DECOMMISSIONING PLAN

FOR

READING SLAG PILE SITE

Prepared for:

Cabot Corporation
Two Seaport Lane
Boston, MA 02210

Prepared by:

ST Environmental Professionals, Inc.
114 Lutz Road
Boyertown, PA 19512

Revision 4
August 2006

ST Environmental Professionals, Inc.

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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.

The Decommissioning Plan was originally submitted in 1998 (DP), and revised in 2000 (DPRV1) to address additional information concerning the extent of slag in the River Road Right-of-Way (ROW). Subsequent to that submission, new studies of the leach rate and weathering of radiological slag were performed and presented in NUREG-1703 (prepared by Johns Hopkins University) and NUREG/CR-6632. A draft version of NUREG-1703 contained incorrect assumptions that the source term may be higher than presented in DPRV1. These errors were the apparent basis for concerns expressed by the Pennsylvania Department of Environmental Protection (PADEP). The Agency for Toxic Substances and Disease Registry (ATSDR) prepared a Health Consultation (Exposure Assessment), in part responding to the draft Johns Hopkins report and the PADEP concerns. Cabot's comments to these documents were provided to the NRC in the "Report on Johns Hopkins Progress Report and Related Items" (Cabot, 2002). The errors were corrected in the final Johns Hopkins report and a revised ATSDR report.

The NRC requested additional information in a letter dated March 21, 2003. In February 2004, Cabot proposed the addition of a riprap erosion barrier over the slope containing the radiological slag. In a letter dated August 27, 2004, the NRC agreed this conceptual approach was appropriate for inclusion in a revised Decommissioning Plan and Radiological Assessment. The NRC letter provided additional comments for Cabot's consideration in developing the revised DP and RA. The comments requested that Cabot address the potential for future erosion to expose a significant (relative to dose) area of slag and any uncertainties regarding the characterization of the slag inventory. This revised Decommissioning Plan (DPRV2) incorporates the riprap erosion barrier, summarizes the responses and corrections, and addresses NRC's additional comments.

The riprap cover eliminates any uncertainty about the potential for future erosion. Characterization issues were largely addressed in the "Report on Johns Hopkins Progress Report and Related Items" (Cabot, 2002) and are summarized in this Decommissioning Plan. In addition, the conservative dose modeling assumptions and low dose results, clearly demonstrate that the small uncertainty regarding the characterization is far less than the amount that would be necessary to change the conclusion that the Site meets the requirements for release without restrictions.

Cabot believes the riprap cover is not necessary to meet the criteria for release without restrictions. The riprap cover will provide additional assurance of long-term stability, avoid the need to resolve any uncertainty in the characterization effort and concerns regarding erosion, and expedite the decommissioning process. The cover design was developed in accordance with NRC guidelines in NUREG-1623. Those guidelines result in a design that is expected to maintain its integrity over the 1,000 year period of interest

without maintenance or attention. Consequently, no institutional controls will be required after license termination. The installation of the cover at the Reading Site is an engineered barrier that will eliminate the future eroded scenario presented in the Radiological Assessment submitted in 2000 (RARV1). The DP and RA are being updated to include the riprap cover.

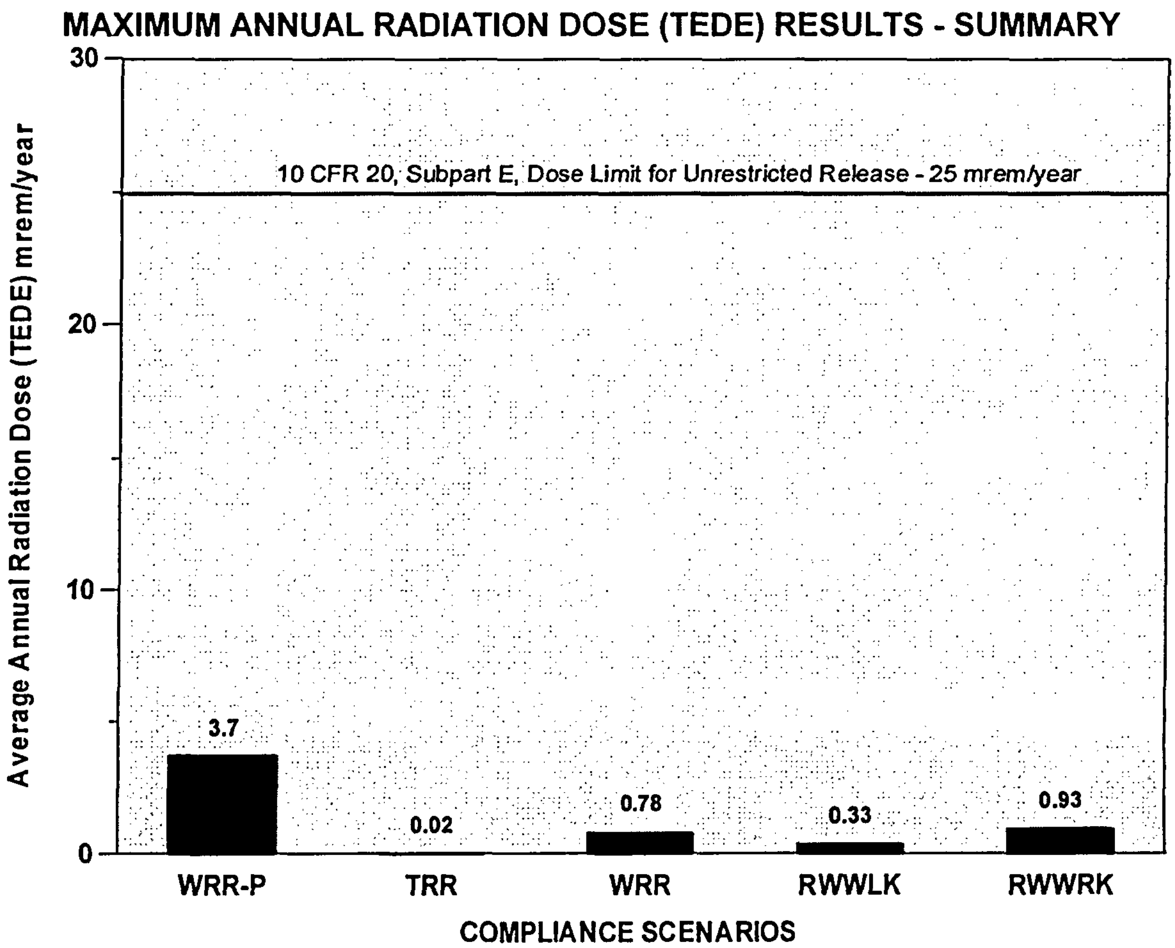
The NRC Radiological Criteria for License Termination, 10 CFR Part 20 Subpart E, became effective on August 20, 1997. This Decommissioning Plan (DP) is being submitted to meet the requirements of this rule.

The objective of the decommissioning process is to terminate the license. During the decommissioning process, Cabot performed a 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, and analysis of the slag pile stability. The results of this work were reported to the NRC in several submittals (Cabot, 1996a, 1996b, 1996c, and 1996d, ERM, 1996, and NES, 1996a and 1996b). The NRC reviewed this information and approved the characterization work (USNRC, 1996). Supplemental decommissioning work has included the preparation of a Hydrologic and Geologic Assessment (STEP, 1997) for the Reading Site, a Report on the Topographic and Radiological Surveys (STEP, 1999), a response to a draft of NUREG-1703 (Cabot, 2002), performance of a Radiological Assessment (STEP, 2006a-+), and preparation of this Decommissioning Plan.

The characterization information was used as recommended in current NRC guidance documents to develop exposure scenarios and assumptions for modeling of theoretical radiation doses that might result from unrestricted use of the Site. The NRC guidance documents provide a framework for dose assessment that consists of using prudently conservative assumptions modified as appropriate by site-specific conditions.

There are two topographically distinct areas where radiological slag has been identified: on an embankment (Slag Pile Area) and within the River Road right of way (ROW). Five realistic exposure scenarios were analyzed for compliance with the dose limit in 10 CFR 20 Subpart E. Seven alternate scenarios were modeled to aid in evaluation of the robustness of the assessment. The exposure scenarios were developed following NRC RIS 2004-08 guidance. Detailed descriptions of the modeling input parameters and results are contained in the revised Radiological Assessment, (STEP, 2006, a) and are summarized in Section 1.5.2 of this report. The calculated dose for each basic scenario are presented below in both tabular and graphic form and are compared to the 25 mrem/y limit (10 CFR 20 Subpart E) for unrestricted release. As shown, the calculated doses are all substantially less than the limit for unrestricted release.

CASE	MAXIMUM ANNUAL TOTAL DOSE (mrem/y TEDE)
Slag Pile; Worker installing riprap (WRR-P)	3.7
Slag Pile with Riprap; Trespasser (TRR)	0.020
Slag Pile with Riprap; Worker (WRR)	0.78
ROW; Walker, Current Conditions (RWWLK)	0.33
ROW; Worker, Current Conditions (RWWRK)	0.93
The 10 CFR Part 20 dose criterion for license termination with no restrictions on use is 25 mrem/y.	



These calculations use prudently conservative assumptions that are likely to overestimate the doses that might result from unrestricted use of the Site.

Much less-likely alternative scenarios were also evaluated. The calculated doses for the alternative scenarios were also well below 25 mrem/y. These calculated doses provide additional assurance of the robustness of the analysis.

An analysis to demonstrate that 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 exposure levels for any reasonable future conditions involving unrestricted use of the site are all well below the 25 mrem/y criteria for unrestricted release, particularly given the added assurance provided by the riprap. Evaluation of alternate scenarios demonstrates this conclusion is robust. Further analysis demonstrates that additional remedial action is unwarranted and that doses from unrestricted release as proposed would be as low as reasonably achievable (ALARA).

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 portion of a much larger pre-existing slag disposal area. 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 led 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 (waste slag) in which the naturally occurring thorium and uranium remained. Period documents indicate that those operations were conducted only during 1967 and 1968.

The glass-like slag residues from Kawecki's processing operations were placed on an embankment at the southwest end of the property in accordance with a Pennsylvania Department of Health permit. The embankment was comprised of a much larger non-radiological slag disposal area. This same area had been used before 1967 for slag disposal from manufacturing operations conducted by one or more companies unaffiliated with Kawecki Chemical. Some radiological slag is also present at the base of the slope in the ROW. The slag pile location is shown on the Site Vicinity Map (Figure 1-2). The slag extends approximately 160 feet along the top of the embankment.

The available records of the Reading Site activities indicate that approximately 600 tons of waste slag was deposited on the slope. Some reviewers of the DPRV1 commented that, based on a flow chart presented in a paper by Kawecki personnel (Gustison, 1971), 600 tons appeared to be low. However, that flow chart represents the planned full production throughput, and does not represent the throughput that was actually achieved. Available records show that the waste slag was the product of a not particularly successful start-up operation. The documents describe:

- Extensive efforts obtaining numerous permits and approvals
- Descriptions of projected production rates
- Measurements of test runs to determine appropriate radiological safety standards for future production

What is noticeably absent from the records is any reference to actual production. It seems clear that the work was primarily a start-up effort that never went into full production. This conclusion is supported by the fact that operations ceased after only two years. In addition, the personnel performing the work were working on the Reading project part time. All the information is consistent with the 600 tons of waste slag reportedly deposited on the slope.

Debris containing essentially background levels of radiological material were placed on the slope in 1977 through 1978 as a result of decontamination and decommissioning of the former process area. In 1976, the tin slag, stored at Baltimore, was shipped to West Germany. During subsequent final decommissioning of the Baltimore storage yard, sand mixed with negligible traces of tin slag was shipped to Reading and placed on the slope. The concentration of radiological material in the Baltimore sand is below natural background levels at the Reading Site.

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

1.2.2 Operating Occurrences Affecting Decommissioning Safety

There are no known radiological operating occurrences that would affect the safety of personnel during decommissioning of the slag pile. Currently there are no licensed materials used within the industrial property containing the Site. Other than the Slag Pile Area and the River Road ROW area, all areas where licensed material was handled have been decommissioned and released for unrestricted use.

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 Southern 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 radiological slag 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 approximately 2/3 acre and 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 vegetated with trees and brush on the slope and brush in the ROW.

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 Southern ROW and River Road ROW range in elevation from approximately 210 to 215 feet MSL. As shown in Figure 1-3 the embankment occupied by the slag pile has an overall slope of approximately 30 °. Locally the slope on the embankment is as great as 40 ° to 45 °. A licensed Pennsylvania land surveyor provided elevation contours for the slope.

The upper area, from the top of the slope east, is generally flat with elevations ranging from 264 MSL to 270 MSL. Following the razing of the buildings and preparation of the property for development, the entire upper area slopes gently away from the slope toward an existing storm drain and outfall.

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

Based on the boring logs (NES, 1996) and piezometer logs (Appendix A) a contour map depicting the top of bedrock elevation was developed (Figure 1-5). The map shows that as would be expected the top of bedrock surface slopes toward the Schuylkill River.

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 weedy shrubs and 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 clay material at a depth of approximately 38 feet below the top of the embankment. The approximate locations of 1996 borings and other sampling locations are shown on Figure 1-6.

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 potential 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 are 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 to 260 feet above MSL, is above the 100 year and the maximum reported flood level.

Following installation of the riprap cover the surface elevations of the slag pile will range from approximately 214 feet to 261 feet above MSL, entirely above the 100-year 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 1-7, a cross section showing the subsurface conditions beneath the Site. Figure 1-8 depicts a cross section across the entire industrial property. As shown in Figure 1-7, a zone of seasonal groundwater occurs in the soil immediately above bedrock. This zone of saturation is thin and discontinuous. The gradient in this zone follows the surface contour of the top of rock (Figure 1-5) and is toward the Schuylkill River. A perched groundwater condition may also occur above the clayey-silt layer during seasonal wet periods.

An apparent seep near the base of the slag pile is active during precipitation events. Analyses of the seep-water samples demonstrated that the seep water meets EPA Drinking Water Standards criteria for gross alpha and gross beta activity and is indistinguishable from the background water quality in the Schuylkill River.

Most of the groundwater passing through the radiological slag flows to the Schuylkill River via the perched zone above the bedrock. This zone is too thin and does not have sufficient yield to support even a single domestic supply well. During the sampling effort it took several hours to a full day for the wells to yield the required two liters for analysis. The expected hydraulic gradient in the underlying bedrock is convergent toward the river. This typical situation precludes the migration of the water in the soil zone from migrating downward into the bedrock because near the river the bedrock gradient is upward. The pathway for water that has passed through the radiological slag is restricted to a short very shallow zone that can not support a domestic supply well.

The small surface area limits the volume of infiltration passing through the slag. Approximately 20-inches of the 40-inches of annual precipitation is lost through evapotranspiration and approximately 10-inches is lost as direct run-off. Therefore, only approximately 10-inches is available to infiltrate through the slag. Ten inches of precipitation over the approximately 25,000 ft^2 of the slag pile and slag in the ROW is equivalent to an average flow of less than 0.3 gallons per minute (gpm).

Based on published reports and the geologic setting, permanent regional groundwater table occurs deeper in the bedrock, below the zone in the soil. 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 flow in the deep permanent groundwater system will be convergent toward the river. The flow direction near the River will be upward. This flow regime restricts the pathway between the slag and the river to a very thin (no more than several feet thick) short (80-feet to 200-feet long) shallow zone.

The groundwater is not expected to be contaminated because the leach rate of the slag is so low. To confirm this conclusion, groundwater samples were collected on two occasions from wells installed in the River Road ROW directly downgradient from the slope and within the ROW area. Those samples were analyzed for gross alpha activity, gross beta activity, and for uranium and thorium using alpha spectroscopy. 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 individual standards in Table 1-1. The details of the groundwater sampling program and results are described in Section 1.5.1.

The 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 similar to Schuylkill River background water quality. The groundwater directly downgradient of the slag pile and directly beneath the radiological slag in the ROW 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 and is unlikely to be used in the future. 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. Regardless of the low probability of groundwater use near the Site, the low leach rate of radionuclides from the slag ensures that there has not and will not be an impact to groundwater.

Any future groundwater supply could only be obtained from the deeper bedrock. The groundwater that has passed through the slag could supply only a miniscule fraction of the total yield of a deep well. Typical deep supply wells require yields of 100 or more gpm to be viable as an industrial or public supply. Therefore, the already low (below Drinking water Standards) levels of radiological constituents in the perched zone would be diluted by a factor of approximately 300 and be equal to background levels.

Based on the following considerations the deep 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, is currently planned to remain, and is expected to continue to be utilized as a transportation corridor in the foreseeable future. Transportation uses preclude the development of groundwater supply in this area.

SUMMARY

The Site conditions preclude the possibility of any completed groundwater exposure pathways.

- Radionuclide concentrations in leachate from the slag are below Drinking Water Standards. Migration and mixing can only lower the concentrations. Therefore, Drinking Water Standards can not be exceeded.

- The groundwater flow path between the slag and the river is limited to a shallow, thin, short zone unsuitable for installation of a well.

- There is insufficient yield downgradient of the slag to support even a domestic supply well.

- The total volume of the infiltration through the slag and subsequent leachate could represent only a miniscule fraction of the volume of an industrial or water supply well in the bedrock resulting in dilution of the already low constituents from the slag to background levels.

- It is unlikely that the bedrock will be developed for use as a water supply source.

In conclusion, there are no current or future 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. That survey, performed in 1997, delineated the top and bottom of the embankment. The survey results showed that the overall slope was approximately 30 ° and are discussed in the Hydrologic and Geologic Assessment report (STEP, 1997). A detailed topographic survey was performed in 1999 as is described in the Report on Topographic and Radiological Surveys (STEP, 1999) and is contained in Appendix B. The detailed topographic survey was used in the figures contained in this Decommissioning Plan.

A 30 ° to 33° slope is typical 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 C.

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 and the associated storm. The slope containing the slag remained stable even under that extreme condition.

Following installation of the riprap cover, the slope will be even more stable. The design criteria in NUREG-1623 are calculated to provide assurance that the slope will be stable from both down slope movements and erosion for the 1,000 year period of interest without maintenance.

1.3.8 Slag Pile Volume

The detailed topographic survey information (STEP, 1999) 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 was estimated based on all the characterization information and the conceptual model presented within this report. The topographic and radiological surveys indicated that there was a topographic bench on the embankment at approximately elevation 220 that limited the lower extent of the pile. The pile extended to the base of the embankment only in the middle section northwest of the concrete block

foundation. The lateral extent of the slag in the ROW may have been the result of some subsequent grading activities in that area.

The volume of slag mixed with non-radiological materials on the embankment and in the River Road ROW was estimated to be 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 volume of slag in the ROW was estimated by multiplying the area of the slag (10,000 ft^2) by the depth range of one to two feet resulting in a volume of 10,000 ft^3 to 20,000 ft^3. The characterization of radiological slag in the ROW area is described in the Report on Topographic and Radiological Surveys (STEP, 1999).

The current estimated total volume of approximately 180,000 ft^3 represents the maximum expected volume where radiological slag or radiological slag mixed with non-radiological materials (soil and debris) is likely to occur. It is not directly related to the volume of pure radiological slag.

The total amount of pure waste slag deposited on the pile was reported by personnel involved with the effort to be 600 tons. This amount was questioned by some reviewers as seeming low relative to the projected daily production throughput described in the period planning documents. Based on the records, the effort never went into full production.

Despite an exhaustive search of all known documents for the Reading site, no production or quality control records have been identified. The only records located were analyses of test melts performed by the radiation safety consultant at the time.

The response prepared by Cabot in 2002 details the inventory of slag present in the Reading Slag Pile. There are two types of radiological slag present; raw tin slag that was the feedstock for the process and waste slag from the process. Due to removal of the desired product, the concentration of U and Th in the waste slag was slightly higher than in the feedstock.

The reported 600 tons of waste slag is consistent with the period documents. No records or physical evidence indicate more than 600 tons were placed on the pile. Inventory records reveal that the amount of tin ore present at the Baltimore storage yards during the operations was shipped overseas to West Germany in 1976 (Cabot 2002).

Following shipping of the tin slag overseas, sand and soil containing negligible traces of tin slag were removed from the Baltimore storage yard. This material was shipped to Reading and deposited on the slope. Descriptions of the material at Baltimore and test results of sand samples collected at Reading demonstrate that the average concentration of U and Th in the sand is at or below the natural background at the Reading site.

The total inventory of thorium, based on all the reported material placed on the pile is summarized in table 2 of Cabot's 2002 response. Thorium was used because analytical data for thorium was available for all of the material. Uranium concentrations and activities are consistently lower than thorium. The total thorium present in the slag pile based on the available records was 2.19 tons. Distributed in the 180,000 ft^3 envelope containing slag, this results in a calculated average Th activity of 47 pCi/g. The average subsurface activity of Th based on the characterization measurement results was 45 pCi/gm. The close agreement of the two different approaches provides confidence that the source term used for the dose calculations is reasonably close to the true value. The close agreement in the inventory on-hand at Baltimore versus the inventory shipped overseas also confirms that the amount of radiological slag present at Reading is not significantly different than estimated.

Numerous analyses of tin slag and waste slag were performed during the test operations, as part of the characterization effort, and NUREG-1703. This information provides a sound basis for direct derivation of source term assumptions for application in the Radiological Assessment.

1.4 PREVIOUS DECOMMISSIONING ACTIVITIES

The buildings and surrounding areas of the industrial property were decommissioned 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), the Hydrologic and Geologic Assessment for the Reading, Pennsylvania Slag Pile Site (STEP, 1997), and the Report on Topographic and Radiological Surveys (STEP, 1999). The characterization effort also included sampling and analysis of seep samples collected at the base of the slag slope.

Slag Pile Characterization

Figures 1-2 and 1-3 show the areal extent of the slag pile in plan view. The locations of the 1996 borings, surface soil samples, seep samples, sediment samples, and direct gamma measurements are shown on Figure 1-6. Analyses of surface soil samples and samples collected from the borings, indicate that the average activity in the radiological slag /debris/soil mixture in the Slope area is 45 pCi/g thorium-232 and thorium-228 and 30 pCi/g uranium-238 and uranium-234. 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)

In 2003 Cabot performed a detailed radiological survey along the perimeter of the existing fence surrounding the slag pile. The existing fence was installed by the property owners subsequent to Kawecki's activities and appears to have been related to overall property security and not specifically to the slag material. The 2003 survey indicated that some slag material was located up to approximately 25 feet beyond the existing southeastern fence. Those results are depicted on Figure 1-9. Cabot installed a new fence to completely enclose the area containing radiological slag. All currently existing fences are depicted on Figure 1.3.

ROW Area Characterization

ST Environmental Professionals, Inc. evaluated the extent of radiological slag in the ROW area in 1998 and 1999. The work consisted of performing a radiological survey using a hand held Micro R meter. Measurements were recorded at 1 m above grade and at ground surface at each height a total reading and a shielded reading were recorded. Comparison of the total and shielded measurements was used to calculate the direct radiation contribution from the Slope area and the direct radiation contribution from the material in the ROW area. A measurement in an unaffected area was used to subtract the contribution from natural background sources. A detailed description of the survey, calculations, and results are contained in the Report on Topographic and Radiological Surveys (STEP, 1999) contained in Appendix B. The survey locations and results of the radiological survey are summarized in Figure 1-10, showing the maximum extent of radiological material in the ROW area.

The depth of radiological material in the ROW area was evaluated by collecting three soil samples from each of three locations in the radiological material area and one sample from a background location for comparison. The soil sample locations are shown on 11-10 as S01, S02, S03, and S04 (Background). At each location within the radiological material area, a sample was collected from depths of 0.5-ft to1.0-ft, 1.5-ft to 2.0-ft, and 2.5-ft to 3.0-ft. At the background location (S04) the sample was collected from the upper 0.25-ft. Each soil sample was analyzed by gamma spectroscopy for uranium and

thorium. The laboratory results are contained in Appendix B. The results are summarized in Table 1-2.

The soil sampling results indicate that the radiological material in the ROW is restricted to the upper 1.0-ft to 2.0-ft. Sample location S02 was located in the drainage swale that transmits runoff and seep water from the Slope area toward the Schuylkill River. The surface elevation at S02 is approximately 1.5-feet to 2.0-feet lower than the surface elevations of S01 and S03. The lack of elevated radiological concentrations in the samples from S02 confirms that the radiological material is limited to the upper 1.0-feet to 2.0-feet of soil and indicates that radiological constituents are not leaching or physically migrating from the Slope area.

Leach Rate of Radionuclides from Slag and Weathering of Slag

Because the slag is essentially a glassy silicate and unweathered, its elemental constituents (including uranium and other radionuclides) are locked in the silicate matrix and are not available to the environment. In addition, the radionuclides are likely to remain tightly bound in any weathered material that eventually forms.

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 would 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. As part of the DPRV1 preparation, a geochemical consulting firm (GCX, Inc.) was requested to provide an assessment of the relative leach rates of other important radionuclides (Appendix D). 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.

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 D). GCX's conclusions are consistent with ERM's conclusions.

Subsequent to the DPRV1, two studies were performed (NUREG-1703 and NUREG/CR-6632) relating to the leach rate and weathering of radiological slags. GCX was again requested to review those reports and update the assessment as appropriate. Those comments are also contained in Appendix D.

Based on GCX's comments, the more recent studies confirm that there is no reasonable potential for groundwater contamination from the radiological slag.

Groundwater Characterization

Five temporary piezometers (PZ01 through PZ05) were installed to evaluate groundwater conditions directly downgradient of the Slope area and within the ROW area. The locations of the piezometers (PZ) are shown on 11-10. Each PZ was installed by drilling to the top of bedrock using hollow-stem auger drilling methods. The 1.0-foot long by 1.5-inch outside diameter (OD) porous piezometer tips were installed at the top of bedrock.

The water levels in the wells were limited to a few feet above the top of bedrock. This is consistent with observations made during the 1996 characterization program. The groundwater downgradient from the slag is restricted to a shallow, thin (no more than several feet thick), and short (80-feet to 200-feet long) flow zone between the slag and the river. That zone has insufficient yield to support even a marginal domestic or industrial supply well.

The piezometers were sampled on July 9, 1998 and January 26, 1999. On both occasions, only PZ01, PZ02, and PZ03 contained sufficient water for collection of groundwater samples. The boring logs, water level measurements, and laboratory analytical results are contained in Appendix A. The results of the analyses are summarized in Table 1-1. As shown by those results, groundwater directly below the radiological material meets drinking water standards for radiological parameters and is similar to Schuylkill River water. The results of the seep, wells, and Schuylkill River sampling and analyses are shown below in comparison to EPA drinking water standards.

ANALYTICAL PARAMETER	SEEP SAMPLES AVERAGE	SCHUYLKILL RIVER SAMPLES AVERAGE	FILTERED WELL SAMPLES 2 ROUNDS	EPA DRINKING WATER STANDARDS (10 CFR 40)
GROSS ALPHA (pCi/L) (Table 3-1)	**1.6**	**Not Applicable**	**All <10**	**15.0 Excluding Rn and U $Ra^{226} < 5.0$**
GROSS BETA (pCi/L) (Table 3-1)	**9.8**	**Not Applicable**	**All <10**	**50.0 Screening level**
TOTAL GROSS U^{234}, U^{238}, Th^{228}, U^{232} By Gamma Spectroscopy (pCi/L) (NES, 1996), (STEP, 2000)	**2.47**	**2.27**	**Avg. = 4.77**	**Not Applicable**

1.5.2 Potential Future Uses of Site and Disturbance of Radiological Slag

Based on review of Sanborne maps, the property containing the Site has been used for industrial purposes for at least 100 years. The historical zoning designation for the property was HM (Heavy Manufacturing). The City of Reading and Berks County have designated the area containing the Site as an urban redevelopment area. As part of that process, the area containing the Site has been designated for industrial/commercial and related uses. The Reading Redevelopment Authority has razed the former buildings and is currently in the process of preparing the property for construction. Discussions with potential industrial tenants are in progress

Development of the former Dana property north of the Site has been partially completed with the construction of roads and other infrastructure. Plans by a committed tenant of that property include the use of the River Road ROW as an access route in the near future.

Ground surface elevation data from the 1904 Sanborne map showed an approximately uniform slope from the Schuylkill Canal to Tulpehocken Street. Over the past 101 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 1-8), 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 or commercial 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 100 years have resulted in the current Site profile that is optimal for use of the property. This optimum grade 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 ^{o} to 35 ^{o} 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 (approximately 3,000,000 cubic feet) 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 composed of debris 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 is planned to 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.

Leachate from the slag meets drinking water standards for radiological constituents. Leachate from the slag could comprise only a small fraction of the total yield of an industrial supply well. Therefore, the concentration of radiological constituents in a supply well would be much lower than drinking water standards.

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.

Off-Site Movement of Slag

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. Although it is physically possible to move the radiological slag to an off-site location, it is inconceivable that it could end up in a configuration that would lead to greater exposure than that at the Site. For the exposure to be greater, the radiological slag would have to be selectively excavated and separated from non-radiological slag, moved to a new location, and selectively spread across a surface area larger than the current Site. Because the radiological slag is indistinguishable form the non-radiological slag at the site, selective removal and placement of radiological slag would require the use of radiation detection devices. It is inconceivable that people with the knowledge of sophisticated instruments would either intentionally concentrate radiological material to increase the potential dose or have no knowledge of the potential dose.

Even if the slag were moved, the same physical characteristics that limit the potential exposure on-site would limit the off-site exposure. It would not be used for surface fill in any residential, agricultural, or commercial setting. If someone went through the expense and effort to move the material, it is doubtful that it would remain exposed even in an industrial setting.

As discussed below, the use of the radiological slag as a growing media for farming, turf, or for a residential garden is an unreasonable assumption. There are several factors that each and in itself would prevent that from occurring. Taken together, it is virtually impossible for off-site movement of the slag to result in doses of concern. The following factors are critical for evaluating the potential off-site exposure.

Physical Characteristics

The slag itself is a glassy granular material with many large pieces up to several feet in diameter. It has little moisture retention and no organic humus material. The radiological slag at the Reading Site is mixed with other materials including:

- Concrete slabs greater than 10-feet by 10-feet by 1-foot thick
- Metal trash and debris including structural steel, pipes, wires, hoses, spikes, nails, household items, batteries, pails, bricks, carbon electrodes, wooden timbers, and general commercial industrial and residential trash
- Non-radiological slag that is nearly identical in origin and appearance to the radiological slag

At the Reading Site, only drought tolerant weedy species of trees and brush are able to survive on the slope where approximately 2 feet of material covers the slag. Based on observations of numerous piles of non-radiological steel slag in Pennsylvania, pure slag

does not support any but the hardiest weedy species of plants, if any. The slag is not suitable as a growing medium for crops or turf.

The debris mixed in with the slag severely limits its use. The large objects imbedded in the fill would impede grading to proper slope, tilling, plowing or harvesting any crop, and maintaining a lawn. The smaller nails and spikes would be a deterrent to using the material as surface cover for industrial residential or agricultural use because of the risk of puncturing tires on vehicles and equipment. The material is not aesthetically acceptable for any intentional residential, commercial, or industrial use.

Standards of Construction Practice

Certain standards of construction practice for residential, commercial, and industrial development projects are ubiquitous to Pennsylvania and elsewhere. As much as possible, a construction/development manager uses on-site materials for shaping and grading. During planning stages engineers calculate and match the volume of excavation (cut) and fill to avoid the expense and uncertainties associated with importation or disposal of fill. If present, on-site topsoil is first stripped and stockpiled for later use for final grading. During excavation activities, the select soil (soil that does not contain rocks, boulders, debris, waste, or slag) is also typically separated from the non-select material (subsoil, rocks, boulders, debris, and waste fill such as slag). The non-select material is then used for the rough grading and backfill. The select material is used for final grading and the topsoil is then spread across areas that will be vegetated. If topsoil is not available onsite, then it is imported from an offsite location. Slag or trash and debris are not used as the final cover for areas scheduled for vegetation. The only locations where slag/debris is left as the surface material have been heavy industrial sites where the activities will consist of handling and storage of equipment, bulk materials, or junk. Typically slag and debris materials end up buried or on an embankment away from the regularly used sections of the site, such as the current situation at the Reading industrial property.

Economics

The desire for a visually pleasing and vegetated site is reflected by the ubiquitous effort and cost expended to provide topsoil for residential and commercial site development. The cost to import topsoil typically ranges from approximately five dollars per cubic yard for large projects to more than ten dollars per cubic yard for homeowners. Five dollars per cubic yard equates to over $4,000 for covering an acre with 6 inches of topsoil.

The cost to excavate and ship material is several dollars per cubic yard. The cost of excavating and shipping precludes the use of slag and debris as fill at an off site locations. It is inconceivable that a landowner would pay to import undesirable slag and debris for the final cover at a site when the cost for topsoil is only incrementally greater and results in an acceptable site for development or sale.

In essence, material such as this does not have any aesthetic, economic, or valuable use; it almost always exists as an on-site waste in piles or as subsurface fill. In addition, current environmental regulations (Pennsylvania Residual Waste Regulations) generally prohibit the use of waste slag for offsite fill. Therefore, slag and debris typically remain on the site of origin or are disposed of at a landfill if there is a need for removal.

The proposed riprap cover represents a costly improvement to the property. It provides a stable aesthetic slope and eliminates maintenance costs. It is much more likely that a future owner would extend the cover along the entire slope rather than go through the expense to remove the riprap and expose trash and debris.

Logistics

In the unlikely event that slag from the Reading Site were to be relocated in the future, the process would affect relative distribution of radiological slag relative to the non-radiological slag. The radiological slag and debris are indistinguishable from the non-radiological slag and debris without the use of sensitive instruments or laboratory analyses. Excavation of slag from the Reading Site would be indiscriminant resulting in thorough mixing of radiological and non-radiological slag.

The average activity slag pile mixed with the other fill at the property can be calculated. Based on the inventory records, a total of 2.19 tons of thorium was contained in the materials placed on the slag pile. The 3,000,000 ft^3 of fill at the site would weigh approximately 175,500 tons. This equals a concentration of 0.00125 wt % thorium, corresponding to an activity of 2.7 pCi/g of thorium. Applying the measured ratio of uranium to thorium, there would be 0.00051 wt % uranium, corresponding to an activity of 3.4 pCi/g. Therefore, the result of excavation, shipping, and placement of the slag to a different location would most likely result in a greatly reduced average concentration of radiological constituents.

It is possible that there could still be some small volumes (limited to the size of one truckload) of slag that would be near or at the same concentration as currently exists in the radiological slag pile. At the destination site, these volumes of radiological slag would be randomly distributed as zones scattered throughout the fill in three dimensions (raisin bread provides a useful analogy). The "raisins" would most likely be embedded in the fill and not exposed at the surface. In the few locations where it was exposed at the surface the size of the area and concentration would be less and than the area and concentration modeled for the on-site dose assessments. If the receiving site was residential or commercial, it is certain that slag would be covered with topsoil before use. If it was a heavy industrial site the uses would be similar to the Reading Site and the surface area and concentration of radiological slag would be substantially less than at the Reading Site. Therefore, the potential exposure would also be substantially less.

Burial in a Landfill

Cabot considered the unlikely scenario of assuming that all knowledge and capability to identify radiological slag is lost and there is large-scale excavation and removal of fill at the property, including the slag. Because of the negative aesthetic appeal and potential non-radiological contamination of the debris that compose the fill, it is not likely to be used for surface fill at a new location. If it was removed, the most likely disposition would be in a sanitary or industrial landfill. In such a setting the potential exposure would be zero because the radiological material would be buried having no direct exposure and concentrations of radionuclides in leachate would not exceed drinking water standards. In the reducing environment of a landfill, the uranium and thorium would be more stable and the radiological concentration of any leachate produced would be even lower than at the Site.

The potential dose was also considered if knowledge and maintenance of a landfill containing the radiological slag were somehow lost and excavation and erosion were possible. Because the radiological slag would be dispersed in the landfill any future exposures would be for small areas with low concentrations. Any potential dose would be less that modeled for the Site. In addition, the continued association with garbage and debris would still limit the intentional uses, disposition, and potential exposure.

Alternate exposure scenarios for the highly unlikely excavation and relocation of the slag and debris within which it is embedded were evaluated as part of the Radiological Assessment. Calculated doses were low.

On-Site Movement of Slag

Regrading of the property into a uniform slope was considered unlikely because the elevations at the property boundaries are fixed. Regrading would require the removal and offsite disposal of large volumes of trash and debris.

Excavation and relocation of slag within the industrial property would have the same affects as offsite relocation of slag. The result would be lower average concentrations, smaller areal extent, and likely cover with soil if the industrial property were developed for residential or commercial use. Because of the current location of the slag on an embankment, the radiological slag would likely be buried beneath non-radiological slag. Any development of the areas containing radiological slag would result in a cover of soil or pavement. Either scenario greatly reduces the already low calculated potential dose.

If, as concluded in NUREG-1703, the radiological component is preferentially contained in the large hard glassy blocks of waste slag, then the probability of significant activity being available for exposure is extremely low. The large blocks of slag that do not leach uranium and thorium would not contribute to water-born or air-born pathways. Direct dose would be unlikely because the blocks would not be left exposed in any setting normally occupied for any but short time periods.

The RA calculated potential doses from the thin (1-foot to 2-foot thick) limited area of dilute radiological slag in the River Road ROW. Those results demonstrated that potential dose was below 1 mrem/yr for all scenarios considered. The limited extent and concentration of the ROW material ensures that any movement or change would likely reduce the dose. It is highly unlikely that the material could inadvertently be placed in a configuration that would lead to a dose above the 25 mrem/yr limit for release without restrictions. In addition, approximately 50% of the material will be beneath a4.5-foor thick riprap cover eliminating potential exposure and any reasonable probability of movement.

Reviewers Comments

Reviewer comments on a draft Safety Evaluation Report prepared by the NRC Staff expressed concern regarding the characterization of the slag. Cabot understands that the concern was based on speculation that the auger drilling and split-spoon sampling performed by NES may have underestimated the amount of slag present as large hard glassy blocks. A complete response to this concern, provided in 2002 (Cabot 2002), showed that the results of characterization are confirmed by a variety of methods and the potential range of uncertainty is small. The installation of a riprap cover provides additional assurance that the limited uncertainty regarding the amount of slag is not significant to the potential dose to the public.

Some reviewers have expressed concern that in the current condition of the Slag Pile, future erosion could lead to exposure of concentrated slag on the slope, essentially recreating the conditions that existed when the slag was initially placed on the slope. This scenario is not credible because it requires all the material that has been placed on the slag to be selectively removed by erosion.

The current covering consists of rock placed by Kawecki to cover the slag and debris placed by the property owners following Kawecki operations. That material contains numerous large bodies of reinforced concrete aggregate, rocks, and metallic scrap. The past 30 to 40 year history of the Site provides assurance that the slope is stable and significant erosion has not been observed. If it is assumed that somehow erosion occurs, only the smaller fragments of materials could be removed. The larger pieces of concrete, rock and debris would remain and provide for a durable cover. In addition, material would remain filling the interstitial spaces between the large blocks of slag, reducing the potential exposure.

Based on Site observations, period documents, and characterization results, with the possible exception of a small area near the southwest border of the pile there are sufficient large pieces of durable material covering the pile to ensure a continuous cover following erosion of finer materials.

The potential future dose due to postulated exposure of a limited area of slag can be estimated from the dose assessment calculations performed for the Radiological Assessment (RA, STEP, 2006a). Those results indicate that the potential exposure depends primarily on the area and concentration. In the unlikely event of significant erosion, the small area of slag that could potentially be exposed by erosion would be similar to the assumption in the limited excavation scenario presented in the RA. The calculated potential dose for that scenario is well below the 25 mrem/year limit for release without restrictions.

Another review concern was that the characterization effort may have underestimated the radiological content of the pile. As discussed above, actual available information indicates that the amount of material present could not be significantly more than reported. In any event, the total amount of slag does not significantly affect the dose calculations. A set of unlikely alternate exposure scenarios evaluated in the RA assumed the presence of undiluted waste slag in the lower 4.2 feet of a 6-foot deep trench excavation passing approximately 200 feet through the slag pile. This is an extremely conservative scenario because the only portion of the slag pile where such an excavation could reasonably be postulated to occur would be along the top edge. The characterization results from borings along the top edge clearly demonstrated that encountering pure slag there would be a rare and localized occurrence. Postulating a greater amount of radiological slag does not increase the exposure to the hypothetical person working in a trench because the maximum concentration has already been assumed. Since the areal extent and maximum concentration are well defined, the calculated dose would not be changed by postulating that there is a greater amount of slag.

In addition, the potential range of uncertainty regarding the amount of slag present is small. The inventory records, characterization results, personnel recollections, and the period documents all support the source term value used in the Radiological Assessment. None of the auger borings, including six through the slag pile, encountered refusal above the top of bedrock. Split-spoon samples were collected every two feet in those borings.

Summary

- The Reading Slag Pile Site has been fully characterized
- Groundwater is not a significant pathway for exposure because the radionuclides do not readily leach into the groundwater and any groundwater that could be affected would not be used for any purpose.
- Offsite relocation of the slag is very unlikely and would result in reduced exposure, concentration, and potential dose
- On-site redistribution of slag would result in reduced exposure, concentration, and potential dose

The Radiological Assessment dose modeling considers the slag pile with riprap for purposes of evaluating slag pile compliance with dose limits for release with unrestricted use. Less likely alternate exposure scenarios are evaluated for limited excavation and for major excavation. Results for these alternate scenarios are not needed to demonstrate compliance with dose limits, but do show that the RA conclusions are robust.

1.5.3 Proposed Riprap Cover

The physical characteristics of the slag and the Site ensure that potential doses are less than the NRC limits for unrestricted release. The proposed riprap cover, which is designed to remain stable from down slope movement and erosion for 1,000 years without active maintenance, provides additional assurance that the limits will be met. The cover is designed to withstand events up to and including the probable maximum precipitation (PMP) and the probable maximum flood (PMF) in the Schuylkill River

The riprap cover design was performed by an experienced geotechnical engineering firm using the guidelines in NUREG-1623. The detailed calculations and procedures for installation are contained in Addendum 1 (STEP, 2006b) to this Decommissioning Plan. On the slope above the probable maximum flood (PMF) elevation and top edge of the pile, the cover will consist of a 1.0 foot thick layer of diabase rock with an average size of approximately 6" (D_{50}=6"). On the slope below the PMF elevation the cover will consist of a 2.0 -foot thick layer of diabase rock with an average size of approximately 12" (D_{50}=12").At the base of the slope, a 4.5-foot thick layer of D_{50}=18" diabase rock will extend 231 feet from the slope to form a base to anchor the slope. The riprap cover is depicted in plan view on Figure 1-12. Detailed cross sections are provided in the Addendum (STEP, 2006b).

The riprap cover is an engineered barrier that eliminates any concern regarding possible erosion. The continuous cover of large durable pieces of rock also will ensure a stable and continuous cover over the slag that will prevent exposure to the slag, even without considering the presence of the finer materials in the cover.

1.5.4 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, Revision 4 (STEP, 2006a). 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 in the Radiological Assessment (STEP, 2006a), includes the estimation of the 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 as recommended in current NRC guidance documents to develop exposure scenarios and assumptions for the assessment of theoretical radiation doses that might result from unrestricted use of the Site.

Three basic exposure scenarios were developed and evaluated as a base or primary analysis for the slag pile:

- A worker preparing the Site and constructing the riprap layer (WRR-P)

- A trespasser who walks on the slag pile slope face after license termination (TRR)

- A worker on the Site after license termination who spends part of his work time in a facility assumed to be located on the flat surface at the top of the slag pile and a portion of his work time in activities involving walking on the slag pile slope face. (WRR)

Detailed descriptions of the modeling input parameters and results are contained in the RA (STEP, 2006a).

A separate analysis was performed for the River Road ROW area. Development of scenarios for analysis recognizes the limited potential uses of the ROW segment. The most severe exposure scenarios would likely involve some kind of occasional recreational

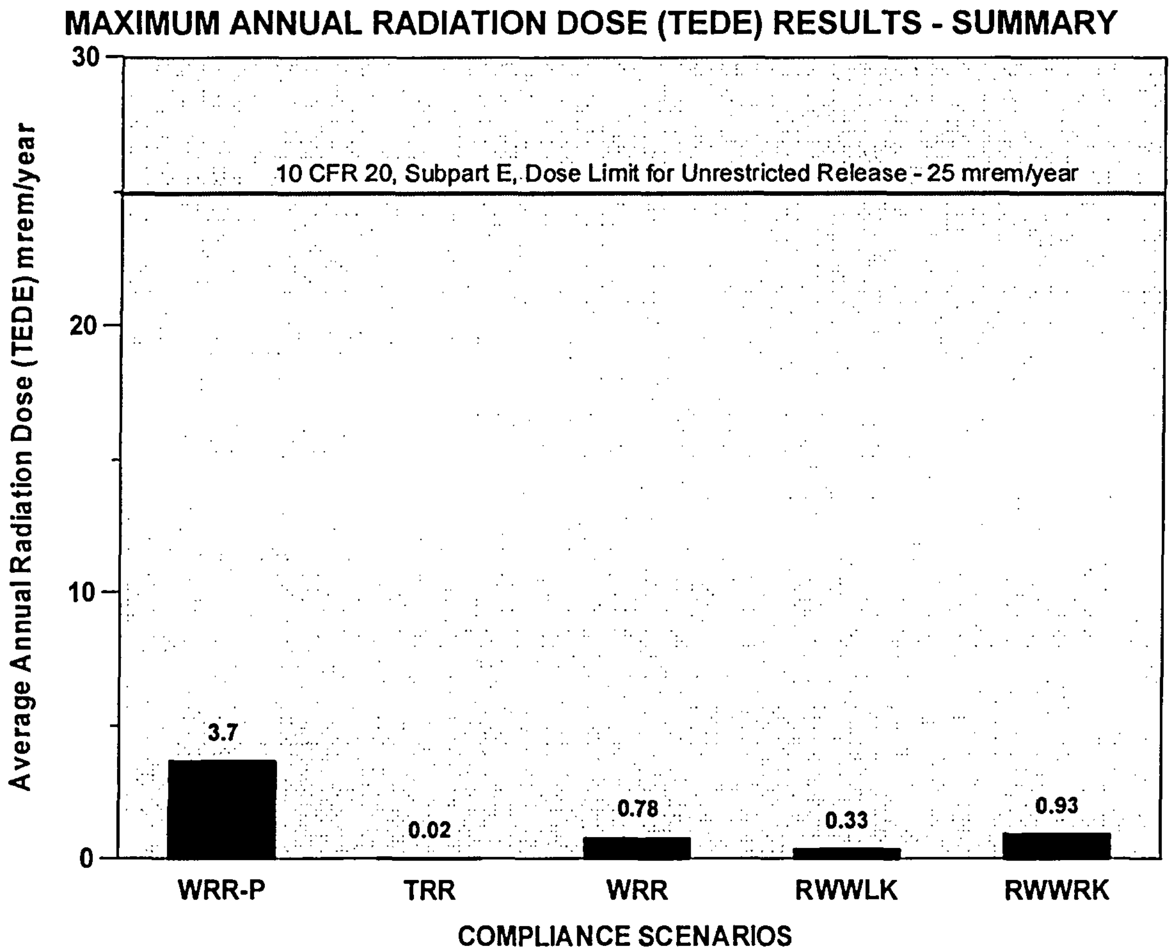
or some occupational use involving excavation. Even in those scenarios, exposure time would be small. Two basic exposure scenarios were developed for purposes of analysis:

- A recreational walker who routinely walks on the ROW segment for exercise or pleasure (RWWLK)

- A worker who participates in excavation in the ROW segment (RWWRK)

The calculated dose for each scenario is presented below in both tabular and graphic form and is compared to the 25 mrem/y limit (10 CFR 20 Subpart E) for unrestricted release. As shown, the calculated doses are all substantially less than the limit for unrestricted release. Approximately 50% of the material in the ROW will be covered with a 4.5-foot thick layer of R-7" rip rap. The riprap cover will eliminate some of the potential exposure and further reduce the modeled dose.

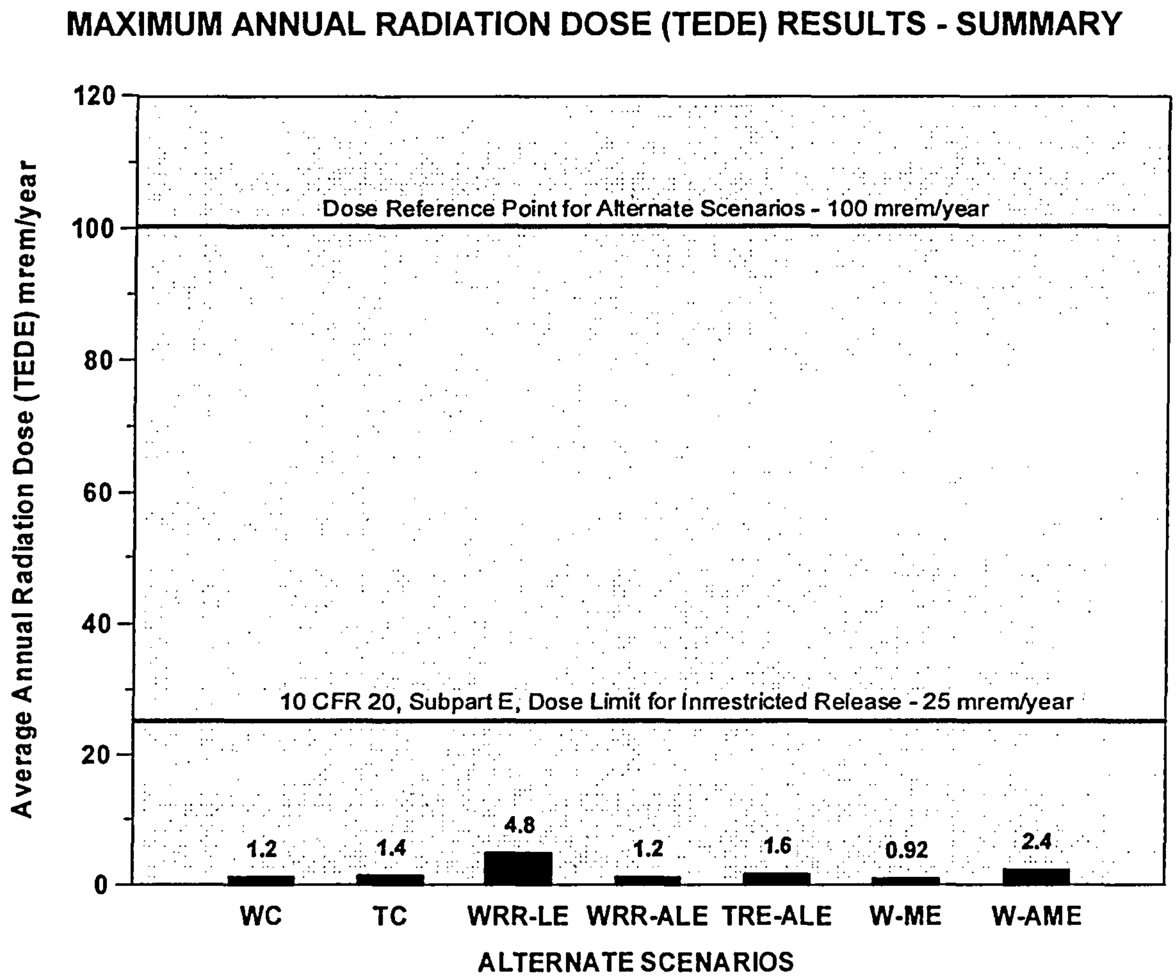
CASE	MAXIMUM ANNUAL TOTAL DOSE (mrem/y TEDE)
Slag Pile; Worker installing riprap (WRR-P)	3.7
Slag Pile with Riprap; Trespasser (TRR)	0.020
Slag Pile with Riprap; Worker (WRR)	0.78
ROW; Walker, Current Conditions (RWWLK)	0.33
ROW; Worker, Current Conditions (RWWRK)	0.93
The 10 CFR Part 20 dose criterion for license termination with no restrictions on use is 25 mrem/y.	



These calculated doses represent the doses that might result from unrestricted use of the Site. The maximum dose (TEDE) calculated for all scenarios is 3.7 mrem/y, substantially less than the 10 CFR Part 20 limit of 25 mrem/y.

Alternate scenarios, simulations of highly unlikely events that might lead to higher doses, were also evaluated. These are not intended to be compliance scenarios, but are included to assist NRC in reaching a risk-informed decision, as envisioned in NRC RIS 2004-08. All the calculated doses for those scenarios were also well below the 25 mrem/y limit, demonstrating the robustness of the conclusions of the assessment. These calculated doses provide additional assurance that the Site qualifies for unrestricted release.

ALTERNATE SCENARIOS	
CASE	MAXIMUM ANNUAL TOTAL DOSE (mrem/y TEDE)
CURRENT CONDITIONS (NO RIPRAP)	
Slag Pile; Trespasser (TC)	1.4
Slag Pile; Worker (WC)	1.2
SLAG PILE—LIMITED EXCAVATION	
Slag Pile: Worker in limited excavation (WRR-LE)	4.8
Slag Pile: Trespasser after limited excavation (TRE-ALE)	1.6
Slag Pile: Worker after limited excavation (WRR-ALE)	1.2
SLAG PILE—MAJOR EXCAVATION	
Slag Pile: Worker in major excavation (W-ME)	0.92
Slag Pile: Worker after major excavation (W-AME)	2.4
The 10 CFR Part 20 dose criterion for license termination with no restrictions on use is 25 mrem/y. However, the appropriate dose reference point for alternate scenarios is 100 millirem per year (USNRC, 2004).	



An analysis to demonstrate that 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
Reading Slag pile Site

SAMPLE ID	PZ-1 *		PZ-2 *		PZ-3 *		
DATE	8/5/1998	1/26/1999	8/5/1998	1/26/1999	8/5/1998	1/26/1999	STANDARD
FILTERED:							
GROSS ALPHA	< 6.0	< 6.0	< 8.0	< 10	< 7.0	< 7.0	15 (a)
GROSS BETA (-K-40)	< 8.0	< 8.0	< 9.0	< 10	< 9.0	< 8.0	50 (b)
THORIUM-228	**1.1**	< 2.0	**0.86**	< 2.0	**0.9**	< 0.9	15 (a)
SIGMA (+/-)	0.5	--	0.52	--	0.52	--	-
THORIUM-230	< 0.1	< 0.4	< 0.2	< 0.4	< 0.2	< 0.3	15 (a)
SIGMA (+/-)	--	--	--	--	--	--	-
THORIUM-232	< 0.1	< 0.4	< 0.2	< 0.4	< 0.1	< 0.3	15 (a)
SIGMA (+/-)	--	--	--	--	--	--	-
URANIUM-233/234	**1.3**	**1.2**	**3.8**	**7.9**	**1.2**	**0.52**	-
SIGMA (+/-)	0.4	0.4	0.7	1.1	0.4	0.28	-
URANIUM-235	< 0.1	< 0.1	**0.18**	**0.25**	< 0.1	< 0.1	-
SIGMA (+/-)	--	--	0.16	0.18	--	--	-
URANIUM-238	**1**	**1.1**	**4.1**	**6.8**	**1.3**	< 0.2	-
SIGMA (+/-)	0.3	0.4	0.8	1	0.4	--	-
UNFILTERED:							
GROSS ALPHA	< 6.0	< 7.0	< 8.0	< 20	< 7.0	< 7.0	15 (a)
GROSS BETA (-K-40)	< 8.0	< 8.0	< 9.0	< 10	< 9.0	< 8.0	50 (b)
THORIUM-228	< 0.7	< 1.0	**1.3**	< 2.0	**0.99**	< 2.0	15 (a)
SIGMA (+/-)	--	--	0.7	--	0.53	--	-
THORIUM-230	< 0.2	< 0.3	< 0.2	< 0.3	< 0.3	< 0.3	15 (a)
SIGMA (+/-)	--	--	--	--	--	--	-
THORIUM-232	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.4	15 (a)
SIGMA (+/-)	--	--	--	--	--	--	-
URANIUM-233/234	**0.68**	**1.2**	**5.1**	**8.3**	**2**	**0.61**	-
SIGMA (+/-)	0.27	0.4	0.9	1.1	0.5	0.34	-
URANIUM-235	< 0.1	< 0.1	< 0.2	**0.34**	< 0.09	< 0.1	-
SIGMA (+/-)	--	--	--	0.22	--	--	-
URANIUM-238	**1.1**	**0.6**	**4.9**	**7.8**	**1.5**	**0.55**	-
SIGMA (+/-)	0.3	0.31	0.8	1.1	0.4	0.3	-

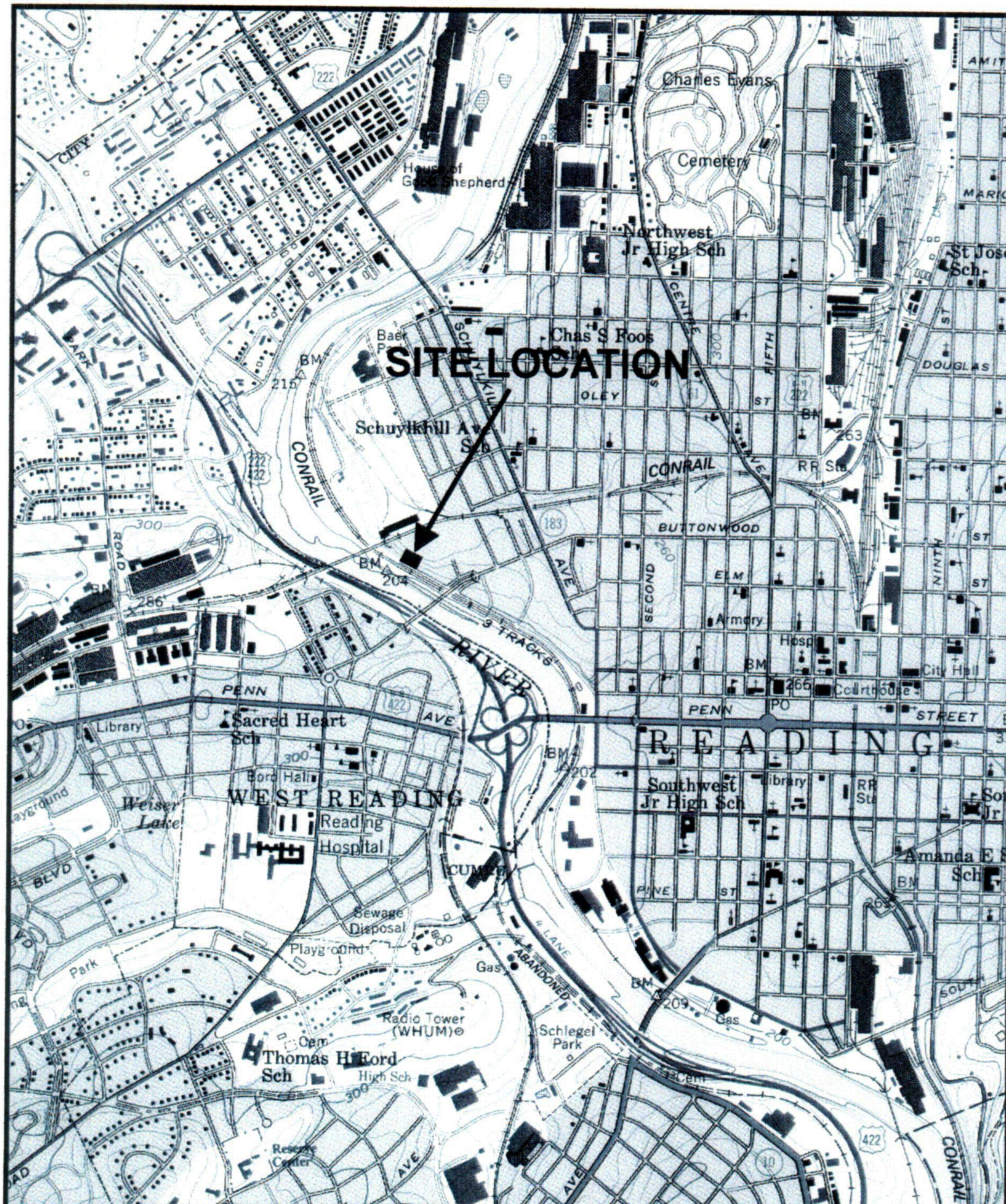
NOTES: * All results in pCi/l
Sigma = 2 Standard Deviations (95% Confidence Interval)
(a) Adjusted gross alpha - screening level (= gross alpha minus radium 226 and uranium)
(b) Gross beta screening level
All standards are from: 56 FR 138, National Primary Drinking Water Regulations; Radionuclides; Proposed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

TABLE 1-2
SUMMARY OF 1999 SOIL SAMPLING RESULTS
Reading Slag Pile Site

	LABORATORY DATA *									CALCULATED RESULTS		
SAMPLE ID	Tl-208	Bi-212	Pb-212	Bi-214	Pb-214	Ac-228	Pa-234m	Th-234	Total U	TOTAL Th (Ac 228 + Tl-208)	TOTAL U (2X Th-234)	Total U+Th
SO1-0.5D	19.61	14.3	20.5	13.39	12.69	20.59	17.9		22.12	40.2	22.12	62.32
ERROR	1.65	2	2.13	0.91	0.8	1.32	13.02		7.73			
MDA	0.54	1.45	0.38	0.36	0.42	0.6	16.16		4.48			
SO1-0.5	19.37	13.15	20.59	12.58	13.24	21.37	18.66		36.3	40.74	36.3	77.04
ERROR	1.65	1.85	2.14	0.9	0.83	1.36	13.8		9.93			
MDA	0.53	1.74	0.38	0.37	0.42	0.54	15.54		4.54			
SO1-1.5	14.74	10.42	16.17	10.22	10.27	15.73	21.49	-6.07		30.47	27.74	58.21
ERROR	1.42	1.8	2.58	0.79	0.82	1.11	13.5	6.7			**(Calculated)	
MDA	0.48	1.32	0.34	0.31	0.37	0.47	13.03	10.25				
SO1-2.5	0.95	0.69	1.52	0.92	1.05	1.01	-0.83		5.47	1.96	5.47	7.43
ERROR	0.16	0.37	0.21	0.16	0.13	0.21	3.88		2.3			
MDA	0.19	0.51	0.09	0.12	0.12	0.23	7.05		1.14			
SO2-0.5	1.07	0.51	1.01	0.89	0.84	1.12	1.53		1.01	2.19	1.01	3.20
ERROR	0.17	0.34	0.13	0.13	0.11	0.15	2.73		3.22			
MDA	0.13	0.4	0.08	0.09	0.1	0.18	5.12		2.59			
SO2-1.5	0.66	0.61	0.49	0.53	0.65	0.72	0.95		2.81	1.38	2.81	4.19
ERROR	0.18	0.4	0.12	0.14	0.15	0.2	4.79		2.54			
MDA	0.18	0.55	0.12	0.13	0.15	0.25	9.42		1.34			
SO2-2.5	2.05	1.09	2.98	1.5	1.89	1.86	1.98		7.06	3.91	7.06	10.97
ERROR	0.27	0.79	0.36	0.23	0.28	0.29	5.01		3.58			
MDA	0.2	0.64	0.12	0.16	0.16	0.29	9.51		1.58			
SO3-0.5	8.93	5.31	9.06	5.88	5.77	9.17	12.81		22.9	18.1	22.9	41.00
ERROR	0.91	1.36	0.98	0.51	0.45	0.74	9.42		6.98			
MDA	0.45	1.27	0.29	0.28	0.34	0.44	13.36		3.68			
SO3-1.5	5.73	4.1	6.18	3.91	4.4	6.59	16.96		9.8	12.32	9.8	22.12
ERROR	0.7	0.98	0.92	0.41	0.41	0.57	10.38		9.4			
MDA	0.35	0.92	0.23	0.22	0.26	0.4	9.9		7.29			
SO3-2.5	1.16	1.43	1.56	1.38	1.05	1.29	24.08		1.94	2.45	1.94	4.39
ERROR	0.26	0.56	0.21	0.23	0.19	0.29	11.55		3.21			
MDA	0.27	0.68	0.13	0.17	0.16	0.32	8.68		1.64			
SO4-0.0 (Background)	0.97	0.47	0.86	0.77	0.92	0.92	1.6		3.51	1.89	3.51	5.40
ERROR	0.15	0.35	0.12	0.13	0.12	0.17	3.13		1.69			
MDA	0.16	0.38	0.08	0.1	0.11	0.18	6.1		0.98			
Blank	-0.1	-0.07	0.01	0	-0.01	-0.08	3.66	0.18				
ERROR	0.07	0.17	0.04	0.05	0.04	0.07	2.56	0.97				
MDA	0.13	0.29	0.06	0.1	0.08	0.1	3.14	1.78				
									AVERAGES	14.15	12.79	26.93

*All Values in pCi/gm

**Caclulated value for Total U (S01-1.5) = Average of Bi-214, Pb-214, Pa-234



SCALE FEET

0 2,000 4,000

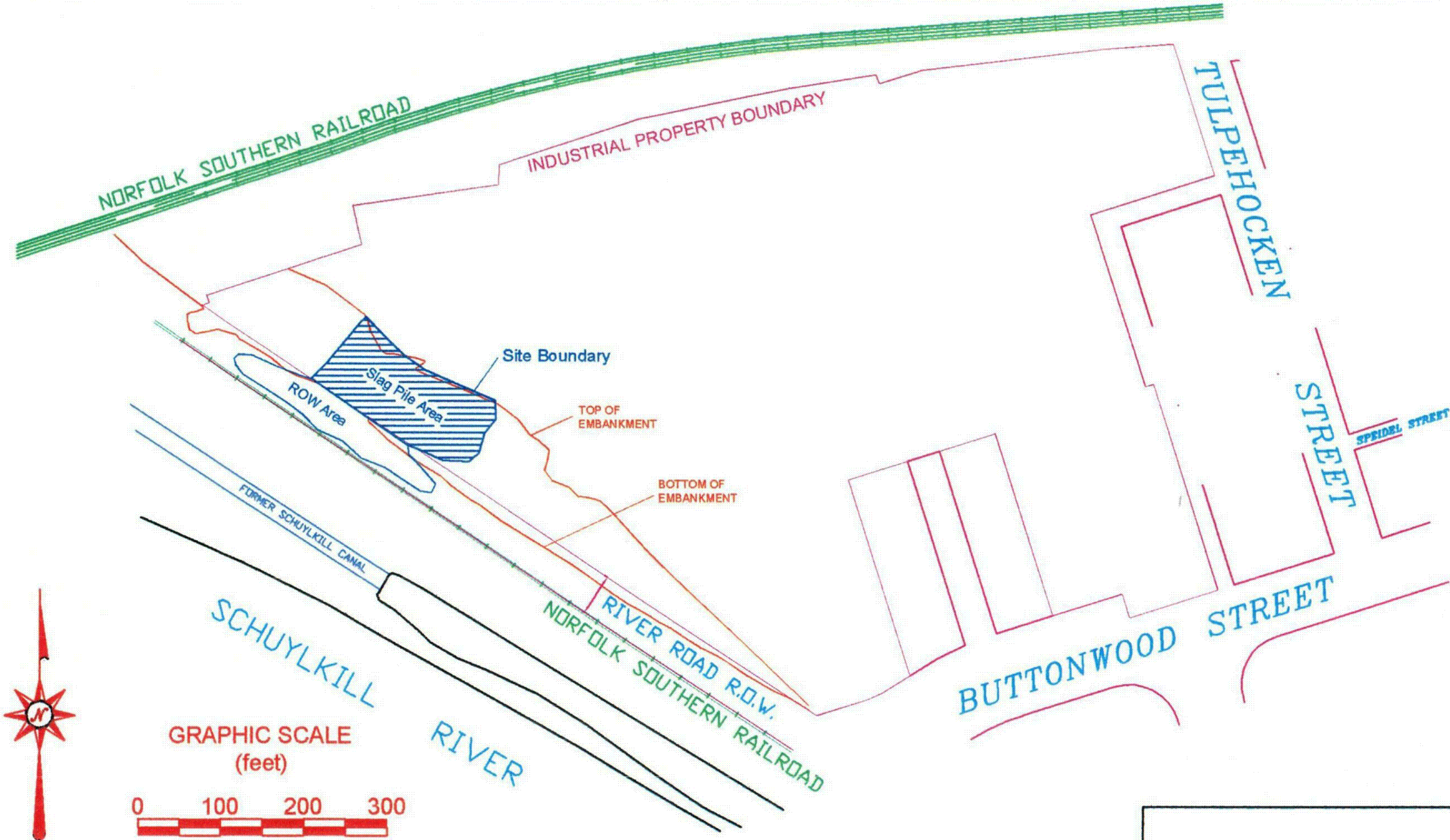
NORTH

FIGURE 1-1
Site Location Map
READING SLAG PILE SITE

SOURCE: USGS, Reading, PA, 7.5 Minute Quadrangle

STEP

ST Environmental Professionals, Inc.
STEP Project Number 90C057
August, 2006



NOTE: The base map (including property boundaries, buildings, rights of way, elevation contours, electric lines, and utility poles) is to scale. It was prepared by a Pennsylvania licensed surveyor. The location of the former Schuylkill Canal and Schuylkill River are approximate and based on the USGS Reading 7 1/2 minute topographic quadrangle.

FIGURE 1-2
SITE VICINITY MAP

Reading Slag Pile Site

ST Environmental Professionals, Inc.
August 2006, Project Number 90C057

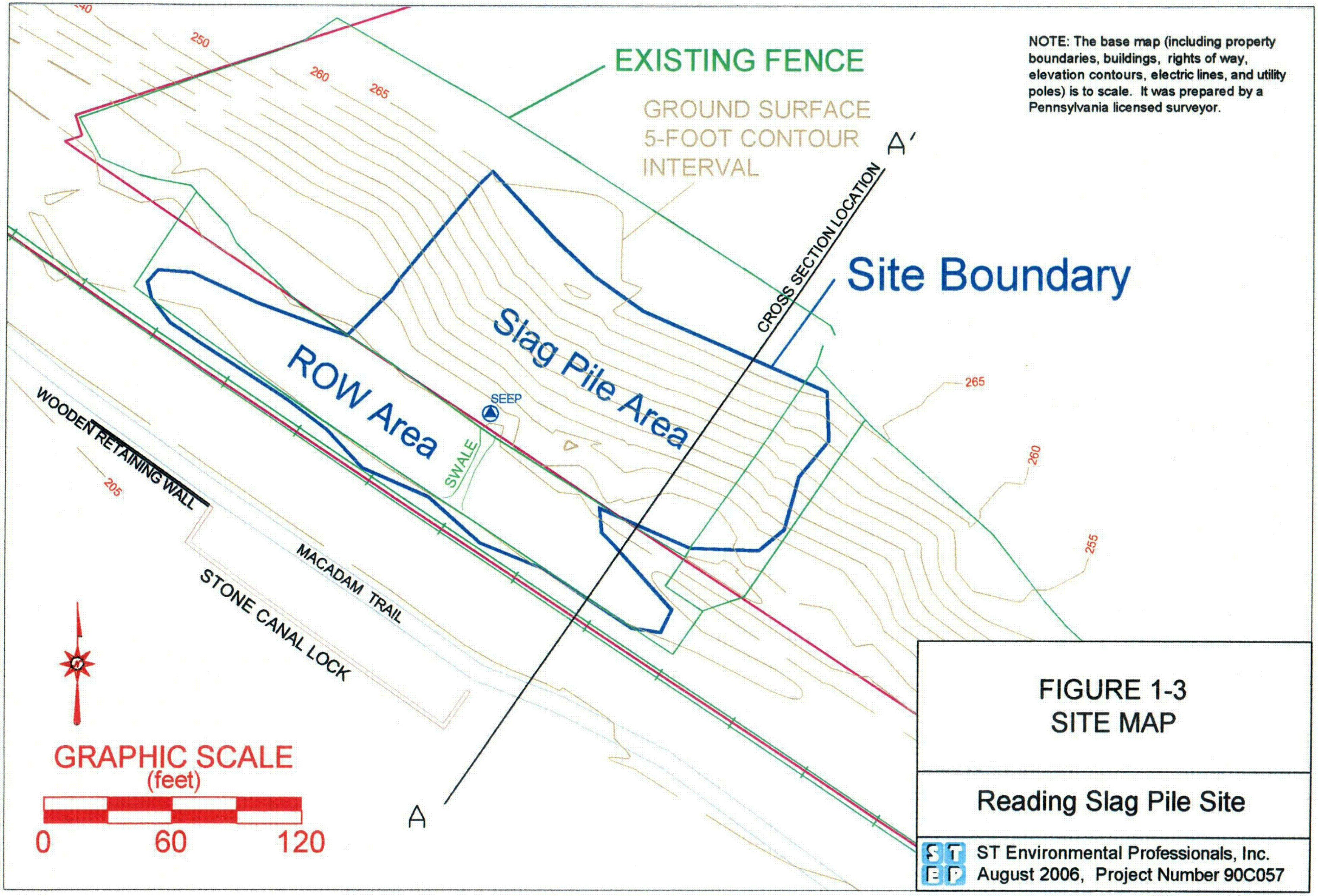
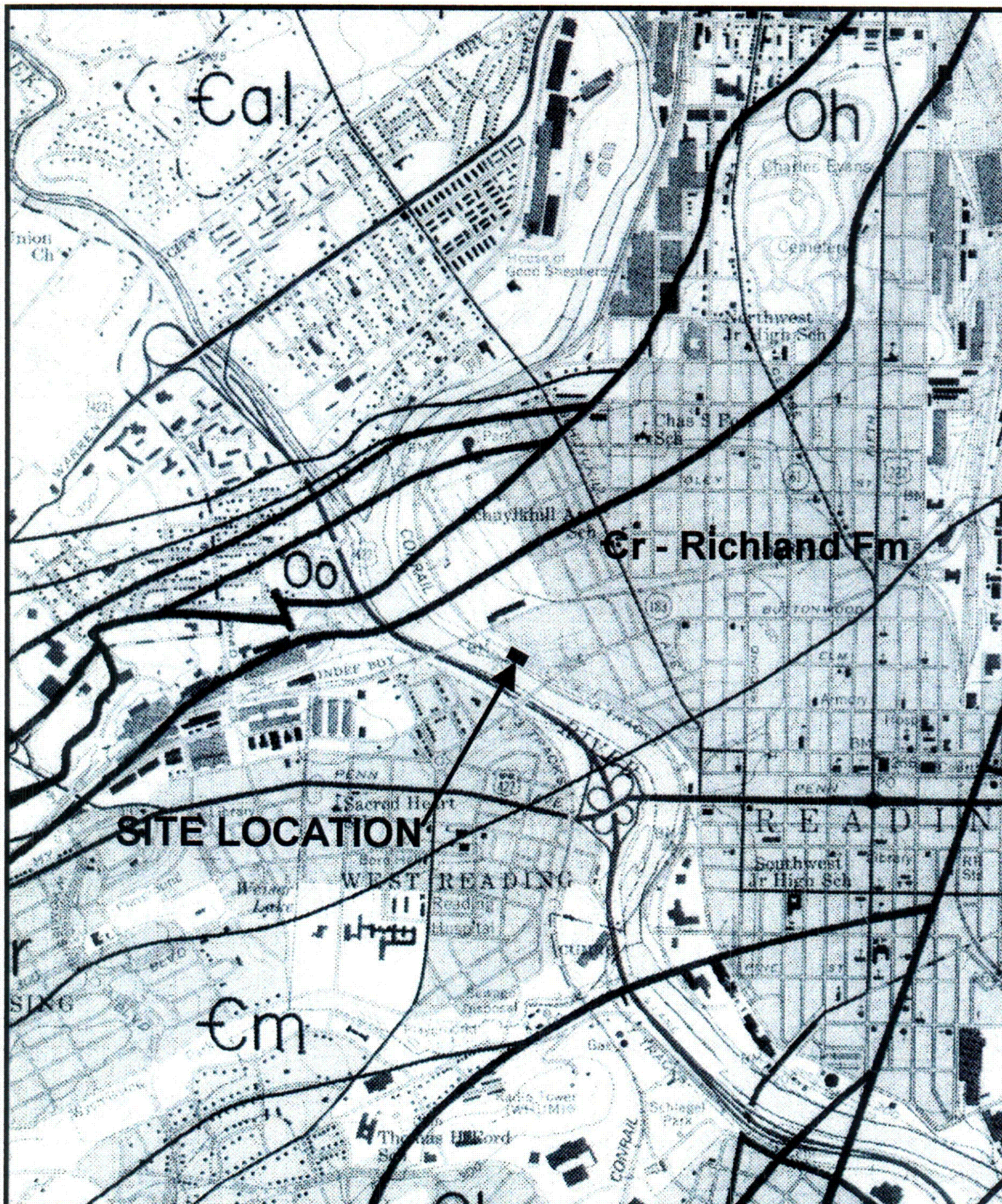


FIGURE 1-3
SITE MAP

Reading Slag Pile Site

ST Environmental Professionals, Inc.
August 2006, Project Number 90C057



SCALE FEET

0 2,000 4,000

NORTH

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

FIGURE 1-4
Geologic Map
READING SLAG PILE SITE

ST Environmental Professionals, Inc.
STEP Project Number 90C057
August, 2006

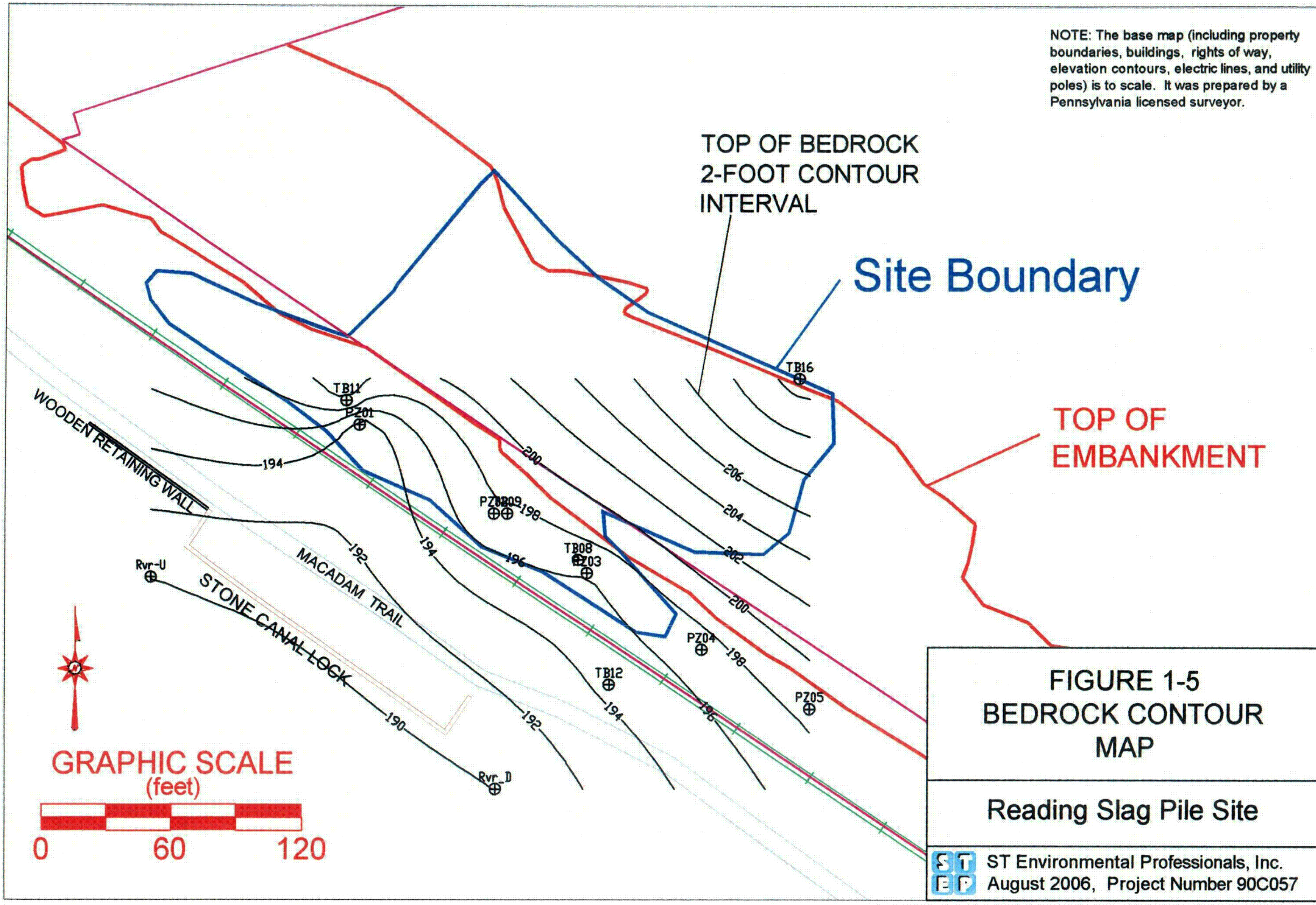


FIGURE 1-5
BEDROCK CONTOUR MAP

Reading Slag Pile Site

ST Environmental Professionals, Inc.
August 2006, Project Number 90C057

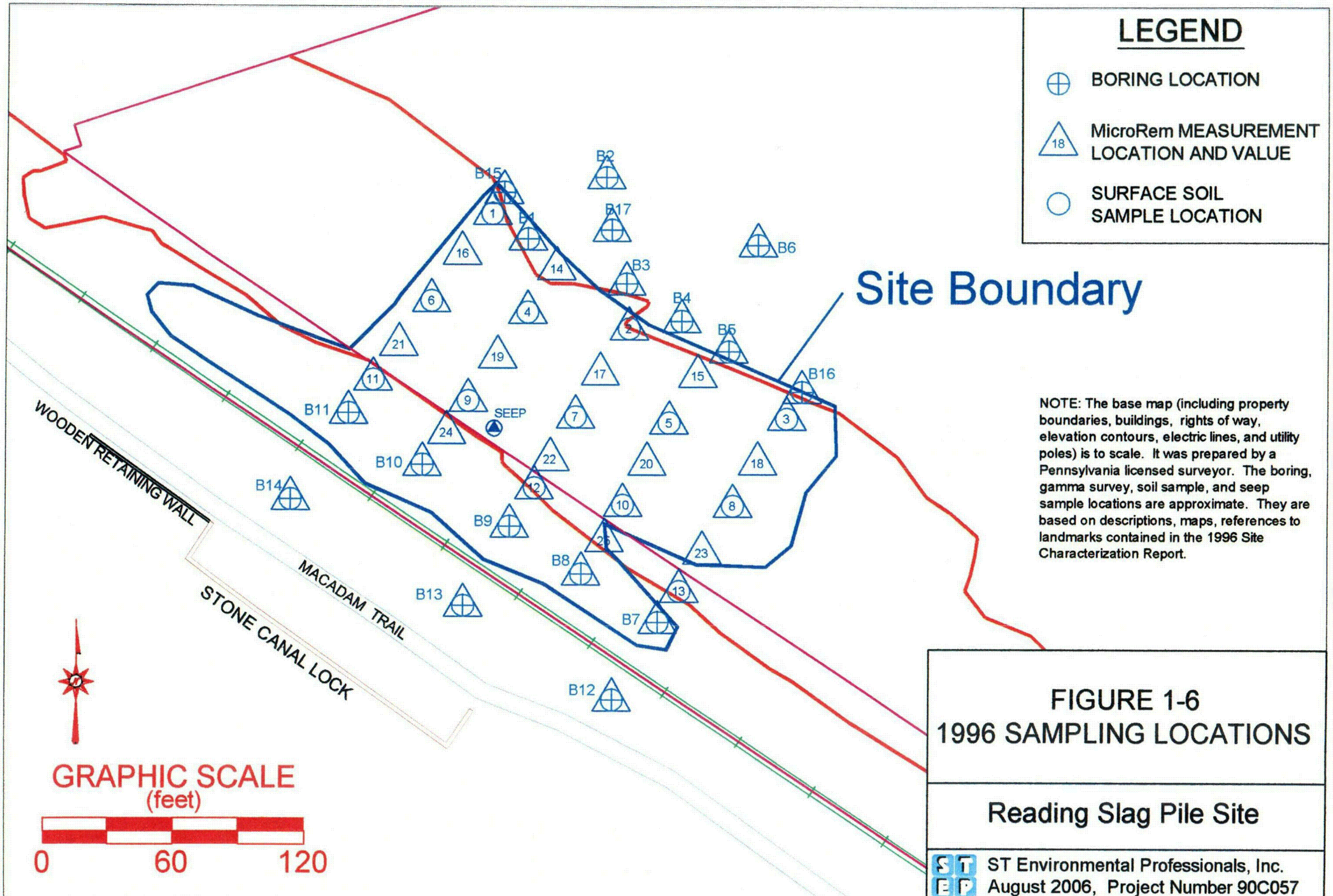


FIGURE 1-6
1996 SAMPLING LOCATIONS

Reading Slag Pile Site

ST Environmental Professionals, Inc.
August 2006, Project Number 90C057

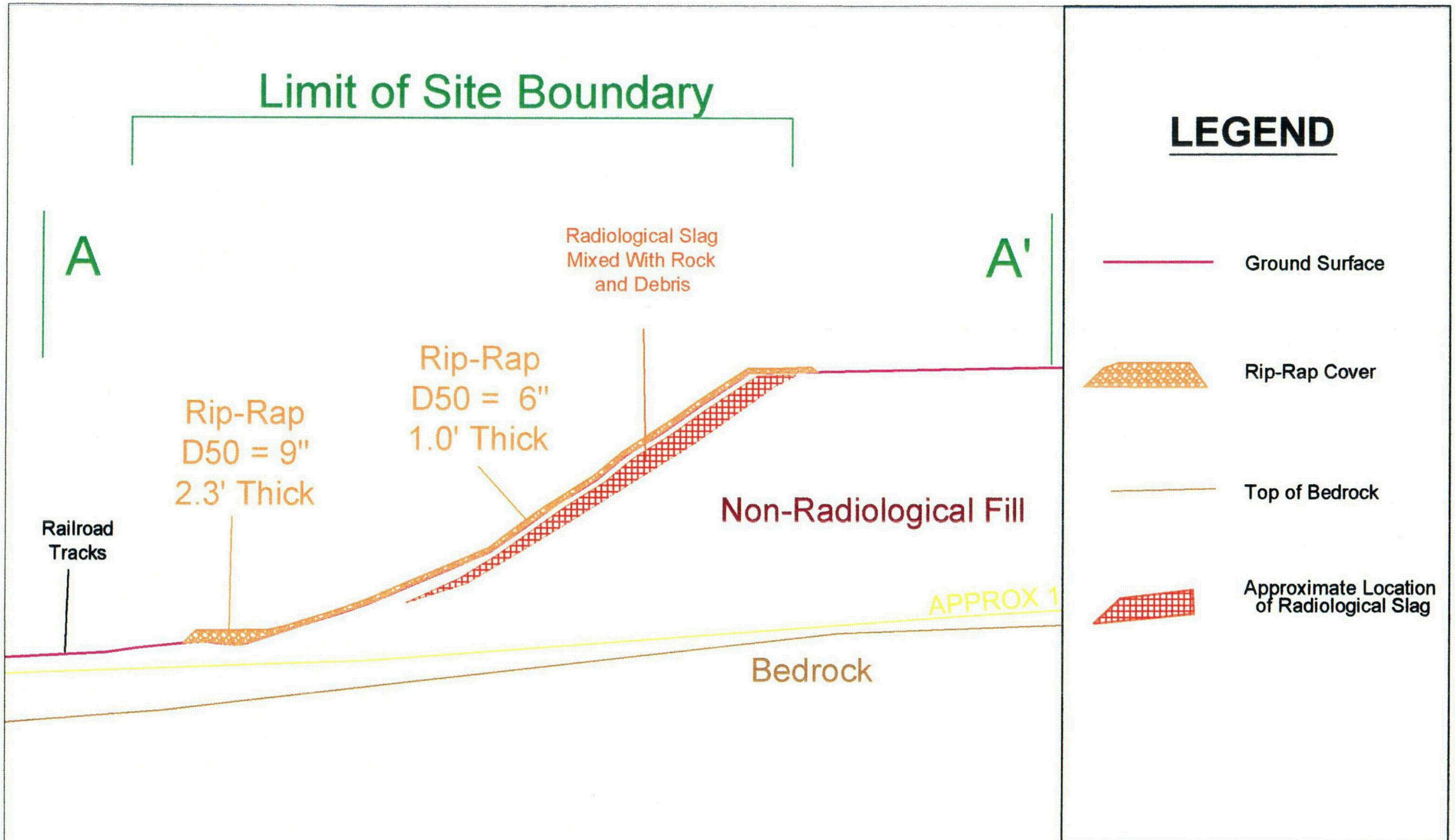
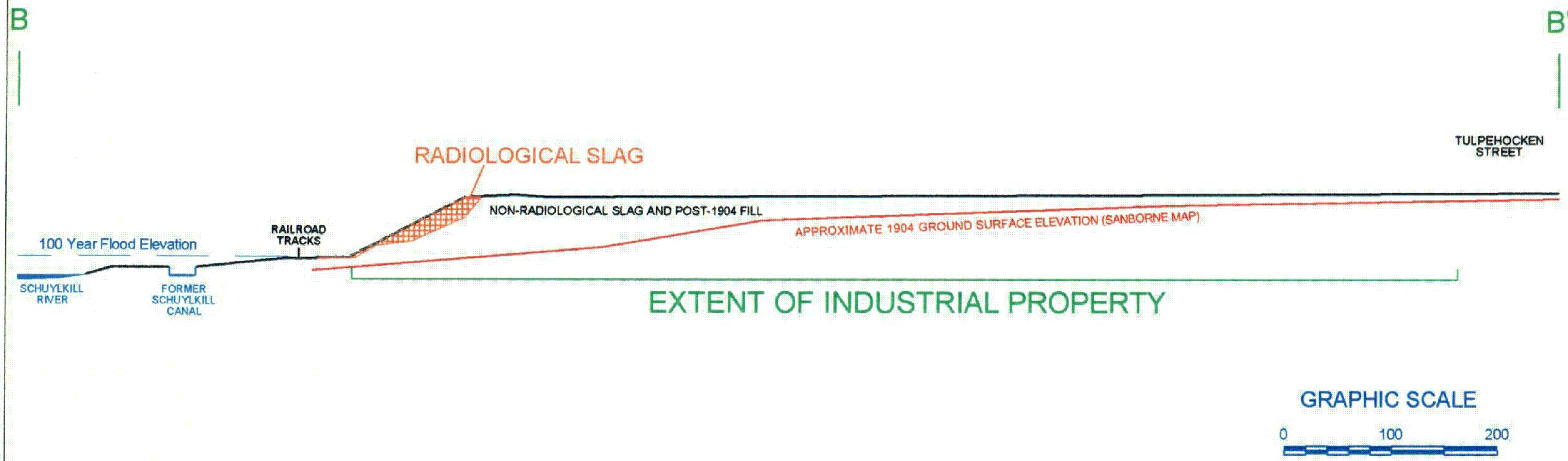


FIGURE 1-7
TYPICAL CROSS SECTION
OF RIPRAP COVER

Reading Slag Pile Site (DA)

ST Environmental Professionals, Inc.
August 2006, Rev. 4, Project No. 90C057



LOCATION OF CROSS SECTION BB' IN PLAN VIEW

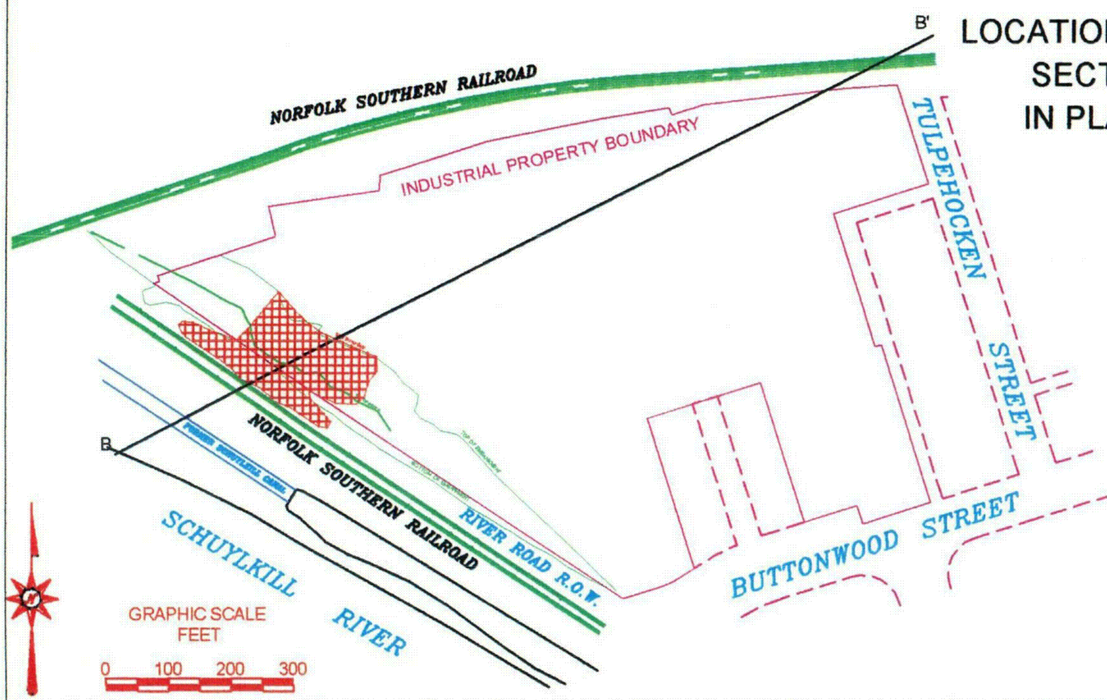


FIGURE 1-8
CROSS SECTION BB'

Reading Slag Pile SIte

STEP ST Environmental Professionals, Inc.
August 2006, Project No. 90C057

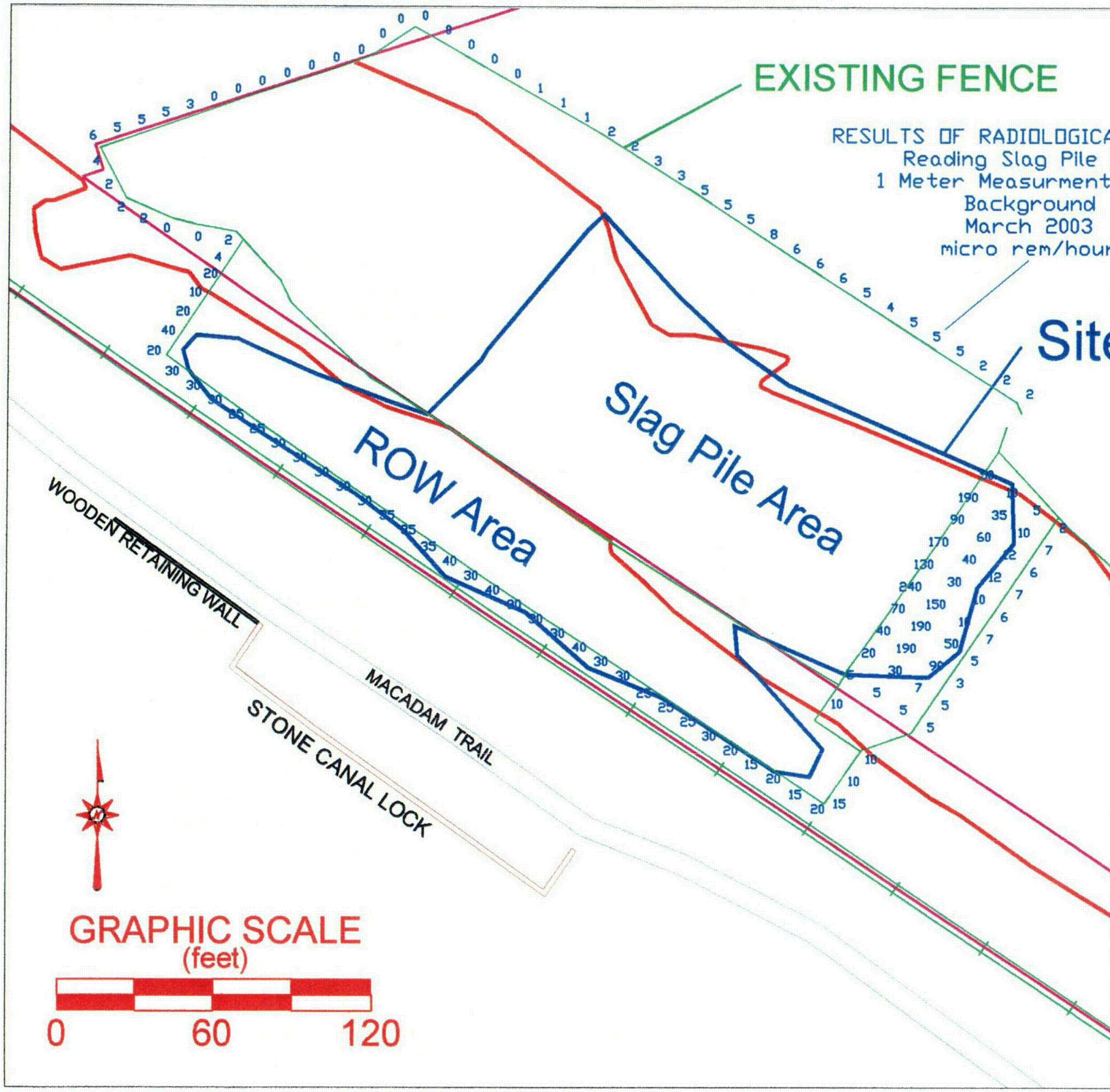


FIGURE 1-9
2003 RADIOLOGICAL SURVEY
LOCATION AND
RESULTS MAP

Reading Slag Pile Site

ST Environmental Professionals, Inc.
August 2006, Project Number 90C057

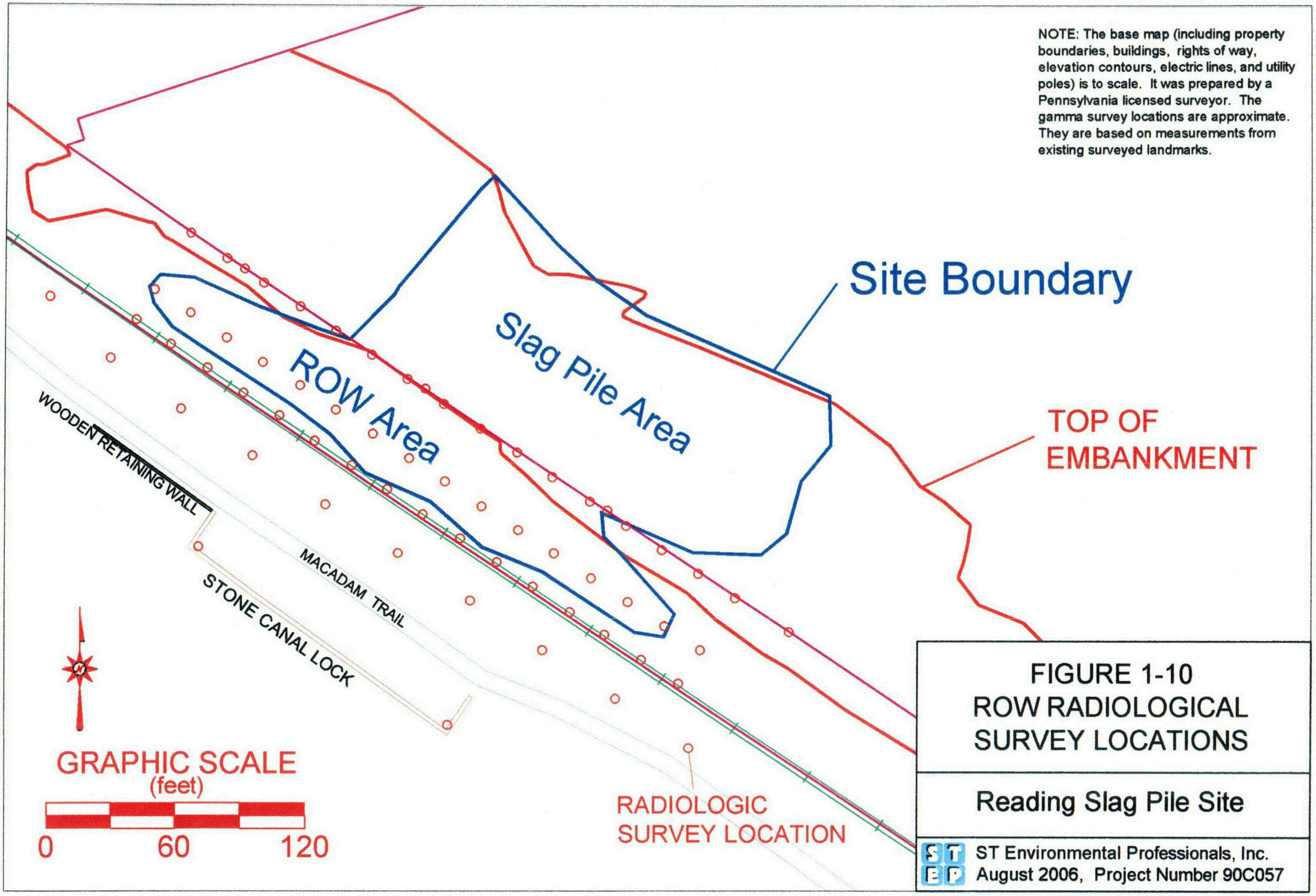
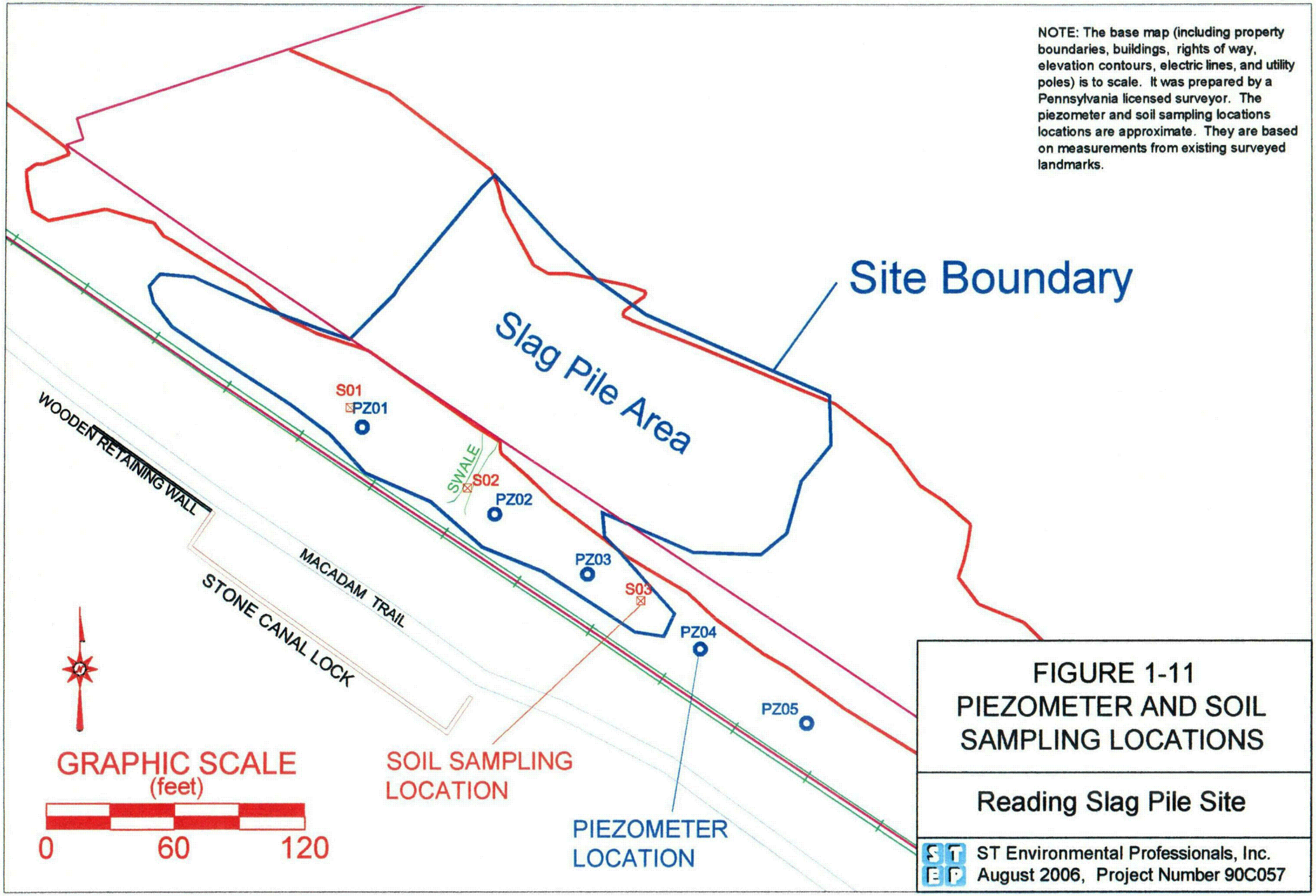


FIGURE 1-10
ROW RADIOLOGICAL SURVEY LOCATIONS

Reading Slag Pile Site

ST Environmental Professionals, Inc.
August 2006, Project Number 90C057


NOTE: The base map (including property boundaries, buildings, rights of way, elevation contours, electric lines, and utility poles) is to scale. It was prepared by a Pennsylvania licensed surveyor. The piezometer and soil sampling locations locations are approximate. They are based on measurements from existing surveyed landmarks.
Site Boundary
Slag Pile Area
S01
PZ01
SWALE
S02
PZ02
PZ03
S03
PZ04
PZ05
WOODEN RETAINING WALL
MACADAM TRAIL
STONE CANAL LOCK
GRAPHIC SCALE
(feet)
0
60
120
SOIL SAMPLING LOCATION
PIEZOMETER LOCATION
FIGURE 1-11
PIEZOMETER AND SOIL SAMPLING LOCATIONS
Reading Slag Pile Site
ST Environmental Professionals, Inc.
August 2006, Project Number 90C057

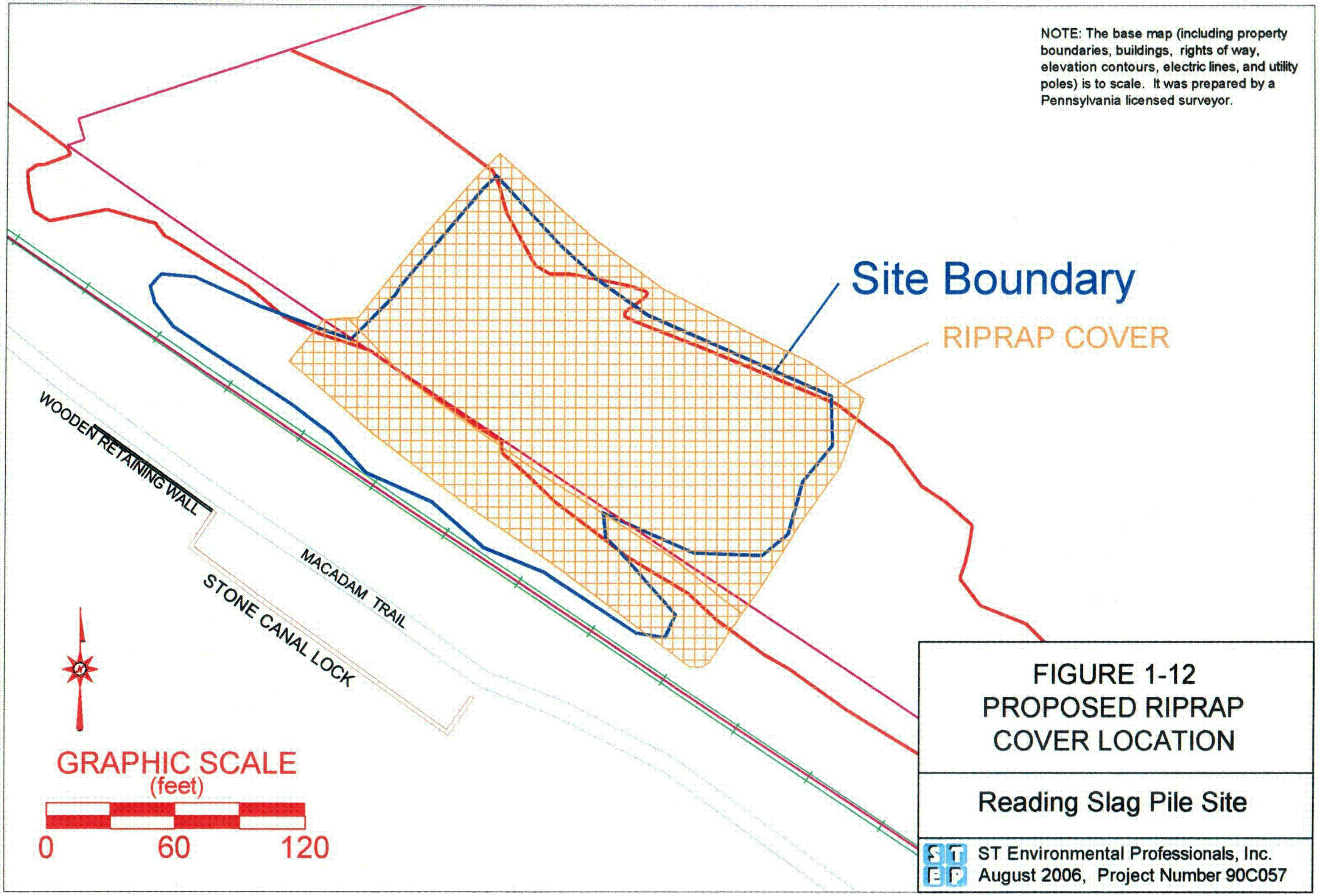


FIGURE 1-12
PROPOSED RIPRAP
COVER LOCATION

Reading Slag Pile Site

ST Environmental Professionals, Inc.
August 2006, Project Number 90C057

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. However, Cabot has proposed the addition of a riprap cover to provide additional assurance that the potential future dose remains well below the 25 mrem/y criteria for unrestricted use. 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 and seep samples collected from the base of the slag pile
- Performance of a Radiological Assessment
- Preparation of this Decommissioning Plan

Using the characterization information and installation of the proposed riprap cover, the Radiological Assessment Report (STEP, 2006a) concludes that the potential exposure levels, with or without the riprap cover, 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 further decommissioning activities are required.

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

During the installation of the riprap cover, Cabot will control and monitor the radiation exposures of workers and the public by exercising project managerial control and by implementing applicable portions of the radiation protection program Cabot operates under NRC license no. SMB-920 at its nearby Boyertown, PA facility. A site-specific radiological health and safety plan has been developed and is contained in Addendum 1 (STEP, 2006b) to this Decommissioning Plan.

4.0 PLANNED FINAL RADIATION SURVEY

Because the radiological assessment demonstrates that the Site meets the10 CFR Part 20, Subpart E criteria for unrestricted release, this section is not applicable.

Cabot has been performing regular surveys of the site as part of their license conditions. Cabot will perform a final routine survey following completion of the cover installation. Following termination of the license and release for unrestricted use, the routine surveys will not be needed or required

5.0 FUNDING

A detailed engineering cost estimate for installation of the riprap cover has been performed and is contained in the Addendum 1 (STEP, 2006b) to this Decommissioning Plan. Under separate cover, Cabot has submitted to the NRC an amendment to the existing irrevocable standby letter of credit number: 50087077 to cover the estimated cost of $460,000.00.

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.

A site-specific radiological health and safety plan that covers the procedures to be utilized during the installation of the riprap cover is incorporated in Addendum 1 (STEP, 2006b) to this Decommissioning Plan. Prior to implementation of the cover installation, a detailed construction design and bid package will be developed that includes the specific site security and control provisions.

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, 2002, Cabot Corporation, *Report on Johns Hopkins Progress Report and Related Items*, 2002.

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-1623, *Design of Erosion Protection for Long-Term Stabilization*, USNRC, September 2002.

NUREG-1703, *Characterization of Radioactive Slags*, USNRC, October 2004.

NUREG-6632/PNNL-12205, Solubility and Leaching of Radionuclides in Site Decommissioning Management Plan (SDMP) Slags, USNRC and PNNL, February 2002.

STEP, 2006a, (ST Environmental Professionals, Inc.) *Radiological Assessment, Reading, Pennsylvania Slag Pile Site, Revision 4*, Prepared for Cabot Corporation, August 21, 2006.

STEP, 2006b, (ST Environmental Professionals, Inc.) *Addendum 1 to the Decommissioning Plan for the Reading Slag Pile Site, Reading, Pennsylvania Slag Pile Site,* Prepared for Cabot Corporation, August 5, 2006.

STEP, 2000 (ST Environmental Professionals, Inc.) *Radiological Assessment, Reading, Pennsylvania Slag Pile Site, Revision 1*, Prepared for Cabot Corporation, February 24, 2000.

STEP, 1999 (ST Environmental Professionals, Inc.), *Report on Topographic and Radiological Surveys, Reading Slag Pile Site*, Prepared for Cabot Corporation, January 25, 1999.

STEP, 1998 (ST Environmental Professionals, Inc.*), Radiological Assessment, Reading, Pennsylvania Slag Pile Site, Revision 0*, 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.

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

APPENDIX A

GROUNDWATER INVESTIGATION

BORING LOGS

ST Environmental Professionals, Inc.

DRILLING LOG

LOCATION IDENTIFICATION: P201	DATE(S): 06/30/98	PAGE 1 OF 1
CLIENT: CABOT	PROJECT: Reading Slag Pile Site	STEP PROJ. NUMBER: 97C9057
CONTRACTOR: Advanced Drilling	DRILLER: Roger Logel	EQUIPMENT: Failing SS-50
GEOLOGIST: S. Helbig	GROUND SURFACE ELEVATION:	WATER LEVEL REFERENCE AND ELEVATION:

BORING DIAMETER(S): 4.25-Inch OD HS Augers

WELL CONSTRUCTION: 1-Foot X 1.5-Inch OD Porous Tip, 3/4-Inch PVC Riser, PVC Cap

WATER LEVEL OBSERVATIONS:

DEPTH (Feet)	SAMPLE ID	RECOVERY	BLOWS/TIME	DESCRIPTION	LITHOLOGY	WELL CONSTRUCTION	COMMENTS
0–4	NONE			Dark Gray FILL Cinders, Slag, Rock Fragments, occ. Boulder Dry.		Cuttings; 3/4" PVC Riser	Start 6/30/98 08:45 Cuttings 20-40 μR/hr. Background 20-40 μR/hr
5–8				silty SAND and GRAVEL moist			
10–12				Soft - Easy Drilling No Cuttings			
14–15							Cobbly Drilling (Driller Obsv.)
16–19						B; S; T	Drill Rig Chatter Refusal - TOR
20							EOB 19.0' 6/30/98 09:20
25							
30							

ST Environmental Professionals, Inc.

DRILLING LOG

LOCATION IDENTIFICATION: P202	DATE(S): 06/30/98	PAGE 1 OF 1
CLIENT: CABOT	PROJECT: Reading Slag Pile Site	STEP PROJ. NUMBER: 97C9057
CONTRACTOR: Advanced Drilling	DRILLER: Roger Logel	EQUIPMENT: Failing SS-50
GEOLOGIST: S. Helbig	GROUND SURFACE ELEVATION:	WATER LEVEL REFERENCE AND ELEVATION:

BORING DIAMETER(S): 4.25-Inch OD HS Augers

WELL CONSTRUCTION: 1-Foot X 1.5-Inch OD Porous Tip, 3/4-Inch PVC Riser, PVC Cap

WATER LEVEL OBSERVATIONS:

DEPTH (Feet)	SAMPLE ID	RECOVERY	BLOWS/TIME	DESCRIPTION	LITHOLOGY	WELL CONSTRUCTION	COMMENTS
0–4				Dark Gray Fill - Cinders occ Gravel Dry to sl. Moist		Cuttings; 3/4" PVC Riser	Start 6/30/98 10:25 Cuttings 20-40 µR/hr Background 20-40 µR/hr
5							
10							
11–13						B; S; T	Cobbly Drilling No Return Boulder/Cobbles ? Refusal TOR
14							EOB 14.0' 6/30/98
15	NONE						
20							
25							
30							

ST Environmental Professionals, Inc.	DRILLING LOG	LOCATION IDENTIFICATION: P203
		DATE(S): 06/30/98 — PAGE 1 OF 1
CLIENT: CABOT	PROJECT: Reading Slag Pile Site	STEP PROJ. NUMBER: 97C9057
CONTRACTOR: Advanced Drilling	DRILLER: Roger Logel	EQUIPMENT: Failing SS-50
GEOLOGIST: S. Helbig	GROUND SURFACE ELEVATION:	WATER LEVEL REFERENCE AND ELEVATION:

BORING DIAMETER(S): 4.25-Inch OD HS Augers

WELL CONSTRUCTION: 1-Foot X 1.5-Inch OD Porous Tip, 3/4-Inch PVC Riser, PVC Cap

WATER LEVEL OBSERVATIONS:

DEPTH (Feet)	SAMPLE ID	RECOVERY	BLOWS/TIME	DESCRIPTION	LITHOLOGY	WELL CONSTRUCTION	COMMENTS
0–1				Dark Gray FILL Cinders, Dry to sl. Moist			Start 6/30/98 11:20
							Cuttings 20-30 μR/hr.
							Background 20-40 μR/hr.
5							
0–12						Cuttings; 3/4" PVC Riser	
10							Soft Drilling
11							Hard Drilling No Return
12–13	NONE			occ. Gravel		B	Soft Drilling
13–16						S; T	
15–16							Refusal TOR
16							BOB 16.0' 6/30/98 12:10
20							
25							
30							

ST Environmental Professionals, Inc.

DRILLING LOG

LOCATION IDENTIFICATION: P204	DATE(S): 06/30/98	PAGE 1 OF 1
CLIENT: CABOT	PROJECT: Reading Slag Pile Site	STEP PROJ. NUMBER: 97C9057
CONTRACTOR: Advanced Drilling	DRILLER: Roger Logel	EQUIPMENT: Failing SS-50
GEOLOGIST: S. Helbig	GROUND SURFACE ELEVATION:	WATER LEVEL REFERENCE AND ELEVATION:

BORING DIAMETER(S): 4.25-Inch OD HS Augers

WELL CONSTRUCTION: 1-Foot X 1.5-Inch OD Porous Tip, 3/4-Inch PVC Riser, PVC Cap

WATER LEVEL OBSERVATIONS:

DEPTH (Feet)	SAMPLE ID	RECOVERY	BLOWS/TIME	DESCRIPTION	LITHOLOGY	WELL CONSTRUCTION	COMMENTS
0–5				Dark Gray FILL Cinders Creosote-Like Odor on Wood Fragments - RR Tie? Dark Gray FILL-Cinders		Cuttings; 3/4" PVC Riser	Start 6/30/98 12:45 Cuttings 20 µR/hr Background 20-40µR/hr
~7				Gravel / Boulder			
~8–13.5				Dark Brown SAND		B; S; T	Cobbly Drilling No Return Refusal TOR
13.5	NONE						EOB 13.5' 6/30/98 13:10
15, 20, 25, 30							

ST Environmental Professionals, Inc.

DRILLING LOG

LOCATION IDENTIFICATION: P205	DATE(S): 06/30/98	PAGE 1 OF 1
CLIENT: CABOT	PROJECT: Reading Slag Pile Site	STEP PROJ. NUMBER: 97C9057
CONTRACTOR: Advanced Drilling	DRILLER: Roger Logel	EQUIPMENT: Failing SS-50
GEOLOGIST: S. Helbig	GROUND SURFACE ELEVATION:	WATER LEVEL REFERENCE AND ELEVATION:

BORING DIAMETER(S): 4.25-Inch OD HS Augers

WELL CONSTRUCTION: 1-Foot X 1.5-Inch OD Porous Tip, 3/4-Inch PVC Riser, PVC Cap

WATER LEVEL OBSERVATIONS:

DEPTH (Feet)	SAMPLE ID	RECOVERY	BLOWS/TIME	DESCRIPTION	LITHOLOGY	WELL CONSTRUCTION	COMMENTS
0–11	NONE			Dark Gray FILL Cinders, Dry to sl. Moist		Cuttings; 3/4 PVC Riser; B; S; T	Start 6/30/98 13:30 Cuttings 20 µR/hr Background 20-40 µR/hr Hard Drilling Gravel? No Return Refusal TOR
11							EOB 6/30/98 14:30 11.0'

Depth scale: 5, 10, 15, 20, 25, 30

WATER LEVEL MEASUREMENTS

TABLE A-1
WATER LEVEL MEASUREMENTS
Reading Slag Pile Site

WELL ID	GROUND SURFACE ELEVATION	TOP OF PVC CASING ELEVATION	TOTAL DEPTH FROM TOC	WATER LEVEL READING BELOW TOC		WATER LEVEL ELEVATION (MSL)	
				7/9/98	8/20/98	7/9/98	8/20/98
PZ01	211.40	211.80	19.50	14.75	16.21	197.05	195.59
PZ02	121.19	212.49	14.25	13.29	14.16	199.20	198.33
PZ03	211.04	211.29	15.83	13.72	DRY	197.57	--
PZ04	210.29	210.54	13.59	13.26	DRY	197.28	--
PZ05	209.89	210.04	10.65	DRY	DRY	--	--

LABORATORY ANALYTICAL RESULTS

GROUNDWATER SAMPLING

AUG 1 1998

TELEDYNE BROWN ENGINEERING Environmental Services

REPORT OF ANALYSIS

Aug 10 1998, 08:01 am

LOGIN # L2156

Address:	Work Order #:	Cust. P.O. #:	Date Received	Delivery Date	PAGE: 1
STEFFAN R HELBIG ST ENVIRONMENTAL PROFESSIONALS INC RR 4 BOX 239 LUTZ ROAD BOYERTOWN PA 19512	L2156	Release #:	07/20/98	08/10/98	Project Manager: C.STARR

Teledyne Sample #	Customer's Identification	Sta. #	Collection-Dates Start Date/Time	Stop Date/Time	Matrix/ Nuclide	Activity	Units	Count Date	Volume Procedure #	Units	Lab Comment
Matrix - W-Ground											
L2156-1	PZ-1A		07/09/98 00:00		Water-Ground						
TI#-81899					GR-A	L.T. 6. E 00	pCi/l	07/30/98			32
					GR-B (-K-40)	L.T. 8. E 00		08/06/98			32
					TH-228	1.1 +-0.5 E 00		08/05/98			62
					TH-230	L.T. 1. E-01		08/05/98			62
					TH-232	L.T. 1. E-01		08/05/98			62
					U-233/234	1.3 +-0.4 E 00		08/05/98			62
					U-235	L.T. 1. E-01		08/05/98			62
					U-238	1.0 +-0.3 E 00		08/05/98			62
L2156-2	PZ-1B		07/09/98 00:00		Water-Ground						
TI#-81900					GR-A	L.T. 6. E 00		07/30/98			32
					GR-B (-K-40)	L.T. 8. E 00		08/06/98			32
					TH-228	L.T. 7. E-01		08/05/98			62
					TH-230	L.T. 2. E-01		08/05/98			62
					TH-232	L.T. 2. E-01		08/05/98			62
					U-233/234	6.8 +-2.7 E-01		08/05/98			62
					U-235	L.T. 1. E-01		08/05/98			62
					U-238	1.1 +-0.3 E 00		08/05/98			62
L2156-3	PZ-2A		07/09/98 00:00		Water-Ground						
TI#-81901					GR-A	L.T. 8. E 00		07/30/98			32
					GR-B (-K-40)	L.T. 9. E 00		08/06/98			32
					TH-228	8.6 +-5.2 E-01		08/05/98			62
					TH-230	L.T. 2. E-01		08/05/98			62
					TH-232	L.T. 2. E-01		08/05/98			62
					U-233/234	3.8 +-0.7 E 00		08/05/98			62
					U-235	1.8 +-1.6 E-01		08/05/98			62
					U-238	4.1 +-0.8 E 00		08/05/98			62
L2156-4	PZ-2B		07/09/98 00:00		Water-Ground						
TI#-81902					GR-A	L.T. 8. E 00		07/30/98			32

Lab Key: 22 - Gas Lab; 32 - Radiochemistry Lab; 42 - GE(Li) Gamma Spec Lab; 52 - Tritium Lab; 62 - Alpha Spec Lab; 12 - Environmental TLD; 72 - Consulting;

TELEDYNE BROWN ENGINEERING Environmental Services

REPORT OF ANALYSIS

Aug 10 1998, 08:01 am

LOGIN # L2156

Address:	Work Order #:	Cust. P.O. #:	Date Received	Delivery Date	PAGE: 2
STEFFAN R HELBIG ST ENVIRONMENTAL PROFESSIONALS INC RR 4 BOX 239 LUTZ ROAD BOYERTOWN PA 19512	L2156	Release #:	07/20/98	08/10/98	Project Manager: C.STARR

Teledyne Sample #	Customer's Identification	Sta. #	Collection Dates Start Date/Time	Stop Date/Time	Matrix/ Nuclide	Activity	Units	Count Date	Volume Units Procedure #	Lab	Comment
Continued											
					GR-B (-K-40)	L.T. 9. E 00	pCi/l	08/06/98		32	
					TH-228	1.3 +-0.7 E 00		08/05/98		62	
					TH-230	L.T. 2. E-01		08/05/98		62	
					TH-232	L.T. 2. E-01		08/05/98		62	
					U-233/234	5.1 +-0.9 E 00		08/05/98		62	
					U-235	L.T. 2. E-01		08/05/98		62	
					U-238	4.9 +-0.8 E 00		08/05/98		62	
L2156-5	PZ-3A		07/09/98 00:00		Water-Ground						
TI#-81903					GR-A	L.T. 7. E 00		07/30/98		32	
					GR-B (-K-40)	L.T. 9. E 00		08/06/98		32	
					TH-228	9.0 +-5.2 E-01		08/05/98		62	
					TH-230	L.T. 2. E-01		08/05/98		62	
					TH-232	L.T. 1. E-01		08/05/98		62	
					U-233/234	1.2 +-0.4 E 00		08/05/98		62	
					U-235	L.T. 1. E-01		08/05/98		62	
					U-238	1.3 +-0.4 E 00		08/05/98		62	
L2156-6	PZ-3B		07/09/98 00:00		Water-Ground						
TI#-81904					GR-A	L.T. 7. E 00		07/30/98		32	
					GR-B (-K-40)	L.T. 9. E 00		08/06/98		32	
					TH-228	9.9 +-5.3 E-01		08/05/98		62	
					TH-230	L.T. 3. E-01		08/05/98		62	
					TH-232	L.T. 2. E-01		08/05/98		62	
					U-233/234	2.0 +-0.5 E 00		08/05/98		62	
					U-235	L.T. 9. E-02		08/05/98		62	
					U-238	1.5 +-0.4 E 00		08/05/98		62	

Lab Key: 22 - Gas Lab; 32 - Radiochemistry Lab; 42 - GE(Li) Gamma Spec Lab; 52 - Tritium Lab; 62 - Alpha Spec Lab; 12 - Environmental TLD; 72 - Consulting;

TELEDYNE BROWN ENGINEERING Environmental Services

REPORT OF ANALYSIS

Aug 10 1998, 08:01 am

LOGIN # L2156

Address:	Work Order #:	Cust. P.O. #:	Date Received	Delivery Date	PAGE: 3
STEFFAN R HELBIG ST ENVIRONMENTAL PROFESSIONALS INC RR 4 BOX 239 LUTZ ROAD BOYERTOWN PA 19512	L2156	Release #:	07/20/98	08/10/98	Project Manager: C.STARR

Teledyne Sample #	Customer Identification	Stat #	Collection Dates Start Date/Time	Stop Date/Time	Matrix/ Nuclide	Activity	Units	Count Date	Volume Units Procedure #	Lab Comment

Approved By: J Guenther

Last Page of Report

Lab Key: 22 - Gas Lab; 32 - Radiochemistry Lab; 42 - GE(Li) Gamma Spec Lab; 52 - Tritium Lab; 62 - Alpha Spec Lab; 12 - Environmental TLD; 72 - Consulting;

Copy: 1 of 1

MAR 22 1999

TELEDYNE BROWN ENGINEERING Environmental Services

REPORT OF ANALYSIS

Mar 17 1999, 08:45 am

LOGIN # L4592

Address:	Work Order #:	Cust. P.O. #:	Date Received	Delivery Date	PAGE: 1
TEPPAN R HELBIG	L4592		02/05/99	03/07/99	
T ENVIRONMENTAL PROFESSIONALS INC		Release #:			Project Manager: C.STARR
R 4 BOX 239 LUTZ ROAD					
OYERTOWN PA 19512					

eledyne ample #	Customer's Identification	Sta. #	Collection Dates Start Date/Time	Stop Date/Time	Matrix/ Nuclide	Activity	Units	Count Date	Volume Procedure #	Units	Lab	Comment
atrix : W-Ground												
4592-1	PZ-1-FILTER		01/26/99 00:00		Water-Ground							
I#-98842					GR-A	L.T. 6. E 00	pCi/l	02/25/99			32	
					GR-B (-K-40)	L.T. 8. E 00		02/19/99			32	
					TH-228	L.T. 2. E 00		03/04/99			62	
					TH-230	L.T. 4. E-01		03/05/99			62	
					TH-232	L.T. 4. E-01		03/04/99			62	
					U-233/234	1.2 +-0.4 E 00		03/04/99			62	
					U-235	L.T. 1. E-01		03/04/99			62	
					U-238	1.1 +-0.4 E 00		03/04/99			62	
4592-2	PZ-2-FILTER		01/26/99 00:00		Water-Ground							
I#-98843					GR-A	L.T. 1. E 01		02/25/99			32	
					GR-B (-K-40)	L.T. 1. E 01		02/27/99			32	
					TH-228	L.T. 2. E 00		03/04/99			62	
					TH-230	L.T. 4. E-01		03/04/99			62	
					TH-232	L.T. 4. E-01		03/04/99			62	
					U-233/234	7.9 +-1.1 E 00		03/04/99			62	
					U-235	2.5 +-1.8 E-01		03/04/99			62	
					U-238	6.8 +-1.0 E 00		03/04/99			62	
4592-3	PZ-3-FILTER		01/26/99 00:00		Water-Ground							
I#-98844					GR-A	L.T. 7. E 00		02/25/99			32	
					GR-B (-K-40)	L.T. 8. E 00		02/19/99			32	
					TH-228	L.T. 9. E-01		03/05/99			62	
					TH-230	L.T. 3. E-01		03/05/99			62	
					TH-232	L.T. 3. E-01		03/05/99			62	
					U-233/234	5.2 +-2.8 E-01		03/05/99			62	
					U-235	L.T. 1. E-01		03/05/99			62	
					U-238	L.T. 2. E-01		03/05/99			62	
4592-4	PZ-1 UNFILTERED		01/26/99 00:00		Water-Ground							
I#-98845					GR-A	L.T. 7. E 00		02/25/99			32	

ab Key: 22 - Gas Lab; 32 - Radiochemistry Lab; 42 - GE(Li) Gamma Spec Lab; 52 - Tritium Lab; 62 - Alpha Spec Lab; 12 - Environmental TLD; 72 - Consulting;

Copy: 1 of 1

TELEDYNE BROWN ENGINEERING Environmental Services

REPORT OF ANALYSIS

Mar 17 1999, 08:45 am

LOGIN # L4592

ddress:	Work Order #:	Cust. P.O. #:	Date Received	Delivery Date	PAGE: 2
TEFFAN R HELBIG	L4592		02/05/99	03/07/99	
T ENVIRONMENTAL PROFESSIONALS INC		Release #:			Project Manager: C.STARR
R 4 BOX 239 LUTZ ROAD					
OYERTOWN PA 19512					

eledyne ample #	Customer's Identification	Sta. #	Collection Dates Start Date/Time	Stop Date/Time	Matrix/ Nuclide	Activity	Units	Count Date	Volume Procedure #	Units	Lab	Comment
Continued												
					GR-B (-K-40)	L.T. 8. E 00	pCi/l	02/19/99			32	
					TH-228	L.T. 1. E 00		03/05/99			62	
					TH-230	L.T. 3. E-01		03/05/99			62	
					TH-232	L.T. 2. E-01		03/05/99			62	
					U-233/234	1.2 +-0.4 E 00		03/05/99			62	
					U-235	L.T. 1. E-01		03/05/99			62	
					U-238	6.0 +-3.1 E-01		03/05/99			62	
4592-5	PZ-2 UNFILTERED		01/26/99 00:00		Water-Ground							
I#-98846					GR-A	L.T. 2. E 01		02/25/99			32	
					GR-B (-K-40)	L.T. 1. E 01		02/19/99			32	
					TH-228	L.T. 2. E 00		03/05/99			62	
					TH-230	L.T. 3. E-01		03/05/99			62	
					TH-232	L.T. 2. E-01		03/05/99			62	
					U-233/234	8.3 +-1.1 E 00		03/05/99			62	
					U-235	3.4 +-2.2 E-01		03/05/99			62	
					U-238	7.8 +-1.1 E 00		03/05/99			62	
4592-6	PZ-3 UNFILTERED		01/26/99 00:00		Water-Ground							
I#-98847					GR-A	L.T. 7. E 00		02/25/99			32	
					GR-B (-K-40)	L.T. 8. E 00		02/19/99			32	
					TH-228	L.T. 2. E 00		03/05/99			62	
					TH-230	L.T. 3. E-01		03/05/99			62	
					TH-232	L.T. 4. E-01		03/05/99			62	
					U-233/234	6.1 +-3.4 E-01		03/05/99			62	
					U-235	L.T. 1. E-01		03/05/99			62	
					U-238	5.5 +-3.0 E-01		03/05/99			62	

ab Key: 22 - Gas Lab; 32 - Radiochemistry Lab; 42 - GE(Li) Gamma Spec Lab; 52 - Tritium Lab; 62 - Alpha Spec Lab; 12 - Environmental TLD; 72 - Consulting;

APPENDIX B

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). Soil Mechanics in Engineering Practice, 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 D. Singh, Ph.D., P.E.
Principal

RDS/pd

APPENDIX C

1999 RADIOLOGICAL SURVEY

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

January 25, 1999

Paul Nightingale, Esq.
Cabot Corporation
75 State Street
Boston, MA 02109

SUBJECT: Report on Topographic and Radiological Surveys
Reading Slag Pile Site
STEP Project Number 97C9057

Dear Mr. Nightingale,

At the request of Cabot Corporation (Cabot), ST Environmental Professionals, Inc. (STEP) has performed two tasks at the Reading Slag Pile Site (Site).

1.) A topographic survey of the radiological slag pile and surrounding area including the slag embankment and River Road right of way (ROW).

2.) A radiological survey in the River Road ROW adjacent to the radiological slag pile.

This letter report provides a description of the activities, results, and analysis of results. The study demonstrates that the presence of radiological slag in the River Road ROW is of limited extent measuring approximately 300 feet long by 50 feet wide. Within the River Road ROW area where radiological slag is present, the calculated radiological dose rate is essentially the same, or slightly lower than, the dose rate on the slag pile face. Using the same scenario assumptions as the Radiological Assessment for the Reading Slag Pile Site (RA) (STEP, 1998), the dose to a trespasser in the River Road ROW would be less than 1.8 mrem/year and well below the NRC guideline of 25 mrem/year.

The following sections provide the details of the work performed and data analysis.

TOPOGRAPHIC SURVEY

A surface topographic survey of the Reading Slag Pile Site and surrounding area was performed by Kent Surveyors & Engineers (under contract to ST Environmental Professionals, Inc.) to determine the extent of features within the River Road (ROW). The topographic survey was bounded: to the southwest by the former Schuylkill Canal, to the northwest by the railroad bridge, to the northeast by the

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President
CompuServe
76323,3061

former gas house located on the industrial property, and to the southeast approximately 300 feet north of the Buttonwood Street Bridge. The field survey was conducted during the week of December 7, 1998.

The survey consisted of determining the elevation at sufficient locations to depict the surface topography with 1-foot contour lines. The survey located property lines and the River Road ROW. Physical features located by the survey included the following:

- Structures
- Railroad Tracks
- Railroad Beds
- A Macadam Trail
- Remaining Structures Relating to the Former Schuylkill Canal
- Concrete Abutments Associated with the Northern Railroad Bridge
- Electric Utility Poles
- The Existing Chain-Link Fence

For future reference, the surveyors installed 11 numbered pins at locations across the survey area. In addition, four unnumbered reference pins were installed along the property line boundary between the industrial property and the River Road ROW in the vicinity of the slag pile.

The results of the topographic survey are presented in the *Topographic Plan, Reading Slag Pile Site* (Attached).

RADIOLOGICAL SURVEY

FIELD SURVEY

A radiological survey was performed on December 21, 1998 to evaluate the extent and magnitude of radiological slag within the River Road ROW. The survey was performed by Steffan R. Helbig of STEP and Kevin Holsopple of Cabot, using a Ludlum Model 19 micro Roentgen meter (serial number 37373). The meter provided measurements of the gamma radiation dose rate in micro Roentgens per hour (uR/hr). Measurements were obtained at 64 locations and one background location. The background measurement was obtained in the railroad ROW just north of the Buttonwood Street Bridge and represents the lowest reading observed in the River Road/Railroad ROW.

Four measurements were recorded for each survey location consisting of:

1.) the gross measurement at 1 meter above the ground surface
2.) the measurement at 1 meter above ground surface with a lead shield placed between the instrument and the slag pile
3.) the gross measurement at the ground surface
4.) the measurement at the ground surface with a lead shield placed between the instrument and the slag pile

The field measurements are contained in Table 1. Radiological survey locations were determined relative to the physical features located in the topographic survey using a tape measure. The radiological survey locations are shown and identified by number on Figure 1.

From the field work, it was determined that radiological slag was present in the River Road ROW in an area approximately 300 feet long by 50 feet wide adjacent to the slag pile. This area is depicted in Figure 2.

DATA ANALYSIS

The gross radiological measurements at each location represent the total radiation due to several sources. The primary components of the total measurement are:

- Natural background
- Radiological slag within the River Road ROW
- Radiological slag on the embankment (slag pile face)

Shielding Calculations

Shielded measurements were collected to differentiate between the radiological contribution from the slag pile face and the contribution from radiological slag in the River Road ROW. The following acronyms have been assigned to expedite description of the calculations:

BG Background – The background measurement.

TDM Total Dose Rate Measurement – The unshielded measurement of the total dose rate at each location.

SDM Shielded Dose Rate Measurement – The shielded dose rate measurement at each location.

RRR River Road Radiation Dose Rate – The dose rate due to radiological slag in the River Road ROW.

SPR Slag Pile Radiation Dose Rate – Direct radiation dose rate from the slag pile face.

SR Shield Reduction – The amount of slag pile face radiation absorbed by the shield. This is equal to the difference between shielded and unshielded measurements at each location. (SR=TDM-SDM)

SRF Shield Reduction Factor – The fractional reduction of the slag pile face radiation by the shield. This is equal to the absorbed radiation divided by the total slag-pile face radiation. (SRF=SR/SPR) and (SPR=SR/SRF)

The formula for calculating the slag pile radiation dose rate (SPR) was derived as follows:

$$SR = TDM - SDM$$

And

$$SPR = SR / SRF$$

Therefore, by substitution:

$$SPR = (TDM - SDM) / SRF$$

The dose rate due to radiological slag within the River Road ROW was then calculated by subtracting the background measurement and the slag pile face contribution from the total dose rate measurement:

$$RRR = TDM - BG - SPR$$

The SRF is related to the linear absorption coefficient of the shield material and the energy of the gamma radiation. The lead shield used for the study had the dimensions of approximately 23-cm wide by 39-cm long by 1.2-cm thick. Based on

the energy spectrum of uranium, thorium, and their decay products, the shield was expected to reduce the slag pile face radiation by approximately 50%. This would equate to an SRF of 0.5.

The direct dose rate due to radiological slag in the River Road ROW was calculated using an SRF value of 0.5. This produced an excessive number of results below background (negative values for the calculated dose). To adjust for this, a higher SRF of 0.6 was substituted producing results that did not have an excessive number of negative values. Using the higher SRF was conservative in that it decreased the calculated slag pile face contribution and therefore increased the calculated contribution of radiation due to radiological slag in the River Road ROW.

RESULTS

The field data and calculated results are contained in Table 1.

The net values for the direct dose rate due to radiological slag within the River Road ROW were mapped to depict the lateral extent of radiological slag within the River Road ROW. Because the natural background radiation varies with time and location, results less than twice background are not considered statistically significant. Areas with a net value greater than 10 uR/hr are considered to contain radiological slag and have been depicted in Figure 2.

Figure 2 also depicts physical features within the ROW. These features include active railroad tracks, the railroad bed, and the embankment from the industrial site that contains non-radiological and radiological slag. Due to incomplete records, the surveyor was not able to determine the exact location of the River Road ROW north of the industrial property. However, it appears that the concrete abutments of the northern railroad bridge (shown in Figure 2) and the Buttonwood Street bridge may be located within the River Road ROW. It was not the purpose of this study to determine encroachments in the River Road ROW beyond the limits of the industrial property.

DISCUSSION OF RESULTS

The significance of the radiological survey results can be assessed by comparing them to the results contained in the Radiological Assessment (RA) for the Reading Slag Pile Site (ST Environmental Professionals, Inc., 1998)

To assess the total dose to a person in the River Road ROW adjacent to the slag pile, the direct radiation dose contribution from all the radiological slag was considered. The average direct dose rate due to all radiological slag (gross measurement minus background) was 17.8 uR/hr (Table 1). This is comparable to the direct dose rate of 19.1 used in the RA. The calculated total effective dose equivalent (TEDE) for the trespasser scenario considered in the RA was 1.8 mrem/yr which is well below the NRC criteria of 25 mrem/yr for unrestricted use.

Based on the above, the TEDE for any given exposure scenario in the River Road ROW will be essentially the same as, or slightly lower than, the TEDE for the slag pile face. Consequently, the TEDE for a person in the River Road ROW adjacent to the slag pile would likely be lower than 1.8 mrem/yr which is well below the NRC guideline of 25 mrem/yr.

If you have any questions, please do not hesitate to call.

Yours truly,

Steffan R. Helbig, P.G.
President

Attachments

TABLE 1
Radiological Survey Data
Reading Slag Pile Site

LOCATION ID	Measurement at 1 m Above Ground Surface: Gross Dose Rate (uR/hr)	Shielded Dose Rate (uR/hr)	Total Direct Dose Rate [1] (uR/hr)	Calculated Dose Rate [2] From Radiological Slag in River Road ROW (uR/hr)	Measurement at Ground Surface: Gross Dose Rate (uR/hr)	Shielded Dose Rate (uR/hr)	Total Direct Dose Rate [1] (uR/hr)	Calculated Dose Rate [2] From Radiological Slag in River Road ROW (uR/hr)
01	15	10	6	-4.3	15	11	5	-1.7
02	18	12	9	-3.0	16	14	6	2.7
03	21	15	12	0.0	17	15	7	3.7
04	20	16	11	2.3	20	15	10	1.7
05	22	18	13	4.3	22	18	12	5.3
06	26	22	17	8.3	27	22	17	8.7
07	29	24	20	9.7	28	22	18	8.0
08	29	20	20	3.0	30	21	20	6.0
09	28	20	19	3.7	26	22	18	8.0
10	26	20	17	5.0	27	22	17	8.7
11	21	17	12	3.3	19	13	9	-1.0
12	20	12	11	-4.3	18	12	8	-2.0
13	19	14	10	-0.3	18	13	8	-0.3
14	17	14	8	1.0	16	11	6	-2.3
15	16	13	7	0.0	14	13	4	2.3
16	15	12	6	-1.0	15	12	5	0.0
17	14	11	5	-2.0	14	11	4	-1.0
18	22	16	13	1.0	23	17	13	3.0
19	19	11	10	-5.3	19	10	9	-6.0
20	12	10	3	-2.3	12	10	2	-1.3
21	23	22	14	10.3	36	28	26	12.7
22	32	32	23	21.0	36	32	26	19.3
23	35	28	26	12.3	34	30	24	17.3
24	38	30	29	13.7	41	32	31	16.0
25	36	32	27	18.3	43	34	33	18.0
26	40	31	31	14.0	38	32	28	18.0
27	36	32	27	18.3	36	31	26	17.7
28	42	36	33	21.0	49	38	39	20.7
29	36	34	27	21.7	40	34	30	20.0
30	45	35	36	17.3	50	42	40	26.7
31	30	28	21	16.7	36	34	26	22.7
32	40	32	31	16.7	50	40	40	23.3
33	40	33	31	17.3	50	40	40	23.3
34	34	30	25	16.3	38	34	28	21.3
35	32	25	23	9.3	36	28	26	12.7
BACKGROUND [3]	9				10			
37	19	15	10	1.3	17	13	7	0.3
38	22	15	13	-0.7	20	12	10	-3.3
39	34	26	25	9.7	32	22	22	5.3
40	30	23	21	7.3	18	14	8	1.3
41	40	36	31	22.3	42	36	32	22.0
42	42	36	33	21.0	50	45	40	31.7
43	42	36	33	21.0	80	65	70	45.0
44	35	30	26	15.7	37	30	27	15.3
45	36	33	27	20.0	46	38	36	22.7
46	32	26	23	11.0	31	23	21	7.7
47	34	30	25	16.3	38	29	28	13.0
48	42	38	33	24.3	60	44	50	23.3
49	32	27	23	12.7	36	25	26	7.7
50	20	18	11	5.7	20	17	10	5.0
51	13	10	4	-3.0	11	9	1	-2.3

TAB[illegible]
Radiological Survey Data
Reading Slag Pile Site

LOCATION ID	Measurement at 1 m Above Ground Surface: Gross Dose Rate (uR/hr)	Shielded Dose Rate (uR/hr)	Total Direct Dose Rate [1] (uR/hr)	Calculated Dose Rate [2] From Radiological Slag In River Road ROW (uR/hr)	Measurement at Ground Surface: Gross Dose Rate (uR/hr)	Shielded Dose Rate (uR/hr)	Total Direct Dose Rate [1] (uR/hr)	Calculated Dose Rate [2] From Radiological Slag In River Road ROW (uR/hr)
52	12	12	3	1.0	13	12	3	1.3
53	12	10	3	-2.3	11	9	1	-2.3
54	13	11	4	-1.3	13	9	3	-3.7
55	13	11	4	-1.3	13	11	3	-0.3
56	13	11	4	-1.3	15	11	5	-1.7
57	15	13	6	0.7	16	13	6	1.0
58	22	15	13	-0.7	21	15	11	1.0
59	26	24	17	11.7	29	24	19	10.7
60	27	20	18	4.3	26	21	16	7.7
61	18	15	9	2.0	18	14	8	1.3
62	15	11	6	-2.7	15	11	5	-1.7
63	14	12	5	-0.3	15	12	5	0.0
64	11	10	2	-1.7	12	9	2	-3.0
65	11	8	2	-5.0	10	7	0	-5.0
AVERAGES:	25.4	21.1	16.7	7.0	27.5	22.1	17.8	8.3

NOTES:

1. Total Direct Dose Rate = The gross dose rate minus background.

2. Dose Rate Due to Radiological Slag in ROW was Calculated as Follows:
   RRR = TDM - BG - SPR Where SPR = (TDM - SDM) / SRF
   BG = Background
   TDM = Total Dose Rate Measurement
   SDM = Shielded Dose Rate Measurement
   RRR = River Road Radiation Dose Rate
   SPR = Slag Pile Face Radiation Dose Rate
   SR = Shield reduction (SR = TDM - SDM)
   SRF = Shield Reduction Factor
   See text of report for a detailed discussion of the calculations.

   Negative values are due to the variations in background and statistical fluctuations in radiation measurement.

3. The background measurements were recorded at a location just north of the Buttonwood Street Bridge in the River Road ROW and represent the lowest measured values in the ROW. (Background = 10 uR/hr at ground surface and 9 uR/hr at 1 m above ground surface)

4. Survey was conducted on December 21, 1998

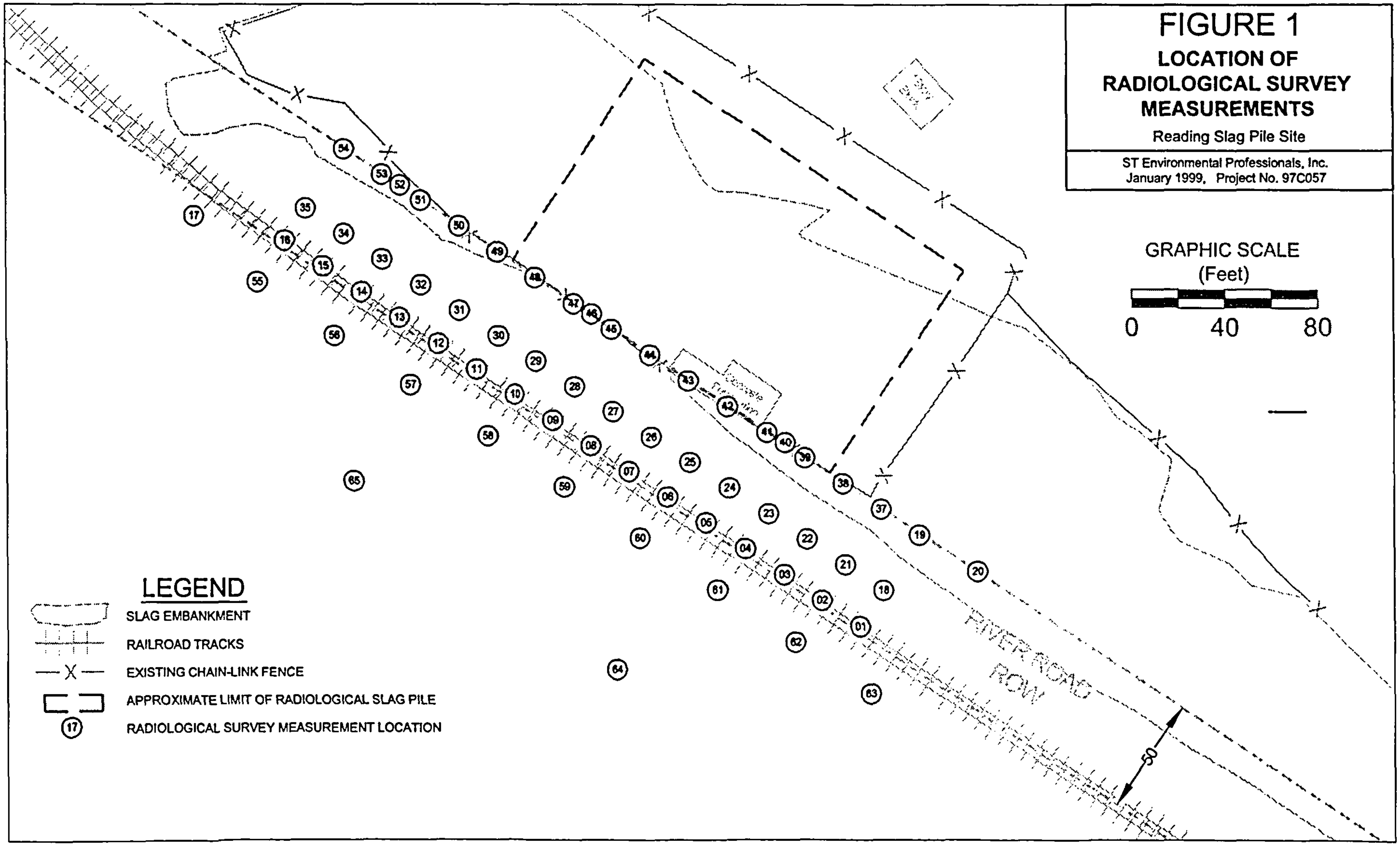
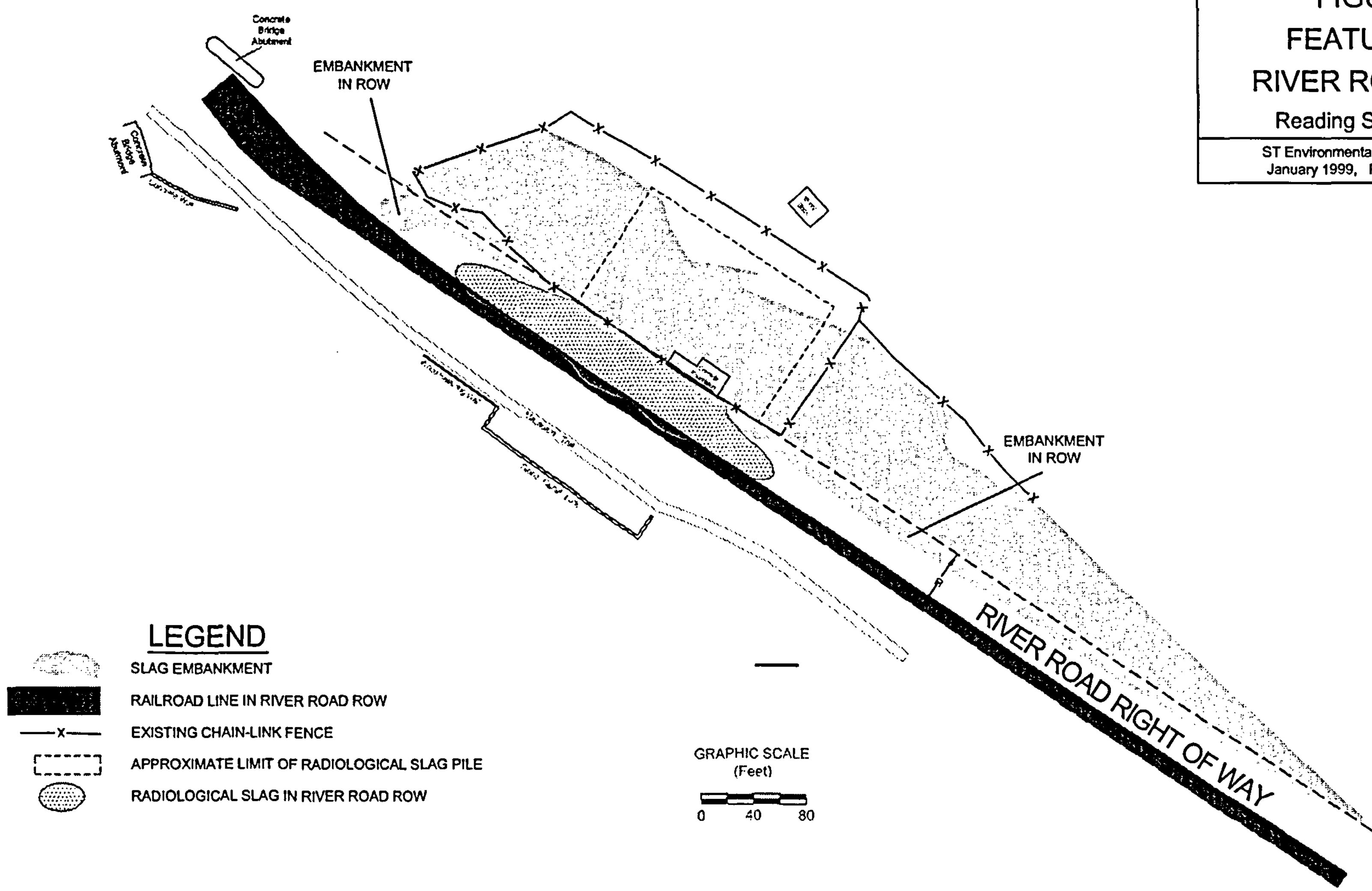


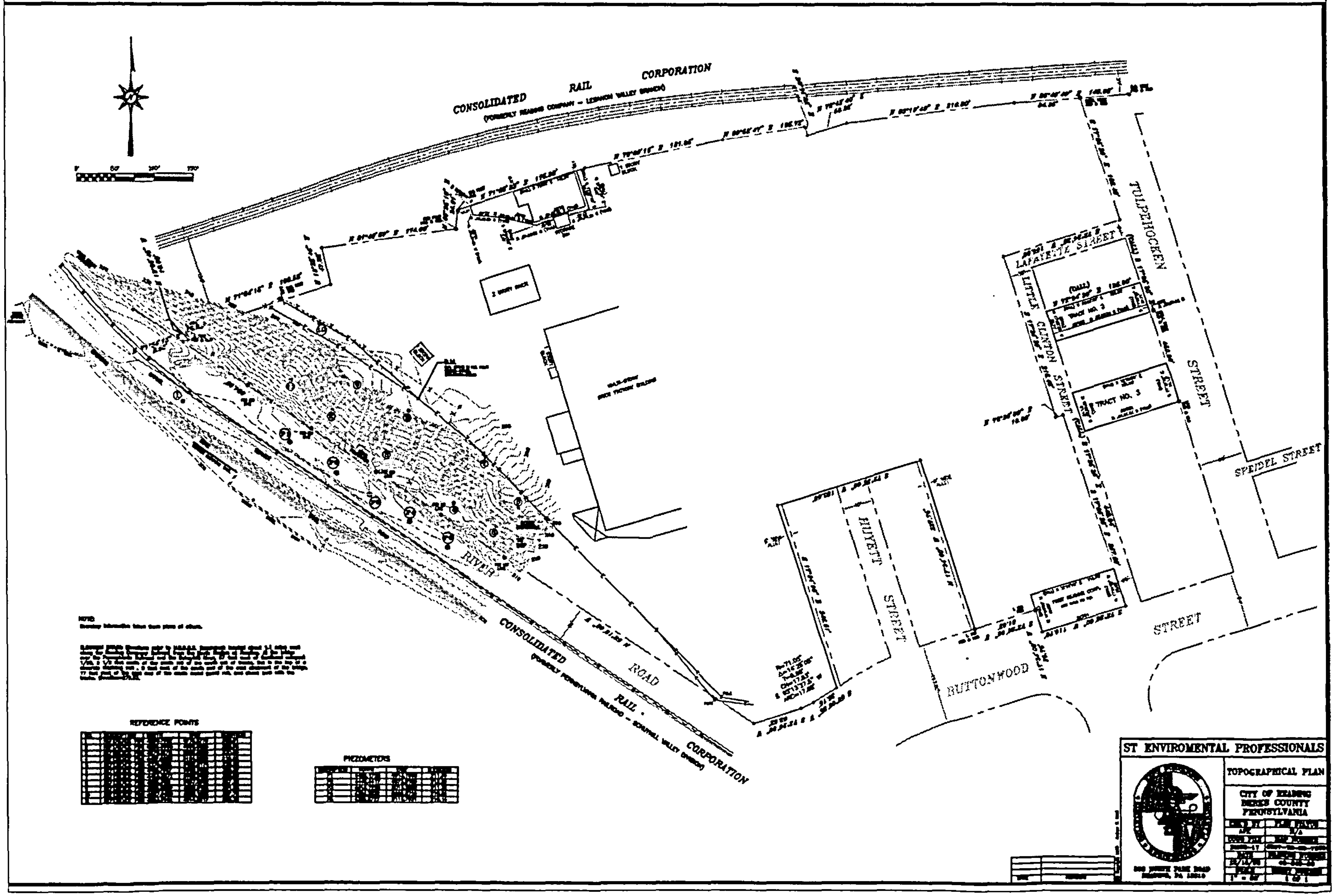
FIGURE 1
LOCATION OF RADIOLOGICAL SURVEY MEASUREMENTS
Reading Slag Pile Site
ST Environmental Professionals, Inc.
January 1999, Project No. 97C057
GRAPHIC SCALE
(Feet)
0
40
80
RIVER ROAD ROW
50
LEGEND
SLAG EMBANKMENT
RAILROAD TRACKS
EXISTING CHAIN-LINK FENCE
APPROXIMATE LIMIT OF RADIOLOGICAL SLAG PILE
17
RADIOLOGICAL SURVEY MEASUREMENT LOCATION

FIGURE 2
FEATURES IN RIVER ROAD ROW

Reading Slag Pile Site

ST Environmental Professionals, Inc.
January 1999, Project No. 97C057





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TNU-OR-10684

July 9, 1999

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

CASE NARRATIVE
Work Order # 99-06084-OR

SAMPLE RECEIPT

This work order contains ten soil samples received 06/14/99. These samples were analyzed by Gamma Spectroscopy.

CLIENT ID	LAB ID	CLIENT ID	LAB ID
SO1-0.5	99-06084-04	SO2-2.5	99-06084-09
SO1-1.5	99-06084-05	SO3-0.5	99-06084-10
SO1-2.5	99-06084-06	SO3-1.5	99-06084-11
SO2-0.5	99-06084-07	SO3-2.5	99-06084-12
SO2-1.5	99-06084-08	SO4-0.0	99-06084-13

ANALYTICAL METHODS

Gamma Spectroscopy was performed using Method LANL ER-130 modified.

SPECIAL PROBLEMS OR UNUSUAL CIRCUMSTANCES

Samples were analyzed by gamma spectroscopy for determination of Total Uranium by assumption that Thorium-234 is in secular equilibrium with its parent, Thorium-234 and Uranium-238. Therefore, results for Thorium-234 have been multiplied by a factor of two (2) based on this assumption. Results for other gamma-emitting radionuclides are included in the full analytical data package for your review. All QC parameters are within acceptable limits. No significant problems were noted during the analysis process.

CERTIFICATION OF ACCURACY

I certify that this data report is in compliance with the terms and conditions of the Purchase Order, both technically and for completeness, for other than the conditions detailed above. Release of the data contained in this hard copy data package has been authorized by the cognizant project manager or his/her designee to be accurate as verified by the following signature.

M.R. McDougall
Laboratory Manager

Date: 7/9/1999

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RR 4, Box 239
239 Lutz Road
Boyertown, PA 19512

SDG: 6084
Matrix: Soil

Final Report of Analysis
Date of Report: 7/9/1999

Lab ID	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	Error	MDA	Units
99-06084-01	K KNOWN	06/14/99	06/14/99	06/29/99	9906084	Cobalt-60	LANL ER-130 Modified	230.96	9.93		PCI/G
99-06084-01	K KNOWN	06/14/99	06/14/99	06/29/99	9906084	Cesium-137	LANL ER-130 Modified	137.76	6.47		PCI/G
99-06084-01	S SPIKE	06/14/99	06/14/99	06/29/99	9906084	Cobalt-60	LANL ER-130 Modified	234.30	16.58	1.31	PCI/G
99-06084-01	S SPIKE	06/14/99	06/14/99	06/29/99	9906084	Cesium-137	LANL ER-130 Modified	137.50	14.42	1.49	PCI/G
99-06084-02	B BLANK	06/14/99	06/14/99	06/29/99	9906084	Thallium-208	LANL ER-130 Modified	-0.01	0.07	0.13	PCI/G
99-06084-02	B BLANK	06/14/99	06/14/99	06/29/99	9906084	Bismuth-212	LANL ER-130 Modified	-0.07	0.17	0.29	PCI/G
99-06084-02	B BLANK	06/14/99	06/14/99	06/29/99	9906084	Lead-212	LANL ER-130 Modified	0.01	0.04	0.06	PCI/G
99-06084-02	B BLANK	06/14/99	06/14/99	06/29/99	9906084	Bismuth-214	LANL ER-130 Modified	0.00	0.05	0.10	PCI/G
99-06084-02	B BLANK	06/14/99	06/14/99	06/29/99	9906084	Lead-214	LANL ER-130 Modified	-0.01	0.04	0.08	PCI/G
99-06084-02	B BLANK	06/14/99	06/14/99	06/29/99	9906084	Actinium-228	LANL ER-130 Modified	-0.08	0.07	0.10	PCI/G
99-06084-02	B BLANK	06/14/99	06/14/99	06/29/99	9906084	Protactinium-234m	LANL ER-130 Modified	3.66	2.56	3.14	PCI/G
99-06084-02	B BLANK	06/14/99	06/14/99	06/29/99	9906084	Thorium-234	LANL ER-130 Modified	0.18	0.97	1.78	PCI/G
99-06084-03	D SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Thallium-208	LANL ER-130 Modified	19.61	1.65	0.54	PCI/G
99-06084-03	D SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-212	LANL ER-130 Modified	14.30	2.00	1.45	PCI/G
99-06084-03	D SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Lead-212	LANL ER-130 Modified	20.50	2.13	0.38	PCI/G
99-06084-03	D SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-214	LANL ER-130 Modified	13.39	0.91	0.36	PCI/G
99-06084-03	D SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Lead-214	LANL ER-130 Modified	12.69	0.80	0.42	PCI/G
99-06084-03	D SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Actinium-228	LANL ER-130 Modified	20.59	1.32	0.60	PCI/G
99-06084-03	D SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Protactinium-234m	LANL ER-130 Modified	17.90	13.02	16.16	PCI/G
99-06084-03	D SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Total Uranium	LANL ER-130 Modified	22.12	7.73	4.48	PCI/G

Approved by: [signature] 7/9/1999
M.R. McDougall, Laboratory Manager

K=Known,S=Spike,B=Blank,D=Duplicate,MS=Matrix Spike

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239 Lutz Road
Boyertown, PA 19512

SDG: 9…6084
Matrix: Soil

Final Report of Analysis
Date of Report: 7/9/1999

Lab ID	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	Error	MDA	Units
99-06084-04	SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Thallium-208	LANL ER-130 Modified	19.37	1.65	0.53	PCI/G
99-06084-04	SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-212	LANL ER-130 Modified	13.15	1.85	1.74	PCI/G
99-06084-04	SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Lead-212	LANL ER-130 Modified	20.59	2.14	0.38	PCI/G
99-06084-04	SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-214	LANL ER-130 Modified	12.58	0.90	0.37	PCI/G
99-06084-04	SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Lead-214	LANL ER-130 Modified	13.24	0.83	0.42	PCI/G
99-06084-04	SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Actinium-228	LANL ER-130 Modified	21.37	1.36	0.54	PCI/G
99-06084-04	SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Protactinium-234m	LANL ER-130 Modified	18.66	13.80	15.54	PCI/G
99-06084-04	SO1-0.5	06/09/99	06/14/99	06/29/99	9906084	Total Uranium	LANL ER-130 Modified	36.30	9.93	4.54	PCI/G
99-06084-05	SO1-1.5	06/09/99	06/14/99	06/29/99	9906084	Thallium-208	LANL ER-130 Modified	14.74	1.42	0.48	PCI/G
99-06084-05	SO1-1.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-212	LANL ER-130 Modified	10.42	1.80	1.32	PCI/G
99-06084-05	SO1-1.5	06/09/99	06/14/99	06/29/99	9906084	Lead-212	LANL ER-130 Modified	16.17	2.58	0.34	PCI/G
99-06084-05	SO1-1.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-214	LANL ER-130 Modified	10.22	0.79	0.31	PCI/G
99-06084-05	SO1-1.5	06/09/99	06/14/99	06/29/99	9906084	Lead-214	LANL ER-130 Modified	10.27	0.82	0.37	PCI/G
99-06084-05	SO1-1.5	06/09/99	06/14/99	06/29/99	9906084	Actinium-228	LANL ER-130 Modified	15.73	1.11	0.47	PCI/G
99-06084-05	SO1-1.5	06/09/99	06/14/99	06/29/99	9906084	Protactinium-234m	LANL ER-130 Modified	21.49	13.50	13.03	PCI/G
99-06084-05	SO1-1.5	06/09/99	06/14/99	06/29/99	9906084	Thorium-234	LANL ER-130 Modified	-6.07	6.70	10.25	PCI/G
99-06084-06	SO1-2.5	06/09/99	06/14/99	06/29/99	9906084	Thallium-208	LANL ER-130 Modified	0.95	0.16	0.19	PCI/G
99-06084-06	SO1-2.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-212	LANL ER-130 Modified	0.69	0.37	0.51	PCI/G
99-06084-06	SO1-2.5	06/09/99	06/14/99	06/29/99	9906084	Lead-212	LANL ER-130 Modified	1.52	0.21	0.09	PCI/G
99-06084-06	SO1-2.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-214	LANL ER-130 Modified	0.92	0.16	0.12	PCI/G
99-06084-06	SO1-2.5	06/09/99	06/14/99	06/29/99	9906084	Lead-214	LANL ER-130 Modified	1.05	0.13	0.12	PCI/G
99-06084-06	SO1-2.5	06/09/99	06/14/99	06/29/99	9906084	Actinium-228	LANL ER-130 Modified	1.01	0.21	0.23	PCI/G
99-06084-06	SO1-2.5	06/09/99	06/14/99	06/29/99	9906084	Protactinium-234m	LANL ER-130 Modified	-0.83	3.88	7.05	PCI/G
99-06084-06	SO1-2.5	06/09/99	06/14/99	06/29/99	9906084	Total Uranium	LANL ER-130 Modified	5.47	2.30	1.14	PCI/G

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SDG: 9906084
Matrix: Soil

Final Report of Analysis
Date of Report: 7/9/1999

Lab ID	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	Error	MDA	Units
99-06084-07	SO2-0.5	06/09/99	06/14/99	06/29/99	9906084	Thallium-208	LANL ER-130 Modified	1.07	0.17	0.13	PCI/G
99-06084-07	SO2-0.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-212	LANL ER-130 Modified	0.51	0.34	0.40	PCI/G
99-06084-07	SO2-0.5	06/09/99	06/14/99	06/29/99	9906084	Lead-212	LANL ER-130 Modified	1.01	0.13	0.08	PCI/G
99-06084-07	SO2-0.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-214	LANL ER-130 Modified	0.89	0.13	0.09	PCI/G
99-06084-07	SO2-0.5	06/09/99	06/14/99	06/29/99	9906084	Lead-214	LANL ER-130 Modified	0.84	0.11	0.10	PCI/G
99-06084-07	SO2-0.5	06/09/99	06/14/99	06/29/99	9906084	Actinium-228	LANL ER-130 Modified	1.12	0.15	0.18	PCI/G
99-06084-07	SO2-0.5	06/09/99	06/14/99	06/29/99	9906084	Protactinium-234m	LANL ER-130 Modified	1.53	2.73	5.12	PCI/G
99-06084-07	SO2-0.5	06/09/99	06/14/99	06/29/99	9906084	Total Uranium	LANL ER-130 Modified	1.01	3.22	2.59	PCI/G
99-06084-08	SO2-1.5	06/09/99	06/14/99	06/29/99	9906084	Thallium-208	LANL ER-130 Modified	0.66	0.18	0.18	PCI/G
99-06084-08	SO2-1.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-212	LANL ER-130 Modified	0.61	0.40	0.55	PCI/G
99-06084-08	SO2-1.5	06/09/99	06/14/99	06/29/99	9906084	Lead-212	LANL ER-130 Modified	0.49	0.12	0.12	PCI/G
99-06084-08	SO2-1.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-214	LANL ER-130 Modified	0.53	0.14	0.13	PCI/G
99-06084-08	SO2-1.5	06/09/99	06/14/99	06/29/99	9906084	Lead-214	LANL ER-130 Modified	0.65	0.15	0.15	PCI/G
99-06084-08	SO2-1.5	06/09/99	06/14/99	06/29/99	9906084	Actinium-228	LANL ER-130 Modified	0.72	0.20	0.25	PCI/G
99-06084-08	SO2-1.5	06/09/99	06/14/99	06/29/99	9906084	Protactinium-234m	LANL ER-130 Modified	0.95	4.79	9.42	PCI/G
99-06084-08	SO2-1.5	06/09/99	06/14/99	06/29/99	9906084	Total Uranium	LANL ER-130 Modified	2.81	2.54	1.34	PCI/G
99-06084-09	SO2-2.5	06/09/99	06/14/99	06/29/99	9906084	Thallium-208	LANL ER-130 Modified	2.05	0.27	0.20	PCI/G
99-06084-09	SO2-2.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-212	LANL ER-130 Modified	1.09	0.79	0.64	PCI/G
99-06084-09	SO2-2.5	06/09/99	06/14/99	06/29/99	9906084	Lead-212	LANL ER-130 Modified	2.98	0.36	0.12	PCI/G
99-06084-09	SO2-2.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-214	LANL ER-130 Modified	1.50	0.23	0.16	PCI/G
99-06084-09	SO2-2.5	06/09/99	06/14/99	06/29/99	9906084	Lead-214	LANL ER-130 Modified	1.89	0.28	0.16	PCI/G
99-06084-09	SO2-2.5	06/09/99	06/14/99	06/29/99	9906084	Actinium-228	LANL ER-130 Modified	1.86	0.29	0.29	PCI/G
99-06084-09	SO2-2.5	06/09/99	06/14/99	06/29/99	9906084	Protactinium-234m	LANL ER-130 Modified	1.98	5.01	9.51	PCI/G
99-06084-09	SO2-2.5	06/09/99	06/14/99	06/29/99	9906084	Total Uranium	LANL ER-130 Modified	7.06	3.58	1.58	PCI/G

Approved by: _______________ 7/9/1999
M.R. McDougall, Laboratory Manager

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SDG: ..06084
Matrix: Soil

Lab ID	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	Error	MDA	Units
99-06084-10	SO3-0.5	06/09/99	06/14/99	06/29/99	9906084	Thallium-208	LANL ER-130 Modified	8.93	0.91	0.45	PCI/G
99-06084-10	SO3-0.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-212	LANL ER-130 Modified	5.31	1.36	1.27	PCI/G
99-06084-10	SO3-0.5	06/09/99	06/14/99	06/29/99	9906084	Lead-212	LANL ER-130 Modified	9.06	0.98	0.29	PCI/G
99-06084-10	SO3-0.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-214	LANL ER-130 Modified	5.88	0.51	0.28	PCI/G
99-06084-10	SO3-0.5	06/09/99	06/14/99	06/29/99	9906084	Lead-214	LANL ER-130 Modified	5.77	0.45	0.34	PCI/G
99-06084-10	SO3-0.5	06/09/99	06/14/99	06/29/99	9906084	Actinium-228	LANL ER-130 Modified	9.17	0.74	0.44	PCI/G
99-06084-10	SO3-0.5	06/09/99	06/14/99	06/29/99	9906084	Protactinium-234m	LANL ER-130 Modified	12.81	9.42	13.36	PCI/G
99-06084-10	SO3-0.5	06/09/99	06/14/99	06/29/99	9906084	Total Uranium	LANL ER-130 Modified	22.90	6.98	3.68	PCI/G
99-06084-11	SO3-1.5	06/09/99	06/14/99	06/29/99	9906084	Thallium-208	LANL ER-130 Modified	5.73	0.70	0.35	PCI/G
99-06084-11	SO3-1.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-212	LANL ER-130 Modified	4.10	0.98	0.92	PCI/G
99-06084-11	SO3-1.5	06/09/99	06/14/99	06/29/99	9906084	Lead-212	LANL ER-130 Modified	6.18	0.92	0.23	PCI/G
99-06084-11	SO3-1.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-214	LANL ER-130 Modified	3.91	0.41	0.22	PCI/G
99-06084-11	SO3-1.5	06/09/99	06/14/99	06/29/99	9906084	Lead-214	LANL ER-130 Modified	4.40	0.41	0.26	PCI/G
99-06084-11	SO3-1.5	06/09/99	06/14/99	06/29/99	9906084	Actinium-228	LANL ER-130 Modified	6.59	0.57	0.40	PCI/G
99-06084-11	SO3-1.5	06/09/99	06/14/99	06/29/99	9906084	Protactinium-234m	LANL ER-130 Modified	16.96	10.38	9.90	PCI/G
99-06084-11	SO3-1.5	06/09/99	06/14/99	06/29/99	9906084	Total Uranium	LANL ER-130 Modified	9.80	9.40	7.29	PCI/G
99-06084-12	SO3-2.5	06/09/99	06/14/99	06/29/99	9906084	Thallium-208	LANL ER-130 Modified	1.16	0.26	0.27	PCI/G
99-06084-12	SO3-2.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-212	LANL ER-130 Modified	1.43	0.56	0.68	PCI/G
99-06084-12	SO3-2.5	06/09/99	06/14/99	06/29/99	9906084	Lead-212	LANL ER-130 Modified	1.56	0.21	0.13	PCI/G
99-06084-12	SO3-2.5	06/09/99	06/14/99	06/29/99	9906084	Bismuth-214	LANL ER-130 Modified	1.38	0.23	0.17	PCI/G
99-06084-12	SO3-2.5	06/09/99	06/14/99	06/29/99	9906084	Lead-214	LANL ER-130 Modified	1.05	0.19	0.16	PCI/G
99-06084-12	SO3-2.5	06/09/99	06/14/99	06/29/99	9906084	Actinium-228	LANL ER-130 Modified	1.29	0.29	0.32	PCI/G
99-06084-12	SO3-2.5	06/09/99	06/14/99	06/29/99	9906084	Protactinium-234m	LANL ER-130 Modified	24.08	11.55	8.68	PCI/G
99-06084-12	SO3-2.5	06/09/99	06/14/99	06/29/99	9906084	Total Uranium	LANL ER-130 Modified	1.94	3.21	1.64	PCI/G

Approved by: M. McDougall 7/9/1999
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SDG: .06084
Matrix: Soil

Final Report of Analysis
Date of Report: 7/9/1999

Lab ID	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	Error	MDA	Units
99-06084-13	SO4-0.0	06/09/99	06/14/99	06/29/99	9906084	Thallium-208	LANL ER-130 Modified	0.97	0.15	0.16	PCI/G
99-06084-13	SO4-0.0	06/09/99	06/14/99	06/29/99	9906084	Bismuth-212	LANL ER-130 Modified	0.47	0.35	0.38	PCI/G
99-06084-13	SO4-0.0	06/09/99	06/14/99	06/29/99	9906084	Lead-212	LANL ER-130 Modified	0.86	0.12	0.08	PCI/G
99-06084-13	SO4-0.0	06/09/99	06/14/99	06/29/99	9906084	Bismuth-214	LANL ER-130 Modified	0.77	0.13	0.10	PCI/G
99-06084-13	SO4-0.0	06/09/99	06/14/99	06/29/99	9906084	Lead-214	LANL ER-130 Modified	0.92	0.12	0.11	PCI/G
99-06084-13	SO4-0.0	06/09/99	06/14/99	06/29/99	9906084	Actinium-228	LANL ER-130 Modified	0.92	0.17	0.18	PCI/G
99-06084-13	SO4-0.0	06/09/99	06/14/99	06/29/99	9906084	Protactinium-234m	LANL ER-130 Modified	1.60	3.13	6.10	PCI/G
99-06084-13	SO4-0.0	06/09/99	06/14/99	06/29/99	9906084	Total Uranium	LANL ER-130 Modified	3.51	1.69	0.98	PCI/G

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APPENDIX D

LEACH RATE ASSESSMENT

NOVEMBER 1997

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November 9, 1997

Steffan R. Helbig
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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 not 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,

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Chief Geochemist

APRIL 2005

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April 20, 2005

Steffan R. Helbig, P.G.
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Subject: Radionuclide Leaching
Reading Slag Pile Site

Dear Mr. Helbig

I have reviewed the three reports you requested; "Characterization of Radiological Slags", NUREG-1703 (Johns Hopkins University 2004), "Solubility and Leaching of Radionuclides in Site Decommissioning Management Plan (SDMP) Slags", NUREG/CR-6632 (Pacific Northwest National Laboratory, 2002), and "Evolution of Pore Water Chemistry During Degradation of Cement in a Radioactive Waste repository Environment" (Berner 2002). Specifically, I considered whether the reports are consistent with the conclusions regarding leaching of radionuclides and impact to groundwater presented in the Decommissioning Plan (DP) and Radiological Assessment (RA) for the Reading Slag Pile Site (STEP 2000).

The first two reports seem the most pertinent to the site you're working on. The third report seems only peripherally significant. Regarding the calculation of radionuclide concentrations resulting from leaching of the slag at Site B, both reports get it only partially right. The PNL report gets closer than the JHU report but is still lacking in some important aspects of "source term calculation."

The JHU report does a great job of characterizing the slag materials. They identify the primary (i.e., when slag was deposited) phases in the slags, the abundance of these phases, the compositions of the phases, the textural features of the slags, and the weathering products formed in the slags since they were deposited on site. This is all interesting stuff and a classic example of the type of work best done in a university setting.

Where this report is weak is in the conceptualization and formulation of equations to calculate leaching concentrations. They do two things that are particularly problematic: (1) they assume the slag leaches congruently and (2) they ignore sorption processes. Regarding (1), they provide an example of an "Estimation of Weathering Rate" calculation in which they use equation (12) of the report to calculate a "bulk mass flux" for radionuclides from the slag. As a measure of the amount of slag dissolved, they use the thickness of the "rind" on some slag sample. The fact that there was a "rind" implies dissolution of the slag was not congruent. They also do not say that the

"rind" has been leached of all its radionuclides which is what would need to be the case to allow the use of equation (12). Their result is a bulk mass radionuclide flux of 230 ng/cm^2-yr for their example. I would view this number with great suspicion.

The more important issue is their total neglect of sorption processes (see Langmuir, 1997; p. 343). Elements such as thorium are known to be very strongly sorbed by most natural surfaces (ref). The sorption mechanism is different from the precipitation process that leads to the crystallization of a pure phase of the radionuclide (e.g., ThO_2). Sorption processes are more akin to a fly sticking to flypaper. Sorption would likely occur in the "rinds" of weathered slag as well as in slag components that do not contain pure radionuclide phases such as ThO_2. The neglect of sorption processes makes the equations presented for fluid concentrations (e.g., equation (7)) incomplete. Thus, the overall approach to the calculation of "radionuclide release rates from slags" (Section 3.2) is incomplete. The result of this oversight is that the calculated release rates are too high.

The report by the PNL group has more direct application to the derivation of radionuclide release rates from the slag but it also has some flaws. The main flaw is that this report also ignores sorption processes. They state that "Analysis of solution phase concentrations and solid phase compositions indicate that aqueous Th concentrations are solubility controlled most likely by thoranite (ThO_2 (c)), which sets an upper limit on the dissolved Th concentrations." Although an "upper limit on dissolved Th concentrations" is an interesting parameter, the real question is "what are the release rates of radionuclides from the slags?"

The impact of sorption processes are evident in their discussion of column test in which they leached radionuclides from a column of crushed slag using a local water as the leaching solution. Under pH conditions representative of the site, the Th solution concentrations (Figure 4-13) were generally below the detection limit (and the solubility limit for ThO_2). This observation could reflect sorption of Th onto the crushed slag. Note that sorption can lower the concentration of a component in solution even if the solution is undersaturated with a pure phase of that component. Because the concentrations were reported to be below the detection limit, they could have been much lower than the detection limit.

For uranium, the situation is somewhat more complicated. The element uranium can occur in more than one oxidation state in natural systems unlike Th which occurs only in the +4 state. The most common oxidation states are +4 and +6 (Langmuir, 1997; p. 495). In the +4 oxidation state, the chemical behavior of uranium is similar to that of Th in natural systems. Thus, we expect to find low solubility for U^{4+} solids and high sorption coefficients for U^{4+} on natural surfaces.

When aqueous uranium comes into contact with dissolved oxygen, it is oxidized to the +6 state. In the +6 state, uranium is much more soluble than it is in the +4 state. It also sorbs to a much lower degree. Because the slags are located in part in the vadose zone, the pore waters in the slag likely contain significant concentrations of dissolved oxygen. Thus, we would expect uranium concentration to be much higher than Th concentrations in these pore waters. This is not what is observed.

The maximum calculated U concentrations in leaching solutions (6.3×10^{-8}M; p. 39) are not consistent with solubility control by a U^{6+} solid. They are much more consistent with solubility control by a U^{4+} solid. This is somewhat puzzling and calls for an explanation. The authors of the PNL report state (p. 33) "It appears (more) likely that the U is tightly bound in a very insoluble or refractory phase." According to the JHU report (p. 12), U and Th in the slag at this site is bound up in the minerals perovskite ($CaTiO_3$), calzirtite ((Ca, U, Th)$ZrTi_2O_7$), and

pyrochlore ((Ca, U, Ce)$_2$(Nb, Ti)$_2$O$_6$). As noted in the JHU report (Table 2-3), the first two of these phases are in the group of phases that make up SYNROC. SYNROC is a man-made material formulated to encapsulate nuclear waste components for long-term isolation with minimal leaching potential. The low leach rates found for U in the slags from this site most likely reflect this fact. Although pyrochlore is not a SYNROC phase, its structure would also lead to low leachability of radionuclides.

The JHU report discusses various types of evidence for the weathering of slags at this site. However, the weathering of the slags at this site is only pertinent if the phases that show evidence of weathering contain significant concentrations of U and/or Th. SYNROC-type phases are "designed" to resist weathering in the natural environment. Figure 3-17 of the JHU report shows that calzirtite and perovskite were not weathered after contact with a pH 2 solution even though glass in the sample was significantly weathered by the solution. Similar results were obtained by contacting samples from the site with solutions with pH = 6 and 12 (Figure 3-18). Thus, the fact that slags at this site weather at some measurable rate does not necessarily imply that the phases containing U and Th will weather at the same rate. In essence, the slag weathers incongruently. This observation contradicts the approach formulated in the JHU report for the calculation of radionuclide leaching rates from slag samples.

One other item of interest to radionuclide release rates from the site is provided by the PNL report. The investigators found that column leaching studies using slag from this site "did not show any evidence for the formation or transport of radiocolloids in any of the samples studied." (p. 41). Thus, particulate transport of radionuclides is not an issue at this site.

The final report to be considered (Berner, 1992) concerns the impact of cement and concrete on the leach rates of radionuclides. This report is not very pertinent to the Reading site because it involves modeling pore water chemistry directly in young cements. At the Reading site, cement and concrete are not major constituents of the slag pile. Further, these cements and concretes are aged. This implies these cements and concretes will not dominate the pore water chemistry in the slag piles. To the extent that they do contribute to pore water chemistry, their age implies they will not release highly alkaline (e.g., pH > 10.0) solutions to pore waters in the slag pile. The Berner (1992) paper presents some modeling results for uranium release from young cementitious matrices. The modeling assumed a redox potential of -300 mv. Under this redox potential, uranium is primarily in the +4 oxidation state. Uranium is less soluble in the +4 redox state than it is in the +6 redox state. At the Reading site, the redox state of pore waters in the slag pile is unknown. Given the presence of iron and other reduced materials in the slag (JHU report), the redox potentials may be as low as -300 mv. If this is indeed the case, U would be in the +4 state in the pore waters of the Reading slag pile.

If the redox potentials in the Reading slag pile are more oxidizing (e.g., > 0.0 mv), then U would be in the +6 state in the pore waters. However, even under oxidizing conditions, the leach rate for U from slag would be low because U is mostly locked up in SYNROC-type phases that are "designed" to be resistant to leaching by aqueous solutions.

Based on my review, the documents are consistent with the conclusions regarding the leaching of radionuclides and impact to groundwater presented in the 2000 Reading Slag Pile DP and RA reports. The potential concentrations of leachate from the slag pile is expected to remain well below drinking water standards.

References: Langmuir, D., 1997, Aqueous Environmental Geochemistry, Prentice Hall, Upper Saddle River, New Jersey

Best Regards,

Arend Meijer, Ph. D.