
5	-	-	-	-

	Component Technology			
		Adsorption		
Alternative	Ion Exchange	Activated Alumina	Granular Activated Carbon	Distillation
1	X	-	X	-
2	X	-	X	-
3	X	X	X	-
4	X	X	X	-
5	-	-	-	X

other with respect to their component processes for chemical addition, solids removal, and "polishing" to remove residual contaminants. In terms of first-stage chemical addition, Alternatives 1 and 2 rely on coagulant addition to achieve precipitation, whereas Alternatives 3 and 4 use lime addition. To achieve second-stage solids separation, Alternatives 1 and 3 rely on clarification and granular media filtration whereas Alternatives 2 and 4 use tubular membrane filtration. In terms of the third-stage removal of residual contaminants, Alternatives 3 and 4 include an activated alumina adsorption step whereas Alternatives 1 and 2 do not. Ion exchange is also included in the four nondistillation alternatives, but not in Alternative 5. Finally, each of the nondistillation alternatives, i.e., Alternatives 1, 2, 3, and 4, includes a third-stage GAC adsorption step, but Alternative 5 does not. The process flow for nondistillation alternatives is depicted in Figure B.1; that for the distillation alternative is depicted in Figure B.2.

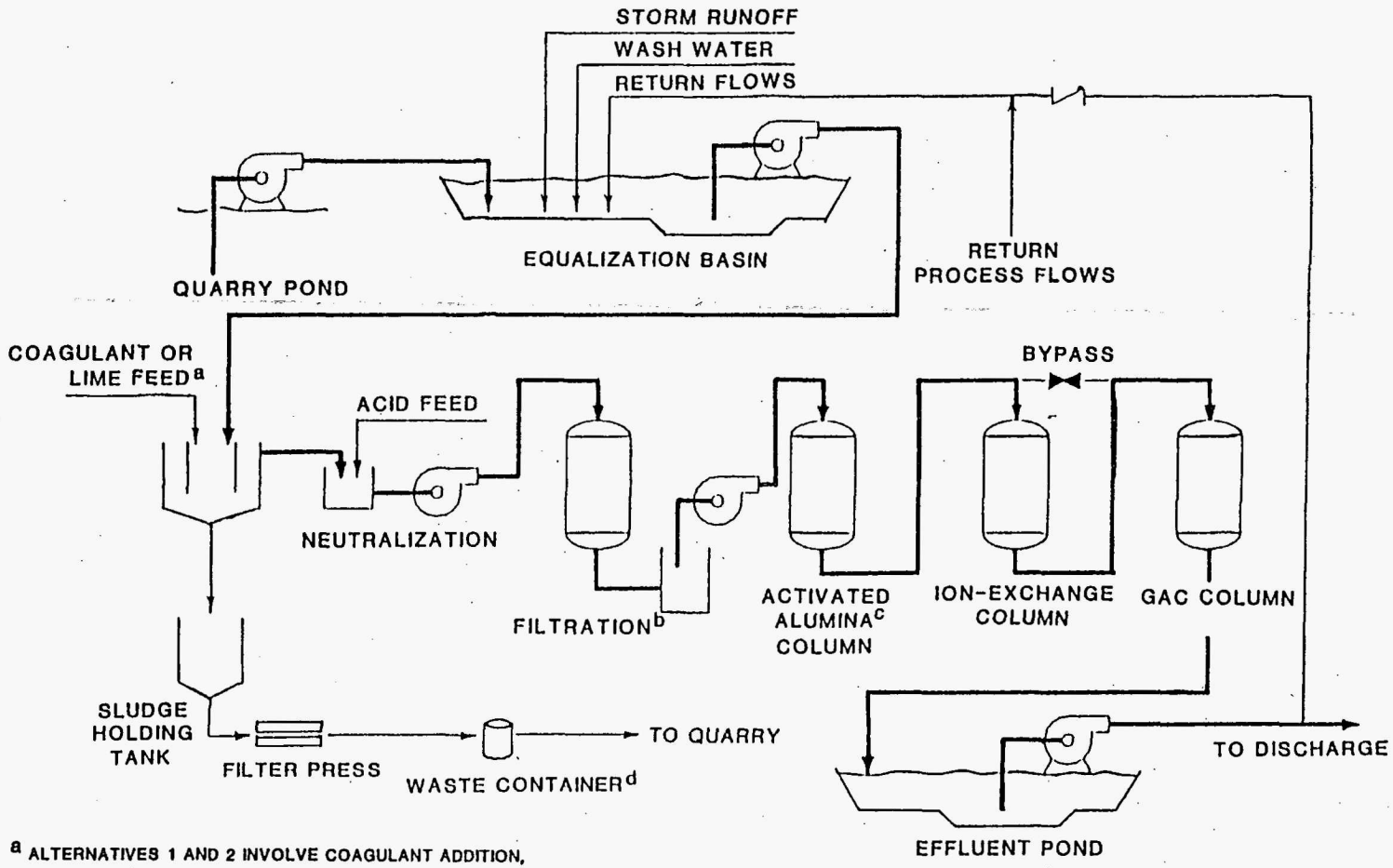
TABLE B.3 Removal of Contaminants Targeted by Staged Process Technologies[a]

Alternative	First-Stage Treatment: Chemical Coagulation	Lime Addition	Distillation
1	As, Mn, U	-	-
2	As, Mn, U	-	-
3	-	Mn, U	-
4	-	Mn, U	-
5	-	-	All

Alternative	Second-Stage Treatment: Clarification/Granular Media Filtration	Membrane Filtration
1	SS	-
2	-	SS
3	SS	-
4	-	SS
5	-	-

Alternative	Third-Stage Treatment: Activated Alumina Adsorption	Ion Exchange	Granular Activated Carbon Adsorption
1	-	U	2,4-DNT
2	-	U	2,4-DNT
3	As, U	U	2,4-DNT
4	As, U	U	2,4-DNT
5	-	-	-

[a]Targeted removal entries defined as follows: As = arsenic; Mn = manganese; U = uranium; SS = suspended solids; 2,4-DNT = 2,4-dinitrotoluene.



[a] ALTERNATIVES 1 AND 2 INVOLVE COAGULANT ADDITION, WHEREAS ALTERNATIVES 3 AND 4 INVOLVE LIME ADDITION

[b] ALTERNATIVES 1 AND 3 INVOLVE GRANULAR MEDIA FILTRATION, WHEREAS ALTERNATIVES 2 AND 4 INVOLVE TUBULAR MEMBRANE FILTRATION

[c] ONLY INCLUDED IN ALTERNATIVES 3 AND 4

[d] SPENT RESINS AND ADSORBENTS WOULD ALSO BE CONTAINERIZED FOR PLACEMENT IN THE QUARRY

FIGURE B.1 Process Flow for the Nondistillation Alternatives

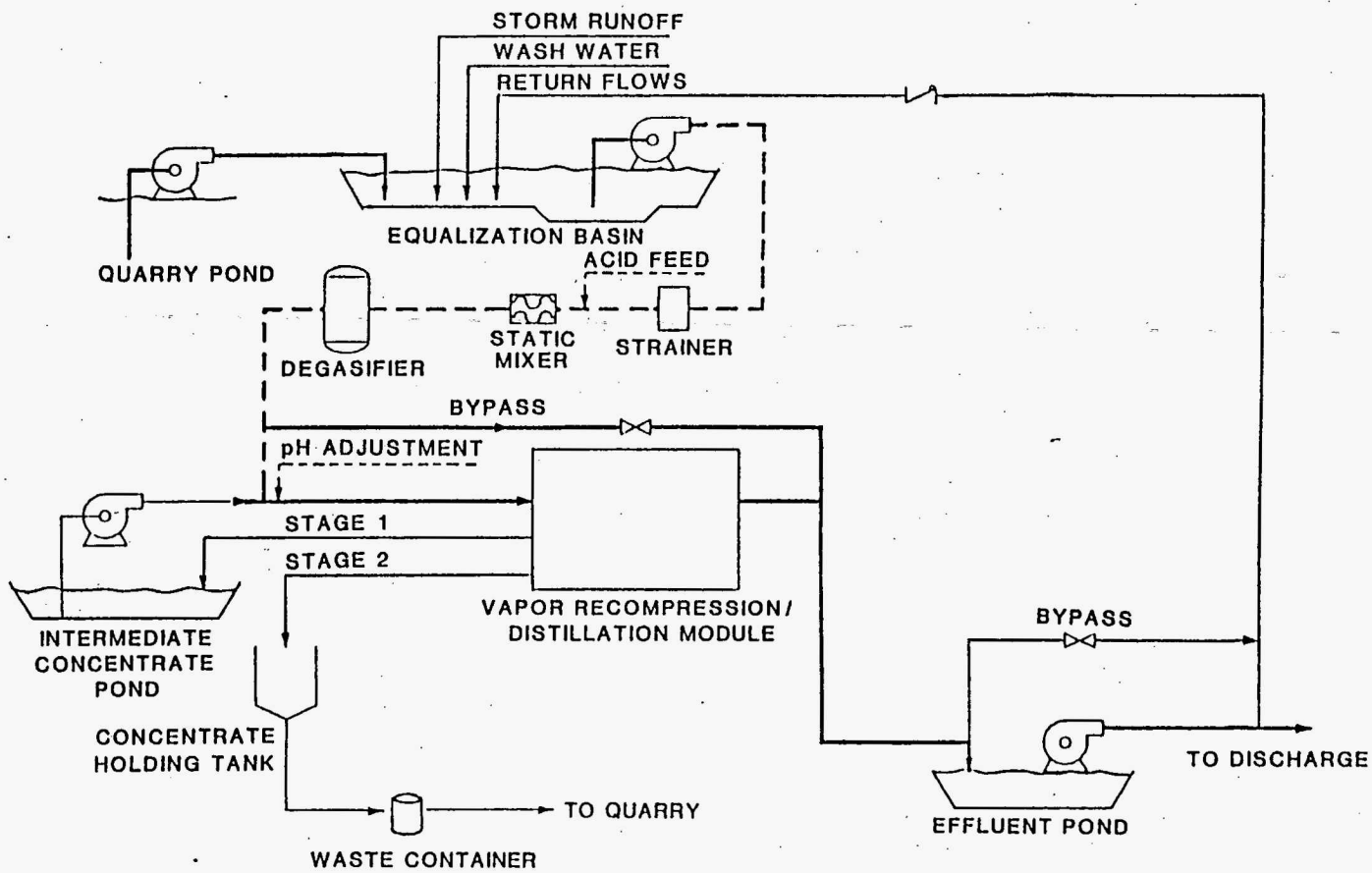


FIGURE B.2 Process Flow for the Vapor Recompression/Distillation Alternative

B.3 GENERAL CONSIDERATIONS FOR TREATMENT ALTERNATIVES

The general applicability and implementation considerations for the screened technologies, as assembled into the five treatment alternatives for the proposed action, are discussed in Sections B.3.1 through B.3.3. The process technologies are addressed in Section B.3.1, contaminants of concern in Section B.3.2, process wastes in Section B.3.3, and the specific treatment system in Section B.4.

B.3.1 Process Technologies

Six broad categories of treatment technologies have been identified as potentially applicable to the proposed action:

- Density separation, which includes clarification, pretreatment by equalization/detention, and flotation and flocculation, as appropriate;
- Coagulation/precipitation, which includes coagulant or lime addition for precipitation and other chemical additions as required (e.g., for flocculation, neutralization, or oxidation/reduction);
- Filtration, which includes granular media or tubular membrane processes as well as a filter press process for follow-on sludge dewatering;
- Ion exchange;
- Adsorption, which includes both granular activated carbon and activated alumina processes; and
- Vapor recompression/distillation.

The roles of these technologies in the comprehensive treatment systems of the proposed alternatives are addressed in Sections B.3.1.1 through B.3.1.6.

B.3.1.1 Density Separation

Under each of the proposed alternatives, quarry water would be pumped from the pond and collected in a lined equalization/detention basin at the treatment plant. The basin would provide the following basic capabilities: (1) storage of surge flows, (2) sedimentation of solids, and (3) maintenance of a constant feed (volume and concentration) to the treatment plant. Initial suspended solids removal would occur in the equalization/detention basin, which would have a capacity of 8,300 m^3 (2.2 million gal) and would be designed for a detention time of greater than one day and an overflow rate of less than 4,000 L/day/m^2 (100 gpd/ft^2). Suspended solids that carry over from the equalization basin into the treatment plant or that are formed during a subsequent treatment step would be removed by such processes as clarification and filtration.

B.3.1.2 Coagulation/Precipitation

Chemical addition for coagulation/precipitation is the first-stage process for each of the four nondistillation alternatives. Its purpose is to reduce solution levels of arsenic, manganese, and uranium using lime or a coagulant (such as ferric chloride) to precipitate out the dissolved solids. A major portion of these contaminants would be removed from solution by this process. Use of lime for pH adjustment (to pH 6), which is required to optimize arsenic removal, would also enhance uranium removal. Solution levels of iron, heavy metals, and suspended solids (e.g., asbestos) would also be reduced during coagulation/precipitation. Neutralization would be achieved, as needed, with hydrochloric acid rather than sulfuric acid to prevent increases in solution sulfate concentrations. Coagulation/precipitation alone would not be expected to achieve the required uranium removal (see Chapter 6 and Section C.2.2); therefore, additional processes must be included in the treatment alternatives to meet the uranium effluent limit.

B.3.1.3 Filtration

Filtration of the quarry water is included in each of the four nondistillation alternatives. This process would remove suspended solids, including fine particulate uranium solids, asbestos, and precipitates that did not settle naturally following chemical addition. Either synthetic tubular membrane filters or conventional granular media filters with air scour and backwash provisions would be used (see Sections C.1.4.1 and C.1.4.2). Filtration of waste sludges is included as a follow-on step for all five alternatives. This dewatering step would be achieved with a filter press (see Section C.1.4.4).

B.3.1.4 Ion Exchange

Ion exchange is a component of the four nondistillation alternatives. The inclusion of this process reflects a conservatism with regard to system reliability for meeting the prescribed uranium effluent limits because of the associated pH optimization and magnesium requirements for precipitation (see Sections C.2.2. and C.2.3). Ion exchange is responsive to the potential for influent variation and the paucity of related operating experience with coagulation/precipitation and activated alumina adsorption for the consistent removal of uranium. Ion exchange may also increase system reliability for arsenic removal. To meet the appropriate effluent limits, the ion-exchange columns could be bypassed and/or used to treat only a portion of the treatment plant flow, as appropriate, by blending part of the influent to a column with its effluent.

B.3.1.5 Adsorption

Adsorption on granular activated carbon is a component of each of the nondistillation alternatives for the removal of 2,4-DNT. This removal is expected to be very efficient (see Section C.1.9) and would be achieved with conventional two-stage, downflow pressure contactors with an empty bed residence time of about 30 minutes.

An activated alumina adsorption step to reduce solution levels of arsenic and to support uranium removal (see Section C.1.9) is included in two of the nondistillation alternatives. For these alternatives, duplicate adsorption beds would be placed in parallel for continuous operation, to allow the emptying and refilling of the standby bed at exhaustion.

B.3.1.6 Vapor Recompression/Distillation

Vapor recompression/distillation is the only single-stage treatment alternative and is expected to meet the specified effluent limits (see Section C.1.11). Adjustment of pH may be necessary prior to the vapor recompression stage if acid pretreatment and carbon dioxide stripping are used to reduce scaling by carbonates. Suspended solids are not typically a problem for vapor recompression equipment unless oil is present. In this case, removal of suspended solids may be required prior to degasification to prevent plugging. However, oil is not expected to be present in the quarry water (and if it were, it would float above the submerged intake in the equalization basin).

To minimize the costs of this energy-intensive process, the proposed system could be designed as a phased process using a single evaporator and an intermediate holding pond for the waste concentrate. Concentrate from the first stage, which is expected to be about 2% solids, would be stored for subsequent treatment to achieve a 20% solids content. Because the process effluent would be of extremely high quality, a portion of the plant influent could be bypassed and blended in the effluent pond to produce an acceptable discharge, which would reduce the amount of concentrate produced. Assuming a bypass volume of 20%, the first-stage concentrate stream would be about 8% of the influent volume at a 90% product recovery rate (Morrison-Knudsen Engineers 1988b).

B.3.2 Contaminants of Concern

Manganese, arsenic, uranium, and 2,4-DNT have been identified as the contaminants of concern with regard to the quarry pond water. To comply with potential health-based effluent limits (see Chapter 5), the water must be treated to remove these contaminants. Distillation, without additional process steps, is capable of reducing the concentrations of manganese, arsenic, uranium, and 2,4-DNT to meet these limits. By contrast, the nondistillation alternatives contain a number of process technologies to ensure compliance with specific effluent limits. The primary contaminants targeted for removal by the treatment processes of these four alternatives are as follows:

- Manganese would be removed by chemical addition for coagulation/precipitation (29% reduction);

- Arsenic would be removed by adsorption on activated alumina, supported by chemical addition for coagulation/precipitation and ion exchange (33% reduction);

- 2,4-DNT would be removed by adsorption on granular activated carbon, supported by chemical addition for coagulation/precipitation, i.e., coprecipitation (99% reduction); and

- Uranium would be removed by chemical addition for coagulation/precipitation, supported by ion exchange and adsorption on activated alumina (96% reduction to achieve 100 pCi/L [see Chapter 6]).

In addition to a reduction in the solution levels of these four contaminants, asbestos, iron, and sulfate removal may also be required because the upper ranges of these contaminants in the quarry water may exceed effluent limits. Although less likely, levels of fluoride may also exceed acceptable limits if influent variability is great. Distillation would effectively remove these and other contaminants. Their removal by nondistillation alternatives is addressed below.

The equalization/detention system and other technologies already included in the overall treatment system of each alternative to remove the four primary contaminants are expected to effectively reduce the levels of other contaminants as well. Thus, no additional process technologies have been identified for their removal. If monitoring of the treated water indicated that any relevant requirements would not be met upon discharge, the effluent stream would be diverted back to the treatment plant as a recycle flow for additional processing.

Asbestos is expected to be removed as a result of the chemical addition/sludge settling and filtration processes that are included in the treatment system for each alternative. If effluent monitoring indicated that asbestos was not adequately removed during a first pass through the system, the flow would be recycled and subsequently filtered as necessary to comply with relevant requirements. The removal of iron is also expected to occur as a result of chemical addition supported by filtration that is included in the treatment systems for the removal of manganese and uranium. In the event that iron was not adequately removed during a first pass through the treatment system, the flow would be recycled. Similarly, chemical (lime) addition and activated alumina adsorption, possibly supported by ion exchange, would be expected to reduce fluoride to acceptable levels.

Achieving sulfate removal might require a process modification to permit the addition of a new chemical, such as barium carbonate or barium chloride, at the existing coagulation/precipitation step. However, the chemical addition of a barium salt would be straightforward and easy to implement. This potential modification requirement is based on the fact that adding lime or chemical coagulants, such as alum or ferrous sulfate, would be counterproductive for sulfate removal because their addition would increase the solution concentration of this anion. For example, precipitation of sulfate by lime, which is limited by the solubility of calcium sulfate, would result in residual sulfate values much greater than the effluent limit (see Table 9), e.g., in excess of 1,000 mg/L (Morrison-Knudsen Engineers 1988b). In any case, the requirement for a minor process modification of the nondistillation treatment systems, if needed to remove sulfate, is independent of the treatment alternative.

B.3.3 Process Wastes

Wastes that would be generated by the various treatment processes include chemical sludges, spent activated alumina and carbon, spent ion-exchange resins, and -- for distillation -- concentrate from the vapor recompression/distillation process (at an estimated 90% recovery). Backwash water from filters, ion-exchange columns, and adsorption beds would be recycled to the equalization basin for solids settling and subsequent treatment. Process wastes would be dewatered and containerized for temporary placement in the quarry. That is, the quarry would serve as a temporary staging area for containerized process wastes pending removal of these wastes, e.g., during the removal operations currently being planned as a distinct response action for the quarry bulk wastes (see Section 1.4).

B.4 SPECIFIC TREATMENT SYSTEM

The treatment system for the proposed action is determined by evaluating the five alternative treatment systems (identified in Section B.2) according to effectiveness, technical feasibility and other implementation considerations, and reasonable cost.

No major distinctions can be made between the five treatment systems in terms of effectiveness (i.e., protecting the public and the environment). Each of the proposed alternatives would reduce levels of the contaminants of concern to meet discharge limits (see Section 5.1). For the nondistillation alternatives, Alternatives 3 and 4 contain a safety factor relative to Alternatives 1 and 2 by including an additional adsorption step, i.e., adsorption onto activated alumina. Alternative 5, the distillation alternative, does not include this step because contaminant levels can be reliably reduced by this system without a supplemental process. Long-term environmental conditions would be improved by each of the alternatives because treatment would reduce the potential for contaminant migration from the quarry pond. In the short term, limited environmental impacts could occur during construction and operation of the treatment facility, but these impacts are expected to be temporary and mitigable (see Section 5.2.1).

With respect to construction, each of the five treatment systems can be constructed in a safe manner. Alternative 5 could include construction of a holding pond for the waste concentrate that would not be required by the other (nondistillation) alternatives. This construction would result in a minor incremental adverse impact related to the additional area disturbed; this impact would be mitigable and reversible following the action period. In addition, the distillation system would be somewhat more difficult to maintain than would the conventional, nondistillation treatment systems because of the relatively high temperature of the distillation process and the pressure requirements of the recompression process. The waste sludges would be dewatered (e.g., by a filter press) prior to being containerized for temporary storage in the quarry.

The distillation alternative is considerably more energy-intensive than the four nondistillation alternatives. For these latter alternatives, the membrane filtration process of Alternatives 2 and 4 is somewhat more energy-intensive than the granular media filtration process of Alternatives 1 and 3. Relative to Alternatives 1 and 3,

Alternative 5 consumes more than 12 times as much energy and Alternatives 2 and 4 consume more than twice as much energy (Morrison-Knudsen Engineers 1988).

With respect to process wastes generated by the five different treatment systems, the distillation alternative would produce a larger volume of waste (liquid) concentrate than the nondistillation alternatives. For the nondistillation alternatives, Alternatives 3 and 4 would produce a lower volume of wastes than Alternatives 1 and 2. The estimated waste volumes generated by the alternative treatment systems, based on a design flow rate of 80 gpm for 24 hours/day, are as follows: (1) Alternatives 1 and 2, 1.37 m^3/day (1.79 yd^3/day); (2) Alternatives 3 and 4, 1.09 m^3/day (1.43 yd^3/day); and (3) Alternative 5, 2.13 m^3/day (2.78 yd^3/day) (Morrison-Knudsen Engineers 1988). In addition to being less voluminous, the process wastes generated by Alternatives 3 and 4 would also be easier to manage than those generated by Alternatives 1 and 2 because sludges resulting from lime addition are typically easier to thicken and dewater than those resulting from coagulant addition. The waste sludges would be dewatered (e.g., by filter press) prior to being containerized for temporary storage in the quarry.

The estimated costs (capital and O&M) for the five alternatives are based on the design flow rate at 24 hours/day, using standard cost guidance (Hansen et al. 1979; DeWolf et al. 1984; U.S. Environ. Prot. Agency 1985). In general, capital costs are somewhat higher for Alternative 5 (about $1.65 million) than for Alternatives 1, 2, 3, and 4 ($1.05 million, $1.09 million, $1.16 million, and $1.20 million, respectively). The O&M costs of Alternative 5 (more than $1,000/day) are significantly higher than similar costs of the nondistillation alternatives; the O&M costs of Alternatives 1 and 3 ($583 and $582, respectively) are somewhat lower than those of Alternatives 2 and 4 ($662 and $661, respectively). Expressed as the 5-year present worth value, the combined capital and O&M costs for Alternative 5 ($2.15 million) are significantly higher than those for Alternatives 1, 2, 3, and 4 ($1.34 million, $1.42 million, $1.44 million, and $1.53 million, respectively). For this present worth analysis, the total costs over five years of operation are discounted to present costs using a 10% discount rate (Morrison-Knudsen Engineers 1988).

In summary, based on the comparative evaluation of the alternative treatment systems, Alternative 3 is identified as the most applicable to the proposed action in terms of effectiveness, technical feasibility, implementation considerations, and cost.

B.5 REFERENCES FOR APPENDIX B

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U.S. Environmental Protection Agency, 1985, *Handbook, Remedial Action at Waste Disposal Sites (Revised)*, EPA-625/6-85/006 (Oct.).

APPENDIX C:

SCREENING OF TREATMENT TECHNOLOGIES FOR APPLICABILITY TO THE PROPOSED ACTION

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SCREENING OF TREATMENT TECHNOLOGIES FOR APPLICABILITY TO THE PROPOSED ACTION

C.1 PHYSICAL TREATMENT TECHNOLOGIES

C.1.1 Equalization/Detention

Equalization/detention involves the storage of influent flows in tanks or basins prior to their introduction into a treatment plant. The purpose of this storage is to reduce variations in influent volume and concentration. This technology permits the averaging of flow volumes and contaminant levels that enter a treatment plant over time periods longer than those of typical influent fluctuations. Because the water to be treated under the proposed action derives from several sources, and because influent variability can adversely affect the efficiency of unit operations of a comprehensive treatment system, equalization is considered an essential process. Thus, equalization/detention is applicable to the proposed action.

C.1.2 Density Separation

Density separation is used to remove suspended solids from liquid waste and is typically combined with other treatment processes, e.g., to remove the solids generated by precipitation and flocculation. It can also be used as a pretreatment step to remove settleable solids in influent wastewater. A less common application of density separation involves centrifugation to separate liquids from other liquids. Density separation technologies are commonly used in wastewater treatment operations and their effectiveness and reliability have been demonstrated in the field.

C.1.2.1 Clarification

Also referred to as sedimentation or gravity settling, clarification is typically carried out in an open tank or basin and involves the natural settling of suspended solids by gravity. Clarification is an effective first-stage treatment for large particles that settle quickly (i.e., in <2 hours) and is applicable to the proposed action.

C.1.2.2 Flotation

Flotation involves the bubbling of air through a waste solution, which causes small particles to rise to the surface with the air bubbles. This process is effective for the removal of finely divided suspended solids from liquid waste streams and is typically carried out in an open tank or basin. As a support step for solids settling, flotation is potentially applicable to the proposed action.

C.1.2.3 Centrifugation

Centrifugation is based on density differences between solids or liquids and other liquids and is achieved by rapid rotation in an enclosed system. For small-scale processes, centrifugation is competitive with filtration, and its effectiveness and reliability have been demonstrated in the field. However, it is not effective for the removal of dissolved solids, which are of major concern for the quarry water. Nor would centrifugation be appropriate as a follow-on process to the precipitation of those dissolved solids, i.e., following the formation of suspended solids, because it is neither effective nor competitive with other proven methods for the removal of solids from large volumes of relatively dilute solutions. Therefore, centrifugation is not considered applicable to the proposed action.

C.1.3 Flocculation

Flocculation involves the slow mixing of a waste solution, e.g., with mechanical or air agitation, to facilitate the aggregation of suspended solids for enhanced settling. Flocculation is typically employed after chemical addition for precipitation to improve settling efficiencies. Chemical flocculant aids can be added to a waste solution to enhance the removal of suspended solids. The effectiveness and reliability of flocculation have been demonstrated in the field, and this conventional treatment process is potentially applicable to the proposed action.

C.1.4 Filtration

Filtration involves the removal of suspended solids from liquid waste by using gravity, suction, or pressure to move the liquid through a filter. As the solution flows directly through the filter, contaminants are trapped on its upstream side. Filtration usually follows density separation or flocculation during conventional wastewater treatment operations, i.e., after most of the solids have been removed from solution. The process is typically used to remove particles that are >25 μm in diameter; in general, smaller particles must be agglomerated prior to filtration. As a broad category, filtration is effective, reliable, and commonly used in water and wastewater treatment operations. Therefore, as a step in the overall treatment system, filtration is considered applicable to the proposed action. Five filtration processes are potentially applicable to treatment of the quarry water: granular media filtration, tubular membrane filtration, rotary drum filtration, microscreening, and filter press filtration.

C.1.4.1 Granular Media Filtration

Granular media filtration is a conventional process that is appropriate for the treatment of liquid waste streams. It involves the entrapment of suspended solids on a natural or artificial medium, such as sand or plastic, that is arranged in a column or basin through which solution flows by gravity or under pressure. The column or basin is equipped with an underdrain system and is backwashed when full to remove the trapped contaminants from the medium's surfaces. Granular media filtration is an energy-

efficient method for removing suspended solids and, as a solids/liquid separation process, is applicable to the proposed action.

C.1.4.2 Tubular Membrane Filtration

Tubular membrane filtration involves the separation of suspended solids from solution by applying pressure to a membrane system. The synthetic membranes used in this filtration process typically have openings of about 0.1 μm, and the system operates at pressures of 275 to 345 kPa (40 to 50 psi). Tubular membrane filtration is more effective at suspended solids concentrations greater than would be present in the influent to the proposed treatment plant. Thus, although it would be inappropriate as a first-stage treatment step, the membrane filtration process could be used as a follow-on to remove the suspended solids formed by a first-stage coagulation/precipitation step. Although this process is more energy-intensive than granular media filtration, it has in fact been used in the field under similar contaminant conditions (e.g., at U.S. Department of Energy sites in Canonsburg, Pennsylvania; Salt Lake City, Utah; and Lakeview, Oregon) (Morrison-Knudsen Engineers 1988). Therefore, tubular membrane filtration is potentially applicable to the proposed action.

C.1.4.3 Rotary Drum Filtration

In the rotary drum filtration process, a vacuum is applied from within a rotating drum that is partially submerged in a waste solution or slurry. Suspended solids are trapped on and subsequently scraped off the drum's outer surface membrane. Vacuum filtration is considerably more energy-intensive than granular media filtration. In addition, this process is not typically effective for the treatment of less concentrated solutions. Although vacuum filtration can be used for sludge treatment, it is not generally as effective as other dewatering methods such as filter press filtration (see Section C.1.4.4). Thus, based on concerns regarding implementation, rotary drum filtration is not considered applicable to the proposed action.

C.1.4.4 Filter Press Filtration

In filter press filtration, a series of plates and sheets are pressed together to force the liquid out of a solution or slurry while trapping the contaminant solids on a fabric filter that covers the sheets. A filter press is typically used to dewater sludges, and this method is not generally effective for removing suspended solids from relatively dilute aqueous streams. Therefore, this treatment technology is not applicable to the initial treatment of contaminated water but is considered applicable as a follow-on process to reduce the volume of sludges generated by the primary treatment processes.

C.1.4.5 Microscreening

Microscreening is a filtration process that traps solids on a metallic surface screen with openings typically ranging from 20 to 40 μm in diameter. Microscreening is a

tertiary water treatment process that could be considered potentially applicable to the proposed action. However, field experience has identified low removal efficiencies for the microscreening of chemically coagulated wastewater. This low efficiency results from rapid shearing and penetration of the microscreen due to the generally low strength of the chemical floc (Culp et al. 1978). Based on concerns regarding implementation, microscreening is not considered applicable to the proposed action.

C.1.5 Dialysis (Osmosis)

Dialysis involves the separation of dissolved contaminants from liquid waste by osmosis. This separation is achieved by the movement of an influent solution through a semipermeable membrane into a more concentrated solution. Dialysis can be effective for the treatment of liquid waste streams having high concentrations of dissolved solids with low molecular weight, such as cyanides. However, because it is both costly and ineffective for the treatment of fairly dilute waste streams, dialysis is not considered applicable to the proposed action.

C.1.6 Ultrafiltration (Reverse Osmosis)

Ultrafiltration achieves the membrane separation of dissolved solids from a waste solution by a process that is the reverse of osmosis, such that the concentration of dissolved solids in the product is increased instead of being decreased. In ultrafiltration, mechanical pumping at 1.4 to 2.8 MPa (200 to 400 psi) is used to exert pressure on the wastewater side of a semipermeable membrane to reverse the natural osmotic flow of the water so that dissolved solids remain behind. Most inorganics, e.g., heavy metals, can be removed from aqueous waste streams by reverse osmosis, as can some organics and very fine particulates.

Although typical removal efficiencies for uranium by this process approximate 70%, some data indicate that 90% removal efficiencies can be achieved (Reid et al. 1985). The trivalent arsenic ion may also be removed from aqueous solutions by ultrafiltration. However, the effectiveness of ultrafiltration for the treatment of large volumes of fairly dilute waste streams has not been demonstrated in the field. In addition, the process requires pretreatment to remove suspended solids, iron, and manganese in order to limit membrane fouling (Morrison-Knudsen Engineers 1988), and both capital and operating costs are quite high. For example, the cost for radionuclide removal by this method is estimated to be more than twice that for removal by other processes such as conventional coagulation and filtration (Reid et al. 1985). Therefore, ultrafiltration is not considered applicable to the proposed action.

C.1.7 Electrolysis

Electrolysis involves the charge separation of dissolved solids from a liquid waste using an electrical current. This physical-chemical process can be used to remove ions such as dissolved heavy metals from solution. Carbon (graphite)-steel electrodes have been used to treat cyanide wastes at high concentrations (e.g., >1,000 mg/L) (Morrison-

Knudsen Engineers 1988). However, cyanide levels in the quarry water are orders of magnitude less than levels amenable to electrochemical oxidation and in fact are not significant enough to require treatment. In addition, this process is quite energy-intensive and is not generally effective for the treatment of large volumes of relatively dilute waste streams. Therefore, electrolysis is not considered applicable to the proposed action.

C.1.8 Electrodialysis

Electrodialysis is a physical-chemical process in which an electrical current is used to enhance ionic movement across a membrane; dissolved solids can be separated from a liquid waste on the basis of differential rates of diffusion through this membrane. Electrodialysis can be used to remove such ions as arsenic and uranium from aqueous solutions. Removal efficiencies for the pentavalent arsenic ion approach 65% whereas those for uranium are typically 70%. However, the effectiveness of electrodialysis has not been demonstrated on a waste stream similar to the quarry water. In addition, because this process is expensive, it is not competitive with other potentially applicable water treatment technologies that can achieve similar removal efficiencies. Therefore, electrodialysis is not considered applicable to the proposed action.

C.1.9 Adsorption

Adsorption is a physical-chemical process that involves the removal of dissolved solids from liquid waste by adsorption onto a treatment medium, e.g., activated carbon or activated alumina. Adsorption is commonly used as a polishing step to remove refractory organics, i.e., those that resist biological degradation, from treated waters and wastewaters prior to discharge. The suspended solids content of the influent to an adsorption process step must typically be restricted to <50 mg/L or system clogging and treatment failure could result. For treatment of the quarry water, this condition could be met by implementing solids-removal processes, such as clarification and/or filtration, prior to the adsorption step in the overall treatment system for the contaminated water. Two adsorption processes are potentially applicable to the proposed action: activated carbon adsorption and activated alumina adsorption.

The most common type of adsorption in water and wastewater treatment operations is activated carbon adsorption. Thermal activation creates sites on carbon particles for the adsorption (physical and chemical) of solution contaminants. The number of these adsorption sites on activated carbon is significant compared to other adsorbents, based on a large surface-to-mass ratio that is typically 1,000 m^2/g. There are two types of activated carbon: granular and powdered. Granular activated carbon (GAC) adsorption is usually carried out in a column or tank whereas powdered activated carbon (PAC) is usually added to the waste solution in a process reactor. Because GAC can typically be regenerated whereas PAC cannot, the former is most commonly used in treatment systems. The effectiveness and reliability of carbon adsorption for the removal of dilute organics and some inorganics from aqueous waste streams have been demonstrated in the field.

Certain dissolved contaminants can also be removed from solution by adsorption onto activated alumina. The principle of activated alumina adsorption is similar to that for activated carbon adsorption, and the process typically involves passing a waste stream through pressure tanks filled with granular aluminum oxide (Al_2O_3).

C.1.9.1 Powdered Activated Carbon

Tests of PAC treatment for the removal of two organics, carbon tetrachloride and 1,1,1-trichloroethane, from river water indicated removal efficiencies of only 25% and 45 to 60%, respectively (Environmental Science and Engineering 1986). Thus, the removal efficiency for 2,4-dinitrotoluene (2,4-DNT) by this process is expected to be poor (especially in light of the required 99% removal for the proposed action). In addition, the effectiveness of PAC for DNT adsorption has not been demonstrated in the field and, based on the kinetics of PAC adsorption for high-efficiency removals, the amount of PAC required for effective 2,4-DNT removal would be excessive (Morrison-Knudsen Engineers 1988). Therefore, PAC adsorption is not considered applicable to the proposed action.

C.1.9.2 Granular Activated Carbon

Based on the physical nature of the GAC treatment operation, i.e., packed columns or beds, the kinetics limitation for PAC does not apply to GAC adsorption. In addition, GAC has been used to remove a number of organics from solution, including DNT, and implementation of the method is straightforward. Carbon adsorption is assigned a "high" rating for 2,4-DNT removal in EPA's *Treatability Manual* (U.S. Environ. Prot. Agency 1982), and related isotherm data identify a good adsorption capacity (Dobbs and Cohen 1980; Patterson 1985). The process constraint for influent suspended solids of 50-100 mg/L could be met by implementing GAC as a follow-on step to solids-separation processes for the quarry water (Morrison-Knudsen Engineers 1988). Because this constraint is similar to that for filtration, GAC can also provide a general filtration capability without sacrificing effluent quality; this dual-purpose use of GAC has been demonstrated in the field. Therefore, GAC adsorption is applicable to 2,4-DNT removal for the proposed action.

Although activated carbon has been shown to adsorb arsenic, experimental data indicate that the pH must be reduced to 3 or 4 to achieve this removal and that, even at optimum pH, the capacity of activated carbon for arsenic removal is only about 8% of that for removal by activated alumina (Gupta and Chen 1978). In addition, because the cost per pound of activated carbon is similar to that of activated alumina, carbon adsorption is not a competitive means for reducing arsenic levels (Morrison-Knudsen Engineers 1988). Therefore, GAC adsorption is not considered applicable to arsenic removal for the proposed action.

C.1.9.3 Activated Alumina

Adsorption onto activated alumina can remove both arsenic and uranium from solution, and implementation of the process is fairly straightforward. Although typical

arsenic removal efficiencies are estimated at 75%, the results of pilot-scale studies indicate that a reduction of 90% (from 0.1 to 0.01 mg/L) can be achieved with fairly constant efficiency at a treatment capacity of 94,000 L/m^3 (7,000 gal/ft^3) over a pH range of 3 to 7 (Jacobs Engineering Group 1987). The activated alumina can be regenerated with sodium hydroxide followed by an acid rinse to readjust the pH (Bellak 1971). In another study, removal efficiencies of 100% were achieved for over 8,500 bed volumes at pH 5.5, with an influent arsenic concentration of 0.09 mg/L, and reduction to the 0.05 mg/L limit was still possible after over 15,500 bed volumes (Hathaway and Rubel 1987). Thus, activated alumina adsorption is applicable to arsenic removal for the proposed action.

Laboratory data indicate that activated alumina adsorption can achieve removal efficiencies of 90% for uranium after 2,500 bed volumes, with exhaustion at 5,000 bed volumes (Reid et al. 1985). Although the process has not been demonstrated in the field for waste streams similar to those at the quarry, activated alumina adsorption is potentially applicable to uranium removal for the proposed action on the basis of promising experimental results.

C.1.10 Stripping

Stripping can remove dissolved contaminants, primarily volatile compounds, from liquid waste streams using air or steam. Air stripping (using aeration towers, spray aeration, diffused air aeration, or air lift pumps) is typically used to treat ammonia and certain organics such as acetone, carbon tetrachloride, benzene, and toluene. The removal is achieved by transferring the targeted compound from solution to air, whereupon treatment of the air generally becomes necessary. Because contaminants in the quarry water are not amenable to air stripping, this process is not considered applicable to the proposed action.

Steam stripping is essentially a steam distillation process in which the targeted contaminants, e.g., volatile organics, become the distillate. The process can be used to remove phenols, chlorohydrocarbons, ammonia, or hydrogen sulfide from solution. However, its competitiveness, effectiveness, and reliability have not been demonstrated for any removal required for the quarry water, specifically for the high-efficiency removal of 2,4-DNT. Therefore, steam stripping is not considered applicable to the proposed action.

C.1.11 Vapor Recompression/Distillation

Distillation by vapor recompression at low temperature (<60°C) is applicable to the treatment of a range of contaminants much greater than that amenable to removal by stripping. The low temperature of this process reduces scaling, corrosion, and total costs relative to other distillation processes. The vapor recompression/distillation process embodies a total treatment approach that has been demonstrated to be both reliable and effective in nonhazardous waste stream applications. Typically applied to the treatment of concentrated influent streams, such as seawater or cooling tower blowdown water, the process involves purification of a waste stream by vaporizing and

recondensing its aqueous fraction in a partial vacuum, leaving behind a concentrated residue. The quality of treatment effluent for this process approaches that of distilled water. Field application of this process to selenium-contaminated wastewater produced removal efficiencies of >98% and a total effluent dissolved-solids content of 10 mg/L (Awerbuck et al. 1986), and it is estimated that vapor recompression/distillation may be able to achieve an effluent uranium concentration of 25 pCi/L, i.e., nearly a 99% removal for the quarry water (Morrison-Knudsen Engineers 1987).

In addition to producing a high-quality effluent, the major advantages of the vapor recompression/distillation process are its ease of start-up, its relatively low work force requirements, and its general insensitivity to variations in influent components and concentrations. This could be important for treatment of the quarry water because influent to the proposed treatment plant is expected to be somewhat variable in the nature and level of contaminants over the long term, i.e., over a longer period of time than would be controlled by an equalization basin. Disadvantages include high operating costs (primarily for the compressor motor) and the production of a large volume of process waste. The volume of this waste concentrate can be minimized by operating the process in a staged mode, with temporary storage of the waste in a holding pond, such that the net concentrate flow would be about 1 to 1.5% of the influent volume at a concentration of 20 to 30% total solids. Based on the multicomponent treatment aspect of this technology and its ability to treat aqueous waste streams, vapor recompression/distillation is potentially applicable to the proposed action.

C.1.12 Thermal Destruction

Thermal destruction is used to destroy combustible wastes such as organics in a solid matrix. Although its effectiveness and reliability as a broad category have been demonstrated in the field, thermal destruction is not typically effective for the treatment of aqueous waste streams. Three types of thermal destruction processes that are potentially applicable to the proposed action are incineration, pyrolysis, and thermal oxidation.

C.1.12.1 Incineration

Incineration is typically used to treat organics such as polychlorinated biphenyls (PCBs), combustible solvents, and gases. Four types of incineration processes are (1) fluidized bed -- in which the waste is introduced into an agitated bed of hot, inert granular material, (2) multiple hearth -- in which the waste falls through heated, tiered layers, (3) rotary kiln -- in which the waste tumbles in a slowly rotating, angled, heated cylinder, and (4) liquid injection -- in which a liquid waste stream is injected into a hot combustion chamber for atomization. Associated operating temperatures typically range from 750 to 980°C for the first two processes and from 650 to 1,650°C for the latter two.

Only liquid injection would be appropriate for treatment of the contaminated quarry water, because the other three thermal destruction processes are generally limited to combustible solids, solvents (organic), or gases. A second constraint is that

incineration, including liquid injection, is typically limited to the treatment of organic solutions because the removal efficiency of metals is low. Because 2,4-DNT is the only organic requiring treatment under the proposed action, and because there are other, much less costly and more easily implemented technologies that can be used to remove this contaminant effectively, incineration processes -- including liquid injection -- are not considered applicable to the proposed action.

C.1.12.2 Pyrolysis

Pyrolysis is a two-stage thermal conversion process that can be used to remove organic or inorganic material from a waste matrix. In the first stage, contaminants are "roasted" (rather than combusted) in an oxygen-deficient atmosphere at temperatures of 480 to 900°C; a second-stage fume incineration is then initiated at temperatures of 1,000 to 1,500°C to destroy the volatile compounds generated during the first stage. Pyrolysis is both energy-intensive and costly, and because of the nature of the quarry waste stream (i.e., a dilute, aqueous solution), it is not competitive with other treatment processes that can achieve the same removal efficiencies. Therefore, pyrolysis is not considered applicable to the proposed action.

C.1.12.3 Thermal Oxidation

Thermal oxidation is a physical-chemical process that is used to remove chlorinated organics from liquid waste streams. Because there are no such contaminants requiring treatment in the quarry water, thermal oxidation is not considered applicable to the proposed action.

C.1.13 Freeze Crystallization

Freeze crystallization results in the separation of contaminants from a liquid waste stream through the physical transformation of the contaminants into crystalline forms by exposure to low temperatures. Because this process is very energy-intensive and costly (its reported total cost is more than double that for membrane separation and distillation processes [Snider 1987]), it is not competitive with other technologies for treatment of the quarry water. Therefore, freeze crystallization is not considered applicable to the proposed action.

C.2 CHEMICAL TREATMENT TECHNOLOGIES

C.2.1 Neutralization

Neutralization involves adding an acidic or caustic solution to a waste in order to change its pH. Precipitates that form as a result of this process may require subsequent treatment. The contaminated quarry water is approximately neutral in pH; therefore, neutralization is not a primary treatment requirement. However, neutralization may be

included as a step in the overall treatment system that depends on pH adjustment to meet its objectives, e.g., in a chemical addition step to achieve precipitation. If used for pH adjustment, neutralization is considered applicable to the proposed action.

C.2.2 Coagulation/Precipitation

Coagulation/precipitation is a physical-chemical process used to reduce the solubility of dissolved contaminants, thereby creating insoluble compounds that can subsequently be removed, e.g., by a density separation or filtration process. Coagulation/precipitation typically relies on chemical addition to generate the formation of suspended solids from dissolved solids. However, the formation of insoluble species can also be effected by changing the temperature or pH of a waste solution. Because the latter two operations are energy-intensive and costly, they are not considered applicable to the proposed action. Therefore, consideration of coagulation/precipitation in this discussion is limited to chemical addition.

Coagulation/precipitation is usually combined with a density separation process, e.g., clarification or flotation, or with filtration to enhance removal of the formed solids. For the proposed action, the addition of chemical coagulants for precipitation and the addition of lime for precipitation are considered to be separate processes. Optimum pH values are generally lower for coagulation than for lime treatment, which is typically effective at a pH greater than 8. Lime treatment, also referred to as lime softening, is a specific precipitation process that is commonly used in water treatment. The process involves adding calcium to a solution as the hydroxide [$Ca(OH)_2$] or oxide (CaO) to effect the removal of dissolved solids by precipitation and subsequent settling. Coagulation involves the addition of a chemical coagulant such as ferric chloride ($FeCl_3$), ferrous sulfate [$Fe(SO)_4$], or alum [$Al_2(SO_4)_3$] to a colloidal suspension in order to effect the agglomeration of dispersed solids into a larger mass for improved settling.

Coprecipitation can also be considered an element of precipitation in that it can involve (1) the flushing of contaminants out of solution with a settling mass, i.e., through mechanical enclosure by the precipitate or (2) the adsorption of ions on the surface of a formed precipitate. Thus, although not specifically intended for organics removal, this process is potentially applicable to 2,4-DNT removal for the proposed action.

Arsenic can be removed from solution by using lime treatment in conjunction with metal coprecipitation. The coprecipitation process would be required to limit the excessive pH (12) and associated lime dose and sludge volume that would otherwise be necessary for the formation of arsenic solids using lime treatment alone (Patterson 1985). In conjunction with other processes, such as flocculation and clarification, field application of lime treatment has attained arsenic removal efficiencies of 95% at a pH of 6 to 6.5 (U.S. Environ. Prot. Agency 1985). Arsenic can also be removed by coprecipitation with the iron oxyhydroxides (FeOOHs) formed following the addition of a chemical, e.g., ferric chloride, to a waste solution (Merrill et al. 1986). The oxidation state of arsenic is sometimes important to the sequence and type of chemical addition steps used in the coagulation/precipitation process. Coprecipitation with alum has achieved 90 to 95% removal efficiencies for the oxidized form of this ion, i.e., arsenate (Patterson 1985). Arsenic precipitation with sulfides at pH 6 to 7 has also been reported

(Hathaway and Rubel 1987). Therefore, coagulation/precipitation is applicable to arsenic removal for the proposed action.

Manganese can also be removed from solution by conventional lime treatment. Because the quarry pond is primarily aerobic, manganese probably exists in its oxidized form as a manganic precipitate. Thus, initial removal could easily be achieved by clarification and/or filtration, without additional treatment steps. However, as the pond water was removed for treatment and groundwater flowed into the quarry, the reduced form of the element could occur. This form would require chemical treatment prior to clarification and/or filtration. Lime treatment can be an effective means of precipitating manganese at pH levels of 9 to 9.5 (Morrison-Knudsen Engineers 1988). Therefore, coagulation/precipitation is applicable to manganese removal for the proposed action.

Uranium removal can also be achieved by conventional lime treatment, and experimental data have identified 85 to 90% removal efficiencies for this radionuclide by lime (Reid et al. 1985). To achieve this reduction, the pH must be elevated to between 10.6 and 11.5, and removal is enhanced by the presence of magnesium (Schlicher and Ghosh 1985). The use of lime treatment for uranium removal has been demonstrated in the field, with typical removal efficiencies reported to exceed 80% (Dyksen and Hess 1986). Uranium can also be removed from solution by precipitation with alum or iron coagulants. A field application of ferrous sulfate addition for coagulation of uranium at an influent concentration of 24 μg/L resulted in 89% removal efficiency at pH 6 (Reid et al. 1985). Because the coagulation process is sensitive to pH, post-screening investigations would be required to optimize coagulant types, doses, and operating pH.

During recent field experience with waste solutions similar to the quarry water, precipitation processes for uranium were coupled with those for arsenic. The system consisted of acid treatment at pH 4, ferrous sulfate coagulation with lime adjustment to pH 6, and lime treatment at pH 9.5. This sequence of reactions resulted in the precipitation of uranium as its hydroxide and the coprecipitation of arsenic with ferric hydroxide (Morrison-Knudsen Engineers 1988). Nearly complete removal of uranium by this process was reported for an influent concentration of 6,400 μg/L (Reid et al. 1985). Based on these results, coagulation/precipitation is applicable to uranium removal for the proposed action.

C.2.3 Oxidation/Reduction

Oxidation/reduction is a conventional treatment process for the removal of organics and some inorganics. The process involves changing the oxidation state of waste contaminants to permit precipitation and clarification, and it is most effective at low solution concentrations. The general effectiveness and reliability of the process have been demonstrated in the field.

Limited experience with uranium removal by reduction involves lowering the pH with chemical addition to reduce uranium from its hexavalent to its tetravalent form, then raising the pH with chemical addition to precipitate the uranium as an insoluble oxide or hydroxide (Morrison-Knudsen Engineers 1988). Because chemical addition/precipitation is the controlling element of this removal and no specific reducing agent is

involved, the potential applicability of oxidation is considered as part of coagulation/precipitation (Section C.2.2). In other applications, reduction is commonly used for the treatment of chromium and mercury; however, the quarry water does not contain these metals. Therefore, reduction is not considered applicable to the proposed action. Similarly, although the oxidation state of arsenic can be a factor in its removal, the use of a specific oxidizing/reducing agent is not required for the effective removal of this contaminant. Therefore, the role of valency in arsenic removal is addressed under coagulation/precipitation (Section C.2.2).

Oxidation could be considered applicable as a general technology for treatment of the quarry water. Chemical agents typically used to oxidize organics and dissolved metals include ozone (O_3), chlorine (Cl_2), hydrogen peroxide (H_2O_2) and sodium hypochlorite (NaOCl). Although manganese and other metals, such as arsenic, may be oxidizable by these agents, the oxidation process is not typically competitive with other treatment processes for their removal. Three oxidation processes that are potentially applicable to the proposed action are ozonation, chlorination, and wet air oxidation.

C.2.3.1 Ozonation

Ozonation can be used to treat refractory organics and cyanides and is most effective for the treatment of dilute solutions, e.g., those with <1% oxidizable materials. The reliability of ozonation has not been widely demonstrated, but its effectiveness can be enhanced by combination with a developmental physical treatment process, i.e., ultraviolet photolysis. The sole organic contaminant requiring treatment under the proposed action is 2,4-DNT. Because the applicability of ozonation to the removal of this compound has not been demonstrated in the field and because this organic can be treated more effectively by other processes, ozonation is not considered applicable to 2,4-DNT removal for the proposed action. Although manganese can be oxidized by ozonation, this process is not effective when lime treatment is included in the overall treatment process (Morrison-Knudsen Engineers 1988). Based on this limitation and the fact that the process is not competitive with other, potentially more effective processes, ozonation is not considered applicable to manganese removal for the proposed action.

C.2.3.2 Chlorination

The oxidation of manganese by chlorine dioxide (chlorination) is a feasible treatment step for removing this metal from solution. However, the capital and operating expenses of this process, combined with the potential creation of a secondary treatment problem (related to chlorine residuals), make chlorination generally inapplicable to the proposed action. Alkaline chlorination is a conventional oxidation process that is typically used to remove cyanides from wastewater. Because cyanide treatment is not part of the proposed water treatment, alkaline chlorination is not considered applicable to the proposed action.

C.2.3.3 Wet Air Oxidation

Wet air oxidation is a physical-chemical combustion process in which air is added to a liquid at high temperature and pressure. Wet air oxidation is typically used to treat oxidizable organics of 5 to 15% by weight in aqueous streams. Because this process is somewhat developmental and because the only organic requiring treatment, i.e., 2,4-DNT, can be removed more effectively by other processes, wet air oxidation is not considered applicable to the proposed action.

C.2.4 Ion Exchange

Ion exchange is a physical-chemical process used to separate dissolved ions (primarily inorganic) from solution by interchanging with ions of a natural or synthetic resin. The effectiveness and reliability of this process have been demonstrated in the field, and ion exchange can be highly effective for the removal of metallic ions from aqueous solutions. Resin beds for cation or anion exchange can usually be regenerated with acidic or caustic solutions.

Arsenic can be removed from solution by either weak base or strong base anion-exchange resins at efficiencies greater than 77% (Patterson 1985). Both arsenite and arsenate species can be removed by this process, and typical efficiencies range from 55 to 99%, depending on the selected resin. However, a low exchange capacity typically results from resin loading by the sulfate ion (Morrison-Knudsen Engineers 1988). Because there is a potential for sulfate interference during treatment of the quarry water, ion exchange is not considered applicable to arsenic removal for the proposed action.

Manganese can be removed from solution by cation-exchange resins. However, rapid resin exhaustion typically occurs when other divalent cations are present, such as calcium and magnesium. Based on the nature of the quarry water, this limitation would likely increase operating time and cost, and the process would not be competitive with other treatment processes. Therefore, ion exchange is not considered applicable to manganese removal for the proposed action.

Organics can be removed from solution using an organic ion-exchange resin. However, this process is not generally competitive with other, more effective processes for the removal of organics. Therefore, ion exchange is not considered applicable to 2,4-DNT removal for the proposed action.

Uranium removal by ion exchange is a feasible technology that has been implemented in the field. Laboratory and field trials for removing uranium from drinking water supplies have identified a high adsorption capacity and selectivity of resins for this radionuclide. Typical uranium removal efficiencies of 70% have been reported for cation-exchange systems, and efficiencies of 95% have been identified for anion-exchange systems (Reid et al. 1985). Resins can be regenerated by sodium chloride or sodium hydroxide solutions, and the spent regenerant typically requires subsequent treatment, e.g., by neutralization and/or solidification. (The decision to regenerate or dispose of the resin at exhaustion would be evaluated at the bid proposal stage. In any

case, the disposition of spent resin is addressed in a separate but related removal action for the Weldon Spring site.) In summary, ion exchange is applicable to uranium removal for the proposed action.

C.2.5 Chlorinolysis

Chlorinolysis is a physical-chemical process used to remove chlorocarbons from solution by pyrolysis in a chlorine-rich environment. Because there are no such contaminants requiring treatment in the quarry water, chlorinolysis is not considered applicable to the proposed action.

C.2.6 Dechlorination

Chemical dechlorination can be used to strip chlorine ions from stable central molecules of polychlorinated biphenyls (PCBs) or pesticides at influent concentrations greater than 50 mg/L. During this process, chemical reagents selectively attack the carbon-chlorine bond with such effectiveness that removal efficiencies of 90% can be achieved (Morrison-Knudsen Engineers 1988). The most widely applied technique for PCB dechlorination uses a naphthalene-based metallic sodium compound as the stripping agent (Calif. Dept. Health Services 1986); other techniques replace the naphthalene reagent with proprietary compounds. Because elevated concentrations of PCBs have not been identified in the quarry water, PCB dechlorination is not considered applicable to the proposed action.

Dechlorination can also be implemented as a support process for the treatment of chlorine residuals to remove contaminants that are generated during a chlorination treatment step, e.g., during the disinfection of drinking water supplies. However, full-scale chlorination of the quarry water -- with the resultant production of residuals -- is not within the scope of the proposed action. If low doses of chlorine were used to support another treatment process associated with the proposed action, e.g., for manganese oxidation to facilitate precipitation, the minor levels of residual chlorine resulting from this step could be removed by activated carbon adsorption (a process that has already been identified as applicable to the proposed action). If necessary, other methods of dechlorination, such as sulfur dioxide treatment, could also be implemented to control the formation of halogenated organics. However, the use of chlorine for chemical oxidation is unlikely based on the technical effectiveness and competitiveness of other processes (see Section C.2.3.2). Therefore, dechlorination of residuals is not considered applicable to the proposed action.

C.2.7 Solvent Extraction

Solvent extraction involves the use of a solvent to separate dissolved solids or liquid organics from a waste matrix. (A variation of this process, solution mining, is used to remove organic contaminants from soils and sludges and is therefore inapplicable to the proposed action.) Solvent extraction of liquid wastes can create secondary problems related to the generation of a new organic waste stream. Based on this limitation and on

the ineffectiveness of this technology compared with other processes for the treatment of 2,4-DNT, solvent extraction is not considered applicable to the proposed action.

C.2.8 Stabilization/Solidification

Stabilization/solidification is a physical-chemical process used to reduce the mobility of waste components by binding them in a solid matrix. Cementation (including pozzolanic processes) is a conventional technology used to treat soils, waste slurries, and dewatered sludges; polymer and thermoplastic binding are two developmental technologies for such stabilization. However, none of these processes is feasible for the treatment of dilute liquid streams such as the quarry water. Therefore, stabilization/solidification is not considered applicable to the proposed action.

C.2.9 In-Situ Permeable Treatment Bed

Implementation of an in-situ permeable treatment bed involves trenching around an area of contamination and filling the trench with a reactive, permeable medium. Under this developmental process, chemical reactions occur beneath the ground surface to render the targeted contaminants in a leachate either insoluble or nonhazardous. For example, if leachate from the quarry pond reached the reactive medium, treatment would be expected to occur in place to mitigate the potential hazards associated with arsenic, manganese, uranium, and/or 2,4-DNT. However, the effectiveness and reliability of this technology have not been demonstrated in the field and, in fact, would be difficult to verify. In addition, this process is not competitive with other, proven treatment technologies. Therefore, the in-situ permeable treatment bed is not considered applicable to the proposed action.

C.2.10 In-Situ Injection

In-situ injection is a developmental technology that involves the injection of chemical reagents into the ground beneath a contaminated area to neutralize, precipitate, or destroy the leachate constituents of concern. Based on limitations similar to those identified for in-situ permeable treatment beds in terms of effectiveness, reliability, and noncompetitiveness with proven technologies (see Section C.2.9), in-situ chemical injection is not considered applicable to the proposed action.

C.3 BIOLOGICAL TREATMENT TECHNOLOGIES

Biological treatment is not generally effective for the removal of metals such as manganese, arsenic, or uranium from solution. Although biological treatment is commonly used to remove organics from solution, nitro-substituted organic compounds have been shown to resist biological degradation (U.S. Environ. Prot. Agency 1985). In addition, biological treatment of 2,4-DNT would cost approximately 85% more than an activated carbon system, which is capable of high rates of DNT removal (U.S. Environ. Prot. Agency 1973; Calif. Dept. Health Services 1986). Furthermore, although there are

several field applications of biodegradation at contaminated sites (U.S. Environ. Prot. Agency 1985), most have addressed the stabilization of organic spills in soil, and none of the treated wastes were similar to the quarry water (Morrison-Knudsen Engineers 1988). Although biological treatment is not generally considered applicable to the proposed action, five biological treatment methods that could be considered are activated sludge, trickling filter, rotating biological disc, surface impoundment, and land treatment.

C.3.1 Activated Sludge

Activated sludge treatment involves the microbial degradation of organic compounds in waste streams of low solids content and is the most common method of aerobic, biological wastewater treatment. In addition to the conventional activated sludge process, there are several treatment variations, including pure oxygen, extended aeration, and contact stabilization processes. Applicability of the activated sludge process to a waste stream is constrained by the presence of metals that may be toxic to bacteria. Because of this limitation, and because the only organic requiring treatment in the quarry water is 2,4-DNT -- for which more effective and appropriate physical and chemical treatment technologies have already been identified -- activated sludge treatment is not considered applicable to the proposed action.

C.3.2 Trickling Filter

Trickling filters involve the aerobic, microbial degradation of organic compounds and the removal of suspended solids from solution, at typically less than 1% by weight, by trickling the waste stream over a bed of rocks or synthetic medium. The filter medium provides a surface for the growth of a microbial slime and also acts to trap influent solids as well as those produced during the degradation process. Although trickling filters are more efficient than activated sludge treatment in terms of space requirements, treatment time, and treatable volume, the constraints identified for the activated sludge process with regard to treating the quarry water (Section C.3.1) also exist for this process. Therefore, trickling filters are not considered applicable to the proposed action.

C.3.3 Rotating Biological Disc

The rotating biological disc constitutes a fixed-film process that is similar in principle to trickling filters (Section C.3.2) and rotary drum filtration (Section C.1.4.3). The rotating biological disc or contactor is commonly used in the treatment of domestic wastewater, and it is considered more reliable than other fixed-bed processes because (1) it can withstand hydraulic and organic surges more effectively and (2) its removal efficiencies are not constrained by plugging in the same manner as those of other biological processes such as trickling filters. However, the effectiveness and reliability of rotating biological discs have not been demonstrated for the treatment of contaminated solutions like the quarry water. In addition, the constraints identified for the

activated sludge process (Section C.3.1) are true for this process as well. Therefore, rotating biological discs are not considered applicable to the proposed action.

C.3.4 Surface Impoundment

A surface impoundment can consist of (1) a waste lagoon aerated by mechanical agitation using mixers or sprays, which is similar in effectiveness to activated sludge treatment for the microbial degradation of organic compounds but requires more space, or (2) a waste stabilization pond, which can aerobically or anaerobically degrade organic compounds in waste streams of <1% solids content and has space requirements similar to those of a waste lagoon, but the treatment can take months to complete. Because of the space and time limitations combined with the general constraints associated with activated sludge treatment (and biological treatment in general), surface impoundments are not considered applicable to the proposed action.

C.3.5 Land Treatment

Land treatment is used to treat aqueous organic compounds in waste streams with low metals content and involves their decomposition in soil rather than in water. Land treatment can consist of (1) spray irrigation -- in which the waste solution is sprayed, flooded, or allowed to flow by gravity over a vegetated land plot; (2) overland flow -- in which the solution is sprayed onto a relatively impervious vegetated incline; (3) infiltration-percolation -- in which large volumes of the solution are applied to the land and allowed to infiltrate the surface and percolate through the soil pores; or (4) leachate recycle -- in which the solution is pumped out of a contaminated area and recycled through the plot. Organics in solution can usually be at least partially treated by land application. However, the space and time requirements associated with this technology, combined with general constraints similar to those identified for activated sludge (Section C.3.1), make land treatment inapplicable to the proposed action.

C.4 REFERENCES FOR APPENDIX C

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APPENDIX D:

ENGLISH/METRIC - METRIC/ENGLISH EQUIVALENTS

TABLE D.1 English/Metric Equivalents

Multiply	By	To obtain
Acres	0.4047	Hectares (ha)
Cubic feet (ft^3)	0.02832	Cubic meters (m^3)
Cubic yards (yd^3)	0.7646	Cubic meters (m^3)
Degrees Fahrenheit (°F) - 32	0.5555	Degrees Celsius (°C)
Feet (ft)	0.3048	Meters (m)
Gallons (gal)	3.785	Liters (L)
Gallons (gal)	0.003785	Cubic meters (m^3)
Inches (in.)	2.540	Centimeters (cm)
Miles (mi)	1.609	Kilometers (km)
Pounds (lb)	0.4536	Kilograms (kg)
Square feet (ft^2)	0.09290	Square meters (m^2)
Square yards (yd^2)	0.8361	Square meters (m^2)
Square miles (mi^2)	2.590	Square kilometers (km^2)

TABLE D.2 Metric/English Equivalents

Multiply	By	To obtain
Centimeters (cm)	0.3937	Inches (in.)
Cubic meters (m^3)	35.31	Cubic feet (ft^3)
Cubic meters (m^3)	1.308	Cubic yards (yd^3)
Cubic meters (m^3)	264.2	Gallons (gal)
Degrees Celsius (°C) + 17.78	1.8	Degrees Fahrenheit (°F)
Hectares (ha)	2.471	Acres
Kilograms (kg)	2.205	Pounds (lb)
Kilometers (km)	0.6214	Miles (mi)
Liters (L)	0.2642	Gallons (gal)
Meters (m)	3.281	Feet (ft)
Square kilometers (km^2)	0.3861	Square miles (mi^2)
Square meters (m^2)	10.76	Square feet (ft^2)
Square meters (m^2)	1.196	Square yards (yd^2)