DECOMMISSIONING PLAN

FOR

READING, PENNSYLVANIA SLAG PILE SITE

Prepared for:

Cabot Corporation
157 Concord Road
Billerica, MA 01821-7001

Prepared by:

ST Environmental Professionals, Inc.
RR 4, Box 239, Lutz Road
Boyertown, PA 19512

Revision 0, August 28, 1998

TABLE OF CONTENTS

1.0	INTRODUCTION AND GENERAL INFORMATION	1-1
1.1	GENERAL INFORMATION	1-2
1.2	FACILITY RADIOLOGICAL HISTORY INFORMATION	1-3
1.2.1	Radiological Material Used at Reading	1-3
1.2.2	Operating Occurrences Affecting Decommissioning Safety	1-3
1.3	SITE DESCRIPTION	1-3
1.3.1	Topography	1-4
1.3.2	Climate	1-4
1.3.3	Physiography and Geology	1-4
1.3.4	Soils	1-5
1.3.5	Surface Water Hydrology	1-6
1.3.6	Groundwater Hydrology	1-6
1.3.7	Slag Pile Stability	1-8
1.3.8	Slag Pile Volume	1-9
1.4	PREVIOUS DECOMMISSIONING ACTIVITIES	1-10
1.5	SUMMARY OF CURRENT RADIOLOGICAL CONDITIONS	1-10
1.5.1	Summary of Site Characterization Results	1-10
1.5.2	Radiological Assessment	1-13
2.0	PLANNED DECOMMISSIONING ACTIVITIES	2-1
3.0	METHOD USED FOR PROTECTION OF OCCUPATIONAL PUBLIC HEALTH AND SAFETY	3-1
4.0	PLANNED FINAL RADIATION SURVEY	4-1
5.0	FUNDING	5-1
6.0	PHYSICAL SECURITY PLAN AND MATERIAL CONTROL AND ACCOUNTING PLAN PROVISIONS IN PLACE DURING DECOMMISSIONING	6-1
7.0	REFERENCES	7-1

TABLES

Table 1-1	**Summary of Groundwater Analytical Results**
Table 1-2	**Scenario Pathways and Key Parameter Values**
Table 1-3	**Results Summary**

FIGURES

Figure 1-1	Site Location Map
Figure 1-2	Site Vicinity Map
Figure 1-3	Site Map
Figure 1-4	Geologic Map
Figure 1-5	Sample Locations Map
Figure 1-6	Cross Section AA'
Figure 1-7	Cross Section BB'
Figure 1-8	Maximum Annual Radiation Dose (TEDE) Results Trespasser Scenarios
Figure 1-9	Maximum Annual Radiation Dose (TEDE) Results Worker Scenarios
Figure 1-10	Maximum Annual Radiation Dose (TEDE) Results Summary

APPENDICES

Appendix A Slope Stability Analysis

Appendix B Leach Rate Assessment

1.0 INTRODUCTION AND GENERAL INFORMATION

The possession of slag at the Reading, Pennsylvania location is licensed by the US Nuclear Regulatory Commission (NRC) License No. SMC-1562 held by Cabot Corporation (Cabot), County Line Road, Boyertown, PA 19512. License SMC-1562 also covers source materials associated with former ore processing activities at their Revere, Pennsylvania facility. This Decommissioning Plan applies only to the Reading, Pennsylvania Site.

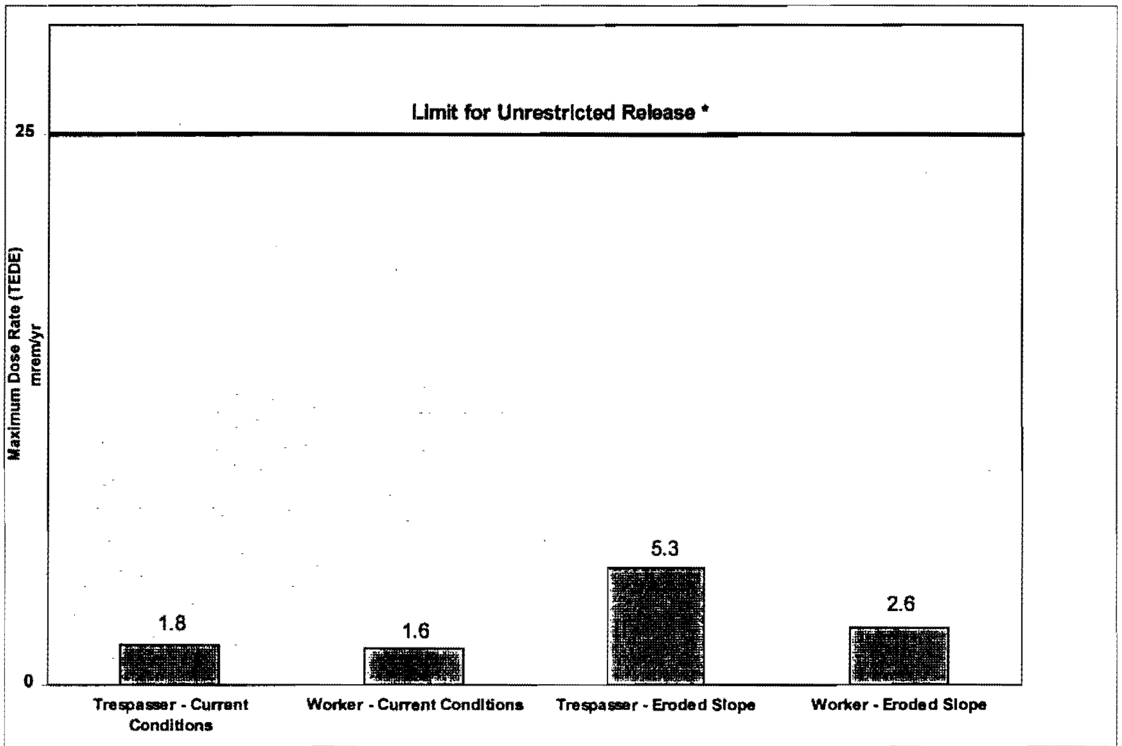
NRC's new rule (10 CFR Part 20 et al., Radiological Criteria for License Termination; Final Rule) became effective on August 20, 1997. This Decommissioning Plan (DP) is being submitted to meet the requirements of the new rule.

The objective of the decommissioning process is to terminate the license. During the decommissioning process, Cabot performed comprehensive site characterization and analysis including: surface gamma measurements, radiological analysis of surface and subsurface soil samples, radiological analysis of groundwater samples, characterization of the site topography, climate, physiography, geology, hydrogeology, and surface water hydrology, measurement of the leach rate of uranium from the slag, determination of the leach rates of thorium and radium, evaluation of the weathering rate of the slag, analysis of the slag pile stability, performance of a Radiological Assessment, and preparation of this Decommissioning Plan.

The characterization information was used to develop input parameters for RESRAD modeling of theoretical maximum radiation doses that might result from unrestricted use of the Site. Two basic exposure scenarios were analyzed; trespasser and worker. Each basic exposure scenario was analyzed for both the current Site conditions and potential future conditions assuming erosion of the soil cover has occurred, exposing the radiological slag. Detailed descriptions of the modeling input parameters and results are contained in the Radiological Assessment (STEP, 1998) and are summarized in Section 1.5.2 of this report. The maximum calculated dose for each are summarized below.

CASE	MAXIMUM ANNUAL TOTAL RADIATION DOSE (mrem/yr TEDE)
Trespasser—current conditions	1.8
Trespasser—eroded slope	5.3
Worker—current conditions	1.6
Worker—eroded slope	2.6
The 10 CFR Part 20 dose criterion for license termination with no restrictions on use is 25 mrem/yr.	

These results are graphically depicted below and compared to the 25 mrem/y limit (10 CFR 20 Subpart E) for unrestricted release. As shown, they are all much less than the limit for unrestricted release.



* Unrestricted Release = Less Than 25 mrem/year (10 CFR 20 Subpart E)

In summary, the potential exposure levels for the current conditions and any reasonable future conditions involving unrestricted use are all well below the 25 mrem/y criteria for unrestricted release and unrestricted release is as low as reasonably achievable (ALARA). As a result no decommissioning activities are required.

1.1 GENERAL INFORMATION

The Reading Slag Pile is located in Reading, Berks County, Pennsylvania. Figure 1-1 shows the location of the Reading Site. Slag materials from metal processing activities performed in the late 1960's were deposited on a preexisting slag. The possession, handling, and disposal of the slag were authorized under the NRC license. Kawecki Chemical (Kawecki), a predecessor to Cabot, leased a portion of the facility when the operations which lead to placement of the slag were conducted. Cabot has never owned or operated the site.

1.2 FACILITY RADIOLOGICAL HISTORY INFORMATION

1.2.1 Radiological Material Used at Reading

The Kawecki process was designed to increase the percentage of tantalum in low grade ores by heating a mixture of iron ore, tantalum ore (tin slags), and coke in an electric arc furnace. The ores used by Kawecki contained naturally occurring uranium and thorium in concentrations defined as "source material" by the Atomic Energy Commission (AEC) The AEC is now the NRC. The possession and handling of these materials was performed under AEC/NRC license. The tantalum alloyed with the iron leaving a glass-like silica gangue in which the naturally occurring thorium and uranium remained. This operation was conducted during 1967 and 1968.

The glass-like slag residues from Kawecki's processing operations were placed on a pre-existing slag disposal area on an embankment at the southern end of the property. This same area had been used before 1967 for slag disposal from manufacturing operations conducted by one or more companies unaffiliated with Kawecki Chemical. Additional material was placed there in 1977 through 1978 as a result of building decontamination activities including sand mixed with tin slag from a location in Baltimore. The slag pile is located southwest of the former gas house shown as the 1-story block building on the Site Vicinity Map (Figure 1-2). The slag extends approximately 160 feet along the length of the embankment.

No activities are currently conducted in the slag area described above.

1.2.2 Operating Occurrences Affecting Decommissioning Safety

Currently there are no licensed materials used within the industrial property containing the Site. Other than the slag pile, all areas where licensed material was handled have been decontaminated. There are no known radiological operating occurrences that would affect the safety of personnel during decommissioning of the slag pile.

1.3 SITE DESCRIPTION

As shown on the Site Location Map (Figure 1-1) and the Site Vicinity Map (Figure 1-2), the slag pile is located east of the Schuylkill River. The area is urban with land use being primarily industrial or related to the transportation corridor along the river. Between the slag pile area and the Schuylkill River there is a currently undeveloped extension of the River Road right-of-way (ROW), a Norfolk Southern (Norfolk) railroad ROW and remnants of the former Schuylkill Canal. Another Norfolk ROW is located approximately 150 feet northwest of the slag pile. Buttonwood Street is located approximately 600 feet to the southeast of the pile. The larger industrial property which contains the small slag area extents northeast to Tulpehocken Street.

Because the property is not owned by the licensee, the area encompassing the slag pile has been defined as the "Site" for purposes of discussion in this Decommissioning Plan. The Site consists of the area containing radiological slag and slag mixed with soil and debris. The areal extent of the Site is shown on the Site Map (Figure 1-3). Currently, there are no buildings, structures or apparent use within the Site area and Site access is controlled by a fence and warning placards. The Site is heavily vegetated with mature trees and brush.

1.3.1 Topography

Figure 1-1 and Figure 1-3 depict the regional and site topography as ground surface elevation contours. The ground surface elevation rises from approximately 193 feet above mean sea level (MSL) at the Schuylkill River to approximately elevation 266 feet MSL at the top of the slag pile. The elevation of the southwestern Norfolk ROW and River Road ROW range in elevation from approximately 210 to 212 feet MSL. As shown in Figure 1-3 the embankment occupied by the slag pile has a vertical relief (rise) of 55 feet over a horizontal distance (run) of 110 feet. Trigonometric calculation shows that this ratio represents a slope of 30° from the horizontal. This can also be expressed as a 2 to 1 slope (2 feet of horizontal run for each 1-foot of vertical rise). The elevation contours for the slope were provided by a licensed Pennsylvania land surveyor.

The upper area, from the top of the slope east, is generally flat with elevations ranging from 264 MSL to 270 MSL. The shallow swale shown in this area focuses surface water runoff onto the northern portion of the slag pile.

1.3.2 Climate

Based on information in Water Resources of the Schuylkill River Basin (Biesecker, 1968), Berks County has a temperate humid, maritime-type climate. Average temperature in the Reading area is approximately 54° F and average annual precipitation is approximately 40 inches. Approximately one half of the precipitation (20.7 inches) is returned to the atmosphere through evapotranspiration with the remainder entering streams as direct runoff and groundwater discharge. Precipitation is fairly evenly distributed throughout the year with the monthly average ranging from approximately 2.5 inches in February to 4.5 inches in August. Despite the higher precipitation in the summer months runoff is lower due to higher rates of evapotranspiration.

1.3.3 Physiography and Geology

The Site is located in the Great Valley Section of the Valley and Ridge physiographic province near the boundary with the Reading Prong of the New England Highlands province. The location of the Site relative to the mapped geologic formations is depicted in Figure 1-4. Bedrock beneath the site is mapped as the Cambrian Period age Richland Formation. The Richland Formation geology is described by MacLachlan, 1983:

> Medium-gray thick-bedded dolomite and subordinate limestone arranged in cycles representing shallow marine deposition. Limestone beds commonly have argillaceous to silty laminae and may be sandy. Throughout the formation, some beds contain scattered nodules and stringers of dark-brownish-gray chert; some oolitic and cryptozoon layers are also present. Discrete dolomitic sandstone beds occur locally. Thickness is about 420 m (1,400 ft).

Between the base of the embankment and the Schuylkill River the geology is mapped as Quarternary age Alluvium. MacLachlan provides the following geologic description:

> Saturated or seasonally wet, unconsolidated deposits along streams. Deposits along minor streams are variable depending on stream gradient and lithologies traversed. Along major streams deposits are predominantly fine grained (silty to sandy), containing only scattered coarser clasts. Alluvial anthracite is locally abundant along Schuylkill River. Maximum Known thickness is about 24 m (80 ft).

The site characterization effort and observations indicate that both geologic formations are covered by fill associated with past operations at the industrial property and the transportation corridor

1.3.4 Soils

The site lies within a large area mapped by the United States Department of Agriculture Soil Conservation Service (SCS, 1970) as "Made land, limestone materials, sloping (MdB)" which consist of "materials that have been moved or disturbed by excavation or filling so that the natural, orderly arrangement of particles and horizons have been destroyed." The Soil Conservation Service states that "This land type is generally not suited to farming."

Based on the site characterization data and visual observations, the surface soils consist of mixed fill materials; primarily non-radiological slag mixed with construction debris, a small volume of radiological slag, and soil. Sufficient soil has been placed over the radiological slag on the slope to support a dense growth of mixed vegetation including trees. The Characterization Report (NES, 1996) identified a green non-radiological slag below the radiological slag at a depth of approximately 20 feet below the top of the embankment and a natural clay material at a depth of approximately 38 feet below the top of the embankment. The approximate locations of borings and other sampling locations are shown on Figure 1-5.

The on-site soils are well drained. It is apparent based on the characterization results and visual observations that there are no wetlands within the site boundaries. The only observed wetlands in the vicinity of the site appear to be immediately adjacent to the Schuylkill River and within portions of the former Schuylkill Canal.

1.3.5 Surface Water Hydrology

No water courses other than the Schuylkill River were identified in the immediate vicinity of the Site. As would be expected for granular fill material, the surface of the Site and adjacent areas appeared to be well drained. The United States Geological Survey (USGS) has maintained a stream gauging station approximately 2,000 feet downstream from the Site. The average daily flow rate was 1,532 cubic feet per second (cfs). The minimum reported daily flow was 98 cfs and the maximum reported daily flow was 26,800 cfs (USGS, 1997)

The flood profile for the June 1972 flood (Tropical Storm Agnes) in Pennsylvania indicates that the maximum water level was at elevation 219.2 feet above mean sea level (MSL) 450 feet upstream from the Reading Railroad bridge (approximately 500 feet upstream from the Site) and at elevation 218.6 feet MSL at the Buttonwood Street Bridge (approximately 600 feet downstream from the Site) (Miller, 1974). Therefore, the flood level at the site was at approximately elevation 219 feet MSL. Because the 1972 flood was reported to far exceed any previously recorded flood levels on the Schuylkill River, these elevations represent the maximum reported flood levels. The 100 year flood elevation at this location is mapped as 211 feet MSL.

Based on the above information, the Norfolk ROW and the River Road ROW are within the flood plain of the Schuylkill River. The majority of the slag pile, which ranges in elevation from approximately elevation 210 feet MSL to 260 feet MSL, is above the 100 year and the maximum reported flood level.

1.3.6 Groundwater Hydrology

The information evaluated for this report was sufficient to develop a comprehensive conceptual model of the Site geologic and hydrogeologic conditions. All the Site-specific and background information supports the model. The conceptual model is depicted in Figure 1-6 which is a cross section showing the subsurface conditions beneath the Site. As shown, the permanent groundwater table occurs just above the bedrock. The gradient in this aquifer is toward the river. A perched groundwater condition occurs above the clayey-silt layer during seasonal wet periods. A seep occurs where the clayey-silt layer intersects the ground surface near the base of the slag pile. Analysis of the seep-water samples demonstrate that the seep water meets EPA drinking water criteria for gross alpha and gross beta activity and is indistinguishable from the background water quality in the Schuylkill River. The results of the seep and Schuylkill River sampling are shown below in comparison to EPA drinking water standards.

ANALYTICAL PARAMETER	SEEP SAMPLES AVERAGE	SCHUYLKILL RIVER SAMPLES AVERAGE	EPA DRINKING WATER STANDARDS (10 CFR 40)
GROSS ALPHA (pCi/L) (Table 3-1)	1.6	Not Applicable	15.0 Excluding Rn and U $Ra^{226} < 5.0$
GROSS BETA (pCi/L) (Table 3-1)	9.8	Not Applicable	50.0 Screening level
TOTAL GROSS U^{234}, U^{238}, Th^{228}, U^{232} By Gamma Spectroscopy (pCi/L) (NES, 1996)	2.47	2.27	Not Applicable

Because the seep water from the slag pile is not contaminated, the deeper regional groundwater aquifer is not expected to be contaminated. To confirm this conclusion, groundwater samples were collected from wells installed in the River Road ROW directly downgradient from the Site. Those samples were analyzed for gross alpha activity, gross beta activity, and alpha spectroscopy for uranium and thorium. Results of that sampling and analysis indicate that the groundwater quality meets the National Primary Drinking Water Standards for radionuclides. Those results are summarized and compared to the individual standards in Table 1-1. The details of the groundwater sampling effort will be submitted separately as an addendum to the Hydrologic and Geologic Assessment report (STEP, 1997)

These results confirm the leach rate calculations indicating that the leach rate of radionuclides from the slag is negligible. Based on measured values, concentrations of radionuclides in leachate from the slag pile are below EPA drinking water standards and are indistinguishable from Schuylkill River background water quality. The groundwater directly downgradient of the slag pile is not contaminated.

It should also be noted that groundwater in the vicinity of the Site is not used as a source for drinking water or industrial process water. The Schuylkill River is the lowest elevation topographic and hydrologic feature in the vicinity of the Site. Based on USGS stream gauge data, the Schuylkill River is a gaining stream (flow volume increases downstream due to groundwater discharge) as is typical for this climatic region. In the absence of significant withdrawals of groundwater from wells, the natural direction of groundwater flow will be toward the river. A different direction of groundwater flow would likely occur only in the vicinity of high-capacity pumping wells. Local public water supplies are derived from surface water sources (Reading Water Bureau, 1998) and there are no known or suspected industrial wells in the vicinity of the Site. Therefore, the Schuylkill River is the hydraulic base level for the area, and all local groundwater gradients are toward the river.

The previous site characterization effort identified a clayey-silt layer below the non-radiological slag and occasional seepage of water at a location near the base of the slope. That location is shown in Figure 1-5. Water was encountered in borings 1, 3, 4 and 5 within a few feet of the top of the clayey-silt layer at an average elevation of 231 feet MSL. In other borings, water was not encountered or was encountered at lower elevations coincident with the top of bedrock. The deeper water levels (borings 12, 13, 14, and 16) represent the permanent regional groundwater table with a gradient toward the Schuylkill River as shown in cross section AA' (Figure 1-6).

Based on the following considerations the groundwater beneath the Site is not likely to be utilized in the future:

- The Reading area currently obtains its public water supply from Lake Ontelaunee, (an impoundment on Maiden Creek, a tributary to the Schuylkill River). The lake is located approximately 8 miles upstream of the Site. The Schuylkill River and its tributaries will be able to support any conceivable future needs for the area.

- Communications with the City of Reading indicate that the City will require future development at the industrial property to connect to the City's public water supply system.

- The quality and quantity of groundwater available within an urban setting, such as Reading is limited. It is not likely that groundwater sources would be utilized in the future with an ample supply of high quality surface water available.

- The area between the Site and the Schuylkill River has been and is expected to continue to be utilized as a transportation corridor. Transportation uses preclude the development of groundwater supply in this area.

In conclusion, there are no completed groundwater pathways and there is no groundwater contamination associated with the Site.

1.3.7 Slag Pile Stability

In the previously submitted Characterization Report (NES, 1996), the slope of the slag pile was visually estimated to be approximately 60 degrees to 70 degrees from the horizontal. Based on that estimate, the NRC requested additional information regarding slope stability. In response to the NRC request, a Pennsylvania Licensed Professional Land Surveyor was contracted to perform a topographic survey of the embankment containing the slag pile. The results of that survey are shown on Figure 1-3. The elevation of the ground surface is depicted as topographic contour lines on the scaled Site map. The survey information was used to calculate the actual slope of the embankment containing the slag pile. As discussed in Section 1.3.1 and shown on Figure 1-3, the slope of the embankment averages slightly less than 30° from the horizontal. Slopes are sometimes also expressed as the ratio of the horizontal (run) to the vertical (rise). Using that method, the 30° slope of the slag pile is equivalent to a 2 to 1 slope.

The 30° slope is less than the typical slope of stable slag piles throughout Pennsylvania. However, to fully respond to the NRC request, a Pennsylvania geotechnical engineering firm (GeoSystems) was contracted to evaluate the stability of the slag pile using standard geotechnical engineering practices. GeoSystems utilized the Site characterization information (surveyed slope, boring log descriptions, and standard penetration test results) as input to the XSTABL computer model (a modified version of the program PCSTABL developed by Purdue University). The model calculates a Factor of Safety for all possible slope failure geometries and reports the minimum Factor of Safety identified. A Factor of Safety greater than 1.0 indicates a stable slope while a value of less than 1.0 represents an unstable slope. The minimum Factor of Safety identified for the Reading slag pile Site was 1.16. Based on the model results and the observations that the slope has been stable for the approximately 30 years since material was placed, GeoSystems concluded that the slope was stable. The complete geotechnical analysis is contained in Appendix A.

As observed during the field reconnaissance performed in August 1997, the slope is covered with heavy vegetation including substantial size trees. There is no evidence of large-scale erosion of the slag pile. It is important to note that since placement of the slag the lower portions of the Site experienced the flood of 1972. The slope containing the slag remained stable even under that extreme condition.

1.3.8 Slag Pile Volume

The topographic survey information was used to refine the estimated volume of radiological slag and slag mixed with soil and debris at the Site. The approximate extent of slag based on the NES Characterization Report information and the conceptual model presented within this report is shown in cross section Figure 1-6. To estimate the volume of slag, the cross sectional area of the slag shown in Figure 1-6 was calculated (approximately 1,125 ft^2) and multiplied by the approximate length of the slag pile reported in the NES Characterization Report (160 ft), resulting in a volume of approximately 180,000 ft^3. This is larger than the estimated volume of approximately 60,000 ft^3 presented in the Characterization Report (NES, 1996). The difference in calculated volume is due primarily to the use of an estimated slope in the 1996 report. Visual estimates of slope are commonly exaggerated by a factor of two or more due to human perceptions associated with slopes. The current estimate of 180,000 ft^3 represents the volume where radiological slag or radiological slag mixed with non-radiological materials (soil and debris) is likely to occur.

1.4 PREVIOUS DECOMMISSIONING ACTIVITIES

Decommissioning of the buildings and surrounding areas of the industrial property were conducted in January 1995. The details of that decommissioning are contained in the Final Decommissioning Project Report for the Main Processing Building and Surrounding area, Reading, Pennsylvania (NES, 1995). That decommissioning resulted in the unrestricted release of the entire industrial property with the exception of the slag pile which was not part of that effort.

1.5 SUMMARY OF CURRENT RADIOLOGICAL CONDITIONS

1.5.1 Summary of Site Characterization Results

The nature and extent of the slag pile have been characterized by borings, radiological analysis of surface and subsurface soil samples, radiological analysis of groundwater samples, surface gamma measurements, characterization of the Site topography, climate, physiography, geology, hydrogeology, and surface water hydrology, measurement of the leach rate of uranium from the slag, determination of the leach rates of thorium and radium, and evaluation of the weathering rate. Details of the procedures and results can be found in the Leaching Analysis for Uranium and Thorium for the Reading Slag Pile (ERM, 1996) and the Hydrologic and Geologic Assessment for the Reading, Pennsylvania Slag Pile Site (STEP, 1997). The characterization effort also included sampling and analysis of seep samples collected at the base of the slag slope.

Slag Pile Characterization

Figure 1-2, 1-3 and 1-5 show the areal extent of the slag pile in plan view. The locations of borings, surface soil samples, seep samples, sediment samples, and direct gamma measurements are shown on Figure 1-5. Analyses of surface soil samples and samples collected from the borings, indicate that the average activity in the radiological slag /debris/soil mixture is 45 pCi/g thorium-232 and associated progeny and 30 pCi/g uranium-238 and associated progeny. Analyses of samples collected from the borings along the top edge of the embankment indicate that the radiological slag extends vertically to a maximum depth of approximately 20 to 22 feet. The lateral extent of the slag to the northeast was demonstrated to be less than 15 feet from the edge of the embankment (NES, 1996)

Leach Rate of Radionuclides From Slag

Because the slag is unweathered, it's elemental constituents (including uranium and other radionuclides) are locked in the silicate matrix and are not available to the environment.

A readily available uranium (RAU) leach test was run on a representative sample of radiological slag as part of the Site Characterization program (NES, 1996). The RAU test is an aggressive leach test which involves grinding up the sample and using an acidic leach solution. Environment Resources Management, Inc. (ERM) developed a methodology for calculating the leach rate of uranium and thorium from the slag based on the RAU results (ERM, 1996). Using published values for the relative distribution coefficients (K_d) for uranium and thorium, ERM determined that the thorium will leach at a much lower rate than uranium. The ERM methodology was approved by the NRC for use in radiological dose assessment calculations (NRC, 1996).

The NRC requested that any radiological dose assessment take into account the leach rates of other important radionuclides from the slag (NRC, March, 1997). Preliminary RESRAD modeling results indicated that other than uranium and thorium only radium isotopes contribute significantly to the total radiological dose. A geochemical consulting firm (GCX, Inc.) was requested to provide an assessment of the relative leach rates of other important radionuclides for the Reading and Revere slag (Appendix B). Based on GCX's assessment, radium would be expected to leach at a slower rate than uranium. The use of the measured uranium leach rate for the calculated leach rate of radium and thorium for the Radiological Assessment, conservatively overestimates the calculated dose.

Weathering Rate of Slag

As stated by ERM, the weathering of the slag is expected to be very slow and would not result in appreciable development of soil within the 1,000 year period of analysis (ERM, 1996). GCX, Inc. has independently evaluated the expected weathering rate of the slag (Appendix B). GCX's conclusions are consistent with ERM's conclusions.

Potential Future Uses of Site

Based on review of Sanborne maps, the property containing the Site has been used for industrial purposes for at least 94 years. The current zoning designation for the property is HM (Heavy Manufacturing). Based on newspaper articles over the past year, the Reading Redevelopment Authority is interested in redeveloping the property for industrial or commercial use. The City of Reading and Berks County are in the process of designating the area containing the Site as a new urban development area. As part of that process, a Redevelopment Proposal was made public on August 11, 1998. That proposal shows that the area containing the Site will be designated for industrial/commercial and related uses.

Ground surface elevation data from the 1904 Sanborne map showed an approximately uniform slope from the Schuylkill Canal to Tulpehocken Street. Over the past 94 years, fill, consisting of slag and other materials, has been used to improve the topographic profile of the industrial property. The improvements have created a large level area extending from Tulpehocken Street to near the southwestern property boundary. As shown in cross section BB' (Figure 1-7), the current profile provides the maximum area of level ground suitable for industrial use within the property boundaries. The following features of the current configuration represent the optimal profile for industrial use.

- The maximum possible area of continuous level ground is available for buildings or parking areas

- The Site has good drainage

- The continuous level area is above the maximum reported flood level

- There is at-grade access to Tulpehocken Street, Buttonwood Street, and the railroad tracks on the northern property boundary

In summary, incremental modifications to grade over approximately 100 years have resulted in the current optimum profile that is not likely to be modified in the future.

The physical characteristics and location of the Site limit the types of future uses and potential exposure scenarios that could reasonably occur. The location of the slag is limited to within 15 feet of the edge of an embankment. This precludes the construction of a basement within the slag. It is not likely that a building will be built closer than 15 feet to the edge of the embankment because there would not be sufficient room for routine maintenance activities or for typically desired landscaping. In addition, structures are not typically sited closer than 15 feet from a 30 ° slope. Even if a building was constructed less than 15 feet from the embankment, only a small fraction of the basement could be within the slag material. For similar considerations construction is not expected on the actual slope.

Extensive regrading of the industrial property is not likely because the topography is currently in the optimum configuration. If large scale regrading of the property were to occur the minor portion of radiological slag would be mixed with the much larger volume of non-radiological slag and fill materials resulting in a lowering of the average activity and reducing the potential dose. In addition, the radiological slag is located along the top edge and the face of the embankment; it would likely be pushed down the slope at the start of any regrading activities and eventually be buried under non-radiological fill. Because of the shallow groundwater level and potential for flooding near the river, the construction of buildings are precluded at the lower elevation where the slag would likely reside following any grading activities.

The urban setting effectively precludes the use of the Site by a farmer (resident or otherwise). The fill material consisting of building debris and various types of slag is not suited for growing crops. In addition, eastern Pennsylvania has ample acreage of productive farmland on gentle slopes. Steep slopes in urban settings are not used for agriculture in Pennsylvania. Available information indicates that the property has been utilized for industrial and commercial activities for at least 100 years. There is no known historical use of the property for farming.

Currently there is no groundwater use between the Site and the Schuylkill River and none would be expected in the future. The intervening property is currently used for a railroad ROW, and would likely remain as a transportation corridor along the Schuylkill River in the future. Such uses preclude the installation of a water supply well. Future use of the groundwater near the Site or anywhere within the City of Reading is not anticipated. The City currently receives its water from an upstream surface water impoundment. The City will require future development of the industrial property to connect to the City's public water supply system.

Groundwater quality in urban environments is typically poor due to exfiltration from sewer lines, industrial compounds, salt used to clear snow from the streets, and a lack of natural soil horizons to filter infiltrating water. The quantity of groundwater in urban environments is also limited due to the large percentage of impervious surfaces that reduce the infiltration rate. Because surface water is readily available, and groundwater quality and quantity are limited, it is highly unlikely that groundwater between the Site and the Schuylkill River will be used for a water supply in the future.

Continued industrial use or new commercial or industrial redevelopment around the Site is the most likely future use scenario. There is no reasonable scenario in which the Site would be used by a farmer.

The potential for the slag to be removed from the site and placed in a location that is suitable for residential development or farming uses was considered. It is unlikely that someone would go to the expense to excavate and transport slag, which is not a growing medium, to a location intended for residential or farming use. It would be necessary to cover or augment the slag with a considerable amount of topsoil before it would be suitable for a lawn or farming. Even if the onsite fill were moved to an off-site location the small percentage of radiological slag would be mixed with non-radiological slag thereby reducing the maximum possible doses.

1.5.2 Radiological Assessment

A detailed discussion of the methods and assumptions used to perform the radiological assessment can be found in the Radiological Assessment for Reading, Pennsylvania Slag pile Site (STEP, 1998). They are summarized in the following section.

The NRC radiological criteria for license termination are expressed in terms of radiation dose that might reasonably be expected from residual radioactive material after decommissioning. As used here, the term "dose" is intended to be interpreted as total effective dose equivalent (TEDE), which is the quantity expressed in the NRC regulation. At the Reading site this dose would depend upon concentrations of residual radioactive materials in soils and other remaining materials. The dose would also depend on site-specific factors that might control potential resource use, potential migration of radioactive materials, and potential access to radioactive materials. Finally, this dose would also depend on potential activities of future users of the site.

The radiation dose assessment process, as applied herein, includes the estimation of the maximum radiation dose (TEDE) that might be received by a typical member of a small group of people that could be expected to receive the highest doses from use of the site as far as 1,000 years into the future, as required in the radiological criteria for license termination. Thus, the assessment considers not only the expected conditions at the site, soon after remediation, but conditions projected for the distant future, as well. The assessment evaluates potential uses of the site and potential migration of radioactive materials through the environment over time, taking account of both natural processes and human activities that could be expected to alter the patterns or rates of constituent movement. In general, the dose assessment process consists of two steps: 1) development of representations of site physical conditions and potentially exposed populations, and expression of these representations in mathematical terms; and 2) use of a mathematical model with input from the representations and/or technical literature to estimate future exposures and radiation doses (TEDE) as a function of time. The dual objective in the development of simplified representations is that the representations be realistic and not result in underestimation of exposures and doses.

Site characterization information was used to develop input parameters for modeling of maximum radiation doses that might result from unrestricted use of the Site. Two basic exposure scenarios were analyzed. The first of these was a trespasser who walks on the Site, and the second a worker on the Site. Radionuclide concentrations in surface soils on the slope of the pile are likely to be significantly lower than concentrations in deeper soils on the slope. The radiation dose that might be received by a person using the Site depends strongly on the radionuclide concentrations in soils near the surface. For this reason, two variations of each of the two basic scenarios were analyzed. In the first, the trespasser or worker was assumed to be exposed to concentrations representative of current conditions. In the second, the trespasser or worker was assumed to be exposed to soils bearing radionuclides expected to be more typical of deeper soils on the slope. This variant can be considered to be conservatively representative of future conditions at the Site, after some erosion has occurred. However, as noted in Section 1.3.7, the slope is stable and has not experienced apparent erosion in the 30 years since placement of the slag. Therefore, this scenario is not likely to occur. Detailed descriptions of the modeling input parameters and results are contained in the Radiological Assessment. Modeling assumptions are summarized in Table 1-2 and results are summarized in Table 1-3.

Results from the analysis show that the maximum radiation dose that might be expected from unrestricted use of the Site is far below the 10 CFR Part 20 limit of 25 millirem per year (TEDE) for release with unrestricted use. Specifically, the maximum dose (TEDE) calculated for the trespasser under current conditions is 1.8 mrem/y. Under eroded slope conditions, the trespasser would receive a maximum dose (TEDE) of 5.3 mrem/y. A worker spending 10% of his work time in the radiological area under current conditions would receive a maximum dose (TEDE) of 1.6 mrem/y. The maximum dose (TEDE) calculated for the worker with eroded slope conditions is 2.6 mrem/y. The maximum dose

(TEDE) calculated for all of these scenarios is 5.3 mrem/y, substantially less than the 10 CFR Part 20 limit of 25 mrem/y.

The doses calculated as described above represent the maximum likely doses that might result from unrestricted use of the site. For purposes of sensitivity analyses, extremely unlikely scenarios that represent bounding exposure conditions were also analyzed. The results of these analyses were also lower than the 10 CFR 20 Subpart E criteria for unrestricted release. Details of those analyses are contained in Appendix B of the Radiological Assessment.

An analysis to demonstrate that maximum doses from unrestricted release of the Site would be as low as reasonably achievable (ALARA), is also included in the Radiological Assessment. The conclusion from this analysis is that release without restrictions meets ALARA criteria.

In summary, the potential doses for the current conditions and any reasonable future conditions involving unrestricted use are all well below the 25 mrem/y criteria for unrestricted release and unrestricted release is ALARA. As a result no decommissioning activities are required.

TABLE 1-1
SUMMARY OF GROUNDWATER ANALYTICAL RESULTS

SAMPLE ID FILTERED	PZ-1A YES	PZ1-B NO	PZ-2A YES	PZ-2B NO	PZ-3A YES	PZ-3B NO	STANDARD
GROSS ALPHA	< 6.0	< 6.0	< 8.0	< 8.0	< 7.0	< 7.0	15 (a)
GROSS BETA (-K-40)	< 8.0	< 8.0	< 9.0	< 9.0	< 9.0	< 9.0	50 (b)
THORIUM-228	1.1	< 0.7	0.86	1.3	0.9	0.99	15 (a)
SIGMA (+/-)	0.5	--	0.52	0.7	0.52	0.53	-
THORIUM-230	< 0.1	< 0.2	< 0.2	< 0.2	< 0.2	< 0.3	15 (a)
SIGMA (+/-)	--	--	--	--	--	--	-
THORIUM-232	< 0.1	< 0.2	< 0.2	< 0.2	< 0.1	< 0.2	15 (a)
SIGMA (+/-)	--	--	--	--	--	--	-
URANIUM-233/234	1.3	0.68	3.8	5.1	1.2	2	-
SIGMA (+/-)	0.4	0.27	0.7	0.9	0.4	0.5	N/A
URANIUM-235	< 0.1	< 0.1	0.18	< 0.2	< 0.1	< 0.09	-
SIGMA (+/-)	--	--	0.16	--	--	--	-
URANIUM-238	1.0	1.1	4.1	4.9	1.3	1.5	-
SIGMA (+/-)	0.3	0.3	0.8	0.8	0.4	0.4	-

NOTES: All results in pCi/l
Sigma = 2 Standard Deviations (95% Confidence Interval)
(a) Adjusted gross alpha - screening level (= gross alpha minus radium 226 and uranium)
(b) Gross beta screening level
All standards are from: 56 FR 138, National Primary Drinking Water Regulations; Radionuclides; Proposed Rule

TABLE 1-2
SCENARIO PATHWAYS AND KEY PARAMETER VALUES

PATHWAY ASSUMPTIONS	SCENARIO TC Trespasser--current conditions	 WC Worker--current conditions	 TF Trespasser--future conditions	 WF Worker--future conditions
General Description	Trespasser walks on slope in current condition 3 h/wk, 6 mo/y	Worker works on radiological area 10% of his work time, 200 h/y, of which 20 h/y is walking on slope in current condition, 180 h/y is in building with 6" concrete floor on top of pile.	Trespasser walks on slope in eroded condition 3 h/wk, 6 mo/y	Worker works on radiological area 10% of his work time, 200 h/y, of which 20 h/y is walking on slope in eroded condition, 180 h/y is in building with 6" concrete floor on top of pile.
Water-independent pathways				
External	Yes	Yes	Yes	Yes
Indoor exposure time (h/y)	NA	180 (top)	NA	180 (top)
Structural shielding factor	NA	0.19	NA	0.19
Outdoor exposure time (h/y)	72 (slope)	20 (slope)	72 (slope)	20 (slope)
Inhalation (dust)	Yes	Yes	Yes	Yes
Indoor exposure time (h/y)	NA	180 (top)	NA	180 (top)
Structural shielding factor	NA	0.5	NA	0.5
Outdoor exposure time (h/y)	72 (slope)	20 (slope)	72 (slope)	20 (slope)
Inhalation rate (m3/y)	1.22E+04	1.22E+04	1.22E+04	1.22E+04
Mass loading (g/m3)	2.00E-04	2.00E-04	2.00E-04	2.00E-04
Inhalation (radon)	NA	NA	NA	NA
Ingestion of vegetables	NA	NA	NA	NA
Ingestion of meat	NA	NA	NA	NA
Ingestion of milk	NA	NA	NA	NA
Ingestion of soil	Yes	Yes	Yes	Yes
Outdoor exposure time (h/y)	72 (slope)	20 (slope)	72 (slope)	20 (slope)
Soil ingestion rate (g/y)	36.5	36.5	36.5	36.5
Water-dependent pathways				
Ingestion of water	NA	NA	NA	NA
Ingestion of aquatic food	NA	NA	NA	NA
Ingestion of vegetables (irrigated)	NA	NA	NA	NA
Ingestion of meat (irrigated)	NA	NA	NA	NA
Ingestion of milk (irrigated)	NA	NA	NA	NA
Inhalation (radon from water)	NA	NA	NA	NA

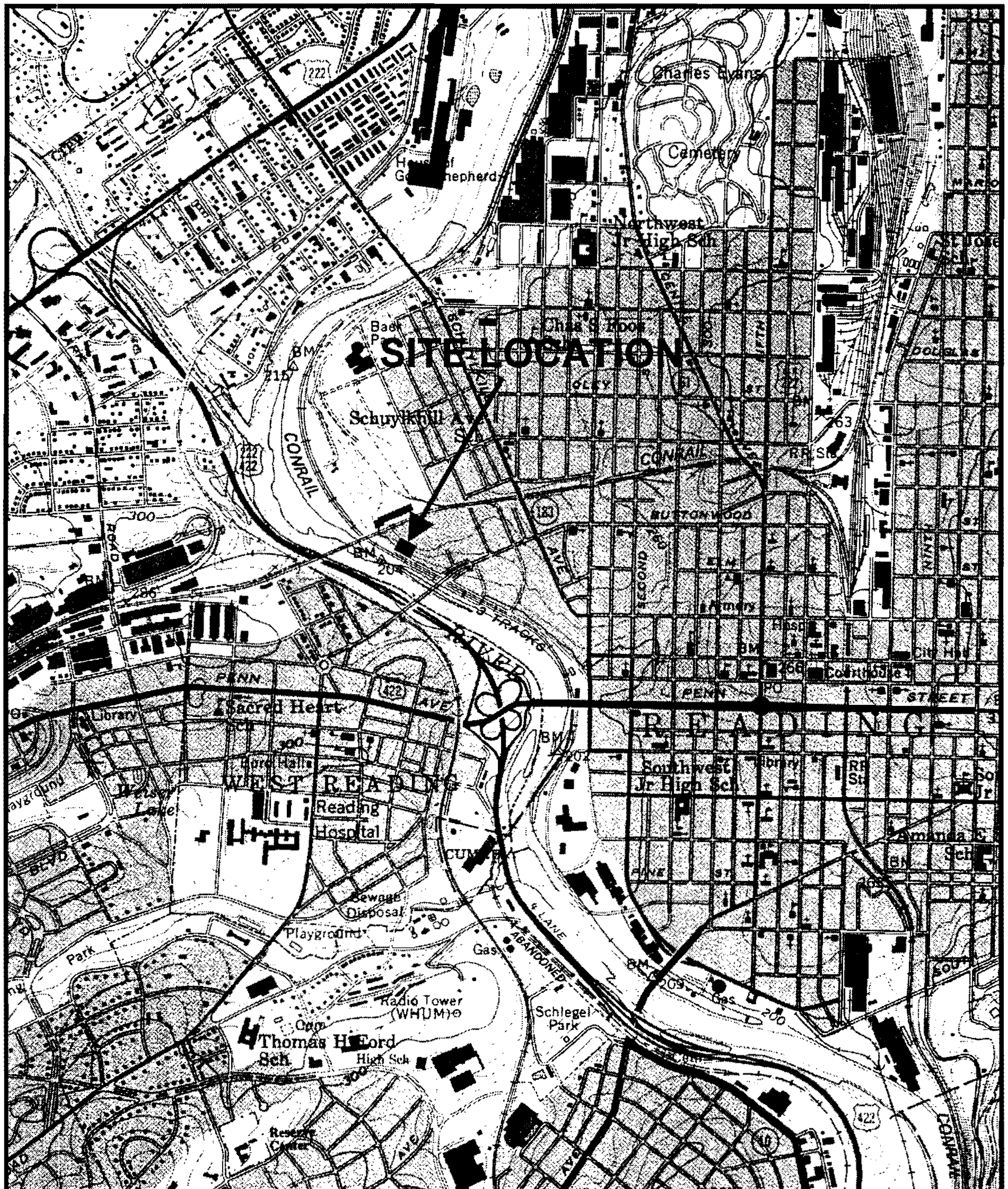
NOTES: All Scenarios - Concentration on top of pile = 25pCi/g total uranium and thorium
Curren tScenario - Concentration on slope = 25pCi/g total uranium and thorium
Future Scenario - Concentration on slope = 75pCi/g total uranium and thorium

TABLE 1-3
RESULTS SUMMARY

UNIT	MAXIMUM ANNUAL DOSE mrem/y			
	CASE TC Trespasser Current Conditions	CASE WC Worker Current Conditions	CASE TE Trespasser Eroded Conditions	CASE WE Worker Eroded Conditions
Slope--ground	1.376	0.383	4.128	1.148
Slope--inhalation	0.349	0.097	1.047	0.291
Slope--soil ingestion	0.026	0.007	0.077	0.021
Top--ground		0.654		0.654
Top--inhalation		0.436		0.436
Top--soil ingestions		0.064		0.064
Total TEDE	1.8	1.6	5.3	2.6

Ground dose is deep dose equivalent, inhalation and soil ingestion doses are CEDE, total is TEDE.

The 10 CFR Part 20 dose criterion for license termination with no restrictions on use is 25 mrem/y TEDE.



SCALE FEET

0 2,000 4,000

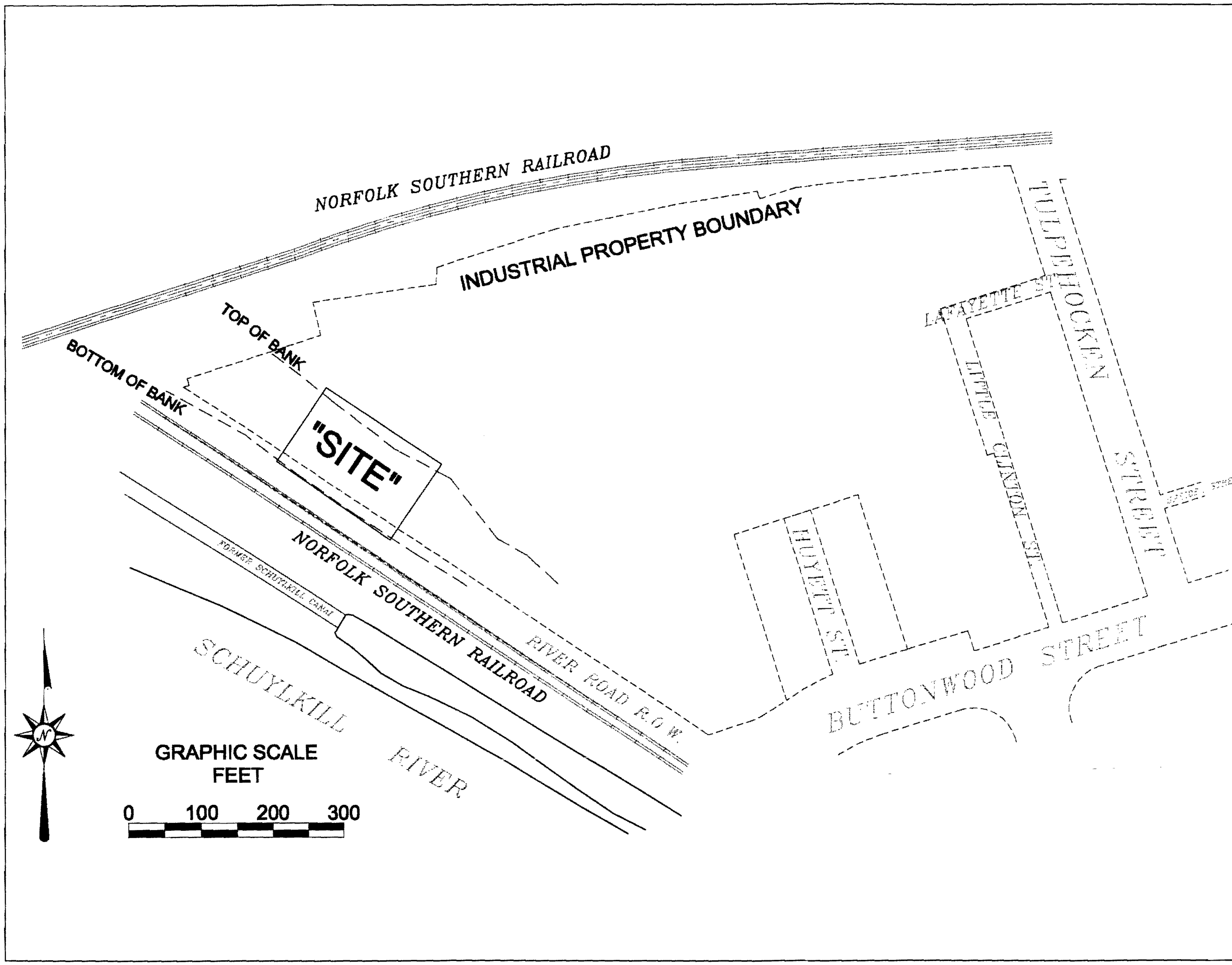
NORTH

SOURCE: USGS, Reading, PA, 7.5 Minute Quadrangle

FIGURE 1-1
Site Location Map

READING SLAG PILE SITE

ST Environmental Professionals, Inc.
STEP Project Number 97C057
August 28, 1998



LEGEND

SITE BOUNDARY

INDUSTRIAL PROPERTY BOUNDARY

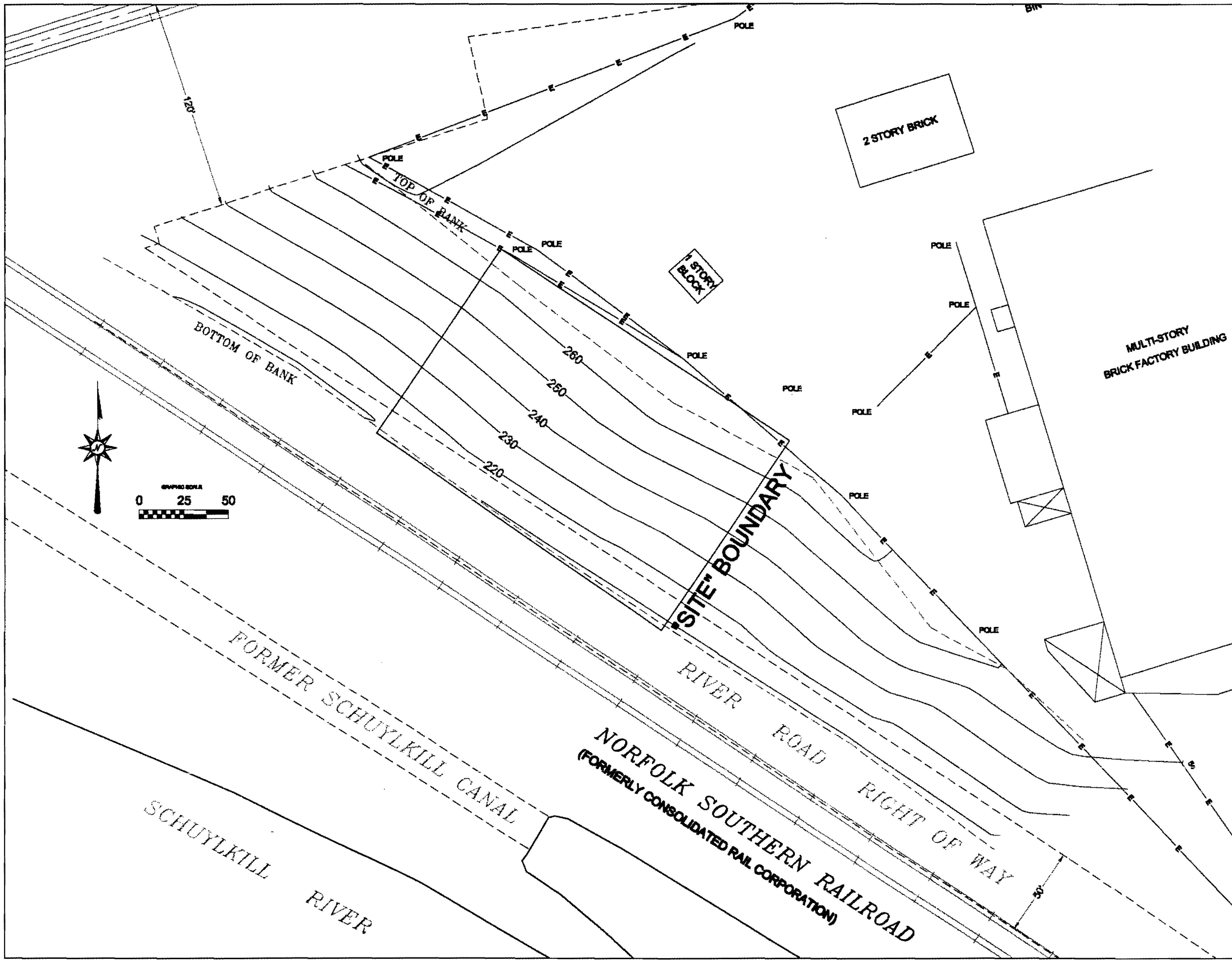
TOP AND BOTTOM LIMITS OF EMBANKMENT

NOTE: The base map (including property boundaries, buildings, rights of way, elevation contours, electric lines and utility poles) is to scale. It was prepared in accordance with the minimum standards for Boundary Surveys section of the Manual of Practice for Professional Land Surveyors in the Commonwealth of Pennsylvania. The boring, gamma survey, soil sample, seep sample, sediment sample, Schuylkill River, and USGS benchmark locations are approximate. They are based on descriptions, maps, and references to landmarks contained in the Site Characterization Report for the Reading Slag Pile and The USGS Reading, Pennsylvania 71/2 minute Quadrangle.

FIGURE 1-2
SITE VICINITY MAP

Reading Slag Pile Site

ST Environmental Professionals, Inc.
August 28, 1998, Project No. 97C057



LEGEND

ELECTRIC UTILITY LINE

TOP AND BOTTOM OF EMBANKMENT

PROPERTY BOUNDARIES

220 ELEVATION CONTOUR LINE AND VALUE (Feet Above MSL)

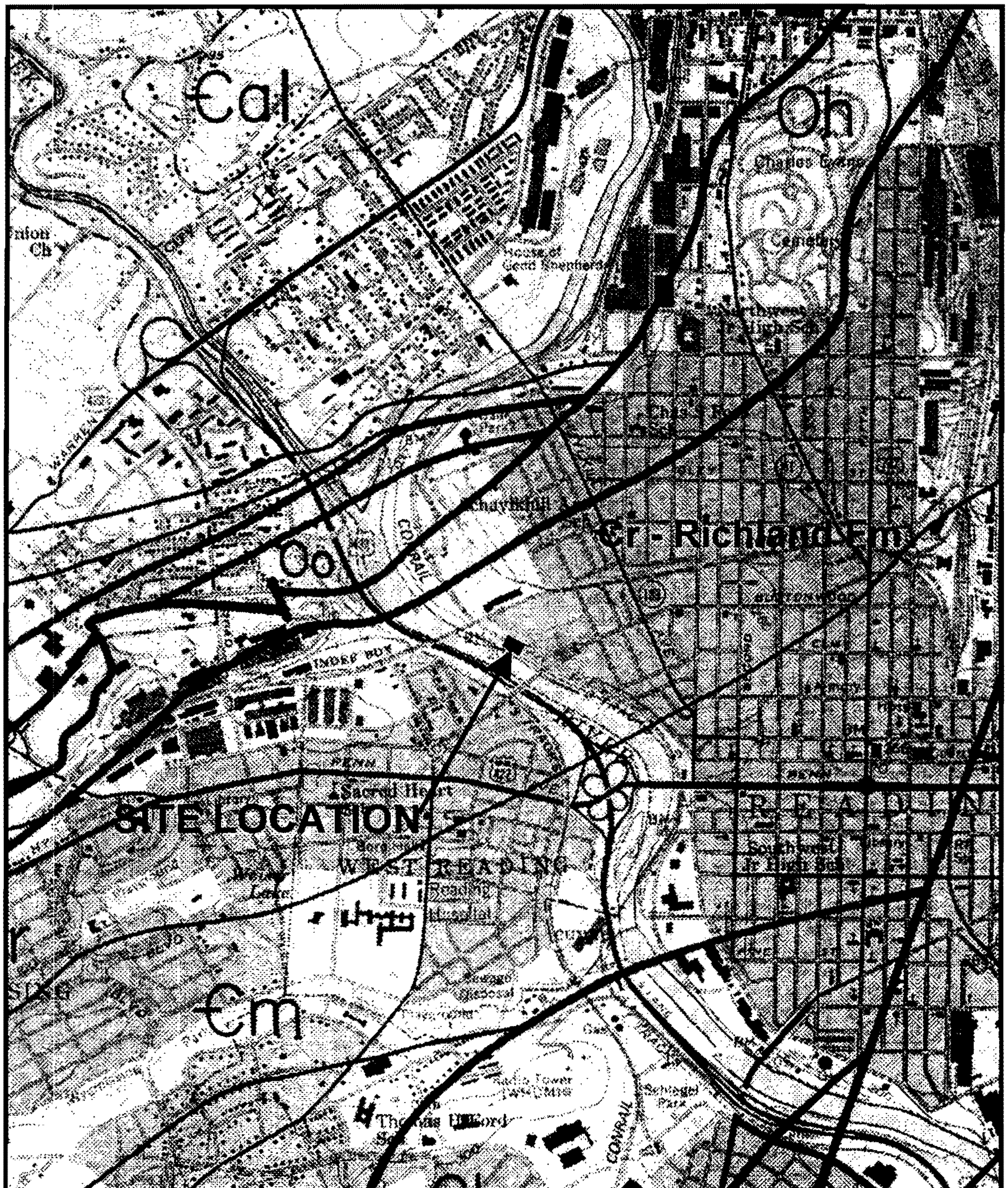
SITE BOUNDARY

NOTE: The base map (including property boundaries, buildings, rights of way, elevation contours, electric lines and utility poles) is to scale. It was prepared in accordance with the minimum standards for Boundary Surveys section of the Manual of Practice for Professional Land Surveyors in the Commonwealth of Pennsylvania. The boring, gamma survey, soil sample, seep sample, sediment sample, Schuylkill River, and USGS benchmark locations are approximate. They are based on descriptions, maps, and references to landmarks contained in the Site Characterization Report for the Reading Slag Pile and The USGS Reading, Pennsylvania 71/2 minute Quadrangle.

FIGURE 1-3
SITE MAP

Reading Slag Pile Site

ST Environmental Professionals, Inc.
August 28, 1998, Project No. 97C057



SCALE FEET

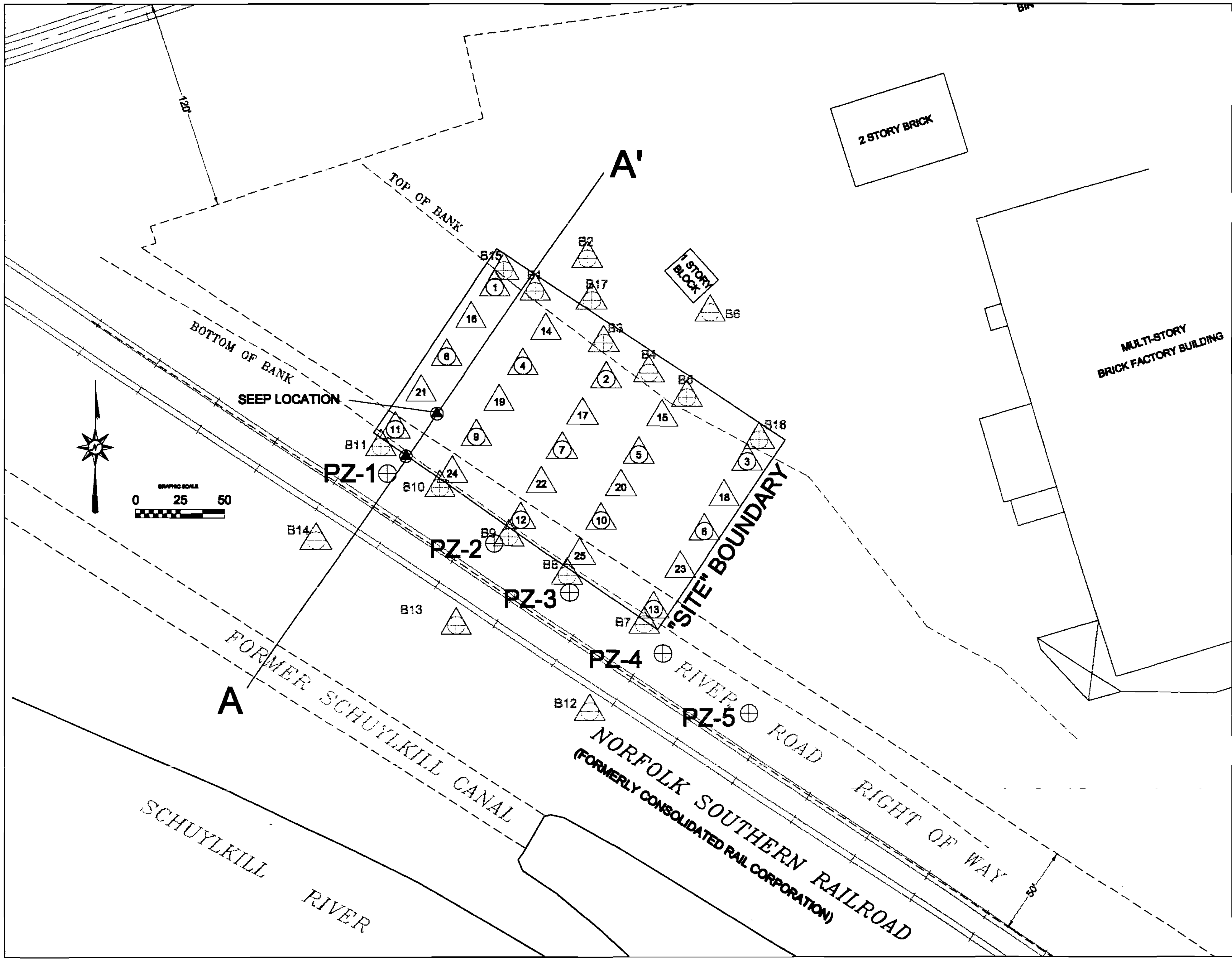
0 2,000 4,000

NORTH

FIGURE 1-4
Geologic Map
READING SLAG PILE SITE

ST Environmental Professionals, Inc.
STEP Project Number 97C057
August 28, 1998

SOURCE: Atlas of Preliminary Geologic Quadrangle Maps of Pennsylvania, Reading Quadrangle, Berg, 1981



LEGEND

B15 BORING LOCATION

SURFACE SOIL SAMPLE

MicroRem MEASUREMENT LOCATION

SEEP OR SEDIMENT SAMPLE LOCATION

A A' LOCATION OF CROSS SECTION AA'

TOP AND BOTTOM LIMITS OF EMBANKMENT

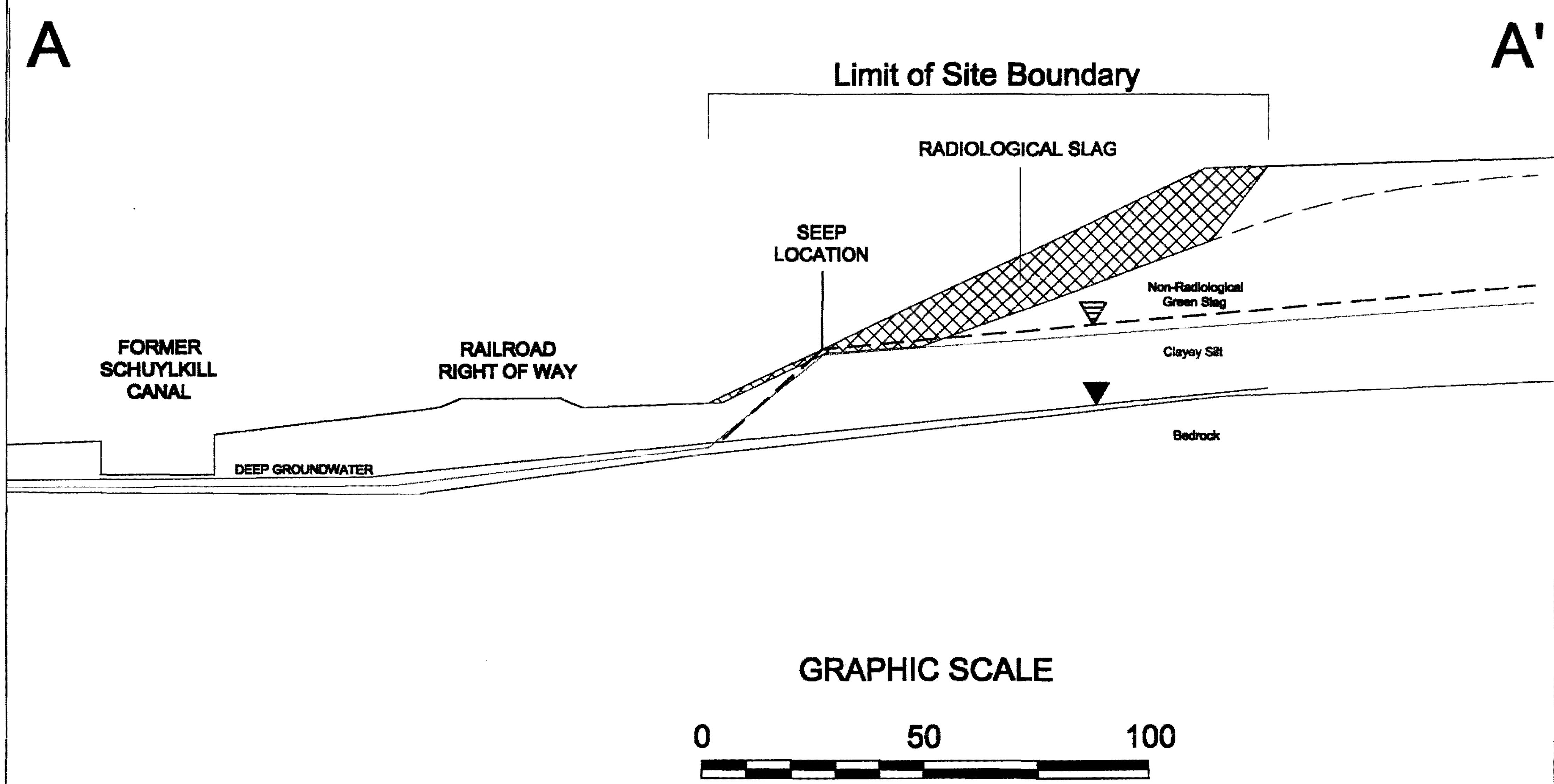
PROPERTY BOUNDARIES

NOTE: The base map (including property boundaries, buildings, rights of way, elevation contours, electric lines and utility poles) is to scale. It was prepared in accordance with the minimum standards for Boundary Surveys section of the Manual of Practice for Professional Land Surveyors in the Commonwealth of Pennsylvania. The boring, gamma survey, soil sample, seep sample, sediment sample, Schuylkill River, and USGS benchmark locations are approximate. They are based on descriptions, maps, and references to landmarks contained in the Site Characterization Report for the Reading Slag Pile and The USGS Reading, Pennsylvania 71/2 minute Quadrangle.

FIGURE 1-5 SAMPLE LOCATIONS MAP

Reading Slag Pile Site

ST Environmental Professionals, Inc.
August 28, 1998, Project No. 97C057



LEGEND

Ground Surface

Top of Clayey Silt Layer

Top of Perched Groundwater

Top of Deep Groundwater

Top of Bedrock

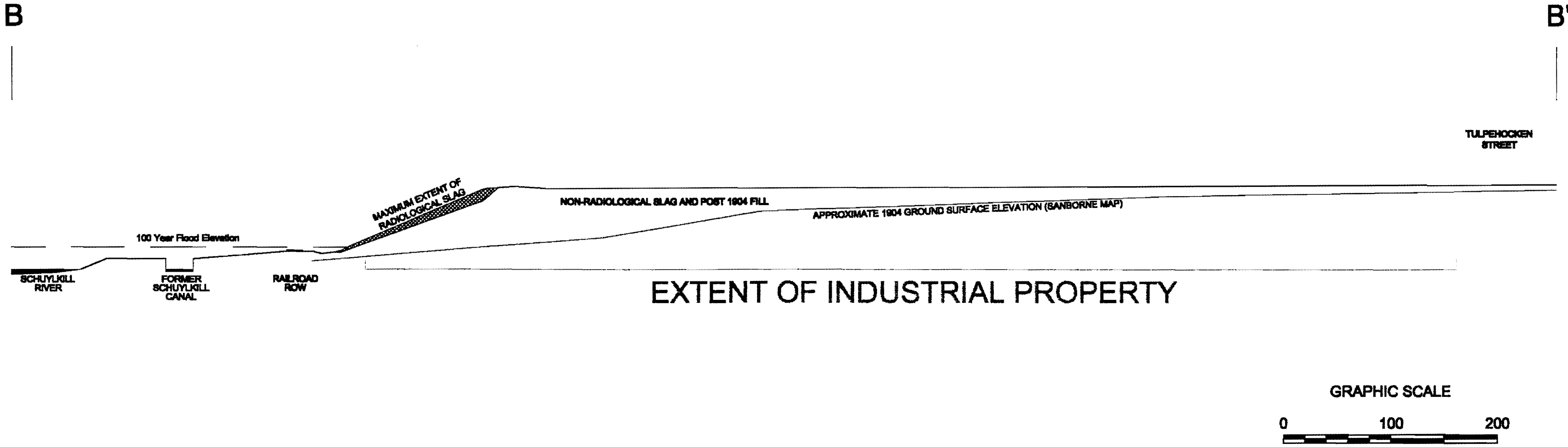
Approximate Location of Radiological Slag and Cover Soil

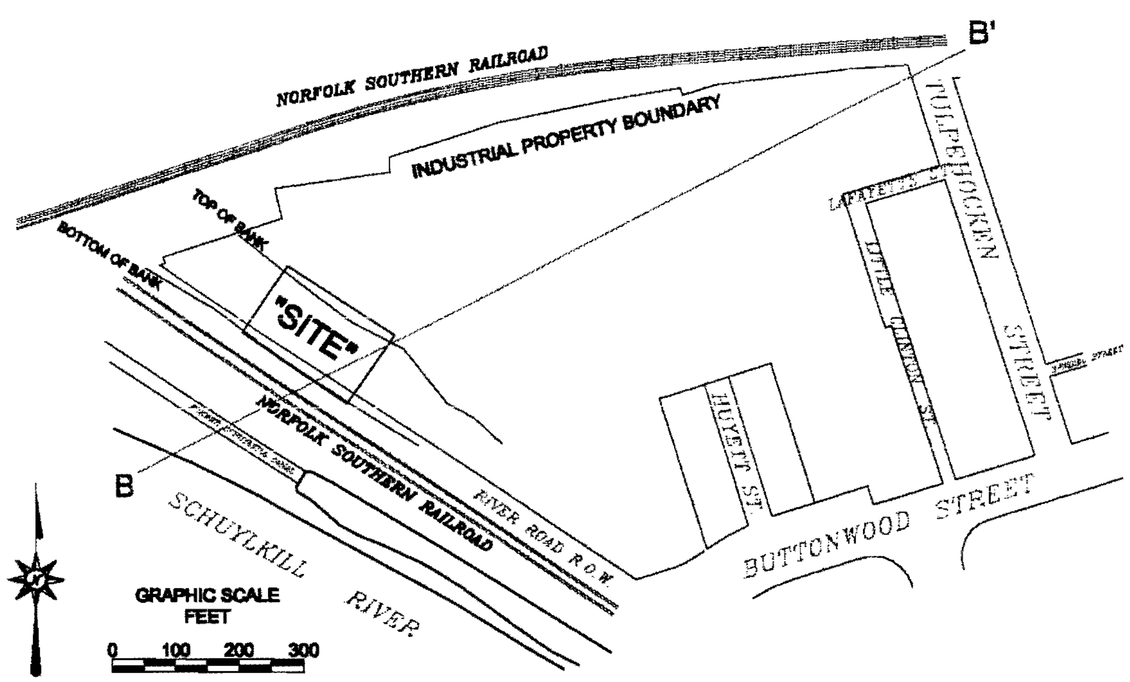
Location of cross section is shown in plan view on Figure 1-5

FIGURE 1-6 CROSS SECTION AA'

Reading Slag Pile Site

ST Environmental Professionals, Inc.
August 28, 1998, Project No. 97C057





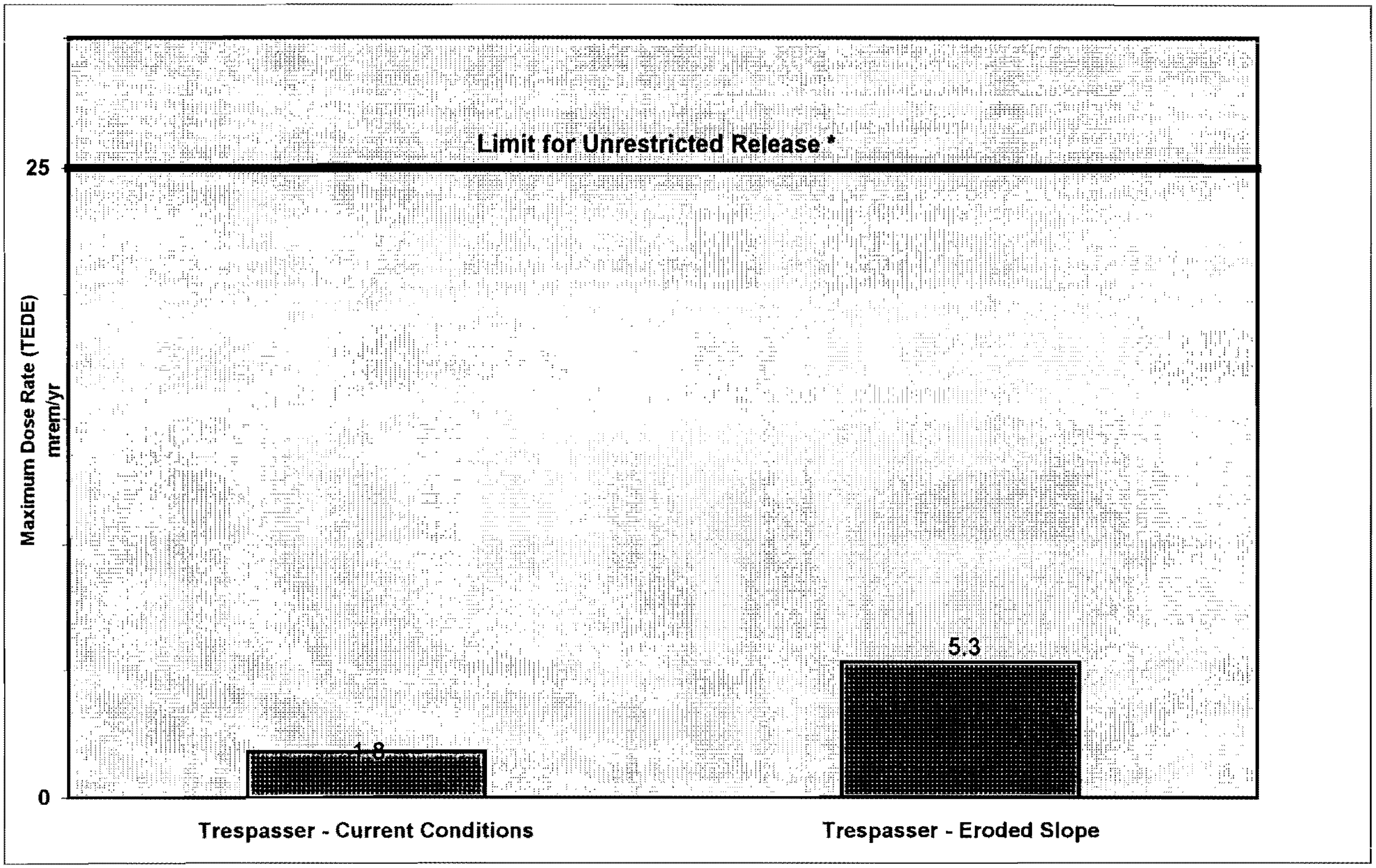
LOCATION OF CROSS SECTION BB' IN PLAN VIEW

FIGURE 1-7
CROSS SECTION BB'

Reading Slag Pile Site
Cabot Corporation

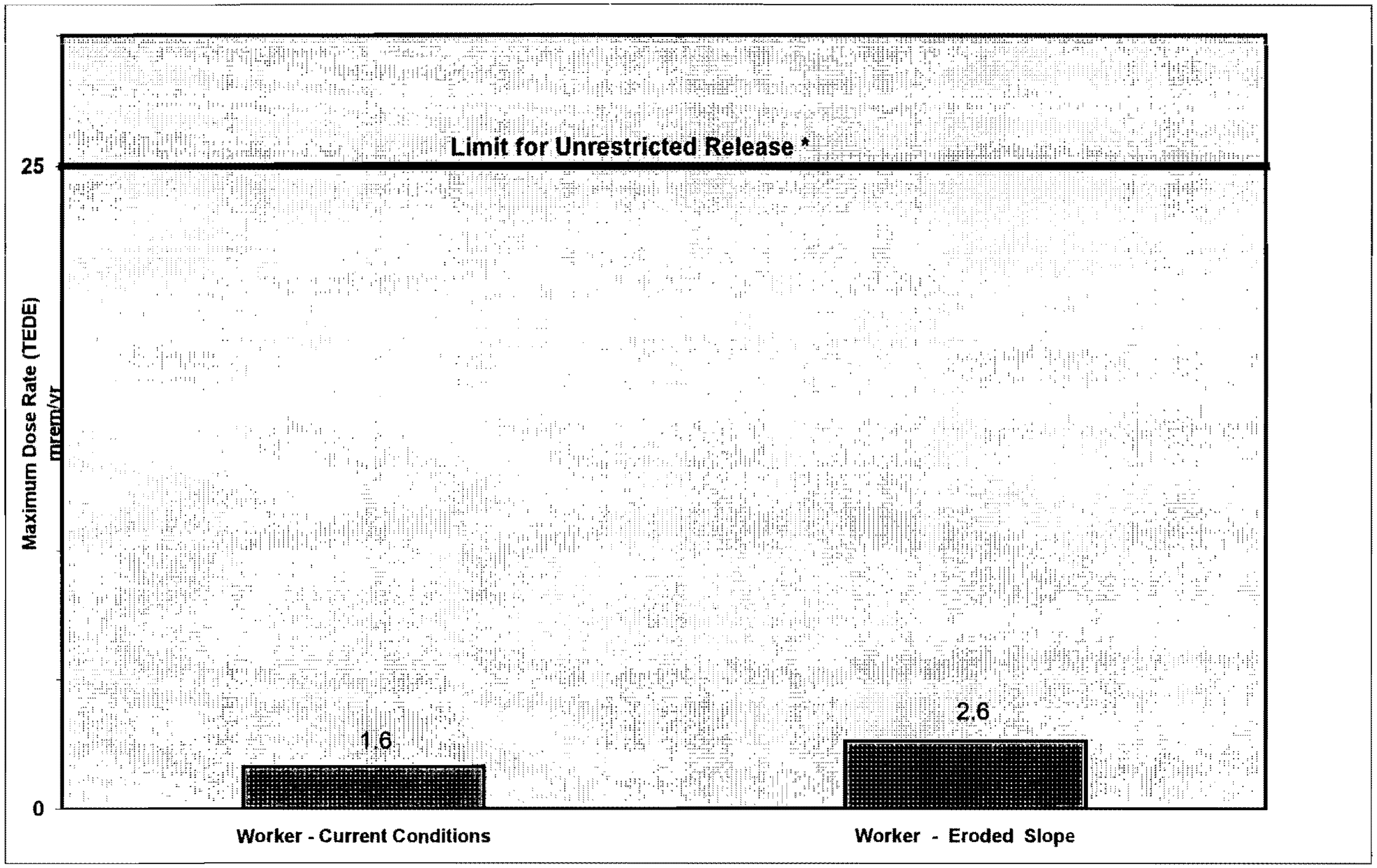
ST Environmental Professionals, Inc.
August 28, 1998, Project No. 97C057

FIGURE 1-8
MAXIMUM ANNUAL RADIATION DOSE (TEDE) RESULTS
TRESPASSER SCENARIO



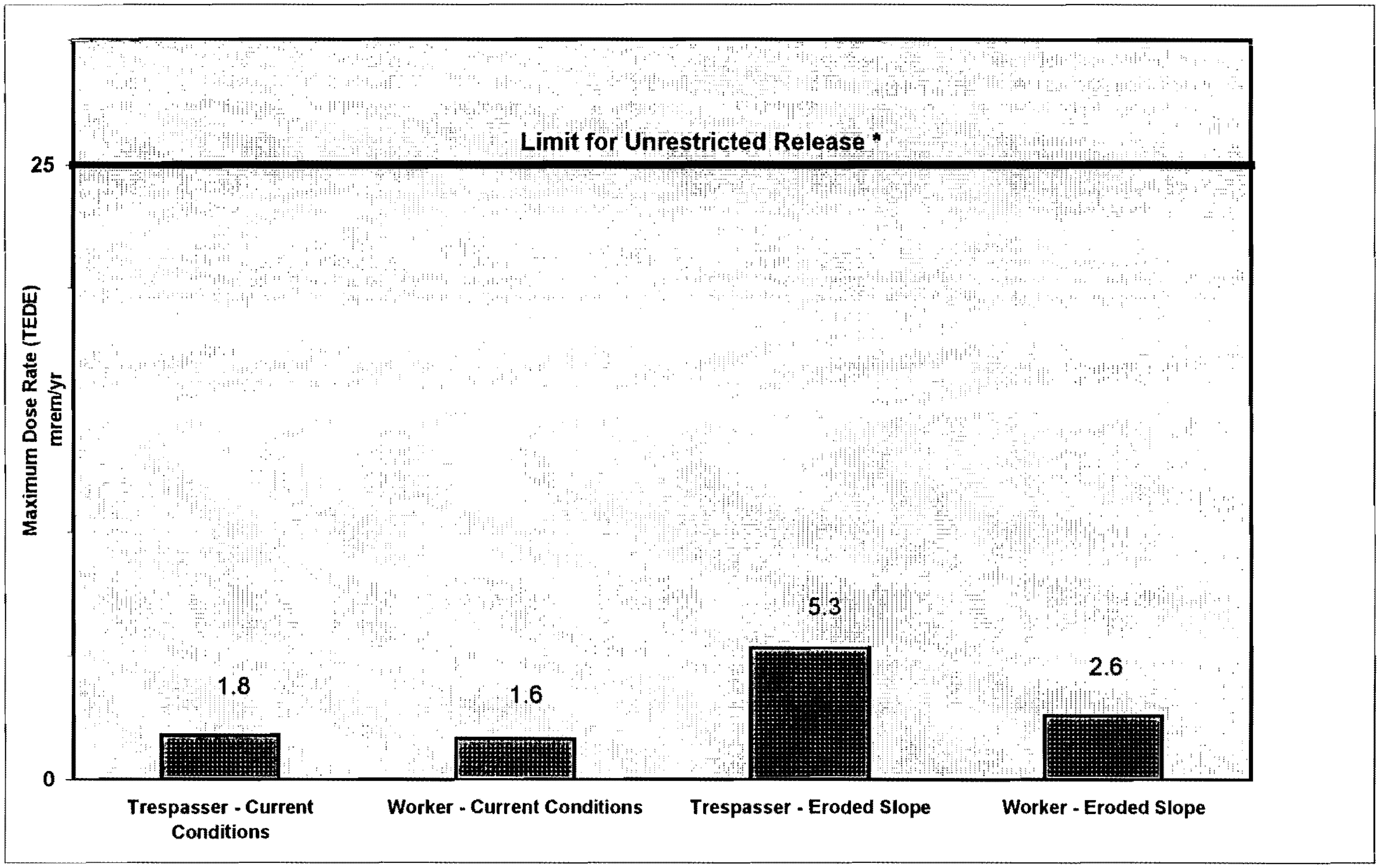
* Unrestricted Release = Less Than 25 mrem/year (10 CFR 20 Subpart E)

FIGURE 1-9
MAXIMUM ANNUAL RADIATION DOSE (TEDE) RESULTS
WORKER SCENARIO



* Unrestricted Release = Less Than 25 mrem/year (10 CFR 20 Subpart E)

FIGURE 1-10
MAXIMUM ANNUAL RADIATION DOSE (TEDE) RESULTS SUMMARY



* Unrestricted Release = Less Than 25 mrem/year (10 CFR 20 Subpart E)

2.0 PLANNED DECOMMISSIONING ACTIVITIES

The objective of the decommissioning process is to terminate the license. During the decommissioning process Cabot performed comprehensive site characterization and analysis which indicate that decommissioning actions are not required because the Site meets the NRC criteria for unrestricted release. The characterization and analytical efforts performed include:

- Surface gamma measurements
- Radiological analysis of surface and subsurface samples
- Characterization of the site topography, climate, physiography, geology, surface water hydrology, and groundwater hydrology
- Measurement of the leach rate of uranium from the slag
- Determination of the leach rates of thorium and radium
- Evaluation of the weathering rate of the slag
- Analysis of slag pile stability
- Sampling and analysis of groundwater seep samples collected from the base of the slag pile
- Performance of a Radiological Assessment
- Preparation of this Decommissioning Plan

Using the characterization information, the Radiological Assessment Report (STEP, 1998) concludes that the potential exposure levels for the current conditions and any reasonable future conditions are all well below the 25 mrem/y criteria for unrestricted release. The Radiological Assessment also concludes that release without restrictions is ALARA. As a result no decommissioning activities are required.

3.0 METHODS USED FOR PROTECTION OF OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

Because there will be no onsite decommissioning activities, and the site meets the criteria for unrestricted release, this section is not applicable.

4.0 PLANNED FINAL RADIATION SURVEY

Because there will be no onsite decommissioning activities, and the site meets the criteria for unrestricted release, this section is not applicable.

5.0 FUNDING

Because there will be no onsite decommissioning activities, and the site meets the criteria for unrestricted release, this section is not applicable.

6.0 PHYSICAL SECURITY PLAN AND MATERIAL CONTROL AND ACCOUNTING PLAN PROVISIONS IN PLACE DURING DECOMMISSIONING

Because there will be no onsite decommissioning activities, and the site meets the criteria for unrestricted release, this section is not applicable.

7.0 REFERENCES

Berg, Thomas M., Dodge, Christine M., *Atlas of Preliminary Geologic Quadrangle Maps of Pennsylvania*, 1981.

Biesecker, J. E., Lescinsky, J. B., and Wood, C. R., *Water Resources of the Schuylkill River Basin*, Commonwealth of Pennsylvania, Department of Forests and Waters, 1968.

Cabot Performance Materials USNRC License Number SMC-1562.

City of Reading, Water Bureau, *Personal Communication*, April, 1998

ERM, 1996, *Leaching analysis for Uranium and Thorium for the Reading Slag Pile*, An attachment to a letter from Anthony Campitelli (Cabot) to Judith M. Greenwald (NRC), Re: Characterization of Reading Slag Pile – Leach Rate Methodology, September 12, 1996.

Miller, R. Adam, *Hydrologic Data of the June 1972 Flood in Pennsylvania*, Commonwealth of Pennsylvania, Department of Environmental Resources, 1974

National Council on Radiation Protection, "*A Handbook of Radioactivity Measurements*;" Report No. 58.

NES, 1996, *Characterization Report for the Reading Slag Pile*, Prepared for Cabot Corporation, April 1996.

NES, 1995, *Final Decommissioning Project Report for the Main Processing Building and Surrounding Area, Reading, Pennsylvania*, Prepared for Cabot Corporation, May 1995.

NUREG/CR-1500, "*Working Draft Regulatory Guide on Release Criteria for Decommissioning: NRC Staff's Draft for Comment*;" August 1994.

NUREG/CR-5849, "*Manual for Conducting Radiological Surveys in Support of License Termination*;" June 1992.

STEP, 1998 (ST Environmental Professionals, Inc.), *Radiological Assessment, Reading, Pennsylvania Slag Pile Site*, Prepared for Cabot Corporation, July 1998.

STEP, 1997 (ST Environmental Professionals, Inc.), *Hydrologic and Geologic Assessment for Reading, Pennsylvania Slag Pile Site*, Prepared for Cabot Corporation, November 12, 1997.

USNRC Policy and Guidance Document, PG-8-08, "*Scenarios for Assessing Potential Dose Associated with Residual Activity*;" May 1994.

USNRC SECY-81-576, "*Disposal or On-Site Storage of Residual Thorium or Uranium from Past Operations*;" October 1981.

10 CFR Part 20, "*Standards for Protection Against Radiation*;" U.S. Nuclear Regulatory Commission, February 26, 1993.

APPENDIX A

SLOPE STABILITY ANALYSIS

GeoSystems Consultants, Inc.
575 Virginia Drive, Suite B
Fort Washington, PA 19034
Telephone: (215) 654-9600 Fax: (215) 643-9440

November 6, 1997
97G162

Mr. Steffan Helbig
ST Environmental Professionals, Inc.
RR4, Box 239 Lutz Road
Boyertown, PA 19512

STABILITY ANALYSIS
READING SLAG PILE SITE

Dear Mr. Helbig:

GeoSystems Consultants, Inc. was requested by ST Environmental Professionals, Inc. (STEP) to provide a geotechnical assessment of slope stability of the reading slag pile site (site). This assessment is based on a site topographic map showing slopes and boring locations, and boring logs from the site characterization report (NES, 1996), provided by STEP.

STABILITY ANALYSIS METHOD

The slope stability analysis was performed using the program XSTABL developed by Interactive Software Designs, Inc. of Moscow, Idaho. XSTABL is a modified version of PCSTABL coded at Purdue University, with preprocessing and post-processing modules. These modules make the input and output easier and serve to facilitate error detection in input. The "Simplified Bishop" method of slope stability analysis was used.

The stability of a slope is a function of the slope angle and other geometry, as well as the mechanical properties of the materials comprising the slope (soil and fill). The computer model utilizes input values for slope angle, the layering of underlying soil and rock, the position of groundwater, and the properties of each of the soil layers, which consist of total unit weight (density) and the strength parameters of cohesion and angle of internal friction. Numerous trial failure surfaces are analyzed and the Factor of Safety for each is calculated as the ratio of forces on the failure surface resisting failure (primarily the soil strength) to the forces tending to cause failure (primarily gravity [soil weight] and seepage forces). The trial failure surface with the lowest factor of safety is termed the "critical" failure surface. A minimum factor of safety greater than 1.0 indicates that a slope is stable while a factor of safety less than 1.0 indicates an unstable slope.

Subsurface conditions, strength parameters of the subsurface materials, and result of the analyses are discussed as follows.

STRENGTH PARAMETERS

Subsurface conditions at the site were explored by 17 test borings. The slope borings encountered successively fill, clayey silt and rock. Strength parameters of the fill and clayey silt are discussed below. The strength of the rock is much higher than that of the soil materials, and is not of concern in this analysis.

Fill

The fill generally consists of fine to coarse sand and contains slag and construction debris, i.e., slag, brick, concrete, wood and cinders. The fill is medium dense near the surface and becomes loose with depth indicating a random nature. The fill was dumped without compaction and has attained the present state after being in place many years. Based on correlation between Standard Penetration Resistance "N" values and relative density by Gibbs and Holtz (1957), an average relative density of 30 percent was estimated for the fill. For granular materials with a relative density of 30 percent, based on correlations in the NAVFAC DM-7 (1982) the following properties were estimated:

Total Unit Weight		=	110 pounds per cubic foot
Strength Parameters:	Cohesion	=	0 pounds per square foot
	Angle of internal friction	=	30 degrees

Clayey Silt

The clayey silt below the fill typically exhibited "N" values in the range of 3 to 20 blows per foot, with an average value of 10. Based on correlations by Terzaghi, Peck and Mesri (1996) between "N" and undrained shear strength, a shear strength estimate of 1,200 psf was obtained. For slope stability analyses the following properties were used:

Total Unit Weight		=	115 pounds per cubic foot
Strength Parameters:	Cohesion	=	1,200 pounds per square foot
	Angle of internal friction	=	0 degrees

RESULTS OF ANALYSIS AND DISCUSSION

Using the above soil properties, XSTABL runs were made. The critical failure surface found in this analysis passes only through the fill materials, and has a Factor of Safety of 1.16. Trial failure surfaces which pass through the underlying clayey silt have a higher

Factor of Safety. The slope has been in existence in essentially the present configuration for approximately 30 years with no distress. It should be noted that the angle of internal friction for the fill, which is the strength parameter most affecting the Factor of Safety, was conservatively estimated. Based on the above discussion, it is concluded that the slope is stable.

Although stable in its current configuration the site would not be suitable for construction of a residential or commercial facility directly on the slope or immediately adjacent to the crest.

REFERENCES

- Gibbs, H.J. and W.G. Holtz (1957). "Research on Determining the Density of Sands by Spoon Penetration Testing", Proc. 4th Int. Conf. Soil Mech., London, Vol. I, 35-39.

- NAVFAC DM-7.1 (1982). Soil Mechanics Design Manual 7.1, Department of the Navy, Naval Facilities Engineering Command, p. 7.1-149.

- Terzaghi, K., R.B. Peck and G. Mesri (1996). <u>Soil Mechanics in Engineering Practice</u>, John Wiley & Sons, Inc., pp. 63.

- NES (1996). "Characterization Report for the Reading Slag Pile", prepared for Cabot Corporation, April 1996.

It has been our pleasure to assist you on this project. If you have any questions concerning this report, please do not hesitate to contact us.

Very truly yours,

GEOSYSTEMS CONSULTANTS, INC.

Arthur H. Dvinoff, Ph.D., P.E.
Principal

Ram Dhani Singh

Ram D. Singh, Ph.D., P.E.
Principal

RDS/pd

APPENDIX B

LEACH RATE ASSESSMENT

GCX INC.
Geochemical/Geological Consultants
P.O. Box 87198-2427 • Albuquerque, New Mexico 87198 • (505) 256-3769

Arend Meijer, Ph.D.
GCX Inc.
3821 Anderson Avenue
Albuquerque, NM 87108

November 9, 1997

Steffan R. Helbig
ST Environmental Professionals, Inc.
RR 4, Box 239 Lutz Road
Boyertown, PA 19512

Subject: LEACHING BEHAVIOR OF RADIONUCLIDES FROM GLASS AND SLAG AT THE REVERE AND READING SITES

Dear Mr. Helbig,

GCX, Inc. (GCX) was requested by ST Environmental Professionals, Inc. (STEP) to assess the relative leach rates of radionuclides from the slag materials at the Revere, Pennsylvania site and the Reading, Pennsylvania slag pile site. Previous characterization testing measured the readily available uranium (RAU) leach rate from the slag for the Revere and Reading sites (NES, 1996a and NES, 1996b). Environmental Resources Management (ERM) developed a methodology to calculate the leach rates of uranium and thorium from the Revere slag based on the RAU values (ERM, 1996). The NRC approved the ERM methodology to calculate leach rates used to perform radiological dose assessment calculations for Revere and Reading (NRC, 1996 and NRC, 1997). This report assesses the leach rate of other important nuclides relative to the RAU rate of uranium.

The leaching behavior of radioactive daughter products in the uranium and thorium decay series from glass or other forms of slag produced in high temperature processes is of importance to calculation of the potential radiation dose. There are basically two potential mechanisms for leaching of these daughter products depending on their individual chemical behavior. One mechanism assumes the slag leaches radionuclides congruently whereas the other mechanism involves incongruent behavior. In the first mechanism, the slag leaches/dissolves layer by layer much like the peeling of an onion. This mechanism would produce daughter product concentrations in solution that are proportional to the concentrations of uranium in solution, the proportionality constant being the ratio of the parent concentration in the solid to the daughter product concentration in the solid. The incongruent dissolution mechanism could result in daughter product concentrations in solution that are <u>not</u> proportional to the uranium concentration in solution. In this case, the dissolution rates of each daughter product may be greater than or less than the dissolution rate of the uranium. This requires that the dissolution rates of the individual daughter products be determined independently.

With this background, the first question to be answered is "Does the glass-like slag leach congruently or incongruently?" Based on studies of the dissolution behavior of natural and nuclear waste glasses (e.g., Clark et al., 1994), the answer to this question appears to be that these glasses leach/dissolve incongruently. Analyses of the near-surface layers of natural and nuclear waste glasses and minerals show that some elements (e.g., sodium, lithium,) are readily leached from these layers in aqueous solutions. The leaching process is actually an ion exchange process in which hydrogen ions (and other ions) replace the ions of alkali elements such as sodium. When only hydrogen ions are involved, this process is also referred to as the hydrolysis of the aluminosilicate framework.

The aluminosilicate framework of the glass or mineral dissolves or leaches at a much slower rate than the rate of the ion exchange processes. This results in surface layers that are enriched in silicon, aluminum and hydrogen and depleted in the light alkali elements and to a lesser extent other elements depending on the chemistry of the aqueous solution. The aluminosilicate surface layers are generally amorphous in structure. That is, they lack a well defined crystallographic structure. Assuming that the slags at the Revere and Reading sites have dissolution/leaching behaviors similar to the natural and nuclear waste glasses, the main question now becomes "What are the relative leaching rates of uranium, thorium and their daughter products"?

Before proceeding on this question it is important to note that not all daughter products of the uranium and thorium decay series are of equal significance from the point of view of potential doses to the public. The daughter products of primary concern are radium isotopes. Therefore, the question is "what are the relative leaching/dissolution rates of uranium, thorium and radium?" There are three useful sources of information that bear on this question. The first source involves experiments with nuclear waste glass. These experiments suggest that thorium and radium leach more slowly than uranium in typical groundwater compositions (Bibler, 1986). As discussed further below, the likely reason for this behavior is that the amorphous nature of the leached surface layers provides favorable sites for the sorption or binding of elements such as thorium and radium.

The second source involves measurements on weathered igneous rocks. Rosholt et al. (1971) and many others have found that, relative to uranium, thorium is leached very slowly from glassy and crystallized silicic volcanic rocks. Because the slags are chemically similar to such volcanic rocks, it is to be expected that thorium will also leach more slowly from the slags. Although specific data on radium leaching from silicic volcanic rocks was not uncovered in the literature, data on the leaching behavior of barium was found in Zielinski et al. (1977). Barium and radium behave similarly in surficial geochemical processes, with radium generally being less mobile due to lower solubilities of radium compounds and higher sorption affinities of radium relative to barium (Langmuir and Riese, 1985). The data presented by Zielinski et al. (1977) indicate that, during weathering, barium actually becomes enriched in weathered volcanic rocks while uranium either is leached or is unchanged. These authors attribute this behavior to ion exchange processes that replace alkali elements such as lithium and sodium in the rocks with alkaline earth elements such as barium and radium. These data suggest that thorium and radium will be leached slower than uranium from the slags at Revere and Reading. As noted above, this behavior likely reflects the high affinity of the leached surface layers on glasses and minerals for the larger alkali (e.g., cesium) and alkaline earth ions (e.g., barium and radium).

A third source of information on the leaching and transport behavior of uranium, thorium and radium involves studies of the uranium and thorium decay series in groundwaters. Krishnaswami et al. (1982) studied the uranium and thorium decay series in various groundwaters in Connecticut. These authors came to the conclusion that "sorption removes radium and thorium from these groundwaters on a time scale of 3 minutes or less." Further, they calculated retardation factors for radium in the range of 4800 to 120,000. Calculated retardation factors for thorium were in the range of 14000 to 200,000. Retardation factors reflect the rate of movement of the radionuclides relative to the rate of water movement through an aquifer. The very large retardation factors reported for radium and thorium indicate these elements migrate very slowly in the investigated aquifer.

Krishnaswami et al., (1982) did not report a retardation factor for uranium. However, relative leaching/migration behavior can be estimated with their data. The retardation factor (RF) is related to K_d by the formula $RF = 1 + (D_b/n)(K_d)$, where D_b equals bulk density and n equals porosity (Freeze and Cherry, 1979). Using typical soil values for bulk density (2.0 gm/cm) and porosity (0.4), the ratio of the median calculated radium K_d to the median calculated thorium K_d is 0.58. ERM cited an average ratio of thorium K_d to uranium K_d of 6.06. Applying the ERM ratios to Krishnaswami's ratios results in a radium K_d to uranium K_d of approximately 3.5. This suggests that radium is much less mobile than uranium and would be expected to leach from the slag at a much slower rate.

Latham and Schwartcz (1987) reached similar conclusions regarding the migration behavior of uranium, thorium and radium in weathered igneous rocks in Ontario, Canada. These authors found that uranium was generally leached from the rocks they studied whereas radium and thorium were largely retained within the rock units. These observations strongly suggest that the leaching rates of radium and thorium from the Revere and Reading slags will be much slower than the leaching rate of uranium.

Variations in the water compositions can affect the behavior of radium in rock/ water systems. For example, radium concentration are often found to be elevated in highly saline waters such as oil field brines (Kolb and Wojcik, 1985). The cause for the high radium concentration in these brines are ion exchange reactions. That is, the saline brines contain high concentrations of sodium and other cations that compete with radium for ion exchange sites in the aquifers from which the brines are produced (Havlik, et al., 1968). Because the waters that could leach the slags at the Revere and Reading sites will be dilute (i.e., essentially precipitation waters), such competitive ion exchange effects will not be important at these sites.

In summary, data from a variety of sources and a variety of rock/water systems point to the conclusion that radium and thorium will be leached more slowly than uranium from the slags at the Revere and Reading sites.

Weathering Rates

The overall weathering rates of the slags at the Revere and Reading sites are also of interest because they will influence the rate of *in-situ* soil formation on the slags. Soils formed *in-situ* on the slags could contain radionuclides that could be available to plants grown on the soils. The rate of soil formation at a given site is a function of many factors including the nature of the parent materials, climate, biota, topography and time (Brady and Weil, 1996). The *in situ* rate of soil formation is here defined as the rate at which slag is converted into soil. This rate is proportional to the weathering rate of the slag. Unfortunately, the proportionality constant is a rather complex function of the soil formation factors listed above.

The weathering rate is here defined as the rate at which primary phases in parent materials (e.g., slags) are altered. Because the alteration processes are likely to involve incongruent dissolution, weathering will generally result in a dissolved component and a residual component. It is the residual component that eventually leads to the formation of *in situ* soils. Studies of the rates of *in situ* weathering of igneous rocks provide bounds on the soil formation rates to be expected at the Revere and Reading sites.

The initial stage of weathering of volcanic glass involves simple hydration and not clay formation (Clark et al., 1994). In fact, the hydration rate of volcanic glass is used as a chronometer for archeological studies. The hydration rind thickness is found to be on the order of 1-3 microns after one thousand years at ambient conditions (Friedman and Long, 1976). Hydration rind thicknesses of 10-20 microns are commonly observed and reflect ages of several hundred thousand years (Friedman and Long, 1976). Note that the relationship between rind thickness and age is not linear but logarithmic. These hydration rinds do not contain significant amounts of secondary minerals (e.g., clays). This suggests the time required for the *in situ* formation of sufficient secondary minerals to form soils is greater than several thousand years and probably greater than several hundred thousand years..

A study by Dorn (1995) of the rate of weathering of well dated (2,000-3,000 year old) volcanic flows on the island of Hawaii corroborates this conclusion. Because Hawaii has a tropical climate with high rainfall and high temperatures, the rates of weathering of volcanic rocks on this island are likely higher than the rates applicable in a cooler climate such as that found at the Revere and Reading sites. Dorn (1995) found that the weathering processes on the volcanic flows on Hawaii produced little if any *in situ* clay.

On the basis of these observations, we would expect *in situ* soil formation ages at ambient surface conditions at the Revere and Reading sites to be in the range of hundreds of thousands of years or more.

REFERENCES

Bibler, N. E. (1986) "Leaching of Fully Radioactive SRP Nuclear Waste Glass in Tuff Ground Water in Stainless Steel Vessels," Adv. Ceram. 20, p.619.

Brady, N. C. and R. R. Weil (1996) The Nature and Properties of Soils 11th ed. Prentice-Hall, New York.

Clark, D. E., R. L. Schulz, G. G. Wicks and A. R. Lodding (1994) "Waste Glass Alteration Processes, Surface Layer Evolution and Rate Limiting Steps", Mat. Res. Soc. Symp. Proc. 233 p. 107.

ERM, 1996, *Leaching Analysis for Uranium and Thorium from the Reading Slag Pile*, An Attachment to a Letter form Anthony T. Campitelli (Cabot) to Judith M. Greenwald (NRC), Re: Characterization of Reading Slag Pile - Leach Rate Methodology, September 12, 1996.

Freeze, R. Allan and Cherry, John A. (1979) "Groundwater", Prentice-Hall, Inc., p. 404.

Friedman, I. and W. Long (1976) "Hydration Rate of Obsidian" Science **191** 347-352.

Havlik, B., B. Nycova and J. Grafova (1968) "Radium-226 liberation from uranium ore processing mill waste solids and uranium rocks into surface streams-II. The effect of different chemical compositions of surface waters" Health Physics 14 423-430.

Kolb, W. A. and M. Wojcik (1985) "Enhanced radioactivity due to natural oil and gas production and related radiological problems" Sci. Total Environment, 45 77-84.

Krishnaswami, S., W. C. Graustein, and K. K. Turekian (1982) "Radium, Thorium and Radioactive Lead Isotopes in Groundwaters: Application of the in Situ Determination of Adsorption-Desorption Rate Constants and Retardation Factors," Water Resources Research 18, p. 1633.

Langmuir, D. and A. C. Riese (1985) "The Thermodynamic Properties of Radium, Geochimica Cosmo. Acta 49, 1593-1601.

Latham, A. G., and H. P. Schwartcz (1987) "The Relative Mobility of U, Th and Ra Isotopes in the Weathered Zones of the Eye-Dashwa Lakes Granite Pluton, Northwestern Ontario, Canada", Geochim. Cosmo. Acta 51, p. 2787-2793.

NES (1996a) "Risk Assessment for the Decommissioning of the Revere Pennsylvania Site", Prepared by NES, Inc. for Cabot Corporation, April 1996.

NES (1996b) "Characterization Report for the Reading Slag Pile"Prepared by NES Inc. for Cabot Corporation, April 1996.

NRC, 1996, Letter from Robert A. Nelson (NRC) to Anthony Campitelli (Cabot), October 12, 1996.

NRC, 1997, Letter from Timothy E. Harris (NRC) to Anthony T. Campitelli (Cabot), March 12, 1997.

Rosholt, J. N., Prijana, and D. C. Noble (1971) "Mobility of Uranium and Thorium in Glassy and Crystalized Silicic Volcanic Rocks", Econ. Geol. 66, p. 1061.

Vebel, M. A. (1986) "The mathematical basis for determining rates of geochemical and geomorphic processes in small forested watersheds by mass balance: Examples and implications" *in* Colman, S. M. and Dethier, D. P. ed., Rates of chemical weathering of rocks and minerals: Orlando, Florida, Academic Press p. 439-451.

Zielinski, R. A., P. W.Lipman and H. T. Millard, Jr. (1977) Minor-element Abundances in Obsidian, Perlite, and Felsite of Calc-alkali Rhyolites, Amer. Mineralogist, 62 p. 426.

If I can provide any additional information, please call.

Yours truly,

Arend Meijer

Arend Meijer, Ph.D.
Chief Geochemist

RECEIVED-REGION I

'99 JAN 22 P3:42