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Estimation of Contamination Volume at Seaway Area A, New York

Environmental Assessment Division
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Notation

BFI	Browning-Ferris Industries
cpm	count(s) per minute
DOE	U.S. Department of Energy
ft	foot (feet)
FUSRAP	Formerly Utilized Sites Remedial Action Program
g	gram(s)
GPS	global positioning system
NaI	sodium iodide
pCi	picocurie(s)
SAIC	Scientific Applications International Corporation
USACE	U.S. Army Corps of Engineers
yd^3	cubic yard(s)

Section 1
Introduction

The purpose of this analysis was to estimate the volume of soil with a radioactive contaminant activity level above the cleanup guideline at Seaway Area A, Tonawanda, New York. A site-specific cleanup guideline of 40 pCi/g thorium-230 was derived for Seaway, as well as for the nearby Ashland 1 and Ashland 2 sites. All three are Formerly Utilized Sites Remedial Action Program (FUSRAP) properties. The level was developed to ensure protection of human health and the environment and compliance with applicable or relevant and appropriate requirements. The available data included historical discrete soil samples taken at the surface and at depth and results of a surficial gamma walkover with a sodium iodide (NaI) 2×2 sensor. The balance of this document provides background information about the site and discusses the available data sets, the methodology used, and the results and conclusions from the analysis.

Section 2
Background

The Seaway site is located on River Road in Tonawanda, New York, just north of Buffalo. Between 1974 and 1982, the site was contaminated during the transfer of soil containing low-level radioactive residues from the Ashland 1 site to the Ashland 2 site. This contamination is primarily soil containing the radionuclides thorium-230, uranium-238, and radium-226. The original contamination resulted from activities involving radioactive material conducted under government contract at Ashland 1. At the time of the soil transfer, the Seaway site was a sanitary landfill operated by Browning-Ferris Industries (BFI). It is believed that contaminated soil was placed on top of existing municipal solid waste. The site is currently owned by the Seaway Industrial Park Development Company, Inc.

Section 3
Available Data

Two sets of information were available for estimating volumes of contaminated soil at Seaway Area A. The first set consisted of historical soil sampling results collected as part of site characterization activities. Figure 1[1] shows the locations of the soil bores that yielded these samples. The second set of data was collected in September 1998 in a gamma walkover survey with a 2×2 NaI sensor combined with a global positioning system (GPS). The latter data set provided systematic surficial coverage of the site. Figure 2 shows a map of these gamma walkover results, color-coded by activity levels.

The radiological activity concentrations of soil samples used for the analysis in this report were compiled by Science Applications International Corporation (SAIC) from three distinct sampling programs separated by several years. The sampling programs were part of a remedial investigation, a preliminary engineering and environmental evaluation of remedial alternatives, and a radiological survey (U.S. Department of Energy [DOE] 1993a-b, 1981, 1978). An important consideration was that while location information existed for all sample data, the reported depth for samples from the first program might no longer be accurate because of topographical changes at the site since then. A total of 278 samples from 106 soil bores were available for the site. All soil samples were analyzed for radium-226 by gamma spectrometry. However, only 141 samples were analyzed for thorium-230 by alpha spectrometry. It is important to note, also, that sample density was greatest at or near the surface of the site. Sample information at depth was much more spotty. The maximum depth sampled was an interval of 28 to 30 ft below existing ground surface at the time of the first study.

For the gamma walkover survey, activity levels were acquired every two seconds with the NaI-GPS system, with results reported in counts per minute (cpm). The gamma walkover survey provided systematic surficial coverage of the site, although the lines were widely spaced (ranging from approximately 20 ft to greater than 30 ft apart). Given the likely sources of elevated activity (i.e., radium-226, uranium-238, and thorium-230), the gamma walkover data provided qualitative information about the presence or absence of contamination in the first 6 in. of soil. The 2×2 NaI sensor used was most sensitive to radium-226 and least sensitive to thorium-230. Consequently, variations in the resulting cpm estimates across the site most likely reflected variations in radium-226 activity concentrations.

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[1] All figures referred to in the text are located at the end of the report.

Section 4
Methodology

Contaminated soil volumes were estimated on a lift-by-lift basis for the site. This approach was used to mimic the likely approach to excavation, if excavation is the remedy selected for the site. Lifts were defined by depth from surface. For the purposes of this analysis, an initial 2-ft lift (0 to 2 ft) was used for the surface, with subsequent 2-ft lifts down to a depth of 8 ft, resulting in 4 lifts. For each lift, soil was divided into three categories. Soil was classified as "contaminated" when available data indicated thorium-230 activity concentrations were in excess of 40 pCi/g. Soil was classified as "clean" when the available data indicated thorium-230 activity concentrations were less than 40 pCi/g. Soil was classified as "uncertain" when the available data were inconclusive regarding the presence or absence of thorium-230 activity concentrations above 40 pCi/g. These categories of soil were converted to volumes on the basis of the thickness of the lift. The volumes of soil classed as contaminated represented the minimum amount of soil above the cleanup guideline expected from that lift. The combination of the soil above the cleanup criterion plus "uncertain soil" represented the maximum volume of soil above the cleanup criterion expected from that lift.

Finally, on the basis of all available data and best engineering judgment, a "most likely" estimate of the volume of soil above the cleanup guideline was determined for each lift. Summing the estimates for each lift produced final soil volume estimates for the Seaway Area A. These final estimates included a minimum volume of soil above the cleanup guideline, a maximum volume of soil above the cleanup guideline, and a best estimate of the volume of soil above the cleanup guideline. This best estimate generally fell somewhere between the minimum and maximum volume of soil present above the cleanup guideline.

The extent of soil above the cleanup criterion in the first, or surface, lift was based on the gamma walkover data collected in September 1998. Because the gamma walkover method primarily detected the presence of elevated radium-226, a relationship between radium-226 levels and the presence or absence of thorium-230 above 40 pCi/g was required. This relationship was based on empirical work from the Ashland 2 site. The Ashland 2 data sets established the gamma walkover reading range that corresponds to the 40 pCi/g thorium-230 specific guideline. The study concluded that activities greater than 24,000 cpm measured by a 2×2 NaI sensor correspond to thorium-230 activity concentrations greater than 40 pCi/g, and soil with activities measured by a 2×2 NaI sensor at less than 20,000 cpm correspond to thorium-230 activity concentrations less than 40 pCi/g (U.S. Army Corps of Engineers [USACE] 1998). On the basis of additional samples collected during the Ashland 2 remediation effort, the correlation was modified to specify that activities measured by a 2×2 NaI sensor detector at less than 16,000 cpm correspond to thorium-230 activity concentrations less than 40 pCi/g. The results of the Ashland 2 remedial data indicated that 97% (122/126) of the soil samples with activities less than 16,000 cpm measured by a 2×2 NaI sensor contained thorium-230 activity concentrations less than 40 pCi/g. The 16,000 cpm reading corresponds to about 3 pCi/g of radium-226. To classify soil from the surficial lift, soil with measurements less than 16,000 cpm was considered to be below the cleanup criterion; surficial soil with measurements greater than 24,000 cpm was considered to be above the cleanup criterion, and surficial soil with activities between 16,000 cpm and 24,000 cpm was considered to be the "uncertain surficial soil."

The extent of soil above the cleanup criterion in subsequent subsurface lifts was calculated by applying indicator geostatistical techniques combined with Bayesian analysis to discrete soil sample data. Geostatistical techniques have several distinct advantages for estimating soil volume on the basis of a limited set of discrete data. Geostatistical techniques account for the presence of spatial autocorrelation in the underlying data sets. When interpolating with geostatistical techniques, data clustering is automatically handled. In addition, besides the estimate of contamination extent, measures of the error associated with that estimate are provided. Indicator geostatistics provide the additional benefit of robustness when data sets with a high degree of variability are used. Finally, the inclusion of Bayesian methods prevents unreasonable results in areas where data are too sparse to provide supportable conclusions.

This approach requires a spatial autocorrelation model for the geostatistical portion of the analysis and an initial conceptual model for the Bayesian portion. Autocorrelation models for indicator geostatistics include a functional form and an assumed range. In the case of Seaway Area A, an exponential model was used. On the basis of the available historical data, the range was assumed to be anisotropic, with the horizontal range much larger (100 ft) than the vertical range (5 ft). This observation was consistent with the likely mode of soil deposition at the site. The initial Bayesian model for the site was assumed to be completely uncertain, i.e., there was an equal probability of contamination being present or absent across the whole site.

The combined geostatistical/Bayesian approach used existing historical discrete sample data to "update" or refine the initial conceptual model for the site. Although the contaminant of concern was thorium-230 at 40 pCi/g, the absence of thorium-230 data for many of the samples prevented this radionuclide from being used directly. Instead radium-226 was used as a proxy, or substitute, for thorium-230. Analysis from Ashland 1, Ashland 2, and Seaway data sets indicated that only 3% (13/448) of the samples containing radium-226 activity concentrations of less than 3 pCi/g had thorium-230 activity concentrations exceeding 40 pCi/g. On the basis of this information, historical samples were coded either 0 (radium-226 activity concentrations less than 3 pCi/g) or 1 (radium-226 activity concentrations greater than 3 pCi/g). These "indicator" sampling results were then used to update the initial site conceptual model with combined geostatistical/Bayesian techniques.

The updating process was done on a lift-by-lift basis, with discrete sample results assigned to lifts on the basis of the midpoint of the sampled interval. For each subsurface lift, however, the data from the lifts immediately above and below were included in the interpolation. Consequently, even if a particular lift might not have samples for a particular location, if data were available from lifts directly above or below, these data were used. When the updating was complete, soils within each subsurface lift were divided into contaminated soil (probability of contamination > 0.7), clean soil (probability of contamination < 0.3), and uncertain soil (probability of contamination between 0.3 and 0.7).

Section 5
Results and Conclusions

Table 1 lists the estimated volumes of in-situ soil above the cleanup guideline for each lift. Estimated volumes of ex-situ soil are also shown in the table. The ex-situ volumes were estimated on the basis of an assumed 25% bulking factor. The following text provides a lift-by-lift discussion of these estimates.

Figure 2 shows the gamma walkover data color-coded by activity levels, with historical surficial soil sample results superimposed. Green gamma walkover data are below 16,000 cpm. Yellow gamma walkover data are between 16,000 and 24,000 cpm. Red gamma walkover data are more than 24,000 cpm.

Superimposed on the gamma walkover data are the thorium-230 results for the surficial borehole samples. The green triangles represent borehole locations with surficial soil samples containing thorium-230 below 40 pCi/g, and the red triangles represent borehole locations containing surficial thorium-230 soil samples above 40 pCi/g. The white triangles represent borehole locations with surficial samples lacking thorium-230 data. As is clear from this figure, the gamma walkover data provided reasonably accurate predictions of the presence or absence of thorium-230 activity levels above 40 pCi/g in historical surficial samples. The one area where this was not the case was at the southern end of the site. Two historical soil sample locations in this area had

Table 1 Estimated Volumes of Soil Exceeding the Cleanup Guideline of 40 pCi/g for Thorium-230 at Seaway Area A

	In-Situ Contaminated Soil Volume (yd^3)			Ex-Situ Contaminated Soil Volume[a] (yd^3)		
Lift	Minimum	Maximum	Best Estimate	Minimum	Maximum	Best Estimate
Surficial (1st lift)	20,000	25,000	25,000	25,000	31,000	31,000
2 to 4 ft (2nd lift)	4,500	36,500	29,500	5,600	46,000	37,000
4 to 6 ft (3rd lift)	3,000	38,000	12,000	3,800	47,500	15,000
6 to 8 ft (4th lift)	2,000	16,000	5,000	2,500	20,000	6,000
Total	29,500	115,500	71,500	36,900	144,500	89,000

[a] Calculated on the basis of a 25% bulking factor.

thorium-230 activity above 40 pCi/g and also radium-226 activity exceeding 3 pCi/g (see Figures 2 and 3) but no indication of contamination in the gamma walkover data. There are several possible reasons for this observation. One is that the original coordinates for the samples were incorrect, and/or error was introduced when the original "local" grid coordinate system was converted to the state plane coordinate system. A second possibility is that the relatively large spacing between walkover lines resulted in these locations being missed. However, a third (and more likely) explanation is that the samples were collected before clean soil was spread over the top of this area.

5.1 Volume Estimates for Surficial Lift

Figure 3 shows the surficial gamma walkover data superimposed with the historical radium-226 results for the surficial borehole samples. The green squares represent borehole locations with surficial soil samples containing radium-226 below 3 pCi/g, and the red squares represent borehole locations containing surficial radium-226 above 3 pCi/g. The gamma walkover data exhibited the same characteristics as those from the Ashland 2 site. A very sharp and distinct separation existed between soil with sensor-detected activities above 24,000 cpm and soil with such activities below 16,000 cpm. For the surficial lift, the minimum volume estimate of soil above the cleanup criterion included soil with sensor-detected activities greater than 24,000 cpm. The maximum volume estimate included soil with sensor activities greater than 24,000 cpm and between 16,000 cpm and 24,000 cpm (i.e., uncertain surficial soil). The conservative estimate, defined here as the best estimate, of volume of surficial soil exceeding the cleanup criterion included soil above 16,000 cpm. The black line on Figure 3 identifies the primary potential excavation area for the surficial lift on the basis of the gamma walkover data. The minimum estimate of the volume of soil above the cleanup criterion for the surficial lift (0 to 2 ft) is 20,000 yd^3, the maximum estimate is 25,000 yd^3, and the conservative or best estimate is 25,000 yd^3 (see Table 1). The relatively small difference between the estimates reflects the relatively precise definition of the footprint of soil above the cleanup guideline obtained from the gamma walkover survey. Of the 25,000 yd^3 estimates, 500 yd^3 included soil south and west of the primary surficial excavation footprint where the gamma walkover data results were greater than 16,000 cpm. The potential exists in these areas for contaminated soil to be present between the walkover lines.

5.2 Volume Estimates for Subsurface Lifts

Figures 4 through 6 show the results of the interpolation of discrete sample data for the subsurface lifts. Results are shown in Figure 4 for the second lift (2 to 4 ft), in Figure 5 for the third lift (4 to 6 ft), and in Figure 6 for the fourth lift (6 to 8 ft). These three figures are color-coded according to the probability that contamination is present on the basis of results from the geostatistical/Bayesian approach that used historical discrete sample data. Greens represent areas that have less than a 50% probability of exceeding the cleanup guideline, and reds indicate a greater than 50% probability of exceeding the cleanup guideline. The red squares represent borehole locations with discrete soil samples containing radium-226 above 3 pCi/g, and the green squares represent borehole locations with soil samples containing radium-226 below 3 pCi/g.

A best estimate, minimum estimate, and maximum estimate of volume of soil above the cleanup criterion were also calculated for each of the subsurface lifts. The minimum volume estimates include only soil with a greater than 70% probability of exceeding the cleanup criterion. The maximum volume estimates include soil with a greater than 30% probability of exceeding the cleanup criterion. The best estimates of the volumes of soil exceeding the cleanup criteria were calculated on the basis of a greater than 50% probability of exceeding the cleanup criterion and took engineering judgment into account. The black lines on Figures 4 through 6 identify the potential excavation areas for each subsurface lift and the area used to calculate the best estimate of volume of soil above the cleanup criterion.

Figure 4 shows the results of the interpolation of discrete sample data for the second lift (2 to 4 ft). The primary footprint of the potential excavation area for this lift is consistent with the surficial gamma walkover data. Note that in the northern area of the potential excavation footprint, a relatively large section appears to be clean (below the cleanup guideline) at depth despite the presence of surficial soil exceeding the cleanup guideline. In this area, four boreholes along the perimeter of the excavation footprint had samples at the 2- to 4-ft range containing radium-226 activity greater than 3 pCi/g. Very few borehole samples were collected within the footprint. In the case of the best estimate, it was assumed that soil within the footprint could potentially contain activities above the cleanup guideline on the basis of surficial gamma walkover data and data from the four borehole samples along the excavation perimeter. An additional area was included as part of the 2- to 4-ft lift at the southern end of the site. This area was included in the best estimate of the volume of soil above the cleanup criterion on the basis of interpolation of the discrete sample results. Additionally, some surficial samples from boreholes in this area had radium-226 activity greater than 3 pCi/g and thorium-230 activity greater than the thorium-230 cleanup criterion of 40 pCi/g (see Figure 3). On the basis of the interpolation of discrete sample results, the minimum (greater than 70% probability) and maximum (greater than 30% probability) estimates of the volumes of soil exceeding the cleanup criterion are 4,500 yd^3 and 36,500 yd^3, respectively. On the basis of the interpolation of the discrete sample data and engineering judgment, the best volume estimate of soil exceeding the cleanup criterion is 29,500 yd^3 (see Table 1). The relatively large differences among these three volume estimates reflect the relatively imprecise definition of the footprint of soil above the cleanup guideline on the basis of historical samples.

Figure 5 shows the results of the interpolation of discrete sample results for the third lift (4 to 6 ft). The amount of discrete sample information available for this depth was markedly less than for surface and near-surface soil, particularly in the northern area. Fifteen boreholes had samples collected at a depth interval of 4 to 6 ft; 5 of those boreholes had samples containing radium-226 activity above 3 pCi/g. Of those five boreholes, two terminated at this depth interval, and one had its next sample collected at depths greater than 24 ft (i.e., no samples were collected between 6 and 24 ft). For those boreholes, soil above the cleanup criterion remains unbounded in the vertical extent. The two small areas to the north with a greater than 50% probability of radium-226 exceeding 3 pCi/g were the result of two different borehole samples at the upper lift containing radium-226 greater than 3 pCi/g. Additionally, one borehole sample in the lower lift in this area had a radium-226 activity slightly above the 3 pCi/g guideline (i.e., 4 pCi/g). The area at the western part of the site with a greater than 50% probability of radium-226 exceeding 3 pCi/g was the result of a single borehole sample with a slightly elevated radium-226 activity concentration of 4.1 pCi/g. The thorium-230 activity measured for this particular borehole sample was 25 pCi/g. These three areas were not included in the best estimate of the volume of soil exceeding the cleanup criterion for the 4- to 6-ft lift. On the basis of interpolation of discrete sample results, the minimum volume estimate of soil above the cleanup guideline for this lift is 3,000 yd^3, the maximum volume estimate is 38,000 yd^3, and the best volume estimate is 12,000 yd^3 (see Table 1). Like the previous lift, the large differences among the three estimates reflect the inexact definition of the footprint of soil exceeding the cleanup guideline obtained from the historical discrete soil samples.

Figure 6 shows the results of the interpolation of discrete sample results for the final lift (6 to 8 ft). This lift has only scattered locations with soil sample data. Samples were collected at depths between 6 and 8 ft from 13 boreholes; 2 of these boreholes had samples containing radium-226 activity above 3 pCi/g. One of these two samples terminated at 7 ft with a radium-226 activity greater than the surrogate criterion of 3 pCi/g. On the basis of the interpolation of discrete sample results, the minimum estimate of the volume of soil exceeding the cleanup criterion for this fourth lift is 2,000 yd^3, the maximum estimate is 16,000 yd^3, and the best estimate is 5,000 yd^3 (see Table 1). Similar to the other subsurface lifts, the large differences among the three estimates reflect the very imprecise definition of the footprint of soil exceeding the cleanup guideline obtained from the historical soil samples.

Figure 7 shows the discrete borehole data collected at depths greater than 8 ft. A total of 16 samples were collected from 8 boreholes at depths ranging between 8 and 30 ft. Of the 16 samples, 12 were collected between 8 and 12 ft, and 4 were collected at deeper intervals. Thorium-230 was measured in seven of the borehole samples, and all of the samples contained activity below 40 pCi/g. All 16 of the radium-226 activity levels were below 3 pCi/g, with the exception of an activity concentration of 3.2 pCi/g in one borehole sample collected between 24 and 26 ft. This borehole was located in an area where soil samples at the upper, shallower lifts exceeded the cleanup criterion. At this particular borehole, a sample collected between 4 and 6 ft contained 7.0 pCi/g radium-226 and 69.0 pCi/g thorium-230. Data were not collected between these two sample intervals, so the extent of soil above the cleanup guideline in this area is unknown. Although volume estimates were not calculated for depths greater than 8 ft, some soil exceeding the cleanup guideline may exist below that depth, which would increase the overall volume estimate.

Section 6
Summary

The volume of soil at Seaway Area A that exceeds the site-specific guideline of 40 pCi/g thorium-230 was estimated from the results of gamma walkover data for the surficial soil and a combined Bayesian/indicator geostatistics approach applied to the historical discrete sample data for the subsurface. For this analysis, volume estimates were calculated for the surface (0 to 2 ft) and subsequent 2-ft lifts to a depth of 8 ft. A best estimate, minimum estimate, and maximum estimate of the volume of soil above the cleanup criterion were calculated for each lift.

The minimum volume of in-situ soil believed to exceed the cleanup guideline of 40 pCi/g thorium-230 at Seaway Area A is 29,500 yd^3. The maximum volume of in-situ soil is 115,500 yd^3. The best estimate of in-situ soil above the cleanup criterion, calculated on the basis of surficial gamma walkover data, results of interpolation of discrete borehole sampling data, and engineering judgment, is 71,500 yd^3 (see Table 1). The range in these three in-situ soil numbers reflects the uncertainty of the extent of soil above the cleanup criterion in the subsurface. This uncertainty occurs for three reasons: (1) the relative paucity of data for subsurface depths, (2) the fact that there appears to be layers of soil above the cleanup criterion and layers of soil below the cleanup criterion at depth, which complicates the analysis, and (3) the fact that sampling terminated in several bores before reaching soil below the cleanup criterion.

The best estimate of ex-situ soil is 89,000 yd^3 on the basis of 71,500 yd^3 in-situ soil above the cleanup criterion with a 25% bulking factor. As experience at the Ashland 2 site has shown, even for sites with relatively large numbers of historical samples, volumetric estimates based on these samples can have significant uncertainty associated with them. In contrast, the surficial gamma walkover data yielded a fairly well-defined footprint of soil above the cleanup guideline and consequently resulted in what are judged to be relatively accurate estimates of near surface-contamination volumes.

Section 7
References

DOE: see U.S. Department of Energy.

U.S. Department of Energy, 1978, *Radiological Survey of the Seaway Industrial Park, Tonawanda, New York, Final Report*, DOE/EV-0005/6, prepared by Oak Ridge National Laboratory, for the U.S. Department of Energy, Oak Ridge, Tenn., May.

U.S. Department of Energy, 1981, *Preliminary Engineering and Environmental Evaluation and Remedial Action Alternatives for the Seaway Industrial Park, Tonawanda, New York*, Report 409-312, prepared by Ford, Bacon and Davis Utah, for the U.S. Department of Energy, Dec.

U.S. Department of Energy, 1993a, *Remedial Investigation Report for the Tonawanda Site, Tonawanda New York, Vol. 1*, DOE/OR21949-300, prepared by Bechtel National, Inc., for the U.S. Department of Energy, Oak Ridge, Tenn., Feb.

U.S. Department of Energy, 1993b, *Remedial Investigation Report for the Tonawanda Site, Tonawanda New York, Vol. 2*, DOE/OR21949-300, prepared by Bechtel National, Inc., for the U.S. Department of Energy, Oak Ridge, Tenn, Feb.

USACE: see U.S. Army Corps of Engineers.

U.S. Army Corps of Engineers, 1998, *FUSRAP Technical Memorandum, Correlation of Radiological Scan Readings with Discrete Soil Samples for Ashland 2 Site*, prepared by Bechtel National, Inc., for the U.S. Army Corps of Engineers, Buffalo District, Buffalo, N.Y., April.

FIGURE 1 Seaway Area A Sampling Locations

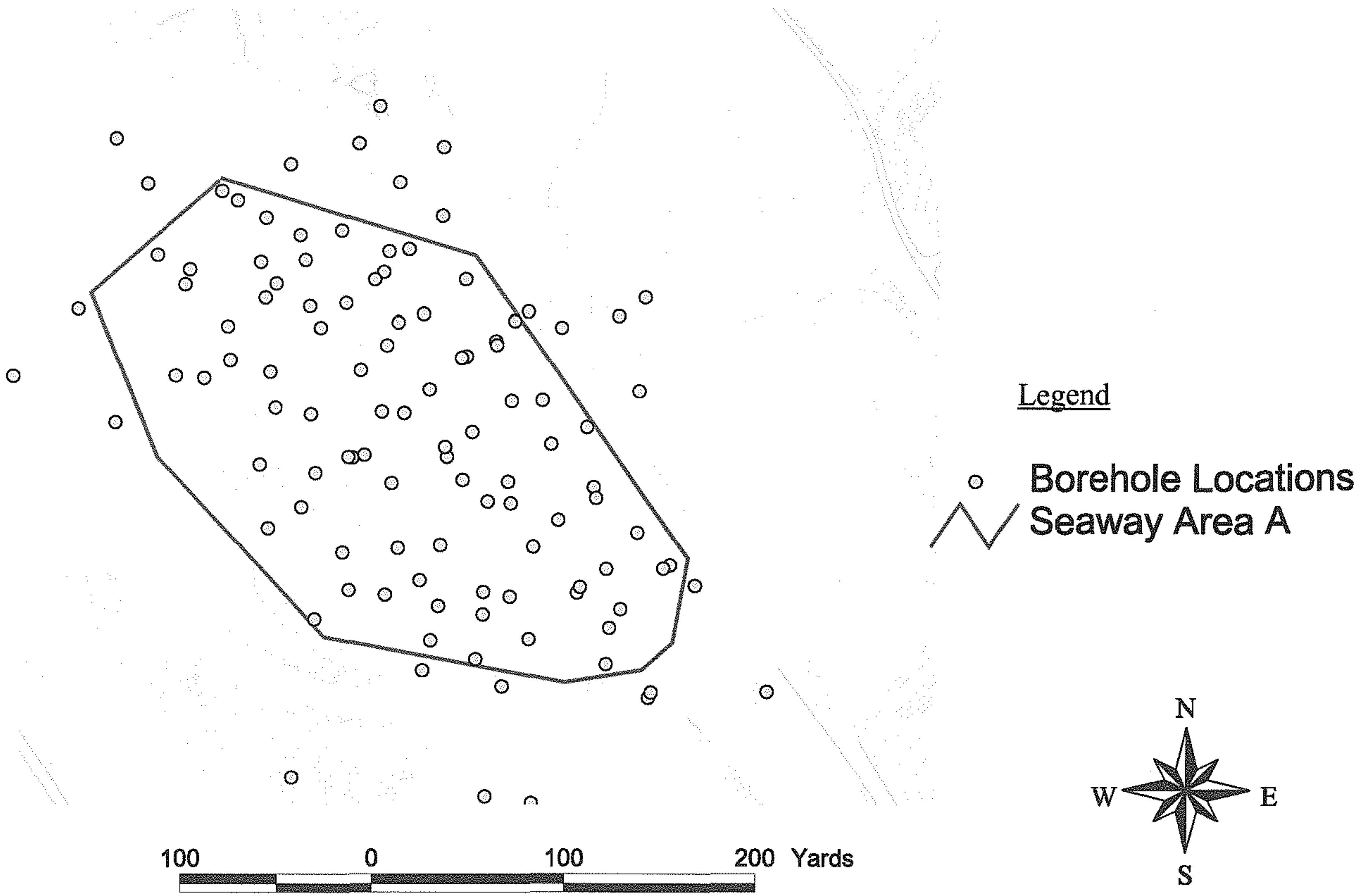

FIGURE 2 Surficial Gamma Walkover Data

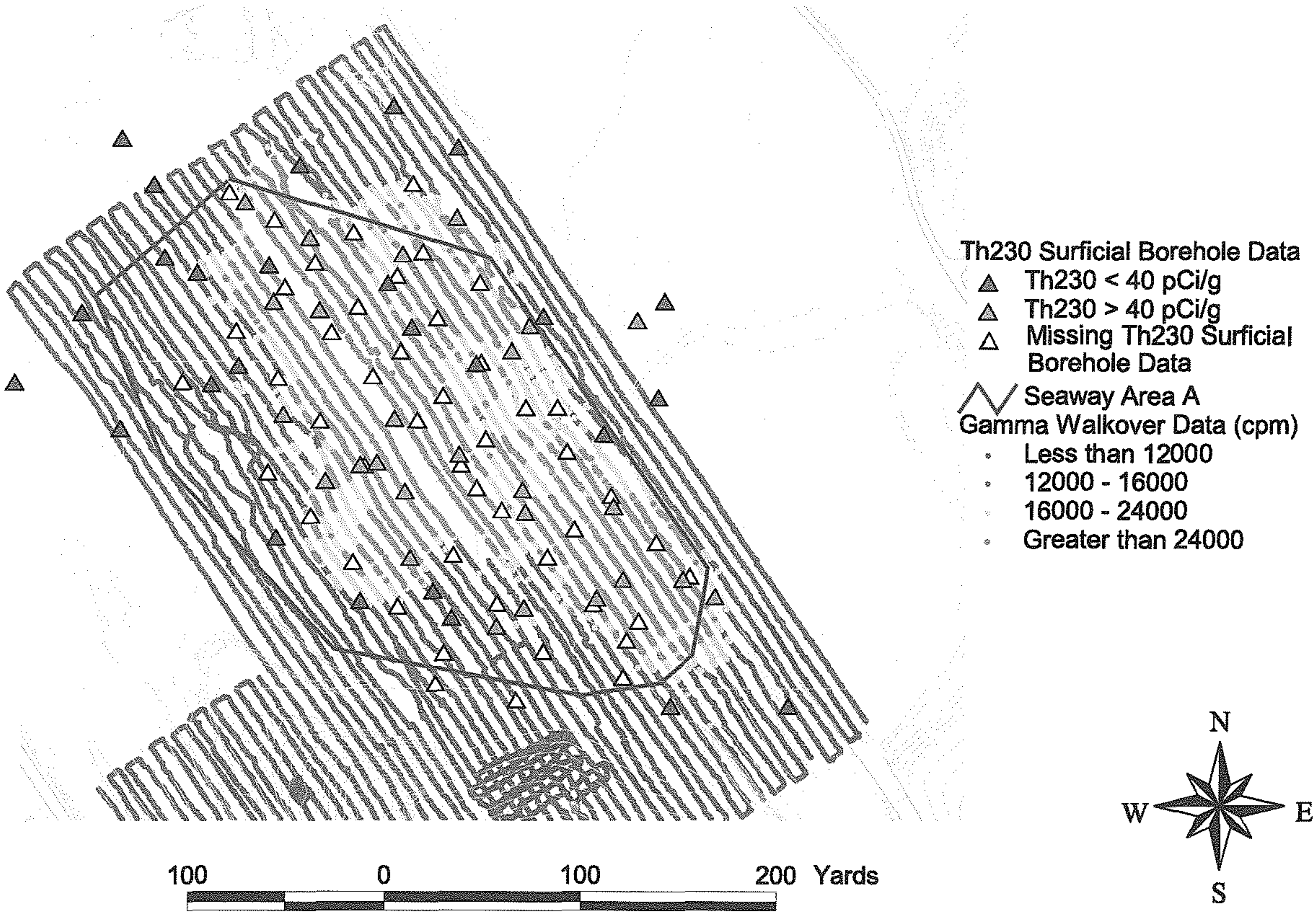

FIGURE 3 0- to 2-ft (Surficial) Lift

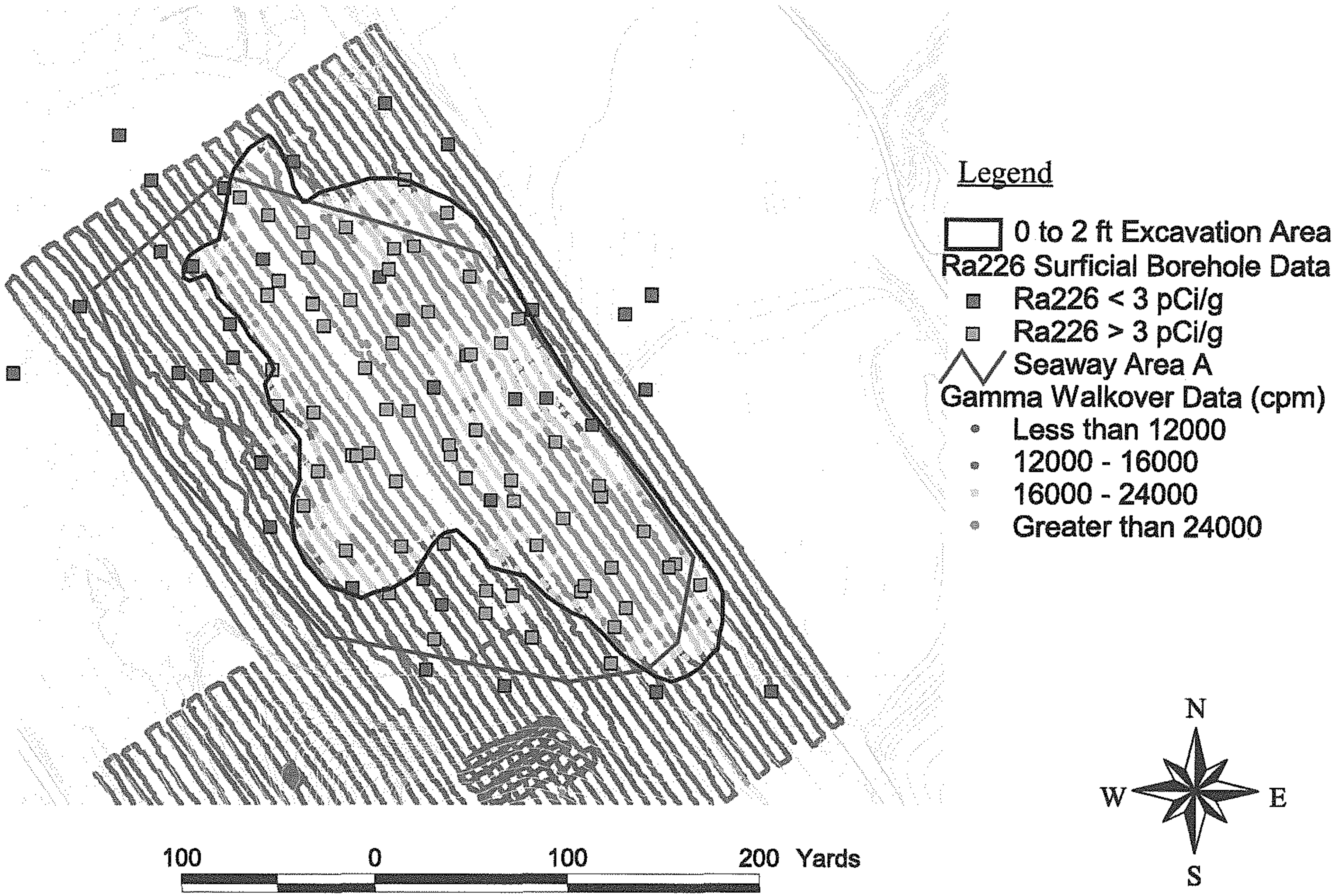

FIGURE 4 2- to 4-ft Lift

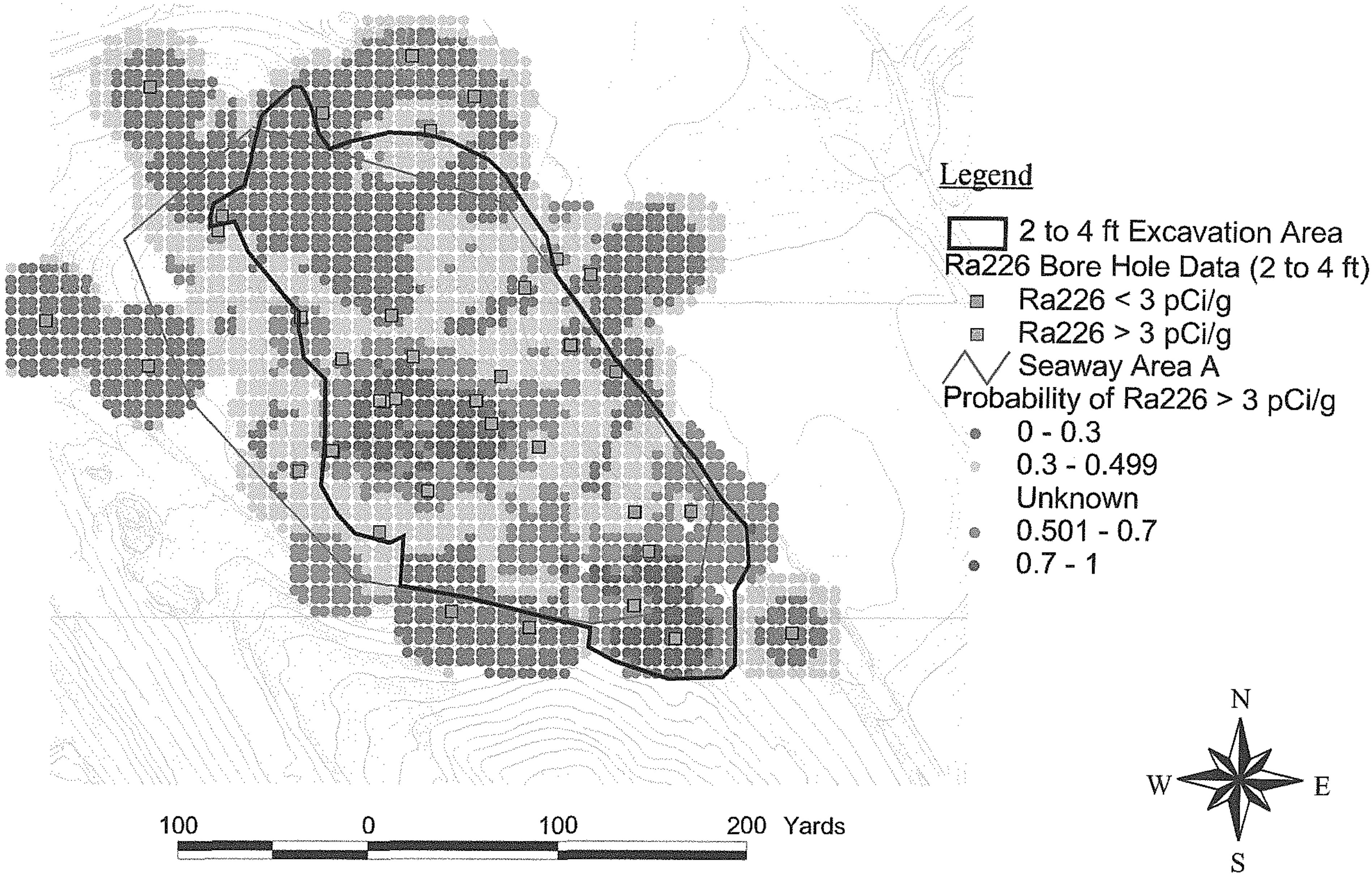

FIGURE 5 4- to 6-ft Lift

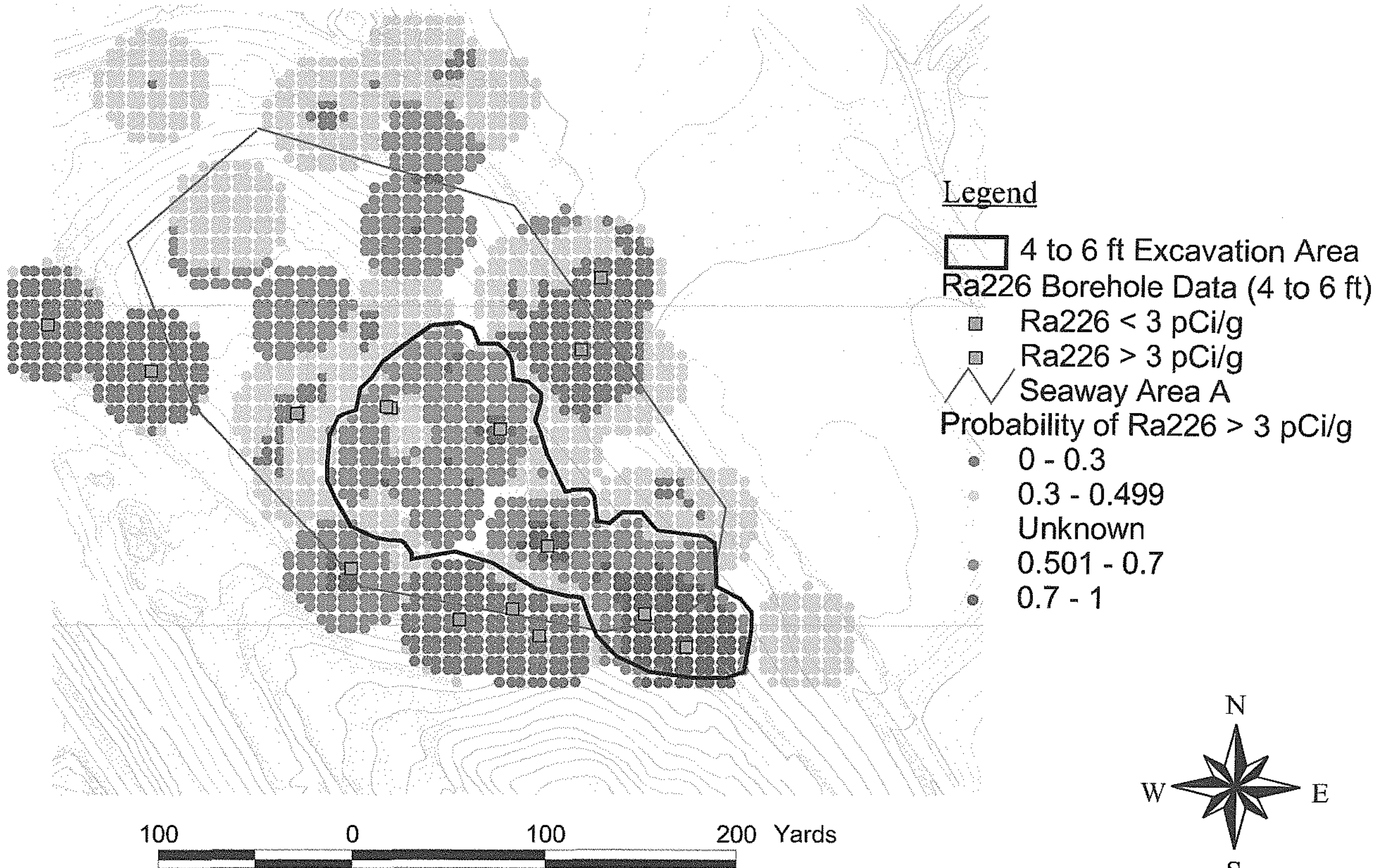

FIGURE 6 6- to 8-ft Lift

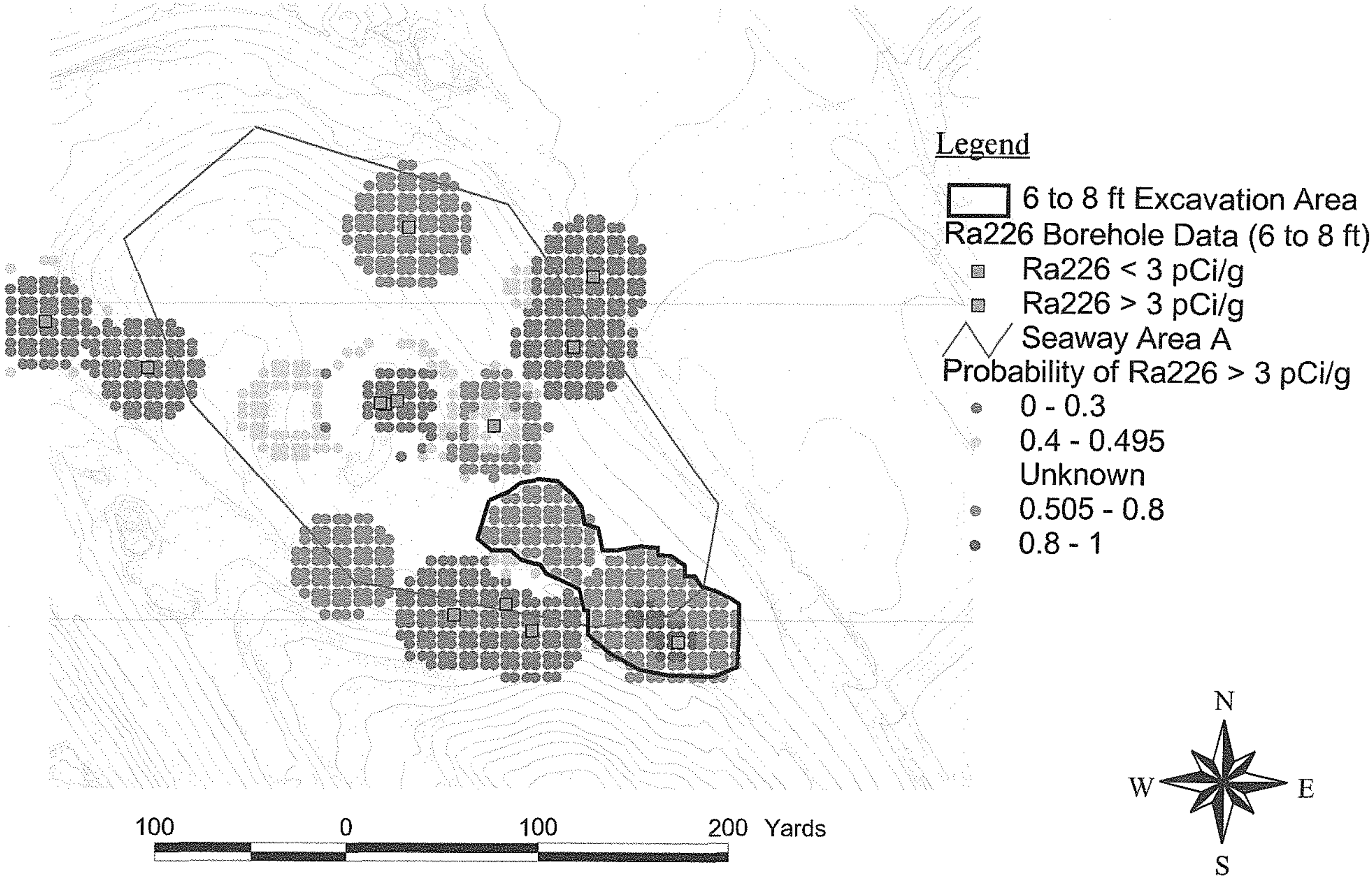

FIGURE 7 Borehole Data for Sample Depths Greater Than 8 ft