

SL-078

DOE/OR/20722-258
VOLUME I
REVISION 1

SLDS
Administrative
Record
9808171003

Formerly Utilized Sites Remedial Action Program (FUSRAP)
Contract No. DE-AC05-81OR20722

**RADIOLOGICAL, CHEMICAL,
AND HYDROGEOLOGICAL
CHARACTERIZATION REPORT FOR THE
ST. LOUIS DOWNTOWN SITE IN
ST. LOUIS, MISSOURI**

September 1990



Bechtel National, Inc.



072091

Department of Energy

Oak Ridge Operations
P.O. Box 2001
Oak Ridge, Tennessee 37831 —

90-745

October 16, 1990

Mr. Greg McCabe
U. S. Environmental Protection Agency
Region VII
726 Minnesota Avenue
Kansas City, KS 66101

Dear Mr. McCabe:

**RADIOLOGICAL, CHEMICAL, AND HYDROGEOLOGICAL CHARACTERIZATION REPORT FOR THE
ST. LOUIS DOWNTOWN SITE IN ST. LOUIS, MISSOURI**

The purpose of this letter is to transmit copies of the subject report for your reference. Information in the subject report will be summarized and referenced in the St. Louis Site Work Plan and the Remedial Investigation report, each of which will be provided to the Environmental Protection Agency and the Missouri Department of Natural Resources for review at a later date. In the interim, if you have any questions or would like to discuss the findings of this report in greater detail, please feel free to contact me.

Sincerely,

A handwritten signature in black ink, appearing to read "David G. Adler", is written over the typed name.

David G. Adler, Site Manager
Technical Services Division

Enclosure

cc: S. Liedle, BNI



Department of Energy

Oak Ridge Operations
P.O. Box 2001
Oak Ridge, Tennessee 37831—

October 16, 1990

072891

90-746

Mr. David E. Bedan
Radioactive Waste Cleanup Coordinator
Missouri Department of Natural Resources
Post Office Box 176
Jefferson City, MO 65102

Dear Mr. Bedan:

**RADIOLOGICAL, CHEMICAL, AND HYDROGEOLOGICAL CHARACTERIZATION REPORT FOR THE
ST. LOUIS DOWNTOWN SITE IN ST. LOUIS, MISSOURI**

The purpose of this letter is to transmit copies of the subject report for your reference. Information in the subject report will be summarized and referenced in the St. Louis Site Work Plan and the Remedial Investigation report, each of which will be provided to the Environmental Protection Agency and the Missouri Department of Natural Resources for review at a later date. In the interim, if you have any questions or would like to discuss the findings of this report in greater detail, please feel free to contact me.

Sincerely,

David G. Adler, Site Manager
Technical Services Division

Enclosure

cc: S. Liedle, BNI

DOE/OR/20722-258
VOLUME I
REVISION 1

RADIOLOGICAL, CHEMICAL, AND HYDROGEOLOGICAL
CHARACTERIZATION REPORT FOR THEN REPORT FOR THE
ST. LOUIS DOWNTOWN SITE IN
ST. LOUIS, MISSOURI

SEPTEMBER 1990

Prepared for

UNITED STATES DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS OFFICE
Under Contract No. DE-AC05-81OR20722

By

M. E. Redmon, M. E. Kaye,
C. A. Clark, and C. M. Sekula

Bechtel National, Inc.
Oak Ridge, Tennessee

Bechtel Job No. 14501

EXECUTIVE SUMMARY

Characterization activities were conducted at the St. Louis Downtown Site (SLDS) under the jurisdiction of the Department of Energy's (DOE) Formerly Utilized Sites Remedial Action Program. The field investigation was performed to determine the lateral and vertical extent of radioactive contamination, to delineate any chemical contamination associated with such radioactive contamination, and to characterize the site's hydrogeological features.

SLDS is located in a highly industrialized area of St. Louis on an 18.2-ha (45-acre) tract. Currently, it is an operating plant for production of various chemical products but was, during the years 1942-1958, involved in developmental work for the Manhattan Engineer District/Atomic Energy Commission. Chemical treatment of impure natural uranium feed materials to produce pure uranium trioxide (UO_3) and other uranium- and thorium-containing compounds was carried out at the facility.

Radioactivity exceeding DOE guidelines for soil was found at various site locations. The primary radioactive contaminants identified were uranium-238, radium-226, and thorium-230. Two hundred ninety-seven surface samples were collected, and 218 boreholes were drilled, sampled, and analyzed for radiological parameters. Although a few limited areas of radioactivity in soil were found to be several times applicable DOE guidelines, there appear to be no immediate health risks to workers at the facility, given current property use. In general, levels of radioactivity in soil were low across most of the site.

The groundwater monitoring locations at SLDS showed levels of radioactivity to be only a fraction of DOE's derived concentration guide for the radionuclides of interest. The

only radionuclide substantially above analytical detection limits, uranium-238, was detected at higher levels in only one of the nine wells.

Some internal building surfaces at SLDS are contaminated in excess of DOE guidelines for residual radioactivity on structural surfaces. These levels are typically low and pose no threat to workers at the site. In addition, average dose rates in these buildings are below the applicable DOE guideline. Three buildings revealed dose rates exceeding the DOE guidelines; however, given the current use of the property and these structures, workers at SLDS are not expected to receive an exposure above DOE's annual basic dose limit of 100 mrem/yr.

Chemical characterization activities involved analysis of soil samples from 110 boreholes. Soil was analyzed for metals, Resource Conservation and Recovery Act (RCRA)-hazardous waste characteristics, base/neutral and acid extractable (BNAE) compounds, and volatile organic compounds.

Seventeen metals were found to exceed maximum expected background concentrations: antimony, barium, boron, cadmium, chromium, cobalt, copper, lead, magnesium, manganese, mercury, molybdenum, silver, selenium, sodium, thallium, and zinc. The elevated levels of the metals may be due to uranium ore processing at the site and their presence in fill used along the riverfront in the area.

In general, concentrations of the volatile organic compounds detected were low, with mean concentrations in the low parts per billion (2.0 to 73 ppb). Concentrations of BNAE compounds were higher (585 to 14,900 ppb) than those observed for volatile compounds. The BNAE compounds detected are not expected to migrate appreciably, given their chemical

characteristics. BNAE contamination was detected across the site, but primarily in Plants 7W, 7S, 6, and 6E. These compounds are natural constituents of coal and coal ash, and their presence on site may be explained by their presence in fill used along the riverfront in the area.

Testing for RCRA-hazardous waste characteristics indicates that a few small, isolated areas exist on site where soil fails the hazardous waste extraction procedure criterion for lead. These areas are surrounded by larger volumes of radioactively contaminated soil that do not "fail" the extraction procedure test. If the material is excavated, it is likely that the resulting waste will not exhibit any hazardous waste characteristics. Therefore, it is anticipated that no RCRA-hazardous/radioactive mixed wastes will be generated during remedial action at SLDS.

Eight wells were installed at SLDS to monitor groundwater and sampled for four quarters. Ten different organic contaminants were found in six of the eight wells. The majority of the organic contaminants appear consistently in well B16W03S (Plant 2). Of the 25 positive values detected for all organic compounds, 17 were in samples from well B16W03S. Concentrations of organics detected were in the low parts per million (ppm) range. Metals were detected in all groundwater samples. One trend recognizable from the data is that barium is detected in all quarters in wells B16W05D and B16W06D, but no others.

Based on data obtained from the field investigation conducted at SLDS, the site's geologic and hydrogeologic features include:

- Two unconsolidated, distinct hydrostratigraphic units and one bedrock unit

- A deposition system consisting of basal coarse-grained sands and gravels, fining upward into silts and clays
- An alluvial aquifer existing under semiconfined conditions
- A strong correlation between Mississippi River stage levels and levels of water in monitoring wells completed in the lower unit
- Groundwater flow to the east toward the Mississippi River, and calculated gradients of 0.01 to 0.02 ft/ft for the flow path

Based on data collected during the remedial investigation at SLDS, approximately 215,000 m³ (280,000 yd³) of radioactively contaminated soil will require some type of remedial action. Alternative options for remedial action will be evaluated during the feasibility study for this site.

CONTENTS

	Page
Figures	I-ix
Tables	I-xi
Abbreviations	I-xii
Acronyms	I-xiv
1.0 INTRODUCTION	I-1
1.1 BACKGROUND	I-1
1.2 SCOPE AND OBJECTIVE	I-2
1.2.1 Radiological Characterization	I-2
1.2.2 Chemical Characterization	I-3
1.2.3 Hydrogeological Characterization	I-4
2.0 SITE DESCRIPTION AND HISTORY	I-5
2.1 LOCATION AND DESCRIPTION	I-5
2.2 SITE HISTORY AND PREVIOUS FIELD INVESTIGATIONS ...	I-5
2.3 PRESENT SITE FEATURES	I-12
3.0 HEALTH AND SAFETY	I-13
3.1 SUBCONTRACTOR TRAINING	I-13
3.2 HEALTH AND SAFETY REQUIREMENTS	I-13
4.0 QUALITY ASSURANCE/QUALITY CONTROL	I-14
4.1 RADIOLOGICAL	I-14
4.2 CHEMICAL	I-14
4.3 HYDROGEOLOGICAL	I-17
5.0 FIELD INVESTIGATION METHODOLOGY	I-18
5.1 SITE PREPARATION	I-18
5.1.1 Civil Survey	I-19
5.1.2 Decontamination Facilities and Procedures..	I-19
5.2 RADIOLOGICAL INVESTIGATION	I-20
5.2.1 Background Data and Measurements	I-20
5.2.2 Walkover Gamma Scans	I-20
5.2.3 Soils	I-21
5.2.4 Drains and Sumps	I-22
5.2.5 Groundwater	I-22
5.2.6 Buildings	I-23
5.3 CHEMICAL INVESTIGATION	I-25
5.3.1 Background Determinations	I-25
5.3.2 Soils	I-25
5.3.3 Groundwater	I-37
5.4 GEOLOGICAL/HYDROGEOLOGICAL INVESTIGATION	I-39
5.4.1 Background/Regional Data	I-43
5.4.2 Monitoring Wells and Boreholes	I-45
5.4.3 Soils	I-49
5.4.4 Groundwater Monitoring	I-49

	Page
6.0 CHARACTERIZATION RESULTS	I-51
6.1 RADIOLOGICAL RESULTS	I-51
6.1.1 Background Measurements	I-51
6.1.2 Walkover Gamma Scans	I-54
6.1.3 Soil	I-59
6.1.4 Drains and Sumps	I-72
6.1.5 Groundwater	I-72
6.1.6 Buildings	I-75
6.2 CHEMICAL RESULTS	I-102
6.2.1 Background	I-102
6.2.2 Soil	I-103
6.2.3 Groundwater	I-117
6.3 GEOLOGICAL/HYDROGEOLOGICAL RESULTS	I-125
6.3.1 Background	I-125
6.3.2 Soil	I-125
6.3.3 Groundwater	I-136
7.0 DISCUSSION OF RESULTS	I-145
REFERENCES	I-149

FIGURES

No.	Title	Page
2-1	Locations of FUSRAP Properties in the St. Louis, Missouri, Area	I-6
2-2	St. Louis Downtown Site	I-7
2-3	Annual Wind Rose for the St. Louis Area	I-8
2-4	Uranium Processing at SLDS	I-11
6-1	Background Sample and Measurement Locations in the St. Louis Area	I-55
6-2	Areas of Walkover Gamma Scan	I-57
6-3	Surface Soil Sampling Locations at SLDS	I-60
6-4	Locations of Phase I and Phase II Boreholes at SLDS	I-61
6-5	Radiological Soil Results for Plant 1	I-63
6-6	Radiological Soil Results for Plant 2	I-65
6-7	Radiological Soil Results for Plant 5	I-66
6-8	Radiological Soil Results for Plants 6 and 6E	I-67
6-9	Radiological Soil Results for Plant 7	I-69
6-10	Radiological Soil Results for Plant 10	I-70
6-11	Radiological Soil Results for City Property	I-71
6-12	Locations of Manholes Surveyed at SLDS	I-73
6-13	Locations of Groundwater Monitoring Wells at SLDS	I-74
6-14	Survey Results for Building 25	I-77
6-15	Survey Results for Building K1E	I-79
6-16	Survey Results for Building 50	I-80
6-17	Survey Results for Building 51	I-81
6-18	Survey Results for Building 51A	I-82
6-19	Survey Results for Building 52	I-83
6-20	Survey Results for Building 52A	I-84
6-21	Survey Results for Building 100	I-85
6-22	Survey Results for Building 101	I-86
6-23	Survey Results for Building 116	I-88
6-24	Survey Results for Building 116B	I-89
6-25	Survey Results for Building 117	I-90
6-26	Survey Results for Building 700	I-91
6-27	Survey Results for Building 704	I-92
6-28	Survey Results for Building 705	I-93
6-29	Survey Results for Building 706	I-94
6-30	Survey Results for Building 707	I-95
6-31	Survey Results for Building 708	I-96
6-32	Survey Results for Building 81	I-98
6-33	Survey Results for Building 82	I-99
6-34	Locations of Additional Roof Surveys at Plant 1	I-100
6-35	Locations of Additional Roof Surveys at Plant 2	I-101
6-36	Locations of Chemical Boreholes	I-104
6-37	Correlation of Subsurface Stratigraphy to Monitored Intervals at SLDS	I-127
6-38	Generalized Stratigraphic Section for SLDS	I-128
6-39	St. Louis Downtown Site Subsurface Profile Section Lines	I-129

		Page
6-40	Subsurface Profile A - A' at SLDS	I-130
6-41	Subsurface Profile B - B' at SLDS	I-131
6-42	Subsurface Profile C - C' at SLDS	I-132
6-43	Subsurface Profile D - D' at SLDS	I-133
6-44	Hydrograph of Stage Elevations of the Mississippi River	I-138
6-45	Hydrograph of Monitoring Wells in Lower Unit of Unconsolidated Deposits	I-139
6-46	Hydrograph of Monitoring Wells in Upper Unit of Unconsolidated Deposits	I-140
6-47	Contours of Groundwater Level Elevations at SLDS, 6 May 1988	I-142
6-48	Contours of Groundwater Level Elevations at SLDS, 9 June 1989	I-143

TABLES

No.	Title	Page
5-1	Summary of Borehole Locations and Chemical Analyses Performed on Samples at SLDS - Phase I.....	I-28
5-2	Summary of Borehole Locations and Chemical Analyses Performed on Samples at SLDS - Phase II ...	I-30
5-3	Methods for Soil Analysis	I-35
5-4	Compounds Included in Volatile Organics Analyses for Soil Samples	I-36
5-5	Organic Compounds Included in Base/Neutral and Acid Extractable Analyses for Soil Samples	I-38
5-6	Volatiles, BNAEs, Pesticides, and PCBs Included in Laboratory Analyses for Groundwater Samples	I-40
5-7	Metal Ions Included in Laboratory Analyses for Groundwater Samples	I-41
5-8	Methods for Analysis of Groundwater	I-42
5-9	St. Louis Downtown Site Monitoring Well Construction	I-48
6-1	Summary of Residual Contamination Guidelines	I-52
6-2	Background Radiation Levels and Radionuclide Concentrations in Soil in the St. Louis Area	I-56
6-3	Summary Results for Walkover Gamma Survey	I-58
6-12	Summary Statistics for Metal Contaminants at SLDS - Phase I	I-106
6-13	Summary Statistics for Metal Contaminants at SLDS - Phase II	I-107
6-16	Summary Statistics for Volatile Organics Detected in Soil at SLDS - Phase I	I-109
6-18	Summary Statistics for BNAEs Detected in Soil at SLDS - Phase I	I-112
6-20	Maximum Concentration, Location, and Number of Samples Contaminated with Volatile and BNAE Compounds - Phase I	I-115
6-21	Ranges of Water Quality Parameters in Groundwater at SLDS	I-118
6-22	Summary Statistics for Volatile Organics, BNAEs, and Pesticide/PCB Compounds Detected in Groundwater at SLDS	I-120
6-23	Ranges of Volatile Organics, BNAEs, and Pesticides/PCBs Detected in Groundwater at SLDS	I-121
6-24	Ranges of Metal Ion Concentrations Detected in Groundwater at SLDS	I-123
6-25	Summary Statistics for Metals in Groundwater at SLDS	I-124
6-26	Summary of Average Hydraulic Conductivities	I-135

NOTE: Full data tables are presented in Volume II of this document.

ABBREVIATIONS

C	Celsius
cm	centimeter
cm ₂	square centimeter
cpm	counts per minute
dpm	disintegrations per minute
F	Fahrenheit
ft	foot
g	gram
gpm	gallons per minute
h	hour
ha	hectare
in.	inch
in. ²	square inch
keV	thousand electron volts
km	kilometer
km/h	kilometers per hour
L	liter
L/min	liters per minute
m	meter
μg	microgram
μg/L	micrograms per liter
μmhos	micromhos (specific conductivity)
μmhos/cm	micromhos per centimeter
m	meters
m ³	cubic meters
mi	mile
mph	miles per hour
mg	milligram
mg/L	milligrams per liter
mg/cm ²	milligrams per square centimeter
ml	milliliter
mrem	millirem
mrem/yr	millirem per year

ppb	parts per billion
ppm	parts per million
pCi	picocurie
pCi/g	picocuries per gram
yr	year
yd ³	cubic yard

ACRONYMS

ASTM	American Society for Testing and Materials
BNAE	base/neutral and acid extractable
BNI	Bechtel National, Inc.
CLP	Contract Laboratory Program
DCG	derived concentration guideline
DOE	Department of Energy
EPA	Environmental Protection Agency
EP	extraction procedure
FID	flame ionization detector
FUSRAP	Formerly Utilized Sites Remedial Action Program
GC	gas chromatograph
G-M	Geiger Müller
HDPE	high-density polyethylene
ICPAES	inductively coupled plasma atomic emission spectrophotometry
MDA	minimum detectable activity
MED/AEC	Manhattan Engineer District/Atomic Energy Commission
MS	mass spectrometry
MSD	Metropolitan Sewer District (St. Louis)
NBL	New Brunswick Laboratory
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PAH	polynuclear aromatic hydrocarbon

PCB	polychlorinated biphenyl
PIC	pressurized ionization chamber
PID	photoionization detector
PMC	project management contractor
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RESRAD	Residual Radioactive Material Code
SLDS	St. Louis Downtown Site
TIC	tentatively identified compound
TMA/E	Thermo Analytical/Eberline
TOC	total organic carbon
TOX	total organic halides
VOA	volatile organics analysis
VOC	volatile organic compounds

1.0 INTRODUCTION

1.1 BACKGROUND

Radiological, chemical, and hydrogeological characterization activities were conducted at the St. Louis Downtown Site (SLDS) in St. Louis, Missouri, as a part of the United States Department of Energy's (DOE) Formerly Utilized Sites Remedial Action Program (FUSRAP). These activities were conducted from December 1987 through April 1989. Characterization was required at SLDS because the site had been used, under contract to the United States Army, for refinement of uranium from 1942 to 1957.

The primary authorizing legislation for FUSRAP is the Atomic Energy Act of 1954 and the Energy and Water Development Appropriations Acts of 1984 and 1985. FUSRAP was established to identify and clean up or otherwise control sites where residual radioactive contamination (exceeding current DOE guidelines) remains from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized DOE to remedy (Ref. 1). DOE currently has 31 sites in 13 states under the FUSRAP project.

FUSRAP was established in 1974; major remedial action activities began in 1981 with Bechtel National, Inc. (BNI) being named as the project management contractor (PMC) for DOE. As the PMC, BNI evaluates site conditions, recommends remedial action alternatives, and carries out the needed cleanup activities as directed by DOE.

The objectives of FUSRAP are to:

- Identify and assess all sites formerly utilized to support early Manhattan Engineer District/Atomic Energy Commission (MED/AEC) nuclear work and sites with conditions that Congress has authorized DOE to remedy in order to determine whether further decontamination and/or control is needed.

- Decontaminate and/or apply controls to these sites to permit conformity with current applicable guidelines.
- Dispose of and/or stabilize all generated residues in a radiologically and environmentally acceptable manner.
- Accomplish all work in accordance with appropriate landowner agreements; local and state environmental and land-use requirements to the extent permitted by federal law; and applicable DOE orders, regulations, standards, policies, and procedures.
- Certify the sites for appropriate future use.

1.2 SCOPE AND OBJECTIVE

Radiological, chemical, and hydrogeological characterization of SLDS was conducted in two separate phases. This phased approach was selected as a cost-effective means of obtaining adequate data to estimate waste volumes at the site and to aid in the development of remedial action alternatives. Phase I was performed primarily to identify areas of radioactive contamination. Phase II was conducted to define the dimensional boundaries of such contamination and to fill data gaps identified during evaluation of Phase I data. Chemical sampling was incorporated into both phases of the investigation to determine whether hazardous chemicals were associated with the radioactivity. Hydrogeological conditions of the site were also evaluated during both phases.

All work was conducted under the guidance of DOE, and sample analyses were performed using approved Environmental Protection Agency (EPA) procedures. The quality assurance/quality control (QA/QC) programs for these procedures are discussed in Section 4.0.

1.2.1 Radiological Characterization

The objective of the radiological characterization effort for soil was to fully delineate the extent of soil contamination. The

objective of the building surface characterization effort was to delineate gross levels of radioactive contamination. Final radiological surveys to determine exact boundaries of contamination on building surfaces, in drainage pathways, and in soils (where appropriate) will be performed immediately prior to remedial action.

The radiological characterization included collecting surface soil samples, drilling boreholes in or near areas of known or suspected contamination, collecting subsurface soil samples, and analyzing all samples for uranium-238, radium-226, thorium-232, and thorium-230. In addition, walkover gamma surveys were conducted to help identify areas of elevated gamma radiation. Groundwater samples were collected and analyzed for radiological parameters.

Radiological surveys of building surfaces and various drainage pathways were conducted. Data from previous surveys were used to guide these limited surveys, which were preliminary and were not intended to define absolute boundaries of contamination.

1.2.2 Chemical Characterization

Chemical characterization of SLDS was conducted concurrently with radiological characterization activities. The objectives of chemical characterization were to determine whether hazardous chemicals were associated with radiological wastes and/or whether mixed wastes were present on the site, to aid in evaluation of remedial action alternatives, and to help define health and safety requirements during remedial action.

Chemical characterization involved collection of soil samples from selected boreholes and subsequent analysis for various chemical parameters including metals, organic compounds, and Resource Conservation and Recovery Act (RCRA)-hazardous waste

characteristics. In addition, groundwater samples were collected and analyzed for chemical constituents.

1.2.3 Hydrogeological Characterization

Geological and hydrogeological characterization of SLDS was conducted to determine the types, distribution, and relationship of subsurface materials underlying the site; to delineate the occurrence of groundwater and its hydraulic properties; and to evaluate the potential for contaminants to migrate off site through the groundwater pathway.

Hydrogeological characterization activities included establishing a representative geologic profile and installing monitoring wells to determine groundwater quality, levels, gradient, and flow direction.

2.0 SITE DESCRIPTION AND HISTORY

2.1 LOCATION AND DESCRIPTION

SLDS is located on the eastern border of St. Louis, Missouri, about 90 m (300 ft) west of the Mississippi River (Figure 2-1). SLDS is an operating plant for the production of various chemical products and is located in a highly industrialized area of St. Louis. The site encompasses approximately 18.2 ha (45 acres) and has numerous buildings and facilities (Figure 2-2). The site is divided into 10 plant areas.

The climate of the St. Louis area is classified as modified continental. The average daily temperature ranges from 7.4 to 18.6°C (45.4 to 65.5°F). The highest average monthly temperature is 31.6°C (89°F) in July and the lowest is -6.7°C (19.9°F) in January. Normal annual precipitation is slightly over 87.5 cm (35 in.). Average annual snowfall is 65.8 cm (26.3 in.). Prevailing winds tend to be from the south in the summer and fall at average speeds of 13.9 km/h (8.7 mph). Winds during the winter months are from the west and west-northwest, averaging 17.6 km/h (11 mph). Figure 2-3 shows the distribution of wind direction and speed for the St. Louis area (Ref. 2).

2.2 SITE HISTORY AND PREVIOUS FIELD INVESTIGATIONS

From 1942 to 1957, Mallinckrodt Chemical Works, under contract with the U.S. Government, operated facilities in St. Louis for processing and producing various forms of uranium compounds. Site activities included machining and recovery of uranium metal.

Activities carried out in several plants involved manufacturing of uranium dioxide from pitchblende ore. Uranium ore was digested in acid and filtered to form uranyl nitrate. A solvent extraction procedure and denitration followed to form uranium oxide.

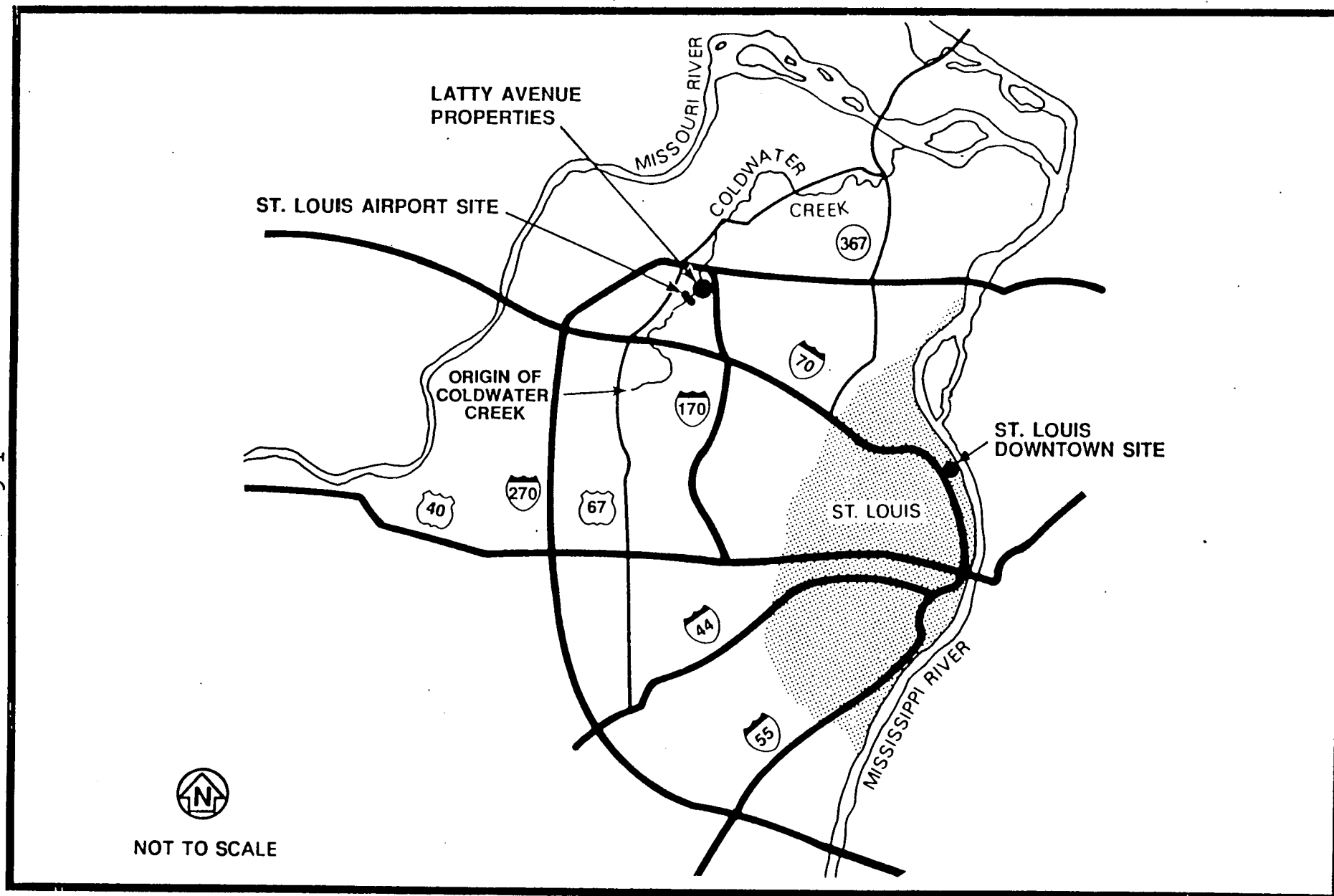


FIGURE 2-1 LOCATIONS OF FUSRAP PROPERTIES IN THE ST. LOUIS, MISSOURI, AREA

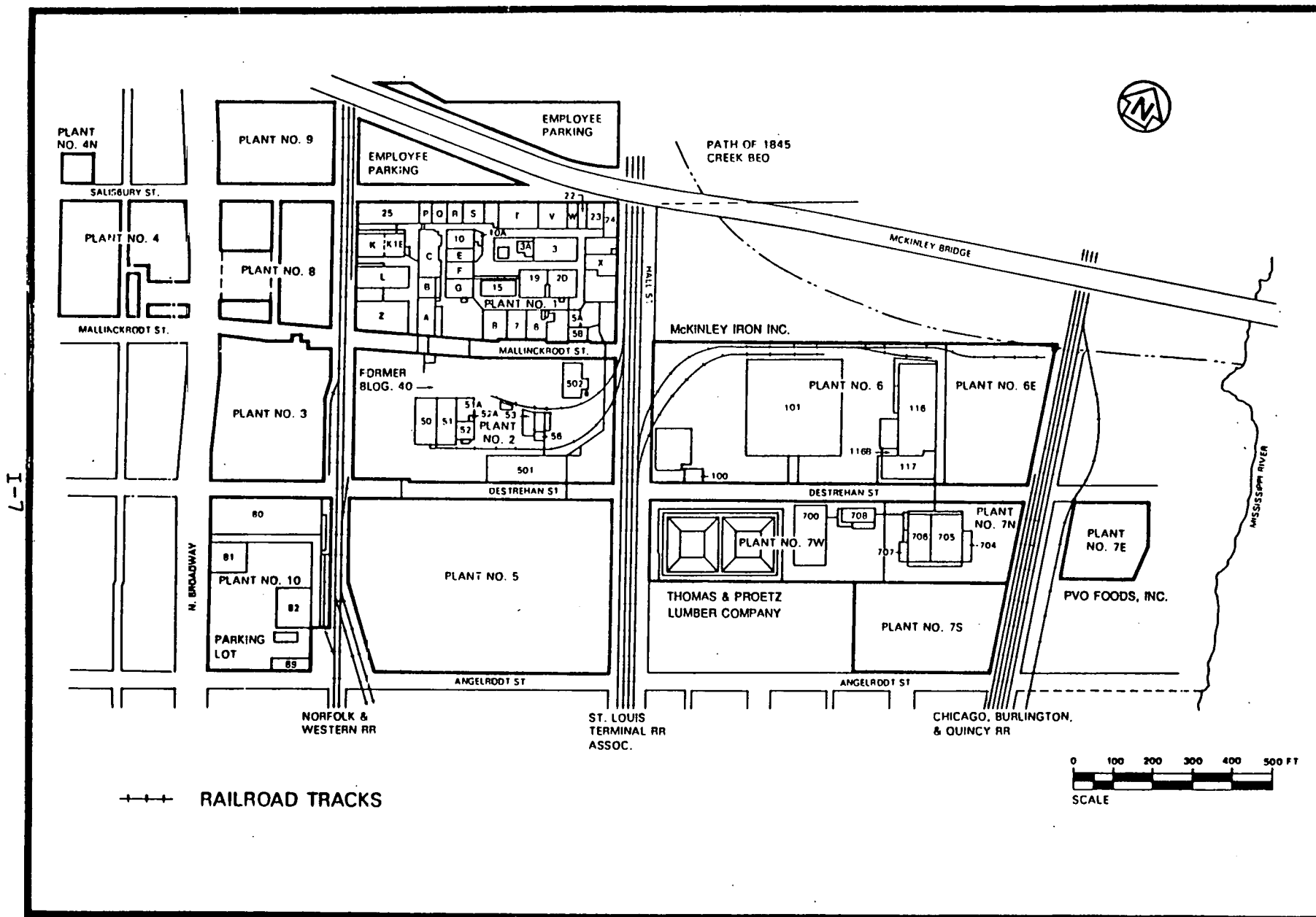


FIGURE 2-2 ST. LOUIS DOWNTOWN SITE

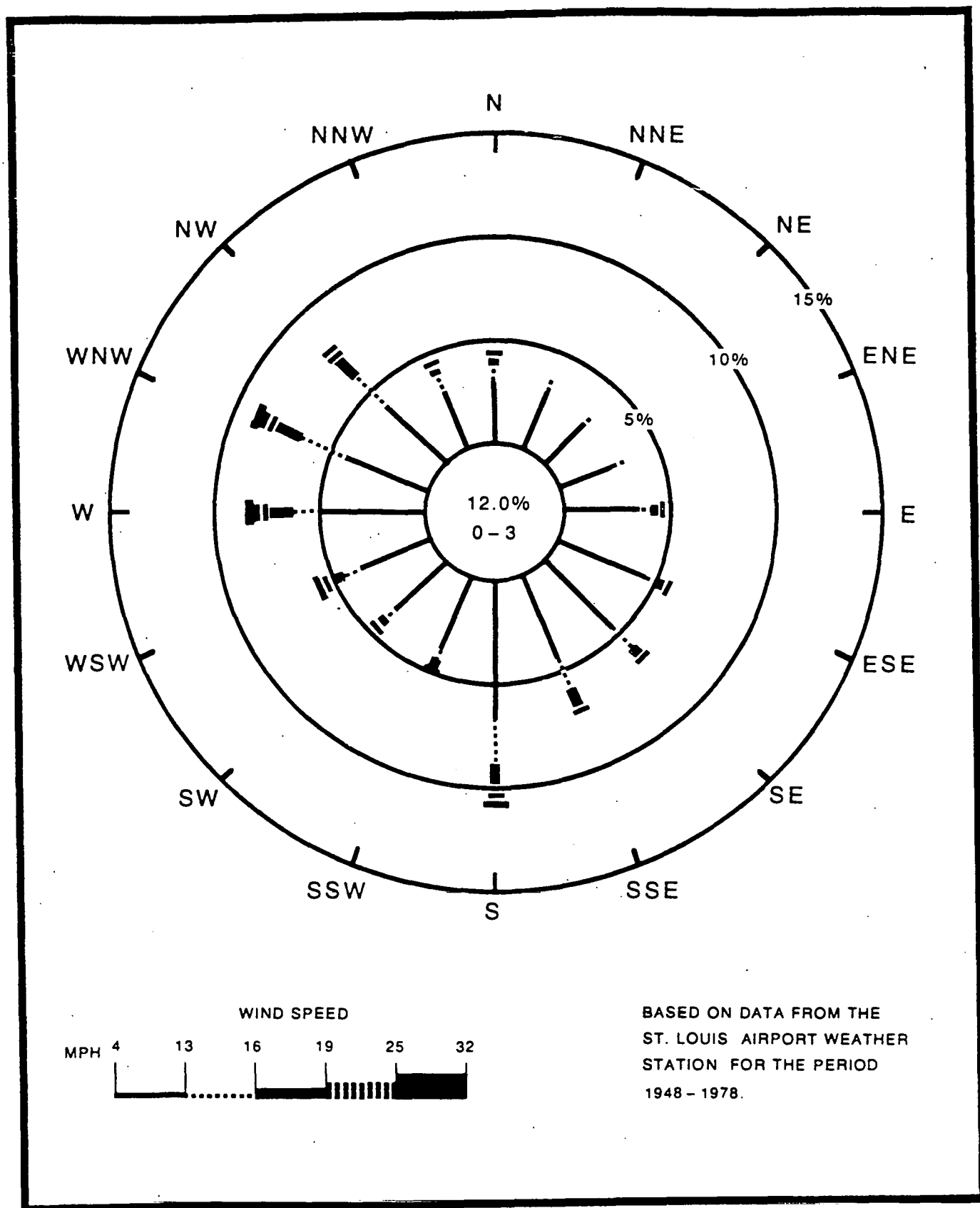


FIGURE 2-3 ANNUAL WIND ROSE FOR THE ST. LOUIS AREA

Fluorination with hydrofluoric acid created uranium tetrafluoride, which after reduction with heat and magnesium produced uranium metal. The following paragraphs describe activities at each plant as well as the date of decontamination and AEC release.

Plant 1

Plant 1, also known as the Main Plant, was the refinery for the U_3O_8 feed and pitchblende. The plant was involved in uranium processing from 1942 to 1945. Decontamination work took place at the plant from 1948 to 1950 according to existing AEC criteria, and the plant was released to the owners in 1951.

Plant 2

Plant 2 was used for digesting and treating U_3O_8 feeds, ether extraction of pitchblende liquor, denitration and hydrogen reduction as well as temporary storage of residues. The plant was involved in processing uranium from 1942 to 1945; decontamination took place from 1948 to 1950. The plant was released for use with no radiological restrictions by AEC in 1951.

Plant 5

No available historical information indicates that MED/AEC activities were conducted at Plant 5. A limited Phase II investigation was performed because Phase I characterization results showed residual radioactive contamination at the plant boundary.

Plant 5 was used for processing columbium-tantalum ores. Because these ores contain natural uranium and natural thorium, the columbium-tantalum operations were carried out under a Nuclear Regulatory Commission (NRC) license; residual radioactivity may be the result of these operations.

Plant 10

Old Plant 4, which is now Plant 10, was used in pilot plant work to develop a continuous furnace green salt (UF_4) process. Its facilities were later modified to be used as a metallurgical pilot plant for developmental work with uranium metal. The plant was involved in uranium processing until it closed in 1956. Old Plant 4 was decontaminated and released in 1962 for use with no radiological restrictions.

Plants 6 and 6E

Plant 6 began refinery operations in 1946, replacing Plant 1 in processing uranium-containing ore and production of UO_2 . Uranium ore was digested in acid and filtered to form uranyl nitrate. A solvent extraction procedure and denitration followed to form uranium oxide. Fluorination with hydrofluoric acid was then initiated to create uranium tetrafluoride, which subsequently led to the production of uranium metal. A simplified flowchart for the manufacture of uranium dioxide is provided in Figure 2-4 (Ref. 3).

Plant 6E, designed for production of uranium metal, began operation in the period 1950-1951. The plant was closed in 1957; decontamination and release followed in 1962.

Plant 7

Plant 7 was designed to produce green salt (UF_4). Plant 7 was used for storing reactor cores, removing metallic uranium from slag by a wet grinding/mill flotation process, and continuous processing of furnace green salt (production of uranium tetrafluoride) (Ref. 4). The green salt process began in 1951. Plant 7 is now used primarily for storage. Operations began in

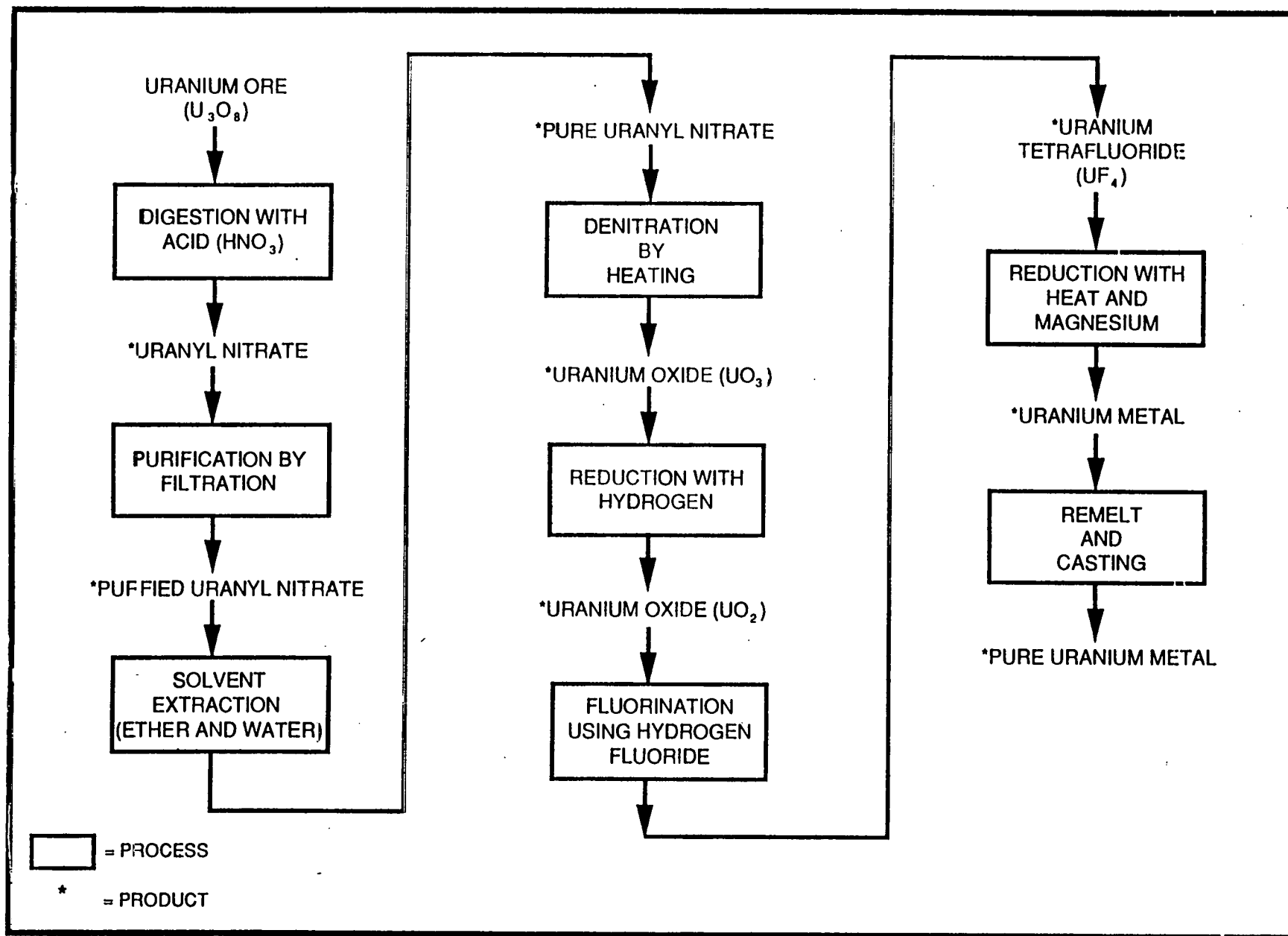


FIGURE 2-4 URANIUM PROCESSING AT SLDS

1950-1951, continuing until the plant closed in 1957. The plant was released for use with no radiological restrictions in 1961-1962 following decontamination.

In 1977, a radiological survey of portions of SLDS was conducted by Oak Ridge National Laboratory (ORNL) at DOE's request (Ref. 5). Results of this survey showed alpha and beta-gamma contamination levels above then-current limits for release of the property for use without radiological restrictions. Elevated external gamma radiation levels were measured at some outdoor locations and in some of the buildings. Subsurface soil concentrations of uranium-238 ranged from 1.1 to 20,000 pCi/g and radium-226 ranged from 0.3 to 2,700 pCi/g. Radon and radon daughter concentrations in three buildings exceeded federal guidelines for nonoccupational radiation exposure.

Based on historical information of processes at SLDS and on previous radiological surveys, the primary radiological contaminants of concern are uranium-238, radium-226, thorium-230, and thorium-232, which may have been associated with non-MED/AEC work.

2.3 PRESENT SITE FEATURES

SLDS is currently owned and operated by Mallinckrodt, Inc. The facility is used primarily as a specialty chemical production plant. As a result of chemical production activities, access is restricted in some areas of the plant, but the restrictions had little impact on the field investigation. The site is mostly covered with buildings and asphalt/concrete surfaces.

3.0 HEALTH AND SAFETY

3.1 SUBCONTRACTOR TRAINING

All workers associated with characterization activities at SLDS who had a potential for exposure to hazardous conditions were trained in compliance with 29 CFR 1910.120 (Ref. 6). In addition, site-specific training was conducted for these workers regarding site hazards not associated with the FUSRAP field investigation, such as underground utilities and ongoing chemical operations at SLDS.

3.2 HEALTH AND SAFETY REQUIREMENTS

The health and safety requirements for characterization activities at SLDS were identified in the FUSRAP health and safety plan (Ref. 7). In addition, a site health and safety officer was present at SLDS during all operations of the field investigation.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The following subsections describe QA/QC measures taken to control sample collection and analysis activities for radiological, chemical, and hydrogeological parameters. Methods for assuring the quality of results are provided for both radiological and chemical analyses. All work at SLDS was guided by EPA documents, including Guidance on Feasibility Studies Under CERCLA, Guidance on Remedial Investigations Under CERCLA, Superfund Compendium of Field Operation Methods, Data Quality Objectives for Remedial Response Activities: Development Process, and Data Quality Objectives for Remedial Response Activities: Example Scenario.

4.1 RADIOLOGICAL

Methods were employed in both the field and the laboratory to check the quality of radiological data. In the field, duplicate samples were collected and sent to the laboratory for the same analytical parameters to evaluate matrix effects on precision and accuracy. In the laboratory, at least one sample per batch was analyzed in replicate. In addition, a minimum of one blank and one standard were analyzed for each batch of samples. Standards were certified reference materials obtained from the New Brunswick Laboratory (NBL).

4.2 CHEMICAL

QC samples were analyzed to determine whether any events in the sampling chain could cause the results to be questionable. The QC measures employed were those approved for EPA's Contract Laboratory Program (CLP), including SW-846 (Test Methods for Evaluating Solid Waste), Statement of Work for Organics Analysis, and Statement of Work for Inorganics Analysis. These controls and the frequency of collection/analysis are described below.

- Field blank - A sample of deionized water proceeds through the sample collection/analysis steps (automatic samplers, bailers, etc.) and some sampling equipment, after the sample collection equipment has been decontaminated. The field blank is handled and treated in the same manner as the other field samples, and it is used to detect possible cross-contamination of samples during collection.
- Field duplicate - A field duplicate is used to document the reproducibility of the analytical results and representativeness of the samples collected. Field duplicates should not be confused with splits or replicates, in that field duplicates require re-collection of the sample using the same procedures used for collection of the first sample.
- Method blank - A method blank (or reagent blank) provides a measure of the positive interferences that may be introduced during laboratory analysis. A method blank is also laboratory-grade deionized water that is carried through all steps of an analytical process. Method blanks are analyzed randomly throughout the course of analysis of a sample batch sequence. A minimum of one method blank or 10 percent of the total number of samples, whichever was greater, was analyzed with each batch of samples. A "batch" is defined as all samples shipped to the laboratory within a 24-h period.
- Method spike (fortified method blank/blank spike) - A blank spike is a method blank to which a known concentration of an analyte(s) is added. Analysis of a blank spike provides a measure of analytical accuracy (i.e., percent analyte recovery) and is used to establish whether a particular analytical procedure is "in control" relative to analytical accuracy. At least three spiked blanks representative of the soil matrix were prepared by the laboratory and analyzed per batch of samples. One blank each was prepared for the low end, the mid-point, and the high end of the linear concentration range of the method.
- Matrix spike (fortified field sample) - This is a field sample to which is added a known concentration of the analyte(s) of interest. Typically, an analyte(s) is added to a sample at approximately 10 times the background concentration or at 2 to 5 times the detection limit of the analyte added. This provides information about the performance of an analytical method relative to a particular sample matrix (e.g., the presence/absence of analytical interferences).

The accuracy and precision of analytical results are determined by analyzing samples and laboratory water blanks. These samples are spiked with known concentrations of the compounds of interest for all parameters for which analyses will be performed.

The amount of spike material recovered from a spiked blank indicates the best result that can be expected from the method. The recovery of these spikes is compared with the accuracy determined from the blank spikes as an indication of matrix effects.

- Surrogate compounds - Surrogates were spiked into all samples including QC samples as specified in contract documents. The procedures for using surrogates in the SW-846 methods were applied to solid samples.
- Replicates - A minimum of one sample per batch was analyzed in replicate. Soil sample replicates were prepared by homogenizing an aliquot of the sample sufficient in size for the specified analysis, dividing the aliquot into the requisite number of replicates, and carrying each replicate through the entire extraction and analytical procedure.

Evaluation of the QC data by project personnel involved several checks. To determine whether any data were missing, a chart was completed listing samples versus analyses requested. A similar chart was designed to determine whether EPA holding times for volatile organics analyses (VOA) and base/neutral and acid extractable (BNAE) analyses were exceeded. Chain-of-custody forms were checked to verify that chain of custody had been maintained.

Statistical calculations performed by the analytical laboratory on QC data were checked, including percent recovery between matrix spikes and matrix spike duplicates, percent difference in spiked amount versus spike recovery, and percent difference in sample and sample replicate recovery. The results indicated acceptable analytical precision and accuracy. Holding times were met for all samples, and no data were rejected based on QC results.

4.3 HYDROGEOLOGICAL

All geotechnical soil testing was performed in accordance with technical specifications that define the technical requirements and quality of workmanship guided by procedures conforming to the standards established by one or more of the following: American Society for Testing and Materials (ASTM), Department of the Army - Engineer Manual, and EPA. Geotechnical soil testing subcontractors are required by BNI to submit a quality assurance program manual and labeling procedure.

Procedures for permeability tests, disturbed and undisturbed soil sampling, standard penetration tests, and all calculations derived from field data are documented and performed in accordance with industry standards and Bechtel Engineering procedures. All sources of design criteria, formulas, and references are documented and reviewed.

5.0 FIELD INVESTIGATION METHODOLOGY

Given the large area of the site to be examined and the fact that previous investigations were several years old, the field investigation was planned in two phases. The first phase consisted of installing 109 boreholes at the site to test the radiological, chemical, and geophysical properties of the soils. During Phase I, eight monitoring wells were established to determine the potential for migration of contaminants via a groundwater pathway. Other Phase I activities consisted of collecting sediment and water samples from drains, sumps, and sewers; conducting a walkover gamma scan of the areas in question; surveying the interior surfaces of buildings associated with the processing operations for radioactivity; and collecting systematic and biased surface soil samples.

Phase II activities were planned to determine the horizontal and vertical boundaries of contaminated areas identified in Phase I. Phase II activities involved drilling, sampling, and logging of 109 additional boreholes for radiological and chemical testing. Phase II activities also included installing one additional monitoring well and surveying additional surfaces of the former processing buildings.

Phase I and II investigations consisted of four major types of activities: site preparation, radiological investigation, chemical investigation, and geological/hydrogeological investigation. Methods for conducting each of these activities are presented in the following subsections.

5.1 SITE PREPARATION

Before characterization activities began at SLDS, various preparatory actions were conducted to support the field

investigation: mobilization of trailers for offices and equipment storage areas, development of a civil survey across the site, and construction of decontamination equipment and facilities.

5.1.1 Civil Survey

A civil survey was conducted at SLDS to establish a site grid system that allowed for identification of surveying and sampling locations. A subcontracted civil surveyor established a 15- by 15-m (50- by 50-ft) grid using the intersection of the centerlines of Broadway Street and Angelrodt Street as the reference point (Figure 2-2). Grid intersections were marked with hub stakes, nails, or chiseled crosses to enable field personnel to determine grid locations for boreholes. The civil surveyor also established grid coordinates for building corners, fences, and other pertinent site features. This information was transmitted to BNI through drawings and field logs to permit cross-reference with previously existing information concerning site topography.

5.1.2 Decontamination Facilities and Procedures

A temporary site decontamination facility was set up to clean drilling equipment, hand tools, and sampling equipment. The decontamination pad and integral inflatable berms were made of high-density polyethylene (HDPE) and were readily available, off-the-shelf items. A steam generator was used to supply hot water and steam to a spray wand. Water used during decontamination activities was collected and stored in covered modular tanks with dual liners. Decontamination water was sampled and analyzed for radiological and chemical parameters that were predetermined in an agreement with the St. Louis Metropolitan Sewer District (MSD) before being filtered and released to the city sewer system.

Chemical sampling instruments were subjected to a seven-step decontamination procedure between samples, as outlined by applicable EPA guidance (Ref. 8). Based on this procedure,

sampling instruments were washed with soap and water; rinsed with tap water, 3-percent hydrochloric acid, tap water, methanol, and deionized water; and then air dried. Radiological sampling instruments were subjected to a hot water/steam decontamination procedure.

5.2 RADIOLOGICAL INVESTIGATION

The following subsections describe the methodology used to conduct the radiological investigation of SLDS. The purpose of each survey type and the rationale for selection of the particular method are also discussed.

5.2.1 Background Data and Measurements

The radionuclides of interest at SLDS occur naturally in low levels in soil. To determine the naturally occurring levels of these radionuclides in the St. Louis area, background data were collected before the start of characterization activities at SLDS. Three locations were surveyed and sampled for radiological parameters. These background measurements were collected at distances of approximately 2.8 km (1.8 mi) (locations 1 and 2) and 1.6 km (1 mi) (location 3) from the St. Louis Airport. SLDS is approximately 17.2 km (10.7 mi) southeast of the St. Louis Airport. A more detailed description of the area where these background samples were collected is provided in Subsection 6.1.1. Background data were collected using the same protocols described in the following subsections for the field investigation.

5.2.2 Walkover Gamma Scans

The purpose of walkover gamma scans performed at SLDS was to identify areas of elevated gamma radiation. In areas exhibiting elevated gamma radiation levels (twice background), biased surface soil samples were collected and analyzed to determine radionuclide concentrations.

The walkover gamma radiation survey was performed by scanning 15- by 15-m (50- by 50-ft) grid sections and recording the ranges of radioactivity as determined by instrument response. A PRS-1 scaler coupled to an unshielded Eberline SPA-3 probe was used for the survey. The SPA-3 probe is a sodium-iodide, thallium-activated [NaI(Tl)] gamma scintillation detector that measures low-level gamma radiation. The NaI(Tl) crystal is coupled to a photomultiplier tube. This probe is then connected to a scaler (PRS-1).

5.2.3 Soils

Soil samples were collected at various locations across the site to determine concentrations of radioactivity and define the boundaries of radioactivity in soil. Two hundred ninety-seven surface soil samples were collected and analyzed (see Section 6.0, Figure 6-3). These surface soil samples were collected by using hand-held sampling devices and/or motor-driven augers from locations where drill rigs could not gain access and from areas requiring biased sampling as a result of the walkover gamma scan. Biased surface soil samples were collected in areas that revealed measurements of more than twice background levels during the walkover gamma scans. Also, 218 boreholes were drilled at SLDS and all were radiologically sampled. During Phase I, most boreholes were biasedly placed to enable identification of radioactively contaminated areas. Some systematic boreholes were drilled to ensure that all areas of contamination were located. Phase II boreholes were biasedly placed just outside identified contaminated areas to define boundaries of contamination. Continuous soil samples were collected from borehole locations. Samples obtained from selected intervals were analyzed for radionuclide content. These gamma logs aided in selecting samples to be analyzed and in defining boundaries of contamination. Samples that were not analyzed for radiological parameters were archived for later retrieval and analysis, if necessary. The drilling and sampling of boreholes is discussed in greater detail in Subsection 5.4.2.

Locations for sample collection and parameters for radiological analysis were determined by historical information, previous surveys, and/or results of this characterization effort. Samples were analyzed for uranium-238, radium-226, thorium-232, and thorium-230.

In addition to sample analysis, boreholes were gamma logged to ascertain whether radiation levels were elevated in subsurface soil. Boreholes were gamma logged by lowering a Bicron BHP-2 detector, which was coupled to an MS-2 scaler, into the hole and recording the instrument reading at a particular depth.

The BHP-2 probe is used to detect gamma radiation in subsurface soil. It consists of a NaI(Tl) crystal coupled to a photomultiplier tube with a section of lead attached to the bottom of the crystal for geometry compensation at the bottom of the hole. The detector is connected to a portable scaler (MS-2) for determining instrument response at a particular depth in the borehole.

5.2.4 Drains and Sumps

Various drains, sumps, and manholes were surveyed to determine whether radiation levels were elevated. This survey was done by lowering the same instruments used to gamma log boreholes (the Bicron BHP-2/MS-2) into the drainage pathway and recording the instrument response. If access permitted, sludge and/or sediment samples were collected from the drainage pathway, and the sample was analyzed for radioactive constituents.

5.2.5 Groundwater

Groundwater was sampled quarterly at SLDS for a period of one calendar year. Nine monitoring wells were installed at the site; eight were monitored for the one-year period. The ninth well was

installed to aid in defining hydrogeological conditions at the site. Subsection 5.4.2 describes the rationale for selecting the locations of the monitoring wells.

Groundwater sampling at SLDS consisted of purging the wells, decontaminating the bailer, and collecting the actual water sample. Purging ensures that fresh aquifer water has entered the well, and decontamination of the sampling equipment ensures that no cross-contamination occurs between wells.

The wells were purged by hand-bailing three casing volumes of water with a Teflon bailer. Samples were collected at the screen level of the well and were analyzed for total uranium, radium-226, and thorium-230. Groundwater samples were not analyzed for thorium-232 because soil samples showed only minimal residual thorium-232. Decontamination of the bailer consisted of a rinse with deionized water followed by a methanol rinse and a final rinse with copious amounts of deionized water. This decontamination procedure is slightly different than that described for soil sampling instruments in Subsection 5.1.2.

5.2.6 Buildings

Various buildings at SLDS were surveyed to determine whether radioactivity existed on structure surfaces. Floors, walls, ceilings, and roofs were surveyed for direct alpha contamination, direct beta-gamma contamination, and removable contamination.

Direct alpha measurements were taken using an AC-3 detector coupled to a PRS-1 scaler, and direct beta-gamma measurements were taken using an HP-210 detector coupled to a PRS-1 scaler. The AC-3 probe is a zinc sulfide (ZnS) detector with a photomultiplier tube, which is coupled to a scaler (PRS-1). The ZnS detector is covered with a very thin aluminized Mylar sheet to keep the instrument shielded from light. A protective metal grid is used to avoid puncturing

the Mylar. The AC-3 has an active area of 59 cm^2 (9.2 in.^2), and it is capable of measuring surface alpha contamination at levels of a few disintegrations per minute (dpm). The probe is relatively insensitive to beta and gamma radiation.

The HP-210 is a portable Geiger-Müller (G-M) survey meter. The HP-210 consists of a large-area [15.5-cm^2 (2.4-in.^2)], thin-window ($1.5\text{- to } 2.0\text{-mg/cm}^2$), halogen-quenched G-M tube housed in a tungsten shield. This probe is coupled to a scaler (PRS-1). Because the G-M tube is sensitive to both alpha and beta-gamma radiation, aluminized Mylar is used to increase the density of the entrance window to 5 to 7 mg/cm^2 for rejection of pulses due to alpha contamination. This extra window can be removed for detection of low-energy beta radiation ($<40 \text{ keV}$).

Removable contamination was determined by wiping an area of about 100 cm^2 (15.5 in.^2) by applying moderate pressure to a smear cloth. The smear was then counted by a SAC-4 alpha counter. The SAC-4 is a ZnS detector with a photomultiplier tube. Smears were placed in a light-tight smear holder and counted. The SAC-4 measures alpha contamination to levels of a few dpm.

In some of the buildings, samples were collected and analyzed for uranium-238, radium-226, thorium-232, and thorium-230. These samples were collected from horizontal surfaces such as window ledges, overhead beams, stairs, and floors where surface deposit buildup was observed. The analytical results aided in determining major contaminant(s) in each building and in determining the appropriate surface criteria for structures (Table 6-1).

The objective of the building surveys was only to determine whether radioactivity exceeding guidelines existed on building surfaces; precise boundaries of contamination were not intended to be determined during this investigation. Previous experience within FUSRAP has shown it to be more practical to perform final building

surveys immediately before remedial action. The implemented survey only identified general areas of contamination and determined gross levels of radioactivity on building surfaces.

5.3 CHEMICAL INVESTIGATION

The following sections describe the sampling and analytical methods used to complete the chemical characterization of SLDS.

5.3.1 Background Determinations

No site-specific chemical background samples were obtained for SLDS; however, results for metals were compared with concentration ranges for metals in soil at various locations in the United States (Ref. 9). No comparable "background" values were identified for organic compounds. In a heavily industrialized area such as SLDS, however, low concentrations of organic compounds are expected in soils. Results from this characterization confirmed this expectation.

5.3.2 Soils

Soil samples were collected at various locations across the site to determine concentrations of chemicals in radioactively contaminated areas and to define the areas where chemicals exceeding typical background concentrations in soil are present. Soil sampling activities are discussed in greater detail in Subsection 5.4.3. Of the 218 boreholes subject to radiological analysis, 24 were analyzed for volatile organic compounds (VOCs), 57 for BNAEs, 63 for RCRA characteristics, and 109 for metals.

In Phase I, 59 boreholes were sampled for chemical constituents to characterize surface and subsurface conditions across the site. During Phase I, composite and discrete samples were taken from each radioactively contaminated plant area. Composite samples were collected from ground surface to undisturbed soil and analyzed for metals, RCRA-hazardous waste characteristics, and BNAEs. Discrete intervals were chosen at random and sampled in 23 of the holes for analysis of VOCs. Discrete samples were collected for the volatiles analysis because compositing the sample on site could have resulted in the loss of volatile compounds prior to analysis. From each contaminated plant area, one sampling location was chosen and samples were collected for analysis for VOCs.

In Phase II, an additional 51 boreholes were sampled for chemical constituents to further delineate any co-occurrence of chemicals the radioactive contamination. Boreholes were drilled to a depth of 0.7 m (2 ft) into undisturbed soil. Samples were collected from two to three intervals per borehole and analyzed for metals. Seven composite samples taken from ground surface to undisturbed soil were collected and analyzed for RCRA-hazardous waste characteristics.

Soil samples were collected with stainless steel, split-spoon samplers. The sampling instruments were subjected to a seven-step decontamination procedure between samples, as described in Subsection 5.1.2. Samples were collected, stored in the appropriate laboratory-supplied containers, packed in polystyrene plastic pellets to minimize breakage, and shipped to the laboratory for analysis. Samples were shipped, on ice, by priority mail on the same day they were collected. Chain-of-custody documentation was maintained for all samples. No field preservatives were required for soil samples before they were shipped to the laboratory for analysis.

The following analyses were completed for soil samples collected from the site in Phase I:

- Metals
- VOCs
- BNAEs
- RCRA-hazardous waste characteristics

Phase II analyses included metals and RCRA-hazardous waste characteristics. The types of analyses performed and locations from which samples were taken are given in Tables 5-1 and 5-2 for Phase I and Phase II, respectively. Boreholes were drilled from ground surface to undisturbed soil. These parameters were selected to define the organic and inorganic constituents that may be present with radionuclides at SLDS.

Methods of soil analysis are given in Table 5-3. Two screening methods, modified to provide both quantification and broad classification of compounds detected, were used to analyze organic compounds.

The volatile organics screening method is based on EPA test method 8010/8015 and modified as follows. A purge and trap apparatus is used to remove volatiles from the matrix. This is followed in the sampling system by a gas chromatograph (GC) in series with a Hall detector (for halogenated compounds) and a photoionization detector (PID). This method provides quantification of screened compounds. Analyses were performed on 40 samples during Phase I and on 1 sample during Phase II. The analyses were performed for 33 volatile compounds. The volatile compounds detected by the modified method are listed in Table 5-4. This modified method was employed because of the cost savings associated with its implementation.

TABLE 5-1
SUMMARY OF BOREHOLE LOCATIONS AND
CHEMICAL ANALYSES PERFORMED ON
SAMPLES AT SLDS - PHASE I

Page 1 of 2

Borehole ID	<u>Coordinate</u>		Depth (ft) ^a	Depth (ft) ^b
	N	E		
B16C01	2108	1507	0.5-8.5	
B16C02	2065	1521	0.5-7.5	4-6
B16C03	2088	1547	0.5-8	
B16C04	2038	1550	1-7.5	
B16C05	1757	1780	0-12	
B16C06	1785	1890	0-13	6-7, 7-8
B16C07	1750	1705	0.5-8	
B16C08	1694	1678	0-8.5	8-9
B16C09	1664	1674	0.5-10.5	
B16C10	1708	1646	0.5-8	
B16C11	1650	1645	0.5-8	6-8
B16C12	1601	1636	0.5-8	
B16C13	1703	1750	2-10.5	6-7, 7-8
B16C14	1685	1795	0.5-7.5	
B16C15	1616	1557	0.5-7.5 ^c	
B16C16	1550	1553	0.5-8	6.5-8
B16C17	1832	2267	0-17	
B16C18	1830	2395	0-12.5	8-9, 9-10
B16C19	1831	2493	0-13	
B16C20	1831	2720	0-11.5	
B16C21	1829	2809	0-11.5	6-7, 7-8
B16C22	1841	2877	0-9.5	
B16C23	1700	2244	0.5-10.5	
B16C24	1799	2448	1-17.5	
B16C25	1761	2540	1-16	9-10, 10-11
B16C26	1797	2616	0.5-17.5	
B16C27	1610	2442	1-16	
B16C28	1613	2540	2-16	8-9, 9-10
B16C29	1609	2606	4-15.5	
B16C30	1791	2749	1-12.5	8-9, 9-10
B16C31	1793	2900	0-12.5	
B16C32	1698	2760	1-12.5	

TABLE 5-1
(continued)

Page 2 of 2

Borehole ID	<u>Coordinate</u>		Depth (ft) ^a	Depth (ft) _b
	N	E		
B16C33	1651	2900	0-15.5	6-7, 7-8
B16C34	1661	2285	0.5-14.5	10-11, 11-12
B16C35	1505	2271	1-15	10-11, 11-12
B16C36	1525	2306	0.5-15	
B16C37	1506	2445	1-12.5	
B16C38	1506	2555	1-15	8-9, 9-10
B16C39	1511	2654	0.1-15.5	
B16C40	1466	2225	0.5-12.5	
B16C41	-	-	Not drilled	
B16C42	1442	2700	0-16.5	8-9, 9-10
B16C43	1400	3050	0-12 ^d	
B16C44	1416	2607	1-15	
B16C45	1392	2550	0-17	9-10, 10-11
B16C46	1323	2582	1-17.5	
B16C47	1401	2945	1-18	
B16C48	1330	2901	1-17	9-11
B16C49	1302	2885	1-17	
B16C50	1350	2180	0-13.5	7-8, 8-9
B16C51	1255	2181	0-15.5	
B16C52	1277	2649	0-13	
B16C53	1268	2506	0-13.5	10-11, 11-12
B16C54	1265	2693	0-13 ^d	
B16C55	1243	3024	0-11	
B16C56	1337	3058	0-13	8-10
B16C57	1260	1330	0.5-6.5	
B16C58	1180	1179	1-4	
B16C59	1135	1337	0-3.75	2-3, 3-4
B16C60	1080	1223	0.5-7	2-3, 3-4

^aDepth over which hole was composited. These samples were analyzed for inductively coupled plasma atomic emission spectrophotometry (ICPAES), BNAEs, and RCRA characteristics.

^bDepth of sample interval from which discrete sample was collected for VOA.

^cThe sample was lost in shipment.

^dSample was not analyzed for BNAEs.

TABLE 5-2
SUMMARY OF BOREHOLE LOCATIONS AND
CHEMICAL ANALYSES PERFORMED ON SAMPLES
AT SLDS - PHASE II

Page 1 of 5

Borehole	<u>Coordinate</u>		Sample Interval ^a (ft)
	N	E	
C-100	2192	1399	2-4 8-10
C-101	2216	1545	4-6 16-18
C-102	2130	1420	0.4-2 4-6 6-7.5
C-103	2133	1535	4-6 8-10
C-104	-	-	Not drilled
C-105 ^b	2100	1480	0.4-10 ^b 2-4 6-8 8-10
C-106	1955	1495	4-6 12-13.5
C-107	1845	1708	2-4 6-8 10-12
C-108	1951	1800	2-4 4-6 10-12
C-109	1850	1900	4-6 10-12
C-110	1973	1963	0.5-2 4-6 10-12
C-111	1910	2020	4-6 10-12

TABLE 5-2
(continued)

Page 2 of 5

Borehole	<u>Coordinate</u>		Sample Interval ^a (ft)
	N	E	
C-112	1743	1600	0.5-2.5 4-6 10-12
C-113	1719	1678	2-4 10-12
C-114 ^c	1675	1675	4-6 0.8-8 ^c
C-115	1671	1590	2-4 8-10 12-14
C-116	-	-	Not drilled
C-117	1590	1700	2-4 12-14
C-118	1420	1665	4-6 6-8 14-16
C-119 ^b	1350	1640	1-20.5 ^b 1-2 4-6 18.5-20.5
C-120	1605	2155	4-6 6-8 14-16
C-121	1500	2165	2-4 8-10 14-16
C-122	-	-	Not drilled
C-123	-	-	Not drilled
C-124	1548	2390	6-8 16-18
C-125	1553	2558	4-6 18-20

TABLE 5-2
(continued)

Page 3 of 5

Borehole	<u>Coordinate</u>		Sample Interval ^a (ft)
	N	E	
C-126	1595	2702	2-4 16-18
C-127	1785	2865	2-4 4-6 18-20
C-128	1407	2670	4-6 8-10 18-20
C-129	1515	2750	6-8 18-20
C-130	1515	2865	8-10 18-20
C-131	1511	2903	6-8 14-16
C-132	1695	3033	2-4 14-16
C-133	1505	3025	0.7-2 6-8 10-12
C-134	1836	3100	2-4 8-10 12-14
C-135 ^b	1345	2515	1-20 ^b 4-6 18-20
C-136 ^b	1410	2625	1-3 3-5 19-21 1-21 ^b

TABLE 5-2
(continued)

Page 4 of 5

Borehole	<u>Coordinate</u>		Sample Interval ^a (ft)
	N	E	
C-137 ^b	1320	2625	2-4 8-10 18-20 0.5-20 ^b
C-138	1375	2840	2-4 6-8 20-22
C-139	1330	2840	2-4 18-20
C-140	1260	2765	2-4 6-8 16-18
C-141	1515	3122	8-10 16-18
C-142	1038	2952	2-4 6-8 10-12
C-143	1050	3000	6-8 12-14
C-144	2000	3588	4-6 19-20.5
C-145	1800	3400	6-8 10.5-12 26-28
C-146	1738	3618	2-4 8-10 18-20
C-147	1500	3305	2-4 18-20

TABLE 5-2
(continued)

Page 5 of 5

Borehole	<u>Coordinate</u>		Sample Interval ^a (ft)
	N	E	
C-148	1400	3400	2-4 6-8 18-20
C-149	1300	3505	8-10 42-44 48-50
C-150	1000	3570	2-4 18-20
C-151	1342	1340	8-10 10-12
C-152 ^b	1196	1112	0-20 ^b 0-2 6-8
C-153	1029	1130	4-6 6-8
C-154	1385	2660	6-8 16-18

^aSample interval on which ICPAES analysis was performed.

^bSample borehole and interval of composite on which RCRA characteristics analyses were performed.

^cSample borehole and interval on which RCRA characteristics, ICPAES, BNAE, and VOA analyses were performed.

TABLE 5-3
METHODS FOR SOIL ANALYSIS

Parameter	Analytical Technique	EPA Method No.	Standard Method No. ^a	ASTM Method No. ^b
Metals	ICPAES ^c	6010	305	D4190-82
Mercury	Cold vapor AA ^d	--	--	--
Volatile organics	GC/Hall/PID ^e	Modified 8010/8015 ^f	--	--
BNAEs	GC/FID ^g and GC/MS	Modified 8250 and 8250 ^h	--	--
EP Toxicity	Various	1310	--	--
Corrosivity	pH	9040/9045	--	--
Ignitability	--	1010	--	D93-77
Reactivity-Sulfide	Titration	9030	--	--
Reactivity-Cyanide	Titration	9010	--	--

^aRef. 10.

^bRef. 11.

^cICPAES - Inductively coupled plasma atomic emission spectrophotometry.

^dAA - Atomic absorption.

^ePID - Photoionization detector.

^fModified to include use of GC/Hall detector/PID instead of GC/MS.

^gFID - Flame ionization detector.

^hModified to include use of GC/FID instead of GC/MS.

TABLE 5-4
COMPOUNDS INCLUDED IN VOLATILE ORGANICS ANALYSES
FOR SOIL SAMPLES

Chloromethane	Trans-1,3-dichloropropene
Bromomethane	Trichloroethene
Vinyl chloride	Dibromochloromethane
Chloroethane	1,1,2-trichloroethane
Methylene chloride	Benzene
1,1-dichloroethene	Cis-1,3-dichloropropene
1,1-dichloroethane	2-chloroethylvinylether
Trans-1,2-dichloroethene	Bromoform
Chloroform	Tetrachloroethene
1,2-dichloroethane	1,1,2,2-tetrachloroethane
1,1,1-trichloroethane	Total xylenes
Carbon tetrachloride	1,2-dichlorobenzene
Bromodichloromethane	1,3-dichlorobenzene
1,2-dichloropropane	1,4-dichlorobenzene
Trichlorofluoromethane	Dichlorodifluoromethane
Toluene	Ethylbenzene
Chlorobenzene	

The screen for BNAEs is based on EPA test method 8250. BNAEs are extracted from the sample and then injected into a system that includes a GC and a flame ionization detector (FID) in series. This method provides a broad classification of compounds present. The screen was employed to determine whether BNAE compounds were present in the samples. If there were BNAEs, the samples were sent on for confirmatory analysis and quantification by GC/mass spectroscopy (MS) EPA test method 8250. Analyses were performed on 56 samples during Phase I and on 1 sample during Phase II. The confirmatory analyses were performed for 65 BNAE compounds; those detected by this method are listed in Table 5-5.

Metals measured in soil samples using EPA test method 6010 included aluminum, arsenic, antimony, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, mercury, potassium, selenium, silver, sodium, thallium, vanadium, and zinc. These metals were chosen because of their presence in ores and feed materials used in the MED/AEC activities.

Composite samples were analyzed to determine whether the soil exhibited any of the RCRA-hazardous waste characteristics [i.e., reactivity, corrosivity, ignitability, and extraction procedure (EP) toxicity]. A material is considered a hazardous waste if it exhibits any of these characteristics as defined by 40 CFR 261, "Environmental Protection Agency Regulations for Identifying Hazardous Waste." Analyses were performed on 58 samples during Phase I and 7 samples during Phase II. Composite samples were used for the analyses because they would be representative of the material that is radioactively contaminated.

5.3.3 Groundwater

Quarterly sampling was conducted at SLDS during the period between July 1988 and April 1989. Groundwater from eight wells was

TABLE 5-5
ORGANIC COMPOUNDS INCLUDED IN BASE/NEUTRAL
AND ACID EXTRACTABLE ANALYSES FOR SOIL SAMPLES

Acenaphthene	Hexachlorocyclopentadiene
Acenaphthylene	Indeno(1,2,3-cd)pyrene
Anthracene	Isophorone
Benzo(a)anthracene	Naphthalene
Benzo(k)fluoranthene	Nitrobenzene
Benzo(a)pyrene	N-nitrosodi-n-propylamine
Benzo(g,h,i)perylene	N-nitrosodiphenylamine
Bis(2-chloroethyl)ether	Phenanthrene
Bis(2-chloroethoxy)methane	Pyrene
Bis(2-chloroisopropyl)ether	1,2,4-trichlorobenzene
Bis(2-ethylhexyl)phthalate	2-chlorophenol
4-Bromophenyl phenyl ether	2,4-dichlorophenol
Butylbenzyl phthalate	2,4-dimethylphenol
2-chloronaphthalene	2,4-dinitrophenol
4-chlorophenyl phenyl ether	2-nitrophenol
Chrysene	4-nitrophenol
Dibenzo(a,h)anthracene	Pentachlorophenol
1,2-dichlorobenzene	2-methylphenol
1,3-dichlorobenzene	4-methylphenol
1,4-dichlorobenzene	Phenol
3,3'-dichlorobenzidine	2,4,6-trichlorophenol
Diethyl phthalate	Benzo(b)fluoranthene
Dimethyl phthalate	3-nitroaniline
2,4-dinitrotoluene	4,6-dinitro-2-methylphenol
2,6-dinitrotoluene	Dibenzofuran
Di-n-octyl phthalate	4-chloroaniline
Benzyl alcohol	4-chloro-3-methylphenol
Fluoranthene	2-methylnaphthalene
Fluorene	2,4,5-trichlorophenol
Hexachlorobenzene	2-nitroaniline
Hexachlorobutadiene	4-nitroaniline
Hexachloroethane	Benzoic acid
Di-n-butyl phthalate	

collected and analyzed for various chemical parameters in July, October, January, and April. The rationale for selection of the location of the monitoring wells is discussed in Subsection 5.4.2.

Baseline chemical concentrations were determined by performing a broad spectrum of chemical analyses on samples. Tests were conducted for volatile and BNAE organic compounds, pesticides and polychlorinated biphenyls (PCBs), fluorides, nitrates, and water quality parameters including pH, specific conductance, total organic carbon (TOC), and total organic halides (TOX). For a specific listing of chemicals included in the analyses, see Tables 5-6 and 5-7. Methods for groundwater analyses are shown in Table 5-8.

Before water is drawn for samples, wells are purged. Standing water is removed with a 0.9-m (3-ft) Teflon bailer, and fresh water is allowed to enter, recharging the wells. After each well is purged, the bailer is decontaminated by standard EPA methods to prevent cross-contamination between the wells. The decontamination procedure consists of a deionized water rinse, a rinse of methanol to remove excess organics, and a last rinse with large amounts of deionized water.

Water samples are drawn by a Teflon bailer and stored in containers supplied by the laboratory. Samples are stored on ice, packed in vermiculite to prevent breakage during transport, and shipped to the laboratory on the same day they are collected.

5.4 GEOLOGICAL/HYDROGEOLOGICAL INVESTIGATION

The geologic and hydrogeologic characterization activities were conducted for the purpose of:

TABLE 5-6
VOLATILES, BNAEs, PESTICIDES, AND PCBs INCLUDED IN LABORATORY ANALYSES
FOR GROUNDWATER SAMPLES

Acetone	Benzo(k)fluoranthene	N-nitrosodi-n-propylamine
Acrolein	Benzo(a)pyrene	N-nitrosodiphenylamine
Acrylonitrile	Benzo(g,h,i)perylene	4-nitroaniline
Benzene	Benzyl alcohol	Phenanthrene
2-butanone	Benzoic acid	Pyrene
Bromoform	Bis(2-ethylhexyl)phthalate	2-chlorophenol
Bromomethane	Bis(2-chloroethyl)ether	2,4-dichlorophenol
Carbon disulfide	Bis(2-chloroethoxy)methane	2,4-dimethylphenol
Carbon tetrachloride	Bis(2-chloroisopropyl)ether	2,4-dinitrophenol
Chlorobenzene	4-bromophenyl phenyl ether	2-nitrophenol
Chlorodibromomethane	Butylbenzyl phthalate	4-nitrophenol
Chloroethane	2-chloronaphthalene	Pentachlorophenol
Chloroform	4-chlorophenyl phenyl ether	Phenol
2-Chloroethyl vinyl ether	4-chloroaniline	1,2,4-trichlorobenzene
Chloromethane	4-chloro-3-methylphenol	2,4,5-trichlorophenol
Dichlorobromomethane	Chrysene	2,4,6-trichlorophenol
1,3-dichloropropylene	Dibenzo(a,h)anthracene	Aldrin
1,2-trans-dichloroethylene	Dibenzofuran	BHC, alpha
1,1-dichloroethane	Di-n-butyl phthalate	BHC, beta
1,2-dichloroethene	Di-n-octyl phthalate	BHC, gamma
1,2-dichloroethane	1,2-dichlorobenzene	BHC, delta
1,1-dichloroethylene	1,3-dichlorobenzene	Alpha chlordane
1,2-dichloropropane	1,4-dichlorobenzene	Beta chlordane
1,3-dichloropropene	3,3'-dichlorobenzidine	Dieldrin
2-hexanone	Diethyl phthalate	Endosulfan, I
Ethylbenzene	Dimethyl phthalate	Endosulfan, II
4-methyl-2 pentanone	2,4-dinitrotoluene	Endosulfan sulfate
Methylene chloride	2,6-dinitrotoluene	Endrin
Toluene	4,6-dinitro-2-methylphenol	Endrin ketone
Total xylenes	Fluoranthene	Heptachlor
Styrene	Fluorene	Heptachlor epoxide
Tetrachloroethane	Hexachlorobenzene	4,4'-DDT
1,1,2,2-tetrachloroethane	Hexachlorobutadiene	4,4'-DDE
1,1,1-trichloroethane	Hexachloroethane	4,4'-DDD
Trichlorofluoromethane	Hexachlorocyclopentadiene	Methoxychlor
1,1,2-trichloroethane	Indeno(1,2,3-cd)pyrene	PCB 1016
Tetrachloroethylene	Isophorone	PCB 1221
Vinyl acetate	2-methylnaphthalene	PCB 1232
Vinyl chloride	2-methylphenol	PCB 1242
Anthracene	4-methylphenol	PCB 1248
Acenaphthene	Naphthalene	PCB 1254
Acenaphthylene	Nitrobenzene	PCB 1260
Benzo(a)anthracene	2-nitroaniline	Toxaphene
Benzo(b)fluoranthene	3-nitroaniline	

TABLE 5-7
METAL IONS INCLUDED
IN LABORATORY ANALYSES
FOR GROUNDWATER SAMPLES

Silver
Aluminum
Arsenic
Boron
Barium
Beryllium
Calcium
Cadmium
Cobalt
Chromium
Copper
Iron
Potassium
Magnesium
Manganese
Molybdenum
Sodium
Nickel
Lead
Antimony
Selenium
Thallium
Vanadium
Zinc

TABLE 5-8
METHODS FOR ANALYSIS OF GROUNDWATER

Parameter	Analytical Technique
ICPAES ^a	ICP Scans: EPA method 200-7 As: EPA 206.2 Tl: EPA 279.2 Se: EPA 270.2 Pb: EPA 239.2 All others: U.S. EPA ^b
Volatile organics	EPA method 8240 (SW 846)
Semivolatile organics	EPA method 8270 (SW 846)
Pesticide/PCBs	EPA method 8080 (SW 846)
pH	U.S. EPA ^b
Total organic carbon	See methods for pH
Specific conductance	See methods of pH
Fluoride	See methods for pH
Nitrate	See methods for pH
Total organic halides	EPA method 9020 (SW 846)

^aInductively coupled plasma atomic emission spectrophotometry.

^bRef. 12.

- Determining distribution and relationships of subsurface geologic materials
- Determining water table or potentiometric surfaces of aquifers in the system
- Establishing access for collection of water samples
- Evaluating potential for contaminants to migrate off site

5.4.1 Background/Regional Data

SLDS is located on the western boundary of the Mississippi River, 11.2 km (7 mi) downstream from the confluence of the Mississippi and Missouri rivers. The area is situated in the Dissected Till Plains, within the stable structural Province of the Central Lowlands (Ref. 13). This province is marked by low altitude, with broad, level uplands between valleys that have steep sides and broad floodplains. Most of the area was glaciated twice during Pleistocene time. Differences in landforms reflect the rate of melting and retreat of the glaciers. Quaternary glacial tills, loess and stream deposits of gravel, and sands and silts from the Mississippi and Missouri rivers are the primary overburden materials.

The stratigraphically highest bedrock units underlying the St. Louis area are of lower Pennsylvanian- and Mississippian-age carbonate rock with minor amounts of chert, shale, and sandstone. Most deposition occurred in shallow epicontinental seas. Many periods of emergence, nondeposition, and erosion are implied by local unconformities. The present structural attitude is the result of compressional, tensional, and uplift forces that have produced a slight regional tilt (Refs. 14 and 15).

Crystalline basement in east-central Missouri is regarded as the southernmost extension of the Proterozoic Canadian Shield. The

depth to basement is variable; in the St. Louis area it is approximately 1,830 m (6,000 ft) (Ref. 16).

SLDS lies within the tectonically quiet Central Stable Region. This region borders the Mississippi Embayment to the south, and includes the New Madrid seismic zone. Some scattered earthquake activity is known to occur throughout this area, primarily south of the site in the New Madrid seismic zone (Ref. 17).

Groundwater occurs in unconsolidated alluvial terrace deposits, sand and gravel channel fills, and bedrock aquifers. At SLDS, the bedrock aquifers thought to exist are the Roubidoux Formation sandstone, Gunter Member sandstone, Potosi Formation limestone, and St. Louis Formation limestone (Refs. 15, 18, and 19). Most of the bedrock is relatively impermeable, although not thought to be confining, and yields little water to wells. Major alluvial aquifers in the area are the basal sand and gravel units of the Mississippi floodplain (Ref. 19). These aquifers are generally recharged by infiltration of river water during periods of high stage levels.

Generally, well yields in the alluvial deposits are low because of the fine-grained nature of the material and the thin saturated thickness. However, because of the scour-and-fill method of deposition, alluvial deposits may vary considerably within a small area. Buried channels containing extensive layers of permeable sands and gravels would yield large quantities of water. Because of the complex bedrock stratigraphy, it is difficult to define parameters to describe yield capabilities for specific bedrock aquifers. Wells completed in zones penetrating the bedrock formations in the vicinity normally yield 38 to 3,800 L/min (10 to 1,000 gpm); some of the deeper [45 m (150 ft)] wells in alluvium yield more than 2,000 gpm (Refs. 15 and 19).

The chemical quality of bedrock groundwater varies from a calcium-magnesium-bicarbonate type to a sodium-sulfate, sodium-bicarbonate, or sodium-chloride type (Ref. 19). The water is generally very hard and high in dissolved solids, particularly iron, chlorides, bicarbonates, and manganese (Ref. 14). Water from alluvial deposits along the Mississippi River exhibits a uniform calcium-magnesium-bicarbonate type, with a variable dissolved-solids content. Chemical characteristics of water from alluvial deposits vary based on the composition of the aquifer materials.

Approximately 82 percent of the 1,200 million gallons of water used daily in the St. Louis area is pumped from the Mississippi River; the other 18 percent is pumped from the Meramec and Missouri rivers near St. Charles (Ref. 19). The Mississippi River intakes are well upstream of SLDS.

5.4.2 Monitoring Wells and Boreholes

Ninety-eight radiologic-specific boreholes, 110 chemical/radiological boreholes, and 10 geologic boreholes were completed for Phases I and II (see Section 6.0, Figure 6-4). All 218 boreholes were radiologically sampled; 110 boreholes were chemically sampled. One borehole's chemical sample was lost in transit to the analytical laboratory. Nine geologic boreholes were completed as monitoring wells. A subcontractor to BNI performed the drilling, monitoring well installation, and well development. All boreholes were geologically logged by a BNI geologist; radiological and chemical samples were collected by field personnel. Boreholes were advanced using hollow-stem augers and cutter head to a minimum of 0.7 m (2 ft) into undisturbed soil, as determined by the BNI geologist. Samples were collected continuously using 2-in. stainless steel split-spoon samplers. Boreholes were reamed to total depth and 4-in. PVC temporary casing was installed. All boreholes were gamma logged by Thermo

Analytical/Eberline (TMA/E) (Subsection 5.2.3). BNI geologists measured static water levels before the temporary casing was removed. All boreholes were backfilled with bentonite cement.

Primary considerations for geologic borehole locations were property access and physical plant obstructions. Monitoring wells were sited to establish a representative geologic profile, background groundwater quality, hydraulic gradients, and flow direction.

Ten geologic boreholes were drilled and nine were completed as monitoring wells. The boreholes were initially advanced using 8-1/4-in. hollow-stem augers and cutter head. Boreholes were geologically logged, and radiological or chemical samples were obtained by TMA/E continuously into undisturbed material. The borehole was temporarily cased with 4-in. PVC and gamma logged to identify areas of elevated subsurface gamma radiation. Boreholes were then reamed to 11-1/2 in. using a 2-ft auger bucket. A 10-in. PVC conductor casing was installed and tremie-grouted with bentonite cement before advancing into undisturbed material. Boreholes were advanced using 8-1/4-in. hollow-stem augers and 2-in. split spoons. Standard penetration tests were driven at 1.5-m (5-ft) intervals to refusal at top of rock. At monitoring well locations B16W06D, B16W07D, and B16W09D, the drill hole was advanced and core samples retrieved using an NX split-barrel tube and coring equipment. Drill holes at B16W06D and B16W07D were advanced 3 m (10 ft) into bedrock, and B16W09D was advanced 1.1 m (3.5 ft) into bedrock. Drilling fluid was hydrant water, which was sampled and chemically analyzed. Constant-head packer permeability tests were performed in the cored intervals of B16W06D and B16W07D.

Monitoring wells were completed in the unconsolidated alluvial zone above bedrock in all nine geologic boreholes. Monitoring wells are

assigned a letter-number designation prior to drilling activities. The shallow (S) and deep (D) letters are provided for the subcontractor's estimation of material quantities for procurement. No inference is made by these letter designations to assign individual wells to a particular saturated material or formation. Boreholes were reamed to dimensions designated on design drawings and technical specifications (Ref. 20). All well construction materials were submitted to BNI for approval prior to installation. Well materials incorporated a 2-in. type 316L stainless steel screen with 0.01-in. openings, excluding B16W09D, and 2-in. reinforced epoxy fiberglass riser casing. A 2-in. reinforced epoxy fiberglass screen with 0.01-in. slot size was installed in B16W09D. The filter pack and bentonite seal were placed by a tremied slurry. Monitoring well construction elevations, dimensions, and monitored intervals for each well are detailed in Table 5-9.

All wells were developed using an alternating air-lift and swab procedure; the four shallow wells required additional water injection. The objectives of well development were to (1) restore formation material damaged by drilling and construction activities, (2) stabilize the formation zone adjacent to the screen, (3) recover the volume of fluids lost during drilling and/or permeability testing, (4) produce a turbidity-free water sample with few suspended solids, and (5) establish initial physical properties and behavior of the groundwater. Specific conditions encountered at each well dictated individual development activities.

In general, the shallower wells (B16W01S-B16W04S) could be pumped dry with continuous pumping. It was determined that the most efficient method was to alternate an air-lift session, which recovered one well volume, with a monitored recovery period. The deeper wells (B16W05D-B16W09D) were pumped continuously, at the capacity of the air-lift system. Drawdown was difficult to monitor

TABLE 5-9

ST. LOUIS DOWNTOWN SITE MONITORING WELL CONSTRUCTION

Well Number ^a	<u>Coordinates</u>		Elevation (ft) ^b	<u>Bottom of Sump</u>		<u>Bottom of Screen</u>		<u>Top of Screen</u>		<u>Bottom of Seal</u>	
	North	East		Depth (ft)	Elevation (ft)	Depth (ft)	Elevation (ft)	Depth (ft)	Elevation (ft)	Depth (ft)	Elevation (ft)
B16W01S	2075.70	1079.68	426.70	24.3	402.4	23.0	403.7	18	408.7	16.0	410.7
B16W02S	2110.69	1536.49	420.24	33.0	387.2	30.7	389.5	20.4	399.8	18.0	402.2
B16W03S	1646.06	1746.30	418.77	34.9	383.9	32.6	386.2	22.6	396.2	20.7	398.1
B16W04S	1089.21	1313.40	425.53	28.6	397.0	27.2	398.3	22.2	403.3	19.9	405.6
B16W05D	1600.57	2899.87	422.99	69.9	353.1	67.7	355.3	57.3	365.6	53.7	369.3
B16W06D	1629.07	3272.85	423.50	82.5	341.1	80.2	343.3	70.2	353.4	66.7	356.8
B16W07D	1299.88	3006.00	421.89	79.1	342.8	76.8	345.0	66.5	355.4	62.2	359.7
B16W08D	1257.63	3231.41	423.48	72.3	351.1	70.1	353.4	59.7	363.7	53.7	369.8
B16W09D	1836.29	2244.52	421.87	55.9	360.3	54.8	367.0	44.8	377.0	42.0	379.8

^aSee Figure 6-13 for location.

^bElevation in feet above mean sea level.

because of the limited working space within the 2-in. well casing. The well screen was surged by shutting off the air lift and allowing the head of water within the well to fall.

5.4.3 Soils

Physical soil testing was conducted at SLDS primarily to obtain input to the DOE Residual Radioactive Material Code (RESRAD) (Ref. 21). RESRAD is a computer pathway analysis model used to establish site-specific guidelines for allowable residual concentrations of uranium in soil based on a radiation dose limit of 100 mrem/yr to persons inhabiting the site after remedial action. Because the pathways evaluated include ingestion of crops, livestock, and water from the site, determination of soil parameters relating to movement of or capacity to immobilize radionuclides is the primary objective.

Particle size analysis, following the procedure described by ASTM D422, was performed on 14 samples from across the site to assist in soil classification. One sample was analyzed to determine the distribution coefficient, k_d , for uranium and the cation exchange coefficient in accordance with ASTM D4319 and ASTM STP805, respectively. Determination of the distribution coefficient and cation exchange coefficient was necessary because those parameters give an indication of the capacity of the soil to retard uranium migration. These parameters are also key input values to the RESRAD program used to establish site cleanup guidelines for uranium.

5.4.4 Groundwater Monitoring

Water level measurements have been recorded continuously on a weekly basis since July 1988. Daily gauge heights for the gauging station known as Mississippi River at St. Louis were obtained

for the same time period from the United States Department of the Interior, Geological Survey--Water Resources Division.

Radiological and chemical analytical results of groundwater sampling are summarized in Subsection 6.1.5 and Subsection 6.2.3, respectively.

6.0 CHARACTERIZATION RESULTS

6.1 RADIOLOGICAL RESULTS

The following subsections summarize the results of the radiological characterization of SLDS and include summary tables; full data tables are provided in Volume II of this report.

Current DOE guidelines governing remedial action for radiological constituents at SLDS are presented in Table 6-1. Additionally, a site-specific guideline for uranium in soil will be developed by DOE. For the purpose of this report, a value of 50 pCi/g for uranium-238 in soil will be assumed as this guideline (Ref. 22). Accordingly, all graphical representations of contaminated soil areas presented in this report are based on the assumption that soils contaminated in excess of 50 pCi/g uranium exceed DOE guidelines. This value is in the range of uranium cleanup guidelines developed for other FUSRAP sites.

For residual surface contamination, the natural uranium guideline will be assumed for the purpose of evaluating the radiological status of structural surfaces (Ref. 23). This will provide a conservative estimate of radioactive contamination on structural surfaces. The final surface contamination guideline for SLDS will be established during the identification of applicable or relevant and appropriate requirements for the St. Louis area remedial investigation report.

6.1.1 Background Measurements

Background data are compared with site data to establish whether site radiological measurements are elevated. Background data are also important because guidelines governing remedial action are typically presented in terms of acceptable levels above background.

TABLE 6-1
SUMMARY OF RESIDUAL CONTAMINATION GUIDELINES

BASIC DOSE LIMITS

The basic limit for the annual radiation dose received by an individual member of the general public is 100 mrem/yr.

SOIL GUIDELINES

Radionuclide	Soil Concentration (pCi/g) Above Background ^{a,b,c}
Radium-226 Radium-228 Thorium-230 Thorium-232	5 pCi/g when 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.

STRUCTURE GUIDELINES

Airborne Radon Decay Products

Generic guidelines for concentrations of airborne radon decay products shall apply to existing occupied or habitable structures on private property that has no radiological restrictions on its use; structures that will be demolished or buried are excluded. The applicable generic guideline (40 CFR 192) is: In any occupied or habitable building, the objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL^d. In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL. Remedial actions are not required in order to comply with this guideline when there is reasonable assurance that residual radioactive materials are not the cause.

External Gamma Radiation

The average level of gamma radiation inside a building or habitable structure on a site that has no radiological restrictions on its use shall not exceed the background level by more than 20 μ R/h.

Indoor/Outdoor Structure Surface Contamination

Radionuclide ^f	Allowable Surface Residual Contamination ^e (dpm/100 cm ²)		
	Average ^{g,h}	Maximum ^{h,i}	Removable ^{h,j}
Transuranics, Ra-226, Ra-228, Th-230, Th-228 Pa-231, Ac-227, I-125, I-129	100	300	20
Th-Natural, Th-232, Sr-90, Ra-223, Ra-224 U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000 α	15,000 α	1,000 α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000 B - γ	15,000 B - γ	1,000 B - γ

TABLE 6-1
(CONTINUED)

^aThese guidelines take into account ingrowth of radium-226 from thorium-230 and of radium-228 from thorium-232, and assume secular equilibrium. If either thorium-230 and radium-226 or thorium-232 and radium-228 are both present, not in secular equilibrium, the guidelines apply to the higher concentration. If other mixtures of radionuclides occur, the concentrations of individual radionuclides shall be reduced so that (1) the dose for the mixtures will not exceed the basic dose limit, or (2) the sum of ratios of the soil concentration of each radionuclide to the allowable limit for that radionuclide will not exceed 1 ("unity").

^bThese guidelines represent allowable residual concentrations above background averaged across any 15-cm-thick layer to any depth and over any contiguous 100-m² surface area.

^cLocalized concentrations in excess of these limits are allowable, provided that the average concentration over a 100-m² area does not exceed these limits. In addition, every reasonable effort shall be made to remove any source of radionuclide that exceeds 30 times the appropriate soil limit, regardless of the average concentration in the soil.

^dA working level (WL) is any combination of short-lived radon decay products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

^eAs used in this table, disintegrations per minute (dpm) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

^fWhere surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

^gMeasurements of average contamination should not be averaged over more than 1 m². For objects of less surface area, the average shall be derived for each such object.

^hThe average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

ⁱThe maximum contamination level applies to an area of not more than 100 cm².

^jThe amount of removable radioactive material per 100 cm² of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm² is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. The numbers in this column are maximum amounts.

The locations from which background samples and measurements were taken are shown in Figure 6-1. Location 1 is open, grassy land with no trees. The area is owned by the City of St. Louis and is expected to become part of the St. Louis Airport during a planned expansion project. There are no structures within about 0.2 km (0.1 mi) of the area. Location 2 is also open, grassy land with no trees. There are no structures within 0.5 km (0.3 mi) of the area. Location 3 is an open area near a school with some grass and trees. A park surrounds the school; a gasoline station is located several hundred feet from the area. Background measurements and results are shown in Table 6-2.

6.1.2 Walkover Gamma Scans

Walkover gamma scans were conducted on the property between the Chicago, Burlington, and Quincy Railroad and the Mississippi River (hereafter referred to as the city property) and accessible portions of SLDS. Biased surface samples were collected in areas exhibiting gamma readings of twice background (10,000 cpm) or more.

Figure 6-2 shows the locations where walkover gamma surveys were conducted. Table 6-3 summarizes the results of this survey for each plant. These near-surface gamma radiation measurements ranged from background levels to 2,000,000 cpm.

Walkover gamma scan data can be used to estimate a dose rate equivalent. Based on a calibration of the walkover gamma scan instrument with radium-226, a conversion of $1,250 \text{ cpm} = 1 \mu\text{R/h}$ was established. It should be noted that this conversion is based on a radium-226 calibration; therefore these are estimated exposure rates that depend on the primary radionuclide contaminant for a given area. These dose rate equivalents are conservative assumptions, because radium-226 has higher gamma energy than other radioactive contaminants of concern at SLDS. The dose rate

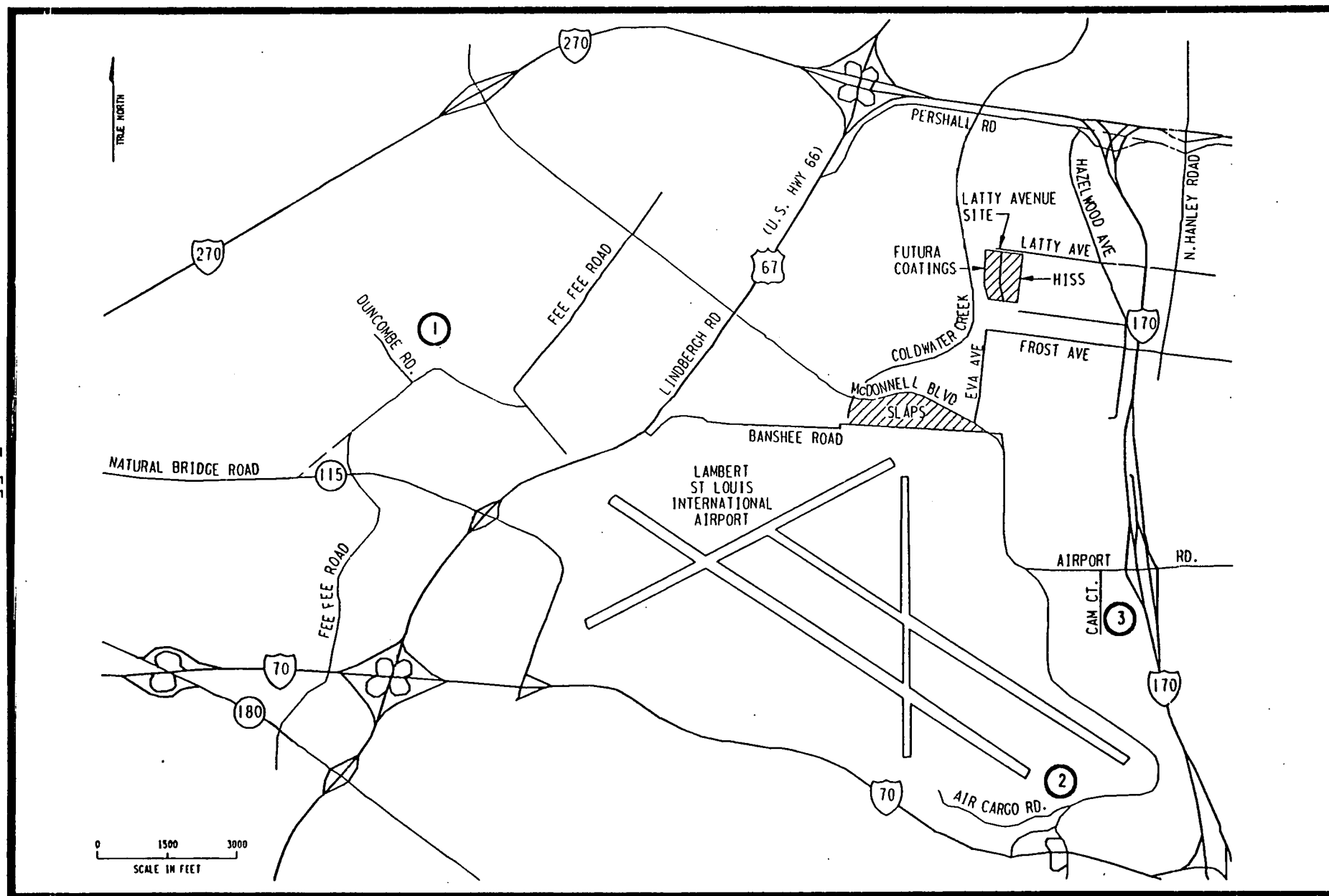


FIGURE 6-1 BACKGROUND SAMPLE AND MEASUREMENT LOCATIONS IN THE ST. LOUIS AREA

TABLE 6-2

BACKGROUND RADIATION LEVELS AND RADIONUCLIDE CONCENTRATIONS IN SOIL IN THE ST. LOUIS AREA

Measurement Location ^a	Gamma Exposure Rate at 3 ft (μ R/h)	Gamma Radiation at 3 ft (cpm)	Near-Surface Gamma Radiation (cpm)	Radionuclide Concentration (pCi/g \pm 2 sigma)					
				Uranium-234	Uranium-235	Uranium-238	Radium-226	Thorium-232	Thorium-230
1	10	10,000	10,000	1.2 ± 0.3	< 0.1	1.2 ± 0.3	0.9 ± 0.4	1.0 ± 0.6	1.2 ± 0.3
2	10	9,000	9,000	1.0 ± 0.2	< 0.1	1.0 ± 0.2	0.9 ± 0.4	1.0 ± 0.5	1.3 ± 0.3
3	10	10,000	10,000	1.2 ± 0.2	0.1 ± 0.1	1.0 ± 0.2	0.9 ± 0.4	1.1 ± 0.3	1.5 ± 0.5
Average	10	10,000	10,000	1.1 ± 0.2	0.1 ± 0.1	1.1 ± 0.2	0.9 ± 0.4	1.0 ± 0.5	1.3 ± 0.4

^a Locations are shown in Figure 6-1.

FIGURE 6-2
WALKOVER GAMMA SURVEY LOCATIONS

TABLE 6-3

SUMMARY RESULTS FOR WALKOVER GAMMA SURVEY

Plant/Area	Range		Maximum Reading	
	cpm	$\mu\text{R/h}$	cpm	$\mu\text{R/h}$
Plant 1	7,000- 9,000	5.6- 7.2	150,000	120
Plant 2	6,000- 8,000	4.8- 6.4	75,000	60
Plant 6	9,000-33,000	7.2-26.4	640,000	512
Plant 7	9,000-29,000	7.2-23.2	2,000,000	1,600
Plant 10	6,000- 8,000	4.8- 6.4	24,000	60
City Property	7,000-19,000	5.6-15.2	105,000	84

equivalent, at contact, for each plant is also shown in Table 6-3. These dose rates ranged from background to 1,600 $\mu\text{R/h}$.

6.1.3 Soil

Soil samples were collected from SLDS and the city property to determine concentrations of radioactivity in the soil. Locations for sample collection and parameters for radiological analysis were determined by historical information, previous surveys, and/or results of this characterization effort. Historical information, along with previous surveys, provided the basis for identifying the areas of SLDS where sampling efforts should be concentrated during Phase I activities. Results of the Phase I characterization effort revealed additional areas where sampling was required. Radioactivity exceeding DOE guidelines was found in all general areas that were sampled.

Systematic surface sampling was conducted on the city property, and biased surface sampling was conducted on both SLDS and the city property. Systematic surface sampling within SLDS was performed on the edges of streets. The results of all surface sample analyses are provided in Table 6-4 (Volume II). Figure 6-3 shows surface sampling locations where measurements are above and below DOE guidelines.

Analytical results of subsurface samples from boreholes are provided in Table 6-5 (Volume II). Figure 6-4 shows all borehole locations with symbols that indicate where samples from a particular borehole were above or below DOE guidelines. In addition to sampling and analysis of soils, gamma logging was conducted in boreholes to identify areas of elevated radioactivity in subsurface soil. In general, the elevated readings obtained from the downhole gamma logs were substantiated by the results of sample analysis. Table 6-6 (Volume II) gives the results of the downhole gamma logs. Diagrams of various portions of the site and

the city property are provided to show borehole locations, range and average concentrations of each radionuclide of interest (for borehole and surface samples), maximum depth of radioactive contamination, and whether established guidelines for radioactivity in soil were exceeded. A discussion of each area follows.

Plant 1

Based on historical information and previous surveys, Phase I sampling efforts were concentrated around Buildings 25 and K1E in the northwest corner of Plant 1. Phase I results revealed that additional sampling was required in the southeast portion of the plant.

Twenty-three boreholes were drilled and sampled in Plant 1. Five of these showed soil sample measurements that exceeded DOE guidelines. In general, most elevated radioactivity in soil was found to be near Building K1E. Radium-226 is the major soil contaminant in Plant 1. Figure 6-5 summarizes the results of the Plant 1 radiological investigation.

Plant 2

Historical information and data from previous surveys indicated that sampling activities should be concentrated near the 50 series of buildings in Plant 2. Phase I results showed that sampling should be expanded away from the 50 series to define boundaries of radioactive contamination.

Twenty-seven boreholes were drilled and sampled in Plant 2; 11 contained soil samples exceeding DOE guidelines. Most radioactivity in soil exceeding guidelines was found near or beneath Buildings 51, 51A, 52, and 52A. Uranium-238 and thorium-230 are the major soil contaminants in Plant 2.

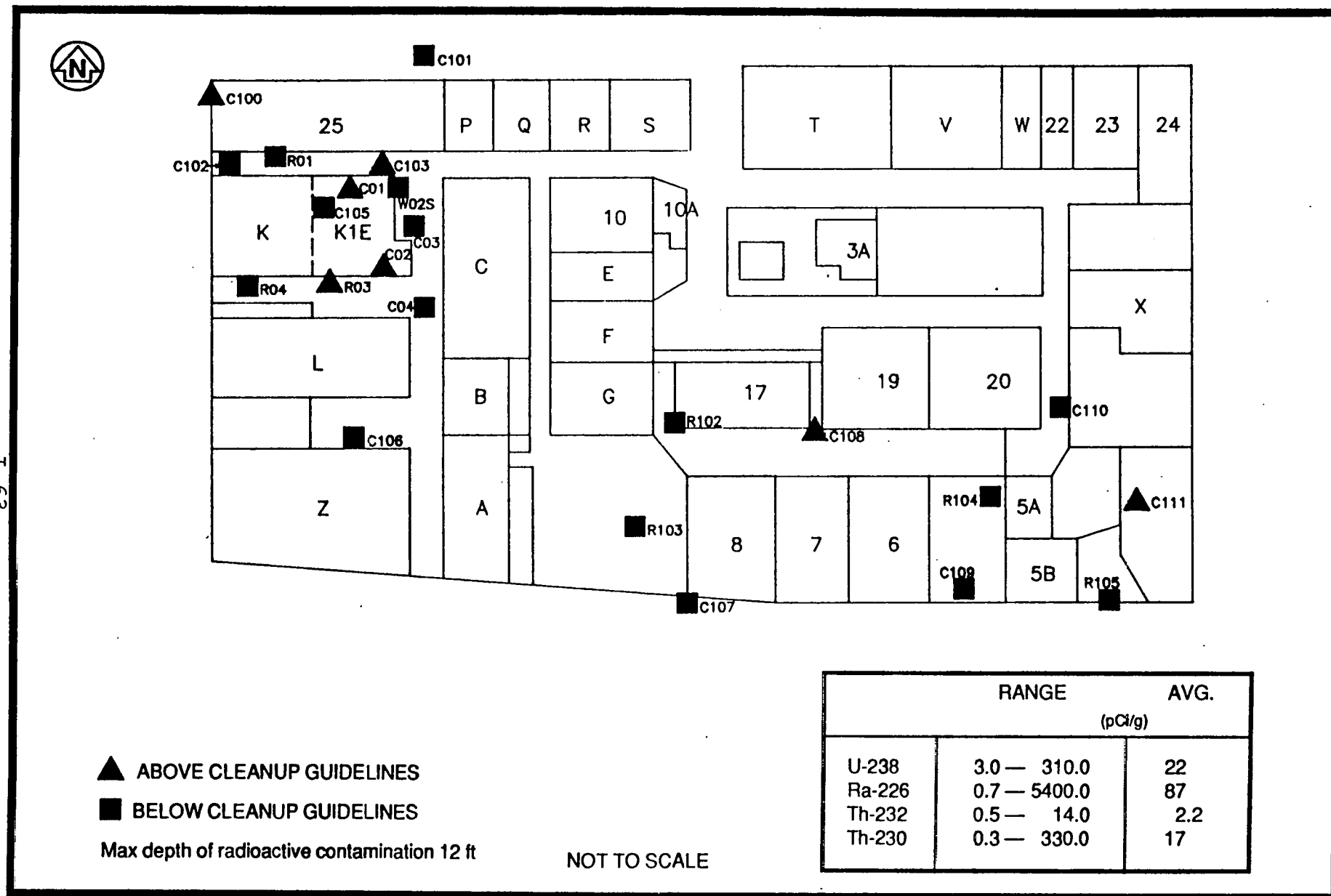


FIGURE 6-5 RADIOLOGICAL SOIL RESULTS FOR PLANT 1

Figure 6-6 summarizes the results of the Plant 2 radiological investigation.

Plant 5

Historical data did not indicate that MED/AEC activities were conducted at Plant 5. However, Phase I results determined that it was necessary to perform limited sampling in the northern portion of the plant. In Phase II, eight boreholes were drilled at Plant 5 to determine whether radioactivity in soil is present in concentrations in excess of DOE guidelines. Six of the eight boreholes revealed radioactivity in soil exceeding DOE guidelines; thorium-230 is the major contaminant. Figure 6-7 summarizes the results for Plant 5.

Plant 6

Previous survey data and historical information indicated that the entire Plant 6 area required sampling. Sampling efforts were widespread throughout the plant, with limited sampling in Plant 6E.

Sixty-four boreholes were drilled and sampled in Plants 6 and 6E. Samples from 23 of the 64 boreholes did not exceed the DOE guidelines. In general, Plant 6 contains soil that exceeds guidelines across the entire area, and Plant 6E shows little residual radioactivity. The primary contaminant in the Plant 6 area is uranium-238. Figure 6-8 is a summary of the radiological soil characterization in Plants 6 and 6E.

Plant 7

Plant 7 historical data and previous survey information indicated that the entire area required sampling. Sampling activities were widespread throughout the plant.

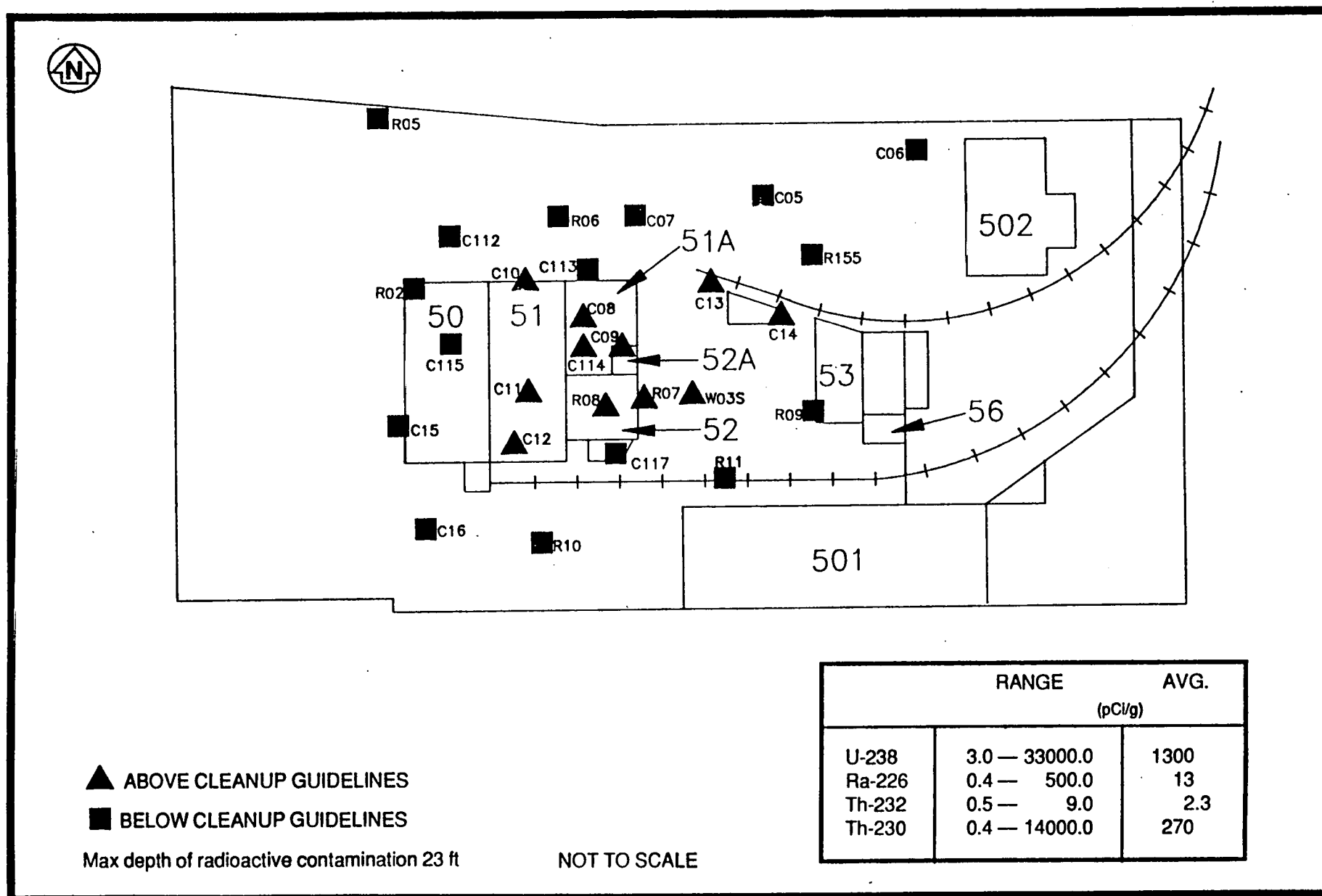


FIGURE 6-6 RADIOLOGICAL SOIL RESULTS FOR PLANT 2

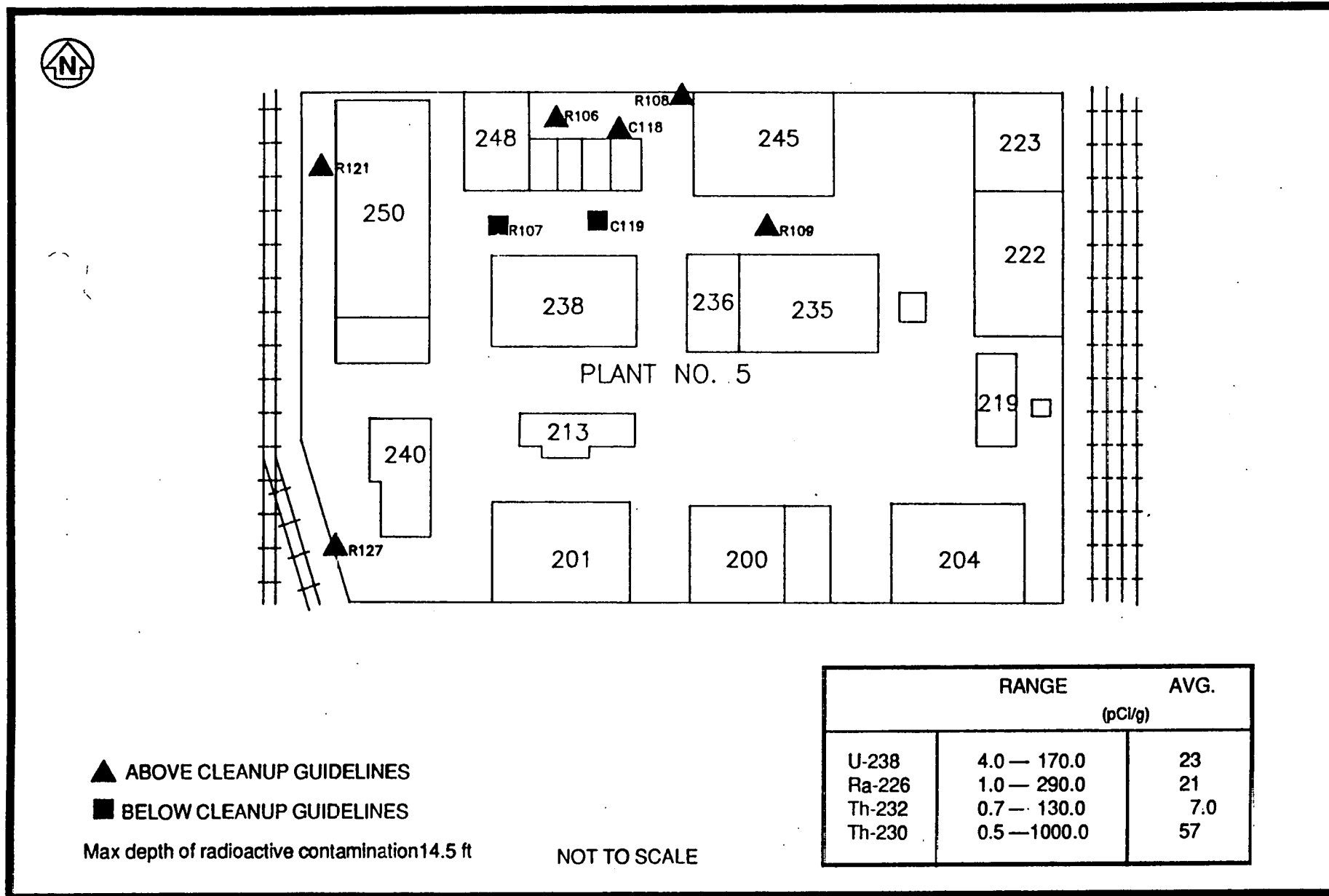


FIGURE 6-7 RADIOLOGICAL SOIL RESULTS FOR PLANT 5

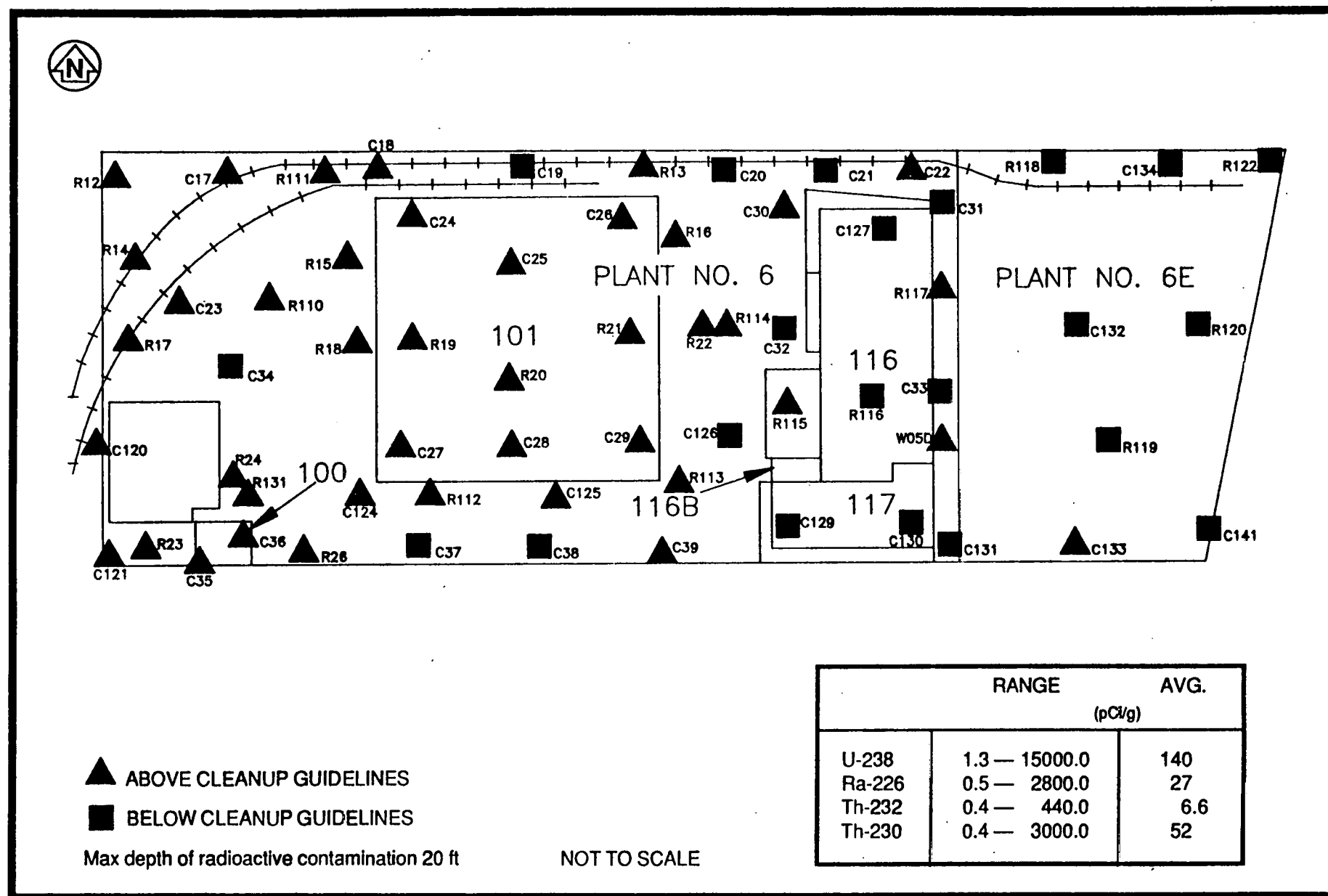


FIGURE 6-8 RADIOLOGICAL SOIL RESULTS FOR PLANTS 6 AND 6E

Forty-five boreholes were drilled in the Plant 7 area. Twenty-four of these showed radioactivity in soil in excess of DOE guidelines. This radioactivity is distributed across the entire plant area, but some isolated boreholes showed no residual radioactivity in soil. All radionuclides of concern (uranium-238, radium-226, and thorium-230) are major contaminants in this area. Figure 6-9 summarizes the results of the Plant 7 radiological investigation.

Plant 10

Previous survey data and historical information showed that it was necessary to perform only limited sampling in Plant 10. The efforts were concentrated on the eastern portion of the plant and near Buildings 81 and 82.

Of 13 boreholes drilled in Plant 10, 6 contained soil samples that exceed DOE guidelines for residual radioactivity. The radioactive contamination is distributed across the investigation area. Major contaminants in Plant 10 are uranium-238 and thorium-230. Figure 6-10 summarizes the results.

City Property

Very little data from previous surveys existed for the city property; however, available data indicated that radioactive contamination extends to the SLDS property boundary. Historical information on extreme flooding in the area suggested the necessity for sampling over a widespread portion of the city property.

Twenty-one boreholes were drilled on the city property. Thirteen of these contain soil with radionuclide concentrations exceeding DOE guidelines. The major contaminants are uranium-238, radium-226, and thorium-230; Figure 6-11 summarizes the results. Contamination is generally spread over the entire area of the city property that was characterized.

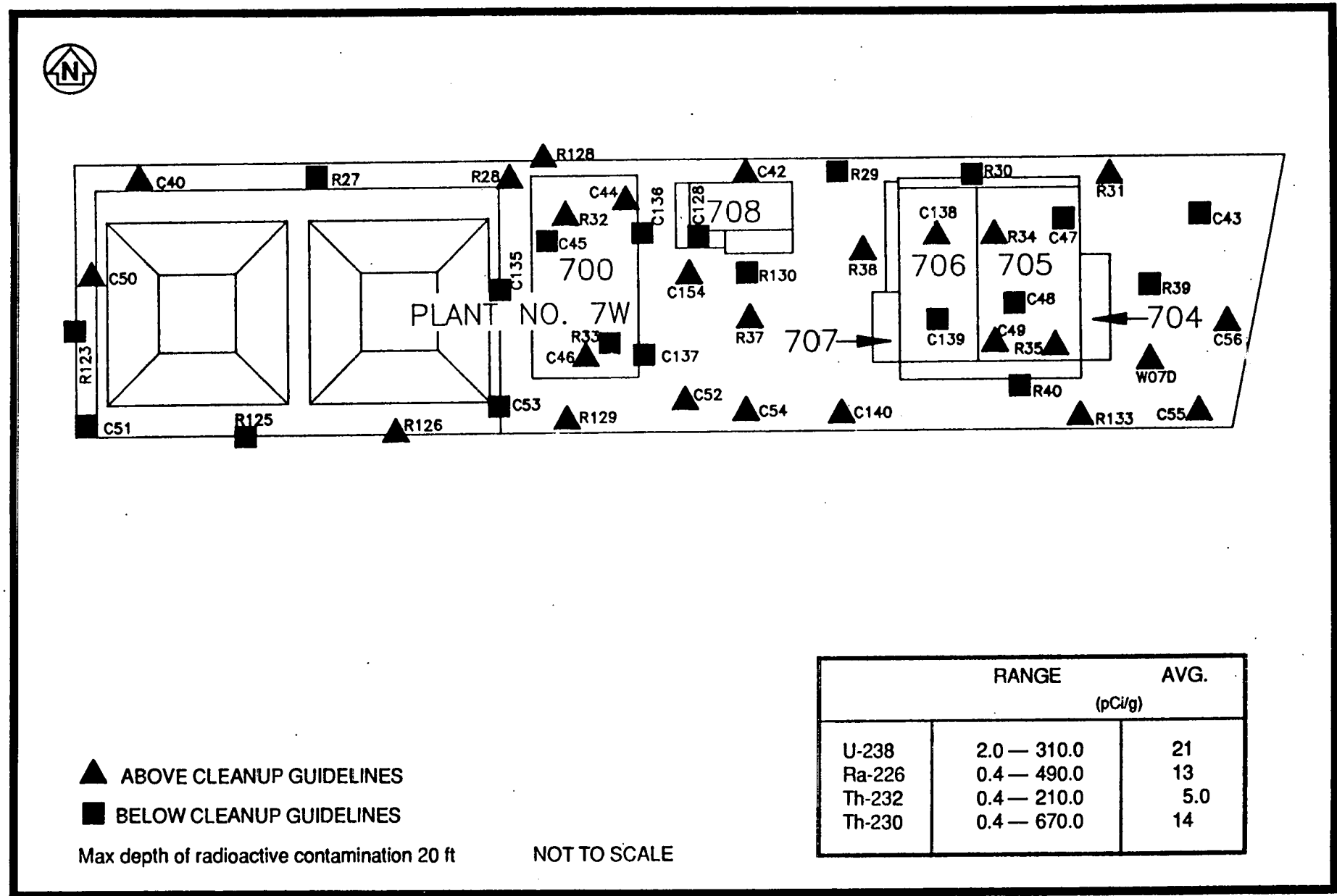


FIGURE 6-9 RADIOLOGICAL SOIL RESULTS FOR PLANT 7

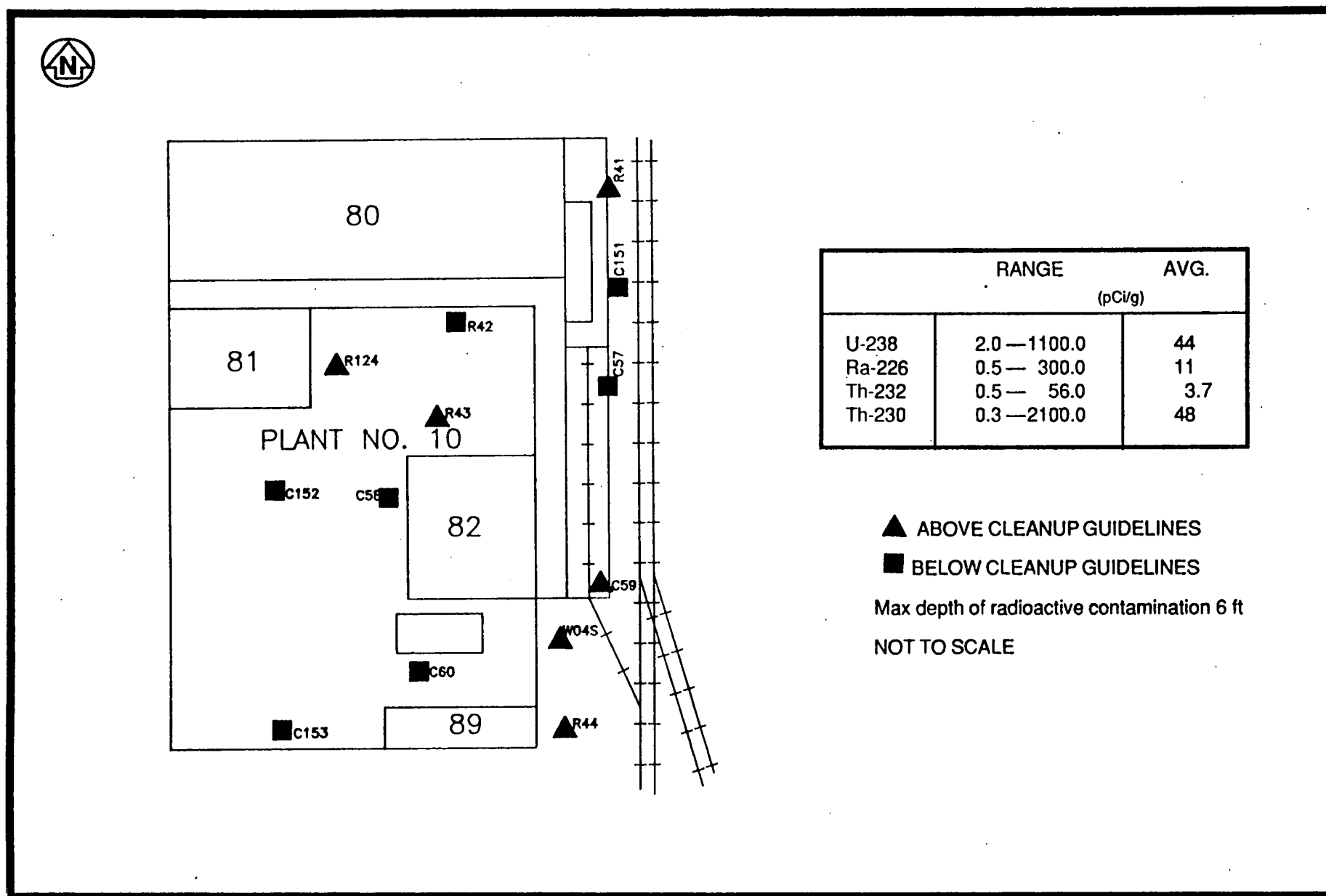


FIGURE 6-10 RADIOLOGICAL SOIL RESULTS FOR PLANT 10

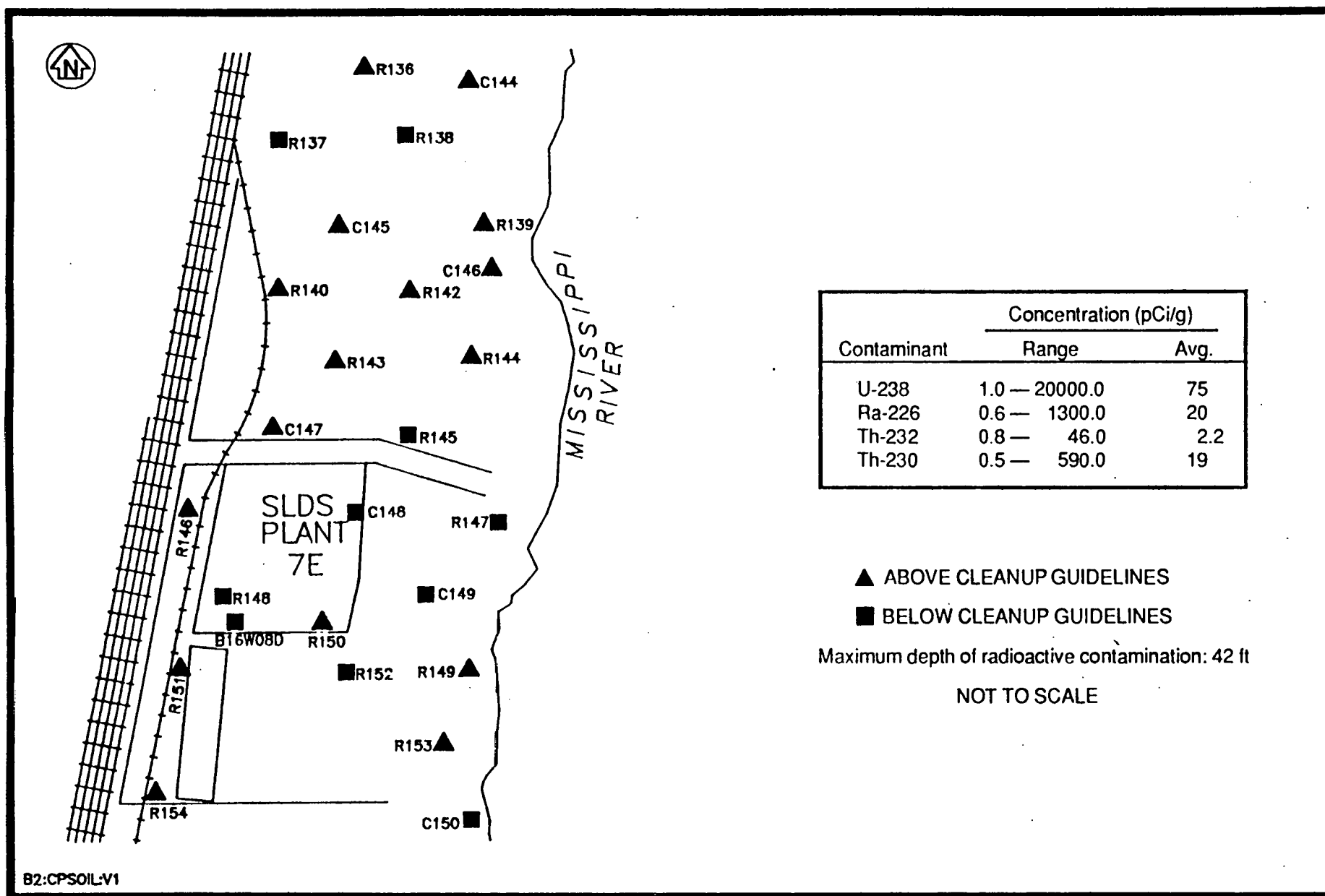


FIGURE 6-11 RADIOLOGICAL SOIL RESULTS FOR CITY PROPERTY AND PLANT 7-E

Of the five boreholes drilled in Plant 7E, two showed radioactivity near the surface exceeding guidelines. The boreholes were drilled at locations around the perimeter of the property because the entire site is covered with a stockpile of coal. Radium-226 and thorium-230 are the primary contaminants.

6.1.4 Drains and Sumps

Eighty-four manholes at SLDS were surveyed to determine whether residual radioactivity exists in these drainage pathways. Samples were collected from several of them if sample material was available and if the manhole was accessible. The results of the manhole surveys and samples are provided in Tables 6-7 and 6-8 (Volume II). Several of these manholes showed residual radioactivity exceeding DOE guidelines. The locations of these manholes are shown in Figure 6-12; those containing samples exceeding DOE guidelines are denoted by the appropriate symbol.

When final building surveys are performed, shortly before remedial action begins, the extent of contamination in each drainage pathway will be determined. This methodology was selected because of ongoing operations at the site.

6.1.5 Groundwater

Analytical results for concentrations of uranium, radium, and thorium in groundwater are presented in Table 6-9 (Volume II). Figure 6-13 shows the locations of the groundwater monitoring wells.

Averages for uranium ranged from less than 3.0×10^{-9} to 1.62×10^{-7} $\mu\text{Ci/ml}$ (less than 3.0 to 162 pCi/L). The minimum detectable activity (MDA) for uranium is 3.0×10^{-9} $\mu\text{Ci/ml}$ (3.0 pCi/L). Only one well had an average uranium concentration that substantially exceeded the detection limit. Well B16W02S contained uranium (at 162 pCi/L; this is approximately 30 percent of the DOE derived concentration guideline (DCG) of 6.0×10^{-7} $\mu\text{Ci/ml}$ (600 pCi/L).

The DCG is a DOE guideline for concentrations of radionuclides at FUSRAP sites. If laboratory analyses indicate that radionuclides exceed concentrations listed in the DCG, action must be taken to reduce or control on-site concentrations.

Average radium-226 concentrations ranged from 5×10^{-10} to 2.3×10^{-9} $\mu\text{Ci/ml}$ (0.5 to 2.3 pCi/L). The MDA for radium-226 is 1×10^{-10} $\mu\text{Ci/ml}$ (0.1 pCi/L) and the DCG is 1×10^{-7} $\mu\text{Ci/ml}$ (100 pCi/L). Well B16W01S contained the highest average radium-226 concentration (2.3 pCi/L, which is less than 3 percent of the DCG).

Average thorium-230 results ranged from 1×10^{-10} to 1.9×10^{-9} $\mu\text{Ci/ml}$ (0.1 to 1.9 pCi/L). The DCG for thorium-230 is 3×10^{-7} $\mu\text{Ci/ml}$ (300 pCi/L). The highest average concentration, which was approximately 1 percent of the DCG, occurred in well B16W01S.

6.1.6 Buildings

Twenty buildings were surveyed to determine whether radioactive contamination exceeding DOE guidelines was present. (The DOE guidelines governing surface contamination are shown in Table 6-1.) For SLDS, the natural uranium criterion (5,000 dpm/100 cm^2 , average) will be used as the surface contamination guideline based on the analytical results of building deposit samples (Ref. 23). These buildings are 25, K1E, 81, 82, 50, 51, 51A, 52, 52A, 100, 101, 116, 116B, 117, 700, 704, 705, 706, 707, and 708. Walls, ceilings, floors, and roofs were surveyed in most of these buildings. In addition, the roofs of Buildings X, 501, R, P, Q, C, B, L, Z, 53, 56, F, G, 10, T, V, and W were surveyed to determine whether emissions from buildings used for MED/AEC operations had contaminated adjacent building roofs. These buildings were chosen to be included in the field investigation because of their use during and/or their proximity to MED/AEC operations. Because the

objective of these building surveys was to determine whether radioactivity exceeding DOE guidelines existed and not to determine absolute boundaries of contamination, only general statements about the radiological status of these buildings are provided.

Background was not subtracted from the exposure rate values for each building. The St. Louis area background values were determined (out of doors) with a pressurized ionization chamber (PIC). Exposure rates inside the plants at SLDS were determined by NaI(Tl) gamma scintillation probe. Because the insides of the buildings are shielded from cosmic radiation, average exposure rates indoors are sometimes lower than background values.

Building 25

Surveys of Building 25 revealed that most radioactive contamination in excess of DOE guidelines is found on walls and floors. Removable contamination was not found in excess of guidelines and the average exposure rate is below the DOE guideline for habitable structures. The highest exposure rate readings were found near cabinets used to store radiation sources. These radiation source materials are used in current analytical procedures and equipment and are not associated with any past or present DOE operations. Figure 6-14 summarizes the results of the Building 25 survey.

Building K1E

Contamination was found in Building K1E. Most radioactivity exceeding guidelines was of the beta-gamma type.

Floor areas were not surveyed because extensive storage of products in the building made them inaccessible. Because of the contamination found on other surfaces, the floors are also expected to have residual radioactivity above guidelines. No removable



BUILDING
25

RANGE (dpm/100 cm ²)		AVG.
REMOVABLE: α β - γ	0 — 160	19
	0 — 164	89
EXPOSURE RATES (μ R/h)	6 — 72	7

NOT TO SCALE

RANGE (dpm/100 cm ²)		AVG.
ALPHA: FLOORS WALLS CEILINGS ROOFS	6 — 13238	590
	2 — 1904	40
	7 — 72	31
	5 — 582	120
BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	43 — 620619	17000
	29 — 151718	1900
	127 — 1349	600
	28 — 2096	800

FIGURE 6-14 SURVEY RESULTS FOR BUILDING 25

contamination was found in excess of guidelines, and the average exposure rate is 48 $\mu\text{R/h}$. This exposure rate is in excess of DOE guidelines, although it should not pose a risk to SLDS employees because the building is currently uninhabited. Figure 6-15 summarizes the results of the Building K1E survey.

50 Series of Buildings

The 50 series consists of Buildings 50, 51, 51A, 52, and 52A, connected as a single unit. Most residual surface contamination was found on floors and walls. No roof areas showed residual radioactivity exceeding guidelines. The average exposure rate for the series is nearly 13 $\mu\text{R/h}$, which is below the DOE guideline. The range is 6 to 21 $\mu\text{R/h}$. No removable contamination above guidelines was detected. Figures 6-16 through 6-20 summarize the results of these building surveys.

Building 100

Surveys of Building 100 revealed contamination exceeding guidelines to be present on all measured surfaces. The average exposure rate is 6 $\mu\text{R/h}$, and no measurements for removable contamination were found to be above DOE guidelines. Figure 6-21 summarizes these results.

Building 101

Only beta-gamma measurements on floors were taken in Building 101 because it was constructed after MED/AEC operations were completed at the site. No readings exceeded DOE guidelines. The average exposure rate is 24 $\mu\text{R/h}$, which is believed to be a result of storing products containing potassium-40. Potassium-40 is a naturally occurring gamma emitter. Figure 6-22 summarizes the results of the Building 101 survey.



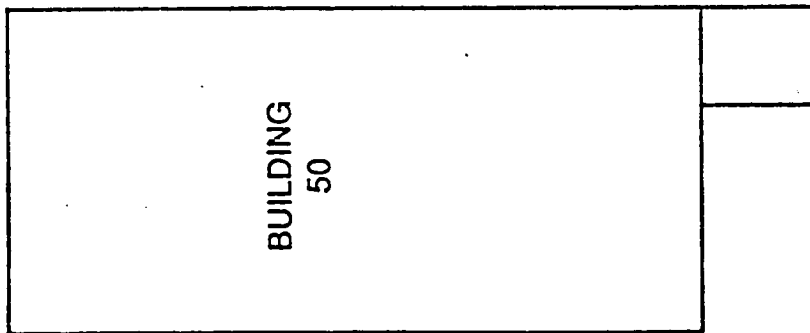
BUILDING
K1E

RANGE (dpm/100 cm ²)		AVG. (dpm/100 cm ²)
ALPHA: FLOORS WALLS CEILINGS ROOFS	NO MEASUREMENTS TAKEN	37 33 170
	7 — 91 7 — 70 6 — 1051	
BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	NO MEASUREMENTS TAKEN	2100 2600 1500
	127 — 34957 1089 — 5869 69 — 27204	

RANGE (dpm/100 cm ²)		AVG. (dpm/100 cm ²)
REMOVABLE: α β - γ	1 — 5 10 — 120	1.7 73
	EXPOSURE RATES (μ R/h)	18 — 200 48

FIGURE 6-15 SURVEY RESULTS FOR BUILDING K1E

NOT TO SCALE



BUILDING
50

RANGE		AVG.
		(dpm/100 cm ²)
ALPHA: FLOORS WALLS CEILINGS ROOFS	5 — 190	20
	6 — 621	80
	INACCESSIBLE	
	7 — 254	59
BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	43 — 43645	3200
	502 — 9024	2300
	INACCESSIBLE	
	269 — 4120	780

RANGE		AVG.
		(dpm/100 cm ²)
REMOVABLE: α	0 — 3	0
	6 — 10	6
EXPOSURE RATES (μ R/h)		

NOT TO SCALE

FIGURE 6-16 SURVEY RESULTS FOR BUILDING 50



BUILDING
51

RANGE		AVG. (dpm/100 cm ²)
ALPHA: FLOORS WALLS CEILINGS ROOFS	7 — 57	19
	6 — 2529	170
	INACCESSIBLE	
	5 — 143	33
BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	43 — 110639	3100
	43 — 268406	27000
	INACCESSIBLE	
	525 — 2750	SAME AS RANGE

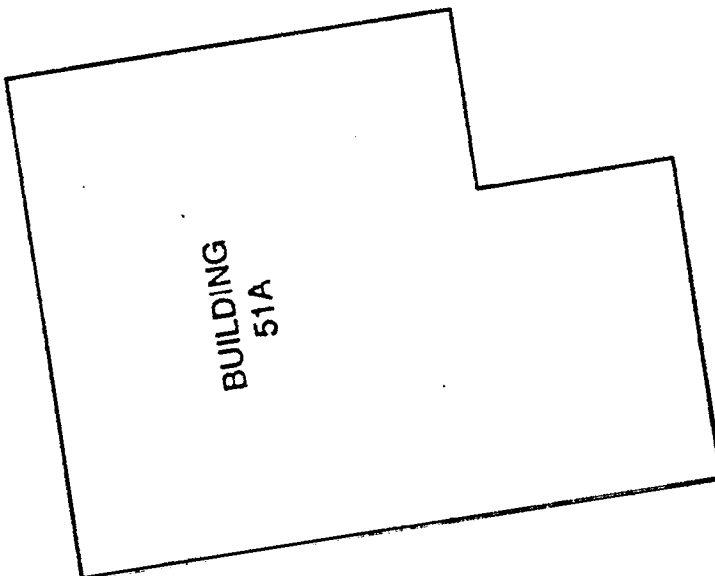
RANGE		AVG. (dpm/100 cm ²)
REMOVABLE: α EXPOSURE RATES (μ R/h)	5 — 14	10
	6 — 32	16

NOT TO SCALE

FIGURE 6-17 SURVEY RESULTS FOR BUILDING 51



I-82



RANGE (dpm/100 cm ²)		AVG.
ALPHA: FLOORS WALLS CEILINGS ROOFS	8 — 1472	130
	7 — 380 INACCESSIBLE SEE BLDG. 51	58
BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	258 — 51901 172 — 49315 INACCESSIBLE SEE BLDG. 51	2900 4500

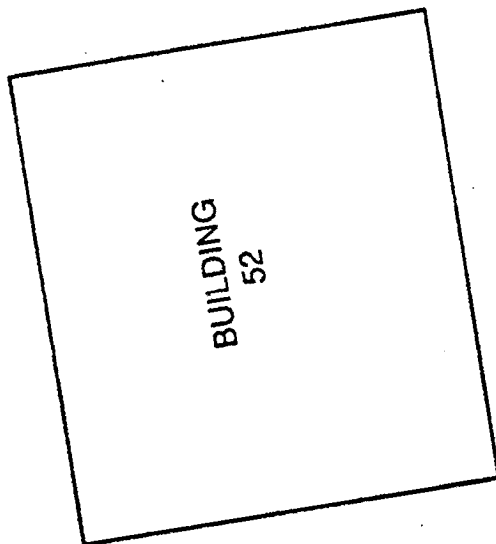
RANGE (dpm/100 cm ²)		AVG.
REMOVABLE: α	1 — 1	1
EXPOSURE RATES (μ R/h)	6 — 18	10

FIGURE 6-18 SURVEY RESULTS FOR BUILDING 51A

NOT TO SCALE



I-83



RANGE (dpm/100 cm ²)		Avg.
ALPHA: FLOORS WALLS CEILINGS ROOFS	18 — 680	85
	7 — 5397	230
	7 — 108	50
	SEE BLDG. 51	
BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	679 — 6154	2400
	172 — 98895	4200
	195 — 2106	1400
	SEE BLDG. 51	

RANGE (dpm/100 cm ²)		Avg.
REMOVABLE: α	147*	
EXPOSURE RATES (μ R/h)	8 — 34	10

*ONE MEASUREMENT ONLY

FIGURE 6-19 SURVEY RESULTS FOR BUILDING 52

NOT TO SCALE



BUILDING
52A

RANGE (dpm/100 cm ²)		AVG. (dpm/100 cm ²)
ALPHA: FLOORS WALLS CEILINGS ROOFS	INACCESSIBLE 70 — 11015 INACCESSIBLE SEE BLDG. 51	1500
BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	INACCESSIBLE 1414 — 250817 INACCESSIBLE SEE BLDG. 51	29000

RANGE (dpm/100 cm ²)		AVG. (dpm/100 cm ²)
REMOVABLE: α	139 — 183	160
EXPOSURE RATES (μ R/h)	17 — 30	21

FIGURE 6-20 SURVEY RESULTS FOR BUILDING 52A



BUILDING
100

RANGE		AVG.
		(dpm/100 cm ²)
ALPHA:		
FLOORS	48 — 3053	430
WALLS	39 — 3312	370
CEILINGS	7 — 1658	230
ROOFS	17 — 23510	6900
BETA-GAMMA:		
FLOORS	430 — 75637	16000
WALLS	525 — 30181	6200
CEILINGS	293 — 17159	3800
ROOFS	865 — 41570	25000

RANGE		AVG.
		(dpm/100 cm ²)
REMOVABLE:		
α	1 — 34	6
β - γ	2 — 149	68
EXPOSURE RATES (μ R/h)	6 — 7	6

NOT TO SCALE

FIGURE 6-21 SURVEY RESULTS FOR BUILDING 100

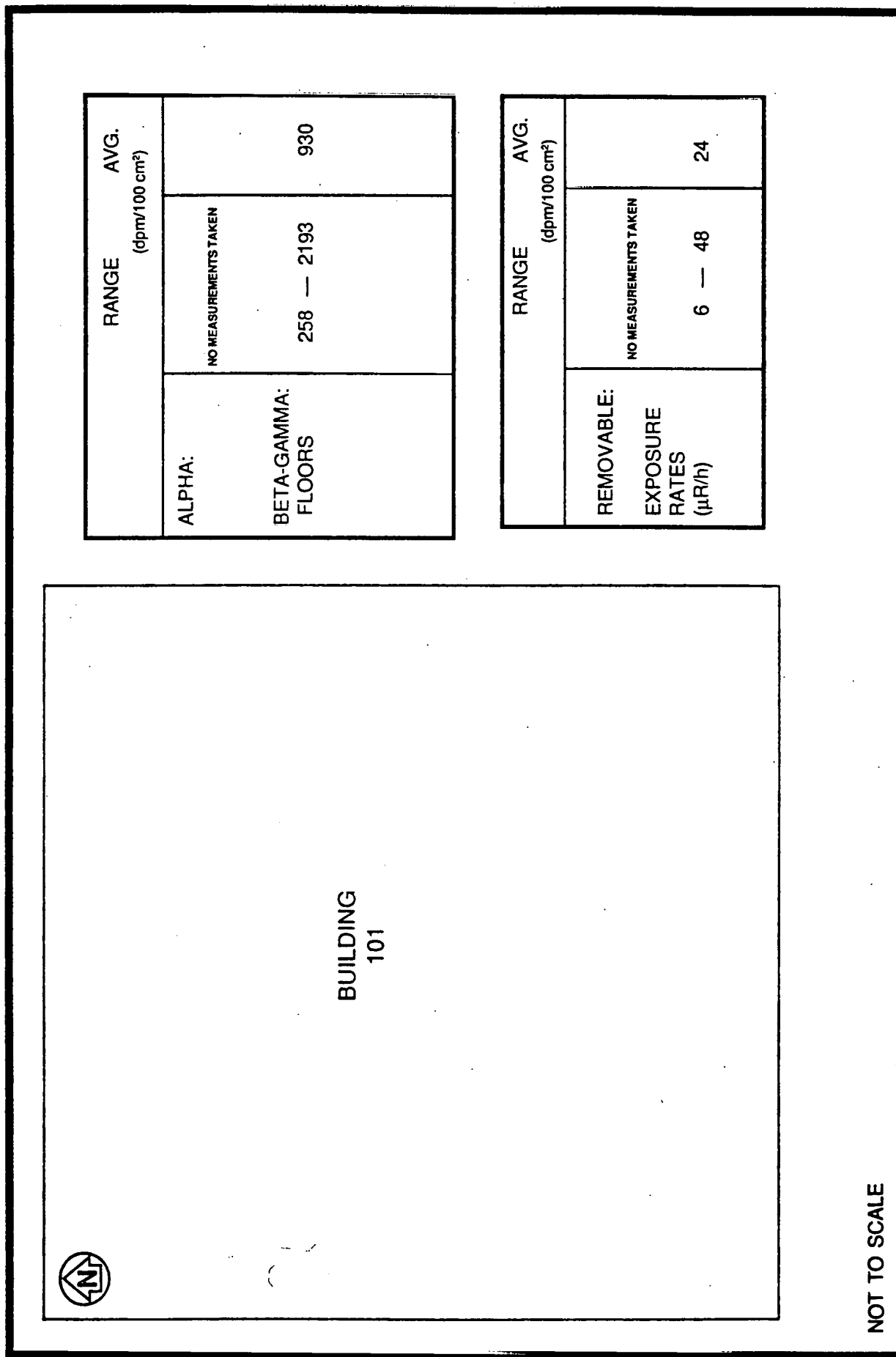


FIGURE 6-22 SURVEY RESULTS FOR BUILDING 101

116 Series of Buildings

The 116 series consists of Buildings 116, 116B, and 117. Several beta-gamma measurements in these buildings exceed DOE guidelines. However, no removable contamination in excess of average guidelines was found. The average exposure rate for the series is 7 $\mu\text{R/h}$, which is below the DOE criterion for habitable structures. Figures 6-23 through 6-25 summarize the results for these buildings.

Building 700

Several surfaces in Building 700 exceed DOE guidelines for residual beta-gamma surface contamination. The contamination is not removable and the average exposure rate is 6 $\mu\text{R/h}$. Figure 6-26 summarizes the results of the surveys conducted in Building 700.

704 Series of Buildings

The 704 series consists of Buildings 704, 705, 706, and 707. Several surfaces of these buildings have residual beta-gamma radioactivity exceeding DOE guidelines. No removable contamination was found in any of the buildings in excess of DOE guidelines. The average exposure rate for the series is 5 $\mu\text{R/h}$. Figures 6-27 through 6-30 summarize the results of each individual building survey.

Building 708

Several surfaces in Building 708 have levels of residual beta-gamma radioactivity exceeding DOE guidelines. No removable contamination exceeding guidelines was detected. The average exposure rate is 7 $\mu\text{R/h}$. Figure 6-31 summarizes the results of the survey conducted on Building 708.



BUILDING
116

RANGE (dpm/100 cm ²)		AVG. (dpm/100 cm ²)
ALPHA: FLOORS WALLS CEILINGS ROOFS	20 — 2006 5 — 2953 NO MEASUREMENTS TAKEN 14 — 9050	170 160 1300
	BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	19000 2600
150 — 929058 43 — 137041 NO MEASUREMENTS TAKEN 1200 — 81000		SAME AS RANGE

RANGE (dpm/100 cm ²)		AVG. (dpm/100 cm ²)
REMOVABLE: α EXPOSURE RATES (μ R/h)	1 — 93	6.2
	5 — 10	6

NOT TO SCALE

FIGURE 6-23 SURVEY RESULTS FOR BUILDING 116



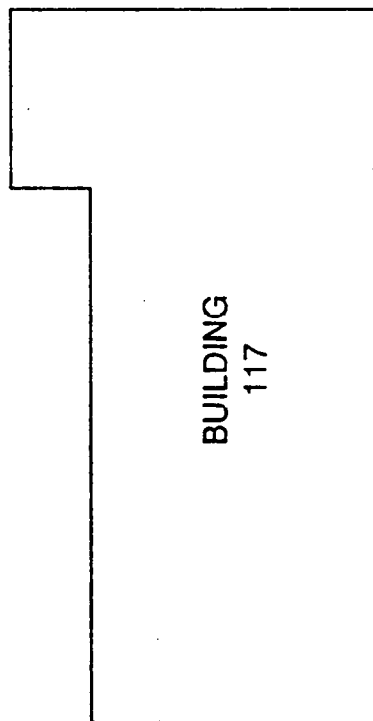
BUILDING
116B

RANGE		AVG. (dpm/100 cm ²)
ALPHA: FLOORS WALLS CEILINGS ROOFS	27 —	265
	46 —	485
	43 —	2203
	17 —	2630
BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	599 —	10234
	393 —	4928
	851 —	73721
	2600 —	6930
		3600
		1400
		13000
		SAME AS RANGE

RANGE		AVG. (dpm/100 cm ²)
REMOVABLE: α β - γ	1 —	82
	14 —	176
EXPOSURE RATES (μ R/h)		
	6 —	20
		9

NOT TO SCALE

FIGURE 6-24 SURVEY RESULTS FOR BUILDING 116B



RANGE		AVG. (dpm/100 cm ²)
ALPHA: FLOORS WALLS CEILINGS ROOFS	7 — 4596	160
	5 — 1323	120
	7 — 6447	320
	33 — 6100	1200
BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	43 — 117347	2800
	91 — 20548	1500
	361 — 98798	3900
	1370 — 35800	SAME AS RANGE

RANGE		AVG. (dpm/100 cm ²)
REMOVABLE: α	1 — 382	12
EXPOSURE RATES (μ R/h)	5 — 29	6

NOT TO SCALE

FIGURE 6-25 SURVEY RESULTS FOR BUILDING 117



BUILDING
700

RANGE		AVG.
		(dpm/100 cm ²)
ALPHA:		
FLOORS	6 — 482	37
WALLS	7 — 110	36
CEILINGS	6 — 454	55
ROOFS	116 — 1582	880
BETA-GAMMA:		
FLOORS	387 — 254775	9100
WALLS	133 — 34688	2100
CEILINGS	328 — 62483	2500
ROOFS	4931 — 6986	5900

RANGE		AVG.
		(dpm/100 cm ²)
REMOVABLE: α	1 — 11	1.7
EXPOSURE RATES (μ R/h)	5 — 13	6

NOT TO SCALE

FIGURE 6-26 SURVEY RESULTS FOR BUILDING 700



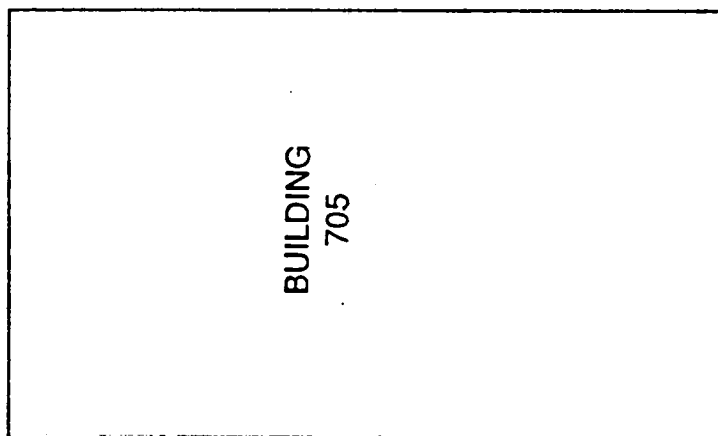
BUILDING
704

RANGE		AVG. (dpm/100 cm ²)
ALPHA: FLOORS WALLS CEILINGS ROOFS	46 — 470	140
	6 — 558	120
	6 — 190	49
	8 — 5026	1400
BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	6839 — 42322	18000
	7 — 14999	1400
	8 — 4510	1400
	915 — 25623	SAME AS RANGE

RANGE		AVG. (dpm/100 cm ²)
REMOVABLE: α EXPOSURE RATES (μ R/h)	2 — 25	10
	6 — 8	6

NOT TO SCALE

FIGURE 6-27 SURVEY RESULTS FOR BUILDING 704

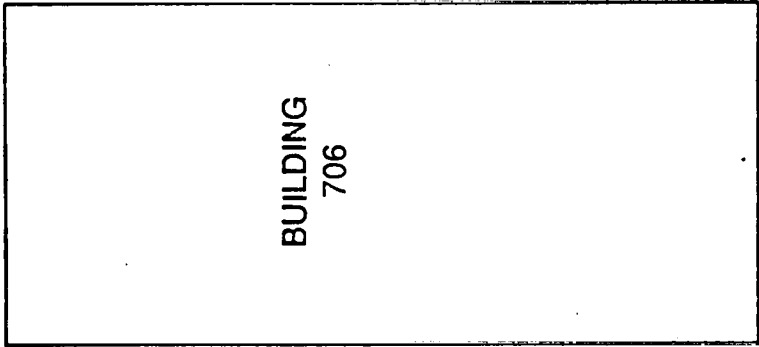


RANGE		AVG. (dpm/100 cm ²)
ALPHA: FLOORS WALLS CEILINGS ROOFS	3 — 16298	370
	3 — 16298	280
	7 — 10002	420
	101 — 4850	2200
BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	129 — 529932	17000
	49 — 217494	4200
	100 — 35833	7600
	15600 — 97900	SAME AS RANGE

RANGE		AVG. (dpm/100 cm ²)
REMOVABLE: α β - γ	1 — 235	31
	81 — 207	130
EXPOSURE RATES (μ R/h)	3 — 10	5

NOT TO SCALE

FIGURE 6-28 SURVEY RESULTS FOR BUILDING 705

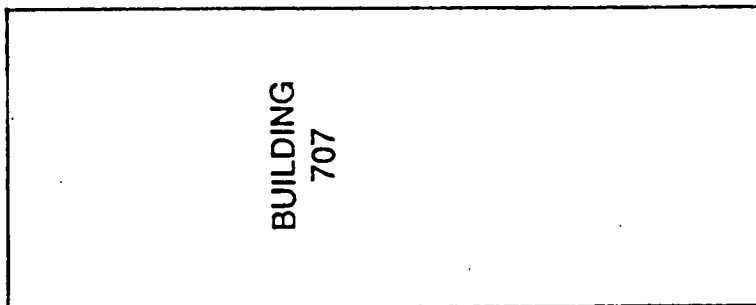


RANGE		AVG.
		(dpm/100 cm ²)
ALPHA:		
FLOORS	NO MEASUREMENTS TAKEN	
WALLS	28 — 706	220
CEILINGS	31 — 2098	380
ROOFS	659 — 2290	1300
BETA-GAMMA:		
FLOORS	215 — 150672	26000
WALLS	200 — 6968	1000
CEILINGS	40 — 26230	5400
ROOFS	1344 — 7616	SAME AS RANGE

RANGE		AVG.
		(dpm/100 cm ²)
REMOVABLE:		
α	8 — 26	17
β - γ	2 — 186	100
EXPOSURE RATES (μ R/h)	4 — 6	5

NOT TO SCALE

FIGURE 6-29 SURVEY RESULTS FOR BUILDING 706



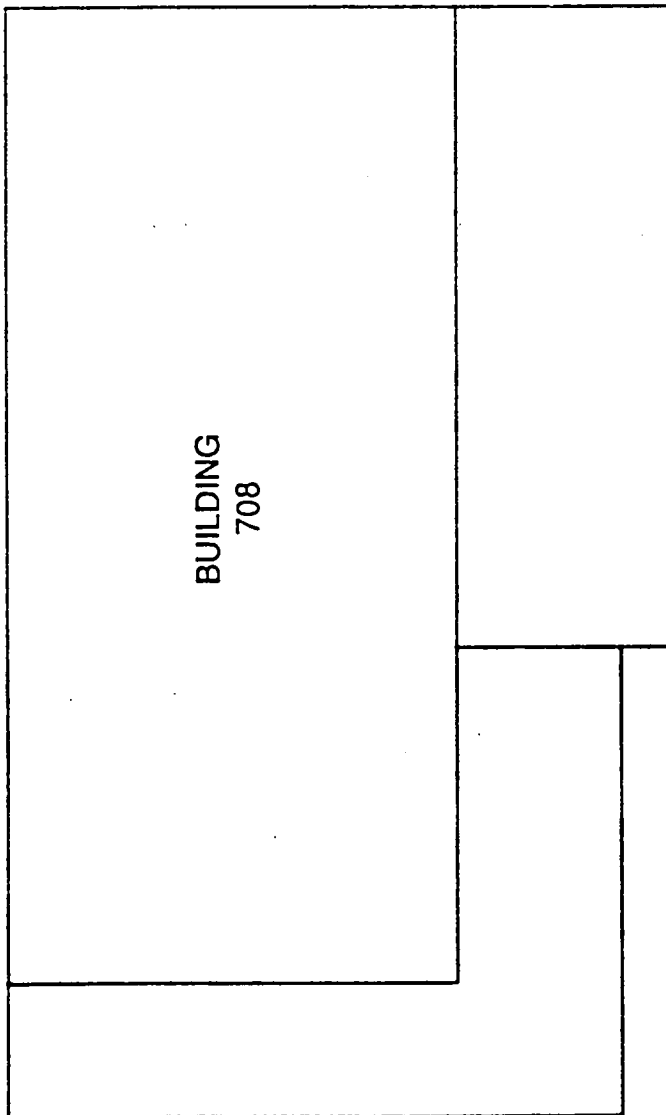
BUILDING
707

RANGE		AVG.
		(dpm/100 cm ²)
ALPHA: FLOORS WALLS CEILINGS ROOFS	20 — 186	72
	6 — 688	140
	23 — 808	350
	1154 — 2125	1600
BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	817 — 12857	5000
	25 — 6989	2600
	657 — 5917	2500
	3136 — 7616	SAME AS RANGE

RANGE		AVG.
		(dpm/100 cm ²)
REMOVABLE: α β - γ	1 — 8	4
	24 — 127	88
EXPOSURE RATES (μ R/h)	4 — 6	5

NOT TO SCALE

FIGURE 6-30 SURVEY RESULTS FOR BUILDING 707



RANGE		AVG.
		(dpm/100 cm ²)
ALPHA: FLOORS WALLS CEILINGS ROOFS	NO MEASUREMENTS TAKEN	
	7 — 514	82
	7 — 71	39
	157 — 3667	1800
BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	129 — 11825	2200
	35 — 5556	930
	575 — 1726	920
	4931 — 6986	5900

RANGE		AVG.
		(dpm/100 cm ²)
REMOVABLE: α EXPOSURE RATES (μ R/h)	1 — 9	2.3
	5 — 21	7

NOT TO SCALE

FIGURE 6-31 SURVEY RESULTS FOR BUILDING 708

Building 81

No alpha or beta-gamma readings on interior surfaces of Building 81 exceed guidelines, and no removable contamination was found in excess of guidelines. The average exposure rate is 4 μ R/h. Figure 6-32 summarizes these results.

Building 82

Building 82 surveys reveal that no residual contamination exceeding DOE guidelines exists on any building surfaces. No removable contamination in excess of DOE guidelines was detected. The average exposure rate is 6 μ R/h. Figure 6-33 summarizes the results of Building 82 surveys.

The roofs of several buildings in Plant 1 were surveyed to determine whether radioactivity exceeding guidelines existed on these surfaces. The surveyed buildings are shown in Figure 6-34. None of these building roofs had residual radioactivity above DOE guidelines. This subset of roofs in Plant 1 was chosen because of their proximity to MED/AEC process buildings and predominant wind directions.

The interiors of four additional buildings, and the roofs of three of these buildings, in Plant 2 were surveyed to determine whether levels of radioactivity on structural surfaces exceeded DOE guidelines (see Figure 6-35). No surfaces in these buildings revealed residual radioactivity in excess of DOE guidelines.

In each building, samples were collected, if available, from areas of surface deposit buildup such as dirt, dust, paint chips, and plaster. The results of these sample analyses are provided in Table 6-10 (Volume II). These results show that many of the buildings contain residual materials with radionuclide



BUILDING
81

RANGE		AVG.
		(dpm/100 cm ²)
ALPHA: FLOORS WALLS CEILINGS ROOFS	6 — 39	21
	7 — 52	26
	7 — 39	25
	70 — 573	320
BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	43 — 43	43
	105 — 740	430
	14 — 378	270
	443 — 2877	1000

RANGE		AVG.
		(dpm/100 cm ²)
REMOVABLE: α	2 — 7	4
EXPOSURE RATES (μ R/h)	2 — 6	4

NOT TO SCALE

FIGURE 6-32 SURVEY RESULTS FOR BUILDING 81



BUILDING
82

RANGE		AVG. (dpm/100 cm ²)
ALPHA: FLOORS WALLS CEILINGS ROOFS	6 — 52	27
	7 — 730	35
	NO MEASUREMENTS TAKEN	
	7 — 1364	570
BETA-GAMMA: FLOORS WALLS CEILINGS ROOFS	43 — 2107	92
	51 — 2835	840
	NO MEASUREMENTS TAKEN	
	866 — 2165	1400

RANGE		AVG. (dpm/100 cm ²)
REMOVABLE: α	2 — 5	2.2
	6 — 10	6

NOT TO SCALE

FIGURE 6-33 SURVEY RESULTS FOR BUILDING 82

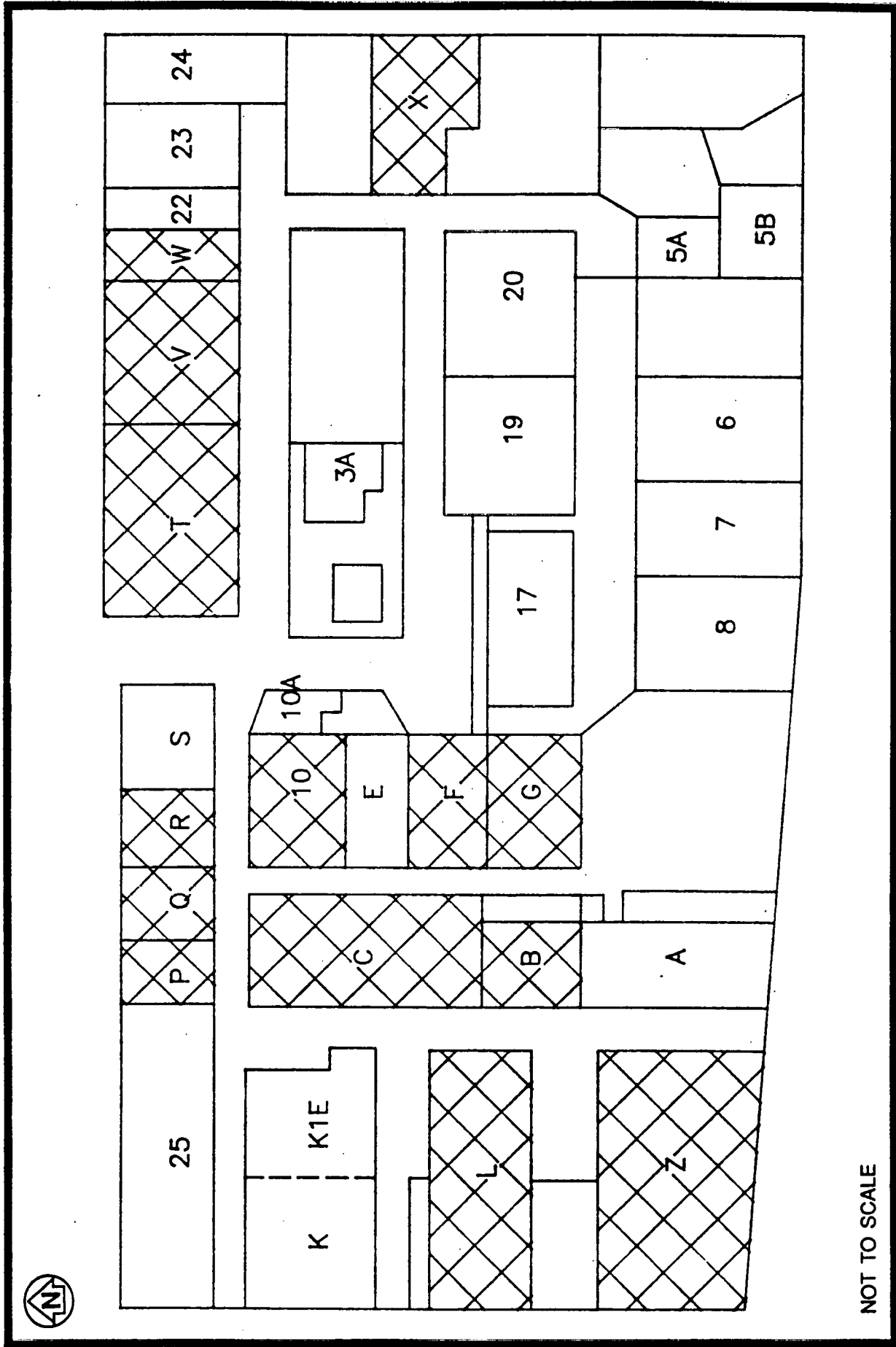


FIGURE 6-34 LOCATIONS OF ADDITIONAL ROOF SURVEYS AT PLANT 1

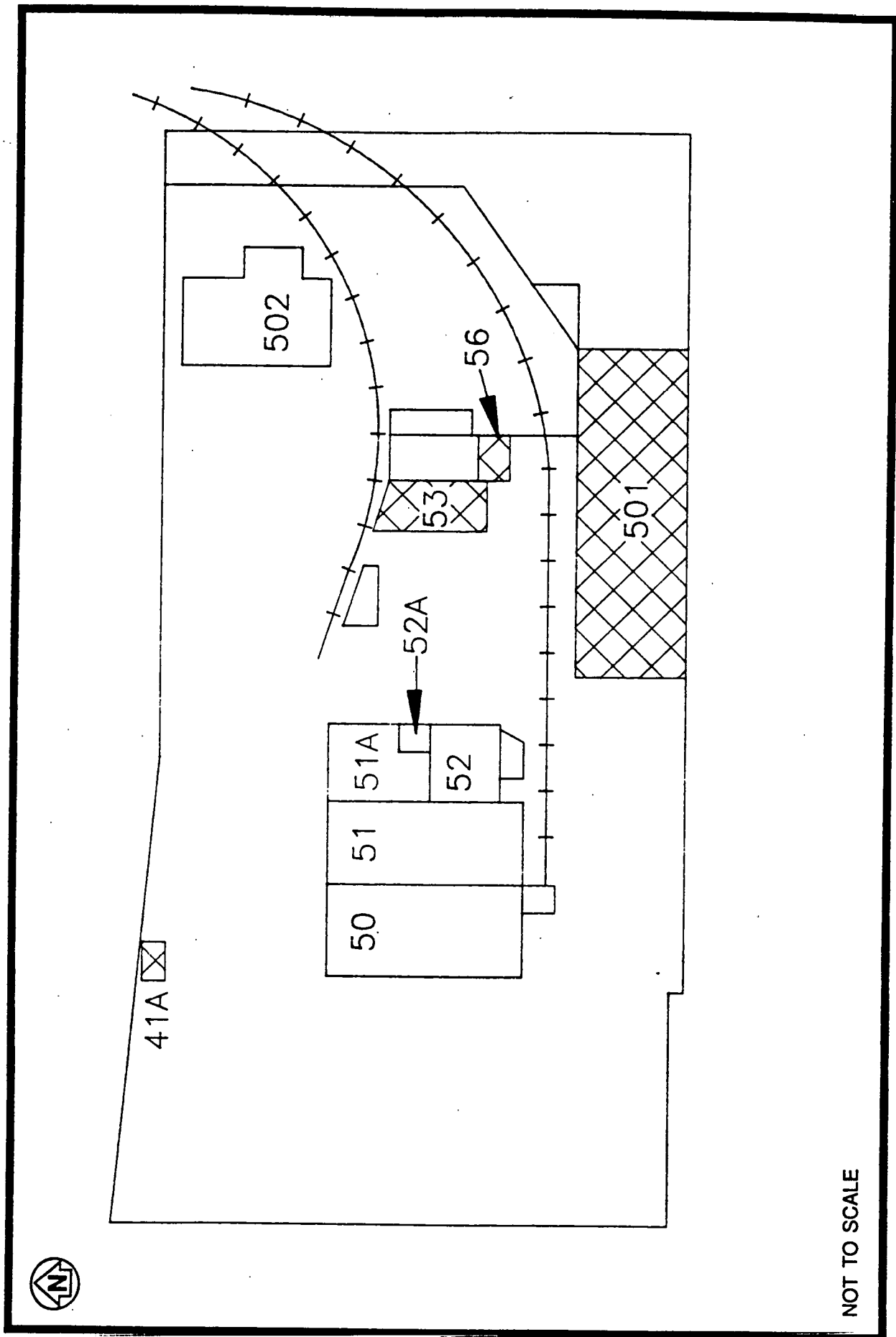


FIGURE 6-35 LOCATIONS OF ADDITIONAL ROOF SURVEYS AT PLANT 2

concentrations well in excess of DOE guidelines. These sample results aided in determining which DOE surface structure criteria would be applicable at SLDS as major contaminants were identified.

The additional roof surveys revealed that some of the adjacent buildings have residual radioactive contamination exceeding DOE guidelines. In all cases, all roofs had direct alpha measurements that were below guidelines; only a few readings on each building were above guidelines for direct beta-gamma contamination.

6.2 CHEMICAL RESULTS

This section discusses the chemical characterization results and their significance.

6.2.1 Background

Several factors were considered in the design of the chemical characterization program. First, no chemical characterization data were available on which the FUSRAP characterization efforts could be based. Second, the site has been used for chemical production and packaging since the mid-1800s. In addition, the site is located in a heavily industrialized area. Given these facts, it was understood that chemicals could be present that were independent of FUSRAP-related uranium processing activities. Third, substantial development has taken place at the site since the early 1940s. This development would certainly have affected, to some degree, the distribution of chemicals present in soil across the site. For these reasons, the chemical characterization did not focus on a limited number of compounds at isolated locations. Rather, analyses for a wide range of chemical compounds in broad chemical groups were conducted on samples collected from numerous locations known to be radioactively contaminated. Based on results of this investigation, no materials are expected to require management as hazardous or mixed wastes.

6.2.2 Soil

Chemical characterization of soil at the site was completed in two phases. Figure 6-36 shows chemical borehole locations. The objective of Phase I was to determine the presence or absence of chemicals and a general indication of chemical distribution in relation to the radioactive constituents known to be present at the site. To satisfy these objectives, 58 samples were composited for analysis of metals, BNAEs, and RCRA characteristics, and 40 discrete samples were analyzed for volatile organics. (Table 5-1 indicates sample locations, intervals over which composite samples were collected, and depths from which discrete samples were collected.)

The objective of Phase II was to gain additional information concerning the presence of metals associated with the radioactively contaminated materials. To satisfy this objective, discrete samples were submitted for analysis of metals and RCRA characteristics. One hundred thirty-two samples were submitted for analysis; only seven of these were composites. (Table 5-2 indicates locations and depths from which samples were collected.)

Metals

The results for metals from site soils collected during both phases of characterization were compared with a range of background metal concentrations for soil [see Table 6-11 (Volume II) and Ref. 9]. The values shown in this table represent a range of average concentrations for metals in soils at various locations in the United States. The highest value of this range (or the maximum expected background value from undisturbed sites) was compared with the sample results as an indication of potential metal contamination. These results are summarized in Tables 6-12 (Phase I) and 6-13 (Phase II). Each table lists the metals found

at levels exceeding maximum expected background, range of values (i.e., minimum and maximum), mean, total number of samples analyzed, number of samples above maximum expected background, and sample detection limit. The last column in Tables 6-12 and 6-13 is presented because, in some instances, the reported sample detection limit was greater than the maximum expected background. Only samples with values exceeding the sample detection limit and the maximum expected background value are included in the last column of these tables.

As indicated in Table 6-12, 14 metals exceeded the maximum expected background values from composite samples collected during Phase I. These metals are antimony, arsenic, barium, boron, cadmium, copper, lead, magnesium, mercury, molybdenum, silver, selenium, thallium, and zinc. In general, these metals compared favorably with those found in discrete samples collected in Phase II; the differences were the presence of chromium, cobalt, and manganese (at levels exceeding maximum expected background concentrations) in Phase II while absent in Phase I. The presence of chromium, cobalt, and manganese in Phase II result is probably insignificant because they occurred at levels exceeding maximum expected background concentrations in very low frequency (i.e., less than 2 percent of the total samples analyzed).

The metals that exceeded the maximum expected background concentrations with the greatest frequency in discrete samples were thallium, selenium, cadmium, lead, and zinc. These metals (with the exception of thallium) are commonly found in some uranium ore deposits and would be expected to be present, given that uranium ores were processed at the site. These same metals, with thallium, are also found in coal and fly ash from coal combustion (Ref. 9). Other metals commonly associated with uranium ores, including molybdenum, chromium, cobalt, and magnesium, did not occur frequently in elevated concentrations. Some metal compounds

TABLE 6-12
SUMMARY STATISTICS FOR METAL CONTAMINANTS AT SLDS - PHASE I

Metal	Concentration (ppm) ^a			Number of Samples		
	Mean ^b	Min.	Max.	Analyzed	Above Background	Above Background and SDL ^c
Antimony	83.1	10.9	3,190	58	58	26
Arsenic	37.8	16.1	96.2	58	23	23
Barium	388	57.7	5,220	58	1	1
Boron	64.3	17.6	253	58	12	12
Cadmium	3.6	0.88	44.1	58	58	44
Copper	106	27.4	617	58	21	21
Lead	1,460	46.2	32,300	58	36	36
Magnesium	3,310	916	17,500	58	4	4
Mercury	3.5	0.12	37.9	58	54	54
Molybdenum	21.6	16.1	35.7	58	58	10
Silver	6.3	1.8	49.7	58	22	22
Selenium	28.3	16.1	253	58	58	9
Thallium	39.3	16.1	234	58	58	16
Zinc	421	38.6	1,530	58	31	31

^aMaximum and minimum values include results reported below background values.

^bAll values, including those reported as the sample detection limit, were used to calculate the mean.

^cSample detection limit.

TABLE 6-13
SUMMARY STATISTICS FOR METAL CONTAMINANTS AT SLDS - PHASE II

Metal	Concentration (ppm) ^a			Number of Samples		
	Mean ^b	Min.	Max.	Analyzed	Above Background	Above Background and SDL ^c
Antimony	33.8	9.3	385	126	125	31
Arsenic	32.0	15.6	200	126	23	22
Barium	321	31.1	7,670	126	2	2
Boron	44.3	15.6	229	126	12	11
Cadmium	1.7	0.78	18.4	126	126	39
Chromium	57.0	4.3	4,400	126	1	1
Cobalt	13.7	7.8	231	126	2	1
Copper	74.6	6.4	1,120	126	21	21
Lead	276	17.1	8,340	126	34	34
Magnesium	4,490	778	44,500	126	20	20
Manganese	544	25.1	5,200	126	2	2
Molybdenum	23.2	15.6	200	126	126	0
Selenium	104	16.3	1,330	126	126	78
Silver	5.7	1.6	159	126	21	20
Sodium	1,230	778	10,000	126	1	1
Thallium	41.9	18.2	318	126	126	79
Zinc	370	29.9	11,300	126	34	34

^aMaximum and minimum values include results reported below background values.

^bAll values, including those reported as the sample detection limit, were used to calculate the mean.

^cSample detection limit.

known to have been used during uranium processing at the site occurred infrequently and in low concentrations. Barium as barium carbonate, for example, was used to precipitate radium and sulfate during processing. However, barium exceeded maximum expected background concentrations in only 2 of 126 samples collected during Phase II.

The vertical distribution of metals in soil is presented in Tables 6-14 (Phase I) (Volume II) and 6-15 (Phase II) (Volume II). These tables identify the boreholes, depths, and metals that exceeded the maximum expected background values. Because of sample characteristics, actual concentrations for some metals were not measurable and are so noted. The results reported for these metals are the sample detection limit.

Each of the borings completed during Phase I and Phase II contained metals at levels that exceeded maximum expected background concentrations. In general, most metals exceeding these concentrations were found at depths less than 1.8 m (6 ft). Selenium and thallium appear to be the exception and, as indicated in Table 6-15 (Volume II), appear at levels that exceed maximum expected background concentrations at depths as great as 5.5-6.1 m (18-20 ft) (boring C-137 in Plant 7).

Volatile Organics

Forty samples were collected for volatile organics analysis from each of 23 boreholes drilled during Phase I.

Thirteen compounds were detected in 20 of the boreholes from which samples were collected. Volatile organics were not detected in the other three boreholes (C02, C08, and C42). A summary of the data is provided in Table 6-16, which identifies the compounds detected,

TABLE 6-16
SUMMARY STATISTICS FOR VOLATILE ORGANICS DETECTED IN SOIL
AT SLDS - PHASE I

Compound	Number of Samples	Number of Samples in Which Compound Was Detected	Concentration (ppb ^a)		
			Min.	Max.	Mean
Benzene	40	3	2.2	16	9.3
Carbon tetrachloride	40	1	4.9	4.9	4.9
Chlorobenzene	40	1	4.5	4.5	4.5
Chloroform	40	12	1	62	12
1,1-dichloroethane	40	3	2.2	5.5	4.3
Ethylbenzene	40	4	1	3.6	2.0
Methylene chloride	40	11	4.1	77	14
Toluene	40	31	1.2	340	43
Total xylenes	40	10	1.5	66	11
1,1,1-trichloroethane	40	4	1.4	47	14
Trichloroethene	40	8	1.4	430	73
Trichlorofluoromethane	40	12	1.8	70	10
Trans-1,2-dichloroethene	40	1	6.4	6.4	6.4

^aParts per billion.

the number of samples in which the compound was detected, the range in concentration (i.e., minimum and maximum values), and mean concentrations.

The actual data are provided in Table 6-17 (Volume II), which identifies the compounds and the concentrations at which they were detected in each borehole. As indicated in Table 6-16, toluene occurred with the greatest frequency of the compounds detected (31 of 40 samples). Chloroform and trichlorofluormethane occurred in the next highest frequency (12 of 40 samples), followed by methylene chloride (11 of 40 samples). Chlorobenzene, trans-1,2-dichloroethene, and carbon tetrachloride were detected in only one sample.

In general, the concentrations of the compounds detected were low, with mean concentrations in the low parts per billion (2.0 to 73 ppb). Trichloroethene exhibited the highest concentration (430 ppb, with a mean value of 73 ppb). Toluene occurred in the next highest concentration, with a maximum of 340 ppb and a mean value of 43 ppb, followed by methylene chloride, with a maximum of 77 ppb and a mean value of 36.1 ppb. The remaining compounds all had mean concentrations less than 20 ppb. Volatile organics analyses were not conducted on soil samples collected in Phase II. This decision was based on the following:

- The low average concentrations of volatile organics detected in Phase I
- The fact that none of the compounds detected in Phase I is believed to have been associated with uranium processing at the plant
- The objectives of the chemical characterization were met in that the results indicated which volatile organics could be associated with radioactively contaminated soil

BNAEs

One composite sample for BNAE analysis was collected and analyzed from 56 of the 109 boreholes drilled during Phase I. (The boreholes and depths over which the soil was composited for analyses are indicated in Table 5-1.)

Twenty-seven BNAE compounds were detected, occurring in most of the boreholes sampled (52 of 56). All but 9 of the 27 compounds detected were polynuclear aromatic hydrocarbons (PAHs), which are typically found in coal, coal products, or coal breakdown residues (Ref. 24). A summary of the data is provided in Table 6-18, which identifies the compounds detected, the number of samples collected, the number of samples in which the compound was detected, the range in concentration (i.e., minimum and maximum values), and mean concentrations. The actual data are provided in Table 6-19 (Volume II), which identifies the compounds detected in each borehole. As indicated in Table 6-18, pyrene occurred with the greatest frequency of the compounds detected (52 of 56 samples). Fluoranthene and phenanthrene occurred in the next highest frequencies (50 and 49 of 56 samples, respectively), followed by benzo(a)anthracene, chrysene, benzo(b)fluoranthene, and benzo(a)pyrene (48, 47, 40, and 40 of 56 samples, respectively).

The compounds identified above are PAHs, which typically contain three or more linked benzene rings. The PAHs that occurred with the greatest frequency at the site are those associated with coal combustion residues (see Ref. 24). The origin of these PAHs is thought to be related to the chemical makeup of coal. Coal is composed of minerals and macerals; minerals derive from inorganic inclusions in coal and macerals derive from organic plant matter. Macerals decompose to desirable organic fuel compounds but also to some less desirable compounds such as PAHs.

TABLE 6-18
SUMMARY STATISTICS FOR BNAEs DETECTED IN SOIL
AT SLDS - PHASE I

Compound	Number of Samples	Number of Samples in Which Compound Was Detected	Concentration (ppb ^a)		
			Min.	Max.	Mean
2,4-dimethylphenol	56	2	2,600	5,500	4,050
Phenol	56	1	5,700	5,700	5,700
Acenaphthylene	56	9	450	4,200	1,600
Anthracene	56	34	420	84,000	4,700
Benzyl alcohol	56	1	7,000	7,000	7,000
Benzo(a)anthracene	56	48	400	34,000	4,300
Benzo(a)pyrene	56	40	400	110,000	5,400
Benzo(g,h,i)perylene	56	18	540	6,400	2,400
Benzo(k)fluoranthene	56	31	540	94,000	6,300
Benzo(b)fluoranthene	56	40	510	78,000	5,400
Bis(2-ethylhexyl)phthalate	56	11	310	1,600	820
Chrysene	56	47	430	110,000	6,700
Dibenzo(a,h)anthracene	56	6	440	3,900	1,600
Dibenzofuran	56	17	400	11,000	1,900
Fluoranthene	56	50	410	300,000	14,900
Fluorene	56	16	500	15,000	2,700
Hexachlorobutadiene	56	1	1,900	1,900	1,900
Indeno(1,2,3-cd)pyrene	56	25	430	12,000	2,600
2-methylnaphthalene	56	10	410	8,600	1,600
Naphthalene	56	12	460	32,000	3,600
Phenanthrene	56	49	520	280,000	14,600
Pyrene	56	52	500	63,000	7,300
Acenaphthene	56	19	400	7,400	1,700
Di-n-butyl phthalate	56	2	410	760	585
2-chlorophenol	56	1	660	660	660
4-methylphenol	56	1	3,200	3,200	3,200
4-chloro-3-methylphenol	56	1	880	880	880

^aParts per billion.

PAHs other than those identified above were detected with less frequency. Nine non-PAHs were detected; however, six of the nine were detected in only one sample. These compounds were phenol, benzyl alcohol, hexachlorobutadiene, 2-chlorophenol, 4-methylphenol, and 4-chloro-3-methylphenol. Bis(2-ethylhexyl) phthalate was detected in 11 samples. Di-n-butyl phthalate and 2,4-dimethylphenol were detected in two samples.

In general, the concentrations of BNAE compounds detected were higher than those of the volatile organic compounds observed at the site, with mean concentrations ranging from 660 to 14,900 ppb. Of the PAHs, fluoranthene exhibited the highest concentration (300,000 ppb with a mean value of 14,900 ppb). Phenanthrene, benzo(a)pyrene, and chrysene occurred in the next highest concentrations, with maximum values of 280,000, 110,000, and 110,000 ppb, respectively, and mean values of 14,600, 5,400, and 6,700 ppb, respectively. Phenol, 2-chlorophenol, 4-methylphenol, benzyl alcohol, 4-chloro-3-methylphenol, and hexachlorobutadiene, each occurring in one sample, had concentrations of 5,700, 660, 3,200, 27,000, 880, and 1,900 ppb, respectively. Bis(2-ethylhexyl) phthalate had a maximum concentration of 1,600 ppb and a mean concentration of 820 ppb. 2,4-dimethylphenol had a maximum concentration of 5,500 ppb and a mean concentration of 4,050 ppb.

No pattern of BNAE distribution in soil was discernible across the site; these compounds appear to be evenly distributed. Borings in which semivolatiles were observed in the highest concentrations were widely spaced across the site in Plants 1, 7W, and 10.

The potential for migration of PAHs from site soil to surface water or groundwater is minimal because these compounds exhibit strong tendencies to partition to the soil and will not readily leach into the water phase. This can be determined by examining the organic carbon partition coefficient (K_{oc}) values for these compounds. The K_{oc} is a compound-specific parameter that defines the linear

relationship between the liquid phase concentration and the mass of chemical adsorbed by the organic carbon in the solid phase. Using an estimate of 2 percent by weight for the organic carbon in soil (Ref. 24) and by knowing the concentration of chemical in soil and the coefficient K_{oc} , it is possible to calculate the expected chemical concentration for the water phase that would result from the contact of water with the compound in the soil. For example: for benzo(a)pyrene with $K_{oc} = 5,550,000$, concentration in soil (K_p) = 110,000 (i.e., for $K_p = 5,550,000 \times 2\%$ carbon, the concentration of benzo(a)pyrene in the soil would have to be 110,000 ppb to produce a leachate with concentration equal to 1 ppb). The low mobility of these compounds is also supported by site groundwater sampling results since PAHs were not detected. BNAE analyses were not conducted on soil samples collected in Phase II for the same reasons identified for volatile organics. Table 6-20 summarizes the organic compounds found at the site and provides the maximum concentration of each and the location where it was detected.

RCRA-Hazardous Waste Characteristics

Composite samples from each borehole completed during Phase I were submitted for RCRA-hazardous waste characteristics testing. As discussed in Subsection 5.3.2, these tests include ignitability, corrosivity, reactivity, and EP toxicity. Results indicated that, with the exception of three boreholes, soil did not fail the characteristics tests. Soil from boreholes B16C02, B16C30, and B16C37 failed the EP toxicity test for lead with values of 20,900, 6,250, and 18,700 $\mu\text{g/L}$, respectively. Borehole B16C02 is located at the western side of Plant 1; B16C30 and B16C37 are located at the north and south sides of the Plant 6/6E area.

Discrete samples were collected for RCRA characteristics testing during Phase II of the characterization. None of the samples collected during Phase II failed the characteristics tests.

TABLE 6-20
MAXIMUM CONCENTRATION, LOCATION, AND NUMBER OF SAMPLES CONTAMINATED
WITH VOLATILE AND BNAE COMPOUNDS - PHASE I

Page 1 of 2

Compound	No. of Samples in Which Compound Was Detected	Maximum Concentration (ppb)	Location	Depth (ft)
1,1,1-trichloroethane	4	47	B16C33	6-7
1,1-dichloroethane	3	5.5	B16C33	7-8
2,4-dimethylphenol	2	5,500	B16C50	0-13.5
2-methylnaphthalene	10	8,600	B16C50	0-13.5
Acenaphthene	19	7,400	B16C50	0-13.5
Acenaphthylene	9	4,200	B16C51	0-15.5
Anthracene	34	84,000	B16C51	0-15.5
Benzene	3	16	B16C13	7-8
Benzo(a)anthracene	48	34,000	B16C42	0-16.5
Benzo(a)pyrene	40	110,000	B16C51	0-15.5
Benzo(b)fluoranthene	40	78,000	B16C51	0-15.5
Benzo(g,h,i)perylene	18	6,400	B16C51	0-15.5
Benzo(k)fluoranthene	31	94,000	B16C51	0-15.5
Benzyl alcohol	1	7,000	B16C50	0-13.5
Bis(2-ethylhexyl)phthalate	11	1,600	B16C24	0.5-8.33
Carbon tetrachloride	1	4.9	B16C21	6-7
Chlorobenzene	1	4.5	B16C16	6.5-8
Chloroform	12	62	B16C33	7-8
Chrysene	47	110,000	B16C51	0-15.5
Dibenz(a,h)anthracene	6	3,900	B16C50	0-13.5
Dibenzofuran	17	11,000	B16C50	0-13.5
Di-n-butyl phthalate	2	760	B16C37	1-12.5
Ethylbenzene	4	3.6	B16C13	6-7
Fluoranthene	50	309,000	B16C51	0-15.5
Fluorene	16	15,000	B16C51	0-15.5
Hexachlorobutadiene	1	1,900	B16C08	0-8.58
Indeno(1,2,3-cd)pyrene	25	12,000	B16C57	0.5-6.33
Methylene chloride	11	77	B16C28	9-10
Naphthalene	12	32,000	B16C50	0-13.5
2-chlorophenol	1	660	B16C50	0-13.5
4-methylphenol	1	3,200	B16C50	0-13.5

TABLE 6-20

(continued)

Page 2 of 2

Compound	No. of Samples in Which Compound Was Detected	Maximum Concentration (ppb)	Location	Depth (ft)
4-chloro-3-methylphenol	1	880	B16C50	0-13.5
Phenanthrene	49	280,000	B16C51	0-15.5
Phenol	1	5,700	B16C50	0-13.5
Pyrene	52	63,000	B16C42	0-16.5
Toluene	31	340	B16C28	8-9
Total xylenes	10	66	B16C13	7-8
Trans-1,2-dichloroethene	1	6.4	B16C16	6.5-8
Trichloroethene	8	430	B16C28	8-9
Trichlorofluoromethane	12	70	B16C16	6.5-8

The results indicate that a few very small, isolated areas exist on the site where soil fails the hazardous waste criterion for EP toxicity-lead. This does not imply that these materials will need to be managed as hazardous wastes when excavated. Current extraction procedure regulations allow averaging of analytical results obtained from a waste matrix. Because the observed excesses of the lead criterion are isolated, it is likely that the average values for these areas are below applicable regulatory criteria. It is anticipated that during remedial action, enough of the surrounding soil will be collected with the areas of EP toxicity-lead that the toxicity will be diluted such that the materials will not require management as hazardous or mixed wastes.

6.2.3 Groundwater

Groundwater monitoring for chemical indicator parameters (pH, specific conductance, TOX, and TOC) was conducted for four quarters to reveal possible changes in the inorganic and organic composition of the groundwater. Analytical results are shown in Table 6-21. Fluoride and nitrate samples were collected and analyzed for one quarter.

Ten organic compounds were detected in the wells at SLDS. Benzene was most frequently found (6 of 24 samples); followed by 1,2-dichlorobenzene, 1,2-dichloroethene, and 1,2-dichloropropane, each detected in 3 of 24 samples; and chlorobenzene, bis(2-ethylhexyl)phthalate, aroclor-1254, and vinyl chloride, each detected in 2 of 24 samples.

Bis(2-ethylhexyl)phthalate, detected at 1,100 and 340 $\mu\text{g/L}$, was found at the highest concentrations. Bis(2-ethylhexyl)phthalate was, however, also detected in the blanks associated with the samples at low concentrations. The presence of the bis(2-ethylhexyl)phthalate is probably a laboratory artifact, since the compound was detected in the blank and was not present in the

TABLE 6-21
RANGES OF WATER QUALITY PARAMETERS IN GROUNDWATER AT SLDS

Sampling Location (Well No.) ^c	Parameter ^{a,b}					
	pH (Standard Units)	Total Organic Carbon (mg/L)	Total Organic Halides (µg/L)	Specific Conductance (µmhos/cm)	Fluoride ^d (mg/L)	Nitrates ^d (mg/L)
B16W01S	7.3-7.4	6.5-36.8	19-58	231-1220	0.15	<0.10
B16W02S	6.9-7.0	5.9-7.7	<10- <20	1060-1200	0.48	<0.10
B16W03S	6.9-7.8	12.9-24.2	83-690	1770-9820	6.2	<0.10
B16W04S	7.0-7.7	2.5-7.4	<10-68	896-1050	0.47	0.21
B16W05D	7.0	9.8-26.0	13-450	2480-2780	e	e
B16W06D	6.7-6.9	9.7-11.0	20-520	2150-3470	0.21	<0.10
B16W07D	6.8-6.9	5.1-83.6	<10-51	2150-2950	0.30	<0.10
B16W08D	6.8-7.9	6.8-11.8	<10-78	2210-8030	0.28	<0.10

^aThe "<" symbol indicates that the method did not detect the presence of the analyte above the detection limit.

^bA single value represents the same value for all quarters sampled.

^cMonitoring well locations are shown in Figure 6-13.

^dFluorides and nitrates were sampled for one quarter.

^eSample lost.

following quarter's monitoring results. 1,2-dichloropropane was detected in the next highest concentration, 150 $\mu\text{g/L}$. 1,2-dichloropropane was detected in the third highest concentration at 130 $\mu\text{g/L}$. 1,2-dichlorobenzene was detected in the fourth highest concentration at 93, 92, and 87 $\mu\text{g/L}$. All other volatile organics were found at concentrations less than 50 $\mu\text{g/L}$. 4,4'DDT, a pesticide, and aroclor-1254 were detected in 1 and 2 samples, respectively. Maximum concentrations were low; 4,4'DDT was found at 0.98 $\mu\text{g/L}$ and aroclor-1254 was detected at 1.5 $\mu\text{g/L}$.

Methylene chloride and acetone were also detected in samples of groundwater, but the compounds' presence at similar levels in the blanks would imply that they are laboratory artifacts. For this reason they are not included in the summary tables.

Also detected as a tentatively identified compound (TIC) was diethyl ether. This is of significance because it was a material believed to have been used in uranium processing at SLDS. As a TIC the confidence of the presence of the compound in the samples is high. However, there is less confidence in the reported concentration because assumptions have to be made concerning its behavior compared with the behavior of the internal standard used.

Table 6-22 is a one-year summary of organics detected at SLDS. Listed in the table are the compounds found, range of values (minimum and maximum), mean, total number of samples analyzed, and number of samples above the detection limit. Table 6-23 lists the results for organics analyses for each well.

The majority of the groundwater contaminants appear consistently in well B16W03S, with seven of the ten organic compounds detected in samples from the well. Also, of the 25 positive values detected for all samples, 17 were from well B16W03S.

TABLE 6-22

SUMMARY STATISTICS FOR VOLATILE ORGANICS, BNAES,
AND PESTICIDE/PCB COMPOUNDS DETECTED IN GROUNDWATER AT SLDS

Compound	Concentration ($\mu\text{g/L}$)		Analyzed	Number of Samples	
	Mean ^a	Max.		Above	Detection Limit
<u>Volatile organics</u>					
Benzene	8	< 5	24		6
Chlorobenzene	5	< 5	24		2
1,2-dichloroethene	12	< 5	24		3
1,2-dichloropropane	13	< 5	24		3
Trichloroethene	5	< 5	24		1
Vinyl chloride	11	<10	24		2
<u>BNAES</u>					
1,2-dichlorobenzene	20	<10	24		3
Bis(2-ethylhexyl) phthalate	69	<10	24		2
<u>Pesticides/PCBs</u>					
4,4'-DDT	0.17	< 0.10	24		1
Aroclor-1254	1.6	< 1.0	24		2

^aAll values, including those reported as sample detection limit, were used to calculate the mean.

TABLE 6-23
RANGES OF VOLATILE ORGANICS, BNAEs,
AND PESTICIDES/PCBs DETECTED IN
GROUNDWATER AT SLDS^a

Compound	Sampling Location (Well No.) ^{b,c,d}							
	B16W01S	B16W02S	B16W03S	B16W04S	B16W05D	B16W06D	B16W07D	B16W08D
<u>Volatile organic compounds (µg/L)</u>								
Benzene	ND	6	18-21	21	ND	9	ND	ND
Chlorobenzene	ND	ND	7-8	ND	ND	ND	ND	ND
1,2-dichloroethene	ND	ND	7-150	ND	ND	ND	ND	ND
1,2-dichloropropane	ND	ND	29-130	ND	ND	ND	ND	ND
Trichloroethylene	ND	ND	5	ND	ND	ND	ND	ND
Vinyl chloride	ND	ND	23-29	ND	ND	ND	ND	ND
<u>BNAEs (µg/L)</u>								
1,2-dichlorobenzene	ND	ND	87-93	ND	ND	ND	ND	ND
Bis(2-ethylhexyl) phthalate	ND	ND	ND	ND	340 ^e	ND	1,100 ^e	ND
<u>Pesticides/PCBs (µg/L)</u>								
4,4'-DDT	ND	ND	ND	ND	ND	ND	0.98	ND
Aroclor-1254	ND	ND	ND	1.2-1.5	ND	ND	ND	ND

^aDoes not include parameters for which the concentrations were below the limit of sensitivity of the analytical method used.

^bND - not detectable at levels above the detection limit.

^cSampling locations are shown in Figure 6-13.

^dA single value indicates that the compound was present during one quarter's sampling results.

^eCompound was detected in the blank.

Soil samples obtained during the Phase I sampling efforts contained benzene, chlorobenzene, trichloroethene, and toluene. The presence of these compounds in the groundwater may be due to soil contamination. Concentrations observed in soil are considerably greater than those detected in groundwater. These and other detected organics are typical in a heavily industrialized area.

Sixteen metals were found in the groundwater, as shown in Table 6-24. Aluminum, arsenic, barium, boron, cadmium, calcium, chromium, copper, iron, magnesium, manganese, nickel, potassium, selenium, sodium, and zinc were detected in varying concentrations in both the shallow and deep groundwater systems. These same metals were detected in the soil samples obtained from the site.

Calcium and sodium were found in all 32 samples analyzed. Boron, magnesium, and manganese were detected in 31 of 32 samples. Potassium and zinc were detected in 29 of 32 samples. With the exception of zinc, those metals detected most frequently in soils (thallium, selenium, cadmium, lead, and zinc) were not found frequently in groundwater. Thallium and lead were completely absent in groundwater. Metal statistics are summarized in Table 6-25.

Calcium, magnesium, and potassium were present in groundwater at the highest concentrations (294,000, 69,800, and 62,700 $\mu\text{g/L}$, respectively). The concentrations of these metals together with iron (20,800 $\mu\text{g/L}$), manganese (4,520 $\mu\text{g/L}$), and boron (1,850 $\mu\text{g/L}$) again reflect the geology of the site.

Metals associated with uranium ores (arsenic, barium, nickel, and selenium) were generally present in concentrations of 100 to 700 $\mu\text{g/L}$. Cadmium, chromium, and copper are also associated with ores, but were detected at much lower concentrations (10.9, 50, and 37.3 $\mu\text{g/L}$, respectively).

TABLE 6-25
SUMMARY STATISTICS FOR METALS IN
GROUNDWATER AT SLDS

Compound	Concentration ($\mu\text{g/L}$)			Number of Samples	
	Mean ^a	Min.	Max.	Analyzed	Above Detection
Aluminum	219	<200	400	32	12
Antimony	<55.0	<40.0	<60.0	32	0
Arsenic	101	<100	126	32	2
Boron	1,050	<100	1,850	32	31
Barium	253	<200	536	32	8
Beryllium	<5.0	<5.0	<5.0	32	0
Calcium (x 1000)	190	43.4	294	32	32
Cadmium	5.2	<5.0	10.9	32	2
Chromium	11.3	<10.0	50.0	32	1
Cobalt	<50.0	<50.0	<50.0	32	0
Copper	25.7	<25.0	37.3	32	4
Iron	2,970	<100	20,800	32	24
Lead	<100	<100	<100	32	0
Magnesium (x 1000)	39.2	<5.00	69.8	32	31
Manganese	1,930.0	<15.0	4,520	32	31
Molybdenum	<100	<100	<100	32	0
Nickel	66	<40.0	714	32	5
Potassium (x 1000)	18.9	<5.00	62.7	32	29
Selenium	100	<100	108	32	1
Silver	<10.0	<10.0	<10.0	32	0
Sodium (x 1000)	134	18.3	506	32	32
Thallium	<100	<100	<100	32	0
Vanadium	<50.0	<50.0	<50.0	32	0
Zinc	79.0	<20.0	301	32	29

^aAll values, including those reported as the sample detection limit, were used to calculate the mean.

TABLE 6-24
RANGES OF METAL ION CONCENTRATIONS DETECTED IN GROUNDWATER AT SLDs^{a,b}

Metal Ion	Sampling Location (Well No.) ^c							
	B16W01S	B16W02S	B16W03S	B16W04S	B16W05D	B16W06D	B16W07D	B16W08D
Aluminum	<200-258	<200	<200	<200-400	<200-238	<200-240	<200-262	<200-217
Arsenic	<100-115	<100	<100-126	<100	<100	<100	<100	<100
Boron	233-519	743-814	659-857	551-897	1170-1310	1370-1550	<100-1750	1550-1850
Barium	<200	<200	<200	<200	345-453	334-536	<200	<200
Calcium (x 1000)	100-256	101-118	43.4-124	100-143	247-294	246-260	25.7-290	270-283
Cadmium	<5.0-10.9	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0-5.0	<5.0
Chromium	<10.0	<10.0	<10.0	<10.0-50.0	<10.0	<10.0	<10.0	<10.0
Copper	<25.0-27.4	<25.0	<25.0	<25.0-37.3	<25.0-30.9	<25.0	<25.0-27.3	<25.0
Iron	<100-611	<100-304	137-8920	<100-274	<100-9440	199-9820	<100-9570	248-20800
Potassium (x 1000)	<5.00-7.17	14.8-18.5	42.1-62.7	<5.00-8.10	10.2-13.4	11.2-14.7	5.37-21.1	28.3-34.9
Magnesium (x 1000)	14.9-46.4	20.0-22.0	9.96-25.7	15.0-24.5	60.8-65.8	64.2-69.8	<5.00-59.1	42.3-47.1
Manganese	372-1480	2860-3840	846-2160	1630-4520	1460-1740	1060-1690	<15.0-1850	2240-2580
Sodium (x 1000)	41.6-139	70.9-89.3	267-506	18.3-35.1	140-167	96.8-236	8.57-128	97.4-118
Nickel	<40.0-176	<40.0	<40.0	<40.0-42.3	<40.0-714	<40.0	<40.0	<40.0-66.9
Selenium	<100	<100	<100	<100	<100	<100	<100	<100-108
Zinc	35.0-193	<20.0-54.9	<20.0-179	20.7-301	29.1-126	48.9-99.1	<20.0-198	21.9-182

^aDoes not include parameters for which the concentrations were below the limit of sensitivity of the analytical method used.

^bConcentrations in µg/L; where only one value is shown, all samples had that value.

^cSampling locations are shown in Figure 6-13.

6.3 GEOLOGICAL/HYDROGEOLOGICAL RESULTS

Eight boreholes were completed as monitoring wells during Phase I field work for the hydrogeological characterization of SLDS. Two additional boreholes to be completed as monitoring wells were drilled in June 1989. One of these (B16W10) was completed as a monitoring well, and the other was abandoned because excessive methane was encountered during drilling, making a total of nine boreholes successfully completed as monitoring wells. Four of these wells were completed in the upper unit of the unconsolidated deposits, and five were completed in the lower unit. The data collected during Phase I form the basis for this assessment of the hydrogeology of the site.

6.3.1 Background

SLDS is located in a present-day floodplain of the Mississippi River. Unconsolidated overburden materials are stratified clays, silts, sands, and gravels. Continuity of subsurface materials varies both laterally and vertically because of the nature of deposition and the high degree of disturbance by mechanical processes. Most of the site is covered by either concrete or asphalt, which interferes with the natural runoff and recharge mechanism for shallow subsurface materials. An extensive levee system parallel with the river was constructed near the riverbank to protect the site from periodic flooding (Ref. 25).

6.3.2 Soil

Subsurface materials encountered at the site are typical of the Mississippi River floodplain. The proximity to the Mississippi River supports a deposition system consistent with a low-gradient river system, with basal coarse-grained sands and gravels, fining upwards into silt and clay overbank deposits. Because most of the radiological and chemical boreholes were advanced only about 0.7 m

(2 ft) into undisturbed material, lithologic drill logs of completed monitoring wells were used in the compilation of subsurface profiles and material descriptions. Classifications of the materials have been generalized to facilitate correlation of the distribution of materials. Figure 6-37 shows the graphic logs of geologic materials beneath the site. A generalized stratigraphic section and geologic descriptions of the respective units are shown in Figure 6-38. Geologic drill logs for all boreholes are included in Volume III of this report. Limited geotechnical soil testing was performed.

Two unconsolidated hydrostratigraphic units and one bedrock unit were distinguished. Differentiation between the unconsolidated units is based on dissimilar hydraulic properties. A variable layer, averaging 4 m (13 ft) of rubble and fill, was present at most borehole locations. This unconsolidated layer consisted of brick, reinforced concrete, and coal slag with minor sand and silt as the matrix. No monitoring wells were installed in this interval.

Figure 6-39 shows the locations of the monitoring wells used for subsurface profiles and the profile orientations. Subsurface profiles are shown in Figures 6-40 through 6-43.

The distributions and relationships of subsurface materials encountered at SLDS are best shown in profile A - A', Figure 6-40. Characterized by a shallow depth to bedrock [5.9 m (19.5 ft) on the western edge of the site], the bedrock slope has a moderate gradient of 0.03 ft/ft to an average depth of 24.4 m (80 ft) near the river. The upper unit is laterally continuous from the western portion of the site to the Mississippi River, generally thickening slightly as it approaches the river. The lower unit is not present beneath the western half of the site. The westward extent of this lower unit is not known in detail.

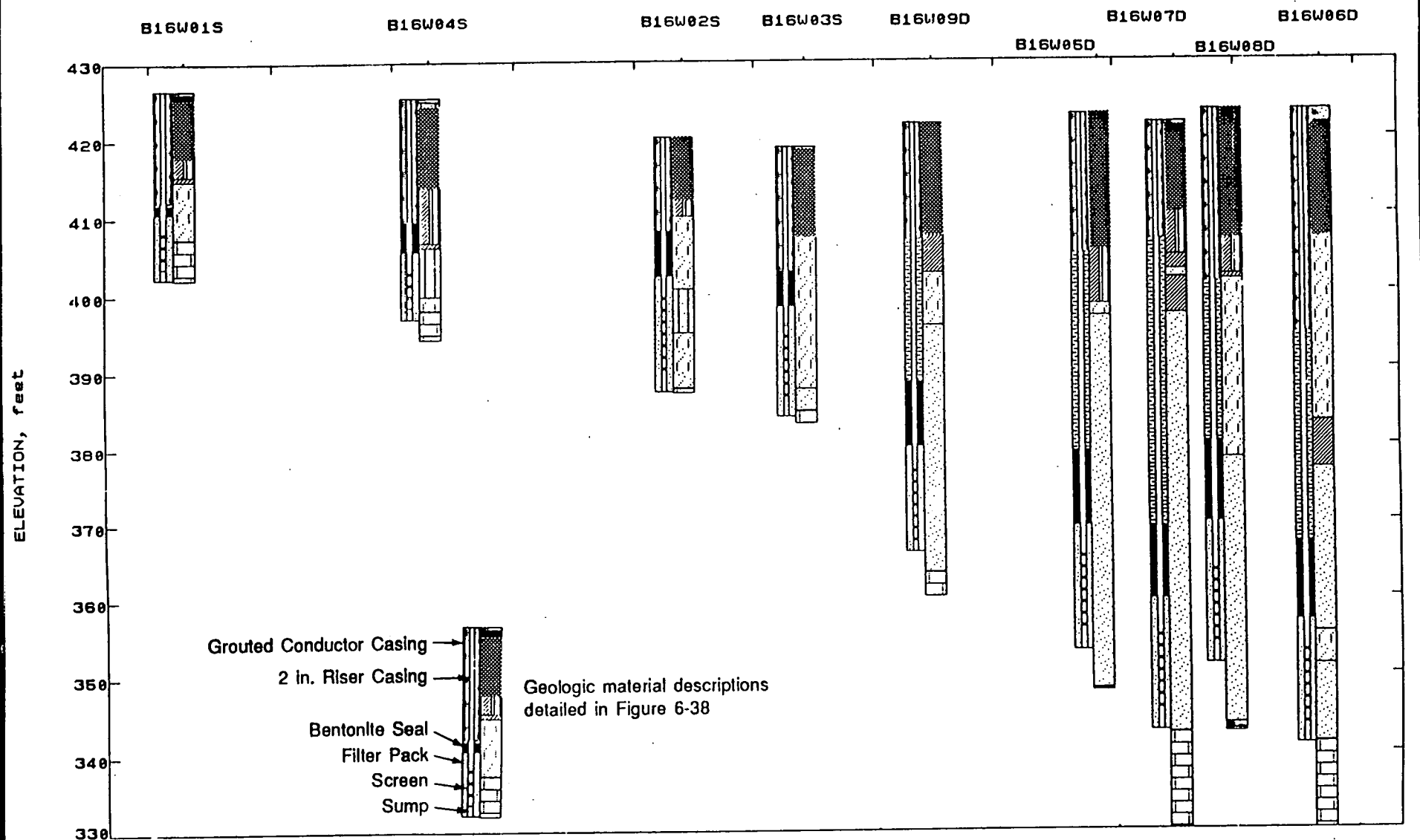


FIGURE 6-37 CORRELATION OF SUBSURFACE STRATIGRAPHY TO MONITORED INTERVALS AT SLDS




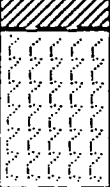

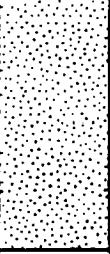

Unit Designation	Graphic Section	Approximate Thickness (ft)	Description
NOT DESIGNATED		0-25	<p>RUBBLE and FILL Grayish black (N2) to brownish black (5YR2/1). Dry to slightly moist, generally becoming moist at 5-6 ft and saturated at 10-12 ft. Slight cohesion, variable with depth, moisture content and percentage of fines present. Consistency or relative density is unrepresentative, due to large rubble fragments.</p> <p>Rubble is concrete, brick, glass, and coal slag. Percentage of fines as silt or clay increases with depth from 5 to 30 percent. Some weakly cemented aggregations of soil particles. Adhesion of fines to rubble increases with depth and higher moisture content. Degree of compaction is slight to moderate with frequent large voids.</p>
UPPER UNIT		0-10	<p>Silty CLAY Layers are mostly Olive gray (5Y2/1), with some Olive black (5Y2/1). Predominantly occurs at contact of undisturbed material, or at boundary of material with elevated activity. Abundant dark, decomposed organics.</p> <p>Variable percentages of silt and clay composition.</p>
		0-3	<p>CLAY Layers are Light olive gray (5Y5/2), or Dark greenish gray (5GY4/1). Slightly moist to moist, moderate cohesion, medium stiff consistency. Tends to have lowest moisture content. Slight to moderate plasticity.</p>
		0-15	<p>Interbedded CLAY, Silty CLAY, SILT and Sandy SILT Dark greenish gray (5GY4/1) to Light olive gray (5Y6/1). Moist to saturated, dependent on percentage of particle size. Contacts are sharp, with structure normal to sampler axis to less than 15 degrees down dip. Layer thicknesses are variable, random in alternation with no predictable vertical gradation, or lateral continuity.</p> <p>Some very fine-grained, rounded silica sand as stringers. Silt is dark mafic, biotite flakes. Some decomposed organics.</p>
		0-10	<p>Sandy SILT Olive gray (5Y4/1). Moist with zones of higher sand content saturated. Slight to moderate cohesion, moderate compaction. Stiff to very stiff consistency, rapid dilatancy, nonplastic.</p> <p>Sand is well sorted, very fine and fine-grained rounded quartz particles.</p>
LOWER UNIT		0-30	<p>Silty SAND and SAND Olive gray (5Y4/1). Saturated, slight cohesion, becoming noncohesive with decrease of silt particles with depth. Dense, moderate compaction.</p> <p>Moderate to well-graded, mostly fine- and medium-grained, with some fine- and coarse-grained particles. Mostly rounded with coarse grains slightly subrounded.</p> <p>Gradual gradation from upper unit, Silty SAND has abundant dark mafic/biotite flakes.</p> <p>Sand is well-graded, fine gravel to fine sand. Mostly medium-grained, with some fine-grained and few coarse-grained and fine gravel.</p>
BEDROCK UNIT		0.5-12	<p>LIMESTONE Light olive gray (5Y4/1) with interbedded chert modules. Generally hard to very hard difficult to scratch with knife. Slightly weathered, moderately fresh with little to no discoloration or staining.</p> <p>Top 5 ft is moderately fractured, with 99 percent of joints normal to the core axis. Joints are open, planar and smooth. Some are slightly discolored with trace of hematite staining.</p>

FIGURE 6-38 GENERALIZED STRATIGRAPHIC SECTION FOR SLDS

031-I

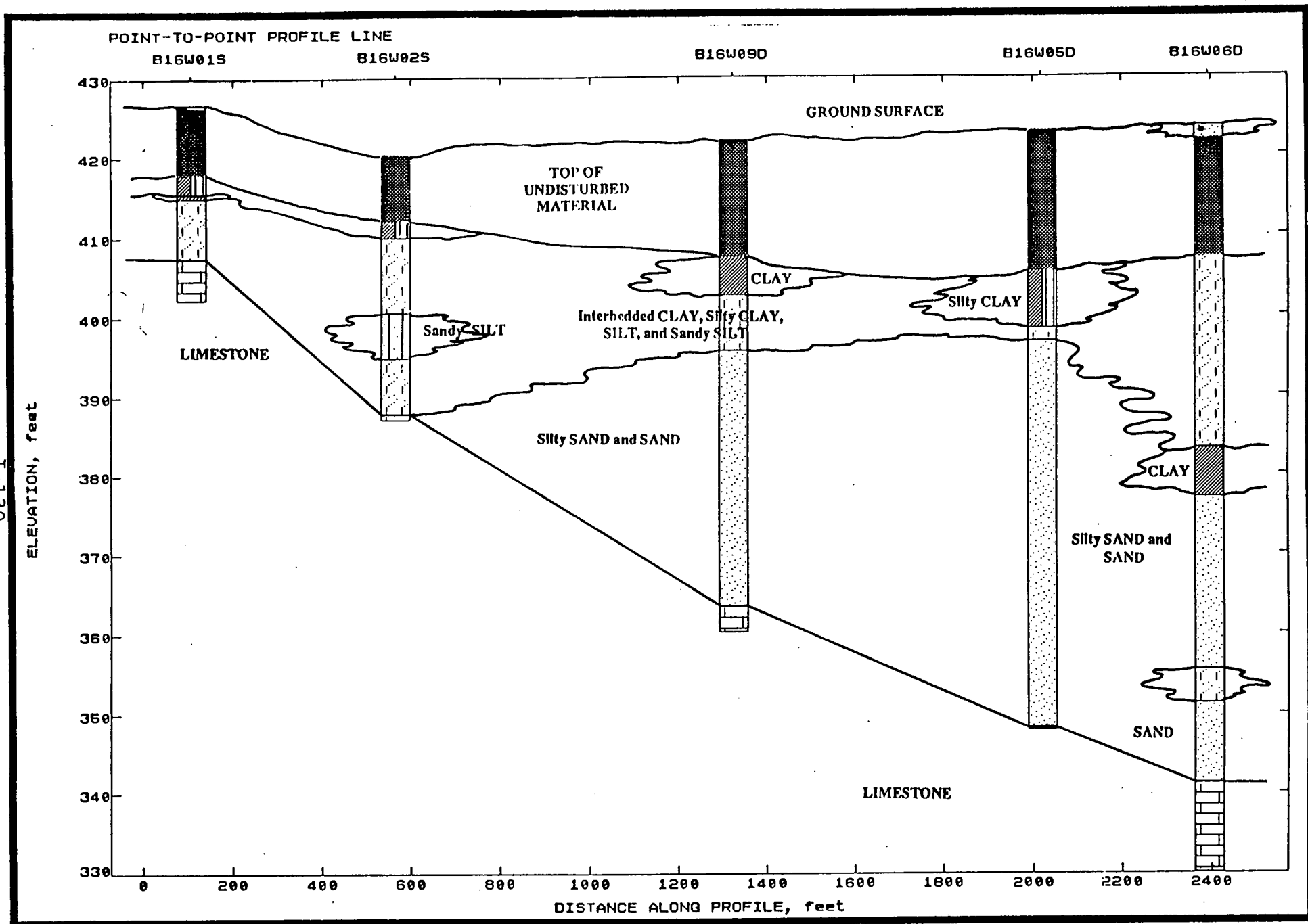


FIGURE 6-40 SUBSURFACE PROFILE A — A' AT SLDS

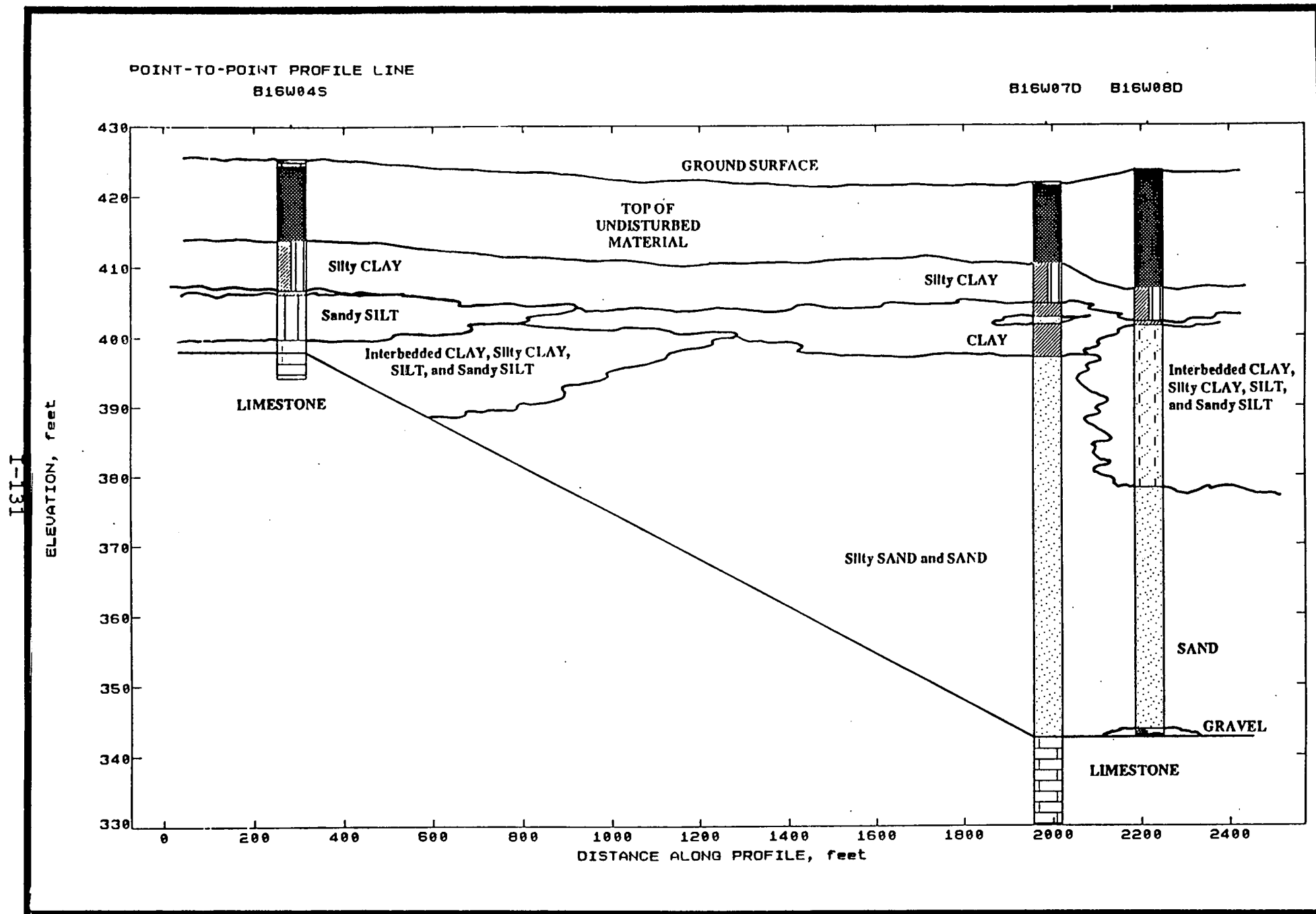


FIGURE 6-41 SUBSURFACE PROFILE B — B' AT SLDS

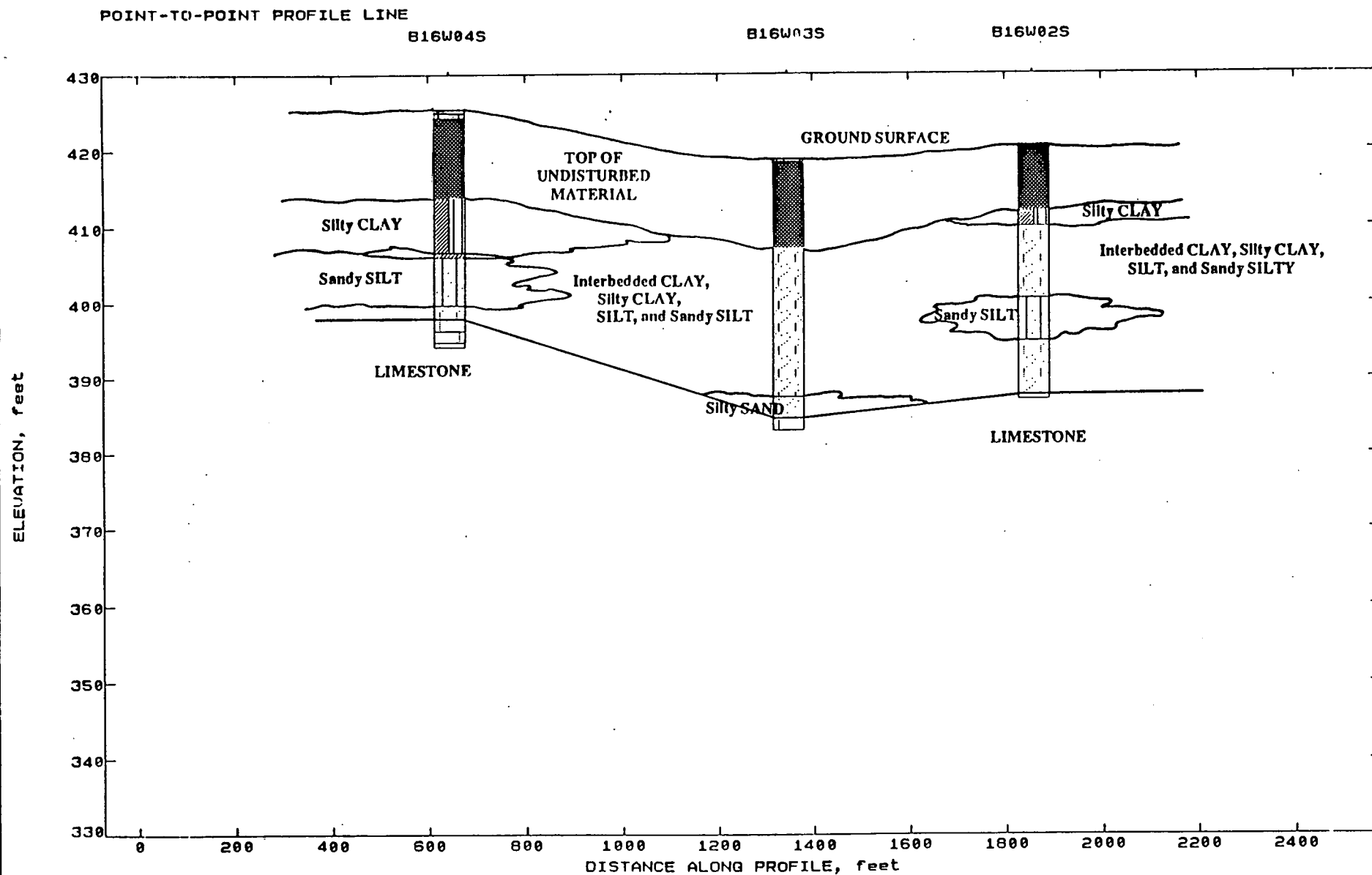


FIGURE 6-42 SUBSURFACE PROFILE C — C' AT SLDS

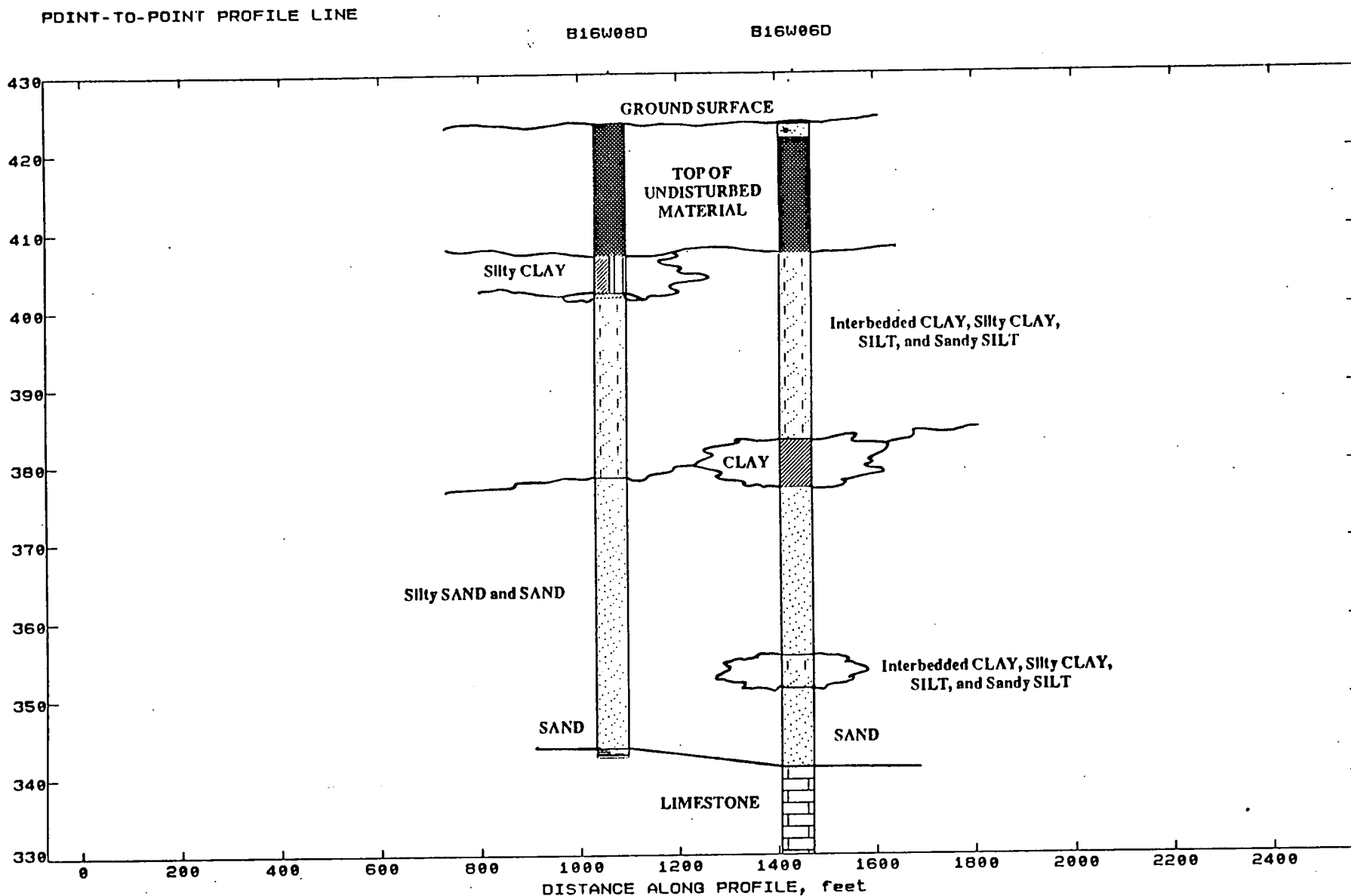


FIGURE 6-43 SUBSURFACE PROFILE D — D' AT SLDS

Borehole B16W10, drilled to confirm contacts, was abandoned before total depth was reached because excessive methane concentrations were encountered during drilling. The lower unit tends to increase in thickness with proximity to the river. Profile B - B', Figure 6-41, illustrates the same lateral features, but shows a slight thickening of both units toward the southern portion of the site. Detailed descriptions of the hydrostratigraphic units follow.

The upper unit consists of interbedded silty clay, clay, silt, and sandy silt. The thickness of this unit ranges from 3.7 to 9 m (12 to 30 ft). It is laterally discontinuous; the interbeds are random in alternation. The south portion of the site tends to show an increase in the percentage of fine grained sands. Bedding is nearly horizontal. Traces of sand stringers were noted in some locations. The upper unit zone was repeatedly encountered as both the contact with the undisturbed material and the boundary of elevated activity. The olive gray to light olive gray soil color indicates a reducing environment, with abundant organics in various stages of decomposition. The presence of organics would tend to increase porosity because the irregular shapes do not allow close packing.

One variable-head permeability test was conducted within the upper unit at borehole B16W09D. Table 6-26 summarizes the hydraulic conductivities calculated. The value, 1×10^{-5} cm/s, should be considered an estimate.

The lower unit is a silty sand that grades into sand. The thickness is variable, increasing with increasing depth to bedrock and proximity to the Mississippi River. Profile D - D', Figure 6-43, displays the material sequence in boreholes drilled into bedrock closest to the river. Bedding is horizontal with slight ripple laminations. The silty sand interval is very fine and fine grained sand grading laterally into fine and medium grained

TABLE 6-26
SUMMARY OF AVERAGE HYDRAULIC CONDUCTIVITIES

Borehole	Interval (ft)	Method	cm/s	ft/yr
B16W09D	18	A	9.9×10^{-6}	10
B16W06D	88.6 - 94.2	B	1.1×10^{-3}	1,190
B16W07D	82.7 - 90.7	C	5.1×10^{-4}	535
	88.3 - 93.3	B	2.9×10^{-4}	304

A - Variable-head, flush bottom in uniform soil.

B - Single-packer constant head.

C - Double-packer constant head.

sand toward the river. These are mostly mature olive gray silica sands with abundant dark mafic silt flakes and substantial organics in various stages of decomposition. Gravel was encountered in B16W08D at the contact with bedrock. No field permeability tests were conducted in this unit.

The bedrock unit encountered is limestone, which is light olive gray with some darker interbedded chert nodules and is microcrystalline, hard to moderately hard. The top 1.5 m (5 ft) shows moderate fracturing, while jointing is normal to core axis, open, planar, and smooth. Some joint surfaces are slightly weathered with trace hematite staining. No confining material was encountered between the bedrock and overlying sand.

Three constant-head packer permeability tests were conducted in the cored intervals of B16W07D (two tests) and B16W06D (one test). Results are summarized in Table 6-26. Average hydraulic conductivities ranged from 1.1×10^{-3} to 5.1×10^{-4} cm/s.

6.3.3 Groundwater

Groundwater in the St. Louis area is known to occur in the alluvium associated with the Mississippi River. Discussions with the City of St. Louis Water Division revealed that none of their water supply comes from aquifer sources near SLDS. Two water purification plants are used; one that pumps surface water is located 9.7 km (6 mi) upstream on the Mississippi River, and another is located northwest on the Missouri River.

In addition, it was indicated that no known wells are producing from alluvial or bedrock aquifers at this time (Ref. 26). Evaluation of information pertaining to the St. Louis area groundwater confirms that there are no producing wells in the vicinity of SLDS (Refs. 15, 19, and 25).

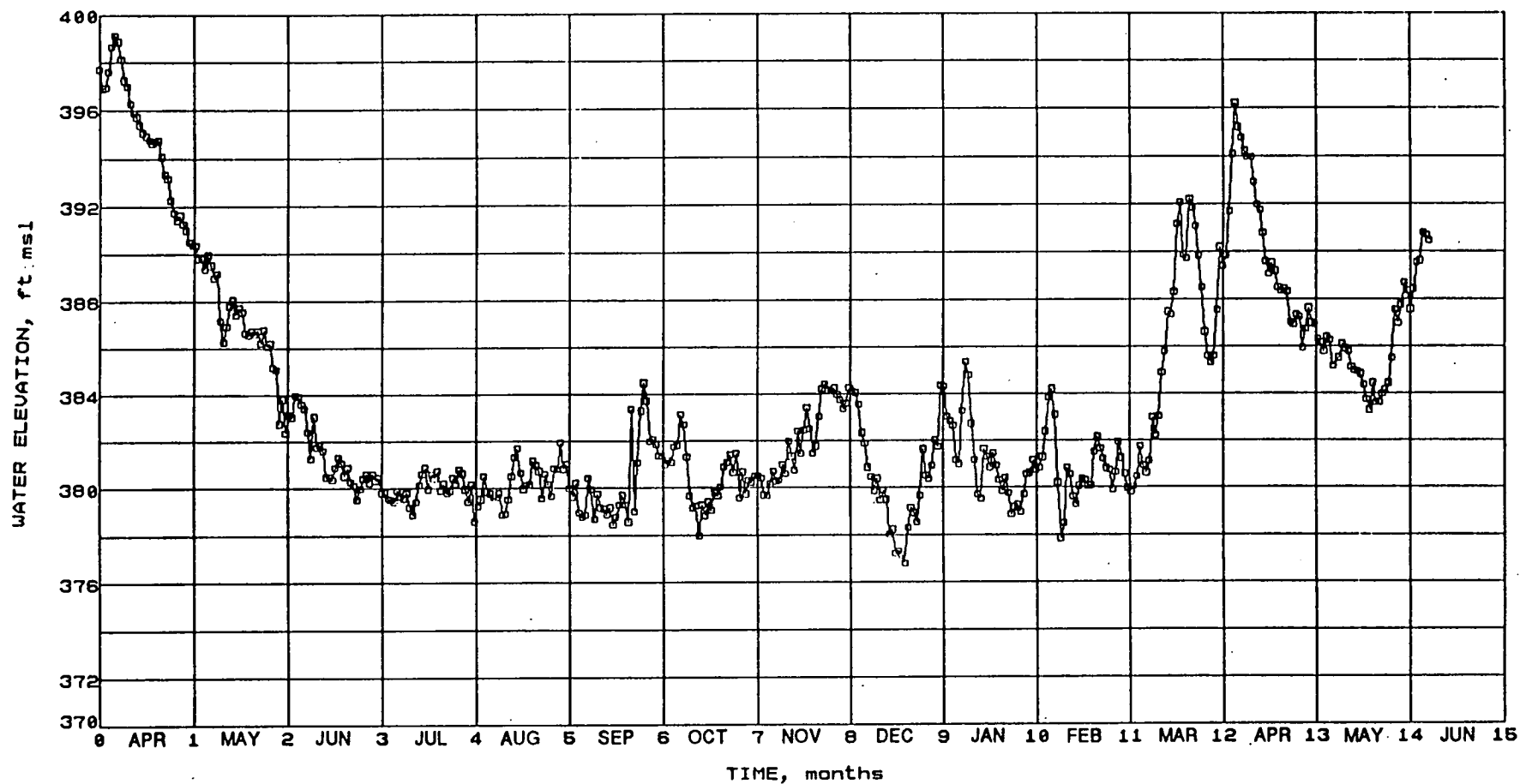
Regional groundwater maps of St. Louis County indicate that movement of groundwater in the alluvial aquifers is generally toward the major streams, except where movement is reversed during periods of high river stages (Ref. 19). The magnitude of the gradient could not be determined from available data. Movement of groundwater in bedrock aquifers could not be established. In most instances, wells penetrated more than one aquifer (Refs. 15 and 19).

Initial evaluations of the data obtained during the field investigation, from published reports, and through compilation of subsequent data indicate that an alluvial aquifer existing under semiconfined conditions has been identified at SLDS. No aquifer testing in completed wells has been performed.

Hydrographs were constructed with water level elevations plotted as a function of time since initial measurements. Figure 6-44 is a hydrograph of the Mississippi River stage elevations. Figures 6-45 and 6-46 are hydrographs of B16W05D-B16W08D in the lower unit and wells B16W01S-B16W04S in the upper unit of the unconsolidated deposits. The dates used to construct contour maps of groundwater level elevations were chosen from the hydrographs to represent and evaluate seasonal fluctuations and their influence on the groundwater system.

Linear regressions on selected water level elevations for all monitoring wells versus the Mississippi River stage elevation were conducted to determine whether the two variables are related and how well they are related. The wells completed in the lower unit (B16W05D-B16W08D) show correlation coefficients of 0.93 to 0.99, with 1 considered a perfect correlation (Ref. 27). This suggests a strong hydraulic connection with the river. Wells completed in the upper unit (B16W01S-B16W04S) show coefficients of 0.13 to 0.60. For this study period, the river stage had not attained sufficient elevation to affect the water levels in the upper unit.

881-I



YEAR 1988 - 1989

LEGEND: □ POINT ID MISSRIV

FIGURE 6-44 HYDROGRAPH OF STAGE ELEVATIONS
OF THE MISSISSIPPI RIVER

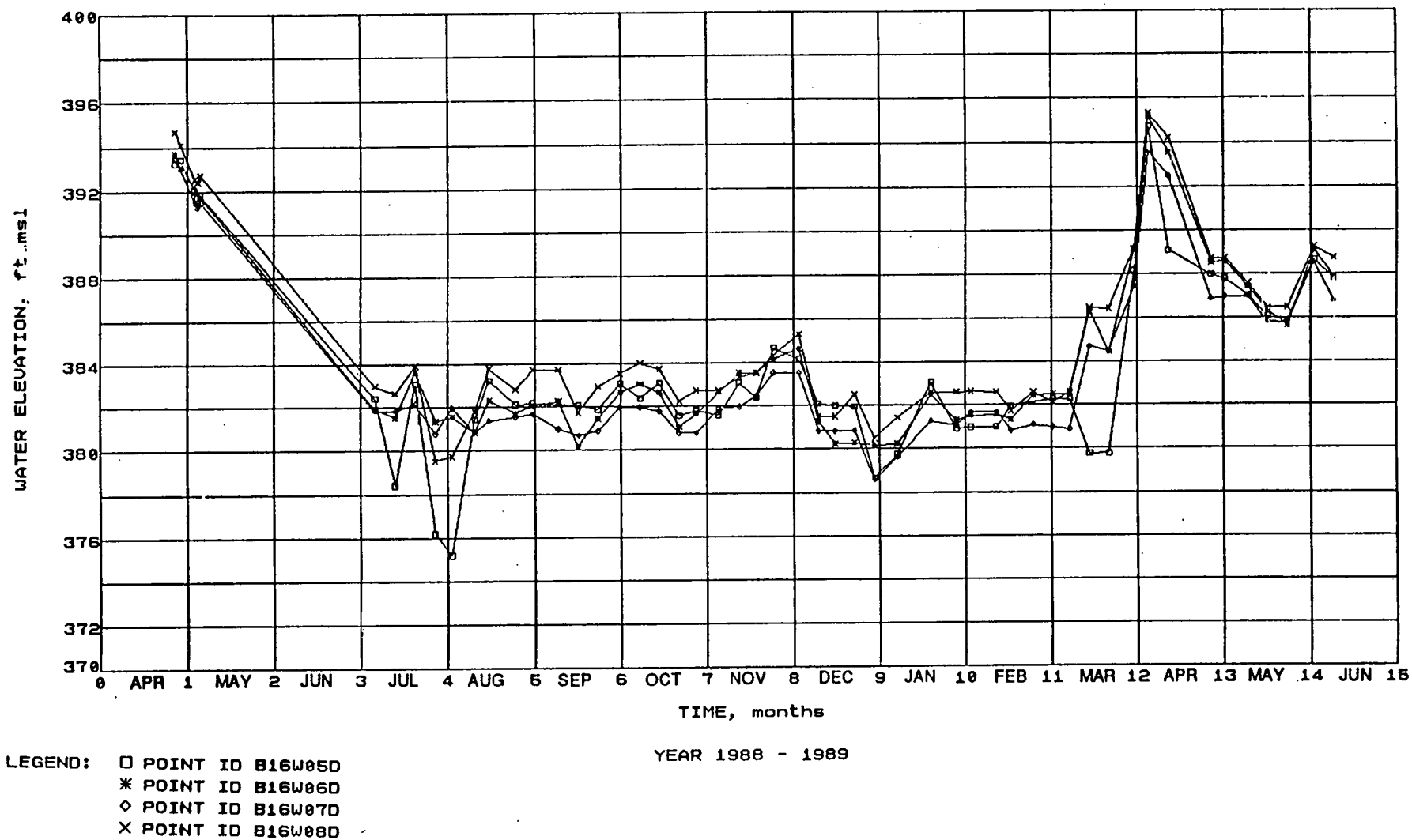


FIGURE 6-45 HYDROGRAPH OF MONITORING WELLS IN LOWER UNIT OF UNCONSOLIDATED DEPOSITS

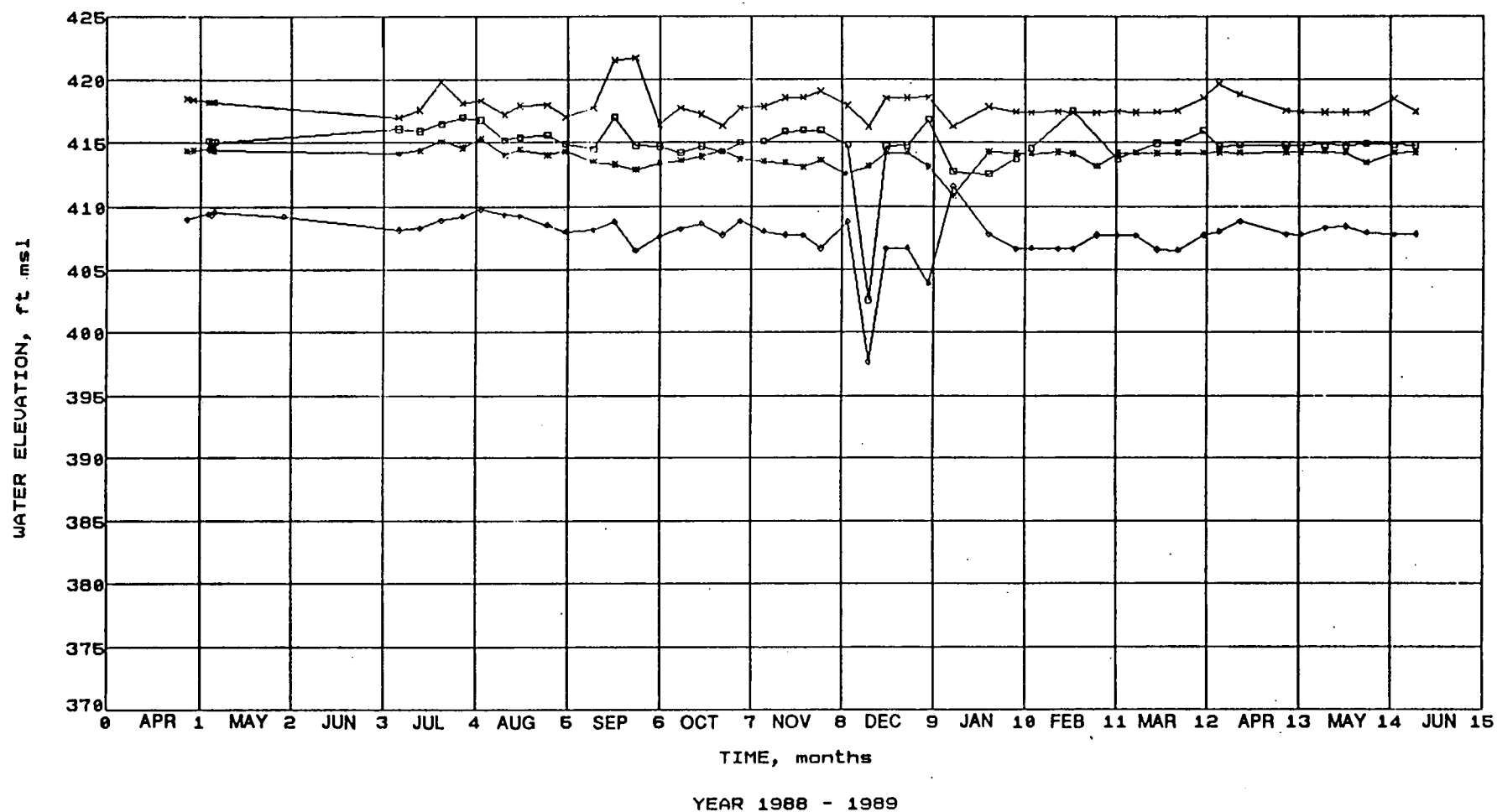


FIGURE 6-46 HYDROGRAPH OF MONITORING WELLS IN UPPER UNIT OF UNCONSOLIDATED DEPOSITS

Contour maps of groundwater elevations are shown in Figures 6-47 and 6-48. Consistently, these elevations indicate a local groundwater flow direction eastward, towards the Mississippi River. Depending on the Mississippi River stage, there are variations of flow direction at the discharge point. The configuration of the interface existing at the discharge point is not known. The interpretation suggests that the water contribution from the alluvium to the river, or from the river to the alluvium, is dynamic and dependent on the river stage. Flow direction would be expected to be from the river into the alluvium during a peak river stage and to reverse direction during periods of low river stages. The hydrograph (Figure 6-44) suggests a rapid response to the changes in the river stage. Horizontal hydraulic gradients calculated from the contour maps range from 0.01 ft/ft to 0.02 ft/ft, depending on the river stage. Vertical gradients with variable direction would be expected at the discharge point.

Periodically, a distinct northeast trend in the gradient is determined from water level measurements in wells completed in the upper unit of the consolidated deposits (Figure 6-47). This may be attributed to preferential recharge or to the questionable integrity of utilities underlying the site. Leakage from the utilities would recharge the groundwater. Exact locations and volumes of the contributions are not known. The field investigation did not address the rubble zone above the undisturbed material. However, the possibility exists that, because the differences between the hydraulic conductivities of the rubble zone and the upper limit are substantial, a perched water table could exist. This perched table could be intermittent and discontinuous laterally within the rubble zone, developing additional recharge sources.

Recharge to the system could occur as infiltration of surface runoff (from precipitation and snow melt), contributions from the river,

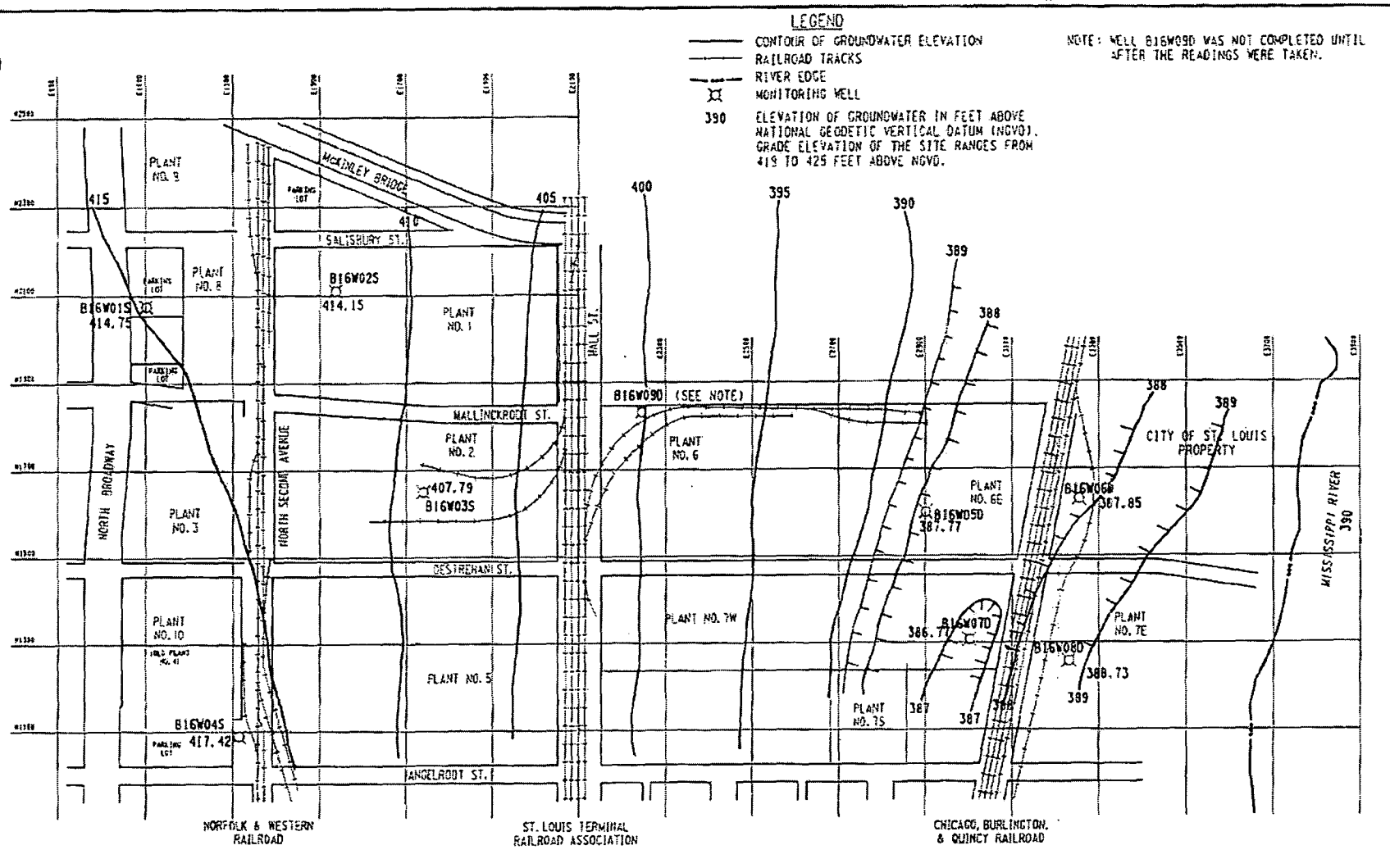


FIGURE 6-48 CONTOURS OF GROUNDWATER LEVEL ELEVATIONS AT SLDS, 9 JUNE 1989

and possible leakage from underground utilities. Because the majority of the site is covered by either asphalt, concrete, or the physical plant, recharge would not be expected to be uniform throughout the site. Discharge is principally to the Mississippi River.

7.0 DISCUSSION OF RESULTS

The purpose of this section is to attempt to identify correlations between radiological, chemical, and hydrogeological parameters. This discussion is based on data collected during the SLDS characterization and on interpretations relating site conditions (hydrogeology) to radiological and chemical analytical results.

Because uranium-238 and thorium-230 were found to be the major radioactive contaminants in soil at SLDS, an attempt was made to correlate the presence of subsurface materials with these radionuclides. Elevated gamma logs and soil analyses (>100 pCi/g for each radionuclide) were compared with drill log data to develop these correlations.

In most cases, the radioactivity was found in the rubble and fill zone, but in some instances, it extends into undisturbed material. Many organic fibers were found in subsurface materials, the result of the decomposition of various materials. In general, organic materials are acidic in nature. Uranium and metals in general are soluble in acidic environments, which would explain why high uranium-238 concentrations were found to be associated with decomposed organic materials. Also, these organic materials were very porous, which would allow uranium-containing compounds to enter and react in the acidic environment. In addition, contaminated soil was typically found to be in silty-clay-type soil or in silty sand materials.

Radioactivity exceeding DOE guidelines was found to be widespread across the site, both in soils and on building surfaces. Groundwater from one monitoring well showed elevated concentrations of uranium, though well below DOE guidelines.

In general, the elevated levels of radioactivity were found in areas of the site where expected, based on historical information.

One exception is Plant 5, where low levels of radioactivity exceeding DOE guidelines were detected. This contamination could be the result of fallout from emissions of MED/AEC operations conducted at nearby Plants 2 and 10, or it could be the result of non-DOE/MED/AEC radiological operations conducted by Mallinckrodt. Another exception is the city property, where radioactivity was found to be widespread across the area, generally at shallow depths. Levels of radioactivity on structural surfaces in excess of DOE guidelines were found primarily in buildings where MED/AEC operations were carried out.

The roofs of several adjacent buildings also contained radioactive contamination exceeding DOE guidelines. This can probably be attributed to emissions from MED/AEC operations at nearby buildings.

The current estimate for the volume of radioactive contamination at SLDS is approximately 215,000 m³ (280,000 yd³) of material. This estimate is for soils only, as building surveys were not intended to define boundaries of contamination.

Based on current site conditions and operations, it is believed that the levels of radioactivity identified do not pose a threat to the workers at SLDS or to the nearby public. Because of the potential for changing conditions at SLDS, radioactivity in soil and on structural surfaces could be moved or concentrations altered. DOE and the plant owner have an agreement that any planned construction activities in identified contaminated areas will be cleared through DOE for an assessment before work begins. It is anticipated that construction activities will not prove to have any significant environmental impacts at the site or in the immediate area.

Chemical sampling was conducted to determine whether chemical contamination exists within areas that are radioactively contaminated. Metals were found in soil above, within, and below

areas of radioactive contamination. Seventeen metals were found to exceed maximum expected background concentrations: antimony, barium, boron, cadmium, chromium, cobalt, copper, lead, magnesium, manganese, mercury, molybdenum, silver, selenium, sodium, thallium, and zinc. The elevated levels of metals may be due to uranium processing at the site and coal and ash storage and disposal practices.

In general, concentrations of the volatile organic compounds detected were low, with mean concentrations in the low parts per billion (2.0 to 73 ppb). Mean concentrations of BNAE compounds were higher than those observed for volatiles (1,585 to 14,900 ppb). However, BNAE compounds detected are not expected to migrate appreciably, given their chemical characteristics. BNAE contamination occurs across the site.

Testing for RCRA-hazardous waste characteristics indicates that a few small, isolated areas exist on the site where soil fails the hazardous waste extraction procedure criterion for lead. These areas are surrounded by larger volumes of soil that do not "fail" the extraction procedure test. If the material is excavated, it is likely that the resulting waste will not exhibit any hazardous waste characteristics. Therefore, there will probably be no wastes that will need to be remediated as hazardous or mixed wastes.

Nine wells were installed at SLDS to monitor groundwater; eight were sampled for four quarters. Ten different organic contaminants were found in six of the eight wells. The majority of the organic contaminants appear consistently in well B16W03S (Plant 2); seven of the ten organic compounds were detected in samples from this well. Also, of the 25 positive values detected for all organic compounds in samples, 17 were in samples from well B16W03S. Metals were detected in all groundwater samples. One trend recognizable from the data is that barium is detected in all quarters in wells B16W05D and B16W06D and no others.

Because the objective of the chemical sampling effort was to determine whether chemical contamination was associated with radioactivity in soil, the relation of chemical contamination to hydrogeological features of the site is difficult to determine. Chemical samples were collected as a single composite sample from each borehole in Phase I; therefore, distinct intervals cannot be related to changing conditions in subsurface materials.

It is recognized that some additional data may be required for the site. Based on the results of this investigation, however, it is believed that the necessary additional data requirements are minor and that the investigation can be completed before remedial action begins. Data requirements include defining exact boundaries of contamination within the SLDS plant and the city property and investigating off-site vicinity properties. Collection of post-remedial action data will ensure that remedial action was conducted in a manner that protects human health and the environment.

REFERENCES

1. U.S. Department of Energy. Description of the Formerly Utilized Sites Remedial Action Program, ORO-777, Oak Ridge, Tenn., September 1980 (as modified by DOE in October 1983).
2. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. Wind - Ceiling - Visibility Data at Selected Airports, Interagency Agreement DOT-FA79WAI-057, National Climatic Data Center, Asheville, N.C., January 1981.
3. Fleishman-Hillard, Inc. Fuel for the Atomic Age, St. Louis, Mo., September 30, 1967.
4. Mason, Mont G. History and Background Relative to the Radiological Re-monitoring of Mallinckrodt by the Energy Research and Development Administration, St. Louis, Mo., August 19, 1977.
5. Oak Ridge National Laboratory. Radiological Survey of the Mallinckrodt Chemical Works, St. Louis, Missouri, DOE/EV-0005/27, ORNL-5715, Oak Ridge, Tenn., December 1981.
6. U.S. Code of Federal Regulations. 29 CFR 1910.120, "Hazardous Waste Operations and Emergency Responses."
7. Bechtel National, Inc. Health and Safety Plan for the Formerly Utilized Sites Remedial Action Program, DOE/OR/20722-213, Rev. 1, Oak Ridge, Tenn., April 1989.
8. U.S. Environmental Protection Agency, Region II, Environmental Services Division, Monitoring Management Branch. CERCLA OAPiP Review Guidance, April 1987.

9. Braunstein, H.M., E.D. Copenhaver, and H.A. Pfuderer, Environmental, Health, and Control Aspects of Coal Conversion - An Information Overview. Ann Arbor Science Publishers, Inc., Ann Arbor, Mich., 2 Vols., 1981.
10. American Public Health Association. Standard Methods for the Examination of Water and Wastewater, Washington, D.C., 1985.
11. American Society for Testing and Materials. American Society for Testing and Materials, Section II, Vol. 11.02, Philadelphia, Pa., 1985.
12. U.S. EPA, Methods for Chemical Analysis of Water and Wastes, 600/4-79-020, 16th ed., Washington, D.C., 1985.
13. Hunt, C.B. Natural Regions of the United States and Canada, 2nd ed., San Francisco, W. H. Freeman and Company, 1967.
14. Lutzen, E.E., and J.D. Rockaway. "Engineering Geology of St. Louis County, Missouri," in Engineering Geology Series No. 4. Missouri Department of Natural Resources, Division of Geology and Land Survey, 1971.
15. State of Missouri, Geological Survey and Water Resources. Groundwater Maps of Missouri, Report No. 4, March 1963.
16. Bechtel National, Inc. Preliminary Geological, Hydrogeological, and Chemical Characterization Report for the Ball Field Area, Hazelwood and Berkeley, Missouri, DOE/OR/20722-211, Oak Ridge, Tenn., February 1989.
17. Bechtel National, Inc. Site Seismicity and Design Earthquake Considerations, Weldon Spring Storage Site. Prepared for the Department of Energy, Oak Ridge, Tenn., July 1983.

18. Howe, W.B., and J.W. Koenig. The Stratigraphic Succession in Missouri, Vol. XL, Second Series. State of Missouri, Geological Survey and Water Resources, 1961.
19. Miller, D.E., "Water Resources of the St. Louis Area, Missouri," in Water Resources Report 30: U. S. Geological Survey and Missouri Geological Survey and Water Resources, 1974.
20. Bechtel National, Inc. Borehole and Monitoring Well Installation, SC 14501-116-SC-261, Oak Ridge, Tenn., October 26, 1987.
21. Argonne National Laboratory. A Manual for Implementing Residual Radioactive Material Guidelines, ANL/ES-160, DOE/CH/8901, Argonne, Ill., 1989.
22. Meeting notes, Liedle, S. (BNI) to Distribution. "Notes from SLDS Meeting on 1/18/89," CCN 059899, Oak Ridge, Tenn., March 15, 1989.
23. Memorandum, A. Wallo, U.S. Department of Energy, to Distribution. "Guidance on Implementation and Use of the Uranium Surface Contamination Limits in the DOE and NRC Guidelines and Application of Limits to the St. Louis Downtown Site," October 7, 1988.
24. Swann, S.M., and A. Eschenroeder. Fate of Chemicals in the Environment. American Chemical Society, Washington, D.C., 1983.
25. CH₂M Hill. Preliminary Hydrogeologic Assessment, St. Louis Plant. Prepared for Mallinckrodt, Inc., Oak Ridge, Tenn., August 1986.

26. Telephone conversation, C. A. Clark (Bechtel) to Dave Visintainer (City of St. Louis Water Division, St. Louis, Missouri), July 20, 1989.
27. Kreyszig, Erwin. Introductory Mathematical Statistics, John Wiley and Sons, Inc., New York, 1970.

Administrative Record for the Formerly Utilized Sites Remedial Action Program (FUSRAP) – St. Louis Downtown Site (SLDS)

St. Louis, Missouri

Volume 3b

October 1998



**US Army Corps
of Engineers**
St. Louis District

SI.DOWN 000363

**ST. LOUIS DOWNTOWN SITE
ADMINISTRATIVE RECORD
CONTENTS**

October 26, 1998

Document No.	Title Description	Author Affiliation	Recipient Affiliation	Document Location	Document Date
		<u>Volume 3a</u>			
9808171003	Radiological, Chemical, and Hydrogeological Characterization Report for the St. Louis Downtown Site, Vol I	BNI		Vol. 3a	9/90
9808171004	Radiological, Chemical, and Hydrogeological Characterization Report for the St. Louis Downtown Site, Vol. II	BNI		Vol. 3a	9/90
9808171005	Radiological, Chemical, and Hydrogeological Characterization Report for the St. Louis Downtown Site, Vol. III	BNI		Vol. 3a	9/90