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Calendar Year 1987

WELDON SPRING SITE REMEDIAL ACTION PROJECT

Weldon Spring Site Remedial Action Project

WELDON SPRING SITE
ANNUAL ENVIRONMENTAL MONITORING REPORT
CALENDAR YEAR 1987

PREPARED FOR:
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WELDON SPRING SITE ANNUAL ENVIRONMENTAL MONITORING REPORT
WELDON SPRING, MISSOURI
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EXECUTIVE SUMMARY

This report summarizes the environmental monitoring activities conducted during 1987 in and around the Weldon Spring Site (WSS), a U.S. Department of Energy (DOE) surplus facility located in St. Charles County, Missouri. The WSS is part of the Surplus Facilities Management Program, a DOE program to plan and manage the final disposition of retired DOE-owned facilities. The WSS comprises two (2) physically separate areas: the 89.5-hectare (221-acre) Weldon Spring Chemical Plant (WSCP) and adjoining Weldon Spring Raffinate Pits (WSRP) area, and the 3.6-hectare (9-acre) Weldon Spring Quarry (WSQ) area.

The WSS was formerly used for the processing of uranium and thorium concentrates to produce pure metal and oxides. Prior to its use for uranium and thorium purification, the site was used for explosive production during World War II. The WSRP and WSQ areas are presently used for the interim storage of radioactively and chemically contaminated waste materials. Radioactivity above current applicable limits for areas of unrestricted use exists at the site, and elevated levels of radiation will be present until remedial action is completed.

With the initiation of the Weldon Spring Site Remedial Action Project (WSSRAP) by DOE in 1985, all areas of the WSS became a part of the Site Environmental Monitoring Program for 1987. This program has been greatly expanded over monitoring programs of previous years. During late 1986, additional groundwater monitoring wells were installed and surface water sampling locations added on and around the WSCP. The analytic parameters for both radiological and chemical contamination were also expanded. In addition, air particulate monitoring devices installed around the perimeter of the WSRP/WSCP became operational in early 1987. Detailed explanations regarding both radiation and chemical levels measured in 1987 are presented in Section 2.0 and related activities and special studies are

described in Section 3.0 of this report.

Radiological monitoring at the WSS during 1987 measured uranium, Radium-226, and Thorium-230 concentrations in surface water, groundwater, and sediment; radon gas concentrations in air; all long-lived natural series isotopes in air particulates; and external gamma radiation exposure rates. Potential radiation doses to the public were calculated based on assumed exposure periods and the above measurements. Radon concentrations, external gamma exposure rates, and radionuclide concentrations in groundwater and surface water at the site were generally equivalent to previous years' levels.

The maximum calculated annual radiation dose to a hypothetically exposed individual at the WSRP and WSCP area was 1 mrem, or 1 percent of the DOE radiation protection standard of 100 mrem. The maximum calculated annual radiation dose to a hypothetically exposed individual at the WSQ was 14 mrem, or about 14 percent of the standard. Thus the WSS currently complies with DOE Off-site Dose Standards.

Chemical contamination monitoring at the WSS during 1987 measured nitroaromatics, total organic carbon and the inorganic anions chloride, nitrate, fluoride and sulfate in surface water, groundwater and sediment. While exposure to these non-radiological substances is unregulated by DOE, the degree of environmental degradation from release of these contaminants can only be judged in light of measurements of the magnitude of the release. Off-site discharge (by surface water runoff) of nitroaromatic compounds is extremely small, although detectable. Discharge of nitrate compounds is relatively large. However, due to its generally beneficial effect within the ecosystem, the environmental impact of nitrate discharge is not of major concern.

The most important contamination release pathways from the

WSRP/WSCP continue to be both surface and subsurface discharge of uranium which flows via several different pathways to three lakes on the August A. Busch Wildlife Area. Fish tissue consumption was assumed to be the primary exposure pathway for the hypothetically exposed individual. Uranium activities were conservatively assumed. Actual uranium and chemical uptake studies are currently underway. Several impoundment and dump areas are believed to be the source of this uranium. The most important contamination release pathway from the WSQ continues to be subsurface discharge of uranium which flows into the alluvial aquifer system bordering the St. Charles County drinking water well field. However, no detectable levels of uranium or chemical contaminants above background have been measured entering the well field.

1.0 INTRODUCTION

This report presents the findings of the environmental monitoring conducted at the Weldon Spring Site (WSS) during calendar year 1987. 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 21.1, 68.4 and 3.6 hectares (ha) (52, 169, 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 caretaker status by the DOE. The WSCP was controlled by the DA. Environmental monitoring programs during those years were performed to determine changes (if any) in the radiological levels in and around the WSRP and WSQ. Quarterly environmental monitoring data were not collected by DA in and around the WSCP. With the transfer of the WSCP 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 and WSRP as well as the WSQ. Six additional monitoring wells were installed in the WSQ area in 1986 and an additional seven

monitoring wells were installed further out into the alluvium from the WSQ in 1987. At the WSCP, 19 new wells were sited and installed where no monitoring wells had previously existed. These well installations were completed in late 1986. 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 for 1987 is provided in Section 1.4 of this report.

DOE Order 5484.1 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:

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

b. Compliance with applicable environmental standards for radioactivity and other pollutants specified by DOE and EPA.

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

This 1987 Environmental Monitoring Report meets these requirements. Section 2.0 presents the results of the measurement activities and compares the environmental levels of both radioactivity and chemical contaminants released from the site with applicable standards.

In addition to the routine environmental monitoring conducted in 1987, there were a number of related activities and special studies performed which are directly applicable to an assessment of the overall impact of site operations on the environment. A

description and the results of these activities are discussed in Section 3.0.

Based on the sampling results from 1987, Section 4.0 of this report presents calculations of the maximum radiation dose to hypothetically exposed individuals at the WSCP/WSRP and WSQ areas. Differences in occupancy factors and exposure assumptions between the two locations account for the different calculated doses. In addition, the doses to the population at large in the vicinity of the WSS are calculated.

The following sections provide a brief history of the site, its environmental setting and a summary of the results from monitoring in 1987. For a definition of most of the technical terms used in this report, the reader is urged to consult Appendix A. Although each acronym used in this report is defined when it is first used, a list of all abbreviations used throughout this report is provided in Appendix B. Appendix C contains a description of the quality assurance methods applied to sampling and analysis performed for this monitoring effort. Appendix D presents a discussion of the Environmental Guidelines that apply to the monitoring program. Appendix E provides a useful conversion table, and Appendix F the distribution list for the 1987 Environmental Monitoring 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 location of these properties is illustrated in Figure 1-1.

The WSS is used for the storage of uranium and thorium residues, waste materials, and contaminated rubble. In addition to environmental monitoring, engineering activities are being conducted to minimize the migration of contaminants from these facilities into surface water and groundwater.

Some characterization activities have been conducted at the WSRP and WSQ, and more are in progress at all areas of the WSS, to provide information on the types and magnitude of contamination present. This information will be used in evaluating the course of remedial actions to be conducted at the site. Brief descriptions of each area 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 21.1-ha (52-acre) WSRP area includes four pits that cover approximately 10.5 ha (26 acres) (see Figure 1-3). The raffinate pits were constructed by excavating down into the existing clay soils and using the removed clay for construction of the dikes. These pits contain radioactive residues (called raffinates) from uranium and thorium processing operations at the former Weldon Spring Uranium Feed Materials Plant (now the WSCP). The surface area, volume, and preliminary estimates of the contents of the pits are summarized in Table 1-1.

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 4 feet in height. The pit drains and all transfer lines from the pits to the WSCP process sewer have been sealed (NLO, 1981). Water normally covers the

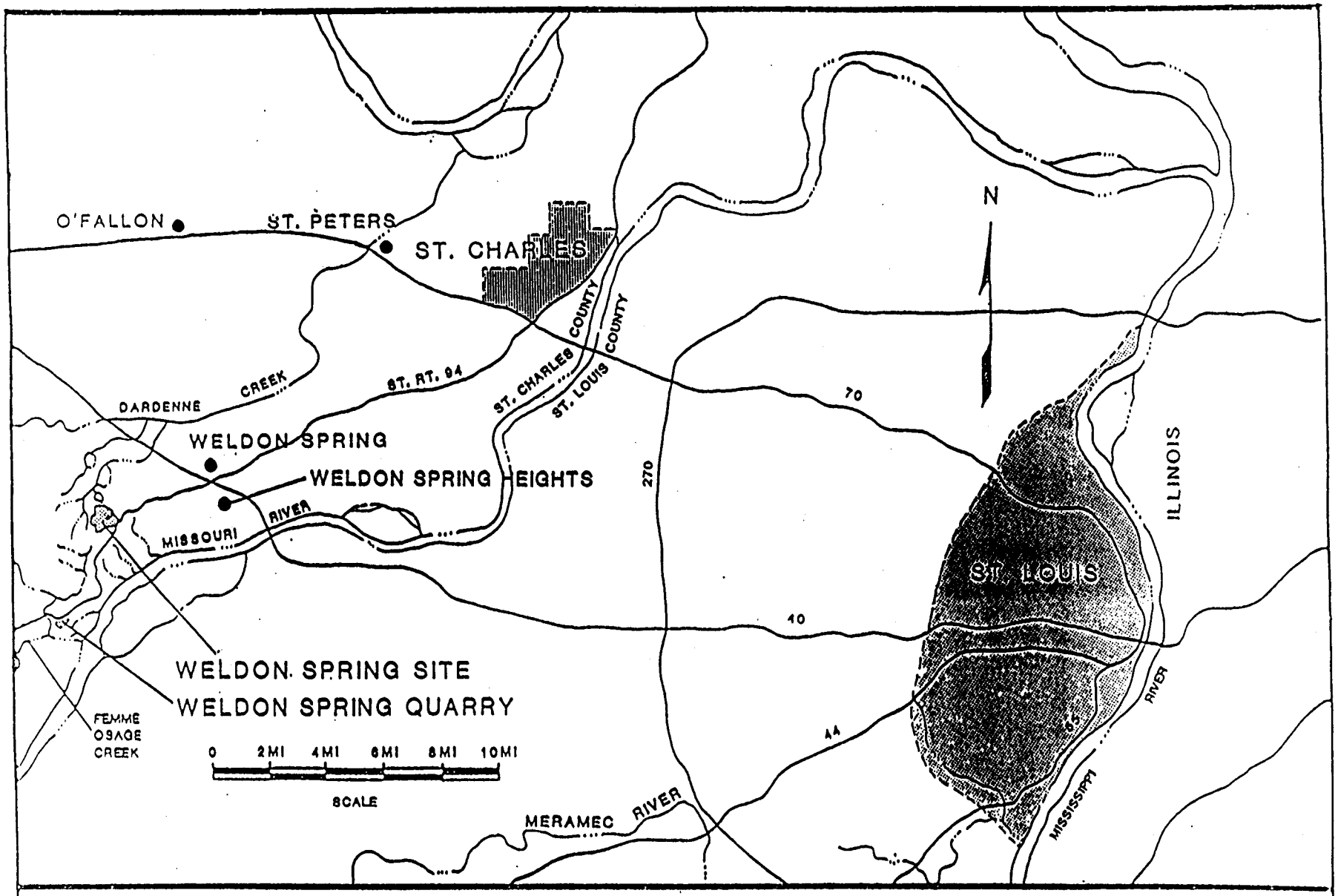


FIGURE 1-1

LOCATION OF THE WELDON SPRING SITE

FIGURE 1-2

AERIAL PHOTOGRAPH OF THE WSRP AREA

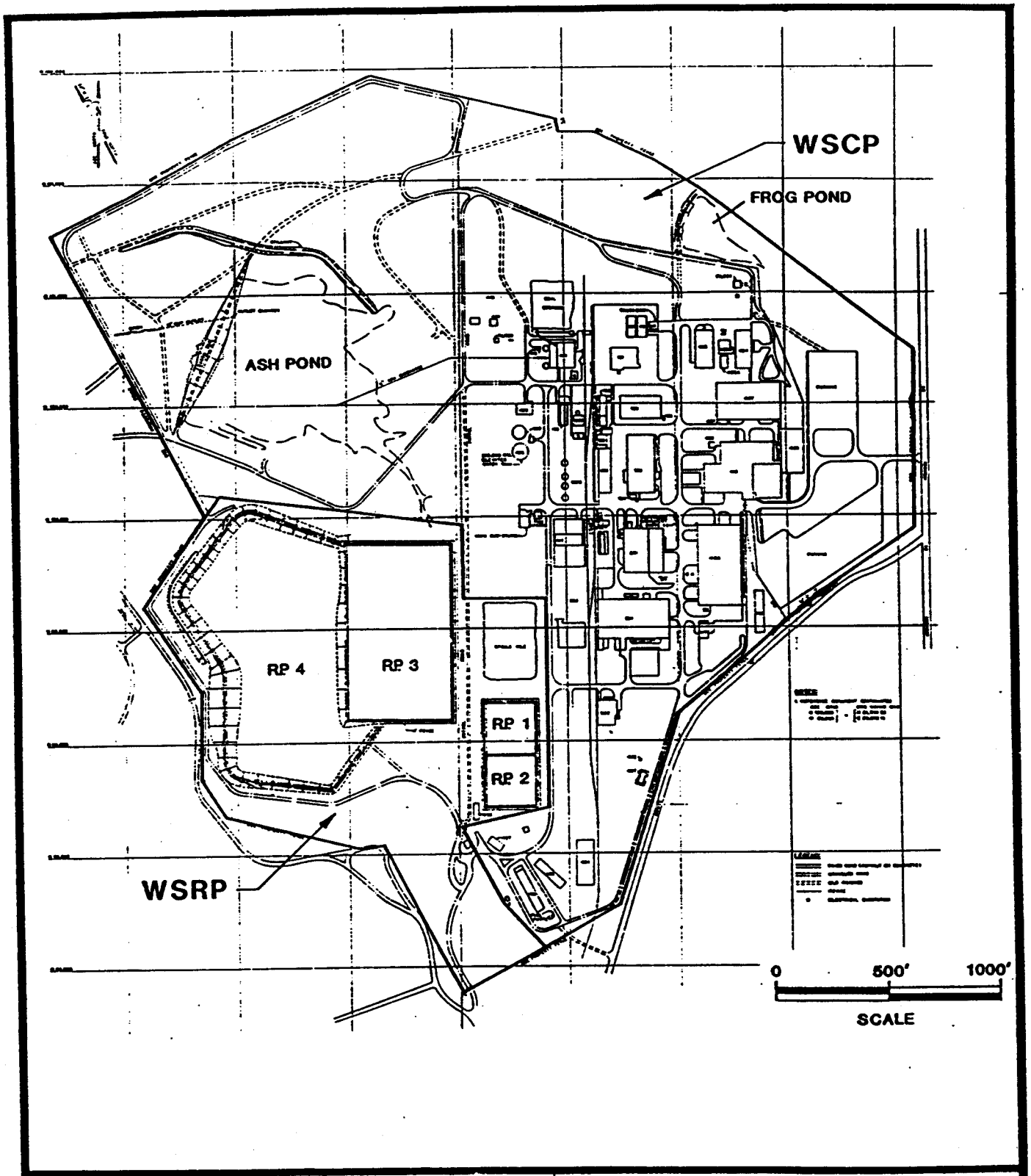


FIGURE 1-3

MAP OF THE WSRP & WSCP

TABLE 1-1

SUMMARY OF THE PHYSICAL & RADIOLOGIC CHARACTERISTICS OF THE RAFFINATE PITS

Characteristic	Pit 1	Pit 2	Pit 3	Pit 4
Year Constructed	1958	1958	1959	1964
Surface Area, ha (acres)	0.5 (1.2)	0.5 (1.2)	3.4 (8.4)	6.1 (15.0)
Pit Volume, m^3 (cubic yards)	14,060 (18,500)	14,060 (18,500)	126,692 (166,700)	337,744 (444,400)
Waste Volume, m^3 (cubic yards)	13,224 (17,400)	13,224 (17,400)	98,496 (129,600)	42,256 (55,600)
Radionuclide	**Average Activity (pCi/g)***			
Uranium (total)	2,000	2,480	2,460	3,960
Thorium-232	16	108	355	45
Thorium-230	1,540	26,670	32,900	740
Radium-228	100	200	190	180
Radium-226	2,400	1,450	1,210	50

* To convert to Bq/g, multiply by 3.7×10^{-2}

Source: Raffinate Pit Sampling Plan, MK-Ferguson, 1988.

residues in the pits. In past summers, however, the water in Pits 1 and 2 has evaporated, leaving the exposed residue surface dry and cracked.

The water levels in Pits 3 and 4 fluctuate, but surface water has always been present.

Weldon Spring Chemical Plant

The 68.4-ha (169-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 (WSUFMP) 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 24-hour guards routinely patrolling the site.

The interiors of the eight major buildings on-site are heavily contaminated with most of the uranium "fixed" on surfaces. The remainder of the buildings contain only small quantities of uranium as contamination.

Surface water drainage from the WSCP primarily follows three channels. These lead from outlet structures in Ash Pond, 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 Uranium Feed Materials Plant. Surface water draining into these areas picks up soluble uranium which is then transported off-site.

There are also small quantities of chemically hazardous substances present both in the buildings and as contamination in the soil in several areas of the site. These include asbestos,

PCB's, 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. A gravel road enters the site from Route 94 at the quarry floor, and a short dirt road provides access to the security gate at the upper level. 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 sump pond, which covers approximately 0.2 ha (0.5 acre). The pond contains approximately 12 million liters (3 million gallons) of water and is up to 6.1 m (20 feet) deep. The amount of water in the pond varies according to seasonal variations in precipitation and temperature.

The only structures on the site are a small storage shed and a sampling platform in the sump area. Access to the site is restricted by a locked, 2.1-m (7-ft) high chain-link fence topped by three strands of barbed wire; the fence completely surrounds the DOE property. The amounts and types of known wastes in the WSQ are summarized in Table 1-2.

1.2 SITE HISTORY

In April of 1941, the Department of the Army (DA) acquired 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

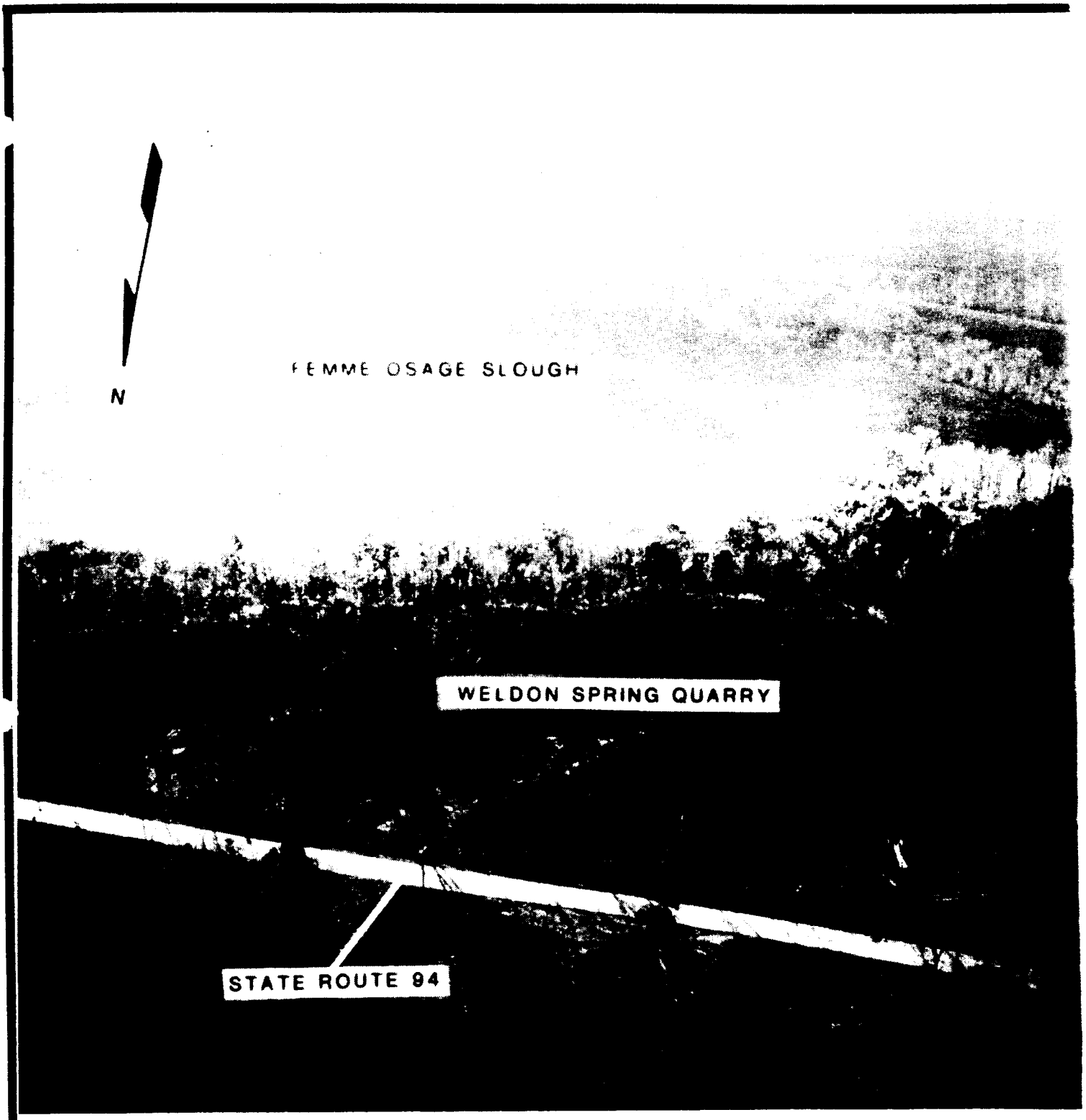


FIGURE 1-4

AERIAL PHOTOGRAPH OF THE WSQ

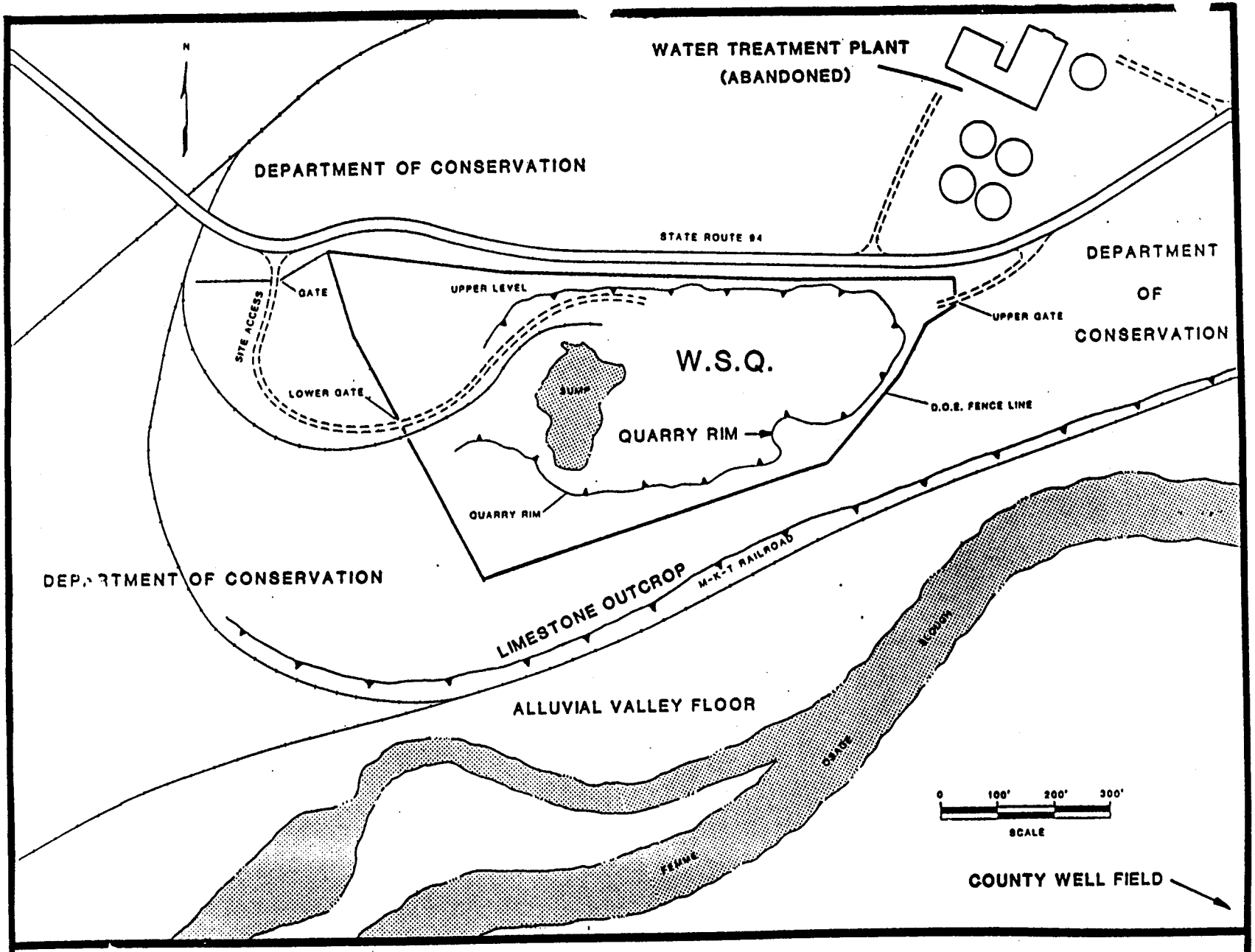


FIGURE 1-5

MAP OF THE WSQ

TABLE 1-2

ESTIMATED VOLUMES OF RADIOACTIVE WASTES STORED IN THE WSQ

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.
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 is Uranium-238 decay series.
High Thorium/ Rare Earth Wastes From DA Granite City Arsenal	1963-1965	760 (1000)	Fraction of drummed residues later recovered for the rare earth elements.
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 Plant Rubble	1967-1968	4,000 (5,000)	Contaminated equipment, building rubble; uranium and thorium content and radioactivity not available; principal sources of radioactivity are Uranium-238 and Thorium-232 decay series.

Weldon Spring Ordnance Works (WSOW). The WSOW was closed and declared surplus to Army needs in April 1946. By 1949, all but approximately 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), 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 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 in the WSRP area. 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 a predecessor uranium plant in downtown St. Louis, were deposited in the WSQ (See Table 1-2) (NLO, 1977).

Following the shutdown of the WSUFMP in 1966, the AEC returned the facility to the DA in 1967 for planned use as a defoliant production plant (to be known as the Weldon Spring Chemical Plant). The Army started removing equipment and decontaminating the 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 Pit 4 at the WSRP.

The defoliant project was cancelled in 1969 before any process equipment was installed for herbicide production. The DA retained the responsibility for the land and the facilities at the WSCP, but the 21.1-ha (52-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 (NLO) to periodically visit the WSRP and WSQ sites to perform environmental monitoring, maintain the pit embankments, and perform maintenance and surveillance tasks as necessary. In October 1981, Bechtel National, Incorporated, (BNI) under contract to DOE (successor to AEC), assumed management responsibility for the WSRP and WSQ from NLO. BNI managed these facilities in caretaker status until 1986.

In November 1984, 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, 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.

1.3 ENVIRONMENTAL SETTING

The WSRP and WSCP areas are 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 nine meters (3 to 30 feet) thick.

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

The Burlington-Keokuk cherty limestone is the first bedrock unit and the first aquifer underlying the WSCP/WSRP. Bedrock topography varies in elevation from about 585 feet mean sea level (msl) to 635 feet 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 inches wide) and may or may not be clay filled. No collapse sinks 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

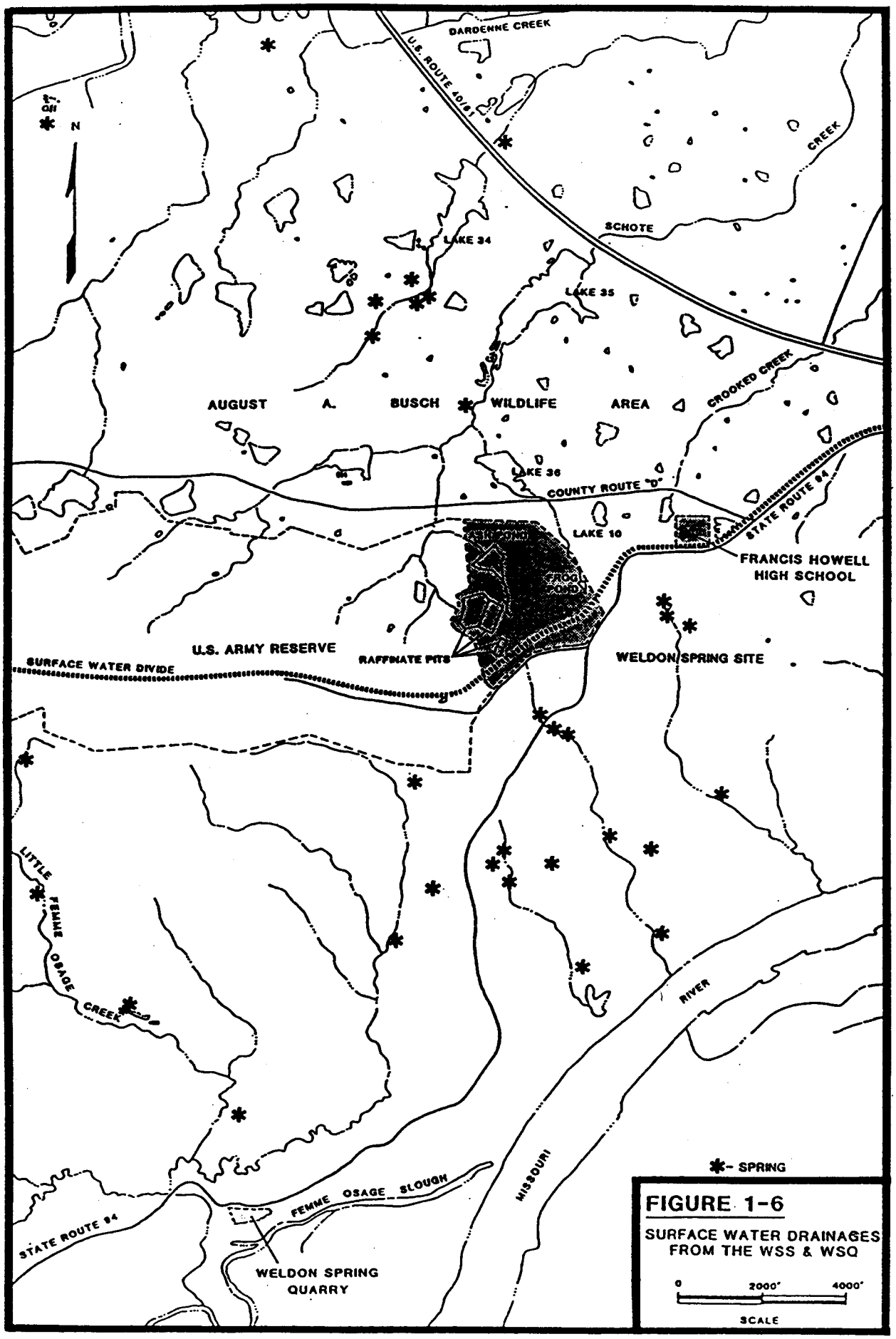


FIGURE 1-6

SURFACE WATER DRAINAGES FROM THE WSS & WSQ

combine near County Road D and flow northward into Schote Creek, and from there enter 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 (concrete surfaces draining into the storm-water sewer). Surface water flow from the northeastern edge of the WSCP also drains to Frog Pond.

Drainage from the southern portion of the WSCP property flows southeast to the Missouri River. This drainage originates from two sources. The first is from the sanitary and process sewer systems which merge prior to off-site discharge for the WSCP. The sanitary sewer system was taken out of service in 1986. It does, however, receive some flow as leakage from the storm-water runoff system into the sanitary sewer system. The second portion of the flow down the southeast drainage is due to overland flow from the southern portion of the site during precipitation events.

The WSQ is located on the northern bluff of the Missouri River valley. The unconsolidated upland material overlying bedrock consists of up to 30 feet 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 100 feet. The alluvium "pinches out" at the base of the bedrock bluffs along the now-abandoned MK&T 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 (50 to 60 feet thick) appear to pinch out southeast of the slough near the WSQ. The potentiometric surface in the alluvial aquifer fluctuates in response to the stage of the Missouri River. This indicates that the Missouri River is the primary recharge source for this aquifer.

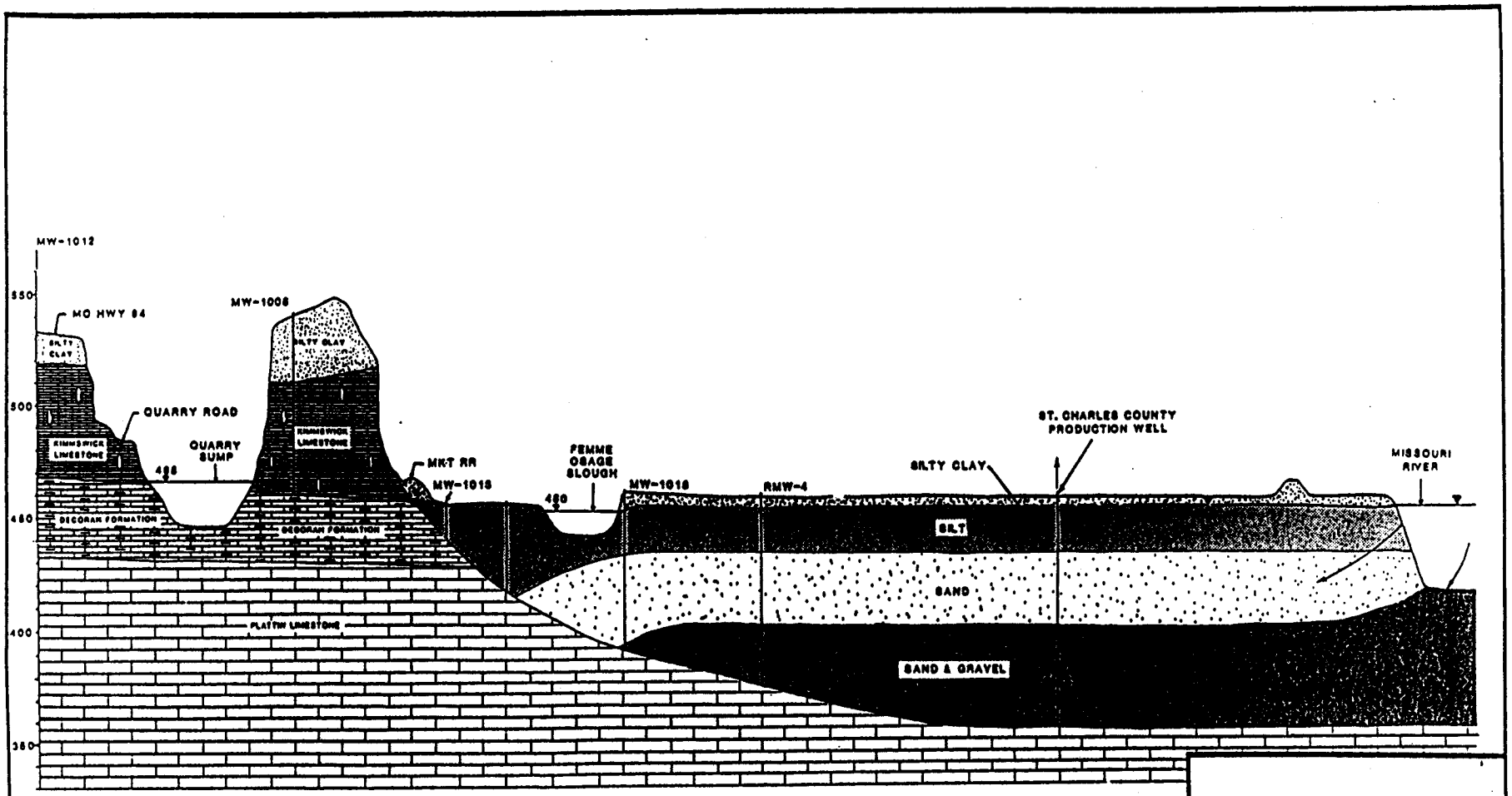
The WSQ bedrock consists of three distinct Ordovician formations. In descending order, they are the Kimmswick Formation, the Decorah Formation and the Plattin Formation. The Bushberg Formation, a Devonian sandstone, overlies the Kimmswick Formation to the north, west and east of the WSQ at higher elevations 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° west. The Decorah Formation consist of interbedded limestones and green shale. This bedrock unit is approximately 30 feet thick and is horizontally fractures.

The Plattin Formation is a thinly bedded, finely crystalline gray limestone. Thickness varies from 100 to 125 feet 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



10 TO 1 HORIZONTAL TO VERTICAL SCALE

FIGURE 1-7
TYPICAL HYDRO-GEOLOGIC CROSS-SECTION OF WSQ AREA

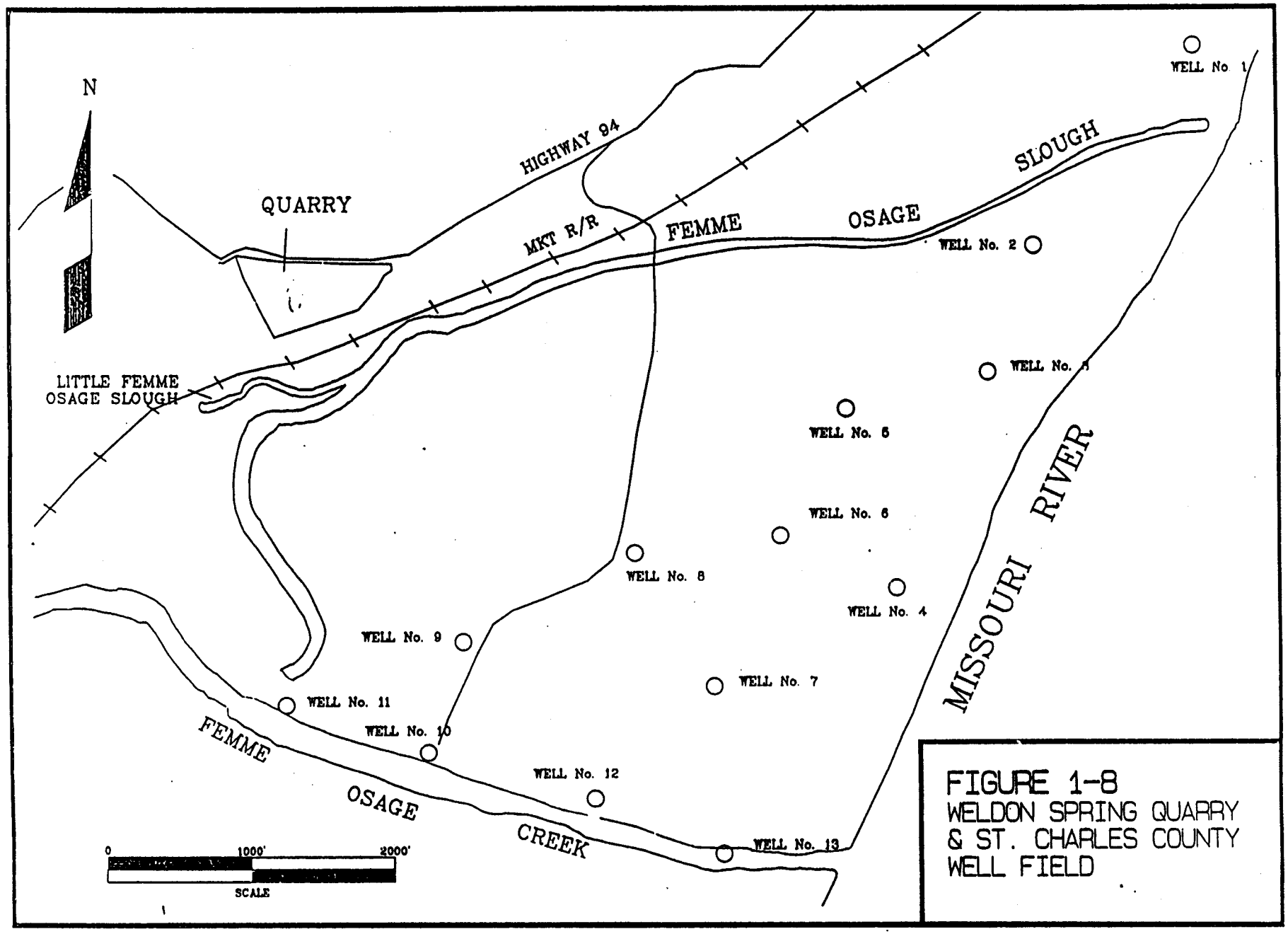


FIGURE 1-8
WELDON SPRING QUARRY
& ST. CHARLES COUNTY
WELL FIELD

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 (NLO, 1975). Southwest of the slough lies the area from which water is drawn by St. Charles County for drinking water production. There are eight operational production wells in this area, of which only 5 usually operate. Average production from the county 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 is present at the WSCP/WSRP and trends roughly northeast to southwest through the eastern portion of the plant. Groundwater in the 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 clays of low permeability (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) (Gale Research, 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 (70 and 144, respectively), the population of St. Charles County is more than 140,000 (U.S. Department of Commerce, 1980) and continues to grow.

1.4 SUMMARY OF 1987 ENVIRONMENTAL MONITORING ACTIVITIES

In 1987, 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, or as release pathways are better understood. These release pathways include: groundwater (via subsurface migration), surface water (via storm-water runoff), and air. Previous years' programs 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, or accidental spills related to the former ordnance works and the existing uranium processing facility, certain inorganic and organic constituents were added to the radiological parameters in the Environmental Monitoring Program for 1987. Inorganic constituents included substances such as nitrate, sulfate, chloride, fluoride, and total organic carbon. Organic constituents included nitroaromatic compounds such as TNT and DNT and their breakdown products.

Table 1-3 summarizes the routine quarterly environmental activities performed during the 1987 Environmental Monitoring Program. In 1987, 49 monitoring wells were sampled quarterly, compared to 26 wells sampled routinely in 1986. This includes 19 new wells installed at the chemical plant in addition to 2 previously installed wells not included in previous monitoring programs, 4 new locations at the raffinate pit area in addition to the 2 existing wells, 5 new off-site wells and 19 monitoring wells at the WSQ.

The removal and grouting of monitoring wells that were not in conformance with EPA Guidelines, plus the addition of 7 new wells in the slough area, resulted in a new groundwater monitoring scheme at the WSQ (see Section 2.1). Of the 19 groundwater locations sampled at the quarry area, 7 were from newly installed wells, and 12 from wells sampled previously. Two damaged monitoring wells (previously dry) at the WSRP were also grouted.

Surface water samples were collected from 20 locations where measurable impacts from drainage originating at the Weldon Spring Site could be detected. This includes 15 quarterly sampling locations, and storm-water runoff from 5 outfalls at

TABLE 1-3

COMPARISON OF MONITORING LOCATIONS IN 1986 AND 1987

LOCATION	YEAR 1986	YEAR 1987	COMMENTS
Groundwater			
WSCP/WSRP	6	25	Increase in well monitoring locations in 1987 is due to the increased characterization activities.
WSQ	20	19	
Off-site	0	5	
Surface Water			
WSCP/WSRP	6	0	Now covered under the monthly NPDES monitoring program.
WSQ Off-site	5	7	Two locations, the quarry sump and the county raw-water intake added in 1987.
WSCP/WSRP Off-site	15	9	Only locations near the WSS were sampled in 1987.
Radon/TLD			
WSCP/WSRP	21	10	Only locations at the perimeter fence were included in the 1987 monitoring program.
WSQ	6	6	Locations are same as in 1986.
Off-site	4	3	One background monitoring location at the Busch Wildlife Area not included in 1987 program.
Air Particulate			
WSCP/WSRP	0	5	A twice weekly monitoring program initiated in 1987 to evaluate exposure of students at Francis Howell High School on weekdays versus potential exposure of weekend trainees at the Army Reserve training facilities.
Off-site	0	3	
NPDES			
WSCP/WSRP	1	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.

the WSCP and the WSRP which were collected monthly, as required by the proposed National Pollutant Discharge Elimination System (NPDES) Permit (storm water) for the Weldon Spring Site.

A total of 19 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. Thus, while the number of locations is half the previous year's program, the total number of detectors remained the same.

Fugitive dust sampling for radiological parameters at the site perimeter was not performed as part of past years' environmental monitoring programs. Eight samplers were installed in late 1986 at 5 perimeter locations and 3 nearby sensitive receptor locations. Air monitoring was performed at these locations to establish ambient baseline data and to monitor for potential off-site releases. This program will also assess the effectiveness of engineering controls at the site during remedial action activities in the future.

2.0 ENVIRONMENTAL MONITORING RESULTS

The 1987 Environmental Monitoring Program Plan expanded the 1986 activities to accommodate the ongoing characterization efforts and the identification of additional potential migration pathways and contaminants. The discovery of nitroaromatics, nitrate and sulfate contamination in groundwater, the installation of new monitoring wells, the consolidation of sampling locations based on data analysis, and the identification of springs and seeps potentially influenced by either surface runoff and/or groundwater migration have resulted in changes to the previous year's plan. In addition, a new numbering system has been devised to easily identify samples by type and monitoring location. A six-digit alphanumeric code is used. The first two characters represent the sample type, as shown below.

AP - Air Particulate
RD - Radon Detector
SW - Surface Water
TD - Thermoluminescent Detector
NP - NPDES
MW - Monitoring Well

The second four digits indicate location as follows:

0001 - 0999 - NPDES Outfalls
1001 - 1999 - Weldon Spring Quarry Area
2001 - 2999 - Weldon Spring Chemical Plant
3001 - 3999 - Weldon Spring Raffinate Pits
4001 - 4999 - Off-site Locations

This section provides the results of the 1987 environmental monitoring program. Each subsection contains a description of the sampling, monitoring and analytical procedures followed as well as a comparison of results with applicable DOE guidelines.

Data from these measurements are presented in summary tables by sample matrix category or are described in the text. Summaries of data may include sampling location, maximum, minimum and average values, and percent of the Derived Concentration Guides (DCG). Each average value listed is the arithmetic average of the sum of individual results for each radionuclide at a given sampling location. DCG's are guidelines incorporated into DOE executive orders which follow methodologies established by the International Commission on Radiologic Protection (ICRP) based on a 100 mrem/yr standard. DCG's include concentration of radionculide in water, or air that could be continuously consumed or inhaled. Appendix D part C lists the DCG's relevant to this site.

2.1 GROUNDWATER MONITORING

As mentioned previously, the groundwater monitoring program was greatly expanded in 1987. This expansion is a direct result of the Phase I Water Quality Assessment performed in March 1987, which was designed to establish baseline surface water and groundwater quality at the WSS. A more thorough description of the Phase I Water Quality Assessment and an interpretation of the results are presented in Section 3.2 of this report. Groundwater samples were analyzed for a broad range of potential or suspected contaminants based on known processes at the WSS. Elevated nitroaromatic, inorganic anion and radionuclide concentrations were detected during this investigation. The Phase I Water Quality Assessment was conducted coincident with the first quarter Environmental Monitoring Program sampling. Based on the first quarter, the Environmental Monitoring Program Plan was updated to include quarterly monitoring of all perimeter wells at the WSCP/WSRP, all contaminated wells at the WSS and all monitoring wells at the WSQ.

Monitoring wells installed prior to 1987 were numbered using several different numbering systems. Tables 2-1 and 2-2 detail

TABLE 2-1
WSCP/WSRP MONITORING WELL INFORMATION

WELL NUMBER	OLD WELL NUMBER	TOP-OF-CASING ELEVATION FT MSL	TOTAL DEPTH FT.	SCREENED INTERVAL	SCREEN LENGTH
MW-2001	GMW-1	613.45	61.0	50-60	10
MW-2002	GMW-2	625.65	61.0	50-60	10
MW-2003	GMW-3	638.74	61.0	50-60	10
MW-2004	GMW-4	644.73	78.5	67-77	10
MW-2005	GMW-5	637.45	78.5	67-77	10
MW-2006	GMW-6	636.00	68.5	57-67	10
MW-2007	GMW-7	653.70	96.0	85-95	10
MW-2008	GMW-8	624.73	58.5	47-57	10
MW-2009	GMW-9	638.71	61.0	50-60	10
MW-2010	GMW-10	644.75	61.0	50-60	10
MW-2011	GMW-11	655.37	76.0	65-75	10
MW-2012	GMW-12	636.70	61.0	50-60	10
MW-2013	GMW-13	647.12	70.9	60-70	10
MW-2014	GMW-14	649.33	61.1	50-60	10
MW-2015	GMW-15	659.90	81.0	70-80	10
MW-2016	B-3	636.89	151.8	140-147	7
MW-2017	GMW-17	659.84	66.1	55-65	10
MW-2018	GMW-18	663.44	66.1	55-65	10
MW-2020	B-4	656.88	121.4	38-122	84
MW-3007	B-17	647.72	99.9	42-102	60
MW-3008	B-19A	646.43	104.0	41-103	62
MW-3009	B-21	646.43	101.5	47-101	54
MW-3010	B-23	666.94	92.6	55-93	38
MW-3013	W-2	642.10	222	19-22	3
MW-3018	B-2	633.58	29.2	25-28	3
MW-4001	GMW-16	622.74	41.8	31-41	10
MW-4002	B-9	635.32	87.4	43-86	43
MW-4003	B-11	671.67	108.1	53-108	55
MW-4006	B-16	622.96	29.8	23-28	5
MW-4019	GMW-19	647.17	61.0	50-60	10

TABLE 2-2
WELDON SPRING QUARRY MONITORING WELL INFORMATION

WELL NUMBER	OLD WELL NUMBER	TOP-OF-CASING ELEVATION FT. MSL	TOTAL DEPTH (FT)	SCREENED INTERVAL	SCREEN LENGTH (FT)
MW-1001	TW-S	548.29	121.5	110-120	10
MW-1002	TW-7	558.12	113.9	102-112	10
MW-1003	TW-8	543.82	111.5	100-110	10
MW-1004	TW-9	538.21	94.3	84- 94	10
MW-1005	TW-10	540.96	94.0	83- 93	10
MW-1006	OB-6A	456.37	11.9	5- 10	5
MW-1007	OB-6B	456.86	14.5	9- 12	3
MW-1008	OB-10A	456.09	11.8	6- 9	3
MW-1009	OB-10B	456.99	17.5	9- 14	5
MW-1010	OBS-16A	457.42	27.5	18- 23	5
MW-1011	OBS-16B	457.97	17.5	10- 15	5
MW-1012	TW-N	532.25	92.4	79- 89	10
MW-1013	NEW	460.39	37	27- 37	10
MW-1014	NEW	460.30	23	18- 23	5
MW-1015	NEW	462.17	33	23- 33	10
MW-1016	NEW	461.55	17	12- 17	5
MW-1017	NEW	460.16	57	37- 57	20
MW-1018	NEW	462.10	51	31- 51	20
MW-1019	NEW	464.11	70	50- 70	20

monitoring well numbers under the current numbering system and the corresponding old monitoring well numbers for the WSCP/WSRP and WSQ areas, respectively. These tables also provide additional monitoring well information.

Due to the physical separation and differing geologic settings, the WSCP/WSRP and the WSQ will be discussed separately in Sections 2.1.1 and 2.1.2, respectively. Groundwater samples were collected from 19 locations at the WSCP, 6 locations at WSRP, 5 locations off-site and 19 locations at the WSQ (Figure 2-1).

2.1.1 Groundwater Monitoring at WSCP/WSRP

Groundwater samples were collected quarterly from 25 locations at the WSCP/WSRP areas and 5 off-site locations. These locations are presented in Figure 2-1. Samples were analyzed for radionuclides, nitroaromatics and inorganic anions. Analytical parameters for each group of contaminants are discussed in further detail in the following sections.

Radiological Results

Groundwater samples were analyzed for natural uranium, Radium-226, Thorium-230 and Thorium-232. No elevated levels of Radium-226 or Thorium-230 and -232 were observed. Elevated natural uranium activities were observed in only two monitoring wells, MW-2020 and MW-3009. Monitoring Well 3009 is located at the southwest corner of Raffinate Pit No. 4 and averaged 31 pCi/L, which is 6% of the Derived Concentration Guides (DCG). The probable source of this uranium activity is Raffinate Pit No. 3 and/or 4. This well also contained elevated nitrate concentrations during the first and third quarters. No elevated sulfate levels were observed in this well. The other well (MW-2020), also contained elevated uranium activities

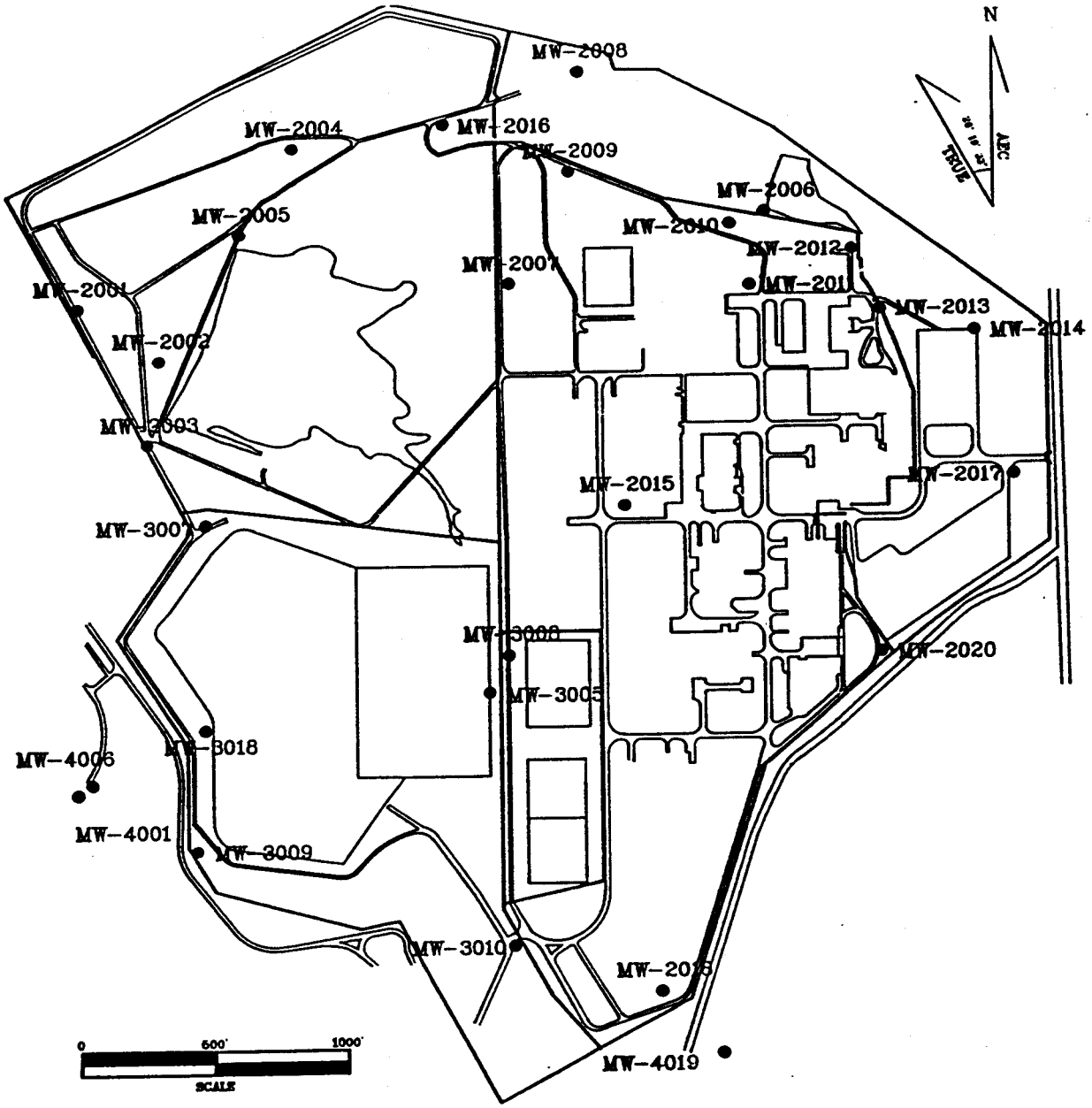


FIGURE 2-1

MONITORING WELLS SAMPLED AT THE WSCP/WSRP DURING 1987

averaging 20 pCi/L, which is 4% of the DCG. The contamination source cannot be determined from the existing data. However, the raffinate pits and/or the losing segment of the southeast easement are likely sources.

Nitroaromatic Results

Nitroaromatic compounds were detected in 28 monitoring wells during the Phase I Water Quality Assessment. Most wells contain trace levels (ug/L) of nitroaromatics with three monitoring wells (MW's-2013, -2012, -2011), located in the northeast portion of the WSCP, containing the highest concentrations. Average nitroaromatic concentrations are presented in Table 2-3. General low-level nitroaromatic contamination continued throughout the remaining quarters of 1987, with higher concentrations present in the same three monitoring wells. The exception to this is MW-3018, completed in the overburden just west of Raffinate Pit No. 4, which contained water only during the last three quarters of 1987. Samples from this well contained the highest nitroaromatic concentrations detected on-site. This monitoring well is located at the fence between the WSCP/WSRP and the Weldon Spring Training Area, and the contamination source is difficult to determine based on the available data.

Inorganic Anions Results

Groundwater samples were analyzed for four inorganic anions - nitrate, sulfate, chloride and fluoride. Groundwater underlying the raffinate pits contains elevated nitrate and sulfate concentrations. Elevated concentrations, for the purpose of this report, are those in excess of the U.S. EPA Drinking Water Standards of 10 mg/L (as N) for nitrate and 250 mg/L for sulfate. The apparent sources of this contamination are Raffinate Pit Nos. 3 and 4, respectively. The data from which these conclusions were drawn is presented in the Phase I Water

TABLE 2-3

Average Nitroaromatic* Concentrations in Groundwater at the

WSCP/WSRP for 1987 Based on Quarterly Sampling

Well No.	No. of Samples	2,4,6-TNT (ug/L)	2,4-DNT (ug/L)	2,6-DNT (ug/L)	Nitro benzene (ug/L)	1,3,5-Trinitro benzene (ug/L)	1,3-Dinitro benzene (ug/L)
MW-2001	4	0.5	<0.7	<1.05	<0.7	<0.04	<0.4
MW-2002	1	0.6	<0.2	<0.6	<0.6	<0.03	<0.4
MW-2003	4	<0.5	<0.4	<0.7	<0.6	<0.03	<0.4
MW-2004	4	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-2005	4	<0.5	<0.3	<0.7	<0.6	<0.05	<0.4
MW-2006	4	<1.9	<1.2	<18.9	<3.8	4.6	<0.4
MW-2007	3	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-2008	4	<0.5	<0.2	<0.7	<0.9	<0.03	<0.5
MW-2009	3	<0.5	0.3	0.7	<0.6	<0.03	<0.4
MW-2010	4	<0.8	<0.2	<0.7	<0.6	<0.04	<0.4
MW-2011	4	<1.9	<0.7	<20.3	<0.6	<0.04	<0.8
MW-2012	4	1.2	3.3	<0.6	<0.6	0.9	<1.4
MW-2013	4	41.5	247	175	<2.8	8.0	<2.2
MW-2014	4	<1.1	<0.5	<0.9	<1.4	0.8	<0.4
MW-2015	4	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-2016	4	<0.5	<0.2	<0.7	<0.6	<0.03	<0.4
MW-2017	4	<0.5	<0.3	<0.6	<0.6	<0.03	<0.4
MW-2018	4	<0.5	<0.2	<0.5	<0.6	<0.03	<0.4
MW-2020	4	<0.5	<0.2	<0.6	<0.9	<0.03	<0.4
MW-3001	1	18.0	2.2	2.9	4.6	2.2	<0.4
MW-3006	1	1.5	0.58	2.9	2.0	0.63	<0.4
MW-3007	4	<0.5	<1.1	<2.1	<0.6	<0.03	<0.4
MW-3008	4	<0.5	<0.4	<0.6	<0.6	<0.03	<0.4
MW-3009	4	<0.5	<0.4	<0.6	<0.6	<0.03	<0.4
MW-3010	4	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-3013	4	<0.5	<0.3	<0.6	<0.6	<0.03	<0.4
MW-3018	3	<8.6	<42.7	765.3	<20.6	<2.2	<0.8
MW-4001	4	<14.2	2.1	<2.5	<1.6	11.6	<0.98
MW-4002	3	<1.43	<0.38	<0.95	<0.60	<0.03	<0.40
MW-4006	4	<0.93	<0.42	<2.3	<1.43	1.56	<0.40
MW-4019	4	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4

* Nitroaromatics Analysis Following USATHAMA Method (HPLC)

Quality Assessment (see Section 3.2).

The general nitrate and sulfate contamination pattern remains consistent with the findings in the Phase I Water Quality Assessment. Elevated nitrate and sulfate levels continued in monitoring wells around Raffinate Pits Nos. 3 and 4. Elevated sulfate levels were also observed in monitoring wells MW-2017 and -2020 during 1987. The contamination source for these two wells is not known at this time. Elevated chloride levels were observed in monitoring well MW-2006. This monitoring well is located near Frog Pond, which receives drainage from the Missouri State Highway Department Maintenance Facility salt pile. The elevated chloride concentration in this well suggests that Frog Pond or its drainage may be losing water to the subsurface. Average nitrate, sulfate, chloride and fluoride values are presented in Table 2-4.

Hydrogeologic and soil investigations scheduled for 1988 are designed to determine the source, extent and magnitude of this contamination. Dye studies performed in 1988 by the Missouri Department of Natural Resources will attempt to define the surface/subsurface connections at the WSCP/WSRP.

2.1.2 Groundwater Monitoring at the WSQ

During the first two quarters of 1987, groundwater samples were collected from twelve locations at the WSQ: monitoring wells MW-1001 to MW-1012. In June, 1987, seven additional monitoring wells, MW-1013 to MW-1019, were installed near the Femme Osage Slough to replace wells that did not meet current EPA guidelines for monitoring wells as detailed in the "RCRA Groundwater Monitoring Technical Enforcement Guidance Document" (U.S. EPA, 1986). All monitoring well locations at the WSQ are shown in Figure 2-2. Quarterly groundwater samples were analyzed for radionuclides, nitroaromatics and inorganic anions. Analytical parameters for each group of contaminants will be further

Table 2-4

Average Inorganic Anion Concentrations
at the WSCP/WSRP for 1987 Based on Quarterly Sampling

	Concentration Mg/L			
	Nitrate (as N)	Sulfate	Chloride	Fluoride
Drinking Water Standard mg/L	10	250	250	2
Well Number				
MW-2001	5.5	9.2	4.8	0.2
MW-2002	201.5	49.5	5.8	3.7
MW-2003	582.5	132.7	16.0	4.7
MW-2004	0.7	3.4	2.1	0.2
MW-2005	165.1	45.0	2.3	0.5
MW-2006	7.3	41.6	220.5	0.4
MW-2007	0.0	12.6	0.7	0.3
MW-2008	155.7	256.8	223.4	4.5
MW-2009	1.4	55.1	13.3	0.3
MW-2010	0.8	43.0	66.5	0.3
MW-2011	4.8	10.2	2.8	0.3
MW-2012	0.3	65.4	73.5	0.4
MW-2013	0.7	34.1	11.4	0.5
MW-2014	2.1	35.5	20.6	0.6
MW-2015	1.8	399.1	1.7	0.4
MW-2016	188.1	56.3	15.3	4.4
MW-2017	0.9	571.0	451.5	0.9
MW-2018	130.1	12.2	5.4	0.4
MW-2020	0.3	255.3	14.7	0.6
MW-3007	960.2	345.4	32.7	5.0
MW-3008	1058.6	49.7	25.7	3.3
MW-3009	139.7	45.9	1.7	0.5
MW-3010	75.3	14.3	2.7	0.4
MW-3013	119.5	850.5	2.3	1.2
MW-3018	102.0	92.2	6.5	0.1
MW-4001	149.2	87.7	2.1	0.5
MW-4002	1.6	14.6	1.2	0.2
MW-4003	0.2	9.0	1.9	0.1
MW-4006	113.8	56.9	1.2	0.4
MW-4019	0.1	9.3	0.9	0.3

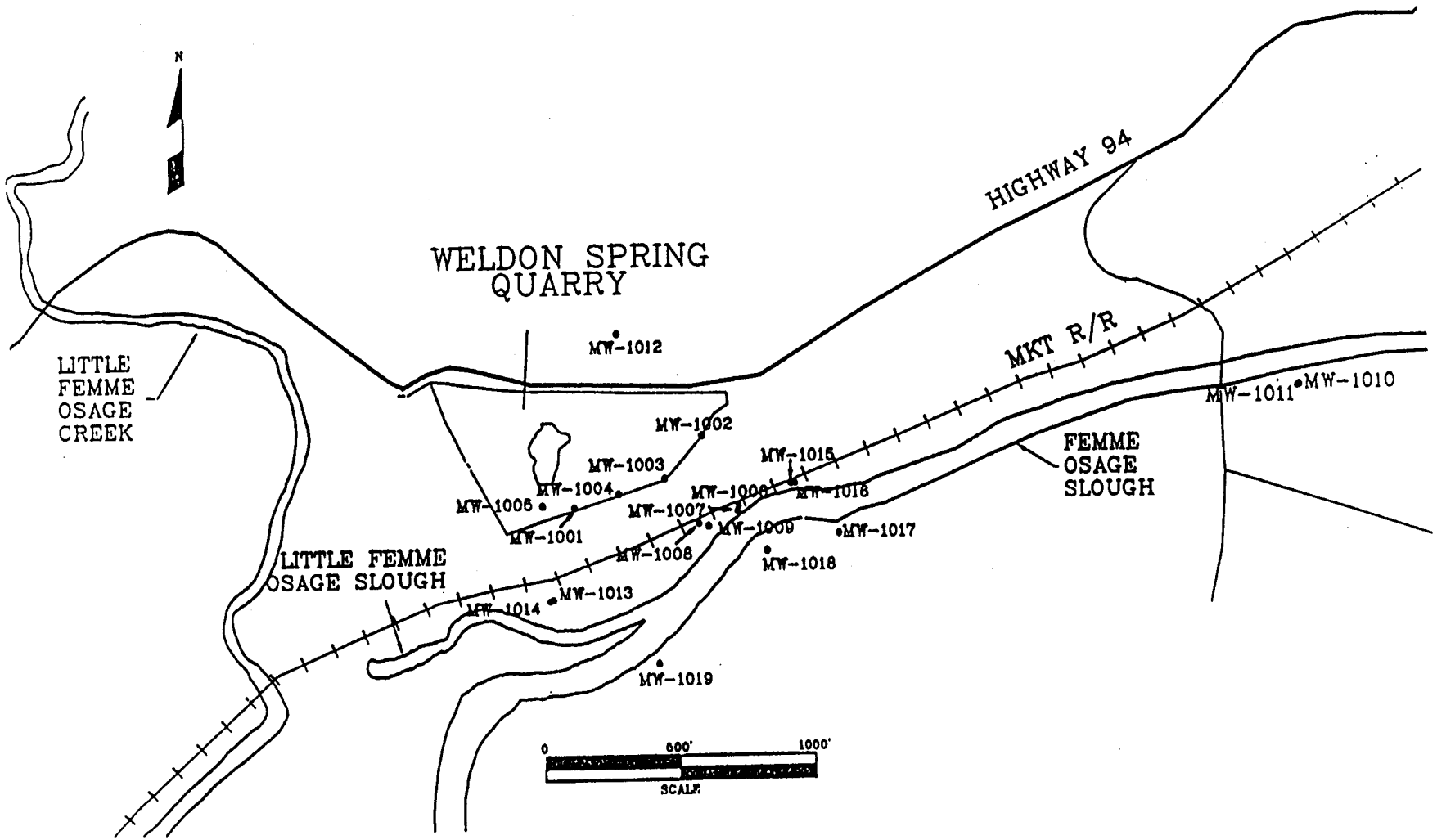


FIGURE 2-2

GROUNDWATER MONITORING LOCATIONS AT THE WSQ FOR 1987

discussed in the following sections.

Groundwater at the WSQ originates as precipitation falling within the Quarry and percolating through the wastes. Contaminant migration varies with precipitation. Increased precipitation will increase the hydraulic head and dissolve additional contaminants, thereby causing seasonal fluctuations in contaminant concentrations.

Radiological Results

As stated above, twelve monitoring wells were sampled during each quarter of 1987. Radiological analyses included total natural uranium, Radium-226, and Thorium-230 and -232. These analyses indicated elevated uranium activities in five of these twelve wells. Monitoring well MW-1012 contained 12 pCi/L Thorium-230 during the Phase I Water Quality Assessment but background levels at subsequent samplings. No elevated Radium-226 activities were observed in any of the original twelve monitoring wells.

Seven additional monitoring wells were installed during June 1987 to increase monitoring capabilities in the WSQ area. These wells were added to the Environmental Monitoring Program Plan and sampled in the third and fourth quarters of 1987. Four of these monitoring wells were installed north of the Femme Osage Slough to define groundwater contamination. Three monitoring wells were installed south of the slough to monitor potential contaminant migration beyond the slough and toward the St. Charles County Well Field. No elevated radium or thorium levels were observed in any new monitoring wells.

Elevated uranium levels were observed in all four new monitoring wells north of the slough. These monitoring wells were installed in two well clusters with one well monitoring the alluvium and the other completed in the upper portions of the

Decorah Formation. These results indicate contaminated groundwater migrating through the horizontally-fractured Decorah Formation into the fine-grained alluvium north of the Femme Osage Slough. In the past, contamination was believed to move primarily through the solution-enlarged vertically fractured Kimmswick Formation which overlies the Decorah Formation.

The monitoring wells south of the slough, also sampled during the third and fourth quarters, did not contain elevated radionuclide levels, indicating that radiological contamination has not migrated beyond the Femme Osage Slough.

Average uranium levels for all monitoring wells at the WSQ are presented in Table 2-5. Average activities ranged from 0 pCi/L (0% of the DCG) to 3050 pCi/L (555% of the DCG).

Nitroaromatic Results

Nitroaromatic compounds were detected in five of the twelve wells sampled during the first two quarters of 1987. Monitoring wells MW-1002, -1004, -1005, -1006 and -1012 contained low nitroaromatic concentrations, with monitoring well MW-1006 containing the highest concentrations. Nitroaromatics were also observed in monitoring wells MW-1013, -1014 and -1015 during the third and fourth quarters.

The source of these nitroaromatics is the wastes disposed of in the WSQ by the DA during production and as a result of decontamination efforts at the WSOW. Nitroaromatics were observed during the 1986 chemical characterization of the WSQ and in surface soil samples collected in 1987 from the stained aggregate present in the northeast end of the WSQ. This related study is described, and a summary of the results presented in Section 3.1 of this report. Table 2-6 presents average nitroaromatic concentrations for 1987 in the groundwater near the WSQ.

Table 2-5

Average Uranium Concentrations for Groundwater at the WSQ for 1987

Well Number	Average Uranium (pCi/L)*	Percentage of DCG **
MW-1001	11.1	2
MW-1002	2.2	0
MW-1003	0.6	0
MW-1004	3050.0	555
MW-1005	610.0	111
MW-1006	1235.0	225
MW-1007	222.5	40
MW-1008	522.5	95
MW-1009	7.1	1
MW-1010+	0.6	0
MW-1011+	0.0	0
MW-1012	4.4	1
MW-1013	650.0	118
MW-1014	600.0	109
MW-1015	292.5	53
MW-1016	21.0	4
MW-1017+	0.3	0
MW-1018+	0.0	0
MW-1019+	0.0	0

\+ Monitoring wells located south of the Femme Osage Slough
* To convert to Bq/L multiply by $3.7X10^{-2}$
** DCG is 550 pCi/L (20.4 Bq/L) for natural uranium

Table 2-6

Average Nitroaromatic Concentrations in Groundwater at the WSQ for 1987 Based on Quarterly Sampling

Well Number	2,4,6-TNT (ug/L)	2,4 DNT (ug/L)	2,6 DNT (ug/L)	Nitro benzene (ug/L)	1,3,5-Trinitro benzene (ug/L)	1,3-Dinitro benzene (ug/L)
MW-1001*	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-1002	<3.7	<0.3	<0.7	<1.0	1.3	<0.4
MW-1003*	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-1004	<2.9	<0.3	<0.8	<0.6	0.4	<0.4
MW-1005	<0.4	<0.4	<0.9	<0.9	<0.2	<0.4
MW-1006	<14.8	<0.3	<3.4	<5.1	<8.1	<0.4
MW-1007	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-1008	<0.5	<1.7	<0.6	<0.6	<0.3	<0.4
MW-1009	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-1010+	<0.5	<0.2	<0.7	<0.6	<0.03	<0.4
MW-1011+	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-1012	<0.5	<0.2	<1.3	<0.6	<0.03	<0.4
MW-1013**	<0.5	<0.3	<0.6	<0.7	<0.2	<0.4
MW-1014**	<0.5	<0.2	<0.6	<0.9	<0.1	<0.4
MW-1015**	<9.2	<0.2	<0.6	<11.5	<3.4	<2.0
MW-1016**	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-1017+**	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-1018+**	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-1019+**	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4

\+ Monitoring wells located south of the Femme Osage Slough
* Sampled in second quarter only
** Sampled in third and fourth quarters only

Nitroaromatics were not detected south of the Femme Osage Slough, indicating that nitroaromatic contamination has not migrated beyond the hydrogeologic boundary created by the slough. This is consistent with the uranium contamination pattern in this area.

Inorganic Anion Results

Elevated inorganic anion concentrations were detected during the Phase I Water Quality Assessment at the WSQ and during routine monitoring in subsequent quarters. Sulfate and nitrate were the primary inorganic contaminants present above U.S. EPA Primary or Secondary Drinking Water Standards. Average inorganic anion concentrations measured in the groundwater near the WSQ are presented in Table 2-7.

Sulfate concentrations varied throughout the year, but the general contamination pattern remained constant. The highest sulfate concentrations were observed during the fourth quarter of 1987. This observation coincides with the increased precipitation during December, preceded by dry conditions, indicating that contaminant migration may increase during wet conditions.

The sulfate concentration increase was observed primarily in the four new monitoring wells installed north of the Femme Osage Slough. Data were available from these wells only during the last two quarters of 1987.

Elevated nitrate concentrations were observed during the first and second quarters of 1987 in monitoring wells MW-1004 and MW-1005. This may indicate normal seasonal fluctuations and/or change in groundwater migration due to precipitation response.

Elevated chloride concentrations were observed in monitoring wells MW-1013, -1014, -1015, and -1016 during the fourth quarter

Table 2-7

Average Inorganic Anion Concentrations
at the WSQ for 1987 Based on Quarterly Sampling

	Concentration (mg/L)			
	Nitrate (as N)	Sulfate	Chloride	Fluoride
Drinking Water Standard mg/L	10	250	250	2
Well Number				
MW-1001	0.2	307.8	17.9	0.7
MW-1002	18.2	63.5	7.3	0.4
MW-1003	0.2	81.2	10.8	0.4
MW-1004	134.7	157.5	12.4	0.8
MW-1005	150.8	221.0	39.0	0.6
MW-1006	3.6	235.0	41.3	0.5
MW-1007	1.3	141.3	39.9	0.8
MW-1008	0.2	153.5	34.6	0.7
MW-1009	0.1	116.4	19.1	0.6
MW-1010	0.5	36.7	15.3	0.6
MW-1011	0.0	79.5	8.0	0.2
MW-1012	0.4	482.3	124.6	0.7
MW-1013	2.1	361.0	132.1	0.4
MW-1014	191.2	485.0	142.6	0.5
MW-1015	0.1	464.8	102.6	0.4
MW-1016	0.0	40.5	7.6	0.4
MW-1017	0.0	234.1	140.9	0.5
MW-1018	0.0	13.0	11.2	0.4
MW-1019	0.1	413.0	5.0	0.4

of 1987. The source of chloride contamination is not known. No elevated fluoride concentrations were observed in WSQ groundwater during 1987.

2.2 SURFACE WATER MONITORING RESULTS

During 1987, surface water samples were collected quarterly from locations on and around the WSS. To limit the sampling locations to those where measurable effects of site influence could be observed the size of the area to be monitored was decreased substantially beginning in 1987.

Surface water samples were collected from both on-site and off-site locations under two distinct programs, each having different periods of sampling. First, samples were collected on-site and at the site boundary (point of off-site discharge) to monitor surface storm water discharge of contaminants in accordance with the NPDES guidelines. Secondly, off-site locations were sampled on a quarterly basis to monitor down-gradient surface water receptors for discharge from the site.

2.2.1 Monthly NPDES Sampling Results

NPDES samples were collected on a monthly basis following the first appropriate precipitation event, at the five locations shown in Figure 2-3. NPDES points NP-001 and NP-005 deserve special mention. NP-005 represents water leaving the site from overland flow over the southeast portion of the site. NP-001 represents precipitation that is intercepted by the process and sanitary sewer system at the WSCP. Since some of the roofs of buildings are in disrepair, some water enters various building sumps and drains which eventually discharge from NP-001.

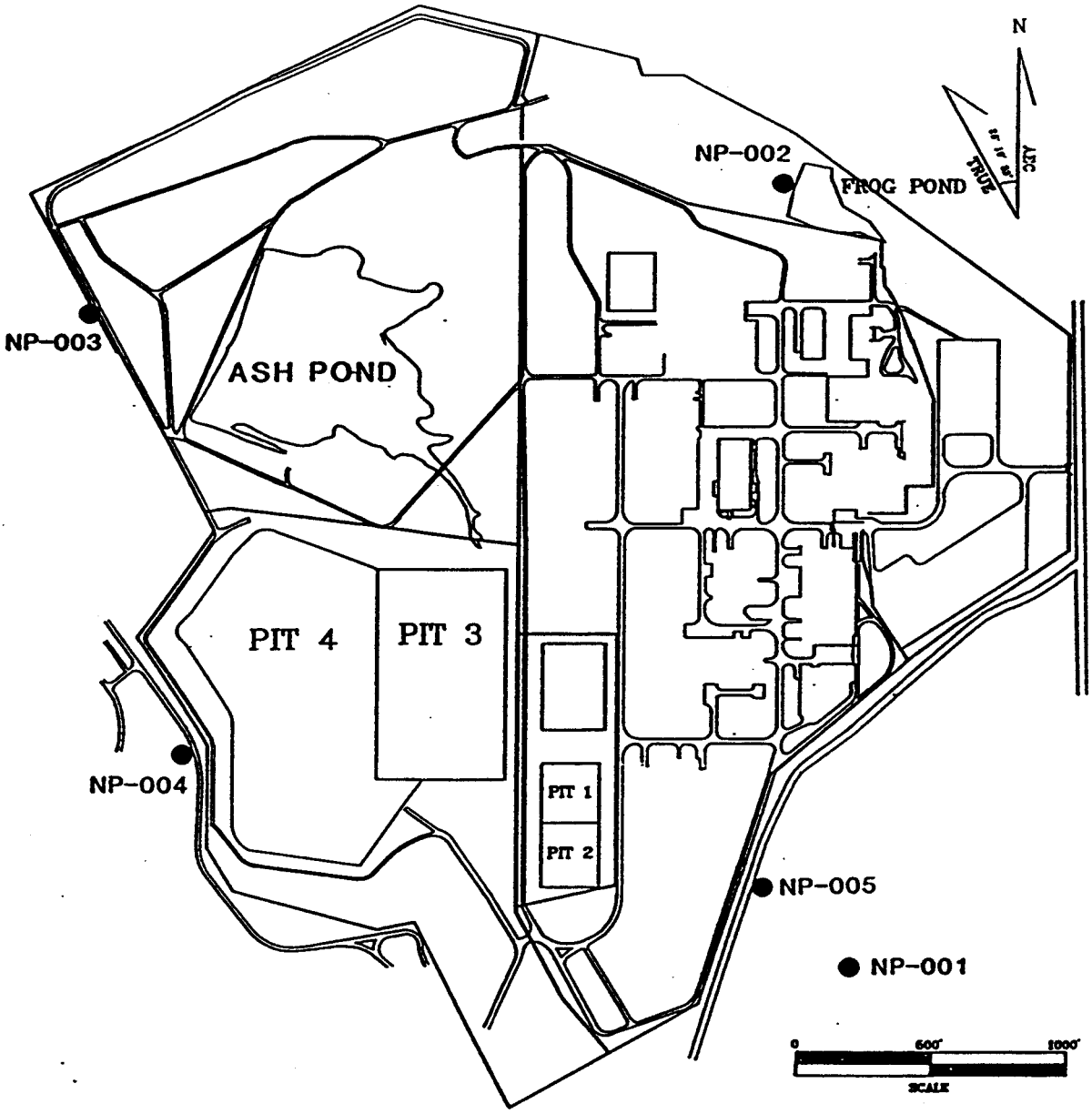


FIGURE 2-3

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

Uranium levels ranged from 2.7 pCi/L to 23.0 pCi/L (4% DCG) at the minimum concentration discharge point (NP-004), and 250 pCi/L (45% DCG) to 3500 pCi/L (636% DCG) at the maximum range discharge point (NP-003). This highest activity level was measured at the off-site discharge point downstream of Ash Pond. The majority of the discharge flows to Lakes 34 (subsurface pathway) and 35 from Ash Pond and Lake 36 from Frog Pond (see Figure 1-6).

The results of the NPDES sampling are presented in Table 2-8. The correspondence between the average uranium values and the gross alpha results indicates that virtually all of the off-site radionuclide release is in the form of soluble uranium. Other radionuclides measured (Ra-226, Th-230, Th-232) were in the range of their respective background levels for this area.

While the flow rate averages in Table 2-8 indicate substantial 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 significantly 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.

2.2.2 Quarterly Surface Water Sampling Results

Fifteen off-site locations were sampled on a quarterly basis to monitor the off-site migration and existing source conditions, both at the WSCP/WSRP and the WSQ. Several locations were found

TABLE 2-8

ANNUAL AVERAGE RESULTS OF NPDES SAMPLING SURROUNDING WSCP/MSRP **

	pH (s.i.)	FLOW (gpm)	TOTAL SETTLEABLE SOLIDS (mg/L)	NUMBER OF SAMPLES +	TOTAL SUSPENDED SOLIDS (mg/L)	NATURAL URANIUM +/- ERROR* (pCi/L)	GROSS ALPHA +/- ERROR* (pCi/L)	NITRATE (AS N) (mg/L)	2,4-DNT (ug/L)	2,6-DNT (ug/L)	NITROBENZENE (ug/L)
NP-001	7.7	40	<0.1	5	28	680 ± 45	500 ± 30	5.7	<0.2	<0.7	<0.6
NP-002	7.9	50	<0.1	7	18	210 ± 10	110 ± 10	2.4	<0.2	<0.6	<0.6
NP-003	7.5	200	<0.1	4	12	2240 ± 145	2030 ± 130	28	<0.9	<0.6	<0.6
NP-004	7.4	25	<0.1	4	3	9.5 ± 1.0	36 ± 10	1.1	<0.2	<0.6	<0.6
NP-005	7.7	40	<0.1	4	30	780 ± 75	560 ± 35	146	<0.3	<0.7	<0.6

* First value indicates average, second value is the 95% confidence level of the average.

** To convert to Bq/L, multiply by 3.7×10^{-2}

\+ Samples collected monthly following precipitation sufficient to cause runoff and allow discharge sample collection.

Table 2-9

ESTIMATED ANNUAL RELEASE OF NATURAL URANIUM FROM

NPDES DISCHARGE POINTS IN 1987

DISCHARGE POINT	DRAINAGE AREAS (ACRES)	PERCENT OF PRECIPITATION AS RUNOFF	AVERAGE CONCENTRATION (pCi/L)*	UPPER BOUND TOTAL VOLUME (Mgal/yr)	UPPER BOUND TOTAL URANIUM (Ci/yr)	UPPER BOUND TOTAL URANIUM (kg/yr)
NP-001 & NP-005	20.2	60	730	11.8	0.033	49
NP-002	39.1	65	210	24.8	0.020	30
NP-003	60.1	20	2240	11.8	0.102	151
NP-004	5.6	50	9.5	2.7	0.0001	0.2
				TOTAL	0.153	230.2

* To convert to Bq/L, multiply by 3.7×10^{-2}

to be dry on more than one of the quarterly sampling occasions. However, the data obtained indicate uranium levels below 5 pCi/L (accepted background concentration for natural uranium) at six of the fifteen locations sampled. Other samples showed average uranium concentrations ranging from 15 to 170 pCi/L. These results represent concentrations from surface water bodies and flow corridors of very different natures. The surface water type and the historical aspects of each source must be considered when making determinations of potential impact.

Quarterly Surface Water Sampling at WSCP/WSRP Area

The locations of the off-site surface water sampling points near the WSCP/WSRP are shown in Figure 2-4. Eight of the locations monitor surface water bodies which receive groundwater or surface water discharged from the WSCP area. Five (5) of these locations are within or upstream of lakes on the Busch Memorial Wildlife Area property. These sampling points were selected to monitor the waters for contaminants which may pose risks to public health and the environment, and to help determine whether the lakes receive the contamination by overland flow or through groundwater discharge. Data from the quarterly sampling at the WSS are presented in Table 2-10.

Samples from the upstream tributary of Busch Lake 36 (immediately downstream of Frog Pond) showed the highest average concentration of natural uranium at 170 pCi/L (30% DCG) of any of the off-site sampling locations. However, dilutional effects within the lake apparently decrease the average concentrations so that natural uranium was measured at 25 pCi/L (4% of DCG) at the outfall end of the lake. Equally close to the site boundary, yet not directly downstream of any site outfalls, Busch Lake 10 delivered samples which measured below background for all four quarters. Further away, yet downstream of both Frog and Ash ponds, Busch Lake 35 was sampled at its upstream end, and was shown to contain an average concentration of approximately 15 pCi/L (2.7% DCG).

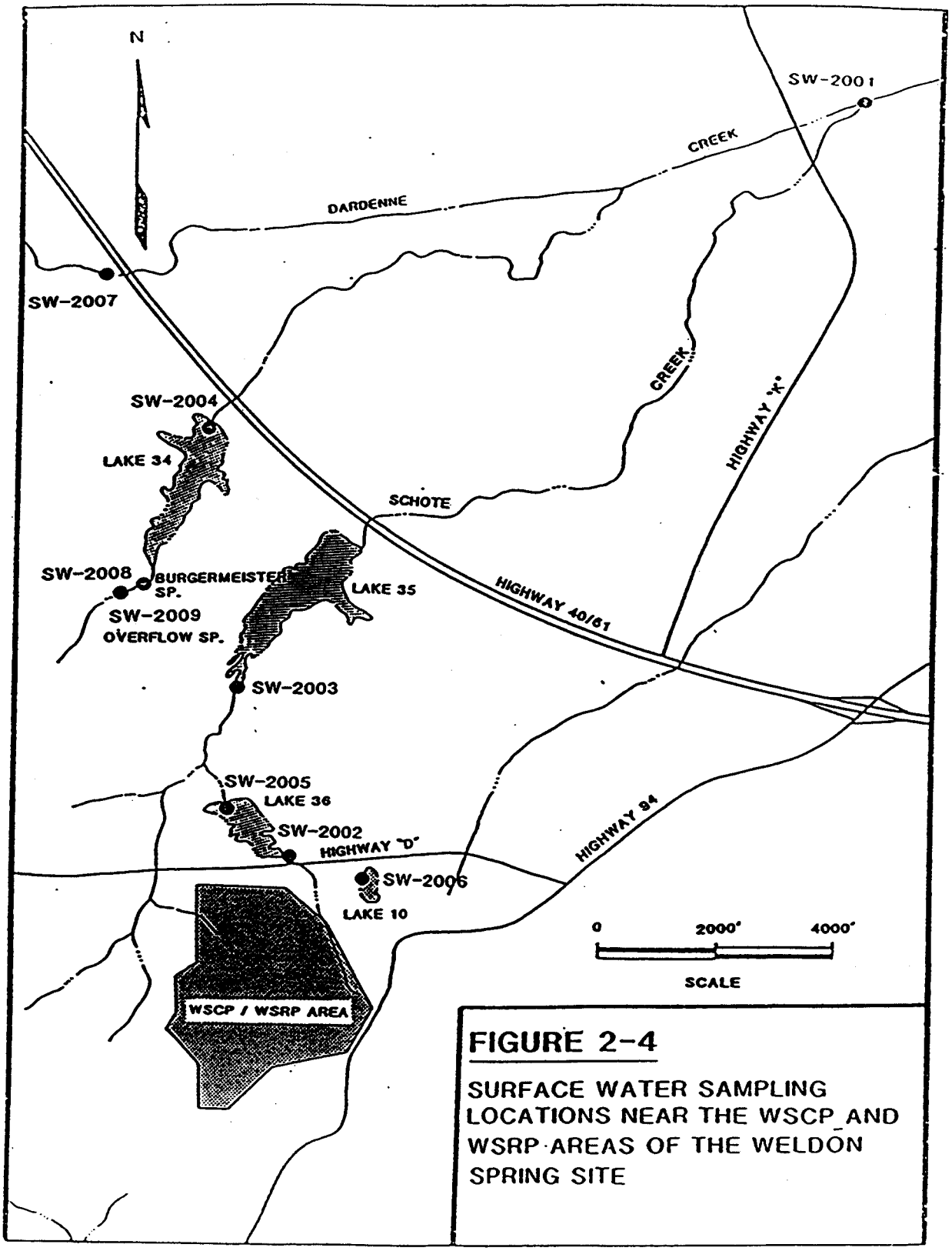


FIGURE 2-4

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

Table 2-10

ANNUAL AVERAGE RESULTS FROM SURFACE WATER SAMPLES COLLECTED FROM THE WSS AREAS

	GROSS ALPHA (pCi/L)**	GROSS BETA (pCi/L)**	NATURAL URANIUM (pCi/L)**	Ra-226 (pCi/L)**	Th-230 (pCi/L)**	Th-232 (pCi/L)**	NITRATE (AS N) mg/L	SULFATE mg/L
WSQ AREA								
SW-1001	<8	12	3	<2	<1	<1	1.4	55
SW-1002	<4	<8	<1	<1	<1	<1	1.0	48
SW-1003	25	24	28	<1	<1	<1	<0.2	47
SW-1004	26	32	34	<1	<1	<1	<0.1	48
SW-1005	16	16	29	<1	<1	<1	<0.2	51
SW-1006+	<4	<10	<1	<1	<1	<1	<0.1	48
WSCP/WSRP AREA								
SW-2001	<3	<8	3	<1	<1	<1	*	52
SW-2002	70	42	170	<1	<1	<1	0.8	63
SW-2003	12	13	15	<1	<1	<1	1.1	18
SW-2004	19	18	25	<1	<1	<1	4.9	22
SW-2005	21	24	25	<1	<1	<1	0.3	36
SW-2006	<3	<7	2	<1	<1	<1	0.5	9
SW-2007	4	9	<1	<1	<1	<1	*	50
SW-2008	57	39	92	<1	<1	<1	111	53

* Inconsistent data from these locations make calculation of annual average values suspect.

** To convert to Bq/L, multiply by 3.7×10^{-2}

\+ St. Charles County Well Field Samples

Busch Lake 34 is still further away from the site boundary and is not directly downstream of surface drainages from the site. Samples collected at the overflow end of the lake averaged concentrations of approximately 25 pCi/L (4% DCG).

These elevated levels in Lake 34 are probably due, in part, to the inflow of contaminated water discharged upstream of the lake at Burgermeister Spring. Burgermeister Spring flows at an average rate of approximately twenty to thirty gallons per minute (gpm) with high flows exceeding 100 gpm. In 1987, waters from Burgermeister Spring averaged uranium concentrations of 92 pCi/L (15% DCG), with the highest level measured at 160 pCi/L (26% DCG) in the first quarter of the year.

Finally, two sampling locations were set along Dardenne Creek to monitor whether concentrations of contaminants were detectable within distant flow corridors, both up- and down-stream of the confluence of Dardenne Creek and Schote Creek.

Analyses of samples from these two locations revealed average uranium concentrations ranging from 1 pCi/L to 3 pCi/L (<1% DCG). Samples from the downstream location revealed slightly higher levels of natural uranium than the upstream samples. However, the average quarterly concentrations were within the accepted background range for uranium of 3 pCi/L (0.5% DCG). And the annual averages for Radium-226, Thorium-230, and Thorium-232 were well below the background levels of 3 pCi/L for surface water in the WSCP/WSRP area.

Surface Water Sampling at the WSQ Area

Six surface water locations in and around the WSQ were sampled quarterly. Collected and analyzed on a quarterly basis, these samples indicate the concentrations of contaminants in the surface water bodies nearby to the west and south of the WSQ. The sampling locations are shown on Figure 2-5.

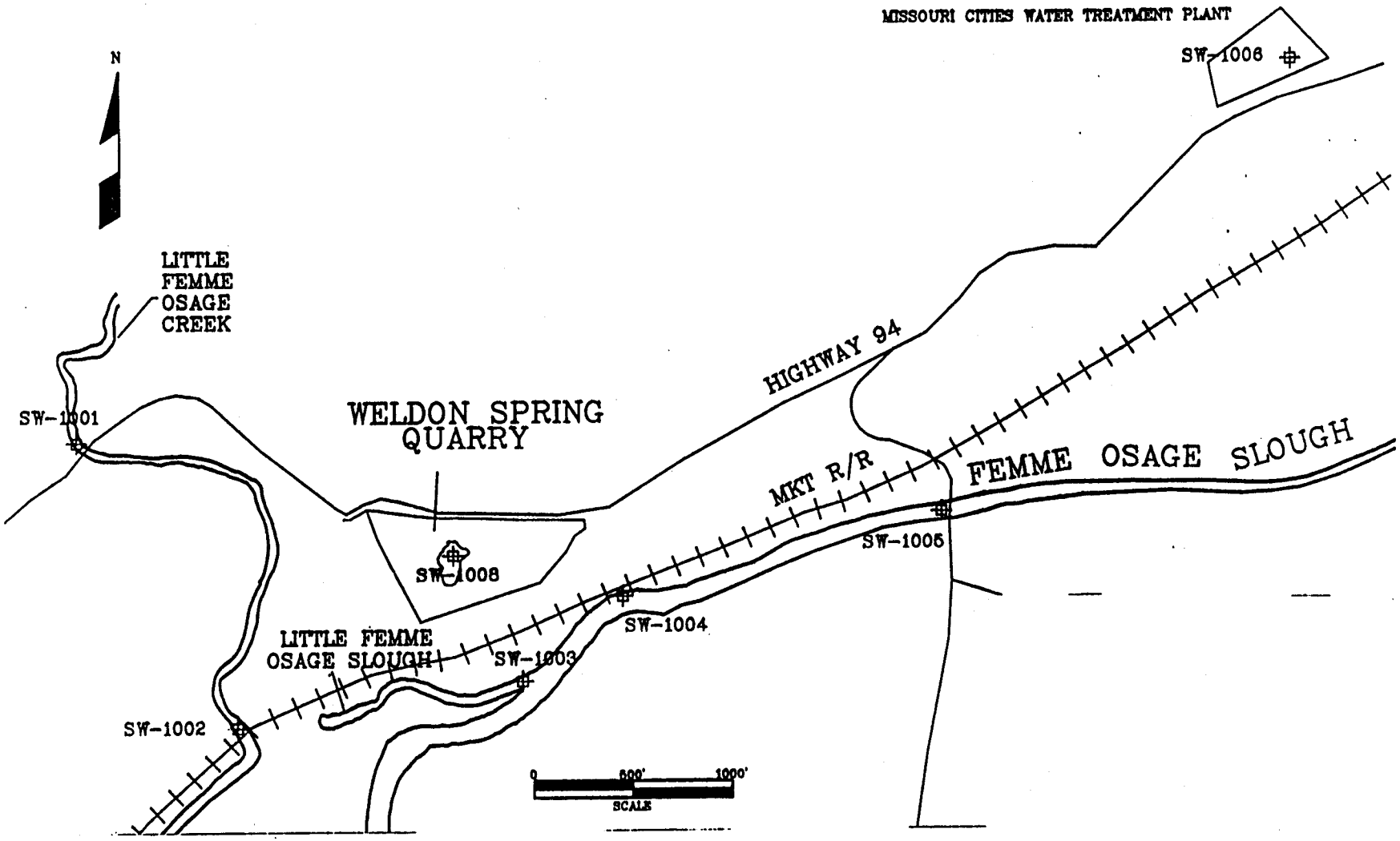


FIGURE 2-5

SURFACE WATER SAMPLING LOCATIONS NEAR THE WELDON SPRING QUARRY

Two sampling locations on the Little Femme Osage Creek upstream and downstream of the quarry showed average uranium activity levels less than 4 pCi/L (<1% DCG). Radium-226 and Thorium-230 activity levels averaged less than 3 pCi/L, also less than one percent of their respective DCG's. These data indicate that no measurable contribution is made to the background levels in the Little Femme Osage Creek by either runoff or subsurface migration.

Three of the remaining locations were spaced along the Femme Osage Slough. Average uranium concentrations ranged from 28 pCi/L to 34 pCi/L. These elevated levels are due to subsurface migration of uranium-bearing water in the alluvium north of the slough. Radium-226 and Thorium-230 and -232 concentrations have remained below detection limits of 1 pCi/L at all of these locations.

Location SW-1006 monitored well field water from the Missouri River alluvium entering the St. Charles County Water Treatment Plant. The levels of radionuclides in the quarterly samples of the raw water were always below detectable levels (background).

2.3 RADON MONITORING

The Radon Gas Monitoring Program continued at the Weldon Spring Site in 1987. This section presents a summary of the monitoring results and an interpretation of the levels measured.

The Radon Gas Monitoring Program involved replicate radon detectors exchanged quarterly at nineteen different locations. These locations include six locations at the WSCP, six locations at the WSQ, four locations at the WSRP, and three locations off-site (Figure 2-6). One offsite location RD-4001, at the Busch Wildlife Area headquarters, was selected to monitor background activity levels near the Weldon Spring Site. Figure

2-7 shows the monitoring locations near the WSQ.

The radon detectors used in this program were Terradex Track Etch Type F. These detectors are housed in protective plastic cups and are mounted (inverted) on posts at their respective locations. These detectors were exchanged at the beginning and end of each calendar quarter. The collected detectors were then sealed and shipped to the Terradex Corporation of Glenwood, Illinois for analysis.

Detectors were spaced along the entire site perimeter fence, to ensure adequate detection capability of radon gas dissipating from the on-site properties under various atmospheric conditions.

A few detectors at the WSQ were vandalized during the first quarter of 1987. Both detector cups at location RD-1005 and one detector cup at RD-1006 were missing. In order to minimize vandalism to the detectors at WSQ, the posts were moved 10 ft. inside the fence at the beginning of the second quarter. This curbed vandalism at the quarry. However, detectors were still vandalized at other properties. A third-quarter cup at WSRP location RD-3001 was missing, and a third-quarter cup at RD-4002, Francis Howell School, was damaged.

One radon monitor for the second quarter of 1987 was cracked upon arrival at the site and could not be used. Therefore, only one detector could be placed at location RD-1004, the south side of the quarry.

2.3.1 Radon Monitoring Results

The radon monitoring data received from the manufacturer was validated for measurement uncertainties. This validation process was based on the method presented in Nelson, 1987 (see Section 6.0, References). By this process, four detector values were identified as outlying measurements. Subsequently, these

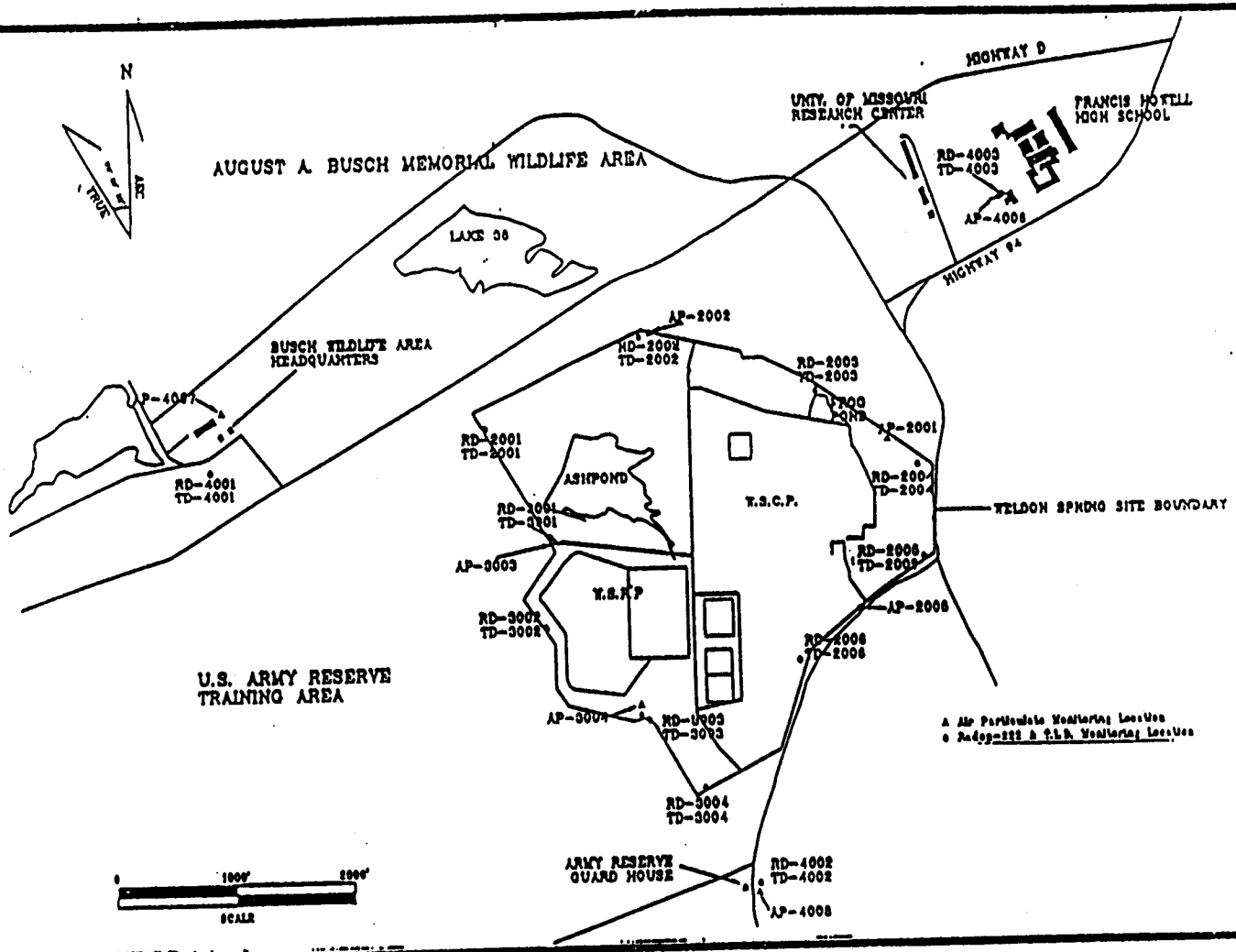


FIGURE 2-6
RADON-222, TLD, AND AIR PARTICULATE MEASUREMENT LOCATIONS AT THE WSCP/WSRP AREA

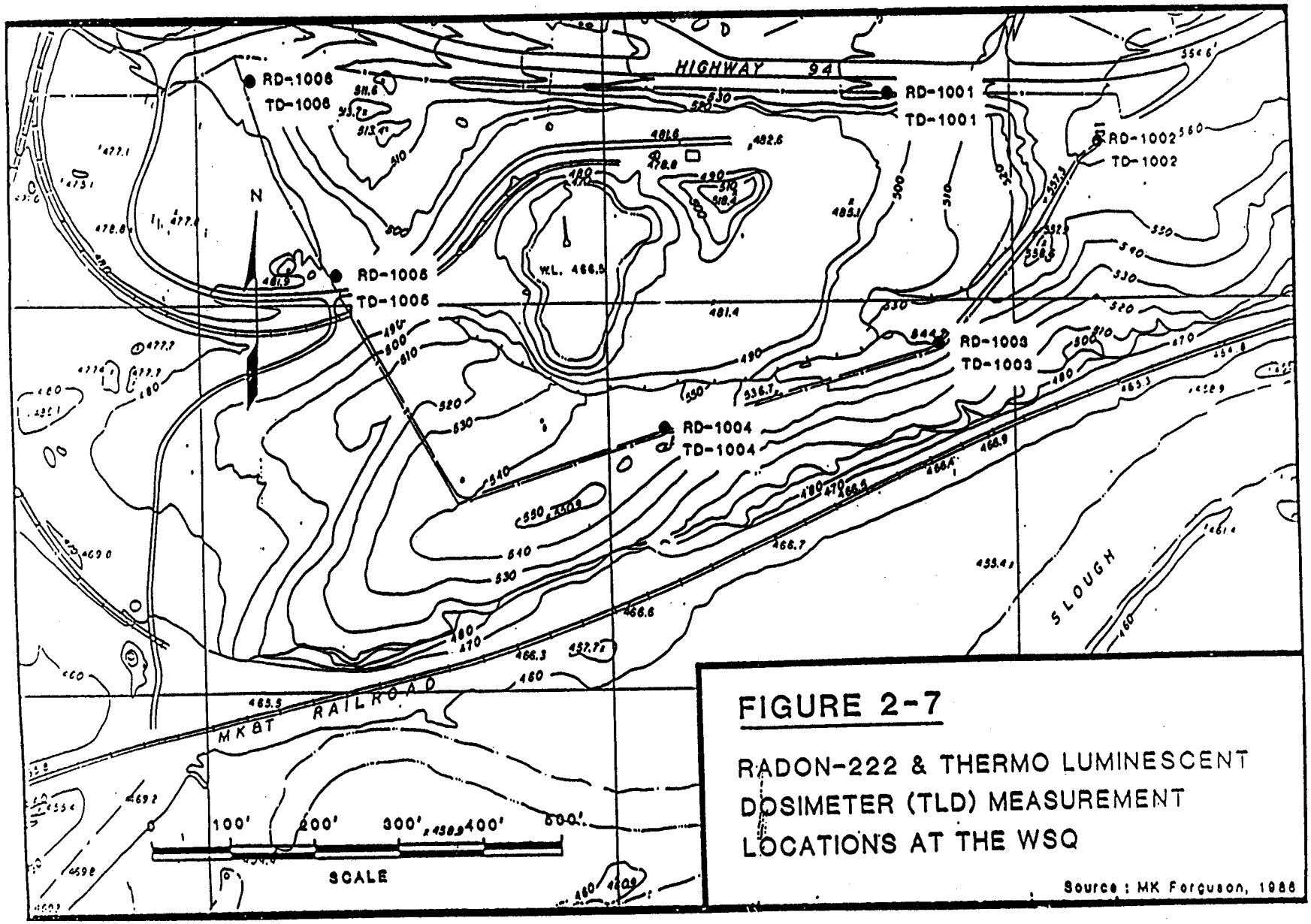


FIGURE 2-7

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

Source : MK Ferguson, 1988

outliers were rejected in all computation work. Table 2-11 summarizes minimum, maximum, and the annual average concentrations of radon gas detected at all locations.

Radon is produced by the decay of Radium-226, one of the long-lived daughters in the uranium chain. Because uranium is present naturally in the soil, the background concentration of radon fluctuates with both soil conditions and meteorological dispersion conditions. In moist soil, many of the microscopic channels through which radon can diffuse are filled with water. In winter, atmospheric inversions keep the radon close to the surface, thereby elevating air concentrations of the gas.

Radon resulting from Radium-226 contamination in soil is regulated. Radon from naturally occuring Radium-226 is considered background. The DOE Order 5480.1A, Chapter XI establishes Derived Concentration Guide (DCG) values of radon for controlled and uncontrolled areas. The Guide is 3 pCi/L for uncontrolled areas and 100 pCi/L for controlled areas. To determine percentage of standard for the annual average concentration above background in Table 2-11, the DCG for uncontrolled areas was applied.

At the WSQ, the average annual concentration ranged from 0.6 pCi/L to 2.6 pCi/L. The highest concentration, 2.6 pCi/L at location RD-1002, equals 77 percent of the DOE guideline.

At the WSCP, the average annual concentration ranged from 0.3 pCi/L to 0.5 pCi/L. The highest annual average above background at RD-2006 was 7 percent of the DOE guideline.

At the WSRP, the average annual concentration ranged from 0.2 pCi/L to 0.5 pCi/L. The highest annual average above background at RD-3003 was 7 percent of the DOE guideline.

At off-site location RD-4002, the Army Reserve Guard House, the

TABLE 2-11
RADON MEASUREMENTS AT THE WSS IN 1987 (pCi/L)*

LOCATION I.D.	(a) MIN	(a) MAX	(a) ANNUAL AVG	EST. OF ERROR 2-SIGMA	(b) % OF GUIDELINE
WSQ					
RD-1001	0.5	2	1.5	0.08	40
RD-1002	0.7	4	2.6	0.1	77
RD-1003	1.2	1.9	1.5	0.1	40
RD-1004	0.2	1	0.6	0.06	10
RD-1005	0	1.3	0.6	0.06	10
RD-1006	0.2	1	0.5	0.04	7
WSCP					
RD-2001	0.1	0.7	0.4	0.04	3
RD-2002	0.1	0.6	0.4	0.04	3
RD-2003	0.1	0.8	0.4	0.04	3
RD-2004	0.1	0.7	0.3	0.04	0
RD-2005	0.1	0.7	0.4	0.04	3
RD-2006	0.1	1.2	0.5	0.04	7
WSRP					
RD-3001	0.1	0.4	0.2	0.04	0
RD-3002	0.1	0.7	0.4	0.04	3
RD-3003	0.1	0.8	0.5	0.04	7
RD-3004	0.1	0.8	0.4	0.04	3
OFF-SITE LOCATIONS					
RD-4001(c)	0	0.5	0.3	0.04	0
RD-4002	0.2	0.6	0.4	0.04	3
RD-4003	0.1	0.5	0.3	0.04	0

SOURCE: WSSRAP, 1987

(a) Includes background
(b) DOE Concentration Guideline for Radon-222 is 3 pCi/L (annual average above background) for uncontrolled areas
(c) Location RD-4001, Busch Wildlife HQ, used as the background location
* To convert to Bq/L, multiply by 3.7×10^{-2}

average annual concentration above background was only 3 percent of the DOE guideline. The average concentrations at location RD-4003, the Francis Howell School, were at background levels.

2.3.2 Interpretation of Radon Data

There are several environmental and geological factors that determine radon gas concentrations in an area. Background levels of radon should be about the same in the WSCP/WSRP and WSQ areas. However, due to the different settings of the Radium-226 in the two areas, the total ambient concentrations of radon gas are different. The only significant quantity of Radium-226 at the WSCP/WSRP area is that material in the raffinate pits themselves (see Table 1-1). While the Radium-226 concentration in the raffinate sludge is high, the diffusion of radon gas produced by Radium-226 below the sludge and water interface is extremely slow due to the small grain size and saturated conditions. Because the half life of Radon-222 is 3.8 days, only that radon produced near the interface can diffuse to the surface, and the surrounding ambient air concentrations are indistinguishable from background levels.

The values of radon around the WSQ area are measurably above background levels. This is primarily due to the heterogeneity and unconsolidated nature of the waste materials in the quarry. Radon produced from the Radium-226 in the waste is relatively free to diffuse to the surface, thus raising the ambient air concentration in the surrounding area. In addition, the quarry is a large depression in the terrain with side walls ranging from 10 to 40 feet in height. During meteorological inversion conditions (usually nocturnally in the summer and fall), this tends to trap the radon being emanated and raises the concentrations along the quarry perimeter.

To demonstrate the seasonal dependence of the radon concentration, the values measured were used to calculate a

seasonal fraction of the annual average for all locations at WSCP/WSRP and at the WSQ. Each quarterly value was normalized to the annual average at each location. Then the average normalized fraction was calculated over all locations. These seasonal fractions are presented in Figure 2-8. It can be seen that at both the quarry and the main plant area that the winter concentrations are only about 30% of the annual average. This seasonal dependence continues through the year with the fall concentrations at about 50% more than the annual average.

2.4 GAMMA RADIATION EXPOSURE RATE MONITORING RESULTS

To monitor exposure from gamma radiation at the WSS, nineteen monitoring stations were employed using Eberline spherical environmental thermoluminescent dosimeters (TLD's). The TLD's are composed of five lithium fluoride chips in a rugged spherical polyethylene holder which is designed with internal filters to measure penetrating radiation. The TLD's were exchanged quarterly and returned to Eberline for processing. Eberline's service is accredited by the U.S. National Bureau of Standards under the National Voluntary Laboratory Accreditation Program (NVLAP), and meets requirements of the American National Standards Institute and Regulatory Guides of the U.S. Nuclear Regulatory Commission. The data is presented in Table 2-12. The monitoring locations are the same as for ambient radon monitoring locations shown in Figures 2-6 and 2-7.

To determine the external gamma radiation exposure near the WSS, normal levels of gamma radiation for this environmental and geographical area had to be characterized. Normal levels of gamma radiation are due to radioactive materials in the earth and cosmic radiation through the atmosphere. Previous contractors of the DOE (formerly AEC) have determined normal radiation exposure rates in the WSS area ranging from 60 to 105 mR/year (BNI, 1985a; BNI, 1985b; BNI, 1984; ORAU, 1986a; ORNL,

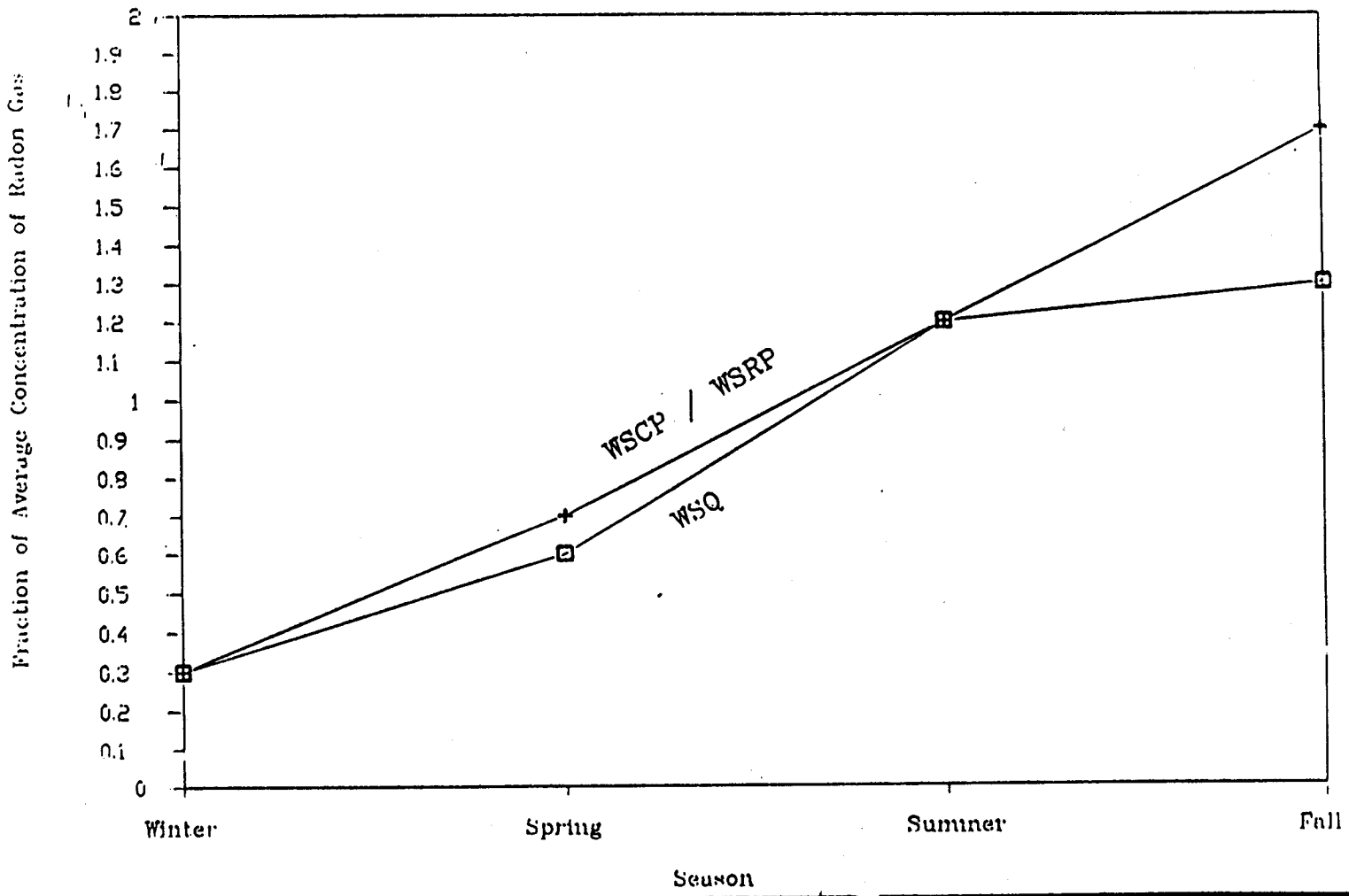


FIGURE 2-8 Fraction of Average Concentration of Radon Gas VS Seasons

1981; ANL, 1986). Radiological characterization activities performed in 1987 by the PMC and UNC determined normal average radiation exposure rates (within a 5 mile radius of the site) ranging from 78 to 96 mR/year with an average of 85 mR/year and a statistical error (two sigma) of 12 mR/year. There is good agreement between past studies and the recent quarterly measurements made for this report.

At the WSCP/WSRP sites, ten monitoring stations are located along the perimeter fence (Figure 2-6). Annual average exposure rates including normal background levels ranged from 58 to 88 mR/year. There are no monitoring locations along the WSCP/WSRP perimeter fence recording measurements that exceed normal background radiation exposure rates. There has been no significant change over the years.

At the WSQ site, six monitoring stations are located along the perimeter fence (Figure 2-7). Annual average exposure rates including normal background levels ranged from 62 to 110 mR/year. While four of the six locations indicated an average measurement above background, the large error associated with each of these measurements indicates that the true mean may fall within normal background levels or could be significantly higher. Because of the variability in measurement at these locations, no real difference will be assigned to these locations. No significant increase over the years can be drawn from data with this magnitude of error.

At three off-site monitoring stations, gamma radiation exposure rates were measured (Figure 2-6). The locations are at the Francis Howell High School, August Busch Wildlife Area headquarters office, and the guard station on the U.S. Army Training Area. All results indicate normal background exposure levels. Therefore, the WSS does not contribute any increased gamma radiation exposure to public, workers, and students at these facilities.

TABLE 2-12

GAMMA RADIATION EXPOSURE RATE MONITORING RESULTS
EXPOSURE RATES IN MILLIROENTGEN PER YEAR
INCLUDING NATURAL BACKGROUND (mR/year) *

LOCATION I.D.	MINIMUM	MAXIMUM	AVERAGE	ERROR (TWO SIGMA)	PERCENT OF STANDARD[a]
WSQ					
TD-1001	95	125	110	30	0
TD-1002	91	133	110	42	0
TD-1003	84	135	102	52	0
TD-1004	53	119	106	30	0
TD-1005	43	84	62	36	0
TD-1006	50	102	77	44	0
WSCP					
TD-2001	37	96	69	52	0
TD-2002	48	100	66	52	0
TD-2003	48	118	80	58	0
TD-2004	19	91	58	66	0
TD-2005	50	130	88	66	0
TD-2006	29	106	73	58	0
WSRP					
TD-3001	57	108	77	52	0
TD-3002	30	107	66	58	0
TD-3003	46	107	77	44	0
TD-3004	36	69	58	36	0
OFF-SITE LOCATIONS					
TD-4001	45	103	73	66	0
TD-4002	31	117	69	73	0
TD-4003	34	124	62	95	0

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

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

2.5 AIR PARTICULATE MONITORING RESULTS

The environmental monitoring program at the WSS includes an evaluation to determine whether and to what extent radioactivity and other pollutants are released from the WSS via particulates through the air. Compliance with applicable environmental quality and public exposure limits and other environmental commitments is also assessed. The air particulate environmental monitoring program aids in evaluating the overall impact of WSSRAP operations and WSS conditions on the environment.

Air samples were collected at five site perimeter stations and three nearby off-site stations (Figure 2-6). Air monitoring was performed at these locations to establish ambient baseline data and to monitor for potential off-site contamination. 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) include particulate matter (radioactive and non-radioactive), asbestos, radon and radon daughters, metals, and other unknown chemicals. A separate program (site characterization study) will determine 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.

The three contaminants of concern at this time are radioactive particulates, asbestos, and radon. Radon is discussed in Section 2.3. Even though the site is in a non-construction mode, the radioactive particulates and asbestos are susceptible to release from the site through the air. Section 2.5.1 discusses the radioactive particulate monitoring program and results obtained for 1987. Section 2.5.2 presents results of

asbestos fiber concentration measurements made in 1987. A more extensive asbestos sampling program to be initiated in 1988 is presented in Section 5.0.

2.5.1 Radionuclide Monitoring

During 1987, air particulate samples were collected at five site perimeter air sampling stations and three nearby off-site stations. The locations of these air particulate sampling stations are shown in Figure 2-6. Table 2-13 indicates the sampling frequency, sampling parameters, and purpose for each sampling station.

Air samples were collected for each station twice a week, once during the week and once on the weekend. During the third quarter of 1987 perimeter sampling station AP-3004 was taken out of service for repair. It was returned to operation at the beginning of the fourth quarter of 1987. At the beginning of the fourth quarter of 1987 all perimeter sampling stations except AP-3004 were taken out of service for repair. The samplers were returned to operation at various times during the first quarter of 1988. The data for the fourth quarter of 1987 is incomplete and was not considered in this report. This is not considered significant since there was no remedial action activity at the WSS during 1987, implying air monitoring data from the first three quarters of 1987 are representative of the fourth quarter.

The twice weekly sample collection allowed for the potential exposure evaluation of students at Francis Howell High School on weekdays, and potential weekend exposure of trainees and visitors at the Army Reserve Training Facility and the Busch Wildlife Areas. This sampling schedule allows for determination of whether releases occur during remedial action operations, which will be performed only on weekdays at the WSS.

Although there was no remedial action activity in 1987, this sampling schedule did allow us to determine the background levels to which future data can be compared. Specifically, the sampling station at the Busch Wildlife Area (AP-4007) is considered a background sampling location for the period prior to remedial action. This station is furthest from the WSCP, is usually upwind, and the terrain between the site and the sampling station (being hilly and forested) provides a significant physical barrier.

The air samplers are continuous flow dichotomous sampler units operating at a constant total flow rate of 16.7 liters per minute (one cubic meter per hour). These sampling units divide suspended particles into two sizes: 2.5 to 10 micrometers in diameter (coarse, non-respirable particles) and less than 2.5 micrometers in diameter (fine, respirable particles). Particles larger than 10 micrometers are not collected. In terms of risk from inhalation, particles larger than 10 micrometers do not pose a significant risk to human health. Each particle group was collected uniformly on a 37-millimeter diameter teflon membrane filter. The effective pore size of the filter is 0.3 micrometer.

One filter for coarse particles and one for fine particles as described above were collected for each period at each sampling station. A total of 16 sample filters plus two blank (control) filters were collected for each sampling period (a total of 32 sample filters plus four blank filters each week).

The collected air filters were each analyzed on-site for gross alpha radiation. The air filters were then composited on a quarterly basis for radionuclide analyses. Weekday and weekend sampling periods, as well as coarse and fine size fractions, were composited individually. A total of 32 composite samples and two composite blanks were analyzed each quarter except the fourth. The parameters chosen for analysis were Uranium-238, Uranium-235, Uranium-234, Thorium-232, Thorium-230, Radium-228,

TABLE 2-13

ANALYTICAL PARAMETERS FOR AIR MONITORING LOCATIONS

SAMPLING LOCATION	SAMPLING FREQUENCY	PARAMETERS	PURPOSE
WSS Perimeter	Twice Weekly	Gross Alpha	Assess exposure at boundary and correlate with on-site engineering controls.
	Quarterly [1]	U-238, U-235, U-234 Th-232, Th-230, Th-228 Ra-228, Ra-226 Pb-210	
Francis Howell High School	Twice Weekly	Gross Alpha	Assess exposure of students during week.
	Quarterly [1]	U-238, U-235, U-234 Th-232, Th-230, Th-228 Ra-228, Ra-226 Pb-210	
Busch Wildlife Area	Twice Weekly	Gross Alpha	Assess exposure of visitors to Wildlife Area. Background location [2].
	Quarterly [1]	U-238, U-235, U-234 Th-232, Th-230, Th-228 Ra-228, Ra-226 Pb-210	
Army Reserve	Twice Weekly	Gross Alpha	Assess exposure of hunters and Army Reserve personnel.
	Quarterly [1]	U-238, U-235, U-234 Th-232, Th-230, Th-228 Ra-228, Ra-226 Pb-210	

1 Weekday and weekend samples were analyzed separately.

2 Considered a background location prior to remedial action; see Section 2.5.1 for further explanation.

Radium-226, and Lead-210. The second, third, and fourth quarters also included analysis for Thorium-228.

The gross alpha measurements were made with a standard-type zinc-sulfide detector. The actual counts were then converted to net alpha radioactivity per filter. The analytical method followed for uranium and thorium analyses was EPA 520/5-84-006 "Eastern Environmental Radiation Facility Radiochemistry Procedures Manual". The analytical method followed for radium and lead analysis was EPA 600/4-80-32 "Prescribed Procedures for Measurement of Radiation in Drinking Water". The results were reported as total radioactivity per composite. Given the volume at which each sampling station operated, the net activities were converted to activity concentrations in air.

For each sampling station, the annual average net alpha activity was not statistically different (at the 95% confidence level) from the background station (AP-4007) activity. The estimated total (coarse plus fine) net alpha activity at station AP-4007 is less than 3×10^{-15} uCi/mL ($<1 \times 10^{-11}$ Bq/m^3). This sample concentration (given sample volume and detection instrument characteristics), is the smallest activity concentration measurable. The weekday net sample activity was not statistically different from the weekend net sample activity.

For each sampling station, the radionuclide analyses indicated total net activity less than an isotope-specific detection limit. These detection limits are shown in Table 2-14 for the background sampling station (AP-4007). In each case, except for Pb-210, the radionuclide detection limit was less than the gross alpha detection limit. In all cases the radionuclide detection limits and the gross alpha detection limits were less than the DOE Derived Concentration Guides (DCG) (see Table 2-14 and Appendix D) for each radionuclide. The significance here is that the radiological contaminants at the WSS can be detected at levels low enough to indicate an increase but before the

TABLE 2-14
ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN AIR PARTICULATES*

ISOTOPE	ANNUAL AVERAGE** BACKGROUND CONCENTRATIONS (pCi/m^3)	DCG (pCi/m^3)
U-234	$<2.0 \times 10^{-3}$	9.0×10^{-2}
U-235	$<1.0 \times 10^{-3}$	1.0×10^{-1}
U-238	$<1.4 \times 10^{-3}$	1.0×10^{-1}
Th-228	$<1.1 \times 10^{-3}$	4.0×10^{-2}
Th-230	$<1.8 \times 10^{-3}$	4.0×10^{-2}
Th-232	$<1.1 \times 10^{-4}$	7.0×10^{-3}
Ra-226	$<6.4 \times 10^{-3}$	1.0
Ra-228	$<1.6 \times 10^{-3}$	3.0
Pb-210	$<9.6 \times 10^{-3}$	9.0×10^{-1}
GROSS ALPHA	$<3 \times 10^{-3}$	N/A

* To convert to Bq/m^3, multiply by 3.7×10^{-2}.

** These concentrations represent the annual composite average for each radionuclide at station AP-4007 and the annual average gross alpha at station AP-4007.

increase exceeds the DCG(s). As shown in Table 2-14, sample results are reported as less than a specific concentration or detection limit. This lower limit of detection is the smallest amount of sample activity that can be detected at a predetermined level of statistical confidence. These detection limits are controlled by detection instrument performance and sample volume. It is expected that the calculated activity concentrations would decrease significantly with improved detection instrument performance and/or increased sample volume.

2.5.2 Asbestos Monitoring

Asbestos surveys of WSCP buildings and related process and utility piping were performed in 1987. These surveys included selected bulk sampling of piping insulation and other building components. The results confirmed that a major portion of the piping insulation inside the buildings and on the outdoor piping system is asbestos-containing material. A significant portion of the outdoor pipe insulation is in a friable and deteriorated condition. In addition to the pipe insulation, many of the WSCP process buildings are constructed of corrugated cement asbestos siding. The siding material is generally intact and non-friable.

Air monitoring to determine personnel exposures and asbestos fiber concentrations at selected locations in the WSCP area was performed in 1987. A summary of the asbestos air-monitoring data is provided in Table 2-15. The results of the personnel-exposure monitoring indicate that detectable concentrations of asbestos fibers were present during grass mowing operations and during the performance of the electrical pole and line removal work. These activities were performed in close proximity to areas where fallen asbestos-containing insulation was present on the ground below the overhead piping system. The exposure levels were in the range of <0.01 to 0.02 fibers per cubic

TA' ?-15

WSSRAP ASBESTO. .ITORING RESULTS

SAMPLE ID NO.	DATE SAMPLED	SAMPLE TYPE	SAMPLE DESCRIPTION	SAMPLING DURATION (MIN)	SAMPLE VOLUME (L)	(a) NO. OF FIBERS /NO. FIELDS	(b) CONCENTRATION (FIBERS/CC)	(c) TWA CONCENTRATION (FIBERS/CC)
AA-2001-0687	06/18/87	AREA	GRASS MOWING OPERATION	180 MIN	324	1/100	<0.02	N/A
AA-2002-0687	06/18/87	AREA	GRASS MOWING OPERATION	180 MIN	337	2/100	<0.02	N/A
B2-2001-0687	06/19/87	PERSONNEL	LABORER OPERATING RIDING MOWER	230 MIN	430.1	39/100	0.044	0.021
B2-2002-0687	06/19/87	PERSONNEL	LABORER WALKING IN FRONT OF RIDING MOWER	230 MIN	414	8/100	<0.02	<0.01
8787-01	08/07/87	AREA	NEAR WATER TOWER BEFORE & DURING MOWING OPERATION	240 MIN	432	22/100	0.025	N/A
8787-02	08/07/87	PERSONNEL	LABORER OPERATING RIDING MOWER	150 MIN	280.5	39/105	0.065	0.020
8787-003	08/07/87	AREA	ON DECK OF RIDING MOWER DURING MOWING OPERATION	150 MIN	285	100/90 (d)	0.191	N/A

(a) Those samples which had 8 fibers or less per 100 fields are reported as less than a specified detection limit. The reported detection limit is a function of the volume of air sampled for the particular sample. All samples were analyzed using Phase Contrast Microscopy.

(b) This is the fiber concentration based on the actual sampling period.

(c) Eight-hour time weighted averages (TWA's) are applicable only to personnel samples. The TWA exposure is based on an assumption that there was a zero exposure level during the non-sampled time period. The OSHA 8-hour TWA exposure limit is 0.2 f/cc; the action level 0.1 f/cc (8-hour TWA).

(d) The laboratory reported this level as a minimum value, because the filter contained a heavy particulate loading which made fiber counting difficult.

TABLE 2-15

WSSRAP ASBESTOS MONITORING RESULTS (CONTINUED)

SAMPLE ID NO.	DATE SAMPLED	SAMPLE TYPE	SAMPLE DESCRIPTION	SAMPLING DURATION (MIN)	SAMPLE VOLUME (L)	(a) NO. OF FIBERS /NO. FIELDS	(b) CONCENTRATION (FIBERS/CC)	(c) TWA CONCENTRATION (FIBERS/CC)
8787-01	08/26/87	AREA	FENCE LINE ADJACENT TO ARMY RESERVE TRAINING AREA	425 MIN	765	4/100	<0.007	N/A
8787-02	08/26/87	AREA	FENCE LINE ADJACENT TO GUARD TRAILER	425 MIN	794.8	5/105	<0.007	N/A
8787-03	08/26/87	AREA	BETWEEN TRAILER NO. 4 & NO. 8	425 MIN	876.3	2/117	<0.007	N/A
B2-2001-1287	12/29/87	PERSONNEL	POLE/LINE REMOVAL ACTIVITIES	259 MIN	617.9	9/100	.008	.004
B2-2002-1287	12/29/87	PERSONNEL	POLE/LINE REMOVAL ACTIVITIES	373 MIN	855.8	18/100	.011	.009
B2-2003-1287	12/29/87	PERSONNEL	POLE/LINE REMOVAL ACTIVITIES	395 MIN	907.6	18/100	.011	.009
B2-2004-1287	12/29/87	BLANK	N/A	N/A	N/A	0/100	- -	- -
AA-2001-1287	12/29/87	AREA	WEST OF TRAILER NO. 15	385 MIN	3652	1/100	<.002	N/A

(a) Those samples which had 8 fibers or less per 100 fields are reported as less than a specified detection limit. The reported detection limit is a function of the volume of air sampled for the particular sample. All samples were analyzed using Phase Contrast Microscopy.

(b) This is the fiber concentration based on the actual sampling period.

(c) Eight-hour time weighted averages (TWA's) are applicable only to personnel samples. The TWA exposure is based on an assumption that there was a zero exposure level during the non-sampled time period. The OSHA 8-hour TWA exposure limit is 0.2 f/cc; the action level 0.1 f/cc (8-hour TWA).

(d) The laboratory reported this level as a minimum value, because the filter contained a heavy particulate loading which made fiber counting difficult.

centimeter of air (f/cc), measured as an 8-hour time-weighted average (TWA). These concentrations are well below the action level of 0.1 f/cc, 8-hour TWA, established by the Occupational Safety and Health Administration (OSHA). The OSHA Asbestos Standard for the construction industry (29 CFR 1926.58) requires that engineering controls and work practices be used to maintain asbestos fiber concentrations at or below 0.2 f/cc, 8-hour TWA. Respiratory protection is required during operations where feasible engineering and work practice controls are not available to maintain asbestos fiber concentrations to within the 0.2 f/cc permissible exposure limit.

Area monitoring at site perimeter locations indicated that asbestos fiber concentrations were less than 0.007 f/cc. The reported concentrations represent the limit of detection of the analytical method, i.e. NIOSH Method 7400, at the air volumes collected for these samples.

Typical ambient air asbestos fiber concentrations in urban areas range from 0-0.045 f/cc (US EPA, 1985). Based on the limited air monitoring performed at the WSS in 1987, concentrations measured at the site perimeter locations are indicative of normal background fiber concentrations.

3.0 RELATED ACTIVITIES AND SPECIAL STUDIES

There were a number of measurement activities conducted during 1987 that were related to the Environmental Monitoring Program, but were not part of the routine quarterly sampling. These characterization efforts represent only a portion of the Remedial Investigation/Feasibility Study activities currently underway at the WSS.

A characterization of the WSQ waste was conducted by BNI during the period from April to May 1985 (BNI, 1985a). While this effort characterized the waste in the quarry radiologically, the number of samples analyzed for chemical parameters was not sufficient to allow statistical confidence due to the heterogeneous waste in the WSQ. An additional confirmatory sampling effort was conducted by BNI from October to December 1986. This investigation focused on the level of organic compounds present in the soils, debris and water of the WSQ. Sixteen boreholes were drilled, with composite samples analyzed for priority pollutant organics, PCB's and nitroaromatic species. A summary of the results from this chemical characterization effort is presented in Section 3.1 below.

In March 1987, an extensive water sampling program was conducted by the PMC to evaluate the water quality at 19 new monitoring wells (installed in 1986), 30 previously existing wells, and 17 surface water locations. The purpose of this program was to formulate a Phase I Water Quality Assessment providing a complete overview of the quality of the water influenced by all areas of the WSS. The results of this effort (summarized in Section 3.2) indicated significant off-site releases of both radiological and chemical substances from several different areas. Some of these releases were previously unsuspected. Groundwater transport of high concentrations of nitrate and nitroaromatics were found at the WSRP and WSCP. At the WSQ, only uranium was found to be transported by groundwater in

significant quantities, although trace amounts of other substances were found as well. This Phase I Water Quality Assessment formed the basis for additional well installation to determine the extent of the groundwater contamination. This is discussed more completely in Section 3.2 and Section 5.0.

A program to determine the biological uptake of uranium and other radiological and chemical substances in fish and mammals living in or near contaminated areas around the WSRP/WSCP and WSQ was initiated in the fall of 1987. The purpose of the bio-uptake measurement program was to determine the levels of radiological and chemical contaminants in fish and mammals which are routinely caught in the WSS area since land-use patterns currently emphasize fishing and hunting. While sample collection is not complete and will continue through the winter and spring of 1988, a description of these activities is presented in Section 3.3.

During 1987, several radiological characterization programs were undertaken to determine the extent and magnitude of the uranium (and other radionuclides) contamination within the WSCP, WSRP and Weldon Spring Vicinity Property (WSVP) areas. These characterization activities and their results are presented in Sections 3.4 and 3.5.

3.1 CHEMICAL CHARACTERIZATION OF THE WSQ

In October 1986, a chemical characterization of the quarry waste material was initiated. This program was developed to supplement the Radiologic Characterization Program completed in 1985 which performed some limited chemical (non-radiologic) analyses (BNI, 1985a). The 1985 report and subsequent review concluded that additional information concerning chemical composition of the quarry wastes was needed.

The subsequent chemical characterization program consisted of seventeen boreholes at preselected locations through the quarry. Borehole location rationale included historical data on disposal location, types of material stored, past radiologic characterization and topography. The sampling and analysis program was designed to detect the presence of organic compounds in the quarry waste including: volatile organic compounds, semi-volatile organic compounds, pesticides, PCB's and nitroaromatic compounds. The results of the program are presented in a report prepared by BNI in 1987 titled The Chemical Characterization Report for the Weldon Spring Quarry.

Despite the problems of sample collection through the quarry rubble, a representative population of samples was collected. In general the samples indicated chemical contamination throughout the quarry material, but the distribution of the various contaminants was extremely heterogeneous.

Volatile organics detected in one or more boreholes included methylene chloride, xylene, and ethyl benzene at concentrations ranging from 1 to 50 ppm. Semi-volatile organic compounds detected in one or more boreholes included the polyaromatic compounds phenanthrene, fluoranthene, and benzo(b) fluoranthene at maximum concentrations of 150, 190, and 110 ppm, respectively. The maximum value detected for subsurface nitroaromatic compounds was 1,600 ppm for TNT and the maximum value for PCB's was 120 ppm for PCB 1254. Surficial discoloration of soils at the eastern portion of the quarry indicated nitroaromatic compounds at levels of 1 to 2 percent by weight.

The presence of these organic compounds, mixed with the radiological wastes in the quarry means that removal, transport and storage of the material will be regulated under RCRA as well as applicable radiological standards.

3.2 PHASE I WATER QUALITY ASSESSMENT

In March 1987, a Phase I Water Quality Assessment was performed for all water bodies associated with the WSS. This effort consisted of sampling 41 monitoring wells and 21 surface water locations on and around the WSS. The 41 monitoring wells sampled during the Phase I Water Quality Assessment included all monitoring wells that contained water. Additional wells have been installed since the Phase I Assessment, damaged wells have been grouted and a dry well has yielded water during subsequent sampling events. Therefore, the inventory of wells sampled as part of the routine program is currently 49. The routine surface water monitoring program monitors essentially the same locations as the Phase I Water Quality Assessment, with one location in the Femme Osage Slough deleted.

Groundwater samples were analyzed for the complete hazardous substance list, nitroaromatics, select inorganic anions, water quality indicators and radionuclides. Surface water samples were analyzed for radionuclides, select inorganic anions, water quality indicators and metals at selected locations.

The most significant finding of the Phase I Assessment was that the raffinate pits appear to be leaking. This conclusion was reached by correlating inorganic anion and metals concentrations in raffinate pit water and sludges and in groundwater. Inorganic anion data from the Phase I Water Quality Assessment are presented in Table 3-1. Significantly elevated nitrate levels were observed in monitoring wells surrounding the raffinate pits. Figure 3-1 presents nitrate isopleths from the Phase I Assessment. Based on trace metals and nitrate concentrations in raffinate sludge the nitrate contamination in the groundwater appears to be originating in Raffinate Pit No. 3. Elevated concentrations of nickel, vanadium, chromium and magnesium also implicate Raffinate Pit No. 3 as the source of the groundwater contamination. Nitrate concentrations ranged up

Table 3-1

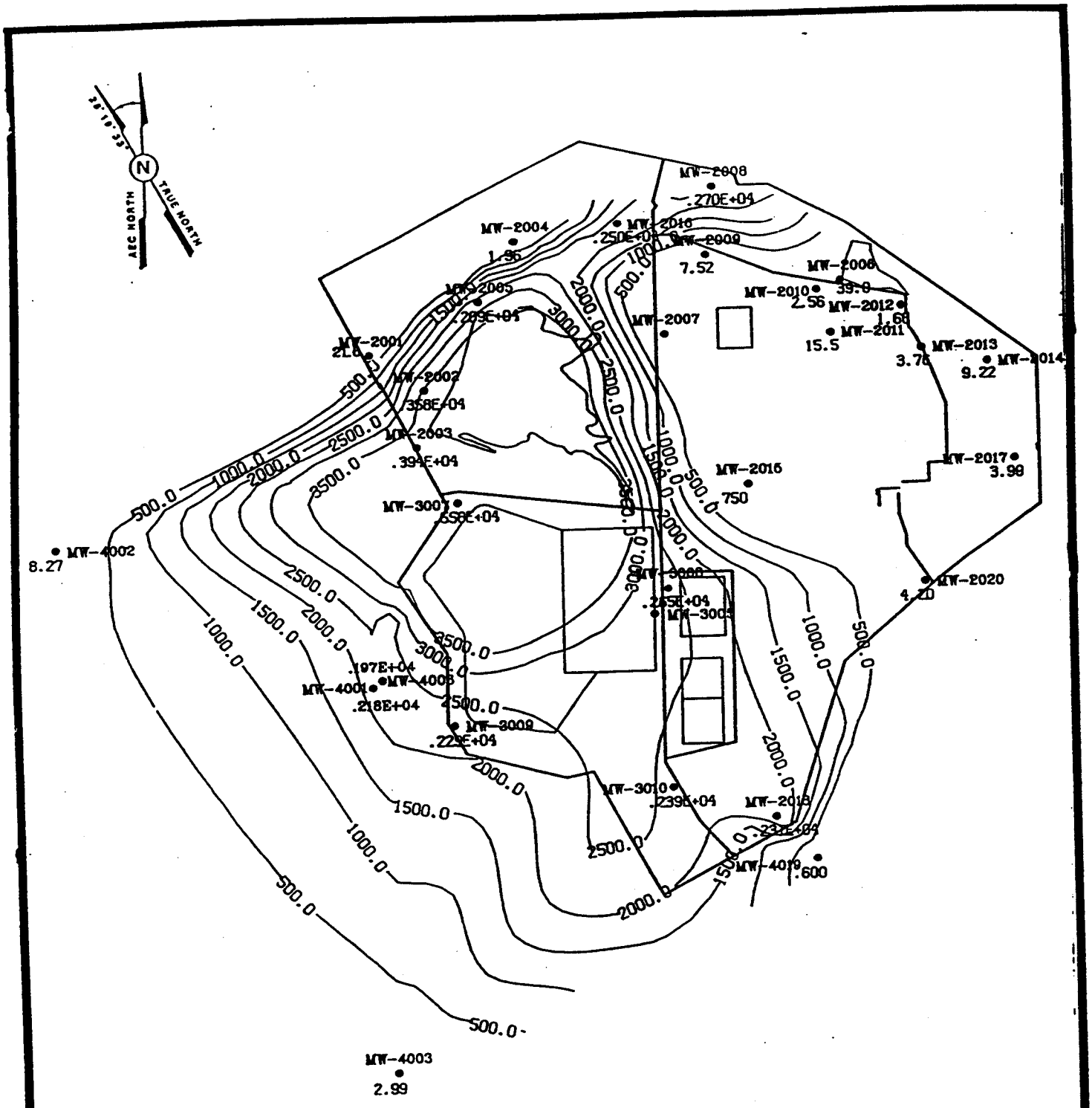
INORGANIC ANION DATA FOR GROUNDWATER AT THE WSCP/WSRP

		Concentration mg/L								
U.S. EPA Primary/Secondary Drinking Water Standard	mg/L	Nitrate (as N) 10	Sulfate – 250	Chloride 250	Fluoride 2	TDS 500	TOC S	Hardness S	Cyanide CWA Standard 0.2	Phenol 3.5
Well No.	Date Sampled									
MW-2001	3/3/87	4.8	22.5	5.12	<0.25	362	<1	307	U	U
MW-2002	3/4/87	806	198	23.2	14.9	1360	1	664	U	U
MW-2003	3/4/87	886	223	33.2	14.7	2724	16	985	U	U
MW-2003-D	3/4/87	945	232	32.8	14.6	2520	<1	1331	U	U
MW-2004	3/3/87	0.4	6.26	1.14	<0.25	374	63	305	U	U
MW-2005	3/5/87	605	172	4.43	1.01	1562	2.12	419	U	U
MW-2006	3/2/87	8.8	31.4	87.1	<0.25	570	7	411	U	0.016
MW-2007	3/2/87	<0.1	17.9	1.34	<0.25	320	<1	312	U	U
MW-2008	3/4/87	608	166	64.2	17.0	622	1	375	U	0.013
MW-2009	3/3/87	1.7	38.2	8.04	<0.25	596	2	448	U	U
MW-2010	3/3/87	0.6	56.8	32.2	<0.25	590	2	374	U	U
MW-2011	3/3/87	3.5	11.3	4.44	<0.25	314	1	279	U	U
MW-2012	3/3/87	0.4	74.2	32.2	<0.25	546	57	352	U	U
MW-2013	3/2/87	0.9	26.9	8.62	0.40	688	6	415	U	U
MW-2014	3/2/87	2.2	34.5	2.83	0.28	570	3	460	U	U
MW-2015	3/6/87	0.2	158	2.46	<0.25	570	3.26	502	U	0.011
MW-2015-D	3/6/87	<0.1	158	2.12	0.25	568	2.96	514	U	U
MW-2016	3/4/87	562	112	18.1	15.3	656	2	328	U	U
MW-2017	3/2/87	0.9	462	10.8	0.62	1000	1	735	U	U
MW-2018	3/5/87	519	18.8	2.45	0.54	642	0.98	352	U	U
MW-2020	3/6/87	0.9	241	38.4	<0.25	680	8.21	434	U	U
MW-3007	3/4/87	1251	866	52.2	12.4	5260	10	2594	U	U
MW-3008	3/10/87	597	100	31.7	1.51	6028	2.06	3482	U	0.014
MW-3009	3/5/87	515	34.2	1.64	0.58	728	2.20	478	U	0.020
MW-3010	3/5/87	296	23.8	2.21	0.38	500	1.85	322	U	U
MW-3010-D	3/5/87	537	23.0	2.34	0.55	506	1.55	333	U	U
MW-3013	3/5/87	468	915	2.30	1.09	1436	3.51	997	U	U
MW-4001	3/5/87	491	159	1.48	0.55	652	14.1	367	0.018	0.011
MW-4002	3/6/87	1.9	25.0	2.16	<0.25	232	24.8	219	U	U
MW-4003	3/6/87	0.7	36.0	7.40	<0.25	308	8.78	294	U	U
MW-4006	3/5/87	444	129	0.78	0.44	402	17.7	226	U	0.011
MW-4019	3/6/87	0.1	9.01	0.91	<0.25	278	3.77	280	U	0.026

S = No Drinking Water Standard

D = Duplicate Sample CWA = Clean Water Act

U = Undetected at method detection limit



NOTE : NITRATE SHOWN AS NO3

CONTOUR INTERVAL 500mg/L

FIGURE 3-1

NITRATE ISOPLETH - PHASE I WATER QUALITY REPORT

MK-FERGUSON 1987

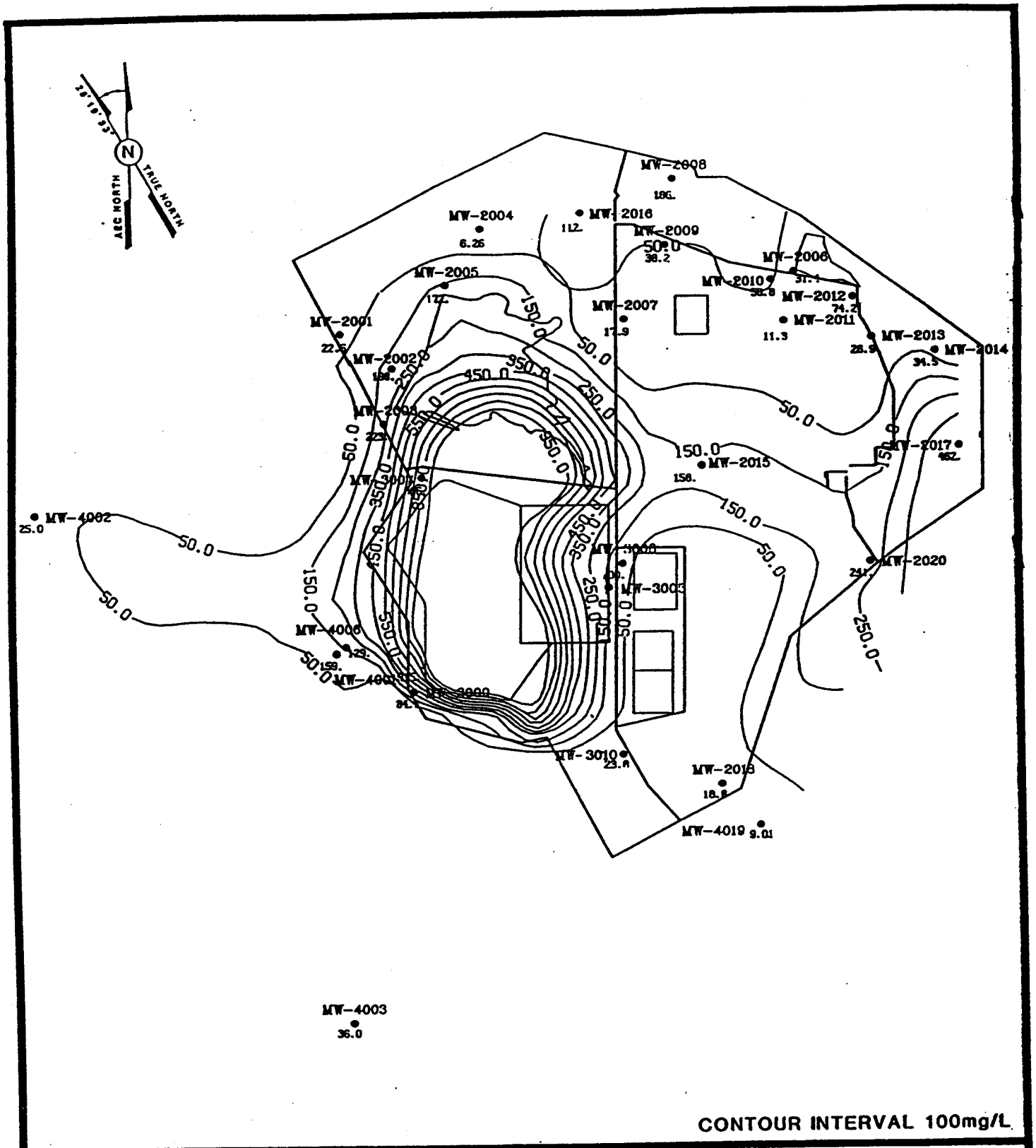
to 1,251 mg/L (as N) in groundwater at the WSCP/WSRP.

Elevated sulfate levels were also detected in the vicinity of the raffinate pits. The pattern of sulfate contamination indicated Raffinate Pit No. 4 as the probable source. Sulfate isopleths are presented in Figure 3-2. Sulfate concentrations ranged up to 915 mg/L with the highest concentration in a monitoring well in the unconsolidated material just west of Raffinate Pit No. 4 (MW-3013).

Another significant finding of the Phase I Water Quality Assessment was the presence of nitroaromatics in the groundwater at the WSCP. The highest concentrations (approximately 340 ug/L) of total nitroaromatics were observed between the final production area of WSOW TNT Production Line No. 1 and the old WSOW waste lagoon located just north of the WSCP. General low-level nitroaromatic contamination was observed in the groundwater under most of the WSCP/WSRP. The nitroaromatic concentrations from the Phase I Assessment are presented in Table 3-2.

The Phase I Water Quality Assessment also revealed that areas of WSQ groundwater are contaminated with nitroaromatics as well as radiological species. Radiological and chemical contaminant migration toward the south at the WSQ appears to be controlled by the Femme Osage Slough. No elevated contaminant levels were observed on the south side of the Femme Osage Slough.

Water level analyses at the WSQ indicated that the sump may be causing a seasonal mounding effect in the immediate vicinity of the WSQ. This analysis was substantiated by the presence of 12 pCi/L Thorium-230 in MW-1012 located just north of the WSQ to provide background data. During the Phase I Water Quality Assessment, the static water level in MW-1012 was approximately 12 feet below the sump level (see Figure 2-2).



CONTOUR INTERVAL 100mg/L

FIGURE 3-2

SULFATE ISOPLETH - PHASE I WATER QUALITY REPORT

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Table 3-2

Nitroaromatic Concentrations in the Groundwater at the WSCP/WSRP

Well No.	Date Sampled	2,4,6-TNT (ug/L)	2,4 DNT (ug/L)	2,6 DNT (ug/L)	Nitro benzene (ug/L)	1,3,5-Trinitro benzene (ug/L)	1,3-Dinitro benzene (ug/L)
MW-2001	3/3/87	<0.5	2.1	2.4	1.0	0.05	<0.4
MW-2002	3/4/87	0.6	<0.2	<0.6	<0.6	<0.03	<0.4
MW-2003	3/4/87	<0.5	0.3	0.7	<0.6	<0.03	<0.4
MW-2003-D	3/4/87	<0.5	0.4	0.7	<0.6	<0.03	<0.4
MW-2004	3/3/87	<0.5	<0.2	0.6	<0.6	<0.03	<0.4
MW-2005	3/5/87	<0.5	0.4	0.9	<0.6	0.1	<0.4
MW-2006	3/2/87	<0.5	3.7	50.1	8.3	4.6	0.5
MW-2007	3/2/87	<0.5	0.3	<0.6	<0.6	<0.03	<0.4
MW-2008	3/4/87	<0.5	<0.2	<0.6	<0.6	0.04	<0.4
MW-2009	3/3/87	<0.5	0.4	0.9	0.6	<0.03	<0.4
MW-2010	3/3/87	1.7	0.3	0.9	<0.6	0.06	<0.4
MW-2011	3/3/87	<0.5	2.2	25.8	<0.6	<0.05	<0.4
MW-2012	3/3/87	1.8	1.3	<0.6	<0.6	0.6	<0.4
MW-2013	3/2/87	29	172	138	<0.6	4.9	0.5
MW-2014	3/2/87	<0.5	1.1	1.5	4.0	0.6	<0.4
MW-2015	3/6/87	<0.5	0.2	<0.6	<0.6	<0.03	<0.4
MW-2015-D	3/6/87	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-2016	3/4/87	<0.5	<0.2	1.0	<0.6	<0.03	<0.4
MW-2017	3/2/87	<0.5	0.2	<0.6	<0.6	<0.03	<0.4
MW-2018	3/5/87	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-2020	3/6/87	<0.5	0.2	<0.6	1.7	<0.03	<0.4
MW-3007	3/4/87	<0.5	1.8	3.3	<0.6	0.1	<0.4
MW-3008	3/10/87	<0.5	0.4	<0.6	<0.6	<0.03	<0.4
MW-3009	3/5/87	<0.5	0.5	<0.6	<0.6	0.05	<0.4
MW-3010	3/5/87	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-3010-D	3/5/87	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4
MW-3013	3/5/87	<0.5	0.3	<0.6	<0.6	<0.03	<0.4
MW-4001	3/5/87	37	1.4	4.2	<0.6	18.3	<0.4
MW-4002	3/6/87	2.7	0.7	1.3	<0.6	<0.03	<0.4
MW-4003	3/6/87	<0.5	0.3	0.8	<0.6	<0.03	<0.4
MW-4006	3/5/87	1.2	<0.2	3.0	2.5	1.7	<0.4
MW-4019	3/6/87	<0.5	0.2	<0.6	<0.6	<0.03	<0.4

Source: WSSRAP, 1987

Note: Nitroaromatics Analysis Following USATHAMA Method (HPLC)

Surface water studies during the Phase I Water Quality Assessment confirmed that the Femme Osage Slough receives recharge from contaminated WSQ groundwater. Samples collected from the Femme Osage Slough contained uranium at levels matching those determined from routine quarterly sampling (see Section 2.2). No other contaminants were observed.

Surface water analyses at or near the WSCP/WSRP yielded seven locations with elevated uranium activities. As expected, Frog Pond and Ash Pond were the most contaminated. Surface water bodies receiving direct runoff (Busch Area Lakes 35 and 36) from Ash and Frog Ponds also exhibited elevated uranium levels. Burgermeister Spring, which receives WSCP runoff via a losing stream, and Busch Area Lake 34 also contained elevated uranium activities (see Section 2.2).

Besides establishing a groundwater contamination baseline consisting of radiological, nitroaromatic and inorganic species, the Phase I Water Quality Assessment established the absence of volatile and semi-volatile compounds, PCB's, and pesticides in groundwater at the WSS.

The Phase I Water Quality Assessment also made numerous recommendations regarding future characterization and monitoring activities at the WSS. Additional groundwater investigations are currently being developed including the installation of additional monitoring wells and aquifer testing. In addition, contaminated monitoring wells at the WSCP/WSRP were added to the Environmental Monitoring Program Plan (EMPP) for routine sampling. During 1987, seven new monitoring wells were installed near the WSQ. These wells were also added to the EMPP for quarterly sampling.

Overall, the Phase I Water Quality Assessment provided the water quality baseline data needed to guide additional investigations and future monitoring activities.

3.3 SAMPLING FOR BIOLOGICAL UP-TAKE OF WSS CONTAMINANTS

In September, 1987, a study plan and scope of work was prepared to determine and characterize the level of potential human exposure to radionuclides, polychlorinated biphenyls (PCB's), and Hazardous Substance List (HSL) Metals from biota samples in the food pathways at the WSS. The sampling effort was initiated in October, 1987. A final report of the findings will be available in late 1988. The scope of work called for the sampling and analysis of fish, frogs, and small mammals which are available for human consumption. Samples were designated for collection at various locations around and within the WSS. This section describes the edible biota and goals of the sampling plan and presents preliminary results.

The intent of the biological up-take investigation was to combine estimates of average consumption rates by humans as determined by the U.S. Department of Agriculture (USDA, 1986) with measured residual amounts of WSS contaminants in biota edible tissues. Real characterization data will then be calculated as a supplement to a site risk assessment. The calculation will assume metabolic parameters of reference man published by the International Commission on Radiation Protection (ICRP Publication No. 23).

The goal of the sampling program was to collect 90 kilograms of various fish species, 32 kilograms of frogs, and 7 kilograms each of rabbits and squirrels. Sample locations on and adjacent to the WSCP area and WSQ area are shown in Figures 3-3 and 3-4. Deer, turkey, geese, and ducks were not sampled because these animals are very mobile, readily moving on and off the WSS, making data extremely difficult to interpret since no estimate of the percentage of their time spent on site can be substantiated.

The investigation of biological intake of radiological

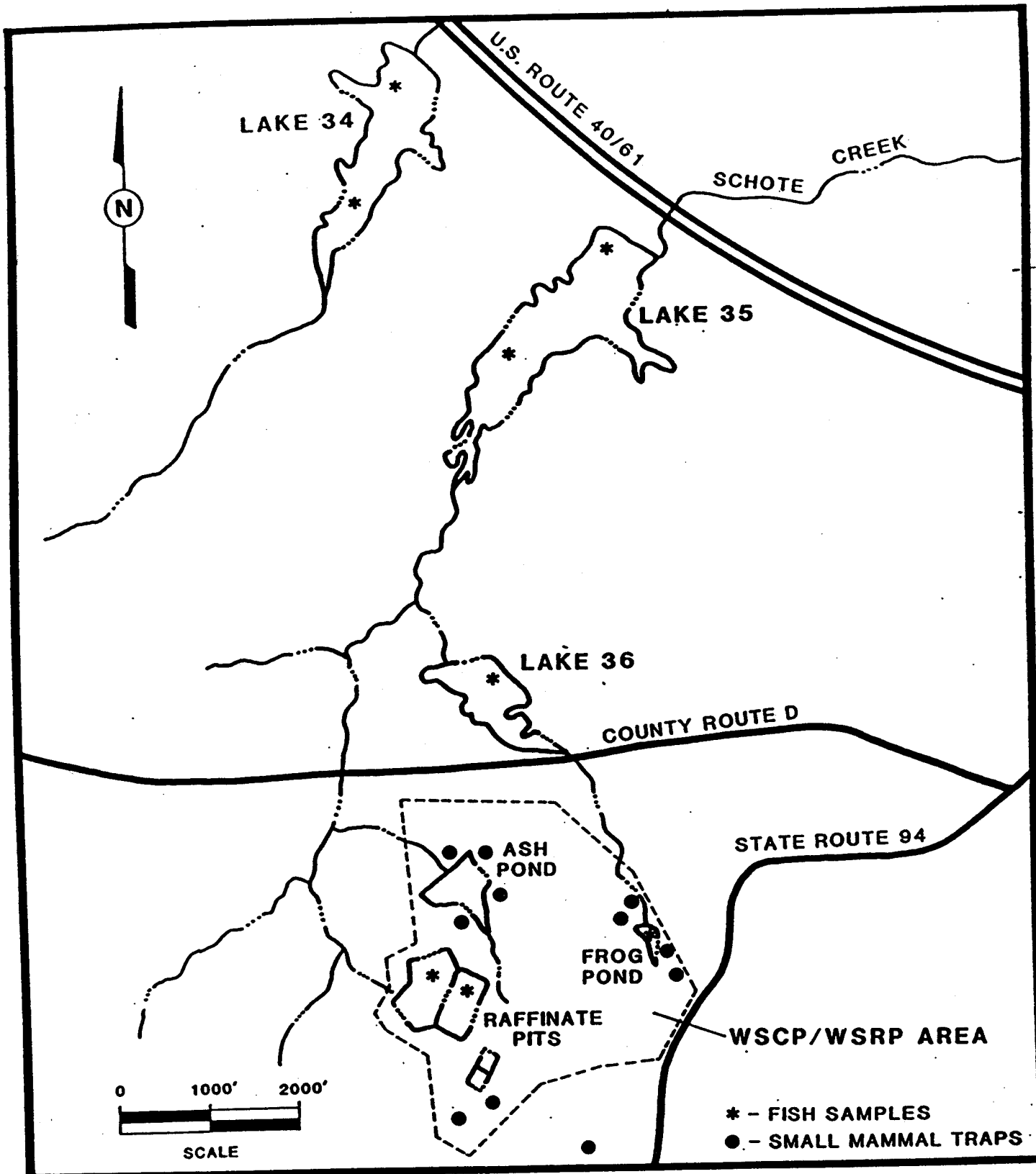

FIGURE 3-3

WSCP/WSRP AND SURROUNDING PROPERTIES
BIOLOGICAL SAMPLING LOCATIONS

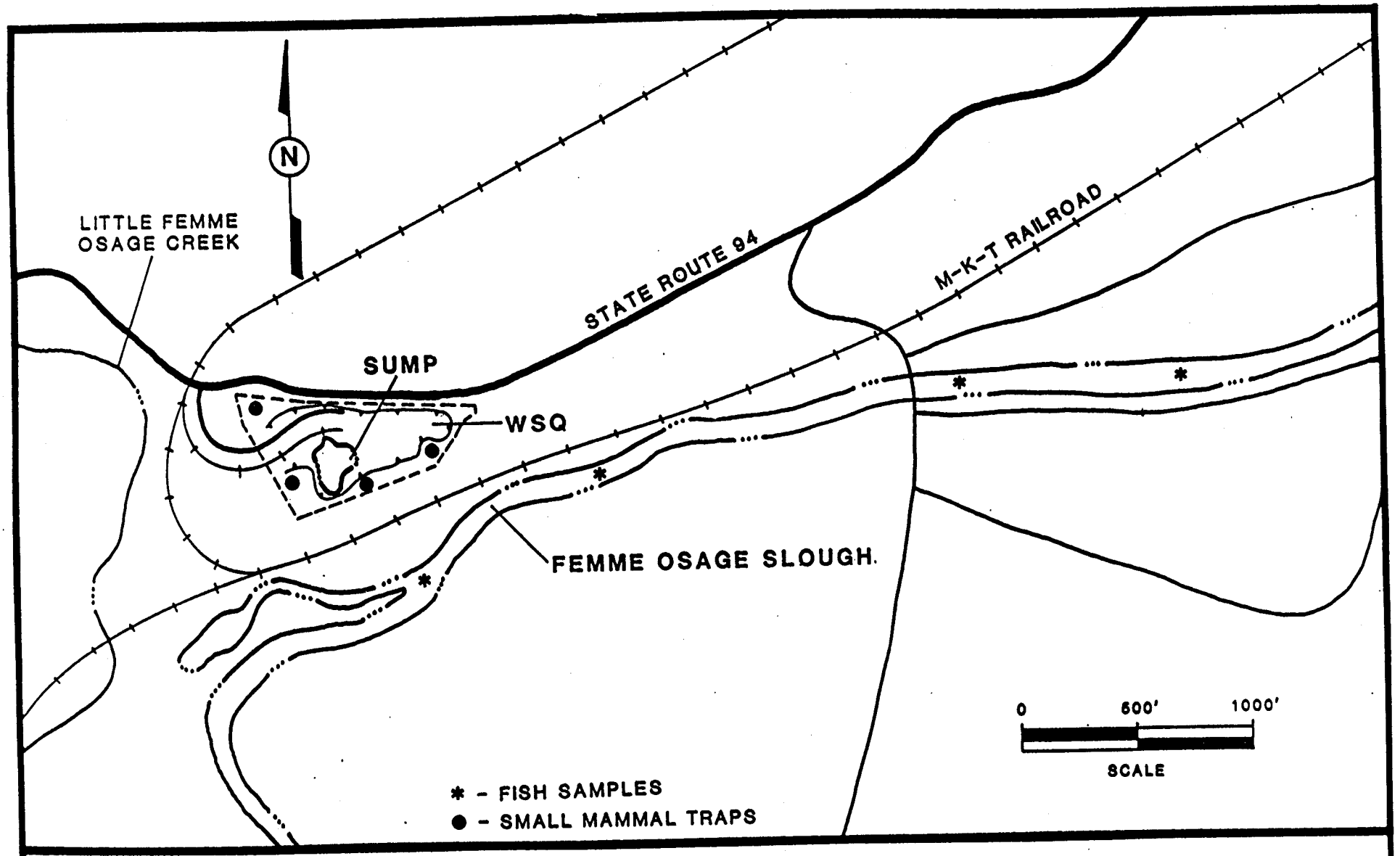

FIGURE 3-4

WSQ AND SURROUNDING PROPERTIES BIOLOGICAL SAMPLING LOCATIONS

contaminants at off-site locations focused on natural uranium due in part to its higher solubility and quantities compared to radium and thorium, and other nonradiologic metals which are also present at the WSS. Surface water outfall sample results around the WSS contain only background concentrations of radium and thorium (see Section 2.2). Fish and frog samples from off-site water bodies were not analyzed for radium or thorium. Fish and frog samples from the on-site water bodies and all small mammals are being analyzed for radium and thorium. All on-site and off-site biota samples are being analyzed for natural uranium.

Past characterization activities have indicated PCB's and HSL Metals to be present in low concentrations on the WSS. Therefore, one composite fish sample from each off-site water body was analyzed for PCB's and HSL Metals. In contrast, nitroaromatic compounds have also been detected in both soil and water samples taken in and around the WSS. However there is a general lack of knowledge about the uptake and biodegradation/metabolism of these compounds by animals and humans. Analytical results for nitroaromatics are anticipated to be very difficult to interpret because biodegradation products may not be detected, recovery of target compounds may be extremely low, and there is not an accepted methodology for the analysis. Therefore, nitroaromatic analyses were not performed on any biota samples. Future sampling efforts may include these compounds.

In October, 1987, the sampling effort was initiated and all designated fish samples were collected for the off-site water bodies (Lakes 34, 35, 36, 37 and the Femme Osage Slough). Fish samples were collected in Frog Pond. However, the raffinate pits and quarry sump did not contain any fish; therefore, no samples were collected. Frog samples were not attempted at either on- or off-site locations. A number of small mammals have been trapped; however, not all sampling requirements have

been met.

While laboratory analysis is not complete, some data can be presented at this time. Though it would not be prudent to draw final conclusions from a portion of the data, results have been received for fish samples at the off-site water bodies. Lake 37 was designated and sampled as a background location for this study since it does not receive runoff from any of the drainages leading from the site and is located approximately six miles NW of the WSCP/WSRP site.

Fish sample results from Lakes 34, 35, 36, and the Femme Osage Slough indicate that residual amounts of uranium are below detectable limits (0.01 pCi Nat-U/gram). Sampling of the water in Lake 34, 35, 36, and the Femme Osage Slough has shown an annual average natural uranium concentration of 25, 14, 24, and 27 pCi/liter (see Section 2.2) respectively. This would indicate that the fish have an extremely low uptake in their edible tissues and bones. It may also be concluded that human consumption of these fish yields an insignificant and still immeasurable radiation dose. Section 4.0 of this report presents dose calculations due to assumed (not measured) uptake values for uranium in ingested fish. Until all results of the biological up-take program have been received, uranium transfer factors published in the literature represent the most acceptable means of estimating human doses due to fish ingestion.

3.4 RADIOLOGICAL CHARACTERIZATION OF THE WSCP/WSRP

Previous contractors of the DOE (former AEC) and DA studied radiological conditions and levels of contamination on the WSS. The WSSRAP reviewed the associated documents of these studies and many other historical documents and found them insufficient in determining remedial action excavation boundaries or quantities and radionuclide sources. A characterization

sampling plan to determine the large scale horizontal and vertical extent of radioactive contamination within the WSCP/WSRP site boundaries was then prepared.

United Nuclear Corporation (UNC) - Geotech, Inc. performed the sampling effort during the summer of 1987. In-situ measurements and soil samples were collected at 756 locations based on a systematic grid-coordinate system. There were six types of sampling schemes chosen; near-surface soil sampling, borehole soil sampling, in-situ spectrometer measurements, in-situ delta-gamma measurements, in-situ FIDLER (Field Instruments for the Detection of Low Energy Radiation) measurements, and exposure rate measurements (UNC, 1988).

The mechanisms used for the collection of soil samples were near-surface and borehole subsurface sampling. Near-surface soil samples were collected using specially constructed shovels designed to collect uniform vertical samples in 6-inch layers. Truck-mounted hollow-stem augers and split-tube samplers were used for drilling and subsurface sampling. Borehole soils were cut into one-foot sections and then packaged for subsequent laboratory analysis. Soil sample analyses for Radium-226, Potassium-40, and Thorium-232 were performed by high-resolution germanium gamma-ray spectroscopy at an UNC Analytical Chemistry Laboratory. Soil sample analyses for uranium and Thorium-230 were performed by fluorimetric, alpha spectroscopy, or gas chromatograph analytical methods. The laboratory procedures used are described in detail in the Handbook of Analytical and Sample Preparation Methods (Bendix Field Engineering Corp., 1984).

In-situ sampling mechanisms were gamma spectrometer, FIDLER, delta-gamma, and exposure rate measurements. The spectrometer, Geometrics Model GR-410, was equipped with a 3-inch by 3-inch sodium iodide (NaI) detector connected to a console which measured Radium-226, Potassium-40, and Thorium-232 soil

concentrations. The UNC delta-gamma systems contain internal collimators and prefilters which use differential counting techniques in deriving radium concentrations from gamma radiation in soil. FIDLERs, Bicron Model G-5, measure low energy gamma radiation and are useful for detecting the low energy gamma rays from Uranium-238 decay products within the top few centimeters of soil. Direct gamma exposure rates were measured using Mount Sopris SC-132 scintillation counters or a Reuter-Stokes RSS-111 Pressurized Ionization Chamber (PIC).

In-situ measurements and laboratory analysis of soil samples identified radionuclide constituents and concentrations in many suspected locations on the WSCP and WSRP sites. These locations are shown in Figure 3-5. With the exception of the raffinate pits, uranium was clearly identified as the predominant radioactive contaminant.

Subsurface or near-surface soil samples were also collected at locations in the drainage pathways. None of the samples collected at these locations had Uranium-238 concentrations greater than the DOE residual soil guideline of 60 pCi/g for vicinity property locations. However, many locations in Ash Pond and Frog Pond drainages had Uranium-238 concentrations greater than 25 percent of the guideline at depths of 3 feet in Frog Pond drainage and 5 feet in Ash Pond drainage. The sediments and soils in these drainages will be investigated further when the surface outfalls have been stopped.

3.5 RADIOLOGICAL CHARACTERIZATION ACTIVITIES AT VICINITY PROPERTIES

This section briefly discusses the results of ongoing radiological and chemical characterization activities on WSS vicinity properties. WSS vicinity properties are land areas in locations surrounding the DOE-controlled WSCP, WSRP, and WSQ

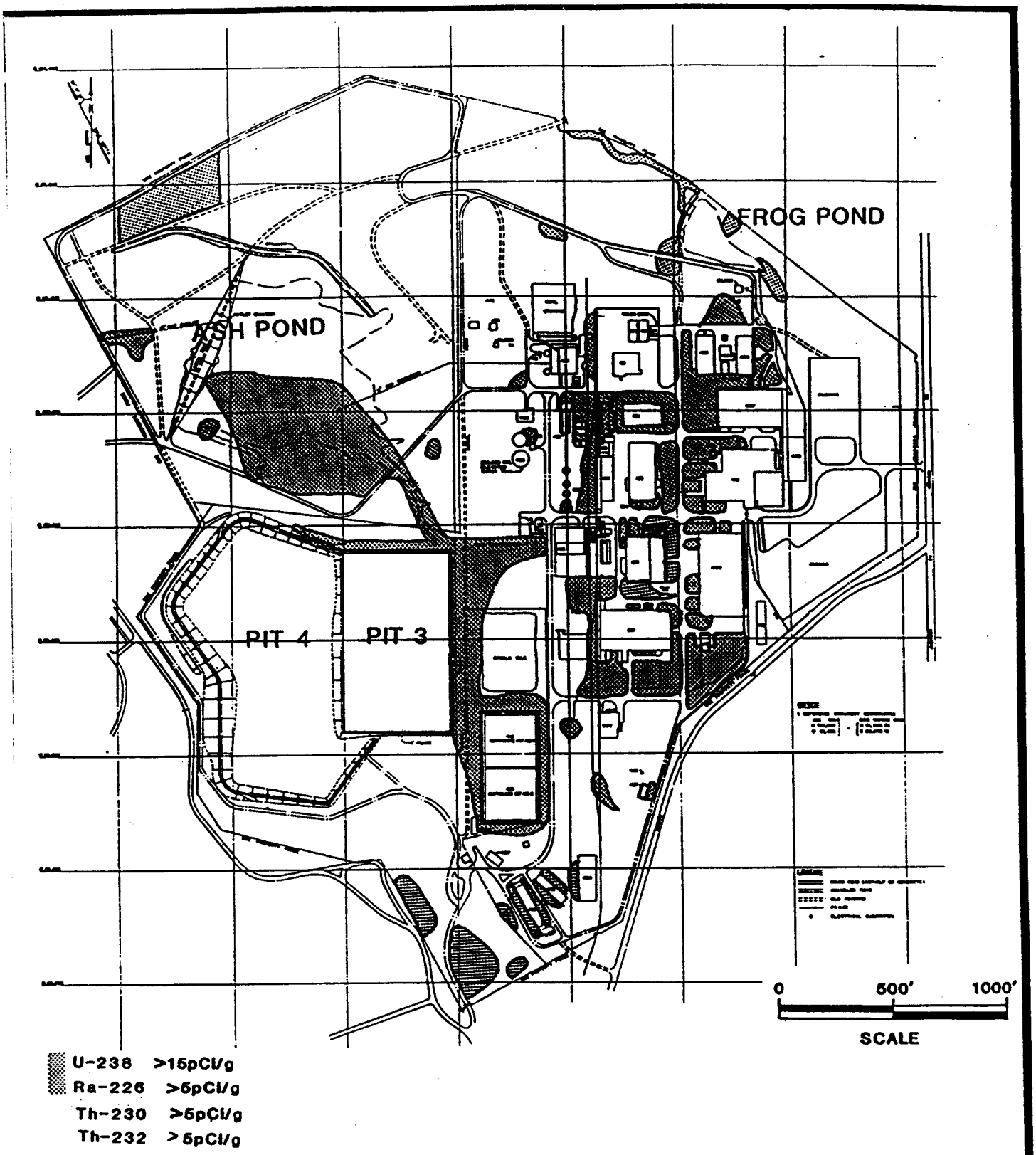

FIGURE 3-5

ESTIMATED SOIL EXCAVATION AREAS BASED ON CURRENT WSSRAP RESIDUAL CRITERIA

sites that have been identified as containing soil concentrations of radioactivity in excess of current DOE residual contamination guidelines.

For natural uranium, the guidelines are tentatively set at 60 pCi/g U-238 averaged over any 15-cm-thick soil layer per 100 square meter area for all properties except the Femme Osage Slough floodplain where the guideline is tentatively set at 10 pCi/g. The guidelines for uranium were derived based on an extremely conservative site-specific pathway dose assessment for these vicinity properties (Gilbert, 1986). The specific pathway analysis would limit the effective dose equivalent to individuals residing on the decontaminated properties to 100 mrem/year (1 mSv/year).

Eleven contaminated areas were identified in the WSS vicinity during a radiological survey performed by Oak Ridge Associated Universities (ORAU) at the request of the DOE (ORAU, 1986A and ORAU, 1986B). Six contaminated areas are located on the Weldon Spring U.S. Army Training Reserve Area (WSTA), four contaminated areas are on Missouri Department of Conservation Property (DOC), and one contaminated area is located partially on WSTA land and partially on DOC land. All contaminated areas are identified on Figure 3-6.

Characterization activities began in the summer of 1987 and will continue to better define the horizontal and vertical extent of radiologic and chemical contamination on the vicinity properties. The data collected during the WSSRAP study have been and will be used to develop excavation and removal plans for the contaminated material. More detailed information is needed for remedial action because ORAU performed the survey mainly to designate and document the need for further study of these areas of elevated radionuclide concentrations.

The contaminated areas can be grouped into two categories: (1)

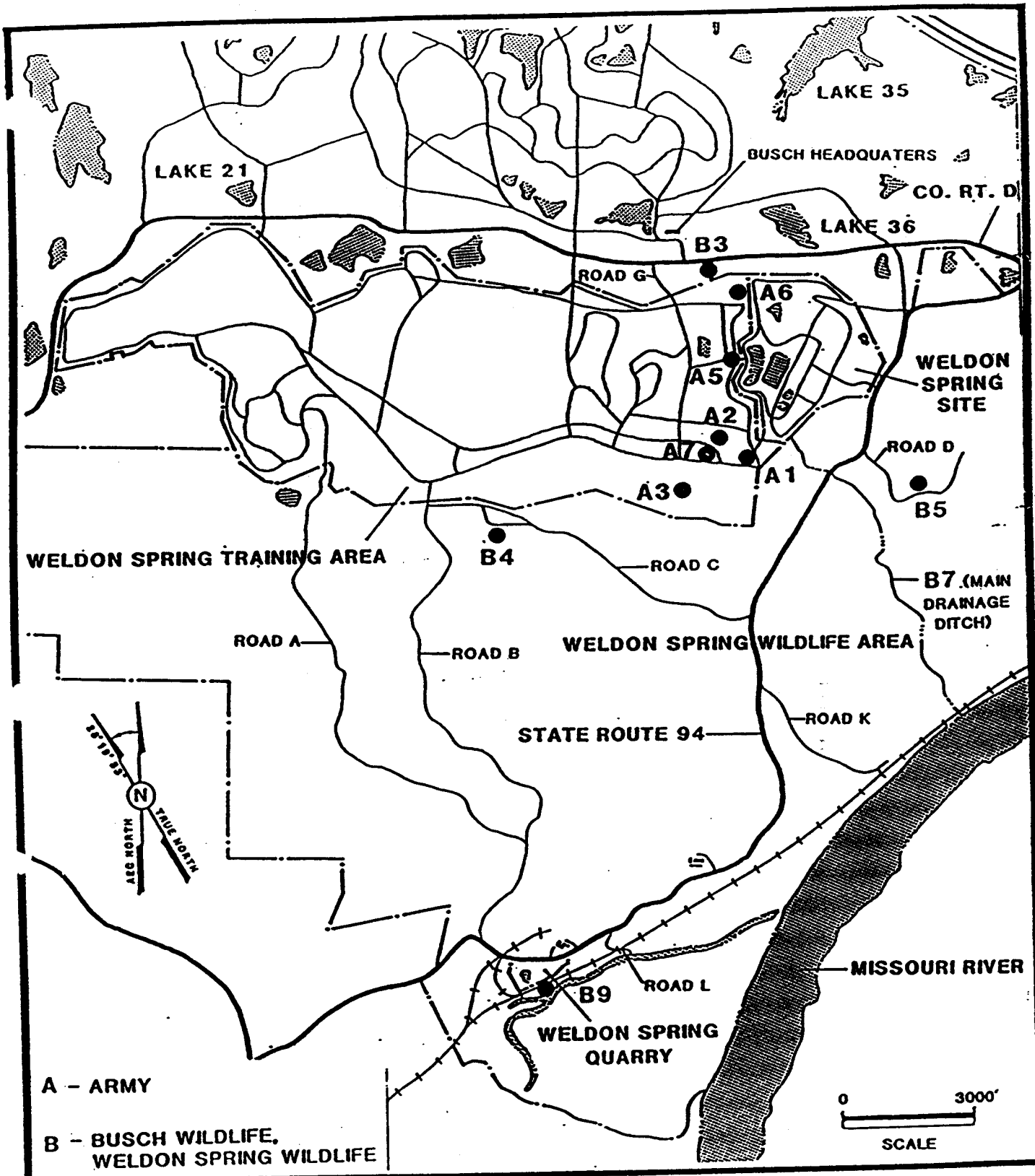

FIGURE 3-6

VICINITY PROPERTY LOCATIONS

contaminated areas that became contaminated as a result of surface water or groundwater discharges from the WSCP/WSRP or the WSQ, and (2) areas that became contaminated by disposal of contaminated material off-site or by railcars carrying radioactive materials to or from the WSCP or the WSQ. The WSSRAP vicinity property characterization activities are currently involved with the second category until the discharge of contaminated water from the WSS has been halted. The exception to this is the radiological characterization performed at the Femme Osage Slough floodplain which is hydraulically connected to the WSQ sump. UNC performed a characterization of this property for the WSSRAP in the summer of 1987 (UNC, 1988) since equipment was available for soils evaluation at the WSCP.

The potential for exposure to contaminated material on the seven non-drainageway areas resulting in adverse human health impacts is extremely low. This is primarily due to the fact that these properties are uninhabited and access to them is difficult. The areas range in size from 4 to 2,200 square yards. Five of the properties are either located in remote areas of the Weldon Spring Wildlife Preserve or access-controlled areas of the WSTA. The sixth is a 15-square-yard area located near a State of Missouri roadway where the maximum gamma exposure rate at 1 meter above the ground surface was 15 uR/hr and the maximum soil radionuclide concentration was 3,020 pCi/g U-238 (ORAU, 1986a). Considering that the maximum gamma exposure rate is less than twice natural background and that this property is small, no adverse human health effects may be expected. The seventh contaminated area contains three half-buried drums exhibiting gamma ray exposure rates ranging from 15 to 100 uR/hr at contact with the drums. No materials have leaked from these drums and a plan to remove the drums is currently being drafted with remedial action scheduled for completion by early summer 1988.

The three contaminated areas associated with drainage of surface water from the WSCP are the Southeast Drainage (B7), the Ash

Pond Drainage (A6) and the Raffinate Pit Drainage (A5). The Ash Pond and Raffinate Pit drainageways discharge into Lakes 34 and 35 on the Busch Wildlife Area. Annual average natural uranium concentrations measured in these waters in 1987 were 25 and 15 pCi/L respectively. However, these are not used as drinking water sources; therefore, no human exposure would occur via this pathway. An evaluation of exposures which may occur from eating fish caught in these lakes or from using these lakes for recreational purposes is assessed in Sections 4.1 and 4.5.

The Femme Osage Slough became contaminated by groundwater movement from the WSQ sump. In the summer of 1987, UNC collected samples from 13 boreholes on the Femme Osage Slough vicinity property (UNC, 1988). Analytical results showed uranium to be the only radioactive contaminant with soil concentrations greater than 10 pCi/g in 11 borehole locations.

Figures 3-7 and 3-8 show uranium concentrations in soil samples collected in one-foot increments beneath the surface. The isopleths drawn are for U-238 concentrations in pCi/gram on a dry weight basis. Since significant interstitial water concentrations have been measured in wells in this area, the values shown should be interpreted as the total U-238 present both in the soil material and as dissolved U-238 in water present in the sample. Nevertheless, the general patterns of the U-238 extent are correct. Because no samples were collected directly beneath the slough, little can be inferred about the U-238 distribution in this area; however, samples collected from immediately south of the slough indicate no detectable levels. Therefore, the isopleths drawn under the slough have been indicated with dashes to show that the distribution is only estimated.

Figure 3-7 represents a N-S cross section, while Figure 3-8 represents an E-W cross section through the Femme Osage Slough area. Figure 3-9 shows the locations of boreholes used to

establish cross-sections shown in Figures 3-7 and 3-8. In general, U-238 concentrations range from natural background to 106.9 pCi/g. As in the case with the other vicinity properties, public access to this vicinity property is difficult. However, fishermen have been seen in this area on occasion, and a hypothetical exposure from this property has been assessed in Section 4.3.

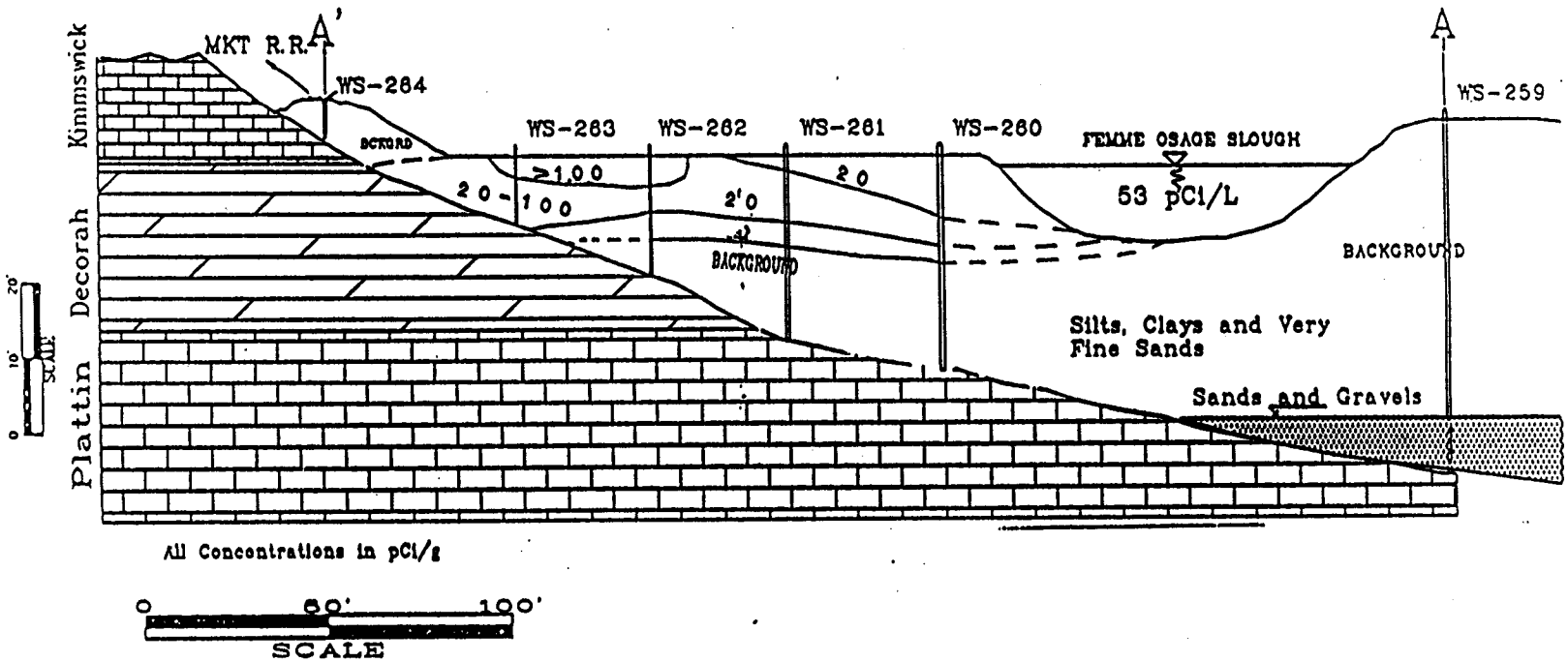

FIGURE 3-7

ALLUVIAL NATURAL URANIUM CONCENTRATIONS - GEOLOGICAL CROSS SECTION A-A'

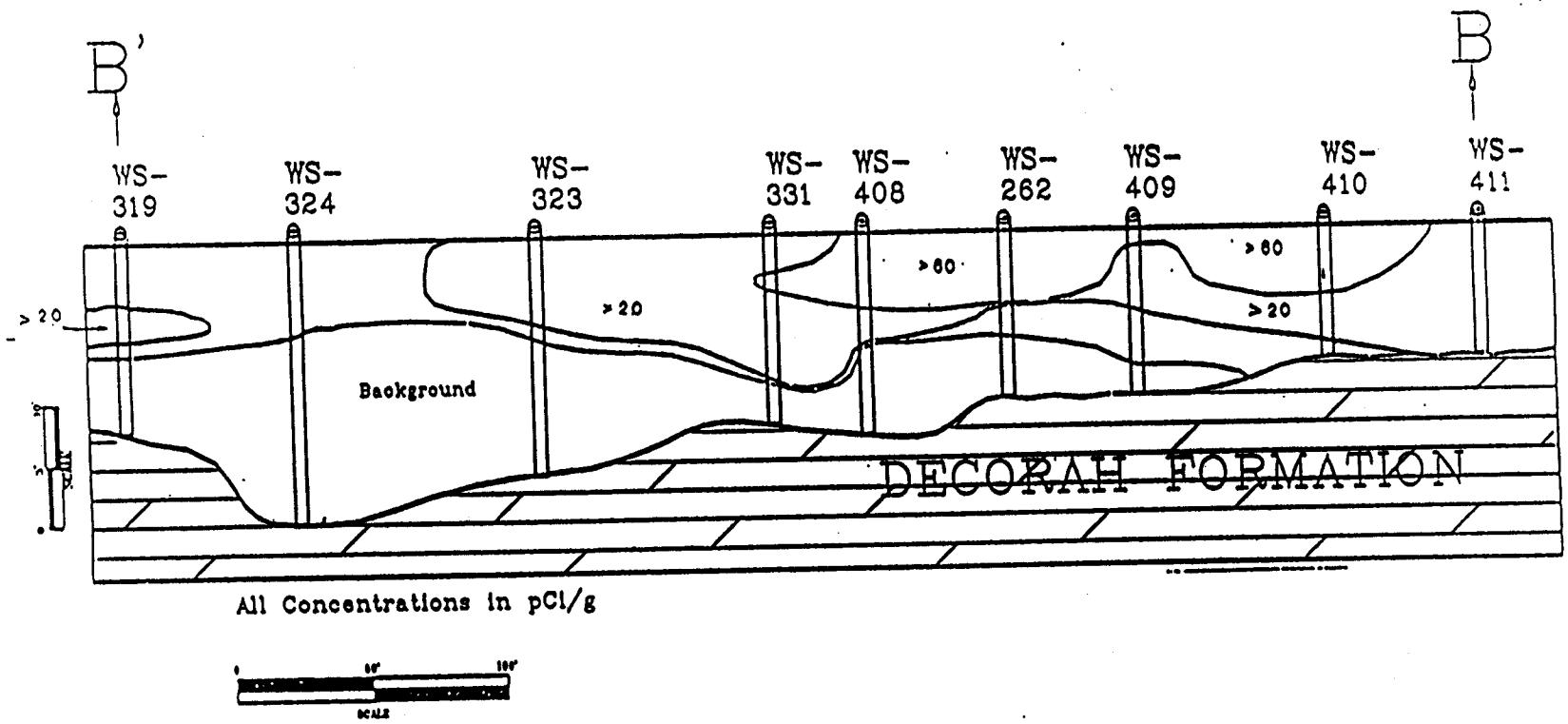

FIGURE 3-8

ALLUVIAL NATURAL URANIUM CONCENTRATIONS GEOLOGIC CROSS SECTION B-B'

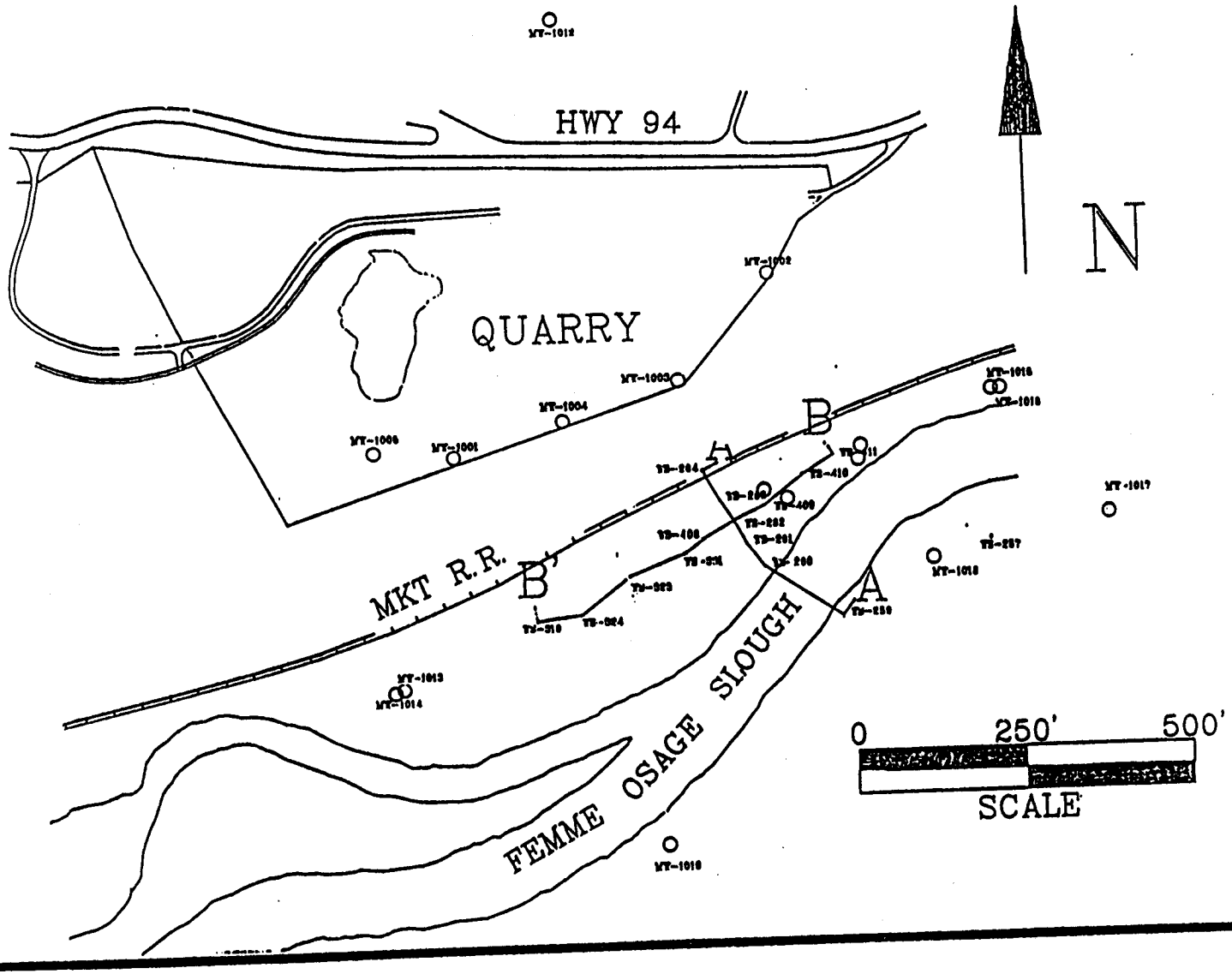

FIGURE 3-9

LOCATION OF SLOUGH BOREHOLES

4.0 RADIOLOGICAL EXPOSURE

In assessing the health effects of the radioactive materials stored at the WSCP/WSRP, WSQ, and vicinity properties as required by DOE Order 5484.1, an evaluation of the radiological exposure to persons at neighboring facilities (Francis Howell High School), recreational activities at the Busch Wildlife Area lakes and Femme Osage Slough, the general population within 50 miles of the WSS, and a maximally exposed individual was prepared. A maximally exposed individual is a hypothetical individual assumed to receive the highest realistic exposure to radiation. Exposures to maximally exposed individuals and individuals near the off-site water bodies are given in terms of an effective dose equivalent. Exposures to 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 are performed using the methodology described in ICRP's 26 and 30 for a 50-year committed dose equivalent and effective dose equivalent.

There are five principal pathways by which individuals could be exposed to radioactivity from the WSS: (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 individuals. Pathway (4) is 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 water bodies receiving runoff from the WSS. An evaluation of radiological exposures from these lakes when used for recreational purposes is provided as a thorough assessment.

4.1 MAXIMUM RADIATION DOSE TO A HYPOTHETICALLY EXPOSED INDIVIDUAL FROM WSCP/WSRP

This section derives 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 mentioned previously. No private residences are adjacent to the WSCP/WSRP sites, therefore, all direct gamma exposure, airborne dust particle inhalation exposure, and radon daughter inhalation exposure calculations assume a realistic, noncontinuous (less than 100 percent of resident) time exposure. 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. Department of Agriculture statistics (USDA, 1986). None of these water bodies are used as drinking water sources; therefore this pathway was not included in the exposure calculations.

Three environmental TLD monitoring stations were used in evaluating direct gamma exposures for the most frequently exposed individual at a neighboring facility who may be either employees at the Weldon Spring Training Area (WSTA), Missouri State Highway Department (MSHD), or August A. Busch Memorial Wildlife Area (AABMWA). Employees at each facility were expected to spend 40 hours per week and 50 weeks per year at work and in these areas. The average direct gamma exposure rates were not significantly above background levels at the WSTA, MSHD, and AABMWA. Therefore, the calculated effective dose equivalent from direct gamma exposure is not measurable above normal background exposure.

Three airborne particle sampler locations were used in evaluating the dose by inhalation of airborne dust particles for the most frequently exposed individual at a neighboring facility who may be employed at the WSTA, MSHD, or AABMWA. Individuals were assumed to inhale 2,400 m^3 of air at these locations a year. The average airborne particle concentrations were not

significantly above background levels at the WSTA, MSHD, or AABMWA. Therefore, the highest calculated effective dose equivalent from inhalation of airborne dust particles at all three locations is not measurable above normal background exposure.

Three track-etch radon monitoring stations were used in evaluating the dose by inhalation of radon daughters for the most frequently exposed individual who may be employed at the WSTA, MSHD, or AABMWA. The same assumptions as for inhalation of airborne dust particles are applied for inhalation of radon daughters. The average measured radon gas concentrations were not significantly above background at the WSTA, MSHD, and AABMWA. For this reason the calculated effective dose equivalent from inhalation of radon daughters is not measurable above normal background exposure.

Three off-site water bodies (Lakes 34, 35, and 36) receive runoff from drainage or ponds located at the WSCP/WSRP site. All three water bodies are located on the AABMWA and are presently used for recreational activities such as fishing and boating. Average surface water concentrations were used to calculate the tissue concentration of fish who live in these waters. Annual average concentrations of natural uranium in surface water measured during 1987 in Lakes 34, 35, and 36 were 25, 15, and 24 pCi/L respectively. Radium and thorium concentrations were not above normal background levels.

Brodsky (CRC, 1982) has compiled radionuclide aquatic transfer factors for freshwater fish in examining the environmental release of radioactivity. Using the transfer factor of 2.0 uCi/kg wet weight per uCi/liter in water for natural uranium, the concentrations in fish tissue would be expected to be 0.05, 0.03, and 0.05 pCi/g for Lakes 34, 35, and 36 respectively. Using an average annual consumption rate of 4086 grams/year for freshwater fish (USDA, 1986), the highest calculated dose from

ingestion of fish living in contaminated water bodies would be less than 1 mrem (<0.01 mSv).

The effective dose equivalent from each of the pathways described above was assumed to be received by a hypothetically exposed individual. A maximally exposed individual would receive a sum less than 1 mrem (<0.01 mSv) from direct gamma exposure, inhalation of airborne dust particles, inhalation of radon daughters, and ingestion of fish from contaminated waters.

4.2 MAXIMUM RADIATION DOSE TO A HYPOTHETICALLY EXPOSED INDIVIDUAL FROM WSQ

This section calculates an estimated effective dose equivalent to a hypothetical individual assumed to most frequent the perimeter of the WSQ and receive a radiation dose by the five pathways mentioned previously. No private residences are adjacent to the WSQ site, therefore, all direct gamma exposure and radon daughter inhalation exposure calculations assume a realistic, noncontinuous or less than 100 percent of resident time exposure. Airborne dust particle concentrations were not measured; however, the quarry is not suspected of having significant radionuclide airborne particle concentrations above normal background since most of the contaminated soils on the quarry floor are saturated and there are no remedial activities occurring on-site at this time. The amount of fish obtained and ingested from nearby water bodies receiving recharge or runoff from the quarry assumes the average consumption rate per year by the U.S. Department of Agriculture statistics (USDA, 1986). The Femme Osage Slough and Creek are not used as drinking water sources; therefore, this pathway was not included in the exposure calculations.

Four environmental TLD monitoring stations were used in evaluating the dose by direct gamma exposure for the most

frequently exposed individual. A realistic, but very insignificant exposure would occur to an individual who drives by the site twice per day on Highway 94. In past EMR's, a conservative approach was used in which an individual was assumed to walk by the site along Highway 94 twice per day, thus assuming a residence time of 20 minutes per day, 365 days per year. Using this conservative assumption, and noting the average measured gamma exposure rates were not significantly above background along the northern perimeter of the WSQ, the calculated dose from direct gamma exposure is not measurable above normal background exposure.

Four track-etch radon monitoring stations were used in evaluating the dose by inhalation of radon daughters for the most frequently exposed individual. The hypothetical individual who walks by the site twice per day is assumed to be the most frequently exposed individual. The average measured radon gas concentration was 2.3 pCi/L above normal background. Assuming fifty percent equilibrium between radon gas and its decay products or daughters and 1.7 rem/Working Level Months (NCRP Publication No. 78, ICRP Publication 26), the annual calculated effective dose equivalent from inhalation of radon daughters would be 14 mrem (0.14 mSv).

The Femme Osage Slough is hydraulically connected to the quarry sump, thereby receiving recharge from the WSQ. The slough is located on the Weldon Spring Wildlife Area and is presently used for recreational activities such as fishing. Average surface water concentrations were used to calculate the tissue concentration of fish in the slough. The annual average natural uranium surface water concentration measured in 1987 was 27 pCi/L. Using Brodsky's transfer factor of 2.0 uCi/kg wet weight per uCi/liter in water for natural uranium, the tissue concentrations of fish would be 0.05 pCi/g. Using the average annual consumption rate of 4,086 grams/year (USDA, 1986), the calculated effective dose equivalent from ingestion of fish

living in contaminated waters would be less than 1 mrem (<0.01 mSv).

The effective dose equivalent from each of the pathways mentioned above was assumed to be received by a hypothetically exposed individual. A maximally exposed individual would receive a sum of 14 mrem (0.14 mSv) from direct gamma exposure, inhalation of radon daughters, and ingestion of fish from contaminated waters.

4.3 MAXIMUM RADIATION DOSE TO A HYPOTHETICALLY EXPOSED INDIVIDUAL FROM WSVP'S

This section calculates an estimated effective dose equivalent to a hypothetical individual assumed to most frequent the largest vicinity property (VP) located south of the WSQ and receive a radiation dose by the five pathways mentioned previously. Occupancy of this vicinity property is considered to represent a conservative realistic exposure assessment. No private residences are adjacent to the VP, therefore, all direct gamma exposure will assume a realistic, noncontinuous or less than 100 percent of resident time exposure. Airborne dust particle and radon daughter concentrations were not measured; however, the VP is not suspected of having radionuclide airborne particle concentrations and radon daughter concentrations above normal background since this floodplain has saturated soil which would minimize airborne migration, and is contaminated with natural uranium and its immediate daughter products. The amount of fish obtained and ingested from the Femme Osage Slough, which receives recharge through the VP from the quarry sump, assumes the average consumption rate per year by the U.S. Department of Agriculture statistics (USDA, 1986). The Femme Osage Slough is not used as a drinking water source; therefore, this pathway was not included in the dose calculations.

Radionuclide concentrations in soil were used to derive the effective dose equivalent by direct gamma exposure for the most frequently exposed individual who is assumed to sit and fish on this vicinity property four hours per week and 50 weeks per year. The average soil concentration near the bank of the Femme Osage Slough is 10 pCi Nat-U/gram (UNC, 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).

Using the same assumptions as Section 4.2, the calculated effective dose equivalent from ingestion of fish from the slough would be less than 1 mrem (<0.01 mSv).

The effective dose equivalent from each of the pathways mentioned above was assumed to be received by a hypothetically exposed individual. A maximally exposed individual would receive less than 1 mrem (<0.01 mSv) from direct gamma exposure and ingestion of fish from contaminated waters.

4.4 POPULATION DOSES

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 from a large group of people exposed to radiation under different circumstances. Accepted statistical models are not applicable to the dose-response of a single individual.

An estimate of the total risk to a large population from exposure to radiation may be made by multiplying average calculated doses by the entire number of persons expected to be exposed to an average radiation dose. Such multiplication is referred to as a measure of collective dose equivalent in

person-rem (person-sievert). Statistical models may then be applied to the large population in order to estimate health risk.

4.4.1 Dose to Francis Howell High School Population

To accurately determine the collective radiation dose equivalent, the radiation exposure should be measured at the point where the collective dose equivalent is to be estimated. The Francis Howell High School is located 0.5 miles northeast of the WSCP and has a monitoring station continuously measuring three pathways of exposure. Samples of radioactive air particulates are collected and exchanged on a weekly basis while radon concentrations and external gamma exposure rates are collected and exchanged quarterly. Water supplied to the school from the St. Charles County well field is also sampled and analyzed quarterly. The instrumentation and analytical methods used for these determinations are sensitive to radiation levels equal to or less than 10 percent 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. Since the contributions to population dose via all exposure pathways do not significantly exceed natural or normal background, there is no statistically determinate collective effective dose equivalent above background levels.

4.4.2 Population Doses Within 80 km (50 miles)

This section evaluates the conceptual collective effective dose equivalent to the population (i.e. general public) within an 80-km (50-mile) radius of the WSS. The dose must be calculated or estimated, since it is unreasonable to attempt pathway specific measurements relative to every individual. The exposure pathways considered here are: external exposure to gamma radiation, inhalation of radon and radon daughters, inhalation of radioactive air particulates, and ingestion of water, fish or game animals containing radioactivity.

At the three off-site gamma radiation monitoring stations all measurements were at normal background levels (See Section 2.4). Similarly the three off-site radon monitoring stations and air particulate monitoring stations provided measurements 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 from 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 any dose evaluation. Preliminary assessment of the fish and game animal consumption pathway indicates no detectable concentrations of radioactivity above background, hence this is not an 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.

The effective dose equivalent from radioactively contaminated water from the water bodies is estimated using total natural uranium concentration levels and the dose conversion factors presented in Table 4-1 (ANL, 1986). For calculational purposes, Uranium-238 and its immediate transformation products (Thorium-234, Protactinium-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 units of millirem per year (mrem/yr) and millisievert per year (mSv/yr).

Summaries of the potential radiation dose to individual members of the general public from these exposure pathways are given in Table 4-1. 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.

TABLE 4-1

SUMMARY OF THE ESTIMATED RADIATION DOSES TO AN INDIVIDUAL FROM RECREATIONAL ACTIVITIES AT LAKES 34, 35, 36 AND THE FEMME OSAGE SLOUGH

Pathway	Ingestion/ Time Spent	Dose (Lake 34) (mrem/yr)*	Dose (Lake 35) (mrem/yr)*	Dose (Lake 36) (mrem/yr)*	Dose (Femme Osage Slough) (mrem/yr)*
Direct radiation along water shores	12 hr/yr	1.1×10^{-6}	6.6×10^{-7}	1.0×10^{-6}	1.2×10^{-6}
Direct radiation from swimming	12 hr/yr	8.1×10^{-6}	4.9×10^{-6}	7.7×10^{-6}	8.7×10^{-6}
Direct radiation from boating	12 hr/yr	2.2×10^{-6}	1.4×10^{-6}	2.2×10^{-6}	2.4×10^{-6}
Internal exposure from accidental ingestion of water	1.0 liter/yr (33 oz/yr)	6.3×10^{-3}	3.8×10^{-3}	6.0×10^{-3}	6.8×10^{-3}

PATHWAY	DOSE CONVERSION FACTORS
Direct radiation along water shores	7.3×10^{-9} (mrem/hr)
Direct radiation from swimming	5.4×10^{-8} (mrem/hr)
Direct radiation from boating	1.5×10^{-8} (mrem/hr)
Internal exposure from accidental ingestion of water	2.5×10^{-4} (mrem/pCi)

* To convert mrem/yr to mSv/yr, multiply by 0.01

5.0 FUTURE ENVIRONMENTAL MONITORING AT THE WELDON SPRING SITE

In 1987, several site characterization activities were conducted in addition to the routine environmental monitoring at the WSS. The data collected have led to a better understanding of the contaminant migration from the site. This knowledge has allowed the WSSRAP to tailor the environmental monitoring program to address all potential receptors for all hazardous materials potentially being released to the environment. In 1988, additional detailed site characterization efforts will be conducted at the WSCP/WSRP areas, and at off-site locations such as lakes and streams where potential contaminant migration has occurred. The data from these new characterization activities are likely to lead to changes in the routine Environmental Monitoring Program Plan for the WSSRAP.

The Phase I Water Quality Assessment has led to the installation of 31 new monitoring wells (Figure 5-1) at the WSCP/WSRP area. Subsequent sampling and analysis of these wells will provide additional subsurface data concerning groundwater contaminant migration.

The completion of an additional year of sampling and analysis has created a useful data base on chemical and radiologic contaminants present in different media. Analysis of this data will allow selection of specific indicators for monitoring and exposure evaluations. Trends or fluctuations in data as a function of temperature, season, or precipitation events are currently under evaluation.

Specific locations on-site have been identified as potential source areas, and migration from these locations is under investigation. By combining the existing chemical and radiological data, knowledge of source areas, and preliminary information on groundwater migration direction and surface water-discharge, a more focused monitoring plan will be developed for

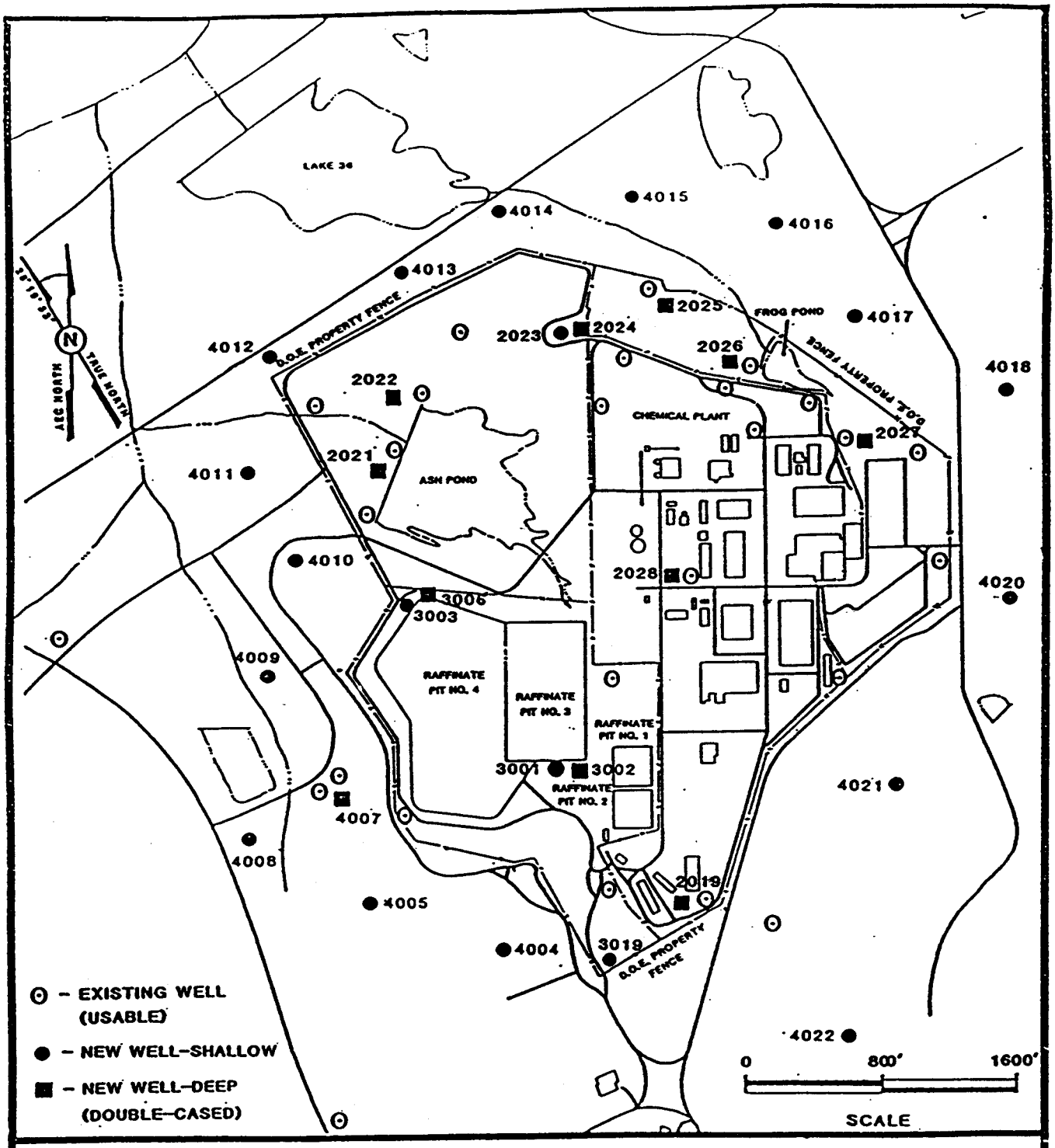

FIGURE 5-1

LOCATIONS OF EXTENDED MONITORING WELL NETWORK

1988. This plan will include the quarterly sampling of locations where migration is expected to occur or presently occurs at concentrations which may pose an increased risk. Certain locations will be sampled on an annual or semiannual basis rather than a quarterly basis. Additional locations will be added to provide a statistical evaluation of background levels for parameters such as uranium, metals, and radon.

The 1988 Environmental Monitoring Program Plan will describe the location, frequency and chemical and radiological analytical parameters which will be analyzed from the various media. This data will be used to establish baseline conditions prior to any remedial actions, and provide a monitoring and detection program which ensures public health and safety.

A more extensive asbestos air monitoring program is being implemented at the WSS, beginning in March 1988. Site perimeter asbestos air monitoring will be performed routinely at the airborne particulate sampler locations AP-2001, AP-3002, and AP-4006 (Refer to Figure 2-6). Samples will be collected twice per week, under a variety of weather conditions. This program will result in an improved data base of airborne asbestos concentrations before, during and after asbestos removal work activities which are planned as part of the interim response actions to be carried out in 1988.

In addition to the above monitoring activities, asbestos air monitoring will be performed on a continual basis both inside and outside of controlled asbestos removal areas during all asbestos removal work activities. The expedited sampling results will enable the containment measures to be evaluated and allow any necessary corrective measures to be initiated.

All asbestos air samples will be analyzed using Phase Contrast Microscopy (PCM). This analytical method is non-specific for asbestos fibers, but rather measures all airborne fibers having

specified size and shape characteristics. On a periodic basis, duplicate sample analysis will be performed using both PCM and Transmission Electron Microscopy (TEM) analytical methods. TEM analysis is specific for asbestos fibers and allows the detection of smaller fibers than does the PCM methodology. This will provide a basis for comparing levels of total airborne asbestiform fibers (PCM method) with airborne asbestos fibers (TEM method).

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APPENDICES

APPENDIX A

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 = 2.703×10^{-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: The inclusion of foreign substances 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} dis/s), which is approximately equal to the decay of one gram of Radium-226.

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: Radiation 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 film badge (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).

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 require dense materials (such as lead) for shielding.

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 is 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 occuring 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.

RELATIVE PERCENT DIFFERENCE: Measure of the relative percent difference between recoveries of duplicate samples. RPD is used to evaluate long-term precision of analytical methods

RPD = Relative Percent Difference
R_1 = Recovery Sample
R_2 = Recovery of Sample Duplicate

$$RPD = \frac{R_1 + R_2}{(R_1 - R_2)/2} * 100$$

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.

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 occuring, 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 B

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
ORNL	Oak Ridge National Laboratory

APPENDIX B

ABBREVIATIONS (Continued)

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 C - QUALITY ASSURANCE

The quality assurance (QA) program conducted in 1987 for both routine environmental monitoring and characterization activities was composed of two components: field and analytical QA evaluations.

The field QA program for field activities included the following:

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

- Annual audit of all field procedures with follow-up corrective action programs, if required.

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

- The routine collection and analysis of QC blanks including trip blanks and equipment blanks.

The analytical QA program for laboratory analyses made use of 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, batch not to exceed 20 samples). Method blanks contain all the reagents used in the preparation and analysis of samples to assess contamination rising from reagents, glassware and other materials used in the analysis.

- Laboratory Control Samples/Spiked Blanks (LCS - one per batch, batch not to exceed 20 samples). These samples were prepared by adding known quantities of compounds of interest to deionized water and were used to establish that

an instrument or procedures were in control.

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

- Duplicate and Spike Samples (5% duplicate; 5% spike). Analysis of duplicate samples was performed to enable an estimate of the precision of the analytical procedures. Spike samples were measured to determine the accuracy of the analytical procedure and access matrix effects. For analyses conducted according to the Contract Laboratory Program (CLP) methodology, these controls are termed matrix spike and matrix spike 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 analyst. These samples, in addition to the standard duplicate sample analysis discussed above, were used to access analytical precision.

- EPA Laboratory Performance Evaluation (PE) (Annually) In order to access overall performance of the primary analytical laboratory spike samples were submitted annually by EPA Region VII to the PMC primary laboratory.

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

The specific monitoring activities included in the environmental monitoring program were measurement of external gamma dose rate, measurement of radon concentration, air particulate analysis for radioactivity, and surface water and groundwater analyses for various organic, inorganic, and radioactive species. The

quality assurance results for each monitoring activity, except radon, are discussed in the following text. The radon quality assurance results are included in Section 2.3 of this report.

C 1 EXTERNAL GAMMA MONITORING QUALITY ASSURANCE

During each calendar quarter the radiation levels at two gamma monitoring stations were measured with duplicate thermoluminescent dosimeters (TLD). This allowed an assessment of the precision of the external gamma measurements.

The field duplicate results for 1987 are summarized per station and per quarter in Table C.1. These data are considered incomplete since three of eight measurement results are missing. The measurement results at each first quarter station and at one fourth quarter station were not available because one or both of the TLD's at these stations had been vandalized. A statistical comparison between duplicates indicated reasonable agreement. Third quarter duplicate at station 2003 was outside the acceptable confidence internal.

TABLE C 1
DUPLICATE RESULTS AT THE EXTERNAL GAMMA ENVIRONMENTAL MONITORING STATIONS FOR 1987

STATION[a]	RESULT[b] (mrem)*	DUPLICATE[b] RESULTS (mrem)*
	FIRST QUARTER (both field duplicates missing)	
	SECOND QUARTER	
TD-1004	39.0 ± 5.1	40.0 ± 12.3
TD-2003	33.6 ± 6.1	37.0 ± 8.3
	THIRD QUARTER	
TD-1004	44.2 ± 3.8	44.8 ± 4.0
TD-2003	44.0 ± 3.3	32.4 ± 2.7
	FOURTH QUARTER (one field duplicate missing)	
TD-2005	26.2 ± 3.3	18 ± 4.9

(a) The locations of these sampling stations are shown in Figure 2.6.

(b) The indicated error is the 95 percent confidence limit around the mean.

* To convert to Sv, multiply by 1×10^{-5}

C 2 AIR PARTICULATE QUALITY ASSURANCE

The accuracy of the radiochemical analyses of the air particulate filters was assessed through the use of field blanks and lab blanks. The field blanks are filters prepared as if used for sampling, carried through the week or weekend filter exchange process, and radiochemically analyzed like the air particulate samples. The laboratory blanks are laboratory filter preparation solutions, minus any filters, that are carried through the laboratory analyses. In each case, for the field blanks and laboratory blanks, the analytical results were less than method detection limits.

The precision of the radiochemical analyses of the air particulate filters was assessed through the use of laboratory blank spike samples. The blank spikes were analyzed in duplicate and the relative percent difference (RPD) of the results evaluated. In all cases, the RPD was within laboratory control limits. Because of the field sampling methodology, field duplicates were not collected and so corresponding RPD's were not developed.

The gross alpha measurements were performed on-site, and duplicate measurements of filters were within the error bounds attributable to counting statistics at the 95 percent confidence limits. The air particulate quality assurance data is considered representative but incomplete. Third and fourth quarter quality assurance data were pending at the time of EMR completion.

C 3 GROUNDWATER AND SURFACE WATER QUALITY ASSURANCE

Field Evaluation

Field audits of all procedures associated with the collection of environmental samples were conducted during 1987. These audits were conducted by individuals from the Quality Assurance staff, who function independent from the field sampling team. All field personnel were trained and knowledgeable of the procedures used for sample collection. Standard Operating Procedures associated with the collection of environmental samples included:

- Surface Water Sampling
- Groundwater Sampling
- pH Measurement in Water
- Specific Conductance Measurement in Water
- Water Sample Filtering
- Sampling Equipment Decontamination
- Sample Packaging for Shipment
- Chain of Custody

QA/QC audit report of field procedures cited no findings of nonconformance, and no corrective action resulted.

Evaluation of trip blanks and equipment blanks were audited quarterly to access field performance. Table C 3.1 shows the results from the equipment blanks from first and second quarter sampling. The blank samples were prepared by adding deionized water into the sampling pump and bailer after normal field decontamination. The DI water was then transfered into sample containers and analyzed. The results from the equipment blank showed carry over of low levels of metals (particularly metals found at high concentration) in field samples and nitroaromatics from previously sampled locations.

In order to eliminate contaminant carry over, dedicated sampling pumps and dedicated tubing was installed in the monitoring wells routinely sampled. Surface water samples are taken as grab samples using the original sample containers. Intermediate containers were not used. Trip blanks prepared at the laboratory accompanied all sample containers during sample collection shipment and analysis. Trip blanks are used to evaluate the possible introduction of contaminants during field activities. Trip blanks were compared with method blanks to access possible laboratory contamination. A total of 50 trip blanks were analyzed during 1987 and contamination as a result of field activities was not indicated. Several volatile organic compounds were identified (i.e. methylene chloride) in both the method blank and trip blanks and dismissed as laboratory contaminants.

Analytical Quality Assurance

The analytical quality assurance program included audits of the primary laboratory is QA/QC program, and an evaluation of the analytical quality control data which included: (1) a review of the QC duplicate samples analytical results; (2) a measure of interlaboratory variance by comparison of duplicate sample results obtained from independent laboratories; (3) an evaluation of analytical accuracy by review of percent recovery data; (4) an evaluation of analytical precision by review of relative percent difference between internal duplicate analysis; (5) and a review of the EPA performance evaluation results.

The audit of the laboratory was conducted to evaluate the conformance of laboratory personnel with required methodologies and the laboratory's QA/QC program. The audit was conducted by a member of the PMC QA staff. The audit report did not contain any observations or findings of non conformance. In addition, quality assurance summaries were included with the data results indicating conformance to appropriate methods. No variance from

standard methodology was reported.

The results of duplicate analyses are presented in Table C 3.2. Generally good agreement exists between duplicate samples. Relative percent difference (RPD) between duplicates were calculated and appeared within acceptable analytical intervals for precision. Significant variance in TOC results were noted in the first and second quarter samples. The laboratory was notified and an evaluation of the variance conducted. It was determined that modifications of the method would correct the problem. Subsequent analytical result of third and fourth quarter sampled appeared within acceptable ranges.

A total of 36 QC samples were analyzed in 1987 to evaluate intralaboratory variance or analytical bias. This evaluation included the selection of both identical and alternative methods of analysis for the parameters requested. A review of the data noted generally good correspondence between laboratories especially for low level contaminant concentrations. Some variance between laboratories was observed at higher contaminant concentrations for two parameters: nitrate and uranium. These variances appear related to differing methodologies employed. The variances are currently being evaluated through the analysis of blind reference standards submitted to both independent laboratories. Upon review of the data, a determination of the variance will be made and a preferred method selected.

Performance samples provided by EPA Region VII QC section were submitted to the PMC's primary laboratory. The spike samples contained a variety of inorganic and organic contaminants, many of which were not associated with the Weldon Spring Site. While some minor transcription reporting errors were noted, the overall analytical correspondence between the true and reported results was considered within acceptable laboratory limits.

TABLE C 3.1 - EQUIPMENT BLANK RESULTS

SAMPLE ID	2,4,6-TNT (ug/l)	2,4-DNT (ug/l)	2,6-DNT (ug/l)	Nitro-benzene (ug/l)	1,3,5-Trinitro-benzene (ug/l)	1,3-Dinitro-benzene (ug/l)	Nitrate (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Fluoride (mg/l)	TOC (mg/l)	Nat. Uranium Total (pCi/L)**	Ra-226 (pCi/L)**	Ra-228 (pCi/L)**	Th-230 (pCi/L)**	Th-232 (pCi/L)**
QUARTER 1 SAMPLING RESULTS:																
SAMPLE PRIOR TO EQUIPMENT BLANK																
GW-3008	<0.5	0.4	<0.6	<0.6	<0.03	<0.4	2654	100	31.7	1.51	2.06	7.5(1.5)	<1	<3	*	*
BAILER BLANK	<0.5	0.2	<0.6	<0.6	<0.03	<0.4	1.35	<1	<0.25	<0.25	0.8	1.8(0.8)	<1	<3	<2	<2
QUARTER 2 SAMPLING RESULTS:																
SAMPLE PRIOR TO EQUIPMENT BLANK																
GW-3007	<0.5	1.2	2.7	<0.6	<0.03	<0.4	4559	236	34	<10	<10	<1	<1		<1	<1
PUMP BLANK	<0.5	0.31	1.1	<0.6	<0.03	<0.4	0.1	<1	<0.25	<0.25	9	<1	<1		<1	<1
BAILER BLANK	<0.5	0.38	0.69	<0.6	<0.03	<0.4	0.1	<1	<0.25	<0.25	9	4.8(1.1)	<1		<1	<1

* = ANALYTICAL INTERFERENCE

** = TO CONVERT TO Bq/L, MULTIPLY BY 3.7×10^{-2}

TABLE C 3.2 - QC AND DUPLICATE ANALYTICAL RESULTS

SAMPLE ID	2,4,6-TNT (ug/l)	2,4-DNT (ug/l)	2,6-DNT (ug/l)	Nitro-benzene (ug/l)	1,3,5-Trinitro-benzene (ug/l)	1,3-Dinitro-benzene (ug/l)	Nitrate (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Fluoride (mg/l)	TOC (mg/l)	Nat. Uranium Total (pCi/L)**	Ra-226 (pCi/L)**	Ra-228 (pCi/L)**	Th-230 (pCi/L)**	Th-232 (pCi/L)**
QUARTER 1 SAMPLING RESULTS:																
GW-2015	<0.5	0.2	<0.6	<0.6	<0.03	<0.4	0.75	158	2.46	<0.25	326	8.4(1.8)	<1	<4	<5	<5
GW-2015-DU	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4	<0.1	158	2.12	0.25	2.96	4.6(1.3)	<1	<3	<3	<3
GW-3010	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4	1316	23.8	2.21	0.38	0.85	2.4(1.2)	<1	<2	<3	<3
GW-3010-DU	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4	2387	23.0	2.34	0.55	1.55	2.1(1.3)	<1	<4	<3	<3
GW-2003	<0.5	0.3	0.7	<0.6	<0.03	<0.4	3940	223	33.2	14.7	16	2.7(1.3)	<1	*	<3	<3
GW-2003-DU	<0.5	0.4	0.7	<0.6	<0.03	<0.4	4200	232	32.8	14.6	<1	<2	<1	<2	<2	<2
QUARTER 2 SAMPLING RESULTS:																
GW-1002	9.5	<0.2	<0.6	<0.6	3.2	<0.4	320	70.9	7.9	0.4	28	2.1(0.8)	<1		<1	<1
GW-1002-DU	9.5	0.84	<0.6	<0.6	3.1	<0.4	2.7	65.6	5.1	0.4	11	2.0(0.8)	<1		<1	<1
GW-2001	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4	23.6	5.5	5.6	<0.25	<1	2.4(0.8)	<1		<1	<1
GW-2001-DU	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4	23.9	5.4	5.7	<0.25	2	2.1(0.8)	<1		<1	<1
GW-3008	<0.5	0.63	<0.6	<0.6	<0.03	<0.4	4834	49.2	22.5	<10	27	3.8(1.0)	<1		<1	<1
GW-3008-DU	<0.5	0.43	<0.6	<0.6	<0.03	<0.4	4743	48.8	22.8	<10	1.0	4.0(1.0)	<1		<1	<1
QUARTER 3 SAMPLING RESULTS:																
GW-1006	7.6	<0.2	1.0	8.5	1.5	<0.4	4.4	374	51	1.2	4.49	1900(200)	<1		<1	<1
GW-1006-DU	21.7	<0.2	5.2	18.6	15.0	<0.4	4.7	365	51	1.2	4.57	1400(200)	<1		<1	<1
GW-1015	28.9	<0.2	<0.6	44.0	8.3	<0.4	1.3	160	31.5	1.0	2.55	470(50)	<1	<1	<1	<1
GW-1015-DU	25.5	<0.2	<0.6	40.8	7.5	<0.4	1.5	156	30.6	1.0	6.58	470(50)	<1	3.5(1.2)	<1	<1
GW-2013	62.1	328	222.6	5.0	13.6	7.5	2.5	29.5	9.6	0.4	7	<1	<1		<1	<1
GW-2013-DU	63.6	333.2	226	4.0	17.2	7.3	2.5	30.7	10.3	0.4	1	<1	<1		<1	<1
GW-4001	1.4	3.0	<0.6	<0.6	15.3	<0.4	182	75.9	3.0	0.4	8	<1	<1		<1	<1
GW-4001-DU	1.3	1.5	<0.6	<0.6	14.8	<0.4	160	68.2	6.2	<0.25	10	<1	<1		<1	<1

* = ANALYTICAL INTERFERENCE

** = TO CONVERT TO Bq/L, MULTIPLY BY 3.7×10^{-2}

TABLE C 3.2 - QC BLIND DUPLICATE ANALYTICAL RESULTS (continued)

SAMPLE ID	2,4,6-TNT (ug/l)	2,4-DNT (ug/l)	2,6-DNT (ug/l)	Nitro-benzene (ug/l)	1,3,5-Trinitro-benzene (ug/l)	1,3-Dinitro-benzene (ug/l)	Nitrate (mg/l)	Sulfate (mg/l)	Chloride (mg/l)	Fluoride (mg/l)	TOC (mg/l)	Nat. Uranium Total (pCi/L)**	Ra-226 (pCi/L)**	Ra-228 (pCi/L)**	Th-230 (pCi/L)**	Th-232 (pCi/L)**
QUARTER 4 SAMPLING RESULTS:																
GW-1004	<0.5	<0.2	<0.6	<0.6	0.6	<0.4	<0.10	259	31	1	<1	2800(300)	<1		<1	<1
GW-1004-DU	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4	<0.10	267	395	1	<1	2000(200)	<1		<1	<1
GW-1015	19.5	<0.2	<0.6	<0.6	5.4	6.7	1.3	1686	472	0.8	1.85	700(70)	<1		<1	<1
GW-1015-DU	20	<0.2	<0.6	<0.6	5.2	5.9	1.3	1651	480	0.8	2.08	450(50)	<1		<1	<1
GW-2001	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4	28	4.4	2.6	0.5	<0.10	1.3(0.7)	<1		<1	<1
GW-2001-DU	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4	28	4.4	2.4	0.5	0.48	1.9	<1		<1	<1
GW-2003	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4	2378	153	11.5	1.8	1.54	2.8(0.9)	<1		<1	<1
GW-2003-DU	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4	2512	160	12.3	2	1.23	2.6	<1		<1	<1
GW-2020	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4	0.5	336	4.1	0.67	<0.10	23(3)	<1		<1	<1
GW-2020-DU	<0.5	<0.2	<0.6	<0.6	<0.03	<0.4	0.6	323	3.9	0.67	<0.10	29(3)	<1		<1	<1
SW-2008	<0.5	0.5	<0.6	<0.6	<0.03	<0.4	15.5	24.4	4.1	0.31		21(2)	<1		<1	<1
SW-2008-DU	<0.5	0.5	<0.6	<0.6	<0.03	<0.4	15.4	24.7	4.0	0.31		9.9(1.6)	<1		<1	<1

** TO CONVERT TO Bq/L, MULTIPLY BY 3.7×10^{-2}

APPENDIX D

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 uCi/mL; 3) drinking water DCG in units of Bq/mL; 4) inhalation DCG in units of uCi/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.

Radionuclide	Drinking Water uCi/mL	Drinking Water Bq/mL	Inhaled Air uCi/mL	Inhaled Air 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	2**
Hardness	NS
TDS	500**
TOC	NS

---

* Primary maximum contaminant level

** Secondary maximum contaminant level

NS - No Drinking Water Standard

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

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