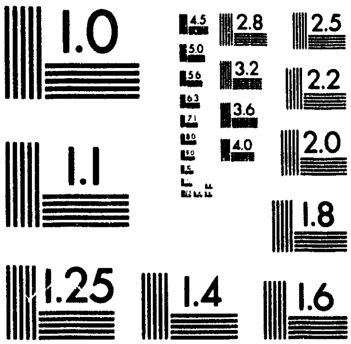
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1 of 2

DOE/OR/21949-369

HAZELWOOD INTERIM STORAGE SITE

ENVIRONMENTAL REPORT

FOR CALENDAR YEAR 1992

9200 LATTY AVENUE

HAZELWOOD, MISSOURI

MAY 1993

Prepared for

United States Department of Energy

Oak Ridge Operations Office

Under Contract No. DE-AC05-91OR21949

Bechtel National, Inc.

Oak Ridge, Tennessee

Bechtel Job No. 14501

EXECUTIVE SUMMARY

This report describes the environmental surveillance program at the Hazelwood Interim Storage Site (HISS) and surrounding area, provides the results for 1992, and discusses applicable environmental standards and requirements with which the results were compared. HISS is located in eastern Missouri in the City of Hazelwood (St. Louis County) and occupies approximately 2.2 ha (5.5 acres). Environmental monitoring of HISS began in 1984 when the site was assigned to the U.S. Department of Energy (DOE) as part of the decontamination research and development project authorized by Congress under the 1984 Energy and Water Development Appropriations Act. DOE placed responsibility for HISS under the Formerly Utilized Sites Remedial Action Program (FUSRAP), which was established to identify and decontaminate or otherwise control sites where residual radioactive materials remain from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized DOE to remedy.

In 1966 uranium ore and uranium- and radium-bearing process residues, which had been generated by a plant under contract with the Atomic Energy Commission and its predecessor, the Manhattan Engineer District, were moved to a storage site at 9200 Latty Avenue. Part of that location is occupied by the present-day HISS, and the remainder of the property is occupied by Futura Coatings, Inc. The HISS property includes three office trailers, a decontamination pad, a storage building, a water storage tank, and two interim storage piles. The interim storage piles consist of low-level radioactively contaminated soil resulting from the cleanup of industrial and residential properties in the vicinity of HISS (vicinity properties) and a partial cleanup of the site. The piles are covered with a low-permeability geomembrane, which is secured with steel cables and a geogrid fabric.

The environmental surveillance program at HISS includes sampling networks for radon concentrations in air; external gamma radiation exposure; and radium-226, thorium-230, and total uranium concentrations in surface water, sediment, and groundwater. Additionally, indicator parameters are measured in groundwater, but routine surveillance of chemical parameters is not warranted. Stormwater and radon flux monitoring are also conducted at the site.

Results obtained from routine environmental monitoring are used to assess the conditions at the site over the past year and to identify any changes. Results are compared with applicable U.S. Environmental Protection Agency (EPA) and state standards, DOE guidelines and requirements [such as derived concentration guides (DCGs) for radionuclides in water and air], federal and state maximum contaminant levels (MCLs) for drinking water, and other federal standards. These standards and guidelines are discussed in the Compliance Summary.

Results of environmental monitoring of HISS during 1992 are summarized below:

- Radon concentrations in air during 1992 were comparable to background, well below the DCG.

- Average radon flux rates were well below the federal standard in the National Emission Standards for Hazardous Air Pollutants (NESHAPs).

- External gamma radiation exposure rates were below the DOE public exposure standard at all locations except one; however, the area surrounding that location is heavily wooded, making prolonged exposure unlikely. This does not constitute a violation of DOE's policy of limiting exposure of members of the public to less than 100 mrem/yr.

- Stormwater monitoring results were within the limitations of the state-authorized National Pollutant Discharge Elimination System (NPDES) permit for the site.

- Concentrations of radium-226, thorium-230, and total uranium in surface water and groundwater were well below their respective DCGs. In a few wells, the MCL for radium-226 was exceeded; this is discussed further in the Compliance Summary.

- Total uranium and radium-226 in sediment were below the FUSRAP site-specific soil guideline. Samples of sediment from several locations exceeded the soil guideline for thorium-230; this is discussed further in the Compliance Summary.

The potential radiation dose calculated for a hypothetical maximally exposed individual from all sources at HISS is 0.13 mrem/yr (1.3 $\times$ 10^{-3} mSv/yr) above background [100 mrem/yr (1 mSv/yr)]. This dose is almost 800 times lower than the DOE dose limit and is approximately 80 times lower than the EPA inhaled dose limit. The calculated total population dose is 0.11 person-rem/yr (1.3 $\times$ 10^{-3} person-Sv/yr).

In addition to the routine monitoring activities, the following site activities were performed in 1992:

- Nonroutine sampling to fill data gaps as part of the Comprehensive Environmental Response, Compensation, and Liability Act/National Environmental Policy Act (CERCLA/NEPA) remedial investigation/feasibility study-environmental impact statement (RI/FS-EIS) process at HISS

- Routine maintenance of the storage piles and the site

- Minor site modifications and upgrades to prepare the site for additional storage capacity should the need arise

In 1992 there were no environmental occurrences or unplanned contaminant releases as defined in DOE requirements and in the Superfund Amendment and Reauthorization Act (SARA) Title III of CERCLA.

COMPLIANCE SUMMARY

The primary regulatory guidelines, limits, and DOE requirements for environmental monitoring applicable to HISS originate in the following federal acts: CERCLA as amended by SARA Title III; the Clean Air Act (CAA); the Clean Water Act (CWA); the Resource Conservation and Recovery Act (RCRA); the Toxic Substances Control Act (TSCA); the National Historic Preservation Act; NEPA; and the Safe Drinking Water Act (SDWA).

Environmental remediation of HISS is being conducted in accordance with CERCLA, the protocol for remediating low-level radioactive contamination at FUSRAP sites, and applicable DOE requirements authorized by the Atomic Energy Act. The following summaries identify applicable or relevant and appropriate requirements (ARARs) as they existed in 1992 and the first quarter of 1993, define the status of compliance with the ARARs, and forecast the regulatory changes that may affect the site in the near future.

PRIMARY REGULATORY GUIDELINES

DOE Requirements for Radionuclide Releases

Site releases must comply with specific DOE requirements that establish conservative quantitative limits, DCGs, and dose limits for radiological releases from DOE facilities. DCGs are reference values calculated for each radionuclide. A DCG is the concentration that would give a member of the public a dose of 100 mrem/yr, conservatively calculated for continuous exposure conditions. Internal DOE policy states that the exposure of members of the public to radiation sources as a consequence of all routine DOE activities must not cause an effective dose equivalent greater than 100 mrem (1 Sv) in a year.

Results of environmental monitoring during 1992 indicate that the concentrations of the contaminants of concern were below applicable standards and DCGs. Currently there are no DCGs for contaminants in sediment; therefore, monitoring results for sediments collected from the bed of Coldwater Creek and its tributaries are compared with the site-specific FUSRAP guidelines for surface soil contamination. For thorium-230, the guideline is

5 pCi/g above background [averaged over the first 15 cm (6 in.) of the soil]. This is a conservative standard of comparison because many of the exposure pathways for contaminated soil (e.g., inhalation of contaminated dust, consumption of crops grown in contaminated soil) do not apply to sediment. At two locations on Coldwater Creek, annual average thorium-230 concentrations exceeded the soil guideline, but no regulations were violated. The elevated thorium-230 values result from migration of contaminated material known to exist on numerous vicinity properties around HISS, in a small drainage ditch south of HISS, and in Coldwater Creek. These elevated values were identified during characterization activities and will be factored into the decision-making process for selecting a final remedy for the site. In 1992 there were no environmental occurrences or unplanned contaminant releases as defined in SARA Title III and DOE requirements.

Clean Air Act and National Emission Standards for Hazardous Air Pollutants

The primary federal statute governing air emissions is the CAA. The only potential sources of air emissions from HISS are radionuclide particulates and radon gas from the waste piles and the remainder of the site. HISS is not required to have any state or federal air permits. Subpart H ("National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities") and Subpart Q ("National Emission Standards for Radon Emissions from Department of Energy Facilities") of NESHAPs are applicable. NESHAPs Subpart M contains the "National Emission Standard for Asbestos." To date, asbestos-containing materials have not been detected at HISS, but if they are, all applicable requirements of Subpart M will be met.

A strategy for determining compliance with the radon flux standard in Subpart Q was approved by EPA in 1990, and compliance with the EPA-approved strategy was maintained throughout 1992 at HISS. Radon flux rates were measured to demonstrate compliance with the radon emission standard. Radon abatement efforts, including the placement of additional sealant on seams, have been successful in significantly reducing radon emissions at the site to less than 5 percent of the regulatory standard. As a result, radon flux monitoring is now being conducted annually rather than semiannually.

Airborne radioactivity (excluding radon) from the HISS storage piles and the remainder of the site has been modeled, and the hypothetical effective dose to members of the public has been calculated for 1992 using the EPA-approved Clean Air Act Assessment Package-1988 (CAP88) PC computer model, as required by Subpart H of NESHAPs. Radionuclide emissions were in compliance with applicable regulations in 1992.

Clean Water Act

Pollutants discharged to waters of the United States are regulated under the CWA through regulations promulgated and implemented by the State of Missouri. The federal government grants regulatory authority for implementation of CWA provisions to those states with a regulatory program that is at least as stringent as the federal program.

The Missouri Department of Natural Resources (MDNR) regulates stormwater discharge under its state-authorized NPDES permit program. Stormwater converges at two outfalls at HISS and is conveyed to Coldwater Creek. A revised NPDES permit (No. MO-0111252) was issued for HISS on February 21, 1992, requiring monthly discharge monitoring and quarterly reporting of the results. Monitoring parameters and requirements are listed in Table CS-1. During a few months in 1992, stormwater samples were not collected as required. Appropriate quality assurance documentation was prepared. MDNR was notified of all instances of failure to meet the terms of the NPDES permit.

In the fall of 1992, a letter agreement was negotiated with the St. Louis Metropolitan Sewer District (MSD) for the discharge of wastewater from HISS. Wastewater generated during decontamination operations and groundwater monitoring well purging is treated to meet MSD criteria and then discharged to a sanitary sewer that conveys the water to the Coldwater Creek Treatment Plant.

Safe Drinking Water Act

The SDWA was enacted by Congress in 1974 to regulate drinking water systems, require EPA to set national standards for levels of contaminants in drinking water, and

Table CS-1

Required Monitoring Parameters for NPDES Permit (No. MO-0111252) for Outfalls 001 and 002 at HISS

Parameter[a]	Units[b]
Daily	
Flow	MGD
Rainfall	inches
Monthly	
Settleable solids	ml/L/h
Quarterly	
pH	SU
Specific conductivity	μmhos/cm
Total organic carbon	mg/L
Total organic halides	mg/L
Gross alpha	pCi/L
Gross beta	pCi/L
Lead-210	pCi/L
Radium-226	pCi/L
Radium-228	pCi/L
Total uranium	pCi/L
Thorium-230	pCi/L
Thorium-232	pCi/L

[a]The final discharge limitations for settleable solids are 1.5 ml/L/h (daily maximum) and 1.0 ml/L/h (monthly average). The limitation for pH is a set range from 6.0 to 9.0. All other parameters are monitoring requirements without specific permit limits.

[b]MGD = millions of gallons per day; SU = standard units.

provide for protection of aquifers. Under SARA, drinking water standards and goals set under the SDWA became groundwater standards for CERCLA cleanups.

MCLs and maximum contaminant level goals (MCLGs) set by the SDWA are ARARs under CERCLA for the environmental remediation of HISS. Currently, there are no promulgated MCLs or MCLGs for radionuclides.

Under its state program, Missouri has also promulgated MCLs for various radionuclides. Monitoring results for HISS were compared with these state levels. Concentrations of total uranium and thorium-230 were below the respective state MCLs; concentrations of radium-226 were above the MCL in a few groundwater monitoring wells. Contaminant concentrations exceeding MCLs do not constitute a regulatory violation. However, MCLs may be the basis for establishing a cleanup goal, depending on the remedial action alternative selected for the site. The alternative selected in the CERCLA record of decision will address groundwater remediation.

Resource Conservation and Recovery Act

RCRA is the principal federal statute governing the management of hazardous waste and radioactive mixed waste that contains hazardous constituents. Missouri is authorized to implement the RCRA program.

Results from past characterization studies indicate that neither RCRA-regulated wastes nor radioactive wastes containing RCRA-regulated wastes (mixed wastes) are present at HISS.

Toxic Substances Control Act

The most common toxic substances regulated by TSCA are polychlorinated biphenyls and asbestos. TSCA-regulated waste has not been detected at HISS.

Comprehensive Environmental Response, Compensation, and Liability Act

CERCLA, as amended by SARA, and the National Oil and Hazardous Substances Pollution Contingency Plan are the primary sources of statutory authority for the response actions to be conducted at HISS. Because HISS is a DOE facility on the National Priorities List, a federal facilities agreement (FFA) is required for site remedial action. EPA and DOE signed an FFA on June 26, 1990, that integrates all response actions at the HISS/Futura Coatings, Inc. site as well as at other FUSRAP properties that compose the St. Louis site (i.e., the St. Louis Airport Site, the St. Louis Downtown Site, and vicinity properties).

The FFA integrates the provisions of CERCLA with other laws deemed as ARARs. Specifically, the parties to the FFA agreed that activities covered by the agreement will achieve compliance with CERCLA and will meet or exceed ARARs. Regular interaction with EPA Region VII ensures conformance to the requirements of the FFA and compliance with CERCLA during remediation of the St. Louis site.

No reports under SARA Title III, Section 313, were required. FUSRAP sites were not subject to toxic chemical release reporting provisions under 40 CFR 372.22 in 1992. To ensure that Section 313 reporting is performed if needed, FUSRAP evaluates and inventories chemicals maintained onsite.

DOE's policy is to integrate NEPA documentation requirements with the procedural and documentation requirements of CERCLA. The two laws have significant similarities in content; however, they have differences in scope, specific procedures, and definition of terms. DOE integrates CERCLA and NEPA to avoid the duplication of effort and the larger commitment of resources needed to implement both statutes separately.

National Environmental Policy Act

Remedial action activities at HISS will be conducted under an integrated CERCLA/NEPA RI/FS-EIS that is being developed. A CERCLA engineering evaluation/cost analysis-environmental assessment is also being developed to assess waste removal activities for HISS. Routine maintenance, monitoring, and site characterization studies have been determined to be categorically excluded from the need for further NEPA documentation.

National Historic Preservation Act

FUSRAP is actively committed to its responsibilities for managing cultural resources that may be affected by environmental restoration activities. The FUSRAP cultural resource management program ensures that the early stages of project planning provide for a thorough consideration of the areas of potential effects of environmental restoration activities on any cultural resources that may be located on FUSRAP sites. Consultation with state historical preservation officers, Native American groups, and local historians is ongoing to identify cultural resources that may be eligible for nomination to the *National Register of Historic Places* in accordance with requirements of Section 106 of the National Historic Preservation Act.

To date, the FUSRAP cultural resource management program has not identified any historic properties, such as districts, sites, buildings, and structures, at any of the FUSRAP sites that are currently undergoing environmental restoration.

Other Major Environmental Statutes and Executive Orders

In addition to DOE requirements and statutes, several other major environmental statutes have been reviewed for applicability at HISS. For example, the Federal Insecticide, Fungicide, and Rodenticide Act and the Endangered Species Act have been found to impose no current requirements on HISS. Executive Orders 11988 ("Floodplain Management") and 11990 ("Protection of Wetlands") and Missouri laws and regulations have been reviewed for applicability and compliance, and HISS currently meets these requirements. Applicable environmental statutes, regulations, and executive orders are reviewed regularly to maintain continual regulatory compliance at HISS.

APPLICABLE ENVIRONMENTAL PERMITS

The only environmental permit applied for or issued for HISS is the stormwater discharge permit issued by MDNR. A comprehensive explanation, including monitoring parameters, is presented in the CWA section of this compliance summary.

SUMMARY OF REGULATORY COMPLIANCE IN CALENDAR YEAR 1993 (FIRST QUARTER)

In 1993 radon concentrations will be monitored quarterly; external gamma radiation exposure, groundwater, surface water, and sediment will be monitored semiannually; radon flux will be measured annually; and, contingent upon the weather, stormwater will be sampled monthly.

During the first quarter of 1993, environmental monitoring continued, as did review of potential federal and state ARARs. Stormwater monitoring results continue to maintain compliance with the MDNR stormwater permit. HISS is in compliance with all ARARs identified to date. Self-assessment activities are conducted to identify areas of noncompliance or circumstances that fail to meet best management practices. To date, self-assessments have not identified any instances of noncompliance. There have been no environmental occurrences or unplanned releases as defined in SARA Title III and DOE requirements.

CONTENTS

CONTENTS

(continued)

FIGURES

FIGURES
(continued)

TABLES

TABLES

(continued)

ACRONYMS

BNI	Bechtel National, Inc.
CAA	Clean Air Act
CAP88	Clean Air Act Assessment Package - 1988
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CSR	Code of State Regulations
CWA	Clean Water Act
DCG	derived concentration guide
DOE	Department of Energy
DQO	data quality objective
EE/CA-EA	engineering evaluation/cost analysis-environmental assessment
EPA	Environmental Protection Agency
FFA	federal facilities agreement
FUSRAP	Formerly Utilized Sites Remedial Action Project
HISS	Hazelwood Interim Storage Site
KPA	kinetic phosphorescence analysis
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDA	minimum detectable activity
MDNR	Missouri Department of Natural Resources
MSD	Metropolitan Sewer District

ACRONYMS

(continued)

NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
PARCC	precision, accuracy, representativeness, comparability, and completeness
PERALS	photon/electron-rejecting alpha liquid scintillation
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RI/FS-EIS	remedial investigation/feasibility study - environmental impact statement
SDWA	Safe Drinking Water Act
SLAPS	St. Louis Airport Site
TDS	total dissolved solids
TETLD	tissue-equivalent thermoluminescent dosimeter
TPQ	threshold planning quantity
TSCA	Toxic Substances Control Act
WMPPAP	Waste Management and Pollution Prevention Awareness Plan

UNITS OF MEASURE

Bq	becquerel
°C	degrees Celsius
cfs	cubic foot per second
cm	centimeter
°F	degrees Fahrenheit
ft	foot
ft MSL	feet above mean sea level
g	gram
gpm	gallons per minute
h	hour
ha	hectare
in.	inch
km	kilometer
L	liter
m	meter
μCi	microcurie
μg	microgram
mg	milligram
mi	mile
ml	milliliter
mm	millimeter
μmhos	micromhos

UNITS OF MEASURE

(continued)

mph	miles per hour
mR	milliroentgen
mrem	millirem
mSv	millisievert
pCi	picocurie
rem	roentgen equivalent man
s	second
Sv	sievert
yd	yard
yr	year

1.0 INTRODUCTION

Environmental monitoring of the U.S. Department of Energy's (DOE) Hazelwood Interim Storage Site (HISS) and surrounding area began in 1984. This document describes the environmental surveillance program, implementation of the program, and results for 1992.

HISS was assigned to DOE as part of the decontamination research and development project authorized by Congress under the 1984 Energy and Water Development Appropriations Act. DOE placed responsibility for HISS under the Formerly Utilized Sites Remedial Action Program (FUSRAP), which was established to identify and decontaminate or otherwise control sites where residual radioactive materials remain from the early years of the nation's atomic energy program or (as is the case for HISS) from commercial operations causing conditions that Congress has authorized DOE to remedy.

1.1 SITE DESCRIPTION

HISS occupies approximately 2.1 ha (5.3 acres) in eastern Missouri within the City of Hazelwood (St. Louis County) (Figure 1-1). The HISS property includes three office trailers, a decontamination pad, a storage building, a water storage tank, and two interim storage piles. The piles are covered with a low-permeability geomembrane (i.e., geotextile coated with a urethane waterproofing compound) secured with steel cables and a geogrid fabric. The piles contain soils that are being held in interim storage until a suitable disposal alternative is selected. The piles were generated as a result of a partial cleanup of the site in 1977 and 1985 and from installation of a municipal storm sewer system along Latty Avenue in 1986 during which contamination from some vicinity properties was excavated. The piles have surface areas of approximately 5,546 and 1,486 m^2 (59,700 and 16,100 ft^2) (Figure 1-2). The site is entirely fenced, and public access is restricted (BNI 1987).

Wastewater is periodically generated at the site during equipment decontamination and well purging activities. The wastewater is treated, analyzed for specific radionuclides and chemicals, and released from the site upon approval from the St. Louis Metropolitan Sewer District (MSD) (refer to Subsection 2.2).

In early 1966, uranium ore and uranium- and radium-bearing process residues that had been stored at the St. Louis Airport Site (SLAPS) were purchased by the Continental Mining and Milling Company, Chicago, Illinois. The residues had been generated by a plant at the St. Louis Downtown Site from 1942 through 1957 under contract with the Atomic Energy Commission and its predecessor, the Manhattan Engineer District. The residues were moved to a storage site at 9200 Latty Avenue, a part of which is the present-day HISS. The Commercial Discount Corporation of Chicago, Illinois, purchased the residues on January 1, 1967; much of the material was dried and sold to the Cotter Corporation, which shipped the material to facilities in Canon City, Colorado. In December 1969, Cotter purchased the remaining source material. From August through November 1970, Cotter dried some of the remaining residues at the site and shipped them to its mill in Canon City.

In April 1974, Cotter informed the newly established Nuclear Regulatory Commission (NRC) that some of the residues had been shipped in mid-1973 to Canon City without drying and that the remainder had been diluted with site soil and transported, without NRC consent, to a landfill in St. Louis County. Reportedly, 30.5 to 45.7 cm (12 to 18 in.) of topsoil had been removed with the residues. The NRC license for storage was terminated because it was believed that all residues had been removed. The entire 9200 Latty Avenue property was released for sale. The property, which is now owned by Jarboe Realty and Investment Company, is divided by a chain-link fence into two sections. The western section is leased by Futura Coatings, Inc., and the eastern section, HISS, is leased by DOE for use as a storage facility for low-level radioactively contaminated materials.

1.2 REGIONAL DEMOGRAPHY

As shown in Figure 1-3, land use in the vicinity of HISS is predominantly industrial and commercial. The site is bordered by manufacturing companies to the north, east, and west, and a wooded area and Coldwater Creek to the south.

The principal source of potable water in the HISS area is treated water from the Mississippi River; approximately 100 percent of the City of Hazelwood uses this source. Water to be treated for public use is taken from the Mississippi River approximately 40 km (25 mi) downstream of HISS (Chain-of-Rocks Water Treatment Facility). Coldwater Creek (not used as a source of drinking water) empties into the Missouri River, which discharges into the Mississippi River. The nearest potable surface water supply facilities on the Missouri River are Central Plant and Howard Bend Plant, both of which are upstream of the point at which Coldwater Creek empties into the river.

The nearest residential areas are approximately 0.5 km (0.3 mi) east of HISS in Hazelwood (population 26,653) and 0.8 km (0.5 mi) south in Berkeley (population 12,450). The residences are primarily single-family dwellings. The total population of the area within an 80-km (50-mi) radius of HISS is approximately 2.5 million.

1.3 HYDROGEOLOGIC SETTING

HISS has little natural topographic variation. The site slopes gently to the south. The two waste piles occupy a large portion of the site, and several man-made ditches have been added along the perimeter of the piles to enhance drainage. Areas of the site that do not lie under the piles are open and covered with either grass or uncontaminated gravel.

1.3.1 Geology

HISS is located over a shallow subsurface depression in bedrock known as the Florissant Basin, the site of a Pleistocene-age glacial lake that was filled with more than 29 m (95 ft) of silts, clays, and fine-grained sand.

Bedrock, which is 29 m (95 ft) deep at HISS, is a homogeneous white to buff-colored, sandy limestone that has been tentatively identified as the Mississippian-age Ste. Genevieve Formation. The unconsolidated sediments overlying bedrock are a sequence of interlayered silts and clays that were deposited in a glacial lake environment. The low-permeability, clay-rich units within these lake deposits act as a confining layer above bedrock and prevent downward movement of surface water in the area around the site. The lake sediments underlying HISS are as thick as 21 m (70 ft). Overlying the lake clays, the uppermost sedimentary unit is composed of clayey silt that has been identified as a combination of the Roxanna Silt and the Peoria Loess. This silt unit ranges from 4.6 to 9.1 m (15 to 30 ft) in thickness at HISS and may contain recent flood deposits associated with Coldwater Creek. More detailed descriptions of these geologic units are presented in Appendix A.

1.3.2 Groundwater

Groundwater Quality and Usage

The most productive bedrock aquifers in the HISS area are Pennsylvanian- and Mississippian-age limestones and sandstones. Wells installed in these units yield 0.06 to 0.6 L/s (1 to 10 gpm) and were completed at various depths to 137 m (450 ft). Below 137 m (450 ft), the aquifers yield mineralized water with high chloride and sulfate content that is considered unsuitable for drinking (State of Missouri 1963). Water obtained from the glaciolacustrine deposits overlying bedrock tends to have high iron and magnesium content, significant quantities of sulfate, and variable dissolved solids content (Miller et al. 1974), but not at levels that are above drinking water standards.

A well canvas of the combined HISS and SLAPS areas conducted in 1987 and 1988 yielded records for eight wells within 4.8 km (3 mi) from HISS; four had been drilled to obtain water for irrigation, one was for industrial purposes, and three were for domestic (assumed to be for private drinking water) use. The three domestic wells were abandoned in 1962, 1968, and 1979. Figure 1-4 shows the locations of private wells in the vicinity of HISS. There are no known wells within 4.8 km (3 mi) of HISS that are used to furnish drinking water for the public. Public water needs in the area are primarily met by using treated Mississippi River water.

Groundwater in the sediments beneath HISS is not considered sensitive by the State of Missouri (10 CSR 23-3, 1992). The guidelines for classification of groundwater discussed in the Environmental Protection Agency's (EPA) *Groundwater Protection Strategy* (EPA 1986) indicate that groundwater underlying HISS falls into Subclass IIb, "Potential Source of Drinking Water."

Site Hydrogeology

Groundwater in the unconsolidated sediments above the lake clays exists under unconfined conditions. Permeabilities in these sediments range from 1.08×10^{-5} to 1.03×10^{-3} cm/s (11.2 to 1,063.8 ft/yr). Groundwater flow is characterized by radial flow away from a central area near the western edge of the main storage pile. Flow rates have not been measured directly; however, calculations using permeabilities and groundwater flow gradients indicate velocities that are generally less than 18 m/yr (60 ft/yr). Groundwater is shallow, ranging from 2.0 to 5.2 m (6.7 to 17.2 ft) deep in August to 1.2 to 4.5 m (3.9 to 14.9 ft) deep in November. Onsite observation well data indicate seasonal fluctuations of 0.7 to 3 m (2.5 to 10 ft) in individual wells.

Details of groundwater well construction and hydrographs showing groundwater level fluctuations are included in Appendix A.

1.3.3 Surface Water

Surface water runoff from HISS drains into two ditches (Figure 1-5). The northern ditch collects runoff from the northern waste pile. Water in the ditch flows off the site at outfall 001 to a storm sewer on Latty Avenue, which then discharges to Coldwater Creek. Outfall 001 drains an area of approximately 0.8 ha (2 acres). The southern ditch receives runoff from the southern pile and crosses the site boundary at outfall 002. The ditch discharges into a tributary of Coldwater Creek and drains an area of approximately 1.2 ha (3 acres).

In December 1991, 0.76-m (2.5-ft) H-flumes were installed at outfalls 1 and 2. Surface water flow is monitored continuously at both flumes. In June the flume at outfall 002 was moved because of construction activities and reinstalled at the end of these activities. After reinstallation, flow was observed under the flume during storm events, but more than

75 percent of the flow probably passes through the flume during storm events. The peak flow measured at outfall 002 between January and May was 15.9 L/s (0.56 cfs) on February 14. Outfall 001 had a peak flow of 85 L/s (3.0 cfs) on August 27. A report has been issued that documents the observed leak and necessary repair and tracks the progress to completion.

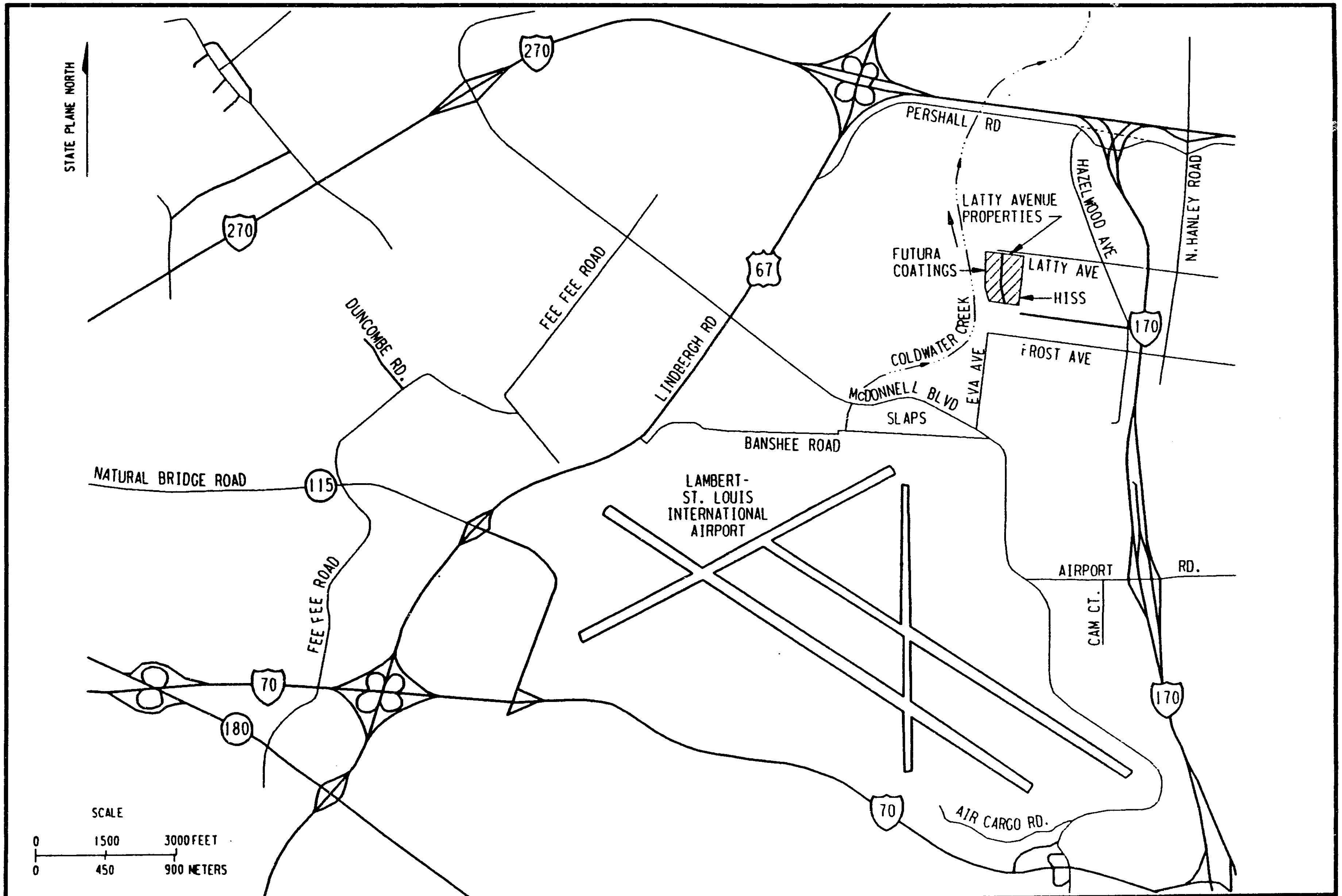
Runoff from HISS drains primarily to Coldwater Creek, which drains an area of 122 km^2 (47 mi^2) in north St. Louis County. The creek flows northeastward approximately 32 km (20 mi) before discharging into the Missouri River. HISS is located 20.7 km (12.9 mi) upstream of the mouth of Coldwater Creek. Approximately 40 km^2 (16 mi^2) of the Coldwater Creek watershed is upstream of HISS.

The State of Missouri classifies Coldwater Creek as a Class C stream from its mouth to U.S. Highway 67 approximately 10.8 km (6.7 mi) upstream from the mouth. The Class C classification is defined as intermittent flow with permanent pools that support aquatic life (MO 10 CSR 20-7.031, 1992). Coldwater Creek is designated for the following uses: livestock and wildlife watering, fish consumption, and drinking water supply. Coldwater Creek is currently not used as a drinking water supply.

1.4 CLIMATE

Table 1-1 summarizes climatological data from the National Oceanic and Atmospheric Administration (NOAA) for the St. Louis vicinity for 1992. Temperature extremes ranged from -13°C (8°F) in January to 36°C (97°F) in July. Monthly average wind speeds ranged from 12 km/h (7.6 mph) in August to 18.2 km/h (11.3 mph) in March. Climatological events that could have affected data results were the extremely high precipitation experienced during major rain and storm events during the third quarter (0.94 in. of rain in 30 minutes in July and 2.88 in. in 22 hours in August) and the low precipitation during the first and second quarters (6.57-in. deficit for the first six months of 1992). The effects of climatological conditions on data results are discussed further in Section 3.0.

FIGURES FOR SECTION 1.0



134 R34F002.DGN

Figure 1-1
Location of HISS

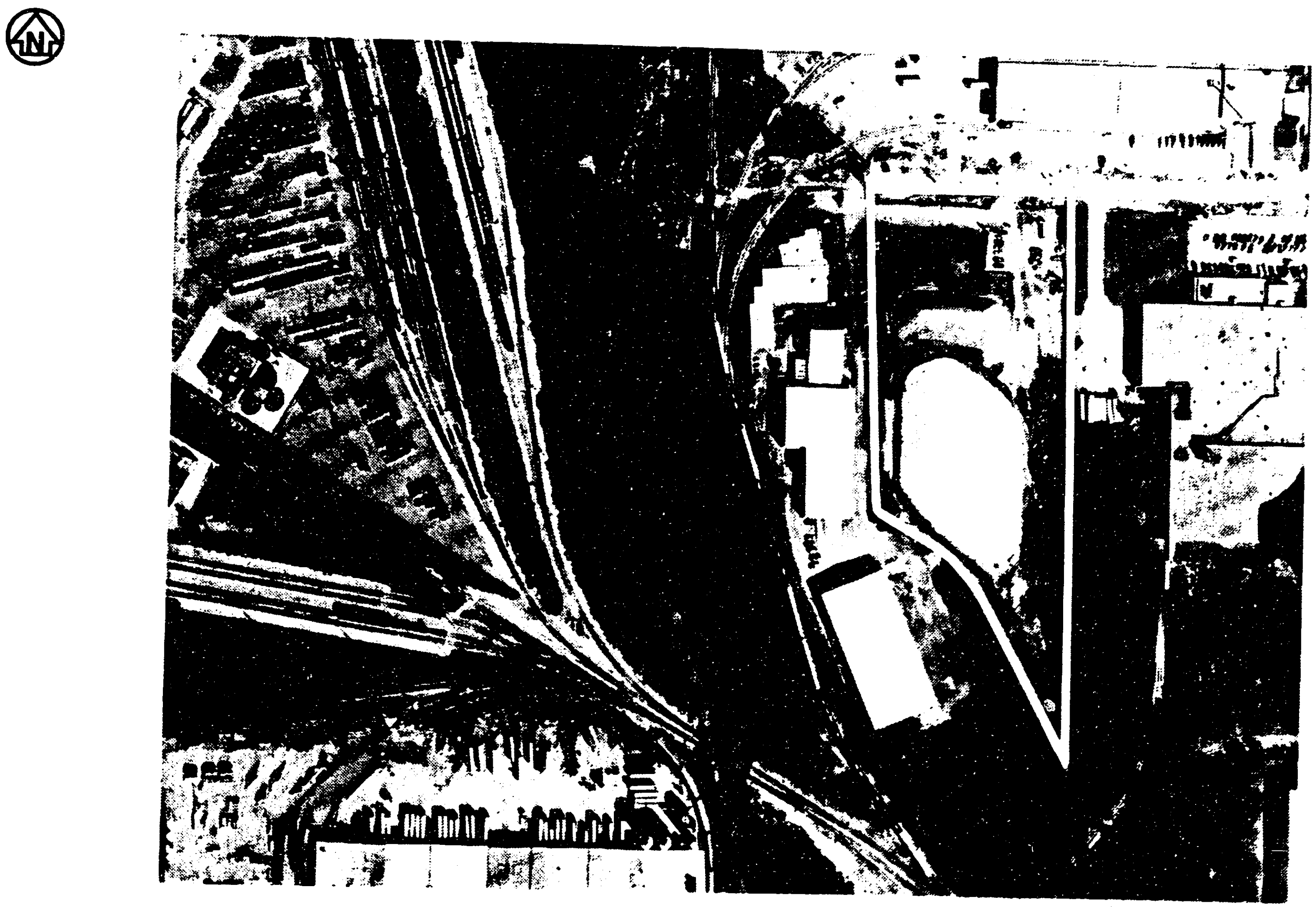
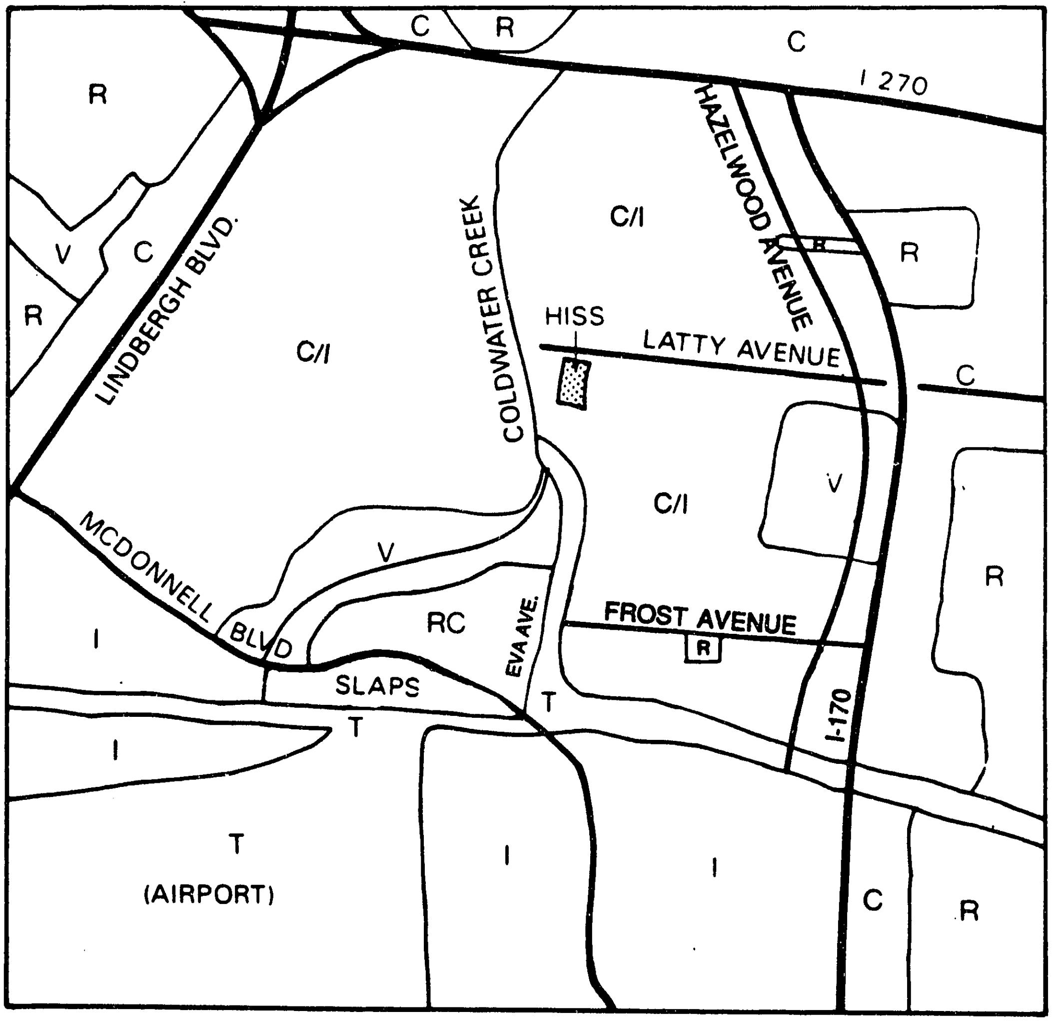


Figure 1-2
Aerial View of HISS and Its Vicinity



BASED ON AERIAL PHOTOGRAPHS, SITE VISITS AND USGS TOPOGRAPHIC MAP 1:24000 SCALE. FLORISSANT, MO (PHOTO REVISED 1982)

R RESIDENTIAL
C COMMERCIAL
T TRANSPORTATION
I INDUSTRIAL
C/I MIXED COMMERCIAL AND INDUSTRIAL
V VACANT
RC RECREATIONAL

0 0.5 MI
0 0.8 KM

N

Figure 1-3
Generalized Land Use in the Vicinity of HISS

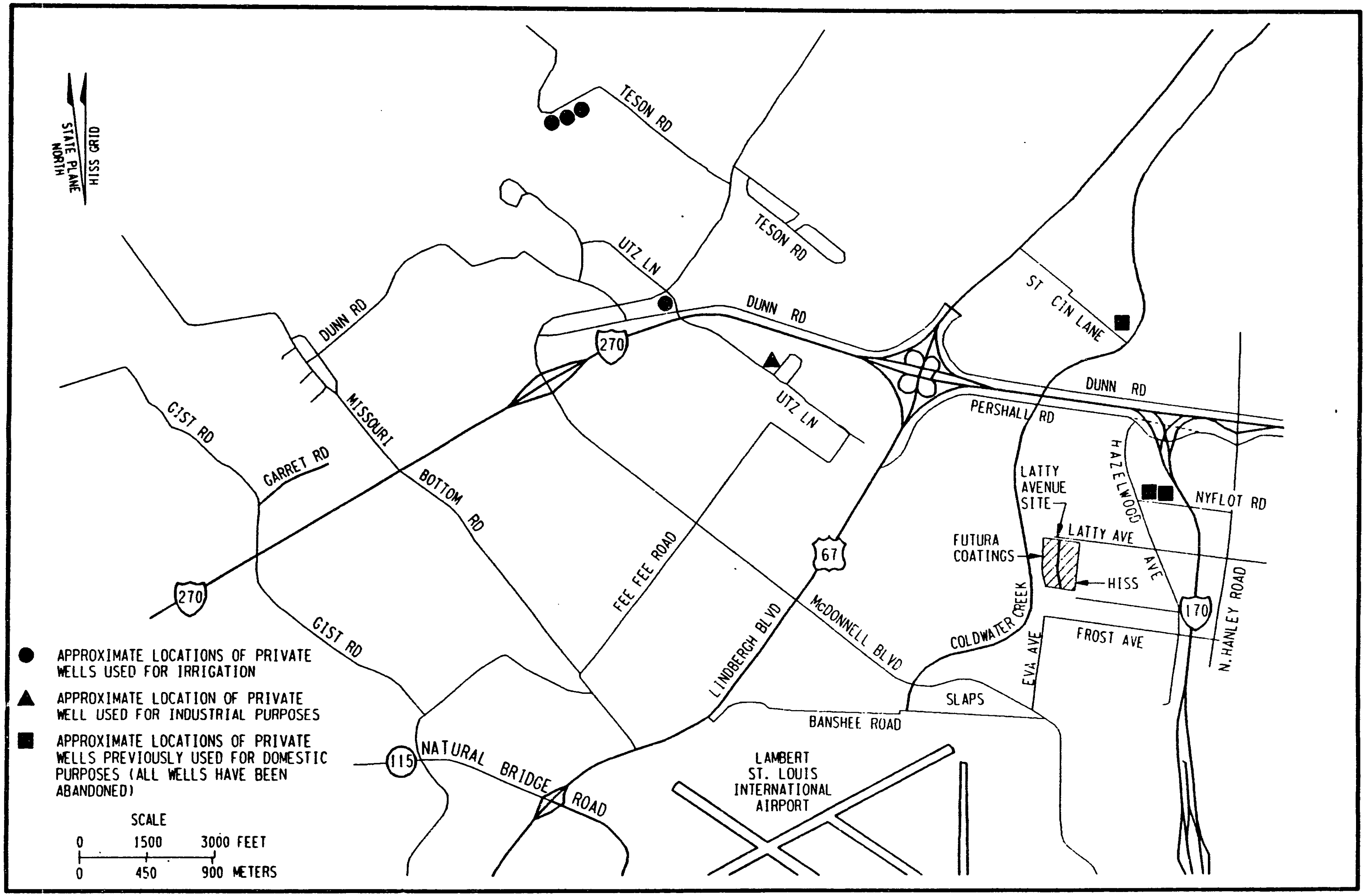


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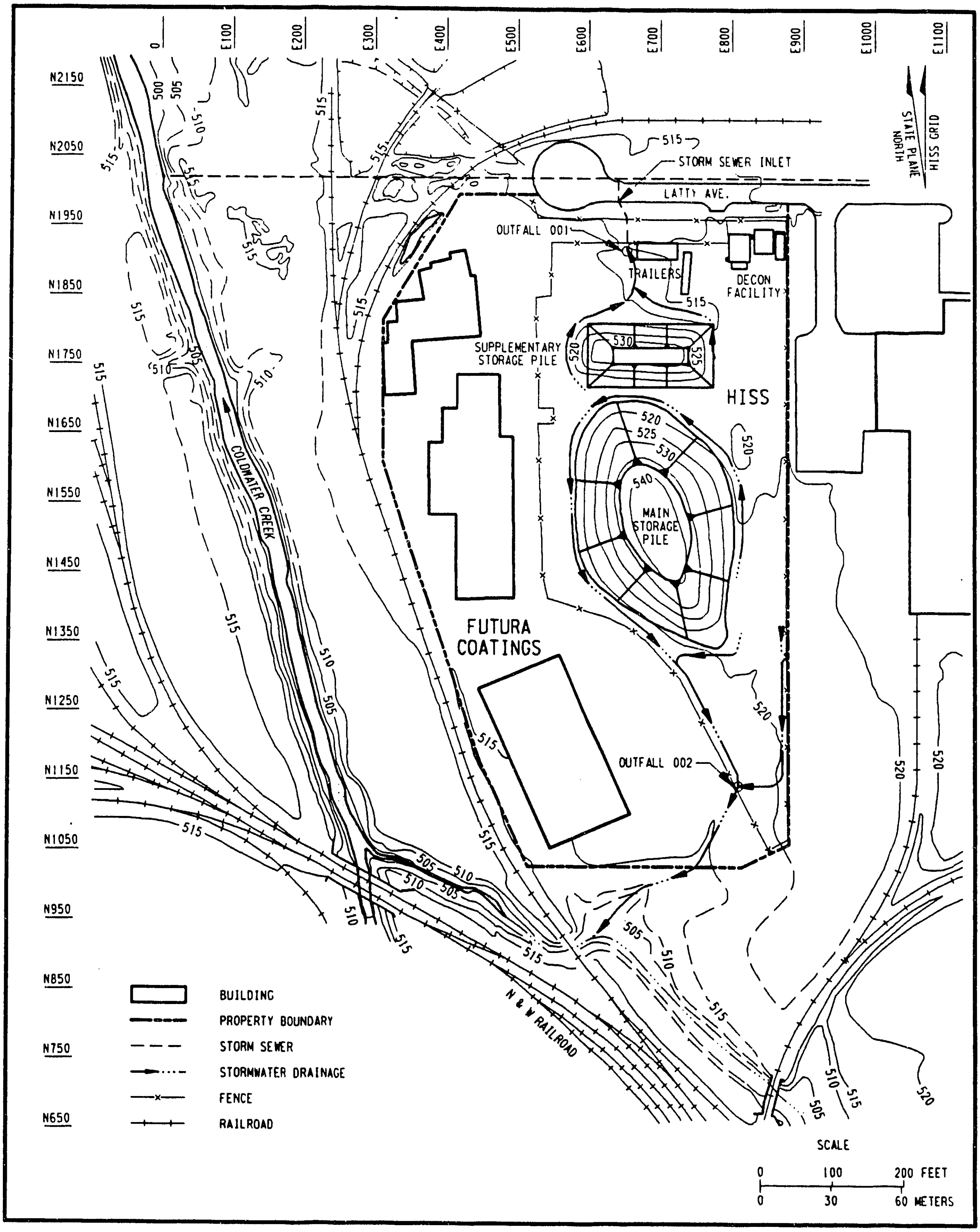
Figure 1-4
Locations of Private Wells in the HISS Vicinity



140 R34F003.DGN

Figure 1-5
Stormwater Drainage at HISS

TABLE FOR SECTION 1.0

Table 1-1

Summary of Climatological Data for the St. Louis Vicinity, 1992

Month	Temperature (°F) Min	Max	Avg	Total Precip (in.)	Wind Avg Speed (mph)	Wind Resultant Direction
January	8	59	37.0	1.12	10.5	WSW
February	18	71	42.7	1.89	9.8	WNW
March	20	79	48.5	3.45	11.3	WSW
April	30	87	57.8	2.46	10.5	SW
May	40	87	65.1	1.45	8.2	ENE
June	51	94	73.8	1.19	8.2	ESE
July	58	97	79.0	4.31	9.5	SW
August	51	96	73.4	3.45	7.6	N
September	43	91	69.2	2.98	8.3	S
October	34	88	59.4	1.21	9.7	SSW
November	27	67	44.3	6.32	9.8	SW
December	11	66	35.9	3.66	9.8	SSW

Source: NOAA 1993.

2.0 ENVIRONMENTAL PROGRAM INFORMATION

This section describes programmatic activities conducted at HISS other than those conducted as part of routine environmental monitoring. Environmental program information discussed in this section includes descriptions of the following:

- Permit-driven activities at HISS
- Emissions monitoring
- Environmental documentation activities
- Significant environmental activities at the site (including special studies and changes made in the 1992 monitoring program)
- Environmental awareness activities such as employee education programs to help promote waste minimization at the site, site safety inspections, and employee training programs
- Self-assessment activities

Information regarding routine environmental surveillance at the site is provided in Section 3.0.

2.1 PERMIT ACTIVITIES

The floodplain assessment in the engineering evaluation/cost analysis-environmental assessment (EE/CA-EA) for HISS identified the floodplain ordinance in the Hazelwood City code as a requirement. Section 121 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) relieves HISS from obtaining a floodplain building permit, but the substantive requirements of a permit must be met. In 1992 all of the substantive directives of the Hazelwood Public Works Department were met.

DOE holds National Pollutant Discharge Elimination System (NPDES) permit MO-0111252, which expires on December 31, 1994 (MDNR 1992). The permit specifies monitoring, reporting, and control requirements for the HISS stormwater management system. To comply with the permit, a stormwater monitoring system of collecting and analyzing samples for potential pollutants was established. As part of an effort to protect the quality of waters in the United States, the permit mandates monitoring for certain potential contaminants that may be discharged from the site into Coldwater Creek and places concentration limits on some of the parameters. Throughout 1992 the stormwater discharge from HISS was in compliance with the permit limits. During a few months, samples were not collected as required; however, appropriate quality assurance documentation was prepared, and the Missouri Department of Natural Resources (MDNR) was notified of everything that failed to meet terms of the permit.

2.2 EMISSIONS MONITORING

In addition to routine environmental sampling discussed in Section 3.0, various emissions are monitored at the site. During 1992 radon flux monitoring which determines the rate at which radon is emitted, was conducted once at HISS, as approved by EPA, to evaluate compliance with National Emission Standards for Hazardous Air Pollutants (NESHAPs) requirements. Annual monitoring is sufficient for demonstrating compliance with NESHAPs because average site emissions are consistently less than 5 percent of the regulatory standard. Airborne particulates were monitored during site construction operations to evaluate worker health hazards (e.g., inhalation of dust). Lapel air samplers monitored occupational exposure via inhalation. Additionally, during site upgrade work, which included construction of an onsite access road, perimeter air sampling was conducted to monitor for any unexpected releases. A high-volume air sampler was operated downwind of the controlled area to measure the level of airborne particulate radioactivity at a specific perimeter distance from the activity (i.e., the closest that a member of the public could get to the field activity).

Wastewater is periodically generated at the site during equipment decontamination and groundwater monitoring activities. The water is collected in a large storage tank and is treated using a system of ion exchange columns and filters. In accordance with a letter agreement between DOE and MSD (DOE 1992), a sample of the treated water is analyzed for volatile organics, metals, standard indicator parameters (i.e., pH, specific conductivity, total organic carbon, total suspended solids), and gross alpha and beta radioactivity. MSD reviews the analytical results and approves discharge of the treated water based on a favorable comparison with DOE release criteria and applicable MSD ordinances, including state maximum contaminant levels (MCLs). MSD specifies a discharge rate to meet the drinking water standard. Upon approval by MSD, the water is discharged to the sanitary sewer that conveys the water to the Coldwater Creek Treatment Plant. Discharged water contains less than 30.0 pCi/L (1.11 Bq/L) of gross alpha radioactivity, as specified in the letter agreement with MSD. Additionally, results for water analyses show that concentrations of heavy metals and most volatile organic compounds are either undetectable or very low.

During 1992 there were no unplanned releases or environmental occurrences as defined in Section 103 of CERCLA.

No reports under SARA Section 313 (the Emergency Preparedness and Community Right-to-Know Act) were required. FUSRAP sites were not subject to toxic chemical release reporting provisions under 40 CFR 372.22 in 1992. To ensure that Section 313 reporting is performed if needed, FUSRAP evaluates and inventories chemicals maintained onsite. Chemicals such as nitric acid are used in small quantities at FUSRAP sites for sample preservation and other purposes.

2.3 ENVIRONMENTAL DOCUMENTATION

Completion of an environmental impact statement (EIS) is required as part of the overall effort for the St. Louis FUSRAP properties on the National Priorities List. Compliance with the National Environmental Policy Act (NEPA) for site remedial actions will be accomplished by incorporating those elements required by an EIS into the format of the CERCLA remedial investigation/feasibility study (RI/FS) (currently being developed) to produce an RI/FS-EIS for the St. Louis site. This document is scheduled for completion in fiscal year 1994.

A CERCLA/NEPA EE/CA-EA that assesses waste removal alternatives for the HISS/SLAPS vicinity properties was released by DOE-Headquarters for public comment on April 8, 1992. A responsiveness summary will be prepared after the Radioactive and

Hazardous Waste Oversight Commission of the St. Louis County Council has had an opportunity to review and comment on the document.

NEPA categorical exclusions were obtained for routine site maintenance and monitoring, site characterization studies, and installation of a trailer to house the equipment for conducting photon/electron-rejecting alpha liquid scintillation (PERALS) analysis for thorium-230.

2.4 SIGNIFICANT ENVIRONMENTAL ACTIVITIES

2.4.1 Special Studies

During 1992 special sampling was conducted at all of the St. Louis sites to collect additional site characterization information to fill remedial investigation data gaps. At HISS soil and groundwater samples were collected and analyzed for chemical and radioactive contaminants to further delineate the vertical and horizontal extent of existing contamination in soil and to determine whether these contaminants are in the groundwater. The work was performed in accordance with the field sampling plan (BNI 1992d) and quality assurance project plan (BNI 1992b). The results and conclusions from the data gap sampling effort will be reported in an addendum to the RI report (BNI 1992a) to be prepared in fiscal year 1993.

2.4.2 Environmental Surveillance Program Changes

The following changes were made in the program for 1992 (monitoring locations are shown in Section 3.0).

In 1992 the strategy for external gamma radiation and radon monitoring changed; the quarters are now based on the calendar year rather than the fiscal year. Radon results for October 16, 1991, through January 22, 1992, and external gamma radiation rates for January 1991 through January 1992 were not reported in last year's environmental report; therefore, they are included in this report.

External gamma radiation and radon monitoring at station 10, located on the western boundary of the Futura Coatings property (adjacent to HISS), were discontinued in 1992. In five years of monitoring at that location, the external gamma radiation exposures detected were always significantly less than the DOE radiation protection standard of 100 mrem/yr (1 mSv/yr) above background, and the detected radon concentrations were well below the federal guideline of 3.0×10^{-9} μCi/ml (0.11 Bq/L). DOE requirements mandate fenceline monitoring. Because location 10 is beyond the fenceline and has consistently registered exposure levels that are well below the applicable guidelines, continued monitoring of that station was deemed not necessary. Monitoring at all fenceline locations will continue.

The frequency of collecting the tissue-equivalent thermoluminescent dosimeters (TETLDs) that are used to measure external gamma radiation exposure rates was decreased from quarterly to semiannually in 1992. During each quarter in 1991, one dosimeter, which had been placed at a monitoring location during the same quarter of the previous year, was collected and analyzed. However, in 1992 the approach was modified to collect data that would be more representative of a calendar year. Short-term exposure of TETLDs at the relatively low exposure rates found at FUSRAP sites may yield high percent error; consequently, quarterly monitoring was determined to be insufficient. Instead, modified semiannual monitoring was conducted in 1992. Four dosimeters were placed at each location at the beginning of the year; two were collected and analyzed after six months, and the remaining two were collected and analyzed at the end of the year. Although data collected at the end of the year are the most accurate, monitoring after six months is conducted to ensure that no unusual exposures have occurred. The exposure monitoring program provides information to help protect public health and the environment.

An additional downstream monitoring location in Coldwater Creek, approximately 914 m (3,000 ft) downstream of location 3, was added to the 1992 surface water and sediment monitoring program. This location, designated location 7, provides additional information regarding the extent of contaminant transport in Coldwater Creek. A duplicate sample (designated 8) was collected at location 6.

In 1992 surface water and sediments were sampled semiannually, based on the following rationale. The contaminants at the site are the result of chemical processing of ores using acid digestion, which results in relatively insoluble products. Consequently, any contaminants migrating from the site would be in particulate form. Particulate transport is most active during and after storm events, which would enhance movement of sediments into drainage ditches and in Coldwater Creek. Therefore, sampling was conducted semiannually during periods when the potential for sediment transport was greatest.

Well HISS-5 was deleted from the groundwater monitoring program in 1992. In previous years this well was determined to be contaminated; consequently, downgradient wells were sampled to provide surveillance of contaminant transport away from HISS-5. In addition, wells B53W01S and B53W01D, used in previous years for collection of background samples, were not used in 1992. Although these wells are in a remote area isolated from contamination at SLAPS, they are downgradient of contamination; therefore, it was decided that these wells should not be used as background wells. Instead, background data were collected from B53W15S [located in a remote area approximately 0.8 km (0.5 mi) south of HISS], which is upgradient of contamination. Groundwater was also sampled semiannually, at times when water levels were near maximum and minimum for the year and when the impact on contaminant concentrations could be expected to be the greatest.

2.4.3 Response Actions

No removal or remedial actions were conducted during the reporting period.

2.5 ENVIRONMENTAL AWARENESS ACTIVITIES

FUSRAP is committed to minimizing the generation of waste at FUSRAP sites by giving preference to source reduction, material substitution, and recycling over treatment, control, and disposal of such wastes, where appropriate. The development of waste minimization goals, waste generation information, and a process for continual evaluation of the program are primary elements of this philosophy. Pollution prevention awareness is promoted and various waste minimization techniques are implemented as part of continuing employee training and awareness programs to reduce waste and meet the requirements for quality, safety, and environmental compliance. No hazardous waste minimization certifications or waste reduction reports for waste generators were required during this reporting period.

Extensive training of site workers is conducted to ensure that they work in a safe manner. All site workers must complete a 40-h hazardous waste training program to comply with Occupational Safety and Health Administration requirements (29 CFR 1910.120) and take an 8-h refresher course annually thereafter. During their first three days onsite, workers must participate in site-specific, on-the-job training. Additional training includes, but is not limited to, annual fire extinguisher training, annual respirator training, and semiannual self-contained breathing apparatus training.

Routine safety and security inspections are conducted at the site to ensure that the site is in good repair and is safe for site workers and the public. These inspections include assessments of site security (daily), pile covers (weekly), first-aid kits (weekly), fire extinguishers (weekly), and housekeeping (weekly).

2.6 SELF-ASSESSMENTS

Bechtel National, Inc. (BNI), the project management contractor for FUSRAP, implemented an informal self-assessment program for HISS in August 1992. Compliance with the following was assessed: NESHAPs Subparts H and Q, stormwater permits, CERCLA (for removal actions and administrative record retention), the St. Louis FFA (EPA 1990), and DOE Order 5400.5 (DOE 1990). No violations of regulatory requirements were identified during the self-assessments, although areas were identified where best management practices could be improved.

A formalized self-assessment approach for all FUSRAP sites was approved on April 22, 1993, specifically addressing self-assessment activities for the program during the remainder of fiscal year 1993 and in fiscal year 1994.

3.0 MONITORING NETWORKS AND RESULTS

HISS is not an operating facility and therefore produces little waste material. Wastewater is treated and discharged to the St. Louis MSD, as discussed in Subsection 2.2. Any disposable supplies (e.g., personal protective equipment, sampling supplies) that become contaminated during field operations are stored onsite. The greatest possibility for contamination to be released from the site would be through contaminant migration.

Routine environmental monitoring at HISS in 1992 included sampling for:

- Radon concentrations in air
- External gamma radiation exposure
- Total uranium, radium-226, and thorium-230 concentrations in surface water, sediment, and groundwater
- Concentrations of selected ions and other water quality indicator parameters in groundwater

Additionally, stormwater and radon flux monitoring are conducted at HISS. Routine surveillance of chemical parameters in groundwater, surface water, and sediment is not warranted.

Readers not familiar with radiation units may benefit from reviewing Appendix B before proceeding.

The monitoring systems included onsite, property-line, and offsite stations to provide sufficient information on the potential effects of the site on human health and the environment. The analytical methods performed on each matrix are presented in Appendix C.

This section of the report contains the data for each sampling point, yearly averages, and trend information. The methodology for calculating the averages and standard deviations is provided in Appendix D. Expected ranges are calculated for each monitoring location using the average result from the previous five years, plus or minus 2 standard deviations. This methodology is also provided in Appendix D. All data are reported as received from the laboratory; however, the averages and expected ranges are reported using the smallest number of significant figures from the data (e.g., 3.2 and 32 both have two significant figures). Where appropriate, values are presented using powers of ten (e.g., $0.32 = 3.2 \times 10^{-1}$). The results are compared with the standards listed in Appendix E.

The following subsections discuss the monitoring program, results for 1992, and any possible radioactive contaminant migration indicated by the results. In each monitoring network section, trend tables summarize the analytical results for 1992 and the preceding five years and present the statistical expected range for each monitoring location.

3.1 AIR AND EXPOSURE MONITORING

Routine air monitoring at HISS consists of nonintrusive, cumulative measurement of radon concentrations and external gamma radiation rates in the air at onsite and offsite locations.

Air samples are not collected as part of routine site monitoring. Monitoring of airborne particulates was conducted in 1992 during well drilling activities and construction activities related to the site upgrade to evaluate worker and public health hazards (e.g., inhalation of dust) and to monitor any unexpected releases.

Lapel samplers were worn by personnel performing field work to monitor occupational exposure via inhalation. Additionally, a high-volume air sampler was operated downwind of the work area to measure the ambient level of airborne particulate radioactivity.

Because the quarters are now based on the calendar year rather than fiscal year and a 1991 quarter of radon and external gamma radiation data was not reported in last year's environmental report (see Subsection 2.4.2), the data are reported with the 1992 results. The 1991 data have not been included in the calculation of averages or dose rates for 1992.

3.1.1 Radon

One potential pathway of radiation exposure from the uranium-238 decay series is inhalation of the short-lived radionuclide radon and its daughter products. Radon is an alpha-particle-emitting gas that is very mobile in air. Radon concentrations are measured using Alpha-Track detectors, each of which contains a piece of alpha-sensitive film. The detectors are placed at breathing level, 1.5 to 1.7 m (5 to 5.5 ft) above the ground, at monitoring stations along the perimeter of the site and at various background locations. Radon is monitored quarterly at the locations shown in Figure 3-1. Monitoring results aid in assessing the impacts of the contaminants at the site on radon levels near the site and in evaluating compliance with environmental regulations.

Quarterly and annual average radon concentrations are presented in Table 3-1. Onsite and property-line annual averages ranged from 0.3×10^{-9} to 0.5×10^{-9} μCi/ml, and background measurements were 0.3×10^{-9} and 0.4×10^{-9} μCi/ml. Thus, at all monitoring locations, radon concentrations were comparable to background and were well below the radon derived concentration guide (DCG) of 3.0×10^{-9} μCi/ml (0.11 Bq/L). The DCG value represents the concentration that would give a member of the general public a dose of 100 mrem/yr above background, conservatively calculated for continuous exposure conditions. All measured concentrations fell within the expected range, which is a statistical range calculated from data collected during the preceding five years (Table 3-2). Monitoring results show that the radon concentrations at the site are consistently low, approximately 10 percent of the DCG. Low concentrations are to be expected because the waste pile is covered with a low-permeability geomembrane.

In addition to quarterly monitoring of radon concentrations in the air, radon flux data are collected annually to assess site compliance with NESHAPs requirements. Measurement of radon flux provides an indication of the rate at which radon is emitted from a surface. Radon flux at HISS is measured using large area activated charcoal collectors placed at 7.6-m (25-ft) intervals across the surface of each pile for a 24-h exposure period.

Radon flux was monitored at HISS on July 6 and 7, 1992. Monitoring locations on the piles are shown in Figure 3-2, and results are given in Table 3-3. Radon flux readings from the small pile ranged from 0.08 to 0.17 pCi/m^2-s (0.0030 to 0.0063 Bq/m^2-s) with an average of 0.11 pCi/m^2-s (0.0041 Bq/m^2-s); readings from the large pile ranged from 0.09 to 4.27 pCi/m^2-s (0.0033 to 0.16 Bq/m^2-s) with an average of 0.32 pCi/m^2-s (0.012 Bq/m^2-s). Thus, the radon flux readings at all individual monitoring locations on the piles and the average flux value for each pile were significantly less than the radon flux standard of 20 pCi/m^2-s (0.74 Bq/m^2-s) specified in 40 CFR Part 61, Subpart Q. In previous years elevated radon flux readings were detected along the northwestern corner of the large pile, in particular at locations 4B (107 pCi/m^2-s on May 20 through 21, 1991) and 8B (50.6 pCi/m^2-s on May 20 through 21, 1991) revealing pile cover weakness in that area. In September 1991, the pile cover was reinforced. The low radon flux readings obtained in 1992 (4B, 0.39 pCi/m^2-s; 8B, 4.27 pCi/m^2-s) testify to the success of the repair work.

3.1.2 External Gamma Radiation

External gamma radiation exposure rates were measured as part of the routine environmental monitoring program at HISS to confirm that they were not significantly above natural background rates and to ensure compliance with environmental regulations.

At the locations shown in Figure 3-1, TETLDs were placed along the fenceline of the site at gonadal height, approximately 3 ft (1 m) from the ground, to measure the dose that would be received by the organ located nearest the waste. At the beginning of the year, four dosimeters were placed in the monitoring station; two were removed after six months, and the remaining two were removed at the end of the year. Although the TETLDs are state-of-the-art, the dosimeter accuracy is approximately ±10 percent at radiation exposure rates between 100 and 1,000 mR/yr and ±25 percent at rates between 0 and 100 mR/yr.

The external gamma radiation background value is not constant for a given location or from one location to another, even over a short time, because the value is affected by a combination of both natural terrestrial and cosmic radiation sources and factors. For instance, the location of the dosimeter in relation to surface rock outcrops, stone or concrete structures, or highly mineralized soil may influence the exposure measured by the dosimeter. Dosimeters are also affected by site altitude, annual barometric pressure cycles, and the occurrence and frequency of solar flare activity (Eisenbud 1987). Thus, external gamma radiation exposure rates at the boundary could be less than the background rate measured some distance from the site, and rates onsite could be lower than at the boundary.

Table 3-4 and Figure 3-3 present the results for TETLDs exposed or analyzed during 1992. Background levels have been subtracted from these results. At five of nine monitoring locations (1, 3, 5, 6, and 8) onsite and at the property line, average external gamma radiation exposure rates were below background levels. Exposure rates exceeded background at the locations in the southern half of the site and at one location in the northern half. However, at all locations except for station 2, the dose rates were less than the DOE guideline of 100 mrem/yr (1 mSv/yr) above background. This is consistent with results found in previous years (Table 3-5). The offsite area near location 2 is heavily wooded; it is unlikely that an individual would occupy that area for 24 hours a day for one year, which would be necessary for the individual to receive a dose exceeding 100 mrem/yr above background. Table 3-6 compares the annual exposure rate at location 2 to background rates for Missouri, the United States, and well-known locations in the country. The waste stored at HISS does not present a threat to the public from external gamma radiation exposure because the rates are low and the access to the waste is restricted.

Water is capable of absorbing gamma radiation, thereby acting as a shield. As a consequence, during wet periods when the soil and air have a high moisture content, gamma radiation exposure tends to be lower. Conversely, during periods of dryness, exposure may be higher. This phenomenon could explain the increase in external gamma radiation exposure measured in 1992 at locations 2, 16, and 19. Total annual precipitation for 1992 was 14.9 cm (5.82 in.) below the historical average [16.7 cm (6.57 in.) below average for the first six months]. Thus, at background locations 16 and 19 where the source is probably underground, the rate would be higher because of low soil moisture. At the site, however, the waste is covered by a low-permeability geomembrane; consequently, the rate would not likely fluctuate because of changes in moisture levels. Measured exposure rates for most locations during 1992 fell within the expected range. The increased exposure rate at location 2 may indicate the presence of a buried source in that area.

3.2 SURFACE WATER AND SEDIMENT MONITORING

3.2.1 Monitoring Network

Surface water monitoring is conducted to ensure compliance with environmental regulations and to assess whether runoff from HISS contributes to contamination of surface water in the area. Stormwater samples are collected to comply with the site NPDES permit. Sediment monitoring is conducted to determine whether contaminants are accumulating in onsite and/or offsite sediment.

Surface water and sediment are collected from Coldwater Creek and its tributaries; the sampling locations are shown in an overview map (Figure 3-4) and a more detailed map of the site (Figure 3-5). The six sampling locations include: one upstream of the site (location 2) to establish background conditions; four downstream of the site (locations 3, 5, 6, and 7) to monitor the effect of runoff from the site on Coldwater Creek; and one (location 4) to detect the upstream contaminant contribution from SLAPS to Coldwater Creek. Location 7 will be used for sampling accumulated sediments at an inside bend of Coldwater Creek about 900 m (3,000 ft) downstream (north) of location 3. Grab samples of water and sediments were collected at the six locations semiannually. Stormwater samples were collected at outfalls 001 and 002 (Figure 3-4).

3.2.2 Surface Water Results

Table 3-7 lists the concentrations of radionuclides of concern found in surface water samples collected near HISS (background values have not been subtracted). Samples were analyzed for total uranium, radium-226, and thorium-230. All measured concentrations were well below the DOE guidelines of 600×10^{-9} μCi/ml for total uranium, 100×10^{-9} μCi/ml for radium-226, and 300×10^{-9} μCi/ml for thorium-230.

Trends in average annual radionuclide concentrations measured in surface water from 1987 through 1992 are presented in Table 3-8. Measured concentrations of total uranium at background location 2 were below the statistical expected range established by data collected from that location during the previous five years. At all other locations, 1992 total uranium results fell within the lower half of the expected ranges. This may be attributed to the laboratory procedural change at the end of 1991 when kinetic phosphorescence analysis (KPA) replaced fluorometric analysis. All total uranium concentrations were less than 1.5 percent of applicable DOE guidelines. KPA has a minimum detectable activity (MDA) of 0.03 μg/L, whereas fluorometric analysis has an MDA of 5 μg/L. Consequently, KPA is a much more sensitive analysis and is capable of detecting lower concentrations of uranium. As a result, some concentrations that were previously below the analytical detection limit can now be quantified.

At all locations thorium-230 concentrations fell within the expected range for that contaminant and were well below the applicable guidelines.

The radium-226 concentrations measured in surface water are well below DOE and Safe Drinking Water Act guidelines. At three downstream locations, however, radium-226 concentrations in surface water exceeded the expected range. Beginning at the end of 1991, analyses were conducted at a new laboratory facility. Radium-226 values are higher for samples analyzed since that change (all data not shown) and may be indicative of a procedural difference between the two facilities. DOE is currently investigating this apparent discrepancy. This slight elevation in radium-226 concentrations is not believed to represent a trend for this radionuclide in surface water.

Stormwater monitoring information for compliance with the site NPDES permit is provided to MDNR in quarterly reports. A summary of 1992 stormwater results (ranges and averages) is provided in Table 3-9. Throughout the monitoring year, the site was in compliance with all permit final effluent limitations (for pH and settleable solids).

3.2.3 Sediment Results

Table 3-10 contains 1992 data for total uranium, thorium-230, and radium-226 concentrations in sediment (background values have not been subtracted). Figure 3-6 shows the thorium-230 results for each monitoring location. Currently there are no DCGs for radionuclides in sediment; however, FUSRAP soil guidelines (Appendix E) have been applied for comparative purposes. All total uranium and radium-226 concentrations were well below the FUSRAP soil guidelines of 50 and 5 pCi/g above background, respectively, although total uranium levels appear to be elevated in samples collected in March. Two of six sediment samples collected in March (from locations 4 and 7) contained thorium-230 concentrations that exceeded the soil guideline of 5 pCi/g above background. Samples collected in September were all below the guideline, but the annual average concentrations of thorium-230 exceeded the guideline at locations 4 and 7. Heavy rain associated with Hurricane Hugo in late August could have caused sediment migration in Coldwater Creek before sampling in late September and could account for the fluctuation in thorium-230 concentrations between the March and September sampling events.

As shown in Table 3-11, for several years thorium-230 has been detected in Coldwater Creek sediment at concentrations exceeding the soil guideline. This contamination resulted from erosion of contaminated soil from the creek banks adjacent to SLAPS. Erosion control measures such as the installation of a gabion wall at SLAPS have minimized continued migration of contamination; however, thorium-230 has been found on numerous properties near HISS, in a small drainage ditch south of HISS, and in Coldwater Creek.

Table 3-11 shows the trends in average annual concentrations of the three target radionuclides measured in sediment from 1987 through 1992. Radium-226 results for 1992 are consistent with results obtained in previous monitoring years. At location 4 the total uranium and thorium-230 concentrations were above the expected range; at location 3 and at the background location, total uranium concentrations were somewhat higher than expected. Contaminant migration caused by dynamic conditions in Coldwater Creek and the drainage ditch south of HISS accounts for the elevated concentrations at some locations and the lack of discernible trends. Additionally, blank contamination noted during analysis of March samples (discussed in Subsection 5.3) could account for the apparent elevation in annual average total uranium concentrations. All total uranium results for September (Table 3-10) were within the expected range (Table 3-11).

3.3 GROUNDWATER MONITORING

Groundwater monitoring is conducted to provide information on migration of contaminants through the groundwater system and to ensure compliance with environmental regulations. Onsite groundwater sampling locations for 1992 are shown in Figure 3-7, and approximate locations of background monitoring wells are shown in Figure 3-8.

Concentrations of radionuclides were below DCGs in all groundwater samples collected in 1992. However, analysis of samples collected from the background wells in 1992 yielded values for radionuclide concentrations that were anomalously high when compared with historic background data. The results for these background wells are included in Tables 3-12 and 3-16 but have been disregarded in the following discussion. All comparisons with background refer to historic background. Because of this anomaly, background sampling will be conducted at a different well during future sampling events.

3.3.1 Well Network

Thirteen 2-in. and five 4-in. diameter wells are distributed radially around the waste storage piles (see Figure A-1, Appendix A). Most of the wells range in depth from 5.64 to 8.69 m (18.5 to 28.5 ft), but one deep well, HISS-5D, is 30 m (97 ft) deep. Five of the wells, including the deep well (HISS-5D, HISS-17S, HISS-18S, HISS-19S, and HISS-20S) were installed in the fall of 1992 as part of the St. Louis data gap sampling program. Sampling results for HISS-5D will be discussed later in this section. Sampling results for all new wells will be addressed in the addendum to the St. Louis RI report to be completed in fiscal year 1994. Monitoring well construction details are provided in Table A-1 in Appendix A.

Ten wells were sampled in March 1992. Four of those wells, located on the northern portion of the site, were also sampled in September. Because groundwater flow rates are higher at the northern end of the site, more frequent sampling of wells in that area is necessary (refer to Appendix A, Figures A-10, A-11, and A-12). Samples were analyzed for selected radionuclides. Three wells were also sampled in September for water quality parameters to obtain annual information for use in characterizing the groundwater.

3.3.2 Groundwater Results

The analytical results for groundwater samples collected in 1992 are presented in Tables 3-12 through 3-15. Table 3-12 presents the radiological results for routinely monitored wells and includes the historic range of values for contaminants in each well; the historic range is provided as an indicator of contamination in groundwater. In 1992 monitoring results indicated that radionuclide concentrations were below DCGs. Table 3-13 presents radiological results for deep well HISS-5D, Table 3-14 reports field measurements taken in routinely monitored wells, and Table 3-15 reports data on water quality parameters for three of the routinely monitored wells. The trend table (Table 3-16) includes the expected range of data for each well.

Total uranium values presented in Table 3-12 ranged from 3.76×10^{-9} μCi/ml (HISS-9) to 63.62×10^{-9} μCi/ml (HISS-6) in the March samples and were between 0.88×10^{-9} μCi/ml (HISS-9) and 29.86×10^{-9} μCi/ml (HISS-6) in the September samples. All the values were below the historic maximums for total uranium in the same wells and were far below the DOE guideline of 600×10^{-9} μCi/ml. As in previous years, contaminant levels tended to be lower in the second half of the year. There is an apparent seasonal correlation between water levels and contaminant concentrations in the monitoring wells. Higher concentrations of radionuclides have been observed during periods when water levels (and flow gradients) are higher, implying that when movement of particulates in groundwater is greater, the transport of uranium is facilitated. Higher radionuclide concentrations during periods when water levels are higher may also indicate increased proximity to contaminated soils. Elevated uranium levels observed in HISS-6 and HISS-16 are discussed later in this section.

Measured radium-226 values above laboratory detection limits (0.18×10^{-9} μCi/ml) ranged from 0.92×10^{-9} μCi/ml (HISS-14) to 17.7×10^{-9} μCi/ml (HISS-9) in the March samples and from 0.67×10^{-9} μCi/ml (HISS-15) to 1.9×10^{-9} μCi/ml (HISS-16) in the September samples (Table 3-12). Approximately 60 percent of the values were above the historic range; however, as has been the case in previous years, all values were well below the DOE guideline of 100×10^{-9} μCi/ml. Averages presented for 1992 in the trend table (Table 3-16) were also above the expected range. Elevated radium-226 values were first observed at the end of 1991, at the same time that analyses were being conducted at a new laboratory facility. The cause of elevated radium values is being investigated and may be a problem with counting times used during analyses [2-sigma error values for radium-226 are higher than expected (Table 3-12)].

Thorium-230 values are presented in Table 3-12. Measured values above laboratory detection limits ranged from less than 1.4×10^{-9} μCi/ml (HISS-7) to 8.58×10^{-9} μCi/ml (HISS-6) in samples collected in March and from 0.97×10^{-9} μCi/ml (HISS-16) to 4.80×10^{-9} μCi/ml (HISS-15) in those collected in September. Approximately 30 percent of the values were above the historic range (also apparent in Table 3-16); however, as has been the case in previous years, all values were well below the DOE guideline of 300×10^{-9} μCi/ml. Levels of thorium-230 were above the historic maximum in three of the wells; this trend has been observed over the past three years. Elevated thorium-230 levels may indicate increased colloidal transport of thorium; however, because the measured levels are two orders of magnitude below DOE (and EPA) guidelines, no further evaluation has been conducted.

Samples from HISS-6 and HISS-16 yielded elevated (above background) levels of total uranium. Thorium-230 values were high in HISS-6 and HISS-15. Historically, total uranium and thorium-230 values for these wells (and for HISS-5, which was not sampled in 1992) are higher than background (Table 3-16). The approximate extent of groundwater containing levels of uranium exceeding historic background concentrations is shown in Figure 3-9, which provides analytical results for March 1992 samples and the historic range of uranium values for each well.

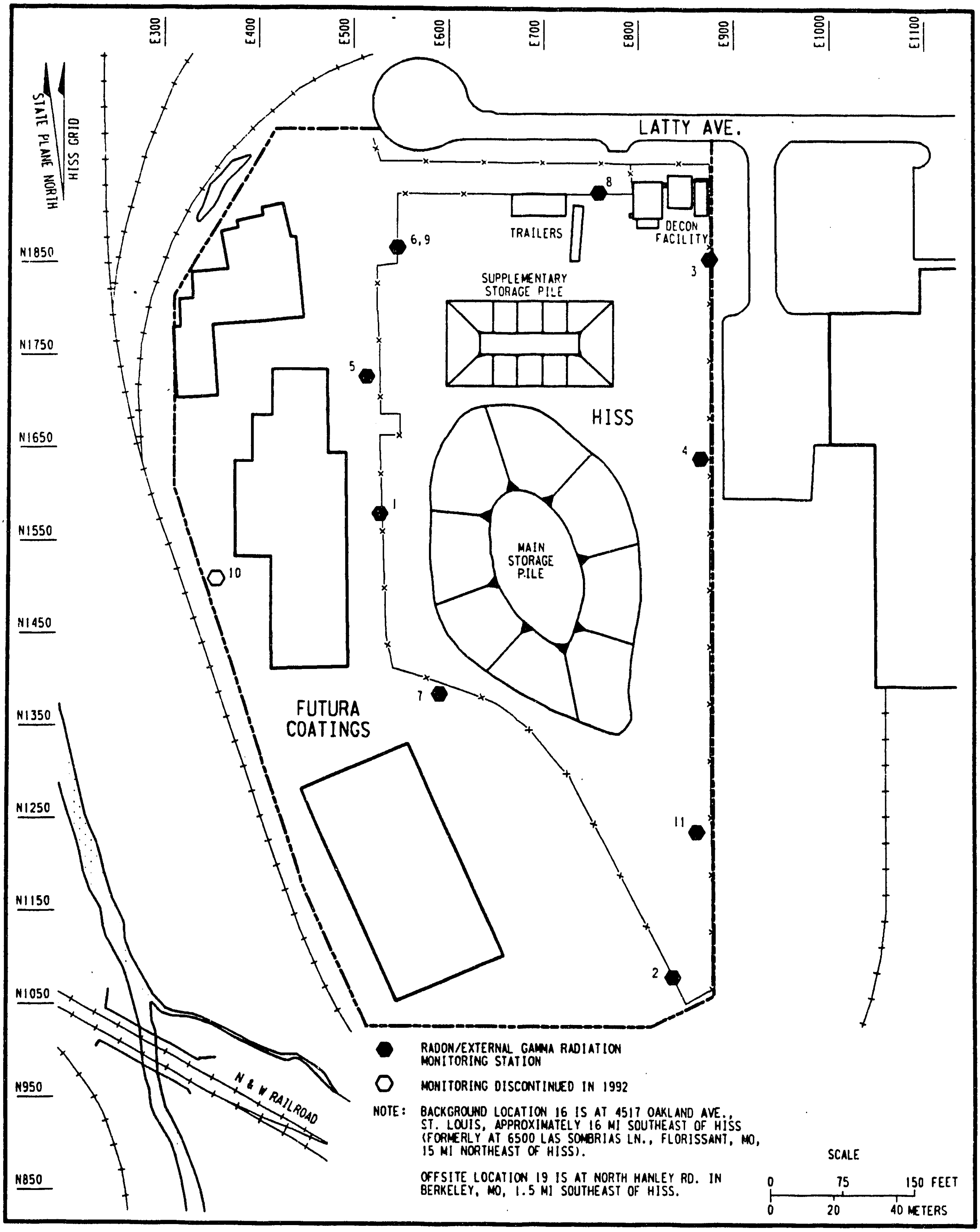
The figure shows a plume of groundwater containing above-background levels of uranium coming from the northern end of the large pile and migrating towards Latty Avenue. The historic range of values was considered during preparation of the map, and 24×10^{-9} μCi/ml was chosen as the minimum criterion for defining the plume; this value was chosen to reflect DOE's dose limit for drinking water. Wells that exceeded the 24×10^{-9} μCi/ml criterion during only one sampling iteration were not plotted as part of the plume. The data were included on the figure; however, unless the concentration elevation was chronic (i.e., occurring during more than sampling event), the results were considered to be anomalous. HISS-4 was the only exception to this rule. During the period in which HISS-4 was sampled (1984-1985), five samples yielded elevated total uranium values. HISS-4 was replaced by HISS-14 in 1984. Since its installation, HISS-14 has not shown elevated levels of uranium. The reason for the discrepancy is not known; however, it is surmised that HISS-4 was improperly constructed. Historic ranges for total uranium analyses for both HISS-4 and HISS-14 are noted in Figure 3-9.

HISS-5D, installed in the rubble layer immediately above bedrock, was sampled for radiological parameters in the fall of 1992. The results are presented in Table 3-13. All contaminant levels are below DOE guidelines and background levels measured in B53W01D (Table 3-16) and B53W11D (Table 3-12).

Conductivity, pH, and temperature values measured in the field during sampling for radioactive contamination in groundwater are presented in Table 3-14. Groundwater pH at HISS (6.6 to 7.5) is slightly more acidic than in the alluvial river sediments in the St. Louis region (pH of 7.0 to 8.2) (Miller et al. 1974); however, the values are typical of industrial settings. Conductivity values measured in the field (270 to 8,040 μmhos/cm) are slightly higher than typical conductivity values for alluvial sediments (316 to 1,760 μmhos/cm) (Miller et al. 1974). High conductivity values may reflect increased cation concentrations in groundwater. Wells closer to the pile also tend to have higher conductivities than those farther away. Elevated conductivity values may be a result of dissolved salts in groundwater associated with phosphatic salts from monazite sands. Temperature values fall within the range of reported values for groundwater in the St. Louis area (Miller et al. 1974).

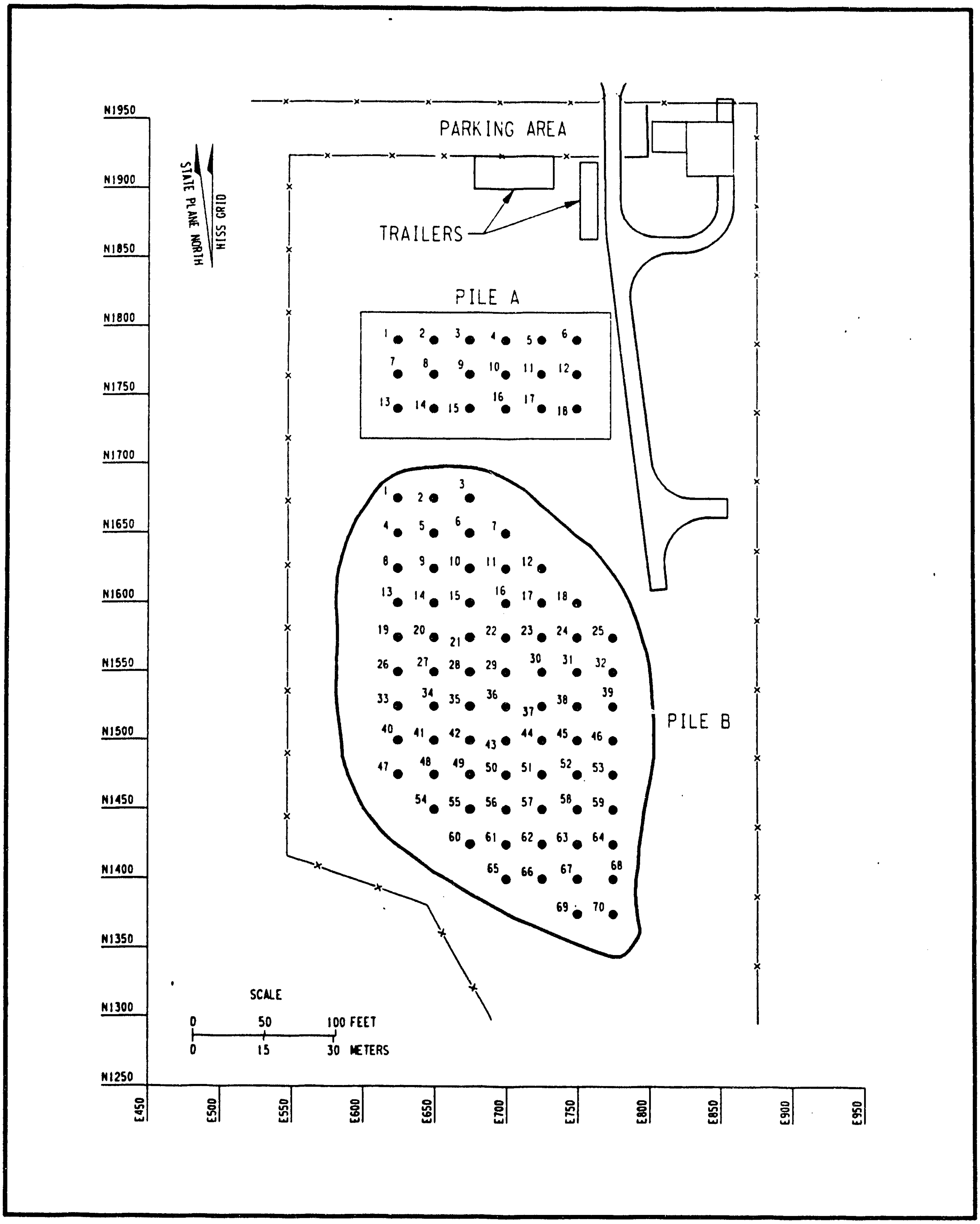
Water quality data are summarized in Table 3-15. Analyses for water quality parameters were performed to ascertain the impact of the storage piles on near-surface groundwater at the site. Measured values reported for sulfate and total dissolved solids (TDS) in samples from HISS-12 and for potassium, chlorine, sulfate, and TDS from HISS-16 are elevated when compared with values reported in the literature (Miller et al. 1974). The other ion concentrations fall within the ranges reported in the literature. Charge balance calculations were performed using the reported values. (A charge balance calculation is a summation of the positive and negative milliequivalent charges contributed by the ions in solution. The solution should be electrically neutral; therefore, theoretically, if all ions in solution are accurately quantified, the result of a charge balance calculation should be zero. A deviation of plus or minus 10 percent is considered acceptable.) The results of the HISS charge balance calculations have a significant margin of error (Table 3-15), which implies that the impact of the contamination at HISS on the groundwater has not been completely assessed. The large margin of error in the charge balance calculations may be a result of erroneously reported sulfate values or may reflect anions such as nitrates or phosphates present in groundwater but not included in the laboratory analysis. Phosphate levels in groundwater at SLAPS approach saturation. The calculated values for TDS are similar to concentrations reported in Miller et al. (1974).

FIGURES FOR SECTION 3.0



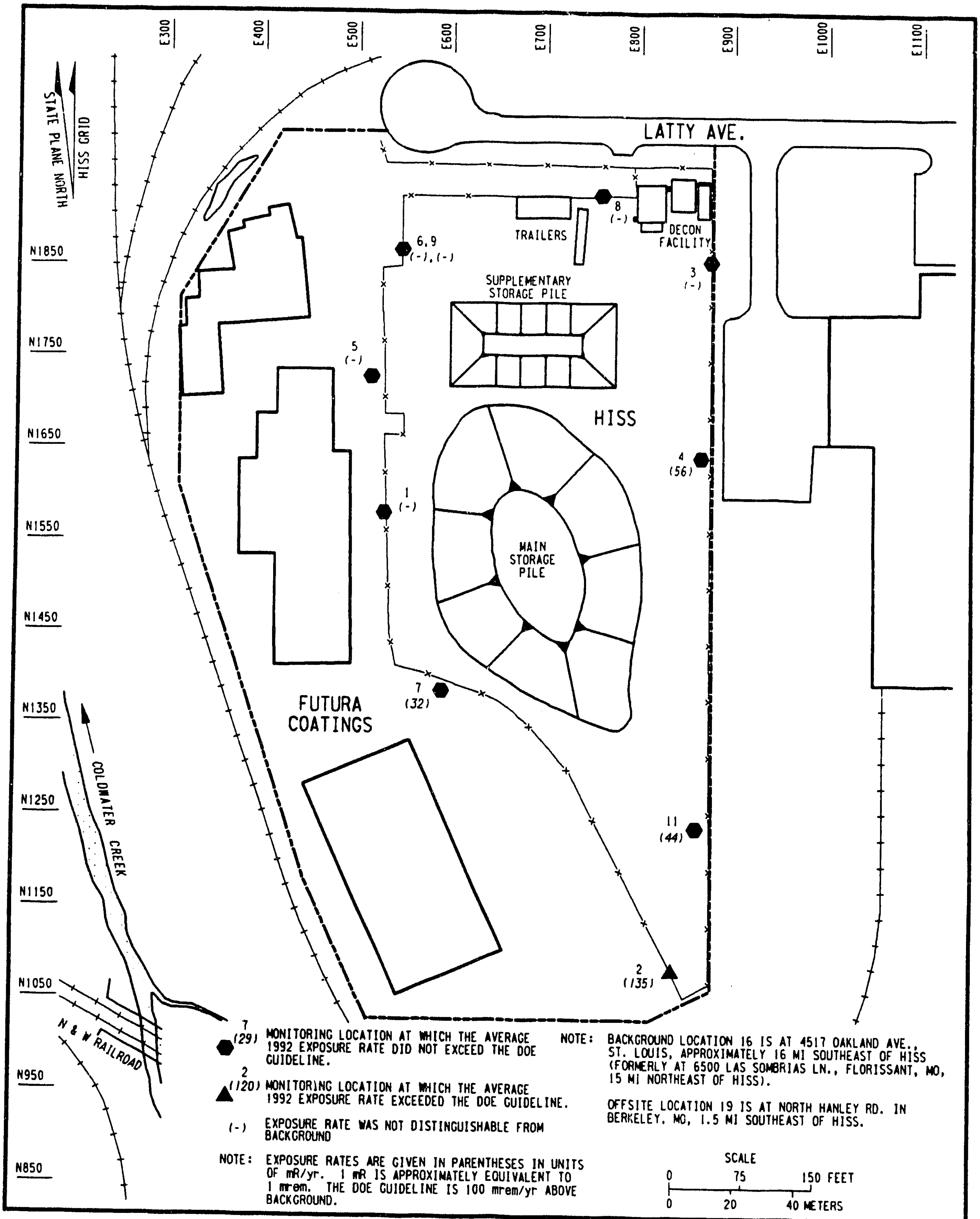
140 R34F005.DGN

Figure 3-1
Radon and External Gamma Radiation Monitoring Locations at HISS



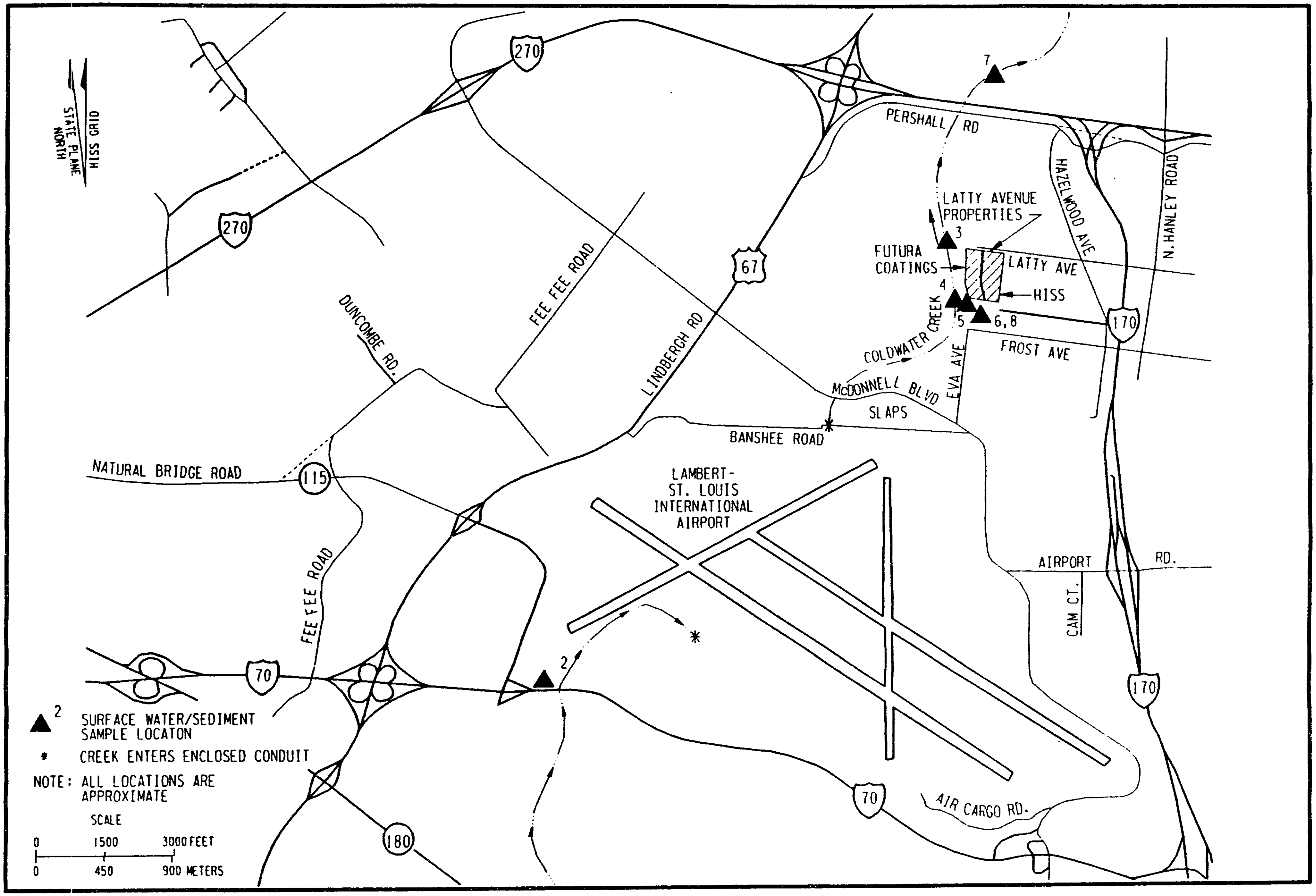
140 R34F017.DGN

Figure 3-2
Approximate Radon Flux Monitoring Locations at HISS



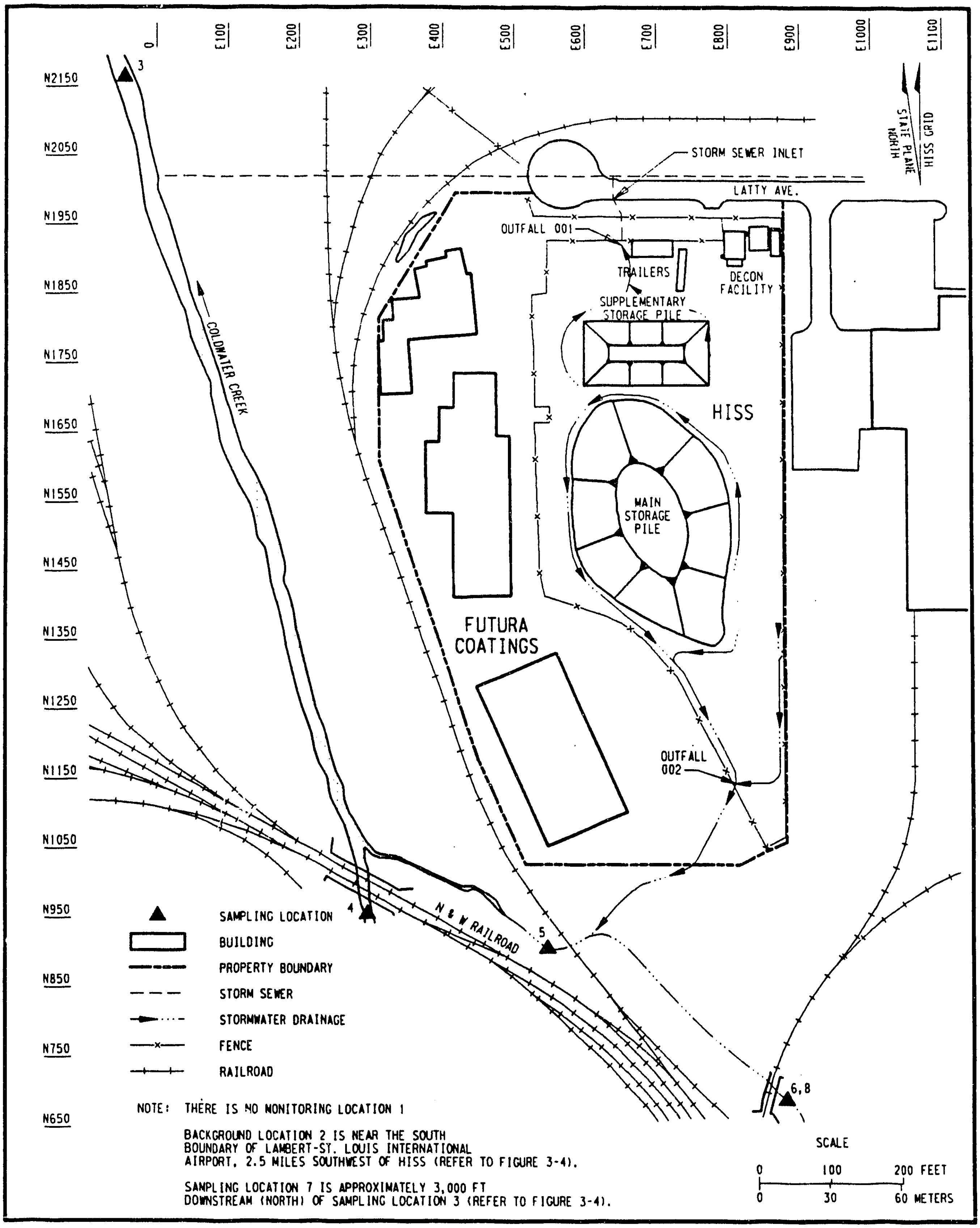
140 R34F006.DGN

Figure 3-3
Average External Gamma Radiation Exposure Rates Above Background at HISS



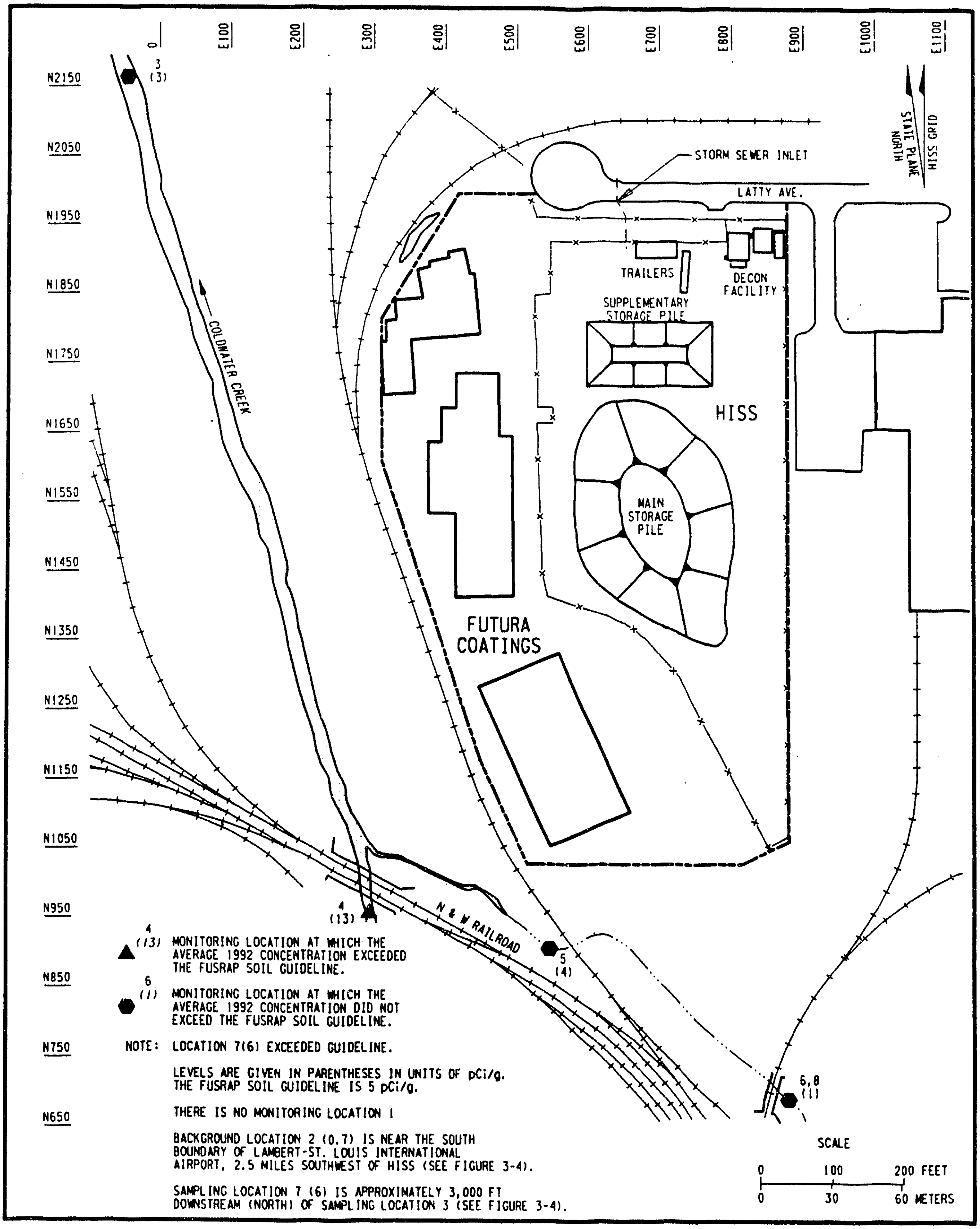
140 R34F018.DGN

Figure 3-4
Approximate Locations for Surface Water and Sediment Sampling in the Vicinity of HISS



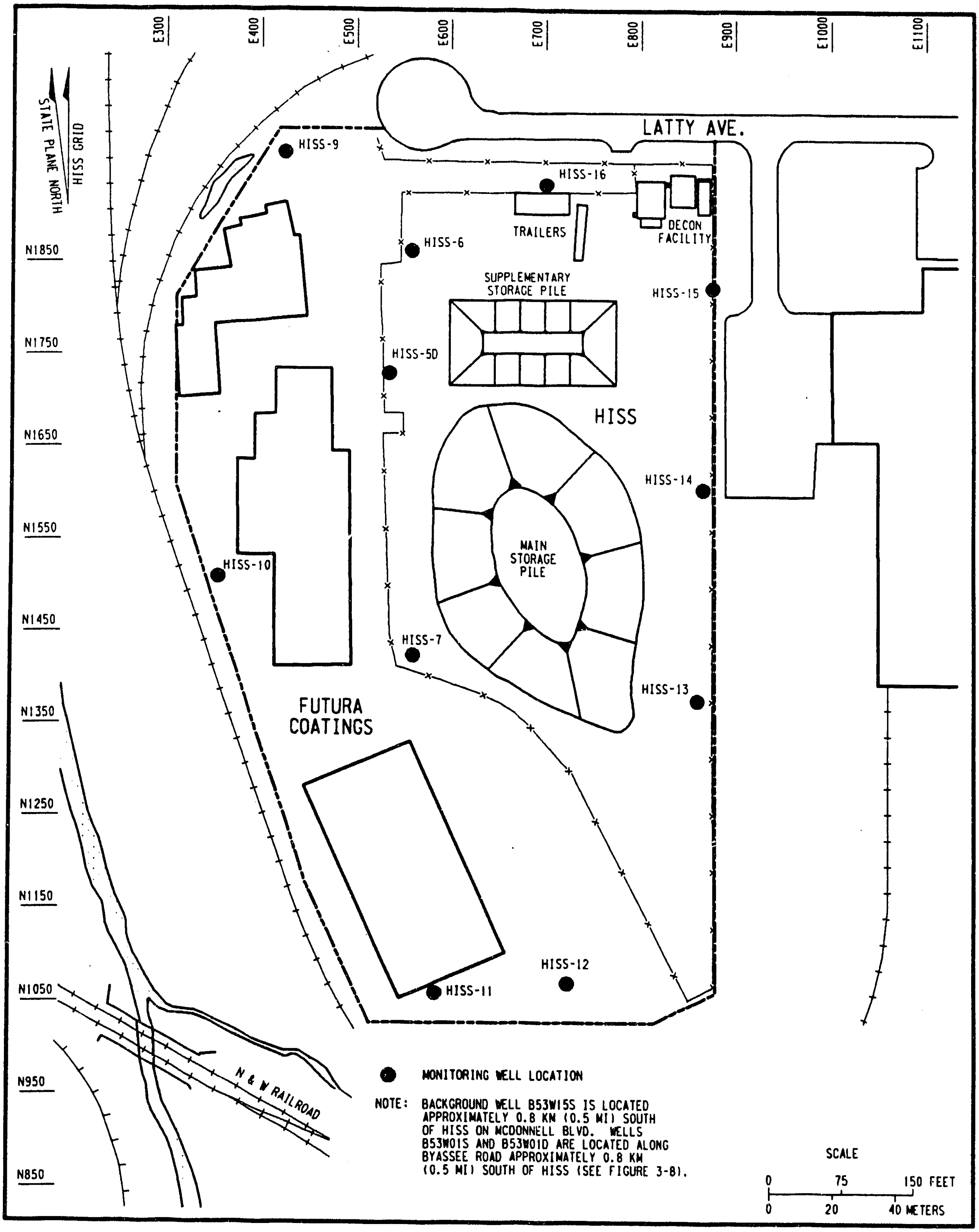
140 R34F013.DGN

Figure 3-5
Surface Water, Sediment, and Stormwater Sampling Locations in the Vicinity of HISS



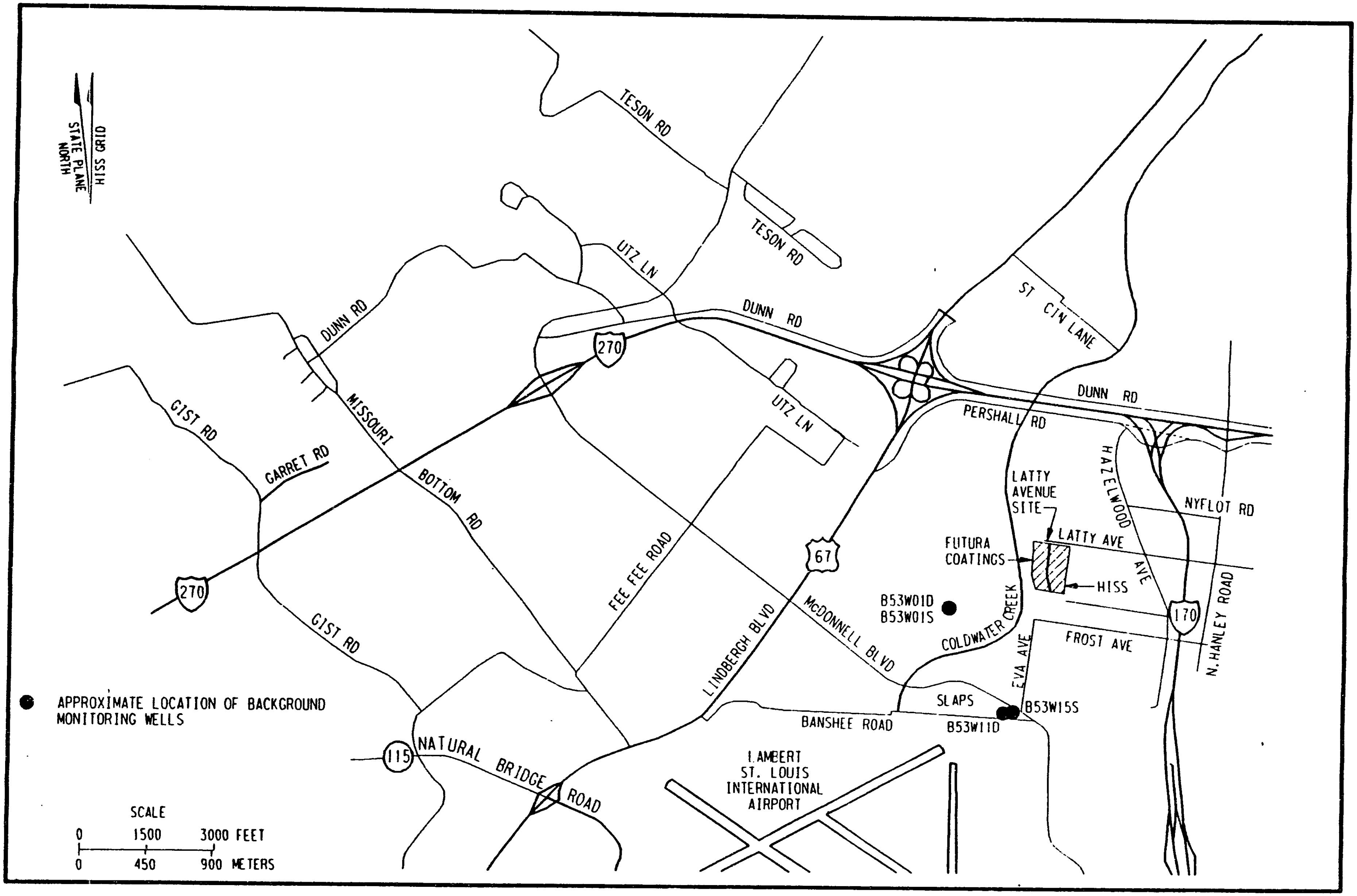
140 R34F014.DGN

Figure 3-6
Annual Average Thorium-230 Concentrations in Sediment at HISS in 1992



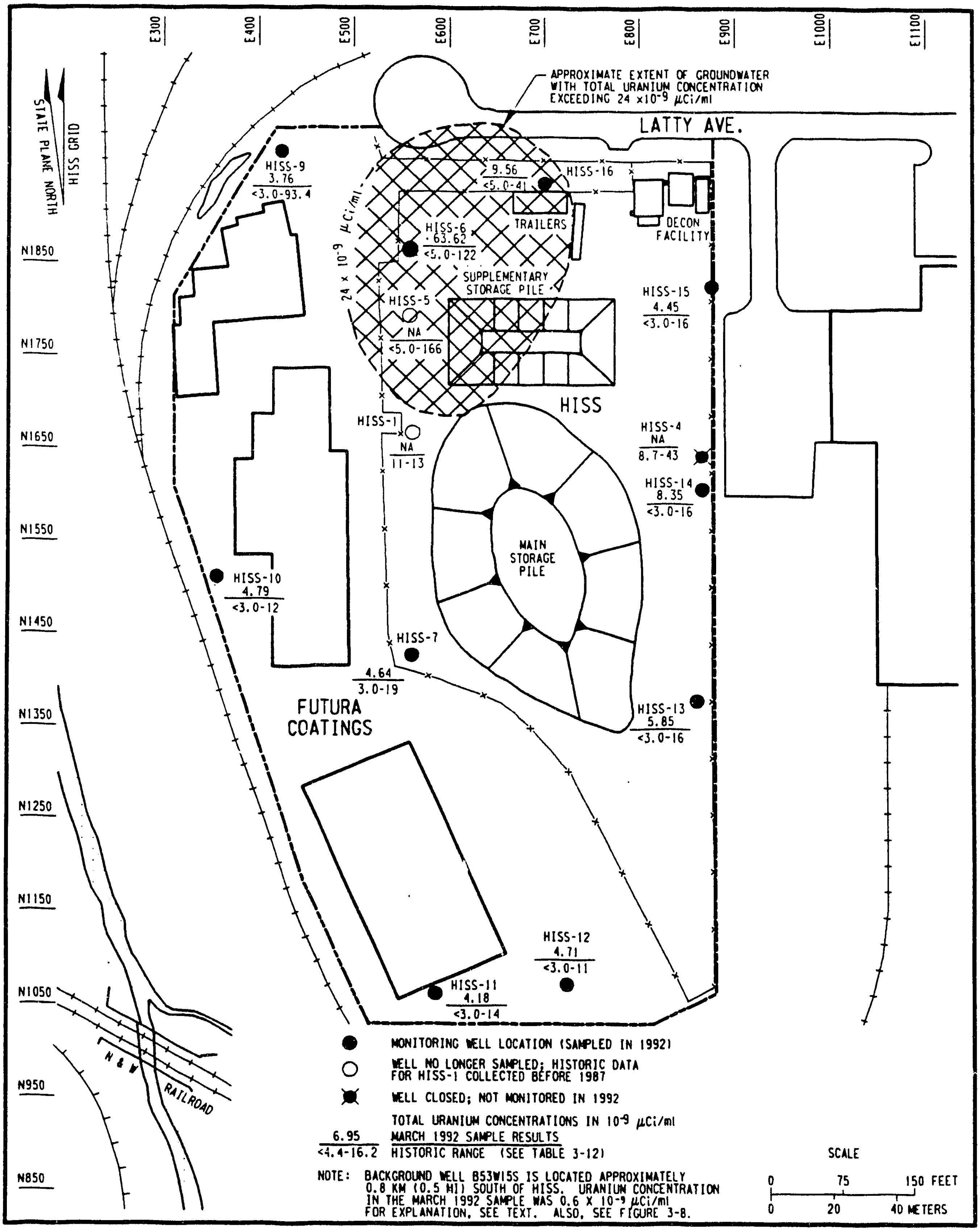
140 R34F007.DGN

Figure 3-7
Groundwater Sampling Locations at HISS



134 R34F019.DGN

Figure 3-8
Background Monitoring Well Locations in the Vicinity of HISS



140 R34F012.DGN

Figure 3-9
Uranium Concentrations in Groundwater at HISS

TABLES FOR SECTION 3.0

Table 3-1

Average Concentrations[a,b] of Radon[c] at HISS, 1992

Sampling Location[d]	Exposure Period 10/26/91-01/22/92[e]	01/22/92-03/30/92	03/30/92-06/30/92	06/30/92-10/01/92	10/01/92-01/19/93	1992 Avg
	(Concentrations are in 10^{-9} μCi/ml)					
Property Line (HISS and Futura)						
2	0.4	0.5	0.5	0.6	0.4	0.5
3	<0.3	<0.4	<0.3	0.3	<0.3	0.3
4	0.6	<0.4	0.7	0.4	<0.3	0.5
10	<0.3	--[f]	--[f]	--[f]	--[f]	--[f]
11	<0.3	0.5	0.4	0.4	<0.3	0.3
Onsite (HISS/Futura Boundary)						
1	<0.3	0.5	0.4	0.4	<0.3	0.4
5	0.6	<0.4	0.4	0.5	<0.3	0.4
6	<0.3	<0.4	<0.3	0.4	<0.3	0.4
7	<0.3	<0.4	0.7	<0.3	<0.3	0.4
8	<0.3	0.5	0.4	<0.3	<0.3	0.4
Quality Control						
9[g]	<0.3	<0.4	<0.3	<0.3	<0.3	0.3
Background						
16[h]	<0.3	0.7	<0.3	<0.3	<0.3	0.4
19[i]	0.4	<0.4	<0.3	<0.3	<0.3	0.3

[a]1 x 10^{-9} μCi/ml is equivalent to 0.037 Bq/L. The DOE guideline is 3.0 x 10^{-9} μCi/ml.
[b]Background level has not been subtracted from property-line and onsite readings. Concentrations at some stations were below the background level.
[c]The half-life of radon-222 is 3.82 days.
[d]Sampling locations are shown in Figure 3-1. Property-line locations are those on the boundary surrounding HISS and Futura; onsite locations are those on the boundary between HISS and Futura.
[e]Data not previously reported. See Subsection 2.4.2 for explanation.
[f]Station deleted from program in 1992.
[g]Quality control for station 6.
[h]Located at 4517 Oakland Avenue, St. Louis, approximately 26 km (16 mi) southeast of HISS.
[i]Located at North Hanley Road, Berkeley, Mo., approximately 2.5 km (1.5 mi) east of HISS.

Table 3-2

Trend Analysis for Radon[a] Concentrations[b,c] at HISS, 1987-1992

Page 1 of 2

Sampling Location[d]	Average Annual Concentration 1987	1988	1989	1990	1991	Expected Range[e] ($\bar{x} \pm 2s$)	Average Annual Concentration 1992
			(Concentrations are in 10^{-9} μCi/ml)				
Property Line							
2	0.7	0.7	0.9	0.4	0.8	0.3 - 1.1	0.5
3	0.6	0.6	0.5	0.4	0.4	0.3 - 0.7	0.3
4	1.5	1.3	0.9	0.5	0.8	0.2 - 1.8	0.5
10	0.4	0.4	0.5	0.4	0.4	0.3 - 0.5	--
11	1.2	0.8	0.6	0.4	0.6	0.1 - 1.3	0.3
Onsite							
1	1.0	0.9	0.8	0.4	0.5	0.2 - 1.2	0.4
5	0.3	0.9	0.5	0.4	0.5	0.1 - 1.0	0.4
6	0.8	0.7	0.5	0.4	0.6	0.3 - 0.9	0.4
7	1.8	0.6	0.6	0.4	0.4	0.0 - 1.9	0.4
8	0.3	0.5	0.5	0.4	0.7	0.2 - 0.8	0.4
Background							
16[f]	0.4	0.4	0.5	0.6	0.5	0.3 - 0.6	0.4
19[g]	--	0.7	0.5	0.4	0.5	0.3 - 0.8	0.3

Source for 1987-1991 data: BNI 1992c.

[a]The half-life of radon-222 is 3.82 days.
[b]1×10^{-9} μCi/ml is equivalent to 0.037 Bq/L. The DOE guideline is 3.0×10^{-9} μCi/ml.

Table 3-2

(continued)

[c]Measured background has not been subtracted from property-line and onsite readings.

[d]Sampling locations are shown in Figure 3-1. Property-line locations are those on the boundary surrounding HISS and Futura; onsite locations are those on the boundary between HISS and Futura.

[e]Average value ±2 standard deviations (approximately 95 percent confidence level).

[f]Relocated during fourth quarter 1990 to 4517 Oakland Avenue, St. Louis, approximately 26 km (16 mi) southeast of HISS; formerly located in Florissant, Mo., approximately 24 km (15 mi) southeast of HISS.

[g]Located at North Hanley Road, Berkeley, Mo., approximately 2.5 km (1.5 mi) east of HISS; established in April 1988.

Table 3-3

Radon[a] Flux Rates at HISS, 1992

Sample Identification[b]	Approximate Sampling Location[b]	Activity (pCi/m^2-s)
Small Pile		
01A	N 1790 E 625	<0.12
02A	N 1790 E 650	<0.12
03A	N 1790 E 675	<0.12
04A	N 1790 E 700	<0.12
05A	N 1790 E 725	0.15 ± 0.16
06A	N 1790 E 750	<0.12
07A	N 1765 E 625	<0.12
08A	N 1765 E 650	<0.12
09A	N 1765 E 675	<0.12
10A	N 1765 E 700	<0.12
11A	N 1765 E 725	0.09 ± 0.13
12A	N 1765 E 750	<0.08
13A	N 1740 E 625	<0.08
14A	N 1740 E 650	<0.08
15A	N 1740 E 675	0.11 ± 0.11
16A	N 1740 E 700	<0.09
17A	N 1740 E 725	0.17 ± 0.13
18A	N 1740 E 750	0.11 ± 0.11
		Ave. = 0.11
		Max. = 0.17
		Min. = 0.08
Large Pile		
01B	N 1690 E 625	0.27 ± 0.16
02B	N 1690 E 650	<0.12
03B	N 1690 E 675	0.14 ± 0.16
04B	N 1690 E 625	0.39 ± 0.16
05B	N 1690 E 650	0.16 ± 0.16
06B	N 1690 E 675	<0.12
07B	N 1690 E 700	<0.12
08B	N 1640 E 625	4.27 ± 0.22
09B	N 1640 E 650	0.39 ± 0.16
10B	N 1640 E 675	0.16 ± 0.17
11B	N 1640 E 700	1.24 ± 0.17

Table 3-3

(continued)

Sample Identification[b]	Approximate Sampling Location[b]		Activity (pCi/m^2-s)
Large Pile (cont.)			
12B	N 1640	E 725	<0.12
13B	N 1615	E 625	3.90 ± 0.21
14B	N 1615	E 650	0.39 ± 0.16
15B	N 1615	E 675	0.31 ± 0.16
16B	N 1615	E 700	0.19 ± 0.16
17B	N 1615	E 725	0.19 ± 0.16
18B	N 1615	E 750	<0.12
19B	N 1590	E 625	1.48 ± 0.16
20B	N 1590	E 650	0.40 ± 0.14
21B	N 1590	E 675	0.17 ± 0.13
22B	N 1590	E 700	0.22 ± 0.13
23B	N 1590	E 725	0.16 ± 0.13
24B	N 1590	E 750	<0.10
25B	N 1590	E 775	<0.10
26B	N 1565	E 625	0.64 ± 0.14
27B	N 1565	E 650	0.56 ± 0.14
28B	N 1565	E 675	<0.10
29B	N 1565	E 700	<0.10
30B	N 1565	E 725	<0.10
31B	N 1565	E 750	<0.10
32B	N 1565	E 775	<0.10
33B	N 1540	E 625	0.60 ± 0.14
34B	N 1540	E 650	0.59 ± 0.14
35B	N 1540	E 675	<0.09
36B	N 1540	E 700	0.10 ± 0.13
37B	N 1540	E 725	0.12 ± 0.13
38B	N 1540	E 750	<0.09
39B	N 1540	E 775	<0.10
40B	N 1515	E 625	0.42 ± 0.13
41B	N 1515	E 650	0.30 ± 0.13
42B	N 1515	E 675	0.13 ± 0.13
43B	N 1515	E 700	<0.10
44B	N 1515	E 725	<0.10
45B	N 1515	E 750	<0.10
46B	N 1515	E 775	<0.10
47B	N 1490	E 625	<0.10

Table 3-3

(continued)

Sample Identification[b]	Approximate Sampling Location[b]		Activity (pCi/m^2-s)
Large Pile (cont.)			
48B	N 1490	E 650	0.12 ± 0.13
49B	N 1490	E 675	<0.10
50B	N 1490	E 700	<0.10
51B	N 1490	E 725	<0.09
52B	N 1490	E 750	0.16 ± 0.13
53B	N 1490	E 775	<0.09
54B	N 1465	E 650	<0.09
55B	N 1465	E 675	0.12 ± 0.13
56B	N 1465	E 700	0.12 ± 0.13
57B	N 1465	E 725	<0.09
58B	N 1465	E 750	<0.09
59B	N 1465	E 775	<0.09
60B	N 1440	E 675	<0.10
61B	N 1440	E 700	0.17 ± 0.16
62B	N 1440	E 725	<0.10
63B	N 1440	E 750	0.10 ± 0.13
64B	N 1440	E 775	0.11 ± 0.13
65B	N 1415	E 700	0.17 ± 0.16
66B	N 1415	E 725	0.12 ± 0.15
67B	N 1415	E 750	<0.11
68B	N 1415	E 775	<0.11
69B	N 1390	E 750	0.15 ± 0.15
70B	N 1390	E 775	<0.11
			Ave. = 0.32
			Max. = 4.27
			Min. = 0.09

[a]The half-life of radon-222 is 3.82 days.
[b]Monitoring locations are shown in Figure 3-2.

Table 3-4

Average External Gamma Radiation Exposure Rates[a]

at HISS, 1992

Sampling Location[b]	Exposure Period 1/91 to 1/92[c]	1/92 to 6/92[d]	1/92 to 1/93[d]	1992 Avg
(Rates are in mR/yr)				
Property Line (measured background subtracted)[e] (HISS and Futura)				
2	151	136	134	135
3	0	0	0	0
4	74	57	54	56
10	0	f	f	f
11	31	44	44	44
Onsite (measured background subtracted)[d] (HISS/Futura Boundary)				
1	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	34	31	33	32
8	0	0	0	0
Quality Control				
9[g]	0	0	0	0
Background				
16[h]	83	95	73	84
19[i]	105	131	104	118
	94	113	89	101

[a]The DOE guideline is 100 mrem/yr above background. 1 mrem is approximately equivalent to 1 mR.

[b]Sampling locations are shown in Figure 3-1. Property-line locations are those on the boundary surrounding HISS and Futura; onsite locations are those on the boundary between HISS and Futura.

[c]Data not previously presented. See Subsection 2.4.2 for explanation.

[d]For this exposure period, the result for each monitoring location is the average of two dosimeters.

[e]Average annual measured background for each exposure period has been subtracted from the property-line and onsite readings for the same exposure period.

[f]Sampling location deleted from program in 1992.

[g]Quality control for station 6.

[h]Located at 4517 Oakland Avenue, St. Louis, approximately 26 km (16 mi) southeast of HISS.

[i]Located at North Hanley Road, Berkeley, Mo., approximately 2.5 km (1.5 mi) east of HISS.

Table 3-5

Trend Analysis for External Gamma Radiation Exposure Rates[a]

at HISS, 1987-1992

Page 1 of 2

Sampling Location[b]	Average Annual Rate					Expected Range[c]	Average Annual Rate Above Background
	1987	1988	1989	1990	1991	($\bar{X} \pm 2s$)	1992
				(Rates are in mR/yr)			
Property Line (measured background subtracted)[d]							
2	113	116	129	107	120	101 - 133	135
3	20	14	2	0	0	0 - 26	0
4	74	83	68	62	63	53 - 87	56
10	17	13	1	0	0	0 - 23	[e]
11	45	56	36	35	34	22 - 60	44
Onsite (measured background subtracted)[d]							
1	44	40	6	0	0.5	0 - 62	0
5	46	51	5	0	0.3	0 - 72	0
6	29	44	5	0	0	0 - 55	0
7	50	61	61	28	29	13 - 79	32
8	27	11	0	0	0	0 - 31	0
Background							
16[f]	77	73	61	59	63	51 - 83	84
19[g]	--	--	92	96	97	90 - 100	118

Source for 1987-1991 data: BNI 1992c.

[a]The DOE guideline is 100 mrem/yr above background. 1 mrem is approximately equivalent to 1 mR.

Table 3-5

(continued)

[b]Sampling locations are shown in Figure 3-1. Property-line locations are those on the boundary surrounding HISS and Futura; onsite locations are those on the boundary between HISS and Futura.

[c]Average value ±2 standard deviations (approximately 95 percent confidence level).

[d]Average annual measured background for each monitoring period has been subtracted from the property-line and onsite readings for the same monitoring period.

[e]Sampling location deleted from program in 1992.

[f]Relocated during fourth quarter 1990 to 4517 Oakland Avenue, St. Louis, approximately 26 km (16 mi) southeast of HISS; formerly located in Florissant, Mo., approximately 24 km (15 mi) southeast of HISS.

[g]Located at North Hanley Road, Berkeley, Mo., approximately 2.5 km (1.5 mi) east of HISS; established in April 1988.

Table 3-6

External Gamma Radiation Exposure Rates for Comparison

Location	Rate[a] (mR/yr)
Maximum fenceline exposure at HISS including background (1992)	236
Site background (1992)	100
U.S. background[b]	103
Grand Central Station[c]	525
Statue of Liberty base[c]	325

[a]The rate for HISS is the maximum exposure measured; all other rates are averages.

[b]Shleien 1989.

[c]Appendix B.

Table 3-7

Concentrations[a,b] of Total Uranium, Radium-226, and Thorium-230 in Surface Water in the Vicinity of HISS, 1992

Sampling Location[c]	March Concentration	March 2-Sigma Error[d]	September Concentration	September 2-Sigma Error[d]	Avg
(Concentrations are in 10^{-9} μCi/ml)					
Total Uranium[e]					
Downstream					
3	3.62	0.37	2.23	0.22	2.93
4	4.73	0.48	2.64	0.27	3.69
5	3.23	0.33	2.23	0.23	2.73
6	2.54	0.28	1.83	0.19	2.19
7	3.99	0.41	3.39	0.35	3.69
Quality Control[f]					
8	1.81	0.18	1.96	0.20	1.89
Background[g]					
2	1.10	0.12	1.02	0.10	1.06
Radium-226[e]					
Downstream					
3	1.07	0.62	0.34	0.23	0.71
4	0.38	0.29	0.35	0.21	0.37
5	1.01	0.66	0.25	0.19	0.63
6	3.01	1.32	0.41	0.24	1.71
7	<0.87		0.17	0.18	0.52
Quality Control[f]					
8	1.20	0.72	0.07	0.11	0.6
Background[g]					
2	<0.35		0.32	0.26	0.34

Table 3-7

(continued)

Sampling Location[c]	March Concentration	March 2-Sigma Error[d]	September Concentration	September 2-Sigma Error[d]	Avg
	(Concentrations are in 10^{-9} μCi/ml)				
	Thorium-230[e]				
Downstream					
3	0.51	0.29	0.04	0.19	0.28
4	<0.22		0.27	0.32	0.25
5	0.32	0.22	0.40	0.42	0.36
6	<0.18		0.48	0.48	0.33
7	<0.19		1.7	2.1	0.95
Quality Control[f]					
8	0.13	0.14	0.15	0.26	0.14
Background[g]					
2	0.19	0.18	0.26	0.38	0.23

[a]1 × 10^{-9} μCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L. DOE guidelines for total uranium, radium-226, and thorium-230 are 600 × 10^{-9}, 100 × 10^{-9}, and 300 × 10^{-9} μCi/ml, respectively.

[b]Measured background has not been subtracted.

[c]Sampling locations are shown in Figures 3-4 and 3-5.

[d]2-sigma error measures instrument background plus error induced by counting time and count rate.

[e]The half-life of this radionuclide is provided in Appendix F, Table F-1.

[f]Quality control sample was collected at location 6.

[g]Background sampling station located south of runway 6 at Lambert-St. Louis International Airport, upstream of any influence from HISS.

Table 3-8

Trend Analysis for Total Uranium, Radium-226, and Thorium-230 Concentrations[a,b] in Surface Water in the Vicinity of HISS, 1987-1992

Sampling Location[c]	Average Annual Concentration 1987	1988	1989	1990	1991	Expected Range[d] ($\bar{x} \pm 2s$)	Average Annual Concentration 1992
(Concentrations are in 10^{-9} µCi/ml)							
Total Uranium[c,f]							
2[g]	3	4	3	3	4	2 - 4	1.06
3	4	4	4	3	8	1 - 8	2.93
4	5	4	5	4	6	3 - 6	3.69
5	3	4	4	3	5	2 - 6	2.73
6	3	3	4	3	7	1 - 7	2.19
7[h]	--	--	--	--	--	--	3.69
Radium-226[f]							
2[g]	0.3	0.5	0.3	0.3	0.2	0.1 - 0.5	0.34
3	0.2	0.3	0.4	0.3	0.3	0.2 - 0.4	0.71
4	0.2	0.3	0.3	0.4	0.2	0.1 - 0.4	0.37
5	0.3	0.3	0.3	0.3	0.2	0.2 - 0.4	0.63
6	0.2	0.3	0.3	0.2	0.3	0.2 - 0.4	1.71
7[h]	--	--	--	--	--	--	0.52
Thorium-230[f]							
2[g]	0.2	0.1	0.1	0.2	0.4	0.0 - 0.4	0.23
3	0.3	0.2	0.2	0.1	0.5	0.0 - 0.6	0.28
4	0.4	0.3	0.2	0.2	0.6	0.0 - 0.7	0.25
5	0.3	0.1	0.1	0.5	0.5	0.0 - 0.7	0.36
6	0.1	0.3	0.1	0.1	0.5	0.0 - 0.6	0.33
7[h]	--	--	--	--	--	--	0.95

Table 3-8

(continued)

Source for 1987-1991 data: BNI 1992c.

[a]1×10^{-9} μCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L. DOE guidelines for total uranium, radium-226, and thorium-230 are 600×10^{-9}, 100×10^{-9}, and 300×10^{-9} μCi/ml, respectively.

[b]Measured background has not been subtracted.

[c]Sampling locations are shown in Figures 3-4 and 3-5.

[d]Average value ±2 standard deviations (approximately 95 percent confidence level).

[e]Total uranium concentrations were determined by fluorometric analysis during 1986 through 1990 and the first three quarters of 1991 and by kinetic phosphorescence analysis (KPA) since the last quarter of 1991. KPA is 100 times more sensitive than fluorometric analysis.

[f]The half-life of this radionuclide is provided in Appendix F, Table F-1.

[g]Background sampling station located south of runway 6 at Lambert-St. Louis International Airport, upstream of any influence from HISS.

[h]Monitoring location 7 was added in 1992.

Table 3-9

Stormwater Monitoring Results

for Outfalls 001 and 002 at HISS

(NPDES Permit No. MO-0111252)

Parameter (unit)[a,b]	Minimum	Maximum	Average
Outfall 001			
Flow (MGD)[c]	ND[d]	1.944	3.03×10^{-5}
Rainfall (inches)	0.0	1.76	0.10
Settleable solids (ml/L/h)	0.50[e]	0.50[e]	0.50[e]
pH (SU)[c]	6.7	7.31	--
Specific conductivity (μmhos/cm)	129	390	236
Total organic carbon (mg/L)	4.1	12.3	8.7
Total organic halides (mg/L)	0.0050[e]	0.0955	0.03
Gross alpha (pCi/L)	9.9	76.02	37
Gross beta (pCi/L)	12.5	31.17	18.6
Lead-210 (pCi/L)	1.40	11.46	4.74
Radium-226 (pCi/L)	0.12	2.69	1.2
Radium-228 (pCi/L)	0.40[e]	1.7	1.0
Total uranium (pCi/L)	1.76	11.0	24.4
Thorium-230 (pCi/L)	9.00	31.6	22.7
Thorium-232 (pCi/L)	0.1[e]	0.13	0.14
Outfall 002			
Flow (MGD)[c]	ND	0.866	0.89×10^{-5}
Rainfall (inches)	0.0	1.76	0.10
Settleable solids (ml/L/h)	0.50[e]	0.50[e]	0.50[e]
pH (SU)[c]	6.6	7.14	--
Specific conductivity (μmhos/cm)	68	130	110
Total organic carbon (mg/L)	4.2	15.7	8.6
Total organic halides (mg/L)	0.0050[e]	0.0289	0.011
Gross alpha (pCi/L)	14.5	196.0	80
Gross beta (pCi/L)	8.90	54.6	27
Lead-210 (pCi/L)	0.50[e]	20.50	10
Radium-226 (pCi/L)	0.46	8.9	3.0
Radium-228 (pCi/L)	0.70	2.2	1.2
Total uranium (pCi/L)	1.35	30.7	57.4
Thorium-230 (pCi/L)	12.50	160.5	53.4
Thorium-232 (pCi/L)	0.1[e]	0.36	0.2

Table 3-9

(continued)

[a]The final effluent limitations for settleable solids are 1.5 ml/L/h (daily maximum) and 1.0 ml/L/h (monthly average). The limitation for pH is a set range from 6.0 to 9.0. All other parameters are monitoring requirements without specific permit limits.

[b]Samples were collected in the first quarter, on 2/14/92 and 3/18/92; third quarter, on 8/26/92; and fourth quarter, on 12/15/92. During the second quarter, rainfall was insufficient to generate discharge through the outfalls during regular working hours; therefore, no second quarter samples were collected.

[c]MGD = millions of gallons per day; SU = standard units.

[d]ND = no discharge.

[e]Parameter not detected at or above the detection limit.

Table 3-10

Concentrations[a,b] of Total Uranium, Radium-226, and Thorium-230 in Sediment in the Vicinity of HISS, 1992

Sampling Location[c]	March Concentration	March 2-Sigma Error[d]	September Concentration	September 2-Sigma Error[d]	Avg
		(Concentrations are in pCi/g)			
		Total Uranium[e,f]			
Downstream					
3	4.25	0.43	2.23	0.22	3.24
4	5.35	0.54	2.23	0.22	3.79
5	4.01	0.40	2.17	0.22	3.09
6	4.44	0.45	1.90	0.19	3.17
7	4.87	0.47	1.96	0.19	3.42
Quality Control[g]					
8	4.80	0.48	1.76	0.18	3.28
Background[h]					
2	4.22	0.42	1.76	0.18	2.99
		Radium-226[f]			
Downstream					
3	0.56	0.07	0.90	0.24	0.73
4	0.72	0.09	0.88	0.08	0.80
5	1.40	0.18	0.84	0.11	1.12
6	1.30	0.51	0.81	0.21	1.06
7	1.30	0.35	0.62	0.16	0.96
Quality Control[g]					
8	1.10	0.57	0.79	0.07	0.95
Background[h]					
2	1.00	0.05	1.10	0.10	1.05

Table 3-10

(continued)

Sampling Location[c]	March Concentration	March 2-Sigma Error[d]	September Concentration	September 2-Sigma Error[d]	Avg
		(Concentrations are in pCi/g)			
		Thorium-230[f]			
Downstream					
3	2.82	0.94	3.30	0.99	3.06
4	21.90	2.3	4.00	1.1	12.95
5	5.33	1.22	2.40	0.84	3.87
6	1.42	0.74	0.78	0.50	1.10
7	11.60	1.7	0.85	0.52	6.23
Quality Control[g]					
8	0.86	0.64	0.59	0.43	0.73
Background[h]					
2	0.88	0.65	0.57	0.44	0.73

[a]1 pCi/g is equivalent to 0.037 Bq/g. FUSRAP soil guidelines for total uranium, radium-226, and thorium-230 are 50, 5, and 5 pCi/g above background, respectively.

[b]Measured background has not been subtracted.

[c]Sampling locations are shown in Figures 3-4 and 3-5.

[d]Total uranium concentrations were determined by summing the concentrations of uranium-234, uranium-235, and uranium-238.

[e]2-sigma error measures instrument background plus error induced by counting time and count rate.

[f]The half-life of this radionuclide is provided in Appendix F, Table F-1.

[g]Quality control sample was collected at location 6.

[h]Background sampling station located south of runway 6 at Lambert-St. Louis International Airport, upstream of any influence from HISS.

Table 3-11

Trend Analysis for Total Uranium, Radium-226, and Thorium-230 Concentrations[a,b] in Sediment in the Vicinity of HISS, 1987-1992

Sampling Location[c]	Average Annual Concentration					Expected Range[d]	Average Annual Concentration
	1987	1988	1989	1990	1991	($\bar{X} \pm 2s$)	1992
(Concentrations are in pCi/g)							
Total Uranium[c,f]							
2[g]	1.6	1.7	1.9	1.6	2.0	1.4 - 2.1	2.99
3	2.0	1.4	2.1	1.0	1.8	0.7 - 2.6	3.24
4	2.1	2.2	1.9	2.3	2.2	1.8 - 2.4	3.79
5	1.8	2.1	1.9	2.0	3.1	1.1 - 3.2	3.09
6	1.5	1.4	1.9	1.6	3.0	0.6 - 3.2	3.17
7[h]							3.42
Radium-226[f]							
2[g]	1.0	1.5	1.2	3.0	1.1	0.0 - 3.2	1.05
3	1.2	1.0	2.3	1.4	0.9	0.2 - 2.5	0.73
4	1.2	1.2	1.2	2.0	1.1	0.6 - 2.1	0.80
5	1.4	1.6	1.4	1.0	1.0	0.7 - 1.8	1.12
6	1.2	0.8	1.4	1.0	1.4	0.6 - 1.7	1.06
7[h]							0.96
Thorium-230[f]							
2[g]	1.6	1.3	0.8	0.7	1.3	0.4 - 1.9	0.73
3	2.7	5.8	44.4	12.0	4.9	0.0 - 49	3.06
4	0.9	4.3	2.2	5.0	3.3	0.0 - 6.4	12.95
5	2.9	7.5	2.1	6.0	16.0	0.0 - 18	3.87
6	20.0	1.5	2.0	1.0	8.7	0.0 - 23	1.10
7[h]							6.23

Table 3-11

(continued)

Source for 1987-1991 data: BNI 1992c.

[a]1 pCi/g is equivalent to 0.037 Bq/g. DOE guidelines for total uranium, radium-226, and thorium-230 are 50, 5, and 5 pCi/g, respectively.

[b]Measured background has not been subtracted.

[c]Sampling locations are shown in Figures 3-4, 3-5, and 3-6.

[d]Average value ±2 standard deviations (approximately 95 percent confidence level).

[e]Total uranium concentrations were determined by summing the concentrations of uranium-234, uranium-235, and uranium-238.

[f]The half-life of this radionuclide is provided in Appendix F, Table F-1.

[g]Background sampling location located south of runway 6 at Lambert-St. Louis International Airport, upstream of any influence from HISS.

[h]Location 7 was added in 1992.

Table 3-12

Concentrations[a,b] of Total Uranium, Radium-226, and Thorium-230 in Groundwater at HISS, 1992

Sampling Location[c]	March Concentration	March 2-Sigma Error[e]	September Concentration	September 2-Sigma Error[e]	Historic Range[d]
	(Concentrations are in 10^{-9} µCi/ml)				
Total Uranium[f]					
HISS-5	--	--	--	--	<5.0-166 (8)
HISS-6	63.61	6.47	29.9	3.45	<5.0-122 (32)
HISS-7	4.64	0.50	--[g]	--	3.0-19 (12)
HISS-9	3.76	0.39	0.88	0.09	<3.0-93.4 (27)
HISS-9 (duplicate)	2.92	0.30	0.95	0.09	--
HISS-10	4.79	0.50	--	--	<3.0-12 (28)
HISS-11	4.18	0.43	--	--	<3.0-14 (28)
HISS-12	4.71	0.48	--	--	<3.0-11 (28)
HISS-13	5.85	0.60	--	--	<3.0-16 (28)
HISS-14	8.35	0.96	--	--	<3.0-13 (10)
HISS-15	4.45	0.47	1.35	0.14	<3.0-16 (28)
HISS-16	9.56	1.10	13.88	1.63	<5.0-41 (8)
Background					
B53W15S[h,i]	6.15	0.63	--	--	--
B53W01S[h]	--	--	--	--	3.0-11 (14)
B53W11D[h,i]	18.6	2.2	--	--	--
Radium-226[f]					
HISS-5	--	--	--	--	0.1-0.7 (8)
HISS-6	4.82	1.52	1.4	0.51	0.3-3.7 (32)
HISS-7	1.31	0.56	--	--	0.1-3.8 (12)
HISS-9	17.7	8.75	0.18[j]	0.17	<0.1-2.6 (27)
HISS-9 (duplicate)	8.12	2.88	0.24	0.19	--
HISS-10	4.49	1.95	--	--	<0.07-2.7 (28)
HISS-11	4.94	1.94	--	--	0.1-9.3 (28)
HISS-12	2.85	1.17	--	--	<0.1-1.5 (28)
HISS-13	2.28	1.41	--	--	<0.1-5.2 (28)
HISS-14	0.92	0.59	--	--	0.7-7.0 (10)
HISS-15	10.5	3.24	0.67	0.33	<0.1-2.5 (28)
HISS-16	7.56	2.33	1.9	0.54	0.2-5.6 (8)

Table 3-12
(continued)

Sampling Location[c]	March Concentration	March 2-Sigma Error[e]	September Concentration	September 2-Sigma Error[e]	Historic Range[d]
Radium-226[f] (cont'd)					
Background					
B53W15S[h,i]	2.29	0.97	--	--	--
B53W01S[h]	--	--	--	--	0.2-1.9 (14)
B53W11D[h,i]	33.8	10.4	--	--	--
Thorium-230[f]					
HISS-5	--	--	--	--	0.1-1.7 (5)
HISS-6	8.58	2.33	0.41[j]	0.61	0.1-64 (32)
HISS-7	<1.4	--	--	--	<0.2-4.2 (12)
HISS-9	5.12	1.37	0.31[j]	0.45	<0.1-1.5 (27)
HISS-9 (duplicate)	3.34	1.01	0.00[j]	0.33	--
HISS-10	2.65	0.83	--	--	<0.1-1.9 (28)
HISS-11	3.44	1.07	--	--	<0.1-9.3 (28)
HISS-12	3.01	0.93	--	--	<0.1-3.4 (28)
HISS-13	7.8 [k]	6.0	--	--	<0.1-3.4 (28)
HISS-14	1.65	1.5	--	--	0.1-11.0 (10)
HISS-15	5.98	1.19	4.80	3.30	0.1-45.0 (28)
HISS-16	2.82	0.84	0.97	1.00	0.2-7.0 (8)
Background					
B53W15S[h,i]	0.6	0.33	--	--	--
B53W01S[h]	--	--	--	--	<0.1-2.2 (14)
B53W11D[h,i]	8.9	1.8	--	--	--

[a]1 × 10^{-9} µCi/ml is equivalent to 1 pCi/L or 0.037 Bq/L. DOE guidelines for total uranium, radium-226, and thorium-230 are 600, 100, and 300 × 10^{-9} µCi/ml, respectively. Laboratory values for total uranium are reported in µg/L; a correction factor of 0.67 has been used to convert values to 10^{-9} µCi/ml.

[b]Measured background has not been subtracted.

[c]Sampling locations are shown in Figures 3-7 and 3-8.

[d]Total number of analyses is in parentheses. Periods of record: HISS-5 (1980-1991), HISS-6 (1984-1991), HISS-7 (1984, 1990-1991), HISS-9 through HISS-13 and HISS-15 (1985-1991), HISS-14 (1985, 1990-1991), HISS-16 (1990-1991), B53W01S (1988-1991), B53W15S (1991), and B53W11D (1991).

[e]2-sigma error measures instrument background plus error induced by counting time and count rate.

Table 3-12

(continued)

[f]Total uranium determined by kinetic phosphorescence, radium-226 determined by gamma spectroscopy, and thorium-230 determined by alpha spectroscopy. Historic values may reflect the use of other analytical techniques. The half-life of each radionuclide is provided in Appendix F, Table F-1.

[g]-- = well not sampled.

[h]B53W15S and B53W11D are 0.8 km (0.5 mi) south of HISS; B53W01S is 0.8 km (0.5 mi) southwest of HISS. B53W15S was sampled in 2nd quarter; B53W01S was sampled for comparison.

[i]1992 values for background were anomalously high (refer to text in Subsection 3.3).

[j]Value reported is below method detection limits.

[k]Value determined by photon/electron-rejecting alpha liquid scintillation.

Table 3-13

Radionuclide Concentrations in Groundwater at Deep Well HISS-5D[a,b]

Radionuclide[c]	Concentration[d]	2-Sigma Error[e]
	(Concentrations are in $10^{-9}\mu$Ci/ml)	
Total uranium[f]	0.068	0.068
Radium-226	0.88	0.48
Thorium-230	0.25[g]	0.25
Thorium-232	0.11[g]	0.15
Thorium-228	0.04[g]	0.11
Gross alpha	5.50	4.70
Gross beta	10.00	4.50

[a]Well location shown in Figure 3-7.

[b]Well sampled during third quarter of 1992.

[c]Total uranium concentrations determined by kinetic phosphorescence, radium-226 by gamma spectroscopy, thorium by alpha spectroscopy, gross alpha and beta by alpha/beta gross proportional counting. The half-life of each radionuclide is provided in Appendix F, Table F-1.

[d]1×10^{-9} μCi/ml is equivalent to 1 pCi/L and 0.037 Bq/L. DOE guidelines for total uranium, radium-226, and thorium-230 are 600, 100, and 300×10^{-9} μCi/ml, respectively.

[e]2-sigma error measures instrument background plus error induced by counting time and count rate.

[f]Laboratory values for total uranium are reported in μg/L; a correction factor of 0.67 has been used to convert values to 10^{-9} μCi/ml.

[g]Value is below method detection limits.

Table 3-14

Field Measurements of pH, Conductivity, and Temperature in Groundwater at HISS, 1992

Sampling Location[a]	pH		Conductivity (μmhos/cm)		Temp (°C)	
	March	September	March	September	March	September
HISS-6	6.93	6.61	3,630	4,860	15	19
HISS-7	6.83	--[b]	3,780	--	13	--
HISS-9	7.17	7.06	884	908	16	18
HISS-10	7.22	--	740	--	16	--
HISS-11	6.76	--	270	--	13	--
HISS-12	6.90	6.70	1,775	1,883	14	18
HISS-13	7.31	--	6,170	--	17	--
HISS-14	7.43	--	8,040	--	15	--
HISS-15	6.73	6.61	290	868	12	20
HISS-16	7.52	6.95	2,610	1,785	13	19
Background						
B53W15S[c]	7.06	--	917	--	13	--

[a]Sampling locations are shown in Figures 3-7 and 3-8.

[b]-- = well not sampled.

[c]B53W15S is located approximately 0.8 km (0.5 mi) south of HISS.

Table 3-15

Cation/Anion Concentrations in Groundwater at HISS, September 1992

Parameter[b]	HISS-15	HISS-16	HISS-12	HISS-12 (Duplicate)
	Well Location[a]			
Calcium	110	158	195	186
Magnesium	44.9	43.6	96.0	90.5
Sodium	27.2	75.9	61.0	59.0
Potassium	[c]	11.3	[c]	[c]
Bicarbonate	410	230	350	340
Chlorine	37.0	92.1	11.9	11.7
Sulfate	37.2	134	176	226
Total dissolved solids	545	1,080	1,330	1,360
Calculated Values				
Total dissolved solids	458	628	712	740
Charge balance %	+9.6	+24.4	+35.1	+29.0
Field Measurements				
pH (pH units)	6.56	6.95	6.70	6.70
Temperature (°C)	20	19	18	18
Conductivity (μmhos/cm)	887	1,785	1,883	1,883

[a]Sampling locations are shown in Figure 3-7.

[b]Unless otherwise stated, concentrations are in units of mg/L.

[c]Value was below detection limits.

Table 3-16

Trend Analysis for Total Uranium, Radium-226, and Thorium-230

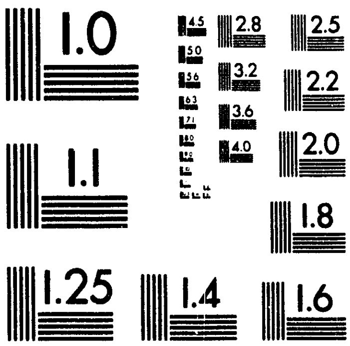
Concentrations[a,b] in Groundwater at HISS, 1987-1992

Sampling Location[c]	Average Annual Concentration 1987	1988	1989	1990	1991	Expected Range[d] ($\bar{X} \pm 2s$)	Average Annual Concentration 1992
(Concentrations are in 10^{-9} μCi/ml)							
Total Uranium[e,f]							
HISS-5	--	--	--	57	78	--	--
HISS-6	40	50	82	48	40	18 - 87	46.7
HISS-7[g]	--	--	--	4	10	0 - 16	4.6
HISS-9	3	3	3	3	6	0.7 - 7	2.3
HISS-10	4	4	5	3	7	1 - 8	4.8
HISS-11	4	5	6	3	10	0.2 - 11	4.2
HISS-12	5	6	4	4	9	1 - 10	4.7
HISS-13	8	8	5	5	9	3 - 11	5.9
HISS-14[g]	--	--	--	6	9	3 - 13	8.4
HISS-15	3	6	5	3	9	0.2 - 10	2.9
HISS-16[g]	--	--	--	22	8.3	0 - 35	11.7
B53W01S[h]	--	3	3	3	6	0.8 - 7	--
B53W01D[h]	--	4	3	3	5	2 - 6	--
B53W15S[i,j]	--	--	--	--	--	--	6.2
B53W11D[i,j]	--	--	--	--	--	--	18.6
Radium-226[f]							
HISS-5	--	--	--	0.6	0.2	--	--
HISS-6	1.2	1.8	1.6	1.0	1.0	0.6 - 2.0	3.1
HISS-7[g]	--	--	--	1.0	1.2	0.8 - 1.4	1.3
HISS-9	0.2	0.6	0.6	0.4	1.4	0.0 - 1.6	8.9

Table 3-16

(continued)

Sampling Location[c]	Average Annual Concentration 1987	1988	1989	1990	1991	Expected Range[d] ($\bar{X} \pm 2s$)	Average Annual Concentration 1992
Radium-226 (cont'd)[f]							
HISS-10	0.2	0.4	0.3	0.2	1.0	0.0 - 1.1	4.5
HISS-11	0.2	1.0	0.7	0.5	3.0	0.0 - 3.3	4.9
HISS-12	0.5	1.3	0.7	0.6	1.1	0.2 - 1.5	2.9
HISS-13	0.3	0.6	0.7	0.6	1.6	0.0 - 1.7	2.3
HISS-14[g]	--	--	--	0.8	3.5	0.0 - 6.0	0.9
HISS-15	0.4	0.8	1.2	0.8	0.8	0.2 - 1.4	5.6
HISS-16[g]	--	--	--	0.4	2.3	0.0 - 4.0	4.7
B53W01S[h]	--	0.6	0.7	0.4	0.9	0.2 - 1.1	--
B53W01D[h]	--	1.1	1	1	0.9	0.8 - 1.2	--
B53W15S[i,j]	--	--	--	--	--	--	2.3
B53W11D[i,j]	--	--	--	--	--	--	33.8
Thorium-230[f]							
HISS-5[g]	--	--	--	0.5	1.4	-- --	--
HISS-6	2.9	24	5	3.7	7.7	0.0 - 26.2	4.5
HISS-7[g]	--	--	--	0.7	2.6	0.0 - 4.3	1.4
HISS-9	0.2	0.2	0.2	0.2	1.2	0.0 - 1.3	2.7
HISS-10	0.3	0.7	0.1	0.2	0.7	0.0 - 1.0	2.7
HISS-11	0.8	1.5	0.7	0.4	3.9	0.0 - 4.3	3.4
HISS-12	0.8	2.3	2.3	2.0	5.0	0.0 - 5.6	3.0
HISS-13	0.3	0.6	0.9	0.7	2.1	0.0 - 2.3	7.8
HISS-14[g]	--	--	--	0.8	5.6	0.0 - 10.0	1.7
HISS-15	0.8	5.7	8.6	11.0	35.8	0.0 - 39.6	5.4


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

2 of 2

Table 3-16

(continued)

Sampling Location[c]	Average Annual Concentration 1987	1988	1989	1990	1991	Expected Range[d] ($\bar{x} \pm 2s$)	Average Annual Concentration 1992
Thorium-230 (cont'd)[f]							
HISS-16[g]	--	--	--	0.5	3.1	0.0 - 5.5	1.9
B53W01S[h]	--	0.2	0.3	0.2	0.8	0.0 - 0.9	--
B53W01D[h]	--	0.2	0.4	0.4	0.6	0.0 - 0.8	--
B53W15S[i,j]	--	--	--	--	--	--	0.6
B53W11D[i,j]	--	--	--	--	--	--	8.9

Source for 1987-1991 data: BNI 1992c.

[a]1 × 10^{-9} μCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L. DOE guidelines for total uranium, radium-226, and thorium-230 are 600 × 10^{-9}, 100 × 10^{-9}, and 300 × 10^{-9} μCi/ml, respectively.

[b]Measured background has not been subtracted.

[c]Sampling locations are shown in Figures 3-7 and 3-8.

[d]Average value ±2 standard deviations (approximately 95 percent confidence level).

[e]Total uranium concentrations were determined by fluorometric analysis during 1986 through 1990 and the first three quarters of 1991 and kinetic phosphorescence analysis since the fourth quarter of 1991.

[f]The half-life for each radionuclide is provided in Appendix F, Table F-1.

[g]Added to the monitoring program in first quarter of 1990.

[h]Background wells located at Byassee Road, approximately 0.8 km (0.5 mi) southwest of the site; added to the monitoring program in July 1988 and deleted in 1991. Used for comparison with B53W15S and HISS-5D only.

[i]B53W15S and B53W11D are located approximately 0.8 km (0.5 mi) south of HISS.

[j]1992 values for background were anomalously high (refer to text in Subsection 3.3).

4.0 ESTIMATED DOSE

The information in Section 3.0 was evaluated as described in Appendix F to estimate the potential radiation doses from the radioactive material at HISS to a hypothetical maximally exposed individual and to the general public. Doses to the general public can come from either external or internal exposures. Exposures to radiation from radionuclides outside the body are called external exposures; exposures to radiation from radionuclides deposited inside the body are called internal exposures. The distinction is important because external exposures occur only when a person is near the external radionuclides, but internal exposures continue as long as the radionuclides reside in the body. As expected for a relatively stable site such as HISS, all calculated doses were below the DOE guidelines. The total dose to the hypothetical maximally exposed individual adjacent to HISS was calculated to be 0.13 mrem/yr (1.3×10^{-3} mSv/yr), which is well below the DOE guideline of 100 mrem/yr above background.

To assess the potential health effects of the materials stored at HISS, radiological exposure pathways were evaluated and radiation doses were calculated for a hypothetical maximally exposed individual and for the population within 80 km (50 mi) of the site. The combined effects from all pathways (surface water, groundwater, air, and direct exposure) from all DOE sources at HISS were then compared with DOE guidelines. Exposures from radon and radon daughters are not considered in these calculations because radon exposure is in compliance with concentration requirements for site boundaries (Appendix F). All doses presented in this section are estimates and do not represent actual doses. A summary is provided in Table 4-1.

4.1 HYPOTHETICAL MAXIMALLY EXPOSED INDIVIDUAL

The hypothetical maximally exposed individual is assumed to live near the site and work 40 hours per week at Futura Coatings (next to HISS). This individual's average distance from the site would be approximately 46 m (150 ft). Using these assumptions and only credible pathways, the following doses have been calculated.

4.1.1 Direct Gamma Radiation Pathway

The yearly dose to a hypothetical worker at Futura Coatings was calculated by using the equation in Appendix F for direct gamma radiation exposure. The calculated dose for this individual is 0.11 mrem/yr (1.1×10^{-3} mS/yr), well below the DOE guideline of 100 mrem above background for effective dose equivalent in a year. This approach is conservative because an individual would not likely work outside at Futura Coatings for an entire year.

4.1.2 Drinking Water Pathway

Only one water pathway, either groundwater or surface water, is used, if credible, to determine the committed dose to the hypothetical maximally exposed individual. This individual would obtain 100 percent of his/her drinking water from either surface water or groundwater in the vicinity of the site. Concentrations of total uranium, radium-226, and thorium-230 in groundwater near HISS are barely detectable above normal background levels. Because there are currently no domestic wells in use within 4.8 km (3 mi) of the site and because a local water distribution system is available, groundwater is not a credible exposure pathway; therefore, the dose contribution from these radionuclides in groundwater to the hypothetical individual was not calculated. Radionuclide concentrations in surface water samples collected from sampling locations upstream and downstream of HISS are essentially equivalent to the background levels measured at location 2; therefore, no dose would be received from exposure to the water. As a result, surface water is not a credible exposure pathway.

4.1.3 Air Pathway (Ingestion, Air Immersion, Inhalation)

On October 31, 1989, EPA issued final rules for radionuclide emissions to air under NESHAPs (40 CFR Part 61). Emission monitoring and compliance procedures for DOE facilities [40 CFR 61.93(a)] require the use of Clean Air Act Assessment Package-1988 (CAP88) or AIRDOS PC computer models, or other approved procedures, to calculate effective dose equivalents to members of the public.

The CAP88-PC computer model is a set of computer programs, databases, and associated utility programs for estimation of dose and risk from radionuclide emissions to air. CAP88-PC is composed of modified versions of AIRDOS-EPA (Mo79) and DARTAB (ORNL5692). The original CAP88-PC program is written in FORTRAN77 and has been compiled and run on an IBM 3090 under OS/VS2, using the IBM FORTRAN compiler, at the EPA National Computer Center in Research Triangle Park, North Carolina. CAP88-PC is distributed by the Oak Ridge National Laboratory Radiation Shielding Information Center.

The CAP88-PC programs represent the best available verified programs for the purpose of making comprehensive dose and risk assessments. The Gaussian plume model used in CAP88-PC to estimate dispersion of radionuclides in air is one of the most commonly used models in government guidebooks. It produces results that agree with experimental data as well as any model, is fairly easy to work with, and is consistent with the random nature of turbulence.

Air doses determined using the CAP88-PC computer model, Version 1.0, were found to be negligible, 0.023 mrem/yr, which is well below the regulatory limit of 10 mrem/yr given in 40 CFR 61, Subpart H.

4.1.4 Total Dose

The total dose for the hypothetical maximally exposed individual adjacent to HISS is the sum of the 50-yr committed effective dose equivalent and the external effective dose equivalent, based on the total estimated radioactive particulates released in 1992 and the effective dose equivalent from total external direct gamma radiation measured at the fenceline in 1992. When these doses are added together, the total dose is 0.13 mrem/yr (1.3×10^{-3} mSv/yr), which is less than the 0.5-mrem (5×10^{-3} mSv) exposure a person would receive from a one-hour flight at 12,000 m (39,000 ft) (Appendix B).

4.2 GENERAL POPULATION

The collective dose to the general population living within 80 km (50 mi) of the site was calculated. Consideration was given to the same pathways as for the hypothetical maximally exposed individual.

4.2.1 Direct Gamma Radiation Pathway

HISS is located in an industrial area and thus is remote from residential developments. Distance from the site to the nearest residential areas and the presence of intervening structures reduce direct gamma radiation exposure from HISS (see Table 4-1). Therefore, it is assumed that there is no detectable exposure to the general public.

4.2.2 Drinking Water Pathway

There are no wells used for public drinking water within 4.8 km (3.0 mi) of the site, and there is a significant distance [32 km (20 mi)] to a drinking water intake point on the Mississippi River; therefore, it is reasonable to assume that the general public would not receive a committed dose in drinking water from radionuclides from HISS.

4.2.3 Air Pathway (Ingestion, Air Immersion, Inhalation)

The CAP88-PC model provides an effective dose equivalent for contaminants transported via the atmospheric pathway at different distances from the site (Table 4-1). The collective dose for the general population within 80 km (50 mi) of HISS was calculated using this effective dose equivalent and the population density. The calculated collective population dose is 0.11 person-rem/yr (1.1×10^{-3} person-Sv/yr).

4.2.4 Total Population Dose

The total population dose is the sum of the doses from all exposure pathways. Because air is the only pathway with a major potential contribution to the collective population dose, the total population dose is equal to that calculated for the air pathway.

TABLE FOR SECTION 4.0

Table 4-1

Summary of Calculated Doses[a] for HISS, 1992

Exposure Pathway	Dose to Hypothetical Maximally Exposed Individual[b] (mrem/yr)[c]	Collective Dose for Population Within 80 km of Site (person-rem/yr)[c]
Direct gamma radiation[d]	0.11	0
Drinking Water	--[e]	--[e]
Ingestion	--[e]	--[e]
Air immersion	--[e]	--[e]
Inhalation[f,g]	0.023	0.11
Total[h]	0.13	0.11
Background[i]	100	3×10^5 [j]

[a]Does not include radon.

[b]A hypothetical Futura Coatings worker 46 m (150 ft) from the western fenceline.

[c]1 mrem/yr = 0.01 mSv/yr; 1 person-rem/yr = 0.01 person-Sv/yr.

[d]Does not include contribution from background.

[e]No realistic pathway.

[f]Calculated using the Clean Air Act Assessment Package-1988 (CAP88) computer model.

[g]The EPA standard (from NESHAPs) for an inhaled dose is 10 mrem/yr.

[h]The DOE guideline for total exposure to an individual is 100 mrem/yr above background (DOE 1990b).

[i]Direct gamma radiation exposure only.

[j]Calculated by the following: (100 mrem/yr) (2.6×10^6 persons).

5.0 QUALITY ASSURANCE

5.1 INTRODUCTION

This section summarizes the quality assurance (QA) assessment of environmental activities at the site, which were conducted to ensure that onsite contamination does not pose a threat to human health or the environment. Using this criterion, the overall project data quality objectives (DQOs) for the environmental monitoring program are to provide data of sufficient quality to allow reliable detection and quantitation of potential release of contaminated material from the site and to allow determination of potential radiation exposure from contamination at the site (Section 4.0). The DQOs are assessed annually during review of the environmental monitoring plan (BNI 1991b) and are updated based on historical information, trends identified, and changes in environmental regulations.

5.2 PROCEDURES

The *Quality Assurance Program Plan for the U.S. DOE FUSRAP* (BNI 1992e) addresses the quality requirements for work being performed under FUSRAP. This plan requires all subcontractors to implement a compatible plan for QA or to use the DOE plan. This is done to ensure compatibility with all requirements in order to maintain protection of human health and the environment.

QA procedures are detailed in project procedures and instructions and are implemented for all field activities. Sampling techniques have been derived from *A Compendium of Superfund Field Operations Methods* (EPA 1987). Laboratory QA procedures have been derived from applicable EPA methods to ensure compatibility of the results. Also, activities such as data reviews, calculation checks, and data evaluations have been incorporated in procedures to monitor results and prevent or identify quality problems.

5.3 QUALITY ASSURANCE SUMMARY

QA/quality control (QC) activities are an integral part of all environmental monitoring activities at the site. The specific methods, definitions, and formulas used to evaluate the QA/QC program are described in the *Quality Assurance Document for Site Environmental Reports* (BNI 1993). This document also discusses, in detail, the precision, accuracy, representativeness, comparability, and completeness (PARCC) parameters. For informational purposes, brief definitions or explanations will be given throughout this section for terms and processes used during the QA/QC evaluation.

The QA/QC program satisfies the requirements of DOE Orders 5400.1, 5400.5, and 5700.6C. The programmatic controls in place for the environmental monitoring program are discussed in project instruction guides.

5.3.1 Data Usability

To determine data usability, a verification process is used that evaluates items such as holding times and results for method blanks, spike recoveries, and duplicates. The information from this evaluation is then used to verify whether the data are of sufficient quality to make decisions about the site. During this process, two qualifiers are used if there is any question concerning data usability: 1) "J" - the data result is estimated and should be used with discretion, and 2) "R" - the data result is rejected and should not be used.

The data are then evaluated using the PARCC parameters to determine whether there is enough information to make decisions concerning the site. Any major problems encountered are documented as nonconformances and are tracked to ensure correction.

The results of the PARCC evaluation are presented as a percentage that met requirements. The formula used is:

$$\frac{\text{number of results that met requirements}}{\text{total number of results}} \times 100 = \text{percent acceptable}$$

The criteria used for evaluation of the PARCC parameters for radionuclides are internal standards, which are closely patterned after those defined in EPA guidance documents for inorganic standards. For Tables 5-1 and 5-2, a generic 80 percent was used as an acceptable level; evaluation criteria are discussed in Subsections 5.3.2 and 5.3.3. Representativeness and comparability cannot have a percentage applied; see Subsections 5.3.4 and 5.3.5 for definitions and discussions about the use of these two parameters.

5.3.2 Precision

Precision is defined as a measurement of the agreement of a set of replicate results among themselves without assumption of any prior information about the true result. Precision is assessed through the use of duplicate results. Field duplicates are also used to assess field precision. The precision results were assessed using a 20 percent relative percent difference window. The results for laboratory and field precision are presented together because both met the 80 percent level. Table 5-1 shows that all results evaluated for precision met the requirements for acceptability.

5.3.3 Accuracy

Accuracy is defined as the nearness of a result or the mean of a set of results to the true, known, or reference value. The assessment of accuracy was determined through analysis of laboratory control samples using an acceptance window of 75 to 125 percent recovery. Table 5-2 provides results of the accuracy evaluation. Accuracy for all parameters was above the 80 percent level.

5.3.4 Representativeness

Field and laboratory representativeness express the degree to which the data accurately and precisely represent the matrix from which the samples were obtained. Representativeness generally expresses the extent to which the data generated define an environmental condition.

To ensure field sampling representativeness, several controls were used during the course of sampling, including the use of dedicated sampling equipment and field duplicates.

To ensure representativeness in the laboratory, constraints are placed on analytical methodology. A method (or preparation) blank is prepared with each parameter analyzed to determine whether contaminants are present in the laboratory that could have an impact on the samples associated with that method blank. The presence of contaminants can indicate the possibility for false positive results.

Table 5-3 lists the contaminants found in laboratory method blanks. Both instances of blank contamination occurred during the second quarter. The uranium and radium-226 contamination found in the blanks was evaluated during the verification process.

In the quantification of uranium, the acid leach procedure used may cause some contamination present in glassware to leach. A corrective action, an improved glassware cleaning methodology, has since been implemented to help prevent this type of contamination from occurring in the future. The elevated levels of uranium measured in second quarter sediment samples may have been a direct result of the blank contamination; nevertheless, it is important to note that the measured concentrations were much lower than the 50 pCi/g uranium guideline for soil.

The apparent radium-226 contamination in the blank is most likely a result of counting time error. According to the laboratory data report, the radium-226 concentration (shown in Table 5-3) was the MDA. The MDA is a function of counting time (i.e., the amount of time during which the radioactivity is measured). In general, the longer the counting time, the lower the MDA. Therefore, if the counting time is insufficient, the error is higher, and the MDA subsequently determined is also high. However, this counting time error did not compromise the data for that quarter; all data fell within the expected range.

5.3.5 Comparability

Comparability expresses the confidence with which data are compared with each other, taking into account the use of equivalent instrumentation and methodology. The laboratories follow approved procedures that are consistent with industry-accepted practices, and comparability is maintained. Results are listed in Table 5-1.

5.3.6 Completeness

Completeness measures the amount of usable data resulting from the data collection activities compared with the total data possible. For environmental monitoring, all samples were taken as required in the instruction guide for usability. Subsection 5.3.1 discussed data rejected during the verification process. Table 5-4 summarizes the acceptability rate for all analytes. All analytes met the completeness goal.

5.3.7 Interlaboratory Programs

The radiochemistry laboratory participates in the Environmental Measurements Laboratory's Quality Assessment Program, EPA's Cross-Check Program, and the Nuclear Fuel Services' Interlab Quality Control Comparison. Results for these programs are submitted to FUSRAP. Repeated failure of an analyte for consecutive periods results in the suspension of that analyte until corrective actions have been taken. Table 5-5 provides the radiochemistry laboratory results from the DOE Quality Assessment Program. Table 5-6 gives the results from the EPA Intercomparison Program.

TABLES FOR SECTION 5.0

Table 5-1

Results for Duplicates

Parameters	Percent Acceptable[a]	Meets Established DQOs
Radium-226	83	Yes
Thorium-230	100	Yes
Total uranium	100	Yes

[a]DOE acceptability criteria for radiochemical data are patterned after those defined in EPA guidance for inorganic data.

Table 5-2

Results for Spike Recoveries

Parameters	Percent Acceptable[a]	Meets Established DQOs
Radium-226	100	Yes
Thorium-230	92	Yes
Total uranium	100	Yes

[a]DOE acceptability criteria for radiochemical data are patterned after those defined in EPA guidance for inorganic data.

Table 5-3

Results for Blank[a] Contamination

Parameters	Maximum Concentration
Radium-226	1.7 pCi/g
Total uranium	1.56 μg/g[b]

[a]The above blanks consisted of reagent-grade deionized water, analyzed in the second quarter. DOE acceptability criteria for radiochemical data are patterned after those defined in EPA guidance for inorganic data.

[b]1.56 μg/g = 1.06 pCi/g.

Table 5-4

Results for Completeness

Parameters	Percent Acceptable[a]	Meets Established DQOs
Radium-226	100	Yes
Thorium-230	100	Yes
Total uranium	100	Yes

[a]DOE acceptability criteria for radiochemical data are patterned after those defined in EPA guidance for inorganic data.

Table 5-5

Radiochemistry Laboratory Performance on DOE Quality Assessment Program Samples, 1992

Sample Media	Radionuclides	Number of Results Reported	Number Within Control Limits
Air filters	Uranium (mass)	1	1
Soil	Potassium-40 Strontium-90 Cesium-137 Uranium (mass)	4	3
Vegetation	Potassium-40 Strontium-90 Cesium-137	3	3
Water	Tritium Manganese-54 Cobalt-60 Cesium-134 Cesium-137 Cerium-144 Plutonium-238 Plutonium-239 Americium-241 Uranium (mass)	10	9

Table 5-6

Radiochemistry Laboratory Performance on EPA Intercomparison Program Samples, 1992

Sample Media	Radionuclides	Number of Results Reported	Number Within Control Limits
Water	Alpha Beta Zinc-65 Cobalt-60 Ruthenium-106 Cesium-134 Cesium-137 Barium-133	26	24
Water	Radium-226 Radium-228 Plutonium-239 Uranium (natural)	16	16
Water	Strontium-89 Strontium-90	7	6
Water	Tritium	2	2
Air filters	Alpha Beta Strontium-90 Cesium-137	7	5

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APPENDIX A Hydrogeologic Details

HYDROGEOLOGIC DETAILS

Geology

HISS overlies a shallow subsurface depression in bedrock known as the Florissant Basin, the site of a glacial lake that was filled with more than 29 m (95 ft) of silts, clays, and fine-grained sand of lacustrine, Eolian/Fluvial origin. Bedrock underlies these deposits and is a homogeneous white to buff-colored, sandy limestone. This limestone has been tentatively identified as the Ste. Genevieve Formation, which is Mississippian in age.

The sedimentary package overlying bedrock consists of deposits from several different depositional environments. The lowermost sediments were deposited in a glacial lake and are represented by a sequence of interlayered silts and clays. These lacustrine deposits are homogeneous, olive gray clayey silts, silty clays, and clays that contain occasional organic material and shell fragments. The lacustrine deposits have been further subdivided into three subunits based on physical characteristics: 1) the basal subunit, which contains clayey silts, sands, and regolith; 2) the mid-subunit, which is clay-rich; and 3) the upper subunit, which consists of silty clays and clayey silts. The clay subunit that occurs in the middle of the lake deposits controls the flow of groundwater in the area.

The surficial sedimentary unit at HISS is composed of clayey silt that has been tentatively identified as a combination of the Roxanna Silt and the Peoria Loess. This unit is yellowish-brown and highly mottled, contains organic material and iron nodules, and ranges from 4.6 to 9.1 m (15 to 30 ft) in thickness. In some areas at HISS, this surficial deposit is intermixed with flood deposits from Coldwater Creek.

The unconsolidated sedimentary package above bedrock that has been observed at HISS is also present at SLAPS [about 0.4 km (0.25 mi) south of HISS] and has been shown to be laterally extensive to the north and west of HISS (Goodfield 1965).

Well Placement

Groundwater monitoring wells (Figure A-1) were installed at HISS in three phases. Eight first-phase wells (HISS-1 through HISS-8) were installed in 1982 as part of the radiological site assessment program conducted by Oak Ridge Associated Universities. The geologic logs and details of construction methods for the first-phase wells are not available. BNI installed seven second-phase wells (HISS-9 though HISS-15) in late 1984 and an additional well (HISS-16) in June 1989 to supplement readings from HISS-8, which was permanently closed in August 1990. Five third-phase wells (HISS-5D and HISS-17 through HISS-20) were installed in August and September of 1992. HISS-3 and HISS-4 were closed during the 1992 field effort. A typical well construction diagram is shown in Figure A-2.

Monitoring wells were sampled during March 1992 for radionuclides and during September 1992 for radionuclide and water quality parameters. Water levels were measured weekly at monitoring wells included in the water level monitoring program. Automatic water level recorders were installed at HISS-1, HISS-12, and HISS-16 during November 1992. The automatic water level recorders will supplement the manual water level readings. Initial results from the automatic water level recorders are not available yet and thus are not reported herein.

In 1991 and 1992 inspections of the wells at HISS revealed several problems including (but not limited to) cracked or frost-heaved surface seals, missing riser caps, and damaged surface casings. Some of the problems may result in erroneous water levels or contaminant levels because of the potential for surface water to enter the well. All outstanding problems were repaired during the fall of 1992 to ensure that data quality will not continue to be compromised by surface water infiltration.

Hydrogeologic Results

The following hydrogeological interpretations are based on groundwater levels measured at weekly intervals using an electric downhole water level indicator.

Water level measurements from monitoring wells are used to prepare two types of graphic exhibits (hydrographs and potentiometric surface maps) that demonstrate hydrogeological conditions at the site. Hydrographs are line graphs that display changes in water levels for each monitoring well throughout the year (Figures A-3 through A-9). The HISS hydrographs also include bar graphs showing precipitation measurements taken at the site as an aid in evaluating the influence of precipitation on water level behavior.

The hydraulic gradient and flow direction of the HISS groundwater system are determined from potentiometric surface (water level) maps (Figures A-10 through A-12). These maps are prepared by plotting water level elevations for selected dates on a base map and contouring the values. The potentiometric surface of the groundwater system can change as a result of varying amounts of recharge to the groundwater system. Recharge varies in relation to the amount of precipitation and net infiltration. These temporal variations are expressed in the potentiometric surface maps.

Hydrographs for 1992 (Figures A-3 through A-9) are similar to those for previous years, showing slight seasonal fluctuations in groundwater levels. During the spring of 1992, there was a slight rise in water level elevations because of increased rainfall and net infiltration. During the summer, a decrease in precipitation and an increase in evapotranspiration resulted in a net decrease in water levels until the seasonal low was reached during the fall. A marked increase in precipitation in the fall resulted in water levels rising to an annual high in November and December. As in previous years, the hydrographs show that response of water levels to precipitation occurred relatively rapidly. This indicates that the areas around the wells are experiencing rapid infiltration from precipitation events.

The general groundwater flow pattern is radial, with the flow outward from the area around HISS-1 and HISS-5 toward the other wells. The hydraulic gradients for 1992 were calculated for several flow directions. The eastern flow direction, representative of flow beneath the pile, was similar to that of previous years; the flow gradients were 0.02 in the winter, 0.01 in the spring, and 0.01 in the fall. Flow to the south was also similar to flow in previous years, with flow gradients of 0.01, 0.009, and 0.01 in the winter, spring, and fall, respectively. Flow gradients to the north were greater than those of the other directions: 0.03 in the winter, 0.02 in the spring, and 0.04 in the fall.

The slight seasonal variations from spring to winter shown on the hydrographs do not affect the slope of the potentiometric surface or the direction of groundwater flow (Figures A-10 through A-12). In all seasons the hydraulic gradients and flow direction are radial, away from HISS-1 and HISS-5, which are located in an area of greater surface recharge. To detect contaminants that might migrate from the HISS pile, groundwater downgradient of HISS-1 and HISS-5 was sampled and analyzed. Results of groundwater monitoring in 1992 for radiological and chemical parameters are reported in Subsection 3.3.

The presence of radial flow at HISS is thought to be the result of two factors. The first factor is related to current and historic surface water flow, and the second factor is preferential recharge in the areas where groundwater elevations are high. Groundwater flow on the western side of HISS is towards Coldwater Creek; to the south, flow is toward a tributary to Coldwater Creek; and to the north, flow appears to be controlled by a second tributary to Coldwater Creek and a sewer line installed in the 1980s. The second tributary to Coldwater Creek has been identified in historic aerial photographs of the HISS area. The tributary was backfilled between 1958 and 1965. Although the nature of the backfill material is not known, it is reasonable to assume that it is more permeable than natural sediments and therefore would serve as a conduit for groundwater flow. Preferential recharge along the western side of HISS results from runoff of precipitation from surrounding impermeable areas—the Futura parking lot and both piles on HISS. Water has been frequently observed standing in the ditch along the western edge of the southern pile at HISS, suggesting that recharge to groundwater underlying this area is relatively consistent year-round. Electromagnetic terrain conductivity measurements taken in this area support this theory. Values are high, which suggests that the underlying soils are saturated most of the time.

FIGURES FOR APPENDIX A

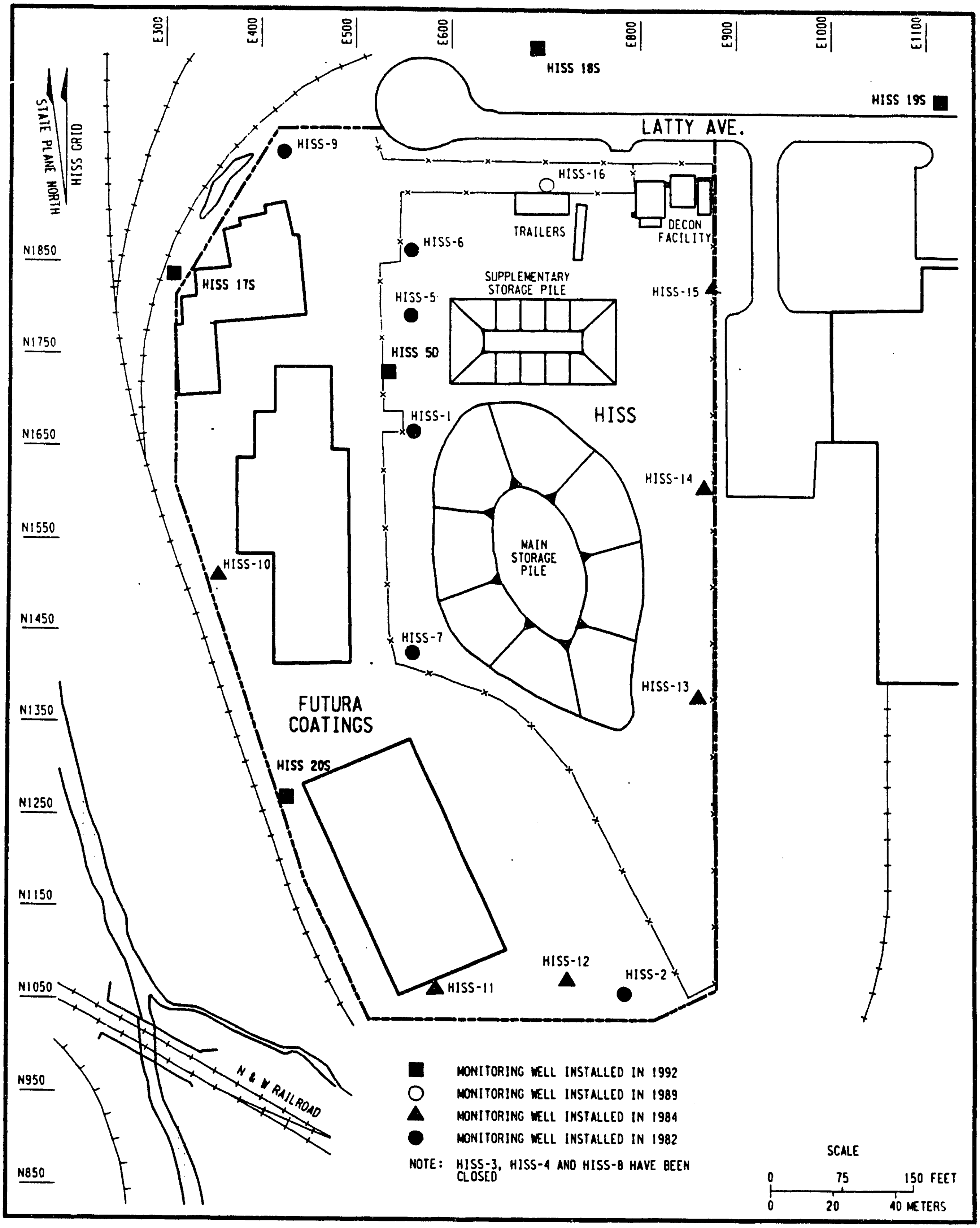

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Figure A-1
Monitoring Wells Used for Water Level Readings at HISS

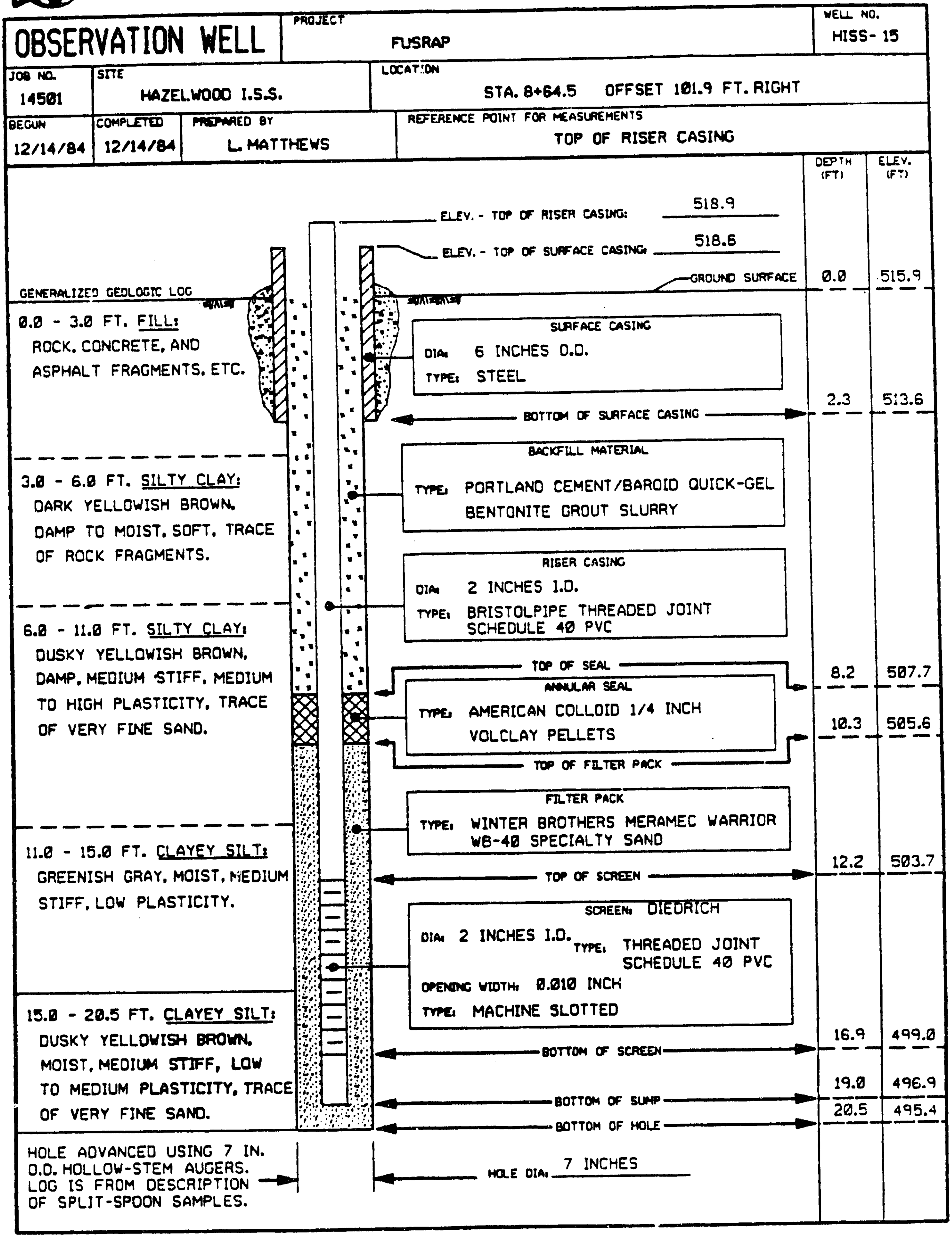

Figure A-2
Typical Well Construction at HISS

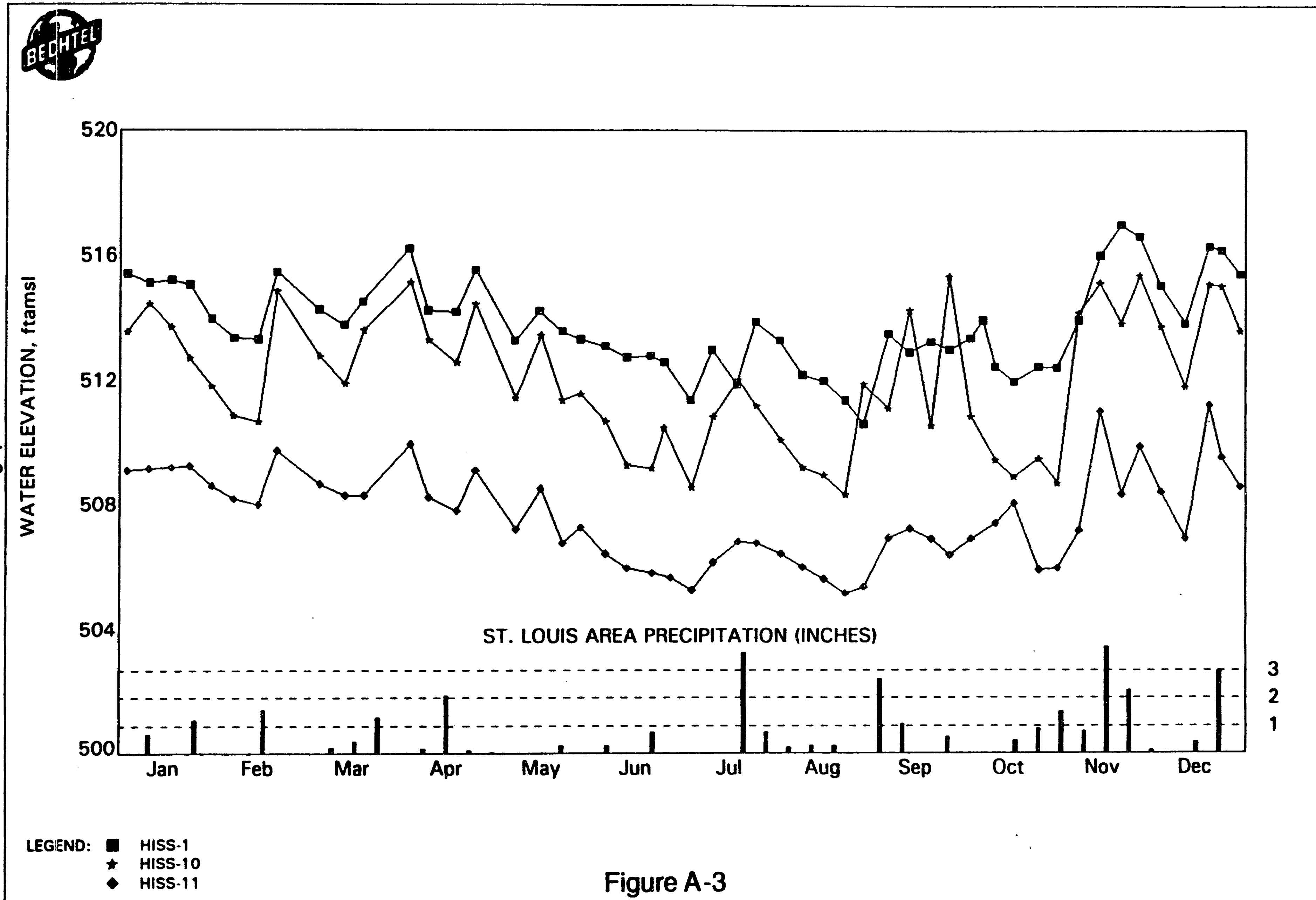

Figure A-3
Hydrograph for HISS-1, HISS-10, and HISS-11

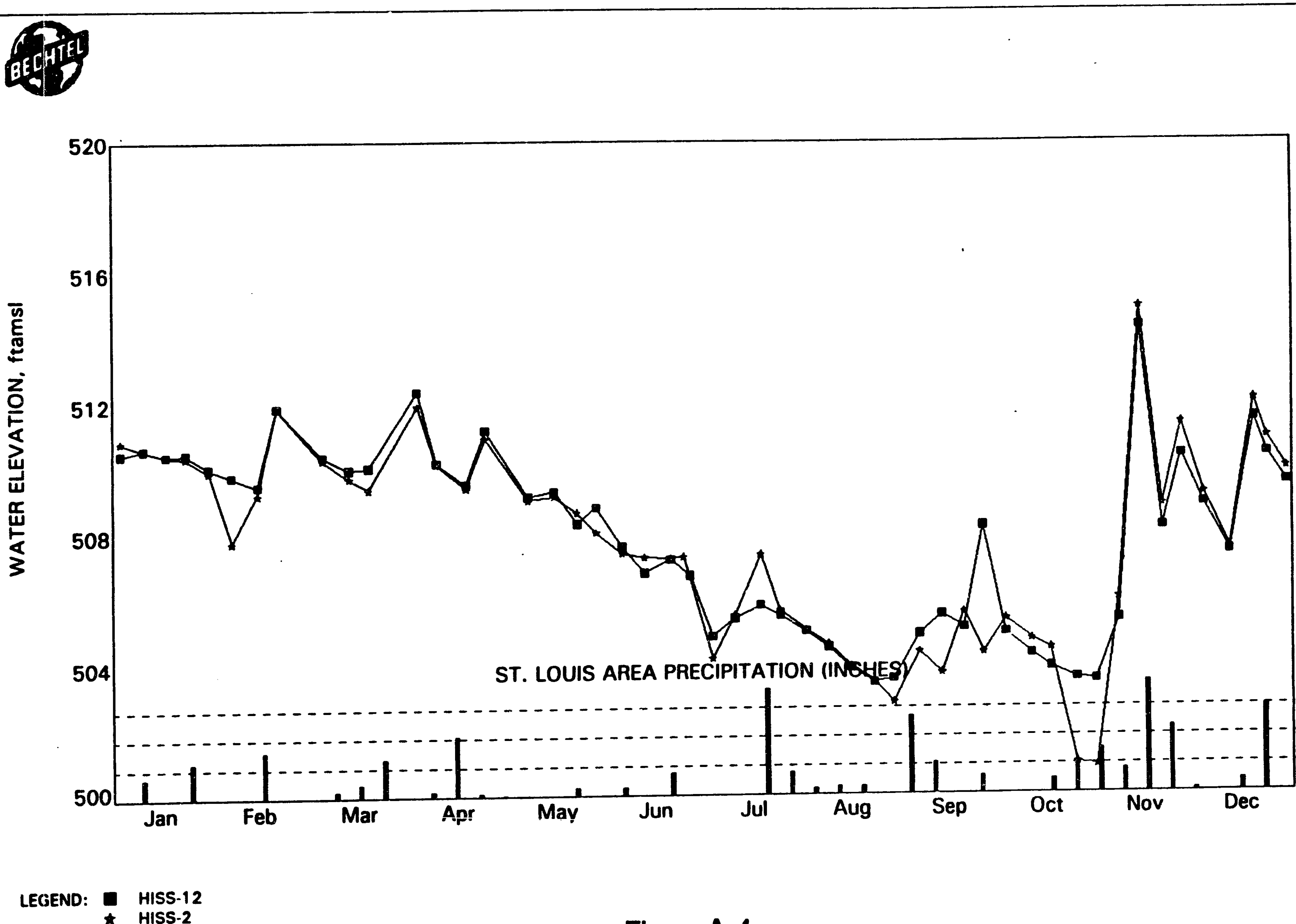

Figure A-4
Hydrograph for HISS-12, HISS-2

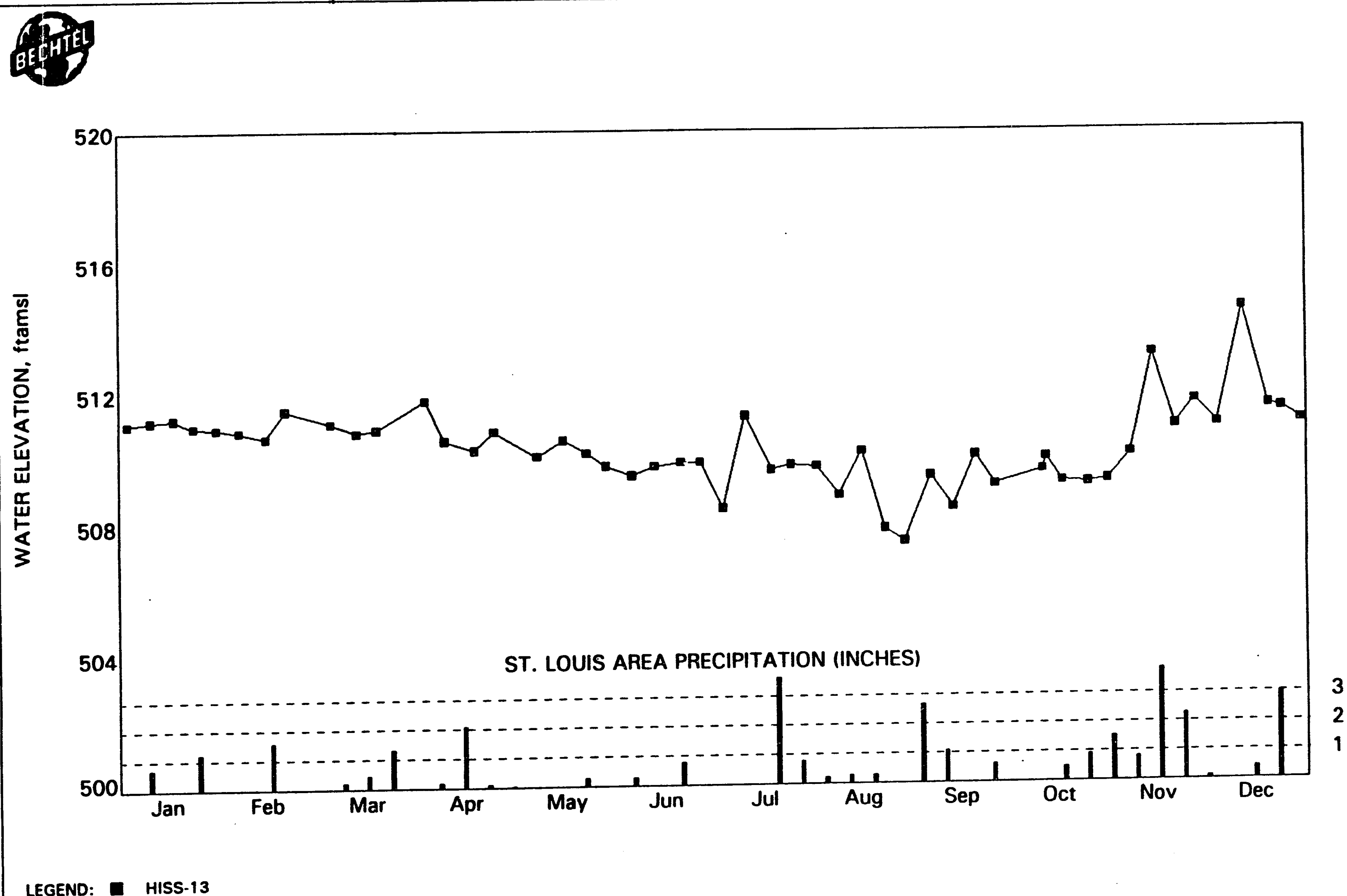

Figure A-5
Hydrograph for HISS-13

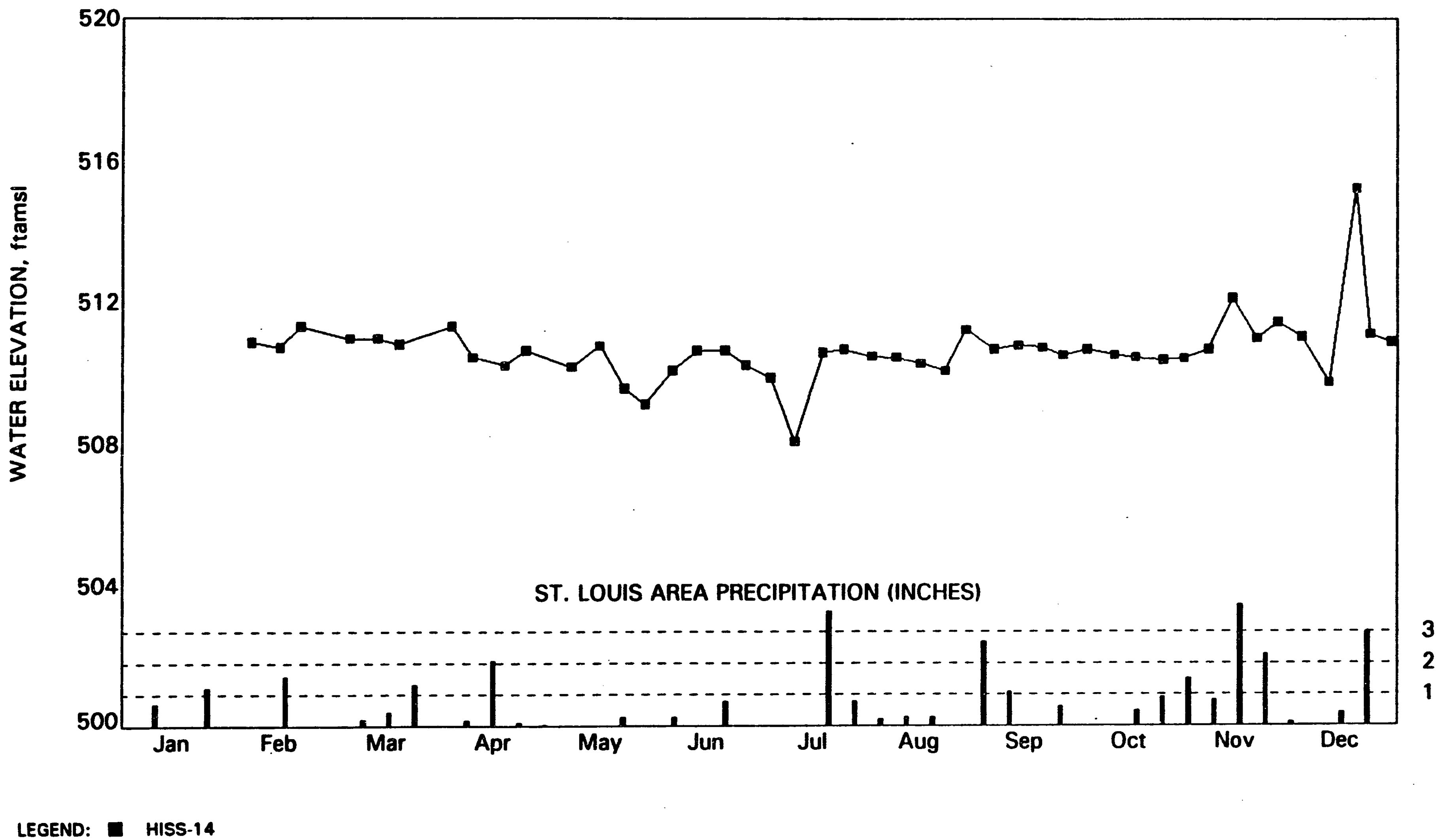

Figure A-6
Hydrograph for HISS-14

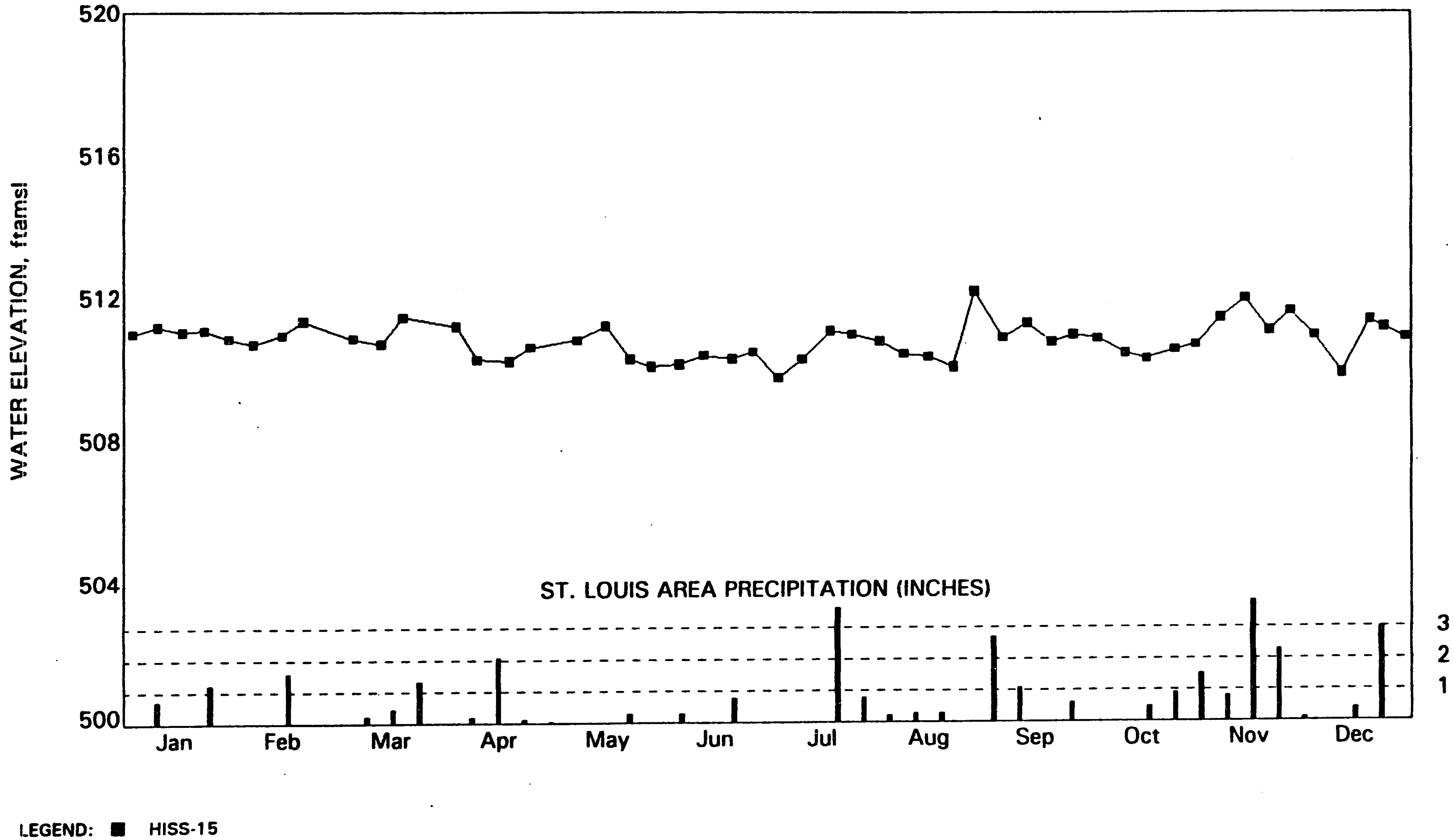

Figure A-7
Hydrograph for HISS-15

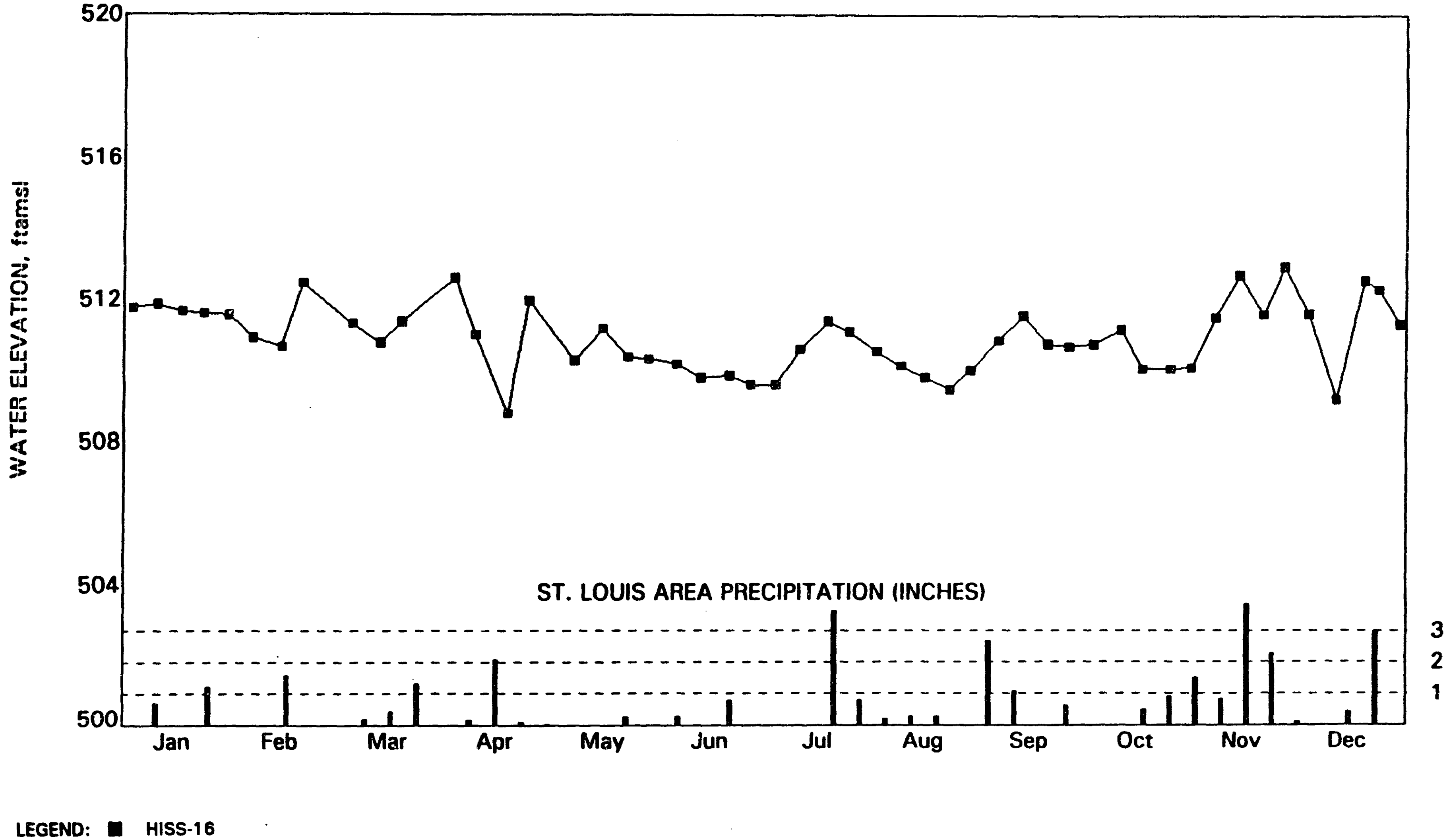

Figure A-8
Hydrograph for HISS-16

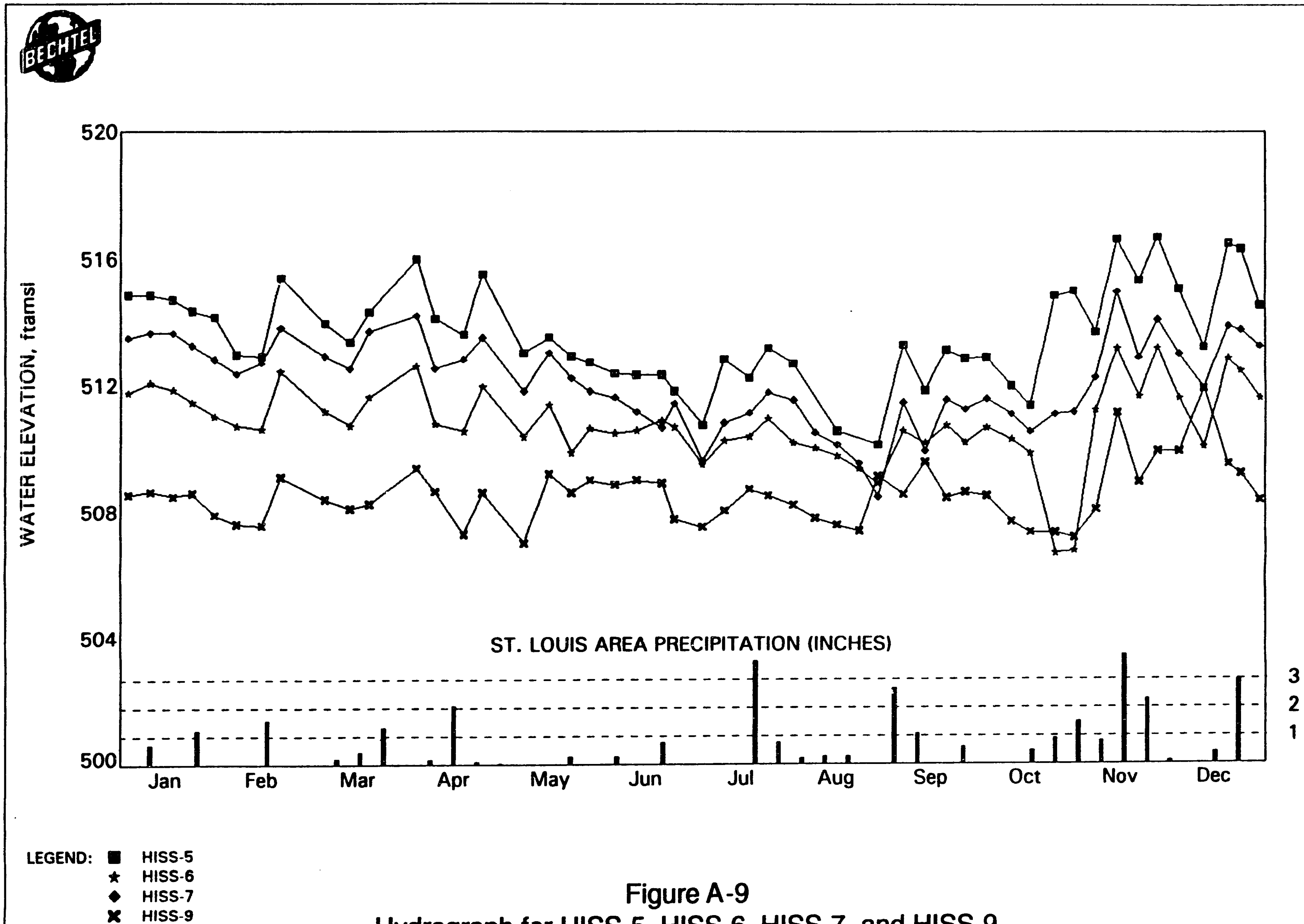

Figure A-9
Hydrograph for HISS-5, HISS-6, HISS-7, and HISS-9

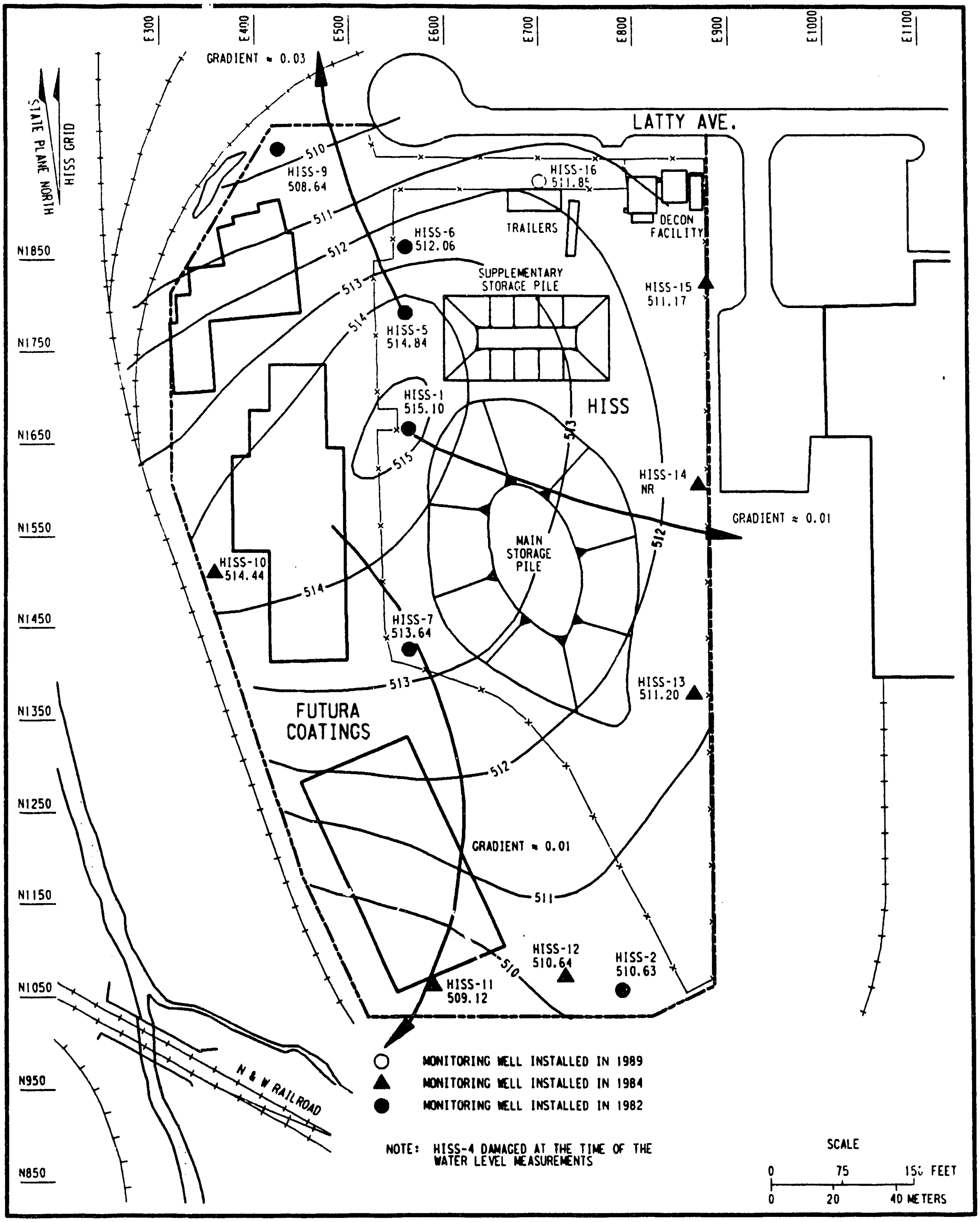

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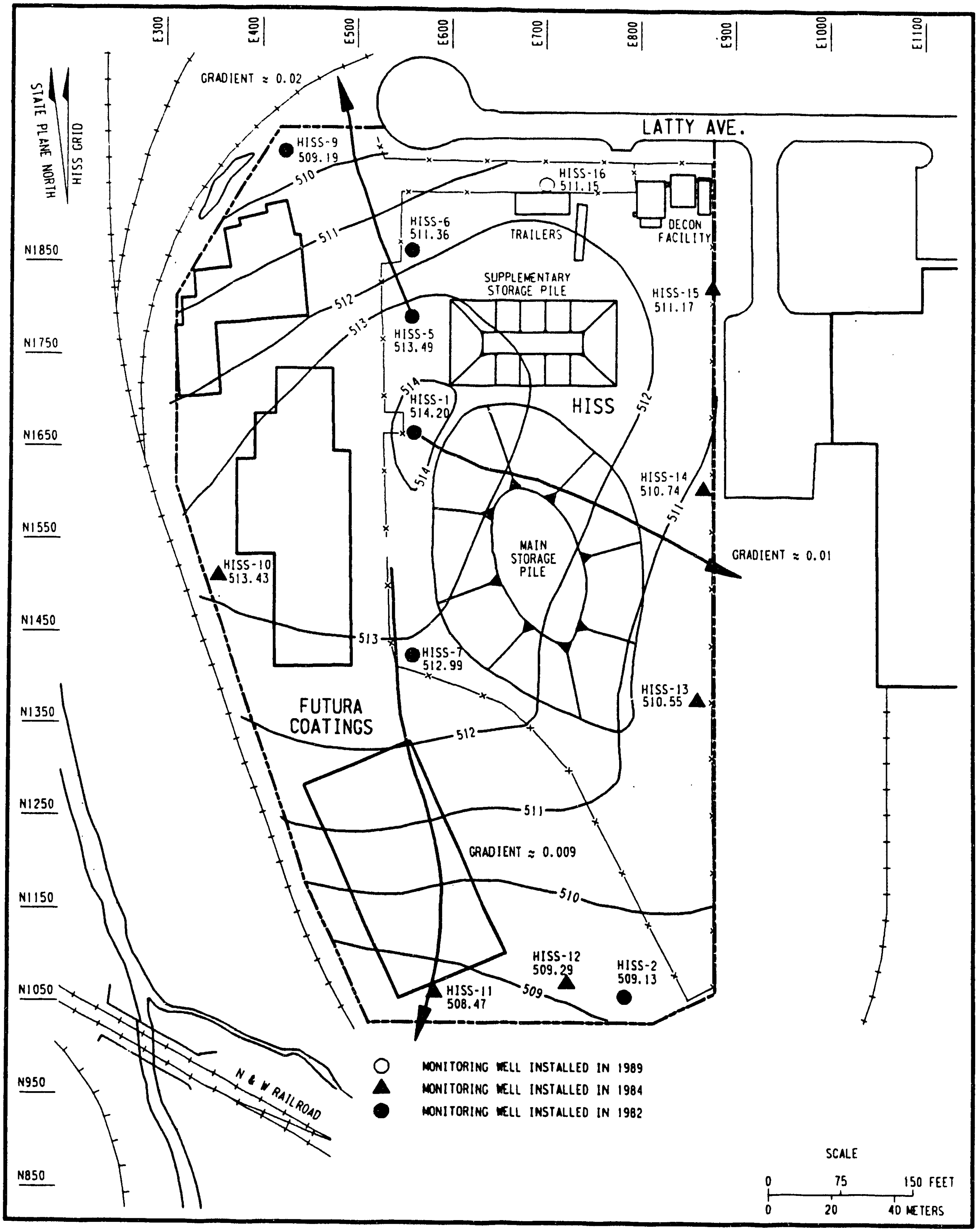
Figure A-10
Potentiometric Surface Map (1/9/92)



140 R34F010.DGN

Figure A-11
Potentiometric Surface Map (5/14/92)

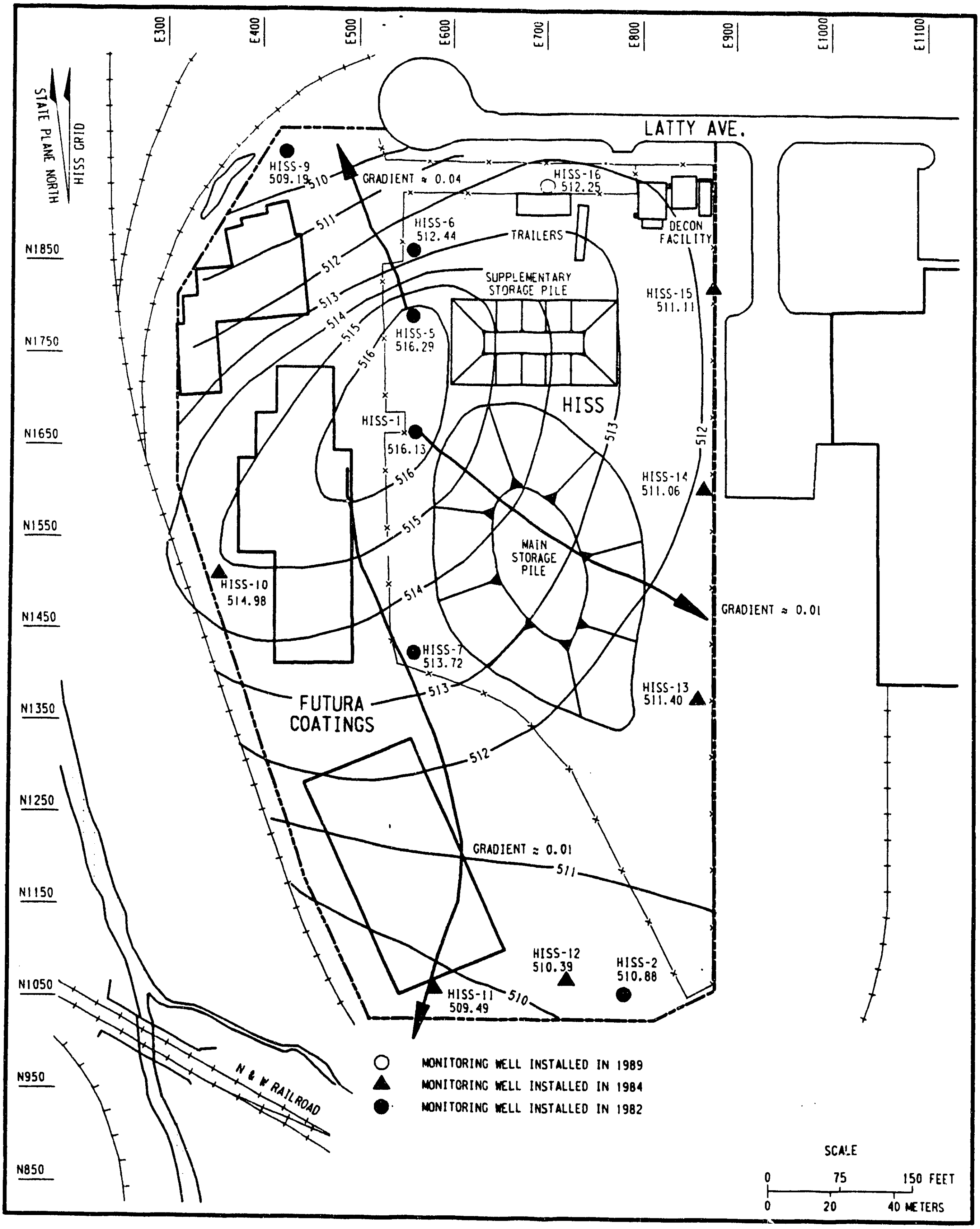


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Figure A-12
Potentiometric Surface Map (12/22/92)

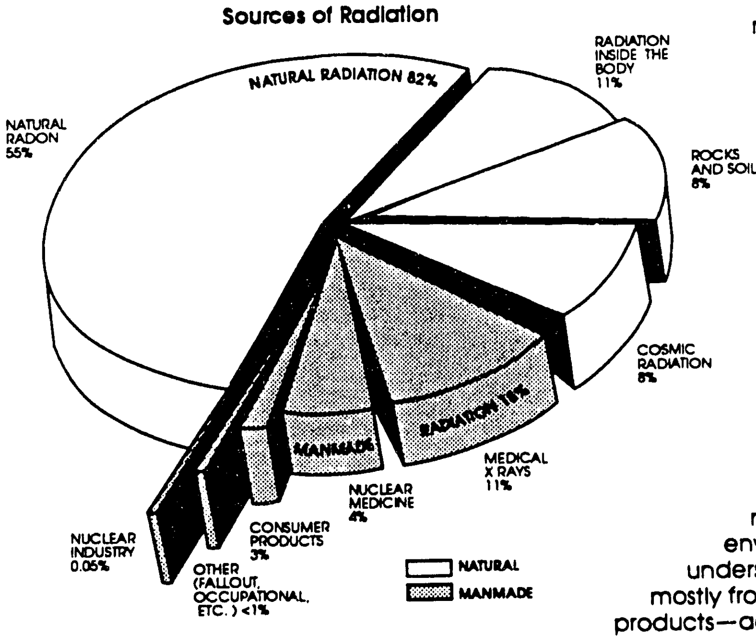
APPENDIX B Radiation and the Environment

Radiation in the Environment

Radiation is a natural part of our environment. When our planet was formed, radiation was present—and radiation surrounds it still. Natural radiation showers down from the distant reaches of the cosmos and continuously radiates from the rocks, soil, and water on the Earth itself.

During the last century, mankind has discovered radiation, how to use it, and how to control it. As a result, some manmade radiation has been added to the natural amounts present in our environment.

Sources of Radiation



Many materials—both natural and manmade—that we come into contact with in our everyday lives are radioactive. These materials are composed of atoms that release energetic particles or waves as they change into more stable forms. These particles and waves are referred to as *radiation*, and their emission as *radioactivity*.

As the chart on the left shows, most environmental radiation (82%) is from natural sources. By far the largest source is radon, an odorless, colorless gas given off by natural radium in the Earth's crust. While radon has always been present in the environment, its significance is better understood today. Manmade radiation—mostly from medical uses and consumer products—adds about eighteen percent to our total exposure.

TYPES OF IONIZING RADIATION

Radiation that has enough energy to disturb the electrical balance in the atoms of substances it passes through is called *ionizing radiation*. There are three basic forms of ionizing radiation.

Alpha

Alpha particles are the largest and slowest moving type of radiation. They are easily stopped by a sheet of paper or the skin. Alpha particles can move through the air only a few inches before being stopped by air molecules. However, alpha radiation is dangerous to sensitive tissue inside the body.

Beta

Beta particles are much smaller and faster moving than alpha particles. Beta particles pass through paper and can travel in the air for about 10 feet. However, they can be stopped by thin shielding such as a sheet of aluminum foil.

Gamma

Gamma radiation is a type of electromagnetic wave that travels at the speed of light. It takes a thick shield of steel, lead, or concrete to stop gamma rays. X rays and cosmic rays are similar to gamma radiation. X rays are produced by manmade devices; cosmic rays reach Earth from outer space.

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Units of Measure

Radiation can be measured in a variety of ways. Typically, units of measure show either 1) the total amount of radioactivity present in a substance, or 2) the level of radiation being given off.

The radioactivity of a substance is measured in terms of the number of transformations (changes into more stable forms) per unit of time. The *curie* is the standard unit for this measurement and is based on the amount of radioactivity contained in 1 gram of radium. Numerically, 1 curie is equal to 37 billion transformations per second. The amounts of radioactivity that people normally work with are in the millicurie (one-thousandth of a curie) or microcurie (one-millionth of a curie) range. Levels of radioactivity in the environment are in the picocurie, or pCi (one-trillionth of a curie) range.

Levels of radiation are measured in various un The level of gamma radiation in the air is measured the *roentgen*. This is a relatively large unit, so measurements are often calculated in milliroentge Radiation absorbed by humans is measured in eith *rad* or *rem*. The rem is the most descriptive becaus it measures the ability of the specific type of radiation to do damage to biological tissue. Aga typical measurements will often be in the millir (mrem), or one-thousandth of a rem, range. In the international scientific community, absorb dose and biological exposure are expressed in *gr* and *seiverts*. 1 gray (Gy) equals 100 rad. 1 seivert (equals 100 rem. On the average, Americans receive about 360 mrem of radiation a year. M of this (97%) is from natural radiation and medical exposure. Specific examples of common sources radiation are shown in the chart below.

RADIATION IN THE ENVIRONMENT

Because the radioactivity of individual samples varies, the numbers given here are approximate or represent an average. They are shown to provide a perspective for concentrations and levels of radioactivity rather than dose.

mrem = millirem
pCi = picocurie

Cosmic Radiation

Cosmic radiation is high-energy gamma radiation that originates in outer space and filters through our atmosphere.

Sea Level .... 26 mrem/year
(increases about 1/2 mrem for each additional 100 feet in elevation)
Atlanta, Georgia (1,050 feet) .... 31 mrem/year
Denver, Colorado (5,300 feet) .... 50 mrem/year
Minneapolis, Minnesota (815 feet) .... 30 mrem/year
Salt Lake City, Utah (4,400 feet) .... 46 mrem/year

Terrestrial Radiation

Terrestrial sources are naturally radioactive elements in the soil and water such as uranium, radium, and thorium. Average levels of these elements are 1 pCi/gram of soil.

United States (average) .... 26 mrem/year
Denver, Colorado .... 63 mrem/year
Nile Delta, Egypt .... 350 mrem/year
Paris, France .... 350 mrem/year
Coast of Kerala, India .... 400 mrem/year
McAipe, Brazil .... 2,558 mrem/year
Pocos De Caldas, Brazil ...... 7,000 mrem/year

Buildings

Many building materials, especially granite, contain naturally radioactive elements.

U.S. Capitol Building .... 85 mrem/year
Base of Statue of Liberty .... 325 mrem/year
Grand Central Station .... 525 mrem/year
The Vatican .... 800 mrem/year

Radon

Radon levels in buildings vary, depending on geographic location, from 0.1 to 200 pCi/liter.

Average Indoor Radon Level .... 1.5 pCi/liter
Occupational Working Limit ..... 100.0 pCi/liter

Food

Food contributes an average of 20 mrem/year, mostly from potassium-40, carbon-14, hydrogen-3, radium-226, and thorium-232.

Beer .... 390 pCi/liter
Tap Water .... 20 pCi/liter
Milk .... 1,400 pCi/liter
Salad Oil .... 4,900 pCi/liter
Whiskey .... 1,200 pCi/liter
Brazil Nuts .... 14 pCi/g
Bananas .... 3 pCi/g
Flour .... 0.14 pCi/g
Peanuts & Peanut Butter .. 0.12 pCi/g
Tea .... 0.40 pCi/g

Medical Treatment

The exposures from medical diagnosis vary widely according to the required procedure, the equipment and film used for x rays, and the skill of the operator.

Chest X Ray .... 10 mrem
Dental X Ray,Each .... 100 mrem

Consumer Goods

Cigarettes-two packs/day (polonium-210) .... 8,000 mrem/y
Color Television .... <1 mrem/y
Gas Lantern Mantle (thorium-232) .... 2 mrem/y
Highway Construction .... 4 mrem/y
Airplane Travel at 39,000 feet (cosmic) .... 0.5 mrem/h
Natural Gas Heating and Cooking (radon-222) .... 2 mrem/y
Phosphate Fertilizers .... 4 mrem/ye

Natural Radioactivity in Florida Phosphate Fertilizers (in pCi/gram)

	Normal Superphosphate	Concentrated Superphosphate	Gypsum
Ra-226	21.3	21.0	33.0
U-238	20.1	58.0	6.0
Th-230	18.9	48.0	13.0
Th-232	0.6	1.3	0.3

Porcelain Dentures (uranium) .... 1,500 mrem/yea
Radioluminescent Clock (promethium-147) .... <1 mrem/yea
Smoke Detector (americium-241) .... 0.01 mrem/yea

International Nuclear Weapons Tes Fallout from pre–1980 atmospheric tests
(average for a U.S. citizen) ...... 1 mrem/yea

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Radiation in Medicine and Industry. A.P. Jacoboson and G.P. Sakolosky, 1980.
Radioactivity in Consumer Products. U.S. Nuclear Regulatory Commission, 1978.

PERSPECTIVE: How Big is a Picocurie?

The *curie* is a standard measure for the intensity of radioactivity contained in a sample of radioactive material. It was named after French scientists Marie and Pierre Curie for their landmark research into the nature of radioactivity.

The basis for the curie is the radioactivity of one gram of radium. Radium decays at a rate of about 2.2 trillion disintegrations (2.2×10^{12}) per minute. A *picocurie* is one trillionth of a curie. Thus, a picocurie represents 2.2 disintegrations per minute.

To put the relative size of one *trillionth* into perspective, consider that if the Earth were reduced to one trillionth of its diameter, the "pico earth" would be smaller in diameter than a speck of dust. In fact, it would be six times smaller than the thickness of a human hair.

The difference between the curie and the picocurie is so vast that other metric units are used between them. These are as follows:

Millicurie = $\frac{1}{1{,}000}$ **(one thousandth) of a curie**

Microcurie = $\frac{1}{1{,}000{,}000}$ **(one millionth) of a curie**

Nanocurie = $\frac{1}{1{,}000{,}000{,}000}$ **(one billionth) of a curie**

Picocurie = $\frac{1}{1{,}000{,}000{,}000{,}000}$ **(one trillionth) of a curie**

The following chart shows the relative differences between the units and gives analogies in dollars. It also gives examples of where these various amounts of radioactivity could typically be found. The number of disintegrations per minute has been rounded off for the chart.

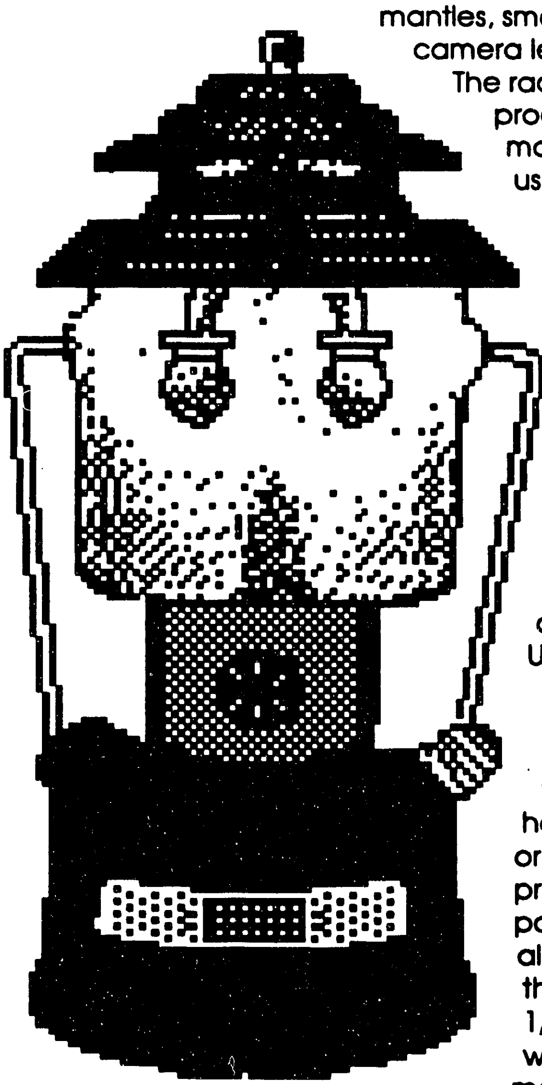
UNIT OF RADIOACTIVITY	SYMBOL	DISINTEGRATIONS PER MINUTE	DOLLAR ANALOGY	EXAMPLES OF RADIOACTIVE MATERIALS
1 Curie	Ci	2×10^{12} or 2 Trillion	2 Times the Annual Federal Budget	Nuclear Medicine Generator
1 Millicurie	mCi	2×10^{9} or 2 Billion	Cost of a New Interstate Highway from Atlanta to San Francisco	Amount Used for a Brain or Liver Scan
1 Microcurie	µCi	2×10^{6} or 2 Million	All-Star Baseball Player's Salary	Amount Used in Thyroid Tests
1 Nanocurie	nCi	2×10^{3} or 2 Thousand	Annual Home Energy Costs	Consumer Products
1 Picocurie	pCi	2	Cost of a Hamburger and Coke	Background Environmental Levels

Chart provided by W.L. Beck, Bechtel National, Inc.

PERSPECTIVE: Radioactivity in Gas Lantern Mantles

Around the House

Many household products contain a small amount of radioactivity. Examples include gas lantern mantles, smoke detectors, dentures, camera lenses, and anti-static brushes. The radioactivity is added to the products either specifically to make them work, or as a result of using compounds of elements like thorium and uranium in producing them. The amount of radiation the products gives off is not considered significant. But with today's sensitive equipment, it can be detected.



Lanterns: In a New Light

About 20 million gas lantern mantles are used by campers each year in the United States.

Under today's standards, the amount of natural radioactivity found in a lantern mantle would require precautions in handling it at many Government or industry sites. The radioactivity present would contaminate 15 pounds of dirt to above allowable levels. This is because the average mantle contains 1/3 of a gram of thorium oxide, which has a specific activity (a measure of radioactivity) of approximately 100,000 picocuries per gram. The approximately 35,000 picocuries of radioactivity in the mantle would, if thrown onto the ground, be considered low-level radioactive contamination.

From information provided by W.L. Beck, Bechtel National, Inc.

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APPENDIX C Parameters for Analysis

Table C-1

Analyses Performed on Samples from HISS

Page 1 of 2

Parameter	Recommended Analytical Technique	Method	Detection Limit
Water Samples (s = surface water, g = groundwater, stw = stormwater)			
Lead-210 (stw)	Beta GPC[a]	EML[b] Pb-01	1.0 pCi/L
Radium-226 (s, g, stw)	Alpha spectroscopy	EML Ra-05[b,c]	0.5 pCi/L
Radium-228 (stw)	Beta GPC[a]	EPA 904.0[d]	1.0 pCi/L
Thorium-230 (s, g, stw)	PERALS[e]	TMA/E	0.5 pCi/L
Thorium-232 (stw)	Alpha spectroscopy	EML Th-01[b,c]	0.5 pCi/L
Total uranium (s, g, stw)	KPA[f]	ASTM D-5174[g]	0.03 μg/L
Gross alpha (stw)	Alpha GPC[a]	EPA 900.0[d]	10 pCi/L
Gross beta (stw)	Beta GPC[a]	EPA 900.0[d]	10 pCi/L
Settleable solids (stw)	Imhoff cone	EPA 160.5[d]	0.2 ml/L/h
TOC[h] (stw)	Carbonaceous analyzer	EPA 415.1[d]	0.5 mg/L
TOX[i] (stw)	Coulometric determination	EPA 450.1[d]	20 μg/L
Sodium (g)	ICPAES[j]	EPA 6010	5,000 μg/L
Potassium (g)	ICPAES[j]	EPA 6010	5,000 μg/L
Calcium (g)	ICPAES[j]	EPA 6010	5,000 μg/L
Magnesium (g)	ICPAES[j]	EPA 6010	5,000 μg/L
Bicarbonate (g)	Potentiometric	EPA 310.1	2 mg/L
Carbonate (g)	Potentiometric	EPA 310.1	2 mg/L
Sulfate (g)	Turbidimetric	EPA 9038	25 mg/L
Chloride (g)	Colorimetric	EPA 9251	5 mg/L
Total dissolved solids (g)	Gravimetric	EPA 160.1	5 mg/L
Sediment Samples			
Radium-226	Gamma spectroscopy	EML C-02[b]	0.5 pCi/g
Thorium-230	PERALS[e]	TMA/E	0.5 pCi/g
Total uranium	KPA[f]	ASTM D-5174[g]	0.1 μg/L
Air Monitoring			
External gamma radiation	Thermoluminescence	---[l]	20 mR
Radon	Track-Etch	---[m]	0.3 pCi/L[n]
Radon flux	LAACC[k] using gamma spectroscopy	EML C-02[b]	0.01 pCi/m^2-s

Table C-1

(continued)

[a]GPC - gross proportional counting.

[b]Thermo Analytical/Eberline (TMA/E) utilizes laboratory procedures developed by Environmental Measurements Laboratory-300 (EML-300) (DOE 1990b).

[c]Modified EML procedure to accommodate matrix.

[d]EPA methods taken from EPA 600 series documents.

[e]PERALS - photon/electron-rejecting alpha liquid scintillation.

[f]KPA - kinetic phosphorescence analysis.

[g]ASTM - American Society for Testing and Materials.

[h]TOC - total organic carbon.

[i]TOX - total organic halides.

[j]ICPAES - inductively coupled plasma atomic emission spectrophotometry.

[k]LAACC - large area activated charcoal collectors.

[l]Gamma exposure is measured using tissue-equivalent thermoluminescent dosimeters. The dosimeters contain lithium fluoride chips that absorb penetrating radiation. When heated, the chips emit a proportional, measurable amount of light.

[m]Detectors contain an alpha-sensitive piece of film which, when developed, will contain a countable track for each alpha particle collision. The number of tracks per unit area is related through calibration to radon concentration.

[n]Approximate detection limit is dependent upon exposure duration. This value was the minimum detectable during quarterly monitorings in 1992.

APPENDIX D Methodology for Statistical Analysis of Data

METHODOLOGY FOR STATISTICAL ANALYSIS OF DATA

Treatment of "Less than Zero" Values

Beginning with the third quarter 1992 environmental monitoring, less-than-zero radiological values have been reported when they occur. This practice will be continued for all future environmental monitoring, which will result in more accurate statistical analysis. For 1992 this results in both negative values and values reported as less than a detection limit being used in the site environmental report. The negative values are used as reported in the statistical calculations. For values that are reported as less than the detection limit, the detection limit is used in the statistical calculations.

Treatment of Rounding and Significant Figures

When performing calculations, the answer can be no more accurate than the least accurate number in the data (i.e., the number with the least number of significant digits). Regardless of whether a number contains a decimal, the number of significant digits is the total number of digits starting with the left-most, non-zero digit and ending with the right-most digit (even if it is a zero). For example, 231, 230, and 23.0 each have three significant digits, while 0.05 and 5 each have one significant digit. Rounding is performed on final calculation results only, not on interim results.

Treatment of Annual Average Concentrations

Average annual concentrations are calculated by adding the results for the year and dividing by the number of quarters for which data have been taken and reported (usually four). An example follows.

Thorium-230 Results (pCi/L)

Sampling Location	Quarter			
	1	2	3	4
1	13	7	12	5

First, results reported for the year are added.

$13 + 7 + 12 + 5 = 37$

Next, the sum of all results is divided by the number of quarters for which data were taken and reported. In this example there were data for all four quarters.

$37 \div 4 = 9.25$

Because there are two single-digit numbers (5 and 7), the result is rounded to 9 (number of significant figures is 1). This value is entered into the average value column.

Thorium-230 Results (pCi/L)

Sampling Location	Quarter				Average Value
	1	2	3	4	
1	13	7	12	5	9

Expected concentration ranges are calculated to provide a basis for trend analysis of the data. These expected ranges are calculated by taking the average of the annual average concentrations for the past five years (when possible) and calculating a standard deviation for these data. The lower expected range is calculated by subtracting two standard deviations from the average value, and the upper range is calculated by adding two standard deviations to the average values. If site conditions do not change, 95 percent of the data points would be expected to fall within this range. An example of these calculations is shown below.

Thorium-230 Results (pCi/L)

Sampling Location	Year					Average Value	Standard Deviation
	1986	1987	1988	1989	1990		
1	10	5	14	8	5	8	4

The formula for calculation of the standard deviation of a sample xi, ..., xn is:

$$S = \sqrt{S^2} = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 1}}$$

where: S = Standard deviation

x_i = Individual values

x = Average of values

n = Number of values

n	x_i	$\bar{x}$	$(x_i - \bar{x})$	$(x_i - \bar{x})^2$
1	10	8	2	4
2	5	8	-3	9
3	14	8	6	36
4	8	8	0	0
5	5	8	-3	9

$$\sum (X_i - \bar{x})^2 = 58$$

$$S = \sqrt{\frac{58}{5 - 1}} = \sqrt{\frac{58}{4}} = \sqrt{14.5} = 3.807,$$

which rounds to 4 because there is only one significant figure.

The calculation for the expected ranges for this example is shown below.

Lower expected range: 8 - 2(4) = 0

Upper expected range: 8 + 2(4) = 20 (rounded to one significant figure)

Annual average values for the site for the current year are compared with these ranges to indicate a possible anomaly or trend. If a discernible trend is found from this comparison, the data are presented in the appropriate section of the report.

APPENDIX E Environmental Standards

ENVIRONMENTAL STANDARDS

The DOE long-term radiation protection standard of 100 mrem/yr in excess of the background level includes exposure from all pathways except medical treatments and exposures from radon (DOE 1990b). Evaluation of exposure pathways and resulting dose calculations are based on assumptions such as the use of occupancy factors in determining dose caused by external gamma radiation; subtraction of background concentrations of radionuclides in air, water, and soil before calculating dose; closer review of water use; use of the data that most closely represent actual exposure conditions rather than maximum values (as applicable); and use of average consumption rates of food and water per individual rather than maximums. Use of such assumptions results in calculated doses that more accurately reflect the exposure potential from site activities.

DERIVED CONCENTRATION GUIDES

As referenced in the compliance summary, DOE orders provide the standards for radionuclide emissions from DOE facilities. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," provides the procedures and requirements for radionuclide releases.

Applicable standards are found in Chapter III of DOE Order 5400.5 and are set as derived concentration guides (DCGs). A DCG is defined as the concentration of a single radionuclide in air or water that, under conditions of continuous exposure for one year by one exposure mode (e.g., ingestion of water, inhalation), would result in an effective dose equivalent of 100 mrem. The following table provides reference values for conducting radiological environmental protection programs at operational DOE facilities and sites.

Radionuclide	F1 Value[a]	Ingested[b] Water DCG (μCi/ml)	Inhaled Air DCGs[c]		
			D	W	Y
Radium-226	2E-1	1E-7	--	1E-12	--
Thorium-230	2E-4	3E-7	--	4E-14	5E-14
Thorium-232	2E-4	5E-8	--	7E-15	1E-14
Uranium-234	2E-3	5E-6	--	--	9E-14
Thorium-235	2E-3	5E-6	--	--	1E-13
Thorium-238	2E-3	6E-6	--	--	1E-13
Radon-222[d]	3E-9	3E-9	--	--	3E-9
Thorium-220[d]	3E-9	3E-9	--	--	3E-9

[a]F1 is defined as the gastrointestinal tract absorption factor. This unitless value measures the uptake fraction of ingestion of a radionuclide into the body.

[b]1E-9 μCi/ml = 0.037 Bq/L = 1 pCi/L.

[c]Inhaled air DCGs are expressed as a function of time. D, W, and Y represent a measure of the time required for contaminants to be removed from the system (D represents 0.5 day; W represents 50 days; and Y represents 500 days).

[d]DOE is reassessing the DCGs for radon. Until review is completed and new values issued, the values given in the chart above will be used for releases from DOE facilities.

SOIL GUIDELINES

Guidelines for residual radioactivity in soil established for FUSRAP are shown below.

Radionuclide	Soil Concentration (pCi/g) Above Background
Radium-226 Radium-228 Thorium-230 Thorium-232	5 pCi/g, averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over any 15-cm-thick soil layer below the surface layer.
Other Radionuclides	Soil guidelines will be calculated on a site-specific basis using the DOE manual developed for this use. A proposed guideline of 50 pCi/g is being used for uranium for planning purposes.

Source: DOE 1987.

APPENDIX F Population Exposure Methodology

POPULATION EXPOSURE METHODOLOGY

DOE Order 5400.5 requires that the impacts of the site on both the hypothetical maximally exposed individual and the population within 80 km (50 mi) of the site be evaluated. For radioactive materials, this evaluation is usually conducted by calculating the dose received by the hypothetical individual and the general population and comparing this dose with DOE guidelines. This appendix describes the methodology used to calculate the doses discussed in Section 4.0.

PATHWAYS

The purpose of the dose calculation is to identify the potential routes or pathways that are available to transmit either radioactive material or ionizing radiation to the receptor. In general, the pathways are (1) direct exposure to gamma radiation, (2) atmospheric transport of radioactive material, (3) transport of radioactive material via surface water or groundwater, (4) bioaccumulation of radioactive materials in animals used as a food source, and (5) uptake of radioactive materials by plants used as a food source. For FUSRAP sites, the primary pathways are direct gamma radiation and transport of radioactive materials by the atmosphere, groundwater, and surface water. The others are not considered primary pathways because FUSRAP sites are not located in areas where significant sources of livestock are raised or foodstuffs are grown.

Gamma rays can travel until they expend all their energy in molecular or atomic interactions. In general, these distances are not very great, and the exposure pathway would affect only the hypothetical maximally exposed individual.

Contamination transported via the atmospheric pathway may take the form of contaminated particulates or dust and can provide a potential dose only when it is inhaled. Doses from radon are intentionally excluded; radon exposure is in compliance with concentration requirements for boundaries.

Contamination is transported in surface water when runoff from a rainfall event or some other source of overland flow carries contamination from the site to the surface water system. This contamination poses an exposure problem only when the surface water is used to provide municipal drinking water or to water livestock and/or to irrigate crops. Contamination transported via groundwater when contaminants migrate into the groundwater system becomes a problem if there is a potential receptor.

PRIMARY RADIONUCLIDES OF CONCERN

The primary radionuclides of concern for these calculations are uranium-238, uranium-235, uranium-234, thorium-230, radium-226, and the daughter products (excluding radon). For several of the dose conversion factors used in these calculations, the contributions of the daughters with half-lives of less than one year are included with the parent radionuclide. Table F-1 lists the pertinent radionuclides, their half-lives, and dose conversion factors for ingestion.

DOSE CALCULATION METHOD

Direct Gamma Radiation Pathway

As previously indicated, direct gamma radiation exposure is important in calculating the dose to the hypothetical maximally exposed individual. The dose from direct gamma radiation exposure is determined by using data collected through the tissue-equivalent thermoluminescent dosimeter (TETLD) program (described in Section 4.0). These data provide a measure of the amount and energy (in units of mrem) of the ionizing radiation at 1 m (3 ft) above the ground. For the purposes of this report, it is assumed that the hypothetical individual works 40 hours per week at Futura Coatings at an average distance of 46 m (150 ft) from the site; there are no houses and, therefore, no residents near the site.

Table F-1

Radionuclides of Interest

Radionuclide	Half-life[a]	Dose Conversion Factor[b] for Ingestion (mrem/pCi)
Uranium-238	4.51E+9 years	2.5E-4
Thorium-234	24.1 days	--[c]
Protactinium-234 m	1.17 minutes	--[c]
Protactinium-234	6.75 hours	--[c]
Uranium-234	2.47E+5 years	2.6E-4
Thorium-230	8.0E+4 years	5.3E-4
Radium-226	1602 years	1.1E-3
Uranium-235	7.1E+8 years	2.5E-4
Thorium-231	25.5 hours	--[d]
Protactinium-231	3.25E+4 years	1.1E-2
Actinium-227	21.6 years	1.5E-2
Thorium-227	18.2 days	--[e]
Radium-223	11.43 days	--[e]

[a]Source: Radiological Health Handbook (HEW 1970).

[b]Source: Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation Submersion (EPA-520/1-88-020) and International Dose Conversion Factors for Calculation of Dose to the Public (DOE/EH-0071).

[c]Included in the uranium-238 dose conversion factor.

[d]Included in the uranium-235 dose conversion factor.

[e]Included in the actinium-227 dose conversion factor.

The dose to the hypothetical maximally exposed individual can be determined by assuming that the individual is exposed to a line source located along the HISS/Futura fenceline. Because the average exposure rate is known (from the TETLD program) for a distance of 1 m (3 ft) from the fenceline, the exposure at 46 m (150 ft) from the fenceline can be calculated by using the following equation (Cember 1983).

$$\text{Exposure at 46 m} = (\text{Exposure at 1 m}) \times \frac{h_1}{h_2} \times \frac{\tan^{-1}(L/h_2)}{\tan^{-1}(L/h_1)}$$

where: h_1 = TETLD distance from the fenceline [1 m (3 ft)]

h_2 = Hypothetical maximally exposed individual's distance from the fenceline [46 m (150 ft)]

L = Half of the length of the site toward Futura Coatings [152 m (500 ft)]

The exposure rate at 1 m (3 ft) can be calculated by taking the average of the results from the five dosimeters along this portion of the fenceline (1, 2, 5, 6, and 7) and then subtracting background. The average above-background exposure rate for these dosimeters was 26 mR/yr. Using the formula above, the exposure rate at 46 m (150 ft) is approximately 0.46 mR/yr. Because 1 mR is approximately equal to 1 mrem, the resulting dose would be 0.46 mrem, assuming 24-h continuous residence. However, this is the dose for the entire year; to calculate the dose to a worker (8 h/day), the following equation must be used.

$$\text{Dose} = (\text{Dose at 46 m}) \times \frac{(40 \text{ h/wk})}{(7 \text{ days/wk} \times 24 \text{ h/day})} = 0.11 \text{ mrem/yr}$$

Therefore, the dose from direct gamma radiation to the hypothetical maximally exposed individual would be 0.11 mrem/yr (1.1×10^{-3} mSv/yr).

This exposure scenario should provide a conservative estimate of the dose from direct gamma exposure to the hypothetical maximally exposed individual.

Surface Water Pathway

Exposures from contaminants in surface water are important in calculating the dose to both the hypothetical maximally exposed individual and the nearby population. The data used to support the surface water dose calculation consist of measurements of concentrations of contaminants in surface water at the site and of the amount of dilution provided by tributaries or rivers between the site and the intake. Thus, the dose to the individual can be calculated by the following:

$$D_s = \sum_{i=1}^{N} C_i \times (F_s \div F_i) \times U_a \times DCF_i$$

where:

D_s	=	Committed effective dose from surface water
C_i	=	Average annual concentration of the i^{th} radionuclide in surface water at the site
F_s	=	Average annual flow of surface water at the site
F_i	=	Average flow of surface water at the intake
U_a	=	Annual consumption of liquid [approx. 730 L/yr, 90th percentile (EPA 1989)]
DCF_i	=	Dose conversion factor for the i^{th} radionuclide

To determine the dose to the population, the same equation would be used and the dose would be multiplied by the population group served by the drinking water supply. It is important to note that for the population dose, the intake point is probably not the same as that for the hypothetical maximally exposed individual.

The approach outlined above should provide a very conservative dose calculation for the surface water pathway because it does not account for radionuclides settling out or for any municipal water treatment.

Groundwater Pathway

Exposures from contaminants in groundwater are important in calculating the dose to both the hypothetical maximally exposed individual and the nearby population. The data used to support the groundwater dose calculations consist of measurements of the concentrations of the contaminants in groundwater and an estimate of the dilution that occurs between the measurement location and the intake point. The dose for the hypothetical maximally exposed individual can be calculated by using the following equation:

$$D_{gw} = \sum_{i=1}^{N} (C_i) \times (D) \times (U_a) \times (DCF_i)$$

where: D_{gw} = Committed effective dose from groundwater

C_i = Average annual concentration of the i^{th} radionuclide in groundwater at the site

D = Estimated dilution factor

U_a = Annual consumption of liquid [approx. 730 L/yr, 90th percentile (EPA 1989)]

DCF_i = Dose conversion factor for the i^{th} radionuclide

To determine the dose to the population, the same equation would be used and the dose would be multiplied by the population group served by the drinking water supply. It is important to note that the population intake point is usually different from that of the hypothetical maximally exposed individual.

The approach given above should provide a conservative dose calculation for the groundwater pathway because it does not account for any water treatment.

Air Pathway (Ingestion, Air Immersion, Inhalation)

The dose to the hypothetical maximally exposed individual from particulate radionuclides transported via the air pathway is calculated using EPA's computer model CAP88-PC. Doses to the general public via this pathway are also calculated using CAP88-PC results; these results are provided in Subsection 4.2.

The release of particulates was calculated using a model for wind erosion because there are no other likely or credible mechanisms for releasing particulates from the site. The wind erosion model used was taken from the DOE "Remedial Action Priority System Mathematical Formulation." The input for the model consisted of site-specific average soil concentrations, local meteorological data (see Section 1.0), and areas of contamination.

The site was modeled as one area. The average particle size for the soil at HISS is estimated at 0.05 mm for determining the emission factor for windblown material. This greatly overestimates the fraction of the airborne material that is respirable because most particles greater than 0.01 mm in diameter either would not be inhaled or would be quickly removed. Nevertheless, to provide a conservative calculation, all airborne particles were assumed to be respirable with an activity median aerodynamic diameter of 0.001 mm. Because the calculated dose was a small fraction of the NESHAPs standard of 10 mrem/yr, no effort was made to estimate the fraction of the airborne material that would be in the respirable range. Other assumptions used in the model were that the contamination at the site is 90 percent covered by vegetation and that there are three mechanical disturbances at the site each month.

APPENDIX G Distribution List for Hazelwood Interim Storage Site Environmental Report for Calendar Year 1992

The Department of Energy distributes this report to local, state, and federal agencies; U.S. Congress; the public; and the media (upon request).15

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