COLUMBIUM-TANTALUM PLANT

CHARACTERIZATION PLAN

MALLINCKRODT, INC.

ST. LOUIS, MISSOURI PLANT

January 10, 1994

C-T CHARACTERIZATION PLAN

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLES

FIGURES

APPENDICES

A. MED PLANT OPERATIONS DESCRIPTION

B. DESCRIPTION OF DECONTAMINATION TESTS

C. HEALTH AND SAFETY PLAN

D. R.S.O. EXPERIENCE AND QUALIFICATIONS

1.0 INTRODUCTION

This plan describes the activities to be performed to characterize radioactive residues associated with the Mallinckrodt, Inc. (Mallinckrodt) former Columbium-Tantalum (C-T) facility operated under Nuclear Regulatory Commission (NRC) Source Material License STB-401. Section 2.0 describes the site, radiological processing activities which have occurred at the site, including C-T operations and those performed under the direction of the Manhattan Engineer District and the Atomic Energy Commission (MED-AEC), and provides a discussion of Department of Energy (DOE) responsibilities under the Federal Facilities Agreement (FFA) and the Formerly Utilized Sites Remedial Action Program (FUSRAP). Section 3.0 describes Mallinckrodt's overall approach to site characterization and decommissioning. Sections 4 through 10 describe the data quality objectives for the investigation, the specific surveys, sampling and analysis to be performed in site characterization; analytical techniques to be employed; program implementation and schedule; decontamination tests to be performed; characterization waste management; and program administration, including discussions of the organization performing the project, and health and safety practices to be employed.

Mallinckrodt is submitting this characterization plan to the Nuclear Regulatory Commission for review and concurrence prior to plan implementation. Mallinckrodt believes that NRC concurrence with the scope and technical aspects of the plan is an important initial step in the timely and cost-effective termination of license STB-401.

2.0 BACKGROUND INFORMATION

2.1 SITE INFORMATION

2.1.1 Site Description

The Mallinckrodt St. Louis plant is a 43 acre site located at 3600 North 2nd Street on the west bank of the Mississippi River in an area that is zoned and developed for industrial uses (Figure 2-1). The plant is generally bounded by Salisbury Street on the north, Angelrodt Street on the south, Broadway on the west, and Wharf Street on the east. The plant has been in operation since 1867 and has produced a wide range of products, including metallic oxides and salts, ammonia, gun cotton, organic chemicals, and various weapons-related uranium products. The plant currently manufactures a variety of products for food, drug, cosmetic, pharmaceutical, and specialty chemical uses.

The plant property and equipment is owned by Mallinckrodt, Inc. (Mallinckrodt), a Delaware corporation. The plant is operated by Mallinckrodt Specialty Chemicals Company (MSCC), a Delaware corporation, on behalf of Mallinckrodt.

The St. Louis plant has evolved with time. The plant currently consists of approximately 100 buildings in over ten sub-plants encompassing twelve city blocks. Plant departments and buildings are designated by numbers or single letters. A current plant plot plan is provided in Figure 2-2. A 1991 aerial photograph of the plant is shown in Figure 2-3. The present-day Plant 10 includes the area formerly described as Plant 4. Plant support facilities include maintenance shops, research and quality control laboratories, warehouses, steam boilers, wastewater neutralization basins and a RCRA-permitted facility for drum storage of hazardous waste. The site also operates numerous tanks for the bulk storage of both organic and inorganic chemical liquids, one large fuel tank, and two above-ground gasoline storage tanks.

2.0 BACKGROUND INFORMATION (CONTINUED)

2.1 SITE INFORMATION (CONTINUED)

2.1.1 Site Description (Continued)

The St. Louis plant and adjacent industrial areas to the north and south were developed over the past century by placing fill over the alluvial soils of the Mississippi River floodplain. The fill typically consisted of bricks, coal, slag, cinder, concrete, construction rubble, glass, sand and clay. Construction of the Mississippi River levee east of Wharf Street started around 1964, and it now protects the plant from floodwater. Most of the plant is covered by buildings or by asphalt or concrete pavement.

2.1.2 Site Radiological History

Various past production operations at the Mallinckrodt plant have employed radioactive materials:

- From 1942 to 1957, Mallinckrodt refined uranium for national defense purposes, first as a contractor for the Manhattan Engineer District (MED), and later for the U.S. Atomic Energy Commission (AEC).

- From 1956 to 1960, Mallinckrodt Chemical Works extracted columbium, tantalum, uranium, thorium, and rare earth elements from euxenite mineral ore for delivery to the AEC and the General Services Administration (GSA) as part of the Defense Materials Procurement Program. The euxenite operation was performed under AEC source material license No. R-226 which expired in 1960.

- Between 1956 and 1977, Mallinckrodt subdivided small quantities of uranyl and thorium salts for resale under NRC license SUC-872. A report of Mallinckrodt's final radioactivity survey was submitted to NRC on December 13, 1979.

2.0 BACKGROUND INFORMATION (CONTINUED)

2.1 SITE INFORMATION (CONTINUED)

2.1.2 Site Radiological History (Continued)

- From 1961 to 1985, Mallinckrodt performed a commercial operation to extract columbium and tantalum (C-T) oxides and salts from feed materials containing low levels of natural uranium and thorium. The C-T operation was performed under AEC and later U.S. Nuclear Regulatory Commission (NRC) source material license No. STB-401. A two month trial production run was performed in early 1987, and the operation has been on standby status since that time.

2.1.3 Site Remediation of MED-AEC Wastes

The U.S. Department of Energy (DOE) is required to investigate and remediate all residual contamination resulting from MED-AEC operations at the St. Louis plant, pursuant to the Federal Facility Agreement (FFA) signed by DOE and the U.S. Environmental Protection Agency (EPA) in June 1990. As discussed in Section 2.4 below, this requirement extends to both the investigation and remediation of all waste associated with the MED-AEC uranium processing activities, as well as any other waste which may have become commingled with the MED-AEC uranium processing waste. DOE is addressing the contamination through the Formerly Utilized Sites Remedial Action Program (FUSRAP). DOE is preparing a proposed plan for remediation of areas within its responsibility. Pursuant to the FFA, the DOE must obtain EPA approval of the selected remedial action plan for the site. Implementation of a remedy is anticipated to commence within the next several years.

2.0 BACKGROUND INFORMATION (CONTINUED)

2.1 SITE INFORMATION (CONTINUED)

2.1.4 Hydrologic Setting

Subsurface investigations indicate the presence of four unconsolidated hydrostratigraphic units and one bedrock unit beneath the plant. These are, from top down (Figures 2-4 and 2-5): 1) an upper unconsolidated unit, 12-20 ft thick, consisting of perched groundwater in fill material; 2) relatively impermeable alluvial silt and clay; 3) a lower unconsolidated unit, 0-60 feet thick, consisting of relatively permeable sandy alluvial sediments; and, 4) limestone bedrock. Bedrock is exposed in highway cuts west of the site, and the bedrock surface slopes eastward to a depth of over 100 feet beneath the Mississippi River.

Groundwater in the sandy alluvial unit is locally saline and generally very hard, with high iron and manganese content. Groundwater found in the underlying bedrock is generally saline and non-potable. Groundwater beneath the plant and surrounding industrial areas is not used as a drinking water source. There are no known drinking water wells in the vicinity of the plant. The City of St. Louis obtains its drinking water from the Missouri River and Mississippi River (Chain of Rocks Water Works, 6.5 miles upstream from the plant).

2.2 THE COLUMBIUM-TANTALUM (C-T) OPERATION

2.2.1 Historical Background

Mallinckrodt extracted columbium and tantalum compounds from natural and synthetic ores and tin slags from approximately 1956 to 1985. Columbium and tantalum are naturally occurring metallic elements with various uses. Columbium, also called niobium, is used as an alloying agent in carbon and alloy steels and in nonferrous metals to improve material strength and provide other desirable properties. Tantalum is used in electronic components, chemical process equipment, and aircraft and missile parts.

From approximately 1956 to 1960, Mallinckrodt Chemical Works (MCW) extracted columbium, tantalum, uranium, thorium, and rare earth elements from euxenite mineral ore for national defense purposes. The operation was performed in connection with the Defense Materials Procurement Agency (General Services Administration) and Atomic Energy Commission. MCW was a subcontractor, and performed the euxenite processing under an AEC source material license R-226. The license expired March 1, 1960. Former euxenite process and support areas are shown on Figure 2-6.

In 1961, after the end of the euxenite operation, MCW began production of columbium and tantalum compounds at the St. Louis plant under a new AEC license number STB-401 issued on August 23, 1961. C-T process and support areas are shown on Figure 2-9. The C-T operations were conducted from 1961 to 1985. A brief pilot run was conducted in 1987.

2.2 THE COLUMBIUM-TANTALUM (C-T) OPERATION (CONTINUED)

2.2.1 Historical Background (Continued)

The business nature and feed materials of the C-T operation changed with time. From 1961 to approximately 1974, MCW purchased feed materials for processing from Malaysia, Thailand and other countries. From approximately 1975 to 1985, feed materials were processed under a long-term contract with National Research Corporation, Inc., of Newton, Massachusetts, which was owned partially by a West German company, H. C. Starck, Co., and a trading company called Salmon Corp. The feed materials during this period (1975-1985) consisted of a blend of upgraded synthetic tin slag concentrates and natural columbite and tantalite mineral ores.

In February 1986, Mallinckrodt informed the NRC that National Research Corporation, Inc. did not renew its contract and that the C-T plant would be placed on standby. Following a one year shutdown, a two month pilot production run was performed in early 1987 to explore new business opportunities. The pilot run processed approximately 20,000 pounds of tin slag from Thailand. The C-T plant was returned to standby mode following the trial run. No further C-T operations have occurred since that time.

Mallinckrodt's NRC source material license for the C-T operation expires March 31, 1994. On July 12, 1993, NRC amended Mallinckrodt's license to a possession-only license for decontamination and decommissioning (D&D) and license termination upon completion of D&D.

2.2 THE COLUMBIUM-TANTALUM (C-T) OPERATION (CONTINUED)

2.2.1 Historical Background (Continued)

It is estimated that a total of 105 curies of natural uranium (U-238, U-234, U-235) and natural thorium (Th-232, Th-228) were processed during the euxenite operation. Original contract documents suggest that 95 Ci of natural uranium and 10 Ci of natural thorium were contained in the ores processed.

Approximately 25 curies of natural uranium and thorium were processed during C-T operations under license STB-401. It is estimated that 6 Ci of natural uranium and 19 Ci of natural thorium were contained in the ores and tin slags processed.

2.2.2 Plant 5 Development History

Most of the C-T operations occurred in portions of Plant 5. The current Plant 5 area was used for manufacturing prior to its purchase by Mallinckrodt. Mallinckrodt began to develop Plant 5 in 1947 with the construction of buildings 200 West, 200 East, and 201 along Angelrodt Street at the southern end of the block. These buildings are still in operation and house organic and inorganic manufacturing processes. A new sewer system was installed in sections as Plant 5 developed. Wastewater was conveyed in underground sewers to the northwest corner of Plant 7. From this point, an underground sewer carried Plant 5 effluent east and connected to the sewer and outfall system constructed to support the MED-AEC Destrehan Street Facility. A pair of wastewater neutralization basins was constructed in the northeast corner of Plant 7 in the early 1970's.

2.2 THE COLUMBIUM-TANTALUM (C-T) OPERATION (CONTINUED)

2.2.2 Plant 5 Development History (Continued)

The building 219 warehouse/shed structure was built in 1949.

Buildings 213 and 236 were constructed in 1953. Building 213 was constructed as a locker and change facility for Plant 5 operations. It now houses plant utility operations, as well as a break room. Building 236 is currently used as a Plant 5 maintenance shop. At one time, C-T product was dried in tray dryers in building 236.

Building 238 was constructed in 1954 to house the euxenite process, the predecessor to the C-T operation. C-T operations performed in building 238 are described in Section 2.2.4 below.

Buildings 235 and 245 were constructed in 1959. Building 235 was used as a returned goods warehouse and at one time was used to store C-T feed materials and unreacted ore (URO). The east end of building 235 has recently been converted for chemical manufacturing. All areas of building 235 are currently being renovated for manufacturing and associated support activities. Building 245 was used for organic chemical processing unrelated to C-T.

Warehouse buildings 222 and 223 were built in 1960.

The building 204 inorganic chemical manufacturing facility was constructed in 1961.

2.2 THE COLUMBIUM-TANTALUM (C-T) OPERATION (CONTINUED)

2.2.2 Plant 5 Development History (Continued)

Buildings 246A and 246B were built about 1961 as building 238 was converted for C-T processing. C-T operations offices were located in building 246A. The original C-T extraction operations were performed in building 246B.

Building 250 was built in 1967 to support C-T and other manufacturing operations. The C-T quality control and research laboratories were relocated to building 250, as were manufacturing and laboratory facilities for other Mallinckrodt products. Prior to building 250 construction, C-T research laboratories were located in building 25, in Plant 1. This building was also used to support AEC-MED operations and will be addressed by DOE under FUSRAP.

Buildings 247A, 247B, and 248 were constructed in 1967 to house expanded C-T extraction and finishing equipment.

Building 240 was built in 1970 to provide office space for Plant 5 production personnel.

All Plant 5 streets are paved with asphalt or concrete. Paved streets were installed to serve manufacturing and warehouse buildings as they were constructed.

2.2 THE COLUMBIUM-TANTALUM (C-T) OPERATION (CONTINUED)

2.2.3 Plant 5 Hydrogeological Conditions

The hydrogeologic setting of the Mallinckrodt St. Louis Plant was previously summarized in Section 2.1. The subsurface hydrogeologic conditions in the vicinity of the C-T production and support areas in Plant 5 have been studied during previous investigations. These investigations have included the installation of over fifty exploratory borings within Plant 5, some of which were completed as monitoring wells.

The hydrostratigraphy, groundwater flow directions, and hydraulic gradient in the Plant 5 area are described below. Groundwater level contours and select boring locations in the Plant 5 area are shown on Figure 2-7. A subsurface profile of Plant 5 is shown on Figure 2-8.

Plant 5 is underlain by four stratigraphic units. These are, from top down (Profile A-A', Figure 2-8):

- fill, 7-18 feet thick;
- a relatively impermeable fine-grained alluvial unit, 20-30 feet thick;
- a sandy alluvial unit, 0-10 feet thick; and
- limestone bedrock.

The fill consists of bricks, clay, coal slag, cinder, concrete, construction rubble, glass, and sand. A perched groundwater unit occurs within the fill in Plant 5 at depths ranging from approximately three to nine feet below ground surface. Groundwater elevation measurements performed between 1982 and 1989 indicate that the perched groundwater flows generally to the northeast (Figure 2-7) with a horizontal hydraulic gradient of approximately 0.006 ft/ft.

2.2 THE COLUMBIUM-TANTALUM (C-T) OPERATION (CONTINUED)

2.2.3 Plant 5 Hydrogeological Conditions (Continued)

The fine grain alluvial unit beneath the fill consists of interbedded silty clay, clay, silt, and sandy silt. Representative hydraulic and geotechnical properties of this unit were evaluated by DOE. An in-situ, changing head test performed in this unit in Plant 7 yielded a horizontal hydraulic conductivity of 9.9×10^{-6} cm/sec. DOE also collected fourteen undisturbed samples of this unit from various boreholes across the St. Louis Plant and tested them for laboratory permeability, cation exchange, and geotechnical parameters. The vertical hydraulic conductivity ranged from 4×10^{-4} to 1×10^{-6} cm/sec with a geometric mean of 1×10^{-5} cm/sec. Cation exchange capacities ranged from 70 to 200 meq/100 g, with an average value of 39 meq/100 g.

The sandy alluvial unit beneath Plant 5 consists of fine to coarse sand. Groundwater in this unit may be confined or semi-confined by the overlying relatively impermeable fine-grained unit. The groundwater potentiometric surface occurs at depths of about 10 to 35 feet below ground surface. Groundwater in this unit flows eastward towards the Mississippi River with a horizontal hydraulic gradient ranging from 0.01 to 0.02 ft/ft (Figure 2-5).

The bedrock surface beneath Plant 5 occurs at depths ranging from approximately 30 to 55 feet and slopes gently eastward towards the Mississippi River (Profile A-A', Figure 2-8).

2.2 THE COLUMBIUM-TANTALUM (C-T) OPERATION (CONTINUED)

2.2.3 Plant 5 Hydrogeological Conditions (Continued)

Some monitoring wells in and around Plant 5 have been sampled for radionuclides by Mallinckrodt or DOE (see Table 2-1). The site groundwater is not a source of drinking water, but even if it were, it is noteworthy that the reported radionuclide activities are well below USEPA's proposed maximum contaminant levels (MCLs).

2.2.4 Former C-T Process and Support Areas

C-T production and support areas are listed in Table 2-2 and shown on Figure 2-9. All of the C-T process operations occurred in Plant 5. C-T support areas were located in Plants 1, 3, 5, 6, 7, and 8. Process building 238 in Plant 5 was used previously during the euxenite operation, while other process buildings in Plant 5 were constructed specifically for the C-T operation. Selected buildings and areas in Plants 6 and 7 were used to receive and store feed materials and drummed URO waste. Some URO was buried in the western portion of Plant 6 in 1972 and 1973 in conformance with 10 CFR 20.304 (Figure 2-10).

A generalized C-T process flow diagram is shown in Figure 2-11. C-T process raw materials are identified in Table 2-3. Columbium and tantalum oxides and salts were produced in a batch process that included five major steps:

2.2 THE COLUMBIUM-TANTALUM (C-T) OPERATION (CONTINUED)

2.2.4 Former C-T Process and Support Areas (Continued)

Step 1: Feed materials were received by truck in burlap bags and drums. The bags were generally placed in drums or boxes for storage. These were stored in Plants 6 and 7 prior to forklift transport to the ore staging area in Plant 5, where ore batches were selected.

The ore (feed material) was arranged into feed batches in the ore staging area east of Building 245. Ore was also staged on other paved areas in Plant 5. The feed material was ground into a fine grained slurry in the ball mill room (building 238 annex) using a wet milling process. The slurry was then pumped into boildown tanks where excess water was boiled off.

Due to the value of columbium and tantalum, the burlap ore bags were incinerated, and the ash was recycled into the process stream to recover columbium-tantalum. The incinerator was originally located west of building 248. In 1980, a new incinerator was located in its present position west of building 101 in Plant 6.

Step 2: The ore slurry was pumped into large rubber-lined acid dissolving tanks in building 238. Hydrochloric acid, sulfuric acid, and hydrofluoric acid were used during the tin slag processing. Hydrofluoric and sulfuric acids alone were used in dissolving/leaching columbite and tantalite ores and synthetically upgraded tin slags.

Step 3: The acid C-T mother liquor was decanted from the unreacted ore by mixing and settling. A flocculating agent was utilized to enhance separation. The decanted liquor was filtered and pumped to building 247 for Step 4 processing. Initially, the URO was filtered on

a plate and frame filter press as an acid slurry, washed with water, and the cake discharged to the plant sewer system. Between 1975 and 1980, the URO press cake was drummed and stored for future use or disposal. Beginning in 1980, the stored URO was reprocessed and URO generated by the process was neutralized with caustic or ammonia, dewatered in a filter press, dried in a pancake drier, and drummed for transfer to a licensed uranium mill or to a licensed low level radioactive waste disposal facility. All of the above URO processing was performed in building 238.

Step 4: The acid mother liquor was subjected to a two-series extraction/purification process. In the first series, the C-T mother liquor was subjected to an extraction process using methyl isobutylketone (MIBK) and sulfuric acid. This generated a columbium-tantalum-MIBK stream (organic end) and a raffinate (aqueous end) consisting of hydrofluoric acid, sulfuric acid, salts (e.g., iron, manganese), and residual URO material. In the second series, the columbium-tantalum-MIBK stream was contacted with water in a second extractor to separate the columbium from the MIBK phase. This yielded a tantalum-MIBK stream (organic end) and a fluocolumbic acid stream (aqueous end). MIBK was removed from the tantalum-MIBK stream by steam stripping, yielding a fluotantalic acid stream. The raffinate waste stream was steam stripped to remove minute quantities of MIBK, and then used to wash columbium and tantalum acid liquors from the URO and reused as feed liquors for the solvent extraction step, or was neutralized and discharged to the sewer. The MIBK was recovered and recycled back into the process. These process steps were performed in buildings 246B and 247A. Solvent extraction was not utilized until approximately 1964. Prior to this time, the columbium and tantalum are believed to have been separated from the mother liquor by precipitation.

2.2 THE COLUMBIUM-TANTALUM (C-T) OPERATION (CONTINUED)

2.2.4 Former C-T Process and Support Areas (Continued)

Step 5: The primary C-T process products were columbium oxide and potassium fluotantalate salt. Approximately five percent of the tantalum product was produced as tantalum oxide. Columbium and tantalum oxides were precipitated from their respective product streams (fluocolumbic acid, fluotantalic acid) by addition of ammonia. Finishing steps included filtration, drying, and calcining. Columbium oxide precipitation and finishing were performed in buildings 247B and 248. Tantalum oxide precipitation and finishing were performed in building 238; tray drying was also performed for a short period in building 236. The potassium fluotantalate salt was precipitated from the fluotantalic acid stream by addition of potassium chloride, separated in a centrifuge, and dried in tray dryers. These steps were conducted in building 238.

2.2.5 Environmental Controls and Waste Management

Process environmental controls employed by the C-T operation included air emission controls and floor sumps with controlled discharge to sewers. The emission controls included a dust collector in the ball mill area, two acid fume scrubbers and an ammonia scrubber in building 238, and dryer/calciner scrubbers. The C-T operation was supported by a radiation safety program.

During the C-T operation, decanted wash liquors, raffinate, and C-T filtrate from the final process steps were discharged to the plant sewer.

2.2 THE COLUMBIUM-TANTALUM (C-T) OPERATION (CONTINUED)

2.2.5 Environmental Controls and Waste Management (Continued)

The management of URO solids changed with time. Prior to 1975, URO was discharged to the sewers. Starting in 1975, all URO solids were drummed and stored on-site. This material was processed starting in 1980 using the new URO neutralization, filtration and drying system. All URO processed through this system was drummed for transfer to a licensed uranium mill or a licensed low level radioactive waste disposal facility.

In 1972 and 1973, approximately 300 cubic yards of URO were buried on-site in conformance with 10 CFR 20.304 (Figure 2-10). This material had been drummed and held for further processing due to high levels of insoluble tantalum. Because of the high cost of recovery, only the drums with the highest levels of tantalum were reprocessed and the rest, which amounted to 300 cubic yards, was buried on-site.

2.3 THE MED-AEC OPERATIONS

2.3.1 Historical Background

In April 1942, Mallinckrodt, then called Mallinckrodt Chemical Works (MCW), was selected by the United States War Department to produce the key uranium compounds used in the first self-sustaining nuclear chain reactor at the University of Chicago. To produce the needed uranium fuel, MCW purified uranium ore concentrates by ether extraction. The company was the sole supplier of uranium compounds for the Manhattan Project well into 1943 and provided high purity uranium for the duration of the war.

Within 50 days of accepting the assignment from the War Department, MCW began producing highly purified uranium dioxide (UO_2) at a rate of one ton per day in Plant 2. Later in 1942, MCW started production of uranium tetrafluoride (UF_4 or green salt). In July 1943, MCW started the first uranium metal plant in the area called Plant 4 (this area is now designated Plant 10). Laboratory and process

2.3 THE MED-AEC OPERATIONS

2.3.1 Historical Background (continued)

development support for Plant 2 and 4 activities were provided from facilities in Plant 1. In 1945, the Destrehan Plant (Plants 6, 6E, and 7 on Destrehan Street, Figure 2-12) was built to process pitchblende ore and to increase the capacity of the refinery. Plant 6 production began in 1946. By 1948, the project employed 250 people and operated approximately $12 million worth of equipment. In 1958, the plant was put on standby, and the uranium processing was transferred to the Weldon Spring Plant.

The St. Louis plant manufactured approximately 50,000 tons of uranium products during the MED-AEC operations. Feed materials containing approximately 30,000 Ci natural uranium and 10 Ci natural thorium activity were processed between 1942 and 1958.

In 1950 and 1951, the MED-AEC facilities in Plants 1 and 2 were partially decommissioned. In 1960 and 1961, the MED-AEC facilities in the former Plant 4 area and the Destrehan Plant were decommissioned. These decommissioning activities are described further in Section 2.3.4.

As described in Section 2.4 below, DOE will remediate these facilities under the FUSRAP program.

2.3.2 Former MED-AEC Process and Support Areas

Figure 2-12 shows the former MED-AEC production process and support areas, and Figure 2-13 shows a generalized process flow diagram for the MED-AEC operation. Table 2-4 lists the feed materials, other raw materials, products, and byproducts of the MED-AEC production process.

The production of uranium metal in the Destrehan Plant involved eight basic process steps: (1) acid digestion of feed material in nitric acid; (2) adjustment of the the resulting liquor; (3) solvent (ether)

2.3 THE MED-AEC OPERATIONS (CONTINUED)

2.3.3 Environmental Controls and Waste Management (Continued)

Recycled liquid waste streams included ether, nitric acid, and hydrofluoric acid. Some liquids were recycled on-site. Others, such as spent hydrofluoric acid, were shipped off-site to the original supplier. Hydrofluoric acid waste streams from the UF_4 processing were neutralized and discharged to the sewers. Contract No. W-14-108-Eng-8, Supplement Agreement No. 11 (March 1, 1947) indicated that sewer lines were installed in Plant 6 to drain three sumps, located outside the north wall of the manufacturing building. Weak acid concentrates and tail water from the nitric acid concentrator were discharged to the plant sewer. A 1956 description of the Destrehan Plant operations indicated that raffinate filtrate from pitchblend extraction was discharged to the sewer at a rate of 12,000 gallons per day.

The sewer systems from Plants 1 and 2 drained north into the deeper of two sewers beneath Salisbury Street. This sewer flowed east by gravity and discharged into the Mississippi River. The Plant 4 sewers flowed west to the Broadway sewer which flowed to the south and ultimately to the Mississippi River. The Destrehan Plant (plants 6 and 7) discharged wastewater to the shallow Salisbury Street sewer and to a dedicated sewer built beneath Destrehan Street by MED/AEC. Both sewers discharged into the Mississippi River.

From 1942 to 1945 MED-AEC solid wastes were shipped to the Lake Ontario Ordnance Works in Lewiston, New York. Most of this material was subsequently transferred to National Lead in Fernald, Ohio in 1952.

2.3 THE MED-AEC OPERATIONS (CONTINUED)

2.3.3 Environmental Controls and Waste Management (Continued)

From 1946 to 1958, process wastes were sent to a 22-acre AEC storage site next to the St. Louis airport. The lead gangue cake (K-65) from pitchblende processing was packaged in drums and stored in building 114 until removed by the AEC. The barium sulfate and raffinate cakes were collected in dumpsters, loaded in AEC dump trucks, and transferred daily to the AEC-owned St. Louis airport storage site. The raffinate, a byproduct from the wet processes, was dewatered, stripped of ether, precipitated, and filtrated to a cake. The St. Louis airport storage site received approximately 74,000 tons of Belgian Congo pitchblende raffinate cake, 32,500 tons of Colorado raffinate cake, and 8,700 tons of barium sulfate cake. Other MED-AEC wastes sent to the site included metal scrap, dolomite slag, and tailings of uranium scalping operations from magnesium fluoride slag.

2.3.4 Previous MED-AEC Decontamination Activities

Programs to decontaminate surfaces and structures in Plants 1 and 2 were performed in 1950, 1954 and 1970.

In 1960 and 1961, the AEC initiated decontamination of Plant 4 and the Destrehan Plant. In general, all buildings in Plant 4 and all buildings in the wet processing areas of Plant 6 were demolished. The salvageable material and equipment were decontaminated and sold. If the material could not be decontaminated to levels below the acceptable cleanup standards, it was either sold as non-salvageable material with usage restrictions or disposed of.

2.3 THE MED-AEC OPERATIONS (CONTINUED)

2.3.4 Previous MED-AEC Decontamination Activities (Continued)

The goal of the decommissioning effort was to decontaminate the area to then permissible levels. The levels applied during the decontamination activities were:

- average beta-gamma radiation no greater than 0.1 milliroentgen-equivalent-physical per hour with peaks no greater than 1 mrep/hr.
- average alpha activity of 1,000 dpm/100 cm^2 with peaks no greater than 5,000 dpm/100 cm^2.

Decontamination methods used to remove gross contamination included:

- broom sweeping to clean floors of accumulated dust and debris
- water rinsing using fire hydrants at maximum pressure
- dry sandblasting to clean concrete and steel surfaces, followed by a water rinse
- pneumatic hammer chipping where contamination penetrated deep into concrete
- spot cleaning of certain surfaces with an acid-detergent solvent.

2.4 DEPARTMENT OF ENERGY FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM AND FEDERAL FACILITY AGREEMENT

2.4.1 DOE's Formerly Utilized Sites Remedial Action Program (FUSRAP)

The Atomic Energy Act of 1954 contained a Congressional finding that the "regulation . . . of the production and utilization of atomic energy and of the facilities used in connection therewith is necessary in the national interest . . . to protect the health and safety of the public." 42 U.S.C. §2012(e). The Act also states "in order to protect the public and to encourage the development of the atomic energy industry . . . the United States may make funds available for a portion of the damages suffered by the public from nuclear incidents [defined to include any "occurrence . . . causing damage to property"], and may limit the liability of those persons liable for such losses." Id. at 2012(i). The Act directs DOE to establish standards to "minimize danger to life or property" Id. at 2201(b), and authorizes the appropriation and expenditure of funds by DOE "for the restoration or replacement of any plant or facility destroyed or otherwise seriously damaged . . ." Id. at 2017(c). Thus, DOE's authority under the Act extends to the "restoration" of facilities damaged by authorized activities, owned by contractors, such as Mallinckrodt, that assisted with the development of the program.

DOE, in turn, has used that authority to establish the FUSRAP. When DOE established FUSRAP, it stated that the objective of the program was "to ensure that sites formerly used by the Manhattan Engineer District and the Atomic Energy Commission are not contaminated with radioactive residues that may present a radiological hazard to the general public" (FUSRAP Summary Protocol; January 1986). FUSRAP is a recognition of the partnership that allowed the expansion of the wartime and peacetime nuclear programs, and an acknowledgement of the government's responsibility to remediate formerly utilized sites.

2.4 DEPARTMENT OF ENERGY FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM AND FEDERAL FACILITY AGREEMENT

2.4.1 DOE's Formerly Utilized Sites Remedial Action Program (FUSRAP) (Continued)

Review of Mallinckrodt's St. Louis site occurred in 1977, when the Energy Research and Development Agency (ERDA) commissioned a study of former MED/AEC activities at the site. This was followed by a radiological survey completed by Oak Ridge National Laboratory (ORNL) in 1981. The survey identified residual MED-AEC contamination above DOE guidelines. In 1992, DOE gave formal notice in the Federal Register of its intent to Prepare a Remedial Investigation and Feasibility Study and an Environmental Impact Statement for the response action at the St. Louis Site. DOE states in that notice that the primary objective of FUSRAP is to "identify and remediate sites where radioactive contamination remains from the early years of the nations' (sic) atomic energy program or from other activities that resulted in conditions that Congress has authorized DOE to remediate" (57 Fed. Reg. 887, Column 3, Jan. 9, 1992). The Notice also states that the goals of FUSRAP are to:

(1) Control radioactive contamination at the sites, in compliance with applicable or relevant and appropriate requirements for the protection of human health and the environment, and

(2) To the extent possible, certify the sites for use without radiological restrictions following removal of the contamination.

2.4 DEPARTMENT OF ENERGY FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM AND FEDERAL FACILITY AGREEMENT (CONTINUED)

2.4.1 DOE's Formerly Utilized Sites Remedial Action Program (FUSRAP) (Continued)

Mallinckrodt participated in the early nuclear program as a contractor acting under the strict control of the government and following rigid plans and procedures. It was clear at the time that there were risks associated with the program, but the government deemed the benefits to outweigh the risks, and proceeded with the program, taking precautions that it believed appropriate at the time. It is also clear from the Atomic Energy Act, and from the design of the FUSRAP program, that the government has accepted responsibility for the consequences of its early nuclear program, including the remediation of residual radioactive contamination at FUSRAP sites, such as Mallinckrodt's.

2.4.2 DOE Obligations under Federal Facility Agreement

The DOE's obligation to remediate the St. Louis Downtown Site is further described in the Federal Facility Agreement (FFA) for the Site. The United States Environmental Protection Agency (EPA) Region VII and DOE executed this Agreement in June, 1990. DOE had previously investigated and performed radiological surveys at the St. Louis Site in connection with designation of the site for remediation under FUSRAP. The FFA further defines the conditions dictated by EPA to manage remediation at St. Louis. The document creates broad obligations for DOE to clean up all residual waste from uranium processing, including such waste that might have mixed with other contamination at the site. The FFA specifically requires that the DOE remediate (FFA §III at 2):

2.4 DEPARTMENT OF ENERGY FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM AND FEDERAL FACILITY AGREEMENT (CONTINUED)

2.4.2 DOE Obligations under Federal Facility Agreement (Continued)

1. All waste, including but not limited to, radiologically contaminated waste, resulting from or associated with uranium manufacturing or processing activities conducted at the St. Louis Downtown Site, and

2. Other chemical or non-radiological waste which have been mixed or commingled with radiologically contaminated waste resulting from or associated with uranium manufacturing or processing activities conducted at the St. Louis Downtown Site.

Many areas at the St. Louis plant have already been characterized and indicate various levels of radiological contamination from MED/AEC uranium processing activities. Some of these areas which were used for MED/AEC processing activities were also used for C-T support activities. The DOE must remediate these areas pursuant to the terms of the FFA.

Through implementation of DOE's FUSRAP goals and objectives and as required by the FFA, DOE will remediate and remove residual radioactive contamination at the St. Louis plant in areas where MED-AEC activities occurred as part of the FUSRAP remediation, in a manner to prevent any harm to human health and the environment.

2.5 PREVIOUS INVESTIGATIONS OF C-T PROCESS AND SUPPORT AREAS

Several previous site assessments have been conducted in Plant 5 and in and around the C-T facilities. These have included radiological, chemical and hydrogeologic investigations, and are summarized below:

John Mathes and Associates, Inc.

In September, 1984, Eberline and John Mathes and Associates, Inc. collected and analyzed subsurface samples from 21 borings in and around building 238 (Reference 10.2). Borings were taken to a depth of 10 feet or bit refusal. Boring logs indicate that all soil samples were taken in fill material.

Sixty-four soil samples were analyzed for Ra-226. The average concentration, with one 560 pCi/g outlier removed, was 4 pCi/g. A total of 9 samples, collected from six boreholes, had activity greater than 5 pCi/g.

Gamma logging was performed on 20 of the bore holes. Eberline was unable to correlate the gamma logs with the Ra-226 analysis.

Department of Energy

In 1988, the DOE contractor, Bechtel National, Inc., performed soil sampling at eight locations in Plant 5 (Reference 10.1). Soil samples were analyzed for the radioisotopes: U-238, Th-230, Ra-226, and Th-232. Two samples were analyzed for specific metals (antimony, arsenic, cadmium, copper, lead, molybdenum, selenium, tellurium, and zinc). Samples were obtained via split spoons from the surface to depths up to 20 feet.

2.5 PREVIOUS SITE INVESTIGATIONS (CONTINUED)

Department of Energy (Continued)

Elevated U-238 and Th-230 were identified north of building 247, north west of building 245, and in the street north of buildings 238 and 235. Maximum U-238 and Th-230 activities were 23 and 55 pCi/g, respectively. Maximum Ra-226 activity was 150 pCi/g. Maximum depth of elevated activity was 14 feet in the street north of building 235. Thorium-232 was not identified above guideline values in any of these samples, with the exception of one sample at 8 pCi/l.

Elevated U-238, Th-230, and Ra-226 activity were identified northwest of building 250 at depths up to seven feet. U-238 and Th-230 activity in shallow samples (0.5-2.0 feet) was 170 and 250 pCi/g, respectively. Activity decreased with sample depth. Thorium-232 was not identified above guideline values in these samples. Bechtel also obtained samples southwest of building 240. The shallow sample (0 - 2.0 feet) indicated slightly elevated Th-230 activity (6.8 pCi/g). None of the other samples exceeded guideline values. Mallinckrodt believes that the elevated activity in DOE samples taken west of buildings 240 and 250 is attributable to MED-AEC material handling activities in Plant 4 and along Second Street. Mallinckrodt believes that the elevated activity in DOE samples taken west of buildings 240 and 250 is attributable to MED-AEC material handling activities in Plant 4 and along Second Street.

2.5 PREVIOUS SITE INVESTIGATIONS (CONTINUED)

Malcolm Pirnie, Inc.

In 1989, Malcolm Pirnie performed environmental investigations at the Mallinckrodt St. Louis Plant. Groundwater samples from wells in and adjacent to Plant 5 were filtered with a 0.45 micron filter and analyzed for radionuclides (see Table 2-1). Well locations are shown on Figure 2-7. None of the samples contained Ra-226, Th-230, or Th-232 activity above 1 pCi/l. Well W-152, located northeast of building 238, contained U-238 at an activity of 2.2 pCi/l.

TMA/Eberline

In 1992, TMA/Eberline removed loose contamination from equipment, interior walls, and floors of selected C-T process buildings in Plant 5 (Reference 10.4). Wastes generated from this activity were disposed of as low level radioactive material at Richland, Washington. Following this removal activity, TMA/Eberline performed a Preliminary Radiological Investigation of loose and fixed contamination in selected C-T and Plant 5 buildings (Reference 10.5). Eberline performed a walkover gamma survey of Plant 5 streets and collected and analyzed limited residue samples. This activity provides a significant portion of the surface scanning required for the C-T characterization.

Rust Remedial Services, Inc.

In 1993, Rust Remedial Services, Inc. (Rust) performed a radiological scoping survey in selected C-T support areas; Buildings 90, 91, and 236 maintenance shops; Buildings 62 and 213 locker rooms; and Building 250 laboratories (Reference 10.6). Gross and removable alpha and beta/gamma measurements were performed.

3.0 APPROACH TO C-T SITE CHARACTERIZATION AND DECOMMISSIONING

3.1 SITE-SPECIFIC CONSIDERATIONS AND OBJECTIVES

Based on the information presented in the prior sections, a site-specific characterization approach is proposed. The proposal is based on facts related to the St. Louis site that are important considerations for C-T site characterization and decontamination and decommissioning (D&D) pursuant to license No. STB-401:

- The areal extent and scale of MED-AEC operations as shown by historical records, maps, and photographs, as well as the radioactivity throughput, indicate that virtually all of the radiological contamination outside the well defined Plant 5 C-T process and support areas is derived from MED-AEC operations and is unrelated to the NRC licensed operations.

- The areal extent of the former MED-AEC process and support areas surrounding Plant 5 (see Figure 2-12), and routes of contaminant dispersal (e.g. loss during materials transport, atmospheric deposition, and flooding) suggest that MED-AEC contamination may have migrated into Plant 5.

- The DOE is investigating and remediating residual contamination from the MED-AEC operations under FUSRAP and in accordance with the terms of the FFA. The DOE will propose a remedial action for the site and in coordination with the EPA and with public notice and comment will select and implement the appropriate remediation activities. The DOE is preparing a proposed remediation plan which will be implemented within the next several years.

3.0 APPROACH TO C-T SITE CHARACTERIZATION AND DECOMMISSIONING (CONTINUED)

3.1 SITE-SPECIFIC CONSIDERATIONS AND OBJECTIVES (CONTINUED)

The presence of MED-AEC contamination at the St. Louis plant, and the overlap of the Plant 6 and 7 MED-AEC process areas and C-T support areas indicate that the plans for C-T site characterization and decommissioning must seek to limit the potential for conflict, duplication, and inconsistency between Mallinckrodt's responsibilities under NRC License No. STB-401 and those of DOE under the FFA and FUSRAP. Therefore, the objectives considered in developing the C-T site characterization and decommissioning plans are as follows:

- Develop decontamination and decommissioning (D&D) goals and approaches that are protective of human health and the environment and consistent with applicable NRC, EPA, and state regulations.

- Develop practical, cost-effective D&D approaches that limit potential interference and duplication of effort with DOE's remediation activities pursuant to the FFA and FUSRAP.

- Limit major inconsistencies with the remedial goals and approaches established by DOE, EPA, and Missouri Department of Natural Resources (MDNR) for remedial work under the FFA and FUSRAP.

3.2 PROPOSED APPROACH AND RATIONALE

To achieve the objectives listed above, Mallinckrodt proposes an approach to C-T characterization pursuant to NRC License No. STB-401 that addresses the unique mix of regulatory and technical issues at this facility. The approach is designed to protect human health and the environment consistent with NRC goals and accommodate DOE's FUSRAP activities.

3.2 PROPOSED APPROACH AND RATIONALE (CONTINUED)

The proposed scope of the characterization and decommissioning program involves all C-T processing and support areas in Plant 5 (except as described in the following paragraph) and certain C-T support areas in Plants 3, 6, 7, and 8. Although the presence of MED-AEC contamination cannot be precluded, the contamination in these areas appears to be primarily related to the operations under license No. STB-401 or AEC license No. R-226.

DOE has identified radiological contamination in Plant 10 (the former MED-AEC Plant 4 area) and in areas along Second Street between Angelrodt and Salisbury Streets. Surficial and subsurface contamination at the northwest corner of building 250 has been documented by DOE. Mallinckrodt has also identified radiological contaminants along the west side of building 250. The area was used by Mallinckrodt as an employee parking lot prior to building 250 construction. Contamination of these areas including the soils beneath buildings 250 and 240 is believed to be the result of MED-AEC activity (MED activities in Plant 4 and materials transport along streets and tracks west of Plant 5), and therefore subject to remediation by DOE under FUSRAP and the FFA. These areas are therefore not addressed in this plan.

Certain of the C-T support areas in Plants 1, 6, and 7 contain widespread MED-AEC contamination that is subject to DOE remediation under the FFA and FUSRAP. Because these C-T support areas will be addressed pursuant to DOE activities under the FUSRAP program and the FFA, they are not included in the C-T characterization plan.

3.3 CHARACTERIZATION SCOPE

C-T process and support areas are shown in Figure 2-9, and are described in Table 2-2. C-T areas to be addressed by Mallinckrodt are listed in Table 3-1. Site characterization will be focused on the former C-T process and support areas in Plant 5. The scope will also include: Building 62 (a change room) in Plant 3; Buildings 90 and 91 (maintenance areas) in Plant 8; C-T incinerator and adjacent building 101 roof in Plant 6; and the wastewater basin structures in Plant 7, excluding the soil beneath them. Mallinckrodt believes that the historical records and recent DOE investigations indicate that the soils beneath the basins contain MED-AEC residues subject to DOE remediation under the FFA and FUSRAP (see Appendix A).

Mallinckrodt will perform no further characterization of the URO burial cells in Plant 6 as the locations are relatively well documented (Figure 2-10) and surgical excavation and disposal in the decommissioning phase are planned. An estimated 300 cubic yards of URO are present in these burial cells. DOE investigations have identified widespread MED-AEC contamination at depths up to 18 feet. The URO was buried in trenches in this area which will be remediated by DOE under FUSRAP.

Plant 5 characterization will include affected and potentially affected structures, subsoils, sewers, groundwater, and outdoor ore and URO staging and handling areas. The structures will include the Plant 5 buildings listed in Table 3-1.

The sewer characterization will include affected lines within Plant 5, the lines connecting Plant 5 to the Plant 7 lift station, and the concrete structure of the Plant 7 wastewater neutralization basins.

Subsurface characterization will be focused on C-T wet process areas, sewer lines, and outdoor areas where surface scans indicate the potential for subsurface contamination. This will be a phased approach with a subsequent, second phase of subsurface sampling, if necessary.

3.3 CHARACTERIZATION SCOPE (CONTINUED)

The former C-T incinerator in Plant 6 will be characterized as required to properly decontaminate, dismantle, and dispose of the structural components and adjacent pavement within the restricted area. The incinerator stack is mounted against the west wall of building 101 with the exhaust point emerging above the roof line. Therefore, the roof of building 101 will be further characterized to evaluate the presence of potential contamination from former stack emissions.

Groundwater is not withdrawn for drinking water use in the plant locale, and Mallinckrodt does not foresee its' future drinking water use. Groundwater characterization activities are therefore not included in this plan. It is highly unlikely that the shallow groundwater beneath the Mallinckrodt site will ever be used as a source of water for drinking or irrigation. There are several reasons for this belief:

- The Mallinckrodt plant is within the City of St. Louis, which has an established public water supply system. This system treats and distributes water obtained from the Mississippi River north of Mallinckrodt.

- Groundwater beneath the plant and surrounding industrial areas is not currently used as a drinking water source. There are no known drinking water wells in the vicinity of the plant.

- Groundwater in bedrock is generally saline and non-potable. Groundwater in the sandy alluvial unit is locally saline and generally very hard, with high iron and manganese content.

- The Mallinckrodt plant is built on fill consisting of cinders, soil, rubble and debris. The fill is underlain by clay and silts, which are underlain by a sand layer of varying thickness and limestone bedrock. There is insufficient organic soil cover to support crop growth.

3.3 CHARACTERIZATION SCOPE (CONTINUED)

- It is reasonable to expect the Mallinckrodt site to continue in the current industrial land use. If future St. Louis development were to preclude such land use in the urban areas, likely alternative uses would include commercial or multifamily residential. These uses will not result in the withdrawal of groundwater.

- The Mississippi River is located immediately east of the Mallinckrodt plant and could provide sufficient quantities of water if the municipal supply were disrupted.

In addition, DOE is investigating and evaluating groundwater under FUSRAP and the FFA. As previously described, MED-AEC activities were performed to the west, north, and east of the C-T facility. Mallinckrodt anticipates that a groundwater remedy under FUSRAP, if required, will be of a site-wide nature and, as required by the FFA, will meet EPA requirements.

3.4 CHARACTERIZATION PLAN OBJECTIVES

In support of the ultimate decommissioning of the C-T Site, the main objectives of the characterization include:

- Quantifying the physical and chemical characteristics and the geographic extent of radioactive contamination in C-T process and support areas as described above to the degree necessary for development of the decommissioning and decontamination plan. Associated non-radioactive constituents will be characterized as necessary to assess the potential impact on decommissioning and decontamination waste disposal alternatives.

- Quantifying environmental parameters as necessary to allow prediction of potential human exposure from existing or post-decontamination radioactive residues.

3.4 CHARACTERIZATION PLAN OBJECTIVES (CONTINUED)

- Supporting evaluation of alternative decommissioning actions and detailed planning of a preferred approach for decommissioning, decontamination, and waste disposal.

The approach used to achieve these objectives will ensure that the health and safety of employees and subcontractors performing the characterization will not be compromised, that the characterization activities will not produce environmental damage, that the quality of the data obtained will be appropriate to the purpose for which they were obtained, and that the characterization will provide a defensible basis on which to design and evaluate site decommissioning alternatives.

4.0 SCOPE OF WORK

4.1 RADIONUCLIDES AND CHARACTERIZATION GUIDELINES

4.1.1 Radionuclides of Concern

Based on the knowledge of site operations and the results of previous radiological assessments, the significant radioactive contaminants have been determined to be the radionuclides found in natural uranium and natural thorium. As the C-T plant did not use enriched uranium material, it is not expected that uranium contamination will be enriched in the U-238 isotope. However, the uranium and thorium decay chains are expected to be found in varying degress of secular equilibrium because of the chemical extraction processes performed on the licensed material. The isotopes of concern for this characterization are:

Uranium Decay Series	Thorium Decay Series
U-238	Th-232
U-234	Th-228
Th-230	Ra-228
Ra-226	

Potassium-40 (K-40) is potentially prevalent on the site in concentrations greater than would be found in nature. This is due to the use of large quantities of potassium chloride used in the C-T process and other areas of the Mallinckrodt site. K-40 will also be included in soil and solid sample analysis.

The presence of other radioactive contaminants will be investigated if significant activities are encountered in gamma spectroscopy analyses. Specific guideline values will be determined on the basis of data obtained through this characterization.

4.1 RADIONUCLIDES AND CHARACTERIZATION GUIDELINES (CONTINUED)

4.1.2 Characterization Guideline Values

For the purpose of ensuring that the appropriate data are collected during the characterization, Mallinckrodt will establish a series of Guideline Values. The guidelines are of primary usefulness in defining required minimum detectable activity (MDA), detection limit (DL), accuracy, and precision for field and laboratory instruments to be employed. These guidelines are reflective of, but not necessarily identical to the final release criteria upon which the decommissioning plan is expected to be based. Guideline values have been developed for each radionuclide of concern and have generally been based on NRC's Branch Technical Position (BTP) Option 1 (Reference 10.9) and Policy and Guidance Directive FC 83-23 (Reference 10.14).

These guidelines apply as "above background" levels.

Surface Contamination Guideline

Surface contamination guideline values will be established for each support and process building as recommended by the NRC (Reference 10.14). Six surface contamination samples will be obtained from each building and analyzed to define the presence and distribution of radionuclides. A gross surface activity guideline will be derived based upon the relative distribution of radionuclide activity and NRC's Acceptable Surface Contamination Guidelines (Reference 10.14) for nuclide groups using the equation:

4.1 RADIONUCLIDES AND CHARACTERIZATION GUIDELINES (CONTINUED)

Surface Contamination Guideline (Continued)

Derived Guideline = $1/(f_1/G_1 + f_2/G_2 + \ldots f_n/G_n)$,

where: f_n = fraction of total sample activity contributed by radionuclide "n", and

G_n = NRC free release surface guideline value for radionuclide "n".

Soil Contamination Guideline

The BTP Option 1 values were chosen as soil contamination guidelines.

- 10 pCi/g natural thorium (Th-232 + Th-228)
- 10 pCi/g natural uranium (U-238 + U-234)
- 30 pCi/g uranium (U-238 + U-234) (when Th-230 and Ra-226 are not present at <50% of radioactive equilibrium)
- 5 pCi/g Th-230, Ra-226, Ra-228 (when enriched over equilibrium)

4.1 RADIONUCLIDES AND CHARACTERIZATION GUIDELINES (CONTINUED)

Direct Exposure Guideline

Ten micro-Roentgens/hours (μR/hr) above natural background at one meter from the nearest surface is the characterization guideline for gamma exposure rate measurement. This is the same as the NRC specifies as an acceptable exposure rate above contaminated land (Reference 10.0 and 10.14). Since is it most unlikely that any Plant 5 building will ever be used as a residence, the same 10 μR/hr guideline will be applied indoors as the basis to derive a gamma exposure rate measurement sensitivity goal.

4.2 IDENTIFICATION OF POTENTIALLY CONTAMINATED AREAS

The C-T process and support areas were separated into affected and unaffected categories to facilitate cost-effective radiological surveying. Areas with known contamination and areas for which previous surveys identified activities in excess of 25% of the guideline values (Reference 10.7) were identified as affected areas. C-T areas for which there was a low likelihood of contamination or for which previous surveys identified activities less than 25% of the guideline values were identified as unaffected areas. Each area is discussed briefly below:

4.2.1 Building Interiors and Roofs

As described in Section 4.1.2 above, surface contamination samples will be obtained and guideline values will be determined for each building. The areas will be surveyed as unaffected areas and compared to guidelines. The areas will be resurveyed as affected areas if any activities exceeding 25% of the weighted guideline values are identified.

Some Plant 5 roofs were surveyed during a previous investigation (Reference 10.5). Additional roof surveys will be conducted as discussed in Section 5.2.5 below.

4.2 IDENTIFICATION OF POTENTIALLY CONTAMINATED AREAS (CONTINUED)

4.2.2 Plant 5 Streets

Eberline performed a 100% walkover gamma survey of Plant 5 streets in 1992. The survey identified eighty one areas with surface activity greater than twice background. The anomalous areas ranged from single points to areas of 100 ft^2 or more, though spots and small areas form the bulk of the anomalous measurements. Seven areas with surface activity over 100k cpm were identified: north of buildings 246 and 247, east of building 238, southeast of building 238, southwest of building 238, south of building 250, southeast of building 240, and southeast of building 245. Direct alpha and beta/gamma measurements will be taken as described in section 5.2.7. The subsurface soils beneath areas with surface activity in excess of 75% of the guideline will be characterized as affected areas.

4.2.3 Plant 5 Sewers

The Plant 5 sewers (and the soils adjacent to them) serving building 250 and the C-T process areas will be surveyed as affected areas. Plant 5 sewers connected to manholes containing residues in excess of 25% of the guideline will also be surveyed as affected areas.

4.2.4 C-T Incinerator

The C-T incinerator and adjacent pavement within the restricted area in Plant 6 will be surveyed as an affected area.

4.2 IDENTIFICATION OF POTENTIALLY CONTAMINATED AREAS (CONTINUED)

4.2.5 Wastewater Neutralization Basins

The concrete liner of these basins was exposed to effluent from the C-T plant and therefore may exhibit contamination in excess of 25% of guideline values. In 1990, synthetic liners were installed in each basin; removal and intact replacement of the liner is not feasible. To the degree practical, the basins will be surveyed as an affected area. As discussed in Section 3.3, remediation of the soils beneath the basins is the responsibility of DOE.

4.2.6 Subsurface Soils

Soils beneath affected Plant 5 C-T structures, sewers, and streets will be sampled as appropriate to delineate areas above guideline values. As discussed below, both fill and underlying silt/clay soils will be sampled and analyzed; locations will be chosen on both biased and systematic bases, depending upon the potential for subsurface contamination.

5.0 CHARACTERIZATION PLAN

This section describes the phased approach to be followed regarding radiological survey work and subsurface sampling to be conducted. It also outlines the data quality objectives identified for this investigation, along with the planned physical sampling work and the target schedule.

5.1 DATA QUALITY OBJECTIVES

The purpose of sampling and analysis is to provide analytical measurements of sufficient quality to support site characterization, dose assessment and a basis for decontamination and decommissioning as required for termination of Mallinckrodt's Source Material License No. STB-401. Towards this end, field and laboratory analytical data will be generated under a quality assurance program consistent with NRC Regulatory Guide 4.15 and in accordance with the guidance provided in NUREG/CR 5849. This process involves the use of Data Quality Objectives (DQOs) to ensure that data are of acceptable quality. Data Quality Indicators (DQI's) are the performance measurements of DQOs. For this project, the DQI listed below will be used to direct the sampling and analytical program:

- Completeness
- Comparability
- Representativeness
- Precision
- Accuracy

5.1.1 Detection/Measurement Sensitivities

At least a minimum number of data points for all determinations shall be collected to enable a statistically valid evaluation in accordance with NRC guidance (Reference 10.7). The detection and measurement sensitivities for all analytical determinations shall be documented as

5.1 DATA QUALITY OBJECTIVES (CONTINUED)

5.1.1 Detection/Measurement Sensitivities (Continued)

outlined in the Eberline standard operating procedures describing these activities. For laboratory determinations, the minimum detectable activity (MDA) values for all determinations shall be calculated as defined by EPA (Reference 10.10), and as listed in Table 5-1. The desired sensitivity for all field measurements is 50% of the guideline value for that radionuclide.

5.1.2 Field Data Confidence Limits

Radioactivity measurements will have the necessary precision, accuracy, and lower limit of detection (LLD) to enable data to be presented with an overall confidence of 95%. Estimates of measurement uncertainty will include each measurement method, calibration, sampling, sample preparation, and measurement procedure, as well as random or counting error.

5.1.3 Reporting Data

Reported radioactivity measurements will include the qualities:

- The actual measurement, even when a value is < MDA or < LLD or is negative;
- the estimated uncertainty, including counting error;
- for non-significant results, the estimated MDA or LLD; and
- the decision outcome: detected versus not detected.

5.2 RADIOLOGICAL SURVEYS

As summarized in section 2.1.4 above, a Preliminary Radiological Investigation (PRI) (reference 10.5) was conducted in the former C-T processing buildings in mid-1992, and scoping surveys (reference 10.6) were conducted in C-T support buildings in May, 1993. The radiological surveys to be conducted as part of this site characterization will make maximum use of these existing data to complete the surveys of these buildings.

5.2.1 Building Interiors

A 6-foot grid system will be installed on the floors and mezzanines of each area requiring additional surveys. The grid will extend vertically through all floors, walls and ceiling areas. The origin of the grid system will be the southwest corner of the respective building or room.

Direct radiological measurements for alpha, beta and/or beta/gamma activity will be taken at each 6-foot grid intersection using instrumentation in Table 5-2. Removable measurements will be taken at locations where the direct measurement value exceeds the established removable criteria.

Table 5-3 summarizes the planned surveys in the Plant 5 buildings and in the building 101 incinerator area.

5.2 RADIOLOGICAL SURVEYS (CONTINUED)

5.2.2 Piping, Vessels and other Equipment

Several items of equipment in the C-T buildings were surveyed as part of the PRI. The remaining vessels and other equipment in these buildings will be surveyed during the site characterization work.

Surveying of small diameter pipe is not cost-effective. All pipelines which are known, suspected or had the possibility of handling radioactive materials and are 4" or less in diameter will not be surveyed, and will be considered radioactive waste and managed accordingly.

5.2.3 Building Exterior Walls

The exterior walls of buildings 213, 238, 246A&B, 247A&B and 248A&B will be surveyed on a 6-foot grid for alpha, beta and/or beta/gamma activity by taking direct measurements. Removable measurements will be taken at locations where direct measurement values exceed established surface activity criteria. Buildings 235, 236 and 245 will be surveyed on a 12-foot grid. See Table 5-3.

5.2.4 Building Roofs

Based upon operating history, proximity to C-T operations, and data obtained during the PRI and scoping surveys, the roofs of buildings 213, (including A and B), 222, 223, 235, 236 and 245 will be surveyed using a gamma walkover scan. Four sample cores will be taken on each roof at locations with elevated gamma activity, or at locations identified in the PRI or scoping surveys for sample analysis and direct beta/gamma measurements.

5.2 RADIOLOGICAL SURVEYS (CONTINUED)

5.2.4 Building Roofs (Continued)

Insufficient data exist for the roofs of buildings 250, 240 and 101. A six foot grid will be installed on each of these roofs. Direct measurements will be taken for alpha and beta/gamma activity. Removable contamination measurements will be taken at locations where direct measurement values exceed the established removable contamination criteria.

Buildings 200E, 200W and 204 are not adjacent to the former C-T process operations, yet in order to do a complete roof investigation of the Plant 5 area, these buildings will be surveyed as unaffected areas. A total of 20% of the surface area will be surveyed with a gamma walkover scan, and direct measurements for alpha and beta/gamma activity. Areas that exceed the release criteria will be sampled and analyzed as discussed above.

Roof drains on C-T process buildings will be surveyed at their determined end point. All roof penetrations, ventilation systems will be surveyed at access/discharge points on the roof.

Table 5-4 summarizes the roof surveys planned for these buildings, along with roof core samples to be taken.

5.2 RADIOLOGICAL SURVEYS (CONTINUED)

5.2.5 C-T Incinerator Area

The C-T incinerator is located within a fenced area adjacent to building 101 in Plant 6. The incinerator and the surrounding surface area will be surveyed as an affected area.

A six foot grid will be established on the surface within the fenced area. Direct alpha and beta/gamma measurements will be taken at each grid intersection. A large area floor monitor will be used to monitor for beta/gamma activity across the entire area to locate any "hot spots" not identified at grid intersections.

5.2.6 Plant 5 Streets

A gamma walkover survey was performed during the PRI, indicating areas of elevated gamma activity in the Plant 5 streets. The survey did not include direct alpha or beta/gamma survey measurements.

The streets in Plant 5 will first be surveyed for beta/gamma activity using a large area gas proportional beta/gamma floor monitor providing direction for the identification of localized "hot spots" where direct measurements will be taken for alpha and beta/gamma activity. Direct measurements will then be taken on a six foot grid. The grid will be located on the street through the use of removable road striping, and anomalous areas will be noted on data sheets and/or sketches.

Streets in the unaffected areas will be surveyed on a 12-foot grid and at a maximum of two biased locations within each grid section identified as a potential migration pathway. Floor monitor use is not planned unless the boundary of an affected area requires extension into an unaffected area.

5.2 RADIOLOGICAL SURVEYS (CONTINUED)

5.2.7 Wastewater Neutralization Basins

A surface gamma walkover scan will be conducted across each of the two basins. One square foot sections of the liner will then be removed, and direct measurements for alpha and beta/gamma activity will be taken at 30 locations (15 in each basin) in areas with the highest gamma activity. Core samples will also be taken in this area as described in section 5.3.4 below.

5.3 SAMPLES FOR RADIOLOGICAL CHARACTERIZATION

Previous subsurface radiological sampling in Plant 5 was summarized in Section 2.5. Additional subsurface soil sampling will be conducted as part of this characterization to determine the nature and extent of subsurface contamination resulting from past C-T operations.

5.3.1 Methodology

In accessible areas, continuous samples from boreholes will be collected by stainless steel split spoon samplers advanced ahead of hollow stem augers. Sampling spoons will be decontaminated before and after each sampling event. Boreholes will proceed to the interface with undisturbed soil and two to three feet into undisturbed soil, with 10% of the borings advanced an additional 15 feet into the natural clay strata.

Each borehole will be logged with a gamma scintillation detector (NaI) to determine the presence of gamma emitting radionuclides in the soil. This information will be used to assist in guiding further drilling activities and in the selection of samples to be analyzed. All borings will be logged by a qualified geologist. Sample collection and equipment decontamination will follow procedures in TMA/Eberline

5.3 SAMPLES FOR RADIOLOGICAL CHARACTERIZATION (CONTINUED)

5.3.1 Methodology (Continued)

procedure 4.A.2 (Reference 10.12). An enclosed decontamination area will be constructed to ensure that contamination is not spread during decontamination of sampling equipment and to collect the decontamination residues in an orderly manner. Drill spoils and decontamination wastes will be collected and drummed for on-site storage. See Section 8.0.

Certain sample locations inside buildings may be inaccessible to the drilling rig. In these cases, a coring machine will be used to drill a hole thorugh the concrete floor, and a hand auger or skid mounted drill rig will be used to obtain soil samples to a maximum depth of eight feet.

All samples will be labeled and retained subject to chain-of-custody. Samples not sent for analysis soon after collection will be archived for potential future analysis. The initial soil or fill samples sent for radionuclide anlaysis will be selected in accordance with Table 5-5 from areas exhibiting elevated gamma activity, if any. Regardless of activity level detected by gamma logging, samples will be selected for radionuclide analysis in all borings from near ground surface and in the top of the undisturbed alluvial material. From all the deep borings, additional samples will be sent for radionuclide analysis from a depth about 15 feet into the alluvial material in accordance with Table 5-5. When selecting the actual samples from these depths to be analyzed, preference will be given to finer-grained material, i.e., silt and or clay, rather than coarser-grained material, i.e., sand.

Samples will be analyzed for radionuclides, as specified in Section 6.0, and for chemical properties, as described in Section 5.7.

5.3 SAMPLES FOR RADIOLOGICAL CHARACTERIZATION (CONTINUED)

5.3.2 Building Interiors

Subsurface samples will be collected for radiological analysis inside buildings 238, 246B, 247 A and B, and 248. Table 5-5 shows the number and depth of samples to be taken, along with the total number of alpha and gamma spectroscopic analyses to be performed.

Figures 5-1 through 5-3 show the locations of the subsurface samples to be collected in these buildings.

5.3.3 Plant 5 Streets

A total of 32 boreholes will be drilled along sewer lines and at locations of high gamma readings determined during the PRI. The locations of these borings are shown on Figure 5-4. Table 5-5 shows the number and depth of the samples to be taken, along with the total number of alpha and gamma spectroscopic analyses to be performed.

5.3.4 Other Samples

Several other samples will be collected for chemical/radiological characterization, including the following:

Roof Cores

A minimum of four core samples of roofing material will be collected on the roofs of buildings in Plant 5 at locations corresponding to the two highest and two lowest survey measurement readings. If the core samples show that the survey did not identify areas of contamination, additional samples will be taken on a 12-foot systematic grid and at other biased locations that exhibit elevated direct measurements. Table 5-4 summarizes the planned roof coring activity.

5.3 SAMPLES FOR RADIOLOGICAL CHARACTERIZATION (CONTINUED)

5.3.4 Other Samples (Continued)

Sewer Line Manholes

Sewers which carried process effluent will be sampled at all manhole access points. This includes the sewer lines servicing buildings 235, 236, 238, 247, 248 and 250. Other access points that could collect runoff from ore storage and handling east and south of building 235, and east of building 213 will be sampled. This sampling will follow the sewer line until it reaches the wastewater basins in the Plant 7 area. A sludge sample will also be collected from the Plant 5 lift station at the wastewater basins in Plant 7. Figure 5-7 shows the locations of the manholes to be sampled, and Table 5-5 summarizes the Plant 5 street inlets and sewer manholes to be sampled. Each sample will be analyzed by gamma spectrometry for radionuclide concentration.

Wastewater Basins

Following the alpha and beta/gamma survey described in section 5.2.7, two concrete core samples will be taken from each basin at locations with the highest direct readings. These cores will be sliced, and direct measurements taken to determine the depth of contamination. These cores will then be analyzed for the radionuclides described in Section 6.0.

Building Materials

Samples of surface contamination on concrete and brick will be collected and analyzed for relevant radionuclides to determine average surface release guidelines. A minimum of six samples each will be collected from buildings 90/91, 62, 213, 238, 246, 247 and 248.

These samples will be analyzed for the radionuclides described in Section 6.0.

5.4 BACKGROUND DETERMINATION

Guidelines for residual radioactivity at sites undergoing D&D are presented in terms of radiation levels, or activity levels, above natural background for the area, or facility. It will therefore be necessary to perform background determinations to measure both direct radiation levels and the concentrations of the potential radionuclide contaminates in constructions materials, soil, and groundwater in the vicinity of the site. Background is determined by measurements and/or sampling at locations on site, or in the immediate vicinity of the site, which have been unaffected by site operations. The soil matrix beneath the C-T Plant contains coal cinders, brick, rubble and various soils and clays. Since much of the fill is cinders and clays having naturally occurring radionuclides, a background will be determined for each of these materials by sampling cinders and natural clays upgradient of the facility. At least six samples of each will be collected for analysis.

Construction materials of interest consist mainly of bricks in the C-T plant buildings. Six bricks with low activity will be surveyed and removed from C-T plant buildings for analysis. Each brick will be cut in half to expose fresh clay material. Direct alpha and beta/gamma measurements will be taken on the cut face of the brick. The alpha and beta/gamma activity will be averaged and used as natural background for bricks in C-T plant buildings. Samples will also be analyzed for radionuclide concentrations. This will be done in other buildings as applicable.

Concrete and asphalt surface backgrounds will be established at six locations off site.

Gamma exposure rates will be measured at six locations off site using a Pressurized Ionization Chamber (PIC) and reported in microR/hour.

5.4 BACKGROUND DETERMINATION (CONTINUED)

Background determination methods are presented in TMA/Eberline procedure 3C.2 (Reference 10.13).

5.5 EXPOSURE RATE MEASUREMENTS

Gamma exposure rates will be measured for characterization purposes in certain background areas (Section 5.5) and in all unaffected areas.

Exposure rate measurements for health and safety considerations are reflected in the site characterization health and safety plan.

5.6 CHEMICAL CHARACTERIZATION

This section describes the sampling and chemical constituent analyses to be performed to characterize soils, which may be disposed during the D&D activity. Of interest is whether soils will need to be disposed of as hazardous and/or mixed waste. Based on the chemical nature of the materials used in the former euxenite and C-T processes, however, it is unlikely that mixed (RCRA hazardous and radioactive) waste will be discovered as a result of the planned chemical characterization activities.

5.6.1 Constituents of Concern

In addition to the ore feed materials, the majority of the chemicals used and handled in both the euxenite and C-T processes was inorganic in nature. One organic chemical was used in a solvent extraction step in the C-T process.

5.6 CHEMICAL CHARACTERIZATION (CONTINUED)

5.6.1 Constituents of Concern (Continued)

Inorganics

Hydrochloric acid was used for digestion of the euxenite ore slurry, and mixtures of ammonium biflouride sulfuric and hydrofluoric acids were used to dissolve columbite and tantalite ores.

From a potential mixed waste standpoint, the only inorganic constituents of concern are the trace metals (cadmium, chromium, lead and selenium) which were contained in the ore feed materials. Additional RCRA metals not associated with the C-T process, however, will be analyzed in selected samples to complete the mixed waste characterization of the subsurface in the Plant 5 area.

The only other inorganic parameter of concern is the hazardous characteristic of corrosivity of building floors and subsoils due to potential spills and leaks of the acids used in the process.

Organics

Methyl isobutylketone (MIBK) was the only organic chemical used in the C-T process, and it was used in relatively small quantities. MIBK was used only in buildings 246B and 247A for solvent extraction purposes. Following extraction of the C-T product streams and subsequent steam stripping of tantalum-MIBK mixtures, the MIBK fraction was decanted, and the MIBK rich stream recycled to the process.

5.6 CHEMICAL CHARACTERIZATION (CONTINUED)

5.6.1 Constituents of Concern (Continued)

Organics (Continued)

If MIBK is discarded as a spent solvent, it is a solid waste that is regulated under RCRA as a listed hazardous waste (EPA Hazardous Waste No. F003). MIBK is also a listed hazardous waste if it is deemed a discarded commercial chemical product (EPA Hazardous Waste No. U161). Because the MIBK used in the C-T process was recovered and reused consistent with one or more exemptions in the RCRA regulations, it never became a "solid waste" to which the F003 or U161 listings could apply. Similarly, the water phase from the decanter came into contact only with MIBK which was performing its process function and which was not a "waste" at the time; therefore, the decanter water that was sewered did not contain a listed hazardous waste and was not regulated as a listed hazardous waste under RCRA.

Based on the above, if any soil or groundwater at the C-T plant contains MIBK residues (which has not ben shown to date), the soil or groundwater would not need to be addressed as listed hazardous waste under RCRA.

It is likely that low concentrations of methyl ethyl ketone (MEK) were contained as an impurity in the MIBK. MEK is included on the RCRA Toxicity Characteristics (TC) list. MEK will therefore be analyzed in subsurface samples taken in the building 246/247 area.

As with the inorganic constituents discussed above, the remainder of the organic constituents on the TC list will be analyzed in selected samples to complete the chemical characterization of the subsurface in the Plant 5 area.

5.6 CHEMICAL CHARACTERIZATION (CONTINUED)

5.6.2 Samples To Be Analyzed

Subsurface samples will be collected and analyzed for chemical/mixed waste characterization as noted above. In general, the samples collected for chemical characterization will be obtained from the same boreholes as those collected for radiochemical analyses. Table 5-6 lists the specific chemical analyses to be performed.

Inside Buildings

Subsurface samples will be collected and analyzed to determine both lateral and vertical delineation of potential chemical contamination. Samples of the fill materials (slag, gravel, brick, sand, cinders and silty clay) and undisturbed soil will be obtained. Based on previous subsurface investigations in the Plant 5 area (Reference 10.1), the thickness of the fill ranges from 14-18' below grade.

- **Building 238.** Figure 5-1 shows the location, and Table 5-5 the depths of the samples to be collected.

- **Building 246 and 247.** Figure 5-2 shows the location of the boreholes in buildings 246B and 247 A&B, and Table 5-5 shows the depths of the samples to be collected.

- **Building 248.** Figure 5-3 shows the location, and Table 5-5 the depths of the samples to be collected.

Plant 5 Streets

Figure 5-4 shows the approximate location, and Table 5-5 the depths of the samples to be collected. These locations will check potential subsurface chemical contamination as a result of sewer leakage and other spills and leaks of plant used materials.

5.6 CHEMICAL CHARACTERIZATION (CONTINUED)

5.6.2 Samples To Be Analyzed (Continued)

Sewer Manholes

The location of the Plant 5 manholes to be sampled is shown on Figure 5-5, which includes the Plant 5 wastewater lift station located adjacent to the neutralization basins in Plant 7.

5.6.3 Analytes, Parameters and Methods

The selection of analytes and parameters to be analyzed is based on the following:

1) Ores and other materials which were handled in and around the C-T process buildings,

2) Other TC constituents which, through spills and leaks, may have contaminated subsoils which also exhibit radioactive levels of concern, and

3) Materials which were never known to be handled on site will not be included.

Table 5-6 shows the constituents and parameters to be analyzed for all the subsurface samples to be obtained.

5.6 CHEMICAL CHARACTERIZATION (CONTINUED)

5.6.3 Analytes and Parameters (Continued)

The constituents to be analyzed are those included on the RCRA TC list with the exception of the two herbicides and the seven pesticides will be excluded, since these materials were never known to be handled in the Plant 5 area.

Volatiles

Total concentrations of the 10 volatile constituents will be determined in selected samples using the EPA 8240 method. If the total concentration of any of these constituents exceed their TC regulatory limit by more than 20%, the TCLP will be determined for that constituent.

Metals and Semi-Volatiles

TCLP analysis will be obtained on selected samples using EPA methods 1311/8270 for the thirteen semi-volatile constituents, and 6010/7470 for the TC list metals.

6.0 RADIOLOGICAL ANALYTICAL TECHNIQUES

The analysis of samples to support the characterization activities at the C-T site will be conducted at the TMA/Eberline Oak Ridge facility or the TMA/Eberline Albuquerque facility. Both of these facilities are full service radiochemistry laboratories supporting both government and commercial clients, and are licensed by their respective state agencies to receive low-level radioactive samples. All analyses are conducted in strict accordance with standard operating procedures, and both laboratories successfully participate in the EPA and EML intercomparison performance evaluation programs.

6.1 GAMMA SPECTROSCOPIC ANALYSIS

Gamma spectroscopic analysis will be conducted on samples of various matrices collected during the characterization of the CT site. Soil, sediment, and building materials will be analyzed in the TMA/Eberline laboratory in Oak Ridge, Tennessee. This facility utilizes a Digital VAX/VMS system customized with the Canberra Genie software to control and process all gamma spectroscopic counting. The detector system consists of a high purity n-type thin window beryllium detector.

TMA/Eberline will utilize Marinelli beaker and Nalgene jar geometries during the counting process. These geometries typically contain approximately 500 ml of sample, and allow for a reproducible geometry in relation to the counting standard used for system calibration. Report output will be controlled by the Canberra Genie Procount software and radioisotope concentrations will be reported in pCi/g with a reporting error of two standard deviation units also expressed in pCi/g. The specific radioisotopes to be reported include uranium-238, radium-226 and 228, thorium 232, and potassium-40. Additional gamma-emitting radioisotopes will be identified and reported when the Canberra Procount software identifies positive activity during data processing.

6.0 RADIOLOGICAL ANALYTICAL TECHNIQUES (CONTINUED)

6.1 GAMMA SPECTROSCOPIC ANALYSIS (CONTINUED)

During the collection of subsurface samples, the TMA/Eberline Oak Ridge laboratory will analyze select samples in a wet geometry to assist the TMA/Eberline site manager in the identification of borehole depths and locations. TMA/Eberline has used this technique extensively on previous site characterization and remedial projects as a screening method to assist field personnel.

6.2 ALPHA SPECTROSCOPIC ANALYSIS

Alpha spectroscopy for isotopic thorium will be conducted on all samples. Soil, water and building material samples will undergo specific chemical separation procedures followed by alpha spectroscopy. TMA/Eberline will utilize the aforementioned Digital system with customized Canberra Genie software to control and process all samples undergoing alpha spectroscopic analysis. The detectors used by TMA/Eberline for this analysis are Canberra ion-implant diode detectors. Reports will be issued presenting radioisotopic concentrations in units of either pCi/l or pCi/g. A two standard deviation counting error will be included with the analytical result, and also presented in the aforementioned units. The alpha spectroscopic analysis will report isotopic thorium for all samples, and isotopic uranium for approximately 10% of the samples to confirm gamma spectroscopic results.

6.3 RADIOLOGICAL INSTRUMENTATION

The radiation detection instruments used for performing fixed contamination, removable contamination and radiation surveys are listed in Table 5-2. The combination of instruments and techniques used in field data collection will be such that a desired detection sensitivity of less than 50% of the appropriate guideline value will be targeted. Actual sensitivity levels for each instrument are dependent on site backgrounds and conditions and will be evaluated on a daily basis for each instrument in use.

6.4 QUALITY ASSURANCE/QUALITY CONTROL (CONTINUED)

6.4.2 Duplicate Field Measurements

Duplicate fixed radiation measurements will be taken on 1 in 20 measurements performed for alpha and beta/gamma readings. Measurements may be predetermined by the site manager, or selected by a random number generator. Measurements will be recorded and marked as "D" or "Dup" on the appropriate form.

Duplicates on smears (transferrable contamination) will be performed on 10% of the smears collected.

6.4.3 Data Review

Data sheets and calculations will undergo an independent peer review by the site manager or designee of all forms collected to document surveys performed in the field.

6.4.4 Audits

Project management responsible for delegating assignments shall visit the site on an as needed basis in order to review program activities and assess the effectiveness of radiological services.

6.4.5 Sample and Document Custody Procedures

Sample custody will be initiated at the time of sample collection. The site manager will ensure that field samples will be identified by sample labels with the following information: unique sample identification number, date and time of sampling, sampling location or station, preservation, analysis and any additional applicable comments. Field chain-of-custody forms containing the same information will be

6.4 QUALITY ASSURANCE/QUALITY CONTROL (CONTINUED)

6.4.6 Laboratory Quality Control

Work performed by laboratories will perform spikes, blanks, and duplicate analysis with each batch of samples. Each set of samples will have at least one blank and spike performed. There will be at least one duplicate count performed, or 10% of the samples based on the number of samples in each batch. All instruments will be calibrated to NIST traceable standards.

8.2 EQUIPMENT DECONTAMINATION WASTES (CONTINUED)

8.2.1 Sludges

Potentially contaminated sludges and solid wastes will be generated from steam cleaning drill augers and sampling equipment. These wastes will be collected and placed in 55-gallon drums, and temporarily stored pending chemical/radiological analyses of the samples collected from the boreholes. Each drum of sludge waste will be properly labeled to identify the specific borehole source for the augers and sampling equipment.

The contaminant characterization of this sludge waste will be determined from the analyses of the samples taken from the identified boreholes. This waste will be disposed of in accordance with the requirements of NRC license STB-401.

8.2.2 Wastewater

Potentially contaminated wastewater will be generated from steam cleaning drill augers and sampling equipment. All such water will be collected and placed in an on-site storage tank for subsequent chemical/radiological characterization.

This water will be sent to the plant sewer following treatment, as indicated by the chemical/radiological test results, and approval from the St. Louis Metropolitan Sewer District.

9.0 ADMINISTRATION

This section describes the overall administrative aspects of implementing this plan, including the project organization, and health and safety requirements.

9.1 ORGANIZATION

The implementation of this plan will be administered and managed by Mallinckrodt. TMA/Eberline will serve as the prime radiological contractor, and will be responsible for the safe, timely implementation of this plan. Eberline will be supported by experienced radiological consultants (contracted by Mallinckrodt) to assist in data interpretation (including QA/QC), and by a drilling firm who is licensed in the State of Missouri and familiar with the St. Louis plant.

Figure 9-1 shows the C-T characterization plan implementation organization.

Thomas J. Byrd is the site Radiation Safety Officer (RSO). Mr. Byrd's experience and qualifications are summarized in Appendix D.

9.2 HEALTH AND SAFETY

The health and safety of all personnel associated with the field activities of this characterization plan is a key project goal.

A site specific/field activity specific health and safety plan has been prepared for this project. This plan, which shall be strictly followed during all phases of the field work, is contained in Appendix C. This plan outlines and evaluates all potential health hazards, and addresses each with specific personnel protection and monitoring requirements.

All personnel involved in actual radiological survey work, media sampling, decon tests, borehole drilling, etc., will be trained as outlined in 29 CFR 1910.12, and will be required to be familiar with and adhere to all applicable provisions of this health and safety plan.

9.3 TRAINING

Due to the potential health hazards associated with remedial investigations and remedial action, personnel will be informed of any health risks prior to assignment. Training programs, medical assessment programs, and the need for personal protective equipment will be discussed with the site employees.

Site orientation and training shall be provided by the TMA/Eberline Project Manager or Industrial Hygiene Specialist. This individual shall be experienced in field operations and familiar with the safety and health program. Through daily interactions with the site staff members, the Project Manager communicates, implements and enforces the safety and health program.

All site employees must have received 40 hours of preassignment training consistent with 29 CFR 1910.120 (e)(2). Each employee must also have eight hours of annual refresher training. TMA/Eberline will provide documentation of worker training before work begins at the C-T plant.

Before commencing site activities, each assigned individual shall be instructed of any potential hazards in the work area, exposure pathways by which toxic materials may enter the body, specific measures to prevent or reduce exposure to radioactive materials and/or chemicals, proper maintenance and usage of safety equipment and personnel protective equipment, avoidance of unsafe work practices, emergency procedures and good housekeeping.

Personnel will also be required to fulfill Mallinckrodt training requirements to work at the site.

9.3 TRAINING (CONTINUED)

Weekly meetings shall be conducted which will serve as continuous safety training. Topics discussed will provide information on hazardous situations, identification of problems and preventive measures. The extent of safety training shall be adequate to cover OSHA General Industry Standards (29 CFR 1910) and Construction Standards (29 CFR 1926). Site Specific training includes, but is not limited to, the topics listed in Table 9.1.

Training records which include dates of instruction, curriculum, and copies of certificates shall be maintained in each employee's individual permanent personnel file, in Oak Ridge, TN. Training records for contractor personnel shall also be retained in a permanent personnel file.

10.0 REFERENCES

10.1 *Radiological, Chemical, and Hydrogeological Characterization Report for the St. Louis Downtown Site in St. Louis, Missouri-Volumes I, II, and III,* Bechtel National, 1990.

10.2 *Eberline Letter Report,* December 10, 1984.

10.3 *Revised Draft Report Phase 1 Environmental Assessment,* Malcolm Pirnie, 1989.

10.4 *Waste Assistance Draft Report,* Eberline, 1992.

10.5 *Preliminary Radiological Investigation, Mallinckrodt Columbium Tantalum Plant,* Eberline, 1993.

10.6 *Rust Letter Report,* June 8, 1993.

10.7 *NUREG 5849, Manual for Conducting Radiological Surveys in Support of License Termination - Draft Report for Comment,* J.D. Berger, Oak Ridge Associated Universities for the Division of Regulatory Applications, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, June, 1992.

10.8 *Quality Assurance Manual, Revision 7,* TMA/Eberline, June 30, 1992.

10.9 *USNRC: NMSS, Branch Technical Position "Disposal or On-Site Storage of Thorium or Uranium Wastes from past Operations*; 46 FR 52601, October 23, 1981.

10.10 *EPA 1980-1 - EPA 520/1-80-012, Upgrading Environmental Radiation Data,* U.S. Environmental Protection Agency, August, 1980.

10.11 *EPA 1980-2 - EPA 600/4-80-032, Prescribed Procedure for Measurement of Radioactivity in Drinking Water,* March, 1980.

10.0 REFERENCES (CONTINUED)

10.12 *TMA/Eberline Health Physics Operational Procedures Manual, No. 4A.2, "Subsurface Soil Sampling (Radiological), Rev. 2,* April 24, 1991.

10.13 *TMA/Eberline Health Physics Operational Procedures Manual, No. 3C.2, "Determination of Background", Rev. 2,* April 17, 1991.

10.14 *USNRC "Policy and Guidance Directive FC 83-23: Termination of Byproduct, Source and Special Nuclear Material Licenses",* 1983, Rev. 1987.

TABLES

TABLE 2-1

MALLINCKRODT JUNE 13, 1989 SAMPLING EVENT

Analytical Parameter	Analytical Results (1), (2) Well W-128 (pCi/L)	Well W-151 (pCi/L)	Well W-152 (pCi/L)	Well B16W03S (pCi/L)
Total Uranium	<7.3	<7.1	<7.6	<8.6
Uranium-238	2.3	2.6	2.2	4.4
Radium-226	<1	<1	<1	<1
Thorium-230	<1	<1	<1	<1
Thorium-232	<1	<1	<1	<1

(1) All groundwater samples were filtered with a 0.45 micron filter and preserved to a pH of 2 or lower with nitric acid.

(2) Uranium and Thorium: EPA Method 520/5-84-006, 00-07; Radium: EPA Method 600/4-80-032, 903.1

DOE/FUSRAP GROUNDWATER ANALYTICAL RESULTS

Analytical Parameter	Analytical Results (1), (2), (3) Well B16W03S (pCi/L)	Well B16W04S (pCi/L)	Well B16W12S (pCi/L)
Total Uranium	<3 to <3	<3 to <3	5
Radium-226	0.3 to 0.6	0.3 to 1.3	0.4
Thorium-230	0.2 to 0.6	<0.1 to 0.8	0.2
Thorium-232	N/A	N/A	<0.1

(1) Uranium: Fluorimetry EML-U-03.
Radium: Radon emanation: EPA Method 903.1.
Thorium: Alpha spectrometry EML-Th-03 (modified).

(2) Wells B16W03S and B16W04S were sampled quarterly from July 1988 to April 1989. Analytical results represent the historical range of values from four sampling events. The data are from "DOE Radiological, Chemical, and Hydrogeological Characterization Report for the St. Louis Downtown Site in St. Louis, Missouri," dated September 1990 (prepared by Bechtel National, Inc.)

(3) Well B16W12S was sampled once during the fall of 1992. The data are from "DOE Remedial Investigation Addendum Report for the St. Louis Site," dated May 1993.

TABLE 2-2
C-T PROCESS AND SUPPORT AREAS

Location	Use
Plant No. 1 Area	
Building 25	Laboratory
Plant No. 3 Area	
Building 62	Change rooms
Plant No. 5 Areas	
Building 213	Change rooms
Building 235	Feed material/URO storage in eastern half of building
Building 235 Yard	Drummed feed material/URO storage east of building
Building 236	Maintenance area
Building 238	Cb-Ta ore grinding, dissolving and processing; Ta processing
Building 245 Yard	Ore staging area southeast of building
Building 246	Offices and unused solvent extraction plant
Building 247A	Cb-Ta solvent extraction and product storage
Building 247B	Cb filtration and drying
Building 248	Cb filtration, drying and calcining
Building 250	Offices and quality control laboratories
Plant No. 6 Areas	
Building 101 Area	URO burial cells
Building 101 Area	C-T incinerator on west side of building; use to incinerate burlap bags for ore recycling
Building 116	Receipt/unloading of Cb-Ta ore
Building 116 Yard	Storage of feed material and URO
Building 117	URO drum preparation and staging
Plant No. 7 Areas	
Building 700	Storage of tin slag feed material
Building 700/708 Yard	Storage of tin slag feed material
Building 704	URO drum storage
Building 705	Cb-Ta ore storage
Building 706	Cb-Ta ore storage
Building 708	Storage of tin slag feed material
Wastewater Basins	Used to neutralize C-T waste streams discharged to MSD
Plant No. 8 Areas	
Buildings 90, 91	Maintenance areas

TABLE 2-3

C-T CHEMICAL RAW MATERIALS

Raw Material

Ore
Sodium Hydroxide
Hydrofluoric Acid
Sulfuric Acid
Separan
Aqueous Ammonia
Methyl Isobutyl Ketone
Hydrochloric Acid
Potassium Chloride

Products

Tantalum Oxide
Potassium Fluotantalate
Columbium Oxide

TABLE 2-4

MED-AEC FEED MATERIALS, OTHER RAW MATERIALS, PRODUCTS, AND BYPRODUCTS

High Volume Feed Materials

Canadian ore concentrates
Colorado Plateau ore concentrates
Colorado sodium salts (sodium di-uranate)
Belgian Congo pitchblende ore

Low Volume Feed Materials

Uranyl nitrate, UO_3, UO_2, UF_4 from other MED sites
Portuguese ores from Africa
Magnesium uranate
Calcium uranate
Scrap U-metal, slag, pickling liquor and other by-products

Other MED-AEC Raw Materials

Diethyl Ether
Nitric Acid
Barium Carbonate
Sulfuric Acid
Calcium Hydroxide
Caustic Soda
Sodium Bicarbonate and Carbonate
Magnesium Oxide
Anhydrous Hydrofluoric Acid (AHF)
Anhydrous Ammonia
Graphite

MED-AEC FEED MATERIALS, OTHER RAW MATERIALS, PRODUCTS, AND BYPRODUCTS (CONTINUED)

Products

UO_3 (orange oxide)
UO_2 (black oxide)
UF_4 (green salt)
U-metal (ingots, derbies, billets, buscuits, dingots, etc.)
Uranium Nitrate Liquor produced from U_3O_8
Molybdenum- or zirconium-uranium alloy (biscuits or ingots)
U-metal produced from slightly enriched UF_4 (<1.035 weight % U-235)
UO_2 from slightly enriched UO_3 (<0.9 weight % U-235)
Uranium product from slightly enriched UF_6 (<1.3-1.6 weight % U-235)
Uranium Derbies containing niobium or molybdenum
Ingots produced from depleted derbies from other MED-AEC sites
UO_2F_2

TABLE 3-1

C-T PROCESS AND SUPPORT AREAS TO BE ADDRESSED BY C-T CHARACTERIZATION PLAN

Location	Use
Plant No. 3 Area	
Building 62	Locker rooms
Plant No. 5 Areas	
Building 213	Locker and break rooms
Building 235	Feed material/URO storage in eastern half of building
Building 236	Maintenance area, product drying
Building 238	Cb-Ta ore grinding, dissolving and processing; Ta precipitation, separation, drying
Building 246A	Offices
Building 246B	Solvent extraction
Building 247A	Solvent extraction and product storage
Building 247B	Cb precipitation, filtration and drying
Building 248	Cd precipitation, filtration, drying and calcining
Building 248, West Yard	Former location of C-T incinerator
Building 250	Offices, locker room and laboratories
Streets and Yards	Feed material staging and URO handling
Sewers	C-T and building 250 sewers and line to Plant 7 lift station
Plant No. 6 Areas	
Building 101 Area	URO burial cells/storage
Building 101, West Yard	C-T incinerator and building 101 roof
Plant No. 7 Area	
Wastewater Basins	Concrete structure only
Plant No. 8 Areas	
Buildings 90, 91	Maintenance shops

TABLE 5-1

REQUIRED SENSITIVITY FOR LABORATORY ANALYSES

Radionuclide	Guideline Value	Required Sensitivity	
		Alpha Spectroscopy	Gamma Spectroscopy
Natural Th (Th-228/232)	10	0.5	1.0
Natural U (U-234/238)	10	0.5	5.0
Th-230	5	0.5	
Ra-226	5	0.5	1.0

NOTE: All values in pCi/gram

TABLE 5-2

INSTRUMENTATION FOR CHARACTERIZATION SURVEY

Survey Type	Instrument	Detector	Units
Direct Beta/gamma	ESP-2	GM Detector	DPM
Direct Alpha	ESP-2	ZnS Scintillation	DPM
Exposure Rate	Reuter-Stokes	Pressurized Ionization Chamber	μR/Hr
Removable Alpha	SAC-4	ZnS Scintillation	DPM/100cm^2
Removable Beta/ Gamma	ESP-2	GM Detector	DPM/100cm^2

NOTE: Tables 5-3 and 5-4 list the buildings planned for radiological surveys.

TABLE 5-3

ADDITIONAL RADIOLOGICAL SURVEYS

BUILDING/ AREA	101	213	235	236	238	245	246A	246B	247 A	247B	248 A	248B
First Floor, Floors		X	X						X	X	X	
First Floor, Walls		X	X	X					X	X	X	X
First Floor, Ceiling		X	X					X	X	X		
Second Floor, Floors										X	X	X
Second Floor, Walls					X				X	X		X
Second Floor, Ceiling					X				X			
Equipment	X	X			X			X	X	X	X	X
Exterior Walls		X	X	X	X	X	X	X	X	X	X	X
Outside Fenced Area	X											

ote: Additional surveys for Buildings 62 and 90/91 to be based on the specific average release criteria for ese buildings.

TABLE 5-4

BUILDING ROOFS

BUILDING	RADIOLOGICAL SURVEY	CORE SAMPLES
101	Alpha/Beta/Gamma(2)	4
200E	Alpha/Beta/Gamma	(1)
200W	Alpha/Beta/Gamma	(1)
204	Alpha/Beta/Gamma	(1)
213	Gamma	4
222	Gamma	4
223	Gamma	4
235	Gamma	4
236	Gamma	4
238	None	4
240	Alpha/Beta/Gamma	4
245	Gamma	4
246A	None	2
246B	None	2
247A	None	2
247B	None	2
248	None	4
250	Alpha/Beta/Gamma(2)	4

Note 1: Roof to be cored only if elevated activity is determined.
2: Surveys to be conducted on 6' grids.

TABLE 5-5

SUBSURFACE SAMPLE IDENTIFICATION

LOCATION	SAMPLE LOCATION DESIGNATION	NUMBERS & DEPTHS OF SAMPLES (1) 1-2'	7-8'	20'-22'	30'-32'	TOTAL
Bldg. 238	B-1 to 7	7	7	4	1	19
Bldg. 246B	B-8 to 9	2	2			4
Bldg. 247A	B-10 to 11	2	2			4
Bldg. 247B	B-12 to 13	2	2			4
Bldg. 248	B-14 to 16	3	3	1		7
Plant 5 Streets	B-17 to 49	32	32	25	5	94
Plant 5 Sewer Manholes	MH-1 to 6					6
			Total Number of Samples =			**138**

RADIOLOGICAL ANALYSIS

Total Gamma Spectroscopy = 138

Total Alpha Spectroscopy = 138

NOTE: 1. These depths are approximate. The actual depths at which samples will be taken depend on spoon recoveries achieved and the actual depth of undisturbed soil at the specific drilling locations.

TABLE 5-6

SUBSURFACE SAMPLE ANALYTE LIST

SAMPLE DESIGNATION	SAMPLE LOCATIONS	ANALYTE SUITES/SAMPLE DEPTHS A	B	C	D	E
B-1 to 7	7	1,2	3			1,2,3
B-8 to 11	4			1,2	3	1,3
B-12 to 16	5	1,2				1,2
B-17, 19, 21	3	1,3		1,3		1,2
B-22 to 24	3	1,3	2	1,2		
B-25 to 29	5	1,3		1,2		
B-30 to 32	3		1,3	1,2		1,2
B-33, 34, 45, 46	4	1,3				1,2,3
B-38, 40, 42, 44	4		1,3		1,2	
MH-1, 4, 6	3	(3)				
TOTALS	41	57	24	36	12	63

ANALYTE SUITES

A = C-T Metals Pb, Cd, Se, Cr

B = All Eight TC List Metals

C = Ten TC List Volatiles

D = 10 TC List Volatiles & 13 Semi-Volatiles

E = Corrosivity Characteristic

SAMPLE DEPTH LEGEND

1 = 1-2' depth

2 = 7-8' depth

3 = 20-22' depth

4 = 30-32' depth

TABLE 9-1

SITE SPECIFIC TRAINING

Site Health and Safety Plan, 29 CFR 1910.120(e)(1)
Site Characterization and Analysis, 29 CFR 1910.120(i)
Chemical Hazards
Radiological Hazards
Personal Protective Equipment, 29 CFR 1910.134
Medical Surveillance Requirements
Respiratory Protection, 29 CFR 1910.134
Overhead and Underground Utilities
Tools
Decontamination, 29 CFR 1910.120(k)
Air Monitoring
Handling Drums and Other Containers, 29 CFR 1910.120(j)
Radioactive Wastes
RCRA Wastes, 40 CFR 265.16
Buddy System
Heat and Cold Stress
Hazard Communication, 29 CFR 1910.1200
Fire Prevention and Protection
Good Housekeeping
Reporting Non-compliance and Potential Hazards
Instrument Maintenance and Operation
Sampling Procedures
Drilling
Confined Spaces, 29 CFR 1910.146
Barricades, 29 CFR 1926.202
Arc Welding and Cutting, 29 CFR 1926.351
Lockout and Tagout of Electrical Sources, 29 CFR 1926.417
Material Hoists, 29 CFR 1926.552
Ladders, 29 CFR 1926.1053
High Lifts
Emergency Procedures and Evacuation

C-T SITE CHARACTERIZATION PLAN

APPENDIX A

MED PLANT OPERATIONS DESCRIPTION

APPENDIX A

MED PLANT OPERATIONS DESCRIPTION

Plant 1 and 2 - Batch Operations

Uranium dioxide processing from ore concentrates began in 1942 in Plant 2. Facilities for batch production were installed in buildings 50, 51, 51A, and 52 (Figure 2-12).

In 1942, laboratory development work was conducted in Plant 1 in the building 25 laboratory and in the alley between buildings K-1-E and 25 (Figure 2-12). The original feed materials were ore concentrates from Canada consisting of uranium black oxide, U_3O_8. The concentrates were produced at off-site uranium mills and were free of radium and its decay products.

The U_3O_8 was digested in nitric acid in building 51, producing uranyl nitrate. This was transferred to building 52 and purified by ether extraction to yield pure uranyl nitrate hexahydrate (UNH). In building 51A, the UNH was converted to UO_3, which was further converted to UO_2. The UO_2 powder was packaged and transferred to Plant 4 or to off-site government installations. Building 50 was used as a warehouse to store incoming feed materials, product, and tanks of process liquids. Solid residues from the extraction process were drummed and transferred to government sites for scrap recovery, and liquid residues were neutralized and discarded into the sewer system.

By July 1942, Plant 2 was producing approximately 1 ton of UO_2 per day. Production continued until 1945-1946 when the area was closed in preparation for start-up of the Destrehan Plant. According to production contracts between MCW and MED/AEC, a total of approximately 4,400 tons of UO_2 was produced in Plant 2.

Plant 4 - UF_4 and Uranium Metal Operations

In 1942, MCW began a batch process to manufacture uranium tetrafluoride (UF_4 or green salt) by the high temperature gas-solid reaction of UO_2 with hydrofluoric acid (HF). This process was conducted in building 400 in the former Plant 4 area (Figure 2-12). Figure A-1 attached is a historical photograph of the Plant 4 area. The UF_4 was created by heating UO_2 powder with anhydrous HF gas. The UF_4 was then emptied into fiberboard containers for storage. Excess HF and water vapor were condensed, neutralized with lime, and discharged to the sewer.

MCW began manufacturing uranium metal in 1943 in buildings 400 and 401B (Figure 2-12) in a two stage batch process. The first stage reacted UF_4 with ground magnesium metal to produce a solid uranium metal called "derby." The thermite reaction was carried out in dolomite lined, steel reaction vessels which were heated inside electric muffle furnaces. The cooled shells were "broken out" to expose the derby and the magnesium fluoride slag. The derby was cleaned and made ready for the second step.

The second stage involved melting and recasting derbies inside in induction heated vacuum furnace. The molten metal was poured into graphite molds to form a cylindrical ingot rod or other forms of uranium metal which were cut and packaged for storage in building 400. The slag, dross, and other furnace residues were packaged for shipment to an off-site government facility. The uranium residues consisted entirely of scrap metal or black oxide.

In Plant 4, uranium metal production ceased in 1950 and green salt production ceased in 1951. Afterward, Plant 4 was utilized for various pilot and experimental uranium metal projects until 1956.

Destrehan Plant - Plants 6, 6E and 7

The Destrehan Plant (Plant 6, 6E, and 7, Figure 2-12) was built in 1945 to increase the capacity of the uranium refinery and to process pitchblende ores. Figure A-2 attached is a historical photograph of the Plant 6, 6E and 7 area.

The engineering design of the Destrehan Plant was based on experimental pitchblende processing performed by MCW in Plant 1 in 1944. The pitchblende ore contained 30% to 55% uranium as uranium oxide (U_3O_8) in equilibrium with its decay products. Processing the pitchblende required extraordinary health and safety precautions due to the presence of Ra-226, a decay product of U-238. The laboratory in building 25-2 was used for development work, and a pilot plant to extract the radium was installed in building K-1-E (Plant 1, Figure 2-12). In the production process, pitchblende was dissolved in nitric acid and "adjusted" by stripping the radium. Lead and radium decay products were precipitated from the liquor by sulfate precipitation and filtration to yield K-65, a "lead gangue cake." A second step treated the filtered liquor with barium to neutralize excess sulfate and yield a barium sulfate precipitate that stripped any remaining radium.

The Destrehan refinery, Plants 6, 6E, and 7 (Figure 2-12) was brought on line in 1946. Incoming pitchblende ore and ore concentrates arrived by rail and were stored in building 110. The southwest yard area, which is the present-day location of the wastewater basins (Figure 2-2), was also used to store MED-AEC feed materials as well as contaminated equipment. The continuous process reactor, located in building 104, was designed for pitchblende and included new operations to recover radium-bearing residues and raffinate cake and to concentrate and convert U_3O_8 to UO_2. The feed liquor was extracted with ether in a manner similar to that used in Plant 2, yielding pure uranyl nitrate hexahydrate (UNH). The UNH was denitrated to yield UO_3, and the UO_3 was reduced with hydrogen to yield UO_2. The UO_2 product was sent to Plant 4, Plant 7, or an off-site government facility for further processing. In 1949, a second digest line was added to building 104 to process uranium ore concentrates from uranium mills. From 1949 to 1953, approximately 50% of the feed material was pitchblende ore. In June 1955, the last shipment of pitchblende ore was processed in the Destrehan Plant. Afterward, all of the feed material consisted of ore concentrates.

Building 116 (Plant 6E, Figure 2-12) was constructed in 1950 as a replacement for uranium metal production area in Plant 4. The objectives were to increase capacity of uranium metal production, improve the quality, and reduce the processing costs. To increase the capacity,

- Conversion of feed materials slightly enriched in U-235 to metal or uranium nitrate liquor
- Extraction of Ionium (Th-230) from pitchblende raffinate
- Production of U_3O_8 and uranium dioxide (UO_2) using an experimental continuous denitration furnace
- Experimental extraction of uranium using Tributyl Phosphate (TBP) in hexane to replace ether, since TBP was much safer to handle
- Production of uranium metal dingots, using a thermite reduction process
- Recycling of slag for use as liner material in the processing of uranium metal

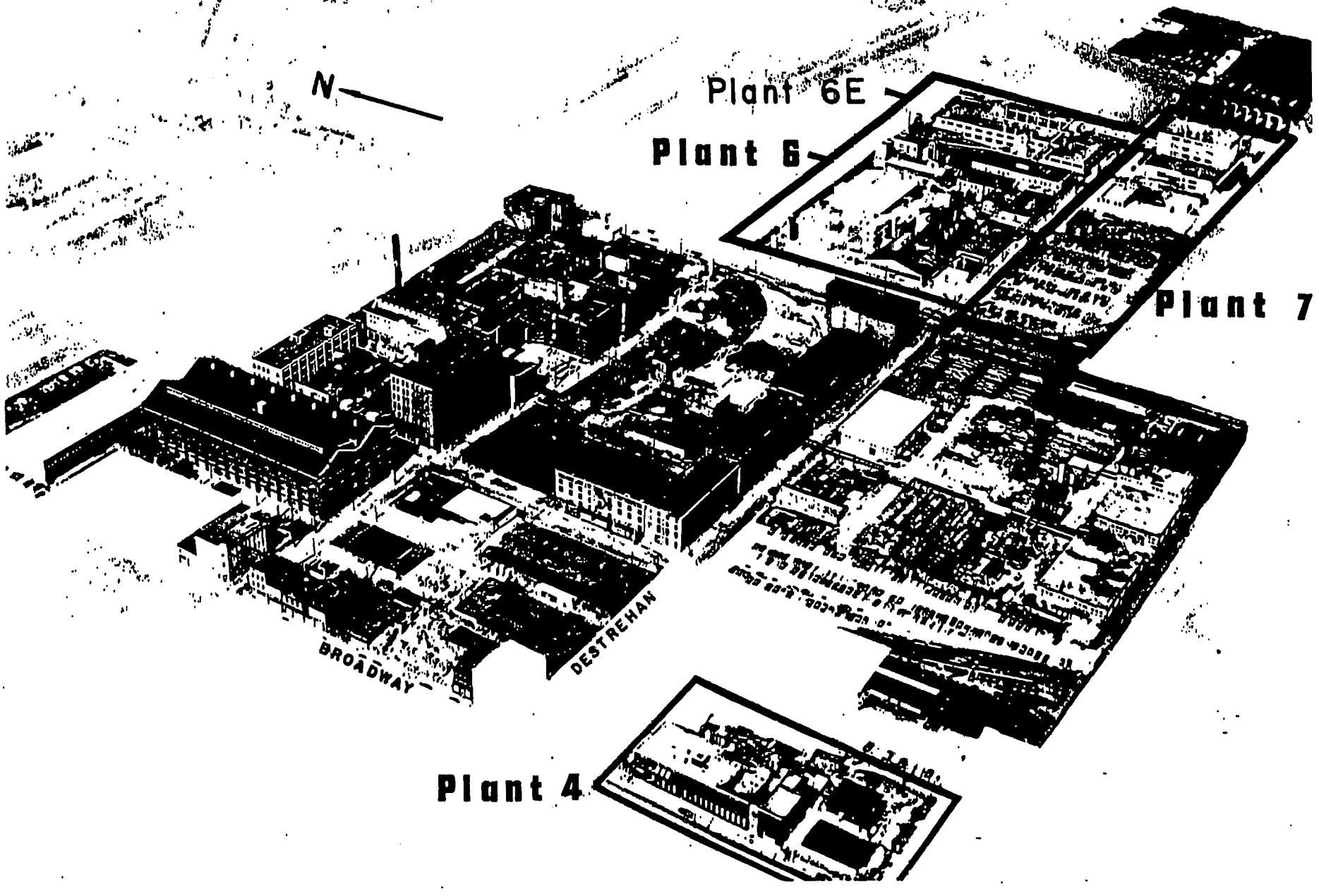
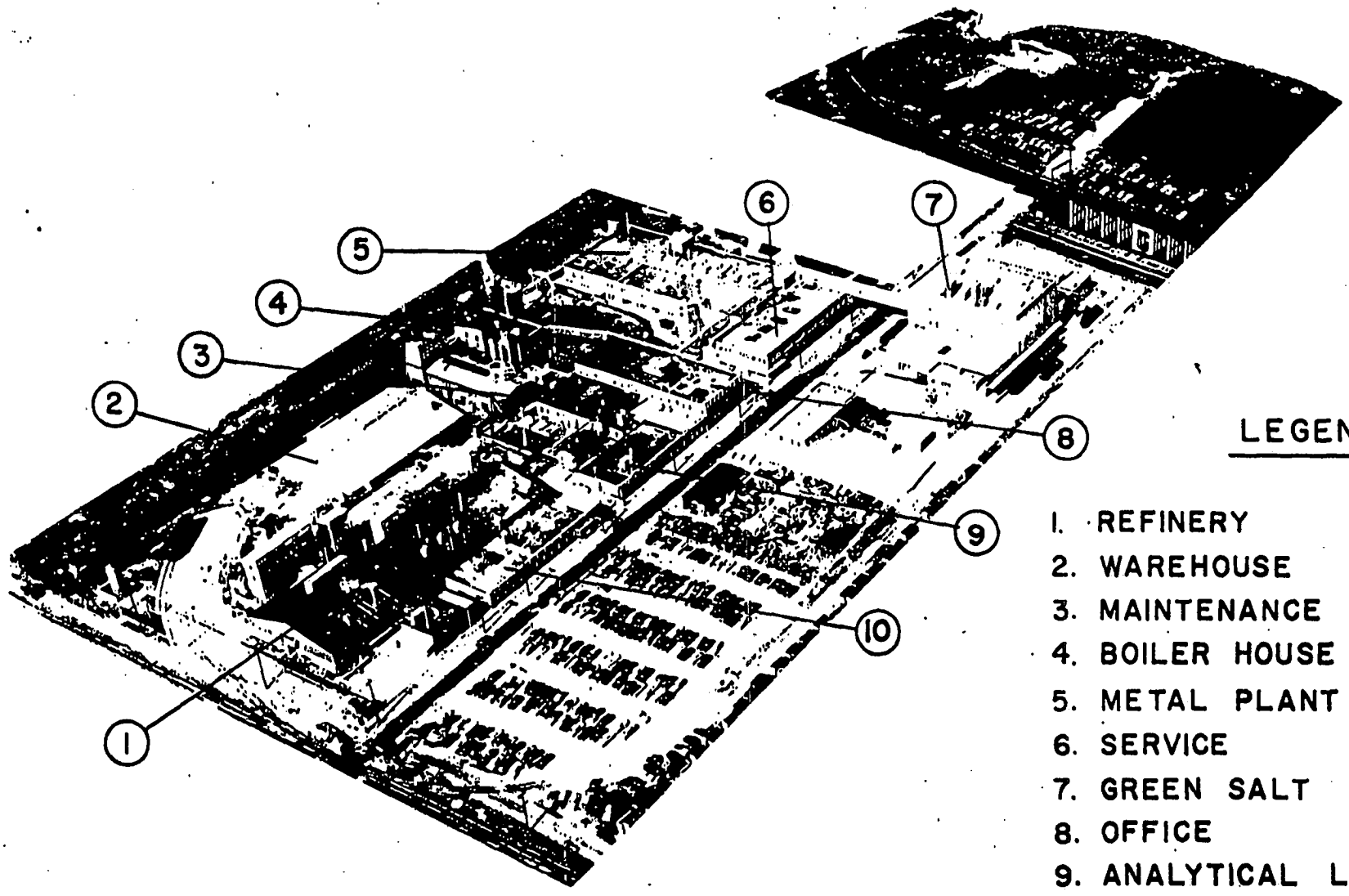


FIGURE A-1

DESTREHAN STREET FACILITIES



LEGEND

1. REFINERY
2. WAREHOUSE
3. MAINTENANCE
4. BOILER HOUSE
5. METAL PLANT
6. SERVICE
7. GREEN SALT
8. OFFICE
9. ANALYTICAL LABORATORY
10. PROCESS & DEVELOPMENT LABORATORY

MALLINCKRODT CHEMICAL WORKS

PLANT 6, 6E, AND 7

FIGURE A-2

C-T SITE CHARACTERIZATION PLAN

APPENDIX B

DESCRIPTION OF DECONTAMINATION TESTS

APPENDIX B

DESCRIPTION OF DECONTAMINATION TESTS

1.0 Introduction

This Appendix summarizes general methods for decontamination and is presented as a guide in planning and selecting decontamination procedures for radioactively contaminated materials and equipment being cleaned for unrestricted release. Decontamination procedures, in general, follow acceptable industrial practices for maintaining cleanliness and removing contaminants such as surface dirt, oils, scale deposits, and oxide film. Decontamination methods range from simple procedures such as hand wiping to complex operations involving large facilities, heavy mechanical equipment, and extensive logistical support. The choice of a method depends on the resources, experience, and innovativeness of those responsible for accomplishing the tasks. techniques vary widely on the basis of the type of material contaminated, the extent, concentration, and the chemical and physical characteristics of the contaminant. Detailed treatment of decontamination methods is beyond the scope of this standard; however, techniques and experiences are well documented in the literature.

2.0 Basic Considerations

2.1 Resources

The availability of adequate resources is a key factor in selecting a decontamination method. Resources which should be evaluated include decontamination facilities, auxiliary equipment, decontamination supplies, protective clothing, monitoring equipment, and manpower. Particular emphasis should be placed on adequacy of containment and waste-handling facilities.

2.0 Basic Considerations (continued)

2.2 Cost

Essentially all decontamination efforts are influenced by the cost of the procedure compared with the value of the material, equipment, or facilities being cleaned. In some instances it may be more economical to dispose of the objects as contaminated waste than to clean them to uncontrolled release levels.

2.3 Personnel Safety

Protection of personnel performing the decontamination and of those in surrounding areas should be considered in initial planning. Respiratory protection is a key consideration since many decontamination procedures generate airborne contamination. The toxicity of the cleaning agent should be considered along with the potential for evolution of toxic fumes when the cleaning agent comes in contact with the surface being cleaned. In addition, the potential for the presence or generation of explosive or flammable gas mixtures should be evaluated. Procedures with significant radiological, industrial hygiene, or safety hazards should be performed under an approved written job plan in which all workers understand the requirements of the job plan before starting work.

2.4 Effects of Decontamination

The effect of the decontamination procedure on the material being cleaned should be considered in the initial planning. In addition to the obvious destructive effect of procedures such as sandblasting, grinding, etc., corrosion or insidious changes associated with various chemical reactions should also be evaluated.

3.0 Decontamination Methods

3.1 General

It is often of advantage to try several different decontamination procedures or techniques on a test basis before making a commitment to a single method. In most procedures the decontamination factor (DF) is high on the initial cleaning but significantly reduced in successive steps.

3.2 Manual Cleaning

Manual cleaning includes such procedures as wiping, scrubbing, mopping, etc., and in general, is an effective method of removing low or moderate levels os contamination on nonporous or nearly nonporous surfaces. Water or a variety of detergents, solvents, chelating agents, and other chemicals may be used. Manual cleaning usually presents minimal airborne and surface contamination control problems.

3.3 Mechanical Cleaning

Mechanical cleaning includes such decontamination methods as vacuuming, high-pressure steam and water cleaning, soaking, ultrasonics, and electropolishing. These methods are generally associated with the decontamination of high contaminated equipment but have application with lower levels of contamination.

3.3.1 Jet Cleaning

High-pressure steam and water used alone or mixed with chemicals an detergents are effective in attaining high decontamination factors. Commercial systems using the jet cleaning principle are available. Equipment of this type is ideally suited for remote operation and for cleaning large surface areas. High-pressure jet cleaning has the disadvantage of spreading contamination over a large area and is more effective when used in a cave or cell designed especially for this purpose.

3.0 Decontamination Methods (continued)

3.4 Grinding and Abrasive Action

Cleaning procedures employing grinding or abrasive action are effective means of decontaminating metal and concrete surfaces, provided alteration of the surface area of the object being cleaned can be tolerated.

3.4.1 Grinding

Grinding of surfaces to remove contamination is usually limited to small objects or isolated spots of contamination where the surface is reasonably smooth. Grinding normally produces a high decontamination factor and is economical. A variety of commercial grinders may be used. Grinding inherently leaves residual contamination on the surface of the object being cleaned and therefore usually requires final cleaning by some other method (vacuuming, wiping, etc.).

Grinding frequently produces particulate air activity and is generally not economical for large surface areas.

3.4.2 Abrasive Blasting

Abrasive blasting has a number of advantages over grinding. It is rapid, provides a high DF, is effective on irregular shaped surfaces and can be used for large areas. Abrasive blasting makes use of a large variety of abrasives (sand, shells, glass beads, metals, etc.) with velocity, shape, and size of the abrasive blasting is that it usually generates high airborne contamination and spreads surface contamination; however, this can be minimized by wet blasting techniques, vacuum systems, or filtered enclosures.

3.0 Decontamination Methods (continued)

3.5 Destructive Decontamination

Destructive decontaminating procedures include physical removal of contaminated parts or sections. Generally, little or no effort is made to clean the contaminated parts before disposal as waste. Containment and other radiological controls associated with destructive cleaning are dependent on contamination levels, the nature of the contaminant, and the physical characteristics of the parts being removed.

4.0 Decontamination Test Detail

The decontamination tests have been designed to obtain information needed to evaluate proper decontamination methods for the site decommissioning. Building 238 will be the site for most of the decontamination tests. This building was chosen for the following reasons:

1) It was the main process building
2) The majority of the acids were used in this building. The use of these acids would cause worst case penetration into the building materials. Because of this, conservation information would be obtained from the tests.
3) This building contains a wide variety of building materials.
4) Since the majority of the building is contaminated, there is a high probability that good test specimens can be identified. Additionally, there would be very small potential for contaminating a clean area.

The tests to be conducted have been limited to those materials that have a good probability of being decontaminated. These materials are concrete, brick, block, wood and metal.

Areas to be used in test decontamination will be identified as having levels of contamination requiring remediation with preference given to areas of highest contamination. Direct surface contamination levels will be established prior to testing and recorded on the Test Decontamination Report.

A technician will then attempt to decontaminate the designated areas, one at a time using a different technique in each specified area. In general, one eighth of an inch will be removed on each pass. The area would then be resurveyed. This process would continue until the area met the release guidelines, or until it was decided that it would not be worth while to continue trying the method (i.e., using a wire brush and it appears that the contamination if deep). If 1/2 inch of material is removed and the release guidelines have not been met, a 2 inch core will be taken to determine the depth of the contamination. The core will then be cut into 1/4 inch slices. Direct measurements will be taken on each slice to determine the depth.

The decontamination tests will include the following:

Scabbling, high-pressure water blasting, and chemical extraction of selected concrete floor areas in buildings 238, 246 and 247.

Scabbling, and chemical extraction of selected brick wall areas in buildings 238, 246 and 247.

Water blasting, wire brushing, acid cleaning and chemical extraction of metal components from Building 238 including at least two sections from vessels and two from steel plate floors.

Manual cleaning and chemical extraction of rubber lined tanks in building 238.

Chemical extraction of wood components in building 238.

A use of bead/grit blasting techniques has not been considered due to the likely contamination of this system during the test. The depth of contamination found in the scabbler testing will identify the depth of contamination at the selected locations. This depth and the rate of surface removal for typical bead/grit blasting will be applied to estimate the success of a bead/grit blasting application.

4.0 Decontamination Test Detail (continued)

4.1 Decontamination Procedures

4.1.1 Floor and Walls

Tests will be performed on the following floors and walls in building 238:

Main process area - three floor areas receive scabbling, water blasting and chemical extraction tests. Total nine tests.

Main process area - three wall areas receive scabbling and chemical extraction tests. Total six tests.

Ball mill room - one floor area receives scabbling, water blasting and chemical extraction tests. Total three tests.

Tests will be performed on the following floors and walls in building 246B:

One floor area receives scabbling, water blasting and chemical extraction tests. Total three tests.

One wall area receives scabbling and chemical extraction tests. Total two tests.

Tests will be performed on the following floors and walls in Building 247A:

One floor area receives scabbling, water blasting and chemical extraction tests. Total three tests.

One wall area receives scabbling and chemical extraction tests. Total two tests.

4.0 Decontamination Test Detail (continued)

4.1 Decontamination Procedures (continued)

4.1.1 Floor and Walls (continued)

Tests will be performed on the following floors and walls in Building 247B:

One floor area receives scabbling, water blasting and chemical extraction tests. Total three tests.

One wall area receives scabbling and chemical extraction tests. Total two tests.

Test results including the method, contamination reductions and time requirements will be recorded on the Test Decontamination Report form. (See attached.)

4.1.2 Metal Components

Metal components will be removed from the structures for test decontamination where applicable in order to obtain lower background measurements and control of the solution and methods proposed. Chemicals used in these tests will be stored and properly identified under the waste management directions of this plan.

Two vessel wall sections of approximately one square foot will be tested using water blasting, wire brushing, acid cleaning and chemical extraction. Total of eight tests.

Two steel plate floor sections of approximately one square foot from the steps, mezzanines, or other flat components will be tested using water blasting, wire brushing, acid cleaning, and chemical extraction. Total of eight tests.

Test results including the method, contamination reductions and time requirements will be recorded on the Test Decontamination Report form.

4.0 Decontamination Test Detail (continued)

4.1 Decontamination Procedures

4.1.3 Rubber Lining in Vessels

Two rubber liner sections of approximately one square foot will be removed from contaminated vessels and tested using detergent/water scrubbing and chemical extraction. Total of four tests.

Test results including the method, contamination reductions and time requirements will be recorded on the Test Decontamination Report form.

4.1.4 Wood Components

Wood components will be removed from the filter press and from other accessible areas for testing using chemical extraction techniques. Total of 2 tests.

Test results including the method, contamination reductions and time requirements will be recorded on the Test Decontamination Report form.

4.1.5 Subsurface Soils/Fill Materials

The chemical extraction test decon procedure will be performed on subsurface materials. A cursory gamma screen will be done on site to identify those samples with elevated gamma activity. These samples will be split for isotopic analysis and a test decontamination performed using chemical extraction techniques. The sample that has been tested using chemical extraction will then be analyzed for isotopic concentrations and compared to the analysis of the original untested sample split. Four samples will be tested using this method.

Test results including the method, isotopic concentration reductions and time requirements will be recorded on the Test Decontamination Report form.

4.2 Analysis of Results

The information obtained from the tests will be used to determine if a decontamination technique would be cost effective. The evaluation would take into effect the cost of performing the decontamination, the volume of material decontaminated for that cost, the cost of disposal of the secondary waste generated, the cost to release the material and the benefits of reuse or recycling the material. This information would be balanced against the cost to just dispose of the material without performing any decontamination. Costs due to health and safety requirements will not be included in the analysis.

TEST DECONTAMINATION REPORT

DECONTAMINATION TECHNIQUE: _____

TEST AREA LOCATION

Floor Level: _____
Grid Number: _____

INITIAL RADIATION AND CONTAMINATION SURVEY RESULTS

Initial Radiation levels: _____
Initial Contamination levels: _____
(Attach Copy of Initial Survey Documents)

DECONTAMINATION EFFORTS

Equipment/Materials Used: _____
(incl. approx. quantities: _____
_____

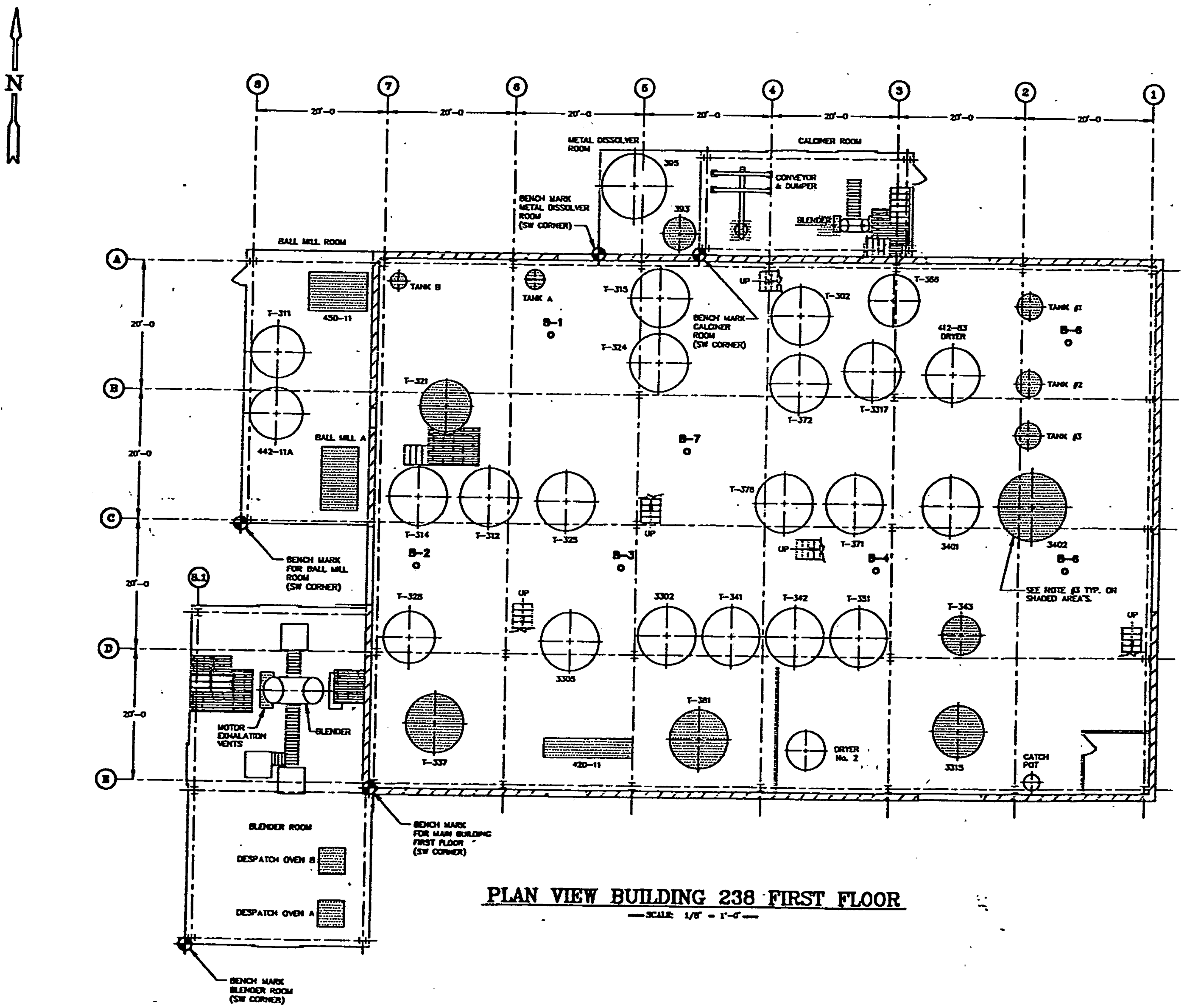
Dimensions of Test Area: _____
Time of Test Decon Start: _____
Time of Test Decon Finish: _____
Elapsed Time (Min. and Sec.): _____

POST TEST DECONTAMINATION RESULTS

Final Radiation levels: _____
Final Contamination levels: _____
(Attach Copy of Final Survey Documents)

_____ _____
Performed By Date

FIGURES



EQUIPMENT LOCATION TABLE

FIRST FLOOR MAIN BUILDING

LOCATION NORTH	LOCATION EAST	EQUIPMENT NUMBER	REMARKS
78 ft	24 ft	TANK A	
57 ft	9 ft	TANK T-321	
78 ft	3 ft	TANK B.	
36 ft	105 ft	TANK 3402	
30 ft	96 ft	TANK T-343	
9 ft	88 ft	TANK 3315	
8 ft	51 ft	TANK T-361	
8 ft	27 ft	PRESS-PAN TA205	420-11
10 ft	10 ft	TANK T-337	
55 ft	102 ft	TANK #3	
63 ft	102 ft	TANK #2	
75 ft	102 ft	TANK #1	
60 ft	90 ft	DRYER 412-83	

BALL MILL ROOM

LOCATION NORTH	LOCATION EAST	EQUIPMENT NUMBER	REMARKS
38 ft	14 ft	BALL MILL	450-11
12 ft	12 ft	BALL MILL A	

BLENDER ROOM

LOCATION NORTH	LOCATION EAST	EQUIPMENT NUMBER	REMARKS
5 ft	22 ft	DESPATCH OVEN A	
13 ft	22 ft	DESPATCH OVEN B	
39 ft	15 ft	MOTOR EXHALATION VENTS	

CALCINER ROOM

LOCATION NORTH	LOCATION EAST	EQUIPMENT NUMBER	REMARKS
3 ft	7 ft	DUMPER	TANK TOP
6 ft	15 ft	BLENDER	MACHINE

METAL DISSOLVER ROOM

LOCATION NORTH	LOCATION EAST	EQUIPMENT NUMBER	REMARKS
6 ft	12 ft	DISSOLVER TANK	393

NOTES:

1. ALL DIMENSIONS WERE TAKEN FROM THE SOUTHWEST CORNER OF THE BUILDING OR ROOMS (SEE PLAN).
2. ALL DIMENSIONS ARE FOR REFERENCE ONLY.
3. SHADED EQUIPMENT INDICATES SURVEYED AREAS.

FIGURE 5-1

ENGR. JOB NO. 7085	PROJECT NO. 7085

REV. NO.	DATE	REVISIONS
0	01/08/04	ISSUED FOR REVIEW & COMMENTS

MALLINCKRODT, INC.
ST. LOUIS, MO.

BOREHOLE LOCATIONS
BUILDING 238

PLANT STL-3	BLDG. 238	FLOOR FIRST
SCALE 1/8"=1'-0"		DATE 01/08/04
DR. R.W.P.		PLOT @ 0104
FILE 7085\200006		ENGR. ART HEINZE

DRAWING NO. **7085-200-006** REV. 0

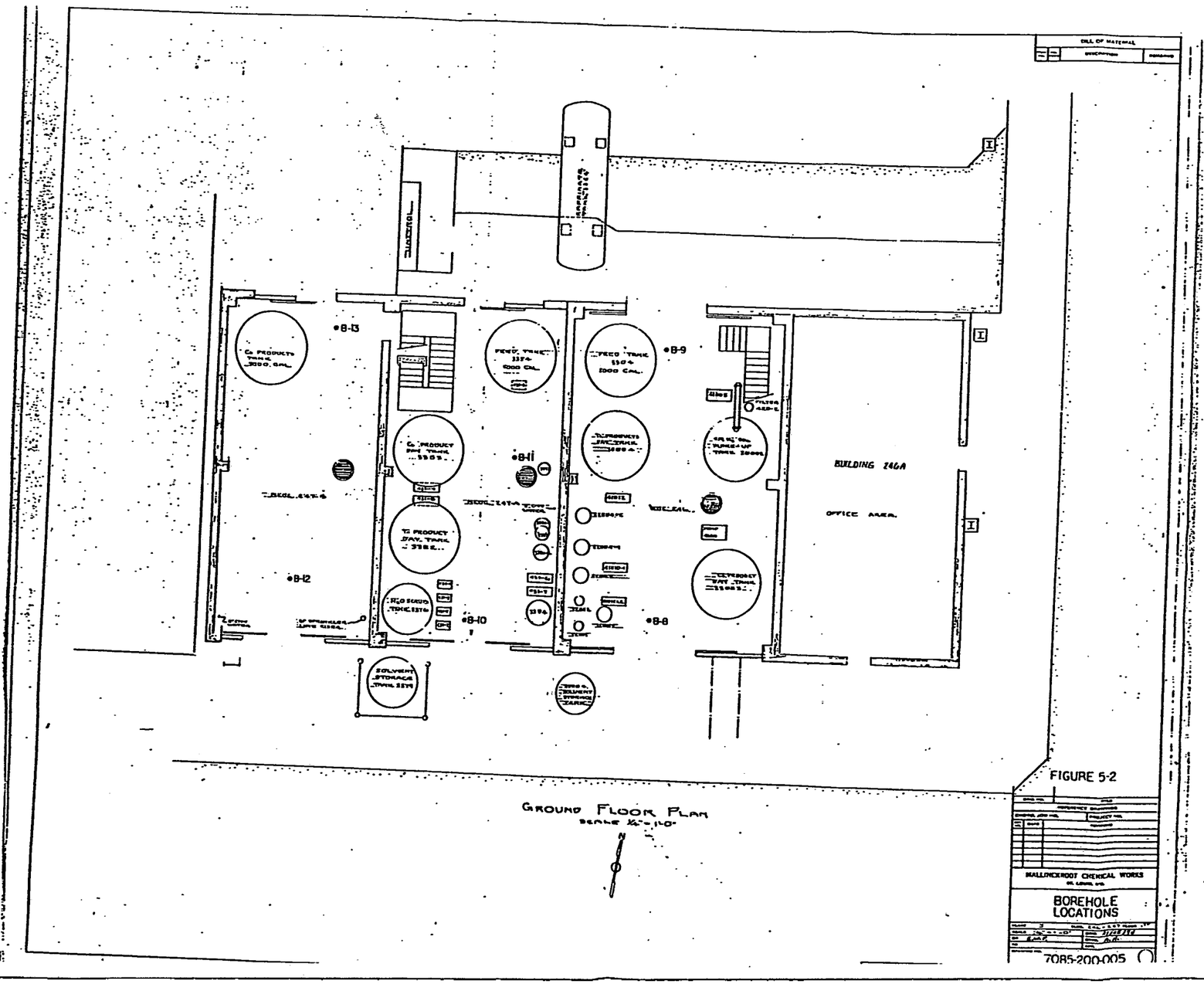
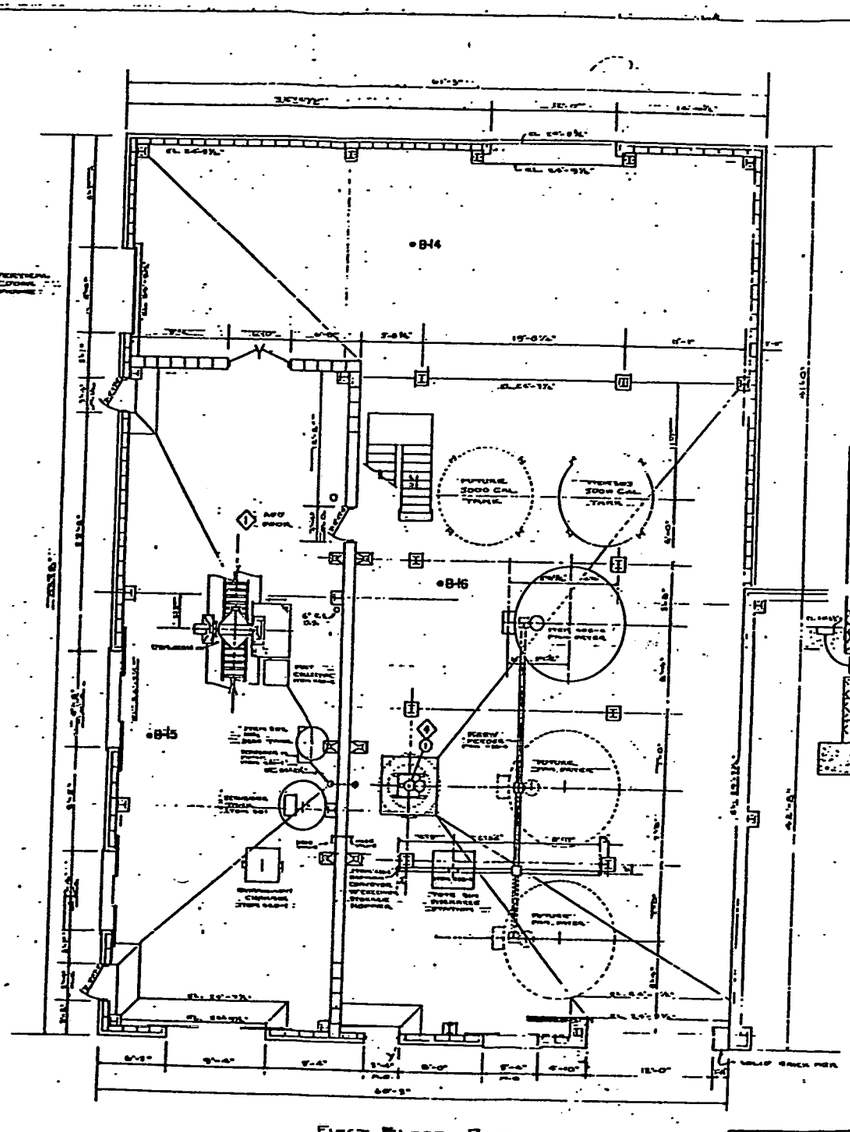


FIGURE 5-2

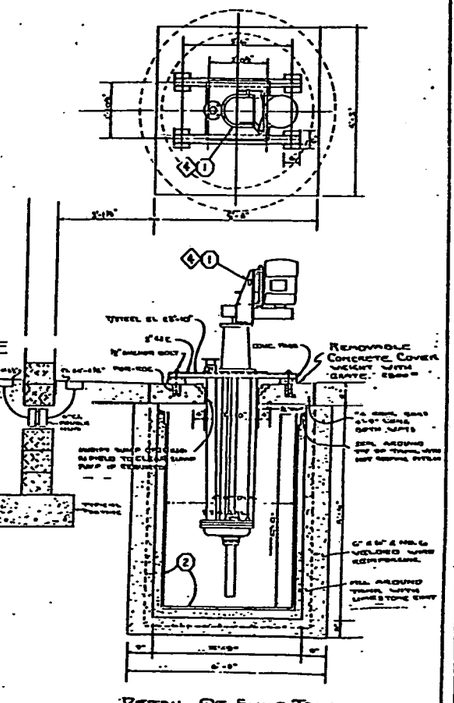
HALLINCKRODT CHEMICAL WORKS

BOREHOLE LOCATIONS

7085-200-005



FIRST FLOOR PLAN
SCALE 1/4"=1'-0"



DETAIL OF SUMP TANK
SCALE 3/4"=1'-0"

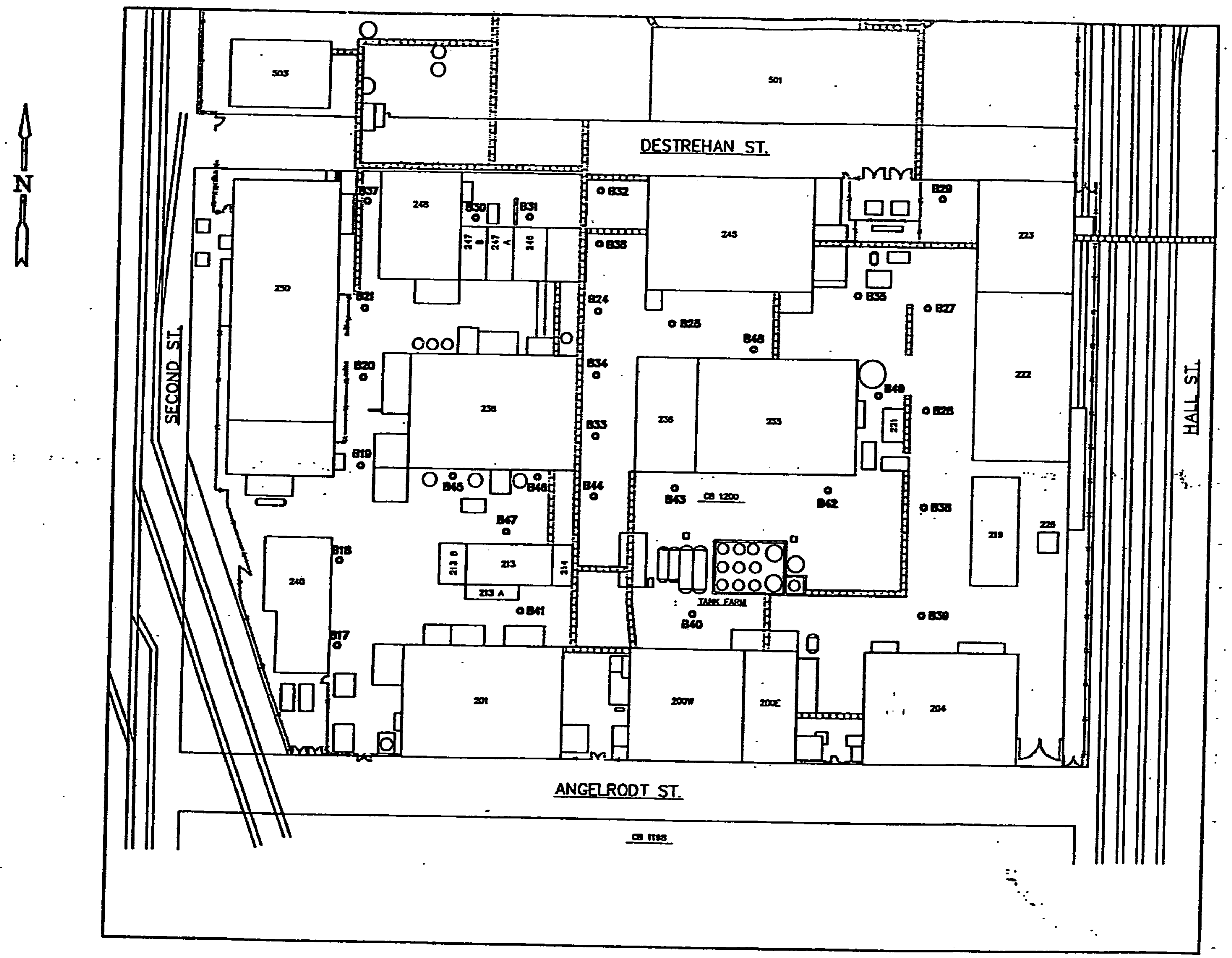
FIGURE 5-3

APPROVED FOR CONSTRUCTION
WALLACE & TIERNAN DIVISION OF PENNWALT CORPORATION
SIGNED
DATE

MALLINCKRODT CHEMICAL WORKS
ST. LOUIS, MO.

BOREHOLE LOCATIONS

7085-200-004



PLANT 5 AREA SITE PLAN

0 25' 50' 75' 100'
SCALE

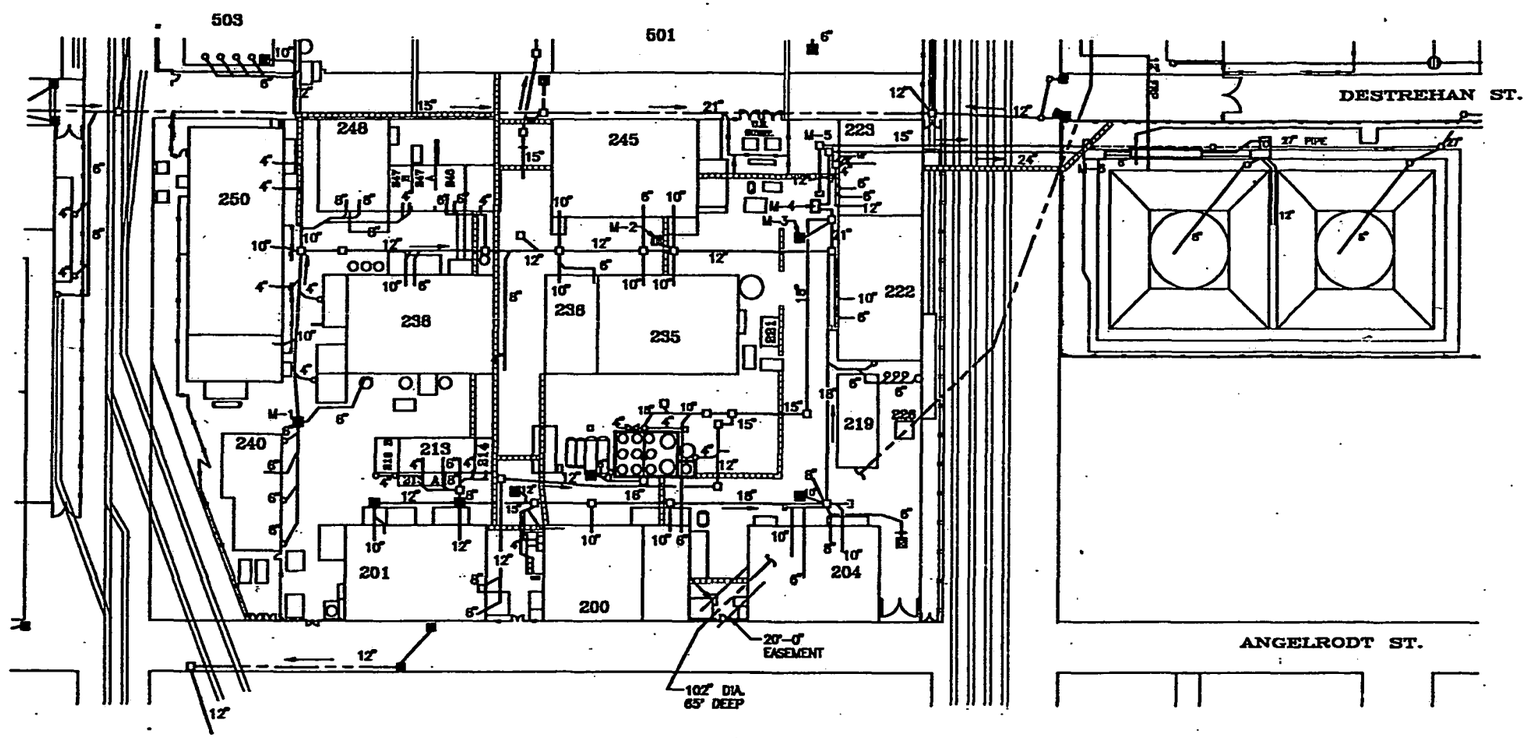
FIGURE 5-4

REFERENCE DRAWINGS

MALLINCKRODT, INC.

BOREHOLE LOCATIONS
PLANT 5

7085-200-007



◈ FIGURE 5-5

NOTES:

1. LOUVER SCHEDULE & HANDS FREEZER 01 THIS DOR.

LEGEND

SCALE:

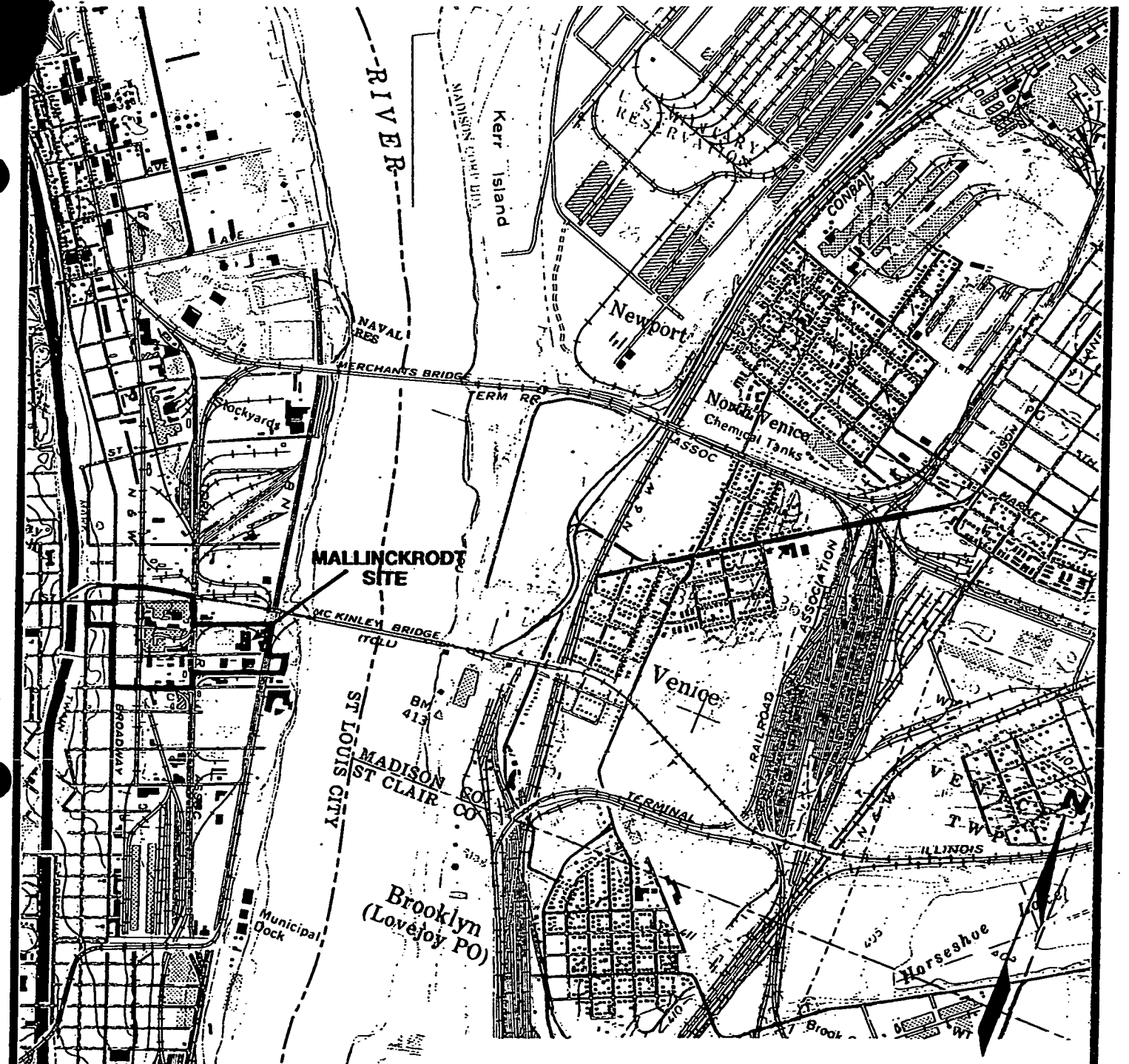
0 50' 100' 150'

NO.	DATE	REVISIONS
0	10/29/98	AS BUILT
1	01/05/00	ADDED MAN HOLES #16 (CORE)

MALLINCKRODT, INC.
ST. LOUIS, MO.

ST. LOUIS PLANT UTILITIES
PLANT #5
SEWER LINE SYSTEMS

PLANT	INT.-5
SCALE	1"=50'
DR.	R.V.P.
FILE	5000\5000004
DRAWING NO.	5000-202-004 ◈
FLOOR	
DATE	10/10/98
PLOT	1"=50'
CHK.	A.R.



NOTE: DRAWING TAKEN FROM U.S.G.S. – GRANITE CITY, ILL–MO QUADRANGLE DATED 1954.

SCALE: 1IN = 2000FT

MALLINCKRODT SPECIALTY CHEMICALS COMPANY ST. LOUIS, MISSOURI	PROJECT NO. 90C8150–D

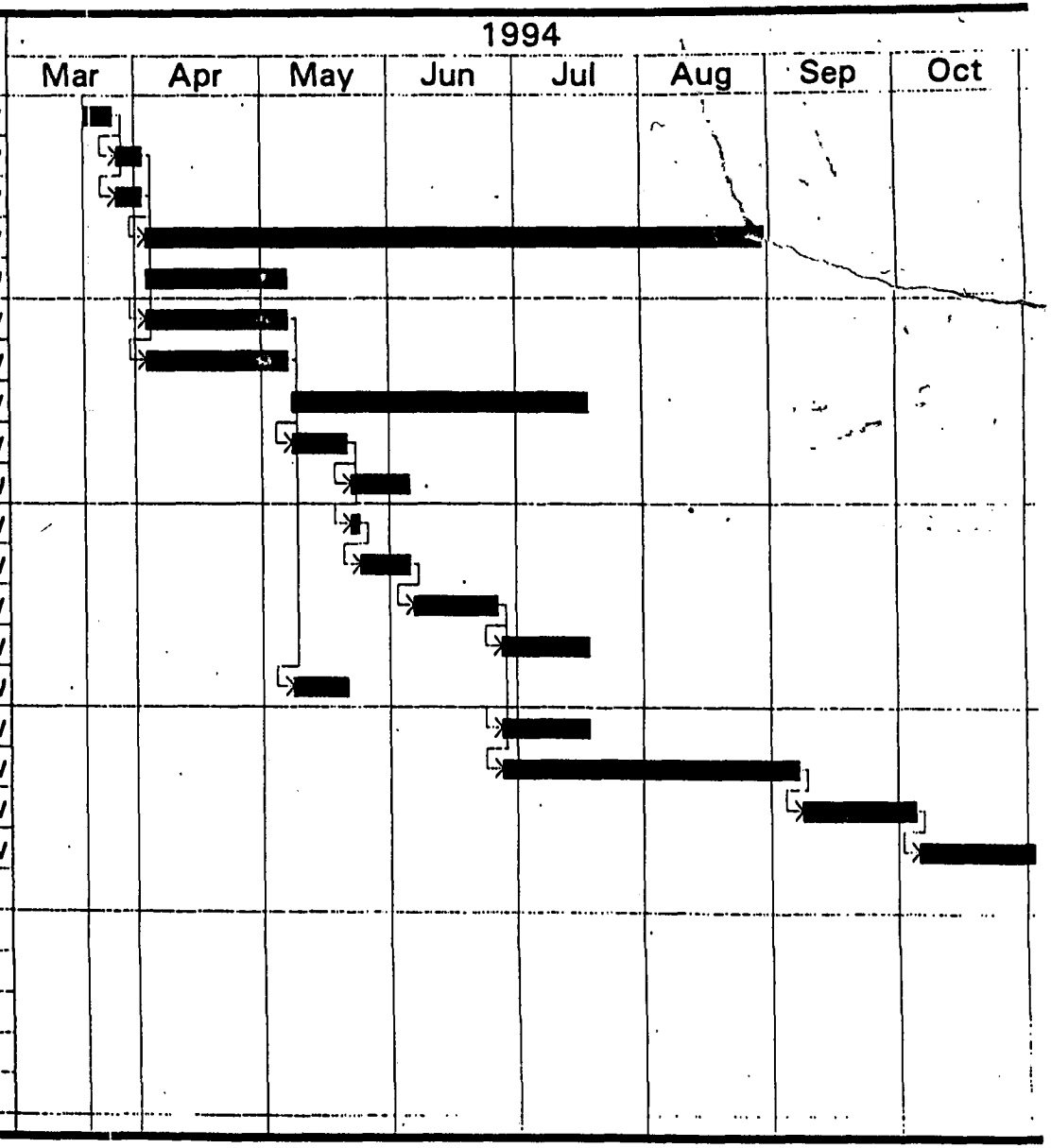
Woodward-Clyde Consultants

Engineering & sciences applied to the earth & its environment

DRN. BY: kdw 6/9/93 DSGN. BY: CHKD. BY: CFP 6/21/93	Site Location Map	FIG. NO. 2-1

CHARACTERIZATION PLAN

Task Name	Duration
TMA/E MOB	1.20 w
BACKGROUND SURVEY	1.00 w
SEWERLINE SURVEY	1.00 w
LAB ANALYSIS - ALL SUMPS	21.00 w
SUBSURFACE INVESTIGATION	5.00 w
RIG 1	5.00 w
RIG 2	5.00 w
RAD SURVEYS	10.00 w
ROOFS	2.00 w
EXTERIOR WALLS	2.00 w
INCINERATOR & B101 ROOF	0.50 w
STREETS	1.50 w
INTERIOR/EQUIPMENT	3.00 w
BLDGS. 90/91, 62	3.00 w
TEST DECONTAMINATION	2.00 w
ADDITIONAL. DRILLING	3.00 w
DRAFT REPORT	10.00 w
REVIEW REPORT	4.00 w
FINAL REPORT	4.00 w

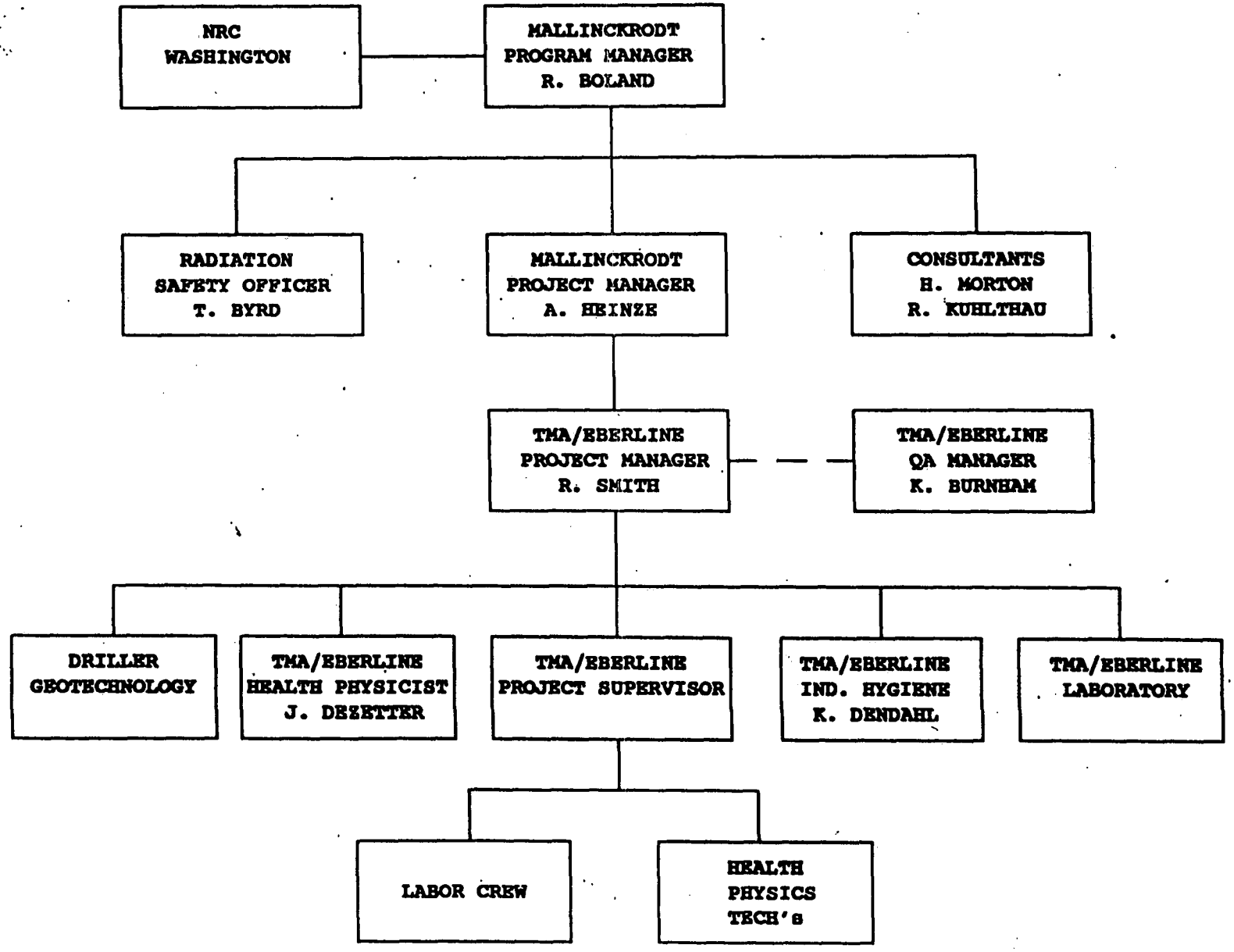


Printed: 10/Jan/94
Page 1

FIGURE 5-6

FIGURE 9-1

C-T CHARACTERIZATION PLAN ORGANIZATION



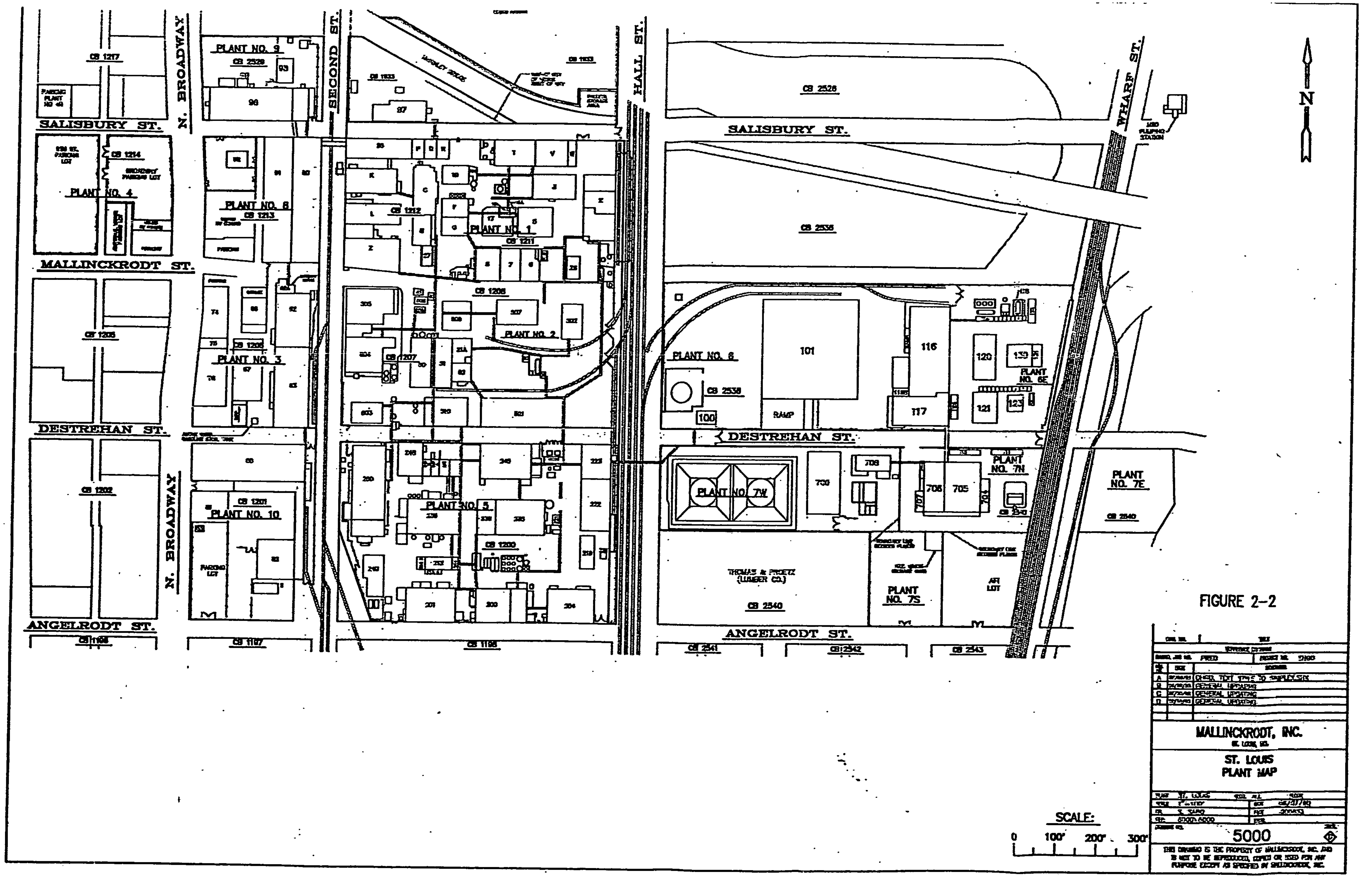
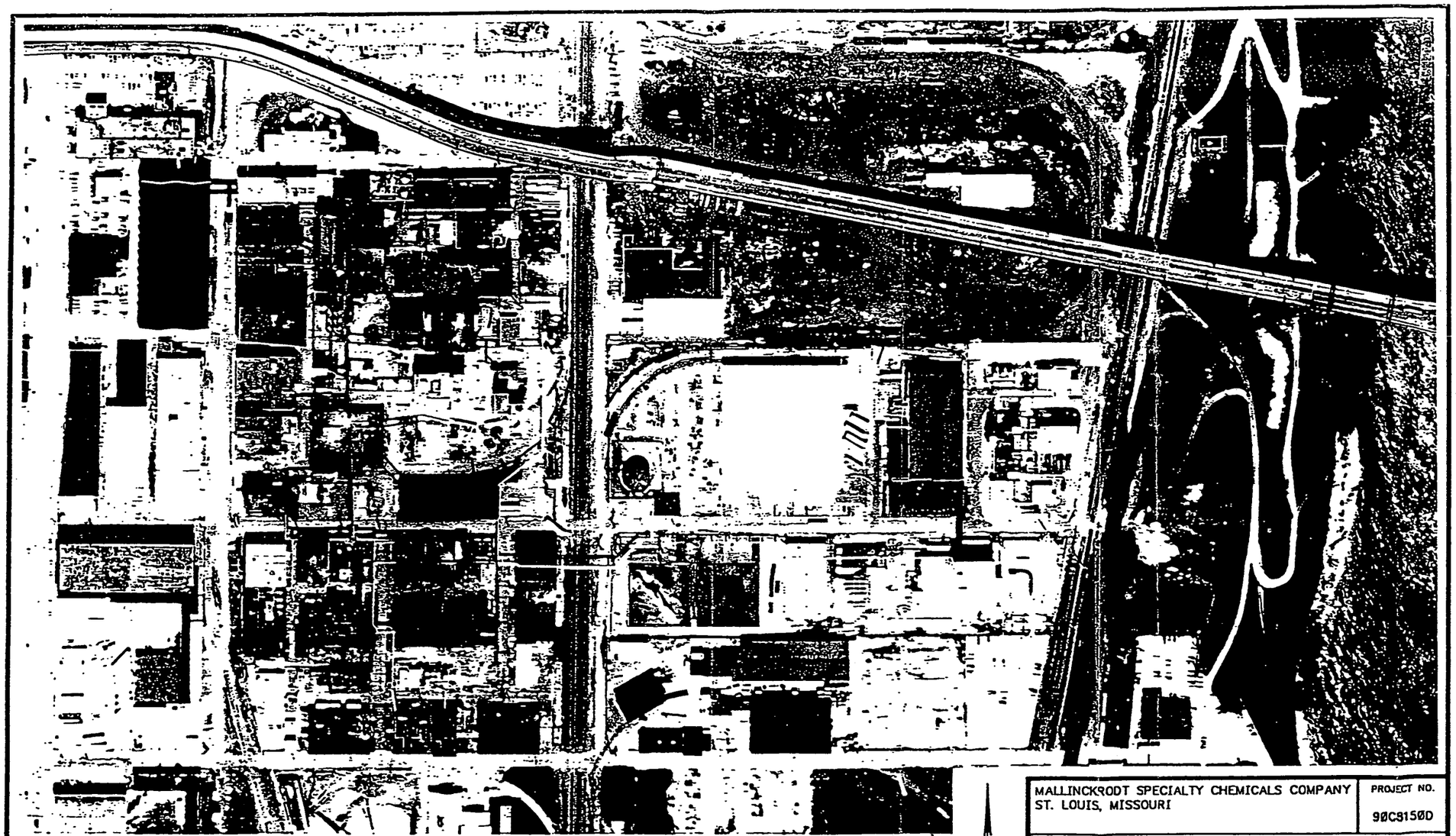

SALISBURY ST.
MALLINCKRODT ST.
DESTREHAN ST.
ANGELRODT ST.
N. BROADWAY
SECOND ST.
HALL ST.
WHARF ST.
PLANT NO. 9
PLANT NO. 4
PLANT NO. 8
PLANT NO. 1
PLANT NO. 2
PLANT NO. 3
PLANT NO. 6
PLANT NO. 6E
PLANT NO. 5
PLANT NO. 10
PLANT NO. 7W
PLANT NO. 7N
PLANT NO. 7E
PLANT NO. 7S
THOMAS & PROETZ (LUMBER CO.)
CB 2528
CB 2536
CB 2538
CB 2540
CB 2541
CB 2542
CB 2543
101
116
117
120
121
123
139
100
RAMP
700
705
706
707
708
N
MALLINCKRODT, INC.
ST. LOUIS PLANT MAP
5000
SCALE:
0
100'
200'
300'

FIGURE 2-2

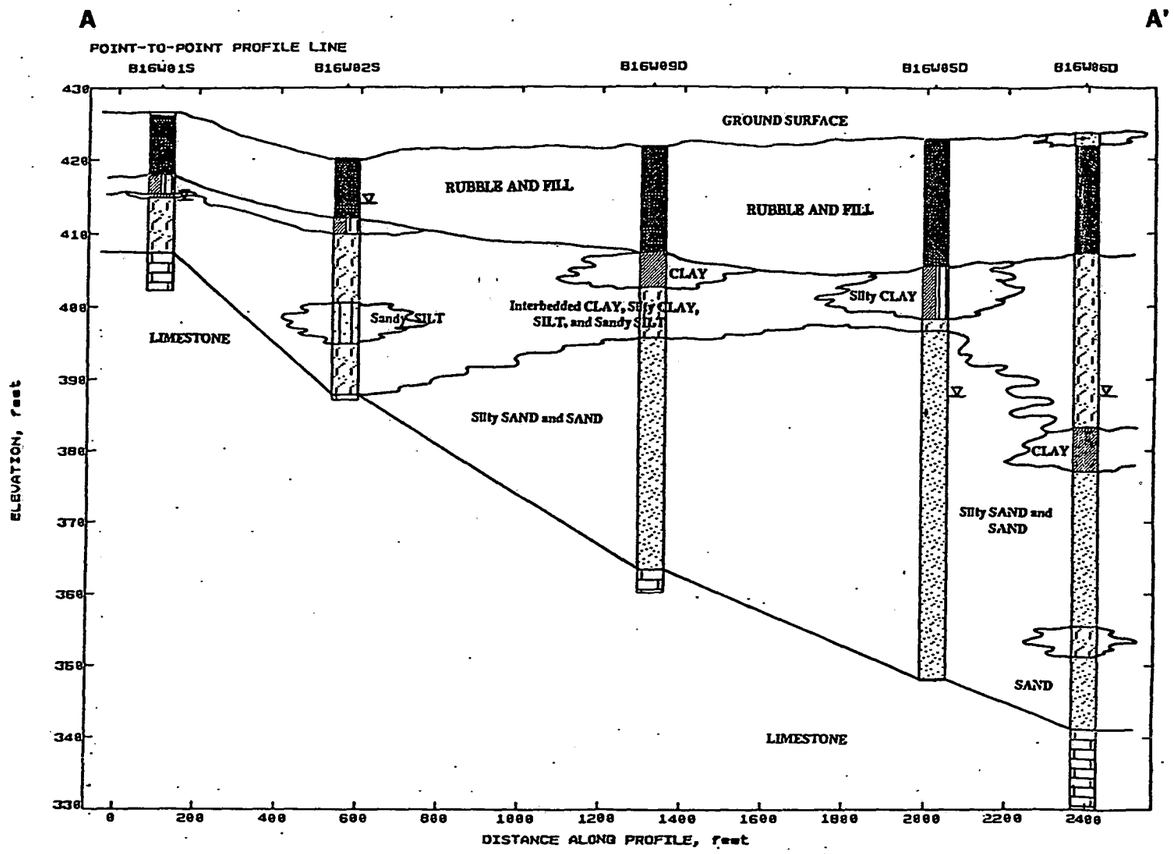


SOURCE: SURDEX CORPORATION

Ø 155
SCALE FEET

N

MALLINCKRODT SPECIALTY CHEMICALS COMPANY ST. LOUIS, MISSOURI		PROJECT NO. 90C8150D
Woodward-Clyde Consultants Engineering & sciences applied to the earth & its environment		
DRN. BY: kdw 6/15/93 DSGN. BY: CHKD. BY:	Mallinckrodt St. Louis Plant April 24. 1991	FIG. NO. 2-3

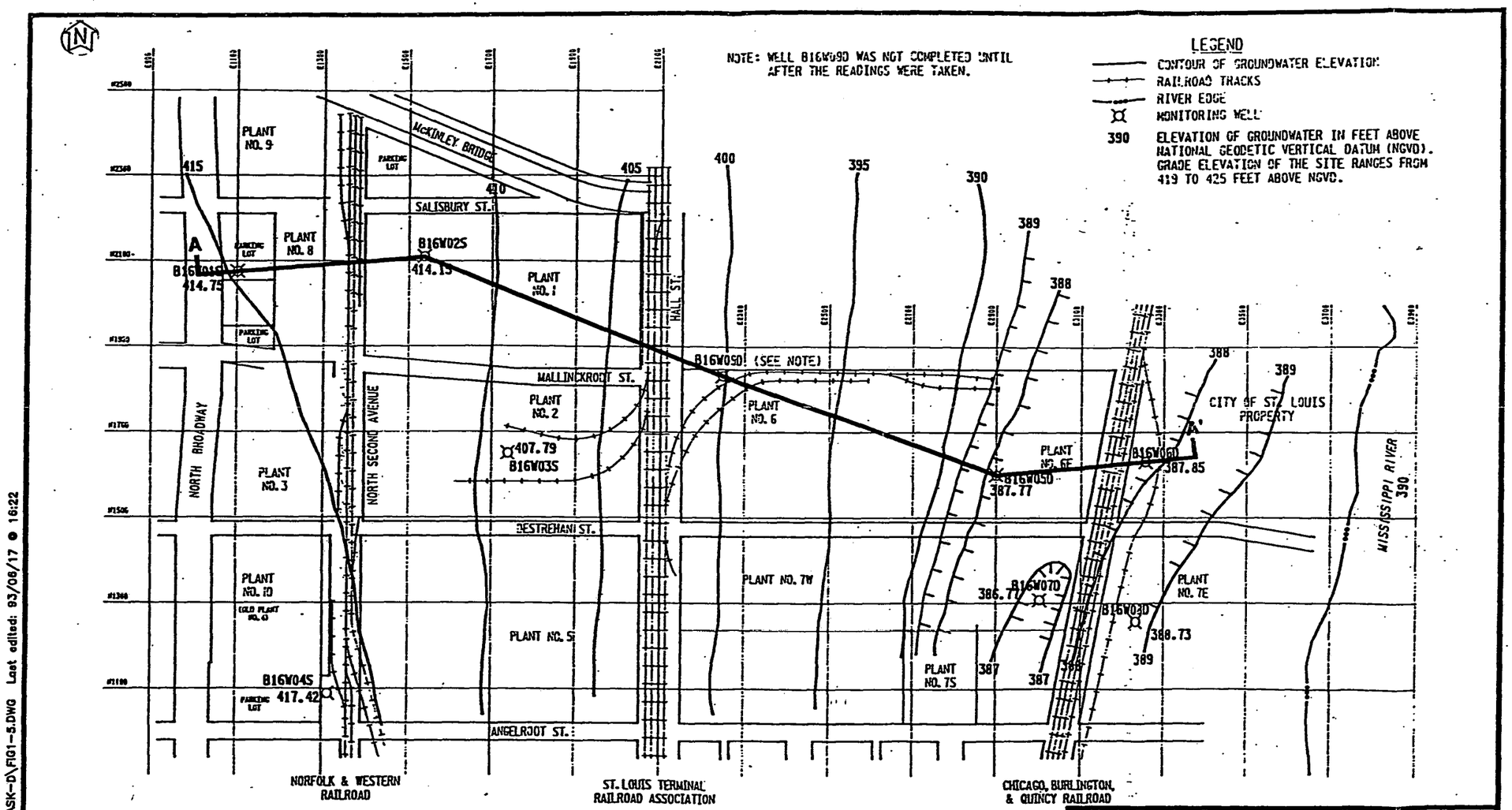


SOURCE:
Bechtel National, Inc. September 1990. Radiological, Chemical, and Hydrogeological Characterization Report for the St. Louis Downtown Site in St. Louis, MO. Formerly Utilized Sites Remedial Action Program (FUSRAP). Volumes I–III: Revision 1. DOE/OR/20722–258.

NOTE:
Cross Section Trace shown on Fig. 2–5.
Water Levels were measured on June 9, 1989.

MALLINCKRODT SPECIALTY CHEMICALS COMPANY ST. LOUIS, MISSOURI		PROJECT NO. 90C8150D
Woodward–Clyde Consultants Engineering & sciences applied to the earth & its environment		
DRN. BY: kdw 6/11/93 DSGN. BY: RET 6/21/93 CHKD. BY: [illegible]	Hydrogeologic Cross Section	FIG. NO. 2–4

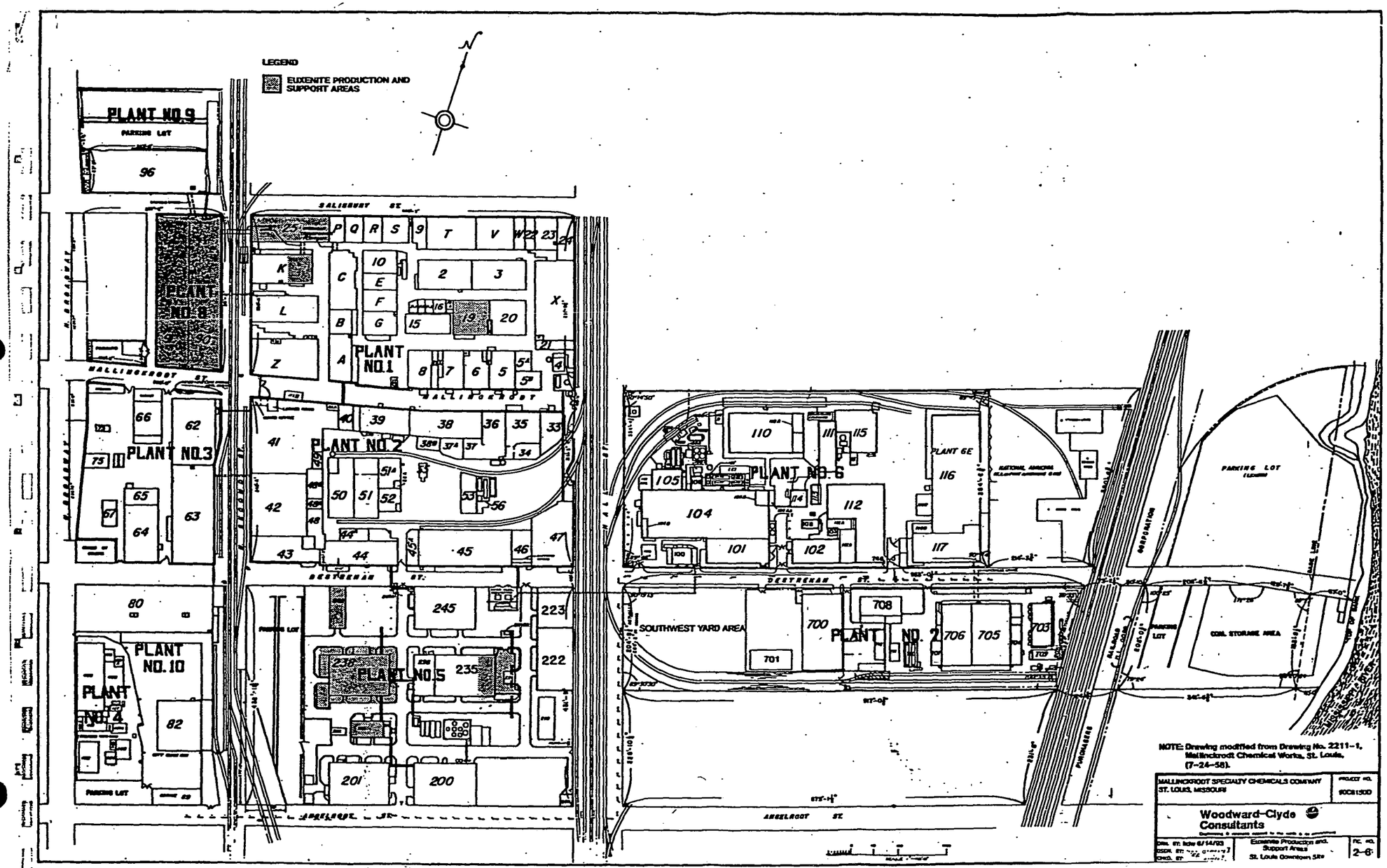
File name: G:\90C8150\TASK-D\FIG1-4.DWG Last edited: 93/06/17 @ 18:18

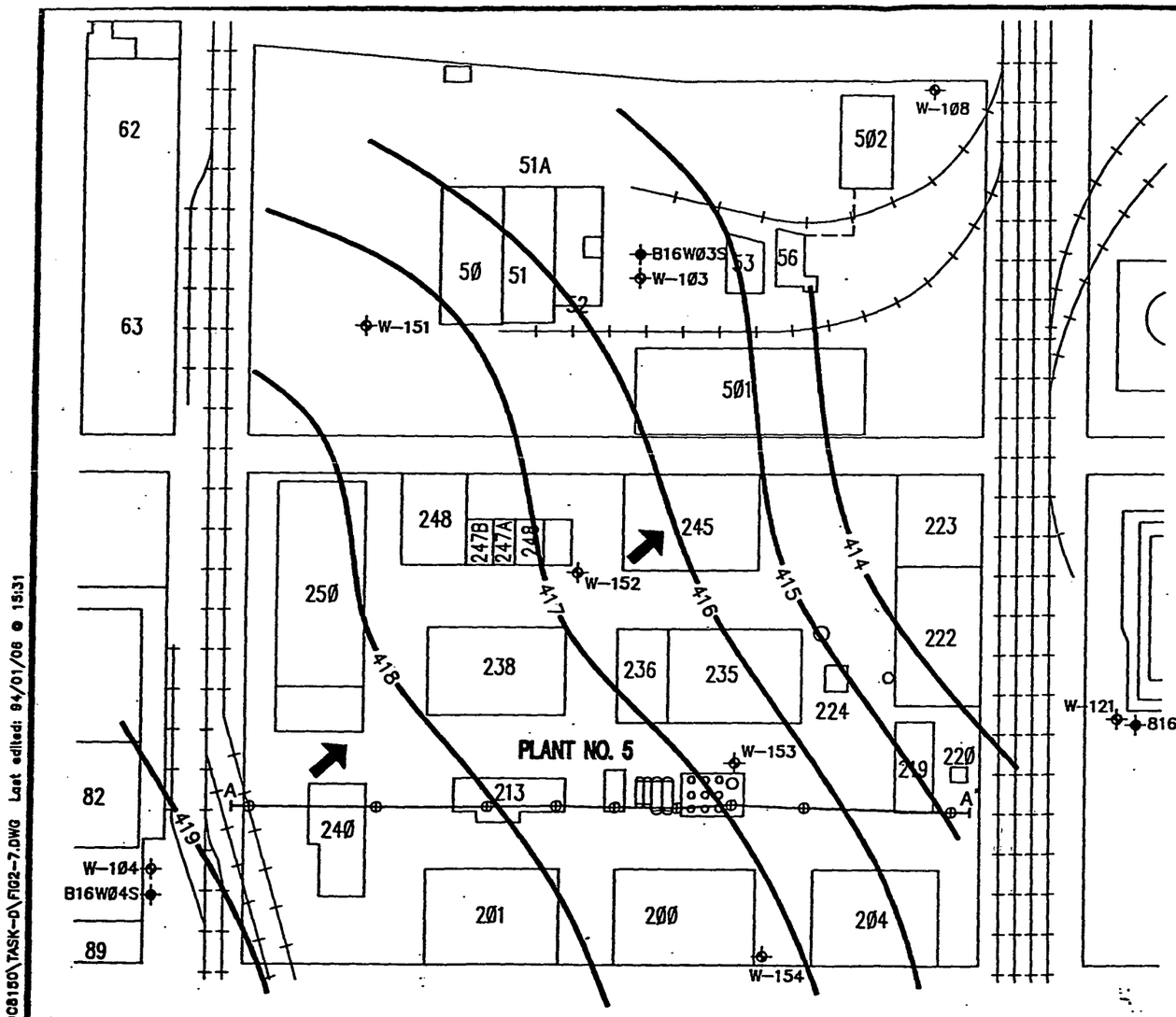


SOURCE:
Bechtel National, Inc. September 1990. Radiological, Chemical, and Hydrogeological Characterization Report for the St. Louis Downtown Site in St. Louis, MO. Formerly Utilized Sites Remedial Action Program (FUSRAP). Volumes I–III: Revision 1. DOE/OR/20722–258.

MALLINCKRODT SPECIALTY CHEMICALS COMPANY ST. LOUIS, MISSOURI		PROJECT NO. 90C8150D
Woodward-Clyde Consultants Engineering & sciences applied to the earth & its environment		
DRN. BY: kdw 6/17/93 DSGN. BY: RET 6/21/93 CHKD. BY: CPP 6/21/93	Water Level Contour Map, Alluvial Sand Unit, June 9, 1989	FIG. NO. 2-5

File name: G:\90C8150\TASK-D\FIG1-5.DWG Last edited: 93/06/17 @ 16:22

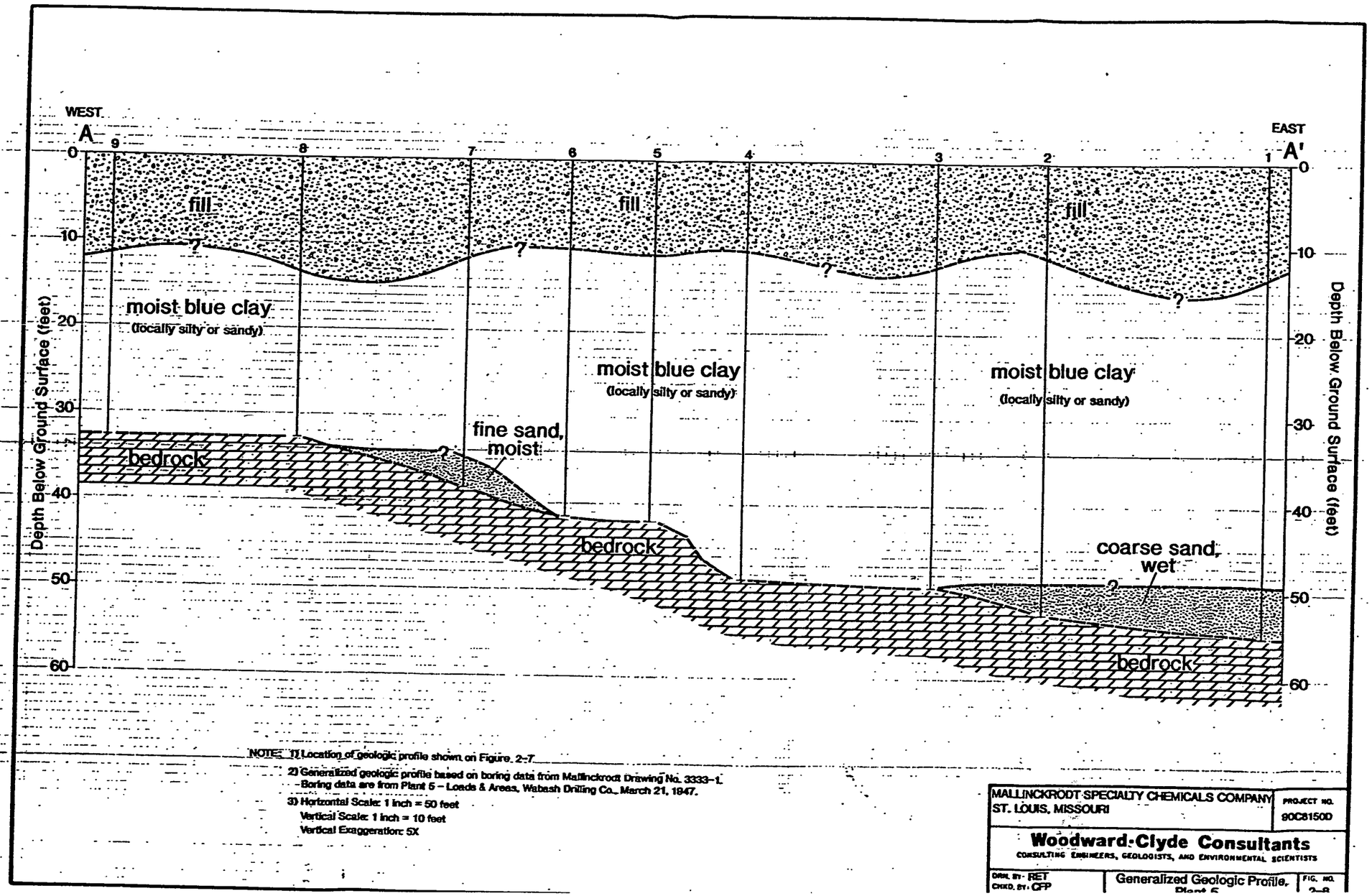

LEGEND
ELEMITE PRODUCTION AND SUPPORT AREAS
N
PLANT NO 9
PARKING LOT
96
SALISBURY ST.
PLANT NO. 9
PLANT NO.1
PLANT NO.2
PLANT NO.3
PLANT NO. 4
PLANT NO.10
PLANT NO.5
PLANT NO.6
PLANT 6E
PLANT NO. 7
SOUTHWEST YARD AREA
PARKING LOT
COIL STORAGE AREA
MALLINCKRODT ST.
DESTREHAN ST.
ANGELROOT ST.
MISSOURI PACIFIC
NOTE: Drawing modified from Drawing No. 2211-1, Mallinckrodt Chemical Works, St. Louis, (7-24-58).
MALLINCKRODT SPECIALTY CHEMICALS COMPANY
ST. LOUIS, MISSOURI
PROJECT NO. 90C8150D
Woodward-Clyde Consultants
Elemite Production and Support Areas
St. Louis Downtown Site
FIG. NO. 2-6



MAP REFERENCE:
Bechtel National, Inc. September 1990. Radiological, Chemical, and Hydrogeological Characterization Report for the St. Louis Downtown Site in St. Louis, MO. Formerly Utilized Sites Remedial Action Program (FUSRAP). Volumes I-III: Revision 1. DOE/OR/20722-258.

MALLINCKRODT SPECIALTY CHEMICALS COMPANY ST. LOUIS, MISSOURI	PROJECT NO: 90C8150D
Woodward-Clyde Consultants — Engineering & sciences applied to the earth & its environment	
DRN. BY: kdw 1/6/94 DSGN. BY: RET 1/6/94 CHKD. BY: CFP 1/6/94	Monitoring Well Locations and Flow Direction of Perched Groundwater, Plant 5 — FIG. NO. 2-7

File name: G:\90C8150\TASK-D\FIG2-7.DWG Last edited: 04/01/08 @ 15:31



NOTE: 1) Location of geologic profile shown on Figure 2-7.

2) Generalized geologic profile based on boring data from Mallinckrodt Drawing No. 3333-L.
- Boring data are from Plant 5 – Loads & Areas, Wabash Drilling Co., March 21, 1947.

3) Horizontal Scale: 1 inch = 50 feet
Vertical Scale: 1 inch = 10 feet
Vertical Exaggeration: 5X

MALLINCKRODT SPECIALTY CHEMICALS COMPANY
ST. LOUIS, MISSOURI

PROJECT NO. 90C8150D

Woodward-Clyde Consultants
CONSULTING ENGINEERS, GEOLOGISTS, AND ENVIRONMENTAL SCIENTISTS

DRN. BY: RET
CHKD. BY: CFP

Generalized Geologic Profile, Plant 5

FIG. NO. 2-8

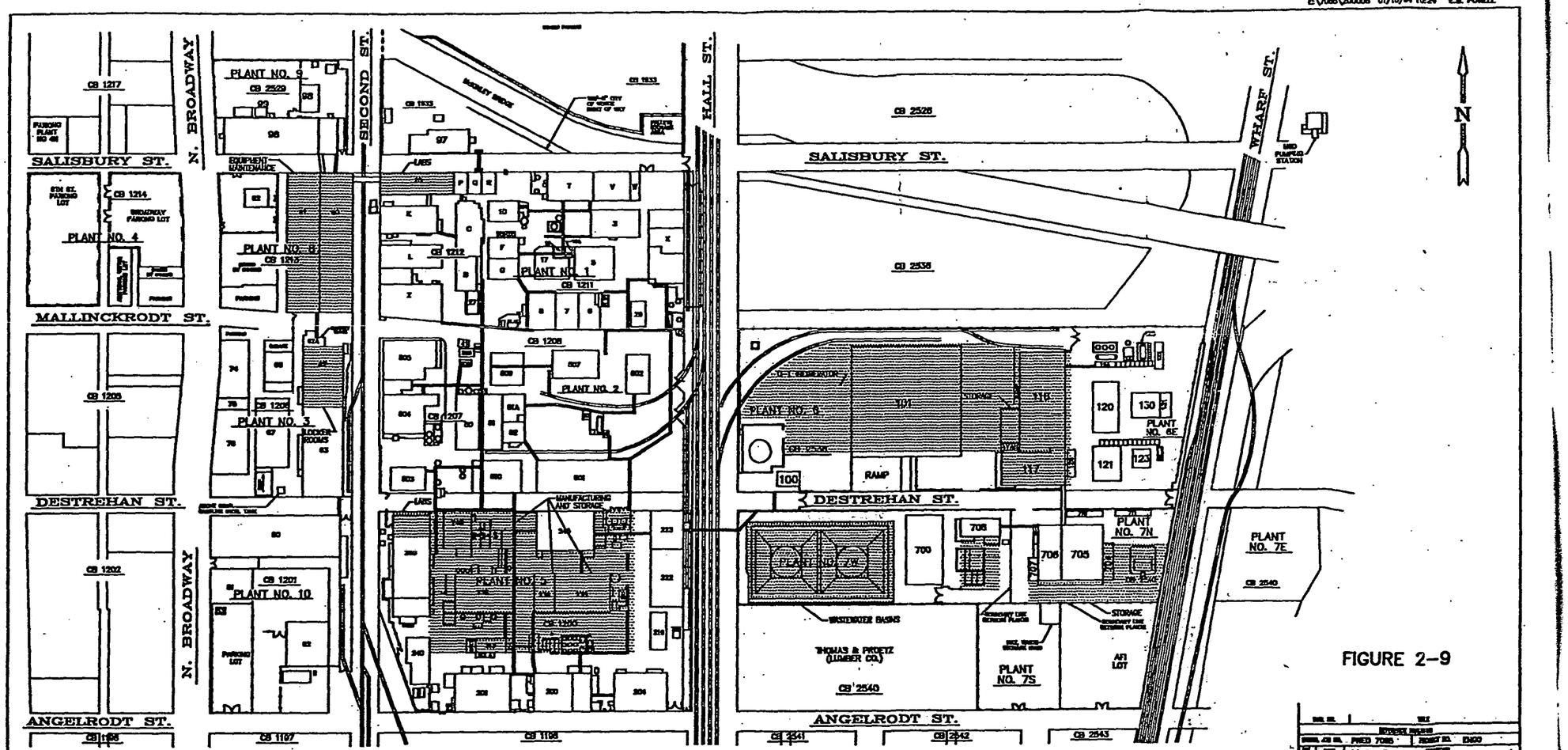


FIGURE 2-9

LEGEND

C-T PRODUCTION AND SUPPORT AREAS

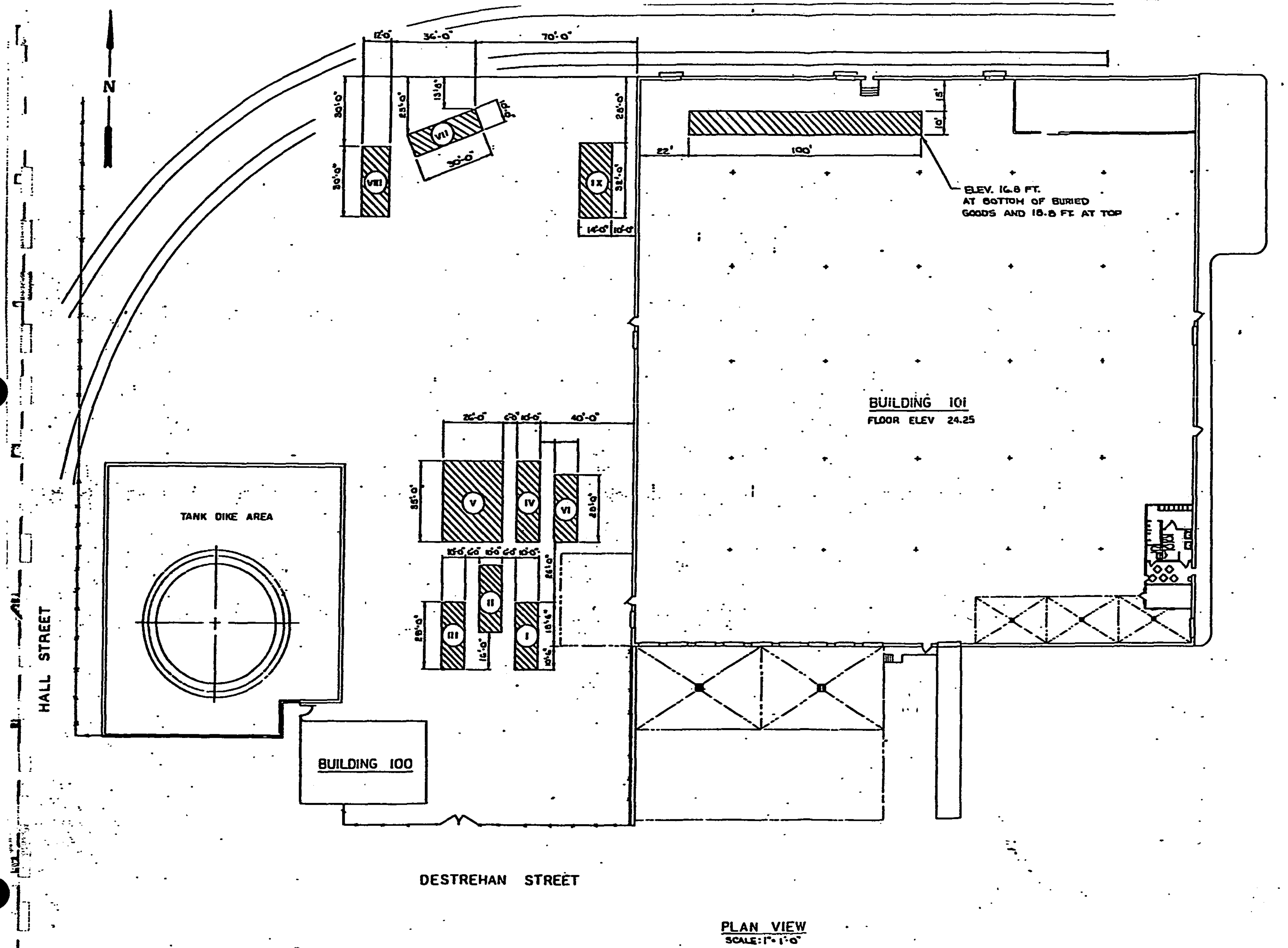
SCALE:

0 100' 200' 300'

MALLINCKRODT, INC.

SITE REMEDIATION
C-T PRODUCTION
PROCESS AND SUPPORT AREAS

7085-200-008



BURIAL LEGEND URO

7-3-73 Thru 7-17-73

Burial Site #	Bottom Elev.(MSV)	Top Elev.(MSV)	Volume Cu.FT.
I	18.00	20.00	580
II	17.50	19.00	435
III	17.50	19.00	580
IV	17.50	19.50	700
V	17.50	18.50	910
VI	18.00	20.00	580
VII	16.25	18.25	600
VIII	16.25	18.25	720
IX	17.00	19.00	896

REFERENCE DRAWINGS

SK# 11,819 - URO BURIAL DETAILS

SK# 11,706 - URO BURIAL SITE

DWG. 4332-201-1 - PLANT No. 7 SOUTH PIT LOCATIONS.

DWG. 4332-202-1 URO BURIAL LAYOUT

FIGURE 2-10

MALLINCKRODT, INC.
ST. LOUIS, MO.

URO BURIAL LAYOUT

St. Louis - G
1" = 20'-0"
01/03/94
EWP
A.H.

7085-200-003 0

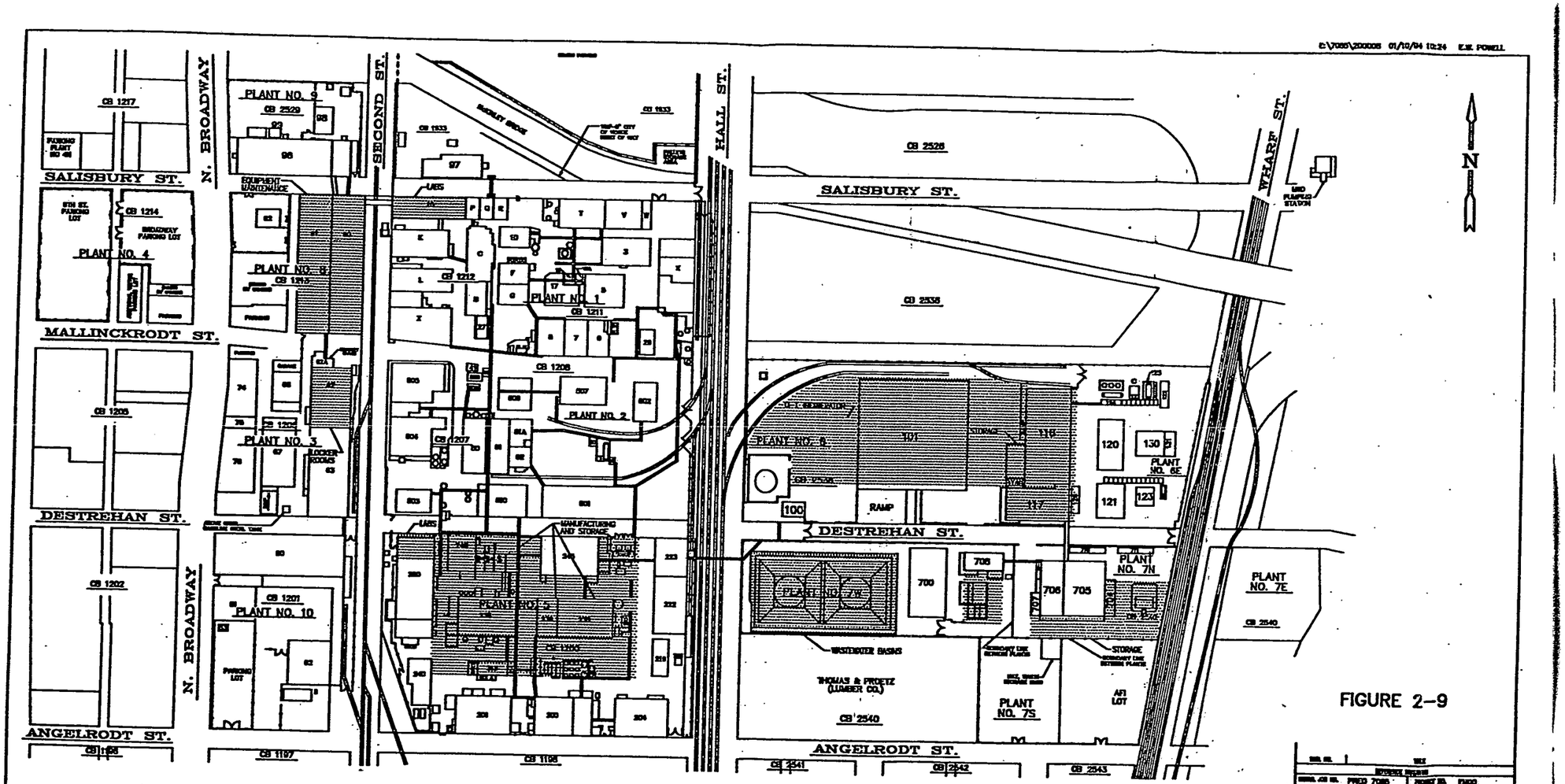

E:\7085\200008 01/10/94 10:24 E.M. POWELL
SALISBURY ST.
N. BROADWAY
SECOND ST.
HALL ST.
MALLINCKRODT ST.
DESTREHAN ST.
ANGELRODT ST.
WHARF ST.
PLANT NO. 1
PLANT NO. 2
PLANT NO. 3
PLANT NO. 4
PLANT NO. 5
PLANT NO. 6
PLANT NO. 7E
PLANT NO. 7N
PLANT NO. 7S
PLANT NO. 8
PLANT NO. 9
PLANT NO. 10
CB 1277
CB 1214
CB 1205
CB 1202
CB 1201
CB 1212
CB 1211
CB 1206
CB 1207
CB 1933
CB 2529
CB 2526
CB 2536
CB 2540
CB 1166
CB 1197
CB 1198
CB 2541
CB 2542
CB 2543
RAMP
STORAGE
WASTEWATER BASINS
THOMAS & PROETZ (LUMBER CO.)
ART LOT
LEGEND
C-T PRODUCTION AND SUPPORT AREAS
SCALE:
0 100' 200' 300'
N
MALLINCKRODT, INC.
SITE REMEDIATION
C-T PRODUCTION
PROCESS AND SUPPORT AREAS
7085-200-008

FIGURE 2-9