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ANNUAL ENVIRONMENTAL MONITORING REPORT 1988

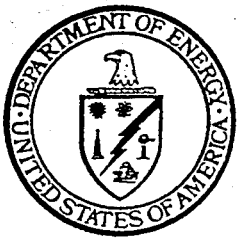
For The :

Weldon Spring Site Remedial Action Project

Weldon Spring, Missouri

Prepared By MK-Ferguson Company And Jacobs Engineering Group

JUNE 1989 REV. 0



U.S. Department Of Energy

Oak Ridge Operations Office

Weldon Spring Site Remedial Action Project

Weldon Spring Site Remedial Action Project

Annual Environmental Monitoring Report 1988

Revision 0

June 1989

Prepared by
MK-FERGUSON COMPANY
and
JACOBS ENGINEERING GROUP
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St. Charles, Missouri 63303

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Oak Ridge Operations Office
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ABSTRACT

Numerous exposure pathways were monitored in 1988, including groundwater, surface water, and air. Analytical parameters included radionuclides, nitroaromatic compounds, inorganic anions, and direct gamma exposure. The results are being used to calculate exposure doses (where applicable) so the impact of the site on potentially exposed populations can be assessed.

Off-site exposures did not dramatically increase in 1988 over exposures calculated in previous years. Contaminated groundwater did not affect private water supplies or the St. Charles County Well Field. Surface water containing elevated uranium activity continued to impact the Femme Osage Slough and several lakes in the August A. Busch Memorial Wildlife Area. Radon exposures increased slightly in 1988 due to the unusually dry conditions. Off-site gamma and air particulate exposures remained indistinguisable from background. Off-site monitoring demonstrated that exposure at the Francis Howell High School, the Busch Wildlife Area Headquarters, and the Weldon Spring Training area is indistinguishable from background levels. No spills occurred at the Weldon Spring Site in 1988.

Numerous characterization activities have increased the overall understanding of contamination and transport pathways. This increased understanding has led to an improved monitoring program in 1989.

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1 INTRODUCTION

This report presents the findings of the environmental monitoring program conducted at the Weldon Spring Site (WSS) in 1988. Annual environmental monitoring reports have been prepared for this site (or portions thereof) since 1981. The WSS is part of the Department of Energy (DOE) Surplus Facilities Management Program (SFMP), one of two remedial action programs under the direction of the DOE Division of Facility and Site Decommissioning Projects. The WSS comprises the Weldon Spring Raffinate Pits (WSRP), the Weldon Spring Chemical Plant (WSCP), and the Weldon Spring Quarry (WSQ). These areas encompass 20.7, 67.2 and 3.6 hectares (ha) (51, 166, and 9 acres), respectively. The WSRP and WSCP areas are contiguous. The WSQ is approximately 6.4 km (4 miles) to the south-southwest.

When custody of the WSCP was transferred in 1985 from the Department of the Army (DA) to the DOE, the WSCP became part of the WSS. In conjunction with this transfer, the Weldon Spring Site Remedial Action Project (WSSRAP) was created as DOE Major Project Number 182 (DOE Order 4240.1E - 05/14/85). Consistent with the DOE mission under SFMP, the WSSRAP will eliminate potential hazards to the public and the environment and make surplus real property available for other uses.

During the years 1981 through 1985, the WSRP and WSQ were under the caretaker status of the DOE. The WSCP was controlled by the DA. The DOE conducted environmental monitoring programs during this period to identify changes (if any) in the radiological levels in and around the WSRP and WSQ. The DA did not collect environmental monitoring data in and around the WSCP. When the WSCP was transferred to the DOE in 1985, the DOE began revision of the overall Environmental Monitoring Program to more adequately determine the levels of contamination in and around the WSCP, WSRP, and the WSQ. Six additional monitoring

wells were installed in the WSQ area in 1986, seven more were installed in 1987, and nine in 1988. In 1986, 19 new wells were installed around the WSCP at previously unmonitored locations. In 1988, another 33 wells were installed in and around the WSCP/WSRP. Many of these wells were installed for characterization purposes. Not all of these wells were included in routine environmental monitoring. In addition, air particulate samplers were installed around the WSS perimeter and at nearby locations in late 1986. A more complete description of the much expanded WSS Environmental Monitoring Program Plan (EMPP) (MKF and JEG, 1987) for 1988 is provided in Section 1.4 of this report.

DOE Order 5400.1 requires that an environmental radioactivity monitoring program be maintained at existing sites and, as determined on a case-by-case basis, at certain former sites to determine:

- Background levels and site contribution of radioactivity and other pollutants to the site environs from DOE operations.

- Compliance with applicable and appropriate environmental standards for radioactivity and other pollutants specified by the DOE and the U.S. Environmental Protection Agency (EPA).

- Compliance with environmental commitments in official documents such as environmental impact statements and Federal Facility Compliance Agreements (FFCA).

This DOE Order also requires a listing of environmental permits. The only permit in effect at the WSS in 1988 was the National Polution Discharge Elimination System - Storm Water

Runoff Permit Number MO-0107701. Compliance with this permit is discussed in Section 2.2.1 of this report.

This Annual Environmental Monitoring Report 1988 explains how the WSSRAP environmental monitoring program meets these requirements. Section 2 reports the results of the measurements and compares the environmental levels of radioactivity and chemical contaminants released from the site with applicable standards.

In addition to the routine environmental monitoring conducted in 1988, a number of related activities and special studies were performed. These activities and studies are directly applicable to the assessment of the overall impact of site operations on the environment. Therefore, these activities are described and the results are discussed in Section 3.

Section 4 presents calculations, based on the 1988 sampling results, of the maximum radiation dose to a hypothetical maximally exposed individual at the WSCP/WSRP and WSQ areas. Calculations of the doses to the general population in the vicinity of the WSS are also reported.

For definitions of the uncommon technical terms used in this report, the reader may consult Appendix B. Although each acronym used in this report is defined when it is first used in each main section, a list of all abbreviations used is provided in Appendix C. Appendix D contains a description of the quality assurance methods that are applied to sampling and analysis activities in this monitoring program. Appendix E presents a discussion of the environmental guidelines that apply to the monitoring program. Appendix F provides a useful conversion table, and Appendix G the distribution list for this report.

1.1 LOCATION AND DESCRIPTION

The WSS is located in St. Charles County, Missouri, about 48 km (30 miles) west of St. Louis. The WSRP and WSCP areas are accessed from Missouri State Route 94, approximately 3.2 km (2 miles) southwest of the junction of Route 94 and U.S. Route 40/61. The WSQ is accessed from Route 94, approximately 6.4 km (4 miles) south-southwest of the WSRP and WSCP areas. The Missouri River is located approximately 2.4 km (1.5 miles) southeast of the WSRP and WSCP areas and 1.6 km (1 mile) east of the WSQ. The Mississippi River lies approximately 22.4 km (14 miles) northeast of the WSRP and WSCP areas and roughly 28.8 km (18 miles) northeast of the WSQ. The general locations of these properties are illustrated in Figure 1-1.

Uranium and thorium residues, waste materials, and contaminated rubble are stored at the WSS. In addition to environmental monitoring, engineering activities are being conducted to minimize the migration of contaminants from these facilities into surface water and groundwater.

Extensive characterization activities have been conducted at the WSCP and WSRP during 1988 and more are in progress in all areas of the WSS. These activities provide information on the types and magnitudes of the contamination. This information will be presented in a Remedial Investigation (RI) report and used to evaluate the course of remedial actions. Brief descriptions of each major area of the site are given below.

Weldon Spring Raffinate Pits

Figure 1-2 is an aerial view of the WSRP area with part of the WSCP in the background. The 20.7-ha (51-acre) area includes four pits that cover approximately 10.5 ha (26 acres) (see Figure 1-3). The raffinate pits were constructed by excavating

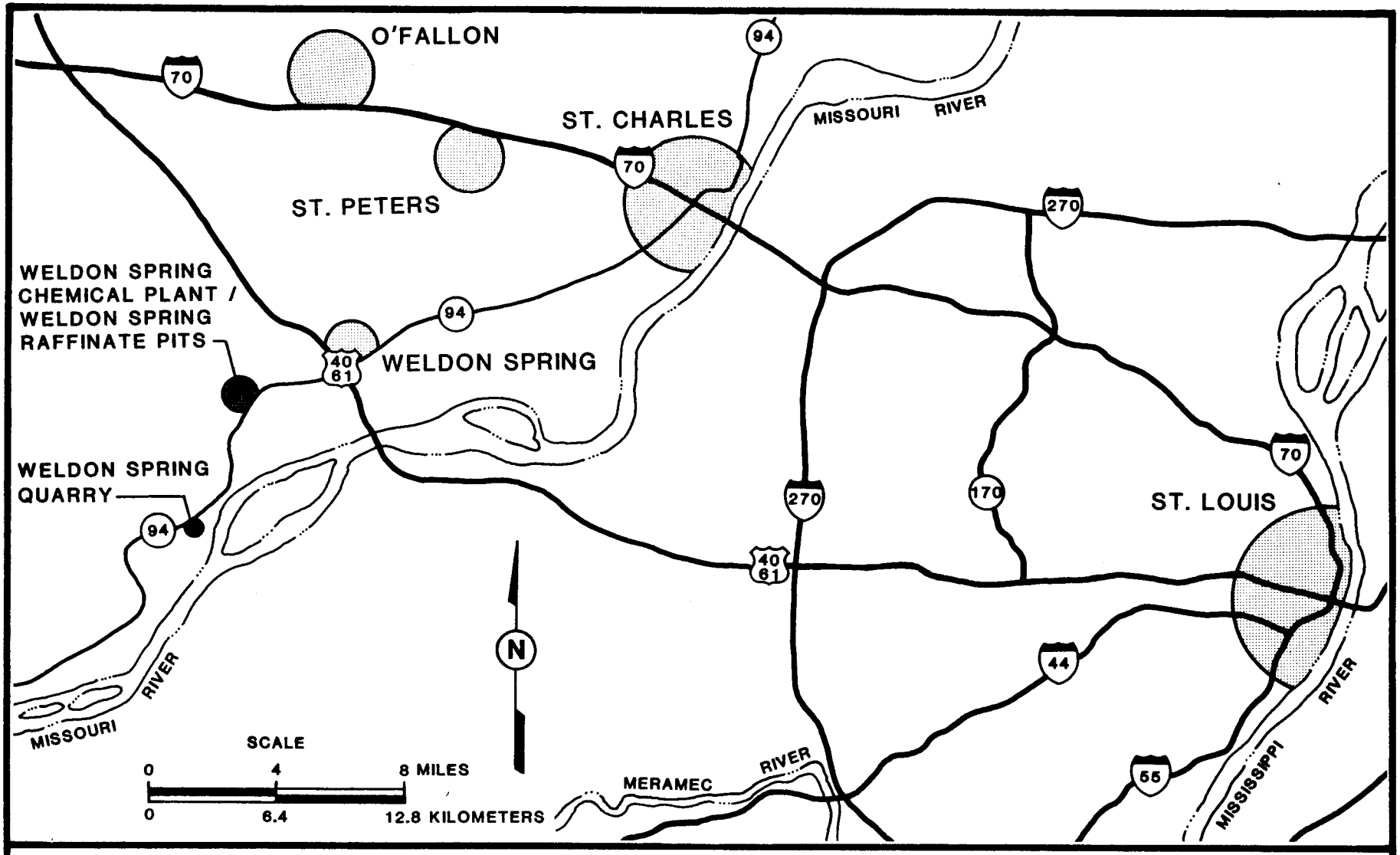


FIGURE 1-1

LOCATION OF THE WELDON SPRING SITE

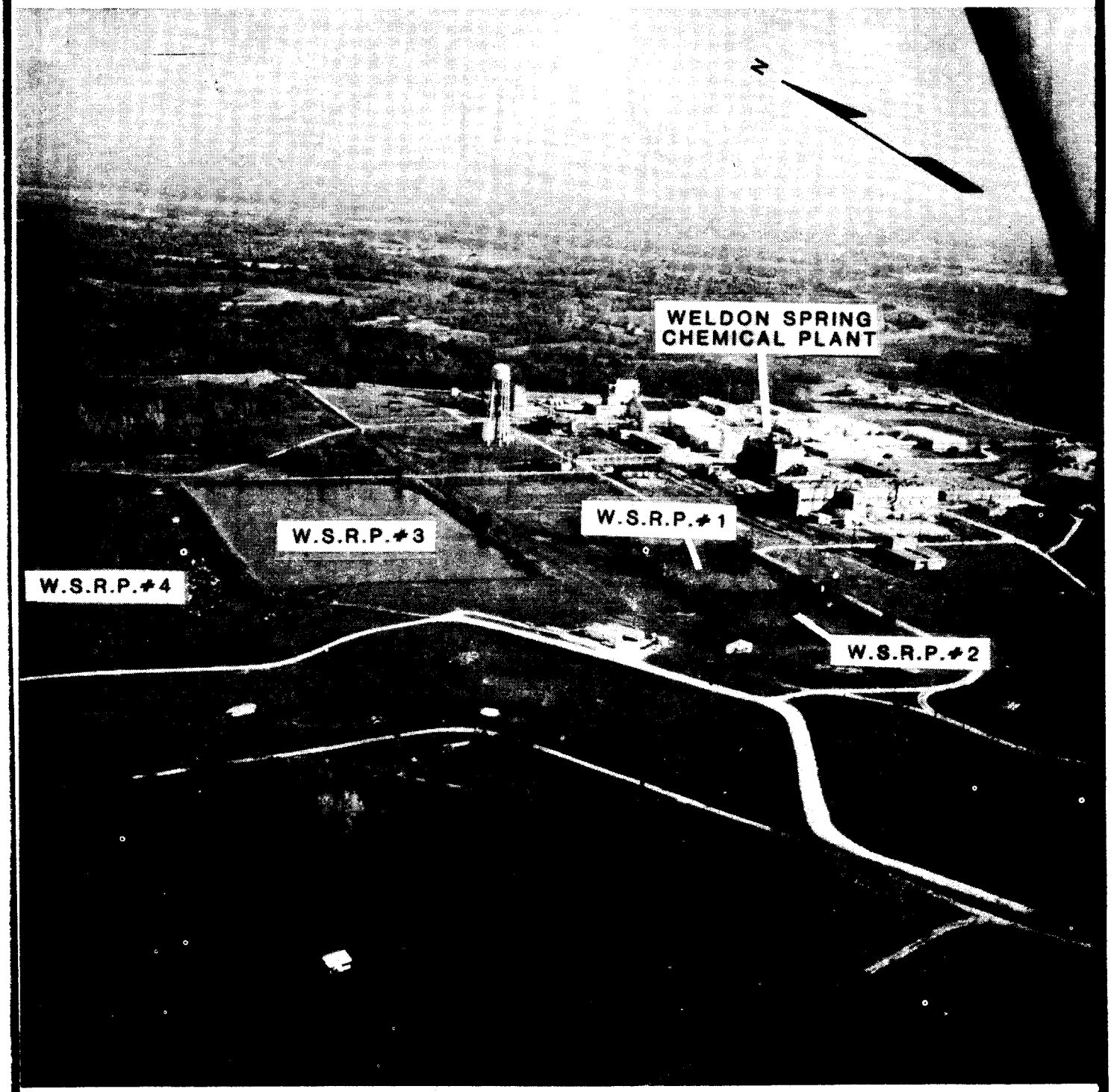


FIGURE 1-2

AERIAL PHOTOGRAPH OF THE WSRP AREA

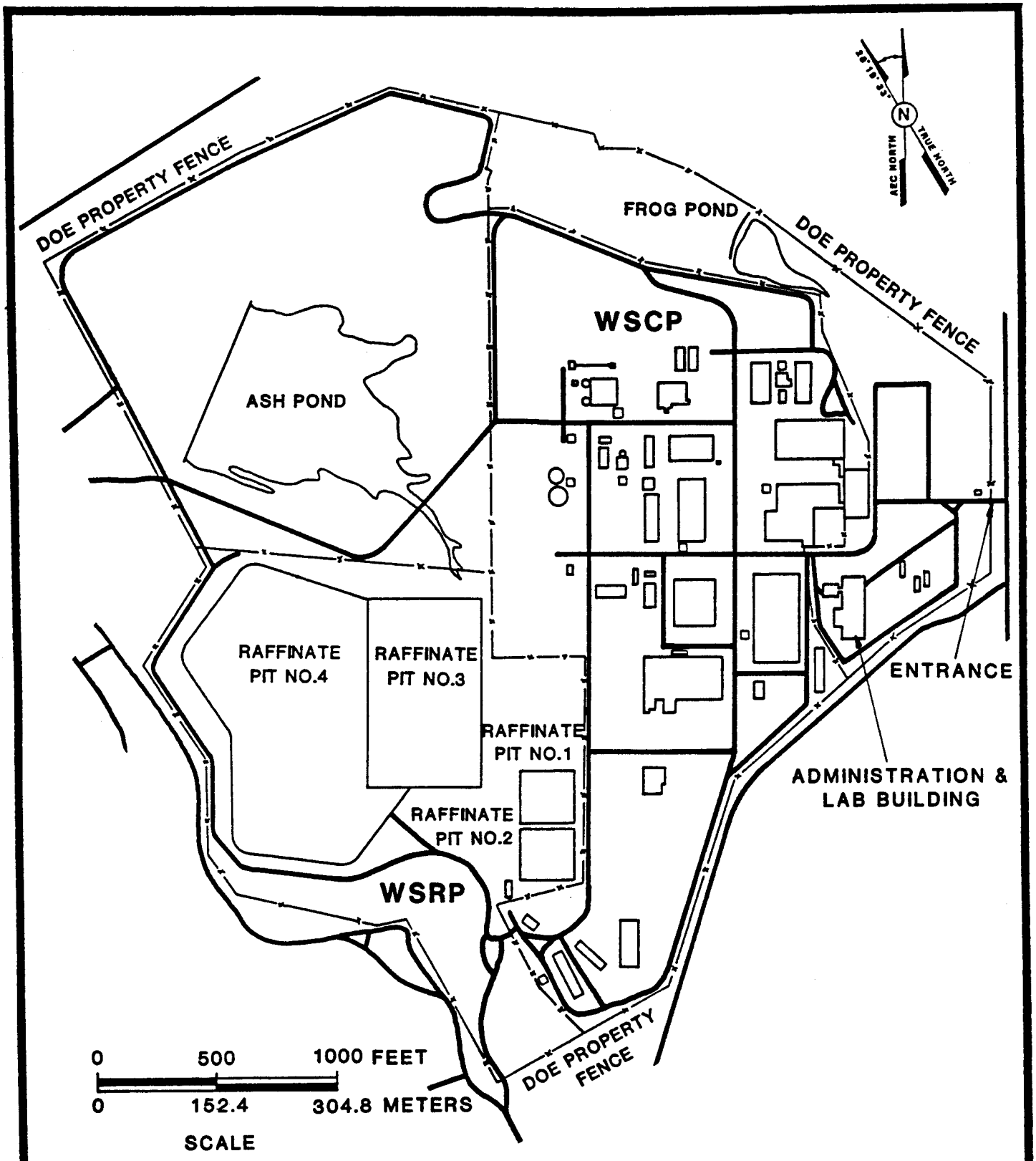


FIGURE 1-3

MAP OF THE WSCP & WSRP

into the existing clay soils and using the removed clay for construction of dikes. These pits contain radioactive residues (raffinates) from uranium and thorium processing operations at the former Weldon Spring Uranium Feed Materials Plant (WSUFMP) which is now the WSCP. Section 3.4 provides specific information regarding the WSRP.

Access to the area is controlled by a 2.1-m (7 ft.) high fence that encloses the DOE property. In addition, each pit is enclosed by a fence at least 1.3 m (4 ft) high. The pit drains and all transfer lines from the pits to the WSCP process sewer have been sealed (Ficker, 1981). Water normally covers the residues in the pits.

Weldon Spring Chemical Plant

The 67.2-ha (166-acre) WSCP is located to the north and east of the WSRP area (Figure 1-3). The WSCP, which operated as the Weldon Spring Uranium Feed Materials Plant until 1966, comprises 13 major buildings and approximately 30 smaller buildings. Of the former, five were used as process buildings, and eight were major support buildings. The entire site is fenced. Access is controlled at a manned gate-house and site security is presently maintained by guards routinely patrolling the site 24 hours per day.

The interiors of the eight major buildings are heavily contaminated with uranium that is mostly "fixed" on surfaces. The rest of the buildings contain only small quantities of uranium contamination.

Surface water drains from the WSCP primarily in three channels. These lead from outlet structures in Ash Pond and Frog Pond, and from a storm-water system which exits the site to the southeast. These drainageways are more thoroughly discussed

in Sections 1.3 and 2.2. Both Ash Pond and Frog Pond contain significant uranium levels from past operations at the WSUFMP. Surface water drains into these ponds where it picks up soluble uranium and continues off site.

Small quantities of chemically hazardous substances are also present both in the buildings and as contamination in the soil in several areas of the site. These substances include asbestos, PCBs, dinitrotoluene, ammonia, hydrofluoric acid, sulfuric acid, and nitric acid.

Weldon Spring Quarry

The WSQ, an abandoned 3.6-ha (9-acre) limestone quarry, is located approximately 6.4 km (4 miles) south-southwest of the WSRP/WSCP area. Figure 1-4 is an aerial photograph of the WSQ. As shown in Figure 1-5, the WSQ is accessible at both the upper and lower levels from Missouri State Route 94. An unused railroad spur enters the site at the lower level and extends approximately one-third the length of the WSQ. The WSQ is essentially a closed basin; surface water within the rim flows to the quarry floor and into a pond which covers approximately 0.2 ha (0.5 acre). The pond contains approximately 12 million liters (3 million gallons) of water and is 6.1 m (20 feet) deep at its deepest point. The amount of water in the pond varies according to seasonal variations in precipitation and evaporation.

The only structures at the WSQ site are a small storage shed and a sampling platform in the pond area. Access to the site is restricted by a locked, 2.1-m (7-ft) high chain link fence. The amounts and types of known wastes in the WSQ are summarized in Table 1-1.

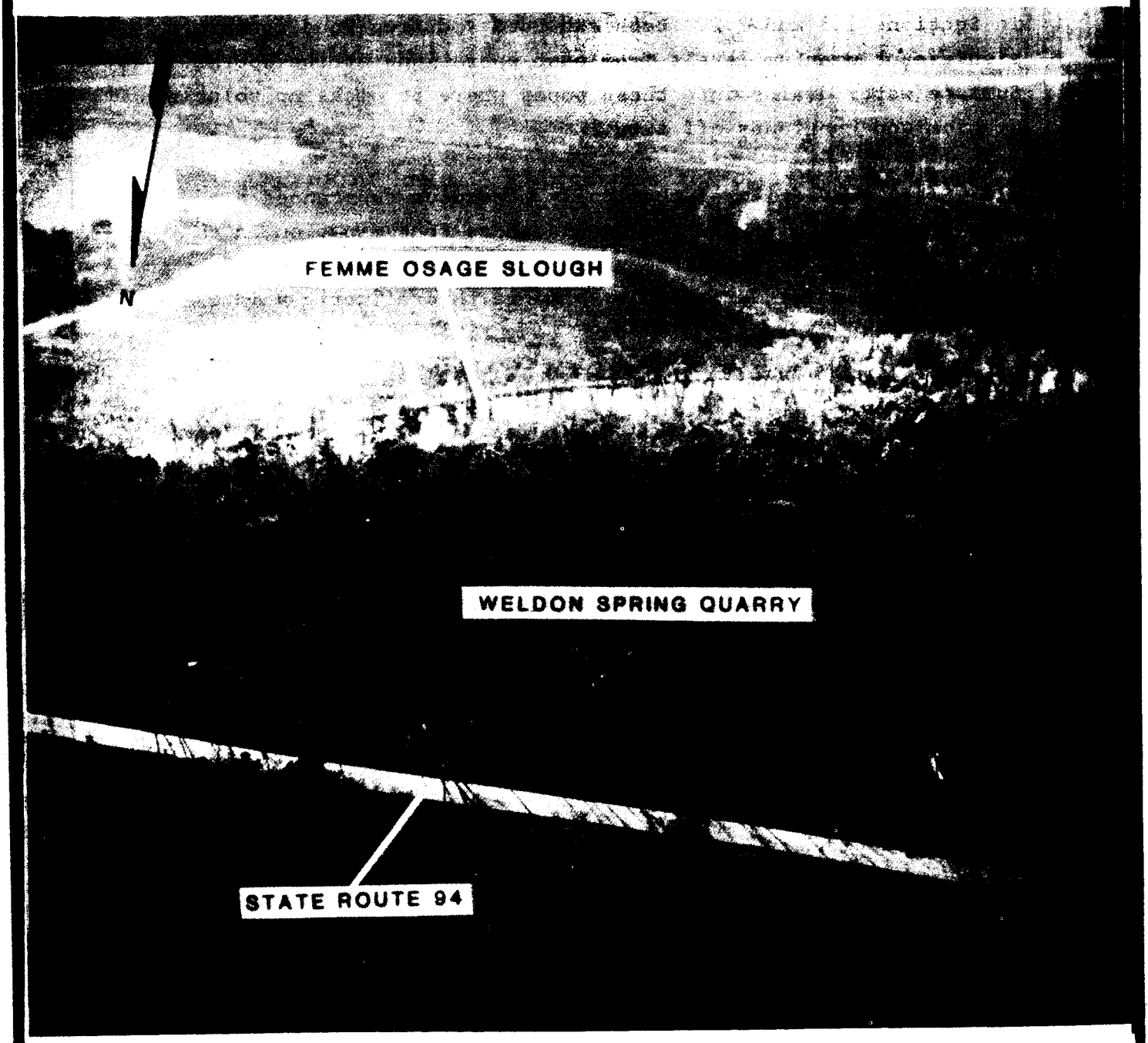


FIGURE 1-4

AERIAL PHOTOGRAPH OF THE WSQ

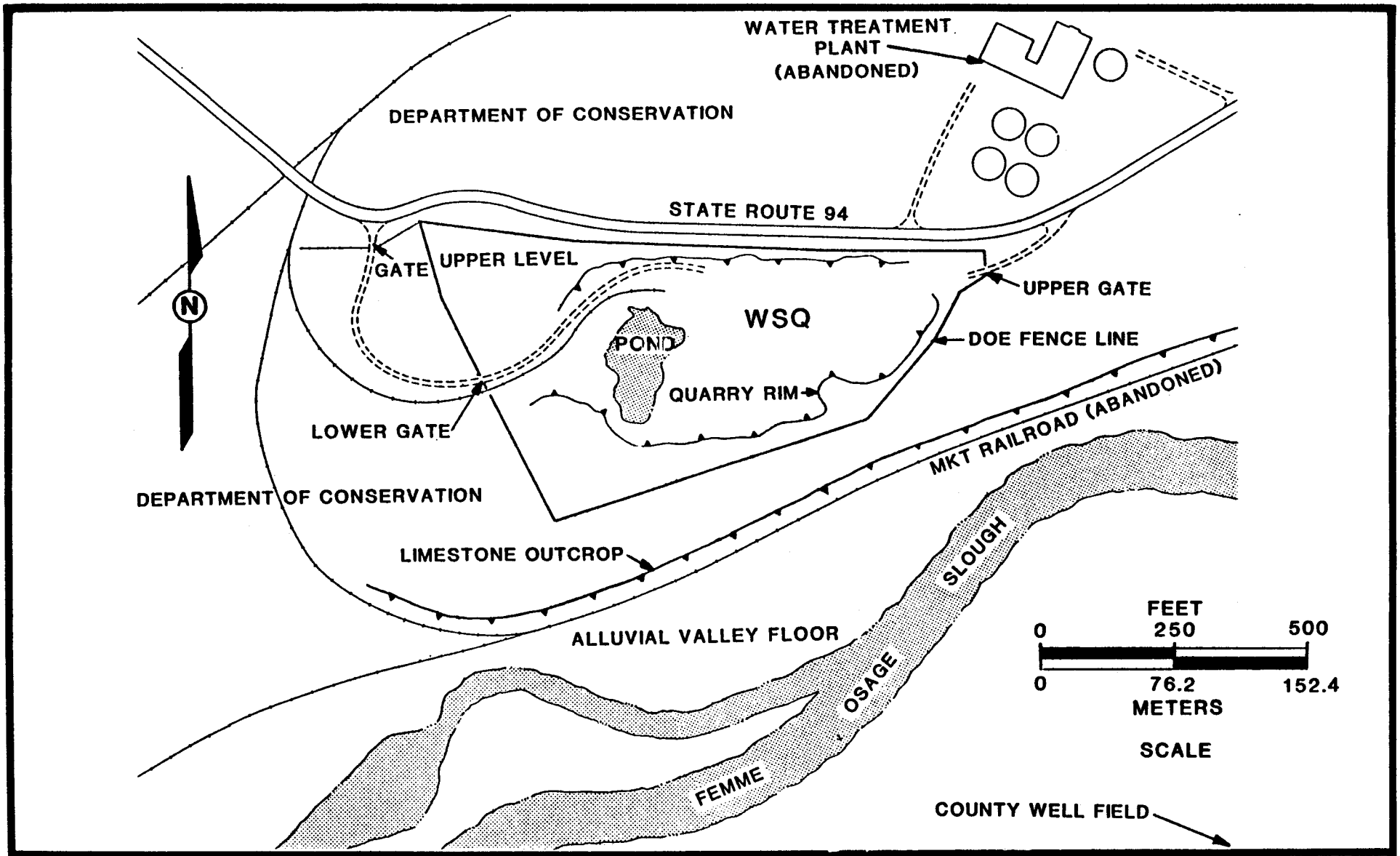


FIGURE 1-5

MAP OF THE WSQ

TABLE 1-1
ESTIMATED VOLUMES OF WASTES STORED IN THE WELDON SPRING QUARRY

Type of Waste	Date Deposited	Volume in Cubic Meters (cubic yards)	Comments
TNT/DNT Residues	1942-1945	Unknown	WSQ used as a burn pit for TNT/DNT wastes by the Army.
Nitroaromatic Residues	1946	90 Tons	Quarry used as burn pit for TNT/DNT wastes.
TNT Residues	1946-1957	Unknown	Residues and rubble dumped in deepest part of the Quarry and in northeast corner.
3.8 Percent Thorium Residues	1959	140.1 (185)	Drummed residues; volume estimated; most of the residues under water; principal source of radioactivity is thorium-232 decay series.
Destrehan St. Plant Demolition Rubble	1960-1961	38,000 (50,000)	Contaminated equipment, building rubble; estimate of uranium and thorium content not available; principal source of radioactivity in uranium-238 decay series.
High Thorium/ Rare Earth Wastes From DA Granite City Arsenal	1963-1965	760 (1,000)	Fraction of drummed residues later recovered for the rare earth elements.
Thorium Residues	1966	Unknown	Drums and residues from shutdown and cleanup of Weldon Spring Chemical Plant process equipment.
3 Percent Thorium Residues	1966	400 (500)	Drummed residues; volume estimated; stored above water level; principal source of radioactivity is thorium-232 decay series.
TNT/DNT Residues	1966	Unknown	Army disposed of TNT residues over the thorium. This material is currently exposed at the upper end of the quarry.
Weldon Spring Feed Materials Rubble	1968-1969	4,000 (5,000)	Contaminated equipment, building rubble; uranium and thorium content and radioactivity not available; Plant principal sources of radioactivity are uranium-238 and thorium-232 decay series.

1.2 SITE HISTORY

In April 1941, the Department of the Army acquired 6,977 ha (17,232 acres) of land where, from November 1941 through January 1944, Atlas Powder Company operated a trinitrotoluene (TNT) and dinitrotoluene (DNT) explosives production facility known as the Weldon Spring Ordnance Works (WSOW). The WSOW was closed and declared surplus to Army needs in April 1946. By 1949, all but approximately 810 ha (2,000 acres) had been transferred to the State of Missouri (August A. Busch Memorial Wildlife Area) and the University of Missouri (agricultural land). Except for several small parcels transferred to St. Charles County, the remaining property became the Weldon Spring U.S. Army Reserve and National Guard Training Area (WSTA).

Through a Memorandum of Understanding between the Secretary of the Army and the General Manager for the Atomic Energy Commission (AEC), 83 ha (205 acres) of the former WSOW were transferred in May 1955 to the AEC for construction and operation of the WSUFMP to process uranium and thorium ore concentrates. Considerable explosives decontamination was performed by Atlas Powder and the DA prior to WSUFMP construction (DA, 1976).

The WSUFMP was operated as an integrated facility for the conversion of processed uranium ore concentrates to pure uranium trioxide, intermediate compounds, and uranium metal. A relatively small amount of thorium was also processed. Wastes generated during these operations were stored in the four raffinate pits. The WSUFMP ceased operations in 1966.

In 1958, the AEC acquired title to the WSQ from the DA. The WSQ had been used earlier by the DA for disposal of TNT-contaminated rubble during the operation of the WSOW. The AEC used the WSQ as a disposal area for a small amount of

thorium residue, but most of the material disposed of there consisted of uranium and radium contaminated building rubble and soils from the demolition of a uranium ore processing facility in St. Louis. Approximately 38,000 cubic meters (50,000 cubic yards) of contaminated materials from the St. Louis facility (Destrehan Street Facility) were deposited in the WSQ (See Table 1-1) (NLCO, 1977).

The WSUFMP was shut down in 1966, and in 1967 the AEC returned the facility to the DA for use as a defoliant production plant (to be known as the Weldon Spring Chemical Plant). The Army started removing equipment and decontaminating several buildings in 1968. Approximately 4,222 cubic meters (5,555 cubic yards) of contaminated material were hauled to the WSQ. In addition, an undetermined amount of contaminated piping, ducting, drums, and other scrap were dumped into Raffinate Pit 4.

The defoliant project was cancelled in 1969 before any process equipment was installed. The DA retained the responsibility for the land and the facilities at the WSCP, but the 20.7-ha (51-acre) tract encompassing the raffinate pits was transferred back to the AEC. The 3.6-ha (9-acre) WSQ also remained under the control of the AEC. The AEC contracted with National Lead Company of Ohio (NLCO) to visit the WSRP and WSQ sites periodically for environmental monitoring and maintenance of the pit embankments, and to perform other maintenance and surveillance tasks as necessary. In October 1981, Bechtel National, Incorporated, (BNI) under contract to the DOE (successor to the AEC), assumed management of the WSRP and WSQ. BNI managed the facilities in caretaker status until 1986.

In November 1984, the DOE was directed by the Office of Management and Budget to assume custody and accountability for the WSCP from the DA. This transfer occurred on October 1, 1985.

In February 1985, the DOE proposed designating the control and decontamination of the WSRP, WSCP, and WSQ as a major project. Designation was effected by DOE Order 4240.1E dated May 14, 1985. A Project Management Contractor (PMC) for the Weldon Spring Site Remedial Action Project (WSSRAP) was selected in February 1986. In July 1986, a DOE project office was established on site. The PMC, MK-Ferguson Company, assumed control of the WSS on October 1, 1986. The WSQ was placed on the National Priorities List (NPL) in July 1987. The WSCP/WSRP was added to the NPL in March 1989.

1.3 ENVIRONMENTAL SETTING

The WSRP/WSCP area is located on the Missouri-Mississippi River surface-drainage divide. The topography is gently undulating and generally slopes northward to the Mississippi River. To the southeast are bluffs that overlook the Missouri River floodplain. Though the bedrock under the site is fractured, it is overlain by low permeability clays ranging from one to 9 m (3 to 30 feet) thick.

Four separate units make up the unconsolidated materials overlying competent bedrock at the WSCP/WSRP. The deposits in descending order are loess, Ferrelview clay, glacial till, and weathered bedrock. These overburden units are generally not saturated, but perched lenses exist.

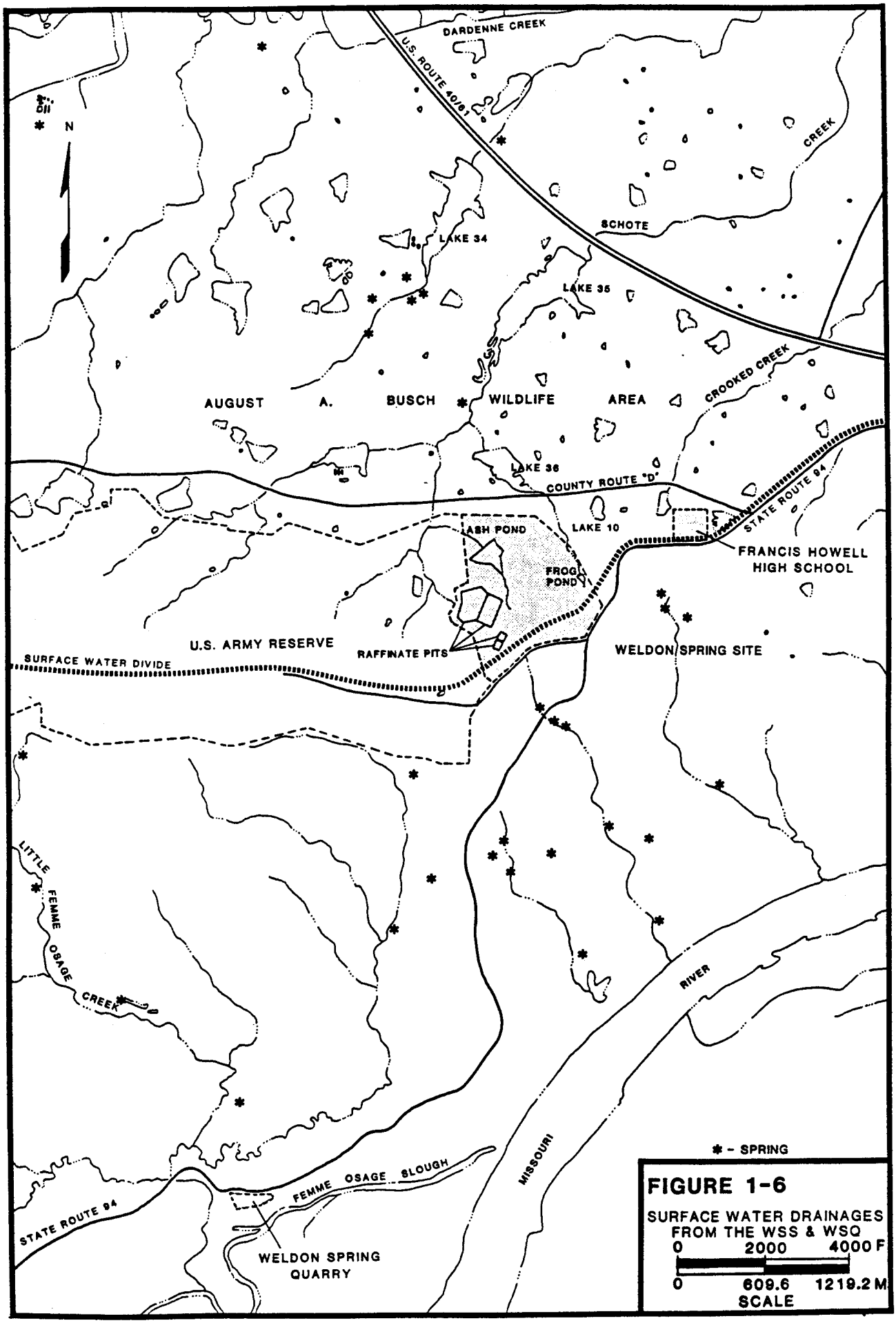
Burlington-Keokuk cherty limestone is the first bedrock unit and the first aquifer underlying the WSCP/WSRP. Bedrock topography varies in elevation from about 178.3 m (585 ft) mean sea level (MSL) to 193 m (635 ft) msl.

The Burlington-Keokuk limestone is vertically fractured with two primary joint sets trending between N30^{o}E and N72^{o}E and between N30^{o}W and N65^{o}W (BNI, 1987) and is susceptible

to natural solution processes. Burlington-Keokuk solution features normally develop along fractures and bedding planes. Most solution features are small (up to several centimeters wide) and may or may not be clay filled. No collapse sinks (i.e. sinkholes) are known to exist in the Burlington-Keokuk formation on or near the WSCP/WSRP area.

Streams do not cross the properties, but incipient drainageways convey surface water runoff to off-site streams. Most surface drainage from the WSRP area discharges either via an intermittent stream in the Army Reserve Training Area to the west or into Ash Pond on the WSCP property as shown in Figure 1-6. Discharges from the intermittent stream and Ash Pond combine near County Road D and flow northward into Schote Creek, which in turn, enters Dardenne Creek, which discharges into the Mississippi River. An additional surface drainage system reaching the Mississippi River exits the WSCP area from Frog Pond. Frog Pond drains storm-water from most of the plant area where concrete surfaces drain into a storm-water sewer. Surface water from the northeastern portion of the WSCP also drains to Frog Pond. Frog Pond drainage also enters Schote Creek. Dardenne Creek, portions of Schote Creek, and lakes on the August A. Busch Memorial Wildlife area support aquatic life and are accessible to the public for recreational activites (such as fishing). Species include black bass, channel catfish, and sunfish.

Drainage from the southern portion of the WSCP property flows southeast to the Missouri River. This drainage originates from two sources. The first is the sanitary and process sewer systems which merge prior to discharge from the WSCP. The sanitary sewer system was taken out of service in 1986, but it receives some leakage from the storm-water runoff system. The second source is surface runoff from the southern portion of the site.


DARDENNE CREEK
U.S. ROUTE 40/61
N
CREEK
SCHOTE
LAKE 34
LAKE 35
AUGUST A. BUSCH WILDLIFE AREA
CROOKED CREEK
LAKE 36
COUNTY ROUTE "D"
STATE ROUTE 94
ASH POND
LAKE 10
FROG POND
FRANCIS HOWELL HIGH SCHOOL
U.S. ARMY RESERVE
RAFFINATE PITS
WELDON SPRING SITE
SURFACE WATER DIVIDE
LITTLE FEMME OSAGE CREEK
RIVER
* - SPRING
FEMME OSAGE SLOUGH
MISSOURI
STATE ROUTE 94
WELDON SPRING QUARRY
FIGURE 1-6
SURFACE WATER DRAINAGES FROM THE WSS & WSQ
0 2000 4000 F
0 609.6 1219.2 M
SCALE

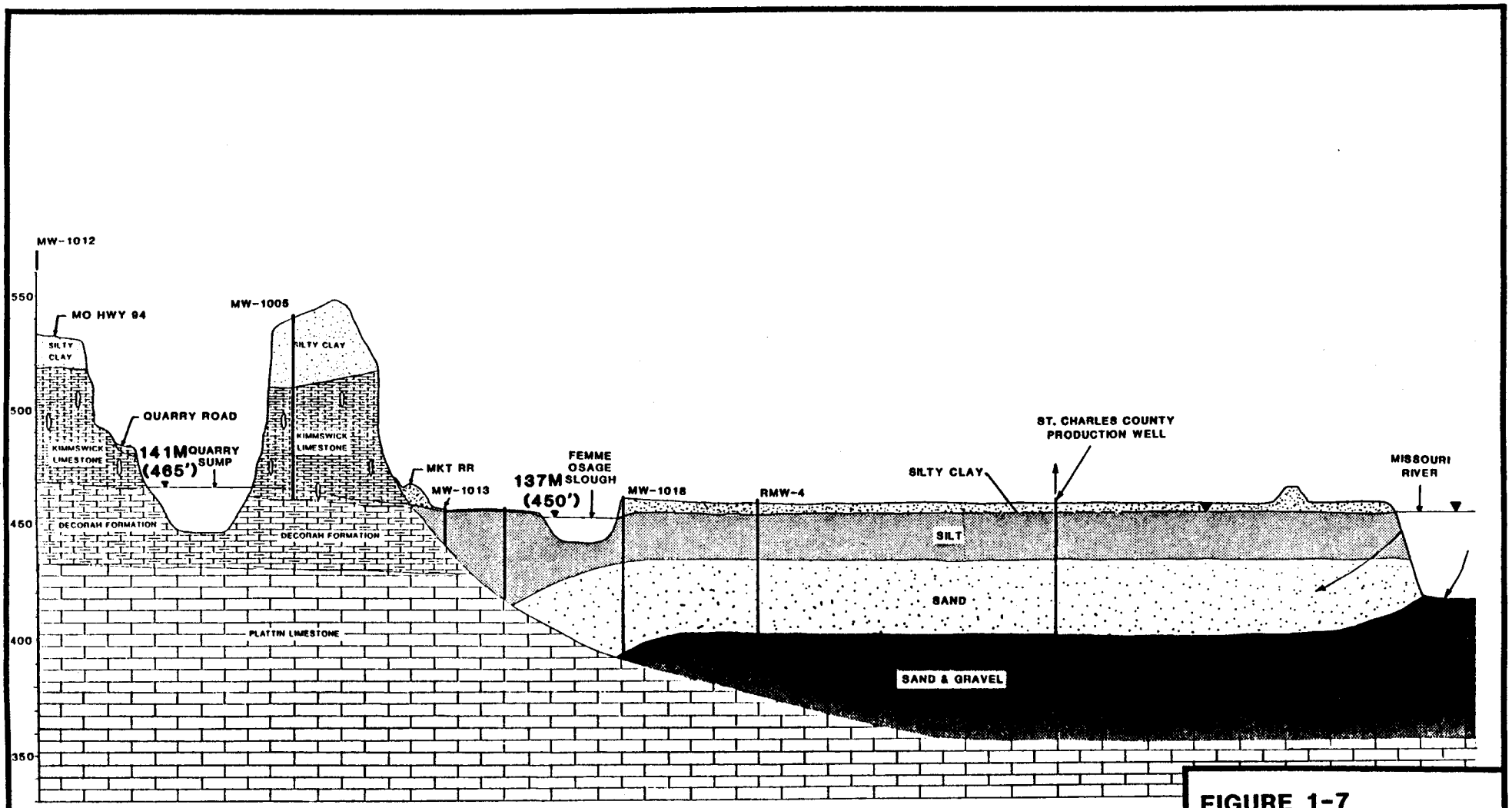
The WSQ is located on the northern bluff of the Missouri River valley. The unconsolidated upland material overlying bedrock consists of up to 10 m (30 ft) of silty clay soil developed from loess deposits. A residual soil is present in some areas between the silty clay and bedrock. The upland soils near the WSQ are generally not saturated and are therefore not monitored.

Sediments along the Missouri River vary from clays and silts through sands, gravels, cobbles, and boulders. The maximum alluvium thickness near the WSQ is approximately 30 m (100 ft). The alluvium "pinches out" at the base of the bedrock bluffs along the now-abandoned Missouri-Kansas-Texas (MKT) rail line. The alluvium thickness increases dramatically as distance from the Missouri River valley wall increases and then levels out.

Figure 1-7 shows silts and clays with minor amounts of sand as the primary sediments between the bluff and the Femme Osage Slough. The water producing sands and gravels, 15 to 20 m (50 to 60 ft) thick, appear to pinch out southeast of the slough near the WSQ. The potentiometric surface (water table) in the alluvial aquifer fluctuates in response to the stage of the Missouri River.

The WSQ bedrock consists of three distinct Ordovician formations. In descending order, they are the Kimmswick Formation, the Decorah Formation, and the Plattin Formation. The Bushberg Formation, a Devonian sandstone, overlies the Kimmswick Formation to the north, west, and east of the WSQ at higher elevations but is not present at the WSQ.

The Kimmswick Formation is a coarsely-crystalline, light gray, massive limestone with numerous solution-enlarged joints and cavities. The predominant joint set trends approximately north 70^{o} west. The Decorah Formation consists of interbedded



10 TO 1 HORIZONTAL TO VERTICAL SCALE

FIGURE 1-7

TYPICAL HYDRO-GEOLOGIC CROSS-SECTION OF WSQ AREA

limestones and green shales. This bedrock unit is approximately 10 m (30 ft) thick and is horizontally fractured.

The Plattin Formation is a thinly bedded, finely crystalline gray limestone. Thickness varies from 30 to 38 m (100 to 125 ft) in the vicinity of the WSQ. The extent and orientation of fracturing in the Plattin at the WSQ is not known at this time.

With the exception of the Missouri River floodplain to the south, the topography of the WSQ area is rugged. Drainage in the area flows to the Missouri River, 1.6 km (1 mile) to the east, through the Femme Osage Creek and Little Femme Osage Creek (Figure 1-8).

Approximately 213.4 m (700 feet) to the south of the WSQ, toward the Missouri River, lies a 2.4 km (1.5 mile) section of the original Femme Osage Creek that was dammed at both ends between 1960 and 1963 by the University of Missouri. This section is now called the Femme Osage Slough. The average water level in the slough is approximately 137.2 m (450 feet) above mean sea level; its level is affected, however, by the levels of the Missouri River and groundwater (Pennak, 1975). Southwest of the slough lies the area from which St. Charles County draws its drinking water. Eight production wells are in this area, of which only five usually operate at one time. Average production from the well field is about 40 million liters (10 million gallons) per day.

Groundwater in the vicinity of the WSRP and WSCP areas occurs in two separate zones: perched lenses and the underlying bedrock. Perched groundwater may be present in small, isolated deposits of coarse-grained glacial drift. A groundwater divide at the WSCP/WSRP trends roughly northeast to southwest through the eastern portion of the plant. Groundwater in the

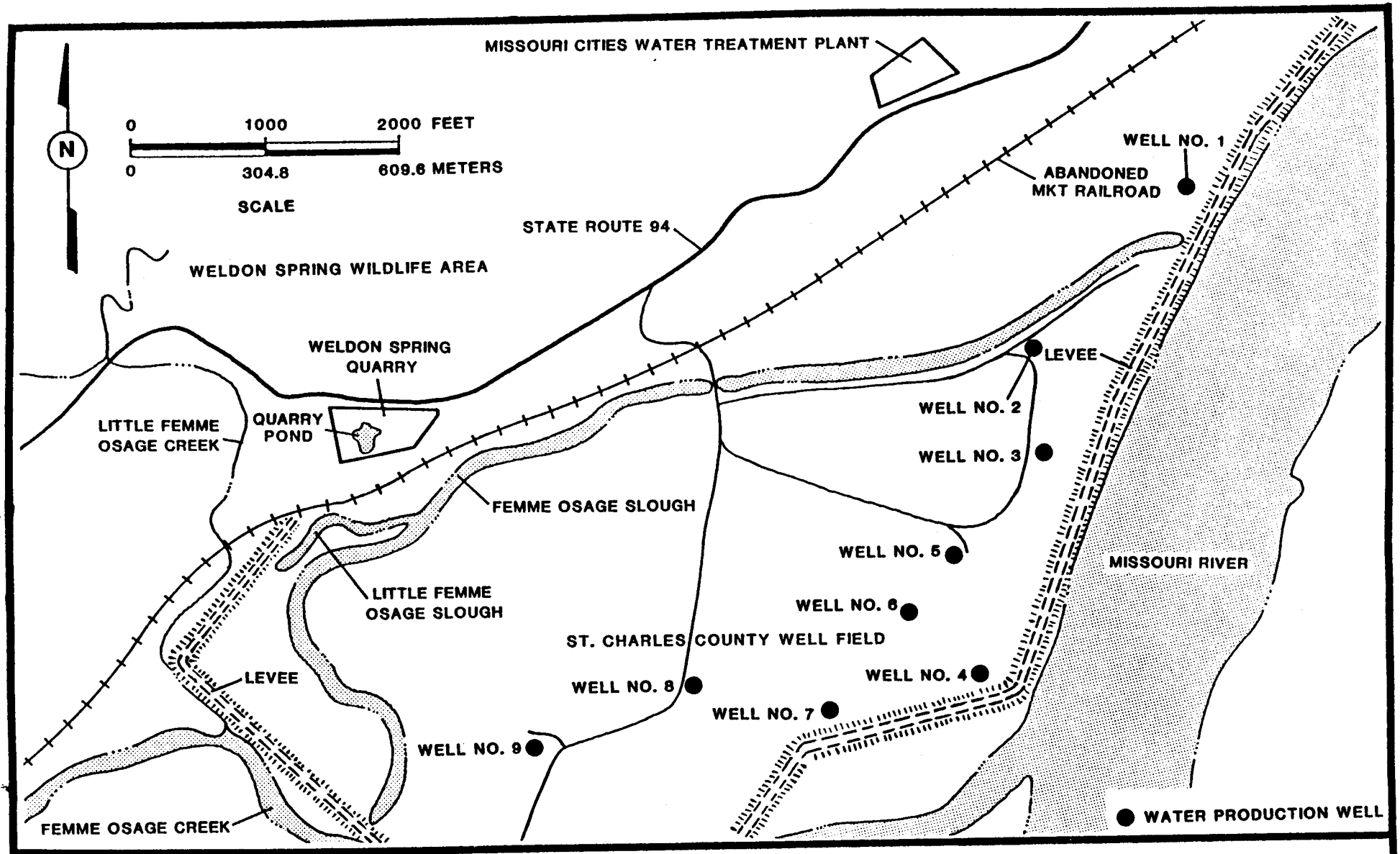


FIGURE 1-8

WELDON SPRING QUARRY & ST. CHARLES COUNTY WELL FIELD

Burlington-Keokuk Formation flows to the northwest and to the southeast on opposite sides of the divide. Groundwater contamination sources include the raffinate pits, Ash and Frog Ponds, and losing streams draining the site. The Burlington-Keokuk Formation is not a heavily utilized aquifer, but private wells do supply rural areas. No private wells are completed in the Burlington-Keokuk Formation within 2 km (1.25 miles) of the WSCP/WSRP. The raffinate pits are separated from the underlying groundwater by low permeability clays (BNI, 1984).

Groundwater in the WSQ vicinity occurs both in bedrock and alluvium (Figure 1-7). The limestone bedrock contains solution channels and fractures that exhibit highly complex flow paths. Groundwater flow near the WSQ is influenced by the Missouri River and pumpage from the St. Charles County well field and varies with river stages and pumping rates. This well field supplies water from the previously described alluvial aquifer for a portion of St. Charles County. These production wells are controlled and monitored under public drinking water regulations. No additional active water supply wells are completed in the alluvial aquifer near the WSQ.

The climate in the WSS area is continental, with moderately cold winters and warm summers. Alternating warm/cold, wet/dry air masses converge and pass eastward through the area almost daily. Normal annual precipitation in the area is approximately 85 cm (39 inches), with the heaviest rainfall occurring in spring and early summer. The average temperature is 13 degrees C (56 degrees F). Prevailing winds in the vicinity of the WSS are from the south during the summer and fall. Wind speeds during these months average 13.9 km/h (8.7 mph). Winds during the winter months are from the northwest and west-northwest, averaging 17.6 km/h (11 mph) (GRC, 1985).

The nearest communities, Weldon Spring and Weldon Spring Heights (Figure 1-1), are located approximately 3.2 km (2 miles) east of the WSRP and WSCP areas. While the population of each community is small (605 and 130, respectively), the population of St. Charles County is more than 140,000 (USDC, 1980) and continues to grow.

1.4 SUMMARY OF 1988 ENVIRONMENTAL MONITORING ACTIVITIES

In 1988, the Environmental Monitoring Program was expanded over previous years in order to identify, characterize, and monitor release pathways for both radiological and chemical constituents. The program is dynamic, changing to meet the monitoring needs of the site as new physical and analytical data are assimilated and as release pathways are better understood. These release pathways include groundwater (via subsurface migration), surface water (via storm-water runoff), and air. Programs prior to 1987 focused attention on potential exposure due to release of radiological constituents only.

In order to evaluate potential releases associated with former solid waste management units, past management practices, and accidental spills related to the WSOW and the WSUFMP, certain inorganic and organic constituents were added to the radiological parameters in the Environmental Monitoring Program in 1987. Inorganic constituents include substances such as nitrate, sulfate, chloride, and fluoride. Organic constituents include nitroaromatic compounds such as TNT and DNT and their breakdown products.

Table 1-2 summarizes the routine quarterly environmental activities performed during the 1988 Environmental Monitoring Program. In 1988, 50 monitoring wells were sampled quarterly, compared to 49 wells sampled in 1987 and 26 in 1986. This

TABLE 1-2 - COMPARISON OF MONITORING LOCATIONS IN 1986, 1987 AND 1988

LOCATION	YEAR 1986	1987	1988	COMMENTS
Groundwater				
WSCP/WSRP	6	25*	23++	Increase in well monitoring locations in 1987 and 1988 is due to the increased characterization activities at the WSQ.
WSQ	20	19	26	
Off-site	0	5	1	
Surface Water				
WSCP/WSRP	6	0	0	Now covered under the monthly NPDES monitoring program.
WSQ Off-site	5	7	7	Two locations, the quarry sump and the county raw-water intake added in 1987.
WSCP/WSRP				Only locations near the WSS were
Off-site	15	9	9	sampled in 1987 and 1988.
NPDES				
WSCP/WSRP	1**	5+	5+	All on-site outfalls included in the monthly NPDES monitoring in 1987. Ten additional on-site surface water locations were sampled periodically to determine surface contaminant transport on- and off-site.
Radon/TLD				
WSCP/WSRP	21	10	10	Only locations at the perimeter fence were included in the 1987/88 monitoring programs.
WSQ	6	6	6	Locations are same as in 1986.
Off-site	4	3	6	Additional background monitoring locations added in 1988.
Air Particulate				
WSCP/WSRP	0	5	5	The monitoring program was changed in 1988 to evaluate weekly exposure of students at Francis Howell High School and personnel at the Army Reserve training facilities.
Off-site	0	3	3	

* Included off-site wells sampled but not listed in the EMPP
** Sanitary Discharge Requirements
\+ Storm water runoff
++ Number of locations - some locations contain several wells

includes 23 wells installed at the chemical plant and raffinate pits, one off-site well, and 26 wells at the WSQ.

The addition of nine new monitoring wells in the WSQ area resulted in an expanded groundwater monitoring scheme at the WSQ (see Section 2.1). Of the 26 groundwater locations sampled in the quarry area, nine were from newly installed wells, and 17 were from wells sampled previously. Two monitoring wells were damaged during installation at the WSQ and were removed from the routine monitoring network (MKF and JEG, 1988c).

Surface water samples were collected from 20 locations where measurable impacts from drainage originating at the Weldon Spring Site could be detected. This includes 16 quarterly sampling locations and samples of storm-water runoff from five outfalls at the WSCP and the WSRP as required by the National Pollutant Discharge Elimination System (NPDES) Permit (storm water) for the Weldon Spring Site.

A total of 22 locations were monitored quarterly for radon gas and external gamma exposure. Duplicate radon gas detectors were installed at each location to improve the precision and accuracy of the measurements. Three additional off-site monitoring locations were added in the second quarter of 1988 to better determine average annual background gamma exposure rates and radon concentrations near the WSSRAP.

Fugitive dust sampling for radiological parameters at the site perimeter continued through 1988, but no new sampling stations were installed. In the first quarter of 1988, the monitoring program was changed from weekday and weekend sampling to weekly sampling due to statistically insignificant differences between the 1987 weekday and weekend sampling data. The air was monitored at these locations to establish ambient baseline data and to monitor for potential off-site releases.

Data from this program will also be used to assess the effectiveness of engineering controls at the site during future remedial action activities.

2 ENVIRONMENTAL MONITORING RESULTS

This section discusses the routine environmental monitoring program for all media: groundwater, surface water, radon, gamma radiation, and air particulates. Each medium is discussed in the following subsections. Only results from sampling detailed in the Environmental Monitoring Program Plan (EMPP) (MKF and JEG, 1987) are discussed in this section. Other (special) studies are discussed in Section 3.

2.1 GROUNDWATER MONITORING

As a result of site characterization, the overall understanding of the groundwater in both the chemical plant and raffinate pits (WSCP/WSRP) and the quarry (WSQ) areas has been greatly increased since the 1987 Environmental Monitoring Report (EMR) (MKF and JEG, 1988c) was published. This increased understanding is presented in greater detail in the Phase II Water Quality Assessment, which is discussed and summarized in Section 3.3. The Phase II Water Quality Assessment was performed in conjunction with the third quarter routine environmental monitoring program sampling. An additional 33 monitoring wells were installed in the WSCP/WSRP area to provide data for characterization. These wells were not included in the 1988 EMPP but were added to the 1989 EMPP following data interpretation. This increased knowledge of the groundwater has led to a revised environmental monitoring program plan as discussed in Section 5.

All groundwater samples were collected according to site-approved procedures, which include purging three to five well volumes prior to sampling and filtering with 0.45 micron filters before the samples were preserved and analyzed. Therefore, all analytical results discussed in this report are

derived from dissolved concentrations and accurately represent groundwater conditions.

The analytical results presented and discussed in this section represent the annual average for each compound. Quarterly data tables are presented in Appendix A. The numbers in the column headed with a "#" in the annual average tables for the various contaminant parameters for both the WSCP/WSRP and the WSQ areas indicate the number of times a parameter was detected in that particular well during the year. This is the number by which the averages are calculated. For example, if a parameter was not detected during 1988, a zero appears in the "#" column. Detection limits for all analytical parameters are also listed on each Table.

In the quarterly tables which are supplied in Appendix A, blank spaces are often present. There are several possible reasons for this. The well may not have existed during that quarter (as mentioned above, several wells were taken out of service and replaced during the year); the well may have been dry due to drought conditions; or the sample may have been destroyed and could not be duplicated. It is also possible that Quality Assurance/Quality Control (QA/QC) review of the data indicated unacceptable error and the value was therefore omitted.

Because of the physical separation and differing geologic settings in the WSCP/WSRP and the WSQ, these areas are discussed separately in Sections 2.1.1 and 2.1.2, respectively. Only results from monitoring wells designated to be sampled in the 1988 EMPP or wells specifically installed for routine monitoring are discussed. Results from characterization efforts are presented in Section 3.

2.1.1 Groundwater Monitoring at the WSCP/WSRP

During 1988, the routine groundwater monitoring well network consisted of 23 WSCP/WSRP area wells (19 locations) and one off-site well, MW-4019. MW-4019 is the former MW-2019. The PMC continues to monitor it routinely in order to develop trend data. All monitoring well locations are shown in Figure 2-1. Two wells reported in the 1987 EMR were replaced in 1988 with four wells. MW-2016 was removed from the system and replaced with two wells, MW-2023 and MW-2024, in order to monitor more discrete horizons. Also, MW-3007 was replaced with MW-3003 and MW-3006 for similar reasons.

2.1.1.1 Radiological Results

Quarterly groundwater samples were collected from 24 wells and were analyzed for natural uranium, radium-226, thorium-230, and thorium-232. Analytical results are presented in Table 2-1.

Natural Uranium

As part of the Phase II Groundwater Quality Assessment, a statistical analysis of natural background for natural uranium was performed. The results indicate that a level of 3.4 pCi/L is the upper bound (95% confidence limit) of natural uranium background (mean = 1.6 pCi/L and standard deviation = 0.9 pCi/L) at the WSCP/WSRP. It was not possible to determine background levels for the other radiochemical parameters because of the very low levels of these natural series radionculides (they are relatively insoluble with respect to uranium) coupled with the laboratory detection limits presented in Table 2-1.

In comparing the measured results of groundwater analyses with applicable standards, it is important to note that the U.S.

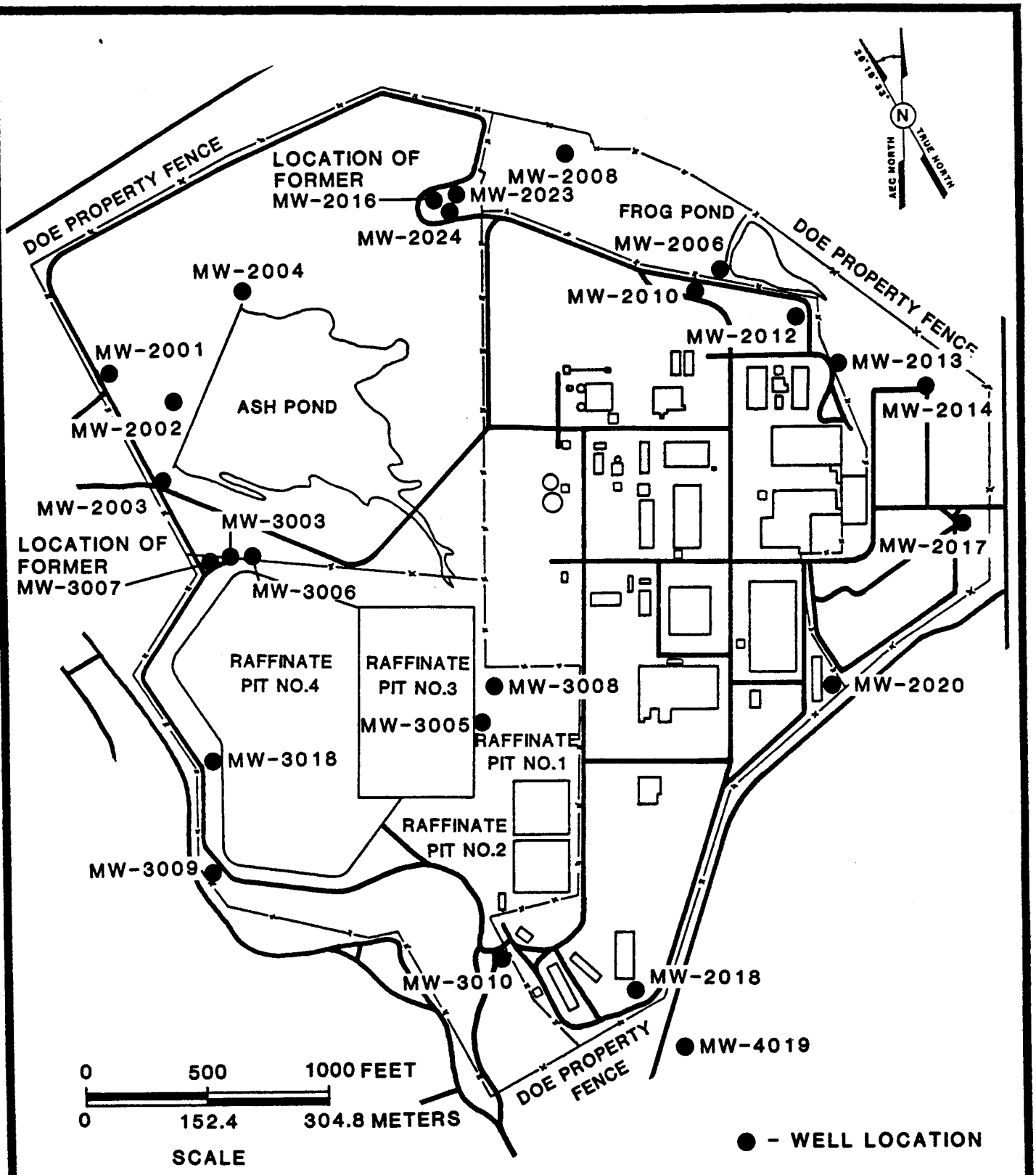


FIGURE 2-1

MONITORING WELLS SAMPLED AT THE WSCP/WSRP DURING 1988

TABLE 2-1

ANNUAL AVERAGES FOR RADIONUCLIDES IN GROUNDWATER AT THE WELDON SPRING CHEMICAL PLANT AND RAFFINATE PITS

AVERAGE CONCENTRATION - PCI/L

LOCATION* NUMBER	TH-230	#	% OF DCG	TH-232	#	% OF DCG	TOTAL U	#	% OF DCG
Detection Limit	1			1			1		
GW-2001	ND	0	0.0%	ND	0	0.0%	ND	0	0.0%
GW-2003	ND	0	0.0%	ND	0	0.0%	2.15	2	0.4%
GW-2004	ND	0	0.0%	ND	0	0.0%	2.9	4	0.5%
GW-2006	ND	0	0.0%	ND	0	0.0%	1.75	2	0.3%
GW-2008	ND	0	0.0%	ND	0	0.0%	2.6	2	0.5%
GW-2010	ND	0	0.0%	ND	0	0.0%	1.57	3	0.3%
GW-2012	ND	0	0.0%	ND	0	0.0%	2.3	1	0.4%
GW-2013$_3$	ND	0	0.0%	ND	0	0.0%	1.5	1	0.3%
GW-2014$_1$	ND	0	0.0%	1.2	1	2.4%	1.9	1	0.3%
GW-2016	ND	0	0.0%	ND	0	0.0%	1.1	1	0.2%
GW-2017	ND	0	0.0%	ND	0	0.0%	6.55	4	1.2%
GW-2018	ND	0	0.0%	ND	0	0.0%	2.83	3	0.5%
GW-2020$_1$	ND	0	0.0%	ND	0	0.0%	12.68	4	2.3%
GW-2023$_1$	ND	0	0.0%	ND	0	0.0%	ND	0	0.0%
GW-2024$_1$	ND	0	0.0%	ND	0	0.0%	ND	0	0.0%
GW-3003$_1$	ND	0	0.0%	ND	0	0.0%	15	1	2.7%
GW-3006$_1$	ND	0	0.0%	ND	0	0.0%	ND	0	0.0%
GW-3007$_1$	ND	0	0.0%	ND	0	0.0%	4.5	1	0.8%
GW-3008$_3$	ND	0	0.0%	ND	0	0.0%	8.23	3	1.5%
GW-3009$_3$	ND	0	0.0%	ND	0	0.0%	33.23	4	6.0%
GW-3010$_3$	4.3	1	1.2%	ND	0	0.0%	1.53	3	0.3%
GW-3013$_1$	ND	0	0.0%	ND	0	0.0%	10.88	4	2.0%
GW-3018$_1$	ND	0	0.0%	ND	0	0.0%	3.2	1	0.6%
GW-4019	ND	0	0.0%	ND	0	0.0%	2.7	4	0.5%

* See Figure 2.1

\# - NUMBER OF QUARTERLY SAMPLES WITH DETECTED CONCENTRATIONS

Location Number GW- is interchangeable with designation MW, i.e., GW-2001 = MW-2001.

Superscript number is number of quarterly samples collected if less than 4 .

Environmental Protection Agency (EPA) will adopt a drinking water standard for uranium within the next few years (none currently exists). That standard is expected to be within the range of 10 to 40 pCi/L. The U.S. Department of Energy (DOE) has determined that a Derived Concentration Guideline (DCG) of 550 pCi/L for natural uranium in water leads to an annual effective dose commitment of 100 mrem/yr (DOE, 1988). The DOE has adopted this criterion for release of uranium bearing water from operating facilities.

Seventeen of the 24 wells in the WSCP/WSRP area reported annual average levels of uranium below the upper limit of natural background. Four of these wells had annual averages below the 1 pCi/L detection limit.

If the low end of the drinking water standard range (10 pCi/L) is adopted, the annual average from four wells, MW-2020, MW-3003, MW-3009 and MW-3013, would have been in excess of the standard. If the high end of the range (40 pCi/L) is adopted, no single well would show an annual average in excess of that level. In fact, only one well, MW-3009, had a quarterly value over 40 pCi/L. During the first quarter of 1988, it registered a value of 41.0 pCi/L (7% of the DCG).

These data indicate that elevated uranium levels are not widespread and, depending on which level of standards is adopted, water from those wells may be in compliance with drinking water standards. All wells with values above 10 pCi/L, except MW-2020, are located at or near the perimeter of the raffinate pits, a known source of uranium. The source in MW-2020 is not readily explainable. However, the groundwater recharge on the southeast drainage easement is a strong possibility. No uranium levels exceeding DOE's guidelines were detected.

Radium-226, Thorium-230 and Thorium-232

The laboratory detection limits for Ra-226, Th-230, and Th-232 is 1 pCi/L. Ra-226 was not detected in any monitoring well in 1988. Th-230 was detected in one well, MW-3010. As stated above, MW-3010 is in close proximity to the raffinate pits. Th-232 was detected in only one well, MW-2014, at a very low level, 1.2 pCi/L (<3% of the DCG of 50 pCi/L).

2.1.1.2 Nitroaromatic Compounds

Nitroaromatic compounds, which are presumed to have originated from the former WSOW operations, were detected in 18 monitoring wells. The annual averages are presented in Table 2-2. Many of the 18 wells contained only trace levels of nitroaromatic compounds. Twenty-four monitoring wells were sampled and analyzed on a quarterly basis for six nitroaromatic compounds: 2,4,6-TNT, 2,4-DNT, 2,6-DNT, nitrobenzene, 1,3,5-TNB and 1,3-DNB.

Nitroaromatic compounds were introduced into the environment during World War II from production lines at the WSOW, and they are widely dispersed in the WSCP/WSRP area (MKF and JEG, 1989a). The nature of nitroaromatic contamination amounts, locations, compounds, and combinations of compounds are highly variable. At least one nitroaromatic compound was detected in 18 of 24 monitoring wells during 1988. The 1987 EMR (MKF and JEG, 1988c) reported nitroaromatic compounds in 13 wells.

Although this may seem to indicate an increase in nitroaromatic contamination, it most likely does not. The overall contamination pattern and magnitude of contamination did not change significantly. The increase in the number of wells

TABLE 2-2

ANNUAL AVERAGES FOR NITROAROMATIC COMPOUNDS IN GROUNDWATER AT THE WELDON SPRING CHEMICAL PLANT AND RAFFINATE PITS

AVERAGE NITROAROMATIC COUMPOUND CONCENTRATION - UG/L

LOCATION* NUMBER	2,4,6-TNT	#	2,4-DNT	#	2,6-DNT	#	NB	#	1,3,5-TNB	#	1,3-DNB	#
Detection Limits	0.5		0.2		0.6		0.6		0.03		0.4	
GW-2001	ND	0	ND	0	ND	0	ND	0	0.05	1	0.45	1
GW-2003	ND	0	0.33	3	0.75	4	ND	0	0.06	1	ND	0
GW-2004	ND	0	ND	0	ND	0	ND	0	0.14	1	ND	0
GW-2006	0.78	1	ND	0	2.45	4	1.61	1	10.69	4	1.7	2
GW-2008	ND	0	0.24	1	0.96	3	ND	0	1.03	4	0.65	3
GW-2010	0.59	2	ND	0	0.68	2	ND	0	0.36	2	0.55	3
GW-2012	0.88	4	ND	0	4.88	2	1.31	1	9.18	3	ND	0
GW-2013	12.92	4	98.11	4	55.37	4	1.8	1	21.47	4	10.82	2
GW-2014[3]	2.33	1	ND	0	1.14	3	ND	0	2.99	3	1.05	1
GW-2016[1]	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0
GW-2017	ND	0	ND	0	ND	0	ND	0	0.12	2	ND	0
GW-2018	ND	0	ND	0	ND	0	ND	0	0.14	2	ND	0
GW-2020	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0
GW-2023[1]	ND	0	ND	0	ND	0	ND	0	0.32	1	ND	0
GW-2024[1]	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0
GW-3003[1]	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0
GW-3006[1]	ND	0	ND	0	ND	0	5.28	1	0.17	1	ND	0
GW-3007[1]	ND	0	1.65	1	1.59	1	ND	0	ND	0	ND	0
GW-3008[3]	ND	0	ND	0	ND	0	ND	0	0.06	1	ND	0
GW-3009	ND	0	ND	0	ND	0	ND	0	0.22	1	ND	0
GW-3010[3]	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0
GW-3013[1]	ND	0	ND	0	ND	0	ND	0	0.03	1	ND	0
GW-3018	7.1	1	134	1	875	1	22.2	1	0.78	1	ND	0
GW-4019	ND	0	0.58	1	ND	0	ND	0	0.08	1	ND	0

* - See Figure 2.1

- NUMBER OF DETECTED QUARTERLY SAMPLES IN ANNUAL AVERAGE ND - NOT DETECTED

Location Number GW- is interchangeable with designation MW, i.e., GW-2001 = MW-2001.

Superscript number is number of quarterly samples collected if less than 4.

where nitroaromatic compounds were detected is due to several wells with very low concentrations that were detected at different times. These low sporadic concentrations may indicate general, very low level contamination under most of the site.

All nitroaromatic compounds are man made. Therefore, natural background for them is zero, and when they are detected, there must also be a detectable source for them. Furthermore, the area of highest nitroaromatic groundwater contamination at the WSCP is a well-defined area encompassing MW-2010 through MW-2014. The single most contaminated well in the northeast corner is MW-2013 which has a total annual average nitroaromatic level of 200 µg/L. On the other hand, MW-2006 and MW-2008 are hydraulically downgradient of this area, but are less contaminated. This indicates that the groundwater contamination may be residual contamination that is present only in the groundwater since soil investigations have not identified a source.

The well with the highest amount of nitroaromatic compounds in the raffinate pit area is MW-3018. This well is located in the overburden west of the raffinate pits. This is not to say that the pits themself are a source of nitroaromatics; other data indicate they are not. It is more likely that the area in which the well was installed was contaminated during ordnance production.

2.1.1.3 Inorganic Anions

Quarterly groundwater samples were analyzed for nitrate, sulfate, fluoride, and chloride. Table 2-3 displays the annual averages for 1988. Primary and secondary drinking water standards are presented in Appendix E and are used for comparison purposes.

Sulfate

The Phase II Groundwater Quality Assessment Report places the upper bound of sulfate background at the WSCP/WSRP at 50 mg/L (Average = 22.6 mg/L, standard deviation = 14 mg/L). Any value above 50 mg/L should be considered elevated. The EPA secondary drinking water standard is 250 mg/L.

Thirteen of the 24 monitoring wells exhibited annual average values that fell below the 50 mg/L upper bound for sulfate background. These wells are distributed over the site, so it is reasonable to conclude that sulfate contamination does not encompass the whole site. There are, however, isolated areas of elevated sulfate contamination including areas which have sulfate levels in excess of the EPA secondary drinking water standard. Eight wells have concentrations between the upper background value (50 mg/L) and the EPA drinking water standard (250 mg/L). These are MW-2012, MW-2014, MW-2020, MW-3003, MW-3006, MW-3007, MW-3008 and MW-3018. Again these wells are irregularly distributed, indicating several individual sources.

The monitoring wells which exhibit the highest sulfate levels in the WSCP/WSRP area are MW-2003, MW-2017, and MW-3013 where sulfate levels exceed the 250 mg/L drinking water standard. MW-3013 and MW-2003 have high sulfate levels because of their proximity to the raffinate pits. MW-2017 is located near the position of former WSOW buildings in which sulfuric acid was used.

TABLE 2-3

ANNUAL AVERAGES FOR INORGANIC ANIONS IN GROUNDWATER AT THE WELDON SPRING CHEMICAL PLANT AND RAFFINATE PITS

AVERAGE CONCENTRATIONS - MG/L

LOCATION* NUMBER	CHLORIDE	#	FLUORIDE	#	NITRATE	#	SULFATE	#
Drinking Water Standard	250		4.0		45		250	
Detection Limits	0.25		0.25		0.1		0.25	
GW-2001	4.6	4	0.5	3	32.1	4	8.8	4
GW-2003	39.9	4	0.7	2	3039.0	4	258.5	4
GW-2004	1.1	3	0.6	2	3.0	4	3.4	4
GW-2006	152.3	4	0.4	1	25.5	4	42.2	4
GW-2008	49.1	4	0.6	1	15.7	4	29.2	4
GW-2010	72.5	4	0.4	1	3.9	4	35.9	4
GW-2012	88.7	4	0.9	1	1.8	3	78.0	4
GW-2013	8.4	4	ND	0	3.7	4	27.3	4
GW-2014[3]	26.3	3	0.4	1	9.1	3	124.0	3
GW-2016[1]	1.4	1	0.4	1	ND	0	31.7	1
GW-2017	12.9	4	0.6	2	3.2	4	764.5	4
GW-2018	6.4	4	0.8	1	16.2	4	9.6	4
GW-2020	11.6	4	ND	0	3.4	4	215.8	4
GW-2023[1]	2.1	1	0.3	1	1.3	1	37.1	1
GW-2024[1]	2.7	1	0.3	1	ND	0	38.6	1
GW-3003[1]	13.1	1	ND	0	ND	0	232.0	1
GW-3006[1]	9.4	1	0.3	1	ND	0	75.0	1
GW-3007[1]	24.1	1	ND	0	4270.0	1	230.0	1
GW-3008[3]	30.7	3	2.2	2	5090.0	3	63.1	3
GW-3009	149.5	4	0.5	2	231.2	4	39.4	4
GW-3010[3]	1.4	3	0.6	2	5.2	3	6.7	3
GW-3013	1.9	4	0.8	4	8.4	4	494.3	4
GW-3018[1]	42.7	1	0.5	1	842	1	193.0	1
GW-4019	1.0	4	0.4	2	0.8	4	9.1	4

* - See Figure 2.1

\# - NUMBER OF QUARTERLY SAMPLES COMPRISING ANNUAL AVERAGE

ND - NOT DETECTED

Location Number GW- is interchangeable with designation MW, i.e., GW-2001 = MW-2001.

Superscript number is number of quarterly samples collected if less than 4.

Generally, sulfate levels did not change drastically between 1987 and 1988. The minor changes that did occur can be attributed to local drought conditions.

Nitrates

Background nitrate concentrations were also calculated in the Phase II Water Quality Assessment Report. The upper bound for nitrate background in the WSCP/WSRP area is 14 mg/L (average = 4 mg/L, std dev. = 5 mg/L). The EPA primary drinking water standard for nitrogen (but not nitrate) is set at 10 mg/L. Converted, this standard is 45 mg/L of nitrate.

Nitrate levels in 15 of the 24 wells were below background. Levels in three wells, MW-2001, MW-2006, and MW-2008, were above background but still below 44 mg/L. Five wells, all near the raffinate pit area, contain nitrate at levels above the drinking water standard. These are MW-2003, MW-3007, MW-3008, MW-3009, and MW-3018.

Chloride

The EPA secondary drinking water standard for chloride is 250 mg/L. The upper limit of background for chloride in the WSCP/WSRP is 22 mg/L (average = 7.4 mg/L, std. deviation = 7.4 mg/L). Five wells show annual averages at levels twice the upper limit of background. Four of these, MW-2006, MW-2008, MW-2010, and MW-2012, are located in or near the Frog Pond drainage which receives runoff from the Missouri State Highway Facility salt pile. The fourth, MW-3009, is a raffinate pit perimeter well. No wells have annual averages above the EPA standard secondary drinking water standard.

Fluoride

The EPA primary drinking water standard for fluoride is 4 mg/L. None of the 24 wells monitored exhibited values in excess of this standard. All values except MW-3008 are within the background limit of 1.0 mg/L (average = 0.5 mg/L, standard deviation = 0.25 mg/L). The annual average for fluoride in MW-3008 was 2.2 mg/L and may be related to raffinate wastes.

2.1.2 Groundwater Monitoring at the WSQ

Seventeen monitoring wells installed prior to 1988 (see Figures 2-2, 2-3) were sampled at the WSQ during all four quarters of 1988. Two wells, MW-1001 and MW-1003, were removed from the routine monitoring program because they are not representative of actual groundwater conditions, based on construction (MKF and JEG, 1988c). As a result of discussions with the US Geological Survey and the Missouri Department of Natural Resources during April 1988, an additional nine monitoring wells (see Figures 2-2 and 2-3) were installed to provide additional sampling locations south of the Femme Osage Slough and to monitor groundwater to the north and west of the WSQ. These wells were installed during the summer of 1988 and were first sampled in the third quarter of 1988. They are numbered MW-1020 through MW-1028.

Four new wells, MW-1020 through MW-1023, were installed on the south bank along the section of the slough which passes near the quarry. One well, MW-1024, was installed near the east end of the slough, along the south bank near Production Well 2. MW-1025, completed in the Decorah Formation; MW-1026, screened in the alluvium; and MW-1027 and MW-1028, both screened in the Plattin Limestone, were installed to diversify, both laterally and vertically, the existing monitoring system at the quarry. 11 of these locations are shown in Figures 2-2 and 2-3.

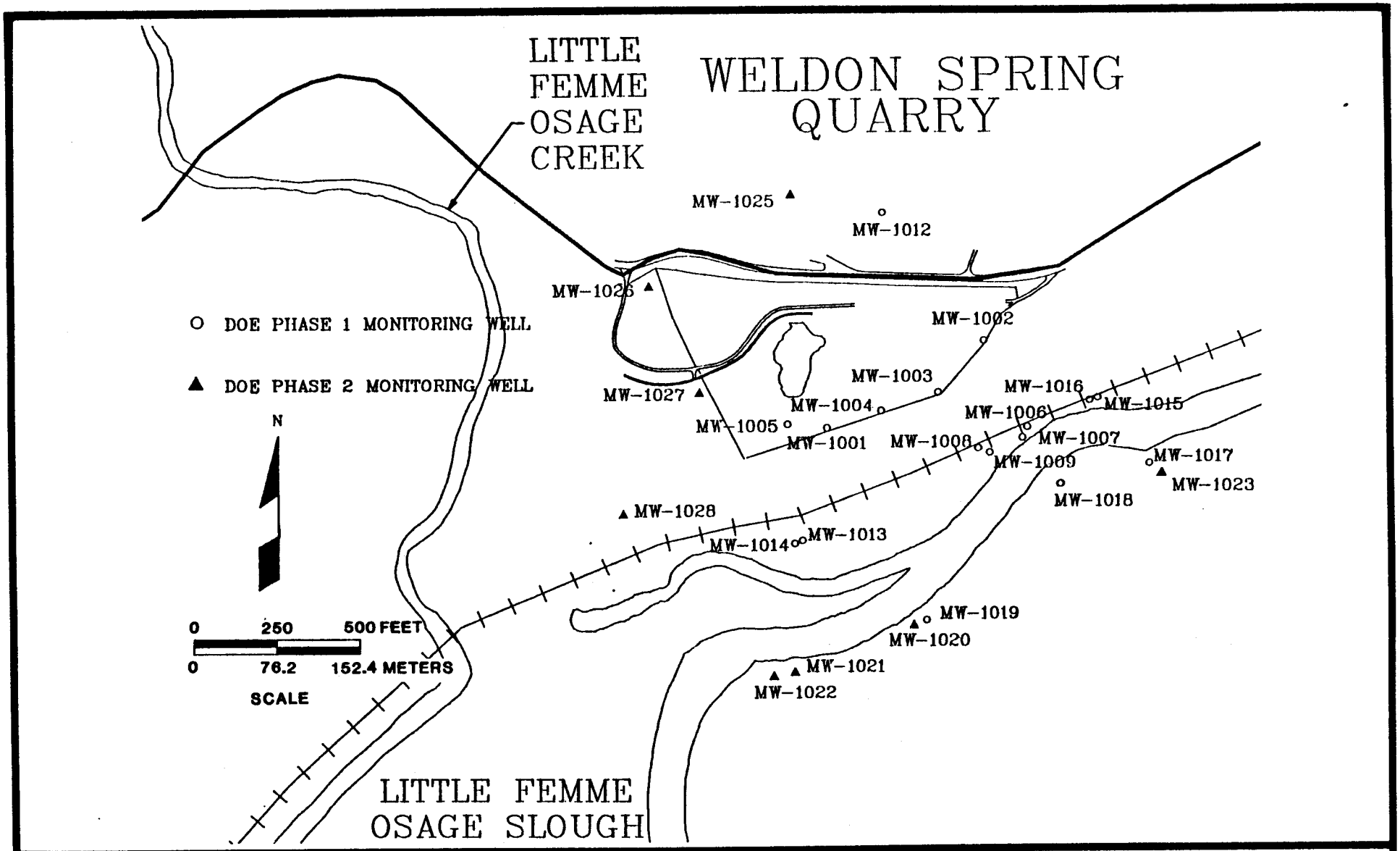


FIGURE 2-2

GROUNDWATER MONITORING LOCATIONS AT THE WSQ FOR 1987

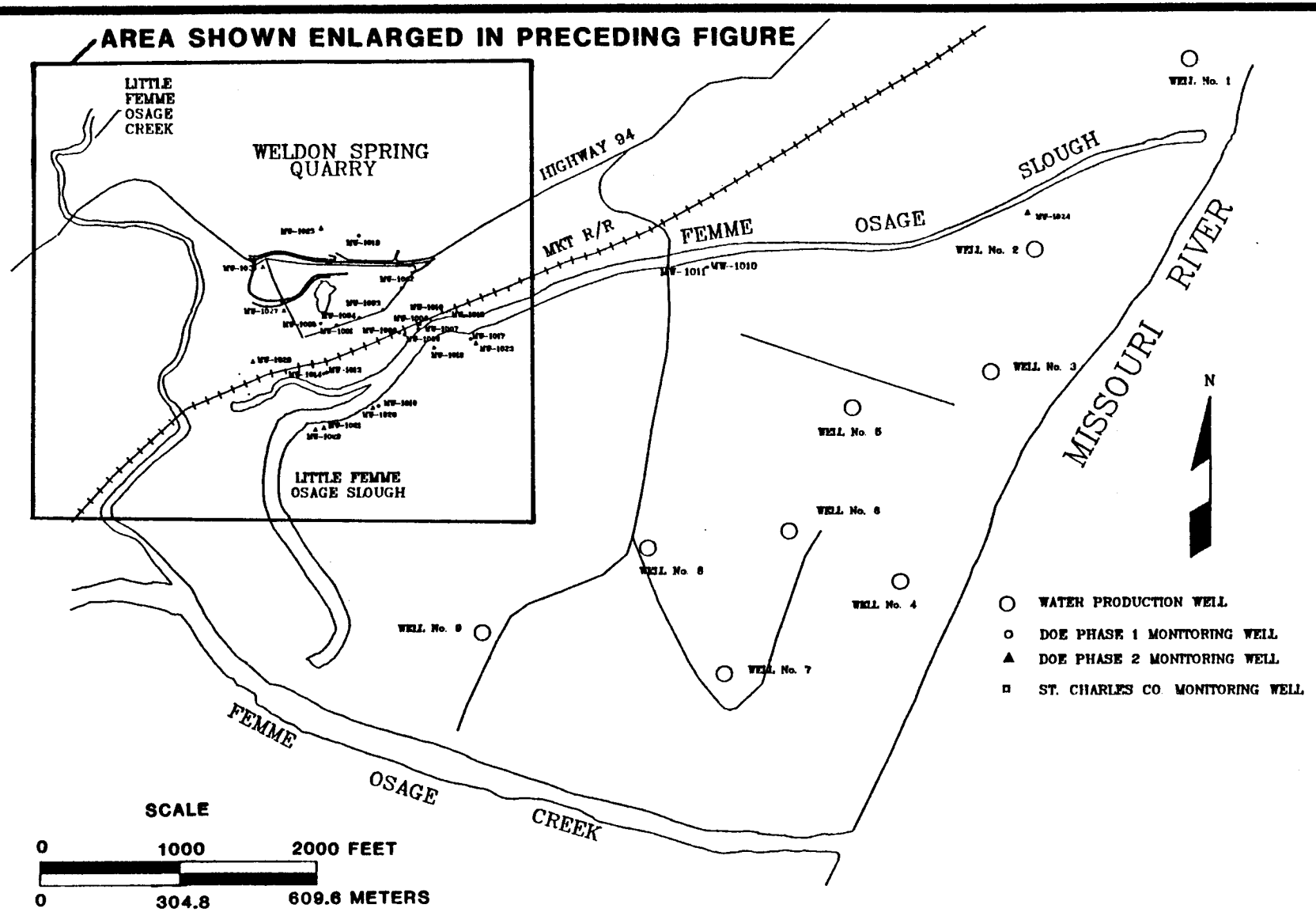


FIGURE 2-3

GROUNDWATER MONITORING LOCATIONS AT THE WSQ FOR 1987

Groundwater samples were analyzed quarterly for radionculides, nitroaromatic compounds, and inorganic anions. Analytical results are discussed in the following sections.

The drought conditions of 1988--low river stage and high water demand--presented the potential for increased contaminant migration towards the St. Charles County Well Field. In response to this concern, a study was conducted to evaluate the effects of the drought on the well field (MKF and JEG, 1988b). This study, which is discussed in greater detail in Section 3.1, consisted of monitoring groundwater and surface water elevations and groundwater sampling.

Groundwater at the WSQ originates as precipitation falling within the quarry and percolating through the wastes. Contaminant migration varies with respect to precipitation, leading to substantial seasonal fluctuations.

2.1.2.1 Radiological Results

All twenty-six monitoring wells in the WSQ area were analyzed for natural uranium, radium-226, thorium-230 and thorium-232. The annual averages and percentages of the DCG are presented in Table 2-4. Quarterly data tables are presented in Appendix A.

Natural Uranium

A private well upstream of the St. Charles County Well Field which produces water from Missouri River alluvium was sampled in an attempt to estimate the range of background levels for several parameters. The uranium content in this well was 5.0 pCi/L.

TABLE 2-4
ANNUAL AVERAGES FOR RADIONUCLIDES IN GROUDWATER AT THE
WELDON SPRING QUARRY

AVERAGE CONCENTRATION PCI/L

LOCATION* NUMBER	TH-230	#	% OF DCG	TH-232	#	% OF DCG	TOTAL U	#	% OF DCG
Detection Limits	1			1			1		
GW-1002	1.6	1	0.5%	ND	0	0.0%	3.0	4	0.5%
GW-1004	ND	0	0.0%	ND	0	0.0%	4200.0	3	763.6%
GW-1005[3]	ND	0	0.0%	ND	0	0.0%	1222.5	4	222.3%
GW-1006[3]	ND	0	0.0%	ND	0	0.0%	1933.3	3	351.5%
GW-1007[3]	2.0	1	0.7%	ND	0	0.0%	139.0	3	25.3%
GW-1008[3]	3.4	1	1.1%	ND	0	0.0%	936.7	3	170.3%
GW-1009[3]	ND	0	0.0%	ND	0	0.0%	1.6	2	0.3%
GW-1010[2]	0.9	3	0.3%	0.8	2	1.6%	ND	0	0.0%
GW-1011[2]	ND	0	0.0%	ND	0	0.0%	3.3	1	0.6%
GW-1012[3]	ND	0	0.0%	ND	0	0.0%	7.6	4	1.4%
GW-1013[3]	ND	0	0.0%	ND	0	0.0%	855.0	4	155.5%
GW-1014	1.1	1	0.4%	ND	0	0.0%	882.5	4	160.5%
GW-1015[3]	ND	0	0.0%	ND	0	0.0%	450.0	3	81.8%
GW-1016[3]	1.7	1	0.6%	ND	0	0.0%	136.7	3	24.8%
GW-1017	1.3	2	0.4%	ND	0	0.0%	1.1	1	0.2%
GW-1018	ND	0	0.0%	ND	0	0.0%	1.2	1	0.2%
GW-1019[2]	ND	0	0.0%	ND	0	0.0%	ND	0	0.0%
GW-1020[2]	ND	0	0.0%	ND	0	0.0%	ND	0	0.0%
GW-1021[2]	ND	0	0.0%	ND	0	0.0%	ND	0	0.0%
GW-1022[2]	ND	0	0.0%	ND	0	0.0%	1.2	1	0.2%
GW-1023[2]	ND	0	0.0%	ND	0	0.0%	ND	0	0.0%
GW-1024[2]	ND	0	0.0%	ND	0	0.0%	ND	0	0.0%
GW-1025[1]	ND	0	0.0%	ND	0	0.0%	2.2	1	0.4%
GW-1026[1]	ND	0	0.0%	ND	0	0.0%	2.5	1	0.5%
GW-1027[1]	ND	0	0.0%	ND	0	0.0%	270.0	1	49.1%
GW-1028[1]	ND	0	0.0%	ND	0	0.0%	2.4	1	0.4%

* - See Figure 2-1
# - NUMBER OF QUARTERLY SAMPLES WITH DETECTED CONCETRATIONS
ND Not Detected
Location number GW- is interchangeable with designation MW, i.e., GW-1002 = MW-1002.
Superscript number is number of quarterly samples collected if less than 4.

When this value is used as the upper limit for natural background uranium, 15 of the 26 monitoring wells contain natural background levels of uranium. Eleven are above background and ten of these will significantly exceed the possible EPA proposed drinking water standard of 40 pCi/L. The uranium activity in these wells ranges from 4,200 pCi/L (764% of the DCG) in MW-1004, located on the quarry rim, to 136.7 pCi/L (24.9% of the DCG) in MW-1016, which is located on the north bank of the slough well. Other wells with high uranium concentrations are MW-1005 through MW-1008, MW-1013 through MW-1015, and MW-1027.

All of these wells with elevated uranium concentrations are north of the slough. No monitoring wells located to the south of the slough exhibited quarterly concentrations or annual averages of uranium above natural background. This includes MW-1024, which is located at the east end of the slough on the south bank, near Production Well No. 2.

This condition is the same as was reported in the 1987 EMR (MKF and JEG, 1988c).

Radium-226, Thorium-230, and Thorium-232

Radium-226 was not detected in any WSQ monitoring wells during 1988 (as was the case in 1987).

When annual averages were calculated for thorium-230, nineteen wells were below detection limits. Low concentrations of Th-230 were reported in wells MW-1002, MW-1010, MW-1014, MW-1016, and MW-1017. However, if the analytical error is subtracted, all are below detection limits. Monitoring wells MW-1007 and MW-1008, both located on the north bank of the slough, have Th-230 concentrations of 2.0 and 3.4 pCi/L (<1 to 1.1% of the DCG), respectively. This level is above background.

Thorium-232 was not detected in any well except MW-1010 which reported an annual average concentration of 0.8 pCi/L. This is below the method detection limit of 1 pCi/L.

2.1.2.2 Nitroaromatic Compound Results

Nitroaromatic compounds were placed in the WSQ during WSOW operations and also in 1969. Additionally, the Little Femme Osage Creek (now the Femme Osage Slough, after diversion) is reported to have flowed red with nitroaromatic manufacturing by-products originating from the WSOW (Meyer, 1989). This suggests at least two potential sources and at least two possible time periods of contaminant infiltration affecting the WSQ area.

Nitroaromatic compounds were detected in 19 of the 26 wells sampled during 1988. As the annual averages presented in Table 2-5 indicate, seven wells did not contain nitroaromatic compounds; 15 wells have levels below 10 µg/L. Three monitoring wells have concentrations between 10 and 100 µg/L, and only one, MW-1006, has nitroaromatic concentrations above 100 µg/L.

Well MW-1006 is located on the north bank of the slough and had an annual average concentration of nitroaromatic compounds of 204 µg/L. This is a significant increase from the total reported (30 ug/L) for that well in the 1987 EMR (MKF and JEG, 1988c). It is possible that this increase is due to the severe drought conditions during 1988, although nearby wells do not indicate increases of this order of magnitude. Because MW-1006 was completed to monitor groundwater entering the alluvium from a solution-enlarged joint, the highest nitroaromatic compound and high uranium concentrations were detected in this well. Levels in adjacent wells may increase in the future.

TABLE 2-5
ANNUAL AVERAGES FOR NITROAROMATIC COMPOUNDS IN GROUNDWATER AT THE WSQ

AVERAGE CONCENTRATION - UG/L

LOCATION* NUMBER	2,4,6-TNT	#	2,4-DNT	#	2,6-DNT	#	NB	#	1,3,5-TNB	#	1,3-DNB	#
Detection Limits	0.5		0.2		0.6		0.6		0.3		0.4	
GW-1002	6.66	4	ND	0	2.56	3	ND	0	13.22	4	3.83	3
GW-1004	14.01	4	0.39	1	7.85	4	ND	0	2.24	4	3.08	4
GW-1005[3]	ND	0	0.86	3	ND	0	0.64	1	0.65	4	ND	0
GW-1006[3]	40.95	3	0.92	1	5.46	3	1.72	2	120.79	3	33.90	1
GW-1007[3]	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0
GW-1008[3]	ND	0	ND	0	ND	0	ND	0	0.50	2	ND	0
GW-1009[3]	ND	0	ND	0	ND	0	0.05	1	0.03	1	ND	0
GW-1010[2]	0.71	1	ND	0	ND	0	ND	0	0.33	1	ND	0
GW-1011[2]	ND	1	ND	0	ND	1	ND	1	ND	1	ND	0
GW-1012[3]	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0
GW-1013[3]	ND	0	0.36	2	ND	0	ND	0	0.14	2	ND	0
GW-1014	ND	0	ND	0	ND	0	ND	0	0.22	2	ND	0
GW-1015[3]	17.87	4	4.73	2	0.66	1	16.83	1	25.58	4	6.50	2
GW-1016[3]	0.98	1	ND	0	ND	0	ND	0	2.07	2	ND	0
GW-1017	ND	0	ND	0	ND	0	ND	0	0.68	2	ND	0
GW-1018	ND	0	ND	0	ND	0	ND	0	0.55	2	ND	0
GW-1019[2]	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0
GW-1020[2]	ND	0	ND	0	ND	0	ND	0	0.63	1	ND	0
GW-1021[2]	0.55	1	0.51	1	ND	0	ND	0	0.39	2	ND	0
GW-1022[2]	ND	0	ND	0	ND	0	ND	0	0.15	1	ND	0
GW-1023[2]	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0
GW-1024[1]	ND	0	0.4	1	ND	0	ND	0	0.38	1	ND	0
GW-1025[1]	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0
GW-1026[1]	ND	0	ND	0	ND	0	ND	0	0.16	1	ND	0
GW-1027[1]	5.03	1	ND	0	4.17	1	ND	0	0.05	1	0.48	1
GW-1028[1]	ND	0	ND	0	ND	0	ND	0	ND	0	ND	0

* - See Figure 2-1
# - NUMBER OF QUARTERLY SAMPLES WITH DETECTED CONCETRATIONS
ND Not Detected
Location number GW- is interchangeable with designation MW, i.e., GW-1002 = MW-1002.
Superscript number is number of quarterly samples collected if less than 4.

The 1987 EMR reported that nitroaromatics were not detected south of the Femme Osage Slough. However, analysis of samples from several additional monitoring wells installed on the south bank during 1988 did detect nitroaromatics in that area. Wells detecting nitroaromatic compounds south of the slough during 1988 were MW-1010, MW-1018, MW-1019, MW-1021, MW-1022, and MW-1024. As a result of this new information, the sampling frequency has been increased to a quarterly rate in 1989 to evaluate short-term fluctuations and to ensure that the water from the well field is safe. Analytical methods are also being modified to lower detection limits. The levels observed in these wells are below 1 µg/L. The only potentially relevant criterion or standard for detected compounds is the EPA's ambient water quality criterion of 0.11 µg/L for 2,4-DNT for the protection of human health.

2.1.2.3 Inorganic Anion Results

Elevated inorganic anion concentrations are known to be present at the WSQ. Therefore, the WSQ monitoring well network was sampled quarterly for nitrate, sulfate, fluoride, and chloride. During some quarters, certain wells were dry due to the drought conditions. The averaged results of this year's routine sampling effort are presented in Table 2-6.

Sulfate

The monitoring well network at the WSQ does not include enough wells that are totally unaffected by the WSQ to allow a statistical background calculation. The wells are also completed in different geologic settings, making background calculations more complex. Since WSQ background cannot be accurately determined at this time, the upper background limit of 50 mg/L at the WSCP/WSRP was used. The EPA secondary

TABLE 2-6

ANNUAL AVERAGES FOR INORGANIC ANION IN GROUNDWATER AT THE WELDON SPRING QUARRY

AVERAGE CONCENTATION - MG/L

LOCATION* NUMBER	CHLORIDE	#	FLUORIDE	#	NITRATE	#	SULFATE	#
Drinking Water Standard	250		4.0		45		250	
Detection Limits	0.25		0.25		0.1		0.25	
GW-1002	10.3	4	0.3	3	1.9	4	47.5	4
GW-1004	25.3	4	0.8	3	3.7	4	258.5	4
GW-1005[3]	15.1	4	0.7	2	4.9	1	202.8	4
GW-1006[3]	48.6	3	0.7	1	15.2	3	423.0	3
GW-1007[3]	75.8	3	0.6	1	1.61	3	92.1	3
GW-1008[3]	27.3	3	0.5	2	0.6	1	270.7	3
GW-1009[3]	37.4	3	0.5	1	1.40	3	150.0	3
GW-1010[2]	10.6	4	0.4	2	0.3	1	2.2	2
GW-1011[2]	15.7	2	0.3	1	0.4	2	68.1	2
GW-1012	10.4	4	0.7	3	6.3	4	167.8	4
GW-1013	28.3	4	0.8	2	ND	0	102.1	3
GW-1014	21.5	4	0.5	4	ND	0	110.1	4
GW-1015[3]	21.1	4	0.5	4	6.0	4	181.3	4
GW-1016[3]	10.7	3	0.5	3	3.4	3	111.7	3
GW-1017	22.3	4	0.7	2	0.11	2	1.0	1
GW-1018	27.6	4	0.6	3	0.1	1	43.4	4
GW-1019[2]	6.9	4	0.6	2	ND	0	ND	0
GW-1020[2]	12.2	2	0.0	1	ND	0	1.4	2
GW-1021[2]	11.3	2	0.3	1	0.6	1	1.4	2
GW-1022[2]	14.2	1	3.6	2	0.3	1	1.0	1
GW-1023[2]	4.4	2	ND	0	ND	0	6.0	2
GW-1024[2]	6.0	2	0.3	1	ND	0	5.2	2
GW-1025[1]	12.3	1	ND	0	0.3	1	165.0	1
GW-1026[1]	2.5	1	ND	0	ND	0	2.1	1
GW-1027[1]	15.5	1	ND	0	1.3	1	107.0	1
GW-1028[1]	15.5	1	ND	0	ND	0	63.7	1

* - See Figure 2-1
# - NUMBER OF QUARTERLY SAMPLES WITH DETECTED CONCENTRATIONS
ND - NOT DETECTED
Location Number GW- is interchangeable with designation MW, i.e,. GW-1002 = MW-1002
Superscript number is number of quarterly samples collected if less than 4

drinking water standard of 250 mg/L was also used for comparison purposes.

Three wells averaged more than 250 mg/L sulfate during 1988. All of these wells are located north of the slough. MW-1004, located in the bedrock of the quarry rim, also contains the highest uranium concentrations. This indicates elevated sulfate and uranium levels are related at some or all monitoring locations.

Eleven wells exhibit sulfate levels above 50 mg/L but below 250 mg/L. These medium concentrations are either natural fluctuations in background or truly represent groundwater contamination. Eight of 11 wells with elevated sulfate levels also contain elevated uranium and are definitely affected by the WSQ. The remaining three of these wells may just be indicating natural fluctuations.

Eleven wells were below 50 mg/L. There is an apparent geographical distribution associated with these low sulfate levels. Most of the wells are located south of the slough, indicating that the area is not affected by the WSQ. These data agree with and support the radiological data.

Seventeen wells were analyzed during 1987, and the results can be compared to the results of 1988. Of these wells, ten indicated a lower annual average of sulfate in 1988 while seven were higher. In no case were these changes dramatic. Rather, the changes should be described as subtle changes in concentration caused by seasonal water level changes and/or related climatic variations.

Nitrate

Nitrate was found in detectable quantities in 18 of the 26 wells monitored during 1988. In all cases, the annual average concentrations are low. The EPA primary drinking water standard is 10 mg/L for nitrogen, which may also be expressed as 45 mg/L for nitrate. The highest nitrate value was observed in MW-1006 at a level of 15.2 mg/L, significantly below the drinking water standard. The nitrate levels have remained generally constant from 1987 to 1988. As in 1987, no wells exhibited individual sample values and therfore no annual average above the drinking water standard for nitrogen.

Chloride

The 1987 EMR reported five wells with apparently elevated (>100 mg/L) chloride levels. However, in 1988, none of the 26 wells indicated elevated annual chloride concentrations. Additionally, no well yielded an elevated quarterly value. The highest value was measured at 76 mg/L from MW-1007. This value is solitary and above the average values for other wells. The chloride levels in the WSQ area have apparently diminished in 1988 as compared to 1987. No additional information regarding chloride contamination has been obtained since 1987.

Fluoride

The EPA primary drinking water standard for fluoride is 4 mg/L. No annual average for any well was in excess of that level. However, MW-1022 approaches that level with an annual average reported at 3.6 mg/L. This is due to a third quarter 1988 fluoride concentration of 6.8 mg/L. With this exception, all concentration averages for 1988 are below 1.0 mg/L. This is similar to the fluoride concentrations reported in the 1987 EMR.

2.2 SURFACE WATER MONITORING

Surface water samples were collected around the WSS at locations where measurable impacts could be monitored. Samples were collected from both on-site and off-site locations under two distinct programs. Samples were also collected at the site boundary to monitor off-site discharge of contaminants through storm water runoff. These samples were collected in compliance with the National Pollutant Discharge Elimination System (NPDES) permit for storm water runoff which was issued in July 1988. Off-site locations were sampled quarterly to monitor downstream receptors for discharge from the site.

The surface water systems are more dynamic than the groundwater systems at the WSS, and contaminant levels in surface water tend to fluctuate more over time than in groundwater. Both the quarterly and the annual average results are discussed below.

2.2.1 Monthly NPDES Sampling Results

Samples were collected monthly following significant rainfall events at the five outfalls shown in Figure 2-4 from January through June of 1988. After the permit was issued, the sampling frequency and analytical parameters were adjusted to comply with NPDES Permit No. MO-0107701. A summary of the permit requirements is presented in Table 2-7. These are monitoring requirements only, with no limits placed on discharges at this time. Annual averages of analytical results from the program are presented in Table 2-8. Tables of analytical results from the monthly NPDES sampling events may be found in Appendix A.

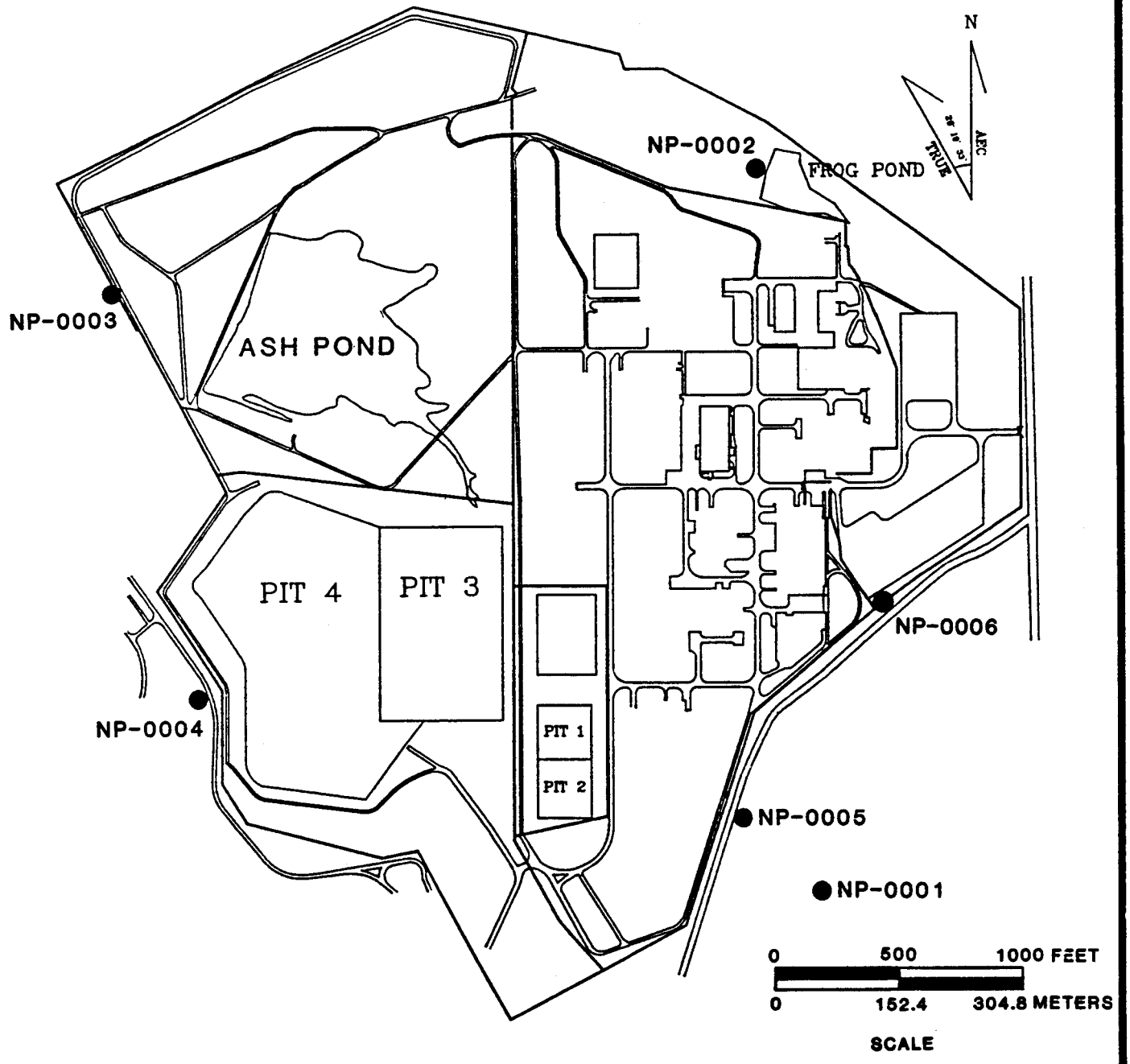


FIGURE 2-4

N.P.D.E.S. SURFACE WATER SAMPLING LOCATIONS

TABLE 2-7 NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM PERMIT MONITORING REQUIREMENTS

	OUTFALL NUMBER **				
PARAMETERS*	0001	0002	0003	0004	0005
Flow	Q	M	M	Q	M
Settlable Solids	Q	M	M	Q	M
Total Suspended Solids	Q	M	M	Q	M
Nitrate	Q	M	M	Q	M
Uranium	Q	M	M	Q	M
Lithium	Q	M	M	Q	M
Gross Alpha	Q	M	M	Q	M
pH	Q	M	M	Q	M

* - Monitoring requirements only; no discharge limits

** - See Figure 2-4 for locations

Q - Quarterly sampling

M - Monthly sampling

TABLE 2-8

ANNUAL AVERAGE RESULTS FOR NPDES SAMPLING AT THE
WELDON SPRING CHEMICAL PLANT AND RAFFINATE PITS

LOCATION NUMBER*	pH	FLOW (gpm)	TOTAL SETTLABLE SOLIDS (ml/l)	NUMBER OF SAMPLES	TSS (mg/l)	NATURAL URANIUM (pCi/l)	GROSS ALPHA (pCi/l)	NITRATE (AS N) (mg/l)	LITHIUM (ug/l)
NP-0001	7.54	40	<0.1	7	14.0	539+/-57	307+/-34	4.5	ND
NP-0002	7.12	160	<0.1	11	63.0	141+/-16	75+/-9	2.6	ND
NP-0003	7.19	140	5.3 (2)	7	515.0	1178+/-152	592+/-62	21.6	ND
NP-0004	7.23	18	<0.1	6	9.2	6.2+/-1.1	5.1+/-2.8	1.8	ND
NP-0005	7.39	60	<0.1	9	39.0	497+/-53	280+/-29	63.9	ND

* see Figure 2-4
(2) - Number of samples comprising average
ND - NOT DETECTED

2.2.1.1 Radiological Analysis

Annual average natural uranium levels ranged from 6.2 pCi/L (1% DCG) at the minimum concentration discharge point (NP-0004) to 1,178 pCi/L (214% DCG) at the maximum concentration discharge point (NP-0003). The highest average activity level was measured at the off-site discharge point downstream of Ash Pond. This discharge flows via subsurface pathway to Lake 34 and overland to Lake 35 in the August A. Busch Wildlife Area (see Figure 1-6). Frog Pond's off-site discharge (NP-0002) exhibited an annual average natural uranium level of 141 pCi/L (25% of the DCG). This discharge flows into Lake 36 in the Busch Wildlife Area. Outfall NP-0001 receives runoff resulting from rainfall intercepted by the process and sanitary sewer systems at the WSCP. This outfall exhibited an annual average natural uranium level of 539 pCi/L (98% of the DCG). Outfall NP-0005 receives runoff from the southeast portion of the WSCP and had an annual average natural uranium level of 497 pCi/L (90% of the DCG). These two outfalls combine and flow into the southeast drainage easement.

Annual average gross alpha levels generally followed the same pattern as the natural uranium results. The generally good correlation between the average uranium and the gross alpha values indicates that virtually all of the off-site radionuclide release is in the form of soluble uranium. However, gross alpha measurements are biased low, probably due to measurement interference from dissolved solids.

While the flow rate averages in Table 2-8 indicate susbstantial levels, these flow rates are biased high by the nature of the sampling program. Since samples were collected only after sufficient precipitation to cause consistent runoff, the true average flow rate from these discharge points over the entire year would be signficantly less than the values shown.

No measurements were made of the total flow from these points during the entire year. However, if it is assumed that the entire annual precipitation runoff is discharged from these points and that the discharge from each point is proportional to the portion of the site that each point drains, an upper bound to the total uranium released off-site during 1987 can be calculated as presented in Table 2-9.

2.2.1.2 Chemical Analysis

The average total settlable solids (mL/L) and total suspended solids (mg/L) were highest at the off-site discharge of Ash Pond (NP-0003). These elevated average values were primarily caused by high values from samples taken in November and December. During that time, a construction project was initiated in the Ash Pond drainage, causing increased erosion during storm events. Additional erosion control measures were implemented in response to these high values.

Lithium was added to the list of parameters analyzed as specified in the official issuance of the permit. Lithium was not detected in any samples collected at a detection limit of 50 µg/L. Annual average nitrate values ranged from 1.8 mg/L at NP-0004 to 63.9 mg/L at NP-0005. These average values are generally the same as results from 1987.

2.2.2 Quarterly Surface Water Sampling at the WSCP/WSRP Area

Surface water samples were collected quarterly from the nine locations shown in Figure 2-5. Seven of these locations monitor surface water bodies which receive groundwater or surface water discharged from the WSCP/WSRP area. Five of these locations are within, or upstream of, lakes on the August A. Busch Memorial Wildlife Area. These sampling locations were selected to monitor surface waters for contaminants which may

Table 2-9 Estimated Annual Release of Natural Uranium from NPDES Discharge Points in 1988

Discharge Point**	Drainage Areas (acres)	Percent of Precipitation as Runoff*	Average Conc. (pCi/L)	Upper Bound Total Volume (Mgal/yr)	Upper Bound Total Uranium (Ci/yr)	Upper Bound Total Uranium (kg/yr)
NP-0001 & NP-0005	20.2	60%	518	12.8	0.025	37.2
NP-0002	39.1	65%	141	26.9	0.014	21.2
NP-0003	60.1	20%	1,178	12.7	0.057	83.9
NP-0004	5.6	50%	6.2	3.0	0.00007	0.103

* - Estimated

** - see Figure 2-4

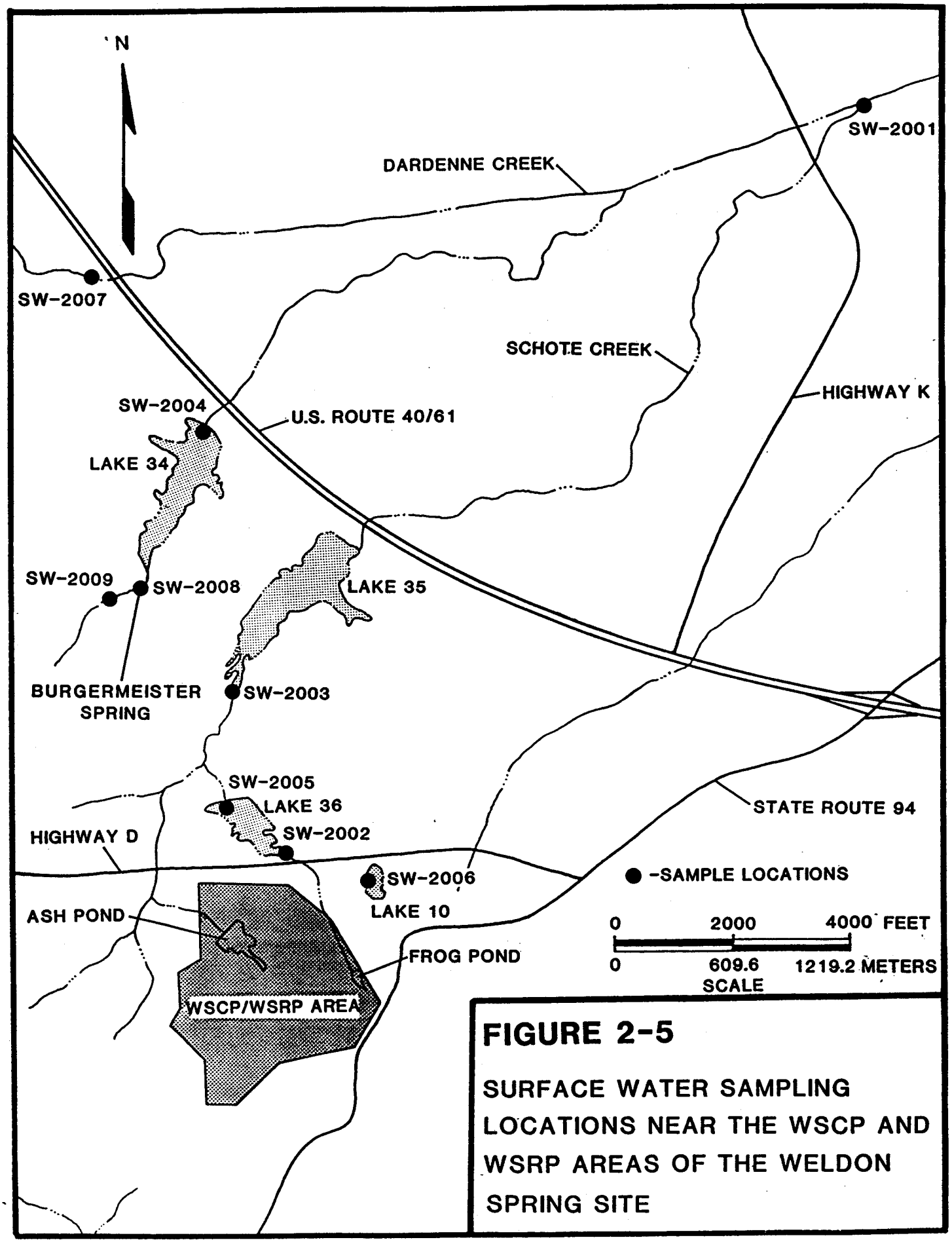


FIGURE 2-5

SURFACE WATER SAMPLING LOCATIONS NEAR THE WSCP AND WSRP AREAS OF THE WELDON SPRING SITE

pose risks to the public health and the environment. The individual sample results and annual averages for these sampling locations are presented in Table 2-10.

The samples were analyzed for radiologic species and inorganic anions. Two of the nine locations exhibited no measurable affects of uranium in surface water discharged from the site. These locations include SW-2006 (Lake 10 on the Busch Wildlife Area) which receives no direct surface discharge from the site, and SW-2007 (Dardenne Creek) which is monitored at a point upstream of any known contamination discharge route.

2.2.2.1 Radiological Analysis

Overall, total uranium activities range from below the lower detection limit of 1 pCi/L to as high as 150 pCi/L at Burgermeister Spring on the Busch Wildlife Area. This highest value at Burgermeister Spring was consistent with levels previously measured at that location.

SW-2001, which monitors water in Dardenne Creek at the confluence of Schote Creek, displayed one quarterly data point (of the four collected) which represented elevated uranium activity. In the second quarter of 1988, 4.3 pCi/L total uranium was measured at that location. This value contrasts with the data from the other quarters of 1988 which remained at or below 1.1 pCi/L. Further, three of the four other downgradient surface-water monitoring wells showed high values for uranium in the second quarter. This increase was most likely caused by the drought, which may have had a concentrating affect on uranium levels. The fact that a measurable elevation in total uranium activity was detectable at SW-2001, the furthest surface water sampling location downstream of the WSCP/WSRP area supports this conclusion.

TABLE 2-10: SURFACE WATER ANNUAL AVERAGES-WELDON SPRING CHEMICAL PLANT AND RAFFINATE PITS

Location Number *	Q1	Q2	Q3	Q4	AVERAGE
		CHLORIDE - MG/L			
SW-2001	10.9	10.0	9.7	14.3	11.2
SW-2002	41.0	DRY	DRY	DRY	41.0
SW-2003	13.0	10.9	11.2	13.1	12.1
SW-2004	10.5	10.6	12.6	15.2	12.2
SW-2005	73.0	68.8	87.5	88.5	79.5
SW-2006	7.0	8.2	9.6	10.5	8.8
SW-2007	8.9	9.1	8.1	9.9	9.0
SW-2008	6.8	21.2	10.5	34.4	18.2
SW-2009	6.9	DRY	DRY	DRY	6.9
		FLUORIDE - MG/L			
	Q1	Q2	Q3	Q4	AVERAGE
SW-2001	0.3	0.5	0.3	ND	0.4
SW-2002	ND	DRY	DRY	DRY	ND
SW-2003	ND	ND	0.3	ND	0.3
SW-2004	0.3	0.3	0.3	ND	0.3
SW-2005	ND	ND	ND	ND	ND
SW-2006	0.3	0.3	0.3	ND	0.3
SW-2007	0.3	0.4	0.3	ND	0.3
SW-2008	0.3	ND	ND	ND	0.3
SW-2009	0.3	DRY	DRY	DRY	0.3
		NITRATE - MG/L			
	Q1	Q2	Q3	Q4	AVERAGE
SW-2001	5.5	1.5	0.6	ND	2.5
SW-2002	4.0	DRY	DRY	DRY	4.0
SW-2003	3.0	0.1	ND	ND	1.6
SW-2004	6.2	0.7	0.9	2.7	2.6
SW-2005	1.0	0.3	LE	0.3	0.5
SW-2006	ND	ND	0.1	0.2	0.2
SW-2007	5.0	1.5	0.3	ND	2.3
SW-2008	15.5	22.1	29.9	ND	22.5
SW-2009	15.6	DRY	DRY	DRY	15.6

LE - Laboratory Error
ND - Not Detected
* - see Figure 2-5

TABLE 2-10: SURFACE WATER ANNUAL AVERAGES - WELDON SPRING CHEMICAL PLANT AND RAFFINATE PITS
(Continued)

Location Number	SULFATE - MG/L Q1	Q2	Q3	Q4	AVERAGE
SW-2001	23.7	17.6	8.0	15.1	16.1
SW-2002	18.0	DRY	DRY	DRY	18.0
SW-2003	16.0	9.9	10.6	30.3	16.7
SW-2004	18.5	15.1	14.9	19.1	16.9
SW-2005	14.0	18.5	93.0	26.8	38.1
SW-2006	8.4	7.7	4.3	7.6	7.0
SW-2007	23.6	21.3	7.2	42.9	23.8
SW-2008	24.6	44.3	22.2	72.3	40.9
SW-2009	24.9	DRY	DRY	DRY	24.9

URANIUM ACTIVITY - pCi/L

	Q1	Q2	Q3	Q4	AVERAGE	% OF DCG
SW-2001	ND	4.3	1.0	1.1	2.1	0.4%
SW-2002	67.0	DRY	DRY	DRY	67.0	12.2%
SW-2003	69.0	16.0	8.5	12.0	26.4	4.8%
SW-2004	13.0	19.0	12.0	15.0	14.8	2.7%
SW-2005	14.0	21.0	10.0	4.1	12.3	2.2%
SW-2006	ND	ND	ND	ND	ND	0.0%
SW-2007	ND	ND	ND	1.8	1.8	0.3%
SW-2008	49.0	150.0	42.0	34.0	68.8	12.5%
SW-2009	49.0	DRY	DRY	DRY	49.0	8.9%

ND - NOT DETECTED
* - see Figure 2-5

Radium-226, Thorium-230, and Thorium-232

Radium-226 was not detected at any of the nine surface water sampling locations during the four quarters of 1988.

Low concentrations of Th-230 were detected at two locations downgradient of the WSCP/WSRP area. The first location, SW-2005, at the outfall of Lake 36, indicated a level of 1.5 pCi/L for the third quarter of 1988. The remaining three quarters yielded results below the detection limit of 1 pCi/L resulting in an average of 1.5 pCi/L (0.5% of the DCG).

The other location which yielded detectable levels of Th-230 was SW-2007 at Dardenne Creek near U.S. Highway 40/61. This location is upgradient of all surface drainages influenced by site discharge and has never previously indicated impacts by site related contaminants. Samples from the third and fourth quarters yielded levels of 1.6 pCi/L and 2.4 pCi/L, respectively. These values calculate to an annual average of 2.0 pCi/L (0.6% of the DCG). It is believed that this level reflects background concentrations when analytical error is factored into the measured values. Samples from SW-2001 (downstream) do not support these levels.

2.2.2.2 Inorganic Anion Analysis

The inorganic anions of interest at the WSS are chloride, fluoride, nitrate, and sulfate. Following is a discussion of each of these anions and their implications to environmental safety and health.

Chloride

Quarterly chloride levels measured in the nine surface water sampling locations ranged from a low of 6.8 mg/L at

SW-2008 to a high of 88 mg/L at SW-2005 in Lake 36. The annual average results ranged from 6.9 mg/L at SW-2009 to 79.5 mg/L at SW-2005, which is well below the EPA secondary drinking water standard of 250 mg/L for chloride. These results indicate that chloride levels in surface water downstream of the WSCP/WSRP are not a threat to health and safety at this time. No standards exist for protection of aquatic life or biota.

Fluoride

The quarterly fluoride concentrations in all of the surface water sampling locations remained within the calculated background concentration of 0.57 mg/L for surface water emanating at local springs (MKF and JEG, 1988a). The annual averages of these results ranged from below the lower detection limit of 0.3 mg/L to a high value of 0.4 mg/L. These concentrations also remain within the EPA's maximum contaminant level (MCL) of 4 mg/L for fluoride.

Nitrate

Surface water samples were analyzed for nitrate to the minimum detection limit of 0.1 mg/L. The nitrate concentrations ranged from below the detection limit to a quarterly high of 29.9 mg/L at Burgermeister Spring. Two groups of concentration numbers are apparent in the annual averages. Water samples from locations SW-2001 to SW-2007 range between 0.2 mg/L to 4.0 mg/L, and SW-2008 and SW-2009 (Burgermeister and Overflow Springs) contain levels of nitrate at 22 mg/L and 15 mg/L, respectively.

This grouping suggests that some of the nitrate contamination in the groundwater system is discharging to the surface; however, the levels remain below the EPA primary drinking water standard of 45 mg/L (as nitrate). The measured

levels of nitrate in the surface water constitute no particular threat to human health or the environment.

Sulfate

The surface water downgradient of the site was also analyzed for sulfate. The quarterly measurements ranged from a low of 4.3 mg/L at SW-2006 to a high of 93 mg/L at SW-2005 (Lake 36). The range of annual averages was more moderate, with a low of 7.0 mg/L at SW-2006 and a high of 40.9 mg/L in SW-2008 (Burgermeister Spring). The quarterly high values are most likely indicative of some non-natural influence from a sulfate source. However, these levels are not significantly higher than the calculated background limit (mean plus two standard deviations) of 60.9 mg/L for sulfate in spring waters, nor do they approach the EPA secondary drinking water standard of 250 mg/L.

2.2.3 Quarterly Surface Water Sampling at the WSQ Area

The six surface water locations in Figure 2-6 were sampled quarterly and analyzed for uranium, radium-226, thorium-230, thorium-232, nitrate, sulfate, chloride, and fluoride. These locations were chosen for the purpose of investigating and documenting the possibility that surface waters near the WSQ might pose a risk to human health or the environment. Locations SW-1001 and SW-1002 monitor the Little Femme Osage Creek at points upstream and downstream of the WSQ. Three sampling locations, SW-1003 through SW-1005, are distributed along the Femme Osage Slough adjacent to and east of the WSQ. Location SW-1008 monitors the ponded water within the WSQ. The samples from this location permit a rough determination of the concentrations of the various contaminants in the water that may migrate to groundwater. They also document those levels for use in the determination of health risks.

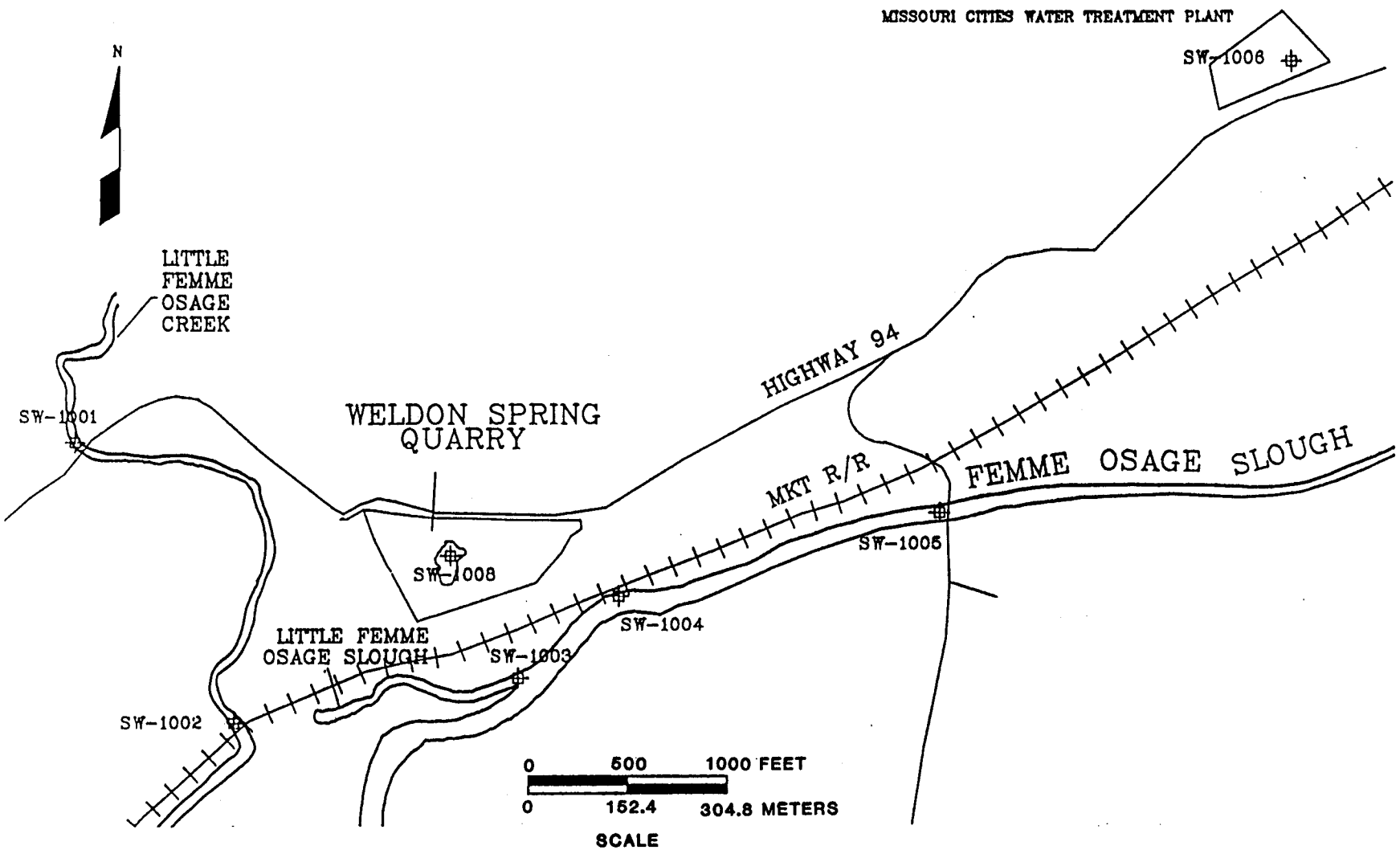


FIGURE 2-6

SURFACE WATER SAMPLING LOCATIONS NEAR THE WELDON SPRING QUARRY

The quarterly results and annual averages for inorganic anions and uranium are presented in Table 2-11. Only one of these locations, SW-1008, receives direct surface runoff from the WSQ.

Chloride

The quarterly and annual average results for chloride were consistent and ranged from 3.9 to 13.2 mg/L. The chloride levels in all quarters and for all locations fell within the single applicable reference level, the EPA's secondary drinking water standard of 250 mg/L. The chloride levels in surface water near the quarry indicate no apparent environmental contamination by this substance.

Fluoride

Fluoride was detected at low levels, representing natural background concentrations. Quarterly levels ranged from undetectable (detection limit of 0.3 mg/L) to 0.7 mg/L. These levels are below the drinking water standard for fluoride of 4 mg/L.

Nitrate

Nitrate concentrations in the surface waters at the six monitored locations remained well within acceptable levels, ranging from below the detection limit of 0.1 mg/L to a maximum quarterly value of 1.5 mg/L at SW-1002. The EPA primary drinking water standard for nitrate (as NO_3) is 45 mg/L. The levels represented by the quarterly environmental samples indicate no environmental contamination by nitrate.

TABLE 2-11: SURFACE WATER ANNUAL AVERAGES - WELDON SPRING QUARRY

Location Number *	Q1	Q2	Q3	Q4	AVERAGE
		CHLORIDE - MG/L			
SW-1001	4.5	3.9	4.3	6.8	4.9
SW-1002	5.2	4.5	5.0	6.3	5.3
SW-1003	7.9	12.5	12.5	4.5	9.4
SW-1004	8.2	11.4	12.3	4.9	9.2
SW-1005	10.8	12.5	13.1	5.3	10.4
SW-1006	9.3	13.2	10.0	9.0	10.4
SW-1008	2.9	LE	11.0	14.6	8.5
		FLUORIDE - MG/L			
SW-1001	0.4	0.4	ND	ND	0.4
SW-1002	0.4	0.5	ND	ND	0.5
SW-1003	0.4	0.5	ND	ND	0.5
SW-1004	0.4	0.6	0.3	ND	0.4
SW-1005	0.4	0.6	0.3	ND	0.4
SW-1006	0.7	0.7	0.3	ND	0.6
SW-1008	0.4	LE	0.6	0.7	0.7
		NITRATE - MG/L			
SW-1001	1.1	0.2	1.3	ND	0.9
SW-1002	1.5	0.4	1.4	ND	1.1
SW-1003	ND	ND	ND	LE	ND
SW-1004	ND	ND	ND	LE	ND
SW-1005	ND	ND	ND	LE	ND
SW-1006	ND	0.9	ND	ND	0.9
SW-1008	0.2	ND	ND	0.6	0.6

ND - NOT DETECTED
AVERAGE - ONLY DETECTED CONCENTRATIONS USED IN AVERAGE CALCULATION
LE - Laboratory Error, data not reported. Annual averages calculated based on reportable quarterly data.
* - See Figure 2-6

TABLE 2-11: SURFACE WATER ANNUAL AVERAGES - WELDON SPRING QUARRY (continued)

SULFATE - MG/L

Location Number *	Q1	Q2	Q3	AVERAGE
SW-1001	29.5	22.9	25.0	25.8
SW-1002	32.3	21.7	26.6	26.9
SW-1003	53.6	55.7	50.3	53.2
SW-1004	53.3	46.5	49.5	49.6
SW-1005	57.5	53.8	50.0	53.8
SW-1006	70.2	62.0	49.6	60.6
SW-1008	117.0	LE	84.9	100.9

URANIUM ACTIVITY - pCi/L

	Q1	Q2	Q3	Q4	AVERAGE	% OF DCG
SW-1001	ND	1.1	ND	**	7.1	1.3%
SW-1002	ND	1.2	ND	ND	1.2	0.2%
SW-1003	83.0	110.0	42.0	21.0	64.0	11.6%
SW-1004	67.0	120.0	50.0	18.0	63.8	11.6%
SW-1005	14.0	82.0	4.8	10.0	27.7	5.0%
SW-1006	ND	ND	ND	ND	ND	0.0%
SW-1008	330	1600.0	910.0	1400.0	1303.3	237.0%

ND - NOT DETECTED
AVERAGE - ONLY DETECTED CONCENTRATIONS USED IN AVERAGE CALCULATION
LE - Laboratory Error, data not reported. Annual averages calculated based on reportable quarterly data.
* - See Figure 2-6
** - See explanation in Section 2.2.3

Sulfate

Sulfate levels were also measured in the six monitored surface water locations. Quarterly levels ranged from a low of 21.7 mg/L in SW-1002 to a high of 117 mg/L in the quarry sump water (SW-1008).

The quarterly sulfate values were calculated to annual averages which ranged from 25.8 to 100.9 mg/L. The annual averages at five of six sampling locations remained below the calculated background concentration of 60.9 mg/L for local spring waters, and all of the annual averages remained well below the secondary drinking water standard of 250 mg/L.

Uranium

Uranium is the only radiological surface water contaminant at the WSQ. The WSQ pond contained the highest concentration of uranium with an annual average of 1,303 pCi/L (237% of the DCG). The three locations monitored on the Femme Osage Slough exhibited a maximum annual average of 64 pCi/L (11.6% of the DCG). The source of this contamination is groundwater discharge to the slough. Two locations on the Little Femme Osage Creek and the untreated well field water were not affected by the WSQ.

The uranium activity measurement from SW-1001 for the fourth quarter of 1988 (Q488) was 13.0 pCi/L. Surface water sample SW-1002-Q488, collected downstream of SW-1001 on the same day and using the same method, did not substantiate that relatively high value. Nor did previous quarterly data from either location substantiate such a high value. This value of 13.0 pCi/L is believed to reflect laboratory error and was not factored into the annual average for that location.

Radium-226 and thoruim-232 were not detected in surface waters near the WSQ. Thorium-230 was detected in the Femme Osage Slough (Location SW-1004) at 4.8 pCi/L in the third quarter of 1988. When analytical errors are discounted from the measured value, no other levels above the detected limit were measured in the slough for the remaining three quarters of 1988. The single measured value was not expected and may represent analytical error; however, no evidence to that affect is readily available. That level of thorium-230 is above background.

2.3 RADON MONITORING

Radon is a naturally occurring radionuclide in the uranium and thorium decay series. Radon-222 and radon-220, two isotopes of radon, are produced in soil as naturally occuring Ra-226 and Ra-228 decay. A fraction of the radon diffuses into the atmosphere and accounts for natural background radon concentrations. Radon is also produced at the WSS as Ra-226 and Ra-228 contained in the waste material undergo radioactive decay. Exposure to radon is a potentially serious environmental impact from the WSS. Therefore, radon has been monitored since 1981. This section presents the summary of the monitoring results and a discussion of factors which contributed to an apparent increase in radon emanation during 1988.

The radon gas monitoring program involved duplicate radon detectors exchanged quarterly at 22 different locations. These detectors were spaced around the perimeter fence to ensure adequate detection of radon dissipating from the properties under various atmospheric conditions. Radon monitoring locations are shown in Figure 2-7, 2-8, and 2-9.

The detectors were deployed at six locations at the WSCP, six locations at the WSQ, four locations at the WSRP, and six

locations off site. Three off-site locations near the Busch Wildlife Area, RD-4004, RD-4005, and RD-4006, were added to the monitoring program in the second quarter of 1988. These three locations, together with RD-4001, were used to monitor background levels near the Weldon Spring Site.

The radon detectors used in this program were Terradex Track Etch Type F. Type F detectors are sensitive to all isotopes of radon. These detectors were housed in protective plastic cups and mounted inverted on posts. The detectors were placed and collected at the beginning and end of each quarter. The detectors were deployed in duplicate to evaluate and reduce the natural uncertainties associated with this type of measurement. The collected detectors were then sealed and shipped to the Terradex Corporation of Glenwood, Illinois, for analysis.

One location at the WSQ, RD-1005, was vandalized during the fourth quarter of 1988. Both detectors at this location were destroyed.

2.3.1 Summary of Radon Monitoring Results

Ra-226 and Ra-228 occur naturally in soil and produce Rn-222 and Rn-220, respectively, as they decay. A fraction of this radon diffuses through the soil pore spaces and enters the atmosphere at the soil/air interface. This accounts for the background concentrations of radon.

Table 2-12 summarizes the minimum, maximum, and annual average concentrations of radon detected at all four monitoring locations across the WSS properties.

The above-background Rn-222 guidelines applicable to the WSS are: (1) an off-site annual average of 3 pCi/L, and (2) an

annual average of 30 pCi/L on site with no on-site location exceeding 100 pCi/L (Gilbert et al., 1989). The off-site guideline was applied in Table 2-12 to determine the percentage of standard for annual average concentration above background.

To determine the background value used to assess the percentage of the standard, the arithemtic average of the annual average concentrations for the four background locations was calculated. These four locations are: RD-4001, RD-4004, RD-4005, and RD-4006. This data yielded a background value for radon in 1988 of 0.6 pCi/L. This background level was subtracted before the concentrations were compared with applicable standards.

Background concentrations of radon vary quarterly (see Table 2-12) and annually (MKF and JEG, 1987 and 1988c). This is because the amount of radon that actually enters the atmosphere varies depending on the radium concentration, moisture content, porosity and density of the soil, and the emanating fraction. The moisture content of the soil is the most variable of these parameters and is primarily responsible for quarterly and annual changes in background concentrations.

The annual averages in Table 2-12 were calculated by finding the arithmetic average of the four quarterly replicate values. The estimate of error was calculated by averaging the square root of the sum of the squared errors for the four quarterly replicate data points.

At the WSQ, the average annual concentration ranged from 0.6 pCi/L to 4.3 pCi/L. The highest concentration, 4.3 pCi/L was at location RD-1002, which represents 123% of the DOE guideline value.

At the WSCP, the annual average concentration ranged from 0.3 pCi/L to 0.8 pCi/L. The highest annual average above

Table 2-12
Radon Measurements at the WSS in 1988 (pCi/L)*

Location I.D	No.	(a)	(a) Annual[a]	Est. of Err	% of[b]
			WSQ		
RD-1001	8	0.45	3.85	1.9	0.18	43
RD-1002	8	1.55	7.15	4.3	0.38	123
RD-1003	8	0.55	3.2	2.1	0.2	50
RD-1004	8	0.3	1.6	1.1	0.14	17
RD-1005	6	0.35	1.6	1	0.14	13
RD-1006	8	0.3	0.8	0.6	0.1	0
			WSCP		
RD-2001	8	0.3	1.25	0.8	0.12	7
RD-2002	8	0.3	0.8	0.5	0.08	0
RD-2003	8	0.3	0.8	0.5	0.1	0
RD-2004	8	0.3	0.45	0.4	0.08	0
RD-2005	8	0.25	0.35	0.3	0.08	0
RD-2006	8	0.3	1.4	0.8	0.12	7
			WSRP		
RD-3001	8	0.3	0.55	0.5	0.1	0
RD-3002	8	0.3	1.3	0.8	0.12	7
RD-3003	8	0.3	1	0.6	0.1	0
RD-3004	8	0.3	0.7	0.5	0.1	0
			OFF SITE		
RD-4001[c]	8	0.3	0.65	0.4	0.08	0
RD-4002	8	0.3	0.35	0.3	0.08	0
RD-4003	8	0.15	0.75	0.4	0.08	0
RD-4004[c]	6	0.35	0.5	0.4	0.1	0
RD-4005[c]	6	0.65	1.45	1.0	0.14	13
RD-4006[c]	6	0.65	0.8	0.7	0.12	3

Source: WSSRAP, 1988

* See Figures 2-7, 2-8 and 2-9
(a) Includes background
(b) DOE concentration guidelines for radon-222 is 3 pC/L (annual average above background) for uncontrolled areas
(c) Background measurement location
* To convert o Bq/L, multiply by 3.7×10^{-2}

background was at RD-2001 and RD-2006 with 7% of the DOE guideline value.

At the WSRP, the average annual concentration ranged from 0.5 pCi/L to 0.8 pCi/L. The highest annual average above background was 7% of the DOE guideline value.

At off-site locations, the annual average concentration ranged from 0.4 pCi/L to 1.0 pCi/L. The highest level was at location RD-4005 and was 13% of the DOE guideline value.

2.3.2 Interpretation of Radon Data

The radon concentrations in the WSCP/WSRP area were generally higher in 1988 than in 1987. However, they were still below, or at, 1988 background levels. Several environmental factors influenced these increases. The dryness of the soil due to the regional drought was most likely the critical factor.

The radon concentrations in the WSQ area were also higher in 1988. The concentrations at location RD-1002 were above the DOE guidelines for uncontrolled areas. This increase can also be attributed to the drought. The drought reduced the moisture content of the quarry waste, and the low moisture content allowed a greater fraction of the radon in the voids to diffuse into the atmosphere. Large voids within the waste (Kaye and Davis, 1987) give the radon a more direct diffusion path to the surface than would be the case in a more consolidated medium. In addition, the quarry is a large depression in the terrain with side walls ranging from 10 to 40 high. This tends to trap emanating radon within the quarry and raises the concentrations along the quarry perimeter.

2.4 GAMMA RADIATION EXPOSURE RATE MONITORING

To monitor exposure from gamma radiation at the Weldon Spring Site (WSS), 22 monitoring stations using Eberline spherical environmental thermoluminescent dosimeters (TLDs) were deployed. The TLDs are composed of five lithium fluoride chips in a rugged spherical polyethylene holder which is designed with internal filters to measure penetrating radiation. The TLDs were exchanged quarterly and returned to the Eberline laboratory for processing. The data are presented in Table 2-13. The monitoring locations are the same as the ambient radon monitoring locations shown in Figures 2-7, 2-8, and 2-9.

To determine the external gamma radiation exposure near the WSS, background levels of gamma radiation for the area were identified. Background levels of gamma radiation are the result of naturally occuring radioactive materials in the earth and cosmic radiation penetrating the atmosphere. Previous DOE contractors identified background radiation exposure rates in the WSS area ranging from 60 to 105 mR/year (BNI, 1985a, 1985b, 1984; Deming, 1986). Radiological characterization in 1987 identified average background radiation exposure rates (within an 8 km (5 mile) radius of the site) ranging from 78 to 96 mR/year with an average of 85 mR/year and a statistical error (2 sigma) of 12 mR/year. The past studies and the recent quarterly measurements correlate well.

At the WSCP/WSRP site, ten monitoring stations were located along the perimeter fence (Figure 2-7). Annual average exposure rates including normal background levels ranged from 49 to 71 mR/year. No monitoring locations along the perimeter fence recorded measurements that exceeded background rates. In fact, there has been no significant change since the measurement of gamma exposure rates began in 1980.

TABLE 2-13
GAMMA RADIATION EXPOSURE RATE MONITORING RESULTS
EXPOSURE RATES IN MILLIROENTGEN PER YEAR
INCLUDING NATURAL BACKGROUND (mR/year)

LOCATION I.D.	MINIMUM	MAXIMUM	AVERAGE	ERROR 2 SIGMA	PERCENT OF STANDARD(a)
			QUARRY		
TD-1001	83	86	82	32	0
TD-1002	84	110	91	29	0
TD-1003	72	79	72	16	0
TD-1004	58	76	66	11	0
TD-1005	56	75	65	20	0
TD-1006	54	70	63	14	0
			CHEMICAL PLANT		
TD-2001	50	74	63	34	0
TD-2002	55	81	64	40	0
TD-2003	60	75	68	34	0
TD-2004	56	75	63	29	0
TD-2005	45	64	56	11	0
TD-2006	59	64	65	15	0
			RAFFINATE PITS		
TD-3001	58	83	66	21	0
TD-3002	40	56	49	18	0
TD-3003	60	90	71	29	0
TD-3004	41	67	53	26	0
			OFF SITE		
TD-4001	60	75	69	13	0
TD-4002	40	50	45	8	0
TD-4003	52	80	61	20	0
TD-4004	57	59	59	20	0
TD-4005	50	56	55	14	0
TD-4006	50	74	61	35	0

* See Figures 2-7, 2-8 and 2-9

(a) Compared to the basic dose limit of 100 mrem/yr:
For gamma radiation 1 mR = 1 mrad = 1 mrem

To convert to Sv/Year multiply 1 X 10^{-5}

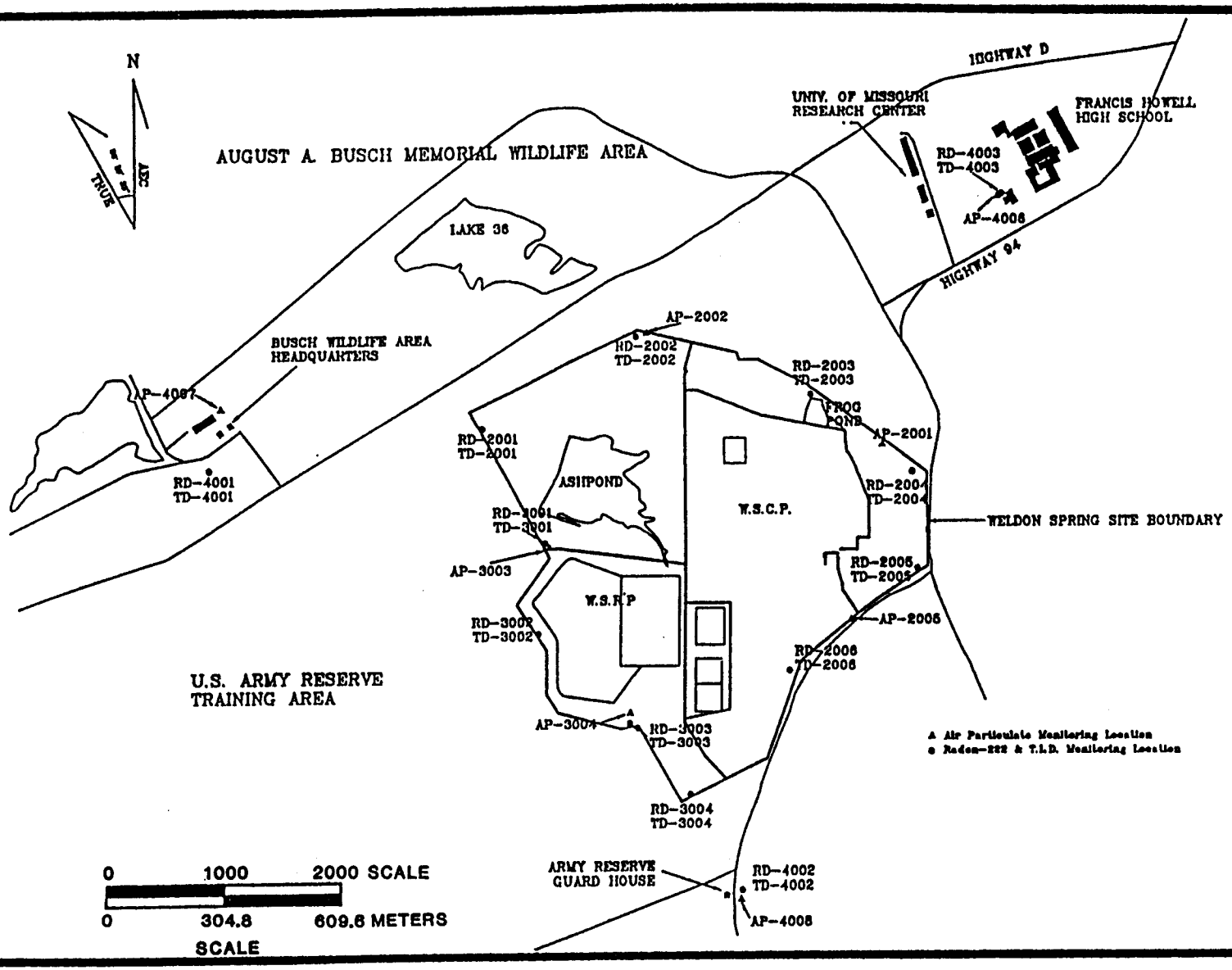


FIGURE 2-7

RADON-222, TLD, AND AIR PARTICULATE MEASUREMENT LOCATIONS AT THE WSCP/WSRP AREA

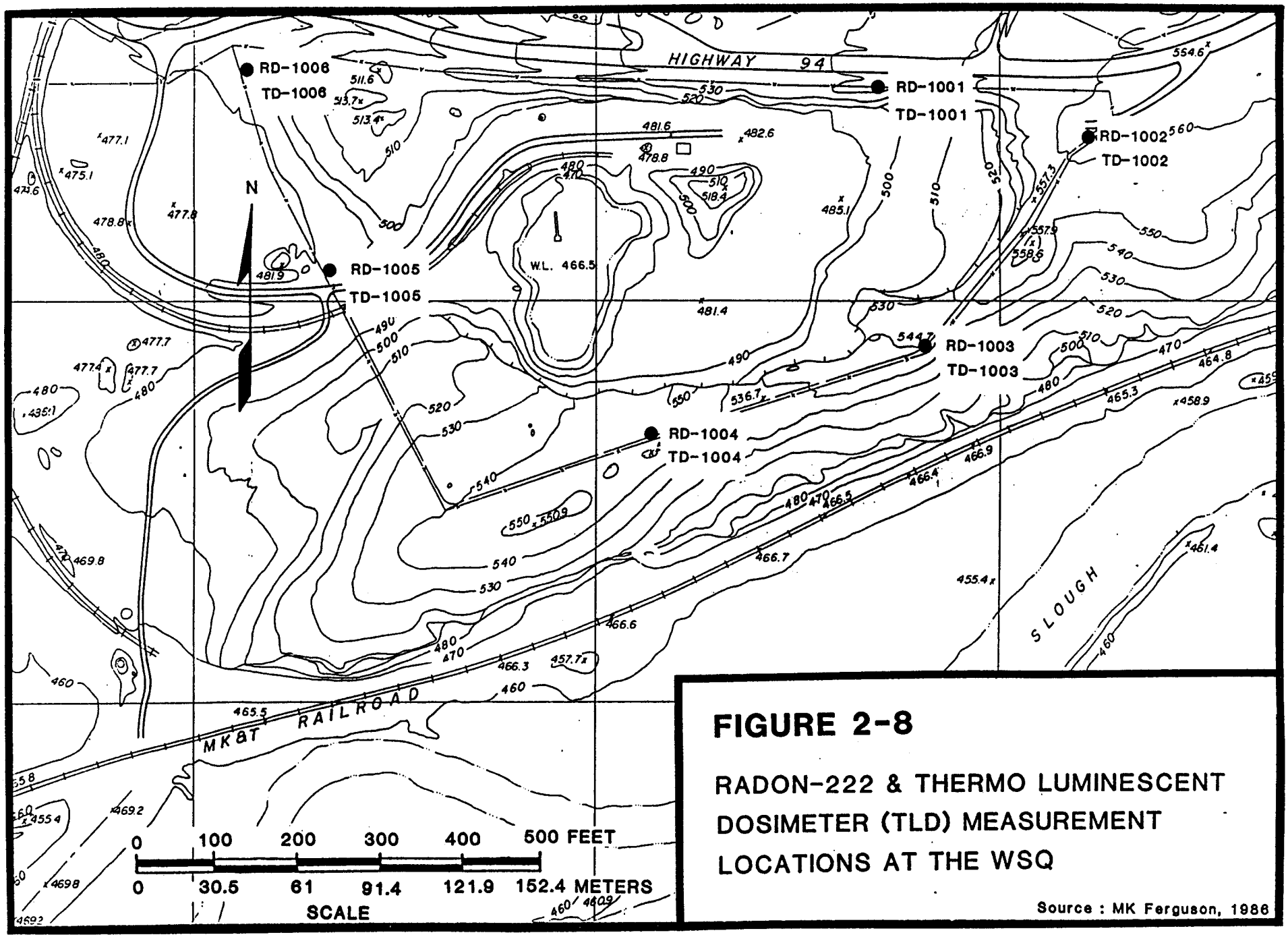
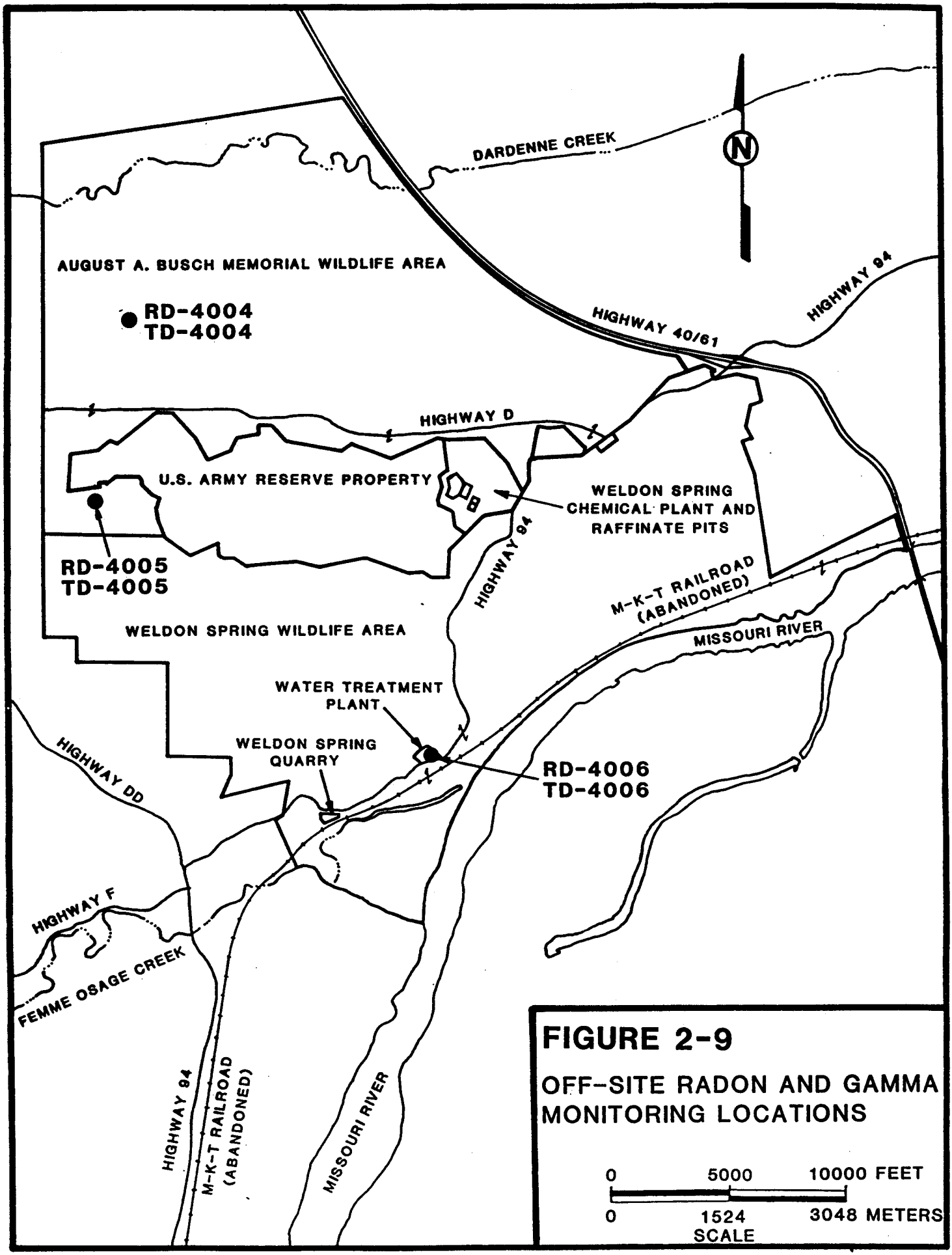


FIGURE 2-8

RADON-222 & THERMO LUMINESCENT DOSIMETER (TLD) MEASUREMENT LOCATIONS AT THE WSQ

Source : MK Ferguson, 1986


DARDENNE CREEK
N
AUGUST A. BUSCH MEMORIAL WILDLIFE AREA
RD-4004
TD-4004
HIGHWAY 40/61
HIGHWAY 94
HIGHWAY D
U.S. ARMY RESERVE PROPERTY
WELDON SPRING CHEMICAL PLANT AND RAFFINATE PITS
RD-4005
TD-4005
HIGHWAY 94
M-K-T RAILROAD (ABANDONED)
WELDON SPRING WILDLIFE AREA
MISSOURI RIVER
WATER TREATMENT PLANT
WELDON SPRING QUARRY
RD-4006
TD-4006
HIGHWAY DD
HIGHWAY F
FEMME OSAGE CREEK
HIGHWAY 94
M-K-T RAILROAD (ABANDONED)
MISSOURI RIVER
FIGURE 2-9
OFF-SITE RADON AND GAMMA MONITORING LOCATIONS
0 5000 10000 FEET
0 1524 3048 METERS
SCALE

At the WSQ site, six monitoring stations are located along the perimeter fence (Figure 2-8). Annual average exposure rates including normal background levels ranged from 63 to 91 mR/year. No monitoring locations along the WSQ perimeter fence recorded measurements that exceed normal background radiation exposure rates. Here, too, there has been no significant change since gamma exposure rate measurements were started.

Gamma radiation exposure rates were also measured at six off-site monitoring stations, (Figures 2-7 and 2-9). These are at the Francis Howell High School; August Busch Wildlife Area headquarters office, Rifle Range, and Archery Range; the St. Charles County Water Treatment Plant; and the guard station at the U.S. Army Training Area. All results indicate normal background exposure levels. Therefore, it can be concluded that the WSS does not contribute any increased gamma radiation exposure to the public, workers, or students at these locations.

2.5 AIR PARTICULATE MONITORING

The environmental monitoring program includes determination of whether radioactivity and other pollutants are released from the WSS via airborne particles, and if so, to what extent. Compliance with applicable environmental quality and public exposure limits is also assessed. The airborne particle monitoring program aids in evaluating the overall impact on the environment of Weldon Spring Site Remedial Action Project (WSSRAP) operations and WSS conditions. The program will also be used to assess the effectiveness of engineering controls at the site during remedial action in future years.

Potential emissions from the site (primarily during remedial action construction) are particulate matter (radioactive and non-radioactive), asbestos, radon and radon daughters, metals, and other unknown chemicals. A separate

program (the site characterization study) will confirm the presence of these chemicals at the site. If the presence of other chemicals is confirmed, and if airborne transport of the chemicals presents a potential hazard, air sampling for additional parameters may be instituted.

2.5.1 Radionuclide Monitoring

During 1988, air particulate sampling followed two schedules. In the first quarter, two sampling periods were used at the Francis Howell High School (FHHS): a weekday period (Monday morning to Friday afternoon), and a weekend period (Friday afternoon to Monday morning).

Except for the one at FHHS, all monitors were out of service for the first 10 to 12 weeks of the year for repair. This period was selected for instrument refurbishment because little construction was in progress and the wet or snow-covered ground conditions minimized possible transportation of particulates. In the second, third, and fourth quarters all monitors (Figure 2-7) were in service. All samples were analyzed for gross alpha activity.

During these quarters, the schedule was changed to taking one sample per week. This change was made because the 1987 and first quarter 1988 sampling showed no detectable levels of radiological particulate at any of the monitoring locations. There were also no significant differences between the weekday and weekend samples. It was expected that lengthening the sampling time would increase the sensitivity of the radiological measurements.

Sampling Methods

The air samplers used for collecting airborne particles were continuous flow dichotomous virtual impactor units operating at a constant total flow rate of one cubic meter per hour. These samplers divide suspended particles into two sizes: 2.5 to 10 micrometers in diameter (coarse respirable particles) and less than 2.5 micrometers in diameter (fine respirable particles). Particles larger than 10 micrometers (non-respirable) are not collected because they do not pose a significant risk to human health through inhalation. Each group was collected uniformly on 37-millimeter diameter membrane filters with an effective pore size of 0.8 micrometers.

Alpha Activity Measurement

The gross alpha measurements were made with a standard zinc-sulfide detector. The actual counts were then converted to net alpha radioactivity per filter.

For each sampling station, the annual average net alpha activity was not statistically different (with 95% confidence) from the background station (AP-4007) activity. The estimated total (coarse plus fine) net alpha activity at station AP-4007 was less than 4.7×10^{-15} µCi/mL.

2.5.2 Asbestos Monitoring

In 1988, airborne asbestos monitoring was performed at monitoring stations located at the WSS site perimeter and at the Francis Howell High School. The locations of the monitoring stations are indicated on Figure 2-7.

Two interim response actions involving asbestos abatement activities were initiated in 1988. During November and December

1988, insulated sections of outdoor process and utility piping located between the WSCP buildings were wrapped in polyethylene sheeting and asbestos insulation removal operations began, utilizing the glovebag method. In December 1988, glovebag removal of utility piping insulation was also performed in Building 409, prior to its demolition. Personnel samples collected in the work area during the above mentioned activities ranged from <0.005 fibers per cubic centimeter of air (f/cc) to 0.071 f/cc with an average of 0.015 f/cc.

A total of 137 samples from the WSS site perimeter and Francis Howell High School monitoring stations were collected and analyzed using Phase Contrast Microscopy (PCM). This method detects all airborne fibers of a specified size and shape typical of asbestos fibers. Airborne fiber concentrations ranged from <0.005 f/cc to 0.038 f/cc. The value 0.038 f/cc was obtained at location AP-2001 on July 8. On that day, the value of 0.037 f/cc was obtained from the sample collected at location AP-2002. There is no obvious reason for the elevated values. However, it is believed that the samples consisted of non-asbestos fibers since no asbestos related activity was conducted at the WSSRAP during that time. Annual average concentrations of airborne fibers are presented in Table 2-14.

In addition to the samples analyzed by PCM, three samples were analyzed using Transmission Electron Microscopy (TEM). This method is utilized to specifically detect asbestos fibers. Results of TEM analyses are reported in structures per cubic centimeter of air (s/cc). Two of the samples analyzed by TEM were duplicates of samples collected for PCM analysis. One was collected at the site perimeter (AP-2001) and two were from the Francis Howell High School (AP-4006).

The results of the TEM analyses and the corresponding PCM results are summarized below:

Date	Sampling Location	Fiber Concentration PCM Method (f/cc)	Asbestos Concentration TEM Method (s/cc)
08/15/88	AP-2001	0.004	<0.005
12/06/88	AP-4006	<0.0005	<0.001
12/29/88	AP-4006	Not Analyzed	<0.002

Although no ambient air limits have been established for asbestos fibers, the following discussion provides a reference with which to compare the results presented above. Typical ambient air asbestos concentrations in urban areas, as measured by TEM analysis, range from 0 to 0.045 s/cc (EPA, 1985). The EPA clearance air limit for reoccupancy of school buildings following completion of an asbestos abatement project is 70 structures per square millimeter of filter area. This corresponds to an airborne asbestos concentration of approximately 0.005 s/cc.

TABLE 2-14 Summary of Airborne Fiber Concentrations Analyzed by PCM

Sampling Location	Fiber Concentration (f/cc) Min	Max	Ave[1]	No. of Samples Reported As Below Detection Limit	Total number of Samples Collected
AP-2001	<0.0005	0.038	<0.0042	25	42
AP-2002	<0.0005	0.037	<0.0039	27	41
AP-3003	0.0009	0.0009	0.0009	0	1
AP-3004	<0.001	<0.001	<0.001	1	1
AP-4006	<0.0005	0.013	<0.0024	24	52

(1) For these samples with fiber concentrations less than the limit of detection, the limit of detection was used to calculate the overall average fiber concentration for each sampling location

3 RELATED ACTIVITIES AND SPECIAL STUDIES

Numerous characterization and special monitoring studies were performed as a part of the environmental documentation process. Many of these studies apply primarily to site characterization and will be summarized in the Remedial Investigation (RI) report which is a part of the overall environmental documentation process. Other studies performed in 1988 have environmental monitoring implications through assessment of off-site exposure. Table 3-1 presents the additional environmentally important studies that were worked on or completed in 1988. Studies relating specifically to off-site exposure or off-site migration of contaminants are summarized in the following subsections.

Studies performed in 1987 included chemical characterization of the quarry (WSQ), Phase I water quality assessment, and radiological soil characterization of the chemical plant and raffinate pits (WSCP/WSRP) and vicinity properties. Two additional studies, the bio-uptake and the Phase I chemical soil investigations, were initiated in 1987 and completed in 1988. All studies performed in 1987 and 1988 were designed as a part of the environmental documentation process whose goal is to reach a record of decision on ultimate waste disposal.

3.1 DROUGHT STUDY

The drought of 1988 provided a unique opportunity to evaluate the short-term potential for increased contaminant migration from the WSQ toward the St. Charles County well field. The drought caused very high demand on the well field and an unusually low Missouri River stage. To evaluate potential short-term negative affects, a special monitoring program was developed and implemented.

TABLE 3-1

CHARACTERIZATION AND ENVIRONMENTAL MONITORING STUDIES PERFORMED IN 1988 AT THE WELDON SPRING SITE

STUDY NAME	MEDIA SAMPLED	AREA INVESTIGATED	STATUS
Phase I Chemical Soil Investigation	Soil	WSCP/WSRP	Complete
IRA Chemical Soil Investigation	Soil	WSCP/WSRP	Complete
Phase II Chemical Soil Investigation	Soil	WSCP/WSRP	Complete
Waste Assessment-Buildings	Buildings	WSCP	Ongoing
Bio-uptake Assessment	Biota	VP/WSCP	Complete
Drought Study *	Groundwater	WSQ	Complete
Lake/Stream Sediment *	Sediment	Vicinity Properties	Complete
Phase II Water Quality Assessment *	Groundwater	WSCP/WSRP	Ongoing
Waste Assessment Raffinate Pits*	Sludge	WSRP	Complete
WSQ Construction Staging Area*	Soil	WSQ	Complete

* Summarized in following subsections.

This monitoring program consisted of monitoring water levels to evaluate groundwater flow patterns, followed by groundwater sampling of certain monitoring wells to assess changes in contaminant concentration. Three complete sets of water level measurements were performed and eight monitoring wells were sampled.

Water levels south of the slough decreased to a level significantly below the elevation of the slough. This indicates that the slough is hydrologically isolated from the alluvial aquifer. This isolation is probably caused by the fine-grained material in and near the slough. Water levels north of the slough did not decrease significantly below the slough level. This indicates that groundwater is discharged to the slough as had been suspected. Analytical results did not indicate increased short-term contaminant migration toward the St. Charles County well field.

A detailed discussion of the entire drought study is presented in a report entitled "Initial Assessment of the Effect of Drought Conditions on Contaminant Migration from the Weldon Spring Quarry." (MKF and JEG, 1988b)

3.2 LAKE AND STREAM SEDIMENT CHARACTERIZATION

In the years following the operation of both the WSOW and the WSUFMP, potentially contaminated sediments have been transported off-site and deposited in the lakes and streams surrounding the Weldon Spring Site (WSS). In order to determine the presence, locations, and concentrations of potential contaminants, a special sampling program was developed and implemented.

The program consisted of sampling sediments from lakes and streams that receive direct or indirect runoff from the WSS.

The samples were then analyzed to detect chemical and radiological contamination that originated at the WSS. The results indicate chemical contamination is not present, but some of the sediments do contain measurable levels of uranium. These uranium contaminated sediments are restricted to Busch Lakes 34, 35, and 36 and the streams draining the site to those lakes.

A detailed discussion of the entire sediment characterization program may be found in a report entitled "Preliminary Characterization of Chemical and Radiological Contamination in Lake and Stream Sediments on Properties Surrounding the Weldon Spring Site" (MKF, 1989).

3.3 PHASE II GROUNDWATER QUALITY ASSESSMENT

The Phase I Water Quality Assessment detected groundwater contamination and identified the need for additional monitoring wells to define the extent and magnitude of contamination. Thirty-three additional monitoring wells were installed to supplement the 25 existing wells at the WSCP/WSRP.

The Phase II Groundwater Quality Assessment focused on data acquired from these 58 monitoring wells, which are shown in Figure 3-1, during the third quarter of 1988. However, all previous quarterly sampling data (where available) was compared to the third quarter 1988 information to ensure that these data are consistent with historical data. Groundwater samples were analyzed for inorganic anions, radiological parameters, and nitroaromatic compounds. The results were consistent with historical and expected data.

3.3.1 Inorganic Anions

Groundwater samples were analyzed quarterly, subsequent to and during the sampling for the Phase I Water Quality Assessment

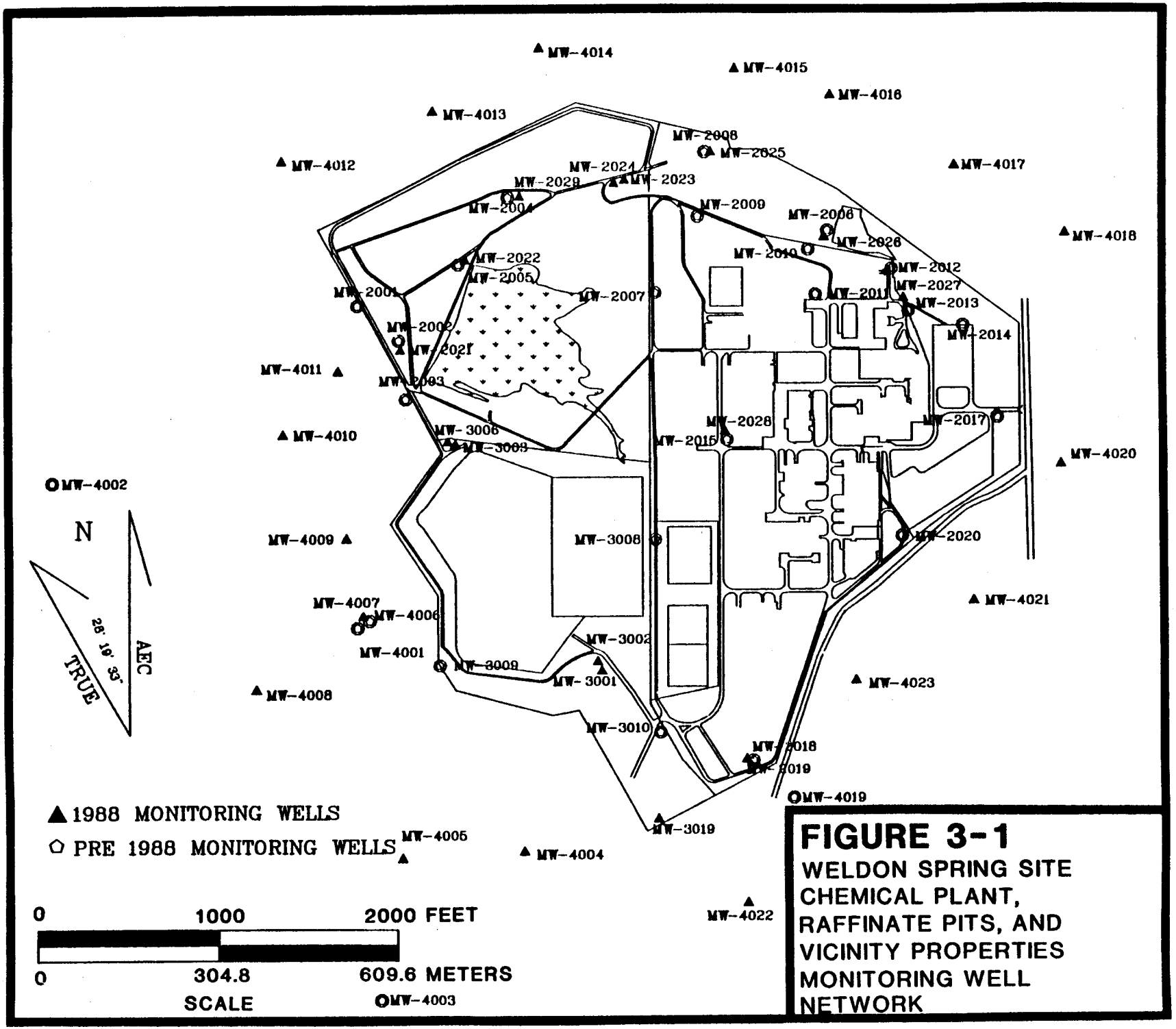


FIGURE 3-1

WELDON SPRING SITE
CHEMICAL PLANT,
RAFFINATE PITS, AND
VICINITY PROPERTIES
MONITORING WELL
NETWORK

Report, which took place during the first quarter of 1987. The inorganic anion parameters were nitrate, sulfate, chloride, and fluoride.

Nitrate concentrations above the U.S. Environmental Protection Agency (EPA) primary drinking water standard were detected in six wells. The standard for nitrate (as nitrogen) (N) is 10 mg/L which converts to 45 mg/L as NO_3. Sulfate concentrations in excess of the EPA secondary drinking water standard (250 mg/L) were present in only four wells. However, 20 wells showed elevated amounts (>50 mg/L) of sulfates.

The maximum contaminant level for fluoride is 4.0 mg/L (40 CFR 141.11). One well that is adjacent to Raffinate Pit No. 3 was above the secondary fluoride standard, but below the primary standard. No monitoring wells exceeded the EPA secondary drinking water standard for chloride of 250 mg/L. Each of the contaminant types is discussed separately below.

Nitrate

Nitrate levels ranged from not detected in 16 wells to a high concentration of 4,640 mg/L in MW-3008.

Figure 3-2 is a nitrate concentration isopleth map. It shows the extent and shape of the affected area. The additional monitoring bounded the nitrate contamination and confirmed that the WSRP is the source. These elevated nitrate concentrations would be harmful to young children and expectant mothers. However, no one drinks this water, so there is no actual exposure.

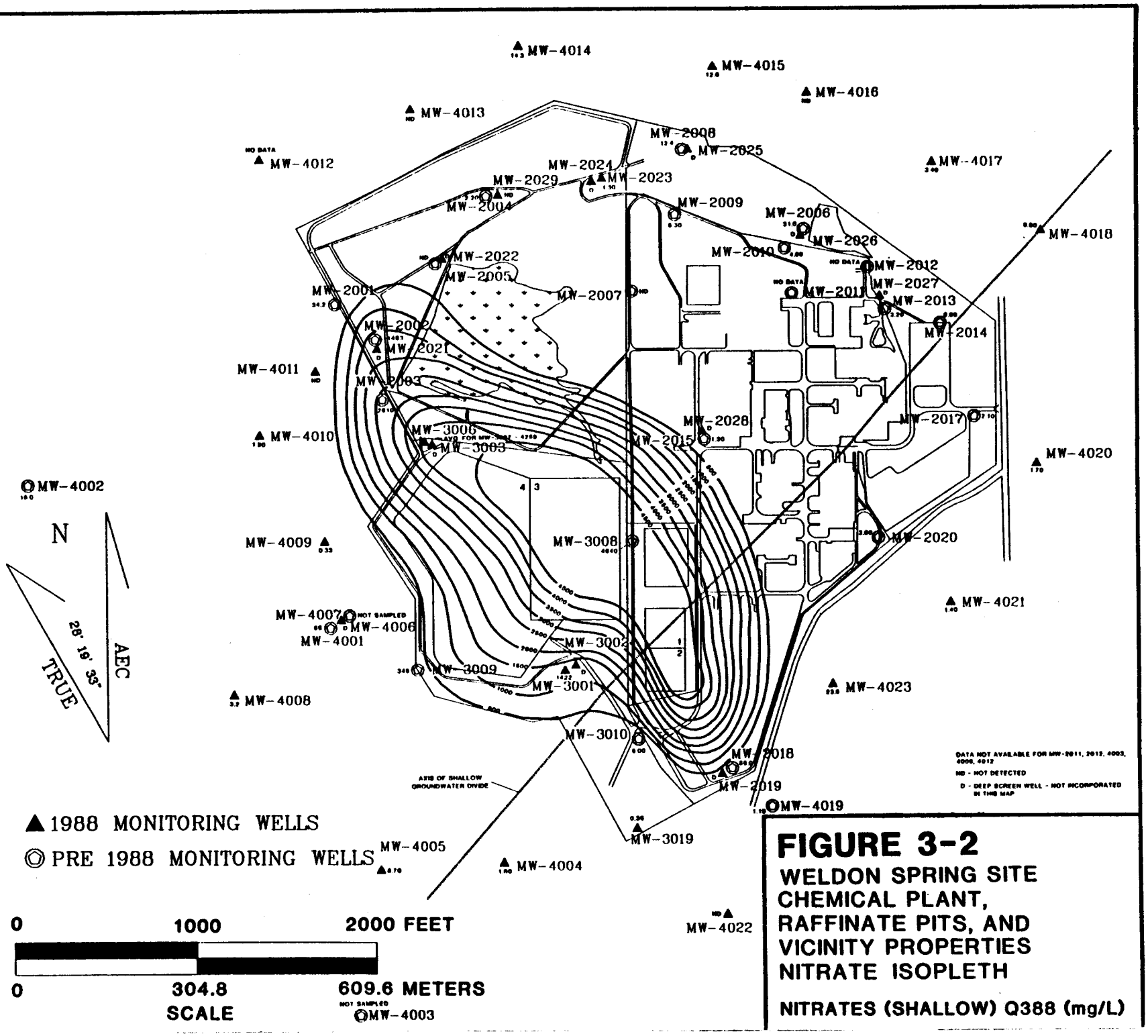


FIGURE 3-2

WELDON SPRING SITE CHEMICAL PLANT, RAFFINATE PITS, AND VICINITY PROPERTIES NITRATE ISOPLETH

NITRATES (SHALLOW) Q388 (mg/L)

Sulfates

Sulfate concentrations above the EPA secondary drinking water standard (250 mg/L) were detected in monitoring wells MW-2014, MW-2017, MW-3013, and MW-4022. Elevated levels (>50 mg/L) were present in 20 wells. The levels ranged from 2.6 mg/L to 710 mg/L.

Third quarter sampling of the extended monitoring well network identified the source of the sulfate and distribution mechanism. A sulfate isopleth map (Figure 3-3) shows two areas which have sulfate concentrations above 250 mg/L. These areas are apparently related to Weldon Spring Ordnance Works (WSOW) process areas. Like the nitrate contamination, the sulfate contamination does not reach private or public drinking water supplies. Therefore, no exposure is taking place.

3.3.2 Radiochemistry

Groundwater samples collected from monitoring wells in the WSCP, WSRP, and Vicinity Properties (WSVP) areas were analyzed for total uranium, Ra-226, Th-230, and Th-232.

Thorium-230 was detected in nine wells, always below 5 pCi/L. Thorium-230 is in the uranium-234 decay chain while thorium-232, a separate isotope, is not. Thorium-232 and Ra-226 were not detected in any monitoring well during this phase of sampling. This is as expected, given the solubility of these compounds. Uranium is the most prevelant and soluble radionuclide at the WSS and would be expected to appear in the groundwater first. The only additional discovery in the Phase II Groundwater Quality Assessment was 17 pCi/L of uranium in MW-4021. This discovery laterally extends an area of known above-background uranium concentrations. Again, this

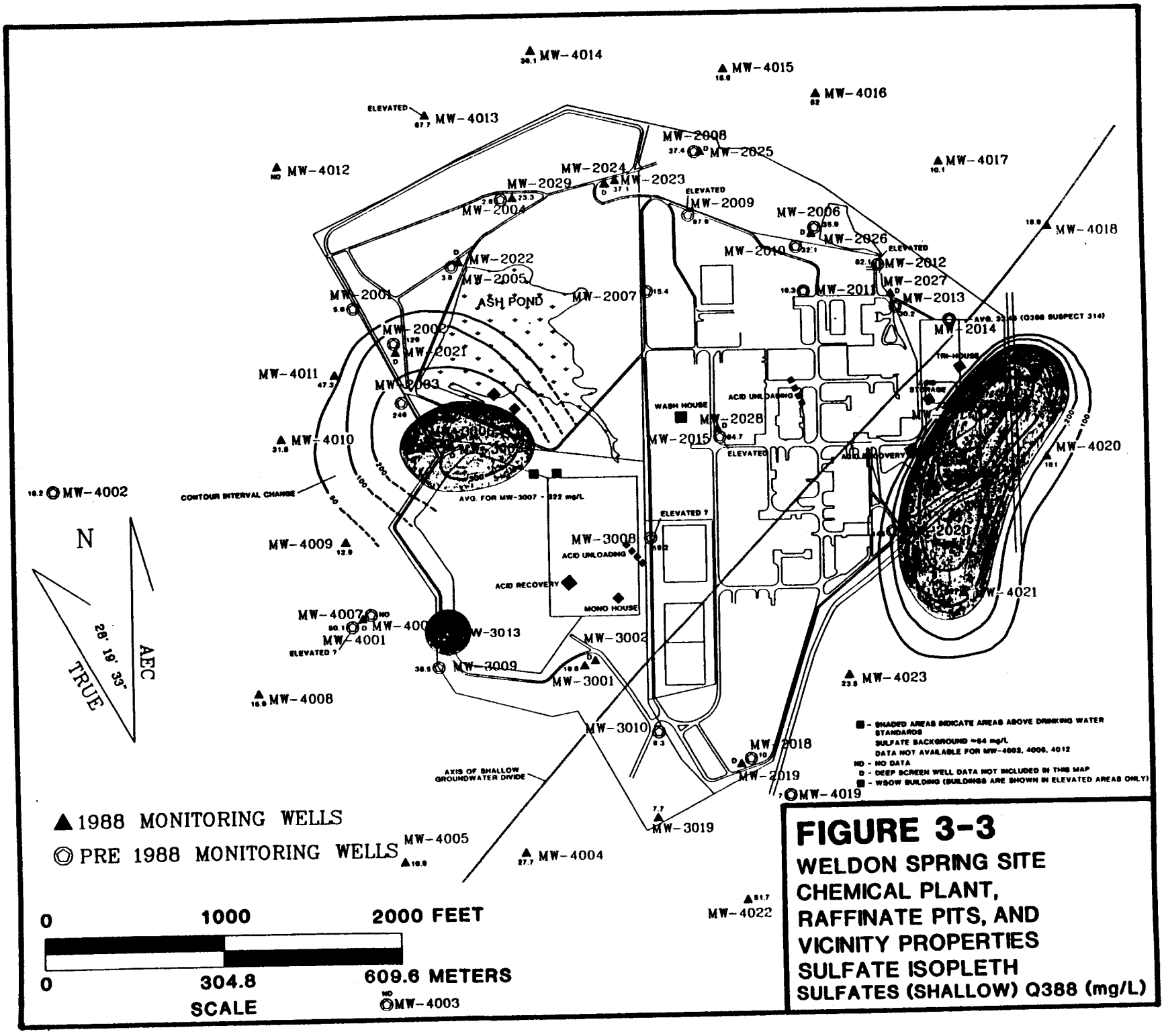


FIGURE 3-3
WELDON SPRING SITE CHEMICAL PLANT, RAFFINATE PITS, AND VICINITY PROPERTIES SULFATE ISOPLETH SULFATES (SHALLOW) Q388 (mg/L)

contamination does not reach private or public drinking water supplies. Therefore, no exposure is taking place.

3.3.3 Nitroaromatic Compounds

Nitroaromatic compounds, including trinitrotoluene (TNT); 2,4-dinitrotoluene (2,4-DNT); 2,6-dinitrotoluene (2,6-DNT); 1,3,5-trinitrobenzene (1,3,5-TNB); 1,3-dinitrobenzene; and nitrobenzene were detected in 30 of the 58 wells sampled in the WSCP/WSRP area in the third quarter of 1988. However, these data do not completely represent the total inventory of wells yielding nitroaromatic contamination since March 1987. A total of 39 wells have shown some measure of nitroaromatic presence above the various minimum detection limits.

Currently, no primary or secondary drinking water standards have been promulgated for any of the six nitroaromatic derivatives. The most applicable regulatory guideline or comparative standard for nitroaromatic compounds in water are the Ambient Water Quality Criteria for 2,4-dinitrotoluene at 0.11 µg/L (10^{-6} cancer risk) and for nitrobenzene at 30 µg/L (toxicity). Both 2,6-DNT and 2,4-DNT are suspected carcinogens.

2,6-DNT

Concentrations of 2,6-DNT in the groundwater ranged from 0.6 µg/L to 72 µg/L in ten monitoring wells in the third quarter of 1988. Data from previous quarters indicate that as many as 27 of the wells have shown detectable levels of 2,6-DNT. 2,6-DNT levels greater than 10 µg/L occurred in only one well during this sampling program.

2,4-DNT

Six monitoring wells contained 2,4-DNT contamination in the third quarter of 1988. The levels ranged from 0.24 µg/L to 78.9 µg/L and were generally well-distributed across the site. The general pattern matches with locations which have previously shown elevated concentrations of 2,4-DNT. Also, several of these locations correspond to production areas at the former WSOW. The highest value measured in Phase II sampling, 78.9 µg/L, was in MW-2013 near the former Production Line No. 1. All other Phase II sampling results for 2,4-DNT were below 3 µg/L.

Nitroaromatic Compound Summary

Nitroaromatic compounds were detected in monitoring wells in all areas of the site. These compounds were also detected at various levels outside the site boundary toward the west, north, and southeast in wells installed in 1988. The concentrations in most wells remain near the minimum detection limits. This widespread low level contamination suggests the possibility that those wells which did not indicate the presence of nitroaromatic contamination may, in fact, yield water which is contaminated by levels below the detection limits. This means that, depending upon the risks associated with this low level of nitroaromatic contamination, considerable additional effort may be necessary to bound the extent of migration of these compounds laterally and vertically.

Another complicating factor is the Army training area (WSTA) which covers over 640 ha (1,600 acres) west of the WSCP/WSRP. No decontamination efforts have been undertaken in this area. However, some parts of the area are contaminated with significant levels of nitroaromatic compounds in surface and subsurface soils. The U.S. Army Corps of Engineers is currently conducting

an investigation to determine the overall extent and magnitude of contamination.

Given the time (>45 years) that these compounds have had to migrate and the widespread discharge of contaminated water to all drainages from the WSOW, it is difficult to determine the actual extent and exposures. However, any exposures should be very low, given the operating dilutional effects; and affected populations should be small, given the widespread public water systems in place.

3.4 WASTE ASSESSMENT AND CHARACTERIZATION OF THE WSRP

To support the Remedial Investigation, it was recognized that an additional assessment of the nature and extent of the waste types in the WSRP was necessary. In order to assess the waste, the sludge and sediment material in the raffinate pits were characterized radiologically and chemically. The intent of the radiological characterization was to define the degree of contamination and to provide information to be used to evaluate technologies for ultimate disposal of the waste. The intent of the chemical characterization was to identify substances that may have been disposed of in the pits during operation of the Uranium Feed Materials Plant (WSUFMP) and subsequent clean-up activities.

The sampling effort consisted of collecting 137 samples from 39 locations. Sampling locations were evenly distributed with regard to area and depth across each pit. Table 3-2 shows the average concentrations of the predominant radionculides in each raffinate pit. Table 3-3 lists physical data and waste volumes in each pit.

Chemical parameters investigated included EPA Contract Laboratory Program (CLP) metals (plus lithium, molybdenum, and

TABLE 3-2

Weldon Spring Raffinate Pit
Sludge Radionuclide Activities

Radionuclide		Concentrations (pCi/g - dry)			
		Pit 1	Pit 2	Pit 3	Pit 4
Total Uranium	avg.	840	630	620	580
Thorium-230	avg.	23000	28000	17000	2600
Radium-226	avg.	840	570	330	78
Thorium-232[c]	avg.				370
Radium-228[b]	avg.	61	160	66	298
Thorium-228[b]	avg.	60	98	99	352
Locations Sampled		3	2	7	17
Total No. Samples		9	3	34	(a)

a. The number of samples varied for each parameter in Pit 4: 20 for total U, 20 for Th-230, 20 for Ra-226, 20 for Th-232, 18 for Th-228, and 14 for Ra-228.

b. The analysis dates for these samples were August 1988 for Pit 3, September 1988 for Pit 4, and October 1988 for Pit 1 and Pit 2.

c. The Th-232 values for Pits 1, 2, and 3 are not reported here because of errors caused by interferences from high Th-230 concentrations during laboratory analysis (See Section 3.3.5).

TABLE 3-3

Surface Area and Volume of the Weldon Spring Raffinate Pits

Pit	Year Constructed	Surface Area ha (acres)	Total Pit Volumea m3 (cy)	Total Waste Volume m3 (cy)	Percent Filled
1	1958	.5 (1.2)	14,145 (18,500)	13,686 (17,900)	97
2	1958	.5 (1.2)	14.145 (18,500)	14,527 (19,000)	103
3	1959	3.4 (8.4)	127,459 (166,700)	98,786 (129,200)	78
4	1964	6.1 (15.0)	339,788 (444,400)	23,091 (30,200)	7
TOTALS		**10.5 (25.8)**	**495,537 (648,100)**	**150,091 (196,300)**	

a. - Design Volume

Source: MKF, 1989

zirconium), volatile organics, nitroaromatics, PCBs/pesticides, and inorganic anions (including nitrite, nitrate, sulfate, chloride, and fluoride). The results of these analyses may be found in the report "Waste Assessment Chemical Characterization of Raffinate Pits-Weldon Spring Site" (MKF and JEG, 1989d).

3.5 CHARACTERIZATION OF QUARRY CONSTRUCTION STAGING AREA

The area west of the WSQ was characterized the in 1988 in order to determine what effort would be necessary to clean up property for use as a Quarry Construction Staging Area (QCSA) and water treatment facility. The area is expected to be used when the bulk waste is removed from the quarry. The survey area borders the western edge of the quarry perimeter and is bounded on the west by the Little Femme Osage Creek, on the north by Missouri State Highway 94, and on the south by the abandoned Missouri-Kansas-Texas (MKT) railroad now known as the Katy Trail as shown on Figure 3-4.

The radiological characterization program included a walk-over survey and soil sampling during which 102 samples were collected at 52 locations. The soil samples were analyzed for U-238, Ra-226, Th-232, and Th-230. The results are presented in the characterization report of the QCSA (MKF and JEG, 1989b).

The radiological characterization indicated that approximately 0.2 ha (0.5 acres) of land is contaminated, based on residual contamination guidelines. This land includes the railroad spur and gravel access road that enter the quarry from the west (Figure 3-4). This contamination is believed to be the result of transporting radiological waste to the quarry.

Four composite samples were collected and analyzed for metals and nitroaromatic compounds. No elevated concentrations of these contaminants were identified.

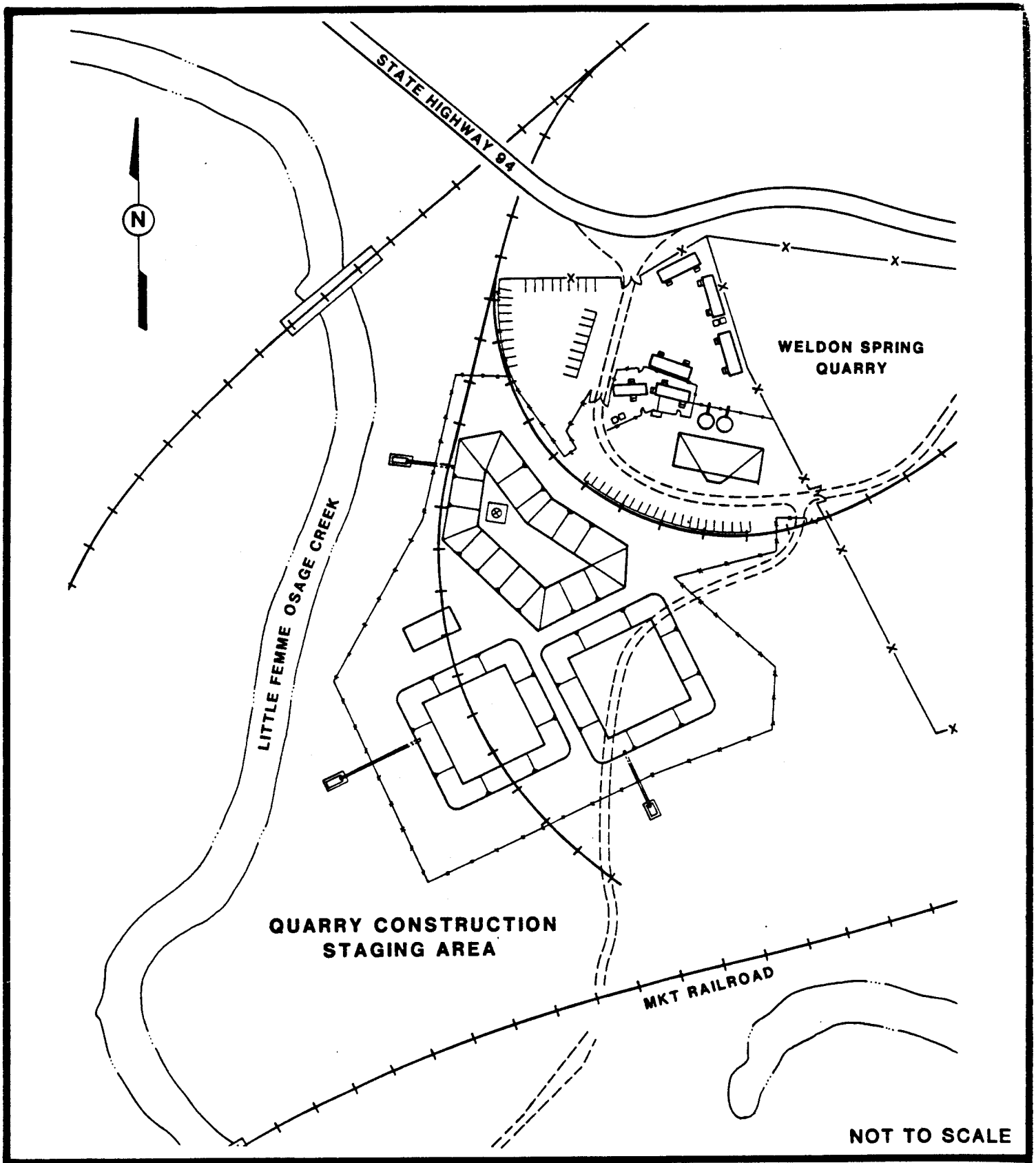


FIGURE 3-4

WSQ CONSTRUCTION AREA (FACILITIES PLAN)

This area has posed little risk to the public and will be cleaned up before construction begins in 1990. This will protect workers and prevent the spreading of contamination.

4 RADIOLOGICAL EXPOSURE

In assessing the health effects of the radioactive materials stored at the chemical plant/raffinate pits, (WSCP/WSRP), quarry (WSQ), and vicinity properties (WSVP) as required by U.S. Department of Energy (DOE) Order 5484.1, an evaluation of the radiological exposure to persons at Francis Howell High School, the Busch Wildlife Area lakes and the Femme Osage Slough; to the general population within 50 miles of the Weldon Spring Site (WSS); and to a maximally exposed individual was prepared.

Individuals could be exposed to radioactivity from the WSS via five principal pathways: (1) direct external gamma radiation, (2) inhalation of radon and radon daughters, (3) inhalation of airborne radioactive dust particles, (4) ingestion of fish from nearby lakes that receive runoff from the WSS, and (5) ingestion of drinking water from sources contaminated with radionuclides from the WSS. All five pathways were evaluated for the hypothetical maximally exposed individual. Pathway 4 was not considered in the population dose assessments because it is not reasonable or realistic to expect all members of a population to eat fish from bodies of water that receive runoff from the WSS. An evaluation of radiological exposures from these lakes when they are used for recreational purposes was included to ensure that the assessment would be thorough.

Although radiation doses can be calculated or measured for single individuals, it is not practical to predict the health risk to a single individual. Estimates of health risk are based on statistical data on large groups of people exposed to radiation under various circumstances. Statistical models are not applicable to single individuals. Therefore, health risks to single individuals are estimated by hypothesizing a maximally

exposed individual and placing this individual in a reasonable, but very conservative scenario.

Exposures to maximally exposed individuals and individuals near the off-site water bodies are given in terms of an effective dose equivalent. Exposures to people in neighboring facilities and populations within 50 miles of the WSS are expressed in terms of collective effective dose equivalents or person-rems (person-sievert). All calculations were performed using the methodology described in International Commission on Radiation Protection (ICRP) Reports 26 and 30 for a 50-year committed effective dose equivalent.

4.1 RADIATION DOSE FROM THE WSCP/WSRP TO A MAXIMALLY EXPOSED INDIVIDUAL

This section identifies an estimated effective dose equivalent to a hypothetical individual assumed to frequent the perimeter of the WSCP/WSRP and receive a radiation dose by the five pathways identified above. No private residences are adjacent to the WSCP/WSRP sites; therefore, all calculations of direct gamma exposure, airborne dust particle inhalation exposure, and radon daughter inhalation exposure assume a realistic, less than 100% residence time. The amount of fish obtained and ingested from lakes receiving effluents from the WSCP/WSRP site assumes the average consumption rate per year by U.S. Environmental Protection Agency statistics (EPA, 1988). None of these bodies of water are used as sources of drinking water. However, an evaluation of this pathway is included on the assumption that people could conceivably drink from them.

Gamma exposure rates were detemined by means of thermoluminescent detector (TLD) monitoring stations at the Weldon Spring Training Area, the Missouri State Highway Department facility, and the Busch Wildlife Area. Airborne

particles were sampled using particle samplers, and radon exposures were measured with track-etch radon monitoring stations at the same three locations. Average gamma exposure rates, airborne particle concentrations, and radon gas concentrations are not significantly above normal background levels at these locations. Therefore, the effective dose equivalent to a hypothetical individual receiving the maximum reasonable exposure from these three pathways is not measurable above normal background exposure.

Three off-site bodies of water (Busch lakes 34, 35, and 36) receive runoff from drainage or ponds located at the WSCP/WSRP site. All three lakes are used for fishing and boating. In 1988 a bio-uptake study was performed to investigate the possible exposure to chemical and radiological contamination by humans from ingestion of fish and game effected by previous operations at the WSS. This study included fish samples from the three Busch lakes. No measurable radionuclide concentrations above the detection limits were detected.

If it is assumed that the uranium concentration in the fish is equal to the detection limits of the analyses performed on the fish tissue, the concentration in fish from the three lakes would be 0.01, 0.02, and 0.01 pCi/g, respectively. Radium and thorium concentrations in lake sediments and water were not above normal background levels and thus were not considered as a source of possible exposure. Using an average annual consumption rate of 6.5 grams/day for fresh-water fish (EPA, 1988), the highest calculated dose from ingestion of fish living in these lakes would be less than 1 mrem (<0.01 mSv).

None of the lakes are presently used for drinking or irrigation, but ingestion of lake water could possibly occur by an individual during recreational activites. In this scenario it is assumed that an individual ingests lake water while

swimming. Swimming can result in the ingestion of 0.05 liters per hour on average (EPA, 1988). Assuming that the individual swims in Lake 35, which has the highest average surface water concentration (26 pCi/L), for 12 hours per year, the calculated dose would be much less than 1 mrem (<0.01mSv).

It is also possible for an individual to ingest lake sediments during visits to the lakes. The hypothetical individual is assumed to spend an average of approximately two days per year at the lakes consuming 200 mg per day. Using the average uranium concentration of surface sediments for Lake 34 which has the highest value (46.8 pCi/g), the calculated dose would be far below 1 mrem (<0.01 mSv).

A maximally exposed individual could receive a total dose of about 1 mrem (<0.01 mSv) from direct gamma exposure, inhalation of airborne dust particles, inhalation of radon daughters, ingestion of water and sediment, and ingestion of fish from contaminated waters.

4.2 RADIATION DOSE FROM THE WSQ TO A MAXIMALLY EXPOSED INDIVIDUAL

This section discusses the estimated effective dose equivalent to a hypothetical individual assumed to frequent the perimeter of the WSQ and receive a radiation dose by two of the five pathways identified above. No private residences are adjacent to the WSQ site; therefore, all calculations of direct gamma exposure, airborne particle concentrations, and radon daughter inhalation assume a realistic, less than 100% residence time. Access to the quarry is controlled by a barbed wire fence, thus fishing, swimming, and drinking water from the quarry pond need not be evaluated.

The exposure scenario consists of a hypothetical individual who routinely walks along the northern boundary of the quarry on State Route 94. The individual makes this trip twice per day, 250 days per year. His or her average residence time per day is 12 minutes. An actual exposure would occur to an individual who drives by the site twice per day, but it would be so insignificant that it was not used in the calculation.

Data from three environmental TLD monitoring stations were used to evaluate the dose by direct gamma exposure to the hypothetical individual. The dose from external gamma radiation was calculated by multiplying the length of time the individual is exposed to the by the radiation field strength. Using these conservative assumptions, and noting that the average measured gamma exposure rates are not significantly different from background along the northern perimeter of the WSQ, the calculated dose from direct gamma exposure is not measurable above normal background exposure, which is 85 mR/yr.

Airborne particle concentrations were not measured during 1988. However, concentrations of airborne particles have been estimated for the only large area in the quarry where the surface is exposed to wind erosion. This estimate was based on an approach developed for evaluating respirable particulate emissions from uncontrolled waste sites. The estimates were far below DOE guidelines and would not result in any exposure above background.

The risk associated with radon-222 is due primarily to inhalation of its short-lived decay products. Data from three track-etch radon monitoring stations were used to evaluate the dose by inhalation of radon daughters for the hypothetical individual. The highest average measured radon gas concentration was 3.7 pCi/L above normal background. Assuming 50% equilibrium between radon gas and its daughters and

1.7 rem/Working Level Month (NCRP, 1985; ICRP, 1977), the annual calculated effective dose equivalent from inhalation of radon daughters is 9 mrem (0.09 mSv).

The dose to the maximally exposed individual from the three pathways discussed above consists of a total of 9 mrem (0.09 mSv) from direct gamma exposure and inhalation of radon daughters. No measured exposure above background results from gamma radiation or airborne particles.

4.3 RADIATION DOSE FROM WSVPs TO A MAXIMALLY EXPOSED INDIVIDUAL

This section discusses the estimated effective dose equivalent to a hypothetical individual assumed to frequent the largest vicinity property (VP), the Femme Osage Slough, located south of the WSQ. This scenario provides a very conservative, but plausible exposure assessment. No private residences are adjacent to the slough (it is on land that is currently managed by the Missouri Department of Conservation as part of the Weldon Spring Wildlife Refuge); therefore, all direct gamma exposure calculations assume a realistic, less than 100% time of residence. Airborne particles and radon daughter concentrations were not measured. The slough is not suspected of having radionuclide airborne particle concentrations and radon daughter concentrations above normal background because it is in a floodplain with saturated soil. The water in the soil minimizes airborne migration. In addition, the slough is contaminated only with uranium.

The amount of fish obtained and ingested from the Femme Osage Slough assumes the average consumption rate per year by the U.S. Department of Argiculture statistics (USDA, 1986). Because of the stagnant water conditions, the slough is not a source of drinking water, nor is it a place for recreational

swimming. Therefore, these pathways were not included in the dose calculations.

Radionuclide concentrations in the soil were used to derive the effective dose equivalent by direct gamma exposure for the maximally exposed individual who is assumed to sit on the bank of the slough and fish four hours per week, 50 weeks per year. The average concentration of radionuclides in the soil near the bank is 10 pCi Nat-U/gram (Muratzky et. al., 1988). Using the dose conversion factor for natural uranium 6.55×10^{-8} mrem/yr per pCi/m^3, the effective dose equivalent received from direct gamma exposure is less than 1 mrem (<0.01 mSv).

As part of the bio-uptake study, fish samples were collected and analyzed for total uranium, Th-230, Th-232, and Ra-226. All results were below detection limits. Uranium is the only radionuclide in the slough sediments and water that is elevated above background concentrations; therefore, it is the only radionuclide that was considered for possible uptake. Assuming that the uranium concentration in fish is equal to the detection limit acheived during tissue analysis, it is 0.01 pCi/g. Using the average annual consumption rate of 4,086 grams/year (USDA, 1986), the calculated effective dose equivalent to the maximally exposed individual from ingestion of fish living in contaminated waters would be less than 1 mrem (<0.01 mSv).

4.4 POPULATION DOSES

The risk from radiation exposure to the general population in the WSS region was estimated by multiplying average calculated doses by the number of persons expected to be exposed. This is a measure of collective dose equivalent. Statistical models using this person-rem (person-sievert)

calculation were then applied to the larger population to estimate health risk.

4.4.1 Dose to Francis Howell High School Population

To determine collective dose equivalents accurately, the radiation exposure should be measured at the point where the collective dose equivalent is to be estimated. The Francis Howell High School (FHHS) is located 0.5 miles northeast of the WSCP and has a monitoring station continuously measuring three pathways of exposure. It was therefore selected as the measurements point.

Samples of radioactive airborne particles were collected weekly at the FHHS station, and radon concentrations and external gamma exposure rates are monitored quarterly. Water supplied to the school from the St. Charles County well field was also sampled and analyzed quarterly. The instrumentation and analytical methods used are sensitive to radiation levels equal to or less than 10% of the population basic dose limits.

No radiation level or radionuclide concentration in air or water has ever significantly exceeded natural or normal background radioactivity at the FHHS station. This being the case, there is no statistically determined collective effective dose equivalent above background levels.

4.4.2 Population Doses Within 80 km (50 miles)

The collective effective dose equivalent to the the general public within an 80-km (50-mile) radius of the WSS was calculated. This dose must be calculated or estimated, since it is unreasonable to attempt pathway specific measurements relative to every individual. The exposure pathways considered were: external exposure to gamma radiation, inhalation of radon

and radon daughters, inhalation of radioactive airborne particles, and ingestion of water, fish, or game containing radioactivity.

At the three off-site gamma radiation monitoring stations, all measurements were at normal background levels (See Section 2.4). Likewise, measurements at the three off-site radon monitoring stations and air particulate monitoring stations were indistinguishable from background levels (See Sections 2.3 and 2.5, respectively). Therefore, the WSS does not contribute any measurable radiation dose to the general public via these three pathways.

None of the surface water or groundwater bodies that receive runoff or recharge from the WSS are used as drinking water sources; therefore, this pathway was not included in the dose evaluation. An assessment of the fish and game consumption pathway indicates no detectable concentrations of radioactivity above background, hence this is not a significant exposure pathway (see Section 3.3). Therefore, cumulative radiation dose to the population within an 80-km (50-mile) radius resulting from radioactive materials present at the WSS is indistinguishable from the dose that the same population receives from naturally occurring radiation sources.

4.5 RADIATION DOSE TO INDIVIDUALS FROM CONTAMINATED LAKES

This section calculates the realistic effective dose equivalent of an individual who uses Lakes 34, 35, 36, and the Femme Osage Slough solely for recreational purposes. The lakes are located in the Busch Wildlife Area and the Femme Osage Slough in the Weldon Spring Wildlife Area. They are used for recreational activities such as fishing and boating. None of the water bodies are presently used for drinking water or irrigation. In contrast to the previous sections, the analyses

presented here attempt to realistically estimate the dosage to an individual in very plausible settings.

The potential radiation dose to individuals resulting from recreational activities at these lakes was estimated for the following potential pathways:

External: Swimming, boating, and direct exposure from the water body; and
Internal: Accidental ingestion of contaminated water.

The assumed individual spent 12 hours per year swimming and boating at the location of the contaminated water bodies. Also, this individual was assumed to ingest one liter of water that he filled in a canteen from one of the water bodies.

For purposes of calculation, thorium-234, protactinium-234, and uranium-234 were assumed to be in a state of secular equilibrium. In this analysis, the dose represents the 50-year effective dose equivalent commitment expressed in millirem per year (mrem/yr) and millisievert per year (mSv/yr).

The total dose commitments estimated for a hypothetical individual from these exposure assumptions is much less than one mrem (<0.01 mSv). These radiation pathways contribute an insignificant health risk to individuals or the general population.

5 FUTURE ENVIRONMENTAL MONITORING AT THE WELDON SPRING SITE

Numerous site characterization activities were conducted at the Weldon Spring Site (WSS) in 1988. The data collected from these studies have led to a better understanding of the contaminants present and their migration from the site. This additional information has led to a more refined Environmental Monitoring Program Plan (EMPP) (MKF and JEG, 1987) for the WSS.

The installation of new monitoring wells at the chemical plant and raffinate pits (WSCP/WSRP) and the quarry (WSQ) has greatly increased the number of groundwater monitoring locations. Eight quarters of chemical and radiological data on wells installed prior to 1987 have provided sufficient information to assess seasonal variations. These two factors have led to a refinement in the groundwater monitoring program. The monitoring program for 1989 consists of quarterly sampling of monitoring wells with less than four quarters of data, quarterly sampling of monitoring wells in sensitive locations such as those south of the Femme Osage Slough, and annual sampling of the remaining wells.

The surface water monitoring program has been expanded for 1989 to include quarterly sampling of nearby springs and on-site bodies of surface water. Sampling locations were also added on the Missouri River to obtain baseline information prior to discharge of treated water from the WSQ.

Air particulate monitoring is being expanded in 1989 to include sampling for radioactive airborne particles at the WSQ. Asbestos monitoring will continue in 1989 as will radon and gamma radiation monitoring.

The entire scope of routine monitoring is detailed in the 1989 EMPP for the WSS.

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ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission
BNI	Bechtel National, Incorporated
CLP	U.S. Environmental Protection Agency Contract Laboratory Program
DA	U.S. Department of the Army
DCG	Derived Concentration Guideline
DNT	dinitrotoluene
DOE	U.S. Department of Energy
EMPP	Environmental Monitoring Program Plan
EMR	Environmental Monitoring Report
EPA	U.S. Environmental Protection Agency
FFCA	Federal Facility Compliance Agreement
FHHS	Francis Howell High School
ha	hectare
ICRP	International Commission on Radiation Protection
km	kilometer
L	liter
m	meter
MCL	Maximum Contaminant Level
mg	milligram
MKT	Missouri-Kansas-Texas Railroad
mrem	millirem
MSL	Mean Sea Level
mSv	millisievert
NLOC	National Lead Company of Ohio
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
pCi	picocurie
PCM	Phase Contrast Microscopy
PMC	Project Management Contractor
QA	Quality Assurance
QC	Quality Control

CSA	Quarry Construction Staging Area
RI	Remedial Investigation
SFMP	Surplus Facilities Management Program
TEM	Transmission Electron Microscopy
TLD	thermoluminescent dosimeter
TNT	trinitrotoluene
WSCP	Weldon Spring Chemical Plant
WSOW	Weldon Spring Ordnance Works
WSQ	Weldon Spring Quarry
WSRP	Weldon Spring Raffinate Pits
WSS	Weldon Spring Site
WSSRAP	Weldon Spring Site Remedial Action Project
WSTA	U.S. Army Reserve and National Guard Training Area
WSUFMP	Weldon Spring Uranium Feed Material Plant
WSVP	Weldon Spring Vicinity Properties
yr	year
µg	microgram

APPENDIXES

APPENDIX A

QUARTERLY DATA TABLES

INORGANIC ANION QUARTERLY RESULTS - WSCP/WSRP

LOCATION NUMBER	Chloride Q1	Chloride Q2	Chloride Q3	Chloride Q4	AVERAGE
GW-2001	4.8	2.6	7.0	3.9	4.6
GW-2003	12.4	48.9	85.2	13.0	39.9
GW-2004	1.2	1.0	1.0	ND	1.1
GW-2006	363.0	204.0	22.9	19.1	152.3
GW-2008	81.7	1.4	16.2	97.0	49.1
GW-2010	88.5	56.2	87.4	57.7	72.5
GW-2012	67.8	54.8	101.0	131.0	88.7
GW-2013	6.7	11.6	9.2	5.9	8.4
GW-2014	29.4	23.3	26.1		26.3
GW-2016		1.4			1.4
GW-2017	12.3	14.1	17.1	8.0	12.9
GW-2018	9.3	4.1	6.0	6.3	6.4
GW-2020	12.5	8.7	15.1	9.9	11.6
GW-2023			2.1		2.1
GW-2024			2.7		2.7
GW-3003			13.1		13.1
GW-3006			9.4		9.4
GW-3007	24.1				24.1
GW-3008	23.3	41.5	27.4		30.7
GW-3009	2.4	3.2	3.5	589.0	149.5
GW-3010	1.4	1.0	1.7		1.4
GW-3013	2.1	1.8	2.5	1.2	1.9
GW-3018		36.3			36.3
GW-4019	1.0	0.9	1.3	0.9	1.0

ND - NOT DETECTED

INORGANIC ANION QUARTERLY RESULTS - WSCP/WSRP

	Fluoride Q1	Fluoride Q2	Fluoride Q3	Fluoride Q4	AVERAGE
GW-2001	0.5	0.6	0.3	ND	0.5
GW-2003	ND	-0.3	1.6	ND	0.7
GW-2004	0.5	0.7	ND	ND	0.6
GW-2006	ND	ND	0.4	ND	0.4
GW-2008	ND	0.6	ND	ND	0.6
GW-2010	ND	ND	0.4	ND	0.4
GW-2012	ND	ND	0.9	ND	0.9
GW-2013	ND	ND	ND	ND	0.0
GW-2014	ND	ND	0.4		0.4
GW-2016		0.4			0.4
GW-2017	0.3	ND	0.8	ND	0.6
GW-2018	ND	0.8	ND	ND	0.8
GW-2020	ND	ND	ND	ND	0.0
GW-2023			0.3		0.3
GW-2024			0.3		0.3
GW-3003			ND		0.0
GW-3006			0.3		0.3
GW-3007	ND				0.0
GW-3008	ND	2.3	2.1		2.2
GW-3009	ND	0.5	0.4		0.5
GW-3010	ND	0.8	0.3		0.6
GW-3013			0.9	0.7	0.8
GW-3018		1.0			1.0
GW-4019	0.3	0.4	ND	ND	0.4

ND - NOT DETECTED

INORGANIC ANION QUARTERLY RESULTS - WSCP/WSRP

	Nitrate Q1	Nitrate Q2	Nitrate Q3	Nitrate Q4	AVERAGE
GW-2001	6.5	43.0	34.2	44.7	32.1
GW-2003	3156.0	3640.0	2610.0	2750.0	3039.0
GW-2004	0.8	5.3	2.2	3.7	3.0
GW-2006	6.1	28.7	31.0	36.3	25.5
GW-2008	3.6	32.1	12.4	14.6	15.7
GW-2010	1.0	4.9	4.0	5.7	3.9
GW-2012	0.6	3.7		1.2	1.8
GW-2013	3.2	3.8	3.2	4.4	3.7
GW-2014	9.4	10.0	8.0		9.1
GW-2016		ND			0.0
GW-2017	5.4	3.6	2.1	1.7	3.2
GW-2018	2.5	4.1	56.0	2.3	16.2
GW-2020	2.6	5.2	3.8	2.0	3.4
GW-2023			1.3		1.3
GW-2024			ND		0.0
GW-3003			ND		0.0
GW-3006			ND		0.0
GW-3007	4270.0				4270.0
GW-3008	4620.0	6010.0	4640.0		5090.0
GW-3009	2.3	566.0	345.0	11.5	231.2
GW-3010	4.1	6.6	5.0		5.2
GW-3013	6.4	9.4	7.1	10.7	8.4
GW-3018		842			842
GW-4019	0.6	0.6	1.1	0.7	0.7

ND - NOT DETECTED

INORGANIC ANION QUARTERLY RESULTS - WSCP/WSRP

	Sulfate Q1	Sulfate Q2	Sulfate Q3	Sulfate Q4	AVERAGE
GW-2001	5.1	11.4	5.6	13.0	8.8
GW-2003	192.0	298.0	246.0	298.0	258.5
GW-2004	1.9	2.4	2.6	6.7	3.4
GW-2006	32.9	49.9	35.9	50.2	42.2
GW-2008	29.4	9.1	37.4	40.8	29.2
GW-2010	33.3	50.7	32.1	27.5	35.9
GW-2012	56.5	62.2	82.1	111.0	78.0
GW-2013	15.8	27.5	30.2	35.7	27.3
GW-2014	31.0	27.1	314.0		124.0
GW-2016		31.7			31.7
GW-2017	620.0	615.0	710.0	1113.0	764.5
GW-2018	9.5	9.3	10.0	9.5	9.6
GW-2020	207.0	191.0	145.0	320.0	215.8
GW-2023			37.1		37.1
GW-2024			38.6		38.6
GW-3003			232.0		232.0
GW-3006			75.0		75.0
GW-3007	230.0				230.0
GW-3008	53.4	76.6	59.2		63.1
GW-3009	42.1	71.9	38.5	5.2	39.4
GW-3010	6.7	7.0	6.3		6.7
GW-3013	230.0	503.0	563.0	681.0	494.3
GW-3018		193.0			193.0
GW-4019	9.1	11.5	7.0	8.8	9.1

ND - NOT DETECTED

FIRST QUARTER NITROAROMATIC COUMPOUND RESULTS - WSCP/WSRP

DETECTION LIMITS - 0.5 0.2 0.6 0.6 0.03 0.4
UG/L

CONCENTRATION - UG/L

LOCATION NUMBER	TNT	2,4-DNT	2,6-DNT	NB	1,3,5-TNB	1,3-TNB
GW-2001-Q188	ND	ND	ND	ND	ND	ND
GW-2003-Q188	ND	0.45	0.72	ND	ND	ND
GW-2004-Q188	ND	ND	ND	ND	ND	ND
GW-2006-Q188	ND	ND	5.13	ND	5.6	ND
GW-2008-Q188	ND	ND	0.88	0.05	0.85	ND
GW-2010-Q188	ND	ND	ND	ND	ND	ND
GW-2012-Q188	0.63	ND	ND	ND	0.69	ND
GW-2013-Q188	7.25	43.19	15.91	ND	3.54	ND
GW-2014-Q188	ND	ND	0.99	ND	0.74	ND
GW-2017-Q188	ND	ND	ND	ND	ND	ND
GW-2018-Q188	ND	ND	ND	ND	ND	ND
GW-2020-Q188	ND	ND	ND	ND	ND	ND
GW-3007-Q188	ND	1.65	1.59	ND	ND	ND
GW-3008-Q188	ND	ND	ND	ND	ND	ND
GW-3009-Q188	ND	ND	ND	ND	ND	ND
GW-3010-Q188	ND	ND	ND	ND	ND	ND
GW-3013-Q188	ND	ND	ND	ND	ND	ND
GW-4019-Q188	ND	ND	ND	ND	ND	ND

ND - NOT DETECTED

SECOND QUARTER NITROAROMATIC COUMPOUND RESULTS - WSCP/WSRP

DETECTION LIMITS - UG/L	0.5	0.2	0.6	0.6	0.03	0.4
		CONCENTRATION - UG/L				
LOCATION NUMBER	TNT	2,4-DNT	2,6-DNT	NB	1,3,5-TNB	1,3-TNB
GW-2001-Q288	ND	ND	ND	ND	ND	0.45
GW-2003-Q288	ND	0.29	0.84	ND	ND	ND
GW-2004-Q288	ND	ND	ND	ND	ND	ND
GW-2006-Q288	0.78	ND	0.87	ND	5.37	ND
GW-2008-Q288	ND	0.24	1.04	ND	1.17	0.57
GW-2010-Q288	0.62	ND	0.77	ND	ND	0.54
GW-2012-Q288	1.31	ND	2.23	ND	22.3	ND
GW-2013-Q288	25.8	182	83.2	ND	35.1	ND
GW-2014-Q288	2.33	ND	1.66	ND	4.76	ND
GW-2016-Q288	ND	ND	ND	ND	ND	ND
GW-2017-Q288	ND	ND	ND	ND	0.11	ND
GW-2018-Q288	ND	ND	ND	ND	ND	ND
GW-2020-Q288	ND	ND	ND	ND	ND	ND
GW-3008-Q288	ND	ND	ND	ND	ND	ND
GW-3009-Q288	ND	ND	ND	ND	ND	ND
GW-3010-Q288	ND	ND	ND	ND	ND	ND
GW-3013-Q288	ND	ND	ND	ND	ND	ND
GW-3018-Q288	7.1	134	875	ND	0.78	ND
GW-4019-Q288	ND	0.58	ND	ND	ND	ND

ND - NOT DETECTED

THIRD QUARTER NITROAROMATIC COUMPOUND RESULTS - WSCP/WSRP

DETECTION LIMITS - UG/L	0.5	0.2	0.6	0.6	0.03	0.4
		CONCENTRATION - UG/L				
LOCATION NUMBER	TNT	2,4-DNT	2,6-DNT	NB	1,3,5-TNB	1,3-TNB
GW-2001-Q388	ND	ND	ND	ND	ND	ND
GW-2003-Q388	ND	0.24	0.81	ND	ND	ND
GW-2004-Q388	ND	ND	ND	ND	ND	ND
GW-2006-Q388	ND	ND	1.64	ND	15.7	1.75
GW-2008-Q388	ND	ND	ND	ND	0.58	0.53
GW-2010-Q388	0.55	ND	0.59	1.31	0.4	0.57
GW-2012-Q388	0.74	ND	ND	ND	ND	ND
GW-2013-Q388	9.42	78.41	71.97	ND	26.4	12
GW-2014-Q388	ND	ND	0.76	ND	3.47	1.05
GW-2017-Q388	ND	ND	ND	ND	0.13	ND
GW-2018-Q388	ND	ND	ND	ND	0.06	ND
GW-2019-Q388	ND	ND	ND	ND	0.15	ND
GW-2020-Q388	ND	ND	ND	1.8	ND	ND
GW-2023-Q388	ND	ND	ND	ND	0.32	ND
GW-2024-Q388	ND	ND	ND	ND	ND	ND
GW-3003-Q388	ND	ND	ND	1.09	ND	ND
GW-3006-Q388	ND	ND	ND	ND	0.17	ND
GW-3008-Q388	ND	ND	ND	ND	0.06	ND
GW-3009-Q388	ND	ND	ND	ND	0.22	ND
GW-3010-Q388	ND	ND	ND	ND	ND	ND
GW-3013-Q388	ND	ND	ND	ND	0.03	ND
GW-4019-Q388	ND	ND	ND	ND	ND	ND

ND - NOT DETECTED

FOURTH QUARTER NITROAROMATIC COUMPOUND RESULTS - WSCP/WSRP

DETECTION LIMITS - UG/L	0.5	0.2	0.6	0.6	0.03	0.4
		CONCENTRATION - UG/L				
LOCATION NUMBER	TNT	2,4-DNT	2,6-DNT	NB	1,3,5-TNB	1,3-TNB
GW-2001-Q488	ND	ND	0.96	ND	0.05	ND
GW-2003-Q488	ND	ND	ND	ND	0.06	ND
GW-2004-Q488	ND	ND	ND	ND	0.14	ND
GW-2006-Q488	ND	ND	ND	ND	16.09	1.65
GW-2008-Q488	ND	ND	ND	ND	1.51	0.85
GW-2010-Q488	ND	ND	ND	ND	0.32	0.54
GW-2012-Q488	0.85	ND	ND	ND	4.56	ND
GW-2013-Q488	9.2	88.83	ND	ND	20.84	9.63
GW-2017-Q488	ND	ND	ND	ND	ND	ND
GW-2018-Q488	ND	ND	ND	ND	0.21	ND
GW-2020-Q488	ND	ND	4.17	ND	ND	ND
GW-3009-Q488	ND	ND	ND	ND	ND	ND
GW-3013-Q488	ND	ND	ND	ND	ND	ND
GW-4019-Q488	ND	ND	ND	ND	0.08	ND

ND - NOT DETECTED

WSQ FIRST QUARTER INORGANIC ANION RESULTS

CHLORIDE CONCENTRATIONS - MG/L

LOCATION NUMBER	Q1	Q2	Q3	Q4	AVERAGE
GW-1002	7.0	10.7	14.8		10.2
GW-1004	32.9	30.9	13.0		25.6
GW-1005	15.5		17.4	12.0	15.0
GW-1006	40.3	38.5	67.0		48.6
GW-1007	43.8	84.7	99.0		75.8
GW-1008	22.8	27.1	32.0		27.3
GW-1009	24.2	36.1	52.0		37.4
GW-1010	5.7	10.6	14.9	11.0	10.6
GW-1011	13.7	17.7			15.7
GW-1012	8.5	8.1	13.0	11.8	10.4
GW-1013	23.0	43.0	22.6	24.6	28.3
GW-1014	15.6	24.8	21.3	24.3	21.5
GW-1015	10.6	26.8	19.1	27.7	21.1
GW-1016	8.6	12.1	11.4		10.7
GW-1017	12.0	24.8	27.0	25.2	22.3
GW-1018	31.0	32.4	31.4	15.4	27.6
GW-1019	3.0	6.9	8.6	9.0	6.9
GW-1020			9.3	15.1	12.2
GW-1021			11.4	11.1	11.3
GW-1022			ND	14.2	14.2
GW-1023			6.8	1.9	4.4
GW-1024			8.8	3.1	6.0
GW-1025				12.3	12.3
GW-1026				2.5	2.5
GW-1027				15.5	15.5
GW-1028				15.5	15.5

ND - NOT DETECTED

WSQ QUARTERLY INORGANIC ANION RESULTS

FLUORIDE CONCENTRATIONS - MG/L

LOCATION NUMBER	Q1	Q2	Q3	Q4	AVERAGE
GW-1002	ND	0.3	0.4	0.3	0.3
GW-1004	ND	0.7	0.9	0.7	0.8
GW-1005	ND	0.6	0.7	ND	0.7
GW-1006	ND	ND	0.7		0.7
GW-1007	ND	ND	0.6		0.6
GW-1008	ND	0.3	0.6		0.5
GW-1009	ND	ND	0.5		0.5
GW-1010	0.4	ND	0.3	ND	0.4
GW-1011	0.3	ND			0.3
GW-1012	ND	0.5	0.8	0.7	0.7
GW-1013	1.0	ND	0.5	ND	0.8
GW-1014	0.9	0.3	0.5	0.4	0.5
GW-1015	0.9	0.3	0.4	0.3	0.5
GW-1016	0.8	0.3	0.4		0.5
GW-1017	0.9	ND	0.4	ND	0.7
GW-1018	0.9	ND	0.4	0.4	0.6
GW-1019	0.8	ND	0.3	ND	0.5
GW-1020			0.5	ND	0.5
GW-1021			0.3	ND	0.3
GW-1022			6.8	0.3	3.6
GW-1023			ND		ND
GW-1024			0.3		0.3
GW-1025				ND	ND
GW-1026				ND	ND
GW-1027				ND	ND
GW-1028				ND	ND

ND - NOT DETECTED

WSQ QUARTERLY INORGANIC ANION RESULTS

NITRATE CONCENTRATION - MG/L

LOCATION NUMBER	Q1	Q2	Q3	Q4	AVERAGE
GW-1002	0.2	3.6	1.6	2.0	1.9
GW-1004	12.6	1.3	0.5	0.4	3.7
GW-1005	ND	4.9	ND	ND	4.9
GW-1006	13.9	16.1	15.6		15.2
GW-1007	1.6	0.6	2.5		1.6
GW-1008	ND	ND	0.6		0.6
GW-1009	0.4	3.6	0.1		1.4
GW-1010	ND	ND	0.3	ND	0.3
GW-1011	0.2	0.5			0.4
GW-1012	8.2	6.7	4.4	6.0	6.3
GW-1013	ND	ND	ND	ND	ND
GW-1014	ND	ND	ND	ND	ND
GW-1015	5.9	12.9	3.9	1.4	6.0
GW-1016	2.2	7.7	0.4		3.4
GW-1017	ND	ND	0.2	ND	0.2
GW-1018	ND	0.1	ND	ND	0.1
GW-1019	ND	ND	ND	ND	ND
GW-1020			ND	ND	ND
GW-1021			0.6	ND	0.6
GW-1022			0.3	ND	0.3
GW-1023			ND	ND	ND
GW-1024			ND	ND	ND
GW-1025				0.3	0.3
GW-1026				ND	ND
GW-1027				1.3	1.3
GW-1028				ND	ND

ND - NOT DETECTED

WSQ QUARTERLY INORGANIC ANION RESULTS

SULFATE CONCENTRATION - MG/L

LOCATION NUMBER	Q1	Q2	Q3	Q4	AVERAGE
GW-1002-Q188	42.0	49.0	42.4	56.6	47.5
GW-1004-Q188	329.0	320.0	121.0	264.0	258.5
GW-1005-Q188	167.0	147.0	185.0	312.0	202.8
GW-1006-Q188	421.0	467.0	381.0		423.0
GW-1007-Q188	114.0	149.0	13.3		92.1
GW-1008-Q188	258.0	322.0	232.0		270.7
GW-1009-Q188	155.0	162.0	133.0		150.0
GW-1010-Q188	ND	2.0	2.3	ND	2.2
GW-1011-Q188	54.1	82.0			68.1
GW-1012-Q188	242.0	126.0	177.0	126.0	167.8
GW-1013-Q188	117.0		81.8	109.0	102.1
GW-1014-Q188	172.0	114.0	76.1	78.4	110.1
GW-1015-Q188	171.0	212.0	147.0	195.0	181.3
GW-1016-Q188	30.0	170.0	135.0		111.7
GW-1017-Q188	ND	ND	ND	1.0	1.0
GW-1018-Q188	48.0	43.0	42.3	40.2	43.4
GW-1019-Q188	ND	ND	ND	ND	0.0
GW-1020			1.7	1.0	1.4
GW-1021			1.7	1.0	1.4
GW-1022			1.0	ND	1.0
GW-1023			3.2	8.7	6.0
GW-1024			2.8	7.5	5.2
GW-1025				165.0	165.0
GW-1026				2.1	2.1
GW-1027				107.0	107.0
GW-1028				63.7	63.7

ND - NOT DETECTED

FIRST QUARTER NITROAROMATIC RESULTS FOR GROUNDWATER AT THE WSQ

DETECTION LIMITS - UG/L	0.5	0.2	0.6	0.6	0.3	0.4

CONCENTRATION - UG/L

LOCATION NUMBER	TNT	2,4-DNT	2,6-DNT	NB	1,3,5-TNB	1,3-DNB
GW-1002-Q188	6.61	ND	3.68	ND	3.67	1.12
GW-1004-Q188	29.22	ND	18.23	16.83	3.01	2.54
GW-1005-Q188	ND	0.96	ND	0.64	0.66	ND
GW-1006-Q188	28.74	ND	6.42	ND	27.37	ND
GW-1007-Q188	ND	ND	ND	ND	ND	ND
GW-1008-Q188	ND	ND	ND	ND	ND	ND
GW-1009-Q188	ND	ND	ND	ND	ND	ND
GW-1010-Q188	ND	ND	ND	ND	ND	ND
GW-1011-Q188	ND	ND	ND	ND	ND	ND
GW-1012-Q188	ND	ND	ND	ND	ND	ND
GW-1013-Q188	ND	0.52	ND	ND	ND	ND
GW-1014-Q188	ND	ND	ND	ND	0.2	ND
GW-1015-Q188	10.2	ND	0.66	ND	6.66	3.89
GW-1016-Q188	ND	ND	ND	ND	0.27	ND
GW-1017-Q188	ND	ND	ND	ND	ND	ND
GW-1018-Q188	ND	ND	ND	ND	ND	ND
GW-1019-Q188	ND	ND	ND	ND	ND	ND

ND - NOT DETECTED

SECOND QUARTER NITROAROMATIC RESULTS FOR GROUNDWATER AT THE WSQ

DETECTION LIMITS - UG/L	0.5	0.2	0.6	0.6	0.3	0.4
		CONCENTRATION - UG/L				
LOCATION NUMBER	TNT	2,4-DNT	2,6-DNT	NB	1,3,5-TNB	1,3-DNB
GW-1002-Q288	11.9	ND	2.63	ND	30.6	ND
GW-1004-Q288	15.6	ND	7.52	ND	4.28	4.78
GW-1005-Q288	ND	1.19	ND	ND	0.38	ND
GW-1006-Q288	51.1	ND	5.2	ND	162	ND
GW-1007-Q288	ND	ND	ND	ND	ND	ND
GW-1008-Q288	ND	ND	ND	ND	0.09	ND
GW-1009-Q288	ND	ND	ND	ND	0.03	ND
GW-1010-Q288	ND	ND	ND	ND	ND	ND
GW-1011-Q288	ND	ND	ND	ND	ND	ND
GW-1012-Q288	ND	ND	ND	ND	ND	ND
GW-1013-Q288	ND	0.2	ND	ND	0.14	ND
GW-1014-Q288	ND	ND	ND	ND	ND	ND
GW-1015-Q288	18.6	ND	ND	ND	65.5	ND
GW-1016-Q288	0.98	ND	ND	ND	3.87	ND
GW-1017-Q288	ND	ND	ND	ND	0.79	ND
GW-1018-Q288	ND	ND	ND	ND	0.59	ND
GW-1019-Q288	ND	ND	ND	ND	ND	ND

ND - NOT DETECTED

THIRD QUARTER NITROAROMATIC RESULTS FOR GROUNDWATER AT THE WSQ

DETECTION LIMITS - 0.5 0.2 0.6 0.6 0.3 0.4
UG/L

CONCENTRATION - UG/L

LOCATION NUMBER	TNT	2,4-DNT	2,6-DNT	NB	1,3,5-TNB	1,3-DNB
GW-1002-Q388	5.47	ND	1.37	ND	12.7	7.22
GW-1004-Q388	6.56	0.39	2.68	ND	0.92	2.84
GW-1005-Q388	ND	0.43	ND	ND	0.66	ND
GW-1006-Q388	43	0.92	4.76	2.39	173	33.9
GW-1007-Q388	ND	ND	ND	ND	ND	ND
GW-1008-Q388	ND	ND	ND	ND	0.91	ND
GW-1009-Q388	ND	ND	ND	0.05	ND	ND
GW-1010-Q388	ND	ND	ND	ND	0.33	ND
GW-1012-Q388	ND	ND	ND	ND	ND	ND
GW-1013-Q388	ND	ND	ND	ND	0.14	ND
GW-1014-Q388	ND	ND	ND	ND	0.23	ND
GW-1015-Q388	18.7	0.64	ND	ND	29	9.11
GW-1017-Q388	ND	ND	ND	ND	ND	ND
GW-1018-Q388	ND	ND	ND	ND	ND	ND
GW-1019-Q388	ND	ND	ND	ND	ND	ND
GW-1020-Q388	ND	ND	ND	ND	ND	ND
GW-1021-Q388	0.55	0.51	ND	ND	0.39	ND
GW-1022-Q388	ND	ND	ND	ND	ND	ND
GW-1023-Q388	ND	ND	ND	ND	ND	ND
GW-1024-Q388	ND	0.4	ND	ND	0.38	ND

ND - NOT DETECTED

FOURTH QUARTER NITROAROMATIC RESULTS FOR GROUNDWATER AT THE WSQ

DETECTION LIMITS - UG/L	0.5	0.2	0.6	0.6	0.3	0.4
			CONCENTRATION - UG/L			
LOCATION NUMBER	TNT	2,4-DNT	2,6-DNT	NB	1,3,5-TNB	1,3-DNB
GW-1002-Q488	2.64	ND	ND	ND	5.91	3.15
GW-1004-Q488	4.67	ND	2.95	ND	0.74	2.15
GW-1005-Q488	ND	ND	ND	0.86	0.89	ND
GW-1010-Q488	0.71	ND	ND	0.69	ND	ND
GW-1012-Q488	ND	ND	ND	ND	ND	ND
GW-1013-Q488	ND	ND	ND	ND	ND	ND
GW-1014-Q488	ND	ND	ND	ND	ND	ND
GW-1015-Q488	23.99	8.82	ND	16.83	1.16	ND
GW-1017-Q488	ND	ND	ND	ND	0.56	ND
GW-1018-Q488	ND	ND	ND	ND	0.5	ND
GW-1019-Q488	ND	ND	ND	ND	ND	ND
GW-1020-Q488	ND	ND	ND	ND	0.63	ND
GW-1021-Q488	ND	ND	ND	ND	0.39	ND
GW-1022-Q488	ND	ND	ND	ND	0.15	ND
GW-1023-Q488	ND	ND	ND	ND	ND	ND
GW-1024-Q488	ND	ND	ND	ND	ND	ND
GW-1025-Q488	ND	ND	ND	ND	ND	ND
GW-1026-Q488	ND	ND	ND	ND	0.16	ND
GW-1027-Q488	5.03	ND	ND	ND	0.05	0.48
GW-1028-Q488	ND	ND	ND	ND	ND	ND

ND - NOT DETECTED

QUARTERLY URANIUM RESULTS - WSQ

Total Uranium - pCi/L

	Q1	Q2	Q3	Q4	AVERAGE
GW-1002	4.5	1.6	15		7.0
GW-1004	5900	2900	3800		4200.0
GW-1005	1400	790	1000	1700	1222.5
GW-1006	1100	2200	2500		1933.3
GW-1007	200	130	87		139.0
GW-1008	330	1300	1180		936.7
GW-1009	ND	1.4	1.8		1.6
GW-1010	ND	ND	ND	ND	ND
GW-1011	ND	3.3			3.3
GW-1012	9.4	7.3	11	2.5	7.6
GW-1013	930	980	830	680	855.0
GW-1014	1000	930	840	760	882.5
GW-1015	380	550	420	ND	450.0
GW-1016	110	190	110		136.7
GW-1017	ND	ND	1.1	ND	1.0
GW-1018	ND	ND	1.2	ND	1.2
GW-1019	ND	ND	ND	ND	ND
GW-1020			ND	ND	ND
GW-1021			ND	ND	ND
GW-1022			1.2	ND	1.2
GW-1023			ND		ND
GW-1024			ND		ND
GW-1025				2.2	2.2
GW-1026				2.5	2.5
GW-1027				270	270.0
GW-1028				2.4	2.4

ND - NOT DETECTED

QUARTERLY URANIUM ACTIVITIES AT THE WSCP/WSRP

URANIUM CONCENTRATION - pCi/L

	Q1	Q2	Q3	Q4	AVERAGE
GW-2001	ND	ND	ND	ND	ND
GW-2003	ND	3.0	ND	1.3	2.2
GW-2004	5.9	2.0	2.4	1.3	2.9
GW-2006	2.4	ND	1.1	ND	1.8
GW-2008	3.6	ND	1.6	ND	2.6
GW-2010	2.0	ND	1.4	1.3	1.6
GW-2012	ND	ND	2.3	ND	2.3
GW-2013	ND	1.5	ND	ND	1.5
GW-2014	ND	1.9	ND		1.9
GW-2016		1.1		7.4	4.3
GW-2017	4.4	8.9	5.5	3.2	5.5
GW-2018	ND	2.4	2.9	12.0	5.8
GW-2020	20.0	14.0	4.7	ND	12.9
GW-2023			ND		ND
GW-2024			ND		ND
GW-3003			15.0		15.0
GW-3006			ND		ND
GW-3007	4.5				4.5
GW-3008	9.1	7.3	8.3		8.2
GW-3009	41.0	39.0	3.9	3.1	21.8
GW-3010	1.2	1.6	1.8	4.8	2.4
GW-3013	5.0	2.4	33.0		13.5
GW-3018		3.2			3.2
GW-4019	1.7	1.6	2.7		2.0

ND - NOT DETECTED

	pH	Temp. C	Total Uranium pCi/L	Gross Alpha pCi/L	Nitrate mg/L	Lithium ug/L	Tot. Settl. Solids ml/L	Tot. Susp. Solids mg/L	Flow GPM
NP-0001-0188	7.29	6.2	930 ± 100	310 ± 40	4.4	*	<0.1	26	10
-0288	7.32	5.3	360 ± 40	410 ± 50	6.0	*	<0.1	3	20
-0388	7.43	9.1	260 ± 30	99 ± 10	2.8	*	<0.1	36	150
-0488	7.86	11.7	400 ± 40	350 ± 40	4.5	*	<0.1	8	20
-0588	NO FLOWS								
-0688	NO FLOWS								
-0788	7.84	21.5	650 ± 65	370 ± 37	4.3	*	<0.1	11	30
-0888	7.72	22.0	720 ± 72	340 ± 34	5.2	ND	<0.1	4	10
-0988	**								
-1088	**								
-1188	7.32	10.9	450 ± 50	270 ± 27	4.0	ND	<0.1	9	20
-1288	**								
Average	7.54	12.4	539	307	4.5	ND	<0.1	14	40

* Lithium was added to NPDES permit August 1988.
** NP-0001 is now only required to be sampled quarterly.

	pH	Temp. C	Total Uranium pCi/L	Gross Alpha pCi/L	Nitrate mg/L	Lithium ug/L	Tot. Settl. Solids ml/L	Tot. Susp. Solids mg/L	Flow GPM
NP-0002-0188	6.82	2.9	280 ± 30	100 ± 10	2.2	*	<0.1	11	60
-0288	7.16	3.3	88 ± 19	88 ± 10	2.0	*	<0.1	8	250
-0388	7.25	13.0	300 ± 30	82 ± 9	2.3	*	<0.1	12	300
-0488	7.42	13.8	140 ± 20	200 ± 20	2.6	*	<0.1	17	150
-0588	NO FLOWS								
-0688	7.37	21.8	110 ± 20	60 ± 8	3.6	*	<0.1	48	100
-0788	7.19	24.5	95 ± 10	37 ± 6.2	1.6	*	<0.1	39	250
-0888	7.27	24.7	110 ± 11	70 ± 8	1.9	*	<0.1	323	200
-0988	7.18	22.8	100 ± 10	50 ± 7.2	1.3	ND	<0.1	6	100
-1088	7.16	19.9	110 ± 10	54 ± 6.7	1.4	ND	<0.1	2	100
-1188	6.70	8.0	160 ± 16	60 ± 7.6	2.2	ND	<0.1	21	200
-1288	6.82	3.9	55 ± 3.7	21 ± 4.9	7.1	ND	<0.1	204	81
AVERAGE	7.12	14.4	141	75	2.6	ND	<0.1	63	160

* Lithium was added to NPDES permit August 1988.

	pH	Temp. C	Total Uranium pCi/L	Gross Alpha pCi/L	Nitrate mg/L	Lithium ug/L	Tot. Settl. Solids ml/L	Tot. Susp. Solids mg/L	Flow GPM
NP-0003-0188	7.14	1.9	1400 ± 200	320 ± 40	31.9	*	0.5	310	100
-0288	7.06	1.2	1700 ± 200	780 ± 80	32.0	*	<0.1	16	150
-0388	7.66	13.2	2300 ± 200	910 ± 100	20.8	*	<0.1	14	200
-0488	7.39	13.0	1200 ± 200	1300 ± 130	23.3	*	<0.1	6	100
-0588	NO FLOWS								
-0688	NO FLOWS								
-0788	7.31	22.8	500 ± 50	290 ± 29	13.2	*	<0.1	166	10
-0888	NO FLOWS								
-0988	NO FLOWS								
-1088	NO FLOWS								
-1188	6.72	6.6	44 ± 4	44 ± 6.4	5.3	ND	<0.1	777	180
-1288	7.08	4.2	1100 ± 110	500 ± 50	ND	ND	10	2314	263
AVERAGE	7.19	8.9	1178	592	21.6	<0.05	5.3	515	140

* Lithium was added to NPDES permit August 1988.

	pH	Temp. C	Total Uranium pCi/L	Gross Alpha pCi/L	Nitrate mg/L	Lithium ug/L	Tot. Settl. Solids ml/L	Tot. Susp. Solids mg/L	Flow GPM
NP-0004-0188	7.39	1.8	9.8 ± 1.0	ND	1.2	*	<0.1	5	5
-0288	7.19	1.5	5.8 ± 1.1	ND	4.0	*	<0.1	9	20
-0388	7.58	8.8	4.0 ± 1.0	3.7 ± 2.2	0.7	*	<0.1	22	75
-0488	7.49	12.5	6.5 ± 1.2	6.4 ± 3.3	0.4	*	<0.1	6	75
-0588	NO FLOWS								
-0688	NO FLOWS								
-0788	NO FLOWS								
-0888	7.12	19.7	7.2 ± 1.2	ND	0.2	-	<0.1	2	5
-0988	**								
-1088	**								
-1188	6.63	12.8	4.1 ± 1.1	ND	4.1	ND	<0.1	11	1
-1288	**								
AVERAGE	7.23	9.5	6.2	5.1	1.8	<0.05	<0.1	9	18

* Lithium was added to NPDES permit August 1988.
** NP-0004 is now only required to be sampled quarterly.

	pH	Temp. C	Total Uranium pCi/L	Gross Alpha pCi/L	Nitrate mg/L	Lithium ug/L	Tot. Settl. Solids ml/L	Tot. Susp. Solids mg/L	Flow GPM
NP-0005-0188	7.49	2.9	840 ± 90	390 ± 40	76.6	*	<0.1	3	10
-0288	7.53	2.5	450 ± 50	370 ± 40	71.0	*	<0.1	8	20
-0388	7.52	9.0	290 ± 30	100 ± 10	27.7	*	<0.1	35	200
-0488	7.64	12.1	430 ± 50	340 ± 40	77.1	*	<0.1	11	20
-0588	NO FLOWS								
-0688	NO FLOWS								
-0788	7.42	23.5	330 ± 33	220 ± 22	37.9	*	<0.1	6	25
-0888	7.55	23.5	400 ± 40	230 ± 25	3.4	ND	<0.1	59	10
-0988	NO FLOWS								
-1088	7.45	19.1	700 ± 70	370 ± 37	0.72	ND	<0.1	15	10
-1188	6.97	7.8	450 ± 50	300 ± 30	34.8	ND	<0.1	2	20
-1288	6.91	5.1	580 ± 60	200 ± 20	246	ND	<0.1	212	230
AVERAGE	7.39	11.7	497	280	63.9	<0.05	<0.01	39	60

* Lithium was added to NPDES permit August 1988.

APPENDIX B

GLOSSARY OF TECHNICAL TERMS

ABSORBED DOSE: The amount of energy absorbed in any material from incident radiation. Measured in rads, where 1 rad equals 100 ergs of energy absorbed in 1 gram of matter.

ACTIVITY: A measure of the rate at which radioactive material is undergoing radioactive decay; usually given in terms of the number of nuclear disintegrations occurring in a given quantity of material over a unit of time. The unit of activity is the Curie (Ci) (see also Bequerel and Curie).

ALARA: An acronym for "As Low as Reasonably Achievable". This refers to the DOE goal of keeping releases of radioactive substances to the environment and exposures of human to radiation as far below regulatory limits as "reasonably achievable".

ALLUVIAL AQUIFER: A subsurface zone, formed by the deposition of sediments by running water, capable of yielding usable quantities of groundwater to wells.

ALPHA PARTICLE: A positively charged particle emitted from the nucleus during the radioactive decay of certain radionuclides. It consists of two protons and two neutrons bound together; it is identical to the nucleus of a helium-4 atom.

BACKGROUND RADIATION: Radiation due to cosmic rays and radiation from the naturally radioactive elements in the surface of earth.

BEDROCK: A rock formation usually underlying one or more unconsolidated formations.

BEQUEREL: SI unit for activity. 1 becquerel (Bq) = 1 disintegration/second = $2.703X10^{-11}$ Ci (curie).

BETA PARTICLE: Charged particle emitted from the nucleus of an atom, with a mass and charge equal in magnitude to that of the electron.

CHAIN OF CUSTODY: Standardized form tracing the possession and handling of individual samples from the time of field collection through laboratory analysis.

COMMITTED DOSE EQUIVALENT: The total dose equivalent averaged throughout a tissue in the 50 years after intake of a radionuclide into the body.

CONTAMINATION: A foreign substance in or on the surfaces of soils, structures, areas, objects, or personnel.

COUNTING STATISTICS: Statistical analysis required to process the results of nuclear counting experiments and to make predictions about the expected precision of quantities derived from these measurements.

CURIE: A measure of the rate of radioactive decay. One Curie (Ci) is equal to 37 billion disintegrations per second (3.7×10^{10} dps), which is equal to the decay rate of one gram of radium-226.

DAUGHTER: An element that results immediately from the disintegration of a radioactive element.

DECAY PRODUCTS: Isotopes that are formed by the radioactive decay of some other isotope. In the case of radium-226, for example, there are 10 successive decay products, ending in the stable isotope Lead-206.

DERIVED CONCENTRATION GUIDE (DCG): Concentrations of radionuclides in water and air that could be continuously consumed or inhaled respectively, and not exceed an effective dose equivalent of 100 mrem/year.

DISCHARGE: In groundwater hydrology, the rate of flow (usually from a well or spring) at a given instant in terms of volume per unit time.

DOSE: Total radiation delivered to a specific part of the body, or to the body as a whole, also called dose equivalent.

DOSE RATE: Dose or dose equivalent per unit time (i.e., millirem per year) as it is being delivered to the body.

DOSIMETER: A device used in measuring radiation dose. Such as a lithium fluoride (LiF) thermoluminescent detector (TLD).

EFFECTIVE DOSE EQUIVALENT: The proportion of the stochastic risk resulting from irradiation of a tissue to the total risk when the whole body is irradiated uniformly. A term used to express the amount of effective radiation when modifying factors have been considered. It is the product of absorbed dose (rads) multiplied by a quality factor and any other modifying factors. It is measured in rem (Roentgen Equivalent Man).

ERG: 1 ERG = 2.8×10^{-14} KWH

EXPOSURE PATHWAY: The route by which a contaminant/health hazard may enter and move through the environment or individual.

EXPOSURE RADIATION: The amount of ionization produced in air by X-rays or gamma rays, measured in Roentgens (R).

GAMMA RADIATION: Penetrating high energy, short wave-length, electromagnetic radiation (similar to x-rays) emitted during radioactive decay. Gamma rays are very penetrating and can be attenuated only by dense materials such as lead.

GROSS ALPHA: Measurement of all alpha emitting radionuclides in a sample.

GROSS BETA: Measurement of all beta emitting radionuclides in a sample. Gross alpha and beta are useful analyses for screening to determine whether further analyses for specific radionuclides are merited.

HALF LIFE: The time it takes for half the atoms of a quantity of a particular radioactive element to decay into another form. Half-lives of different isotopes vary from millionths of a second or less to billions of years.

HECTARE: A unit of area in the metric system equal to approximately 2.5 acres. It is 10,000 square meters.

HYDROLOGIC: Pertaining to study of the properties, distribution, and circulation of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere.

ISOTOPE: Nuclides having the same atomic number but different mass numbers.

NATURAL URANIUM: A naturally occurring radioactive element that consists of 99.2830% by weight uranium-238, 0.7110% uranium-235 and 0.0054% uranium-234.

NUCLIDE: A general term referring to isotopes, both stable (279) and unstable (about 500), of the chemical elements.

PERCHED LENSES: A small, localized water-saturated zone of subsurface material surrounded by unsaturated material.

RAD: Unit of absorbed dose; acronym for radiation absorbed dose.

RADIATION: A very general term that covers many forms of particles and energy, from sunlight and radiowaves to the energy that is released from inside an atom. Radiation can be in the form of electromagnetic waves (gamma rays, x-rays) or particles (alpha particles, beta particles, protons, neutrons).

RADIONUCLIDE: An unstable nuclide that undergoes radioactive decay.

RAFFINATE: A waste product from a refining process, i.e., that portion of a treated liquid mixture that is not dissolved and not removed by a selective solvent.

REM (Roentgen Equivalent Man): A quantity used in radiation protection to express the effective dose equivalent for all forms of ionizing radiation. A rem is the product of the absorbed dose in rads and factors related to relative biological effectiveness.

SI: International System of Units.

SIEVERET: SI unit used to express the effective dose equivalent for all forms of ionizing radiation. 1Sv = 100 rem

STOCHASTIC: "Stochastic" effects are those for which the probability of an effect occurring, rather then its severity, is regarded as a function of dose, without a threshold.

WORKING LEVEL: Any combination of radon-222 decay products in 1 liter of air that will result in the ultimate emission of 0.21 erg of alpha energy is defined as 1 WL. It is based on the 0.21 erg of alpha energy that would be emitted by the decay products of 100 pCi of radon-222 in 1 liter of air, where the decay products are in radioactive equilibrium with the parent.

WORKING LEVEL MONTH: The product of WL and duration of exposure, normalized to a 1-month exposure period.

X-RAYS: Penetrating electromagnetic radiation having a wave length that is much shorter than that of visible light. It is customary to refer to rays originating in the nucleus as gamma rays and to those originating in the electron field of the atom as x-rays.

APPENDIX C

ABBREVIATIONS

AABMWA	August A. Busch Memorial Wildlife Area
ACM	Asbestos Containing Material
AEC	Atomic Energy Commission
ANL	Argonne National Laboratory
BNI	Bechtel National Inc.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
DA	Department of the Army
DCG	Derived Concentration Guides
DI	Deionized Water
DNT	Dinitrotoluene
DOC	Department of Conservation
DOE	U.S. Department of Energy
EMPP	Environmental Monitoring Program Plan
EMR	Environmental Monitoring Report
EPA	Environmental Protection Agency
FCCA	Federal Facility Compliance Agreement
FIDLER	Field Instrument for the Detection of Low Energy Radiation
HSL	Hazardous Substance List
ICRP	International Commission on Radiation Protection
LCS	Laboratory Control Samples
MDNR	Missouri Department of Natural Resources
MSHD	Missouri State Highway Department
NCRP	National Council on Radiation Protection
NIOSH	National Institute for Occupational Safety & Health
NLO	National Lead of Ohio
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
NVLAP	National Voluntary Laboratory Accreditation Program

ABBREVIATIONS (Continued)

ORNL	Oak Ridge National Laboratory
ORAU	Oak Ridge Associated Universities
OSHA	Occupational Safety & Health Administration
PCB	Polychlorinated Biphenyl
PCM	Phase Contrast Microscopy
PE	Performance Evaluation
PIC	Pressurized Ionization Chamber
PMC	Project Management Contractor
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RPD	Relative Percent Difference
SARA	Superfund Amendments and Reauthorization Act
SFMP	Surplus Facilities Management Program
SWMU	Solids Waste Management Unit
TEM	Transmission Electron Microscopy
TLD	Thermoluminescent Dosimeter
TNT	Trinitrotoluene
TWA	Time-Weighted Average
UNC	United Nuclear Corporation
USDA	United States Department of Agriculture
WSCP	Weldon Spring Chemical Plant
WSOW	Weldon Spring Ordnance Works
WSQ	Weldon Spring Quarry
WSRP	Weldon Spring Raffinate Pit
WSS	Weldon Spring Site
WSSRAP	Weldon Spring Site Remedial Action Project
WSTA	Weldon Spring Training Area
WSUFMP	Weldon Spring Uranium Feed Materials Plant
WSVP	Weldon Spring Vicinity Property

APPENDIX D - QUALITY ASSURANCE

A comprehensive quality assurance (QA) program was maintained in 1988 to ensure that the data collected were precise, accurate, representative, complete, and comparable to the historical database. The scope of work under this QA program was all routine environmental and radiological monitoring and all chemical and radiological characterization activities. The QA program was composed of two components, field and analytical QA evaluations.

The QA program for field activities included the following:

- Preparation of site-specific sampling plans and sampling procedures for collection of all environmental samples.

- Proper documentation of sample collection including sample collection forms, field notebooks, and chain-of-custody records.

- Collection of quality control (QC) blanks, trip blanks, and equipment blanks for characterization sampling.

The analytical QA program for laboratory analyses used a number of different types of quality control samples to document the validity of the data generated. These samples included:

- Method Blanks (one per batch, each batch not to exceed 20 samples). Method blanks contain all the reagents used in the preparation and analysis of samples to assess contamination arising from reagents, glassware and other materials used in the analysis.

- Laboratory Control Samples/Spiked Blanks (LCS - one per batch, each batch not to exceed 20 samples). These samples

were prepared by adding known quantities of compounds of interest to deionized water. They were used to establish that instruments and procedures were in control.

- Calibration Check Samples (as needed, or per method). Calibration standards were periodically used to verify that the original calibrations were still valid.

- Duplicate and Spiked Samples (5% duplicate; 5% spike). Duplicate samples were analyzed to enable an estimate of the precision of the analytical procedures. Spiked samples were measured to determine the accuracy of the analytical procedure and assess matrix effects. For analyses conducted according to the Contract Laboratory Program (CLP) methodology, these controls are termed matrix spiked and matrix spiked duplicate samples.

- Blind QC Samples (one per 20 samples). Blind QC samples were inserted into the sample load in a fashion unrecognizable to the laboratory. These samples were used in addition to the standard duplicate sample analysis discussed above, to assess analytical precision.

- Interlaboratory Evaluation (Annually). In order to assess comparability of data, sample splits were shipped to different laboratories to provide a measure of analytical or method bias.

The laboratories performing analyses maintained internal quality assurance programs that involved routine calibration of counting instruments, source and background counts, routine yield determinations for radiochemical procedures, and replicate analyses to check precision.

In addition, the PMC conducted a laboratory performance audit of the primary analytical laboratory. This audit was performed to assess the overall laboratory performance in terms of internal laboratory QA/QC, corrective action, methodology, general laboratory practice, and data management.

APPENDIX E

STANDARDS FOR PROTECTION OF THE PUBLIC IN THE VICINITY OF DOE FACILITIES

RADIATION STANDARDS

A. DOSE LIMITS

1. All Pathways

The effective dose equivalent for any member of the public from all routine DOE operations[1] (natural background and medical exposures excluded) shall not exceed the values given below:

	Effective dose equivalents[2]	
	mrem/year	(mSv/year)
Occasional annual exposures	500	(5)
Prolonged period of exposures[3]	100	(1)

No individual organ shall receive an annual dose equivalent in excess of 5 rem/year (50 mSv/year).

2. Air Pathway Only (Limits of 40 CFR 61, Subpart H)

	Dose Equivalent	
	mrem/year	(mSv/year)
Whole body dose	25	(.25)
Any organ	75	(.75)

1. Routine DOE operations means normal planned operations and does not include actual or potential accidental or unplanned releases.

2. Effective dose equivalent will be expressed in rem (or millirem) with the corresponding value in sievert (or millisievert) in parenthesis. As used in this standard, effective dose equivalent includes both the effective dose equivalent from external radiation and the committed effective dose equivalent to individual tissues from ingestion and inhalation during the calendar year.

3. For the purposes of these standards, a prolonged exposure will be one that lasts, or is predicted to last, longer than 5 years.

B. DERIVED CONCENTRATION GUIDES (DCG)

The following table contains a listing of the DCG values for the ingestion of drinking water and inhalation of air for members of the public. The values are based on an annual dose equivalent rate of 100 mrem/yr. Five columns of information are shown in the table: 1) radionuclide; 2) drinking water ingestion DCG in units of μCi/mL; 3) drinking water DCG in units of Bq/mL; 4) inhalation DCG in units of μCi/mL; 5) inhalation DCG in units of Bq/mL.

Only a single mode of exposure was considered--either ingestion or inhalation.

The DCG values are given for individual radionuclides. For known mixtures of radionuclides, the sum of the ratio of the observed concentration of a particular radionuclide and its corresponding DCG for all radionuclides in the mixture must not exceed 1.0.

It should be noted that the values given in the table only account for drinking water and inhaling air, and do not include other potentially significant environmental pathways. A more

complete pathway analysis is required for calculating public radiation dose equivalent resulting from the operation of DOE facilities when more complex environmental pathways are involved.

	Drinking Water		Inhaled Air	
Radionuclide	µCi/mL	Bq/mL	µCi/mL	Bq/mL
Uranium-238	6.0E-07	2.0E-02	1.0E-13	4.0E-09
Uranium-235	6.0E-07	2.0E-02	1.0E-13	4.0E-09
Uranium-234	5.0E-07	2.0E-02	9.0E-14	3.0E-09
Thorium-232	5.0E-08	2.0E-03	7.0E-15	3.0E-10
Thorium-230	3.0E-07	1.0E-02	4.0E-14	1.0E-09
Radium-228	1.0E-07	4.0E-03	3.0E-12	1.0E-07
Radium-226	1.0E-07	5.0E-03	1.0E-12	6.0E-08

C. RADON

Above-background radon-222 concentrations in the atmosphere at or above any location outside the facility site shall not exceed an annual average concentration of 3 pCi/L (DOE Order 5480.1A, Attachment XI-1).

CHEMICAL STANDARDS

U.S. EPA Drinking Water Standards (mg/L) as noted in 40 CFR 141

Drinking water standards are presented only for comparison purposes. These should not necessarily be construed as relevant cleanup standards.

A. HSL-Metals

Aluminum	NS	Lithium	NS
Antimony	NS	Magnesium	NS
Arsenic	0.05*	Manganese	0.05**
Barium	1.0*	Mercury	0.002
Beryllium	NS	Nickel	NS
Cadmium	0.01*	Potassium	NS
Calcium	NS	Selenium	0.01
Chromium	0.05*	Silver	0.05
Cobalt	NS	Sodium	NS
Copper	1.0**	Thallium	NS
Iron	0.3**	Vanadium	NS
Lead	0.5*	Zinc	5.0**

B. Inorganic Anion and Water Quality

Nitrate	10*
Sulfate	250**
Chloride	250**
Fluoride	4*2**
Hardness	NS
TDS	500**
TOC	NS

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* Primary maximum contaminant level
** Secondary maximum contaminant level
NS - No Drinking Water Standard

APPENDIX F

CONVERSION FACTORS

1 mSv	=	100 mrem
1 mr	=	1 mrem (for gamma radiation)
1 Ci	=	3.7×10^{10} dps (disintegration/sec)
1 Bq	=	1 disintegration per second
1 M^3	=	1000 litres
1 Bq/M^3	=	3.7×10^{-2} pCi/M^3
1 Bq/L	=	3.7×10^{-2} pCi/L
1 Bq/kg	=	3.7×10^{-2} pCi/kg

APPENDIX G
DISTRIBUTION LIST FOR WELDON SPRING SITE ANNUAL ENVIRONMENTAL MONITORING REPORT

CONGRESSIONAL:

The Honorable Christopher S. Bond
U. S. Senate
293 Russell Senate Office Building
Washington, DC 20510

The Honorable John Danforth
U. S. Senate
249A Russell Office Building
Washington, DC 20510

The Honorable Harold L. Volkmer
U. S. House of Representatives
2411 Rayburn House Office Building
Washington, DC 20515

The Honorable Jack Buechner
U.S. House of Representatives
502 Cannon House Office Building
Washington, DC 20515

The Honorable William L. Clay
U. S. House of Representatives
2470 Rayburn House Office Building
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Mr. Rob McDonald
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The Honorable John Danforth, Senator
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Mr. Lee Viorel
District Administrator
The Honorable Harold L. Volkmer, Congressman
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Ms. Liz Harris
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The Honorable Craig Kilby
Missouri House of Representatives
56 Freymuth Street
Lake St. Louis, Missouri 63367

The Honorable Joseph Ortwerth
Missouri House of Representatives
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The Honorable Gerald Ohlms
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The Honorable Robert Perkins
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