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RADIOLOGICAL ASSESSMENT
AND
STABILIZATION SCENARIOS
PARKERSBURG, W. VA.

September 1980

SUMMARY

During July 1978, Chem-Nuclear Systems, Inc. (CNSI) began an assessment program for AMAX Specialty Metals Corp. (AMAX) to locate, quantify, and evaluate the extent of environmental radioactive contamination at the AMAX Parkersburg, West Virginia former zirconium/hafnium processing facility. In addition, preliminary assessments were to be made to assist AMAX in evaluating alternative methods for site cleanup.

The facility and environs encompass an area of approximately 126 acres located in Wood County, West Virginia near the city of Parkersburg. Processing at the facility was conducted under authority and contract of the Atomic Energy Commission (AEC) from about 1961 to 1968 for the purpose of producing high-grade zirconium metal used in the assembly of nuclear reactors for the U. S. Navy. Additional operations were conducted at the facility under contract and license to the Nuclear Regulatory Commission during 1974 and 1975.

CNSI's Division of Decommissioning conducted an in depth monitoring, sampling, and analysis program on site to ascertain the extent of environmental radioactive contamination, and evaluated several scenarios to facilitate the cleanup and stabilization of the material. During this program specialized water-jet boring techniques were developed and utilized to preclude combustion/explosion of suspected pyrophoric material beneath the ground's surface.

CNSI's program produced a three-dimensional picture of radioactive contamination at the site with contamination gradients in soil depth, area, and activity. In addition, several preliminary cleanup/stabilization scenarios were identified and assessed for more detailed evaluation.

CONTENTS

ABBREVIATIONS

AEC - Atomic Energy Commission

AMAX - AMAX Specialty Metals Corporation

ANSI - American National Standards Institute

CNSI - Chem-Nuclear Systems, Inc.

CFR - Code of Federal Regulations

DOE - Department of Energy

DOT - Department of Transportation

EPA - Environmental Protection Agency

ICRP - International Commission on Radiological Protection

NCRP - National Committee on Radiation Protection (and Measurements)

NOAA - National Oceanic and Atmospheric Administration

NRC - Nuclear Regulatory Commission

1.0 INTRODUCTION

1.1 General

Chem-Nuclear Systems, Inc. (CNSI) contracted with AMAX Specialty Metals Corporation (AMAX) to perform a radiological assessment of property located near Parkersburg, West Virginia. During July 1978, CNSI began a program to locate, quantify, and evaluate the extent, if any, of the radioactive material found on, or associated with, the property. After the completion of the studies, CNSI evaluated and proposed several possible alternative methods for cleanup and stabilization of the property.

Chapter 1 of this report presents a brief description of CNSI's experience in the radiological field, the licenses the company possesses, the scope/objectives of this study, and the description/history of the property. A complete discussion of the radiological characteristics of the property, instrumentation and methodology used are provided in Chapter 2. Radiation protection standards and an evaluation of direct gamma exposure rates, alpha smears, and soil contamination are included in Chapter 3. The alternative methods are described and evaluated as scenarios in Chapter 4. The conclusion containing the identification of those alternative methods (scenarios) warranting further evaluation is found in Chapter 5. The directory, list of references, and appendices describing disposal costs and property grids are supplied at the end of this document.

1.2 CNSI Experience

CNSI has had over ten years of evaluating, developing, and operating radioactive and chemical waste disposal facilities in the United States. The company presently operates a hazardous chemical disposal site in Arlington, Oregon and a commercial radioactive waste disposal site in Barnwell, South Carolina.

CNSI has and is participating in decontamination programs at facilities throughout the country.

1.3 CNSI Licenses

CNSI has been granted a license (#46-13536-01) by the United States Nuclear Regulatory Commission (NRC), a license (#097) by the state of South Carolina, a license (#J-051-1) by the state of Washington, and a license (#HW-1) by the state of Oregon to operate the hazardous waste disposal sites located in the states to which the licenses apply and to carry out the required support services. Also, CNSI's ATCOR division retains the only broad-based decontamination license issued by the NRC which allows CNSI to perform decontamination projects under already approved ATCOR safety procedures.

1.4 Objectives and Scope

The main objectives of this report are to describe the radiological characteristics of the property, to evaluate the results in terms of health physics aspects, and to assist AMAX in the evaluation and selection of alternative methods for site cleanup and stabilization.

The scope shall be limited to five alternative methods. To focus on a set of alternatives suitable to handle the disposal of suspected radioactive material on the property, the NRC, AMAX, and CNSI chose five alternative methods to be described and evaluated. These methods are hypothetical and may not be practical alternatives because of legal and/or economic restrictions. For the sake of accuracy, the term "scenario" has been used throughout the report in lieu of "alternative methods."

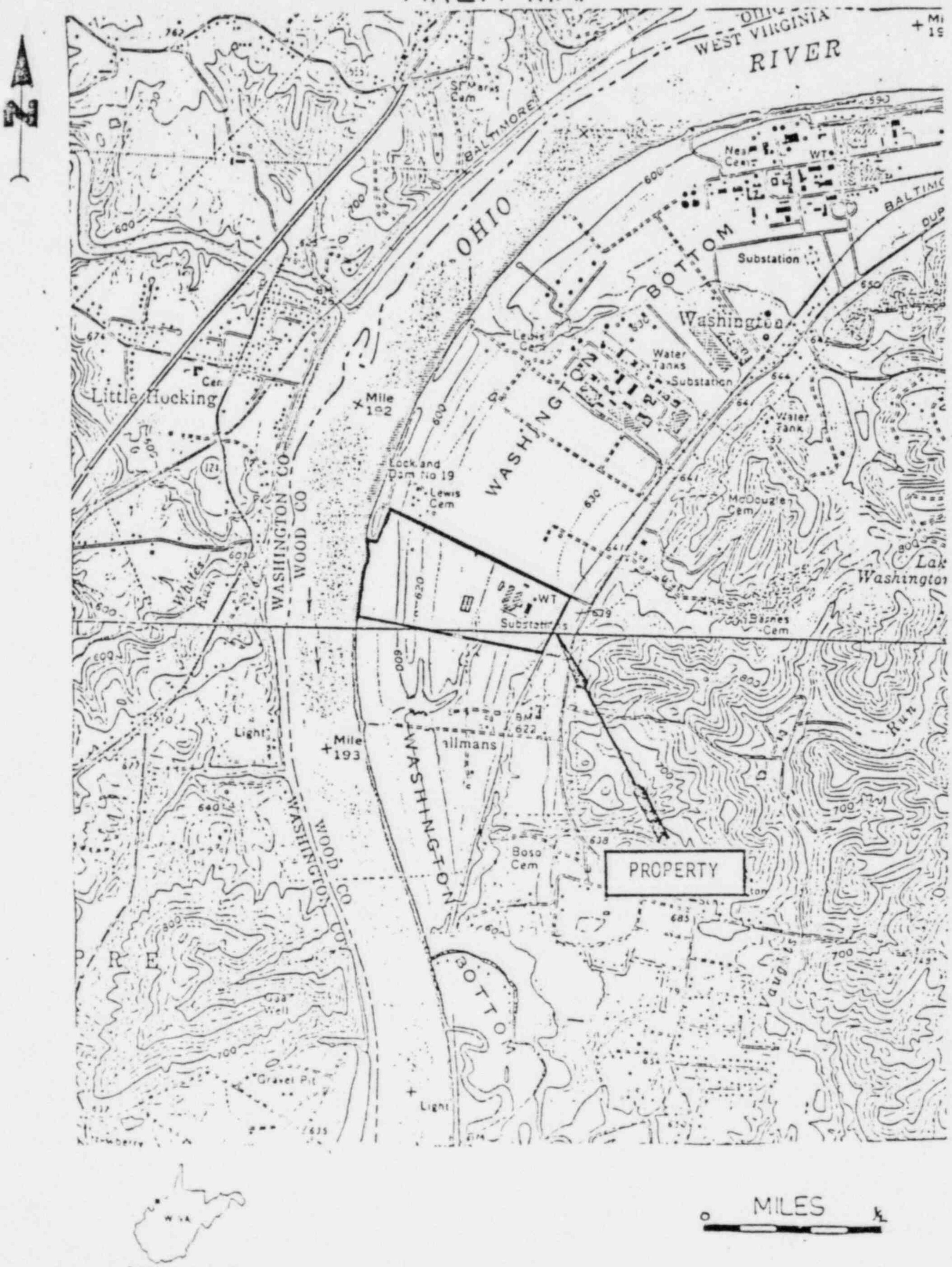
1.5 Description of Property

The property comprises approximately 126 acres located in the Washington Bottom of Wood County, West Virginia. The site is situated west of the Ohio River in an industrial area surrounded by former farmlands. The Ohio River generally forms the site's western boundary; and Dupont Road, the primary access road from the site to Parkersburg, demarcates the northern boundary. (Figure 1 and Figure 2)

The site's facilities on the property consist of an office building, new plant buildings, roadways, old building foundation slabs and floors, storage areas, water and gas mains, a water storage tank and well field, a storm drainage system, and a railroad spur leading to the new plant. (Figure 3)

FIGURE 2

AREA MAP



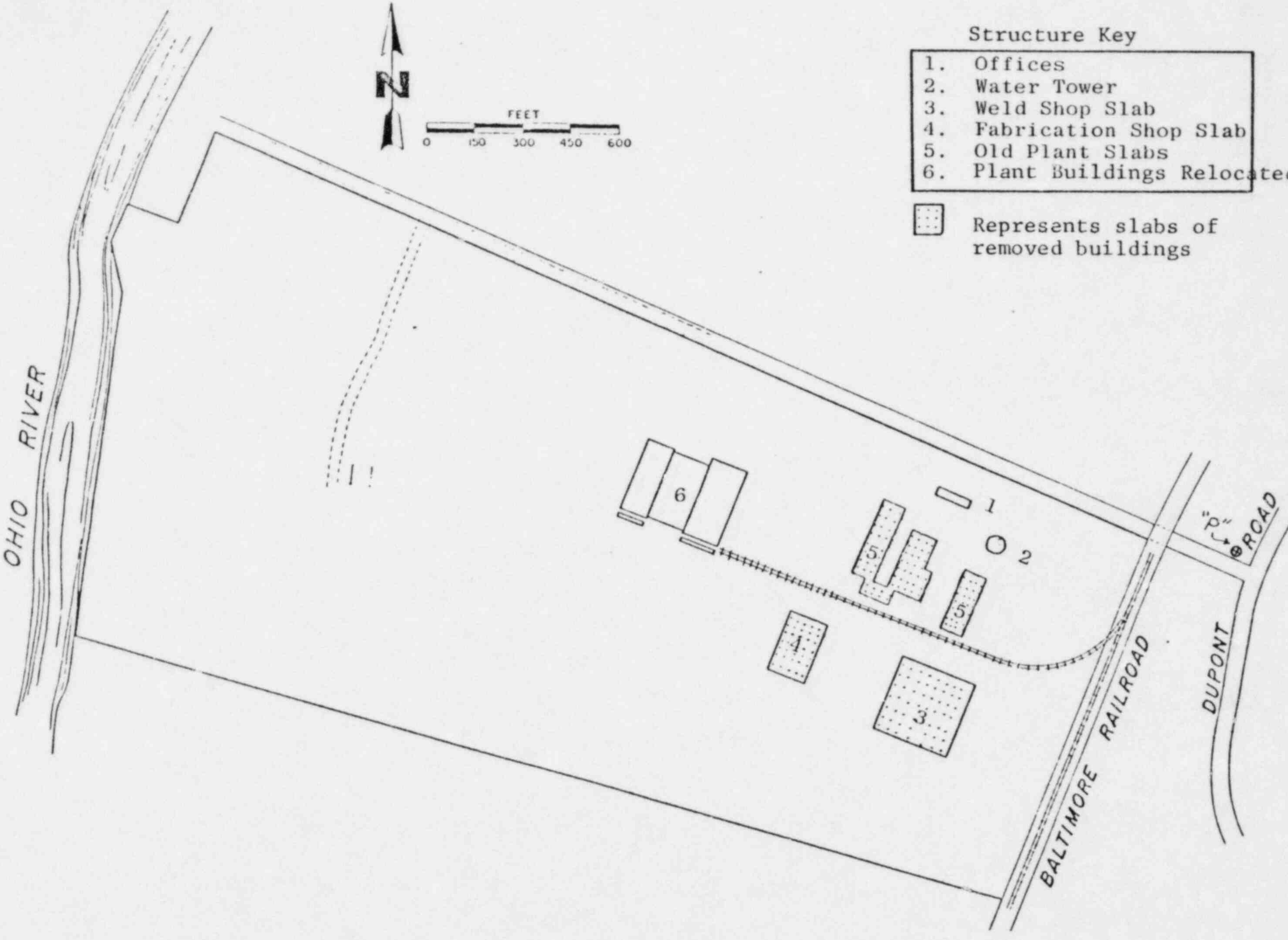


FIGURE 3

PROPERTY

The general topography of the area is primarily shaped by a series of river bank terraces. The physical facilities are located on the highest bench of these terraces. The resulting drainage patterns are generally toward the river to the west, with some drainage to a ditch along the railroad to the east. An incised gully drains some surface runoff to the southwest.

1.2 History of Property

According to AMAX Inc., the Parkersburg site was developed by The Carborundum Company in 1957 for the production of high-grade zirconium metal for use in the construction of nuclear reactors for the U. S. Navy under an AEC contract. The Atomic Energy Commission (AEC) and Bureau of Mines Process was used. This process started with the conversion of zircon ore to zirconium carbonitride followed by the chlorination of the carbide to zirconium tetrachloride (98% zirconium and 2% hafnium metal). The metal complex was then separated into the zirconium and hafnium fractions and the metal was recovered by the Kroll Process. Magnesium metal was reacted with the zirconium tetrachloride under pressure in the Kroll Process. A solid reject from the reaction can be pyrophoric and is commonly called "sidewall material."

During 1961 and 1962, the Carborundum Company processed Nigerian zirconium ore under an AEC license. In addition to zirconium this ore contained 6% hafnium, up to 6% ThO_2 and 0.2% UO_2. The processing of the Nigerian concentrate was under the surveillance of the AEC, and both the ore and all residuals were stored in drums on the site. The use of Nigerian ore stopped in 1962 and zircon was again processed by the original system until 1970.

AMAX and Carborundum operated the Parkersburg facility as a joint venture, Carborundum Metals Climax, from 1965 to 1967. AMAX then became the owner of the business. The Nigerian ore and radioactive residual were stored on the site until September, 1968. During the seven years of storage, many drums had deteriorated and it was necessary to dispose of soil located beneath the stored drums to reduce the residual radiation to approved levels. Nearly 3000 drums of ore, residual material, and soil were transported from the property to an approved AEC burial site at Morehead, Kentucky.

The processing of zirconium ore stopped in late 1969, when purchased zirconium tetrachloride was substituted. AMAX produced zirconium and hafnium metal sponge until November, 1974, when production was terminated.

In November, 1974, AMAX received a license from the NRC to conduct laboratory scale experiments on Baddeleyite ore (ZrO_2)

which contained less than 0.5% total thorium and uranium. After the laboratory tests were conducted in late 1975, all remaining Baddeleyite ore was sold and its process residuals were transported to an approved NRC burial site.

In March, 1977, the Parkersburg property and buildings were sold to L. B. Foster Company. Based on a site inspection by the NRC concerning the closeout of AMAX's Baddeleyite license, 70 drums of earth identified by the NRC as above background, were transported in late 1977 to an approved NRC disposal site.

As a result of problems with pyrophoric and radioactive material found on the property in 1978, AMAX repurchased the property from L. B. Foster Company and undertook a program to clear the site. As a first step, Chem-Nuclear Systems, Inc. completed a radiological assessment of the site in December, 1978.

During 1979, AMAX leased that portion of the property west of the old metallurgical plant, which was found to be free of radioactivity, to the L. B. Foster Company; and their pipe manufacturing buildings were relocated as shown in Figure 3 and the accompanying aerial photographic view to the north, Figure 1. The manufacture of pipe was begun again in late 1979 by L. B. Foster Company.

Plans for managing the radioactive material and providing for its disposition are under investigation.

2.0 RADIOLOGICAL CHARACTERISTICS OF THE SITE

In order to assess relative radiological hazards to individuals who may work or be present on the site, an in depth radiological survey was performed by Chem-Nuclear Systems, Inc. during the months of July through October, 1978. The results of this survey yielded the following data:

1. Identification of surface areas of radioactive contamination at the site;
2. Quantification of radiation levels present at the site;
3. Identification of radioactive contamination as a function of soil depth present at the site;
4. Identification of radionuclides present at detectable levels on or near the site in soil and water for selected samples.

2.1 Radiological Assessment Instrumentation

2.1.1 Gamma Radiation Assessments

Low level gamma radiation measurements (0-500 μR/hr) were performed using a Reuter Stokes Environmental Radiation Monitor, Model RSS-111. This instrument is a pressurized ion chamber capable of making accurate measurements of gamma radiation encountered in the natural environment.

Gamma radiation measurements taken in drill holes (soil radiation profiles), or above the useful range of the RSS-111, were made using a sodium iodide (NaI) scintillation detector. This instrument was a Ludlum Model 3 equipped with a 44-2 probe (1 inch by 1 inch NaI).

2.1.2 Alpha Radiation Assessments

Alpha radiation measurements were made using an Eberline Portable Scaler Model PS-2 equipped with a Model RD-13A detector (scintillation detector) and an Eberline LIN-LOG alpha survey meter model PAC-4S with the AC-3-7 probe (scintillation detector).

2.1.3 Beta-Gamma Radiation Measurements

General field survey instruments used for Beta-Gamma radiation measurements were the Eberline E-120 meter equipped with either the HP-177 or HP-210 probes.

2.2 Radiological Assessment Methodology

2.2.1 Instrument Calibration and Source Checks

All project instruments were calibrated by Eberline Instrument Corporation or Rutgers University prior to the start of the assessment survey with the exception of the RSS-111. This instrument was factory calibrated in July of 1978 (prior to survey). All instruments were source checked daily using the appropriate radioactive check sources for the particular instrument.

2.2.2 Background Radiation Measurement and Verification

In order to assure accurate gamma radiation measurements, and to establish general area natural radiation levels, background gamma radiation measurements were made daily at a selected background position at the site periphery. These measurements included 2 readings with the NaI scintillation crystal, one at 6 inches above soil surface and one at a soil depth of 2 feet. In addition, a reading was made with the RSS-111 pressurized ion chamber approximately one meter above soil surface. All measurements made with the NaI scintillation crystal were above or into a drill hole bored with the same water jetting technique used for site survey. (Figure 3, pt. "P")

Natural radiation background as measured with the pressurized ion chamber ranged from 12.0 μR/hr to 12.4 μR/hr (measured at the selected background position at the site periphery).

2.2.3 Soil Analysis

Twenty three soil samples were taken and forwarded to Teledyne Isotopes for analysis. (Table 1) These samples were intended to establish relative quantities of contaminants present and establish data trends between gamma exposure rates made in the field and the soil thorium and uranium content. The majority of the isotopes were identified utilizing Ge(Li) gamma spectrometry. The uranium and thorium analysis was determined by chemical digestion, chemical separation, electrodeposition, and finally alpha spectral analysis.

Comparison of these data shows reasonable correlation between field measurements and soil analysis as follows:

(1) Soil analysis at the selected background position at the site periphery indicates background quantities of thorium, uranium, and the associated decay progeny. The NaI scintillation detector displayed a relatively low count rate in comparison to on-site readings. The pressurized ion chamber indicated background exposure rates (12μR/hr or 105 mR/yr) found at point P as shown in Figure 3.

(2) Soil analysis at grid positions (Appendix I) with high gamma exposure rates indicates elevated levels of thorium, uranium, and the associated decay progeny. There were no significant levels of fission products from nuclear weapons testing found in any of the soil samples. One of the fission products, cesium, was present in a few samples, but the levels were such that no interference on the gamma readings was assumed.

Analysis of (1) and (2) above indicate that in general the field sampling techniques utilized were sensitive to radiological

TABLE 1

SUMMARY OF TELEDYNE SOIL SAMPLES

(NOVEMBER 15, 1979)

	Nuclides, pCi/g dry	
Location of Samples	Ac-228*	U-238
Point P	1.35 ± 0.18	0.5 ± 0.1
Grid #2: Surface	13.60 ± 1.40	0.9 ± 0.2
Grid #2: 2 Ft. Depth	408.00 ± 41.00	40.0 ± 4.0
Grid #8: Surface	13.20 ± 1.30	1.2 ± 0.2
Grid #8: 2 Ft. Depth	8.36 ± 0.84	0.9 ± 0.2
Grid #12: 2 Surface	1270.00 ± 130.00	42.0 ± 6.0
Grid #12: 2 Ft. Depth	5.66 ± 0.57	0.8 ± 0.2
Grid #11: Surface	337.00 ± 34.00	
Grid #20: Surface	712.00 ± 71.00	
DRN SMPL NR PMP Surface	378.00 ± 38.00	
Grid #1063: Surface	1810.00 ± 180.00	
Grid #1030: Surface	339.00 ± 34.00	
Grid #65: Surface	-- --	
Grid #13: Surface	192.00 ± 19.00	
Grid #38: Surface	39.40 ± 3.90	
Grid #113: Surface	332.00 ± 33.00	
Grid #681: Surface	372.00 ± 37.00	
Grid #892: Surface	229.00 ± 23.00	
25 Ft. EXT DRN MN GHLA	45.60 ± 4.60	
Grid #80RR: Surface	306.00 ± 31.00	
Grid #80: 2 Ft. Depth	1.14 ± 0.18	
Grid #224RR: Surface	256.00 ± 26.00	
Grid #224RR: 2 Ft. Depth	30.30 ± 3.00	

* The activity of ^{228}Ac is equivalent to the activity of ^{232}Th.

contaminants present from facility operations. These measurements do not appear to be biased by other naturally occurring radionuclides or fission products from weapons testing or other sources. The significance of the levels of uranium and thorium in the soil samples will be discussed in section 3.4.

2.2.4 Surface Radiation Measurement

In general, surface radiation measurement for outdoor mapping was performed with the pressurized ion chamber and NaI detector. Measurements were made as follows:

(1) The manufacturing site and storage areas were marked off into areas approximately 25 feet by 25 feet. Appendix I

(2) Corners of each grid (Appendix I) were identified with wooden stakes or other field expedient means.

(3) A gamma scan of each 25' x 25' area was made with the NaI scintillation detector.

(4) At the highest gamma flux detected with the NaI scintillation detector, the exposure rate was measured with the pressurized ion chamber.

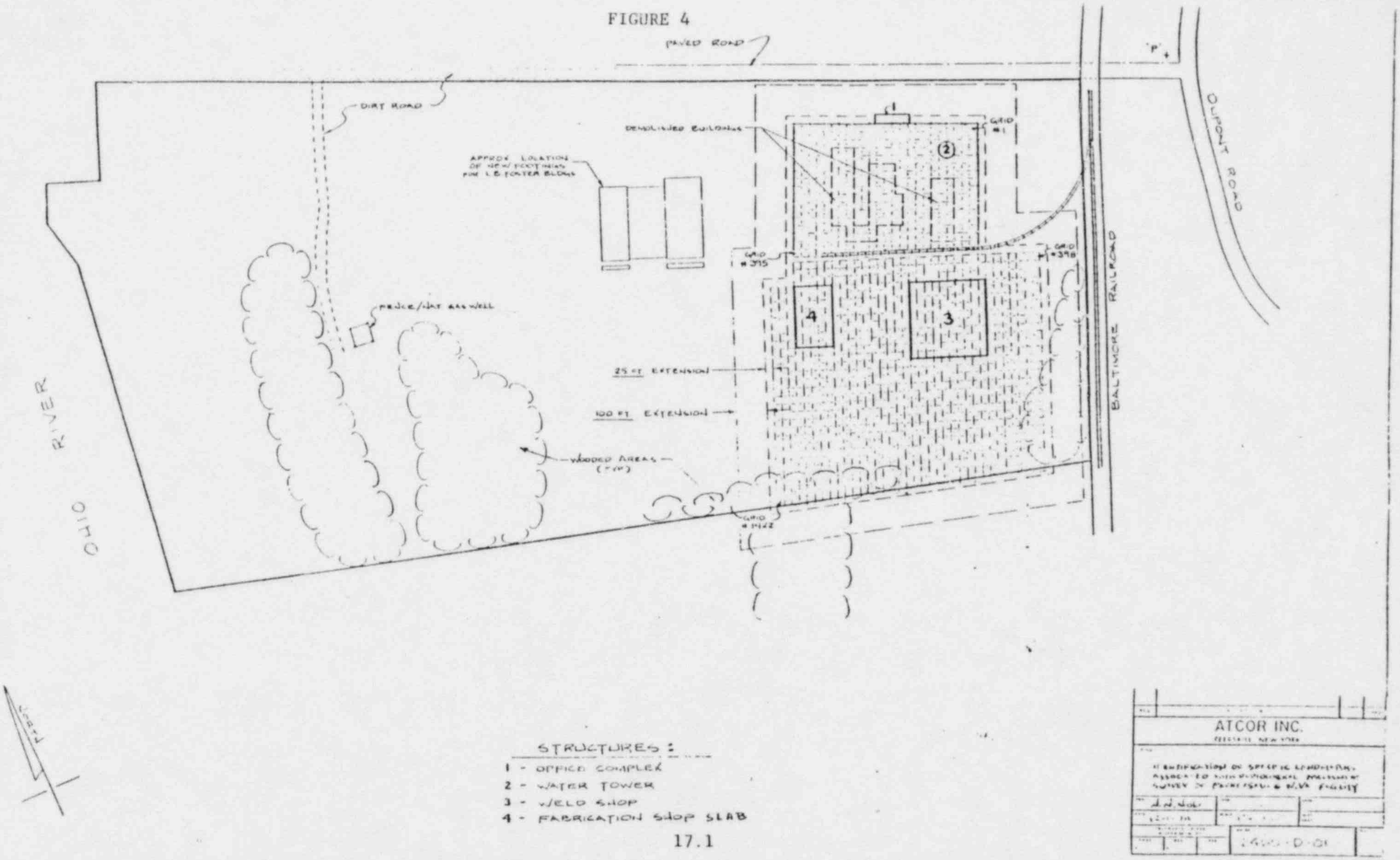
(5) At the few positions where exposure rates exceeded the capabilities of the ion chamber (500 μR/hr), readings were taken with the NaI detector. The detector was field calibrated by taking measurements in an adjoining grid, determining the ratio between the measurements, and applying the ratio to the NaI count rate.

Figure 5 depicts the areas greater than two times, five times, and ten times above background measured at point P of Figure 3.

2.2.5 Sub-Surface Radiation Measurements

In order to determine the depth of radioactive material, holes twelve feet deep were water jetted into the ground. Water jetting was utilized due to the possibly pyrophoric nature of the material. The holes were sunk in rows separated by about eight feet and at about nine feet intervals along the row. A gamma scan was performed with the NaI detector at two feet intervals in each hole. The unit of measurement was count rate and was compared to the count rate of the background hole at point P. The depths at which greater than twice background was detected is graphically shown in Figure 6.

FIGURE 4



STRUCTURES:

1 - OFFICE COMPLEX
2 - WATER TOWER
3 - WELD SHOP
4 - FABRICATION SHOP SLAB

17.1

FIGURE 5

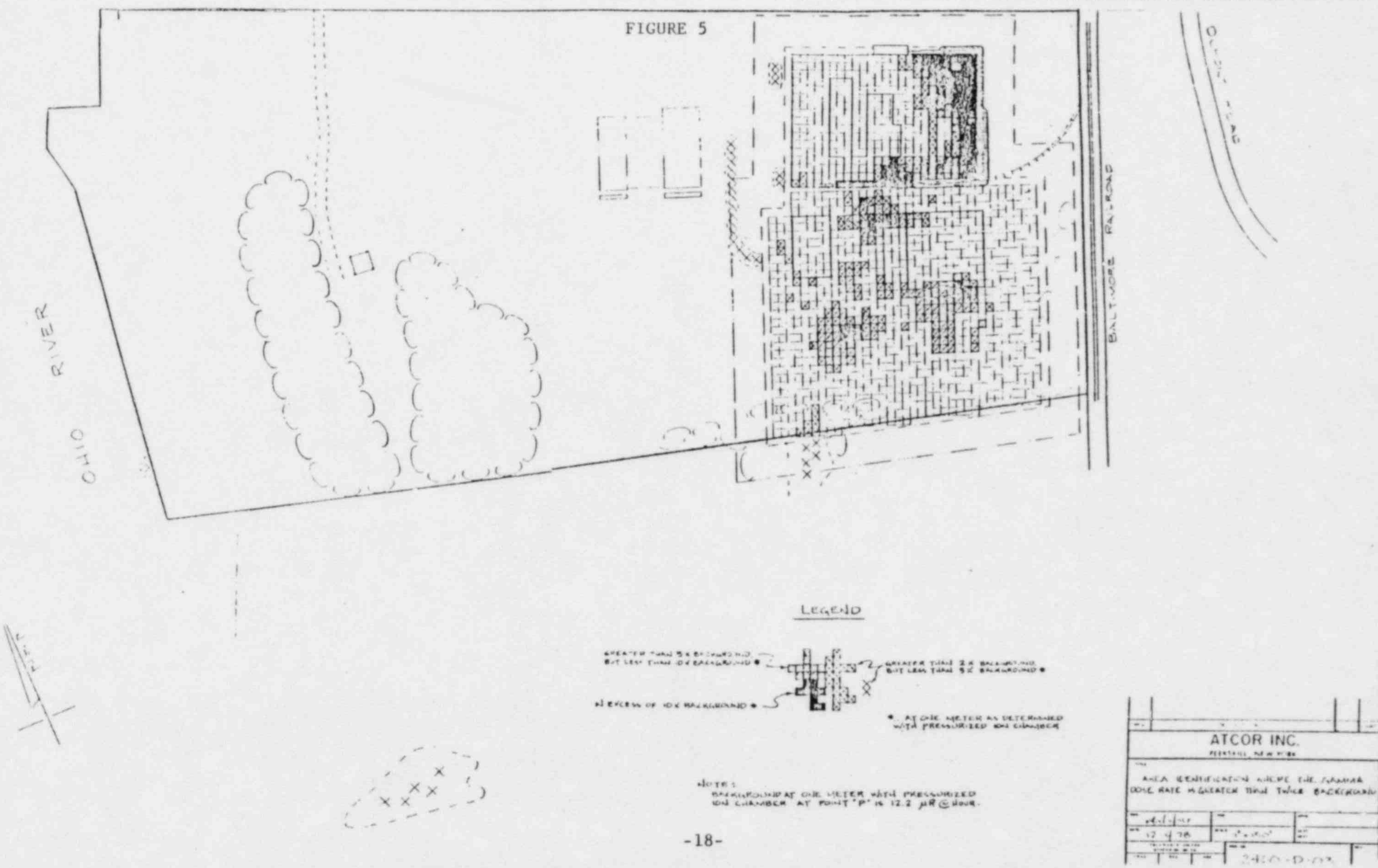
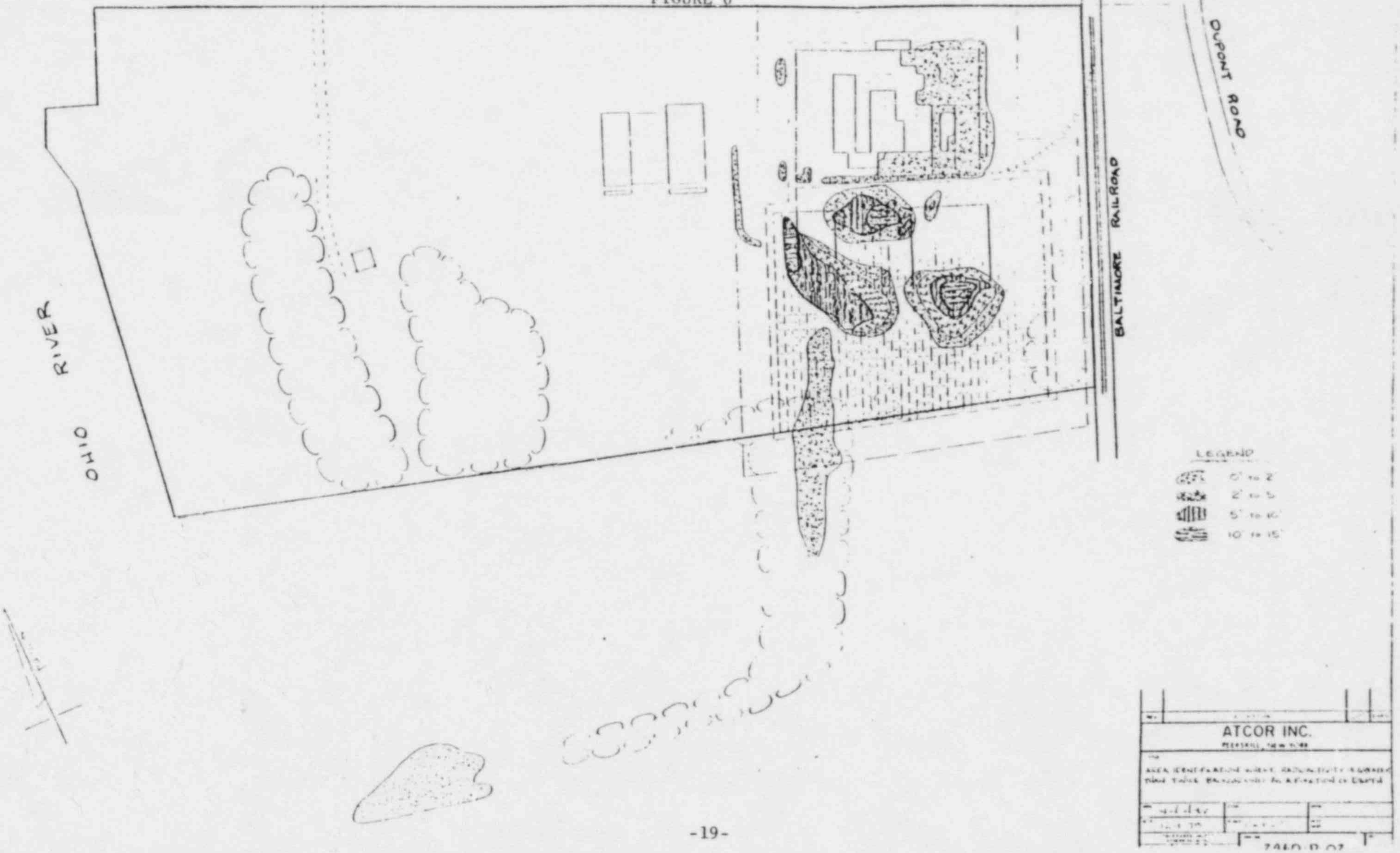

OHIO RIVER
BALTIMORE RAILROAD
LEGEND
GREATER THAN 5 X BACKGROUND BUT LESS THAN 10 X BACKGROUND *
IN EXCESS OF 10 X BACKGROUND *
GREATER THAN 2 X BACKGROUND BUT LESS THAN 5 X BACKGROUND *
* AT ONE METER AS DETERMINED WITH PRESSURIZED ION CHAMBER
NOTE:
BACKGROUND AT ONE METER WITH PRESSURIZED ION CHAMBER AT POINT "P" IS 12.2 μR @ HOUR.
ATCOR INC.
AREA IDENTIFICATION WHERE THE GAMMA DOSE RATE IS GREATER THAN TWICE BACKGROUND
12 4 78

FIGURE 6


DUPONT ROAD
BALTIMORE RAILROAD
OHIO RIVER
LEGEND
0' to 2'
2' to 5'
5' to 10'
10' to 15'
ATCOR INC.

3.0 HEALTH PHYSICS ASSESSMENT

3.1 Radiation Protection Standards

The following is a review of existing radiological standards, guidelines, and regulations which will be used in evaluating the potential hazards associated with the radioactive material detected on the site. The following terms are defined:

Standard - A method, technique or numerical value established by a recognized authority based on the best scientific opinion or data available.

Guideline - A recommended approach, procedure, or technique which may be utilized and has been found acceptable by the issuing authority.

Regulation - Requirements issued by responsible authority or government body carrying the force of law.

3.1.1 External Gamma Radiation

The recommendations of the International Commission on Radiological Protection (ICRP) have constituted the internationally accepted standards for radiation protection since 1928. The fundamental philosophy of ICRP is that any level of radiation may be potentially harmful. Any unnecessary exposure should be avoided and radiation exposure should be kept as low as reasonably achievable.

Due to the radiation levels found naturally in the earth's environment, however, exposure to radiation is unavoidable. Annual limits for whole body exposure have been recommended by this recognized authority as 0.17 rem for the general population, 0.50 rem for any single individual in the population, and 5.0 rem for an adult exposed in the course of their work. All exposure limits are defined as radiation exposure above that due to background radiation.

Federal regulations found in 10 CFR 20 limit radiation exposure to the whole body in unrestricted areas (general population) to 0.50 rem/yr, 0.002 rem in one hour, or 0.10 rem in 7 consecutive days. In restricted areas, the exposure limit to the whole body of a worker is limited to 1.25 rem in any calendar quarter. Appendix B of 10 CFR 20 has limiting concentrations in air and water for radioactive isotopes. These concentrations are calculated to result in radiation exposure to the whole body or certain critical organs of the body that are equivalent to the previously stated limits. The above doses are the upper limits for radiation exposure. In all cases, exposure to radiation must be as low as reasonably achievable. The term "as low as reasonably achievable", as defined in 10 CFR 20.1, means "as low as is reasonably achievable taking into account the state of technology, and the economics of improvements in relation to benefits to the public health and safety."

Although not directly applicable to this site, the Environmental Protection Agency has set the radiation dose standard for the uranium fuel cycle (40 CFR 190) such that the annual dose to a member of the general public "shall not exceed 0.025 rem to the whole body."

3.1.2 Surface Contamination

The NRC's Division of Fuel Cycle and Material Safety has issued "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material" (Nov. 1976). This document specifies the limits for surface radioactivity and radiation exposure rates associated with the surface contamination which should be met prior to release of equipment or facilities for unrestricted use. These guidelines are in general agreement with standards issued by the American National Standards Institute in the draft document "Control of Radioactive Surface Contamination on Materials, Equipment, and Facilities to be Released for Uncontrolled Use" (N13.12). The surface contamination limits for removable natural thorium and uranium is 1000 dpm/100 cm^2.

3.1.3 Soil Contamination

Uranium and thorium are naturally occuring radionuclides that are found in varying degrees in most soils.

Thorium-232 can naturally range from about 0.2 pCi/g in sand stone up to 2.2 pCi/g in igneous rock. Uranium-238 can range from about 0.2 pCi/g in basalt up to 1.6 pCi/g in salic (NCRP 45, p. 59). There are localized areas where uranium and thorium can be found at much higher concentrations up to several hundred picocuries per gram. With such a wide spectrum of concentrations, a cut-off point is needed to separate material containing innocuous levels of uranium and thorium from material with significant levels. This delineation is made by designating material or soil as source material. Source material is defined in 10 CFR 20.3 as "(i) uranium or thorium, or any combination thereof, in any physical or chemical form or (ii) ores which contain by weight one-twentieth of one percent (0.05%) or more of a) uranium, b) thorium or c) any combination thereof."

3.2 Direction Gamma Exposure Rates

At three locations on the survey grid, #11, 12, 175, (Appendix I), the gamma exposure rates exceed 595 μR/hr. A continuous exposure of 595 μR/hr for 7 consecutive days will result in a dose of 100 mrem. Access to this area by the general public is currently restricted and controlled by a fence. The area is used by L. B. Foster as a storage compound with administrative controls to prevent unnecessary access by employees.

The highest gamma exposure rate found was 900 μR/hr with the majority of the readings much smaller. These gamma exposure rates will not expose workers to an excessive amount of radiation during any cleanup operation. Every reasonable precaution should be made, however, to minimize the exposure. CNSI employees received approximately 0.44 rem for 2000 hours of exposure. An average exposure of 0.22 mrem/hr is consistent with the observed data.

3.3 Alpha Smears

Smears were taken in all of the buildings as they existed at the time of the survey on July 1978 to determine the level of removable (smearable) radioactive material. The smears were counted for alpha radiation due to the preponderence of alpha decay in the potential contaminants. As discussed in section 3.1.2, the limit for removable uranium or thorium is 1000 dpm/100 cm^2 for alpha contamination. The buildings surveyed meet the guidelines and standards, and were released for unrestricted use.

3.4 Soil Contamination

The background soil sample indicates that the Th-232 concentration is about 1.4 pCi/g and that the U-238 concentration is about 0.5 pCi/g. This is consistent with the background values reported in NCRP 45. In order to classify the material as source material, a calculation must be made to express 0.05% by weight as pCi/g.

This calculation was made and 55 pCi/g of Th-232 or 170 pCi/g of U-238 corresponds to the 0.05% by weight. Twelve of the 23 soil samples exceed these levels and indicate the presence of source material (Figure 4). The highest soil sample is from grid 4 (Appendix I) with a concentration of 1.8 ηCi/g. This would calculate for thorium to a value of 1.6% by weight as opposed to the 6% thorium content of the Nigerian ore.

4.0 SCENARIOS CONSIDERED

A satisfactory disposal program should attain the following objectives*: 1) eliminate or reduce to acceptable levels any airborne or surface emissions, 2) eliminate or reduce impacts on the groundwater, and 3) ensure long-term stability and isolation of the radioactive material without the need for perpetual active maintenance (responsibility of disposal site). The five scenarios considered in this report are representative of hypothetical methods as chosen by the NRC, CNSI and AMAX. Some may not necessarily meet the above objectives or current government regulations. These scenarios are provided for comparative purposes only and are summarized in Table 2. Estimated costs are included in the appendices III, IV, and V.

4.1 Scenario I -- Transporation by Truck to Land Disposal Sites

4.1.1 Procedures

The material identified as containing radioactive substances would be excavated with suitable machinery. Using the appropriate safety equipment and necessary manpower, the excavated material would be packaged (as bulk or in drums) according to the applicable federal/state regulations. The packaged material would then be loaded into the trucks for shipment to the disposal sites in Nevada or South Carolina.

* B. J. Macbeth, and others, Screening of Alternative Methods for the Disposal of Low-Level Radioactive Wastes, NUREG/CR-0308.

4.1.2 Discussion

As CNSI studies have shown, some portion of the radioactive material on the site and environs meets the criteria for source material (10 CFR 40) and must be packaged according to government regulations (10 CFR 40). These regulations permit the material to be shipped as bulk or in drums. If, however, suspect pyrophorics are also present in the excavated materials, then additional regulations apply (49 CFR 173). Radioactive-pyrophoric material can only be shipped in drums; bulk shipments are not permitted.

Any shipments destined for the disposal sites at Barnwell or Beatty are subject to strict criteria developed by the site management. These rules contain restrictions banning pyrophoric materials. Both disposal sites may refuse to accept any shipments containing pyrophoric material; however, under certain conditions, a waiver may be obtained. In addition, the Barnwell site, under its present allocation program may not be able to handle the possible quantity of waste from the AMAX property. See Appendix II for volume estimate.

4.2 Scenario II -- Transportation by Barge to Sea

4.2.1 Procedures

The material identified as containing radioactive substances would be excavated with suitable machinery. Using the appropriate safety equipment and necessary manpower, the excavated material would be packaged (as bulk or in drums) according to applicable federal/state regulations. The packaged material would be loaded onto the trucks. The trucks would travel to a designated loading area near the Ohio River where a conveyor system would transfer the packaged material to the barges. The loaded barges would be towed down the Ohio River and then down the Mississippi River to New Orleans. Upon arrival in New Orleans, the material would be transferred by conveyor system to ocean-going barges. The loaded ocean-going barges would be towed to and area designated as a dumping site in the Gulf of Mexico. The empty barge would return to New Orleans for another shipment.

4.2.2 Discussion

The packaging regulations described in section 4.1.2 would apply to this scenario.

The transport of radioactive waste down the Ohio and Mississippi Rivers to the Gulf of Mexico would probably require various state and federal permits and licenses. If sea disposal were permitted, these regulatory avenues would have been investigated.

As of 1970, the United States no longer practiced dumping low-level radioactive wastes into the oceans. According to 10 CFR 20.302, "the Commission will not approve any application for a license for disposal of licensed material at sea unless the applicant shows that sea disposal offers less harm to man or the environment than other practical alternative methods of disposal."

4.3 Scenario III -- Transporation by Barge to DOE Disposal Site

4.3.1 Procedures

Similar methods would be used as described in 4.2 for excavation, packaging, loading, transporting, and conveying to a barge.

Likewise, the loaded barges would be towed down the Ohio and Mississippi Rivers but only to Paducah, Tennessee. Upon arrival in Paducah, the material would be transferred by a conveyor system to trucks which would haul the material to the DOE burial site for disposal.

4.3.2 Discussion

The packaging regulations described in section 4.1.2 would apply to this scenario.

The disposal sites operated by the DOE do not currently accept radioactive materials from private industry.

As in Scenario II, licenses and permits would undoubtedly be required by various state and federal agencies for the transport of radioactive waste through public waterways. These regulatory requirements were not studied because disposal at the DOE site was not considered feasible by they study team.

4.4 Scenario IV -- Injection Into an Abandoned Mine

4.4.1 Procedures

The material identified as containing radioactive substances would be excavated with suitable machinery. Using the appropriate equipment and necessary manpower, the excavated material would be packaged as bulk or in drums according to applicable state/federal regulations. The packaged material would then be loaded onto trucks for shipment to the abandoned mine. The material would be stockpiled at the mine site, and a series of bore holes would be drilled into the existing cavities of the mine. A mud slurring unit and a pump truck would mix and inject the bulk material via the bore holes into the mine. The drummed material would be lowered into the mine through larger bore holes. All drilling operations would be conducted at the surface.

4.4.2 Discussion

To date, the disposal of low-level radioactive material in an abandoned mine has never been performed. Other methods, less complicated than mine disposal, have been utilized.

Prior to the development of the mine as a hypothetical disposal site, various permits and licenses would have to be procured from local and federal authorities. Preliminary studies would have to be performed. At the very least, the federal agencies would require an extensive environmental study to accurately define the geohydrological characteristics of the site and determine that the radioactive material will remain isolated from the biosphere for a specified period of time. The depth and extent of the mine makes the continual surveillance of the migration of radionuclides from the site difficult. Likely, the area would be considered restricted because of the nature and quantity of radionuclides on site. Security provisions would be needed. Ultimately, the site's control and long term care could be transferred from the owner (AMAX) to a government custodian. This action would require specific arrangements by the present owner.

4.5 Scenario V -- On-Site Stabilization

4.5.1 Procedures

A portion of the property would be designated as the on-site disposal area. After extensive evaluation of the site's characteristics, a suitable disposal technique, above or below grade, would be chosen. All material identified as containing radioactive substances would be excavated (if necessary), transported, and disposed of by the selected technique.

Below grade disposal would consist of excavating a cell to a depth of approximately 9 feet. Site drainage and proper erosion preventive measures would have to be provided for the site. The cell would be filled with contaminated debris, compacted, and covered with clay. Top soil would be added as a final cover. Additional cover would be provided if the dose rate was unacceptably high above background.

Above grade disposal would consist of preparing a base pad by building an approved drainage system as the bottom of the pad. The same erosion and drainage measures described in the below grade section apply. The contaminated debris would be placed on the prepared pad to a predetermined height. A permanent cover of clay and top soil would be placed over the waste material. The final topography would resemble a mound. As in below grade disposal, additional cover would be provided if the dose rate was unacceptably high.

Costs for below grade and above grade disposal are shown in Appendix III.

4.5.2 Discussion

Prior to the establishment of a disposal area, various permits and licenses would have to be obtained from appropriate authorities. The federal agency may require preliminary studies, including an environmental study, demonstrating that the interred radioactive material will remain isolated from the biosphere for a specified period of time. A surveillance program may be required to monitor the possible migration of the radionuclides from the disposal area. Ultimately, the area's control and long-term care would be transferred to a government custodian and the owner (AMAX) would make those arrangements.

4.6 Scenario Cost Estimates

Estimated costs were assembled for preceding scenarios and summarized in the Appendix III.

TABLE 2

SCENARIO COMPARISON

Scenario		Potential Applicable Federal Agencies	Risk
I	Truck to Commercial Disposal Site	DOT NRC EPA	Transportation accident possible due to high number of trucks needed.
II	Dispoal at Sea	DOT NRC NOAA Army Corp of Engineers EPA	Possible radiological and health physics risk due to handling frequency.
III	Barge to DOE Site	NRC DOE DOT Army Corp of Engineers EPA	Possible radiological and health physics risk due to handling frequency.
IV	Injection into Mine	NRC DOT Bureau of Mines EPA	Possible radiological health physics risk due to handling frequency. Future area mining risk
V	On-site Stabilization	NRC other agencies(?)	

5.0 CONCLUSION

Based on the preceding studies, current federal/state regulations, and risks involved, the CNSI study team supports on-site stabilization as the most viable disposal method of the five scenarios considered. The study team recommends that formal topographical, geological, meteorological, and hydrogical studies be performed. In addition, detailed studies should be conducted to determine the identification, location, and hazard of any pyrophoric residues on the property.

DIRECTORY

Technical Contacts

AMAX Environmental Services, Inc.

James E. Kerrigan, Senior Environmental Engineer

4704 Harlan Street
Denver, Colorado 80212
Phone: 303/433-6151

AMAX Inc.

Stanley A. Thielke, Manager of Industrial Hygiene

AMAX Center
Greenwich, Connecticut 06830
Phone: 203-622-3000

Chem-Nuclear Systems, Inc.

Ronald Mencarelli, Project Engineer, Decommissioning

P. O. Box 726
Barnwell, SC 29812

John Coffman, Manager, Compliance Assistance and Technical Services
Robert Levesque, Assistant Director, Field Services
Kenneth Sterbenz, Project Engineer, Decommissioning

240 Stoneridge Drive, Suite 100
Columbia, SC 29210

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APPENDIX I

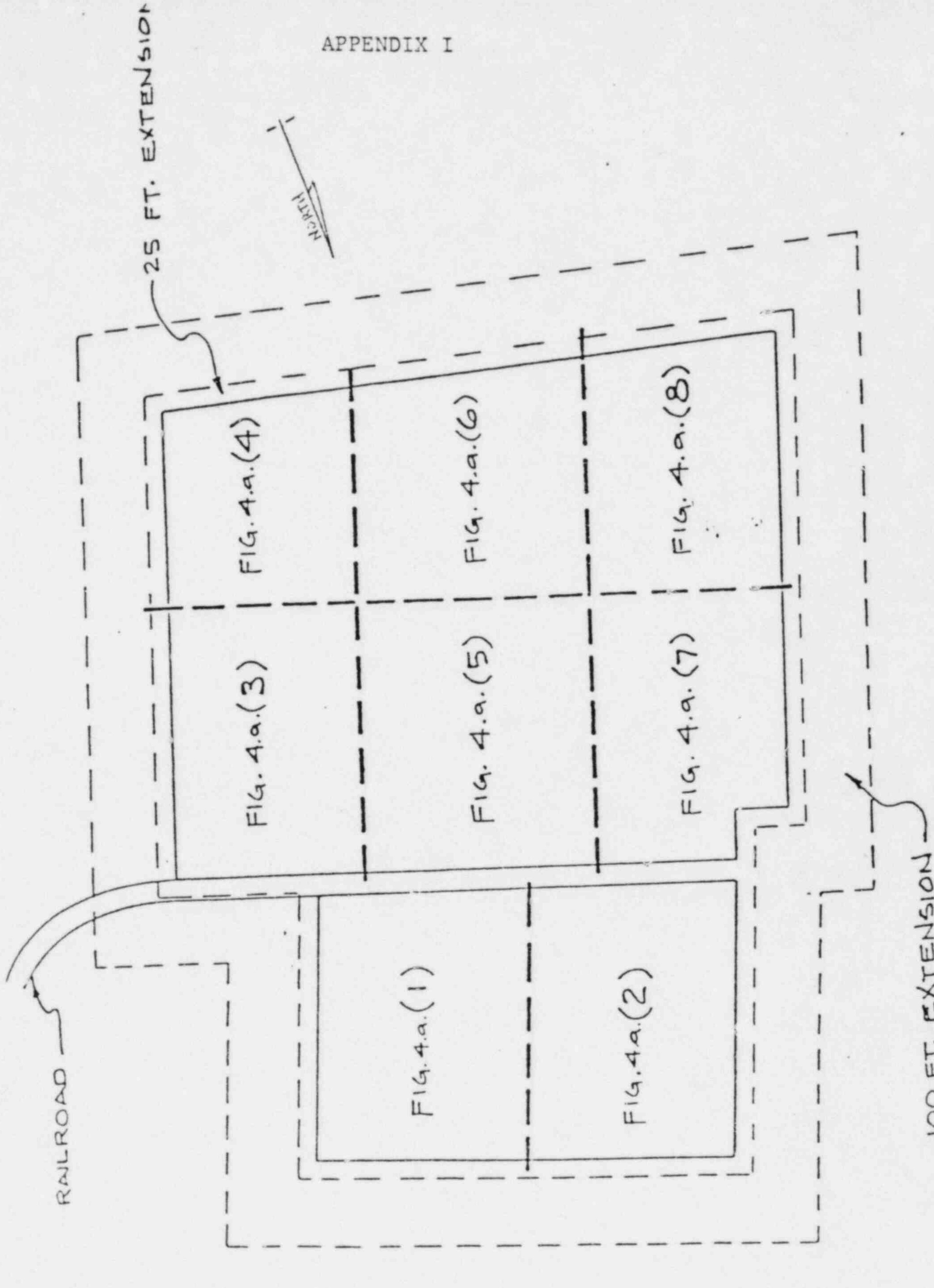
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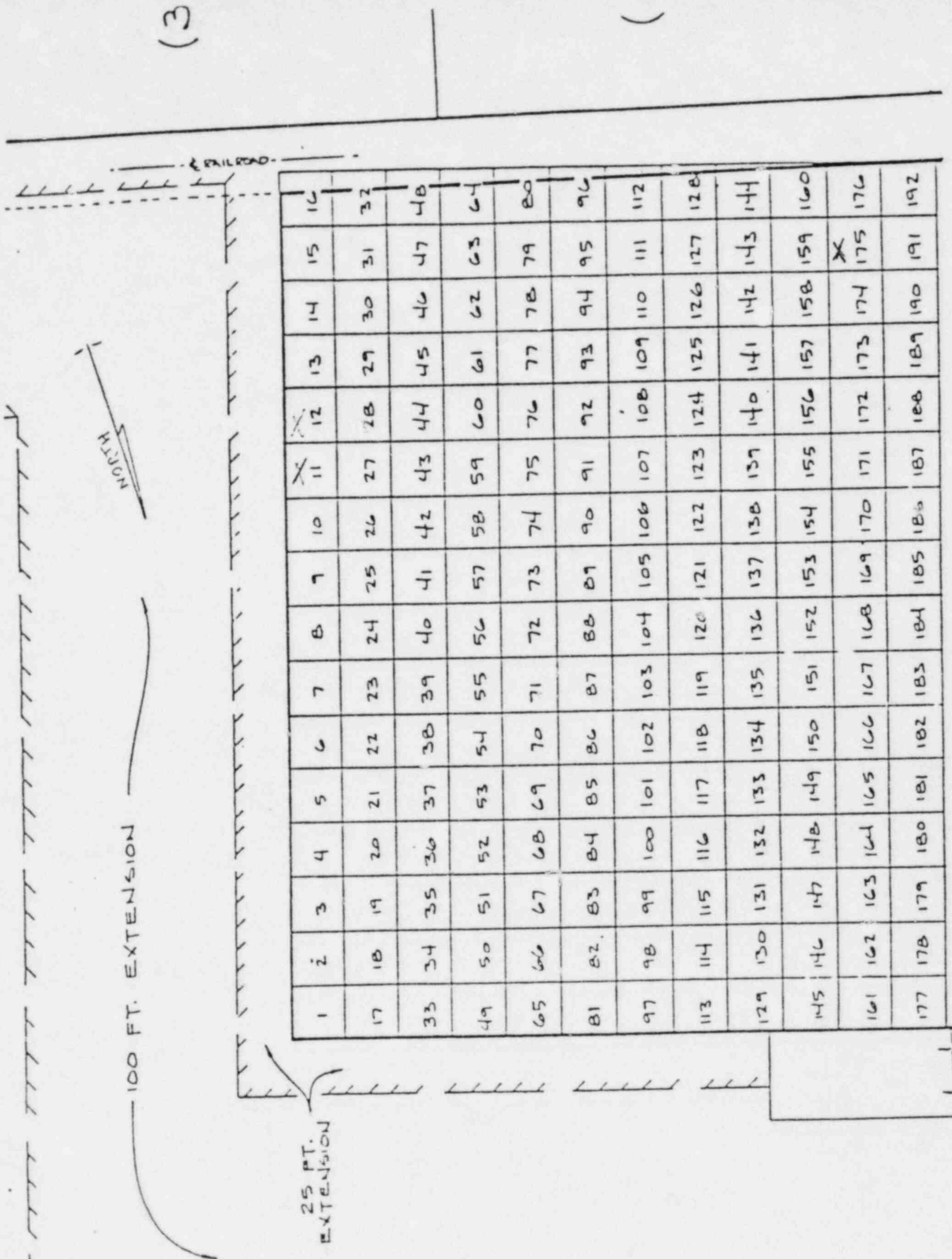
FIG. 4.a.(4)
FIG. 4.a.(6)
FIG. 4.a.(8)
FIG. 4.a.(3)
FIG. 4.a.(5)
FIG. 4.a.(7)
FIG. 4.a.(1)
FIG. 4.a.(2)
RAILROAD
100 FT. EXTENSION



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(2)
RAILROAD
NORTH
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25 FT. EXTENSION
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33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64
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97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112
113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128
129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144
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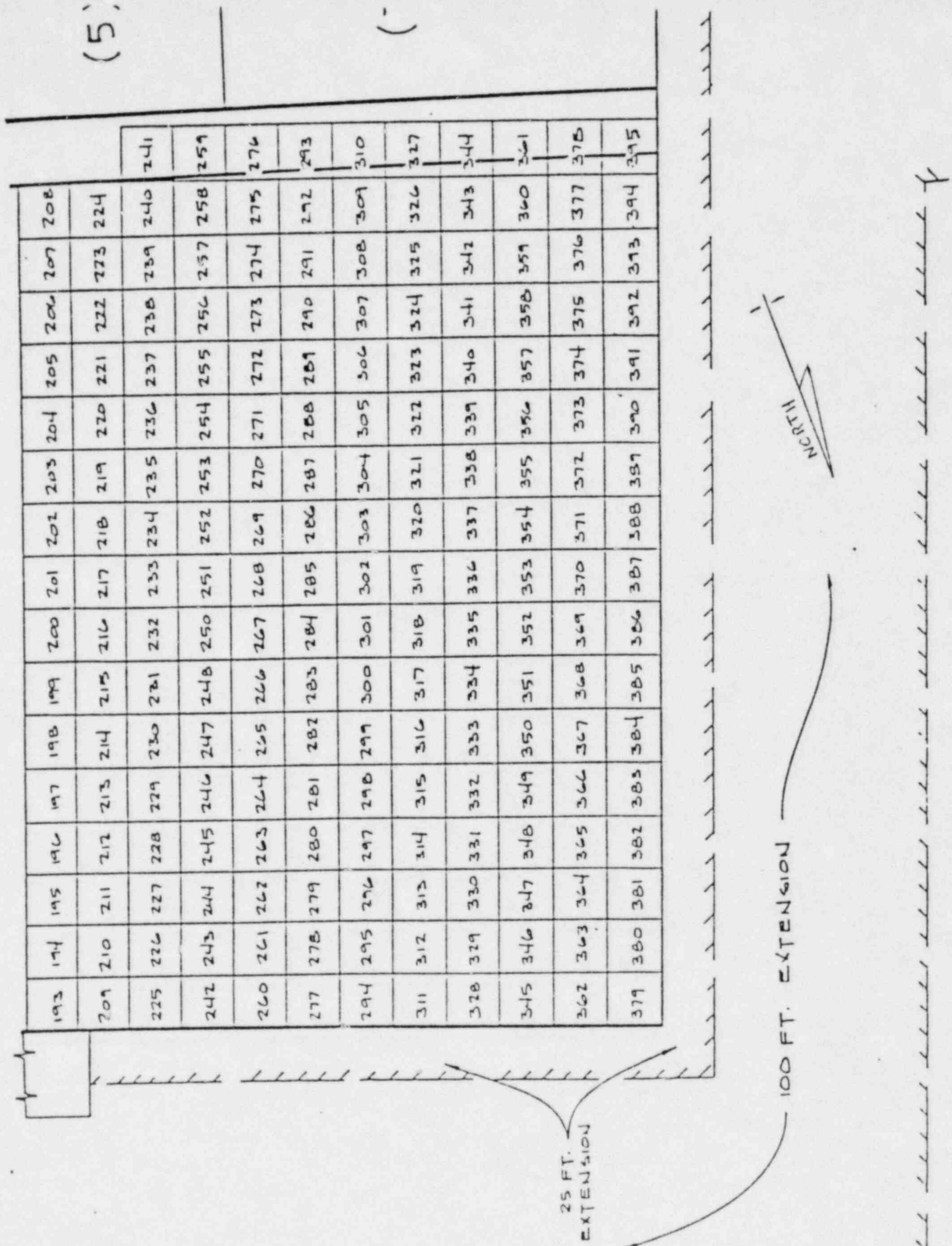
(1)
(5)
NORTH
25 FT. EXTENSION
100 FT. EXTENSION

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454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469
482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497
510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525
538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553
566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581
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622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637
651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666
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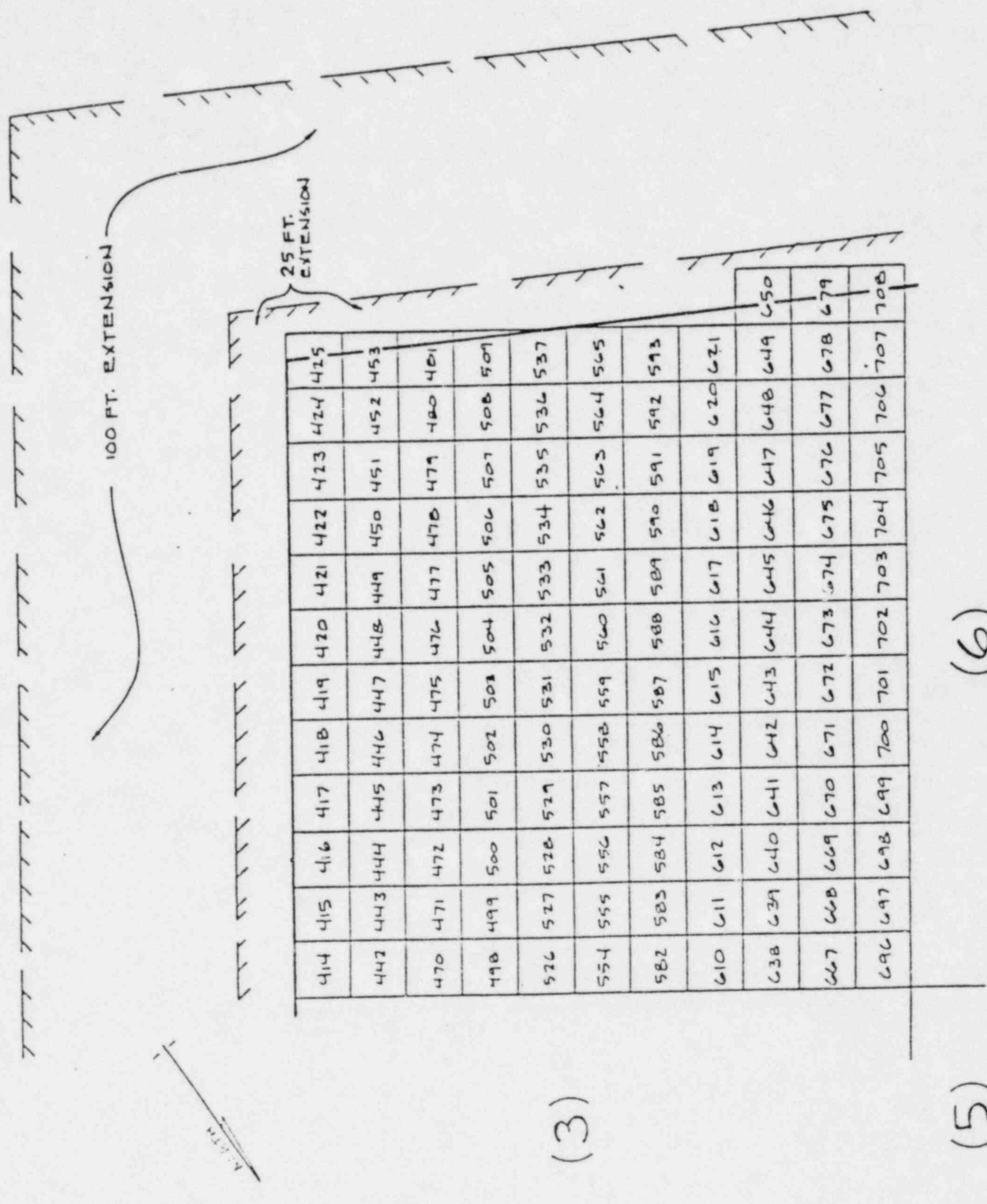
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526 527 528 529 530 531 532 533 534 535 536 537
554 555 556 557 558 559 560 561 562 563 564 565
582 583 584 585 586 587 588 589 590 591 592 593
610 611 612 613 614 615 616 617 618 619 620 621
638 639 640 641 642 643 644 645 646 647 648 649 650
667 668 669 670 671 672 673 674 675 676 677 678 679
696 697 698 699 700 701 702 703 704 705 706 707 708
(3)
(5)
(6)

(3) (4)

(1) (6)

(2) (7) (3)

℄ RAILROAD

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767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782
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883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898
913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928
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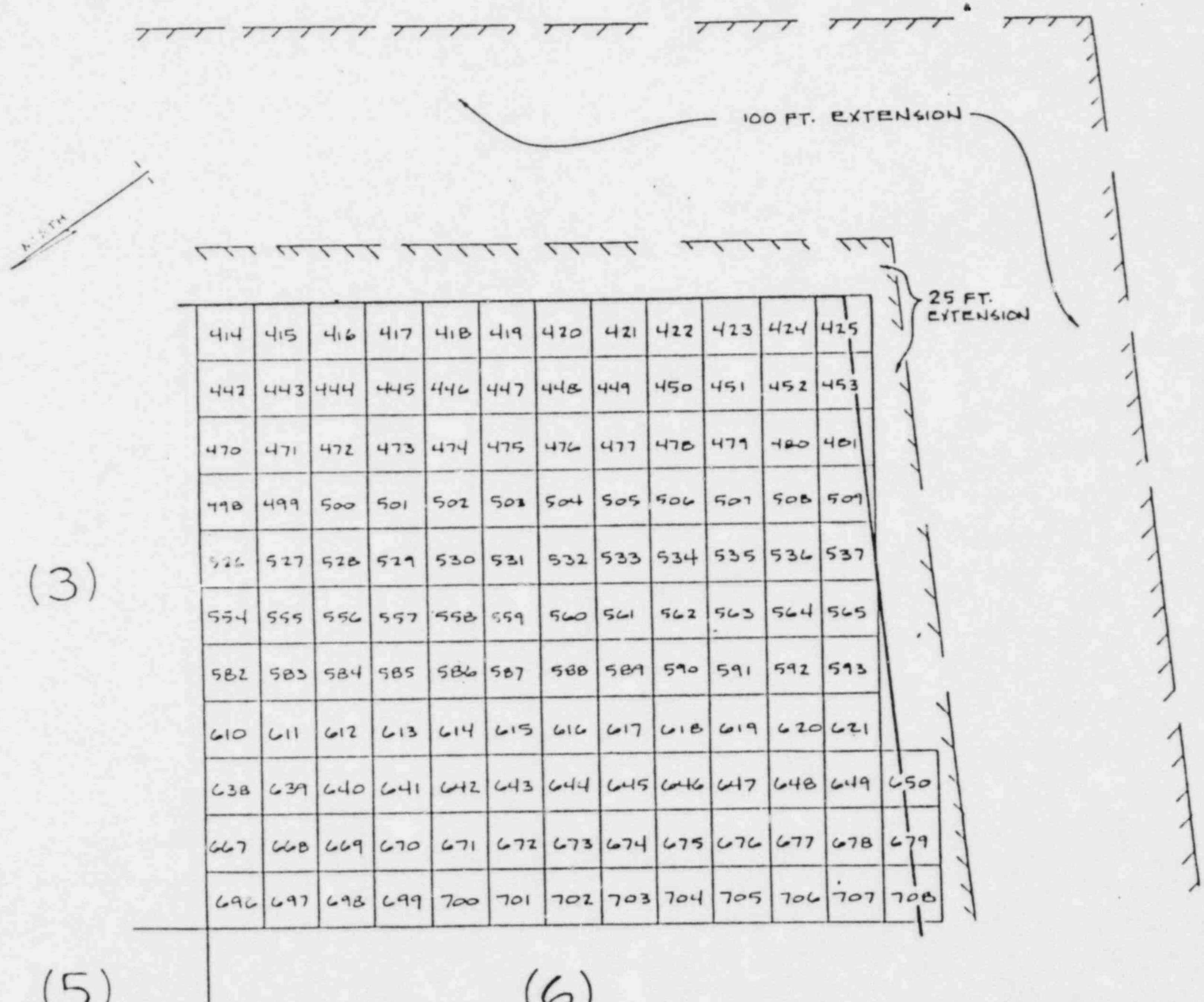
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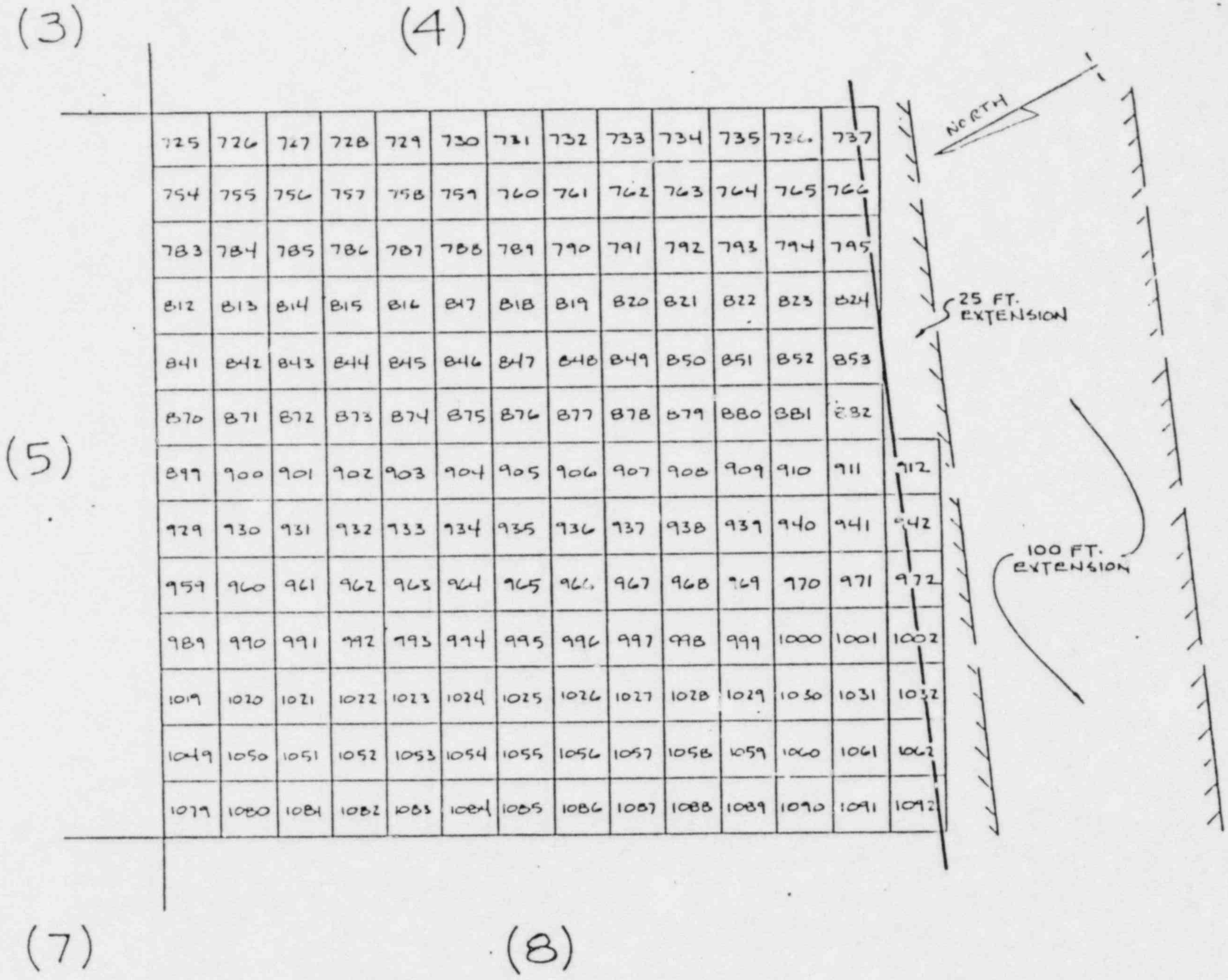
(5)
(6)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812 813 814 815 816 847 818 819 820 821 822 823 824
841 842 843 844 845 846 847 848 849 850 851 852 853
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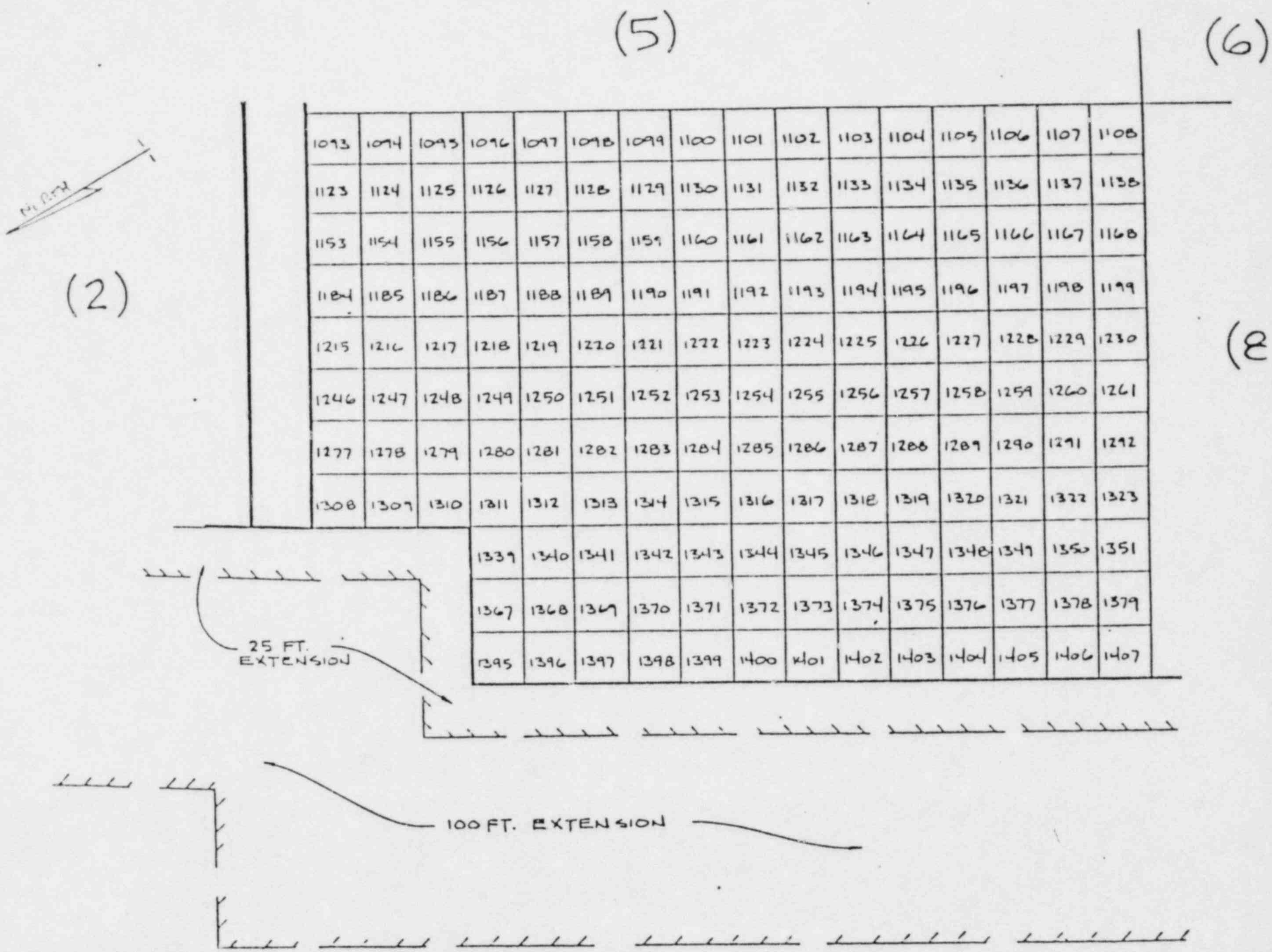
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1246 1247 1248 1249 1250 1251 1252 1253 1254 1255 1256 1257 1258 1259 1260 1261
1277 1278 1279 1280 1281 1282 1283 1284 1285 1286 1287 1288 1289 1290 1291 1292
1308 1307 1310 1311 1312 1313 1314 1315 1316 1317 1318 1319 1320 1321 1322 1323
1339 1340 1341 1342 1343 1344 1345 1346 1347 1348 1349 1350 1351
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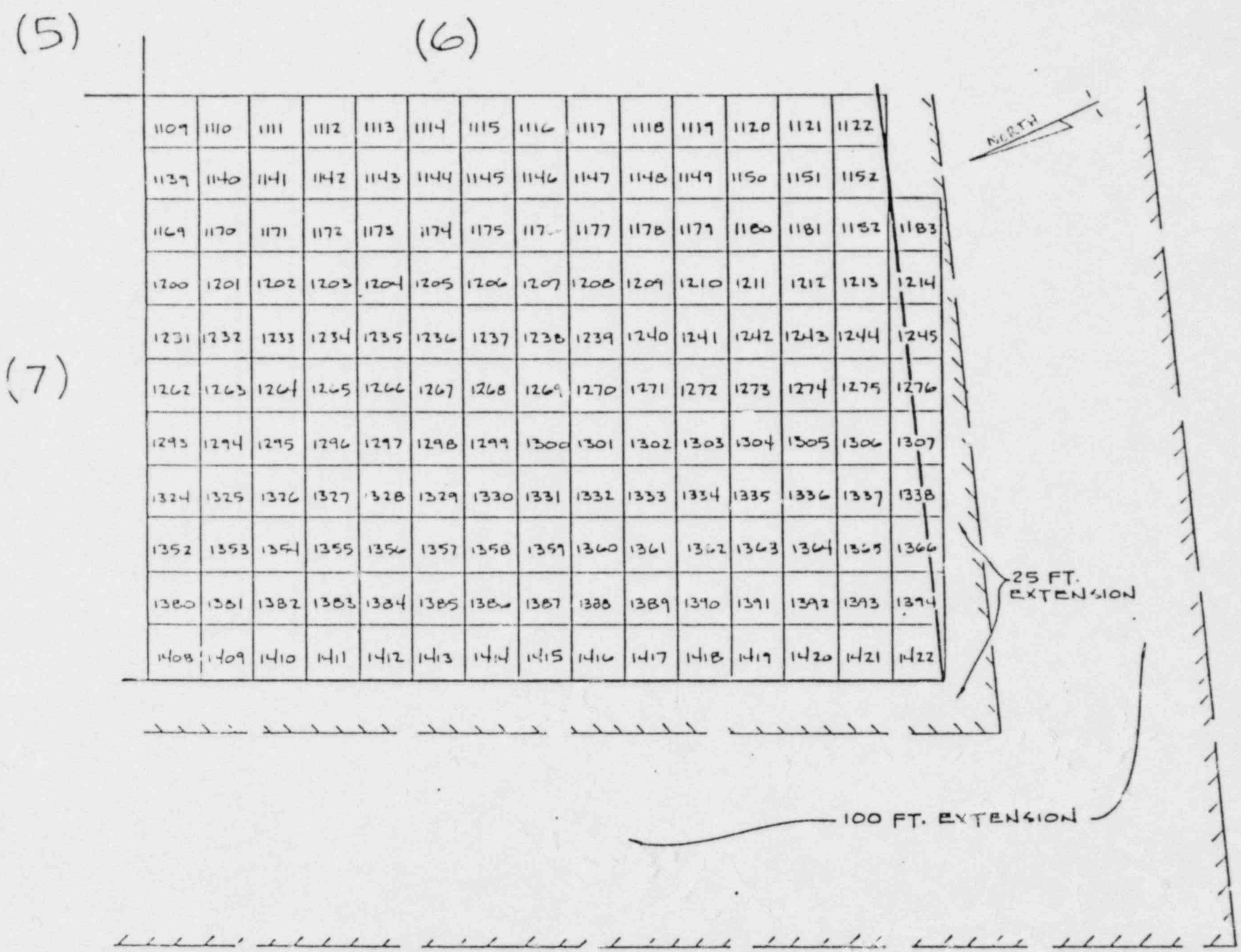
100 FT. EXTENSION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1169 1170 1171 1172 1173 1174 1175 1177 1178 1179 1180 1181 1182 1183
1200 1201 1202 1203 1204 1205 1206 1207 1208 1209 1210 1211 1212 1213 1214
1231 1232 1233 1234 1235 1236 1237 1238 1239 1240 1241 1242 1243 1244 1245
1262 1263 1264 1265 1266 1267 1268 1269 1270 1271 1272 1273 1274 1275 1276
1293 1294 1295 1296 1297 1298 1299 1300 1301 1302 1303 1304 1305 1306 1307
1324 1325 1326 1327 1328 1329 1330 1331 1332 1333 1334 1335 1336 1337 1338
1352 1353 1354 1355 1356 1357 1358 1359 1360 1361 1362 1363 1364 1365 1366
1380 1381 1382 1383 1384 1385 1387 1388 1389 1390 1391 1392 1393 1394
1408 1409 1410 1411 1412 1413 1414 1415 1416 1417 1418 1419 1420 1421 1422
NORTH
25 FT. EXTENSION
100 FT. EXTENSION

APPENDIX II

Calculations

1. Method for calculation of volume:

The grids and other defined areas which exceed twice background were determined. The depth to which the deposit of radioactive material exceeded twice background was then determined for each of the above areas. The total volume was then calculated by summing the products of each surface area by the depth of the deposit. The following is a summary of the above defined products:

Area	Cubic Feet (rounded where appropriate)
(a) 100 ft. extension east of grids No. 1 - 16	
1,500 square feet x 1.5 feet	2,250
(b) 25 foot extension east of grids No. 1 - 16	
10,000 square feet x 1.5 feet	15,000
(c) Grids No. 1 - 192 with no concrete beneath	
53,750 square feet x 2.0 feet	107,500
(d) Grids No. 1 - 192 with concrete beneath	
23,125 square feet x 0.25 feet	5,800
(e) Grids No. 193 - 395	
3,125 square feet x 1.5 feet	4,700
(f) 25 foot extension North of Grids (between Grid No. 1 & 129)	
6,250 square feet x 1.5 feet	9,400
(g) 100 foot extension West of Grids No. 193 - 395	
1,825 square feet x 2.0 feet	3,650
3,125 square feet x 0.5 feet	1,550
contaminated rubble	450
(h) Area in grids No. 398 - 1422	
83,750 square feet x 2 feet	167,500
39,375 square feet x 4 feet	157,500
34,700 square feet x 7.5 feet	260,300
18,750 square feet x 14 feet	262,500
(i) South west drainage flood plain	
28,000 square feet x 2 feet	56,000
(j) Build up on adjacent property S. SW of mfg. sites	
700 square feet x 2 feet	1,400
(k) Sediment catch tank at Ohio River	
Estimated volume in tank	7

(1) Area along railroad siding
19,700 square feet x 2.5 feet 49,250

Original Volume = 1,105,000 ft.^{3}

2. <u>Contingency volume estimates</u>:

Removal of contaminated soil will most likely result in the cross contamination of the underlying soil which then has to be removed and controlled. This additional depth is estimated to be four (4) inches over the areas defined in #1 of this section. In addition, the building rubble placed over the northern portion of the manufacturing site grids would also have to be considered as being radioactive as there is very little chance it could be removed practically without it being mixed with contaminated subsoil. The sum of these two volumes are:

Contingency Volume = 122,600 ft.^{3}

The original volume (1,105,000 ft.^{3}) plus the contingency volume (122,600 ft.^{3}) equals 1,227,600 ft.^{3}. To present a conservative estimate, the 1,227,600 ft.^{3} calculation was rounded up to 1,500,000 ft.^{3}.

APPENDIX III-A

ESTIMATED COST SUMMARY

SCENARIO	DESCRIPTION OF SCENARIO	PACKAGING COST	TRANSPORTATION	BURIAL FEE	TOTAL COST
1	Transportation by truck to disposal sites				
	A. Bulk	A. $0.53/ft^3=$0.78 mill			
	1. To Barnwell, SC		1. $3.8 mill	1. $8.9 mill	1. $13.5 mill
	2. To Beatty, NV		2. $16.0 mill	2. $11.4 mill	2. $28.2 mill
	B. Drums	B. $1.50/ft^3=$2.2 mill			
	1. To Barnwell, SC		1. $4.6 mill	1. $9.1 mill	1. $15.9 mill
	2. To Beatty, NV		2. $19.3 mill	2. $11.8 mill	2. $33.3 mill
	C. Combination Bulk/Drum	C. $1.09/ft^3=$1.6 mill			
	1. To Barnwell, SC		1. $4.3 mill	1. $9.0 mill	1. $14.9 mill
	2. To Beatty, NV		2. $17.9 mill	2. $11.6 mill	2. $31.1 mill

mill = million

APPENDIX III-B

ESTIMATED COST SUMMARY

SCENARIO	DESCRIPTION OF SCENARIO	PACKAGING COSTS	TRANSPORTATION	BURIAL FEE	TOTAL COST
II	By barge for disposal at sea	$\$0.90/ft^3 = \$1.3$ mill	\$7.8 mill	N/A	\$9.1 mill
III	By barge for disposal at DOE Site	$\$0.98/ft^3 = \$1.4$ mill	\$1.4 mill	\$4.4 mill	\$7.2 mill
IV	Injection into an abandoned mine	$\$0.53/ft^3 = \$0.78$ mill	\$1.5 mill	\$3.5 mill	\$5.7 mill
V	On-site Stabilization				
	A. Below Grade	$\$1.16/ft^3 = \$1.7$ mill	N/A	N/A	\$1.7 mill
	B. Above Grade	$\$1.63/ft^3 = \$2.4$ mill	N/A	N/A	\$2.4 mill

mill = million

Additional Information

for

Appendices IIIA and IIIB

The estimated costs listed in Appendices IIIA and IIIB are subject to change.

For Scenario I, transportation to Barnwell costs $1.25 per mile and to Beatty, $1.19 per mile. The burial fees are described in Appendices IV and V for both sites. Specifically, burial fees for Barnwell and Beatty are $6.00 per cubic foot and $7.75 per cubic foot, respectively. These fees do not include the additional surcharges such as those for decommissioning and perpetuity funds.

For Scenario I-III, transportation costs include truck and barge rental. Burial fees do not apply for Scenario II. There is a $3.00 per cubic foot burial fee for Scenario III.

For Scenario IV, burial fees include the cost of the mine and the injection process.

CHEM-NUCLEAR SYSTEMS INC.

One Greystone West Building • 240 Stoneridge Drive • Columbia, South Carolina 29210 • 803/798-9042

LOW LEVEL RADIOACTIVE WASTE DISPOSAL RATES FOR CHEM-NUCLEAR SYSTEMS, INC. BARNWELL, SOUTH CAROLINA SITE

All radwaste material shall comply with Department of Transportation packaging specifications in accordance with Title 49 and Title 10 of the Code of Federal Regulations, CNSI's Nuclear Regulatory Commission and South Carolina Radioactive Material Licenses, CNSI's Barnwell Site Disposal Criteria, and amendments thereto.

1. DISPOSAL CHARGES:

a. Steel Drum and Wooden Boxes:

Maximum Radiation Level at Package Surface	Disposal Price per Cubic Foot
0 - 200 mr/hr	$6.00
201 mr/hr - 1 R/hr	7.68
1.001 R/hr - 5 R/hr	9.78
5.001 R/hr - 10 R/hr	12.18
10.001 R/hr - 25 R/hr	16.38
25.001 R/hr - 50 R/hr	20.88
50.001 R/hr - 75 R/hr	25.08
75.001 R/hr - 100 R/hr	33.18
100.001 R/hr - 125 R/hr	37.62
Greater than 125 R/hr	By Special Request Only

b. Disposable Liners:

Maximum Radiation Level at Unshielded Liner Surface	Disposal Price per Cubic Foot	Radiation Surcharge per Liner
0 - 200 mr/hr	$6.00	No Surcharge
201 mr/hr - 1 R/hr	6.00	$ 90.00
1.001 R/hr - 5 R/hr	6.00	270.00
5.001 R/hr - 10 R/hr	6.00	420.00
10.001 R/hr - 25 R/hr	6.00	510.00
25.001 R/hr - 50 R/hr	6.00	690.00
50.001 R/hr - 75 R/hr	6.00	810.00
75.001 R/hr -100 R/hr	6.00	1,020.00
100.001 R/hr -125 R/hr	6.00	1,140.00
Greater than 125 R/hr	6.00	By Request Only

c. Minimum Disposal Charge (excluding other Surcharges): $120.00 per shipment

2. SURCHARGES

a. Weight Surcharges

Weight of Container	Surcharge
0 - 5,000 pounds	No surcharge
5,001 - 10,000 pounds	$ 90.00
10,001 - 15,000 pounds	150.00
15,001 - 20,000 pounds	210.00
20,001 - 30,000 pounds	360.00
30,001 - 40,000 pounds	420.00
40,001 - 50,000 pounds	630.00
Greater than 50,000 pounds	By Request Only

b. Biological Tissue Surcharge: $ 0.60 per cubic foot

c. Special Handling Surcharge: Applicable on unusually large or bulky containers

d. Radioactivity Surcharge (per disposable container):

Less than 250 Curies	No surcharge
Greater than 250 Curies	$60.00 plus $0.12/Curie

CHEM-NUCLEAR SYSTEMS, INC.
LOW-LEVEL RADIOACTIVE WASTE DISPOSAL RATES

3. CASK HANDLING FEE: $210.00 per cask, minimum

4. ADDITIONAL FEES:

   a. Perpetuity Escrow Fund Charge:

      (1) February 14 - April 5, 1980 — $0.55 per cubic foot
      (2) April 6, 1980 - April 5, 1981 — $0.75 per cubic foot

   b. Decommissioning Escrow Fund Charge: $0.78 per cubic foot

5. BARNWELL COUNTY BUSINESS LICENSE TAX: A 2.4 per cent Barnwell County Business License Tax shall be added to the total of ALL disposal fees.

NOTE: Fees noted in Items #4a, #4b and #5 shall be displayed as separately stated items on all disposal invoices.

6. MISCELLANEOUS:

   a. Transport vehicles and vans (besides shielded transport casks) which are provided with additional shielding features may be subject to a minimum handling fee of $120.00 per use. Such a fee covers additional handling and labor required for special equipment setup and temporary shield removal.

   b. Decontamination services (if required): $22.50 per manhour plus supplies at current CNSI rate

   c. Customers will be charged for all special services as described in the Barnwell Site Disposal Criteria.

   d. Terms of payment are NET 30 DAYS upon presentation of invoices. A service charge in the amount of one percent (1%) per month may be levied on accounts paid after thirty (30) days.

   e. Company purchase orders or a written letter of authorization in form and substance acceptable to CNSI shall be received before receipt of radioactive waste material at the Barnwell Disposal Site and refer to CNSI's Radioactive Material Licenses, the Barnwell Site Disposal Criteria, and subsequent changes thereto.

   f. All shipments shall receive a CNSI allocation number and conform to the Prior Notification Plan. Additional information may be obtained at (803) 259-3577/3578.

   g. This Rate Schedule is subject to change and does not constitute an offer of contract which is capable of being accepted by any party.

Washington Nuclear Center and Nevada Nuclear Center

Schedule of Charges

Radioactive Waste

1. Disposal Charges

A. Solid Material

Steel Drums, Wood Boxes, Liners:

R/HR AT CONTAINER SURFACE	PRICE PER CU. FT.
0.00 - 0.20	$ 7.75
0.201 - 1.00	8.50
1.01 - 2.00	9.50
2.01 - 5.00	11.60
5.01 - 10.00	13.70
10.01 - 20.00	17.75
20.01 - 40.00	22.60
40.01 - 60.00	33.70
60.01 - 80.00	40.65
80.01 - 100.00	44.65
Over 100.00	By Request

Disposable Liners Removed From Shield:

R/HR AT CONTAINER SURFACE	SURCHARGE PER LINER	PRICE PER CU. FT.
0.00 - 0.20	No Charge	$ 7.75
0.201 - 1.00	$ 106.00	7.75
1.01 - 2.00	261.00	7.75
2.01 - 5.00	367.00	7.75
5.01 - 10.00	530.00	7.75
10.01 - 20.00	677.00	7.75
20.01 - 40.00	840.00	7.75
40.01 - 60.00	996.00	7.75
60.01 - 80.00	1,150.00	7.75
80.01 - 100.00	1,306.00	7.75
Over 100.00	By Request	By Request

B. Liquid Scintillation Vials $10.25/cu. ft.

C. Biological Waste, Animal Carcasses $ 8.45/cu. ft.

2. Surcharge For Heavy Objects:

Less than 10,000 pounds	No Charge
10,001 pounds to Capacity of Site Equipment	$ 76.00 plus $.02 per lb. above 10,000 lbs.

3. Surcharge For Curies (Per Load):

Less than 100 curies	No Charge
101 - 300 curies	$ 590.00
301 - License Limits	$ 590.00 plus $.08 per curie

4. Minimum Charge Per Shipment: $ 200.00

5. Cask Handling Fee: $ 300.00 minimum each

6. Waste Containing Chelating Agents in Packages Amount Greater than 1% of Package Volume: By Request

7. Surcharge for Non-routine Man-Rem Exposure (due to design or physical defect of container or shield): $11.00 per man millirem

8. Decontamination Services (if required) $40.00 per man hour plus supplies at cost plus 15%

9. Container Volumes:

55 Gallon Drums - 7.50 cu. ft.
30 Gallon Drums - 4.01 cu. ft.
5 Gallon Drums - 0.67 cu. ft.

Prices Effective March 1, 1980