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Proposed Plan for Remedial Action for the Groundwater Operable Unit at the Chemical Plant Area of the Weldon Spring Site, Weldon Spring, Missouri

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prepared by

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NOTATION

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

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

General

ARAR	applicable or relevant and appropriate requirement
BRA	baseline risk assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CO_2	carbon dioxide
DA	U.S. Department of the Army
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
$FeSO_4$	ferrous sulfate
FS	feasibility study
GAC	granular activated carbon
GWOU	groundwater operable unit
MCL	maximum contaminant level
NCP	National Oil and Hazardous Substances Contingency Plan
PRG	preliminary remediation goal
RA	remedial action
RD	remedial design
RI	remedial investigation
ROD	Record of Decision
TBC	to-be-considered (requirement)
WSSRAP	Weldon Spring Site Remedial Action Project
WSTA	Weldon Spring Training Area

Chemicals

1,3-DNB	1,3-dinitrobenzene
DNT	dinitrotoluene
2-amino-4,6-DNT	2-amino-4,6-dinitrotoluene
4-amino-2,6-DNT	4-amino-2,6-dinitrotoluene
2,4-DNT	2,4-dinitrotoluene

2,6-DNT	2,6-dinitrotoluene
TCE	trichloroethylene
1,3,5-TNB	1,3,5-trinitrobenzene
TNT	trinitrotoluene
2,4,6-TNT	2,4,6-trinitrotoluene

UNITS OF MEASURE

cm	centimeter(s)
ft	foot (feet)
gpm	gallon(s) per minute
ha	hectare(s)
in.	inch(es)
km	kilometer(s)
L	liter(s)
µg	microgram(s)
m	meter(s)
mg	milligram(s)
mi	mile(s)
pCi	picocurie(s)

PROPOSED PLAN FOR REMEDIAL ACTION FOR THE GROUNDWATER OPERABLE UNIT AT THE CHEMICAL PLANT AREA OF THE WELDON SPRING SITE

1 INTRODUCTION

This proposed plan addresses the remediation of groundwater contamination at the chemical plant area of the Weldon Spring site in Weldon Spring, Missouri. The site is located approximately 48 km (30 mi) west of St. Louis in St. Charles County (Figure 1). Remedial activities at the site will be conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Consistent with U.S. Department of Energy (DOE) policy, National Environmental Policy Act (NEPA) values have been incorporated into the CERCLA process. In accordance with CERCLA, DOE, in conjunction with the U.S. Department of the Army (DA), conducted a combined remedial investigation/feasibility study (RI/FS) to jointly evaluate groundwater contamination at the Weldon Spring chemical plant area and the Weldon Spring ordnance works area, which is an Army site adjacent to the chemical plant area.

This proposed plan summarizes information about chemical plant area groundwater that is presented in three documents:

1. The Remedial Investigation (RI), which presents information on the nature and extent of contamination (DOE and DA 1998c);
2. The Baseline Risk Assessment (BRA), which evaluates impacts to human health and the environment that could occur if no cleanup action of the groundwater were taken (DOE and DA 1998a); and
3. The Feasibility Study (FS), which develops and evaluates remedial action alternatives for groundwater remediation (DOE and DA 1998b).

This Proposed Plan is required under CERCLA. The purpose of the Proposed Plan is to:

- Present to the public a notice and a brief analysis of the remedial action alternatives developed in the FS;
- Present the rationale for the preferred remedial action alternative;

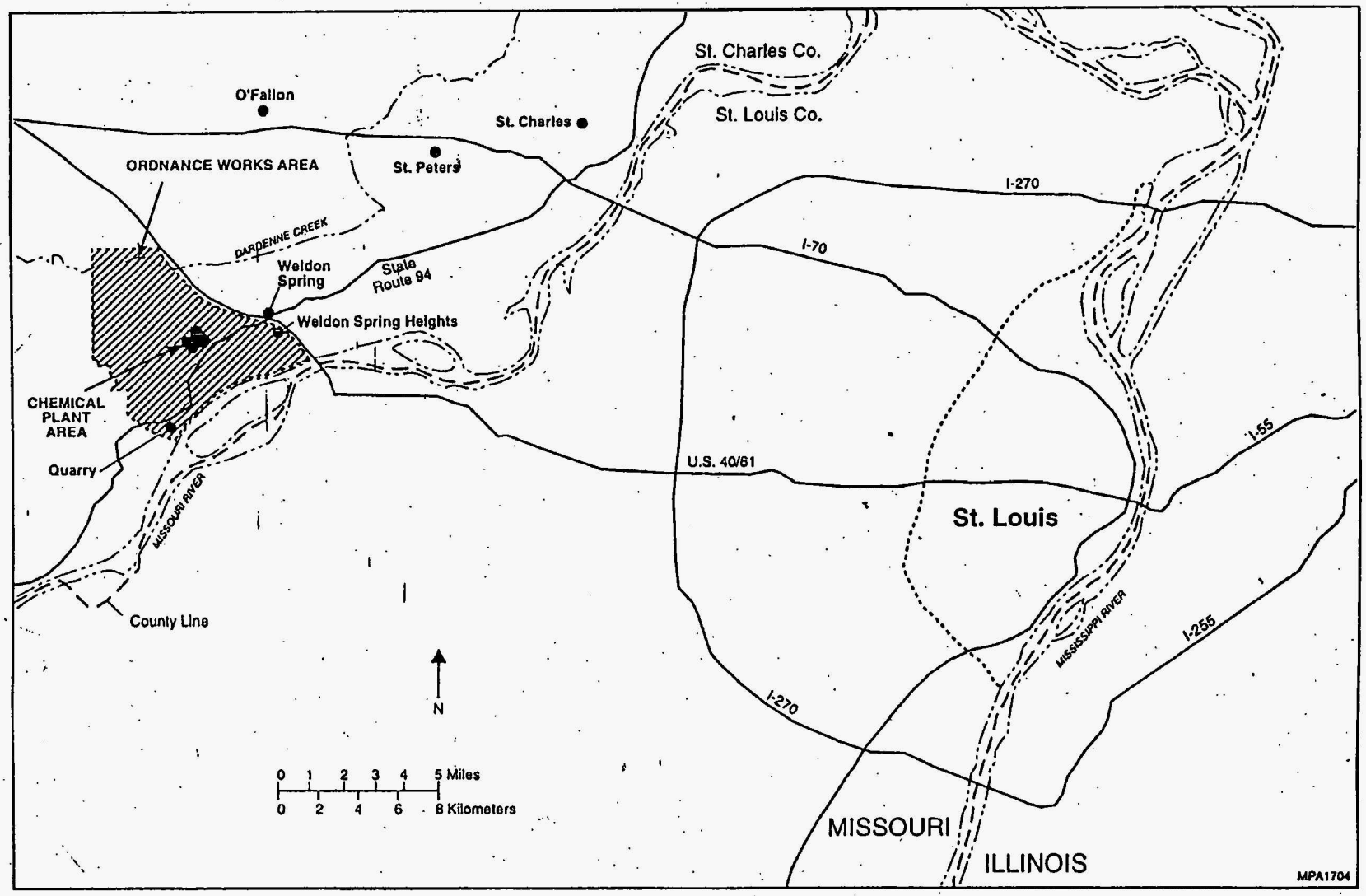

FIGURE 1 Locations of the Weldon Spring Chemical Plant Area and the Weldon Spring Ordnance Works

- Summarize key information from the RI, BRA, and FS; and
- Inform the public of its role in the remedial selection process and provide the public the opportunity to participate in that process.

Under current conditions, the groundwater at the chemical plant area poses no imminent risk to human health or the environment. The groundwater is not used at the site. None of the domestic wells located in the area of influence from the chemical plant area are active. Existing wells screened in the same geologic units are separated from the aquifer present beneath the chemical plant area by a regional groundwater divide (Dardenne Creek; see Figure 1) and, therefore, cannot be affected by the site. The preferred remediation alternative presented in this plan involves active remediation of trichloroethylene (TCE)-contaminated groundwater in close proximity to the raffinate pits area of the chemical plant and allows for natural abatement of other contaminant concentrations to proceed. Such abatement is expected to occur naturally over time because the sources of contamination that are being addressed under the chemical plant Record of Decision (ROD) (DOE 1993) will no longer be present. The progress of the natural remediation would be monitored until acceptable levels are reached.

This alternative was selected from among nine potential remedial action alternatives that were presented in the FS (DOE and DA 1998b). These nine alternatives were developed after careful analysis of available geological, environmental, and human health and ecological risk data, and an evaluation of the effectiveness, implementability, and cost of the various technologies available for groundwater remediation at the chemical plant area. However, final selection of the remedial action alternative has not yet been made; the alternative selected for implementation will be documented in the ROD, following receipt and consideration of public comments on this plan and any significant new information that may become available. Public input may result in modifications to the ultimate remedial action selected; therefore, public comment on this plan and its supporting documents is an important element of the decision-making process.

DOE encourages public review and comment on this proposed remedial action plan for groundwater at the chemical plant area. Additional details about the site and the remedial action alternatives may be found in the RI (DOE and DA 1998c), BRA (DOE and DA 1998a), and FS (DOE and DA 1998b) and in supporting technical reports in the Administrative Record. The

remedial action alternatives are evaluated in detail in Chapters 3, 4, and 5 of the FS and are summarized in Chapters 4 and 5 of this proposed plan.

The remainder of this proposed plan is organized as follows:

- Chapter 2 presents the history and environmental setting of the chemical plant area and a summary of the nature and extent of contamination,
- Chapter 3 summarizes the human health and ecological risks from groundwater contamination at the site,
- Chapter 4 summarizes the screening process for the nine preliminary remedial action alternatives considered,
- Chapter 5 describes the final remedial action alternatives considered for the remedial action,
- Chapter 6 presents the preferred remedial action alternative, and
- Chapter 7 describes the community's role in this action.

2 SITE BACKGROUND

2.1 SITE DESCRIPTION AND POTENTIAL AREAS OF CONTAMINATION

The 88-ha (217-acre) chemical plant area lies within the boundaries of the ordnance works area (Figure 2). The chemical plant was used for trinitrotoluene (TNT) and dinitrotoluene (DNT) production from 1941 to 1945 and later as a uranium-processing facility from 1957 to 1966. The sources of contamination at the chemical plant area are those shown in the original layout of the chemical plant area (Figure 3). These consisted of approximately 40 buildings, four waste retention ponds (referred to as raffinate pits), two ponds (Ash Pond and Frog Pond), and two former dumps (north and south). Remediation of the buildings, Frog Pond, and the north dump has been completed. The remaining source areas are in the process of being remediated or are scheduled for cleanup within the next year. The chemical plant is currently fenced to restrict public access. Burgermeister Spring, which is hydrologically connected to the chemical plant area groundwater, is in the August A. Busch Memorial Conservation Area.

2.2 ENVIRONMENTAL SETTING

The geology and hydrogeology of the Weldon Spring area govern the rate, path, and extent of groundwater flow. Land use in the surrounding areas affects the potential for human or ecological exposure to any contaminants the groundwater may contain.

2.2.1 Geology

Locally, the subsurface consists of porous, unconsolidated deposits that unconformably overlie bedrock. This unconsolidated overburden material consists primarily of modified loess, glacial drift, preglacial deposits, and residuum (DOE and DA 1998c). The thickness of these glacial and preglacial deposits, known as the "overburden," generally ranges from 4 to 18 m (13 to 59 ft) across the chemical plant area.

The Burlington-Keokuk Limestone, the uppermost bedrock unit at the chemical plant area, has been separated into two distinct subunits, the weathered and unweathered. The weathered unit ranges in thickness from 3 to 17 m (10 to 55 ft). At the chemical plant area, fracturing in the bedrock

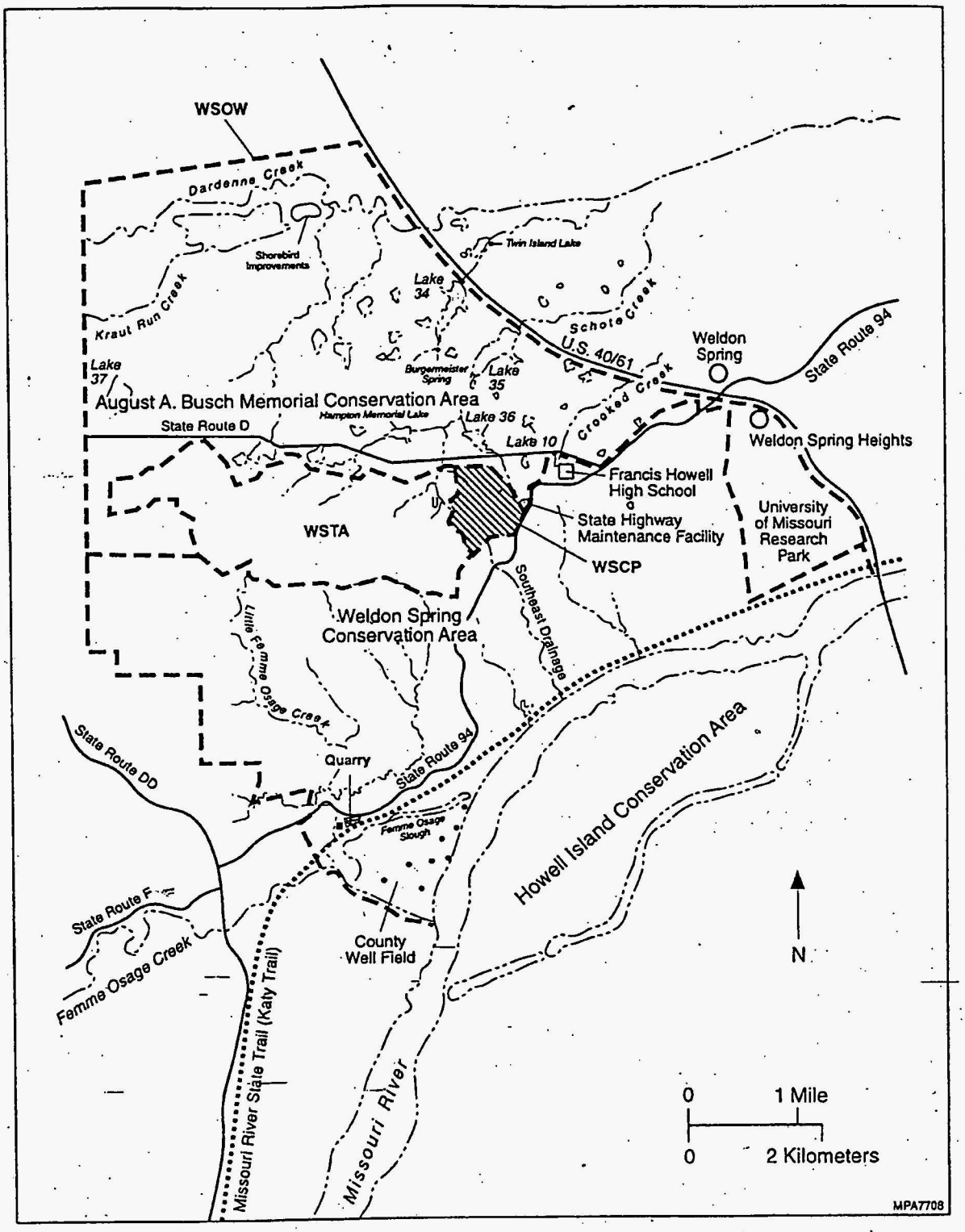

FIGURE 2 Map of the Chemical Plant Area and Immediate Vicinity

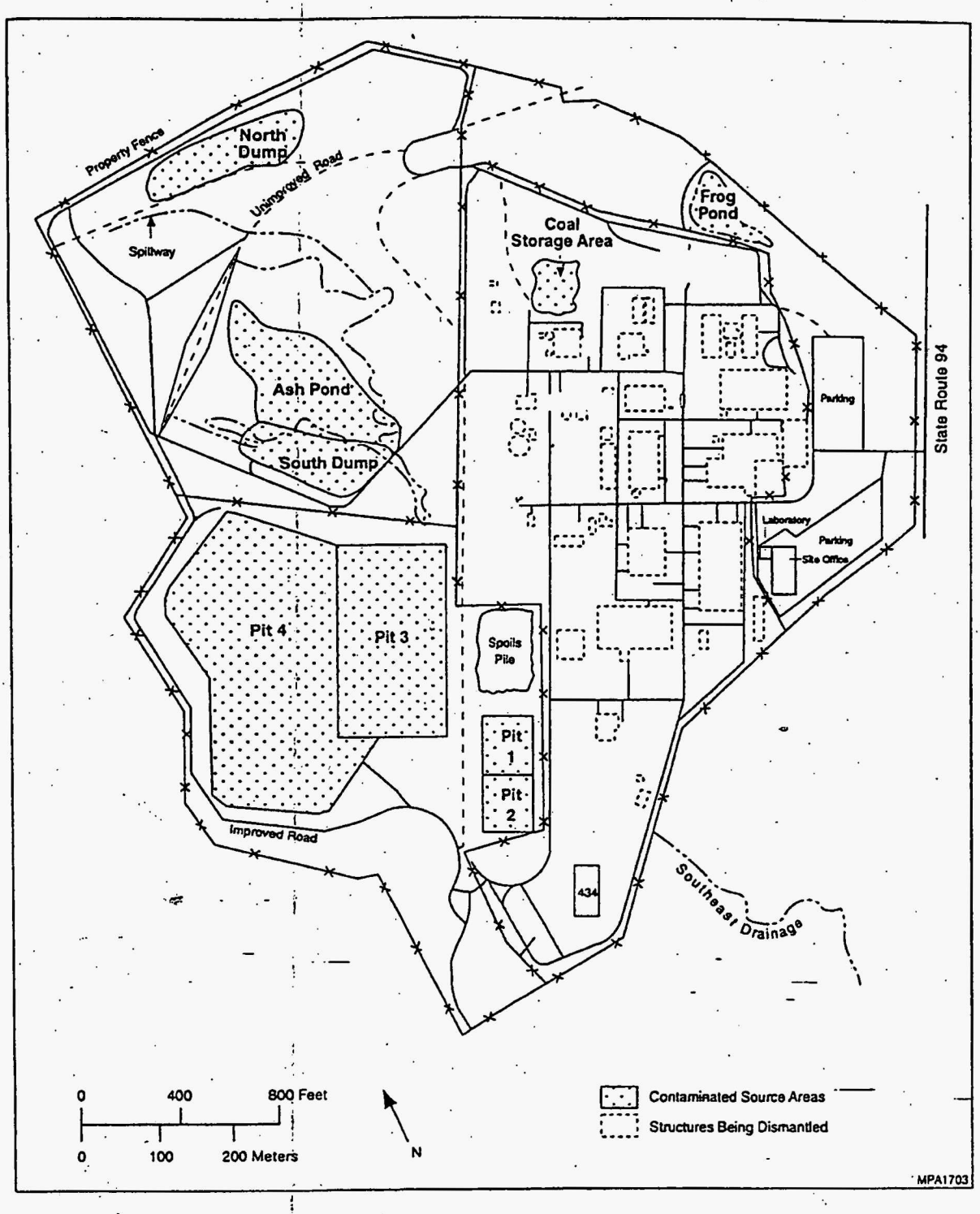

FIGURE 3 Original Layout of the Chemical Plant Area

is predominantly horizontal. Solution features are common in the weathered portion of the Burlington-Keokuk Limestone and range from pinpoint vugs to small zones of core loss, typically less than 1.5 m (5 ft). The larger zones in many cases appear to be at least partially filled with clay or clay mixture (DOE 1992). Significantly fewer horizontal and vertical fractures exist in the unweathered unit than in the weathered unit. Field data indicate a decrease in hydraulic conductivity with depth, which is attributed to decreased weathering. Hydraulic conductivity is controlled by the size, abundance, and geometry of the open fractures within the bedrock and affects the transport of groundwater through the bedrock.

2.2.2 Hydrogeology

The three principal bedrock aquifer systems in the Weldon Spring region are a shallow unconfined aquifer (although it may be confined in some local areas), a middle confined aquifer, and a deep confined aquifer. Groundwater used for drinking water in the area comes primarily from the deep aquifer and from an alluvial aquifer near the Missouri River. In St. Charles County, the shallow and middle aquifers are also used (primarily for rural domestic water supply), although that usage may occur outside the influence of the groundwater contamination at the chemical plant area.

Because the shallow unconfined aquifer has been affected by former activities at the chemical plant area, it is the groundwater system of primary interest in the Weldon Spring area. This aquifer consists of the Burlington-Keokuk Limestone and the Fern Glen Formation, both limestone units, and, in some locations, the overburden. The principal recharge to this shallow groundwater system is through infiltration of precipitation from the overburden or from losing streams. The water table elevation fluctuates seasonally and with precipitation, but remains within the upper bedrock or overburden. An east-west trending groundwater divide, which coincides with the topographic highpoint of the area, results in two distinct drainage systems.

Shallow groundwater north of the divide flows to the north, and shallow groundwater south of the divide flows to the south following natural gradients. The eventual surface discharge points for groundwater flow are tributaries of the Mississippi and Missouri Rivers. In the northern and southwestern portions of the chemical plant area, subsurface conduit systems rapidly transport water to Burgermeister Spring (Figure 4).

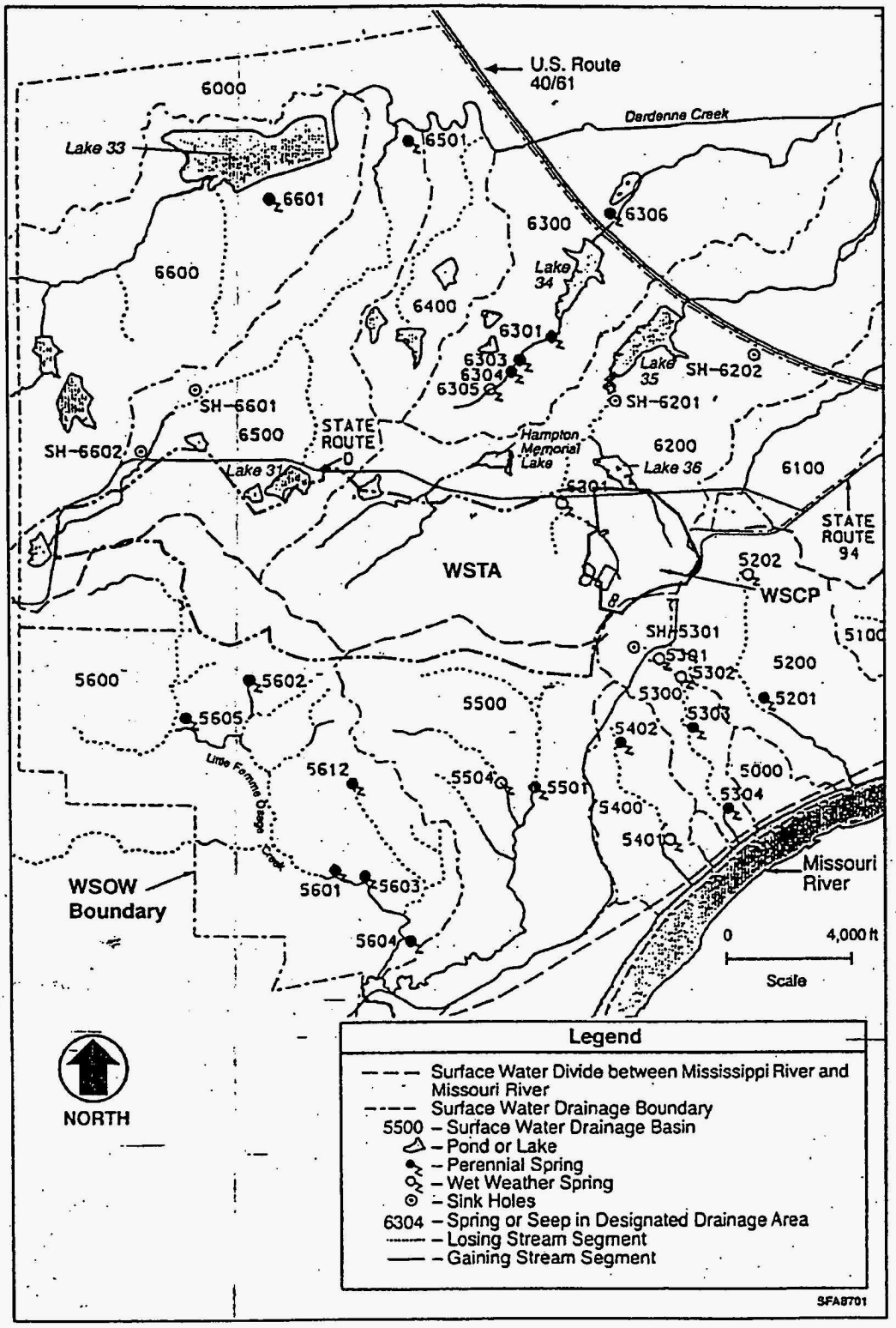

FIGURE 4 Springs and Drainage Areas in the Ordnance Works Area and the Chemical Plant Area

At the chemical plant area, groundwater to the north of the divide flows north and west toward Burgermeister Spring and eventually toward Dardenne Creek, a tributary of the Mississippi River (see Figure 2). Groundwater to the south of the divide flows south to southeast toward the Missouri River, primarily through the Southeast Drainage. Because these drainages are losing streams in portions of their upper reaches, mixing between groundwater and surface water runoff can occur. The direction of groundwater flow in the drainages is from the chemical plant area to the adjacent ordnance works area.

2.2.3 Surface Water

The chemical plant area is located on an east-west drainage divide between the Missouri and Mississippi watersheds. At the chemical plant area, surface drainage to the south of the divide flows through the Southeast Drainage and discharges to the Missouri River. Surface drainage to the north of the divide flows toward Dardenne Creek and its tributaries. Schote Creek, the largest of the tributaries, drains a major portion of the chemical plant area. Dardenne Creek flows east to the Mississippi River. The drainage divide causes surface water from the chemical plant area to flow to the ordnance works area.

2.2.4 Land Use

The Weldon Spring site is located in St. Charles County, which has a population of approximately 100,000. The largest city in the county is St. Charles, which is located approximately 24 km (15 mi) northeast of the site and has a population of about 50,000 (DOE 1998).

The chemical plant area is fenced, and access by the general public is restricted. Adjacent to the chemical plant area, portions of the Weldon Spring Training Area (WSTA) that are within the ordnance works area are currently used for field training and outdoor maneuvers by the U.S. Army Reserve, the Missouri Army National Guard, and other military and police units. An estimated 3,300 local Army reservists and 3,400 other reserve troops use the training area each year. The DA intends to continue using the WSTA for future training activities.

A large portion of the ordnance works area has been converted into conservation areas. The August A. Busch Memorial Conservation Area and the Weldon Spring Conservation Area

(see Figure 2) are managed by the Missouri Department of Conservation and are open throughout the year for recreational use. These areas receive an estimated 1.2 million visitors each year.

A state highway maintenance facility just east of the chemical plant area employs nine full-time staff and one mechanic. The former staff housing complex for the ordnance works area, located southeast of the intersection of State Route 94 and U.S. Route 40/61, is currently a private housing development known as Weldon Spring Heights; it has about 80 residents.

Francis Howell High School, located about 1 km (0.6 mi) east of the chemical plant area, employs about 175 faculty and staff (including employees at the Francis Howell Administration Annex) and is attended by about 1,930 students.

2.3 NATURE AND EXTENT OF CONTAMINATION

As presented in the RI report (DOE and DA 1998c), the nature and extent of contamination within the groundwater system for the chemical plant area was jointly evaluated with that of the ordnance works area by using data collected during DOE and DA monitoring programs from 1987 through 1995 and a joint sampling effort conducted in 1995. Data for the chemical plant area and the ordnance works area were combined and evaluated together because the groundwater system is continuous beneath both areas. Data obtained since 1995 from the chemical plant area monitoring wells and springs were also reviewed and are summarized in this section to provide the latest contaminant profile.

2.3.1 Groundwater

On the basis of the results of the evaluation in the RI (DOE and DA 1998c) and BRA (DOE and DA 1998a), the primary contaminants in chemical plant area groundwater are TCE, nitroaromatic compounds, nitrate, and uranium.

TCE contamination in groundwater is a recent occurrence (i.e., 1996). Contamination is localized at the chemical plant area, primarily in the vicinity of the raffinate pits. The horizontal extent of contamination extends from east of raffinate pit 3 to the south and southeast of raffinate pit 4, just beyond the adjacent boundary with the WSTA (see Figure 3). Contamination is limited to seven wells that are open to the weathered portion of the aquifer. In 1996, TCE concentrations in groundwater ranged from 1 to 9,000 µg/L. The maximum concentration is a one-time, but

analytically suspect, detection; the next highest concentration detected was 1,100 µg/L. Post-1996 concentrations have ranged from 0.6 to 1,300 µg/L. A decreasing trend in concentrations has been observed in one well (MW-2038), and concentrations in other affected wells have remained relatively the same.

The extent of uranium and nitrate contamination in groundwater is primarily limited to the chemical plant area and nearby vicinity. Contamination occurs predominantly in the overburden and weathered units of the aquifer. Recent data collected for uranium in 1997 to 1998 from the 56 monitoring wells ranged from 0.02 to 55 pCi/L. The maximum concentration was detected from a well in the raffinate pit area (MW-3024), where previous concentrations were at background levels. This well may have been affected by recent sludge removal and other remediation activities in the raffinate pit area. The next highest uranium concentrations occurred in MW-3003, MW-4020, and MW-2017 at 17, 20, and 12 pCi/L, respectively. These wells also previously indicated elevated levels relative to the other wells.

The highest concentrations of nitrate have typically been measured in the vicinity of the raffinate pits and Ash Pond (see Figure 3). Up until 1995, concentrations as high as 12,000 mg/L were detected. More recent data show a range of 0.02 to 1,000 mg/L. Recent remediation activities in the raffinate pit area have resulted in some changes in contaminant concentrations in several of the vicinity wells. A few wells have shown increases in nitrate concentrations.

Nitroaromatic compounds occur sporadically at low levels across the groundwater system; higher levels have generally been detected in the overburden and weathered units of the aquifer. The primary nitroaromatic compounds in groundwater include 2,4-DNT, 2,6-DNT, 1,3,5-trinitrobenzene (1,3,5-TNB), 2,4,6-TNT, and the amino-DNT degradation compounds. Recently, maximum concentrations of 6.0 µg/L for 2,4-DNT; 110 µg/L for 2,6-DNT; 62 µg/L for 1,3,5-TNB; 0.32 µg/L for 1,3-DNT; and 25 µg/L for 2,4,6-TNT have been detected.

2.3.2 Springwater

The primary contaminants in the springwater at surface springs in the chemical plant area are uranium, nitrate, and nitroaromatic compounds. Elevated levels of uranium and nitrate have been routinely detected at Burgermeister Spring (6300 drainage). Nitrate concentrations at this location have historically ranged from 0.5 to 10,000 mg/L; more recent data collected since 1995 indicated

a range of from 3.8 to 47 mg/L. The wide range of concentrations for nitrate at this location have been correlated with changes in flow rate. Uranium levels have been elevated in Burgermeister Spring and the Southeast Drainage. Uranium concentrations have ranged from 0.48 to 370 pCi/L; the maximum concentration was reported from the Southeast Drainage. Recent levels (1997–1998) of uranium detected in the Burgermeister Spring drainage and the Southeast Drainage range from 0.03 to 110 pCi/L and 51 to 120 pCi/L, respectively.

Data collected in 1995 indicate a maximum 2,4,6-TNT concentration of 120 µg/L for Spring 5201 and 280 µg/L for the Southeast Drainage. Maximum concentrations of the other nitroaromatic compounds (1987 to 1998) are 11 µg/L for 2,4-DNT; 18 µg/L for 2,6-DNT; 15 µg/L for 1,3,5-TNB; 1.2 µg/L for 1,3-DNB; 1.4 µg/L for nitrobenzene; 19 µg/L for 2-amino-4,6-DNT; and 24 µg/L for 4-amino-2,6-DNT.

3 SUMMARY OF SITE RISKS AND REMEDIATION GOALS

As part of the joint DOE and DA RI/FS, potential risks to human health and the environment from groundwater and springwater contamination were evaluated for the chemical plant area and the ordnance works area on the basis of current and likely future land uses. Future land use at both the chemical plant area and the ordnance works area is likely to be recreational, which is the same as current land use. Accordingly, potential risks were estimated with reference to current and future recreational users.

The results of the risk assessments were used to determine areas and contaminants that may require remediation. Preliminary remediation goals (PRGs) are identified in the FS (DOE and DA 1998b) for each of the contaminants that are considered significant. PRGs are concentrations of contaminants that are within the U.S. Environmental Protection Agency's (EPA's) acceptable risk range. The cleanup alternatives discussed in the FS were evaluated with respect to their ability to achieve the PRGs.

3.1 HUMAN HEALTH RISK ASSESSMENT

Potential cancer risks for the recreational visitor posed by exposure to radiation and chemicals were assessed by using standard methods developed by the EPA and other agencies. The EPA has established an acceptable risk range of 1 in 1 million to 1 in 10,000 (EPA 1990).

To put this risk range in context, it is estimated that about one in three Americans will develop cancer during their lifetime from all sources (American Cancer Society 1992), and that the risk of developing cancer from exposure to radiation naturally present in the environment (primarily radon) is about 1 in 100 (EPA 1989). Thus, the acceptable range is a very small percentage of the cancer risk expected in the general U.S. population from everyday exposures. For example, the incremental risk at the upper end of the EPA's range means that if all persons in a population of 10,000 were assumed to be repeatedly exposed to site contaminants, one additional person might get cancer as a result of those exposures compared with the estimated 3,000 cancer cases expected from all other exposures; that is, the number of persons who would be expected to develop cancer in that population would be 3,001 rather than 3,000.

Potential health effects other than cancer that could result from exposure to chemical contaminants were also assessed. The quantitative measure of noncarcinogenic health effects is the hazard index. The EPA has defined a hazard index of greater than 1 as indicating possible adverse noncarcinogenic health effects.

The most likely receptor for site-related groundwater contamination is a recreational visitor to the area. The human health risk assessment concluded that a recreational visitor ingesting springwater from any of the 15 springs evaluated was not at risk for cancer or systemic toxicity;[1] these results are expected to be representative of all springs in the study area. The recreational visitor was assumed not to have any exposure to the contaminated groundwater itself. This assumption is consistent with land use conditions at the chemical plant, where a recreational visitor would not have direct access to the groundwater. The risk of developing radiation-induced cancer was estimated to range from 4 in 1 billion to 2 in 1 million. These values are low and well within the acceptable risk range of 1 in 1 million to 1 in 10,000 recommended by the EPA (EPA 1989). The estimated risk for developing chemical-induced cancer is similarly low and ranges from 3 in 10 billion to 6 in 10 million. The hazard indices estimated for a recreational visitor at the springs ranged from 0.001 to 0.4.

3.2 ECOLOGICAL ASSESSMENT

The results of the ecological assessment indicate that contaminant concentrations in springwater and sediment pose little or no risk to ecological resources of the area, and that remediation from an ecological perspective is not needed.

Biotic surveys of macroinvertebrates, fish, and amphibians that inhabit the Burgermeister Spring drainage indicated no evidence of adverse effects. The spring was determined to contain generally good aquatic habitat, and the species present are typical of those found in similar habitats throughout the Midwest. Although the fish community was limited in diversity and the macroinvertebrate community was categorized as slightly impaired, the communities are likely

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[1] The assessment presented in the BRA (DOE and DA 1998a) also included risk estimates for a hypothetical future resident exposed to groundwater contaminants. These estimates indicate potential risks from three wells to be slightly higher than 1 in 10,000 and (for a hypothetical future resident) to be primarily attributable to TCE. The hazard index for several wells containing nitroaromatic compounds and nitrate also exceed 1.

affected by the physical nature of the spring and its drainage rather than by contaminant levels. Flow in the uppermost portion of Burgermeister Spring is maintained by groundwater discharge at the spring. Under low-flow conditions, as commonly occur in the summer, the stream drainage below the spring becomes intermittent, and portions of the habitat become dry. Surveys of amphibians found a community typical of similar habitats in the Midwest.

The results of toxicity testing of surface water and sediment indicate the potential for some toxicity to fish and macroinvertebrates from within Burgermeister Spring proper, but not downstream of the spring. However, the presence of apparently unaffected macroinvertebrate, fish, and amphibian communities in these locations suggests that local populations are tolerant of (or have adapted to) the contaminant levels present in surface water and sediment in the Burgermeister Spring drainage. Tissue analyses revealed relatively low levels of contaminant bioconcentration, all below levels of concern.

Modeling of contaminant uptake by the white-tailed deer and American robin drinking from Burgermeister Spring predicted very low levels of contaminant uptake by these species. No risk of harm was found to be caused by the modeled contaminant doses to land-based plants and animals drinking from Burgermeister Spring or other springs in the area.

Risk estimates for aquatic biota based on media concentrations indicate that surface water concentrations of iron, manganese, mercury, uranium, 1,3,5-TNB, and 2,4,6-TNT, and sediment concentrations of arsenic, lead, and silver might pose low to moderate risks to aquatic biota. However, the aquatic community in Burgermeister Spring is typical of similar habitats elsewhere in the Midwest and does not appear to be adversely affected by contaminant concentrations at this time. Few of the other springs in the area provide suitable habitat and, at best, support only very limited aquatic communities.

3.3 REMEDIATION GOALS FOR GROUNDWATER

On the basis of the results of evaluations presented in the RI (DOE and DA 1998c) and BRA (DOE and DA 1998a), the focus of the FS (DOE and DA 1998b) was the identification of options that allow for verification of decreasing contaminant concentrations resulting from source removals and options that reduce or remove contaminant concentrations (i.e., nitrate, TCE, nitroaromatic compounds, and uranium in groundwater). Nitrate and TCE contamination is primarily

a concern at the raffinate pits area at the chemical plant area. Nitroaromatic compounds have been identified as contaminants of concern in a few wells at the chemical plant area. Although uranium concentrations in groundwater are above background levels, concentrations are generally low and within the acceptable risk range (see Section 2.3.1).

Preliminary remediation goals (PRGs) for TCE, nitrates, nitroaromatic compounds, and uranium are identified in the FS (DOE and DA 1998b) as a basis for evaluating the effectiveness of the various remediation technologies and alternatives being considered. In accordance with the National Oil and Hazardous Substances Contingency Plan (NCP) (EPA 1990), the PRGs are concentrations of contaminants for each exposure route that are believed, on the basis of site land use information, to be protective of human health or the environment. PRGs are based on applicable or relevant and appropriate requirements (ARARs) such as maximum contaminant levels (MCLs). When ARARs are not available, the EPA sets remediation goals by developing risk-based values.

The following MCLs have been identified as ARARs:

- 5 µg/L for TCE;
- 10 µg/L for nitrate as nitrogen;
- 17 µg/L for nitrobenzene;
- 0.11 µg/L for 2,4-DNT; and
- 1.0 µg/L for 1,3-DNB.

No federal or state MCL exists for uranium in groundwater. Although the EPA has proposed an MCL of 20 µg/L for uranium in its Proposed National Primary Water Regulations (Volume 56, page 33050, of the *Federal Register* [56 FR 33050] [July 18, 1991]), this standard is not an ARAR because it has not been promulgated. However, the proposed MCL might be treated as a to-be-considered requirement (TBC).

Because there are no ARARs for eight other nitroaromatic compounds and uranium, risk-based values were developed for those contaminants in accordance with protocols authorized in the NCP. Risk-based values are developed on the basis of reference doses or slope factors provided by the EPA. The reasonable maximum exposure estimate for future use provides the basis for developing protective exposure levels. Concentrations of carcinogenic contaminants equivalent to

the 1 in 10,000 and 1 in 1 million risk range were estimated for the recreational scenario. Calculations were performed to determine the concentrations of noncarcinogenic contaminants that would be equivalent to a hazard index of 1 for the recreational scenario. Assumptions and methodologies were similar to those used for risk estimates in the BRA (DOE and DA 1998a) and are further discussed in Appendix B of the FS (DOE and DA 1998b).

Table 1 summarizes regulatory criteria, risk-based values, and PRGs for chemical plant groundwater contaminants of concern. For each of the contaminants, PRGs are based on ARARs, or the 10^{-6} risk, or the hazard index of 1 for the recreational scenario. (Risk-based values were also calculated for a hypothetical residential scenario for all contaminants, including those with determined ARARs, in order to provide information for comparison). Table 2 lists the wells at which PRGs are exceeded for groundwater contaminants of concern considered for the chemical plant area.

TABLE 1 Summary of Regulatory Criteria, Risk-Based Values, and Preliminary Remediation Goals for Groundwater Contaminants of Concern

			Risk-Based Values[b]				
			Residential Scenario		Recreational Scenario		
Contaminant of Concern	Unit	Regulatory Criteria[a]	10^{-6} to 10^{-4} Carcinogenic Risk Range[c]	Hazard Index of 1[d]	10^{-6} to 10^{-4} Carcinogenic Risk Range[e]	Hazard Index of 1[f]	Proposed PRGs for the GWOUs[g]
2-Amino-4,6-DNT	µg/L	-[h]	NA[i]	2.2	NA	190	190
4-Amino-2,6-DNT	µg/L	-	NA	2.2	NA	190	190
1,3-DNB	µg/L	1.0[j]	NA	3.7	NA	320	1.0
2,4-DNT	µg/L	0.11[j]	0.13 – 13	73	11 – 1,100	6,400	0.11
2,6-DNT	µg/L	-	0.13 – 13	37	11 – 1,100	3,200	11
Nitrobenzene	µg/L	17[j]	NA	18	NA	1,600	17
Nitrate-N	mg/L	10	NA	58[k]	NA	5,100	10
m-Nitrotoluene	µg/L	-	NA	37	NA	3,200	3,200
o-Nitrotoluene	µg/L	-	NA	37	NA	3,200	3,200
p-Nitrotoluene	µg/L	-	NA	37	NA	3,200	3,200
TCE	µg/L	5	7.7 – 770	NA	680 – 68,000	NA	5
1,3,5-TNB	µg/L	-	NA	1.8	NA	160	160
2,4,6-TNT	µg/L	-	2.8 – 280	18	250 – 25,000	1,600	250
Uranium	pCi/L	-	0.90–90[l]	110 µg/l[m]	78 – 7,800[l]	9,600 µg/l[m]	78

[a] The values in this column include MCLs, EPA drinking water health advisories, Missouri water quality standards, and Missouri health advisories for groundwater. A detailed tabulation of ARARs is presented in Appendix A of the FS (DOE and DA 1998b).

[b] Risk-based values were estimated for the recreational and residential scenarios following the risk methodology and equations used for risk calculations as presented in the BRA (DOE and DA 1998a) and in Appendix B of the FS (DOE and DA 1998b). The forseeable future land use at the chemical plant area is likely to be recreational, which is the same as current land use.

[c] Values in this column represent concentations for each contaminant that would be within the acceptable risk range for the residential scenario.

[d] Values in this column represent the highest concentration for each contaminant that would be acceptable or within the hazard index of 1 for the residential scenario.

[e] Values in this column represent concentations for each contaminant that would be within the acceptable risk range for the recreational scenario.

[f] Values in this column represent the highest concentration for each contaminant that would be acceptable or within the hazard index of 1 for the recreational scenario.

[g] The proposed PRGs for ~~TCE~~, nitrate-N, 2,4-DNT, 1,3-DNB, and nitrobenzene were based on ARARs. PRGs for carcinogenic nitroaromatic compounds (i.e., 2,4,6-TNT, 2,4-DNT) and uranium were based on concentrations equivalent to the 1 in 1 million risk for the recreational scenario. PRGs for noncarcinogenic nitroaromatic compounds (i.e., 2-amino-4,6-DNT, 4-amino-2,6-DNT, 1,3-DNB, m-nitrotoluene, o-nitrotoluene, and p-nitrotoluene) were based on concentrations equivalent to a hazard index of 1 for each compound for the recreational scenario.

TABLE 1 (Cont.)

[h] A hyphen (-) indicates that no regulatory criteria are available.

[i] NA = not applicable; a slope factor or reference dose, whichever is appropriate, was not available.

[j] Missouri water quality standard that is an ARAR.

[k] Value based on an adult residential receptor; the value for infants would be less because nitrate-N would be more toxic to infants than adults.

[l] Based on the radiological risk for uranium.

[m] Based on the chemical toxicity of uranium.

TABLE 2 Maximum Contaminant Concentrations for the GWOU Monitoring Network[a]

Well	TCE (µg/L)	Nitrate (mg/L)	1,3,5-TNB (µg/L)	2,4,6-TNT (µg/L)	2,4-DNT (µg/L)	2,6-DNT (µg/L)	Nitro-benzene (µg/L)	1,3-DNB (µg/L)	Uranium (pCi/L)
PRG[b]	5	10	160	250	0.11	11	17	1.0	80
Weathered									
MW-2001	-[c]	(68)	0.062	0.015	0.083	0.062	0.015	0.045	0.52
MW-2002	-	(46)	0.015	0.015	0.046	0.26	0.015	0.045	0.70
MW-2003	-	(290)	0.015	0.015	(0.12)	0.46	0.015	0.045	2.6
MW-2005	-	(83)	0.058	0.015	0.048	0.11	0.015	0.049	0.56
MW-2006	-	-	7.0	0.015	(0.13)	1.3	0.054	0.078	4.5
MW-2010	-	-	0.12	0.13	0.088	0.66	0.015	0.049	0.16
MW-2012	-	-	7.2	25	(6.0)	(110)	0.015	0.09	0.12
MW-2013	1.1	-	4.3	0.88	(0.17)	2.1	0.015	0.045	0.84
MW-2014	-	-	2.8	0.015	(0.16)	0.49	0.015	0.082	0.57
MW-2017	-	-	0.015	0.015	0.015	0.0050	0.015	0.045	12
MW-2018	-	0.72	0.015	0.015	0.015	0.0050	0.015	0.045	2.0
MW-2032	1.6	(105)	2.0	4.4	0.11	1.3	0.015	0.073	5.2
MW-2033	ND	0.78	5.3	1.4	(0.12)	1.5	0.015	0.045	1.1
MW-2034	-	5.0	0.015	0.015	0.015	0.0050	0.015	0.045	5.0
MW-2035	-	3.6	0.015	0.015	0.015	0.0050	0.015	0.045	3.6
MW-2036	-	3.6	0.015	0.015	0.015	0.0050	0.015	0.045	6.6
MW-2037	(1,300)	(320)	0.20	0.015	(0.73)	0.13	0.030	0.094	1.3
MW-2038	(950)	(1,000)	0.18	0.015	(1.4)	0.24	0.056	0.067	1.6
MW-2039	-	(88)	0.015	0.015	0.019	0.005	0.015	0.045	4.1
MW-2040	-	(170)	0.015	0.015	0.022	0.005	0.030	0.045	4.6
MW-2041	-	(210)	0.015	0.015	0.015	0.005	0.015	0.045	5.7
MW-3003	-	(410)	0.015	0.015	(0.13)	0.19	0.015	0.045	17
MW-3019	-	3.7	0.015	0.015	0.015	0.0050	0.015	0.045	2.0
MW-3023	-	(190)	0.015	0.030	(0.73)	2.4	0.015	0.070	-
MW-3025	(50)	(510)	0.015	0.015	0.099	0.27	0.015	0.045	3.6
MW-3027	4	(450)	0.077	0.015	0.037	0.039	0.015	0.045	1.5
MW-3028	-	(300)	0.47	0.015	(0.80)	0.14	0.024	0.081	1.0
MW-4001	(5.5)	(47)	62	2.4	(0.13)	2.5	0.030	0.045	2.4
MW-4002	-	1.2	0.015	0.049	0.018	0.040	0.015	0.045	0.34
MW-4003	-	-	13	0.015	0.097	2.2	0.015	0.045	2.1

TABLE 2 (Cont.)

Well	TCE (µg/L)	Nitrate (mg/L)	1,3,5-TNB (µg/L)	2,4,6-TNT (µg/L)	2,4-DNT (µg/L)	2,6-DNT (µg/L)	Nitro-benzene (µg/L)	1,3-DNB (µg/L)	Uranium (pCi/L)
PRG[b]	5	10	160	250	0.11	11	17	1.0	80
Weathered (Cont.)									
MW-4005	-	-	0.015	0.015	0.015	0.005	0.015	0.045	-
MW-4006	-	-	21	0.015	0.078	2.3	0.015	0.045	3.4
MW-4010	-	-	-	-	-	-	-	-	12
MW-4013	-	-	-	-	-	-	-	-	5.1
MW-4014	-	-	-	-	-	-	-	-	1.2
MW-4015	-	-	7.1	0.015	0.082	0.83	0.015	0.045	3.2
Unweathered									
MW-3024	-	(460)	0.015	0.015	0.015	0.0030	0.015	0.045	55
MW-3026	-	(510)	0.095	0.015	0.099	0.063	0.015	0.045	2.5
MW-4004	-	(23)	-	-	-	-	-	-	-
MW-4011	-	(280)	0.015	0.015	0.051	0.061	0.015	0.045	8.4
MW-4026	-	9.7	0.015	0.015	0.015	0.0050	0.020	0.045	0.34

[a] Concentrations are the maximum reported for data collected in 1997–1998. Well concentrations that exceed the PRGs are denoted within parentheses. Sampling performed in 1995 for the five nitroaromatic compound degradation products of DNT and TNT indicate maximum concentrations as follows: 16 µg/L for 2-amino-4,6-DNT, 24 µg/L for 4-amino-2,6-DNT, 54 µg/L for 2-nitrotoluene, 4.3 µg/L for 3-nitrotoluene, and 0.70 µg/L for 4-nitrotoluene.

[b] PRGs are risk-based values for the recreational scenario, except for TCE, 2,4-DNT, 1,3-DNB, and nitrobenzene.

[c] A hyphen indicates the well was either not sampled or was reported at below detection limit.

4 SCREENING OF PRELIMINARY ALTERNATIVES

4.1 PRELIMINARY ALTERNATIVES CONSIDERED

The alternatives discussed in this chapter were considered in the FS (DOE and DA 1998b) in the context of follow-on activities after source removal and control response actions have been implemented at the chemical plant area. These source removals are stipulated in the ROD addressing soil and structural contamination at the chemical plant area (DOE 1993).

In the development of preliminary alternatives, a broad range of remediation technologies, both in-situ and ex-situ, were considered for application at the chemical plant area to address the contaminated groundwater. In-situ technologies considered included containment approaches such as barrier walls or immobilization methods and in-situ treatment approaches such as natural processes or newer innovative technologies like electrokinetics, phytoremediation, Fenton-like reagents, and treatment walls. Groundwater removal technologies, including conventional and nonconventional well extraction, interceptor trenches, and excavation, were considered if treatment was to be performed ex-situ. Conventional and newer innovative technologies for ex-situ groundwater treatment using physical, chemical, and biological methods were evaluated. From these technologies, nine broad alternatives were developed in the FS (DOE and DA 1998b) that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste. The nine broad alternatives outlined below ranged from those considered to address all groundwater contaminants in the entire affected aquifer, to those that focused on more localized treatment of TCE only. Treatment or remediation of TCE as a "hot spot" was considered because it is the most significant contributor to the estimated potential risk and because TCE contamination is more or less confined to one area or plume. Alternatives 2, 3, 4, 5, and 6 presented in the FS were developed and evaluated to determine their feasibility in addressing all contaminants in the affected aquifer at the chemical plant area. Although Alternatives 7, 8, and 9 were evaluated for their feasibility in addressing the TCE-contaminated groundwater, they address the rest of the contaminants via monitoring.

Alternative 1: No Action Alternative. CERCLA regulations require that this alternative be considered. It is intended to provide a baseline against which other alternatives can be compared. No further action would be taken at the site under the no action alternative, and any existing, ongoing

maintenance, monitoring, and remedial actions associated with the groundwater would be discontinued. Although contaminant concentrations are expected to decrease with time as a result of source removals at the chemical plant area, no monitoring data would be available to verify this occurrence.

Alternative 2: Monitoring with No Active Remediation. Involves routine sampling and analysis to provide monitoring data that would verify expected decreasing contaminant concentrations. Under this alternative, lower contaminant concentrations are expected in the future because natural processes will continue to occur.

Alternative 3: Natural Attenuation. Includes the construction of new monitoring wells and the implementation of a sampling and analysis scheme that is more elaborate than required under Alternative 2 to verify and monitor parameters that would document performance of the natural remediation processes. Natural attenuation is defined in the NCP (EPA 1990) as "biodegradation, dispersion, dilution, and adsorption" of contaminants in groundwater. The implementation of this alternative would require advanced groundwater modeling capabilities to demonstrate that natural processes of contaminant degradation would reduce contaminant concentrations below regulatory standards before potential exposure pathways are encountered.

Alternative 4: Groundwater Removal, On-Site Treatment Using Granular Activated Carbon. Involves using conventional vertical extraction wells to remove groundwater with contaminant levels exceeding PRGs, pumping and treating the groundwater at an aboveground treatment system, and releasing or managing the treated groundwater consistent with overall site strategies. Adsorption by granular activated carbon (GAC), which is a well-developed, effective, and widely applied technology, would be used to remove organic materials, including nitroaromatic compounds (such as 2,4-DNT and TNT) and TCE by chemically and physically binding them to the carbon.

Alternative 5: Groundwater Removal, On-Site Treatment Using Ultraviolet Oxidation. Similar to Alternative 4, this alternative involves extraction and treatment of groundwater to achieve maximum contaminant concentrations that are within PRGs. Ultraviolet oxidation is a relatively new treatment technology that can be effective for water contaminated with TCE and nitroaromatic

compounds. Unlike adsorption on GAC, it destroys the compounds rather than simply transferring them to a more easily disposable medium.

Alternative 6: Groundwater Removal, On-Site Treatment Using Phytoremediation. The objectives and design of Alternative 6 are similar to those of Alternatives 4 and 5, except that this alternative assumes on-site treatment using phytoremediation. Phytoremediation is the use of plants to remediate contaminated groundwater. It exploits an enzymatic activity occurring in plants at the root level and has been shown to be effective in a number of studies. Groundwater exceeding the PRGs would be removed by using conventional vertical extraction wells and pumped to and treated at an aboveground constructed wetland. A constructed wetland is a lined, man-made lagoon that contains a variety of plants that accumulate and remove nitroaromatic compounds and other contaminants from influent waters. The treated groundwater would be managed consistent with overall site strategies.

Alternative 7: Removal and Ex-Situ Treatment of TCE-Contaminated Groundwater. Involves extraction and ex-situ treatment of groundwater contaminated with TCE primarily at the chemical plant area near the raffinate pits area. An approach identical to that described in Alternative 2 would be applied to manage other contaminants in the groundwater. This alternative provides for active remediation of TCE only.

The objectives and design of Alternative 7 are similar to those for Alternative 4 and 5, except that only groundwater exceeding PRGs for TCE would be removed and treated under this alternative. This groundwater would be removed by using conventional wells, pumped to and treated in an aboveground treatment system consisting of a sequence of physical and chemical unit operations, and released at a discharge point.

Alternative 8: In-Situ Treatment of TCE Using In-Well Vapor Stripping. Monitoring similar to that described in Alternative 2 would be implemented for the management of nitroaromatic compounds and nitrates in the groundwater. In-well vapor stripping technology involves the creation of a groundwater circulation pattern and simultaneous aeration within the vapor stripping well to volatilize the TCE from the circulating groundwater. This process would not be amenable to removal of nonvolatile or highly soluble compounds like nitrates and nitroaromatic compounds that may also be present. Air-lift pumping is used to lift groundwater and strip it of contaminants. Contaminated

vapors are drawn off for aboveground treatment. Partially treated groundwater is forced out of the well into the vadose zone where it reinfiltrates to the water table. Untreated groundwater enters the well at its base, thereby replacing the water lifted through pumping. Eventually, the partially treated water is cycled back through the well via this process until PRGs are met.

Alternative 9: In-Situ Chemical Oxidation of TCE Using Fenton-Like Reagents. Involves in-situ chemical oxidation of TCE-contaminated groundwater with Fenton-like reagents. Monitoring similar to that described in Alternative 2 would be applied to manage other groundwater contaminants. This alternative provides for active remediation of TCE only.

This in-situ treatment process would involve the direct sequential injection into the shallow bedrock aquifer of aqueous solutions of hydrogen peroxide, a ferrous compound, and acidic solutions (e.g., acetic acid). Acetic acid would be introduced beforehand to establish acidic conditions conducive to production of hydroxyl radicals by the Fenton-like reagents. The generated hydroxyl radicals would react with the TCE in the groundwater to form mostly carbon dioxide (CO_2) and water.

4.2 ALTERNATIVES ELIMINATED FROM CONSIDERATION

Alternatives 1 through 9 were evaluated in the FS (DOE and DA 1998b) in terms of the three screening criteria defined in the *Code of Federal Regulations*, Title 40, Part 300 (40 CFR Part 300)—effectiveness, implementability, and cost. On the basis of this screening process, Alternatives 3, 5, and 6 were not retained for further consideration for the following reasons.

- *Alternative 3*— It would be difficult to demonstrate natural attenuation for all of the constituents of concern, and this alternative does not provide better protection of human health and the environment than Alternative 2.
- *Alternative 5*—Similar to Alternative 4 in that preliminary simulation results indicate that remediation would take on the order of 100 years, and the ultraviolet oxidation technology is not well established.
- *Alternative 6*—Remediation would take on the order of 100 years, and the phytoremediation technology is not well established.

4.3 ALTERNATIVES RETAINED FOR FURTHER EVALUATION

On the basis of the screening process, the following alternatives were retained for detailed evaluation (see Chapter 5):

- Alternative 1: No Action,
- Alternative 2: Monitoring with No Active Remediation,
- Alternative 4: Groundwater Removal, On-Site Treatment Using GAC,
- Alternative 7: Removal and Ex-Situ Treatment of TCE-Contaminated Groundwater,
- Alternative 8: In-Situ Treatment of TCE Using In-Well Vapor Stripping, and
- Alternative 9: In-Situ Chemical Oxidation of TCE Using Fenton-Like Reagents.

5 DESCRIPTION AND ANALYSIS OF FINAL ALTERNATIVES

5.1 DESCRIPTION OF FINAL ALTERNATIVES

Six of nine preliminary alternatives were retained for detailed analysis in the FS (DOE and DA 1998b) and are summarized in this chapter. Again, these alternatives are being considered in the context of follow-on activities after source removal and control response actions have been implemented at the chemical plant area (DOE 1993).

5.1.1 Alternative 1: No Action

This alternative is used as a baseline against which to compare the other alternatives being considered. Under the no action alternative, groundwater at the chemical plant area would remain "as is." No containment, removal, treatment, or other mitigating actions would be implemented. The no action alternative does not include groundwater monitoring or any other active or passive institutional controls that may reduce any potential for human exposure (e.g., land use restrictions). Under Alternative 1, it is assumed that all current activities, including groundwater monitoring by DOE, would be discontinued. Contaminant concentrations are expected to decrease as a result of natural processes that will continue to occur and from current source removals being conducted per the chemical plant ROD (DOE 1993).

5.1.2 Alternative 2: Monitoring with No Active Remediation

Under Alternative 2, no active remediation would take place; however, long-term monitoring of the groundwater would be performed. The concentrations of contaminants in groundwater at the chemical plant area are expected to decrease with time. This decrease could result from any or a combination of the following: (1) source removals; (2) biodegradation, photolysis, volatilization, sorption, and hydrolysis; and (3) dilution from infiltration of rainwater and runoff. Further evaluation through long-term monitoring and associated activities would determine whether these processes decreased contaminant levels to or below PRGs.

Groundwater monitoring would be conducted by using the existing monitoring well network. It is possible that this network would be expanded or reduced on the basis of subsequent

design of an optimal network. Monitoring would be performed for an appropriate period of time that would be defined in the remedial design/remedial action (RD/RA) phase.

5.1.3 Alternative 4: Groundwater Removal, On-Site Treatment Using GAC

This alternative involves using conventional vertical extraction wells to remove groundwater with contaminant levels exceeding PRGs. In the evaluation presented in the FS, an estimated 330 to 1,000 vertical extraction wells would be required to address all contaminants at the chemical plant area (see Appendix C of the FS [DOE and DA 1998b]) to achieve a reasonable extraction rate and to provide wide enough coverage to prevent any bypass of groundwater contaminated above the PRGs. However, on the basis of data from recent field investigations within the TCE-contaminated portion of the shallow bedrock aquifer, revised estimates indicate that between 130 to 390 vertical extraction wells may be required to remove groundwater with contaminant concentrations exceeding PRGs.

The extracted groundwater would be pumped and treated at an aboveground treatment system. Organic materials such as TCE and nitroaromatic compounds would be removed by using the well-established GAC adsorption technology.

As required by CERCLA, a review would be conducted every five years because contaminants would remain in site groundwater at levels above those that allow for unlimited use and unrestricted exposure.

5.1.4 Alternative 7: Removal and Ex-Situ Treatment of TCE-Contaminated Groundwater

This alternative involves the extraction of TCE-contaminated groundwater in the vicinity of the raffinate pits of the chemical plant area. Long-term monitoring would be conducted to collect data that would verify expectations about decreasing concentrations resulting from natural processes and source removals conducted under the chemical plant ROD (DOE 1993). In the evaluation presented in the FS, approximately 200 to 650 vertical extraction wells (see Appendix C of the FS [DOE and DA 1998b]) were estimated to be required to achieve a reasonable extraction rate and to provide wide enough coverage to prevent any bypass of the TCE. However, on the basis of data from recent field investigations within the TCE-contaminated portion of the shallow bedrock aquifer,

revised estimates indicate that between 10 to 23 vertical extraction wells may be required to remove TCE-contaminated groundwater in the vicinity of the raffinate pits.

As required by CERCLA, a review would be conducted every five years because contaminants would remain in site groundwater at levels above those that allow for unlimited use and unrestricted exposure.

5.1.5 Alternative 8: In-Situ Treatment of TCE Using In-Well Vapor Stripping

In-well vapor stripping technology involves the creation of a groundwater circulation pattern and simultaneous aeration within the vapor stripping well to volatilize the TCE from the circulating groundwater. This alternative is focused on remediating the TCE-contaminated groundwater that has been identified near the raffinate pits area of the chemical plant area. Because of the nature of the technology involved, this alternative would not directly remediate the nitrate, nitroaromatic compounds, and uranium that may also be present. As in Alternatives 2 and 7, long-term monitoring would be conducted to obtain data that would verify expected decreases in contaminant concentrations as a result of natural processes that would continue to occur and from source removals conducted under the chemical plant ROD (DOE 1993).

The in-well vapor stripping technology consists primarily of a screened well submerged beneath the water table and an air line within the well extending to below the water table. A compressor delivers air or an inert gas such as nitrogen to the water column aerating the water within the well. The gas bubbles cause the water within the well to be less dense than the nonaerated water outside. As a result, the dense water flows in through the well screen and forces the aerated water upward within the well. The result is a rising column of aerated water within the well, which forms an air-lift pumping system.

As required by CERCLA, a review would be conducted every five years because contaminants would remain in site groundwater at levels above those that allow for unlimited use and unrestricted exposure.

5.1.6 Alternative 9: In-Situ Chemical Oxidation of TCE Using Fenton-Like Reagents

This alternative involves in-situ chemical oxidation of the TCE-contaminated groundwater that has been identified near the raffinate pits area of the chemical plant area. Because this

technology has been proven to address organic compounds only, this alternative would primarily address TCE. Long-term monitoring would be conducted, as in Alternatives 2, 7, and 8, to obtain data that would verify decreasing nitrate, nitroaromatic compounds, and uranium concentrations as a result of natural processes that would continue to occur and from source removals per the chemical plant ROD (DOE 1993).

The application of this technology consists of injection into the shallow bedrock aquifer of aqueous solutions of hydrogen peroxide, ferrous sulfate ($FeSO_4$), and other chemicals (e.g., acetic acid) through a series of injection wells. Preliminary engineering estimates indicate the installation of approximately two sets of nested application or injection wells, with multiple rounds (a minimum of two) of chemical reagent application.

As required by CERCLA, a review would be conducted every five years because contaminants would remain in site groundwater at levels above those that allow for unlimited use and unrestricted exposure.

5.2 DETAILED ANALYSIS OF FINAL ALTERNATIVES

As required by CERCLA and the NCP (EPA 1990), the detailed analysis of the six final alternatives considered nine evaluation criteria.

1. *Overall protection of human health and the environment*—Addresses whether the alternative adequately protects human health and the environment. Describes how site risks posed by each pathway are eliminated, reduced, or controlled through natural processes, treatment, engineering, or institutional controls. Allows for consideration of any unacceptable short-term impacts associated with the alternative.

2. *Compliance with ARARs*—Addresses whether all applicable or relevant and appropriate state and federal laws and regulations are met. (Appendix A of the FS [DOE and DA 1998b] presents a detailed discussion of ARARs).

3. *Long-term effectiveness and permanence*—Addresses the risk remaining at the operable unit after remediation goals have been met. Focuses on the ability of

the alternative to maintain reliable protection of human health and the environment over time, once remediation goals have been met.

4. *Reduction of toxicity, mobility, or volume*—Addresses the statutory preference for selecting alternatives that permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances at a site. Focuses on the extent to which this is achieved by the alternative.
5. *Short-term effectiveness*—Addresses the potential impacts to workers, the general public and the environment during implementation of the alternative.
6. *Implementability*—Addresses technical and administrative feasibility, including the availability and reliability of resources or materials required during implementation and the need to coordinate with other agencies.
7. *Cost*—Addresses both capital costs and annual operation and maintenance costs.
8. *State acceptance*—Addresses the statutory requirements for substantial and meaningful state involvement. This criterion will be evaluated in the responsiveness summary and ROD that will be prepared following the public comment period on the Proposed Plan.
9. *Community acceptance*—Assesses the community's preference for, or concerns about, the remediation alternatives being considered. This criterion will be evaluated in the responsiveness summary and ROD that will be prepared following the public comment period on the Proposed Plan.

5.2.1 Overall Protection of Human Health and the Environment

The no action alternative should be adequately protective of human health and the environment over the long term. Under current conditions, the contaminated groundwater at the chemical plant area poses no imminent risk to human health or the environment. Currently, the groundwater is not accessible and is not used at the site. Land use in the foreseeable future would be similar to current land use. Groundwater contaminant levels are also expected to decrease with

time as a result of source removals (DOE 1993) and naturally occurring processes that would further attenuate contaminant concentrations.

Alternative 2 would also be adequately protective of human health and the environment over the long term. Potential migration of groundwater contamination toward the springs would be monitored. Monitoring data would be obtained to ensure continued protectiveness and to verify expectations for decreasing contaminant concentrations. Natural processes and source removals at the chemical plant (DOE 1993) are expected to attenuate contaminant concentrations. Dilution of the contaminated groundwater with uncontaminated groundwater drawn from infiltration of rainwater and runoff could also result in decreased concentrations.

Alternatives 4, 7, 8, and 9 would be protective of human health and the environment.

5.2.2 Compliance with Potential ARARs

Chemical-Specific ARARs. Potential regulatory requirements that might be applicable or relevant and appropriate to the final remedial action alternatives are identified and evaluated in Appendix A of the FS (DOE and DA 1998b). Chemical-specific ARARs (MCLs) have been identified for nitrate (10 mg/L), TCE(5 µg/L), and three nitroaromatic compounds (nitrobenzene at 17 µg/L, 2,4-DNT at 0.11 µg/L, and 1,3-DNB at 1.0 µg/L). The current levels of nitrate, TCE, and 2,4-DNT in groundwater at the chemical plant area exceed the respective chemical-specific ARARs.

All of the alternatives meet chemical-specific ARARs. Under no action, decreases in concentrations for these contaminants are expected as a result of source removals being performed per the chemical plant ROD (DOE 1993). Natural processes that are occurring are likewise expected to continue and lower contaminant concentrations. Alternative 2 would meet chemical-specific ARARs as a result of natural processes that would continue to occur and from source removals per the chemical plant ROD (DOE 1993). Monitoring data would be obtained to verify the expected decreases in contaminant concentrations.

Alternative 4 would meet chemical-specific ARARs because groundwater extraction and treatment would be performed.

Alternative 7 would meet chemical-specific ARARs as a result of groundwater extraction and treatment and from natural processes and source removals at the chemical plant (DOE 1993). Alternatives 8 and 9 would meet chemical-specific ARARs as a result of treatment and from natural processes and source removals at the chemical plant (DOE 1993).

Location-Specific ARARs. Location-specific ARARs are discussed in Appendix A of the FS (DOE and DA 1998b). Location-specific ARARs would be similar for all alternatives. All alternatives would meet location-specific ARARs.

Action-Specific ARARs. Action-specific ARARs would vary depending on the alternative or technology involved. Action-specific ARARs are discussed in Appendix A of the FS (DOE and DA 1998).

For the no action alternative, there would be no action-specific ARAR associated with this alternative because there would be no action taken. Alternatives 2, 4, 7, 8, and 9 would meet substantive requirements related to any action-specific ARARs (e.g., construction, monitoring, extraction, injection wells, treatment plants, and discharge limits).

5.2.3 Long-Term Effectiveness and Permanence

For Alternative 1, under current recreational land use conditions, current contaminant concentrations of groundwater at the chemical plant area pose no unacceptable risk to human health or the environment. Although monitoring data would not be available for verification, the long-term effectiveness of this alternative is expected to be maintained by further decreases of contaminant concentrations as a result of natural processes and source removals at the chemical plant area currently being performed per the chemical plant ROD (DOE 1993).

Alternatives 2, 7, 8, and 9 require monitoring and maintenance activities. For Alternatives 7, 8, and 9, in addition to contaminant decreases resulting from natural processes and source removals per the chemical plant ROD (DOE 1993), some treatment would be performed. Monitoring data would be obtained to verify if reduction is permanent.

Alternative 4 would reduce all contaminant concentrations through extraction and treatment and would afford long-term effectiveness and permanence.

5.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 1 and 2 would not result in the reduction of toxicity, mobility, or volume because these alternatives do not provide for any treatment of the contaminated groundwater. Alternatives 7, 8, and 9 utilize treatment to reduce the toxicity, mobility, or volume associated with TCE contamination at the chemical plant area. Alternative 7 is focused on extracting and treating the TCE plume at the chemical plant area. Other contaminants present in this plume would also be extracted. The technologies involved in Alternative 8 target volatile organic compounds only, like TCE. The technology in Alternative 9 addresses all organic compounds, which means some treatment of nitroaromatic compounds in addition to TCE might also occur. Treatment under Alternative 4 is expected to reduce the toxicity, mobility, or volume associated with all contaminants in groundwater within the shallow bedrock aquifer.

5.2.5 Short-Term Effectiveness

For Alternative 1, there would be no short-term impacts to human health or the environment because no remedial action would be conducted. For Alternatives 2, 7, and 9, construction activities are estimated to result in less than one case of occupational injury and no occupational fatalities (projections regarding installation of new wells were based on industry-specific statistics from the U.S. Bureau of Labor Statistics, as reported by the National Safety Council [1995]). Because of the large number of vertical extraction wells required for Alternatives 4 and 7, construction activities are estimated to result in less than one occupational fatality and up to approximately 50 cases of occupational injury.

Some short-term impacts on recreational use of the surrounding wildlife areas might occur as the result of noise, exhaust fumes, and dust associated with possible monitoring well construction. Impacts to natural resources during construction of any new groundwater monitoring wells would be mitigated by avoiding unnecessary damage to vegetation, wildlife, and soil by controlling traffic and minimizing the areas of disturbance.

5.2.6 Implementability

No concerns regarding implementability would be posed by Alternative 1, because no action would be taken. Few implementability concerns would be posed by Alternative 2 because of the limited actions taken. Site operations would continue using readily available resources for monitoring and maintaining institutional controls. Construction of any proposed monitoring wells would require mobilization of a drilling rig for installation.

Groundwater monitoring is readily implementable. Presently, numerous wells are located at these operable units, and additional wells could be easily installed and monitored. Monitoring any off-site plume migration could easily be implemented.

The administrative feasibility of Alternative 2 would be relatively straightforward. Weldon Spring Remedial Action Project (WSSRAP) and remedial action project activities at the ordnance works area are coordinated with the State of Missouri and EPA Region VII. That coordination would continue during implementation. The implementation of this alternative would not require coordination with any other agencies beyond that already occurring.

The implementability of the active remediation alternatives (Alternatives 4, 7, and 8) hinges on the ability to accurately identify the area-specific hydrogeologic characteristics of the aquifer. Recent pump test data taken from the TCE-contaminated area indicate that Alternatives 4, 7, and 8 may not be feasible. A pump-and-treat technology required for Alternatives 4 and 7 could not be implemented on a continuous basis because the acquifier dewatered during the pump test, and it is still recovering after four months. The successful generation of a vertical circulation pattern needed for Alternative 8 was also not indicated. However, this same pump test indicated that introduction of materials into the aquifer in the TCE-contaminated area is possible.

5.2.7 Cost

There are no net present worth, capital, or annual operation and maintenance costs associated with the no action alternative because no activities would be undertaken. On the basis of the FS (DOE and DA 1998b), costs for Alternative 2 are associated with continuing the existing environmental monitoring program and constructing and operating possible additional monitoring wells. Annual costs for Alternative 2 are estimated to be approximately $0.4 million.

On the basis of the FS (DOE and DA 1998b), capital costs for Alternative 4 are estimated to range from $41 million to $120 million because of the large number of extraction wells (between 330 to 1,000); annual costs would range from $2 million to $4 million per year. Taking into account recent field investigations within the TCE-contaminated portion of the shallow bedrock aquifer, capital costs for Alternative 4 are estimated to range from $24 million to $60 million; annual costs would range from $2 million to $4 million per year. (The actual number of extraction wells required to achieve a reasonable extraction rate that would not result in dewatering of the shallow bedrock aquifer while providing wide enough coverage to prevent groundwater bypass would be determined in subsequent RD/RA reports.) This alternative is the most costly of the six alternatives considered.

On the basis of the FS (DOE and DA 1998b), capital costs for Alternative 7 are estimated to range from $23 million to $71 million; annual costs would range from $1 million to $2 million per year. Taking into account recent field investigations within the TCE-contaminated portion of the shallow bedrock aquifer, capital costs for Alternative 4 are estimated to range from $6 million to $12 million; annual costs would range from $1 million to $2 million per year. For Alternative 8, capital costs are estimated to be between $1 million and $3 million; annual costs would be approximately $0.5 million.

Capital costs for Alternative 9 are estimated to be on the order of $0.5 million and incorporate costs for the installation of injection or application wells and the application of chemical reagents. Costs for additional monitoring wells were also incorporated into this estimate. Annual costs would be approximately $0.4 million per year, primarily for long-term monitoring. This is the most cost-effective alternative with regard to TCE treatment. The cost-effectiveness determination could have been different if the cost of this remedy was significantly higher, since treatment of TCE was not needed to ensure protectiveness.

5.3 COMPARATIVE ANALYSIS OF FINAL ALTERNATIVES

This section compares the six final remedial action alternatives with regard to the nine evaluation criteria. The nine evaluation criteria are categorized into the following three groups, as stipulated in the NCP: threshold criteria, primary balancing criteria, and modifying criteria. However, the benefit (the ability to meet the ARAR for TCE in a shorter time period) gained by implementation of this alternative is commensurate to its cost.

The threshold category contains the two criteria that each alternative must meet in order to be eligible for selection:

- Overall protection of human health and the environment and
- Compliance with ARARs, unless a waiver condition applies.

These threshold criteria ensure that the remedial action selected will be protective of human health and the environment and that the action will attain the ARARs identified at the time of the ROD or provide grounds for invoking a waiver.

The primary balancing category contains the five criteria that are used to assess the relative advantages and disadvantages of each alternative:

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume through treatment;
- Short-term effectiveness;
- Implementability; and
- Cost.

Cost-effectiveness is determined by evaluating three of the five balancing criteria: long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; and short-term effectiveness. Overall effectiveness is then compared with cost to ensure that the costs are proportional to the overall effectiveness of a remedial action.

The modifying category consists of the two criteria considered in remedy selection:

- State acceptance and
- Community acceptance.

These two modifying criteria will be addressed in the responsiveness summary and ROD that will be prepared following the public comment period, and are, therefore, not addressed in the comparative analysis. The results of the comparative analysis performed for the final alternatives on the basis of the first seven criteria are summarized in Table 3.

TABLE 3 Comparative Analysis of Alternatives

	Overall protection of human health and the environment	Compliance with ARARs
Alternative 1: No Action	Like all of the alternatives, would be adequately protective of human health and the environment, although monitoring data would not be available to verify this occurrence.	Complies with ARARs; ARARs for TCE, nitrate, and nitroaromatic compounds would be met after a period of time because of source removals performed under the chemical plant ROD (DOE 1993).
Alternative 2: Monitoring with No Active Remediation	Like all of the alternatives, would be adequately protective of human health and the environment. Monitoring data would be collected to verify that conditions continue to be protective of human health and the environment.	Complies with ARARs; similar to Alternative 1.
Alternative 4: Groundwater Removal, On-Site Treatment Using GAC	Like all of the alternatives, would be adequately protective of human health and the environment.	Complies with ARARs. Could take a similar amount of time as Alternatives 1 and 2 for all contaminants to meet ARARs. However, TCE ARARs could be met in a shorter period of time.
Alternative 7: Removal and Ex-Situ Treatment of TCE-Contaminated Groundwater	Like all of the alternatives, would be adequately protective of human health and the environment. Monitoring data would be collected to verify that conditions continue to be protective of human health and the environment.	Complies with ARARs; similar to Alternatives 1 and 2 for all contaminants except TCE. The ARAR for TCE could be met in a similar amount of time as Alternative 4 but longer than Alternatives 8 and 9.
Alternative 8: In-Situ Treatment of TCE Using In-Well Vapor Stripping	Like all of the alternatives, would be adequately protective of human health and the environment. Monitoring data would be collected to verify that conditions continue to be protective of human health and the environment.	Similar to Alternative 7; could meet ARAR for TCE in a shorter period of time than Alternative 7 and in a slightly longer time than Alternative 9.
Alternative 9: In-Situ Chemical Oxidation of TCE Using Fenton-Like Reagents	Like all of the alternatives, would be adequately protective of human health and the environment. Monitoring data would be collected to verify that conditions continue to be protective of human health and the environment.	Complies with ARARs. Requires the least time to comply with ARARs for TCE as compared with all other alternatives, including Alternatives 7 and 8.

TABLE 3 (Cont.)

	Long-term effectiveness and permanence	Reduction of toxicity, mobility, or volume through treatment
Alternative 1: No Action	Is expected to afford long-term effectiveness and permanence, although investigative and monitoring activities would not be performed.	Not applicable because the contaminated groundwater would not be treated. Restoration of the water-bearing zone within the operable unit would be provided by natural processes such as biodegradation, adsorption, and chemical reactions with subsurface materials and by dilution of the contaminated groundwater with uncontaminated groundwater drawn through infiltration of rainwater and runoff.
Alternative 2: Monitoring with No Active Remediation	Provides for long-term effectiveness and performance; unlike Alternative 1, would provide verification monitoring of the groundwater within the operable unit.	Not applicable because the contaminated groundwater would not be treated. Restoration of the water-bearing zone within the operable unit would be provided by natural processes such as biodegradation, adsorption, and chemical reactions with subsurface materials and by dilution of the contaminated groundwater with uncontaminated groundwater drawn through infiltration of rainwater and runoff.
Alternative 4: Groundwater Removal, On-Site Treatment Using GAC	Would remove or reduce the contaminant concentrations through extraction and treatment and afford long-term protection.	Reduction of the toxicity, mobility, or volume associated with all groundwater contamination within the shallow bedrock aquifer would be accomplished upon successful implementation of this alternative.

TABLE 3 (Cont.)

	Long-term effectiveness and permanence (Cont.)	Reduction of toxicity, mobility, or volume through treatment (Cont.)
Alternative 7: Removal and Ex-Situ Treatment of TCE-Contaminated Groundwater	Would reduce concentrations of TCE and other contaminants present in the plume. Would provide monitoring data to verify positive impacts from source removals via the chemical plant ROD (DOE 1993). Decreases in contaminant concentrations other than TCE as a result of natural processes would also be verified via monitoring.	Reduction of the toxicity, mobility, or volume associated with TCE contamination at the chemical plant area would be accomplished. Further restoration of the water-bearing zone within the operable unit would be provided by natural processes such as biodegradation, adsorption, and chemical reactions with subsurface materials and dilution of the contaminated groundwater with uncontaminated groundwater drawn through infiltration of rainwater and runoff.
Alternative 8: In-Situ Treatment of TCE Using In-Well Vapor Stripping	TCE in the plume would be reduced or removed by treatment of groundwater. Natural processes and source removals per the chemical plant ROD (DOE 1993) are expected to result in further contaminant decreases.	Similar to Alternative 7.
Alternative 9: In-Situ Chemical Oxidation of TCE Using Fenton-Like Reagents	TCE in the plume would be reduced or removed. Natural processes and source removals per the chemical plant ROD (DOE 1993) are expected to result in further contaminant decreases.	Similar to Alternative 7.

	Short-term effectiveness	Implementability
Alternative 1: No Action	No potential impacts on workers or the environment because no activities would be undertaken.	No implementability concerns because no action would be taken nor would any future activities be considered.
Alternative 2: Monitoring with No Active Remediation	Expected to be low, with less than one case of occupational injury and no occupational fatalities during proposed monitoring well construction. Any potential short-term environmental impacts would be limited to the immediate vicinity of the operable unit, and mitigative measures would be applied to ensure minimal impacts to off-site areas.	Few implementability concerns—because of the limited actions taken. Current monitoring operations would continue with the use of readily available resources.

TABLE 3 (Cont.)

	Short-term effectiveness (Cont.)	Implementability (Cont.)
Alternative 4: Groundwater Removal, On-Site Treatment Using GAC	Expected to be relatively high compared with other alternatives because of a large number of extraction wells (between 130 to 390 wells, on the basis of recent pump test data). Construction activities are estimated to result in up to 50 cases of occupational injury and less than one occupational fatality. Any potential short-term environmental impacts would be limited to the immediate vicinity of the operable unit, and mitigative measures would be applied to ensure minimal impacts to off-site areas.	Uncertainties with implementation of this alternative are associated with the need for location (or area)-specific hydrogeologic data to verify the appropriateness of assumptions applied in the evaluations. Groundwater treatment technologies have been demonstrated at full-scale implementation for similar contaminants.
Alternative 7: Removal and Ex-Situ Treatment of TCE-Contaminated Groundwater	Expected to be low, with less than nine cases of occupational injury and no occupational fatalities during operations and well construction activities. Any potential short-term environmental impacts would be limited to the immediate vicinity of the operable unit, and mitigative measures would be applied to ensure minimal impacts to off-site areas.	Uncertainties with implementation of this alternative are associated with specific hydrogeologic data that indicate dewatering and very slow recovery of the aquifer as indicated by the recent pump test.
Alternative 8: In-Situ Treatment of TCE Using In-Well Vapor Stripping	Similar to Alternative 7.	Uncertainties with implementation of this alternative are relative to the generation of a vertical circulation pattern.
Alternative 9: In-Situ Chemical Oxidation of TCE Using Fenton-Like Reagents	Similar to Alternative 7.	Implementability indicated by recent pump test performance; introduction of materials was possible.

TABLE 3 (Cont.)

	Cost
Alternative 1: No Action	Lowest future cost.
Alternative 2: Monitoring with No Active Remediation	Could be considered cost effective because it would provide overall protection of human health and the environment for a reasonable cost. Costs would be associated with continuing the existing environmental monitoring program, constructing and operating the proposed new monitoring wells, and conducting a performance review at least every five years. Could be implemented with existing resources and maintained at a relatively low cost. Annual monitoring costs are estimated to be $0.4 million.
Alternative 4: Groundwater Removal, On-Site Treatment Using GAC	On the basis of an estimate of 130 to 390 extraction wells, capital costs are estimated to range from $24 million to $60 million, with the 30-year present worth cost estimated to range from $34 million to $73 million. Least cost-effective of the six alternatives because the degree of protectiveness provided is not commensurate with the significantly greater cost.
Alternative 7: Removal and Ex-Situ Treatment of TCE-Contaminated Groundwater	On the basis of recent pump test data obtained at the TCE area of the chemical plant, 10 to 23 extraction wells were estimated to be required. Capital costs are estimated to range from $6 million to $12 million, with the 30-year present worth cost estimated to range from $16 million to $21 million. Provides some increases in protection because of TCE removal or reduction, but at a much higher cost.

TABLE 3 (Cont.)

	Cost (Cont.)
Alternative 8: In-Situ Treatment of TCE Using In-Well Vapor Stripping	Capital cost estimated to range between $1 million and $3 million. Annual costs are estimated to be $0.4 million for monitoring.
Alternative 9: In-Situ Chemical Oxidation of TCE Using Fenton-Like Reagents	Most cost-effective for management of TCE contamination as compared with Alternatives 7 and 8; capital cost estimated to be approximately $0.5 million and includes the material costs of the chemical reagents. Annual costs are estimated to be $0.4 million and are associated with groundwater monitoring. This alternative provides an increase in protectiveness that is proportionate to the cost.

6 PREFERRED ALTERNATIVE

DOE's preferred alternative is a combination of Alternatives 2 and 9. The preferred remedial action provides remediation of the TCE-contaminated groundwater via in-situ chemical oxidation combined with long-term monitoring of groundwater and springs at the chemical plant area. The treatment method requires the introduction of Fenton-like reagents (e.g., hydrogen peroxide and a ferrous compound) into the groundwater as a means of treating TCE in place. Once introduced into the aquifer, the chemicals would produce hydroxyl radicals under controlled acidic conditions. These highly reactive radicals would then be expected to react with the TCE in the groundwater to form innocuous end products (i.e., chloride salts, carbon dioxide, and water). This chemical reaction can be completed in a relatively short period of time (days), once injection is achieved. The period of time required for remediation by using this technology is estimated to be on the order of a few months. Long-term monitoring of an optimized network of wells and springs would generate the necessary data to verify assumptions and ensure continued protection.

The preferred alternative was developed after careful consideration of the contaminant conditions at the chemical plant area and after a thorough evaluation of available and applicable technologies. The technologies evaluated in the FS (DOE and DA 1998b) represent a range of remediation options. They ranged from those considered to address all groundwater contaminants in the entire affected aquifer, to those that focused on more localized treatment of TCE only. Alternatives 2, 3, 4, 5, and 6 presented in the FS were developed and evaluated to determine their feasibility in addressing all contaminants in the affected aquifer at the chemical plant area. Alternatives 7, 8, and 9 were evaluated for their feasibility in addressing the TCE-contaminated groundwater.

Various factors were considered in the selection of the TCE-contaminated area as the focus of a more limited active remediation effort. These factors include the distribution of contaminants, contribution to estimated potential human health risk, time required to effectively evaluate the effects of source removal activities, and the complex site hydrogeology.

Distribution of Contaminants. The TCE contamination has been observed to be confined to one defined plume in the upper portion of the weathered Burlington-Keokuk Limestone. This condition makes remediation for the TCE plume more feasible and manageable. Nitrate,

nitroaromatic compounds, and uranium contamination is distributed in small, noncontiguous areas throughout the chemical plant area. Nitroaromatic contamination is observed only in the weathered unit; nitrate and uranium contamination, however, have been detected in isolated areas of the deeper, unweathered portion of the Burlington-Keokuk limestone.

Contribution to Potential Risk. On the basis of risk calculations presented in the BRA (DOE and DA 1998a), TCE has been indicated to contribute the most to the estimated potential human health risk. The removal or reduction of TCE concentrations from groundwater would reduce these estimates to acceptable levels for a hypothetical residential scenario. Current levels for TCE are already protective for current land use, which is that for a recreational user. Land use in the foreseeable future is expected to be similar to current land use.

Time Required to Effectively Evaluate the Effects of Source Removal Activities. Although individual or isolated areas with nitrate, nitroaromatic compounds, and uranium contamination were also considered in terms of "hot spot" cleanup, implementation of an active remediation effort to address these areas would be premature because source removal activities are currently taking place and in the final stages under the chemical plant ROD (DOE 1993). Final sources to be removed include the Ash Pond and the raffinate pits; nitrate, nitroaromatic compounds, and uranium contamination are located primarily in the vicinity of the Ash Pond and the raffinate pits. The full benefit of source removal in attenuating the groundwater concentrations of these contaminants could not be gleaned until several years from now. Data obtained from a long-term monitoring effort would provide the needed information to evaluate any future positive impacts from the source removals. These data would also allow for the verification of whether protective conditions continue to exist or whether additional action maybe necessary to ensure protectiveness. It is expected that decreasing concentrations of nitroaromatic compounds and uranium would be observed, similar to those observed in the groundwater at the Weldon Spring Quarry as a result of quarry bulk waste removal. The source removals are also expected to result in decreasing nitrate concentrations within a relatively short period of time (i.e., several years).

Complex Site Hydrogeology. The results of the evaluation presented in the FS (DOE and DA 1998b) indicate that the success of implementing Alternatives 4 and 7 (alternatives involving groundwater extraction) would be limited by the complex hydrogeology and heterogeneous geology of the site. Previous investigations indicate that the average sustainable yield from the Burlington-

Keokuk limestone is 0.3 gallon per minute (gpm). These wells were constructed in both the weathered and unweathered portions of the bedrock unit. Because uranium and nitrate contamination is observed in both the weathered and unweathered portions of the Burling-Keokuk Limestone, evaluations of the implementability of the groundwater extraction remedial alternative were made on the basis of the 0.3 gpm extraction rate. This particular characteristic of the aquifer results in implementability limitations.

In an effort to obtain additional information to use further examining the technologies considered for the TCE-contaminated area, additional field studies were performed. Since TCE contamination has been limited to only the upper weathered unit, field studies were concentrated in this portion of the aquifer. A pump test was conducted to determine the response of the aquifer to groundwater withdrawal. This test indicated that although the aquifer was more transmissive than previously estimated, recharge to this portion of the aquifer is limited by structural controls, which results in dewatering of the area. This information, in addition to other hydrogeologic parameters estimated from this field study, was useful in the determination that the application of a pump-and-treat technology is not feasible.

In addition, the aquifer characteristics derived from the field study, coupled with the predominantly horizontal bedding and fracturing of the limestone aquifer, indicate that the generation of a vertical circulation pattern may be difficult. This particular circulation pattern is critical for the successful implementation of an in-well stripping technology, a technology required for Alternative 8.

A subsurface tracer test was also performed in the area affected by TCE to establish groundwater movement patterns in this area. During the test, potable water was allowed to flow under gravity drainage into the subsurface to facilitate the movement of the tracer. This area of the aquifer (i.e., upper weathered zone) accepted an injection rate of 25 gpm. These data suggest that technologies such as that of Alternative 9, which require the introduction of materials into the subsurface, could be feasible in this portion of the aquifer.

In summary, the preferred alternative is expected to result in a more immediate decrease in TCE concentrations and provide monitoring data to verify assumptions and ensure continued protectiveness. The preferred alternative meets the first seven criteria in that it is expected to provide

overall protection to human health and the environment; meets ARARs; provides long-term effectiveness and permanence; reduces toxicity, mobility, or volume through treatment of the TCE plume; provides for short-term effectiveness; and is implementable and cost effective.

Activities related to the design of an optimum monitoring network of wells, the monitoring scheme, and details regarding the design and implementation of the TCE remediation effort via in-situ chemical oxidation would be presented in subsequent RD/RA reports. As required by CERCLA, a review would be conducted every five years because contaminants would remain in the site groundwater at levels above those that allow for unlimited use and unrestricted exposure.

7 COMMUNITY PARTICIPATION

Input from the public is an important element of the decision-making process for cleanup actions at the chemical plant area. Comments on the proposed remedial action will be received during the public review period (tentatively planned for March, 1999) following issuance of this document. Oral comments will be received at a public meeting to be held for this action. Written comments may be either submitted at the public meeting or mailed before the close of the comment period to:

Stephen H. McCracken
Project Manager for WSSRAP
U.S. Department of Energy
Weldon Spring Site Remedial Action Project Office
7295 Highway 94 South
St. Charles, Missouri 63304

Information relevant to the proposed remedial action is located in the administrative record and public document rooms at the WSSRAP site office. Additional information repositories have been established at the following five locations:

Kathryn M. Linneman Branch
St. Charles City/County Library
2323 Elm Street
St. Charles, Missouri 63301

Francis Howell High School
7001 Highway 94 South
St. Charles, Missouri 63304

Spencer Creek Branch
St. Charles City/County Library
427 Spencer Road
St. Peters, Missouri 63376

Middendorf-Kredell Library
St. Charles City/County Library
2750 Highway K
O'Fallon, Missouri 63366

Kisker Road Branch
St. Charles City/County Library
1000 Kisker Road
St. Peters, Missouri 63304

Information on file at these repositories includes the RI (DOE and DA 1998c), BRA (DOE and DA 1998a), FS (DOE and DA 1998b), and this proposed plan for remedial action. Supporting technical reports are available in the public reading room at the WSSRAP site office. For additional information, the DOE can be contacted at the address provided above. The telephone number for the

WSSRAP site office is (314) 441-8086. The remedial project manager for the EPA who can supply additional information is:

Mr. Daniel Wall
U.S. Environmental Protection Agency
Region VII
726 Minnesota Avenue
Kansas City, Kansas 66101
(913) 551-7710

8 REFERENCES

American Cancer Society, 1992, *Cancer Facts & Figures—1992*, Atlanta, Georgia.

DOE and DA: see U.S. Department of Energy and Department of the Army.

EPA: see U.S. Environmental Protection Agency.

Meyer, L., 1993, "Number of Students and Employees at Francis Howell High School," "Report of Telecon" (conversation with D. Oakly, Francis Howell School District) from L. Meyer to J. Reitinger (MK-Ferguson Company, Weldon Spring Site Remedial Action Project, St. Charles, Mo.), Nov. 5.

National Safety Council, 1995, *Accident Facts*, 1995 Edition, Itasca, Ill.

U.S. Army Corps of Engineers, 1989, *Computer Aided Cost Engineering Support System: Description and Overview*, Office of the Chief of Engineers, May 1.

U.S. Department of Energy, 1992, *Remedial Investigation for the Chemical Plant Area of the Weldon Spring Site*, DOE/EIS-0185D (DOE/OR/21548-074, Vol. I), prepared by MK-Ferguson Company and Jacobs Engineering Group, Inc., Weldon Spring, Mo., for U.S. Department of Energy, Oak Ridge Field Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Mo., Nov.

U.S. Department of Energy, 1993, *Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site*, DOE/OR/21548-376, prepared by U.S. Department of Energy, Oak Ridge Field Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Mo., Sept.

U.S. Department of Energy, 1998, *Weldon Spring Site Environmental Report for Calendar Year 1997, Revision 0*, DOE/OR/21548-730, prepared by MK-Ferguson Company and Jacobs Engineering Group, St. Charles, Mo., for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tenn., Aug.

U.S. Department of Energy and U.S. Department of the Army, 1998a, *Baseline Risk Assessment for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area, Weldon Spring, Missouri*, DOE/OR/21548-568, Draft Final, prepared by Argonne National Laboratory, Argonne, Ill., for U.S. Department of Energy, Weldon Spring Site Remedial Action Project, Weldon Spring, Mo., and U.S. Department of the Army, Corps of Engineers, Kansas City District, Kansas City, Mo., March.