

**Review and Evaluation of Characterization Data Provided
for Safety Light Corporation, Bloomsburg, Pennsylvania**

Submitted to:

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1.0 Introduction

The Safety Light Corporation (SLC) site is one of approximately 40 sites the U.S. Nuclear Regulatory Commission (NRC) has identified in its Site Decommissioning Management Plan (SDMP) as exceeding NRC criteria for unrestricted use that require special attention to ensure timely decommissioning.¹ In SRM-SECY-00-180, the Commission recently directed the staff to develop decommissioning cost estimates for such sites.

Beginning in the late 1940's, under a series of owners, the site has been used for a variety of activities involving radionuclides, including Ra-226, Sr-90, Cs-137, Am-241, and, most recently, H-3. Work with all radionuclides except H-3 ceased at the site in 1969.

The SLC site, located in central Pennsylvania, is about 10 acres in extent and contains numerous structures and contaminated areas, including lagoons, dumps, an abandoned canal, and buildings. Studies of the site have found contamination by radioactive material in buildings, soil, and groundwater. Groundwater monitoring wells were installed on the site in 1978 and 1979. Studies of the site were conducted in 1979 by Radiation Management Corporation; in 1982 by the Oak Ridge Institute for Science and Education (ORISE); and in 1990-1991 by Chem-Nuclear Systems, Inc. (CNSI). The U.S. Environmental Protection Agency also completed a Preliminary Site Assessment in 1991. Based on these studies, the licensee in 1991 estimated the cost of decommissioning the site to be in the range of \$2.2 to \$20 million.

A Settlement Agreement renewing SLC's byproduct licenses was entered into by NRC in 1995, but at that time the cost of decommissioning was not accurately known because a comprehensive site characterization had not yet been performed. A site characterization study was commissioned by SLC and performed by Monserco, Inc. in 1995. In 1998, SLC prepared and submitted a Decommissioning and Decontamination Plan for the site and a Health and Safety Plan for remediation of the underground silos at the site, and remediation work on the underground silos began in October 1999. The site was considered again for license renewal in November 1999. The NRC staff noted in SECY-99-269² that the estimated cost to decommission the land, buildings, and facilities contaminated from previous operations was approximately \$14 million.³ SECY-99-269 also noted that SLC had not yet prepared a cost estimate for decommissioning the buildings and facilities contaminated from the ongoing H-3 operations.⁴

During 2000, the Pennsylvania Department of Environmental Protection (PADEP) carried out an assessment of the site, with particular emphasis on collection and analysis of samples of

¹ NUREG-1444, Site Decommissioning Management Plan, October 1993.

² SECY-99-269, Renewal of the Safety Light Corporation License at Bloomsburg, Pennsylvania, November 17, 1999.

³ These operations are licensed under License No. 37-00030-02.

⁴ These operations are licensed under License No. 37-00030-08.

groundwater from monitoring wells on the site, surface water from the adjacent Susquehanna River, and nearby residential well water.

In October and December, 2000, SLC prepared and submitted to NRC a Decommissioning Cost Estimate for License No. 37-00030-08 and a Decommissioning Plan and Cost Estimate for License No. 37-00030-02. Costs were estimated as approximately \$29 million (including a 25 percent contingency) to remediate the facilities and soil to a condition that would permit unrestricted use.

This report presents ICF's review of the prior characterization data, including a summary of the available data, an evaluation of the completeness of these data, and suggests where additional data could increase the current understanding of the site and refine future cost estimates. ICF notes that the data gaps identified through our analysis should not be construed to be resultant from past "inadequate" characterization activities, as many of these data were collected for various other purposes. We also note that the identified data gaps will aid in the formulation of assumptions used to estimate decommissioning costs under Tasks 3 and 4 of this Task Order, and do not constitute a "request" for SLC to additional characterization. Lastly, ICF neither validated nor reevaluated the quality assurance/quality control data associated with the analytical data provided by NRC and SLC. ICF used these data at "face value" to gain an understanding of the SLC site.

Section 2 of this report provides an overview of the site history and Section 3 discusses the characterization review methodology. Sections 4 through 8 discuss the various investigations of buildings, surface soils, sub-surface soils, groundwater, and other various media, respectively. Section 9 presents ICF's conclusions regarding the adequacy of site characterization, the need for additional characterization activities, and the costs of such additional sampling and analysis by media.

2.0 Background

This section presents an overview of the site, a short summary of the site's history, an overview of characterization studies to date, and a description of known decontamination and remediation events conducted at the site.

2.1 Site History

2.1.1 Site Location

The Safety Light Corporation (SLC) site is located in South Centre Township of Columbia County in central Pennsylvania, about 6 miles east of Bloomsburg and 6 miles west of Berwick. The north site boundary is the Old Berwick Road and the south site boundary is the Susquehanna River. SLC owns the Vance-Walton property located along the southeast corner of the site. Other residential tracts of land are adjacent to the east and west boundaries of the site. The site is located on the U.S. Geological Survey Bloomsburg, Pennsylvania quadrangle topographical map at North 41° 1' 56" latitude and West 76° 22' 40" longitude. Active SLC operations occupy approximately two acres of the 10-acre site.

2.1.2 History of Site Operations

Activities conducted at the site have varied over time and involved a number of different radionuclides. In 1948, the United States Radium Corporation (USRC) radium operations were relocated from Brooklyn, New York, to the Bloomsburg site. At the time, USRC used mainly Ra-226 and minor amounts of Po-210 in the manufacture of self-illuminating watch and instrument dials. From 1948 until 1954, USRC used the East Lagoon for the disposal of sewage and process wastewater from the Old Radium Laboratory located in the Main Building. During the early 1950s, USRC expanded its operations to include the manufacturing of civil defense check sources and radiation sources utilizing Cs-137 and the production of deck markers for the U.S. Navy involving the use of Sr-90. During the time period, radium was also used primarily for clocks and watches (dials and hands) and in the production of high level neutron and radiation therapy sources.

During the 1950s, USRC began producing light sources using H-3, C-14, Tl-104, and Kr-85; low-level ionization sources using Ni-63 and H-3; and radiation beta sources using Kr-85. Waste from these operations were buried in two underground silos. In 1956, the Atomic Energy Commission (AEC), a predecessor of the U.S. Nuclear Regulatory Commission (NRC), issued AEC License No. 37-00030-02 to USRC. The discussions of radionuclides covered by the original license are conflicting. However, it appears that this license may have authorized the use and distribution of products containing a variety of other radionuclides, including C-14, Fe-55, Co-60, Ni-63, Zn-65, Sr-90, Cs-137, Po-210, Np-237, U-238, Pm-147, Ce-144, Ru-106, Ac-227, and Am-241. All operations using Ra-226 were discontinued in 1968, and in 1969 USRC sold all of the radioisotope business except for the H-3 production.

On November 24, 1982, USRC changed its name to Safety Light Corporation (SLC). SLC is licensed by the NRC to use H-3 in the production of luminous signs and dials, paints, gas chromatograph foils, and accelerator targets. Although only H-3 has been used in the SLC facilities, most of the buildings on the U.S. Radium site were used for the previously discussed radioactive materials work.

The current product line includes a variety of H-3 products:

- Self-luminous safety devices for use in commercial/military aircraft, commercial buildings, and marking of aircraft and helicopter landing areas;
- Research and industrial applications;
- H-3 tritide-coated rods and pins for use in military and industrial type electron tubes; and
- H-3 targets for use in neutron-generating devices.

USR Metals, Inc. leases portions of the remaining eight acres of the site to conduct non-radioactive operations involving the manufacture of dials, nameplates, and other speciality products used in a variety of industrial and military applications. USR Metals, Inc.'s operations also involve anodizing of aluminum products and application of specialty protective films to the surfaces of various metal items.

2.1.3 Facility Layout and Site Structures

Figure 1 in Appendix 1 presents a map of the facility layout and site structures. Table 1 presents a key identifying each building or area in Figure 1 by number. Figures included in this report represent a best guess of the site layout based on available documents. These figures are not to scale. Locations and sizes of features (e.g. the canal) have not been confirmed with on-site measurements.

Table 1. Identification of Buildings and Areas in Figure 1

1.	Personnel Office Building
2.	Water Tank
3.	Machine Shop
4.	Water Tank
5.	Pipe Shop
6.	Multimetals Waste Treatment Plant
7.	Carpenter Shop
8.	Well House
9.	Lacquer Storage Building
10.	Radium Vault
11.	Utility Building
12.	Contaminated Soil South East of 8'X8' building
13.	Liquid Waste Building
14.	Old House
15.	Solid Waste Building
16.	Metal Silo (Above Ground)
17.	Contaminated Soil Area (Adjacent to Old Berwick Road)
18.	Contaminated Soil Area (North of Machine Shop)
19.	Approximate Location of Abandoned Canal
20.	Contaminated Soil Area (Between Abandoned Canal and River)
21.	Contaminated Soil Area (Between Abandoned Canal and River)
22.	Contaminated Soil Area (Between Abandoned Canal and River)
23.	Contaminated Soil Area (Between Abandoned Canal and River)
24.	Contaminated Soil Area (In Front of the Above Ground Silo)
25.	Etching Building
26.	Annex to Etching Building
27.	Main Building
28.	Hand Application Areas (Second Floor of Main Building)
29.	Nuclear Building
30.	Tritium Stack
31.	Cesium Ion Exchange Unit
32.	Contaminated Soil Area (South of Radium Vault)
33.	Cement Through/Sewer Grate (Behind Main Building)
34.	Contaminated Soil Area (Under Loading Dock)
35.	Contaminated Soil Area (From Vance/Walton Property)
36.	Contaminated Soil Area (North of Lacquer Storage Building)
37.	West Plant Dump
38.	West Lagoon
39.	East Plant Dump
40.	East Lagoon
41.	Buried Silo Area
42.	Sidewalk Areas
43.	Garage

2.2 Overview of Site Characterization

According to site documents, seven environmental investigations of the SLC site have been conducted since 1978. Three environmental summary reviews were also prepared from available data. These investigations and environmental reviews are further described below.

- 1978** Giles Drilling Corporation initiated groundwater monitoring with the installation of monitoring wells 1, 2, and 3 located in the southern portion of the facility south of the underground silo area. No investigational report or initial groundwater monitoring data is available from this investigation; however, boring logs for these wells are included in the Meiser & Earl Report.
- 1979** Meiser & Earl Hydrogeologists conducted a hydrogeological investigation, including installation of thirteen monitoring wells and three wells for background (wells 4 through 19). Investigation activities commenced on January 29, 1979, and were completed in March 1979. Objectives of the investigation were to determine the depths to groundwater, water-table gradients and flow directions, existing water quality, extent of any radiological contamination from abandoned disposal areas, and to propose appropriate pollution abatement techniques. Investigation activities included the collection of interval soil samples for textural classification and radioactivity analysis and the construction of screened or cased wells from which water samples could be collected.
- 1979** Radiation Management Corporation (RMC) conducted a radiological investigation in conjunction with the Meiser & Earl investigation. RMC reportedly used soil and groundwater collected both by Meiser & Earl and by themselves for radiological analyses. The report for this investigation was not reviewed as part of this study; however, ground water data for wells 1, 2, and 3 were included in the Meiser & Earl report.
- 1981** Oak Ridge Associated Universities (ORAU) performed an environmental survey under contract to the NRC. ORAU conducted survey activities at the SLC site during the periods of June 8-12 and August 24-28, 1981. This survey reviewed the SLC's program for controlling and monitoring radiation and radioactivity levels. Data were collected to confirm measurements performed by the licensee, to evaluate the adequacy and accuracy of environmental controls and monitoring procedures, and to determine if environmental contamination was occurring. Survey activities included the measurement of direct radiation levels in unrestricted areas around the entire property, monitoring routine releases of tritium in stack air and liquid effluents from SLC activities, and measurement of radionuclide concentrations in the environment as a result of present and previous operations of SLC and U.S. Radium. Boreholes were drilled for the collection of subsurface soils; however, no monitoring wells were installed.

Note: The facility description in this report indicates 23 wells had been installed for monitoring groundwater. Only 19 wells had been installed as of the 1979 Meiser & Earl Hydrogeologic Investigation.

- 1988** NRC performed an environmental evaluation of the site using available monitoring data. The objective of this evaluation was to compile information about on-site contamination, to assess the hazards to nearby residents, and to make recommendations about further remediation actions. Although the report for this evaluation was not reviewed as part of this study, the 1995 Monserco report discusses NRC's conclusions.
- 1990** Chemical Nuclear Systems, Inc. (CNSI) conducted a hydrogeological and radiological evaluation of the SLC facility between June 18, 1990, and July 18, 1990. This study was a response to a Partial Interim Settlement Agreement between USR Industries and the NRC. This settlement required partial studies of the nature, scope, location, and movement of radioactive contamination at the SLC facility. This evaluation was also intended to provide characterization data required to be collected by the NRC according to the settlement agreement. The evaluation was not considered comprehensive in scope. The primary objectives of this study were to assess the hydrogeologic flow regime and the potential for off-site radiological migration from the site. Activities conducted include soil coring, installation of 9 monitoring wells (wells A through I), and groundwater sampling.
- 1991** NUS Corporation Superfund Division prepared a summary document using all existing SLC reports. Although this report was not reviewed as part of this study, the 1995 Monserco report discusses the report's conclusions. The March 2001 PADEP report references a July 1991 USEPA Preliminary Assessment, which is based on the NUS Corporation Documents. It is unclear whether this assessment and the NUS Corporation document are related.
- 1995** Monserco Limited conducted site characterization activities between May 1995 and December 1995. Objectives of the site characterization were to determine the extent of radiological contamination on ground surfaces, determine whether radioactive contaminated items are buried under the SLC grounds, gain access to the two underground silos and obtain information on their contents, sink new boreholes and wells (wells M1 through M13), sample and analyze the subsurface soils and waters, and determine the extent of radiological contamination inside the buildings.
- 2000** A Health Consultation Report documenting past sampling data was issued by the Agency for Toxic Substances and Disease Control in April 2000. This report was not reviewed as part of this study.
- 2001** The Pennsylvania Department of Environmental Protection (PADEP) implemented a Hazardous Sites Cleanup Act (HSCA) funded assessment of the SLC property. Foster Wheeler Environmental Corporation was contracted to conduct the site assessment activities, which commenced on August 7, 2000, and were completed on August 9, 2000. The primary objectives of this assessment were to perform sample collection and analysis of surface water and groundwater in and around the site. Activities included collection of groundwater from monitoring wells, collection of surface water from the adjacent Susquehanna River, and collection of water from nearby residential wells.

2.3 Decontamination and Remediation Activities

Few details of decontamination and remediation activities conducted at the site are provided in the Monserco Site Characterization Plan and Site Characterization Report. Several buildings appear to have been partially decontaminated since 1958, but are not well documented. The Characterization Report indicates that plans were made to precipitate radioactive constituents out of canal water and discharge the treated water to the Susquehanna River around 1960. Contaminated sediments were to be excavated, however there is no documentation confirming that these plans were carried out. The Characterization Plan notes that the full extent of decontamination in the canal is not known but that some remediation and backfilling of the three eastern-most lagoons were carried out in the late 1970's. The only other known outdoor remediation activity is the 2000 remediation of the underground silos, discussed below.

The site history provided in the Characterization Report indicates that the south end of the Well House was decontaminated in 1958 and that decontamination activities took place in the Main Building and on the roof of the Main Building in 1969. The extent and location of these activities is not specified. However, the activities were intended to allow unrestricted access to the first and second floors of the building. The former Hand Painting Department on the second floor has been decontaminated, but the attic above still contains contaminated ducts from the old radium painting operations.

The H-3 operations in the Machine Shop were moved in 1969 when the current Tritium Building was constructed. The Machine shop is thought to have been partially decontaminated at that time. According to the site history provided in the Characterization Plan, decontamination of facilities currently occupied by USR Metals was intended to allow a safe working environment for staff. According to the Characterization Report, part of the east wall in the Carpenter shop was replaced with polyblock due to the explosion of a Sr-90 source. Finally, the Characterization Report indicates that the Utility Building has been partially decontaminated.

Remediation of the two underground silos was conducted in 2000. The two silo bases remain, as well as the surrounding contaminated soil. The waste has not yet been sent off site. A Work Plan for a silo waste removal project has been requested by NRC and PADEP, and as of August 3, 2001, Safety Light is awaiting bid proposals. This waste has not been removed from the site to date and is currently stored in B-25s and drums in a storage area between the above ground silo and the Solid Waste Building.

3.0 Site Characterization Review Methodology

In this section we describe the guidances used to develop our methodology for assessing the adequacy of prior characterization efforts, the regulatory levels of interest, and our methodology for determining whether SLC adequately characterized the building/structures, surface soils, subsurface soils, and groundwater.

3.1 Review of Applicable Sampling Guidance

We reviewed several characterization methodologies to develop our methodology for evaluating the adequacy of the characterization data. Specifically, to evaluate the adequacy (i.e., degree of characterization and representativeness) of the collected sampling and monitoring data, we used sampling guidance for characterizing hazardous wastes managed in land-based management units, Envirocare's waste acceptance criteria, NRC guidance documents, and best professional judgment. We describe these sampling guidances and their application below.

Characterizing Hazardous Wastes in Land-Based Management Units

The problem of characterizing wastes that are randomly heterogeneous (i.e., the makeup of the waste changes by process and time, such as tritium wastes in one location and radium wastes in another location) is not a unique one. Whether one is looking for radioactive wastes, hazardous wastes, or mixed wastes, the problem is the same – “how many samples do I need to collect to ensure that I find the waste?” In evaluating sampling data provided by disposal facility operators attempting to demonstrate that their wastes are not hazardous, we review their sampling plans to see if they meet our minimum threshold for total number of samples, which is typically derived by:

- dividing the land-based management unit (impoundment or landfill) into equal-sized sections or grids (a minimum of four) of no greater than 10,000 ft² each
- selecting four sampling points at random from each section
- collecting full-depth core samples (to the base of unit or top of ground water table)
- compositing the four, full-depth core samples collected from each section in the laboratory to produce a four-point composite sample (and repeat for each section).

For subsurface sampling, when there is significant depth and a reasonable possibility of variability, we follow the same methodology, only we would require that the full-depth core samples be divided to represent specific depth intervals. For example, several full-depth core samples could be collected and composited within a section by specific depth intervals (e.g., 0-5 feet, 5-10 feet, 10-15 feet) until the ground water table is encountered (or lower, if contamination is known or shown to have migrated below the water table).

We used this approach, which is based on SW-846 and is used by EPA⁵, to further develop our methodology for determining whether a sufficient number of samples was collected to characterize the soils and subsoils at the SLC site.

For ground water, we generally like to see a minimum of three monitoring wells installed at intervals of no more than 250 feet apart along the entire downgradient boundary of the unit, and at least one upgradient well (which must be unaffected by the disposal unit). We typically review groundwater monitoring data collected from all the wells over four quarters, spanning an entire year for all analytes potentially present, so as to characterize seasonal variations in the underlying groundwater regime and contaminant levels. We used this methodology, which is based on SW-846 and is used by EPA⁶, to determine whether a sufficient number of samples was collected to characterize the underlying groundwater.

Waste Acceptance Criteria

Envirocare of Utah, Inc., as a condition of its acceptance of waste, requires facilities both to complete a detailed characterization of the waste stream and prepare a waste stream profile. Specifically, Envirocare requires that the history of the waste and the process by which the waste was generated be fully understood and documented. Hazardous waste determinations, radiological testing and evaluation, and related information must be made before the waste stream profile can be prepared. The generator is responsible for accurately and fully characterizing the waste and completing the waste stream profile. Although Envirocare does not specify a minimum number of samples on which the characterization and profile are to be based, it does require the generator to know the chemical and radiological composition of the waste and specifies:

“Please obtain sufficient samples to adequately determine a range and weighted average of activity in the waste. Analyze all waste streams by gamma spectroscopy. Obtain sufficient samples to ensure that results represent the waste. If Uranium, Plutonium, Thorium, or other non-gamma emitting nuclides are present in the material, the waste must be analyzed using radiochemistry to determine the concentrations of these additional contaminants in the material...”

We weighed Envirocare's requirements in our decision-making process to determine whether a sufficient number of samples and analytes was characterized.

⁵ See “Petitions to Delist Hazardous Waste - A Guidance Manual,” U.S. EPA, Office of Solid Waste, (EPA/530-SE-85-003), April 1985.

⁶ See 40 CFR Part 264 Subpart F.

NRC Guidance Documents

Two NRC guidance documents were consulted, the *Draft Branch Technical Position on Site Characterization For Decommissioning*, (Branch Technical Position), Division of Waste Management, NMSS, November 1994; and the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM), NUREG-1575, EPA 02-R-97-016, December 1997.

The Branch Technical Position provides a generic approach to site characterization and to preparation of a site characterization report (SCR). It describes NRC's expectations for how an SCR should describe the history and general physical setting of a site, the nature and extent of contamination, the physical characteristics of the site, and the dose assessment. The Branch Technical Position also provides references to more specialized documents addressing data collection, radiological surveys, testing methods, modeling, and quality assurance/quality control. In this task, the Branch Technical Position provided a framework for evaluation of data from previous characterization.

Broadly speaking, MARSSIM provides detailed guidance for planning, implementing, and evaluating environmental and facility radiological studies to demonstrate compliance with a dose-based or risk-based regulation. However, MARSSIM focuses on demonstrating compliance through a final status survey following scoping, characterization, and any necessary remedial action. Thus, MARSSIM's usefulness is limited in its application to the SLC site, because the focus of this investigation is characterization and because the MARSSIM methodology assumes that the results of a characterization or scoping study are available. Specifically, a characterization study has different data needs than a final status survey. For example, one of the objectives of a characterization survey is to determine if sampling areas are homogeneous or heterogeneous. That is, is the radioactive contamination consistent over a sampling area, or is it prone to hot spots? If the contamination is heterogeneous, more samples will be required to adequately characterize the site for the final survey. In addition, one of the variables needed to determine the number of samples for the final status survey is a measure of the homogeneity or heterogeneity of the sampling area. Thus, the MARSSIM methodology cannot be used to determine the number of samples needed in a characterization survey, because it assumes the availability of the results of the characterization survey as inputs to the final status survey. We did not use MARSSIM to determine the adequacy of the available characterization data provided to ICF.

We were cognizant of the principles in the Branch Technical Position and MARSSIM while conducting our assessment, including the following:

- Use of historical site assessment information to divide the site into classification areas (i.e., non-impacted areas and impacted areas). Areas that have no reasonable potential for residual contamination are classified as non-impacted areas. These areas have no radiological impact from site operations. Examples of non-impacted areas usually include residential or other administrative buildings that have or had nothing more than smoke detectors or exit signs with sealed radioactive sources. Impacted areas can be divided into three classes:

- Class 1 areas are areas that have, or had prior to remediation, a potential for radioactive contamination (based on operating history) or known contamination (based on previous radiation studies) *above the DCGL*.⁷
 - Class 2 areas are areas that have, or had prior to remediation, a potential for radioactive contamination or known contamination, but are *not expected to exceed the DCGL*.
 - Class 3 areas are any impacted areas that are not expected to contain any residual radioactivity, or are expected to contain levels of radioactive activity at a small fraction of the DCGL based on site operation history and previous radiation studies.
- Division of the site into sample grids.⁸
 - Review of analytical data to the detection sensitivity of the instrumentation and comparison to the applicable DCGL.
 - For direct measurements and sample analyses, MARSSIM states that minimum detectable concentrations (MDCs) less than 10 percent of the DCGLs are preferable, while MDCs up to 50 percent of the DCGLs are acceptable.

3.2 Regulatory Levels of Interest (DCGLS, etc.)

As noted earlier, one of the main objectives of this characterization study is to determine whether SLC has adequately characterized the nature and extent of the radiological and mixed (radiological and chemical) contamination at the site. Although one typically compares the observed characterization data to the regulatory levels to determine if decontamination or remediation is necessary, one can also use the regulatory levels of interest (or concern) as a tool for assessing the degree of sampling accuracy (i.e., how representative are the samples of the average "waste" being characterized) and precision (i.e., how representative are the samples of the expected variation in contaminant levels) that is required. For example, a higher degree of accuracy and precision would be required if one or more contaminant is present at a level (activity or concentration) that is close to the applicable regulatory threshold. Alternatively, relatively low precision can be tolerated if the contaminants of concern occur at levels far below or far above their applicable thresholds. However, one should ensure that a sufficient number of

⁷ In this review, we accept the DCGLs presented in the Monserco Report.

⁸ The Branch Technical Position references NRC's *Manual for Conducting Radiological Surveys in Support of License Termination*, NUREG/CR-5849, ORAU-92/C57, for additional guidance on classification of areas by contamination potential and on establishing reference grid systems. Our assessment is consistent with this approach.

samples are collected to be representative of the entire population, and care should be used when designing a sampling plan to ensure that the entire area of interest is characterized.

As instructed by the NRC, we used the release criteria that have been translated into derived concentration guideline levels (DCGLs), as calculated by SLC, as levels of regulatory concern. Table 3 lists the DCGLs proposed in the SLC Decommissioning Plan. Table 2 also lists the NRC soil and ground water limits, which were given in the Monserco Characterization plan, which cited *Current Guidelines on Acceptable Levels of Contamination in Soil and Groundwater on Property to be Released for Unrestricted Use*, U.S. NRC, January 1992.

**Table 2. Radiological Limits for Soil and Groundwater
(DCGLs calculated by SLC)**

Nuclide	Surface DCGL (dpm/100 cm ²)	Soil DCGL (to 2 m) (pCi/g)	NRC Soil Limit ^a (pCi/g)	Ground Water Limit ^a (pCi/L)
H-3	1.10E+08	1024	--	20,000
Co-60	--	--	8	100
Sr-90	43,160	5	5	8
Cs-137	40,500	11	15	200
Am-241	112	1	30	--
Ra-226	2,170	1.5	5	5
Bi-214 ^b	--	--	5	--
Pb-214 ^b	--	--	5	--
gross alpha	--	--	--	15

^a A blank in this column indicates that a limit was not provided.

^b NRC soil limits provided in Appendix 10 of Monserco Characterization Report.

3.3 Integrated Review Methodology

The methodology for evaluating the adequacy of SLC's sampling data is based on the approach described for assessing hazardous wastes disposed in land-based management units, Envirocare's waste acceptance criteria, and best professional judgment (which included factors such as sampling accuracy and precision, site history, and relative comparisons of observed contaminant levels to regulatory levels of concern), and the insights gained from NRC guidance documents. Our methodology employs a series of questions and answers to form the basis for determining if a particular media was adequately characterized. Based on the number of "No" answers received and the relative importance of each question, best professional judgment was used to determine if each building/structure or media type is sufficiently characterized. The application of this methodology to each media type is further described in the following sections.

Buildings

1. Have historical records been kept for all rooms in a building?
2. Has each building been classified as impacted or non-impacted?
3. Has each room in an impacted building been assigned a Class 1, 2, or 3 ranking and appropriately divided into sampling grids?
4. Has a sampling plan been prepared based on the Class ranking for that room/building?
5. Does the sampling plan address QA/QC requirements?
6. Has sampling been conducted in each room according to the sampling plan?
7. Is the number of samples taken known for each room?
8. Are the detection limits for each analytical instrument known for each room?
9. Has sampling been conducted for each room using appropriate instrumentation with appropriate sensitivity?
10. Are all sample results below the DCGL?
11. Were samples collected from beneath the building or areas of known releases?

Surface Soils

1. Have historical records been kept for all surface areas on the site?
2. Has each distinct surface area been classified as impacted or non-impacted?
3. Has each distinct surface area been assigned a Class 1, 2, or 3 ranking and appropriately divided into sampling grids?
4. Has a sampling plan been prepared based on the Class ranking for all sample grids?
5. Does the sampling plan address all analytes of concern?
6. Does the sampling plan address QA/QC requirements?
7. Has sampling been conducted in each grid according to the sampling plan?
8. Is the number of samples taken known for each grid?
9. Is the number of samples equal to or greater than the minimum that would be calculated using our land-based management unit characterization methodology?
10. Are the detection limits for each analytical instrument known for each grid?
11. Has sampling been conducted for each grid using appropriate instrumentation with appropriate sensitivity?
12. Are all sample results below the DCGL?

Subsurface Soils

1. Have historical records been kept for all burial activities on the site?
2. Has each distinct sub-surface area been classified as impacted or non-impacted?
3. Has each distinct sub-surface area been assigned a depth of concern and appropriately divided into surface sampling grids?
4. Has a sampling plan been prepared for each impacted subsurface area based on the historical knowledge and surface contamination?
5. Does the sampling plan address all analytes of concern?
6. Does the sampling plan address QA/QC requirements?
7. Has sampling been conducted in each distinct subsurface area according to the sampling plan?
8. Are the number and depths of samples taken known for each distinct subsurface area?

9. Is the number of samples equal to or greater than the minimum that would be calculated using land-based management unit characterization methodology?
10. Are the detection limits for each analytical instrument known for each distinct subsurface area?
11. Has sampling been conducted for each distinct subsurface area using appropriate instrumentation with appropriate sensitivity?
12. Has clean soil been found below the deepest level of contamination?
13. Are all sample results below the DCGL?

Ground Water

1. Have historical records been kept for prior groundwater sampling events on the site?
2. Are the depth, direction, and flow of groundwater at the site known?
3. Are the uses of all aquifers known?
4. Has each distinct aquifer been classified as likely-impacted or non-impacted?
5. Has a sufficient number of wells been located downgradient of each known source, or on the downgradient portion of the facility?
6. Has a sampling plan been prepared for each likely-impacted aquifer based on historical knowledge, known surface and sub-surface contamination, and seasonal changes in groundwater flow and depth?
7. Does the sampling plan address all analytes of concern?
8. Does the sampling plan address QA/QC requirements?
9. Has sampling been conducted in each aquifer according to the sampling plan?
10. Are the number and depths of samples taken known for each well?
11. Are the detection limits for each analytical instrument known for all samples?
12. Has sampling been conducted for each well using appropriate instrumentation with appropriate sensitivity?
13. Are all sample results below the NRC or State regulatory levels?

These questions were applied to buildings/structures, surface soils, subsurface soils, and groundwater, and used the answers as a tool for identifying gaps in the site characterization.

At this point it is appropriate to emphasize the reason for this report's evaluation of whether or not additional characterization is needed for this site. As the overall focus of this Task Order is to develop cost estimates for site decommissioning, one obvious reason for understanding the magnitude (and cost) of additional characterization, is to allow for any additional costs to be incorporated into site decommissioning cost estimates. SLC's current cost estimates assume that no additional characterization work is required at the site prior to the commencement of whole site remediation; this report will answer if that assumption is reasonable. An additional reason for investigating whether additional characterization is required, is to allow the government as regulators or as site owners (if the site ever becomes a federal liability) to make informed decisions about the site. One example is that this report recommends additional groundwater characterization, to address a previous misunderstanding in groundwater flow. The report presents this information for NRC's evaluation as the current regulator. Additionally, if the site were to ever become a federal liability, this report could serve to assist an agency in developing

financial plans to deal with the site (e.g. based on this report an agency could choose to seek an appropriation of \$500K to finish site characterization, then refine the cost estimate to "\$X" M with the new characterization data, then seek an appropriation of "\$X" M for remediation).

Recommendation of areas for additional characterization 1) does not indicate immediate health and safety issues; 2) is not meant to direct NRC to take any specific actions as regulators; 3) is not meant to be a criticism or indication that previous studies of the site were inadequate for their intended purposes; and 4) in no way is meant to be a request of SLC to perform additional characterization.

3.4 Steps to Determine If Additional Characterization Is Needed

In order to determine whether additional characterization is necessary, and if so, how much additional characterization should be conducted, the questions described above were answered and considered in conjunction with the following: 1) the approach described for assessing hazardous wastes disposed in land-based management units; 2) Envirocare's waste acceptance criteria; 3) relative comparisons of observed concentrations to levels of regulatory concern; 4) best professional judgement; and 5) insights gained from NRC guidance documents. Absent "hard" guidelines for calculating exact numbers of samples, the methodology described in Sections 3.1 through 3.3 was invoked and operated between two extremes. One of these extremes is if, based on the sampling-to-date, the surrounding areas (e.g., grids) are sufficiently contaminated that additional characterization will not change the ultimate management of these areas, we assumed that the non-characterized area would exhibit the same characteristics exhibited by the characterized (and contaminated) areas. For example, if the methodology shows that a specific grid is inadequately characterized, but data show that surrounding grids have contaminants with levels or concentrations above the DCGL, the inadequately characterized grid was assumed to also be contaminated above the DCGL and would need to be remediated in the same manner as the surrounding grids. Thus, little benefit would be gained by further characterizing this previously under-characterized grid and a recommendation was made that no additional pre-remediation characterization be conducted in this grid.

The other extreme is a situation in which so little information is known about a contaminant of interest or area or media type that NRC would be forced to make worst-case assumptions absent further sampling, even though these assumptions might be overly conservative relative to the contamination actually present. For example, if a particular surface soil grid had a contaminant above the DCGL, yet the underlying subsurface grid had not been sampled for this contaminant, the assumption was made that the underlying soil grid is also contaminated. In addition, absent any information on the possible vertical extent of contamination, the depth of contamination was assumed to extend to the top of underlying groundwater table. This assumption is conservative and could result in several meters of subsurface soil being remediated.

A third consideration in recommending additional characterization is the relative cost of additional sampling versus worst-case cost assumptions regarding treatment and/or disposal. For example, it may be more cost effective to require SLC to demolish a structure, super compact (or otherwise process) the debris, survey the debris, and ship the debris off-site for disposal, than it

would be to require SLC to shore-up the unstable structure, survey the structure, remediate the structure, process the debris, survey the debris, ship the debris off-site, and then resurvey the structure.

The specific application of the methodology described in this section and the determination of whether additional samples need to be collected by media is further described in Sections 4 through 8.

3.5 Cost of Additional Sampling

Unit costs for sample collection and analysis by media have been developed and are presented in Table 3. These unit costs are based upon costs presented in the 2001 R.S. Means *Cost Assemblies* and 2001 RS Means *Environmental Remediation Cost Data - Unit Price*, the 1997 *Mineral Processing Regulatory Impact Analysis*, and the 2000 *Decommissioning Cost Estimate for Safety Light Corporation for License 37-00030-02*. These unit costs have been used to calculate the costs of additional sample collection and analysis.

Table 3. Unit Costs of Additional Sampling by Media

Item	Unit cost	Unit	Source	Page
Water Analysis				
TAL Metals	\$ 298.36	per sample	RS Means Cost Assemblies	p. 3-258
VOCs	\$ 188.83	per sample	RS Means Cost Assemblies	p. 3-258
Total Pet. Hydrocarbon	\$ 60.96	per sample	RS Means Cost Assemblies	p. 3-258
gamma isotopic spectroscopy	\$ 128.75	per sample	RS Means Cost Assemblies	p. 3-269
Ra-226, alpha spectroscopy	\$ 96.13	per sample	RS Means Cost Assemblies	p. 3-269
Soil Analysis				
TAL Metals	\$ 298.36	per sample	RS Means Cost Assemblies	p. 3-261
VOCs	\$ 188.83	per sample	RS Means Cost Assemblies	p. 3-261
Total Pet. Hydrocarbons	\$ 60.96	per sample	RS Means Cost Assemblies	p. 3-261
Gamma isotopic spectroscopy	\$ 103.00	per sample	RS Means Cost Assemblies	p. 3-272
Gross beta counting	\$ 63.52			
Tritium - liquid scintillation	\$ 78.97	per sample	RS Means Cost Assemblies	p. 3-272
Soil Borings				
Drilling 4" dia. 0-10 ft	\$ 25.55	per ft	RS Means Unit Price	p. 9-24
Drilling 4" dia. 11-20 ft	\$ 16.36	per ft	RS Means Unit Price	p. 9-24
Drilling 4" dia. 21-30 ft	\$ 13.94	per ft	RS Means Unit Price	p. 9-24
Split Spoon Sampling	\$ 37.68	per sample	RS Means Unit Price	p.9-242
Monitoring Wells				
Installation	\$ 5600.00	per well	1997 Mineral Processing RIA	p. D-57
Building Sampling Equipment Rental				
MICROSPEC-2 NaI(Tl), Gamma Spec System w/ Detector, PC, Software, Case and Accessories	\$1,877	Cost per Month	Decommissioning Cost Estimate For SLC, License 02, Rev. 0	App. A-8
GENI PC, Gamma Spec System w/ Detector, PC, Software, Case and Accessories Model 4610J/GC4519	\$3,646	Cost per Month	Decommissioning Cost Estimate For SLC, License 02, Rev. 0	App. A-8

Item	Unit cost	Unit	Source	Page
Eberline - Portable Alpha Courier, Model SAC-4	\$701	Cost per Month	Decommissioning Cost Estimate For SLC, License 02, Rev. 0	App. A-8
Eberline - Portable Beta Courier, Model BC-4	\$578	Cost per Month	Decommissioning Cost Estimate For SLC, License 02, Rev. 0	App. A-8
Ludlum - Model 19 Micro R Meter w/ hard case	\$185	Cost per Month	Decommissioning Cost Estimate For SLC, License 02, Rev. 0	App. A-8
Ludlum - Model 177 Alarm Rate Meter w/44-9 Probe and Case	\$177	Cost per Month	Decommissioning Cost Estimate For SLC, License 02, Rev. 0	App. A-8
Ludlum - Model 2350 Date Logger KR, w/ Keypad, Barcode Reader, Case and Detectors	\$1,561	Cost per Month	Decommissioning Cost Estimate For SLC, License 02, Rev. 0	App. A-8
Ludlum - Model 43-5 Alpha Scintillation Detector	\$80	Cost per Month	Decommissioning Cost Estimate For SLC, License 02, Rev. 0	App. A-8
Gamma Spec. NIST Traceable Mixed Soil Equivalent 1 Liter Marinelli	\$205	Cost per Month	Decommissioning Cost Estimate For SLC, License 02, Rev. 0	App. A-8
Gamma Spec. NIST Traceable Mixed Water Equivalent 1 Liter Marinelli	\$205	Cost per Month	Decommissioning Cost Estimate For SLC, License 02, Rev. 0	App. A-8
Gamma Spec. NIST Traceable Mixed Filter Paper Equivalent 1 Liter Marinelli	\$185	Cost per Month	Decommissioning Cost Estimate For SLC, License 02, Rev. 0	App. A-8
NIST Tc-99 47mm source per each (1,10,100 or 100nCi)	\$74	Cost per Month	Decommissioning Cost Estimate For SLC, License 02, Rev. 0	App. A-8
NIST Th-230 47mm source per each (1,10,100 or 1000nCi)	\$89	Cost per Month	Decommissioning Cost Estimate For SLC, License 02, Rev. 0	App. A-8

4.0 Buildings

This section provides an overview of the characterization activities performed on the 19 facility buildings during the 1995 Monserco Site Characterization. Current operations are limited to approximately six of these buildings. The remaining buildings are used for storage or have been abandoned due to disrepair. In Section 4.1, survey methodologies from both the Characterization Report and Characterization Plan are described and a detailed description and history for each of the facility buildings is provided. Characterization findings are summarized in Table 2. Section 4.2 identifies potential gaps in characterization. Section 4.3 provides recommendations for further characterization and Section 4.4 identifies potential costs of additional characterization.

4.1 Summary of Existing Characterization

4.1.1 Building Gridding System

In order to characterize each of the buildings, Monserco divided each room into manageable sections (or grids). Gridded sections were identified by temporary numbered labels. The normalized gridding arrangement was used to allow areas of contamination to be identified at a later date for decontamination and/or decommissioning without reliance on the temporary labels.

Room walls were gridded starting at the southwest corner of the room. Monserco sectioned the south facing wall into gridded areas of approximate equal length and moved in a counterclockwise direction until all wall surfaces had been gridded. The horizontal and vertical distances between grids are both approximately 2 meters. Variations in this method were caused by fixed or unmovable equipment inside a room. Hot spots on walls were designated by a grid number and x,y coordinates with reference to the southwest corner of the grid

Room floors were similarly sectioned into gridded areas of approximate equal length. Starting again in the southwest corner of the room, the floor was sectioned first by moving west to east and then east to west until the entire floor surface was covered. Hot spots on floors were designated with reference to the northeast corner of each grid.

Ceilings were sectioned into 1, 2, or 4 gridded areas, with larger numbers used occasionally.

4.1.2 Characterization Methodology

Although the Characterization Report did not provide a detailed methodology for the building survey, the Characterization Plan discussed specific survey requirements for each building based on building history and potential for contamination.

The Characterization Plan referenced the NUREG/CR-5849 methodology of categorizing buildings as affected or unaffected depending upon the expectation that radiological contamination would be present in the area. The Characterization Plan further indicated that due to site operations and lack of documentation for radiological clearance, all buildings would be classified as affected. The Characterization Report stated that the radiological survey method

was based on historical information for each room and rooms were categorized as having a high probability of being contaminated (affected) or a low probability of being contaminated (unaffected). The report states that affected rooms were 100% surveyed and approximately 10% of accessible areas in unaffected rooms were surveyed. The Characterization Report does not discuss which rooms were considered affected or unaffected. Safety concerns were also considered and sometimes resulted in variation from this standard.

The survey methodology provided in the Characterization Plan indicates that the following general considerations were to be used in monitoring for contamination:

- Where there is low potential for a contaminant to be present, minimal monitoring for that contaminant will be conducted.
- Where there is high potential for a contaminant to be present, monitoring for that contaminant will be conducted.
- Where radiation levels detected with the Bicon survey meter are close to the clearance levels, detailed monitoring will be conducted and recorded to establish whether decontamination is required.
- Where radiation levels detected with the Bicon survey meter are clearly in excess of the clearance levels, monitoring will be conducted to determine activity and ease of decontamination.

According to the Characterization Plan, affected floors, lower walls, and basements required 100% scans of 2 m grids for alpha, beta, and gamma emissions when radiation levels approached clearance levels. Locations with radiation levels exceeding 2 to 3 times the ambient count rate for any survey unit were to be assessed as elevated for recording purposes and similarly required 100% scans of 2 m grids for alpha, beta, and gamma emissions. Locations with radiation levels obviously in excess of clearance levels required only a record of the average contamination in the whole survey unit (with a maximum size of 100 m²). In these cases, areas with highly elevated radiation levels up to 10 times ambient count rate were to be recorded separately.

A single, 100 cm² smear sample for H-3 and Ni-63 was to be collected in each grid when radiation levels approached clearance levels, so long as H-3 and Ni-63 were expected to be present. Where H-3 and Ni-63 were not expected to be present, four 100 cm² smear samples were to be taken per 100 m² survey unit. Where smear results indicated contamination levels obviously in excess of the clearance levels, smears would be analyzed with less frequency (up to a maximum of one in ten samples).

For upper walls and ceilings where contamination was not suspected or where surveys of the lower walls and floors indicated minimal contamination, a minimum of one measurement per 20 m² would be collected where contamination would be most likely to accumulate. For upper walls and ceilings where contamination was suspected or where surveys of the lower walls and floors indicated contamination was present, and in areas where the radiation clearance levels

were approached, the survey methodology followed that of lower walls and floors. Locations with radiation levels obviously in excess of clearance levels required only a record of the average contamination in the whole survey unit (with a maximum size of 100 m²). In these cases, areas with highly elevated radiation levels up to 10 times ambient count rate were to be recorded separately.

Earthen basements were to be assessed as indicated for floors, walls, and ceilings in the above discussions. Given the porous nature of floors in earthen basements, 100% of floor areas were to be scanned for gamma radiation and samples of surface soil were to be collected. Accessible portions of all ducts and drains present in buildings were to be surveyed. When gamma emitting nuclides were likely, these areas were to be scanned for gamma radiation and when non gamma emitting nuclides were likely, smears were to be collected from these areas and analyzed for the nuclides suspected to be present.

The Site Safety Officer was responsible for making determinations about characterization of collapsed and unsound buildings. Where characterization was possible and safe, assessments were to be completed according to the methodologies described above.

4.1.3 Characterization Techniques

Monserco used the following radiation survey methods for buildings:

- Radiation fields surveys using the Bicon survey meter.
- Gamma energy radiation identification using a portable gamma spectrometer.
- Fixed beta/gamma contamination using Eberline ESP-1 or ESP-2 monitors with HP260 probes.
- Fixed alpha/beta contamination using a Berthold LB122 monitor.
- Loose alpha/beta contamination with cloth swipes.
- Loose H-3 contamination with polyfoam swipes.

Bicon Survey Methodology

One exposure reading using the Bicon survey meter was collected at a distance of 1 cm from each grid of an affected or unaffected room. Measurements could be taken with less frequency where contamination levels were obviously in excess of the clearance levels.

Gamma Spectrometry Survey Methodology

Gamma spectrometry was not performed in every building. No rationale for the selection of buildings with gamma spectrometer readings taken was provided in the Characterization Report. When used, the gamma spectrometer readings were taken in the center of the room and data collected for 30 seconds. These gamma readings did not differentiate between gamma emissions from the building structure and gamma emissions from the equipment or fixtures in the room.

Results of gamma emissions, when done, identified the presence of Cs-137, Ra-226, or Bi-214. We could not conduct any quantitative interpretation of gamma spectrometry results in Appendix 20 of the Characterization Report because information on the location, size, and configuration of the radioactive source relative to the detector was not documented.

Fixed Beta/Gamma Contamination Survey Methodology

Contamination surveys were conducted for walls, floors, and ceilings of the rooms. Available room surface area was scanned at a rate of approximately 1 foot per second. Variations in the loudspeaker clicks and/or increases in the digital output indicated the presence of contamination. When hot spots were encountered, the x and y coordinates within the grid were recorded.

Fixed Alpha/Beta Contamination Survey Methodology

Contamination surveys were conducted for floors primarily, with occasional wall measurements. The available surface area was scanned at a rate of approximately 1 foot per second. Variations in the loudspeaker clicks and/or increases in the digital output indicated the presence of contamination. When hot spots were encountered, the x and y coordinates within the grid were recorded.

Cloth Smear and Polyfoam Smear Methodology

Rad-wipe smears were used to sample loose alpha, beta, and gamma contamination from the walls, floor, and ceilings of a room. Polyfoam smears were used to sample loose H-3 contamination from the walls, floor and ceiling of a room. The sampling procedure was the same for both smears and involved the following steps:

- (1) Applying pressure to the center of the smear, it was brought into contact with about 100 cm² of each grid.
- (2) The smear was assigned a unique identification number incorporating information on the location where the smear was collected.
- (3) The smears were analyzed for total alpha, total beta, and H-3 content in the laboratory.
- (4) Activity in Bq/cm² was converted to dpm/cm² for both alpha and beta.

The Characterization Report does not include any discussion of the methodology used to determine the number and location of smear samples collected.

Loose alpha, beta, and H-3 results for grids and pieces of equipment were compared to the NRC guideline value provided in Table 4 for removable beta/gamma contamination. Similarly, fixed alpha, beta, and gamma results were compared to the NRC guideline value for average beta/gamma contamination. Determination of hot spots was made when fixed contamination was above the NRC guideline value for maximum beta/gamma contamination.

Table 4. NRC Guideline Values for Removable Beta/Gamma Contamination

Survey Type	Removable	Average ¹	Maximum ¹
NRC guideline for beta/gamma emitters (except Sr-90)	1,000 dpm/100cm ²	5,000 dpm/100cm ²	15,000 dpm/100cm ²

Reference: *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material*, U.S. NRC, August 1987.

¹ Average and maximum contamination levels apply to areas not exceeding 1 m² and 100 cm² respectively.

There were a number of variations from the Characterization Plan. Acknowledged variations include:

- Planned characterization of building exteriors was not completed during the investigation because the chances of widespread external contamination were expected to be low and external surfaces had been exposed to the weather.
- The Nuclear Building was not surveyed because operations are currently active and the long-term validity of the survey would be questionable.
- Concrete floors of buildings were not sampled due to potential permanent damage to floors.

Other site-wide variations include:

- Gamma spectrometry readings were taken to identify specific gamma emitting radionuclides present in some buildings.
- Smear samples were analyzed for H-3, gross alpha, and/or gross beta instead of H-3 and/or Ni-63.
- Cloth smears were analyzed using the Eberline Scintillation Alpha Counter, Model SAC-4 and the Eberline Model BC-4 Beta Counter.
- Polyfoam smears were analyzed using a LKB Wallac RacBeta Liquid Scintillation Counter.

4.1.4 Characterization Results

Contamination was identified in all but one of the buildings surveyed. Loose contamination was found in 10 of the 19 buildings. Fixed contamination and hot spots were each found in 14 of the 19 buildings. The discussion below provides a detailed explanation of each building, its history, and a brief evaluation of characterization activities for the building.

Personnel Office Building (Old Nurses Station)

This building is in poor structural condition and is currently used for miscellaneous storage. The building is located outside of the fenced portion of the facility. The building consists of one

room with a below grade cellar which is accessed by an external trap door. In the past, it was used as the personnel office building, as a nurses station, and for storage of Ra-226 and Sr-90 screening machines and strontium chloride. The basement reportedly contains a contaminated cesium screening machine and a contaminated dry well. A 2 foot diameter, 2 inch thick concrete slab beneath the trap door is believed to cover an old dry well. SLC personnel believe that this dry well is the "primary suspicious" dry well on site. Material surplus may have been disposed of in this dry well. A concrete floor was poured over the wooden first floor at some point in time. The building was abandoned when this floor collapsed.

The only variation from the Characterization Plan during survey of this building was a failure to collect survey measurements and swipe samples from the ceiling. However, given the poor structural condition of the building this may have been a worker safety measure. Isotopic concentration results provided in Appendix 19 include a fallen ceiling sample from this building. None of the isotopes were detected in the sample. Given instrument minimum detectable activity levels (MDAs), characterization results for this building may not reflect Sr-90 contamination.

Water Tank/Pump House

The water tank is a large metal tank used to hold municipal water in the event of fire. During the site visit ICF observed rust corrosion on the tank. Located beside the tank is a small building used as a pump house. This building was not included in the 1995 Monserco Characterization.

Machine Shop (Former Tritium Building)

This building is located on the north side of the Tritium Building and is currently used as a machine shop for non-radioactive materials. A H-3 drain is located near the center of the building and a small H-3 pit is located to the left on the floor. The H-3 drain consists of a small pipe projecting about one foot upward from the floor and is capped with masking tape. An electric motor is supported by a small concrete block structure at the southeast corner of the building exterior. The soil under the motor is at ground level. In the early 1960's, the building was used for manufacturing and handling of H-3 foils and H-3 luminous compounds. Prior to 1969, glove boxes were located along the walls and connected to a 3 inch diameter pipe serving as an exhaust duct. The H-3 operations were moved in 1969 when the current Tritium Building was constructed. The building is thought to have been partially decontaminated at that time.

Variation from the Characterization Plan during survey of this building included failure to collect 100% survey measurements for fixed contamination. Specifically, walls and floors were not surveyed for fixed contamination. This is a deficiency given the H-3 history for the building; however, because radiation levels for this building were low it was not considered significant.

Water Tower

This water tower is located west of the Main Building and is no longer used. It was once used to provide water to the sprinkler system. A small shed in front of the tower contained hoses. This building was not included in the 1995 Monserco Characterization.

Pipe Shop (Maintenance Shop)

This one room building was constructed in 1948/1949 over a filled-in portion of the old canal, which had been used for disposal of Ra-226 contaminated ductwork from the New York USR facility. The building has concrete walls, a wooden roof, and a concrete floor. The north wall has two large windows and a door. The south wall has a sliding door at the west end. The east wall has two large windows and two large doors. The west wall contains one doorway covered with plywood. The building was previously used for maintenance work and lead melting. The building is currently used for storage of H-3 screening machines, painting tables, and lead melting pots. The building has a high radon concentration and is ventilated regularly. The back portion of this building has an approximately 12 feet by 12 feet porch area covered by a roof. A partial inventory of waste observed by ICF during the site visit includes an old toilet, gasoline cans, heavy equipment, piping of varying diameters (both plastic and metal), a tractor, wheelbarrow, and old tanks. This pile of waste is approximately 6 feet high throughout the porch area. SLC personnel indicated that several septic tanks were located next to the pipe shop.

There were no significant variations from the Characterization Plan for this building.

Multi-Metals Waste Treatment Plant (USR Metals Liquid Waste Building)

This is a two story building consisting of three rooms: the boiler room, the waste room, and the compressor room. The building is constructed of cinderblock walls, a concrete floor, and a wood roof with asbestos insulation. In the boiler room there is a garage door in the north wall, a large window in the east wall, and a large wooden sliding door and glass window in the west wall of this room. Small sections of the lower west wall have been replaced by cement blocks covered with plaster. There is a 4 feet by 8 feet overflow sump in the northeast quadrant of the floor. A stack that is not currently used is covered at the inlet by the ceiling. The waste room contains a long sump which runs the full length of the floor 2 feet from and parallel to the north wall. There is also a sink and a smaller sump in this room. There is a garage door at the west end of the north wall and a window and door in the west wall. There is one door at the north end of the east wall. The compressor room has cinderblock walls covered in plaster. There are three windows on the north wall, a door and large window on the east wall, two doors and two windows on the west wall, and two windows and a door on the south wall.

The waste room in the building is currently used for treatment of USR Metals liquid wastes. Equipment in this room includes four large treatment tanks and control panels, as well as several smaller epoxy coated tanks and piping. According to the site history provided in the Characterization Plan, decontamination of facilities currently occupied by USR Metals may have occurred to allow a safe working environment for staff.

The compressor room houses five large compressors, two small compressors, an electrical panel, a diesel powered generator, pipes, and a metal storage cabinet. The boiler room was once used to store liquid wastes from anodizing processes and now contains two empty overflow tanks, twenty 55 gallon drums (some containing chemicals), and 40 bags of lime. There is no

radiological history for these rooms; however, they are constructed next to the carpenter shop in which Ra-226 was stored and a Sr-90 source is believed to have exploded. An underground storage tank once used to store diesel fuel is located adjacent to this building.

Variation from the Characterization Plan for this building included failure to collect 100 % survey measurements for fixed contamination. However, the number of grids without fixed measurements is small and this deficiency was not considered significant. Given instrument MDAs, characterization results for this building may not reflect Sr-90 contamination.

Carpenter Shop (Old Maintenance Shop)

This building is in poor structural condition and currently houses contaminated cabinets, steel cupboards, wooden tables, and a sprinkler system. The building has a concrete floor and includes five large windows in the south wall and one window in the west wall. During a 1995 interview, a former employee indicated that the drill press and vacuum cleaner were alpha contaminated. The building was used for storage of Ra-226 in the late 1940's and early 1950's. The building has been sealed. A Sr-90 source exploded near the east wall at some point in time and contamination was reported in 1978. Part of the lower east wall was replaced with polyblock. At the time of the ICF site visit, there was some orange colored metal debris that might have been safety railing sitting on the south side of this building.

There were no significant variations from the Characterization Plan for this building. Given instrument MDAs, characterization results for this building may not reflect Sr-90 contamination.

Well House

This building is built of cinderblock walls with a wood roof and a dirt floor. ICF personnel observed torn insulation hanging from the ceiling at the time of the site visit. There are two windows in the east wall and an 8 inch diameter pipe is located in the floor. The north end of the building contains an old water supply well. The south end is known as the Adhesive Lab and is currently used for the storage of shredded packaging paper. According to the Characterization Report, the south end was decontaminated in 1958. The building contains a 30 gallon water tank and a 530 gallon water tank. The building may still house an underground acetone storage tank (acetone has been found in the ground water). In addition, an underground oil storage tank was found between the Well House and the USR Metals Liquid Waste Building.

Oil has been found in monitoring wells 11 and 12. SLC personnel indicated that there had been an oil spill in the past and that a spill of Sr-90 had occurred inside the building. Ra-226 is also a suspected contaminant.

Variation from the Characterization Plan for this building included failure to collect 100 % survey measurements for fixed contamination. Surveys for fixed contamination were not conducted for the ceilings of the Adhesive Lab. This was not considered significant since none of the measurements in this room were elevated. Surveys for fixed contamination were not conducted for the floor of the Well House. A concrete sample collected from the floor of the

Well House had elevated levels of Ra-226, Bi-214, and Pb-214. Given this result, surveys for fixed contamination in the Well House floor are warranted. Given instrument MDAs, characterization results for this building may not reflect Sr-90 contamination.

Lacquer Storage Building

This is a one room explosion-proof building that was once used to store drums of solvents. There is no history of radioactive materials being stored in this structure. The building is empty now and the roof appears to be collapsing. Old fencing and posts are stored on the ground outside this building.

The only variation from the Characterization Plan during survey of this building was a failure to collect radiation level measurements. However, this was not considered significant since the building has no radiological history and there were no elevated measurements for fixed average or loose contamination measurements recorded for the floors, walls, or ceilings.

Old Radium Vault

This building is in very poor structural condition. The roof has collapsed, inhibiting entry into the building, and beams lie on the floor and against the south wall. The building was used for the pouring of lead and handling/storage of radium bromide, radium foil, and radium radiation sources. All radioactive materials are believed to have been removed from the building. ICF observed vegetation (shrubbery) growing out of the building.

Variation from the Characterization Plan for survey of this building included failure to collect 100% survey measurements for fixed contamination and failure to collect any smear samples for measurement of loose contamination. This is expected given the structural condition of the building and was not considered significant.

Utility Building (Sr-90 Source Vault)

This building is currently used for the storage of non-radioactive materials and supplies. The building was previously used as a Sr-90 source vault. Rust colored I-beams were sunk into the foundation of a porch-like concrete area immediately outside this building. The building itself has a concrete foundation. Reportedly, the building has been partially decontaminated. The roof has partially collapsed. The floor is reportedly tiled, but there are gaps where the walls of the vault used to stand. ICF personnel observed crumbling concrete and the door left open during the site visit. A partial inventory observed by ICF during the site visit included 5-gallon pails of corrosives, bags of salt for de-icing in the winter, and assorted "junk." In addition, a pile of debris was located next to the east wall of this building.

There were no significant variations from the Characterization Plan for this building. Given instrument MDAs, characterization results for this building may not reflect Sr-90 contamination.

8' x 8' Building

This small building has concrete block walls. The building is currently used for storage of H-3 contaminated equipment. In the past, this building was used for the storage of Sr-90 deck markers. A former employee indicated that this building was "comfortably" packed with waste and old equipment, including a large number of concrete blocks assumed not to be contaminated. He further stated that the building was entered only if a piece of equipment is required to carry out the annual contamination check.

The presence of Cs-137, Ra-226, and Bi-214 in the building was identified by gamma spectrometry, however the instrument used for survey of fixed contamination only reflects detection of alpha and beta emissions. Given the presence of these gamma emitters, survey for fixed contamination using an instrument that detects gamma emissions is warranted. Given instrument MDAs, characterization results for this building may not reflect Sr-90 contamination.

Liquid Waste Building

The liquid waste building is a one story building with corrugated metal walls and a metal roof. The building is currently used for dilution of low level H-3 contaminated wastewater from H-3 operations in the Tritium Building. Wastewater is transported by a below grade drain line to a below grade concrete sump within the building and then to one of the four 2,400 gallon dilution tanks before discharge. Before 1960, the building contained below ground vaults used to dilute low level radioactive wastewater from the Main Building and Acid Etching Building. In 1960, a holding tank and evaporator were constructed in the basement for liquid effluents from production buildings. A large flood of the Susquehanna river in 1972 caused the tank and evaporator to float up. The holding tank and evaporator were subsequently filled and the vaults were capped. The remainder of the basement was filled in with soil and covered with a cement slab, which now serves as the floor for the current structure. The slab is now cracked. Contaminated pipes from the old basement are most likely under the slab.

The walls have blown on insulation and plywood is attached to the walls in several locations. The sump (about 7 feet deep) is near the northwest corner of the room and is covered by metal safety grating. The room has a garage door built into the west wall (to allow access for the lawn tractor) and has a fan for ventilation. A partial inventory of equipment observed by ICF personnel during the site visit includes four large metal tanks (2,400 gallon capacity) that were approximately 8 feet high and 8 feet in diameter, four tables/work benches, water samples in plastic gallon containers, pallets, a lawn tractor (i.e., riding mower), a sink, ladders, gardening tools, a jig saw, a hand truck, empty metal 55-gallon drums, an empty overpack, an empty plastic drum, several boxes of returned signs, drums of uncontaminated waste containing the plastic parts of exit signs, several pairs of boots, an old oven, lockers, and cleaning chemicals.

According to the Characterization Plan the suspected contaminants for this building also include Ra-226, Sr-90, Cs-137, Co-60, Am-241, Ni-63, Kr-85.

There were no significant variations from the Characterization Plan for this building. Fixed contamination measurements were collected from walls using an instrument that detects beta and gamma emissions. Fixed contamination measurements were collected from floors using an instrument that detects alpha and beta emissions. Given the history of radioisotopes used or suspected in this building, using an instrument that detects gamma emissions for the floor is warranted. Alternatively, performance of gamma spectrometry in the room may rule out the presence of gamma emitters. Given instrument MDAs, characterization results for this building may not reflect Sr-90 contamination.

Old House

The old house is a two story wood structure with a dug out earthen basement and was built in the 1800's. The interior of the house is in poor structural condition with only remnants of the roof which was largely destroyed by fire in 1998. The first floor is used for the storage of contaminated equipment (pipes/ductwork), wall blocks from the Sr-90 vaults, and other H-3 waste. SLC personnel stated that the second floor was empty but records indicate that the second floor is still used for the storage of contaminated records and supplies. Debris from the fire is piled beside the old house. The Characterization Report indicates that Co-60, Ni-63, Kr-85, Cs-137, Po-210, Ra-226, and Am-241 are also suspected contaminants.

Variation from the Characterization Plan for survey of this building included failure to collect 100% survey measurements for fixed contamination and failure to collect surface soil samples. However, the number of grids without fixed measurements is small and this deficiency was not considered significant. Surface soil samples were collected from grids surrounding the building. Given instrument MDAs, characterization results for this building may not reflect Sr-90 contamination.

Solid Waste Building

This building is a single story concrete block building with a concrete slab floor, wood beam and sheet metal ceiling, metal door, and several small windows. This building is ventilated using a vent line (PVC pipe) that runs from this building to the main H-3 processing building stack in order to reduce H-3 activity. This building is used to store waste from current H-3 processing along with older waste. ICF observed the following inventory of waste during the site visit: drummed waste (about 20 drums), soft packages of waste in brown paper wrappers, "uranium traps," "tube stubs," two old glove boxes, a compactor, scrubber tubes, ladders, assorted smaller containers of radioactive waste, a cabinet, a wall fan (previously used to vent the building), a gas line for heater, and a heater. An approximately 8 feet tall, by 15 feet long, by 5 feet wide wooden bin (made with 2 x 4 inch boards) was completely filled to the ceiling with boxes of waste. The building is also known to house pots contaminated with various radionuclides, filing cabinets, a fume hood, pipework, a drill press, and other miscellaneous equipment. The drummed waste has been there for at least 20 years and may contain paper and H-3 signs. These drums were filled to have no more than 100 Ci/drum.

The Characterization Plan indicates that Ra-226, Sr-90, Cs-137, Co-60, Am-241, Ni-63, and Kr-85 are also suspected contaminants.

Variation from the Characterization Plan for survey of this building included failure to collect 100% survey measurements for fixed contamination. However, the number of grids without fixed measurements is small and this deficiency was not considered significant. Given instrument MDAs, characterization results for this building may not reflect Sr-90 contamination.

Metal Silo (above ground)

The small silo is located near the south east edge of the property and reportedly contains H-3 contaminated equipment (a H-3 pump) and scintillation fluids. The cement foundation is degrading. The silo was once used for storage of Ra-226 ionitrons.

There were no significant variations from the Characterization Plan for this building. Fixed contamination measurements were collected from walls, floors, and ceiling using an instrument that detects alpha and beta emissions. Given the history of radioisotopes used or suspected in this structure, using an instrument that detects gamma emissions might have been preferable. A sand sample taken in the vicinity of this structure had elevated concentrations of Cs-137. This result and the number of elevated results for loose, fixed average, and hot spot contamination make further surveys of this structure unnecessary.

Acid Etching Building

The acid etching building was constructed in the 1940's. The acid etching building consists of many rooms (some of which have drop ceilings). This building is a single story structure and is in poor structural condition in many areas. The soil is exposed in many areas with rotting wood floors. In some rooms the roof has caved in due to snow loading. Some areas of the building are closed off due to either structural damage or high radiation readings. Some areas are currently used for silver plating, chemical storage, maintenance activities, machine tools and dies, and office space. The attic is used to store documents, records, and filing cabinets known to be alpha contaminated.

Between 1949 and 1976, the building was expanded from 16,025 ft² to 32,000 ft². Primary past radioactive processes in this building involved assembly/manufacture of radium and H-3 instruments and dials. The former shipping room has a wooden floor with dirt directly beneath. This room housed radium screening machines. The tritium screening rooms still house exhaust ducts, an absolute filter bank, a blower, and a discharge stack, although the roof has caved in. The discharge stack is 0.6 m in diameter and 18 m high. The main areas of concern are the tritium screening room, the watch dial screening room, the maintenance area, and the former shipping room area.

In 1974, a manufacturing addition (the Butler Annex) was built on the northern end of the building. The Butler Annex houses some of the current USR Metals operations.

The USR Metals cake storage area on the south side of the building, which is used to store 84 drums marked as hazardous waste, as well as old equipment, a pallet truck, pallets, and shelving was observed by ICF during the site visit. It was not clear if the drums were full (they were labeled as hazardous waste, but the start/fill dates were left blank on all of the drums).

There is a small storage area on the west side of the building. Several rooms in the building are closed off with plywood. Some have 1 foot by 1 foot "doors" that could be opened to sample air quality and view the contents. This building has peeling paint in a number of places and the floor tiles are chipped. ICF observed a sagging wood roof in the former shipping room that looked ready to collapse. This room is about 60 feet by 40 feet. This room was once a toy shop. There are a few sinks in this room and some ducting, but not much debris. SLC personnel indicated that sources may have fallen through the floor during the shipping process, but that they had not found any.

The carpenter shop (in this building) has ladders, piping, and wood working equipment (e.g., table saws, a radial arm saw, a drill press). Precious metals plating (gold and silver) was conducted in this room at one time. Off this room are several smaller rooms, including a small room that had been closed off because it contains a cesium source and has radiation readings approaching 1,200 $\mu\text{rem/hr}$. The radium screening room has large quantities of contaminated equipment in poor shape. The finishing room houses current operations.

Variation from the Characterization Plan for survey of this building included failure to collect 100% survey measurements for fixed contamination and loose contamination. Further evaluation of characterization for this building was not feasible given the lack of historical information.

Annex to Etching Building (Butler Annex)

The Butler annex was added to the Acid Etching Building between 1949 and 1976 and expanded the building from 16,025 ft² to 32,000 ft². It is constructed of metal correlated walls. It currently houses a portion of USR Metals operations. A hotspot of soil contamination has been identified outside the Butler annex near the west property line.

This portion of the Etching Building was not evaluated separately during characterization.

Main Building

The original building was 8,000 ft² on the first floor, 5,000 ft² on the second floor, and 600 ft² on the third floor. A one story, 14,000 ft² addition was added south of the main structure and east of the mechanical application room in the late 1940s. In 1948/1949, a one story 2,000 ft² addition was added to the east side of the earlier addition. There is a dirt crawl space beneath the first floor. At one point the second floor was used as housing. The floors are hardwood and the ceilings are supported by steel I-beams. Some of the rooms have drop ceilings. The walls are sheet rock or plaster. There is a hole in the ceiling of one room revealing sheet rock and 2" x 8" wood trusses. These upstairs rooms house large-scale photography equipment and records contaminated with alpha radiation, including hundreds of boxes of files, and three large stacks of

federal registers. The stairs to the third floor are closed off and are designated as an airborne contamination area. The first floor has known radon contamination and is currently vented using large fans. The back of the Main Building has drain lines and a grate that drains to an unknown sump (possibly the east lagoon). At the time of the ICF site visit, there was water under the grate. Plant personnel indicated that it did not often have water in it.

A 5,000 ft² portion of the first floor was renovated and currently houses SLC and USR Metals offices. The remaining 3,000 ft² of original building and the 14,000 ft² is used by USR Metals for non-radiological operations. The 2,000 ft² addition is used for storage. The east half of the second floor also houses non-radiological operations, equipment storage, and waste storage. The west half of the second floor exists as it did for earlier H-3 and Ra-226 operations. Both the 14,000 ft² and 2,000 ft² addition were previously used for radiological operations.

Attic rafters, ceilings, ducting, and subfloors are known to be alpha contaminated. Drain lines are contaminated with Sr-90. The Characterization Report indicates that the Main Building and the roof of the Main Building were decontaminated in 1969. The extent and location of these decontamination activities is not specified. However, this decontamination was to allow unrestricted access to the first and second floors of the building. The former Hand Painting Department on the second floor has been decontaminated, but the attic above this room still contains contaminated ducts from the old radium painting operations.

The Characterization Plan indicates that Cs-137, Co-60, C-14, Ni-63, Kr-85, and Tl-204 may have also been used in this building.

Variation from the Characterization Plan for survey of this building included failure to collect 100% survey measurements for fixed contamination and loose contamination. Further evaluation of characterization for this building was not feasible given the lack of historical information. Given instrument MDAs, characterization results for this building may not reflect Sr-90 contamination.

Hand Application Areas (Second Floor of Main Building)

These areas were partially decontaminated in 1968, but attic above still contains contaminated ductwork from radium operations.

This portion of the Main Building was not evaluated separately during characterization.

Nuclear Building (or Tritium Building)

This building houses SLC's H-3 light source production operations and was constructed in 1969. The one story building was built on a concrete slab with corrugated metal walls and a metal roof. The building is only known to have been used for H-3 operations. It is operated under negative pressure and has a smoke stack that vents both this building and the solid waste building.

This building was not surveyed during characterization.

Cesium Ion Exchange Hut

This building is a small annex on the East side of the Main Building. The building has been gutted, but once housed cesium ion exchange columns used for treatment of wastewater. Contamination is known to remain on the walls and the floor. Drain lines from a sink in the cesium laboratory portion of the Main Building are routed to this building and then join a drain line from the parking lot and flow to a 10 foot sump that was found underground about three years ago near the north side of the lacquer storage building. The sump was once covered with a two to four inch cap, which had been removed. Several meters of soil contamination were found, but it was not clear whether this material has been excavated or left in place.

There were no significant variations from the Characterization Plan for this building.

Old Garage Foundation

The old garage was used in 1948/1949 to store radioactive materials. A Cs-137 source reportedly exploded in the garage. Only the partial concrete foundation of the garage remains. B-25s and drums on pallets are currently stored over the foundation. The drums and B-25s contain the waste soil excavated from the old underground silos. The waste containers are located in the shade of several large oak trees and some of the containers are covered with blue tarps. The storage area is cordoned off with a rope and marked with placards indicating radioactivity. The Characterization Report indicates that Sr-90, Po-210, and Ra-226 are also suspected contaminants.

There were no significant variations from the Characterization Plan for this building.

Vance/Walton House

This house is a wooden structure located outside of the active H-3 operation fencing, on the property to the east of the fenced area. SLC bought the Vance/Walton property after surface contamination was found on the property. During excavation of the silos, the contractor used the house as office space.

This building was not surveyed during characterization.

Building Adjacent to Personnel Office Building

Site drawings from 1980 indicate that a building once stood adjacent to the west wall of the Personnel Office Building; this drawing also showed a gasoline pump. This building, however, is not included on later drawings and was no longer present during the ICF site visit. It is unclear when this building was removed.

Table 5 below summarizes the findings of the building contamination survey undertaken by Monserco.

Table 5. Building Contamination Survey

Building Name	Radioisotopes Used or Suspected	Approximate Building Dimensions	Number of Survey Areas	Characterization Surveys Planned	Characterization Results
Personnel Office Building (Old Nurses Station)	Ra-226, Sr-90	One story (~540 sq. ft.)	1 (13 grids, 1 fixture)	Floors, lower walls 100% alpha, beta, and gamma survey and 4 swipe samples for H-3 per 100m ² Ceilings 1 measurement per 20m ²	Loose beta contamination > 1,000 dpm/cm ² was identified in only 1 grid. Fixed contamination > 5,000 dpm/cm ² was found on top of the well in the basement. Actual fixed contamination at this location was 20,272,016 dpm/cm ² . Gamma spec. identified the presence of Cs-137, Ra-226, Bi-214.
Machine Shop (Former Tritium Building)	H-3	30 ft. long by 20 ft. wide (~940 sq. ft.)	1 (45 grids, 7 pieces of equipment or fixtures)	Floors, lower walls 100% alpha, beta, and gamma survey and swipe sampling for H-3 and Ni-63 Ceilings 1 measurement per 20m ²	Fixed contamination > 5,000 dpm/cm ² was found in 1 grid and on the sink in the bathroom. Gamma spec. not performed.
Pipe Shop (Maintenance Shop)	H-3, Ra-226	One story	1 (34 grids, 19 pieces of equipment or fixtures)	Floors, lower and upper walls, ceilings, rafters 100% alpha, beta, and gamma survey and swipe sampling for H-3	Loose H-3 contamination > 1,000 dpm/cm ² was identified on 2 pieces of equipment. Fixed contamination > 5,000 dpm/cm ² was identified on 3 pieces of equipment or fixtures (ceiling pipes and lead pots). Hot spot contamination > 15,000 dpm/cm ² was found in grid 6. The actual value was 22,967 dpm/cm ² . Gamma spec. not performed.

Table 5. Building Contamination Survey

Building Name	Radioisotopes Used or Suspected	Approximate Building Dimensions	Number of Survey Areas	Characterization Surveys Planned	Characterization Results
Multi-Metals Waste Treatment Plant (USR Metals Liquid Waste Building)	None in these rooms, but Ra-226 and Sr-90 in adjacent Carpenter Shop	Two story - 60 ft. by 24 ft. (~2100 sq. ft.)	3 (95 grids, 20 pieces of equipment or fixtures)	Floors, lower walls 100% alpha, beta, and gamma survey and 4 swipe samples for H-3 per 100m ² Ceilings 1 measurement per 20m ²	Fixed contamination > 5,000 dpm/cm ² was identified in 1 grid of the Boiler room. Hot spot contamination > 15,000 dpm/cm ² was found in the Boiler Room for 2 grids. The actual values were 268,424 dpm/cm ² and 865,063 dpm/cm ² . Hot spot contamination > 15,000 dpm/cm ² was found in the Compressor Room for 5 grids. Gamma spec. not performed.
Carpenter Shop (Old Maintenance Shop)	Ra-226, Sr-90	Building is not square (4 walls), 30 ft., 20 ft., 32 ft., 7 ft. (~2870 sq. ft.)	1 (33 grids, 10 pieces of equipment or fixtures)	Floors, lower walls 100% alpha, beta, and gamma survey and 4 swipe samples for H-3 per 100m ² Ceilings 1 measurement per 20m ²	Fixed contamination > 5,000 dpm/cm ² was identified in 5 grids. The actual value for grid 10 was 267,141 dpm/cm ² . Hot spot contamination > 15,000 dpm/cm ² was found in 8 grids. The actual value for grid 10 was 11,904,820 dpm/cm ² and 831,703 for grid 30. Loose alpha, beta, and H-3 contamination > 1,000 dpm/cm ² , fixed contamination > 5,000 dpm/cm ² , and hot spot contamination > 15,000 dpm/cm ² were all identified during additional survey of grid 10. Fixed contamination > 5,000 dpm/cm ² was found on a light fixture and a vacuum cleaner in grid 10. Gamma spec. indicated the presence of Ra-226 and Bi-214. 2,767 pCi/g Bi-214, 3,156 pCi/g Pb-214 and 1,852 pCi/g Ra-226 in concrete sample collected from HS East Wall.

Table 5. Building Contamination Survey

Building Name	Radioisotopes Used or Suspected	Approximate Building Dimensions	Number of Survey Areas	Characterization Surveys Planned	Characterization Results
Well House	Ra-226, Sr-90	50 long ft. by 30 ft. wide by 20 ft. tall (~545 sq. ft.)	3 (38 grids, 1 fixture)	Floors, lower walls 100% alpha, beta, and gamma survey and 4 swipe samples for H-3 per 100m ² Ceilings 1 measurement per 20m ²	Hot spot contamination > 15,000 dpm/cm ² was found in grid 6 and on bottom shelf fixture in grid 7. Gamma spec. indicated the presence of Cs-137, Ra-226, and Bi-214. 58 pCi/g Bi-214, 50 pCi/g Pb-214, and 109 pCi/g Ra-226 in solid sample collected from floor. 37.04 pCi/g beta in solid sample collected from floor.
Lacquer Storage Building	None	One story - 68 ft. by 18 ft. (~1170 sq. ft.)	1 (20 grids, 3 pieces of equipment or fixtures)	Floors, lower walls 100% alpha, beta, and gamma survey and 4 swipe samples for H-3 and Ni-63 per 100m ² Ceilings 1 measurement per 20m ²	Hot spot contamination > 15,000 dpm/cm ² was found in grid 6. Gamma spec. was not performed.
Old Radium Vault	Ra-226	Not known (~390 sq. ft.)	1 (34 grids)	Alpha, beta, and gamma survey when accessible 1 swipe sample for H-3 and Ni-63 per 20m ²	Loose contamination measurements not taken. Gamma spec. not performed. No contamination above NRC guideline levels was identified. 19 pCi/g Cs-137 in solid sample collected from roof. 26 pCi/g Cs-137, 255 pCi/g Bi-214, 257 pCi/g Pb-214 and 479 pCi/g Ra-226 in solid sample collected from building top. 174.79 pCi/g beta in solid sample collected from top shelf.

Table 5. Building Contamination Survey

Building Name	Radioisotopes Used or Suspected	Approximate Building Dimensions	Number of Survey Areas	Characterization Surveys Planned	Characterization Results
Utility Building (Sr-90 Source Vault)	Sr-90	Not known (~340 sq. ft.)	1 (18 grids, 10 pieces of equipment or fixtures)	Floors, lower walls 100% alpha, beta, and gamma survey and 4 swipe samples for H-3 and Ni-63 per 100m ²	Fixed contamination > 5,000 dpm/cm ² was found in 7 grids and on boxes in room. Hot spot contamination > 15,000 dpm/cm ² was found in 8 grids. The actual value of hot spot contamination in grid 13 was 1,217,430 dpm/cm ² . Gamma spec. not performed.
8' x 8' Building	Sr-90, H-3	8 ft. long by 8 ft. wide (~60 sq. ft.)	1 (7 grids, 6 pieces of equipment or fixtures)	Floors, lower walls 100% alpha, beta, and gamma survey and swipe sampling for H-3 and Ni-63 Ceilings 1 measurement per 20 m ²	Fixed contamination > 5,000 dpm/cm ² was found in two grids and on 5 pieces of equipment and fixtures. Fixed contamination on wall light switch and outside lock hasp were 3,348,880 dpm/cm ² and 3,400,204 dpm/cm ² respectively. Hot spot contamination > 15,000 dpm/cm ² was found in 7 grids. The value of hot spot contamination in grid 4 was 14,644,146 dpm/cm ² . Gamma spec. indicated the presence of Cs-137, Ra-226, and Bi-214.
Liquid Waste Building	H-3, Ra-226, Sr-90, Cs-137, Co-60, Am-241, Ni-63, Kr-85	One story - 60 ft. long by 20 ft. wide (~1,230 sq. ft.)	1 (62 grids, and 4 pieces of equipment or fixtures)	Floors, lower walls 100% alpha, beta, and gamma survey and swipe sampling for H-3 and Ni-63 Ceilings 1 measurement per 20 m ² Sample of sludge from below grade sump	Loose H-3 contamination > 1,000 dpm/cm ² was found in 1 grid. Hot spot contamination > 15,000 dpm/cm ² was found on 3 fixtures. Gamma spec. not performed. 1,203,428 pCi/L H-3 in liquid sample collected from well.

Table 5. Building Contamination Survey

Building Name	Radioisotopes Used or Suspected	Approximate Building Dimensions	Number of Survey Areas	Characterization Surveys Planned	Characterization Results
Old House	Ra-226, H-3, Sr-90, Co-60, Ni-63, Kr-85, Cs-137, Po-210, Am-241	Two story - 25 ft. long by 25 ft. wide and smaller area 12 ft. long by 18 ft. wide (~1,800 sq. ft. - includes basement)	7 (51 grids, 7 pieces of equipment or fixtures)	Floors, lower walls 100 % alpha, beta, and gamma survey and 4 swipe samples per 100 m ² Ceilings 1 measurement per 20 m ² Surface soil sampling in basement 4 per 10 m grid	Loose H-3 contamination > 1,000 dpm/cm ² was found in 2 grids and on 1 piece of equipment and 1 fixture. Fixed contamination > 5,000 dpm/cm ² was found in 2 grids. Hot spot contamination > 15,000 dpm/cm ² was found in 2 grids and on 5 pieces of equipment or fixtures. Gamma spec. not performed.
Solid Waste Building	H-3, Ra-226, Sr-90, Cs-137, Co-60, Am-241, Ni-63, Kr-85	One story - 30 ft. long by 30 ft. wide by 12 ft. tall (~980 sq. ft.)	1 (34 grids, 13 pieces of equipment or fixtures)	Floors, lower walls, ceilings 100% alpha, beta, and gamma survey and swipe sampling for H-3 and Ni-63	Loose H-3 contamination > 1,000 dpm/cm ² was found in 7 grids. The actual value in grid 26 was 99,840 dpm/cm ² . Loose H-3 contamination > 1,000 dpm/cm ² was also found on 2 fixtures and 2 pieces of equipment. Fixed contamination > 5,000 dpm/cm ² was found in 4 grids. Fixed contamination > 5,000 dpm/cm ² was identified on a cabinet inside grid 14. Hot spot contamination > 15,000 dpm/cm ² was found in 2 grids. Hot spot contamination > 15,000 dpm/cm ² was found on 7 pieces of equipment or fixtures. Gamma spec. not performed.

Table 5. Building Contamination Survey

Building Name	Radioisotopes Used or Suspected	Approximate Building Dimensions	Number of Survey Areas	Characterization Surveys Planned	Characterization Results
Metal Silo (above ground)	Ra-226, H-3	5 ft. diameter and 8 ft. tall	1 (8 grids)	Floors and lower walls 100% alpha, beta, and gamma survey and swipe sampling for H-3 Ceilings 1 measurement per 20 m ²	Loose H-3 contamination > 1,000 dpm/cm ² was found in 16 grids. Fixed contamination > 5,000 dpm/cm ² was found in 5 grids. Gamma spec. not performed. 763 pCi/g Cs-137 in sand sample collected in vicinity of silo. 75.52 pCi/g beta in sand sample collected in vicinity of silo.
Acid Etching Building	H-3, Ra-226	One story (~33,670 sq. ft.)	80	Floors, lower walls 100% alpha, beta, and gamma survey and swipe sampling for H-3 Equipment 10% swipe sampling for H-3 Ceilings 1 measurement per 20m ² Shipping room below surface samples 4 per 10m grid	Some rooms in poor structural condition not surveyed due to safety concerns (rooms 5, 6, 8, 11, 13, 21-33, 45, 61). Remaining numbered rooms through 84 were surveyed, as well as Attics 1-3 and the Attic ramp. Rooms with one or more grids (or equipment) with loose contamination > 1,000 dpm/100cm ² : 3, 14, 49, 56, 63, 73, Attic 2, Attic 3. Rooms with one or more grids (or equipment) with fixed contamination > 5,000 dpm/100 cm ² : 2, 3, 7, 9, 17A, 55, 56, 69, 70, Attic 2, Attic 3. Rooms with one or more grids (or equipment) with hot spots > 15,000 dpm/100cm ² : 3, 10, 20, 48, 55, 62, 65, 67, 70, 71, 75, 76, 81, 83, 84, Attics 1-3, Attic ramp. Gamma spec. was not performed. 30 pCi/g Bi-214 in solid sample collected from North Wall of Room 55.

Table 5. Building Contamination Survey

Building Name	Radioisotopes Used or Suspected	Approximate Building Dimensions	Number of Survey Areas	Characterization Surveys Planned	Characterization Results
Main Building	H-3, Ra-226, Sr-90, Cs-137, Co-60, C-14, Ni-63, Kr-85, Tl-204	Three story - 24,000 ft ² 1 st floor; 5,000 ft ² 2 nd floor, 600 ft ² 3 rd floor	77	Floors, lower walls 100% alpha, beta, and gamma survey and swipe sampling for H-3 and Ni-63 Attic ceilings average for 100m ² survey unit Ceilings 1 measurement per 20m ²	<p>Surveyed rooms 85 through 302, B1-B3, and Edock, Wdock.</p> <p>Rooms with one or more grids (or equipment) with loose contamination > 1,000 dpm/100cm²: 86, 88, 91, 92, 93, 100, 106, 108, 113A, 136, 214, 218, B1.</p> <p>Rooms with one or more grids (or equipment) with fixed contamination > 5,000 dpm/100 cm²: 86, 88, 93, 95, 97, 98, 100, 104, 107, 108, 88, 95, 97, 98, 107, 202, 209, 214, 218, 302, B1, B3, Wdock.</p> <p>Rooms with one or more grids (or equipment) with hot spots > 15,000 dpm/100cm²: 85, 86, 87, 88, 88A, 88B, 91, 92, 93, 95, 97, 100, 103, 104, 105, 106, 107, 108, 113A, 113B, 114, 120, 121, 125S, 27, 135, 136, 201, 202, 205, 209, 211, 214, 215, 216, 217, 218, 301, 301A, B1, B2, B3.</p> <p>Gamma spec. results in Room 86 indicate the presence of Cs-137, Ra-226, and Bi-214. Gamma spec. results in Room 88 indicate the presence of Ra-226 and Bi-214. No Cs-137 detected.</p> <p>176 pCi/g Bi-214, 168 pCi/g Pb-214, and 305 pCi/g Ra-226 in solid sample collected beneath Office.</p> <p>51 pCi/g Bi-214 and 33 pCi/g Pb-214 in solid sample collected from crawl space in Room 98.</p> <p>9.82 pCi/g beta in solid sample collected from crawl space in Room 98.</p>
Nuclear Building (Tritium Building)	H-3	One story - 120 ft. by 50 ft. (~6125 sq. ft.)	Not Applicable	Floors and lower walls 100% alpha, beta, and gamma survey and swipe sampling for H-3	Not Surveyed

Table 5. Building Contamination Survey

Building Name	Radioisotopes Used or Suspected	Approximate Building Dimensions	Number of Survey Areas	Characterization Surveys Planned	Characterization Results
Cesium Ion Exchange Hut	Cs-137	Not known	1 (9 grids, 4 fixtures)	Floors, lower walls 100% alpha, beta, and gamma survey and 4 swipe samples for low energy beta emitters per 100m ² Ceilings 1 measurement per 20m ²	Loose H-3 contamination > 1,000 dpm/cm ² was found in 3 grids and loose beta contamination > 1,000 dpm/cm ² was found in 1 grid and on the chimney. Fixed contamination > 5,000 dpm/cm ² was found in all 9 grids. Hot spot contamination > 15,000 dpm/cm ² was found in all 9 grids with multiple hot spots in some grids. Gamma spec. not performed.
Old Garage Foundation	Ra-226, Sr-90, Cs-137, Po-210	20 ft. by 12 ft. (~240 sq. ft.)	1 (6 grids)	100% alpha, beta, and gamma surveys No swipe sampling since exposed to elements.	Loose contamination measurements not taken. Fixed contamination > 5,000 dpm/cm ² was found in all 6 grids. Hot spot contamination > 15,000 dpm/cm ² was found in all 6 grids with multiple hot spots in some grids. Gamma spec. indicated the presence of Cs-137, Ra-226, and Bi-214.

4.2 Identification of Potential Gaps in Characterization

4.2.1 Characterization Methodology

Early investigations of the SLC site did not include survey of the buildings. Consequently, the methodology presented in Section 3.1 was used to evaluate only the 1995 Monserco building characterization data. The characterization methodology provided in Section 4.1.2 is generally consistent with methodology outlined in NRC guidance documents. Although the Characterization Report did not identify the total number of grids for each building, based on the 4 m² survey unit (2m x 2m), the number of grids surveyed was likely adequate. Similarly the number of samples collected from a grid (generally one) also was considered adequate. We based our evaluation of the adequacy of Monserco's characterization on several factors, including review of the site history for each building (e.g. radionuclides known or suspected to have been used), the surveys conducted and samples collected, the instrumentation used, the instrumentation detection limits, and the NRC guideline values for surface contamination.

We note that the adequacy of the Acid Etching Building characterization and the Main Building characterization was difficult to assess given the large number of rooms and limited room-specific history. Although DCGL values were calculated for individual radionuclides, characterization results did not quantify individual radionuclide concentrations. Consequently, characterization results were compared to the NRC guideline values for removable, average, and maximum contamination provided in Section 4.1.3 for beta/gamma emitters.

4.2.2 Characterization Techniques

Survey instrumentation used in building characterization and detection sensitivity were significant considerations in evaluation of the adequacy of characterization. MARSSIM suggests that the detection sensitivity be as far below the DCGL as possible. For direct measurements and sample analyses, MARSSIM states that a minimum detectable concentration less than 10 percent of the DCGL is preferable, while minimum detectable concentrations up to 50 percent of the DCGLs are acceptable. Because DCGLs were calculated for specific radionuclides, the NRC reference values for removable and average beta/gamma contamination were used as reference levels. The minimum detectable activity (MDA) provided for each instrument fell within these acceptance criteria. The MDA and the percentage of the NRC reference values is provided below for each instrument detecting beta and gamma emissions. The MDA for the liquid scintillation counter used to count H-3 smears is compared to the DCGL.

Table 6. Summary of Survey Equipment

Survey Equipment	MDA	Percentage of NRC Reference Value
Eberline Model BC-4 Beta Counter	325 dpm/100 cm ²	32.5 %
Wallac RacBeta Liquid Scintillation Counter	330 dpm/100 cm ²	3 x10 ⁻⁴ %
Eberline ESP-1 and ESP-2 Monitors with HP260 probe	Beta: 1,300 dpm/100 cm ² Gamma: 1,500 dpm/100 cm ²	26 % 30%
Berthold LB122 Monitor	1100 dpm/100cm ²	22%

The most significant gap is in the Sr-90 characterization of the buildings. Survey instrumentation used to measure beta emissions are listed above with their MDA. The NRC guideline values for Sr-90, a beta emitter, are provided below.

Survey Type	Removable	Average ¹	Maximum ¹
NRC guideline for Sr-90	200 dpm/100cm ²	1,000 dpm/100cm ²	3,000 dpm/100cm ²

Reference: *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material*, U.S. NRC, August 1987.

¹ Average and maximum contamination levels apply to areas not exceeding 1 m² and 100 cm² respectively.

Given the MDAs for these instruments, both loose and fixed average contamination from Sr-90 would not have been identified during the investigation.

No guideline value was provided for comparison with alpha characterization results, however this is not considered a significant deficiency. Most of the alpha emitting radionuclides used on the site and their alpha emitting daughter products are also gamma emitters or have relatively short half lives.

The Monserco Characterization Report does not provide a discussion of the calculation of background for each of the instruments used in survey of the buildings. However, Section 5.5.1 of the report, which describes the use of the Bicon Survey Meter for outdoor radiation surveys, indicated that background measurements were subtracted from the actual field values to produce background corrected radiation results. This protocol appears to have been applied to radiation surveys using the Bicon Survey Meter in the buildings. Box 1 included on each building characterization data report in Appendix 20 includes an average background value for each of the three scanning instruments. Results from these surveys are frequently less than the background which would seem to indicate that the results are corrected.

The appearance of zeros in the fixed average contamination column from Appendix 20 data led to some confusion during our review. Zeros appear in this column for a number of buildings and rooms. A zero would not be expected given the greater than zero MDAs for the instruments used in these scans. Data in Appendix 20 for the Well House Adhesives North Room includes zeros for fixed average contamination. Table 12.7.2 in the Characterization Report indicates that fixed contamination measurements were not taken in this room. However, Box 1 of the report in Appendix 20, indicates that measurements were made using the Berthold LB122 Monitor, which measures fixed contamination. Box 1 in other data reports with zeros for fixed contamination also indicate that these measurements were made. However, these results may also be an indication of data correction. For the purposes of our evaluation we assumed that a zero in this column was intended to identify a non-detect.

4.2.3 Characterization Results

In order to fully assess the adequacy of building characterization we used the Integrated Review Methodology described in Section 3.3. The questions presented in Section 3.3 are repeated below and yes/no answers to each question have been summarized in Table 7. Based on the number of "No" answers received for each building and the relative importance of the question, we applied best professional judgement to determine if the building was sufficiently characterized. Answers to these questions are provided below.

1. Have historical records been kept for all rooms in a building?

Historical records have not been kept for each room in a building; however, limited site histories describe radionuclides known or suspected for each building. Evaluation of characterization results was based on these limited site histories.

2. Has each building been classified as impacted or non-impacted?

The Characterization Report does not specifically classify each building as impacted or non-impacted. However, the Characterization Plan indicates that due to site operations and lack of documentation for radiological clearance, all buildings will be classified as affected.

3. Has each room in an impacted building been assigned a Class 1, 2, or 3 ranking and appropriately divided into sampling grids?

The Characterization Report and the Characterization Plan were not required to classify rooms using the MARSSIM Class 1, 2, or 3 rankings, however, the Table 4-1 of the October 2000 Decommissioning Plan does classify each building or room under NRC License No. 37-00030-02 into one of these MARSSIM rankings. Buildings not covered under this license have not been ranked (i.e. Machine Shop, Liquid Waste Building, Solid Waste Building, and the Nuclear Building).

4. Has a sampling plan been prepared based on the Class ranking for that room/building?

As indicated above, the Characterization Plan did not classify buildings or rooms according to the MARSSIM rankings. However, MARSSIM suggests survey unit areas for Class 1 structures up to 100 m². Given the 4 m² size of building grids, this was not considered a significant deficiency.

5. Does the sampling plan address QA/QC requirements?

Section 10 of the Characterization Plan addresses QA/QC requirements including: organizational structure and responsibilities; specification of qualification of personnel; operating procedures and instructions; records; quality control in sampling, packaging, shipping, and storage; quality control in the radiological laboratory; review and analysis of data; and audits.

6. Has sampling been conducted in each room according to the sampling plan?

Variations from the Characterization Plan are described above in the building-specific discussions of Section 4.1.4.

7. Is the number of samples taken known for each room?

The number of samples taken for each room has not been summarized in the Characterization Report. However, Appendix 20 appears to present data for all samples taken during the investigation.

8. Are the detection limits for each analytical instrument known for each room?

Room specific detection limits for each analytical instrument were not provided. However, MDAs for each instrument were provided in the Characterization Plan. Background measurements for each room are provided in Appendix 20.

9. Has sampling been conducted for each room using appropriate instrumentation with appropriate sensitivity?

Building surveys were not always conducted using appropriate instrumentation with appropriate sensitivity. The significance of building-specific deficiencies are described below.

10. Are all sample results below the DCGL?

Sample results were not compared to DCGLs. Although DCGL values were calculated for individual radionuclides, characterization results did not quantify individual radionuclide concentrations. The NRC guideline values for loose beta/gamma contamination, fixed average contamination, and hot spot contamination were used as

reference levels. The only building with no contamination identified above these reference levels was the old Radium Vault.

11. Were samples collected from beneath the building or areas of known releases?

The discussion of characterization results in the Monserco Characterization Report does not discuss collection of samples beneath the buildings. However, Appendix 9 and Appendix 19 both include a minimum number of results for miscellaneous solid samples collected from various buildings. Generally, the sample location descriptions provided therein are not adequate to determine whether floor samples refer to floor samples or below floor samples. (However, as discussed in Section 6 of this report, Monserco did not collect subsurface samples beneath any building because they did not want to damage the floor.)

Table 7. Application of Integrated Review Methodology

Building Name	Questions for Evaluation of Characterization Adequacy										
	1	2	3 ²	4	5	6	7	8	9	10	11
Personnel Office Bldg.	●	○	○	●	○	●	○	○	○	●	●
Machine Shop	●	○	●	●	○	●	○	○	●	●	●
Pipe Shop	●	○	○	●	○	○	○	○	○	●	●
Multi-Metals Waste Treatment Plant	●	○	○	●	○	●	○	○	○	●	●
Carpenter Shop	●	○	○	●	○	○	○	○	○	●	●
Well House	●	○	○	●	○	●	○	○	●	●	●
Lacquer Storage Building	●	○	○	●	○	●	○	○	○	● ³	●
Old Radium Vault	●	○	○	●	○	●	○	○	●	○	●
Utility Building	●	○	○	●	○	○	○	○	○	●	●
8' x 8' Building	●	○	○	●	○	○	○	○	●	●	●
Liquid Waste Building	●	○	●	●	○	○	○	○	●	●	●
Old House	●	○	○	●	○	●	○	○	○	●	●
Solid Waste Building	●	○	●	●	○	●	○	○	○	●	●
Metal Silo (Above Ground)	●	○	○	●	○	○	○	○	●	●	●

Building Name	Questions for Evaluation of Characterization Adequacy										
	1	2	3 ²	4	5	6	7	8	9	10	11
Acid Etching Building	●	○	○	●	○	●	○	○	U ⁴	●	●
Main Building	●	○	○	●	○	●	○	○	U ⁴	●	●
Nuclear Building ¹	●	○	●	●	○	●	○	○	●	●	●
Cesium Ion Exchange Hut	●	○	○	●	○	○	○	○	○	●	●
Old Garage Foundation	●	○	○	●	○	○	○	○	○	●	●

○ = Yes

● = No

¹ Assumed worst case scenario for Nuclear Building since it was not characterized.

² Survey Unit Classification was provided in October 2000 Decommissioning Plan for License No. 37-00030-02 and does not appear to have been done for 1995 Characterization. No survey unit classification was provided for buildings under License No. 37-00030-08.

³ The only contamination identified was on equipment stored in room.

⁴ Assessment cannot be made without a more complete history of radionuclide use for each room.

4.3 Recommendations for Additional Characterization

Gaps in building characterization were identified, however, further characterization at this time is unnecessary. Gaps in building characterization can be addressed at the time of building decontamination and decommissioning. Both site-wide and building-specific recommendations for additional building characterization are minimal. These recommendations are summarized below:

- The licensee should provide NRC with both a discussion of background measurements/calculations and a report of uncorrected survey results.
- Buildings with a history of Sr-90 use or a suspected history of Sr-90 use should be reassessed. Surveys should be conducted using instrumentation with detection limits at least 50% of the NRC guideline values used for identification of contamination.
- Fixed contamination measurements were collected from floors in the Liquid Waste Building using an instrument that detects alpha and beta emissions. Given the history of radioisotopes used or suspected in this building, using an instrument that detects gamma emissions for the floor is warranted. Alternatively, performance of gamma spectrometry in the room may rule out the presence of gamma emitters.

- The presence of Cs-137, Ra-226, and Bi-214 in the 8' x 8' Building was identified by gamma spectrometry. However, the instrument used for survey of fixed contamination only reflects detection of alpha and beta emissions. Given the presence of these gamma emitters, survey for fixed contamination using an instrument that detects gamma emissions is warranted.
- Surveys for fixed contamination were not conducted for the floor of the Well House. A concrete sample collected from the floor of the Well House had elevated levels of Ra-226, Bi-214, and Pb-214. Given this result, surveys for fixed contamination in the Well House floor are warranted.
- Surveys were not conducted in any of the buildings/rooms that were judged to be to unstable to permit entry and subsequent survey activities. Although not an issue for additional survey costs, all of these buildings/rooms should be considered contaminated and will need to be monitored as they are torn down.
- Although visual observations indicated that several rooms/building may contain asbestos, lead, and other hazardous (or listed hazardous wastes) materials, none of the rooms were characterized for these or other hazardous constituents. The presence of these materials could lead to remediation debris being classified as either mixed waste or LLW containing asbestos, and would influence disposal options and costs. SLC could use site history and process information to prepare a building-by-building inventory listing potential hazardous materials likely to be present as a result of past operations or spills/leaks. The affected areas of these buildings/rooms likely to contain hazardous materials should be characterized for these materials during the remediation process.

Table 8. Gaps Identified in Building Characterization

Building Name	Does structural condition allow 100% survey?	Characterization Gaps (✓ = a gap)			
		1	2	3	4
Personnel Office Bldg.	No	✓			✓
Machine Shop	Yes			✓	✓
Pipe Shop	Yes				✓
Multi-Metals Waste Treatment Plant	Yes	✓			✓
Carpenter Shop	Yes	✓			✓
Well House	Yes	✓			✓
Lacquer Storage Building	No				✓
Old Radium Vault	No			✓	✓

Building Name	Does structural condition allow 100% survey?	Characterization Gaps (✓= a gap)			
		1	2	3	4
Utility Building	No	✓			✓
8' x 8' Building	Yes	✓	✓		✓
Liquid Waste Building	Yes	✓	✓		✓
Old House	No	✓			✓
Solid Waste Building	Yes	✓			✓
Metal Silo (Above Ground)	Yes		✓		✓
Acid Etching Building	No		✓	✓	✓
Main Building	No	✓	✓	✓	✓
Nuclear Building ¹	Yes			✓	✓
Cesium Ion Exchange Hut	Yes				✓
Old Garage Foundation	Yes	✓			✓

Column Explanation:

- 1 Building has Sr-90 history and may not have been adequately characterized due to instrument sensitivity.
- 2 Portion of building may not have been characterized using appropriate instrumentation.
- 3 Portion of building may not have been characterized.
- 4 Building was not adequately characterized for hazardous materials (e.g. asbestos, lead) or hazardous constituents (e.g. TC metals).

4.4 Costs Associated with Additional Characterization

Table 8 above provides a summary of the gaps we identified in the building characterization study. These gaps are discussed in greater detail in the building-specific discussions in Section 4.1.4. Although we identified the above gaps in building characterization, we believe that further characterization at this time is unnecessary. Specifically, we believe that these gaps in building characterization can be addressed at the time of building decontamination and decommissioning, when materials are remediated, packaged, and surveyed.

5.0 Surface Soils

Surface soils at the SLC site have been contaminated with a number of different isotopes over the years as well as metals and possibly organic compounds. The primary radioactive isotopes of concern are Ra-226, Cs-137, Am-241, and Sr-90. Daughter isotopes of Ra-226, such as Pb-214 and Bi-214, have also been found in the surface soils. The known presence of metal and organic constituents at the site raises the possibility that soil at the site might be considered mixed waste and would require disposal currently available at a single facility (Envirocare in Clive, Utah). Specifically, soil with radioactive contamination that either fails EPA's TCLP test for these constituents, or that was contaminated with one of EPA's listed wastes (such as electroplating sludge -- F006/09, spent solvents -- F001-05, etc.) would be classified as a mixed waste.

Over the last 20 years, various soil sampling efforts have been undertaken. In 1995, SLC contracted Monserco, Ltd. to conduct an in-depth study of the site. The Monserco study was the most recent comprehensive study of radiological contamination of soils and is the central focus of our review. Earlier studies include a 1979 Meiser & Earl Hydrogeologic Investigation which references an earlier Radiation Management Corporation (RMC) study that was not available for review, an 1982 Oak Ridge Associated Universities (ORAU) investigation, and a 1990 Chem-Nuclear Systems, Inc. (CNSI) study. In 1999 a small study of the East lagoon was conducted by Oak Ridge Institute for Science and Education (ORISE).

In Section 5.1 we present the results of the Monserco study, followed by results of the other investigations. Section 5.2 presents our assessment of the adequacy of the surface soil characterization to date, while Section 5.3 presents our assessment of whether additional sampling is needed. Finally, Section 5.4 presents the costs associated with the additional sampling requirements.

5.1 Summary of Existing Characterization

Available Site History

Limited historical site history was available in the Monserco Report for several distinct surface areas in the site. This information is supplemented in a few cases with observations from ICF's site visit (conducted May 31, 2001) and is presented below.

Abandoned Canal

The old canal, which ran from Sunbury to Scranton, was reportedly 100 feet wide and 15 feet deep according to site personnel (site maps indicate that the width was approximately 50 feet). The actual width of the canal on the SLC property is not documented. At one time the portion of the canal on the SLC site contained as many as 7 lagoons. During 1948/1949 the canal was used for disposal of Ra-226 contaminated ductwork. Prior to 1960, all liquid waste from radiological production activities was routed to open portions of the canal. In 1960, plans were made to precipitate out the radioactive contaminants from the canal water, excavate the contaminated sediments, and discharge treated water to river. There is no evidence to confirm that these plans

were carried out. In the early 1960's, three eastern lagoons were found to be contaminated with considerable radioactive contaminants. The radioactive constituents were precipitated out and the two most easterly lagoons were backfilled. Between 1976 and 1978, the third most easterly lagoon was backfilled.

East Lagoon

This lagoon was built in a portion of the old canal which ran from Sunbury to Scranton, and was at least 100 feet wide and 15 feet deep. There was no accumulated liquid or debris in the lagoon at the time of the ICF site visit, but there was an oily looking spot in the middle of the base of the lagoon. Grass and wild flowers grow in the lagoon. Just to the north of this lagoon are two telephone poles connected by crossbeams with electrical transformers for electricity. An 8 or 10 inch diameter outfall drains into the lagoon. This outfall was dry at the time of the site visit and plant personnel did not know its source. This lagoon was used to dispose of sewage and process wastewater from the radium laboratory in the main building from 1948 to 1954. In 1960, contents of the lagoon were pumped into the West Lagoon. The Lagoon contents were likely dispersed in the surrounding soils during the 1972 flood of the Susquehanna River.

West Lagoon

This lagoon lies in a portion of the old canal. The lagoon was used to dispose of silver plating wastes and anodizing solutions. In the 1960's, the contents of the East Lagoon were pumped into the West Lagoon. There was no accumulated liquid or debris in the west lagoon at the time of the ICF site visit. The lagoon contents were likely dispersed in the surrounding soils during the 1972 flood of the Susquehanna River.

East Plant Dump

The east plant dump is an area between the east and west lagoons and was identified during the installation of a storm sewer in 1972. A portion of the canal near the dump was used for disposal of Ra-226 contaminated ductwork during the early years of operation. The dump currently contains a pile of pallets, old chain link fences and pipes, old pipes, windows, cinder blocks, and sheet metal. The outfall from current USR Metals operations is located south of the East Plant Dump and behind the fencing. Liquid was draining from this outfall during the ICF site visit.

West Plant Dump

The west plant dump abuts the western property line and fence. The dump is a pit used in 1948/1949 for disposal of solid waste. Before 1970, the dump was used for disposal of Ra-226 dials and Sr-90 deck markers. In the late 1960's or early 1970's, 78 drums of Ra-226 contaminated soil (including radium dials) were removed from this area and shipped off-site. SLC personnel indicated that radium dials are still found in this area from time-to-time.

A ground penetrating radar survey carried out during the 1995 Characterization revealed reflections characteristic of metallic objects/drums on the north, east and west sides of the West dump.

Monserco Site Characterization 1995

During the 1995 site characterization conducted by Monserco, the study areas were gridded to allow radiological and non-radiological surveys to be undertaken in a methodical and reproducible manner. The outdoor study area was divided into a total of 307 grids. Grids where contamination was not anticipated (or unaffected areas) measured 25 meters by 25 meters. Grids where contamination was anticipated (or affected areas) measured 10 meters by 10 meters. Figure 2 in Appendix 1 presents a map of the site with the grid numbers and locations. Because the Monserco gridding system allows for an easy method of describing the location of any point of the site, we have incorporated this grid reference system throughout the remainder of this report.

Surface soils in the grids were both field surveyed and sampled for analysis. A Bicon survey meter was used to give a tissue equivalent photon response for 262 of the 307 outdoor grids. A SCOUT portable gamma spectrometer was used to survey one third of site grounds (primarily the areas south of the Main Building). Results of the Bicon survey provided evidence of radiation fields within those grids that were identified either as hot spots or higher than average background radiation. Results of the gamma spectrometer survey provided evidence of three gamma emitting parent radionuclides within the grids (Cs-137, Ra-226, and Am-241). The gamma spectrometer output data were processed using a software package that manipulates the data to produce a series of contour lines. The software joined together points with identical values to create a series of isopleths providing an overview of contaminated areas. These isopleths are provided in the Monserco Characterization Report as Figures 8.4 through 8.10 and are reproduced in Appendix 2. The report notes that this software may distort data to show phantom ripples around areas with positive values.

Soil sampling was also performed within outdoor grids. According to the Monserco Working Document for Characterization of the Safety Light Corporation Site, between one and four samples were to be collected from affected grids based on the following criteria:

- If historical evidence suggested contamination was likely and clearance levels were being approached, four samples would be taken in a 10 x 10 m grid.
- If no historical evidence suggested contamination, one sample would be taken in a 10m x 10m grid.
- Where soil contamination levels were obviously in excess of clearance levels, sampling frequencies would be reduce to one sample in a 10 m x 10 m grid.

In addition, one soil sample was to be collected from unaffected grids. There was no tabulated information in the Monserco documents presenting what historical evidence was known for each

grid. However, the majority of grids with four samples were taken in the area of the old canal and in an area on the northwest corner of the site where contamination had been found in previous studies. A number of grids had two or three samples; no explanation is given. In addition, about 40 grids had no samples at all; again, no explanation is given.

Samples were collected at a depth of about one foot. Although the Monserco report indicates that 523 samples were collected from the soil on the SLC site and analyzed by gross beta counting, data for only 502 samples have been provided in Appendix 9 of the report. An Eberline model BC-4 Beta Counter was used to directly count soil samples for gross beta. Although Monserco reported that 113 samples had beta readings above the Minimum Detectable Activity (MDA), review of the data in Appendix 9 indicates 124 samples had beta readings above the MDA. Note that the MDA was 7.0 pCi/g, which is greater than the 5 pCi/g minimum value used in the gross beta isopleths provided in the Monserco report. Table 9 summarizes gross beta readings above the MDA. For grids with multiple samples, the highest gross beta value in the grid is reported. Monserco reported that these laboratory results showed a correlation with Cs-137 and Bi-214 from portable gamma spectrometry surveys. Figure 3 in Appendix 1 shows grids with beta concentrations above 5 pCi/L.

Table 9. Beta Concentrations in Surface Soil Samples

Grid Number	Beta Concentrations in Soil Samples (pCi/g)	Grid Number	Beta Concentrations in Soil Samples (pCi/g)	Grid Number	Beta Concentrations in Soil Samples (pCi/g)
13	66.5	130	249.89	228	9.49
19	76.92	135	142.61	229	28.07
20	129.78	148	568.5	230	8.74
26	13.43	151	80.61	232	14.81
27	13.34	157	79.56	233	22.43
29	31.51	163	11.09	235	12.79
30	39.39	164	11.98	236	12.49
31	12.37	169	7.57	238	12.46
32	7.9	182	26.94	243	24.8
33	91.63	183	33.48	244	35.68
45	45.47	185	228.99	245	18.03
46	481.22	188	21.62	247	64.14
47	20.6	189	18.92	248	55.16
58	7.37	191	11.88	249	16.61
69	12.29	195	8.66	251	35.86
71	107.33	200	11.01	252	15.59
80	8.83	201	50.36	253	191.46
92	12.45	202	15.77	254	71.26
101	158.54	203	79.1	255	24.35
102	127.42	205	11.8	256	15.49
108	13.29	206	136.56	268	22.79
110	896.67	217	22.12	269	31.44
111	170.72	220	13.38	270	30.72
113	423.51	221	11.61		
114	24.18	222	18.12		
115	11.08	223	57.03		
116	171.44	224	7.91		
120	11.44	225	14.41		
126	62.97	226	183.69		
129	111.2	227	10.1		

The Monserco report indicates that 505 samples were analyzed by gamma spectroscopy; however, data were provided for only 504 samples. This analysis resulted in the detection of Cs-137, Bi-214, Pb-214, Ra-226, and Am-241. However, the detection limit for Bi-214, Pb-214, and Ra-226 were frequently above the NRC regulatory limits or DCGL. Consequently, it is impossible to tell if concentrations of these isotopes are actually above or below these regulatory limits, when a sample was reported as a “non-detect.” Nevertheless, Bi-214 and Pb-214 are daughter isotopes of Ra-226, and can be used to provide an indication of the presence of Ra-226.

Monserco reported that the laboratory results for the 505 samples showed correlation with portable gamma spectrometry surveys. Monserco reported

- 181 (ICF counted 178) positive Cs-137 results with 61 (ICF counted 59) above NRC guideline values;
- 154 (ICF counted 149) positive Bi-214 results with 112 (ICF counted 104) above NRC guideline values;
- 94 positive Pb-214 results with 94 above NRC guideline values;
- 21 (ICF counted 19) positive Ra-226 results with 21 (ICF counted 19) above NRC guideline values; and
- 8 positive Am-241 results were reported with 3 above NRC guideline values.

These results are summarized in Table 10, along with the number of samples per grid. For grids with multiple samples analyzed, the highest value reported for a given radionuclide is reported. Although Co-60 was included in Monserco’s results, this isotope was never detected. We did not include Co-60 in Table 10.

Figures 4 through 10 in Appendix 1 present maps of the grids with detections and concentrations indicated. Figure 4 presents a map of the grids with Cs-137 concentrations above the DCGL of 11 pCi/g in red, and grids where Cs-137 was detected below the DCGL in green. Likewise, Figures 5 and 6 show the grids with Ra-226 and Am-241 above the DCGLs. Figures 7 and 8 show grids with Bi-214 and Pb-214 above the NRC regulatory levels in red. Because in many cases the detection limits were above the regulatory levels of interest, non-detected values shown in Figures 5, 7, and 8 may be contaminated. Figure 9 shows any grid with a Cs-137, Am-241, Ra-226, Bi-214 or Pb-214 above the DCGL (or NRC regulatory level if a DCGL is not available). Beta contamination is not shown on Figure 9 because there is no clear regulatory limit. Figure 10 shows these known affected grids (from Figure 9) in red, and shows the grids in which the detection limit was above the DCGL or NRC regulatory level in green. These grids marked in green are considered to be potentially affected because they have not been shown to have concentrations of Ra-226, Pb-214, or Bi-214 below the DCGL or NRC regulatory level.

Table 10. Isotopic Concentrations in Surface Soil Samples (pCi/g)

Grid Numbers	Number of Samples	Cs-137 DCGL = 11 NRC Level = 15	Bi-214 NRC Level = 5	Pb-214 NRC Level = 5	Ra-226 DCGL = 1.5 NRC Level = 5	Am-241 DCGL = 1 NRC Level = 30
1	1	ND	ND	ND	ND	ND
2	1	ND	ND	ND	ND	ND
3	1	ND	ND	ND	ND	ND
4	1	ND	ND	ND	ND	ND
5	1	ND	ND	ND	ND	ND
6	1	ND	ND	ND	ND	ND
7	1	ND	ND	ND	ND	ND
8	1	ND	ND	ND	ND	ND
9	1	ND	ND	ND	ND	ND
10	1	ND	ND	ND	ND	ND
11	1	ND	ND	ND	ND	ND
12	1	ND	ND	ND	ND	ND
13	2	ND	118	123	152	ND
14	1	ND	ND	ND	ND	ND
15	1	ND	5	6	ND	ND
16	1	ND	3	ND	ND	ND
17	1	ND	ND	ND	ND	ND
18	1	ND	ND	6	ND	ND
19	2	ND	125	118	152	ND
20	2	ND	215	224	354	ND
21	1	ND	6	18	ND	ND
23	1	ND	ND	ND	ND	ND
24	1	ND	ND	ND	ND	ND
25	1	ND	ND	ND	ND	ND
26	4	ND	24	24	ND	ND
27	4	ND	21	36	ND	ND
28	1	ND	4	8	ND	ND
29	5	ND	47	68	ND	ND
30	4	ND	18	38	ND	ND
31	4	ND	16	28	ND	ND
32	4	ND	8	12	ND	ND
33	2	ND	117	114	260	ND
34	1	ND	ND	ND	ND	ND
35	1	ND	ND	ND	ND	ND
36	1	ND	ND	ND	ND	ND
37	1	ND	ND	ND	ND	ND

Grid Numbers	Number of Samples	Cs-137 DCGL = 11 NRC Level = 15	Bi-214 NRC Level = 5	Pb-214 NRC Level = 5	Ra-226 DCGL = 1.5 NRC Level = 5	Am-241 DCGL = 1 NRC Level = 30
38	1	ND	ND	ND	ND	ND
39	1	ND	ND	ND	ND	ND
40	1	ND	ND	ND	ND	ND
41	1	ND	ND	ND	ND	ND
42	1	ND	ND	ND	ND	ND
43	1	ND	ND	ND	ND	ND
44	2	ND	14	10	ND	57
45	1	ND	652	676	891	ND
46	2	ND	547	562	864	ND
47	3	6	33	47	ND	ND
56	1	ND	ND	ND	ND	ND
58	1	4	ND	ND	ND	ND
59	1	ND	ND	ND	ND	ND
60	1	3	5	11	ND	ND
61	1	2	ND	ND	ND	ND
62	1	ND	ND	ND	ND	ND
65	1	3	ND	ND	ND	ND
69	1	5	ND	ND	ND	ND
71	2	38	ND	ND	ND	ND
72	1	ND	ND	ND	ND	ND
73	1	ND	ND	ND	ND	ND
74	1	ND	ND	ND	ND	ND
78	1	ND	ND	ND	ND	ND
82	1	ND	ND	ND	ND	ND
84	1	ND	ND	ND	ND	ND
85	1	ND	ND	ND	ND	ND
86	1	ND	ND	ND	ND	ND
87	1	ND	ND	ND	ND	ND
89	1	2	ND	ND	ND	ND
91	1	ND	ND	ND	ND	ND
92	1	ND	8	8	ND	ND
94	1	ND	ND	ND	ND	ND
95	1	ND	ND	ND	ND	ND
96	1	6	ND	ND	ND	ND
97	1	4	ND	ND	ND	ND
98	1	7	ND	ND	ND	ND
99	1	4	8	ND	ND	ND
101	3	961	12	18	ND	ND

Grid Numbers	Number of Samples	Cs-137 DCGL = 11 NRC Level = 15	Bi-214 NRC Level = 5	Pb-214 NRC Level = 5	Ra-226 DCGL = 1.5 NRC Level = 5	Am-241 DCGL = 1 NRC Level = 30
102	3	664	7	8	ND	ND
103	1	ND	ND	ND	ND	ND
106	1	ND	ND	ND	ND	ND
107	2	9	ND	ND	ND	ND
108	2	64	ND	ND	ND	ND
109	1	32	ND	ND	ND	ND
110	3	7265	ND	ND	ND	ND
111	4	1233	ND	ND	ND	ND
112	1	9	ND	ND	ND	ND
113	2	11	82	81	123	ND
114	1	38	33	32	ND	ND
115	1	8	13	12	ND	ND
116	1	57	2289	2148	3335	ND
118	1	ND	6	6	ND	ND
119	1	ND	4	8	ND	ND
120	1	ND	24	18	ND	ND
122	1	ND	6	ND	ND	ND
123	1	ND	3	8	ND	ND
124	1	ND	ND	ND	ND	ND
125	1	ND	ND	ND	ND	ND
126	1	ND	71	76	115	ND
128	2	17	ND	ND	ND	ND
129	4	1031	ND	ND	ND	ND
130	4	2248	ND	ND	ND	ND
131	3	65	ND	ND	ND	ND
132	4	11	ND	ND	ND	ND
133	1	ND	ND	ND	ND	ND
134	1	ND	ND	ND	ND	ND
135	2	12	9	6	ND	ND
136	2	2	5	ND	ND	ND
137	2	9	11	10	ND	ND
138	2	ND	ND	ND	ND	ND
139	1	ND	ND	ND	ND	ND
140	1	ND	ND	ND	ND	ND
141	1	ND	ND	ND	ND	ND
142	1	ND	ND	ND	ND	ND
143	1	ND	3	ND	ND	ND
145	1	ND	ND	ND	ND	ND

Grid Numbers	Number of Samples	Cs-137 DCGL = 11 NRC Level = 15	Bi-214 NRC Level = 5	Pb-214 NRC Level = 5	Ra-226 DCGL = 1.5 NRC Level = 5	Am-241 DCGL = 1 NRC Level = 30
146	1	ND	3	ND	ND	ND
147	1	4	ND	ND	ND	ND
148	2	ND	718	734	1347	ND
150	2	15	ND	ND	ND	ND
151	4	537	ND	ND	ND	ND
154	3	5	9	7	ND	ND
155	2	ND	ND	ND	ND	ND
156	2	ND	ND	ND	ND	ND
157	2	671	ND	ND	ND	ND
158	1	ND	ND	ND	ND	ND
159	1	ND	ND	ND	ND	ND
160	1	ND	ND	ND	ND	ND
161	1	ND	6	10	ND	ND
162	2	ND	6	ND	ND	ND
163	1	ND	ND	ND	ND	ND
164	2	ND	14	22	ND	ND
165	2	ND	16	10	ND	ND
166	1	ND	ND	ND	ND	ND
168	1	ND	ND	ND	ND	ND
169	2	ND	7	11	ND	ND
172	4	14	4	ND	ND	ND
173	4	21	4	ND	ND	ND
174	4	6	ND	ND	ND	ND
175	2	ND	ND	ND	ND	ND
176	3	2	4	ND	ND	ND
177	2	ND	15	14	ND	ND
178	3	4	3	ND	ND	ND
179	2	7	4	ND	ND	ND
180	1	ND	ND	ND	ND	ND
181	1	ND	6	ND	ND	ND
182	4	4	5	ND	ND	ND
183	4	6	6	ND	ND	ND
184	4	ND	4	ND	ND	ND
185	4	ND	18	ND	ND	72
187	2	ND	ND	ND	ND	6
188	1	ND	ND	ND	ND	ND
189	1	ND	28	29	ND	ND
190	1	ND	25	ND	ND	ND

Grid Numbers	Number of Samples	Cs-137 DCGL = 11 NRC Level = 15	Bi-214 NRC Level = 5	Pb-214 NRC Level = 5	Ra-226 DCGL = 1.5 NRC Level = 5	Am-241 DCGL = 1 NRC Level = 30
191	1	ND	22	ND	ND	ND
192	1	ND	ND	ND	ND	ND
193	1	ND	ND	ND	ND	ND
194	4	3	ND	ND	ND	ND
195	4	18	6	ND	ND	ND
196	4	3	ND	ND	ND	ND
197	4	ND	ND	ND	ND	ND
199	2	ND	ND	ND	ND	ND
200	2	6	ND	ND	ND	ND
201	4	195	17	16	ND	ND
202	4	59	12	29	ND	ND
203	4	ND	92	91	204	ND
205	4	3	7	12	ND	ND
206	3	75	146	157	246	54
207	3	ND	ND	ND	ND	ND
209	2	ND	ND	ND	ND	ND
210	1	ND	4	ND	ND	ND
211	1	ND	4	ND	ND	ND
212	1	ND	3	ND	ND	ND
213	1	ND	ND	ND	ND	ND
214	1	ND	ND	ND	ND	ND
215	1	ND	ND	ND	ND	ND
216	2	ND	ND	ND	ND	ND
217	5	121	7	ND	ND	ND
218	4	28	ND	ND	ND	ND
219	4	4	ND	ND	ND	ND
220	4	18	ND	ND	ND	ND
221	4	18	30	47	ND	ND
222	3	20	5	ND	ND	ND
223	4	259	30	31	ND	ND
224	4	29	10	ND	ND	ND
225	4	8	6	ND	ND	ND
226	4	3	4	ND	ND	22
227	4	3	ND	ND	ND	ND
228	4	5	15	16	ND	23
229	5	69	294	305	421	ND
230	4	ND	ND	ND	ND	8
231	4	ND	3	ND	ND	ND

Grid Numbers	Number of Samples	Cs-137 DCGL = 11 NRC Level = 15	Bi-214 NRC Level = 5	Pb-214 NRC Level = 5	Ra-226 DCGL = 1.5 NRC Level = 5	Am-241 DCGL = 1 NRC Level = 30
232	2	9	16	21	ND	ND
233	2	ND	ND	ND	ND	ND
234	3	24	29	21	ND	ND
235	4	4	5	ND	ND	ND
236	4	ND	ND	ND	ND	ND
237	3	ND	ND	ND	ND	ND
238	4	73	6	ND	ND	ND
239	3	9	ND	ND	ND	ND
240	4	8	ND	ND	ND	ND
241	4	9	ND	ND	ND	ND
242	4	8	7	ND	ND	ND
243	4	30	ND	ND	ND	ND
244	4	7	ND	ND	ND	ND
245	2	ND	ND	ND	ND	ND
246	2	12	ND	ND	ND	ND
247	2	7	ND	ND	ND	ND
248	2	ND	5	ND	ND	ND
249	2	18	ND	ND	ND	ND
250	3	7	19	14	ND	ND
251	4	25	56	61	ND	ND
252	3	10	29	21	ND	ND
253	4	68	208	215	327	ND
254	4	142	104	102	218	ND
255	4	6	18	13	ND	ND
256	3	ND	ND	ND	ND	ND
257	2	ND	ND	ND	ND	ND
258	2	ND	ND	ND	ND	ND
259	2	ND	ND	ND	ND	ND
260	1	3	ND	ND	ND	ND
261	1	ND	ND	ND	ND	ND
262	1	ND	ND	ND	ND	ND
263	1	ND	4	ND	ND	ND
264	1	ND	ND	ND	ND	ND
265	1	ND	ND	ND	ND	ND
266	1	ND	3	ND	ND	ND
267	1	4	ND	ND	ND	ND
268	1	ND	ND	ND	ND	ND
269	1	ND	ND	ND	ND	ND

Grid Numbers	Number of Samples	Cs-137 DCGL = 11 NRC Level = 15	Bi-214 NRC Level = 5	Pb-214 NRC Level = 5	Ra-226 DCGL = 1.5 NRC Level = 5	Am-241 DCGL = 1 NRC Level = 30
270	1	2	ND	ND	ND	ND
271	1	3	ND	ND	ND	ND
272	1	ND	ND	ND	ND	ND
273	1	ND	ND	ND	ND	ND
274	1	ND	ND	ND	ND	ND
275	3	3	4	ND	ND	ND
276	4	ND	ND	ND	ND	ND
277	4	ND	5	ND	ND	ND
278	1	ND	ND	ND	ND	ND
279	1	ND	4	ND	ND	ND
280	1	ND	ND	ND	ND	ND
281	2	ND	11	ND	ND	ND
282	1	ND	ND	ND	ND	ND
283	1	ND	ND	ND	ND	ND
284	1	ND	ND	ND	ND	ND
285	1	ND	ND	ND	ND	ND
286	1	ND	ND	ND	ND	ND
287	1	7	ND	ND	ND	ND
288	1	ND	ND	ND	ND	ND
289	1	ND	ND	ND	ND	ND
290	1	ND	ND	ND	ND	ND
291	1	ND	ND	ND	ND	ND
292	1	2	ND	ND	ND	ND
293	1	ND	ND	ND	ND	ND
294	1	ND	ND	ND	ND	ND
295	1	ND	ND	ND	ND	ND
296	1	ND	ND	ND	ND	ND
297	1	ND	ND	ND	ND	ND
305	1	20	ND	ND	ND	ND
306	3	55	ND	ND	ND	ND
309	1	2	ND	ND	ND	ND
310	1	48	ND	ND	ND	ND

A very small number of soil samples were also analyzed for non-radiological analyses. Four soil samples were analyzed for volatile organics using SW-846 methodology and EPA Method 8260A. These samples were collected from south of the buried silo area, the loading dock, and the side of well M7 between the well house and the underground silo area. No volatile organics were detected in these samples above the EPA health-based levels (HBLs). A single sample analyzed for hydrocarbons from behind the Lacquer Storage Building gave a result of 461 µg/g Total Hydrocarbons. Four soil samples were collected for metals analysis. These soil samples were collected from the grid 223 in the abandoned canal, the side of well M7 between the well house and the underground silo area, south of the buried silo area, and the loading dock. The results of non-radiological analyses are provided in Tables 11 and 12. Table 12 shows that beryllium and cadmium are present above HBLs (for soil ingestion) and that five of the metals used to determine the EPA's toxicity characteristic are present: barium, cadmium, chromium, lead, and silver. However, because TCLP tests were not performed, the presence of these metals does not indicate whether or not the soil would be considered hazardous, and thus whether the soil would be considered a mixed waste. Figure 11 in Appendix 1 shows that 5 of the 6 grids that were sampled for organic chemical constituents or metals have concentrations above the MCLs or HBLs. It is also clear from Figure 11 that the vast majority of the site has not been characterized for non-radiological analytes.

Table 11. Chemical Constituents in Surface Soil Samples

Grid Numbers	Volatile Organics in Soil Samples (µg/g)				Total Extractable Hydrocarbons (µg/g)
	1,1,1-Trichloroethane	Toluene	Tetrachloroethene	Xylenes (total)	
113	0.5	0.1	0.5	0.9	ND
202	ND	ND	ND	ND	461

Table 12. Selected Metals in Surface Soil Samples (ppm)*

	Metal	Ag	Ba	Be	Cd	Cr	Ni	Pb	Sr	Th	V	Zn
	HBL	400	6,000	0.2	40	400	2,000				600	20000
Grid Numbers												
115		2.3	135	0.41	40.6	239	91	630	159	2	33.1	1800
183		ND	126	0.62	4.2	17.8	22	48	21.7	2	38.6	151
204		1.3	39.8	0.4	1	24.1	14	21	28.8	4	13.5	68.7
223		ND	119	0.52	0.5	13.1	18	28	19.8	4	17.7	98.2

* **Bold** = Above MCL or HBL.

Sample results were also available for Al, Ca, Co, Cu, Fe, Mg, Mn, Mo, P, Ti, and Zr

Meiser & Earl Hydrogeologic Investigation 1979

A radiological investigation including analysis of surface and near surface soil is known to have been conducted by Radiation Management Corporation (RMC) in conjunction with the Meiser & Earl Hydrogeologic Investigation. The report for the RMC investigation was not available for our review.

Oak Ridge Associated Universities Environmental Survey 1982

Oak Ridge Associated Universities (ORAU) performed an independent environmental radiation survey in 1982 under contract to NRC. Gamma radiation exposure rates at the ground surface and at 1 m above the ground surface were systematically measured at approximately 30 m intervals around the perimeter of the site. Additional exposure rate measurements were performed in the vicinity of previous waste burial and storage activities and along the drainage ditch from the lagoon area to the river. These measurements were taken with a NaI(Tl) scintillation detector and ratemeter. Count rates were converted to exposure rates ($\mu\text{R/h}$) using factors determined by cross calibration of the detector with a pressurized ionization chamber. Beta-gamma surface measurements were also collected using a Geiger-Mueller (G-M) detector at the same locations. Measurements were collected with both open and closed-shield configuration to determine if a significant beta component was present.

Gamma radiation levels measured at 1 m above the ground surface ranged from 7 to 33 $\mu\text{R/h}$ at the property boundary. Elevated measurements were recorded at the northwest corner of the property (18 $\mu\text{R/h}$) and along the southeast perimeter (33 $\mu\text{R/h}$). Elevated measurements were also recorded in the vicinity of the waste disposal areas. The maximum direct radiation measured at 1 m above the surface was 133 $\mu\text{R/h}$, south and southeast of the East Lagoon.

Radiation levels recorded at the surface were elevated at several locations on the property. The maximum surface radiation level was approximately 1,500 $\mu\text{R/h}$ at locations near the waste disposal areas. Comparisons with open and closed-shield G-M detector measurements indicated that these measurements were primarily from gamma emitting radionuclides, with only a small non-penetrating component. The direct radiation levels measured at the surface and at 1 m above the ground surface were below the NRC guidelines for doses in unrestricted areas. ORAU concluded that the pattern of direct radiation indicated small regions of surface contamination that suggests both isolated surface residues and migration from waste disposal areas.

The ORAU survey also included the collection and analysis of 6 baseline samples, 46 surface soil samples, and one sediment sample. The six baseline soil samples were collected 2.5 to 10 km from the site for comparison with other samples collected in the area of the SLC facility. Baseline samples were analyzed for Ra-226, Cs-137, Sr-90, and H-3 and the detected radionuclide concentrations of baseline soil samples are shown in Table 13 below.

Table 13. Radionuclide Concentrations In Baseline Soil Samples (pCi/g)

ORAU Sample Location	Ra-226	Cs-137	Sr-90 ¹	H-3 ¹
1	0.74	0.35		< 0.36
2	0.44	0.21		0.58
3	0.52	0.74		
4	0.56	0.04		
5	0.56	0.21	0.63	
6	< 0.05	< 0.02		< 0.36

¹ A blank in these columns indicates that the sample was not analyzed for that radionuclide.

The 46 site surface samples were analyzed for Ra-226 and Cs-137 with a few samples also analyzed for Sr-90. 39 samples were collected at randomly selected locations around the site and seven samples were collected at locations where direct radiation measurements identified elevated levels including:

- the northeast corner of the property
- in the West Plant Dump
- along the USR Metal Liquid Waste Building (Multi-Metals plant) discharge line
- south of the underground silos
- along the discharge line from the Liquid Waste Building.

One sample of sediment was collected from the storm drainage ditch. Of the 46 samples, 39 were taken in the third of the site south of the buildings.

Surface soil samples from the northwest corner of the property contained elevated Ra-226 levels of 2.3 pCi/g, 5.78 pCi/g, and 67.1 pCi/g. All other soil samples containing levels of Ra-226, Cs-137, or Sr-90 were collected from the southern portion of the property. Surface soil samples with Ra-226 levels greater than the 1.5 pCi/g (the DCGL proposed by SLC in the Decommissioning Plan) were collected from the following locations:

- near the southwest entrance to the Etching Building
- in the West Plant Dump
- on the southeast edge of the facility near the Vance Walton property
- south of abandoned canal just east of USR Metals Liquid Waste Building (Multi-Metals plant) discharge line
- along USR Metals Liquid Waste Building (Multi-Metals plant) discharge line
- on the southwest edge of the property near the West Plant Dump
- south of the Laquer Storage Building
- south of the underground silos
- along discharge line from Liquid Waste Building.

Surface soil samples with Cs-137 levels greater than 11 pCi/g (the DCGL proposed by SLC in the Decommissioning Plan) were collected from the following locations:

- just south of the West Lagoon
- along the USR Metals Liquid Waste Building (Multi-Metals plant) discharge line
- along the discharge line from Liquid Waste Building
- on the southeast edge of the facility near the Vance Walton property
- on the Vance Walton property.

Surface soil samples with Sr-90 levels greater than 5 pCi/g (the reference value used for Gross Beta isopleths in the Monserco Site Characterization Report) were collected from the following locations:

- south of the West Lagoon
- along the river edge directly south of the underground silos
- along the discharge line from the Liquid Waste Building
- on the southeast edge of the facility near the Vance Walton property
- on the Vance Walton property.

Biased surface samples collected in areas of maximum direct radiation levels contained up to 672 pCi/g of Ra-226, 631 pCi/g of Cs-137, and 15.4 pCi/g of Sr-90. Radionuclide concentrations in on-site surface soils are shown in Table 14. The ORAU report included a map showing elevated levels of surface radiation (ORAU Figure 19). This map is included in Appendix 2.

Off-site soil and sediment samples were also collected during the ORAU survey 0.5 to 1 km from the site. A total of 19 samples were collected from an island southeast of the facility and from the Susquehanna River 2 km upstream of the facility; at the outfall; and 100 m, 500 m, and 2 km downstream of the facility. Samples collected off-site did not have concentrations of radionuclides used by U.S. Radium and SLC that were significantly different from the baseline concentrations or guideline levels.

Table 14. Radionuclide Concentrations In On-Site Surface Soil (pCi/g)

ORAU Location ¹	Approximate Monserco Grid Location ²	Ra-226 (DCGL = 1.5)	Cs-137 (DCGL = 11)	Sr-90 ³ (DCGL = 5)
1	9	0.26	0.30	
2	1	0.61	0.69	
3	3	0.53	1.06	
4	34/35	2.34	0.92	
5	5	0.71	0.77	
6	208	0.92	1.77	

ORAU Location ¹	Approximate Monserco Grid Location ²	Ra-226 (DCGL = 1.5)	Cs-137 (DCGL = 11)	Sr-90 ³ (DCGL = 5)
7	211/212	0.59	0.17	
8	169	4.17	1.02	
9	194	0.71	2.28	
10	306	2.12	304	4.68
11	Vance/Walton Property	1.19	14.8	5.31
12	261	0.49	0.25	
13	266	0.63	0.83	
14	246/247	0.58	0.83	
15	249	0.83	1.34	
16	251	2.99	1.95	
17	256	0.73	0.13	
18	254	0.70	0.18	
19	259	0.58	0.12	
20	215	1.71	1.22	
21	213	1.03	0.37	
22	232	1.21	11.8	11.7
23	229	0.58	0.76	
24	205	0.95	1.68	
25	203	2.06	3.01	
26	201	1.34	19.5	6.85
27	199	0.78	3.81	
28	218	0.93	10.9	
29	27	5.78	1.33	
30	Along river bank just outside southwest corner of property	0.60	0.03	
31	280	0.67	0.03	1.50
32	277	0.81	< 0.02	

ORAU Location ¹	Approximate Monserco Grid Location ²	Ra-226 (DCGL = 1.5)	Cs-137 (DCGL = 11)	Sr-90 ³ (DCGL = 5)
33	275	0.86	1.24	
34	273	0.63	0.19	
35	270	0.66	0.41	10.3
36	289	0.61	0.16	
37	286	0.66	0.19	
38	284	0.76	0.34	0.12
39	310 or just south along river bank	1.29	0.06	
40B ³	31	67.1	2.77	
41B	192	220	4.79	
42B	204	0.86	3.28	
43B	225/226	353	8.2	0.64
44B	230	11.8	21.6	4.3
45B	253	672	227	1.2
46B	200	22.0	631	15.4

¹ A "B" indicates sample is biased based on elevated surface radiation levels.

² Locations approximated by comparison with gridded map developed for 1995 Monserco Site Characterization.

³ A blank in these columns indicates that the samples was not analyzed for that radionuclide.

Chem-Nuclear Systems, Inc. Hydrogeological and Radiological Evaluation 1990

A surface gamma radiological survey was conducted during the evaluation conducted by Chem-Nuclear Systems, Inc. (CNSI) in 1990. The survey was conducted at locations of proposed drilling using a portable micro-R meter in order to place the drill holes away from elevated levels of surface contamination. Initial area surveys indicated no surface abnormalities within the Vance Walton property with the exception of the areas along the SLC property line. Surveys indicated areas up to 1.5 times background. No further data or discussion were provided in the CNSI report regarding this gamma survey.

Although not included in the scope of work, limited surface contamination assessments were conducted around work areas. Readings were taken using a NaI low energy gamma detector and are summarized below:

- In marsh area southwest of monitoring well 2 (which is located in grid 226) readings were 6 to 10 times background.

- In the area near monitoring well 5 (which is located in grid 254) a localized “hot spot” was discovered. Yellow/white powder was uncovered with readings 100 times background. SLC personnel believed the powder to be from a buried radium rope.
- In the open disposal pit 10 feet west of this well readings were 20-50 times background.
- The drainage ditch located near monitoring well 5 for discharge from SLC property to Susquehanna River contained numerous underwater hot spots that varied from 50-100 times background.
- In an area near monitoring well 6 (which is located on the line between grids 253 and 275, and near well 5) readings were 20 times background.
- In area south of monitoring well 12 (which is located in grid 160) along the fence readings were 10-15 times background.
- At the old garage foundation, approximately 200 feet south of monitoring well 14 readings were 10-15 times background.
- Various isolated hot spots were identified along south fence line near monitoring well 18 (which is located in grid 309) with readings 10-25 times background.
- The area of the tank discharge line near monitoring well 19 (which is located in grid 224) also had isolated hot spots on surface with readings 3-10 times background.
- In the depression around well 23 (which is the eastern well in grid 170) readings were 10-15 times background.

Oak Ridge Institute for Science and Education 1999

In October 1999, NRC tasked Oak Ridge Institute for Science and Education (ORISE) (formerly Oak Ridge Associated Universities or ORAU) with conducting additional sampling on sediment and water from the East Lagoon. Surface scans for gamma activity were performed over approximately 50 percent of the lagoon. The remainder of the lagoon was inaccessible due to overgrowth of vegetation. Surface scans were performed using NaI scintillation detectors coupled to ratemeters with audible indicators. Exposure rate measurements were performed at one meter above the surface with a Bicron microrem meter. Because the sampling conditions were unfavorable for collecting most of the sediment samples at the typical surface (0 to 15 cm) and/or subsurface (greater than 15 cm) depths, ORISE used a sediment sampling tool with a 60 cm sampling depth. The majority of the samples were taken at a 0 to 60 cm depth. As a result of this sampling method, detritus (i.e., loose debris, vegetation, rocks) was also collected in the sampling tubes but was analyzed separately. At four of the 10 sediment sampling locations, samples were also taken at depths below 60 cm to determine the depth of contamination or until the sample depths were limited by gravel. Table 15 presents sampling depths and radionuclide concentrations.

Gamma surface scans detected elevated gamma activity throughout the lower portion of the East Lagoon. Sediment sample locations included several areas of elevated gamma activity that were detected during the gamma scans. Background exposure rates at one meter above the surface near the lagoon were 15 $\mu\text{rem/hr}$. Exposure rates within the East Lagoon ranges from 15 to 40 $\mu\text{rem/hr}$. Radionuclide concentrations in the East Lagoon sediment/detritus samplers are presented in Table 15. Concentration ranges were as follows:

- Am-241 <0.11 to 4.35 pCi/g
- Ra-226 4.7 to 2,540 pCi/g
- Cs-137 0.38 to 519 pCi/g
- Sr-90 0.46 to 186.4 pCi/g.

Radionuclide concentrations in the East Lagoon were as follows:

- Am-241 <7.33 pCi/g
- Ra-226 0.27 pCi/g
- Cs-137 <6.08 pCi/g
- Sr-90 1.27 pCi/g
- H-3 9,000 pCi/g.

Table 15. Radionuclide Concentrations in East Lagoon Sediment Samples (pCi/g)

ORISE Location	Depth (cm)	Am-241	Ra-226	Cs-137	Sr-90
1-detritus ^a	0-60	1.19	15.6	10.24	--- ^b
1-sediment ^a	0-60	1.94	42.4	20.49	2.89
2-detritus	0-60	0.77	8.97	4.39	---
2-sediment	0-60	4.35	114.0	51.9	5.89
3-detritus	0-60	2.00	200	519	---
3-sediment	0-60	<0.45	75.8	46.4	3.72
4-sediment	0-15	1.04	7.05	4.52	1.10
4-sediment	15-30	1.34	4.7	3.10	1.89
4-sediment	30-45	3.31	442	18.01	38.1
4-sediment	45-60	<2.99	2,540	3.17	186.4
4-sediment	60-75	3.80	1,280	1.78	48.9
4-sediment	75-90	<0.40	119.1	0.38	31.5
5-sediment	0-15	1.11	16.2	8.10	2.16

ORISE Location	Depth (cm)	Am-241	Ra-226	Cs-137	Sr-90
5-sediment	15-30	0.86	6.7	4.33	2.11
6-sediment	0-60	0.83	6.58	5.69	0.46
7-sediment	0-60	0.95	17.3	7.17	1.90
8-detritus	0-60	3.35	24.2	10.16	---
8-sediment	0-60	0.45	87.3	37.2	5.24
9-detritus	0-45	1.77	21.9	13.45	---
9-sediment	0-45	0.30	179	93.5	11.08
9-sediment	45-60	<0.46	138	40.6	7.48
9-sediment	60-75	<0.14	24.2	6.17	6.53
9-sediment	75-93	<0.11	7.79	1.61	6.88
10-detritus	0-60	1.31	32.3	13.64	---
10-detritus	0-60	1.90	17.0	2.31	---
10-sediment	0-60	3.02	133	44.1	7.92

- a. Samples containing both detritus and sediment were collected at a depth of 0 to 60 cm. Due to compaction during the collection of the sample, the actual depth of the detritus to sediment is unknown. It is estimated that the upper 1/3 of the sample was detritus and the lower 2/3 was sediment.
- b. Analysis is not performed.

5.2 Identification of Potential Gaps in Characterization

In reviewing the adequacy of the surface soil sampling data, we used the Monserco report as the major source of information, with some supplemental information from the other reports. Although the 1980 ORAU study is over 20 years old, we believe that because of the long half-lives of the isotopes involved (Ra-226 = 1600 years; Am-241 = 432 years; Cs-137 = 30 years; Sr-90 = 29.1 years; and H-3 = 12.4 years), unless rain/ground water has moved the contamination, it should still be present in approximately the same location. We compared the 1980 ORAU Sr-90 data with Figure 3 (because strontium is the major beta emitter expected to be present), the Cs-137 data with Figure 4, and the Ra-226 data with Figure 5. In general, the 1980 ORAU data are consistent with the Monserco report, with the exception that a few additional grids in the 1980 ORAU report show Ra-226 contamination above regulatory levels (grids 27, 31, 34, 169, 192, 200, 215, 225, 226, 230, and 251). These exceptions may be due to hot spot contamination not picked up in the sampling locations used by Monserco or migration of contaminants further into subsurface soil. However, the most likely explanation is that because of the high detection limits for Ra-226 in the Monserco sampling effort, the contamination may exist but was not identified. When these grids are compared to the Pb-214 and Bi-214 Monserco data, only five of the ORAU

grids show contamination, while the Monserco data does not (grids 192, 200, 215, 226, and 230). Furthermore, Monserco only took one sample in grids 192 and 215, and two samples in grid 200 (as opposed to four samples that were taken in other areas expected or known to be contaminated).

Although the Chem-Nuclear study did not take soil samples, the soil survey results are consistent with known contamination found in the Monserco and ORAU studies. The ORISE study of the East Lagoon provides supplemental data to the Monserco report, because Monserco did not sample two grids in the East Lagoon. Nonetheless, the ORISE findings of high levels of Am-241, Cs-137, Ra-226, and Sr-90 are not unexpected given the site history.

To assess whether there are gaps in the characterization of surface soils we used the check list presented in Section 3.3.

1. Have historical records been kept for all surface areas on the site?

No. Some information is available about disposal activities in different parts of the site, but this information is not comprehensive. For example, the location and history of the seven lagoons is not known. Further, much of the history is recreated from the memory of longtime and retired employees and thus subject to gaps.

2. Has each distinct surface area been classified as impacted or non-impacted?

Yes.

3. Has each distinct surface area been assigned a Class 1, 2, or 3 ranking and appropriately divided into sampling grids?

No. The Monserco report does not provide a grid-by-grid classification scheme. However, it seems as though some ranking must have been applied to the grids to determine the number of samples taken in each grid (between 0 and 4 samples were taken).

4. Has a sampling plan been prepared based on the Class ranking for all sample grids?

Yes. Although the explanation for when one versus four samples were to be taken is not reproducible given the information presented in the Monserco documents.

5. Does the sampling plan address all analytes of concern?

No. Given the probability for mixed waste at the site, the sampling plan does not adequately address non-radiological contamination.

6. Does the sampling plan address QA/QC requirements?

Yes.

7. Has sampling been conducted in each grid according to the sampling plan?

No. Some grids were not sampled at all, and some grids had two or three samples taken with no explanation given, even though the sampling plan indicated either 1 or 4 samples would be taken from each affected grid. While the explanation is obvious in some grids that buildings/roads obscure the sampling area, in other grids there is no explanation for the non-standard number of samples.

8. Is the number of samples taken known for each grid?

Yes.

9. Is the number of samples equal to or greater than the minimum that would be calculated using our land-based management unit characterization methodology?

Yes, but because the distribution of samples is skewed, there may be areas on the site that are still inadequately characterized. For example, more samples may be needed in "unaffected" grids that measure 25 m x 25 m (or 6,724 ft²) where only one sample was taken.

10. Are the detection limits for each analytical instrument known for each grid?

Yes, the detection limits are known. However, these limits are considerably higher than stated in the characterization working document.

11. Has sampling been conducted for each grid using appropriate instrumentation with appropriate sensitivity?

No. Due to high detection limits, non-detectable concentrations of Ra-226, Pb-214, and Bi-214 cannot be used to show that these isotopes are not present above levels of concern.

12. Are all sample results below the DCGL or NRC limit?

No. Many grids were found to have concentrations of Cs-137, Ra-226, Am-241, Pb-214, and Bi-214 above the DCGL or NRC limit. Further, high concentrations of beta radiation were found, indicating the likely presence of Sr-90.

As a result of the above evaluation, we have found four significant gaps in the surface soil characterization to date. First, some affected grids in the Monserco study are not sampled at all or seem to be under sampled (grids in suspect areas that have a single sample with no reason given). Second, the Ra-226 has not been fully characterized due to high detection limit problems with Ra-226 and daughter isotopes Pb-214 and Bi-214. Third, although there is a possibility that much of the site contains mixed waste, almost no sampling has been performed to identify metal

or organic constituents. Knowing whether the site has mixed waste or merely low level radioactive waste will make a significant difference in off-site disposal availability and cost. Fourth, off-site sampling of surface soils collected from the western side of the SLC property has not been conducted and additional characterization of the surface soils along the eastern side of the SLC property is necessary.

5.3 Recommendations for Additional Characterization

Given the four gaps in characterization, and the possibility that additional sampling will be needed if the soil is to be disposed at an off-site disposal facility (such as Envirocare), we recommend that additional soil sampling be conducted in the following circumstances.

1. If grids that were not sampled or under sampled (only one sample with no immediately obvious reason why) are adjacent to a grid above regulatory levels, assume the grid that was not sampled is also contaminated above regulatory levels. An example of this would include grids near the southern end of the acid etching building (such as grids 126, 127, 149, 160, 171, 192, 193, 210-215). For under sampled grids (grid with only one sample) in areas where contamination was not expected, yet found, such as the north east parking lot and the area by the water tank north east of the nuclear building, additional sampling may be needed. We recommend regriding eight "unaffected" 25m x 25m grids (grids 4, 5, 9-12, 17, and 18) to 10m x 10m grids (resulting in 50 new grids) and taking four samples in each grid because of the contamination in nearby "unaffected" grids. We also recommend taking three additional samples in grids 40-43, 58, 61, 62, 65, 72-74. Further, we recommend taking four samples in grids 48-55, 63, 64, 66-68, 75-77, 80 and 81, which were not sampled at all. Finally, we recommend that sampling be conducted in six 100ft x 100ft grids to be established on property to the east and west of the site (for a total of 12 grids). In these grids, we recommend four samples be taken. All of these samples should be analyzed for the gross beta and gamma isotopes.
2. Given the detection limits problems for Ra-226, Bi-214, and Pb-214, we recommend that the grids in the northeast parking lot and by the water tower northeast of the nuclear building be analyzed for these three isotopes.
3. Additional metal and organic sampling will be needed to determine the extent of mixed waste contamination at the site. Because this characterization is only needed for disposal, we believe that this sampling can be conducted as the site is being prepared for disposal, and that in deriving the cost estimates for restricted and unrestricted release, a large percentage (30-50 percent) of the soils at the site may be considered mixed.

An alternative to the sampling recommended in (1) and (2) above would be to assume the entire surface of the site (and adjacent to the eastern and western borders of the site) is contaminated. Along these lines, in some cases it may be possible to make assumptions based on other measurements (e.g. gross alpha) and minimize the amount of sample analyses to be performed

prior to the commencement of remediation. However, some level of additional characterization will still be required for disposal.

5.4 Costs Associated with Additional Characterization

To calculate the cost associated with additional soil characterization, the number of samples was multiplied by the unit cost per sample for soil analysis of gamma spectroscopy and gross beta counting. From Table 4 in Section 3.5, the unit cost associated with gamma spectroscopy was \$103 per sample, and the unit cost for gross beta counting is \$63.52 per sample. Therefore, the combined unit analytical cost is \$167 per sample. As shown in Table 16, a total of 353 samples will require analysis, at a total cost of \$58,752. To account for sample collection and associated costs of sampling, we added 10 percent of the total analytical cost on to this estimate, which results in a total cost of \$64,660.

Table 16. Estimated Costs Associated with Additional Soil Sampling

Grids requiring 4 samples	Number of samples needed
50 new grids (from regriding of grids 4, 5, 9-12, 17, 18)	200
6 new 100 ft ² grids (east of property line)	24
6 new 100 ft ² grids (west of property line)	24
Non-sampled grids (48-55, 63,64, 66-68, 75-77, 80, 81)	72
Grids Requiring 3 additional samples	
3 additional samples (grids 40-43, 58, 61, 62, 65, 72-74)	33
Total number of samples needed	
	353
Unit Cost for Sample Analysis	
	\$ 167
Total Analysis Cost	
	\$ 58,782
Associated sampling costs (10 percent)	
	\$ 5,878
Total Cost	
	\$ 64,660

6.0 Sub-Surface Soils

Surface and subsurface soils at the SLC site have been contaminated with a number of different isotopes over the years as well as metals and possibly organic compounds. The primary radioactive isotopes of concern are Ra-226, Cs-137, Am-241, and Sr-90. Daughter isotopes of Ra-226, such as Pb-214 and Bi-214, have also been found in the subsurface soils. As noted in Section 5.0, the presence of metal and organic contaminants in the surface soil at the site raises the possibility that the soil might be considered mixed waste and would require disposal currently available at a single facility (Envirocare in Clive, Utah). Specifically, soil with radioactive contamination that either fails EPA's TCLP test for these constituents, or contains EPA's listed wastes (such as electroplating sludge -- F006 or F009, spent solvents -- F001 - F005, etc.) would be classified as a mixed waste.

Over the last 20 years, various subsurface soil sampling efforts have been undertaken. In 1995, SLC contracted Monserco, Ltd. to conduct an in-depth study of the site. The Monserco study was the most recent comprehensive study of radiological contamination of soils and is the central focus of our review. Earlier studies include a 1979 Meiser & Earl Hydrogeologic Investigation which references an earlier Radiation Management Corporation study that was not available for our review, an 1982 Oak Ridge Associated Universities investigation, and a 1990 Chem-Nuclear Systems, Inc. study.

In Section 6.1, we present the results of the Monserco study, followed by results of the other investigations. Section 6.2 presents our assessment of the adequacy of the subsurface soil characterization to date, while Section 6.3 presents our assessment of whether additional sampling is needed. Finally, Section 6.4 presents the costs associated with the additional sampling.

6.1 Summary of Existing Characterization

Available Subsurface History

Limited historical site information was presented on (1) buried objects or (2) distinct surface and subsurface areas in the site in the Monserco Report. In addition, subsurface samples have not been collected from beneath any of the buildings or along drain lines/sumps. We summarize this information below, which is supplemented in a few cases with observations from ICF's site visit in May 2001.

Underground Piping/Utilities/Drain Lines

Low level radioactive wastewater from the Nuclear Building is transported by a below grade drain line to a sump located in the Liquid Waste Building. The wastewater is subsequently pumped into dilution tanks. During our May 2001 site visit, SLC personnel reported that numerous underground cisterns, pipes, and sumps exist at the site. It is uncertain as to whether the locations of all these structures are known. For instance, during our May 2001 site visit, SLC personnel noted that they had just found a large cistern and sump system north of the lacquer

storage building that they had not known about. In addition, apparent discharge lines or discharge ditches have been observed from the Liquid Waste Building to the river and from the Multi-Metals Waste Treatment Plant to the river.

Cement Trough/Sewer Grate

This is a drain conveyance which transferred process water from the Main Building to the East Lagoon. No further information is available.

Underground Storage Tank

An electromagnetic survey conducted during the 1995 Characterization revealed an underground storage tank north of the underground silo area, as well as adjacent buried piping. During our May 2001 site visit, SLC personnel indicated that other underground storage tanks were used at the site to store petroleum products and chemicals (such as acetone).

Underground Silo Area

Two underground silos that were both about 12 feet deep and 10 feet in diameter were used to store miscellaneous radioactive wastes, including Ra-226, Sr-90, and Cs-137. These silos were excavated in 2000. Soil from the excavation is currently stored in 55 gallon drums and B-25 containers in the storage area over the old garage foundation and the storage area between the above ground silo and the solid waste building. During this excavation, the silos and their contents were entirely removed, with the exception of the bottom of the silos and one steel ring (these were encased in concrete and could not be removed without breaking up the concrete pads). The concrete pads were not removed because the sandy soil started to cave in on the excavation. Both the remaining underlying soil and surrounding soil are contaminated and will require remediation. A wood frame structure covered with plastic sheeting and a plywood roof was built over the old silo area during remediation of the silos to contain contamination. There is a beta source outside the southeast corner of this structure.

Abandoned Canal

The old canal, which ran from Sunbury to Scranton, was 100 feet wide and 15 feet deep according to site personnel. The actual width of the canal on the SLC property during that time is not documented. At one time the portion of the canal on the SLC site contained as many as 7 lagoons. During 1948/1949 the canal was used for disposal of Ra-226 contaminated ductwork. SLC personnel believe this ductwork is still buried in the portion of the abandoned canal over which the pipe shop was built. Prior to 1960, all liquid waste from radiological production activities was routed to open portions of the canal. In 1960, plans were made to precipitate out the radioactive contaminants from the canal water, excavate the contaminated sediments, and discharge treated water to river. There is no evidence to confirm that these plans were carried out. In the early 1960's three eastern lagoons were found to be contaminated with considerable radioactive contaminants. The radioactive constituents were precipitated out and the two most

easterly lagoons were backfilled. Between 1976 and 1978, the third most easterly lagoon was backfilled.

East Lagoon

This lagoon was built in a portion of the old canal which ran from Sunbury to Scranton, and was at least 100 feet wide and 15 feet deep. Although there were no accumulated liquids or debris visible on the surface of the lagoon at the time of the ICF site visit, there was an oily looking spot in the middle of the base of the lagoon. Grass and wild flowers grow in the lagoon. An 8 or 10 inch diameter outfall drains into the lagoon. This outfall was dry at the time of the site visit and plant personnel did not know its source. This lagoon was used to dispose of sewage and process wastewater from the radium laboratory in the main building from 1948 to 1954. In 1960, the contents of the lagoon were pumped into the West Lagoon. It is likely that the lagoon contents were dispersed into the surrounding soils during the 1972 flood of the Susquehanna River.

West Lagoon

This lagoon lies in a portion of the old canal. The lagoon was used to dispose of silver plating wastes and anodizing solutions. In the 1960's, contents of the East Lagoon were pumped into the West Lagoon. There was no accumulated liquid or debris in the west lagoon at the time of the ICF site visit. The lagoon contents were likely dispersed into the surrounding soils during the 1972 flood of the Susquehanna River.

East Plant Dump

The east plant dump is an area between the east and west lagoons and was identified during the installation of a storm sewer in 1972. A portion of the canal near the dump was used for disposal of Ra-226 contaminated ductwork during the early years of operation. The dump currently contains a pile of pallets, old chain link fences and pipes, old pipes, windows, cinder blocks, and sheet metal. The outfall from current USR Metals operations is located south of the East Plant Dump and behind the fencing. Liquid was draining from this outfall during the ICF site visit.

West Plant Dump

The west plant dump abuts the west property line and fence. The dump is a pit used in 1948/1949 for disposal of solid waste. Before 1970, the dump was used for disposal of Ra-226 dials and Sr-90 deck markers. In the late 1960's or early 1970's, 78 drums of Ra-226 contaminated soil (including radium dials) was removed from this area and shipped off-site. SLC personnel indicated that radium dials are still found in this area from time to time.

A ground penetrating radar survey carried out during the 1995 Characterization revealed reflections characteristic of metallic objects/drums on the north, east and west sides of the West dump.

Buried Metallic Objects

The ground penetrating radar survey carried out during the 1995 Characterization revealed reflections characteristic of metallic objects/drums south of the Liquid Waste Building. The anomalies were estimated at 6 to 8 feet below grade and approximately 3 to 4 feet wide. A magnetic survey was conducted during the 1990 CNSI evaluation to assist in identifying buried metal objects within the Vance/Walton property. The survey was conducted using a Schonstedt Model GA-52B magnetic locator which detects the magnetic field of any ferrous object covered by soil, pavement, or shallow water. A grid pattern was established covering the suspected boundaries of the abandoned canal. Numerous small to large buried magnetic (ferrous) objects were detected within the Vance/Walton property. A concentration of metal objects was observed within the suspected boundaries of the canal and near the SLC eastern property line.

Monserco Site Characterization 1995

An electromagnetic survey was conducted during the Monserco Site Characterization. An EM31 electromagnetic instrument was used to indicate soil electrical conductivity and soil magnetic susceptibility. The EM31 has a depth penetration of over 3 meters. An EM61 high sensitivity/high resolution time-domain instrument was used to detect ferrous and non-ferrous metallic objects. The EM31 surveys were conducted over all outdoor grids. The EM61 surveys conducted in specific areas (fenced area of underground silos, north of the silos, and two asphalt-paved driveways adjacent to the Main Building) to provide complementary information to the EM31 survey to resolve ambiguities or anomalies in the data.

The EM31 survey results revealed uniform distributions of soil conductivity within the surveyed property. Soil conductivities increased in the southern portion of the facility. Monserco indicated this may be associated with the shallower ground water levels near the Susquehanna River. Three areas of elevated soil conductivity and anomalies associated with buried metallic objects were detected in the vicinity of the two lagoons. The Monserco report indicates that these anomalies may represent areas affected by inorganic contamination. Four anomalies indicating large metallic objects were detected using the EM31 and EM61 surveys. Two round shaped anomalies were identified as the underground silos. The anomaly located just east of the Well House may be indicative of an underground storage tank. The apparent depth of this anomaly is 1.1 m. Linear anomalies located in the same vicinity may be buried pipes associated with the underground storage tank. Two anomalies representing large metallic objects are also located south of the Etching Building and west of the Pipe Shop. Numerous anomalies associated with isolated buried objects were detected. The highest density of these anomalies is located south of the Solid Waste Building and Liquid Waste Building in the abandoned canal area. A number of linear anomalies identified across the property may indicate buried pipes or cables.

A Ground Penetrating Radar (GPR) survey was also carried out during the Monserco Site Characterization. GPR was used to obtain a profile of the subsurface conditions in two main areas and to locate underground discharge pipework for the Liquid Waste Building. Area 1 was a 900 ft² area in the inaccessible parts of the West Dump. GPR reflections characteristic of metallic objects/drums were observed primarily on the north, east and west sides of Area 1. The presence of surface metallic debris in the actual dump area limited the effectiveness of the GPR

for this area. Area 2 was a 50 ft² area located over a small surface depression adjacent to the south side of the Liquid Waste Building. This area had produced anomalous results when surveyed using the EM31 survey meter. GPR reflections characteristic of metallic objects/drums were observed in this area 6 to 8 feet below grade level and approximately 3 to 4 feet wide.

Eight trenches were excavated during the Monserco Site Characterization in order to obtain an understanding of the nature and extent of possible buried materials on the site. Six parallel trenches were excavated in grid 221 and two parallel trenches were excavated in grid 240. Grid 221 trenches were approximately located from north to south and were 8 to 10 feet long, 3 to 4 feet wide, and 5 feet deep. Grid 240 trenches were approximately located from northeast to southwest and were 15 feet long, 3 to 4 feet wide, and 5 feet deep. Excavations in grid 221 revealed slab rock (suspected to be canal bottom) at a depth of 5 feet for one trench. A drum ring and curved metal plate were found inside another trench and were not radioactive. Finally, glass was found in a third trench at a depth of 5 feet. Excavations in grid 240 did not uncover any objects.

Thirteen boreholes were drilled at various locations on the SLC site to assess the radiological and non-radiological condition of the subsurface soils and to install additional groundwater monitoring wells. The number and location of boreholes were selected after review of existing radiological information and concurrence between SLC and NRC. Boreholes were placed south of the affected or potentially affected areas to provide soil and water samples downstream of these areas. Boreholes were drilled using a hollow stem auger with a split spoon sampler and sampler retainer. Boreholes were cored to a minimum depth of 20 feet and/or to the water table and were subsequently converted into wells. Table 17 describes the locations of these wells and provides the depth and depth to groundwater for each well.

Cored material was monitored every two feet for radiation using the HP260 contamination probe. Positive radiation readings were recorded for soils from boreholes M2, M3, M4, M5, M6, M7, M9, M10, M11, M12, and M13. Hydrocarbon odors were reported by field crew during drilling of boreholes M1, M8, M9, and M13. Organic vapors were monitored using a Photo Ionization Detector (PID). Positive results were obtained from boreholes M1 and M7. Soil samples were brought to the surface for every 2 to 2.5 feet drilled. Samples were analyzed by gross alpha and gross beta counting and by gamma spectroscopy. Results of these analyses are provided in Table 18. Although Monserco analyzed each sample for Co-60 and Am-241, neither of these isotopes were ever detected. As a result, we have not included either of these radionuclides in Table 18. The highest gross beta result of 249 pCi/g was from well M10, inside grid 182 and south of the East Silo. The highest Cs-137 result of 99 pCi/g was from well M12, inside grid 223 and south of the Lacquer Storage Building. The highest Ra-226 result of 215 pCi/g was from well M5, inside grid 250 and south of the East Lagoon. The highest value and deepest value of beta concentration are shown in Figure 12 in Appendix 1 for each well.

Gamma emitting isotope concentrations greater than the DCGLs suggested by SLC in the Decommissioning Plan or greater than the NRC reference value are shown in Figures 13 through 16 in Appendix 1. Figure 17 in Appendix 1 provides the highest concentration of detected isotopes for each well with the corresponding depth of the sample.

As with surface soil results, detection limit problems limit the usefulness of these results. The detection limits for Bi-214, Pb-214, and Ra-226 were higher than the NRC levels or DCGLs listed in Appendix 17 of the Monserco Characterization Report. Consequently, the non-detected values cannot be used to show that these isotopes are not present in the soil above levels of concern.

Table 17. Monserco Site Characterization Monitoring Well Installation Data

Well Number	Grid	Location	Depth of Borehole (m)	Depth to Groundwater Table (m)
M1	180	North of Lacquer Storage Building	5.9	4.27
M2	240	Southeast quadrant of SLC property downgradient of abandoned canal	4.3	2.26
M3	233	South of West Lagoon beside effluent stream	3.0	1.04
M4	229	Southeast of East Lagoon	4.3	2.29
M5	250	Southeast of East Lagoon outside fenced property	3.0	1.52
M6	244	South of Liquid Waste Building in vicinity of abandoned canal and liquid waste discharge line	3.0	1.66
M7	161	Southeast of Well House and northwest of Underground Silos	4.9	4.11
M8	178	South of Liquid Waste Building inside fenced restricted area	4.8	3.35
M9	183	South of West Silo	5.5	3.96
M10	182	South of East Silo	5.5	3.96
M11	203	Southwest of Lacquer Storage Building	4.4	3.35
M12	223	Southeast of Lacquer Storage Building in vicinity of Cs-137 log hot spot	3.6	1.83
M13	170	West Plant Dump	5.5	4.88

Table 18. Beta and Isotopic Concentrations in Subsurface Soil Samples (pCi/g)

Well Number	Grid	Depth of soil samples (m)	Beta	Cs-137 DCGL = 11	Bi-214 NRC Level = 5	Pb-214 NRC Level = 5	Ra-226 DCGL = 1.5
M1	180	1.65	ND	ND	ND	ND	ND
		2.26	ND	ND	ND	ND	ND
		2.87	ND	ND	ND	ND	ND
		3.48	ND	ND	ND	ND	ND
		4.09	ND	ND	ND	ND	ND
		4.7	ND	ND	ND	ND	ND
		5.31	ND	ND	ND	ND	ND
		5.92	ND	ND	ND	ND	ND
M2	240	0.61	ND	ND	7	ND	ND
		1.22	ND	ND	ND	ND	ND
		1.83	ND	48	ND	ND	ND
		2.44	ND	5	ND	ND	ND
		3.05	ND	40	ND	ND	ND
		3.66	ND	18	ND	ND	ND
		4.27	ND	18	ND	ND	ND
M3	233	0.61	14.43	11	ND	ND	ND
		1.22	22.98	31	44	48	ND
		1.83	ND	ND	ND	ND	ND
		2.44	ND	ND	ND	ND	ND
		3.05	ND	ND	ND	ND	ND
M4	229	0.61	ND	ND	ND	ND	ND
		1.22	8.91	7	25	30	ND
		1.83	ND	6	22	25	ND
		2.44	ND	ND	ND	ND	ND
		3.05	70.99	ND	ND	ND	ND
		3.66	81.75	ND	6	ND	ND
		4.27	97.23	ND	ND	ND	ND
M5	250	0.61	120.03	99	160	154	215
		1.22	ND	4	ND	ND	ND
		1.83	ND	ND	ND	ND	ND
		2.44	ND	11	ND	ND	ND
		3.05	ND	6	ND	ND	ND

Well Number	Grid	Depth of soil samples (m)	Beta	Cs-137 DCGL = 11	Bi-214 NRC Level = 5	Pb-214 NRC Level = 5	Ra-226 DCGL = 1.5
M6	244	0.61	95.77	102	11	ND	ND
		1.22	ND	ND	ND	ND	ND
		1.83	ND	ND	ND	ND	ND
		2.44	20.41	19	ND	ND	ND
		3.05	8.65	6	ND	ND	ND
M7	161	0.61	ND	2	ND	ND	ND
		1.22	ND	ND	ND	ND	ND
		1.83	ND	2	ND	ND	ND
		2.44	ND	ND	4	ND	ND
		3.05	ND	ND	ND	ND	ND
		3.66	ND	ND	ND	ND	ND
		4.27	ND	ND	ND	ND	ND
		4.88	ND	ND	ND	ND	ND
5.49	ND	ND	2	ND	ND		
M8	178	0.61	ND	2	4	ND	ND
		1.22	ND	ND	ND	ND	ND
		1.83	ND	ND	3	ND	ND
		2.44	ND	ND	ND	ND	ND
		3.05	ND	ND	ND	ND	ND
		3.66	7.75	ND	ND	ND	ND
		4.27	ND	ND	ND	ND	ND
		4.88	ND	ND	ND	ND	ND
5.49	ND	ND	ND	ND	ND		
M9	183	1.22	16.48	ND	ND	ND	ND
		1.83	11.42	ND	ND	ND	ND
		2.44	77.28	ND	3	ND	ND
		3.05	ND	ND	ND	ND	ND
		3.66	144.41	ND	ND	ND	ND
		4.27	10.61	ND	ND	ND	ND
		4.88	67.57	ND	ND	ND	ND
5.49	86.22	ND	ND	ND	ND		

Well Number	Grid	Depth of soil samples (m)	Beta	Cs-137 DCGL = 11	Bi-214 NRC Level = 5	Pb-214 NRC Level = 5	Ra-226 DCGL = 1.5
M10	182	0.61	165.8	82	5	ND	ND
		1.22	72.32	ND	ND	ND	ND
		1.83	8.74	ND	ND	ND	ND
		2.44	ND	ND	11	ND	ND
		3.05	20.99	ND	ND	ND	ND
		3.66	17.72	ND	ND	ND	ND
		4.27	646.22	ND	ND	ND	ND
		4.88	648.74	ND	ND	ND	ND
		5.49	91.78	ND	ND	ND	ND
M11	203	1.36	7.57	ND	14	9	ND
		1.97	10.77	ND	9	0	ND
		2.58	25.07	15	28	18	ND
		3.19	21.04	4	10	ND	ND
		3.8	8.84	ND	ND	ND	ND
		4.41	21.99	ND	ND	ND	ND
M12	223	0.61	16.67	72	15	11	ND
		1.22	48.42	99	21	11	ND
		1.83	37.91	61	5	ND	ND
		2.44	10.91	3	ND	ND	ND
		3.05	ND	ND	3	ND	ND
		3.66	8.23	ND	2	ND	ND
M13	170	0.61	ND	ND	10	ND	ND
		1.22	ND	ND	ND	ND	ND
		1.83	ND	ND	4	ND	ND
		2.44	ND	ND	4	ND	ND
		4.88	ND	ND	ND	ND	ND
		5.49	ND	ND	ND	ND	ND

Meiser & Earl Hydrogeologic Investigation 1979

During the hydrogeologic investigation conducted by Meiser & Earl Hydrogeologists in 1979 two backhoe test pits were excavated. Test Pit No. 1 was located 50 feet toward the river from the SE corner of the Lacquer Storage Building and was excavated to a depth of 7 feet. Test Pit No. 2 was located 125 feet toward the river from the SE corner of the Lacquer Storage Building and was excavated to a depth of 6.5 feet. Excavation of Test Pit No. 1 uncovered boards and logs, a strong oily smell, and radioactive debris that had been buried in the old canal. Ground water was encountered at a depth of 5 feet. Excavation of Test Pit No. 2 did not reveal buried materials or encounter groundwater.

Soil samples were collected from borehole cores during the Meiser & Earl investigation for textural classification and for radioactivity analysis. The radiological investigation was conducted separately by RMC. The RMC report was not available for our review. For the Meiser & Earl investigation, core samples were used to estimate the permeability of the deposits to allow calculation of groundwater flow-rate.

Oak Ridge Associated Universities (ORAU) Environmental Survey 1982

During the 1982 survey by ORAU, 29 boreholes were drilled using either a truck-mounted drill rig or a portable motorized auger unit. Six of these boreholes were located in the Northern unrestricted portion of the site, and the remaining 23 boreholes were located in the southern third of the site south of the buildings. Approximately 13 of the 23 boreholes appear to have been located in the area of the abandoned canal. Radiation measurements were made at 30 cm intervals in holes 1-10 using a collimated NaI scintillation detector. Soil samples were collected at several depths from these holes and from holes 11-29 and were analyzed for Ra-226 and Cs-137. Selected samples were also analyzed for Sr-90. Subsurface samples were generally collected starting at 0.3 m. The deepest sample was collected at 3.6 m near the above-ground silo within the fenced portion of the facility.

A subsurface sample from a depth of 0.3 m in the northwest corner of the property had a Ra-226 concentration of 4.1 pCi/g. Surface samples from this area also contained elevated radionuclide concentrations. The maximum subsurface concentration was 286 pCi/g Cs-137 and was collected along the eastern property line south of the above ground silo at 0.3 m (in approximately grid 306). The radionuclide concentrations in subsurface soil are summarized below in Table 19.

Table 19. Radionuclide Concentrations In Subsurface Soil (pCi/g)

Sample Location	Approximate Grid Location ¹	Depth (m)	Ra-226 DCGL = 1.5	Cs-137 DCGL = 11	Sr-90 ² DCGL = 5	H-3 ² DCGL = 1024
1	9	1	0.46	0.09		
2	1	1	0.43	0.09		
		1.5	0.35	< 0.02		
3	3	0.3	0.54	0.23		
		1	0.47	0.14		
4	34/35	0.3	1.6	0.441		1.7
5	5	1	0.40	< 0.02		
6	208	1	0.84	0.08	0.56	
		2	0.73	0.07		
		3	0.55	0.04	1.6	
7	211/212	1	0.59	0.05	< 0.08	
		2	0.62	0.03		
8	169	1	2.5	< 0.02		
		1.5	1.7	1.1		
		2.3	1.6	0.09	0.56	1.0
9	194	1	0.54	0.08		
		2	0.46	0.03		
		2.7	0.29	0.03		3.1
		3.6	0.39	0.03	1.5	
10	306	0.3	1.9	286		
11	Vance/Walton Property	0.3	0.93	3.1		
		0.9	0.58	1.7		
		1.2	0.64	0.71		
12	261	0.3	0.54	0.96		
		1	0.56	0.06		
13	266	0.3	0.60	1.7		
		1	0.54	0.15		
14	246/247	0.3	0.82	0.44		
		1	0.93	1.4		
15	249	0.3	0.87	2.1		
		1	0.59	0.11		
16	251	0.3	3.8	2.5	0.82	
		1	19.8	21.7		
17	256	0.3	0.60	0.97		
		1	0.68	0.20		
18	254	0.3	0.91	0.63		
		1	18.9	44.0	0.56	
19	259	0.3	0.79	1.1		
		1	1.2	0.77		

Sample Location	Approximate Grid Location ¹	Depth (m)	Ra-226 DCGL = 1.5	Cs-137 DCGL = 11	Sr-90 ² DCGL = 5	H-3 ² DCGL = 1024
20	215	0.3	1.5	0.74		
		0.6	1.5	0.75		
21	213	0.3	4.6	6.5	1.3	
		1	1.8	2.7		
22	232	0.3	7.1	10.0		
		1	3.5	2.0	13.3	
23	229	0.3	0.89	0.40	0.17	
		1	0.67	0.07		
24	205	0.3	0.74	0.26	0.67	
		0.8	1.9	1.6		
25	203	0.3	0.87	0.55		
		0.8	0.86	0.36		
		1	0.86	0.97	0.93	
26	201	0.3	0.60	0.18		
		1	0.66	0.19		
27	199	0.3	0.60	1.0		
		1	0.66	0.19		
28	218	0.3	0.81	13.7		
		0.8	0.81	8.3		
29	27	0.3	4.1	0.49	0.74	

¹ Locations approximated by comparison with gridded map developed for 1995 Monserco Site Characterization.

² A blank in these columns indicates that the samples was not analyzed for that radionuclide.

Subsurface soil samples with Ra-226 levels greater than 1.5 pCi/g (the DCGL proposed by SLC in the Decommissioning Plan) were collected from the following locations:

- outside the Northwest corner of the Etching Building
- near the Southwest entrance to the Etching Building
- on the Southeast edge of the facility near the Vance Walton property
- South of abandoned canal just East of the USR Metals Liquid Waste Building (Multi-Metals plant) discharge line
- South of the abandoned canal just West of the USR Metals Liquid Waste Building (Multi-Metals plant) discharge line
- just South of the West Lagoon
- South of the underground silos
- in the Northeast corner of the property.

Subsurface soil samples with Cs-137 levels greater than 11 pCi/g (the DCGL proposed by SLC in the Decommissioning Plan) were collected from the following locations:

- along the Eastern property line South of the above ground silo at 0.3 m
- South of abandoned canal just East of the USR Metals Liquid Waste Building (Multi-Metals plant) discharge line at 1 m

- South of the abandoned canal just West of the USR Metals Liquid Waste Building (Multi-Metals plant) discharge line at 1 m
 - South of the above-ground silo outside the fenced portion of the facility at 0.3 m.
- Chem-Nuclear Systems, Inc. (CNSI) Hydrogeological and Radiological Evaluation 1990

A magnetic survey was conducted during the CNSI evaluation to assist in identifying buried metal objects within the Vance/Walton property. The survey was conducted using a Schonstedt Model GA-52B magnetic locator which detects the magnetic field of any ferrous object covered by soil, pavement, or shallow water. A grid pattern was established covering the suspected boundaries of the abandoned canal. Numerous small to large buried magnetic (ferrous) objects were detected within the Vance/Walton property. A concentration of metal objects was observed within the suspected boundaries of the canal and near the SLC eastern property line. Based on these results and the recollections of a local resident drill sites were selected north, south, and in the middle of the abandoned canal.

The CNSI evaluation also included drilling nine boreholes. Five of these were located on the Vance/Walton property, one on the Eastern portion of the SLC site, two in the southeast corner of the SLC site south of the canal, and one just beyond the western property boundary. Drilling sites were biased away from observed elevated contamination areas due to the project scope of work and health and safety considerations. Borehole drilling was done using a 4.25 inch hollow stem auger. Core samples were collected using a 5 foot split core barrel and 2 foot split spoon sampler. The target depth for soil coring was at or near the top of shale bedrock. Core samples collected from the initial boring at drill site A were not high quality or quantity. Consequently, a new borehole was drilled approximately 10 feet East of the original drill site. Drill site A was abandoned with cement grout. Auger refusal prevented drilling beyond 13 feet at drill sites D and E. Difficulties were experienced at drill sites C and I in penetrating boulder material. Soil cores were collected at approximately 2 foot intervals and contained various quantities of pebbles and rocks. Consequently, some of the samples were composited to achieve the required aliquot for analysis.

Core samples were analyzed for H-3, Sr-90, and gamma isotopic analysis. Intrinsic germanium detectors were used to analyze soil samples. Analyses of Ra-226 and Ra-228 in soil were based on the photo peaks of Bi-214 at 609 keV and Ac-228 at 911 keV. Analysis of Sr-90 was performed on 68 soil cores. Due to the close proximity of drill sites B and H, soil cores were only collected from drill site B.

High concentrations of H-3 were observed in the surface sediments (0-4 feet) and decreased with depth. H-3 concentrations appeared to increase slightly below the water table surface, and then continued to decrease with depth. Results of Sr-90 and gamma isotopic analyses indicated the presence of Sr-90, Cs-137, Ra-226, and Ra-228 at low concentration. Radionuclides were detected between baseline levels and twice baseline levels established during the ORAU survey. However, only one sample (From well G) was found above the DCGL or NRC regulatory levels. Ra-226 was found at 1.74 pCi/g at 4-6 ft. Sr-90 was found at baseline levels for drill sites B, C, F, and I except for one composite sample from drill site F at 6-10 feet deep. CNSI concluded that the elevated level for this sample might be due to migration of Sr-90 contamination from the

SLC property when the canal was open. Drill sites B, C, and I are all located North of the abandoned canal. Drill sites A, D, E, and G are all located south of the abandoned canal and had elevated levels of Sr-90. These elevated soil samples corresponded to elevated levels of Sr-90 in the groundwater. Cs-137 was detected above baseline levels at several drill sites in the surficial deposits only. Ra-226 and Ra-228 levels were consistent with baseline values. Results of analysis of H-3 levels in subsurface soils is presented below in Table 20. Results of analyses for Sr-90, Cs-137, Ra-226, and Ra-228 are summarized below in Table 21. Tritium soil samples were analyzed using an azeotropic distillation procedure so that results are provided in pCi/L.

Table 20. Tritium Concentrations in Subsurface Soils (pCi/L)

Test Hole	Approximate Location ¹	Depth (ft)	H-3 Concentration DCGL= 1,024
A	East of grid 309 on Vance/Walton Property	0 - 2	24,300
		2 - 4	12,800
		4 - 6	11,100
		6 - 8	12,100
		8 - 10	13,200
		10 - 12	17,700
		12 - 14	12,000
		14 - 16	12,700
		16 - 18	10,800
		18 - 20	14,500
		20 - 22	15,200
		22 - 24	9,640
		24 - 25	13,500
		25 - 25.5	10,800
B	East of grid 305 on Vance/Walton Property	0 - 2	39,900
		2 - 4	39,400
		4 - 6	34,800
		6 - 8	34,300
		8 - 10	38,400
		10 - 12	44,300
		12 - 14	32,300
		14 - 16	22,400
		16 - 18	23,200
		18 - 20	18,400
		20 - 22	13,300
		22 - 24	11,400
		24 - 26	10,400
		26 - 28	10,800
28 - 30	10,200		

Test Hole	Approximate Location ¹	Depth (ft)	H-3 Concentration DCGL= 1,024
C	East of grid 106 on Vance/Walton Property	0 - 2	45,100
		2 - 4	38,100
		4 - 6	26,800
		6 - 8	22,600
		8 - 10	12,300
		10 - 12	9,590
		12 - 14	9,620
		14 - 16	9,470
		16 - 18	13,400
		18 - 20	9,960
		20 - 22	7,540
D	Grid 262	22 - 24	7,670
		0 - 2	49,600
		2 - 4	76,700
		4 - 6	42,300
		6 - 8	49,100
		8 - 10	49,400
		10 - 12	49,500
E	Grid 260	12 - 13	42,400
		0 - 2	84,200
		2 - 4	90,100
		4 - 6	22,500
		6 - 8	30,100
		8 - 10	23,300
		10 - 12	32,900
F	East of grid 306 on Vance/Walton property in abandoned canal	12 - 13	24,700
		0 - 2	69,600
		2 - 4	66,300
		4 - 6	23,700
		6 - 8	17,600
		8 - 10	11,300
		10 - 12	7,960
		12 - 14	7,130
		14 - 16	7,530
		16 - 18	8,150
		18 - 20	9,380
		20 - 22	9,010
		22 - 24	7,640
24 - 26	7,620		
26 - 27	7,800		
	26.8-27	7,940	

Test Hole	Approximate Location ¹	Depth (ft)	H-3 Concentration DCGL= 1,024
G	West of grid 259 outside southwest property line	0 - 2	13,800
		2 - 4	8,700
		4 - 6	11,300
		6 - 8	7,560
		8 - 10	6,720
		10 - 12	7,100
		12 - 14	7,810
		14 - 16	6,180
		16 - 18	5,330
		18 - 20	4,600
I	Grid 106	19.8 - 20	4,640
		0 - 2'	70,500
		2 - 4'	85,700
		4 - 6'	51,200
		6 - 8'	42,700
		8 - 10'	57,200
		10 - 11'	45,000
		12 - 14'	NA ²
		20 - 22'	34,700
22 - 24'	26,400		
	24 - 26'	22,500	

¹ Locations approximated by comparison with gridded map developed for 1995 Monserco Site Characterization.

² Insufficient sample for analysis.

Table 21. Radionuclide Concentrations in Subsurface Soils (pCi/g)

Test Hole	Approximate Location ¹	Sample Depth (ft)	Sr-90 DCGL=5	Cs-137 DCGL = 11	Ra-226 DCGL = 1.5	Ra-228 DCGL NA
A	East of grid 309 on Vance/Walton Property	0-2	0.7	2.57	1.11	1.44
		2-4	0.45	<0.09	0.97	1.31
		4-6	0.89	<0.06	0.83	0.96
		6-10	0.78	<0.09	0.7	1.19
		10-16	0.78	0.07	0.53	1.07
		16-22	1.3	0.08	0.54	0.85
		22-25.5	0.22	0.09	0.59	0.7
B	East of grid 305 on Vance/Walton Property	0-2	<0.03	<0.10	0.98	1.07
		2-4	<0.03	<0.11	0.66	0.82
		4-6	<0.05	<0.06	0.69	0.96
		6-8	<0.04	<0.07	0.79	1.04
		8-12	<0.04	<0.08	0.7	1.11
		12-16	0.17	<0.09	0.57	0.98
		16-20	<0.50	<0.09	0.54	0.86
		20-22	<0.20	<0.11	0.46	0.95
		22-24	0.17	<0.08	0.55	0.94
		24-26	0.34	<0.09	0.57	0.96
		26-30	<0.2	<0.05	0.65	0.8
C	East of grid 106 on Vance/Walton Property	0-2	<0.1	0.87	0.83	0.53
		2-6	<0.05	0.32	0.83	0.8
		6-8	0.14	<0.11	0.67	0.63
		8-10	<0.04	<0.08	0.72	0.64
		10-12	<0.06	<0.08	0.71	0.95
		12-14	<0.07	<0.06	0.55	0.86
		14-18	<0.08	<0.09	0.7	0.51
		18-20	<0.09	<0.09	0.61	0.69
		20-22	<0.07	<0.07	0.54	0.68
		22-24	<0.1	<0.07	0.53	0.72
D	Grid 262	0-2	0.51	<0.09	0.75	0.91
		2-4	0.74	0.46	0.96	0.96
		4-6	0.33	<0.06	0.99	1.43
		6-8	0.37	0.1	0.82	1.02
		8-10	1	0.08	0.72	1.35
		10-12	1.3	<0.06	0.58	0.67
		12-13	1.7	<0.06	0.67	1.35
E	Grid 260	0-4	0.45	1.32	0.83	1
		4-6	0.85	0.05	0.84	1.14
		6-8	1.2	0.39	0.74	1.32
		8-10	1.4	0.15	0.89	1.34
		10-13	0.94	0.09	0.79	1.24

Test Hole	Approximate Location ¹	Sample Depth (ft)	Sr-90 DCGL=5	Cs-137 DCGL = 11	Ra-226 DCGL = 1.5	Ra-228 DCGL NA
F	East of grid 306 on Vance/Walton property in abandoned canal	0-6	0.68	1.45	0.87	1.17
		6-10	2.2	0.46	0.55	0.56
		10-12	0.19	<0.08	0.39	0.81
		12-14	<0.07	<0.08	0.38	0.6
		14-16	0.12	<0.06	0.48	0.6
		16-18	0.11	<0.07	0.48	0.91
		18-20	0.22	<0.07	0.53	0.77
		20-22	0.14	<0.07	0.38	0.57
		22-24	0.06	<0.08	0.38	0.58
		24-26	0.06	<0.04	0.46	0.48
		26-27	0.07	<0.05	0.41	0.73
G	West of grid 259 outside southwest property line	0-2	0.17	0.47	0.98	1.09
		2-4	0.34	0.24	1.04	1.42
		4-6	0.52	0.31	1.74	0.95
		6-8	0.37	0.16	1.2	0.74
		8-10	1.9	<0.11	0.76	0.87
		10-12	0.82	<0.08	1.03	1.2
		12-14	0.13	<0.07	0.51	0.89
		14-18	<0.10	<0.07	0.54	0.84
18-20	<0.09	<0.07	0.61	0.78		
I	Grid 106	0-2	<0.08	0.58	0.86	0.65
		2-4	0.24	0.25	0.8	0.77
		4-6	<0.03	<0.06	0.58	1.07
		6-9	<0.03	<0.05	0.6	0.89
		8-10	<0.02	<0.07	0.34	1.25
		10-11	<0.04	<0.08	0.61	1.01
		20-24	<0.07	0.17	0.49	0.94
24-26	<0.02	<0.08	0.7	0.76		

¹ Locations approximated by comparison with gridded map developed for 1995 Monserco Site Characterization.

6.2 Identification of Potential Gaps in Characterization

In reviewing the adequacy of the subsurface soil sampling data, we used the Monserco report as the major source of information, with some supplemental information from the other reports. In general, the Monserco study found subsurface contamination in almost all of the new boreholes (except M1 and M7). However, this contamination tends to exist in pockets. For example, in M6, Cs-137 is found at high concentrations near the surface, then is not found at 1.22 m and 1.83m, but is found again at 2.44 m.⁹ In addition, the subsurface contamination found by Monserco exists both above and below the top of the ground water table. (The bottom of the groundwater table was not identified in the Monserco report).

⁹ Contamination of Ra-226, Pb-214 and Bi-214 also shows "pocketing," although detection limit problems with these three isotopes limit the conclusions that may be drawn.

In comparing the Monserco subsurface characterization results to the Monserco surface contamination, we found that most grids with subsurface contamination above regulatory levels also had surface contamination above regulatory levels. There were only three grids in which subsurface contamination was found and surface contamination was not. However, one of the grids (170) was not sampled, and all three of these grids (170, 240, and 244) were adjacent to grids with surface contamination above regulatory levels. Similarly, there is a high correspondence between surface contamination identified by Monserco and the location of ORAU subsurface samples above regulatory levels even though these studies were performed 13 years apart. Only one ORAU sample that exceeded the DCGL for Ra-226 was located in a grid (213) that did not have surface contamination above regulatory levels. Monserco only analyzed a single sample for this grid (213) just south of the west lagoon (for reasons that were not apparent to ICF). All of the locations in both the Monserco report and the ORAU report with isotopes above regulatory levels (i.e., Ra-226, Cs-137, Pb-214, Bi-214, or Sr-90) were either in or south of the abandoned canal, near the hotspot in the northwest corner of the site, or near the buried silo area. Because we do not have a regulatory level or DCGL for beta radiation we have not evaluated the distribution of beta contamination. Only a few H-3 subsurface soil samples were evaluated by ORAU and none were evaluated by Monserco. The ORAU H-3 samples did not show any concentrations above the DCGL.

The Chem-Nuclear study generally evaluated different areas than either Monserco or ORAU. Six of the nine boreholes sampled by Chem-Nuclear were off-site (either on the Vance-Walton Property or on the property west of the SLC site). The three on-site samples were in grids where no surface soil contamination was found by Monserco (although, because of detection limit problems these grids have not been shown to be "clean"). Nonetheless, these grids (106, 260, and 262) are not located in areas that were expected to have contamination. Every sample of subsurface soil in the Chem-Nuclear study appears to exceed the H-3 DCGL of 1,024 pCi/g.¹⁰

To assess whether there are gaps in the characterization of subsurface soils, we used the check list presented in Section 3.3.

1. Have historical records been kept for all burial activities on the site?

No. Some information is available about disposal activities in different parts of the site, but this information is not comprehensive. For example, the location and history of the seven lagoons is not known. Further, much of the history is recreated from the memory of longtime and retired employees and thus subject to gaps.

2. Has each distinct sub-surface area been classified as impacted or non-impacted?

¹⁰ This DCGL is designed for 15 cm to 2 m.

No. There has been no attempt to divide the site into distinct subsurface areas and no attempt to classify subsurface soils as impacted or non-impacted.

3. Has each distinct sub-surface area been assigned a depth of concern and appropriately divided into surface sampling grids?

No. Impacted subsurface areas have not been systematically identified in Monserco's documentation.

4. Has a sampling plan been prepared for each impacted subsurface area based on the historical knowledge and surface contamination?

No. Impacted subsurface areas have not been systematically identified in Monserco's documentation. However, Monserco's Characterization Working Document states that subsurface sampling will be carried out in areas where historical evidence indicates that contamination may be present underground or where survey data identifies new areas of contamination for investigation. Holes will be drilled to a depth commensurate with the extent of the suspected contaminants.

5. Does the sampling plan address all analytes of concern?

No. Given the high probability for mixed waste at the site, the sampling plan does not adequately address non-radiological contamination.

6. Does the sampling plan address QA/QC requirements?

Yes.

7. Has sampling been conducted in each distinct subsurface area according to the sampling plan?

Yes.

8. Are the number and depths of samples taken known for each distinct subsurface area?

Yes.

9. Is the number of samples equal to or greater than the minimum that would be calculated using land-based management unit characterization methodology?

No. Assuming a minimum rate of about one sample per quarter acre (a quarter acre is 10,890 ft²) about 40 boreholes would be required. If each quarter acre area required four borehole samples to be composited, about 160 boreholes would be required.

10. Are the detection limits for each analytical instrument known for each grid?

Yes, the detection limits are known. However, these limits are considerably higher than stated in the characterization working document.

11. Has sampling been conducted for each distinct subsurface area using appropriate instrumentation with appropriate sensitivity?

No. Due to high detection limits, the non-detectable concentrations of Ra-226, Pb-214, and Bi-214 cannot be used to show that these isotopes are present at levels below concern.

12. Has clean soil been found below the deepest level of contamination?

Not in all cases.

13. Are all sample results below the DCGL or NRC Limits?

No. Several boreholes were found to have concentrations of Cs-137, Ra-226, Pb-214, and Bi-214 above the DCGL or NRC limit. Further, high concentrations of beta radiation were found, indicating the likely presence of Sr-90.

As a result of the above evaluation, we have found four significant gaps in the subsurface soil characterization to date. First, large portions of the site either have not been sampled at all (no samples were collected beneath any of the buildings or along drainage pipes or sumps), or were sampled by ORAU over 20 years ago. Second, as was the case with the surface soil sampling, Ra-226 has not been fully characterized due to detection limit problems associated with the analyses of Ra-226 and daughter isotopes Pb-214 and Bi-214. Third, although there is a strong possibility that much of the site contains mixed waste, almost no sampling has been performed to identify metal or organic constituents. Knowing whether the site has mixed waste or merely low level radioactive waste will make a significant difference in off-site disposal availability and cost. Fourth, little off-site sampling of subsurface soils collected from the western side of the SLC property has been conducted and additional characterization of the subsurface soils along the eastern side of the SLC property also is necessary.

6.3 Recommendations for Additional Characterization

Given the four gaps in characterization and the understanding that additional sampling will be needed if the soil is to be disposed of at an off-site disposal facility (such as Envirocare), we recommend conducting additional subsurface sampling of the entire site. Because of the detection limit problems with Ra-226, Pb-214, and Bi-214, we find that there are significant gaps in the existing characterization, and as such, believe that new sampling is required. However, before conducting this additional sampling, the problems causing the high detection limits for

these three isotopes should be identified and corrected. We recommend that, based on the size of the site (10 acres), a total of approximately 160 boreholes will need to be drilled. An additional six sections with four boreholes in each section (24 boreholes in total) should be drilled off-site along both the western edge and the eastern edge of the site. Samples should be taken to represent each strata (0-5 ft, 5-10 ft) and composited by strata within each section. We recommend that sampling be conducted to a depth of at least 25 ft. unless a confining layer is found (e.g., bedrock). Therefore, assuming that five strata samples are taken from each borehole and four boreholes are drilled in each section, a total of 260, four-point composite samples (200 onsite, 30 along the eastern side and 30 along the western side of the SLC facility) would require analysis. In addition to radiological analyses, we recommend that analyses for inorganic and organic constituents also be conducted. These data will be useful for determining the extent of mixed waste contamination at the site.

However, before any such sampling effort is undertaken, we recommend that the intended disposal facility be contacted to determine if this sampling would fulfill the requirements of their waste acceptance criteria. That is, would the facility accept waste based on result of in-ground sampling before any contaminated soil is excavated, or would they require extensive sampling for each shipment after the contaminated soil has been excavated and packaged. In this latter case, we believe that less sampling could be conducted in advance of remediation, with more confirmatory sampling conducted during remediation and packaging. We also note that less sampling could be conducted if one were to use worst-case assumptions to define the extent and nature of the contamination (e.g., assume that all the soil from the surface to the groundwater table would need to be excavated). Along these lines, in some cases it may be possible to make exceptions based on other measurements (e.g. gross alpha) and therefore minimize the amount of additional analyses needed prior to commencement of remediation. However, some level of characterization will still be required for disposal.

6.4 Costs Associated with Additional Characterization

To calculate the cost associated with additional characterization of subsurface soils, we first calculated the number of boreholes needed, the number of samples that needed to be taken (5 per borehole), and the number of samples that would require analysis (a smaller number because of the compositing by strata within each 10,000 ft² sections). As shown in Table 22, 208 boreholes would be needed (160 in the site, 24 on the property to the east of the site, and 24 on the property to the west of the site). Unit costs for installation of boreholes, sample collection, and sample analysis were multiplied by the numbers of boreholes needed, samples requiring collection, and samples requiring analysis to calculate the cost of the additional characterization of subsurface soils. Unit costs were taken from Table 4 in Section 3.5. Required analysis included TAL metals, VOCs, total petroleum hydrocarbons, gamma spectroscopy, and tritium liquid scintillation, for a total unit cost for analysis of \$793 per sample. As shown in table 22, unit costs for the installation of boreholes, sample collection, and sample analysis were multiplied by the numbers of boreholes needed, samples requiring collection, and samples requiring analysis and were summed to calculate a cost of \$347,204. To account for sample collection and

associated costs of sampling, we added 10 percent of the sub-total cost on to this estimate, which results in a total cost of \$381,924.

Table 22. Estimated Costs Associated with Additional Subsurface Soil Sampling

Number of boreholes needed	208
Number of samples per borehole	5
Number of samples taken	1040
Number of samples analyzed	260
Unit cost to install each 25 ft borehole	\$ 488.80
Unit cost to take each sample	\$ 37.68
Unit cost to analyze each sample	\$ 793.64
Total cost to install boreholes	\$ 101,670
Total cost to take samples	\$ 39,187
Total cost of analysis	\$ 206,346
Subtotal Cost	\$ 347,204
Associated sampling costs (10 percent)	\$ 34,720
Total Cost	\$ 381,924

7.0 Groundwater

Due to contamination of surface and subsurface soils at the SLC site over the years, there has been concern about the existence and extent of groundwater contamination as well. Due to site activities, groundwater may have been contaminated with a number of different isotopes over the years as well as metals and possibly organic compounds. The primary radioactive isotopes of concern are H-3, Ra-226, Cs-137, Am-241, and Sr-90. Daughter isotopes of Ra-226, such as Pb-214 and Bi-214, have also been found in the groundwater. As noted in Section 5.0, the presence of metal and organic constituents at the site raises the possibility that soil at the site might be considered mixed waste and would require disposal currently available at a single facility (Envirocare in Clive, Utah). While groundwater would not necessarily be considered mixed waste, elevated levels of metal or organic constituents in groundwater serve as an indication that surface and subsurface soil may also be contaminated with these constituents. In addition, knowledge about the types and quantities of metallic and organic contamination in groundwater are necessary inputs to designing a treatment system, as these constituents may interfere with treatment.

Various groundwater sampling efforts have been undertaken for more than 20 years. In 1995, SLC contracted Monserco, Ltd. to conduct an in-depth study of the site. In 2000, the Pennsylvania Department of Environmental Protection (PADEP) conducted an additional groundwater study to gather more information. These two studies are the most recent and comprehensive studies of radiological contamination of groundwater and are the central focus of our review. Earlier studies include a 1979 Meiser & Earl Hydrogeologic Investigation, which references an earlier Radiation Management Corporation study that was not available for review; an 1982 Oak Ridge Associated Universities investigation; and a 1990 Chem-Nuclear Systems, Inc. study. Appendix 4 includes a reproduction of Figure 1 from the 1990 Chem-Nuclear report, which is a map of the monitoring well locations on the site. This figure includes all the wells except the 13 new wells installed by Monserco. The location of the Monserco wells are shown on site maps presented in this section.

The Meiser and Earl Investigation established that groundwater generally flows toward the river at the site, identified permeabilities of some of the formations that underlie the site formations, and developed a water table contour map. Supplemental information of general groundwater quality was also provided in the Chem-Nuclear Systems Report. A summary of this background information is included in Appendix 5.

In Section 7.1, we present the results of the Monserco and PADEP studies, followed by results of the other investigations. Section 7.2 presents our assessment of the adequacy of the groundwater characterization to date, while Section 7.3 presents our assessment of whether additional sampling is needed. Finally, Section 7.4 presents the costs associated with the additional sampling.

7.1 Summary of Existing Characterization

Monserco Site Characterization 1995

As discussed in Section 6.1, 13 boreholes were drilled at various locations on the SLC site to assess the radiological and non-radiological condition of both the subsurface soils and waters. The number and location of boreholes were selected after review of existing radiological information and concurrence between SLC and NRC. The intent was to drill boreholes and install wells south of affected or potentially affected areas to provide soil and water samples downstream of these areas. Boreholes were cored to a minimum depth of 20 feet and/or to the water table and were subsequently converted into wells. Table 17 in Section 6.1 describes the locations of these wells and provides the depth and depth to groundwater for each well. Hydrocarbon odors were reported when drilling wells M1, M8, M9, and M13. Quantities of oil were drawn from well M7.

Groundwater samples were collected from each of the 13 wells and analyzed for H-3, Sr-90 and gamma emitters. H-3 and Sr-90 concentrations in groundwater were analyzed using an LKB Wallac RacBeta Liquid Scintillation Counter. Gamma emitter concentrations in groundwater were analyzed using an intrinsic germanium monitor. H-3 levels above NRC guidelines were detected in well water from M9 and M10, which are located downgradient of the underground silo area. Sr-90 levels above NRC guidelines were detected in well water from M4, M9, M10, and M11. Cs-137 levels above NRC guidelines were detected in well water from M2, M5, M10, and M12. These results are summarized in Table 23. No Ra-226, Pb-214, Bi-214, or Am-241 was detected in any of these samples, and were therefore not included in Table 23.

Isotopic concentrations detected above NRC guidelines are presented in Figure 18 in Appendix 1. However, these results presented in the Monserco Site Characterization Report are misleading. The radiological limits for groundwater given in the Monserco Characterization plan are provided in Table 3 in Section 3.2. The detection limits listed in Appendix 17 of the Monserco Characterization Report for Sr-90, Co-60, Cs-137, and Ra-226 are significantly higher than these radiological limits. No radiological limits were provided for Bi-214, Pb-214, and Am-241. Consequently, the non-detects cannot be used to show that the groundwater is not contaminated with these isotopes.

Groundwater samples collected from the 13 wells were also analyzed for volatile organics and heavy metals by Barringer Laboratories. Samples were analyzed for 39 VOCs by gas chromatography/mass spectrometry. Although the text of the Monserco Characterization Report states that none of the 39 VOCs were detected in any of the samples, a review of the data in Appendix 18 of the report indicates that a number of volatile organics were detected. The levels of detected organics and detected metals were compared with the MCLs or HBLs when applicable. Of the volatile organics, only vinyl chloride was detected at values greater than the MCL. Of the metals, barium, beryllium, cadmium, chromium, nickel, lead, vanadium, and zinc were found at concentrations above their respective MCL or HBL. A summary of detected

volatile organics is provided below in Table 24. Figure 19 in Appendix 1 shows organic constituents in groundwater above the MCL or HBL. A summary of detected metals is provided below in Table 25. We note that the detection and concentrations of metals found in the monitoring wells was not displayed in Figure 19 because of the prevalence of metals found in the groundwater at concentrations exceeding applicable MCLs/HBLs.

Table 23. Concentrations of Isotopes in Groundwater (pCi/L)

Well Number	Grid	H-3 NRC Limit = 20,000	Sr-90 NRC Limit = 8	Cs-137 NRC Limit = 200
M1	180	5,690	ND	ND
M2	240	4,564	ND	2,482
M3	233	4,046	ND	ND
M4	229	12,702	3,823	ND
M5	250	2,468	ND	10,216
M6	244	9,908	ND	ND
M7	161	ND	ND	ND
M8	178	ND	ND	ND
M9	183	24,187	17,175	ND
M10	182	65,557	99,346	1,225
M11	203	3,153	977	ND
M12	223	9,039	ND	1,306
M13	170	6,885	ND	ND

Table 24. Detected Volatile Organics in Groundwater (ug/L)

Well Number	Vinyl Chloride	Chloro-ethane	1,1-Dichloro-ethane	cis-1,2-Dichloro-ethene	1,1,1-Trichloro-ethane	Benzene	1,2-Dichloro-ethane	Trichloro-ethene	1,2-Dichloro-propane	Toluene	Tetrachloro-ethene	Ethylbenzene	Xylenes (total)
MCL	2			70	200	5	5	5	5	1000	5	700	10000
HBL			4000										
M1	30.2	ND	5.4	0.9	0.5	ND	0.2	0.4	0.3	0.6	0.4	0.3	1
M2	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4	ND	ND	0.3
M3	1.6	ND	4.1	0.7	ND	ND	ND	ND	0.4	0.4	ND	ND	0.4
M4	ND	ND	1.3	0.7	ND	ND	ND	ND	0.4	0.4	ND	ND	0.4
M5	ND	ND	4.1	2.9	ND	ND	ND	ND	0.2	0.5	0.2	ND	0.4
M6	ND	ND	ND	ND	0.2	ND	ND	ND	ND	0.4	0.6	ND	0.3
M7	ND	7.1	1.2	ND	ND	1.2	ND	ND	ND	1	ND	ND	ND
M8	12.9	175	48.6	48.2	15.9	ND	ND	ND	ND	ND	ND	3.6	2
M9	1.3	1.7	6.2	1.5	ND	0.2	ND	0.5	ND	1	0.4	ND	0.3
M10	ND	4.2	3.2	0.9	ND	ND	ND	0.8	ND	1.9	1.8	ND	ND
M11	16.9	ND	33.3	13.3	169	ND	ND	ND	ND	ND	ND	ND	5.8
M12	ND	31.8	27.3	2.5	17.2	ND	ND	0.7	0.8	ND	2.7	ND	ND
M13	ND	ND	0.5	1	ND	ND	ND	ND	ND	0.6	1.5	ND	0.3

Table 25. Detected Metals in Groundwater (mg/L)

Metal	HBL	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
Ag	0.2	ND	ND	0.015	ND	0.006	ND	ND	ND	ND	ND	ND	ND	0.054
Al		131	189	42.2	38.8	79.5	100	106	124	303	173	61.2	120	136
As	0.05	ND	0.1	ND	ND	ND	ND	ND	ND	0.4	ND	ND	ND	0.3
B		0.29	0.06	0.22	0.12	0.05	0.04	0.24	0.2	0.32	0.29	0.08	0.04	0.14
Ba	2	3.65	7.21	0.511	0.301	2.29	2.96	3.74	3.53	3	4.12	1.29	3.02	1.73
Be	0.004	0.0166	0.0419	0.0057	0.0035	0.0098	0.0172	0.0133	0.0133	0.0364	0.019	0.0081	0.0186	0.0103
Ca		175	259	89.7	103	89.2	76.3	78.3	89.6	214	118	62	75.7	69.7
Cd	0.005	0.007	0.017	0.016	0.007	0.061	ND	0.01	0.006	0.042	ND	0.116	ND	0.299
Co		0.34	0.5	0.11	0.09	0.15	0.55	0.22	0.3	0.52	0.34	0.12	0.4	0.19
Cr	0.1	0.19	0.26	0.53	0.08	0.29	0.13	0.2	0.23	0.75	0.4	0.19	0.28	26.6
Cu		0.8	1.71	0.9	0.16	0.59	0.71	0.72	0.78	2.81	0.84	2.19	0.78	98.5
Fe		230	297	98	84	134	242	263	293	687	460	159	280	380
K		17	17	6	11	7	7	10	13	21	19	8	8	12
Mg		57.6	55.6	22.8	22.1	32.9	36.5	36.5	41.4	79.7	61	24.4	41.1	42.6
Mn		48.9	83.8	10.7	14.3	19	16.2	29.4	20.4	103	40.6	19.3	28.3	10.3
Na		27.3	13.5	33.3	18.1	12.9	8.6	13.3	39.6	20.6	12.3	9.3	10.7	11
Ni	0.1	0.46	0.62	0.26	0.19	0.26	0.39	0.35	0.96	1.01	0.91	0.41	0.73	3.76
P		6.3	13.2	2.9	1.8	2.4	2.7	7.3	9.1	16	9.9	2.8	6	13.2
Pb	0.02	0.51	1.83	0.28	0.12	0.54	0.76	0.69	1.28	7.6	1.09	0.79	0.98	3.66
S		32.2	7.7	92.4	96.1	5.5	6	8.2	6.5	37.1	14.3	17.9	4.5	49.9
Si		91.4	92.9	44.5	48.1	74	79.1	81.4	80.2	122	94.3	62.4	91	85.3
Sn	20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.1
Sr		1.15	1.74	0.546	0.484	0.774	0.521	0.501	0.489	1.64	0.875	0.517	0.629	0.632
Ti		0.041	0.045	0.024	0.019	0.013	0.021	0.043	0.052	0.06	0.06	0.034	0.045	0.088
V	0.2	0.133	0.339	0.072	0.56	0.081	0.102	0.17	0.264	0.798	0.357	0.081	0.126	0.323
Zn	7	1.9	2.83	1.55	0.57	1.37	0.9	1.74	3.1	242	7.68	2.38	2.63	175

PADEP Groundwater and Surface Water Assessment 2000

In 2000, PADEP contracted Foster Wheeler Environmental to implement a Hazardous Sites Cleanup Act funded assessment of the SLC site groundwater and surface water. Prior to initiating sample collection, Foster Wheeler Environmental collected one round of groundwater level measurements to determine static water levels and record the well depth. Measurements were collected using a oil/water interface probe. These measurements were used to determine the minimum amount of water to be evacuated from each well prior to sampling. Twenty three monitoring wells were selected for sampling during this assessment, including wells M1-M13 (installed by Monserco in 1995), wells A-I (installed by CNSI in 1990), and well 15 (installed by Meiser & Earl in 1979). The Monserco and CNSI wells were selected because of their good condition and their locations throughout the site. Well 15 was selected because it was also in good condition and could provide "background" conditions for the site as an upgradient well.

Three volumes of water were purged from wells, when possible, prior to sample collection. Water quality parameters were obtained with a Horiba model U-22 to ensure that the aquifer groundwater was stabilized. Samples were analyzed by Severn Trent Laboratory for radiological and chemical constituents. All groundwater samples were analyzed for gross alpha, gross beta, gamma emitting isotopes, and total and dissolved target analyte list (TAL) inorganics. Samples collected from wells B, M7, M9, and 15 were also analyzed for volatile and semi-volatile organics.

Foster Wheeler Environmental compared groundwater radiological results to the EPA Drinking Water Standards, Maximum Contaminant Levels (MCLs) for Radionuclides. Similarly, groundwater results for volatile organics, semi-volatile organics, and TAL inorganics to the PADEP Medium Specific Concentrations for Organic Regulated Substances in Groundwater, Used Aquifer, Total Dissolved Solids < 2,500 µg/L, Residential Criteria (PADEP Act 2 MSCs).

Because two wells (CN-C and CN-E) did not recharge sufficiently after purging to enable sample collection, only 21 groundwater samples were analyzed. Groundwater results ranged from non-detect to 3,580 pCi/L for gross alpha analysis and from non-detect to 66,500 pCi/L for gross beta analysis. Groundwater results for H-3 ranged from non-detect to 9,050 pCi/L. Analysis for gamma emitting isotopes detected Cs-137, Co-60, and Pb-214 in groundwater samples. The following ranges were detected for each radionuclide:

- Cs-137 concentrations from non-detect to 1,830 pCi/L.
- Co-60 concentrations from non-detect to 4.07 pCi/L.
- Pb-214 concentrations from non-detect to 197 pCi/L.

Because of problems with strontium interference, ICF was instructed to omit the Ra-226 results from our evaluation. Individual radiological scans detected C-14, Sr-90, Ni-63, Am-241, and Po-210 in groundwater samples. The following ranges were detected for each radionuclide:

- C-14 concentrations from non-detect to 16.6 pCi/L.
- Sr-90 concentrations from non-detect to 29,500 pCi/L.
- Ni-63 concentrations from 3.02 pCi/L to 83 pCi/L.
- Am-241 concentrations from non-detect to 1.46 pCi/L.
- Po-210 concentrations from non-detect to 110 pCi/L.

These results are summarized in Table 26 below.

Table 26. Radionuclide Concentrations in Groundwater (pCi/L)

Well No.	Gross Alpha NRC Level = 15	H-3 NRC Level = 20000 ^a	Cs-137 NRC Level = 200 ^b	Co-60 NRC Level = 100 ^b	Pb-214	C-14	Sr-90 NRC Level = 8 ^a	Ni-63	Am-241	Po-210
A	301	1980	<SDL	<SDL	79	4.78	21	9.01	<SDL	4.27
B	0.846	2060	<SDL	<SDL	32.5	<SDL	1.8	5.78	<SDL	<SDL
D	64	5560	7.8	1.3	78	3.93	68.9	8.45	0.1	2.5
F	0.506	1920	<SDL	<SDL	10.8	0.989	0.67	12.3	<SDL	0.144
G	9.3	1280	<SDL	<SDL	<SDL	3.12	5.98	4.97	0.18	1.93
H	17.8	2720	<SDL	<SDL	57.3	<SDL	0.205	9.81	<SDL	3.92
I	26.6	1820	<SDL	2.61	0.242	<SDL	1.36	4.92	0.043	4.05
M1	52.1	4290	<SDL	<SDL	5.06	<SDL	345	7.32	0.0623	0.407
M2	20	9050	34.5	<SDL	55.4	0.604	87.6	2.46	0.174	4.73
M3	39.1	5790	0.785	1.36	<SDL	0.14	44.5	1.41	0.00696	0.208
M4	496	3780	<SDL	1.38	62.1	2.6	6450	36.3	0.2077	38.1
M5	387	2860	1830	0.9	197	2.77	159	16.7	1.46	110
M6	264	4210	21.6	<SDL	16	<SDL	140	9.09	0.144	10.2
M7	25.7	1600	<SDL	<SDL	<SDL	2.33	35.5	11.8	0.454	1.91
M8	89.3	5700	<SDL	<SDL	<SDL	<SDL	696	5.98	0.3	2.28
M9	413	3830	<SDL	1.64	17.2	12.6	10000	34	0.209	0.78
M9	1570	3600	9.22	<SDL	24.3	10.5	9410	31.4	<SDL	0.614
M10	3580	2940	3.11	<SDL	57.5	11.4	29500	83	0.103	11.6
M11	144	1510	5.94	4.07	37.9	<SDL	1110	4.23	0.107	6.01
M12	27.4	1830	15.8	<SDL	5.6	<SDL	351	1.89	<SDL	7.16
M13	70.2	2960	<SDL	0.0416	62.8	0.522	10.6	4.37	0.0374	22.5
15	3.14	325	<SDL	<SDL	<SDL	1.47	1.03	6.59	0.131	1.07

^a EPA Drinking Water Standard

^b NRC Guideline Value

SDL - sample detection limit

These groundwater samples were also evaluated for organic and metallic contamination. Well M9 exceeded the MSCs for vinyl chloride with a measurement of 3.4 µg/L and bis(2-ethylhexyl)phthalate with a measurement of 14 µg/L. Approximately 0.14 feet of free-phase product was measured in well M7 before sampling. The product was a black, viscous, oily liquid with a strong petroleum odor and was described as a light non-aqueous phase liquid (LNAPL).

The groundwater sample from this well was slightly turbid water with small globules of LNAPL. The only volatile organic detected in this sample was acetone and low levels of semi-volatile organics were detected. Groundwater samples from several wells exceeded the MSCs for inorganics. These results are summarized below in Table 27.

Meiser & Earl Hydrogeologic Investigation 1979

Thirteen approximate locations for test drilling were identified by Meiser & Earl personnel to allow for maximum definition of groundwater conditions, emphasizing the area of the abandoned canal, lagoons, and disposal pits. An additional three locations were identified for background definition. Three wells had been previously installed in October 1978 by Giles Drilling Corporation.

The pH level from water samples collected from wells and borings was the least variable parameter and averaged 7.1 pH units. Conductivity values were highest in Well No. 11 (which was reported to be heavily polluted by an oily solvent material) and in Well No. 5 (which is adjacent to a waste discharge stream from the plant to the river). Well No. 5 had the highest calcium, sulfate, and alkalinity values. The Meiser & Earl report notes that Well Nos. 1, 2, 12, and 13, which are within 120 feet of each other, had similar chemistries reflecting some pollution from reported surface dumping in the past. The remaining wells were said to show insignificant amounts of variation in their chemical nature.

Gross beta results from the Radiation Management Corporation's report, "Radiological Investigation of the Grounds and Groundwater, USRC, Bloomsburg, PA" (April 23, 1979) are listed below in Table 28 as depicted in Figure 1 in the Meiser & Earl report. Water samples for radiological analyses are known to have been collected for all wells by Radiation Management Corporation (RMC), however these data are not reported in the Meiser & Earl report.

Table 27. Total Inorganics Detected above MSCs (µg/L)

Well No.	As MSC = 50	Ba MSC = 2,000	Be MSC = 4	Cd MSC = 5	Cr MSC = 100	Cu MSC = 1,000	Pb MSC = 5	Ni MSC = 100	Ag MSC = 100	Tl MSC = 2	V MSC = 2.1	Zn MSC = 2,000
A	7.2B	1,930	ND	3.1B	7.8B	25.8	9.7	28.2B	11.7	7B	9.9B	85.9
B	ND	44.2B	ND	5,000U	ND	ND	ND	ND	ND	ND	ND	4.6B
D	24.8	458	2.4B	5,000U	60.5	72.9	44.9	73.3	ND	8.8B	61.1	238
F	ND	44.9B	ND	5,000U	ND	ND	ND	19.7B	ND	ND	ND	6.2BE
G	6.7B	117B	ND	5,000U	164	62.2	3.8	ND	ND	ND	ND	29.5
H	13.6	237	0.72B	5,000U	18	54.7	26.6	29.4B	ND	ND	8.9B	73.8
I	42.3	986	5.4	5,000U	68,100	252	66.6	559	ND	8.8B	82.6	305
M1	17.2	239	ND	5,000U	13	38.9	41.8	25.9B	ND	ND	7.5B	65.4E
M2	3.5B	96.6B	ND	5,000U	ND	8B	3.8	ND	ND	ND	ND	22.7
M3	3.9B	96.1B	ND	5,000U	13.5	14B	3.3	13.6B	ND	ND	ND	26.5E
M4	26.2	331	0.67B	5,000U	22.1	49.5	20.1	31.3B	8.5B	4.8B	13.7B	118
M5	211	2,470	18.2B	14.3B	589	614	689	494	189	43.6	410	2,060
M6	46.9	654	4.8B	5,000U	73.8	181	111	129	ND	10.5	99.3	311E
M7	26.7	536	2.6B	0.79B	40.7	94.7	54.8	55.7	ND	7.7B	63	192N
M8	234	610	0.96B	5,000U	18.9	34.5	26.6	26.3B	14.7	27.4	28.4B	100E
M9	3.1B	179B	ND	5,000U	ND	ND	ND	ND	ND	5.8B	ND	56.5
M9(2)	1.8B	178B	ND	5,000U	ND	ND	ND	ND	ND	4.2B	ND	73
M10	55	902	5.7	5,000U	161	243	182	304	ND	21.2	137	530E
M11	9B	134B	ND	4.1B	14.2	32.5	14.2	24B	ND	ND	ND	108E
M12	37.6	529	3.9B	3.7B	157	136	132	203	ND	14.4	91.8	479E
M13	30.4	405	1.2B	78.7B	2,980	14,500	326	373	77.4	21.1	60.3	21,100E
15	ND	156B	ND	0.95B	1.3B	18.8B	ND	ND	ND	9.9B	ND	18.9BN

Qualifiers.

B: Result is between instrument detection limit and reporting limit

E: Problem with Serial Dilution*

N: Matrix Spike Failure*

*Qualifiers E and N were not defined in the PADEP report and/ or appendices. Definitions of these qualifiers are from common laboratory usage and may be inaccurate.

Table 28. Gross Beta Results from RMC Radiological Investigation

Well No.	Approximate Grid Location ¹	Formation	Gross β (pCi/L)
1	204	sands and gravel	71,000
2	226	silts and sandy silts	29,000
3	270	silts and sandy silts	4000

¹ Locations approximated by comparison with gridded map developed for 1995 Monserco Site Characterization.

Oak Ridge Associated Universities Environmental Survey 1982

During the ORAU survey, subsurface water samples were collected from the 23 on-site monitoring wells using a bailer or hand pump technique. Water was also collected from boreholes 6 and 9 drilled during this survey. Water samples were collected from four private wells, and the city of Bloomsburg water supply. Four water samples were collected 2.5 to 10 km from the site and served as baselines for comparison with other samples collected in the area of the SLC facility. The groundwater samples were analyzed by Oak Ridge Laboratories for Ra-226 and Cs-137. Selected samples were also analyzed for Sr-90.

Ra-226 baseline concentrations in the two water samples analyzed were 0.10 and 0.15 pCi/L. Cs-137 baseline concentrations in water ranged from 12 to 37 pCi/L, with one non-detect. The one Sr-90 baseline concentration in water was 1.1 pCi/L. The H-3 baseline concentrations ranged from 874 to 2,330 pCi/L, with one non-detect. These results are summarized in Table 29.

The maximum tritium level in groundwater samples from the 23 monitoring wells and 2 boreholes was 72,200 pCi/L and came from Well 21. Wells 4, 9, 20, and 22 also contained tritium concentrations above 10,000 pCi/L. Although above the baseline levels for surface water, all groundwater samples were below the NRC guideline for unrestricted areas. Ra-226 concentrations were in the range of the baseline levels except for Well 5, which had a concentration of 9.1 pCi/L. The maximum Cs-137 concentration of 57 pCi/L came from Well 13. These Ra-226 and Cs-137 concentrations were below the NRC guideline levels for unrestricted areas. Monitoring wells 1, 3, and 4 contained Sr-90 concentrations of 62,100 pCi/L, 2,130 pCi/L, and 477 pCi/L. These concentrations exceeded the NRC guideline levels for unrestricted areas. ORAU contributed these high concentrations to migration from the previous disposal area north of the wells. Analytical results for groundwater are summarized in Table 30.

In addition, ORAU evaluated groundwater from several nearby residential wells. The analytical results for these wells are summarized in Table 31. There were no radionuclide concentrations from these offsite wells that exceeded NRC limits.

Table 29. Radionuclide Concentrations In Baseline Water Samples

Baseline Sample	Radionuclide Concentration (pCi/g) ¹			
	Ra-226	Cs-137	Sr-90	H-3
1		37		2,330
2		35		1,170
3	0.15	12	1.1	< 250
6	0.10	< 8		874

¹ A blank in these columns indicates that the sample was not analyzed for that radionuclide.

Table 30. Radionuclide Concentrations in Groundwater (pCi/L)

Sample Location	Approximate Grid Location ¹	Water Depth (m)	Ra-226 ² NRC Limit =5	Cs-137 ² NRC Limit = 200	Sr-90 ² NRC Limit =8	H-3 ² NRC Limit =20,000
Monitoring Wells						
1	204	2.1	<0.10	15	62,100	7,140
2	226	0.6		<8		5,100
3	270	1.5	0.08	<8	2,130	6,120
4	228	0.9	<0.07	32	477	13,500
5	254	0.9	9.1	<8	3.4	4,690
6	253	1.2		<8		4,490
7	279	2.1		<8	91	5,920
8	235	0.6	0.20	<8		3,470
9	145/146	4.4	0.25	<8		11,000
10	237	1.2	<0.07	<8		6,120
11	141	4.4		<8		
12	160	4.4	<0.07	21		3,670
13	158/159	4.2	0.15	57		6,530
14	94	5.0	0.28	<8		5,920
15	14	7.7	0.24	<8		820
16	37	7.1		<8		1,020
17	140	5.5		<8		3,270
18	309	1.2		<8		3,670
19	224	3.2	<0.07	<8	142	8,980
20	East of 309 on Vance/Walton Property	1.4	<0.07	<8		18,800
21	216/238	2.7	0.36	<8		72,200
22	200	3.0				20,600
23	170	3.2	0.16	<8		9,180
Boreholes						
6	208	4.2	0.25	<8		6,530
9	194	4.2	<0.10	<8		6,120

¹ Locations approximated by comparison with gridded map developed for 1995 Monserco Site Characterization.

² A blank in these columns indicates the sample was not analyzed for that radionuclide.

Table 31. Radionuclide Concentrations in Private Off-Site Well Samples (pCi/L)

Location	Ra-226 NRC Limit =5	Cs-137 NRC Limit = 200	Sr-90 NRC Limit =8	H-3 NRC Limit =20,000
R. Johns Well	0.22	16	1.27	<250
B. Johns Well	<0.10	<8	0.77	1,630
Murphy Well	<0.10	<8	<0.31	1,630
Folk Nursery Well	<0.10	26	<0.31	<250
City Water	<0.10	<8	<0.31	610

Chem-Nuclear Systems, Inc. Hydrogeological and Radiological Evaluation 1990

The CNSI evaluation included groundwater sampling at existing monitoring wells for baseline H-3 data and to compare with preliminary radiological soil results to guide in the selection of drilling sites. Nine new monitoring wells were installed and sampled for radiological analyses. CNSI reported that SLC monitoring wells are sampled on a staggered basis, but are not evacuated before sampling. CNSI collected samples from these wells prior to new well installation. Three well volumes were evacuated from each well when possible. Monitoring wells 2, 3, and 17 were not sampled due to inaccessibility or poor condition of casing. Monitoring well 11 was not sampled due to the presence of oil in the well. Groundwater samples were also collected from the Vance/Walton well.

Following well installation and development, three well volumes were evacuated from each well and samples were collected for H-3, Sr-90, gamma isotopic, and gross alpha/beta analyses. Gross alpha/beta radioassay was performed using a Tennelec Model LB-5100 gas flow proportional counter. Tritium assay was performed using a Beckman Model LS-7500 Liquid Scintillation System. Gamma spectroscopy was performed using intrinsic germanium detectors. Analysis for Sr-90 was performed using a multi-step process for sample preparation, iron scavenge, and counting in a low level beta counter to infer Sr-90 activity.

Twenty existing wells were sampled and data compared to the ORAU survey. The new samples indicated a general increase in H-3 concentrations throughout the site since the 1981 sampling activities and a significant increase in the southeast quadrant of the site. CNSI used these results as an indicator that radiological evaluations should be concentrated in this portion of the site. Many existing wells were noted to be poorly constructed and/or in poor structural condition. Wells in the southern portion of the property near the river appeared to be poorly constructed and damaged. The wells in the northern portion of the property appeared to be in good condition. Oil was observed in wells 11, 12, and 13.

Wells located in and around the southeastern quadrant of the site showed the highest concentrations of H-3 in groundwater. H-3 levels in the new wells were consistent with levels of the existing wells. Groundwater results were consistent with the corresponding soil results. Groundwater data support H-3 data for subsurface soils showing higher H-3 concentrations in the surficial sediments decreasing with depth. Table 32 summarizes H-3 concentrations in groundwater of existing wells during the CNSI evaluation. Table 33 provides H-3 concentrations in groundwater for new wells. Gross beta data for both existing wells and new wells show high activity in the south-central part of the site. Monitoring wells upgradient of the underground silos had low beta activity and wells located downgradient had higher beta activity. Gross beta results for new wells are provided in Table 33.

Table 32. H-3 Concentrations in Groundwater (pCi/L)

Monitoring Well No.	Approximate Grid Location ^a	H-3 Concentration NRC Limit = 20,000
1	204	14,400 ^b
4	228	28,700
5	254	8,200 ^b
6	253	8,200
7	279	6,800
8	235	8,300
9	145/146	10,200
10	237	8,500
12	160	8,700
13	158/159	15,500
14	94	23,600
15	14	7,300
16	37	6,200
18	309	22,200
19	244	75,400
21	216/238	69,400
22	200	51,100 ^b
23	170	13,500
24	194	138,200
Vance/Walton	East of grid 150 on Vance/Walton Property	13,600

^a Locations approximated by comparison with gridded map developed for 1995 Monserco Site Characterization.

^b Liquid Scintillation results indicate radioisotopes other than H-3 may be present.

In its report, CNSI referenced data from samples collected between 1978 and 1980 by Radiation Management Corporation. According to CNSI, groundwater samples collected from wells 1, 2, and 3 in 1979, had very high levels of Sr-90 (2,340 to 33,300 pCi/L) and samples collected in wells 4, 5, 6, and 19 had elevated concentrations of Sr-90 (222 to 770 pCi/L). Sr-90 was detected in groundwater samples collected from the new wells located in or south of the abandoned canal. Sr-90 was not detected in samples collected north of the canal. CNSI suggested that Sr-90 groundwater contamination in the south central portion of the site appeared to be migrating from the underground silos and that the abandoned canal may be the source of contamination along the southeastern and southwestern portions of the site. Table 33 provides Sr-90 concentrations in groundwater for the new wells.

Results of gamma isotopic analyses were not discussed in the body of the CNSI report. However, Table 33 provides Cs-137 concentrations in groundwater for the new wells.

Table 33. Radiological Concentrations in Groundwater (pCi/L)

Well	Approximate Location ¹	Sr-90 NRC Limit = 8	Cs-137 NRC Limit = 200	Gross Alpha NRC Limit = 15	Gross Beta	H-3 NRC Limit = 20,000
A	East of grid 309 on Vance/Walton property	3.4	<5.00	<1.14	15.80	10,700
B	East of grid 305 on Vance/Walton property	<2.0	<4.34	<1.39	3.25	11,300
C	East of grid 106 on Vance/Walton property	<1.0	<3.99	<1.94	8.58	8,890
D	Grid 262	44.0	<4.63	<1.25	64.70	46,500
E	Grid 260	25.0	<4.80	<1.39	38.30	23,800
F	East of grid 306 on Vance/Walton property in abandoned canal	1.9	<4.39	<1.56	3.76	7,640
G	West of grid 259 outside southwest property line	3.9	<2.52	<1.39	7.62	5,790
H	East of grid 305 on Vance/Walton property	<0.9	<5.21	<1.81	5.59	11,800
I	Grid 106	<1.0	<3.34	<0.91	<1.73	27,700

7.2 Identification of Potential Gaps in Characterization

In reviewing the adequacy of the groundwater monitoring data, we used the Monserco and PADEP reports as the major sources of information, with some supplemental information from

the other reports. Between the Monserco and PADEP reports, radiological contamination was found above NRC levels in 17 wells. When ORAU and Chem-Nuclear data are considered, a total of 29 wells had contamination above NRC levels at some point in time over the past 20 years. These wells are located:

- along the eastern property line (wells 14, 18, 21, 24, E and I),
- near the liquid waste building (wells 19, 22, M1, M6, M8, and M12),
- south and southeast of the silo area (wells 1, 3, 4, M4, M5, M9, M10, and M11),
- southwest of the well house (well M7),
- south of the west lagoon (wells 5, 7, and M3), and
- in the west plant dump (well M13).

Comparisons of these data over time are of limited usefulness because few investigations sampled the same wells. In addition, because of the movement of groundwater, we would not necessarily expect static results over time. In this sense, our evaluation of groundwater is different from building and soil contamination, which we generally expect to stay in one place. Nonetheless, the PADEP study evaluated all of the wells installed by Monserco (M1 - M13) and found contamination in all of them (as opposed to the Monserco results for these wells, which only identified contamination in 7 of the 13 wells.) As stated above, Monserco may have missed contamination due to detection limit problems.

In terms of constituents, the earliest study (Meiser and Earl) found high levels of gross beta south of the silo area. A few years later the ORAU study found high levels of Sr-90 (a beta emitter) south of the silo. The ORAU study also found Sr-90 in other locations, along with Ra-226 and H-3. Later, the CNSI study found H-3 and Sr-90 in several locations. The next study was the Monserco study which found H-3, Sr-90, and Cs-137. Lastly, when compared to the Monserco results, the PADEP study found lower levels of Cs-137 and more frequent occurrences of Sr-90. The PADEP study also found many occurrences of gross alpha above the NRC levels.

Non-radiological contamination of underlying groundwater at the site has been found in several studies as well. Monserco found one organic constituent and eight metallic constituents above the HBLs. At least one of these constituents was found in each of the 13 wells sampled by Monserco. The PADEP study found 12 inorganic constituents present above MSCs. At least one of these constituents was found in each of the 21 well samples except for well 15.

Given these results, we now answer the questions from Section 3.3 to identify whether gaps exist in this groundwater characterization.

1. Have historical records been kept for prior groundwater sampling events on the site?

Yes. However, it appears that not all of the data from these sampling events was available for our review. For instance, during the site visit, site personnel reported

conducting monthly off-site monitoring of groundwater at two wells, one east of the site and one west of the site. Results from these sampling efforts were not available.

2. Is the depth, direction, and flow of groundwater at the site known?

Generally. The aquifer directly beneath the site has been well documented. However, none of the documents we reviewed evaluated the possibilities of deeper aquifers beneath the site.

3. Are the uses of all aquifers known?

Yes. Groundwater is used as a source of drinking water by local residents near the facility.

4. Has each distinct aquifer been classified as likely-impacted or non-impacted?

The uppermost aquifer is clearly contaminated. No consideration has been given to any deeper aquifers that may underlie the site.

5. Has a sufficient number of wells been located downgradient of each known source, or on the downgradient portion of the facility?

No. Given the north to south flow of groundwater at the site, not enough wells have been located on the property to the west of the site to determine if groundwater is being contaminated by the hotspot on the northwest corner of the site, by the contamination in and around the acid etching building, and from the western edge of the abandoned canal.

6. Has a sampling plan been prepared for each likely-impacted aquifer based on historical knowledge, known surface and sub-surface contamination, and seasonal changes in groundwater flow and depth?

To some extent. Sampling plans appear to have been developed and implemented for each of the sampling efforts. (Not all of these were available for our review.) The Monserco sampling plan does not attempt to address seasonal changes in groundwater flow and depth, and prior to the Monserco sampling effort, knowledge about surface and subsurface soil contamination was limited. The PADEP sampling effort was a one time effort and as such does not appear to address seasonal changes in groundwater flow and depth.

7. Does the sampling plan address QA/QC requirements?

Yes.

8. Has sampling been conducted in each aquifer according to the sampling plan?

Yes.

9. Are the number and depths of samples taken known for each well?

Yes.

10. Are the detection limits for each analytical instrument known for all samples?

Yes, the detection limits are known. However, in the Monserco study these limits are considerably higher than stated in the Monserco characterization working document.

11. Has sampling been conducted for each well using appropriate instrumentation with appropriate sensitivity?

No. Due to high detection limits, non-detects of Ra-226, Pb-214, and Bi-214 results do not necessarily reflect the absence of these isotopes above levels of concern.

12. Are all sample results below NRC or State regulatory levels?

No.

Based on these answers, we find the following gaps in the groundwater characterization at the site. First, given the southward flow of groundwater on the site, groundwater on the western property has not been adequately characterized. Wells located to the magnetic south of the acid etching building would be on the property to the west of the site, rather than in the west lagoon. As a result, contamination near the western property line may be migrating off-site. Second, the groundwater has not adequately been analyzed to account for seasonal variations and variations due to significant rainfall events, etc. It is clear that the groundwater is affected by site activities, but the extent (area) and degree (concentration ranges) of contamination have not been sufficiently established. Third, Ra-226 has not been fully characterized.

We also note that the close proximity of soil contamination detected near monitoring well 15 (which is frequently referred to as the "clean" upgradient well) makes this well unsuitable for statistical analyses of upgradient/downgradient monitoring results.

7.3 Recommendations for Additional Characterization

Given the three gaps in characterization and the need to understand groundwater contamination to design appropriate remedial measures, we recommend conducting additional groundwater monitoring for both radiological and chemical constituents. We believe that quarterly sampling should be conducted over a one year period for about 15 wells in the southern portion of the site (including at least one well on the Vance/Walton property) and wells 15 and 16 in the northern portion of the site. In addition, we recommend installing three additional wells on the property west of the site, designed to identify contamination from the hot spot in the northwest corner of the site, from the contamination in and around the acid etching building, and from the western end of the abandoned canal. These three wells should also be sampled on a quarterly basis. All of the samples should be analyzed for Sr-90, Cs-137, Ra-226, H-3, metallic and organic constituents. In addition, wells that have previously been reported to have oil in them should be monitored for hydrocarbons. Identification of these non-radiological parameters is important for the design of a groundwater treatment system.

It may be possible that less extensive sampling is needed if records of previous sampling efforts are available. For instance, if the monthly off-site sampling records are available, fewer samples may be needed.

7.4 Costs Associated with Additional Characterization

To calculate the cost associated with additional ground water monitoring, we first identified the number of new wells to be installed (three) and the number of existing wells to be sampled (17). Given four sampling events, we then calculated that 80 samples would need to be analyzed. Next, we calculated the total unit cost of analysis, assuming all of the water analyses from Table 4 in Section 3.5 would be needed except for alpha spectroscopy, resulting in a total unit cost of \$676.90. As shown in Table 34, we then multiplied the unit cost to install additional wells by the number of additional wells needed, and multiplied the unit cost of sampling by the number of samples requiring analysis. We summed the costs to arrive at a subtotal of \$70,952. To account for sample collection and associated costs of sampling, we added 10 percent of this subtotal cost on to this estimate, which results in a total cost of \$78,047.

Table 34. Estimated Costs Associated with Additional Groundwater Monitoring

Number of new wells needed	3
Number of samples needed per event	20
Number of sampling events	4
Number of samples analyzed	80
Unit cost to install each well	\$5,600.00
Unit cost to analyze each sample	\$ 676.90
Total cost to install 3 wells	\$ 16,800
Total cost of analysis	\$ 54,152
Subtotal cost	\$ 70,952
Associated sampling costs (10 percent)	\$ 7,095
Total cost	\$ 78,047

8.0 Other Sampling - Surface Water, Vegetation, Air, Rain Water, Hold-up Tank Effluent

In this section we only summarize previous characterization efforts related to other media, including surface water, vegetation, air, rain water, and liquid effluent to further demonstrate that releases of radioactive materials have occurred in the past. We make no conclusions regarding the adequacy of these data, nor recommendations for additional characterization.

8.1 Summary of Existing Characterization

8.1.1 Surface Water

Oak Ridge Associated Universities Environmental Survey 1982

Surface water samples were collected on site from the drainage ditch and the East Lagoon. Surface water samples also were collected off-site from one private pond and the Susquehanna River during the time in which a release of SLC's hold-up tank was made (2 km upstream of the facility; at the outfall; and 100 m, 500 m, and 2km downstream of the facility). Samples were analyzed by Oak Ridge Laboratories for H-3, Ra-226, and Cs-137. Selected samples were also analyzed for Sr-90.

The Ra-226 concentrations of 0.33 and 0.30 pCi/L in the surface water samples from the drainage ditch and East Lagoon were twice that of the baseline water. The concentration of tritium in the East Lagoon was 7,140 pCi/L, which is three times the level of the maximum baseline sample. The concentration of H-3 in water from the drainage ditch was 610 pCi/L, which is in the range of the baseline samples. Radionuclide concentrations in both surface water and baseline samples are summarized in Table 35 below.

Table 35. Radionuclide Concentrations in Surface Water Samples

Location	Radionuclide Concentration ¹ (pCi/L)			
	Ra-226	Cs-137	Sr-90	H-3
<i>On-Site</i>				
Drainage Ditch	0.33	<8	6.4	610
East Lagoon	0.3	<8		7,140
<i>Off-Site</i>				
Marr Pond	0.11	<8	<0.31	410
River 2 km upstream		<8		<250
Outfall		13		<250

Location	Radionuclide Concentration ¹ (pCi/L)			
	Ra-226	Cs-137	Sr-90	H-3
River 100 m. downstream	<0.10	<8		<250
River 500 m downstream	0.27	<8		<250
River 2 km downstream		16		<250
Baseline Water -1		37 ± 18		2330 ± 550
Baseline Water -2		35 ± 29		1170 ± 530
Baseline Water -3	0.15 ± 0.15	12 ± 18	1.1 ± 0.6	<250
Baseline Water -6	0.10 ± 0.19	<8		874 ± 525

¹ A blank in these columns indicates the sample was not analyzed for that radionuclide.

Monserco Site Characterization 1995

One effluent stream water sample was collected during the Monserco Site Characterization and analyzed for 39 volatile organics and heavy metals. Chloroform was detected at 3.3 µg/L, 1,2-Dichloropropane was detected at 1.1 µg/L, and xylene (m- and p-) were detected at 0.3 µg/L. Heavy metals were detected at low levels (below the maximum contaminant levels - MCLs); however, chromium and lead were detected at 0.23 mg/L and 0.11 mg/L, respectively, which exceeds EPA's health-based levels for ingestion of water (0.1 mg/L and 0.015 mg/L, respectively).

PADEP Groundwater and Surface Water Assessment 2000

Four surface water samples were collected along the banks of the Susquehanna River, three south of the property and one approximately one mile upstream of the site within Columbia Park. The upstream location was used to represent "background." The three samples collected south of the property were collected from the eastern edge of the site (southeast of the benchmark located near the Vance/Walton property), along the western edge of the site (in front of the Murphy property), and 50 feet upstream along the western edge of the site in the free flowing current. Samples were collected by submerging laboratory prepared bottles into the river.

Surface water samples were analyzed by STL for gross alpha, gross beta, gamma emitting isotopes, and TAL inorganics. Foster Wheeler Environmental compared surface water inorganic results to Pennsylvania Title 25, Part 1, Subpart A, Chapter 16, Water Quality Toxics Management Strategy, Water Quality Criteria for Toxic Substances, Human Health Criteria. Radiological results for surface water were not compared to any criteria.

Surface water results for TAL inorganics indicate only half of the analytes were present above detection limits. None of these results exceeded the criteria for inorganics. Radiological

analyses indicated gross beta concentrations in surface water up to 3.3 pCi/L. H-3 concentrations ranged from 260 pCi/L to 390 pCi/L. Only Cs-137 was detected by the gamma scan and results ranged from non-detect to 2.9 pCi/L. Individual radiological scans detected Ra-226, C-14, Sr-90, Ni-63, Am-241, and Po-210 in surface water samples. The following ranges were detected for each radionuclide:

- Ra-226 concentrations from 0.325 pCi/L to 0.553 pCi/L.
- C-14 concentrations from 0.442 pCi/L to 3.08 pCi/L.
- Sr-90 concentrations from non-detect to 19.5 pCi/L.
- Ni-63 concentrations from 6.12 pCi/L to 13.1 pCi/L.
- Am-241 concentrations from non-detect to 0.073 pCi/L.
- Po-210 concentrations from non-detect to 0.0417 pCi/L.

8.1.2 Surface Vegetation

Oak Ridge Associated Universities Environmental Survey 1982

Six surface vegetation samples (1 kg each) were collected at six onsite locations. Samples collected south of the restricted (fenced) portion of SLC property contained the highest concentrations of radionuclides. A sample collected south of the above ground silo exhibited 424 pCi/g of tritium. A sample collected south of the Liquid Waste Building along the tank discharge line contained a 2.8 pCi/g of Cs-137. Two surface vegetation samples were collected from the island southeast of the facility. Vegetables with high water content (tomatoes and cucumbers) were collected from four private residences. Results of radiological analyses for these samples are summarized below in Table 36.

Table 36. Radionuclide Concentrations in Vegetation Samples Collected On and Off-site

Sample Number	Approximate Grid/ Location	Radionuclide Concentration (pCi/g wet wt.)		
		Ra-226	Cs-137	H-3
On-site				
V1	29/31	0.23	0.05	25.8
V2	244	0.16	0.71	76
V3	275	0.08	0.75	8.82
V4	203/204	0.07	0.05	17.7
V5	222	0.10	2.78	53.9
V6	238	<0.03	0.06	424
Off-site				

Sample Number	Approximate Grid/ Location	Radionuclide Concentration (pCi/g wet wt.)		
		Ra-226	Cs-137	H-3
V7	Island 500 m southeast of facility in river	0.08	0.03	7.35
V8 Island	Island 500 m southeast of SLC facility in river	0.07	0.03	4.41
V9 Vegetables	250 m east of SLC facility	<0.03	<0.03	16.9
V10 Vegetables	500 m northeast of SLC facility	<0.03	<0.03	9.7
V11 Vegetables	1250 m east of facility	<0.03	<0.03	1.22
V12 Vegetables	1500 m southeast of SLC facility	<0.03	<0.03	13.6

8.1.3 Aquatic Samples

Oak Ridge Associated Universities Environmental Survey 1982

Samples of aquatic vegetation, macroinvertebrates, and two species of fish were collected from the Susquehanna River in the vicinity of the outfall. Samples of similar aquatic life were collected 0.5 to 1.0 km upstream. Aquatic vegetation sample results were similar to on-site vegetation samples for Ra-226 and Cs-137. The H-3 concentration was 2.21 pCi/g wet wt. in the sample collected upstream of the facility and 21.4 pCi/g wet wt. in the sample collected near the SLC outfall. Radionuclides were not detected in the aquatic organisms collected from the Susquehanna River.

8.1.4 Air Monitoring

Oak Ridge Associated Universities Environmental Survey 1982

Air samples were collected at three onsite locations, 60-80 m southeast of the SLC stack. Samplers were suspended in trees approximately 15-20 m above the ground. Each sampler consisted of a particulate filter and a two-stage molecular sieve cartridge. The sampling rate for each unit was 5 L/min. A fraction of the combined stream from the three samplers was passed through an oxidizer furnace and molecular sieve cartridge to determine the average gaseous tritium concentration. Sampling was conducted for 48 hours with wind speed and direction monitored by a portable weather station. Air samples were collected from a molecular sieve

cartridge placed in parallel with the SLC's off-site sampler located approximately 0.3 km east of the site. This sampler was operated at 1.2 L/min for a period of approximately 3 days.

The three on-site air samples collected southeast of the stack, in the prevailing downwind direction, contained concentrations of all forms of tritium below guidelines for unrestricted areas. The concentration of aqueous tritium, measured in the off-site sample was considerably less than the guideline level.

The single exhaust stack was sampled for tritium concentrations. Two holes were drilled in the duct approximately 6 m downstream of the point where the fan discharge enters the stack. To determine isokinetic sampling rate, stack velocities were measured using a pitot tube and a swinging vane anemometer. Eight measurements were made along a traverse at each access hole. After installation of the probe assemblies and connection of the vacuum, control, and measurement equipment, air flows were adjusted to the desired sampling rate and samples were collected over a 24-hour period. A second and third set of 24-hour samples were collected following replacement of sampling media after each set.

The levels of aqueous and gaseous tritium measured in the stack on all three days of monitoring were significantly less than anticipated. Examination of the sampling systems revealed a leak which permitted outside air into the section containing the molecular sieve collectors. Stack concentrations determined by SLC were consistent with ORAU results for particulate tritium. The aqueous and gaseous tritium concentrations determined by SLC were all greater than those determined by ORAU due to the leakage. Licensee reported data was approximately 0.9 and 23 times the average annual limits for restricted and unrestricted areas respectively. A revision in calibration factors reduced these numbers to 0.7 and 17.

8.1.5 Rain Water

Chem-Nuclear Systems, Inc. Hydrogeological and Radiological Evaluation 1990

After elevated concentrations of H-3 in soil were detected, CNSI suspected contamination could be due to an atmospheric H-3 source. SLC internal monitoring data supported this observation. Consequently, 37 rainwater samples were collected on July 10-12, 1990, along the east and south fence line of the property. On July 10 and 11, 5 rainwater samples were collected from well 14 and drill sites B, C, E, and F. On July 12, 32 aluminum pans placed at 40 foot intervals along the fence line and one on top of the Vance/Walton well were used to collect rainwater. Continuous rainfall occurred during the 3.5 hour time period in which samples were collected. Wind speed and direction were recorded during this collection period from the SLC on-site weather station. The wind direction during this time was towards the southwest. Samples were analyzed by CNSI Barnwell Laboratory for H-3.

CNSI reported known atmospheric release points at this time included the Main Building, the Solid Waste Building, and the Liquid Waste Building. Samples collected on July 10 and 11

contained H-3 concentrations ranging from 24,900 pCi/L to 130,000 pCi/L. Thirteen samples collected along the eastern fence line on July 12 had non-detectable concentrations of H-3. The remaining 19 samples collected along the southern fence line exhibited H-3 concentrations ranging from 309 pCi/L to 24,600 pCi/L. The maximum concentration was collected south of the underground silos. Assuming the predominant wind direction was toward the southeast (based on the ORAU report wind rose), CNSI concluded that elevated H-3 in soil and groundwater could be related to atmospheric releases.

8.1.6 Liquid Waste Treatment Building - Effluent Hold-up Tank

Oak Ridge Associated Universities Environmental Survey 1982

The contents of one of the liquid waste effluent hold-up tanks were agitated and a sample was withdrawn. The sample was split with the SLC for analytical comparison. The concentration of H-3 measured in the liquid effluent from the hold-up tank was 41×10^6 pCi/L, which was consistent with SLC's result of 37×10^6 pCi/L. Dilution and release of this liquid effluent to meet the average annual limit for unrestricted areas was conducted over a period of 24 hours.

9.0 Conclusions

Over the last 20 years, numerous studies have been conducted at the SLC site in an attempt to characterize the nature and extent of the radiological and chemical contamination at the site. As a result of these studies, it is apparent that site operations spanning more than 50 years have generated significant quantities of radioactive and mixed wastes, contaminated virtually all of the buildings, and affected the soils and groundwater at this site. On the basis of our review of the characterization data generated by SLC and various contractors, we make the following conclusions.

- Operations have resulted in the radiological contamination of every building (except for the Old Radium Vault) at the site. Although many of the buildings likely can be remediated, a significant portion of the buildings present significant challenges for remediation due to degraded structural conditions, which make entry for characterization and remediation difficult if not impossible.
- Significant quantities of radiologically contaminated waste, contaminated equipment, and source material are presently located in buildings at the SLC site. A complete (and recent) inventory of the volume, radionuclides, and activities has not been made available to ICF and we have not included these materials in our assessment of whether additional characterization is necessary. Details on site history and past management practices also are incomplete.
- The majority of the surface soils at the site are contaminated with at least one radionuclide at levels exceeding the DCGLs as reported as either actually detected concentrations or presumed by analytical detection limits in excess of the DCGLs. The primary radioactive isotopes of concern are Ra-226, Cs-137, Am-241, and Sr-90. Daughter isotopes of Ra-226, such as Pb-214 and Bi-214, have also been found in the surface soils.
- Radium contamination at the site has been difficult to assess for reasons that are not clear. One possible explanation is analytical interference caused by Sr-90.
- Significant subsurface contamination of the site exists due to historical operations and disposal practices, including buried wastes at numerous known and unknown locations at the site. The primary radioactive isotopes of concern are Ra-226, Cs-137, Am-241, and Sr-90. Daughter isotopes of Ra-226, such as Pb-214 and Bi-214, have also been found in the subsurface soils.
- A large portion of the subsurface site remains uncharacterized, including areas beneath the buildings and areas adjacent to underground process lines, drainage lines, septic tanks, underground storage tanks, sumps, and cisterns (information on the locations of all such items is incomplete).

- Groundwater monitoring events have been sporadic and the number and identity of the monitoring wells vary by monitoring event. Nonetheless, results of these monitoring events indicate that the underlying groundwater is contaminated with various radionuclides, metals, and to a lesser extent, organics. The primary radioactive isotopes of concern are H-3, Ra-226, Cs-137, Am-241, and Sr-90. Daughter isotopes of Ra-226, such as Pb-214 and Bi-214, have also been found in the ground water.
- There is a potential for past and present off-site migration of contaminants and this potential needs to be considered in future characterization efforts in areas adjacent to the SLC site.

As a result of our evaluation of the site characterization information, we believe that additional characterization is necessary. We present a summary of the costs associated with this additional characterization by medium in Table 37.

Table 37
Summary of Costs of Recommended Additional Characterization

Medium	Cost of Additional Characterization
Buildings	NA
Soil	\$ 64,660
Subsurface Soil	\$ 381,924
Groundwater	\$ 78,047
Total	\$ 524,631

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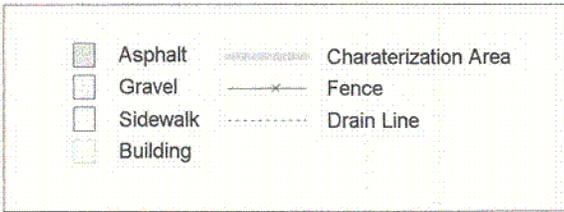
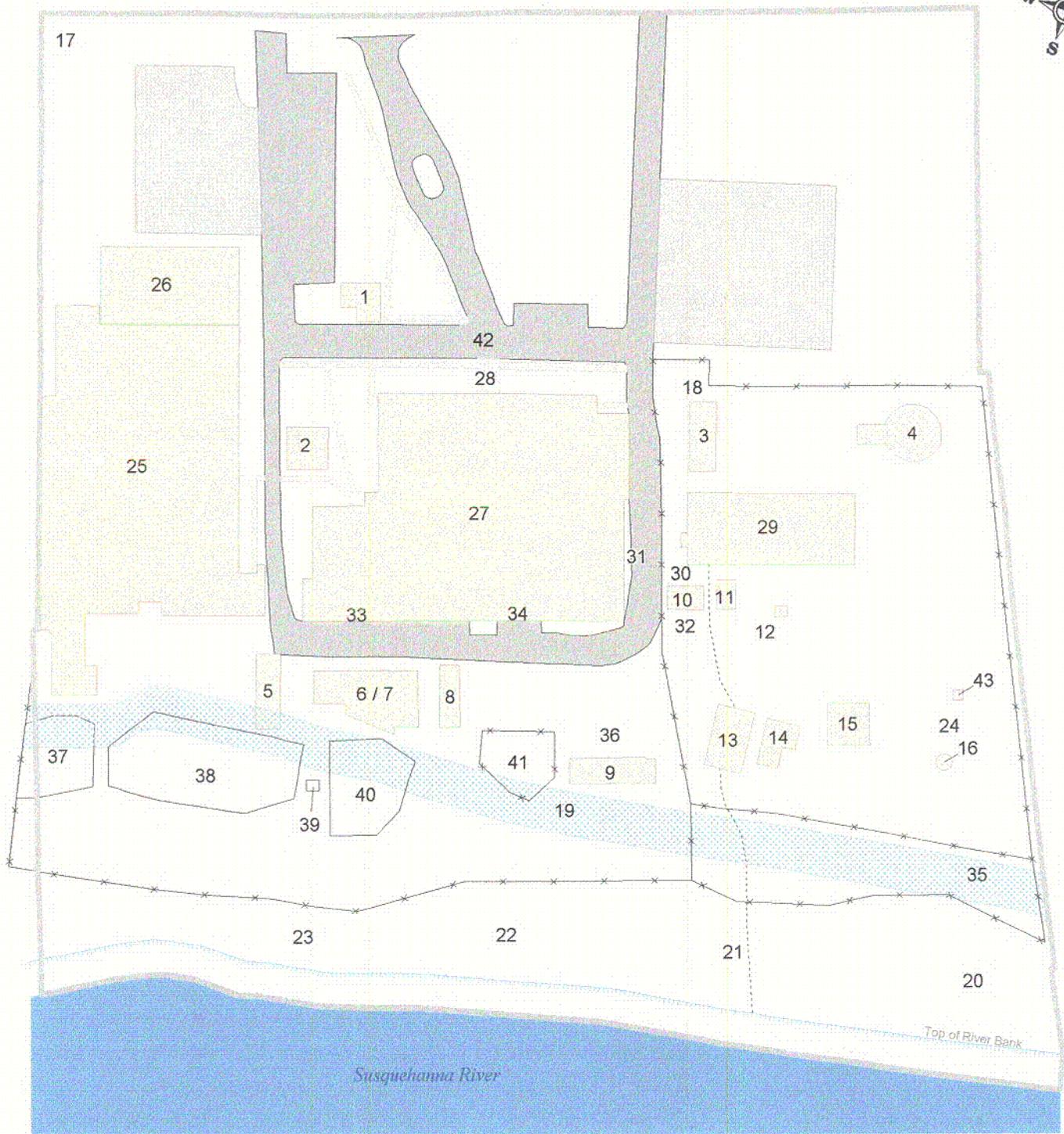
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APPENDICES

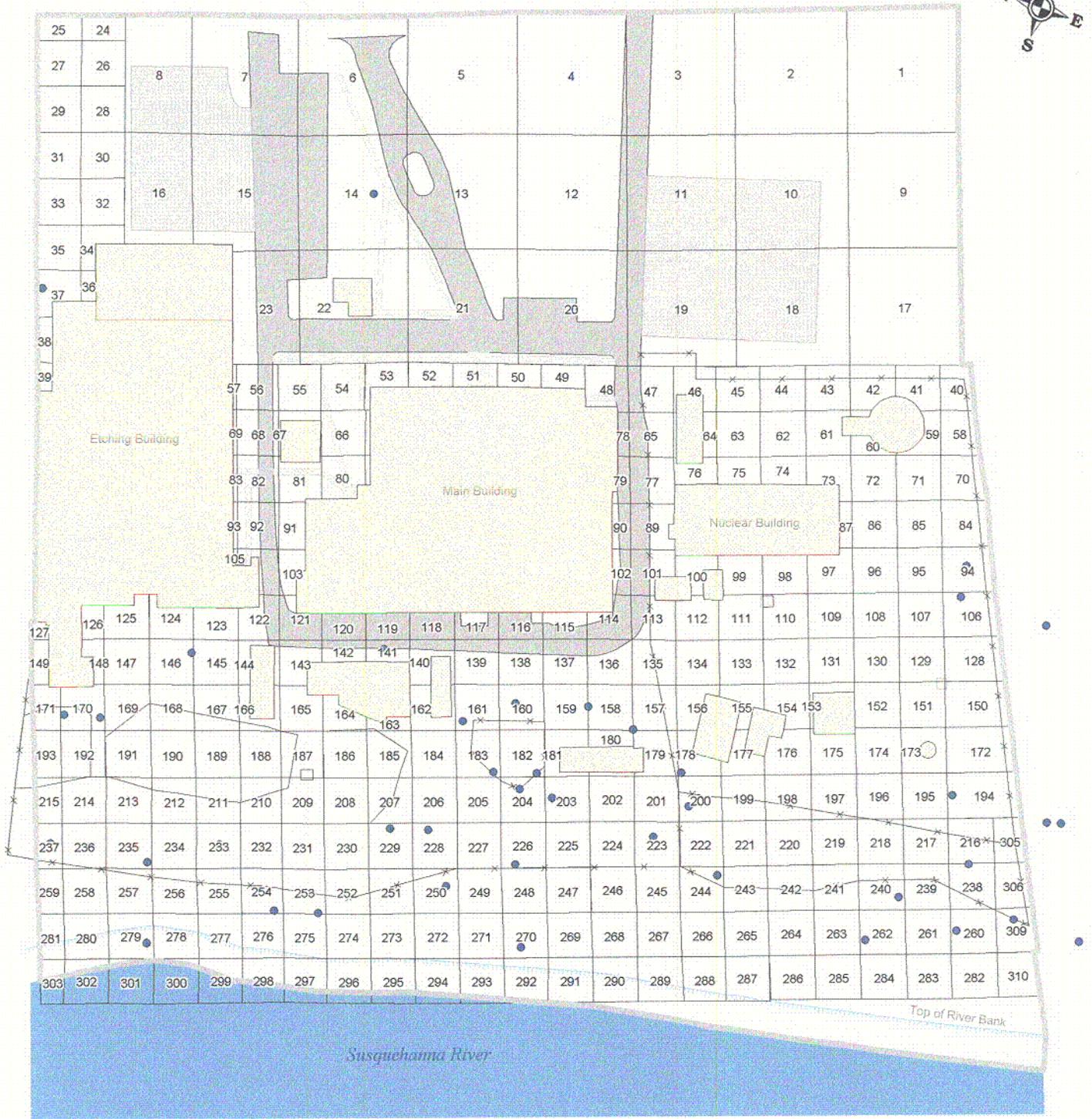
APPENDIX 1
Figures

Figure 1



Study Area Location

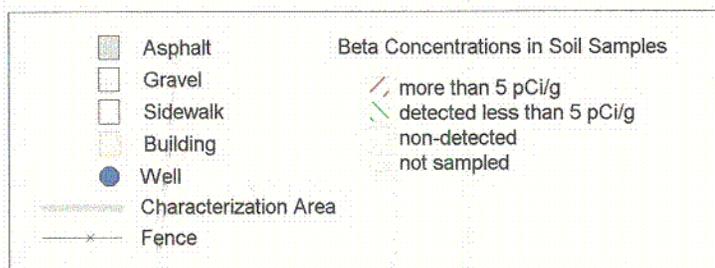
Figure 2



	Asphalt		Well
	Gravel		Characterization Area
	Sidewalk		Fence
	Building		

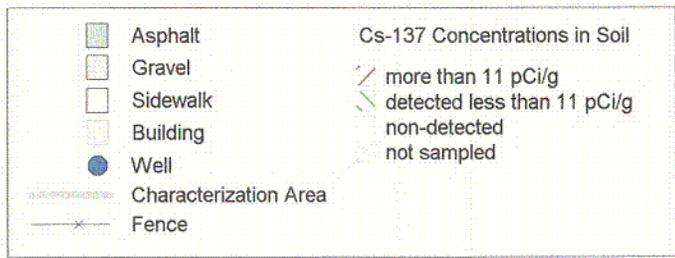
Grids

Figure 3



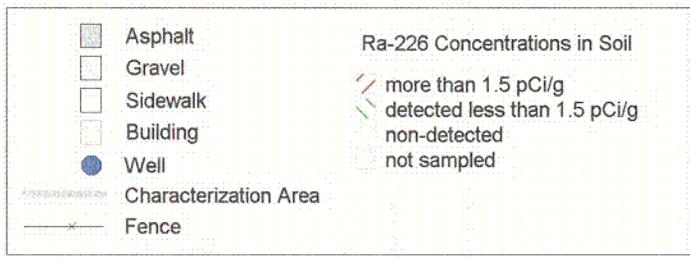
Beta Concentrations in Soil Samples

Figure 4



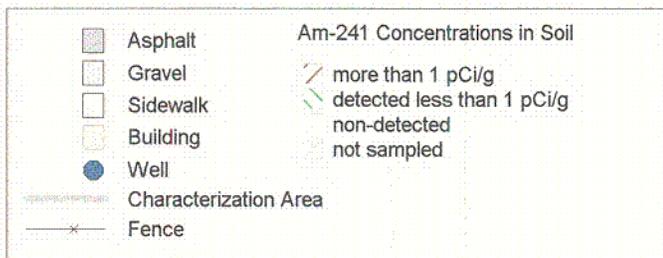
Cs-137 Concentrations in Soil

Figure 5



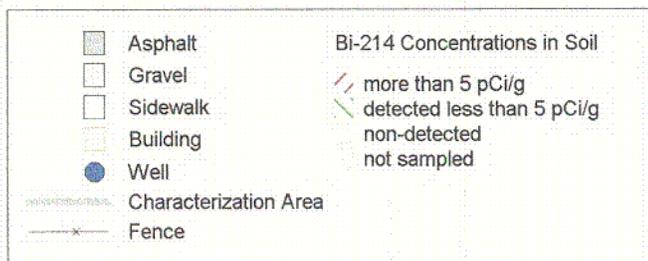
Ra-226 Concentrations in Soil

Figure 6



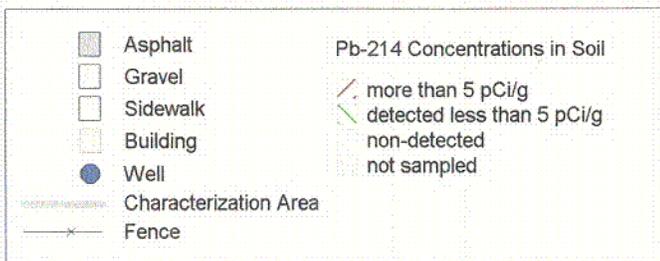
Am-241 Concentrations in Soil

Figure 7



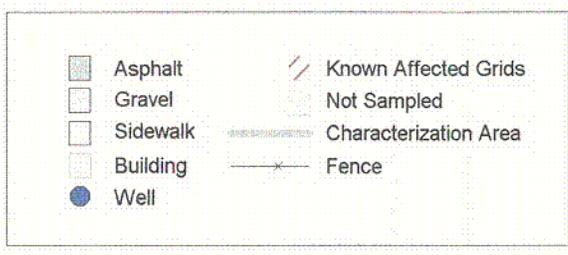
Bi-214 Concentrations in Soil

Figure 8



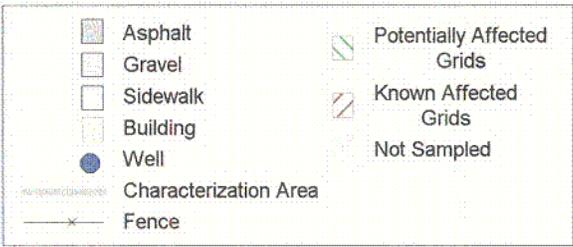
Pb-214 Concentrations in Soil

Figure 9



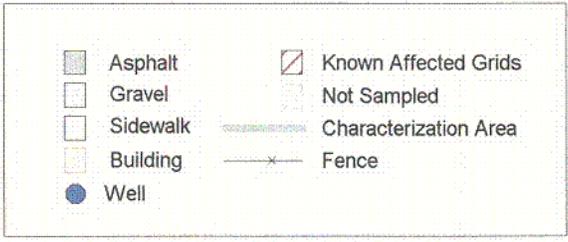
Known Affected Grids

Figure 10



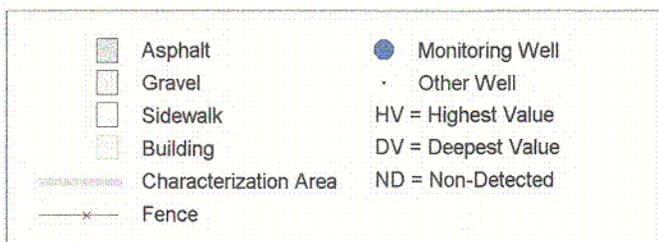
Known and Potentially Affected Grids

Figure 11



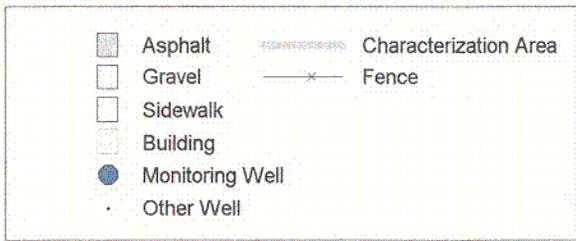
Chemical Constituents Detected

Figure 12



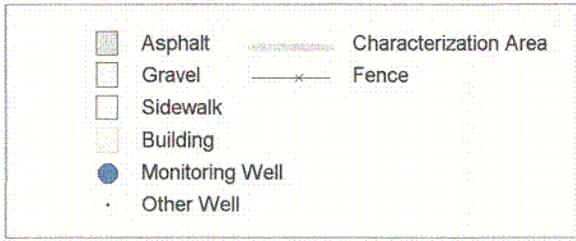
Beta Concentrations in Soil Samples

Figure 13



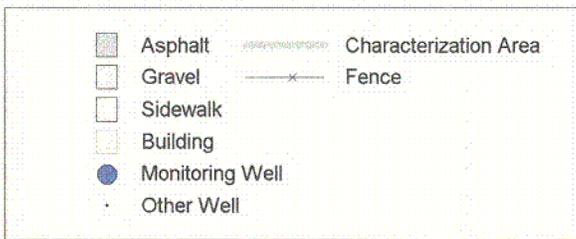
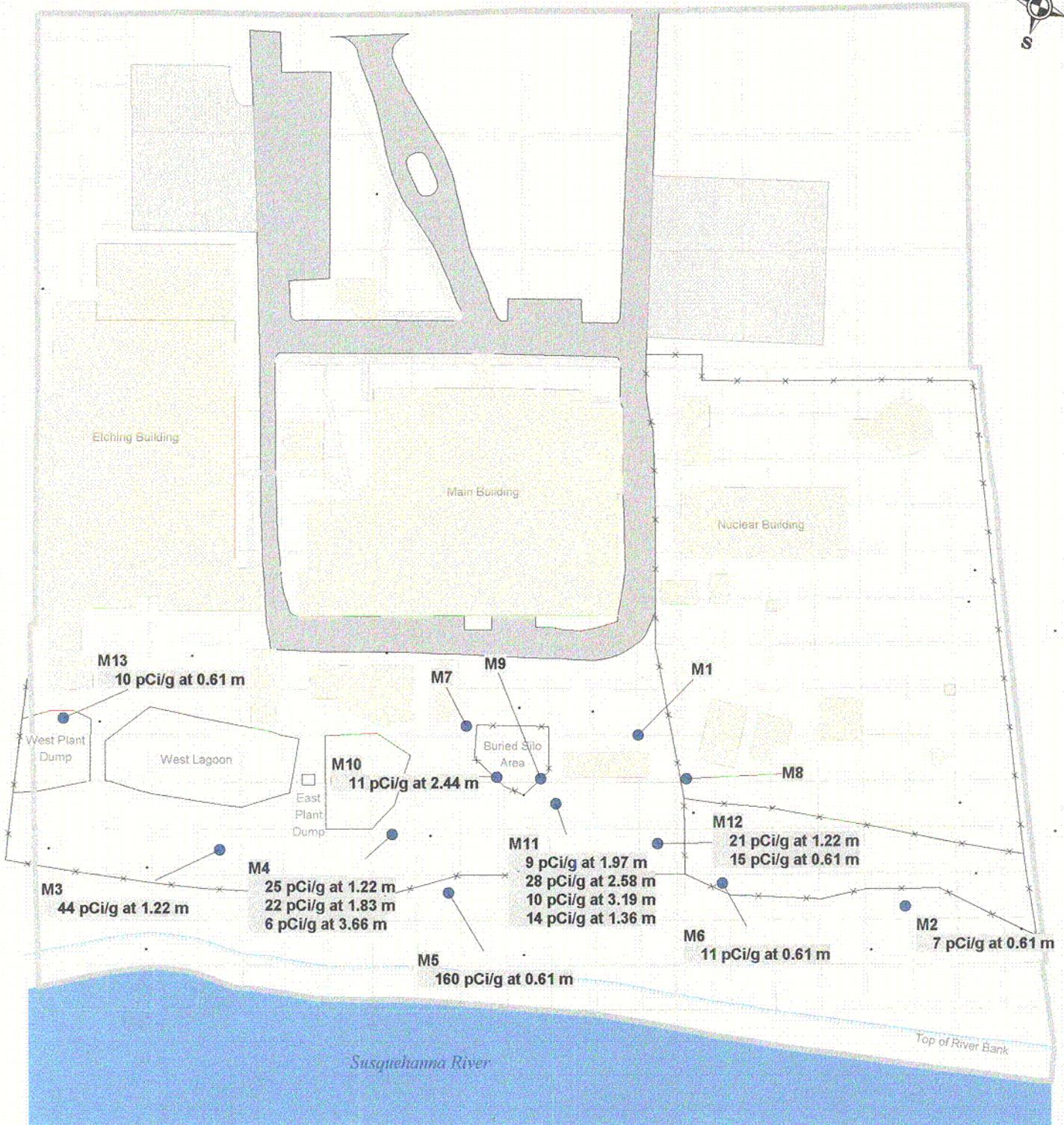
Cs-137 Concentrations above DCGL in Soil Samples

Figure 14



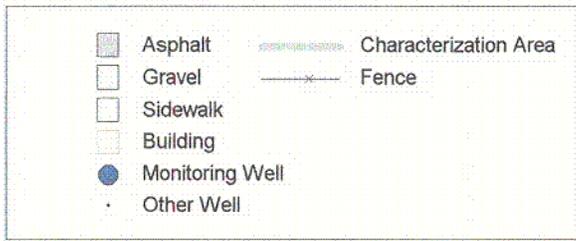
Ra-226 Concentrations above DCGL in Soil Samples

Figure 15



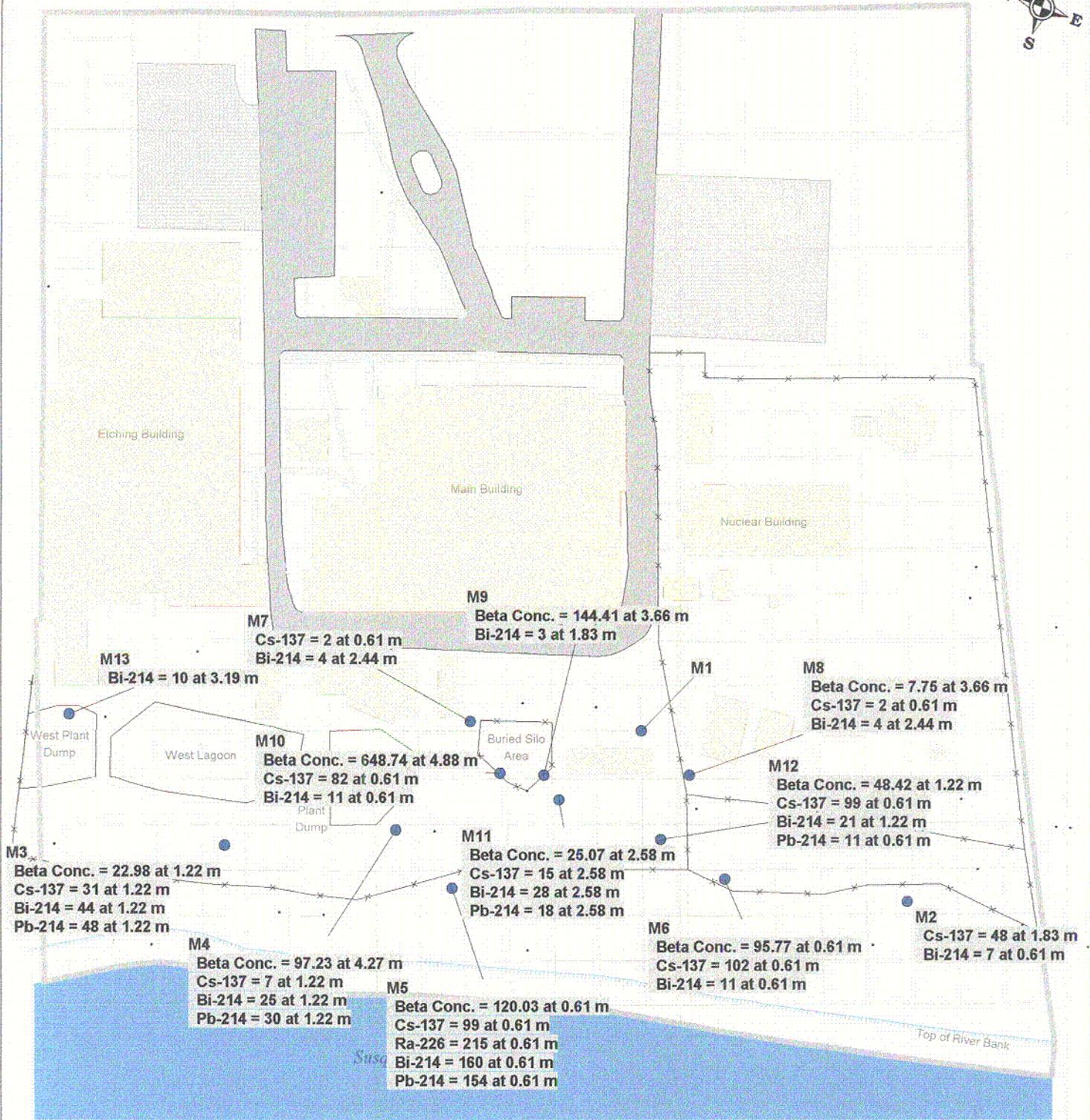
Bi-214 Concentrations above NRC Reference Level in Soil Samples

Figure 16



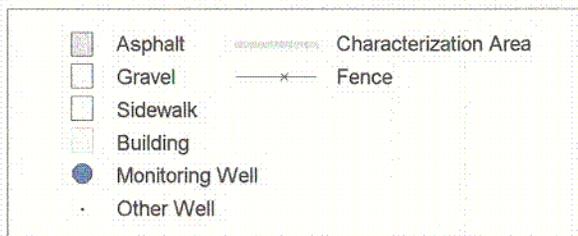
Pb-214 Concentrations above NRC Reference Level in Soil Samples

Figure 17



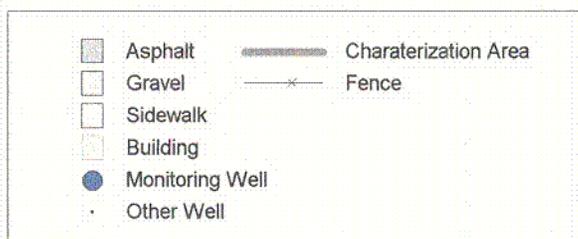
- Asphalt
- Gravel
- Sidewalk
- Building
- Monitoring Well
- Other Well
- Characterization Area
- Fence

Figure 18



Isotope Concentration in Groundwater

Figure 19

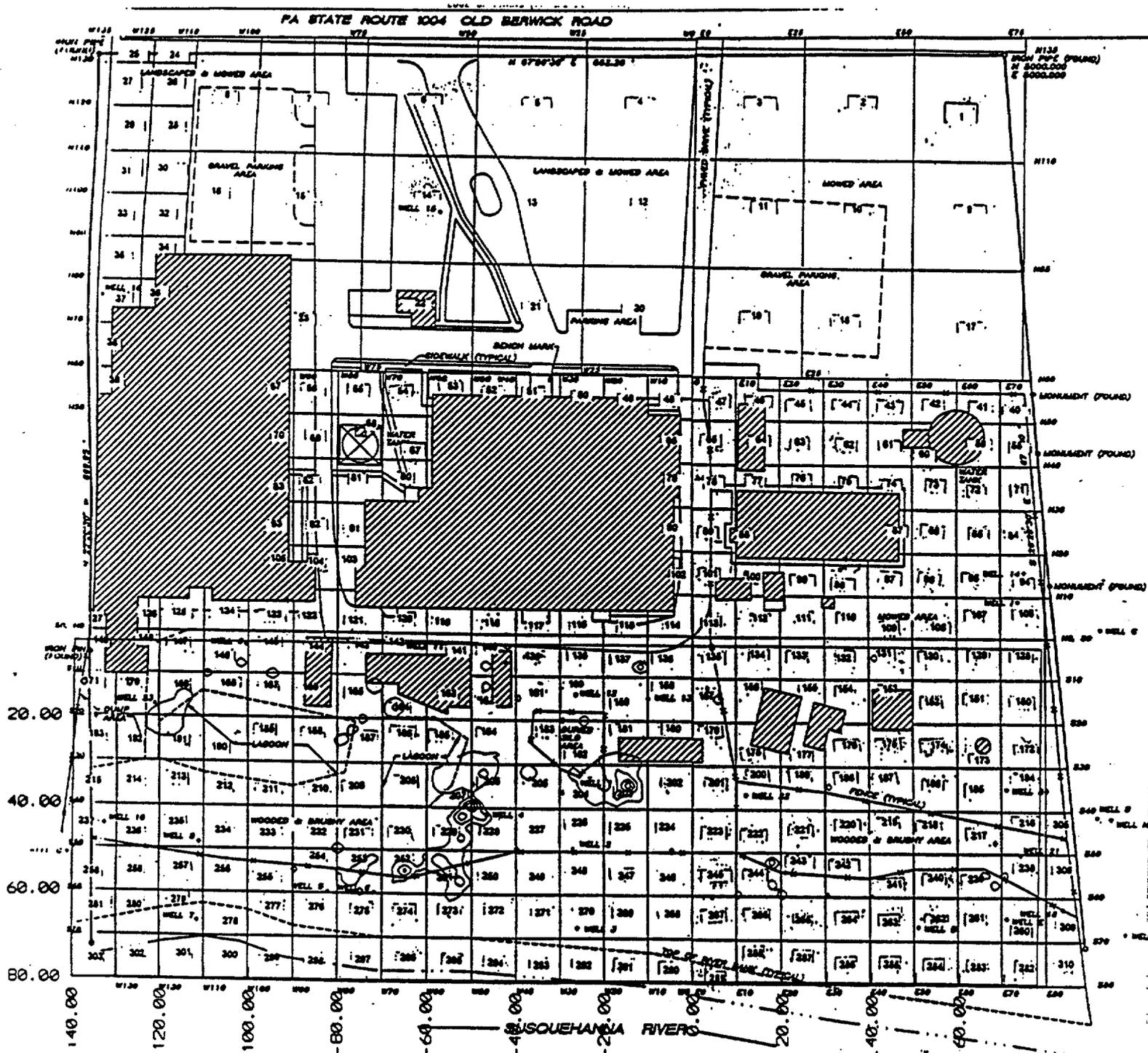


Organic Constituents in Groundwater Above MCL or HBL

APPENDIX 2
Isopleths of Contaminated Areas

FIGURE 8.4

DISTRIBUTION OF Bi-214 AT CONCENTRATIONS GREATER THAN 1 COUNT PER SECOND



DISTRIBUTION OF Cs-137 AT CONCENTRATIONS GREATER THAN
1 COUNT PER SECOND (AFTER REMOVAL OF THE Cs-137
CONTAMINATED LOG)

FIGURE 8.6

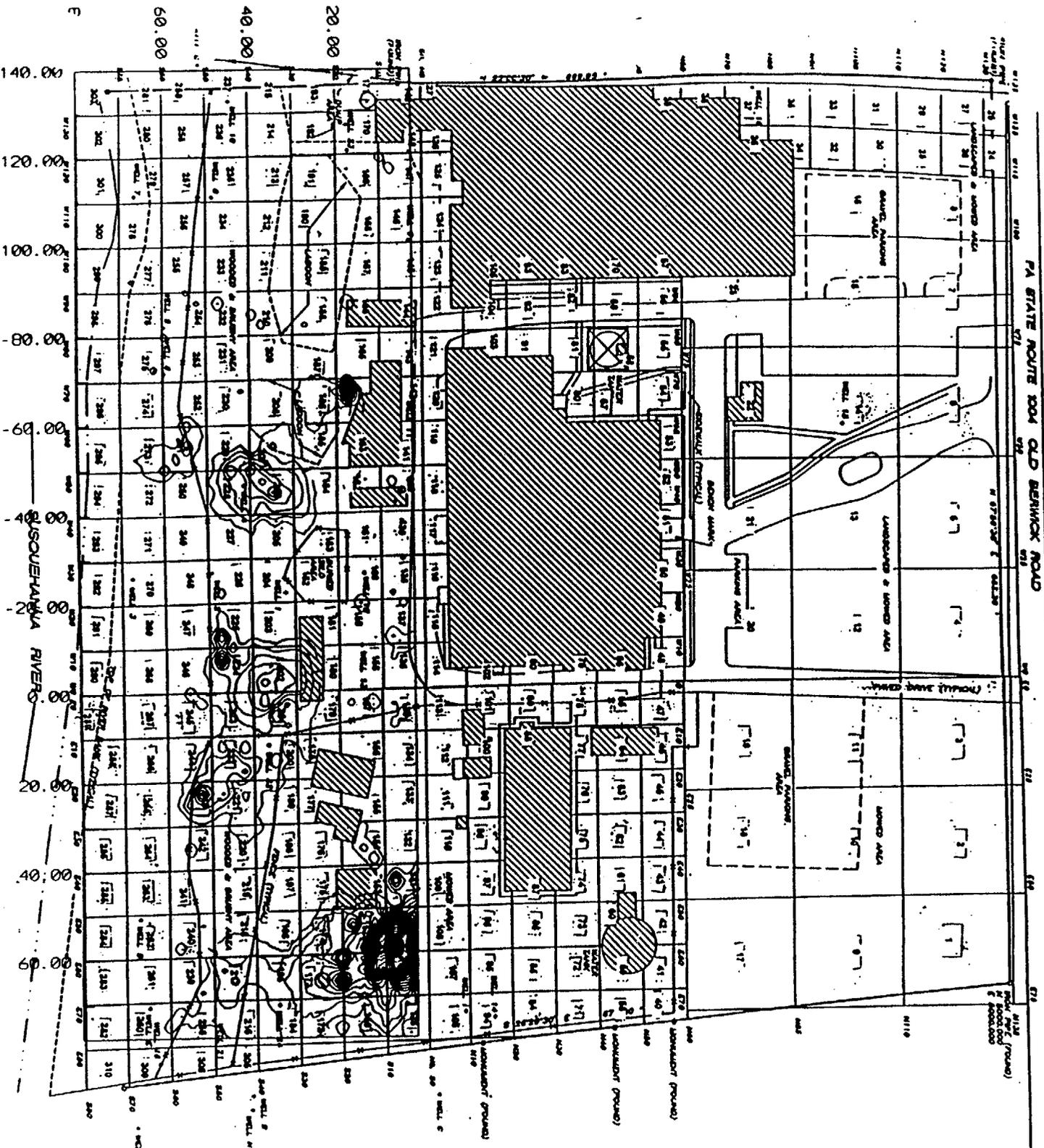


FIGURE 8.7

BETA SOIL CONCENTRATION ISOPLETH

(Minimum value = 5 pCi/g)

(1 line increment = 5 pCi/g)

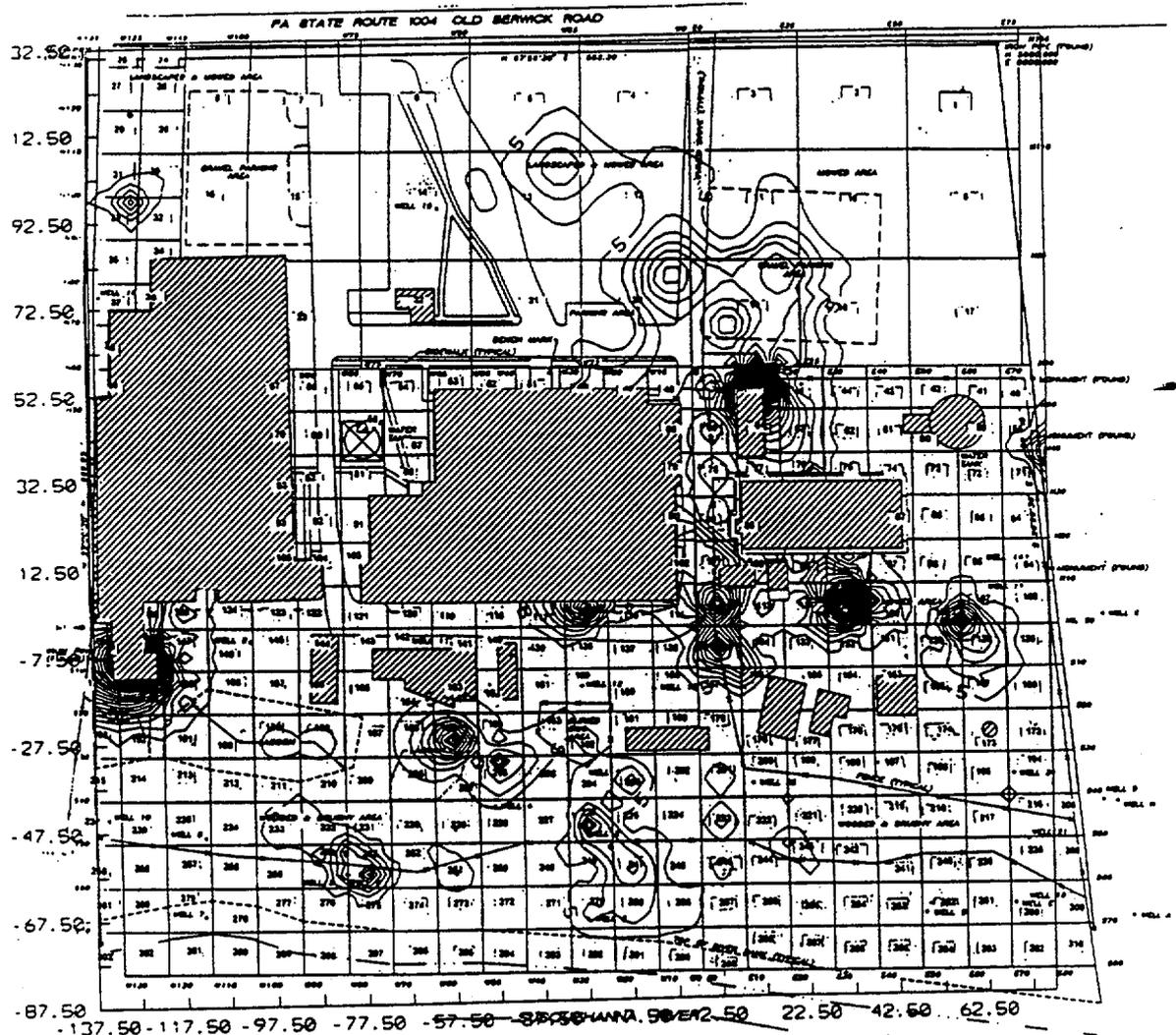


FIGURE 8.8

Cs-137 SOIL CONCENTRATION ISOPLETH

(Minimum value = 15 pCi/g)

(1 line increment = 5 pCi/g)

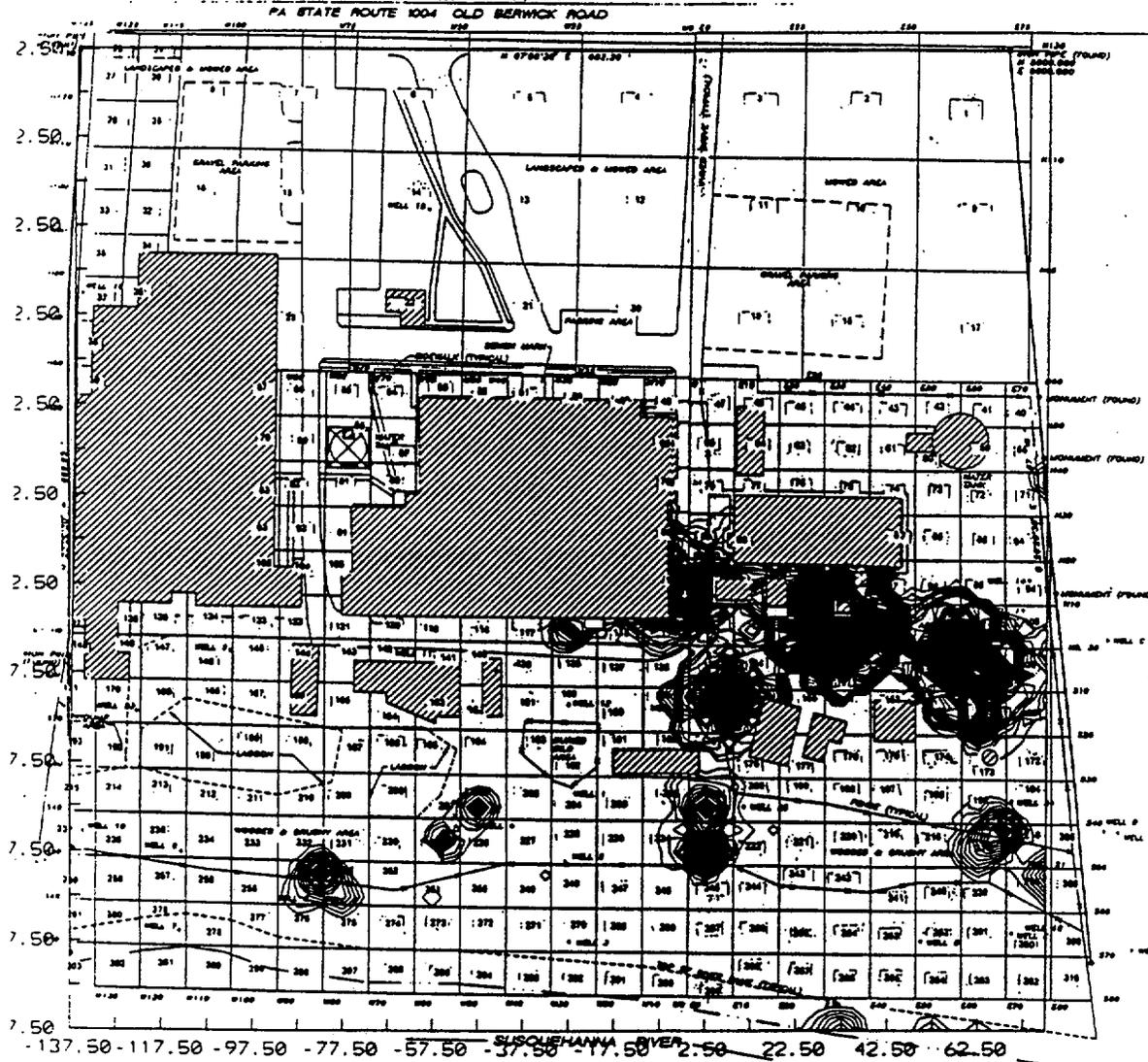


FIGURE 8.9

Bi-214 SOIL CONCENTRATION ISOPLETH

(Minimum value = 5 pCi/g)

(1 line increment = 5 pCi/g)

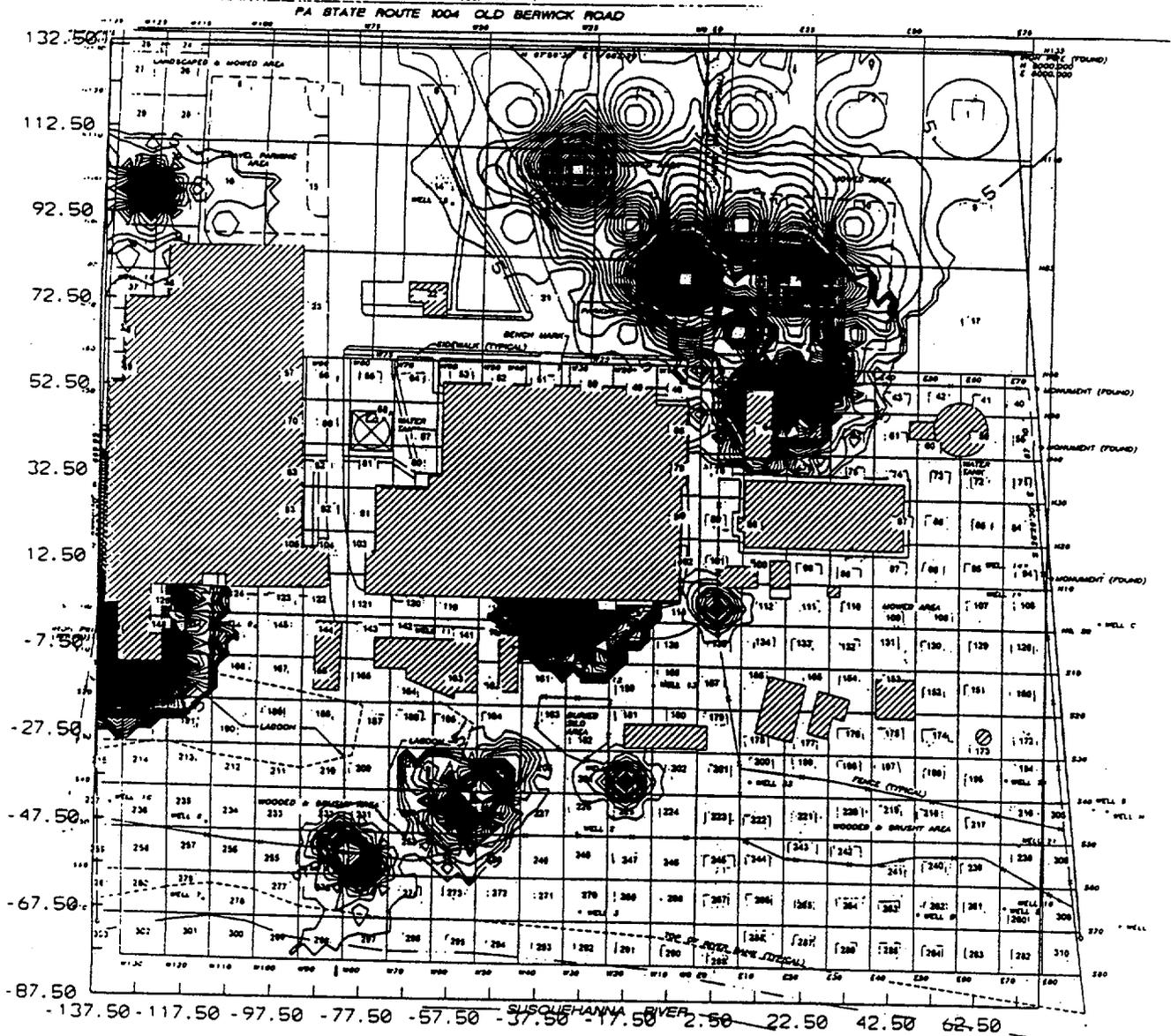
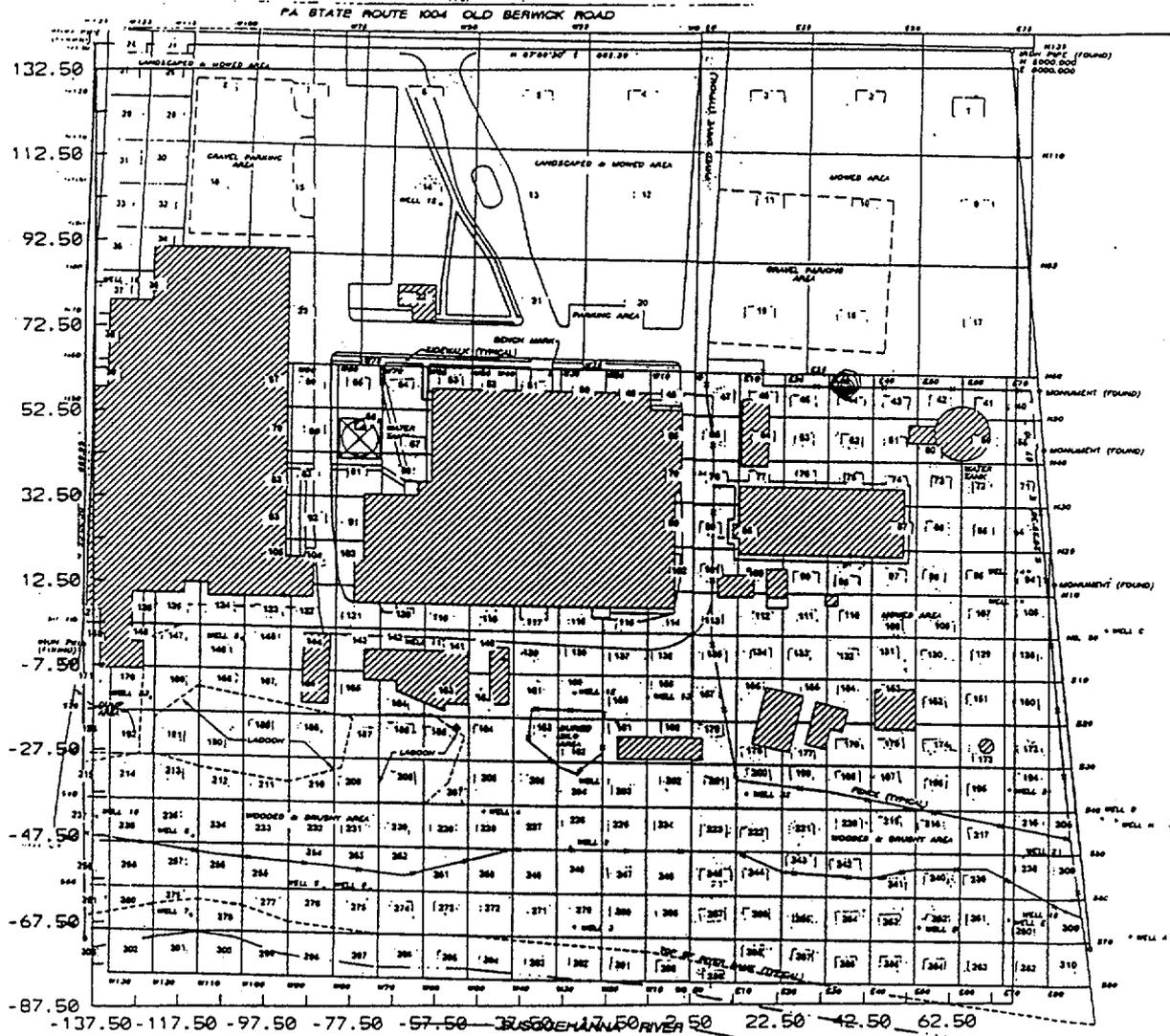


FIGURE 8.10

Am-241 SOIL CONCENTRATION ISOPLETH
(Minimum value = 30 pCi/g)
(1 line increment = 5 pCi/g)



APPENDIX 3
Location of Elevated Surface Radiation Levels on the U.S. Radium/SLC Site

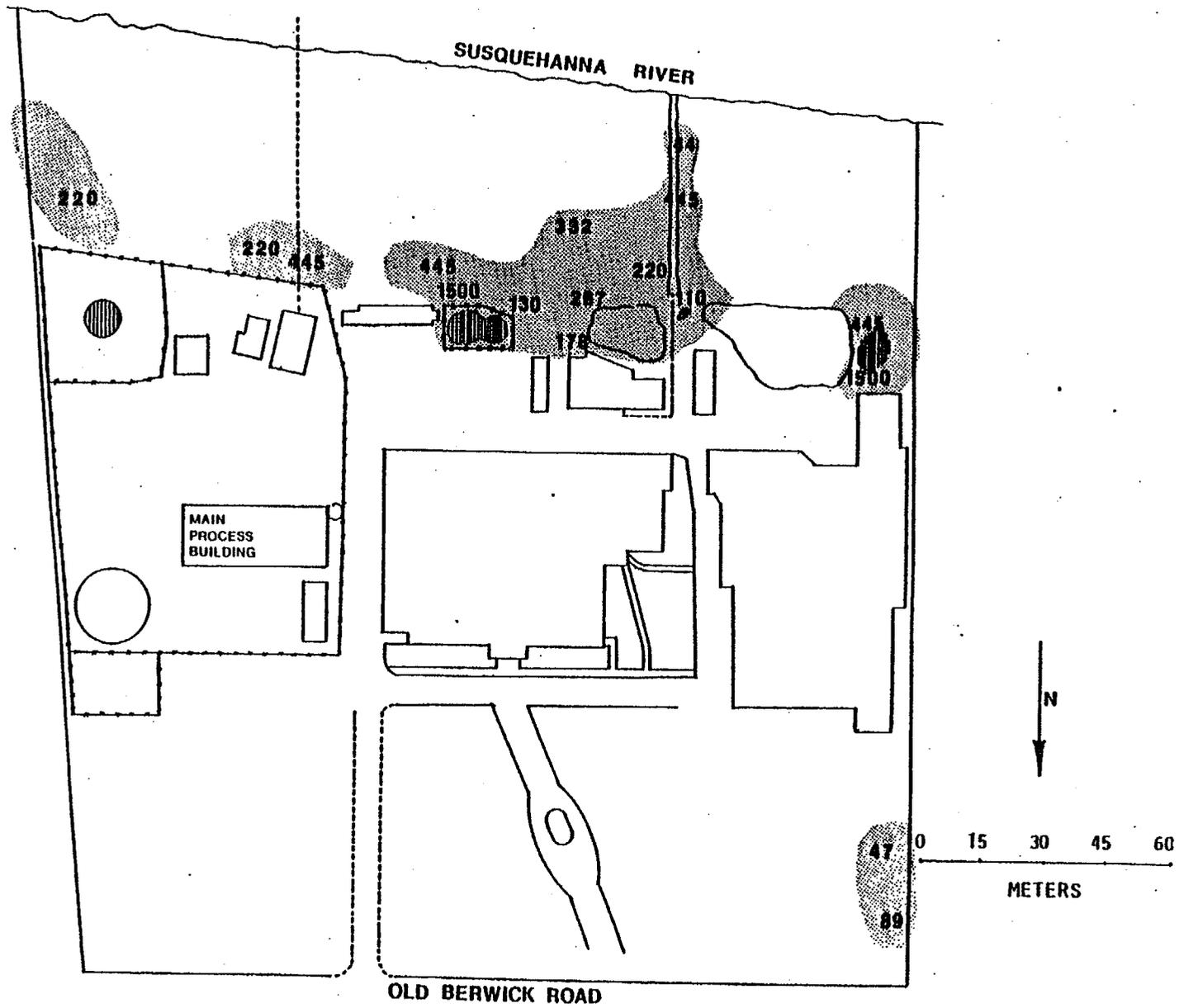
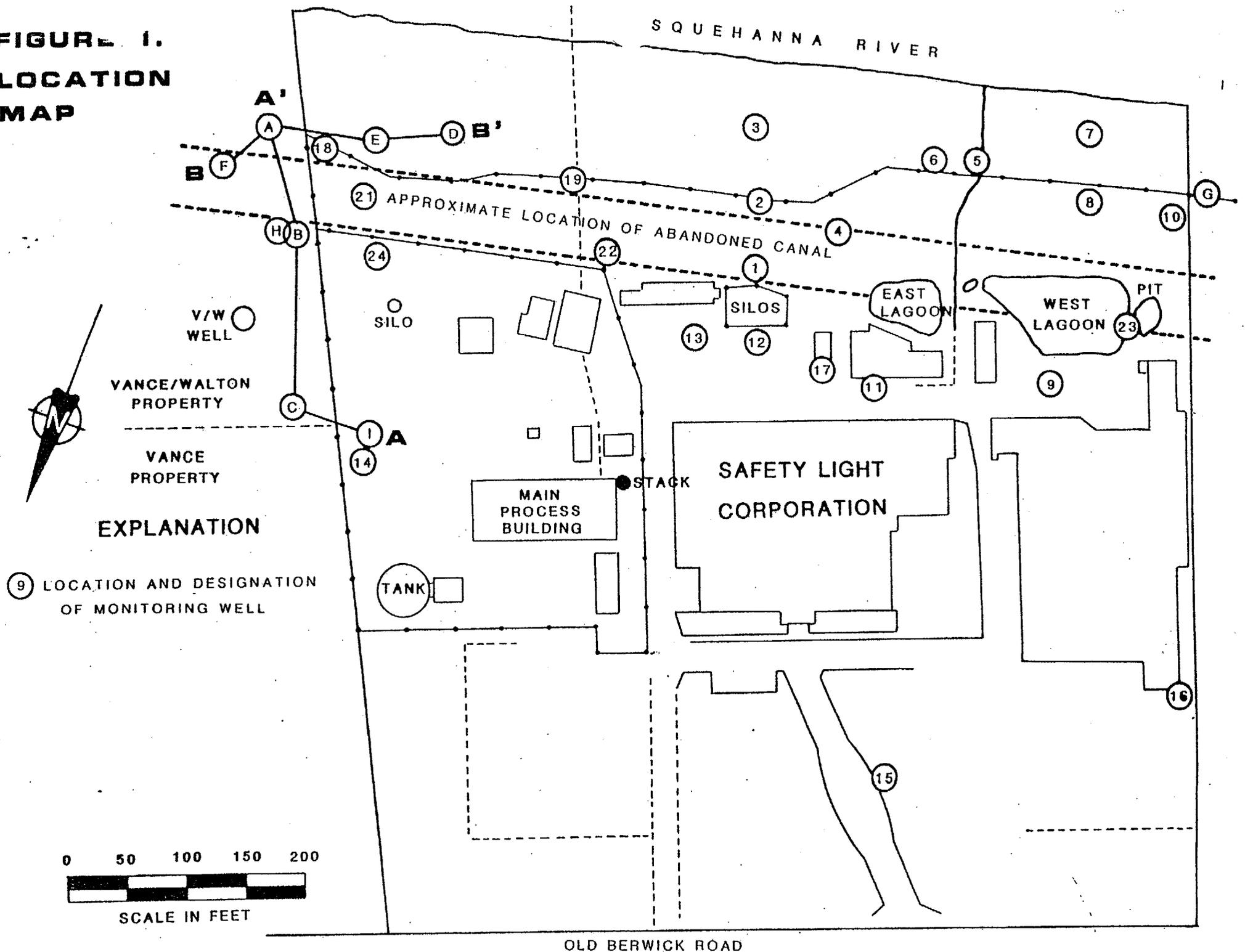


FIGURE 19. Locations of Elevated Surface Radiation Levels on the U.S. Radium/SLC Site. Maximum exposure rates ($\mu\text{R/h}$) also are indicated.

APPENDIX 4
Location Map of Safety Light Corporation Facility

**FIGURE 1.
LOCATION
MAP**



APPENDIX 5

Background Information on Groundwater at the SLC Site

In 1979 Meiser and Earl conducted a hydrogeologic investigation at the SLC site. The results establishing groundwater flows and identifying permeabilities are summarized here. In addition, the 1990 Chem-Nuclear Study provided supplemental information, which is also included below.

Meiser & Earl Hydrogeologic Investigation 1979

Thirteen approximate locations for test drilling were identified by Meiser & Earl personnel to allow for maximum definition of groundwater conditions, emphasizing the area of the abandoned canal, lagoons, and disposal pits. An additional 3 locations were identified for background definition. Three wells had been previously installed in October 1978 by Giles Drilling Corporation.

The original approach for drilling was to advance a hollow stem auger or to employ drive casing, sample the soil inside with a split spoon every 2 feet, and then set 2-inch schedule 80 PVC pipe and screen for a permanent well. This technique was unsuccessful for five locations (12, 13, 14, 15, and 16). Consequently, drilling was performed using an air rotary well drill and setting 5-foot increments of 6-inch steel casing with welded joints, slotted to about 5 feet above the water table.

Core samples were used to estimate the permeabilities of the deposits to allow calculation of groundwater flowrate. Estimated permeabilities were expressed in terms of flowrate through a unit area of aquifer under a hydraulic gradient of unity (i.e. the slope on the water table is 1:1). Laboratory tests were performed for sands and gravels from wells 9 and 13 using a falling head permeameter. Static water levels were measured in all available wells and borings and were corrected to elevations with respect to an assumed datum of elevation zero at the center of the burial pit.

Pumping tests were conducted on four wells (6, 9, 12, and 14) in the sand and gravel aquifer and the silt aquitard. Pumping tests measuring drawdown and recovery water levels were presumed to provide the most realistic and representative determination of field permeabilities. Assuming a low and high value of permeability and using the gradients measured from the water-table configurations, Meiser & Earl calculated flow velocities at different locations in the sand and gravel aquifer. The volumetric flow rate was calculated for the aquifer extending vertically from the bedrock base to the top of the aquifer using Darcy's Law.

Half gallon water samples were collected from all completed test wells (except 1, 2, and 3) in February and 2 gallon water samples were collected from each of the 19 total wells and borings in March. Water samples were submitted to USRC for radiological analyses. 250 mL water samples were collected from each point for water chemistry analysis including pH, calcium, conductivity, alkalinity, and sulfate.

Meiser & Earl's report provides a description of the subsurface geologic condition. The site lies about 5 miles downstream (west) from the edge of the most recent glacial ice advance during Late Wisconsin time, 10,000 years BP. The site is within the outwash plain produced by torrential flooding of ice meltwater down the Susquehanna River valley. The nearly level elevation of the shale bedrock seen in boreholes 3, 6, and 12 show the bedrock floor beneath the site to be relatively horizontal. Overlying the bedrock is a deposit of poorly sorted sands and gravels, the outwash plain from the melting Wisconsin glacier, approximately 35-45 feet thick under most of the plant site. The dense shale bedrock floor defines a lower boundary to the hydrogeologic system of the overlying sedimentary deposits.

The gravelly deposits can be divided into two units, including a coarser sand and gravel with large sandstone boulders, approximately 15-25 feet thick and underlying sands and finer gravels. The river has cut a fairly steep bank against the sand and gravel outwash plain and deposited a blanket of silts, fine sandy silts, clayey silts, and coal silts.

The "textbook" permeability of the sands and gravels (expressed in terms of flowrate through a unit area of aquifer under a hydraulic gradient of unity) was estimated to be on the order of 1000-3000 gpd/ft². The permeability of the silts was estimated to be about 0.1 gpd/ft². Falling head permeameter tests on gravels from wells 9 and 13 revealed considerable variability. Meiser & Earl concluded that the permeability of these gravels varies with increased silt content but is at least 200 gpd/ft². Using pumping test data, Meiser & Earl calculated the permeability of various formations from the wells provided in Table 1-1.

Table 1-1. Permeability of Various Formations at the SLC Site

Well No.	Approximate Grid Location ¹	Data Type	Formation	Permeability (gpd/ft ²)
6	253	Recovery	silts	0.28
14	94	Drawdown	sands and gravels	2600 ² 2300 ³
9	145/146	Recovery	sands and gravel aquifer (near the western property line)	560 ¹ 500 ²
12	160	Drawdown	sands and gravel aquifer (directly below burial pits)	700
12	160	Recovery	sands and gravel aquifer (directly below burial pits)	830
13	158/159	Drawdown	not provided	3100 ¹ 2700 ²
1	204	Recovery	not provided	2900

¹ Locations approximated by comparison with gridded map developed for 1995 Monsarco Site Characterization.

² Number provided in text of report.

³ Number provided in Table 7 of report.

Based on the corrected static water levels, Meiser & Earl developed a water-table contour map (February 21, 1979) and concluded that the water table is nearly flat in the front of the plant property with gradients on the order of 0.3%. Meiser & Earl indicate that as the gravel aquifer is pinched between the overlying river flood plain silts and the underlying shale bedrock, the water table steepens dramatically. The water table gradient through the burial pit was reported to be about 0.7% and steepens to 5% beneath the canal bank. The water table gradient in the flood plain area was reported to be 10%. Using these water table gradients and high and low permeabilities, Meiser & Earl report groundwater flow rates ranging from 0.47 to 2.8 ft/day through the burial pit (Well Nos. 1 and 12), 0.20 to 1.2 ft/day for the front of the plant, and 6.7 to 40 for the floodplain. The volumetric daily flow through a one-foot window of the aquifer extending vertically from the bedrock base to the top of the aquifer was given as 320 gallons/day.

Meiser & Earl report that groundwater flow in the areas of the disposal pit and old dumps appears to head toward the river. The water-table contour map from February 1979 indicates groundwater flow through the burial pits is 180° (where magnetic north = 0°). Acknowledging that contouring the water-table configuration in mid-March was considerably more difficult, Meiser & Earl conclude that there may be an elongated, subdued groundwater mound parallel to the edge of the active flood plain. Meiser & Earl indicate that this may be caused by the flooding of the river which had receded only a few days before the measurements were taken and had saturated the entire flood plain area to the ground surface. The report further states that this high water configuration is a temporary situation, reflecting bank storage in the silts.

Chem-Nuclear Systems, Inc. Study 1990

The CNSI report gave a limited description of the geologic setting of the facility which is provided here. The facility lies within the Valley and Ridge province of Pennsylvania and is underlain by unconsolidated deposits. Unconsolidated deposits were laid down during the glacial age and are underlain by Paleozoic bedrock formations which have experienced significant folding. The Berwick Anticline controls the structure of the bedrock in the area. The southeast limb of the Berwick Anticline dips toward the Susquehanna River.

Near the flood plain the upper outwash deposit reported by Meiser & Earl had eroded and were replaced by silts, clayey silts, and coal silts by the river. The contact between the shale bedrock surface and the overlying gravelly sands was sharp and distinct. The bedrock surface was eroded to a flat surface approximately 455 feet above mean sea level. Gravelly sands characterized by variable amounts of fine gravel and coarse grain sand overlie the bedrock surface. These outwash deposits range from 10-20 feet thick. Clayey gravels characterized by variable amounts of cobbles and boulders overlie the gravelly sands and are predominate in the north side of the abandoned canal. Clayey gravels south of the Susquehanna River have eroded and been replaced by fluvial silty clay or silt. Cobbles occur in this unit to the east but are not found in the western edges of the site.

The water table was described by CNSI as nearly flat from the northern portion of the site to the northern extent of the abandoned canal. The water table falls rapidly toward the Susquehanna River. Groundwater appeared to flow southward toward the river.